SHADOZ (Southern Hemisphere Additional Ozonesondes): Recent Accomplishments & Upcoming Activities

Anne Thompson, PI – amt16@psu.edu

GMAC, 22 May 13

With: J C Witte (SSAI at NASA/GSFC), S K Miller (PSU), S J Oltmans (CU/CIRES, NOAA/GMD), B J Johnson (NOAA/GMD)

Road Map

- What, Where, When, Who is SHADOZ?

- Accomplishments
  - Satellites supported for validation: Aura, GOME-2, NPP-Suomi, etc
  - Superior tropical O_3 climatologies with seasonality, QBO/ENSO other oscillations identified
  - Trends studies enabled by 15-yr record at some locations

- Current Activities related to WMO/SI2N Assessments
  - Technical issues, eg sensing solution strength, instrument manufacturer, affect O_3 measurement [*Smit et al.* 2007, *Thompson et al*., 2007; 2012] in SHADOZ, other global sonde stations
  - SHADOZ re-processing with WMO/O3S-DQA protocol – focus on recently characterized issues in O_3 measurement [*Deshler et al.,* 2012]
  - New issue emerges: radiosonde pressure errors affect O_3 reading

Why-What-Where-When-How SHADOZ? (Southern Hemisphere Additional Ozonesondes)

Strategic Design Addresses Questions – 1998->

1> Satellite/model validation & optimization

2> Req'ts: operational, addl supplies <-> data archive

3> Ozone variability on multiple time, space scales

- Full zonal coverage – 9 sites in 1998, now 13; 2-4 soundings/month
- **2013 - > 6000 profiles** at **http://croc.gsfc.nasa.gov/shadoz**

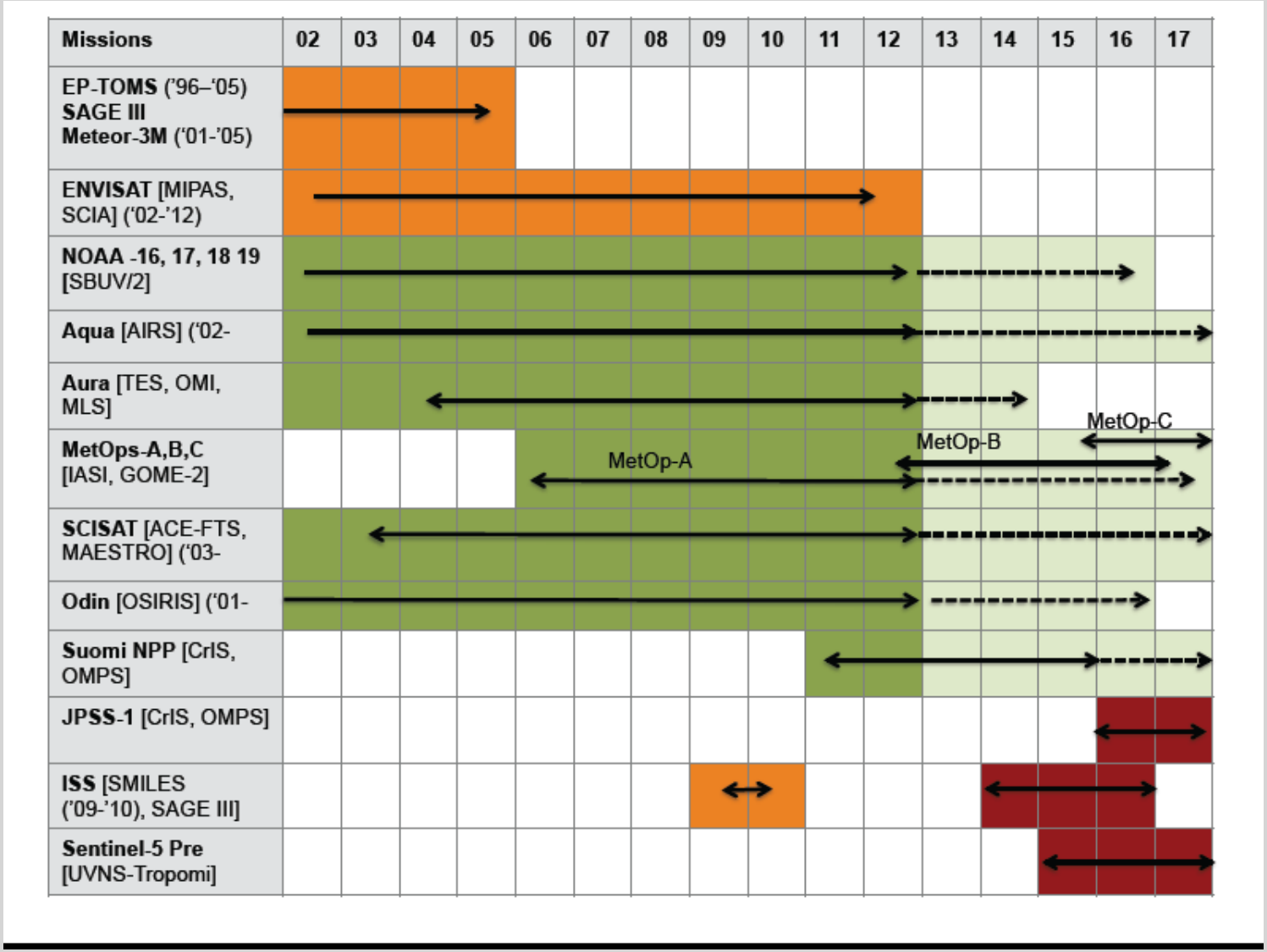
4> Keys to success: Leveraged resources. Open access. Distribute via WOUDC (woudc.org); NDACC.

SHADOZ Sites

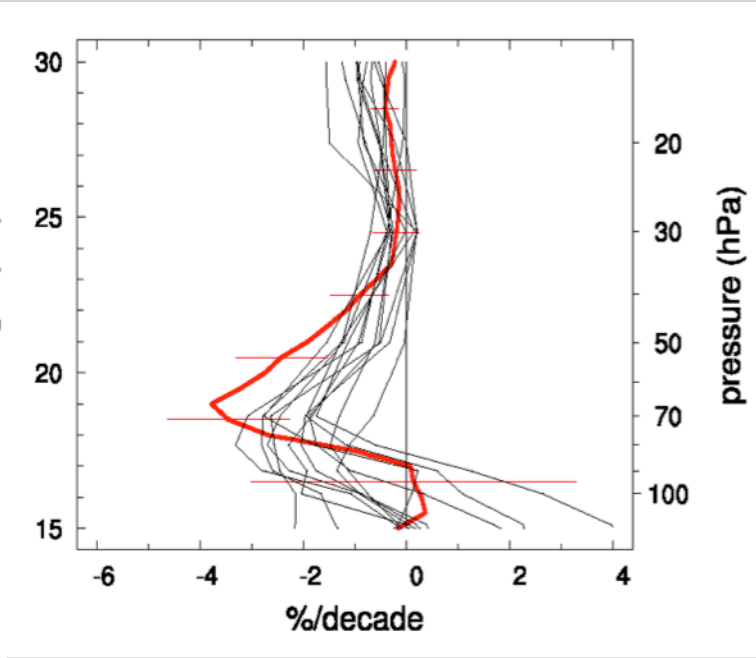
Red Stations operated or supported by NOAA/GMD

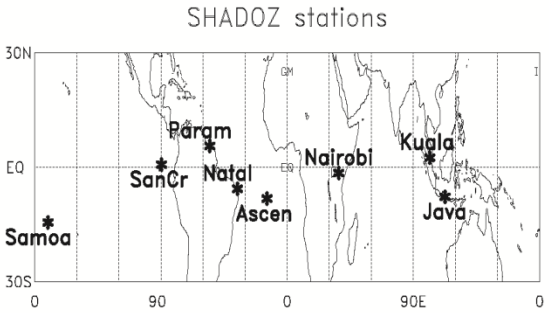
Thompson et al. *J Geophys. Res.* 2012

Accomplishments (1): Satellites Supported. Add TEMPO (new NASA EVi)



Accomplishments (2): Tropical Lower Stratospheric Ozone Trend; Free Tropospheric Ozone Trend at Sub-Tropical Station

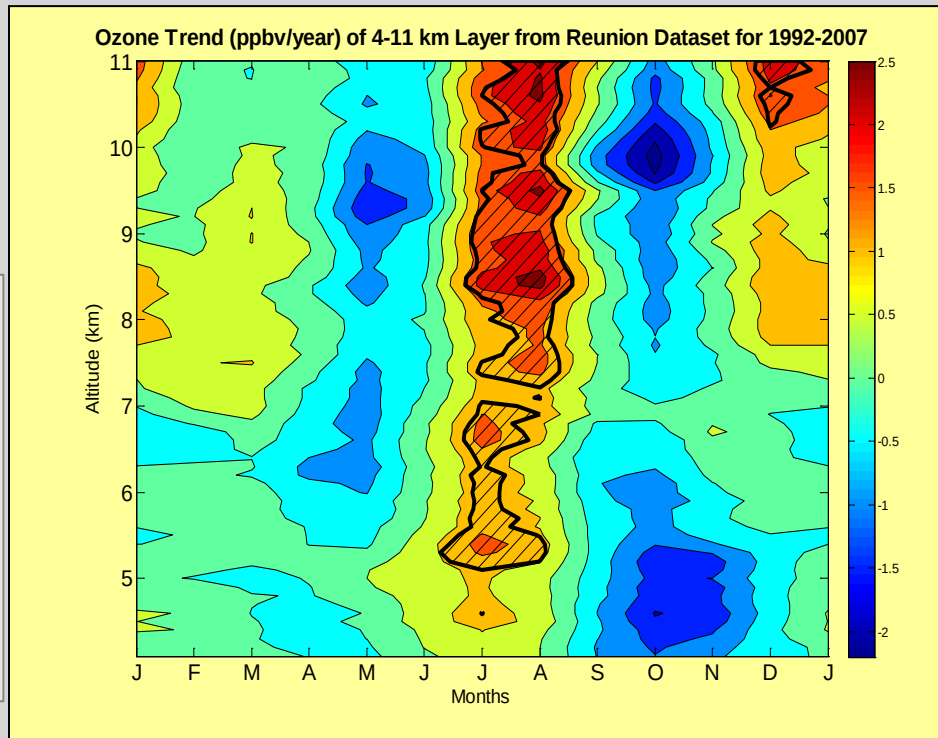




Randel & Thompson, *JGR*, 2011

Above: Combined SAGE II-SHADOZ trend. Defines standard for evaluation of Coupled Chem-Climate Models (CCMs)

Right: Free tropospheric ozone increase. Most prominent in winter, Reunion & Irene (Thompson, Balashov et al, in prep, ACP)



Current Activities

- Driven by ozone-climate community requirements for more accurate profiles for trends studies throughout troposphere, TTL, stratosphere
- Mid-upper stratosphere: chemical changes (ODS decrease) & trends
- TTL – ozone-temperature

Interactions, dehydration, climate

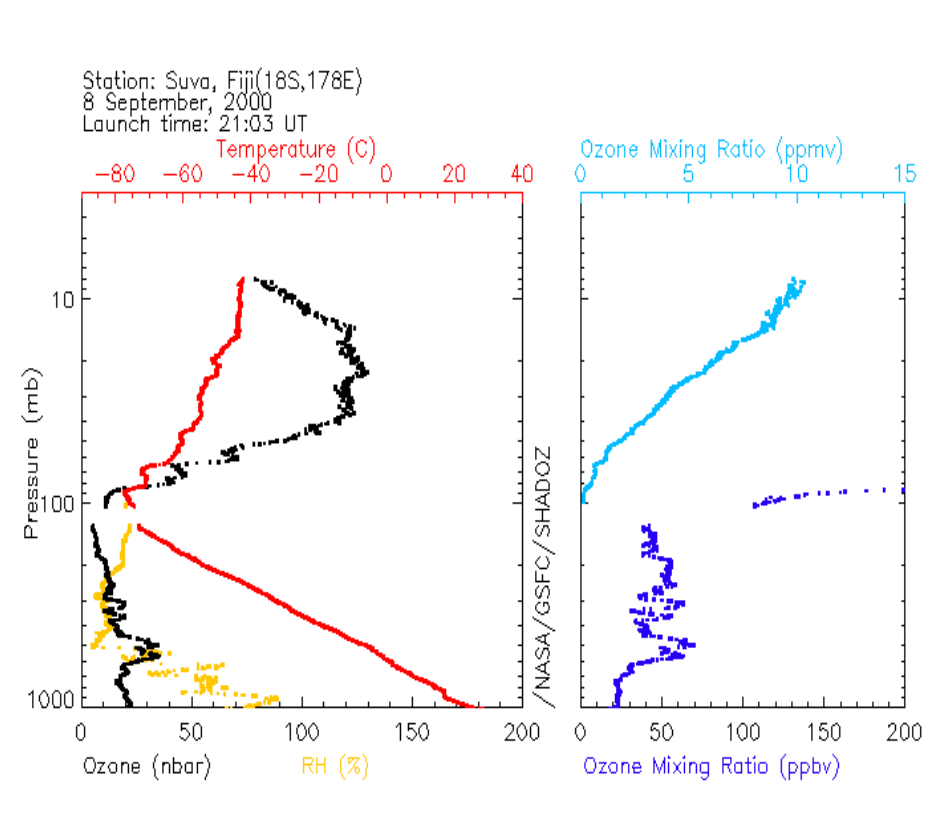
Sensitivity

- Tropospheric O_3 – pollutant,

GHG importance **Mid-strat --->**

TTL --->

Troposphere --->



Variables Affecting Measurement. Some Affect Entire Profile, Others Affect Stratosphere, Troposphere, TTL

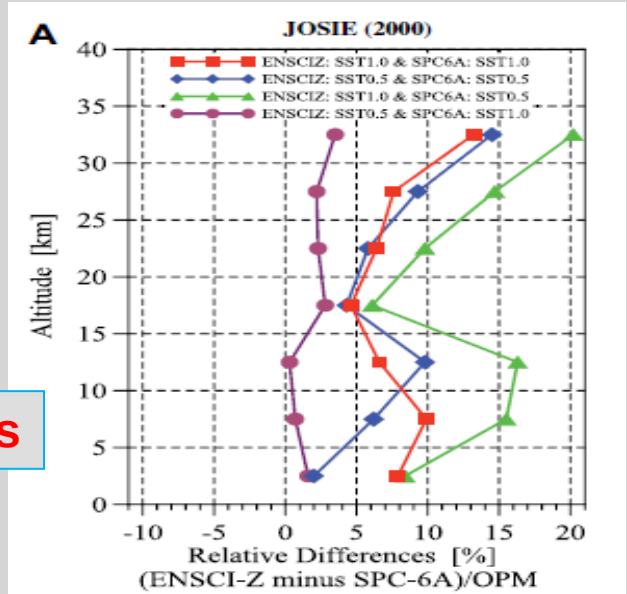
- Every sonde launched is a new instrument; I_{bg} and **PCF** measured in lab
- $P_{O3} = 4.31 \times 10^{-2}$ (I_{ascent} - $I_{background}$) x T_{pump} x **PCF** (1/F)
- Mixing ratio = [Partial pressure of ozone = PO3]/P(total $_{Atm)}$

  O_3-sonde Radiosonde
- Lab, field studies show that two instrument components may affect ozone measurement, I_{ascent} by 5-15%
  - **SST = sonde solution type.** KI strength, buffering, eg 0.5%, buffered; 1% buffered, 2% unbuffered, etc
  - Instrument manufacturer **(two "types")**

- Biases characterized in "JOSIE"

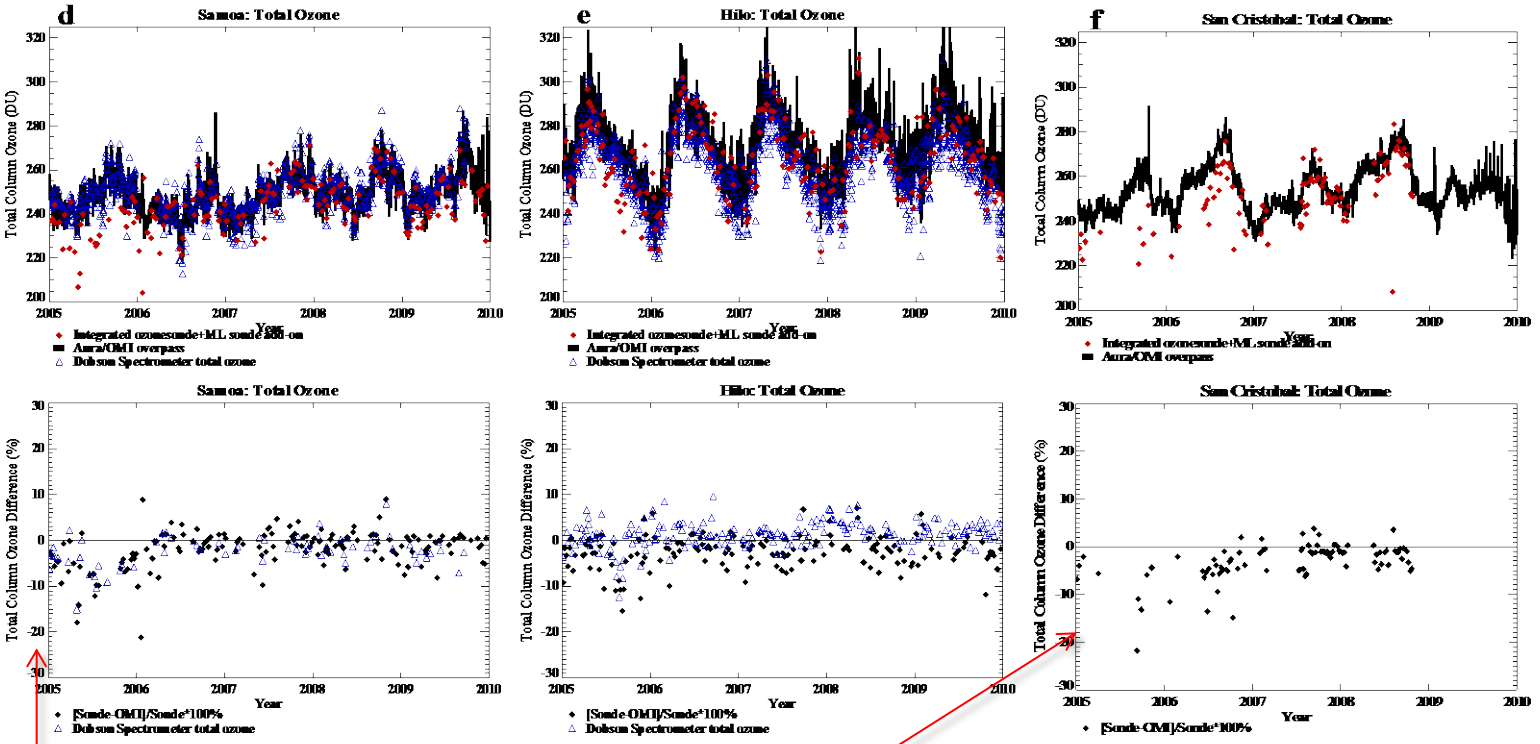
& field experiments explain SHADOZ Stratospheric biases

SST, Type Bias



Re-processing SHADOZ Data Set from 1998-2013

- Done: JOSIE/BESOS led to technique changes (below)
- Result: Overall OMI-sonde total O_3 agreement ~5%, 2005-09
- Underway: "Transfer function" adopted by O3S-DQA (WMO) applied by individual Pis to "homogenize" data for trends



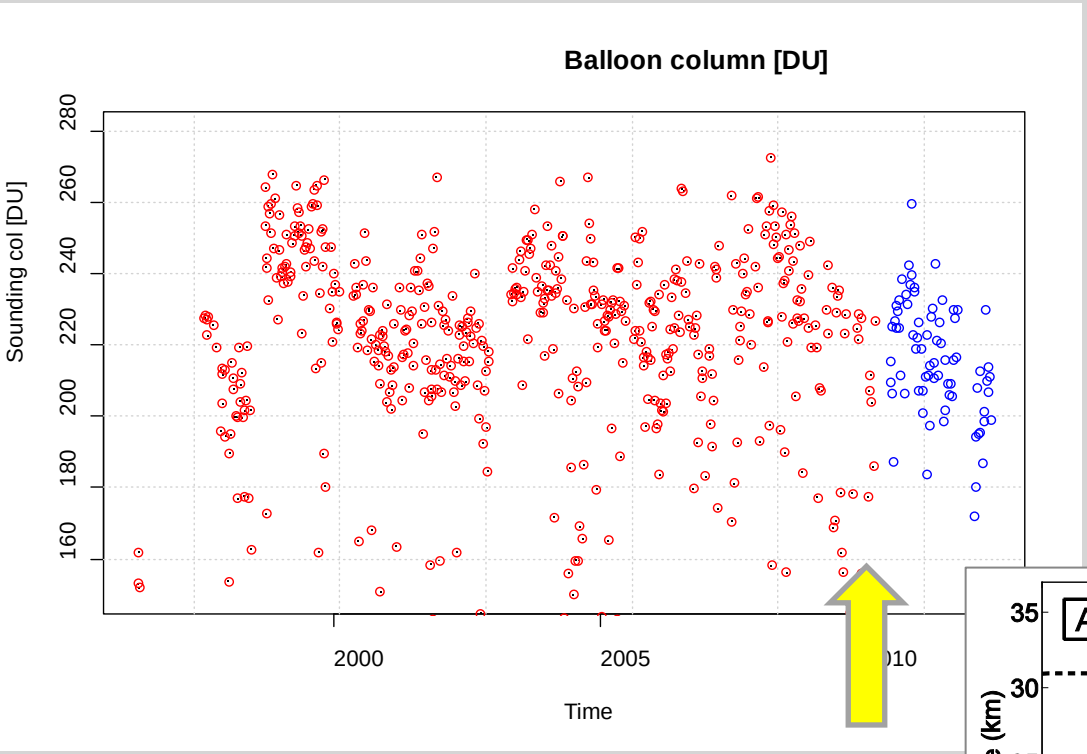
These sites changed solution ~2005-2006

SHADOZ Re-processing – Iterative Process over 2-3 Years, Consultative with WMO O3-DQA

- WMO O3S-DQA, Data Quality Assurance activity, 2011-2012, convened in 3 Workshops with recommendations to "homogenize" O_3 data to compensate for biases in instrument type, SST
- Present schedule calls for SHADOZ stations to re-process in 2013.
  - NOAA/GMD stations ~50% complete
  - Asian, African, Latin American stations paired with "coaches," eg S Oltmans
- Will re-evaluate SHADOZ biases, ground-ozone/OMI comparisons
- Results to serve as guidelines for a follow-on JOSIE (2014, 2015?). Anticipate evaluation of radiosonde impacts.
- Mixing ratio = [Partial pressure of ozone = PO3]/P(total $_{Atm)}$

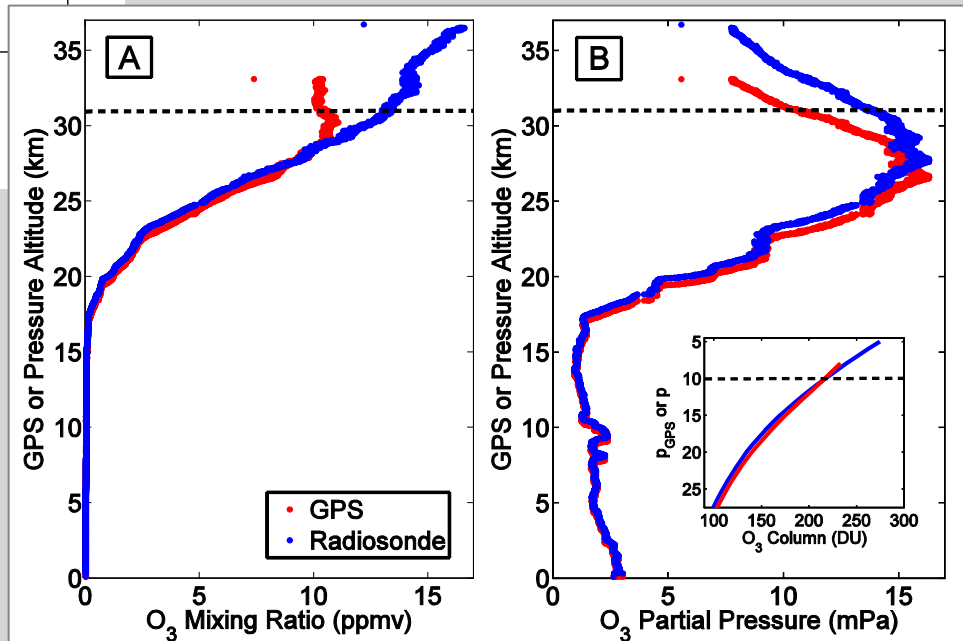
  O_3-sonde Radiosonde
- Radiosondes have changed, introducing additional source of uncertainty, eg Vaisala RS-80 to RS-92, Intermet. Modem at 2 sites
- RS-80, Intermet pressure sensors tend to read 1-2 hPa low (higher altitude at burst). May give ~20% error in ozone reading at 10 hPa

Pressure difference RS 80 vs. RS92 (Left)
Pressure-GPS Offsets & O_3 Impact (Right)



Below: Sample of ozone mixing ratio with Intermet pressure sensor (blue) 20% greater than with GPS on RS-80 sonde, TC4 Panama sonde in SHADOZ database

Above: Integrated ozone to burst over Nairobi SHADOZ station with RS-80 Until 2010 switch to RS-92



THANK YOU FOR YOUR ATTENTION!

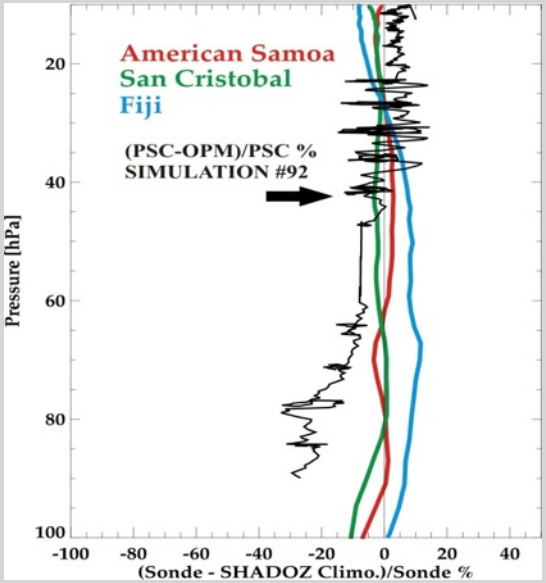
Acknowledgments & References

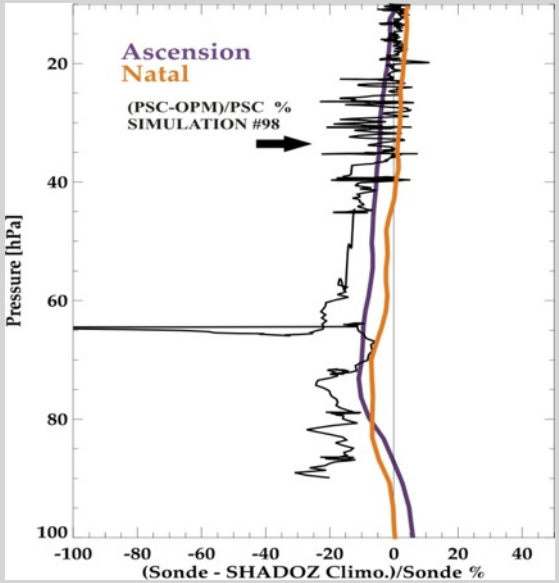
- **Support from NASA, NOAA, with JOSIE and O3S-DQA sponsored by WMO.**

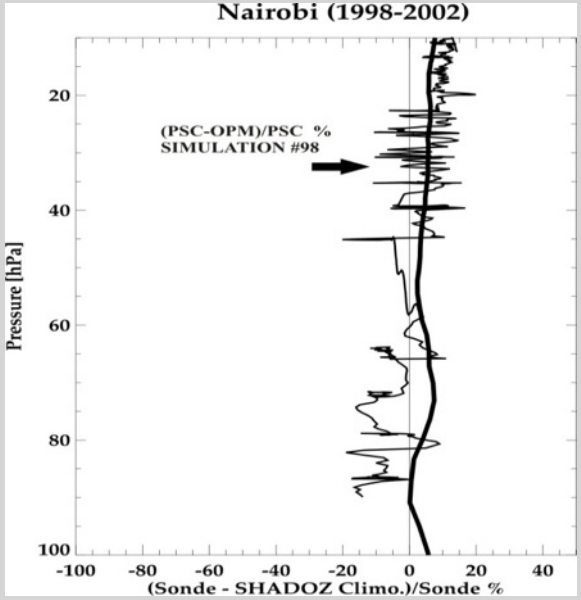
- **T. Deshler, et al., Balloon Experiment to Test ECC-ozonesondes from Different Manufacturers, and with Different Cathode Solution Strengths: Results of the BESOS flight, J. Geophys. Res., 113, D04307, doi:10.1029/2007JD008975, 2008.**
- **H. G. J. Smit et al, Assessment of the performance of ECC-ozonesondes under quasi-flight conditions in the environmental simulation chamber: Insights from the Jülich Ozone Sonde Intercomparison Experiment, *JGR,* 112. D19306, doi: 10.1029/ 2006JD007308, 2007.**
- **A. M. Thompson et al, Southern Hemisphere ADditional Ozonesondes (SHADOZ) 1998-2000 tropical ozone climatology. 1. Comparison with TOMS and ground-based measurements, *JGR,* 108, 8238, doi: 10.1029/ 2001JD000967, 2003.**
- **A. M. Thompson, et al., Southern Hemisphere Additional Ozonesondes (SHADOZ) 1998-2004 tropical ozone climatology. 3. Instrumentation, station variability, evaluation with simulated flight profiles, *JGR,* 112, D03304, doi: 10.1029/ 2005JD007042, 2007.**
- **A. M. Thompson et al., SHADOZ (Southern Hemisphere Additional Ozonesondes) ozone climatology (2005-2009): Tropospheric and lower stratospheric profiles with comparisons to OMI-based ozone products, J*GR,* 117, D23301, doi: 10.1029/2011JD016911, 2012.**

Extras

SHADOZ BIASES Compared to UV Photometer & JOSIE-2000 Chamber Tests





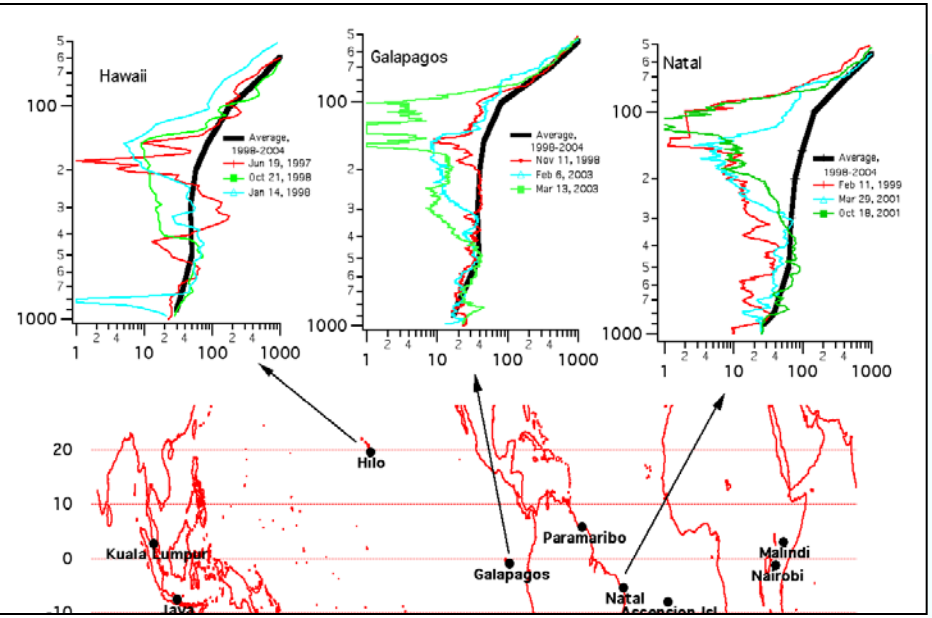


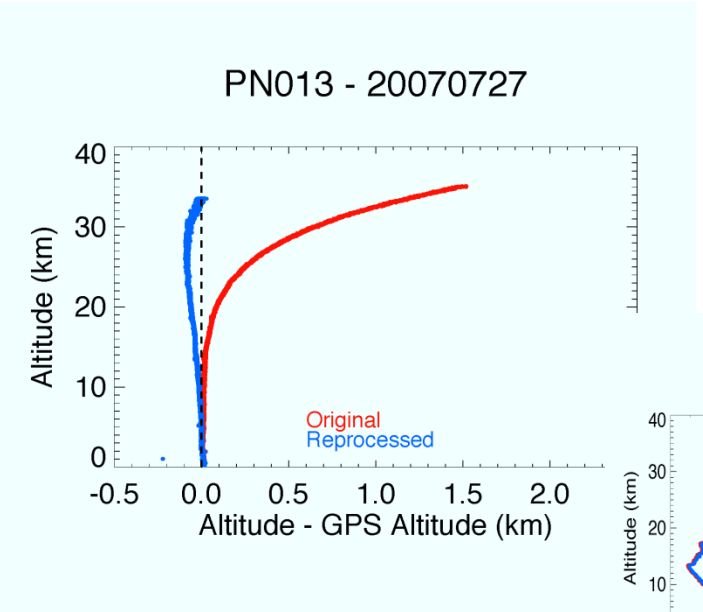
Above – Ascen/Natal & Pac differences Right -- JOSIE-2000 explains Nairobi.
Results appear consistent with JOSIE-2000 strat. Ozone biases

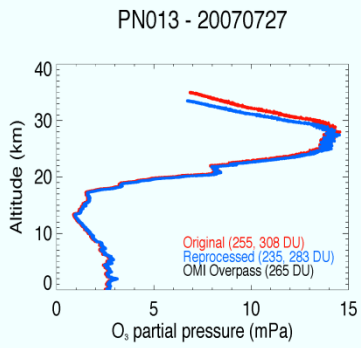
Methods tested:	Buffer	Instrument
(1) NOAA/CMDL = Fiji, Samoa, San Cristöbal	No	SPC
(2) NASA/WFF = Ascension/Natal	Yes	SPC
(3) MeteoSwiss/Payerne = Nairobi	Yes	SPC & Ensci

Looking Forward. New Technical Issues

- **Background Current** (Voemel & Diaz, 2009; Stuebi & Levrat, 2009). Implication for SHADOZ at certain sites. *Solomon et al.* 2005, **Left***
- **New Radiosondes** (RS80-> RS92->Imet). Pressure offsets! **Right**
- **Third instrument type.** SPC stable, ENSCI-> DMT ? – TBDl!



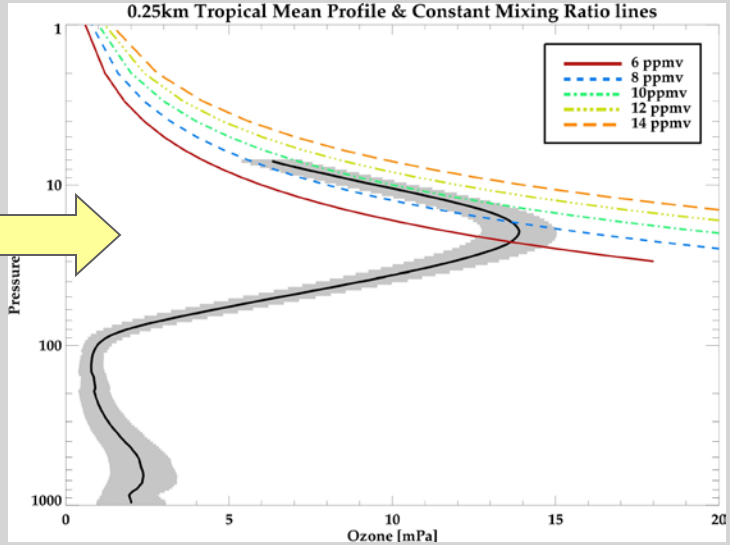


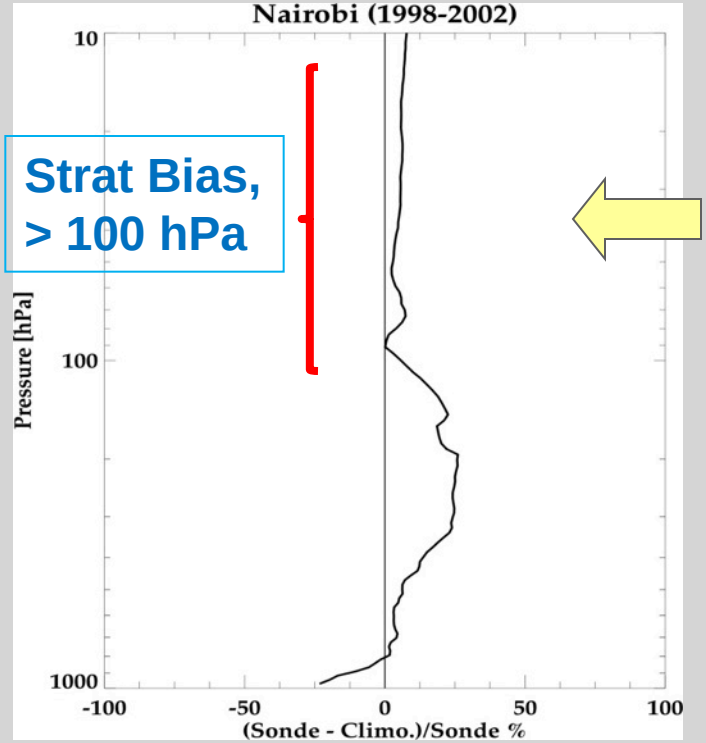


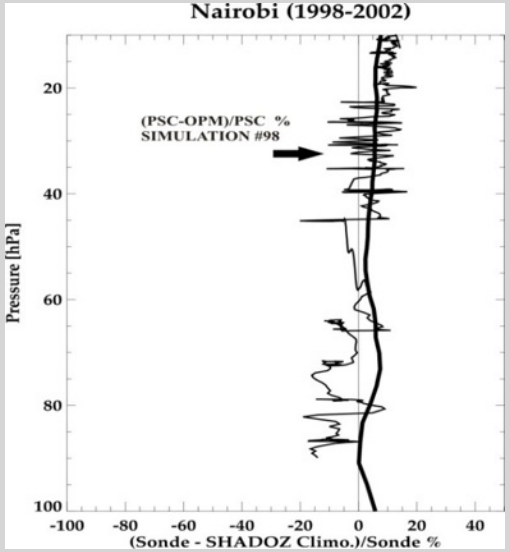
* < 1% of soundings near-zero in TTL

SHADOZ Tropical Climatology Illustrates Bias at Individual Stations – Thompson et al., *JGR*, 2007

- Individual stations show bias in *stratospheric* profile compared to SHADOZ tropical mean.
- Nairobi relatively high. Interpret in terms of JOSIE-2000 lab tests?

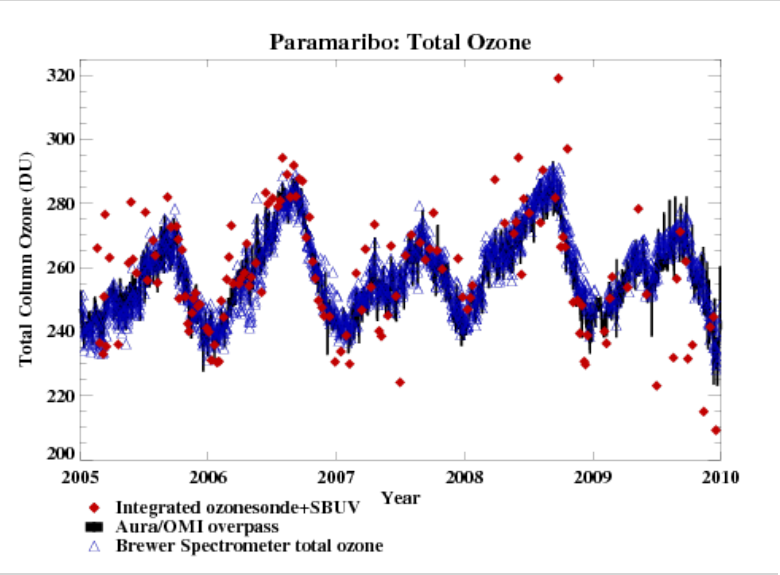


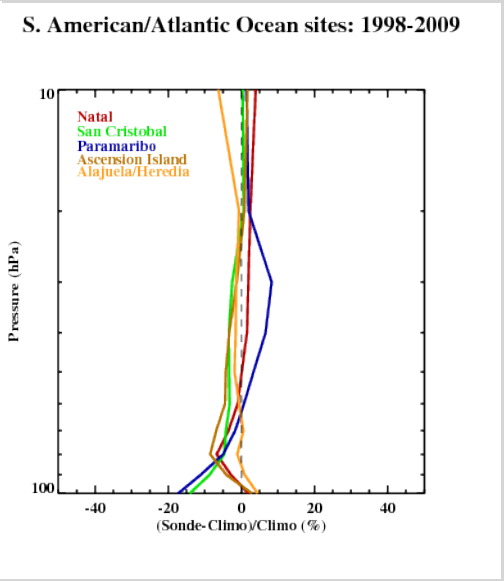


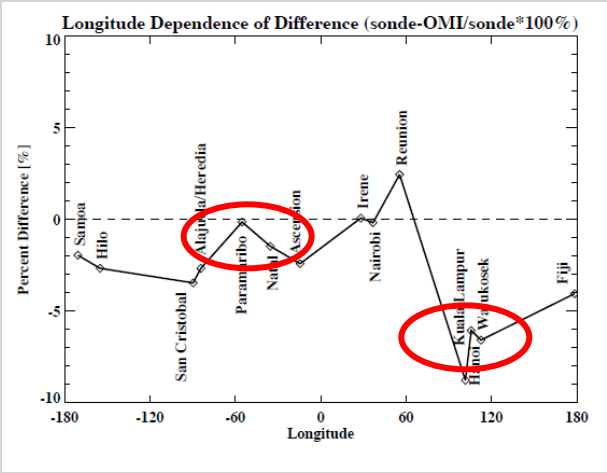


Current Status. SHADOZ Biases due to Solution, Instrument Type, PCF Characterized.

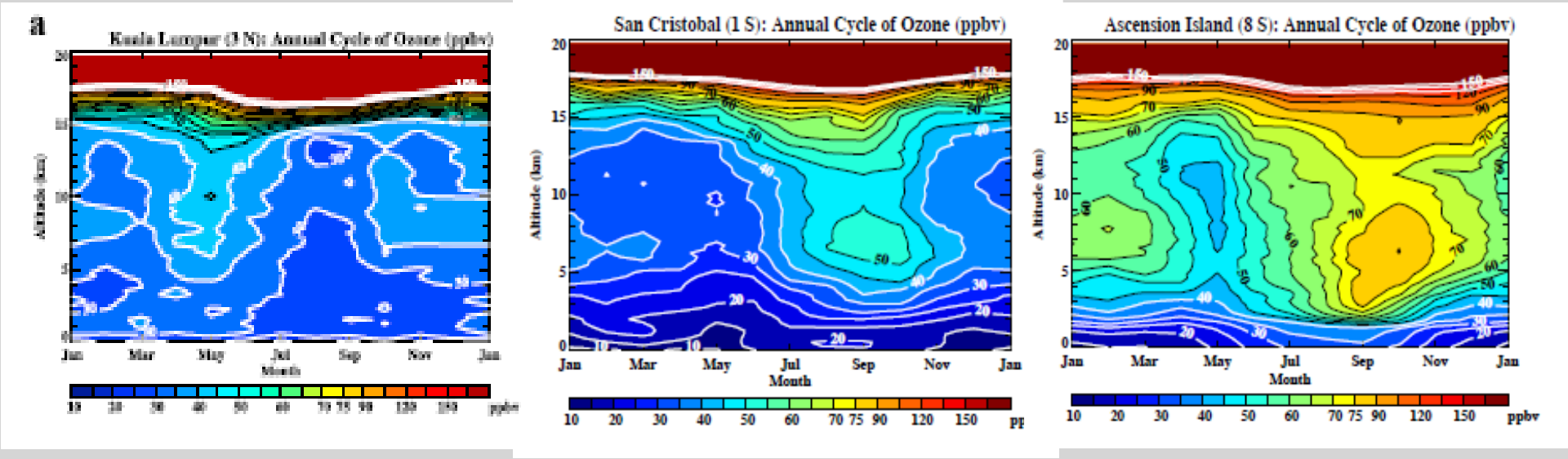
- In T07 (not shown) mean total ozone offset relative to *TOMS* - 10 stations ~7% low, range 1-11% low
- In T12 (left, center), “re-processing” eliminated Paramaribo offset; 13-site mean offset < 5% relative to *OMI*. Hanoi, KL, Watukosek largest (low sonde) offset (right). Unknown cause.







Three Distinct Regions:
W Pacific, 'Equatorial Americas', Atlantic
GWI = Convective Proxy, Declines West to East.
Pollution Increases West to East



Property	Kuala Lumpur	San Cris.	Ascen.
T'pause Altitude	16.6 km	16.6 km	16.0 km
5-12 km Mean Mixing Ratio	36 ppbv	48 ppbv	64 ppbv
Mean GWI [arbitrary unit]	19.4	12.6	8.35

SHADOZ Schedule 2013-2016 - Deadlines & Deliverables

Timeline	SHADOZ PI, Collaborator/Partner Activities for O3S-DQA & SI2N	Deliverables, Reporting & Publications
April 2012	Sonde Technical Issues in O3S-DQA, Greenbelt Workshop, attended by PI, NASA, NOAA collaborators and Members of the WMO Ozone SAG	- Processing with first set of Transfer Functions by SHADOZ volunteers. - O3S-DQA Report to SI2N Workshop, Columbia, MD.
June – Dec. 2012	Preliminary data re-processing at selected stations - Transfer function implementation. - Re-process SHADOZ data set for stations with instrument, sensor solution changes. Optimize background current correction. (First scheduled: Fiji, Samoa, San Cristóbal)	AGU Special Session on O3S-DQA and related sonde technical results: Dec. 2012, San Francisco
Jan. – June 2013	Workshop, O3S-DQA Report, Publication preparations for SI2N and UNEP/WMO 2014 Assessment deadline.	- SHADOZ Deliverable: O3S-DQA Report(s). - SHADOZ PI, Collaborators submit 1 or more journal articles for publication.
June – Dec. 2013	Workshop: (1) evaluate Transfer Function and other re-processing changes on SHADOZ dataset; (2) Assess needs and protocol for Tropical-JOSIE to be conducted in 2014-2015.	Re-process all SHADOZ datasets (V06) for self-consistency within given station. Apply Transfer Function as needed.
Jan. 2014 – Dec. 2015	Review Results at WMO-sponsored Workshop.	Conduct Tropical-JOSIE at WCCOS, Jülich.
Jan. – Dec. 2016	Report at Quadrennial Ozone Symposium.	- Reprocess & homogenize the 1998-2015 SHADOZ Data. - Prepare publication(s) for 2018 UNEP/WMO Ozone Assessment.
Timeline	SHADOZ Statistical Analyses, Classifications with LID & SOM, Interannual Variability & Trends	Deliverables, Reporting & Publications
2013 – 2014	- Classified profiles on SHADOZ website or link - Comparisons of LID & SOM for Ascension, Natal, Irene	Prepare journal article, 2014
	SHADOZ comparisons with TES	Prepare journal article, 2015
2014 - 2015	Classified profiles for KL, Hilo, Nairobi, Samoa	
	Analyze reprocessed, homogenized data for climate signals, trends	Prepare journal article, 2016

2013:
Initial Re-Processing.

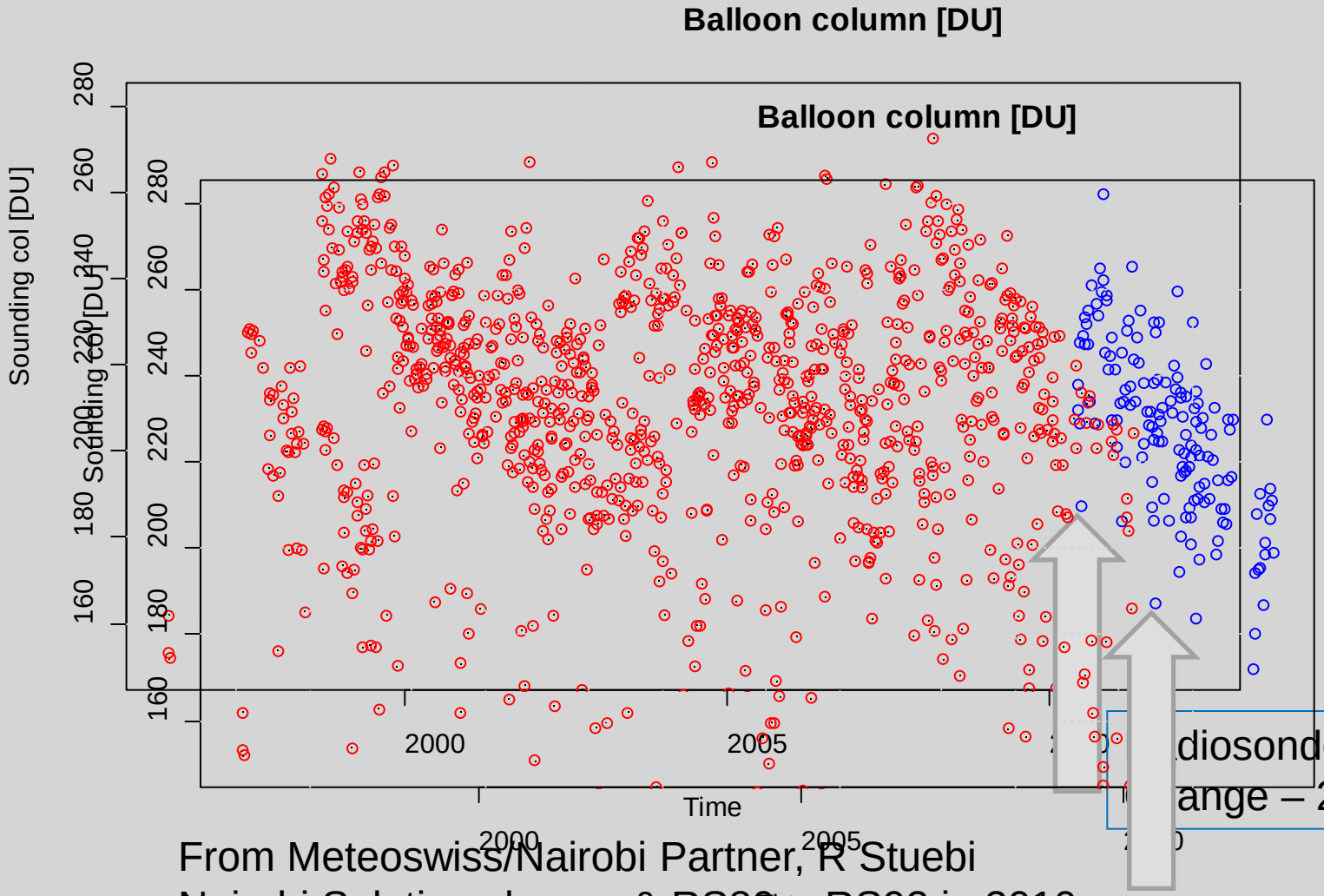
Re-analyze
(1) Total Ozone Comparisons

(2) Tropical Stratospheric Ozone biases

? Write up for SI2N 6/13, UNEP Deadlines

NEXT STEPS?

Column integral [DU] up to burst «ARTIFACT» CHANGE IN NAIROBI!



From Meteoswiss/Nairobi Partner, R Stuebi
Nairobi Solution change & RS80 -> RS92 in 2010.
Balloon burst is “lower”, an artifact of differenct P readings