Global Monitoring Division

Logistics, Agenda and Tour Schedule

2013-2017 Review

May 21-24, 2018

Contents:

2018 Global Monitoring Division Review Logistics

Points of Contact

- Julie Singewald, office (303) 497-6891, cell (303) 990-3023 (hotel and logistics)
- Ann Thorne, office (303) 497-4600, cell (720) 438-1925 (visitor info and site access)
- Susan Abenilla-Brown (303) 497-6074, cell (720) 683-2794 (travel)
- Diane Stanitski (303) 497-6375, cell (717) 816-0242 (general questions)

Review Panel transportation between Denver International Airport and Boulder

- Upon arrival at Denver International Airport (DIA), GMD will provide transportation for Review Panelists to their hotel in Boulder, if desired. Pick up will take place on the west side of the airport, Level 4. Note that this is one level below Baggage Claim, but the best place to make a connection. Contact information for the GMD driver will be provided prior to flight departure.
- GMD will also offer van service for Review Panelists from Boulder to DIA following lunch and the close of the formal Review on Thursday, May 24.

Lodging Information

- The review hotel is the
  - Millennium Harvest House Boulder, (303) 443-3850
  - Room block name: NOAA GMD Review
  - **Deadline for room block reservation: April 15**

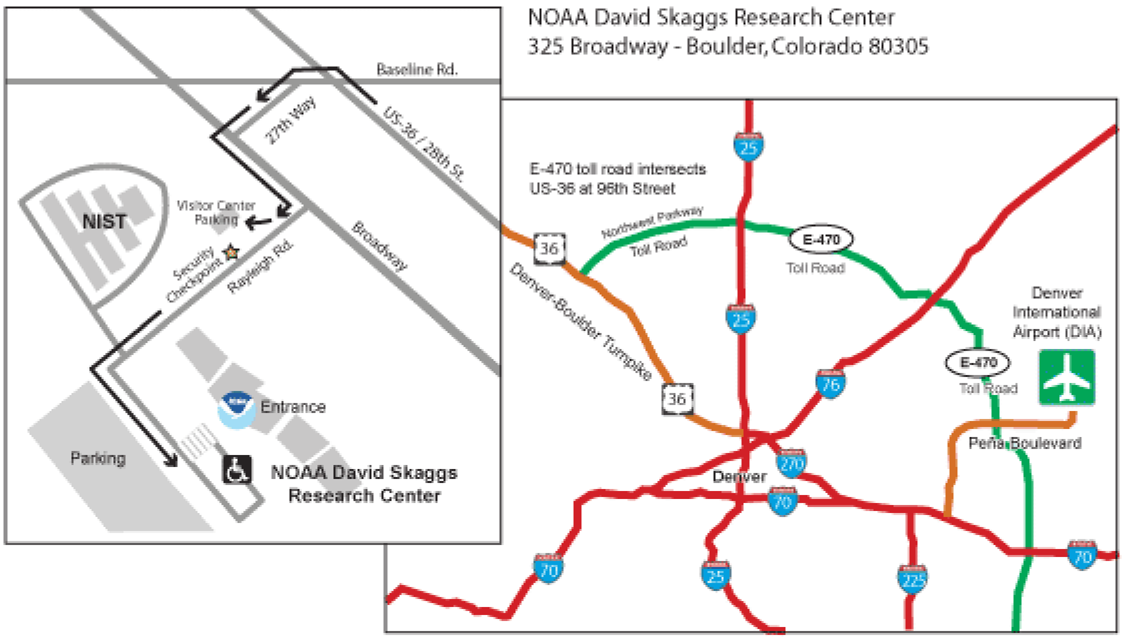
Reservations have been made for GMD Reviewers. Please present your credit card upon check-in. The rooms will be charged to your credit card and reimbursed to you after the review when the travel voucher is processed for reimbursement. If driving to the hotel from Denver International Airport, follow the directions detailed below.

Transportation from Millennium to David Skaggs Research Center (DSRC)

Transportation will be provided for the GMD Review Panelists from the Millennium to the meeting site (DSRC) and back each day via a GMD van. Pick up is at the hotel at 9:45 AM on Monday, May 21 and 7:45 AM from Tuesday through Thursday, May 22-24. The Review will take place in GC-402 in the DSRC.

For those Driving: Directions to ESRL

ESRL is located in the David Skaggs Research Center (DSRC) at 325 Broadway in Boulder, Colorado, next to the Department of Commerce National Institute of Science and Technology (NIST) building.



Driving Directions from DIA to Boulder

Toll Road (42.5 mi via E-470 N toll road) to DSRC:

- Take Peña Boulevard to E-470 Toll Road North, Exit 6B - toward Fort Collins (approx. 4 miles). Merge onto E-470 North and follow E-470 to US-36 toward Boulder/Fort Collins (approx. 18 miles).
- Merge onto US-36 West.
- In ~9 miles, exit US-36 at Baseline Road (University of Colorado Main Campus exit).
- Keep left and turn left (West) onto Baseline (toward mountains).
- Keep left and turn left at the first light onto 27th Way.
- Stay in the middle lane and turn left onto Broadway.
- Turn left onto Broadway / CO-93.
- Take the second right at the light onto Rayleigh Rd. and bear right into the Visitors Center parking lot to pick up your badge.
- Tolls are ~$9.00 each way (~$5.90 if you have ExpressToll). Expense will be reimbursed on travel voucher.

Toll Free (44.4 mi via US-36 W) to DSRC:

- Exit Denver International Airport via Peña Boulevard.
- Take Peña Boulevard to I-70 West.
- Split right on I-270 West (Exit 279), toward Ft. Collins and follow to US-36 toward Boulder.
- Take US-36 West and follow instructions above to get to NOAA Visitor's Center.

Driving Directions from DIA to Millennium Hotel:

- Follow driving directions above to US-36 West.
- After ~9 miles US-36 West turns into 28th Street taking you directly into Boulder.
- The Millennium Hotel is on the left side of 28th Street, just past Colorado Avenue and before Arapahoe Avenue.

By Bus

Regional bus service to Boulder is available through the RTD. The AB1 bus provides service between the Denver International Airport and Boulder ($9.00 each way). Broadway and 27th is the closest main stop to the NOAA visitor center, which is located at Broadway and Rayleigh, and is served by the SKIP, DASH, AB1, Bound, and GS bus routes.

By Airport Shuttle

SuperShuttle (https://www.supershuttle.com, 303-227-0000, mobile app available for discounts and additional information) provides service from the airport to locations in Boulder for $84.00 one way ($75.60 with AAA discount).

You will need to make your own reservations with SuperShuttle using your own credit card. This expense will be reimbursed though your travel voucher. When making reservations you can specify round trip and that your destination is the Millennium Hotel in Boulder, Colorado. Departures from Denver International Airport to Boulder run on demand between 8:00 am and 10:00 pm. Return trips to Denver International Airport are scheduled when you schedule your initial shuttle ride to Boulder.

The SuperShuttle counter at Denver International Airport is located across from the Ground Transportation desk on Level 5/Baggage Claim in the center of the main terminal (and near the women's restroom). Counter staff will issue tickets and give directions to the van loading areas.

If you prefer that Susan Abenilla make the reservations for you, she will need your credit card information.

Security Procedures for Visitors (those without a NOAA-issued CAC card)

- All visitors are required to sign in and receive a visitor badge at the Visitor's Center near the Security Checkpoint in front of the David Skaggs Research Center (see map above) unless they have a NOAA-issued CAC card. Visitors will only need to go to the Visitor's Center on the first day to get a temporary ID good for the week. The Visitor's Center does not accept CACs issued by any other agency.
- Visitors to the site who are U.S. citizens need to present a U.S. photo ID, such as a current state driver's license. Foreign Nationals must present a valid passport or a "green card" (originals only -- no photocopies accepted).
- To receive a visitor badge, all visitors are required to park next to the Security Checkpoint and enter the Visitor's Center to be screened before proceeding to their destination.
- These are Homeland Security requirements regardless of security threat level. If you have any questions, please contact Keith Turbitt at (303) 497-4332.

Area Restaurants

Boulder Convention & Visitors Bureau listing of restaurants in Boulder.

Boulder Weather

Please check the National Weather Service forecast for Boulder, Colorado before your trip. If there is a chance that severe weather may close the campus, check the Boulder Labs Site Status website or call 303-497-4000.

NOAA ESRL GLOBAL MONITORING DIVISION REVIEW
May 21-24, 2018
David Skaggs Research Center (DSRC), Room GC-402
325 Broadway, Boulder, Colorado 80305

GMD Review AGENDA
Monday, May 21, 2018

Morning	*Millennium Hotel, informal breakfast buffet at restaurant "Thyme on the Creek" or other*
0945–1015	Review Panel to be picked up at 0945 (look for Chevy Equinoxes), main Millennium entrance Security check-in at David Skaggs Research Center (DSRC); proceed to Room GC-402
Session A	***Welcome to Review and Overview***
1015–1020	Welcome and Logistics *Russell Schnell, GMD Deputy Director of Science*
1020-1045	Introduction of Review Panel; Charge to Reviewers; Overview of NOAA and OAR Research *Robert Webb, ESRL Director*
1045-1130	ESRL GMD Overview *James Butler, GMD Director*
1130-1145	CIRES Overview *Waleed Abdalati, CIRES Director*
1145-1300	***Lunch meeting (closed)**, GB-124 - Reviewers and OAR Leadership* ***– Charge to reviewers, internal discussion – OAR AA, OAR DAA, Review Panel***
Session B	***GMD's Research Themes***
1300-1350	**Theme 1: Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks** *Arlyn Andrews, Scientist, Carbon Cycle Greenhouse Gases Group*
1350-1430	**Theme 2: Monitoring and Understanding Changes in Surface Radiation, Clouds, and Aerosol Distributions** *Allison McComiskey, Chief, Global Radiation Group*
1430-1445	***Afternoon Break***
1445-1525	**Theme 3: Guiding Recovery of Stratospheric Ozone** *Steve Montzka, Scientist, Halocarbons Group*
1525-1640	***Concurrent tours of GMD Facilities*** *- James Butler, GMD Director* *- Russell Schnell, GMD Deputy Director of Science*
Session C	***GMD's Supporting Infrastructure***
1640-1705	**Calibrations and Standards** *Brad Hall, Scientist, Halocarbons Group*
1705-1730	**Atmospheric Baseline Observatories** *Brian Vasel, Chief, Observatory Operations*
1745	Vehicles pick up Review Panel at DSRC main entrance to return to Millennium
1800-2000	**Icebreaker Reception** including food and refreshments - Millennium Patio

NOAA ESRL GLOBAL MONITORING DIVISION REVIEW
May 22, 2018
David Skaggs Research Center, Room GC-402
325 Broadway, Boulder, Colorado 80305

GMD Review AGENDA
Tuesday, May 22, 2018

0700-0730 *Millennium Hotel, informal breakfast buffet at Thyme on the Creek*

0745 Review Panel to be picked up at 0745 (look for Chevy Equinoxes) - double doors to left of Millennium main entrance - transit to DSRC

0745-0830 ***DSRC check-in and morning snacks – coffee, tea, fruit, bagels, donuts at GMAC***

- **Session 1**

0830-0945 **Introduction, Keynote Address, and Setting the Stage**

0945-1015 *Morning Break*

- **Session 2**

1015-1145 **Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks**

1145-1300 ***Lunch (closed) with Review Panel and Theme 1 Scientists – 2C-406***
GMD Scientists: CCGG – Arlyn Andrews, Lori Bruhwiler, Andrew Crotwell, Andy Jacobson, John Miller, Gaby Petron, Colm Sweeney; OZWV – Dale Hurst

- **Session 3**

1300-1430 **Monitoring and Understanding Changes in Surface Radiation, Clouds, and Aerosol Distributions**

1430-1500 *Afternoon Break*

- **Session 4**

1500-1645 **Guiding Recovery of Stratospheric Ozone**

1700-1930 ***Poster Session*** *- food and refreshments - DSRC Cafeteria*
Discussion with stakeholder poster presenters

NOAA ESRL GLOBAL MONITORING DIVISION REVIEW
May 23, 2018
David Skaggs Research Center, Room GC-402
325 Broadway, Boulder, Colorado 80305

GMD Review AGENDA
Wednesday, May 23, 2018

0700-0730 *Millennium Hotel, informal breakfast buffet at Thyme on the Creek*

0745 Review Panel to be picked up at 0745 (look for Chevy Equinoxes) - double doors to left of Millennium main entrance - transit to DSRC

0745-0830 ***Morning coffee, tea, fruit, bagels, donuts (demonstration projects displayed in atrium)***

- **Session 5**
0830-0945 **Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks**

0945-1015 *Morning Break (demonstration projects on display in atrium near cafeteria)*

- **Session 6**
1015-1145 **Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks**

1145-1300 ***Lunch (closed) with Review Panel and Theme 2/3 Scientists – 2C-406***
GMD Scientists: Aerosols - Betsy Andrews; G-RAD - Gary Hodges, Kathy Lantz; HATS - Brad Hall, Stephen Montzka; OZWV – Glen McConville, Bryan Johnson; OBOP – Christy Schultz

- **Session 7**
1300-1430 **Monitoring and Understanding Changes in Surface Radiation, Clouds, and Aerosol Distributions**

1430-1500 *Afternoon Break (demonstration projects on display in atrium near cafeteria)*

- **Session 8**
1500-1645 **Cross-cutting Topics – Water Vapor, Tropospheric Ozone, and Other Measurements**

1700-1815 ***Feedback session (closed) – LO reps, OAR and GMD Mgmt Staff, Chiefs – cafeteria***
Participants: Don Hillger (NESDIS), Alisa Young (NESDIS), Craig Long (NWS), Ivanka Stajner (NWS), CDR Catherine Martin (OMAO), Ko Barrett, James Butler, Russell Schnell, Diane Stanitski, James Elkins, Allison McComiskey, Irina Petropavlovskikh, Patrick Sheridan, Pieter Tans, Brian Vasel

1700-1815 ***Review Panel (closed session) – GB-124***

1830-2030 ***Dinner (closed) Carelli's –*** **Reviewers, OAR AA & DAA, GMD Mgmt, Group Chiefs**
Participants: Reviewers, Ko Barrett, John Holdren, James Butler, Waleed Abdalati, Russell Schnell, Diane Stanitski, Arlyn Andrews, James Elkins, Allison McComiskey, Irina Petropavlovskikh, Brian Vasel

NOAA ESRL GLOBAL MONITORING DIVISION REVIEW
May 24, 2018
David Skaggs Research Center, Room GC-402
325 Broadway, Boulder, Colorado 80305

GMD Review AGENDA
Thursday, May 24, 2018

0700-0730 *Millennium Hotel, informal breakfast buffet at Thyme on the Creek*

0745 Review Panel to be picked up at 0745 (look for Chevy Equinoxes) - double doors to left of Millennium main entrance - transit to DSRC

0800 ***Session begins in conference room GC-402***

Session D *Reviewer Closed Session*

0800-0830 Open reviewer session with GMD Staff

0830-0915 Reviewer session with GMD Management Staff, Group Chiefs and OAR Management for review summary, Q&A
Participants: Reviewers, Ko Barrett, James Butler, Russell Schnell, Diane Stanitski, James Elkins, Allison McComiskey, Irina Petropavlovskikh, Patrick Sheridan, Pieter Tans, Brian Vasel

0915-1000 Reviewer closed session; team formulates recommendations and begins writing (breaks as needed)

1000-1015 *Morning Break with refreshments*

Session E *Reviewer Closed Session (cont'd)*

1015-1115 Reviewer closed session; team formulates recommendations and begins writing (breaks as needed)
1115-1215 Review team provides preliminary feedback to OAR and GMD Management
1215-1230 Closing Remarks

1230-1315 ***Lunch*** - Reviewer's executive lunch in conference room
GMD Review complete

Tour of GMD Facilities

May 21, 3:25-4:40 pm (two concurrent, 75-min tours)

Tour leaders: Scientists/technicians in each lab along with …

- Russ Schnell (listed on left schedule) - Tour 1 of Carbon Cycle and Halocarbons facilities - David Crisp, Ken Davis, Ray Weiss, Steve Wofsy, Ken Mooney, Neil Christerson, Victoria Kile
- Jim Butler (listed on right schedule) - Tour 2 of Ozone-Water Vapor, Aerosols, and Surface Radiation facilities - Eric Saltzman, Paul Stackhouse, Anne Thompson, Ko Barrett, Wayne Higgins, Brian Cole, Monique Baskin

Stop #	Facility	POC on site (with Russ)	Facility	POC on site (with Jim)
1	Transition from GC-402 to Flask Lab	Russ Schnell	Transition from GC-402 to GMD 3rd floor	Jim Butler
2	Flask Logistics Lab	Eric Moglia	Core C-D Wall / Movie	Jim Butler
3	Standards Lab	Brad Hall	AERO Lab	Pat Sheridan
4	HATS Lab	Steve Montzka	OZWV Lab – ozonesondes	Emrys Hall
			OZWV – water vapor sondes	Patrick Cullis
5	CO_2 Cal Transfer Lab	Mefford & Kitzis	Dobson Lab	Glen McConville
6	CCGG Lab	Lang & A Crotwell	Transition to roof	
7	PFP Lab	Ben Miller	Roof Tour: G-RAD	Emiel Hall
8	Core C-D Wall / Movie	Russ Schnell	Transition to G-RAD CUCF spectral calib Lab	Jim Butler
9			G-RAD Lab	Patrick Disterhoft
10	Rm GC-402 for wrap-up, to icebreaker	Russ, Jim, reviewers	Rm GC-402 for wrap-up, to icebreaker	Jim, Russ, reviewers

Global Monitoring Division

Charge to Reviewers

2013-2017 Review

May 21-24, 2018

Contents:

Global Monitoring Division Science Review
May 21-24, 2018
Charge to Reviewers

Purpose of the Review
The National Oceanic and Atmospheric Administration (NOAA) Office of Oceanic and Atmospheric Research (OAR) conducts laboratory science reviews every five years to evaluate the quality, relevance, and performance of research conducted in its laboratories. This review is useful both for internal OAR/NOAA planning, programming, and budgeting, and for the laboratory's strategic planning of its future science. These reviews should also ensure that OAR research is linked to the NOAA Strategic Plan, relevant to NOAA's research mission and OAR corporate priorities, of high quality as judged by preeminence criteria, and carried out with a high level of performance. Each reviewer will independently prepare his or her written evaluations of at least one research area. The chair, a federal employee, will create a report summarizing the individual evaluations. The chair will not analyze individual comments or seek a consensus of the reviewers.

Scope of the Review
This review will cover the research of the Earth System Research Laboratory, Global Monitoring Division (GMD) over the last five years. The research areas and related topics for the review are: 1) Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks; 2) Monitoring and Understanding Changes in Surface Radiation, Clouds, and Aerosol Distributions; and 3) Guiding Recovery of Stratospheric Ozone. There are also two supporting infrastructure areas for review: 1) Calibrations and Standards and 2) Atmospheric Baseline Observatories.

Description of GMD Research Areas

<u>Research Area #1: Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks</u>

Today's anthropogenic climate change is largely driven by increasing greenhouse gases (GHGs) in the atmosphere, modified to some extent by the distribution of aerosols and aerosol properties. To understand the influence of changing atmospheric composition on climate change and minimize its eventual magnitude, society needs the best possible information on the trends, distributions, emissions and removals of greenhouse gases. It is necessary to develop a solid scientific understanding of their natural cycles, and how human management and the changing climate influence those cycles. Our atmospheric measurements can also provide fully transparent and objective quantification of emissions, supporting national and regional emissions reduction policies and generating trust in international agreements.

The NOAA Global Monitoring Division (GMD) is a world leader in producing the regional to global-scale, long-term measurement records that allow quantification of the most important drivers of climate change today. Global monitoring of atmospheric greenhouse gases, in particular carbon dioxide (CO_2), has been part of NOAA's mission for over 50 years. GMD provides and interprets high-accuracy measurements of the history of the global abundance and spatial distribution of a suite of long-lived greenhouse gases. The spatial distributions, together with models of the winds and mixing (derived from weather forecasts) allow us to infer time-dependent patterns of emissions/removals that are consistent with our observations. Because the measurements are calibrated they stand on their own, and can be used far into the future with better models, and also to compare with satellite retrievals of column-averaged GHGs that cannot be calibrated, but still need to be used together with calibrated data.

NOAA measurements of climatically important gases began in the late-1960s and expanded in the mid-to-late 1970s for CO_2, nitrous oxide (N_2O), and chlorofluorocarbons (CFCs). Over the years other gases and isotopic ratios have been added, including methane (CH_4), carbon monoxide (CO), hydrogen (H_2), numerous hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs), methyl halides, and sulfur hexafluoride (SF_6). GMD produces and maintains global standards for most of the climate-relevant gases. The use of common standards enables measurements by different methods, and by different countries and organizations to be used together, greatly increasing the value of the international cooperative measurement system.

Research Area #2: Monitoring and Understanding Changes in Surface Radiation, Clouds, and Aerosol Distributions

Changes in the radiative energy balance at Earth's surface and at the top of the atmosphere result from forcing by greenhouse gases, aerosols, and related changes in the global atmospheric circulation. The distribution of clouds is the primary influence on the surface radiation budget and is sensitive to changes in the circulation, but the nature of the response of different cloud types in different climatic regions is uncertain. Cloud radiative properties are also sensitive to aerosols which are highly variable in space, time, and composition. Their role in radiative forcing is complex and can be either positive or negative and, in addition to their impacts on clouds, can influence the climate directly via long term changes in light absorption and scattering. The uncertainty in cloud responses to climate forcing constituents, either through direct interaction with aerosols or through circulation changes, is the primary factor limiting our ability to narrow estimates of the climate sensitivity, or the warming resulting from a change in a climate forcing agent.

GMD observatories host long-term measurements of globally representative, climate-critical radiation variables such as the continuous measurement of the solar energy reaching Mauna Loa Observatory that began in 1958, the longest such record on Earth. Broadband measurements of incoming and outgoing solar and terrestrial radiation are made in the U.S. and at global baseline observatories to quantify the surface radiation balance and to track changes in cloud radiative properties. GMD has focused on the direct radiative effects of aerosols with measurements of aerosol optical properties that began in the 1970s. In response to the finding that anthropogenic aerosols create a significant perturbation in the earth's radiative balance on regional scales, GMD expanded its aerosols research program to include stations for monitoring aerosol properties in regions where significant aerosol forcing was anticipated.

To support these measurements, GMD maintains calibration facilities tied to the world standards and also shares calibration services with collaborators worldwide. GMD and its national and international partners have made substantial improvements in the accuracy of both solar and infrared measurements over the past 25 years, allowing detection of small changes in the radiation balance that have dramatic consequences for weather and climate. GMD also provides leadership to the international aerosol and surface radiation monitoring communities by providing technical expertise, calibrations, consistent sampling and measurement protocols, and open source data acquisition, processing, visualization and editing software.

Research Area #3: Guiding Recovery of Stratospheric Ozone

Depletion of stratospheric ozone can result in enhanced UV radiation levels that increase skin cancer rates and adversely affect organisms and ecosystems. Concern over these effects provided impetus for ratifying the 1987 Montreal Protocol, enacting the U.S. Clean Air Act of 1990, and initiating GMD's global-scale monitoring of stratospheric ozone and the gases responsible for its destruction.

GMD has implemented a carefully designed network to monitor variations in ozone, ozone-depleting substances, stratospheric aerosols, and UV radiation. GMD research has been critical in determining long-term changes in concentrations of stratospheric ozone and chemicals causing ozone depletion. Our unique long-term observational records have led to an improved understanding of the production and fate of stratospheric ozone and the compounds and processes that influence ozone's abundance. These advances have furthered our understanding of the fundamental atmospheric processes affecting stratospheric ozone and provide usable information to policy-makers for guiding the recovery of the ozone layer.

GMD conducts year round balloon-borne vertical structure and total column optical measurements of ozone over the South Pole. During the winter preceding the early springtime Antarctic "ozone hole", satellites are unable to measure polar ozone without sunlight. GMD monitors stratospheric ozone at lower latitudes and in the Arctic, measures the gases responsible for depletion of stratospheric ozone, and monitors changes in ultraviolet radiation that is controlled by the amount of ozone in the stratosphere. As such, understanding the production and fate of ozone and the ozone-depleting compounds is a focal point of GMD research.

Ground based measurements of total-column ozone have been made for over 50 years with the Dobson spectrophotometer; the 14-station GMD Cooperative Dobson Network is a significant portion of the global Dobson network as are the six GMD balloon-borne ozonesonde stations. These stratospheric ozone measurements, along with the GMD greenhouse gas, surface ozone, aerosols, radiation and halocarbons measurement networks are linked to the world calibration standards maintained by GMD as are a preponderance of the stations in other international global networks.

Three gases that make a significant contribution to stratospheric ozone depletion, CFC-11, CFC-12 and N_2O, have been monitored by GMD since the mid-1970s. Since then, numerous additional CFCs, HCFCs, and other halogenated gases have been incorporated into the measurement program as the number of monitoring sites increased. Most of the gases that are responsible for depleting stratospheric ozone are anthropogenic, but some, such as methyl bromide and methyl chloride have natural contributions as well.

Supporting Infrastructure #1: Calibrations and Standards

Accurate and reliable calibrations are an essential component of all high-quality measurement programs. This is particularly true of measurements made to carry out research within GMD. Bias or drift in reference materials can have a significant impact on our ability to interpret measured spatial gradients and trends. Further, for data from multiple instruments or measurement networks to be interpreted together, they must be linked to common calibration scales.

GMD calibration activities support measurements of greenhouse gases, ozone-depleting gases, column ozone, and solar radiation. GMD serves as the World Meteorological Organization, Global Atmosphere Watch (WMO/GAW) Central Calibration Laboratory for five gases (CO_2, CH_4, N_2O, SF_6, CO), and serves as the World Calibration Center for Dobson ozone (total column ozone). The goal is to minimize bias among measurements made within the WMO/GAW network, of which NOAA GMD is a major contributor. GMD performs research on the preparation of primary standards, scale development, scale propagation, and comparison. In practice, GMD offers trace gas reference materials and calibration services to WMO/GAW and other partners, calibrates WMO Dobson standard instruments by the Langley method, and WMO regional standard instruments and other Dobson instruments in North America by direct comparison, and calibrates standard ultra-violet lamps to promote compatibility in solar radiation measurements. Much of this work is done on a cost-reimbursable or cost-sharing basis.

GMD collaborates with other institutions to compare and improve traceability, including National Metrology Institutes (such as NIST), the Bureau of International Weights and Measures (BIPM), WMO/GAW central facilities, and others that maintain long-term measurement programs. The Central UV Calibration Facility is a joint NOAA/NIST project.

Supporting Infrastructure #2: Atmospheric Baseline Observatories

At the core of the Global Monitoring Division’s global observation networks are the Atmospheric Baseline Observatories (ABOs). GMD’s four ABOs are strategically located far from human influence and local pollutants, to prevent contamination and sample the cleanest air possible. The long-term measurements from the ABOs are considered among the best in the world for understanding background atmospheric composition.

The ABOs are the only sites where measurements from GMD’s three research themes converge; NOAA instruments supporting greenhouse gas and carbon cycle feedback, surface radiative energy budget, and stratospheric ozone research are co-located in these remote locations. Four decades of data are critical to GMD’s understanding of atmospheric changes over time. Data from the ABOs are downloaded by thousands of researchers, resource managers, and policy makers and viewed by tens of thousands of people every year.

Not only are the ABOs critical for GMD research, they are also the backbone measurement sites for the WMO/GAW network and support numerous cooperative research projects. Being staffed by full-time NOAA and university employees, the ABOs provide world-class scientific support to U.S. state and federal agencies, universities, and foreign researchers. Collaboration at the

ABOs encourages data collection beyond GMD's research scope enhancing NOAA's understanding of the atmosphere.

Barrow: The Barrow Observatory (BRW), established in 1973, is located on the northern most point of the United States. It is about 8km northeast of the village of Utqiaġvik (formerly Barrow) and has a prevailing east-northeast wind off the Beaufort Sea.

Mauna Loa: The Mauna Loa Observatory (MLO), originally established in 1956, is located on the north flank of the Mauna Loa Volcano at 3,397 masl on the Big Island, Hawaii. GMD is currently the steward of 8 acres of land where buildings for MLO are located.

American Samoa: The American Samoa Observatory (SMO), established in 1974, is located on Cape Matutula, the northeastern tip of American Samoa. The observatory is situated on a 26.7-acre site that receives prevailing winds off the ocean.

South Pole: The South Pole Observatory (SPO), originally established in 1957, is located on Antarctica's polar plateau at 2,840 masl. SPO is the primary tenant of the NSF's Atmospheric Research Observatory, a building upwind of the main station on the border of the internationally recognized and managed Clean Air Sector. The NSF provides housing and logistical support for GMD's research at South Pole.

Evaluation Guidelines

For each research area reviewed, each reviewer will provide one of the following overall ratings:

- *Highest Performance:* Laboratory greatly exceeds the Satisfactory level and is outstanding in almost all areas.
- *Exceeds Expectations:* Laboratory goes well beyond the Satisfactory level and is outstanding in many areas.
- *Satisfactory:* Laboratory meets expectations and the criteria for a Satisfactory rating.
- *Needs Improvement:* Laboratory does not reach expectations and does not meet the criteria for a Satisfactory rating. The reviewer will identify specific problem areas that need to be addressed.

Reviewers are to consider the Quality, Relevance, and Performance of the Laboratory, and to provide one of the overall ratings above for each research area reviewed. We also ask that, in addition to the overall ratings for each research area, if possible, also assign one of these ratings for the subcategories of Quality, Relevance, and Performance within the research area reviewed. Ratings are relative to the Satisfactory definitions shown below.

1. **Quality:** Evaluate the quality of the Laboratory's research and development. Quality is a measurement of merit within the scientific community based on the novelty, soundness, accuracy, and reproducibility of a specific body of research, as represented by outputs delivered by the Laboratory. Assess whether appropriate policies are in place to ensure that high quality work will be performed in the future. Assess progress toward meeting OAR's

goal to conduct preeminent research as listed in the “Indicators of Preeminence.” Preeminence is tied to the frequency and level of peer review publication undertaken or supported by the Laboratory along with corresponding bibliometric data, as this information serves as a benchmark with which to compare the Laboratory to other organizations of similar size and scope.

- **Quality Rating Criteria:**
- *Satisfactory* rating – Laboratory scientists and leadership are often recognized for excellence through collaborations, research accomplishments, and national and international leadership positions. While good work is done, Laboratory scientists are not usually recognized for leadership in their fields.
- **Evaluation Questions to consider:**
  - Does the Laboratory conduct or support/fund preeminent research? Are the scientific products and/or technological advancements meritorious and do they significantly contribute to the scientific community?
  - How does the quality of the Laboratory’s research and development rank among Research and Development (R&D) programs in other U.S. federal agencies? Other science agencies/institutions?
  - Are appropriate approaches in place to ensure that high quality work will be done in the future?
  - Do Laboratory researchers demonstrate scientific leadership and excellence in their respective fields (e.g., through collaborations, research accomplishments, externally funded grants, awards, membership and fellowship in societies)?
  - Is the Laboratory supporting the right people doing the best science?
- **Indicators of Quality:** Indicators can include, but not be limited to the following (note: not all may be relevant to each Laboratory)
  - The Laboratory’s total number of refereed publications per unit time and/or per scientific Full Time Equivalent scientific staff (FTE).
  - A list of technologies (e.g. observing systems, information technology, numerical modeling algorithms) transferred to operations/application and an assessment of their significance/impact on operations.
  - The number of citations for the Laboratory’s scientific staff by individual or some aggregate.
  - A measure (often in the form of an index) that represents the value of either an individual scientist or the Laboratory’s integrated contribution of refereed publications to the advancement of knowledge (e.g., Hirsch Index). NOAA librarians recommend percentile analysis as the preferred bibliometric approach.
  - A list of awards won by groups and individuals for research, development, and/or application.
  - Elected positions on boards or executive level offices in prestigious organizations (e.g., the National Academy of Sciences, National Academy of Engineering, or fellowship in the American Meteorological Society, American Geophysical Union or the American Association for the Advancement of Science etc.).
  - Service of individuals in technical and scientific societies such as journal editorships, service on U.S. interagency groups, service of individuals on boards, steering groups, and committees of international research-coordination organizations. Evidence of collaboration with other national and international

research groups, both inside and outside of NOAA as well as within the Laboratory itself, including Cooperative Institutes and universities, as well as reimbursable support from non-NOAA sponsors.
- Significance and impact of involvement with patents, invention disclosures, Cooperative Research and Development Agreements and other activities with industry.
- Other forms of recognition from NOAA information customers such as decision-makers in government, private industry, the media, education communities, and the public.
- Contributions of data to national and international research, databases, and programs, and involvement in international quality-control activities to ensure accuracy, precision, inter-comparability, and accessibility of global data sets.

2. **Relevance**: Evaluate the degree to which the Laboratory's research and development is relevant to NOAA's and OAR's missions and of value to the Nation. It is a direct expression of the OAR Vision and corporate priorities– to deliver NOAA's Future needs. Relevance refers to the value of the Laboratory's activities to users beyond the scientific community, both in terms of hypothetical value and actual impact. It is measured by how well the specific research or activity supports OAR's and NOAA's missions and broader societal needs. This can come in the form of applying scientific knowledge to policy decisions, improving operational capabilities at NOAA's service lines, or patenting and licensing new products for commercial use. Assess whether the Laboratory identifies the overarching problem(s) it seeks to address and whether its activities address its goals, the goals of relevant inter-agency working groups, relevant legislative requirements, and impacts to society at large.
   - ➢ **Relevance Rating Criteria:**
     - *Satisfactory* rating -- The R&D enterprise of the Laboratory shows linkages to NOAA's and OAR's missions, Strategic Plan, OAR corporate priorities and Research Plan, and is of value to the Nation. There are some efforts to work with customer needs but these are not consistent throughout the research area. Transition plans for delivery of research products to customers or operators are being developed constantly abut do not yet cover all applicable activities.
   - ➢ **Evaluation Questions to consider:**
     - Does the research address existing (or future) societally relevant needs (national and international)?
     - How well does the research address issues identified in the NOAA strategic plan and research plans or other policy or guiding documents, including inter-agency working group goals and relevant legislative requirements?
     - Are customers engaged to ensure relevance of the research? How does the Laboratory foster an environmentally literate society and the future environmental workforce? What is the quality of outreach and education programming and products? Does the Lab have an identified Transition pathway (R2X) so their products are moved to the relevant customers?
     - Does the science and outreach conducted or funded by the Laboratory fulfill stakeholder needs, including the needs of other Line Offices?
     - Are there R&D topics relevant to national needs that the Laboratory should be pursuing but is not? Are there R&D topics in NOAA and OAR plans that the

Laboratory should be pursuing but is not?

- ➢ **Indicators of Relevance:** Indicators can include, but should not be limited to the following (note: not all may be relevant to each Laboratory)
  - A list of research products, information and services, models and model simulations, and an assessment of their impact by end users, including participation or leadership in national and international state-of-science assessments.
  - Evidence of linkages to objectives in the NOAA strategic plan (e.g., milestones completed in the Annual Operating Plan).
  - Successfully implemented transition plans with documentation of effective transitions to customers.
  - Economic value of Laboratory products, as demonstrated by cost-effectiveness and impacts analyses conducted by NOAA's Office of the Chief Economist.
  - Access to Laboratory products, as demonstrated by counts of hits/usage of and downloads from Laboratory web sites.
  - Evidence of public outreach, such as visitors to Laboratory, product demonstrations or local education efforts conducted by Laboratory personnel.

3. **Performance**: Evaluate the overall effectiveness with which the Laboratory executes its mission and meets NOAA Strategic Plan objectives and the needs of the nation, given its resources. Performance is a measurement of effectiveness (ability to achieve useful results) and efficiency (ability to achieve quality, relevance, and effectiveness in a timely fashion with minimal waste). It refers not only to how well tasks are executed, but also to the adequacy of the leadership, workforce, and infrastructure in place to meet the Laboratory's goals. One of the key criteria of performance is the quality of management: how well Laboratory leadership interacts with stakeholders, articulates its strategic direction, and manages its R&D portfolio. Performance therefore is also a measure of accountability: how well the Laboratory oversees and directs its own operations and how well those operations adhere to and further the goals of NOAA's and the Laboratory's strategic plans. Laboratories are judged on how well they plan and conduct their research and development. The evaluation will be conducted within the context of three sub-categories: **a) Research Leadership and Planning, b) Efficiency and Effectiveness, c) Transition of Research to Applications (when applicable and/or appropriate)**.
   - ➢ **Performance Rating Criteria:**
     - *Satisfactory* rating --
       - o The Laboratory generally has documented scientific objectives and strategies through strategic and implementation plans (e.g., Annual Operating Plan) and a process for evaluating and prioritizing activities.
       - o Laboratory management generally functions as a team and works to improve operations.
       - o The Laboratory usually demonstrates effectiveness in completing its established objectives, milestones, and products.
       - o The Laboratory often works to increase efficiency (e.g., through leveraging partnerships).
       - o The Laboratory is generally effective and efficient in delivering most of its products/outputs to applications, operations or users.

A. **Research Leadership and Planning**: Assess whether the Laboratory has clearly defined objectives, scope, and methodologies for its key projects.

- ➢ **Evaluation Questions to consider:**
  - Does the Laboratory have clearly defined and documented scientific objectives, rationale and methodologies for key projects?
  - Does the Laboratory have an evaluation process for projects: selecting/continuing those projects with consistently high marks for merit, application, and priority fit; ending projects; or transitioning projects? If so, how well does it adhere to that process?
  - How does the laboratory manage its transition process? What does the lab do throughout its research and development activities to enhance the likelihood of successful transitions?
  - Does the Laboratory identify the overarching problem(s) it seeks to address through research and development or science and outreach? Are scientists required to develop a good plan, execute that plan, and report on it?
  - Does the Laboratory have the leadership and flexibility (i.e., time and resources) to respond to unanticipated events or opportunities that require new research and development activities?
  - Does the Laboratory provide effective scientific leadership to and interaction with NOAA and the external community on issues within its purview?
  - Does Laboratory management function as a team and strive to improve operations? Are there institutional, managerial, resource, or other barriers to the team working effectively?
  - Has the Laboratory effectively responded to and/or implemented recommendations from previous science reviews?
- ➢ **Indicators of Leadership and Planning:** Indicators can include, but not be limited to, the following (Note: Not all may be relevant to each Laboratory).
  - Research Plan
  - Program/Project Implementation Plans
  - Transition Plans
  - Annual Operation Plan performance measures and milestones
  - Active involvement in NOAA planning and budgeting process
  - Early engagement with end users for technology
  - Final report of implementation of recommendations from previous reviews

B. **Efficiency and Effectiveness**: Assess the efficiency and effectiveness of the Laboratory's research and development, given its goals, resources, and constraints and how effective it is in obtaining needed resources through NOAA and other sources.

- ➢ **Evaluation Questions to consider:**
  - Does the Laboratory execute its research in an efficient and effective manner given its goals, resources, and constraints?
  - Is the Laboratory organized and managed to optimize the planning and execution of research, including the support of creativity? How well integrated is the work with NOAA's and OAR's planning and execution activities? Are there adequate inputs to NOAA's and OAR's planning and

budgeting processes?
  - Is the proportion of the Laboratory's external funding appropriate relative to its NOAA base funding?
  - Is the Laboratory leveraging relationships with internal and external collaborators and stakeholders to maximize research outputs?
  - Are human resources adequate to meet current and future needs? Is the Laboratory organized and managed to ensure diversity in its workforce? Does it provide professional development opportunities for staff?
  - Are appropriate resources and support services available? Are investments being made in the right places?
  - Is infrastructure sufficient to support high quality research and development?
  - How effective is oversight of the Laboratory? Are projects on track and meeting appropriate milestones and targets? What processes does management employ to monitor the execution of projects?
- ➢ **Indicators of Efficiency and Effectiveness:** Indicators can include, but should not be limited to, the following (Note: Not all may be relevant to each Laboratory).
  - List of active collaborations
  - Number, types, and longevity of partnerships (indicates how well the Laboratory leverages relationships with collaborators to maximize research outputs)
  - Funding breakout by source (indicates involvement and commitment of NOAA vs. external stakeholders)
  - Laboratory demographics (e.g. diversity)
  - Ability to meet required deadlines (e.g. reports to Congress)
  - Performance metrics of products and services.
  - Employee satisfaction (e.g. from internal surveys)

C. Transition of Research to Applications: How well has the Laboratory delivered products and communicated the results of their research? Evaluate its effectiveness in transitioning and/or disseminating its research and development into applications (operations, commercialization, and/or information services).
- ➢ **Evaluation Questions to consider:**
  - How well is the transition of research to applications, commercialization, and/or dissemination of knowledge planned and executed?
  - Are end users of the research and development involved in the planning and delivery of applications and/or information services? Are they satisfied?
  - Are the research results communicated to stakeholders and the public?
- ➢ **Indicators of Transition:** Indicators can include, but not be limited to, the following (Note: Not all may be relevant to each Laboratory).
  - A list of technologies (e.g. observing systems, information technology, numerical modeling algorithms) transferred to operations/application and an assessment of their significance/impact on operations/applications.
  - Significance and impact of transition to industry, including patents, license agreements and other related activities.

- Discussions or documentation from stakeholders.

Proposed Schedule and Time Commitment for Reviewers:
The review will be conducted May 21-24, 2018, in Boulder, Colorado, to coincide with GMD's annual science conference. Two teleconferences before the review are planned with the OAR Deputy Assistant Administrator for Programs and Administration, Ko Barrett, who will be the Executive liaison with the review team and for the completion of the report. All relevant information requested by the review team will be provided on the review website at least two weeks before the review.

Each reviewer is asked to independently prepare their written evaluations on each research theme, including an overall rating for the theme and provide these to the Chair with a copy to Philip Hoffman in OAR headquarters. The Chair, Dr. Anne Thompson, will create a report summarizing the individual evaluations. The Chair will not analyze individual comments or seek a consensus of the reviewers. We request that within 45 days of the review, the review team provide the draft summary report to Ko Barrett. Once the report is received, OAR staff will review the report to identify any factual errors and will send corrections to the review team. The final individual evaluations and the summary report are to be submitted to the OAR Assistant Administrator, Craig McLean.

Review Team Resources:
OAR will provide resources necessary for the review team to complete its work.
1. Review Team Support: Information to address each of the laboratory's research themes to be reviewed will be prepared and posted on a public review website. A copy of all the information on the website will also be provided to reviewers at the review.
2. Travel arrangements for the onsite review will be made by GMD and paid for by OAR.
3. On-site review team support to acquire and deliver to the team any additional relevant documents requested during the review which will aid in assessing the Laboratory.

Evaluation Worksheets
(Note in WORD the boxes below will expand to fit the text)
Evaluation Worksheet 1

Research Theme: Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks
Reviewer: **Overall Evaluation:** ☐ *Highest Performance*--Laboratory greatly exceeds the Satisfactory level and is outstanding in almost all areas. ☐ *Exceeds Expectations*--Laboratory goes well beyond the Satisfactory level and is outstanding in many areas. ☐ *Satisfactory*--Laboratory meets expectations and the criteria for a Satisfactory rating. ☐ *Needs Improvement*--Laboratory does not reach expectations and does not meet the criteria for a Satisfactory rating. The reviewer will identify specific problem areas that need to be addressed.
QUALITY ☐ Highest Performance ☐ Exceeds Expectations ☐ Satisfactory ☐ Needs Improvement
Comments and observations/findings:
RELEVANCE ☐ Highest Performance ☐ Exceeds Expectations ☐ Satisfactory ☐ Needs Improvement
Comments and observations/findings:
PERFORMANCE ☐ Highest Performance ☐ Exceeds Expectations ☐ Satisfactory ☐ Needs Improvement
Comments and observations/findings:
Recommendations for Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks **Please provide specific, actionable recommendations based on your observations/findings**

Evaluation Worksheet 2

Research Theme: Monitoring and Understanding Changes in Surface Radiation, Clouds, and Aerosol Distributions
Reviewer: **Overall Evaluation:** ☐ *Highest Performance*--Laboratory greatly exceeds the Satisfactory level and is outstanding in almost all areas. ☐ *Exceeds Expectations*--Laboratory goes well beyond the Satisfactory level and is outstanding in many areas. ☐ *Satisfactory*--Laboratory meets expectations and the criteria for a Satisfactory rating. ☐ *Needs Improvement*--Laboratory does not reach expectations and does not meet the criteria for a Satisfactory rating. The reviewer will identify specific problem areas that need to be addressed.
QUALITY ☐ Highest Performance ☐ Exceeds Expectations ☐ Satisfactory ☐ Needs Improvement
Comments and observations/findings:
RELEVANCE ☐ Highest Performance ☐ Exceeds Expectations ☐ Satisfactory ☐ Needs Improvement
Comments and observations/findings:
PERFORMANCE ☐ Highest Performance ☐ Exceeds Expectations ☐ Satisfactory ☐ Needs Improvement
Comments and observations/findings:
Recommendations for Monitoring and Understanding Changes in Surface Radiation, Clouds, and Aerosol Distributions **Please provide specific, actionable recommendations based on your observations/findings**

Evaluation Worksheet 3

Research Theme: Guiding Recovery of Stratospheric Ozone
Reviewer: **Overall Evaluation:** ☐ *Highest Performance*--Laboratory greatly exceeds the Satisfactory level and is outstanding in almost all areas. ☐ *Exceeds Expectations*--Laboratory goes well beyond the Satisfactory level and is outstanding in many areas. ☐ *Satisfactory*--Laboratory meets expectations and the criteria for a Satisfactory rating. ☐ *Needs Improvement*--Laboratory does not reach expectations and does not meet the criteria for a Satisfactory rating. The reviewer will identify specific problem areas that need to be addressed.
QUALITY ☐ Highest Performance ☐ Exceeds Expectations ☐ Satisfactory ☐ Needs Improvement
Comments and observations/findings:
RELEVANCE ☐ Highest Performance ☐ Exceeds Expectations ☐ Satisfactory ☐ Needs Improvement
Comments and observations/findings:
PERFORMANCE ☐ Highest Performance ☐ Exceeds Expectations ☐ Satisfactory ☐ Needs Improvement
Comments and observations/findings:
Recommendations for Guiding Recovery of Stratospheric Ozone **Please provide specific, actionable recommendations based on your observations/findings**

Evaluation Worksheet 4

Supporting Infrastructure #1: Calibrations and Standards

Reviewer:
Overall Evaluation:

☐ *Highest Performance*--Laboratory greatly exceeds the Satisfactory level and is outstanding in almost all areas.
☐ *Exceeds Expectations*--Laboratory goes well beyond the Satisfactory level and is outstanding in many areas.
☐ *Satisfactory*--Laboratory meets expectations and the criteria for a Satisfactory rating.
☐ *Needs Improvement*--Laboratory does not reach expectations and does not meet the criteria for a Satisfactory rating. The reviewer will identify specific problem areas that need to be addressed.

QUALITY ☐ Highest Performance ☐ Exceeds Expectations ☐ Satisfactory ☐ Needs Improvement

Comments and observations/findings:

RELEVANCE ☐ Highest Performance ☐ Exceeds Expectations ☐ Satisfactory ☐ Needs Improvement

Comments and observations/findings:

PERFORMANCE ☐ Highest Performance ☐ Exceeds Expectations ☐ Satisfactory ☐ Needs Improvement

Comments and observations/findings:

Recommendations for Calibrations and Standards
Please provide specific, actionable recommendations based on your observations/findings

Evaluation Worksheet 5

Supporting Infrastructure #2: Atmospheric Baseline Observatories
Reviewer: **Overall Evaluation:** ☐ *Highest Performance*--Laboratory greatly exceeds the Satisfactory level and is outstanding in almost all areas. ☐ *Exceeds Expectations*--Laboratory goes well beyond the Satisfactory level and is outstanding in many areas. ☐ *Satisfactory*--Laboratory meets expectations and the criteria for a Satisfactory rating. ☐ *Needs Improvement*--Laboratory does not reach expectations and does not meet the criteria for a Satisfactory rating. The reviewer will identify specific problem areas that need to be addressed.
QUALITY ☐ Highest Performance ☐ Exceeds Expectations ☐ Satisfactory ☐ Needs Improvement
Comments and observations/findings:
RELEVANCE ☐ Highest Performance ☐ Exceeds Expectations ☐ Satisfactory ☐ Needs Improvement
Comments and observations/findings:
PERFORMANCE ☐ Highest Performance ☐ Exceeds Expectations ☐ Satisfactory ☐ Needs Improvement
Comments and observations/findings:
Recommendations for Atmospheric Baseline Observatories **Please provide specific, actionable recommendations based on your observations/findings**

Reviewer Feedback Worksheet – Additional Comments and Feedback on the Review Process

Reviewer:
Additional comments for OAR and laboratory management:
Additional comments and suggestions on conduct of the review for use in future laboratory reviews Please help OAR improve our science review process by telling us what worked well and did not work well throughout the process. In order to reduce the burden on you and the Laboratory staff, we would like to provide only the useful background information. What information provided was especially useful or not useful in your evaluations? What additional information would have helped you in your evaluation? What information could have been omitted without impacting the quality of your review?

Global Monitoring Division

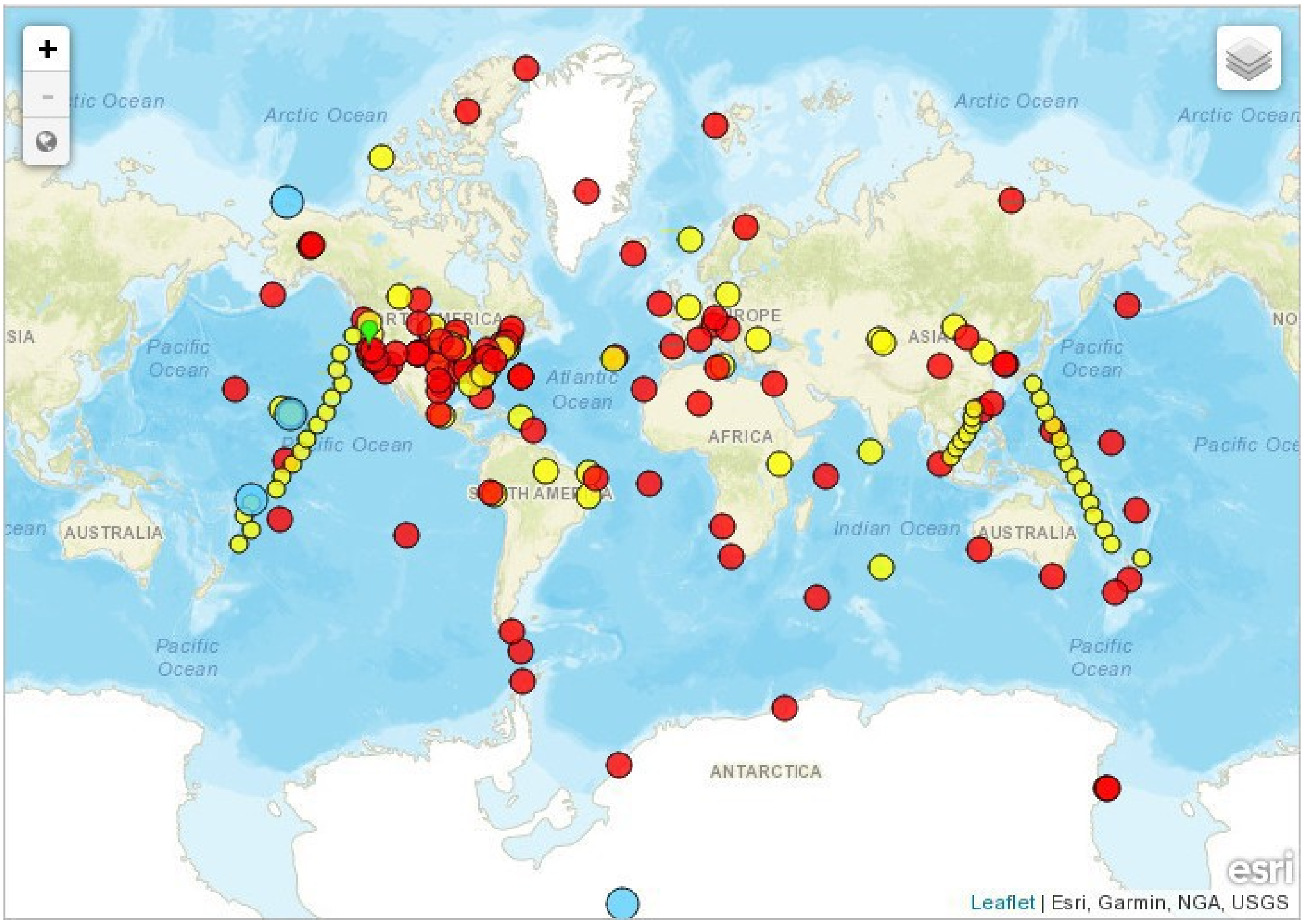
Sampling Sites, Measurement Programs and Data Sets

Contents:

Part 1: Observatory Measurements and Data Sets

Global Monitoring Division
NOAA, Boulder, Colorado

GMD Measurement and Data Set Locations



January 2018

Contacts:

Brian Vasel – 303-497-6655 – Brian.Vasel@noaa.gov
Russell Schnell – 303-497-6733 – Russell.C.Schnell@noaa.gov

Contents: Part 1: Observatory Measurements and Data Sets

Following two photographs of each observatory, the species measured at that observatory, first sample date and current status of the measurements can be found. All of the observatories are included even though Summit and Trinidad Head are not conducting the full complement of measurements as the other four Baseline Observatories, and are no longer considered a full GMD ABO. The data from all observatories and cooperative programs are archived and openly available to researchers.

All GMD data sets are available through GMD FTP sites or by contact with the GMD PI responsible for the data set. All data are available at the respective World Data Centers and are being formatted for archiving in the NOAA's National Centers for Environmental Information (NCEI).

These data sets are not the only GMD data sets available from the observatories and cooperative programs, but represent a sampling of the most requested data by scientists from around the globe.

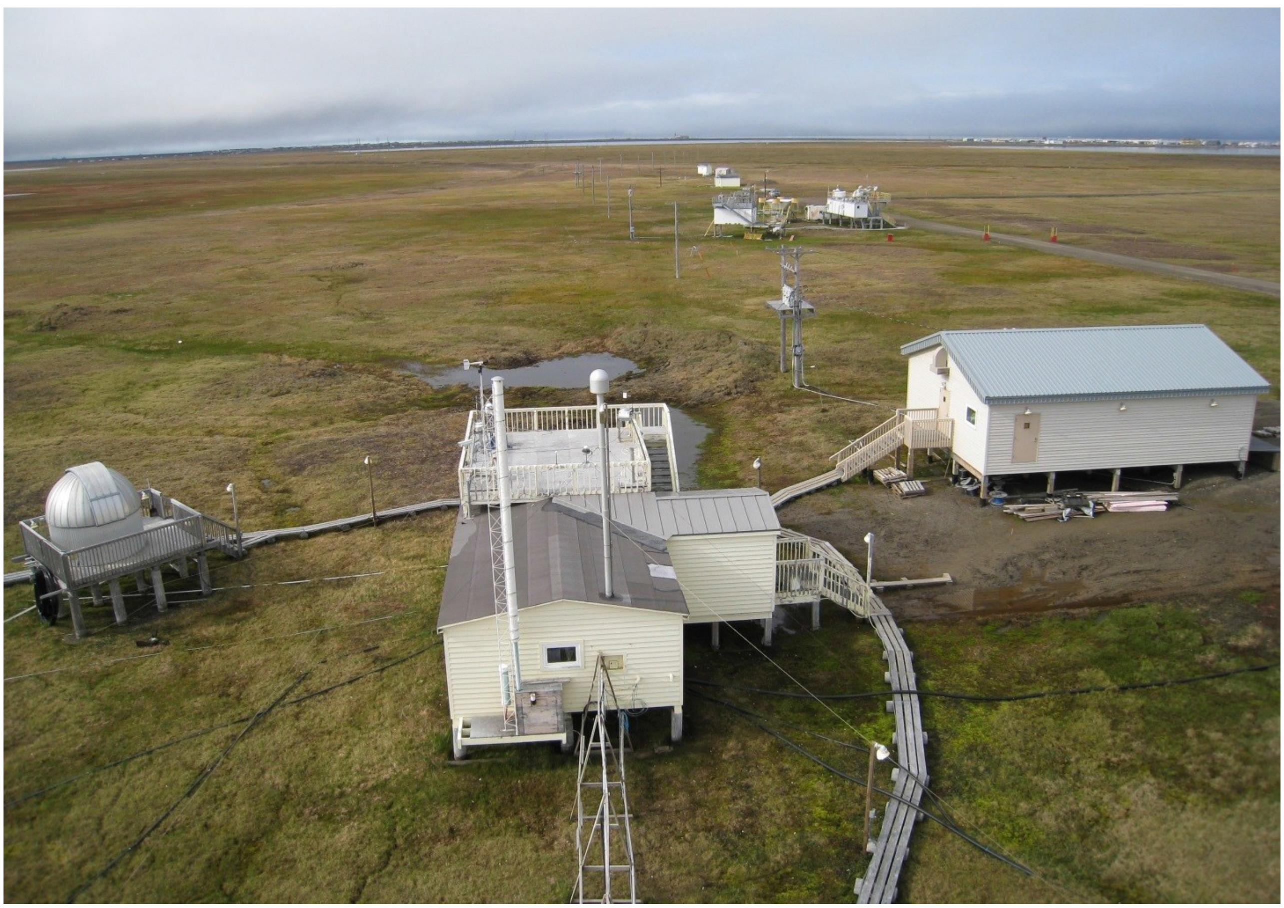
Part 2: GMD Measurements: National, International and Cooperative Programs

In Part 2, GMD measurements are listed by species and location of the measurements.

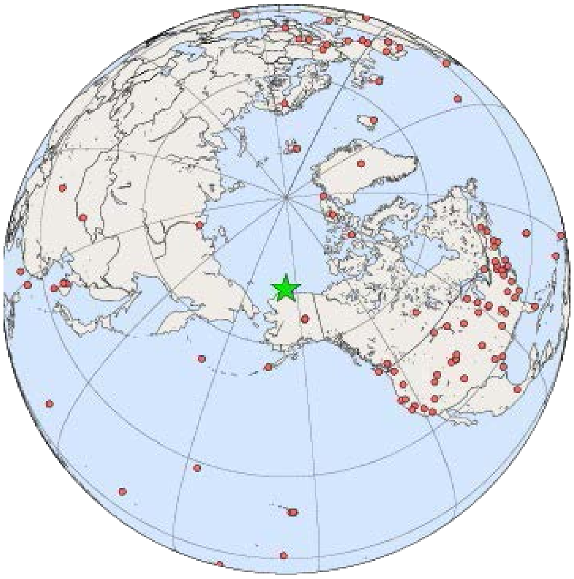
A summary of the species measured at the cooperative sites and in cooperative programs with a list of the programs and contact points round out Part 2.

GMD collects data from 196 sites globally with 76 being in the United States. The complete list is on the final page of Part 2.

Utqiaġvik (Barrow) Atmospheric Baseline Observatory in early winter.



Utqiaġvik (Barrow) Atmospheric Baseline Observatory in mid-summer.



Location

- Country: United States
- Latitude: 71.3230° North
- Longitude: 156.6114° West
- Elevation: 11.00 masl
- Time Zone: Local Standard Time + 9.0 hour(s) = UTC

Contact

- Contact Name: Bryan Thomas
- Address: Barrow Observatory
  P.O. Box 888
  Barrow, Alaska, 99723, United States
- Phone: (907) 852-6500
- Fax: (907) 852-4622

Data

- Available datasets
- Data visualization
- Photo Gallery

Description

Barrow Observatory, established in 1973, is located near sea level 8 km east of UtqiaÄ¡vik, Alaska at 71.32 degrees north. This facility is manned year around by 2 engineers/scientists who often commute to work in winter on snow machines. Due to its unique location, dedicated and highly trained staff, excellent power and communications infrastructure, the Barrow Observatory is host to numerous cooperative research projects from around the world.

BRW is located so that it receives minimal influence from anthropogenic effects. It is about 8 km northeast of the village of UtqiaÄ¡vik (formerly Barrow) and has a prevailing east-northeast wind off the Beaufort Sea. It is attended at least 5 days a week for routine inspection and maintenance of the instrumentation. In addition, the National Weather Service (NWS) maintains a weather observing facility in Barrow. Although the measurements at Barrow are made over open tundra, there are large lagoons and a number of lakes in the vicinity, and the Arctic Ocean is less than 3 km northwest of the site. Because of its proximity to these bodies of water and the fact that the prevailing winds are off the Beaufort Sea, BRW is perhaps best characterized as having an Arctic maritime climate affected by variations of weather and sea ice conditions in the Central Arctic.

GMD Projects at Barrow, Alaska

Carbon Cycle Surface Flasks

Parameter	Formula	First Sample Date	Status
Carbon Dioxide	CO_2	1971-04-25	Ongoing
Methane	CH_4	1983-04-06	Ongoing
Carbon Monoxide	CO	1988-07-24	Ongoing
Molecular Hydrogen	H_2	1988-07-24	Ongoing
Nitrous Oxide	N_2O	1997-05-02	Ongoing
Sulfur Hexafluoride	SF_6	1997-05-02	Ongoing
Carbon-13/Carbon-12 in Carbon Dioxide	$d^{13}C\ (CO_2)$	1990-01-06	Ongoing
Oxygen-18/Oxygen-16 in Carbon Dioxide	$d^{18}O\ (CO_2)$	1990-01-06	Ongoing
Carbon-13/Carbon-12 in Methane	$d^{13}C\ (CH_4)$	1998-01-03	Ongoing
D/H in Methane	$dD\ (CH_4)$	2005-04-01	Terminated - 2010-03-12
Methyl Chloride	CH_3Cl	2005-05-20	Ongoing
Benzene	C_6H_6	2007-02-16	Ongoing
toluene	C_7H_8	2007-02-16	Ongoing
ethane	C_2H_6	2005-05-20	Ongoing
ethene	C_2H_4	2005-05-20	Ongoing
propane	C_3H_8	2005-05-20	Ongoing
propene	C_3H_6	2005-05-20	Ongoing
i-butane	$i\text{-}C_4H_{10}$	2005-05-20	Ongoing

Parameter	Formula	First Sample Date	Status
n-butane	n-C_4H_{10}	2005-05-20	Ongoing
i-pentane	i-C_5H_{12}	2005-05-20	Ongoing
n-pentane	n-C_5H_{12}	2005-05-20	Ongoing
n-hexane	n-C_6H_{14}	2005-05-20	Ongoing
isoprene	C_5H_8	2007-02-16	Ongoing
Acetylene	C_2H_2	2007-05-25	Ongoing
Carbon-14/Carbon in Methane	$D^{14}C$ (CH_4)	2013-03-26	Ongoing
Carbon-13/Carbon-12 in Carbon Monoxide	$d^{13}C$ (CO)	1990-03-28	Terminated - 1996-08-21

Carbon Cycle In Situ Observatory

Parameter	Formula	First Sample Date	Status
Carbon Dioxide	CO_2	1973-07-24	Ongoing
Methane	CH_4	1986-01-29	Ongoing
Carbon Monoxide	CO	1991-09-11	Ongoing
Nitrous Oxide	N_2O	2013-06-27	Ongoing

HATS Flask Sampling

Parameter	Formula	First Sample Date	Status
Nitrous Oxide	N_2O	1994-12-24	Ongoing
Sulfur Hexafluoride	SF_6	1994-12-24	Ongoing
HFC- 134a	CH_2FCF_3	1994-11-25	Ongoing
HCFC-22	CHF_2Cl	1992-04-08	Ongoing
CFC- 12	CCl_2F_2	1994-12-24	Ongoing
Methyl Chloride	CH_3Cl	1994-04-15	Ongoing
CFC-114	CFC-114	1992-02-14	Ongoing
HCFC-142b	CH_3CF_2Cl	1992-04-08	Ongoing
Halon-1211	$CBrClF_2$	1992-02-14	Ongoing
methyl bromide	CH_3Br	1994-01-26	Ongoing
HCFC-141b	CH_3CCl_2F	1993-01-07	Ongoing
methyl iodide	CH_3I	1994-03-23	Ongoing
CFC-113	CCl_2FCClF_2	1992-02-14	Ongoing
dichloromethane	CH_2Cl_2	1994-04-15	Ongoing
chloroform	$CHCl_3$	1992-12-17	Ongoing
carbon tetrachloride	CCl_4	1995-01-10	Ongoing
dibromomethane	CH_2Br_2	1998-03-07	Ongoing
tetrachloroethylene	C_2Cl_4	1993-12-11	Ongoing
bromoform	$CHBr_3$	1998-01-17	Ongoing
Benzene	C_6H_6	1999-02-12	Ongoing
carbonyl sulfide	COS	2000-03-25	Ongoing
HCFC-21	$CHCl_2F$	2000-08-03	Ongoing
HFC-152a	CH_3CHF_2	2000-08-03	Ongoing
toluene	C_7H_8	2014-10-03	Terminated - 2017-04-24
carbonyl disulfide	CS_2	2005-04-22	Terminated - 2015-03-13
ethane	C_2H_6	2014-10-03	Ongoing
propane	C_3H_8	2007-01-19	Ongoing
i-butane	i-C_4H_{10}	2014-10-03	Ongoing

Parameter	Formula	First Sample Date	Status
n-butane	n-C_4H_{10}	2007-01-19	Ongoing
i-pentane	i-C_5H_{12}	2007-01-19	Ongoing
n-pentane	n-C_5H_{12}	2007-01-19	Ongoing
n-hexane	n-C_6H_{14}	2013-04-30	Ongoing
Halon 1301	CF_3Br	2004-02-14	Ongoing
Halon 2402	$CBrF_2CBrF_2$	1995-02-25	Ongoing
HFC- 143a	CH_3CF_3	2007-01-19	Ongoing
HFC-227ea	CF_3CHFCF_3	2011-06-13	Ongoing
HFC-365mfc	$CH_3CF_2CH_2CF_3$	2009-08-10	Ongoing
CFC-115	$CClF_2CF_3$	2007-01-19	Ongoing
HFC-125	CHF_2CF_3	2007-01-19	Ongoing
CFC- 13	$CClF_3$	2007-01-19	Ongoing
Perfluoropropane	C_3F_8	2014-10-03	Ongoing
Acetylene	C_2H_2	2007-01-19	Ongoing
HFC-32	CH_2F_2	2009-03-26	Ongoing
Methyl Chloroform	CH_3CCl_3	1992-04-08	Ongoing
Chloroiodomethane	CH_2ClI	2017-02-10	Ongoing
diiodomethane	CH_2I_2	2017-02-10	Ongoing
Bromoiodomethane	CH_2BrI	2017-02-10	Ongoing
Bromochloromethane	CH_2BrCl	2017-02-10	Ongoing
Bromodichloromethane	$CHBrCl_2$	2017-02-10	Ongoing
CFC- 11	CCl_3F	1994-12-24	Ongoing
tetrafluoromethane	CF_4	2014-10-03	Ongoing
hexafluoroethane	CF_3CF_3	2014-10-03	Ongoing
nitrogen trifluoride	NF_3	2014-10-03	Ongoing
sulfuryl fluoride	SO_2F_2	2015-06-19	Ongoing
HFC-236fa	$CF_3CH_2CF_3$	2014-10-03	Ongoing
HCFC-133a	CH_2ClCF_3	2014-10-03	Ongoing
CFC-112	CCl_3CClF_2	2014-10-10	Ongoing
HFO-1234yf	$CH_2=CFCF_3$	2016-08-29	Ongoing
1,2-dichloroethane	CH_2ClCH_2Cl	2017-01-24	Ongoing
2,2-Dichloro-1,1,1-Trifluoroethane	$CHCl_2CF_3$	2017-11-27	Ongoing
1,1-dichloroethane	$C_2H_4Cl_2$	2017-02-10	Ongoing
dibromochloromethane	$CHBr_2Cl$	2017-02-10	Ongoing
Ethyl Chloride	C_2H_5Cl	2011-06-13	Ongoing
Propyne	C_3H_4	2011-06-13	Ongoing
Trichloroethylene	C_2HCl_3	2014-10-03	Ongoing

HATS InSitu Observatory

Parameter	Formula	First Sample Date	Status
Nitrous Oxide	N_2O	1998-06-16	Ongoing
Sulfur Hexafluoride	SF_6	1998-06-15	Ongoing
HCFC-22	CHF_2Cl	1998-11-12	Ongoing
CFC- 12	CCl_2F_2	1998-06-16	Ongoing
Methyl Chloride	CH_3Cl	1998-08-30	Ongoing

Parameter	Formula	First Sample Date	Status
HCFC-142b	CH_3CF_2Cl	1998-09-03	Ongoing
Halon-1211	$CBrClF_2$	1998-06-15	Ongoing
CFC-113	CCl_2FCClF_2	1998-06-16	Ongoing
chloroform	$CHCl_3$	1998-06-01	Ongoing
carbon tetrachloride	CCl_4	1998-06-16	Ongoing
Methyl Chloroform	CH_3CCl_3	1998-06-16	Ongoing
CFC- 11	CCl_3F	1998-06-16	Ongoing

Aerosol Surface In-Situ

Parameter	Formula	First Sample Date	Status
Light Scattering Coefficient	Ïƒ$_{sp}$	1976-05-07	Ongoing
Light Absorption Coefficient	Ïƒ$_{ap}$	1988-01-01	Ongoing
Particle Number Concentration	N_t	1976-05-07	Ongoing
Aerosol Chemical Composition		1998-01-01	Ongoing
Cloud condensation nucleus number concentration	N_{ccn}	2006-08-12	Terminated - 2012-12-22
Aerosol Hygroscopic Growth	f(RH)	2006-08-21	Terminated - 2013-10-18

Radiation In-Situ Observatory

Parameter	Formula	First Sample Date	Status
Direct Normal		1976-03-01	Ongoing
Downwelling Shortwave		1976-03-01	Ongoing
Diffuse		1995-07-05	Ongoing
Upwelling Shortwave		1985-01-01	Ongoing
Downwelling Longwave		1993-04-20	Ongoing
Upwelling Longwave		1993-04-20	Ongoing
Spectral		2001-04-01	Ongoing

Surface Ozone

Parameter	Formula	First Sample Date	Status
Ozone	O_3	1973-03-14	Ongoing

Dobson Total Ozone

Parameter	Formula	First Sample Date	Status
Ozone	O_3	1973-07-29	Ongoing

Meteorology

Parameter	Formula	First Sample Date	Status
Wind Speed	ws	1973-02-17	Ongoing
Wind Direction	wd	1973-02-17	Ongoing
Temperature	temp	1976-01-01	Ongoing
Ambient Pressure	press	1976-01-01	Ongoing
Relative Humidity	rh	1976-01-01	Ongoing

GMD Datasets for Barrow, Alaska

	Site	Category	Name	Type	Frequency	Year
1	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Daily Averages	Multiple
2	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Daily Averages	Multiple
3	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Daily Averages	Multiple
4	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-113 (cfc113)	Insitu	Daily Averages	Multiple
5	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Daily Averages	Multiple
6	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloride (ch3cl)	Insitu	Daily Averages	Multiple
7	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	Halon-1211 (h1211)	Insitu	Daily Averages	Multiple
8	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-142b (hcfc142b)	Insitu	Daily Averages	Multiple
9	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-22 (hcfc22)	Insitu	Daily Averages	Multiple
10	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Daily Averages	Multiple
11	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Sulfur Hexafluoride (sf6)	Insitu	Daily Averages	Multiple
12	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Hourly Averages	Multiple
13	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Hourly Averages	Multiple
14	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Hourly Averages	Multiple
15	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-113 (cfc113)	Insitu	Hourly Averages	Multiple
16	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Hourly Averages	Multiple
17	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloride (ch3cl)	Insitu	Hourly Averages	Multiple
18	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	Halon-1211 (h1211)	Insitu	Hourly Averages	Multiple
19	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-142b (hcfc142b)	Insitu	Hourly Averages	Multiple
20	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-22 (hcfc22)	Insitu	Hourly Averages	Multiple
21	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Hourly Averages	Multiple
22	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Sulfur Hexafluoride (sf6)	Insitu	Hourly Averages	Multiple
23	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Monthly Averages	Multiple
24	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Monthly Averages	Multiple
25	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Monthly Averages	Multiple
26	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-113 (cfc113)	Insitu	Monthly Averages	Multiple

	Site	Category	Name	Type	Frequency	Year
27	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Monthly Averages	Multiple
28	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloride (ch3cl)	Insitu	Monthly Averages	Multiple
29	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	Halon-1211 (h1211)	Insitu	Monthly Averages	Multiple
30	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-142b (hcfc142b)	Insitu	Monthly Averages	Multiple
31	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-22 (hcfc22)	Insitu	Monthly Averages	Multiple
32	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Monthly Averages	Multiple
33	Barrow, Alaska, United States (BRW) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Sulfur Hexafluoride (sf6)	Insitu	Monthly Averages	Multiple
34	Barrow, Alaska, United States (BRW) Continuous in-situ RITS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Daily Averages	Multiple
35	Barrow, Alaska, United States (BRW) Continuous in-situ RITS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Daily Averages	Multiple
36	Barrow, Alaska, United States (BRW) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Daily Averages	Multiple
37	Barrow, Alaska, United States (BRW) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Daily Averages	Multiple
38	Barrow, Alaska, United States (BRW) Continuous in-situ RITS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Daily Averages	Multiple
39	Barrow, Alaska, United States (BRW) Continuous in-situ RITS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Hourly Averages	Multiple
40	Barrow, Alaska, United States (BRW) Continuous in-situ RITS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Hourly Averages	Multiple
41	Barrow, Alaska, United States (BRW) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Hourly Averages	Multiple
42	Barrow, Alaska, United States (BRW) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Hourly Averages	Multiple
43	Barrow, Alaska, United States (BRW) Continuous in-situ RITS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Hourly Averages	Multiple
44	Barrow, Alaska, United States (BRW) Continuous in-situ RITS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Monthly Averages	Multiple
45	Barrow, Alaska, United States (BRW) Continuous in-situ RITS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Monthly Averages	Multiple
46	Barrow, Alaska, United States (BRW) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Monthly Averages	Multiple
47	Barrow, Alaska, United States (BRW) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Monthly Averages	Multiple
48	Barrow, Alaska, United States (BRW) Continuous in-situ RITS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Monthly Averages	Multiple
49	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1973
50	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1974
51	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1975
52	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1976
53	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1977

	Site	Category	Name	Type	Frequency	Year
54	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1978
55	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1979
56	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1980
57	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1981
58	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1982
59	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1983
60	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1984
61	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1985
62	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1986
63	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1987
64	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1988
65	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1989
66	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1990
67	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1991
68	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1992
69	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1993
70	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1994
71	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1995
72	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1996
73	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1997
74	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1998
75	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1999
76	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2000
77	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2001
78	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2002
79	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2003
80	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2004
81	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2005
82	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2006
83	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2007

	Site	Category	Name	Type	Frequency	Year
84	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2008
85	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2009
86	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2010
87	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2011
88	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2012
89	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2013
90	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2014
91	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2015
92	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2016
93	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2017
94	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1988
95	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1989
96	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1990
97	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1991
98	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1992
99	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1993
100	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1994
101	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1995
102	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1996
103	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1997
104	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1998
105	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1999
106	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2000
107	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2001
108	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2002
109	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2003
110	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2004
111	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2005
112	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2006
113	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2007

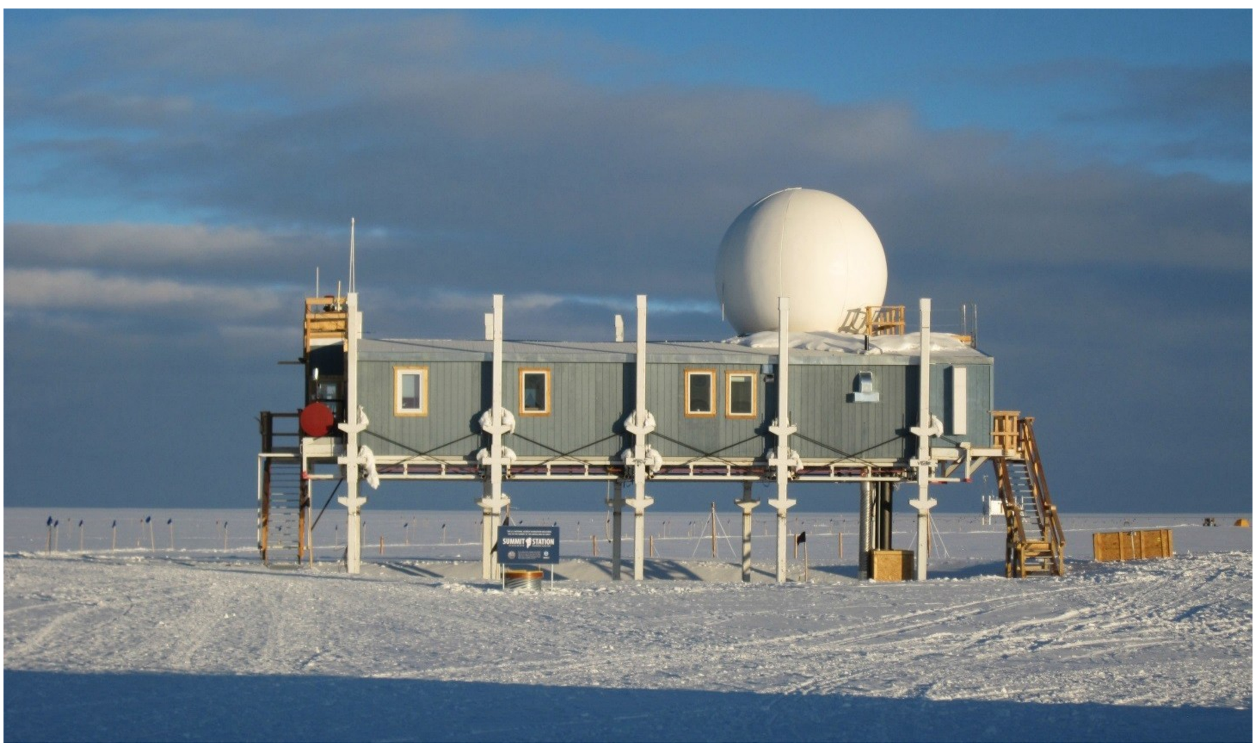
	Site	Category	Name	Type	Frequency	Year
114	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2008
115	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2009
116	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2010
117	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2011
118	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2012
119	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2013
120	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2014
121	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2015
122	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2016
123	Barrow, Alaska, United States (BRW) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2017
124	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1976
125	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1977
126	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1978
127	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1979
128	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1980
129	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1981
130	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1982
131	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1983
132	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1984
133	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1985
134	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1986
135	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1987
136	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1988
137	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1989

	Site	Category	Name	Type	Frequency	Year
138	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1990
139	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1991
140	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1992
141	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1993
142	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1994
143	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1995
144	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1996
145	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1997
146	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1998
147	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1999
148	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2000
149	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2001
150	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2002
151	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2003
152	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2004
153	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2005
154	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2006
155	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2007
156	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2008
157	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2009
158	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2010
159	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2011

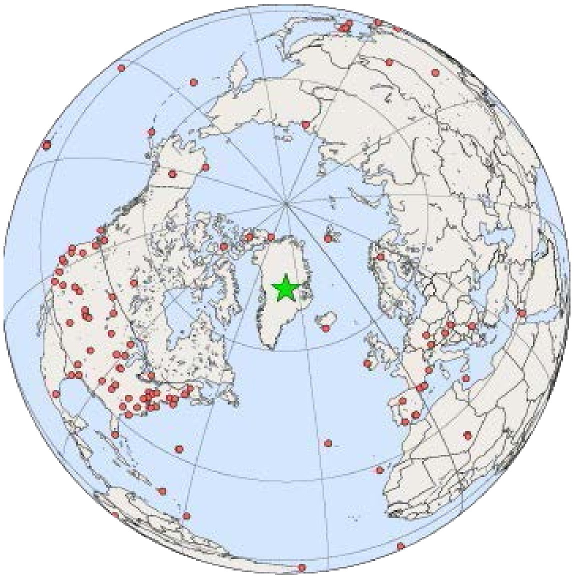
	Site	Category	Name	Type	Frequency	Year
160	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2012
161	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2013
162	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2014
163	Barrow, Alaska, United States (BRW) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2015
164	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	ethane (C_2H_6)	Flask	Discrete	Multiple
165	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	propane (C_3H_8)	Flask	Discrete	Multiple
166	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	isoprene (C_5H_8)	Flask	Discrete	Multiple
167	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Greenhouse Gases	Methane (CH_4)	Flask	Discrete	Multiple
168	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Methane ($d^{13}C$ (CH_4))	Flask	Discrete	Multiple
169	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Monoxide (CO)	Flask	Discrete	Multiple
170	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Dioxide (CO_2)	Flask	Discrete	Multiple
171	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Carbon Dioxide ($d^{13}C$ (CO_2))	Flask	Discrete	Multiple
172	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Greenhouse Gases	O18/O16 in Carbon Dioxide ($d^{18}O$ (CO_2))	Flask	Discrete	Multiple
173	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Greenhouse Gases	Molecular Hydrogen (H_2)	Flask	Discrete	Multiple
174	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	i-butane (i-C_4H_{10})	Flask	Discrete	Multiple
175	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	i- pentane (i- C_5H_{12})	Flask	Discrete	Multiple
176	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	n- butane (n-C_4H_{10})	Flask	Discrete	Multiple
177	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	n- pentane (n- C_5H_{12})	Flask	Discrete	Multiple
178	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Greenhouse Gases	Methane (CH_4)	Flask	Monthly Averages	Multiple
179	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Methane ($d^{13}C$ (CH_4))	Flask	Monthly Averages	Multiple
180	Barrow, Alaska, United States (BRW)	Greenhouse Gases	Carbon Monoxide (CO)	Flask	Monthly	Multiple
181	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Dioxide (CO_2)	Flask	Monthly Averages	Multiple
182	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Carbon Dioxide ($d^{13}C$ (CO_2))	Flask	Monthly Averages	Multiple
183	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Greenhouse Gases	O18/O16 in Carbon Dioxide ($d^{18}O$ (CO_2))	Flask	Monthly Averages	Multiple
184	Barrow, Alaska, United States (BRW) Air samples collected in glass flasks.	Greenhouse Gases	Molecular Hydrogen (H_2)	Flask	Monthly Averages	Multiple

	Site	Category	Name	Type	Frequency	Year
185	Barrow, Alaska, United States (BRW) Continuous in-situ measurements of solar radiation.	Radiation	Surface Radiation (grad)	Insitu	Minute Averages	Multiple
186	Barrow, Alaska, United States (BRW) Continuous measurements of surface ozone.	Ozone	Ozone (O_3)	Insitu	Hourly Averages	Multiple
187	Barrow, Alaska, United States (BRW) In-situ ch4 daily averages	Greenhouse Gases	Methane (CH_4)	Insitu	Daily Averages	Multiple
188	Barrow, Alaska, United States (BRW) In-situ ch4 hourly averages	Greenhouse Gases	Methane (CH_4)	Insitu	Hourly Averages	HourlyData
189	Barrow, Alaska, United States (BRW) In-situ ch4 monthly averages	Greenhouse Gases	Methane (CH_4)	Insitu	Monthly Averages	Multiple
190	Barrow, Alaska, United States (BRW) In-situ co2 daily averages	Greenhouse Gases	Carbon Dioxide (CO_2)	Insitu	Daily Averages	Multiple
191	Barrow, Alaska, United States (BRW) In-situ co2 hourly averages	Greenhouse Gases	Carbon Dioxide (CO_2)	Insitu	Hourly Averages	Multiple
192	Barrow, Alaska, United States (BRW) In-situ co2 monthly averages	Greenhouse Gases	Carbon Dioxide (CO_2)	Insitu	Monthly Averages	Multiple

Summit, Greenland, Atmospheric Watch Observatory where 108 trace gas (weekly flasks, aerosol and continuous meteorological measurements are maintained.



Central support, kitchen and communications (the “Big House”) building, Summit, Greenland.



Location

- Country: Greenland
- Latitude: 72.5962° North
- Longitude: 38.422° West
- Elevation: 3209.54 masl
- Time Zone: Local Standard Time + 2.0 hour(s) = UTC

Data

- Available datasets
- Data visualization
- Publications
- Personnel
- Current Weather
- Photo Gallery

Cooperating Agencies

- National Science Foundation Office of Polar Programs

Description

The Greenland Environmental Observatory (GEOSummit) on the summit of the Greenland Ice Sheet (3200 m above sea level) was established by the U.S. National Science Foundation (NSF) and the Danish Commission for Scientific Research in Greenland to provide year-round, long-term measurements for monitoring and investigations of the Arctic environment. The multidisciplinary facility is home to several year-round investigations as well as numerous seasonal campaigns which take advantage of the unique location of the observatory. GEOSummit provides investigators ease of access to the highest site north of the Arctic Circle. Since 1989, when the GISP II ice-coring activities began, the site has hosted numerous atmospheric and glaciological investigations. Following two trial winter over periods (1997-1998, and 2000-2002), the NSF Long Term Observatory (LTO) program committed funding to maintain year-round measurements of key baseline variables of climate change at the site. In addition, several programs funded through European agencies have a year round presence at the site.

Logistical support at Summit is provided by CH2M HILL Polar Services, under contract to NSF. NOAA has maintained a presence at Summit since the mid 1990s, begun mainly to conduct greenhouse gas measurements, with NOAA and NSF technicians working together to ensure continuity of data. From 2005 to present, NOAA Corps Officers have served as technicians during various phases throughout the year. Beginning in August of 2009, NOAA staff became a year-round permanent addition to the station crew, ensuring the long-term continuity of NOAA data and providing additional scientific support for the site.

The NOAA Summit Atmospheric Baseline Observatory was downgraded from its status as a full “Observatory” to a “Sampling Site” on August 1, 2017. NOAA technician time and cargo intensive projects in the NOAA measurement suite were removed from the site. However, surface ozone monitoring instrumentation, a basic meteorology system, aerosol instrumentation, and halocarbon and greenhouse gas flask sampling capabilities continue to operate at the site in partnership with the NSF. The downgrade follows a Global Monitoring Division-wide evaluation of scientific goals and global observing network capabilities that resulted in realignment to best meet NOAA's mission and the nation's scientific needs.

All data from Summit are available on the Global Monitoring Division's website: https://esrl.noaa.gov/gmd/dv/data/index.php?site=sum

GMD Projects at Summit

Carbon Cycle Surface Flasks

Parameter	Formula	First Sample Date	Status
Carbon Dioxide	CO_2	1997-06-23	Ongoing
Methane	CH_4	1997-06-23	Ongoing
Carbon Monoxide	CO	1997-06-23	Ongoing
Molecular Hydrogen	H_2	1997-06-23	Ongoing
Nitrous Oxide	N_2O	1997-06-23	Ongoing
Sulfur Hexafluoride	SF_6	1997-06-23	Ongoing
Carbon-13/Carbon-12 in Carbon Dioxide	$d^{13}C$ (CO_2)	1997-06-23	Ongoing
Oxygen-18/Oxygen-16 in Carbon Dioxide	$d^{18}O$ (CO_2)	1997-06-23	Ongoing
Carbon-13/Carbon-12 in Methane	$d^{13}C$ (CH_4)	2010-04-27	Ongoing
Methyl Chloride	CH_3Cl	2004-10-18	Ongoing
Benzene	C_6H_6	2006-07-17	Ongoing
toluene	C_7H_8	2006-07-17	Ongoing

Parameter	Formula	First Sample Date	Status
ethane	C_2H_6	2004-10-18	Ongoing
ethene	C_2H_4	2004-10-18	Ongoing
propane	C_3H_8	2004-10-18	Ongoing
propene	C_3H_6	2004-10-18	Ongoing
i-butane	i-C_4H_{10}	2004-10-18	Ongoing
n-butane	n-C_4H_{10}	2004-10-18	Ongoing
i-pentane	i-C_5H_{12}	2004-10-18	Ongoing
n-pentane	n-C_5H_{12}	2004-10-18	Ongoing
n-hexane	n-C_6H_{14}	2004-10-18	Ongoing
Wind Speed	ws	1997-06-23	Ongoing
Wind Direction	wd	1997-06-23	Ongoing
Temperature	temp	2004-05-10	Terminated - 2004-08-09
isoprene	C_5H_8	2006-07-17	Ongoing
Acetylene	C_2H_2	2007-09-24	Ongoing

HATS Flask Sampling

Parameter	Formula	First Sample Date	Status
Nitrous Oxide	N_2O	2004-06-20	Ongoing
Sulfur Hexafluoride	SF_6	2004-06-20	Ongoing
HFC- 134a	CH_2FCF_3	2004-06-20	Ongoing
HCFC-22	CHF_2Cl	2004-06-20	Ongoing
CFC- 12	CCl_2F_2	2004-06-20	Ongoing
Methyl Chloride	CH_3Cl	2004-06-20	Ongoing
CFC-114	CFC-114	2004-06-20	Ongoing
HCFC-142b	CH_3CF_2Cl	2004-06-20	Ongoing
Halon-1211	$CBrClF_2$	2004-06-20	Ongoing
methyl bromide	CH_3Br	2004-06-20	Ongoing
HCFC-141b	CH_3CCl_2F	2004-06-20	Ongoing
methyl iodide	CH_3I	2004-06-20	Ongoing
CFC-113	CCl_2FCClF_2	2004-06-20	Ongoing
dichloromethane	CH_2Cl_2	2004-06-20	Ongoing
chloroform	$CHCl_3$	2004-06-20	Ongoing
carbon tetrachloride	CCl_4	2004-06-20	Ongoing
dibromomethane	CH_2Br_2	2004-06-20	Ongoing
tetrachloroethylene	C_2Cl_4	2009-03-10	Ongoing
bromoform	$CHBr_3$	2004-06-20	Ongoing
Benzene	C_6H_6	2004-06-20	Ongoing
carbonyl sulfide	COS	2004-06-20	Ongoing
HCFC-21	$CHCl_2F$	2004-06-20	Ongoing
HFC-152a	CH_3CHF_2	2004-06-20	Ongoing
toluene	C_7H_8	2014-08-13	Terminated - 2016-08-30
carbonyl disulfide	CS_2	2005-03-08	Ongoing
ethane	C_2H_6	2014-08-13	Ongoing
propane	C_3H_8	2014-08-13	Ongoing
i-butane	i-C_4H_{10}	2014-08-13	Ongoing
n-butane	n-C_4H_{10}	2014-08-13	Ongoing

Parameter	Formula	First Sample Date	Status
i-pentane	i-C_5H_{12}	2014-08-13	Ongoing
n-pentane	n-C_5H_{12}	2012-08-15	Ongoing
n-hexane	n-C_6H_{14}	2012-08-15	Ongoing
Halon 1301	CF_3Br	2005-03-22	Ongoing
Halon 2402	$CBrF_2CBrF_2$	2009-03-10	Ongoing
HFC- 143a	CH_3CF_3	2014-08-13	Ongoing
HFC-227ea	CF_3CHFCF_3	2011-05-08	Ongoing
HFC-365mfc	$CH_3CF_2CH_2CF_3$	2009-06-08	Ongoing
CFC-115	$CClF_2CF_3$	2014-08-13	Ongoing
HFC-125	CHF_2CF_3	2014-08-13	Ongoing
CFC- 13	$CClF_3$	2014-08-13	Ongoing
Perfluoropropane	C_3F_8	2014-08-13	Ongoing
Acetylene	C_2H_2	2014-08-13	Ongoing
HFC-32	CH_2F_2	2014-08-13	Ongoing
Methyl Chloroform	CH_3CCl_3	2004-06-20	Ongoing
Chloroiodomethane	CH_2ClI	2016-09-13	Ongoing
diiodomethane	CH_2I_2	2016-09-13	Ongoing
Bromoiodomethane	CH_2BrI	2016-09-13	Ongoing
Bromochloromethane	CH_2BrCl	2016-09-13	Ongoing
Bromodichloromethane	$CHBrCl_2$	2016-09-13	Ongoing
CFC- 11	CCl_3F	2004-06-20	Ongoing
tetrafluoromethane	CF_4	2014-08-13	Ongoing
hexafluoroethane	CF_3CF_3	2014-08-13	Ongoing
nitrogen trifluoride	NF_3	2014-08-13	Ongoing
sulfuryl fluoride	SO_2F_2	2014-08-13	Ongoing
HFC-236fa	$CF_3CH_2CF_3$	2014-08-13	Ongoing
HCFC-133a	CH_2ClCF_3	2014-08-21	Ongoing
CFC-112	CCl_3CClF_2	2014-08-21	Ongoing
HFO-1234yf	$CH_2=CFCF_3$	2016-07-28	Ongoing
1,2-dichloroethane	CH_2ClCH_2Cl	2016-09-13	Ongoing
1,1-dichloroethane	$C_2H_4Cl_2$	2016-09-13	Ongoing
dibromochloromethane	$CHBr_2Cl$	2016-09-13	Ongoing
Ethyl Chloride	C_2H_5Cl	2011-05-08	Ongoing
Propyne	C_3H_4	2011-05-08	Ongoing
Trichloroethylene	C_2HCl_3	2014-08-13	Ongoing

HATS InSitu Observatory

Parameter	Formula	First Sample Date	Status
Methane	CH_4	2007-07-01	Ongoing
Carbon Monoxide	CO	2007-07-01	Ongoing
Molecular Hydrogen	H_2	2007-07-01	Ongoing
Nitrous Oxide	N_2O	2007-07-16	Ongoing
Sulfur Hexafluoride	SF_6	2007-07-16	Ongoing
CFC- 12	CCl_2F_2	2007-07-24	Ongoing

Parameter	Formula	First Sample Date	Status
Halon-1211	$CBrClF_2$	2007-11-22	Ongoing
CFC-113	CCl_2FCClF_2	2007-07-20	Ongoing
chloroform	$CHCl_3$	2007-07-01	Ongoing
carbon tetrachloride	CCl_4	2007-07-20	Ongoing
Methyl Chloroform	CH_3CCl_3	2007-07-20	Ongoing
CFC- 11	CCl_3F	2007-07-20	Ongoing

Aerosol Surface In-Situ

Parameter	Formula	First Sample Date	Status
Light Scattering Coefficient	Ïƒ$_{sp}$	2011-01-10	Ongoing
Light Absorption Coefficient	Ïƒ$_{ap}$	2011-01-10	Ongoing
Particle Number Concentration	N_t	2011-01-10	Terminated - 2011-07-21

Radiation In-Situ Observatory

Parameter	Formula	First Sample Date	Status
Direct Normal		2006-05-28	Terminated - 2017-04-30
Downwelling Shortwave		2006-05-28	Terminated - 2017-04-30
Diffuse		2006-05-28	Terminated - 2017-04-30
Upwelling Shortwave		2006-05-28	Terminated - 2017-04-30
Downwelling Longwave		2006-05-28	Terminated - 2017-04-30
Upwelling Longwave		2006-05-28	Terminated - 2017-04-30

Surface Ozone

Parameter	Formula	First Sample Date	Status
Ozone	O_3	2000-06-01	Ongoing

Ozonesonde

Parameter	Formula	First Sample Date	Status
Ozone	O_3	2005-02-12	Terminated - 2017-07-25

Meteorology

Parameter	Formula	First Sample Date	Status
Wind Speed	ws	2008-06-25	Ongoing
Wind Direction	wd	2008-06-25	Ongoing
Temperature	temp	2008-06-26	Ongoing
Ambient Pressure	press	2008-06-25	Ongoing
Relative Humidity	rh	2008-08-15	Ongoing

GMD Datasets for summit, Greenland

	Site	Category	Name	Type	Frequency	Year
1	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Daily Averages	Multiple
2	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Daily Averages	Multiple
3	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Daily Averages	Multiple
4	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-113 (cfc113)	Insitu	Daily Averages	Multiple
5	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Daily Averages	Multiple
6	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Halocompounds	Halon-1211 (h1211)	Insitu	Daily Averages	Multiple
7	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Daily Averages	Multiple
8	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Sulfur Hexafluoride (sf6)	Insitu	Daily Averages	Multiple
9	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Hourly Averages	Multiple
10	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Hourly Averages	Multiple
11	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Hourly Averages	Multiple
12	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-113 (cfc113)	Insitu	Hourly Averages	Multiple
13	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Hourly Averages	Multiple
14	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Halocompounds	Halon-1211 (h1211)	Insitu	Hourly Averages	Multiple
15	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Hourly Averages	Multiple
16	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Sulfur Hexafluoride (sf6)	Insitu	Hourly Averages	Multiple
17	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Monthly Averages	Multiple
18	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Monthly Averages	Multiple
19	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Monthly Averages	Multiple
20	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-113 (cfc113)	Insitu	Monthly Averages	Multiple
21	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Monthly Averages	Multiple
22	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Halocompounds	Halon-1211 (h1211)	Insitu	Monthly Averages	Multiple
23	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Monthly Averages	Multiple
24	Summit, Greenland (SUM) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Sulfur Hexafluoride (sf6)	Insitu	Monthly Averages	Multiple
25	Summit, Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2008
26	Summit, Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2009

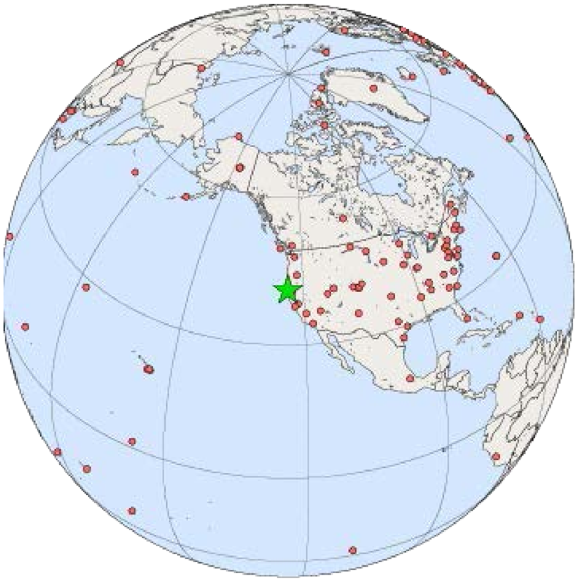
	Site	Category	Name	Type	Frequency	Year
27	Summit,Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2010
28	Summit,Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2011
29	Summit,Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2012
30	Summit,Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2013
31	Summit,Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2014
32	Summit,Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2015
33	Summit,Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2016
34	Summit,Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2017
35	Summit,Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2008
36	Summit,Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2009
37	Summit,Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2010
38	Summit,Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2011
39	Summit,Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2012
40	Summit,Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2013
41	Summit,Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2014
42	Summit,Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2015
43	Summit,Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2016
44	Summit,Greenland (SUM) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2017
45	Summit,Greenland (SUM) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2003
46	Summit,Greenland (SUM) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2004
47	Summit,Greenland (SUM) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2005
48	Summit,Greenland (SUM) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2006
49	Summit,Greenland (SUM) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2007
50	Summit,Greenland (SUM) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2008
51	Summit,Greenland (SUM) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2009
52	Summit,Greenland (SUM) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2010

	Site	Category	Name	Type	Frequency	Year
53	Summit, Greenland (SUM) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2011
54	Summit, Greenland (SUM) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2012
55	Summit, Greenland (SUM) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2013
56	Summit, Greenland (SUM) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2014
57	Summit, Greenland (SUM) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2016
58	Summit, Greenland (SUM) Vertical Profile of Ozone from Balloon flight.	Ozone	Ozone (O_3)	Balloon	Vertical Profile	Multiple
59	Summit, Greenland (SUM) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	ethane (C_2H_6)	Flask	Discrete	Multiple
60	Summit, Greenland (SUM) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	propane (C_3H_8)	Flask	Discrete	Multiple
61	Summit, Greenland (SUM) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	isoprene (C_5H_8)	Flask	Discrete	Multiple
62	Summit, Greenland (SUM) Air samples collected in glass flasks.	Greenhouse Gases	Methane (CH_4)	Flask	Discrete	Multiple
63	Summit, Greenland (SUM) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Methane ($d^{13}C$ (CH_4))	Flask	Discrete	Multiple
64	Summit, Greenland (SUM)	Greenhouse Gases	Carbon Monoxide (CO)	Flask	Discrete	Multiple
65	Summit, Greenland (SUM) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Dioxide (CO_2)	Flask	Discrete	Multiple
66	Summit, Greenland (SUM) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Carbon Dioxide ($d^{13}C$ (CO_2))	Flask	Discrete	Multiple
67	Summit, Greenland (SUM) Air samples collected in glass flasks.	Greenhouse Gases	O18/O16 in Carbon Dioxide ($d^{18}O$ (CO_2))	Flask	Discrete	Multiple
68	Summit, Greenland (SUM)	Non- Methane	i- butane (i-C_4H_{10})	Flask	Discrete	Multiple
69	Summit, Greenland (SUM) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	i- pentane (i- C_5H_{12})	Flask	Discrete	Multiple
70	Summit, Greenland (SUM) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	n- butane (n-C_4H_{10})	Flask	Discrete	Multiple
71	Summit, Greenland (SUM) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	n- pentane (n- C_5H_{12})	Flask	Discrete	Multiple
72	Summit, Greenland (SUM) Air samples collected in glass flasks.	Greenhouse Gases	Methane (CH_4)	Flask	Monthly Averages	Multiple
73	Summit, Greenland (SUM) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Methane ($d^{13}C$ (CH_4))	Flask	Monthly Averages	Multiple
74	Summit, Greenland (SUM) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Monoxide (CO)	Flask	Monthly Averages	Multiple
75	Summit, Greenland (SUM) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Dioxide (CO_2)	Flask	Monthly Averages	Multiple
76	Summit, Greenland (SUM) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Carbon Dioxide ($d^{13}C$ (CO_2))	Flask	Monthly Averages	Multiple
77	Summit, Greenland (SUM) Air samples collected in glass flasks.	Greenhouse Gases	O18/O16 in Carbon Dioxide ($d^{18}O$ (CO_2))	Flask	Monthly Averages	Multiple

	Site	Category	Name	Type	Frequency	Year
78	Summit, Greenland (SUM) Continuous in-situ measurements of solar radiation.	Radiation	Surface Radiation (grad)	Insitu	Minute Averages	Multiple
79	Summit, Greenland (SUM) Continuous measurements of surface ozone.	Ozone	Ozone (O_3)	Insitu	Hourly Averages	Multiple

Trinidad Head, CA, Atmospheric Baseline Observatory (2002-2017).

Trinidad Head Observatory where 126 trace gas (weekly flasks and aircraft profiles), ozonesonde and continuous meteorological measurements are maintained.



Location

- Country: United States
- Latitude: 41.0541° North
- Longitude: 124.151° West
- Elevation: 107.00 masl
- Time Zone: Local Standard Time + 8.0 hour(s) = UTC

Data

- Available datasets
- Data visualization
- Publications
- Personnel
- Photo Gallery

Cooperating Agencies

- Scientific Aviation, Inc
- AGAGE
- Scripps Institution of Oceanography
- Humboldt State University Marine Laboratory

Description

Trinidad Head Observatory (THD) is located on a point jutting into the ocean along the remote northern coast of California approximately 40 km (25 miles) north of Eureka, California, the main regional population center. The coastal climate is dominated by maritime influences, with moderate year-round temperatures and moderate-to-high humidity. To the immediate west of Trinidad Head is the unobstructed Pacific Ocean. To the east, the coastal range is dominated by redwood forests. The town of Trinidad represents the primary community in the immediate vicinity and supports approximately 400 year-round residents. The Telonicher Marine Laboratory (TML), a satellite facility of Humboldt State University (HSU), is also located in Trinidad.

NOAA established an atmospheric baseline observatory at Trinidad Head in 2002. Because of its relatively remote coastal location and prevailing maritime airflow, NOAA felt the site would provide scientists with an opportunity to observe and monitor both regional and global atmospheric conditions reasonably free from local influences.

An instrument trailer was installed in April 2002 allowing measurements of aerosols, surface ozone, radiation, and flask sampling for halocarbons and carbon cycle gases. Bi-weekly airborne vertical profile measurements provide a continuous baseline of pollution and climate forcing agents in air entering the U.S. Co-located with the Trinidad Head Observatory, the Scripps Institution of Oceanography operates two in situ instruments, one as part of the Advanced Global Atmospheric Gases Experiment (AGAGE), the other for measuring changes in atmospheric oxygen concentrations.

The NOAA Trinidad Head Atmospheric Baseline Observatory was downgraded from its status as a full “Observatory” to a “Sampling Site” on June 5, 2017. Most long-term projects and infrastructure were removed from the site. Three research projects remain at THD in partnership with other entities: surface ozone monitoring instrumentation (partnership with SIO), ozonesonde launching capabilities (partnership with HSU), and halocarbons flask sampling capabilities (partnership with AGAGE). The downgrade follows a Global Monitoring Division-wide evaluation of scientific goals and global observing network capabilities that resulted in realignment to best meet NOAA's mission and the nation's scientific needs.

All Trinidad Head data are available on the Global Monitoring Division's website: https://esrl.noaa.gov/gmd/dv/data/index.php?site=thd

GMD Projects at Trinidad Head, California

Carbon Cycle Surface Flasks

Parameter	Formula	First Sample Date	Status
Carbon Dioxide	CO_2	2002-04-19	Terminated - 2017-06-01
Methane	CH_4	2002-04-19	Terminated - 2017-06-01
Carbon Monoxide	CO	2002-04-19	Terminated - 2017-06-01
Molecular Hydrogen	H_2	2002-04-19	Terminated - 2017-06-01
Nitrous Oxide	N_2O	2002-04-19	Terminated - 2017-06-01
Sulfur Hexafluoride	SF_6	2002-04-19	Terminated - 2017-06-01
Carbon-13/Carbon-12 in Carbon Dioxide	$d^{13}C$ (CO_2)	2002-04-19	Terminated - 2017-06-01
Oxygen-18/Oxygen-16 in Carbon Dioxide	$d^{18}O$ (CO_2)	2002-04-19	Terminated - 2017-06-01
Methyl Chloride	CH_3Cl	2004-10-07	Terminated - 2017-06-01
Benzene	C_6H_6	2004-10-07	Terminated - 2017-06-01
toluene	C_7H_8	2004-10-07	Terminated - 2017-06-01

Parameter	Formula	First Sample Date	Status
ethane	C_2H_6	2004-10-07	Terminated - 2017-06-01
ethene	C_2H_4	2004-10-07	Terminated - 2017-06-01
propane	C_3H_8	2004-10-07	Terminated - 2017-06-01
propene	C_3H_6	2004-10-07	Terminated - 2017-06-01
i-butane	i-C_4H_{10}	2004-10-07	Terminated - 2017-06-01
n-butane	n-C_4H_{10}	2004-10-07	Terminated - 2017-06-01
i-pentane	i-C_5H_{12}	2004-10-07	Terminated - 2017-06-01
n-pentane	n-C_5H_{12}	2004-10-07	Terminated - 2017-06-01
n-hexane	n-C_6H_{14}	2004-10-07	Terminated - 2017-06-01
Wind Speed	ws	2002-04-19	Terminated - 2017-06-01
Wind Direction	wd	2002-04-19	Terminated - 2017-06-01
Temperature	temp	2004-08-20	Terminated - 2004-09-22
isoprene	C_5H_8	2004-10-07	Terminated - 2017-06-01
Acetylene	C_2H_2	2004-10-07	Terminated - 2017-06-01

Carbon Cycle Airborne Flasks

Parameter	Formula	First Sample Date	Status
Carbon Dioxide	CO_2	2003-09-02	Ongoing
Methane	CH_4	2003-09-02	Ongoing
Carbon Monoxide	CO	2003-09-02	Ongoing
Molecular Hydrogen	H_2	2003-09-02	Ongoing
Nitrous Oxide	N_2O	2003-09-02	Ongoing
Sulfur Hexafluoride	SF_6	2003-09-02	Ongoing
Sulfur Hexafluoride	SF_6	2014-09-27	Ongoing
Carbon-13/Carbon-12 in Carbon Dioxide	$d^{13}C$ (CO_2)	2003-10-08	Ongoing
Oxygen-18/Oxygen-16 in Carbon Dioxide	$d^{18}O$ (CO_2)	2003-10-08	Ongoing
HFC- 134a	CH_2FCF_3	2004-11-12	Ongoing
HCFC-22	CHF_2Cl	2004-11-12	Ongoing
CFC- 12	CCl_2F_2	2004-11-12	Ongoing
Methyl Chloride	CH_3Cl	2004-11-12	Ongoing
CFC-114	CFC-114	2004-11-12	Ongoing
HCFC-142b	CH_3CF_2Cl	2004-11-12	Ongoing
Halon-1211	$CBrClF_2$	2004-11-12	Ongoing
methyl bromide	CH_3Br	2004-11-12	Ongoing
CFC-11 (ion 101)	CCl_3F (ion 101)	2004-11-12	Terminated - 2015-11-12
CFC-11 (ion 103)	CCl_3F (ion 103)	2010-05-23	Ongoing
HCFC-141b	CH_3CCl_2F	2004-11-12	Ongoing
methyl iodide	CH_3I	2004-11-12	Ongoing
CFC-113	CCl_2FCClF_2	2004-11-12	Ongoing
dichloromethane	CH_2Cl_2	2004-11-12	Ongoing
chloroform	$CHCl_3$	2004-11-12	Ongoing
methyl chloroform (ion 97)	CH_3CCl_3	2004-11-12	Ongoing
methyl chloroform (ion 99)	CH_3CCl_3	2010-05-23	Terminated - 2012-10-04
carbon tetrachloride	CCl_4	2004-11-12	Ongoing
dibromomethane	CH_2Br_2	2004-11-12	Ongoing
tetrachloroethylene	C_2Cl_4	2004-11-12	Ongoing

Parameter	Formula	First Sample Date	Status
bromoform	$CHBr_3$	2004-11-12	Ongoing
Benzene	C_6H_6	2004-11-12	Ongoing
carbonyl sulfide	COS	2004-11-12	Ongoing
HCFC-21	$CHCl_2F$	2015-10-15	Ongoing
HFC-152a	CH_3CHF_2	2004-11-12	Ongoing
HCFC-124	$CHClFCF_3$	2004-11-12	Ongoing
toluene	C_7H_8	2007-07-25	Ongoing
carbonyl disulfide	CS_2	2004-11-12	Ongoing
Sample Pressure	press	2007-06-09	Terminated - 2010-06-20
ethane	C_2H_6	2014-09-27	Ongoing
ethene	C_2H_4	2014-09-27	Ongoing
propane	C_3H_8	2007-06-09	Ongoing
propene	C_3H_6	2014-09-27	Ongoing
i-butane	i-C_4H_{10}	2014-09-27	Ongoing
n-butane	n-C_4H_{10}	2007-06-09	Ongoing
i-pentane	i-C_5H_{12}	2007-06-09	Ongoing
n-pentane	n-C_5H_{12}	2007-06-09	Ongoing
n-hexane	n-C_6H_{14}	2014-09-27	Ongoing
Temperature	temp	2003-09-02	Ongoing
Ambient Pressure	press	2004-01-22	Terminated - 2013-04-18
Relative Humidity	rh	2003-09-02	Ongoing
Halon 1301	CF_3Br	2007-06-09	Ongoing
Halon 2402	$CBrF_2CBrF_2$	2007-06-09	Ongoing
HFC- 143a	CH_3CF_3	2007-06-09	Ongoing
HFC-227ea	CF_3CHFCF_3	2007-06-09	Ongoing
HFC-365mfc	$CH_3CF_2CH_2CF_3$	2007-06-09	Ongoing
CFC-115	$CClF_2CF_3$	2007-06-09	Ongoing
HFC-125	CHF_2CF_3	2007-06-09	Ongoing
CFC- 13	$CClF_3$	2007-06-09	Ongoing
Chloroethane	CH_3CH_2Cl	2007-06-09	Terminated - 2014-05-11
HFC-23	CHF_3	2007-06-09	Ongoing
Perfluoropropane	C_3F_8	2008-03-22	Ongoing
Acetylene	C_2H_2	2008-03-22	Ongoing
HFC-32	CH_2F_2	2009-04-04	Ongoing
HFC-134	CHF_2CHF_2	2009-04-04	Ongoing
Bromochloromethane	CH_2BrCl	2014-09-27	Ongoing
tetrafluoromethane	CF_4	2014-09-27	Ongoing
hexafluoroethane	CF_3CF_3	2014-09-27	Ongoing
nitrogen trifluoride	NF_3	2015-10-15	Ongoing
sulfuryl fluoride	SO_2F_2	2014-09-27	Ongoing
HFC-236fa	$CF_3CH_2CF_3$	2014-09-27	Ongoing
HCFC-133a	CH_2ClCF_3	2015-10-15	Ongoing
CFC-112	CCl_3CClF_2	2014-09-27	Ongoing
C2HCl3	C_2HCl_3	2014-09-27	Ongoing

Parameter	Formula	First Sample Date	Status
HFO-1234yf	$CH_2=CFCF_3$	2016-09-17	Ongoing
HFO-1234ze	$CHF=CHCF_3$	2016-09-17	Ongoing
1,2-dichloroethane	CH_2ClCH_2Cl	2018-01-13	Ongoing
2,2-Dichloro-1,1,1-Trifluoroethane	$CHCl_2CF_3$	2018-01-13	Ongoing
morpholine	$C_5F_{11}NO$	2017-12-08	Ongoing
PFTEA	$(C_2F_5)_3N$	2017-12-08	Ongoing
PFTPA	$(C_3F_7)_3N$	2017-12-08	Ongoing

HATS Flask Sampling

Parameter	Formula	First Sample Date	Status
Nitrous Oxide	N_2O	2002-02-26	Ongoing
Sulfur Hexafluoride	SF_6	2002-02-26	Ongoing
HFC- 134a	CH_2FCF_3	2002-02-26	Ongoing
HCFC-22	CHF_2Cl	2002-03-06	Ongoing
CFC- 12	CCl_2F_2	2002-02-26	Ongoing
Methyl Chloride	CH_3Cl	2002-03-06	Ongoing
CFC-114	CFC-114	2002-02-26	Ongoing
HCFC-142b	CH_3CF_2Cl	2002-02-26	Ongoing
Halon-1211	$CBrClF_2$	2002-02-26	Ongoing
methyl bromide	CH_3Br	2002-03-06	Ongoing
HCFC-141b	CH_3CCl_2F	2002-02-26	Ongoing
methyl iodide	CH_3I	2002-02-26	Ongoing
CFC-113	CCl_2FCClF_2	2002-02-26	Ongoing
dichloromethane	CH_2Cl_2	2002-03-06	Ongoing
chloroform	$CHCl_3$	2002-02-26	Ongoing
carbon tetrachloride	CCl_4	2002-02-26	Ongoing
dibromomethane	CH_2Br_2	2002-02-26	Ongoing
tetrachloroethylene	C_2Cl_4	2002-03-06	Ongoing
bromoform	$CHBr_3$	2002-02-26	Ongoing
Benzene	C_6H_6	2002-02-26	Ongoing
carbonyl sulfide	COS	2002-04-03	Ongoing
HCFC-21	$CHCl_2F$	2002-02-26	Ongoing
HFC-152a	CH_3CHF_2	2002-02-26	Ongoing
toluene	C_7H_8	2014-09-09	Terminated - 2017-04-18
carbonyl disulfide	CS_2	2005-04-08	Terminated - 2015-03-08
ethane	C_2H_6	2014-09-09	Ongoing
propane	C_3H_8	2007-01-17	Ongoing
i-butane	$i\text{-}C_4H_{10}$	2014-09-09	Ongoing
n-butane	$n\text{-}C_4H_{10}$	2007-01-17	Ongoing
i-pentane	$i\text{-}C_5H_{12}$	2006-12-27	Ongoing
n-pentane	$n\text{-}C_5H_{12}$	2006-12-27	Ongoing
n-hexane	$n\text{-}C_6H_{14}$	2013-05-05	Ongoing
Halon 1301	CF_3Br	2004-02-26	Ongoing
Halon 2402	$CBrF_2CBrF_2$	2004-02-26	Ongoing
HFC- 143a	CH_3CF_3	2007-01-17	Ongoing

Parameter	Formula	First Sample Date	Status
HFC-227ea	CF_3CHFCF_3	2011-06-19	Ongoing
HFC-365mfc	$CH_3CF_2CH_2CF_3$	2009-08-10	Ongoing
CFC-115	$CClF_2CF_3$	2007-01-07	Terminated - 2015-10-03
HFC-125	CHF_2CF_3	2007-01-17	Ongoing
CFC- 13	$CClF_3$	2007-01-17	Ongoing
Perfluoropropane	C_3F_8	2014-09-09	Ongoing
Acetylene	C_2H_2	2007-01-17	Ongoing
HFC-32	$CH_2 F_2$	2009-03-14	Ongoing
Methyl Chloroform	CH_3CCl_3	2002-02-26	Ongoing
Chloroiodomethane	CH_2ClI	2017-02-12	Ongoing
diiodomethane	CH_2I_2	2017-02-12	Ongoing
Bromoiodomethane	$CH_2 BrI$	2017-02-12	Ongoing
Bromochloromethane	CH_2BrCl	2017-02-12	Ongoing
Bromodichloromethane	$CHBrCl_2$	2017-02-12	Ongoing
CFC- 11	CCl_3F	2002-02-26	Ongoing
tetrafluoromethane	CF_4	2014-09-09	Ongoing
hexafluoroethane	$CF_3 CF_3$	2014-09-09	Ongoing
nitrogen trifluoride	NF_3	2014-09-09	Ongoing
sulfuryl fluoride	SO_2F_2	2014-09-09	Ongoing
HFC-236fa	$CF_3CH_2CF_3$	2014-09-09	Ongoing
HCFC-133a	$CH_2 ClCF_3$	2014-09-28	Ongoing
CFC-112	CCl_3CClF_2	2014-10-13	Ongoing
HFO-1234yf	$CH_2{=}CFCF_3$	2016-08-16	Ongoing
1,2-dichloroethane	$CH_2 ClCH_2 Cl$	2017-01-28	Ongoing
2,2-Dichloro-1,1,1-Trifluoroethane	$CHCl_2CF_3$	2017-12-19	Ongoing
1,1-dichloroethane	$C_2H_4 Cl_2$	2017-02-12	Ongoing
dibromochloromethane	$CHBr_2Cl$	2017-02-12	Ongoing
Ethyl Chloride	C_2H_5Cl	2011-06-19	Ongoing
Propyne	C_3H_4	2011-06-19	Ongoing
Trichloroethylene	$C_2 HCl_3$	2014-09-09	Ongoing

Aerosol Surface In-Situ

Parameter	Formula	First Sample Date	Status
Light Scattering Coefficient	Ïƒ$_{sp}$	2002-01-01	Terminated - 2017-06-01
Light Absorption Coefficient	Ïƒ$_{ap}$	2002-01-01	Terminated - 2017-06-01
Particle Number Concentration	N_t	2002-01-01	Terminated - 2017-06-01
Aerosol Chemical Composition		2002-01-01	Terminated - 2005-01-01
Aerosol Hygroscopic Growth	f(RH)	2002-01-01	Terminated - 2006-01-01

Radiation In-Situ Observatory

Parameter	Formula	First Sample Date	Status
Direct Normal		2002-04-10	Terminated - 2017-04-30
Downwelling Shortwave		2002-04-10	Terminated - 2017-04-30
Diffuse		2002-04-10	Terminated - 2017-04-30
Downwelling Longwave		2003-05-20	Terminated - 2017-04-30

Surface Ozone

Parameter	Formula	First Sample Date	Status
Ozone	O_3	2002-04-18	Ongoing

Ozonesonde

Parameter	Formula	First Sample Date	Status
Ozone	O_3	1997-08-21	Ongoing

Lidar

Parameter	Formula	First Sample Date	Status
Aerosol backscatter (532 nm)		2005-05-06	Terminated - 2014-03-25

Meteorology

Parameter	Formula	First Sample Date	Status
Wind Speed	ws	2002-06-29	Ongoing
Wind Direction	wd	2002-06-29	Ongoing
Temperature	temp	2002-04-10	Ongoing
Ambient Pressure	press	2002-04-10	Ongoing
Relative Humidity	rh	2002-04-10	Ongoing

Ozone Airborne

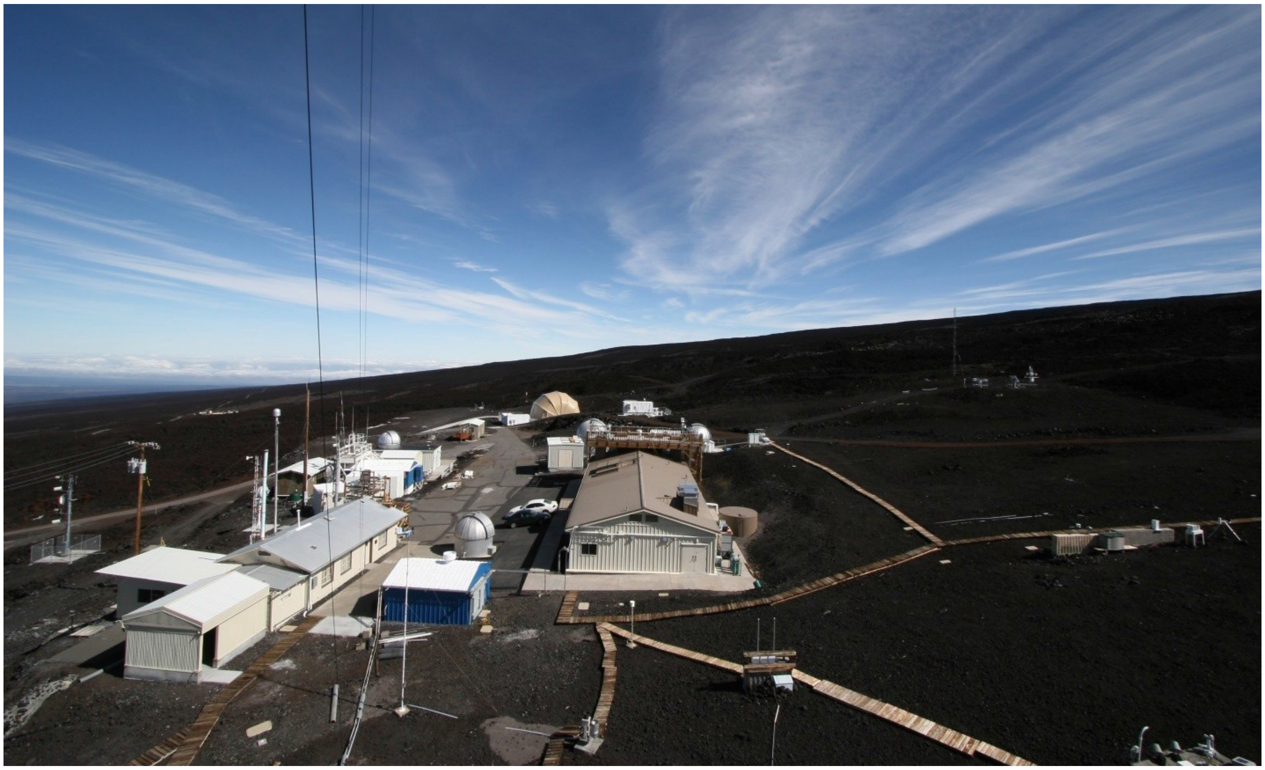
Parameter	Formula	First Sample Date	Status
Ozone	O_3	2005-07-13	Terminated - 2011-10-08

GMD Datasets for Trinidad Head, California

	Site	Category	Name	Type	Frequency	Year
1	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2007
2	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2008
3	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2009
4	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2010
5	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2011
6	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2012
7	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2013
8	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2014
9	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2015
10	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2016
11	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2017
12	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2000
13	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2001
14	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2002
15	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2003
16	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2004
17	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2005
18	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2006
19	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2007
20	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2008
21	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2009
22	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2010
23	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2011
24	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2012
25	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2013
26	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2014
27	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2015
28	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2016
29	Trinidad Head, California, United States (THD) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2017

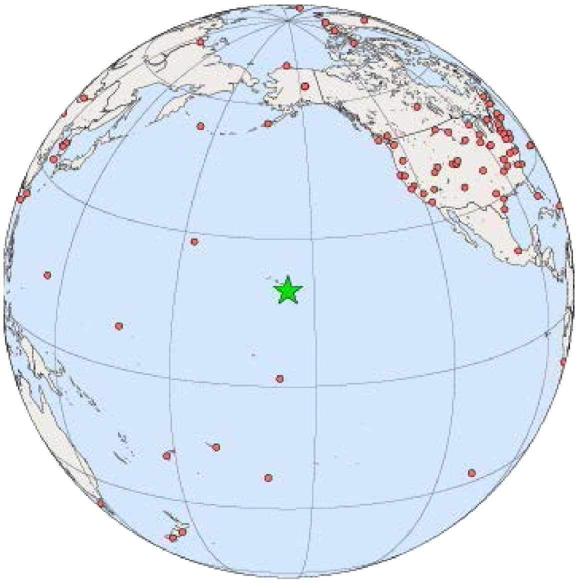
	Site	Category	Name	Type	Frequency	Year
30	Trinidad Head, California, United States (THD) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2002
31	Trinidad Head, California, United States (THD) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2003
32	Trinidad Head, California, United States (THD) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2004
33	Trinidad Head, California, United States (THD) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2005
34	Trinidad Head, California, United States (THD) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2006
35	Trinidad Head, California, United States (THD) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2007
36	Trinidad Head, California, United States (THD) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2008
37	Trinidad Head, California, United States (THD) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2009
38	Trinidad Head, California, United States (THD) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2010
39	Trinidad Head, California, United States (THD) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2011
40	Trinidad Head, California, United States (THD) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2012
41	Trinidad Head, California, United States (THD) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2013
42	Trinidad Head, California, United States (THD) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2014
43	Trinidad Head, California, United States (THD) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2015
44	Trinidad Head, California, United States (THD) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2016
45	Trinidad Head, California, United States (THD) Vertical Profile of Ozone from Balloon flight.	Ozone	Ozone (O_3)	Balloon	Vertical Profile	Multiple
46	Trinidad Head, California, United States (THD) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	ethane (C_2H_6)	Flask	Discrete	Multiple
47	Trinidad Head, California, United States (THD) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	propane (C_3H_8)	Flask	Discrete	Multiple
48	Trinidad Head, California, United States (THD) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	isoprene (C_5H_8)	Flask	Discrete	Multiple
49	Trinidad Head, California, United States (THD) Air samples collected in glass flasks.	Greenhouse Gases	Methane (CH_4)	Flask	Discrete	Multiple
50	Trinidad Head, California, United States (THD) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Monoxide (CO)	Flask	Discrete	Multiple
51	Trinidad Head, California, United States (THD) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Dioxide (CO_2)	Flask	Discrete	Multiple
52	Trinidad Head, California, United States (THD) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Carbon Dioxide ($d^{13}C(CO_2)$)	Flask	Discrete	Multiple

	Site	Category	Name	Type	Frequency	Year
53	Trinidad Head, California, United States (THD) Air samples collected in glass flasks.	Greenhouse Gases	O18/O16 in Carbon Dioxide ($d^{18}O$ (CO_2))	Flask	Discrete	Multiple
54	Trinidad Head, California, United States (THD) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	i- butane (i-C_4H_{10})	Flask	Discrete	Multiple
55	Trinidad Head, California, United States (THD) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	i- pentane (i- C_5H_{12})	Flask	Discrete	Multiple
56	Trinidad Head, California, United States (THD) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	n- butane (n-C_4H_{10})	Flask	Discrete	Multiple
57	Trinidad Head, California, United States (THD) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	n- pentane (n- C_5H_{12})	Flask	Discrete	Multiple
58	Trinidad Head, California, United States (THD) Air samples collected in glass flasks.	Greenhouse Gases	Methane (CH_4)	Flask	Monthly Averages	Multiple
59	Trinidad Head, California, United States (THD) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Monoxide (CO)	Flask	Monthly Averages	Multiple
60	Trinidad Head, California, United States (THD) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Dioxide (CO_2)	Flask	Monthly Averages	Multiple
61	Trinidad Head, California, United States (THD) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Carbon Dioxide ($d^{13}C$ (CO_2))	Flask	Monthly Averages	Multiple
62	Trinidad Head, California, United States (THD) Air samples collected in glass flasks.	Greenhouse Gases	O18/O16 in Carbon Dioxide ($d^{18}O$ (CO_2))	Flask	Monthly Averages	Multiple
63	Trinidad Head, California, United States (THD) Continuous in-situ measurements of solar radiation.	Radiation	Surface Radiation (grad)	Insitu	Minute Averages	Multiple
64	Trinidad Head, California, United States (THD) Continuous measurements of surface ozone.	Ozone	Ozone (O_3)	Insitu	Hourly Averages	Multiple



Mauna Loa Atmospheric Baseline Observatory viewed from the sampling tower.

Mauna Loa Atmospheric Baseline Observatory viewed from the south looking across the valley to the Mauna Kea astronomical facilities. The MLO NDACC building is in the foreground.



Location

- Country: United States
- Latitude: 19.5362° North
- Longitude: 155.5763° West
- Elevation: 3397.00 masl
- Time Zone: Local Standard Time + 10.0 hour(s) = UTC

Contact

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Data

- Available datasets
- Data visualization
- Photo Gallery

Description

Mauna Loa Observatory is located on the Island of Hawaii at an elevation of 3397 m on the northern flank of Mauna Loa volcano at 200 north. Established in 1957, Mauna Loa Observatory has grown to become the premier long-term atmospheric monitoring facility on earth and is the site where the ever-increasing concentrations of global atmospheric carbon dioxide were determined. The observatory consists of 10 buildings from which up to 250 different atmospheric parameters are measured by a complement of 12 NOAA/ESRL and other agency scientists and engineers.

GMD Projects at Mauna Loa, Hawaii

Carbon Cycle Surface Flasks

Parameter	Formula	First Sample Date	Status
Carbon Dioxide	CO_2	1969-08-20	Ongoing
Methane	CH_4	1983-05-06	Ongoing
Carbon Monoxide	CO	1989-07-07	Ongoing
Molecular Hydrogen	H_2	1989-07-07	Ongoing
Nitrous Oxide	N_2O	1995-12-15	Ongoing
Sulfur Hexafluoride	SF_6	1995-12-15	Ongoing
Carbon-13/Carbon-12 in Carbon Dioxide	$d^{13}C$ (CO_2)	1990-01-12	Ongoing
Oxygen-18/Oxygen-16 in Carbon Dioxide	$d^{18}O$ (CO_2)	1990-01-12	Ongoing
Carbon-13/Carbon-12 in Methane	$d^{13}C$ (CH_4)	1998-01-02	Ongoing
D/H in Methane	dD (CH_4)	2005-04-06	Terminated - 2009-11-03
Methyl Chloride	CH_3Cl	2005-05-11	Ongoing
Benzene	C_6H_6	2006-12-13	Ongoing
toluene	C_7H_8	2006-12-13	Ongoing
ethane	C_2H_6	2005-05-11	Ongoing
ethene	C_2H_4	2005-05-11	Ongoing
propane	C_3H_8	2005-05-11	Ongoing
propene	C_3H_6	2005-05-11	Ongoing
i-butane	i-C_4H_{10}	2005-05-11	Ongoing
n-butane	n-C_4H_{10}	2005-05-11	Ongoing
i-pentane	i-C_5H_{12}	2005-05-11	Ongoing
n-pentane	n-C_5H_{12}	2005-05-11	Ongoing
n-hexane	n-C_6H_{14}	2005-05-11	Ongoing
isoprene	C_5H_8	2006-12-13	Ongoing

Parameter	Formula	First Sample Date	Status
Acetylene	C_2H_2	2006-12-13	Ongoing

Carbon Cycle In Situ Observatory

Parameter	Formula	First Sample Date	Status
Carbon Dioxide	CO_2	1974-05-17	Ongoing
Methane	CH_4	1987-04-03	Ongoing
Carbon Monoxide	CO	1992-05-29	Ongoing

HATS Flask Sampling

Parameter	Formula	First Sample Date	Status
Nitrous Oxide	N_2O	1994-12-19	Ongoing
Sulfur Hexafluoride	SF_6	1994-12-19	Ongoing
HFC- 134a	CH_2FCF_3	1994-11-07	Ongoing
HCFC-22	CHF_2Cl	1991-12-30	Ongoing
CFC- 12	CCl_2F_2	1994-12-19	Ongoing
Methyl Chloride	CH_3Cl	1993-08-30	Ongoing
CFC-114	CFC-114	1991-12-30	Ongoing
HCFC-142b	CH_3CF_2Cl	1992-02-10	Ongoing
Halon-1211	$CBrClF_2$	1991-12-30	Ongoing
methyl bromide	CH_3Br	1993-08-30	Ongoing
HCFC-141b	CH_3CCl_2F	1992-12-28	Ongoing
methyl iodide	CH_3I	1994-04-11	Ongoing
CFC-113	CCl_2FCClF_2	1991-12-30	Ongoing
dichloromethane	CH_2Cl_2	1994-01-18	Ongoing
chloroform	$CHCl_3$	1992-12-28	Ongoing
carbon tetrachloride	CCl_4	1994-12-19	Ongoing
dibromomethane	CH_2Br_2	1998-03-09	Ongoing
tetrachloroethylene	C_2Cl_4	1993-11-22	Ongoing
bromoform	$CHBr_3$	1998-01-15	Ongoing
Benzene	C_6H_6	1999-02-01	Ongoing
carbonyl sulfide	COS	2000-03-13	Ongoing
HCFC-21	$CHCl_2F$	2000-08-14	Ongoing
HFC-152a	CH_3CHF_2	2000-08-14	Ongoing
toluene	C_7H_8	2014-09-09	Terminated - 2017-04-18
carbonyl disulfide	CS_2	2005-04-13	Terminated - 2015-03-10
ethane	C_2H_6	2014-09-09	Ongoing
propane	C_3H_8	2006-12-27	Ongoing
i-butane	i-C_4H_{10}	2014-09-09	Ongoing
n-butane	n-C_4H_{10}	2006-12-27	Ongoing
i-pentane	i-C_5H_{12}	2006-12-27	Ongoing
n-pentane	n-C_5H_{12}	2006-12-27	Ongoing
n-hexane	n-C_6H_{14}	2013-04-30	Ongoing
Halon 1301	CF_3Br	2004-03-08	Ongoing
Halon 2402	$CBrF_2CBrF_2$	1995-03-13	Ongoing
HFC- 143a	CH_3CF_3	2006-12-27	Ongoing
HFC-227ea	CF_3CHFCF_3	2011-06-14	Ongoing

Parameter	Formula	First Sample Date	Status
HFC-365mfc	$CH_3CF_2CH_2CF_3$	2009-08-13	Ongoing
CFC-115	$CClF_2CF_3$	2006-12-27	Ongoing
HFC-125	CHF_2CF_3	2006-12-27	Ongoing
CFC- 13	$CClF_3$	2006-12-27	Ongoing
Perfluoropropane	C_3F_8	2014-09-09	Ongoing
Acetylene	C_2H_2	2006-12-27	Ongoing
HFC-32	CH_2F_2	2009-03-12	Ongoing
Methyl Chloroform	CH_3CCl_3	1991-12-30	Ongoing
Chloroiodomethane	CH_2ClI	2017-02-01	Ongoing
diiodomethane	CH_2I_2	2017-02-01	Ongoing
Bromoiodomethane	CH_2BrI	2017-02-01	Ongoing
Bromochloromethane	CH_2BrCl	2017-02-01	Ongoing
Bromodichloromethane	$CHBrCl_2$	2017-02-01	Ongoing
CFC- 11	CCl_3F	1994-12-19	Ongoing
tetrafluoromethane	CF_4	2014-09-09	Ongoing
hexafluoroethane	CF_3CF_3	2014-09-09	Ongoing
nitrogen trifluoride	NF_3	2014-09-09	Ongoing
sulfuryl fluoride	SO_2F_2	2014-09-09	Ongoing
HFC-236fa	$CF_3CH_2CF_3$	2014-09-09	Ongoing
HCFC-133a	CH_2ClCF_3	2014-09-30	Ongoing
CFC-112	CCl_3CClF_2	2014-10-14	Ongoing
HFO-1234yf	$CH_2{=}CFCF_3$	2016-08-16	Ongoing
1,2-dichloroethane	CH_2ClCH_2Cl	2017-01-03	Ongoing
2,2-Dichloro-1,1,1-Trifluoroethane	$CHCl_2CF_3$	2017-12-19	Ongoing
1,1-dichloroethane	$C_2H_4Cl_2$	2017-02-01	Ongoing
dibromochloromethane	$CHBr_2Cl$	2017-02-01	Ongoing
Ethyl Chloride	C_2H_5Cl	2011-06-14	Ongoing
Propyne	C_3H_4	2011-06-14	Ongoing
Trichloroethylene	C_2HCl_3	2014-09-09	Ongoing

HATS InSitu Observatory

Parameter	Formula	First Sample Date	Status
Nitrous Oxide	N_2O	1999-07-08	Ongoing
Sulfur Hexafluoride	SF_6	1999-06-25	Ongoing
HCFC-22	CHF_2Cl	1998-11-28	Ongoing
CFC- 12	CCl_2F_2	1999-06-25	Ongoing
Methyl Chloride	CH_3Cl	1999-04-23	Ongoing
HCFC-142b	CH_3CF_2Cl	1999-01-01	Ongoing
Halon-1211	$CBrClF_2$	1998-12-03	Ongoing
CFC-113	CCl_2FCClF_2	1999-12-14	Ongoing
chloroform	$CHCl_3$	1998-09-01	Ongoing
carbon tetrachloride	CCl_4	1999-06-25	Ongoing
Methyl Chloroform	CH_3CCl_3	1999-04-23	Ongoing
CFC- 11	CCl_3F	1999-06-25	Ongoing

Aerosol Surface In-Situ

Parameter	Formula	First Sample Date	Status
Light Scattering Coefficient	Ïƒ$_{sp}$	1974-01-01	Ongoing
Light Absorption Coefficient	Ïƒ$_{ap}$	1990-01-01	Ongoing
Particle Number Concentration	N_t	1974-01-01	Ongoing

Radiation In-Situ Observatory

Parameter	Formula	First Sample Date	Status
Direct Normal		1976-03-01	Ongoing
Downwelling Shortwave		1976-03-01	Ongoing
Diffuse		1976-03-01	Ongoing
Downwelling Longwave		1993-10-31	Ongoing
Spectral		2001-07-01	Ongoing

Surface Ozone

Parameter	Formula	First Sample Date	Status
Ozone	O_3	1973-09-20	Ongoing

Dobson Total Ozone

Parameter	Formula	First Sample Date	Status
Ozone	O_3	1957-12-01	Ongoing

Lidar

Parameter	Formula	First Sample Date	Status
Aerosol backscatter (694 nm)		1974-12-03	Terminated - 1998-10-27
Aerosol backscatter (532 nm)		1994-04-04	Ongoing
Aerosol backscatter (1064 nm)		2001-01-05	Ongoing
Water vapor density		2005-10-26	Ongoing

Meteorology

Parameter	Formula	First Sample Date	Status
Wind Speed	ws	1977-01-01	Ongoing
Wind Direction	wd	1977-01-01	Ongoing
Temperature	temp	1977-01-01	Ongoing
Ambient Pressure	press	1977-01-01	Ongoing
Relative Humidity	rh	1977-01-01	Ongoing

GMD Datasets for Mauna Loa, Hawaii

	Site	Category	Name	Type	Frequency	Year
1	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Daily Averages	Multiple
2	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Daily Averages	Multiple
3	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Daily Averages	Multiple
4	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-113 (cfc113)	Insitu	Daily Averages	Multiple
5	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Daily Averages	Multiple
6	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloride (ch3cl)	Insitu	Daily Averages	Multiple
7	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	Halon-1211 (h1211)	Insitu	Daily Averages	Multiple
8	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-142b (hcfc142b)	Insitu	Daily Averages	Multiple
9	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-22 (hcfc22)	Insitu	Daily Averages	Multiple
10	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Daily Averages	Multiple
11	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Sulfur Hexafluoride (sf6)	Insitu	Daily Averages	Multiple
12	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Hourly Averages	Multiple
13	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Hourly Averages	Multiple
14	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Hourly Averages	Multiple
15	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-113 (cfc113)	Insitu	Hourly Averages	Multiple
16	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Hourly Averages	Multiple
17	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloride (ch3cl)	Insitu	Hourly Averages	Multiple
18	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	Halon-1211 (h1211)	Insitu	Hourly Averages	Multiple
19	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-142b (hcfc142b)	Insitu	Hourly Averages	Multiple
20	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-22 (hcfc22)	Insitu	Hourly Averages	Multiple
21	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Hourly Averages	Multiple
22	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Sulfur Hexafluoride (sf6)	Insitu	Hourly Averages	Multiple
23	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Monthly Averages	Multiple
24	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Monthly Averages	Multiple
25	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Monthly Averages	Multiple
26	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-113 (cfc113)	Insitu	Monthly Averages	Multiple

	Site	Category	Name	Type	Frequency	Year
27	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Monthly Averages	Multiple
28	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloride (ch3cl)	Insitu	Monthly Averages	Multiple
29	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	Halon-1211 (h1211)	Insitu	Monthly Averages	Multiple
30	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-142b (hcfc142b)	Insitu	Monthly Averages	Multiple
31	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-22 (hcfc22)	Insitu	Monthly Averages	Multiple
32	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Monthly Averages	Multiple
33	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Sulfur Hexafluoride (sf6)	Insitu	Monthly Averages	Multiple
34	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ RITS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Daily Averages	Multiple
35	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ RITS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Daily Averages	Multiple
36	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Daily Averages	Multiple
37	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Daily Averages	Multiple
38	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ RITS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Daily Averages	Multiple
39	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ RITS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Hourly Averages	Multiple
40	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ RITS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Hourly Averages	Multiple
41	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Hourly Averages	Multiple
42	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Hourly Averages	Multiple
43	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ RITS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Hourly Averages	Multiple
44	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ RITS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Monthly Averages	Multiple
45	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ RITS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Monthly Averages	Multiple
46	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Monthly Averages	Multiple
47	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Monthly Averages	Multiple
48	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ RITS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Monthly Averages	Multiple
49	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1977
50	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1978
51	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1979
52	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1980
53	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1981

	Site	Category	Name	Type	Frequency	Year
54	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1982
55	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1983
56	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1984
57	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1985
58	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1986
59	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1987
60	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1988
61	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1989
62	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1990
63	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1991
64	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1992
65	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1993
66	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1994
67	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1995
68	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1996
69	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1997
70	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1998
71	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1999
72	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2000
73	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2001
74	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2002
75	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2003
76	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2004
77	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2005
78	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2006
79	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2007
80	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2008
81	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2009
82	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2010
83	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2011

	Site	Category	Name	Type	Frequency	Year
84	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2012
85	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2013
86	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2014
87	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2015
88	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2016
89	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2017
90	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1991
91	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1992
92	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1993
93	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1994
94	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1995
95	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1996
96	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1997
97	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1998
98	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1999
99	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2000
100	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2001
101	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2002
102	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2003
103	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2004
104	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2005
105	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2006
106	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2007
107	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2008
108	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2009
109	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2010
110	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2011
111	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2012
112	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2013
113	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2014

	Site	Category	Name	Type	Frequency	Year
114	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2015
115	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2016
116	Mauna Loa, Hawaii, United States (MLO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2017
117	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1974
118	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1975
119	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1976
120	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1977
121	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1978
122	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1979
123	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1980
124	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1981
125	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1982
126	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1983
127	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1984
128	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1985
129	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1986
130	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1987
131	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1988
132	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1989
133	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1990
134	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1991
135	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1992
136	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1993

	Site	Category	Name	Type	Frequency	Year
137	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1994
138	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1995
139	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1996
140	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1997
141	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1998
142	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1999
143	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2000
144	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2001
145	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2002
146	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2003
147	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2004
148	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2005
149	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2006
150	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2007
151	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2008
152	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2009
153	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2010
154	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2011
155	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2012
156	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2013
157	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2014
158	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2015

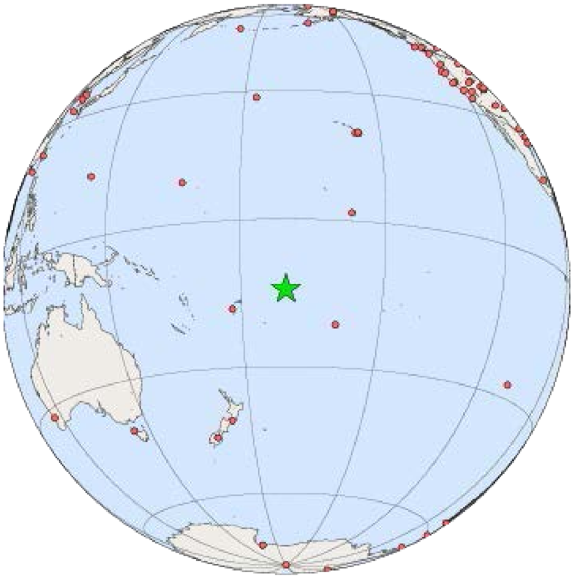
	Site	Category	Name	Type	Frequency	Year
159	Mauna Loa, Hawaii, United States (MLO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2016
160	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	ethane (C_2H_6)	Flask	Discrete	Multiple
161	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	propane (C_3H_8)	Flask	Discrete	Multiple
162	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	isoprene (C_5H_8)	Flask	Discrete	Multiple
163	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Greenhouse Gases	Methane (CH_4)	Flask	Discrete	Multiple
164	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Methane ($d^{13}C$ (CH_4))	Flask	Discrete	Multiple
165	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Monoxide (CO)	Flask	Discrete	Multiple
166	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Dioxide (CO_2)	Flask	Discrete	Multiple
167	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Carbon Dioxide ($d^{13}C$ (CO_2))	Flask	Discrete	Multiple
168	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Greenhouse Gases	O18/O16 in Carbon Dioxide ($d^{18}O$ (CO_2))	Flask	Discrete	Multiple
169	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Greenhouse Gases	Molecular Hydrogen (H_2)	Flask	Discrete	Multiple
170	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	i-butane (i-C_4H_{10})	Flask	Discrete	Multiple
171	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	i-pentane (i-C_5H_{12})	Flask	Discrete	Multiple
172	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	n-butane (n-C_4H_{10})	Flask	Discrete	Multiple
173	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	n-pentane (n-C_5H_{12})	Flask	Discrete	Multiple
174	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Greenhouse Gases	Methane (CH_4)	Flask	Monthly Averages	Multiple
175	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Methane ($d^{13}C$ (CH_4))	Flask	Monthly Averages	Multiple
176	Mauna Loa, Hawaii, United States (MLO)	Greenhouse Gases	Carbon Monoxide (CO)	Flask	Monthly	Multiple
177	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Dioxide (CO_2)	Flask	Monthly Averages	Multiple
178	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Carbon Dioxide ($d^{13}C$ (CO_2))	Flask	Monthly Averages	Multiple
179	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Greenhouse Gases	O18/O16 in Carbon Dioxide ($d^{18}O$ (CO_2))	Flask	Monthly Averages	Multiple
180	Mauna Loa, Hawaii, United States (MLO) Air samples collected in glass flasks.	Greenhouse Gases	Molecular Hydrogen (H_2)	Flask	Monthly Averages	Multiple
181	Mauna Loa, Hawaii, United States (MLO) Continuous in-situ measurements of solar radiation.	Radiation	Surface Radiation (grad)	Insitu	Minute Averages	Multiple
182	Mauna Loa, Hawaii, United States (MLO) Continuous measurements of surface ozone.	Ozone	Ozone (O_3)	Insitu	Hourly Averages	Multiple
183	Mauna Loa, Hawaii, United States (MLO) In-situ ch4 daily averages	Greenhouse Gases	Methane (CH_4)	Insitu	Daily Averages	Multiple
184	Mauna Loa, Hawaii, United States (MLO) In-situ ch4 hourly averages	Greenhouse Gases	Methane (CH_4)	Insitu	Hourly Averages	HourlyData

	Site	Category	Name	Type	Frequency	Year
185	Mauna Loa, Hawaii, United States (MLO) In-situ ch4 monthly averages	Greenhouse Gases	Methane (CH_4)	Insitu	Monthly Averages	Multiple
186	Mauna Loa, Hawaii, United States (MLO) In-situ co2 daily averages	Greenhouse Gases	Carbon Dioxide (CO_2)	Insitu	Daily Averages	Multiple
187	Mauna Loa, Hawaii, United States (MLO) In-situ co2 hourly averages	Greenhouse Gases	Carbon Dioxide (CO_2)	Insitu	Hourly Averages	Multiple
188	Mauna Loa, Hawaii, United States (MLO) In-situ co2 monthly averages	Greenhouse Gases	Carbon Dioxide (CO_2)	Insitu	Monthly Averages	Multiple

American Samoa Atmospheric Baseline Observatory viewed from the sampling tower. The prevailing winds are at the back of the photographer looking north-west.

American Samoa Atmospheric Baseline Observatory viewed from the south-east with the Dobson ozone spectrometer dome and radiation deck on the second level.

Tutuila, American Samoa [SMO]



Location

- Country: American Samoa 
- Latitude: 14.2474° South
- Longitude: 170.5644° West
- Elevation: 42.00 masl
- Time Zone: Local Standard Time + 11.0 hour(s) = UTC

Contact

- Contact Name: Ben Kaiser
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  P.O. Box 2568
  Pago Pago, Cape Matatula, 96799, American Samoa
- Phone: 684-258-2848
- Fax:

Data

- Available datasets
- Data visualization
- Photo Gallery

Description

The Samoa Observatory is located on the northeastern tip of Tutuila island, American Samoa, on a ridge overlooking the South Pacific Ocean. Established in 1974 on a 26.7 acre site, the observatory is one of four GMD Baseline Observatories. Cape Matatula is approx. 1 km from the village of Tula. Prevailing winds are marine. Since its construction, the Samoa Observatory has survived two major hurricanes with only minor damage. A staff of 2 operates the year around facility commuting to work. This Observatory has the distinction of obtaining 30% of its daytime power from solar panels.

GMD Projects at Tutuila

Carbon Cycle Surface Flasks

Parameter	Formula	First Sample Date	Status
Carbon Dioxide	CO_2	1972-01-15	Ongoing
Methane	CH_4	1983-04-23	Ongoing
Carbon Monoxide	CO	1988-09-22	Ongoing
Molecular Hydrogen	H_2	1989-01-05	Ongoing
Nitrous Oxide	N_2O	1997-05-07	Ongoing
Sulfur Hexafluoride	SF_6	1997-05-07	Ongoing
Carbon-13/Carbon-12 in Carbon Dioxide	$d^{13}C$ (CO_2)	1990-01-04	Ongoing
Oxygen-18/Oxygen-16 in Carbon Dioxide	$d^{18}O$ (CO_2)	1990-01-04	Ongoing
Carbon-13/Carbon-12 in Methane	$d^{13}C$ (CH_4)	1998-01-06	Ongoing
D/H in Methane	dD (CH_4)	2005-03-28	Terminated - 2009-09-11
Methyl Chloride	CH_3Cl	2005-05-12	Ongoing
Benzene	C_6H_6	2007-01-16	Ongoing
toluene	C_7H_8	2007-01-16	Ongoing
ethane	C_2H_6	2005-05-12	Ongoing
ethene	C_2H_4	2005-05-12	Ongoing
propane	C_3H_8	2005-05-12	Ongoing
propene	C_3H_6	2005-05-12	Ongoing
i-butane	i-C_4H_{10}	2005-05-12	Ongoing
n-butane	n-C_4H_{10}	2005-05-12	Ongoing
i-pentane	i-C_5H_{12}	2005-05-12	Ongoing
n-pentane	n-C_5H_{12}	2005-05-12	Ongoing
n-hexane	n-C_6H_{14}	2005-05-12	Ongoing

Parameter	Formula	First Sample Date	Status
isoprene	C_5H_8	2007-01-16	Ongoing
Acetylene	C_2H_2	2007-05-25	Ongoing

Carbon Cycle In Situ Observatory

Parameter	Formula	First Sample Date	Status
Carbon Dioxide	CO_2	1976-01-01	Ongoing

HATS Flask Sampling

Parameter	Formula	First Sample Date	Status
Nitrous Oxide	N_2O	1994-11-29	Ongoing
Sulfur Hexafluoride	SF_6	1994-11-29	Ongoing
HFC- 134a	CH_2FCF_3	1994-11-29	Ongoing
HCFC-22	CHF_2Cl	1991-11-26	Ongoing
CFC- 12	CCl_2F_2	1994-11-29	Ongoing
Methyl Chloride	CH_3Cl	1993-11-09	Ongoing
CFC-114	CFC-114	1991-12-30	Ongoing
HCFC-142b	CH_3CF_2Cl	1992-02-11	Ongoing
Halon-1211	$CBrClF_2$	1991-12-30	Ongoing
methyl bromide	CH_3Br	1993-11-09	Ongoing
HCFC-141b	CH_3CCl_2F	1993-01-14	Ongoing
methyl iodide	CH_3I	1993-01-14	Ongoing
CFC-113	CCl_2FCClF_2	1991-12-30	Ongoing
dichloromethane	CH_2Cl_2	1994-01-12	Ongoing
chloroform	$CHCl_3$	1993-01-14	Ongoing
carbon tetrachloride	CCl_4	1994-11-29	Ongoing
dibromomethane	CH_2Br_2	1998-03-11	Ongoing
tetrachloroethylene	C_2Cl_4	1993-12-15	Ongoing
bromoform	$CHBr_3$	1998-01-06	Ongoing
Benzene	C_6H_6	1999-01-19	Ongoing
carbonyl sulfide	COS	2000-03-07	Ongoing
HCFC-21	$CHCl_2F$	2000-08-16	Ongoing
HFC-152a	CH_3CHF_2	2000-08-09	Ongoing
toluene	C_7H_8	2014-09-15	Terminated - 2017-04-22
carbonyl disulfide	CS_2	2005-04-11	Terminated - 2015-02-25
ethane	C_2H_6	2014-09-15	Ongoing
propane	C_3H_8	2007-01-12	Ongoing
i-butane	i-C_4H_{10}	2014-09-15	Ongoing
n-butane	n-C_4H_{10}	2007-01-12	Ongoing
i-pentane	i-C_5H_{12}	2007-01-12	Ongoing
n-pentane	n-C_5H_{12}	2007-01-12	Ongoing
n-hexane	n-C_6H_{14}	2013-04-17	Ongoing
Halon 1301	CF_3Br	2007-01-12	Ongoing
Halon 2402	$CBrF_2CBrF_2$	1995-02-13	Ongoing
HFC- 143a	CH_3CF_3	2007-01-12	Ongoing
HFC-227ea	CF_3CHFCF_3	2011-04-06	Ongoing
HFC-365mfc	$CH_3CF_2CH_2CF_3$	2009-07-02	Ongoing

Parameter	Formula	First Sample Date	Status
CFC-115	$CClF_2CF_3$	2007-01-12	Terminated - 2015-09-05
HFC-125	CHF_2CF_3	2007-01-12	Ongoing
CFC- 13	$CClF_3$	2007-01-12	Ongoing
Perfluoropropane	C_3F_8	2014-09-15	Ongoing
Acetylene	C_2H_2	2007-01-12	Ongoing
HFC-32	CH_2F_2	2009-03-12	Ongoing
Methyl Chloroform	CH_3CCl_3	1991-11-26	Ongoing
Chloroiodomethane	CH_2ClI	2017-01-27	Ongoing
diiodomethane	CH_2I_2	2017-01-27	Ongoing
Bromoiodomethane	CH_2BrI	2017-01-27	Ongoing
Bromochloromethane	CH_2BrCl	2017-01-27	Ongoing
Bromodichloromethane	$CHBrCl_2$	2017-01-27	Ongoing
CFC- 11	CCl_3F	1994-11-29	Ongoing
tetrafluoromethane	CF_4	2014-09-15	Ongoing
hexafluoroethane	CF_3CF_3	2014-09-15	Ongoing
nitrogen trifluoride	NF_3	2014-09-30	Ongoing
sulfuryl fluoride	SO_2F_2	2014-09-15	Ongoing
HFC-236fa	$CF_3CH_2CF_3$	2014-09-15	Ongoing
HCFC-133a	CH_2ClCF_3	2014-09-30	Ongoing
CFC-112	CCl_3CClF_2	2014-10-06	Ongoing
HFO-1234yf	$CH_2=CFCF_3$	2016-08-20	Ongoing
1,2-dichloroethane	CH_2ClCH_2Cl	2017-01-21	Ongoing
2,2-Dichloro-1,1,1-Trifluoroethane	$CHCl_2CF_3$	2017-12-08	Ongoing
1,1-dichloroethane	$C_2H_4Cl_2$	2017-01-27	Ongoing
dibromochloromethane	$CHBr_2Cl$	2017-01-27	Ongoing
Ethyl Chloride	C_2H_5Cl	2011-04-06	Ongoing
Propyne	C_3H_4	2011-04-06	Ongoing
Trichloroethylene	C_2HCl_3	2014-09-15	Ongoing

HATS InSitu Observatory

Parameter	Formula	First Sample Date	Status
Nitrous Oxide	N_2O	1998-12-08	Ongoing
Sulfur Hexafluoride	SF_6	1998-12-03	Ongoing
HCFC-22	CHF_2Cl	1999-02-16	Ongoing
CFC- 12	CCl_2F_2	1998-12-08	Ongoing
Methyl Chloride	CH_3Cl	1999-01-28	Ongoing
HCFC-142b	CH_3CF_2Cl	1999-01-28	Ongoing
Halon-1211	$CBrClF_2$	1999-03-02	Ongoing
CFC-113	CCl_2FCClF_2	1998-12-03	Ongoing
chloroform	$CHCl_3$	1998-12-01	Ongoing
carbon tetrachloride	CCl_4	1998-12-08	Ongoing
Methyl Chloroform	CH_3CCl_3	1998-12-08	Ongoing
CFC- 11	CCl_3F	1998-12-08	Ongoing

Aerosol Surface In-Situ

Parameter	Formula	First Sample Date	Status
Light Scattering Coefficient	Ïƒ$_{sp}$	1977-01-01	Terminated - 1991-03-29
Light Absorption Coefficient	Ïƒ$_{ap}$	1977-01-01	Terminated - 1991-03-29
Particle Number Concentration	N_t	1977-01-01	Terminated - 2017-07-21

Radiation In-Situ Observatory

Parameter	Formula	First Sample Date	Status
Direct Normal		1976-02-01	Ongoing
Downwelling Shortwave		1976-02-01	Ongoing
Diffuse		1995-08-21	Ongoing
Downwelling Longwave		1999-08-06	Ongoing

Surface Ozone

Parameter	Formula	First Sample Date	Status
Ozone	O_3	1975-12-14	Ongoing

Dobson Total Ozone

Parameter	Formula	First Sample Date	Status
Ozone	O_3	1975-12-18	Ongoing

Ozonesonde

Parameter	Formula	First Sample Date	Status
Ozone	O_3	1986-04-01	Ongoing

Lidar

Parameter	Formula	First Sample Date	Status
Aerosol backscatter (532 nm)		2005-04-13	Terminated - 2010-07-30

Meteorology

Parameter	Formula	First Sample Date	Status
Wind Speed	ws	1976-01-21	Ongoing
Wind Direction	wd	1976-01-21	Ongoing
Temperature	temp	1976-01-05	Ongoing
Ambient Pressure	press	1976-01-09	Ongoing
Relative Humidity	rh	1976-01-06	Ongoing

GMD Datasets for Tutuila, American Samoa

	Site	Category	Name	Type	Frequency	Year
1	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Daily Averages	Multiple
2	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Daily Averages	Multiple
3	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Daily Averages	Multiple
4	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-113 (cfc113)	Insitu	Daily Averages	Multiple
5	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Daily Averages	Multiple
6	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloride (ch3cl)	Insitu	Daily Averages	Multiple
7	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	Halon-1211 (h1211)	Insitu	Daily Averages	Multiple
8	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-142b (hcfc142b)	Insitu	Daily Averages	Multiple
9	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-22 (hcfc22)	Insitu	Daily Averages	Multiple
10	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Daily Averages	Multiple
11	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Sulfur Hexafluoride (sf6)	Insitu	Daily Averages	Multiple
12	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Hourly Averages	Multiple
13	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Hourly Averages	Multiple
14	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Hourly Averages	Multiple
15	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-113 (cfc113)	Insitu	Hourly Averages	Multiple
16	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Hourly Averages	Multiple
17	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloride (ch3cl)	Insitu	Hourly Averages	Multiple
18	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	Halon-1211 (h1211)	Insitu	Hourly Averages	Multiple
19	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-142b (hcfc142b)	Insitu	Hourly Averages	Multiple
20	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-22 (hcfc22)	Insitu	Hourly Averages	Multiple
21	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Hourly Averages	Multiple
22	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Sulfur Hexafluoride (sf6)	Insitu	Hourly Averages	Multiple
23	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Monthly Averages	Multiple
24	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Monthly Averages	Multiple
25	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Monthly Averages	Multiple
26	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-113 (cfc113)	Insitu	Monthly Averages	Multiple

	Site	Category	Name	Type	Frequency	Year
27	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Monthly Averages	Multiple
28	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloride (ch3cl)	Insitu	Monthly Averages	Multiple
29	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	Halon-1211 (h1211)	Insitu	Monthly Averages	Multiple
30	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-142b (hcfc142b)	Insitu	Monthly Averages	Multiple
31	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-22 (hcfc22)	Insitu	Monthly Averages	Multiple
32	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Monthly Averages	Multiple
33	Tutuila, American Samoa (SMO) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Sulfur Hexafluoride (sf6)	Insitu	Monthly Averages	Multiple
34	Tutuila, American Samoa (SMO) Continuous in-situ RITS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Daily Averages	Multiple
35	Tutuila, American Samoa (SMO) Continuous in-situ RITS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Daily Averages	Multiple
36	Tutuila, American Samoa (SMO) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Daily Averages	Multiple
37	Tutuila, American Samoa (SMO) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Daily Averages	Multiple
38	Tutuila, American Samoa (SMO) Continuous in-situ RITS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Daily Averages	Multiple
39	Tutuila, American Samoa (SMO) Continuous in-situ RITS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Hourly Averages	Multiple
40	Tutuila, American Samoa (SMO) Continuous in-situ RITS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Hourly Averages	Multiple
41	Tutuila, American Samoa (SMO) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Hourly Averages	Multiple
42	Tutuila, American Samoa (SMO) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Hourly Averages	Multiple
43	Tutuila, American Samoa (SMO) Continuous in-situ RITS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Hourly Averages	Multiple
44	Tutuila, American Samoa (SMO) Continuous in-situ RITS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Monthly Averages	Multiple
45	Tutuila, American Samoa (SMO) Continuous in-situ RITS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Monthly Averages	Multiple
46	Tutuila, American Samoa (SMO) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Monthly Averages	Multiple
47	Tutuila, American Samoa (SMO) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Monthly Averages	Multiple
48	Tutuila, American Samoa (SMO) Continuous in-situ RITS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Monthly Averages	Multiple
49	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1976
50	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1977
51	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1978
52	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1979
53	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1980

	Site	Category	Name	Type	Frequency	Year
54	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1981
55	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1982
56	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1983
57	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1984
58	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1985
59	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1986
60	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1987
61	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1988
62	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1989
63	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1990
64	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1991
65	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1992
66	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1993
67	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1994
68	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1995
69	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1996
70	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1997
71	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1998
72	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1999
73	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2000
74	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2001
75	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2002
76	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2003
77	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2004
78	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2005
79	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2006
80	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2007
81	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2008
82	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2009
83	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2010

	Site	Category	Name	Type	Frequency	Year
84	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2011
85	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2012
86	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2013
87	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2014
88	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2015
89	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2016
90	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2017
91	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1994
92	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1995
93	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1996
94	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1997
95	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1998
96	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1999
97	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2000
98	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2001
99	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2002
100	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2003
101	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2004
102	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2005
103	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2006
104	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2007
105	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2008
106	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2009
107	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2010
108	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2011
109	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2012
110	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2013
111	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2014
112	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2015
113	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2016

	Site	Category	Name	Type	Frequency	Year
114	Tutuila, American Samoa (SMO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2017
115	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1974
116	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1975
117	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1976
118	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1977
119	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1978
120	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1979
121	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1980
122	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1981
123	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1982
124	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1983
125	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1984
126	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1985
127	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1986
128	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1987
129	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1988
130	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1989
131	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1990
132	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1991
133	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1992
134	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1993
135	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1994

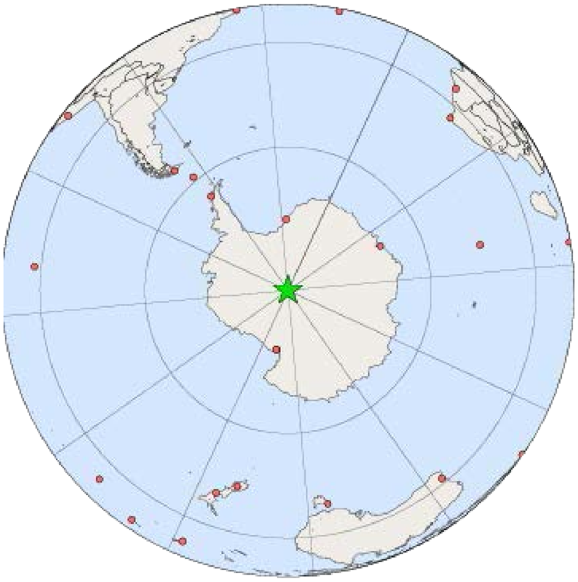
	Site	Category	Name	Type	Frequency	Year
136	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1995
137	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1996
138	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1997
139	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1998
140	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1999
141	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2000
142	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2001
143	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2002
144	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2003
145	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2004
146	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2005
147	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2006
148	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2007
149	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2008
150	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2009
151	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2010
152	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2011
153	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2012
154	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2013
155	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2014
156	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2015
157	Tutuila, American Samoa (SMO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2016

	Site	Category	Name	Type	Frequency	Year
158	Tutuila, American Samoa (SMO) Vertical Profile of Ozone from Balloon flight.	Ozone	Ozone (O_3)	Balloon	Vertical Profile	Multiple
159	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Non-Methane Hydrocarbons	ethane (C_2H_6)	Flask	Discrete	Multiple
160	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Non-Methane Hydrocarbons	propane (C_3H_8)	Flask	Discrete	Multiple
161	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Non-Methane Hydrocarbons	isoprene (C_5H_8)	Flask	Discrete	Multiple
162	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Greenhouse Gases	Methane (CH_4)	Flask	Discrete	Multiple
163	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Methane (d^{13}C (CH_4))	Flask	Discrete	Multiple
164	Tutuila, American Samoa (SMO)	Greenhouse Gases	Carbon Monoxide (CO)	Flask	Discrete	Multiple
165	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Dioxide (CO_2)	Flask	Discrete	Multiple
166	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Carbon Dioxide (d^{13}C (CO_2))	Flask	Discrete	Multiple
167	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Greenhouse Gases	O18/O16 in Carbon Dioxide (d^{18}O (CO_2))	Flask	Discrete	Multiple
168	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Greenhouse Gases	Molecular Hydrogen (H_2)	Flask	Discrete	Multiple
169	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Non-Methane Hydrocarbons	i-butane (i-C_4H_{10})	Flask	Discrete	Multiple
170	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Non-Methane Hydrocarbons	i-pentane (i-C_5H_{12})	Flask	Discrete	Multiple
171	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Non-Methane Hydrocarbons	n-butane (n-C_4H_{10})	Flask	Discrete	Multiple
172	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Non-Methane Hydrocarbons	n-pentane (n-C_5H_{12})	Flask	Discrete	Multiple
173	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Greenhouse Gases	Methane (CH_4)	Flask	Monthly Averages	Multiple
174	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Methane (d^{13}C (CH_4))	Flask	Monthly Averages	Multiple
175	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Monoxide (CO)	Flask	Monthly Averages	Multiple
176	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Dioxide (CO_2)	Flask	Monthly Averages	Multiple
177	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Carbon Dioxide (d^{13}C (CO_2))	Flask	Monthly Averages	Multiple
178	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Greenhouse Gases	O18/O16 in Carbon Dioxide (d^{18}O (CO_2))	Flask	Monthly Averages	Multiple
179	Tutuila, American Samoa (SMO) Air samples collected in glass flasks.	Greenhouse Gases	Molecular Hydrogen (H_2)	Flask	Monthly Averages	Multiple
180	Tutuila, American Samoa (SMO) Continuous in-situ measurements of solar radiation.	Radiation	Surface Radiation (grad)	Insitu	Minute Averages	Multiple
181	Tutuila, American Samoa (SMO) Continuous measurements of surface ozone.	Ozone	Ozone (O_3)	Insitu	Hourly Averages	Multiple
182	Tutuila, American Samoa (SMO) In-situ co2 daily averages	Greenhouse Gases	Carbon Dioxide (CO_2)	Insitu	Daily Averages	Multiple
183	Tutuila, American Samoa (SMO) In-situ co2 hourly averages	Greenhouse Gases	Carbon Dioxide (CO_2)	Insitu	Hourly Averages	Multiple

	Site	Category	Name	Type	Frequency	Year
184	Tutuila, American Samoa (SMO) In-situ co2 monthly averages	Greenhouse Gases	Carbon Dioxide (CO_2)	Insitu	Monthly Averages	Multiple

South Pole Atmospheric Baseline Observatory in time lapse with lidar beam.

GMD South Pole staff releasing a large plastic balloon carrying an ozonesonde to measure stratospheric ozone concentrations. Temperature -80°F (-62°C).



Location

- Country: United States
- Latitude: 89.98° South
- Longitude: 24.8° West
- Elevation: 2810.00 masl
- Time Zone: Local Standard Time + -12.0 hour(s) = UTC

Contact

- Contact Name: NOAA
- Address: NOAA/ ESRL Project O-257-S
  South Pole Station
  PSC 768 Box 400, APO AP, 96598-5400, Antarctica
- Phone: (303) 497-6655
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Data

- Available datasets
- Data visualization
- Photo Gallery

Cooperating Agencies

- National Science Foundation

Description

The South Pole Observatory was established at the geographical south pole at 2837 m above sea level in 1957 as part of the International Geophysical Year. The South Pole Observatory (SPO) is one of six atmospheric baseline observatories for NOAA's Earth System Research Laboratory, Global Monitoring Division (GMD). The National Science Foundation provides the infrastructure for the NOAA/ESRL scientific operations including a state of the art science building named the Atmospheric Research Observatory opened in 1997. ARO was built to house current atmospheric research and replaced NOAA's Clean Air Facility in operation from 1977 to 1997. Two GMD observatory staff spend one year tours of duty at the station which includes a 9 month period of isolation and six months of darkness. Atmospheric data has been collected from South Pole since the International Geophysical Year (IGY), 1957 - 1958.

GMD Projects at South Pole, Antarctica

Carbon Cycle Surface Flasks

Parameter	Formula	First Sample Date	Status
Carbon Dioxide	CO_2	1975-01-21	Ongoing
Methane	CH_4	1983-02-20	Ongoing
Carbon Monoxide	CO	1989-12-15	Ongoing
Molecular Hydrogen	H_2	1989-12-15	Ongoing
Nitrous Oxide	N_2O	1997-01-16	Ongoing
Sulfur Hexafluoride	SF_6	1997-01-16	Ongoing
Carbon-13/Carbon-12 in Carbon Dioxide	$d^{13}C$ (CO_2)	1993-03-28	Ongoing
Oxygen-18/Oxygen-16 in Carbon Dioxide	$d^{18}O$ (CO_2)	1993-03-28	Ongoing
Carbon-13/Carbon-12 in Methane	$d^{13}C$ (CH_4)	1998-01-01	Ongoing
D/H in Methane	dD (CH_4)	2005-02-11	Terminated - 2010-01-08
Methyl Chloride	CH_3Cl	2005-01-28	Ongoing
Benzene	C_6H_6	2006-10-15	Ongoing
toluene	C_7H_8	2006-10-15	Ongoing
ethane	C_2H_6	2005-01-28	Ongoing
ethene	C_2H_4	2005-01-28	Ongoing
propane	C_3H_8	2005-01-28	Ongoing
propene	C_3H_6	2005-01-28	Ongoing
i-butane	i-C_4H_{10}	2005-01-28	Ongoing

Parameter	Formula	First Sample Date	Status
n-butane	n-C_4H_{10}	2005-01-28	Ongoing
i-pentane	i-C_5H_{12}	2005-01-28	Ongoing
n-pentane	n-C_5H_{12}	2005-01-28	Ongoing
n-hexane	n-C_6H_{14}	2005-01-28	Ongoing
isoprene	C_5H_8	2006-10-15	Ongoing
Acetylene	C_2H_2	2007-01-01	Ongoing

Carbon Cycle In Situ Observatory

Parameter	Formula	First Sample Date	Status
Carbon Dioxide	CO_2	1975-11-25	Ongoing

HATS Flask Sampling

Parameter	Formula	First Sample Date	Status
Nitrous Oxide	N_2O	1995-01-13	Ongoing
Sulfur Hexafluoride	SF_6	1995-01-13	Ongoing
HFC- 134a	CH_2FCF_3	1994-03-03	Ongoing
HCFC-22	CHF_2Cl	1992-07-04	Ongoing
CFC- 12	CCl_2F_2	1995-01-13	Ongoing
Methyl Chloride	CH_3Cl	1995-10-18	Ongoing
CFC-114	CFC-114	1992-07-04	Ongoing
HCFC-142b	CH_3CF_2Cl	1992-07-04	Ongoing
Halon-1211	$CBrClF_2$	1992-07-04	Ongoing
methyl bromide	CH_3Br	1995-10-18	Ongoing
HCFC-141b	CH_3CCl_2F	1993-01-09	Ongoing
methyl iodide	CH_3I	1992-01-23	Ongoing
CFC-113	CCl_2FCClF_2	1992-07-04	Ongoing
dichloromethane	CH_2Cl_2	1995-10-18	Ongoing
chloroform	$CHCl_3$	1993-01-09	Ongoing
carbon tetrachloride	CCl_4	1995-01-13	Ongoing
dibromomethane	CH_2Br_2	1998-03-01	Ongoing
tetrachloroethylene	C_2Cl_4	1993-02-08	Ongoing
bromoform	$CHBr_3$	1997-12-15	Ongoing
Benzene	C_6H_6	1999-02-01	Ongoing
carbonyl sulfide	COS	2000-05-15	Ongoing
HCFC-21	$CHCl_2F$	2000-02-18	Ongoing
HFC-152a	CH_3CHF_2	2000-01-23	Ongoing
toluene	C_7H_8	2014-02-24	Terminated - 2017-02-12
carbonyl disulfide	CS_2	2006-01-27	Terminated - 2015-02-08
ethane	C_2H_6	2014-02-24	Ongoing
propane	C_3H_8	2006-12-08	Ongoing
i-butane	i-C_4H_{10}	2014-02-24	Ongoing
n-butane	n-C_4H_{10}	2006-12-08	Ongoing
i-pentane	i-C_5H_{12}	2006-12-08	Ongoing
n-pentane	n-C_5H_{12}	2006-12-08	Ongoing
n-hexane	n-C_6H_{14}	2013-01-11	Ongoing
Halon 1301	CF_3Br	2004-02-01	Ongoing

Parameter	Formula	First Sample Date	Status
Halon 2402	$CBrF_2CBrF_2$	1995-10-18	Ongoing
HFC- 143a	CH_3CF_3	2006-12-08	Ongoing
HFC-227ea	CF_3CHFCF_3	2010-11-08	Ongoing
HFC-365mfc	$CH_3CF_2CH_2CF_3$	2009-02-25	Ongoing
CFC-115	$CClF_2CF_3$	2006-12-08	Ongoing
HFC-125	CHF_2CF_3	2006-12-08	Ongoing
CFC- 13	$CClF_3$	2006-12-08	Ongoing
Perfluoropropane	C_3F_8	2014-02-24	Ongoing
Acetylene	C_2H_2	2006-12-08	Ongoing
HFC-32	CH_2F_2	2008-09-08	Ongoing
Methyl Chloroform	CH_3CCl_3	1992-07-04	Ongoing
Chloroiodomethane	CH_2ClI	2016-06-07	Ongoing
diiodomethane	CH_2I_2	2016-06-07	Ongoing
Bromoiodomethane	CH_2BrI	2016-06-07	Ongoing
Bromochloromethane	CH_2BrCl	2016-06-07	Ongoing
Bromodichloromethane	$CHBrCl_2$	2016-06-07	Ongoing
CFC- 11	CCl_3F	1995-01-13	Ongoing
tetrafluoromethane	CF_4	2014-02-24	Ongoing
hexafluoroethane	CF_3CF_3	2014-02-24	Ongoing
nitrogen trifluoride	NF_3	2014-12-08	Ongoing
sulfuryl fluoride	SO_2F_2	2014-12-08	Ongoing
HFC-236fa	$CF_3CH_2CF_3$	2014-02-24	Ongoing
HCFC-133a	CH_2ClCF_3	2014-02-24	Ongoing
CFC-112	CCl_3CClF_2	2014-02-24	Ongoing
HFO-1234yf	$CH_2{=}CFCF_3$	2016-02-25	Ongoing
1,2-dichloroethane	CH_2ClCH_2Cl	2016-08-08	Ongoing
2,2-Dichloro-1,1,1-Trifluoroethane	$CHCl_2CF_3$	2017-03-08	Ongoing
1,1-dichloroethane	$C_2H_4Cl_2$	2016-06-07	Ongoing
dibromochloromethane	$CHBr_2Cl$	2016-06-07	Ongoing
Ethyl Chloride	C_2H_5Cl	2010-11-08	Ongoing
Propyne	C_3H_4	2010-11-08	Ongoing
Trichloroethylene	C_2HCl_3	2014-02-24	Ongoing

HATS InSitu Observatory

Parameter	Formula	First Sample Date	Status
Nitrous Oxide	N_2O	1998-01-26	Ongoing
Sulfur Hexafluoride	SF_6	1998-01-26	Ongoing
HCFC-22	CHF_2Cl	1998-01-25	Ongoing
CFC- 12	CCl_2F_2	1998-01-27	Ongoing
Methyl Chloride	CH_3Cl	1999-07-02	Ongoing
HCFC-142b	CH_3CF_2Cl	1998-01-25	Ongoing
Halon-1211	$CBrClF_2$	1998-01-30	Ongoing
CFC-113	CCl_2FCClF_2	1998-01-30	Ongoing
chloroform	$CHCl_3$	1998-01-01	Ongoing
carbon tetrachloride	CCl_4	1998-02-10	Ongoing

Parameter	Formula	First Sample Date	Status
Methyl Chloroform	CH_3CCl_3	1998-01-30	Ongoing
CFC- 11	CCl_3F	2000-02-16	Ongoing

Aerosol Surface In-Situ

Parameter	Formula	First Sample Date	Status
Light Scattering Coefficient	Ïƒ$_{sp}$	1979-01-01	Ongoing
Light Absorption Coefficient	Ïƒ$_{ap}$	1979-01-01	Ongoing
Particle Number Concentration	N_t	1974-01-01	Ongoing

Radiation In-Situ Observatory

Parameter	Formula	First Sample Date	Status
Direct Normal		1976-02-01	Ongoing
Downwelling Shortwave		1978-01-01	Ongoing
Diffuse		1995-11-10	Ongoing
Upwelling Shortwave		1985-01-01	Ongoing
Downwelling Longwave		1993-11-21	Ongoing
Upwelling Longwave		1993-11-21	Ongoing
Spectral		2000-12-01	Ongoing

Surface Ozone

Parameter	Formula	First Sample Date	Status
Ozone	O_3	1975-01-23	Ongoing

Dobson Total Ozone

Parameter	Formula	First Sample Date	Status
Ozone	O_3	1963-12-04	Ongoing

Ozonesonde

Parameter	Formula	First Sample Date	Status
Ozone	O_3	1967-01-17	Ongoing

Meteorology

Parameter	Formula	First Sample Date	Status
Wind Speed	ws	1975-02-21	Ongoing
Wind Direction	wd	1975-02-21	Ongoing
Temperature	temp	1977-01-01	Ongoing
Ambient Pressure	press	1977-01-01	Ongoing
Relative Humidity	rh	1977-03-29	Ongoing

Antarctic UV

Parameter	Formula	First Sample Date	Status
Total Ozone	O_3	1988-02-01	Ongoing
Spectral UV Irradiance (285-600 nm)		1988-02-01	Ongoing
5 channel narrow-band (~10 nm) filter UV radiometer		1988-02-01	Ongoing
Total solar irradiance		1988-02-01	Ongoing
UV index		1988-02-01	Ongoing
Total UV daily dose		1988-02-01	Ongoing

GMD Datasets for South Pole, Antarctica

	Site	Category	Name	Type	Frequency	Year
1	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Daily Averages	Multiple
2	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Daily Averages	Multiple
3	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Daily Averages	Multiple
4	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-113 (cfc113)	Insitu	Daily Averages	Multiple
5	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Daily Averages	Multiple
6	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloride (ch3cl)	Insitu	Daily Averages	Multiple
7	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	Halon-1211 (h1211)	Insitu	Daily Averages	Multiple
8	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-142b (hcfc142b)	Insitu	Daily Averages	Multiple
9	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-22 (hcfc22)	Insitu	Daily Averages	Multiple
10	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Daily Averages	Multiple
11	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Sulfur Hexafluoride (sf6)	Insitu	Daily Averages	Multiple
12	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Hourly Averages	Multiple
13	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Hourly Averages	Multiple
14	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Hourly Averages	Multiple
15	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-113 (cfc113)	Insitu	Hourly Averages	Multiple
16	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Hourly Averages	Multiple
17	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloride (ch3cl)	Insitu	Hourly Averages	Multiple
18	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	Halon-1211 (h1211)	Insitu	Hourly Averages	Multiple
19	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-142b (hcfc142b)	Insitu	Hourly Averages	Multiple
20	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-22 (hcfc22)	Insitu	Hourly Averages	Multiple
21	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Hourly Averages	Multiple
22	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Sulfur Hexafluoride (sf6)	Insitu	Hourly Averages	Multiple
23	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Monthly Averages	Multiple
24	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Monthly Averages	Multiple
25	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Monthly Averages	Multiple
26	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-113 (cfc113)	Insitu	Monthly Averages	Multiple

	Site	Category	Name	Type	Frequency	Year
27	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Monthly Averages	Multiple
28	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	Methyl Chloride (ch3cl)	Insitu	Monthly Averages	Multiple
29	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	Halon-1211 (h1211)	Insitu	Monthly Averages	Multiple
30	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-142b (hcfc142b)	Insitu	Monthly Averages	Multiple
31	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Halocompounds	HCFC-22 (hcfc22)	Insitu	Monthly Averages	Multiple
32	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Monthly Averages	Multiple
33	South Pole, Antarctica, United States (SPO) Continuous in-situ CATS GC measurements.	Greenhouse Gases	Sulfur Hexafluoride (sf6)	Insitu	Monthly Averages	Multiple
34	South Pole, Antarctica, United States (SPO) Continuous in-situ RITS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Daily Averages	Multiple
35	South Pole, Antarctica, United States (SPO) Continuous in-situ RITS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Daily Averages	Multiple
36	South Pole, Antarctica, United States (SPO) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Daily Averages	Multiple
37	South Pole, Antarctica, United States (SPO) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Daily Averages	Multiple
38	South Pole, Antarctica, United States (SPO) Continuous in-situ RITS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Daily Averages	Multiple
39	South Pole, Antarctica, United States (SPO) Continuous in-situ RITS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Hourly Averages	Multiple
40	South Pole, Antarctica, United States (SPO) Continuous in-situ RITS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Hourly Averages	Multiple
41	South Pole, Antarctica, United States (SPO) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Hourly Averages	Multiple
42	South Pole, Antarctica, United States (SPO) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Hourly Averages	Multiple
43	South Pole, Antarctica, United States (SPO) Continuous in-situ RITS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Hourly Averages	Multiple
44	South Pole, Antarctica, United States (SPO) Continuous in-situ RITS GC measurements.	Halocompounds	Carbon Tetrachloride (CCl4)	Insitu	Monthly Averages	Multiple
45	South Pole, Antarctica, United States (SPO) Continuous in-situ RITS GC measurements.	Halocompounds	Methyl Chloroform (CH3CCl3)	Insitu	Monthly Averages	Multiple
46	South Pole, Antarctica, United States (SPO) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-11 (cfc11)	Insitu	Monthly Averages	Multiple
47	South Pole, Antarctica, United States (SPO) Continuous in-situ RITS GC measurements.	Halocompounds	CFC-12 (cfc12)	Insitu	Monthly Averages	Multiple
48	South Pole, Antarctica, United States (SPO) Continuous in-situ RITS GC measurements.	Greenhouse Gases	Nitrous Oxide (n2o)	Insitu	Monthly Averages	Multiple
49	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1975
50	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1977
51	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1978
52	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1979
53	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1980

	Site	Category	Name	Type	Frequency	Year
54	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1981
55	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1982
56	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1983
57	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1984
58	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1985
59	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1986
60	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1987
61	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1988
62	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1989
63	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1990
64	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1991
65	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1992
66	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1993
67	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1994
68	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1995
69	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1996
70	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1997
71	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1998
72	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	1999
73	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2000
74	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2001
75	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2002
76	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2003
77	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2004
78	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2005
79	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2006
80	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2007
81	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2008
82	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2009
83	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2010

	Site	Category	Name	Type	Frequency	Year
84	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2011
85	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2012
86	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2013
87	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2014
88	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2015
89	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Hourly Averages	2016
90	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1979
91	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1980
92	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1981
93	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1982
94	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1983
95	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1984
96	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1985
97	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1986
98	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1987
99	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1988
100	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1989
101	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1990
102	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1991
103	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1992
104	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1993
105	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1994
106	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1995
107	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1996
108	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1997
109	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1998
110	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	1999
111	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2000
112	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2001
113	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2002

	Site	Category	Name	Type	Frequency	Year
114	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2003
115	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2004
116	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2005
117	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2006
118	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2007
119	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2008
120	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2009
121	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2010
122	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2011
123	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2012
124	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2013
125	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2014
126	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2015
127	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2016
128	South Pole, Antarctica, United States (SPO) Continuous In-situ measurements of meteorology	Meteorology	Meteorology (met)	Insitu	Minute Averages	2017
129	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1974
130	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1975
131	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1976
132	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1977
133	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1978
134	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1979
135	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1980
136	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1981
137	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1982
138	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1983
139	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1984

	Site	Category	Name	Type	Frequency	Year
140	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1985
141	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1986
142	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1987
143	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1988
144	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1989
145	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1990
146	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1991
147	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1992
148	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1993
149	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1994
150	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1995
151	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1996
152	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1997
153	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1998
154	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	1999
155	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2000
156	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2001
157	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2002
158	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2003
159	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2004
160	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2005
161	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2006

	Site	Category	Name	Type	Frequency	Year
162	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2007
163	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2008
164	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2009
165	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2010
166	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2011
167	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2012
168	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2013
169	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2014
170	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2015
171	South Pole, Antarctica, United States (SPO) In-situ Hourly Averages of aerosol properties measured at 10 meters above ground level	Aerosols	Aerosols	Insitu	Hourly Averages	2016
172	South Pole, Antarctica, United States (SPO) Vertical Profile of Ozone from Balloon flight.	Ozone	Ozone (O_3)	Balloon	Vertical Profile	Multiple
173	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	ethane (C_2H_6)	Flask	Discrete	Multiple
174	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	propane (C_3H_8)	Flask	Discrete	Multiple
175	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	isoprene (C_5H_8)	Flask	Discrete	Multiple
176	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Greenhouse Gases	Methane (CH_4)	Flask	Discrete	Multiple
177	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Methane ($d^{13}C$ (CH_4))	Flask	Discrete	Multiple
178	South Pole, Antarctica, United States (SPO)	Greenhouse Gases	Carbon Monoxide (CO)	Flask	Discrete	Multiple
179	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Dioxide (CO_2)	Flask	Discrete	Multiple
180	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Carbon Dioxide ($d^{13}C$ (CO_2))	Flask	Discrete	Multiple
181	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Greenhouse Gases	O18/O16 in Carbon Dioxide ($d^{18}O$ (CO_2))	Flask	Discrete	Multiple
182	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Greenhouse Gases	Molecular Hydrogen (H_2)	Flask	Discrete	Multiple
183	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	i- butane (i-C_4H_{10})	Flask	Discrete	Multiple
184	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	i- pentane (i- C_5H_{12})	Flask	Discrete	Multiple
185	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	n- butane (n-C_4H_{10})	Flask	Discrete	Multiple

	Site	Category	Name	Type	Frequency	Year
186	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Non- Methane Hydrocarbons	n- pentane ($n-C_5H_{12}$)	Flask	Discrete	Multiple
187	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Greenhouse Gases	Methane (CH_4)	Flask	Monthly Averages	Multiple
188	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Methane ($d^{13}C$ (CH_4))	Flask	Monthly Averages	Multiple
189	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Monoxide (CO)	Flask	Monthly Averages	Multiple
190	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Greenhouse Gases	Carbon Dioxide (CO_2)	Flask	Monthly Averages	Multiple
191	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Greenhouse Gases	C13/C12 in Carbon Dioxide ($d^{13}C$ (CO_2))	Flask	Monthly Averages	Multiple
192	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Greenhouse Gases	O18/O16 in Carbon Dioxide ($d^{18}O$ (CO_2))	Flask	Monthly Averages	Multiple
193	South Pole, Antarctica, United States (SPO) Air samples collected in glass flasks.	Greenhouse Gases	Molecular Hydrogen (H_2)	Flask	Monthly Averages	Multiple
194	South Pole, Antarctica, United States (SPO) Continuous in-situ measurements of solar radiation.	Radiation	Surface Radiation (grad)	Insitu	Minute Averages	Multiple
195	South Pole, Antarctica, United States (SPO) Continuous measurements of surface ozone.	Ozone	Ozone (O_3)	Insitu	Hourly Averages	Multiple
196	South Pole, Antarctica, United States (SPO) In-situ co2 daily averages	Greenhouse Gases	Carbon Dioxide (CO_2)	Insitu	Daily Averages	Multiple
197	South Pole, Antarctica, United States (SPO) In-situ co2 hourly averages	Greenhouse Gases	Carbon Dioxide (CO_2)	Insitu	Hourly Averages	Multiple
198	South Pole, Antarctica, United States (SPO) In-situ co2 monthly averages	Greenhouse Gases	Carbon Dioxide (CO_2)	Insitu	Monthly Averages	Multiple

Sampling Sites, Measurement Programs and Data Sets

Part 2: Measurements: National, International and Cooperative Programs

Global Monitoring Division
NOAA, Boulder, Colorado

Atmospheric Research Observatory - South Pole, Antarctica *Photo by: Patrick Cullis*

Sampling Sites and Measurement Programs

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Global Monitoring Division, ESRL, Boulder, Colorado

Measurement	United States and Territories	International
Aerosol - Optics and microphysics	**Surface, Continuous Measurements**	**Surface, Continuous Measurements**
Absorption, scattering, and particle number at most sites. Additional measurements, e.g., cloud condensation nuclei, aerosol hydroscopicity and/or chemical composition at some sites.	Barrow, Alaska	Alert, Canada
	Bondville, Illinois	Anmyeon-do, Korea
	Boone, North Carolina	*Azores, Portugal (campaign, closed)*
	Cape Cod, Massachusetts (campaign, closed)	*Black Forest, Germany (campaign, closed)*
	Cape San Juan, Puerto Rico	Cape Grim, Australia
	Lamont, Oklahoma (discontinued)	Cape Point, South Africa
	Mauna Loa, Hawaii	East Trout Lake, Canada
	Mount Bachelor, Oregon	Egbert, Canada
	Point Reyes, California (campaign, closed)	Gosan, South Korea
	Steamboat Springs, Colorado	Granada, Spain
	Trinidad Head, California (closed)	Hyytiala, Finland
		K'puszta, Hungary
		Manacapuru, Brazil (campaign, closed)
		Mazagon, Spain
		Montsec, Spain
		Montseny, Spain
		Mt. Lulin, Taiwan
		Mt. Moussala, Bulgaria
		Mt. Waliguan, China
		Nainital, India (campaign, closed)
		Niamey, Niger (campaign, closed)
		Resolute Bay, Canada (closed)
		Seoul, South Korea (closed)
		Shouxian, China (campaign, closed)
		Sierra Nevada Station, Spain
		South Pole, Antarctica (United States)
		Summit, Greenland
		Tiksi, Russia
		Tutuila, American Samoa (discontinued)
		Whistler, Canada
		Zugspitze, Germany
Aerosol - Lidar	**Vertical Profiles**	**Vertical Profiles**
Aerosol light scattering versus altitude.	Boulder, Colorado (stratosphere) (weekly)	South Pole, Antarctica (troposphere) (daily)
	Mauna Loa, Hawaii (stratosphere) (weekly)	*Summit, Greenland (strat & trop, discontinued)*
	Trinidad Head, California (troposphere) (closed)	
	Tutuila, American Samoa (stratosphere) (down for repairs)	
Aerosol - Black Carbon	**Surface, Continuous**	**Surface, Continuous**
	Barrow, Alaska	Mt. Lulin, Taiwan
	Mauna Loa, Hawaii	South Pole, Antarctica (United States)
		Summit, Greenland (closed)
		Tiksi, Russia
Carbon Cycle Gases	**Surface, Continuous**	**Surface, Continuous**
	Barrow, Alaska (CO_2, CH_4, CO)	
(Species listed ➔)	Fox, Alaska (CO_2, CO, CH_4)	*Cherskiy, Russia (CH_4) (Inactive funding hold)*
	Martha's Vineyard, Massachusetts (CO_2) (offshore platform)	South Pole, Antarctica (United States) (CO_2)
	Mauna Loa, Hawaii (CO_2, CH_4, CO)	Tutuila, American Samoa (CO_2)
	Mt. Bachelor, Oregon (CO_2)	
	Shenandoah, Virginia (CO_2, CO)	
Carbon Cycle Gases	**Tall Tower, Continuous**	**Tall Tower, Continuous**
(Species listed ➔)	Argyle, Maine (CO_2, CO)	
	Beech Island, South Carolina (CO_2, CO)	
	Erie, Colorado (CO_2, CO) (closed)	
	Grifton, North Carolina (CO_2) (closed)	
	Moody, Texas (CO_2, CO)	
	Park Falls, Wisconsin (CO_2, CH_4, CO)	
	Walnut Grove, California (CO_2, CH_4, CO)	
	West Branch, Iowa (CO_2, CO)	

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Carbon Cycle Gases	Airborne, Light Aircraft (Bi-weekly)	Airborne, Light Aircraft (Bi-weekly)
(Flask Samples) Species Measured In Carbon Cycle Flasks: CO_2, CH_4, CO, H_2, N_2O, SF_6, ^{13}C in CO_2, 18O in CO_2 ^{13}C in CH_4, CH_3D, **plus** CFC-11, -12, -113, -115 HCFC-22, -141b, -142b CH_3CCl_3, CCl_4, CH_2Cl_2, $CHCl_3$, C_2Cl_4 HFC-134a, -152a, -365mfc, -227ea, HFC-143a, -125, -32 Halon 1211,-1301,-2402. CH_3Br, CH_3Cl, CH_3I N_2O, SF_6, COS CH_2Br_2, $CHBr_3$ C_2H_2, C_3H_8, n-C_4H_{10}, n-C_5H_{12}, iC_5H_{12}, C_6H_6	*Beaver Crossing, Nebraska (closed)* *Bondville, Illinois (closed)* *Bradgate, Iowa (closed)* Briggsdale, Colorado Cape May, New Jersey Charleston, South Carolina *Dahlen, North Dakota (closed)* *Fairchild, Wisconsin (closed)* *Harvard Forest, Massachusetts (closed)* Homer, Illinois Isles of Shoals, New Hampshire Kodiak USCG, Alaska (various locations in Alaska) *Oahu, Hawaii (closed)* *Oglesby, Illinois (closed)* Park Falls, Wisconsin Poker Flat, Alaska Ponca City, Oklahoma *Rowley, Iowa (closed)* Sinton, Texas Trinidad Head, California West Branch, Iowa	East Trout Lake, Canada Estevan Point, Canada Raratonga, Cook Islands *Ulaanbaatar, Mongolia (closed)*
Carbon Cycle Gases	**Airborne, Campaigns**	**Airborne, Campaigns**
(In-Situ Continuous and Flask Packages) CO_2, CH_4, CO Species Measured In Carbon Cycle Flasks: CO_2, CH_4, CO, H_2, N_2O, SF_6, ^{13}C in CO , 18O in CO , ^{13}C in CH_4, CH_3D, **plus** CFC-11, -12, -113, -115 HCFC-22, -141b, -142b CH_3CCl_3, CCl_4, CH_2Cl_2, $CHCl_3$, C_2Cl_4 HFC-134a, -152a, -365mfc, -227ea, HFC-143a, -125, -32 Halon 1211,-1301,-2402. CH_3Br, CH_3Cl, CH_3I N_2O, SF_6, COS CH_2Br_2, $CHBr_3$ C_2H_2, C_3H_8, n-C_4H_{10}, n-C_5H_{12}, iC_5H_{12}, C_6H_6	ACT-America NASA (Middle and Eastern U.S.) *CARVE NASA (Alaska) (ended)* Urban Dome/INFlux NIST (Indianapolis and D.C. Area)	ATom NASA (pole-to-pole, Atlantic and Pacific) *HIPPO NSF (pole-to-pole, Atlantic and Pacific) (ended)*
Carbon Cycle Gases	**Ship Sampling, Carbon Cycle Flasks**	**Ship Sampling, Carbon Cycle Flasks**
(Flask Samples) Species Measured In Carbon Cycle Flasks: CO_2, CH_4, CO, H_2, N_2O, SF_6, ^{13}C in CO_2, 18O in CO_2 ^{13}C in CH_4, CH_3D		*Antarctic Ocean, Chinese Shi annual (on hold)* Drake Passage Transect (every 6 weeks) Eastern Pacific Transect (bi-monthly) *North Atlantic, Norway (Station M), weekly (closed)* *South China Sea (semi-monthly) (closed)* *Western Pacific Transect (variable) (closed)*

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Measurement	United States and Territories	International
Carbon Cycle Gases	**Surface, Weekly Flasks**	**Surface, Weekly Flasks**
Species Measured	Barrow, Alaska	Alert, Canada
In Carbon Cycle Flasks:	Cape Kumukahi, Hawaii	*Amsterdam Island, France (clo sed)*
CO_2, CH_4, CO, H_2, N_2O, SF_6,	*Cape Meares, Oregon (closed)*	Anmyeon-do, Republic of Kore a
^{13}C in CO_2, 18O in CO_2	Cold Bay, Alaska	*Arembepe, Brazil (closed)*
^{13}C in CH_4, CH_3D **plus**	*Grifton, North Carolina (CO2) (closed)*	Ascension Island, United Kingc on
Volatile Organic Compounds:	Guam, Marianas Islands	Assekrem, Algeria
ethane, n-hexane,	Key Biscayne, Florida	*Baltic Sea, Poland (closed)*
propane, propene	Lamont, Oklahoma	Baring Head, New Zealand
methyl-chloride, ethane,	Mauna Loa, Hawaii	*Bird Island, United Kingdom (c losed)*
i-pentane, n-pentane	Midway Island, Pacific	*Black Sea, Romania (closed)*
i-butane, n-butane	Niwot Ridge, Colorado	Bukit Kototabang, Indonesia
in a subset of flasks.	*Olympic Peninsula, Washington (closed)*	Cape Grim, Australia
	Park Falls, Wisconsin	Cape Point, South Africa
	Point Arena, California (closed)	Christmas Island, Kiribati
	Shemya Island, Alaska	*Conejo, Mexico (closed)*
	Trinidad Head, California (closed)	Crozet Island, Indian Ocean
	Tutuila, American Samoa	Dongsha Island, Taiwan
	Wendover, Utah	*Dwejra Point, Gozo (closed)*
		Easter Island, Chile
		Gobabeb, Namibia
		Halley Station, Antarctica (United Kingdom)
		Hegyhatsal, Hungary
		Hohenpeissenberg, Germany
		Kaashidhoo, Maldives (closed)
		Kibbutz Ketura, Israel
		Lac La Biche, Canada (closed)
		Lampedusa, Italy
		Mace Head, Ireland
		Mahe Island, Seychelles
		McMurdo Station, Antarctica (closed)
		Mould Bay, Canada (closed)
		Mt. Kenya, Kenya (closed)
		Mt. Lulin, Taiwan
		Mt. Waliguan, China
		Natal, Brazil
		Ny-Alesund, Svalbard
		Obninsk, Russia (closed)
		Ocean Station C, United States (closed)
		Ocean Station M, Norway (clo:)
		Ochsenkopf, Germany
		Palmer Station, Antarctica (United States)
		Plateau Assy, Kazakhstan (closed)
		Ragged Point, Barbados
		Sammaltunturi, Finland
		Sary Takum, Kazakhstan (closed)
		Shangdianzi, China
		Sierra Negra Volcano, Mexico
		South Pole, Antarctica (United States)
		St. Croix, Virgin Islands (closed)
		St. David's Head, Bermuda (closed)
		Summit, Greenland
		Syowa, Antarctica (Japan)
		Tae-ahn Peninsula, Republic c f Korea
		Tenerife, Canary Islands
		Terceira, Azores
		Tiksi, Russia
		Tudor Hill, Bermuda
		Ulaan Uul, Mongolia
		Ushuaia, Argentina
		Valladolid, Spain
		Vestmannaeyjar, Iceland

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Carbon Cycle Gases	Surface, Tower Flasks	Surface, Tower Flasks
Species Measured In Carbon Cycle Flasks: CO_2, CH_4, CO, H_2, N_2O, SF_6, ^{13}C in CO_2, 18O in CO_2 ^{13}C in CH_4, CH_3D, **plus** CFC-11, -12, -113, -115 HCFC-22, -141b, -142b CH_3CCl_3, CCl_4, CH_2Cl_2, $CHCl_3$, C_2Cl_4 HFC-134a, -152a, -365mfc, -227ea, HFC-143a, -125, -32 Halon 1211,-1301,-2402. CH_3Br, CH_3Cl, CH_3I N_2O, SF_6, COS CH_2Br_2, $CHBr_3$ C_2H_2, C_3H_8, n-C_4H_{10}, n-C_5H_{12}, iC_5H_{12}, C_6H_6	Argyle, Maine Beech Island, South Carolina *Erie, Colorado (closed)* Fox, Alaska Lamont, Oklahoma *Martha's Vineyard, Massachusetts (offshore) (closed)* Moody, Texas Mt. Bachelor, Oregon Mt. Wilson, California Niwot Ridge, Colorado Park Falls, Wisconsin Sutro, California Walnut Grove, California West Branch, Iowa	

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Measurement	United States and Territories	International
Halocarbon Network	**Surface, Weekly High Pressure Flasks**	**Surface, Weekly High Pressure Flasks**
Species Measured In Halocarbon Flasks CFC-11, -12, -113, -115 HCFC-22, -141b, -142b CH_3CCl_3, CCl_4, CH_2Cl_2, $CHCl_3$, C_2Cl_4 HFC-134a, -152a, -365mfc, -227ea, -143a, -125, -32 Halon 1211, -1301, -2402 CH_3Br, CH_3Cl, CH_3I, COS N_2O, SF_6, CH_2Br_2, $CHBr_3$ C_2H_2, C_3H_8, n-C_4H_{10}, n-C_5H_{12}, iC_5H_{12}, C_6H_6 Species in blue are measured less frequently then weekly	Barrow, Alaska Cape Kumukahi, Hawaii Harvard Forest, Massachusetts Mauna Loa, Hawaii Niwot Ridge, Colorado Park Falls, Wisconsin Trinidad Head, California Tutuila, American Samoa	Alert, Canada (weekly) Cape Grim, Australia (weekly) Mace Head, Ireland (weekly) Mt Waliguan, China (weekly) Negev Desert, Israel (bi-weekly) Palmer, Antarctica (United States) (bi-weekly) South Pole, Antarctica (United States) (bi-weekly) Summit, Greenland (bi-weekly) *Tierra del Fuego, Chile (closed)*
Halocarbon Species	**Surface, Continuous Measurements**	**Surface, Continuous Measurements**
N_2O, SF_6, CFC-11, CFC-12 CFC-113, halon-1211, $CHCl_3$, CH_3CCl_3, CCl_4, (all but Summit: HCFC-22, HCFC-142b, COS, CH_3Cl (Summit: CO, H_2, CH_4)	Barrow, Alaska Mauna Loa, Hawaii Niwot Ridge, Colorado Tutuila, American Samoa	South Pole, Antarctica (United States) *Summit, Greenland (discontinued)*
Halocarbon Species	**Surface, Tower Flasks**	**Surface, Tower Flasks**
Measured In Carbon Cycle Flasks CFC-11, -12, -113, -115 HCFC-22, -141b, -142b CH_3CCl_3, CCl_4, CH_2Cl_2, $CHCl_3$, C_2Cl_4 HFC-134a, -152a, -365mfc, -227ea, -143a, -125, -32 Halon 1211, -1301, -2402 CH_3Br, CH_3Cl, CH_3I, COS CH_2Br_2, $CHBr_3$ C_2H_2, C_3H_8, n-C_4H_{10}, n-C_5H_{12}, iC_5H_{12}, C_6H_6	Argyle, Maine Beech Island, South Carolina Central Alaska (CRV) Erie, Colorado *Martha's Vineyard, Massachusetts (closed)* Moody, Texas Mt. Bachelor, Oregon Mt. Wilson, California Park Falls, Wisconsin Sutro, California Walnut Grove, California West Branch, Iowa West Lafayette, Indiana (INFLUX campaign)	

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Halocarbon Species	**Airborne, Light Aircraft, Bi-weekly**	**Airborne, Light Aircraft, Bi-weekly**
Measured In Carbon Cycle Flasks	*Beaver Crossing, Nebraska (closed)*	East Trout Lake, Canada
	Bondville, Illinois (closed)	Estevan Point, Canada
CFC-11, -12, -113, -115	*Bradgate, Iowa (closed)*	Raratonga, Cook Islands
HCFC-22, -141b, -142b	Briggsdale, Colorado	*Ulaanbaatar, Mongolia (closed)*
CH_3CCl_3, CCl_4, CH_2Cl_2, $CHCl_3$, C_2Cl_4	Cape May, New Jersey	
HFC-134a, -152a, -365mfc, -227ea, -143a, -125, -32	Central Alaska (CRV) - (periodic NASA campaign)	
Halon 1211, -1301, -2402	Charleston, South Carolina	
CH_3Br, CH_3Cl, CH_3I, COS	Dahlen, North Dakota	
CH_2Br_2, $CHBr_3$	*Fairchild, Wisconsin (closed)*	
C_2H_2, C_3H_8, n-C_4H_{10}, n-C_5H_{12}, iC_5H_{12}, C_6H_6	*Harvard Forest, Massachusetts (closed)*	
	Homer, Illinois	
	Isles of Shoals, New Hampshire	
	Kodiak USCG, Alaska	
	Oahu, Hawaii (closed)	
	Park Falls, Wisconsin	
	Poker Flat, Alaska	
	Ponca City, Oklahoma	
	Rowley, Iowa (closed)	
	Sinton, Texas	
	Trinidad Head, California	
	West Branch, Iowa	
	West Lafayette, Indiana (INFLUX campaign)	
Halocarbon Missions	**Airborne, Large Balloons and Aircraft**	**Airborne, Large Balloons and Aircraft**
Balloon Measurements:	Barbers Point, Hawaii (aircraft, periodic)	Ascension Island, United Kingdon (aircraft periodic)
CH_4, H_2, CO, $N_2$0, SF_6,	ATom 1-4, Aug2016-May2018 (NASA aircraft, global).	Punta Arenas, Chile (aircraft, periodic)
CH_3CCl_3, CCl_4, halon-1211,	Palmdale, CA; Anchorage, AS; Kona, HI,	Christchurch, New Zealand (aircraft, periodic)
$CHCl_3$, CFC-11,-12,-113.	American Samoa; Minneapolis, MN; Bangor ME.	Lajas, Azores (aircraft periodic)
Aircraft: Above list plus	Edwards, California (aircraft, periodic)	Thule and Kangarlussuaq, Greenland (aircraft periodic)
PAN, HFC-134a, COS, CS_2	Fairbanks, Alaska (aircraft/balloons, periodic)	Recife, Brazil and Cabo Verde (aircraft periodic)
HCFC-22,-141b,-142b	Ft. Sumner, New Mexico (balloon, periodic)	Christchurch, New Zealand (aircraft, periodic)
CH_3Br, CH_3I	HIPPO 1-5, Jan2009-Aug2011 (NSF aircraft, global) locations:	COBRA (aircraft, Canada and United States)
Periodic aircraft, from flasks (HIPPO 1-5 only	American Samoa	HIPPO 1-5, Jan2009-Aug2011 (NSF aircraft, global).
CFC-11, -12, -113, -115	Anchorage, Alaska	Christchurch, New Zealand
HCFC-22, -141b, -142b	Arvada, Colorado	Darwin, Australia
CH_3CCl_3, CCl_4, CH_2Cl_2, $CHCl_3$, C_2Cl_4	Barrow, Alaska	Easter Island, Chile
HFC-134a, -152a, -365mfc, -227ea, -143a, -125, -32	Cold Bay, Alaska	Honiara, Australia
Halon 1211,-1301,-2402.	Honolulu, Hawaii	Papiete, Tahiti
CH_3Br, CH_3Cl, CH_3I, COS	Kona, Hawaii	Rarotonga, Cook Islands
CH_2Br_2, $CHBr_3$	Houston, Texas (aircraft, periodic)	Saipan, North Mariana Islands
C_2H_2, C_3H_8, n-C_4H_{10}, n-C_5H_{12}, iC_5H_{12}, C_6H_6	Key West, Florida (aircraft, periodic)	San Jose, Costa Rica
	Kennedy Space Center, Florida, (aircraft, periodic)	Sand Island, Midway Islands
		Kiruna, Sweden (balloon, periodic)
		San Jose, Costa Rica (aircraft)
		Janziero du Norte, Brazil (balloon, periodic)
Halocarbon Species	**Unmanned Aircraft Systems (UAS)**	**Unmanned Aircraft Systems (UAS)**
CH_4, H_2, CO, $N_2$0, SF_6,	Alaska Mission	GloPac (aircraft, Arctic & Pacific)
$CHCl_3$, CFC-11,-12, RH	California Mission	ATTREX (aircraft, Pacific and Indian Oceans)
halon-1211, O_3, H_2O, T	Gray Butte, California (Altair, test phase)	
	Western U.S. (Altair, wildfires, periodic)	

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Measurement	United States and Territories	International
Ozone	**Surface, In Situ, Continuous**	**Surface, In Situ, Continuous**
	Barrow, Alaska	McMurdo, Antarctica (United S tates)
	Erie, Colorado	Lauder, New Zealand
	Mauna Loa, Hawaii	Ragged Point, Barbados
	Moody, Texas	South Pole, Antarctica (United States)
	Niwot Ridge, Colorado	Summit, Greenland
	Trinidad Head, California	Tudor Hill, Bermuda
	Weaverville, California	*Westman Island, Iceland (closed)*
	Mt. Bachelor Observatory, Oregon	Tiksi, Russia
	Table Mountain, Boulder, Colorado	Tutuila, American Samoa
		Pico, Azores, Portugal
Ozone	**Total Column Ozone**	**Total Column Ozone**
	Barrow, Alaska (Dobson)	Lauder, New Zealand** (Dobson)
	Bismarck, North Dakota (Dobson)	Haute Provence, France** (Dobson)
	Bondville, Illinois (Brewer) ***	Maracompoche, Peru (Dobson) (cooperative)
	Boulder, Colorado (Dobson)**	*Perth, Australia** (Dobson) (T emporarily suspended)*
	Caribou, Maine (Dobson)	South Pole, Antarctica (United States) (Dobson)
	Fairbanks, Alaska (Dobson)**	
	Fort Peck, Montana (Brewer)***	** Also conduct Umkehr profile s that give
	Hanford, California (Dobson)	ozone concentrations in 8 successive
	Houston, Texas (Brewer)	layers within the sounding twic e per day.
	Mauna Loa, Hawaii (Dobson)**	
	Nashville, Tennessee (Dobson)	***Also conduct Umkehr profile measurements
	Niwot Ridge (Brewer)***	that yield ozone concentrations in 10
	Raleigh, North Carolina (Brewer)***	successive layers at sunrise an sunset.
	Table Mountain, Colorado (Brewer)***	
	Tallahassee, Florida (Dobson) (closed)	
	Tutuila, American Samoa (Dobson)	
	Wallops Island, Virginia (Dobson)	
Ozone Profiles	**Balloonborne Ozonesondes, Weekly**	**Balloonborne Ozonesondes, Weekly**
	Barrow, Alaska (periodic campaigns)	Galapagos Islands, Ecuador
	Boulder, Colorado	San Jose, Costa Rica
	Houston, Texas (periodic campaigns)	South Pole, Antarctica (United States)
	Huntsville, Alabama (1999-2018 - Support ended 2017)	*Summit, Greenland (discontinued)*
	Mauna Loa, Hawaii (1982 - 2018)	Suva, Fiji
	Narragansett, Rhode Island (2004 - 2011 - Discontinued)	Watukosek, Indonesia (SHADOZ 2013 - Discontinued)
	Trinidad Head, California (1997-2018 Transferred to CARB 2017)	Ha Noi, Vietnam
		Tutuila, American Samoa
		La Reunion, Reunion Island
Ozone Profiles	**Light Aircraft, Weekly Profiles**	**Light Aircraft, Weekly Profiles**
	Beaver Crossing, Nebraska (closed)	Estevan Point, Canada
	Bondville, Illinois (closed)	*Ulaanbaatar, Mongolia (closed)*
	Bradgate, Iowa (closed)	
	Briggsdale, Colorado	
	Cape May, New Jersey	
	Charleston, South Carolina	
	Fairchild, Wisconsin (closed)	
	Homer, Illinois	
	Isles of Shoals, New Hampshire	
	Oglesby, Illinois (closed)	
	Ponca City, Oklahoma	
	Rowley, Iowa (closed)	
	Trinidad Head, California	
	West Branch, Iowa (closed)	
Water Vapor Profiles	**Balloonborne Water Vapor Profiles**	**Balloonborne Water Vapor P rofiles**
	Boulder, Colorado (1980 to present)	Lauder, New Zealand (2004 to present)
	Ft. Sumner, New Mexico (periodic campaigns)	Kunming, China (campaign 20 12)
	Guam (campaigns 2014, 2016)	
	Hilo, Hawaii (2010 to present)	
	Houston, Texas (campaign 2011)	
	Table Mountain, California (campaign 2009)	

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Surface Radiation Budget	SURFRAD Continuous Measurements	SURFRAD Continuous Measurements
Downwelling short wave and long wave radiation, albedo, aerosol	Bondville, Illinois	Barrow, Alaska
optical depth, direct beam and	Desert Rock, Nevada	South Pole, Antarctica
diffuse radiation. UV and UVB radiation,	Fort Peck, Montana	
photosynthetically active radiation,	Goodwin Creek, Mississippi	
and T, RH, WS, WD, P	Penn State, Pennsylvania	
	Sioux Falls, South Dakota	
	Table Mountain (Boulder), Colorado	

Surface Radiation	SOLRAD Continuous Measurements	SOLRAD Continuous Measurements
Downwelling solar total, direct beam and diffuse radiation	Albuquerque, New Mexico	
plus UVB total	Bismarck, North Dakota	
	Hanford, California	
	Madison, Wisconsin	
	Salt Lake City, Utah	
	Seattle, Washington	
	Sterling, Virginia	
	Oak Ridge, Tennessee (closed)	
	Tallahassee, Florida (closed)	

Surface Radiation	BSRN Continuous Measurements	BSRN Continuous Measurements
Downwelling short wave	Barrow, Alaska	Kwajalein, Marshall Islands*(no albedo or long wave up)
and long wave radiation,	*Erie, Colorado (closed) ,*	Prospect Hill, Bermuda* (no albedo or long wave up)
albedo, aerosol optical	Tutuila, American Samoa (no albedo or long wave up)	South Pole, Antarctica (United States)*
depth, direct beam and	Bondville, Illinois	* GMD Operated
diffuse radiation	Fort Peck, Montana	Alert, Canada
and UV radiation, and	Table Mountain, Colorado	Alice Springs, Australia
T, RH, WS, WD, P	Goodwin Creek, Mississippi	Cabauw, Netherlands
	Penn State, Pennsylvania	Cambourne, United Kingdom
	Sioux Falls, South Dakota	Carpentras, France
	Table Mountain (Boulder), Colorado	Cocos Island, Australia
		DeAar, South Africa (closed)
		Dome Concordia, Antarctica (with ISAC, Italy)
		Eureka, Canada
		Florianoplis, Brazil
		Fukuoka, Japan
		Ilorin, Nigeria
		Ishigakijima, Japan
		Izana, Spain
		Lerwick, United Kingdom
		Lindenberg, Germany
		Mt. Waliguan, China (GAW)
		Neumayer, Antarctica (Germany)
		Ny Alesund, Svalbard
		Palaiseauu, France
		Payerne, Switzerland
		Regina, Canada (discontinued)
		Sede Boker, Israel
		Sumatrak, Indonesia (GAW)
		Summit, Greenland (discontinued)
		Syowa, Antarctica (Japan)
		Tamanrasset, Algeria
		Tateno, Japan
		Tiksi, Russia
		Toravere, Estonia
		Xianghe, China

Surface UV Radiation	UV Continuous	UV Continuous
	Bondville, Illinois	McMurdo, Antarctica (United States)
	Boulder, Colorado	South Pole, Antarctica (United States)
	Fort Peck, Montana	Palmer, Antarctica (United States)
	Houston, Texas	
	Mauna Loa, Hawaii	
	Niwot Ridge, Colorado	
	Raleigh, North Carolina	
	Goodwin Creek, Mississippi	
	Penn State, Pennsylvania	
	Sioux Falls, South Dakota	
	Desert Rock, Nevada	
	Table Mountain (Boulder), Colorado	

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Meteorology	**Surface, Continuous Measurements**	**Surface, Continuous Measurements**
Wind Propeller Anemometer	Barrow, Alaska (10 m) Table Mountain (Boulder), Colorado (8 m) Mauna Loa, Hawaii (10 and 38 m) *Trinidad Head, California (10 m) (closed)* Bondville, Illinois (8 m) Goodwin Creek, Mississippi (8 m) Fort Peck, Montana (8 m) Penn State, Pennsylvania (8 m) Sioux Falls, South Dakota (8 m) Desert Rock, Nevada (8 m)	Alert, Canada (SEARH Project) South Pole, Antarctica (United States) (2, 10, and 30 m) Summit, Greenland (10 m) Tutuila, American Samoa (17 m)
Meteorology	**Surface, Continuous Measurements**	**Surface, Continuous Measurements**
Barometric Pressure Pressure transducer	Barrow, Alaska *Table Mountain (Boulder), Colorado* Mauna Loa, Hawaii *Trinidad Head, California (closed)* Bondville, Illinois Goodwin Creek, Mississippi Fort Peck, Montana Penn State, Pennsylvania Sioux Falls, South Dakota Desert Rock, Nevada	Alert, Canada (SEARH Project) South Pole, Antarctica (United States) Summit, Greenland Tutuila, American Samoa
Meteorology	**Surface, Continuous Measurements**	**Surface, Continuous Measurements**
Ambient Temperature Aspirated platinum resistance probes	Barrow, Alaska (3 and 16 m) Table Mountain (Boulder), Colorado (2 and 8 m) Mauna Loa, Hawaii (2, 9, and 37 m) *Trinidad Head, California (2 and 10 m) (closed)* Bondville, Illinois (8 m) Goodwin Creek, Mississippi (8 m) Fort Peck, Montana (8 m) Penn State, Pennsylvania (8 m) Sioux Falls, South Dakota (8 m) Desert Rock, Nevada (8 m)	Alert, Canada (SEARCH Project) South Pole, Antarctica (United States) (2, 10, and 30 m) Summit, Greenland (2 and 8 m) Tutuila, American Samoa (2 and 17 m)
Meteorology	**Surface, Continuous Measurements**	**Surface, Continuous Measurements**
Dewpoint **Temperature** Hygrothermometers and relative humidity probes	Barrow, Alaska (3 m) Table Mountain (Boulder), Colorado (8 m) Mauna Loa, Hawaii (2 m) *Trinidad Head, California (2 m) (closed)* Bondville, Illinois (8 m) Fort Peck, Montana (8 m) Goodwin Creek, Mississippi (8 m)i Sioux Falls, South Dakota (8 m) Penn State, Pennsylvania (8 m) Desert Rock, Nevada (8 m)	Alert, Canada (SEARCH Project) South Pole, Antarctica (United States) (2 m) Summit, Greenland (2 m) Tutuila, American Samoa (2 m)
Meteorology	**Surface, Continuous Measurements**	**Surface, Continuous Measurements**
Precipitation Tipping bucket	*Boulder, Colorado (closed)* Mauna Loa, Hawaii	Tutuila, American Samoa

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American Samoa **Measurement Program**	**Home Institution**	**Websites**
Persistent Organic Pollutants	Environment and Climate Change Canada	https://www.ec.gc.ca/rs-mn/
CFC-11, CFC-12,	NASA/AGAGE	http://agage.eas.gatech.edu/
CFC-113, CCl_4, CH_3CCl_3,	NASA/AGAGE	http://agage.eas.gatech.edu/
CH_4, N_2O, $CHCl_3$	NASA/AGAGE	http://agage.eas.gatech.edu/
Medusa	NASA/AGAGE	http://agage.eas.gatech.edu/
AERONET Photometers	NASA/Goddard Space Flight Center	http://aeronet.gsfc.nasa.gov/
CO_2, ^{13}C, N_2O (flask)	Scripps Institution of Oceanography	http://scrippsco2.ucsd.edu/
O_2/N_2	Scripps Institution of Oceanography	http://scrippsco2.ucsd.edu/
Hydrocarbons	University of California, Irvine	http://www.physsci.uci.edu/
Ionospheric imaging	Johns Hopkins University	http://www.jhuapl.edu/
Barrow, Alaska **Measurement Program**	**Home Institution**	**Websites**
Atmospheric Radiation Measurement (ARM) sit	Department of Energy	http://www.arm.gov/sites/nsa.stm
Mercury analysis (until 2015)	Desert Research Institute	https://www.dri.edu
Persistent Organic Pollutants	Environment and Climate Change Canada	http://www.msc-smc.ec.gc.ca/gaps/
Climate Reference Network (CRN)	NOAA/NESDIS/NCDC	http://www.ncdc.noaa.gov/oa/ climate/uscrn/
POES Satellite downlink	NOAA/NESDIS	http://www.oso.noaa.gov/poes /
POES Satellite uplink	NOAA/NESDIS	http://www.oso.noaa.gov/poes /
Aerosols filter	NOAA Pacific Marine Environmental Laboratory	http://www.pmel.noaa.gov/
EarthScope Plate Boundary Observatory	National Science Foundation	https://www.nsf.gov/funding/ pgm
CO_2 Flux	San Diego State University	http://gcrg.sdsu.edu/?p=149
CO_2, ^{13}C, N_2O (flask)	Scripps Institution of Oceanography	http://scrippsco2.ucsd.edu/
O_2/N_2	Scripps Institution of Oceanography	http://scrippsco2.ucsd.edu/
Thaw depth in permafrost	State University of New York, Albany; University of Delaw are; USDA NRCS	https://www.albany.edu
SoumiNet GPS	UNAVCO	http://www.suominet.ucar.edu/support/
Black Carbon	University of California, Davis	http://delta.ucdavis.edu/index. htm
Hydrocarbons	University of California, Irvine	http://www.physsci.uci.edu/
Detachment 460 radiation monitoring	United States Air Force	Not Applicable
Precip gauge (until 2016)	USDA/Snow Survey	http://www.ak.nrcs.usda.gov/s now/
Geomagnetics	USGS	http://geomag.usgs.gov/obser vatories/barrow/
Mauna Loa, Hawaii **Measurement Program**	**Home Institution**	**Websites**
Radon	ANSTO	http://www.ansto.gov.au/
CMB radiation	ASIAA-AMIBA	http://amiba.asiaa.sinica.edu.tw/
Ionospheric disturbances (TIDDBIT)	ASTRA	http://www.astraspace.net
Cosmic dust fluxes	California Institute of Technology	http://www.caltech.edu
Clidar aerosol lidar	Central Connectict University	http://www2.ccsu.edu
UV	Colorado State University/USDA	http://uvb.nrel.colostate.edu/U VB/
$^{13}C/^{12}C$ and $^{18}O/^{16}O$ in CO_2	CSIRO	http://www.csiro.au/
Persistent Organic Pollutants	Environment and Climate Change Canada	http://www.msc-smc.ec.gc.ca/gaps/
Refractory black, organic, and elemental carbon	Environment and Climate Change Canada	http://www.msc-smc.ec.gc.ca/gaps/
GPS Testbed	FAA/Stanford University	http://aa.stanford.edu/about/control.php
Hawaii Civil Emergency Service	Hawaii State Civil Defense	http://www.hawaiicounty.gov/a ctive-alerts/
Volcano Activity	Hawaii Volcano Observatory	http://hvo.wr.usgs.gov/maunal oa/
Communications	HPA	http://www.hpa.edu/
Airglow studies	Johns Hopkins University	http://www.jhuapl.edu/
Satellite solar radiation calibration	Kindai University, Japan	https://www.kindai.ac.jp
Spectral radiation calibration	Meteorological Research Institute, Japan	http://www.mri-jma.go.jp/index _en.html
Column O_3	MSC Canada	http://exp-studies.tor.ec.gc.ca/ e/ozone/ozonecanada.htm
Sun photometer calibration	NASA AMES	https://www.nasa.gov/ames
AERONET Photometers	NASA Goddard Space Flight Center	http://aeronet.gsfc.nasa.gov/
Pyranometer	NASA Goddard Space Flight Center	http://atmospheres.gsfc.nasa. gov/climate/
Pandora ozone	NASA Goddard Space Flight Center	http://atmospheres.gsfc.nasa. gov/climate/
Stratospheric O_3 & Temp Profiles	NASA Jet Propulsion Laboratory	http://tmf-web.jpl.nasa.gov/
PANOPTES	NASA Jet Propulsion Laboratory	http://tmf-web.jpl.nasa.gov/
CIMEL sun photometer	National Ecological Observatory Network (NEON)	National Ecological Observatory Network (NEON)
Water vapor, chloride oxide	Naval Research Labs	http://www.nrl.navy.mil/
FTIR column spectra of atmospheric gases	NCAR	https://ncar.ucar.edu
Solar Spectra	NCAR FTS	http://www.acd.ucar.edu/irwg/
Stratospheric Composition Change	NDACC	http://www.ndaccdemo.org

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Mauna Loa, Hawaii **Measurement Program**	**Home Institution**	**Websites**
CO_2, ^{13}C, N_2O	NIES	http://www.nies.go.jp/index.html
Carbon monoxide	NOAA Air Resources Lab	www.arl.noaa.gov
Hg^0, Hg^{+2}, Hg^p	NOAA Air Resources Lab	www.arl.noaa.gov
Particulates	NOAA Air Resources Lab	www.arl.noaa.gov
Surface O_3, and SO_2	NOAA Air Resources Lab	www.arl.noaa.gov
Meteorology	NOAA Earth System Research Lab (GSD)	http://gpsmet.noaa.gov/
Meteorology	NOAA National Weather Service	http://www.prh.noaa.gov/hnl/
Rainfall at Kulani Mauka site	NOAA National Weather Service	http://www.prh.noaa.gov/hnl/
Seismic activity	NOAA Pacific Tsunami Warning Center	http://ptwc.weather.gov
Climate Reference Network (CRN)	NOAA/NESDIS/NCDC	http://www.ncdc.noaa.gov/oa/ climate/uscrn/
Seismic activity	NOAA Pacific Tsunami Warning Center	http://ptwc.weather.gov/
BrO	NOAA and NIWA	http://www.niwa.co.nz/
NO_2	NOAA and NIWA	http://www.niwa.co.nz/
UV	NOAA and NIWA	http://www.niwa.co.nz/
Climate Reference Network (CRN)	NOAA/NESDIS/NCDC	https://www.ncdc.noaa.gov/crn
Global Oscillation Network Group (GONG)	National Solar Observatory	https://gong.nso.edu
Stratospheric ozone profiles	Naval Research Labs	https://www.nrl.navy.mil
Multi-filter rotating shadowband radiometer	Pacific Northwest National Laboratory (PNNL)	https://www.pnnl.gov
Solar calibration	Pacific Northwest National Laboratory (PNNL)	https://www.pnnl.gov
Video Surveillance	Pohakuloa Training Area Range Surveillance System	http://cnic.navy.mil/PMRF/inde x.htm
CO_2 (continuous)	Scripps Institution of Oceanography	http://scrippsco2.ucsd.edu/
CO_2, ^{13}C, N_2O (flask)	Scripps Institution of Oceanography	http://scrippsco2.ucsd.edu/
O_2/N_2	Scripps Institution of Oceanography	http://scrippso2.ucsd.edu/
CO_2/CH_4	SIO – Earth Networks Center for Climate Research	http://www.earthnetworks.com /OurNetworks/
GPS-derived column water vapor	Stanford University	https://www.stanford.edu
CO and CO isotopes	State University of New York, Stonybrook	http://www.stonybrook.edu
Aerosol Chemistry	University of California, Davis	http://vista.cira.colostate.edu/i mprove/
Long transport of Aerosols	University of California, Davis - Delta group	http://delta.ucdavis.edu/projec ts.htm
MAX-DOAS	University of Colorado, Boulder	http://climate.colorado.edu/
Variable Young Star Survey	University of Hawaii - Institute for Astronomy	http://www.ifa.hawaii.edu/~reip urth/VYSOS/Home.html
ATLAS	University of Hawaii - Institute for Astronomy	http://www.ifa.hawaii.edu
Sulphate chemistry	University of Hawaii, Honolulu	https://www.hawaii.edu
Corrosion and fungal spores	University of Hawaii, Manoa	http://www.hawaiicorrosionlab. org/index.htm
Extraterrestrial particles	University of Hawaii	https://www.hawaii.edu
Precipitation	University of Hawaii	https://www.hawaii.edu
Atmospheric lidar measurements	University of Michigan	https://www.umich.edu
Mercury studies	University of Nevada - Reno	https://www.unr.edu
Stratospheric ozone	University of New Hampshire/NIWA	http://www.astro.umass.edu/~ fcrao/
CO14 flask sampling	University of Rochester	https://www.rochester.edu
Mercury sampling	USGS	https://www.usgs.gov
Seismometer and strain meters	USGS	http://hvo.wr.usgs.gov/
Video surveillance, communications	United States Navy Pacific Missile Range Facility	http://www.navy.mil
Communications - radio repeaters	United States Postal Inspector	https://postalinspectors.uspis.g
Filter Radiometer/PMOD	World Radiation Center	http://www.pmodwrc.ch/worcc /
South Pole **Measurement Program**	**Home Institution**	**Websites**
$^{13}C/^{12}C$ and $^{18}O/^{16}O$ in CO_2	CSIRO	http://www.csiro.au/
CO_2, CH_4, CO, H_2, N_2O	CSIRO	http://www.csiro.au/
Brewer - Ozone	Environment and Climate Change Canada	http://es-ee.tor.ec.gc.ca/e/ozone/ozone.htm
AERONET Photometers	NASA Goddard Space Flight Center NASA	http://aeronet.gsfc.nasa.gov/
MPLNET Cloud Profiling	Goddard Space Flight Center	http://mplnet.gsfc.nasa.gov/
NIPR All Sky Camera (until 2017)	National Institute of Polar Research (Japan)	http://www.nipr.ac.jp/english/polar-research.html
CO_2, ^{13}C, N_2O (flask)	Scripps Institution of Oceanography	http://scrippsco2.ucsd.edu/
Firn air sampling	Scripps Institution of Oceanography	http://scrippsco2.ucsd.edu/
O_2/N_2	Scripps Institution of Oceanography	http://scrippsco2.ucsd.edu/
Oxygen Isotopes	Scripps Institution of Oceanography	http://scrippso2.ucsd.edu/
Summit, Greenland **Measurement Program**	**Home Institution**	**Websites**
Summit site operation	National Science Foundation	https://www.nsf.gov
Aerosol light absorption and scattering	Georgia Institute of Technology	http://www.gatech.edu
Trinidad Head, California **Measurement Program**	**Home Institution**	**Websites**
Weekly ozonesonde (began 2017)	California Air Resources Board	https://ww2.arb.ca.gov/homep age
Trinidad Head Observatory Operation (until 201	Humboldt State University Humboldt	https://www.humboldt.edu
Weekly ozonesonde (until 2017)	State University NASA/Goddard	https://www.humboldt.edu
AERONET Photometers (until 2017)	Space Flight Center	http://aeronet.gsfc.nasa.gov/
Flask sampling/sharing data (ongoing)	Scripps Institution of Oceanography	http://scrippsco2.ucsd.edu/

GMD Sampling Sites Summary		Feb-18
Global Monitoring Division, ESRL, Boulder, Colorado		
U.S. State and Territory	International Country and Ocean	International Country and Ocean
Key: (1), (2) ... denotes the separate sites or sample locations in each state/territory/country/ocean basin.		
Alaska (1)	Algeria (2)	(continuation of column to the left)
American Samoa (1)	Antarctica (7)	Ireland (1)
California (10)	Arctic Ocean Aircraft (1)	Israel (3)
Colorado (7)	Argentina (1)	Italy (1)
Florida (3)	Atlantic Ocean Aircraft (2)	Japan (3)
Hawaii (6)	Australia (5)	Kiribati (1)
Illinois (2)	Azores (Portugal) (3)	Marshall Islands (1)
Indiana (1)	Barbados (1)	Mexico (1)
Iowa (1)	Bermuda (2)	Midway Islands (1)
Maine (3)	Brazil (4)	Mongolia (1)
Massachusetts (2)	Bulgaria (1)	Namibia (1)
Minnesota (1)	Canada (6)	Netherlands (1)
Mississippi (1)	Canary Islands (Spain) (1)	New Zealand (4)
Montana (1)	Chile (2)	Nigeria (1)
Nevada (1)	China (4)	Northern Mariana Islands (1)
New Hampshire (1)	Cook Islands (1)	Peru (1)
New Jersey (1)	Costa Rica (1)	Republic of Korea (3)
New Mexico (2)	Drake Passage Ship (1)	Reunion Island (France) (1)
North Carolina (2)	Easter Island (Chile) (1)	Russia (1)
North Dakota (2)	Ecuador (1)	Seychelles (1)
Oklahoma (2)	Estonia (1)	Pacific Ocean Aircraft (4)
Oregon (1)	Fiji (1)	Pacific Ocean (Eastern) Ship (1)
Pennsylvania (1)	Finland (2)	Pacific Ocean (Western) Ship (1)
Puerto Rico (1)	France (3)	South Africa (1)
South Carolina (2)	Germany (4)	Spain (7)
South Dakota (1)	Greenland (3)	Svalbard (1)
Tennessee (1)	Guam (1)	Sweden (1)
Texas (3)	Hungary (2)	Switzerland (1)
Utah (2)	Iceland (1)	Tahiti (1)
Virginia (3)	Crozet Island (France) (1)	Taiwan (2)
Washington (1)	Indian Ocean Aircraft (1)	United Kingdom (3)
Wisconsin (2)	Indonesia (2)	Vietnam (1)
	(continued, column right, top)	

GMD SITE TOTALS

Number of different U.S. states and territories operating in = 32

Total Number of all U.S. state and territory locations = 76

Number of different foreign countries operating in = 58

Total Number of all foreign locations = 120

TOTAL NUMBER OF ALL GLOBAL SITES IN OPERATION (U.S. + FOREIGN) = 196

Global Monitoring Division

Trace Gas, Ozone and Radiation Standards/Calibrations

2013-2017 Review

Contents: page

Gas Standards and Instrument Calibrations

A. Trace Gas Calibration Standards

High quality, stable trace gas standards are the basis for sustained atmospheric trace gas measurements on century time scales.

The Global Monitoring Division produces and maintains World Meteorological Organization sanctioned trace gas standards for the three most important long-lived greenhouse gases (CO_2, CH_4, N_2O). GMD also maintains in-house calibration scales for over 60 trace gases associated with greenhouse gases and stratospheric ozone recovery.

B. WMO World Primary and Secondary Total Column Ozone Standards

The Global Monitoring Division maintains the WMO Primary and Secondary World Standard Total Column Dobson Spectrophotometers from which the five WMO Regional Standards are calibrated every two years and the ten NOAA Observatory Dobson instruments are calibrated every four years.

C. Solar Radiation Calibration and Standards

The GMD Central Calibration Laboratory maintains systems for performing calibrations of solar UV monitoring instruments. Each year, over 100 instruments are calibrated in the laboratory. Additionally, many instruments are calibrated in the field using the portable field calibrator. The Calibration Laboratory's systems include: Irradiance scale transfer system, UV spectral responsivity measurement system, Angular response measurement system, Absolute spectral irradiance calibration system and the Portable field calibrator system.

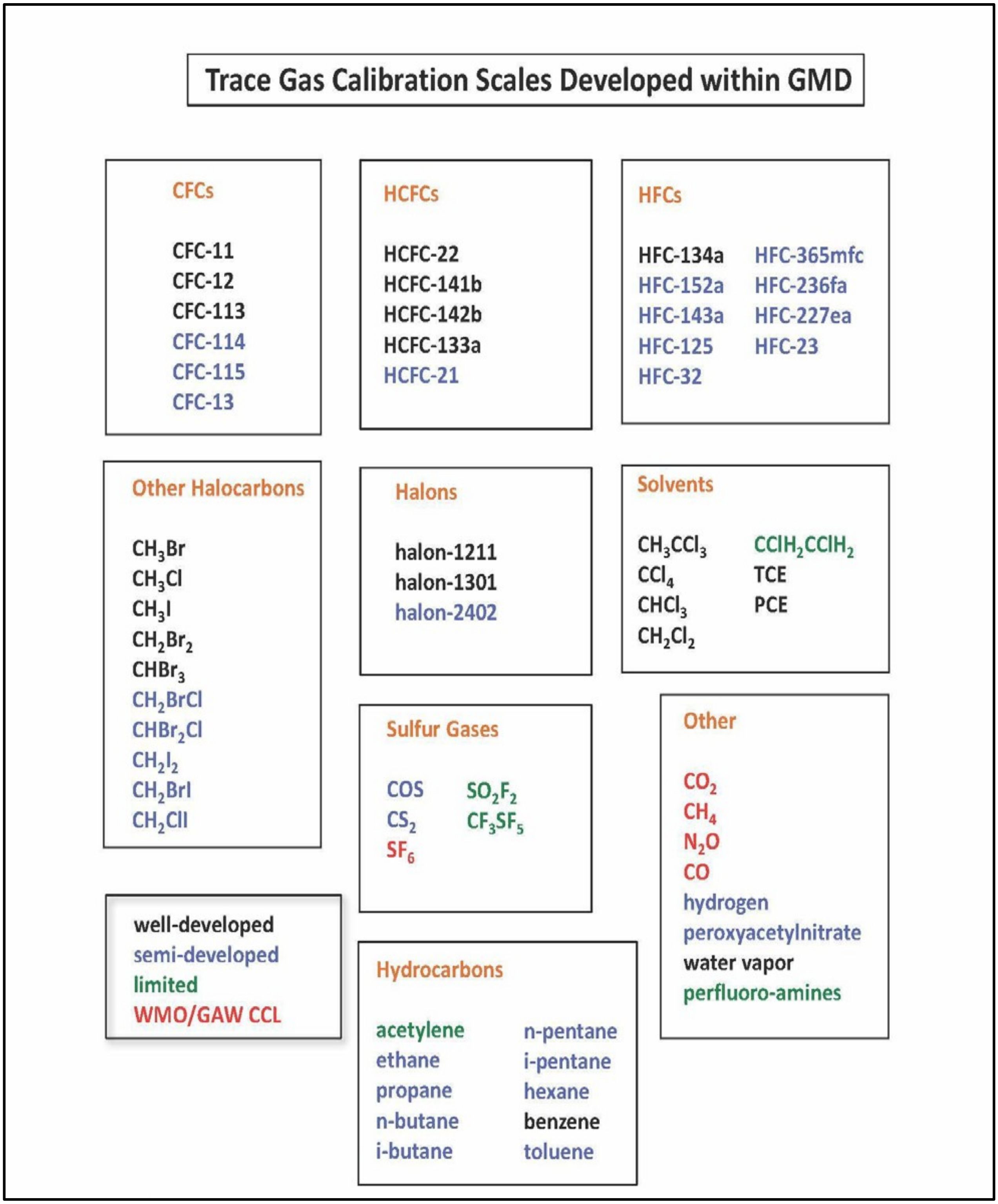
A. GMD Trace Gas Calibration Standards

Accurate, reliable calibrations are an essential component of all high quality monitoring programs, and are required for proper interpretation of measurements of atmospheric gases. Long-term drift or bias among different instruments and components must be characterized or minimized. For data from multiple networks to be interpreted together, they must be linked to a common calibration scale. Many global atmospheric measurement communities rely on GMD to provide that linkage.

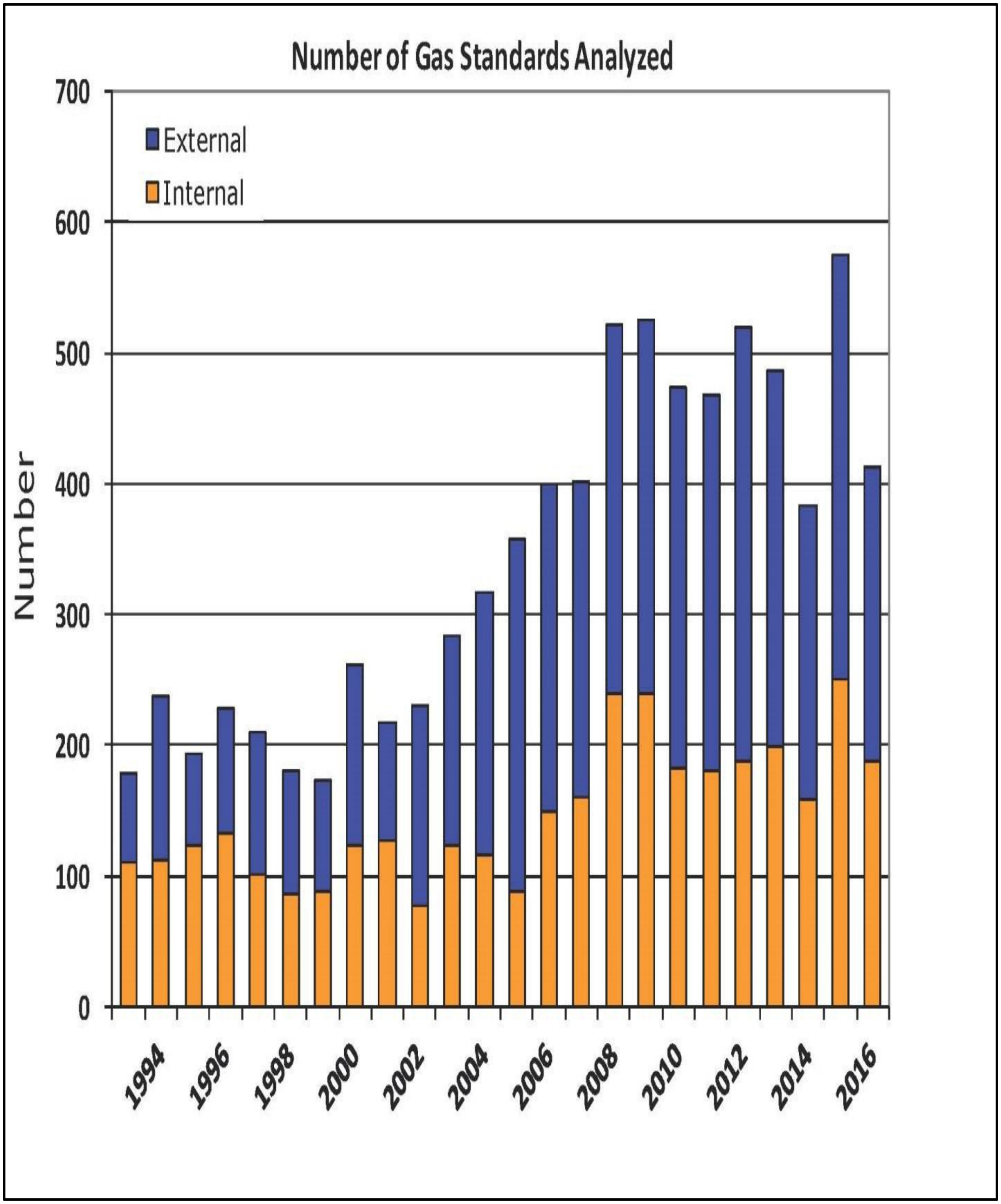
Most gases measured by GMD are traceable to primary standards developed by GMD. Two methods are used to prepare primary gas standards. Primary standards for CO_2 consist of compressed air in aluminum cylinders for which CO_2 mole fractions have been determined manometrically: that is, the mole fraction of CO_2 is determined by measuring state variables (pressure, temperature, volume) as CO_2 is extracted from air. For other gases (CH_4, CO, N_2O, halocarbons) primary standards are prepared gravimetrically by adding known masses of components together to create a gas mixture of known composition. In both cases, the results are traceable to national standards (mass, temperature, pressure) maintained by NIST.

GMD serves as the WMO/GAW Central Calibration Laboratory for CO_2, CH_4, CO, N_2O, and SF_6. In this capacity GMD maintains world reference calibrations scales and distributes calibrated gas mixtures to participating WMO/GAW laboratories and other cooperating institutions. GMD also provides calibrated gas mixtures of other gases to laboratories in support of cooperative research on climate, ozone, and ocean tracer work. In all, GMD maintains calibration scales for over 60 different compounds.

Even though GMD prepares and maintains primary standards, these are used only to calibrate specific instruments in Boulder. Calibrations are transferred to other instruments within GMD and externally through gas cylinders containing real air, filled at a research site west of Boulder at ~3000m elevation. Gas cylinders are filled with air using techniques developed to ensure the integrity of the mixtures, calibrated in Boulder using dedicated instruments, and distributed world-wide. Over the last 20 years, approximately 3070 and 4300 gas mixtures have been prepared and calibrated for use within GMD and by other laboratories, respectively.


Trace Gas Calibration Scales Developed within GMD
CFCs
CFC-11
CFC-12
CFC-113
CFC-114
CFC-115
CFC-13
HCFCs
HCFC-22
HCFC-141b
HCFC-142b
HCFC-133a
HCFC-21
HFCs
HFC-134a
HFC-152a
HFC-143a
HFC-125
HFC-32
HFC-365mfc
HFC-236fa
HFC-227ea
HFC-23
Other Halocarbons
CH_3Br
CH_3Cl
CH_3I
CH_2Br_2
$CHBr_3$
CH_2BrCl
$CHBr_2Cl$
CH_2I_2
CH_2BrI
CH_2ClI
Halons
halon-1211
halon-1301
halon-2402
Solvents
CH_3CCl_3
CCl_4
$CHCl_3$
CH_2Cl_2
$CClH_2CClH_2$
TCE
PCE
Sulfur Gases
COS
CS_2
SF_6
SO_2F_2
CF_3SF_5
Other
CO_2
CH_4
N_2O
CO
hydrogen
peroxyacetylnitrate
water vapor
perfluoro-amines
well-developed
semi-developed
limited
WMO/GAW CCL
Hydrocarbons
acetylene
ethane
propane
n-butane
i-butane
n-pentane
i-pentane
hexane
benzene
toluene

Real Air Standards Prepared and Calibrated Each Year Since 1993



Glass manifold on the CO_2 manometer used for extracting CO_2 from air. The manometer is used to determine the mole fraction of CO_2 on an absolute basis.

Moving gas cylinders into the CO_2 calibration laboratory. Here, CO_2 mole fractions are assigned based on the WMO X2007 scale.

Niwot Ridge, Colorado (~ 3000m a.s.l.), where gas cylinders are filled with clean air.

Collecting a known mass of liquid reagent (gas) in a glass capillary tube that will be later added to a large tank of air to make a calibration standard.

Weighing cylinders on a special balance to determine how much gas was added. These tanks and their contents are weighed to an accuracy of 1 part in a 1,000,0000.

Measuring the concentration of carbon dioxide in cylinders of standard gases.

Institutions the Global Monitoring Division Provided Trace Gas Standards to in the Past 5 Years

Standards are provided on an “at cost” basis.

USA	Aerodyne Research
USA	Atmospheric Observing Systems
USA	Battelle Inst, Ohio State
USA	Bermuda Biological Station
USA	Bigelow Laboratory for Ocean Studies
USA	Bowdoin College, Maine
USA	California Air Resources Board
USA	California Institute of Technology
USA	Campbell Scientific
USA	Colorado State University Department of Atmospheric Science
USA	Colorado University Boulder
USA	Columbia Uuniversity, Lamont Doherty
USA	DOE Sandia National Laboratories
USA	Earth Networks
USA	Harris Corporation
USA	Harvard University
USA	Idaho College of Natural Resources
USA	Indiana State University
USA	Kansas State University
USA	Lawrence Berkeley Lab, LBL
USA	Lawrence Livermore National Security LLNS
USA	Licor Inc.
USA	Los Gatos Research
USA	Massachusetts Institute of Technology MIT
USA	Monterey Bay Aquarium Research Inst., MBARI
USA	NASA AMES
USA	NASA Goddard
USA	NASA LaRC
USA	National Ecological Observatory Network
USA	National Institute of Standards

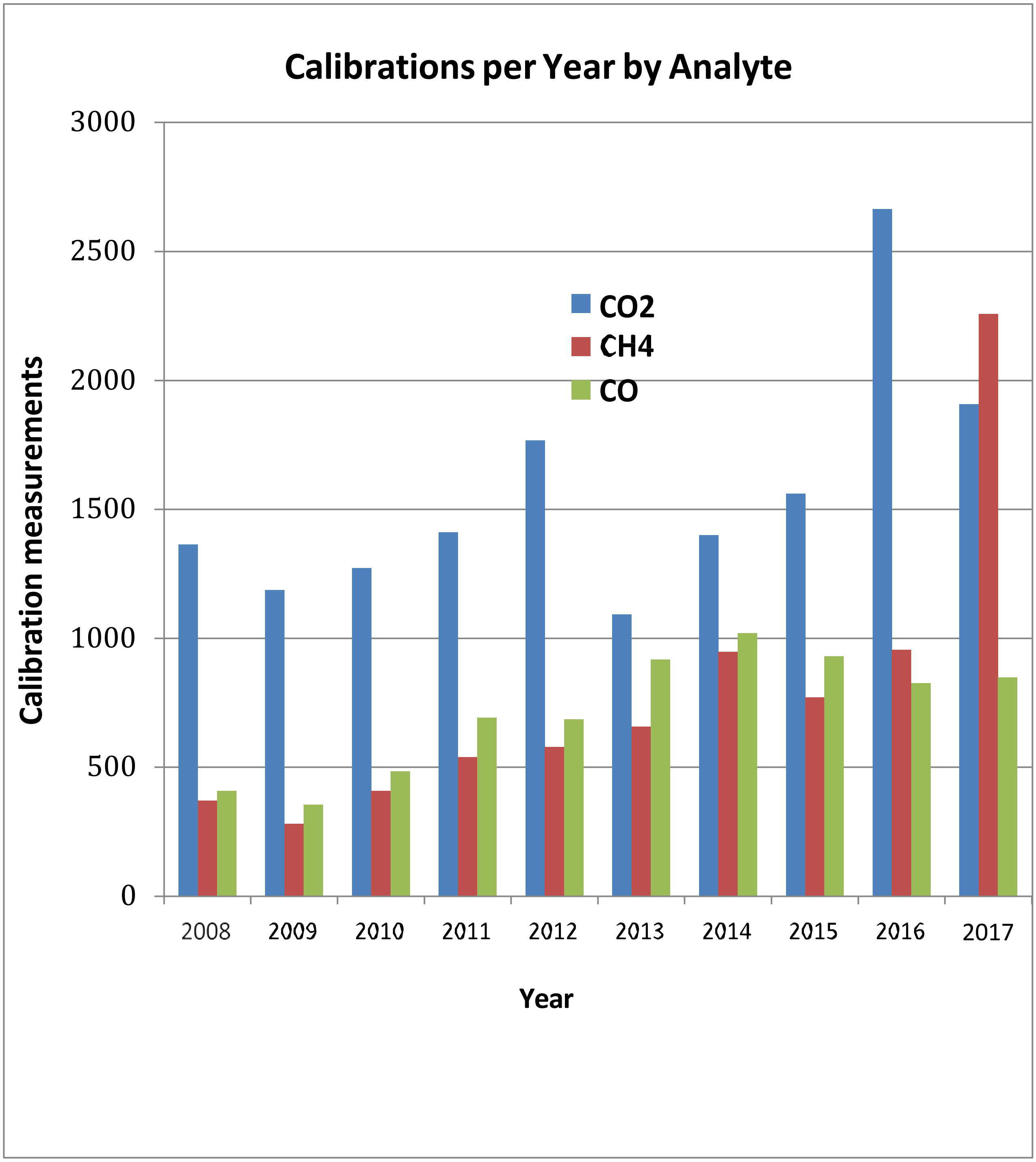
USA	NOAA Kodiak Fisheries Center
USA	NOAA, Atlantic Ocean Marine Labs
USA	NOAA, Chemical Sciences Division
USA	NOAA, Pacific Marine Environmental Laboratory
USA	North Carolina State University
USA	Northwestern University, Illinois
USA	Novawave Technologies, California
USA	Oregon State University, College of Forestry
USA	Oregon State, TERA, Corvallis
USA	Pennsylvania State University PSU
USA	Planetary Mission Management
USA	Portland State University
USA	Princeton University - MIRTHE Center
USA	Purdue University
USA	San Diego State University Research Foundation
USA	Sandia National Laboratories
USA	Sonoma Technology
USA	Southwest Sciences
USA	State University of New York - Albany SUNY
USA	Stony Brook University, New York
USA	Sunburst Sensors
USA	Texas A&M University, Corpus Christi
USA	Thermo Fisher Scientific
USA	United States Forest Service
USA	United States Geological Survey
USA	University Center for Atmospheric Research
USA	University of Alaska Fairbanks
USA	University of Arizona, Biosphere 2
USA	University of California, Berkeley
USA	University of California, Santa Barbara
USA	University of California, Scripps Institute of Oceanography
USA	University of California. LA Dept. of Atmospheric and Oceanic Studies
USA	University of Cincinnati, Ohio
USA	University of Delaware
USA	University of Georgia
USA	University of Hawaii
USA	University of Illinois, Chicago
USA	University of Maryland
USA	University of Michigan
USA	University of Minnesota

USA	University of Missouri
USA	University of Nebraska
USA	University of New Hampshire
USA	University of North Carolina at Chapel Hill
USA	University of Oregon State U., Corvallis
USA	University of Rochester
USA	University of Texas
USA	University of Utah
USA	University of Wisconsin, Madison
USA	US DOE, URS Energy and Construction Inc.
USA	USDA North Dakota
USA	Valdosta State University, Georgia
USA	WOODS HOLE MARINE BIOLOGICAL LABORATORY
USA	Woods Hole Oceanographic Institution WHOI
USA	Woods Hole Research Center WHRC
Australia	CSIRO
Australia	Ecotech
Australia	Hawkesbury University
Australia	Monash University
Australia	Southern Cross University
Bermuda	Bermuda Institute of Ocean Sciences
Brazil	Fundacao de Pesquisa do estado de Sao Paulo, FAPESP , Helber Freitas
Brazil	Instituto de Astronomia, Geofisica e Ciencias Atmosfericas da USP
Brazil	Instituto de Pesquisas Energeticas e Nucleares
Canada	Dalhousie University
Canada	Environment Canada
Canada	Pro-Oceanis Inc.
Canada	UBC, Earth, Ocean and Atmospheric Sciences
Canada	University of Guelph
Canada	University of BC, Land and Food Services
Canada	University of Manitoba
Canada	University of Saskatchewan
Chile	Universidad de Concenption
Costa Rica	Universidad National
Denmark	Niels Bohr Institute, Copenhagen University
Finland	Finnish Meteorological Institute, FMI
France	Energie Atomique, CEA
France	Institut National de la Recherche Agronomique INRA
France	Laboratoire de Glaciologie et Géophysique de l'Environnement, CNRS
France	Laboratoire de Glaciologie Geophysique

France	Universite de Reims
Germany	Alfred Wegener Institute for Polar and Marine Research
Germany	Baltic Sea Research Inst
Germany	Deutsches Zentrum fur Luft- und Raumfahrt DLR
Germany	Fraunhofer University
Germany	GERMAN METEOROLOGICAL SERVICE
Germany	Leibniz Center for Tropical Ecology
Germany	Max Planck Institute
Germany	Riemer Messtechnik
Germany	UBA Plattform Zugspitze
Germany	University of Heidelberg
Greece	National Center for Scientific Research Demokritos NCSRD
Hong Kong	Hong Kong Observatory
Hungary	Hungary Hungarian Meteorological Service
India	Physical Research Laboratory, Ahmedabad
India	CSIR Fourth Paradigm Institute
India	Indian Institute for Tropical Meteorology, Pune IITM
India	National Institute of Oceanography, NIO
India	Vikram Sarabhai Space Centre VSSC, Carbon Associates, Los Gatos LGR purchase
Ireland	Ireland Marine Institute
Italy	ENEA Lampedusa, Capo Grecale (AG)
Italy	European Commission Joint Research Centre
Italy	Institute for Atmospheric Sciences and Climate (ISAC)
Italy	Orion-Srl
Italy	Ricerca Systema Energetico
Italy	SIAD SPA
Italy	University Urbino
Japan	Japan Meteorological Agency
Japan	Japan Nippon ExpressUSA
Japan	Japan Suzuki Shokan Inc
Mexico	CICESE
Netherlands	Air Liquide
Netherlands	Royal Netherlands Institute for Sea Research
New Zealand	National Institute of Water and Atmospheric Research
Norway	Norgwegian Inistitute for Air Research
Norway	University of Bergen
Peoples Republic of China	Campbell Scientific Hong Kong limited

Peoples Republic of China	Huayun Meteorological Technology Group Corp.
Peoples Republic of China	PRI-ECO Company
Russia	State Geophysical Observatory, St Petersburg
South Africa	South Africa Weather Service, SAWS
South Korea	Deokyang Corp
South Korea	GNL Solution for KMA
South Korea	KNJ-Engineering
South Korea	Korea Ocean Research and Development Institute, KORDI
South Korea	Kwanak-gu School of Environmental Sciences
South Korea	Nano Gas Company
South Korea	Polar Research Institute KOPRI
South Korea	POSTECH School of Environmental Science and Engineering
South Korea	Reaserch Institute of Standards and Science, KRISS
South Korea	Seoul National University SNU
South Korea	SNU, School of Earth and Environmental Sciences
Spain	University of Valladolid
Spain	Aemet Izana Station
Spain	Consejo Superior de Investigaciones Cientificas CSIC
Spain	Fundació Institut Català de Ciències del Clima (IC3)
Spain	University of LAS PALMAS
Sweden	Stockholm University
Switzerland	Climate and Environmental Physics Institute
Switzerland	Swiss Federal Laboratories for Materials Science and Technology
Taiwan	Academia Sinica
Taiwan	Department of Atmospheric Sciences
Taiwan	Ko Hsieh Instruments
Taiwan	Le & Der Co.
Taiwan	Lein Wei Chemistry Apparatus Co.
Taiwan	National Central University
Taiwan	Tungsten International for Fulgent Scientific
United Kingdom	British Antarctic Survey BAS
United Kingdom	Cranfield University, FAAM - Facility for Airborne Atmospheric Measurements
United Kingdom	National Physical Laboratory, NPL
United Kingdom	Plymouth Marine Laboratory
United Kingdom	Royal Holloway, University of London
United Kingdom	University of Bristol
United Kingdom	University of East Anglia

United Kingdom	University of Galway
United Kingdom	University of Leicester
United Kingdom	University of Manchester
United Kingdom	University of York
Venezuela	Lab. Quimica Atmosferica



B. WMO World Primary and Secondary Total Column Ozone (Dobson Spectrophotometer) Standards.

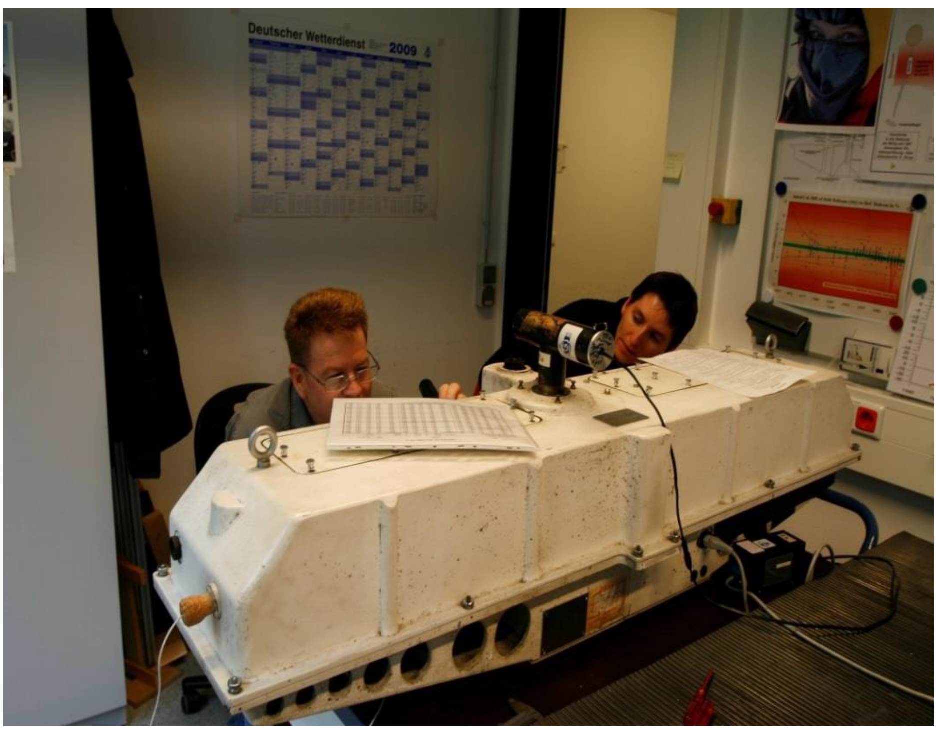
The Global Monitoring Division Provides World Reference Dobson Ozone Calibrations to the following institutions/ countries.

Aerological Observatory, Tsukuba, Japan
Algeria
Argentina
Botswana
Buenos Aires Observatory, Argentina
Bureau of Meteorology Melbourne, Australia
Czech Republic
China
CSIRO Perth
Egypt
India
Kenya
L'observatoire du Haute Provence, France
Marcapomacocha, Peru
Meteorological Observatory Hohenpeissenberg, Germany
Mexico
NASA Wallops, Langley and Goddard
NIWA, Lauder New Zealand
Pakistan
Peru
Philippines
Seychelles
Singapore
South Africa
Thailand
U of Alaska, Fairbanks
Ukraine
Uganda

GMD Stations Calibrated by the Dobson World Standard.

Barrow, AK
Bismark, ND
Caribou, MN
Nashville, TN
Fairbanks, AK
Hanford, WA
Mauna Loa, HI
American Samoa
South Pole, Antarctica
Wallops Island, VA

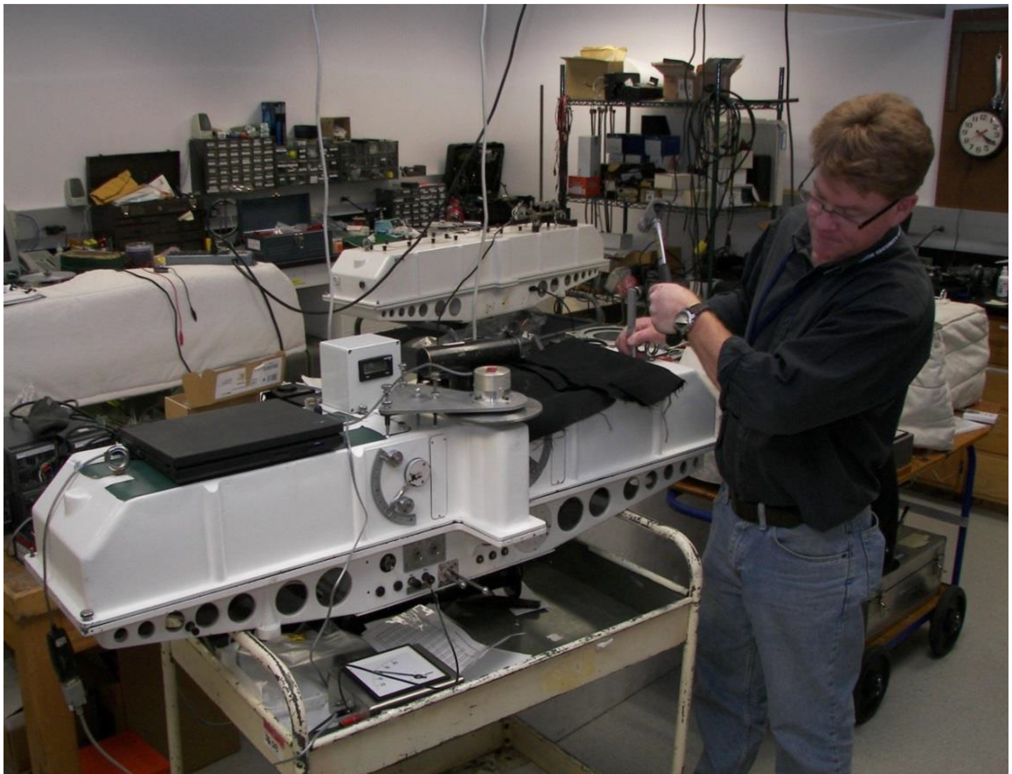
Global Monitoring Division World Secondary Standard Dobson 65 in a WMO sponsored South American Dobson intercomparison, Buenos Aires, Argentina.



Glen McConville assisting with the repair of D049 at Hohenpeissenberg Germany

Comparing Dobson measurements in Hohenpeissenberg, Germany. Transfer of WMO standard calibration to the WMO regional standard for the region IV. It takes multiple measurements to build confidence in accurate calibration of station instruments.

Comparing Dobson measurements in Soldankya, Finland above the Arctic Circle to see how the instruments operate at high latitudes.



Adjusting a repaired Dobson, GMD laboratory, Boulder, Colorado.

Sunrise Dobson calibrations, Boulder, Colorado.

Practicing moon focused image measurements in Boulder, CO in preparation for deployment of NOAA Corps officers for wintering over at NOAA's South Pole observatory.

Conducting Dobson total column ozone measurements during the annual Antarctic Ozone Hole from the Atmospheric Research Observatory, South Pole.

The measurements are conducted at ambient temperatures that may reach -80C.

C. Solar Radiation Calibration Standards.

Institutions the Global Monitoring Division Provides Reference Solar Radiation Calibrations in Boulder.

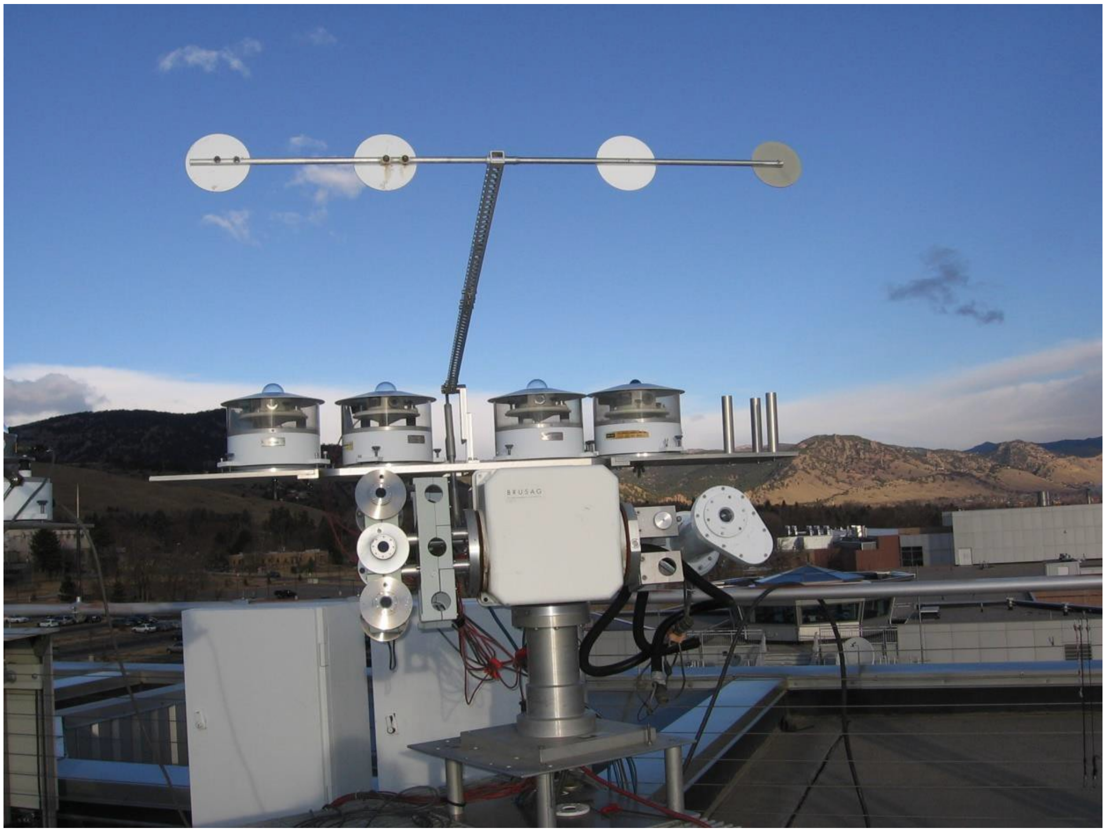
Biospherical Instruments Inc.
Battelle Labs
Bureau of Land Management
Chinese BSRN (Baseline Surface Radiation Network) sites
Colorado State University: IR Calibration exchange and UV calibrations.
DOE/ARM
DRI: Calibrations
Eastern New Mexico University
ENA, Italy, Calibrations
Eppley Laboratory
EU Joint Research Center at Ispra
Global Atmospheric Watch
Hampton University: Balloon-borne radiative flux measurements.
INDOEX (International Experiment in the Indian Ocean)
Kansas State University
METEO Swiss: Calibrations
NASA Goddard
NASA Langley
National Institute of Water & Atmospheric Research (NIWA)
National Renewable Energy Laboratory
National Weather Service
NCAR
NCAR Flight Facility
NOAA Chemical Science Division
NOAA Flight Facility
NOAA ATDD
Queensland University of Technology : Calibrations.
Rosario National University, Argentina, Calibrations
School of Geography & Environmental Studies
Scripps
Sinte Gleska University, South Dakota: Educational partnership
Smithsonian Institute, SERC
Surfrad and SOLRAD networks (NOAA)

Swiss Institute of Technology (ETH), Zurich: BSRN calibrations.
Tiksi, Russia (Roshydromet)
University of Alabama: Cloud detection automation.
University of California, San Diego, Scripps: ABC radiation calibrations.
University of Colorado
University of Houston Institute for Climate & Atmospheric Science:
University of Idaho: Dome Concordia (Antarctica) Satellite (AIRS)
U of Kentucky
University of Maryland: Radiometer calibrations
University of Rome
University of Tasmania, School of Geography
University of Texas El Paso (UTEP): Calibrations
University of Toronto, Canada: SEARCH and CNDAC
University of Washington: Study of snow-air interactions and radiation
US Navy
USDA
Various NOAA campaign projects: SEARCH, SHEBA, ACE, NINA
WMO, Geneva: Calibrations
Woods Hole
NOAA Physical Science Division

Institutions the Global Monitoring Division Provides World Reference Solar Calibrations to at Mauna Loa Observatory, Hawaii.

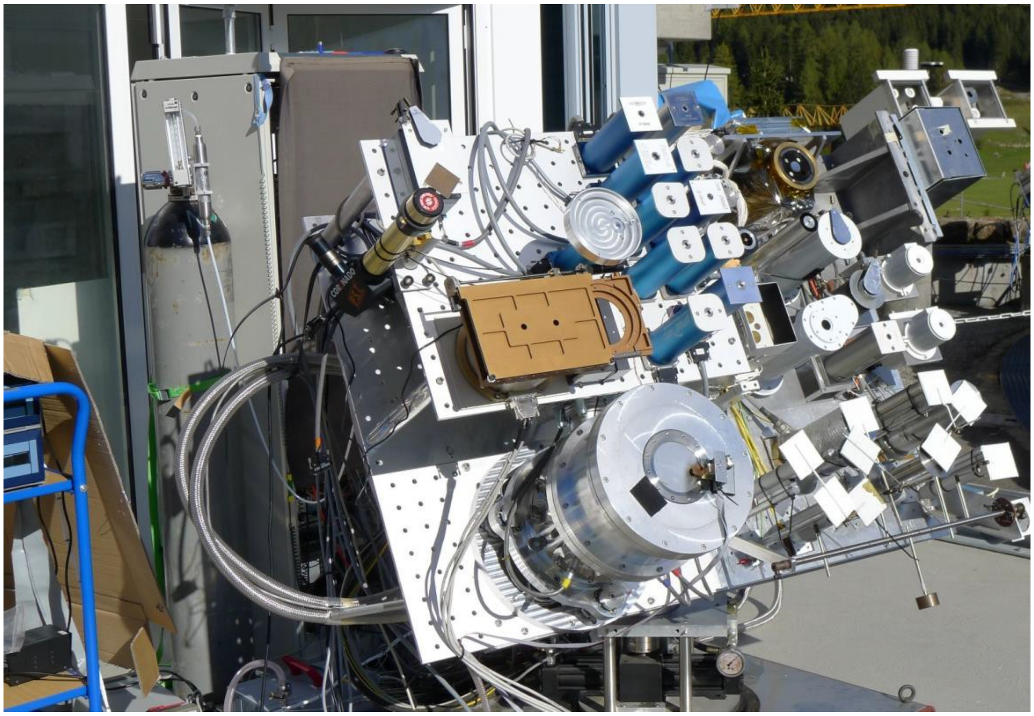
Colorado State University
Environment Canada
Geronimo Peak Observatory
NASA AERONET, Goddard Space Flight Center
NCAR HAO
NIES, Japan
NIWA, New Zealand
Solar Light Corp.
University of Denver
US Department of Agriculture

One year long pyrheliometer intercomparison and calibration at the NREL Solar Radiation Research Laboratory. In this test, commercial radiometers were being tested against NOAA GMD and NREL standards.



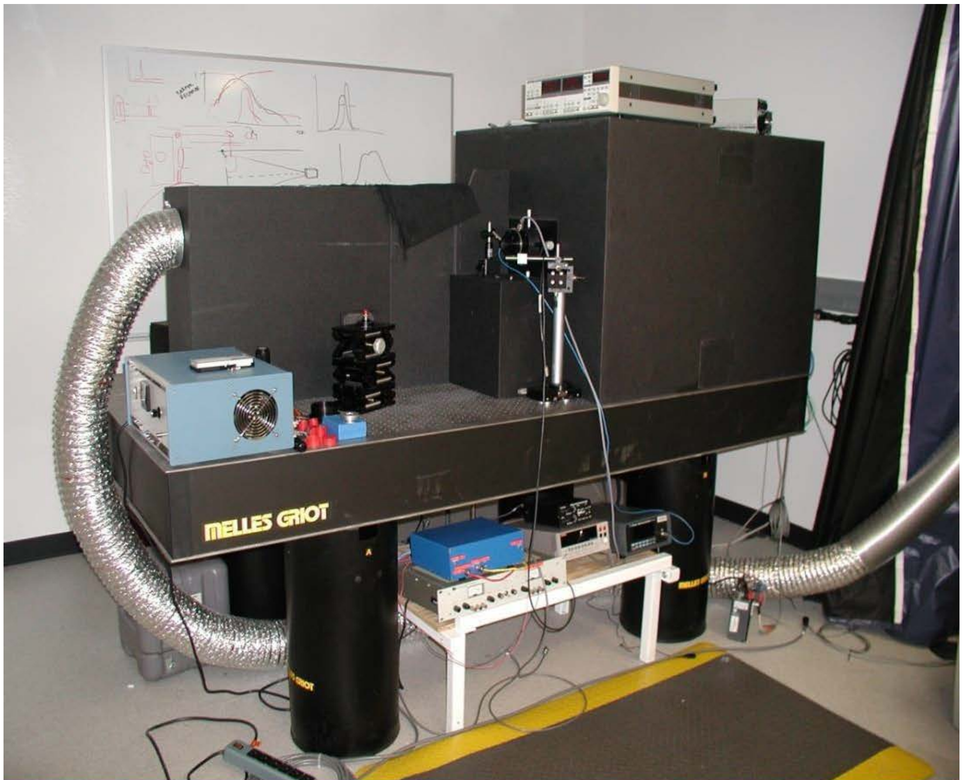
Diffuse and direct solar radiation instrument calibrations at the NOAA GMD Boulder, Colorado rooftop facility.

International pyrheliometer comparison Davos, Switzerland. NOAA GMD scientists are testing NOAA instruments against the World Radiometric Reference.



The World Radiometric Reference for solar measurements, Davos, Switzerland.

NOAA GMD Surface Radiation (SURFRAD) network site at Pennsylvania State University near State College, PA. The data from this and 6 other SURFRAD sites distributed across the U.S. are transmitted daily to GMD, Boulder.



NOAA GMD Central UV Calibration Facility (CUCF) spectral calibration bench.

NOAA GMD Table Mountain Solar Radiation Calibration Facility showing an array of solar and UV radiometers being calibrated.

Global Monitoring Division

Theme 1 Networks: Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks

2013-2017 Review

May 21-24, 2018

Five Observing Networks Arranged in Three Themes

The NOAA GMD Atmospheric Baseline Observatories at Barrow, Mauna Loa, Samoa and South Pole and observatories at Trinidad Head and Summit are well-known components of the NOAA GMD monitoring facilities. In addition to this north-to-south backbone of observatories through the Pacific Ocean, GMD has additional observing networks to address specific scientific needs.

Measurement programs from five networks (greenhouse gases, solar radiation, aerosols, ozone depleting gases and atmospheric ozone) are grouped into three GMD themes as shown below and discussed in the following sections.

Themes:

1) Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks

- Global Greenhouse Gas Reference Network (GGGRN)

2) Monitoring and Understanding Changes in Surface Radiation, Clouds and Aerosol Distributions

- GMD Radiation Networks (G-RAD)
- NOAA Federated Aerosol Network (NFAN)

3) Guiding Recovery of Stratospheric Ozone

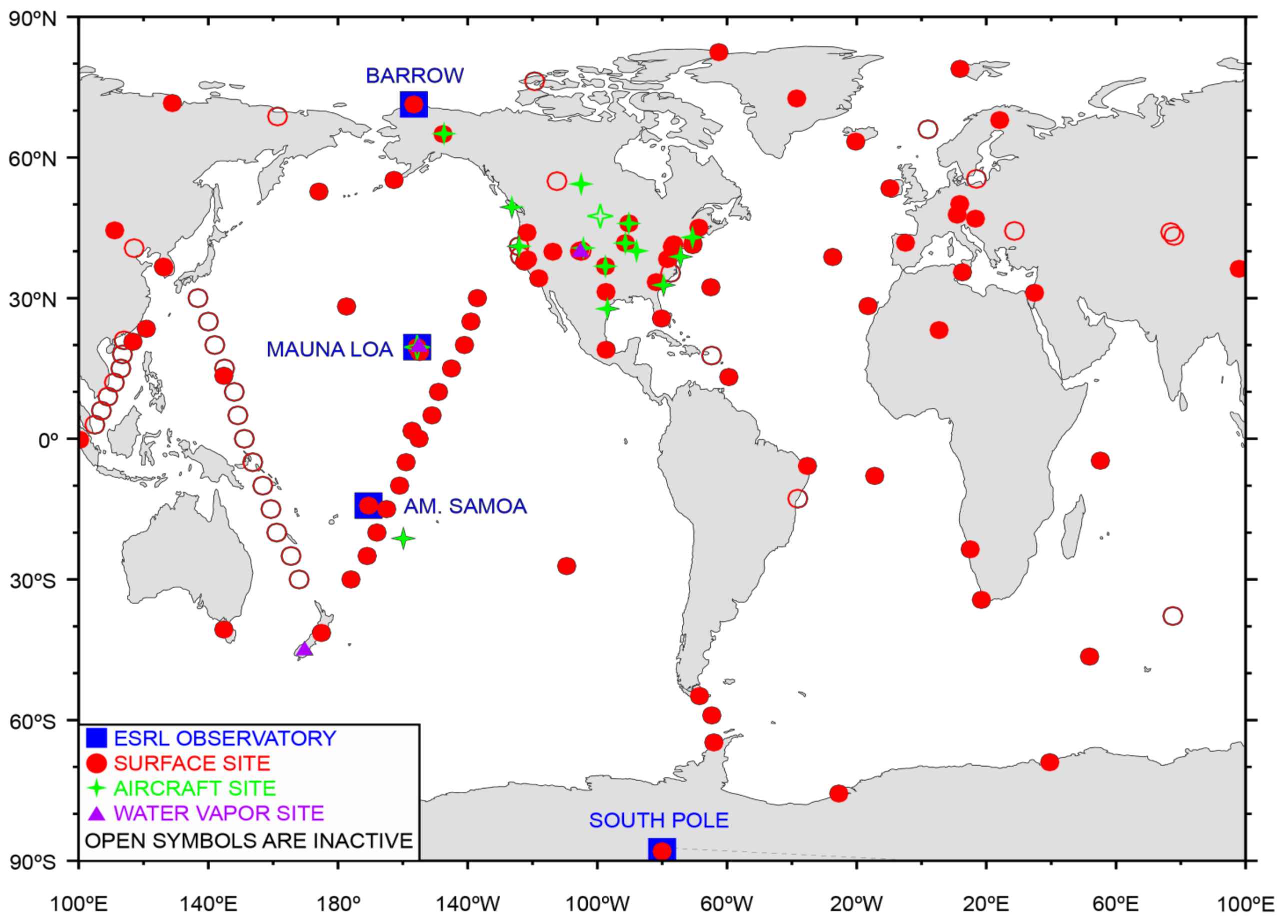
- Ozone and Water Vapor (OZWV) Networks
- Halocarbons (HATS) Network

Theme 1: Global Greenhouse Gas Reference Network (GGGRN)

"Greenhouse gas emissions are currently quantified from statistical data without testing the results against the actual increases of these gases in the atmosphere. This is like dieting without weighing oneself." *Nisbet and Weiss, Science, 238, 1241, 2010.*

GMD makes measurements of the spatial and temporal distributions of greenhouse gases and related tracers from sites in its **Global Greenhouse Gas Reference Network** that provide essential constraints to our understanding of the global carbon cycle and radiative forcing.

Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks



Cooperative Global Greenhouse Gas Reference Network

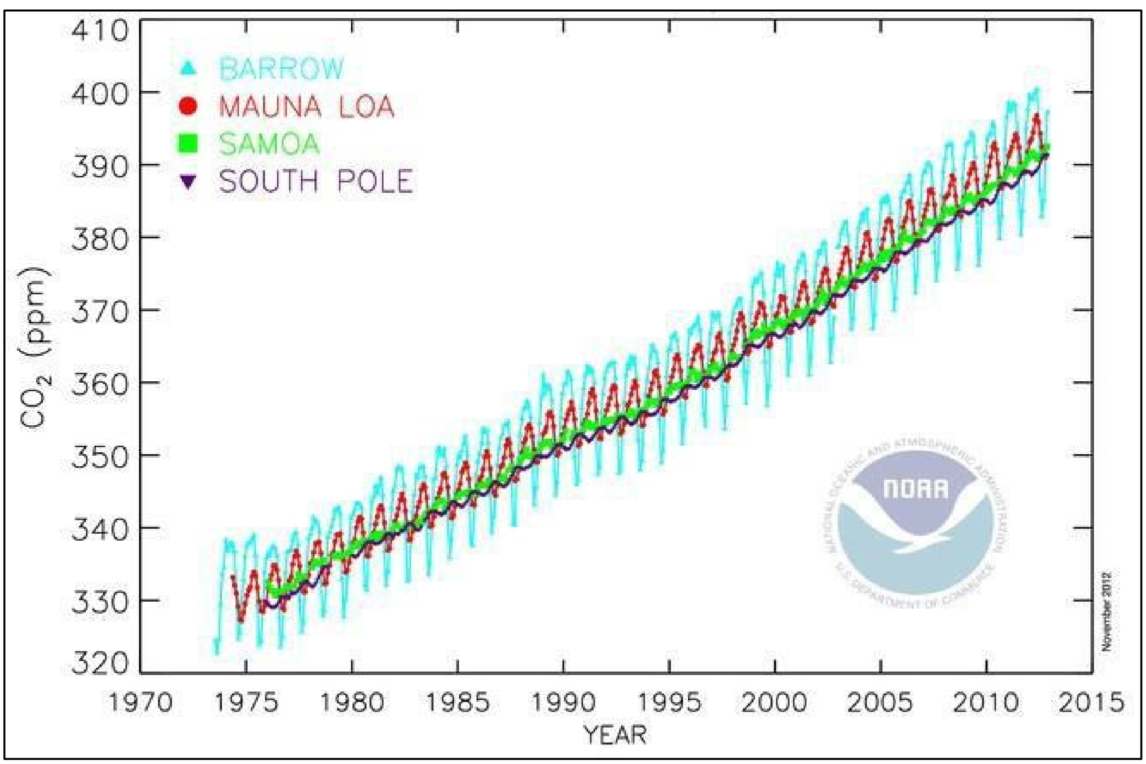
Greenhouse Gas Measurements

The Global Greenhouse Gas Reference Network measures the atmospheric distribution and trends of the main long-lived GHGs, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and sulfur hexafluoride (SF_6), as well as carbon monoxide (CO) which is an important indicator of air pollution. In addition, ~55 other gas species are monitored in air collected weekly in flasks at 60 sites around the globe.

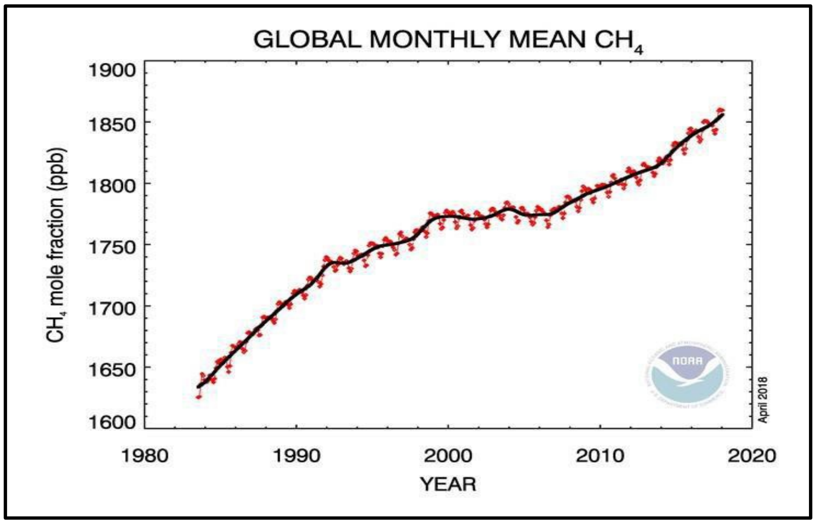
The measurement program includes around the clock measurements at four baseline observatories and 8 tall towers in North America, air samples collected by volunteers at more than 50 sites, and air samples collected regularly from small aircraft mostly above North America. The air samples are returned to the GMD labs in Boulder for analysis.

All measurements are subject to stringent quality control procedures, and are directly traceable to the UN World Meteorological Organization internationally accepted calibration scales where possible. NOAA's Global Greenhouse Gas Reference Network maintains the WMO international calibration scales for CO_2, CH_4, N_2O, SF_6 and CO in air.

WMO has a Mutual Recognition Agreement with the BIPM, which represents the National Metrology Institutes. GMD is party to this agreement.



Monthly average carbon dioxide data for the four NOAA baseline observatories. These data comes from the Global Greenhouse Gas Reference Network (GGGRN) in-situ measurements.



Monthly mean atmospheric methane abundance determined from marine surface sampling sites in the GGGRN from 1983 to 2018.

Global Carbon Dioxide and Methane Growth Rates

The observed increase in CO_2 atmospheric mole fraction is due primarily to emissions from fossil fuel burning and biomass burning and is similar at all four NOAA observatories and uptake by the oceans and the biosphere. It takes centuries to remove CO_2 from the atmosphere and the resulting climate warming persists for millennia.

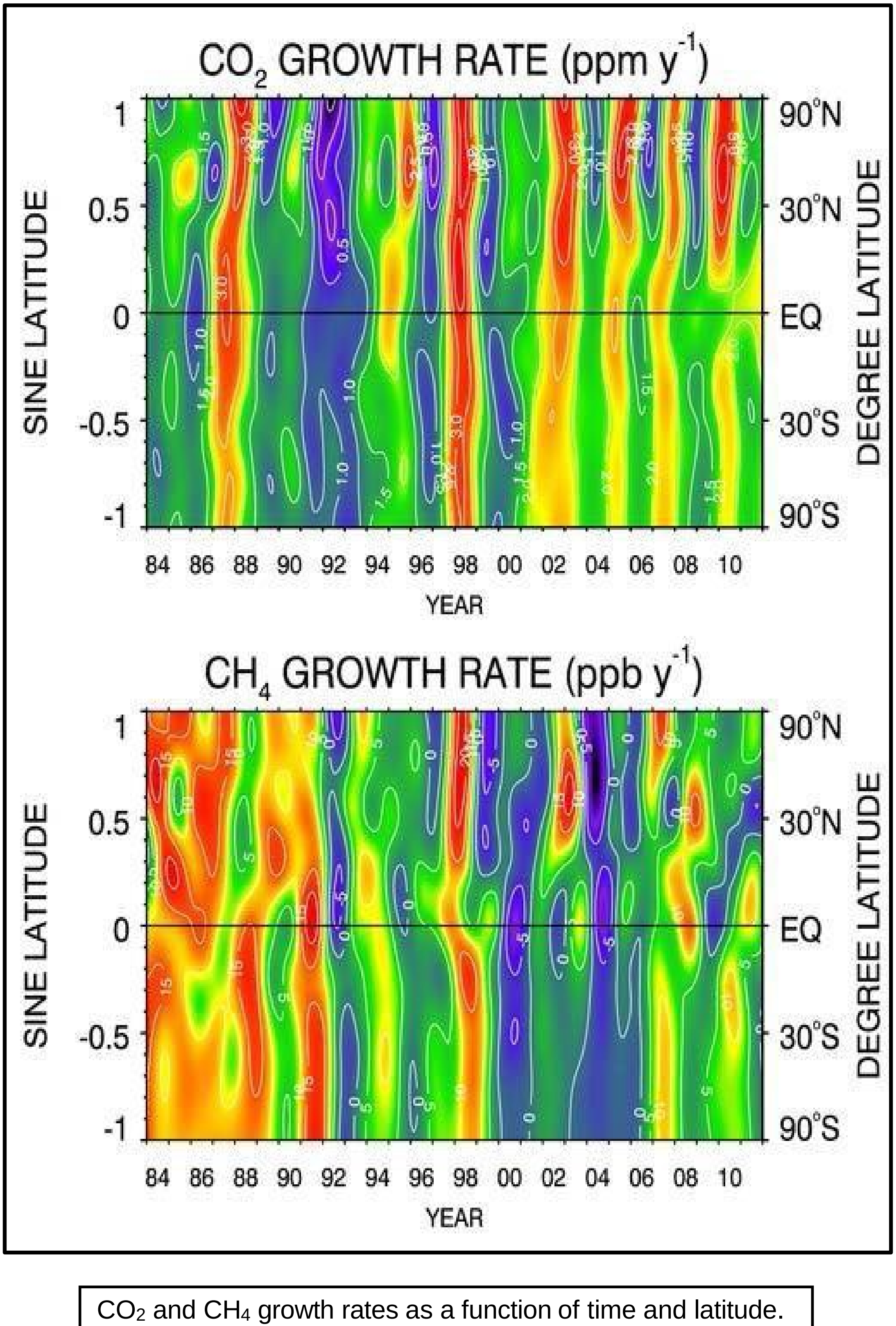
Emissions of long-lived gases from any location mix throughout the atmosphere in about one year (https://www2.cgd.ucar.edu/sites/default/files/asp-colloquium/files/Solomon-Daniel-etal-2010.pdf)

The annual oscillations at the two northern hemisphere sites (Barrow, Alaska and Mauna Loa, Hawaii) are due to the seasonal imbalance between the photosynthesis and respiration of plants on land. During the summer photosynthesis exceeds respiration and CO_2 is removed from the atmosphere, whereas outside the growing season respiration exceeds photosynthesis and CO_2 is returned to the atmosphere.

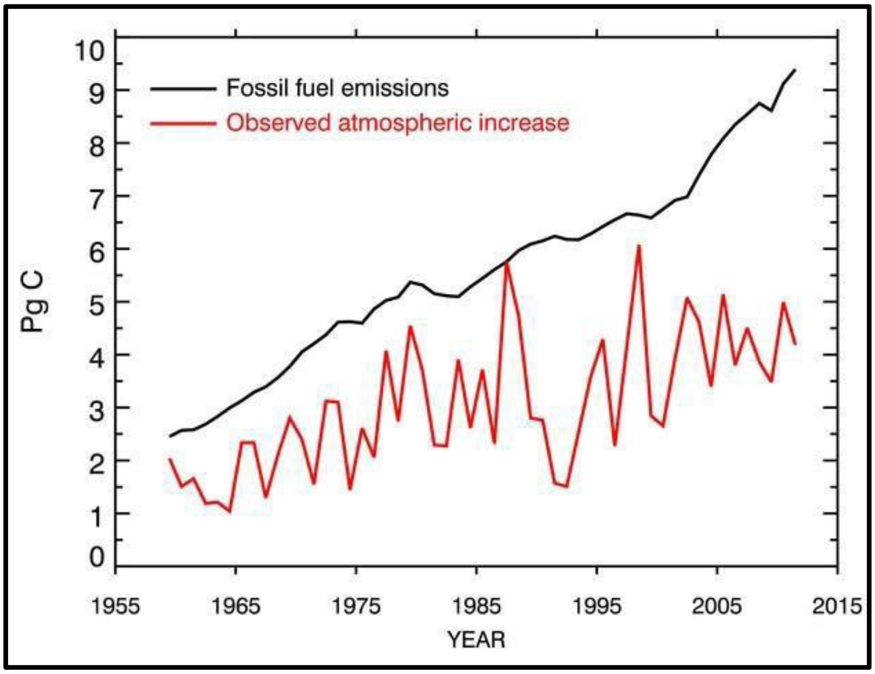
The seasonal cycle is strongest in the northern hemisphere because of the presence of the continents. The difference between Mauna Loa and the South Pole has increased over time as the global rate of fossil fuel burning, most of which takes place in the northern hemisphere, has accelerated.

A quantity of keen interest for each trace gas is the global-average rate of increase ("growth rates") for CO_2 and CH_4 as shown on the following page as a function of time and latitude.

The warmer colors (yellow, orange) indicate periods of higher-than average growth rate and the cooler colors (blue, purple) indicate periods of lower growth rate. The CO_2 growth rate varies from year to year with a higher growth rates since 2000. The CH_4 growth rate slowed during the 1990s. Global CH_4 was relatively stable in the early 2000s, but growth is back since 2007.



CO_2 and CH_4 growth rates as a function of time and latitude.



Annual atmospheric increase of CO_2 and reported annual fossil fuel emissions.

The annual variations of the CO_2 growth rate are not due to variations in fossil fuel emissions. The ups and downs in the atmospheric increase are due to variations in the exchange of CO_2 between the atmosphere, oceans, and land ecosystems. They are primarily due to small annual fluctuations of temperature and precipitation affecting photosynthesis and respiration on land.

It is very important to know that the added CO_2 does not disappear, but, as long as atmospheric CO_2 keeps rising, a portion of it transfers each year from the atmosphere to the oceans and to the biosphere on land. Since CO_2 is an acid, the transfer to the oceans causes the surface oceans to acidify.

The variations in the CH_4 growth rate are also related to climate anomalies. Analysis of the GMD and CU INSTAAR data suggests that the recent increase is related to greater-than-average precipitation in tropical regions resulting in above average emissions from tropical wetlands.

Understanding the processes that cause the CO_2 and CH_4 growth rate variations and long-term trends is crucial to enable governments and society in general to make informed decisions on energy policy and on mitigating climate change. Long-term projections of CO_2, CH_4, and N_2O depend on future emissions trajectories, which include fossil fuel and land use, and on climate feedbacks as they are incorporated into climate-ecosystem models.

An example of the latter would be Arctic warming releasing CH_4 and CO_2 emissions from melting permafrost. For emission models to be credible, it is necessary (but not sufficient) that they reproduce the recent past.

Where and How the Greenhouse Gas Data are Collected

With reference to the map presented on the introduction page, the mole fractions of greenhouse gases and other species of interest are obtained from the:

- Cooperative Global Air Sampling Network (flask-air measurements from the background atmosphere):

  - Weekly sample pair collected in 2.5 L glass flasks at 60 active air sampling sites shown by red dots on the map at the beginning of this section.

- Observatories (quasi-continuous measurements)

  -In situ CO_2 analyzers at 4 NOAA observatories.

  -In situ CH_4 and CO analyzers at BRW and MLO, N_2O at BRW also.

- Tall Tower (flask-air and quasi-continuous measurements)

  -9 active North American sampling and measurement sites.

- Aircraft (weekly or biweekly) vertical profiles of flask-air samples

  -17 active North American sampling sites.

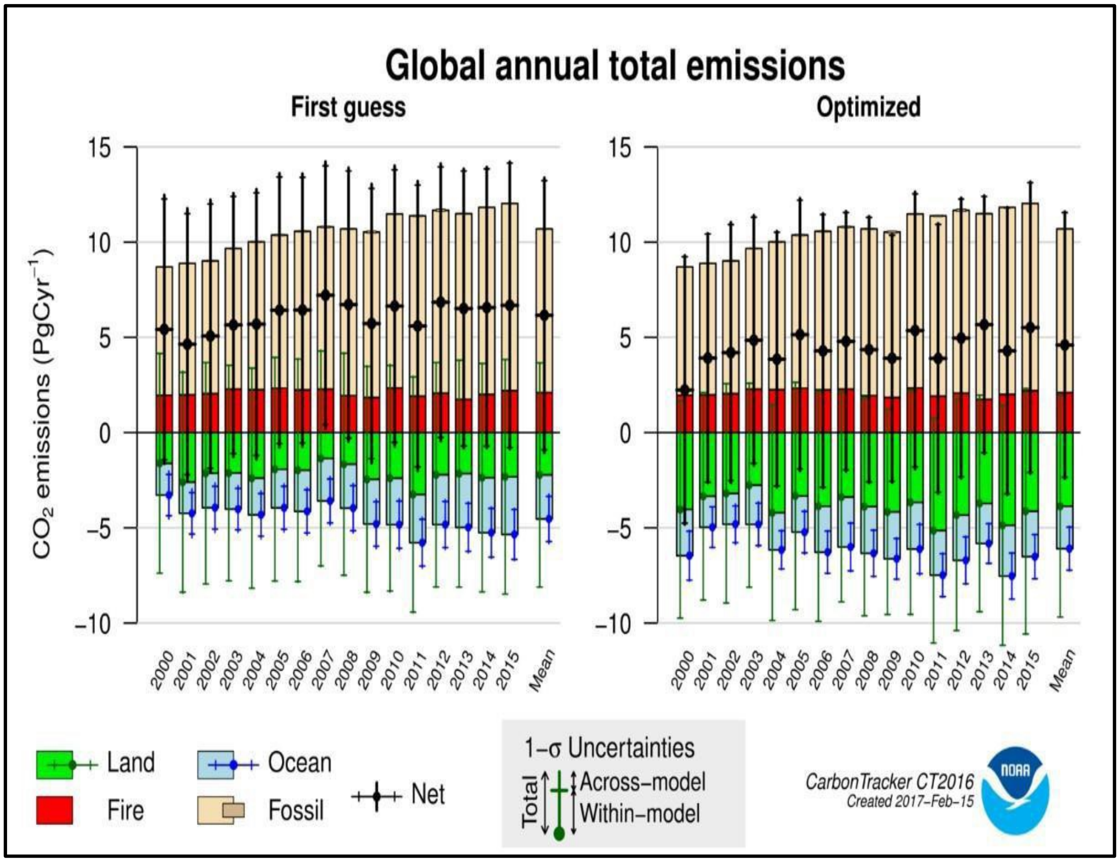
The main gases of interest measured from the networks:

Gas	Repeatability
CO_2	0.07 µmol mol^{-1}
CH_4	0.7 nmol mol^{-1}
CO	1.0 nmol mol^{-1}
N_2O	0.15 nmol mol^{-1}
SF_6	0.03 pmol mol^{-1}
$\delta^{13}CO_2$	0.01‰
$\delta^{13}CH_4$	0.07‰
NMHC	

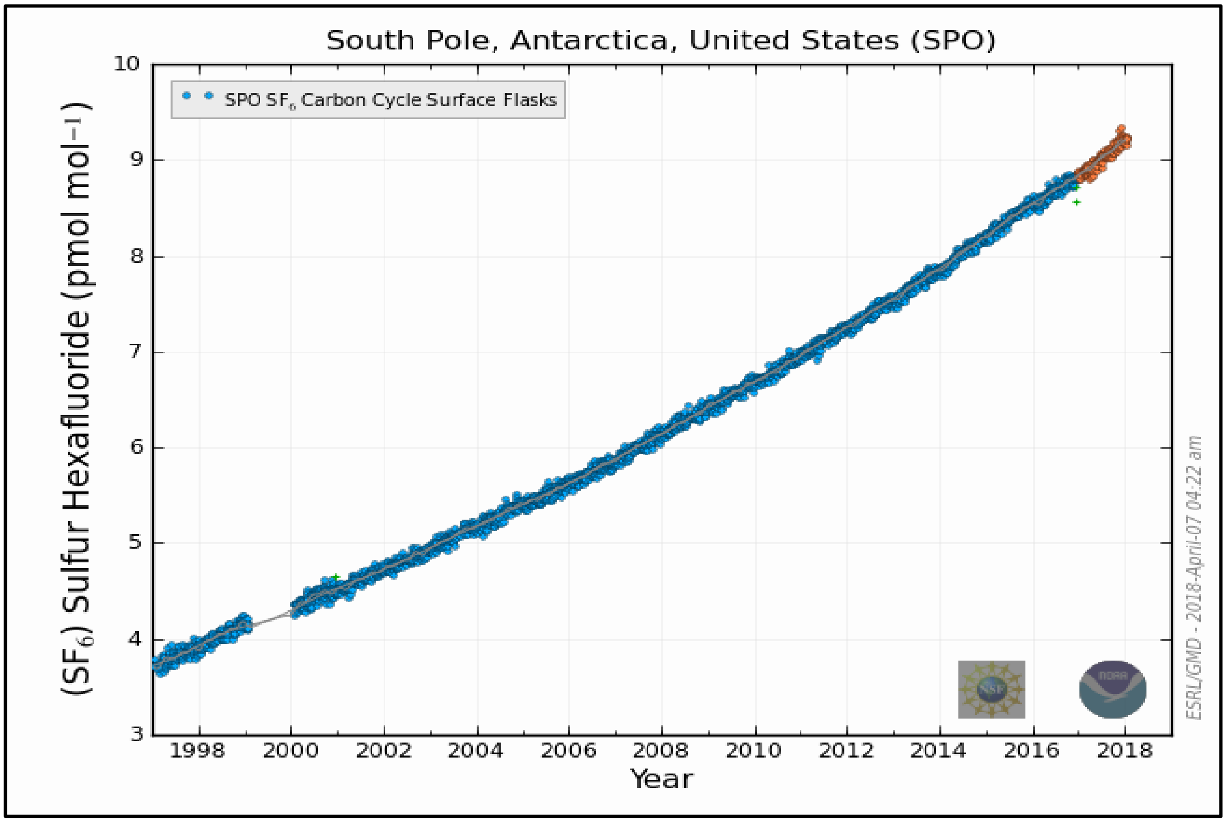
Tower and aircraft flasks are analyzed for 65 additional species, including ozone depleting substances (ODS), hydrocarbons (HCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur containing compounds (S-containing).

Some Important Scientific Results from the CC

From CarbonTracker (CO_2), using a data assimilation system to determine emissions and sinks of GHGs, GMD has developed a new global annual emissions data set for CO_2 as shown below.



Annual total emissions. The bars in this figure represent carbon dioxide emissions for each year in PgC yr^{-1} from the specified region. The final bar, labeled 'Mean', represents the 2001-2015 average. CarbonTracker models four types of surface-to-atmosphere exchange of CO_2, each of which is shown in a different color: fossil fuel emissions (tan), terrestrial biosphere flux (excluding fires) (green), direct emissions from fires (red), and air-sea gas exchange (blue). Negative emissions indicate that the flux removes CO_2 from the atmosphere, and such sinks have bars that extend below zero. The net surface exchange, computed as the sum of these four components, is shown as a **thick black** symbols.

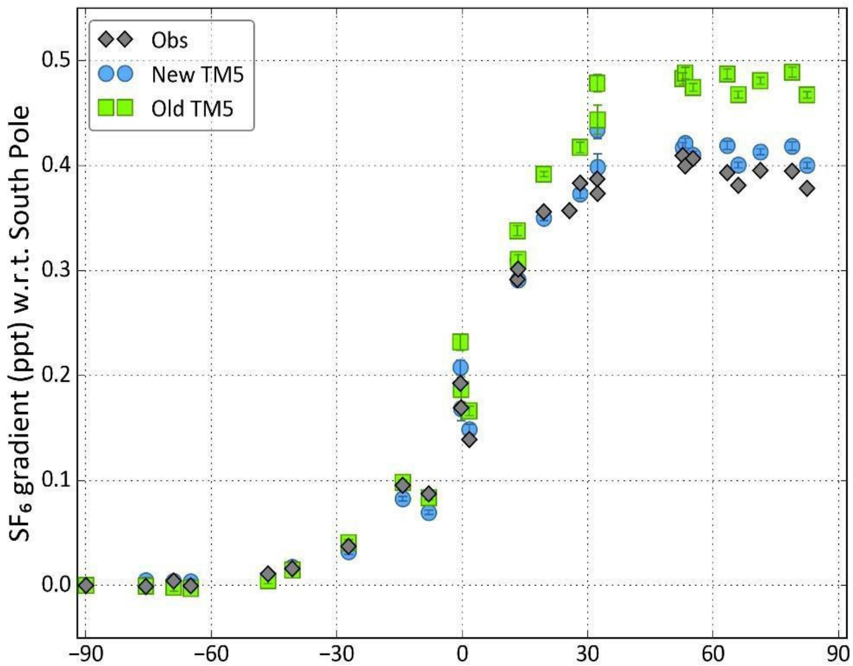


Interactive data visualization software open to the public on the GMD web site allows plotting of all gas data sets for any site and any period from the global networks. A plot of SF_6 concentrations from January 1, 1998 to December 31, 2017 shown above. <https://www.esrl.noaa.gov/gmd/dv/iadv/graph.php?code=SPO&program=hats&type=ts>

SF_6 Used to Constrain Models

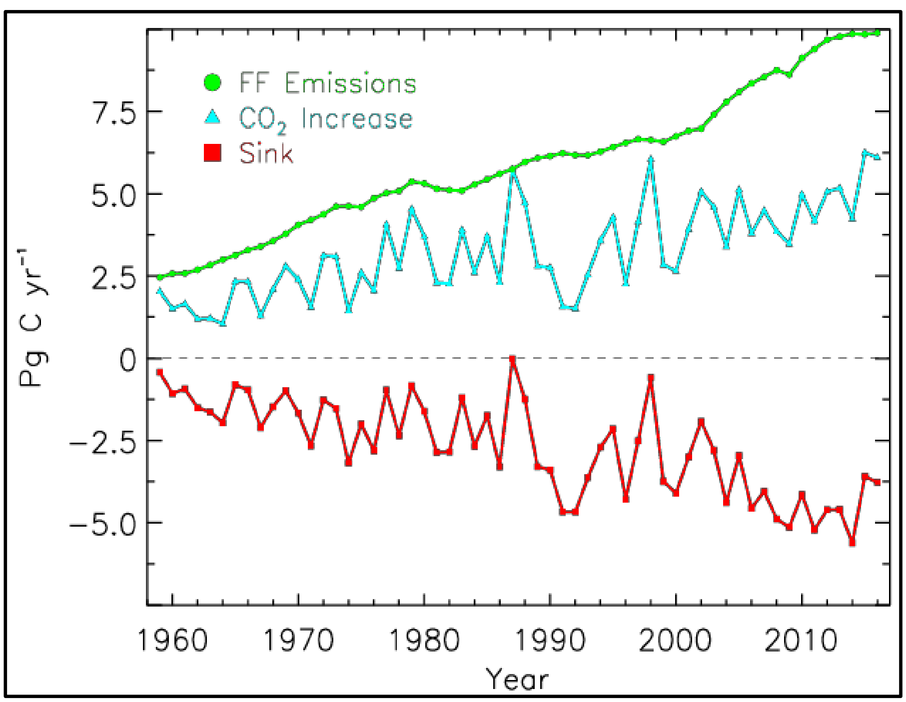
Measurements from the GGGRN are used to constrain nearly every large scale study of CO_2, CH_4, N_2O, SF_6, and CO on the globe. Measurements from tall towers and aircraft vertical profiles are used in many continental to regional scale studies. Examples include using SF_6, a long lifetime gas, as a test for atmospheric transport models.

SF_6, with relatively well-known emission rates and distribution and an atmospheric lifetime of ~700 years, can provide a good test of atmospheric transport models. When measurements of SF_6 from GGGRN air sampling sites were compared with output from an early version of “TM5”, an atmospheric transport model used for global forward and inverse modeling (for ex. CarbonTracker), transport to the free troposphere was not vigorous enough, resulting in over-estimate of the latitudinal gradient. For CH_4 and N_2O, this resulted in under-estimate of emissions at mid-northern latitudes. As the figure below shows, agreement between model and observations improved after the model’s vertical transport parameterization was modified, especially in the northern hemisphere.



Improvement in the widely used TM5 transport model by adding SF_6 atmospheric concentration data (*Basu et al., Atmos. Chem Phys., 2016).*

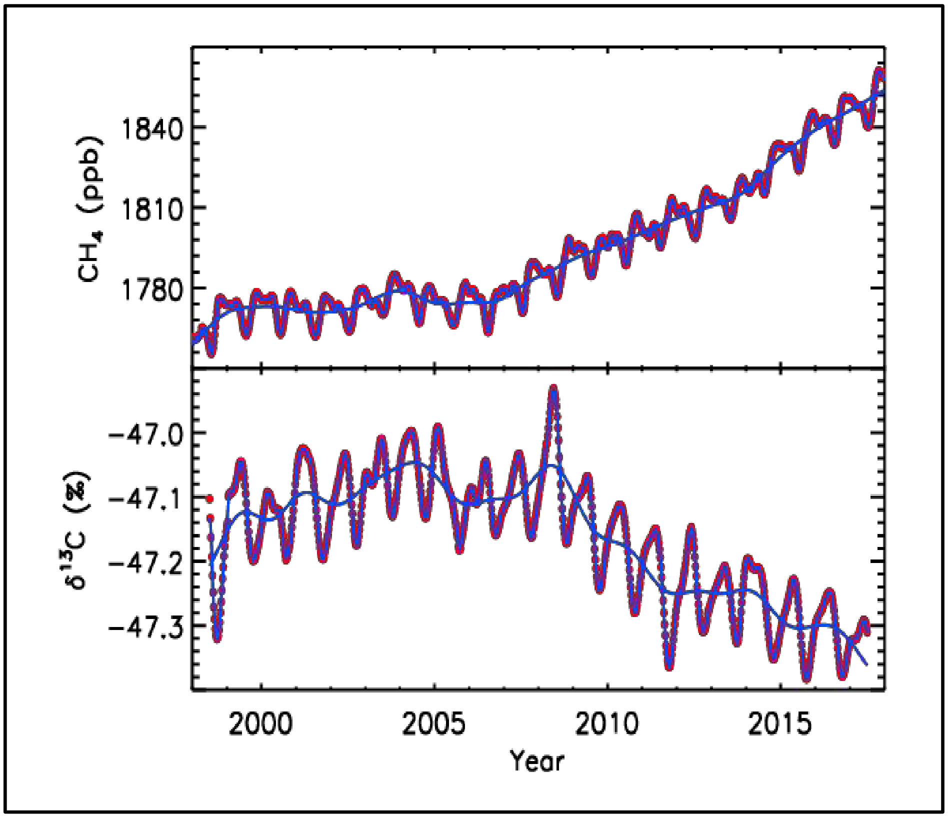
Plants and the Oceans are taking up increasing amounts of Fossil Fuel Combustion CO_2



Fossil fuel emissions, atmospheric CO_2 and the increasing CO_2 sinks *(updated from Ballantyne et al., Nature, 2012).*

When measurements of atmospheric CO_2 are combined with CO_2 emissions from fossil fuel combustion and cement production it is observed that ~45% of the emissions remain in the atmosphere (with no change in this airborne fraction over many years). The remainder is taken up by sinks in the terrestrial biosphere and ocean.

Increasing Atmospheric Methane is not from the Arctic

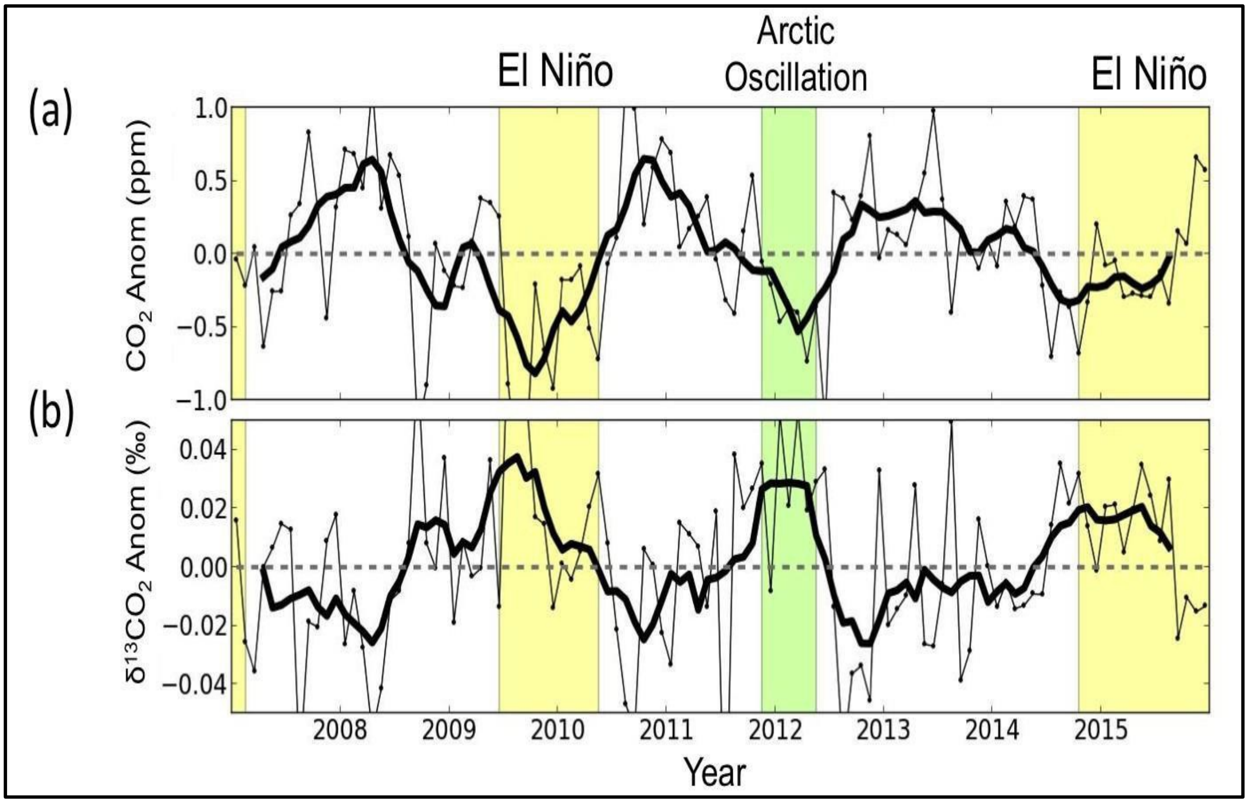


Global average CH_4, 1998-2017 showing an increase since 2007 and $\delta^{13}C$ exhibiting a corresponding decrease.

NOAA Measurements of atmospheric CH_4 combined with CU INSTAAR measurements of methane stable carbon isotopic composition ($\delta^{13}C$) offer clues to the increase in CH_4 burden that renewed in 2007. At about the same time, $\delta^{13}C$-CH_4 began decreasing after ~200 years of increase. Lighter $\delta^{13}C$-CH_4 comes from recent biological activity, not from fossil CH_4. While the exact causes of the increase remain under discussion, increasing emissions from isotopically light biogenic sources are a likely contributor probably from plant decay in tropical wetlands.

El Niño and Arctic Oscillation Effects on Atmospheric CO_2

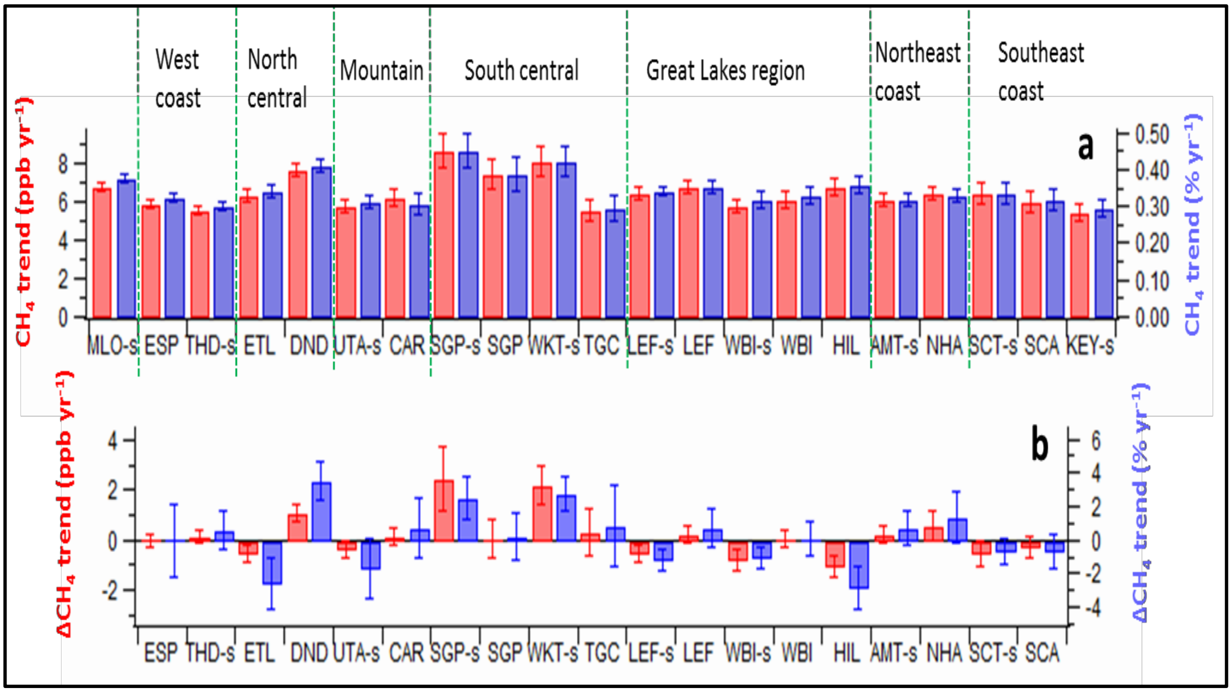
On global scales, observed CO_2 growth rate during El Niño conditions is larger than during La Niña or neutral conditions as a response to drying in the tropics and net increase in respiration and biomass burning returning carbon to the atmosphere. But for North America, as shown in the following figure of CO_2 and $\delta^{13}CO_2$ anomalies for North America (Hu et al., in preparation), CO_2 uptake by terrestrial ecosystems is enhanced during El Niño and Arctic Oscillation years. The changes in CO_2 correlate with North American hydrological parameters, suggesting increased precipitation results in larger net carbon uptake.



Net CO_2 and corresponding $\delta^{13}CO_2$ anomalies observed recently over North America through two El Niños and one Arctic Oscillation.

Increased Oil and Natural Gas Extraction in the U.S.

Rapid expansion of oil and natural gas extraction in the U.S. has been suggested as being a contributor to the increasing global atmospheric burden of CH_4 since 2007. Two studies based on NOAA GMD and University of Colorado INSTAAR measurements of GMD flask-air samples run somewhat counter to this. Schwietzke et al. (Nature, 2016) used isotope mass balance to show that, while CH_4 emissions from geologic sources are much larger than suggested by inventories, there has been no increase over the past 30 years. A group of scientist (Lan et al. in preparation) finds that trends in atmospheric CH_4 and its vertical gradient are consistent with localized increases in emissions near increased oil and gas production sites, but indicate small increases in total U.S. emissions.



Trends in CH_4 time series by NA regions (upper panel) for 2006-2015 from both aircraft and surface data. Trends in the vertical gradient, a sensitive indicator of changes in emissions (lower panel). The only locations where the trends are significantly different than background are located in regions with increasing oil and natural gas production operations, specifically OK and TX (Lan et al., GMD, in preparation).

Applications for the Global Greenhouse Gas Reference Network Data

The carefully calibrated and documented measurements of the Global Greenhouse Gas Reference Network are freely available on the NOAA GMD website (https://www.esrl.noaa.gov/gmd/). They serve as a comparison with measurements made by other international laboratories, and add a global or NA context to more focused regional studies. They are widely used in studies inferring space-time patterns of emissions and removals of greenhouse gases that are optimally consistent with the atmospheric observations. They serve as an early warning for climate feedbacks.

The calibrated observations are also indispensable for the ongoing evaluation of remote sensing technologies: Greenhouse gas abundances derived from optical absorption measurements from space can never be calibrated because one cannot control the abundance of the gases being estimated, nor can we control potential interfering factors in the optical path. Given the requirement that for remote sensing data to be useful any systematic biases need to be kept to an extremely low level, ongoing comparisons with calibrated measurements are a must.

Global Monitoring Division

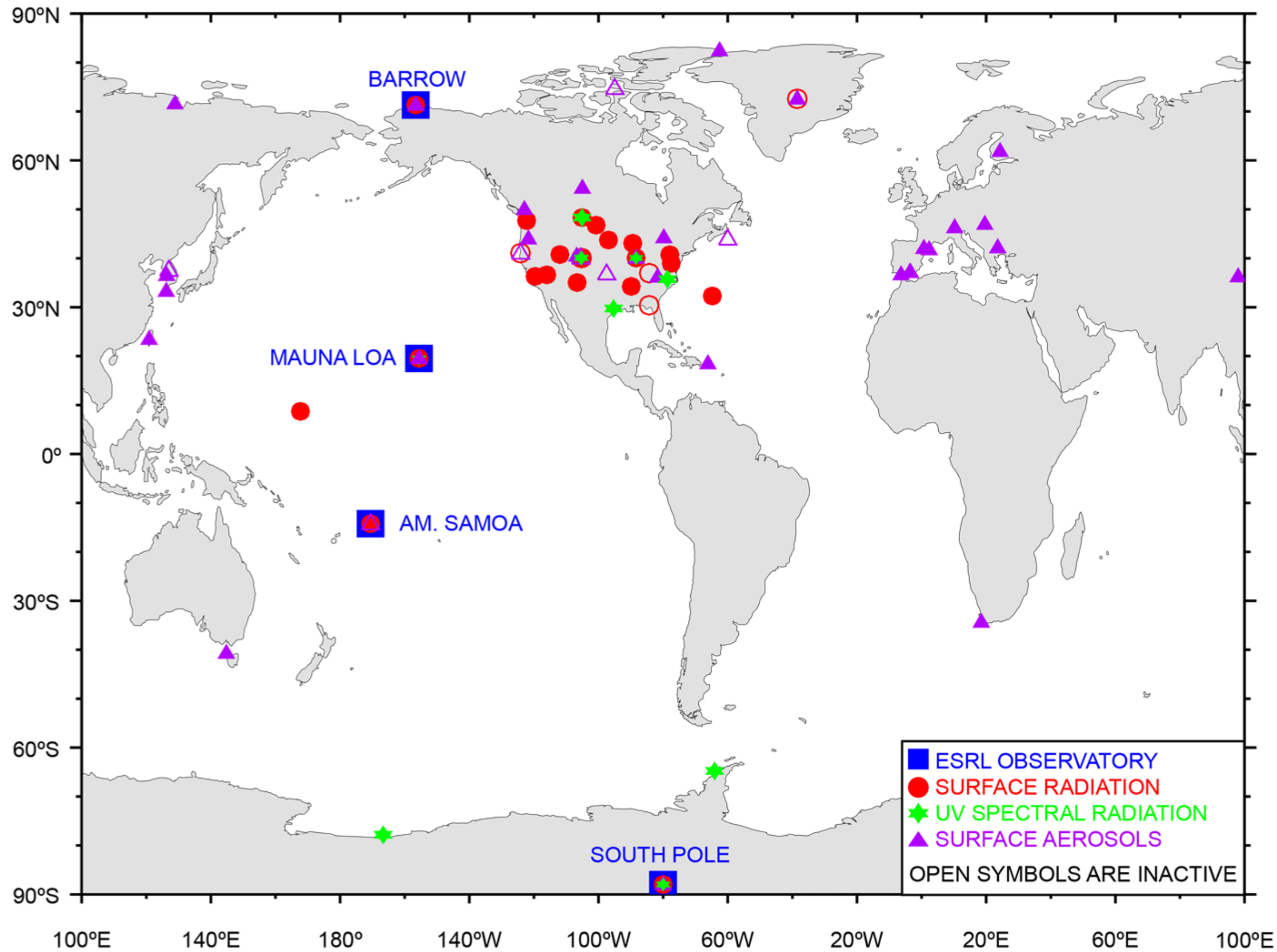
Theme 2 Networks: Monitoring and Understanding Changes in Surface Radiation, Clouds and Aerosol Distributions

2013-2017 Review

May 21-24, 2018

Contents:

Monitoring and Understanding Changes in Surface Radiation, Clouds, and Aerosol Distributions



Theme 2, Part 1: GMD Radiation Networks (G-RAD)

> ***"Without SURFRAD, we would rely on satellites alone for radiation data over the U.S.; this would mean more supposition and speculation, and less sound analysis and prediction."*** *Dr. Bruce Wielicki, first NASA Clouds and the Earth's Radiant Energy System (CERES) satellite program science team leader.*

Why make solar radiation measurements?

The Sun's radiant energy at the earth's surface encompasses the short wavelengths in the UV (ultraviolet), visible, and near infrared. The earth's surface, clouds, and atmosphere emit radiation at long (thermal infrared) wavelengths. The difference between incoming and outgoing shortwave and longwave at the surface, the surface radiation budget (SRB), represents the available energy for atmospheric sensible and latent heat fluxes.

- **The SRB is the major source of energy that drives weather and climate.**
- **Spatial variation in the SRB causes weather.**
- **Systematic changes in the SRB affect climate.**

> **Thus, to succeed, weather and climate models must simulate the SRB well.**

- **G-RAD provides the valuable, high quality SRB and ancillary observations required for better understanding of variability in the SRB and the controls on that variability.**
- **UV measurements are needed for health research and to understand impacts of the changing ozone layer, in Antarctica and also at the more populated mid-latitudes.**

The surface radiation measurements made at G-RAD sites are used to retrieve information on cloud and aerosols, the primary atmospheric components that modulate the surface radiation budget (SRB). Monitoring these components permits improve understanding of the processes that drive changes in the SRB, processes that arise from both natural and anthropogenic perturbations to the Earth system.

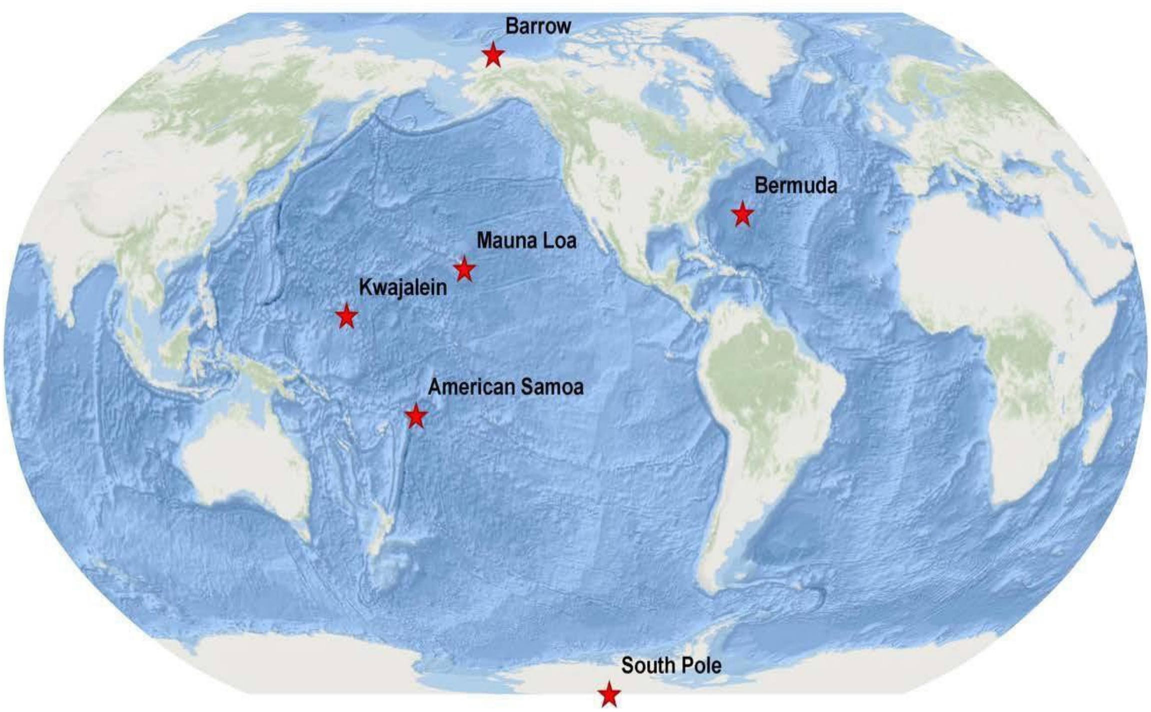
NOAA G-RAD Networks Measure:

- The surface radiation budget and ancillary measurements at 2 global sites and 7 U.S. Surface Radiation Budget (SURFRAD) sites.
- Downwelling* solar and infrared, and ancillary measurements at 4 global sites.
- Downwelling* solar and UVB at 7 U.S. SOLRAD (urban) sites.
- Spectral UV measurements at 6 U.S. and 3 Antarctic stations.

*These stations do not have upwelling radiation measurements because they would not be representative of the greater environment of the station, e.g., islands and cities.

Baseline and Regional Observatories

GMD Baseline Observatories are located in clean locations representative of the global background atmosphere. G-RAD regional observatories at Kwajalein and Bermuda are operated in conjunction with the U.S. Army and Bermuda Biological Station, respectively.



GMD Baseline Observatories are located where the measurements are representative of large regions of the globe. G-RAD operates two additional regional observatories to represent critical marine environments at Kwajalein and Bermuda.

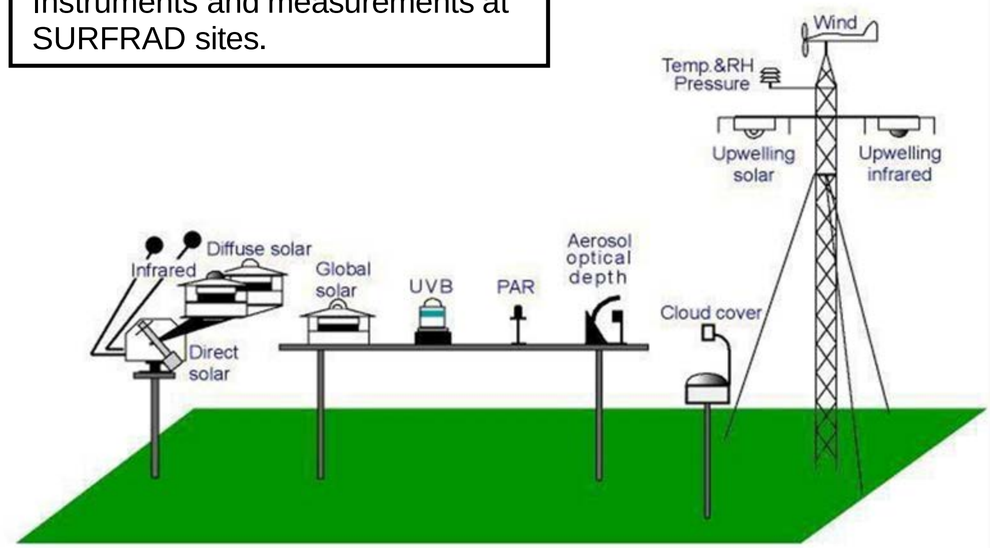
SURFRAD Network

The seven U.S. SURFRAD stations are operating in climatologically diverse regions: Montana, Colorado, Illinois, Mississippi, Pennsylvania, Nevada and South Dakota in regionally representative locations away from local urban aerosol influences and are representative of differing biomes across the U.S. They measure upwelling and downwelling; solar and infrared; direct and diffuse solar; photosynthetically active radiation; UVB, spectral solar (for AOD and spectral albedo); and meteorological variables. Total Sky Imagers are also deployed to visually track cloud cover over the hemispheric view of the sky. Data are ingested, quality controlled, and processed into daily files that are distributed in near real time by anonymous FTP and the WWW (http://www.esrl.noaa.gov/gmd/grad/surfrad/).

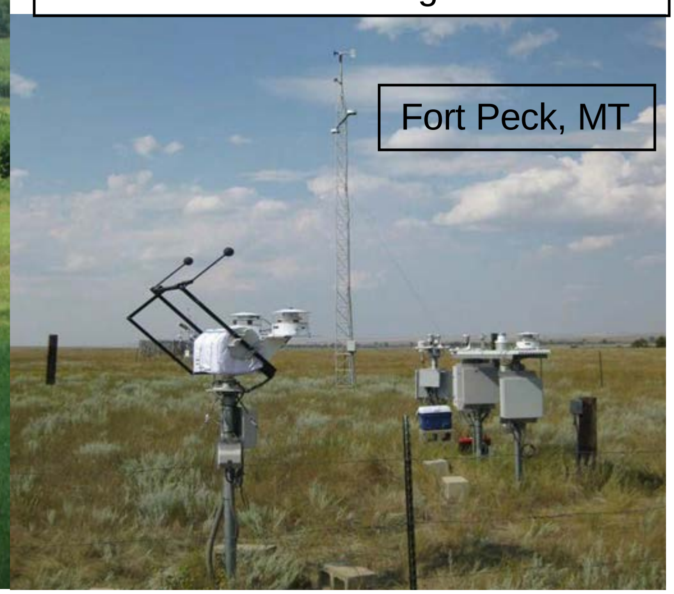
All SURFRAD stations are members of the international World Meteorological Organization Baseline Surface Radiation Network (BSRN).

Observations from SURFRAD are used for basic understanding of atmospheric radiation processes, evaluating satellite-based estimates of surface radiation; validating hydrologic, weather prediction, and climate models; renewable energy research; and many other uses. Quality assurance built into the design and operation of the network and good data quality control ensure that a continuous, high quality product is released.

Instruments and measurements at SURFRAD sites.



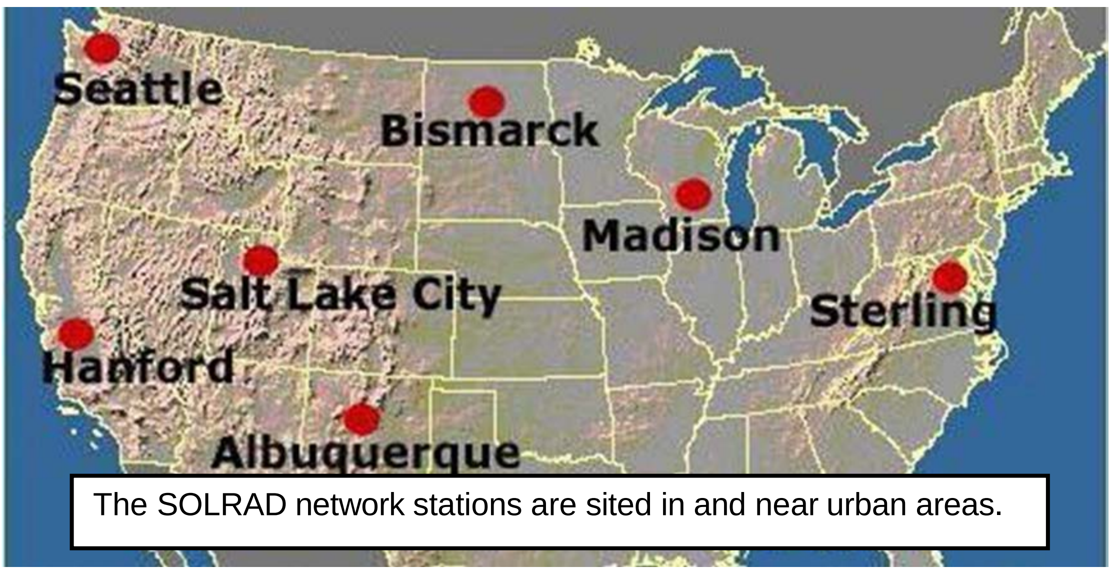
SURFRAD sites are in diverse U.S. climatic and biological zones.



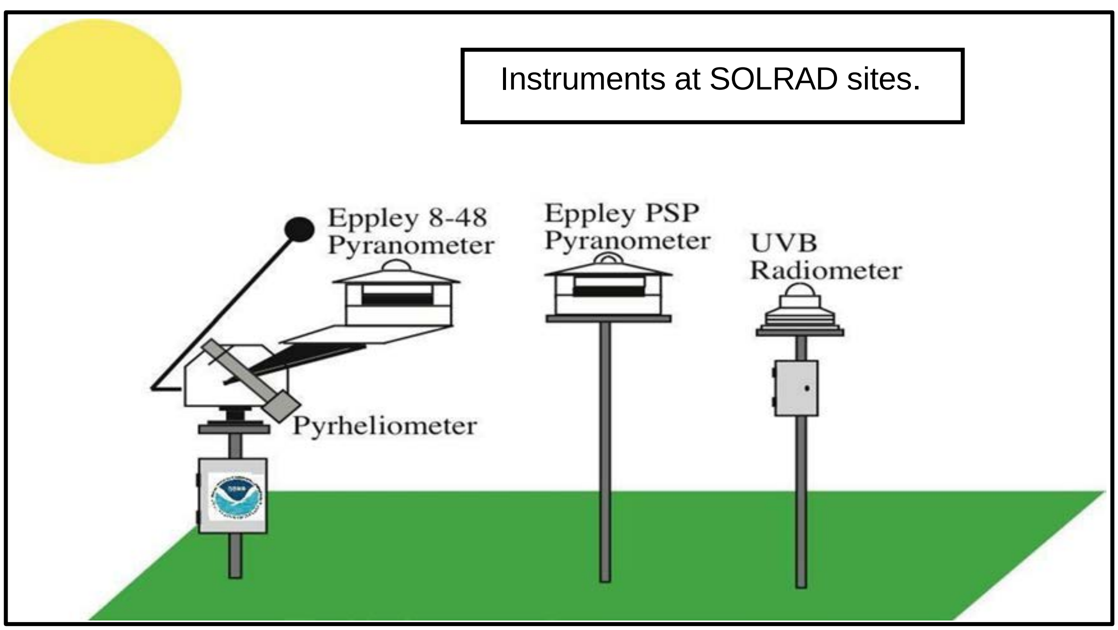
SOLRAD Network

The first SOLRAD stations were inaugurated in the 1970s and placed primarily in urban areas to map solar energy for renewable energy development. Aerosols typical of urban environments are different than background aerosols at SURFRAD sites, and thus have different direct effects on radiation reaching the surface and indirect effects on cloud lifetime and extent. G-RAD plans to deploy spectral solar instruments at SOLRAD sites for monitoring aerosol optical depth in these more urban regions.

These considerations have become important to the numerical modeling communities as forecast models have become more sophisticated. Both SOLRAD and SURFRAD measurements have become indispensable tools in efforts to improve those models.



The SOLRAD network stations are sited in and near urban areas.



Instruments at SOLRAD sites.

SOLRAD site in Seattle, WA.

SOLRAD site in Sterling, VA.

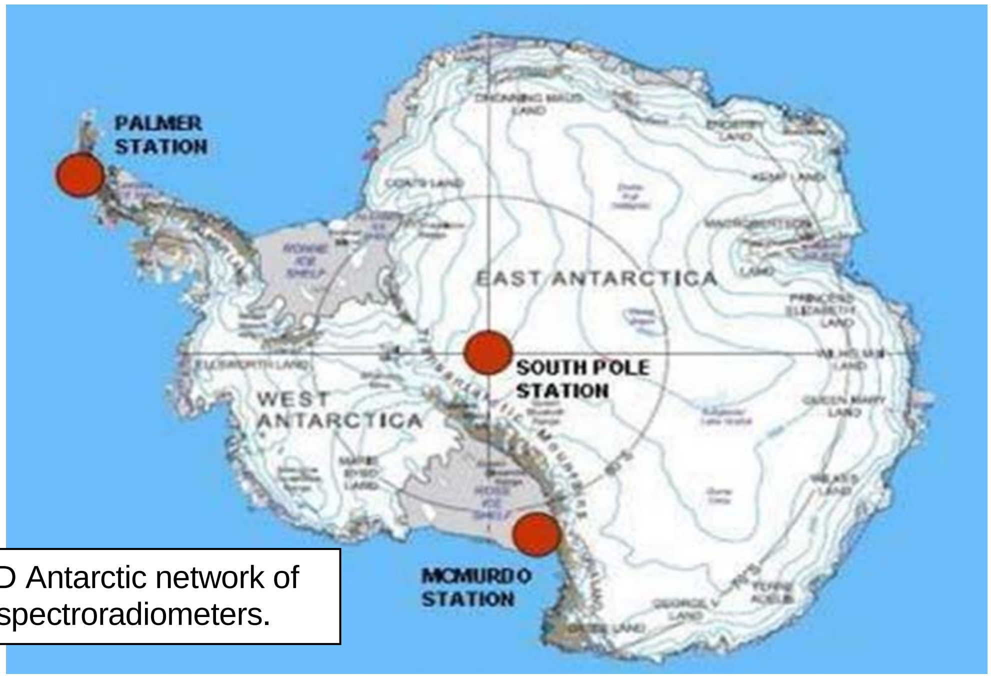
NOAA NEUBrew Measurement Network

The NOAA GMD Brewer Spectrophotometer Network established in 2006 consists of six stations located in the western, central and eastern United States (Ft. Peck, MT; Boulder, CO; Niwot Ridge, CO; Bondville, IL; Houston, TX; and Raleigh, NC. Brewer spectrophotometers provide daily UV irradiance and Total-Column Ozone measurements. Three Brewers are co-located at NOAA SURFRAD stations equipped with Total Surface Radiation Budget instrumentation and Total Sky Imagers.

Antarctic UV Network

The Antarctic UV Monitoring Network was established in 1987 by the National Science Foundation (NSF) in response to ozone depletion in the Antarctic stratosphere. Biospherical Instruments (BSI) installed the first instruments and operated the network until 2009. NSF transitioned operation of the Antarctic UV Network to NOAA/ESRL/GMD in 2010.

This Antarctic UV Network provides data for studying the effects of ozone depletion on terrestrial and marine biological systems, ozone hole monitoring, validation of satellite observations, and verification of atmospheric radiation transfer models. The network consists of three stations: South Pole Station, McMurdo Station, and Palmer Station. Each station is equipped with a BSI SUV-100 Spectroradiometer, a GUV Multi-Channel Radiometer, an Eppley PSP Pyranometer, and an Eppley Total UV (TUVR) Radiometer. Data are collected every 15 minutes and processed into daily UV products.

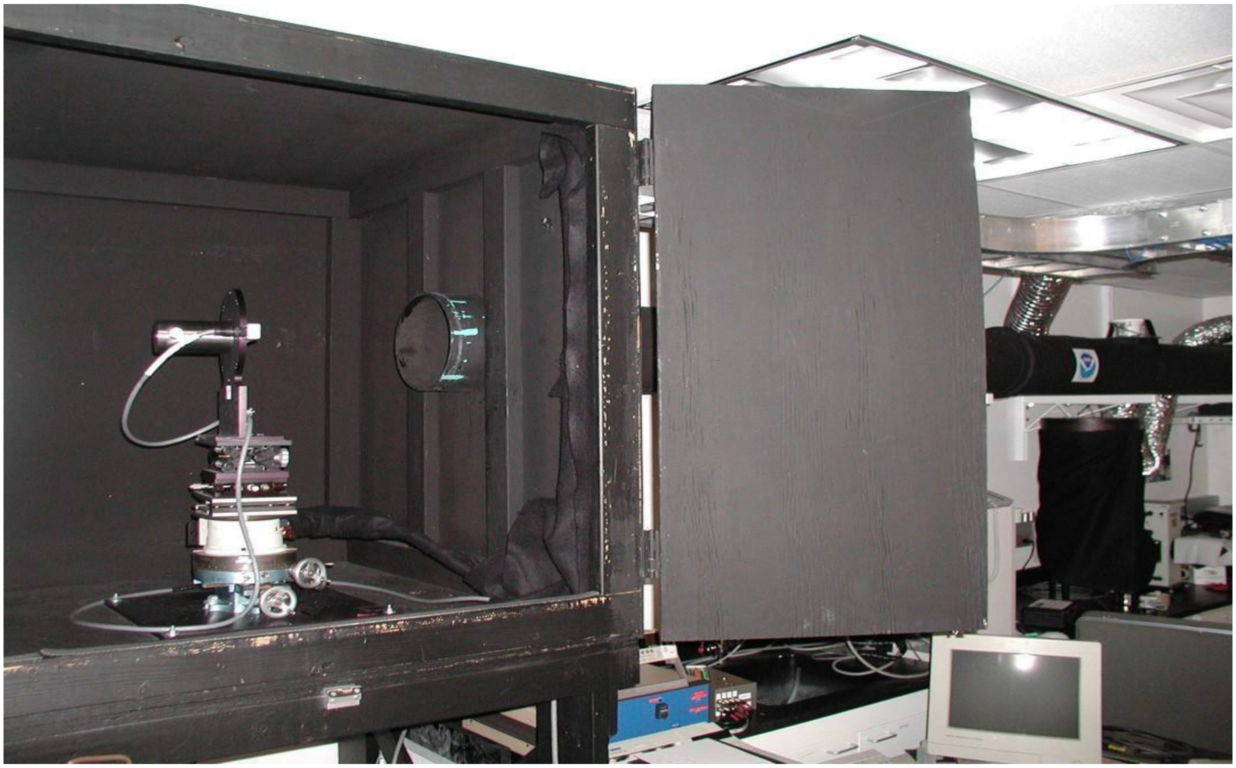


GMD Antarctic network of UV spectroradiometers.

Central UV Calibration Facility (CUCF)

The basic operations of CUCF will be introduced in the Standards and Calibrations section of this report. In addition, the CUCF has several additional functions, such as:

- Generating standard lamps for the calibration of UV radiometers.
- Producing absolute calibrations of UV spectroradiometers both in the lab and in the field.
- Characterizing the angular response of spectral instruments such as the visible and UV Multi-Filter Rotating Shadowband Radiometers (MFRSRs).
- Providing absolute MFRSR channel calibrations for spectral albedo at SURFRAD sites, a measurement that was requested by NESDIS for GOES-R validation.



Characterizing the angular response of an MFRSR head. MFRSRs are used in the SURFRAD network for aerosol optical depth (AOD) and spectral albedo measurements.

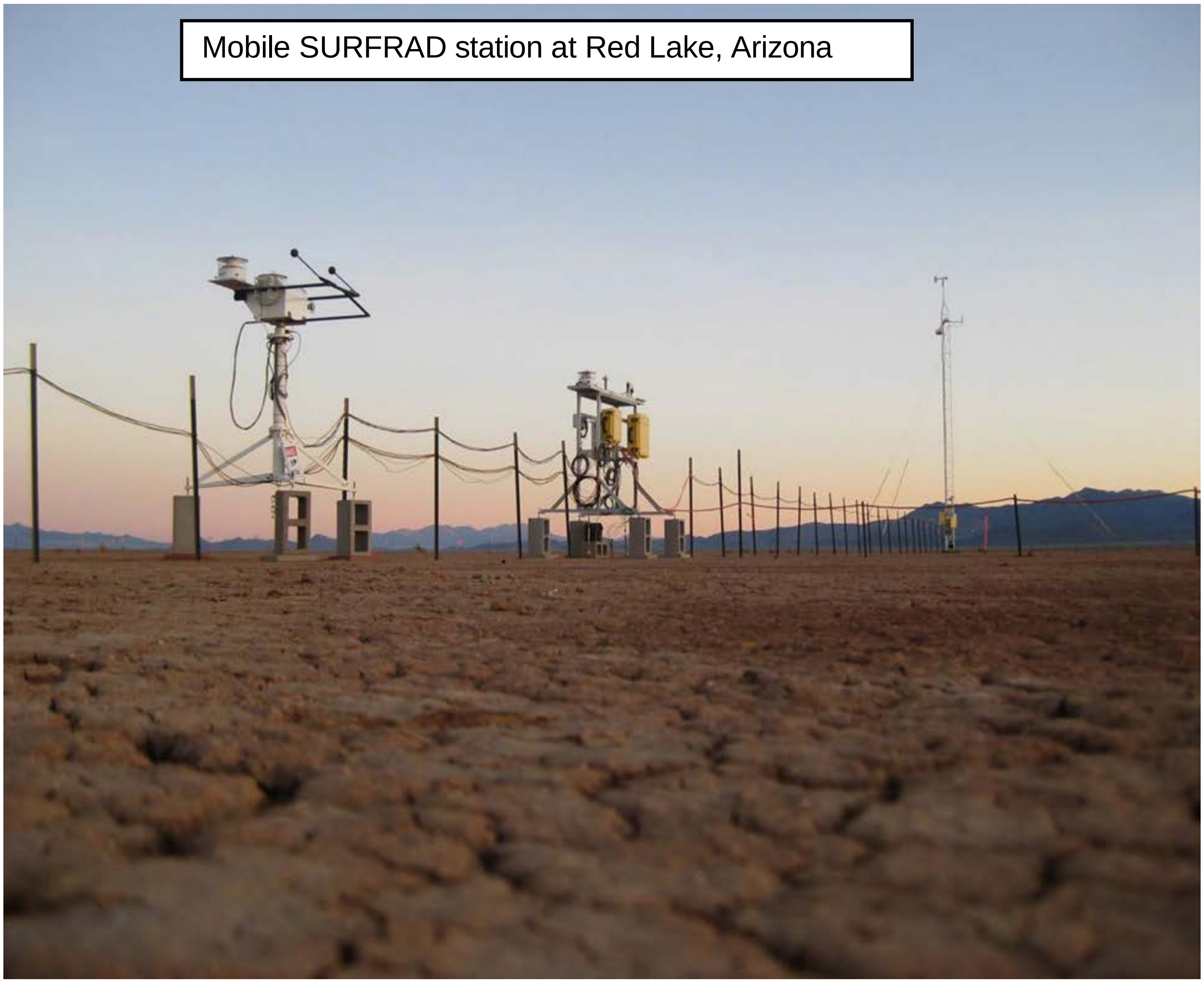
In Boulder, CO World Meteorological Organization (WMO) calibrated-reference-traceable standard instruments are used to transfer calibrations to field radiometers at GMD’s Region IV Regional Radiation Center facility, shown above.

A Brewer UV spectroradiometer being calibrated at the GMD Table Mountain, Boulder CO Measurement and Calibration Facility. Many of the GMD CUCF calibrations are conducted in the field including the three UV instruments distributed across Antarctica.

Mobile SURFRAD Stations

Over the past 5 years two mobile SURFRAD stations were developed to take part in research campaigns and validation experiments where measurements of the SRB, aerosol optical depth, and spectral albedo are needed, such as:

- GOES-R validation, a three-week deployment on a dry lake bed in Arizona.
- In situ data for renewable energy research near large solar arrays for DOE's SunShot Initiative (Rutland, VT, and San Luis, CO).
- The DOE/NOAA Wind Forecasting Improvement Project-2, Columbia River Basin, OR.
- NASA-sponsored DISCOVER-AQ air quality experiments in the Central Valley of CA: and Houston, TX; the FRAPPE campaign along the Front Range of CO, and the DOE-sponsored TCAP (two-column aerosol project) in Massachusetts.


Mobile SURFRAD station at Red Lake, Arizona

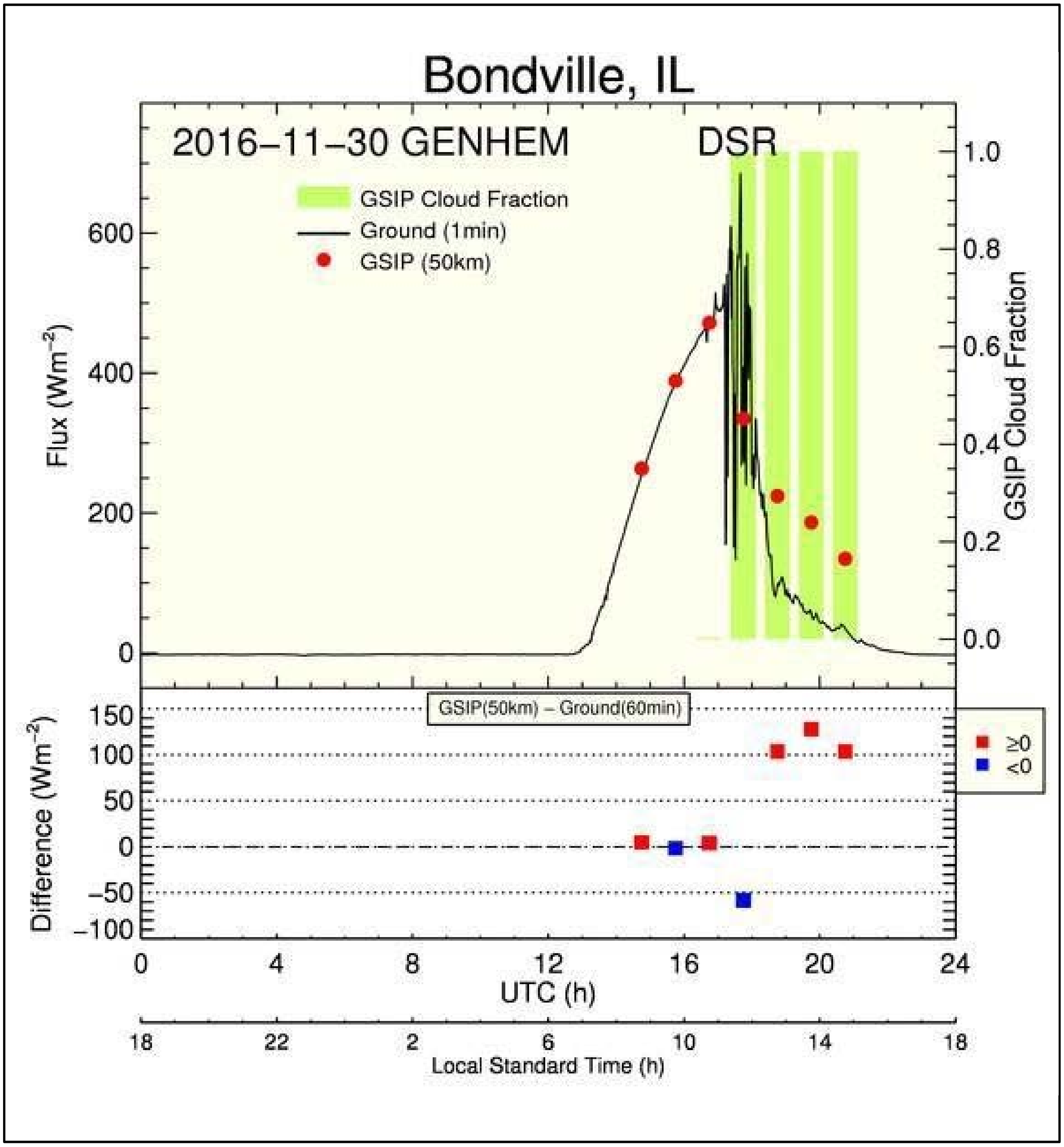
Satellite Validation

Estimates of surface radiation from weather (GOES, JPSS) and climate (NASA EOS A-train) satellites expand surface radiation coverage spatially to the globe.

Unfortunately, satellites only sense upwelling radiation and, from that information, must model the downwelling irradiance at the surface.

G-RAD measurements play a crucial role in validating many satellite-based surface radiation products produced by NASA and NOAA-NESDIS.

Below is an example of a NESDIS GOES product validation using SURFRAD data.



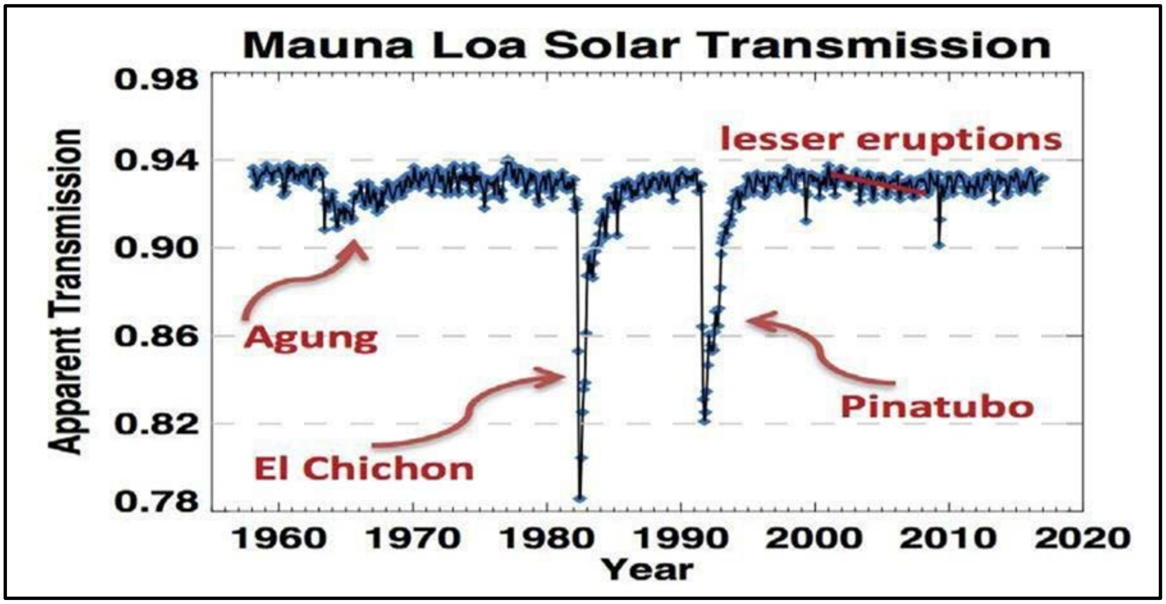
NESDIS GOES satellite estimated shortwave radiation and corresponding G-RAD in situ measurements.

Comparisons of NESDIS daily GOES-estimated shortwave down (red dots) and ground measurements for November 30, 2016 at the Bondville SURFRAD station. Comparisons such as this are published by NESDIS each day.

This example shows that the GOES algorithm generally does well for clear skies (morning in the above plot) but overestimates the actual surface irradiance under cloudy conditions in the afternoon.

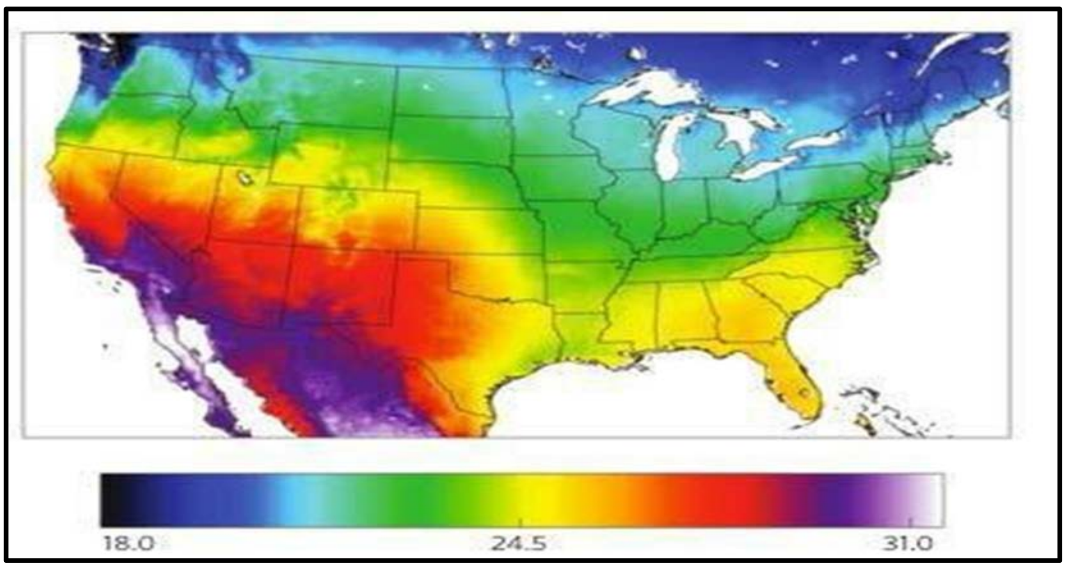
Some Notable GMD G-RAD Network Achievements:

- **Volcanic Reduction of Solar Transmission.**



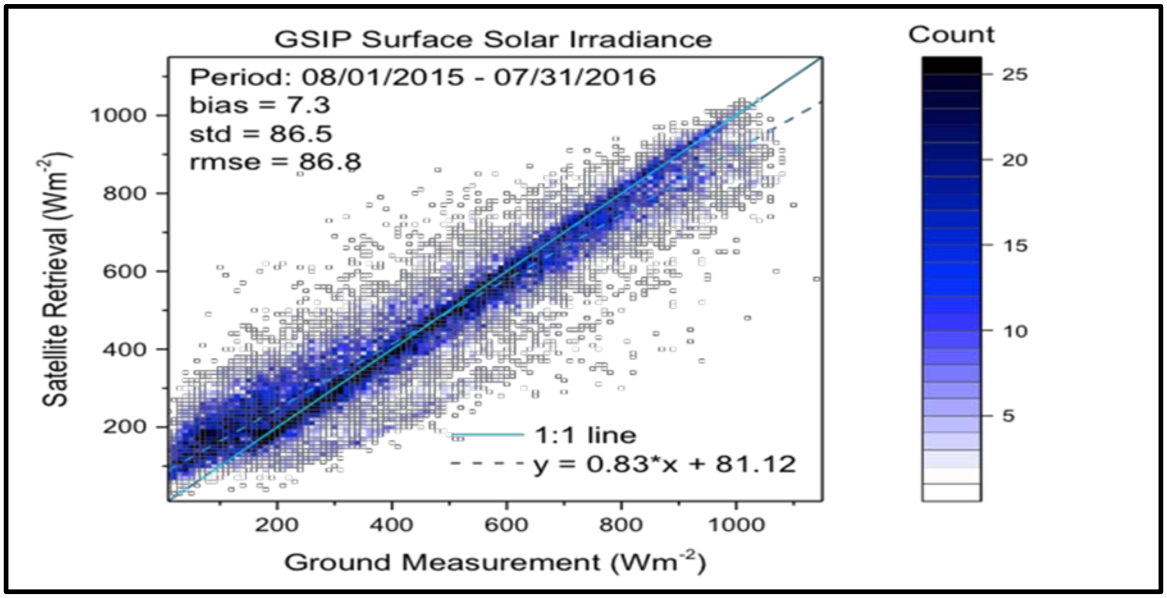
The unbroken Mauna Loa atmosphere transmission record that goes back to the IGY (1956) is the longest such record in existence.

- **Development of a solar resource map for the solar electric industry.**



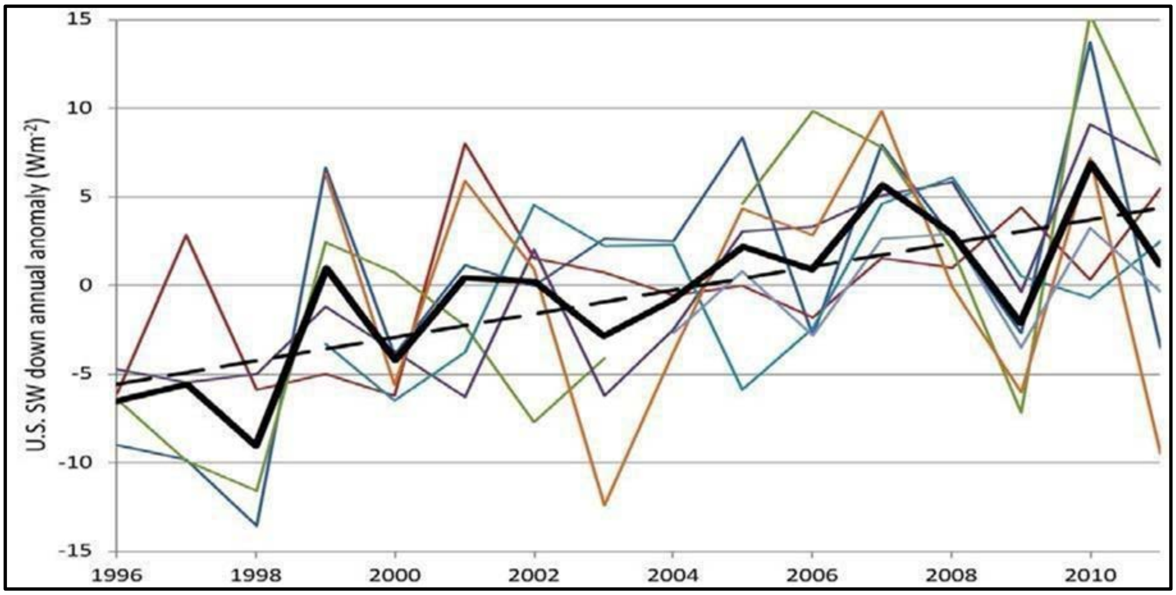
GMD SURFRAD and SOLRAD data were used to produce this unique solar energy resource map (units: "capacity factor" in %) used as the basis for configuration of a cost-competitive alternative electrical system for the U.S.

- **Correcting bias in a GEOES satellite measurement.**



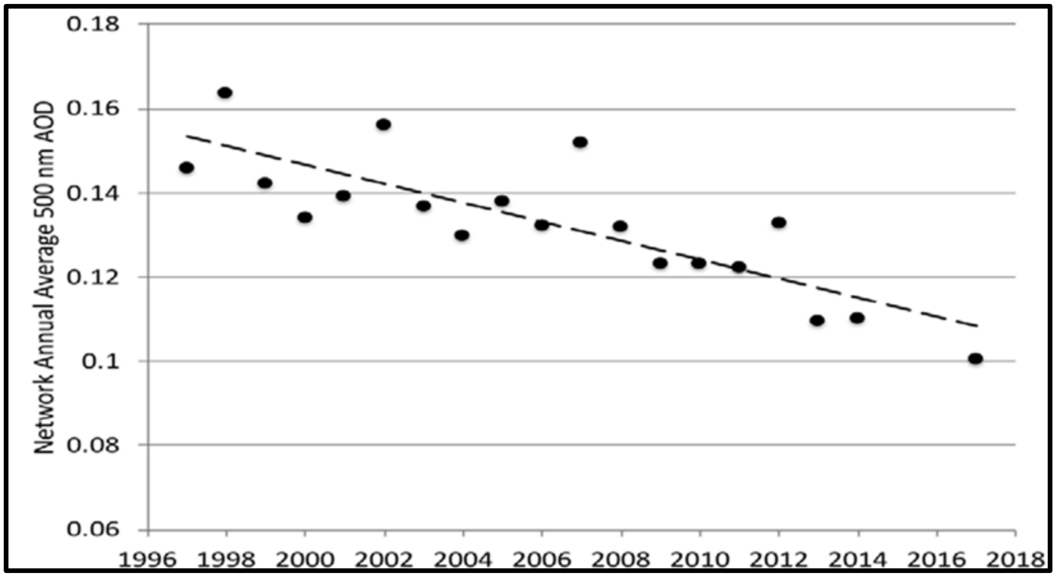
SURFRAD measurements revealed a high bias in GOES-based estimates of surface shortwave under low irradiance (cloudy) skies, that subsequently were corrected for in the GOES-R algorithm.

- **Documenting a persistent solar brightening across the US.**

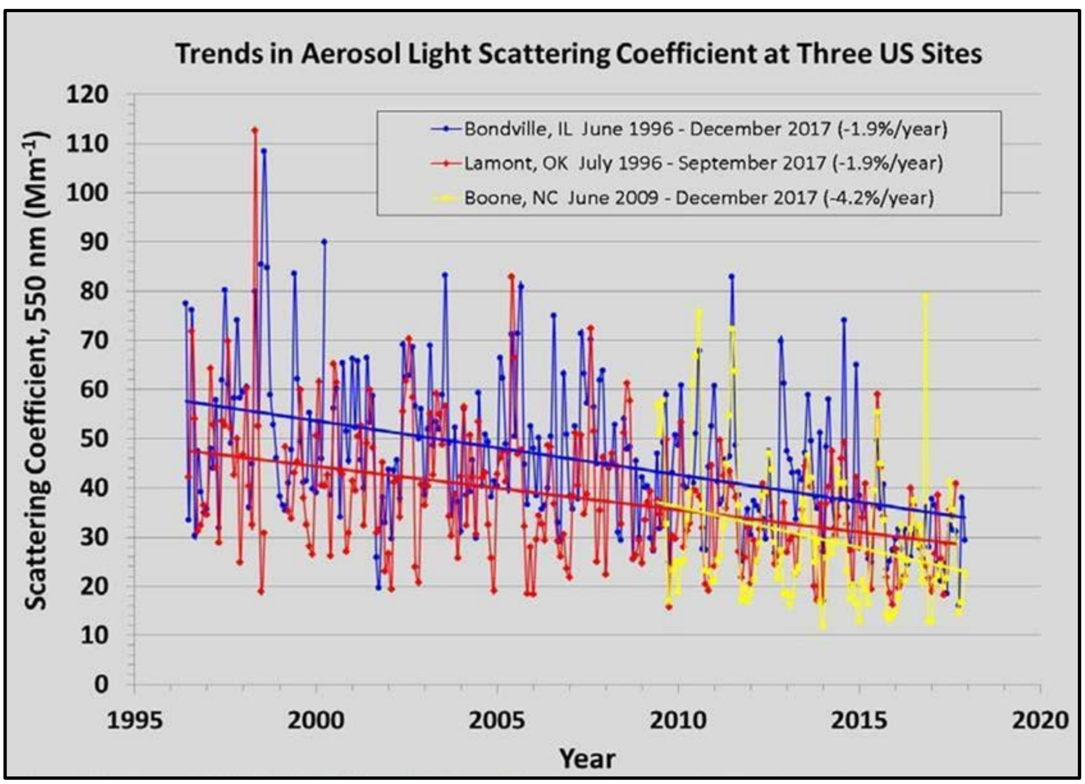


Systematic solar brightening at all SURFRAD stations (colored lines). The U.S. average (thick black line) of 10 Wm^{-2} over 16 years is nearly three times that expected from the doubling of CO_2. Ancillary data from SURFRAD stations revealed that this brightening was caused primarily by a general decrease in cloud cover over that time period.

- **Decrease in aerosol optical depth and aerosol light scattering across the U.S.**

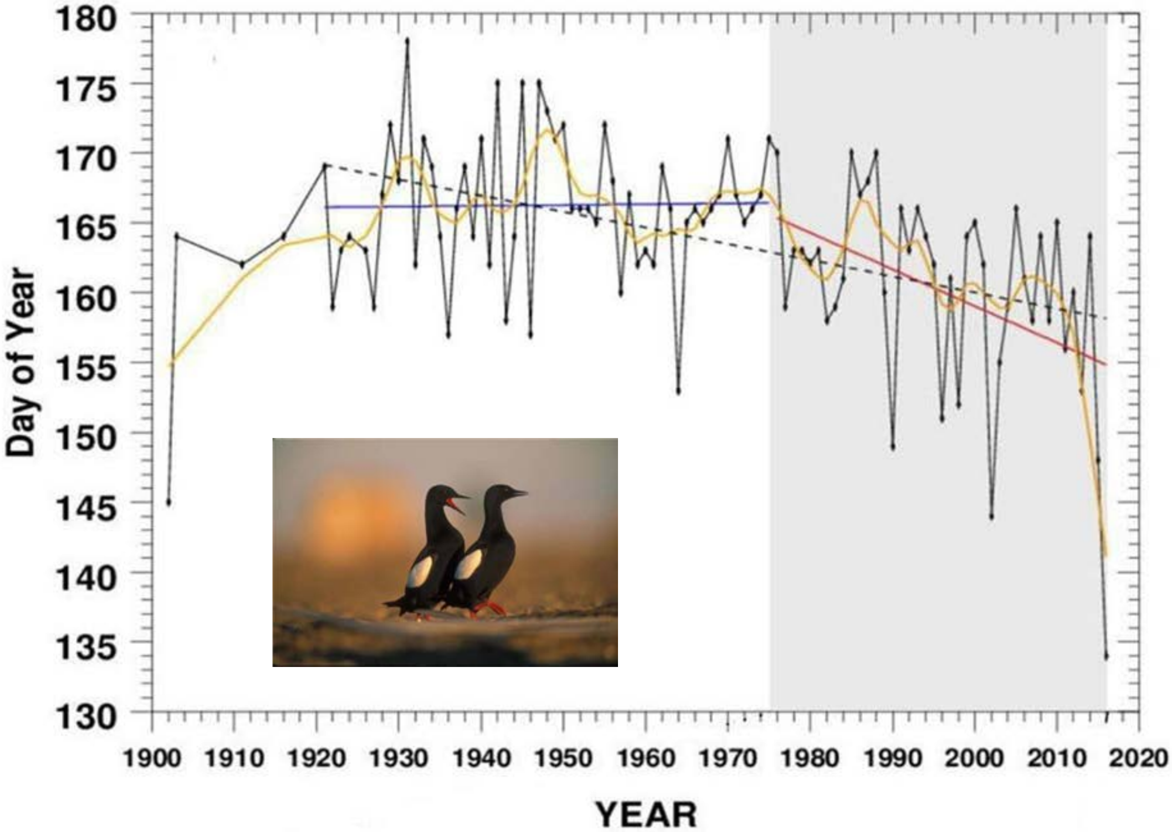


A 20 year decrease in aerosol optical depth over the U.S. in agreement with known reductions in aerosol emissions due to regulations.



Aerosol light scattering at the surface has also been decreasing over the past 20 years across the U.S. as measured in the GMD Surface Aerosol Network and agrees with data on decreasing optical depth in the U.S.

- **Documenting advancing springtime in the Arctic**



Time series of snowmelt dates at Barrow, Alaska; orange line is a ten-year running mean and linear fits are shown for 1920-1975 (blue), 1920-2016 (dashed) and 1975-2016 (red). The 1975-2016 linear trend is -2.86 days decade^{-1}, meaning that the snowmelt is occurring on average almost 3 days earlier each decade since 1975. The date that black guillemots (inset) lay their first egg on nearby Cooper Island is influenced by snow cover and highly correlated with the date of snowmelt at the nearby Barrow Observatory. (Photo credit: Joe McNally, Cooper Island Bird Observatory)

The GMD Barrow Observatory comprises the longest running and most comprehensive set of climate variables in the Arctic. This figure shows the retreat of the snow melt date to earlier in the year since the Barrow Observatory record began (1973). The retreat is occurring at 3 days/decade over this time period. Earlier snow melt dates are a function of many interconnected processes termed Arctic Amplification that work to warm the region at a faster rate than other areas of the globe. (From Cox et al. 2017 BAMS).

- **GMD radiation data used to correct a large error in a NWS weather prediction model.**

SURFRAD and SOLRAD measurements were the key to finding the source of a +3°C temperature bias in the National Weather Service's operational Rapid Update Cycle weather forecast model and its subsequent improvement.

G-RAD Network Data Processing and Storage

Radiation and meteorological data from all G-RAD networks are downloaded, processed, quality controlled, and made available on local FTP servers daily.

SURFRAD and SOLRAD data are downloaded and processed every 15 min. and made available on FTP in near-real time for the model and satellite communities.

Radiosonde soundings are interpolated to all SURFRAD sites for 0000 and 1200 UTC each day using all data from the NWS sounding network. Interpolated soundings at SURFRAD sites and all U.S. soundings used are made available on FTP on a daily basis.

SURFRAD data are compiled as hourly averages and sent in monthly files to NOAA's official archive at NCEI in Asheville, NC. From there they are reformatted and sent to the World Radiation Data Center in St. Petersburg, Russia.

SURFRAD data and baseline site data from Barrow, South Pole, Bermuda, and Kwajalein are periodically processed in monthly files for submission to the BSRN archive in Bremerhaven, Germany.

SURFRAD data are processed using the RadFlux algorithm that produces several computed research products such as clear-sky equivalent irradiance and sky cover fraction. RadFlux files are produced and made available on FTP on a quasi-monthly basis.

Aerosol optical depth from MFRSR data at all SURFRAD sites is produced periodically throughout the year and made available on FTP. SURFRAD AOD data are submitted to the international GAW archive on an annual basis.

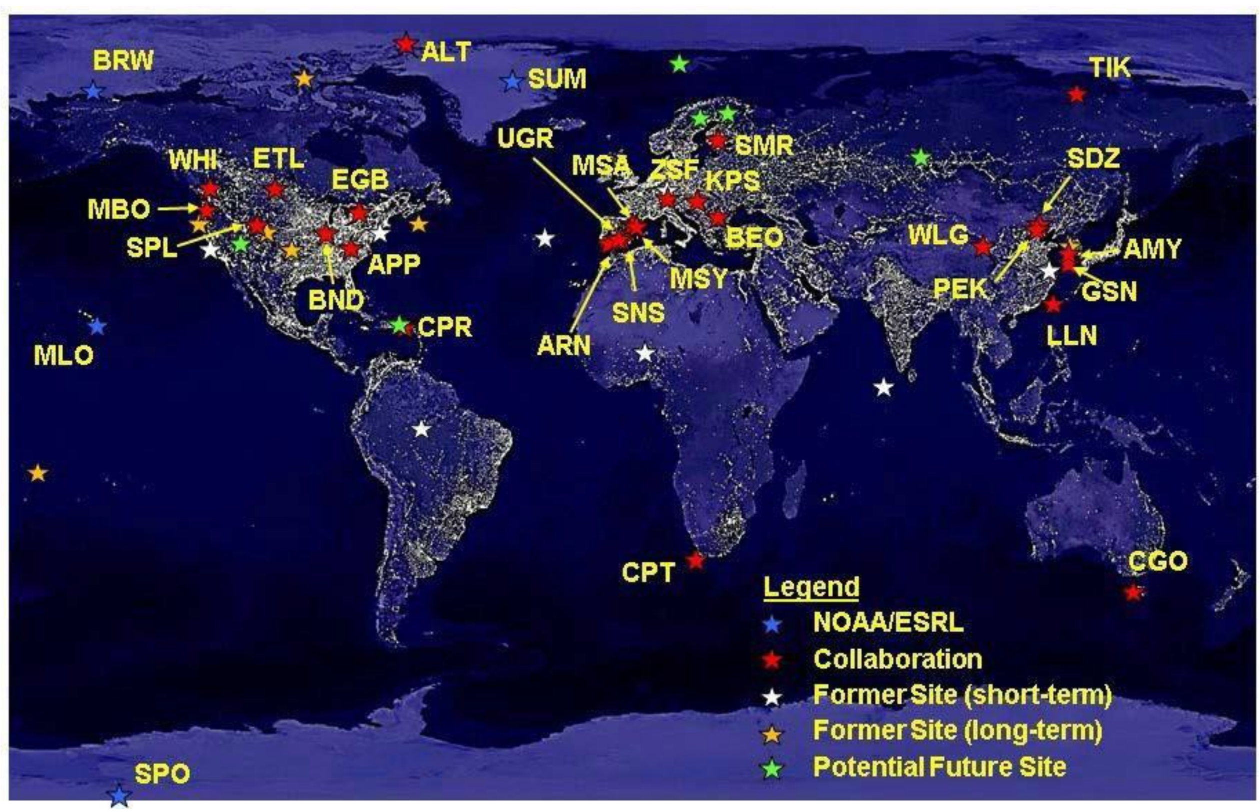
Products from new MFRSRs at SURFRAD sites such as spectral albedo and aerosol property retrievals are currently being developed.

Soon, all radiation data products produced at G-RAD will be available in NetCDF format at NCEI.

Theme 2, Part 2: NOAA Federated Aerosol Network (NFAN)

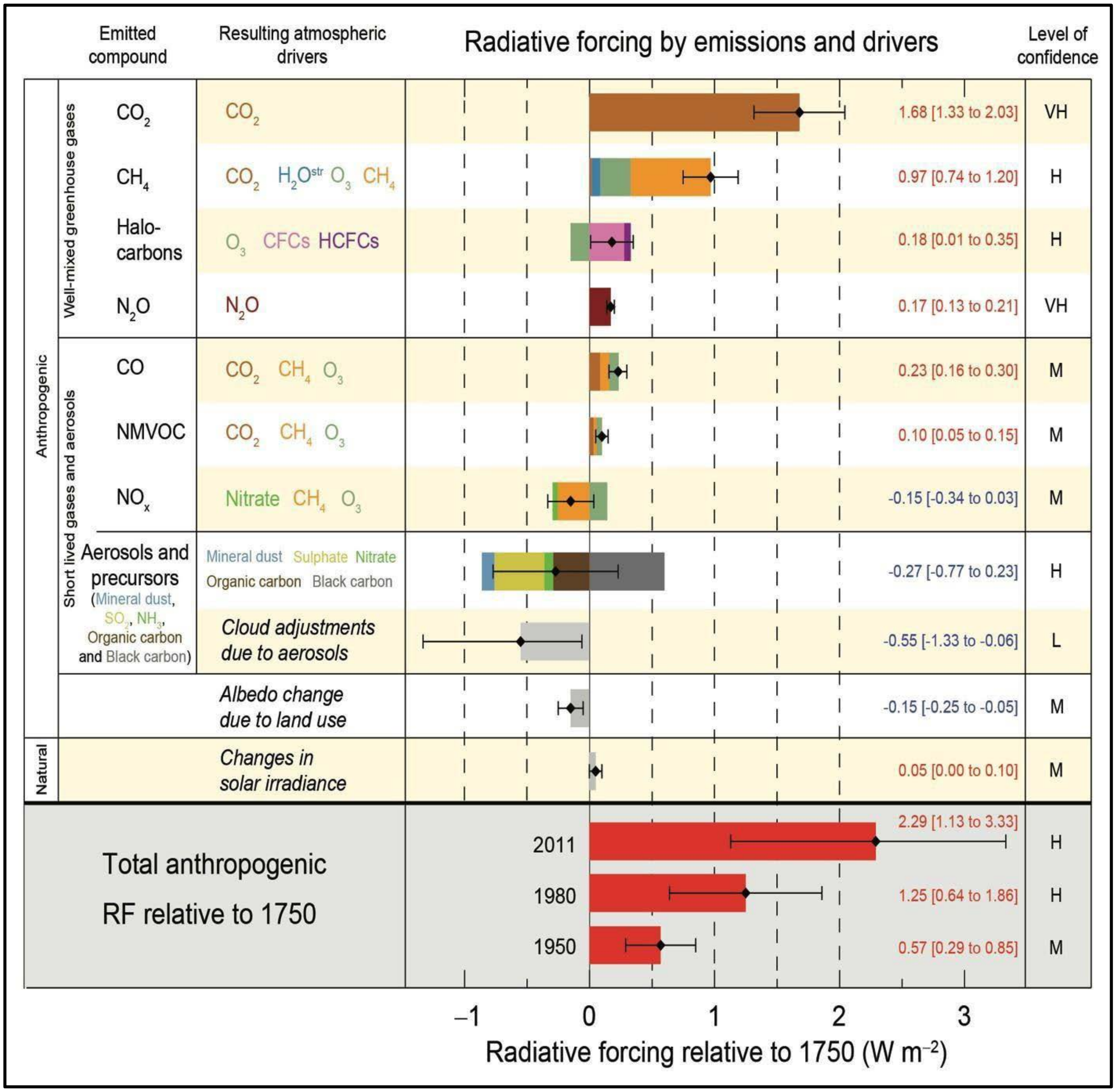
Uncertainties in the effect of aerosols on the radiative balance of the atmosphere result in aerosol particles (and clouds, which form on aerosol particles) having the largest error bars of all atmospheric radiative forcing species. Aerosol particles may either heat or cool the atmosphere. Given these facts, it is important to monitor aerosol particles around the Earth in a consistent and continuous basis.

As such, the global Monitoring Division has established and operates a 30 station (and growing) global aerosol measurement network as shown below.



The station names, locations and cooperating agencies are presented in the following pages as well as important scientific results from the network.

Radiative Forcing by Emissions and Drivers (IPPC AR5, Summary for Policy Makers, 2013)



Radiative forcing estimates in 2011 relative to 1750 and aggregated uncertainties for the main drivers of climate change. Values are global average radiative forcing (RF14), partitioned according to the emitted compounds or processes that result in a combination of drivers. The best estimates of the net radiative forcing are shown as black diamonds with corresponding uncertainty intervals; the numerical values are provided on the right of the figure, together with the confidence level in the net forcing. Albedo forcing due to black carbon on snow and ice is included in the black carbon aerosol bar. Note that aerosol effects have the largest error bars.

Aerosol Systems at the NFAN Stations

Aerosol systems deployed in the NOAA Federated Aerosol Network (NFAN) measure aerosol optical properties (e.g., light scattering and absorption) to determine the effects of aerosol direct radiative forcing. Other standard measurements include particle number concentration and wind speed and direction to augment and interpret the optical measurements. All stations are essentially identical in instrumentation and operating procedures. Data collection is handled with identical software and monitored by a GMD staff scientist and by partners for each site.

All 30 stations measure with identical equipment, operational procedures and data processing software. The 30 station NFAN is operated by 1.5 GMD scientists, 1 programmer and a 0.5 engineer at GMD along with the aid of U.S. and international partners.

Other measurements performed at a subset of stations include the aerosol hygroscopic growth factor, cloud condensation nucleus concentration, particle size distribution, aerosol chemistry, and real-time weather (i.e., fog, haze, drizzle, rain, snow, etc.) conditions.

One minute data from most NFAN stations comes to Boulder electronically on an hourly basis, but a few stations, owing to communication limitations, transfer data less frequently (daily). The incoming data are checked daily for errors and instrument problems that are attended to either from Boulder through remote access and control, or through email interactions with site personnel.

The Aerosol Group archives NFAN aerosol data in-house, at a primary site in NOAA, Boulder and at an offsite location. All aerosol data are also submitted to the WMO/GAW World Data Centre for Aerosols in Norway. (https://www.gaw-wdca.org/). Additionally, within the past year, to comply with the directives set forth in the NOAA Big Earth Data Initiative (BEDI) project, GMD submits aerosol data to the NOAA National Centers for Environmental Information (NCEI) archive (https://doi.org/10.7289/V55T3HJF) .

NOAA Federated Aerosol Network (NFAN) Locations

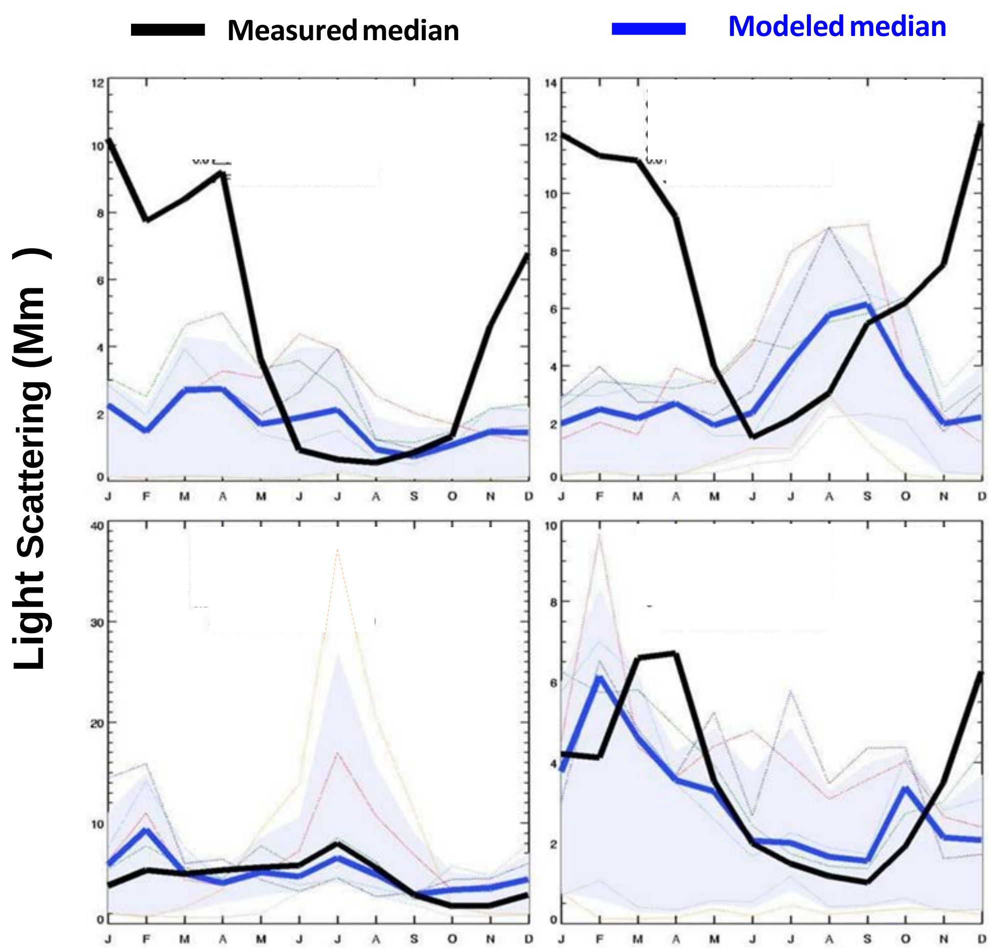
Alert, Nunavut (ALT)
Anmyeon-do, Korea (AMY)
Appalachian State, North Carolina (APP)
Barrow, Alaska (BRW)
Beijing, China (PEK)
Beo Moussala, Bulgaria (BEO)
Bondville, Illinois (BND)
Cape Grim, Australia (CGO)
Cape Point, South Africa (CPT)
Cape San Juan, Puerto Rico (CPR)
East Trout Lake, Saskatchewan (ETL)
Egbert, Ontario (EGB)
El Arenosillo, Spain (ARN)
Granada, Spain (UGR)
Gosan, Korea (GSN)
Hyytiala, Finland (SMR)
K'Puszta, Hungary (KPS)
Mauna Loa, Hawaii (MLO)
Montsec, Spain (MSA)
Montseny, Spain (MSY)
Mount Bachelor, Oregon (MBO)
Mount Lulin, Taiwan (LLN)
Mount Waliguan, China (WLG)
Shangdianzi, China (SDZ)
Sierra Nevada, Spain (SNS)
South Pole, Antarctica (SPO)
Summit, Greenland (SUM)
Tiksi, Russia (TIK)
Whistler, British Columbia (WHI)
Zeppelin, Ny Alesund, Norway (ZEP)
Zugspitze, Germany (ZSF)

Sites in discussion phase for possible set-up in 2018-2023:
Pico del Este, Puerto Rico
New Mexico Tech, New Mexico
Varrio, Finland
Norrunda, Sweden
Pallas, Finland
Tomsk, Russia

Some GMD Aerosol Network Results of Note

(The model results are from widely used global climate models for predicting aerosol characteristics and distributions).

NFAN Arctic In Situ Data vs Modeled Aerosol Light Scattering



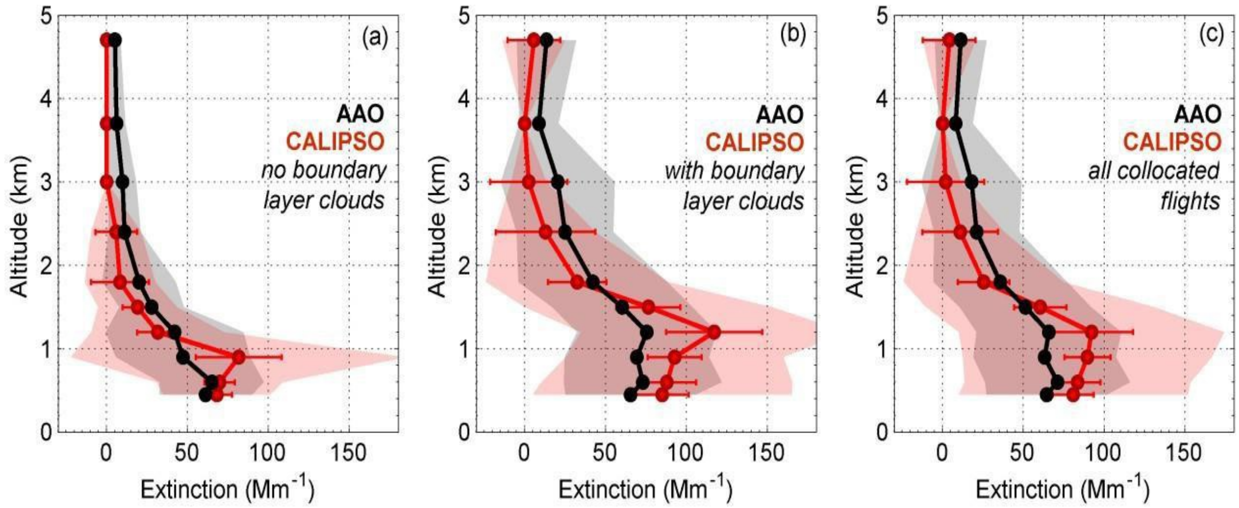
Model/measurement discrepancies can suggest atmospheric processes to focus on. For example, what causes the model peak in summer at Barrow? Could it be overestimating forest fire emissions? Or, underestimating removal processes such as wet deposition?

Why is model/measurement agreement better in the European Arctic than the North American Arctic?

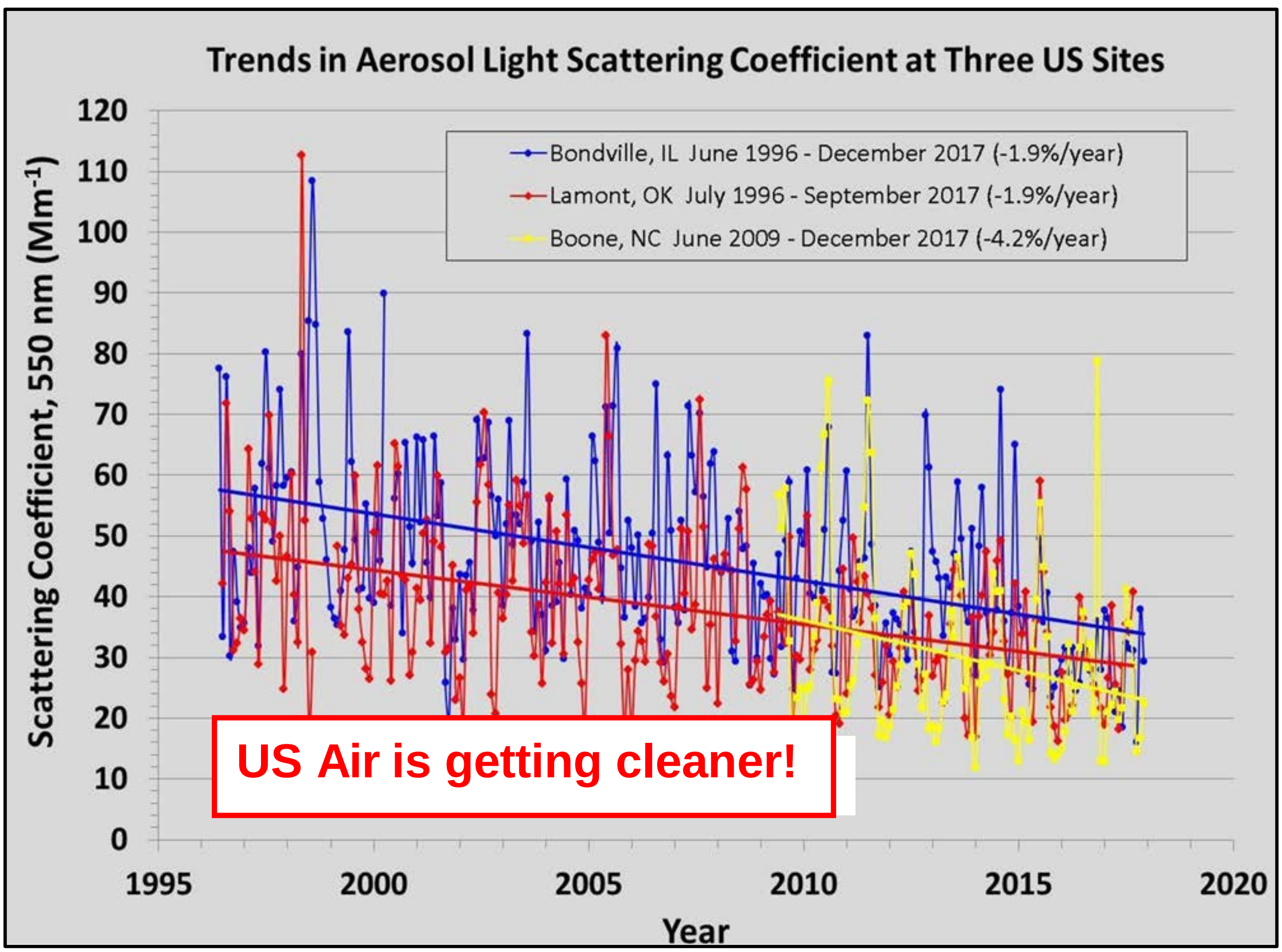
For the 13 models tested, the median is shown in blue, one standard deviation in shaded blue, and the outlier models in red and green.

(The model study by a group of international scientists is in progress).

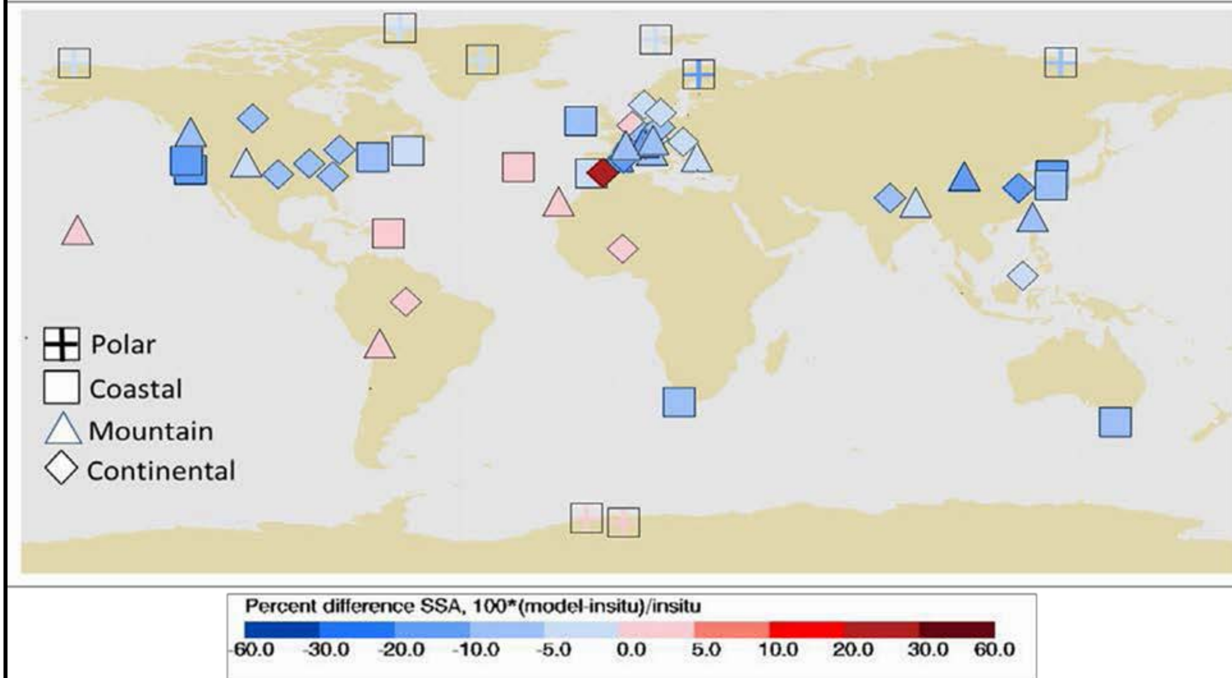
GMD Airborne vs. CALIPSO Satellite Aerosol Extinctions



For 3.25 years GMD operated a light aircraft (AAO) to measure in situ aerosol parameters on 405 profiles at Bondville, IL; 63 coincided with CALIPSO overflights. The shaded envelopes are standard deviations of the data and the CALIPSO error bars are the uncertainties in the CALIPSO lidar measurement. It is apparent that CALIPSO overestimates extinction in the boundary layer and underestimates it in the free troposphere. *From Sheridan et al., 2012.*

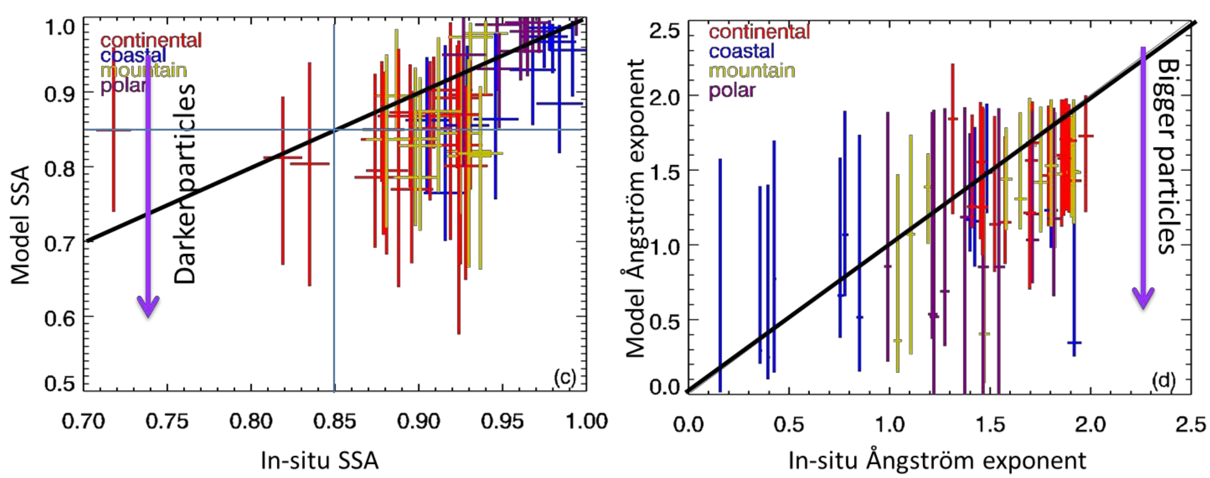


Model Evaluation – Single Scattering Albedo

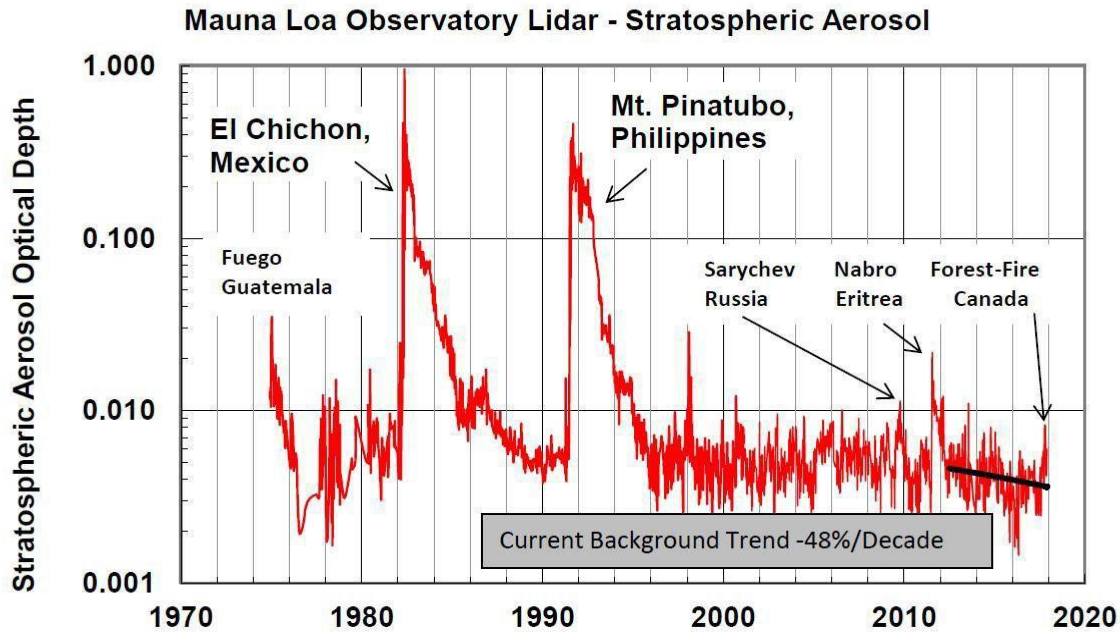


Model median values (based on 14 global climate models) suggests models underestimate observed SSA (i.e., models simulate a darker aerosol than is observed).

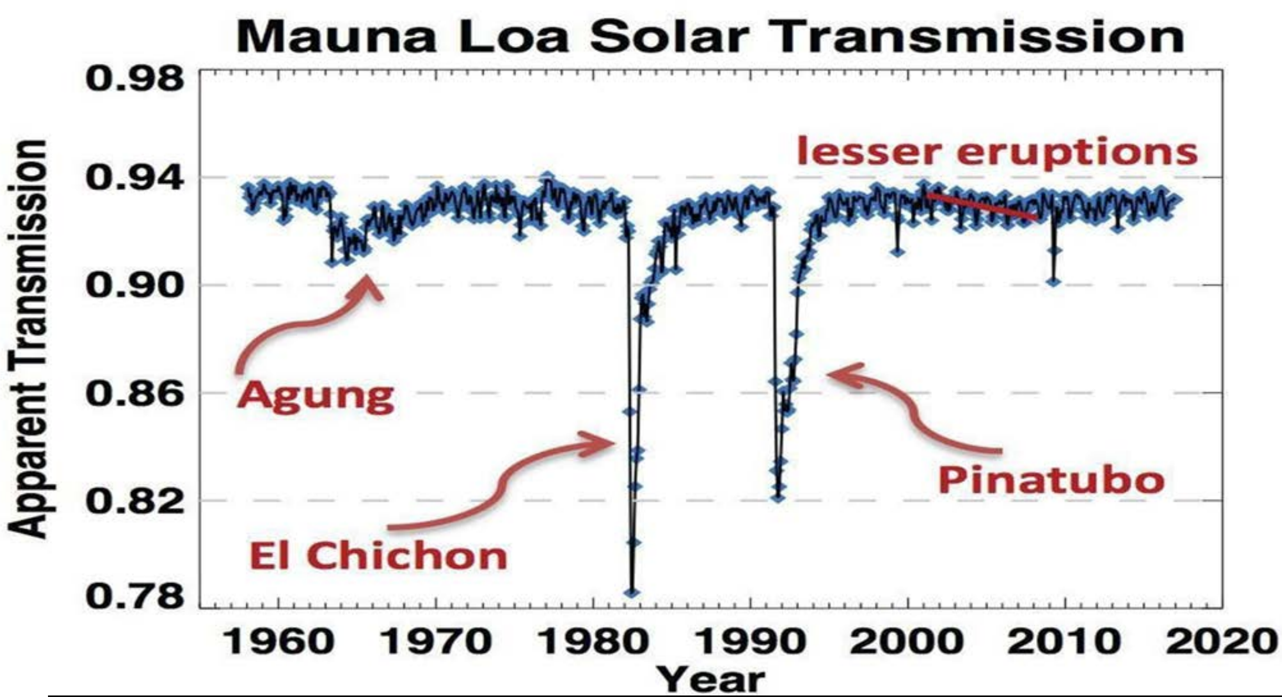
Model Evaluation: Single Scattering Albedo and Ångström Exponent



Model Single Scattering Albedo (SSA) tends to be lower (more absorbing) than in-situ SSA partly driven by model under-prediction of scattering. Modelled Ångström exponents suggest larger particles than observed by in-situ measurements.



This is the longest lidar measurement of stratospheric aerosol in existence. Note the close relationship between elevated stratospheric aerosol and reduced solar radiation transmission in the following graph.



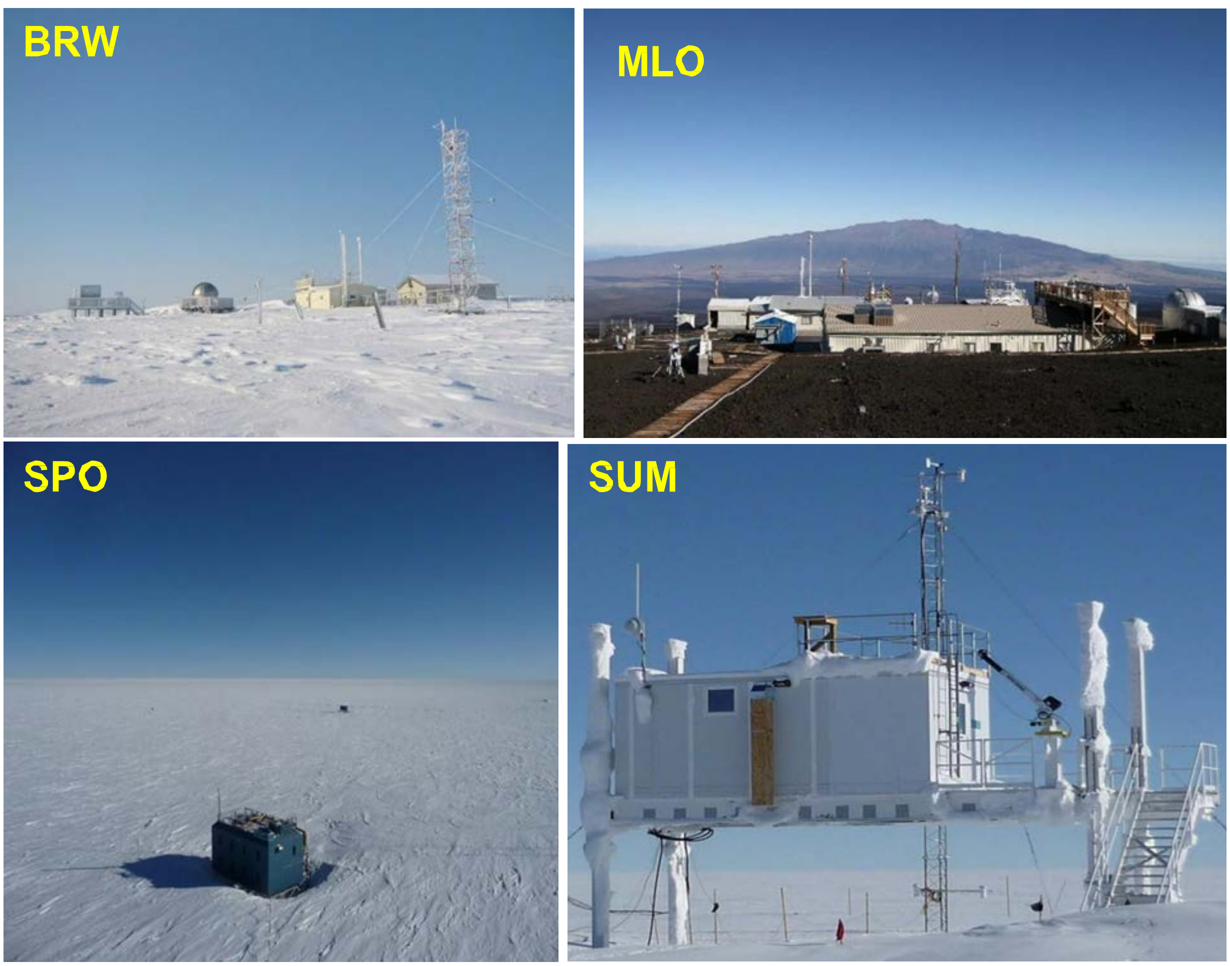
The Mauna Loa atmospheric transmission record began in 1957 and has recorded the effects of three explosive volcanic eruptions (Agung, El Chichon and Pinatubo and lesser events (1999 and 2010). In later years, the annual reduction in solar transmission is from springtime aerosol and air pollution outflow from Asia. This is the oldest record of aerosol effects on solar transmission on Earth.

NOAA Aerosol Cooperative Program Partners: NFAN and other Aerosol Research Partners

Appalachian State University: Cooperative aerosol measurements and research.
Bulgarian Academy of Sciences, Bulgaria: Cooperative aerosol measurements and research.
Center for International Climate and Environmental Research, Norway: Aerosol research.
China Meteorological Agency, China: Cooperative aerosol measurements and research.
CSIRO, Australia: Cooperative aerosol measurements and research.
Desert Research Institute, Steamboat Springs, CO: Aerosol research.
Duke University, Durham, NC: Aerosol research
Environment and Climate Change Canada: Cooperative aerosol measurements and research.
Federal Office of Meteorology and Climatology, Switzerland: Aerosol research.
Finnish Meteorological Institute, Finland: Cooperative aerosol measurements and aerosol research.
German Weather Service, Germany: Cooperative aerosol measurements and research.
Institute of Environmental Assessment and Water Research (IDAEA-CSIC), Spain: Cooperative aerosol measurements and research.
Institute of Nuclear and Radiological Science & Technology, Greece: Aerosol research
Jozef Stefan Institute, Ljubliana, Slovenia: Aerosol research
Korea Meteorological Administration: Cooperative aerosol measurements and research.
Leibniz Institute for Tropospheric Research, Germany: Aerosol research.
NASA Goddard Space Flight Center, Greenbelt, MD: Aerosol research.
NASA Langley Research Center, Hampton, VA: Aerosol research.
National Central University, Taiwan: Cooperative aerosol measurements and research.
National Institute of Aerospace Technology (INTA), Spain: Aerosol research.
National Institute of Polar Research, Japan: Aerosol research
NOAA/ESRL/CSD, Boulder, CO: Aerosol research.
NOAA/ESRL/PSD, Boulder, CO: Aerosol research.
Norwegian Institute for Air Research, Norway: Aerosol research. Norwegian Meteorological Institute (MetNo), Norway: Aerosol research.
Pacific Marine Environmental Laboratory, Seattle, WA: Cooperative aerosol measurements and research.
Paul Scherrer Institute, Switzerland: Aerosol research.
Seoul National University, Republic of Korea: Cooperative aerosol measurements.
Sierra Negre Mexican High Altitude Observatory, Mexico: Cooperative aerosol measurements.
South Africa Weather Service, South Africa: Cooperative aerosol measurements.
Stockholm University, Sweden: Cooperative aerosol measurements and research.
University of California: Aerosol research

University of Granada: Cooperative aerosol measurements and research.
University of Helsinki, Finland: Aerosol research.
University of Illinois, Urbana-Champaign: Cooperative aerosol measurements.
University of Nevada: Cooperative aerosol measurements and research.
University of Pannonia, Hungary: Cooperative aerosol measurements and research.
University of Puerto Rico: Cooperative aerosol measurements and research.
University of Utah: Cooperative aerosol measurements and research.
University of Washington, Seattle, WA: Cooperative aerosol measurements and research.
University of Washington-Bothell, Bothell, WA: Cooperative aerosol measurements and research.
V.E. Zuev Institute of Atmospheric Optics, Tomsk, Russia: Aerosol research.

NOAA Federated Aerosol Network Sites

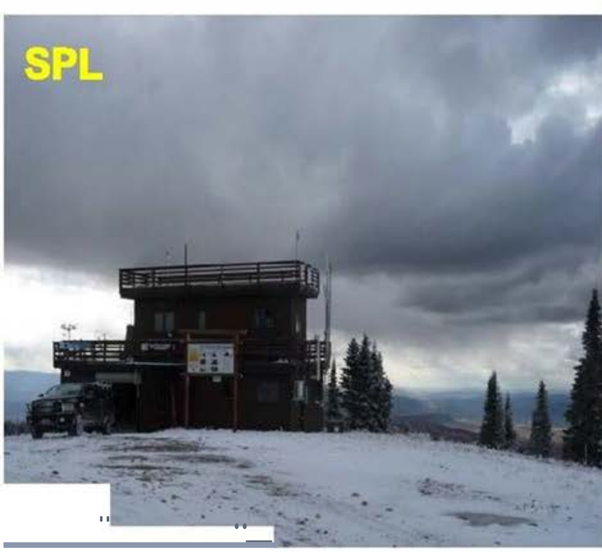



APP


BND


CPR


EGB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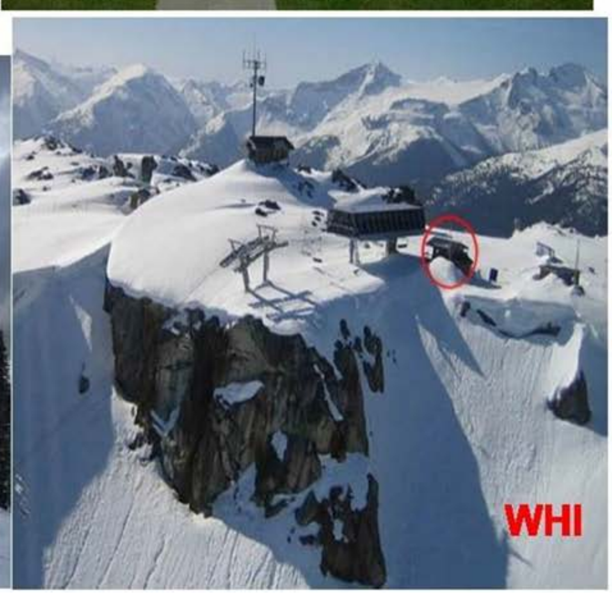
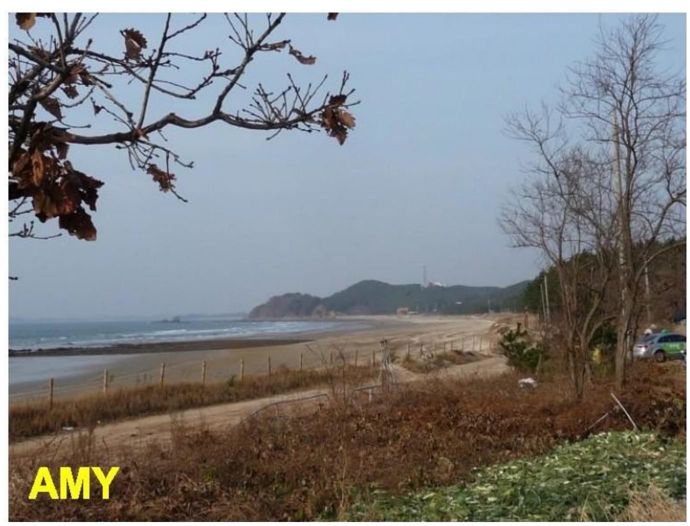

WHI

WLG

GSN




ARN
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KPS


UGR


ZSF
ZUG
ZSF


SMR


MBO


CGO


CPT


SGP – closed 2017


WSA – closed 2000


THD – closed 2017

Global Monitoring Division

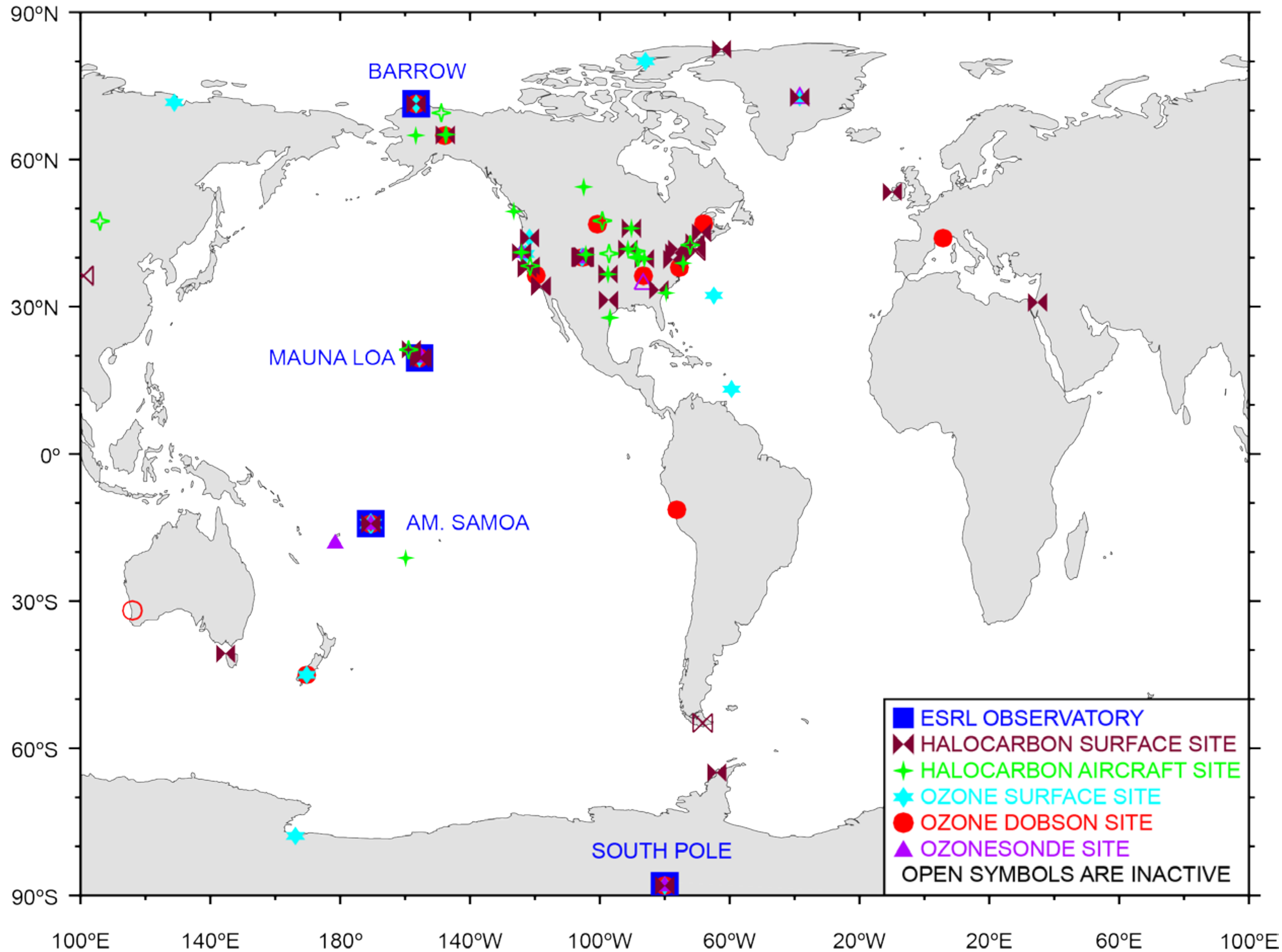
Theme 3 Networks: Guiding Recovery of Stratospheric Ozone

2013-2017 Review

May 21-24, 2018

Contents:

Guiding Recovery of Stratospheric Ozone



Theme 3, Part 1: NOAA Ozone and Water Vapor (OZWV) Networks

"***Without a protective ozone layer in the atmosphere, animals and plants could not exist, at least upon land. It is therefore of the greatest importance to understand the processes that regulate the atmosphere's ozone content." (Royal Academy of Sciences, announcing the 1995 Nobel Prize for Chemistry for Paul Crutzen, Mario Molina, and F. Sherwood Rowland)***

"…***stratospheric water vapor probably increased between 1980 and 2000, which would have enhanced the decadal rate of surface warming during the 1990s by about 30% as compared to estimates neglecting this change. These findings show that stratospheric water vapor is an important driver of decadal global surface climate change." Susan Solomon, Science, 05 March, 2010***

The Global Monitoring Division addresses both of these environmental issues and has compiled the longest continuous stratospheric water vapor measurement record and some of the longest continuous global ozone records available.

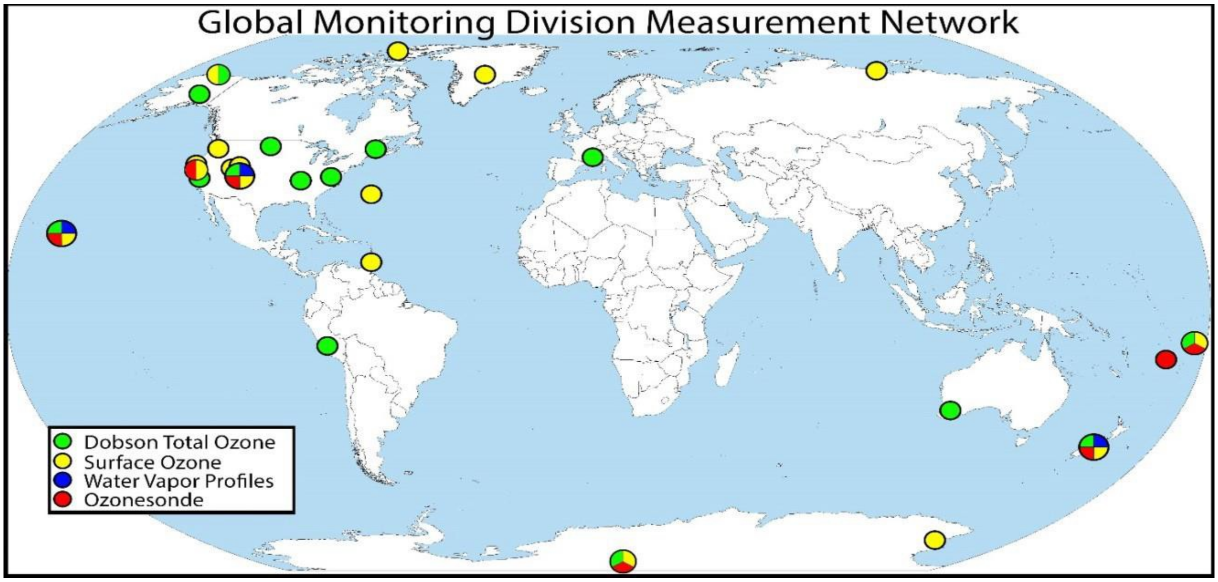
Mission Statement:

The Ozone and Water Vapor research program conducts research on the nature and causes of the depletion of the stratospheric ozone layer and the role of stratospheric and tropospheric ozone and water vapor in forcing climate change. This mission is accomplished through long-term observations and intensive field programs that measure total column ozone, ozone vertical profiles, ground level ozone, and water vapor vertical profiles in the upper troposphere and stratosphere.

Stratospheric Ozone Profile Measurements

Ozonesondes

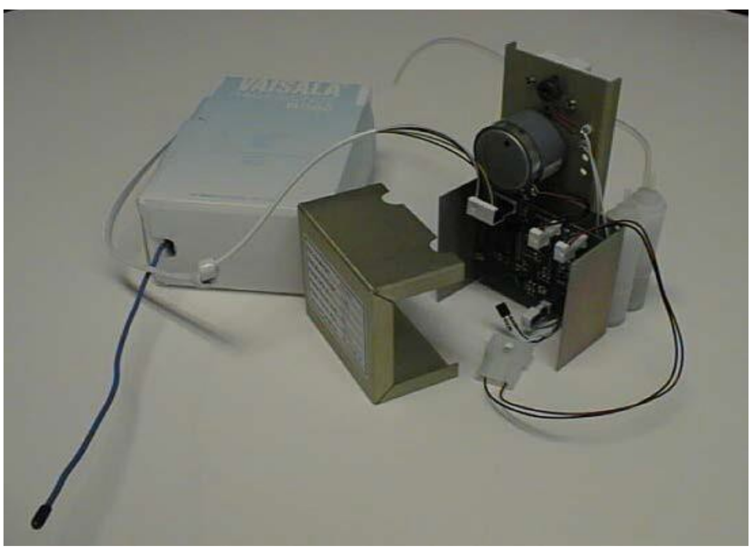
GMD measures stratospheric ozone in two ways; with balloon borne ozonesondes that transmit the data by radiosondes back to surface stations and with Dobson Ozone Spectrophotometers that look at the sun and measure the attenuation produced by the column of ozone in the atmosphere. The ozonesonde was invented by Walter Komhyr in the 1950s, a scientist in a predecessor organization of the present NOAA GMD. The ozonesonde was commercialized and is still making measurements in the same basic configuration.



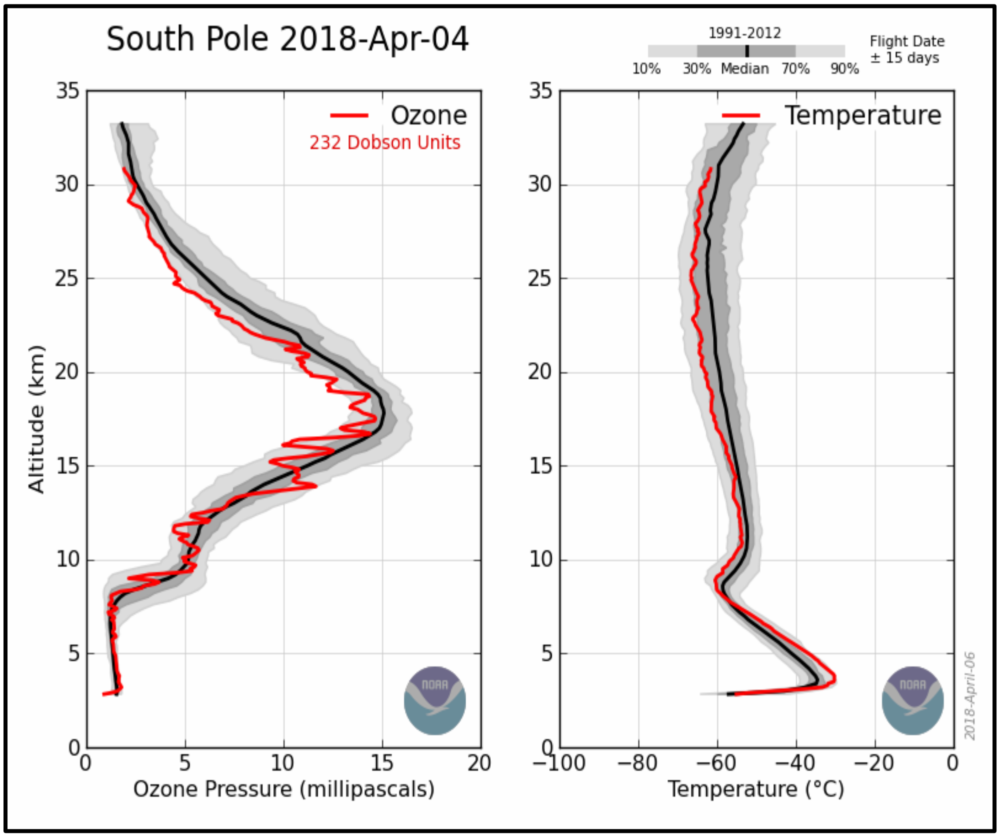
Map of the Dobson total column ozone (green), ozonesondes (red), water vapor sondes (blue) and surface ozone (yellow) GMD OZWV network.

GMD conducts about 600 ozonesonde soundings each year from eight globally distributed sites using the balloon-borne electrochemical (ECC) ozonesondes. The soundings provide vertical profiles of ozone, temperature, and humidity from the surface to approximately 32 km (~100,000 ft). Ozonesondes send back data as they rise and then descend by parachute. Some ozonesondes are recovered and reconditioned for reuse.

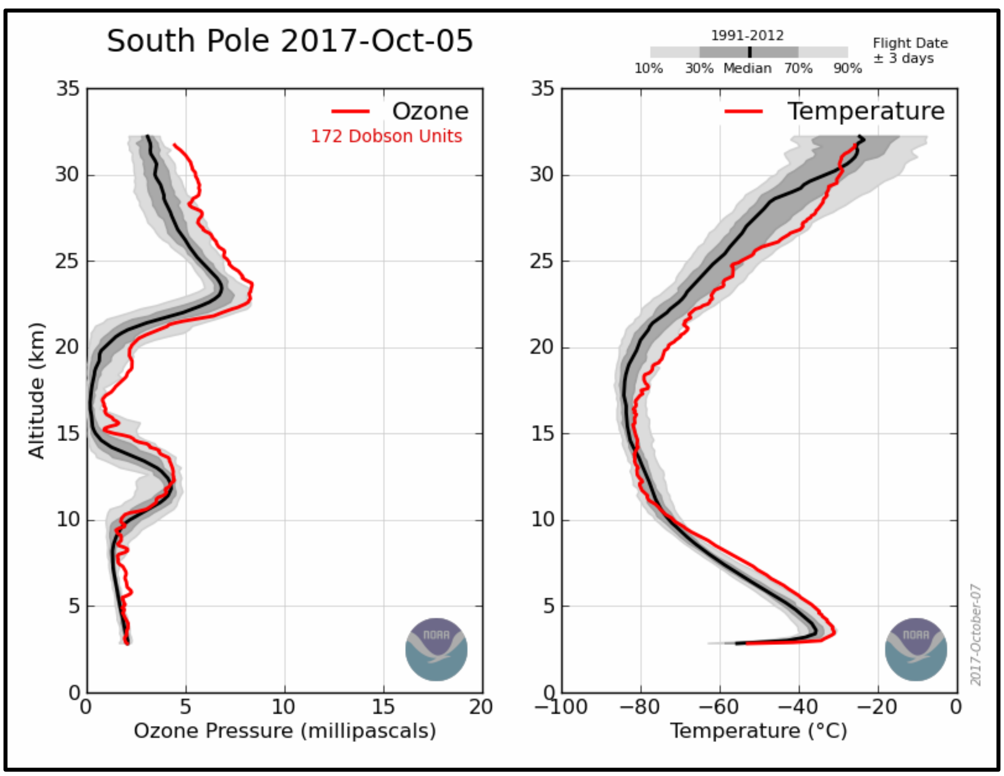
Ozonesondes are especially valuable in monitoring the annual Antarctic "Ozone Hole" as satellites are unable to measure stratospheric ozone at high southern latitudes during the six month dark season. The South Pole ozone and temperature profile for April 4, 2018 is presented on the next page along with the 1991-2012 climatology of profiles.



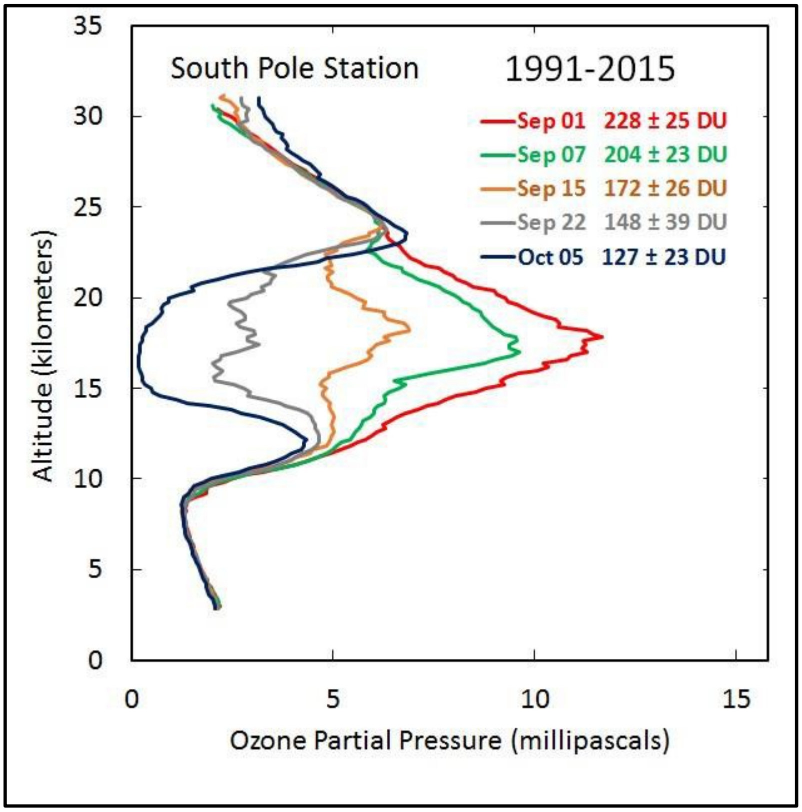
The ozonesonde is a simple and robust instrument that, over decades, has proven its ability to reliably and accurately measure in situ ozone from sea level to 32 km (100,000ft). In a profile, temperature may decrease from +40^{0}C at the surface to -85^{0}C at the tropopause. During descent the ozonesonde is subjected to the reverse temperature gradient.



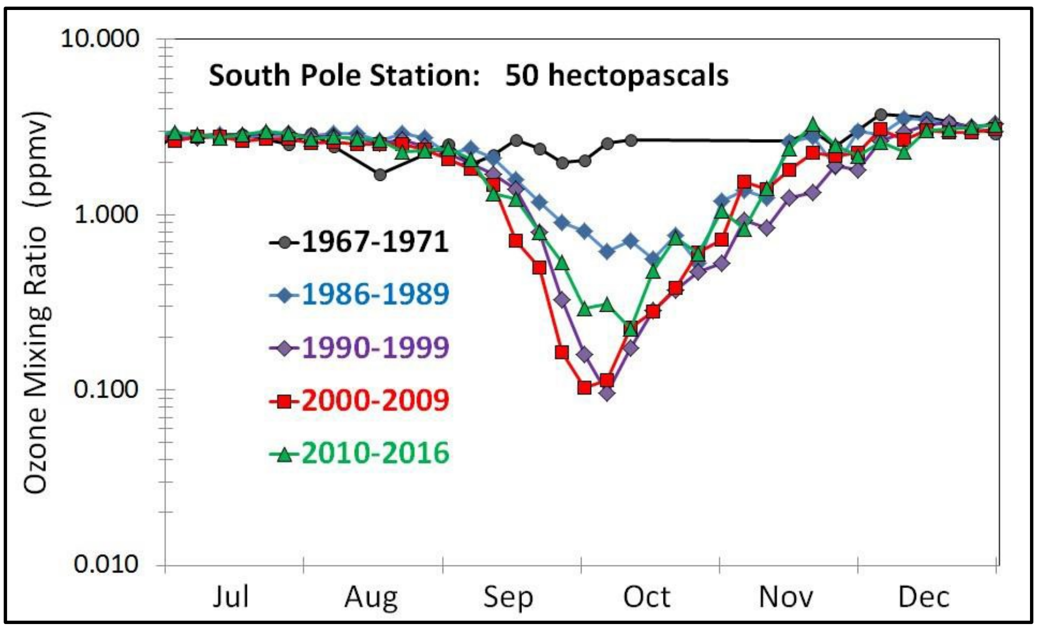
Ozonesonde and temperature profiles from the South Pole, April 4, 2018 (in red) along with long term statistics for April 4 ± 15 days over the period 1991-2012. Note the temperatures are warmer than the ~-80^{0}C temperature required to produce Polar Stratospheric Clouds that provide a base for Cl to destroy ozone in a catalytic reaction.



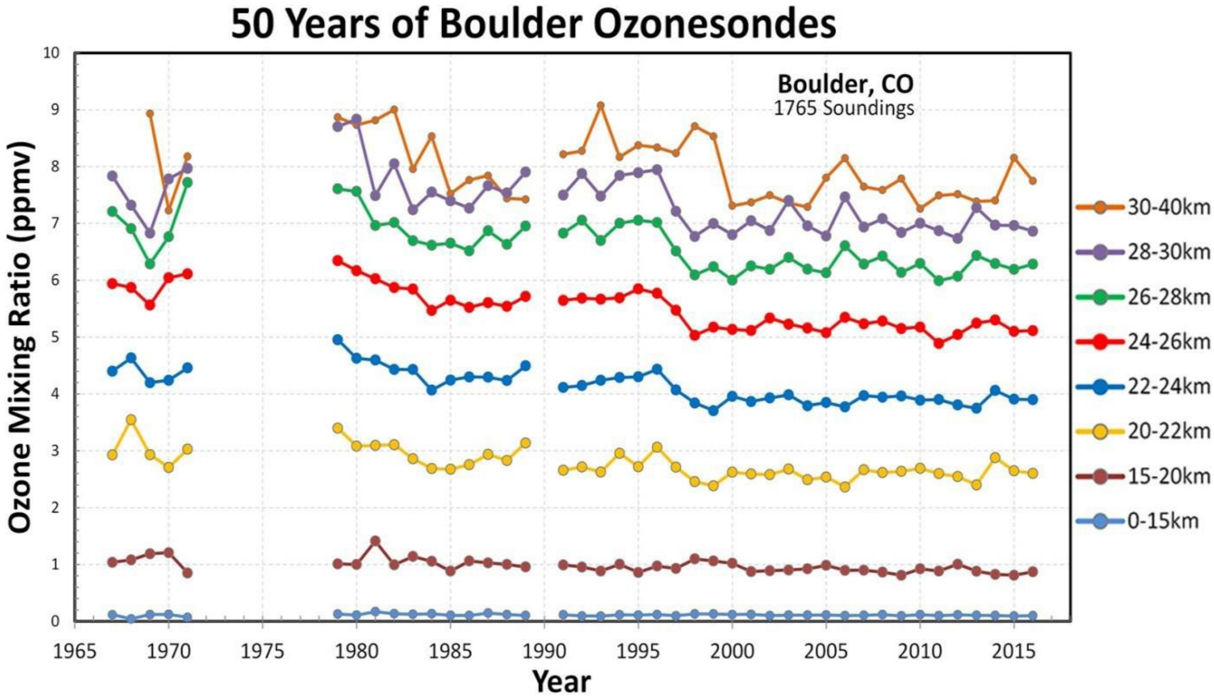
Ozonesonde and temperature profiles from the South Pole, October 5, 2017 (in red) during the 2017 ozone hole. Note the ozone depleted layer between 15 and 20 km where temperatures are ~-80^{0}C and colder which coincides with the zone of depletion.



Average ozone profiles over South Pole for specific days prior to the onset of springtime ozone depletion (September 1); in the middle of the depletion events (September 15): and at their peak (October 5).

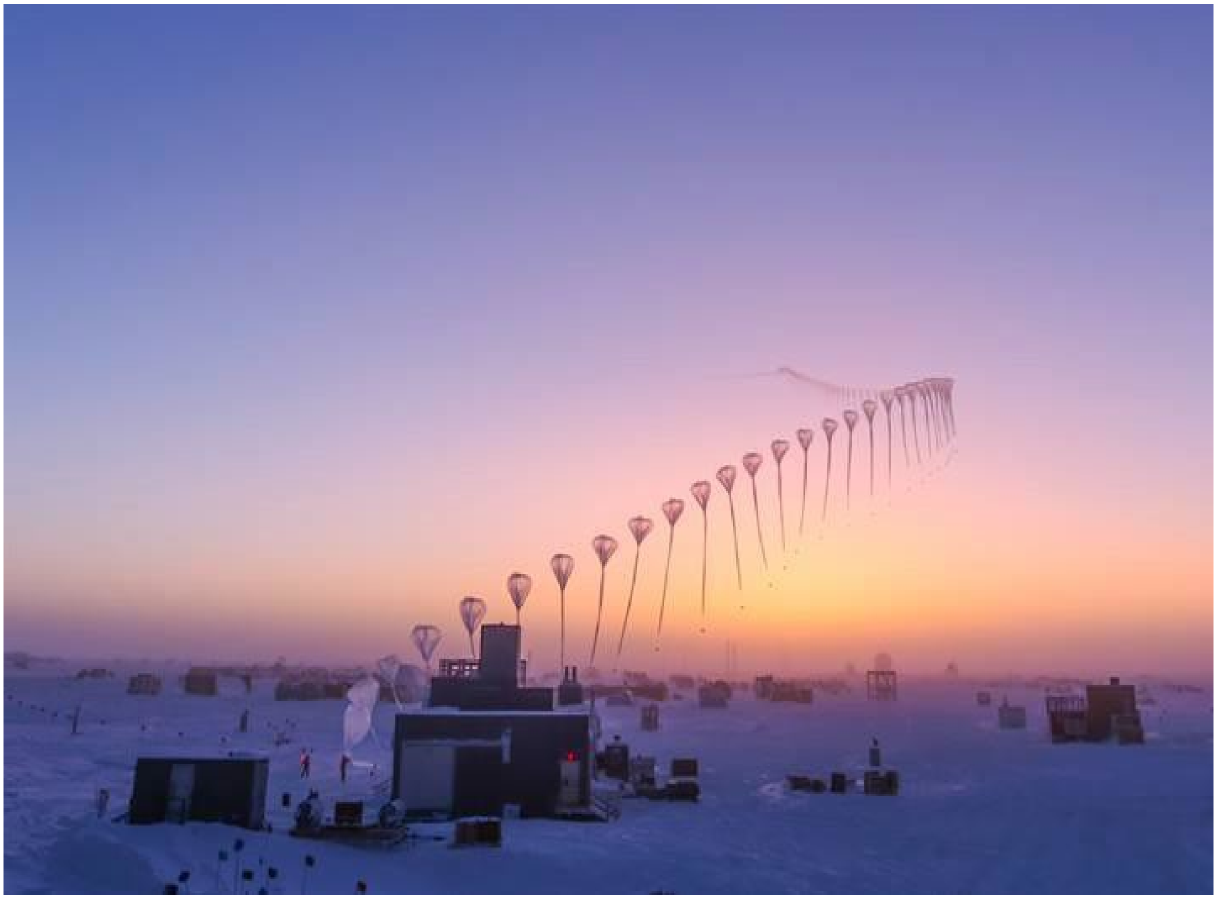


Ozonesonde measurements at South Pole at 50 hectopascals (~18 km) in the upper level of the ozone depletion zone. It appears that the annual ozone depletion at 50 hPa may be lessening.



Boulder ozonesonde data (1765 soundings) averaged over 50 profiles per year at the levels indicated on the right side of the graph. Before 2000 the trends were negative, but after 2000 trends in the upper levels change to increasing or flat.

Preparing to launch a combination ozonesonde and radiosonde package from American Samoa.

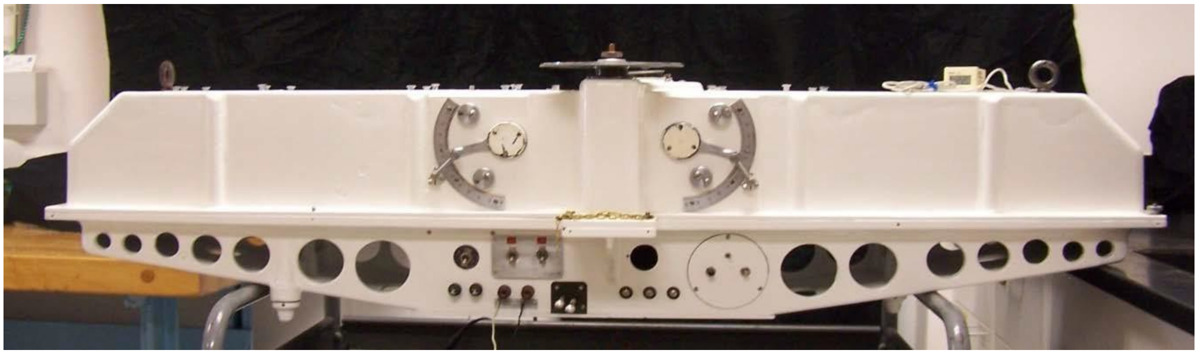


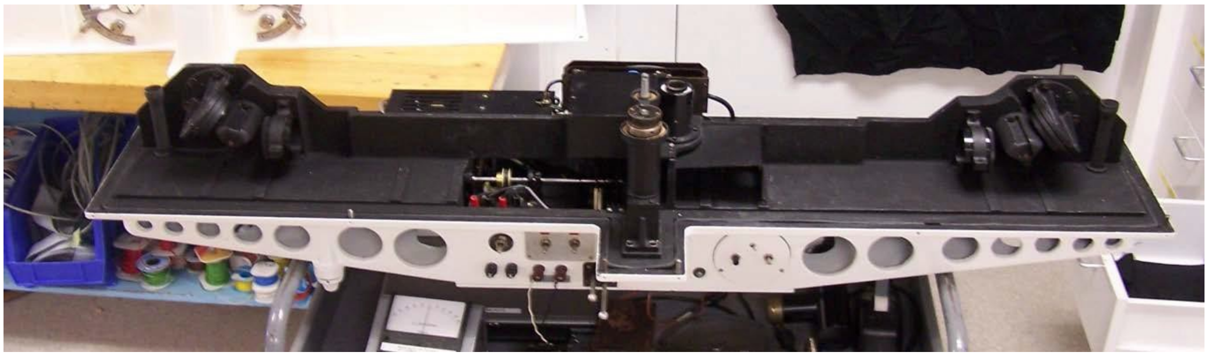
Composite time lapse image of a GMD ozonesonde balloon launched from the Amundsen-Scott South Pole Station. Multiple consecutive exposures track the path of the balloon as it rises in the pre-dawn sky over Antarctica. Photo credit: Robert Schwarz

Total Column Ozone: Dobson Spectrophotometer Measurements

The Dobson Ozone Spectrophotometer has been used to study total ozone since its development in the 1920's. The observations of total ozone, the total amount of ozone in a column from the surface to the top of the atmosphere with this instrument has produced one of the longest geophysical records of this nature in existence.

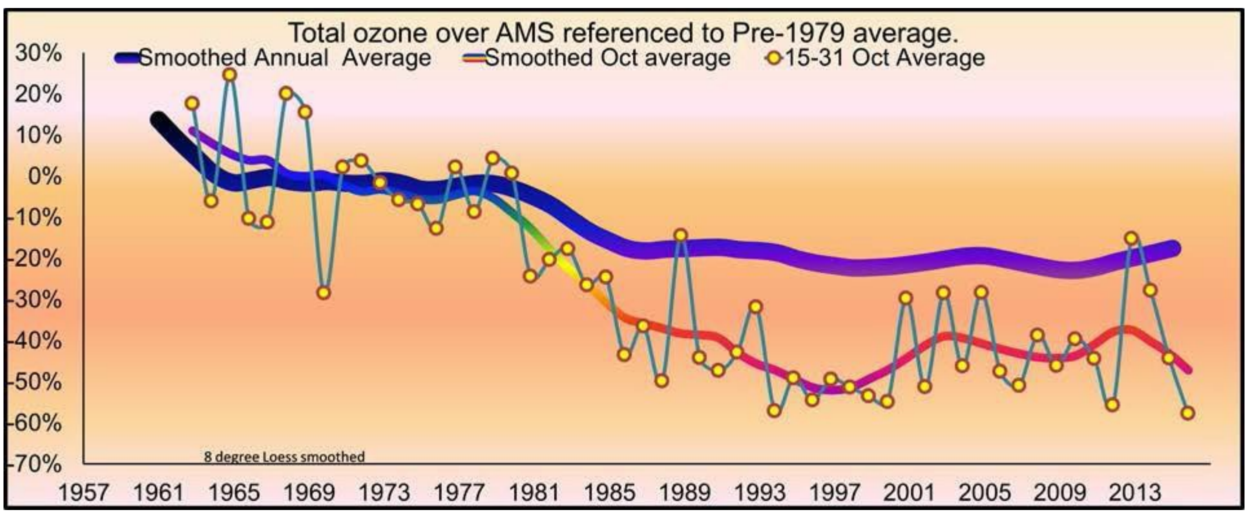
Today, the instrument is an important part of a global effort to understand the role of stratospheric ozone in atmospheric chemistry; biological and ecological effects of solar UV radiation; and climate and weather. Every two years this instrument is sent to our observatory in Mauna Loa, Hawaii for an absolute calibration using the Langley method. From this, the calibration is transferred to fifteen Dobson Ozone Spectrophotometers in the NOAA GMD global network, and to over one hundred instruments worldwide under the auspices of the WMO Global Atmosphere Watch program.



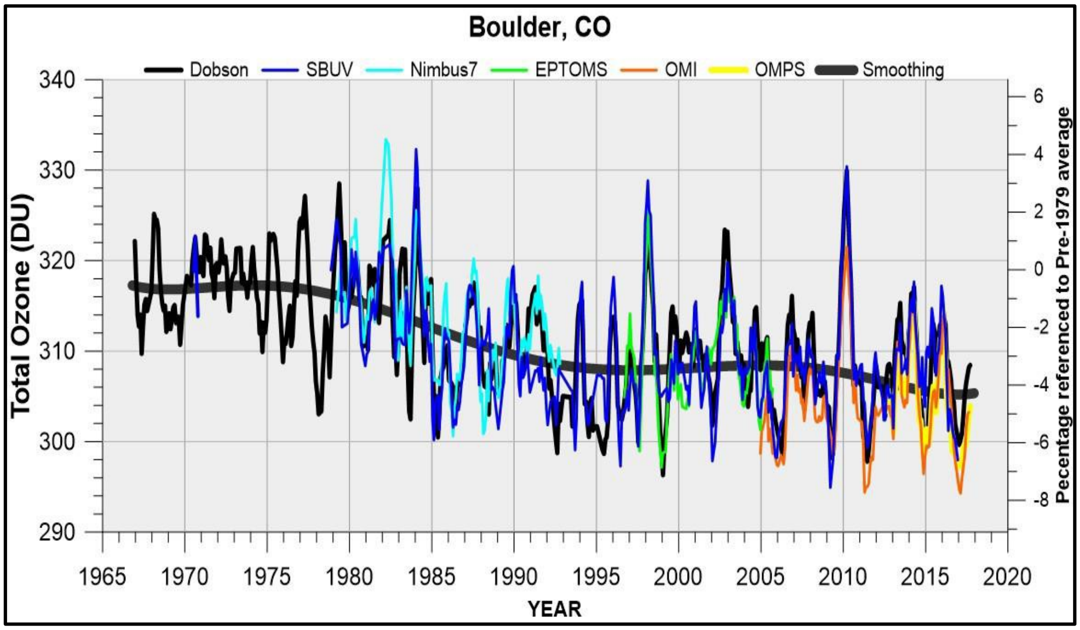


A Dobson Spectrophotometer is constructed of machined steel, is 4.5 ft long and weighs 150 lbs. The interior of the instrument is mainly mechanical hand operated prisms and mirrors. The youngest Dobson Spectrophotometers in the NOAA network were built in the 1950s.

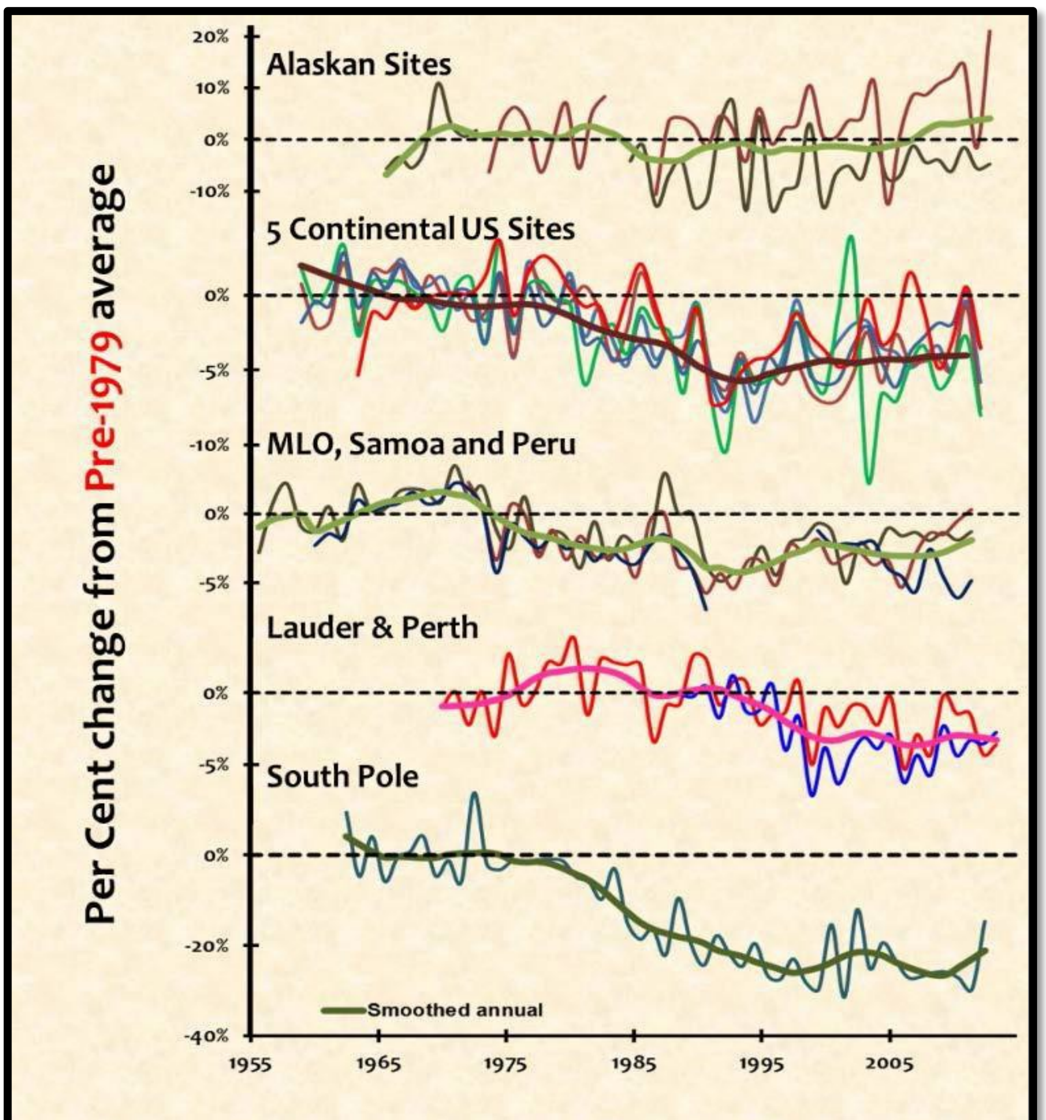
Total Column Dobson Measured Stratospheric Ozone Trends



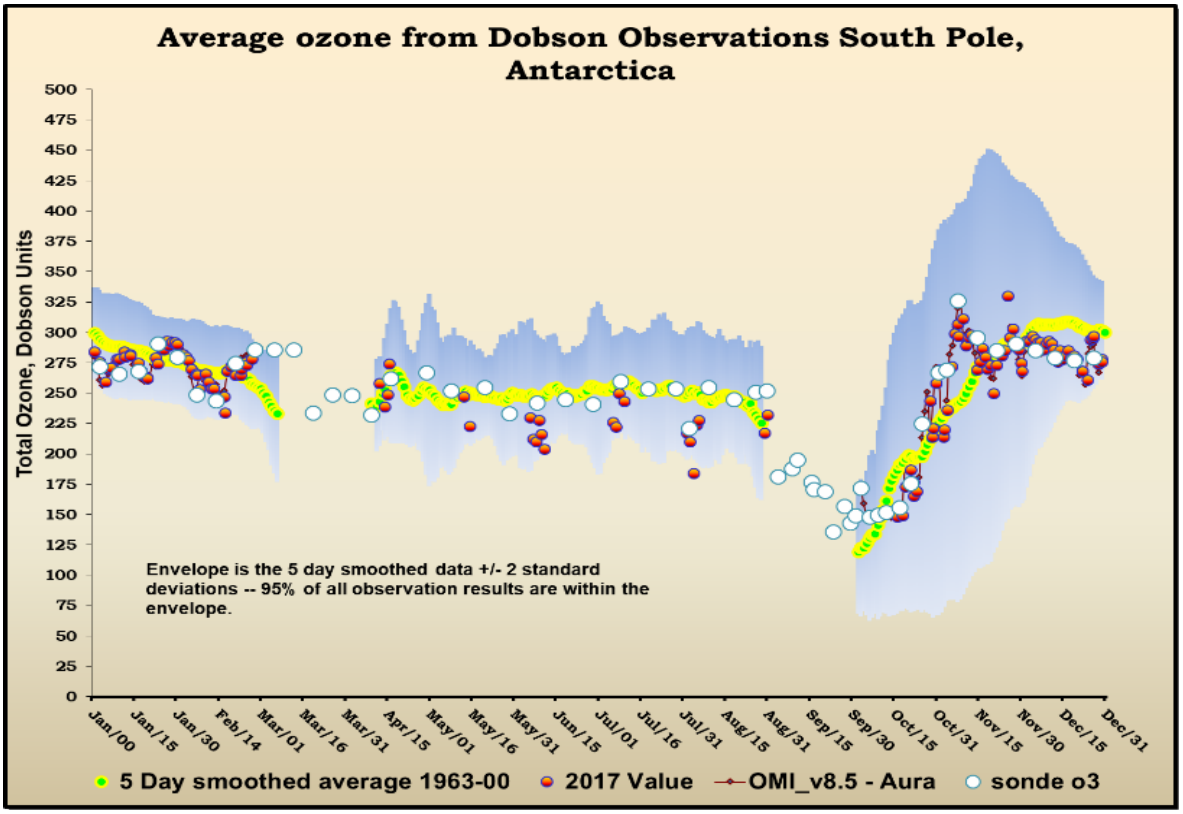
South Pole total column ozone time series. The yearly averages over the 15-31 October observation periods are shown as yellow circles. The annual average is shown with a blue line. In 2015 South Pole station observed the lowest averaged ozone (120 DU) in its 50+ year record (in 1993 ozone was at 121 DU). Stable vortex conditions in 2015 delayed ozone recovery until the end of December.



Dobson total column ozone (black line) and satellite overpass total column data over Boulder, CO. The scale on the right shows percent change in ozone records relative to pre-1978 ozone levels.



Long term ozone changes are shown (top to bottom) for the Alaska region (Barrow and Fairbanks), continental U.S. region (5 stations), tropical region (MLO, Samoa, Peru), South hemisphere middle latitudes (Perth and Lauder), and at South Pole. Data are shown as percent change in ozone column relative to the pre-1997 averaged ozone level.

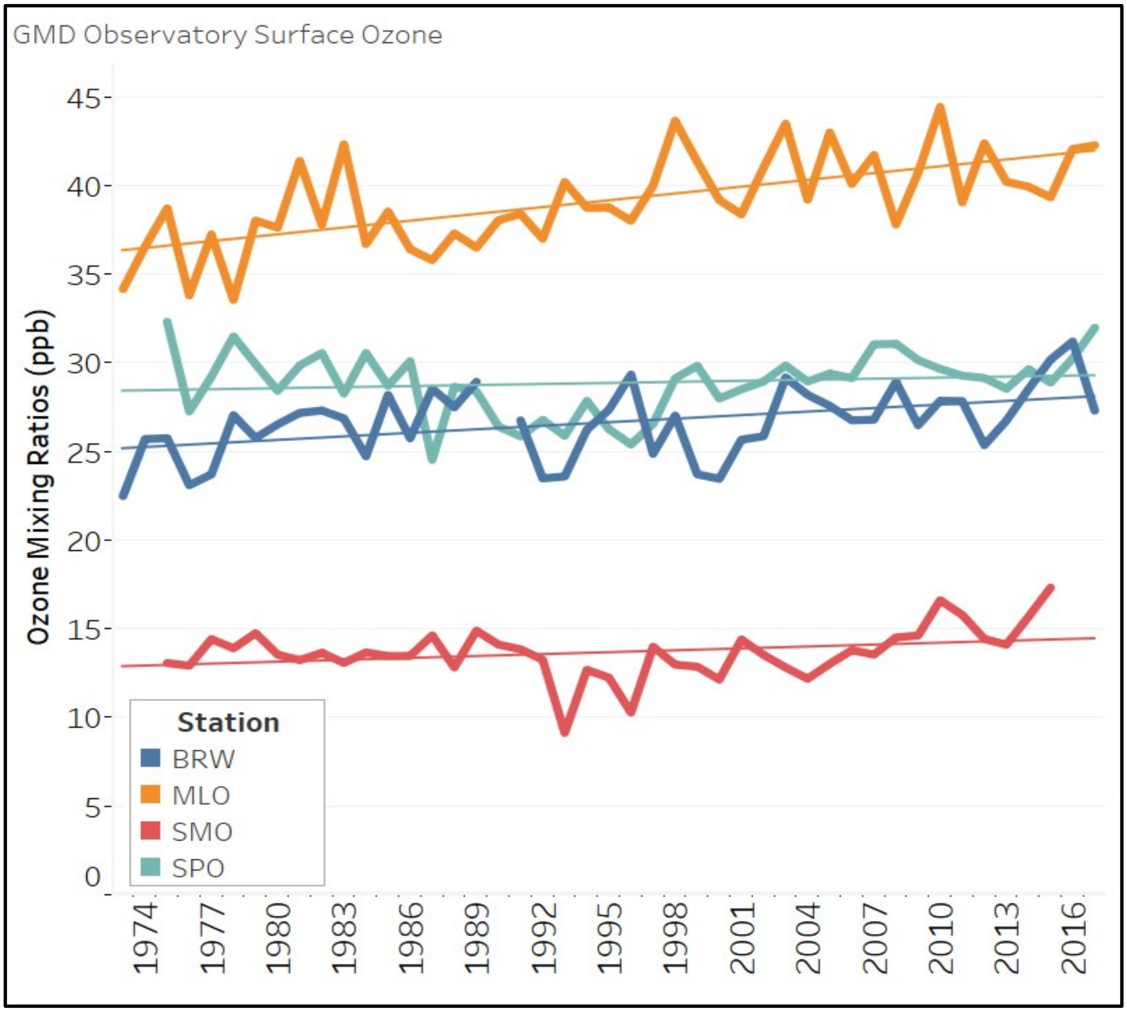


Daily South Pole total column Dobson Ozone measurements (red circles) in 2017. Green-yellow line indicates 5-day smoothing for daily averages during 1963-2000. Blue envelopes represent 2 standard deviations above and below the daily average. Red thin line September 30 to December 15 shows Aura OMI v8.5 overpass data for South Pole. Ozonesonde estimated total ozone column is shown as white circles.

Surface Baseline Ozone Monitoring

In the troposphere, ozone is a short-lived greenhouse gas with a radiative forcing comparable to halocarbons. It is an important regulator of the oxidizing capacity of the atmosphere (both itself and as the main source of hydroxyl radicals, OH), as well as being an important pollutant, with negative effects on vegetation and human health (e.g. Prather et al., 2001; UNEP, 2015). The future evolution of ozone in the troposphere is a concern for climate change and air quality during the 21st century.

The ultimate background level for tropospheric ozone existed before humans began to alter the atmosphere. Baseline O_3 is used here to describe a measurable quantity, the statistically defined lowest abundances of O_3 in the air flowing into a measurement site, which is typical of clean-air at remote marine sites. Baseline air thus includes remote upwind pollution that contributes to the diffuse, uniform increase in O_3 but not the episodic events. **Concisely stated, baseline O_3 is the lower envelope of the frequency distribution of ozone concentrations reflecting conditions of minimum pollutant source influence.**

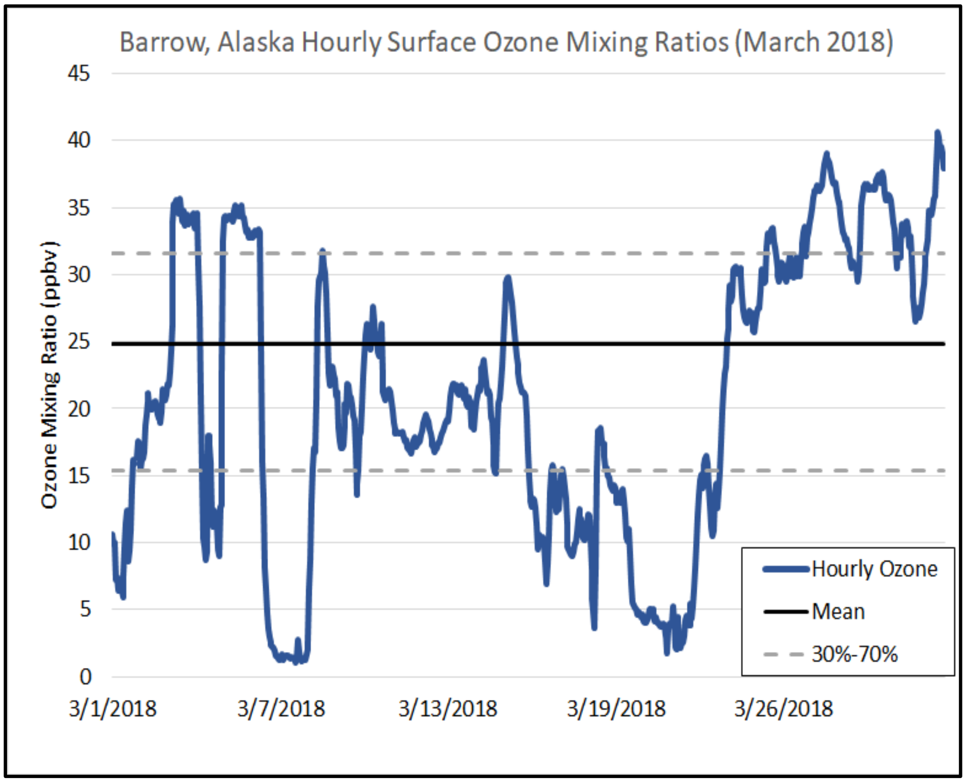


Yearly average surface ozone mixing ratios calculated from QA/QC hourly data measured from the four GMD Baseline Observatories. Mauna Loa, Samoa, and Barrow show a slight positive trend since measurements began in 1973.

NOAA GMD measures baseline ozone at 17 globally distributed sites. The longest continuous records are 45 years at South Pole and 43 years at Mauna Loa. Trends in the yearly average for the four GMD Atmospheric Baseline Observatories are shown above where it may be observed that background ozone has been increasing in the troposphere over the past 40+ years.

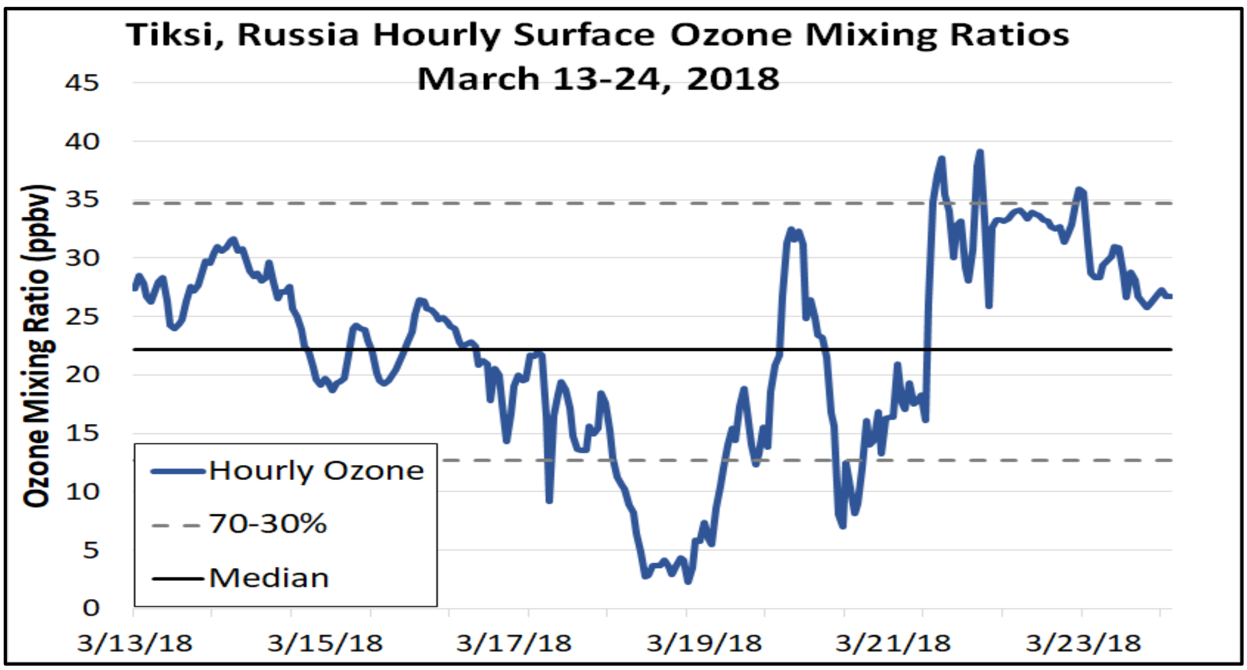
An interesting result from the surface ozone monitoring is the discovery of springtime photolytic ozone destruction in the Arctic boundary layer related to bromine chemistry. Graphs showing the destruction of baseline ozone at Barrow and Tiksi in the spring of 2018 are presented below. The Tiksi, Russia data come to GMD electronically from the station.

End of the winter dark period at the Barrow Baseline (Utqiaġvik) Observatory, Alaska. The small amount of sunlight seen in this photo is capable of destroying ozone throughout the surface boundary layer in air flowing off the frozen Arctic Ocean.



Hourly average concentrations of ozone at Barrow Observatory, spring 2018, showing two depletion events. This same phenomenon, over the same period, was observed in the Russian Arctic at the Tiksi Observatory on GMD supplied instruments.

Tiksi, Russia Atmospheric Observatory located on the Arctic Ocean where GMD has surface ozone, black carbon, solar radiation and greenhouse gas flask sampling operations. The surface ozone record at Tiksi began in 2008. The U.S. NSF paid for the construction of the Tiksi Observatory that is operated by Roshydromet.



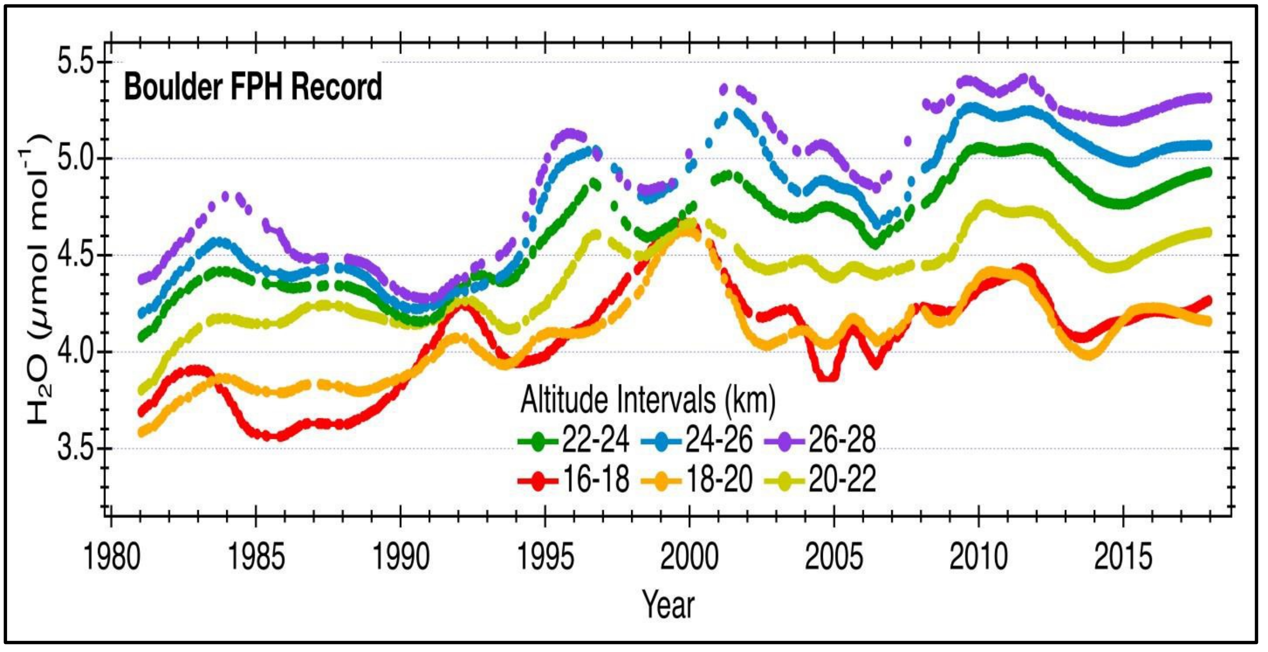
Hourly average ozone concentrations measured at the Tiksi, Russia Atmospheric Baseline Observatory showing a strong surface photolytic ozone depletion event on March 19, 2018 and a lesser event on March 21.

Stratospheric Water Vapor Monitoring

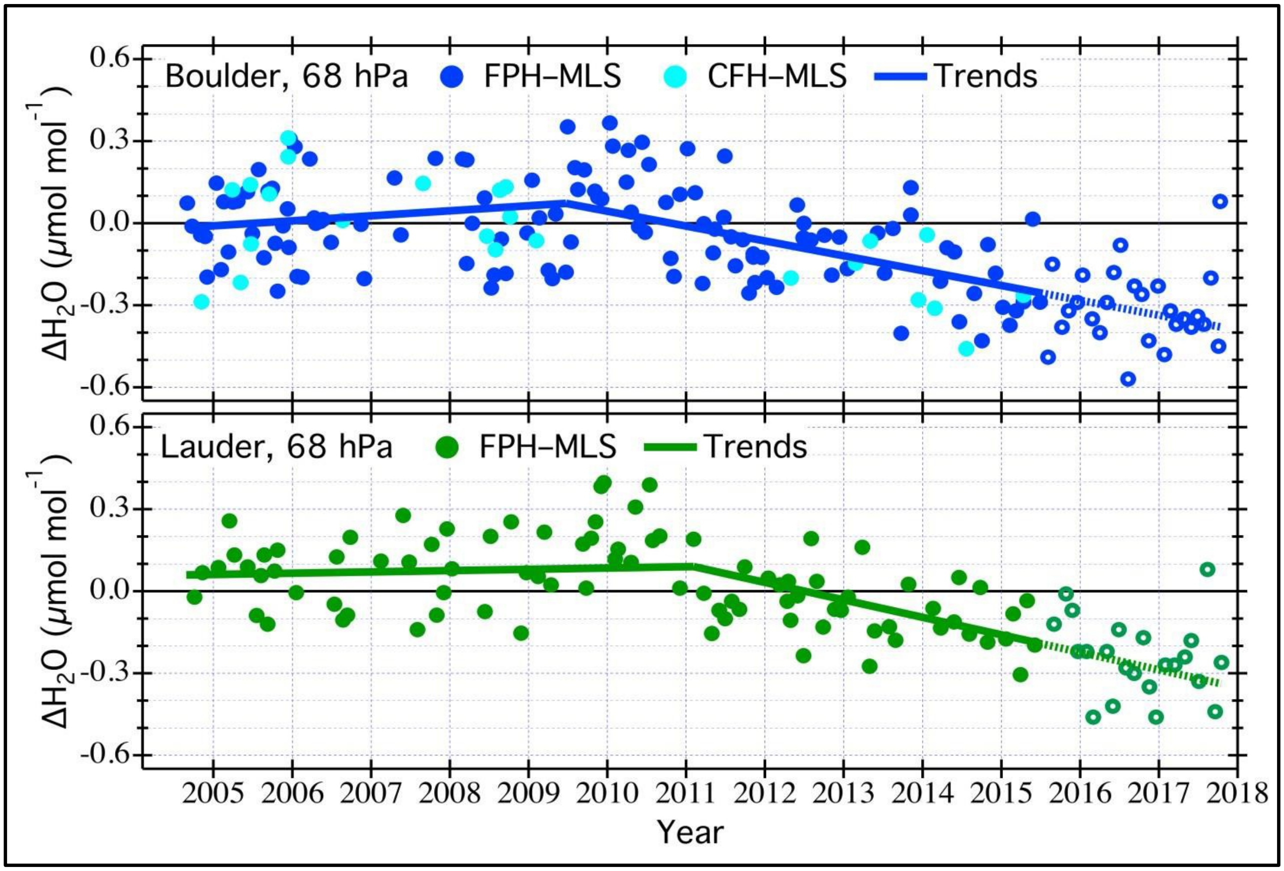
Monthly measurements of water vapor vertical profiles by balloon-borne frost point hygrometers (FPHs) at Boulder began in 1980 and continue today. In the late 1970s, Sam Oltmans of GMD developed the FPH and had the foresight to initiate the measurement program based on his realization that changes in upper tropospheric and/or lower stratospheric (UTLS) water vapor could have a strong impact on Earth's climate. Today, monthly FPH soundings are also performed at Hilo, Hawaii, and Lauder, New Zealand.

The 38-year Boulder Record is the longest continuous set of UTLS water vapor measurements in the world.

The data from the 3 FPH sounding sites are used to examine seasonal and longer-term changes in stratospheric water vapor, such as the 25% increase detected above Boulder during 1980-2010. The data sets provide reality checks for satellite-based water vapor measurements, and are used to test chemistry-climate models' simulations of upper atmospheric water vapor.



Smoothed time series of stratospheric water vapor mixing ratios in six altitude bins over Boulder, Colorado. Each data point represents a uniquely measured vertical profile by a balloon-borne frost point hygrometer. This record depicts a 25% increase in stratospheric water vapor from 1980 through 2017.



Trends in the differences between stratospheric water vapor measurements by frost point hygrometers (FPH, CFH) and the Aura Microwave Limb Sounder (MLS) over Boulder, Colorado, and Lauder, New Zealand. Solid lines depict the trends in FPH-MLS differences through mid-2015, as published in Hurst et al. (2016). Open circles show the FPH-MLS differences from mid-2015 through 2017 and dotted lines are simple extrapolations of the post-breakpoint trends. The downward trends in FPH-MLS differences since 2009-2011 imply that drifts in the MLS retrievals have produced significant and persistent biases through 2017.

Ozone Network Data Archiving

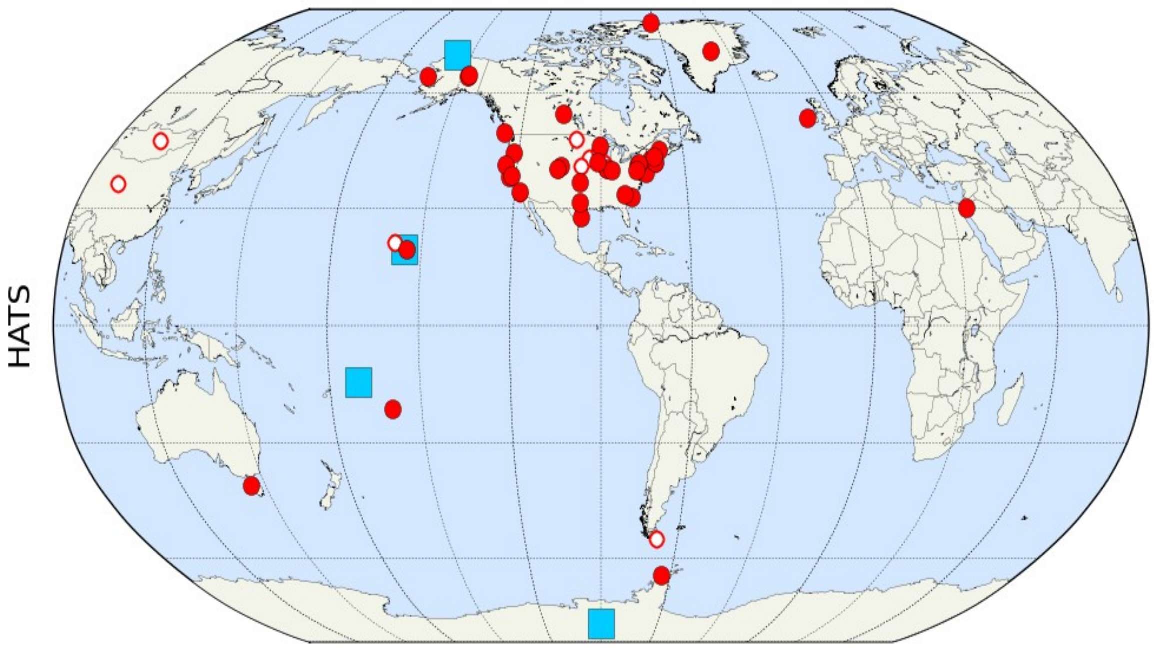
GMD ozone data is archived on site and at a backup off-site location in electronic format and at the World Ozone and Ultraviolet Radiation Data Centre (WOUDC), Downsview, Canada; Network for Detection of Atmospheric Composition Change (NDACC), Asheville, North Carolina; and at the National Center for Environmental Data Information (NCEI) as an outcome of the NOAA Big Earth Data Initiative, Washington, DC.

Theme 3, Part 2: Halocarbons and other Atmospheric Trace Species (HATS) Network

Mission, Justification, and Introduction of the HATS Network

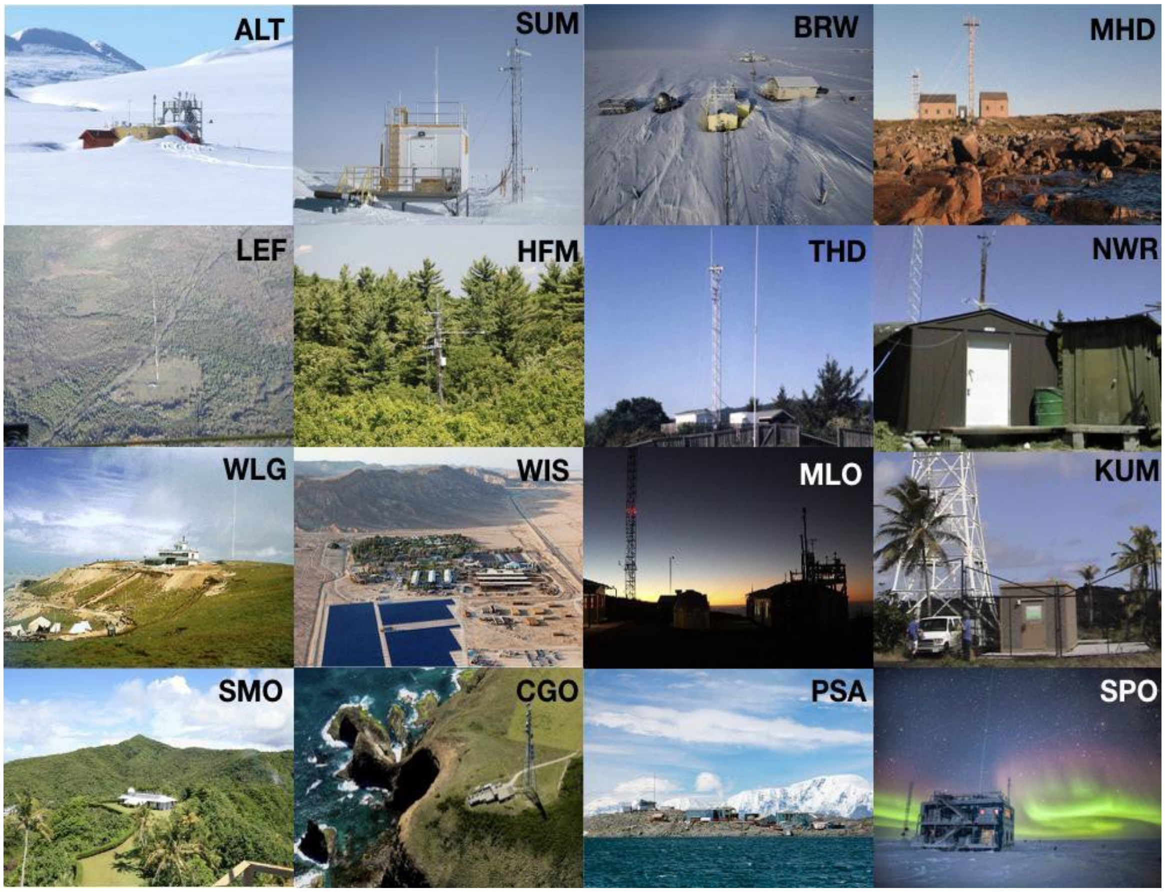
“The Montreal Protocol is a model of cooperation. It is a product of the recognition and international consensus that ozone depletion is a global problem, both in terms of its causes and its effects” President Ronald Reagan after signing the Montreal Protocol, April 1998.

NOAA Observatories ■ Flask sites ● Discontinued ○



HATS ground based sites (16), tall tower sites (13) and light aircraft profiling sites (19) from ground to 8 km (tower and aircraft in collaboration with NOAA GMD CCGG).

Mission Statement: The mission of the Halocarbons and other Atmospheric Trace Species group is to quantify the distributions and magnitudes of sources and sinks for atmospheric nitrous oxide (N_2O) and halogen-containing ozone-depleting compounds. The HATS group utilizes numerous types of platforms, including ground-based stations, towers, ocean vessels, aircraft, and balloons to accomplish its mission.



HATS Network sites (above) and locations sorted by latitude (below).

HATS surface Network sites.

Label	Name	Latitude	Longitude	Elevation (m)
ALT	Alert, Canada	82.5 N	62.3 W	210 asl
SUM	Summit, Greenland	72.6 N	38.4 W	3209 asl
BRW	Barrow, AK, USA*	71.3N	156.6 W	27 asl; 16 agl
MHD	Mace Head, Ireland	53.3 N	9.9 W	42 asl
LEF	Park Falls, WI, USA	45.9 N	90.3 W	868 asl; 396 agl
HFM	Harvard Forest, MA, USA	42.5 N	72.2 W	340 asl; 29 agl
THD	Trinidad Head, CA, USA	41.0 N	124.1 W	120 asl
NWR	Niwot Ridge, CO, USA*	40.1 N	105.5 W	3476 asl (F);3048 asl*
WLG	Mt. Waliguan, China	36.3 N	100.9 E	3890 asl (discontinued)
WIS	Negev Desert, Israel	30.9 N	34.9 E	482 asl
MLO	Mauna Loa, HI, USA*	19.5 N	155.6 W	3422 asl; 36 agl
KUM	Cape Kumukahi, HI, USA	19.5 N	154.8 W	39 asl; 36 agl
SMO	American Samoa, AS, USA*	14.2 S	170.5 W	77 asl
CGO	Cape Grim, Australia	40.7 S	144.7 E	164 asl; 70 agl
PSA	Palmer Station, Antarctica	64.6 S	64.0 W	15 asl
SPO	South Pole, Antarctica*	90.0 S	------------	2837 asl

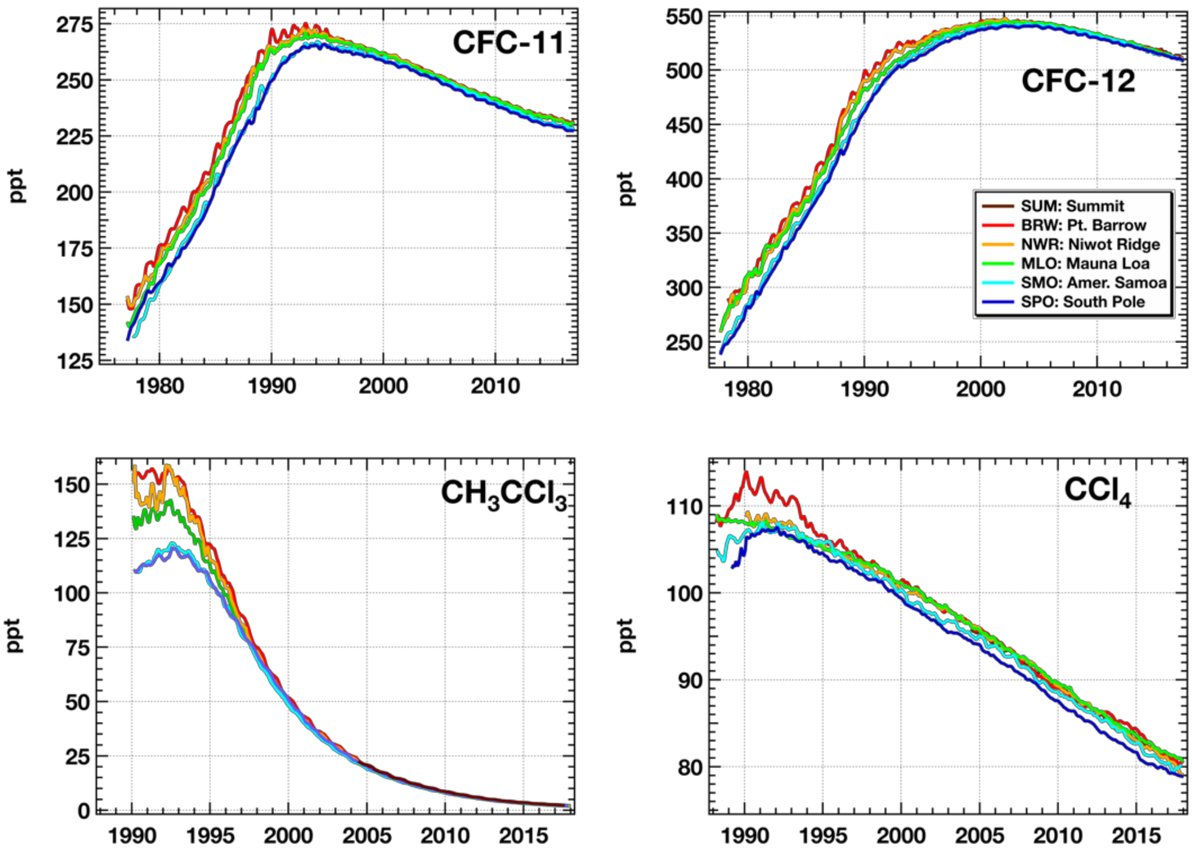
*with in situ instruments. asl = above sea level; agl = above ground level; F=flask elevation

HATS Network Gas Measurements

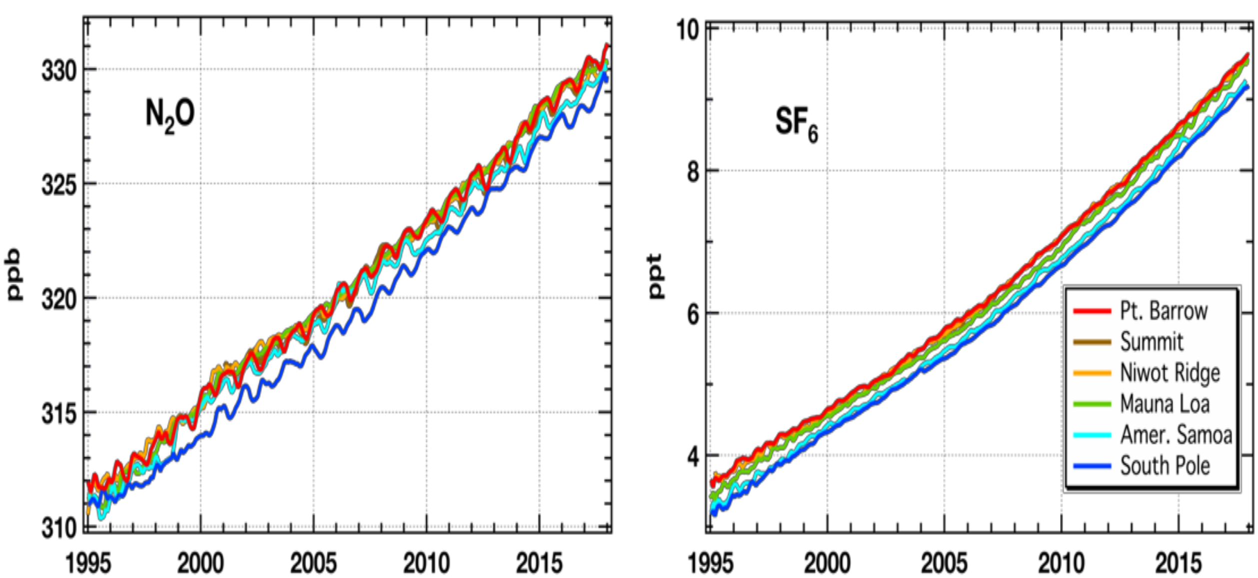
In 1977 the HATS group measured 3 gases, today over 40.

- Major greenhouse gases (GHGs, Kyoto Protocol)
  - (N_2O, SF_6, PFCs, CH_4 on airborne & Summit)
- Halocarbons (Stratospheric ozone depletion and minor GHGs)
  - Chlorofluorocarbons (CFCs,-11,-12,-113,-115)
  - Chlorinated solvents ($CHCl_3$, CH_3CCl_3, CCl_4, C_2Cl_4, CH_2Cl_2). These also affect air quality in the workplace and urban areas
  - Hydrochlorofluorocarbons (HCFCs, -22, -141b, -142b)
  - HFCs (-134a, -143a,-152a, -125, -32, -227ea, -365mfc)
  - Halons (-1211, -1301, -2402)
  - Methyl halides (CH_3Cl, CH_3Br, CH_3I)
  - Other Brominated gases ($CHBr_3$, CH_2Br_2)
- Sulfur gases (SF_6, COS) COS is a major source of sulfate to the stratospheric aerosol layer.
- Air Quality
  - Hydrocarbons (C_2H_2, C_3H_8, nC_4H_{12}, iC_5H_{10}, C_6H_6, nC_6H_{14})
  - Hydrogen (H_2), methane (CH_4), and carbon monoxide (CO) on airborne platforms & at Summit Station (SUM) until 2017
  - Water vapor (H_2O) and ozone (O_3) on airborne platforms
  - Peroxyacetyl nitrate (PAN), airborne (PANTHER only); PAN is the principal tropospheric reservoir for nitrogen oxide radical

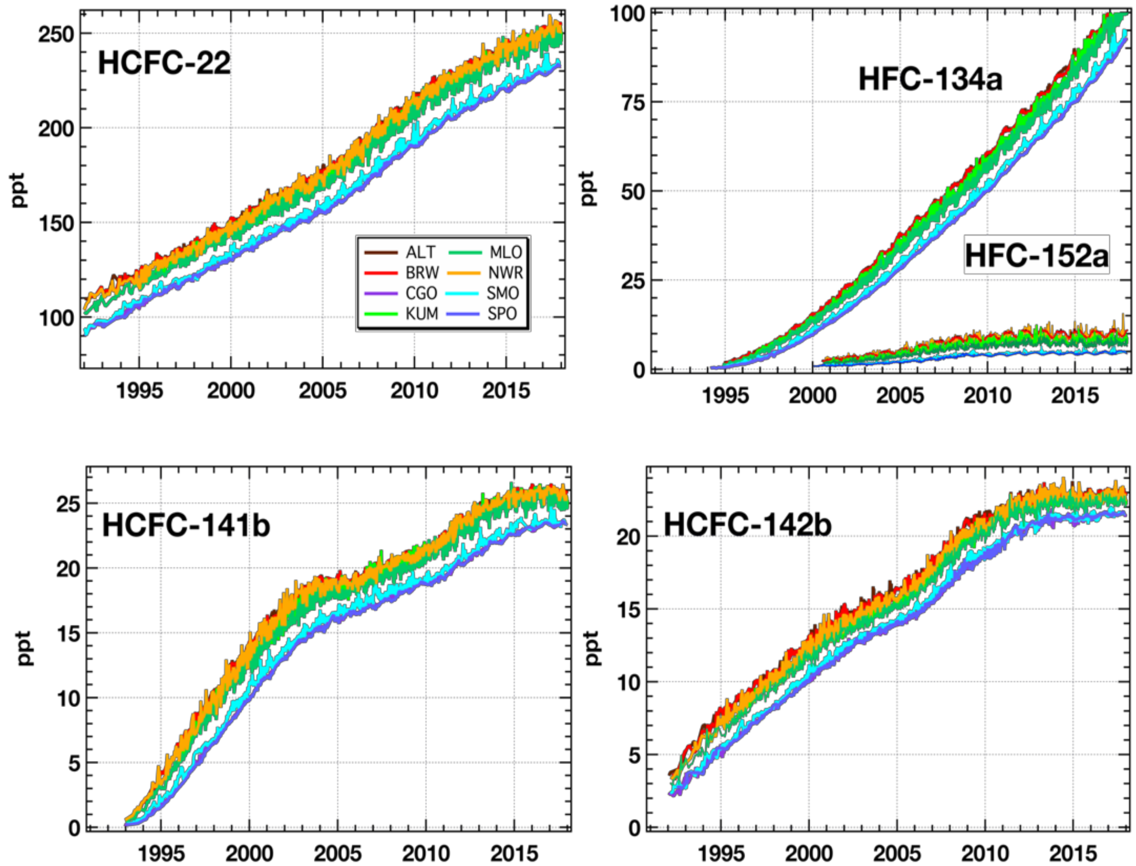
Various instruments for measuring HATS gases. GC/flasks on Otto, MLO CATS/in situ, Perseus GC-MS, CATS GC/in situ, developing standards and M3 GC-MS.



Ground-based measurements of select halocarbons controlled by the Montreal Protocol in parts-per-trillion (ppt). All are in decline, where the rate of decrease is a function of their atmospheric lifetime and emissions.



GMD ground-based measurements of nitrous oxide (N_2O) and sulfur hexafluoride (SF_6)

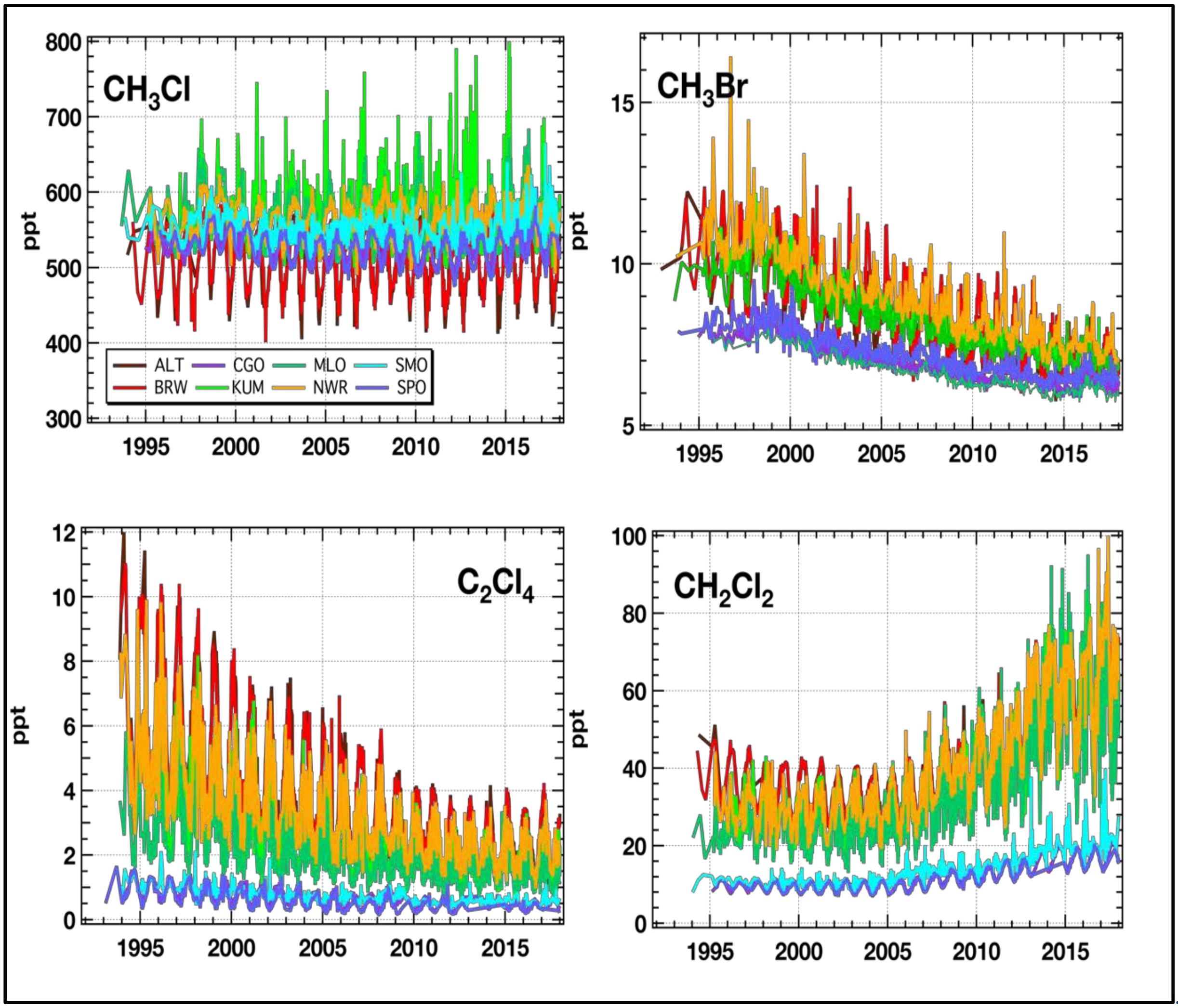


CFC Substitutes (HCFCs & HFCs). Note that the atmospheric abundances of HCFCs are leveling off because of the Montreal Protocol. HFC-134a is linearly increasing and will be subject to restrictions under the Kigali Amendment of the Montreal Protocol.

Why do we continue to measure these compounds?

We need to ensure that the Montreal Protocol is working as expected. There have been some surprises in the recent trends of some ozone-depleting gases CCl_4, CFC-11, CH_2Cl_2, and CH_3Br. N_2O also is the dominant ozone depleting gas based on current and future emissions. In addition to ozone depletion, many gases we measure are also greenhouse gases, including four of the six major greenhouse gases included in the Kyoto Protocol (N_2O, SF_6, HFCs & PFCs).

"From 1990 to 2010, the Montreal Protocol's controls on production and consumption of ODSs will have reduced GHG emissions by the equivalent of a net 135 Gt CO_2, which is equivalent to 11 Gt CO_2 per year. Considering only the direct warming effect, these actions of the Montreal Protocol delayed the increase in climate forcing from CO_2 by 7–12 years." *Mario Molina, PNAS, December 2009*



Ground-based measurements of short lived halocarbons CH_3Cl, CH_3Br, CH_2Cl_2 &, C_2Cl_4. Note a slight increase in CH_3Br after 2016 and a doubling in CH_2Cl_2 since the beginning of measurements; both a potential future threat to

"The Administrators of the National Aeronautics and Space Administration and National Oceanic and Atmospheric Administration shall monitor, and not less often than every 3 years following November 15, 1990, submit a report to Congress on the current average tropospheric concentration of chlorine and bromine and on the level of stratospheric ozone depletion. Such reports shall include updated projections of—

(A) peak chlorine loading;

(B) the rate at which the atmospheric abundance of chlorine is projected to decrease after the year 2000; and

(C)) the date by which the atmospheric abundance of chlorine is projected to return to a level of two parts per billion."

--1990 Amendments of the Clean Air Act, Title VI-Stratospheric Ozone Protection

Current Trends in Ground-based Halocarbon Measurements

- Atmospheric abundances of CFCs, methyl bromide, methyl chloroform, carbon tetrachloride, and most halons have decreased from peak values as a direct result of the Montreal Protocol.
- HCFCs -141b and -142b have leveled off and HCFC-22 is decreasing.
- HFC-134a has continued to increase, because it is still used as a CFC-replacement.
- The chlorinated solvent, tetrachloroethylene (C_2Cl_4), is used as an industrial solvent, particularly in the dry-cleaning industry. Efforts to reduce emissions have been implemented owing to its toxity.
- Recent increases in CFC-11 and CH_3Br, doubling of atmospheric dichloromethane (CH_2Cl_2) and continued increases in atmospheric N_2O are all of concern to stratospheric ozone depletion.

Role of Standards, WMO Central Calibration Lab (CCL)

NOAA GMD is the World Meteorological Organization (WMO), Global Atmosphere Watch (GAW) Central Calibration Laboratory (CCL) for CO_2, CH_4, N_2O, SF_6, and CO. GMD offers calibration services for these gases on a cost-recovery basis and also calibrates compressed gas standards to NOAA/GMD internal scales for other CFCs, HCFCs and the stable isotopes of CO_2.

The WMO has recognized GMD as an institute qualified to operate among the National Metrology Institutes (NMIs) following guidelines for calibrations conforming to ISO 17025 standards. As such, the GMD CCL meets international guidelines for “the competence of testing and calibration laboratories”.

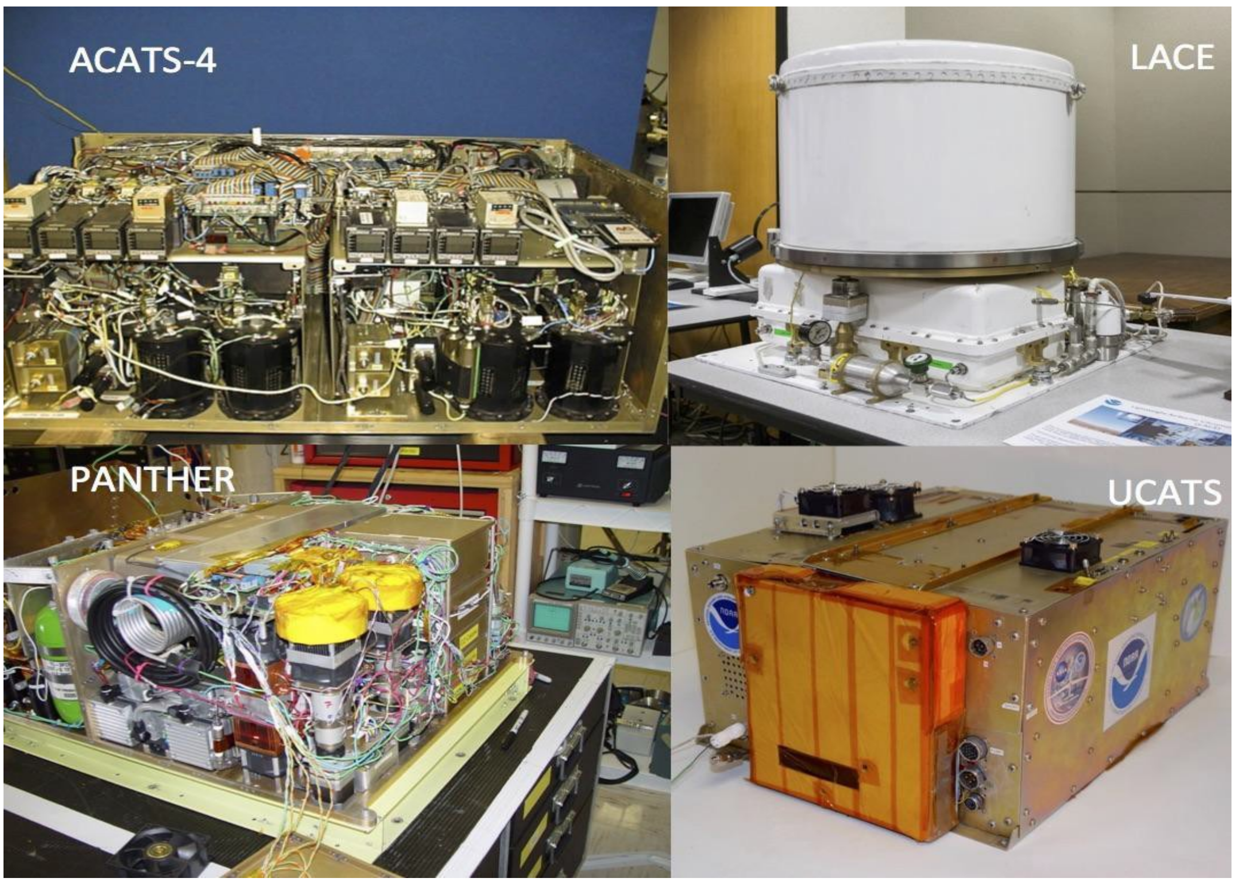
In 2016 GMD Calibration and Measurement Capabilities (CMCs) for CO_2, CH_4, and N_2O were published in the CMC database, maintained by the Bureau of International Weights and Measures (BIPM). This means that GMD’s role as a WMO/GAW Central Calibration Laboratory is internationally recognized as having measurement standards equivalent to NMIs, such as NIST (US), KRISS (Korea), and NPL (United Kingdom).

For the halocarbons and other trace gases measured by HATS and the NASA Advanced Global Atmospheric Gas Experiment (AGAGE), meetings are held every six months to discuss our measurements and calibration scales. The purpose is to resolve differences in trace gas measurements between networks and come up with an intercomparison matrix to relate the different calibration scales to each other.

High Altitude Airborne Measurements Program

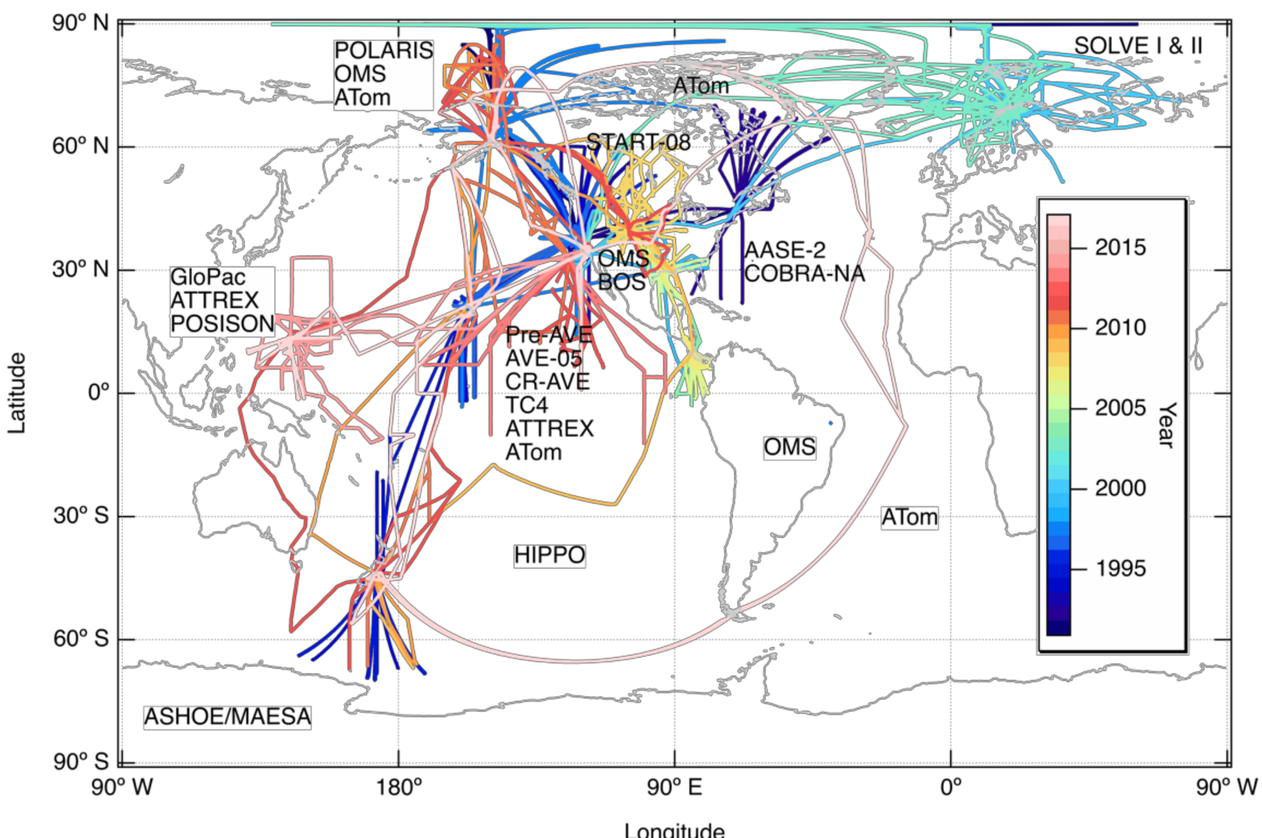
GMD scientists have developed an in situ airborne instrument that has flown many missions on a NASA ER-2 to measure ozone-depleting and climate forcing gases (N_2O, SF_6, CFC-11, -12, -113, halon-1211, CCl_4, CH_3CCl_3, CH_4, CO, and H_2). This instrument is known as the Airborne Chromatograph for Atmospheric Trace Species instrument (ACATS). These gases are also measured in profile with a balloon-borne GC developed by GMD called the Lightweight Airborne Chromatograph Experiment (LACE) that operates up to 32 km.

When CFC replacements began to take hold, GMD developed a gas chromatograph-mass spectrometer system that flies on the NASA DC-8 and WB-57F aircraft. This instrument is known as the "PAN and other Trace Hydro-halocarbon Experiment" (PANTHER). For UAV platforms, GMD built a lightweight gas chromatograph for operation on the NASA Altair and Global Hawk. These airborne measurements complement GMD ground-based measurements. Photos of GMD airborne instruments and some of the platforms they fly on are presented below and on the next page.

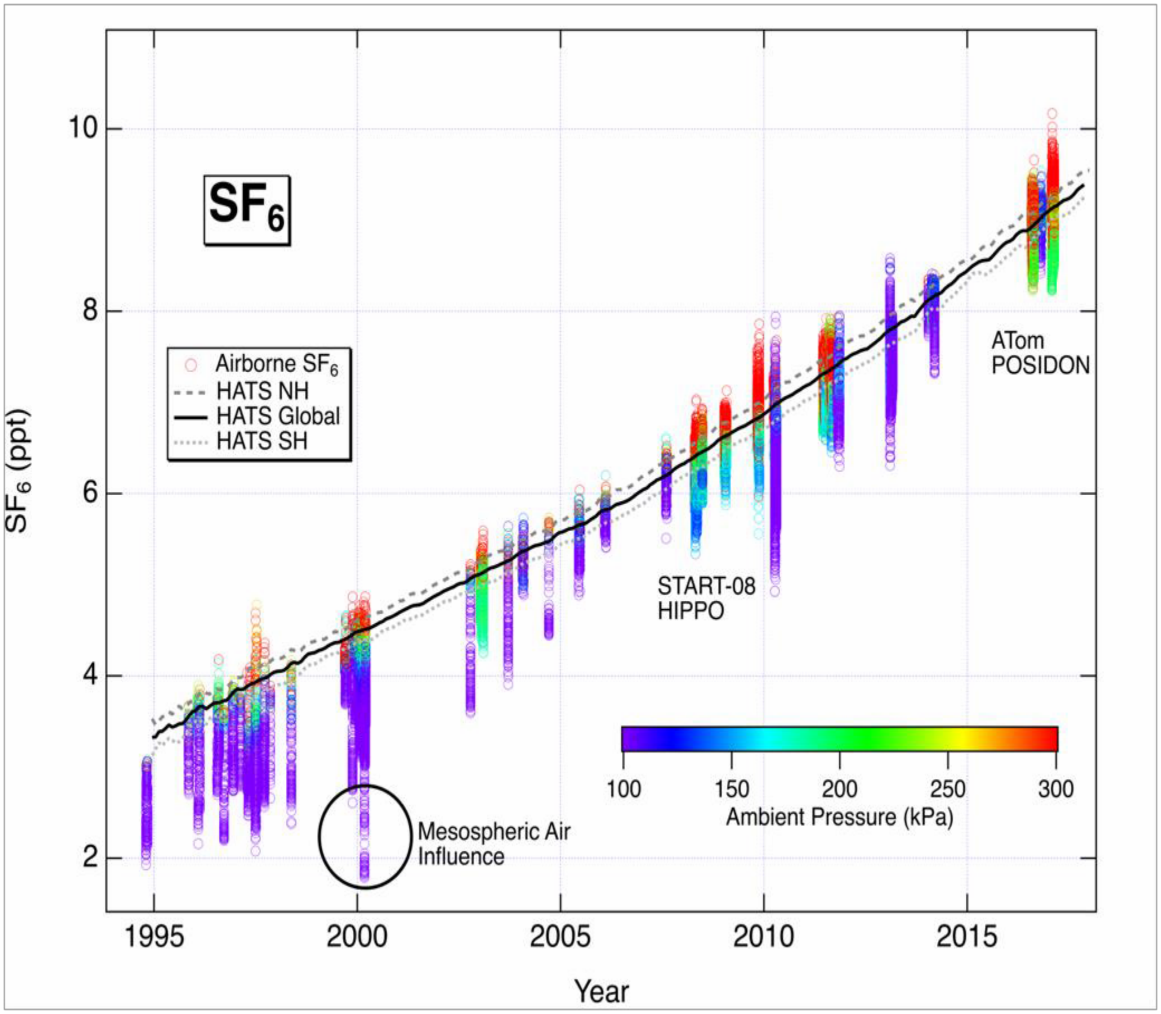


GMD HATS Airborne Instruments: ACATS, LACE, PANTHER, and UCATS.

High altitude airborne platforms used by HATS: NASA ER-2, DC-8, JPL Gondola, Altair, WB-57F and Global Hawk and the NCAR GV.



Flight paths of missions flown with GMD HATS instruments. In April and May 2018 GMD HATS instruments are being flown on the NASA DC-8 global scale ATom mission.



Time Series of airborne and ground based measurements of SF_6. These GMD data were used to calculate a reduction in the accepted atmospheric lifetime of SF_6 lowering its lifetime from 3200 to 850 years.

Collaborations with other Scientific Organizations.

The HATS Halocarbon Network is a cooperating network within the Advanced Global Atmospheric Gas Experiment (AGAGE), the World Meteorological Organization's (WMO) Global Atmospheric Watch (GAW) and the Network for the Detection of Atmospheric Composition Change (NDACC) operations.

HATS data are archived in-house, offsite, at the WMO World Greenhouse Gas Data Center in Japan once every six months, and will soon go to the NOAA NCEI data center.

HATS Scientific Highlights (2013-2017)

- **Ozone treaty taking a bite out of U.S. Greenhouse Emissions.**

  Reductions in emissions of ozone-depleting gases from 2008 to date has eliminated the equivalent of >170 million tons of carbon dioxide (CO_2) emissions each year. That's roughly the equivalent of 50 percent of the reductions achieved by the U.S. for CO_2 and other greenhouse gases over the same period.

  Hu, L., et al. (2017), Considerable contribution of the Montreal Protocol to declining greenhouse gas emissions from the United States: U.S. CFCs, HCFCs, and HFCs Emissions, Geophysical Research Letters, doi:10.1002/2017GL074388.

- **Possible new threat to Earth's ozone layer, dichloromethane**

  Dichloromethane (CH_2Cl_2) mixing ratios have doubled since GMD started measuring the gas. It is not subject to the Montreal Protocol, but the chlorine from this gas is getting into the stratosphere and represents a possible new threat to stratospheric ozone.

  Hossaini, R., M. P. Chipperfield, S. A. Montzka, A. A. Leeson, S. S. Dhomse, and J. A. Pyle (2017), The increasing threat to stratospheric ozone from dichloromethane, Nat Commun., 8 (ARTN 15962), doi:10.1038/ncomms15962.

- **NOAA's annual greenhouse gas index (AGGI) up 40% since 1990**

  Carbon dioxide is the leading contributor to the AGGI. Steadily increasing N_2O is the 3rd most important greenhouse gas and has been measured reliably by GMD since 1977. *https://www.esrl.noaa.gov/gmd/aggi/aggi.html*

- **Unexpected Increase in Ozone Depleting CFC-11 controlled by the Montreal Protocol**

  An unexplained increase in global concentrations of CFC -11 has been documented. This gas is a strong ozone-depleting gas and either some entity is producing the gas outside of the Montreal Protocol guidelines but much more likely it is a by-product of some chemical process not covered under the Montreal Protocol.

  Montzka et al., (2018), An unexpected and persistent increase in global emissions of ozone-depleting CFC-11, Nature, doi:10.1038/s41586-018-0106-2.

- **Study published on reduced lifetime for future strong greenhouse gas, sulfur hexafluoride**

Based on measurements of SF_6 in the stratospheric polar vortex, we estimated that the atmospheric lifetime of SF_6 is 850 years, which is nearly a factor of three lower than the previous estimate of 3200 years.

Ray, E. A., F. L. Moore, J. W. Elkins, K. Rosenlof, J. Laube, T. Röckmann, D. R. Marsh and A. E. Andrews, (2017), Quantification of the SF6 Lifetime Based on Mesospheric Loss Measured in the Stratospheric Polar Vortex , J. of Geophys Res., 10.1002/2016JD026198.

- **GMD has shown that the emission rates of carbon tetrachloride (CCl_4) are 30 to 100 times higher than emission inventories**

The gas, CCl_4, accounts for 10-15 percent of the ozone-depleting substances in the atmosphere and is regulated by the Montreal Protocol. The source of the unexpected emissions in the U.S. appears associated with the production of chlorinated chemicals (such as those ultimately used to create things like Teflon and PVC).

Hu, L., et al. (2016), Continued emissions of carbon tetrachloride from the United States nearly two decades after its phase-out for dispersive uses, P. Natl. Acad. Sci. USA, 113(11), 2880-2885, doi:10.1073/pnas.1522284113.

- **Long term trends of stratospheric age of the air mass deconvoluted from balloon observations of SF_6 and CO_2**

Chemistry Climate Models (CCMs) predict that stratospheric circulation will change from the influence of increasing GHGs. Using 37 years of balloon CO_2 and SF_6 data in the stratosphere, GMD determined a more rapid exchange of air in the stratosphere consistent with CCM predictions.

Ray et al., (2015), An idealized stratospheric model useful for understanding differences between long-lived trace gas measurements and global chemistry-climate model output, J. Geophys. Res. Atmos., 121, 5356–5367, doi:10.1002/2015JD024447.

Global Monitoring Division

Indicators of Preeminence 1: Bibliometrics, h-Index, Citations and Publications

2018 Review

Contents:

Part 1. Indicators of Preeminence 1:

Part 2. Indicators of Preeminence 2:

GMD BIBLIOMETRICS REPORT

h-Index, Category Normalized Citation Impact (CNC), Percentile Analysis, Times Cited and Percent of Documents Cited.

PREPARED FOR

GMD: Global Monitoring Division

BY

Aurelia Mandani, Technology Services Librarian, Boulder Laboratories

March 05, 2018

Note: *The following information is abstracted from the above titled report based upon Web of Science data and software. Web of Science identified 486 reviewed scientific papers from GMD in 2013-17. As a caveat, the use of Web of Science for article collection means that book chapters, technical reports, and some journal articles are not included. Consequently, the publication counts presented in this report are under counts of the actual number of publications produced by GMD. However, despite these limitations, the collections of articles analyzed herein constitute a representative sample of the articles published by GMD between 2013 and 2017.*

h-Index, Category Normalized Citation Impact and Percentile Analyses

NOAA suggests that in addition to presenting an (i) h-Index, the preeminence analysis include (ii) Category Normalized Citation Impact (CNCI), (iii) percent of documents cited, and (iv) percentile analysis. Unlike the h-Index which provides an absolute impact analysis without regard to context, these additional results provide a robust picture of a division's performance and ensure they are not evaluated in a vacuum.

h-Index

The h-index is a metric that is used to measure the "productivity and influence" of a researcher or group of researchers (Hirsch, 2005). The h-index can be used to measure an individual author or the author's institution/research group's impact of the field. The h-index is a time-dependent measure and is based on the total number of publications, citations and citation impact group or entity's h-index (Hirsch,2005).

T*ypical h-indexes for members of the American Physical Society are:*

Faculty at a research university	*~12*
Full Professor	*~18*
Consideration to be a Fellow	*~20*
Nobel Prize winner	*~35*
Membership in the NAS	*~46*

The individual h-indexes for **59** GMD publishing scientists are presented on a following page in graphical form. **Seven GMD scientists have an h-Index over 40 and 20 have an h-Index of 30 and above.**

The total number of career publications of current GMD scientists to December 31, 2017 is **3,874 with 189,921 citations.**

From the Web of Science, the **486** recognized GMD publications for 2013-17 have **10,792** citations with an average of **22** per publication.

The h-Index for GMD as a whole unit, over the same period, is **50.**

Category Normalized Citation Impact (CNCI)

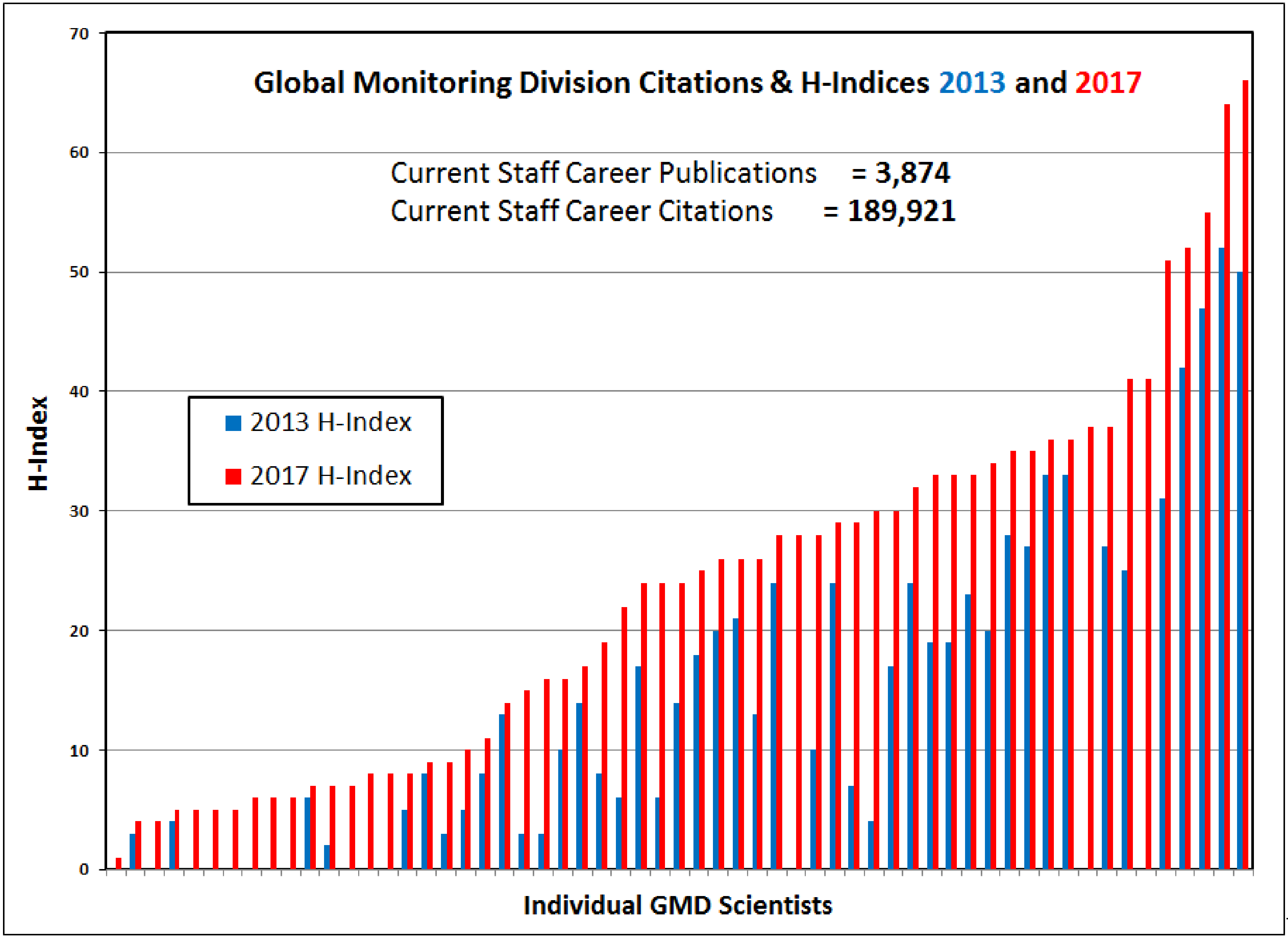
The Category Normalized Citation Impact (CNCI) of documents is calculated by dividing the actual count of citing items by the expected citation rate for documents with the same document type, year of publication, and subject area. When a document is assigned to more than one subject area, an average of the ratios of the actual to expected citations is used. The CNCI of a set of documents for a division is the average of the CNCI values for all the documents in the set.

The CNCI is a valuable and unbiased indicator of impact irrespective of age, subject focus, or document type and it allows comparisons between entities of different sizes and different subject mixes.

A CNCI value of one represents performance at par with world average, values above one (1) are considered above average and values below one (1) are considered below average. A CNCI value of two (2) is considered twice world average; above three (3) is considered world class.

There are known issues with using the CNCI:

- When dealing with small sets of publications, the CNCI value may be inflated by a single highly cited paper.
- Because it is an average, even when looking at larger sets of publications, such as the collected works of an institution, very highly cited papers can have an unduly large influence on the CNCI value.
- The baseline values for current year can be very low (there is a lag between publication and citation) and therefore the CNCI values for current the year can fluctuate more than expected.


Global Monitoring Division Citations & H-Indices 2013 and 2017
Current Staff Career Publications = 3,874
Current Staff Career Citations = 189,921
2013 H-Index
2017 H-Index
H-Index
70
60
50
40
30
20
10
0
Individual GMD Scientists

Category Normalized Citation Impact (CNCI): 2013-2017

(1 is average, > 1 is above average, >3 is World Class)

Top 5 GMD Research Categories (5 year average)	CNCI
Geosciences	**4.32**
Chemistry	**4.27**
Oceanography	**3.82**
Environmental Studies	**3.44**
Meteorology and Atmospheric Sciences	**2.54**
Top 5 Journals GMD Published In (best year in 2013-17)	**CNCI**
Science	**35.68**
Nature	**15.68**
Proceedings, National Academy of Sciences	**12.96**
Earth System Science	**13.23**
Bulletin of the American Meteorological Society	**8.19**

From the above table it is clear that GMD authorship in *Nature, Science* and *Proceedings of the Nation Academy of Sciences* is highly cited. This is also borne out in the following table presenting GMD authorship percentile statistics.

Complementary Indicators alongside the CNCI: Citation Statistics

The NOAA Library Services Bibliometric Study showed that for 2013-17 the **486** papers Web of Science credited to GMD authorship, the **10,792** citations (average of 22/publication) were distributed as shown below.

GMD Citation Statistics from Web of Science: 2013-2017

	% Cited
Chemistry	100
Oceanography	100
Geosciences	94
Meteorology and Atmospheric Sciences	88
Environmental studies	83
Top 5 Journals GMD Published in (5 year average)	**% Cited**
Global Biogeochemical Sciences	100
Nature	100
Atmospheric Physics and Chemistry	93
Journal of Geophysical Research	85
Proceedings of the National Academy of Sciences	83

GMD Authorship in the Top 10% of Web of Science Categories: Percentile Analysis

Percentile analysis provides the percent of documents published by GMD that are among the top 10% of the most cited documents in a given subject, year, and published type. For instance, a score of 10% indicates that 10% of its publications are in the top 10% in the world, which means a laboratory or division is performing about average.

The Web of Science assigns publications into many categories, most which are not at the core of GMD science themes. As such, some influential GMD publications appear in categories such as Oceanography, Biodiversity, and Optics where a small number of GMD authorships have an outsized number of citations in the field.

The tabulation below covers **8 categories** in Web of Science in which GMD authors are well above the top 10% threshold of cited scientific authorship in a particular category averaged over the five years, 2013-17.

1. Geosciences, has **62** Web of Science documents and **51.56%** of documents are in the top 10%;

2. Oceanography, has **5** Web of Science documents and **40%** of documents are in the top 10%;

3. Environmental Studies, has **6** Web of Science documents and **33.33%** of documents are in the top 10%; based on one highly cited paper;

4. Physics, Atomic, Molecular, & Chemical has **3** Web of Science documents **33.33%** of documents are in the top 10%, based on one highly cited paper;

5. Biodiversity, Conservation has **3** Web of Science documents and **33.33%** of documents are in the top 10%, based on one highly cited paper;

6. Optics has **3** Web of Science documents and **33.33%** of documents are in the top 10%; based on one highly cited paper;

7. Meteorology and Atmospheric Sciences, has **297** Web of Science documents and **29.63%** of documents are in the top 10%;

8. Environmental Sciences, has **60** Web of Science documents and **21.67%** of documents are in the top 10%.

In addition to the thousands of distinct data sets the Global Monitoring Division produces that are used by scientists around the world, GMD scientists also publish reviewed scientific papers.

Based on the number of Ph.D.s in the respective OAR laboratories/divisions and the number of publications the laboratory/division produced in 2017, GMD leads by a wide margin.

Division/Laboratory	No. of publications	No. of Ph.D.s	Pubs/Ph.D.s
GMD	119	32	3.7
PMEL	151	54	2.7
CSD	191	83	2.3
GFDL	212	91	2.3
AOML	109	57	1.9
PSD	122	73	1.7

Publications Linked to Observatory Data Sets

PREPARED FOR
GMD: Global Monitoring Division
BY
Sue Visser, Public Services and Bibliometrics Librarian, Boulder Libraries

Date
March 29, 2018

Objective: The purpose of these literature searches is to determine how many published, peer-reviewed papers have relied on data from the atmospheric observatories operated by GMD. The six observatories included in these searches were:

- Barrow Observatory, Barrow, AK
- Mauna Loa Observatory, Hilo, HI
- Samoa Observatory, American Samoa
- South Pole Observatory, Antarctica
- Summit Observatory, Greenland

Summary:

Observatory	Estimated number of published papers that mention this observatory and data, 2013-2017.	Number of publications from the inception of the observatory to 2013.	Estimated total publications from inception of the observatory to 2017.
Trinidad Head	157	81	238
Barrow	343	853	1,196
Mauna Loa	1,032	1,735	2,767
Samoa	181	512	693
South Pole	246	966	1,212
Summit	149	62	211

As described in detail below, these estimates are based on a random sampling of full text papers from our search results. The numbers provided here are the centers of the 95% confidence intervals for each observatory. Below we have provided both the 95% and 99% intervals.

Search Strategy: These searches present some unique challenges in that the key terms (i.e., the names of the observatories) are not usually mentioned in the titles or abstracts of the papers that rely on data from the observatories. More often, the observatories are mentioned in a table, figure, methods section, or acknowledgements. For this reason, traditional indexed databases like Web of Science (WoS) are poorly suited for these searches, because such databases usually search only in the “basic index”, which consists of titles, abstracts, and keywords.

Full text searching is more likely to capture all of the mentions of the observatories in published papers. For full text searching we must turn to Google Scholar (GS), which *searches* full text, but does not allow us to *see* the full text unless we have subscription access to a given publication. However, searching GS presents its own set of challenges.

Because of the imprecise nature of full-text searching, and because GS is an undisciplined, unindexed tool with limited search capabilities, our searches will return large numbers of results, many of which will be irrelevant. The only way to determine the relevancy of a particular publication is to view the full text of the publication for the context in which our search terms appear. Unfortunately, with our search results numbering in the thousands, it would be impractical to examine every record.

Our challenge, then, is to determine what percentage of the GS results is relevant to our search. We downloaded a random sample of full text PDFs from the search results for each observatory, and scored them for relevancy based on the following scoring criteria:

Score	Criteria
0	Some of our downloaded results did not contain the key terms at all. This is most likely due to anomalies in the metadata attached to the document.
1	Not relevant: the terms appear in the document, but in a context unrelated to our search.
2	Very low relevance: the terms appear only in the titles of cited documents; the terms are mentioned in passing (e.g. “We did not use data from Trinidad Head because it did not cover the time period of our investigation”).
3	Relevant: The observatory is listed as a data source for the paper.
4	Highly relevant: The observatory is mentioned multiple times in the text; the observatory one of only a few data sources for the paper; the observatory is used to calibrate a model or validate data. The paper relies heavily on data from the observatory.

For our searches, we searched Web of Science, Meteorological and Geoastrophysical Abstracts, and Google Scholar. We combined the results of the searches in an Excel file, removed duplicates, and then performed a random sort of the list of titles. We then downloaded the first 25% of the randomized titles, skipping those to which we did not have subscription access.

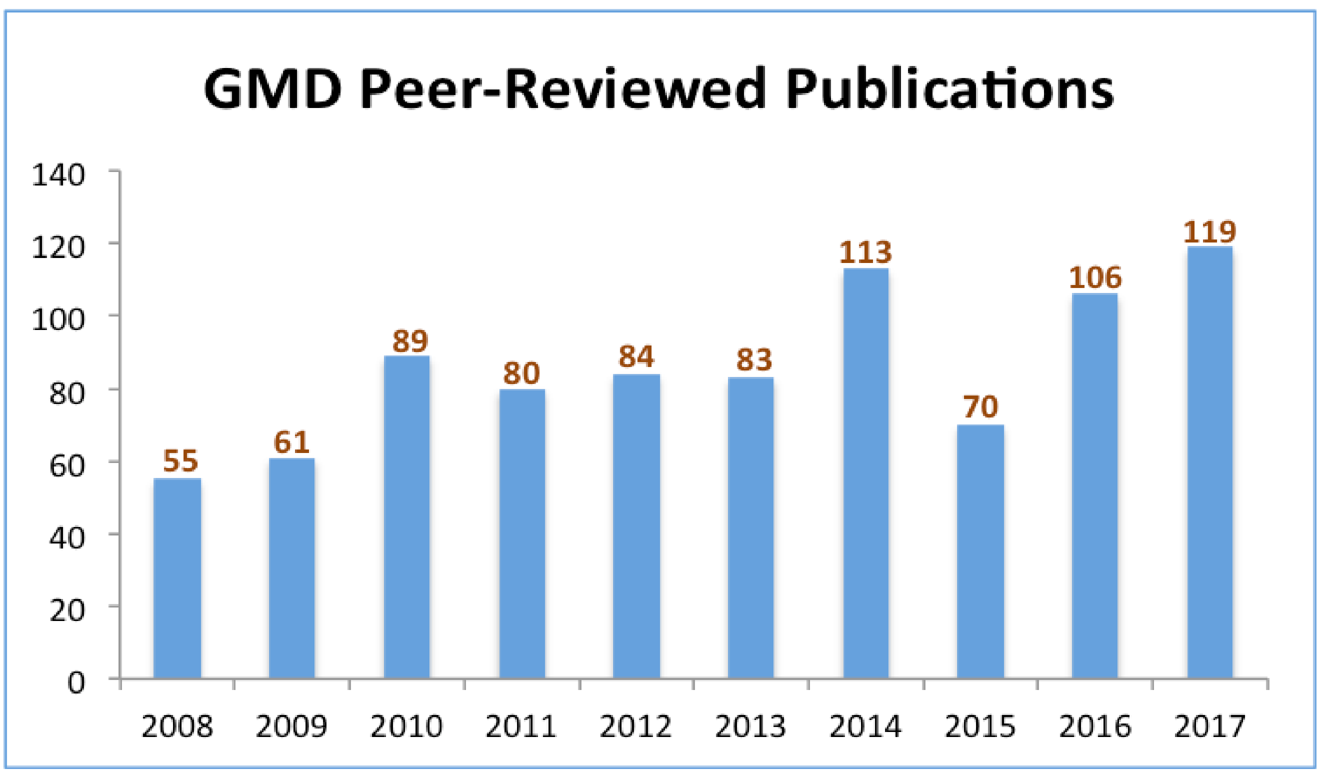
All of our searches were limited to 2013-2017, as requested by GMD.
We calculated 95% and 99% confidence intervals for each observatory, based on the results of our sampling. The results of our analyses are below:

Observatory	Number of records in search results	# of PDFs reviewed	% of records reviewed	% of sample receiving relevancy score of 3 or 4	# of relevant records in search results, based on sample results; 95% confidence interval	# of relevant records in search results, based on sample results; 99% confidence interval)	Number of records listed in the 2013 GMD 5-year review
Trinidad Head	191	50	26%	82%	136-178	130-183	81
Barrow	881	220	25%	39%*	291-396	273-414	853
Mauna Loa	1521	305	20%*	67%	938-1126	897-1156	1735
Samoa	327	86	25%	55%	147-216	134-226	512
South Pole	1016	250	25%	34%*	300-392	286-406	966
Summit	213	83	25%	70%	128-170	120-177	62

*We used a 20% sample for MLO due to time constraints and the size of the set.

Sientific publications from *Google Scholar* mentioning a specific Global Monitoring Division data set. *Please note that the majority of non-GMD authored publications using GMD data do not mention the specific data set.*

2013-2017: 1337 acknowledgements of specific GMD data sets used.



Scientific Publications Using Global Monitoring Division Observatory Data Sets

A. Publications Using Observatory Data Prior to 2013 and in 2013 - 2017.

B. Publications by Coop Programs using MLO Data or Facilities from Project Inception to 2013 and 2013-2017.

(A) Publications Referencing Observatory Data	To 2013	2013-2017
Barrow Observatory, Barrow , Alaska (Established 1974)	843	343
Mauna Loa Observatory, Hilo, Hawaii (Established 1956)	1,735	1,032
Samoa Observatory, American Samoa(Established 1974)	512	181
South Pole Observatory, Antarctica (Established 1956)	966	246
Trinidad Head Observatory, California (Established 2002)	81	157
Summit Observatory, Greenland (Established 2003)	62	149
	4,199	**2,108**
(B) Cooperative Programs at MLO Using Data		
AERONET	136	156
ARL	23	123
Climate Reference Network	22	6
Colorado State University	56	50
CSIRO	118	151
Environment and Climate Change Canada	128	93
EPA	116	66
FAA	21	6
Global Oscillation Network Group	102	3
Goddard Space Flight Center	170	268
JPL	117	154
Naval Research Laboratories	21	28
NCAR HAO	123	261
Network for Detection of Atmospheric Composition Change	97	137
New Mexico State	25	3
NIES, Japan	99	75
NIWA	29	51
NIWA, New Zealand	60	51
Pacific Northwest National Laboratory	12	27
Scripps Institution of Oceanography	116	154
Stanford University	32	9
SUNY	25	7
University of California	184	86
University of Denver	54	31
University of Hawaii	80	31
US Air Force	38	16
US Army Research	38	6
US Navy	49	5
USGS	9	63
	2100	**2117**

Global Monitoring Division

Reviewed Scientific Publications

Arranged by Themes within each year:

- Each paper has one or more Global Monitoring Division authors
- The number has increased ~9 per year since the prior GMD review in 2014
- GMD staff has decreased nearly 9% over the same time
- There are 59 GMD contributing authors, 32 with Ph.Ds.

7.

Theme 1. Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks

Year of Publication: 2017

Andrews, Arlyn, (2017), Strengthening the Observational Basis for Carbon Science, Policy, *Eos*, 98, 10.1029/2017EO080609.

Bagley, Justin E., Seongeun Jeong, Xinguang Cui, Sally Newman, Jingsong Zhang, Chad Priest, Mixtli Campos-Pineda, **Arlyn E. Andrews**, Laura Bianco, Matthew Lloyd, Neil Lareau, Craig Clements and Marc L. Fischer, (2017), Assessment of an atmospheric transport model for annual inverse estimates of California greenhouse gas emissions, *Journal of Geophysical Research: Atmospheres*, 122, 3, 1901-1918, 10.1002/2016JD025361.

Ballantyne, Ashley, William Smith, William Anderegg, Pekka Kauppi, Jorge Sarmiento, **Pieter Tans**, Elena Shevliakova, Yude Pan, Benjamin Poulter, Alessandro Anav, Pierre Friedlingstein, Richard Houghton and Steven Running, (2017), Accelerating net terrestrial carbon uptake during the warming hiatus due to reduced respiration, *Nature Climate Change*, 7, 2,148-152, 10.1038/nclimate3204.

Barkley, Zachary R., Thomas Lauvaux, Kenneth J. Davis, Aijun Deng, Natasha L. Miles, Scott J. Richardson, Yanni Cao, **Colm Sweeney**, Anna Karion, MacKenzie Smith, Eric A. Kort, Stefan Schwietzke, Thomas Murphy, Guido Cervone, Douglas Martins and Joannes D. Maasakkers, (2017), Quantifying methane emissions from natural gas production in north-eastern Pennsylvania, *Atmospheric Chemistry and Physics*, 17, 22, 13941-13966, 10.5194/acp-17-13941-2017.

Basu, Sourish, David F. Baker, Frédéric Chevallier, Prabir K. Patra, Junjie Liu and **John B. Miller**, (2017), The Impact of Transport Model Differences on CO2 Surface Flux Estimates from OCO-2 Retrievals of Column Average CO2, *Atmospheric Chemistry and Physics Discussions*, 1-32, 10.5194/acp-2017-1158.

Blunden, Jessica, Derek S. Arndt, **E.J. Dlugokencky**, **B.D. Hall**, **S.A. Montzka**, **G. Dutton**, J. Muhle, **J.W. Elkins**, (2017), Long-lived greenhouse gases [in "State of the Climate in 2016"], *Bulletin of the American Meteorological Society*, 98, 8, S43-S46, 10.1175/2017BAMSStateoftheClimate.1.

Bruhwiler, L. M., **S. Basu**, P. Bergamaschi, P. Bousquet, **E. Dlugokencky**, S. Houweling, M. Ishizawa, H.-S. Kim, R. Locatelli, S. Maksyutov, **S. Montzka**, S. Pandey, P. K. Patra, **G. Petron**, M. Saunois, **C. Sweeney**, **S. Schwietzke**, **P. Tans** and E. C. Weatherhead, (2017), U.S. CH emissions from oil and gas production: Have recent large increases been detected? , *Journal of Geophysical Research: Atmospheres*, 122, 7, 4070-4083, 10.1002/2016JD026157.

Campbell, J. E., J. A. Berry, U. Seibt, S. J. Smith, **S. A. Montzka**, T. Launois, S. Belviso, L. Bopp and M. Laine, (2017), Large historical growth in global terrestrial gross primary production, *Nature*, 544, 7648, 84-87, 10.1038/nature22030.

Campbell, J. E., M. E. Whelan, J. A. Berry, T. W. Hilton, A. Zumkehr, J. Stinecipher, Y. Lu, A. Kornfeld, U. Seibt, T. E. Dawson, **S. A. Montzka**, I. T. Baker, S. Kulkarni, Y. Wang, S. C. Herndon, M. S. Zahniser, R. Commane and M. E. Loik, (2017), Plant Uptake of Atmospheric Carbonyl Sulfide in Coast Redwood Forests, *Journal of Geophysical Research: Biogeosciences*, 10.1002/2016JG003703.

Campbell, J., Jürgen Kesselmeier, Dan Yakir, Joe Berry, Philippe Peylin, Sauveur Belviso, Timo Vesala, Kadmiel Maseyk, Ulrike Seibt, Huilin Chen, Mary Whelan, Timothy Hilton, **Stephen Montzka**, Max Berkelhammer, Sinikka Lennartz, Le Kuai, Georg Wohlfahrt, Yuting Wang, Nicola Blake, Donald Blake, James Stinecipher, Ian Baker and Stephen Sitch, (2017), Assessing a New Clue to How Much Carbon Plants Take Up, *Eos*, 10.1029/2017EO075313.

Cheng, Siyang, Xingqin An, Lingxi Zhou, **Pieter P. Tans** and **Andy Jacobson**, (2017), Atmospheric CO 2 at Waliguan station in China: Transport climatology, temporal patterns and source-sink region representativeness, *Atmospheric Environment*, 159, 107-116, 10.1016/j.atmosenv.2017.03.055.

Commane, Róisín, Jakob Lindaas, Joshua Benmergui, Kristina A. Luus, Rachel Y.-W. Chang, Bruce C. Daube, Eugénie S. Euskirchen, John M. Henderson, Anna Karion, **John B. Miller**, Scot M. Miller, Nicholas C. Parazoo, James T. Randerson, **Colm Sweeney**, **Pieter Tans**, **Kirk Thoning**, Sander Veraverbeke, Charles E. Miller and Steven C. Wofsy, (2017), Carbon dioxide sources from Alaska driven by increasing early winter respiration from Arctic tundra, *Proceedings of the National Academy of Sciences*, 114, 21, 5361-5366, 10.1073/pnas.1618567114.

Conley, Stephen, Ian Faloona, Shobhit Mehrotra, Maxime Suard, Donald H. Lenschow, **Colm Sweeney**, Scott Herndon, **Stefan Schwietzke**, **Gabrielle Pétron**, Justin Pifer, Eric A. Kort and **Russell Schnell**, (2017), Application of Gauss's theorem to quantify localized surface emissions from airborne measurements of wind and trace gases, *Atmospheric Measurement Techniques*, 10, 9, 3345-3358, 10.5194/amt-10-3345-2017.

Cox, Christopher J., **Robert S. Stone**, David C. Douglas, **Diane M. Stanitski**, George J. Divoky, **Geoff S. Dutton**, **Colm Sweeney**, J. Craig George and **David U. Longenecker**, (2017), Drivers and environmental responses to the changing annual snow cycle of northern Alaska, *Bulletin of the American Meteorological Society*, 10.1175/BAMS-D-16- 0201.1.

Davis, Kenneth J., Aijun Deng, Thomas Lauvaux, Natasha L. Miles, Scott J. Richardson, Daniel P. Sarmiento, Kevin R. Gurney, R. Michael Hardesty, Timothy A. Bonin, W. Alan Brewer, Brian K. Lamb, Paul B. Shepson, Rebecca M. Harvey, Maria O. Cambaliza, **Colm Sweeney**, Jocelyn C. Turnbull, James Whetstone and Anna Karion, (2017), The Indianapolis Flux Experiment (INFLUX): A test-bed for developing urban greenhouse gas emission measurements, *Elem Sci Anth*, 5, 21, 10.1525/elementa.188.

Deeter, Merritt N., David P. Edwards, Gene L. Francis, John C. Gille, Sara Martínez-Alonso, Helen M. Worden and **Colm Sweeney**, (2017), A climate-scale satellite record for carbon monoxide: the MOPITT Version 7 product, *Atmospheric Measurement Techniques*, 10, 7, 2533-2555, 10.5194/amt-10-2533-2017.

Eveleth, R., N. Cassar, S.C. Doney, D.R. Munro and **C. Sweeney**, (2017), Biological and physical controls on O 2 /Ar, Ar and p CO 2 variability at the Western Antarctic Peninsula and in the Drake Passage, *Deep Sea Research Part II: Topical Studies in Oceanography*, 139, 77-88, 10.1016/j.dsr2.2016.05.002.

Feng, Liang, Paul I. Palmer, Hartmut Bösch, Robert J. Parker, Alex J. Webb, Caio S. C. Correia, Nicholas M. Deutscher, Lucas G. Domingues, Dietrich G. Feist, Luciana V. Gatti, Emanuel Gloor, Frank Hase, Rigel Kivi, Yi Liu, **John B. Miller**, Isamu Morino, Ralf Sussmann, Kimberly Strong, Osamu Uchino, Jing Wang and Andreas Zahn, (2017), Consistent regional fluxes of CH4 and CO2 inferred from GOSAT proxy XCH4 : XCO2 retrievals, 2010–2014, *Atmospheric Chemistry and Physics*, 17, 7, 4781-4797, 10.5194/acp-17-4781-2017.

Gvakharia, Alexander, Eric A. Kort, Adam Brandt, Jeff Peischl, Thomas B. Ryerson, Joshua P. Schwarz, Mackenzie L. Smith and **Colm Sweeney**, (2017), Methane, Black Carbon, and Ethane Emissions from Natural Gas Flares in the Bakken Shale, North Dakota, *Environmental Science & Technology*, 51, 9, 5317-5325, 10.1021/acs.est.6b05183.

He, Wei, Ivar R. van der Velde, **Arlyn E. Andrews**, **Colm Sweeney**, **John Miller**, **Pieter Tans**, Ingrid T. van der Laan-Luijkx, Thomas Nehrkorn, Marikate Mountain, Weimin Ju, Wouter Peters and Huilin Chen, (2017), CTDAS-Lagrange v1.0: A high-resolution data assimilation system for regional carbon dioxide observations, *Geoscientific Model Development Discussions*, 1-41, 10.5194/gmd-2017-222.

Heimburger, Alexie M. F., Rebecca M. Harvey, Paul B. Shepson, Brian H. Stirm, Chloe Gore, Jocelyn Turnbull, Maria O. L. Cambaliza, Olivia E. Salmon, Anna-Elodie M. Kerlo, Tegan N. Lavoie, Kenneth J. Davis, Thomas Lauvaux, Anna Karion, **Colm Sweeney**, W. Alan Brewer, R. Michael Hardesty and Kevin R. Gurney, (2017), Assessing the optimized precision of the aircraft mass balance method for measurement of urban greenhouse gas emission rates through averaging, *Elem Sci Anth*, 5, 26, 10.1525/elementa.134.

Hilton, Timothy W., Mary E. Whelan, Andrew Zumkehr, Sarika Kulkarni, Joseph A. Berry, Ian T. Baker, **Stephen A. Montzka**, **Colm Sweeney**, **Benjamin R. Miller** and J. Elliott Campbell, (2017), Peak growing season gross uptake of carbon in North America is largest in the Midwest USA, *Nature Climate Change*, 7, 6, 450-454, 10.1038/nclimate3272.

Hu, Lei, **Stephen A. Montzka**, Scott J. Lehman, David S. Godwin, **Benjamin R. Miller**, **Arlyn E. Andrews**, **Kirk Thoning**, **John B. Miller**, **Colm Sweeney**, **Caroline Siso**, **James W. Elkins**, **Bradley D. Hall**, **Debra J. Mondeel**, **David Nance**, Thomas Nehrkorn, Marikate Mountain, Marc L. Fischer, Sébastien C. Biraud, Huilin Chen and **Pieter P. Tans**, (2017), Considerable contribution of the Montreal Protocol to declining greenhouse gas emissions from the United States, *Geophysical Research Letters*, 44, 15, 8075-8083, 10.1002/2017GL074388.

Jeong, Seongeun, Xinguang Cui, Donald R. Blake, **Ben Miller**, **Stephen A. Montzka**, **Arlyn Andrews**, Abhinav Guha, Philip Martien, Ray P. Bambha, Brian LaFranchi, Hope A. Michelsen, Craig B. Clements, Pierre Glaize and Marc L. Fischer, (2017), Estimating methane emissions from biological and fossil-fuel sources in the San Francisco Bay Area, *Geophysical Research Letters*, 10.1002/2016GL071794.

Johnson, Matthew R., David R. Tyner, Stephen Conley, **Stefan Schwietzke** and Daniel Zavala-Araiza, (2017), Comparisons of Airborne Measurements and Inventory Estimates of Methane Emissions in the Alberta Upstream Oil and Gas Sector, *Environmental Science & Technology*, 51, 21, 13008-13017, 10.1021/acs.est.7b03525.

Kim, Jinwoong, Hyun Mee Kim, Chun-Ho Cho, Kyung-On Boo, **Andrew R. Jacobson**, Motoki Sasakawa, Toshinobu Machida, Mikhail Arshinov and Nikolay Fedoseev, (2017), Impact of Siberian observations on the optimization of surface CO2 flux, *Atmospheric Chemistry and Physics*, 17, 4, 2881-2899, 10.5194/acp-17-2881-2017.

Kulawik, Susan S., O&, apos, Chris Dell, Vivienne H. Payne, Le Kuai, Helen M. Worden, Sebastien C. Biraud, **Colm Sweeney**, Britton Stephens, Laura T. Iraci, Emma L. Yates and Tomoaki Tanaka, (2017), Lower-tropospheric CO_2 from near-infrared ACOS-GOSAT observations, *Atmospheric Chemistry and Physics*, 17, 8, 5407-5438, 10.5194/acp-17-5407-2017.

Lan, Xin, **Pieter Tans**, **Colm Sweeney**, **Arlyn Andrews**, **Andrew Jacobson**, **Molly Crotwell**, **Edward Dlugokencky**, **Jonathan Kofler**, **Patricia Lang**, **Kirk Thoning** and **Sonja Wolter**, (2017), Gradients of column CO2 across North America from the NOAA Global Greenhouse Gas Reference Network, *Atmospheric Chemistry and Physics*, 17, 24, 15151-15165, 10.5194/acp-17-15151-2017.

Lopez, M., O.A. Sherwood, **E.J. Dlugokencky**, R. Kessler, L. Giroux and D.E.J. Worthy, (2017), Isotopic signatures of anthropogenic CH 4 sources in Alberta, Canada, *Atmospheric Environment*, 164, 280-288, 10.1016/j.atmosenv.2017.06.021.

Meinshausen, Malte, Elisabeth Vogel, Alexander Nauels, Katja Lorbacher, Nicolai Meinshausen, David M. Etheridge, Paul J. Fraser, **Stephen A. Montzka**, Peter J. Rayner, Cathy M. Trudinger, Paul B. Krummel, Urs Beyerle, Josep G. Canadell, John S. Daniel, Ian G. Enting, Rachel M. Law, Chris R. Lunder, O&, apos, Simon Doherty, Ron G. Prinn, Stefan Reimann, Mauro Rubino, Guus J. M. Velders, Martin K. Vollmer, Ray H. J. Wang and Ray Weiss, (2017), Historical greenhouse gas concentrations for climate modelling (CMIP6), *Geoscientific Model Development*, 10, 5, 2057-2116, 10.5194/gmd-10-2057-2017.

Membrive, Olivier, Cyril Crevoisier, **Colm Sweeney**, François Danis, Albert Hertzog, Andreas Engel, Harald Bönisch and Laurence Picon, (2017), AirCore-HR: a high- resolution column sampling to enhance the vertical description of CH_4 and CO_2, *Atmospheric Measurement Techniques*, 10, 6, 2163-2181, 10.5194/amt-10-2163-2017.

Miles, Natasha L., Scott J. Richardson, Thomas Lauvaux, Kenneth J. Davis, Nikolay V. Balashov, Aijun Deng, Jocelyn C. Turnbull, **Colm Sweeney**, Kevin R. Gurney, Risa Patarasuk, Igor Razlivanov, Maria Obiminda L. Cambaliza and Paul B. Shepson, (2017), Quantification of urban atmospheric boundary layer greenhouse gas dry mole fraction enhancements in the dormant season: Results from the Indianapolis Flux Experiment (INFLUX), *Elem Sci Anth*, 5, 27, 10.1525/elementa.127.

Pandey, Sudhanshu, Sander Houweling, Maarten Krol, Ilse Aben, Guillaume Monteil, Narcisa Nechita-Banda, **Edward J. Dlugokencky**, Rob Detmers, Otto Hasekamp, Xiyan Xu, William J. Riley, Benjamin Poulter, Zhen Zhang, Kyle C. McDonald, James W. C. White, Philippe Bousquet and Thomas Röckmann, (2017), Enhanced methane emissions from tropical wetlands during the 2011 La Niña, *Scientific Reports*, 7, 45759, 10.1038/srep45759.

Pangala, Sunitha R., Alex Enrich-Prast, Luana S. Basso, Roberta Bittencourt Peixoto, David Bastviken, Edward R. C. Hornibrook, Luciana V. Gatti, Humberto Ribeiro, Luana Silva Braucks Calazans, Cassia Mônica Sakuragui, Wanderley Rodrigues Bastos, Olaf Malm, Emanuel Gloor, **John Bharat Miller** and Vincent Gauci, (2017), Large emissions from floodplain trees close the Amazon methane budget, *Nature*, 10.1038/nature24639.

Piao, Shilong, Zhuo Liu, Tao Wang, Shushi Peng, Philippe Ciais, Mengtian Huang, Anders Ahlstrom, John F. Burkhart, Frédéric Chevallier, Ivan A. Janssens, Su-Jong Jeong, Xin Lin, Jiafu Mao, **John Miller**, Anwar Mohammat, Ranga B. Myneni, Josep Peñuelas, Xiaoying Shi, Andreas Stohl, Yitong Yao, Zaichun Zhu and **Pieter P. Tans**, (2017), Weakening temperature control on the interannual variations of spring carbon uptake across northern lands, *Nature Climate Change*, 7, 5, 359-363, 10.1038/nclimate3277.

Prokopiou, Markella, Patricia Martinerie, Célia J. Sapart, Emmanuel Witrant, Guillaume Monteil, Kentaro Ishijima, Sophie Bernard, Jan Kaiser, Ingeborg Levin, Thomas Blunier, David Etheridge, **Ed Dlugokencky**, Roderik S. W. van de Wal and Thomas Röckmann, (2017), Constraining N₂O emissions since 1940 using firn air isotope measurements in both hemispheres, *Atmospheric Chemistry and Physics*, 17, 7, 4539-4564, 10.5194/acp-17-4539-2017.

Quay, P., R. Sonnerup, D. Munro and **C. Sweeney**, (2017), Anthropogenic CO_2 accumulation and uptake rates in the Pacific Ocean based on changes in the 13C/12C of dissolved inorganic carbon , *Global Biogeochemical Cycles*, 31, 1, 59-80, 10.1002/2016GB005460.

Raczka, B., S. C. Biraud, J. R. Ehleringer, C.-T. Lai, **J. B. Miller**, D. E. Pataki, S. R. Saleska, M. S. Torn, B. H. Vaughn, R. Wehr and D. R. Bowling, (2017), Does vapor pressure deficit drive the seasonality of $\delta^{13}C$ of the net land-atmosphere CO exchange across the United States? , *Journal of Geophysical Research: Biogeosciences*, 122, 8, 1969-1987, 10.1002/2017JG003795.

Richardson, Scott J., Natasha L. Miles, Kenneth J. Davis, Thomas Lauvaux, Douglas K. Martins, Jocelyn C. Turnbull, **Kathryn McKain**, **Colm Sweeney** and Maria Obiminda L. Cambaliza, (2017), Tower measurement network of in-situ CO2, CH4, and CO in support of the Indianapolis FLUX (INFLUX) Experiment, *Elem Sci Anth*, 5, 59, 10.1525/elementa.140.

Rigby, Matthew, **Stephen A. Montzka**, Ronald G. Prinn, James W. C. White, Dickon Young, Simon O'Doherty, Mark F. Lunt, Anita L. Ganesan, Alistair J. Manning, Peter G. Simmonds, Peter K. Salameh, Christina M. Harth, Jens Mühle, Ray F. Weiss, Paul J. Fraser, L. Paul Steele, Paul B. Krummel, Archie McCulloch and Sunyoung Park, (2017), Role of atmospheric oxidation in recent methane growth, *Proceedings of the National Academy of Sciences*, 114, 21, 5373-5377, 10.1073/pnas.1616426114.

Saunois, Marielle, Philippe Bousquet, Ben Poulter, Anna Peregon, Philippe Ciais, Josep G. Canadell, **Edward J. Dlugokencky**, Giuseppe Etiope, David Bastviken, Sander Houweling, Greet Janssens-Maenhout, Francesco N. Tubiello, Simona Castaldi, Robert B. Jackson, Mihai Alexe, Vivek K. Arora, David J. Beerling, Peter Bergamaschi, Donald R. Blake, Gordon Brailsford, **Lori Bruhwiler**, Cyril Crevoisier, Patrick Crill, Kristofer Covey, Christian Frankenberg, Nicola Gedney, Lena Höglund-Isaksson, Misa Ishizawa, Akihiko Ito, Fortunat Joos, Heon-Sook Kim, Thomas Kleinen, Paul Krummel, Jean- François Lamarque, Ray Langenfelds, Robin Locatelli, Toshinobu Machida, Shamil Maksyutov, Joe R. Melton, Isamu Morino, Vaishali Naik, O&, apos, Simon Doherty, Frans-Jan W. Parmentier, Prabir K. Patra, Changhui Peng, Shushi Peng, Glen P. Peters, Isabelle Pison, Ronald Prinn, Michel Ramonet, William J. Riley, Makoto Saito, Monia Santini, Ronny Schroeder, Isobel J. Simpson, Renato Spahni, Atsushi Takizawa, Brett F. Thornton, Hanqin Tian, Yasunori Tohjima, Nicolas Viovy, Apostolos Voulgarakis, Ray Weiss, David J. Wilton, Andy Wiltshire, Doug Worthy, Debra Wunch, Xiyan Xu, Yukio Yoshida, Bowen Zhang, Zhen Zhang and Qiuan Zhu, (2017), Variability and quasi-decadal changes in the methane budget over the period 2000–2012, *Atmospheric Chemistry and Physics*, 17, 18, 11135-11161, 10.5194/acp-17-11135-2017.

Schwietzke, Stefan, **Gabrielle Pétron**, Stephen Conley, Cody Pickering, Ingrid Mielke-Maday, **Edward J. Dlugokencky**, **Pieter P. Tans**, Tim Vaughn, Clay Bell, Daniel Zimmerle, **Sonja Wolter**, Clark W. King, Allen B. White, Timothy Coleman, Laura Bianco and **Russell C. Schnell**, (2017), Improved Mechanistic Understanding of Natural Gas Methane Emissions from Spatially Resolved Aircraft Measurements, *Environmental Science & Technology*, 51, 12, 7286-7294, 10.1021/acs.est.7b01810.

Sherwood, Owen A., **Stefan Schwietzke**, Victoria A. Arling and Giuseppe Etiope, (2017), Global Inventory of Gas Geochemistry Data from Fossil Fuel, Microbial and Burning Sources, version 2017, *Earth System Science Data*, 9, 2, 639-656, 10.5194/essd-9-639-2017.

Smith, Mackenzie L., Alexander Gvakharia, Eric A. Kort, **Colm Sweeney**, Stephen A. Conley, Ian Faloona, **Tim Newberger**, **Russell Schnell**, **Stefan Schwietzke** and **Sonja Wolter**, (2017), Airborne Quantification of Methane Emissions over the Four Corners Region, *Environmental Science & Technology*, 51, 10, 5832-5837, 10.1021/acs.est.6b06107.

Sorribas, M., J.A. Adame, **E. Andrews** and M. Yela, (2017), An anomalous African dust event and its impact on aerosol radiative forcing on the Southwest Atlantic coast of Europe in February 2016, *Science of the Total Environment*, 583, 269-279, 10.1016/j.scitotenv.2017.01.064.

Stephens, Britton B., Matthew C. Long, Ralph F. Keeling, Eric A. Kort, **Colm Sweeney**, Eric C. Apel, Elliot L. Atlas, Stuart Beaton, Jonathan D. Bent, Nicola J. Blake, James F. Bresch, Joanna Casey, Bruce C. Daube, Minghui Diao, Ernesto Diaz, Heidi Dierssen, Valeria Donets, Bo-Cai Gao, Michelle Gierach, Robert Green, Justin Haag, Matthew Hayman, Alan J. Hills, Martín S. Hoecker-Martínez, Shawn B. Honomichl, Rebecca S. Hornbrook, Jorgen B. Jensen, Rong-Rong Li, Ian McCubbin, **Kathryn McKain**, Eric J. Morgan, Scott Nolte, Jordan G. Powers, Bryan Rainwater, Kaylan Randolph, Mike Reeves, Sue M. Schauffler, Mackenzie Smith, Katherine Smith, Jeff Stith, Gregory Stossmeister, Darin W. Toohey and Andrew S. Watt, (2017), The O2/N2 Ratio and CO2 Airborne Southern Ocean (ORCAS) Study, *Bulletin of the American Meteorological Society*, 10.1175/BAMS-D-16-0206.1.

Tans, Pieter P., **Andrew M. Crotwell** and **Kirk W. Thoning**, (2017), Abundances of isotopologues and calibration of CO2 greenhouse gas measurements, *Atmospheric Measurement Techniques*, 10, 7, 2669-2685, 10.5194/amt-10-2669-2017.

Thonat, Thibaud, Marielle Saunois, Philippe Bousquet, Isabelle Pison, Zeli Tan, Qianlai Zhuang, Patrick M. Crill, Brett F. Thornton, David Bastviken, **Ed J. Dlugokencky**, Nikita Zimov, Tuomas Laurila, Juha Hatakka, Ove Hermansen and Doug E. J. Worthy, (2017), Detectability of Arctic methane sources at six sites performing continuous atmospheric measurements, *Atmospheric Chemistry and Physics*, 17, 13, 8371-8394, 10.5194/acp-17-8371-2017.

Thorpe, Andrew K., Christian Frankenberg, David R. Thompson, Riley M. Duren, Andrew D. Aubrey, Brian D. Bue, Robert O. Green, Konstantin Gerilowski, Thomas Krings, Jakob Borchardt, Eric A. Kort, **Colm Sweeney**, Stephen Conley, Dar A. Roberts and Philip E. Dennison, (2017), Airborne DOAS retrievals of methane, carbon dioxide, and water vapor concentrations at high spatial resolution: application to AVIRIS-NG, *Atmospheric Measurement Techniques*, 10, 10, 3833-3850, 10.5194/amt-10-3833-2017.

Tsuruta, Aki, Tuula Aalto, Leif Backman, Janne Hakkarainen, Ingrid T. van der Laan-Luijkx, Maarten C. Krol, Renato Spahni, Sander Houweling, Marko Laine, **Ed Dlugokencky**, Angel J. Gomez-Pelaez, Marcel van der Schoot, Ray Langenfelds, Raymond Ellul, Jgor Arduini, Francesco Apadula, Christoph Gerbig, Dietrich G. Feist, Rigel Kivi, Yukio Yoshida and Wouter Peters, (2017), Global methane emission estimates for 2000–2012 from CarbonTracker Europe-CH4 v1.0, *Geoscientific Model Development*, 10, 3, 1261-1289, 10.5194/gmd-10-1261-2017.

Vaughn, Timothy L., Clay S. Bell, Tara I. Yacovitch, Joseph R. Roscioli, Scott C. Herndon, Stephen Conley, **Stefan Schwietzke**, Garvin A. Heath, **Gabrielle Pétron** and Daniel Zimmerle, (2017), Comparing facility-level methane emission rate estimates at natural gas gathering and boosting stations, *Elem Sci Anth*, 5, 71, 10.1525/elementa.257.

Vimont, Isaac J., Jocelyn C. Turnbull, Vasilii V. Petrenko, Philip F. Place, Anna Karion, Natasha L. Miles, Scott J. Richardson, Kevin Gurney, Risa Patarasuk, **Colm Sweeney**, Bruce Vaughn and James W.C. White, (2017), Carbon monoxide isotopic measurements in Indianapolis constrain urban source isotopic signatures and support mobile fossil fuel emissions as the dominant wintertime CO source, *Elem Sci Anth*, 5, 63, 10.1525/elementa.136.

Weatherhead, Betsy, Bruce A. Wielicki, V. Ramaswamy, Mark Abbott, Thomas Ackerman, Robert Atlas, Guy Brasseur, **Lori Bruhwiler**, Antonio Busalacchi, **James H. Butler**, Christopher T. M. Clack, Roger Cooke, Lidia Cucurull, Sean Davis, Jason M. English, David W. Fahey, Steven S. Fine, Jeffrey K. Lazo, Shunlin Liang, Norman G. Loeb, Eric Rignot, Brian Soden, **Diane Stanitski**, Graeme Stephens, Byron Tapley, Anne M. Thompson, Kevin E. Trenberth and Donald Wuebbles, (2017), Designing the Climate Observing System of the Future, *Earth's Future*, 10.1002/2017EF000627.

Weatherhead, Elizabeth C., Greg E. Bodeker, Alessandro Fassò, **Kai-Lan Chang**, Jeffrey K. Lazo, C. T. M. Clack, **Dale F. Hurst**, Birgit Hassler, Jason M. English and Soner Yorgun, (2017), Spatial Coverage of Monitoring Networks: A Climate Observing System Simulation Experiment, *Journal of Applied Meteorology and Climatology*, 56, 3211-3228, 10.1175/JAMC-D-17-0040.1

Whelan, Mary E., Sinikka T. Lennartz, Teresa E. Gimeno, Richard Wehr, Georg Wohlfahrt, Yuting Wang, Linda M. J. Kooijmans, Timothy W. Hilton, Sauveur Belviso, Philippe Peylin, Róisín Commane, Wu Sun, Huilin Chen, Le Kuai, Ivan Mammarella, Kadmiel Maseyk, Max Berkelhammer, King-Fai Li, Dan Yakir, Andrew Zumkehr, Yoko Katayama, Jérôme Ogée, Felix M. Spielmann, Florian Kitz, Bharat Rastogi, Jürgen Kesselmeier, Julia Marshall, Kukka-Maaria Erkkilä, Lisa Wingate, Laura K. Meredith,

Wei He, Rüdiger Bunk, Thomas Launois, Timo Vesala, Johan A. Schmidt, Cédric G. Fichot, Ulli Seibt, Scott Saleska, Eric S. Saltzman, **Stephen A. Montzka**, Joseph A. Berry and J. Elliott Campbell, (2017), Reviews and Syntheses: Carbonyl Sulfide as a Multi-scale Tracer for Carbon and Water Cycles, *Biogeosciences Discussions*, 1-97, 10.5194/bg-2017-427.

Zhang, Xianming, **John Barnes**, Ying D. Lei and Frank Wania, (2017), Semivolatile Organic Contaminants in the Hawaiian Atmosphere, *Environmental Science & Technology*, 51, 20, 11634-11642, 10.1021/acs.est.7b03841.

Camy-Peyret, C., G. Liuzzi, G. Masiello, C. Serio, S. Venafra and **S.A. Montzka**, (2017), Assessment of IASI capability for retrieving carbonyl sulphide (OCS), *Journal of Quantitative Spectroscopy and Radiative Transfer*, 201, 197-208, 10.1016/j.jqsrt.2017.07.006.

Fu, Congsheng, Xuhui Lee, Timothy J. Griffis, **Edward J. Dlugokencky** and **Arlyn E. Andrews**, (2017), Investigation of the N 2 O emission strength in the U. S. Corn Belt, *Atmospheric Research*, 194, 66-77, 10.1016/j.atmosres.2017.04.027.

Theme 1. Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks

Year of Publication: 2016

Alden, Caroline B., **John B. Miller**, Luciana V. Gatti, Manuel M. Gloor, Kaiyu Guan, Anna M. Michalak, Ingrid T. van der Laan-Luijkx, Danielle Touma, **Arlyn Andrews**, Luana S. Basso, Caio S. C. Correia, Lucas G. Domingues, Joanna Joiner, Maarten C. Krol, Alexei I. Lyapustin, Wouter Peters, Yoichi P. Shiga, **Kirk Thoning**, Ivar R. van der Velde, Thijs T. van Leeuwen, Vineet Yadav and Noah S. Diffenbaugh, (2016), Regional atmospheric CO inversion reveals seasonal and geographic differences in Amazon net biome exchange, *Global Change Biology*, 22, 10, 3427-3443, 10.1111/gcb.13305.

Bakker, Dorothee C. E., Benjamin Pfeil, Camilla S. Landa, Nicolas Metzl, O&, apos, Kevin M. Brien, Are Olsen, Karl Smith, Cathy Cosca, Sumiko Harasawa, Stephen D. Jones, Shin-ichiro Nakaoka, Yukihiro Nojiri, Ute Schuster, Tobias Steinhoff, **Colm Sweeney**, Taro Takahashi, Bronte Tilbrook, Chisato Wada, Rik Wanninkhof, Simone R. Alin, Carlos F. Balestrini, Leticia Barbero, Nicholas R. Bates, Alejandro A. Bianchi, Frédéric Bonou, Jacqueline Boutin, Yann Bozec, Eugene F. Burger, Wei-Jun Cai, Robert D. Castle, Liqi Chen, Melissa Chierici, Kim Currie, Wiley Evans, Charles Featherstone, Richard A. Feely, Agneta Fransson, Catherine Goyet, Naomi Greenwood, Luke Gregor, Steven Hankin, Nick J. Hardman-Mountford, Jérôme Harlay, Judith Hauck, Mario Hoppema, Matthew P. Humphreys, Christopher W. Hunt, Betty Huss, J. Severino P. Ibánhez, Truls Johannessen, Ralph Keeling, Vassilis Kitidis, Arne Körtzinger, Alex Kozyr, Evangelia Krasakopoulou, Akira Kuwata, Peter Landschützer, Siv K. Lauvset, NathalieLefèvre, Claire Lo Monaco, Ansley Manke, Jeremy T. Mathis, Liliane Merlivat, Frank J. Millero, Pedro M. S. Monteiro, David R. Munro, Akihiko Murata, **Timothy Newberger**. Abdirahman M. Omar, Tsuneo Ono, Kristina Paterson, David Pearce, Denis Pierrot, Lisa L. Robbins, Shu Saito, Joe Salisbury, Reiner Schlitzer, Bernd Schneider, Roland Schweitzer, Rainer Sieger, Ingunn Skjelvan, Kevin F. Sullivan, Stewart C. Sutherland, Adrienne J. Sutton, Kazuaki Tadokoro, Maciej Telszewski, Matthias Tuma, Steven M. A. C. van Heuven, Doug Vandemark, Brian Ward, Andrew J. Watson and Suqing Xu, (2016), A multi-decade record of high-quality fCO_2 data in version 3 of the Surface Ocean CO2 Atlas (SOCAT), *Earth System Science Data*, 8, 2, 383-413, 10.5194/essd-8-383-2016.

Barlow, J. M., P. I. Palmer and **L. M. Bruhwiler**, (2016), Increasing boreal wetland emissions inferred from reductions in atmospheric CH4 seasonal cycle, *Atmospheric Chemistry and Physics Discussions*, 1-38, 10.5194/acp-2016-752.

Basu, Sourish, **John Bharat Miller** and Scott Lehman, (2016), Separation of biospheric and fossil fuel fluxes of CO2 by atmospheric inversion of CO2 and 14CO2 measurements: Observation System Simulations, *Atmospheric Chemistry and Physics*, 16, 9, 5665-5683, 10.5194/acp-16-5665-2016.

Berchet, Antoine, Philippe Bousquet, Isabelle Pison, Robin Locatelli, Frédéric Chevallier, Jean-Daniel Paris, **Ed J. Dlugokencky**, Tuomas Laurila, Juha Hatakka, Yrjo Viisanen, Doug E. J. Worthy, Euan Nisbet, Rebecca Fisher, James France, David Lowry, Viktor Ivakhov and Ove Hermansen, (2016), Atmospheric constraints on the methane emissions from the East Siberian Shelf, *Atmospheric Chemistry and Physics*, 16, 6, 4147-4157, 10.5194/acp-16-4147-2016.

Berkelhammer, M., H. C. Steen-Larsen, A. Cosgrove, A. J. Peters, R. Johnson, M. Hayden and **S. A. Montzka**, (2016), Radiation and atmospheric circulation controls on carbonyl sulfide concentrations in the marine boundary layer, *Journal of Geophysical Research: Atmospheres*, 121, 21, 13,113-13,128, 10.1002/2016JD025437.

Bian, Lingen, Zhiqiu Gao, Yulong Sun, Minghu Ding, Jie Tang and **Russell C. Schnell**, (2016), CH4 Monitoring and Background Concentration at Zhongshan Station, Antarctica, *Atmospheric and Climate Sciences*, 06, 01, 135-144, 10.4236/acs.2016.61012.

Coakley, Kevin J, **John B Miller**, **Stephen A Montzka**, **Colm Sweeney** and **Ben R Miller**, (2016), Surrogate gas prediction model as a proxy for C-based measurements of fossil fuel CO , *Journal of Geophysical Research: Atmospheres*, 121, 12, 7489-7505, 10.1002/2015JD024715.

Dlugokencky, E.J., **B.D. Hall**, **M.J. Crotwell**, **S.A. Montzka**, **G. Dutton**, J. Muhle and **J.W. Elkins**, (2016), Long-lived Greenhouse Gases [in "State of the Climate in 2015"], *Bull. Amer. Meteor. Soc.*, 97, 8, S44-S46, 10.1175/2016BAMSStateoftheClimate.1.

Fang, Shuangxi, **Pieter P. Tans**, Martin Steinbacher, Lingxi Zhou, Tian Luan and Zou Li, (2016), Observation of atmospheric CO and CO at Shangri-La station: results from the only regional station located at southwestern China , *Tellus B*, 68, 10.3402/tellusb.v68.28506.

Frankenberg, Christian, Andrew K. Thorpe, David R. Thompson, Glynn Hulley, Eric Adam Kort, Nick Vance, Jakob Borchardt, Thomas Krings, Konstantin Gerilowski, **Colm Sweeney**, Stephen Conley, Brian D. Bue, Andrew D. Aubrey, Simon Hook and Robert O. Green, (2016), Airborne methane remote measurements reveal heavy-tail flux distribution in Four Corners region, *Proceedings of the National Academy of Sciences*, 113, 35, 9734-9739, 10.1073/pnas.1605617113.

Fu, Congsheng, Xuhui Lee, Timothy J. Griffis, **Edward J. Dlugokencky** and **Arlyn E. Andrews**, (2016), Relating atmospheric N2O concentration to N2O emission strength in the U. S. Corn Belt, *Atmospheric Chemistry and Physics Discussions*, 1-22, 10.5194/acp-2016-761.

Hardesty, R. Michael, W. Alan Brewer, Scott P. Sandberg, Ann M. Weickmann, Paul B. Shepson, Maria Cambaliza, Alexie Heimburger, Kenneth J. Davis, Thomas Lauvaux, Natasha L. Miles, Daniel P. Sarmiento, A. J. Deng, Brian Gaudet, Anna Karion, **Colm Sweeney**, James Whetstone, B. Gross, F. Moshary and M. Arend, (2016), Lidar Characterization of Boundary Layer Transport and Mixing for Estimating Urban-Scale Greenhouse Gas Emissions, *EPJ Web of Conferences*, 119, 09001, 10.1051/epjconf/201611909001.

Helmig, Detlev, Samuel Rossabi, Jacques Hueber, **Pieter Tans**, **Stephen A. Montzka**, **Ken Masarie**, **Kirk Thoning**, Christian Plass-Duelmer, Anja Claude, Lucy J. Carpenter, Alastair C. Lewis, Shalini Punjabi, Stefan Reimann, Martin K. Vollmer, Rainer Steinbrecher, James W. Hannigan, Louisa K. Emmons, Emmanuel Mahieu, Bruno Franco, Dan Smale and Andrea Pozzer, (2016), Reversal of global atmospheric ethane and propane trends largely due to US oil and natural gas production, *Nature Geoscience*, 9, 7, 490-495, 10.1038/ngeo2721.

Inoue, Makoto, Isamu Morino, Osamu Uchino, Takahiro Nakatsuru, Yukio Yoshida, Tatsuya Yokota, Debra Wunch, Paul O. Wennberg, Coleen M. Roehl, David W. T. Griffith, Voltaire A. Velazco, Nicholas M. Deutscher, Thorsten Warneke, Justus Notholt, John Robinson, Vanessa Sherlock, Frank Hase, Thomas Blumenstock, Markus Rettinger, Ralf Sussmann, Esko Kyrö, Rigel Kivi, Kei Shiomi, Shuji Kawakami, Martine De Mazière, Sabrina G. Arnold, Dietrich G. Feist, Erica A. Barrow, James Barney, Manvendra Dubey, Matthias Schneider, Laura T. Iraci, James R. Podolske, Patrick W. Hillyard, Toshinobu Machida, Yousuke Sawa, Kazuhiro Tsuboi, Hidekazu Matsueda, **Colm Sweeney**, **Pieter P. Tans**, Arlyn E. Andrews, Sebastien C. Biraud, Yukio Fukuyama, Jasna V. Pittman, Eric A. Kort and Tomoaki Tanaka, (2016), Bias corrections of GOSAT SWIR XCO2 and XCH4 with TCCON data and their evaluation using aircraft measurement data, *Atmospheric Measurement Techniques*, 9, 8, 3491-3512, 10.5194/amt-9-3491-2016.

Karion, Anna, **Colm Sweeney**, **John B. Miller**, **Arlyn E. Andrews**, Roisin Commane, Steven Dinardo, John M. Henderson, Jacob Lindaas, John C. Lin, Kristina A. Luus, **Tim Newberger**, **Pieter Tans**, Steven C. Wofsy, **Sonja Wolter** and Charles E. Miller, (2016), Investigating Alaskan methane and carbon dioxide fluxes using measurements from the CARVE tower, *Atmospheric Chemistry and Physics*, 16, 8, 5383-5398, 10.5194/acp-16-5383-2016.

Kooijmans, Linda M. J., Nelly A. M. Uitslag, Mark S. Zahniser, David D. Nelson, **Stephen A. Montzka** and **Huilin Chen**, (2016), Continuous and high-precision atmospheric concentration measurements of COS, CO2, CO and H2O using a quantum cascade laser spectrometer (QCLS), *Atmospheric Measurement Techniques*, 9, 11, 5293-5314, 10.5194/amt-9-5293-2016.

Kooijmans, Linda M. J., Nelly A. M. Uitslag, Mark S. Zahniser, David D. Nelson, **Stephen A. Montzka** and **Huilin Chen**, (2016), Continuous and high-precision atmospheric concentration measurements of COS, CO2, CO and H2O using a quantum cascade laser spectrometer (QCLS), *Atmospheric Measurement Techniques*, 9, 11, 5293-5314, 10.5194/amt-9-5293-2016.

Kort, E. A., M. L. Smith, L. T. Murray, A. Gvakharia, A. R. Brandt, J. Peischl, T. B. Ryerson, **C. Sweeney** and K. Travis, (2016), Fugitive emissions from the Bakken shale illustrate role of shale production in global ethane shift, *Geophysical Research Letters*, 43, 9, 4617-4623, 10.1002/2016GL068703.

LaFranchi, B. W., K. J. McFarlane, **J. B. Miller**, S. J. Lehman, C. L. Phillips, **A. E. Andrews**, **P. P. Tans**, **H. Chen**, Z. Liu, **J. C. Turnbull**, X. Xu and T. P. Guilderson, (2016), Strong regional atmospheric C signature of respired CO observed from a tall tower over the midwestern United States , *Journal of Geophysical Research: Biogeosciences*, 121, 8, 2275-2295, 10.1002/2015JG003271.

Lauvaux, Thomas, Natasha L. Miles, Aijun Deng, Scott J. Richardson, Maria O. Cambaliza, Kenneth J. Davis, Brian Gaudet, Kevin R. Gurney, Jianhua Huang, Darragh O'Keefe, Yang Song, Anna Karion, **Tomohiro Oda**, Risa Patarasuk, Igor Razlivanov, Daniel Sarmiento, Paul Shepson, **Colm Sweeney**, Jocelyn Turnbull and Kai Wu, (2016), High-resolution atmospheric inversion of urban CO emissions during the dormant season of the Indianapolis Flux Experiment (INFLUX) , *Journal of Geophysical Research: Atmospheres*, 121, 10, 5213-5236, 10.1002/2015JD024473.

Le Quéré, Corinne, Robbie M. Andrew, Josep G. Canadell, Stephen Sitch, Jan Ivar Korsbakken, Glen P. Peters, Andrew C. Manning, Thomas A. Boden, **Pieter P. Tans**, Richard A. Houghton, Ralph F. Keeling, Simone Alin, Oliver D. Andrews, Peter Anthoni, Leticia Barbero, Laurent Bopp, Frédéric Chevallier, Louise P. Chini, Philippe Ciais, Kim Currie, Christine Delire, Scott C. Doney, Pierre Friedlingstein, Thanos Gkritzalis, Ian Harris, Judith Hauck, Vanessa Haverd, Mario Hoppema, Kees Klein Goldewijk, Atul K. Jain, Etsushi Kato, Arne Körtzinger, Peter Landschützer, Nathalie Lefèvre, Andrew Lenton, Sebastian Lienert, Danica Lombardozzi, Joe R. Melton, Nicolas Metzl, Frank Millero, Pedro M. S. Monteiro, David R. Munro, Julia E. M. S. Nabel, Shin-ichiro Nakaoka, O&, apos, Kevin Brien, Are Olsen, Abdirahman M. Omar, Tsuneo Ono, Denis Pierrot, Benjamin Poulter, Christian Rödenbeck, Joe Salisbury, Ute Schuster, Jörg Schwinger, Roland Séférian, Ingunn Skjelvan, Benjamin D. Stocker, Adrienne J. Sutton, Taro Takahashi, Hanqin Tian, Bronte Tilbrook, Ingrid T. van der Laan-Luijkx, Guido R. van der Werf, Nicolas Viovy, Anthony P. Walker, Andrew J. Wiltshire and Sönke Zaehle, (2016), Global Carbon Budget 2016, *Earth System Science Data*, 8, 2, 605-649, 10.5194/essd-8-605-2016.

McNorton, Joe, Martyn P. Chipperfield, Manuel Gloor, Chris Wilson, Wuhu Feng, Garry D. Hayman, Matt Rigby, Paul B. Krummel, O&apos, Simon Doherty, Ronald G. Prinn, Ray F. Weiss, Dickon Young, **Ed Dlugokencky** and **Steve A. Montzka**, (2016), Role of OH variability in the stalling of the global atmospheric CH4 growth rate from 1999 to 2006, *Atmospheric Chemistry and Physics*, 16, 12, 7943-7956, 10.5194/acp-16-7943-2016.

Miller, Scot M., Charles E. Miller, Roisin Commane, Rachel Y.-W. Chang, Steven J. Dinardo, John M. Henderson, Anna Karion, Jakob Lindaas, Joe R. Melton, **John B. Miller**, **Colm Sweeney**, Steven C. Wofsy and Anna M. Michalak, (2016), A multiyear estimate of methane fluxes in Alaska from CARVE atmospheric observations, *Global Biogeochemical Cycles*, 30, 10, 1441-1453, 10.1002/2016GB005419.

Miller, Scot M., Roisin Commane, Joe R. Melton, **Arlyn E. Andrews**, Joshua Benmergui, **Edward J. Dlugokencky**, Greet Janssens-Maenhout, Anna M. Michalak, **Colm Sweeney** and Doug E. J. Worthy, (2016), Evaluation of wetland methane emissions across North America using atmospheric data and inverse modeling, *Biogeosciences*, 13, 4, 1329-1339, 10.5194/bg-13-1329-2016.

Nisbet, E. G., **E. J. Dlugokencky**, M. R. Manning, D. Lowry, R. E. Fisher, J. L. France, S. E. Michel, **J. B. Miller**, J. W. C. White, B. Vaughn, P. Bousquet, J. A. Pyle, N. J. Warwick, M. Cain, R. Brownlow, G. Zazzeri, M. Lanoisellé, A. C. Manning, E. Gloor, D. E. J. Worthy, E.-G. Brunke, C. Labuschagne, E. W. Wolff and A. L. Ganesan, (2016), Rising atmospheric methane: 2007-2014 growth and isotopic shift, *Global Biogeochemical Cycles*, 30, 9, 1356-1370, 10.1002/2016GB005406.

Pandey, Sudhanshu, Sander Houweling, Maarten Krol, Ilse Aben, Frédéric Chevallier, **Edward J. Dlugokencky**, Luciana V. Gatti, Emanuel Gloor, **John B. Miller**, Rob Detmers, Toshinobu Machida and Thomas Röckmann, (2016), Inverse modeling of GOSAT-retrieved ratios of total column CH4 and CO2 for 2009 and 2010, *Atmospheric Chemistry and Physics*, 16, 8, 5043-5062, 10.5194/acp-16-5043-2016.

Parazoo, Nicholas C., Roisin Commane, Steven C. Wofsy, Charles D. Koven, **Colm Sweeney**, David M. Lawrence, Jakob Lindaas, Rachel Y.-W. Chang and Charles E. Miller, (2016), Detecting regional patterns of changing CO flux in Alaska , *Proceedings of the National Academy of Sciences*, 113, 28, 7733-7738, 10.1073/pnas.1601085113.

Patra, Prabir K., Tazu SAEKI, **Edward J. DLUGOKENCKY**, Kentaro ISHIJIMA, Taku UMEZAWA, Akihiko ITO, Shuji AOKI, Shinji MORIMOTO, Eric A. KORT, **Andrew CROTWELL**, Kunchala RAVI KUMAR and Takakiyo NAKAZAWA, (2016), Regional Methane Emission Estimation Based on Observed Atmospheric Concentrations (2002-2012), *Journal of the Meteorological Society of Japan. Ser. II*, 94, 1, 91-113, 10.2151/jmsj.2016-006.

Peischl, J., A. Karion, **C. Sweeney**, E. A. Kort, M. L. Smith, A. R. Brandt, T. Yeskoo, K. C. Aikin, S. A. Conley, A. Gvakharia, M. Trainer, **S. Wolter** and T. B. Ryerson, (2016), Quantifying atmospheric methane emissions from oil and natural gas production in the Bakken shale region of North Dakota, *Journal of Geophysical Research: Atmospheres*, 121, 10, 6101-6111, 10.1002/2015JD024631.

Pollmann, Jan, Detlev Helmig, Daniel Liptzin, Chelsea R. Thompson, Jacques Hueber, **Pieter P. Tans** and Jos Lelieveld, (2016), Variability analyses, site characterization, and regional [OH] estimates using trace gas measurements from the NOAA Global Greenhouse Gas Reference Network, *Elementa: Science of the Anthropocene*, 4, 000128, 10.12952/journal.elementa.000128.

Rhoderick, George C., **Duane R. Kitzis**, Michael E. Kelley, Walter R. Miller, **Bradley D. Hall**, **Edward J. Dlugokencky**, **Pieter P. Tans**, Antonio Possolo and Jennifer Carney, (2016), Development of a Northern Continental Air Standard Reference Material, *Analytical Chemistry*, 88, 6, 3376-3385, 10.1021/acs.analchem.6b00123.

Saunois, Marielle, Philippe Bousquet, Ben Poulter, Anna Peregon, Philippe Ciais, Josep G. Canadell, **Edward J. Dlugokencky**, Giuseppe Etiope, David Bastviken, Sander Houweling, Greet Janssens-Maenhout, Francesco N. Tubiello, Simona Castaldi, Robert B. Jackson, Mihai Alexe, Vivek K. Arora, David J. Beerling, Peter Bergamaschi, Donald R. Blake, Gordon Brailsford, Victor Brovkin, **Lori Bruhwiler**, Cyril Crevoisier, Patrick Crill, Kristofer Covey, Charles Curry, Christian Frankenberg, Nicola Gedney, Lena Höglund-Isaksson, Misa Ishizawa, Akihiko Ito, Fortunat Joos, Heon-Sook Kim, Thomas Kleinen, Paul Krummel, Jean-François Lamarque, Ray Langenfelds, Robin Locatelli, Toshinobu Machida, Shamil Maksyutov, Kyle C. McDonald, Julia Marshall, Joe R. Melton, Isamu Morino, Vaishali Naik, O&, apos, Simon Doherty, Frans-Jan W. Parmentier, Prabir K. Patra, Changhui Peng, Shushi Peng, Glen P. Peters, Isabelle Pison, Catherine Prigent, Ronald Prinn, Michel Ramonet, William J. Riley, Makoto Saito, Monia Santini, Ronny Schroeder, Isobel J. Simpson, Renato Spahni, Paul Steele, Atsushi Takizawa, Brett F. Thornton, Hanqin Tian, Yasunori Tohjima, Nicolas Viovy, Apostolos Voulgarakis, Michiel van Weele, Guido R. van der Werf, Ray Weiss, Christine Wiedinmyer, David J. Wilton, Andy Wiltshire, Doug Worthy, Debra Wunch, Xiyan Xu, Yukio Yoshida, Bowen Zhang, Zhen Zhang and Qiuan Zhu, (2016), The global methane budget 2000–2012, *Earth System Science Data*, 8, 2, 697-751, 10.5194/essd-8-697-2016.

Schaefer, H., S. E. M. Fletcher, C. Veidt, K. R. Lassey, G. W. Brailsford, T. M. Bromley, **E. J. Dlugokencky**, S. E. Michel, **J. B. Miller**, I. Levin, D. C. Lowe, R. J. Martin, B. H. Vaughn and J. W. C. White, (2016), A 21st-century shift from fossil-fuel to biogenic methane emissions indicated by 13CH4, *Science*, 352, 6281, 80-84, 10.1126/science.aad2705.

Schwietzke, Stefan, Owen A. Sherwood, **Lori M. P. Bruhwiler**, **John B. Miller**, Giuseppe Etiope, **Edward J. Dlugokencky**, Sylvia Englund Michel, Victoria A. Arling, Bruce H. Vaughn, James W. C. White and **Pieter P. Tans**, (2016), Upward revision of global fossil fuel methane emissions based on isotope database, *Nature*, 538, 7623, 88-91, 10.1038/nature19797.

Song, Hajoon, John Marshall, David R. Munro, Stephanie Dutkiewicz, **Colm Sweeney**, D. J. McGillicuddy and Ute Hausmann, (2016), Mesoscale modulation of air-sea CO flux in Drake Passage , *Journal of Geophysical Research: Oceans*, 121, 9, 6635-6649, 10.1002/2016JC011714.
K.
Sweeney, Colm, **Edward Dlugokencky**, Charles E. Miller, Steven Wofsy, Anna Karion, Steve Dinardo, Rachel Y.-W. Chang, **John B. Miller**, **Lori Bruhwiler**, **Andrew M. Crotwell**, **Tim Newberger**, **Kathryn McKain**, **Robert S. Stone**, **Sonja E. Wolter**, **Patricia E. Lang** and **Pieter Tans**, (2016), No significant increase in long-term CH emissions on North Slope of Alaska despite significant increase in air temperature , *Geophysical Research Letters*, 43, 12, 6604-6611, 10.1002/2016GL069292.

Tan, Zeli, Qianlai Zhuang, Daven K. Henze, Christian Frankenberg, **Ed Dlugokencky**, **Colm Sweeney**, Alexander J. Turner, Motoki Sasakawa and Toshinobu Machida, (2016), Inverse modeling of pan-Arctic methane emissions at high spatial resolution: what can we learn from assimilating satellite retrievals and using different process-based wetland and lake biogeochemical models?, *Atmospheric Chemistry and Physics*, 16, 19, 12649-12666, 10.5194/acp-16-12649-2016.

Tans, P., (2016), Nurturing natural carbon sinks [in Climate 2020], *UNA-UK*, 44-47,.
1. Tian, Hanqin, Chaoqun Lu, Philippe Ciais, Anna M. Michalak, Josep G. Canadell, Eri Saikawa, Deborah N. Huntzinger, Kevin R. Gurney, Stephen Sitch, Bowen Zhang, Jia Yang, Philippe Bousquet, **Lori Bruhwiler**, Guangsheng Chen, **Edward Dlugokencky**, Pierre Friedlingstein, Jerry Melillo, Shufen Pan, Benjamin Poulter, Ronald Prinn, Marielle Saunois, Christopher R. Schwalm and Steven C. Wofsy, (2016), The terrestrial biosphere as a net source of greenhouse gases to the atmosphere, *Nature*, 531, 7593, 225-228, 10.1038/nature16946.

Zona, Donatella, Beniamino Gioli, Róisín Commane, Jakob Lindaas, Steven C. Wofsy, Charles E. Miller, Steven J. Dinardo, Sigrid Dengel, **Colm Sweeney**, Anna Karion, Rachel Y.-W. Chang, John M. Henderson, Patrick C. Murphy, Jordan P. Goodrich, Virginie Moreaux, Anna 1. Liljedahl, Jennifer D. Watts, John S. Kimball, David A. Lipson and Walter C. Oechel, (2016), Cold season emissions dominate the Arctic tundra methane budget, *Proceedings of the National Academy of Sciences*, 113, 1, 40-45, 10.1073/pnas.1516017113.

Theme 1. Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks

Year of Publication: 2015

Alexe, M., P. Bergamaschi, A. Segers, R. Detmers, A. Butz, O. Hasekamp, S. Guerlet, R. Parker, H. Boesch, C. Frankenberg, R. A. Scheepmaker, **E. Dlugokencky**, **C. Sweeney**, S. C. Wofsy and E. A. Kort, (2015), Inverse modelling of CH4 emissions for 2010–2011 using different satellite retrieval products from GOSAT and SCIAMACHY, *Atmospheric Chemistry and Physics*, 15, 1, 10.5194/acp-15-113-2015.

Babenhauserheide, A., **S. Basu**, S. Houweling, W. Peters and A. Butz, (2015), Comparing the CarbonTracker and M5-4DVar data assimilation systems for CO2 surface flux inversions, *Atmospheric Chemistry and Physics*, 15, 17, 9747-9763, 10.5194/acp-15-9747-2015.

Ballantyne, A. P., R. Andres, R. Houghton, B. D. Stocker, R. Wanninkhof, W. Anderegg, L. A. Cooper, M. DeGrandpre, **P. P. Tans**, J. B. Miller, C. Alden and J. W. C. White, (2015), Audit of the global carbon budget: estimate errors and their impact on uptake uncertainty, *Biogeosciences*, 12, 8, 2565-2584, 10.5194/bg-12-2565-2015.

Barlow, J. M., P. I. Palmer, **L. M. Bruhwiler** and **P. Tans**, (2015), Analysis of CO2 mole fraction data: first evidence of large-scale changes in CO2 uptake at high northern latitudes, *Atmospheric Chemistry and Physics*, 15, 23, 13739-13758, 10.5194/acp-15-13739-2015.

Bergamaschi, P., M. Corazza, U. Karstens, M. Athanassiadou, R. L. Thompson, I. Pison, A. J. Manning, P. Bousquet, A. Segers, A. T. Vermeulen, G. Janssens-Maenhout, M. Schmidt, M. Ramonet, F. Meinhardt, T. Aalto, L. Haszpra, J. Moncrieff, M. E. Popa, D. Lowry, M. Steinbacher and **A. Jordan**, (2015), Top-down estimates of European CH4 and N2O emissions based on four different inverse models, *Atmospheric Chemistry and Physics*, 15, 2, 10.5194/acp-15-715-2015.

Cambaliza, M. O. L., P. B. Shepson, J. Bogner, D. R. Caulton, B. Stirm, **C. Sweeney**, **S. A. Montzka**, K. R. Gurney, K. Spokas, O. E. Salmon, T. N. Lavoie, A. Hendricks, K. Mays, **J. Turnbull**, **B. R. Miller**, T. Lauvaux, K. Davis, **A. Karion**, B. Moser, C. Miller, C. Obermeyer, J. Whetstone, K. Prasad, N. Miles and S. Richardson, (2015), Quantification and source apportionment of the methane emission flux from the city of Indianapolis, *Elementa: Science of the Anthropocene*, 3, 10.12952/journal.elementa.000037

Commane, Róisín, Laura K. Meredith, Ian T. Baker, Joseph A. Berry, J. William Munger, **Stephen A. Montzka**, Pamela H. Templer, Stephanie M. Juice, Mark S. Zahniser and Steven C. Wofsy, (2015), Seasonal fluxes of carbonyl sulfide in a midlatitude forest, *Proceedings of the National Academy of Sciences*, 112, 46, 14162-14167, 10.1073/pnas.1504131112.

Desai, Ankur R., Ke Xu, Hanqin Tian, Peter Weishampel, Jonathan Thom, Dan Baumann, **Arlyn E. Andrews**, Bruce D. Cook, Jennifer Y. King and Randall Kolka, (2015), Landscape-level terrestrial methane flux observed from a very tall tower, *Agricultural and Forest Meteorology*, 201, 10.1016/j.agrformet.2014.10.017.

E. J. Dlugokencky, **B. D. Hall**, **S. A. Montzka**, **G. Dutton** and J. Muhle, **J. W. Elkins**, (2015), Long-Lived greenhouse gases, *Bulletin of the American Meteorological Society*, 96, (8), S44-S46.

Fang, S. X., **P. P. Tans**, M. Steinbacher, L. X. Zhou and T. Luan, (2015), Comparison of the regional CO2 mole fraction filtering approaches at a WMO/GAW regional station in China, *Atmospheric Measurement Techniques*, 8, 12, 5301-5313, 10.5194/amt-8-5301-2015.

Gao, Ru-Shan, **James W. Elkins**, Gregory J. Frost, **Allison C. McComiskey**, **Fred L. Moore**, Daniel M. Murphy, **John A. Ogren**, **Irina Petropavlovskikh** and Karen H. Rosenlof, (2015), A Novel Approach to Atmospheric Measurements Using Gliding UASs, *Dynamic Data-Driven Environmental Systems Science*, 10-15, 10.1007/978-3-319-25138-7, 2.

Ghosh, A., P. K. Patra, K. Ishijima, T. Umezawa, A. Ito, D. M. Etheridge, S. Sugawara, K. Kawamura, **J. B. Miller**, **E. J. Dlugokencky**, P. B. Krummel, P. J. Fraser, L. P. Steele, R. L. Langenfelds, C. M. Trudinger, J. W. C. White, B. Vaughn, T. Saeki, S. Aoki and T. Nakazawa, (2015), Variations in global methane sources and sinks during 1910–2010, *Atmospheric Chemistry and Physics*, 15, 5, 2595-2612, 10.5194/acp-15-2595-2015.

Houweling, S., D. Baker, **S. Basu**, H. Boesch, A. Butz, F. Chevallier, F. Deng, **E. J. Dlugokencky**, L. Feng, A. Ganshin, O. Hasekamp, D. Jones, S. Maksyutov, J. Marshall, T. Oda, C. W. O'Dell, S. Oshchepkov, P. I. Palmer, P. Peylin, Z. Poussi, F. Reum, H. Takagi, Y. Yoshida and R. Zhuravlev, (2015), An intercomparison of inverse models for estimating sources and sinks of CO using GOSAT measurements , *Journal of Geophysical Research: Atmospheres*, 120, 10, 10.1002/2014JD022962.

Karion, Anna, **Colm Sweeney**, Eric A. Kort, Paul B. Shepson, Alan Brewer, Maria Cambaliza, Stephen A. Conley, Ken Davis, Aijun Deng, Mike Hardesty, Scott C. Herndon, Thomas Lauvaux, Tegan Lavoie, David Lyon, **Tim Newberger**, **Gabrielle Pétron**, Chris Rella, Mackenzie Smith, **Sonja Wolter**, Tara I. Yacovitch and **Pieter Tans**, (2015), Aircraft-Based Estimate of Total Methane Emissions from the Barnett Shale Region, *Environmental Science & Technology*, 49, 13, 8124-8131, 10.1021/acs.est.5b00217.

Kuai, Le, John R. Worden, J. Elliott Campbell, Susan S. Kulawik, King-Fai Li, Meemong Lee, Richard J. Weidner, **Stephen A. Montzka**, **Fred L. Moore**, Joe A. Berry, Ian Baker, A. Scott Denning, Huisheng Bian, Kevin W. Bowman, Junjie Liu and Yuk L. Yung, (2015), Estimate of carbonyl sulfide tropical oceanic surface fluxes using Aura Tropospheric Emission Spectrometer observations, *Journal of Geophysical Research: Atmospheres*, 120, 20, 11,012-11,023, 10.1002/2015JD023493.

Le Quéré, C., R. Moriarty, R. M. Andrew, G. P. Peters, P. Ciais, P. Friedlingstein, S. D. Jones, S. Sitch, **P. Tans**, A. Arneth, T. A. Boden, L. Bopp, Y. Bozec, J. G. Canadell, L. P. Chini, F. Chevallier, C. E. Cosca, I. Harris, M. Hoppema, R. A. Houghton, J. I. House, A. K. Jain, T. Johannessen, E. Kato, R. F. Keeling, V. Kitidis, K. Klein Goldewijk, C. Koven, C. S. Landa, P. Landschützer, A. Lenton, I. D. Lima, G. Marland, J. T. Mathis, N. Metzl, Y. Nojiri, A. Olsen, T. Ono, S. Peng, W. Peters, B. Pfeil, B. Poulter, M. R. Raupach, P.

Regnier, C. Rödenbeck, S. Saito, J. E. Salisbury, U. Schuster, J. Schwinger, R. Séférian, J. Segschneider, T. Steinhoff, B. D. Stocker, A. J. Sutton, T. Takahashi, B. Tilbrook, G. R. van der Werf, N. Viovy, Y.-P. Wang, R. Wanninkhof, A. Wiltshire and N. Zeng, (2015), Global carbon budget 2014, *Earth System Science Data*, 7, 1, 47-85, 10.5194/essd-7-47-2015.

Le Quéré, C., R. Moriarty, R. M. Andrew, J. G. Canadell, S. Sitch, J. I. Korsbakken, P. Friedlingstein, G. P. Peters, R. J. Andres, T. A. Boden, R. A. Houghton, J. I. House, R. F. Keeling, **P. Tans**, A. Arneth, D. C. E. Bakker, L. Barbero, L. Bopp, J. Chang, F. Chevallier, L. P. Chini, P. Ciais, M. Fader, R. A. Feely, T. Gkritzalis, I. Harris, J. Hauck, T. Ilyina, A. K. Jain, E. Kato, V. Kitidis, K. Klein Goldewijk, C. Koven, P. Landschützer, S. K. Lauvset, N. Lefèvre, A. Lenton, I. D. Lima, N. Metzl, F. Millero, D. R. Munro, A. Murata, J. E. M. S. Nabel, S. Nakaoka, Y. Nojiri, K. O'Brien, A. Olsen, T. Ono, F. F.

Pérez, B. Pfeil, D. Pierrot, B. Poulter, G. Rehder, C. Rödenbeck, S. Saito, U. Schuster, J. Schwinger, R. Séférian, T. Steinhoff, B. D. Stocker, A. J. Sutton, T. Takahashi, B. Tilbrook, I. T. van der Laan-Luijkx, G. R. van der Werf, S. van Heuven, D. Vandemark, N. Viovy, A. Wiltshire, S. Zaehle and N. Zeng, (2015), Global Carbon Budget 2015, *Earth System Science Data*, 7, 2, 349-396, 10.5194/essd-7-349-2015.

Lee, Temple R., Stephan F. J. De Wekker, Sandip Pal, **Arlyn E. Andrews** and **Jonathan Kofler**, (2015), Meteorological controls on the diurnal variability of carbon monoxide mixing ratio at a mountaintop monitoring site in the Appalachian Mountains, *Tellus B: Chemical and Physical Meteorology*, 67, 1, 25659, 10.3402/tellusb.v67.25659.

Miller, S. M., M. N. Hayek, **A. E. Andrews**, I. Fung and J. Liu, (2015), Biases in atmospheric CO2 estimates from correlated meteorology modeling errors, *Atmospheric Chemistry and Physics*, 15, 5, 2903-2914, 10.5194/acp-15-2903-2015.

Molina, L., G. Broquet, P. Imbach, F. Chevallier, B. Poulter, D. Bonal, B. Burban, M. Ramonet, L. V. Gatti, S. C. Wofsy, J. W. Munger, **E. Dlugokencky** and P. Ciais, (2015), On the ability of a global atmospheric inversion to constrain variations of CO_2 fluxes over Amazonia, *Atmospheric Chemistry and Physics*, 15, 14, 8423-8438, 10.5194/acp-15-8423-2015.

Ogle, Stephen M, Kenneth Davis, Thomas Lauvaux, Andrew Schuh, Dan Cooley, Tristram O West, Linda S Heath, Natasha L Miles, Scott Richardson, F Jay Breidt, James E Smith, Jessica L McCarty, Kevin R Gurney, **Pieter Tans** and A Scott Denning, (2015), An approach for verifying biogenic greenhouse gas emissions inventories with atmospheric CO2 concentration data , *Environmental Research Letters*, 10, 3, 10.1088/1748-9326/10/3/034012.

Ou-Yang, Chang-Feng, Ming-Cheng Yen, Tang-Huang Lin, Jia-Lin Wang, **Russell C Schnell**, **Patricia M Lang**, Somporn Chantara and Neng-Huei Lin, (2015), Impact of equatorial and continental airflow on primary greenhouse gases in the northern South China Sea, *Environmental Research Letters*, 10, 6, 065005, 10.1088/1748- 9326/10/6/065005.

Sweeney, Colm, **Anna Karion**, **Sonja Wolter**, **Timothy Newberger**, **Doug Guenther**, **Jack A. Higgs**, **Arlyn Elyzabeth Andrews**, **Patricia M. Lang**, **Don Neff**, **Edward Dlugokencky**, **John B. Miller**, **Stephen A. Montzka**, **Ben R. Miller**, **Ken Alan Masarie**, Sebastien Christophe Biraud, **Paul C. Novelli**, **Molly Crotwell**, **Andrew M. Crotwell**, **Kirk Thoning** and **Pieter P. Tans**, (2015), Seasonal climatology of CO2 across North America from aircraft measurements in the NOAA/ESRL Global Greenhouse Gas Reference Network, *Journal of Geophysical Research: Atmospheres*, 120, 10, 5155-5190, 10.1002/2014JD022591.

Tans, P., (2015), Our carbon footprint [in Climate 2020}, *UNA-UK*.
1. Thompson, R. L., A. Stohl, L. X. Zhou, **E. Dlugokencky**, Y. Fukuyama, Y. Tohjima, S.-Y. Kim, H. Lee, E. G. Nisbet, R. E. Fisher, D. Lowry, R. F. Weiss, R. G. Prinn, S. O'Doherty, D. Young and J. W. C. White, (2015), Methane emissions in East Asia for 2000-2011 estimated using an atmospheric Bayesian inversion, *Journal of Geophysical Research: Atmospheres*, 120, 9, 4352-4369, 10.1002/2014JD022394.

Turnbull, Jocelyn C., **Colm Sweeney**, **Anna Karion**, **Timothy Newberger**, Scott J. Lehman, **Pieter P. Tans**, Kenneth J. Davis, Thomas Lauvaux, Natasha L. Miles, Scott J. Richardson, Maria Obiminda Cambaliza, Paul B. Shepson, Kevin Gurney, Risa Patarasuk and Igor Razlivanov, (2015), Toward quantification and source sector identification of fossil fuel CO2 emissions from an urban area: Results from the INFLUX experiment, *Journal of Geophysical Research: Atmospheres*, 120, 1, 10.1002/2014jd022555.

Turner, A. J., D. J. Jacob, K. J. Wecht, J. D. Maasakkers, E. Lundgren, **A. E. Andrews**, S. C. Biraud, H. Boesch, K. W. Bowman, N. M. Deutscher, M. K. Dubey, D. W. T. Griffith, F. Hase, A. Kuze, J. Notholt, H. Ohyama, R. Parker, V. H. Payne, R. Sussmann, **C. Sweeney**, V. A. Velazco, T. Warneke, P. O. Wennberg and D. Wunch, (2015), Estimating global and North American methane emissions with high spatial resolution using GOSAT satellite data, *Atmospheric Chemistry and Physics*, 15, 12, 7049-7069, 10.5194/acp-15-7049-2015.

Wells, K. C., D. B. Millet, N. Bousserez, D. K. Henze, S. Chaliyakunnel, T. J. Griffis, Y. Luan, **E. J. Dlugokencky**, R. G. Prinn, S. O'Doherty, R. F. Weiss, **G. S. Dutton**, **J. W. Elkins**, P. B. Krummel, R. Langenfelds, L. P. Steele, E. A. Kort, S. C. Wofsy and T. Umezawa, (2015), Simulation of atmospheric N_2O with GEOS-Chem and its adjoint: evaluation of observational constraints, *Geoscientific Model Development*, 8, 10, 3179-3198, 10.5194/gmd-8-3179-2015.

Xia, Lingjun, Lingxi Zhou, **Pieter P. Tans**, Lixin Liu, Gen Zhang, Hongyang Wang and Tian Luan, (2015), Atmospheric CO2 and its δ13C measurements from flask sampling at Lin'an regional background station in China, *Atmospheric Environment*, 117, 220-226, 10.1016/j.atmosenv.2015.07.008.

Theme 1. Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks

Year of Publication: 2014

Andrews, A. E., **J. D. Kofler**, **M. E. Trudeau**, J. C. Williams, **D. H. Neff**, **K. A. Masarie**, **D. Y. Chao**, **D. R. Kitzis**, **P. C. Novelli**, **C. L. Zhao**, **E. J. Dlugokencky**, **P. M. Lang**, **M. J. Crotwell**, M. L. Fischer, M. J. Parker, J. T. Lee, D. D. Baumann, A. R. Desai, C. O. Stanier, S. F. J. De Wekker, D. E. Wolfe, J. W. Munger and **P. P. Tans**, (2014), CO2, CO, and CH4 measurements from tall towers in the NOAA Earth System Research Laboratory's Global Greenhouse Gas Reference Network: instrumentation, uncertainty analysis, and recommendations for future high-accuracy greenhouse gas monitoring efforts, *Atmospheric Measurement Techniques*, 7, 2, 647-687, 10.5194/amt-7-647-2014 .

Basu, S., M. Krol, A. Butz, C. Clerbaux, Y. Sawa, T. Machida, H. Matsueda, C. Frankenberg, O. P. Hasekamp and I. Aben, (2014), The seasonal variation of the CO flux over Tropical Asia estimated from GOSAT, CONTRAIL, and IASI , *Geophysical Research Letters*, 41, 5, 10.1002/2013GL059105.

Berkelhammer, M., D. Asaf, C. Still, **S. Montzka**, D. Noone, M. Gupta, R. Provencal, **H. Chen** and D Yakir, (2014), Constraining surface carbon fluxes using measurements of carbonyl sulfide and carbon dioxide , *Global Biogeochemical Cycles*, 10.1002/2013GB004644.

Bowling, D. R., A. P. Ballantyne, **J. B. Miller**, S. P. Burns, **T. J. Conway**, O. Menzer, B. B. Stephens and B. H. Vaughn, (2014), Ecological processes dominate the C land disequilibrium in a Rocky Mountain subalpine forest , *Global Biogeochemical Cycles*, 28, 4, 10.1002/2013gb004686.

Brandt, A. R., G. A. Heath, E. A. Kort, F. O'Sullivan, **G. Petron**, S. M. Jordaan, **P. Tans**, J. Wilcox, A. M. Gopstein, D. Arent, S. Wofsy, N. J. Brown, R. Bradley, G. D. Stucky, D. Eardley and R. Harriss, (2014), Methane Leaks from North American Natural Gas Systems, *Science*, 343, 6172, 733-735, 10.1126/science.1247045.

Bruhwiler, L., **E. Dlugokencky**, **K. Masarie**, M. Ishizawa, **A. Andrews**, **J. Miller**, **C. Sweeney**, **P. Tans** and D. Worthy, (2014), CarbonTracker-CH4: an assimilation system for estimating emissions of atmospheric methane, *Atmospheric Chemistry and Physics*, 14, 16, 10.5194/acp-14-8269-2014.

Buizert, C., P. Martinerie, V. V. Petrenko, J. P. Severinghaus, C. M. Trudinger, E. Witrant, J. L. Rosen, A. J. Orsi, M. Rubino, D. M. Etheridge, L. P. Steele, C. Hogan, J. C. Laube, W. T. Sturges, V. A. Levchenko, A. M. Smith, I. Levin, **T. J. Conway**, **E. J. Dlugokencky**, **P. M. Lang**, K. Kawamura, T. M. Jenk, J. W. C. White, T. Sowers, J. Schwander and T. Blunier, (2014), Corrigendum to ``Gas transport in firn: multiple-tracer characterisation and model intercomparison for NEEM, Northern Greenland'' published in Atmos. Chem. Phys., 12, 4259--4277, 2012, *Atmospheric Chemistry and Physics*, 14, 7, 3571-3572, 10.5194/acp-14-3571-2014.

Cambaliza, M. O. L., P. B. Shepson, D. R. Caulton, B. Stirm, D. Samarov, K. R. Gurney, **J. Turnbull**, K. J. Davis, A. Possolo, **A. Karion**, **C. Sweeney**, B. Moser, A. Hendricks, T. Lauvaux, K. Mays, J. Whetstone, J. Huang, I. Razlivanov, N. L. Miles and S. J. Richardson, (2014), Assessment of uncertainties of an aircraft-based mass balance approach for quantifying urban greenhouse gas emissions, *Atmospheric Chemistry and Physics*, 14, 17, 9029-9050, 10.5194/acp-14-9029-2014 .

Caulton, D. R., P. B. Shepson, R. L. Santoro, J. P. Sparks, R. W. Howarth, A. R. Ingraffea, M. O. L. Cambaliza, **C. Sweeney**, **A. Karion**, K. J. Davis, B. H. Stirm, **S. A. Montzka** and **B. R. Miller**, (2014), Toward a better understanding and quantification of methane emissions from shale gas development, *Proceedings of the National Academy of Sciences*, 111, 17, 10.1073/pnas.1316546111.

Chang, Rachel Y.-W., Charles E. Miller, Steven J. Dinardo, **Anna Karion**, **Colm Sweeney**, Bruce C. Daube, John M. Henderson, Marikate E. Mountain, Janusz Eluszkiewicz, **John B. Miller**, **Lori M. P. Bruhwiler** and Steven C. Wofsy, (2014), Methane emissions from Alaska in 2012 from CARVE airborne observations, *Proceedings of the National Academy of Sciences*, 111, 47, 10.1073/pnas.1412953111.

Ciais, P., A. J. Dolman, A. Bombelli, R. Duren, A. Peregon, P. J. Rayner, C. Miller, N. Gobron, G. Kinderman, G. Marland, N. Gruber, F. Chevallier, R. J. Andres, G. Balsamo, L. Bopp, F.-M. Bréon, G. Broquet, R. Dargaville, T. J. Battin, A. Borges, H. Bovensmann, M. Buchwitz, **J. Butler**, J. G. Canadell, R. B. Cook, R. DeFries, R. Engelen, K. R. Gurney, C. Heinze, M. Heimann, A. Held, M. Henry, B. Law, S. Luyssaert, **J. Miller**, T. Moriyama, C. Moulin, R. B. Myneni, C. Nussli, M. Obersteiner, D. Ojima, Y. Pan, J.-D. Paris, S. L. Piao, B. Poulter, S. Plummer, S. Quegan, P. Raymond, M. Reichstein, L. Rivier, C. Sabine, D. Schimel, O. Tarasova, R. Valentini, R. Wang, G. van der Werf, D. Wickland, M. Williams and C. Zehner, (2014), Current systematic carbon-cycle observations and the need for implementing a policy-relevant carbon observing system, *Biogeosciences*, 11, 13, 3547-3602, 10.5194/bg-11-3547-2014.

Cressot, C., F. Chevallier, P. Bousquet, C. Crevoisier, **E. J. Dlugokencky**, A. Fortems-Cheiney, C. Frankenberg, R. Parker, I. Pison, R. A. Scheepmaker, **S. A. Montzka**, P. B. Krummel, L. P. Steele and R. L. Langenfelds, (2014), On the consistency between global and regional methane emissions inferred from SCIAMACHY, TANSO-FTS, IASI and surface measurements, *Atmospheric Chemistry and Physics*, 14, 2, 10.5194/acp-14-577-2014.

Deeter, M. N., S. Martínez-Alonso, D. P. Edwards, L. K. Emmons, J. C. Gille, H. M. Worden, **C. Sweeney**, J. V. Pittman, B. C. Daube and S. C. Wofsy, (2014), The MOPITT Version 6 product: algorithm enhancements and validation, *Atmospheric Measurement Techniques*, 7, 11, 10.5194/amt-7-3623-2014.

Díaz Isaac, Liza I., Thomas Lauvaux, Kenneth J. Davis, Natasha L. Miles, Scott J. Richardson, **Andrew R. Jacobson** and **Arlyn E. Andrews**, (2014), Model-data comparison of MCI field campaign atmospheric CO mole fractions , *Journal of Geophysical Research: Atmospheres*, 119, 17, 10.1002/2014JD021593.

Fang, S. X., L. X. Zhou, **P. P. Tans**, P. Ciais, M. Steinbacher, L. Xu and T. Luan, (2014), In situ measurement of atmospheric CO2 at the four WMO/GAW stations in China, *Atmospheric Chemistry and Physics*, 14, 5, 10.5194/acp-14-2541-2014.

Fraser, A., P. I. Palmer, L. Feng, H. Bösch, R. Parker, **E. J. Dlugokencky**, P. B. Krummel and R. L. Langenfelds, (2014), Estimating regional fluxes of CO2 and CH4 using space-borne observations of XCH4: XCO2, *Atmospheric Chemistry and Physics*, 14, 23, 10.5194/acp-14-12883-2014.

Gatti, L. V., M. Gloor, **J. B. Miller**, C. E. Doughty, Y. Malhi, L. G. Domingues, L. S. Basso, A. Martinewski, C. S. C. Correia, V. F. Borges, S. Freitas, R. Braz, L. O. Anderson, H. Rocha, J. Grace, O. L. Phillips and J. Lloyd, (2014), Drought sensitivity of Amazonian carbon balance revealed by atmospheric measurements, *Nature*, 506, 7486, 10.1038/nature12957.

Hartmann, D.L., A. M. G. Klein Tank, M. Rusticucci, L. V. Alexander, S. Bronnimann, Y. Charabi, F. J. Dentener, **E. J. Dlugokencky**, D. R. Easterling, A. Kaplan, B. J. Soden, P. W. Thorne, M. Wild and P. M. Zhai, (2014), Observations: Atmosphere and Surface, Chapter 2, *Book*, 159-254, 10.1017/CBO9781107415324.

Houweling, S., M. Krol, P. Bergamaschi, C. Frankenberg, **E. J. Dlugokencky**, I. Morino, J. Notholt, V. Sherlock, D. Wunch, V. Beck, C. Gerbig, **H. Chen**, E. A. Kort, T. Röckmann and I. Aben, (2014), Corrigendum to "A multi-year methane inversion using SCIAMACHY, accounting for systematic errors using TCCON measurements" published in Atmos. Chem. Phys., 14, 3991–4012, 2014, *Atmospheric Chemistry and Physics*, 14, 20, 10.5194/acp-14-10961-2014.

Jackson, Robert B., Avner Vengosh, J. William Carey, Richard J. Davies, Thomas H. Darrah, Francis O'Sullivan and **Gabrielle Pétron**, (2014), The Environmental Costs and Benefits of Fracking, *Annual Review of Environment and Resources*, 39, 1, 327-362, 10.1146/annurev-environ-031113-144051.

Jiang, ChuanLi, Sarah T. Gille, Janet Sprintall and **Colm Sweeney**, (2014), Drake Passage Oceanic CO: Evaluating CMIP5 Coupled Carbon–Climate Models Using in situ Observations , *Journal of Climate*, 27, 1, 10.1175/jcli-d-12-00571.1.

Keppel-Aleks, Gretchen, Aaron S. Wolf, Mingquan Mu, Scott C. Doney, Douglas C. Morton, Prasad S. Kasibhatla, **John B. Miller**, **Edward J. Dlugokencky** and James T. Randerson, (2014), Separating the influence of temperature, drought, and fire on interannual variability in atmospheric CO , *Global Biogeochemical Cycles*, 28, 11, 10.1002/2014GB004890.

Kuai, L., J. Worden, S. S. Kulawik, **S. A. Montzka** and J. Liu, (2014), Characterization of Aura TES carbonyl sulfide retrievals over ocean, *Atmospheric Measurement Techniques*, 7, 1, 10.5194/amt-7-163-2014.

Le Quéré, C., G. P. Peters, R. J. Andres, R. M. Andrew, T. A. Boden, P. Ciais, P. Friedlingstein, R. A. Houghton, G. Marland, R. Moriarty, S. Sitch, **P. Tans**, A. Arneth, A. Arvanitis, D. C. E. Bakker, L. Bopp, J. G. Canadell, L. P. Chini, S. C. Doney, A. Harper, I. Harris, J. I. House, A. K. Jain, S. D. Jones, E. Kato, R. F. Keeling, K. Klein Goldewijk, A. Körtzinger, C. Koven, N. Lefèvre, F. Maignan, A. Omar, T. Ono, G.-H. Park, B. Pfeil, B. Poulter, M. R. Raupach, P. Regnier, C. Rödenbeck, S. Saito, J. Schwinger, J. Segschneider, B. D. Stocker, T. Takahashi, B. Tilbrook, S. van Heuven, N. Viovy, R. Wanninkhof, A. Wiltshire and S. Zaehle, (2014), Global carbon budget 2013, *Earth System Science Data*, 6, 1, 10.5194/essd-6-235-2014.

Li, R., C. Warneke, M. Graus, R. Field, F. Geiger, P. R. Veres, J. Soltis, S.-M. Li, S. M. Murphy, **C. Sweeney**, **G. Pétron**, J. M. Roberts and J. de Gouw, (2014), Measurements of hydrogen sulfide (H2S) using PTR-MS: calibration, humidity dependence, inter- comparison and results from field studies in an oil and gas production region, *Atmospheric Measurement Techniques*, 7, 10, 10.5194/amt-7-3597-2014.

Liang, Qing, Paul A. Newman, John S. Daniel, Stefan Reimann, **Bradley D. Hall**, **Geoff Dutton** and Lambert J. M. Kuijpers, (2014), Constraining the carbon tetrachloride (CCl) budget using its global trend and inter-hemispheric gradient , *Geophysical Research Letters*, 41, 14, 10.1002/2014GL060754.

Liu, LiXin, LingXi Zhou, Bruce Vaughn, **John B. Miller**, Willi A. Brand, Michael Rothe and LingJun Xia, (2014), Background variations of atmospheric CO and carbon-stable isotopes at Waliguan and Shangdianzi stations in China , *Journal of Geophysical Research: Atmospheres*, 119, 9, 10.1002/2013JD019605.

Masarie, K. A., W. Peters, **A. R. Jacobson** and **P. P. Tans**, (2014), ObsPack: a framework for the preparation, delivery, and attribution of atmospheric greenhouse gas measurements, *Earth System Science Data*, 6, 2, 10.5194/essd-6-375-2014.

Miller, John B., **Pieter P. Tans** and Manuel Gloor, (2014), Steps for success of OCO-2, *Nature Geoscience*, 7, 10, 10.1038/ngeo2255 .

Nisbet, E. G., **E. J. Dlugokencky** and P. Bousquet, (2014), Methane on the Rise--Again, *Science*, 343, 6170, 10.1126/science.1247828 .

Ou-Yang, Chang-Feng, Neng-Huei Lin, Chia-Ching Lin, Sheng-Hsiang Wang, Guey-Rong Sheu, Chung-Te Lee, **Russell C. Schnell**, **Patricia M. Lang**, Taro Kawasato and Jia-Lin Wang, (2014), Characteristics of atmospheric carbon monoxide at a high-mountain background station in East Asia, *Atmospheric Environment*, 89, 10.1016/j.atmosenv.2014.02.060.

Pétron, Gabrielle, **Anna Karion**, **Colm Sweeney**, **Benjamin R. Miller**, **Stephen A. Montzka**, Gregory J. Frost, Michael Trainer, **Pieter Tans**, **Arlyn Andrews**, **Jonathan Kofler**, Detlev Helmig, **Douglas Guenther**, **Ed Dlugokencky**, **Patricia Lang**, Tim Newberger, **Sonja Wolter**, **Bradley Hall**, **Paul Novelli**, Alan Brewer, Stephen Conley, Mike Hardesty, Robert Banta, Allen White, David Noone, Dan Wolfe and **Russ Schnell**, (2014), A new look at methane and nonmethane hydrocarbon emissions from oil and natural gas operations in the Colorado Denver-Julesburg Basin, *Journal of Geophysical Research: Atmospheres*, 119, 11, 10.1002/2013JD021272.

Rieker, G. B., F. R. Giorgetta, W. C. Swann, **J. Kofler**, A. M. Zolot, L. C. Sinclair, E. Baumann, C. Cromer, **G. Petron**, **C. Sweeney**, **P. P. Tans**, I. Coddington and N. R. Newbury, (2014), Frequency-comb-based remote sensing of greenhouse gases over kilometer air paths, *Optica*, 1, 5, 10.1364/OPTICA.1.000290.

Rigby, M., R. G. Prinn, S. O'Doherty, **B. R. Miller**, D. Ivy, J. Mühle, C. M. Harth, P. K. Salameh, T. Arnold, R. F. Weiss, P. B. Krummel, L. P. Steele, P. J. Fraser, D. Young and P. G. Simmonds, (2014), Recent and future trends in synthetic greenhouse gas radiative forcing, *Geophysical Research Letters*, 41, 7, 2623-2630, 10.1002/2013GL059099.

Ripple, William J., Pete Smith, Helmut Haberl, **Stephen A. Montzka**, Clive McAlpine and Douglas H. Boucher, (2014), Ruminants, climate change and climate policy, *Nature Clim. Change*, 4, 1, 2-5, 10.1038/nclimate2081.

Saikawa, E., R. G. Prinn, **E. Dlugokencky**, K. Ishijima, **G. S. Dutton**, **B. D. Hall**, R. Langenfelds, Y. Tohjima, T. Machida, M. Manizza, M. Rigby, S. O'Doherty, P. K. Patra, C. M. Harth, R. F. Weiss, P. B. Krummel, M. van der Schoot, P. J. Fraser, L. P. Steele, S. Aoki, T. Nakazawa and **J. W. Elkins**, (2014), Global and regional emissions estimates for N2O, *Atmospheric Chemistry and Physics*, 14, 9, 10.5194/acp-14-4617-2014.

Santoni, G. W., B. C. Daube, E. A. Kort, R. Jiménez, S. Park, J. V. Pittman, E. Gottlieb, B. Xiang, M. S. Zahniser, D. D. Nelson, J. B. McManus, J. Peischl, T. B. Ryerson, J. S. Holloway, **A. E. Andrews**, **C. Sweeney**, **B. Hall**, **E. J. Hintsa**, **F. L. Moore**, **J. W. Elkins**, **D. F. Hurst**, B. B. Stephens, J. Bent and S. C. Wofsy, (2014), Evaluation of the airborne quantum cascade laser spectrometer (QCLS) measurements of the carbon and greenhouse gas suite – CO_2, CH_4, N_2O, and CO – during the CalNex and HIPPO campaigns, *Atmospheric Measurement Techniques*, 7, 6, 10.5194/amt-7-1509-2014.

Schwietzke, Stefan, W. Michael Griffin, H. Scott Matthews and **Lori M. P. Bruhwiler**, (2014), Natural Gas Fugitive Emissions Rates Constrained by Global Atmospheric Methane and Ethane, *Environmental Science & Technology*, 48, 14, 10.1021/es501204c .

Schwietzke, Stefan, W. Michael Griffin, H. Scott Matthews and **Lori M. P. Bruhwiler**, (2014), Global Bottom-Up Fossil Fuel Fugitive Methane and Ethane Emissions Inventory for Atmospheric Modeling, *ACS Sustainable Chemistry & Engineering*, 2, 8, 10.1021/sc500163h.

Sun, Yulong, Lingen Bian, Jie Tang, Zhiqiu Gao, Changgui Lu and **Russell Schnell**, (2014), CO2 Monitoring and Background Mole Fraction at Zhongshan Station, Antarctica, *Atmosphere*, 5, 3, 10.3390/atmos5030686.

Takagi, Hiroshi, Sander Houweling, Robert J. Andres, Dmitry Belikov, Andrey Bril, Hartmut Boesch, Andre Butz, Sandrine Guerlet, Otto Hasekamp, Shamil Maksyutov, Isamu Morino and **Tomohiro Oda**, (2014), Influence of differences in current GOSAT retrievals on surface flux estimation , *Geophysical Research Letters*, 41, 7, 10.1002/2013gl059174.

Takahashi, Taro, S.C. Sutherland, D.W. Chipman, J.G. Goddard, Cheng Ho, **Timothy Newberger**, **Colm Sweeney** and D.R. Munro, (2014), Climatological distributions of pH, pCO2, total CO2, alkalinity, and CaCO3 saturation in the global surface ocean, and temporal changes at selected locations, *Marine Chemistry*, 164, 10.1016/j.marchem.2014.06.004.

Thompson, R. L., F. Chevallier, **A. M. Crotwell**, **G. Dutton**, R. L. Langenfelds, R. G. Prinn, R. F. Weiss, Y. Tohjima, T. Nakazawa, P. B. Krummel, L. P. Steele and P. Fraser, (2014), Nitrous oxide emissions 1999 to 2009 from a global atmospheric inversion, *Atmospheric Chemistry and Physics*, 14, 4, 10.5194/acp-14-1801-2014.

van der Velde, I. R., **J. B. Miller**, K. Schaefer, G. R. van der Werf, M. C. Krol and W. Peters, (2014), Terrestrial cycling of 13CO2 by photosynthesis, respiration, and biomass burning in SiBCASA, *Biogeosciences*, 11, 23, 10.5194/bg-11-6553-2014.

Wang, Xuhui, Shilong Piao, Philippe Ciais, Pierre Friedlingstein, Ranga B. Myneni, Peter Cox, Martin Heimann, **John Miller**, Shushi Peng, Tao Wang, Hui Yang and Anping Chen, (2014), A two-fold increase of carbon cycle sensitivity to tropical temperature variations, *Nature*, 506, 7487, 10.1038/nature12915.

Wei, Y., S. Liu, D. N. Huntzinger, A. M. Michalak, N. Viovy, W. M. Post, C. R. Schwalm, K. Schaefer, **A. R. Jacobson**, C. Lu, H. Tian, D. M. Ricciuto, R. B. Cook, J. Mao and X. Shi, (2014), The North American Carbon Program Multi-scale Synthesis and Terrestrial Model Intercomparison Project – Part 2: Environmental driver data, *Geoscientific Model Development*, 7, 6, 10.5194/gmd-7-2875-2014.

Yacovitch, Tara I., Scott C. Herndon, Joseph R. Roscioli, Cody Floerchinger, Ryan M. McGovern, Michael Agnese, **Gabrielle Pétron**, **Jonathan Kofler**, **Colm Sweeney**, **Anna Karion**, Stephen A. Conley, Eric A. Kort, Lars Nähle, Marc Fischer, Lars Hildebrandt, Johannes Koeth, J. Barry McManus, David D. Nelson, Mark S. Zahniser and Charles E. Kolb, (2014), Demonstration of an Ethane Spectrometer for Methane Source Identification, *Environmental Science & Technology*, 48, 14, 10.1021/es501475q.

Zhang, H. F., B. Z. Chen, I. T. van der Laan-Luijkx, J. Chen, G. Xu, J. W. Yan, L. X. Zhou, Y. Fukuyama, **P. P. Tans** and W. Peters, (2014), Net terrestrial CO exchange over China during 2001-2010 estimated with an ensemble data assimilation system for atmospheric CO, *Journal of Geophysical Research: Atmospheres*, 119, 6, 10.1002/2013jd021297.

Zhang, H. F., B. Z. Chen, T. Machida, H. Matsueda, Y. Sawa, Y. Fukuyama, R. Langenfelds, M. van der Schoot, G. Xu, J. W. Yan, M. L. Cheng, L. X. Zhou, **P. P. Tans** and W. Peters, (2014), Estimating Asian terrestrial carbon fluxes from CONTRAIL aircraft and surface CO2 observations for the period 2006–2010, *Atmospheric Chemistry and Physics*, 14, 11, 10.5194/acp-14-5807-2014.

Zhang, Xin, Xuhui Lee, Timothy J. Griffis, **Arlyn E. Andrews**, John M. Baker, Matt D. Erickson, Ning Hu and Wei Xiao, (2014), Quantifying nitrous oxide fluxes on multiple spatial scales in the Upper Midwest, USA, *International Journal of Biometeorology*, 59, 3, 10.1007/s00484-014-0842-4.

Theme 1. Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks

Year of Publication: 2013

Angevine, Wayne M., Jerome Brioude, Stuart McKeen, John S. Holloway, Brian M. Lerner, Allen H. Goldstein, Abhinav Guha, **Arlyn Andrews**, John B. Nowak, Stephanie Evan, Marc L. Fischer, Jessica B. Gilman and Daniel Bon, (2013), Pollutant transport among California regions, *Journal of Geophysical Research: Atmospheres*, 118, 12, 6750-6763, 10.1002/jgrd.50490.

Asaf, David, Eyal Rotenberg, Fyodor Tatarinov, Uri Dicken, **Stephen A. Montzka** and Dan Yakir, (2013), Ecosystem photosynthesis inferred from measurements of carbonyl sulphide flux, *Nature Geoscience*, 6, 186-190, 10.1038/ngeo1730.

Basu, S., S. Guerlet, A. Butz, S. Houweling, O. Hasekamp, I. Aben, P. Krummel, P. Steele, R. Langenfelds, M. Torn, S. Biraud, B. Stephens, **A. Andrews** and D. Worthy, (2013), Global CO2 fluxes estimated from GOSAT retrievals of total column CO2, *Atmospheric Chemistry and Physics*, 13, 17, 10.5194/acp-13-8695-2013.

Bergamaschi, P., S. Houweling, A. Segers, M. Krol, C. Frankenberg, R. A. Scheepmaker, **E. Dlugokencky**, S. C. Wofsy, E. A. Kort, **C. Sweeney**, T. Schuck, C. Brenninkmeijer, H. Chen, V. Beck and C. Gerbig, (2013), Atmospheric CH in the first decade of the 21st century: Inverse modeling analysis using SCIAMACHY satellite retrievals and NOAA surface measurements , *Journal of Geophysical Research: Atmospheres*, 118, 13, 10.1002/jgrd.50480.

Berry, Joe, Adam Wolf, J. Elliott Campbell, Ian Baker, Nicola Blake, Don Blake, A. Scott Denning, S. Randy Kawa, **Stephen A. Montzka**, Ulrike Seibt, Keren Stimler, Dan Yakir and Zhengxin Zhu, (2013), A coupled model of the global cycles of carbonyl sulfide and CO: A possible new window on the carbon cycle , *Journal of Geophysical Research: Biogeosciences*, 118, 2, 10.1002/jgrg.20068.

Biraud, S. C., M. S. Torn, J. R. Smith, **C. Sweeney**, W. J. Riley and **P. P. Tans**, (2013), A multi-year record of airborne CO2 observations in the US Southern Great Plains, *Atmospheric Measurement Techniques*, 6, 3, 10.5194/amt-6-751-2013.
3. Blunden, J., D.S. Arndt, **D.F. Hurst** and K. Rosenlof, (2013), [Global Climate: Atmospheric Composition] Stratospheric Water Vapor, [in State of the Climate in 2012], *Bulletin of the American Meteorology Society*, 94, 8, S37-S41, 10.1175/2013BAMSStateoftheClimate.1.

Brioude, J., W. M. Angevine, R. Ahmadov, S.-W. Kim, S. Evan, S. A. McKeen, E.-Y. Hsie, G. J. Frost, J. A. Neuman, I. B. Pollack, J. Peischl, T. B. Ryerson, J. Holloway, S. S. Brown, J. B. Nowak, J. M. Roberts, S. C. Wofsy, **G. W. Santoni**, **T. Oda** and M. Trainer, (2013), Top-down estimate of surface flux in the Los Angeles Basin using a mesoscale inverse modeling technique: assessing anthropogenic emissions of CO, NOx and CO2 and their impacts, *Atmospheric Chemistry and Physics*, 13, 7, 10.5194/acp-13-3661-2013.

Chatterjee, Abhishek, Richard J. Engelen, Stephan R. Kawa, **Colm Sweeney** and Anna M. Michalak, (2013), Background error covariance estimation for atmospheric CO data assimilation , *Journal of Geophysical Research: Atmospheres*, 118, 17, 10.1002/jgrd.50654.

Chen, H., **A. Karion**, C. W. Rella, J. Winderlich, C. Gerbig, A. Filges, **T. Newberger**, **C. Sweeney** and **P. P. Tans**, (2013), Accurate measurements of carbon monoxide in humid air using the cavity ring-down spectroscopy (CRDS) technique, *Atmospheric Measurement Techniques*, 6, 4, 1031-1040, 10.5194/amt-6-1031-2013.

Gavrilov, N.M., **P. Tans**, **D. Guenther** and **C. Sweeney**, (2013), Multiyear average characteristics of CO2 variations in the free atmosphere over Colorado (40° N, 104° W), *Atmospheric Environment*, 72, 10.1016/j.atmosenv.2013.02.054.

Gomez-Pelaez, A. J., R. Ramos, V. Gomez-Trueba, **P. C. Novelli** and R. Campo-Hernandez, (2013), A statistical approach to quantify uncertainty in carbon monoxide measurements at the Izaña global GAW station: 2008–2011, *Atmos. Meas. Tech.*, 6, 3, 787-799, 10.5194/amt-6-787-2013.

Fraser, A., P. I. Palmer, L. Feng, H. Boesch, A. Cogan, R. Parker, **E. J. Dlugokencky**, P. J. Fraser, P. B. Krummel and R. L. Langenfelds, (2013), Estimating regional methane surface fluxes: the relative importance of surface and GOSAT mole fraction measurements, *Atmospheric Chemistry and Physics*, 13, 11, 10.5194/acp-13-5697-2013.

Hegarty, Jennifer, Roland R. Draxler, Ariel F. Stein, Jerome Brioude, Marikate Mountain, Janusz Eluszkiewicz, Thomas Nehrkorn, Fong Ngan and **Arlyn Andrews**, (2013), Evaluation of Lagrangian Particle Dispersion Models with Measurements from Controlled Tracer Releases, *Journal of Applied Meteorology and Climatology*, 52, 12, 2623-2637, 10.1175/JAMC-D-13-0125.1.

Hossaini, R., H. Mantle, M. P. Chipperfield, **S. A. Montzka**, P. Hamer, F. Ziska, B. Quack, K. Krüger, S. Tegtmeier, E. Atlas, S. Sala, A. Engel, H. Bönisch, T. Keber, D. Oram, G. Mills, C. Ordóñez, A. Saiz-Lopez, N. Warwick, Q. Liang, W. Feng, **F. Moore**, **B. R. Miller**, V. Marécal, N. A. D. Richards, M. Dorf and K. Pfeilsticker, (2013), Evaluating global emission inventories of biogenic bromocarbons, *Atmospheric Chemistry and Physics*, 13, 23, 10.5194/acp-13-11819-2013.

Inoue, M., I. Morino, O. Uchino, Y. Miyamoto, Y. Yoshida, T. Yokota, T. Machida, Y. Sawa, H. Matsueda, **C. Sweeney**, **P. P. Tans**, **A. E. Andrews**, S. C. Biraud, T. Tanaka, S. Kawakami and P. K. Patra, (2013), Validation of XCO2 derived from SWIR spectra of GOSAT TANSO-FTS with aircraft measurement data, *Atmospheric Chemistry and Physics*, 13, 19, 9771-9788, 10.5194/acp-13-9771-2013.

Huntzinger, D. N., C. Schwalm, A. M. Michalak, K. Schaefer, A. W. King, Y. Wei, **A. Jacobson**, S. Liu, R. B. Cook, W. M. Post, G. Berthier, D. Hayes, M. Huang, A. Ito, H. Lei, C. Lu, J. Mao, C. H. Peng, S. Peng, B. Poulter, D. Riccuito, X. Shi, H. Tian, W. Wang, N. Zeng, F. Zhao and Q. Zhu, (2013), The North American Carbon Program Multi-Scale Synthesis and Terrestrial Model Intercomparison Project – Part 1: Overview and experimental design, *Geoscientific Model Development*, 6, 6, 10.5194/gmd-6-2121-2013.

Jeong, Seongeun, Ying-Kuang Hsu, **Arlyn E. Andrews**, Laura Bianco, Patrick Vaca, James M. Wilczak and Marc L. Fischer, (2013), A multitower measurement network estimate of California, *Journal of Geophysical Research: Atmospheres*, 10.1002/jgrd.50854.

Karion, A., **C. Sweeney**, **S. Wolter**, **T. Newberger**, **H. Chen**, **A. Andrews**, **J. Kofler**, **D. Neff** and **P. Tans**, (2013), Long-term greenhouse gas measurements from aircraft, *Atmospheric Measurement Techniques*, 6, 3, 10.5194/amt-6-511-2013.

Karion, Anna, **Colm Sweeney**, **Gabrielle Pétron**, Gregory Frost, R. Michael Hardesty, **Jonathan Kofler**, **Ben R. Miller**, **Tim Newberger**, **Sonja Wolter**, Robert Banta, Alan Brewer, **Ed Dlugokencky**, **Patricia Lang**, **Stephen A. Montzka**, **Russell Schnell**, **Pieter Tans**, Michael Trainer, Robert Zamora and Stephen Conley, (2013), Methane emissions estimate from airborne measurements over a western United States natural gas field, *Geophysical Research Letters*, 10.1002/grl.50811.

Keppel-Aleks, Gretchen, James T. Randerson, Keith Lindsay, Britton B. Stephens, J. Keith Moore, Scott C. Doney, Peter E. Thornton, Natalie M. Mahowald, Forrest M. Hoffman, **Colm Sweeney**, **Pieter P. Tans**, Paul O. Wennberg and Steven C. Wofsy, (2013), Atmospheric Carbon Dioxide Variability in the Community Earth System Model: Evaluation and Transient Dynamics during the Twentieth and Twenty-First Centuries, *Journal of Climate*, 26, 13, 10.1175/JCLI-D-12-00589.1.

Kirschke, Stefanie, Philippe Bousquet, Philippe Ciais, Marielle Saunois, Josep G. Canadell, **Edward J. Dlugokencky**, Peter Bergamaschi, Daniel Bergmann, Donald R. Blake, **Lori Bruhwiler**, Philip Cameron-Smith, Simona Castaldi, Frédéric Chevallier, Liang Feng, Annemarie Fraser, Martin Heimann, Elke L. Hodson, Sander Houweling, Béatrice Josse, Paul J. Fraser, Paul B. Krummel, Jean-François Lamarque, Ray L. Langenfelds, Corinne Le Quéré and Vaishali Naik, (2013), Three decades of global methane sources and sinks, *Nature Geoscience*, 10.1038/ngeo1955.

LaFranchi, B. W., **G. Pétron**, **J. B. Miller**, S. J. Lehman, **A. E. Andrews**, **E. J. Dlugokencky**, **B. Hall**, **B. R. Miller**, **S. A. Montzka**, **W. Neff**, **P. C. Novelli**, **C. Sweeney**, J. C. Turnbull, D. E. Wolfe, **P. P. Tans**, K. R. Gurney and T. P. Guilderson, (2013), Constraints on emissions of carbon monoxide, methane, and a suite of hydrocarbons in the Colorado Front Range using observations of $^{14}CO_2$, *Atmospheric Chemistry and Physics*, 13, 21, 10.5194/acp-13-11101-2013.

Lehman, Scott, Guilderson, T.P., LaFranchi, B., Andrews, A., **Sweeney, C.**, **Montzka, S.A.**, **Tans, P.P.**, Southon, J., Wolak, C., **Miller, J.B.**, Turnbull, J.C., , (2013), Allocation of Terrestrial Carbon Sources Using CO2; Methods, Measurement, and Modeling, *Radiocarbon*, 55, 3–4, 10.2458/azu_js_rc.55.16392.

Liu, M., H. Wang, H. Wang, **T. Oda**, Y. Zhao, X. Yang, R. Zang, B. Zang, J. Bi and J. Chen, (2013), Refined estimate of China's CO2 emissions in spatiotemporal distributions, *Atmospheric Chemistry and Physics*, 13, 21, 10873-10882, 10.5194/acp-13-10873-2013.

Parazoo, Nicholas C., Kevin Bowman, Christian Frankenberg, Jung-Eun Lee, Joshua B. Fisher, John Worden, Dylan B. A. Jones, Joseph Berry, G. James Collatz, Ian T. Baker, Martin Jung, Junjie Liu, Gregory Osterman, Chris O'Dell, Athena Sparks, Andre Butz, Sandrine Guerlet, Yukio Yoshida, **Huilin Chen** and Christoph Gerbig, (2013), Interpreting seasonal changes in the carbon balance of southern Amazonia using measurements of XCO and chlorophyll fluorescence from GOSAT , *Geophysical Research Letters*, 40, 11, 2829-2833, 10.1002/grl.50452.

Maksyutov, S., H. Takagi, V. K. Valsala, M. Saito, **T. Oda**, T. Saeki, D. A. Belikov, R. Saito, A. Ito, Y. Yoshida, I. Morino, O. Uchino, R. J. Andres and T. Yokota, (2013), Regional CO2 flux estimates for 2009–2010 based on GOSAT and ground-based CO2 observations, *Atmospheric Chemistry and Physics*, 13, 18, 10.5194/acp-13-9351- 2013.

Miller, S. M., S. C. Wofsy, A. M. Michalak, E. A. Kort, **A. E. Andrews**, S. C. Biraud, **E. J. Dlugokencky**, J. Eluszkiewicz, M. L. Fischer, G. Janssens-Maenhout, **B. R. Miller**, **J. B. Miller**, **S. A. Montzka**, T. Nehrkorn and **C. Sweeney**, (2013), Anthropogenic emissions of methane in the United States, *Proceedings of the National Academy of Sciences*, 110, 50, 10.1073/pnas.1314392110.

Miyamoto, Y., M. Inoue, I. Morino, O. Uchino, T. Yokota, T. Machida, Y. Sawa, H. Matsueda, **C. Sweeney**, **P. P. Tans**, **A. E. Andrews** and P. K. Patra, (2013), Atmospheric column-averaged mole fractions of carbon dioxide at 53 aircraft measurement sites, *Atmospheric Chemistry and Physics*, 13, 10, 10.5194/acp-13-5265-2013.

Newman, S., S. Jeong, M. L. Fischer, X. Xu, C. L. Haman, B. Lefer, S. Alvarez, B. Rappenglueck, E. A. Kort, **A. E. Andrews**, J. Peischl, K. R. Gurney, C. E. Miller and Y. L. Yung, (2013), Diurnal tracking of anthropogenic CO2 emissions in the Los Angeles basin megacity during spring 2010, *Atmospheric Chemistry and Physics*, 13, 8, 10.5194/acp-13-4359-2013.

Oda, T., A. Ganshin, M. Saito, R. J. Andres, R. Zhuravlev, Y. Sawa, R. E. Fisher, M. Rigby, D. Lowry, K. Tsuboi, H. Matsueda, E. G. Nisbet, R. Toumi, A. Lukyanov and S. Maksyutov, (2013), The Use of a High-Resolution Emission Data Set in a Global Eulerian- Lagrangian Coupled Model, *American Geophysical Union*, 173-184, 10.1029/2012GM001263.

Nassar, Ray, Louis Napier-Linton, Kevin R. Gurney, Robert J. Andres, **Tomohiro Oda**, Felix R. Vogel and Feng Deng, (2013), Improving the temporal and spatial distribution of CO emissions from global fossil fuel emission data sets , *Journal of Geophysical Research: Atmospheres*, 118, 2, 10.1029/2012JD018196.

Peischl, J., T. B. Ryerson, J. Brioude, K. C. Aikin, **A. E. Andrews**, E. Atlas, D. Blake, B. C. Daube, J. A. de Gouw, **E. Dlugokencky**, G. J. Frost, D. R. Gentner, J. B. Gilman, A. H. Goldstein, R. A. Harley, J. S. Holloway, **J. Kofler**, W. C. Kuster, **P. M. Lang**, P. C. Novelli, G. W. Santoni, M. Trainer, S. C. Wofsy and D. D. Parrish, (2013), Quantifying sources of methane using light alkanes in the Los Angeles basin, California, *Journal of Geophysical Research: Atmospheres*, 118, 10, 10.1002/jgrd.50413.

Petrenko, V. V., P. Martinerie, **P. Novelli**, D. M. Etheridge, I. Levin, Z. Wang, T. Blunier, J. Chappellaz, J. Kaiser, **P. Lang**, L. P. Steele, S. Hammer, J. Mak, R. L. Langenfelds, J. Schwander, J. P. Severinghaus, E. Witrant, **G. Petron**, M. O. Battle, G. Forster, W. T. Sturges, J.-F. Lamarque, K. Steffen and J. W. C. White, (2013), A 60 yr record of atmospheric carbon monoxide reconstructed from Greenland firn air, *Atmospheric Chemistry and Physics*, 13, 15, 7567-7585, 10.5194/acp-13-7567-2013.

Peylin, P., R. M. Law, K. R. Gurney, F. Chevallier, **A. R. Jacobson**, T. Maki, Y. Niwa, **P. K. Patra**, W. Peters, P. J. Rayner, C. Rödenbeck, I. T. van der Laan-Luijkx and X. Zhang, (2013), Global atmospheric carbon budget: results from an ensemble of atmospheric CO2 inversions, *Biogeosciences*, 10, 10, 10.5194/bg-10-6699-2013.

Pétron, Gabrielle, Gregory J. Frost, Michael K. Trainer, **Benjamin R. Miller**, **Edward J. Dlugokencky** and **Pieter Tans**, (2013), Reply to comment on "Hydrocarbon emissions characterization in the Colorado Front Range-A pilot study" by Michael A. Levi, *Journal of Geophysical Research: Atmospheres*, 118, 1, 236-242, 10.1029/2012JD018487.

Rella, C. W., **H. Chen**, **A. E. Andrews**, A. Filges, C. Gerbig, J. Hatakka, **A. Karion**, N. L. Miles, S. J. Richardson, M. Steinbacher, **C. Sweeney**, B. Wastine and C. Zellweger, (2013), High accuracy measurements of dry mole fractions of carbon dioxide and methane in humid air, *Atmospheric Measurement Techniques*, 6, 3, 837-860, 10.5194/amt-6-837-2013.

Saeki, T., S. Maksyutov, M. Saito, V. Valsala, **T. Oda**, R. J. Andres, D. Belikov, **P. Tans**, **E. Dlugokencky**, Y. Yoshida, I. Morino, O. Uchino and T. Yokota, (2013), Inverse Modeling of CO2 Fluxes Using GOSAT Data and Multi-Year Ground-Based Observations, *SOLA*, 9, 10.2151/sola.2013-011.

Saeki, T., S. Maksyutov, M. Sasakawa, T. Machida, M. Arshinov, **P. Tans**, **T. J. Conway**, M. Saito, V. Valsala, **T. Oda**, R. J. Andres and D. Belikov, (2013), Carbon flux estimation for Siberia by inverse modeling constrained by aircraft and tower CO measurements , *Journal of Geophysical Research: Atmospheres*, 118, 2, 10.1002/jgrd.50127.

Sarma, V. V. S. S., A. Lenton, R. M. Law, N. Metzl, P. K. Patra, S. Doney, I. D. Lima, **E. Dlugokencky**, M. Ramonet and V. Valsala, (2013), Sea–air CO2 fluxes in the Indian Ocean between 1990 and 2009, *Biogeosciences*, 10, 11, 10.5194/bg-10-7035-2013.

Schuh, Andrew E., Thomas Lauvaux, Tristram O. West, A. Scott Denning, Kenneth J. Davis, Natasha Miles, Scott Richardson, Marek Uliasz, Erandathie Lokupitiya, Daniel Cooley, **Arlyn Andrews** and Stephen Ogle, (2013), Evaluating atmospheric CO inversions at multiple scales over a highly inventoried agricultural landscape , *Global Change Biology*, 19, 5, 10.1111/gcb.12141.

Turner, David P., **Andrew R. Jacobson**, William D. Ritts, Weile L. Wang and Ramakrishna Nemani, (2013), A large proportion of North American net ecosystem production is offset by emissions from harvested products, river/stream evasion, and biomass burning, *Global Change Biology*, 10.1111/gcb.12313.

van der Velde, I. R., **J. B. Miller**, K. Schaefer, **K. A. Masarie**, S. Denning, J. W. C. White, **P. P. Tans**, M. C. Krol and W. Peters, (2013), Biosphere model simulations of interannual variability in terrestrial C/C exchange , *Global Biogeochemical Cycles*, 10.1002/gbc.20048.

Xiang, Bin, Scot M. Miller, Eric A. Kort, Gregory W. Santoni, Bruce C. Daube, Roisin Commane, Wayne M. Angevine, Tom B. Ryerson, Michael K. Trainer, **Arlyn E. Andrews**, Thomas Nehrkorn, Hanqin Tian and Steven C. Wofsy, (2013), Nitrous oxide (N2O) emissions from California based on 2010 CalNex airborne measurements , *Journal of Geophysical Research: Atmospheres*, 118, 7, 10.1002/jgrd.50189.

Zhang, Fang, Lingxi Zhou, Thomas J. Conway, **Pieter P. Tans** and Yuzhao Wang, (2013), Short-term variations of atmospheric CO2 and dominant causes in summer and winter: Analysis of 14-year continuous observational data at Waliguan, China, *Atmospheric Environment*, 77, 10.1016/j.atmosenv.2013.04.067.

Theme 2: Monitoring and Understanding Changes in Surface Radiation, Clouds and Aerosol Distributions

Year of Publication: 2017

Andrews, Elisabeth, **John A. Ogren**, Stefan Kinne and Bjorn Samset, (2017), Comparison of AOD, AAOD and column single scattering albedo from AERONET retrievals and in situ profiling measurements, *Atmospheric Chemistry and Physics*, 17, 9, 6041-6072, 10.5194/acp-17-6041-2017.

Backman, John, Lauren Schmeisser, Aki Virkkula, **John A. Ogren**, Eija Asmi, Sandra Starkweather, Sangeeta Sharma, Konstantinos Eleftheriadis, Taneil Uttal, **Anne Jefferson**, Michael Bergin, Alexander Makshtas, Peter Tunved and Markus Fiebig, (2017), On Aethalometer measurement uncertainties and an instrument correction factor for the Arctic, *Atmospheric Measurement Techniques*, 10, 12, 5039-5062, 10.5194/amt-10-5039-2017.

Bernhard, Germar, **Irina Petropavlovskikh** and Bernhard Mayer, (2017), Retrieving vertical ozone profiles from measurements of global spectral irradiance, *Atmospheric Measurement Techniques*, 10, 12, 4979-4994, 10.5194/amt-10-4979-2017.

Bingen, Christine, Charles E. Robert, Kerstin Stebel, Christoph Brühl, Jennifer Schallock, Filip Vanhellemont, Nina Mateshvili, Michael Höpfner, Thomas Trickl, **John E. Barnes**, Julien Jumelet, Jean-Paul Vernier, Thomas Popp, Gerrit de Leeuw and Simon Pinnock, (2017), Stratospheric aerosol data records for the climate change initiative: Development, validation and application to chemistry-climate modelling, *Remote Sensing of Environment*, 203, 296-321, 10.1016/j.rse.2017.06.002.

Calbó, Josep, **Charles N. Long**, Josep-Abel González, **John Augustine** and **Allison McComiskey**, (2017), The thin border between cloud and aerosol: Sensitivity of several ground based observation techniques, *Atmospheric Research*, 196, 248-260, 10.1016/j.atmosres.2017.06.010.

Chylek, Petr, **John A. Augustine**, James D. Klett, Glen Lesins and Manvendra K. Dubey, (2017), Daily mean temperature estimate at the US SURFRAD stations as an average of the maximum and minimum temperatures, *Theoretical and Applied Climatology*, 10.1007/s00704-017-2277-4.

Collaud Coen, Martine, **Elisabeth Andrews**, Diego Aliaga, Marcos Andrade, Hristo Angelov, Nicolas Bukowiecki, Marina Ealo, Paulo Fialho, Harald Flentje, A. Gannet Hallar, Rakesh Hooda, Ivo Kalapov, Radovan Krejci, Neng-Huei Lin, Angela Marinoni, Jing Ming, Nhat Anh Nguyen, Marco Pandolfi, Véronique Pont, Ludwig Ries, Sergio Rodríguez, Gerhard Schauer, Karine Sellegri, Sangeeta Sharma, Junying Sun, Peter Tunved, Patricio Velasquez and Dominique Ruffieux, (2017), The topography contribution to the influence of the atmospheric boundary layer at high altitude stations, *Atmospheric Chemistry and Physics Discussions*, 1-44, 10.5194/acp-2017-692.

Cox, Christopher J., **Robert S. Stone**, David C. Douglas, **Diane M. Stanitski**, George J. Divoky, **Geoff S. Dutton**, **Colm Sweeney**, J. Craig George and **David U. Longenecker**, (2017), Drivers and environmental responses to the changing annual snow cycle of northern Alaska, *Bulletin of the American Meteorological Society*, 10.1175/BAMS-D-16- 0201.1.

Feingold, Graham, Joseph Balsells, Franziska Glassmeier, Takanobu Yamaguchi, Jan Kazil and **Allison McComiskey**, (2017), Analysis of albedo versus cloud fraction relationships in liquid water clouds using heuristic models and large eddy simulation, *Journal of Geophysical Research: Atmospheres*, 122, 13, 7086-7102, 10.1002/2017JD026467.

Jefferson, A., **D. Hageman**, H. Morrow, F. Mei and T. Watson, (2017), Seven years of aerosol scattering hygroscopic growth measurements from SGP: Factors influencing water uptake, *Journal of Geophysical Research: Atmospheres*, 122, 17, 9451-9466, 10.1002/2017JD026804.

Kahn, Ralph A., Tim A. Berkoff, Charles Brock, Gao Chen, Richard A. Ferrare, Steven Ghan, Thomas F. Hansico, Dean A. Hegg, J. Vanderlei Martins, Cameron S. McNaughton, Daniel M. Murphy, **John A. Ogren**, Joyce E. Penner, Peter Pilewskie, John H. Seinfeld and Douglas R. Worsnop, (2017), SAM-CAAM: A Concept for Acquiring Systematic Aircraft Measurements to Characterize Aerosol Air Masses, *Bulletin of the American Meteorological Society*, 98, 10, 2215-2228, 10.1175/BAMS-D-16-0003.1.

Kassianov, E., M. Pekour, C. Flynn, L. K. Berg, J. Beranek, A. Zelenyuk, C. Zhao, L. R. Leung, P. L. Ma, L. Riihimaki, J. D. Fast, J. Barnard, A. G. Hallar, I. B. McCubbin, E. W. Eloranta, **A. McComiskey** and P. J. Rasch, (2017), Large Contribution of Coarse Mode to Aerosol Microphysical and Optical Properties: Evidence from Ground-Based Observations of a Transpacific Dust Outbreak at a High-Elevation North American Site, *Journal of the Atmospheric Sciences*, 74, 5, 1431-1443, 10.1175/JAS-D-16-0256.1.

Kolesar, Katheryn R., Jillian Cellini, Peter K. Peterson, **Anne Jefferson**, Thomas Tuch, Wolfram Birmili, Alfred Wiedensohler and Kerri A. Pratt, (2017), Effect of Prudhoe Bay emissions on atmospheric aerosol growth events observed in Utqiaġvik (Barrow), Alaska, *Atmospheric Environment*, 152, 146-155, 10.1016/j.atmosenv.2016.12.019.

Michalsky, Joseph J., Mark Kutchenreiter and **Charles N. Long**, (2017), Significant Improvements in Pyranometer Nighttime Offsets Using High-Flow DC Ventilation, *Journal of Atmospheric and Oceanic Technology*, 34, 6, 1323-1332, 10.1175/JTECH-D-16-0224.1.

Moosmüller, Hans and **John A. Ogren**, (2017), Parameterization of the Aerosol Upscatter Fraction as Function of the Backscatter Fraction and Their Relationships to the Asymmetry Parameter for Radiative Transfer Calculations, *Atmosphere*, 8, 8, 133, 10.3390/atmos8080133.

Moreira, Demerval S., Karla M. Longo, Saulo R. Freitas, Marcia A. Yamasoe, Lina M. Mercado, Nilton E. Rosário, Emauel Gloor, Rosane S. M. Viana, **John B. Miller**, Luciana V. Gatti, Kenia T. Wiedemann, Lucas K. G. Domingues and Caio C. S. Correia, (2017), Modeling the radiative effects of biomass burning aerosols on carbon fluxes in the Amazon region, *Atmospheric Chemistry and Physics*, 17, 23, 14785-14810, 10.5194/acp-17-14785-2017.

Ogren, John A., **Jim Wendell**, **Elisabeth Andrews** and **Patrick J. Sheridan**, (2017), Continuous light absorption photometer for long-term studies, *Atmospheric Measurement Techniques*, 10, 12, 4805-4818, 10.5194/amt-10-4805-2017.

Rivera, Héctor, **John A. Ogren**, **Elisabeth Andrews** and Olga L. Mayol-Bracero, (2017), Variations in the physicochemical and optical properties of natural aerosols in Puerto Rico – Implications for climate, *Atmospheric Chemistry and Physics Discussions*, 1-30, 10.5194/acp-2017-703.

Schmale, Julia, Silvia Henning, Bas Henzing, Helmi Keskinen, Karine Sellegri, Jurgita Ovadnevaite, Aikaterini Bougiatioti, Nikos Kalivitis, Iasonas Stavroulas, **Anne Jefferson**, Minsu Park, Patrick Schlag, Adam Kristensson, Yoko Iwamoto, Kirsty Pringle, Carly Reddington, Pasi Aalto, Mikko Äijälä, Urs Baltensperger, Jakub Bialek, Wolfram Birmili, Nicolas Bukowiecki, Mikael Ehn, Ann Mari Fjæraa, Markus Fiebig, Göran Frank, Roman Fröhlich, Arnoud Frumau, Masaki Furuya, Emanuel Hammer, Liine Heikkinen, Erik Herrmann, Rupert Holzinger, Hiroyuki Hyono, Maria Kanakidou, Astrid Kiendler-Scharr, Kento Kinouchi, Gerard Kos, Markku Kulmala, Nikolaos Mihalopoulos, Ghislain Motos, Athanasios Nenes, Colin O'Dowd, Mikhail Paramonov, Tuukka Petäjä, David Picard, Laurent Poulain, André Stephan Henry Prévôt, Jay Slowik, Andre Sonntag, Erik Swietlicki, Birgitta Svenningsson, Hiroshi Tsurumaru, Alfred Wiedensohler, Cerina Wittbom, **John A. Ogren**, Atsushi Matsuki, Seong Soo Yum, Cathrine Lund Myhre, Ken Carslaw, Frank Stratmann and Martin Gysel, (2017), Collocated observations of cloud condensation nuclei, particle size distributions, and chemical composition, *Scientific Data*, 4, 170003, 10.1038/sdata.2017.3.

Schmeisser, Lauren, **Elisabeth Andrews**, **John A. Ogren**, **Patrick Sheridan**, **Anne Jefferson**, Sangeeta Sharma, Jeong Eun Kim, James P. Sherman, Mar Sorribas, Ivo Kalapov, Todor Arsov, Christo Angelov, Olga L. Mayol-Bracero, Casper Labuschagne, Sang-Woo Kim, András Hoffer, Neng-Huei Lin, Hao-Ping Chia, Michael Bergin, Junying Sun, Peng Liu and Hao Wu, (2017), Classifying aerosol type using in situ surface spectral aerosol optical properties, *Atmospheric Chemistry and Physics*, 17, 19, 12097-12120, 10.5194/acp-17-12097-2017.

Sharma, Sangeeta, W. Richard Leaitch, Lin Huang, Daniel Veber, Felicia Kolonjari, Wendy Zhang, Sarah J. Hanna, Allan K. Bertram and **John A. Ogren**, (2017), An evaluation of three methods for measuring black carbon in Alert, Canada, *Atmospheric Chemistry and Physics*, 17, 24, 15225-15243, 10.5194/acp-17-15225-2017.

Telg, Hagen, Daniel M. Murphy, Timothy S. Bates, James E. Johnson, Patricia K. Quinn, Fabio Giardi and Ru-Shan Gao, (2017), A practical set of miniaturized instruments for vertical profiling of aerosol physical properties, *Aerosol Science and Technology*, 1-9, 10.1080/02786826.2017.1296103.

Yu, Pengfei, Karen H. Rosenlof, Shang Liu, **Hagen Telg**, Troy D. Thornberry, Andrew W. Rollins, Robert W. Portmann, Zhixuan Bai, Eric A. Ray, Yunjun Duan, Laura L. Pan, Owen B. Toon, Jianchun Bian and Ru-Shan Gao, (2017), Efficient transport of tropospheric aerosol into the stratosphere via the Asian summer monsoon anticyclone, *Proceedings of the National Academy of Sciences*, 114, 27, 6972-6977, 10.1073/pnas.1701170114.

Zamora, Lauren M., Ralph A. Kahn, Sabine Eckhardt, **Allison McComiskey**, Patricia Sawamura, Richard Moore and Andreas Stohl, (2017), Aerosol indirect effects on the nighttime Arctic Ocean surface from thin, predominantly liquid clouds, *Atmospheric Chemistry and Physics*, 17, 12, 7311-7332, 10.5194/acp-17-7311-2017.

Theme 2. Monitoring and Understanding Changes in Surface Radiation, Clouds and Aerosol Distributions

Year of Publication: 2016

Berg, Larry K., Jerome D. Fast, James C. Barnard, Sharon P. Burton, Brian Cairns, Duli Chand, Jennifer M. Comstock, Stephen Dunagan, Richard A. Ferrare, Connor J. Flynn, Johnathan W. Hair, Chris A. Hostetler, John Hubbe, **Anne Jefferson**, Roy Johnson, Evgueni I. Kassianov, Celine D. Kluzek, Pavlos Kollias, Katia Lamer, **Kathleen Lantz**, Fan Mei, Mark A. Miller, **Joseph Michalsky**, Ivan Ortega, Mikhail Pekour, Ray R. Rogers, Philip B. Russell, Jens Redemann, Arthur J. Sedlacek, Michal Segal-Rosenheimer, Beat Schmid, John E. Shilling, Yohei Shinozuka, Stephen R. Springston, Jason M. Tomlinson, Megan Tyrrell, Jacqueline M. Wilson, Rainer Volkamer, Alla Zelenyuk and Carl M. Berkowitz, (2016), The Two-Column Aerosol Project: Phase I-Overview and impact of elevated aerosol layers on aerosol optical depth, *Journal of Geophysical Research: Atmospheres*, 121, 1, 336-361, 10.1002/2015JD023848.

Cox, Christopher J., Taneil Uttal, **Charles N. Long**, Matthew D. Shupe, **Robert S. Stone** and Sandy Starkweather, (2016), The Role of Springtime Arctic Clouds in Determining Autumn Sea Ice Extent, *Journal of Climate*, 29, 18, 6581-6596, 10.1175/JCLI-D-16-0136.1.

de Boer, Gijs, Scott Palo, Brian Argrow, Gabriel LoDolce, James Mack, Ru-Shan Gao, **Hagen Telg**, Cameron Trussel, Joshua Fromm, **Charles N. Long**, Geoff Bland, James Maslanik, Beat Schmid and Terry Hock, (2016), The Pilatus unmanned aircraft system for lower atmospheric research, *Atmospheric Measurement Techniques*, 9, 4, 1845-1857, 10.5194/amt-9-1845-2016.

Denjean, Cyrielle, Paola Formenti, Karine Desboeufs, Servanne Chevaillier, Sylvain Triquet, Michel Maillé, Mathieu Cazaunau, Benoit Laurent, Olga L. Mayol-Bracero, Pamela Vallejo, Mariana Quiñones, Ian E. Gutierrez-Molina, Federico Cassola, Paolo Prati, **Elisabeth Andrews** and **John Ogren**, (2016), Size distribution and optical properties of African mineral dust after intercontinental transport, *Journal of Geophysical Research: Atmospheres*, 121, 12, 7117-7138, 10.1002/2016JD02478.3.

Evangeliou, N., Y. Balkanski, W. M. Hao, A. Petkov, R. P. Silverstein, R. Corley, B. L. Nordgren, S. P. Urbanski, S. Eckhardt, A. Stohl, P. Tunved, S. Crepinsek, **A. Jefferson**, S. Sharma, J. K. Nøjgaard and H. Skov, (2016), Wildfires in northern Eurasia affect the budget of black carbon in the Arctic – a 12-year retrospective synopsis (2002–2013), *Atmospheric Chemistry and Physics*, 16, 12, 7587-7604, 10.5194/acp-16-7587-2016.

Feingold, Graham and **Allison McComiskey**, (2016), ARM's Aerosol–Cloud–Precipitation Research (Aerosol Indirect Effects), *Meteorological Monographs*, 57, 22.1-22.15, 10.1175/AMSMONOGRAPHS-D-15-0022.1.

Feingold, Graham, **Allison McComiskey**, Takanobu Yamaguchi, Jill S. Johnson, Kenneth S. Carslaw and K. Sebastian Schmidt, (2016), New approaches to quantifying aerosol influence on the cloud radiative effect, *Proceedings of the National Academy of Sciences*, 201514035, 10.1073/pnas.1514035112.

Hallar, A. Gannet, **Elisabeth Andrews**, Nicolas Bukowiecki, Daniel A. Jaffe and Neng-Huei Lin, (2016), Overview of the Special Issue "Selected Papers from the 2nd Atmospheric Chemistry and Physics at Mountain Sites Symposium", *Aerosol and Air Quality Research*, 16, 3, 471-477, 10.4209/aaqr.2016.02.0077.

Hallar, A. Gannet, Ross Petersen, Ian B. McCubbin, Doug Lowenthal, Shanhu Lee, **Elisabeth Andrews** and Fangqun Yu, (2016), Climatology of New Particle Formation and Corresponding Precursors at Storm Peak Laboratory, *Aerosol and Air Quality Research*, 16, 3, 816-826, 10.4209/aaqr.2015.05.0341.

Höpner, F., F. A.-M. Bender, A. M. L. Ekman, P. S. Praveen, C. Bosch, **J. A. Ogren**, A. Andersson, Ö. Gustafsson and V. Ramanathan, (2016), Vertical profiles of optical and microphysical particle properties above the northern Indian Ocean during CARDEX 2012, *Atmospheric Chemistry and Physics*, 16, 2, 1045-1064, 10.5194/acp-16-1045-2016.

Kiedron, P. W. and **J. J. Michalsky**, (2016), Non-parametric and least squares Langley plot methods, *Atmospheric Measurement Techniques*, 9, 1, 215-225, 10.5194/amt-9-215-2016.

Kremser, Stefanie, Larry W. Thomason, Marc von Hobe, Markus Hermann, Terry Deshler, Claudia Timmreck, Matthew Toohey, Andrea Stenke, Joshua P. Schwarz, Ralf Weigel, Stephan Fueglistaler, Fred J. Prata, Jean-Paul Vernier, Hans Schlager, **John E. Barnes**, Juan-Carlos Antuña-Marrero, Duncan Fairlie, Mathias Palm, Emmanuel Mahieu, Justus Notholt, Markus Rex, Christine Bingen, Filip Vanhellemont, Adam Bourassa, John M. C. Plane, Daniel Klocke, Simon A. Carn, Lieven Clarisse, Thomas Trickl, Ryan Neely, Alexander D. James, Landon Rieger, James C. Wilson and Brian Meland, (2016), Stratospheric aerosol-Observations, processes, and impact on climate, *Reviews of Geophysics*, 54, 2, 278-335, 10.1002/2015RG000511.

Long, C. N., J. H. Mather and T. P. Ackerman, (2016), The ARM Tropical Western Pacific (TWP) Sites, *Meteorological Monographs*, 57, 7.1-7.14, 10.1175/AMSMONOGRAPHS- D-15-0024.1.

Long, C.N., (2016), Atmospheric Radiation Measurement MaddenJulian Oscillation Investigation Experiment Field Campaign Report, *Department of Energy*, DOE/SC-ARM-16-039.

McComiskey, Allison and Richard A. Ferrare, (2016), Aerosol Physical and Optical Properties and Processes in the ARM Program, *Meteorological Monographs*, 57, 21.1-21.17, 10.1175/AMSMONOGRAPHS-D-15-0028.1.

Michalsky, Joseph J. and **Charles N. Long**, (2016), ARM Solar and Infrared Broadband and Filter Radiometry, *Meteorological Monographs*, 57, 16.1-16.15, 10.1175/AMSMONOGRAPHS-D-15-0031.1.

Ortega, Ivan, Sean Coburn, Larry K. Berg, **Kathy Lantz**, **Joseph Michalsky**, Richard A. Ferrare, Johnathan W. Hair, Chris A. Hostetler and Rainer Volkamer, (2016), The CU 2-D-MAX-DOAS instrument – Part 2: Raman scattering probability measurements and retrieval of aerosol optical properties, *Atmospheric Measurement Techniques*, 9, 8, 3893-3910, 10.5194/amt-9-3893-2016.

Rosenfeld, Daniel, Youtong Zheng, Eyal Hashimshoni, Mira L. Pöhlker, **Anne Jefferson**, Christopher Pöhlker, Xing Yu, Yannian Zhu, Guihua Liu, Zhiguo Yue, Baruch Fischman, Zhanqing Li, David Giguzin, Tom Goren, Paulo Artaxo, Henrique M. J. Barbosa, Ulrich Pöschl and Meinrat O. Andreae, (2016), Satellite retrieval of cloud condensation nuclei concentrations by using clouds as CCN chambers, *Proceedings of the National Academy of Sciences*, 113, 21, 5828-5834, 10.1073/pnas.1514044113.

Sanchez-Romero, A., J.A. González, J. Calbó, A. Sanchez-Lorenzo and **J. Michalsky**, (2016), Aerosol optical depth in a western Mediterranean site: An assessment of different methods, *Atmospheric Research*, 174-17, 70-84, 10.1016/j.atmosres.2016.02.002.

Sena, Elisa T., **Allison McComiskey** and Graham Feingold, (2016), A long-term study of aerosol–cloud interactions and their radiative effect at the Southern Great Plains using ground-based measurements, *Atmospheric Chemistry and Physics*, 16, 17, 11301-11318, 10.5194/acp-16-11301-2016.

Sharma, Nimmi C.P. and **John E. Barnes**, (2016), Boundary Layer Characteristics over a High Altitude Station, Mauna Loa Observatory, *Aerosol and Air Quality Research*, 16, 3, 729-737, 10.4209/aaqr.2015.05.0347.

Sheridan, Patrick, **Elisabeth Andrews**, **Lauren Schmeisser**, **Brian Vasel** and **John Ogren**, (2016), Aerosol Measurements at South Pole: Climatology and Impact of Local Contamination, *Aerosol and Air Quality Research*, 16, 3, 855-872, 10.4209/aaqr.2015.05.0358.

Ten Hoeve, John E. and **John A. Augustine**, (2016), Aerosol effects on cloud cover as evidenced by ground-based and space-based observations at five rural sites in the United States, *Geophysical Research Letters*, 43, 2, 793-801, 10.1002/2015GL066873.

Titos, G., A. Cazorla, P. Zieger, **E. Andrews**, H. Lyamani, M.J. Granados-Muñoz, F.J. Olmo and L. Alados-Arboledas, (2016), Effect of hygroscopic growth on the aerosol light-scattering coefficient: A review of measurements, techniques and error sources, *Atmospheric Environment*, 141, 494-507, 10.1016/j.atmosenv.2016.07.021.

Uttal, Taneil, Sandra Starkweather, James R. Drummond, Timo Vihma, Alexander P. Makshtas, Lisa S. Darby, John F. Burkhart, Christopher J. Cox, Lauren N. Schmeisser, Thomas Haiden, Marion Maturilli, Matthew D. Shupe, Gijs De Boer, Aurometet Saha, Andrey A. Grachev, Sara M. Crepinsek, **Lori Bruhwiler**, Barry Goodison, Bruce McArthur, Von P. Walden, **Edward J. Dlugokencky**, P. Ola G. Persson, Glen Lesins, Tuomas Laurila, **John A. Ogren**, **Robert Stone**, **Charles N. Long**, Sangeeta Sharma, Andreas Massling, David D. Turner, **Diane M. Stanitski**, Eija Asmi, Mika Aurela, Henrik Skov, Konstantinos Eleftheriadis, Aki Virkkula, Andrew Platt, Eirik J. Førland, Yoshihiro Iijima, Ingeborg E. Nielsen, Michael H. Bergin, Lauren Candlish, Nikita S. Zimov, Sergey A. Zimov, Norman T. O'Neill, Pierre F. Fogal, Rigel Kivi, Elena A. Konopleva-Akish, Johannes Verlinde, Vasily Y. Kustov, **Brian Vasel**, Viktor M. Ivakhov, Yrjö Viisanen and Janet M. Intrieri, (2016), International Arctic Systems for Observing the Atmosphere: An International Polar Year Legacy Consortium, *Bulletin of the American Meteorological Society*, 97, 6, 1033-1056, 10.1175/BAMS-D-14-00145.1.

Wiggins, E. B., S. Veraverbeke, J. M. Henderson, A. Karion, **J. B. Miller**, J. Lindaas, R. Commane, **C. Sweeney**, K. A. Luus, M. G. Tosca, S. J. Dinardo, S. Wofsy, C. E. Miller and J. T. Randerson, (2016), The influence of daily meteorology on boreal fire emissions and regional trace gas variability, *Journal of Geophysical Research: Biogeosciences*, 121, 11, 2793-2810, 10.1002/2016JG003434.

Wood, Robert, Jayson D. Stemmler, Jasmine Rémillard and **Anne Jefferson.**, (2016), Low CCN concentration air masses over the eastern North Atlantic: seasonality, meteorology and drivers., *Journal of Geophysical Research: Atmospheres*, 10.1002/2016JD025557.
Journal of Geophysical Research: Atmospheres, 10.1002/2016JD025130.

Theme 2. Monitoring and Understanding Changes in Surface Radiation, Clouds and Aerosol Distributions

Year of Publication: 2015

Blunden, Jessica, Derek S. Arndt and **K. Lantz**, (2015), Mauna Loa Clear-Sky Atmospheric Solar Transmission [Global Climate] [in "State of the Climate in 2014"], *Bulletin of the American Meteorological Society*, 96, 7, S38-S39, 10.1175/2015BAMSStateoftheClimate.1.

Buller, David B., Marianne Berwick, **Kathy Lantz**, Mary Klein Buller, James Shane, Ilima Kane and Xia Liu, (2015), Evaluation of Immediate and 12-Week Effects of a Smartphone Sun-Safety Mobile Application, *JAMA Dermatology*, 10.1001/jamadermatol.2014.389.

Buller, David B., Marianne Berwick, **Kathy Lantz**, Mary Klein Buller, James Shane, Ilima Kane and Xia Liu, (2015), Smartphone Mobile Application Delivering Personalized, Real- Time Sun Protection Advice, *JAMA Dermatology*, 10.1001/jamadermatol.2014.3889.

Burleyson, Casey D., **Charles N. Long** and Jennifer M. Comstock, (2015), Quantifying Diurnal Cloud Radiative Effects by Cloud Type in the Tropical Western Pacific, *Journal of Applied Meteorology and Climatology*, 54, 6, 10.1175/JAMC-D-14-0288.1.

Gan, C.-M., J. Pleim, R. Mathur, C. Hogrefe, **C. N. Long**, J. Xing, D. Wong, R. Gilliam and C. Wei, (2015), Assessment of long-term WRF–CMAQ simulations for understanding direct aerosol effects on radiation "brightening" in the United States, *Atmospheric Chemistry and Physics*, 15, 21, 12193-12209, 10.5194/acp-15-12193-2015.

Hallar, A. G., R. Petersen, **E. Andrews**, **J. Michalsky**, I. B. McCubbin and **J. A. Ogren**, (2015), Contributions of dust and biomass burning to aerosols at a Colorado mountain-top site, *Atmospheric Chemistry and Physics*, 15, 23, 13665-13679, 10.5194/acp-15-13665-2015.

Kishcha, Pavel, Arlindo da Silva, Boris Starobinets, **Charles Long**, Olga Kalashnikova and Pinhas Alpert, (2015), Saharan dust as a causal factor of hemispheric asymmetry in aerosols and cloud cover over the tropical Atlantic Ocean, *International Journal of Remote Sensing*, 36, 13, 10.1080/01431161.2015.1060646.

Sherman, J. P., **P. J. Sheridan**, **J. A. Ogren**, **E. Andrews**, **D. Hageman**, L. Schmeisser, **A. Jefferson** and S. Sharma, (2015), A multi-year study of lower tropospheric aerosol variability and systematic relationships from four North American regions, *Atmospheric Chemistry and Physics*, 15, 21, 12487-12517, 10.5194/acp-15-12487-2015.

Shinozuka, Y., A. D. Clarke, A. Nenes, **A. Jefferson**, R. Wood, C. S. McNaughton, J. Ström, P. Tunved, J. Redemann, K. L. Thornhill, R. H. Moore, T. L. Lathem, J. J. Lin and Y. J. Yoon, (2015), The relationship between cloud condensation nuclei (CCN) concentration and light extinction of dried particles: indications of underlying aerosol processes and implications for satellite-based CCN estimates, *Atmospheric Chemistry and Physics*, 15, 13, 7585-7604, 10.5194/acp-15-7585-2015.

Sorribas, MAR, **John A. Ogren**, Francisco J. Olmo, Arturo Quirantes, Roberto Fraile, Manuel Gil-Ojeda and Lucas Alados-Arboledas, (2015), Assessment of African desert dust episodes over the southwest Spain at sea level using in situ aerosol optical and microphysical properties, *Tellus B*, 67, 10.3402/tellusb.v67.27482.

Tilmes, S., J.-F. Lamarque, L. K. Emmons, D. E. Kinnison, P.-L. Ma, X. Liu, S. Ghan, C. Bardeen, S. Arnold, M. Deeter, F. Vitt, T. Ryerson, **J. W. Elkins**, **F. Moore**, J. R. Spackman and M. Val Martin, (2015), Description and evaluation of tropospheric chemistry and aerosols in the Community Earth System Model (CESM1.2), *Geoscientific Model Development*, 8, 5, 10.5194/gmd-8-1395-2015.

Tomasi, Claudio, Alexander A. Kokhanovsky, Angelo Lupi, Christoph Ritter, Alexander Smirnov, Norman T. O'Neill, **Robert S. Stone**, Brent N. Holben, Stephan Nyeki, Christoph Wehrli, Andreas Stohl, Mauro Mazzola, Christian Lanconelli, Vito Vitale, Kerstin Stebel, Veijo Aaltonen, Gerrit de Leeuw, Edith Rodriguez, Andreas B. Herber, Vladimir F. Radionov, Tymon Zielinski, Tomasz Petelski, Sergey M. Sakerin, Dmitry M. Kabanov, Yong Xue, Linlu Mei, Larysa Istomina, Richard Wagener, Bruce McArthur, Piotr S. Sobolewski, Rigel Kivi, Yann Courcoux, Pierre Larouche, Stephen Broccardo and Stuart J. Piketh, (2015), Aerosol remote sensing in polar regions, *Earth-Science Reviews*, 140, 108-157, 10.1016/j.earscirev.2014.11.001.

Wood, Robert, Matthew Wyant, Christopher S. Bretherton, Jasmine Rémillard, Pavlos Kollias, Jennifer Fletcher, Jayson Stemmler, Simone de Szoeke, Sandra Yuter, Matthew Miller, David Mechem, George Tselioudis, J. Christine Chiu, Julian A. L. Mann, Ewan J. O'Connor, Robin J. Hogan, Xiquan Dong, Mark Miller, Virendra Ghate, **Anne Jefferson**, Qilong Min, Patrick Minnis, Rabindra Palikonda, Bruce Albrecht, Ed Luke, Cecile Hannay and Yanluan Lin, (2015), Clouds, Aerosols, and Precipitation in the Marine Boundary Layer: An Arm Mobile Facility Deployment, *Bulletin of the American Meteorological Society*, 96, 3, 419-440, 10.1175/BAMS-D-13-00180.1.

Yamaguchi, Takanobu, Graham Feingold, Jan Kazil and **Allison McComiskey**, (2015), Stratocumulus to cumulus transition in the presence of elevated smoke layers, *Geophysical Research Letters*, 42, 23, 10,478-10,485, 10.1002/2015GL066544.

Zhang, L., J. Y. Sun, X. J. Shen, Y. M. Zhang, H. Che, Q. L. Ma, Y. W. Zhang, X. Y. Zhang and **J. A. Ogren**, (2015), Observations of relative humidity effects on aerosol light scattering in the Yangtze River Delta of China, *Atmospheric Chemistry and Physics*, 15, 14, 10.5194/acp-15-8439-2015.

Theme 2. Monitoring and Understanding Changes in Surface Radiation, Clouds and Aerosol Distributions

Year of Publication: 2014

Badosa, J., J. Wood, P. Blanc, **C. N. Long**, L. Vuilleumier, D. Demengel and M. Haeffelin, (2014), Solar irradiances measured using SPN1 radiometers: uncertainties and clues for development, *Atmospheric Measurement Techniques*, 7, 12, 10.5194/amt-7-4267-2014.

Charlevoix, Donna J., Rajul Pandya, Alison Bridger, Thomas E. Gill, Elaine Hampton, Redina Herman, John Knox, Wen-Whai Li and **Diane Stanitski**, (2014), New Directions for the AMS Symposium on Education, *Bulletin of the American Meteorological Society*, 95, 9, ES1465-ES1467, 10.1175/BAMS-D-13-00273.1.

Conley, Stephen A., Ian C. Faloona, Donald H. Lenschow, **Anna Karion** and **Colm Sweeney**, (2014), A Low-Cost System for Measuring Horizontal Winds from Single- Engine Aircraft, *Journal of Atmospheric and Oceanic Technology*, 31, 6, 10.1175/JTECH- D-13-00143.1.

Deng, Min, Pavlos Kollias, Zhe Feng, Chidong Zhang, **Charles N. Long**, Heike Kalesse, Arunchandra Chandra, Vickal V. Kumar and Alain Protat, (2014), Stratiform and Convective Precipitation Observed by Multiple Radars during the DYNAMO/AMIE Experiment, *Journal of Applied Meteorology and Climatology*, 53, 11, 10.1175/JAMC-D-13-0311.1.

Fiebig, M., D. Hirdman, C. R. Lunder, **J. A. Ogren**, S. Solberg, A. Stohl and R. L. Thompson, (2014), Annual cycle of Antarctic baseline aerosol: controlled by photooxidation-limited aerosol formation, *Atmospheric Chemistry and Physics*, 14, 6, 10.5194/acp-14-3083-2014.

Gao, R. S., K. H. Rosenlof, D. W. Fahey, P. O. Wennberg, **E. J. Hintsa** and T. F. Hanisco, (2014), OH in the tropical upper troposphere and its relationships to solar radiation and reactive nitrogen, *Journal of Atmospheric Chemistry*, 71, 1, 10.1007/s10874-014-9280-2.

Hagos, Samson, Zhe Feng, Casey D. Burleyson, Kyo-Sun Sunny Lim, **Charles N. Long**, Di Wu and Greg Thompson, (2014), Evaluation of convection-permitting model simulations of cloud populations associated with the Madden-Julian Oscillation using data collected during the AMIE/DYNAMO field campaign, *Journal of Geophysical Research: Atmospheres*, 119, 21, 10.1002/2014JD022143.

Kassianov, Evgueni, James Barnard, Connor Flynn, Laura Riihimaki, **Joseph Michalsky** and **Gary Hodges**, (2014), Areal-Averaged Spectral Surface Albedo from Ground-Based Transmission Data Alone: Toward an Operational Retrieval, *Atmosphere*, 5, 3, 10.3390/atmos5030597.

Mann, G. W., K. S. Carslaw, C. L. Reddington, K. J. Pringle, M. Schulz, A. Asmi, D. V. Spracklen, D. A. Ridley, M. T. Woodhouse, L. A. Lee, K. Zhang, S. J. Ghan, R. C. Easter, X. Liu, P. Stier, Y. H. Lee, P. J. Adams, H. Tost, J. Lelieveld, S. E. Bauer, K. Tsigaridis, T. P. C. van Noije, A. Strunk, E. Vignati, N. Bellouin, M. Dalvi, C. E. Johnson, T. Bergman, H. Kokkola, K. von Salzen, F. Yu, G. Luo, A. Petzold, J. Heintzenberg, A. Clarke, **J. A. Ogren**, J. Gras, U. Baltensperger, U. Kaminski and S. G. Jennings, (2014), Intercomparison and evaluation of global aerosol microphysical properties among AeroCom models of a range of complexity, *Atmospheric Chemistry and Physics*, 14, 9, 10.5194/acp-14-4679-2014.

Mann, Julian A. L., J. Christine Chiu, Robin J. Hogan, Ewan J. O'Connor, Tristan S. L'Ecuyer, Thorwald H.M. Stein and **Anne Jefferson**, (2014), Aerosol impacts on drizzle properties in warm clouds from ARM Mobile Facility maritime and continental deployments, *Journal of Geophysical Research: Atmospheres*, 119, 7, 10.1002/2013JD021339.

Müller, T., A. Virkkula and **J. A. Ogren**, (2014), Constrained two-stream algorithm for calculating aerosol light absorption coefficient from the Particle Soot Absorption Photometer, *Atmospheric Measurement Techniques*, 7, 12, 10.5194/amt-7-4049-2014.

Neely, R. R., P. Yu, K. H. Rosenlof, O. B. Toon, J. S. Daniel, S. Solomon and H. L. Miller, (2014), The contribution of anthropogenic SO emissions to the Asian tropopause aerosol layer, *Journal of Geophysical Research: Atmospheres*, 119, 3, 10.1002/2013jd020578.

Ridley, D. A., S. Solomon, **J. E. Barnes**, V. D. Burlakov, T. Deshler, S. I. Dolgii, A. B. Herber, T. Nagai, **R. R. Neely**, A. V. Nevzorov, C. Ritter, T. Sakai, B. D. Santer, M. Sato, A. Schmidt, O. Uchino and J. P. Vernier, (2014), Total volcanic stratospheric aerosol optical depths and implications for global climate change, *Geophysical Research Letters*, 41, 22, 10.1002/2014GL061541.

Rollins, A. W., T. D. Thornberry, R. S. Gao, J. B. Smith, D. S. Sayres, M. R. Sargent, C. Schiller, M. Krämer, N. Spelten, **D. F. Hurst**, **A. F. Jordan**, **E. G. Hall**, H. Vömel, G. S. Diskin, J. R. Podolske, L. E. Christensen, K. H. Rosenlof, E. J. Jensen and D. W. Fahey, (2014), Evaluation of UT/LS hygrometer accuracy by intercomparison during the NASA MACPEX mission, *Journal of Geophysical Research: Atmospheres*, 119, 4, 10.1002/2013JD020817.

Ross, RM, LB Quetin, **T Newberger**, TC Shaw, JL Jones, SA Oakes and KJ Moore, (2014), Trends, cycles, interannual variability for three pelagic species west of the Antarctic Peninsula 1993-2008, *Marine Ecology Progress Series*, 515, 10.3354/meps10965.

Shantz, N. C., I. Gultepe, **E. Andrews**, A. Zelenyuk, M. E. Earle, A. M. Macdonald, P. S. K. Liu and W. R. Leaitch, (2014), Optical, physical, and chemical properties of springtime aerosol over Barrow Alaska in 2008, *International Journal of Climatology*, 10.1002/joc.3898.

Stone, R. S., S. Sharma, A. Herber, K. Eleftheriadis and **D. W. Nelson**, (2014), A characterization of Arctic aerosols on the basis of aerosol optical depth and black carbon measurements, *Elem. Sci. Anth.*, 2, 1, 000027, 10.12952%2Fjournal.elementa.000027.

Titos, G., **A. Jefferson**, **P. J. Sheridan**, **E. Andrews**, H. Lyamani, L. Alados-Arboledas and **J. A. Ogren**, (2014), Aerosol light-scattering enhancement due to water uptake during the TCAP campaign, *Atmospheric Chemistry and Physics*, 14, 13, 7031-7043, 10.5194/acp-14-7031-2014.

Theme 2. Monitoring and Understanding Changes in Surface Radiation, Clouds and Aerosol Distributions

Year of Publication: 2013

Asmi, A., O'Dowd, C, Jennings, S.G., Weller, R, Flentie, H, Fjaeraa, A.M, Fiebig, M, Myhre, C.L, Hallar, A.G., Laj, P, M. Collaud Coen, **J. A. Ogren**, **E. Andrews**, **P. Sheridan**, **A. Jefferson**, E. Weingartner, U. Baltensperger, N. Bukowiecki, H. Lihavainen, N. Kivekäs, E. Asmi, P. P. Aalto, M. Kulmala, A. Wiedensohler, W. Birmili, A. Hamed, , (2013), Aerosol decadal trends – Part 2: In-situ aerosol particle number concentrations at GAW and ACTRIS stations, *Atmospheric Chemistry and Physics*, 13, 2, 10.5194/acp-13-895-2013.

Augustine, John A. and **Ellsworth G Dutton**, (2013), Variability of the surface radiation budget over United States from 1996 through 2011 from high-quality measurements, *Journal of Geophysical Research*, 118, 10.1029/2012JD018551.

Buller, D.B., Berwick, M., Shane, J., **Lantz, K.**, Klein Buller, M., , (2013), User-centered Development of a Smart Phone Mobile Application Delivering Personalized Real-time Advice on Sun Protection, Translational Behavioral Medicine, JAMA Dermatol. 2015 May; 151(5):497-504. doi: 10.1001/jamadermatol.2014.3889.

Collaud Coen, M., Weller, R, Weingartner, R, Virkkula, A, **Sheridan, P**, Schichtel, B.A., **Ogren, J.A.**, O'Dowd, C, Lai, P, **E. Andrews**, A. Asmi, U. Baltensperger, N. Bukowiecki, D. Day, M. Fiebig, A. M. Fjaeraa, H. Flentje, A. Hyvärinen, **A. Jefferson**, S. G. Jennings, G. Kouvarakis, H. Lihavainen, C. Lund Myhre, W. C. Malm, N. Mihapopoulos, J. V. Molenar, , (2013), Aerosol decadal trends – Part 1: In-situ optical measurements at GAW and IMPROVE stations, *Atmospheric Chemistry and Physics*, 13, 2, 10.5194/acp-13-869-2013.

Gamon, John A., K. Fred Huemmrich, **Robert S. Stone** and Craig E. Tweedie, (2013), Spatial and temporal variation in primary productivity (NDVI) of coastal Alaskan tundra: Decreased vegetation growth following earlier snowmelt, *Remote Sensing of Environment*, 129, 144-153, 10.1016/j.rse.2012.10.030.

Griffis,, R., J. Howard, C. Auer, R. Beard, N. Bond, T. Boyer, D. Brown, K. Crane, S. Cross, B. Diaz, L. Jewett, R. Lumpkin, J.R. Morrison, J. O'Donnell, J. Overland, R. Parsons, N. Pettigrew, J. Quintrell, J. Runge, U. Send, **D. Stanitski** and Y. Xue, (2013), A Technical Input to the 2013 National Climate Assessment, *Oceans and Marine Resources in a Changing Climate*, 10.5822/978-1-61091-480-2.

Huang, M., G. R. Carmichael, T. Chai, R. B. Pierce, **S. J. Oltmans**, D. A. Jaffe, K. W. Bowman, A. Kaduwela, C. Cai, S. N. Spak, A. J. Weinheimer, L. G. Huey and G. S. Diskin, (2013), Impacts of transported background pollutants on summertime western US air quality: model evaluation, sensitivity analysis and data assimilation, *Atmospheric Chemistry and Physics*, 13, 1, 10.5194/acp-13-359-2013.

Kassianov, Evgueni, James Barnard, Mikhail Pekour, Larry K. Berg, **Joseph Michalsky**, **Kathy Lantz** and **Gary Hodges**, (2013), Do diurnal aerosol changes affect daily average radiative forcing?, *Geophysical Research Letters*, 40, 12, 10.1002/grl.50567.

Kelly, G. M., B. F. Taubman, L. B. Perry, J. P. Sherman, P. T. Soulé and **P. J. Sheridan**, (2013), Relationships between aerosols and precipitation in the southern Appalachian Mountains, *International Journal of Climatology*, 33, 14, 10.1002/joc.3632.

Michalsky, Joseph and Brock LeBaron, (2013), Fifteen-year aerosol optical depth climatology for Salt Lake City, *Journal of Geophysical Research: Atmospheres*, 118, 8, 10.1002/jgrd.50329.

Michalsky, Joseph J. and **G. B. Hodges**, (2013), Field Measured Spectral Albedo–Four Years of Data from the Western U.S. Prairie, *Journal of Geophysical Research: Atmospheres*, n/a-n/a, 10.1002/jgrd.50149.

Neely, Ryan R., Matthew Hayman, Robert Stillwell, Jeffrey P. Thayer, R. Michael Hardesty, **Michael O'Neill**, Matthew D. Shupe and Catherine Alvarez, (2013), Polarization Lidar at Summit, Greenland, for the Detection of Cloud Phase and Particle Orientation, *Journal of Atmospheric and Oceanic Technology*, 30, 8, 1635-1655, 10.1175/JTECH-D- 12-00101.1.

Petzold, A., **J. A. Ogren**, M. Fiebig, P. Laj, S.-M. Li, U. Baltensperger, T. Holzer-Popp, S. Kinne, G. Pappalardo, N. Sugimoto, C. Wehrli, A. Wiedensohler and X.-Y. Zhang, (2013), Recommendations for reporting "black carbon" measurements, *Atmospheric Chemistry and Physics*, 13, 16, 10.5194/ACP-13-8365-2013.

Thompson, R. L., **E. Dlugokencky**, F. Chevallier, P. Ciais, **G. Dutton**, **J. W. Elkins**, R. L. Langenfelds, R. G. Prinn, R. F. Weiss and Y. Tohjima, (2013), Interannual variability in tropospheric nitrous oxide, *Geophysical Research Letters*, 40, 16, 10.1002/grl.50721.

Lin, Neng-Huei, Si-Chee Tsay, Hal B. Maring, Ming-Cheng Yen, Guey-Rong Sheu, Sheng-Hsiang Wang, Kai Hsien Chi, Ming-Tung Chuang, Chang-Feng Ou-Yang, Joshua S. Fu, Jeffrey S. Reid, Chung-Te Lee, Lin-Chi Wang, Jia-Lin Wang, Christina N. Hsu, Andrew M. Sayer, Brent N. Holben, Yu-Chi Chu, Xuan Anh Nguyen, Khajornsak Sopajaree, Shui-Jen Chen, Man-Ting Cheng, Ben-Jei Tsuang, Chuen-Jinn Tsai, Chi-Ming Peng, **Russell C. Schnell**,

Tom Conway, Chang-Tang Chang, Kuen-Song Lin, Ying I. Tsai, Wen-Jhy Lee, Shuenn-Chin Chang, Jyh-Jian Liu, Wei-Li Chiang, Shih-Jen Huang, Tang- Huang Lin and Gin-Rong Liu, (2013), An overview of regional experiments on biomass burning aerosols and related pollutants in Southeast Asia: From BASE-ASIA and the Dongsha Experiment to 7-SEAS, *Atmospheric Environment*, 78, 10.1016/j.atmosenv.2013.04.066 .

Ryerson, T. B., **A. E. Andrews**, W. M. Angevine, T. S. Bates, C. A. Brock, B. Cairns, R. C. Cohen, O. R. Cooper, J. A. de Gouw, F. C. Fehsenfeld, R. A. Ferrare, M. L. Fischer, R. C. Flagan, A. H. Goldstein, J. W. Hair, R. M. Hardesty, C. A. Hostetler, J. L. Jimenez, A. O. Langford, E. McCauley, S. A. McKeen, L. T. Molina, A. Nenes, **S. J. Oltmans**, D. D. Parrish, J. R. Pederson, R. B. Pierce, K. Prather, P. K. Quinn, J. H. Seinfeld, C. J. Senff, A. Sorooshian, J. Stutz, J. D. Surratt, M. Trainer, R. Volkamer, E. J. Williams and S. C. Wofsy, (2013), The 2010 California Research at the Nexus of Air Quality and Climate Change (CalNex) field study, *Journal of Geophysical Research: Atmospheres*, 118, 11, 10.1002/jgrd.50331.

Schmid, B., J. M. Tomlinson, J. M. Hubbe, J. M. Comstock, F. Mei, D. Chand, M. S. Pekour, C. D. Kluzek, **E. Andrews**, S.C. Biraud and G. M. McFarquhar, (2013), The DOE ARM Aerial Facility, *Bulletin of the American Meteorological Society*, 10.1175/BAMS-D- 13-00040.1.

Schwarz, J. P., B. H. Samset, A. E. Perring, J. R. Spackman, R. S. Gao, P. Stier, M. Schulz, **F. L. Moore**, Eric A. Ray and D. W. Fahey, (2013), Global-scale seasonally resolved black carbon vertical profiles over the Pacific, *Geophysical Research Letters*, 40, 20, 10.1002/2013gl057775.

Sharma, S., M. Ishizawa, D. Chan, D. Lavoué, **E. Andrews**, K. Eleftheriadis and S. Maksyutov, (2013), 16-year simulation of Arctic black carbon: transport, source contribution, and sensitivity analysis on deposition, *Journal of Geophysical Research: Atmospheres*, n/a-n/a, 10.1029/2012JD017774.

Wang, Kaicun, Robert E. Dickinson, Qian Ma, **John A. Augustine** and Martin Wild, (2013), Measurement Methods Affect the Observed Global Dimming and Brightening, *Journal of Climate*, 10.1175/JCLI-D-12-00482.1.

Theme 3. Guiding Recovery of the Ozone Layer

Year of Publication: 2017

Bergman, J. W., L. Pfister, D. E. Kinnison, **E. J. Hintsa** and T. D. Thornberry, (2017), The viability of trajectory analysis for diagnosing dynamical and chemical influences on ozone concentrations in the UTLS, *Journal of Geophysical Research: Atmospheres*, 122, 11, 6025-6042, 10.1002/2017JD026487.

Blunden, Jessica, Derek S. Arndt, **B.D. Hall**, **S.A. Montzka**, **G. Dutton**, **J.W. Elkins**, (2017), Ozone Depleting Gases [in "State of the Climate in 2016"], *Bulletin of the American Meteorological Society*, 98, 8, S46-S47, 10.1175/2017BAMSStateoftheClimate.

Blunden, Jessica, Derek S. Arndt, R.J.H Dunn, **D.F. Hurst** and N. GobronK.M. Willett, (2017), Global Climate - Overview [in "State of the Climate in 2016"], *Bulletin of the American Meteorological Society*, 98, 8, S5-S55, 10.1175/2017BAMSStateoftheClimate.1.

Blunden, Jessica, Derek S. Arndt, S.M. Davis, K.H. Rosenlof, **D.F. Hurst**, H.B. Selkirk and H. Vomel, (2017), Stratospheric Water Vapor [in "Atmospheric Composition"] [in "State of the Climate in 2016"], *Bulletin of the American Meteorological Society*, 98, 8, s51-s52, 10.1175/2017BAMSStateoftheClimate.1.

Chang, Kai-Lan, **Irina Petropavlovskikh**, Owen R. Copper, Martin G. Schultz and Tao Wang, (2017), Regional trend analysis of surface ozone observations from monitoring networks in eastern North America, Europe and East Asia, *Elem Sci Anth*, 5, 50, 10.1525/elementa.243.

Cheadle, L. C., **S. J. Oltmans**, **G. Petron**, **R. C. Schnell**, E. J. Mattson, S. C. Herndon, A. M. Thompson, D. R. Blake and **A. McClure-Begley**, (2017), Surface ozone in the Colorado northern Front Range and the influence of oil and gas development during FRAPPE/DISCOVER-AQ in summer 2014, *Elem Sci Anth*, 5, 61, 10.1525/elementa.254.

Cheadle, Lucy, Lauren Deanes, Kira Sadighi, Joanna Gordon Casey, Ashley Collier-Oxandale and Michael Hannigan, (2017), Quantifying Neighborhood-Scale Spatial Variations of Ozone at Open Space and Urban Sites in Boulder, Colorado Using Low-Cost Sensor Technology, *Sensors*, 17, 9, 2072, 10.3390/s17092072.

Cullis, Patrick, **Chance Sterling**, **Emrys Hall**, **Allen Jordan**, **Bryan Johnson** and **Russell Schnell**, (2017), Pop Goes the Balloon!: What Happens when a Weather Balloon Reaches 30,000 m asl?, *Bulletin of the American Meteorological Society*, 98, 2, 216-217, 10.1175/BAMS-D-16-0094.1.

Deshler, Terry, Rene Stübi, Francis J. Schmidlin, Jennifer L. Mercer, Herman G. J. Smit, **Bryan J. Johnson**, Rigel Kivi and Bruno Nardi, (2017), Methods to homogenize electrochemical concentration cell (ECC) ozonesonde measurements across changes in sensing solution concentration or ozonesonde manufacturer, *Atmospheric Measurement Techniques*, 10, 6, 2021-2043, 10.5194/amt-10-2021-2017.

Evans, Robert D., **Irina Petropavlovskikh**, **Audra McClure-Begley**, **Glen McConville**, **Dorothy Quincy** and **Koji Miyagawa**, (2017), Technical note: The US Dobson station network data record prior to 2015, re-evaluation of NDACC and WOUDC archived records with WinDobson processing software, *Atmospheric Chemistry and Physics*, 17, 19, 12051-12070, 10.5194/acp-17-12051-2017.

Herman, Jay, **Robert Evans**, Alexander Cede, Nader Abuhassan, **Irina Petropavlovskikh**, **Glenn McConville**, **Koji Miyagawa** and Brandon Noirot, (2017), Ozone comparison between Pandora #34, Dobson #061, OMI, and OMPS in Boulder, Colorado, for the period December 2013–December 2016, *Atmospheric Measurement Techniques*, 10, 9, 3539-3545, 10.5194/amt-10-3539-2017.

Hossaini, Ryan, Martyn P. Chipperfield, **Stephen A. Montzka**, Amber A. Leeson, Sandip S. Dhomse and John A. Pyle, (2017), The increasing threat to stratospheric ozone from dichloromethane, *Nature Communications*, 8, 15962, 10.1038/ncomms15962
3. Huang, Guanyu, Xiong Liu, Kelly Chance, Kai Yang, Pawan K. Bhartia, Zhaonan Cai, Marc Allaart, Gérard Ancellet, Bertrand Calpini, Gerrie J. R. Coetzee, Emilio Cuevas-Agulló, Manuel Cupeiro, Hugo De Backer, Manvendra K. Dubey, Henry E. Fuelberg, Masatomo Fujiwara, Sophie Godin-Beekmann, Tristan J. Hall, **Bryan Johnson**, Everette Joseph, Rigel Kivi, Bogumil Kois, Ninong Komala, Gert König-Langlo, Giovanni Laneve, Thierry Leblanc, Marion Marchand, Kenneth R. Minschwaner, Gary Morris, Michael J. Newchurch, Shin-Ya Ogino, Nozomu Ohkawara, Ankie J. M. Piters, Françoise Posny, Richard Querel, Rinus Scheele, Frank J. Schmidlin, **Russell C. Schnell**, Otto Schrems, Henry Selkirk, Masato Shiotani, Pavla Skrivánková, René Stübi, Ghassan Taha, David W. Tarasick, Anne M. Thompson, Valérie Thouret, Matthew B. Tully, Roeland Van Malderen, Holger Vömel, Peter von der Gathen, Jacquelyn C. Witte and Margarita Yela, (2017), Validation of 10-year SAO OMI Ozone Profile (PROFOZ) product using ozonesonde observations, *Atmospheric Measurement Techniques*, 10, 7, 2455-2475, 10.5194/amt-10-2455-2017.

Jensen, Eric J., Troy D. Thornberry, Andrew W. Rollins, Rei Ueyama, Leonhard Pfister, Theopaul Bui, Glenn S. Diskin, Joshua P. DiGangi, **Eric Hintsa**, Ru-Shan Gao, Sarah Woods, R. Paul Lawson and Jasna Pittman, (2017), Physical processes controlling the spatial distributions of relative humidity in the tropical tropopause layer over the Pacific, *Journal of Geophysical Research: Atmospheres*, 122, 11, 6094-6107, 10.1002/2017JD026632.

Jensen, Eric J., Leonhard Pfister, David E. Jordan, Thaopaul V. Bui, Rei Ueyama, Hanwant B. Singh, Troy D. Thornberry, Andrew W. Rollins, Ru-Shan Gao, David W. Fahey, Karen H., Rosenlof, **James W. Elkins**, Glenn S. Diskin, Joshua P. DiGangi, R. Paul Lawson, Sarah Woods, Elliot L. Atlas, Maria A. Navarro Rodriguez, Steven C. Wofsy, Jasna Pittman, Charles G. Bardeen, Owen B. Toon, Bruce C. Kindel, Paul A. Newman, Matthew J. McGill, Dennis L. Hlavka, Leslie R. Lait, Mark R. Schoeberl, John W. Bergman, Henry B. Selkirk, M. Joan Alexander, Ji-Eun Kim, Boon H. Lim, Jochen Stutz and Klaus Pfeilsticker, (2017), The NASA Airborne Tropical Tropopause Experiment: High-Altitude Aircraft Measurements in the Tropical Western Pacific, *Bulletin of the American Meteorological Society*, 98, 1, 129-143, 10.1175/BAMS-D-14-00263.

Köhler, Ulf, Saulius Nevas, **Glen McConville**, **Robert Evans**, Marek Smid, Martin Stanek, Alberto Redondas and Fritz Schönenborn, (2017), Optical Characterization of Three Reference Dobsons in the ATMOZ Project – Verification of G. M. B. Dobson's Original Specifications, *Atmospheric Measurement Techniques Discussions*, 1-15, 10.5194/amt-2017-411.

Kuang, Shi, Michael J. Newchurch, Anne M. Thompson, Ryan M. Stauffer, **Bryan J. Johnson** and Lihua Wang, (2017), Ozone Variability and Anomalies Observed During SENEX and SEAC RS Campaigns in 2013 , *Journal of Geophysical Research: Atmospheres*, 122, 20, 11,227-11,241, 10.1002/2017JD027139.

Leonard, Mark, **Irina Petropavlovskikh**, Meiyun Lin, **Audra McClure-Begley**, **Bryan J. Johnson**, **Samuel J. Oltmans** and David Tarasick, (2017), An assessment of 10-year NOAA aircraft-based tropospheric ozone profiling in Colorado, *Atmospheric Environment*, 158, 116-127, 10.1016/j.atmosenv.2017.03.013.

Liang, Qing, Martyn P. Chipperfield, Eric L. Fleming, N. Luke Abraham, Peter Braesicke, James B. Burkholder, John S. Daniel, Sandip Dhomse, Paul J. Fraser, Steven C. Hardiman, Charles H. Jackman, Douglas E. Kinnison, Paul B. Krummel, **Stephen A. Montzka**, Olaf Morgenstern, Archie McCulloch, Jens Mühle, Paul A. Newman, Vladimir L. Orkin, Giovanni Pitari, Ronald G. Prinn, Matthew Rigby, Eugene Rozanov, Andrea Stenke, Fiona Tummon, Guus J. M. Velders, Daniele Visioni and Ray F. Weiss, (2017), Deriving Global OH Abundance and Atmospheric Lifetimes for Long-Lived Gases: A Search for CH3CCl3 Alternatives, *Journal of Geophysical Research: Atmospheres*, 122, 21, 11,914-11,933, 10.1002/2017JD026926.

Lim, Jeong Sik, Jinbok Lee, Dongmin Moon, Jin Seog Kim, Jeongsoon Lee and **Bradley D. Hall**, (2017), Gravimetric Standard Gas Mixtures for Global Monitoring of Atmospheric SF, *Analytical Chemistry*, 89, 22, 12068-12075, 10.1021/acs.analchem.7b02545.

Navarro, Maria A., Alfonso Saiz-Lopez, Carlos A. Cuevas, Rafael P. Fernandez, Elliot Atlas, Xavier Rodriguez-Lloveras, Douglas Kinnison, Jean-Francois Lamarque, Simone Tilmes, Troy Thornberry, Andrew Rollins, **James W. Elkins**, **Eric J. Hintsa** and **Fred L. Moore**, (2017), Modeling the inorganic bromine partitioning in the tropical tropopause layer over the eastern and western Pacific Ocean, *Atmospheric Chemistry and Physics*, 17, 16, 9917-9930, 10.5194/acp-17-9917-2017.

Newman, P.A., E.R. Nash, S.E. Strahan, N. Kramarova, C.S. Long, M.C. Pitts, **B. Johnson**, M.L. Santee, **I. Petropavlovskikh** and G.O. Braathen, (2017), 2016 Antarctic Ozone Hole [in "State of the Climate in 2016"], *Bull. Amer. Meteor. Soc*, 98, 8, S169-S172, 10.1175 /2017BAMSStateoftheClimate.1.

Parrish, D. D., **I. Petropavlovskikh** and **S. J. Oltmans**, (2017), Reversal of Long-Term Trend in Baseline Ozone Concentrations at the North American West Coast, *Geophysical Research Letters*, 44, 20, 10,675-10,681, 10.1002/2017GL074960.

Ray, Eric A., **Fred L. Moore**, **James W. Elkins**, Karen Rosenlof, Johannes Laube, Thomas Röckmann, Daniel R. Marsh and **Arlyn E. Andrews**, (2017), Quantification of the SF6 Lifetime Based on Mesospheric Loss Measured in the Stratospheric Polar Vortex, *Journal of Geophysical Research: Atmospheres*, 10.1002/2016JD026198.

Schultz, Martin G., Sabine Schröder, Olga Lyapina, Owen Cooper, Ian Galbally, **Irina Petropavlovskikh**, Erika Von Schneidemesser, Hiroshi Tanimoto, Yasin Elshorbany, Manish Naja, Rodrigo Seguel, Ute Dauert, Paul Eckhardt, Stefan Feigenspahn, Markus Fiebig, Anne-Gunn Hjellbrekke, You-Deog Hong, Peter Christian Kjeld, Hiroshi Koide, Gary Lear, David Tarasick, Mikio Ueno, Markus Wallasch, Darrel Baumgardner, Ming- Tung Chuang, Robert Gillett, Meehye Lee, Suzie Molloy, Raeesa Moolla, Tao Wang, Katrina Sharps, Jose A. Adame, Gerard Ancellet, Francesco Apadula, Paulo Artaxo, Maria Barlasina, Magdalena

Bogucka, Paolo Bonasoni, Limseok Chang, Aurelie Colomb, Emilio Cuevas, Manuel Cupeiro, Anna Degorska, Aijun Ding, Marina Fröhlich, Marina Frolova, Harish Gadhavi, Francois Gheusi, Stefan Gilge, Margarita Y. Gonzalez, Valerie Gros, Samera H. Hamad, Detlev Helmig, Diamantino Henriques, Ove Hermansen, Robert Holla, Jacques Huber, Ulas Im, Daniel A. Jaffe, Ninong Komala, Dagmar Kubistin, Ka-Se Lam, Tuomas Laurila, Haeyoung Lee, Ilan Levy, Claudio Mazzoleni, Lynn Mazzoleni, **Audra McClure-Begley**, Maznorizan Mohamad, Marijana Murovic, M. Navarro-Comas, Florin Nicodim, David Parrish, Katie A. Read, Nick Reid, Ludwig Ries, Pallavi Saxena, James J. Schwab, Yvonne Scorgie, Irina Senik, Peter Simmonds, Vinayak Sinha, Andrey Skorokhod, Gerard Spain, Wolfgang Spangl, Ronald Spoor, Stephen R. Springston, Kelvyn Steer, Martin Steinbacher, Eka Suharguniyawan, Paul Torre, Thomas Trickl, Lin Weili, Rolf Weller, Xiaobin Xu, Likun Xue and Ma Zhiqiang, (2017), Tropospheric Ozone Assessment Report: Database and Metrics Data of Global Surface Ozone Observations, *Elem Sci Anth*, 5, 58, 10.1525/elementa.244.

Stauffer, Ryan M., Anne M. Thompson, **Samuel J. Oltmans** and **Bryan J. Johnson**, (2017), Tropospheric ozonesonde profiles at long-term U.S. monitoring sites: 2. Links between Trinidad Head, CA, profile clusters and inland surface ozone measurements, *Journal of Geophysical Research: Atmospheres*, 122, 2, 1261-1280, 10.1002/2016JD025254.

Steinbrecht, Wolfgang, Lucien Froidevaux, Ryan Fuller, Ray Wang, John Anderson, Chris Roth, Adam Bourassa, Doug Degenstein, Robert Damadeo, Joe Zawodny, Stacey Frith, Richard McPeters, Pawan Bhartia, Jeannette Wild, Craig Long, Sean Davis, Karen Rosenlof, Viktoria Sofieva, Kaley Walker, Nabiz Rahpoe, Alexei Rozanov, Mark Weber, Alexandra Laeng, Thomas von Clarmann, Gabriele Stiller, Natalya Kramarova, Sophie Godin-Beekmann, Thierry Leblanc, Richard Querel, Daan Swart, Ian Boyd, Klemens Hocke, Niklaus Kämpfer, Eliane Maillard Barras, Lorena Moreira, Gerald Nedoluha, Corinne Vigouroux, Thomas Blumenstock, Matthias Schneider, Omaira García, Nicholas Jones, Emmanuel Mahieu, Dan Smale, Michael Kotkamp, John Robinson, **Irina Petropavlovskikh**, Neil Harris, Birgit Hassler, Daan Hubert and Fiona Tummon, (2017), An update on ozone profile trends for the period 2000 to 2016, *Atmospheric Chemistry and Physics*, 17, 17, 10675-10690, 10.5194/acp-17-10675-2017.

Sterling, Chance W., **Bryan J. Johnson**, **Samuel J. Oltmans**, Herman G. J. Smit, **Allen F. Jordan**, **Patrick D. Cullis**, **Emrys G. Hall**, Anne M. Thompson and Jacquelyn C. Witte, (2017), Homogenizing and Estimating the Uncertainty in NOAA's Long Term Vertical Ozone Profile Records Measured with the Electrochemical Concentration Cell Ozonesonde, *Atmospheric Measurement Techniques Discussions*, 1-39, 10.5194/amt-2017- 397.

Stutz, Jochen, Bodo Werner, Max Spolaor, Lisa Scalone, James Festa, Catalina Tsai, Ross Cheung, Santo F. Colosimo, Ugo Tricoli, Rasmus Raecke, Ryan Hossaini, Martyn P. Chipperfield, Wuhu Feng, Ru-Shan Gao, **Eric J. Hintsa**, **James W. Elkins**, **Fred L. Moore**, Bruce Daube, Jasna Pittman, Steven Wofsy and Klaus Pfeilsticker, (2017), A new Differential Optical Absorption Spectroscopy instrument to study atmospheric chemistry from a high-altitude unmanned aircraft, *Atmospheric Measurement Techniques*, 10, 3, 1017-1042, 10.5194/amt-10-1017-2017.

Thompson, Anne M., Jacquelyn C. Witte, Chance Sterling, **Allen Jordan**, **Bryan J. Johnson**, **Samuel J. Oltmans**, Masatomo Fujiwara, Holger Vömel, Marc Allaart, Ankie Piters, Gert J. R. Coetzee, Françoise Posny, Ernesto Corrales, Jorge Andres Diaz, Christian Félix, Ninong Komala, Nga Lai, H. T. Ahn Nguyen, Matakite Maata, Francis Mani, Zamuna Zainal, Shin-ya Ogino, Francisco Paredes, Tercio Luiz Bezerra Penha, Francisco Raimundo da Silva, Sukarni Sallons-Mitro, Henry B. Selkirk, F. J. Schmidlin, Rene Stübi and Kennedy Thiongo, (2017), First Reprocessing of Southern Hemisphere Additional Ozonesondes (SHADOZ) Ozone Profiles (1998-2016): 2. Comparisons With Satellites and Ground-Based Instruments, *Journal of Geophysical Research: Atmospheres*, 10.1002/2017JD027406.

Wang, Lihua, Michael J. Newchurch, Raul J. Alvarez II, Timothy A. Berkoff, Steven S. Brown, William Carrion, Russell J. De Young, **Bryan J. Johnson**, Rene Ganoe, Guillaume Gronoff, Guillaume Kirgis, Shi Kuang, Andrew O. Langford, Thierry Leblanc, Erin E. McDuffie, Thomas J. McGee, Denis Pliutau, Christoph J. Senff, John T. Sullivan, Grant Sumnicht, Laurence W. Twigg and Andrew J. Weinheimer, (2017), Quantifying TOLNet ozone lidar accuracy during the 2014 DISCOVER-AQ and FRAPPÉ campaigns, *Atmospheric Measurement Techniques*, 10, 10, 3865-3876, 10.5194/amt-10-3865-2017.

Werner, Bodo, Jochen Stutz, Max Spolaor, Lisa Scalone, Rasmus Raecke, James Festa, Santo Fedele Colosimo, Ross Cheung, Catalina Tsai, Ryan Hossaini, Martyn P. Chipperfield, Giorgio S. Taverna, Wuhu Feng, **James W. Elkins**, David W. Fahey, Ru- Shan Gao, **Eric J. Hintsa**, Troy D. Thornberry, **Fred L. Moore**, Maria A. Navarro, Elliot Atlas, Bruce C. Daube, Jasna Pittman, Steve Wofsy and Klaus Pfeilsticker, (2017), Probing the subtropical lowermost stratosphere and the tropical upper troposphere and tropopause layer for inorganic bromine, *Atmospheric Chemistry and Physics*, 17, 2, 1161-1186, 10.5194/acp-17-1161-2017.

Witte, Jacquelyn C., Anne M. Thompson, Herman G. J. Smit, Masatomo Fujiwara, Françoise Posny, Gert J. R. Coetzee, Edward T. Northam, **Bryan J. Johnson**, **Chance W. Sterling**, Maznorizan Mohamad, Shin-Ya Ogino, **Allen Jordan** and Francisco R. da Silva, (2017), First reprocessing of Southern Hemisphere ADditional OZonesondes (SHADOZ) profile records (1998-2015): 1. Methodology and evaluation, *Journal of Geophysical Research: Atmospheres*, 122, 12, 6611-6636, 10.1002/2016JD026403.

Yates, E. L., M. S. Johnson, L. T. Iraci, J.-M. Ryoo, R. B. Pierce, **P. D. Cullis**, W. Gore, M. A. Ives, **B. J. Johnson**, T. Leblanc, J. E. Marrero, **C. W. Sterling** and T. Tanaka, (2017), An Assessment of Ground Level and Free Tropospheric Ozone Over California and Nevada, *Journal of Geophysical Research: Atmospheres*, 122, 18, 10,089-10,102, 10.1002/2016JD026266.

Zerefos, Christos, John Kapsomenakis, Kostas Eleftheratos, Kleareti Tourpali, **Irina Petropavlovskikh**, Daan Hubert, Sophie Godin-Beekmann, Wolfgang Steinbrecht, Stacey Frith, Viktoria Sofieva and Birgit Hassler, (2017), Representativeness of single lidar stations for zonally averaged ozone profiles, their trends and attribution to proxies, *Atmospheric Chemistry and Physics Discussions*, 1-25, 10.5194/acp-2017-1040.

Zhang, Gen, Bo Yao, Martin K. Vollmer, **Stephen A. Montzka**, Jens Mühle, Ray F. Weiss, Simon O'Doherty, Yi Li, Shuangxi Fang and Stefan Reimann, (2017), Ambient mixing ratios of atmospheric halogenated compounds at five background stations in China, *Atmospheric Environment*, 160, 55-69, 10.1016/j.atmosenv.2017.04.017.

Theme 3. Guiding Recovery of the Ozone Layer

Year of Publication: 2016

Ancellet, Gerard, Nikos Daskalakis, Jean Christophe Raut, David Tarasick, Jonathan Hair, Boris Quennehen, François Ravetta, Hans Schlager, Andrew J. Weinheimer, Anne M. Thompson, **Bryan Johnson**, Jennie L. Thomas and Katharine S. Law, (2016), Analysis of the latitudinal variability of tropospheric ozone in the Arctic using the large number of aircraft and ozonesonde observations in early summer 2008, *Atmospheric Chemistry and Physics*, 16, 20, 13341-13358, 10.5194/acp-16-13341-2016.

Bodeker, G. E., S. Bojinski, D. Cimini, R. J. Dirksen, M. Haeffelin, J. W. Hannigan, **D. F. Hurst**, T. Leblanc, F. Madonna, M. Maturilli, A. C. Mikalsen, R. Philipona, T. Reale, D. J. Seidel, D. G. H. Tan, P. W. Thorne, H. Vömel and J. Wang, (2016), Reference Upper-Air Observations for Climate: From Concept to Reality, *Bulletin of the American Meteorological Society*, 97, 1, 123-135, 10.1175/BAMS-D-14-00072.1.

Booth, J F, H E Rieder and Y Kushnir, (2016), Comparing hurricane and extratropical storm surge for the Mid-Atlantic and Northeast Coast of the United States for 1979–2013, *Environmental Research Letters*, 11, 9, 094004, 10.1088/1748-9326/11/9/094004.

Butler, James H., Shari A. Yvon-Lewis, Jurgen M. Lobert, Daniel B. King, **Stephen A. Montzka**, John L. Bullister, Valentin Koropalov, **James W. Elkins**, **Bradley D. Hall**, **Lei Hu** and Yina Liu, (2016), A comprehensive estimate for loss of atmospheric carbon tetrachloride (CCI4) to the ocean, *Atmospheric Chemistry and Physics*, 16, 17, 10899-10910, 10.5194/acp-16-10899-2016.

Butler, Robyn, Paul I. Palmer, Liang Feng, Stephen J. Andrews, Elliot L. Atlas, Lucy J. Carpenter, Valeria Donets, Neil R. P. Harris, **Stephen A. Montzka**, Laura L. Pan, Ross J. Salawitch and Sue M. Schauffler, (2016), Quantifying the vertical transport of CHBr3 and CH2Br2 over the Western Pacific, *Atmospheric Chemistry and Physics Discussions*, 1-35, 10.5194/acp-2016-936.

Chambers, Scott D., Alastair G. Williams, Franz Conen, Alan D. Griffiths, Stefan Reimann, Martin Steinbacher, Paul B. Krummel, L. Paul Steele, Marcel V. van der Schoot, Ian E. Galbally, Suzie B. Molloy and **John E. Barnes**, (2016), Towards a Universal "Baseline" Characterisation of Air Masses for High- and Low-Altitude Observing Stations Using Radon-222, *Aerosol and Air Quality Research*, 16, 3, 885-899, 10.4209/aaqr.2015.06.0391.

Chipperfield, Martyn P., Qing Liang, Matthew Rigby, Ryan Hossaini, **Stephen A. Montzka**, Sandip Dhomse, Wuhu Feng, Ronald G. Prinn, Ray F. Weiss, Christina M. Harth, Peter K. Salameh, Jens Mühle, O&, apos, Simon Doherty, Dickon Young, Peter G. Simmonds, Paul B. Krummel, Paul J. Fraser, L. Paul Steele, James D. Happell, Robert C. Rhew, **James Butler**, Shari A. Yvon-Lewis, **Bradley Hall**, **David Nance**, **Fred Moore**, **Ben R. Miller**, **James W. Elkins**, Jeremy J. Harrison, Chris D. Boone, Elliot L. Atlas and Emmanuel Mahieu, (2016), Model sensitivity studies of the decrease in atmospheric carbon tetrachloride, *Atmospheric Chemistry and Physics*, 16, 24, 15741-15754, 10.5194/acp-16-15741-2016.

Chirkov, M., G. P. Stiller, A. Laeng, S. Kellmann, T. von Clarmann, C. D. Boone, **J. W. Elkins**, A. Engel, N. Glatthor, U. Grabowski, C. M. Harth, M. Kiefer, F. Kolonjari, P. B. Krummel, A. Linden, C. R. Lunder, **B. R. Miller**, **S. A. Montzka**, J. Mühle, O&apos, S. Doherty, J. Orphal, R. G. Prinn, G. Toon, M. K. Vollmer, K. A. Walker, R. F. Weiss, A. Wiegele and D. Young, (2016), Global HCFC-22 measurements with MIPAS: retrieval, validation, global distribution and its evolution over 2005–2012, *Atmospheric Chemistry and Physics*, 16, 5, 3345-3368, 10.5194/acp-16-3345-2016.

Davis, S.M., K.H. Rosenlof, **D.F. Hurst** and H.B. Selkirk, (2016), Stratospheric Water Vapor, [in "State of the Climate in 2015"], *Bull. Amer. Meteor. Soc.*, 97, 8, S51-S53, 10.1175/2016BAMSStateoftheClimate.1.

Davis, Sean M., Karen H. Rosenlof, Birgit Hassler, **Dale F. Hurst**, William G. Read, Holger Vömel, Henry Selkirk, Masatomo Fujiwara and Robert Damadeo, (2016), The Stratospheric Water and Ozone Satellite Homogenized (SWOOSH) database: a long-term database for climate studies, *Earth System Science Data*, 8, 2, 461-490, 10.5194/essd-8-461-2016.

Eckert, E., A. Laeng, S. Lossow, S. Kellmann, G. Stiller, T. von Clarmann, N. Glatthor, M. Höpfner, M. Kiefer, H. Oelhaf, J. Orphal, B. Funke, U. Grabowski, F. Haenel, A. Linden, G. Wetzel, W. Woiwode, P. F. Bernath, C. Boone, **G. S. Dutton**, **J. W. Elkins**, A. Engel, J. C. Gille, F. Kolonjari, T. Sugita, G. C. Toon and K. A. Walker, (2016), MIPAS IMK/IAA CFC-11 (CCl3F) and CFC-12 (CCl2F2) measurements: accuracy, precision and long-term stability, *Atmospheric Measurement Techniques*, 9, 7, 3355-3389, 10.5194/amt-9-3355-2016.

Hall, B.D., **S.A. Montzka**, **G. Dutton** and **J.W. Elkins**, (2016), Ozone-depleting gases, [in "State of the Climate in 2015"] , *Bull. Amer. Meteor. Soc.*, 97, 8, S47-S48, 10.1175/2016BAMSStateoftheClimate.1.

Hall, Emrys G., **Allen F. Jordan**, **Dale F. Hurst**, **Samuel J. Oltmans**, Holger Vömel, Benjamin Kühnreich and Volker Ebert, (2016), Advancements, measurement uncertainties, and recent comparisons of the NOAA frost point hygrometer, *Atmospheric Measurement Techniques*, 9, 9, 4295-4310, 10.5194/amt-9-4295-2016.

Hossaini, R., P. K. Patra, A. A. Leeson, G. Krysztofiak, N. L. Abraham, S. J. Andrews, A. T. Archibald, J. Aschmann, E. L. Atlas, D. A. Belikov, H. Bönisch, L. J. Carpenter, S. Dhomse, M. Dorf, A. Engel, W. Feng, S. Fuhlbrügge, P. T. Griffiths, N. R. P. Harris, R. Hommel, T. Keber, K. Krüger, S. T. Lennartz, S. Maksyutov, H. Mantle, G. P. Mills, **B. Miller**, **S. A. Montzka**, **F. Moore**, M. A. Navarro, D. E. Oram, K. Pfeilsticker, J. A. Pyle, B. Quack, A. D. Robinson, E. Saikawa, A. Saiz-Lopez, S. Sala, B.-M. Sinnhuber, S. Taguchi, S. Tegtmeier, R. T. Lidster, C. Wilson and F. Ziska, (2016), A multi-model intercomparison of halogenated very short-lived substances (TransCom-VSLS): linking oceanic emissions and tropospheric transport for a reconciled estimate of the stratospheric source gas injection of bromine, *Atmospheric Chemistry and Physics*, 16, 14, 9163-9187, 10.5194/acp-16-9163-2016.

Hu, Lei, **Stephen A. Montzka**, **Ben R. Miller**, **Arlyn E. Andrews**, **John B. Miller**, Scott J. Lehman, **Colm Sweeney**, Scot M. Miller, **Kirk Thoning**, **Carolina Siso**, Elliot L. Atlas, Donald R. Blake, Joost de Gouw, Jessica B. Gilman, **Geoff Dutton**, **James W. Elkins**, **Bradley Hall**, Huilin Chen, Marc L. Fischer, Marikate E. Mountain, Thomas Nehrkorn, Sebastien C. Biraud, **Fred L. Moore** and **Pieter Tans**, (2016), Continued emissions of carbon tetrachloride from the United States nearly two decades after its phaseout for dispersive uses, *Proceedings of the National Academy of Sciences*, 113, 11, 2880-2885, 10.1073/pnas.1522284113.

Hubert, Daan, Jean-Christopher Lambert, Tijl Verhoelst, José Granville, Arno Keppens, Jean-Luc Baray, Adam E. Bourassa, Ugo Cortesi, Doug A. Degenstein, Lucien Froidevaux, Sophie Godin-Beekmann, Karl W. Hoppel, **Bryan J. Johnson**, Erkki Kyrölä, Thierry Leblanc, Günter Lichtenberg, Marion Marchand, C. Thomas McElroy, Donal Murtagh, Hideaki Nakane, Thierry Portafaix, Richard Querel, James M. Russell III, Jacobo Salvador, Herman G. J. Smit, Kerstin Stebel, Wolfgang Steinbrecht, Kevin B. Strawbridge, René Stübi, Daan P. J. Swart, Ghassan Taha, David W. Tarasick, Anne M. Thompson, Joachim Urban, Joanna A. E. van Gijsel, Roeland Van Malderen, Peter von der Gathen, Kaley A. Walker, Elian Wolfram and Joseph M. Zawodny, (2016), Ground-based assessment of the bias and long-term stability of 14 limb and occultation ozone profile data records, *Atmospheric Measurement Techniques*, 9, 6, 2497-2534, 10.5194/amt-9-2497-2016.

Hurst, Dale F., William G. Read, Holger Vömel, Henry B. Selkirk, Karen H. Rosenlof, Sean M. Davis, **Emrys G. Hall**, **Allen F. Jordan** and **Samuel J. Oltmans**, (2016), Recent divergences in stratospheric water vapor measurements by frost point hygrometers and the Aura Microwave Limb Sounder, *Atmospheric Measurement Techniques*, 9, 9, 4447-4457, 10.5194/amt-9-4447-2016.

Kräuchi, Andreas, Rolf Philipona, Gonzague Romanens, **Dale F. Hurst**, **Emrys G. Hall** and **Allen F. Jordan**, (2016), Controlled weather balloon ascents and descents for atmospheric research and climate monitoring, *Atmospheric Measurement Techniques*, 9, 3, 929-938, 10.5194/amt-9-929-2016.

Liang, Q., P.A. Newman, S. Reimann, **James H. Butler**, **Bradley Hall** and **Stephen A. Montzka**, (2016), SPARC Report on the mystery of carbon tetrachloride, Liang, Q., P. Newman, S. Reimann, eds., , *SPARC Report No. 7*, WCRP-1, 10.3929/ethz-a-010690647.

McDuffie, Erin E., Peter M. Edwards, Jessica B. Gilman, Brian M. Lerner, William P. Dubé, Michael Trainer, Daniel E. Wolfe, Wayne M. Angevine, Joost deGouw, Eric J. Williams, Alex G. Tevlin, Jennifer G. Murphy, Emily V. Fischer, Stuart McKeen, Thomas B. Ryerson, Jeff Peischl, John S. Holloway, Kenneth Aikin, Andrew O. Langford, Christoph J. Senff, Raul J. Alvarez, Samuel R. Hall, Kirk Ullmann, **Kathy O. Lantz** and Steven S. Brown, (2016), Influence of oil and gas emissions on summertime ozone in the Colorado Northern Front Range, *Journal of Geophysical Research: Atmospheres*, 121, 14, 8712-8729, 10.1002/2016JD025265 .

Müller, Rolf, Anne Kunz, **Dale F. Hurst**, Christian Rolf, Martina Krämer and Martin Riese, (2016), The need for accurate long-term measurements of water vapor in the upper troposphere and lower stratosphere with global coverage, *Earth's Future*, 4, 2, 25-32, 10.1002/2015EF000321.

Nash, E.R., S.E. Strahan, N. Kramarova, **C.S. Long**, M.C. Pitts, P.A. Newman, **B.J. Johnson**, M.L. Santee, **I. Petropavlovskikh** and G.O. Braathen, (2016), Antarctic ozone hole [in "State of the Climate in 2015"], *Bull. Amer. Meteor. Soc.*, 97, 8, S168-S172, 10.1175/2016BAMSStateoftheClimate.1.

Oltmans, S. J., **A. Karion**, **R. C. Schnell**, **G. Pétron**, D. Helmig, **S. A. Montzka**, **S. Wolter**, **D. Neff**, **B. R. Miller**, J. Hueber, S. Conley, **B. J. Johnson** and **C. Sweeney**, (2016), O3, CH4, CO2, CO, NO2 and NMHC aircraft measurements in the Uinta Basin oil and gas region under low and high ozone conditions in winter 2012 and 2013, *Elementa: Science of the Anthropocene*, 4, 000132, 10.12952/journal.elementa.000132.

Orphal, Johannes, Johannes Staehelin, Johanna Tamminen, Geir Braathen, Marie-Renée De Backer, Alkiviadis Bais, Dimitris Balis, Alain Barbe, Pawan K. Bhartia, Manfred Birk, James B. Burkholder, Kelly Chance, Thomas von Clarmann, Anthony Cox, Doug Degenstein, Robert Evans, Jean-Marie Flaud, David Flittner, Sophie Godin-Beekmann, Viktor Gorshelev, Aline Gratien, Edward Hare, Christof Janssen, Erkki Kyrölä, Thomas McElroy, Richard McPeters, Maud Pastel, Michael Petersen, **Irina Petropavlovskikh**, Benedicte Picquet-Varrault, Michael Pitts, Gordon Labow, Maud Rotger-Languereau, Thierry Leblanc, Christophe Lerot, Xiong Liu, Philippe Moussay, Alberto Redondas, Michel Van Roozendael, Stanley P. Sander, Matthias Schneider, Anna Serdyuchenko, Pepijn Veefkind, Joële Viallon, Camille Viatte, Georg Wagner, Mark Weber, Robert I. Wielgosz and Claus Zehner, (2016), Absorption cross-sections of ozone in the ultraviolet and visible spectral regions: Status report 2015, *Journal of Molecular Spectroscopy*, 327, 105-121, 10.1016/j.jms.2016.07.007.

Parrish, D. D., I. E. Galbally, J.-F. Lamarque, V. Naik, L. Horowitz, D. T. Shindell, **S. J. Oltmans**, R. Derwent, H. Tanimoto, C. Labuschagne and M. Cupeiro, (2016), Seasonal cycles of O in the marine boundary layer: Observation and model simulation comparisons , *Journal of Geophysical Research: Atmospheres*, 121, 1, 538-557, 10.1002/2015JD024101.

Ray, Eric A., **Fred L. Moore**, Karen H. Rosenlof, David A. Plummer, Felicia Kolonjari and Kaley A. Walker, (2016), An idealized stratospheric model useful for understanding differences between long-lived trace gas measurements and global chemistry-climate model output, *Journal of Geophysical Research: Atmospheres*, 121, 10, 5356-5367, 10.1002/2015JD024447.

Schnell, Russell C., **Bryan J. Johnson**, **Samuel J. Oltmans**, **Patrick Cullis**, **Chance Sterling**, **Emrys Hall**, **Allen Jordan**, Detlev Helmig, **Gabrielle Petron**, Ravan Ahmadov, **James Wendell**, Robert Albee, Patrick Boylan, Chelsea R. Thompson, Jason Evans, Jacques Hueber, Abigale J. Curtis and Jeong-Hoo Park, (2016), Quantifying wintertime boundary layer ozone production from frequent profile measurements in the Uinta Basin, UT, oil and gas region, *Geophysical Research Letters*,121,18,11,038-11,054, doi.org/10.1002/2016JD025130.

Solomon, Susan, Doug Kinnison, Rolando R. Garcia, Justin Bandoro, Michael Mills, Catherine Wilka, Ryan R. Neely, Anja Schmidt, **John E. Barnes**, Jean-Paul Vernier and Michael Höpfner, (2016), Monsoon circulations and tropical heterogeneous chlorine chemistry in the stratosphere, *Geophysical Research Letters*, 43, 24, 12,624-12,633, 10.1002/2016GL071778.

Tarasick, D. W., J. Davies, H. G. J. Smit and **S. J. Oltmans**, (2016), A re-evaluated Canadian ozonesonde record: measurements of the vertical distribution of ozone over Canada from 1966 to 2013, *Atmospheric Measurement Techniques*, 9, 1, 195-214, 10.5194/amt-9-195-2016.

Van Dam, Brie, Detlev Helmig, Paul V. Doskey and **Samuel J. Oltmans**, (2016), Summertime surface O behavior and deposition to tundra in the Alaskan Arctic , *Journal of Geophysical Research: Atmospheres*, 121, 13, 8055-8066, 10.1002/2015JD023914.

Vollmer, Martin K., Jens Mühle, Cathy M. Trudinger, Matthew Rigby, **Stephen A. Montzka**, Christina M. Harth, **Benjamin R. Miller**, Stephan Henne, Paul B. Krummel, **Bradley D. Hall**, Dickon Young, Jooil Kim, Jgor Arduini, Angelina Wenger, Bo Yao, Stefan Reimann, Simon O'Doherty, Michela Maione, David M. Etheridge, Shanlan Li, Daniel P. Verdonik, Sunyoung Park, **Geoff Dutton**, L. Paul Steele, Chris R. Lunder, Tae Siek Rhee, Ove Hermansen, Norbert Schmidbauer, Ray H. J. Wang, Matthias Hill, Peter K. Salameh, Ray L. Langenfelds, Lingxi Zhou, Thomas Blunier, Jakob Schwander, **James W. Elkins**, **James H. Butler**, Peter G. Simmonds, Ray F. Weiss, Ronald G. Prinn and Paul J. Fraser, (2016), Atmospheric histories and global emissions of halons H-1211 (CBrClF), H- 1301 (CBrF), and H-2402 (CBrFCBrF) , *Journal of Geophysical Research: Atmospheres*, 121, 7, 3663-3686, 10.1002/2015JD024488.

Weigel, K., A. Rozanov, F. Azam, K. Bramstedt, R. Damadeo, K.-U. Eichmann, C. Gebhardt, **D. Hurst**, M. Kraemer, S. Lossow, W. Read, N. Spelten, G. P. Stiller, K. A. Walker, M. Weber, H. Bovensmann and J. P. Burrows, (2016), UTLS water vapour from SCIAMACHY limb measurementsV3.01 (2002–2012), *Atmospheric Measurement Techniques*, 9, 1, 133-158, 10.5194/amt-9-133-2016.

Willett, K.M., **D.F. Hurst**, R.J.H. Dunn and A.J. Dolman, (2016), Global Climate [in "State of the Climate in 2015"], *Bull. Amer. Meteor. Soc.*, 97, 8, S7-S58, 10.1175/2016BAMSStateoftheClimate.1.

Yokouchi, Yoko, Takuya Saito, Jiye Zeng, Hitoshi Mukai and **Stephen Montzka**, (2016), Seasonal variation of bromocarbons at Hateruma Island, Japan: implications for global sources, *Journal of Atmospheric Chemistry*, 10.1007/s10874-016-9333-9.

Zhou, Minqiang, Corinne Vigouroux, Bavo Langerock, Pucai Wang, **Geoff Dutton**, Christian Hermans, Nicolas Kumps, Jean-Marc Metzger, Geoff Toon and Martine De Mazière, (2016), CFC-11, CFC-12 and HCFC-22 ground-based remote sensing FTIR measurements at Réunion Island and comparisons with MIPAS/ENVISAT data, *Atmospheric Measurement Techniques*, 9, 11, 5621-5636, 10.5194/amt-9-5621-2016.

Theme 3. Guiding Recovery of the Ozone Layer

Year of Publication: 2015

Ahmadov, R., S. McKeen, M. Trainer, R. Banta, A. Brewer, S. Brown, P. M. Edwards, J. A. de Gouw, G. J. Frost, J. Gilman, D. Helmig, **B. Johnson**, **A. Karion**, A. Koss, A. Langford, B. Lerner, J. Olson, **S. Oltmans**, J. Peischl, **G. Petron**, Y. Pichugina, J. M. Roberts, T. Ryerson, **R. Schnell**, C. Senff, **C. Sweeney**, C. Thompson, P. R. Veres, C. Warneke, R. Wild, E. J. Williams, B. Yuan and R. Zamora, (2015), Understanding high wintertime ozone pollution events in an oil- and natural gas-producing region of the western US, *Atmos. Chem. Phys.*, 15, 411-429, 10.5194/acp-15-411-2015

Boylan, Patrick, Detlev Helmig and **Samuel Oltmans**, (2015), Ozone in the Atlantic Ocean marine boundary layer, *Elementa: Science of the Anthropocene*, 3, 10.12952/journal.elementa.000045.

Davis, S.M., K.H. Rosenlof and **D.F. Hurst**, (2015), State of the Climate 2014: Stratospheric Water Vapor, *Bulletin of the American Meteorological Society*, 96, 7, S44-S48, 10.1175/2015BAMSStateoftheClimate.1.

Fortems-Cheiney, A., M. Saunois, I. Pison, F. Chevallier, P. Bousquet, C. Cressot, **S. A. Montzka**, P. J. Fraser, M. K. Vollmer, P. G. Simmonds, D. Young, S. O'Doherty, R. F. Weiss, F. Artuso, B. Barletta, D. R. Blake, S. Li, C. Lunder, **B. R. Miller**, S. Park, R. Prinn, T. Saito, L. P. Steele and Y. Yokouchi, (2015), Increase in HFC-134a emissions in response to the success of the Montreal Protocol, *Journal of Geophysical Research: Atmospheres*, 120, 22, 11,728-11,742, 10.1002/2015JD023741.

Graziosi, F., J. Arduini, F. Furlani, U. Giostra, L.J.M. Kuijpers, **S.A. Montzka**, **B.R. Miller**, S.J. O'Doherty, A. Stohl, P. Bonasoni and **M. Maione**, (2015), European emissions of HCFC-22 based on eleven years of high frequency atmospheric measurements and a Bayesian inversion method, *Atmospheric Environment*, 112, 10.1016/j.atmosenv.2015.04.042.

Hall, B. , **S. A. Montzka** and **G. Dutton, J. W. Elkins**, (2015), Ozone depleting gases, [in "State of the Climate 2014"]. *Bulletin of the American Meteorological Society*, 96, (7), S42-43.

Harris, N. R. P., B. Hassler, F. Tummon, G. E. Bodeker, D. Hubert, **I. Petropavlovskikh**, W. Steinbrecht, J. Anderson, P. K. Bhartia, C. D. Boone, A. Bourassa, S. M. Davis, D. Degenstein, A. Delcloo, S. M. Frith, L. Froidevaux, S. Godin-Beekmann, N. Jones, M. J. Kurylo, E. Kyrölä, M. Laine, S. T. Leblanc, J.-C. Lambert, B. Liley, E. Mahieu, A. Maycock, M. de Mazière, A. Parrish, R. Querel, K. H. Rosenlof, C. Roth, C. Sioris, J. Staehelin, R. S. Stolarski, R. Stübi, J. Tamminen, C. Vigouroux, K. A. Walker, H. J. Wang, J. Wild and J. M. Zawodny, (2015), Past changes in the vertical distribution of ozone – Part 3: Analysis and interpretation of trends, *Atmospheric Chemistry and Physics*, 15, 17, 9965-9982, 10.5194/acp-15-9965-2015.

Herman, J., **R. Evans**, A. Cede, N. Abuhassan, **I. Petropavlovskikh** and **G. McConville**, (2015), Comparison of ozone retrievals from the Pandora spectrometer system and Dobson spectrophotometer in Boulder, Colorado, *Atmospheric Measurement Techniques*, 8, 8, 3407-3418, 10.5194/amt-8-3407-2015.

Hossaini, R., M. P. Chipperfield, A. Saiz-Lopez, J. J. Harrison, R. von Glasow, R. Sommariva, E. Atlas, M. Navarro, **S. A. Montzka**, W. Feng, S. Dhomse, C. Harth, J. Mühle, C. Lunder, S. O'Doherty, D. Young, S. Reimann, M. K. Vollmer, P. B. Krummel and P. F. Bernath, (2015), Growth in stratospheric chlorine from short-lived chemicals not controlled by the Montreal Protocol, *Geophysical Research Letters*, 42, 11, 4573-4580, 10.1002/2015GL063783.

Hossaini, R., M. P. Chipperfield, **S. A. Montzka**, A. Rap, S. Dhomse and W. Feng, (2015), Efficiency of short-lived halogens at influencing climate through depletion of stratospheric ozone, *Nature Geoscience*, 8, 3, 10.1038/ngeo2363.

Hu, Lei, **Stephen A. Montzka**, **John B. Miller**, Aryln E. Andrews, Scott J. Lehman, Benjamin R. Miller, **Kirk Thoning**, **Colm Sweeney**, Huilin Chen, David S. Godwin, **Kenneth Masarie**, **Lori Bruhwiler**, Marc L. Fischer, Sebastien C. Biraud, Margaret S. Torn, Marikate Mountain, Thomas Nehrkorn, Janusz Eluszkiewicz, Scot Miller, Roland R. Draxler, Ariel F. Stein, **Bradley D. Hall**, **James W. Elkins** and **Pieter P. Tans**, (2015), U.S. emissions of HFC-134a derived for 2008-2012 from an extensive flask-air sampling network, *Journal of Geophysical Research: Atmospheres*, 120, 2, 10.1002/2014JD022617.

Huang, J., H. Liu, J. H. Crawford, C. Chan, D. B. Considine, Y. Zhang, X. Zheng, **C. Zhao**, V. Thouret, **S. J. Oltmans**, S. C. Liu, D. B. A. Jones, S. D. Steenrod and M. R. Damon, (2015), Origin of springtime ozone enhancements in the lower troposphere over Beijing: in situ measurements and model analysis, *Atmospheric Chemistry and Physics*, 15, 9, 10.5194/acp-15-5161-2015.

Kramer, L. J., D. Helmig, J. F. Burkhart, A. Stohl, **S. Oltmans** and R. E. Honrath, (2015), Seasonal variability of atmospheric nitrogen oxides and non-methane hydrocarbons at the GEOSummit station, Greenland, *Atmospheric Chemistry and Physics*, 15, 12, 10.5194/acp-15-6827-2015.

Leedham Elvidge, E. C., D. E. Oram, J. C. Laube, A. K. Baker, **S. A. Montzka** and S. Humphrey, (2015), Increasing concentrations of dichloromethane, CH2Cl2, inferred from CARIBIC air samples collected 1998–2012, *Atmospheric Chemistry and Physics*, 15, 4, 10.5194/acp-15-1939-2015.

Lennartz, S. T., G. Krysztofiak, C. A. Marandino, B.-M. Sinnhuber, S. Tegtmeier, F. Ziska, R. Hossaini, K. Krüger, **S. A. Montzka**, E. Atlas, D. E. Oram, T. Keber, H. Bönisch and B. Quack, (2015), Modelling marine emissions and atmospheric distributions of halocarbons and dimethyl sulfide: the influence of prescribed water concentration vs. prescribed emissions, *Atmospheric Chemistry and Physics*, 15, 20, 11753-11772, 10.5194/acp-15-11753-2015.

Lin, Meiyun, Larry W. Horowitz, Owen R. Cooper, David Tarasick, Stephen Conley, Laura T. Iraci, **Bryan Johnson**, Thierry Leblanc, **Irina Petropavlovskikh** and Emma L. Yates, (2015), Revisiting the evidence of increasing springtime ozone mixing ratios in the free troposphere over western North America, *Geophysical Research Letters*, 42, 20, 8719-8728, 10.1002/2015GL06531.

Minschwaner, K., G. L. Manney, **I. Petropavlovskikh**, L. A. Torres, Z. D. Lawrence, B. Sutherland, A. M. Thompson, **B. J. Johnson**, Z. Butterfield, M. K. Dubey, L. Froidevaux, A. Lambert, W. G. Read and M. J. Schwartz, (2015), Signature of a tropical Pacific cyclone in the composition of the upper troposphere over Socorro, NM, *Geophysical Research Letters*, 42, 21, 9530-9537, 10.1002/2015GL065824.

Montzka, S. A., M. McFarland, S. O. Andersen, **B. R. Miller**, D. W. Fahey, **B. D. Hall**, **L. Hu**, **C. Siso** and **J. W. Elkins**, (2015), Recent Trends in Global Emissions of Hydrochlorofluorocarbons and Hydrofluorocarbons: Reflecting on the 2007 Adjustments to the Montreal Protocol, *The Journal of Physical Chemistry A*, 10.1021/jp5097376.

Nair, P. J., L. Froidevaux, J. Kuttippurath, J. M. Zawodny, J. M. Russell, W. Steinbrecht, H. Claude, T. Leblanc, J. A. E. van Gijsel, **B. Johnson**, D. P. J. Swart, A. Thomas, R. Querel, R. Wang and J. Anderson, (2015), Subtropical and midlatitude ozone trends in the stratosphere: Implications for recovery, *Journal of Geophysical Research: Atmospheres*, 120, 14, 7247-7257, 10.1002/2014JD022371.

Newman, P. A., E. R. Nash, S. E. Strahan, N. Kramarova, C. S. Long, M. C. Pitts, **B. Johnson**, M. L. Santee, **I. Petropavlovskikh** and G. O. Braathen, (2015), Ozone depletion [in "State of the Climate in 2014"], *Bulletin of the American Meteorological Society*, 96, 7, S165-S167, 10.1175/2015BAMSStateoftheClimate.1.

Ou-Yang, Chang-Feng, Chih-Chung Chang, Shen-Po Chen, Clock Chew, Bo-Ru Lee, Chih-Yuan Chang, **Stephen A. Montzka**, **Geoffrey S. Dutton**, **James H. Butler**, **James W. Elkins** and Jia-Lin Wang, (2015), Changes in the levels and variability of halocarbons and the compliance with the Montreal Protocol from an urban view, *Chemosphere*, 138, 10.1016/j.chemosphere.2015.06.070.

Petropavlovskikh, I., **R. Evans**, **G. McConville**, G. L. Manney and H. E. Rieder, (2015), The influence of the North Atlantic Oscillation and El Niño–Southern Oscillation on mean and extreme values of column ozone over the United States, *Atmospheric Chemistry and Physics*, 15, 3, 10.5194/acp-15-1585-2015.

Rhoderick, George C., **Bradley D. Hall**, Christina M. Harth, Jin Seog Kim, Jeongsoon Lee, **Stephen A. Montzka**, Jens Mühle, Stefan Reimann, Martin K. Vollmer and Ray F. Weiss, (2015), Comparison of halocarbon measurements in an atmospheric dry whole air sample, *Elementa: Science of the Anthropocene*, 3, 000075, 10.12952/journal.elementa.000075.

Lin, Meiyun, Arlene M. Fiore, Larry W. Horowitz, Andrew O. Langford, **Samuel J. Oltmans**, David Tarasick and Harald E. Rieder, (2015), Climate variability modulates western US ozone air quality in spring via deep stratospheric intrusions, *Nature Communications*, 6, 10.1038/ncomms8105.

Theme 3. Guiding Recovery of the Ozone Layer Year of Publication: 2014

Carpenter, L. J., S. Reimann, J. B. Burkholder, C. Clerbaux, **B. D. Hall**, R. Hossaini, J. C. Laube and S. A. Yvon-Lewis, (2014), Ozone-Depleting Substances (ODSs) and Other Gases of Interest to the Montreal Protocol, Chapter 1, *Scientific Assessment of Ozone Depletion: 2014, Global Ozone Research and Monitoring Project - Report No. 55*.

Cooper, O. R., D. D. Parrish, J. Ziemke, N. V. Balashov, M. Cupeiro, I. E. Galbally, S. Gilge, L. Horowitz, N. R. Jensen, J.-F. Lamarque, V. Naik, **S. J. Oltmans**, J. Schwab, D. T. Shindell, A. M. Thompson, V. Thouret, Y. Wang and R. M. Zbinden, (2014), Global distribution and trends of tropospheric ozone: An observation-based review, *Elementa: Science of the Anthropocene*, 2, 10.12952/journal.elementa.000029.

Dirksen, R. J., M. Sommer, F. J. Immler, **D. F. Hurst**, R. Kivi and H. Vömel, (2014), Reference quality upper-air measurements: GRUAN data processing for the Vaisala RS92 radiosonde, *Atmospheric Measurement Techniques*, 7, 12, 10.5194/amt-7-4463-2014.

Dlugokencky, E. J., **B. D. Hall**, **S. A. Montzka**, **G. Dutton**, J. Muhle and **J. W. Elkins**, (2014), Atmospheric Composition, Long-Lived greenhouse gases, [in "State of the Climate 2013"], *Bulletin of the American Meteorological Society*, 95, 7, S33-S34, 10.1175/2014BAMSStateoftheClimate.1.

Dlugokencky, E.J., **Masarie, K.A.**, **Conway, T.J.**, **Novelli, P.C.**, **Lang, P.M.**, **Crotwell, A.M.**, **Crotwell, M.**, **Vaughn, B.**, White, J.W.C., , (2014), Measurements of Greenhouse Gases and Other Atmospheric Tracers by NOAA ESRL from Discrete Air Samples Collected at Cape Grim Baseline Air Pollution Station., *Baseline Atmospheric ProgramAustralia 2009-2010*, 50-50.

Flynn, L., C. Long, X. Wu, R. Evans, C. T. Beck, **I. Petropavlovskikh**, **G. McConville**, W. Yu, Z. Zhang, J. Niu, E. Beach, Y. Hao, C. Pan, B. Sen, M. Novicki, S. Zhou and C. Seftor, (2014), Performance of the Ozone Mapping and Profiler Suite (OMPS) products, *Journal of Geophysical Research: Atmospheres*, 119, 10, 10.1002/2013JD020467.

Hall, B. D., A. Engel, J. Mühle, **J. W. Elkins**, F. Artuso, E. Atlas, M. Aydin, D. Blake, E.-G. Brunke, S. Chiavarini, P. J. Fraser, J. Happell, P. B. Krummel, I. Levin, M. Loewenstein, M. Maione and **S. A. Montzka**, (2014), Results from the International Halocarbons in Air Comparison Experiment (IHALACE), *Atmospheric Measurement Techniques*, 7, 2, 10.5194/amt-7-469-2014.

Hall, B. D., **S. A. Montzka**, **G. Dutton** and **J. W. Elkins**, (2014), Atmospheric composition, ozone-depleting gases [in "State of the Climate in 2013"], *Bulletin of the American Meteorological Society*, 95, 7, S34-S36, 10.1175/2014BAMSStateoftheClimate.1.

Hegglin, M. I., D. A. Plummer, T. G. Shepherd, J. F. Scinocca, J. Anderson, L. Froidevaux, B. Funke, **D. Hurst**, A. Rozanov, J. Urban, T. von Clarmann, K. A. Walker, H. J. Wang, S. Tegtmeier and K. Weigel, (2014), Vertical structure of stratospheric water vapour trends derived from merged satellite data, *Nature Geoscience*, 7, 10, 10.1038/NGEO2236 . Helmig, D., V. Petrenko, P. Martinerie, E. Witrant, T. Röckmann, A. Zuiderweg, R. Holzinger, J. Hueber, C. Thompson, J. W. C. White, W. Sturges, A. Baker, T. Blunier, D. Etheridge, M. Rubino and **P. Tans**, (2014), Reconstruction of Northern Hemisphere 1950– 2010 atmospheric non-methane hydrocarbons, *Atmospheric Chemistry and Physics*, 14, 3, 10.5194/acp-14-1463-2014.

Hoffmann, L., C. M. Hoppe, R. Müller, **G. S. Dutton**, J. C. Gille, S. Griessbach, A. Jones, C. I. Meyer, R. Spang, C. M. Volk and K. A. Walker, (2014), Stratospheric lifetime ratio of CFC-11 and CFC-12 from satellite and model climatologies, *Atmospheric Chemistry and Physics*, 14, 22, 10.5194/acp-14-12479-2014.

Hurst, D.F., Davis, S.M., Rosenlof, K.H., , (2014), [Global Climate: Atmospheric Composition] Stratospheric Water Vapor, [in "State of the Climate in 2013"], *Bull. Amer. Meteor. Soc.*, 95, 7, S40-S41.

Hurst, Dale F., Alyn Lambert, William G. Read, Sean M. Davis, Karen H. Rosenlof, **Emrys G. Hall**, **Allen F. Jordan** and **Samuel J. Oltmans**, (2014), Validation of Aura Microwave Limb Sounder stratospheric water vapor measurements by the NOAA frost point hygrometer, *Journal of Geophysical Research: Atmospheres*, 119, 1612-1625, 10.1002/2013JD020757.

Laeng, A., U. Grabowski, T. von Clarmann, G. Stiller, N. Glatthor, M. Höpfner, S. Kellmann, M. Kiefer, A. Linden, S. Lossow, V. Sofieva, **I. Petropavlovskikh**, D. Hubert, T. Bathgate, P. Bernath, C. D. Boone, C. Clerbaux, P. Coheur, R. Damadeo, D. Degenstein, S. Frith, L. Froidevaux, J. Gille, K. Hoppel, M. McHugh, Y. Kasai, J. Lumpe, N. Rahpoe, G. Toon, T. Sano, M. Suzuki, J. Tamminen, J. Urban, K. Walker, M. Weber and J. Zawodny, (2014), Validation of MIPAS IMK/IAA V5R_O3_224 ozone profiles, *Atmospheric Measurement Techniques*, 7, 11, 10.5194/amt-7-3971-2014.

Lefohn, Allen S., Christopher Emery, Douglas Shadwick, Heini Wernli, Jeagun Jung and **Samuel J. Oltmans**, (2014), Estimates of background surface ozone concentrations in the United States based on model-derived source apportionment, *Atmospheric Environment*, 84, 10.1016/j.atmosenv.2013.11.033.

Lin, Meiyun, Larry W. Horowitz, **Samuel J. Oltmans**, Arlene M. Fiore and Songmiao Fan, (2014), Tropospheric ozone trends at Mauna Loa Observatory tied to decadal climate variability, *Nature Geoscience*, 10.1038/NGEO2066.

Maione, M., F. Graziosi, J. Arduini, F. Furlani, U. Giostra, D. R. Blake, P. Bonasoni, X. Fang and **S. A. Montzka**, (2014), Estimates of European emissions of methyl chloroform using a Bayesian inversion method, *Atmospheric Chemistry and Physics*, 14, 18, 10.5194/acp-14-9755-2014.

Miyagawa, K., **I. Petropavlovskikh**, **R. D. Evans**, **C. Long**, J. Wild, G. L. Manney and W. H. Daffer, (2014), Long-term changes in the upper stratospheric ozone at Syowa, Antarctica, *Atmospheric Chemistry and Physics*, 14, 8, 3945-3968, 10.5194/acp-14-3945- 2014.

Miyagawa, K., **I. Petropavlovskikh**, **R. D. Evans**, C. Long, J. Wild, G. L. Manney and W. H. Daffer, (2014), Long-term changes in the upper stratospheric ozone at Syowa, Antarctica, *Atmospheric Chemistry and Physics*, 14, 8, 10.5194/acp-14-3945-2014.

Montzka, S.A., **Siso, C.**, **Mondeel, D.**, **Miller, B.R.**, **Hall, B.D.**, **Elkins, J.W.**, **Butler, J.H.**, , (2014), Flask measurements at CGBAPS by the HATS Group of NOAA/ESRL/GMD, *Australian Bureau of Meteorology and CSIRO Marine and Atmospheric Research*, 51-55.

Moore, Fred L., Eric A. Ray, Karen H. Rosenlof, **James W. Elkins**, **Pieter Tans**, **Anna Karion** and **Colm Sweeney**, (2014), A Cost-Effective Trace Gas Measurement Program for Long-Term Monitoring of the Stratospheric Circulation, *Bulletin of the American Meteorological Society*, 95, 1, 10.1175/BAMS-D-12-00153.1

Oltmans, S. J., **A. Karion**, **R. C. Schnell**, **G. Pétron**, **C. Sweeney**, **S. Wolter**, **D. Neff**, **S. A. Montzka**, **B. R. Miller**, D. Helmig, **B. J. Johnson** and J. Hueber, (2014), A high ozone episode in winter 2013 in the Uinta Basin oil and gas region characterized by aircraft measurements , *Atmospheric Chemistry and Physics Discussions*, 14, 14, 10.5194/acpd-14-20117-2014.

Oltmans, Samuel, **Russell Schnell**, **Bryan Johnson**, **Gabrielle Pétron**, **Thomas Mefford** and **Ryan Neely**, (2014), Anatomy of wintertime ozone associated with oil and natural gas extraction activity in Wyoming and Utah, *Elementa: Science of the Anthropocene*, 2, 10.12952/journal.elementa.000024 .

Parrondo, M. C., M. Gil, M. Yela, **B. J. Johnson** and H. A. Ochoa, (2014), Antarctic ozone variability inside the polar vortex estimated from balloon measurements, *AtmosphericChemistry and Physics*, 14, 1, 10.5194/acp-14-217-2014.

Patra, P. K., M. C. Krol, **S. A. Montzka**, T. Arnold, E. L. Atlas, B. R. Lintner, B. B. Stephens, B. Xiang, **J. W. Elkins**, P. J. Fraser, A. Ghosh, **E. J. Hintsa**, **D. F. Hurst**, K. Ishijima, P. B. Krummel, **B. R. Miller**, K. Miyazaki, **F. L. Moore**, J. Mühle, S. O'Doherty, R. G. Prinn, L. P. Steele, M. Takigawa, H. J. Wang, R. F. Weiss, S. C. Wofsy and D. Young, (2014), Observational evidence for interhemispheric hydroxyl-radical parity, *Nature*, 513, 7517, 10.1038/nature13721.

Ray, Eric A., **Fred L. Moore**, Karen H. Rosenlof, Sean M. Davis, **Colm Sweeney**, **Pieter Tans**, Tao Wang, **James W. Elkins**, Harald Bönisch, Andreas Engel, Satoshi Sugawara, T. Nakazawa and S. Aoki, (2014), Improving stratospheric transport trend analysis based on SF6 and CO2 measurements , *Journal of Geophysical Research: Atmospheres*, 119, 24, 10.1002/2014JD021802.

Redondas, A., **R. Evans**, R. Stuebi, U. Köhler and M. Weber, (2014), Evaluation of the use of five laboratory-determined ozone absorption cross sections in Brewer and Dobson retrieval algorithms, *Atmospheric Chemistry and Physics*, 14, 3, 1635-1648, 10.5194/acp-14-1635-2014.

Rhoderick, George C., David L. Duewer, Eric Apel, Annarita Baldan, **Bradley Hall**, Alice Harling, Detlev Helmig, Gwi Suk Heo, Jacques Hueber, Mi Eon Kim, Yong Doo Kim, **Ben Miller**, **Steve Montzka** and Daniel Riemer, (2014), International Comparison of a Hydrocarbon Gas Standard at the Picomol per Mol Level, *Analytical Chemistry*, 86, 5, 10.1021/ac403761u.

Rhoderick, George, Franklin Guenther, David Duewer, Jeongsoon Lee, Jin Seog Kim, **Bradley Hall**, Ray Weiss, Christina Harth, Stefan Reimann and Martin Vollmer, (2014), Final report on CCQM-P151: Halocarbons in dry whole air, *Metrologia*, 51, 1A, 10.1088/0026-1394/51/1A/08014.

Saikawa, E., M. Rigby, R. G. Prinn, **S. A. Montzka**, **B. R. Miller**, L. J. M. Kuijpers, P. J. B. Fraser, M. K. Vollmer, T. Saito, Y. Yokouchi, C. M. Harth, J. M.ühle, R. F. Weiss, P. K. Salameh, J. Kim, S. Li, S. Park, K.-R. Kim and D. Young, (2014), Corrigendum to "Global and regional emission estimates for HCFC-22", Atmos. Chem. Phys., 12, 10033–10050, 2012, *Atmospheric Chemistry and Physics*, 14, 10, 10.5194/acp-14-4857-2014.

Serke, David, **Emrys Hall**, John Bognar, **Allen Jordan**, Spencer Abdo, Kirstin Baker, Tom Seitel, Marta Nelson, Randolph Ware, Frank McDonough and Marcia Politovich, (2014), Supercooled liquid water content profiling case studies with a new vibrating wire sonde compared to a ground-based microwave radiometer, *Atmospheric Research*, 149, 10.1016/j.atmosres.2014.05.026.

Thompson, R. L., K. Ishijima, E. Saikawa, M. Corazza, U. Karstens, P. K. Patra, P. Bergamaschi, F. Chevallier, **E. Dlugokencky**, R. G. Prinn, R. F. Weiss, S. O'Doherty, P. J. Fraser, L. P. Steele, P. B. Krummel, A. Vermeulen, Y. Tohjima, A. Jordan, L. Haszpra, M. Steinbacher, S. Van der Laan, T. Aalto, F. Meinhardt, M. E. Popa, J. Moncrieff and P. Bousquet, (2014), TransCom N2O model inter-comparison – Part 2: Atmospheric inversion estimates of N2O emissions, *Atmospheric Chemistry and Physics*, 14, 12, 6177-6194, 10.5194/acp-14-6177-2014.

Thompson, R. L., **P. K. Patra**, K. Ishijima, E. Saikawa, M. Corazza, U. Karstens, C. Wilson, P. Bergamaschi, **E. Dlugokencky**, **C. Sweeney**, R. G. Prinn and R. F. Weiss, (2014), TransCom N2O model inter-comparison – Part 1: Assessing the influence of transport and surface fluxes on tropospheric N2O variability, *Atmospheric Chemistry and Physics*, 14, 8, 10.5194/acp-14-4349-2014.

Umezawa, T., A. K. Baker, D. Oram, C. Sauvage, D. O'Sullivan, A. Rauthe-Schöch, **S. A. Montzka**, A. Zahn and C. A. M. Brenninkmeijer, (2014), Methyl chloride in the upper troposphere observed by the CARIBIC passenger aircraft observatory: Large-scale distributions and Asian summer monsoon outflow, *Journal of Geophysical Research: Atmospheres*, 119, 9, 5542-5558, 10.1002/2013JD021396.

Warneke, C., F. Geiger, P. M. Edwards, W. Dube, **G. Pétron**, **J. Kofler**, A. Zahn, S. S. Brown, M. Graus, J. B. Gilman, B. M. Lerner, J. Peischl, T. B. Ryerson, J. A. de Gouw and J. M. Roberts, (2014), Volatile organic compound emissions from the oil and natural gas industry in the Uintah Basin, Utah: oil and gas well pad emissions compared to ambient air composition, *Atmospheric Chemistry and Physics*, 14, 20, 10.5194/acp-14-10977-2014.
Willett, K. M., A. J. Dolman, **D. F. Hurst**, J. Rennie and P. W. Thorne, (2014), Global Climate [in "State of the Climate in 2013"], *Bulletin of the American Meteorological Society*, 95, 7, S5-S49, 10.1175/2014BAMSStateoftheClimate.1.

Xiang, Bin, Prabir K. Patra, **Stephen A. Montzka**, Scot M. Miller, **James W. Elkins**, **Fred L. Moore**, Elliot L. Atlas, **Ben R. Miller**, Ray F. Weiss, Ronald G. Prinn and Steven C. Wofsy, (2014), Global emissions of refrigerants HCFC-22 and HFC-134a: Unforeseen seasonal contributions, *Proceedings of the National Academy of Sciences*, 111, 49, 10.1073/pnas.1417372111.

Koo, Ja-Ho, Yuhang Wang, Tianyu Jiang, Yi Deng, **Samuel J. Oltmans** and Sverre Solberg, (2014), Influence of climate variability on near-surface ozone depletion events in the Arctic spring, *Geophysical Research Letters*, 41, 7, 10.1002/2014GL059275.
Kassianov, E., J. Barnard, M. Pekour, L. K. Berg, J. Shilling, C. Flynn, F. Mei and **A. Jefferson**, (2014), Simultaneous retrieval of effective refractive index and density from size distribution and light-scattering data: weakly absorbing aerosol, *Atmospheric Measurement Techniques*, 7, 10, 10.5194/amt-7-3247-2014.

Miller, Scot M., Doug E. J. Worthy, Anna M. Michalak, Steven C. Wofsy, Eric A. Kort, Talya C. Havice, **Arlyn E. Andrews**, **Edward J. Dlugokencky**, Jed O. Kaplan, Patricia J. Levi, Hanqin Tian and Bowen Zhang, (2014), Observational constraints on the distribution, seasonality, and environmental predictors of North American boreal methane emissions, *Global Biogeochemical Cycles*, 28, 2, 10.1002/2013gb004580.

Seidel, Dian J., Graham Feingold, **Andrew R. Jacobson** and Norman Loeb, (2014), Detection limits of albedo changes induced by climate engineering, *Nature Climate Change*, 4, 2, 10.1038/nclimate2076.

Theme 3. Guiding Recovery of the Ozone Layer

Year of Publication: 2013

Fueglistaler, S., Y.S. Liu, T.J. Flannaghan, P.H. Haynes, D.P. Dee, W.J. Read, E.E. Remsberg, L.W. Thomason, **D.F. Hurst**, J.R. Lanzante and P.F. Bernath, (2013), The relation between atmospheric humidity and temperature trends for stratospheric water, *Journal of Geophysical Research: Atmospheres*, 118, 2, 10.1002/jgrd.50157.

Ganesan, A. L., A. Chatterjee, R. G. Prinn, C. M. Harth, P. K. Salameh, A. J. Manning, **B. D. Hall**, J. Mühle, L. K. Meredith and R. F. Weiss, (2013), The variability of methane, nitrous oxide and sulfur hexafluoride in Northeast India, *Atmospheric Chemistry and Physics*, 13, 21, 10.5194/acp-13-10633-2013.

Hasebe, F., Peter, T., Komala, N., Iwasaki, S., Shibata, T., Ogino, S.Y., Nishi, N., Vomel, H., Fujiwara, M., Shiotani, M., Inai, Y., **Oltmans, S.J.**, , (2013), Cold trap dehydration in the Tropical Tropopause Layer characterized by SOWER chilled-mirror hygrometer network data in the Tropical Pacific, *Atmospheric Chemistry and Physics*, 4393-4411, 10.5194/acp-13-4393-2013.

Jensen, E.J., Pilewskie, P., **Elkins, J.**, **Hintsa, E.**, **Moore, F.**, Mahoney, M.J., Atlas, E., Stutz, J., Pfeilsticker, K., Wofsy, S.C., Evan, S., Gao, R., Lawson, R.P., Pfister, L., Jordan, D.E., Fahey, D.W., Newman, P.A., Thornberry, T., Rollins, A., Diskin, G.S., Bui, T.P., McGill, M., Hlavka, D., Rosenlof, K., , (2013), The NASA Airborne Tropical TRopopause EXperiment (ATTREX), *SPARC Newsletter*, 41, 15-24.

Kunz, A., R. Müller, V. Homonnai, I. M. Jánosi, **D. Hurst**, A. Rap, P. M. Forster, F. Rohrer, N. Spelten and M. Riese, (2013), Extending water vapor trend observations over Boulder into the tropopause region: Trend uncertainties and resulting radiative forcing, *Journal of Geophysical Research: Atmospheres*, 118, 19, 10.1002/jgrd.50831.

Liu, Yina, Shari A. Yvon-Lewis, Daniel C. O. Thornton, **James H. Butler**, Thomas S. Bianchi, Lisa Campbell, **Lei Hu** and Richard W. Smith, (2013), Spatial and temporal distributions of bromoform and dibromomethane in the Atlantic Ocean and their relationship with photosynthetic biomass, *Journal of Geophysical Research: Oceans*, 118, 8, 10.1002/jgrc.20299.

Nair, P. J., S. Godin-Beekmann, J. Kuttippurath, G. Ancellet, F. Goutail, A. Pazmiño, L. Froidevaux, J. M. Zawodny, **R. D. Evans**, H. J. Wang, J. Anderson and M. Pastel, (2013), Ozone trends derived from the total column and vertical profiles at a northern mid-latitude station, *Atmospheric Chemistry and Physics*, 13, 20, 10373-10384, 10.5194/acp-13-10373-2013.

Nedoluha, Gerald E., R. Michael Gomez, Helen Neal, Alyn Lambert, **Dale Hurst**, Chris Boone and Gabriele Stiller, (2013), Validation of long-term measurements of water vapor from the midstratosphere to the mesosphere at two Network for the Detection of Atmospheric Composition Change sites, *Journal of Geophysical Research: Atmospheres*, 118, 2, 10.1029/2012JD018900.

Oltmans, S.J., A.S. Lefohn, D. Shadwick, J.M. Harris, H.E. Scheel, I. Galbally, D.W. Tarasick, **B.J. Johnson**, E.-G. Brunke, H. Claude, G. Zeng, S. Nichol, F. Schmidlin, J. Davies, E. Cuevas, A. Redondas, H. Naoe, T. Nakano and T. Kawasato, (2013), Recent tropospheric ozone changes – A pattern dominated by slow or no growth, *Atmospheric Environment*, 67, 10.1016/j.atmosenv.2012.10.057.

Papadimitriou, Vassileios C., Max R. McGillen, Shona C. Smith, Aaron M. Jubb, Robert W. Portmann, **Bradley D. Hall**, Eric L. Fleming, Charles H. Jackman and James B. Burkholder, (2013), 1,2-Dichlorohexafluoro-cyclobutane (1,2-c-C4F6Cl2, R-316c) a potent ozone depleting substance and greenhouse gas: atmospheric loss processes, lifetimes, and ozone depletion and global warming potentials for the (E) and (Z) stereoisomers, *The Journal of Physical Chemistry A*, 117, 43, 10.1021/jp407823k.

Park, A., S. Guillas and **I. Petropavlovskikh**, (2013), Trends in stratospheric ozone profiles using functional mixed models, *Atmospheric Chemistry and Physics*, 13, 22, 11473-11501, 10.5194/acp-13-11473-2013.

Rigby, M., R. G. Prinn, O&apos, S. Doherty, **S. A. Montzka**, A. McCulloch, C. M. Harth, J. Mühle, P. K. Salameh, R. F. Weiss, D. Young, P. G. Simmonds, **B. D. Hall**, **G. S. Dutton**, **D. Nance**, **D. J. Mondeel**, **J. W. Elkins**, P. B. Krummel, L. P. Steele and P. J. Fraser, (2013), Re-evaluation of the lifetimes of the major CFCs and CH3CCl3 using atmospheric trends, *Atmospheric Chemistry and Physics*, 13, 5, 2691-2702, 10.5194/acp-13-2691-2013.

Simmonds, P. G., A. J. Manning, M. Athanassiadou, A. A. Scaife, R. G. Derwent, S. O'Doherty, C. M. Harth, R. F. Weiss, **G. S. Dutton**, **B. D. Hall**, **C. Sweeney** and **J. W. Elkins**, (2013), Interannual fluctuations in the seasonal cycle of nitrous oxide and chlorofluorocarbons due to the Brewer-Dobson circulation, *Journal of Geophysical Research: Atmospheres*, 118, 19, 10,694-10,706, 10.1002/jgrd.50832.

Van Dam, Brie, Detlev Helmig, John F. Burkhart, Daniel Obrist and **Samuel J. Oltmans**, (2013), Springtime boundary layer O and GEM depletion at Toolik Lake, Alaska , *Journal of Geophysical Research: Atmospheres*, 118, 8, 10.1002/jgrd.50213.

Waugh, D. W., **A. M. Crotwell**, **E. J. Dlugokencky**, **G. S. Dutton**, **J. W. Elkins**, **B. D. Hall**, **E. J. Hintsa**, **D. F. Hurst**, **S. A. Montzka**, **D. J. Mondeel**, **F. L. Moore**, **J. D. Nance**, E. A. Ray, S. D. Steenrod, S. E. Strahan and **C. Sweeney**, (2013), Tropospheric SF: Age of air from the Northern Hemisphere mid-latitude surface , *Journal of Geophysical Research: Atmospheres*, 118, 19, 10.1002/jgrd.50848.

Ziska, F., B. Quack, K. Abrahamsson, S. D. Archer, E. Atlas, T. Bell, **J. H. Butler**, L. J. Carpenter, C. E. Jones, N. R. P. Harris, H. Hepach, K. G. Heumann, C. Hughes, J. Kuss, K. Krüger, P. Liss, R. M. Moore, A. Orlikowska, S. Raimund, C. E. Reeves, W. Reifenhäuser, A. D. Robinson, C. Schall, T. Tanhua, S. Tegtmeier, S. Turner, L. Wang, D. Wallace, J. Williams, H. Yamamoto, S. Yvon-Lewis and Y. Yokouchi, (2013), Global sea-to-air flux climatology for bromoform, dibromomethane and methyl iodide, *Atmospheric Chemistry and Physics*, 13, 17, 8915-8934, 10.5194/acp-13-8915-2013.

Global Monitoring Division

Indicators of Preeminence 2: Leadership, Public Outreach, Awards and Retired GMD Staff Mentoring/Publications.

Contents:

GLOBAL MONITORING DIVISION

Leadership Roles 2013-present

Editorships

- Arlyn Andrews, Panelist, Decadal Survey for Earth Science and Applications from Space, Climate Variability and Change: Seasonal to Centennial Panel, 2016-2018.
- Charles Long, Team Leader for the review of Chapter 8 of the AR5 IPCC WG1 report (Anthropogenic and Natural Radiative Forcing), 2012-2014.
- Dale Hurst, Chapter Editor for the Bulletin of the American Meteorological Society (BAMS) State of the Climate Reports, 2013-2016.
- Dale Hurst, Expert Reviewer for the Intergovernmental Panel for Climate Change (IPCC) Fifth Assessment Report (AR5), Chapter 2, 2013.
- Diane Stanitski, Chapter Editor for the BAMS State of the Climate Report, 2017
- Diane Stanitski, Invited Editor, Special issue on Arctic Indicators, Environmental Research Letters, 2018.
- Gabrielle Petron, Journal guest editor, Elementa Science of the Anthropocene, Oil and Natural Gas Special Forum, 2015-2016.
- Irina Petropavlovskikh, associate editor for the ACP special issue “Quadrennial Ozone Symposium 2016 – Status and trends of atmospheric ozone”, 2016-2018.
- Irina Petropavlovskikh, Editor of the special issue "Quadrennial Ozone Symposium 2016 – Status and trends of atmospheric ozone" (ACP/AMT inter-journal SI), 2017-2018.
- Irina Petropavlovskikh, Editor of the special issue of the Symposium for the 30th Anniversary of the Montreal Protocol proceedings, published under the umbrella of the Geoscience series of French Academy of Sciences, hosted by the Elsevier publishing company, 2018.
- Irina Petropavlovskikh, invited editor for special issue in the Geosciences journal, “Proceedings of Symposium for the 30th Anniversary of the Montreal Protocol”, 2017-2018.
- John Ogren, Editorial Board Member, Aerosol and Air Quality Research (http://aaqr.org/), 2014-2016.
- Lei Hu, Reviewer, Scientific Assessment of Ozone Depletion: Chapter 1, 2018 Oil and Natural Gas Special Forum 2016-present.
- Patrick Sheridan, Board Member, Aerosol and Air Quality Research (http://aaqr.org/), 2014-2016.
- Pieter Tans, Editor of "Expert recommendations for GHG measurement techniques" following WMO/GAW biannual meetings, 2013 and 2015.
- Pieter Tans, Editorial Board Member, Tellus B, 2013-present.
- Pieter Tans, Review Editor of Chapter 6 (Carbon and other biogeochemical cycles) of IPCC 5th Assessment, 2013.

- Stefan Schwietzke, Journal guest editor, Elementa Science of the Anthropocene, Oil and Natural Gas Special Forum, 2016–present.
- Steve Montzka, Co-Chair for Chapter 2 (HFCs) of WMO/UNEP Scientific Assessment of Ozone Depletion International report, 2018.
- Steve Montzka, Review Editor for Chapter 1 (ODSs) of the WMO/UNEP Scientific Assessment of Ozone Depletion International report, 2014.

Authorship Contributors to National and International Assessments and Reports

- Andy Jacobson, Lead chapter author, 2nd State of the Carbon Cycle Report, 2016-2018.
- Arlyn Andrews, Chapter Lead, North American Carbon Program Science Implementation Plan, 2018 (ongoing).
- Bradley Hall, Co-Author, Scientific Assessment of Stratospheric Ozone (Chapter 1: Long-lived Ozone-Depleting Substances), 2013-2014; 2017-2018.
- Dale Hurst, Contributing Author for the Scientific Assessment of Ozone Depletion, Chapter 4, 2014.
- Irina Petropavlovskikh, co-author of Chapter 2 of the WMO/UNEP Ozone Assessment, 2014; co-author of Chapter 3 of the WMO/UNEP Ozone Assessment, 2012-2018.
- Irina Petropavlovskikh, co-author of the SPARC LOTUS report “Long term trends and uncertainties in Stratosphere”, 2018 (under review, expected publication date May 2018).
- Irina Petropavlovskikh, Contributor/Author, Bulletin of the Meteorological Society (BAMS) State of the Climate Report, 2016-2018.
- John Miller, co-lead author of Atmospheric chapter of the Second State of the Carbon Cycle Report (SOCCR-2), 2016-2018.
- Kathy Lantz, Contributor/Author Bulletin of the Meteorological Society (BAMS) State of the Climate Report, 2013-2015
- Lei Hu, Co-Author, SPARC Report on the Mystery of Carbon Tetrachloride, 2016
- Steve Montzka co-author of the SPARC Report on the Mystery of Carbon Tetrachloride, Q. Liang, P. Newman, and S. Reimann, eds., 2016.

Collaboration Teams

International

- Irina Petropavlovskikh, "LOTUS – Long-term Ozone Trends and Uncertainties in the Stratosphere" activity leader for the SPARC (Stratosphere-troposphere Processes And their Role in Climate), core project of the World Climate Research Programme, 2017-present.
- Irina Petropavlovskikh, ”OCTAV-UTLS – Observed Composition Trends And Variability in the Upper Troposphere and Lower Stratosphere " activity leader for the SPARC (Stratosphere-troposphere Processes And their Role in Climate), core project of the World Climate Research Programme, 2017-present.

- Irina Petropavlovskikh, Dobson/Brewer working group representative, Network for the Detection Atmospheric Composition Change (NDACC), 2015-present.
- James Elkins, HATS Cooperating Network Liaison, Advance Global Atmospheric Gas Experiment (AGAGE), 1986-present.
- James Elkins, HATS Cooperating Network Liaison, Network for the Detection Atmospheric Composition Change (NDACC), 2008-present.
- Russell Schnell, NOAA Pacific Island Regional Collaboration Team, 2013-2016.

U.S.

- Allison McComiskey, Co-Chair, Aerosol Measurement Science Group, DOE Atmospheric Radiation Measurement Climate Research Facility, 2014-present.
- Allison McComiskey, Co-Chair, Atmosphere Collaboration Team, Interagency Arctic Research Policy Committee, 2014-2017.
- Andy Jacobson, Orbiting Carbon Observatory-2 science team, 2011-present.
- Arlyn Andrews, Organizer, Sustained Observations for Carbon Cycle Science and Decision Support Workshop; Boulder, Colorado, 2016.
- Diane Stanitski, Co-chair, Symposium on Education, American Meteorological Society, 2015-2018.
- Diane Stanitski, Member, National Preparedness Science Technology (NPST) Meteorological Hazards Task Force (multiagency), 2015.
- Gabrielle Petron, co-PI for DOE-RPSEA Methane project, 2014-2016.
- John Barnes served on the NASA SAGE III ISS Scientific Utilization Team from 2012 through the launch of the satellite instrument in 2017.
- John Miller, Member of NASA Carbon Monitoring System (CMS) Science Team, 2012-present.
- John Miller, Member of NASA Orbiting Carbon Observatory-2 (OCO-2) Science Team, 2011-present.

NOAA

- Brian Vasel, NOAA Ionizing Radiation Safety Committee, 2012-present.
- Brian Vasel, NOAA/OAR NEPA Team, 2013-present.
- Bryan Thomas, NOAA/OAR Diversity & Inclusion Advisory Council, 2017-present.
- Chris Cornwall, Chair of the NOAA Boulder IT Council (BITC), reporting to the NOAA Boulder Directors Council (NBDC), 2012-present.
- Darryl Kuniyuki, NOAA Pacific Region Executive Board, 2016-present.
- Irina Petropavlovskikh, Co-chair of the Trace Gases working group for the IASOA (International Arctic Systems for Observing the Atmopsher), 2016-present.
- Irina Petropavlovskikh, OMPS (Ozone Mapping and Profiler Suite) Operational Algorithm Team (OOAT) Advisor and member of validation team for NOAA JPSS operational ozone products, 2001-present.
- James Elkins, NOAA Arctic Regional Collaboration Team (ARCTic), 2006-present

Steering and Working Group Committees

- Allison McComiskey, Commissioner, International Radiation Commission, 2017-present.
- Allison McComiskey, Gordon Research Conference for Radiation and Climate, Vice-Chair 2019, Chair 2021.
- Allison McComiskey, Member, Radiation Committee of the American Meteorological Society, 2013-2015, 2017-present.
- Andy Jacobson, North American Carbon Program science steering group, 2011-2015.
- Arlyn Andrews, Member, Carbon Cycle Science Steering Group, 2013-2015.
- Bradley Hall, Member, Working Group: Gas Analysis Working Group (under the Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology), 2013-present.
- Brain Vasel, NSF/OPP McMurdo Area Users Committee, 2007-present.
- Brain Vasel, NSF/OPP South Pole Area Users Committee, 2007-present.
- Brain Vasel, NSF/OPP Summit Greenland Long Range Planning Team, 2007-present.
- Brian Vasel, NSF/OPP Palmer Area Users Committee, 2007-present.
- Bryan Johnson, Member of the Assessment of Standard Operating Procedures for Ozone Sondes panel, 2012-present.
- Bryan Johnson, Steering committee for NDAAC (Network for Detection of Atmospheric Composition Change), Ozone & Aerosol Sonde working group, 2010-present.
- Dale Hurst, Contributing Author for the Stratosphere-Troposphere Processes and their Role in Climate (SPARC) second Water Vapor Assessment (WAVAS-2), 2013-present.
- Dale Hurst, External Water Vapor Measurement Expert for the In-Service Aircraft for a Global Observing System (IAGOS), 2015-present.
- Dale Hurst, Member of the Global Climate Observing System (GCOS) Atmospheric Observation Panel for Climate (AOPC), 2017-present.
- Dale Hurst, Member of the Working Group and a co-chair of the Task Team of Site Representatives of the GCOS Reference Upper Air Network (GRUAN), 2010-present.
- Dale Hurst, Sonde Working Group Representative on the Steering Committee of the Network for the Detection of Atmospheric Composition Change (NDACC), 2016-present.
- Diane Stanitski, Member, Observations Interagency Working Group (ObsIWG), U.S. Global Change Research Program, 2014-present.
- Diane Stanitski, Member, Surface Radiation and Cloud Working Group, International Arctic Systems for Observing the Atmosphere (IASOA), 2016-present.

- Diane Stanitski, NOAA Deputy Representative to the U.S. Global Change Research Program, Subcommittee on Global Change Research, 2013-present.
- Diane Stanitski, Selection Committee for SOARS Portages, UCAR Significant Opportunities in Atmospheric Research and Science (SOARS) program, 2017-2018.
- Diane Stanitski, Steering Committee Member, UCAR Significant Opportunities in Atmospheric Research and Science (SOARS) program, 2016-present.
- Edward Dlugokencky, External advisory board member for EU VERIFY project ("Observation-based system for monitoring and verification of greenhouse gases"), 2018.
- Irina Petropavlovskikh, Secretary of International Ozone Commission (IO_3C) under the IAMAS (International association of Meteorology and Atmospheric Sciences), 2016-present.
- Irina Petropavlovskikh, Steering committee for NDAAC (Network for Detection of Atmospheric Composition Change), Dobson/Brewer working group, 2014-present.
- James Butler, Carbon Cycle Interagency Working Group (CCIWG) in support of the U.S. Climate Change Science Program, 2005-present.
- James Butler, Chair, Science Advisory Board, IAGOS, 2014-present.
- James Butler, Member, Nominating Committee, American Association for the Advancement of Science, 2011-2013.
- James Butler, Member, Science Advisory Board, IGAS (IAGOS for the GMES Atmospheric Service), 2014-2016.
- James Butler, Member, Science Advisory Board, Integrated Carbon Observing System (ICOS), 2016-present.
- James Butler, Member, Science Advisory Board, In-service Aircraft Global Observing System (IAGOS), 2011-present.
- John Miller, Chair of the Users Working Group of the Oak Ridge National Laboratory Distributed Active Archive Center (ORNL/DAAC) for Biogeochemical Dynamics, 2012-present.
- John Ogren, Aerosols, Clouds, and Trace gases Research InfraStructure Network (ACTRIS), Advisory Board Member, 2011-2015.
- Kathy Lantz, Chair Baseline Surface Radiation Network (BSRN) Spectral Working Group, 2016-present.
- Lori Bruhwiler, Chapter Lead, 2nd SOCCR Report, 2017-2018.
- Lori Bruhwiler, Chapter Lead, Arctic Monitoring and Assessment Program, CH_4 Report, 2013-2015.
- Lori Bruhwiler, National Academy of Sciences U.S. Methane Report, 2017-2018
- Patrick Sheridan, Director of the NOAA Federated Aerosol Network, 2013-present.

- Russell Schnell, Department of State, National Council for International Visitors, 2013-present.
- Russell Schnell, Kazakhstan-U.S. Joint Commission on Scientific and Technological Cooperation, 2013-present.
- Russell Schnell, Member, Swedish Research Council: Review Panel on Large Research Infrastructure Proposals, 2015.
- Russell Schnell, U.S. State Department International Climate Change Bi-lateral Agreement Implementation Teams for China, India, Japan, and Korea, 2013-present.
- Russell Schnell, NDAAC Steering Committee, 2013-present.
- Russell Schnell, NOAA Bi-lateral Joint Working Group with China CMA, 2013-18.
- Russell Schnell, NOAA Bi-lateral Joint Working Group with Korea KMA, 2013-18.
- Russell Schnell, NOAA Pacific Island Regional Collaboration team, 2013-date.
- Russell Schnell, NOAA–European Commission JRC Implementing Arrangement Steering Committee, 2013-present.
- Russell, Schnell, Canada Foundation for Innovation: Chair, Review panel for Arctic Funding Proposals, 2014-2016.
- Stefan Schwietzke, CICERO, Oslo, Norway, 2017-present.
- Stefan Schwietzke, Institute for Atmospheric and Climate Science, ETH Zurich, Switzerland, 2016-present.
- Stefan Schwietzke, Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy, 2014-present.

Implementation Panels, Teams, Councils, Advisory Groups - International and National

- Bradley Hall, Member, Scientific Advisory Group, WMO Global Atmosphere Watch (GAW), Greenhouse Gases, 2013-present.
- Charles Long, Member, CINDY/DYNAMO International Science Committee, 2009-2014.
- Charles Long, Member, Global Energy Balance Working Group of the International Radiation Commission, 2010-present.
- Charles Long, Member, Surface Radiation and Cloud Working Group, International Arctic Systems for Observing the Atmosphere (IASOA), 2014-date.
- Charles Long, World Meteorological Organization (WMO) International Baseline Surface Radiation Network (BSRN) Project Manager, 2015-present.
- Edward Dlugokencky, Chair, WMO GAW Scientific Advisory Group for Greenhouse Gases, 2013-2015.
- Edward Dlugokencky, Ex-officio member, WMO GAW Scientific Advisory Group for Greenhouse Gases, 2015-present.
- Edward Dlugokencky, WMO, Member, Executive Team on World Data Centers (ET-WDC), 2017-present.

- James Butler, GCOS Atmospheric Observation Panel for Climate (AOPC), World Meteorological Organization, Geneva, 2005-2017.
- James Butler, U.S. Lead Representative, World Meteorological Organization Commission for Atmospheric Sciences, 2009-2017.
- John Barnes, Stratospheric Sulfur and its Role in Climate. (SSiRC) Implementation Panel, International Space Science Institute (ISSI), Bern, Switzerland, 2012-present.
- John Ogren, Chairman, WMO/GAW Aerosol Science Advisory Group, 2009-15.
- Kathy Lantz, World Meteorological Organization (WMO) UV Instrumentation Working Group 2000-present
- Steve Montzka, Member, International Ozone Commission, 2016.

International Advisory Roles and Advisor or Committee Member for Ph.D. Candidates and Post-doctoral Students

- Diane Stanitski, Ph.D. Committee for student Meghan Helmberger, University of Colorado at Boulder, 2017-present.
- Gabrielle Petron, Advisor of Ingrid Mielke-Maday, Ph.D. student, 2014-present.
- Gabrielle Petron, Defense committee for Joanna Gordon-Casey, 2015-2017.
- John Ogren, co-Advisor for Héctor Rivera Vázquez, Ph.D. candidate, University of Puerto Rico, 2010-present.
- Pieter Tans, Co-advisor of Stefan Schwietzke, Xin Lan, and Isaac Vimont (postdocs).
- Russell Schnell, Advisor, Japan, Mount Fuji Atmospheric Observatory, 2013- present.
- Russell Schnell, Advisor, Mexico, Sierra Negro Atmospheric Observatory, 2013- present.
- Russell Schnell, Advisor, Taiwan, Mount LuLin Baseline Observatory, 2013- present.
- Russell Schnell, Advisor, Tiksi, Russia Atmospheric Observatory Building Implementation (NSF), 2013-2016.
- Russell Schnell, OAR Representative, U.S.-China Science and Technology Secretariat, 2016-17.
- Russell Schnell, Advisory Panel, Alberta Environment and Parks: Environmental Monitoring and Science Division, 2014-present.
- Russell Schnell, Mentored five post-doctoral students, 2013-2018.

Fellows and other Roles

- Stephen Montzka, CIRES Fellow, 2011-present.
- Pieter Tans, CIRA Fellow, 2010-present.
- Pieter Tans, AGU Fellow, 2004-present.
- Pieter Tans, AAAS Fellow, 2011-present.

Patents

- John Barnes, U.S. Patent #8,531,516, Imaging Polar Nephelometer, 2013
- Pieter Tans, U.S. patent 9,310,346 (12 April 2016), together with scientists from Picarro, Pumped AirCore Used as a Tape Recorder for Air Measurements.

AWARDS

2013

- DOC Bronze Medal Award: **Elkins (NOAA), J. W., Hall (NOAA), B.D.**, Fahey, D.W., Ciciora, S., Gao, R., Rosenlof, K.: For the successful demonstration of the Global Hawk Unmanned Aircraft Systems for NOAA's Climate Goal.

- American Geophysical Union Excellence in Refereeing Award: **John Augustine.**

- CIRES Bronze Medal Award: **Geoffrey Dutton, Emrys Hall, Eric Hintsa, Dale Hurst, Allen Jordan, Fred Moore, Samuel Oltmans** and **Audra McClure (all CIRES)**. For the successful demonstration of the Global Hawk Unmanned Aircraft Systems for NOAA's Climate Goal.

- Yorum J. Kaufman Award for Unselfish Cooperation for Research, American Geophysical Union, **Samuel J. Oltmans (CIRES). For being the *preeminent* leader of in situ monitoring of tropospheric and stratospheric ozone and water vapor while multiplying the impact of this work though unmatched national and international collaborations.**

2014

- NOAA Administrator's Award**, Barnes, J. (NOAA)**For highly productive scientific and educational outreach programs at Mauna Loa Observatory above and beyond his full time management duties.

- Colorado Governor's Award for High-Impact Research: **Stephen A. Montzka**, **Gabrielle Petron, Russell C. Schnell.** For Atmospheric Impacts of Rapidly Expanding Oil & Gas Development across the West.

- NOAA and CIRES Silver Medal Award. For establishing an international, cooperative network to make coordinated long-term measurements of aerosol climate forcing properties. **Betsy Andrews** (CIRES), **Derek Hageman** (CIRES), **Anne Jefferson** (CIRES), **John Ogren**, and **Patrick Sheridan**.

2015

- Honorary Doctor of Science**, Russell C. Schnell,** University of Alberta, Canada.

- **Steve Montzka,** Nominated into the Montreal Protocol's Who's Who

- NOAA Technology Transfer Award. For Developing a small and robust instrument to monitor light absorption by atmospheric aerosols and recruiting a manufacturer to produce it commercially. **Patrick Sheridan, James Wendell**, and **John Ogren**.

- NOAA Research Employee of the Year. **Ann Thorne**. For Exceptional Service to NOAA's Global Monitoring Division and Earth System Research Laboratory, and an unsurpassed spirit and dedication to the NOAA Boulder Student Program.

2016

- National Aeronautics and Space Administration (NASA) Achievement Award for participation in the Discover-AQ Science Team. **Kathleen Lantz (CIRES), Joseph Michalsky (NOAA), Gary Hodges (CIRES, Emiel Hall (CIRES) and James Wendell (NOAA).** For outstanding achievement conducting airborne field studies to improve the diagnosis of near-surface air quality from space.

- 2016-06-28 – NASA Group Achievement Award – Airborne Tropical Tropopause Experiment (ATTREX) – For the outstanding achievement in advancing the understanding of the physical processes of the tropical tropopause layer and its role in the Earth's climate. Awardees : **Eric Hinsta, James Elkins, Fred Moore, Jeff Dutton, Brad Hall and Dave Nance.**

- Elected member of the International Ozone Commission, **Irina Petropavlovskihk.**

- Professor Vilho Väisälä Award for Outstanding Research Paper, World Meteorological Organization. Dirksen, R.J., M. Sommer, F.J. Immler, **D.F. Hurst** (CIRES) R. Kivi, and H. Vömel, Reference quality upper-air measurements: GRUAN data processing for the Vaisala RS92 radiosonde, *Atmos. Meas. Tech.*, *7*, 4463–4490, doi:10.5194/amt-7-4463-2014, 2014.

- Governor's Award for High Impact Research. **Brad Hall.** *For Preparing and Maintaining Critical Greenhouse Gas Calibration Standards and Methods Used in the Worldwide Monitoring of these Critical Atmospheric Gases.*

- Excellence in Refereeing Editor's Citation, **Steve Montzka**, Geophysical Research Letters.

2017

- NOAA Technology Transfer Award, **Allison McComiskey.** For improving forecasts of turbine height winds and solar irradiance from their High Resolution Rapid Refresh weather model to improve usage of renewable power by industry.

- Utility Variable Generation Integration Group Achievement Award for Solar Forecasting, **Chuck Long and Kathleen Lantz (CIRES)**.

- CIRES Technology Transfer Award to **Derek Hageman.** For improving forecasts of turbine-height winds and solar irradiance from their HRRR weather model to improve usage of renewal power by industry.

- 2017-06-15 – NASA Group Achievement Award – Pacific Oxidants, Sulfur, Ice, Dehydration, and Convection (POSIDON) – For outstanding achievement of the Pacific Oxidants, Sulfur, Ice, Dehydration, and Convection (POSIDON) airborne Earth Science Mission Team. **James W. Elkins, Geoff Dutton, Brad Hall ,Eric Hintsa, Fred Moore, Jon D. Nance, Dale Hurst, Emrys Hall, Allen Jordan.**

ESRL GLOBAL MONITORING DIVISION OUTREACH (Tours and EEO) 2013-2017

2013:

- **5483 visitors to the GMD** demonstration and interpretation site in the David Skaggs Research Center. Each group is given an escorted 20 minute GMD presentation in the one hour tour. Participants include school, teacher, senior center, international and unidentified groups such as scouts, service organizations and church affiliated.

- **405 visitors to the Mauna Loa Baseline Observatory,** Island of Hawaii. These tours last 2-3 hours and range from students, scientists, government officials and politician including **Senators Schatz (D, Hawaii) and Bill Nelson (D, Florida).**

- **213 visitors to Barrow Baseline Observatory**, Barrow Alaska. These tours last 1- 2 hours and include students, NOAA leadership, politicians and scientists.

- **49 visitors to American Samoa Baseline Observatory**, American Samoa. These tours last from 1-2 hours and are generally students from the island.

- **35 visitors to South Pole Baseline** Observatory. These visitors are various politicians, government funding agency representatives and science program managers brought to the South Pole by the National Science Foundation.

- **Summit Observatory,** the only visitors are guests of the NSF that come to the GMD instrument building on a tour of the site. Over the period 2013-2017 these numbered **245,** not broken down by year.

2014

- **5573 visitors to the GMD** demonstration and interpretation site in the David Skaggs Research Center.

- **401 visitors to the Mauna Loa Baseline Observatory,** Island of Hawaii.

- **100 visitors to Barrow Baseline Observatory,** Barrow Alaska.

- **45 visitors to American Samoa Baseline Observatory,** American Samoa.

- **59 visitors to South Pole Baseline Observatory.**

2015

- **6629 visitors to the GMD** demonstration and interpretation site in the David Skaggs Research Center.
- **377 visitors to the Mauna Loa Baseline Observatory**, Island of Hawaii.
- **147 visitors to Barrow Baseline Observatory**, Barrow Alaska.
- 56 visitors to American Samoa Baseline Observatory, American Samoa.
- 25 visitors to South Pole Baseline Observatory.

2016

- **5960 visitors to the GMD** demonstration and interpretation site in the David Skaggs Research Center.
- **573 visitors to the Mauna Loa Baseline Observatory,** Island of Hawaii.
- **1**52 **visitors to Barrow Baseline Observatory**, Barrow Alaska.
- **53 visitors to American Samoa** Baseline Observatory, American Samoa.
- **9 visitors to South Pole Baseline Observatory**.

2017

- **5840 visitors to the GMD** demonstration and interpretation site in the David Skaggs Research Center.
- **486 visitors to the Mauna Loa Baseline Observatory**, Island of Hawaii.
- **151 visitors to Barrow (Utqiaġvik) Baseline Observatory**, Barrow Alaska. In May, Lamar Smith (House, R) led a 10 member US House of Representatives delegation to a visit of observatory along with 15 additional staffers and aides. *(The town of barrow changed its name back to the original Iñupiat name in 2017).*
- **43 visitors to American Samoa Baseline Observatory,** American Samoa.
- **13 visitors to South Pole Baseline Observatory**.

Craig McClean, NOAA DAA for Research taking a souvenir CO_2 air sample, MLO.

Suzanne Case, Director, Hawaii Department of Land and Natural Resources and 3 staff.

Senators Nelson (D, Florida) and Schatz (D, Hawaii) on the Radiation deck, MLO.

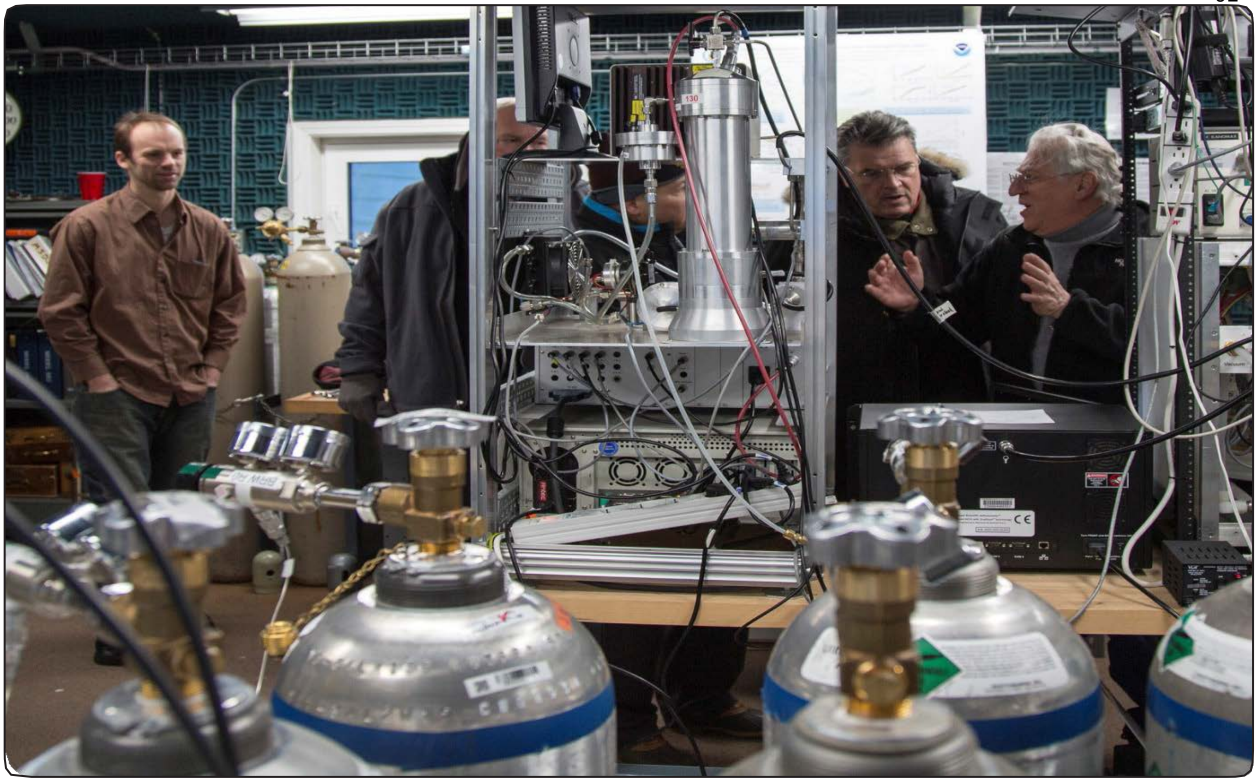
John Chin MLO (ret) and Ralph Keeling. John operated the Dave Keeling CO_2 measurements at MLO for 40 years.

Delegation of Korean Meteorological Agency (KMA) scientists, administrators and interpreter (emphasizing with right hand) and MLO engineer Aidan Colton MLO scientist guiding the tour.

Morristown-Beard High School students, Morristown, NJ visit to MLO.

Participants, AGAGE 52 Conference, Kona, HI on a day visit to MLO, December 2015.

Utqiaġvik high school students setting up air sampling equipment on a day visit and training at the Barrow Observatory, on a hot summer day in 2017.



Marty Martinsen (Barrow Observatory); David Kennedy, Rick Spinrad and Craig McLean (NOAA); and Russ Schnell (GMD) in front of aerosol instruments.

Norwegian Prime Minister, Jens Stoltenberg, filling bottles of air at the South Pole Observatory, 2013.

Julie Singewald demonstrating an ozonesonde balloon launch to 2nd graders at the David Skaggs Research Center, October 2014. Balloon with a letter to the students holding the 200 ft. tail landed in eastern Colorado.

Steve Rackley, visiting teacher from Great Britain, giving a demo of the GMD tour stop including the CO_2 wall mural, November 2017. **29,485 visitors have received the 20 minute GMD presentation** in 2013-17.

Russ Schnell, GMD, explaining that Utqiaġvik (Barrow Observatory) is downwind of Russia to Lamar Smith (R, Texas) Chairman, Committee on Science, Space, and Technology (second person to the left) and other members of a 10 person US House of Representatives delegation visiting the Barrow Atmospheric Baseline Observatory, May 2017.

RETIRED GMD EMPLOYEE MENTORING AND PUBLICATIONS

Background: Employees of the Global Monitoring Division, for the most part, spend their entire career in the division conducting, analyzing and publishing long term observations. After they retire, some stay involved in their specialization and continue to conduct data analyses, mentoring and scientific publications on their own time.

GMD provides a work space for such retirees and access to computers, data and the Internet. Below is a listing of 6 such retirees with their date of retirement and subsequent service to science and the public. Each still comes in to mentor and write papers, some 3-4 days a week.

- **John Barnes** – 6 publications since 2015; mentoring Jalal Butt, Chris Orville, Amir Kabir, Marie McKenzie, Amit Pandit, Nimmi Sharma and Ryan Neely.

- **Bob Evans** – 2 publications since 2016; mentoring Koji Miyagawa.

- **Joe Michalsky** – 9 publications since 2014; mentoring Gary Hodges, Emiel Hall, John Augustine and Patrick Disterhoft.

- **John Ogren** – 11 publications since 2015**;** supporting collaborator in Puerto Rico Professor Olga Mayol-Bracero recover from the devastation caused by Hurricane Maria. That help has included contributing to proposals for funding to replace damaged/destroyed equipment and infrastructure, advising on purchasing those replacements, and assembling/testing replacement measurement systems in the GMD aerosol lab; mentoring Katy Sun and Alex McPherson.

- **Sam Oltmans** – 45 publications since 2011; mentoring Lucy Cheadle and Chance Sterling**.**

- **Bob Stone** – 7 publications since 2014; mentoring Diane Stanitski, Christopher Cox and Sara Morris.

Papers published since retirement.

John Barnes

Zhang, Xianming, John Barnes, Ying D. Lei and Frank Wania, (2017), Semivolatile Organic Contaminants in the Hawaiian Atmosphere, Environmental Science & Technology, 51, 20, 11634-11642, 10.1021/acs.est.7b03841.

Bingen, Christine, Charles E. Robert, Kerstin Stebel, Christoph Brühl, Jennifer Schallock, Filip Vanhellemont, Nina Mateshvili, Michael Höpfner, Thomas Trickl, John E. Barnes, Julien Jumelet, Jean-Paul Vernier, Thomas Popp, Gerrit de Leeuw and Simon Pinnock, (2017), Stratospheric aerosol data records for the climate change initiative: Development, validation and application to chemistry-climate modelling, Remote Sensing of Environment, 203, 296-321, 10.1016/j.rse.2017.06.002.

Solomon, Susan, Doug Kinnison, Rolando R. Garcia, Justin Bandoro, Michael Mills, Catherine Wilka, Ryan R. Neely, Anja Schmidt, John E. Barnes, Jean-Paul Vernier and Michael Höpfner, (2016), Monsoon circulations and tropical heterogeneous chlorine chemistry in the stratosphere, Geophysical Research Letters, 43, 24, 12,624-12,633, 10.1002/2016GL071778.

Sharma, Nimmi C.P. and John E. Barnes, (2016), Boundary Layer Characteristics over a High Altitude Station, Mauna Loa Observatory, Aerosol and Air Quality Research, 16, 3, 729-737, 10.4209/aaqr.2015.05.0347.

Kremser, Stefanie, Larry W. Thomason, Marc von Hobe, Markus Hermann, Terry Deshler, Claudia Timmreck, Matthew Toohey, Andrea Stenke, Joshua P. Schwarz, Ralf Weigel, Stephan Fueglistaler, Fred J. Prata, Jean-Paul Vernier, Hans Schlager, John E. Barnes, Juan-Carlos Antuña-Marrero, Duncan Fairlie, Mathias Palm, Emmanuel Mahieu, Justus Notholt, Markus Rex, Christine Bingen, Filip Vanhellemont, Adam Bourassa, John M. C. Plane, Daniel Klocke, Simon A. Carn, Lieven Clarisse, Thomas Trickl, Ryan Neely, Alexander D. James, Landon Rieger, James C. Wilson and Brian Meland, (2016), Stratospheric aerosol-Observations, processes, and impact on climate, Reviews of Geophysics, 54, 2, 278-335, 10.1002/2015RG000511.

Chambers, Scott D., Alastair G. Williams, Franz Conen, Alan D. Griffiths, Stefan Reimann, Martin Steinbacher, Paul B. Krummel, L. Paul Steele, Marcel V. van der Schoot, Ian E. Galbally, Suzie B. Molloy and John E. Barnes, (2016), Towards a Universal "Baseline" Characterisation of Air Masses for High- and Low-Altitude Observing Stations Using Radon-222, Aerosol and Air Quality Research, 16, 3, 885-899, 10.4209/aaqr.2015.06.0391.

Bob Evans

Köhler, U., Nevas, S., McConville, G., Evans, R., Smid, M., Stanek, M., Redondas, A., and Schönenborn, F.: Optical characterisation of three reference Dobsons in the ATMOZ Project – verification of G. M. B. Dobson's original specifications, Atmos. Meas. Tech., 11, 1989-1999, https://doi.org/10.5194/amt-11-1989-2018, 2018.

Evans, R. D., Petropavlovskikh, I., McClure-Begley, A., McConville, G., Quincy, D., and Miyagawa, K.: Technical note: The US Dobson station network data record prior to 2015, re-evaluation of NDACC and WOUDC archived records with WinDobson processing software, Atmos. Chem. Phys., 17, 12051-12070,https://doi.org/10.5194/acp-17-12051-2017, 2017.

Joseph Michalsky

Berg, Larry K., Jerome D. Fast, James C. Barnard, Sharon P. Burton, Brian Cairns, Duli Chand, Jennifer M. Comstock, Stephen Dunagan, Richard A. Ferrare, Connor J. Flynn, Johnathan W. Hair, Chris A. Hostetler, John Hubbe, Anne Jefferson, Roy Johnson, Evgueni I. Kassianov, Celine D. Kluzek, Pavlos Kollias, Katia Lamer, Kathleen Lantz, Fan Mei1, Mark A. Miller, Joseph Michalsky, Ivan Ortega, Mikhail Pekour, Ray R. Rogers, Philip B. Russell, Jens Redemann, Arthur J. Sedlacek III, Michal Segal-Rosenheimer, Beat Schmid, John E. Shilling, Yohei Shinozuka, Stephen R. Springston, Jason M. Tomlinson, Megan Tyrrell, Jacqueline M. Wilson, Rainer Volkamer, Alla Zelenyuk, and Carl M. Berkowitz, 2016: The two-column aerosol project: Phase I--Overview and impact of elevated aerosols layers on aerosol optical depth, J. Geophys. Res., 121, 336-361, http://onlinelibrary.wiley.com/doi/10.1002/2015JD023848/full, doi:10.1002/2015JD023848.

Haller, A.G., R. Petersen, E. Andrews, J. Michalsky, I.B. McCubbin, and J.A. Ogren, Contributions of dust and biomass burning to aerosols at a Colorado mountain-top site, Atmos. Chem. Phys., 15, 13665-13679, 2015, http://www.atmos-chem-phys.net/15/13665/2015/, doi:10.5194/acp-15-13665-2015.

Hallar, A. Gannet, Noah P. Molotch, Jenny L. Hand, Ben Livneh, Ian B. McCubbin, Ross Petersen, Joseph Michalsky, Douglas Lowenthal, Kenneth E. Kunkel, Impacts of increasing aridity and wildfires on aerosol loading in the intermountain Western U.S., Environmental Research Letters, 12, 014006, 2017, doi:10.1088/1748-9326/aa510a.

Kazadzis, S., Kouremeti, N., Diémoz, H., Gröbner, J., Forgan, B. W., Campanelli, M., Estellés, V., Lantz, K., Michalsky, J., Carlund, T., Cuevas, E., Toledano, C., Becker, R., Nyeki, S., Kosmopoulos, P. G., Tatsiankou, V., Vuilleumier, L., Denn, F. M., Ohkawara, N., Ijima, O., Goloub, P., Raptis, P. I., Milner, M., Behrens, K., Barreto, A., Martucci, G., Hall, E., Wendell, J., Fabbri, B. E., and Wehrli, C. 2018. Results from the 4th WMO Filter Radiometer Comparison for aerosol optical depth measurements. Atmos. Chem. Phys., 18, 3185-3901, https://doi.org/10.5194/acp-18-3185-2018.

Kiedron, P.W. and J.J. Michalsky, Non-parametric and least squares Langley plot methods, Atmos. Meas. Tech., 9, 215-225, 2016, doi:10.5194/amt-9-215-2016, http://www.atmos-meas-tech.net/9/215/2016/.

Michalsky, J, M Kutchenreiter, and CN Long (2017): Significant Improvements in Pyranometer Offsets Using Ventilation Strategies, Journal of Atmospheric and Oceanic Technology, 34, no. 6, 1323–1332, DOI: 10.1175/JTECH-D-16-0224.1. http://journals.ametsoc.org/doi/abs/10.1175/JTECH-D-16-0224.1.

Michalsky, Joseph J. and Charles N. Long, 2016: ARM Solar and Infrared Broadband and Filter Radiometry. *The Atmospheric Radiation Measurement (ARM) Program: The First 20 Years*, Meteor. Monogr., No. 57, Amer. Meteor. Soc., http://dx.doi.org/10.1175/AMSMONOGRAPHS-D-15-0031.1.

Ortega, Ivan, Sean Coburn, Larry K. Berg, Kathy Lantz, Joseph Michalsky, Rich A. Ferrare, Johnathan H. Hair, Chris A. Hostetler, and Rainer Volkamer, The CU 2D-MAX-DOAS instrument – part 2: Raman scattering probability measurements and retrieval of aerosol optical properties, Atmos. Meas. Tech., Atmos. Meas. Tech., 9, 3893-3910, 2016, www.atmos-meas-tech.net/9/3893/2016/, doi:10.5194/amt-9-3893-2016.

Sanchez-Romero, Alejandro, Josep-Abel González, Josep Calbó, Arturo Sanchez-Lorenzo, and Joseph Michalsky, Aerosol optical depth in a western Mediterranean site: an assessment of different methods, Atmospheric Research, 174-175, 70-84, 2016. http://dx.doi.org/10.1016/j.atmosres.2016.02.002.

John Ogren

Schmale, J., Henning, S., Henzing, J., S., Keskinen, H., Sellegri, K., Ovadnevaite, J., Bougiatioti, A., Kalivitis, N., Stavroulas, I., Jefferson, A., Park, M., Schlag, P., Kristensson, A., Iwamoto, Y., Pringle, K., Reddington, C., Aalto, P., Äijälä, M., Baltensperger, U., Birmili, W., Bukowiecki, N., Ehn, M., Fjæraa, A., M., Fiebig, M., Frank, G., Fröhlich, R., Frumau, A., Furuya, M., Hammer, E., Heikkinen, L., Herrmann, E., Holzinger, R., Hyono, H., Kanakidou, M., Kiendler-Scharr, A., Kinochi, K., Kos, G., Kulmala, M., Mihalopoulos, N., Nenes, A., O'Dowd, C., Paramonov, M., Petäjä, T.,

Picard, D., Poulain, L., Prévôt, A., S., H., Slowik, J., Sonntag, A., Swietlicki, E., Svenningsson, B., Tsurumaru, H., Wiedensohler, A., Wittbom, C., Ogren, J., Matsuki, A., Yum, S., S., Myhre, C., L., Carslaw, K., Stratmann, F., Gysel, M. Collocated observations of cloud condensation nuclei, particle size distributions, and chemical composition. *Scientific Data*, *4*, doi:10.1038/sdata.2017.3, 2017.

Andrews, E., Ogren, J. A., Kinne, S., and Samset, B. Comparison of AOD, AAOD and column single scattering albedo from AERONET retrievals and in-situ profiling measurements. *Atmos. Chem. Phys., 17*, 6041–6072, doi:10.5194/acp-17-6041-2017, 2017.

Sinha, P. R., Kondo, Y., Koike, M., Ogren, J. A., Jefferson, A., Barrett, T. E., Sheesley, R. J., Ohata, S., Moteki, N., Coe, H., Liu, D., Irwin, M., Tunved, P., Quinn, P. K., and Zhao,Y. Evaluation of ground-based black carbon measurements by filter-based photometers at two Arctic sites. *J. Geophys. Res. Atmos., 122*, 3544–3572, doi:10.1002/2016JD025843, 2017.

Moosmüller, H., and Ogren, J. A. Parameterization of the Aerosol Upscatter Fraction as Function of the Backscatter Fraction and Their Relationships to the Asymmetry Parameter for Radiative Transfer Calculations. *Atmosphere*, *8*, 133, doi:10.3390/atmos8080133, 2017.

Kahn, R., Berkoff, T., Brock, C., Chen, G., Ferrare, R., Ghan, S., Hanisco, T., Hegg, D., Martins, V., McNaughton, C., Murphy, D., Ogren, J., Penner, J., Pilewskie, P., Seinfeld, J., Worsnop, D. SAM-CAAM: A Concept for Acquiring Systematic Aircraft Measurements to Characterize Aerosol Air Masses. *Bull. Amer. Meteor. Soc.*, 98, 2215-2228, DOI:10.1175/BAMS-D-16-0003.1, 2017.

Backman, J., Schmeisser, L., Virkkula, A., Ogren, J. A., Asmi, E., Starkweather, S., Sharma, S., Eleftheriadis, K., Uttal, T., Jefferson, A., Bergin, M., and Makshtas. A. On Aethalometer measurement uncertainties and an instrument correction factor for the Arctic. Atmos. Meas. Tech., 10, 5039-5062, https://doi.org/10.5194/amt-10-5039-2017, 2017.

Schmeisser, L., Andrews, E., Ogren, J.A., Sheridan, P., Jefferson, A., Sharma, S., Kim, J.E., Sherman, J.P., Sorribas, M., Kalapov, I., Arsov, T., Angelov, C., Mayol-Bracero, O.L., Labuschagne, C., Kim, S.-W., Hoffer, A., Lin, N.-H., Chia, H.-P., Bergin, M., Sun, J.Y., Liu, P., Wu, H. Classifying aerosol type using in situ surface spectral aerosol optical properties. Atmos. Chem. Phys., 17, 12097-12120, https://doi.org/10.5194/acp-17-12097-2017, 2017.

Sharma, S., Leaitch, W.R., Huang, L., Veber, D., Kolonjari, F., Zhang, W., Hanna, S. J., Bertram, A. K., and Ogren, J. A. An Evaluation of three methods for measuring black carbon at Alert, Canada, Atmos. Chem. Phys., 17, 15225-15243, https://doi.org/10.5194/acp-17-15225-2017, 2017.

Ogren, J. A., Wendell, J., Andrews, E., and Sheridan, P. J. Continuous light absorption photometer for long-term studies. Atmos. Meas. Tech., 10, 4805-4818, https://doi.org/10.5194/amt-10-4805-2017, 2017.

Schmale, J., Henning, S., Decesari, S., Henzing, B., Keskinen, H., Sellegri, K., Ovadnevaite, J., Pöhlker, M. L., Brito, J., Bougiatioti, A., Kristensson, A., Kalivitis, N., Stavroulas, I., Carbone, S., Jefferson, A., Park, M., Schlag, P., Iwamoto, Y., Aalto, P., Äijälä, M., Bukowiecki, N., Ehn, M., Frank, G., Fröhlich, R., Frumau, A., Herrmann, E., Herrmann, H., Holzinger, R., Kos, G., Kulmala, M., Mihalopoulos, N., Nenes, A., O'Dowd, C., Petäjä, T., Picard, D., Pöhlker, C., Pöschl, U., Poulain, L., Prévôt, A. S. H., Swietlicki, E., Andreae, M. O., Artaxo, P., Wiedensohler, A., Ogren, J., Matsuki, A., Yum, S. S., Stratmann, F., Baltensperger, U., and Gysel, M.: Long-term cloud condensation nuclei number concentration, particle number size distribution and chemical composition measurements at regionally representative observatories, Atmos. Chem. Phys., 18, 2853-2881, https://doi.org/10.5194/acp-18-2853-2018, 2018.

Schmeisser, L., Backman, J., Ogren, J. A., Andrews, E., Asmi, E., Starkweather, S., Uttal, T., Fiebig, M., Sharma, S., Eleftheriades, K., Vratolis, S., Bergin, M., Tunved, P., and Jefferson, A. Seasonality of aerosol optical properties in the Arctic, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2017-1117, 2018.

Sam Oltmans

Sterling, C. W., B. J. Johnson, S. J. Oltmans, H. G. J. Smit, A. F. Jordan, P. D. Cullis, E. G. Hall, A. M. Thompson, and J. C. Witte (2017), Homogenizing and estimating the uncertainty in NOAA's long term vertical ozone profile records measured with the electrochemical concentration cell ozonesonde, *Atmospheric Measurment Techniques Discussions,* https//doi.org/105194/amt-2017-397.

Cheadle, L. C., S. J. Oltmans, G. Pétron, R. C. Schnell, E. J. Mattson, S. C. Herndon, A. M. Thompson, D. R. Blake, and A. McClure-Begley (2017), Surface ozone in the Colorado northern Front Range and the influence of oil and gas development during FRAPPE/DISCOVER-AQ in summer 2014, *Elem. Sci. Anth.*, 5: 61. https://doi.org/10.1525/elementa.254.

Thompson, A. M., J. C. Witte, C. Sterling, A. Jordan, B. J. Johnson, S. J. Oltmans, M. Fujiwara, H. Vömel, M. Allaart, A. Piters, G. J. B. Coetzee, F. Posny, E. Corrales, J. A. Diaz, C. Féilix, N. Komala, N. Lai, H. T. Ahn Nguyen, M. Maata, F. Mani, Z. Zainal, S. Ogino, F. Paredes, T. L. B. Penha, F. R. de Silva, S. Sallons-Mitro, H. B. Selkirk, F. J. Schmidlin, R. Stübi, and K. Thiongo (2017), First reprocessing of Southern Hemisphere Additional Ozonesondes (SHADOZ) ozone profiles (1998-2016): 2. Comparisons with statellites and ground-based measurements, *J. Geophys. Res. Atmos.,* 122, https//doi.org:10.1002/2017JD027406.

Parrish, D. D., I. Petropavlovskikh, S. J. Oltmans (2017), Reversal of long-term trend in baseline ozone concentrations at the North American west coast, *Geophysical Research Letters*, 44. https://doi.org/10.1002/2017GL074960.

Stauffer, R. M., A. M. Thompson, S. J. Oltmans, B. J. Johnson (2017), Tropospheric ozonesonde profiles at long-term U.S. monitoring sites: Links between Trinidad Head, CA profile clusters and inland surface ozone measurements, *J. Geophys. Res. Atmos.,* 122, 2, 1261-1280, https//doi.org:10.1002/2016JD025254.

Oltmans, S. J., Karion, A., Schnell, R.C, Petron, G., Helmig, D., Montzka, S. A., Wolter, S., Neff, D., Miller, B. R., Hueber, J., Conley, S., Johnson, B. J. and Sweeney, C. (2016), O_3, CH_4, CO_2, CO, NO_2, and NMHC aircraft measurents in the Uinta Basin oil and gas region under low and high ozone conditions in winter 2012 and 2013, *Elem. Sci. Anth.*, 4, 000132, doi: 10.12952/journal.elementa.000132. http://www.elementascience.org/articles/132

Schnell, R. C., Johnson, B. J., Oltmans, S. J., Cullis, P., Sterling, C., Hall, E., Jordan A., Helmig, D., Petron, G. , R. Ahamadov Wendell, J., Albee R., Boylan, P., Thompson, C.R., Evans, J., Hueber, J, Curtis, A. J., and Park, J.-H. (2016), Quantifying wintertime boundary layer ozone production from frequent profile measurements in the Uinta Basin, UT oil and gas region, J. Geophys. Res. Atmos., 121, doi:10.1002/2016JD025130.

Hurst, D. F., W. G. Read, H. Vömel, H. B. Selkirk, K. H. Rosenlof, S. M. Davis, E. G. Hall, A.F. Jordan, and S. J. Oltmans (2016), Recent divergences in stratospheric water vapor measurements by frost point hygrometers and the Aura Microwave Limb Sounder, Atmos. Meas. Tech., 9, 4447-4457, doi:10.5194/amt-9-4447-2016.

Hall, E. G., A. F. Jordan, D. F. Hurst, S. J. Oltmans, H. Vömel, B. Kühnreich and V. Ebert (2016), Advancements, measurement uncertainties, and recent comparisons of the NOAA frost point hygrometer, Atmos. Meas. Tech., 9, 4295-4310, doi:10.5194/amt-9-4295-2016.

Van Dam. B., D. Helmig, P.V. Doskey, S.J. Oltmans (2016), Summertime surface O3 behavior and deposition to tundra in the Alaskan Arctic, J. Geophys. Res. Atmos.,121, 8055-8066, doi:10.1002/2015JD023914. http://onlinelibrary.wiley.com/doi/10.1002/2015JD023914/full

Parrish, D. D., I. E. Galbally, J.-F. Lamarque, V. Naik, L. Horowitz, D. T. Shindell, S. J. Oltmans, R. Derwent, H. Tanimoto, C. Labuschagne, and M. Cupeiro (2016), Seasonal cycles of O3 in the marine boundary layer: Observation and model simulation comparisons, J. Geophys. Res. Atmos., 121, doi:10.1002/2015JD024101.

Tarasick, D.W., J. Davies, H.G.J. Smit, S.J. Oltmans (2016), A re-evaluated Canadian ozonesonde record: measurements of the vertical distribution of ozone over Canada from 1966 to 2013, Atmos. Meas. Tech., 9, 195-214, doi:10.5194/amt-9-195-2016.
Huang, J., H. Liu, J.H. Crawford, C. Chan, D.B. Considine, Y. Zhang, X. Zheng, C. Zhao, V. Thouret, S.J. Oltmans, S.C. Liu, D. Jones, J. Rodriguez, S. Strahan, S. Steenrod, and M. Damon (2015), Origin of springtime ozone enhancements in the lower troposphere over Beijing: In situ measurements and model analysis, Atmos. Chem. Phys. , 15, doi:10.5194/acp-15-5161-2015, 5161-5179.

Boylan, P., D. Helmig, S. Oltmans (2015), Ozone in the Atlantic Ocean marine boundary layer, *Elem. Sci. Anth.,* 3, 000045, doi:10.12952/journal.elementa.000045.

Kramer, L.J., D. Helmig. J. Burkhart, A. Stohl, S.J. Oltmans, and R.E. Honrath (2015), Seasonal variability of nitrogen oxides and hydrocarbons measured a the GOESummit station, Greenland, Atmos. Chem. Phys. ,15, , doi:10.5194/acp-15-6827-2015, 6827-6849.

Lin, M.-Y., A.M. Fiore, L.W. Horowitz, A.O. Langford, S.J. Oltmans, D. Tarasick, H. Reider (2015), Climate variability modulates western U.S. ozone air quality in spring through stratospheric influence, Nature Communications, 6:7105, doi:10.1038/ncomms8105.

Ahmadov, R., S. McKeen, M. Trainer, R. Banta, A. Brewer, S. Brown, P. M. Edwards, J. A. de Gouw, G. J. Frost, J. Gilman, D. Helmig, B. Johnson, A. Karion, A. Koss, A. Langford, B. Lerner, J. Olson, S. Oltmans, J. Peischl, G. Pétron, Y. Pichugina, J. M. Roberts, T. Ryerson, R. Schnell, C. Senff, C. Sweeney, C. Thompson, P. R. Veres, C. Warneke, R. Wild, E. J. Williams, B. Yuan, and R. Zamora (2015), Understanding high wintertime ozone pollution events in an oil- and natural gas-producing region of the western US, Atmos. Chem. Phys., 15, 411-429, doi:10.5194/acp-15-411-2015.

Oltmans, S. J., R. C. Schnell, B. J. Johnson, G. Petron, T. Mefford, R. Neely III (2014), Anatomy of wintertime ozone production associated with oil and gas extraction activity in Wyoming and Utah, *Elem. Sci. Anth.*, 2, 000024, doi:10.12952/journal.elementa.000024.

Cooper, O.R., D. D. Parrish, J. Ziemke, N. V. Balashov, M. Cupeiro, I. E. Galbally, S. Gilge, L. Horowitz, N. R. Jensen, J.-F. Lamarque, V. Naik, S. J. Oltmans, J. Schwab, D. T. Shindell, A. M. Thompson, V. Thouret, Y. Wang, R. M. Zbinden (2014), Global distribution and trends of tropospheric ozone: An observation-based review, *Elem. Sci. Anth.*, 2, 000029, doi:10.12952/journal.elementa.000029.

J.-H. Koo, Y. Wang, T. Jiang, Y. Deng, S.J. Oltmans, and S. Solberg(2014), Influence of climate variability on near-surface ozone depletion events in the Arctic spring, *Geophys. Res. Lett*., 41, 2582-2589, doi:10.1002/2014GL059275.

Hurst, D.F., A. Lambert, W.G. Read, S.M. Davis, K.H. Rosenlof, E.G. Hall, A.F. Jordan, S.J. Oltmans, H. Voemel (2014), Validation of Aura Microwave Limb Sounder stratospheric water vapor measurements by the NOAA frost point hygrometer, *J. Geophys. Res.-Atmos*., 119, doi:10.1002/2013JD020757.

Lin, M., L.W. Horowitz, S.J. Oltmans, A.M. Fiore, and S. Fan (2014), Tropospheric ozone trends at Mauna Loa Observatory tied to decadal climate variability, *Nature Geoscience*, doi:10.1038/NGEO2066.

Lefohn, A.S., C. Emery, D. Shadwick, H. Wernli, J. Jung, S.J. Oltmans (2014), Estimates of background surface ozone concentrations in the United States based on model-derived source apportionment, *Atmos. Environ*., 84, doi:10.1016/j.atmosenv.2013.11.033, 275-288.

Oltmans, S.J., A. S. Lefohn, D. Shadwick , J. M. Harris, H.E. Scheel, I. Galbally, D. W. Tarasick, B. J. Johnson, E.-G. Brunke, H. Claude, G. Zeng, S. Nichol, F. Schmidlin, J. Davies, E. Cuevas, A. Redondas, H. Naoe, T., Nakano, T. Kawasato (2013), Recent tropospheric ozone changes – a pattern dominated by slow or no growth, *Atmos. Environ.,* 67, doi:10.1016/j.atmosenv.2012.10.057, 221-351.

Van Dam, B., D. Helmig, J. F. Burkhart, D. Obrist, and S.J. Oltmans (2013), Springtime boundary layer O_3 and GEM depletion at Toolik Lake, Alaska, *J. Geophys. Res.,* 118,doi:10.1002/jgrd.50213.

F. Hasebe, Y. Inai, M. Shiotani, M. Fujiwara, H. Vömel, N. Nishi, S.-Y. Ogino, T. Shibata, S. Iwasaki, N. Komala, T. Peter, and S. J. Oltmans (2013), Cold trap dehydration in the Tropical Tropopause Layer characterized by SOWER chilled-mirror hygrometer network data in the Tropical Pacific, *Atmos. Chem. Phys*., 13, doi:105194/acp-13-4393-2013, 4393-4411.

Huang, M. G.R. Carmichael, S. Kulkarni, S.N. Spak, T. Chai, S.J.Oltmans, D.A. Jaffe, D.G. Streets, A. Kaduwela, A.J. Weinheimer, G.L. Huey (2013), Source attribution at western U.S. receptors, and the impacts of transported background pollutants and local fires on air quality, *Atmos. Chem. Phys.*, 13, 359-391, doi:10.5194/acp-13-359-2013.

Ryerson, T.B., A.E. Andrews, W.M. Angevine, T.S. Bates, C.A. Brock, B. Cairns, R.C. Cohen, O.R. Cooper, J.A. de Gouw, F.C. Fehsenfeld, R.A. Ferrare, M.L. Fischer, R.C. Flagan, A.H. Goldstein, J.W. Hair, R.M. Hardesty, C.A. Hostetler, J.L. Jimenez, A.O. Langford, E. McCauley, S.A. McKeen, L.T. Molina, A. Nenes, S.J. Oltmans, D.D. Parrish, J.R. Pederson, R.B. Pierce, K. Prather, P.K. Quinn, J.H. Seinfeld, C.J. Senff, A. Sorooshian, J. Stutz, J.D. Surratt, M. Trainer, R. Volkamer, E.J. Williams and S.C. Wofsy (2013), The 2010 California Research at the Nexus of Air Quality and Climate Change (CalNex) field study. *J. Geophys. Res.-Atmos.*: Vol. 118, 5830-5866, doi: 10.1002/jgrd.50331.

Oltmans, S.J., B.J. Johnson, and J.M. Harris (2012), Springtime boundary layer ozone depletion at Barrow, Alaska: Meteorological influence, year to year variation, and long-term change, *J. Geophys. Res.*, 117, D00R18, doi:10.1029/2011JD016889.

Koo, J.-H., Y. Wang, S. Choi, T.P. Kurosu, K. Chance, A. Rozanov, A. Richter, S.J. Oltmans, A.M. Thompson, J.W. Hair, M.A. Fenn, A.J. Weinheimer, T.B. Ryerson, D. MacTavish, M. Shaw, L.G. Huey, J. Liao, J.E. Dibb, J.A. Neuman, R.B. Pierce, M. Natarjan, and J. Al-Saadi (2012), Characteristics of tropospheric ozone depletion events in the Arctic spring, *Atmos. Chem. Phys.*, 12, 9909-9922, doi:10.5194/acp-12-990902012.

Thompson, A. M., S. K. Miller, S. Tilmes, D. W. Kollonige, J. C. Witte, S. J. Oltmans, B. J. Johnson, M. Fujiwara, F. J. Schmidlin, G. J. R. Coetzee, N. Komala, M. Maata, M. bt Mohamad, J. Nguyo, C. Mutai, S.-Y. Ogino, F. R. Da Silva, N. M. P. Leme, F. Posny, R. Scheele, H. B. Selkirk, M. Shiotani, R. Stübi, G. Levrat, B. Calpini, V. Thouret, H. Tsuruta, J. V. Canossa, H. Vömel, S. Yonemura, J. A. Diaz, N. T. Tan Thanh, and H. T. Thuy Ha (2012), SHADOZ (Southern Hemisphere Additional Ozonesondes) climatology (2005-2009). 4. Tropospheric and lower stratospheric profiles with comparisons to OMI total ozone, *J. Geophys. Res.*, 117, D23301, doi:10.1029/2011JD016911.

Helmig, D., P. Boylan, B. Johnson, S. Oltmans, C. Fairall, R. Staebler, A Weinheimer, J. Orlando, D.J. Knapp, D.D. Montzka, F. Flocke, U. Friess, H. Sihler and P.B. Shepson (2012), Ozone dynamics and snow-atmosphere exchanges during ozone depletion events at Barrow AK, *J. Geophys. Res.,* 117, D20303, doi:10.1029/2012JD017531.

Lin, M., A.M. Fiore, O.R. Cooper, L.W. Horowitz, A.O. Langford, H. Levy II, B.J. Johnson, V. Naik, S.J. Oltmans, and C.J. Senff (2012), Springtime high surface ozone events over the western United States: Quantifying the role of stratospheric intrusions, *J. Geophys. Res.,* 117, D00V22, doi:10.1029/2012JD018151.

Lefohn, A.S., H. Wernli, D. Shadwick, S.J. Oltmans, M. Shapiro (2012), Quantifying the importance of stratospheric-tropospheric transport on surface ozone concentrations at high- and low-elevation monitoring sites in the United States, *Atmos. Environ.*, 62, doi:10.1016/j.atmosenv.2012.09.004, 646-656.

Tilmes, S., J.-F. Lamarque, L.K. Emmons, A. Conley, M.G. Schultz, M. Saunois, V. Thouret, A.M. Thompson, S.J. Oltmans, B. Johnson, and D. Tarasick (2012), Technical Note: Ozone climatology between 1995 and 2009: description, evaluation and applications, *Atmos. Chem. Phys.*, 12, doi:10.5194/acp-12-7475-2012, 7475-7497.

Zhang, Y., H. Liu, J.H. Crawford, D.B. Considine, C. Chan, S.C. Liu, S.J. Oltmans (2012), Distribution, variability and sources of tropospheric ozone over South China in spring: Intensive ozonesonde measurements at five locations and modeling analysis, *J. Geophys. Res.*, 117, D12304, doi:10.1029/2012JD017498.

Lin, M., A.M. Fiore, L.W. Horowitz, O.R. Cooper, V. Naik, J. Holloway, B.J. Johnson, S.J. Oltmans, A.M. Middlebrook, I.B. Pollack, T.B. Ryerson, J.X. Warner, C. Wiedinmyer, J. Wilson, B. Wyman (2012), Transport of Asian ozone pollution into surface air over the western United States in spring, *J. Geophys. Res.*, 117, D00V07, doi:10.1029/2011JD016961.

Langford, A.O., J. Brioude, O.R. Cooper, C.J. Senff, R.J. Alvarez II, R.M. Hardesty, B.J. Johnson, and S.J. Oltmans, Stratospheric influence on surface ozone in the Los Angeles area during late spring and early summer 2010 (2012), *J. Geophys. Res.*, 117, D00V06, doi:10.1029/2011JD016766.

Hurst, D. F., E. G. Hall, A. F. Jordan, L. M. Miloshevich, D. N. Whiteman, T. Leblanc, D. Walsh, H. Vömel, and S. J. Oltmans (2011), Comparisons of temperature, pressure and humidity measurements by balloon-borne radiosondes and frost point hygrometers during MOHAVE-2009, *Atmos. Meas. Tech.*, 4, doi:10.5194/amt-4-2777-2011, 2777-2793.

McDonald-Buller, E.C., D.T. Allen, N. Brown, D.J. Jacob, D. Jaffe, C.E. Kolb, A.S. Lefohn, S. Oltmans, D.D. Parish, G. Yarwood, and L. Zhang (2011), Establishing policy relevant background (PRB) ozone concentrations in the United States, *Environ. Sci. Technol.*, 45, doi:10.1021/es2022918, 9484-9497.

Hassler, B., J.S. Daniel, B.J. Johnson, S. Solomon, S.J. Oltmans (2011), Twenty five years of ozonesonde measurements at South Pole: Assessment of changing loss rates, *J. Geophys. Res.,* 116, D22301, doi:10.1029/2011JD016353.

Cooper, O.R., S. J. Oltmans, B. J. Johnson, J. Brioude, W. Angevine, M. Trainer, D. D. Parrish, T. R. Ryerson, I. Pollack, P. D. Cullis, M. A. Ives, D. W. Tarasick, J. Al-Saadi, I. Stajner (2011), First multi-site assessment of baseline ozone along the U.S. west coast from the surface to the tropopause, *J. Geophys. Res.,* 116, DV00V03, doi:10.1029/2011JD016095.

Lefohn, A.S., H. Wernli, D. Shadwick, S. Limbach, S.J. Oltmans, M. Shapiro (2011), Assessing the importance of stratospheric-tropospheric transport processes that affect surface ozone concentrations in western and northern tier of the United States, *Atmospheric Environment*, 45, doi:10.1016/j.atmosenv.2011.06.014, 4845-4857.

Petropavlovskikh, I., R. Evans, G. McConville , S. Oltmans , D. Quincy, K. Lantz, P.Disterhoft, M. Stanek, L. Flynn (2011), Sensitivity of Dobson and Brewer Umkehr ozone profile retrievals to ozone cross-sections and stray light effects, *Atmos. Meas. Tech.*, 4, doi:10.5194/amtd-4-1844-2011, 1841-1853.

Brodin, M., D Helmig, B. Johnson, S. Oltmans (2011), Comparison of ozone concentrations on a surface elevation gradient with balloon-borne ozonesonde measurements, *Atmospheric Environment*, 45, doi:10.1916/j.atmosenv2911.07.002, 5431-5439.

Bob Stone

Cox, C.J., T. Uttal, C.N. Long, M.D. Shupe, R.S. Stone, and S. Starkweather, 2016: The Role of Springtime Arctic Clouds in Determining Autumn Sea Ice Extent. *J. Climate,* **29**, 6581–6596, https://doi.org/10.1175/JCLI-D-16-0136.1.

Cox, C.J., R.S. Stone, D.C. Douglas, D.M. Stanitski, G.J. Divoky, G.S. Dutton, C. Sweeney, J.C. George, and D.U. Longenecker, 2017: Drivers and Environmental Responses to the Changing Annual Snow Cycle of Northern Alaska. *Bull. Amer. Meteor. Soc.,* **98**, 2559–2577, https://doi.org/10.1175/BAMS-D-16-0201.1.

Grachev, A.A., Persson, P.O.G., Uttal, T. et al. Seasonal and latitudinal variations of surface fluxes at two Arctic terrestrial sites. Clim Dyn (2017). https://doi.org/10.1007/s00382-017-3983-4.

Stone, R. S., S. Sharma, A. Herber, K. Eleftheriadis, D. W. Nelson, 2014: A characterization of Arctic aerosols on the basis of aerosol optical depth and black carbon measurements. *Elementa: Sci. Anthropocene*, **2**, 000027, doi:https://doi.org/10.12952/journal.elementa.000027.

Sweeney C, et al. (2016) No significant increase in long-term CH_4 emissions on North Slope of Alaska despite significant increase in air temperature. Geophys Res Lett **43**:6604–6611.

Tomasi C, Kokhanovsky AA, Lupi A, Ritter C, Smirnov A, O'Neill NT, Stone RS, Holben BN, Nyeki S, Wehrli C, Tomasi C, Kokhanovsky, Alexander A, Lupi A, Ritter C, Smirnov A, O'Neill NT, Stone Robert S, Holben BN, Nyeki S, Wehrli C et al. (2015) Aerosol remote sensing in polar regions. Earth Sci Rev 140:108–157.

Uttal, T., S. Starkweather, J.R. Drummond, T. Vihma, A.P. Makshtas, L.S. Darby, J.F. Burkhart, C.J. Cox, L.N. Schmeisser, T. Haiden, M. Maturilli, M.D. Shupe, G. De Boer, A. Saha, A.A. Grachev, S.M. Crepinsek, L. Bruhwiler, B. Goodison, B. McArthur, V.P. Walden, E.J. Dlugokencky, P.O. Persson, G. Lesins, T. Laurila, J.A. Ogren, R. Stone, C.N. Long, S. Sharma, A. Massling, D.D. Turner, D.M. Stanitski, E. Asmi, M. Aurela, H. Skov, K. Eleftheriadis, A. Virkkula, A. Platt, E.J. Førland, Y. Iijima, I.E. Nielsen, M.H. Bergin, L. Candlish, N.S. Zimov, S.A. Zimov, N.T. O'Neill, P.F. Fogal, R. Kivi, E.A. Konopleva-Akish, J. Verlinde, V.Y. Kustov, B. Vasel, V.M. Ivakhov, Y. Viisanen, and J.M. Intrieri, 2016: International Arctic Systems for Observing the Atmosphere: An International Polar Year Legacy Consortium. *Bull. Amer. Meteor. Soc.,* **97**, 1033–1056, https://doi.org/10.1175/BAMS-D-14-00145.1.

Together, GMD scientists who have retired in the past 7 years and continue to come into the office have produced 80 peer reviewed publications and mentored 20 scientists/technicians/students.

Global Monitoring Division

Collaborations/Stakeholders

Contents: page

GLOBAL MONITORING DIVISION
COLLABORATIONS

2013- Present

JOINT INSTITUTES:

- **Cooperative Institute for Research in Environmental Sciences (CIRES):** NOAA Cooperative Institute at the University of Colorado**.** Extensive joint research and atmospheric monitoring projects are conducted at the Boulder facilities.

- **Cooperative Institute for Arctic Research (CIFAR):** NOAA Cooperative Institute at the University of Alaska. Cooperative research in Arctic atmospheric science at the Barrow and Boulder facilities.

- **Cooperative Institute for Mesoscale Meteorological Studies (CIMMS):** NOAA Cooperative Institute at the University of Oklahoma. GMD provides large amounts of high quality data for modelers.

- **Cooperative Institute for Research in the Atmosphere (CIRA):** NOAA Cooperative Institute at the Colorado State University. Joint research projects are conducted at the Boulder facility.

- **Joint Institute for Marine and Atmospheric Research (JIMAR):** NOAA Cooperative Institute at the University of Hawaii. Studies of long range transport of mercury flowing from Asia to Hawaii.

- **National Oceanic and Atmospheric Administration Cooperative Science Center for Earth System Sciences and Remote Sensing Technologies (NOAA-CESSRST):** Under the CESSRST umbrella, GMD collaborates with the National Environmental Satellite, Data and Information Service (**NESDIS**), Center for Satellite Applications and Research (STAR), and Office of Satellite and Product Operations (OSPO) to provide satellite validations.

NOAA DIVISION and LABORATORY COLLABORATIONS:

- **AOML (Atlantic Oceanographic and Meteorological Lab) and PMEL:** GMD conducts cooperative carbon cycle and halocarbon measurements in the marine environment along with the study of sulfur particulates in the global atmosphere with these labs.

- **ARL:** The GMD Radiation Project utilizes some ARL field sites and is developing a plan for future collaboration in surface energy budget monitoring activities with ARL. GMD collaborates with ARL on stratospheric ozone, Pacific Basin mercury measurements, atmospheric chemical modeling, and air quality research.

- **NESDIS NCEI Big Earth Data Initiative (BEDI):** GMD is in the process of archiving its climate data and metadata from funding by the government-wide BEDI project at the NOAA National Center for Environmental Information.

- **CSD (Chemical Sciences Division):** GMD cooperates with CSD in providing halocarbon data for their modeling and laboratory studies of greenhouse gases and ozone depleting substances (ODS). We have worked with them on joint aircraft missions including HIPPO, ATTREX, POSIDON, and Atom.

- **GFDL (Geophysical Fluid Dynamics Lab):** GMD cooperates in conducting Global Carbon Cycle modeling and Global Climate Model results compared to observed radiation.

- **National Geodetic Survey:** Continuously Operating Reference Station (NGS-CORS) –GPS reference station at MLO.

- **NESDIS (National Environmental Satellite, Data, & Information Service):** GMD hosts and supports a polar satellite data downlink antenna for NESDIS at the Barrow Observatory. Dobson ozone network at MLO, Alaska and continental U.S. (7 sites total) provides data for NESDIS satellite validation program (JPSS).

- **NESDIS Climate Reference Network (CRN)** sites are hosted at GMD SURFRAD sites at Bondville, IL; Goodwin Creek MS; Fort Peck, MT; Sioux Falls, SD; and at the Barrow and Mauna Loa Observatories.

- **NESDIS:** GMD supports satellite validation program (GOES-R series), and a mobile SURFRAD for GOES-R Cal/Val activities. The GMD Radiation group is currently developing new products on land surface characteristics (Surface albedo, NDVI) for satellite validation for NESDIS (GOES-R series, MODIS, VIIRS).

- **NWS Pacific Region - MLO** participates in the Cooperative Observer program collecting rainfall at MLO and Kulani Mauka sites, and records daily max and min temperatures.

- **Pacific Tsunami Warning Center:** MLO is host to a tsunami seismometer.

- **PMEL (Pacific Marine Environment Lab):** GMD conducts joint aerosol chemical composition measurements and analyses with PMEL. GMD has assisted PMEL with the development of shortwave radiometer tilt corrections for deployment on buoys and saildrones.

- **PSD (Physical Sciences Division):** The GMD Carbon Cycle and Greenhouse Gases Group collaborates with PSD on data assimilation and with the PSD Arctic Program on IASOA activities and data analysis.

- **Ships of Opportunity Program:** GMD obtains carbon cycle flask air samples on the Atlantic and Pacific Ocean transects.

NOAA OAR PROGRAM COLLABORATIONS:

- **Climate Program Office:** GMD conducts climate, stratospheric ozone, air quality research and monitoring of radiatively important trace gases on a global scale with funding from this office. GMD is also active in the SEARCH program.

- **Arctic Research Program:** GMD participates in a methane sampling program in the Russian Arctic at a site in Cherskiy and in the operation of the Tiksi Arctic Observatory funded in part by NOAA through the Arctic Research Program Office. The International Arctic Systems for Observing the Atmosphere (IASOA) coordinates the activities of individual Observatories (including GMD Barrow and Summit) to provide a networked, observations-based view of the Arctic.

- **National Weather Service (NWS):** GMD has total-column ozone and/or solar radiation instrumentation and cooperative operations at seven NWS stations across the U.S.

- **NWS:** The GMD Radiation group provides UV Index measurements for validation of the UV Index forecast from the Climate Prediction Center (CPC). The NWS also hosts the SOLRAD sites at Albuquerque, NM; Bismarck, ND; Hanford, CA; Seattle, WA; Salt Lake City, UT, and Sterling, VA.

- **Unmanned Aerial Systems Program Office**: In 2015, GMD local Alaska personnel provided logistic support for USCGC Healy-NOAA PUMA mission.

OTHER FEDERAL AGENCIES:

- **ARM Department of Energy** Mobile Facility has deployed with GMD cooperation and staff at Point Reyes, CA; Niamey, Niger; Heselback, Germany; Shouxin, China; Azores Islands; Nainital, India; Cape Cod; MA, Manacapuru, Amazonas; Ascension Island, South Atlantic; Steamboat Springs, CO; Gan Island, Maldives; McMurdo and Ross Ice Shelf, Antarctica; Oliktok Point, Alaska; Cerro Chajnantor, Chile; and Macquarie Island, Southern Ocean.

- **Battelle-Northwest Laboratories:** ESRL samples for Persistent Organic pollutants (POPS) in the Arctic at the Barrow Observatory.

- **Civil Air Patrol:** Mauna Loa Observatory hosts a **USAF**-supported emergency radio rebroadcast facility covering the State of Hawaii.

- **Department of Energy (DOE):** GMD hosts the **Atmospheric Radiation Measurement (ARM)** North Slope of Alaska site at the Barrow facility. GMD scientists operate the surface and airborne aerosol monitoring programs at the DOE/ARM Southern Great Plains site in Oklahoma and the surface aerosol monitoring program at the ARM Mobile Facility.

- **Department of Energy (DOE):** GMD serves as the instrument mentors for **ARM's** Multi-Filter Rotating Shadowband Radiometer (MFRSR) instrument program, their shipborne radiation packages (ShipRad) and also provides technical support to the ARM facility on matters related to broadband radiation and radiometery for ground and airborne measurement programs. ARM provides funding for GMD to further the development of ultiraviolet spectrometers.

- **Department of Interior (Parks Service):** Mauna Loa Observatory maintains two helicopter landing sites used by the Parks Service for patrols, rescues and facility repairs.

- **DOE Atmospheric Science Research Program (ASR):** GMD scientists serve on the team of site scientists for the Oliktok Point, AK facility to provide guidance on measurement and data product methods and to perform program relevant science.

- **DOE Environmental Energy Technologies Division:** GMD cooperates with DOE to operate atmospheric measurements from Tall Towers in Walnut Grove and San Francisco (Sutro Tower), CA.

- **DOE** funds GMD to evaluate models with *in situ* hydroscopicity aerosol measurements.

- **Environmental Protection Agency (EPA):** The EPA studies long-range transport of mercury in the atmosphere in a joint project with GMD at Mauna Loa Observatory through the NOAA Air Resources Laboratory.

- **EPA Mandates:** GMD provides long-term measurements of ozone, and ozone precursors at the surface and in the troposphere in support of monitoring emissions for oil and gas extraction activities.

- **EPA's annual Report on the Environment:** GMD provides updates on the distributions and trends of greenhouse gases and ozone depleting substances (ODS) that are used in reports and some of its Climate Indicators.

- **Federal Aviation Administration (FAA):** Mauna Loa Observatory is host to an FAA GPS system for controlling aircraft in the Pacific Basin.

- **Interdisciplinary Research in Earth Sciences program:** NASA contributes to GMD missions with funding support.
- **Lawrence Berkeley National Laboratory:** Tall Tower sites at Walnut Grove and San Francisco (Sutro Tower), CA.
- **NASA AERONET:** GMD is host to the sunphotometer project's primary calibration site at Mauna Loa Observatory and hosts additional AERONET measurement sites.
- **NASA Clouds and Earth's Radiant Energy System Evaluation:** GMD operates surface radiation sites at Kwajalein and Bermuda, initiated with NASA funding.
- **NASA HIAPER Pole to Pole Observations (HIPPO):** GMD was a key participant in the HIPPO program and participated in the **Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE)** campaigns, as well as NASA's **Atmospheric Carbon and Transport (ACT**-**America**) project and the **Arctic-Boreal Vulnerability experiment (ABoVE)** and in the **Atmospheric Tomography (ATom)** campaigns.
- **NASA Southern Hemisphere Additional Ozonesonde (SHADOZ):** GMD operates three international ozonesonde stations in the network in the Pacific.
- **NASA Stratospheric Aerosol and Gas Experiment (SAGE III):** GMD provides overpass-coordinated, balloon-borne, vertical profile measurements of ozone and water vapor in the upper troposphere/lower stratosphere (UTLS) over Boulder and Lauder for validation of measurements by the spectrometer aboard the International Space Station.
- **NASA** supports the continuity of GMD's long-term measurement records of upper atmospheric water vapor measurements by balloon-borne frost point hygrometers at Boulder, Hilo and Lauder.
- **NASA** Wallops Island Flight Center, VA is host to and operates a GMD Dobson spectrophotometer.
- **NASA**: GMD provides airborne trace gas instrumentation and data analysis for NASA airborne campaigns on aircraft, balloon, and unmanned aircraft for missions.
- **NASA:** GMD provides ozone sonde and Dobson total ozone column and profile data for NASA satellite validation GMD participates in various NASA organized validation/research campaigns (MAPEX, ATTREX, POSIDON, ATom, POSIDON, ATTREX, GloPac, SEAC4RS, SEACIONS, TC4, ARCTAS, CALTEX).

- **NASA's OCO-2:** GMD participates in Science Teams in the areas of validation and flux inversion. Calibrated *in situ* data are a crucial component. Near-real time releases (four times per year) of GMD's CO_2 data assimilation system (CarbonTracker-NRT) support the evaluation of OCO-2 retrievals.

- **National Aeronautics and Space Administration (NASA):** GMD is host to, and provides manpower for a NASA Advanced Global Atmospheric Gas Experiment (AGAGE) site at the American Samoa Observatory.

- **National Center for Atmospheric Research (NCAR) High Altitude Observatory:** Mauna Loa Observatory hosts the facilities supported by the National Science Foundation.

- **National Institute of Standards and Technology (NIST):** Cooperative activities in the development and maintenance of long-term absolute UV calibration, trace gas standards and reference materials.

- **National Science Foundation (NSF):** GMD is host to a wide range of NSF-sponsored university research projects (in excess of 30) across the GMD observatories.

- **National Science Foundation (NSF):** GMD operates the NSF-owned Atmospheric Research Observatory (ARO) at the South Pole, and the NSF Summit, Greenland atmospheric research facility. GMD collects air samples in the Drake Passage aboard the L.M Gould operated by NSF. Air samples are collected at the NSF Palmer Station, Antarctica.

- **NCAR Gulfstream-5:** GMD participated in five intensive campaigns utilizing the aircraft to survey trace gas distributions in the UTLS from high northern to high southern latitudes in different seasons (HIPPO 1-5).

- **NCAR**, NASA and GMD participate in extensive trace gas comparisons to maintain comparability and consistency of measurements.

- **Network for the Detection of Atmospheric Composition Change (NDACC):** GMD conducts NDACC measurements at Mauna Loa, HI; South Pole, Antarctica; Boulder, CO; Wallops Island, VA; Cape Matatula, American Samoa; Observatoire Haute Provence, France; Lauder, New Zealand; and Summit, Greenland.

- **The Northeast Regional Center of the National Institute for Global Environmental Change (NIGEC)** provides funding to both GMD and Harvard University to monitor important trace gases at the Harvard Forest tower site, Massachusetts.

- **The United States Coast Guard (USCG):** The USCG in Kodiak, AK carries a suite of GMD greenhouse gas and ozone instruments, free of charge, on board its C-130 aircraft during Arctic Domain Awareness reconnaissance flights.
- **U.S Fish and Wildlife Service:** Collection of air samples at Midway Island.
- **United States Air Force (USAF):** The USAF ships helium, free of charge, to GMD balloon sites from a depot in Texas to any airbase in the world that is near an ESRL balloon site.
- **United States Air Force** samples air flasks for GMD on Ascension Island in the mid- Atlantic Ocean.
- **United States Air Force:** The Barrow Observatory operates a radioactive aerosol sampling facility for the USAF.
- **United States Air Force:** The BRW Observatory cooperates with the USAF Long Range Radar Site in Barrow, including snow removal and road maintenance.
- **United States Army:** GMD operates a solar radiation facility with the on Kwajalein Island, Pacific Ocean.
- **United States Army:** Mauna Loa Observatory is host to a command and control radio system used by the U.S. Army for the Pacific Army live fire base on the Island of Hawaii.
- **United States Department of Agriculture (USDA):** GMD hosts the USDA solar radiation baseline calibration site at Mauna Loa, HI and operates precipitation gauges at the Barrow Observatory for the USDA. The USDA also hosts the Goodwin Creek SURFRAD site near Batesville, MS.
- **United States Department of Agriculture:** GMD operates the Central UV Calibration Facility in direct support of the USDA UV program.
- **United States Geological Survey (USGS):** The USGS Arctic Magnetic Observatory is located adjacent to the GMD Barrow Observatory and is operated by GMD staff. Also, the USGS EROS Data Center hosts the SURFRAD site at Sioux Falls, SD.
- **United States Navy (USN):** Mauna Loa Observatory is host to a Navy camera system for the control and monitoring of bombing in the Pohakuloa live fire range.
- **United States Geological Survey (USGS) Alaska Science Center:** GMD collaborates with the science center and the **Russian National Academy of Sciences** in a study of Arctic climate variability.

- **United States Geological Survey (USGS):** Mauna Loa Observatory is host to a seismometer and tilt and strain well to monitor local lava flows and earthquakes.

STATE and MUNICIPAL AGENCIES:

- **California Air Resources Board (CARB):** Sponsors tropospheric ozone sampling at Trinidad Head with ozonesondes for air quality program.
- **California Air Resources Board:** Greenhouse gas emissions.
- **Colorado Department of Public Health and Environment, Air Pollution Control Division:** GMD provides background values for a number of trace gases of interest to the division.
- **Denver Water Board, Colorado:** Local solar radiation environment.
- **Fort Peck Tribes** host the SURFRAD site on the Fort Peck Reservation in northeastern Montana.
- **Hawaii County Police, Hawaii:** Mauna Loa Observatory hosts a radio rebroadcast facility for the police and Hawaii Civil Defense radios covering all of the Island of Hawaii.
- **Hawaii State Department of Health (DOH), Honolulu:** Mercury samples collected at Mauna Loa Observatory are analyzed by the DOH.
- **Humboldt State University**: Maintains ozone-measuring instruments at Trinidad Head.
- **Illinois State Water Survey, Urbana:** This agency hosts the GMD Bondville aerosol monitoring site that has been monitoring the climate forcing properties of aerosols at that location since 1994. The Illinois State Water Survey also hosts the Bondville SURFRAD site.
- **Metro Wastewater Reclamation District, Colorado:** Local solar radiation environment.
- **Pennsylvania State University**, Department of Meteorology hosts the Penn State GMD SURFRAD site.
- **Texas Agricultural Experiment Station:** Tall Tower site in Texas.
- **University of Alabama in Huntsville:** Launch ozonesonde balloon for the GMD ozone program.
- **University of Alaska at Fairbanks:** Operates NOAA’s Dobson instrument.

- **University of Colorado INSTAAR:** The Mountain Research Station operates a NEUBrew Brewer spectrophotometer, a visible MFRSR, a Yankee UVB-1, a Yankee UVA-1, an Eppley pyranometer, and a LiCOR pyranometer for GMD.
- **University of Colorado:** Hosts the surface ozone measurements at the Mountain Research Center and collects air samples at the Niwot Ridge Research Station.
- **University of Miami**, Department of Atmospheric Sciences & Rosenstiel School of Marine and Atmospheric Science acquires long-term surface ozone observations at Barbados.
- **University of Washington-Bothell, Washington:** Mountain Bachelor Observatory conducts carbon, aerosols and ozone monitoring with focus on background air sampling and seasonal impacts of the biomass burning.
- **University of Wisconsin:** The Department of Mechanical Engineering at the hosts the Madison SOLRAD site for GMD.
- **Utah Department of Air Quality:** Wintertime ozone research in Utah.
- **Wyoming Department of Air Quality:** Wintertime ozone research in Wyoming.

COLLABORATING NATIONAL and INTERNATIONAL NETWORKS

(see acronym list at the end of the booklet)

- AGAGE
- BIPM
- BSRN
- GAW (WMO)
- GCOS
- GOOS
- GRUAN
- GUAN
- ICOS
- NDACC
- SHADOZ
- IASOA

NON-GOVERNMENT, NON-UNIVERSITY PARTNERSHIPS

- 2B Technology, Boulder, CO: Surface and aircraft ozone measurement.
- Allen Scientific Glass, Boulder, CO: Air sampling flasks.
- Atmospheric Environment Research (AER), Cambridge, MA: Airborne halocarbon data and modeling support.
- ATSC, Norman, OK: Activities at the Kwajalein BSRN site.
- Bermuda Institute of Ocean Sciences: Flask-air sampling and surface ozone.
- Biospherical Instruments, Inc., San Diego, CA: Solar radiation instruments calibration.
- Brechtel Manufacturing Inc., Hayward, CA: Commercialization of GMD CLAP aerosol light absorption instrument.
- DuPont Company, NJ: Halocarbon emission estimates.
- EKO Instruments, Tokyo: Instrument design and testing.
- ENSI, CO: Ozonesondes.
- Eppley Laboratory, RI: Instrument design, modification, and testing.
- Fort Peck Indian Tribes: Fort Peck SURFRAD site operations.
- Friends of Midway: Air sampling at Midway Island.
- High Precision Devices, Boulder, CO: Air sampling equipment.
- Illinois State Water Survey, Bondville, IL: Field site operations.
- M&D Consulting, Germany: Provides halocarbon emission data.

PARTNERSHIPS AT GMD OBSERVATORIES:

The Global Monitoring Division Atmospheric Baseline Observatories are host to a wide variety of cooperative monitoring projects that benefit both NOAA and the cooperating entity. Some of these projects are operated free of charge, but many pay a fee to cover staff time, utilities, communications and road maintenance.

Some universities/agencies have projects at more than one baseline observatory and some have a number of different projects at one observatory. All of the cooperative projects in operation in 2017 are presented in following sections.

Barrow Atmospheric Baseline Observatory, Alaska

Department of Energy: Atmospheric Radiation Measurement (ARM) site.
Desert Research Institute: Mercury analyzer (until 2015).
Environment and Climate Change Canada: Persistent Organic Pollutants (POPs).

NOAA/NESDIS/NCDC: Climate Reference Network (CRN).
NOAA/NESDIS: POES Satellite uplink and downlink facility.
NOAA/OAR/PMEL: Aerosol filters.
NSF EarthScope Plate Boundary Observatory.
San Diego State University and NASA ABoVE: CH_4 Flux.
Scripps Institution of Oceanography: CO_2, ^{13}C, N_2O (flask), O_2/N_2.
State University of New York, Albany, University of Delaware, and USDA NRCS: Thaw depth in permafrost.
UNAVCO: SoumiNet GPS, precipitable water vapor.
University of California, Davis: Black carbon.
University of California, Irvine: Hydrocarbons.
US Air Force: Detachment 460 radiation monitoring.
USDA/Snow Survey: Precipitation gauge (until 2016).
USGS: Geomagnetics.

Summit, Greenland: Prior to and following July 2017

Georgia Institute of Technology: Aerosol light absorption and scattering.

Mauna Loa Atmospheric Baseline Observatory, Hawaii

Academia Sinica Institute of Astronomy and Astrophysics (ASIAA) Array for Microwave Background Anisotropy (AMiBA).
Atmospheric & Space Technology Research Associates (ASTRA) Traveling Ionospheric Disturbance Detector Built In Texas (TIDDBIT).
Australian Nuclear Science and Technology Organization (ANSTO): Radon tracer monitoring.
California Institute of Technology, California: Cosmic dust fluxes.
Central Connecticut University: Clidar aerosol lidar project.
Colorado State University, Fort Collins: Ultraviolet radiation project.
CSIRO (Australia): $^{13}C/^{12}C$ and $^{18}O/^{16}O$ in CO_2.
Environment and Climate Change Canada: Persistent Organic Pollutants (POPs).
Environment and Climate Change Canada: Refractory black carbon, organic carbon, elemental carbon
FAA/Stanford University: GPS test bed.
Hawaii State Civil Defense Radio Amateur Civil Emergency Service (HSCD RACES and ARES).
Hawaii Volcano Observatory: Volcano activity.
HPA: Communications.
John Hopkins University: Airglow studies.
Kinki University, Japan: Solar radiation calibrations for satellites.
Meteorological Research Institute, Japan: Spectral radiation calibrations.

Mount Washington Observatory: Ground Winds lidar.
MSC Canada: Column O_3.
NASA AMES Sunphotometer Calibrations.
NASA Goddard Space Flight Center (GSFC): Pandora total ozone.
NASA Goddard Space Flight Center: AERONET photometers.
NASA Goddard Space Flight Center: Pyranometer.
NASA Jet Propulsion Laboratory (JPL) Panoptic Astronomical Networked Observatories for a Public Transiting Exoplanets Survey (PANOPTES).
NASA Jet Propulsion Laboratory: Stratospheric O_3 & temp profiles.
National Ecological Observatory Network (NEON) CIMEL sunphotometer.
National Solar Observatory (NSO) Global Oscillation Network Group (GONG).
Naval Research Labs: Chloride oxide.
Naval Research Labs: Stratospheric ozone profiles.
Naval Research Labs: Water vapor.
NCAR FTS: Solar spectra.
NCAR: FTIR columns spectra of atmospheric gases.
NDACC: Stratospheric Climate and Atmospheric Composition Change.
NIES: CO_2, ^{13}C, N_2O.
NOAA Air Resources Lab: Carbon monoxide.
NOAA Air Resources Lab: Hg0, Hg+2, Hgp.
NOAA Air Resources Lab: Particulates.
NOAA Air Resources Lab: Surface O_3, and SO_2.
NOAA and NIWA: BrO.
NOAA and NIWA: NO_2.
NOAA and NIWA: UV.
NOAA Earth System Research Lab (GSD): Meteorology.
NOAA National Weather Service: Meteorology.
NOAA National Weather Service: Rainfall at Kulani Mauka site.
NOAA Pacific Tsunami Warning Center: Seismic activity.
NOAA/NESDIS/NCDC: Climate Reference Network (CRN).
Pacific Northwest National Laboratory (PNNL) Multi-Filter rotating shadowband radiometer.
Pacific Northwest National Laboratory (PNNL): Solar calibrations.
Pohakuloa Training Area Range Surveillance System: Video surveillance.
Scripps Institution of Oceanography - Earth Networks Center for Climate Research: CO2/CH_4/water vapor.
Scripps Institution of Oceanography: Carbon cycle gases and oxygen.
Scripps Institution of Oceanography: CO_2, ^{13}C, N_2O (flask).
Scripps Institution of Oceanography: O_2/N_2.
Solar Light: Calibration of Microtops ozone meters.

Stanford University, California: GPS-derived column water vapor.
State University of New York, Stonybrook: Carbon monoxide and its isotopes.
University Nevada-Reno: Mercury studies.
University of California, Davis - Delta group: Long transport of aerosols.
University of California, Davis: Aerosol chemistry.
University of Colorado: MultiAXis Differential Optical Absorption Spectroscopy (CU-MAX DOAS).
University of Hawaii Institute for Astronomy (IFA) Asteroid Terrestrial-impact Last Alert System (ATLAS).
University of Hawaii Institute for Astronomy (IFA): MLONet and VYSOS telescope.
University of Hawaii - Institute for Astronomy: Variable Young Star Survey.
University of Hawaii: Extraterrestrial particles.
University of Hawaii: Precipitation study.
University of Hawaii, Honolulu: Sulphate chemistry.
University of Hawaii, Manoa: Corrosion and fungal spore projects.
University of Michigan: Atmospheric lidar measurements.
University of New Hampshire/NIWA: Stratospheric ozone.
University of Rochester: ^{14}CO flask sampling.
US Navy Pacific Missile Range Facility: Video surveillance, communications.
US Postal Inspector: Radio repeaters.
USGS: Mercury sampling.
USGS: Seismometer and strain meters.
World Radiation Center: Filter radiometer/PMOD.

Trinidad Head, California: Both Before and After 2017

Scripps Institute of Oceanography, La Jolla, CA: Flask samples, surface ozone, and data sharing.

American Samoa Atmospheric Baseline Observatory, Cape Matatula

Environment and Climate Change Canada: Persistent Organic Pollutants (POPs).
Johns Hopkins University: Ionospheric imaging.
NASA/AGAGE: CFC-11, CFC-12, CFC-113, CCl_4, CH_3CCl_3, CH_4, N_2O, $CHCl_3$.
NASA/Goddard Space Flight Center: AERONET photometers.
Scripps Institution of Oceanography: CO_2, ^{13}C, N_2O (flask).
Scripps Institution of Oceanography: O_2/N_2.
University of California, Irvine: Hydrocarbons.

South Pole Atmospheric Baseline Observatory, Antarctica

CSIRO (Australia): CO_2, CH_4, CO, H_2, N_2O, $^{13}C/^{12}C$ and $^{18}O/^{16}O$ in CO_2.
Environment and Climate Change Canada: Brewer spectrophotometer.
NASA/Goddard Space Flight Center: AERONET photometers.
NASA/Goddard Space Flight Center: MPLNET cloud profiling.
National Institute of Polar Research (Japan) - NIPR All Sky Camera (discontinued in 2017).
Scripps Institution of Oceanography: CO_2, ^{13}C, N_2O (flask).
Scripps Institution of Oceanography: Firn air sampling.
Scripps Institution of Oceanography: O_2/N_2.
Scripps Institution of Oceanography: Oxygen isotopes.

OTHER INTERNATIONAL PARTNERSHIPS

GMD has a variety of Partnerships, Cooperative Agreements and Memoranda of Understanding with agencies in other countries to conduct Measurements and Research Separate from the Observatory Programs.

Alfred Wegener Institute, Bremerhaven, Germany: Cooperation in the operation of the WCRP BSRN data archive and various polar aerosol optical depth studies.

Algerian Meteorological Service, Tamanrasset, Algeria: Operates SURFRAD site; collects carbon cycle flask-air samples.

Arctic Research Center, Department of Environmental Science, Denmark: Surface ozone measurements in the Arctic.

Australian CSIRO: Collection of flask-air samples at Cape Grim, Tasmania and comparison of GHG measurements.

Brazilian Meteorological Service: Measurements at Bahia GAW.

British Antarctic Survey: Collection of air samples at Halley Bay, Antarctica.

Brazilian Meteorological Service: Measurements at Bahia GAW.

Bureau International des Poids et Mesures (BIPM), France.

Bureau of Meteorology, Cape Grim (Smithton), Australia: Collects flask samples for trace gases under supervision of GMD.

Bureau of Meteorology, Perth, Australia: Operates a Dobson spectrophotometer under supervision of GMD.

Centre des Faibles Radioactivities/TAAF, France: Collection of discrete air samples at Crozet Island.

Global Carbon Project: Contributions of atmospheric data and interpretations.

Centre National de la Recherche Scientifique, France: Operates a Dobson spectrophotometer under supervision of ESRL and University of Reims.

Centro de Investigacion de la Baja Atmosfera, Univ. of Valladolid, Spain: Collection of discrete air samples.

China Meteorological Administration, Chinese Academy of Meteorological Sciences (CAMS): Cooperative aerosol measurements and flask-air sampling at Mt. Waliguan GAW station.

Copernicus, the European Union’s Earth Observation Programme: GMD is involved in the development of observation infrastructure.

Czech Hydrometeorological Institute: Collaboration on calibrations of Dobson instruments through WMO/GAW.

Deutscher Wetterdienst, Germany: Calibrations of Dobson spectrophotometers through WMO/GAW and collection of discrete air samples at Hohenpeissenberg.

Deutscher Wetterdienst, Lindenberg, Germany: GRUAN Lead Center cooperates with GMD’s certified GRUAN site at Boulder.

Direccion Meteorologica de Chile: Collection of discrete air samples on Easter Island.

Ente per le Nuove tecnologie, l’Energia e l’Ambiente, Italy: Collection of air samples at Lampedusa.

Environment and Climate Change Canada: SEARCH aerosol filters at MLO and joint research operations at Alert, Egbert, Whistler, East Trout Lake and Eureka.

Environment and Climate change Canada: The World Ozone and Ultraviolet Radiation Data Centre (WOUDC).

Finnish Meteorological Institute, Finland: Cooperative flask-air sampling at Pallas, Finland GAW station.

German Aerospace Center (DLR), Oberpfaffenhofen, Germany.

Gobabeb Training and Research Center, Namibia: Discrete air sampling.

Hungarian Meteorological Service: Collection of air samples and comparison of measurements at Hegyhatsal.

Icelandic Meteorological Office: Collection of air samples at Storhofdi, Vestmannaeyjar.

Indonesian Bureau of Meteorology and Geophysics: Measurements at Sumatra GAW station.

Instituto Nacional de Pesquisas Espaciais (INPE), Brazil: Dobson spectrophotometer calibrations with assistance from GMD; joint WMO/GAW operations.

Instituto Nacional de Meteorologia e Geofisica, Portugal: Collection of discrete air samples at Terceira Island, Azores.

Izaña Observatory/Meteorological State Agency of Spain: Collection of air samples.

Japan Meteorological Agency: Collaboration on calibrations of Dobson Instruments through WMO/GAW.

Karlsruhe Institute of Technology, Karlsruhe, Germany: Collaboration in performing comparisons between satellite-based, balloon-borne, and ground-based measurements of stratospheric water vapor for the 2nd SPARC Water Vapor Assessment.

Korea Centre for Atmospheric Environment Research: Air sampling at Yae-ahn Peninsula, Korea.

Korea Meteorological Administration, Korea Global Atmosphere Watch Center, Korea: Collection of discrete air samples at Anmyeon-do.

Leibniz Institute for Tropospheric Research, Leipzig, Germany: Collaborative aerosol measurements at Barrow, joint workshop participation to improve aerosol instruments and measurement methodologies.

Max Planck Institute for Chemie, Mainz, Germany.

Mongolian Hydrometeorological Research Institute: Collect flask-air samples at Ulaan Uul, Mongolia.

National Academy of Sciences, Russia: Cooperation on BSRN site.

National Central University, Taiwan: Collection of air samples at Dongsha Island and Lulin GAW station.

National Institute of Polar Research, Japan: Studies of polar aerosol optical properties.

National Institute of Water & Atmospheric Research, New Zealand: Operates a Dobson spectrophotometer under supervision of GMD, a surface ozone instrument in Lauder, New Zealand and Arrival Heights, Antarctica, and launches water vapor sondes at Lauder supplied by GMD.

National University of Ireland, Galway, Ireland: Collection of air samples at Mace Head.

Paul Scherrer Institute, Villigen, Switzerland: Aerosol research.

Roshydromet, Russia: SEARCH and establishment of climate monitoring station in Northern Siberia.

Servicio Meteorologico Nacional, Argentina: Collect cooperative air samples at Ushuaia for measurements of GHGs.

Seychelles Bureau of Standards: Collection of discrete air samples on Mahe Island.

Sistema Internacional de Monitoreo Ambiental, Mexico: Collection of air samples at high altitude climate observatory.

South African Weather Service: Calibrations of Dobson spectrophotometers through WMO/GAW and aerosol measurements and collection of flask-air samples at Cape Point GAW station.

Stockholm University, Meteorological Institute, Sweden: Cooperative flask-air sampling at the GAW Zeppelin Observatory.

UK Met Office: Collection of discrete air samples on Ascension Island.

University of Guam/Marine Laboratory: Collection of discrete air samples.

University of Kiel, Institute fűr Meerskunde, Kiel, Germany: Halocarbon measurements.

University of Edinburgh, Scotland: CO_2 and CH_4 studies using models and measurements.

Weizmann Institute of Science and Arava Institute for Environmental Studies, Israel: Cooperative air sampling in Negev Desert.

WMO World Climate Research Program - GEWEX: ESRL provides international management of the WCRP Baseline Surface Radiation Network.

World Climate Research Program, Geneva: BSRN and GEWEX activities.

World Meteorological Organization, Switzerland: BSRN, GAW, and GCOS activities.

World Radiation Center, Switzerland: Radiometer calibration and characterization studies.

OTHER RESEARCH COLLABORATIONS, DATA EXCHANGES, STUDENT INTERNSHIPS, and JOINT PUBLICATIONS

- Bay Area Environmental Research Institute
- Baylor University
- Belgian Institute for Space Aeronomy
- Brookhaven National Laboratory
- California Institute of Technology
- California State University, Humboldt
- Centre National de la Recherche Scientifique
- Centre National d'Etudes Spatiales
- China Meteorological Administration
- Colorado State University
- University of Denver
- Department of Energy Pacific Northwest Laboratory
- Department of Interior Mineral Management Service
- Desert Research Institute
- DLR Institute of Atmospheric Physics
- DOE Argonne National Laboratory
- DOE Los Alamos National Laboratory

- Droplet Measurement Technologies
- Duke University
- Ecotech Pty Ltd.
- Eidgenössische Technische Hochschule
- Environment and Climate Change Canada
- Environmental Protection Agency
- European Centre for Medium-Range Weather Forecasting
- European Commission
- European Space Agency
- Federal Aviation Administration
- Florida State University
- Forschungszentrum Jülich
- Fort Hayes State University
- French Meteorological Service
- Georgia Institute of Technology
- German Aerospace Institute
- German Weather Service
- Harvard University (Harvard Forest and SEAS)
- Hokkaido University
- Howard University
- Ibaraki University
- Institut Pierre Simon Laplace
- Japan Meteorological Agency
- Johns Hopkins University
- Karlsruhe Institute of Technology
- Keio University
- Laboratoire d'Aérologie, Toulouse
- Laboratoire des Sciences du Climat et de l'Environnement
- Laboratory for Atmospheric and Space Physics
- Lamar University
- Lawrence Livermore National Laboratory
- Los Angeles World Airports
- Max-Planck-Institut Hamburg
- Max Planck Institute for Biogeochemistry, Jena
- McGill University
- Met Office, U.K.
- Met Service of Slovenia

- National Aeronautics and Space Administration (NASA):
    - Armstrong Flight Research Center (AFRC), Palmdale & Edwards Air Force Base, CA
    - Columbia Scientific Balloon Facility (CSBF), Ft. Sumner, NM
    - Goddard Space Flight Center (GSFC), Greenbelt, MD
    - Headquarters, DC
    - Johnson Space Center (JSC), Houston, TX
- National Center for Atmospheric Research
- National Institute of Standards and Technology
- National Institute of Water and Atmospheric Research
- National Science Foundation
- Netherlands Environmental Assessment Agency
- Nordic Envicon Oy
- North Carolina State University
- Norwegian Institute for Air Research
- Oregon State University
- Pacific Northwest National Laboratory
- Pennsylvania State University
- Physical Sciences Inc.
- Plymouth State College
- Portland State University
- Rice University
- Royal Dutch Meteorological Institute
- Scripps Institution of Oceanography
- Stanford University
- Technical University of Munich
- Tennessee Valley Authority
- Texas A&M University
- Texas Tech University
- Thermo Fisher Scientific
- United States Coast Guard
- University of California Berkeley
- Universidad Nacional de Autonoma Mexico
- Universite de Pierre et Marie Curie
- University of Bremen
- University of Bristol, UK (Mace Head and Barbados)
- University of California Davis
- University of California Irvine
- University of California Los Angeles
- University of California Santa Cruz

- University of Cambridge
- University of Central Florida
- University of Colorado Boulder
- University of East Anglia
- University of Edinburgh
- University of Galway (Mace Head, Ireland)
- University of Helsinki
- University of Houston
- University of Iowa
- University of Jerusalem
- University of Leeds
- University of Leicester
- University of Manchester
- University of Maryland
- University of Massachusetts
- University of Miami
- University of New Hampshire
- University of Reading
- University of Stockholm
- University of Texas
- University of Toronto
- University of Virginia
- University of Washington
- University of Wisconsin
- Valparaiso University
- Volpe National Transportation Systems Center
- Washington State University
- Weismann Institute
- Western Michigan University
- Woods Hole Oceanographic Institution

Global Monitoring Division

NOAA GMD Legislative Drivers and Research to Applications (R2A)

2013-2017 Review

May 21-24, 2018

Contents: page

NOAA GMD Legislative Drivers

Clean Air Act 1990 Title IV and Title VI, 42 U.S.C. § 7401 et seq.: "…NOAA shall monitor, and not less often than every 3 years following November 15, 1990, submit a report to Congress on the current average tropospheric concentration of chlorine and bromine and on the level of stratospheric ozone depletion."

Global Change Research Act of 1990, 15 U.S.C. 2921 et seq.: Ensures the establishment of global measurements and worldwide observations…

Global Climate Protection Act of 1990, 7 U.S.C. § 6701 et seq.: Requires research in climate change needed to protect the environment.

National Climate Program Act, 15 U.S.C. 2901-2908, at 2904(d) (4), et seq.: …authorizes global data collection, monitoring, and analysis activities to provide reliable, useful and readily available information on a continuing basis, authorizes measures for increasing international cooperation.

U. N. Framework Convention on Climate Change (UNFCCC): Requires better quantification of the agents that force climate change by contributing research results and providing expertise to the assessments.

Montreal Protocol on Substances that Deplete the Ozone Layer *(and subsequent amendments)*: Requires an assessment every four years of the state of the ozone layer, its recovery, and the amounts and origins of ozone depleting substances that drive the ozone layer changes.

Global Earth Observation System of Systems (GEOSS): endorses the Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan.

Full List in Detail in 3 following pages if interested.

<u>Legislation:</u>

- *Federal Records Act as amended, 44 U.S.C. §3101 et seq.*: Responsible for the establishment of the National Weather Records Center which archives and services U.S. weather and climate records.
- *Data Quality Act, Public Law 106-554, Section 515, 2001*: Requires that the U.S. government assure the quality of the information disseminated.
- *36 C.F.R., Chapter XII National Archive and Records Administration (NARA) Records and Guidelines*: Stipulates that data maintained for legal purposes and in the national interests must be archived using NARA standards.
- *National Weather Service Organic Act, 15 U.S.C. § 313*: Ensures there are atmospheric, oceanic, and terrestrial measurements suitable for establishing and recording U.S. Climate Conditions.
- *National Climate Program Act, 15 U.S.C. 2901-2908, at 2904(d) (4), et seq.*: Requires that one program element will be the provision of "useful and readily available information on a continuing basis." It authorizes global data collection, monitoring, and analysis activities to provide reliable, useful and readily available information on a continuing basis. In addition, the act authorizes measures for increasing international cooperation in climate research, monitoring, analysis, and data dissemination.
- *Global Change Research Act of 1990, 15 U.S.C. 2921 et seq.*: Ensures the establishment of global measurements and worldwide observations, and requires an early and continuing commitment to the establishment and maintenance of worldwide observations and related data and information systems.
- *Coastal Zone Management Act (CZMA) of 1972, 16 U.S.C. 1450 et seq. (amended 1990 and 1996)*: Requires understanding and predicting long-term climate change which may have large impacts in the Coastal zone such as global warming and associated sea level rise.
- *Clean Air Act 1990 Title IV and Title VI, 42 U.S.C. § 7401 et seq.*: Amendment to the Clean Air Act mandates that “the Administrators of the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration shall monitor, and not less often than every 3 years following November 15, 1990, submit a report to Congress on the current average tropospheric concentration of chlorine and bromine and on the level of stratospheric ozone depletion.”
- *Global Climate Protection Act of 1990, 7 U.S.C. § 6701 et seq.*: Requires research in climate change needed to protect the environment.
- *Oceans Act 2000 (PL 106-256)*: Led to the Congressionally-mandated report of the U.S. Commission on Ocean Policy and the Executive response, the U.S. Ocean Action Plan of 2005: Requires federal agencies to participate in building a Global Earth Observation Network that includes integrated oceans observations. The U.S. is implementing this through the Integrated Ocean Observation System (IOOS), the Integrated Earth Observation System (IEOS), and participation in GEOSS.
- *Consolidated Appropriations Act, 2005, Public Law No. 108-447, 118 Stat. 2908 (Dec. 8, 2004), incorporates S. 1218, the Oceans and Human Health Act*: “Establish[es] a Federal research program that examines ocean resources and their applications to human health.” The Act aims to “…ensure that any integrated ocean and Coastal observing system provides information necessary to monitor, predict and reduce marine public health problems including: (A) baseline observations of physical ocean properties to monitor climate variation; (B) measurement of oceanic and atmospheric variables to improve prediction of severe weather events; …”

U.S. Executive Branch and NOAA Directives and Other Guidelines:

- *Strategic Plan for the U. S. Integrated Earth Observations System (IEOS), USGEO Report, 2005*: This plan addresses the policy-related, technical, and fiscal components of a U.S. integrated Earth observation system.
- *President's Security and Prosperity Program of North America Initiative (SPP):* SPP is a trilateral agreement among the U.S., Canada, and Mexico signed in March 2005. One of the many facets of the agreement relevant to the Climate Program involves "enhancing the joint stewardship of our environment… through cooperation and information sharing."
- *U.S. Ocean Action Plan/ Charting the Course for Ocean Science for the United States for the Next Decade: An Ocean Research Priorities Plan and Implementation Strategy (2007):* Administration's response to the U.S. Commission on Ocean Policy Report: To accomplish actions within the Ocean Action Plan requires the access to and use of archived (new and historical) quality observations of essential climate and ocean variables. The ORPP calls for deployment of "a robust ocean observing system that can describe the actual state of the ocean."
- *Department Administrative Order (DAO) 212-2 Information Technology Handbook*: This handbook defines data management and related activities as: identifying the information needed; defining and documenting data requirements; coding and structuring the data; designing the database; selecting and using the most effective storage technology; collecting the data; processing the data; disseminating the information and facilitating user access; protecting the data against damage and unauthorized access; and archiving and disposing of the data.

Interagency and International Agreements:

- *International Council of Scientific Unions (ICSU) guidelines/policy regarding World Data Centers (WDC) – National Climatic Data Center WDC for Meteorology and Paleoclimatology*: Requires archiving and access to data collected by internationally sponsored observation and research programs. Allows for the active exchange of climate data with foreign countries to support research and other activities.
- *U. N. Framework Convention on Climate Change (UNFCCC)*: Requires better quantification of the agents that force climate change by contributing research results and providing expertise to the assessments.
- *Montreal Protocol on Substances that Deplete the Ozone Layer (and subsequent amendments)*: Requires an assessment every four years of the state of the ozone layer, its recovery, and the amounts and origins of ozone depleting substances that drive the ozone layer changes.
- *Global Earth Observation System of Systems (GEOSS)*: Third Earth Observation Summit held in Brussels, 16 February 2005, endorsing the Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan. Summarizes the essential steps to be undertaken over the next decade by nations, and intergovernmental, international, and regional organizations, to establish a coordinated and comprehensive sustained earth observations system and defines associated fundamental socio-economic benefits supported by a GEOSS approach to observations and monitoring.

<u>Mission Requirements:</u>

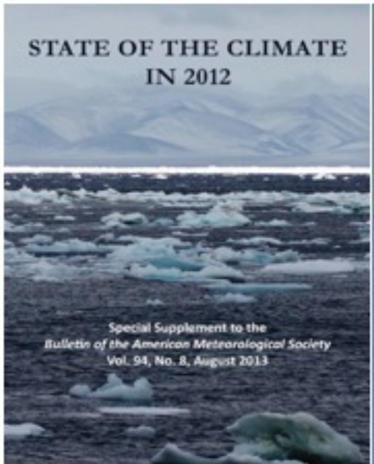
- Establish an Agency Records Center for U.S. Weather and Climate records. (*Federal Records Act)*
- Provide long-term preservation of the Nation's Climate Record. *(Federal Records Act, Data Quality Act, National Climate Program Act, NARA Records and Guidelines, ICSU World Data Center Guidelines & Policy, and U.S. Ocean Action Plan)*
- Provide climate data and information that meets rigorous scientific standards for quality.
- *(Data Quality Act, Coastal Zone Management Act, and U.S. Ocean Action Plan)*
- Provide NOAA customers access to Climate Data and Information (timely, easy, and convenient) related to the state and changing state of the climate system in a variety of formats. *(Federal Records Act, National Climate Program Act, NARA Records and Guidelines, ICSU World Data Center Guidelines & Policy, Consolidated Appropriations Act, and U.S. Ocean Action Plan)*
- Monitor and assess the climate system through adequate quality observations and measurements of atmospheric, ocean, and select terrestrial "essential climate (state) variables". (*Global Change Research Act, National Climate Program Act, National Weather Service Organic Act, Coastal Zone Management Act, and U.S. Ocean Action Plan)*
- Improve quantification of the forces and feedback systems bringing about changes in the earth's climate and related systems. (*Global Change Research Act, Global Climate Protection Act of 1990, Oceans Act 2000, Climate Change Science Program, U.N. Framework Convention on Climate Change, Montreal Protocol, Global Earth Observation System of Systems)*

Research to Applications (R2A)

NOAA is a science-based service agency. NOAA's ability to meet its mission through the delivery of continually improved products and services relies on the conversion of the best available research and development (R&D) endeavors into operation and application products, commercialization, and other uses.

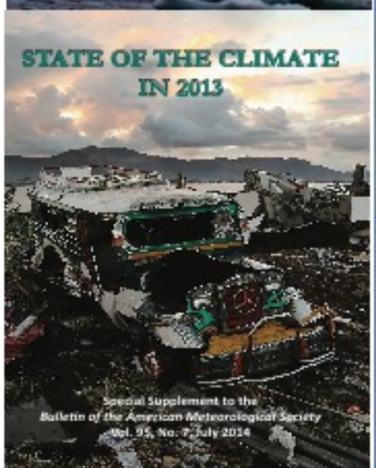
NOAA's Office of Oceanic and Atmospheric Research (OAR) is charged with delivering information, products, and tools to meet the needs of the other NOAA Line Offices, the academic community, and a variety of other key stakeholders. A significant component of meeting this charge is to ensure the efficient transition of OAR’s research to applications or operations. NOAA defines a transition project as “The collective set of activities necessary to transfer a research result, or collection of research results, to operational status or to an information service."

The Global Monitoring Division informs applied work through research to address societal challenges. GMD transitions projects through the public dissemination of atmospheric measurements, release of our research through scientific publications, and participation in scientific assessments. GMD also develops innovative technologies and systems that are transitioned to various applications and industry. Listed below are R2A projects and products in GMD that have successfully completed transition to one or more applications.



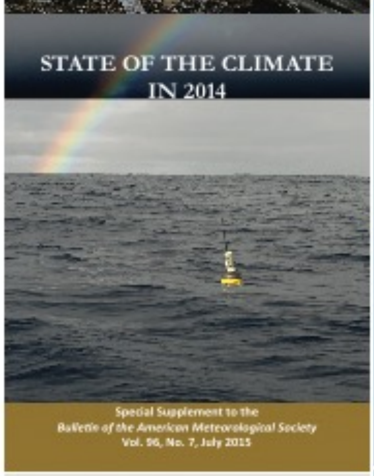
Chapter Editor: Bradley Hall
GMD Authors: Lori Bruhwiler, Ed Dlugokencky, Geoff Dutton, James Elkins, Brad Hall, Dale Hurst, Bryan Johnson, Stephen Montzka

GMD long-term records of greenhouse and ozone-depleting gases, ozone profiles, stratospheric ozone, stratospheric water vapor and solar radiation were extensively used in the report. Reference to GMD publications and analyses were numerous.



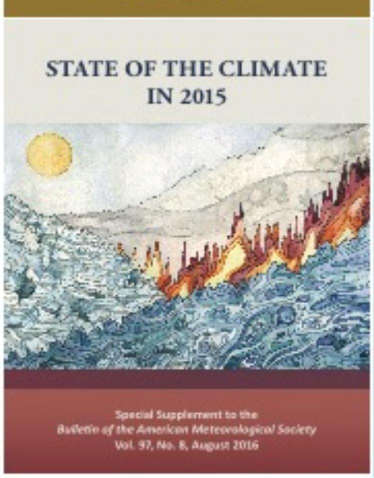
Chapter Editor: Dale Hurst
GMD Authors: John Augustine, Lori Bruhwiler, Ed Dlugokencky, Geoff Dutton, James Elkins, Brad Hall, Dale Hurst, Bryan Johnson, Kathleen Lantz, Stephen Montzka, Robert Stone

GMD long-term records of greenhouse and ozone-depleting gases, ozone profiles, stratospheric ozone, stratospheric water vapor and solar radiation were extensively used in the report. A GMD measured 15-year trend of increasing net radiation over the U.S. was highlighted.



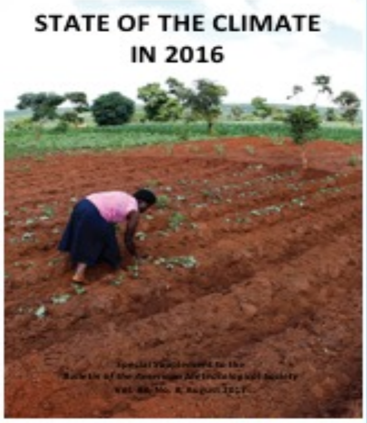
Chapter Editor: Dale Hurst
GMD Authors: Ed Dlugokencky, Geoff Dutton, James Elkins, Brad Hall, Dale Hurst, Bryan Johnson, Kathleen Lantz, Stephen Montzka, Irina Petropavlovskikh

GMD long-term records of greenhouse and ozone-depleting gases, ozone profiles, stratospheric ozone, stratospheric water vapor and solar radiation were extensively used in the report. The GMD-measured 56-year Mauna Loa clear-sky solar transmission record was highlighted.



Chapter Editor: Dale Hurst
GMD Authors: Molly Crotwell, Ed Dlugokencky, Geoff Dutton, James Elkins, Brad Hall, Dale Hurst, Bryan Johnson, Kathleen Lantz, Stephen Montzka, Irina Petropavlovskikh

GMD long-term records of greenhouse gases, ozone-depleting gases, stratospheric ozone, stratospheric water vapor, ozone profiles and solar radiation were extensively used in the report. Reference to GMD publications and analyses were numerous. Significant changes in the one of its kind GMD long-term stratospheric water vapor record were noted.



Chapter Editor: Dale Hurst
GMD Authors: John Augustine, Edward Dlugokencky, James Elkins, Dale Hurst, Bryan Johnson, Kathleen Lantz, Steve Montzka, Irina Petropavloskikh

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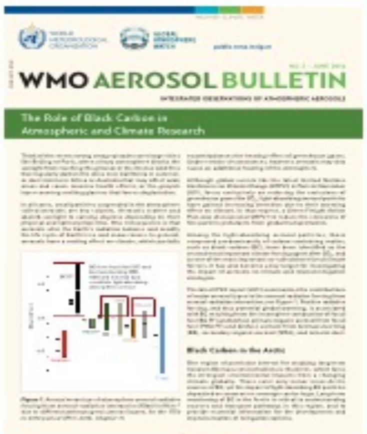
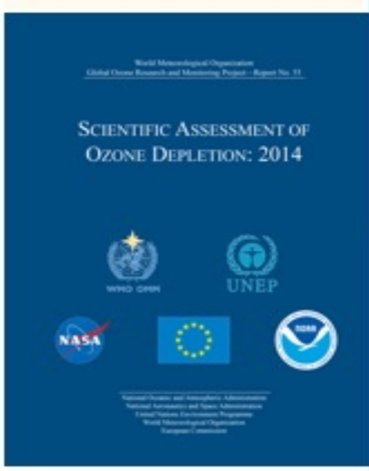


The Aerosol Bulletin provides general information on the aerosol component of GAW and focuses on specific components or applications of GAW aerosol measurements.

The bulletin focused on Black Carbon (BC) in the Arctic, considered the second most important climate forcing agent after carbon dioxide in the Arctic. GMD has the longest record of BC in the Arctic (since 1983). The two basic instruments used to measure BC in the Arctic were developed with GMD funding and expertise.

The Aerosol Bulletin provides general information on the aerosol component of GAW and focuses on specific components or applications of GAW aerosol measurements.

This bulletin focused on measurements of volcanic aerosols and presented data from the GMD Boulder stratospheric aerosol lidar. The Mauna Loa stratospheric aerosol lidar has been in continuous operation since 1974 and has unique data on the large El Chichon and Pinatubo eruptions as well as many smaller volcanoes and aerosols from Asia.



Steve Montzka, GMD, was a Chapter 1 author of the report. GMD scientists Geoffrey Dutton, James Elkins, Dale Hurst, Steve Montzka and Irina Petropavlovskikh were contributing authors and reviewers.

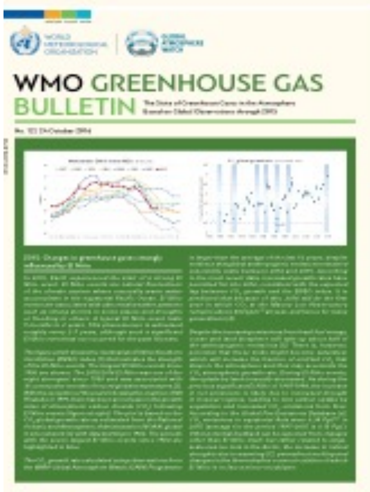
GMD ozonesonde, Dobson ozone spectrophotometer, Umkehr and lidar measurements formed core data sets for the analyses going into the report. GMD maintains the WMO calibration standard for Dobson ozone measurements and a GMD scientist invented the ozonesonde instrument.

Andrew Crotwell, James Elkins, Thomas Conway, Kirk Thoning, Duane Kitzis, Pieter Tans, Steve Montzka, Ken Masarie, Edward Dlugokencky, James Butler and Geoff Dutton were referenced as providing GMD data and publications cited in the report.

Seven of the nine data graphics presented in the report were of GMD data including the Annual Greenhouse Gas Index (AGGI) and the long term carbon dioxide, methane and halocarbon trends.

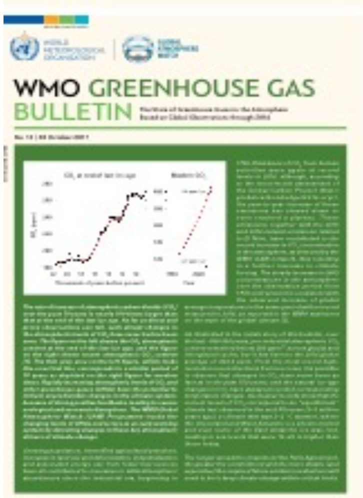
References and links to GMD web sites for greenhouse gases, AGGI, halocarbons, stratospheric water vapor, nitrous oxide and publications on greenhouse gases were used in the report.

Eight of the nine graphs in the bulletin come from GMD data and web sites.



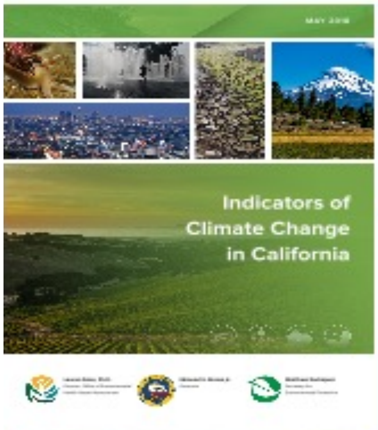
References and links to GMD web sites for greenhouse gases, AGGI, halocarbons, stratospheric water vapor, nitrous oxide and publications on greenhouse gases.

Six of the nine graphs in the bulletin come from GMD data and web sites.



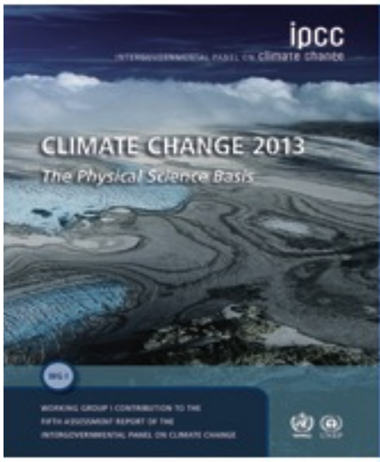
References and links to GMD web sites for greenhouse gases, AGGI, halocarbons and publications on greenhouse gases.

At least 50% of the data and graphs presented in the bulletin are from or based on GMD data. Ten of the 13 graphs/photos in the bulletin are from GMD data and web sites.



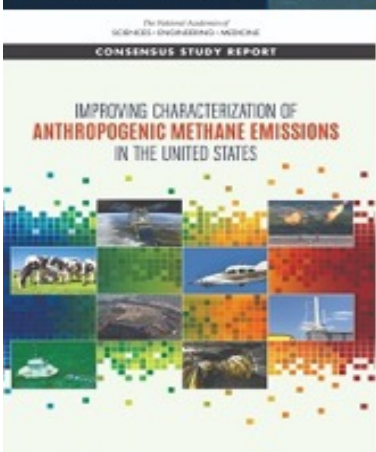
GMD contributors: Edward Dlugokencky and Pieter Tans.

GMD data are used and referenced throughout the report.



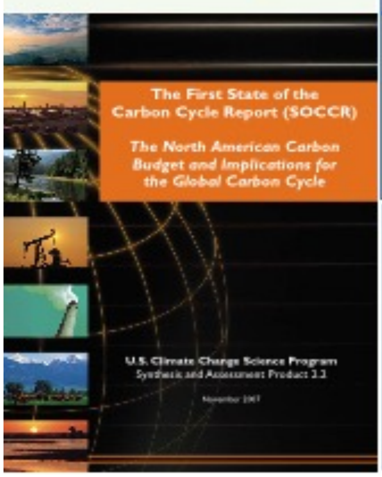
Edward Dlugokencky: Lead Author
Pieter Tans: Reviewer and Editor

GMD data and graphics are used throughout the report and especially in Chapter 2 (Observations: Atmosphere and Surface) and Chapter 6 (Carbon and Other Biogeochemical Cycles).



Lori Bruhwiler, GMD: National Academy Report Committee Member, contributing author and reviewer

Extensive use of GMD global surface network, airborne profile and gas and oil field monitoring and research data on methane.



James Butler, GMD, was a member of the Carbon Cycle Interagency Working Group that produced the report.

Much of the historic carbon dioxide concentration data discussed in the report was based on GMD continuous data records, some of which date back 50 years.

GMD Research to Applications 2013--2017

GMD Project Name	Thing Transitioned	Purpose of Transition	To Where Sample Organization	Comments
	What, exactly, was the thing transitioned from point A to point B?	*What application was the transition intended to improve?*	*Office, lab, sub-unit, or external partner where the project or thing was adopted.*	
Aerosol Data - NOAA Federated Aerosol Network	Approximately 18 variables measured and over 285 data sets available (globally).	The Federated Aerosol Network is a component of WMO Global Atmosphere Watch (GAW) that provides robust data from a global network of sites using similar instrumentation and consistent approaches. Assist in model development.	WMO World Data Center for Aerosols (WDCA), hosted by NILU, Norway, http://ebas.nilu.no/	http://esrl.noaa.gov/gmd/dv/data/?category=Aerosols. The NOAA GMD global aerosol measurement network is the only one of its type on Earth and the data used by modelers, air pollution agencies, policy makers and scientists. It focuses primarily on aerosol optical properties and the direct aerosol effect.
Aerosol Software	Custom, open source (linux-based) software package (CPD3) for data acquisition, processing, visualization, editing, analysis and archiving aerosol data from NOAA and partner stations.	The CPD3 software package used throughout the NOAA Federated Aerosol Network was developed to faciliate consistent and robust data processing over the NOAA Federated Aerosol Network.	Primarily WMO partner research organizations that monitor aerosols on a long-term basis and submit their data to the WDCA	https://www.esrl.noaa.gov/gmd/aero/sw.html
AirCore	Atmospheric sampling system that samples the atmosphere and preserves a profile of the trace(s) gas of interest.	Widespread vertical profiles of CO_2, CH_4, and other greenhouse gases for validation of satellite retrievals and development of Earth System and carbon models.	Southwest Research Institute, and several research organizations worldwide	Developed and patented at NOAA, this sampling tool makes it possible to collect and analyze a vertical (or horizontal) core of the atmosphere, retaining the integrity of the vertical profile. Used and tested as a means for validating satellite retrievals of CO_2 and CH_4. One company (SWRI) is interested in routinely flying a miniaturized version on a SUV and in the process of testing; several of our international partners are adapting it for similar studies in their nations and regions.

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AMAP Assessment 2015: Methane as an Arctic Climate Forcer	Extensive description of GMD methane observations in the Arctic and what can be learned about Arctic Methane Emissions.	The purpose of the report was to review current understanding of the Arctic methane budget, and to make recommendations of how this understanding can be furthered.	Arctic Monitoring and Assessment Program	https://www.amap.no/documents/doc/AMAP-Assessment-2015-Methane-as-an-Arctic-climate-forcer/1285
Annual Greenhouse Gas Index (AGGI)	Accumulated radiative forcing from long-lived Greenhouse Gases. The NOAA Annual Greenhouse Gas Index (AGGI) measures the commitment society has already made to living in a changing climate. It is based on the highest quality atmospheric observations of GMD and from partner sites around the world. Its uncertainty is very low.	Product used annually in EPA Annual Report on the Environment.	EPA's Climate Change Indicators in the U.S. Report	http://esrl.noaa.gov/gmd/aggi/ (NOAA); https://www.epa.gov/climate-indicators/climate-change-indicators-climate-forcing (EPA)
		Selected as a National Physical Indicator of Climate Change in support of the National Assessments.	USGCRP and others	http://esrl.noaa.gov/gmd/aggi/ (NOAA); https://www.globalchange.gov/browse/indicators/indicator-annual-greenhouse-gas-index (USGCRP)
		Update of the WMO Annual Greenhouse Gas Bulletin, which is distributed worldwide in 5 languages.	WMO Global Atmosphere Watch, Geneva	The AGGI stands alone in the document as a NOAA product based on NOAA data -- http://esrl.noaa.gov/gmd/aggi/ (NOAA); http://www.wmo.int/pages/prog/arep/gaw/ghg/GHGbulletin.html (WMO)
		Updated product on cimate.gov website.	OAR/Climate Program Office/climate.gov	http://esrl.noaa.gov/gmd/aggi/ (NOAA-GMD); https://toolkit.climate.gov/tool/annual-greenhouse-gas-index-aggi (NOAA CPO)
Atmospheric Baseline Observatory Network	Use of facilities at 4 globally distributed and manned observatories by other NOAA LOs, U.S. agencies, U.S. universities, and international partners.	The data collected at the observatories cover up to 250 different measurements, many of them collected continuously and transmitted to end users and the public in real time.	One such user out of a 100 is the Scripps Institution of Oceanography, La Jolla, CA.	Data are used by many agencies, universities, industries and especially scientists monitoring the changing composition of the atmosphere and the global radiation balance.

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Atmospheric Tomography Mission (ATom)	Atmospheric sampling of ozone, ozone depleting gases, greenhouse gases, and tracers of atmospheric transport spanning nearly pole-to-pole and vertically from the surface to 12 km.	Samples were used to improve understanding of large-scale atmospheric transport and atmospheric chemistry and the fate of pollutant transport to remote areas of the globe.	Global research community, NOAA and NASA data archives. https://daac.ornl.gov/	Numerous publication are expected once the 4-yr mission is complete.
Boulder GRUAN site	Vertical profiles of T, P, winds, ozone and water vapor from balloon-borne radiosondes, ozonesondes and frost point hygrometers.	Climate data records are built on long-term, internally consistent measurements of essential climate variables (ECVs). GRUAN strives to compile climate data records from 25-30 global sites.	Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN)	Traditionally, balloon-borne measurements of T and P were performed for the application of numerical weather prediction, with frequent and systematic changes to instrumentation. Consequently the measurements cannot be compiled into climate data records without substantial efforts to minimize intermittent biases and step-jumps. GRUAN is improving the accuracy and internal consistency of upper atmospheric measurements of ECVs, through strict operating procedures and centralized data processing, to create climate data records.
Carbon Cycle Data	Approximately 10 compounds measured routinely at ~80 sites and over 1350 data sets available (globally).	The GMD Global Greenhouse Gas Reference Network measures the atmospheric distribution and trends of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), and carbon monoxide (CO), an important indicator of air pollution. Data from individual sites are frequently downloaded and used in publications.	Global research community, World Data Centre of Greenhouse Gases. Disseminated in WMO WDCGG Data Summary and made available on line at Japan Meteorological Agency	Data source for dozens of papers published in the refereed literature every year. http://esrl.noaa.gov/gmd/dv/data/?category=Greenhouse%2B Gases

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Carbon Tracker	Products such as Carbon Weather, global carbon fluxes, etc. CarbonTracker is a CO2 measurement and modeling system developed by NOAA to keep track of sources (emissions to the atmosphere) and sinks (removal from the atmosphere) of carbon dioxide around the world.	CarbonTracker is constrained by NOAA's CO2 and CH4 monitoring network. NOAA's version has a strong focus on North America; other nations and regions are adapting the code to incorporate their more granular observing systems in their nations and regions.	e.g., Wageningen University Meteorology and Air Quality Department, Utrecht, Netherlands	The code is available on the GMD website and is a template for various versions that focus on large-scale regions, e.g., Europe, Asia, and China. Different partners use our code and observations, select specific regions for foci, and update accordingly with our global data and their supplemental, regional data. Following are their websites -- http://esrl.noaa.gov/gmd/ccgg/carbontracker/ and https://www.esrl.noaa.gov/gmd/ccgg/carbontracker-ch4/ (NOAA); http://www.carbontracker.eu/ (Europe); http://www.nimr.go.kr/2/carbontracker/index.html (Asia)
Carbon Tracker - CH4	Estimates of methane emissions for natural and anthropogenic sources constrained by NOAA GMD methane observations and bottom-up estimates of methane emissions using a state of the art global transport model.	The purpose of CarbonTracker-CH4 is to further the understanding of the global methane budget.	CarbonTracker-CH4 results were documented in peer-reviewed literature, and were contributed to the Global Carbon Project Methane studies.	see https://www.esrl.noaa.gov/gmd/ccgg/carbontracker-ch4/. Note that resource limitations have prevented updates to this product.
CO2 Mauna Loa Trends	The Mauna Loa Data record, which NOAA makes available daily, are viewed at this site for the most up-to-date information on CO2.	The "iconic" climate record shared in near real time with the global research community and the public.	WMO/GAW, numerous press reports, Climate.gov	http://esrl.noaa.gov/gmd/ccgg/trends/ (GMD); http://www.climate.gov/news-features/understanding-climate/2013-state-climate-carbon-dioxide-tops-400-ppm (CPO). Supported many news articles in NYTimes, Washington Post, CNN, et al. et al. as CO2 went over 400 ppm. The CO2 data measured at Mauna Loa constitute the longest record of direct measurements of CO2 in the atmosphere.

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Continuous Light Absorption Photometer (CLAP)	Atmospheric sampling system that measures atmospheric aerosol light absorption at three visible wavelengths.	The CLAP instrument improves and makes more consistent the measurement of aerosol light absorption in the atmosphere at Federated Aerosol Network sites around the world.	This technology was successfully transferred to the private sector and Brechtel Manufacturing, Inc., Hayward, CA is now manufacturing and selling a commercial instrument (Tricolor Absorption Photomenter, TAP) based on the CLAP design.	https://www.esrl.noaa.gov/gmd/aero/instrumentation/clap_desc.html
Global CO_2 record	Long-term trend of CO2 from all remote marine boundary layer sites in NOAA's global monitoring network. Uses of the data set are varied (scientists, managers, policy makers, educators, public).	National Indicator for Climate Change in support of the most recent National Climate Assessment	USGCRP	http://esrl.noaa.gov/gmd/ccgg/trends/global.html (NOAA) ; https://www.globalchange.gov/browse/indicators/indicator-atmospheric-carbon-dioxide (USGCRP)
Global Ozonesonde Profile Data	Ozone profile data from balloon borne ozonesondes.	Ozone data are used in UV models and UV forecasts as well as in ozone research.	World Ozone and Ultraviolet Radiation Data Center (WOUDC)	Global stratospheric ozone controls the amount of UV reaching the Earth's surface. GMD maintains a global network of balloon borne ozonesonde sites with weekly balloons. Ozone profile data disseminated globally and used on a regular basis for satellite verification, health alerts, research and monitoring of ozone layer recovery.
Global Total Column Ozone Data	Ozone total column data from Dobson Spectrophotometers.	Ozone data used in UV models and UV forecasts as well as in ozone research.	World Ozone and Ultraviolet Radiation Data Center (WOUDC)	GMD maintains the Dobson global standard. The ozone profile data is disseminated globally. Data used on a regular basis for satellite verification, health alerts, research and monitoring of the ozone layer recovery.
Globally and zonally averaged atmospheric CH4 time series. Similar records availble for other reenhouse gases and related tracers.	Long-term trend of CH4 from remote marine boundary layer sites in NOAA's cooperative global air sampling network. Uses of the data set are varied (scientists, managers, policy makers, educators, public).	Indicator of atmospheric CH4's contribution to climate change for national and international climate assessments.		https://www.esrl.noaa.gov/gmd/ccgg/mbl/; https://www.esrl.noaa.gov/gmd/ccgg/trends_ch4/

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GLOBALVIEW data products	A gridded distribution of CO_2 and CH_4 data based on GMD's monitoring network and updated annually. Data products designed to enhance spatial and temporal distribution of atmospheric observations of CO_2, CH_4 and other related measurements.	GLOBALVIEW products are specifically intended as tools for use in carbon cycle modeling studies.	Used in publications by numerous scientists and modelers around the world	http://esrl.noaa.gov/gmd/ccgg/globalview/ Referenced in several publications every year by partners around the world studying the carbon cycle. It is one of the critical pieces for initializing, developing, and validating models.
IPCC Fifth Assessment Report Contributions	Lead authorship of chapters, Review Editor, Topic Editors, Scientific expertise. Comprehensive, multi-year data sets of GMD's global average greenhouse gas observations, ozone, surface radiation, and aerosols.	The Fifth Assessment Report (AR5) provided a clear and up to date view of the current state of scientific knowledge relevant to climate change. Working Group I provides the physical science basis of climate change.	Intergovernmental Panel on Climate Change, Fifth Assessment Report, Working Group I and Executive Summary	Quintennial Assessment (approx). These assessments inform the parties to the UN Framework Convention on Climate Change, who seek guidance in setting forward plans and programs internationally and institutionally in their efforts to mitigate and adapt to climate change. The U.S. is a signatory.
Mobile SURFRAD sites	Two regional mobile SURFRAD stations measure surface radiation budget (upwelling and downwelling shortwave and longwave radiation), direct normal irradiance (DNI), global horizontal irradiance (GHI), spectral aerosol optical depth, cloud fraction, and spectral surface albedo.	Regional, shorter term studies for: 1) Verification and data assimilation (solar forecasting); 2) Surface radiation budget and aerosol radiative forcing (climate research); 3) Satellite verification (solar and IR radiation, AOD, NDVI, Land Surface Temperature, surface albedo); 4) Aerosol optical depth (verification of estimates of $PM_{2.5}$ for Air Quality).	NOAA/NESDIS/STAR	GOES-R Satellite Verification; http://campaign.arm.gov/tcap/ - DOE ARM TCAP campaign, http://www-air.larc.nasa.gov/missions/discover-aq/discover-aq.html - Satellite Verification Studies - Data archive for DISCOVER-AQ (Colorado, Texas, California)

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Monitoring Water Vapor in the Upper Troposphere and Stratosphere	High-resolution water vapor verticle profile data from balloon-borne frost point hygrometers.	Upper atmospheric water vapor data are used in climate models, to validate satellite-based water vapor measurements, and in climate research.	Network for the Detection of Atmospheric Composition Change (NDACC)	Changes in the abundance of water vapor in the upper troposphere and stratosphere strongly influence global surface temperature. GMD maintains three globally-distributed sites where balloon-borne frost point hygrometers are launched every 2-4 weeks. Water vapor profile data are disseminated via the NDACC data repository.
National Academy of Sciences Report, "Improving Characterization of Anthropogenic Methane Emissions in the United States"	Extensive description of GMD methane observations from global to regional scales. Summary of what was learned from GMD and other measurements. Author contribution from GMD.	The purpose of the report was to review current understanding of the U.S. methane budget, and to make recommendations of where future progress can be made.	National Academy of Sciences	The report may be downloaded from https://www.nap.edu/catalog/24987/improving-characterization-of-anthropogenic-methane-emissions-in-the-united-states
ObsPack Data Products	Brings together direct atmospheric greenhouse gas measurements, prepares them with specific applications in mind, and packages and distributes them in a set of self-documenting files.	Observation Package (ObsPack) data products are intended to stimulate and support carbon cycle modeling studies.	Used in publications by numerous scientists and modelers around the world	http://esrl.noaa.gov/gmd/ccgg/obspack/ - Recently developed by NOAA's Global Monitoring Division, this product is gradually replacing GlobalView, as more and more modelers want real data for their models, rather than a smoothly gridded data set. Hundreds of downloads since 2013. Currently an essential data set for validating CO2 retrievals from NASA's Orbiting Carbon Observatory 2 (OCO-2) satellite.
Oil and gas field data methane emissions	In situ GMD measurements showing large emissions of methane from oil and gas fields have led to new State of CO regulations on allowable methane emissions from these extraction activities. These regulations were made law in February 2014. Additional GMD studies have shown similar high methane emissions in TX, NM and UT. National regulations are being considered.	Methane emitted to the atmosphere during fossil fuel extraction operations is a valuable lost resource and a potent greenhouse gas. If more than 4% of production is lost, the climate benefits of switching from coal to gas fuel for electricity generation is lost.	Colorado Air Quality Control Commission	Colorado is the first U.S. state to control methane emissions from fossil fuel extraction. The problem was brought to light from pioneering oil and gas field ground and airborne methane emission studies conducted by the NOAA Global Monitoring Division. The first scientific publications and many of the subsequent key measurements of elevated methane over Colorado gas and oil fields were published by GMD scientists. Other states are now formulating methane emission regulations using the Colorado template and NOAA is conducting measurements over fields in TX, ND and NM. U.S. EPA is considering nationwide Federal regulations on methane emissions. http://www.colorado.gov/cdphe/aqcc-regs

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Oil and Gas Methane Emission Research	Coordinated bottom-up and top-down CH_4 emission quantification.	Identify causes of differences between top-down and bottom-up estimates	DOE and oil and gas Industry sponsored project to further understand quantification methods and documented differences in outcomes. Research partners included CO School of Mines, DOE NREL, CSU, AECOM	Top-down emission estimates have often been larger than inventories. Some have attributed the difference to superemitters not accounted for in inventories. Our study in the Fayetteville showed that the top-down approach is representative of midday peak emissions when episodic short-term maintenance venting occurs. A time and spatially resolved inventory is able to match the top-down results.
Oil and Gas (O&G) Methane Emission Research	Four Corners Methane Hotspot.	Quantify methane emissions using aircraft mass balance and attribute emissions to various potential sources. Compare with published satellite based estimates.	Local stakeholders interested in the research outcomes include O&G operators, energy and air agencies in NM, CO as well as Southern Ute Indian Tribe, Navajo Nation, Ute Mountain Ute Tribe, and Jicarilla and Apache Tribe.	The aircraft mass balance paper has been published and a follow-up paper on sources and emission attribution in the San Juan Basin will be submitted this summer.
Oil and Gas Methane Emission Research	Leak Detection from Aircraft in a US Shale gas play.	Leak detection is currently done by ground-based teams using IR cameras which are time intensive, require site access, do not give quantitative results , require trained professionals, and are likely ineffective given that most of leaked emissions come frome a small subset of facilities.	Industry sponsored project to compare two different airborne techniques and the traditional ground IR surveys in terms of leaks detected, quantified and cost benefit analysis of 3 approaches.	This is a novel area of research and a scientific paper is in review.

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Oil and Gas (O&G) Methane Emission Research	Top-down estimation of CH4 emissions for several US O&G basins.	CH4 and VOC emission estimates for O&G industry.	States and EPA use inventory models to estimate emissions of grenhouse gases and ozone precursors. Most top-down studies showed higher emissions than estimated by iventories. The CH4 and VOC emission models used by States and the EPA have been progressively and extensively revised since 2011. New emission regulations have also been put in place, including new Leak Detection and Repair requirements.	The top-down regional emission estimation based on aircraft mass-balance technique is an independent approach to quantify emissions and evaluate emission inventories. Top-down field campaigns have been funded by EDF, NSF, DOE, O&G industry to support the EPA effort to revised its greenhouse gas inventory. Results have been published in scientific papers.
Oil and Gas (O&G) Volatile Organic Compounds (VOC) Emissions and Eealth Impacts	Indentify and quantify emissions of air toxics from oil and gas operations.	Investigate new 20+ O&G well pad emissions and ambient levels in nearby communities. Assess if current setback distances are protecting population from exposure to high levels of air toxics.	NSF Sustainability Research Network sponsored project. Interdisciplinary research with > 11 contributing groups.	VOC and air toxics emissions from crude oil, condensate, natural gas and produced water operations are still not well chareacterized. With the co-development of housing and O&G operations in the CO Front Range, it is important to collect measurements to assess potential impacts.
Ozone-Depleting Gas Index (ODGI)	Index of combined ozone depletion potential from all ozone-depleting gases.	To make publicly available a simple measure of society's success in addressing stratospheric ozone depletion, by computing the decline in ozone-depleting potential from all long-lived, ozone-depleting gases.	EPA Report on the Environment	http://esrl.noaa.gov/gmd/odgi/; Data on gases used in this index are employed by numerous researchers and policy makers. The index summarizes ozone-depleting gases and is the template for a similar compilation in the Ozone Assessment.

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NASA Aircraft Data Archive, Cloud1	HATS airborne data from 1991 to the present, including manned aircraft, balloon, and unmanned aircraft systems (UAS, Altair and Global Hawk); CCGG airborne data from ATom Mission, 2016-present.	This archive is used to calibrate global climate model with precise airborne satellite and ground truth NASA satellites for NASA's Upper Atmospheric Research Program, Earth Venture Science, Tropospheric programs.	NASA's Earth Science Program Office (ESPO) started the archive	NIST, NOAA, EPA, NSF, NASA, Smithsonian, WMO, ENEA (Italy), NIWA (New Zealand) are additional users.
National Academy of Sciences Report, "Improving Characterization of Anthropogenic Methane Emissions in the United States"	Extensive description of GMD methane observations from global to regional scales. Summary of what was learned from GMD and other measurements. Author contribution from GMD.	The purpose of the report was to review current understanding of the U.S. methane budget, and to make recommendations of where future progress can be made.	National Academy of Sciences	The report may be downloaded from https://www.nap.edu/catalog/24987/improving-characterization-of-anthropogenic-methane-emissions-in-the-united-states
PERSEUS GC/MS instrument	GMD adapted cryogenic preconcentration of hydrocarbons and halocarbons from atmospheric samples, followed by removal of interferring substances (particularly CO2, O2, N2, noble gases) to allow the highest level sensitivity and reproducibility of analytes.	The new method has allowed GMD to perform high accuracy measurements of ethane (as well as other species), both on the remote, global scale as well as in areas of Oil & Gas exploration.	Partners include Environment Canada; DOE (e.g., RPSEA); INSTAAR/University of Colorado; CSD/NOAA; Industrial (e.g., Southwestern Energy Co., Chevron Co., StatOil Co., American Gas Association, XTO Energy Inc.); NASA, NSF.	Ethane, along with certain other hydrocarbons, is a particularly useful tracer of Oil & Gas emissions, and aids in the attribution of sources in methane studies. Our flask measurements are also valuable in comparisons with in-situ ethane instruments, which typically have less precision and stability.
Profiles of ozone-depleting gases and their replacements over the continental U.S.	Atmospheric sampling of ozone-depleting gases and their replacements of the U.S. from the surface to 5 km.	Provide top-down emissions estimates for the continental U.S.	Global research community	Independent top-down estimates of emissions of ozone-depeting gases and their replacements are used to improve bottom-up, inventory-based estimates for reporting.

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Programmable Flask Package (PFP)	System for manual or automatic sampling of ambient air for later analysis of trace gas concentrations and isotopic ratios.	Sampling and analysis of air at surface sites, tall towers and aircraft to characterize gas concentrations around the world.	Constructed by High Precision Devices (Boulder) and used by numerous research organizations worldwide (e.g., INPE, Brazil)	
Publications and Governments Using GMD Data Outside NOAA	GMD data are made freely available to the world and used in alerts, newscasts, daily/weekly summary reports, government policy documents and publications to inform the public, policy makers, politicians, educators and scientists. GMD data form the core of Environmental Assessments.	NOAA GMD data show that the composition of the atmosphere is changing rapidly. It is important that these data be analyzed and disseminated to the broadest global audience in a timely manner.	Literally 1,000s of users around the Earth, in some cases, on a daily basis. For instance, an article in the New York Times on President Obama's Climate Action Plan.	Over 10 years, NOAA GMD data has been credited as the source in papers on: Ozone = 4,871; Solar radiation = 931; Aerosols = 348; Carbon Cycle = 3,467, and the NOAA GMD Baseline Atmospheric Observatories credited with supporting measurements used by scientists and governments in papers and reports = 6,215 times.
Revised Global Methane Emissions	Repartitioning of global CH4 emissions between natural and anthropogenic sources.	CH4, the second most important long-lived greenhouse gas, has been increasing in the global atmosphere since 2007. Global long-term observations of CH4 and delta-13CH4 provide unique constraints on different CH4 sources and how they have changed over time. The early detection of major shifts in the global C cycle is also paramount.	Understanding factors influencing global methane levels are key to understanding and predicting future climate forcing. Global methane also impacts background tropospheric ozone and OH levels.	A more accurate methane budget allows a better understanding of sources as well as planning and assessment of emission mitigation. Oil, gas and coals emissions are larger than in previously published budgets but they have not changed significantly in recent years.
Solar Calculator	A tool to predict the actual observed values of sunrise, sunset, solar noon, and solar position from any location on the globe.	Research community resource for instrument calibrations and alignments globally.	Massachusetts Institute of Technology	Used by scientists worldwide; its results appear in the published literature or on websites operated by partners. General public uses it; FBI used it to capture an alleged criminal in 2012-2013. http://esrl.noaa.gov/gmd/grad/solcalc/

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Solar Radiation Data	Approximately 20 variables measured and over 135 data sets available (globally).	The GMD Solar Radiation group involved in observational and theoretical research of Earth's surface & atmospheric radiation budgets, focusing on the extent and cause of observed radiation and climate variations, and collaborating with other research groups making satellite observations and climate model calculations.	World Radiation Data Center, St. Petersburg, Russia	http://esrl.noaa.gov/gmd/dv/data/?category=Radiation http://wrdc-mgo.nrel.gov/ (monthly submission)
Standards - Central UV Calibration Facility	Highly accurate and long-term repeatable calibrations and characterizations of UV monitoring instruments.	The Central UV Calibration Facility is a joint project between NOAA & NIST. Mission: to provide highly accurate and long-term repeatable calibrations and characterizations of UV monitoring instruments.	USDA/Colorado State University/UV-B Monitoring and Research Program (UVMRP)	USDA website: http://uvb.nrel.colostate.edu/UVB/index.jsf NIST, NOAA, EPA, NSF, NASA, Smithsonian, WMO, ENEA (Italy), NIWA (New Zealand) are additional users.
Standards - Dobson Regional Standards	Calibration of JMA and BoM Dobson Regional Standards in Boulder	Ensures globally traceable and compatible measurements for validating satellite retrievals of total and stratospheric ozone.	WMO partners with scientists investigating total ozone.	Dobson #83 is housed in Boulder and used to calibrate all Dobson ozone measurements worldwide through WMO coordinated comparison activities.

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Standards - NOAA Scales	NOAA ESRL GMD maintains calibration scales for 21 minor gases (outside of the CCL).	NOAA maintains the Mole Fraction scale for a specified gas in air for the global research community.	Gas standards are used by atmospheric scientists and chemical oceanographers around the world to study lesser greenhouse gases and ensure that their measurements will be compatible.	There are two sets of worldwide standards for many halocarbons. NOAA maintains one set and Scripps Institution of Oceanography maintains another to support (1) CFC measurements in the ocean and (2) NASA's AGAGE program of surface measurements of ozone-depleting substances. Every 6 months results using the two sets of standards and networks are compared to understand small differences and determine if problems are emerging.
Standards - WMO Global Scales	GMD is World Meteorological Organization (WMO), Global Atmosphere Watch (GAW) Central Calibration Laboratory (CCL) for CO2, CH4, N2O, SF6, and CO.	A WMO Central Calibration Laboratory is responsible for maintaining and distributing the WMO Mole Fraction scale for a specified gas in air to the global research community.	WMO partners and other partners and scientists investigating greenhouse gases, private and public sectors.	WMO sets up regional calibration centres that use NOAA standards to propagate the scale to researchers in their regions (e.g., SE Asia, China, Europe, etc.). http://www.esrl.noaa.gov/gmd/ccl/ (NOAA) ; http://www.empa.ch/ (Switzerland); http://ds.data.jma.go.jp/gmd/wcc/wcc.html (Japan); others
State of the Climate Report	Comprehensive atmospheric observations, data sets, analysis, and author contributions by GMD to the annual State of the Climate Report.	Annual updates of atmospheric composition in BAMS State of the Climate Report. The report is read worldwide and GMD contributions on atmosphere have expanded through time. 425 authors from 57 countries, uses climate indicators to track patterns, changes, and trends of global climate system. Indicators reflect thousands of measurements from multiple independent data sets.	NOAA/NESDIS/National Center for Environmental Information	This report gets considerable attention in the U.S. and worldwide, as it is a regular, annual issue of the Bulletin of the American Meteorological Society. All of GMD's data sets (2000) are analyzed by GMD and sections and summaries written for the report. GMD scientists are chapter authors and the lead editor for atmospheric composition.

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	What, exactly, was the thing transitioned from point A to point B?	*What application was the transition intended to improve?*	*Office, lab, sub-unit, or external partner where the project or thing was adopted.*	
SURFRAD Aersosol Optical Depth Data Archival	Aerosol optical depth for six visible spectral channels.	Aerosol optical depth measurements made at the surface validate satelliet estimates of AOD and contribute to the global inventory.	GAW archive at the World Data Centre for Aerosols	https://www.gaw-wdca.org/
SURFRAD NESDIS GOES Comparison	SURFRAD radiation data downloaded daily by NOAA/NESDIS/STAR (Center for Satellite Applications and Research).	SURFRAD data are used for daily comparison to NESDIS/STAR GOES-based estimates of surface radiation.	NOAA/NESDIS/STAR	https://www.star.nesdis.noaa.gov/smcd/emb/radiation/gsip-v3_vs.php
SURFRAD Radiation Data Archival	Surface radiation budget data from seven U.S. stations.	Surface radiation measurements are worldwide are used to validate satellite estimates and weather and climate models.	Baseline Surface Radiation Network (BSRN) archive in Bremerhaven, Germany	http://bsrn.awi.de/
SURFRAD Radiation Data Archival	Surface radiation budget data from seven U.S. stations.	Surface radiation measurements are worldwide are used to validate satellite estimates and weather and climate models.	NOAA National Center for Environmental Information	https://www.ncdc.noaa.gov
SURFRAD Radiation Data Archival	Surface radiation budget data from seven U.S. stations.	Surface radiation measurements are worldwide are used to validate satellite estimates and weath.er and climate models.	World Radiation Data Center, St. Petersburg, Russia	http://wrdc.mgo.rssi.ru/

GMD Project Name	Thing Transitioned	Purpose of Transition	To Where Sample Organization	Comments
	What, exactly, was the thing transitioned from point A to point B?	*What application was the transition intended to improve?*	*Office, lab, sub-unit, or external partner where the project or thing was adopted.*	
SURFRAD Sites	Seven long-term SURFRAD stations provide independent measures of upwelling and downwelling, solar and infrared measurements, direct and diffuse solar, photosynthetically active radiation, UVB, spectral solar, and meteorological parameters.	SURFRAD observations have been used for evaluating satellite-based estimates of surface radiation, and for validating hydrologic, weather prediction, and climate models; modelers; publications.	NASA Langley's Earth Observing System	http://www-cave.larc.nasa.gov/
U.S. National Climate Assessment -- Publications, Data	Scientific expertise; contributions through the Carbon Interagency Working Group of the U.S. Global Change Research Program.	NOAA played a critical role in the development, authorship, and delivery of the report, with many scientists and staff helping develop technical inputs and climate scenarios.	U.S. Global Change Research Program	Quadrennial Assessment. Official report to Congress as part of the U.S. Global Change Research Act, but also made available publicly. NOAA provides the most comprehensive sets of greenhouse gas data for this.
Wintertime ozone in rural Wyoming and Utah	Knowledge of the causes and timing of high wintertime ozone production in rural Wyoming and Utah associated with oil and gas production.	Wintertime ozone production over oil and gas fields in rural WY and Utah has put portions of the state into EPA non-compliance. GMD scientists published the first scientific papers identifying causes & timing of winter ozone production phenomenon. WY subsequently put in place regulations on oil and gas field emissions, resulting in a drop in winter ozone exceedances.	Wyoming and Utah Departments of Environmental Quality and Utah	The States of Wyoming and Utah, NOAA, EPA, Bureau of Reclamation and oil and gas companies funded extensive studies of the winter ozone production problem as EPA regulations require the development and implementation of an ozone mitigation program. The oil and gas industry has subsequently spent in excess of $0.5 Billion on emission controls and successful ozone mitigation efforts.

GMD Project Name	Thing Transitioned	Purpose of Transition	To Where Sample Organization	Comments
	What, exactly, was the thing transitioned from point A to point B?	*What application was the transition intended to improve?*	*Office, lab, sub-unit, or external partner where the project or thing was adopted.*	
WMO Aerosol Bulletin	GMD Aerosol Group contributes to the Aerosol Bulletin pages on a periodic basis, including co-authoring and publishing reports on standard operating procedures (e.g., https://library.wmo.int/opac/index.php?lvl=notice_display&id=6643#.WvMP7q3X3ys) and serving on the Scientific Advisory Group for Aerosols of the Global Atmosphere Watch (GAW) Programme of the World Meteorological Organization (WMO).	The Aerosol Bulletin serves to consolidate global aerosol measurements into a single use document for the global aerosol scientific community.	WMO/GAW Aerosol Working Group	http://www.wmo.int/pages/prog/arep/gaw/AerosolBulletin.html
WMO Antarctic Ozone Hole Bulletins	The state and progression of the annual South Pole Ozone Hole as it is occurring.	Ex. Six bulletins came out monthly in 2013 reporting on progress and understanding of the ozone hole. Strong use of GMD data.	WMO Global Atmosphere Watch, Geneva	Tracks the annual South Pole Ozone Hole formation and recovery. Distributed around the Earth in six languages. GMD provides the only column data from the South Pole and data during the 6 month dark period when satellites are unable to measure Antarctic ozone.
WMO Greenhouse Gas Bulletin	Information, Data, Authorship	Disseminating brief, global summaries and analysis of greenhouse gas trends and distributions. Distributed worldwide in five languages.	WMO Global Atmosphere Watch, Geneva	The World Data Centre for Greenhouse Gases (WDCGG) is one of the WDCs under the GAW programme. It gathers, archives and provides data on greenhouse gases (CO2, CH4, CFCs, N2O, surface ozone, etc.) and related gases (CO, NOx, SO2, VOC, etc.) in the atmosphere and ocean.
WMO WDCGG Data Summary	GMD greenhouse gas data sets transitioned to World Data Centre for Greenhouse Gases.	Reports the latest status of greenhouse and some reactive gases in the atmosphere.	Japan Meteorological Agency	This data repository captures data not explicitly collected in other World Data Centers but there is some overlap.

GMD Project Name	Thing Transitioned	Purpose of Transition	To Where Sample Organization	Comments
	What, exactly, was the thing transitioned from point A to point B?	*What application was the transition intended to improve?*	*Office, lab, sub-unit, or external partner where the project or thing was adopted.*	
WMO/UNEP Scientific Assessment of Ozone Depletion	Co-authors, contributors, and review editors of chapters and GMD's global data on stratospheric ozone trends and trends of all ozone-depleting gases. Scientific expertise.	The most recent WMO/UNEP assessment contains the most up-to-date understanding of ozone depletion. It reflects the thinking of hundreds of international scientific experts. Source of atmospheric data: NOAA ESRL GMD and CSD and NASA.	UNEP Ozone Secretariat	This Quadrennial Assessment informs the Parties to the Montreal Protocol on Substances that Deplete Stratospheric Ozone. It also is used to support a Congressional requirement of NOAA and NASA to report every 3 years on the status of stratospheric ozone and the substances that deplete it -- in support of the Clean Air Act of 1990.

Global Monitoring Division

OAR and GMD Management

Welcome Presentations

2013-2017 Review

May 21-24, 2018

Contents:

- Craig McLean, OAR Assistant Administrator
- James Butler, Director, Global Monitoring Division
- Waleed Abdalati, Director, CIRES

NOAA & OAR Approaches To Research Planning

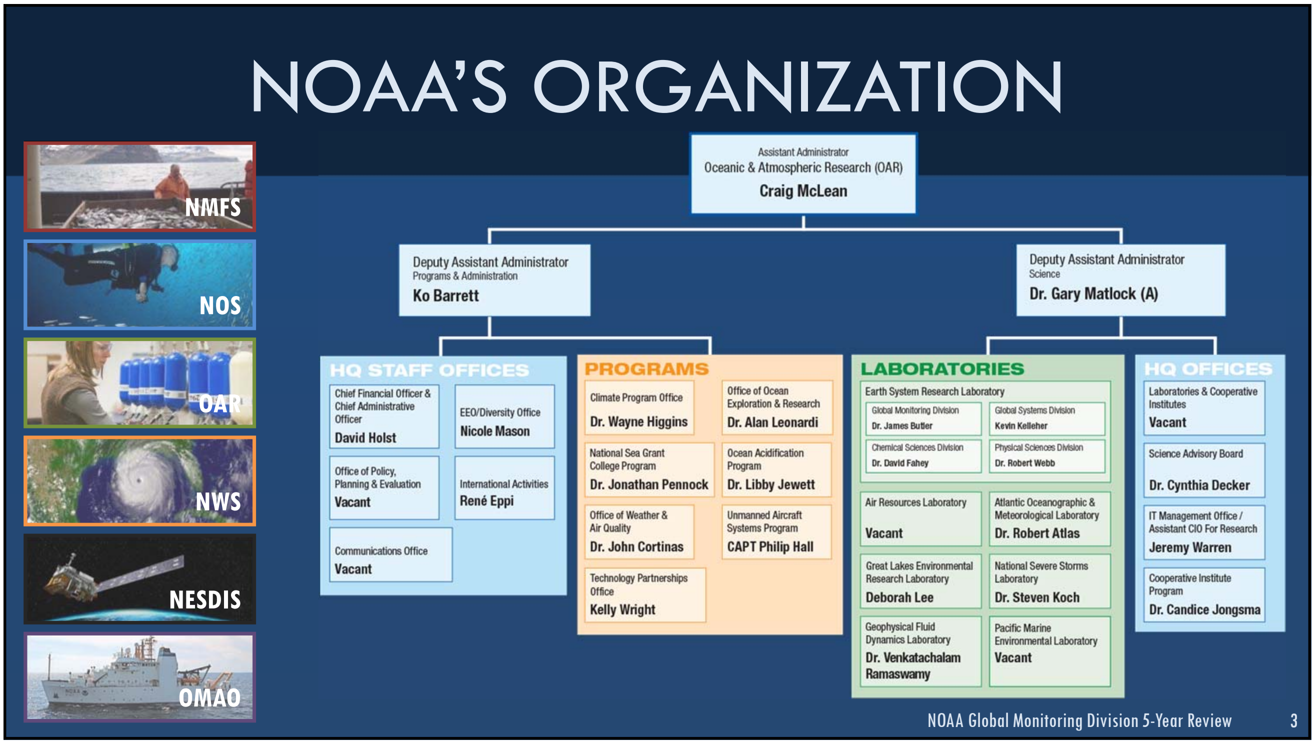
Robert "Robin" Webb, Ph.D.
NOAA/OAR/ESRL Director, Physical Sciences Division
May 21, 2018

NOAA'S NEXT GENERATION STRATEGIC PLAN GOALS

Healthy Oceans	Weather Ready Nation	Climate Adaptation & Mitigation	Resilient Coastal Communities & Economies
			

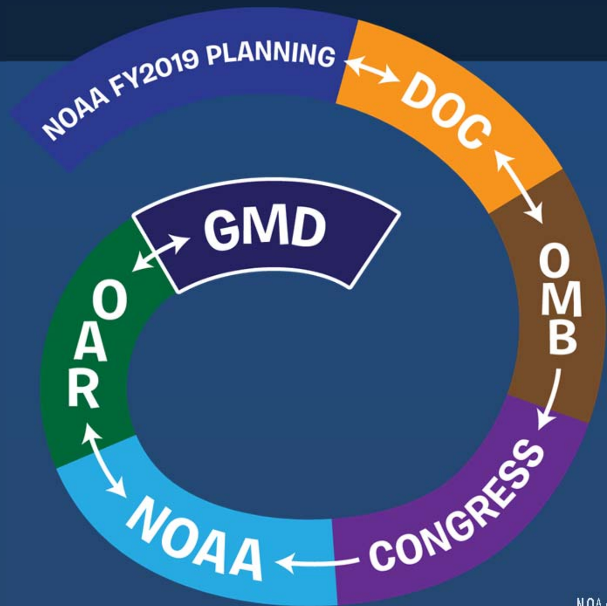
SCIENCE & TECHNOLOGY

NOAA Global Monitoring Division 5-Year Review 2


NOAA'S ORGANIZATION
NMFS
NOS
OAR
NWS
NESDIS
OMAO
Assistant Administrator
Oceanic & Atmospheric Research (OAR)
Craig McLean
Deputy Assistant Administrator
Programs & Administration
Ko Barrett
Deputy Assistant Administrator
Science
Dr. Gary Matlock (A)
HQ STAFF OFFICES
Chief Financial Officer & Chief Administrative Officer
David Holst
EEO/Diversity Office
Nicole Mason
Office of Policy, Planning & Evaluation
Vacant
International Activities
René Eppi
Communications Office
Vacant
PROGRAMS
Climate Program Office
Dr. Wayne Higgins
Office of Ocean Exploration & Research
Dr. Alan Leonardi
National Sea Grant College Program
Dr. Jonathan Pennock
Ocean Acidification Program
Dr. Libby Jewett
Office of Weather & Air Quality
Dr. John Cortinas
Unmanned Aircraft Systems Program
CAPT Philip Hall
Technology Partnerships Office
Kelly Wright
LABORATORIES
Earth System Research Laboratory
Global Monitoring Division
Dr. James Butler
Global Systems Division
Kevin Kelleher
Chemical Sciences Division
Dr. David Fahey
Physical Sciences Division
Dr. Robert Webb
Air Resources Laboratory
Vacant
Atlantic Oceanographic & Meteorological Laboratory
Dr. Robert Atlas
Great Lakes Environmental Research Laboratory
Deborah Lee
National Severe Storms Laboratory
Dr. Steven Koch
Geophysical Fluid Dynamics Laboratory
Dr. Venkatachalam Ramaswamy
Pacific Marine Environmental Laboratory
Vacant
HQ OFFICES
Laboratories & Cooperative Institutes
Vacant
Science Advisory Board
Dr. Cynthia Decker
IT Management Office / Assistant CIO For Research
Jeremy Warren
Cooperative Institute Program
Dr. Candice Jongsma
NOAA Global Monitoring Division 5-Year Review
3


OAR'S VISION & MISSION
To Deliver NOAA's Future.
VISION
Conduct research to understand and predict the Earth's oceans, weather and climate, to advance NOAA science, service and stewardship and transition the results so they are useful to society.
MISSION
NOAA Global Monitoring Division 5-Year Review
4

NOAA'S FUNDING PROCESS



OUR RESEARCH PORTFOLIOS

WEATHER & AIR QUALITY

CLIMATE

OCEAN & COASTAL RESOURCES

NOAA'S PRIORITIES

WEATHER & WATER

BLUE ECONOMY

OAR CORPORATE PRIORITIES

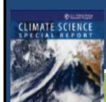
1	**Long-term observations**	Sustain the long-term observations of the Earth System that are needed to fulfill NOAA's mission.
2	**Weather forecasting & climate predictions**	Improve the accuracy of weather forecasting and climate predictions/projections to protect lives, property, and promote economic prosperity.
3	**Environmental information**	Provide the environmental information needed by decision makers and other stakeholders in planning, management and investment decisions.
4	**Ocean Exploration**	Sustain and enhance national ocean exploration and research infrastructure to better understand the characteristics of ocean and coastal areas and the resources contained within them.
5	**Ecosystem processes & change**	Provide the essential scientific understanding of ecosystem processes and change necessary for the informed management, use and preservation of oceanic, marine and coastal areas and the Great Lakes.
6	**Marine resources management**	Enhance marine resources management, including fisheries management, aquaculture, and off-shore energy and mineral resource management.
7	**Early Warning information**	Detect, and provide early warning information for ocean, weather and climate events with adverse impacts on society.

GMD IS THE GO TO PLACE FOR ATMOSPHERIC COMPOSITION OBSERVATIONS

Only sources of long-term observations

Highest quality observations & standards

Respect of global & domestic community

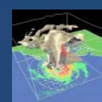


GMD FOR U.S.

- USGCRP
- NCA ASSESSMENT
- INTERAGENCY COOPERATION

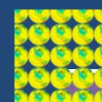
GMD FOR INTERNATIONAL

- IPCC
- WMO GAW
- OZONE ASSESSMENTS



GMD FOR NOAA

- NESDIS SATELLITE VALIDATION
- NWS NUMERICAL WEATHER PREDICTION



GMD FOR OAR

- GFDL - OBSERVATIONS FOR MODELING EFFORTS
- OAP - RISING CO^2 IN ATMOSPHERE IS SINGLE CAUSE OF OCEAN ACIDIFICATION

NOAA Global Monitoring Division 5-Year Review 9

HOW OAR USES YOUR REVIEW

Assist labs in strategically positioning & planning future science

Maintain consistency with NOAA planning, programming, & budgeting

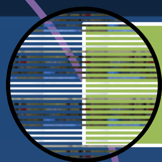
Recognize lab scientists' leadership excellence & contributions in research fields

Identify equipment & facility deficiencies

Locate communication strengths & weaknesses between labs/offices/ leadership

NOAA Global Monitoring Division 5-Year Review 10

CHARGE TO REVIEWERS



QUALITY: Assess quality of lab's R&D

RELEVANCE: Assess lab's R&D relevance to NOAA's mission & value to Nation

PERFORMANCE: Assess overall effectiveness of lab's plans & R&D in meeting NOAA's Strategic Plan objectives & Nation's needs

46th Global Monitoring Annual Conference

Boulder, Colorado

May 22-23, 2018

Housekeeping

- Poster session, 5:00-7:30 pm today!
  - Posters are being collected at the registration table. Poster tubes stored in the "hallway" on the left of the stage.
- Agendas are available at the desk, behind the water, and displayed on screens outside the room.
  - We have memory sticks with the full pdf set of abstracts available to borrow.
  - For those without e-access, we do have some printed abstract booklets available as well. Please ask registration staff.
- A few printed abstract books are kept at the desk for quick reference.
  - Wireless access throughout the building
    - Network name: noaa_guest
    - Username: gmac
    - Password: noaagmac
- Work space during meeting
  - Cafeteria & Classroom
  - Side meeting space – contact organizers.
- Lunches delivered here.
  - Sign up and pay at the registration table.
  - Drop-dead time is morning break.
- Restrooms – across the hallway
- Fire alarm – up the stairs and out the doors, preferably toward parking lot
- Silence your phones.
- Coffee and food in hall during breaks
  - Water is available in room during talks.
- All plates, cups, utensils are compostable.
- Side conversations in the hallway
  - Be sure you are away from the door
- NOAA Gift Shop
  - 12:00-1:00, 4:45-5:15 daily
  - Cash or check only
- Thank you to our local vendors!
- Questions? Find a "Conference Concierge".

ESRL GMAC – 2018 Welcome
JH Butler

May 22-23, 2018

Speakers . . . !

- Take your presentations to the projection booth at least one session earlier than your session.
- Go to the microphone fitting desk at the back, right hand corner of the meeting room one speaker before your time to be fitted with the microphone.
- Then move down the right side of the room to the seat directly behind the timekeeper and session chair.
- Turn on the microphone before you leave your seat to do your presentation. Begin talking immediately. Do not ask "is the microphone working?" It will be if you turned it on. GMD staff will adjust the volume as you speak.
- Return your microphone and pointer to the microphone station at the right rear of the room immediately after your presentation.
- Watch the screen! Speakers have 11 minutes to talk. At 9 minutes the yellow screen comes on alerting you to be finished in 2 minutes. At 11 minutes the red screen comes on starting a 3 minute question period. If you are not finished with your presentation at 11 minutes, a bell will ring and you will be told verbally your time is up.
- Audience: Hold the portable microphone close -- no farther away than 1 inch from your mouth. Speak loud and clear. You will be talking to 150+ people in the room and 100 on the Web connection.

The 2018 GMAC… by the numbers

Attendance – "In the room"

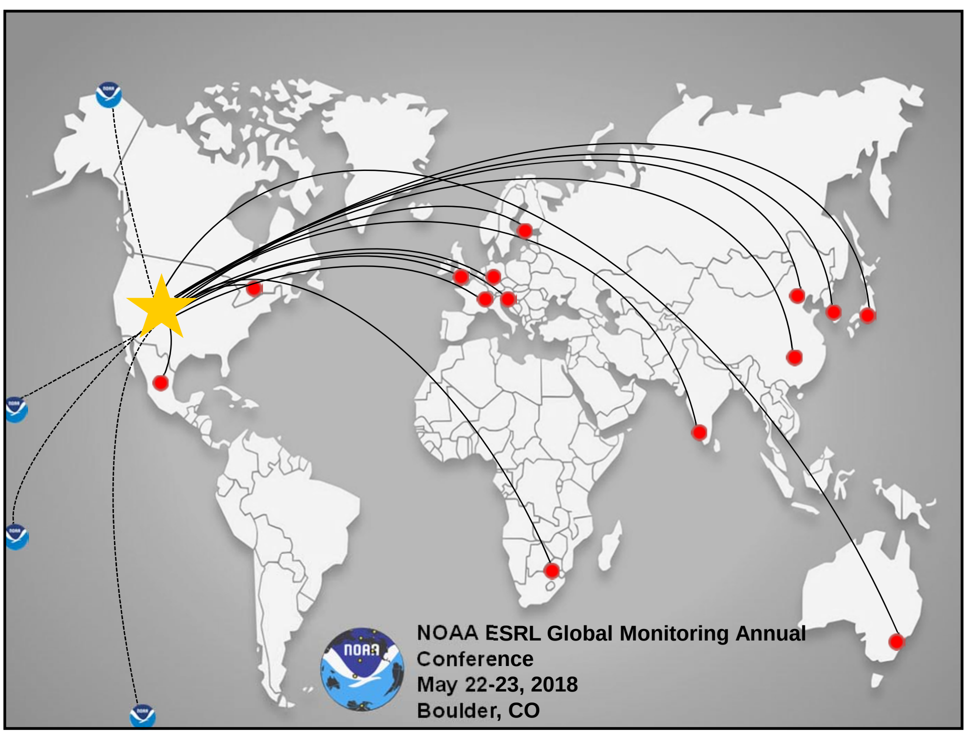
- 220+ Attendees
  - 28 International guests
    - 13 Nations
    - 6 Continents
  - 13 International agencies & organizations
  - 3 International universities
  - 2 International private sector companies
  - 15 U.S. agencies & programs
  - 19 U.S. universities
  - 15 Private sector companies

Contributing Authors

- 118 Presentations
  - 118 Lead authors
    -and-
  - 424 "unique" co-authors

Representing:
- 29 U.S. agencies & labs
- 25 U.S. universities
- 21 Countries
- 32 International organizations
- 22 International universities


China
United Kingdom
Switzerland
South Africa
Mexico
Australia
India
United States
Finland
Japan
Germany
Canada
Korea
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
Sandia National Laboratories
NASA
POLAR FIELD
South African Weather Service
Earth Networks
neon
Appalachian
National Institute of Meteorological Sciences
Cal
Colorado State
PICARRO
NCAR
WMO
SSAI
TENNESSEE TECH UNIVERSITY
CIRA
Airgas
USGS
NPL
NIST
National Institute of Standards and Technology
U.S. Department of Commerce
SUU
HPD
IJS
IAGOS
CIRES
StFX
NiPR
CALIFORNIA AIR RESOURCES BOARD
INSTAAR
UNIVERSITY OF WYOMING
ansto
FMI
Los Alamos
SAN DIEGO STATE UNIVERSITY
EKO
NREL
UNIVERSITY of WASHINGTON
THE UNIVERSITY OF UTAH
CMA
LI-COR
MIRICO
pmod wrc
STC
ASU
Arizona State University
HARVARD
MAX PLANCK INSTITUTE FOR CHEMISTRY
CLIMATE INSTITUTE
SigmaSpace


NOAA ESRL Global Monitoring Annual Conference
May 22-23, 2018
Boulder, CO

Thank you all for coming!

- We look forward to an invigorating 46th Annual Meeting . . .

Global Monitoring Division

GMD Overview (Butler) and

Theme1-3 PPT Presentations

2013-2017 Review

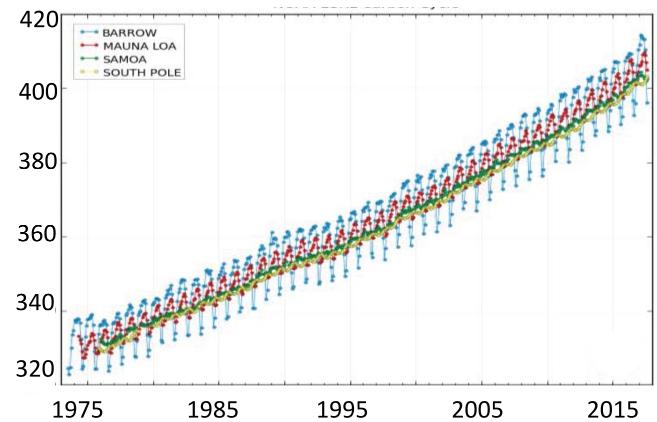
May 21-24, 2018

Contents: page

Laboratory Review NOAA/ESRL Global Monitoring Division

James Butler
Director
21-24 May 2018

Carbon Dioxide at Observatories



Outline

- Summary of Previous (2013) Panel Report
- Mission of NOAA's Global Monitoring Division
- Organization and Management
- How We Plan, Ensure, and Measure Success
- Transformative Opportunities
- Upcoming Sessions

2009-2013 Review Panel Summary

- **Relevance:**
  - "Environmental Security of the nation"
  - "Essential to the NOAA mission"
- **Quality:**
  - "GMD has become a NOAA/ESRL star"
  - "pushing the frontiers in Climate, Greenhouse Gases, Ozone Depletion, and Air Quality"
  - "will be used by the international community for decades to come"
- **Performance:**
  - "The investments into GMD have been well optimized in an underfunded environment"
  - "The work … is of the highest caliber"
  - "The scientific community, nation, and beyond are reaping the benefits, and are heavily dependent on GMD. Now is the time to strengthen the capacity of GMD even further to maintain its global lead in these activities"

2013-2018 Panel Recommendations

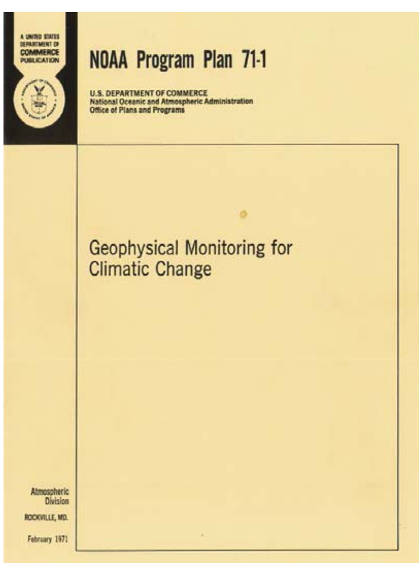
Recommendations:

- Expand the science that GMD does to support other science and regulatory agencies (state, national, and international)
- Sustain operations, scientific analysis, and technological development required for its mission.
- Add additional resources into all aspects of GMD operations, scientific analysis, and innovation.
- Recruit new talent and reinvigorate the both CIRES and NOAA positions
- Ensure continuity in observing network

GMD Mission

NOAA Program Plan 71-1

"Geophysical Monitoring for Climatic Change"



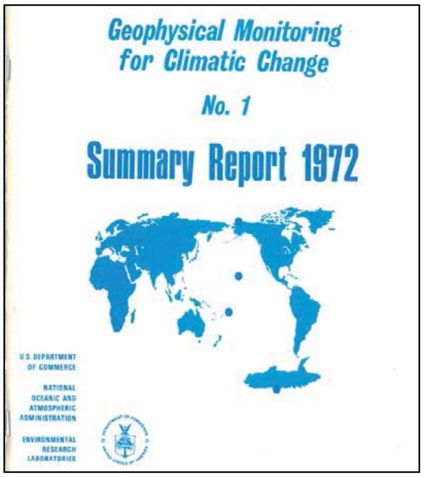
- "This plan, *Geophysical Monitoring for Climatic Change,* is NOAA's program for global monitoring of man's inadvertent modification of weather and climate."
  - *Robert White, Acting Administrator, NOAA*

- "Determination of the trends of the climatically important burden of atmospheric contaminants and resolution into natural vs. man-induced sources is essential to the preservation of environmental quality."

GMD Origins

"... We must achieve a new awareness of our dependence on our surroundings and on natural systems which support all life, but awareness must be coupled with a full realization of our enormous capability to alter these surroundings."

Richard M. Nixon, 1970



"It is the objective of the GMCC program to respond to the need for this new awareness by providing a portion of the quantitative description and analysis needed. Specifically, it is our objective to measure the necessary parameters for establishing trends of trace constituents important to climate change and of those elements that can assist in apportioning the source of changes to natural or anthropogenic sources, or both."

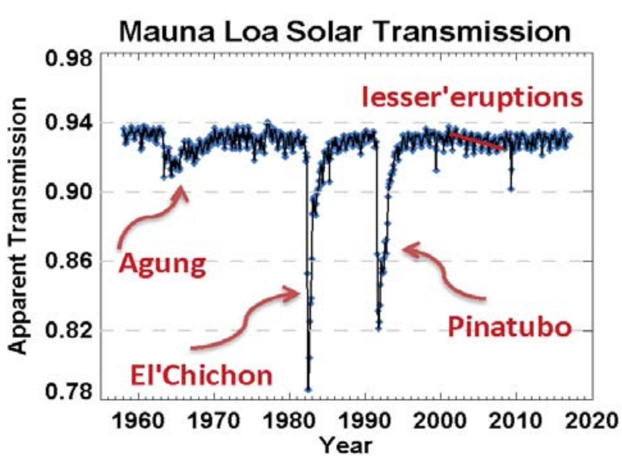
"This program has its special focus in establishing a long-term time series from ground-based information."

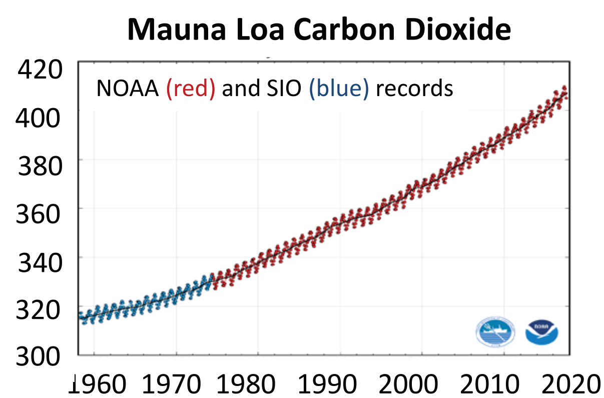
Geophysical Monitoring for Climate Change First Summary Report, 1972

GMD Vision and Mission

Vision

GMD providing and society using the best possible information to inform climate change, weather variability, carbon cycle feedbacks, and ozone depletion





Mission

To acquire, evaluate, and make available accurate, long-term records of atmospheric gases, aerosol particles, clouds, and surface radiation in a manner that allows the causes and consequences of change to be understood

How GMD sets priorities

- Legislative mandates
- Consistency with NOAA's and OAR's strategic plans and priorities
- Relevance to interagency and international plans
- Relevance to national and international assessments
- Within the framework of GMD's mission:
  - Align research along Grand Challenges
  - Identify key scientific questions
  - Determine role of long-term observations to answer those questions
  - Sustain quality and continuity of observations
  - Understand the observed distributions and trends
    - Expand networks as needed
    - Conduct periodic regional-scale studies

Key Legislative Drivers of GMD's Research

- GMD's research contributes to fulfilling requirements for over 25 laws
- Four pieces of US legislation stand out
  - National Climate Protection Act (1978)
  - Global Climate Change Program Act (1990)
  - Global Change Research Act (1990)
  - Clean Air Act (1990)

Plans and Agreements

- **United States**
  - National Global Change Research Program Research Plan
  - US Carbon Cycle Science Plan
  - NOAA Next Generation Strategic Plan
  - NOAA Research Plan & OAR Priorities
  - NOAA/ESRL GMD Research Plan
- **International**
  - WMO Global Atmosphere Watch Strategic Plan
  - GCOS Implementation Plan
  - GEOSS Strategic Plan
  - GEO Carbon Strategy
  - WCRP Strategic Plan

NOAA Plans

NOAA Next Generation Strategic Plan

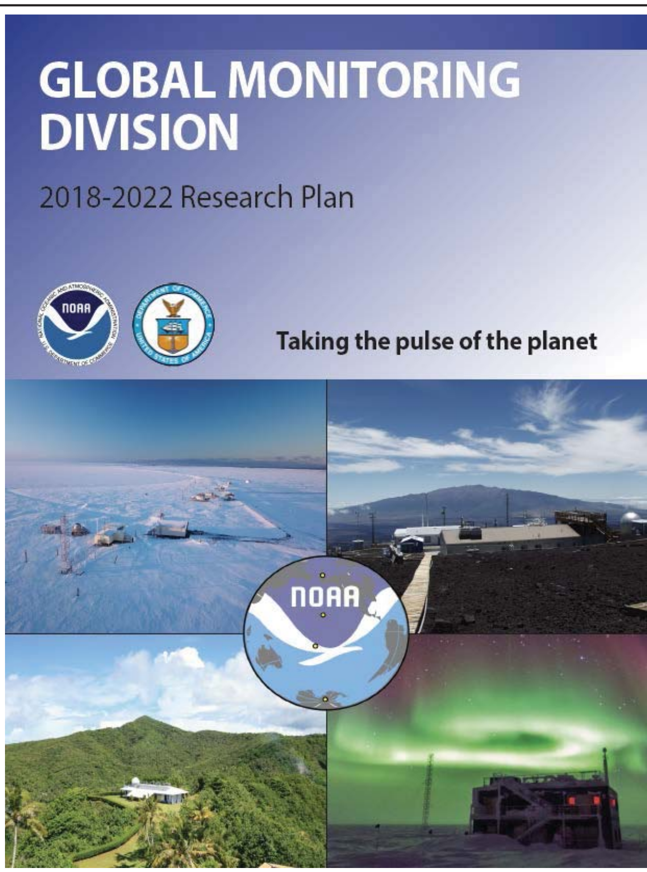
- **Goal:** Climate Adaptation and Mitigation
  - **Primary Objective:** Improved Understanding of Climate Change and its Impacts
  - **Other Objectives:** Assessments, Mitigation and Adaptation, Climate-Literate Public, Partnerships
- **Goal:** Weather Ready Nation
  - **Objectives:** Reduced loss from high impact events, improved water management and air quality, healthy people and economy, and improved transportation

OAR Strategic Plan

- **Aim:** Climate Adaptation and Mitigation
  - What is the state of the climate system and how is it evolving?
  - What causes climate variability and change on global to regional scales?
  - What improvements in global and regional climate predictions are possible?
- **Aim:** Weather Ready Nation
  - How does climate affect seasonal weather and extreme weather events?
  - How can we improve forecasts for freshwater resource management?
  - How are atmospheric chemistry and composition related to each other and ecosystems, climate, and weather?

OAR Priorities

- Sustain the long-term observations of the Earth System
- Improve the accuracy of weather forecasting and climate predictions
- Provide the environmental information needed by decision makers
- Sustain and enhance ocean exploration and research infrastructure
- Provide the essential scientific understanding of ecosystem processes and change
- Enhance marine resources management
- Detect, and provide early warning information for ocean, weather and climate events



GMD Research Plan

- Documents GMD's purpose
- Built around recognized Grand Challenges*
- Identifies key scientific questions
- Shows how GMD activities help answer those questions
- Provides a path forward
- Includes milestones as measures of performance

*Weatherhead et al 2017, Earth's Future, Nov 2: WCRP https://www.wcrp-climate.org/grand-challenges/grand-challenges-overview

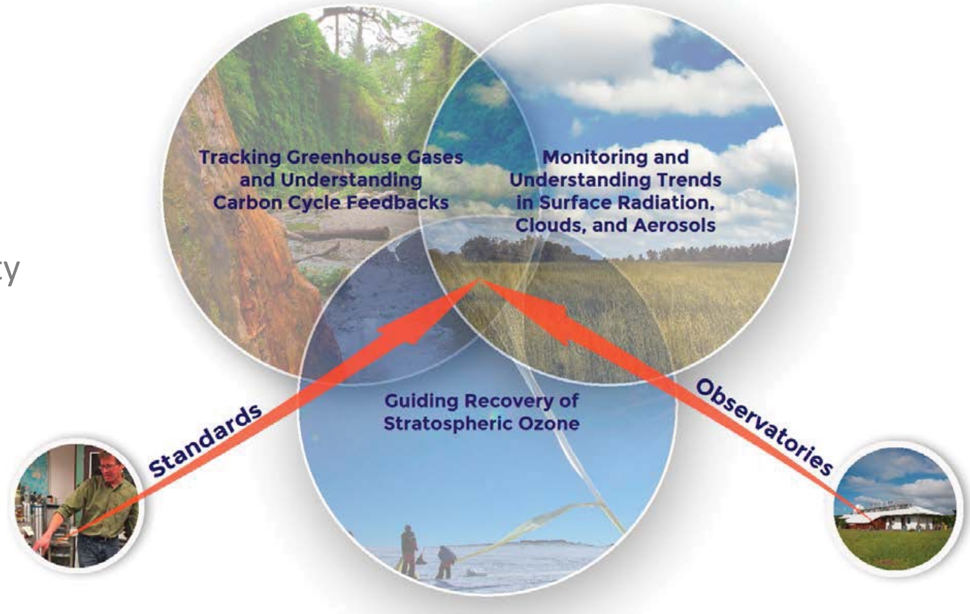
GMD Research Themes and Applications

GMD Research Themes and Applications

Radiative Forcing

Renewable Energy Support

GMD Research Themes and Applications



Climate Sensitivity

Climate Intervention

Air Quality

Arctic Processes

Scientific Questions

(Details in Research Plan)

Greenhouse Gases and Carbon Cycle Feedbacks

- ✓ How do oceanic and terrestrial carbon fluxes vary in a changing climate?
- ✓ How spatially and temporally variable are anthropogenic inputs of greenhouse gases?
- ✓ How is upper tropospheric and lower stratospheric water vapor interacting with climate change?

Recovery of Stratospheric Ozone

- ✓ How well is the Montreal Protocol working to reduce ozone depletion?
- ✓ Is stratospheric ozone recovering as expected?
- ✓ How is climate influencing Brewer-Dobson circulation and its feedbacks?
- ✓ How sensitive is the oxidative capacity of the atmosphere and how is it changing over time?

Surface Radiation, Clouds, and Aerosols

- ✓ How does surface radiation vary in space and time?
- ✓ How do climate change and variability work to redistribute clouds ?
- ✓ How do aerosol optical properties vary as a function of location, time, and atmospheric conditions?
- ✓ How does black carbon influence lower atmospheric heating and cloud prevalence?
- ✓ How do changing sky conditions affect ultraviolet radiation at the Earth's surface?
- ✓ How can information on surface radiation improve renewable energy predictions?

How We Plan, Ensure, and Measure Success

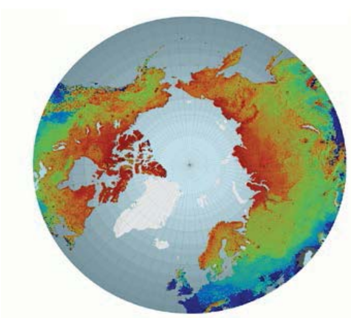
Path To Success

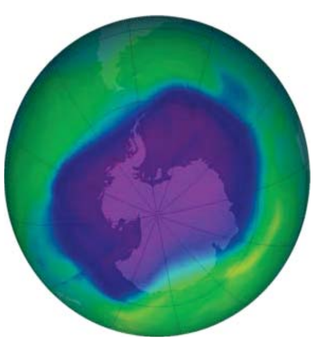
- **Rigor** – role as a world leader in measurements that we do
- **Excellence** – in the science that comes from the measurements
- **Pathfinder** – for new technology to enhance and sustain measurements
- **Transparency** – making measurements, methods, scientific findings accessible to the public
- **Leadership** – providing guidance to the rest of the scientific community to ensure compatibility of global measurements

How We Measure Success

- Sustained high-quality long-term records of atmospheric composition
- Preeminence of our science as documented through the peer-review process
- External recognition of staff
- Ability to update products regularly
- Use of products by external partners
- Leadership on councils, advisory groups, and committees
- Contributions to assessments

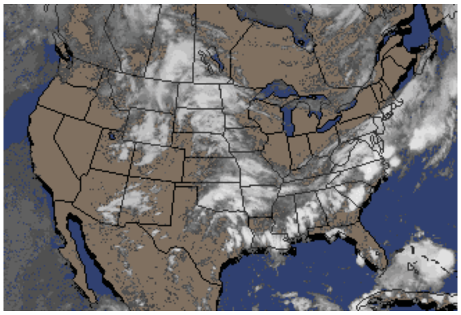
Some Substantive Accomplishments of GMD

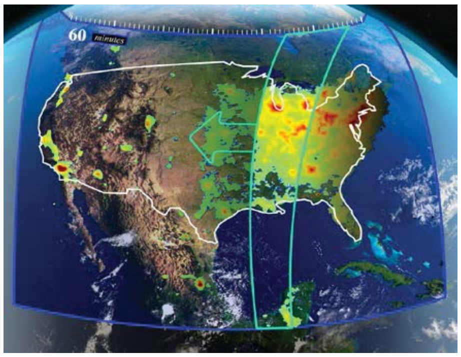




- Magnitude of the terrestrial, northern hemispheric sink for atmospheric carbon dioxide
  - Continuing to provide on-going, solid evidence that half of the CO_2 emitted to the atmosphere is taken up by land and oceans
  - Continuing to investigate the reliability of sinks
- Turnover of ozone-depleting gases and the onset of ozone recovery
  - Annually quantifying the contributions of Montreal Protocol and other gases to potential ozone recovery
- Stability of oxidizing capacity of the troposphere largely derived from these ozone-depleting gases and their replacements
  - Affects lifetimes of many gases in the atmosphere

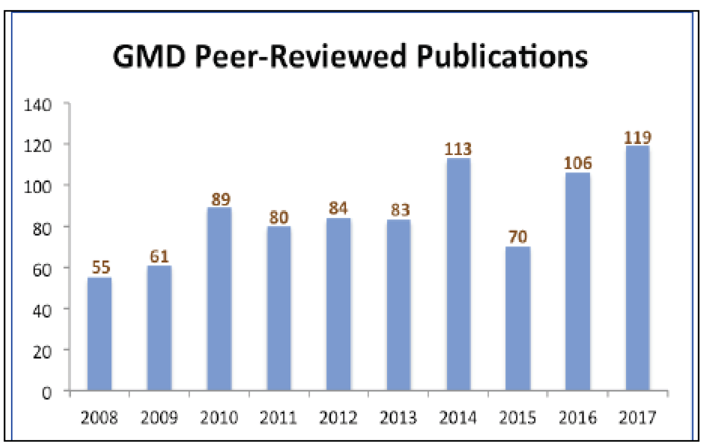
Some Substantive Accomplishments of GMD



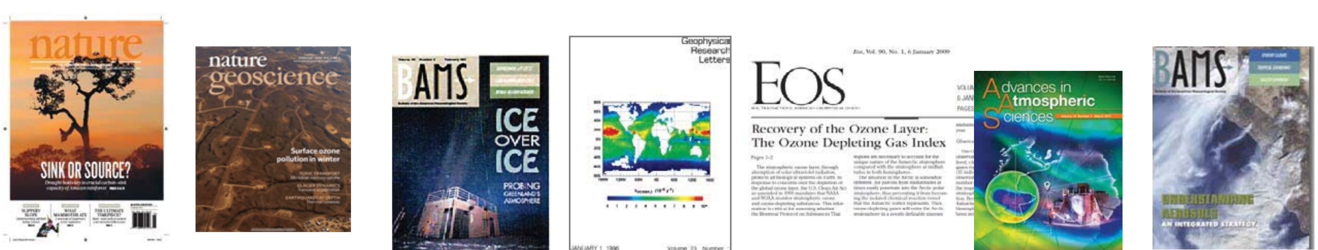


- Large increase in radiative energy at the surface across the United States over the past 15 years (equivalent to twice the forcing from a doubling of CO_2)
  - This, while noting a decrease in aerosol radiative forcing
  - Caused by variability of clouds on decadal scales
- Improving satellite retrievals through continuous evaluation of retrievals for O_3, UV, surface radiation, water vapor, and GHGs
- Primary source for information and data on hundreds of variables in the atmosphere
  - Virtually all of these are identified as GCOS Essential Climate Variables

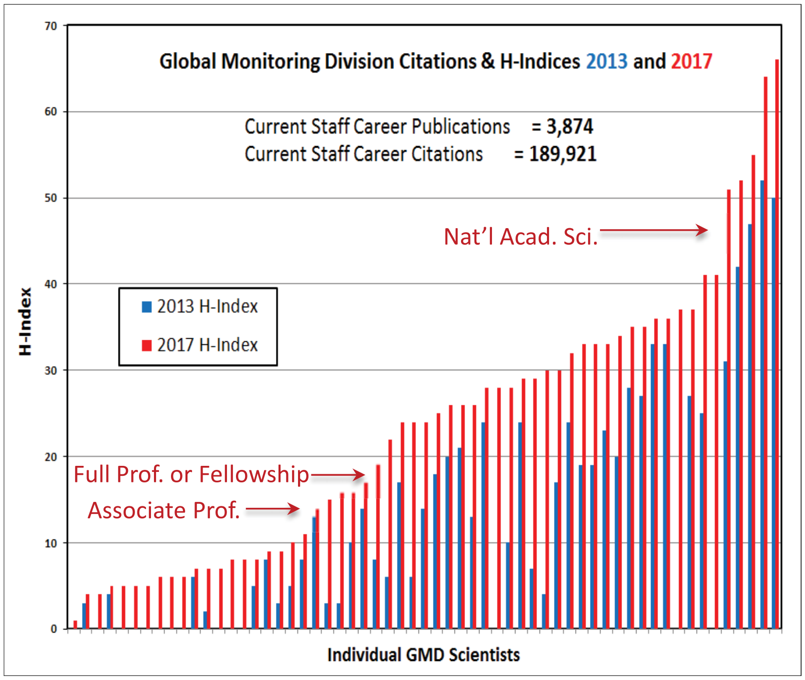
Publications Keep Increasing



- These are publications with GMD authorships.
- The number has increased at ~7 per year since 2013, our last review.
- That's the same rate of increase since 2008.



Staff Performance – Hirsch Index

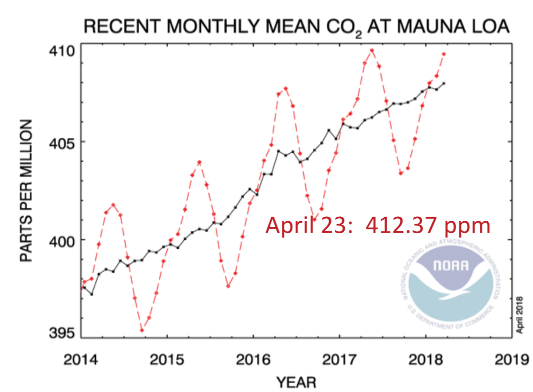


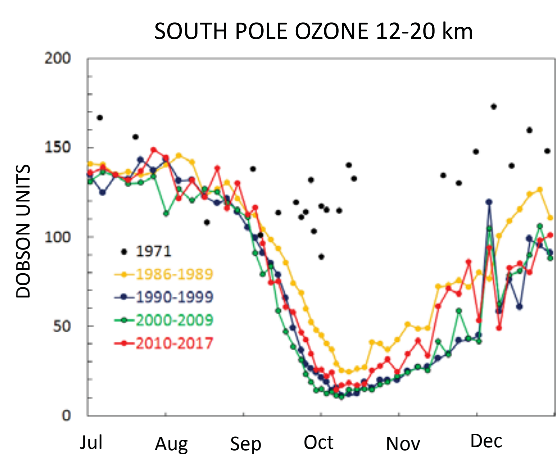
	H-Index*	# Pubs.	# Citations
Tans	66	227	17,195
Oltmans	64	234	13,015
Elkins	55	175	8,799
Ogren	52	159	8,264
Dlugokencky	51	144	8,282
Johnson	41	107	5,008
Sweeney	41	144	7,270
Long	37	94	6,574
Novelli	37	74	4,356
Hintsa	36	76	3,784
Montzka	36	147	7,812
Butler	35	59	3,804
Schnell	35	110	4,028
Bruhwiler	34	59	5,412
Andrews, A.	33	93	3,410
Conway	33	65	7,162
Miller, J.	33	89	4,257
Jefferson	32	65	3,307
Masarie	30	46	6,324
Miller, B.	30	70	4,140
Hurst	29	71	2,708
Moore	29	68	3,513
Michalsky	28	89	2,699
McComiskey	28	118	4111
Sheridan	28	63	3,502

*As of Dec 2017

On-line Products

- Interactive Data Visualization
- Annual Greenhouse Gas Index
- Ozone-Depleting Gas Index
- South Pole Ozone
- GLOBALVIEW and ObsPak
- Mauna Loa and Global Trends
- GMD 3 Dimensional Maps of Composition
- Solar Calculator

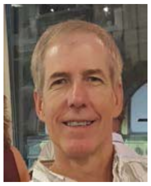




Awards Summary 2013-2017









- DOC Bronze Medal Award (1)
- NOAA/CIRES Silver Medal Award (1)
- Yoram J. Kaufman Award (1)
- OAR Outstanding Paper (2)
- CIRES Outstanding Service Awards(6)
- Governor's Award for High Impact Research (2)
- AGU Excellence in Refereeing (3)
- Vaisala Award (1)
- Total of 28 External Awards honoring 61 individuals in GMD over past 5 years

Partners

- GMD operates instruments or collects samples at 78 locations in 35 states in the US
- Nearly all of the 13 US agencies participating in the USGCRP make use of GMD's data and products
- GMD operates similarly at 161 locations in 67 countries
- Over 100 partnering scientists worldwide, many in association with WMO Global Atmospheric Watch

- NOAA/ESRL Global Monitoring Annual Conference
  - Essentially GMD's annual meeting to engage with partners contributing to, sharing, or using GMD's data and data products routinely.

2018 GMAC

National and Global Leadership

- WMO Commission for Atmospheric Science
  - US Lead Delegate
  - WMO Global Atmosphere Watch (Four members of Scientific Advisory Groups (2 chairs)
  - Many members of GHG Measurement Techniques Group
- European Research Infrastructures
  - Advisory Boards for 3 EU Infrastructures

- Global Climate Observing System (GCOS)
  - Atmospheric Observation Panel for Climate
- US Global Change Research Program
  - Carbon Cycle Interagency Working Group
  - Carbon Cycle Scientific Steering Group
  - North American Carbon Program Scientific Steering Group
  - SOCCR Co authors (3 co-leads)
- Group on Earth Observations
  - GEO Carbon
- WCRP Baseline Surface Radiation Network

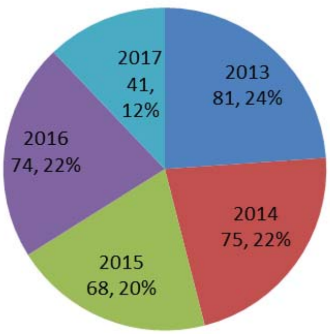
Assessments

- Our contributions to Assessments are the highest level product and ultimate transition for our research:
  - Provide evaluations and syntheses of the most recent research
  - Operate at the interface of science and policy, providing policy-relevant information
- IPCC Assessments
  - Inform nations through UNFCCC on climate and climate change mitigation
    - Significant vehicles for educating global society on climate change
- Ozone Assessments
  - Inform nations through the Vienna Convention on the Ozone layer
    - Resulted in significant amendments to the Montreal Protocol
    - Led to acceleration of production phaseouts, most recently HCFCs
- National Assessments
  - Provide US policy-makers with climate-relevant information

U.S. Global Change Research Program
National Climate Assessment

ESRL Student Program 2013-2017

- CIRES/CIRA
- Educational Partnership Program
- High Schools
- Hollings Scholars
- Research Experience for Undergraduates
- Science and Technology, Corp.
- Significant Opportunities in Atmospheric Research
- Tribal College Collaboration



339 Students served in 2013 – 2017

NOAA/ESRL Global Monitoring Division
Laboratory Review, 21-24 May 2018

GMD Outreach

Building Global Capacity

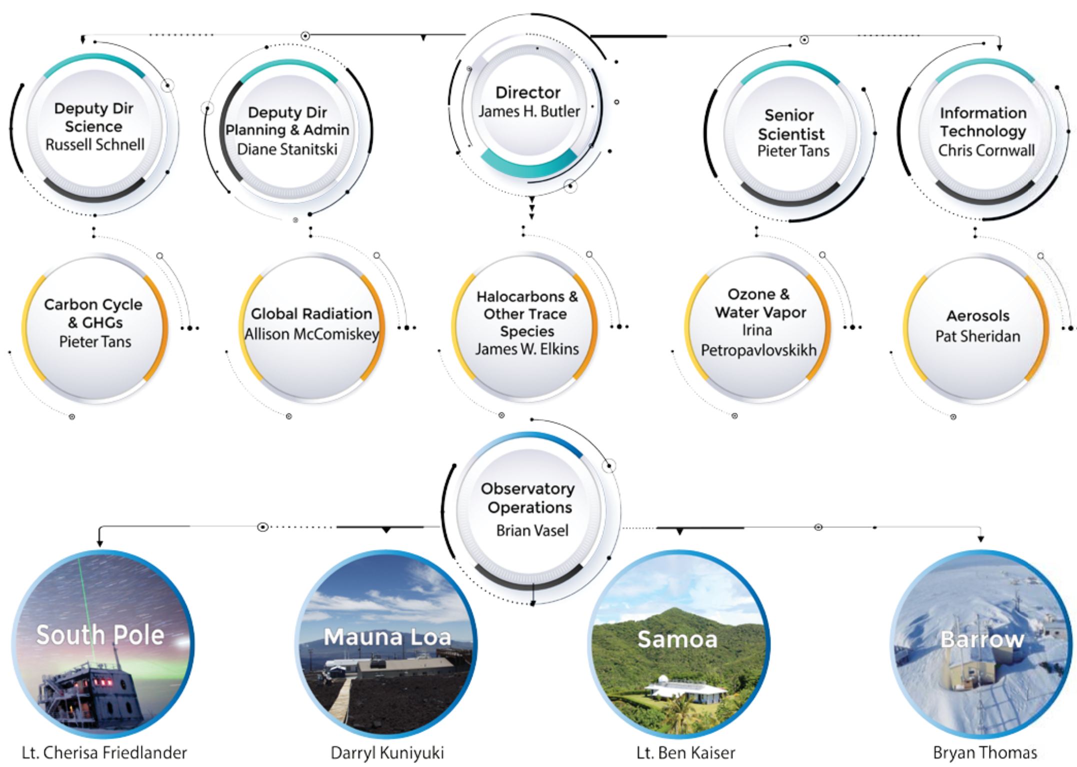
- Coordinates with scientists, universities, agencies around world to add sites to measurement networks
- Trains emerging scientists abroad and WMO partners

Public Outreach

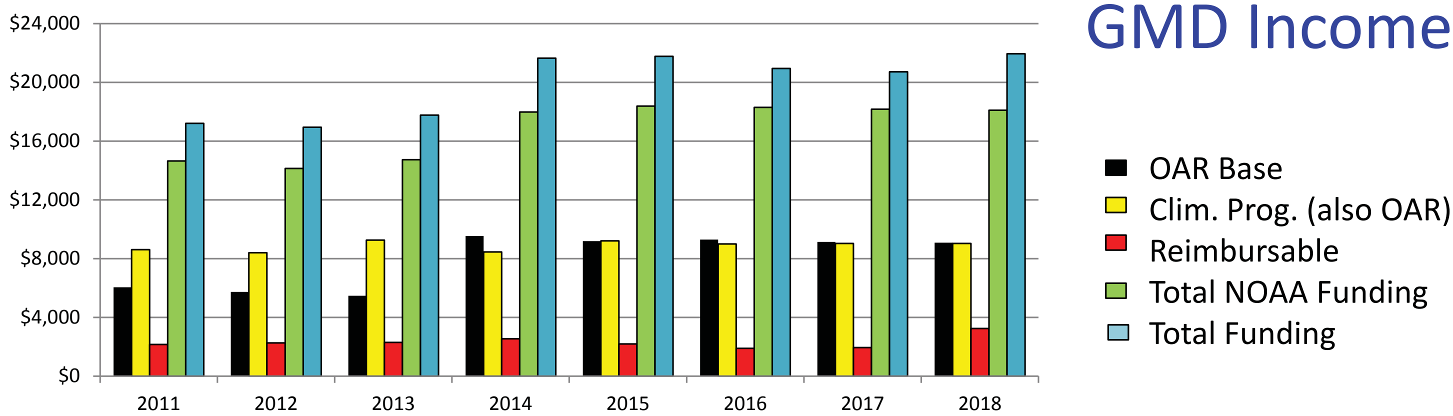
- GMD Observatories provide tours, community presentations, student field work
- 29,485 visitors to our facility in 2013-2017 were shown SOS, the GMD “Wall”, and other activities
- Organized NOAA activities for Native American students and minority groups (e.g., AISES, Howard)
- Served as panelists and presenters in local high school science classes
- Presented GMD science at TEDx Boulder Salon
- Hosted anniversary events with Boulder media

Organization and Management

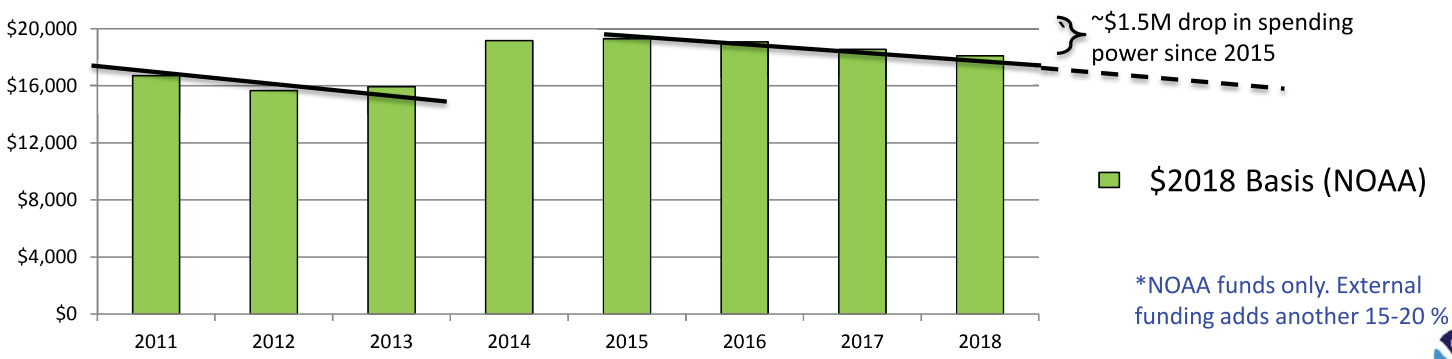
GMD Organization



GMD Income

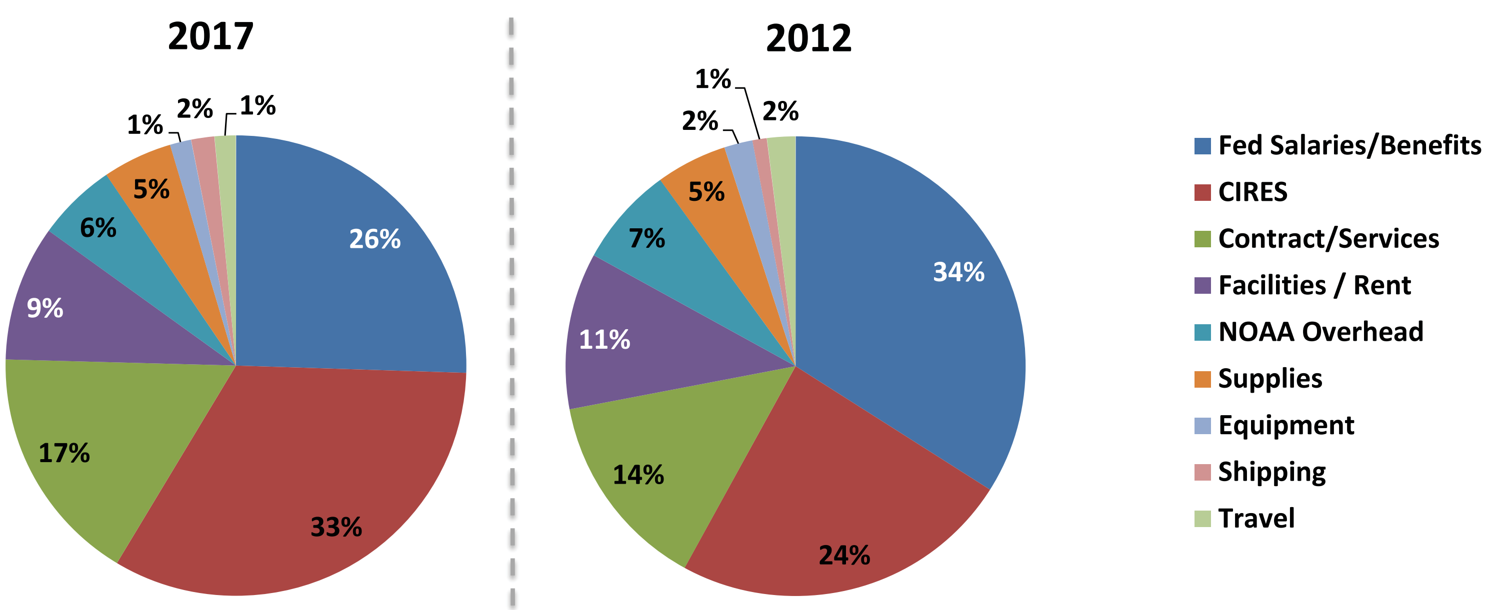


$2018 Basis



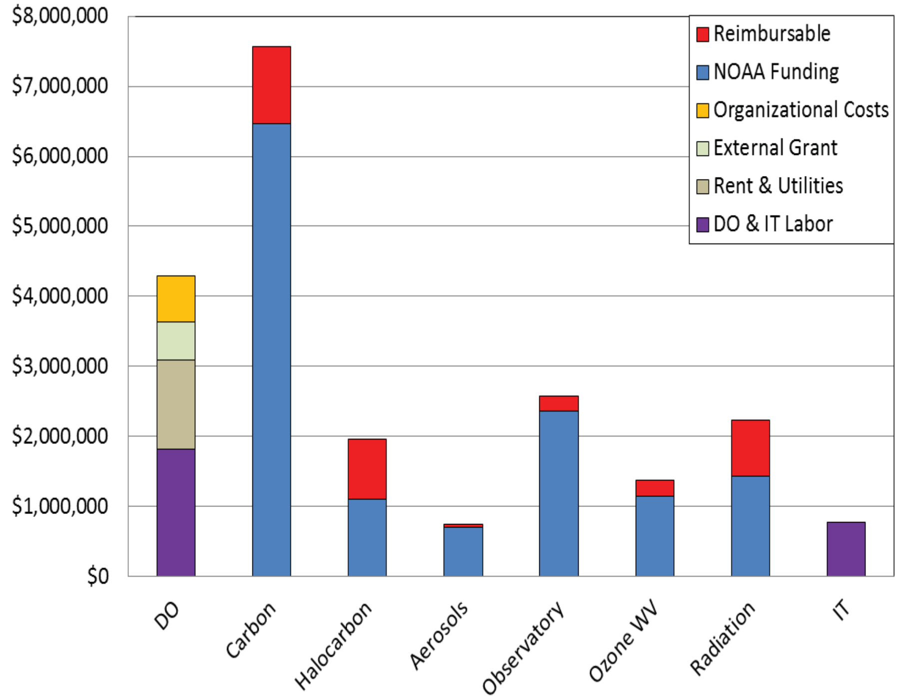
*NOAA funds only. External funding adds another 15-20 %

Expenditures by Function



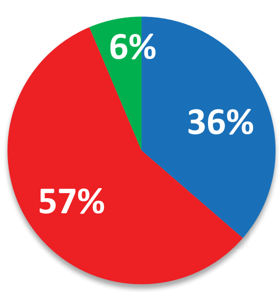
Budget distribution in GMD (2018)

- 5 Research Groups
- Observatory Operations
- Director's Office and IT
  - Includes Admin & Budget
  - Largely non-scalable

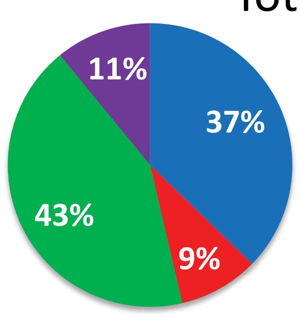


Workforce Profile

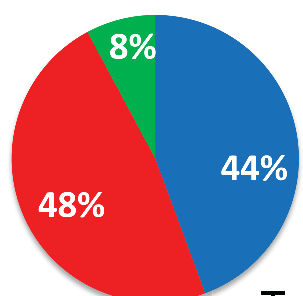
2017



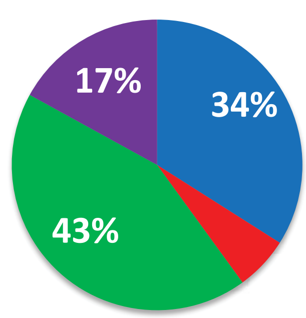
Total "FTE" = 107



2012

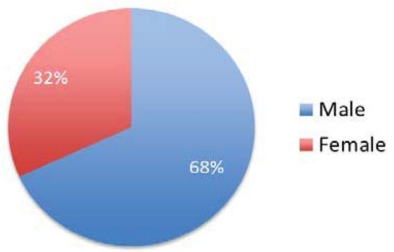


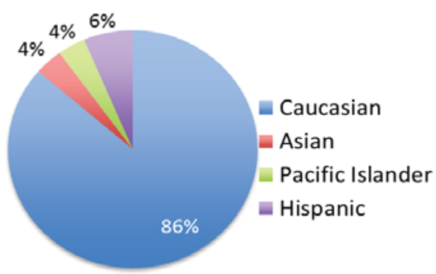
Total "FTE" = 115



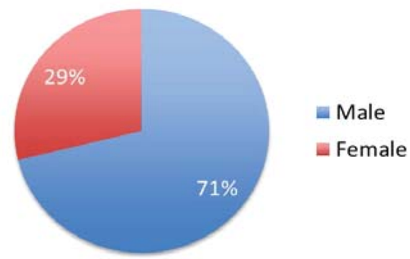
Workforce Demographics

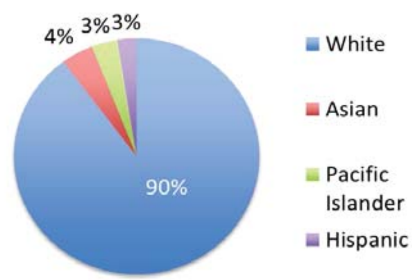
2017





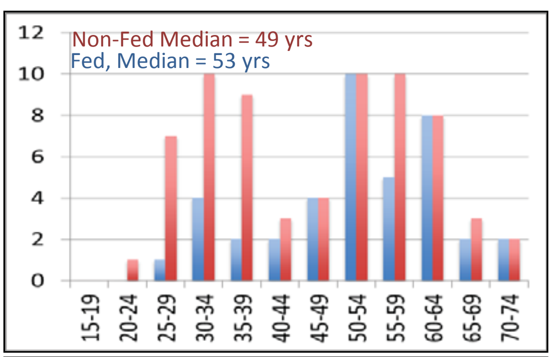
2012

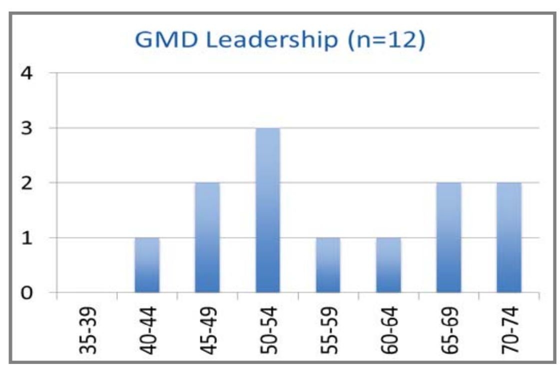




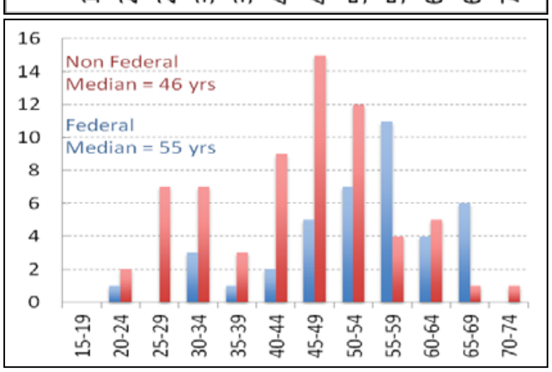
Workforce Age Distribution

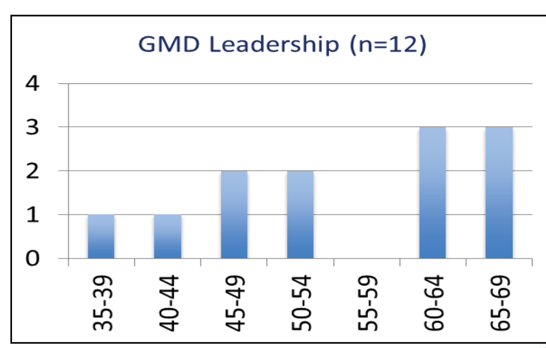
2017





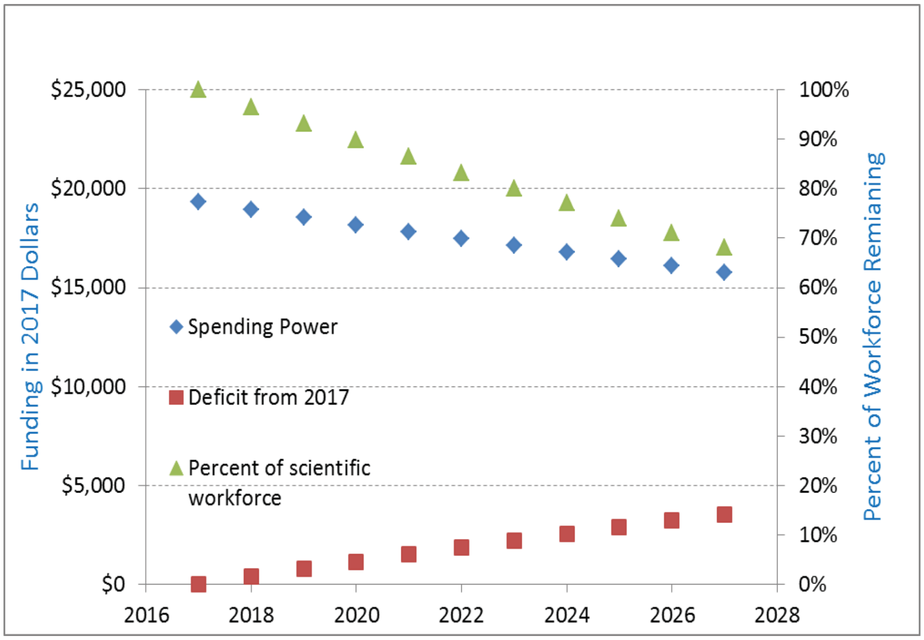
2012



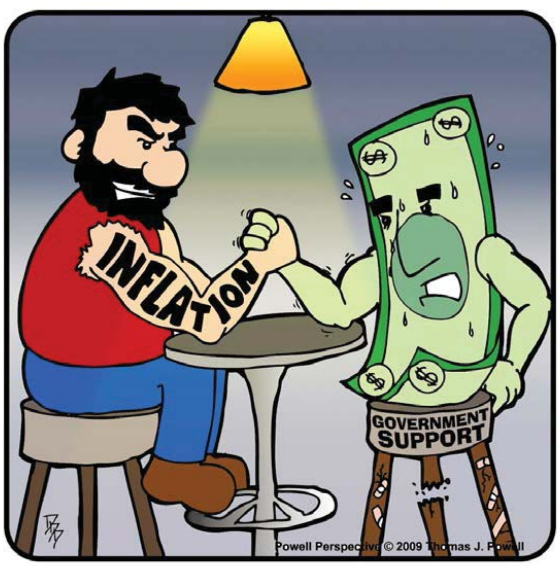


Our Challenge Ahead

- Inflationary erosion (2%/yr) impinges heavily on GMD
  - Extent of observations
  - Quality of observations
  - Number of personnel
- Steady funding means $2M loss in 5 years, $4M in 10 years.
- Steady funding puts GMD on a path to lose 1/3 of current scientific personnel in 10 years

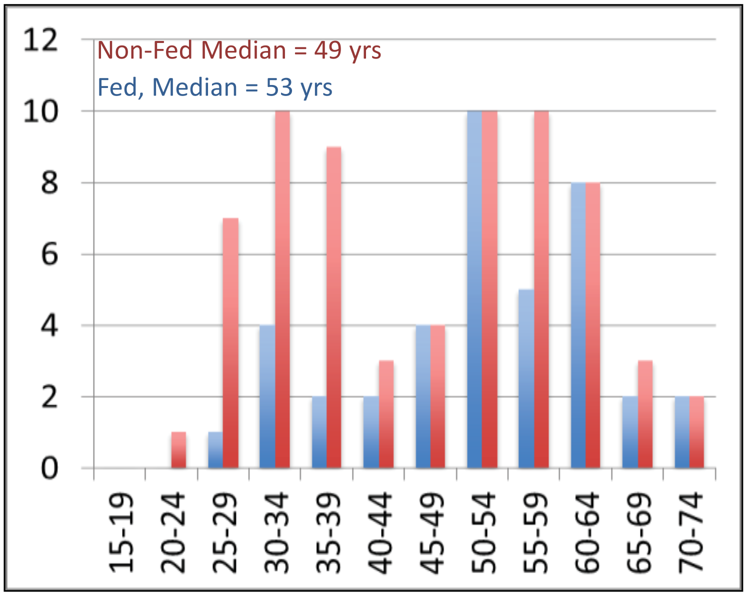


How are we addressing decreasing resources?



- Reimbursable projects
- Increasing efficiency
- Reducing redundancy
- Collaborating with other labs
- Cutting back on sites
- Renewing aging workforce?

Renewing the workforce



- Why
  - New ideas
  - New technology
  - New energy
  - Training leaders for future
  - Protecting a 50 year investment that NOAA has made
- How
  - Postdoc programs
  - Outside grants
  - Collaborations with universities

The Future

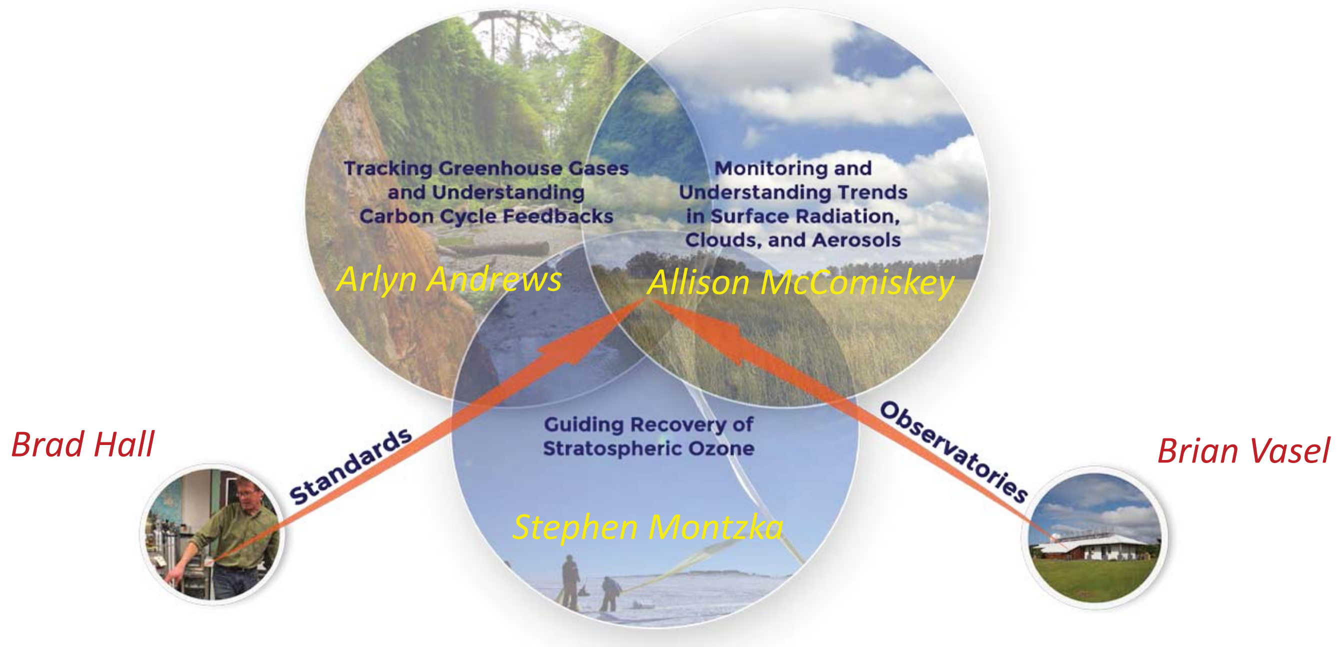
Operational Challenges

- Sustaining long-term observations in global networks
- Ensuring a world-class research workforce
- Addressing succession

Transformative Opportunities

- Build commercial aircraft capability
- Expand C-14 efforts
- Augment Surface Radiation Network to improve predictions
- Enhance upper atmospheric research
- Support renewable energy evaluation
- Advance US tall tower network for boundary layer composition studies

Upcoming Presentations



NOAA Global Monitoring Division

- *. . . providing the best possible information to inform climate change, weather variability, carbon cycle feedbacks, and ozone depletion.*

GMD Mission

- *To acquire, evaluate, and make available accurate, long-term records of atmospheric gases, aerosol particles, clouds, and solar radiation in a manner that allows the causes and consequences of change to be understood.*

Theme 1: Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks

Take Home Messages

- We are creating an unassailable and well-documented record of greenhouse gases.
- We try to help society deal with the climate problem:
  - *Create a quantitative record of climate forcing.*
  - *Quantify and diagnose the response of the natural carbon cycle and greenhouse gas budgets to climate change.*
  - *Evaluate potential "surprises" and give early warning if warranted.*
  - *Support mitigation by providing objective and transparent verification of emissions.*
- Close relationships between measurers and modelers have kept us at the forefront of carbon science and are crucial to continued success.
- NOAA anchors the global and US atmospheric carbon observing network. We established multiple comparisons with Environment Canada, Earth Networks and university researchers. We rely on partnerships with other labs and institutions.
- We have just begun to reap the scientific rewards of our investment in North American monitoring – multiple-species analysis will provide critical process constraints and enable improved source attribution.

Outline

- Tracking Greenhouse Gases at Regional to Global Scales
- Understanding Carbon Cycle Feedbacks
- Monitoring Greenhouse Gases in the Upper Atmosphere
- Looking Forward

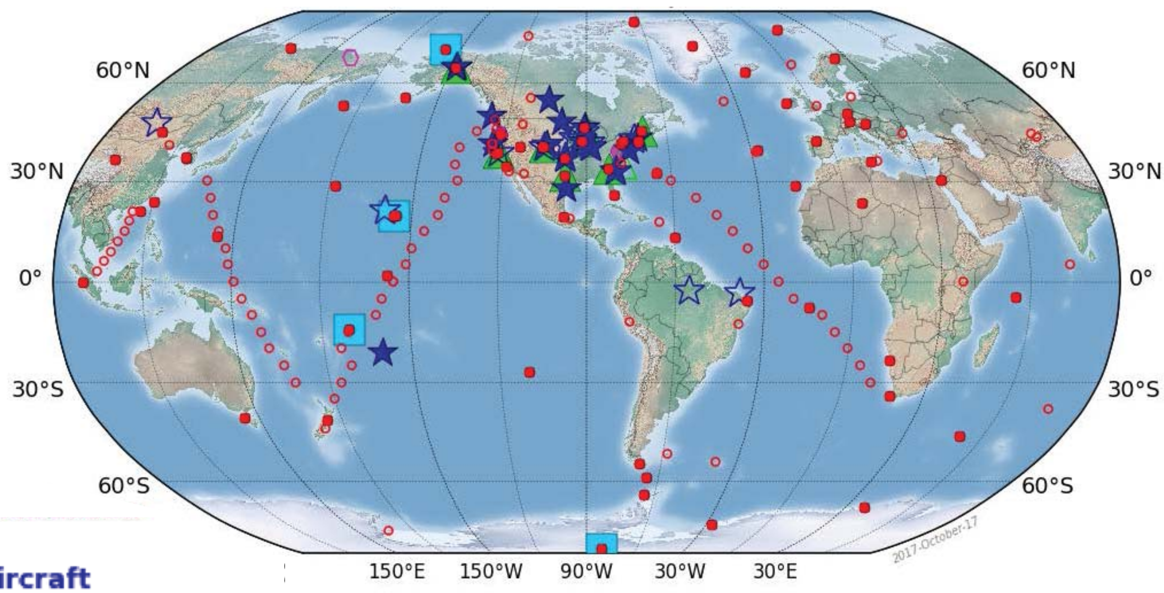
Quality, Transparency, Availability, Capacity Building

Tracking Greenhouse Gases at the Global Scale

Mauna Loa Observatory: Photograph by Forrest Mims III

"Science-driven monitoring of the atmosphere, responding to societal needs"

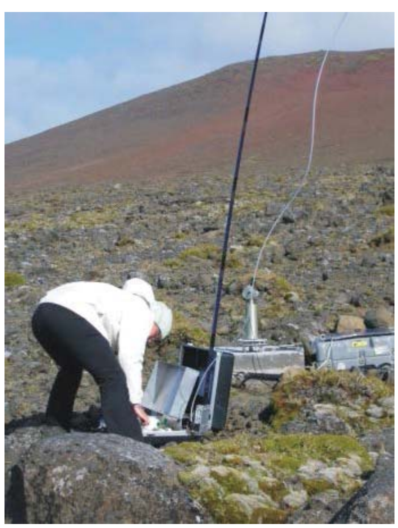
NOAA Global Greenhouse Gas Reference Network

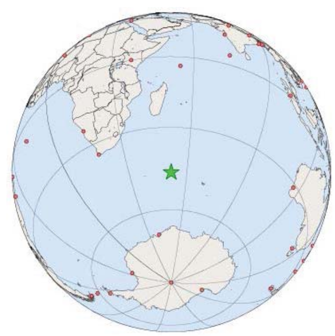


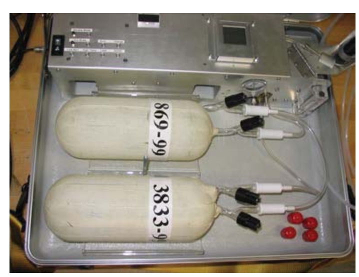
- Aircraft
- Surface Continuous
- Tower
- Observatory
- Surface Discrete

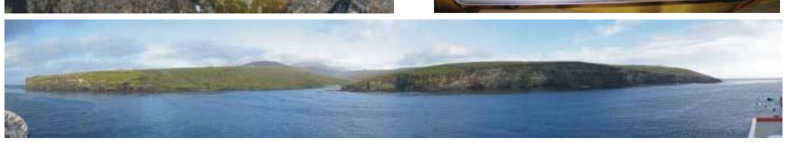
- Data are carefully calibrated relative to WMO scales
- Intra-laboratory and cross laboratory comparisons with other labs ensure data compatability
- Whole air samples are analyzed for many species

Air sampling at Crozet Island



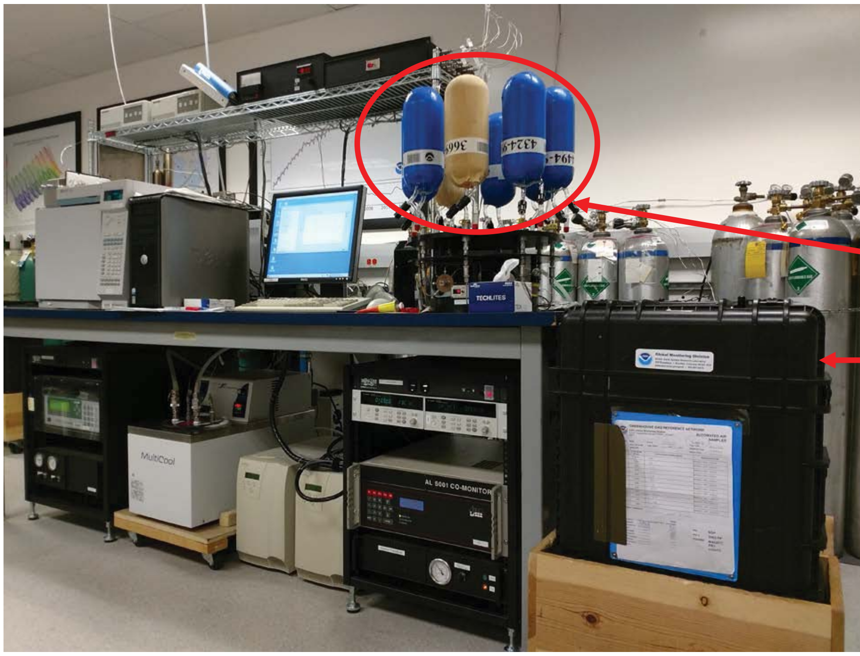






- Weekly whole air samples capture the variability at remote sites.
- Local sources and sinks are avoided.

Measurement of Atmospheric Gases that Influence Climate Change (MAGICC) Whole Air Sample Analysis System

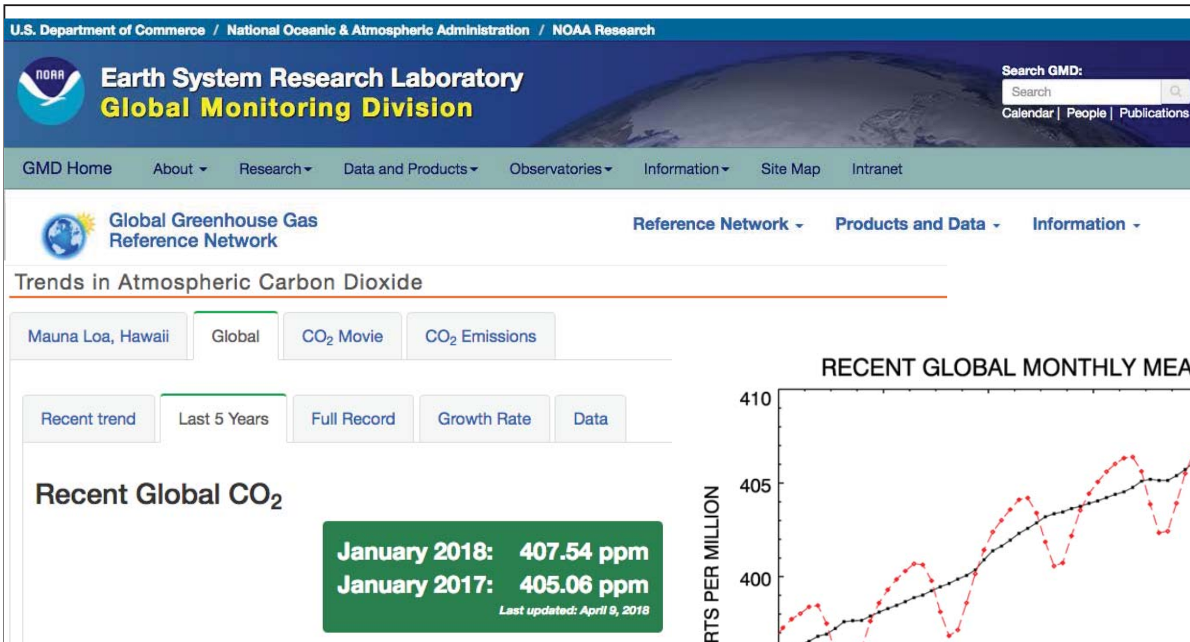


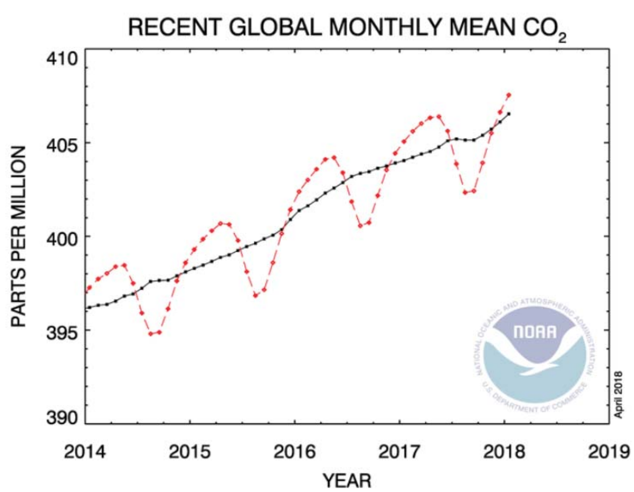
WMO compatibility goals for remote sites:

CO_2: ±0.10 ppm Northern Hemisphere, ±0.05 ppm Southern Hemisphere

CH_4: ±2 ppb

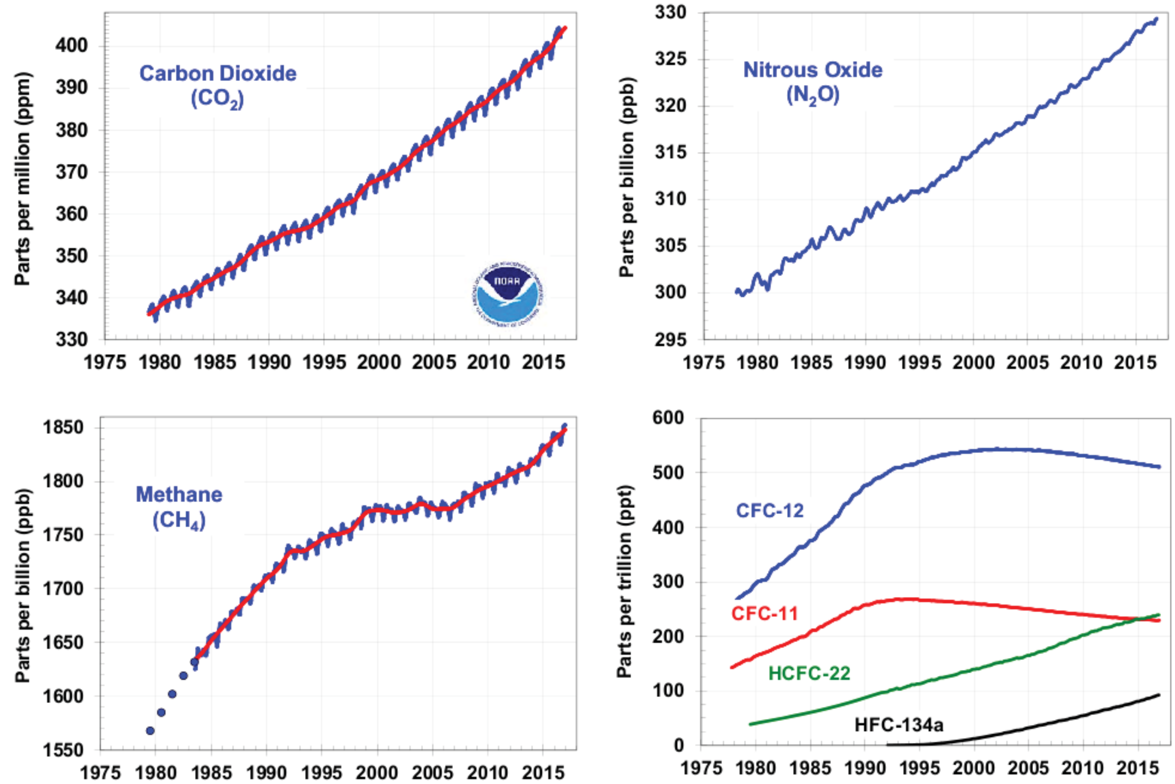
N_2O: ±0.10 ppb



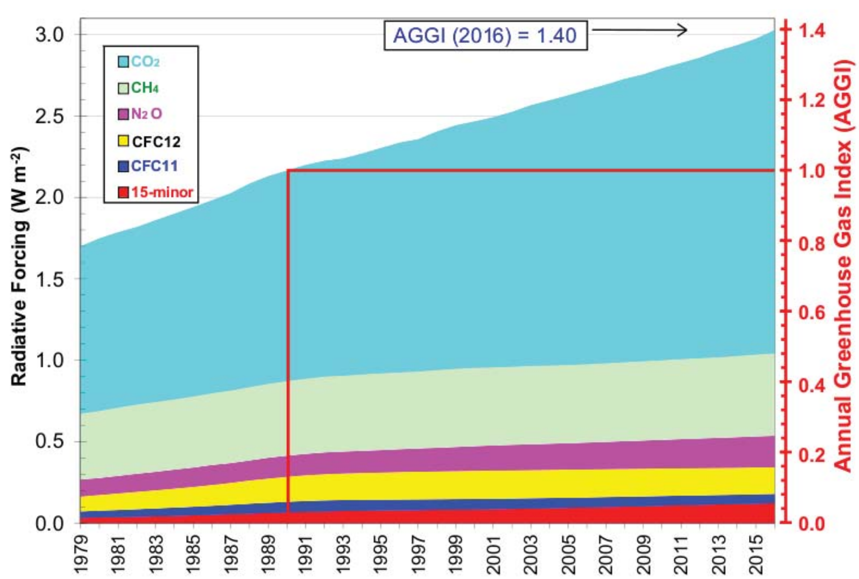


Global Means computed from the MBL reference surface are made readily available with minimal delay.

Global Mean Values for the Major Long-Lived Greenhouse Gases



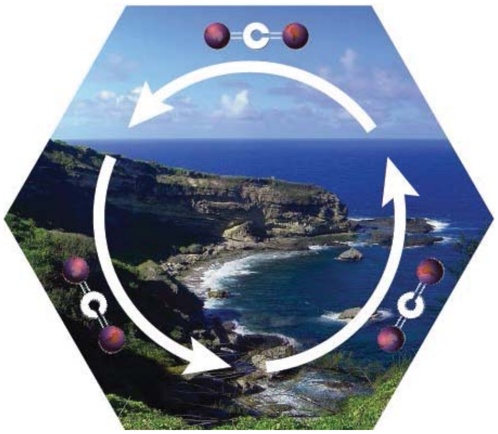
NOAA Annual Greenhouse Gas Index



As of 2016, radiative forcing from anthropogenic greenhouse gases is up by 40% over 1990 levels.

Earth's Surface: 510.1 trillion m^2

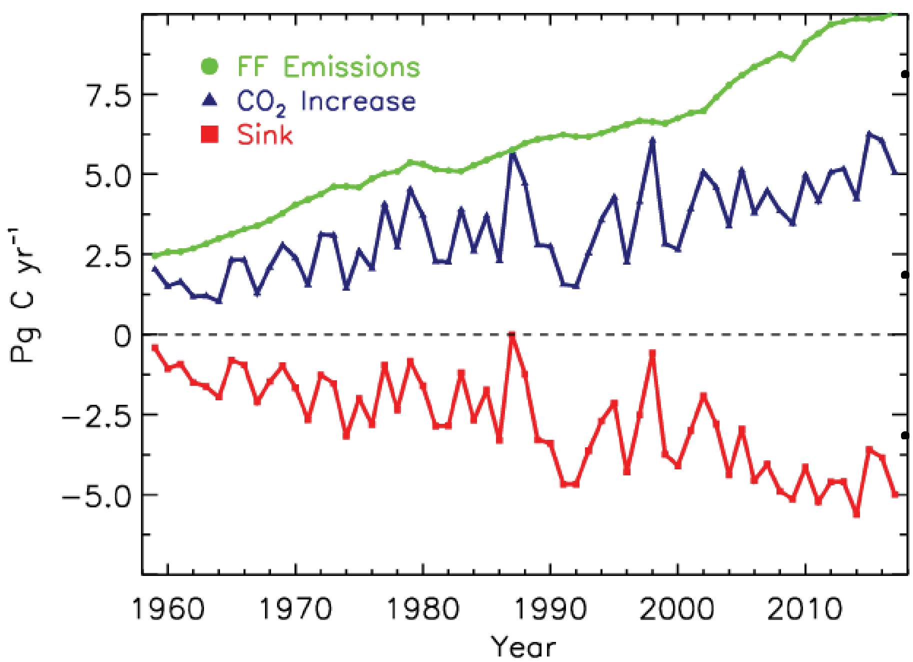
Understanding Carbon Cycle Feedbacks



Grand Challenge: Carbon Feedbacks in the Climate System

- ***What biological and abiological processes drive and control land and ocean carbon sinks?***
- ***Can and will climate-carbon feedbacks amplify climate changes over the 21st century?***
- ***How will highly-vulnerable land and ocean carbon reservoirs respond to a warming climate, to climate extremes, and to abrupt changes?***

Global carbon sinks are increasing

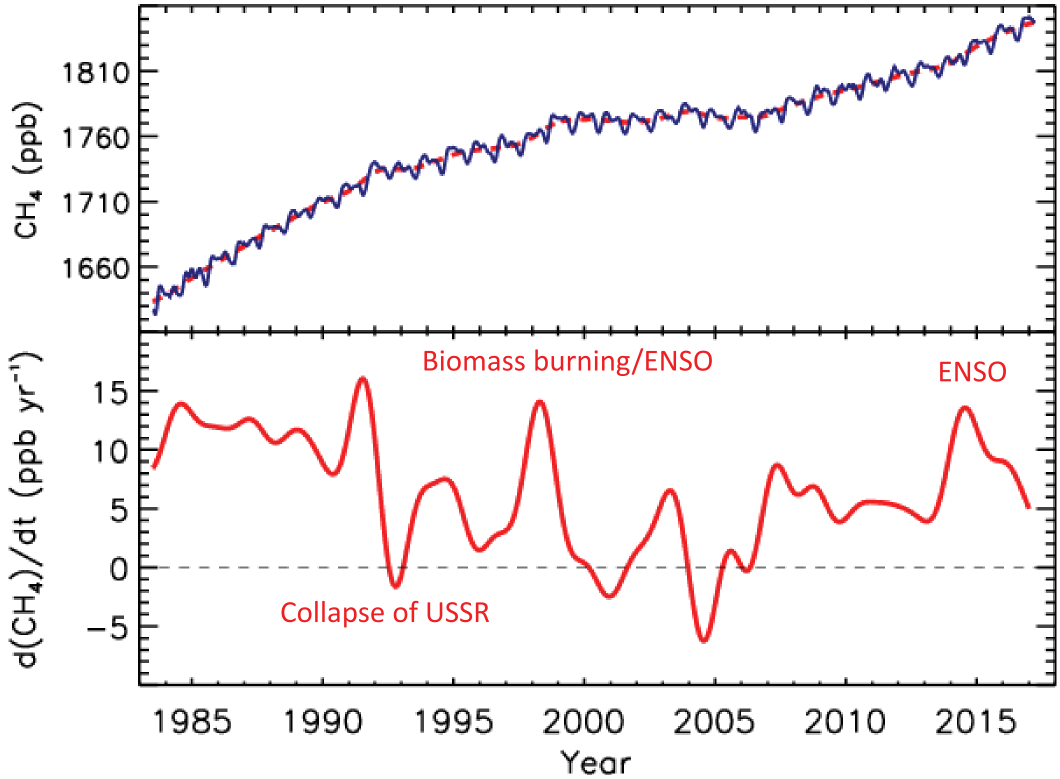


- Carbon sinks keep increasing as fossil fuels keep rising. Global C uptake now ~4 PgC/yr.
- ~50% of fossil fuel emissions are still taken up by sinks.
- Year-to-year variability driven by land uptake. We cannot yet attribute land uptake to specific processes.

Ballantyne et al., Nature, 2012, updated

GMAC presentation by Ed Dlugokencky

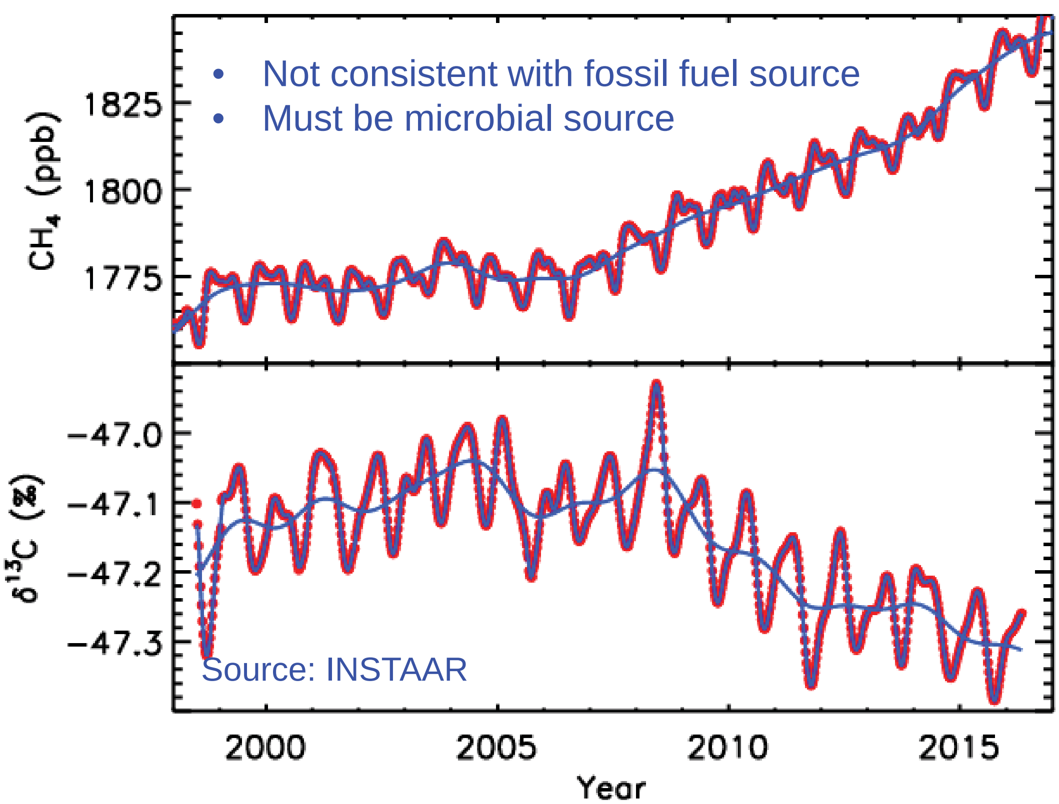
Globally averaged CH_4 and its growth rate



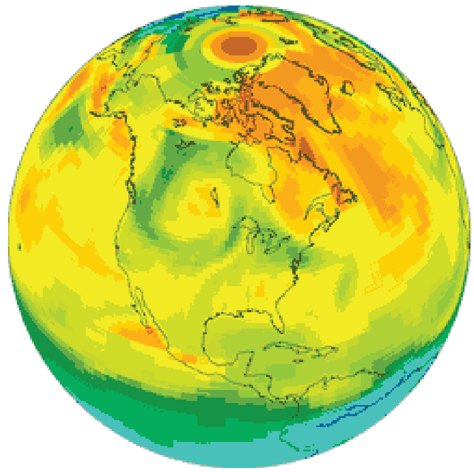
CH_4 data from Ed Dlugokencky

GMAC Presentation by Lori Bruhwiler

CH_4 from Fossil Fuels?

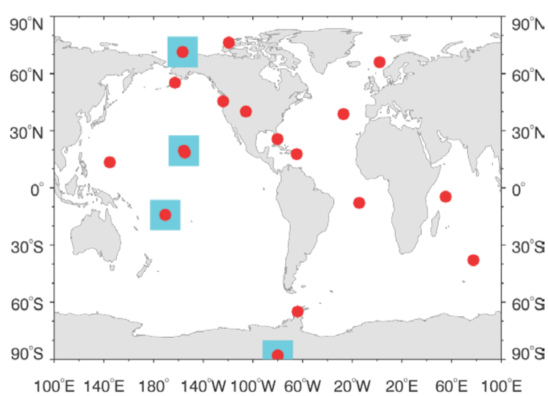


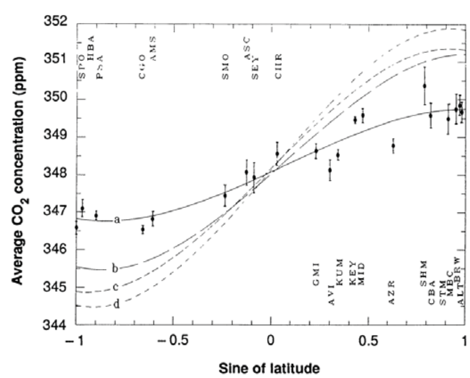
Estimating Emissions and Removals



Observational Constraints on the Global Atmospheric CO_2 Budget

PIETER P. TANS, INEZ Y. FUNG, TARO TAKAHASHI



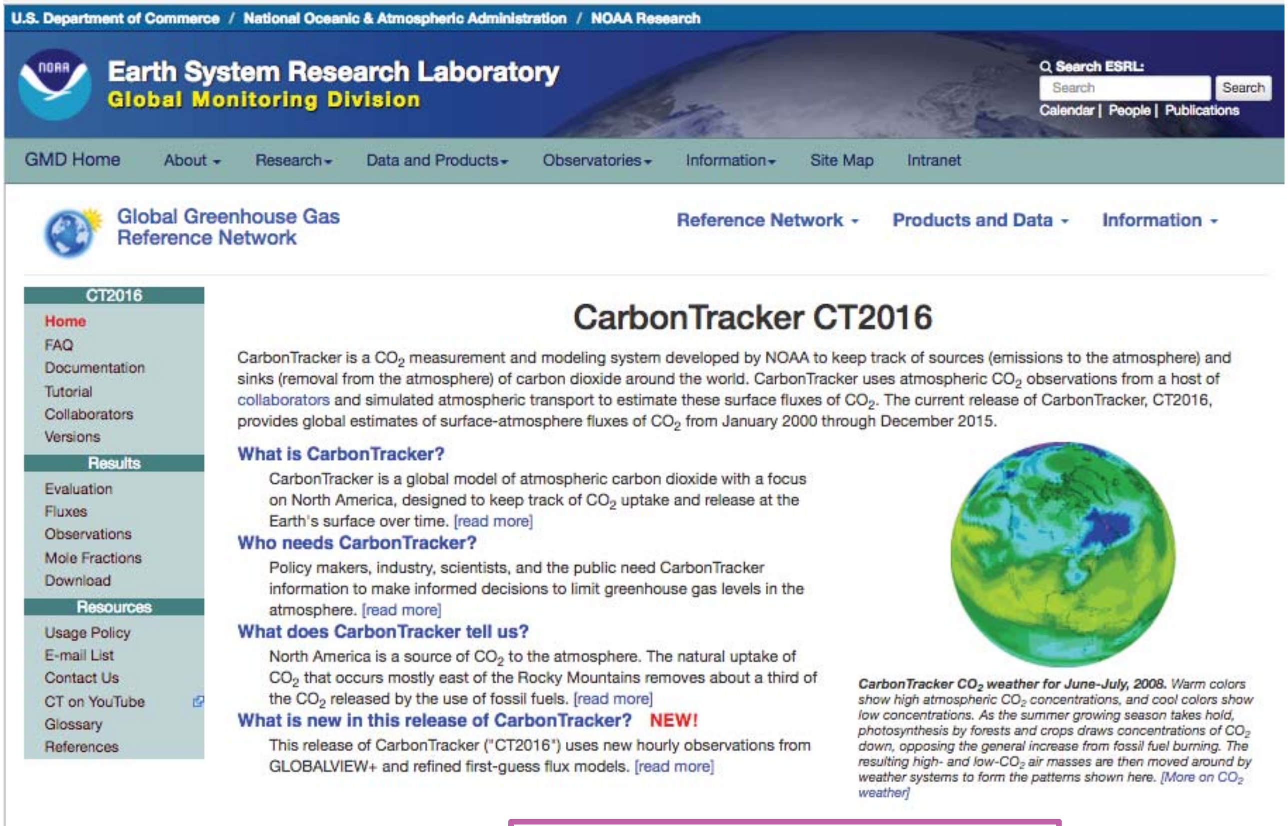


- flask sampling site (weekly)
- observatory (continuous)

Science, Mar. 23, 1990

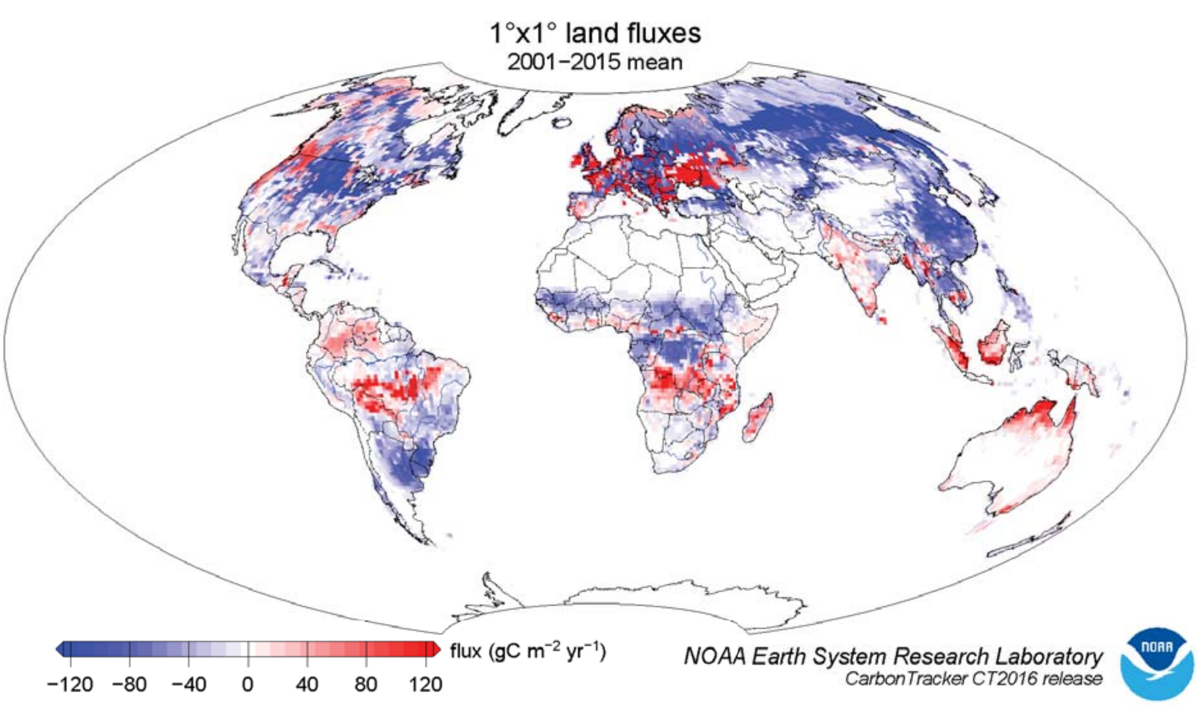
"…a large amount of the CO_2 is apparently absorbed on the continents by terrestrial ecosystems."

1439 citations!

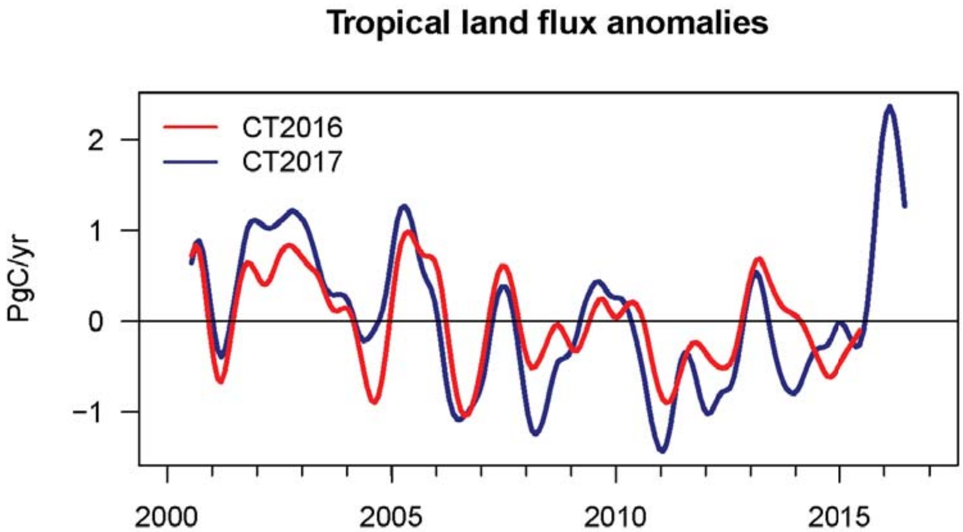


GMAC Presentation by Andy Jacobson

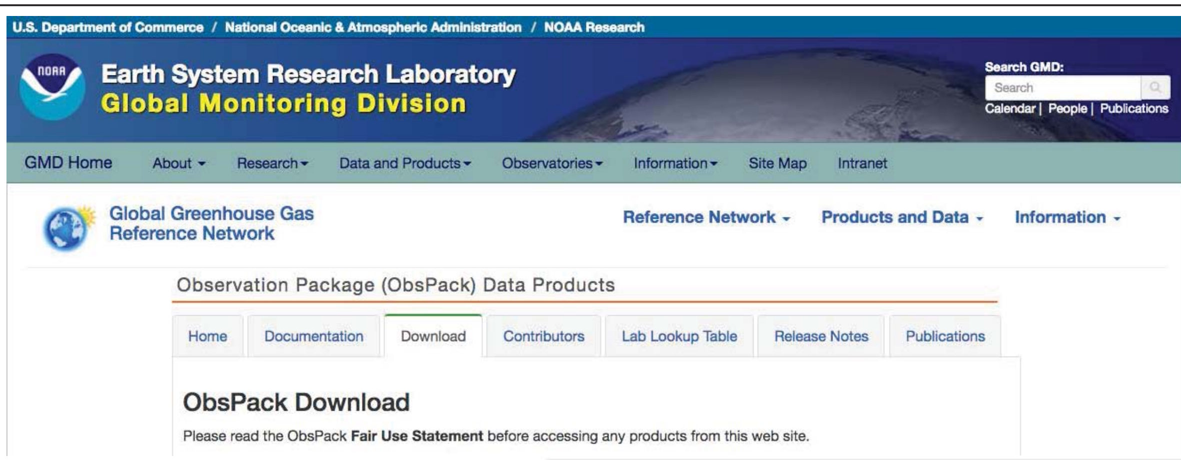
NOAA's CarbonTracker provides up to date estimates of regional carbon fluxes:



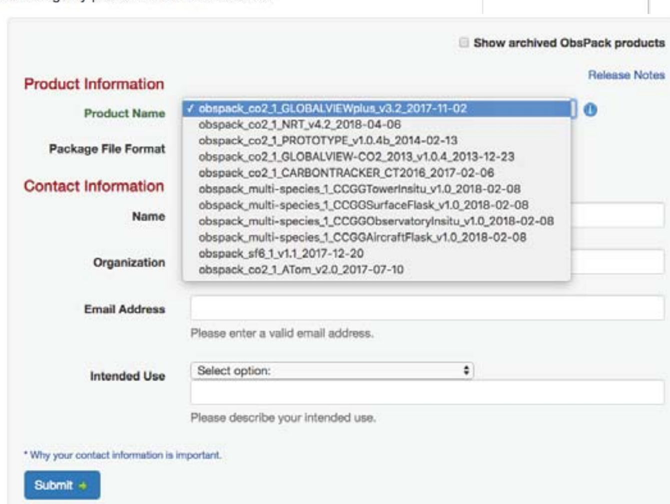
CarbonTracker



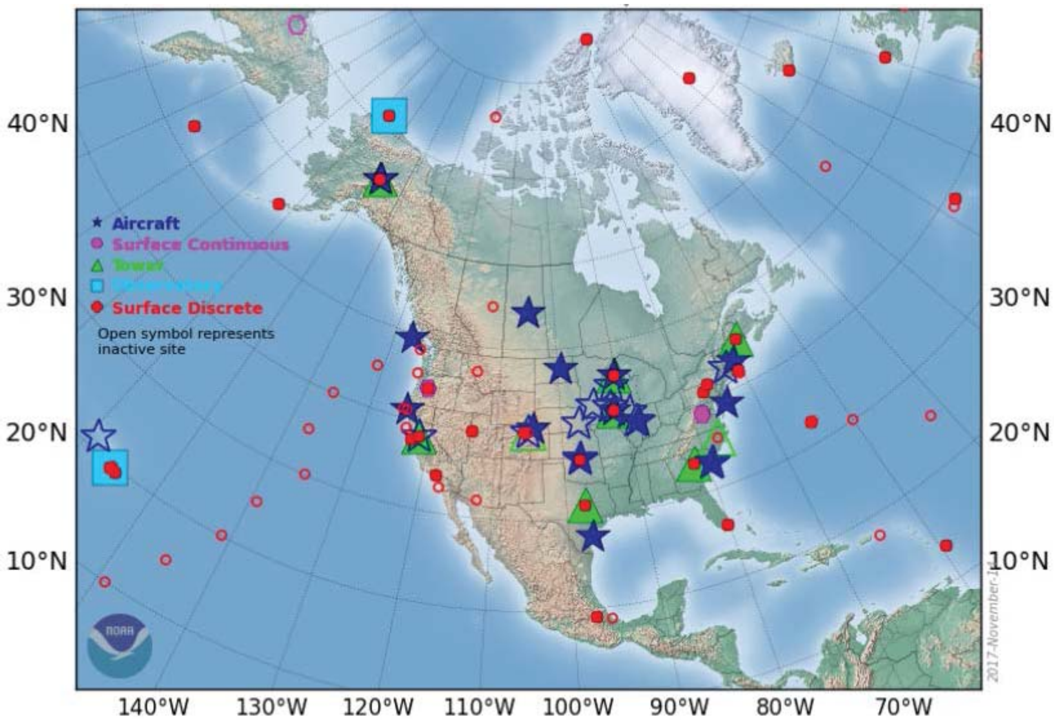
CT2017 is the first CarbonTracker release to simulate impacts of a large El Niño. In 2015 and 2016, we find about 1.2 PgC/yr extra CO_2 in the atmosphere due to this event.



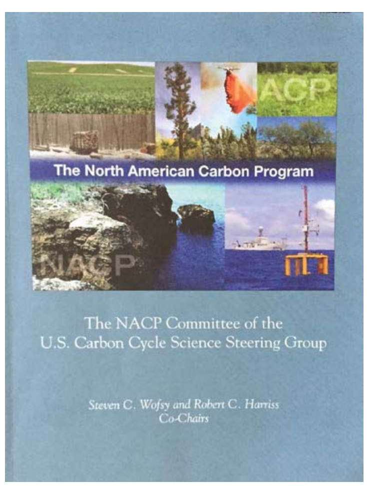
- All of the GGRN CO_2, CH_4, N_2O, SF_6 data are archived and available in ObsPack format
- Near-real time products support OCO-2 retrieval evaluation and data analysis
- GLOBALVIEWplus products are a multi-laboratory community product
- Campaign ObsPacks are available, e.g. ATom, ACT-America

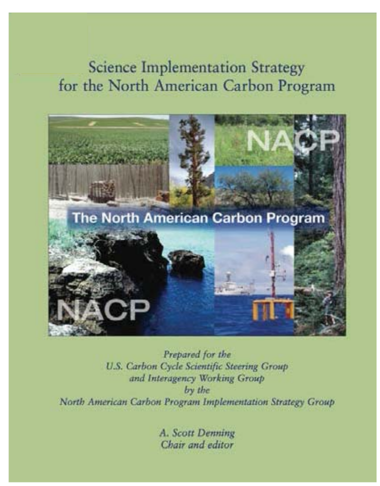


Moving from Global to Regional Scales



North American Carbon Program: A US Inter-Agency Effort





*"Consider uptake of CO_2 due to woody encroachment… 0.12 GtC/yr… spread out over an area the size of Texas, the annual mean decrease of CO_2 in the column would be 0.11 ppm/day…The associated depletion in atmospheric CO_2 over 1000 km could be 0.6 ppm in the lowest 3 km, comparable to the CO_2 from fossil fuels…**A total of 30 sites for North America are anticipated...Vertical profiles should be obtained at frequency of every other day…**"*

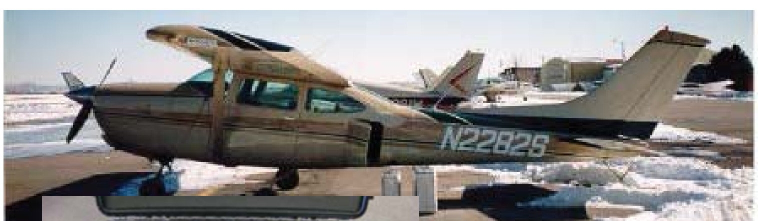
- 0.1 ppm measurement comparability to resolve the signal of important processes

Tall tower in situ and flask sampling

- All NOAA tall tower sites have continuous CO_2 and CO and flask measurements (every other day sampling, $\Delta^{14}CO_2$ 3x per week)
- Three sites also have continuous CH_4
- Additional mountaintop sites have continuous CO_2 and/or flask
- Many partners!

Tall tower program PI: Arlyn Andrews

Aircraft sampling with "Programmable Flask Packages"

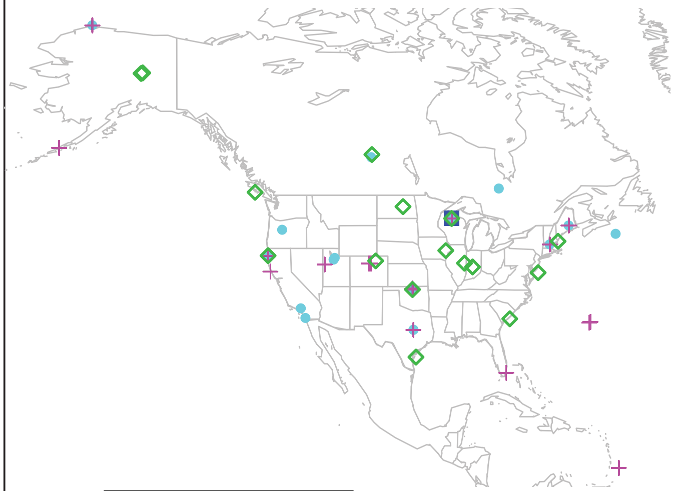


- Nominal schedule 2 flights per month
- Most aircraft max altitude 6000 to 8000 masl
- Twelve flasks per package
- Flasks measured for CO_2, CH_4, CO, N_2O, SF_6, H_2, stable isotopes of CO_2 and sometimes CH_4, $\Delta^{14}CO_2$ (subset of samples), hydrocarbons (recently added ethane!), halocarbons

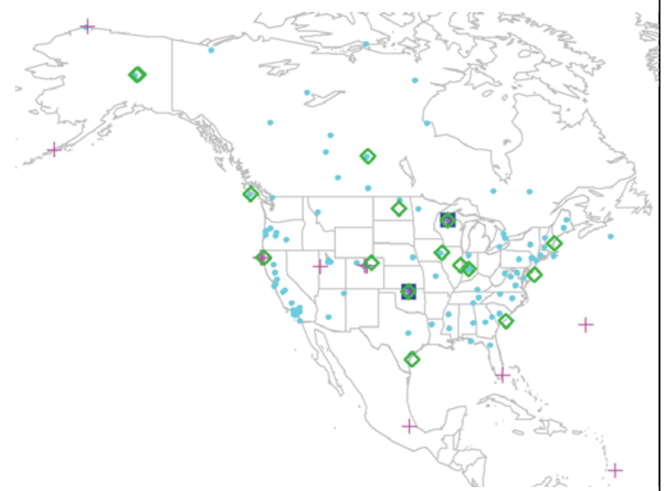
Aircraft program PI: Colm Sweeney

The past decade has seen major expansion of the North American atmospheric carbon observing system:

2005



2015



- weekly flask
- aircraft flask
- surface in situ
- TCCON

- Growth of surface network has exceeded expectations >100 sites in 2015/2016
- NOAA aircraft network: 14 sites profiling once or twice per month up to ~8 km

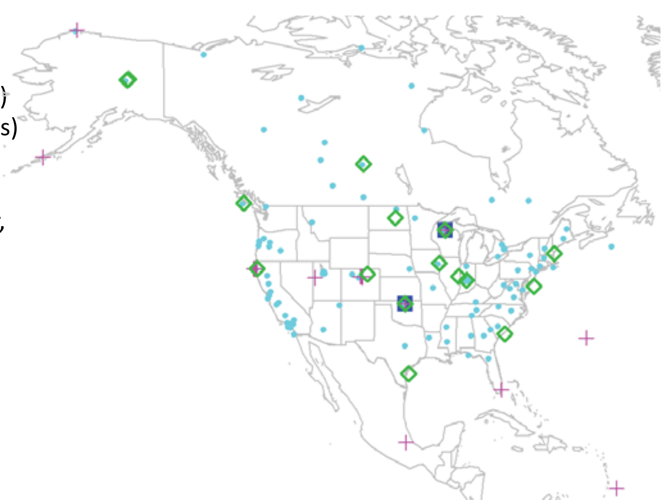
Many different laboratories are providing data, with different levels of quality assurance and stability of funding:

Data Providers

In Situ:
- NOAA Earth System Research Laboratory Global Monitoring Division (A. Andrews, E. Dlugokencky, K. Thoning, C. Sweeney, P. Tans)
- Environment and Climate Change Canada (D. Worthy)
- Penn State University (N. Miles, S. Richardson, K. Davis)
- NCAR (B. Stephens)
- Oregon State University (B. Law, A. Schmidt)
- Lawrence Berkeley National Lab (S. Biraud, M. Fischer, M. Torn)
- Earth Networks (C. Sloop)
- California Air Resources Board (Y. Hsu)
- Harvard University (J. W. Munger, S. Wofsy)
- U of Minnesota (T. Griffis)
- Scripps (J. Kim, R. Keeling, R. Weiss)
- NASA JPL (C. Miller, K Verlhulst)

Remote Sensing:
- TCCON (D. Wunch, P. Wennberg, G. Toon)
- GOSAT-ACOS (C. O'Dell)
- OCO-2 team

2015

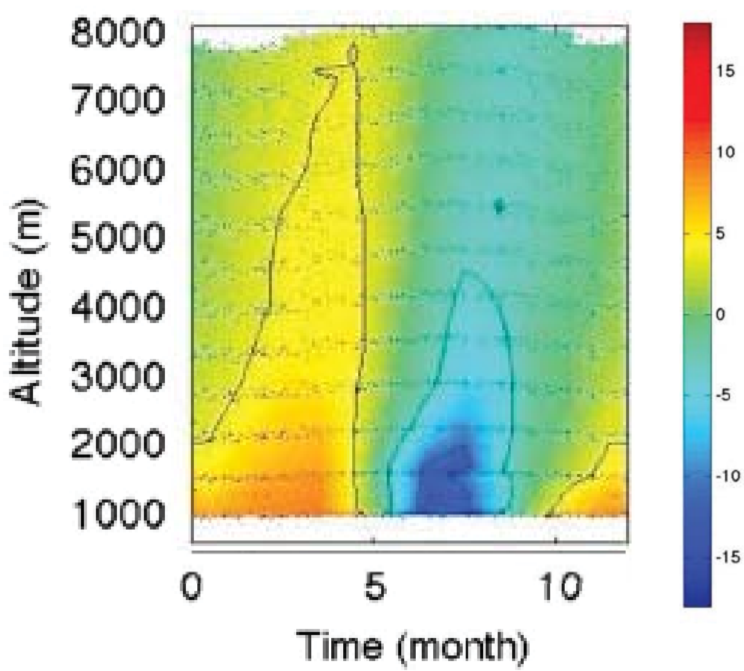


Comparability among datasets is crucial for flux estimation and trend detection.

- weekly flask
- aircraft flask
- surface in situ
- TCCON

What do the data tell us?

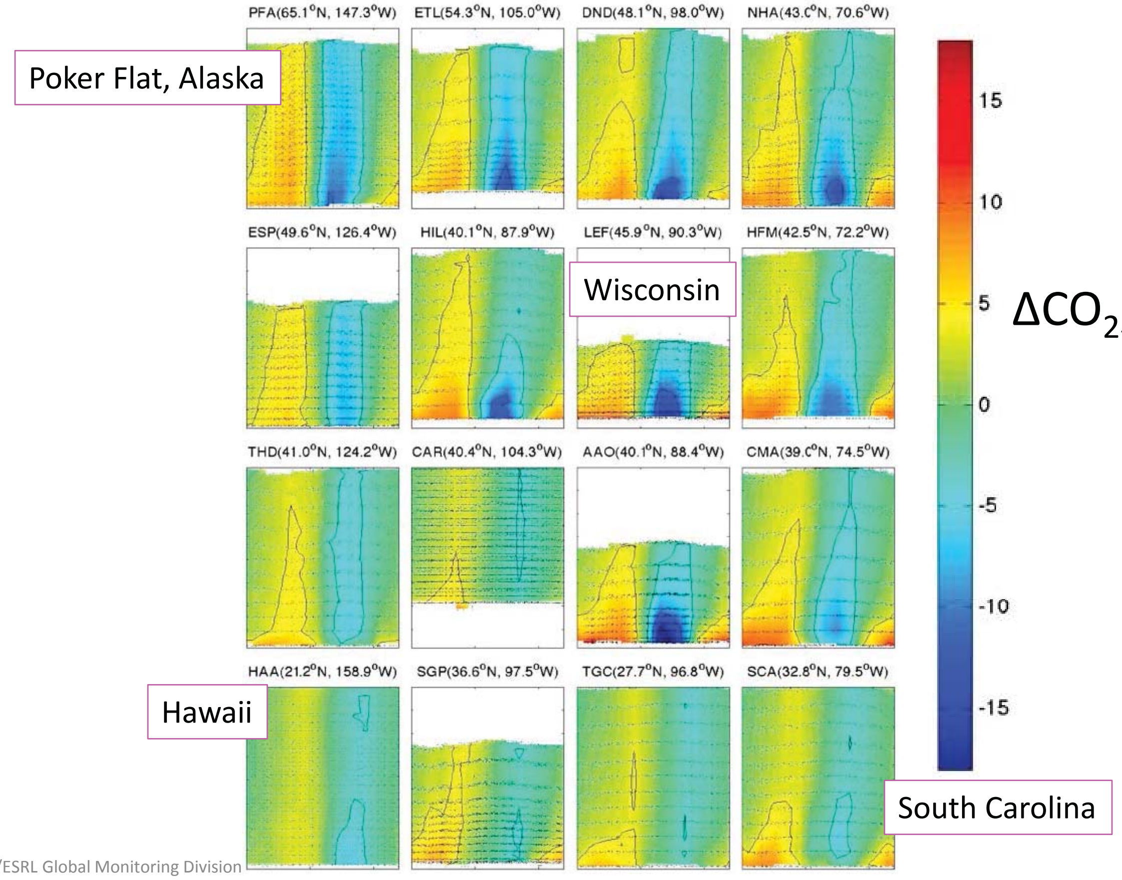
Average Seasonal Cycle of CO_2 above Homer, Illinois:



ΔCO_2, ppm

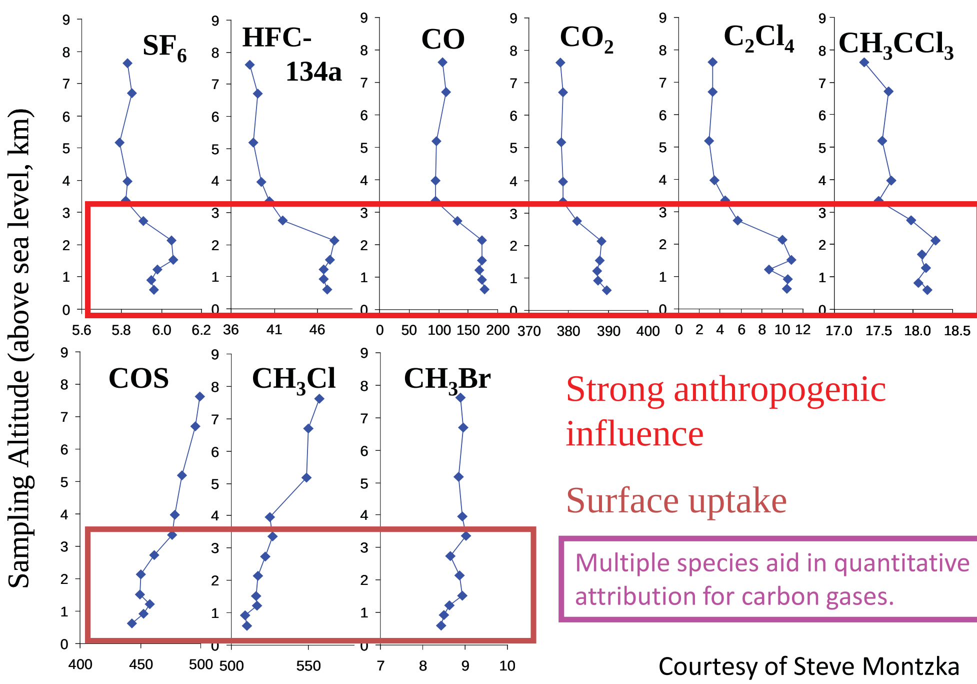
Sweeney et al., JGR, 2015

Annual CO_2 Climatology above North America, from Sweeney et al., JGR, 2015:



Multi-species profiles provide powerful constraints on flux estimates:

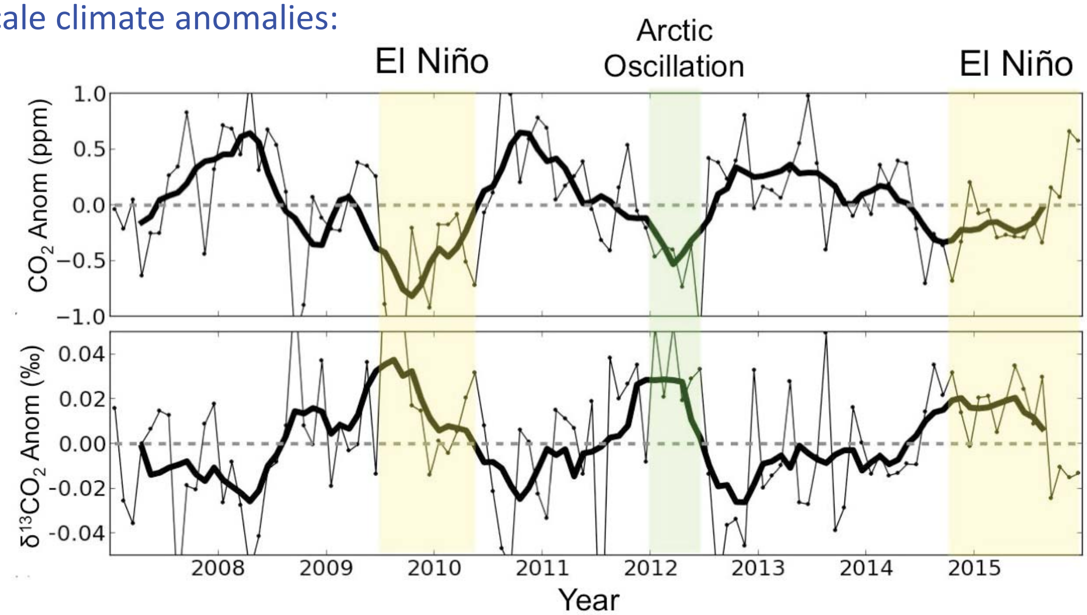
Eastern USA (NHA)
Nov 2005



Multiple species aid in quantitative source attribution for carbon gases.

Courtesy of Steve Montzka

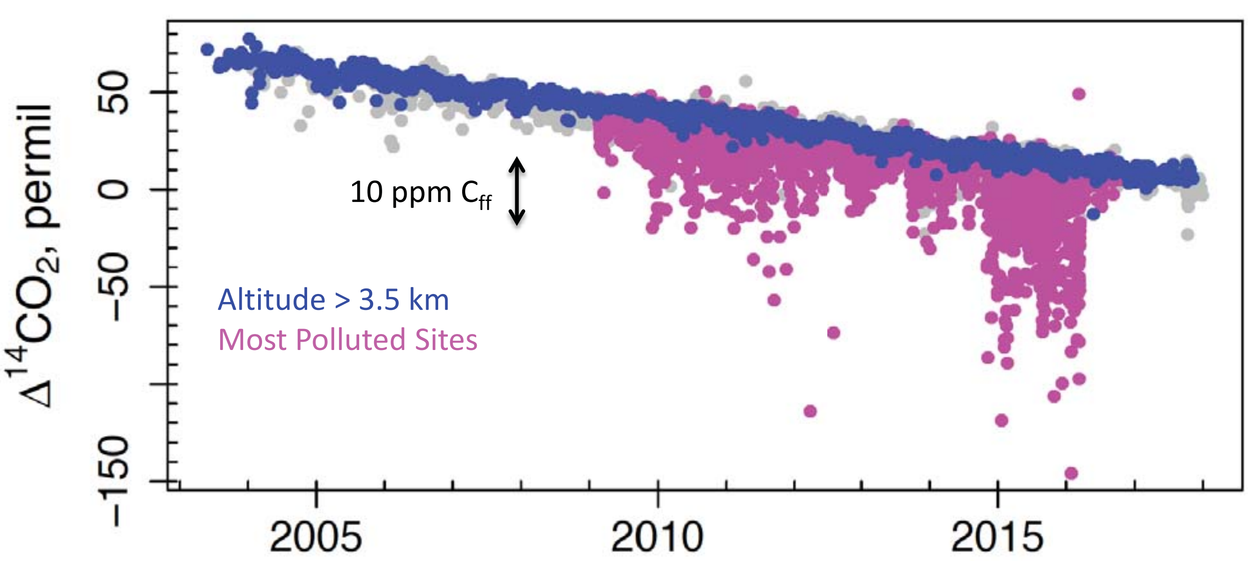
CO_2 and $^{13}CO_2$ anomalies over North America are correlated with large-scale climate anomalies:



- Monthly anomalies (thin lines) of atmospheric CO_2 and $\delta^{13}CO_2$ averaged across North American sampling sites.
- $\delta^{13}CO_2$ provides information about how plants respond to drought stress.

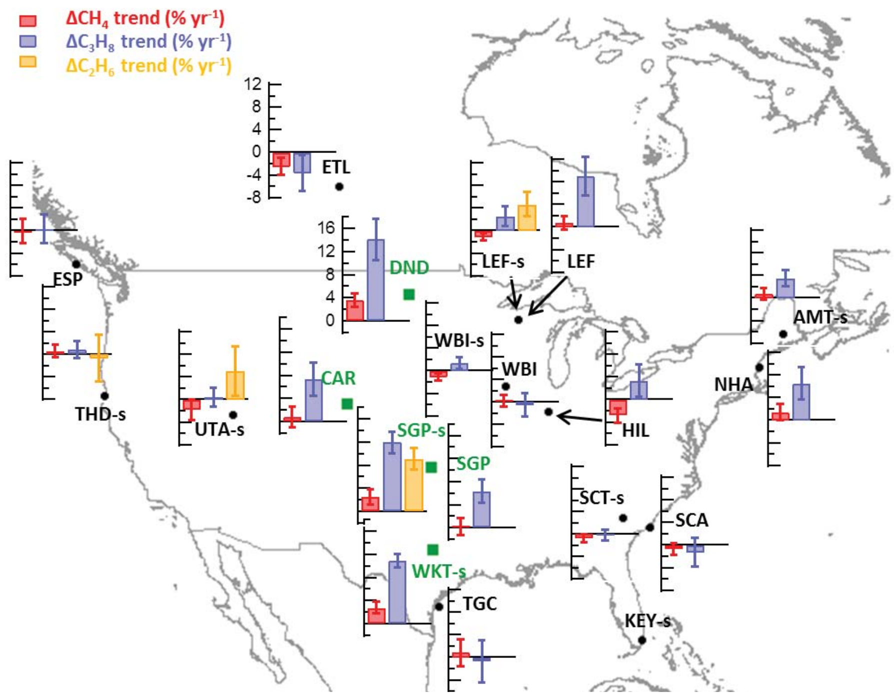
GMAC Talk by Lei Hu
Poster by Ivar van der Velde

Radiocarbon over North America shows decreasing trend due to fossil fuel emissions and local depletion due to local fossil fuel sources:



GMAC Presentations by John Miller and Sourish Basu

Methane and Hydrocarbon trends over North America:



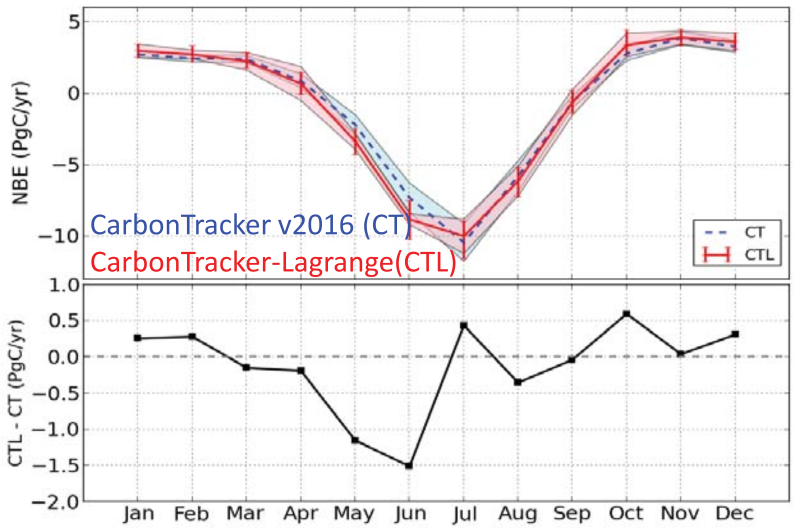
- Methane trends are only observed at a few sites near oil and gas development
- Increasing propane and ethane trends are observed at many sites

GMAC Presentation by Xin Lan

http://www.esrl.noaa.gov/gmd/ccgg/carbontracker-lagrange/

CT Lagrange versus CT2016 Fluxes: Long-term mean

Multi-Year Monthly Averages (2007 – 2015)

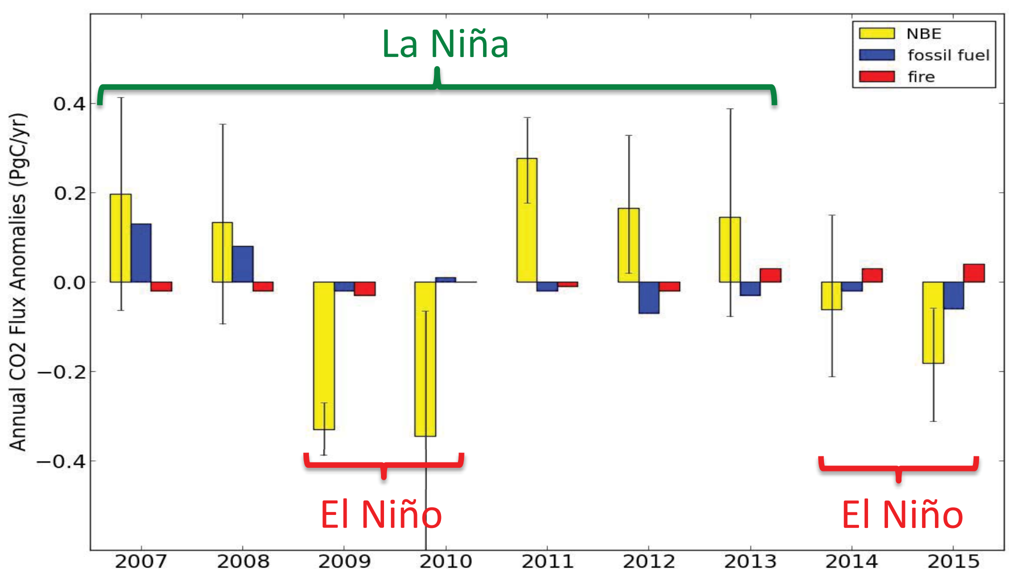


- Net biospheric uptake is similar despite very different atmospheric transport models

CT2016: -0.56±1.29 $PgCyr^{-1}$
CT-L: -0.70±0.92 $PgCyr^{-1}$

GMAC Presentation by Lei Hu

CT-L terrestrial CO_2 fluxes show emergent and persistent response to ENSO



GMAC Presentation by Lei Hu

Research Article

Nitrous oxide emissions estimated with the CarbonTracker-Lagrange North American regional inversion framework

Cynthia Nevison, Arlyn Andrews, Kirk Thoning, Ed Dlugokencky, Colm Sweeney, Scot Miller, Eri Saikawa, Joshua Benmergui, Marc Fischer, Marikate Mountain, Thomas Nehrkorn

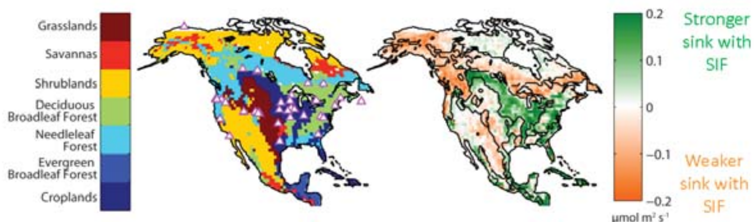
Accepted manuscript online: 1 March 2018 Full publication history

DOI: 10.1002/2017GB005759

Recent papers using the CarbonTracker-Lagrange Framework highlight our close and mutually beneficial relationships with academic researchers.

Atmospheric CO_2 observations reveal strong correlation between regional net biospheric carbon uptake and solar induced chlorophyll fluorescence

Shiga, Y. P., Tadić, J. M., Qiu, X., Yadav, V., Andrews, A. E., Berry, J. A. & Michalak, A. M. (2017) Geophysical Research Letters, 44. https://doi.org/10.1002/2017GL076630



Difference map
No SIF – w/SIF

JGR

RESEARCH ARTICLE

10.1002/2014JD022617

Journal of Geophysical Research: Atmospheres

U.S. emissions of HFC-134a derived for 2008–2012 from an extensive flask-air sampling network

Lei Hu[1,2], Stephen A. Montzka[2], John B. Miller[1,2], Aryln E. Andrews[2], Scott J. Lehman[3], Benjamin R. Miller[1,2], Kirk Thoning[2], Colm Sweeney[1,2], Huilin Chen[4], David S. Godwin[5], Kenneth Masarie[2], Lori Bruhwiler[2], Marc L. Fischer[6], Sebastien C. Biraud[7], Margaret S. Torn[7], Marikate Mountain[8], Th... Janusz Eluszkiewicz[8], Scot Miller[9], Roland R. Draxler[10], Ariel F. Stein[10], Bradley D... James W. Elkins[2], and Pieter P. Tans[2]

PNAS Proceedings of the National Academy of Sciences of the United States of America

Continued emissions of carbon tetrachloride from the United States nearly two decades after its phaseout for dispersive uses

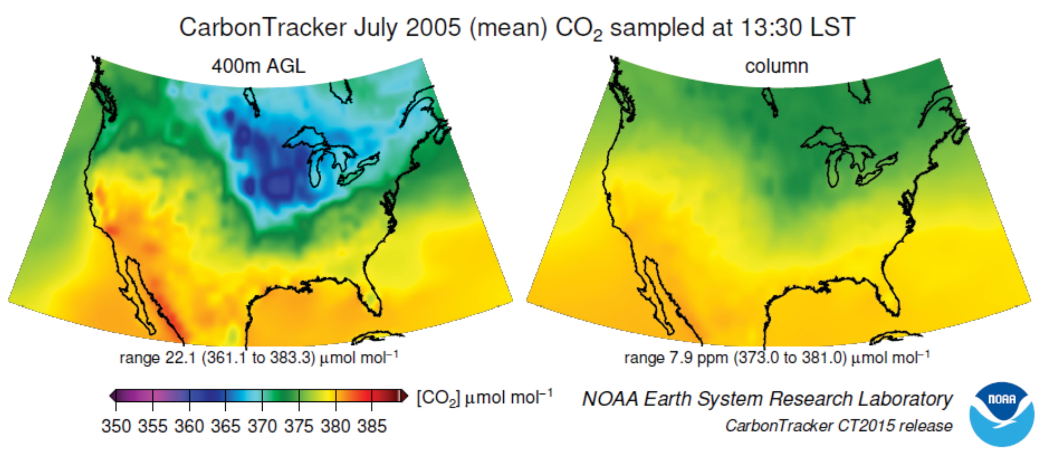
Lei Hu, Stephen A. Montzka, Ben R. Miller, Arlyn E. Andrews, John B. Miller, Scott J. Lehman, Colm Sweeney, Scot M. Miller, Kirk Thoning, Carolina Siso, Elliot L. Atlas, Donald R. Blake, Joost de Gouw, Jessica B. Gilman, Geoff Dutton, James W. Elkins, Bradley Hall, Huilin Chen, Marc L. Fischer, Marikate E. Mountain, Thomas Nehrkorn, Sebastien C. Biraud, Fred L. Moore and Pieter Tans

PNAS March 15, 2016. 113 (11) 2880-2885; published ahead of print February 29, 2016.
https://doi.org/10.1073/pnas.1522284113

We plan to collect top-down emissions estimates from all of these studies and make them available for download.

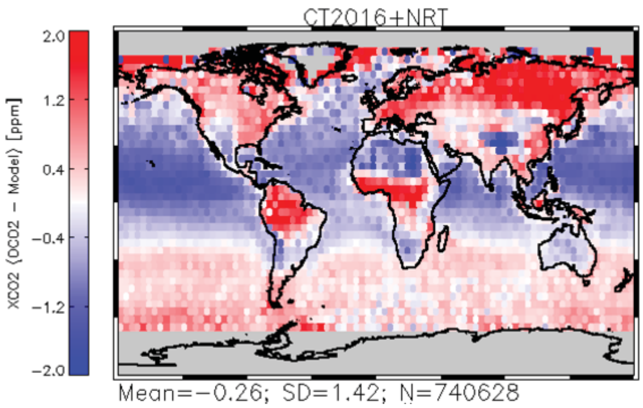
Satellite Retrieval and Model Evaluation

The challenge for satellite column CO_2 sensors:

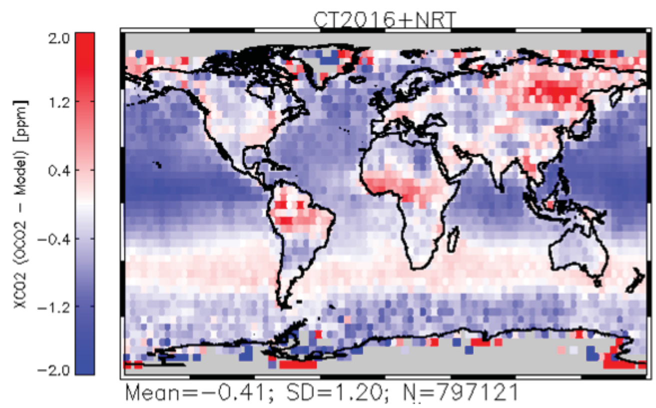


- Mass balance: on average, the total column enhancement of CO_2 downwind of the U.S. is ~0.7 ppm for 1.4 Gton C/yr of emissions.
- For a 20% reduction in emissions, column would change by ~ 0.14 ppm.

OCO-2 Retrieval Evaluation



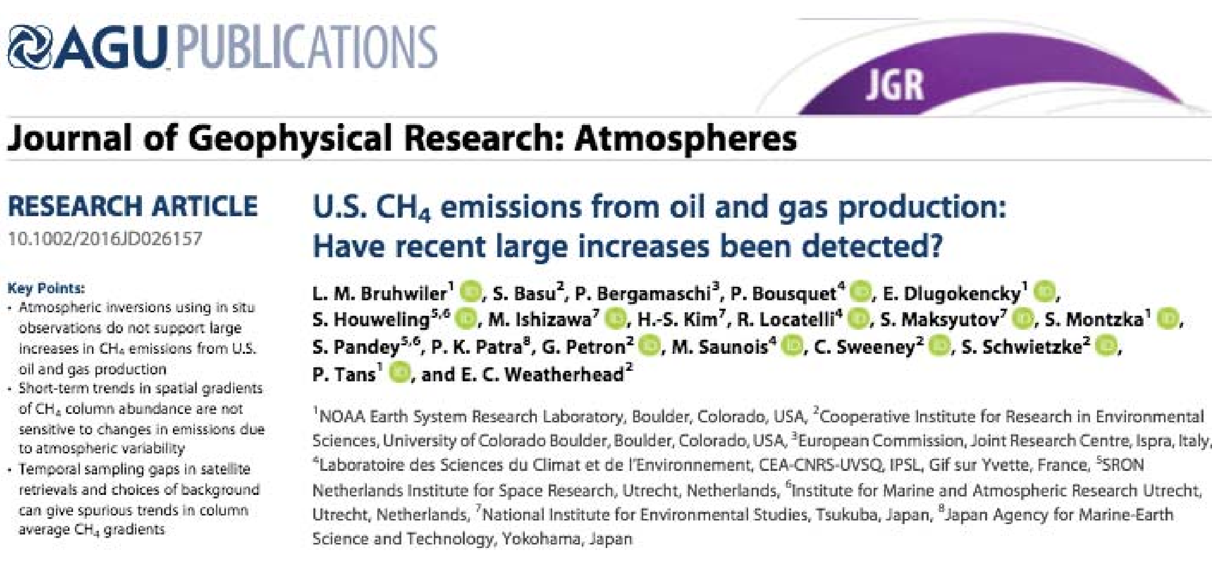
OCO-2 V7



OCO-2 V8

- CarbonTracker-NearRealTime is one of a suite of models used to evaluate and bias-correct OCO-2 retrievals
- CarbonTracker-NRT work is funded by NASA OCO-2 project and enables quick evaluation of retrievals and assessment of information content
- The CarbonTracker Team prepares observations and provides to all the other modeling teams along with information about CarbonTracker data selection and weighting

GMAC Presentation by Andy Jacobson



AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE

10.1002/2016JD026157

Key Points:
- Atmospheric inversions using in situ observations do not support large increases in CH_4 emissions from U.S. oil and gas production
- Short-term trends in spatial gradients of CH_4 column abundance are not sensitive to changes in emissions due to atmospheric variability
- Temporal sampling gaps in satellite retrievals and choices of background can give spurious trends in column average CH_4 gradients

U.S. CH_4 emissions from oil and gas production: Have recent large increases been detected?

L. M. Bruhwiler[1], S. Basu[2], P. Bergamaschi[3], P. Bousquet[4], E. Dlugokencky[1], S. Houweling[5,6], M. Ishizawa[7], H.-S. Kim[7], R. Locatelli[4], S. Maksyutov[7], S. Montzka[1], S. Pandey[5,6], P. K. Patra[8], G. Petron[2], M. Saunois[4], C. Sweeney[2], S. Schwietzke[2], P. Tans[1], and E. C. Weatherhead[2]

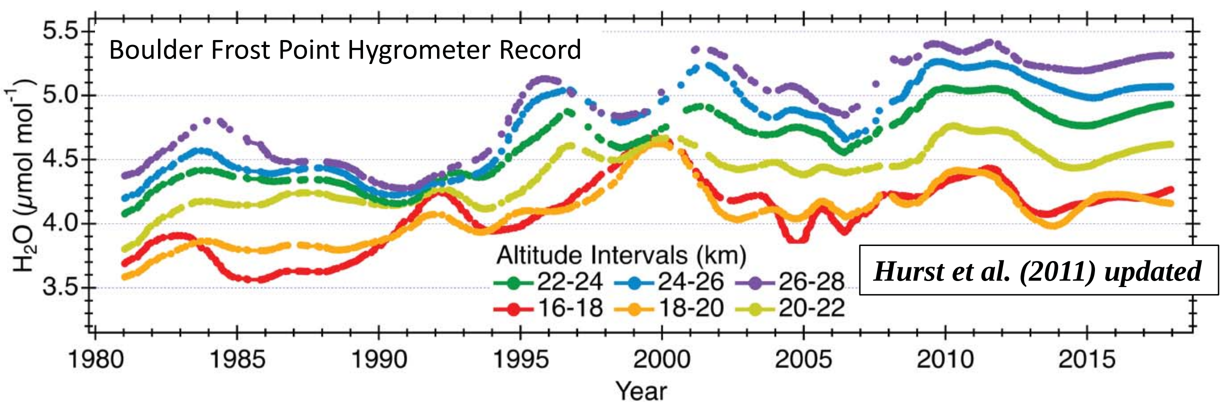
[1]NOAA Earth System Research Laboratory, Boulder, Colorado, USA, [2]Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, Boulder, Colorado, USA, [3]European Commission, Joint Research Centre, Ispra, Italy, [4]Laboratoire des Sciences du Climat et de l'Environnement, CEA-CNRS-UVSQ, IPSL, Gif sur Yvette, France, [5]SRON Netherlands Institute for Space Research, Utrecht, Netherlands, [6]Institute for Marine and Atmospheric Research Utrecht, Utrecht, Netherlands, [7]National Institute for Environmental Studies, Tsukuba, Japan, [8]Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan

- Temporal sampling biases cause apparent relative trends.
- Choice of inappropriate background contributes to spurious trend

Monitoring the Upper Atmosphere

photo credit: Patrick Cullis (patrick.cullis@noaa.gov)

Long-Term Monitoring of Upper Troposphere/Lower Stratosphere (UTLS) Water Vapor



Net increase in UTLS water vapor: Positive climate forcing feedback

- Strong absorber of outgoing long wave radiation, weak thermal emission to space
- Climate change warms the tropical tropopause layer, increasing UTLS water vapor
- Additional UTLS water vapor absorbs more outgoing long wave radiation

Changes in UTLS water vapor have a significant impact on surface temperatures

- The ~1 mmol mol^{-1} (~25%) increase in [UTLS water vapor] between 1980 and 2000 would have enhanced the rate of surface warming in the 1990s by ~30% ***Solomon et al. (2010)***

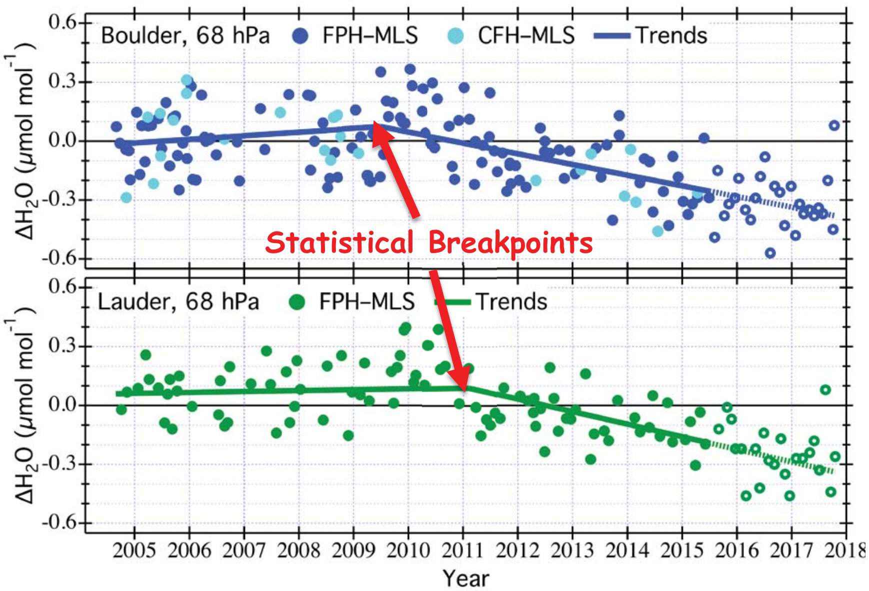
GMAC Presentation by Dale Hurst

Long-Term Monitoring of UTLS Water Vapor

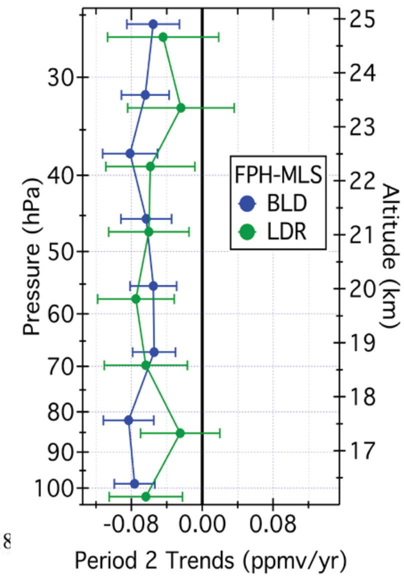
Validation of Satellite-Based Measurements

Satellite-based instruments provide near-global coverage but are
susceptible to biases and/or drifts in their measurements

Differences in Coincident Measurements: FPH-MLS

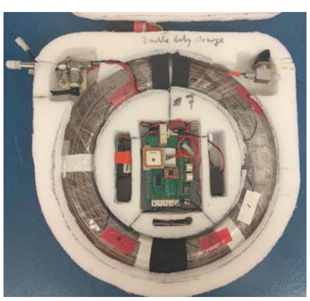


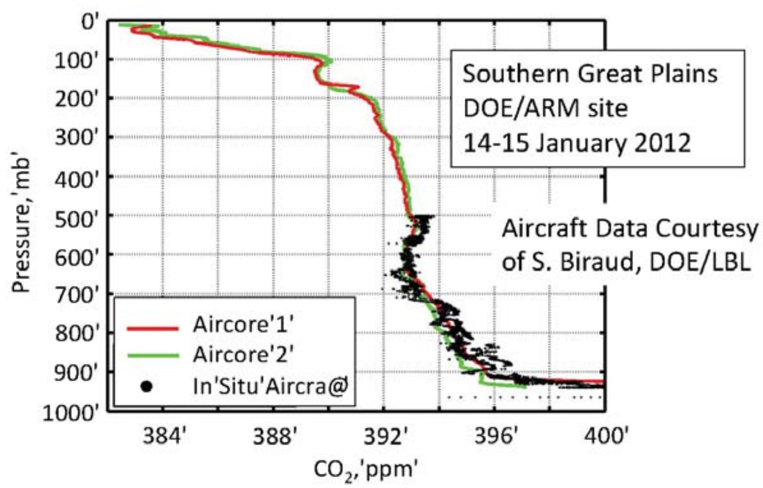
Post-breakpoint Trends



updated from Hurst et al. (2016)

AirCore for Surface to Stratosphere GHG Sampling: CO_2, CH_4, CO





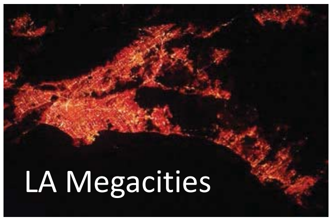
- > 70 flights starting in 2012
  - New twin AirCore provides paired sampling to ensure repeatabilty
- OCO-2 Science Team
  - Direct comparison with TCCON & OCO-2 underflights
  - Improved stratospheric prior
- Analysis of stratospheric Mean Age as a tracer of the Brewer-Dobson circulation
- Evaluation of stratospheric simulations in CarbonTracker and other models

Intensive Field Campaigns & Capacity Building

GMD Participation in Intensive Measurement Campaigns Leverages and Complements our Monitoring Efforts

ECO

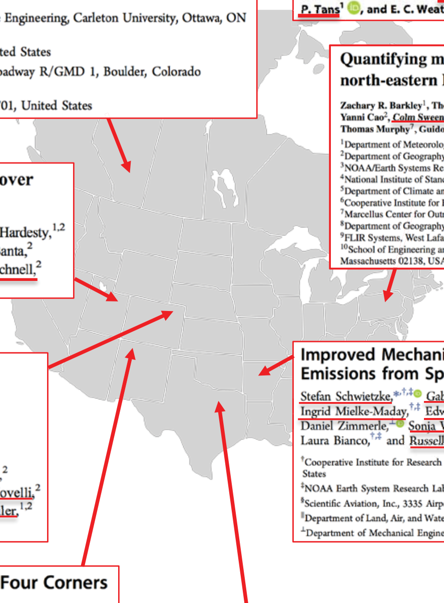
East Coast Outflow



ORCAS

O_2/N_2 Ratio and CO_2 Airborne Southern Ocean Study 2016

GMD's footprint on oil & gas methane research in N. America



Comparisons of Airborne Measurements and Inventory Estimates of Methane Emissions in the Alberta Upstream Oil and Gas Sector

Matthew R. Johnson,[*,†] David R. Tyner,[†] Stephen Conley,[‡] Stefan Schwietzke,[§] and Daniel Zavala-Araiza[‖]

[†]Energy & Emissions Research Laboratory, Department of Mechanical and Aerospace Engineering, Carleton University, Ottawa, ON Canada, K1S 5B6
[‡]Scientific Aviation, Inc., 3335 Airport Road Suite B, Boulder, Colorado 80301, United States
[§]CIRES/University of Colorado, NOAA ESRL Global Monitoring Division, 325 Broadway R/GMD 1, Boulder, Colorado 80305-3337, United States
[‖]Environmental Defense Fund, 301 Congress Avenue Suite 1300, Austin, Texas 78701, United States

U.S. CH_4 emissions from oil and gas production: Have recent large increases been detected?

L. M. Bruhwiler[1], S. Basu[2], P. Bergamaschi[3], P. Bousquet[4], E. Dlugokencky[1], S. Houweling[5,6], M. Ishizawa[7], H.-S. Kim[7], R. Locatelli[4], S. Maksyutov[7], S. Montzka[1], S. Pandey[5,6], P. K. Patra[8], G. Petron[2], M. Saunois[4], C. Sweeney[2], S. Schwietzke[2], P. Tans[1], and E. C. Weatherhead[2]

Quantifying methane emissions from natural gas production in north-eastern Pennsylvania

Zachary R. Barkley[1], Thomas Lauvaux[1], Kenneth J. Davis[1], Aijun Deng[1], Natasha L. Miles[1], Scott J. Richardson[1], Yanni Cao[2], Colm Sweeney[3], Anna Karion[4], MacKenzie Smith[5], Eric A. Kort[6], Stefan Schwietzke[6], Thomas Murphy[7], Guido Cervone[8], Douglas Martins[9], and Joannes D. Maasakkers[10]

[1]Department of Meteorology, The Pennsylvania State University, University Park, PA 16802, USA
[2]Department of Geography, The Pennsylvania State University, University Park, PA 16802, USA
[3]NOAA/Earth Systems Research Laboratory, University of Colorado, Boulder, CO, 80305, USA
[4]National Institute of Standards and Technology, Gaithersburg, MD 20899, USA
[5]Department of Climate and Space Sciences and Engineering, University of Michigan, Ann Arbor, MI, 48109, USA
[6]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, Colorado, USA
[7]Marcellus Center for Outreach and Research, The Pennsylvania State University, University Park, PA 16802, USA
[8]Department of Geography, The Pennsylvania State University, University Park, PA 16802, USA
[9]FLIR Systems, West Lafayette, IN 47906, USA
[10]School of Engineering and Applied Sciences, Harvard University, Pierce Hall, 29 Oxford Street, Cambridge, Massachusetts 02138, USA

Methane emissions estimate from airborne measurements over a western United States natural gas field

Anna Karion,[1,2] Colm Sweeney,[1,2] Gabrielle Pétron,[1,2] Gregory Frost,[1,2] R. Michael Hardesty,[1,2] Jonathan Kofler,[1,2] Ben R. Miller,[1,2] Tim Newberger,[1,2] Sonja Wolter,[1,2] Robert Banta,[2] Alan Brewer,[2] Ed Dlugokencky,[2] Patricia Lang,[2] Stephen A. Montzka,[2] Russell Schnell,[2] Pieter Tans,[2] Michael Trainer,[2] Robert Zamora,[2] and Stephen Conley[3]

Improved Mechanistic Understanding of Natural Gas Methane Emissions from Spatially Resolved Aircraft Measurements

Stefan Schwietzke,[*,†,‡] Gabrielle Pétron,[†,‡] Stephen Conley,[§,‖] Cody Pickering,[⊥] Ingrid Mielke-Maday,[†,‡] Edward J. Dlugokencky,[‡] Pieter P. Tans,[‡] Tim Vaughn,[⊥] Clay Bell,[⊥] Daniel Zimmerle,[⊥] Sonja Wolter,[†,‡] Clark W. King,[‡] Allen B. White,[‡] Timothy Coleman,[†,‡] Laura Bianco,[†,‡] and Russell C. Schnell[‡]

[†]Cooperative Institute for Research in Environmental Sciences, University of Colorado, 216 UCB, Boulder, Colorado 80309, United States
[‡]NOAA Earth System Research Laboratory, 325 Broadway, Boulder, Colorado 80305, United States
[§]Scientific Aviation, Inc., 3335 Airport Road Suite B, Boulder, Colorado 80301, United States
[‖]Department of Land, Air, and Water Resources, University of California, One Shields Avenue, Davis, California 95616, United States
[⊥]Department of Mechanical Engineering, Colorado State University, 400 Isotope Dr, Fort Collins, Colorado 80521, United States

Hydrocarbon emissions characterization in the Colorado Front Range: A pilot study

Gabrielle Pétron,[1,2] Gregory Frost,[1,2] Benjamin R. Miller,[1,2] Adam I. Hirsch,[1,3] Stephen A. Montzka,[2] Anna Karion,[1,2] Michael Trainer,[2] Colm Sweeney,[1,2] Arlyn E. Andrews,[2] Lloyd Miller,[4] Jonathan Kofler,[1,2] Amnon Bar-Ilan,[5] Ed J. Dlugokencky,[2] Laura Patrick,[1,2] Charles T. Moore Jr.,[6] Thomas B. Ryerson,[2] Carolina Siso,[1,2] William Kolodzey,[7] Patricia M. Lang,[2] Thomas Conway,[2] Paul Novelli,[2] Kenneth Masarie,[2] Bradley Hall,[2] Douglas Guenther,[1,2] Duane Kitzis,[1,2] John Miller,[1,2] David Welsh,[2] Dan Wolfe,[2] William Neff,[2] and Pieter Tans[2]

Airborne Quantification of Methane Emissions over the Four Corners Region

Mackenzie L. Smith,[†] Alexander Gvakharia,[†] Eric A. Kort,[*,†] Colm Sweeney,[‡,§] Stephen A. Conley,[‖,⊥] Ian Faloona,[⊥] Tim Newberger,[‡,§] Russell Schnell,[§] Stefan Schwietzke,[‡,§] and Sonja Wolter[‡,§]

[†]Climate and Space Sciences and Engineering, University of Michigan, Ann Arbor, Michigan 48109, United States
[‡]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, Colorado 80309, United States
[§]NOAA Earth System Research Laboratory, Boulder, Colorado 80305, United States
[‖]Scientific Aviation, Boulder, Colorado 80301, United States
[⊥]Department of Land, Air, & Water Resources, University of California Davis, Davis, California 95616, United States

Aircraft-Based Estimate of Total Methane Emissions from the Barnett Shale Region

Anna Karion,[*,†,‡] Colm Sweeney,[†,‡] Eric A. Kort,[§] Paul B. Shepson,[‖] Alan Brewer,[‡] Maria Cambaliza,[‖,△] Stephen A. Conley,[⊥] Ken Davis,[#] Aijun Deng,[#] Mike Hardesty,[†,‡] Scott C. Herndon,[∇] Thomas Lauvaux,[#] Tegan Lavoie,[‖] David Lyon,[○] Tim Newberger,[†,‡] Gabrielle Pétron,[†,‡] Chris Rella,[◆] Mackenzie Smith,[$] Sonja Wolter,[†,‡] Tara I. Yacovitch,[∇] and Pieter Tans[‡]

Brazilian Replica of the NOAA Flask Analysis Lab:

Lab. de Química Atmosférica CQMA/IPEN
Réplica do Laboratório da NOAA/ESRL/GMD
(National Oceanic Atmospheric Administration / Earth System Research Laboratory / Global Monitoring Division)

Luciana V. Gatti , Andrew Crotwell, Kirk Thoning, Ed Dlugokencky, John B. Miller , and many others

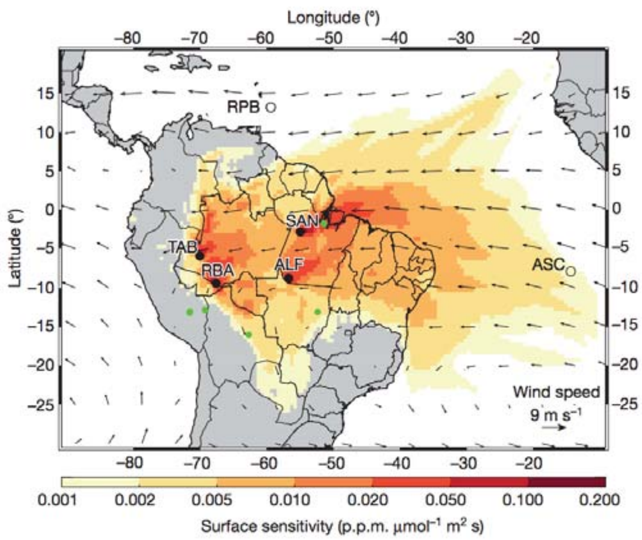
LETTER

doi:10.1038/nature12957

Drought sensitivity of Amazonian carbon balance revealed by atmospheric measurements

L. V. Gatti[1]*, M. Gloor[2]*, J. B. Miller[3,4]*, C. E. Doughty[5], Y. Malhi[5], L. G. Domingues[1], L. S. Basso[1], A. Martinewski[1], C. S. C. Correia[1], V. F. Borges[1], S. Freitas[6], R. Braz[6], L. O. Anderson[5,7], H. Rocha[8],

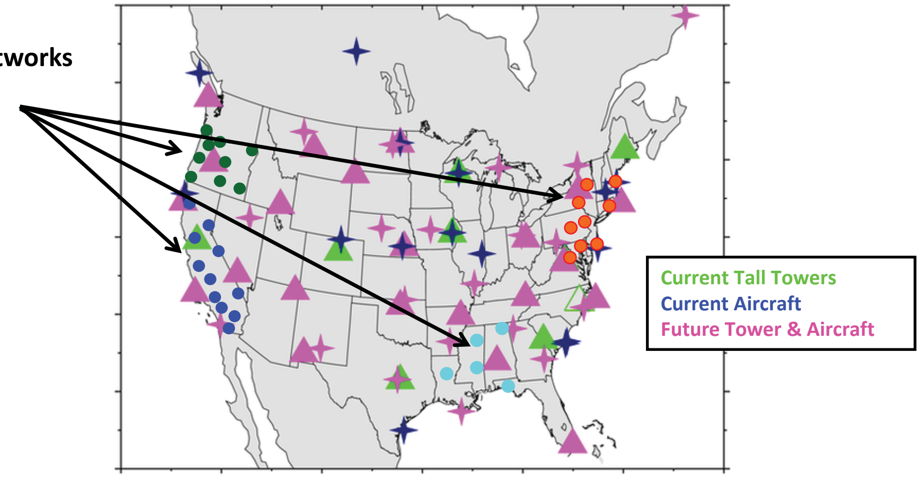
10+ year collaboration has enabled creation of aircraft network and new insights into Amazonian fluxes.



Looking forward

1) Develop Partnerships and Links with Regional Networks

Regional networks



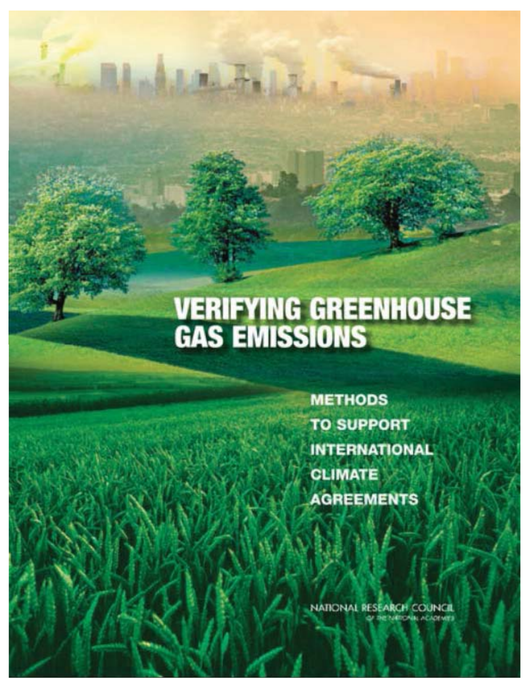
- Obtaining tower leases through the federal government is cost prohibitive and slow. Better to work with partners whenever possible.
- Opportunities exist to strengthen ties with regional monitoring efforts already underway: California Air Resources Board, Earth Networks, Baltimore/DC, Oregon State University, Penn State University

2) Increase radiocarbon sampling to constrain estimates of fossil fuel CO_2 emissions

Separation of biospheric and fossil fuel fluxes of CO_2 by atmospheric inversion of CO_2 and $^{14}CO_2$ measurements: Observation System Simulations

Sourish Basu[1,2], John Bharat Miller[1,2], and Scott Lehman[3]
[1]Global Monitoring Division, NOAA Earth System Research Laboratory, Boulder CO, USA
[2]Cooperative Institute for Research in Environmental Science, University of Colorado, Boulder CO, USA
[3]Institute for Arctic and Alpine Research, University of Colorado Boulder, Boulder CO, USA

Atmos. Chem. Phys., 16, 5665–5683, 2016
www.atmos-chem-phys.net/16/5665/2016/
doi:10.5194/acp-16-5665-2016

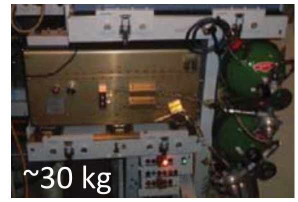


GMAC Presentations by Sourish Basu

3) Commercial Aircraft Measurements of CO_2, CH_4 and H_2O

Japanese and European programs already exist for a limited number of long-haul aircraft (5 CONTRAIL and 10 IAGOS aircraft):

IAGOS
$CO_2/CH_4/H_2O$ Analyzer:



The US National Weather Service has a regional commercial aircraft program to measure water vapor:

3.5 kg

137 aircraft
>1000 profiles per day

These systems use 10-20 year old technology. A next-generation commercial aircraft greenhouse gas analyzer would provide reliable measurements in a lightweight and compact package for deployment on regional jets.

*Route maps shown are examples only to illustrate what type of coverage is possible. The airlines have not been contacted with regard to this project.

Science Priorities

Vulnerable Carbon Reservoirs
- Arctic: Track Emissions from Permafrost Release
- Amazon: Monitor Uptake from Tropical Forests

Carbon Accounting for Decision Support
- CONUS

Estimated Cost: < $10M per year

5 year goal: Implementation on 10 aircraft covering CONUS and Alaska
10 year goal: Establish international partnerships to extend coverage over Arctic and Amazon.

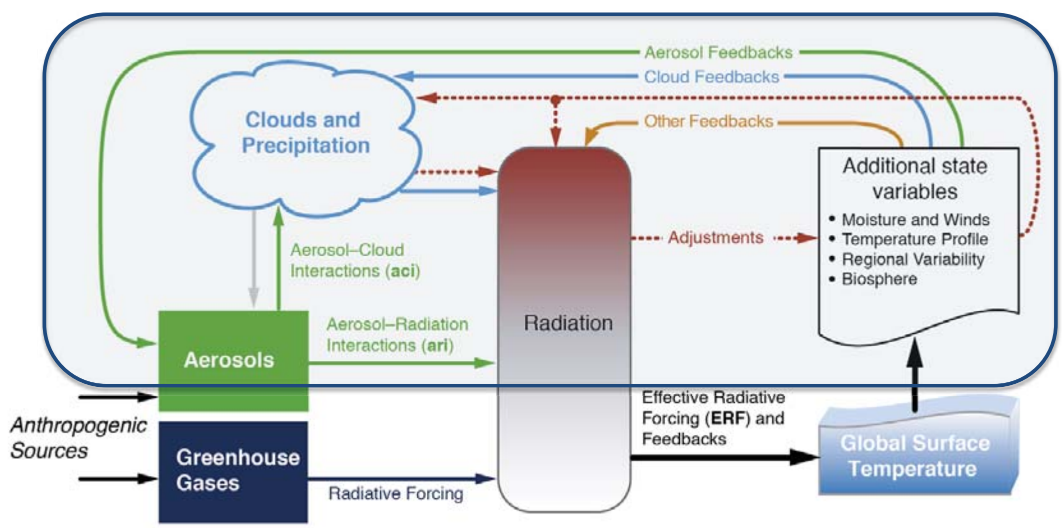
GMD's Role in an Integrated Multi-platform Greenhouse Gas Observing System

Take Home Messages

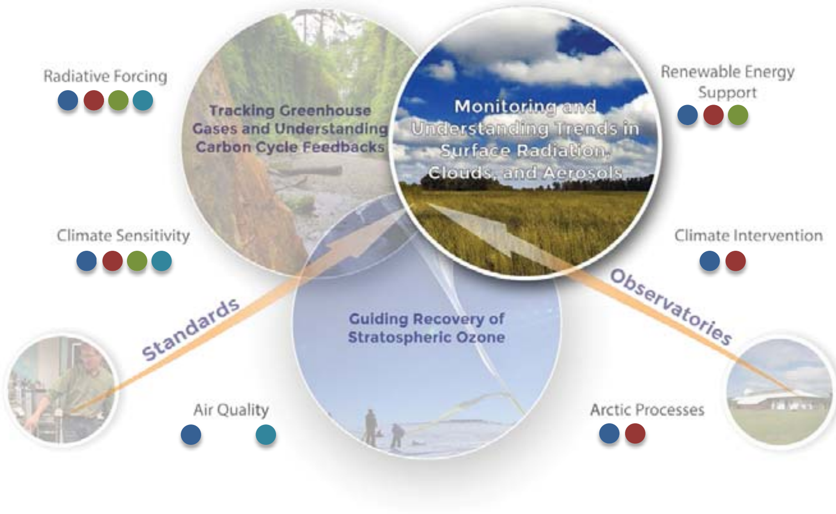
- We are creating an unassailable and well-documented record of greenhouse gases.
- We try to help society deal with the climate problem:
  - *Create a quantitative record of climate forcing.*
  - *Quantify and diagnose the response of the natural carbon cycle and greenhouse gas budgets to climate change.*
  - *Evaluate potential "surprises" and give early warning if warranted.*
  - *Support mitigation by providing objective and transparent verification of emissions.*
- Close relationships between measurers and modelers have kept us at the forefront of carbon science and are crucial to continued success.
- NOAA anchors the global and US atmospheric carbon observing network. We established multiple comparisons with Environment Canada, Earth Networks and university researchers. We rely on partnerships with other labs and institutions.
- We have just begun to reap the scientific rewards of our investment in North American monitoring – multiple-species analysis will provide critical process constraints and enable improved source attribution.

Monitoring and Understanding Trends in Surface Radiation, Clouds, and Aerosols

Monitoring and Understanding Trends in Surface Radiation, Clouds, and Aerosols



Monitoring and Understanding Trends in Surface Radiation, Clouds, and Aerosols



monitoring changes | process understanding | model development | satellite evaluation

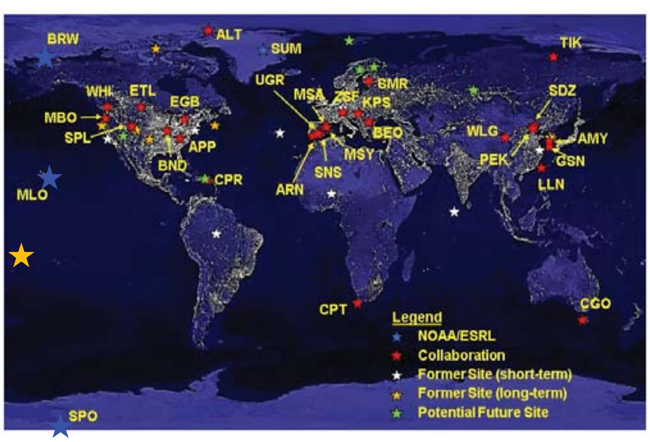
GMD Measurement Networks for Radiation, Clouds, and Aerosols

Sheridan – P-53

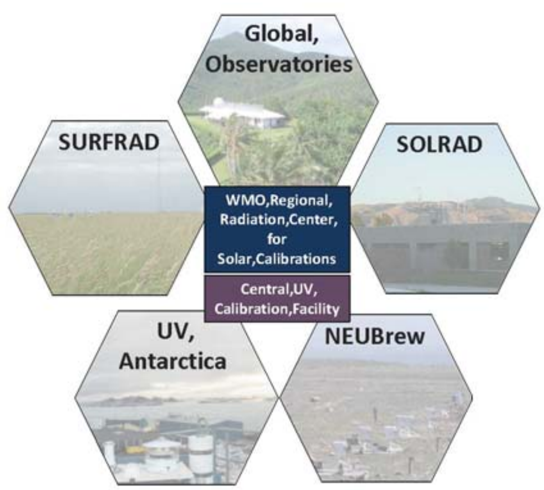
Hall, B. – overview
Hall, E. – P-40

The NOAA Federated Aerosol Network

'A collaborative effort that benefits all parties'



Global Surface Radiation Networks



monitoring changes | process understanding | model development | satellite evaluation

GMD Measurement Networks for Radiation, Clouds, and Aerosols

Broadband Shortwave and Longwave Radiation Networks

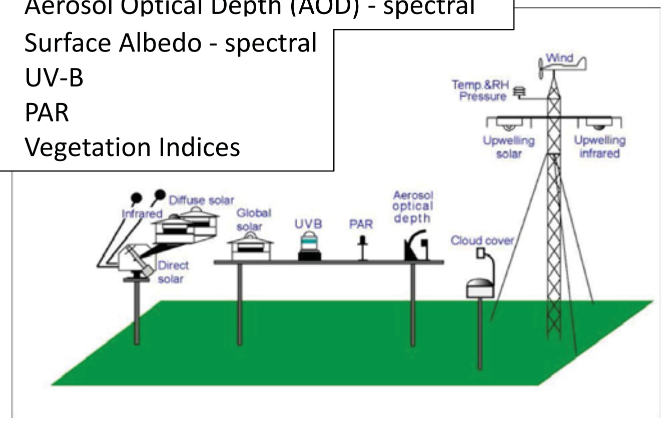
Global,
regionally representative

Continental U.S.,
regionally representative

Continental U.S.,
urban environment

Properties – Measured and Derived:

- Surface Radiation Budget - components
- Sky Cover/Cloud Fraction
- Cloud Optical Depth (overcast)
- Cloud Radiative Effect
- Aerosol Optical Depth (AOD) - spectral
- Surface Albedo - spectral
- UV-B
- PAR
- Vegetation Indices



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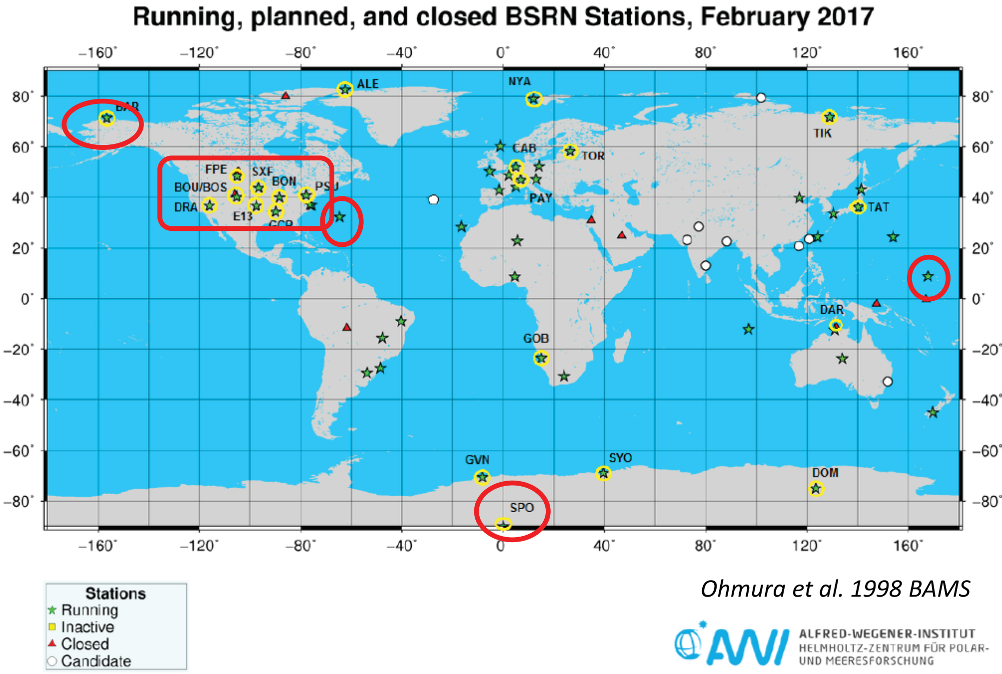
WCRP Baseline Surface Radiation Network (BSRN)



12 stations of 59 directly operated by NOAA ESRL GMD, the largest single contributing organization

Support measurements at an additional 9 sites

GMD is associated with 21 of the 59 sites that have contributed to the BSRN Archive (35%)

Ohmura et al. 1998 BAMS

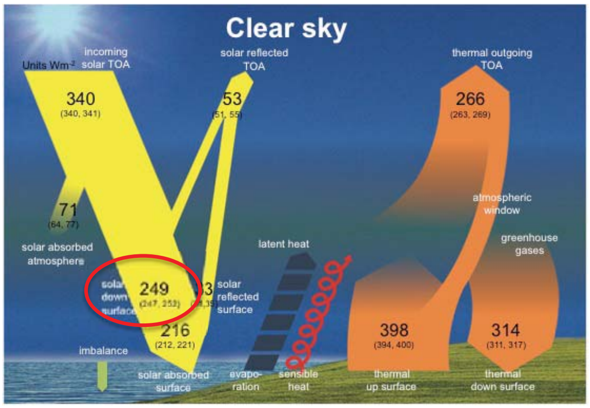
ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

monitoring changes | process understanding | model development | satellite evaluation

Long – Session 3

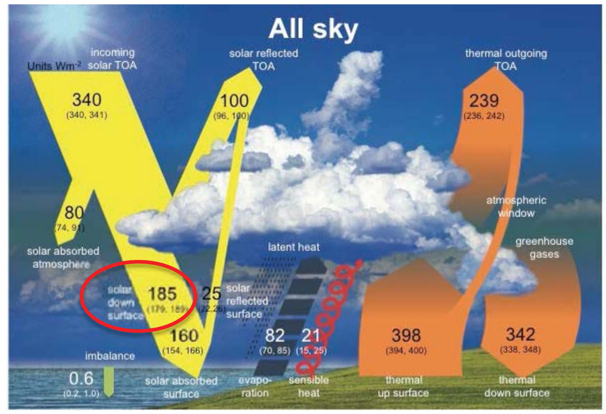
WCRP Baseline Surface Radiation Network (BSRN)

Global All- and Clear-sky Estimates using Observations and Models



New estimates for global mean radiation budget without cloud effects

Wild et al. submitted



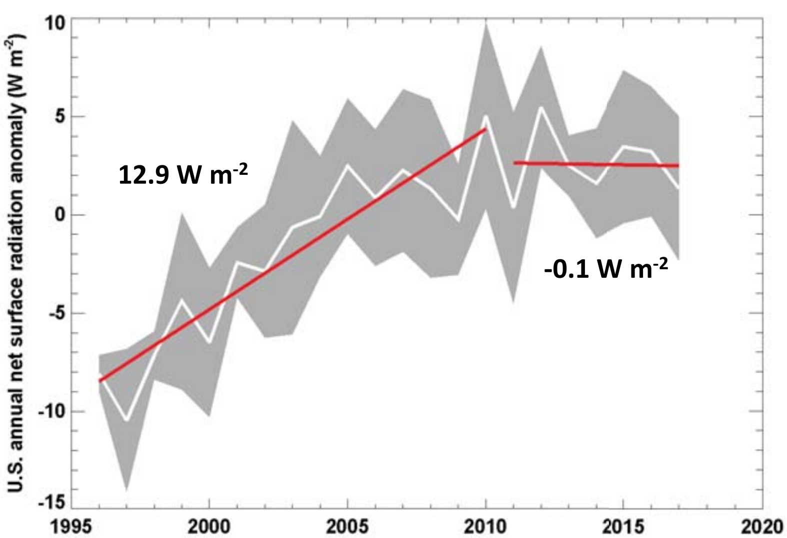
Combined with all sky budgets provides **estimation of global mean surface, atmosphere, and TOA cloud radiative effects**

Wild et al. 2015 Clim. Dyn.

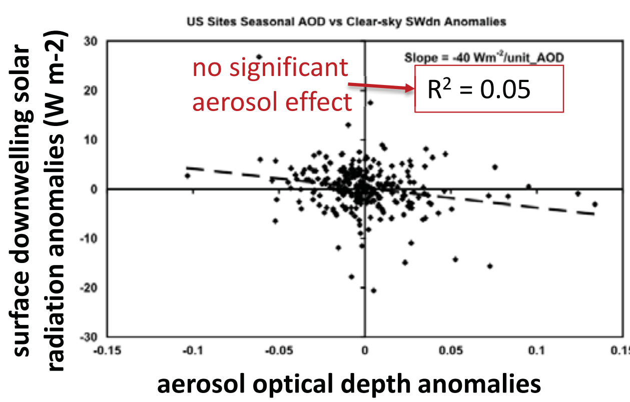
monitoring changes | **process understanding** | model development | satellite evaluation

Augustine – Session 3

Surface Radiation Variability over the U.S.



updated from Augustine and Dutton 2013 JGR

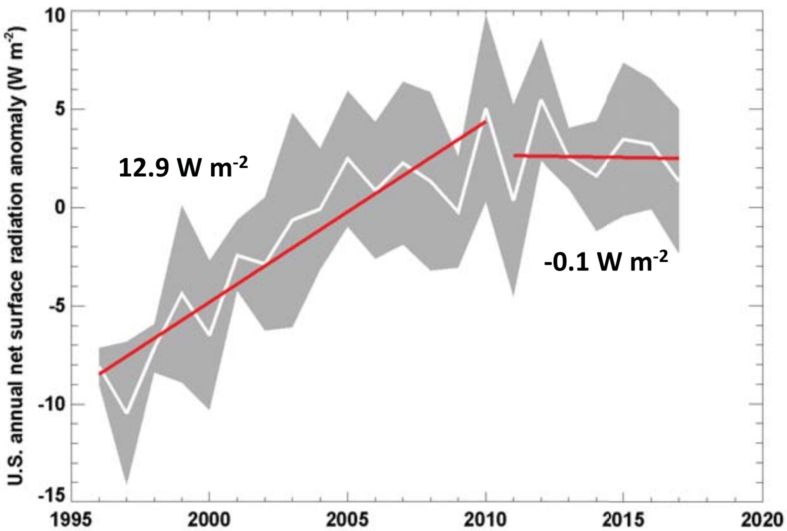


Long et al 2009 JGR

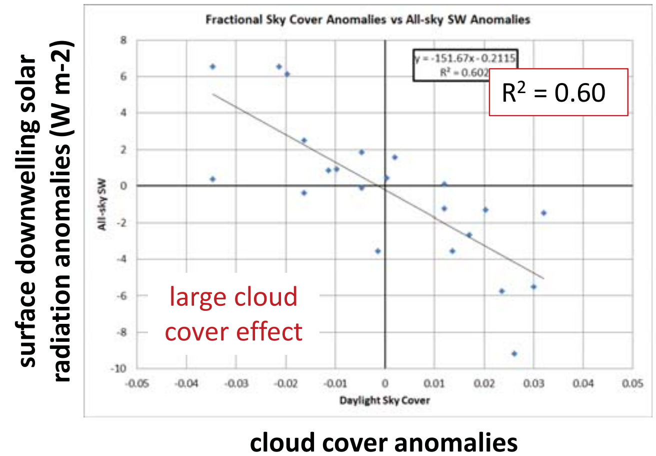
monitoring changes | **process understanding** | model development | satellite evaluation

Augustine – Session 3

Surface Radiation Variability over the U.S.

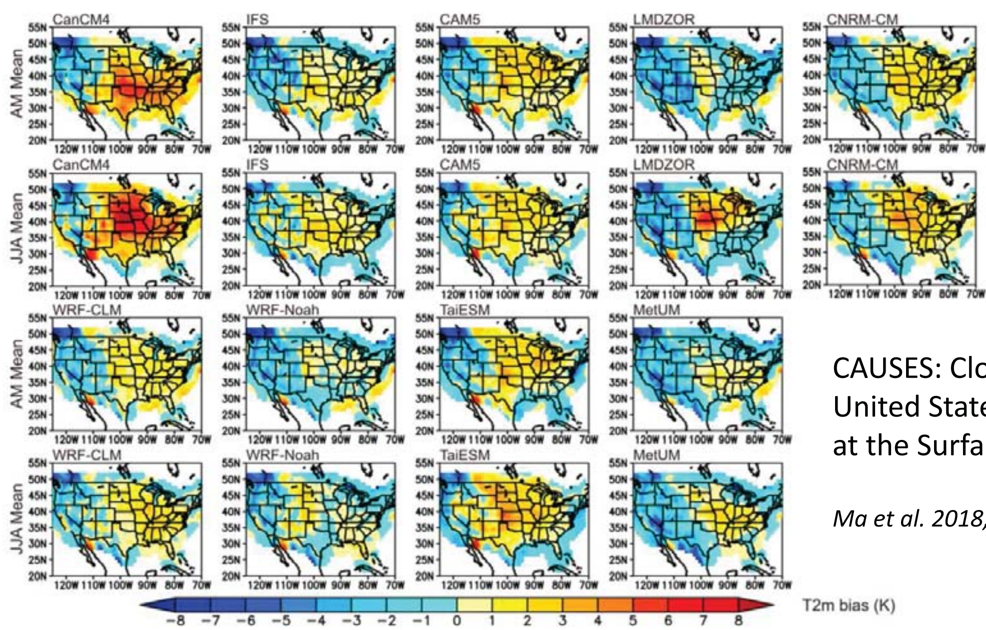


updated from Augustine and Dutton 2013 JGR



monitoring changes | **process understanding** | model development | satellite evaluation

Persistent Model Biases – Relationships to Surface Radiation Budget

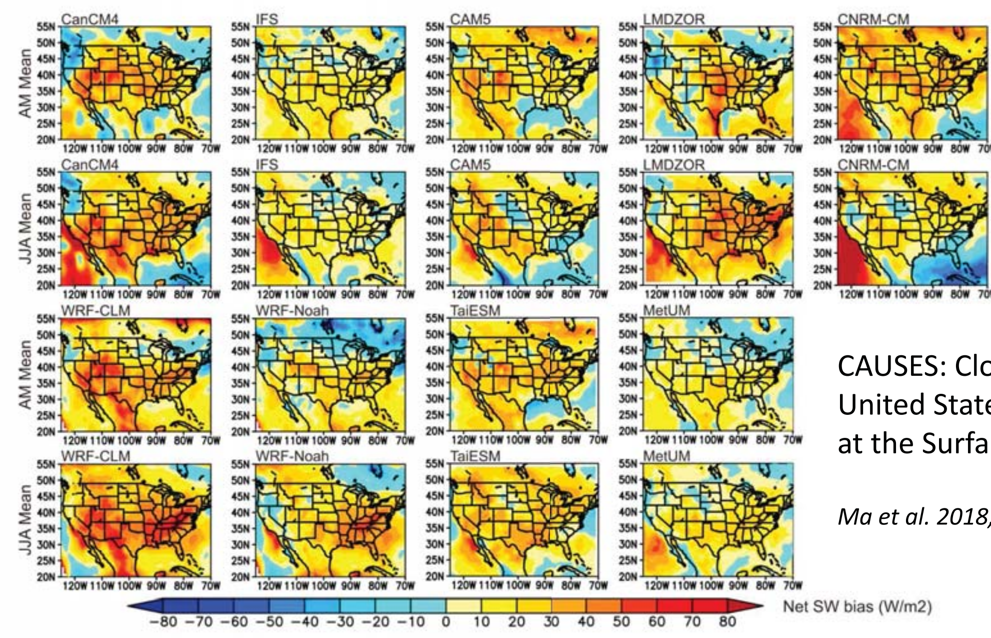


CAUSES: Cloud Above the United States and Errors at the Surface

Ma et al. 2018, JGR

monitoring changes | process understanding | **model development** | satellite evaluation

Persistent Model Biases – Relationships to Surface Radiation Budget



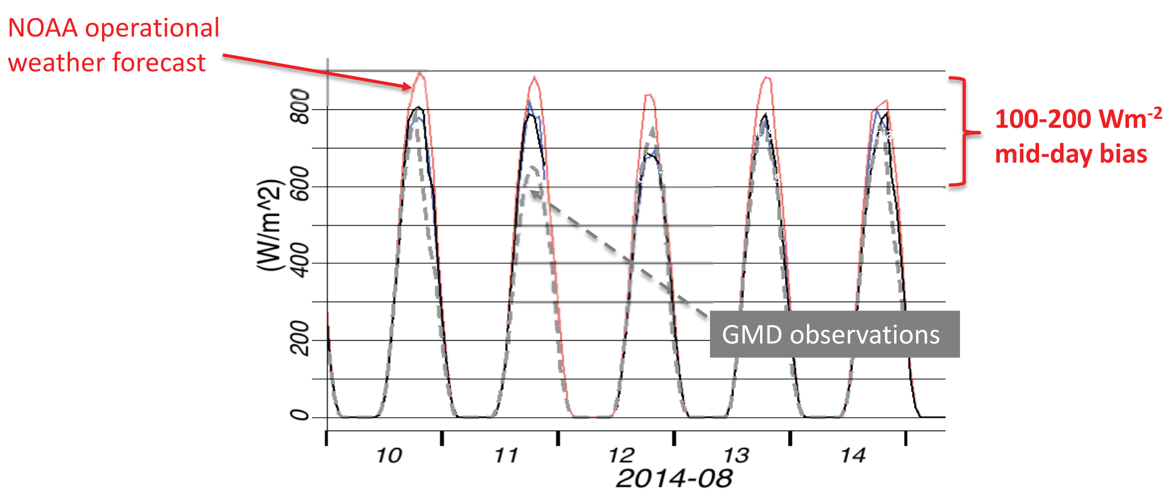
CAUSES: Cloud Above the United States and Errors at the Surface

Ma et al. 2018, JGR

monitoring changes | process understanding | **model development** | satellite evaluation

SURFRAD Observations in Numerical Weather Prediction Model Development

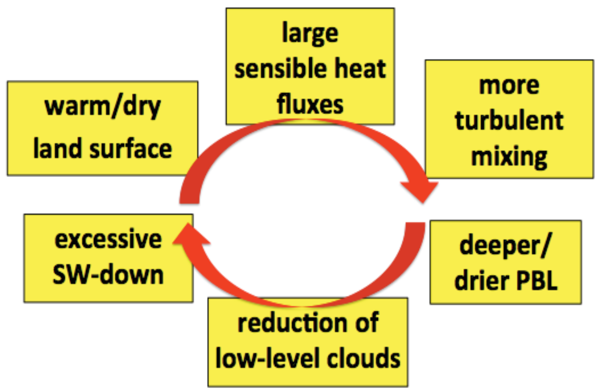
NOAA NWP Rapid Refresh Model (RAP) – SURFRAD comparisons



monitoring changes | process understanding | **model development** | satellite evaluation

SURFRAD Observations in Numerical Weather Prediction Model Development

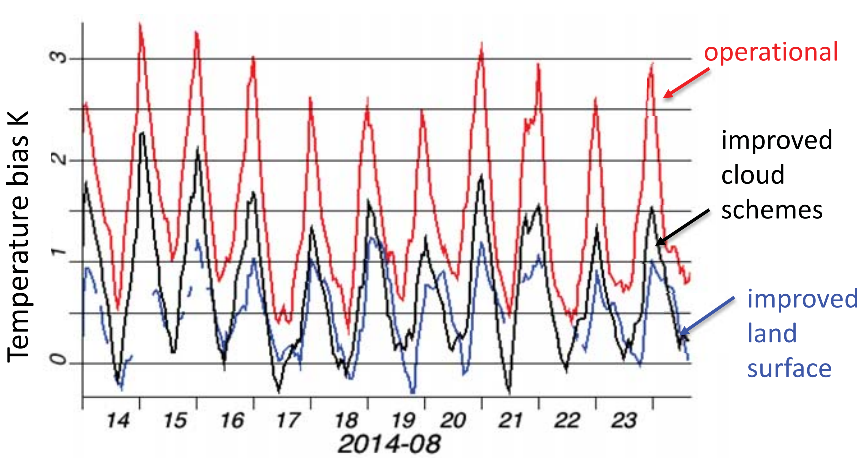
NOAA NWP Rapid Refresh Model (RAP) – SURFRAD comparisons

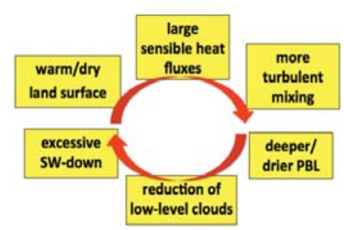


SURFRAD Observations in Numerical Weather Prediction Model Development

Benjamin – Session 7

NOAA NWP Rapid Refresh Model (RAP) – SURFRAD comparisons





~70% reduction in bias

monitoring changes | process understanding | **model development** | satellite evaluation

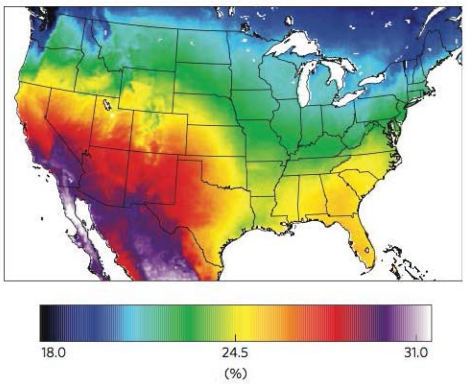
Atmospheric Science for Renewable Energy

Lantz – Session 7

ARTICLES
PUBLISHED ONLINE: 25 JANUARY 2016 | DOI: 10.1038/NCLIMATE2921
nature climate change

Future cost-competitive electricity systems and their impact on US CO_2 emissions

Alexander E. MacDonald[1*†], Christopher T. M. Clack[1,2*†], Anneliese Alexander[1,2], Adam Dunbar[1], James Wilczak[1] and Yuanfu Xie[1]

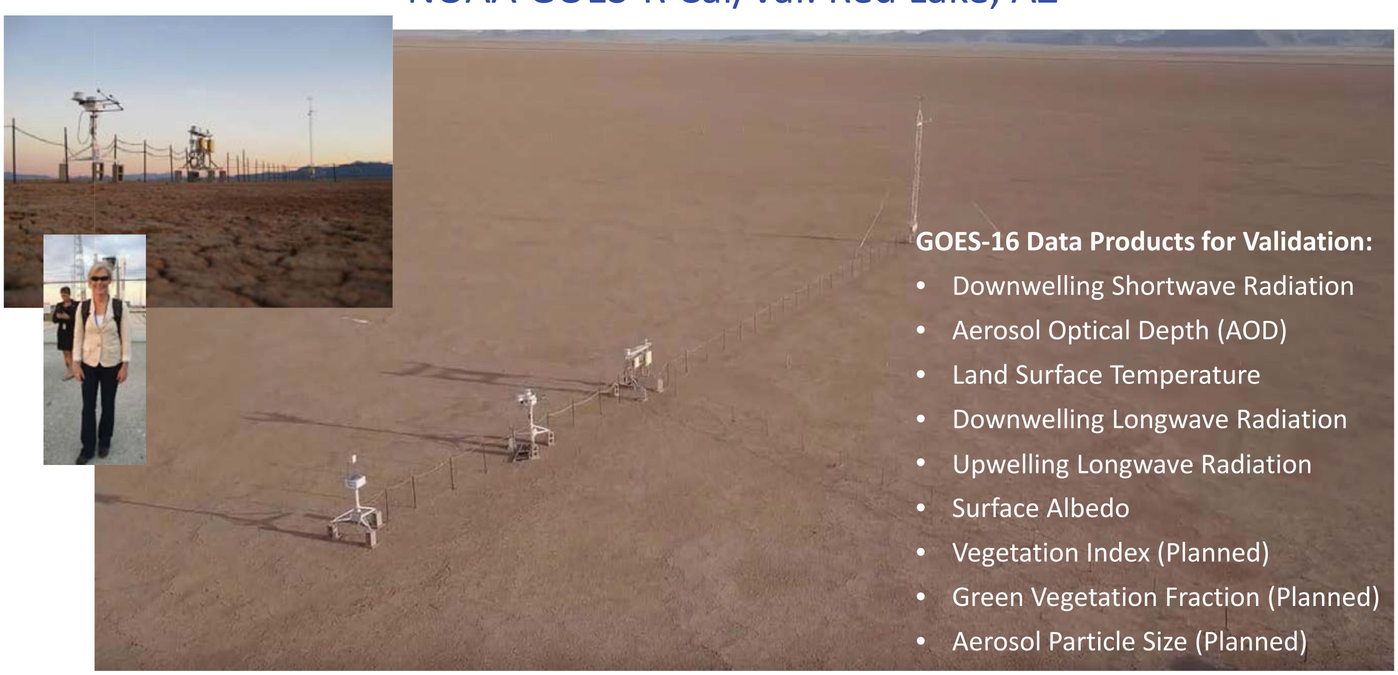


Model treatments and parameterizations addressed:

- Cloud cover – amount, nature, timing
- Land surface cover – albedo
- Aerosol – burden, transport, physical and optical properties
- Radiative transfer – link to cloud and aerosol properties, cloud overlap assumptions
- Diurnal cycles – shortwave and longwave fluxes and relationship to boundary layer growth and decay
- Meteorological regimes – e.g., cold pools

monitoring changes | process understanding | **model development** | satellite evaluation

NOAA GOES-R Cal/Val: Red Lake, AZ



GOES-16 Data Products for Validation:

- Downwelling Shortwave Radiation
- Aerosol Optical Depth (AOD)
- Land Surface Temperature
- Downwelling Longwave Radiation
- Upwelling Longwave Radiation
- Surface Albedo
- Vegetation Index (Planned)
- Green Vegetation Fraction (Planned)
- Aerosol Particle Size (Planned)

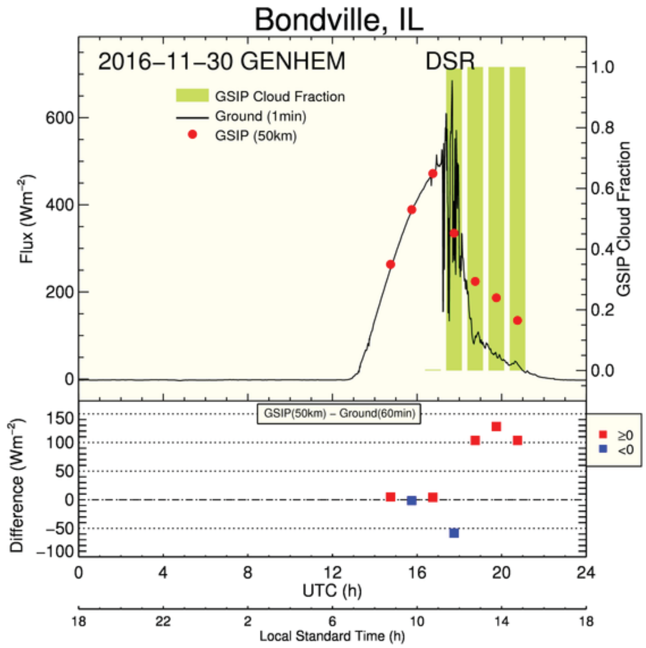
monitoring changes | process understanding | model development | **satellite evaluation**

Operational Satellite Product Evaluation

Long – Session 3

Global Operational Satellite Products:

- GEWEX Surface Radiation Budget (SRB) Product
- Geostationary Surface and Insolation Product (GSIP)



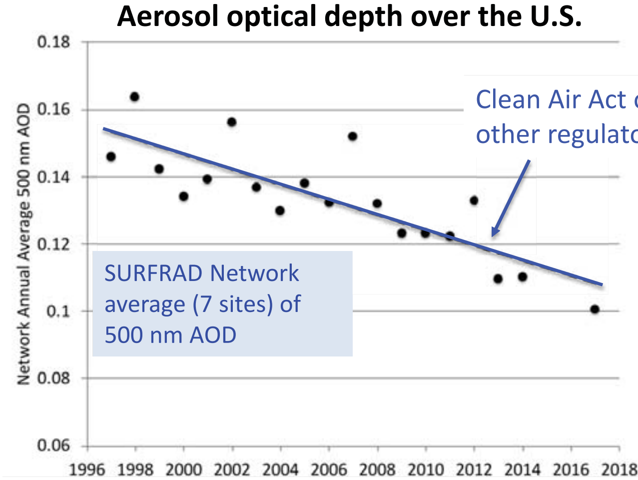
monitoring changes | process understanding | model development | **satellite evaluation**

Trends in Aerosol over the U.S.

Augustine – Session 3
Pagowski – P-7

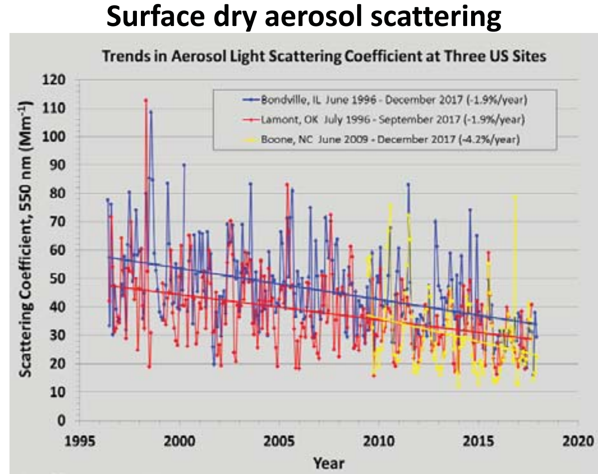
Haller – Session 3
Sherman – Session 7

Aerosol optical depth over the U.S.



Clean Air Act of 1990 and other regulatory efforts

Surface dry aerosol scattering

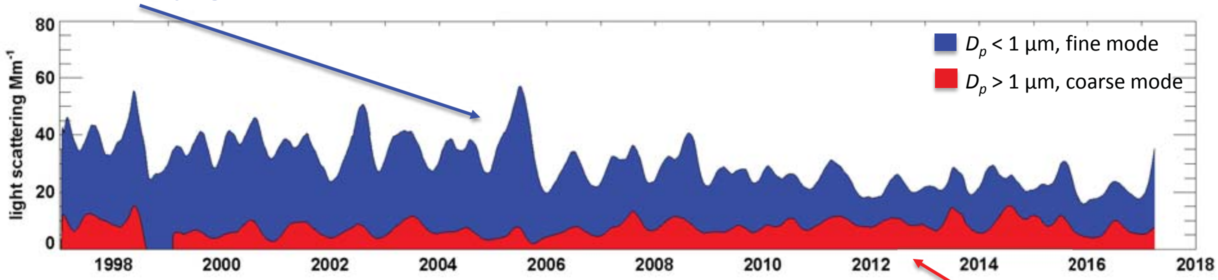


monitoring changes | process understanding | model development | satellite evaluation

Telg – Session 7

Trends in Aerosol over the U.S.

mostly anthropogenic

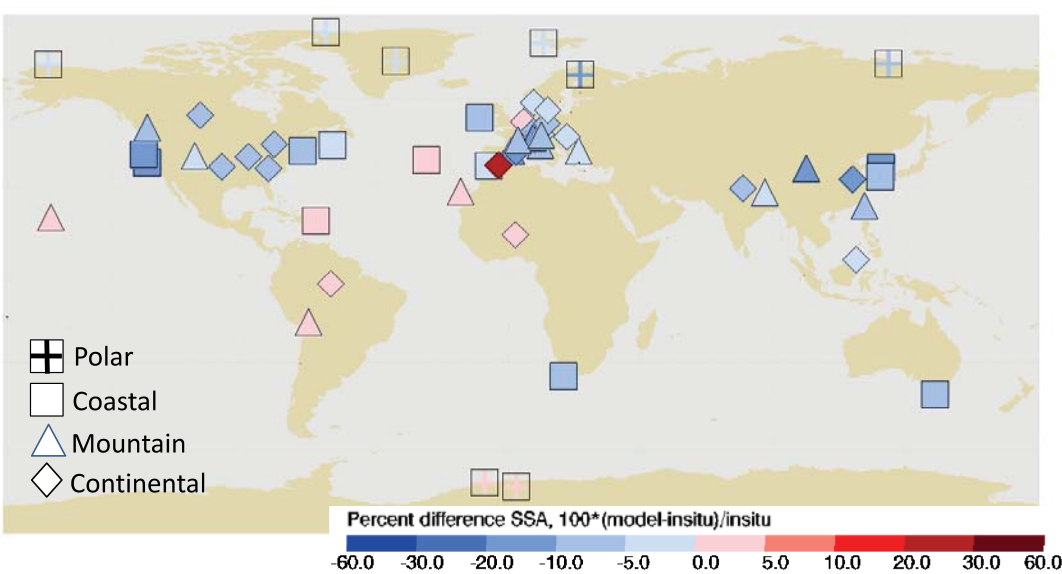


mostly natural

monitoring changes | **process understanding** | model development | satellite evaluation

NOAA Federated Aerosol Network Observations in AEROCOM Experiments

Andrews – Session 7
Pagowski – P-7

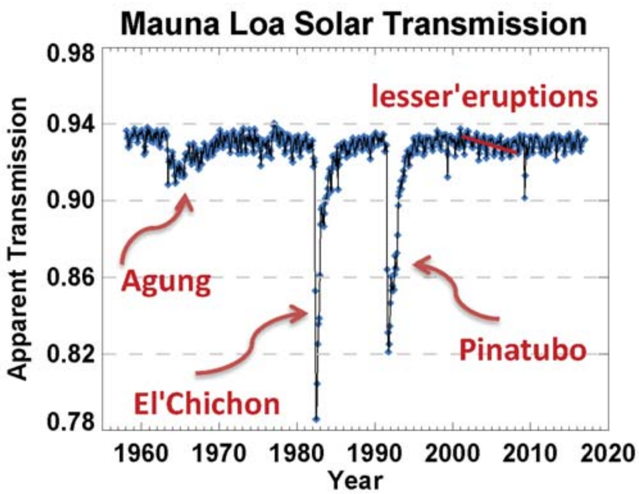


14 global climate models – in situ observations at surface:

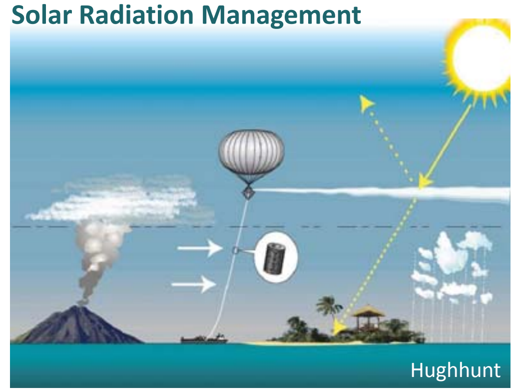
- **model median values**
- **models underestimate observed SSA**
- **models simulate darker aerosol than observed**

monitoring changes | process understanding | **model development** | satellite evaluation

Mauna Loa Transmission and the Stratospheric Aerosol Record



Climate Intervention:
Solar Radiation Management



Barnes – P-43
Keen – P-41

monitoring changes | process understanding | model development | satellite evaluation

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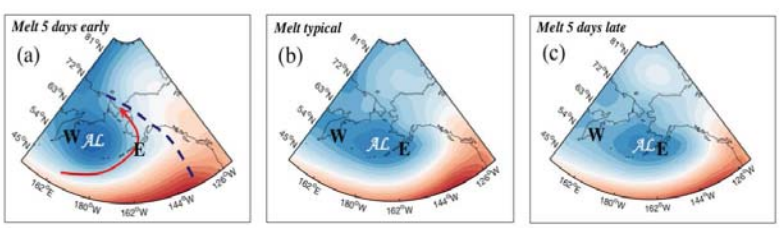
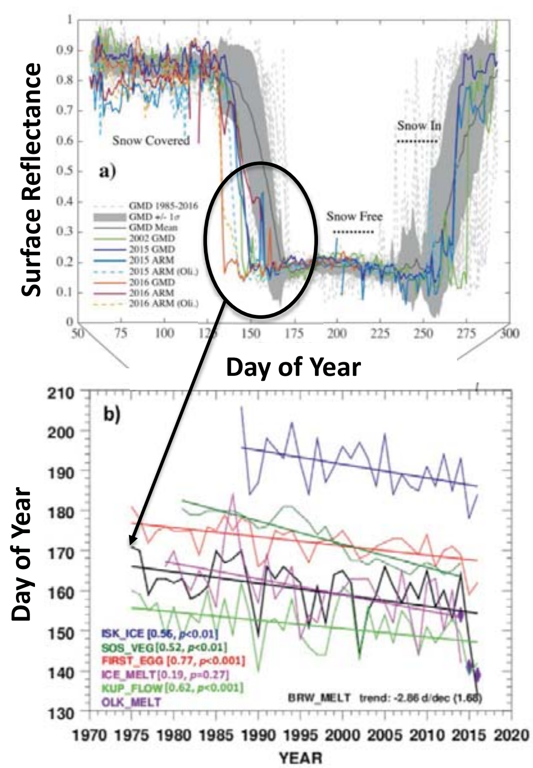
DRIVERS AND ENVIRONMENTAL RESPONSES TO THE CHANGING ANNUAL SNOW CYCLE OF NORTHERN ALASKA

CHRISTOPHER J. COX, ROBERT S. STONE, DAVID C. DOUGLAS, DIANE M. STANITSKI, GEORGE J. DIVOKY, GEOFF S. DUTTON, COLM SWEENEY, J. CRAIG GEORGE, AND DAVID U. LONGENECKER



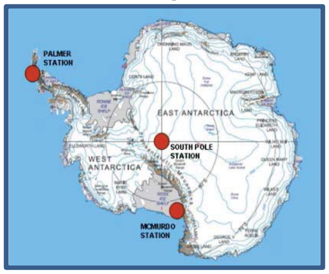


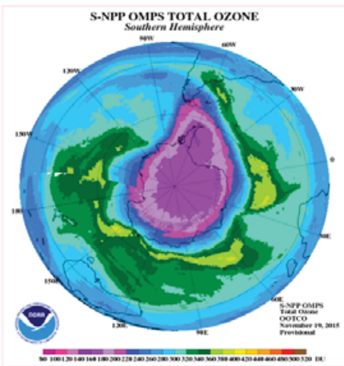
Cox – Session 3
Morris – Session 3

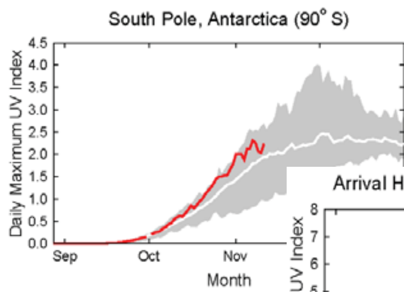
monitoring changes | process understanding | model development | satellite evaluation

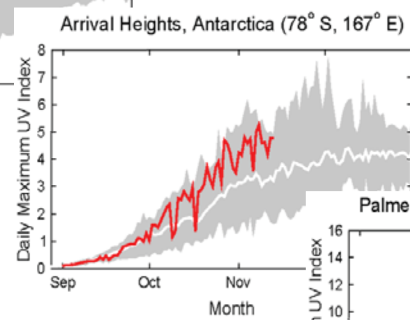
Spectral Ultra-violet (UV) Networks

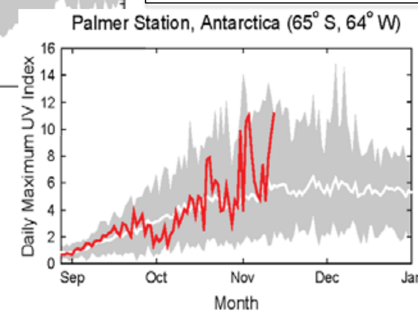
NOAA Antarctic UV Monitoring Network











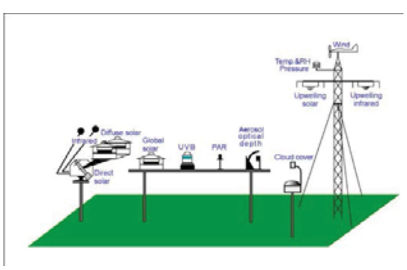
McKenzie – P-48
Shiobara – P-44

NEUBrew
NOAA Environmental Ultraviolet-ozone Brewer Network

Disterhoft – P-49
Montzka – Theme 3

monitoring changes | process understanding | model development | satellite evaluation

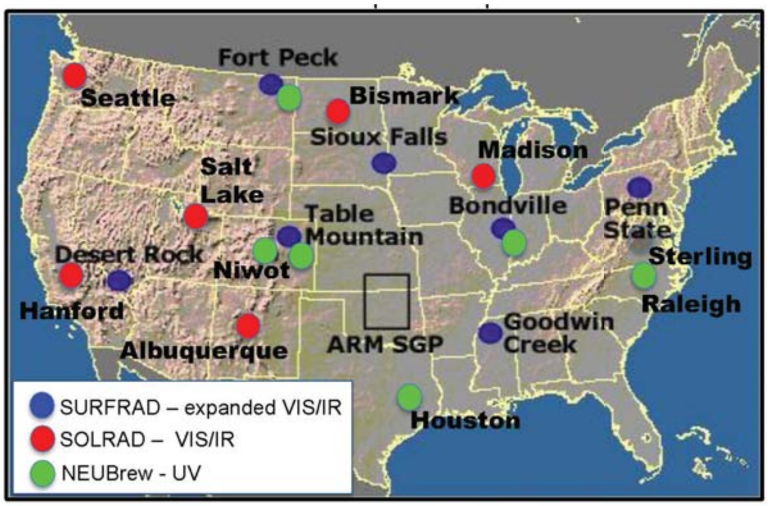
Looking Forward
New Instrumentation for Cloud Properties at SURFRAD Sites



Measurements and Data Products
- Surface Radiation Budget – all components
- Sky cover/cloud fraction
- Cloud optical depth (overcast)
- Aerosol Optical Depth (AOD)
- Surface in situ aerosol optical properties
- Spectral Surface Albedo
- UV-B
- PAR
- Vegetation Indices (NDVI, GVF)
- Spectral UV irradiance, Ozone, UV Index
- Cloud Height, Cloud Layers (overlap)
- Boundary (mixing) Layer Height
- Cloud optical depth (broken cloud)
- Cloud microphysics – effective radius, drop size, phase
- Cloud liquid water path (derived)
- Ambient Column Aerosol Size Distribution, Single scattering Albedo, Asymmetry Parameter
- Spectral AOD – UV to NIR (aerosol type/composition)

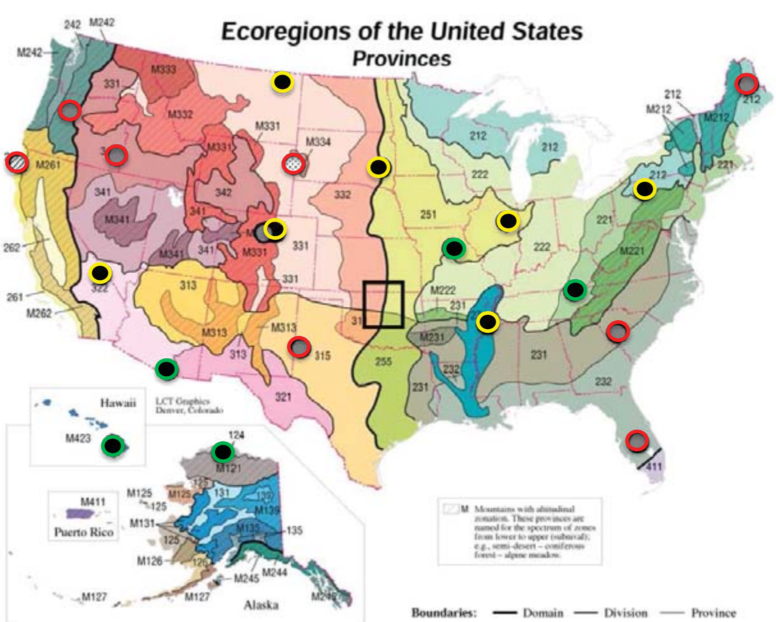
Looking Forward
An Expanded Aerosol Optical Depth Monitoring Network

Instrument upgrades, new deployments, and development of aerosol optical property retrieval algorithms will results in an expanded network.



- use of newly expanded spectral measurements at **SURFRAD** and DOE ARM sites for routine retrievals of improved aerosol microphysical and optical properties
- addition of refurbished instruments to **SOLRAD** sites for expanded spatial coverage of aerosol optical depth
- development of a spectral ultraviolet aerosol optical depth product from Brewer spectrophotometers in the **NEUBrew Network** for information on aerosol composition and its radiative impacts

Looking Forward
A NOAA Surface Energy Budget Network
for Improving Weather and Climate Predictability



- existing radiation measurements
- existing heat flux measurements
- proposed new sites

Monitoring and Understanding Trends in Surface Radiation, Clouds, and Aerosols

WCRP Grand Challenge: Clouds, Circulation, and Climate Sensitivity

How the interaction between clouds, greenhouse gases, and aerosols affect temperature and precipitation in a changing climate

WCRP Initiatives:	GMD Research:
Climate and hydrological sensitivity	
Coupling clouds to circulation →	Small- and large-scale atmospheric dynamical effects on cloud properties
Changing patterns →	Regionality of cloud and aerosol responses to local and large-scale forcing
Leveraging the past record →	Decadal to multi-decadal observations to constrain cloud processes and feedbacks
Towards more reliable models →	Persistent model biases evaluation and improving physical understanding

https://www.wcrp-climate.org/gc-clouds

Guiding Recovery of Stratospheric Ozone

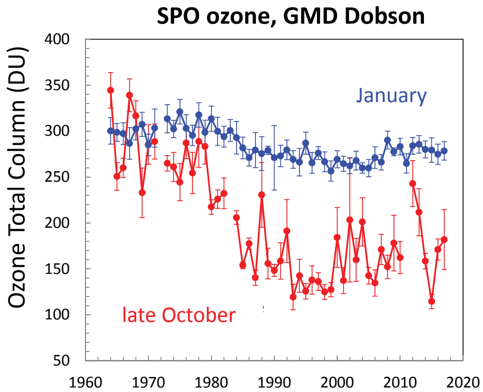
Guiding Recovery of Stratospheric Ozone at GMD

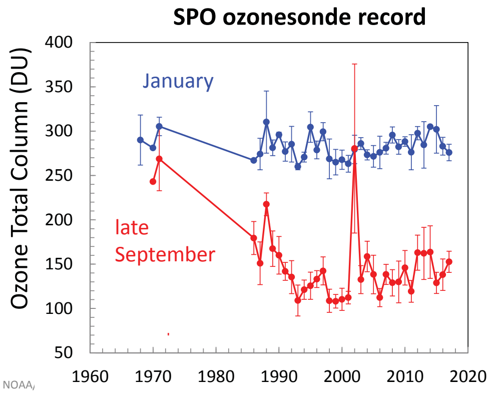
GMD plays a central role in the global effort to monitor stratospheric ozone, ozone-depleting gases, and other processes affecting stratospheric ozone

Our focus:

- ***global-to-regional scale observations*** to assess global changes *and* influences from specific processes and regions (*e.g.*, U.S.)
- ***Diagnosing observed changes*** to clarify the relative influence of policy decisions, other human behaviors, and natural processes
- ***To provide the highest-quality, policy-relevant science***

→ *Guiding the recovery of the ozone layer by informing Parties to the Montreal Protocol on the progress of recovery*





Stratospheric ozone depletion

→ a threat to life on Earth.

1950s: - **NOAA** begins measuring total column ozone

1970s: - Theory suggesting CFCs will deplete ozone
- **NOAA** and NASA begin measuring CFCs

1980s: - Severe ozone depletion reported in Antarctica
- Montreal Protocol controls CFC production
- Antarctic ozone hole attributed to CFCs and other chemicals

1990s: - US Clean Air Act Amended:

***NOAA* and NASA**

***to monitor*:**

tropospheric chlorine & bromine, & stratospheric ozone depletion

***to project*:**

peak chlorine

the rate of chlorine decline after 2000

the date when chlorine returns to two ppb

** 1996: tropospheric chlorine peaks (NOAA-GMD publication)*

** 2003: tropospheric bromine peaks (NOAA-GMD publication)*

Guiding Recovery of Stratospheric Ozone at GMD

A) Measuring chemicals that cause stratospheric ozone depletion

→ One of two global networks tracking long-term changes in ozone-depleting gases

B) Measuring long-term changes in stratospheric ozone

→ Providing reference-quality long-term measurements of stratospheric ozone

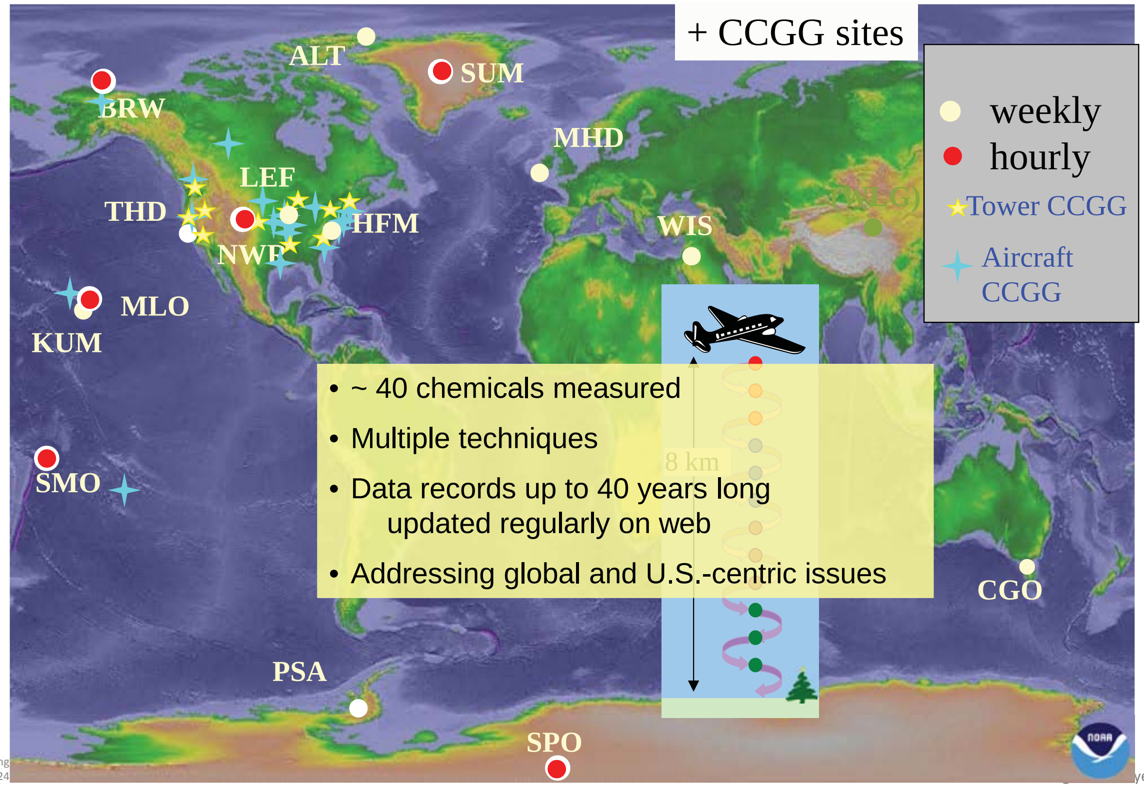
C) Advancing scientific understanding

→ Understanding causes of atmospheric composition change and improving our understanding of atmospheric processes

***D) Communicating results to a broader audience** (stakeholders)*

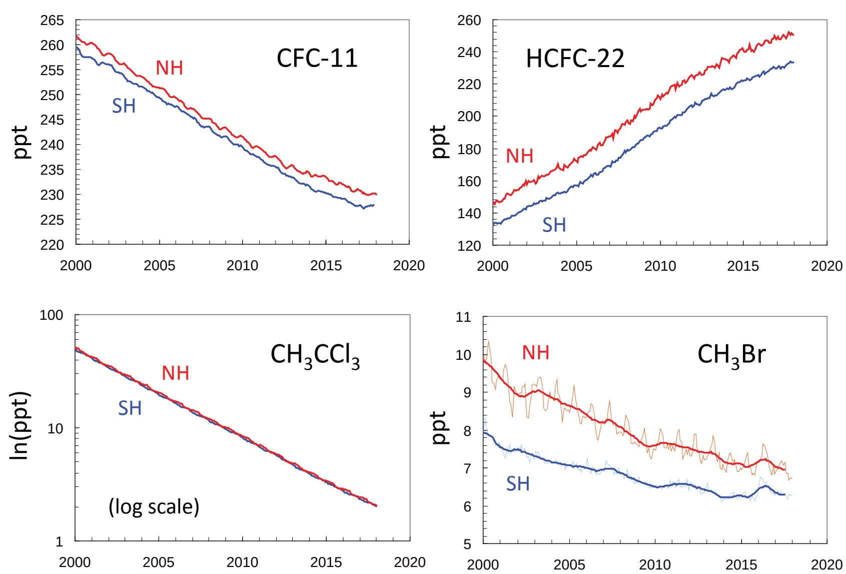
→ through simple indices, web presence, open data policies, publications, and by contributing to national and international Scientific Assessments

A) Measuring chemicals that cause stratospheric ozone depletion



A) Measuring chemicals that deplete stratospheric ozone

– Concentrations of ozone-depleting chemicals for which **PRODUCTION IS CONTROLLED** by the Montreal Protocol



All major ozone-depleting gases are measured at NOAA/GMD.

Emphasis is on high precision and accuracy.

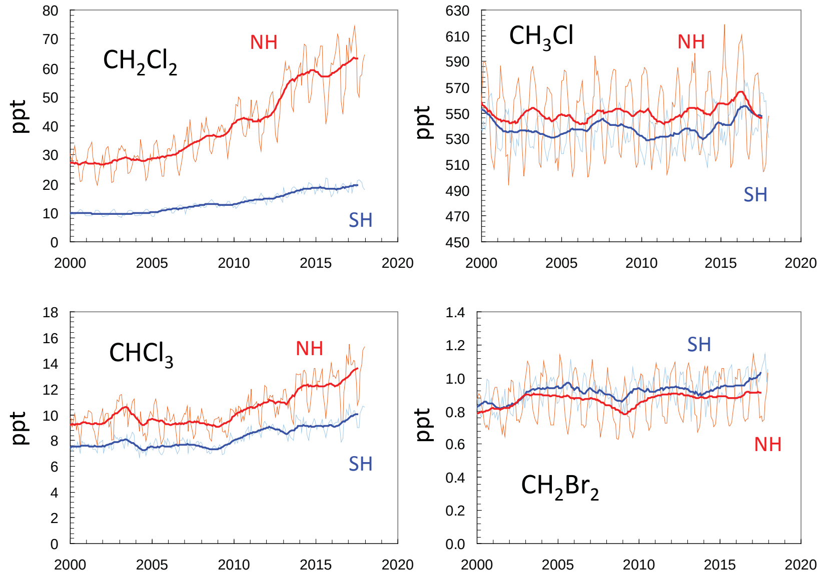
→the better the measurement, the more one can learn…

See talks by S. Montzka, and by P. Yu

Recent related pubs: Montzka *et al*., 2015; 2018; Rigby *et al*., 2017

A) Measuring chemicals that deplete stratospheric ozone

– Concentrations of halogenated chemicals **NOT CONTROLLED** by the Montreal Protocol, but that can influence stratospheric ozone:



Shorter-lived gases also add chlorine and bromine to the atmosphere.

→ having human and natural sources.

→ changing over time?

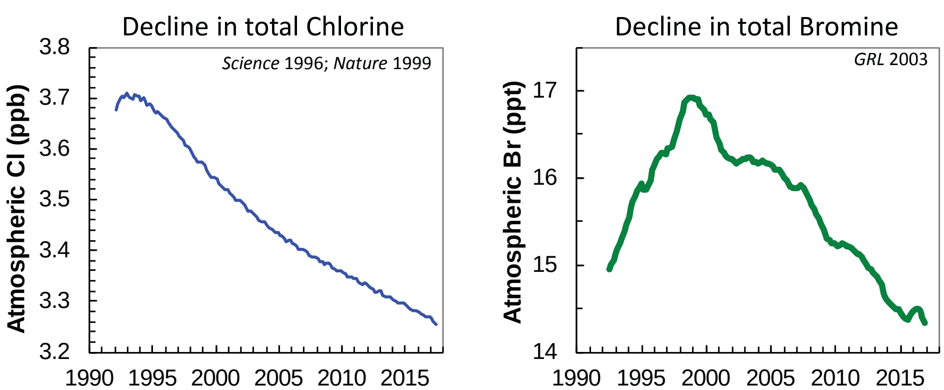
Also: N_2O, COS

See poster by G. Dutton

Recent related pubs: Hossaini *et al*., 2016; 2017

A) Measuring chemicals that deplete stratospheric ozone

– Changes in "controlled" tropospheric chlorine and bromine:



→ Sum of all controlled gases measured at GMD

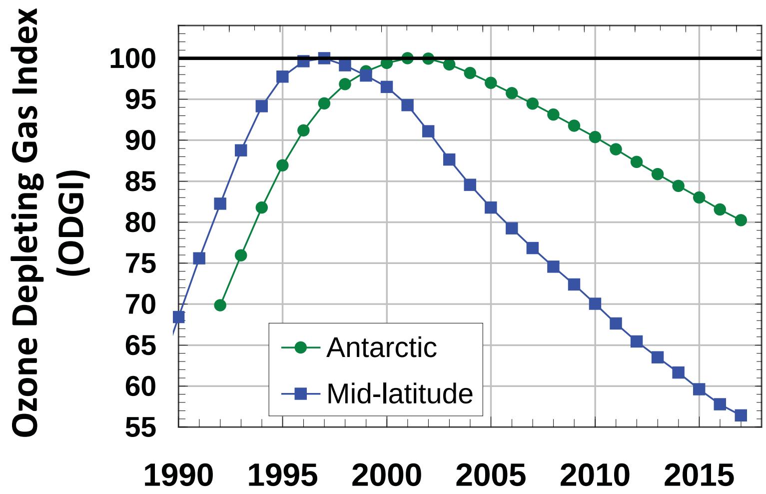
→ directly addressing Congressional mandate

→ updated annually on NOAA web page:
ftp://ftp.cmdl.noaa.gov/hats/

A) Measuring chemicals that deplete stratospheric ozone

– Distilling GMD measurements of controlled gases into a single index:

The Ozone Depleting Gas Index



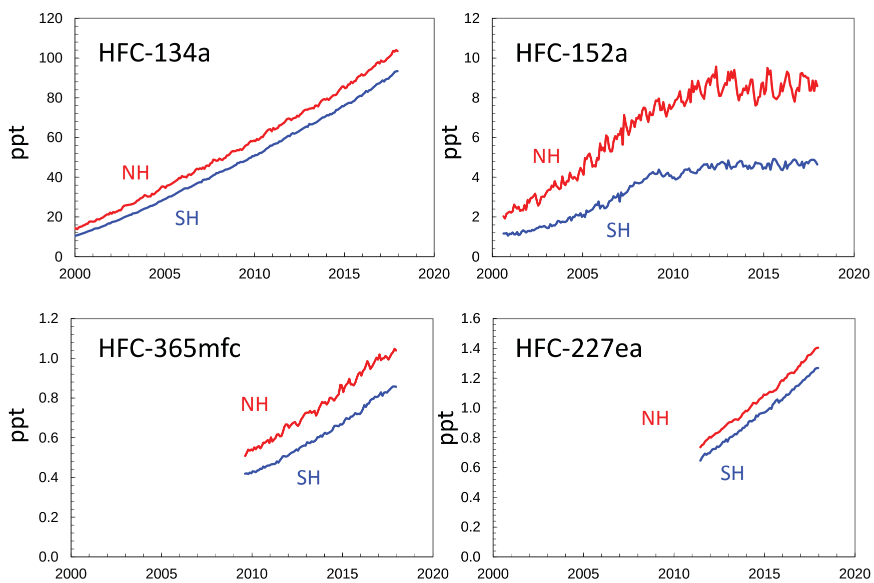
Measuring progress in the decline of ozone-depleting halogen back to 1980 concentrations (pre-ozone hole)

In 2017:
- Antarctic ODGI was 80
- Mid-latitude ODGI was 56

Annually updated at http://www.esrl.noaa.gov/gmd/aggi/

A) Measuring substitute Hydrofluorocarbons

– Concentrations of chemicals for which **PRODUCTION IS CONTROLLED** by the Montreal Protocol, ***but that do NOT deplete ozone***



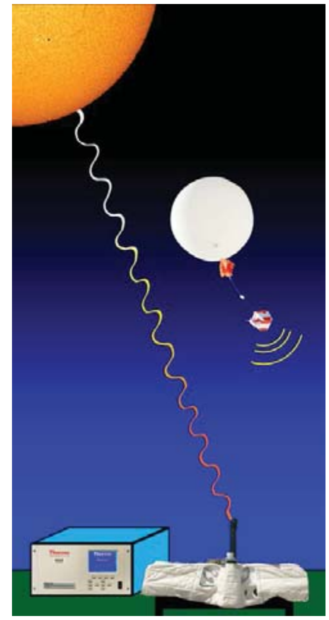
Recently added to the Montreal Protocol list of controlled substances.

These results enable a tracking of radiative forcing from ODS substitution.

Most substitute HFCs are measured at NOAA/GMD.

B) Measuring long-term changes in stratospheric ozone

→ Providing reference-quality long-term measurements of stratospheric ozone



Using a range of techniques to obtain:

Ozone total column density:
- Dobson
- Brewer

Ozone concentration vertical profile :
- Ozone Sondes (highest vertical resolution)
- Umkehr

Ozone concentrations near Earths surface

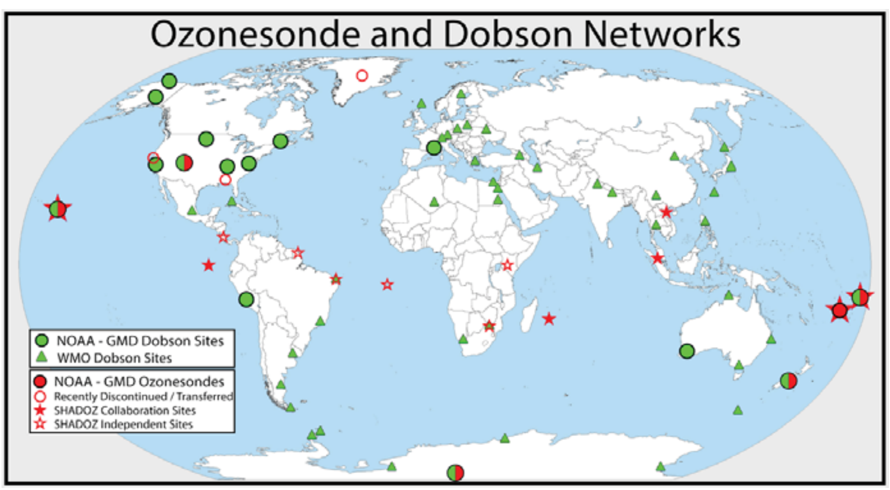
To allow an understanding of ozone concentration changes:

over time
- developing and applying statistical models to provide trend estimates

as a function of altitude
- stratospheric changes (upper vs lower stratosphere)
- tropospheric changes (pollution-related or transported from stratosphere)

as a function of latitude
- future ozone changes are expected to be latitude-dependent
  - aerosol, GHGs, circulation...

B) Measuring long-term changes in stratospheric ozone



NOAA-GMD Dobson ozone program:

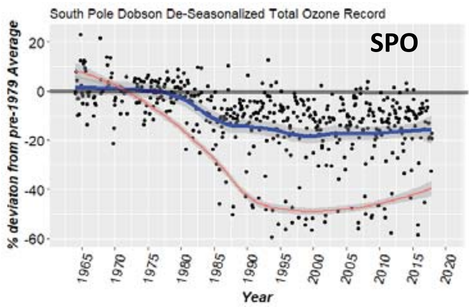
- Forms a global backbone of robust, calibrated total column ozone data
- Provides an essential reference for other ozone measurements (satellites, other Dobsons, etc.) through calibration transfers
- Maintains the WMO reference Dobson instrument (#D083)

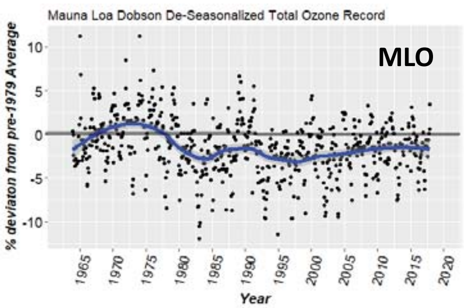
NOAA-GMD ozone sonde program:
- adds high vertical resolution (data were recently homogenized)
- Strengthens and augments the SHADOZ program for tropical ozone data

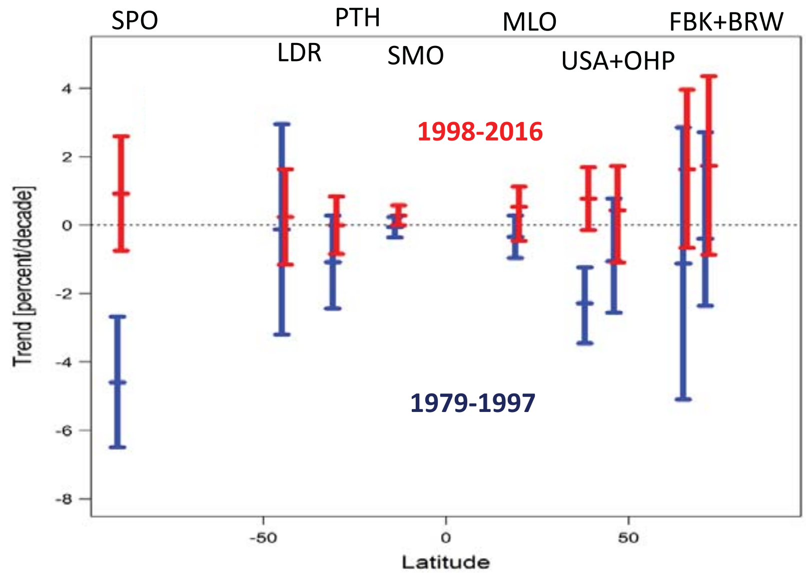
Recent Dobson- and sonde-related pubs: Petropavlovskikh et al. (2015), Nair et al., 2015; Evans et al., 2016, Thompson et al., 2017, Sterling et al, (2018)

B) Measuring long-term changes in stratospheric ozone

– To allow an understanding of ozone column changes by latitude (ODS+GHG+transport)



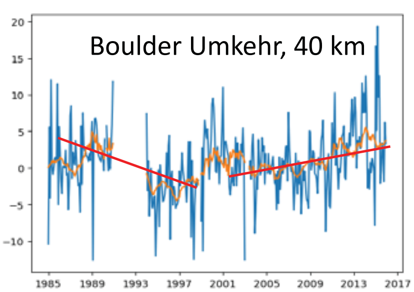


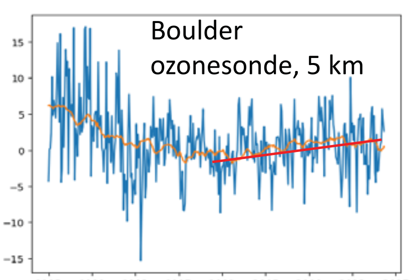


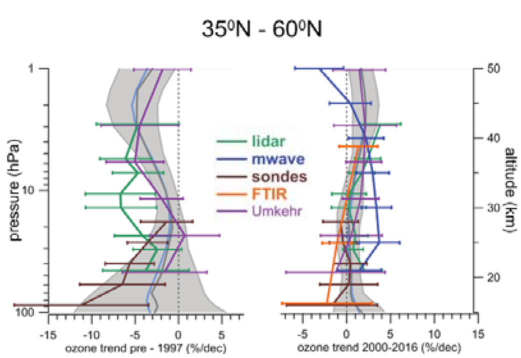
See posters by G. McConville, K. Miyagawa

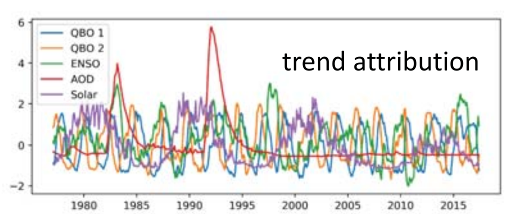
B) Measuring long-term changes in stratospheric ozone

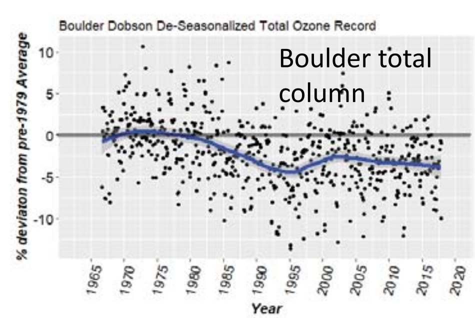
- To allow an understanding of ozone column changes by altitude (ODS+GHG+transport)









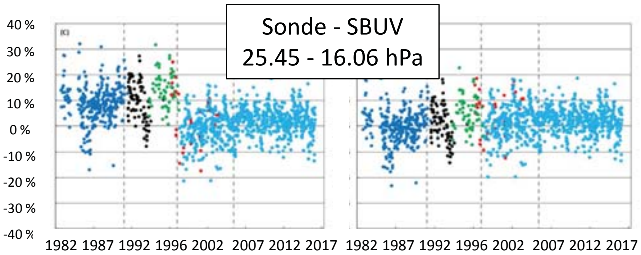


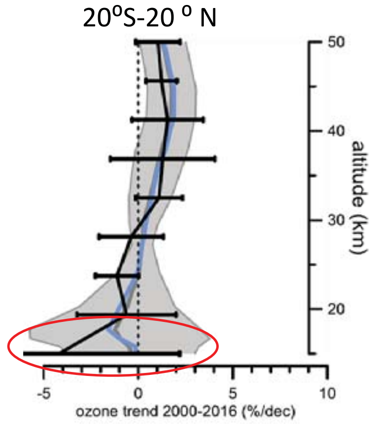
LOTUS 2018 and Ozone Assessment 2018 used GMD data and developed statistical models to derive trends in ozone profiles and total column.

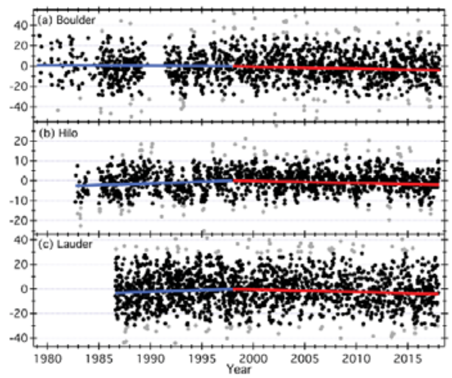
B) Measuring long-term changes in stratospheric ozone

– *To allow an understanding of ozone column changes by altitude (ODS+GHG+transport)*

Is ozone in lower stratosphere still decreasing? Ball et al (2018) analyses are based on satellite records







Homogenization for GMD (Sterling et al, 2018) and SHADOZ (Witte et al, 2017) ozonesonde data - improved records for future trend analyses

SHADOZ Sites: https://tropo.gsfc.nasa.gov/shadoz

Oral presentation by Witte

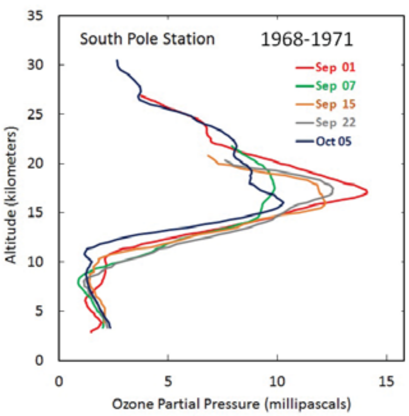
Satellite and **CCMI** model averaged trends (LOTUS, 2018, Ozone Assessment) - disagreement between models and observations?

Trends in the low stratosphere will be soon assessed from homogenized ozone-sonde data in tropics and middle latitudes.

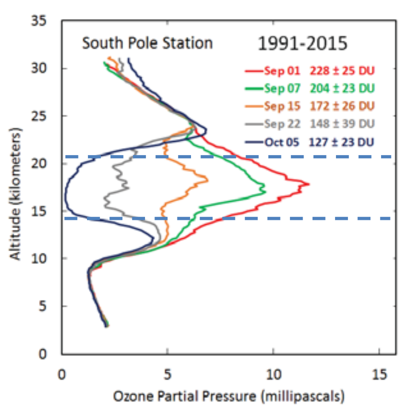
B) Measuring long-term changes in stratospheric ozone

– Ozone, **vertical profiles from ozone sondes** on balloons

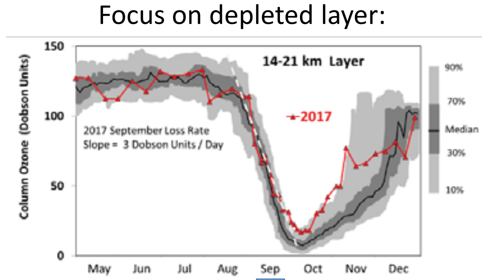
Pre-1971 (pre ozone-hole)

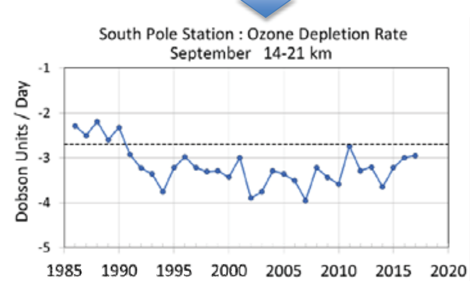


Ozone-hole conditions



Focus on depleted layer:





See talk by B. Johnson, poster by P. Cullis

Recent related pubs: Solomon et al. 2016 – ozone-sonde detected recovery, observed in Septembe
Hofmann(2010)? Recovery after the September depletion rate is less than 2.7 DU/day

C) Advancing scientific understanding (Q3 & Q4 in New Research Plan)

→Understanding the cause of atmospheric composition changes

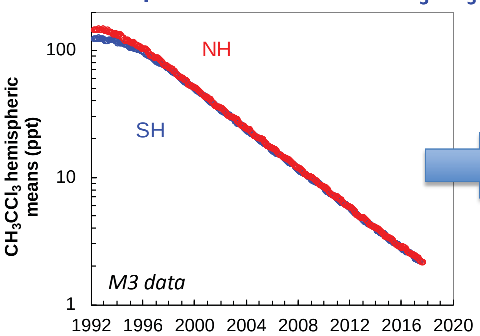
→sources, sinks, and transport

Improving our understanding of trace-gas sources and sinks

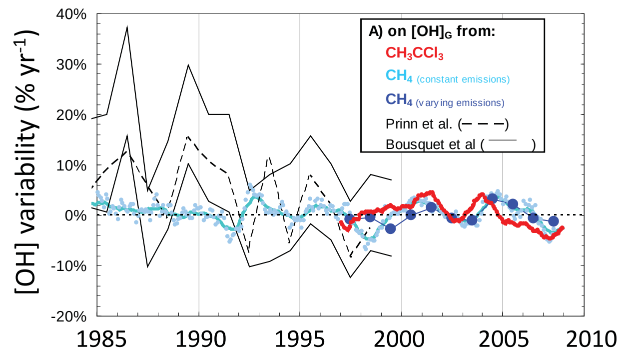
Sinks: Measuring the atmospheric oxidation capacity over time

→ budget analyses of long-lived gases

The exponential decline in CH_3CCl_3



Inferred [OH] inter-annual changes



Science 2000;
Science 2011;
PNAS 2017

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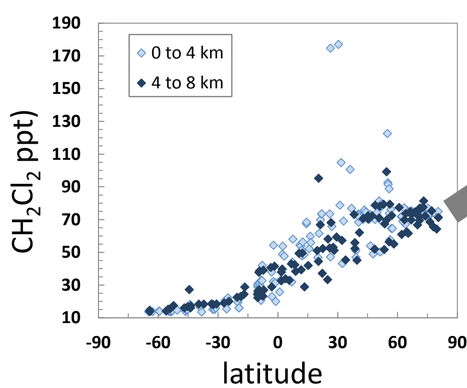
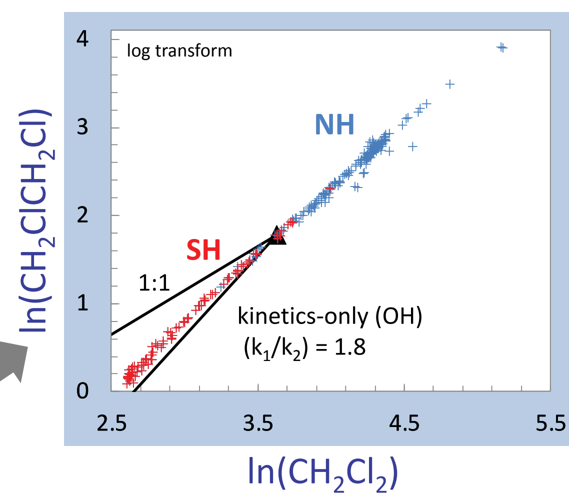
Alternative approaches to CH_3CCl_3:

* Deriving OH loss from consideration of hemispheric mole-fraction differences
- Long-lived gases (Liang *et al.*, 2017)
- **Short-lived gases**
  - From network and special projects (e.g., Atom)





C) Advancing scientific understanding (Q3 & Q4 in New Research Plan)

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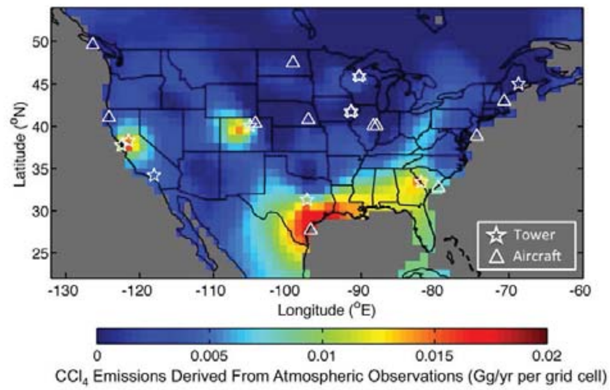
→sources, sinks, and transport

Improving our understanding of trace-gas sources and sinks

Sources, particularly U.S. contributions, but also on a global scale

Why are CCl_4 emissions continuing now that CFC production is negligible?



SPARC Report focus in 2016

What we found:

US emissions are 10% of global total

* associated with chemical industry
* this process likely accounts for much of the remaining global emissions

(Hu et al., 2016)

Other similar findings related to CFC-11 will be discussed in meeting

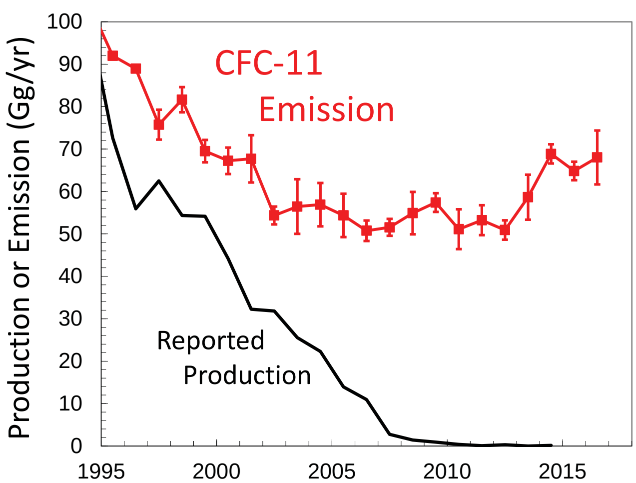
C) Advancing scientific understanding (Q3 & Q4 in Research Plan)

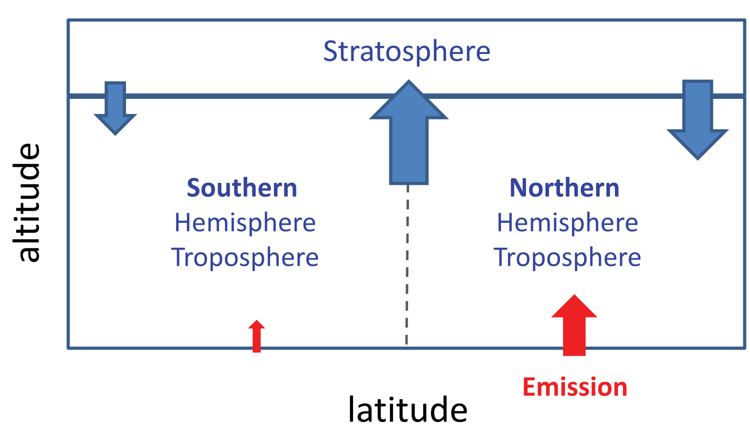
→Understanding the cause of atmospheric composition changes

→sources, sinks, and transport

Improving our understanding of trace-gas sources and sinks

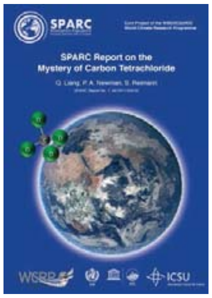
Surface measurements are influenced by variations in sources *and* sinks:



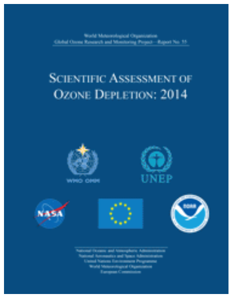


D) Communicating results

- ***Providing expertise*** to national and international Assessments on Ozone and Climate:
  - ***GMD scientists*** have been lead authors, co-authors, contributing authors, and contributors to these Assessments
  - ***GMD data*** are prominent in these Assessments



2016



2014

2013

2014

Also:
•UNEP/WMO, 2018 Scientific Assessment of Ozone Depletion—lead authors
•UNEP/WMO, Twenty questions and answers about the ozone layer, 2015

Guiding ozone layer recovery in the future at GMD:

- **Continue ongoing programs to:**
  - Monitor effectiveness of the Montreal Protocol for diminishing ozone-depleting gases
  - Accurately measure the response of stratospheric ozone to decreasing halogen and increasing greenhouse gas concentrations
- **Especially to address newly emerging issues:**
  - increases in CFC-11, CH_2Cl_2, & CH_3Br; and in future for VSLS-bromine?
  - HFCs and Kigali Amendment – locking in climate gains from the Montreal Protocol
  - lower stratospheric ozone declines (Ball et al. 2018)? Assess better-positioned GMD measurements (Unkehr; ozone-sonde)
- **Add capabilities where possible:**
  - increased sampling frequency in tropics
  - validation of new instruments (*i.e.* Pandora)
  - validation of new operational NOAA satellite products (*i.e.*, IPSS)
- **Participate in periodic field campaigns to:**
  - extend an understanding of surface-based results vertically
  - improve process-based understanding of the atmosphere
  - gauge the atmospheric response to increasing greenhouse gas concentrations

Guiding Recovery of Stratospheric Ozone at GMD

GMD plays a central role in the global effort to monitor stratospheric ozone, ozone-depleting gases, and other processes affecting stratospheric ozone

Our focus:

- ***global-to-regional scale observations*** to assess global changes *and* influences from specific processes and regions (*e.g*., U.S.)
- ***Diagnosing observed changes*** to clarify the relative influence of policy decisions, other human behaviors, and natural processes
- ***To provide the highest-quality, policy-relevant science***

→ *Guiding the recovery of the ozone layer by informing Parties to the Montreal Protocol on the progress of recovery*

Global Monitoring Division

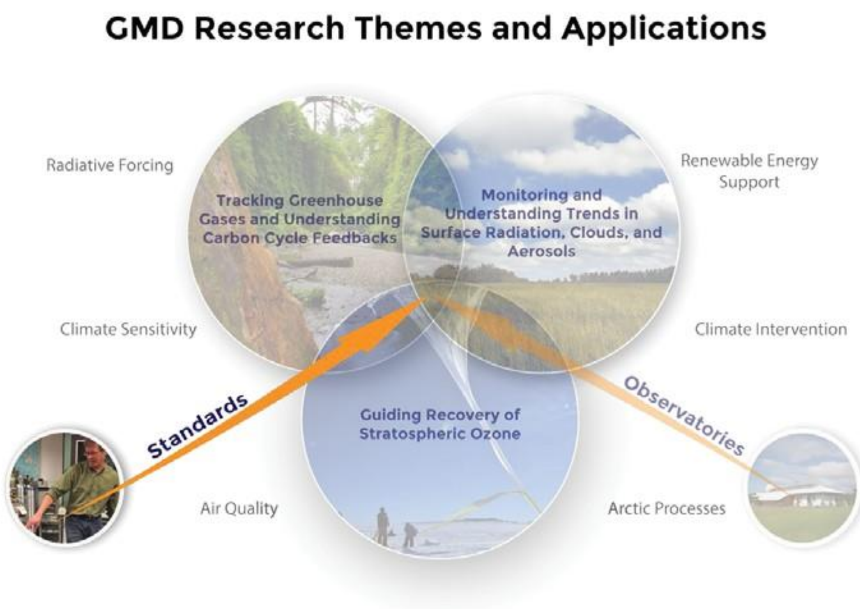
Supporting Infrastructure Presentations

2013-2017 Review

May 21-24, 2018

Contents: page

Calibration and Standards Activities



Solar & Terrestrial Radiation

Dobson Column Ozone

Trace Gases

Federated Aerosol Network

Solar & Terrestrial Radiation

Trace Gases

Dobson Column Ozone

Federated Aerosol Network

NIST

BIPM

NASA

USDA

AGAGE

Max Planck Institute for Biogeochemistry

Common Aspects

- ☐ Support GMD Measurements
- ☐ Commitment to Consistency
- ☐ Regional/Global Scope (e.g. WMO)
- ☐ Hierarchical Approach
- ☐ Collaborative
- ☐ Research Component
- ☐ Cost-Sharing
- ☐ Transparency/Accessibility

NREL

TROPOS

Empa

CSIRO

EPA United States Environmental Protection Agency

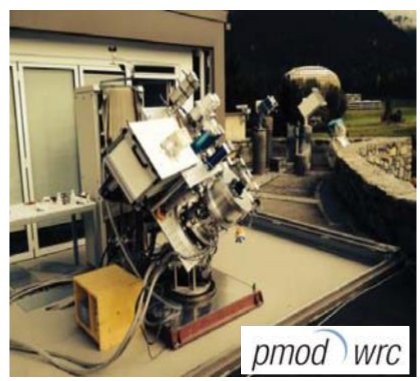
GAW

pmod wrc

Solar & Terrestrial Radiation

- Calibration support for GMD observatories and Baseline Surface Radiation Network (BSRN) sites at Kwajalein, Bermuda
- GMD reference cavity radiometers - traceable to World Radiation Center (Davos, Switzerland)

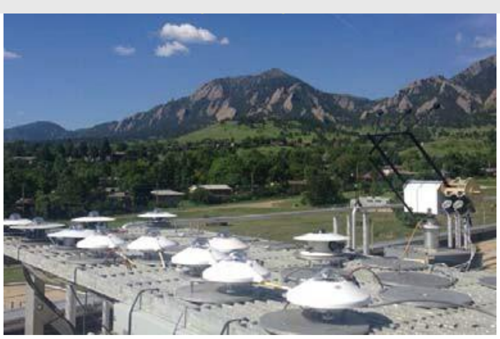
Hall, Traceability to WRC (P-38)



PMOD World Standard Group Cavity Pyrheliometers

IPC 2015 Results for the six NOAA Active Cavity Pyrheliometers

Pyrheliometer	AWX 31114	AWX 32448	AHF 28553	AHF 30710	AHF 14917	TMI 67502
WRR factor	1.002	1.001	0.998	1.002	0.998	1.002



- WMO Region IV National Radiometric Calibration Center for the U.S.
- Expanding calibration services to include instruments in the U.S. Climate Reference Network (NOAA Air Resources Lab)

Solar & Terrestrial Radiation

Central UV Calibration Facility (CUCF)

- NIST traveling primary standards:
  - limited lifetime
  - vertical orientation only
  - high cost (~$15K)
- **Practical Solution**: Collaboration with NIST and others .... GMD calibrates 1000 watt standard lamps in *horizontal and vertical* orientations, traceable to the NIST scale (Yoon, et al. 2003)

Portable Calibration Unit

Solar & Terrestrial Radiation

Hierarchical Approach

Primary

NIST primary standards (2001 NIST detector-based irradiance scale)

Secondary

1st Triad

2nd Triad

Vertical and horizontal tracking standards

Tertiary

NEUBrew field standards

CUCF laboratory standards

Antarctic UV field standards

NOAA-NIWA field standards

Solar & Terrestrial Radiation

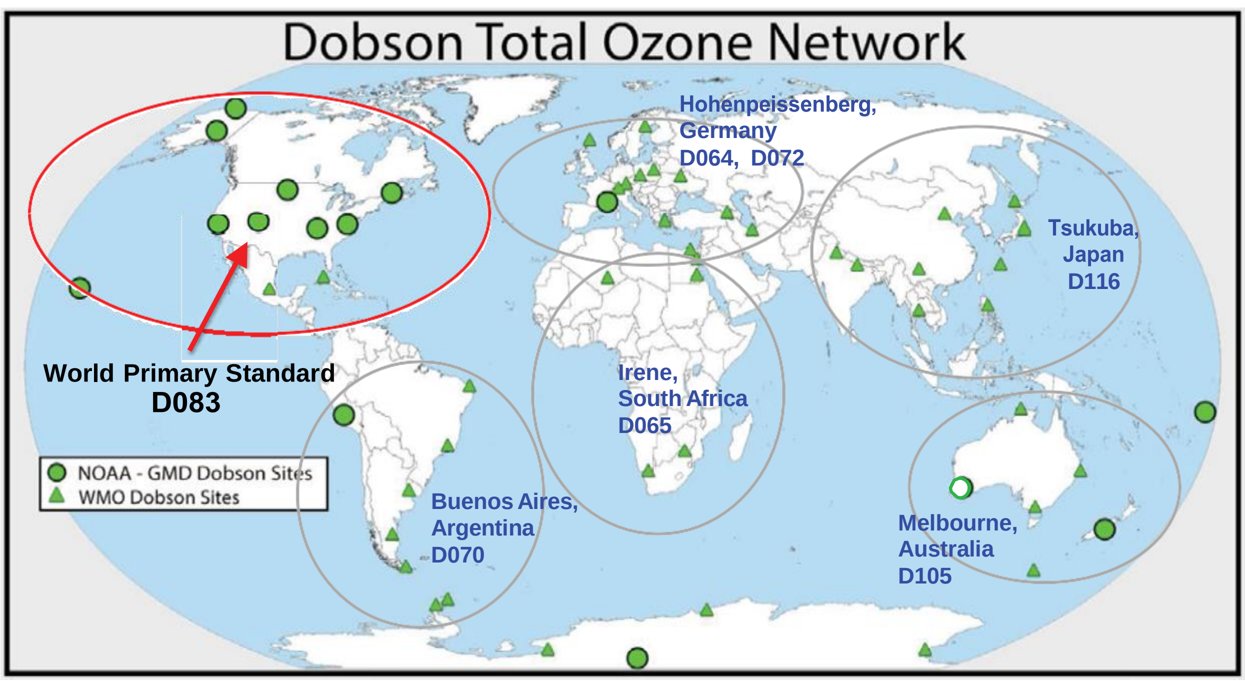
WMO/GAW Regional Calibration Center

- **CUCF Activities:**
  - Absolute spectral irradiance calibrations (~40 per year)
  - Laboratory facility at GMD + portable calibration system
  - Characterization (spectral response, angular response, +more)
  - Host comparison activities (Lantz et al. 2001, Lantz et al. 2008)

Performing a Field Calibration

UV Spectral Response System

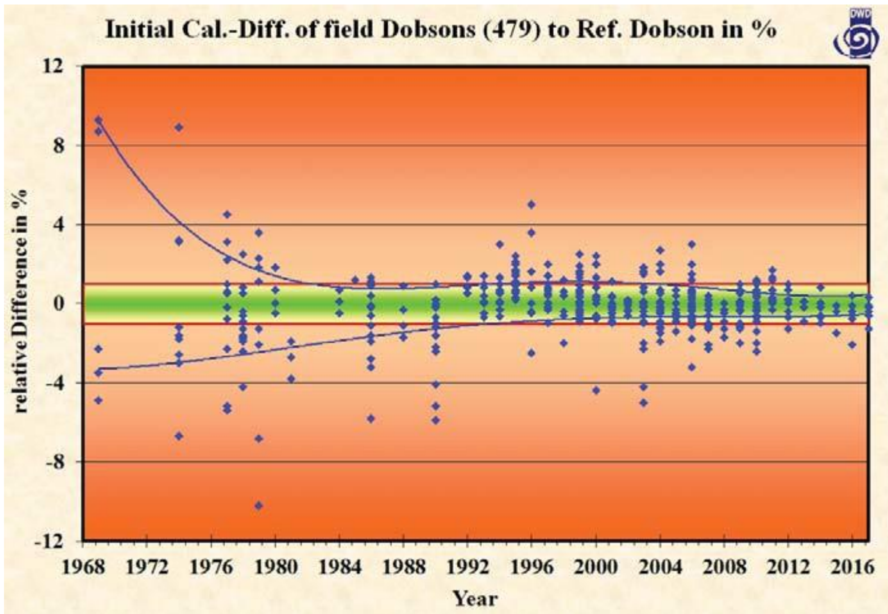
Dobson Column Ozone



McConville, Dobson Ozone Network (P-53)

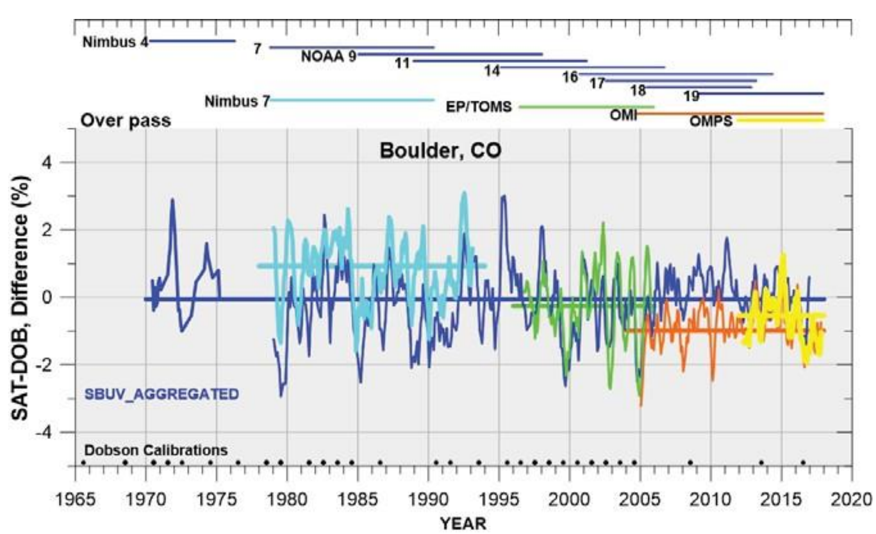
Dobson Column Ozone

Comparison between field instruments and reference instruments



Dobson Column Ozone

- Used to establish consistency of measurement across the network(s)
- Allows us to evaluate:
  - combined datasets
    (important for Ozone Assessment)
  - stability of new satellites (i.e. JPSS)
  - stability of new instruments (i.e. Pandora)

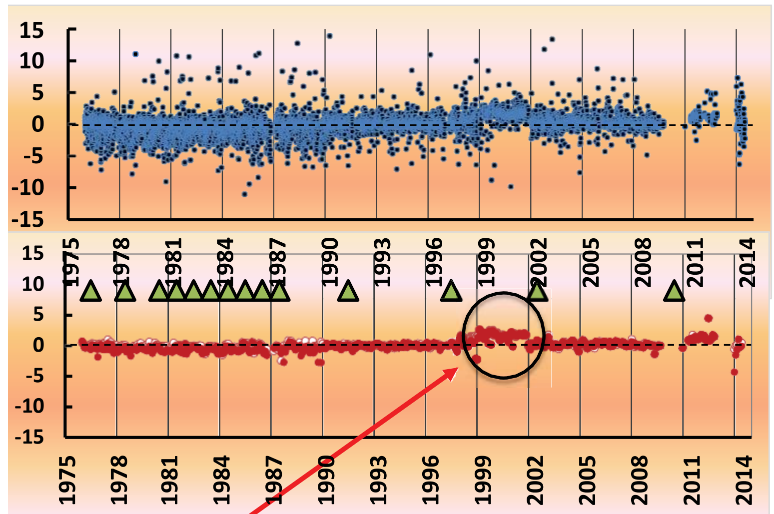


Dobson Column Ozone

Recent Developments: New Software

- WinDobson (developed by the Japan Meteorological Agency)
  - Facilitates near-real-time data
  - Improved QC
  - NRT data needed to support satellites (critical in post-launch year)
  - Efficient reprocessing of archive data

SMO: % Change after reprocessing

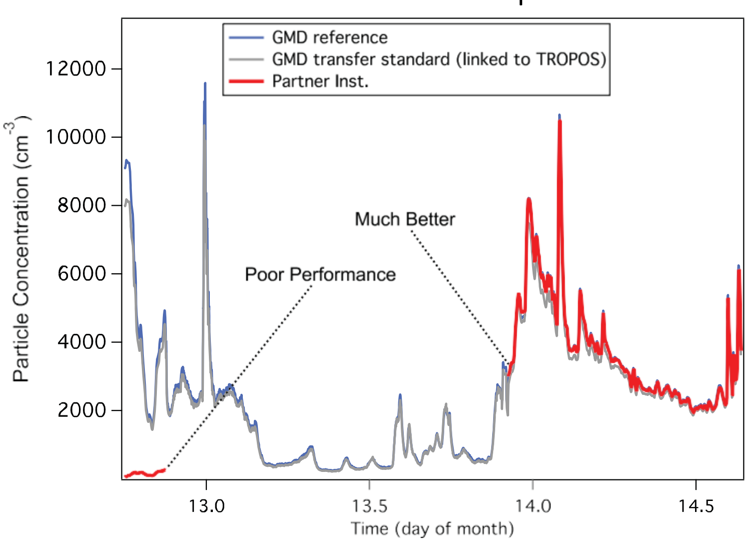


Identified 1-2% errors in SMO record
(overall correction, all stations ~0.1%)

from Evans et al., 2017

Federated Aerosol Network

Particle Counter Comparison



- Calibration derived from TROPOS (Germany)
- Network support, capacity-building role
- QA/QC

Sheridan, Network Overview (P-33)

Trace Gases

- Primary methods – traceable to SI *(to the extent possible)*
- Flexibility – compatible with measurement method
- Support instrument development, complete understanding

Gas Blending Manifold

Compressed Gas Standards

Trace Gases

Scales Developed within GMD

CFCs
CFC-11
CFC-12
CFC-113
CFC-114
CFC-115
CFC-13

HCFCs
HCFC-22
HCFC-141b
HCFC-142b
HCFC-133a
HCFC-21

HFCs
HFC-134a
HFC-365mfc
HFC-152a
HFC-236fa
HFC-143a
HFC-227ea
HFC-125
HFC-23
HFC-32

Other Halocarbons
CH_3Br
CH_3Cl
CH_3I
CH_2Br_2
$CHBr_3$
CH_2BrCl
$CHBr_2Cl$
CH_2I_2
CH_2BrI
CH_2ClI
CF_4

Solvents
CH_3CCl_3
$CClH_2CClH_2$
CCl_4
TCE
$CHCl_3$
PCE
CH_2Cl_2

Halons
Halon-1211
Halon-1301
Halon-2402

Sulfur Gases
COS
SO_2F_2
CS_2
CF_3SF_5
SF_6

Hydrocarbons
acetylene
n-pentane
ethane
i-pentane
propane
hexane
n-butane
benzene
i-butane
toluene

Other
CO_2
CH_4
N_2O
CO
hydrogen
peroxyacetylnitrate
water vapor
perfluoro-amines
NF_3

WMO/GAW CCL
well developed
semi developed
limited

Trace Gases

Designated Institute of WMO

- For select gases: CO_2, CH_4, N_2O, CO, SF_6
- ISO 17025 – Quality Management System reviewed in 2015
- Participate in Key Comparisons – BIPM, National Metrology Institutes

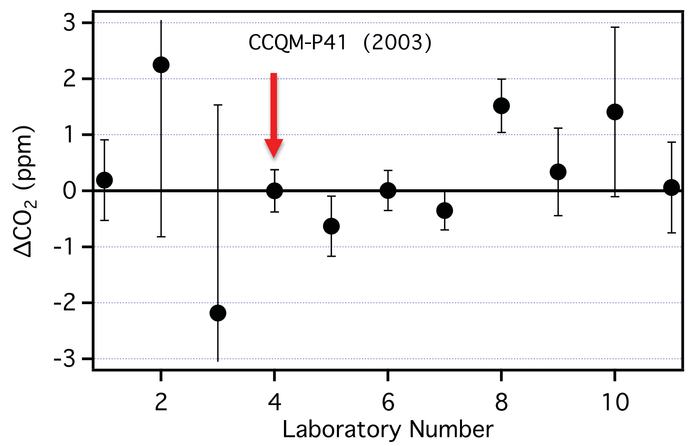

INTERNATIONAL STANDARD

ISO/IEC 17025

Third edition 2017-11

General requirements for the competence of testing and calibration laboratories

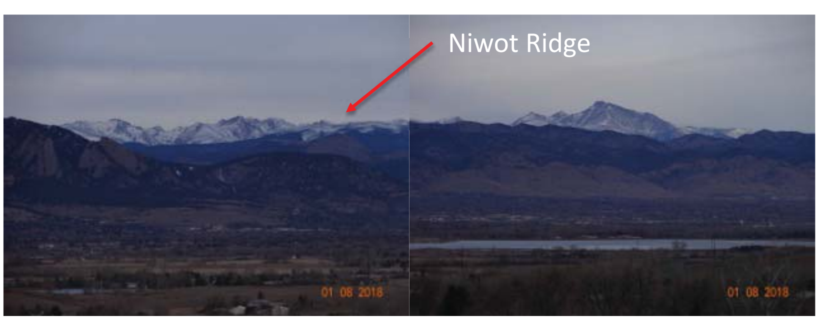
Exigences générales concernant la compétence des laboratoires d'étalonnages et d'essais

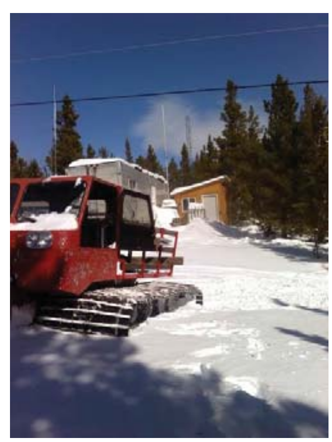


Trace Gases

Whole-Air Standards

- GMD distributes whole-air standards (tertiary)
  - Related to secondary/primary standard by analysis
  - A few other labs also make whole air standards (SIO, CSIRO, ICOS, NIWA)
  - GMD makes **custom mixtures**
  - Access to un-polluted whole air is extremely valuable to GMD

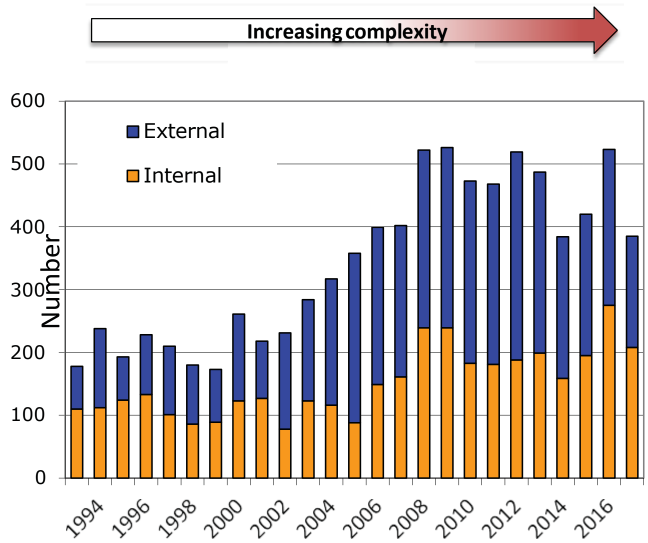




Trace Gases

Tarasova, WMP/GAW (P-1)

WMO/GAW Central Calibration Laboratory



New CO_2/CH_4 analytical system

Since April, 2016

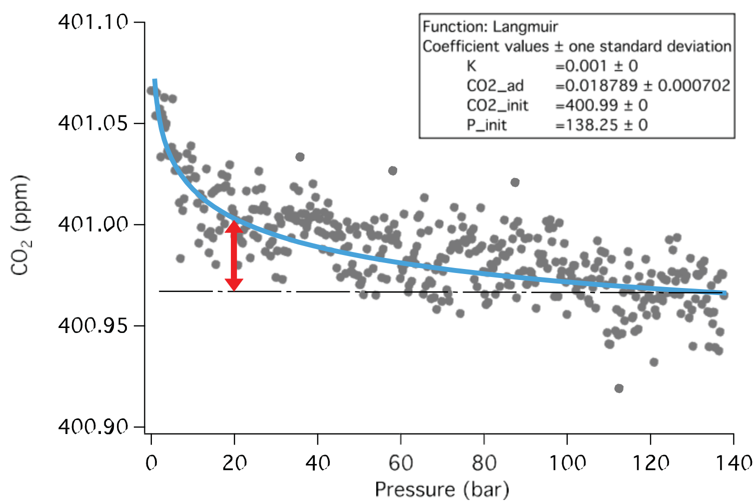
Crotwell, Carbon Monoxide (P-21)

https://www.esrl.noaa.gov/gmd/ccl/ccl.html

Trace Gases

Research Component:

Stability of CO_2 in aluminum cylinders



Schibig et al., 2018

CO_2 increases as pressure drops

Remarkably consistent

~0.04 ppm increase (1 part in 10,000)

(comparable to compatibility goals)

Future Directions

Solar & Terrestrial Radiation

- Continue to facilitate a comparison to evaluate a new standard for longwave irradiance (with NREL/PMOD) (interim standard currently in use)
- Collaborate with NREL and National Central University, Taiwan to improve shortwave irradiance calibrations regarding infrared loss from sensors
- Improve direct-sun calibrations of the Brewer spectrophotometer to improve Aerosol Optical Depth retrievals

Stierle, AOD Retrievals (P-49)

Dobson Column Ozone

- Possibly move D083 to MLO (eliminate risk of transport)
- Continue Dobson/Pandora/Satellite comparisons

Future Directions

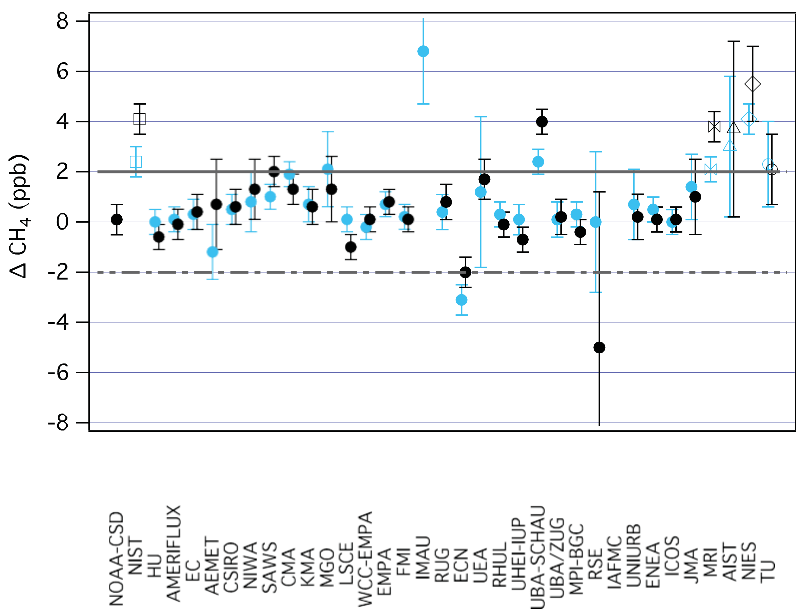
Trace Gases

- Improve uncertainty estimates
- Update CO_2 calibration scale
- Facilitate WMO Round Robin #7

Michel, Stable Isotopes of CO_2 (P-14)

Miller, Uncertainties (P-18)

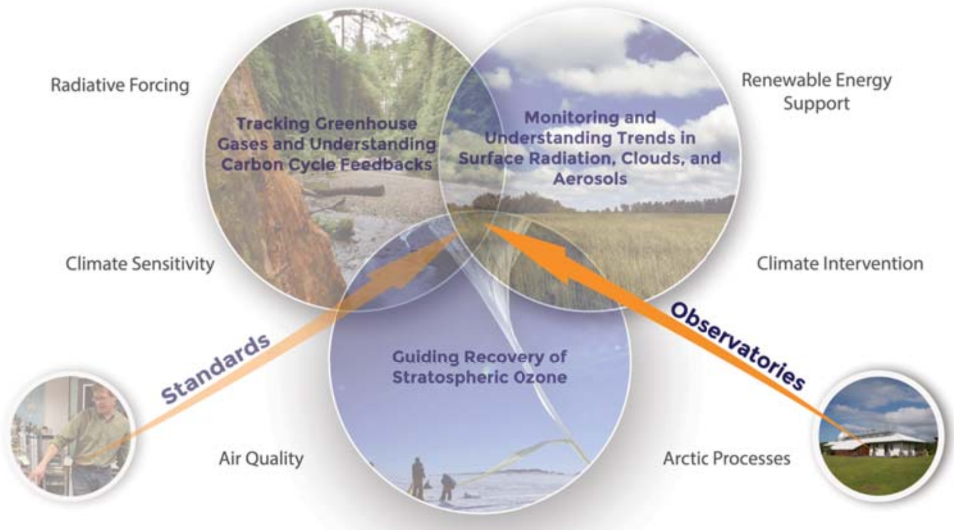
WMO Round Robin Comparison #6 Results: (CH_4)



Summary

- Calibration activities are an essential component of GMD
- We provide calibration links among networks (regional/global scope)
  - Including critical support for WMO/GAW
- We play an active role in improving measurements
- Activities share common aspects: Commitment to consistency

Atmospheric Baseline Observatories

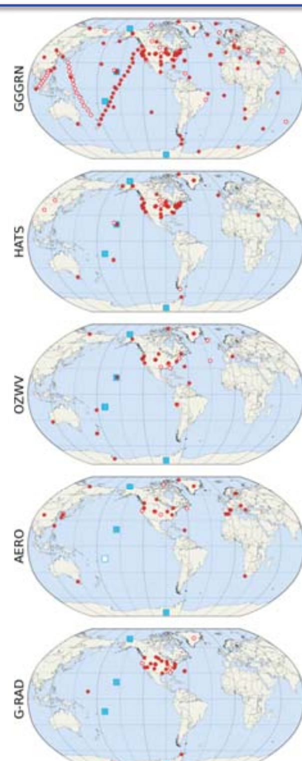


Brian Vasel
Director of Observatory Operations

Backbone of Global Networks

Barrow (BRW)
Elevation: 11m *71.3º N Latitude*

American Samoa (SMO)
Elevation: 42m *14.2º S Latitude*



Mauna Loa (MLO)
Elevation: 3397m *19.5º N Latitude*

South Pole (SPO)
Elevation: 2840m *90º S Latitude*

Observatory Operations Philosophy

ABOs enable and support Science ⇨ Science drives decisions

- **Stewardship** – Build upon foundation of high-quality observations for over 45 years, continue "national treasure" legacy
- **Customer Service** – Plug and play remote field operations for researchers
- **Resources Tool Kit** – Provide highly skilled workforce & core of supporting measurements (meta-data) at each observatory. Updated meteorology, web cams, all-sky imagery, ceilometers, etc.
- **Efficiency** – Thrifty and resourceful operations; every dollar for operations is a dollar less for science
- **Innovation** – Expand and enhance the use of renewable technology, modernize instrumentation
- **Platform for Growth** – Dependable observatory resources + co-location of measurements = increase in interagency & interdisciplinary science collaboration
  - Promotion of observatory platform to audiences external to GMD
    (Other NOAA line offices, Federal partners, & University Pis)

ABO Historical and Relational Significance

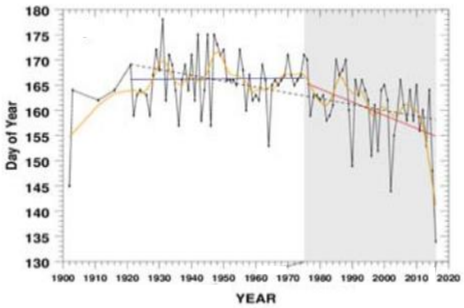
Mauna Loa Dedication June 28, 1956

Staff Collaboration
- Federal
- CIRES & JIMAR (Cooperative Institutes)
- STC contractors
- NOAA Corps Officers
  2-3 officers assigned to GMD at any given time

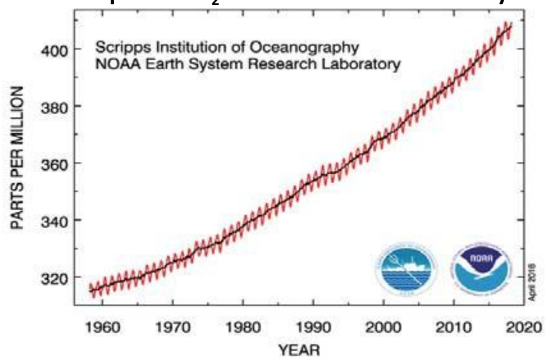
Longevity
- MLO and SPO records date back to 1956 and 1957 (IGY)
- BRW records begin in 1973, SMO in 1974
- First Geophysical Monitoring for Climatic Change (GMCC) Summary Report (1972)
  "… data are collected by a few observatories whose location .chosen to sample representative latitudes within both hemispheres .where local man-made or biota interferences are minimal'.
  First priority is placed on the collection of impeccable measurements of trace constituents."
- WMO Global Atmospheric Watch (GAW) network modeled on ABOs

ABOs - Home of Scientifically Renowned Records

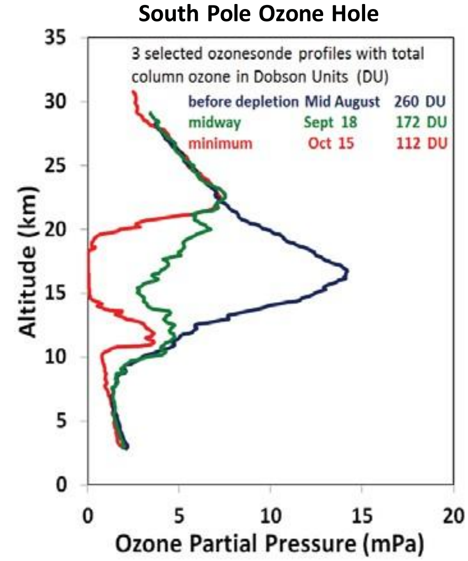
Barrow Snow Melt Date



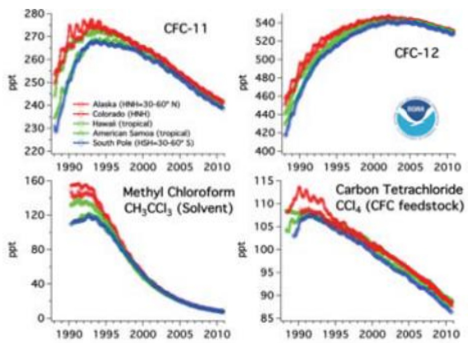
Atmospheric CO_2 at Mauna Loa Observatory



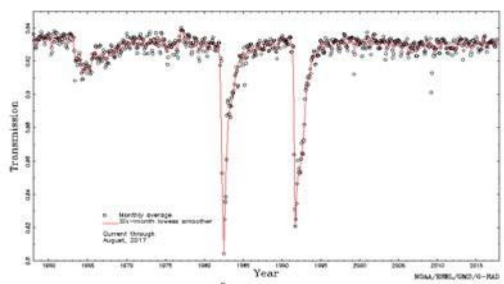
South Pole Ozone Hole



Ozone Depleting Gases



Mauna Loa Apparent Transmission



ABO Stats

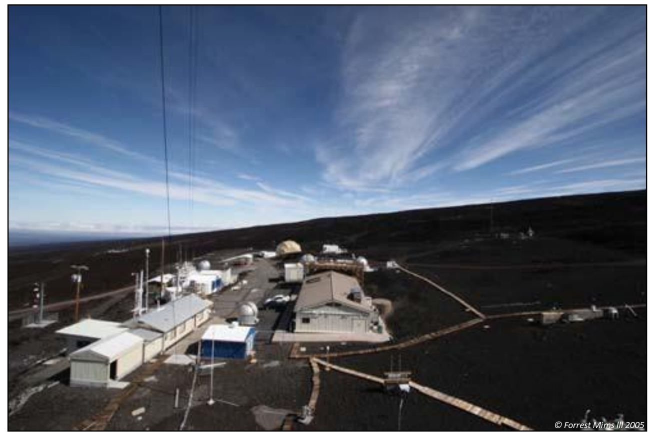
- **Total Peer-reviewed Publications using ABO datasets: 6,307**
- ***2251 Peer-reviewed Publications Since 2013 Review!***
- GMD Data Sets: 775
- Staff: 16
- Vehicle Fleet: 7
- Total Acreage: 135
- Miles of Driveway: 19
- Cooperative Research Projects: 70

Ozonesonde balloon time-lapse at SPO

- Solar Power: 165 panels {SMO = 33% and MLO = 20% of daytime demand)
- Total Structures: 67

Operational Challenges

Operating Field Sites in remote locations poses unique challenges.



Mauna Loa Observatory from tower

- Tight procurement & shipping timelines
- Dirty power
- Cultural considerations
- Natural disasters
- Extreme climates
- Clean Air Sector management
- NEPA & State Historic Preservation Office (SHPO} requirements
- Training of observatory personnel to provide reliable science support workforce
- Infrastructure maintenance

Facility Deferred Maintenance

Facility Condition Assessments (FCAs) - NOAA OCAO effort across agency

BRW - April 2015

- *".the Observatory is in poor condition and appears to have outlived its useful life."* Executive Summary, Page 10

SMO - April 2017

- *". the Observatory Site is in Poor condition and is rated as a D. condition is still somewhat adequate, but the assets are headed toward the latter half of their lifecycle."* Executive Summary, Page 4

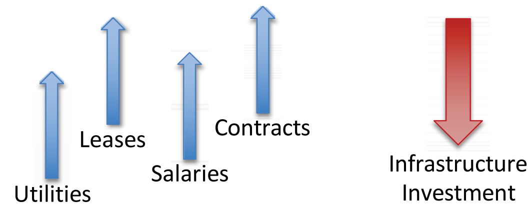
MLO - June 2017

- *". the Observatory is in working order, however, OAR should plan for upcoming capital costs related to component renewals."* Executive Summary, Page 7

Total = $1.BM in deferred maintenance projects

Keeping the Lights On

Simple Math
- Inflation: Increasing Cost of Business
- Steady Science Mission
- Flat Observatory Budget
- Increasingly Difficult to Manage



Prioritized Investments
- Life/facility safety
- Failures/repairs
- Improvements

Critical Mass
- Infrastructure investment essential to service science & maintain quality
- Science suffers without dependable resources

Cyclone Gita Damage at SMO
February 2018

Considerations for THO & SUM

Hard Decisions

No longer support Trinidad Head, CA (THD) or Summit, Greenland (SUM) as NOAA "Atmospheric Baseline Observatories". However, still have critical measurements at each site.

- Rationale for sites & impact to partners
- Current facilities & planned upgrades
- Local influences vs. background? Science requirements.
- Efficiency - logistics requirements for each project:
  - Removed cargo/staff intensive projects
  - Kept low maintenance/power projects
- Ongoing Measurements:

THD	SUM
Aircraft flasks	CCGG flasks
HATS flasks	HATS flasks
Ozonesondes	Aerosol suite
Surface ozone	Meteorology

Trinidad Head, CA

New York ANG LC-130 at SUM

Cooperative Research Projects

- Currently �0 projects across the observatory network are supported

1. Management process redesigned for cooperative projects to leverage Google platform benefits:
   - Email, calendar, forms, drive storage, and secure sharing to field sites
2. New & improved external support webpage created to enhance information sharing with partners, to include:
   - New request/renewal process
   - Logistics
   - Site access,
   - Fee structure, etc.

- ***We currently bring in $250K in reimbursable funds from partners***

Near Term Observatory Goals

Efficiency - Greening the Observatories:
- Renewable energy
- LED Lighting 2018 DOC Green Grant

Building on Partnerships:
- Hilo office {NWS)
- USCG flight/cargo support
- NSF Office of Polar Programs {Arctic & Antarctic)
- Cooperative Projects
- Australia BOM/CSIRO staff training & exchange

Investment in Science:
- New Barrow Observatory Main Building
- New ARO at South Pole
- Additional land buffer at Mauna Loa
- NOTAMs for CAS no-fly zones
- Increase project cost reimbursements

Solar Panels installed at MLO

Observatory Take Away

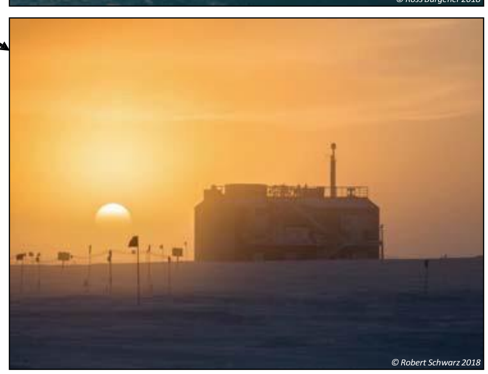
- **Unique to OAR and NOAA**
- **Effective Spending**
- **Collaboration**
- **Innovation and Evolution**
- **Maintenance of Global Leadership**
- **Expand relevance to meet societal need**

World-class science demands world-class facilities

Our Bi-Polar Observatory Team Thanks You!

Sunrise at the Barrow Atmospheric Baseline Observatory - *Vernal Equinox*

March 21st, 2018



Sunset at the South Pole Atmospheric Baseline Observatory - *Autumnal Equinox*

Questions?

The Night Sky over South Pole Station

Observatory Relevant GMAC Presentations:

- Oral Session 3 - Morris
- Oral Session 3 - Cox
- Oral Session 4 - Johnson
- Oral Session 4 - Petropavlovskikh
- Oral Session 4 - Witte
- Oral Session 8 - Davis
- Poster 2 - Williams
- Poster 3 - Ivey
- Poster 35 - He
- Poster 43 - Barnes
- Poster 44 - Shiobara
- Poster 48 - Disterhoft
- Poster 54 - Sun
- Poster 70 - Dix
- Poster 71 - Koenig
- Poster 74 - McClure-Begley
- + 14 additional

Global Monitoring Division

Report of the 2013 Review and Response

2013-2017 Review

May 21-24, 2018

Report of the Review of the NOAA

Earth System Research Laboratory

Global Monitoring Division

April 3-5, 2013

Review Panel

Dr. Kenneth Jucks, NASA, Chair
Dr. Carl Brennikmeijer, Max-Planck Institute for Chemistry Dr. Oystein Hov, Norwegian Meteorological Institute
Dr. Beverly Law, Oregon State University
Dr. Michael McElroy, Harvard University
Dr. Anne Thompson, Pennsylvania State University

Report of the Review of the
NOAA Earth System Research Laboratory Global Monitoring Division
April 3-5 2013

Overview
An on-site, expert peer review of the NOAA Global Monitoring Division (GMD) was conducted April 3-5, 2013 in Boulder, CO. The purpose of the review is to ensure that OAR laboratory research is linked to the National Oceanic and Atmospheric Administration (NOAA) Strategic Plan, is relevant to NOAA Research mission and priorities, is of high quality as judged by preeminence criteria, and is consistent with NOAA planning, budgeting, and budget execution.

The review focused on three research areas: Climate Forcing; Ozone and Ozone Depleting Gases; and Baseline Air Quality. The six-member review panel was provided with written materials before the site visit that included guidance to the reviewers, supporting documentation, NOAA's Strategic and Research Plans, and access to the science presentations to be made during the site visit. During the review, the agenda primarily consisted of presentations on the three research areas, as well as some time allotted for informal discussions with GMD staff and stakeholders. This report summarizes individual panel member evaluations and is not a consensus report.

Summary of Laboratory-Wide Findings and Recommendations

The instructions for this review were to concentrate on the relevance, quality, and performance of the activities being performed at the Global Monitoring Division of the Earth System Research Laboratory of NOAA and to rate the research areas on the criteria outlined in the "Charge to Reviewers" document using the following definitions:
• Outstanding--Laboratory goes well beyond the satisfactory level and is outstanding in all areas.
• Satisfactory--In general, Laboratory meets the expectations of the science criteria.
• Needs Improvement--In general, Laboratory does not reach expectations.
The reviewer will identify specific problem areas that need to be improvement.

	Climate Forcing	Ozone and Ozone Depleting Gases	Baseline Air Quality
Jucks	Outstanding	Outstanding	Satisfactory
Brenninkmeijer	Outstanding	Outstanding	Outstanding
Law	Outstanding	Outstanding	Outstanding
Hov	Outstanding	Outstanding	Outstanding
McElroy	Outstanding	Outstanding	Outstanding
Thompson	Outstanding	Outstanding	Outstanding

The bases of these ratings are summed up with the following statements.

Relevance: The activities of GMD support the "Environmental Security" of the nation and are as essential to the NOAA mission as the rest of NOAA.
Quality: GMD has become a NOAA/ESRL star, carrying on the ever more critical climate mission while pushing the frontiers in Climate, Greenhouse Gases, Ozone Depletion, and Air Quality. Their datasets of changing atmospheric composition and standards are those that will be used by the international community for decades to come.
Performance: The investments into GMD have been well optimized in an underfunded environment. Despite the significant set of responsibilities, the work in the different groups focusing on the themes presented to the panel, is of the highest caliber. The scientific community, nation, and beyond are reaping the benefits, and are heavily dependent on GMD. Now is the time to strengthen the capacity of GMD even further to maintain its global lead in these activities.

All of the areas of focus within the GMD are activities that are highly relevant to NOAA's goals of understanding the Earth System as it relates to addressing the information the US Government and citizens need to understand the impacts of decisions on many scales. The Climate, Ozone, and Air Quality research at GMD are all key areas of focus for NOAA and Earth System Science.

The quality of the work, as proven by the broad range of researchers who either use data obtained by GMD or extensively collaborate with GMD researchers is at the highest level. The trusted data sets GMD distributes are key to advancing science and reducing uncertainties in the international assessment process. GMD personnel are committed to this goal and are highly recognized for their work (reference "Preeminence" document).

The GMD has assembled a very skilled team that takes their obligations very seriously, and this shows in how they achieve their mission. They work tirelessly to establish connections to ensure that all of their partners worldwide meet the performance standards of GMD as well. As a result, data, products, and scientific analysis that ensue from GMD activity are quite high, especially with the constraints on resources in which they currently operate.

The long-term observatories and distributed observations of GMD are essential for the monitoring of key atmospheric parameters. There is no redundancy in these data. Reinforcing infrastructure at the current observatories is essential. Equally important is *expanding* capacity to support monitoring in regions where new problems may erupt that affect the US and international partners (e.g., new oil and shale-gas activity, GAW-type locations affected by intercontinental pollution).

The team reports five Findings and associated Recommendations. These are further spelled out our individual findings. These are summarized below. Note that each

Finding touches on one or more of the 3 Review metrics (Relevance, Quality, Performance). Each Finding and Recommendation pair is followed by important evidence and background.

Finding #1

The NOAA GMD Mission is on target, well aligned with the needs of many stakeholders and supporting the activities of other science and regulatory agencies (state, national, and international). The lab is an environmentally strategic asset of the US that has been carefully optimized to conduct highly successful science in the areas of Climate Forcing, Ozone and Ozone-depleting substances and Air Quality.

Recommendation #1: The science GMD carries out to support other science and regulatory agencies (state, national, and international) should be expanded rather than contracted to accomplish NOAA's mission.

Background and Evidence:

GMD activities and researchers address essential "processes" in the "Earth System" that are only understood with long-term, systematic, quality-assured observations. In many cases no other organization has the capability to do this kind of work. GMD has evolved into a distinguished "scientific" national asset.

No single agency or organization doing global Earth System science has the financial or personnel resources to sufficiently achieve the tasks they have defined as priorities. Most localized Earth Science problems are tasked to State agencies (within the US) to monitor/regulate, and they rarely have the appropriate scientific expertise to sufficiently follow through on their mandates. GMD fully recognizes this and works hard to establish both global and local connections and collaborations to help them achieve their goals and those of their partners.

The work with international partners, especially those connected with WMO, ensure that GMD's "climate" and "ozone" related observations are truly global, which is required to answer the science questions related to these fields. Even with these efforts, the spatial and temporal coverage of the resulting data sets is adequate at best. More, not less, effort is required to advance the science in these areas. GMD is the main international coordinator in enhancing and expanding these coordination activities. The strong, central, and internationally leading role for GMD is essential to US interests and must be sustained.

The work with local US partners primarily relates to Air Quality activities, many of which are delegated to the states, and coordinated with the EPA. The recent work by GMD with some western states for understanding the impacts of emissions from gas and oil extraction is a clear example of how NOAA expertise allows regional policy makers to understand the implications of activities in their individual states that would simply not be possible with their own resources.

Finding #2

The combination of GMD activities and priorities, with a mixture of operations, science and technology is an essential element of its successful approach to carrying out its mission.

Recommendation #2: All three components of GMD work, operations, scientific analysis and technological development, are required for its mission and must be sustained.

Background and Evidence

The term "monitoring" may imply activity that is routine or not important to understanding the basic "mechanisms" of the Earth System. However, it is a synthesis of short term and long term observations that are required to quantify changes and uncertainties in the system as a whole. Both monitoring and process data require interpretation by scientific experts within GMD.

Monitoring implies "operational" in the eyes of many managers within the US government. However, the monitoring activities of GMD require significant scientific and technological expertise that is the foundation of mission success. The types of observations performed by GMD require unique instrumentation, many of which are developed in-house. The operation, upkeep, and improvement of these instruments require a high level of specialization. Having people in-house who are on the forefront of using and interpreting the data scientifically is also critical and makes an internally consistent system. Top- quality scientific data require the full understanding of how random and systematic uncertainties propagate to scientific conclusions and assessments. This requires that GMD scientists who are actively involved in the analysis and interpretation of their data *direct* the operation, upkeep, improvement and deployment of their instrumentation.

Finding #3

GMD "leveraging" of activities done by others is extensive and integral to the scientific mission of GMD and is often an appropriate and required strategy. Although national and international partnerships partially compensate for limited NOAA resources, the continued US leadership role in monitoring and scientific assessments is at risk due to declining budgets!

Recommendation #3: NOAA must put additional resources into all aspects of GMD operations, scientific analysis and innovation.

Background and Evidence

This finding is related to Finding #1 and is illustrated with reference to NOAA's role in the assessment process. NOAA at large makes significant contributions to these mandated assessment activities both within the US Government and in partnership with international organizations where the US Government is a significant contributor. The personnel within GMD play an integral role in many of these assessments and the data sets produced by GMD are at the core of many key findings within these assessments.

- National Climate Assessment
- IPCC assessments
- WMO/UNEP Ozone assessments

Due to the complexity of science and the global scope of GMD research and observations are the backbone of the WMO/GAW, ICOS, and GCOS, especially in the ozone and greenhouse gas areas. Without GMD continuing its leadership role in standards, measurements and reporting, those programs would fall apart and the assessments would be incomplete. The same holds for the collaborative activity within the US agencies where GMD data perform a unique function in integrating climate, ozone and air quality programs. Although NASA and DOI (USGS, USFS) are partners in certain earth observations, no other agency has the expertise, ability, or budget to perform the roles played by GMD within the USGCRP, NACP frameworks nor in connecting air quality to regional composition and climate changes.

The US needs to be prepared for possible future international agreements regarding climate and mitigation. The US Government will need observations from GMD in order to better assess and document how well the US and international partners are meeting their agreed-upon metrics. Only GMD has the multi-decade records and interpretive capability to take on the challenge that such agreements will present.

Finding #4

The scientific capacity of GMD is at risk due to a disproportionately senior workforce, including possible near-term retirements of some of its pre-eminent leadership, and little succession planning for major programs. Most junior and some mid-career scientists with leadership potential in GMD are employed through CIRES, with limited opportunity to advance.

Recommendation #4: Recruitment of new talent and conversion of suitable CIRES staff to NOAA positions are imperative for keeping projects strong.

Background and Evidence

GMD has gathered significant talent within the early and mid-career ranks but most of these individuals are CIRES (the University of Colorado's Cooperative Institute for Research in Environmental Sciences) employees. This limits their ability to advance to leadership positions within GMD. The future of GMD requires that many current CIRES employees be converted to civil servants and assume more active roles in setting direction of GMD activities. Avenues should be put in place now to facilitate development of future GMD leaders.

Finding #5

The GMD observatories are national treasures and strategically located to support their highest priority national and international measurement programs. However, their current number is barely sufficient and NOAA cannot respond to emerging environmental problems with new stations.

Recommendation #5: NOAA should ensure the continued support for the observatory system.

Evidence and Background.

All of the observatories maintained by GMD are in critical locations, and even doubling the number of related observatories would not lead to redundancy. The current set of observatories provides minimal coverage for most of the parameters being observed. There is a need for additional investment in the human resources at the observatories that supporting GMD's measurement program.

Maintaining the current set of GMD observatories is the absolute minimum investment that should be applied to the observatories and should be one of the highest priorities within GMD.

Summary of Findings and Recommendations

1. The GMD mission is strategically aligned with NOAA's mission and stakeholder requirements. Supporting the activities of other science and regulatory agencies (state, national, and international) should be expanded rather than contracted to accomplish NOAA's mission.
2. GMD's programmatic priorities are the "right ones" and are supported by a well-optimized mix of monitoring, science and technology. All of these components of GMD must be sustained.
3. Leveraging national and international partnerships is an integral part of conducting GMD's work, but US leadership in the science and the assessment process is threatened by the current funding environment. Funding for all of GMD's activities must be increased.
4. GMD's pre-eminence in monitoring and science are at risk with a very senior workforce and little succession planning. To remedy this, recruitment of new talent and conversion of suitable CIRES staff to NOAA positions is recommended.

5. The GMD record and scientific output depend heavily on the infrastructure of its observatories. NOAA must ensure continued support for the observatory system.

GMD Final Report to OAR Management re: the 2013 Global Monitoring Division Reviewers' Findings and Recommendations and GMD's Response

[Comments on Actions taken in Blue]

27 July 2015
Revised 10 August 2016

We greatly appreciate the thoughtful comments provided by the Review Panel, and the time they spent in carrying out this review of NOAA's (National Oceanic and Atmospheric Administration) Global Monitoring Division (GMD).

This document responds to issues raised by the reviewers or provides additional information where warranted by the reviewers' comments. In the first section below, we have responded to general comments offered in the written review report. The second section responds to specific points made by the reviewers within the topic areas of the review. Excerpts from the Review Report are shown in italics.

General Comments

We appreciate the positive comments offered by the reviewers concerning the quality, relevance, and performance of atmospheric chemistry, aerosol, and solar radiation research at ESRL. It is good to hear this diverse panel underscore the quality, relevance, essential nature, and value of our data sets and research to assessments and scientists worldwide. We agree that these data and research are essential to the success of international science and are dedicated to maintaining quality and keeping the systems operational under all budget scenarios.

Actions: To sustain the continuity and quality of GMD's data sets, we are aggressively pursuing several options. We actively seek extramural funds from other agencies and we are beginning to charge full cost recovery on services at the observatories. [We have instituted an on-going effort, phasing in charges according to individual agreements at all observatories.] We also have recently engaged the Office of Marine and Aviation Operations (OMAO) for a larger effort by NOAA Corps in providing staff at our observatories, increasing their staffing in GMD and the length of their tours of duty. [This has been completed for a third officer; we continue to seek a fourth.] Though each of these efforts is helpful, none of them is a sufficient amount of funding to provide to adequately upkeep and maintain our sites, nor to cover the plethora of publications our highly productive staff generates from these data. What may be more effective is our effort to secure additional funds through a proposed increase of base funds in the President's budget requests. Although we received a modest increase in base funding beginning in FY2014, fragments of what is needed remain. These were kept in NOAA's request for FY2015 and FY2016 to no avail and we understand these items will again appear in the President's FY2017 request. We will continue to work closely with the

Office of Oceanic and Atmospheric Research (OAR) and NOAA leadership to ensure that GMD has appropriate funding for its critical work.

Specific Comments on the Topic Areas

Finding #1: *The NOAA GMD Mission is on target, well aligned with the needs of many stakeholders and supporting the activities of other science and regulatory agencies (state, national, and international). The lab is an environmentally strategic asset of the US that has been carefully optimized to conduct highly successful science in the areas of Climate Forcing, Ozone and Ozone-depleting substances and Air Quality.*

Recommendation #1: *The science GMD carries out to support other science and regulatory agencies (state, national, and international) should be expanded rather than contracted to accomplish NOAA's mission.*

Response: GMD's mission is essentially unchanged since its inception and that is consistent for an organization designed to provide long-term monitoring to address multi-decadal concerns. GMD's scientific publications, data, and products have become increasingly relevant to other agencies through the US Global Climate Research Program (USGCRP), particularly the Environmental Protection Agency. In addition to their scientific contribution, GMD's ozone observations inform policies on stratospheric ozone and air quality; greenhouse gas observations inform policies on energy development; aerosols and radiation inform policies on energy development and overall air quality.

Actions: GMD will continue to maintain all networks, expand its product base, interact with other agencies to enhance observing systems, inform assessments, build outreach, and publish manuscripts, analyses, and data products in a timely manner. Our Global CO_2 Record and our Annual Greenhouse Gas Index have now been officially adopted as National Climate Indicators. They both also are used routinely in EPA Annual Reports, as are all of our data on ozone depleting gases along with the Ozone Depleting Gas Index. Our studies of oil and gas field emissions of methane are also now used by EPA to evaluate their methane emission inventories and our findings on ozone have influenced recent air quality policy decisions by EPA and we continue our contributions to the ozone assessments that inform the parties to the Montreal Protocol. Internationally, we continue to maintain strong ties with the World Meteorological Organization (WMO) through participation in its Global Atmospheric Watch Programme (GAW) serving on or leading its scientific advisory groups and experts groups, WMO Commission for Atmospheric Sciences (the guiding body for GAW and the World Weather Research Programme), the Baseline Surface Radiation Network, the Federated Aerosol Network, the Global Climate Observing System (GCOS) Atmospheric Observation Panel for Climate, the USGCRP Carbon Cycle Interagency Working Group and Scientific Steering Groups, US Group on Earth Observations (GEO), and the international GEO-Carbon Programme. [GMD continues to leverage its skills and capabilities among these organizations, being key players in the GEO-Carbon Strategy, the emerging WMO Integrated Greenhouse Gas Information System, and the emerging GEO-Carbon Flagship. GMD leads much of the work at the biennial Greenhouse Gas Measurement Techniques meetings where measurement guidelines are evaluated. GMD provides leadership of the Baseline Surface

Radiation Network, two WMO Scientific Advisory Groups, and participation on a third. We continue to update of products, re-establish lost sites with infused funds, participation in WMO, GCOS, GEO events, commissions, panels worldwide, maintain involvement in USGCRP, work to establish Nat'l Climate Indicators, and build capacity through WMO, CEOS, GEO and national partners.]

Overall, we are looking at ways to brand GMD's observing systems for what they are – "Reference Networks for Atmospheric Composition and Radiative Forcing". As reference networks, they have become the core of any global observing system of these variables – other instruments, sites, or systems must yield results that are consistent with GMD's. GMD's observing systems for greenhouse and ozone-depleting gases, ozone, aerosols, and radiation are "reference" networks for several reasons: (1) they are supported internally by world recognized standards, calibration gases, and approaches; (2) their high quality and comprehensive coverage make them particularly useful for comparisons by other observing systems; (3) GMD maintains rigorous, transparent quality control procedures that provide the glue for incorporating outside measurements; (4) products such as GlobalView and CarbonTracker are used universally to initialize and validate climate models; and (5) satellite retrievals similarly use GMD's records for initialization and validation. We are exploring having this "branding" as reference networks for several other of our networks in the near future. A "beta" version for greenhouse gases is currently posted at http://www.esrl.noaa.gov/gmd/ccgg/about.html .

Finding #2: *The combination of GMD activities and priorities, with a mixture of operations, science and technology is an essential element of its successful approach to carrying out its mission.*

Recommendation #2: *All three components of GMD work, operations, scientific analysis and technological development, are required for its mission and must be sustained.*

Response: Our understanding of this finding is that, although much of what we do to ensure the continuity of our observations can be considered operational, it is essential that research and observations be tightly linked under the same roof. This is needed because of the high accuracy and precision of data required, the low concentration levels measured, and the sophistication of the instrumentation. We have maintained this tight linkage since the inception of GMD's predecessor organization (Geophysical Monitoring for Climate Change – GMCC), but especially since 1984, when a review panel for GMCC made it clear to OAR and NOAA leadership that the importance of these observations, the quality needed for them to be of scientific value, and the dependence of the broader community on the observations required an infusion of research scientists within the organization if it is to succeed. The recommendation was acted upon within the following few years and improved the value and impact of what are now GMD's data, products, and research.

Action: GMD will continue to pursue a careful balance between top quality scientists and skilled technicians to ensure the continuity, quality, and relevance of these data. As we work to replace our aging workforce, we will ensure that highly-capable individuals are attracted to oversee and maintain our observing systems. To a great extent such an attraction already exists because of the relevance and quality of GMD data, the opportunity to work in a pool of innovative scientists, and our engagement with national and international partners. We will enhance this with opportunities for succession and leadership development by fostering even closer coordination among our scientists and technicians, by continuing to give mid-level scientists leadership opportunities, and by encouraging retiring senior federal staff to continue part-time in non-federal positions to provide continuity and mentoring for the new generation of leaders. [We have hired two technicians and Group Chief as federal employees and several scientists and technicians as CIRES Associates with new funds. Several federal employees have retired and we are working on filling positions. We have developed succession plans for all research groups.]

Finding #3: *GMD "leveraging" of activities done by others is extensive and integral to the scientific mission of GMD and is often an appropriate and required strategy. Although national and international partnerships partially compensate for limited NOAA resources, the continued US leadership role in monitoring and scientific assessments is at risk due to declining budgets!*

Recommendation #3: *NOAA must put additional resources into all aspects of GMD operations, scientific analysis and innovation.*

Response: This is a critical issue that GMD has long-recognized. For Fiscal Years 2011-2017, NOAA, with considerable push from GMD, OAR, CPO, and even OSTP, has had requests in the President's Budget for amounts ranging from $5.7M to $12.7M augmentation to GMD, mainly through CPO. The requested funds in the FY 2011-2013 budgets were not appropriated by Congress. In FY2014, $3.5M of the $5.7M request was granted by Congress. This brings us back to 2003 levels in real dollars, which helps, but is still not enough to meet current demand and requirements. Also, with a complete design and cost estimates fully laid out, we have had requests to the NOAA Chief Administrative Officer for funds for a new building at Pt. Barrow for about a decade, getting high in the rankings in many years, but not high enough to compete for the limited, available resources.

Action: For FY2015, GMD has worked closely with OAR Leadership, NOAA Headquarters, and NOAA Office of Program Planning and Integration to request $3M additional funding for NOAA's Atmospheric Baseline Observatories, mainly for operational support. This is now in the FY2015 President's Budget Request. The amount is not sufficient for maintaining our unique reference networks at a level to ensure global leadership, but it will at least prevent our observatories from falling further into disrepair. OMB saw fit to add two additional requests for FY2015 that harbor significant increases for GMD observing networks. One is a request for $4.5M, of which $1.0M is targeted at GMD activities regarding the North American Carbon Program. That is intended to recover most of the remaining FY2014 request. The second request was for $8M for North American carbon research, calling for largely expanded monitoring of CO2 and methane from GMD's aircraft and tall tower networks, supported by enhanced measurement of C-14 in CO2, other isotopes in CO2 and methane, and chemical tracers for attributing emissions. Along with OAR and NOAA HQ, we will meet with key committee staff and members of Congress on several occasions this year as the budget is developed. It is essential not just to GMD, but to NOAA, OAR, and the world scientific community that these funds become available. In addition, we will work closely with OAR and NOAA and continue to push for funding for a new Barrow facility at the earliest possible chance. [We continue to push for more resources supporting NOAA's long-term observing systems, adding, once again, a request for funds to construct a new building at Barrow, Alaska (BRW).

Finding #4: *The scientific capacity of GMD is at risk due to a disproportionately senior workforce, including possible near-term retirements of some of its pre-eminent leadership, and little succession planning for major programs. Most junior and some mid-career scientists with leadership potential in GMD are employed through CIRES, with limited opportunity to advance.*

Recommendation #4: *Recruitment of new talent and conversion of suitable CIRES staff to NOAA positions are imperative for keeping projects strong.*

Response: GMD has an urgent need to open up NOAA positions if it is to succeed in maintaining leadership within the organization. GMD and OAR agree to continue to push for these positions.

Action: GMD is working with OAR HQ to fill eight NOAA positions this calendar year. These include four scientists, an administrative officer, a budget analyst and two technicians. [GMD has hired two technicians, an Administrative Officer, and two scientists as federal employees. Several CIRES technicians and scientists have also been hired. We are still waiting on two scientists, one technician, and two administrative positions and are preparing a list for further conversions.]
See also discussion of personnel hiring and succession planning in response to recommendation 2.

Finding #5: *The GMD observatories are national treasures and strategically located to support their highest priority national and international measurement programs. However, their current number is barely sufficient and NOAA cannot respond to emerging environmental problems with new stations.*

Recommendation #5: *NOAA should ensure the continued support for the observatory system.*

Response: This is one of several needs for GMD funding, as noted above in our response to Finding and Recommendation #3. These are (1) additional funds for the current atmospheric baseline observatories to accommodate rapidly rising costs and previous budget cuts; (2) support to strengthen and upgrade GMD's reference networks for atmospheric composition and radiative forcing with up-to-date equipment; and (3) facilities support to replace the greatly aged main building at Pt. Barrow, AK.

Action: The additional funding received in FY2014 has taken some pressure off of GMD's observing system infrastructure, but significant gaps remain. As we noted in our response to Finding and Recommendation #3, OAR's request for funding for GMD's Atmospheric Baseline Observatories has appeared in the President's budget for FY2015, FY2016, and likely FY2017. Other portions of the President's Budget request that support GMD will greatly benefit the overall observing systems that are intricately linked to and support the observatories. These additions will allow NOAA to maintain its leadership position in providing reliable, long term information on global atmospheric composition. [In addition to on-going requests for funds for the ABOs, GMD has solidified its relationship with NOAA Corps, increasing number of NOAA Corps Officers supporting ABOs from 2 to 3. We have also hired additional staff (CIRES) to support and staff observatories.]

Global Monitoring Division

Research Plans: 2013-2018 and 2018-2022

2013-2017 Review

May 21-24, 2018

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May 22-23, 2018

NOAA ESRL GLOBAL MONITORING ANNUAL CONFERENCE 2018

David Skaggs Research Center, Room GC-402
325 Broadway, Boulder, Colorado 80305 USA

Tuesday Morning, May 22, 2018 Agenda

(Only presenter's name is given; please refer to abstract for complete author listing.)

07:00 ***Registration Opens in GC-402 - lunch orders and posters collected at registration table***
07:45 - 08:30 ***Morning Snacks - coffee, tea, fruit, bagels and donuts served***

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Session 1 ***Welcome, Keynote Address & Highlights*** *— Chaired by James H. Butler*

08:30 - 08:45 Welcome and Setting the Stage -
James H. Butler (NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))

08:45 - 09:00 Where GMD Fits in the Big Picture -
Ko Barrett (NOAA Office of Oceanic and Atmospheric Research (OAR))

09:00 - 09:45 KEYNOTE ADDRESS - Science for Policy and Policy for Science in the Federal Government -
John P. Holdren (Harvard University, John F. Kennedy School of Government)

9:45 - 10:15 ***Morning Break & Group Photo on the Stage***

Session 2 ***Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks - Global Constraints on the Carbon Cycle*** *— Chaired by Gabrielle Petron*

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Pieter Tans (NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))

10:30 - 10:45 Constraints on Global Carbon and Heat Exchanges from Measurements of Atmospheric O_2 and Related Tracers 2
Ralph Keeling (Scripps Institution of Oceanography, University of California at San Diego)

10:45 - 11:00 Monitoring Trends and Spatial Distributions of Carbon Cycle Greenhouse Gases and Related Tracers 3
Edward J. Dlugokencky (NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))

11:00 - 11:15 The OCO-2 Model Intercomparison Project Reveals Systematic Transport Model Effects on Inverse Model CO_2 Fluxes 4
Andrew R. Jacobson (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

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Jae-Sang Rhee (National Institute of Meteorological Sciences, Seogwipo-si, South Korea)

11:30 - 11:45 The Mysterious Global Methane Budget 6
Lori Bruhwiler (NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))

11:45 - 13:00 ***Catered Lunch - Outreach Classroom GB-124 (pre-payment of $12.00 at registration)***

NOAA ESRL GLOBAL MONITORING ANNUAL CONFERENCE 2018

David Skaggs Research Center, Room GC-402
325 Broadway, Boulder, Colorado 80305 USA

Tuesday Afternoon, May 22, 2018 Agenda

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NOAA ESRL GLOBAL MONITORING ANNUAL CONFERENCE 2018

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09:00 - 09:15	Arctic-CAP: Northern High Latitude CO_2, CH_4, and CO Airborne Vertical Profile Surveys during the Arctic-Boreal Vulnerability Experiment (ABoVE) *Charles Miller (NASA Jet Propulsion Laboratory, California Institute of Technology)*	21
09:15 - 09:30	ICOS Research Infrastructure, Progress in the European Carbon Cycle and Greenhouse Gas Observing Network *Alex Vermeulen (Integrated Carbon Observation System (ICOS) European Research Infrastructure Consortium (ERIC), Carbon Portal, Lund, Sweden)*	22
09:30 - 09:45	Single-blind Testing of a Regional, Continuous Monitoring System for Finding Methane Leaks from Oil and Gas Operations *Caroline Alden (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)*	23

9:45 - 10:15 ***Morning Break***

Session 6 ***Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks - Urban/Regional Emissions*** *— Chaired by Arlyn Andrews*

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10:30 - 10:45	Development of an Open-path, Laser Dispersion Spectroscopy (LDS) Analyzer for Methane Emissions Mapping and Quantification *Graham Leggett (MIRICO Ltd., Chilton, United Kingdom)*	25
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NOAA ESRL GLOBAL MONITORING ANNUAL CONFERENCE 2018
David Skaggs Research Center, Cafeteria
325 Broadway, Boulder, Colorado 80305 USA

Tuesday, May 22, 2018 Poster Session Agenda

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2018 GMAC and GMD Review Joint Session

P-0 Evaluating the Impact of Baseline Ozone in California using Ozone-Sonde Measurements at Trinidad Head, CA (THD): Overview
Toshihiro Kuwayama (California Air Resources Board)

P-1 Global Atmosphere Watch Programme: the Role of the National Programmes in Supporting the Global Value Chain
Oksana Tarasova (World Meteorological Organisation, Geneva, Switzerland)

P-2 The Radon Measurement Programs at Cape Grim, Mauna Loa, and other Global Atmospheric Monitoring Sites
Alastair G. Williams (Australian Nuclear Science and Technology Organisation (ANSTO), Lucas Heights, Australia)

P-3 NOAA and U.S. Department of Energy/Office of Science Cooperative Efforts in Barrow (Utqiaġvik), Alaska
Mark Ivey (Sandia National Laboratories)

P-4 Ozone, Aerosols and Carbon Gases at the Mt. Bachelor Observatory
James Laing (University of Washington)

P-5 Black Carbon Mass Observations across Canada (2006-2015): Constraining on Regional Emissions in North America
Lin Huang (Environment and Climate Change Canada, Toronto, Canada)

P-6 Aerosol Hygroscopicity during the Haze Red Alert Period in Winter 2016 at a Rural Site of the North China
Junying Sun (Chinese Academy of Meteorological Sciences, Key Laboratory of Atmospheric Chemistry of CMA, Beijing, China)

P-7 Using SURFRAD Aerosol Optical Depth Measurements for Model Evaluation. A Study with FV3-GOCART and WRF-Chem and Their Assimilation Systems
Mariusz Pagowski (NOAA Earth System Research Laboratory, Global Systems Division (GSD))

P-8 Ratios of Greenhouse Gas Emissions Observed over the Yellow Sea and the East China Sea
Lingxi Zhou (China Meteorological Administration, Chinese Academy of Meteorological Sciences, Beijing, China)

P-9 TCCON Updates and Improvements to Precision Requirements
Coleen Roehl (California Institute of Technology)

P-10 Engaging Agencies and the Public in Atmospheric Monitoring Observations Through Real-time Data Posting
Detlev Helmig (Institute of Arctic and Alpine Research (INSTAAR), University of Colorado)

P-11 The Importance of Ozonesonde Quality Assurance and JOSIE-SHADOZ (2017)
Jacquelyn C. Witte (Science Systems and Applications, Inc. (SSAI))

P-12 The Evolving Role of Space-based Measurements in a Global Carbon Monitoring System
Charles Miller (NASA Jet Propulsion Laboratory, California Institute of Technology)

Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks

P-13 AirCore: The Gold Standard for Comparing Remote Sensing Observations to the Ground Network and the Capturing Changes in Stratospheric Circulation Changes
Colm Sweeney (NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))

P-14 Monitoring of Atmospheric Acetylene in the NOAA Global Greenhouse Gas Reference Network
Jacques Hueber (Institute of Arctic and Alpine Research (INSTAAR), University of Colorado)

P-15 Atmospheric Isoprene in the NOAA/INSTAAR Global Greenhouse Gas Reference Network
Jacques Hueber (Institute of Arctic and Alpine Research (INSTAAR), University of Colorado)

P-16 Spatial and Temporal Gradients in Atmospheric CO_2 and CO in the Los Angeles Megacity
Kristal R. Verhulst (NASA Jet Propulsion Laboratory, California Institute of Technology)

P-17 Investigating Hydrocarbon Tracers for Anthropogenic CO_2 at Indianapolis, IN
Isaac Vimont (National Research Council Post-Doc)

P-18 Estimating Uncertainties of GC/MS Analyses of Programmable Flask Package (PFP) Atmospheric Samples from the GGGRN North American Tower and Aircraft Programs
Benjamin R. Miller (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

Tuesday, May 22, 2018 Poster Session Agenda

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Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks (continued)

P-19 Untangling Greenhouse Gas Fluxes and Transport using ACT-America Observations
Sha Feng (Department of Meteorology and Atmospheric Science, The Pennsylvania State University)

P-20 Recent Developments in Using Isotopic Measurements for Constraining Methane Sources and Sinks
Xin Lan (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

P-21 Recent GAW Activities of KMA
Yuwon Kim (Korea Meteorological Administration, Daebang-dong, Dongjak District, Republic of Korea)

P-22 Systematic Differences in Global CO_2 Inverse Model Results
Benjamin Gaubert (National Center for Atmospheric Research (NCAR), Atmospheric Chemistry Observations and Modeling Laboratory)

P-23 Methane Leak Detection and Sizing using Large Eddy Simulations (LES)
Kuldeep Prasad (National Institute of Standards and Technology (NIST))

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Jinwoong Kim (Environment and Climate Change Canada, Toronto, Canada)

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Ivar R. van der Velde (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

P-26 A Reanalysis of Inter-laboratory Comparisons as the Stable Isotope Lab at INSTAAR Switches to the JRAS-06 Realization of the VPDB Scale
Sylvia Englund Michel (Institute of Arctic and Alpine Research (INSTAAR), University of Colorado)

P-27 An Update on the WMO CO X2014A Scale
Andrew Crotwell (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

P-28 Successes and Challenges of Spectroscopic Based Techniques in Enteric Methane Measurements
Wilson Gichuhi (Department of Chemistry, Tennessee Tech University)

P-29 Open-path Spectroscopy to an Airborne Retroreflector on a Quadcopter
Kevin Cossel (National Institute of Standards and Technology (NIST))

P-30 Performance Validation of New High-precision CH_4 and CO_2 Analyzers Based on Optical Feedback Cavity Enhanced Absorption Spectroscopy
Israel Begashaw (LI-COR Biosciences)

P-31 Estimation of Enteric Methane Emissions in Ruminants Using CO_2:CH_4 Ratio Obtained with a Wavelength-scanned Cavity Ring-down Spectrometer
Lahiru P Gamage (School of Environmental Studies, Tennessee Technological University)

P-32 ^{13}C and ^{18}O Isotope Effects Resulting from High Pressure Regulation and CO_2 Cylinder Depletion
Matt C. Matthew (Airgas Specialty Gases)

P-33 CO_2 Urban Synthesis and Analysis ("CO_2-USA") Network
Logan Mitchell (University of Utah)

P-34 Investigating Methane Trends and Variability Using the GFDL-AM4 Model and NOAA GMD Observations
Jian He (Program in Atmospheric and Oceanic Sciences, Princeton University)

P-36 Characterizing and Comparing Anthropogenic CH_4 Sources in the DJ Basin using Mobile Surveys
Chelsea Fougere (St. Francis Xavier University, Antigonish, Canada)

P-37 Effects of Drought Conditions on CO_2 Flux in Semi-arid Chaparral Ecosystems.
Andrea Fenner (San Diego State University, Global Change Research Group)

P-38 Sources and Variability of Air Toxics Downwind of an Oil and Natural Gas-producing Well Pad in a Residential Community
Ingrid Mielke-Maday (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

Tuesday, May 22, 2018 Poster Session Agenda

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Tracking Greenhouse Gases and Understanding Carbon Cycle Feedbacks (continued)

P-39 Ground-truth Calibration for the VIIRS Nightfire Detector of Gas Flares
Mikhail Zhizhin (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

Monitoring and Understanding Changes in Surface Radiation, Clouds, and Aerosol Distributions

P-40 Volcanic Aerosol Optical Depths during the Post-Pinatubo Era, 1996-2018
Richard A Keen (University of Colorado, Department of Atmospheric and Oceanic Sciences)

P-41 Use of Ground- and Space-based Visible Imagery with other Data for Model Evaluation and Assimilation
Steve Albers (Cooperative Institute for Research in the Atmosphere (CIRA), Colorado State University)

P-42 Constraining Aerosol Properties with Ground-based Lidar and other Remote Sensing Techniques
John E. Barnes (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

P-43 Cloud Measurements with an All-sky Camera System for Investigating Long-term Variability of Cloud Properties at South Pole
Masataka Shiobara (National Institute of Polar Research (NIPR), Tokyo, Japan)

P-44 Mutual Information Analysis of Aerosol-cloud interactions by Meteorological State over Oklahoma, U.S.
Ian Glenn (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

P-45 Black Carbon's Contribution to Aerosol Absorption Optical Depth in South Korea
Kara Lamb (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

P-46 NOAA Global Radiation Group Participation in International Comparisons Offering Traceable Calibration to World Solar Radiation Standards
Emiel Hall (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

P-47 Variability of UV at Sites Equipped with NIWA Spectrometer Systems for 20 Years or More
Patrick Disterhoft (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

P-48 Improvements in the Brewer Mark IV Spectrophotometer Ultraviolet AOD Retrievals
Scott Stierle (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

P-49 Shipboard Tilt Corrections for More Accurate Broadband Radiation Data
Chuck Long (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

P-50 Validation of the Stratospheric Aerosol and Gas Experiment-III (SAGE-III) Aerosol Data Product
Travis N. Knepp (Science Systems and Applications, Inc. (SSAI))

P-51 Validation of the Stratospheric Aerosol and Gas Experiment III on the International Space Station (SAGE III/ISS) Science Data Ozone Product: Preliminary Results
Susan Kizer (Science Systems and Applications, Inc. (SSAI))

P-52 Overview and Selected Results from the NOAA Federated Aerosol Network
Patrick Sheridan (NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))

P-53 Relating Chemical and Optical Aerosol Properties at Mauna Loa Observatory
Katy Sun (Science and Technology Corporation)

P-54 Reconciling Evapotranspiration Partitioning Models with Evidence of Anomalously Low Isotopic Fractionation during Evaporation in Semi-arid Landscapes
Aleya Kaushik (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

P-55 Spatial Variations of Soil Temperature and its Environmental Controls across Eurasian Continent
Kang Wang (Institute of Arctic and Alpine Research (INSTAAR), University of Colorado)

Guiding Recovery of Stratospheric Ozone and Other Topics

P-56 A Lamina-based Approach for Interpreting Variability in Ozonesonde Vertical Profiles
Ken Minschwaner (New Mexico Institute of Mining and Technology)

P-57 Analysis of Ozone Trends from NOAA's Newly Homogenized Ozonesonde Data Record
Patrick Cullis (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

NOAA ESRL GLOBAL MONITORING ANNUAL CONFERENCE 2018
David Skaggs Research Center, Cafeteria
325 Broadway, Boulder, Colorado 80305 USA

Tuesday, May 22, 2018 Poster Session Agenda

(Only presenter's name is given; please refer to abstract for complete author listing.)

Guiding Recovery of Stratospheric Ozone and Other Topics (continued)

P-58 Stratospheric Temperature Corrections and Improvement of Total Column Ozone Records in the NOAA Dobson Ozone Spectrophotometer Network
Glen McConville (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

P-59 Uncertainty Improvement Optimized using the GMI Model for Umkehr Ozone Profile Retrieval
Koji Miyagawa (Guest Scientist at NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))

P-60 An Evaluation of C_1-C_3 Hydrochlorofluorocarbon (HCFC) Metrics: Lifetimes, Ozone Depletion Potentials, Radiative Efficiencies, Global Warming and Global Temperature Potentials
James Burkholder (NOAA Earth System Research Laboratory, Chemical Sciences Division (CSD))

P-61 Chloroform Emissions Estimated with the CarbonTracker-Lagrange North American Regional Inversion Framework
Geoff Dutton (NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))

P-62 Using Observations of SF_6 to Examine Inter-annual Variations in Inter-hemispheric Exchange
Brad D. Hall (NOAA Earth System Research Laboratory, Global Monitoring Division (GMD))

P-63 Increased Propane Emissions from the United States over the Last Decade
Lei Hu (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

P-64 Using Carbonyl Sulfide to Explore Coastal Fog and Coast Redwood Interdependence
Timothy W. Hilton (University of California at Merced)

P-65 NO_x Emissions from Switch Yard Locomotives Observed with the TRAX Air Quality Platform
Logan Mitchell (University of Utah)

P-66 Advantages and Limitations of Measuring BTEX with a Commercial GC-PID System *In Situ*
Monica Madronich (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

P-67 One Year of AOD, Halogen Radicals, OVOCs, H_2O and NO_2 Measurements at Mauna Loa Observatory
Barbara Dix (University of Colorado, Department of Chemistry and Biochemistry)

P-68 Toward a High Degree of Freedom Full Atmosphere Retrieval of BrO Profiles from MAX-DOAS Instruments on Remote Tropical Marine Mountaintops
Theodore Koenig (University of Colorado, Department of Chemistry and Biochemistry)

P-69 Contrasting Behavior of Inert and Photochemically Reactive Gases during the August 21, 2017, Solar Eclipse at the Boulder Reservoir
Detlev Helmig (Institute of Arctic and Alpine Research (INSTAAR), University of Colorado)

P-70 Combining Observations and Multiple Models for an Improved Estimate of the Global Surface Ozone Distribution
Kai-Lan Chang (National Research Council Post-Doc)

P-71 Changing Conditions in the Arctic: An Analysis of Trends in Observed Surface Ozone Conditions
Audra McClure-Begley (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

Technology

P-72 Online Inclusion of Chemical Modules Into NOAA's Next Generation Global Prediction System (NGGPS)
Li Zhang (Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado)

P-73 SOS Explorer^{TM}: Interactive Visualizations for Museums and Classrooms
Eric Hackathorn (NOAA Earth System Research Laboratory, Global Systems Division (GSD))