Global Monitoring Division

Trace Gas, Ozone
and
Radiation Standards/Calibrations

2013-2017 Review

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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.

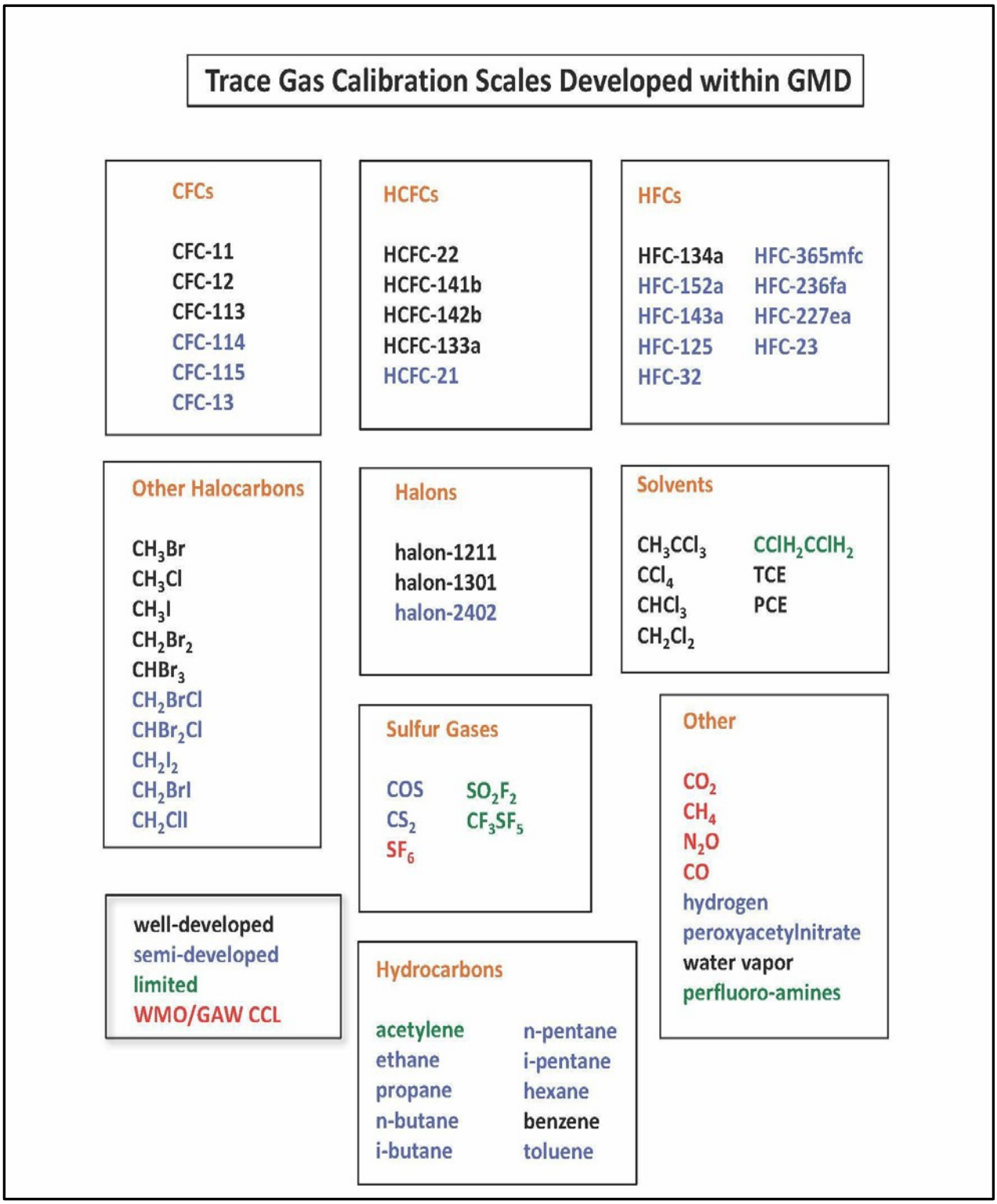
A. GMD Trace Gas Calibration Standards

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.

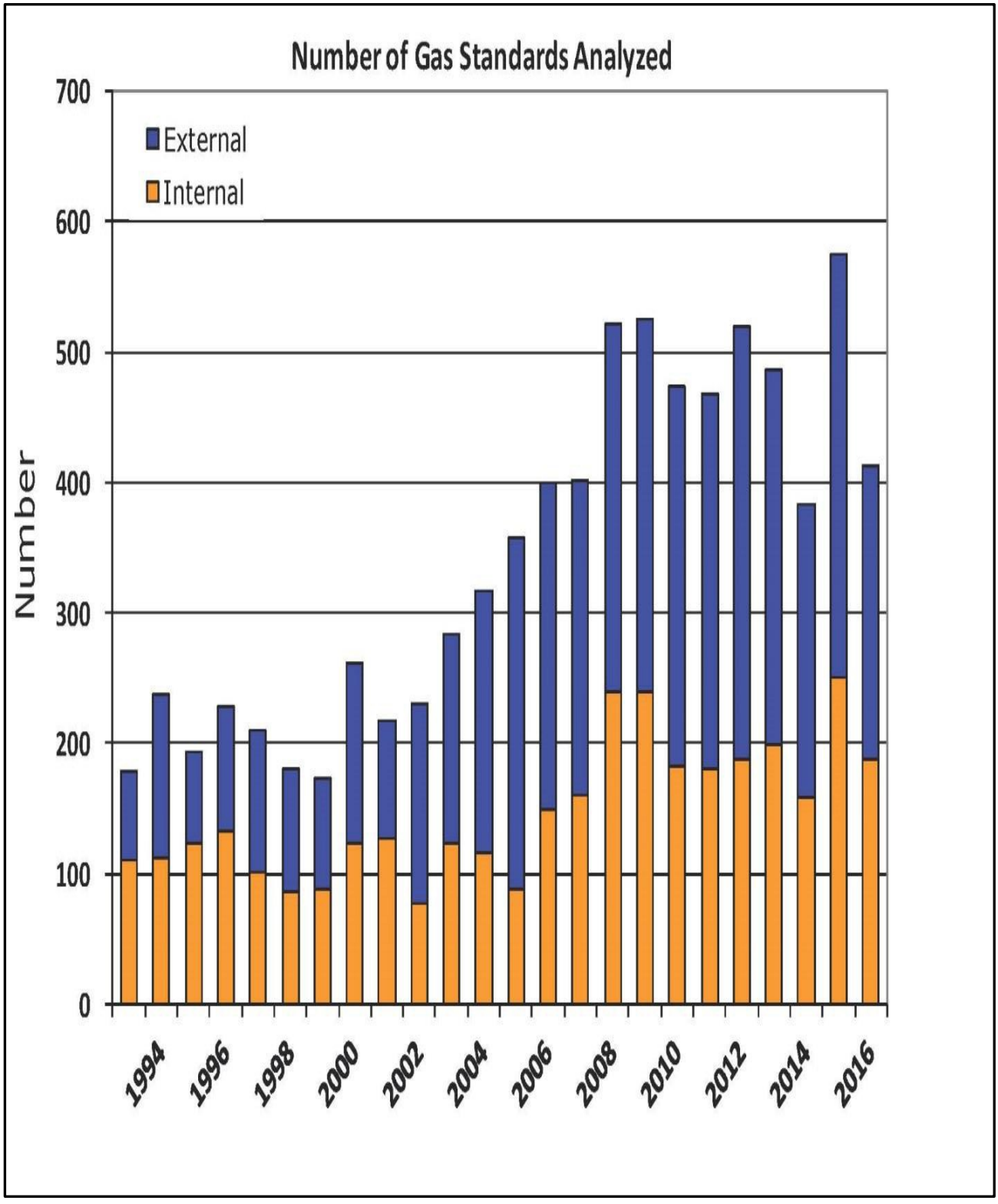
Most gases measured by GMD are traceable to primary standards developed by GMD. Two methods are used to prepare primary gas standards. Primary standards for CO_2 consist of compressed air in aluminum cylinders for which CO_2 mole fractions have been determined manometrically: that is, the mole fraction 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

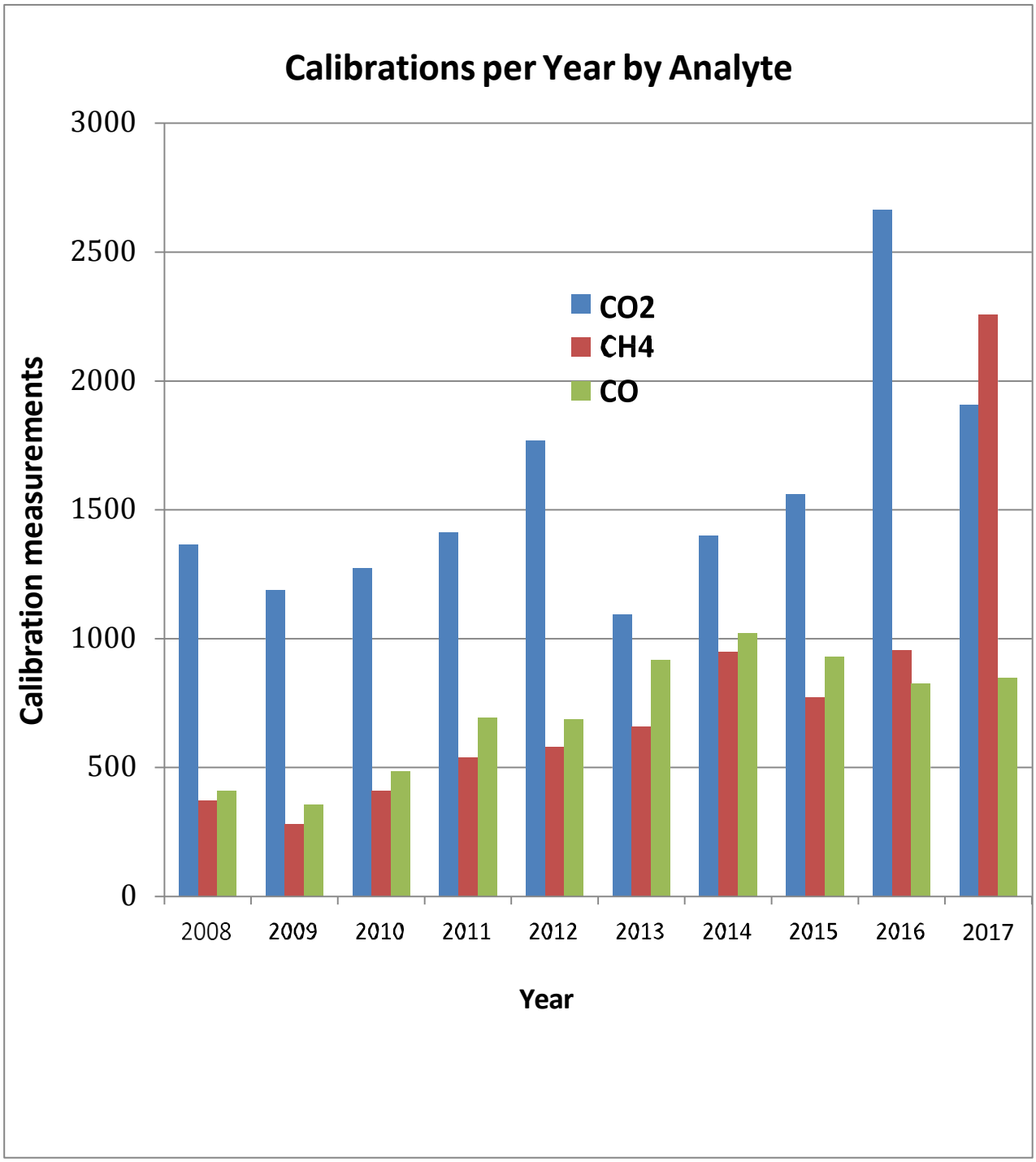
USA	NOAA Kodiak Fisheries Center
USA	NOAA, Atlantic Ocean Marine Labs
USA	NOAA, Chemical Sciences Division
USA	NOAA, Pacific Marine Environmental Laboratory
USA	North Carolina State University
USA	Northwestern University, Illinois
USA	Novawave Technologies, California
USA	Oregon State University, College 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.

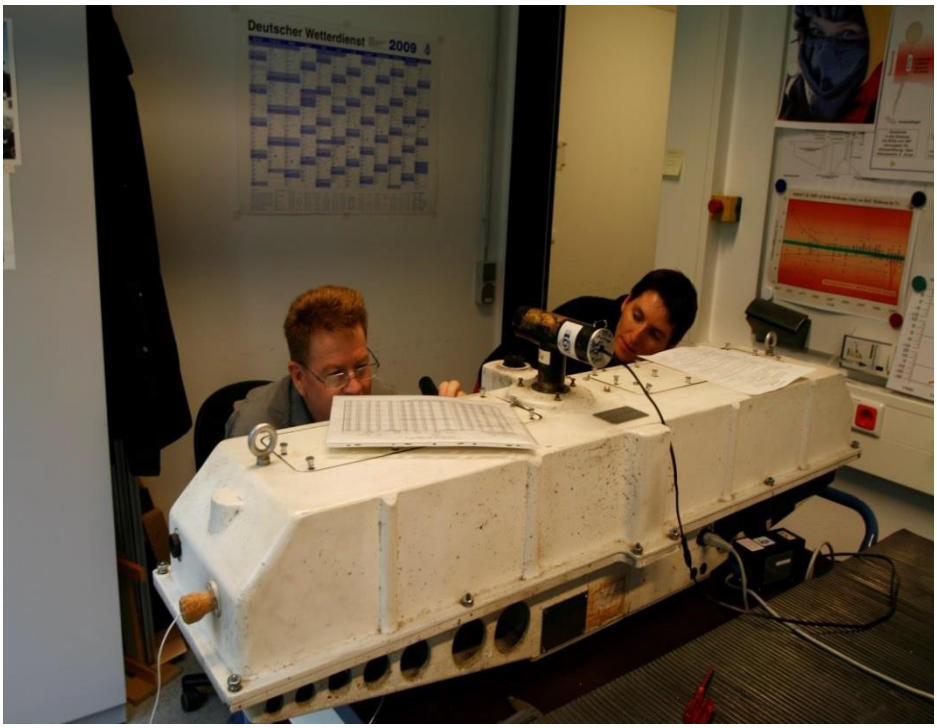
The Global Monitoring Division Provides World Reference Dobson Ozone Calibrations to the following institutions/ countries.

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, W A
Mauna Loa, HI
American Samoa
South Pole, Antarctica
Wallops Island, VA

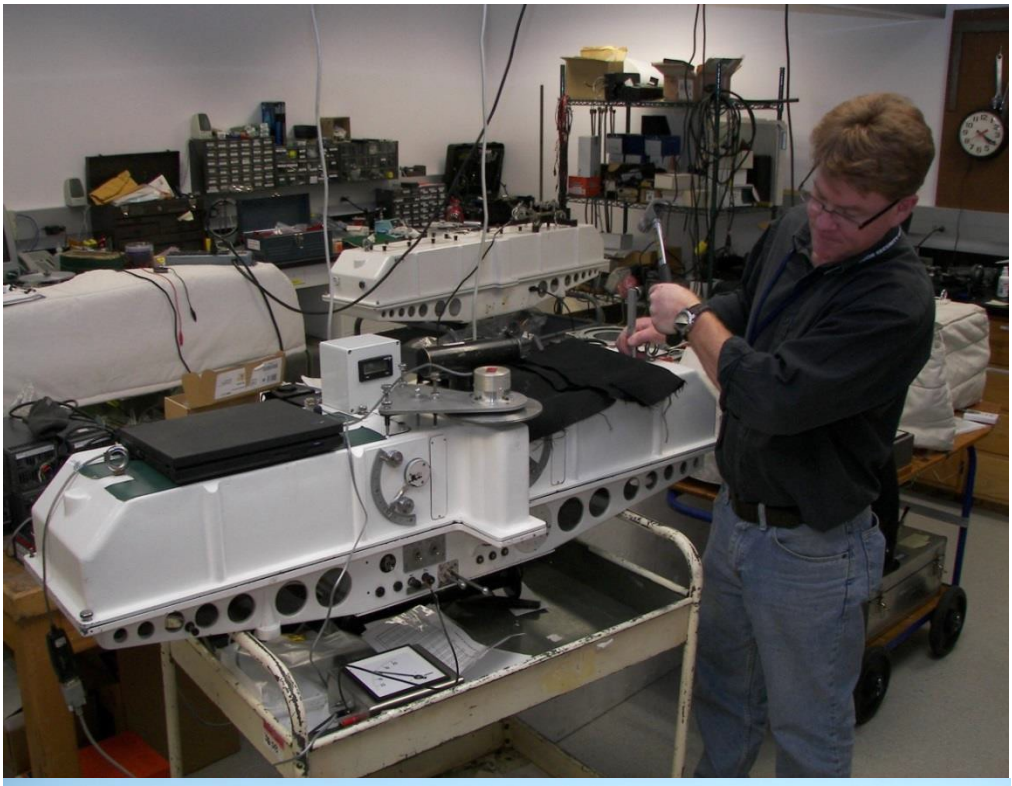
Global Monitoring Division World Secondary Standard Dobson 65 in a WMO sponsored South American Dobson intercomparison, Buenos Aires, Argentina.



Glen McConville assisting with the repair of D049 at Hohenpeissenberg Germany

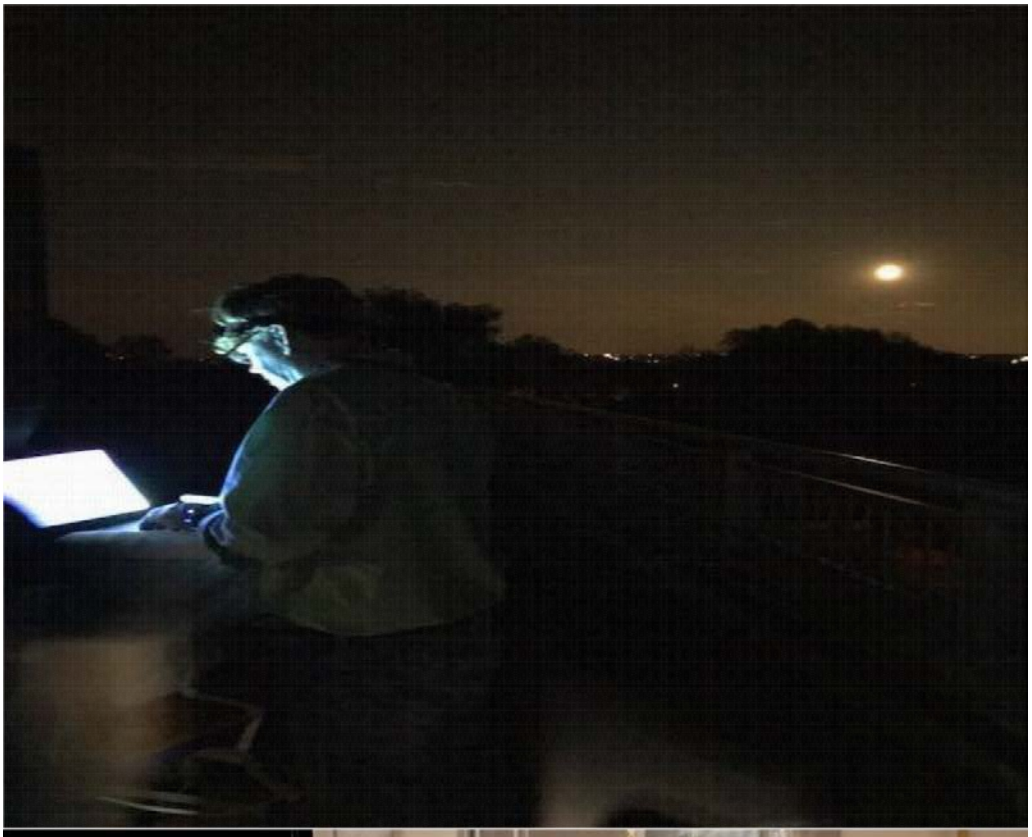
Comparing Dobson measurements in Hohenpeissenberg, Germany. Transfer of WMO standard calibration to the WMO regional standard for the region IV. It takes multiple measurements to build confidence in accurate calibration of station instruments.

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.

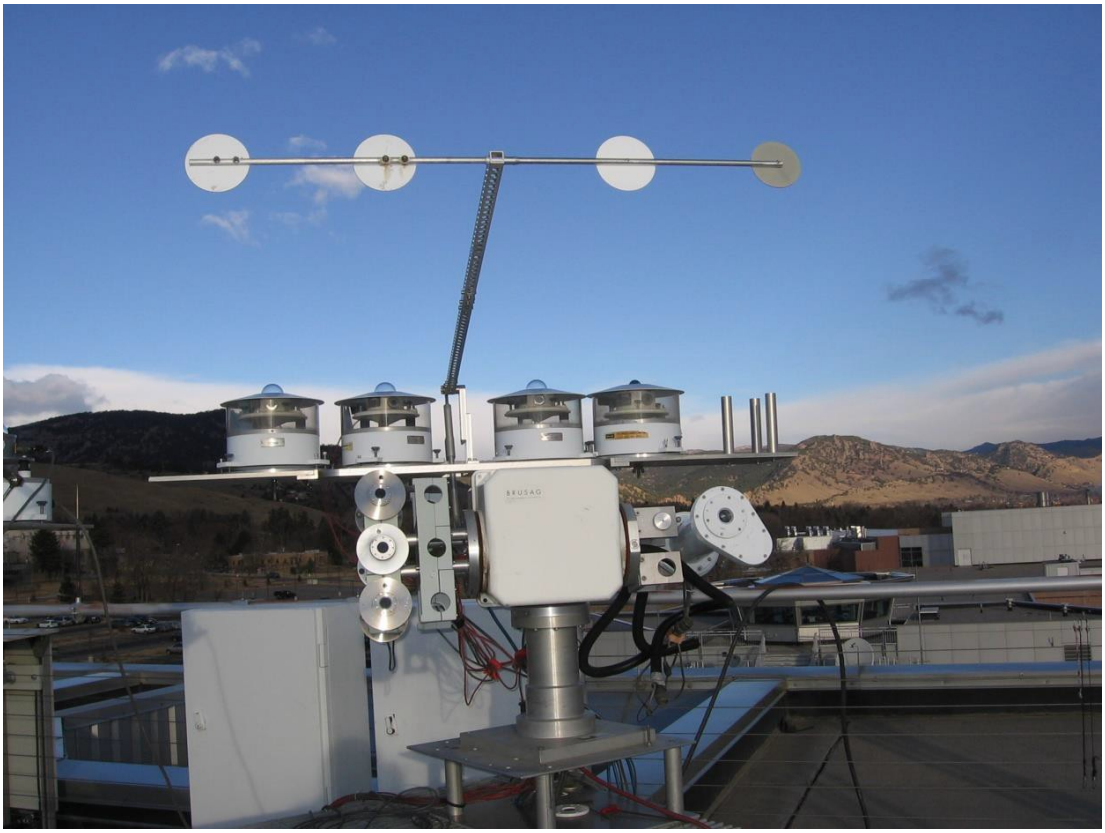
Biospherical Instruments Inc.
Battelle Labs
Bureau of Land Management
Chinese BSRN (Baseline Surface Radiation Network) sites
Colorado State University: IR Calibration exchange and UV calibrations.
DOE/ARM
DRI: Calibrations
Eastern New Mexico University
ENA, Italy, Calibrations
Eppley Laboratory
EU Joint 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.

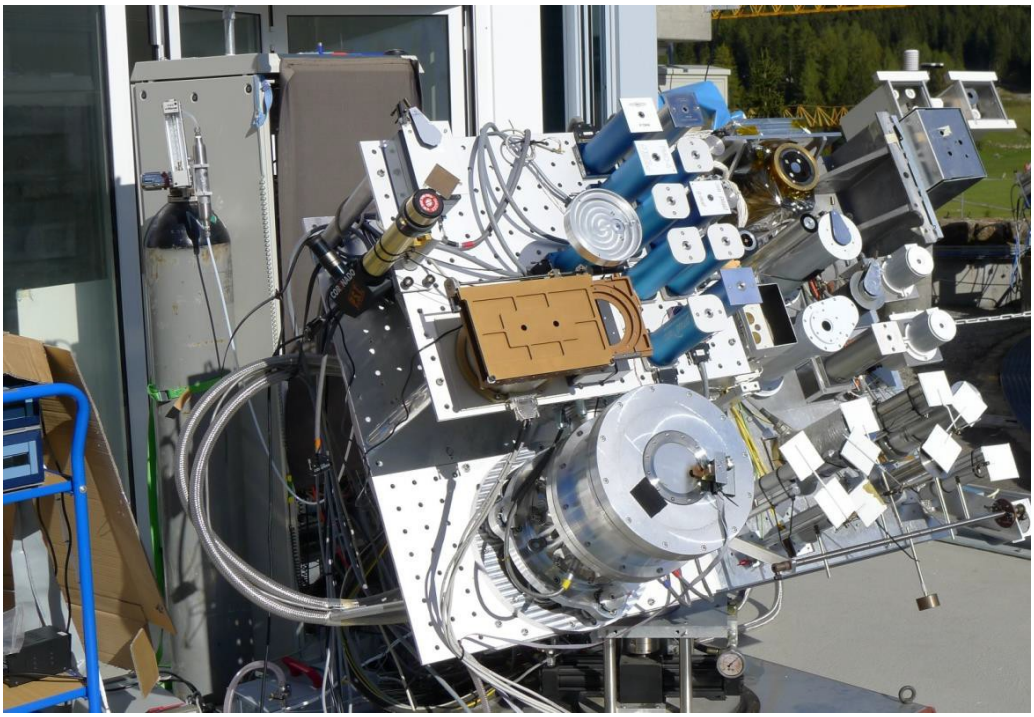
Colorado State University
Environment Canada
Geronimo Peak Observatory
NASA AERONET, Goddard Space Flight Center
NCAR HAO
NIES, Japan
NIWA, New Zealand
Solar Light Corp.
University of Denver
US Department of Agriculture

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.



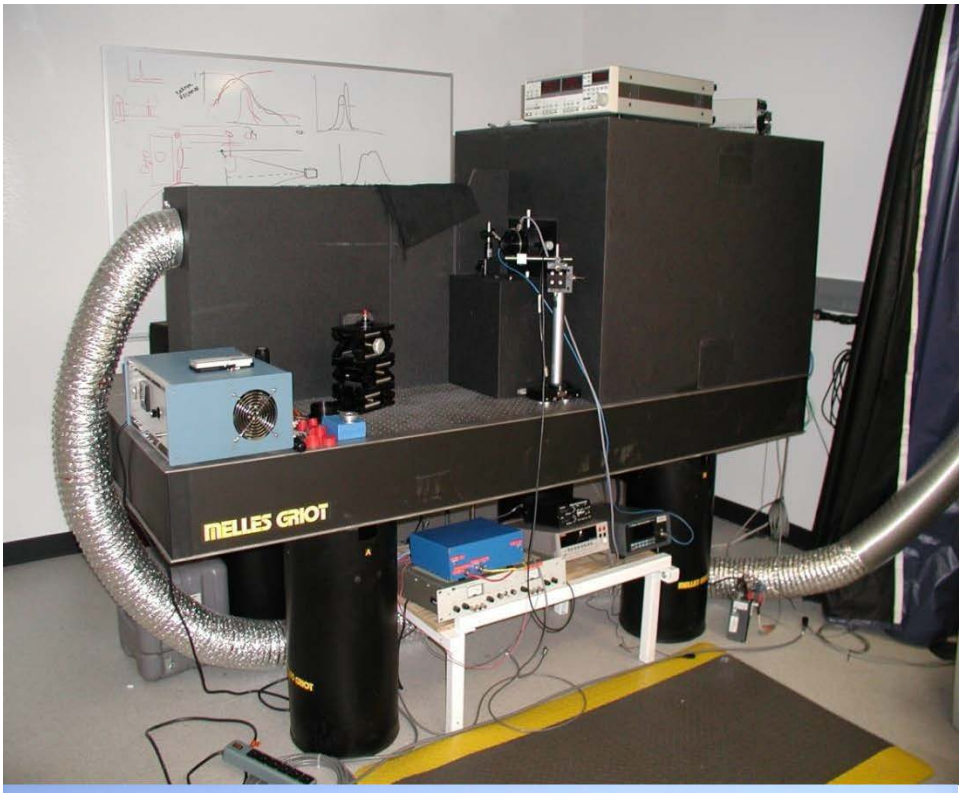
Diffuse and direct solar radiation instrument calibrations at the NOAA GMD Boulder, Colorado rooftop facility.

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.