Atmospheric Chemistry in the Tropics (II): Paradox, ENSO & an Emerging Mega-city

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Noble Talk 4, 14 April 2011

Introduction to Three Related Talks

- SHADOZ & UT/LS Processes **Tuesday** √
  - Importance of Tropical UT/LS (TTL)
  - Regional differences in convection, extra-tropical influence, pollution (biomass burning, urban)
  - Climatological approach, Laminae (LID), SOMs
- Tropical Atmospheric Chemistry (I) **Wednesday** √
  - Interannual variability (QBO, ENSO), trends (LS -yes, UT ?)
  - Remote sensing – SHADOZ motivation, progress, challenges
- Tropical Atmospheric Chemistry (II) **Thursday Today**
  - SHADOZ & related data collection – quantity and quality
  - African Fulbright research – "science & service"
  - Mega-city – Johannesburg, So Africa, trends or no?

Road Map

- Quality Assurance in SHADOZ
  - The ozonesonde measurement
  - Satellite-sonde total ozone comparisons: biases among stations?
  - WMO JOSIE intercomparisons & SHADOZ
- African Fulbright research – “science & service”
  - SHADOZ technical issues
  - Mega-city – Johannesburg, So Africa, trends or no?
  - SANOX – a demonstration campaign

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

Strategic Design Addresses Questions – 1998->

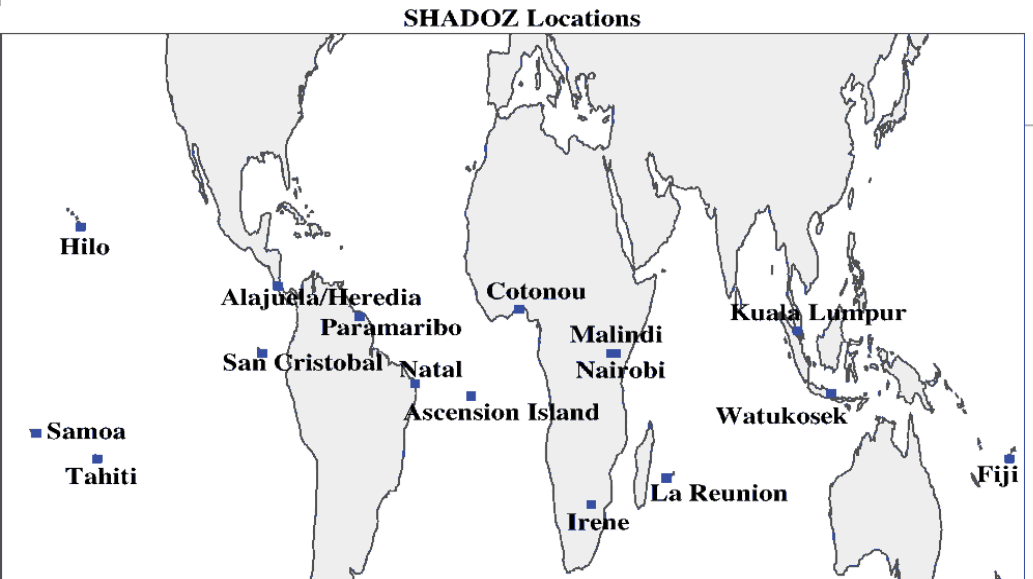
1> Satellite/model validation & optimization

2> Nature of zonal wave-one

3> Ozone variability on multiple time, space scales

- Full zonal coverage – 9 sites in 1998, now 12; weekly soundings
- Complements campaigns & archives data (SAFARI-2000, TC4)
- **2011 - > 5000 profiles at http://croc.gsfc.nasa.gov/shadoz**

4> SHADOZ-WMO comparisons enhance sonde accuracy, precision (Smit et al, 2007; Thompson et al, 2007; Deshler et al, 2008)



Ozonesonde Measurement - 1

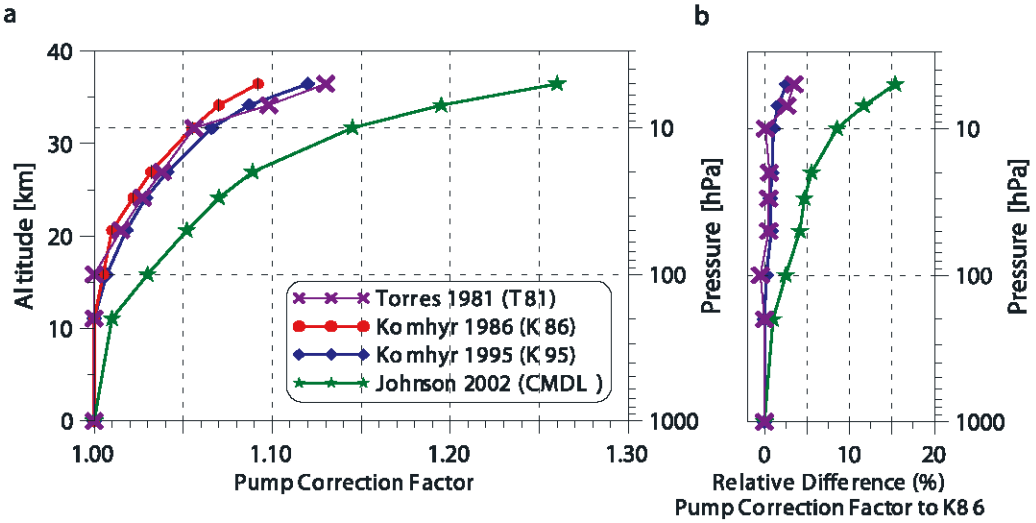
- Every sonde launched is a new instrument
- $P_{ozone} = 4.31 \times 10^{-2} \ (I - I_{bg}) \times T_{pump} \times PCF \ (1/F)$
- Calibrated through exposure to low, high ozone amounts.
- Important variables
  - SST = sonde solution type. KI strength, buffering
  - Response time, background current determined in pre-launch calibration
  - Pump efficiency correction important above 25 km

Ozonesonde Measurement – 2

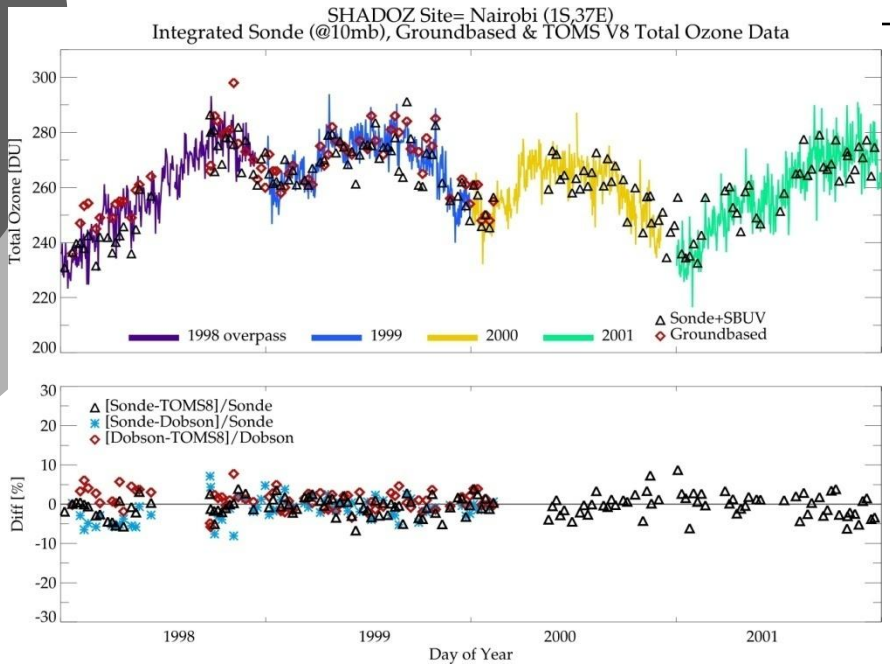
Table 1. SHADOZ Sites and Method, With Parameters During JOSIE-2000 Tests

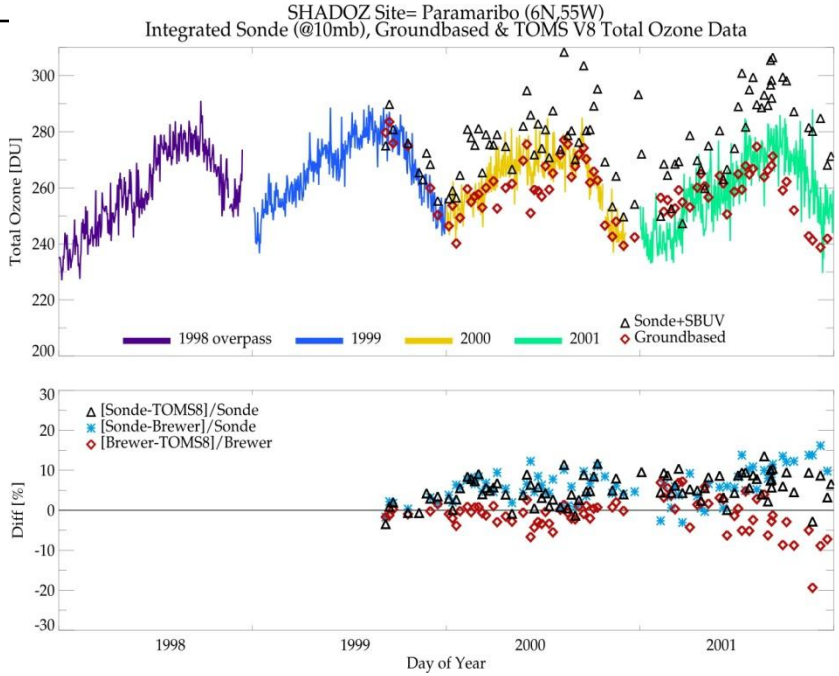
SHADOZ Sites	Latitude, deg	Longitude, deg	Station Method, PCF	Station Instrument	JOSIE Method[a]	JOSIE Instrument
Suva, Fiji	−18.13	178.4	2% KI, N[b]	SPC	2% KI	SPC
Pago Pago, American Samoa	−14.23	−170.6	2% KI, N	SPC	2% KI	SPC
Papeete, Tahiti	−18	−149	2% KI, N	SPC	2% KI	SPC
San Cristóbal, Galapagos	−0.92	−89.6	2% KI, N	SPC	2% KI	SPC
Paramaribo, Surinam	5.81	−55.2	1% KI, K[b]	SPC	. . .	. . .
Natal, Brazil	−5.42	−35.38	1% KI, W[b]	SPC,[c] ENSCI	1% KI	SPC
Ascension Island	−7.98	−14.42	1% KI, W	SPC,[c] ENSCI	1% KI	SPC
Cotonou, Benin (started 2005)	6.21	2.23	1% KI, K	SPC	. . .	. . .
Irene, South Africa	−25.25	28.22	1% KI, K	SPC	. . .	. . .
Nairobi, Kenya	−1.27	36.8	1% KI, K	ENSCI	1% KI	ENSCI
Malindi, Kenya	−2.99	40.19	1% KI, K	SPC	. . .	. . .
Kuala Lumpur, Malaysia	2.73	101.7	1% KI, K	SPC	. . .	. . .
La Réunion	−21.06	55.48	0.5, 1% KI	SPC,[c] ENSCI	.5, 2% KI	ENSCI
Watukosek, Indonesia	−7.57	112.7	2% KI, N	ENSCI	. . .	. . .
Kaashidhoo, Maldives[d]	5	73.5	2% KI, N	ENSCI	. . .	. . .
Aerosols99 Cruise[d]	. . .	. . .	2% KI,N	ENSCI	. . .	. . .

[a]Responsible Co-I JOSIE participant: NOAA/CMDL for Fiji, Samoa, San Cristobal, and Tahiti; NASA Wallops Flight Facility (WFF) for Natal and Ascension; Météosuisse for Nairobi; Univ. Réunion for La Réunion. FZ-Jülich JOSIE participant test method used at Irene, Paramaribo.
[b]PCF key: N, NOAA/CMDL [*Johnson et al.*, 2002]; K, *Komhyr* [1986] and *Komhyr et al.* [1995]; W, Wallops laboratory test [*Torres*, 1981].



Sonde-TOMS Comparisons (to 2001)



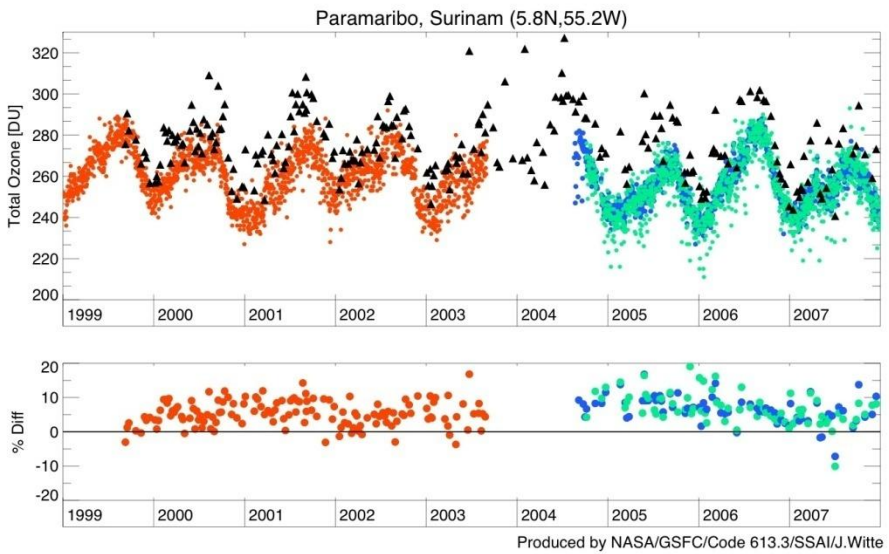


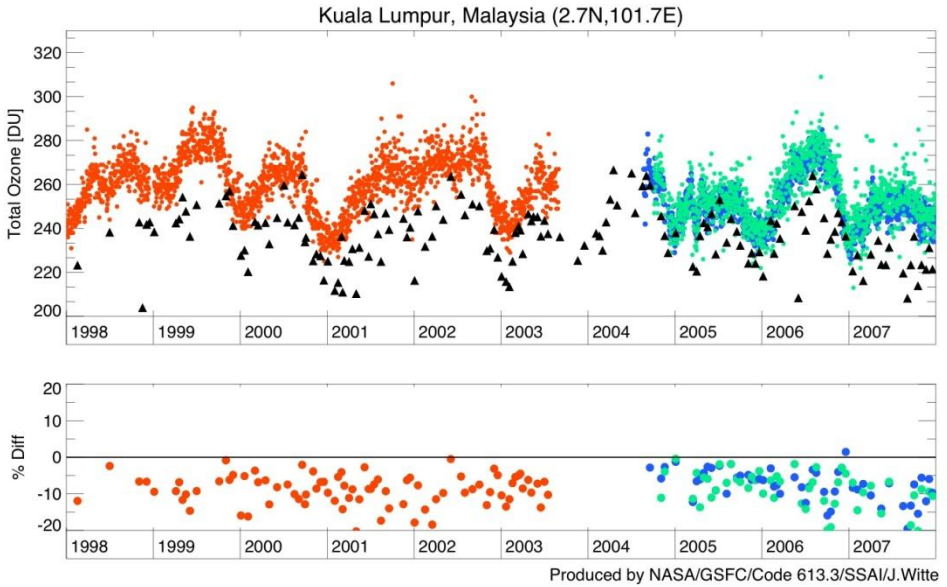
Nairobi - Excellent TOMS-total ozonesonde-Dobson agreement

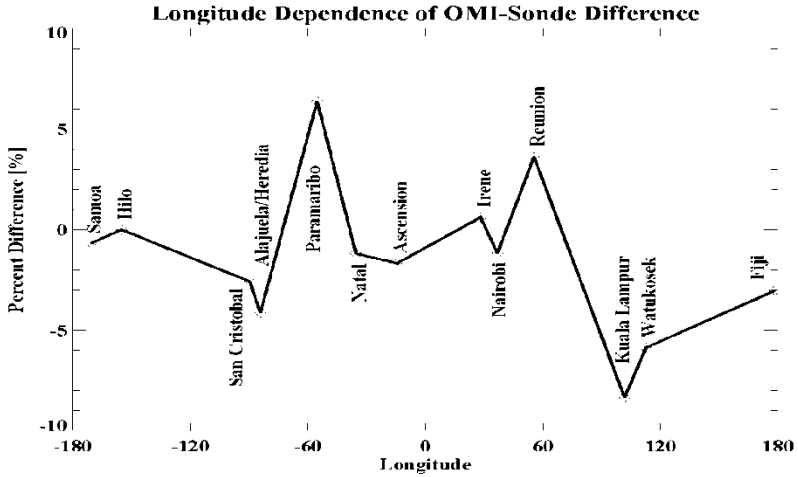
Paramaribo <u>higher</u> sonde than TOMS, drift ?

(Thompson et al., 2007)

Suggestion of Station Biases in Sonde-TOMS/OMI Comparisons



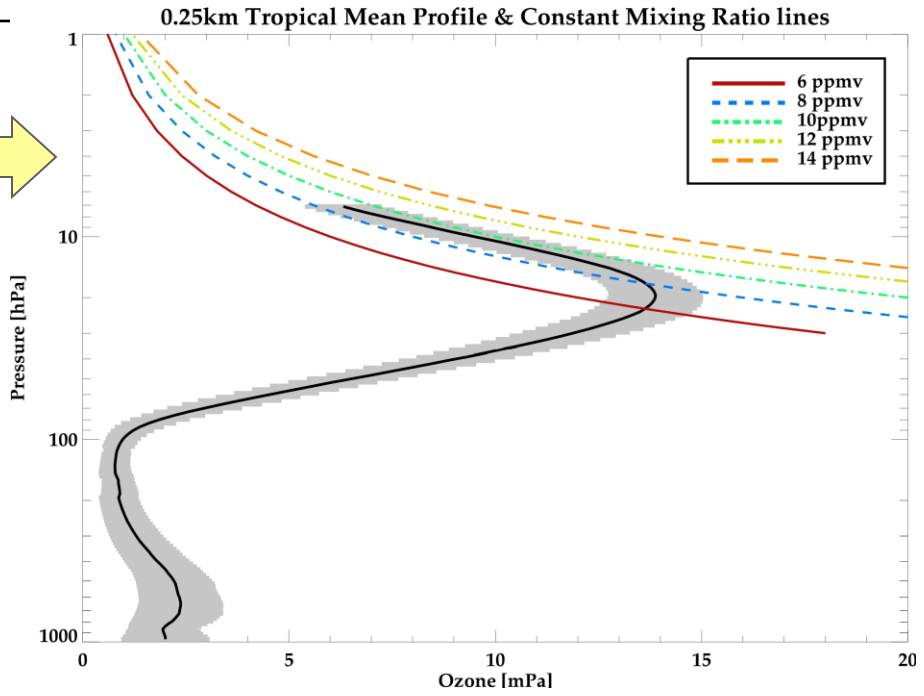


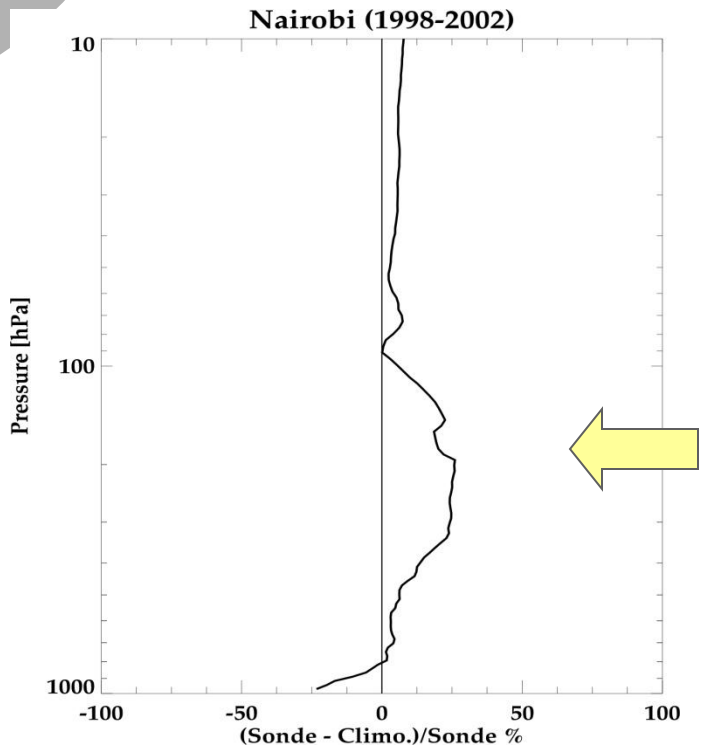


Current Offsets, Based on 2005-2009 OMI comparisons

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

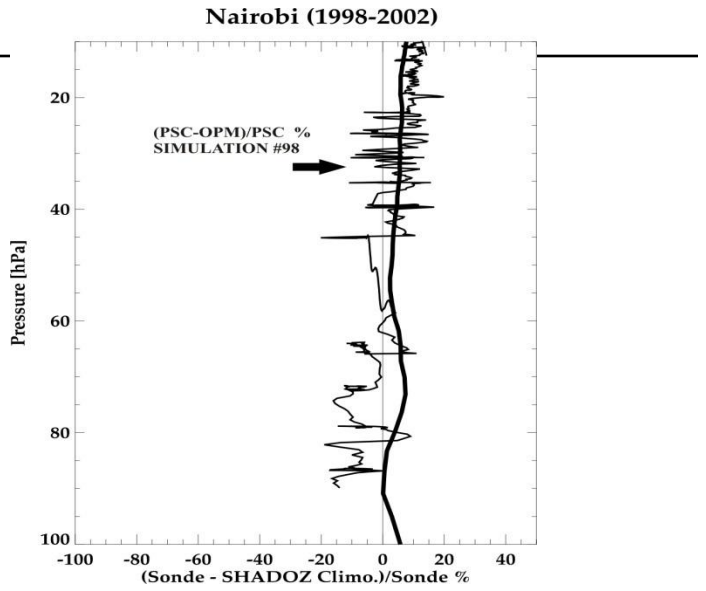
- Individual stations show bias in *stratospheric* profile segment when compared to SHADOZ tropical mean.





- Nairobi is relatively high.
- Interpret based on WMO-JOSIE-2000 comparisons?

SHADOZ & QUALITY ASSURANCE:
UV Photometer & JOSIE-2000 Chamber Tests



Above – JOSIE chamber, 9/2000 Nairobi high-bias.

Right -- JOSIE-2000 explains stratospheric ozone

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

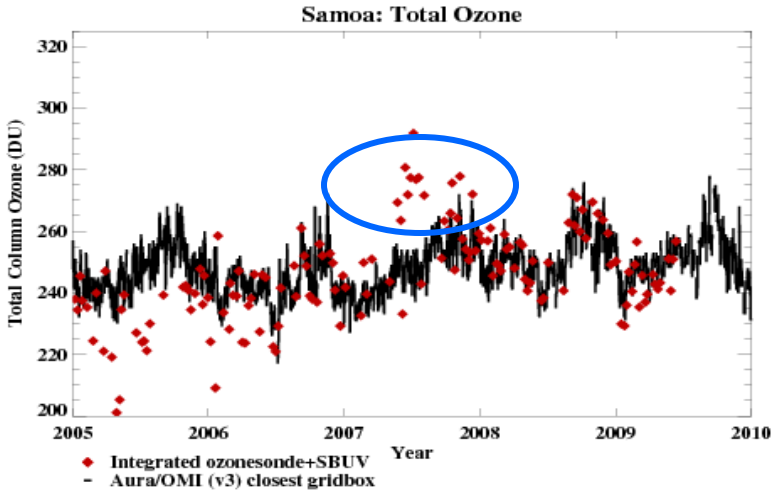
SHADOZ & Sonde Technical Issues – Maintain Intercomparisons/Lab Tests

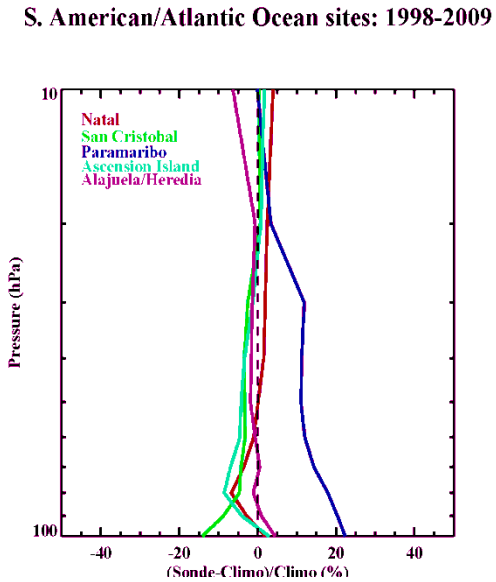
- H Smit/FZ-Juelich: JOSIE 2009/2010, sampled new, used sondes from 2 manufacturers. Results forthcoming

- Vömel & Diaz (2010) -- Background current ("bc") issue checked in lab tests. Affects SHADOZ in mid-upper trop for low-O_3 sites, mostly in very convective west Pacific, east Indian Ocean sites

- SHADOZ PIs no consensus on re-processing. Include background current, pump flow meta-data(?) Re-examine original data carefully. Avoid blanket "corrections" that introduce new errors (Stuebi & Levrat, 2010).

Paper: H. Vömel & K. Diaz, Ozone sonde cell current measurements and implications for observations of near-zero ozone concentrations in the tropical upper troposphere, *Atmos Meas Tech,* 3, 495-505, 2010 ** Cf R. Stuebi & G. Levrat, Comment: 2, C1252–C1256, 2010.





Fulbright Science & Service**

- **Three Scientific Goals**
  - Complete, refine study on Irene ozone trends – underway w/ PSU students, Wits (S Piketh), SAWS (G Coetzee)
  - Work with SHADOZ partners on ozonesonde technical issues (WMO, NDACC) – Input to Jan, April Meetings in 2011
  - Collect data with host institutions – NO_2 "hot spot" a focus

- **Educational, Infrastructure, Capacity Goals**
  - Re-start SHADOZ ozone soundings at Irene (w/ SAWS) √
  - Add to regional data capacity – also websites, archive (?)
  - Contribute to student theses, papers (NWU, Wits, UP)) √
  - Strengthen ties among African AQ (air quality) research community – workshop planning underway √
  - Further student-scholar exchange: PSU <-> host institutions*

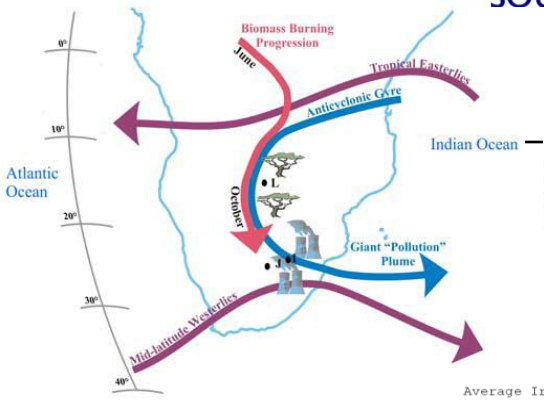
** http://fulbright.state.gov - – Report to Fulbright!

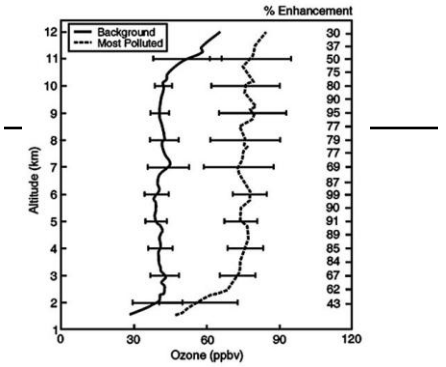
* Wits (Piketh Grp), NWU (Pienaar Grp), CSIR-Pretoria (Laser Grp, Sivakumar), SAWS (G Coetzee)

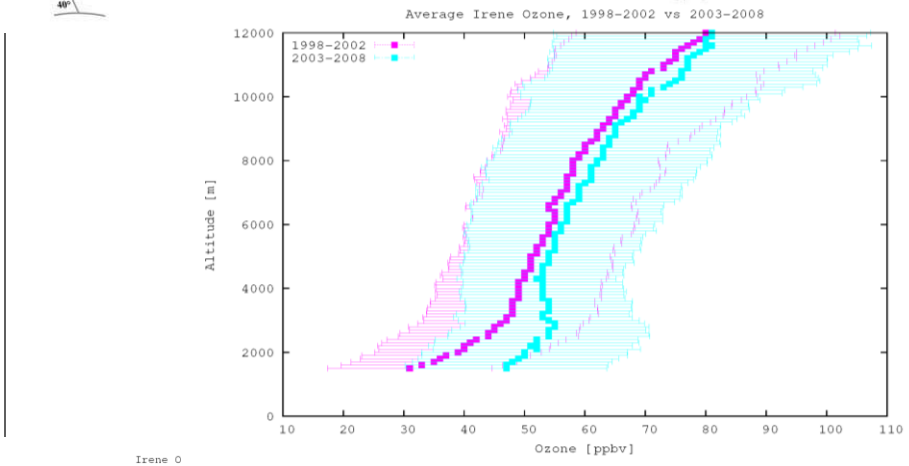
Joburg/Pretoria Trends?

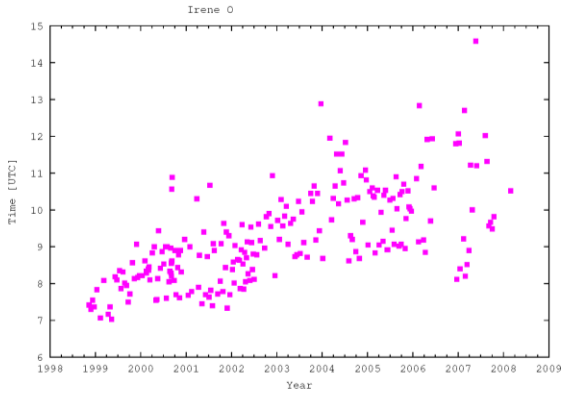
Diab et al. (2003, 2004): MUST classify profiles by meteorology **(Upper)**

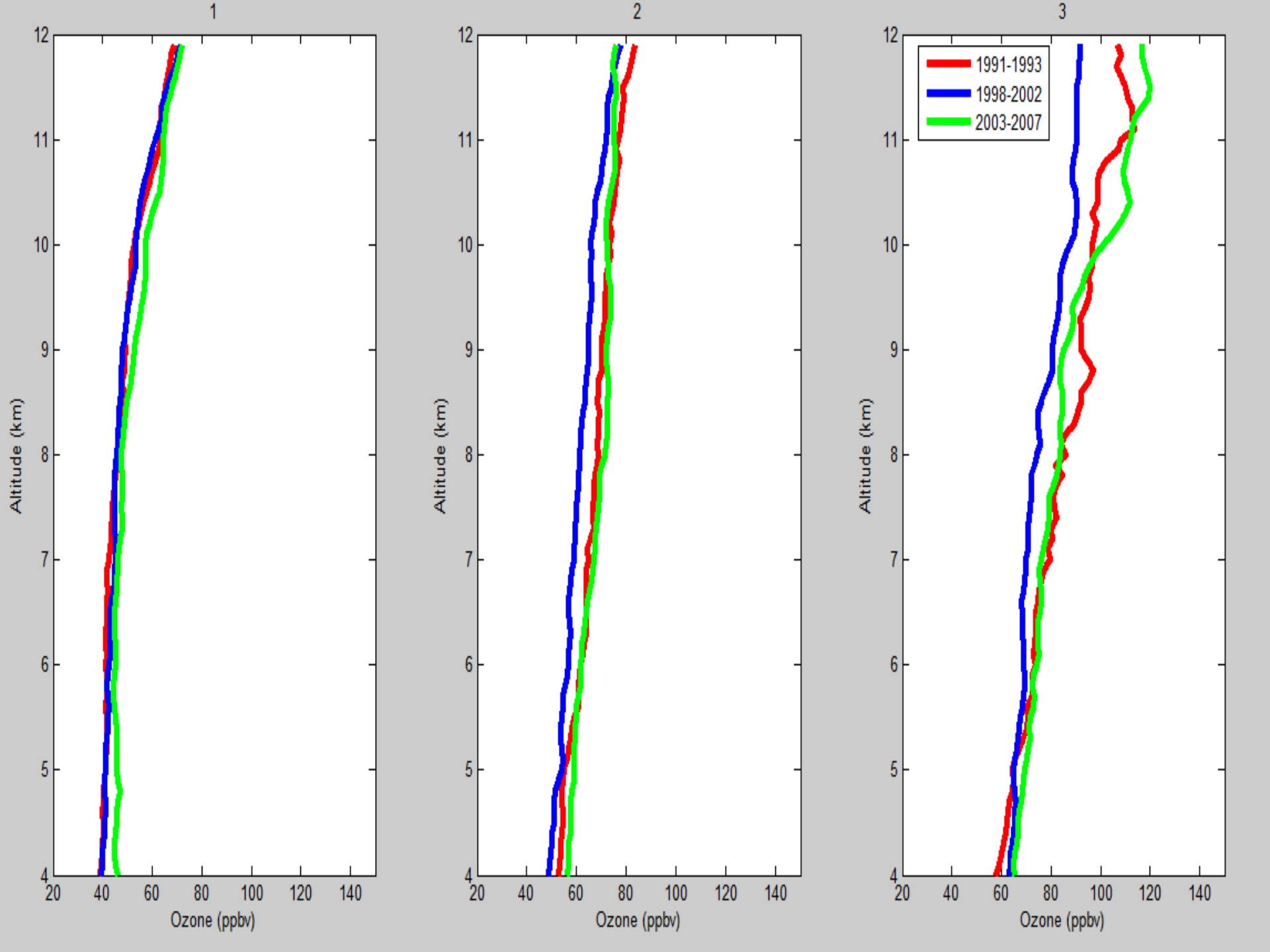
- Study 1 (Diab et al., ACP, 2003) based on MOZAIC L/TO aircraft data from Johannesburg flights. "TWINSPAN" used for types
- Study 2 (Balashov/Jensen/ AMT) finds launch change during SHADOZ record, for overpasses, exaggerates SHADOZ "trends" **(Middle,Lower).**










1
2
3
1991-1993
1998-2002
2003-2007
Altitude (km)
Ozone (ppbv)
4
5
6
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11
12
20
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60
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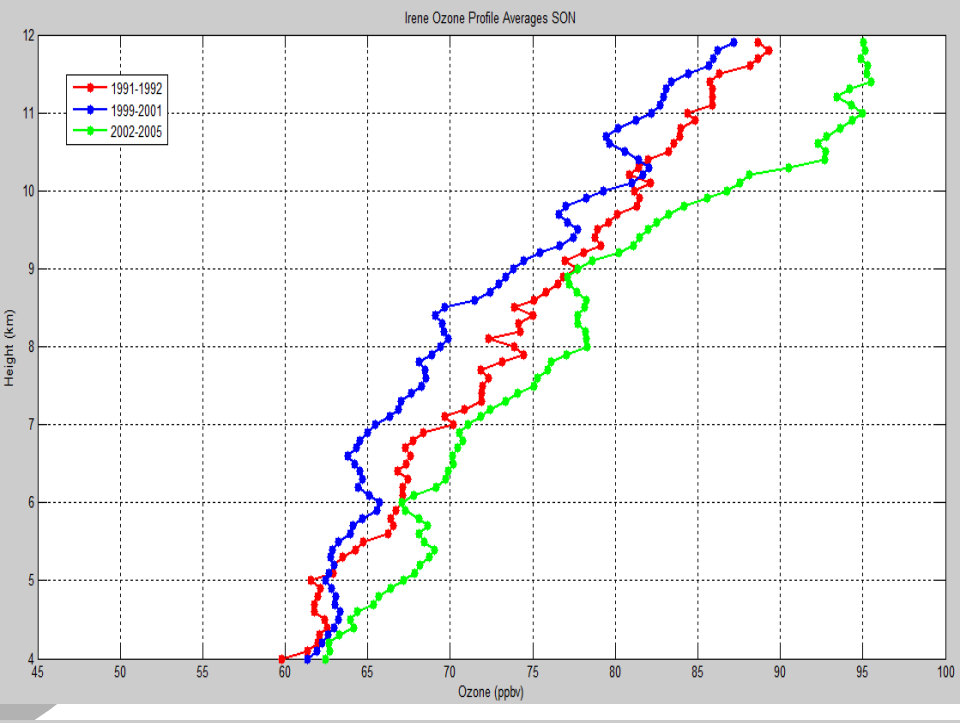
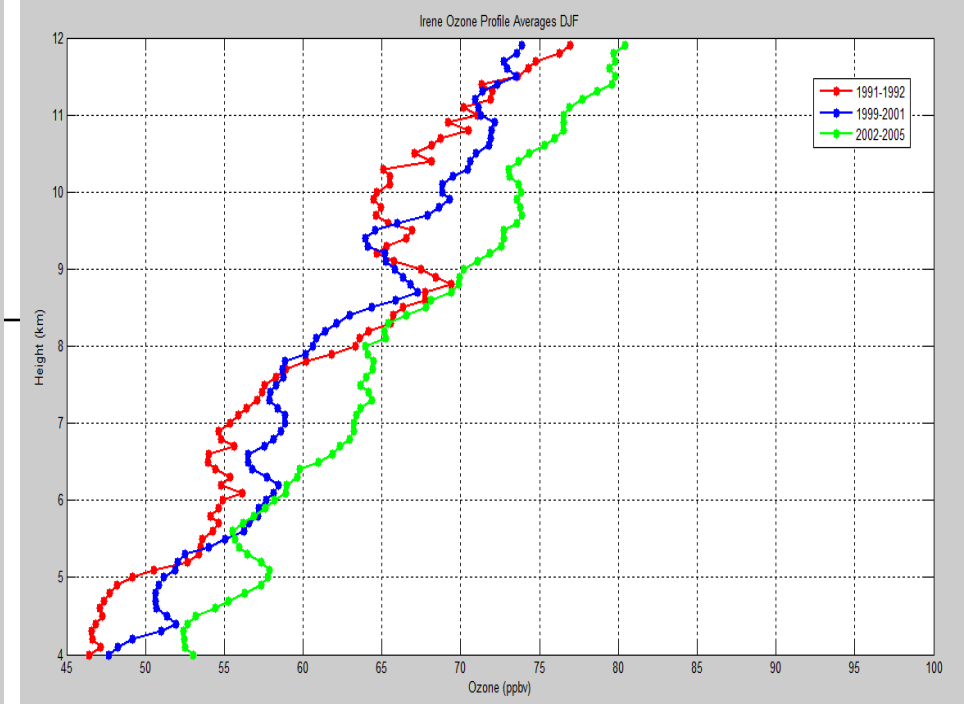
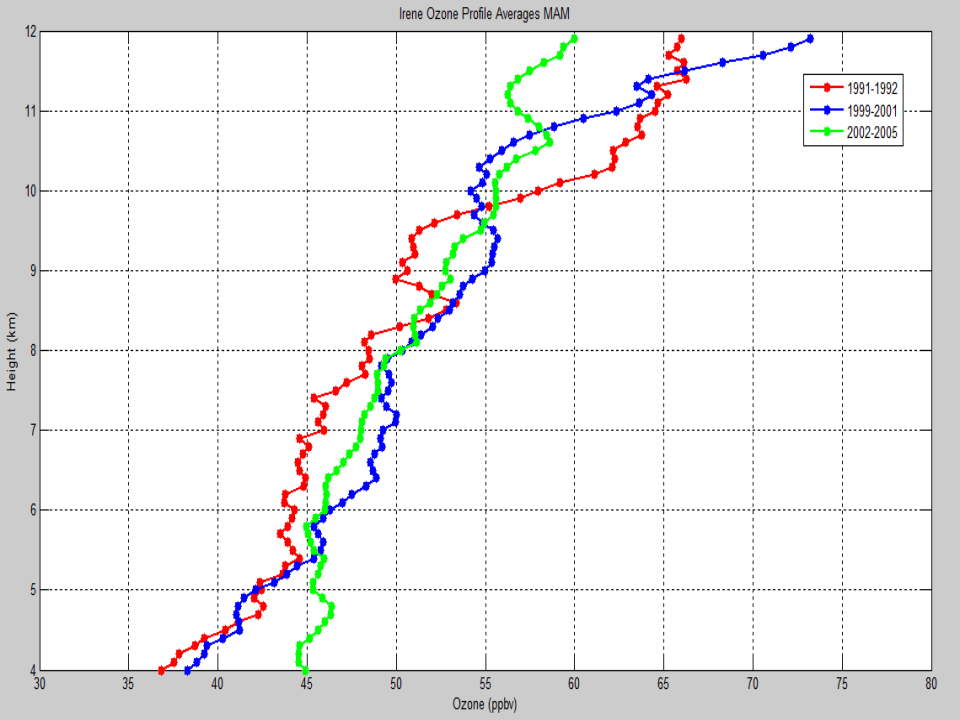
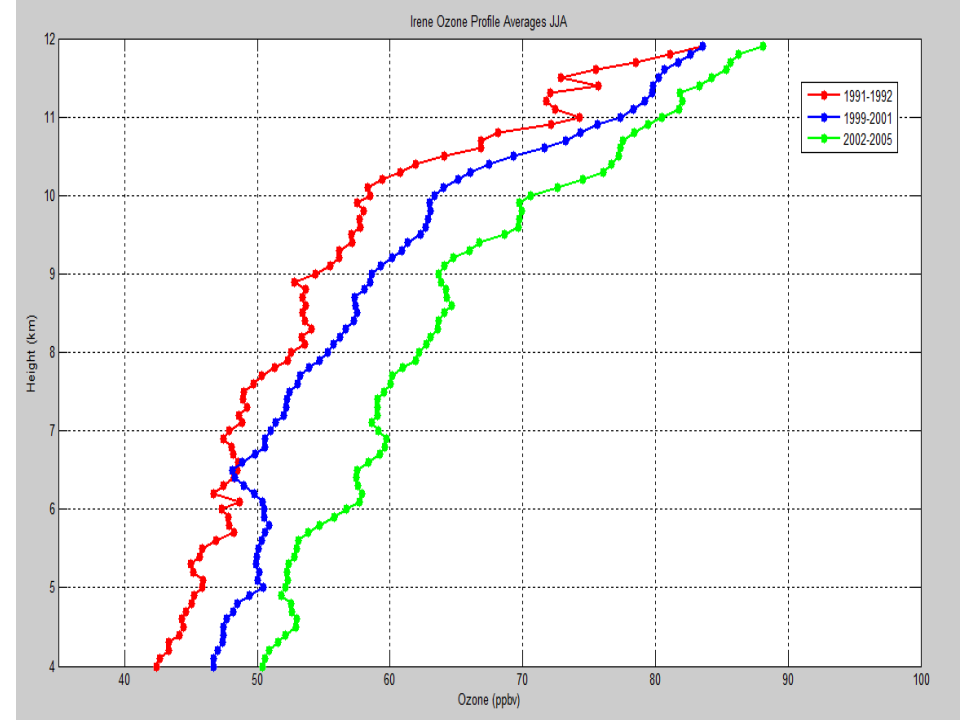
100
120
140

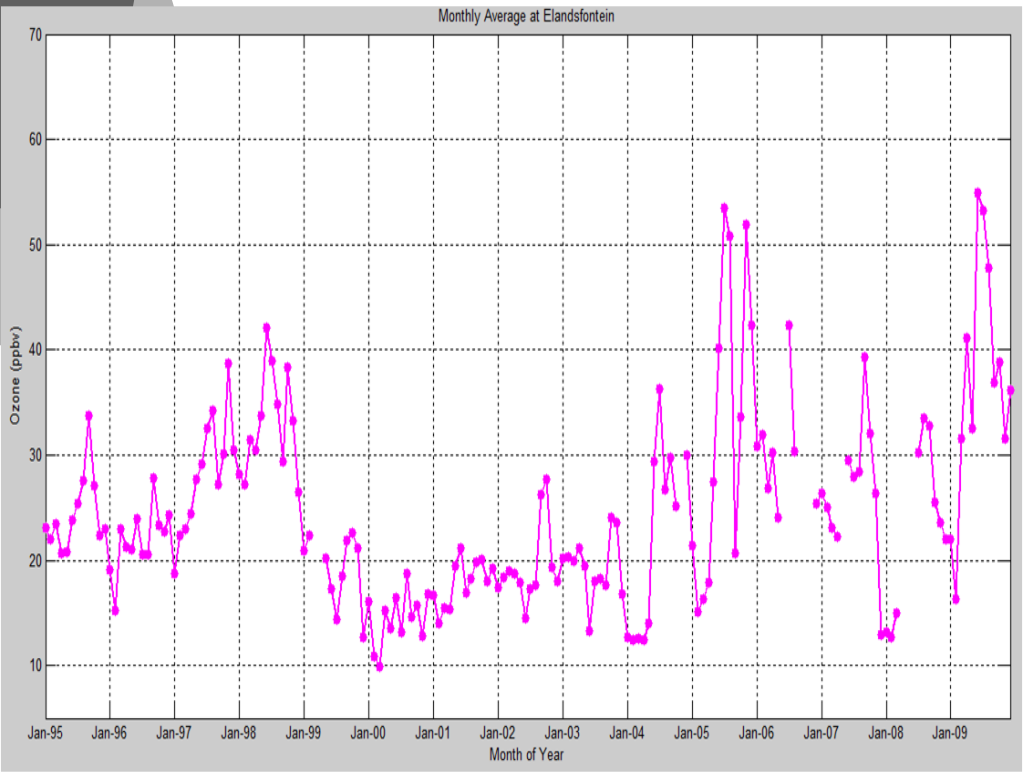

Irene Ozone Profile Averages SON
1991-1992
1999-2001
2002-2005
Height (km)
Ozone (ppbv)

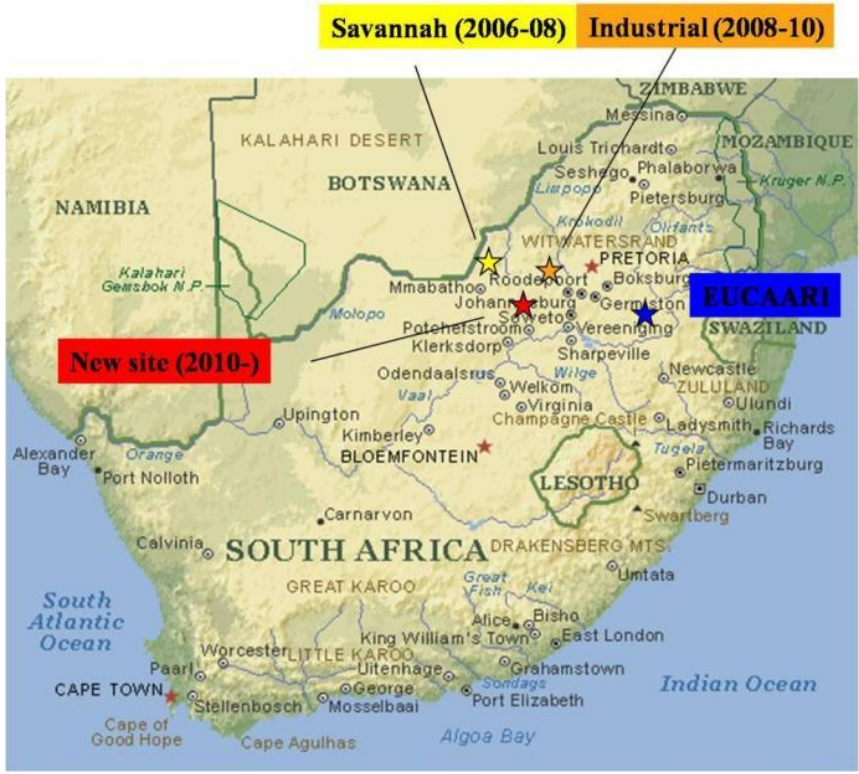

Irene Ozone Profile Averages DJF
1991-1992
1999-2001
2002-2005
Height (km)
Ozone (ppbv)

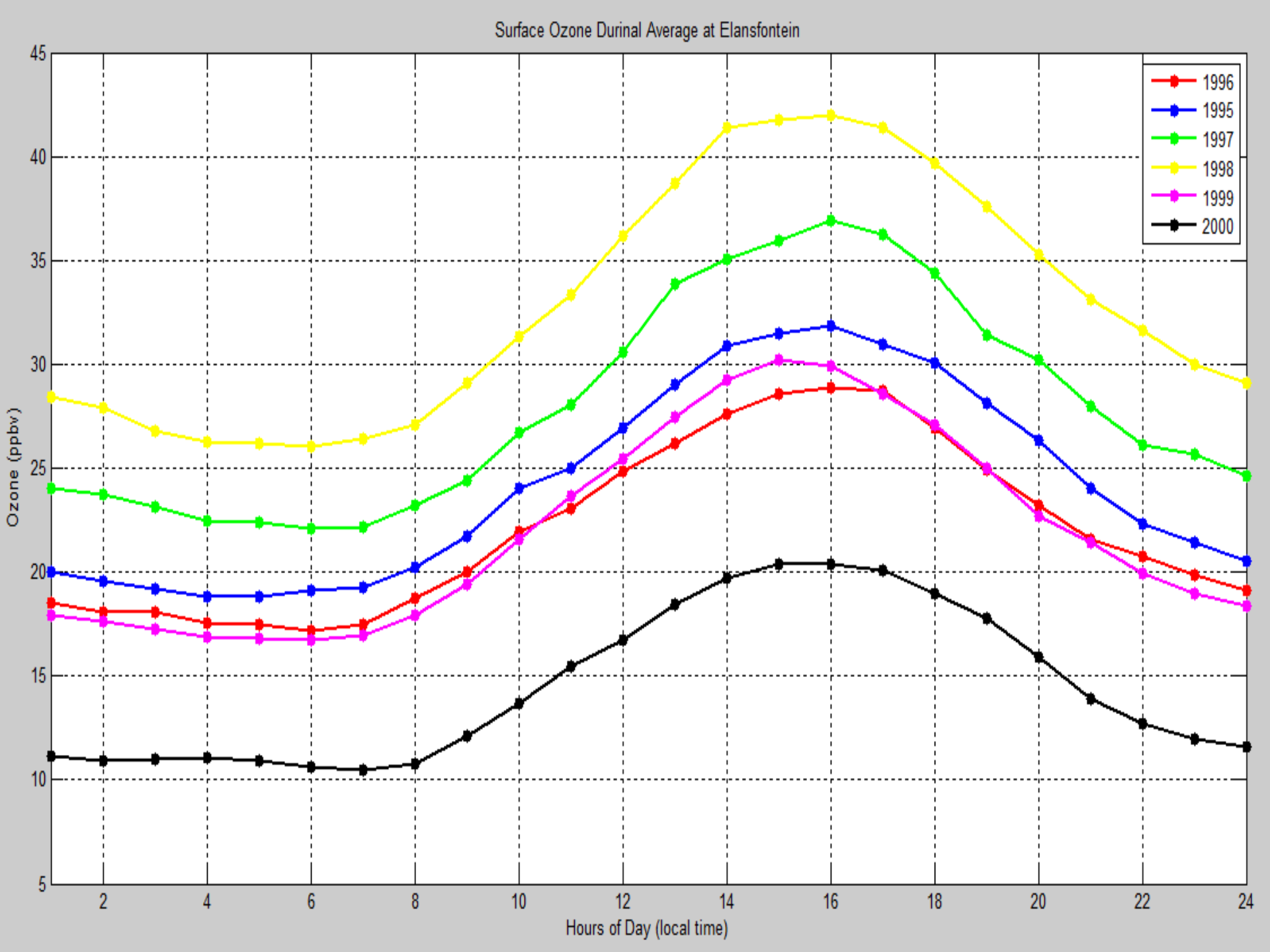

Irene Ozone Profile Averages MAM
1991-1992
1999-2001
2002-2005
Height (km)
Ozone (ppbv)


Irene Ozone Profile Averages JJA
1991-1992
1999-2001
2002-2005
Height (km)
Ozone (ppbv)

15-Year Record near Highveldt Power Plants @ Elandsfontein. Ozone Response to ENSO with Post-2007 Industrial Gorwth (?)






Surface Ozone Durinal Average at Elansfontein
Ozone (ppbv)
Hours of Day (local time)
1996
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1997
1998
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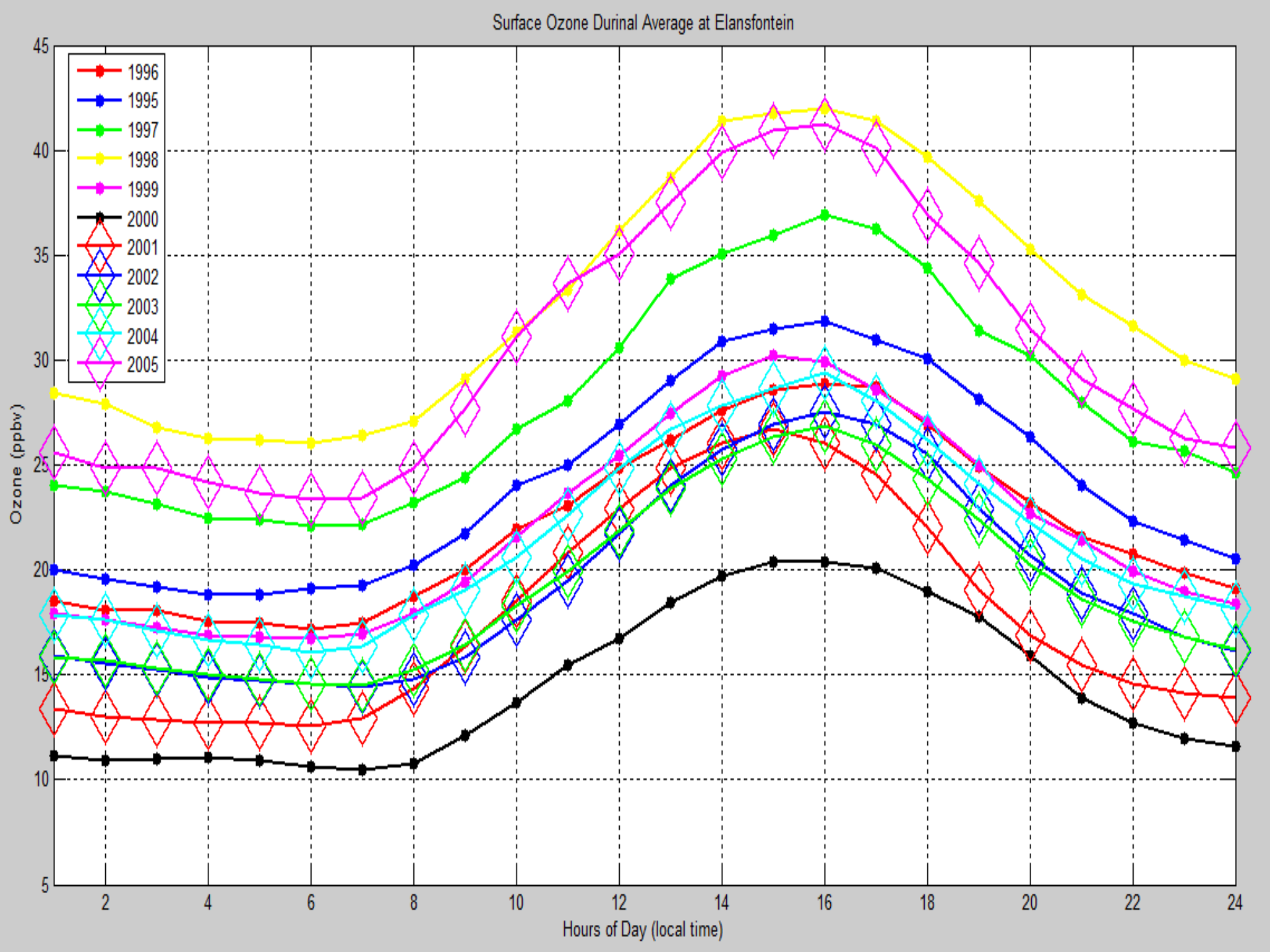
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45
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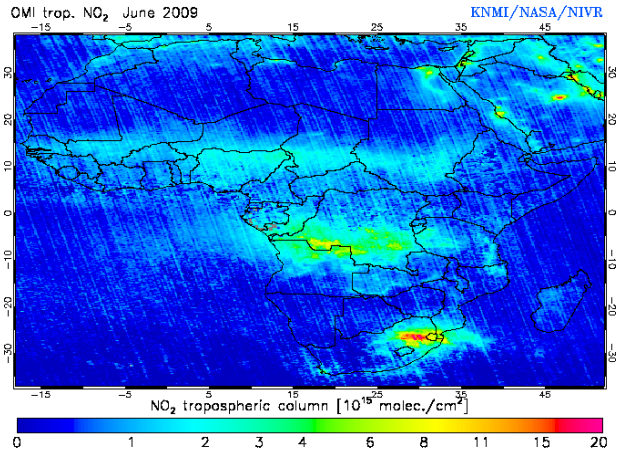
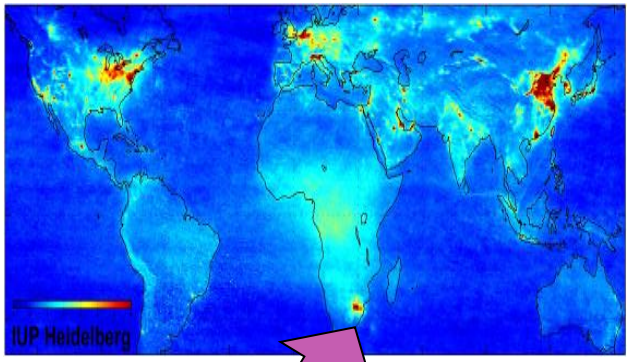
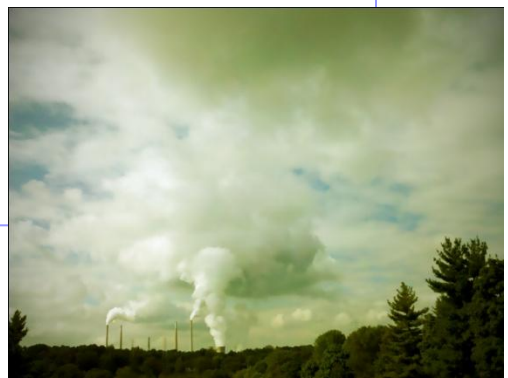
SANOX = South African NO_x

- SA is "global" hotspot for NO_2 OMI /GOME satellites
- NO is Key – SA sources - Large Human (fires, industry, transport) and Natural (lightning, soils). **NOx is/isn't limiting ozone precursor in SA**
- Ground truth w/ column spectrometer, Pandora Direct-sun. Others as CINDI @ Cabauw (?)
- WHERE, WHEN for SANOX? Look at close-up OMI data!







Schedule ?/Partners/ Where?

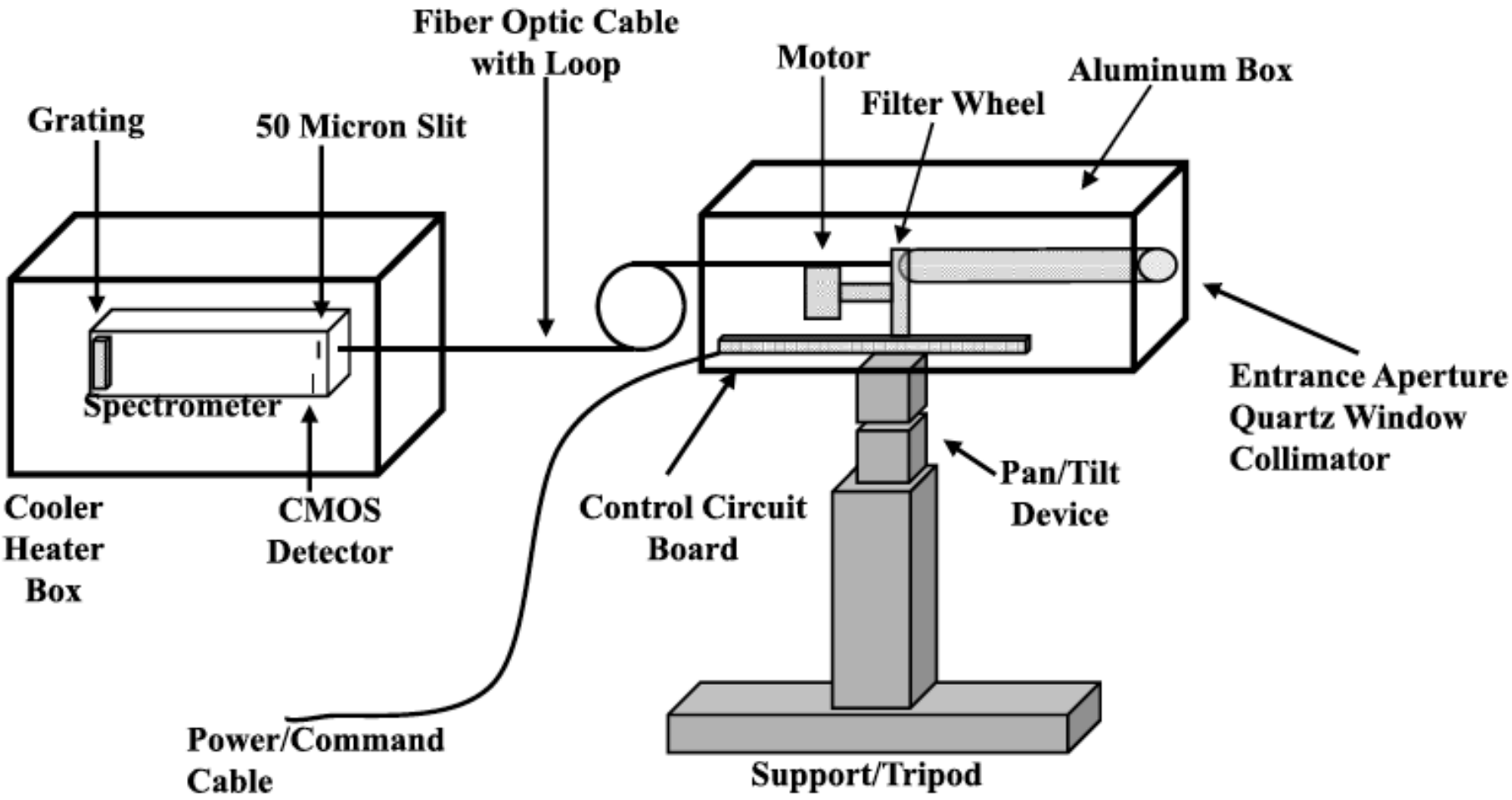
- **A M Thompson Research (Start Nov 2010)**
  - At NWU/SAWS/CSIR: Ozone trends analysis update.
- **SANOX Coordination, Deployment – Jan-June 11**
  - 1st Location near NWU-Potch; Pandora set up Jan 11
  - Ozone analyzer for Irene SAWS site. Add launches, Lidar to study Boundary Layer? Late May 2011

Institution	PI/Team	Instrumentation
NWU	J Pienaar	Ozone, VOCs, Aerosols
PSU	A Thompson	Cimel (?), Pandora
SAWS	G Coetzee	Lightning Netwrk, Uv. Sondes, Dobson
Wits	S Piketh	Ozone-CO-NOx-Aerosol filters
CSIR-Natl Laser Lab	SVentakaraman	Aerosol Lidar

Potch Trailer Resources

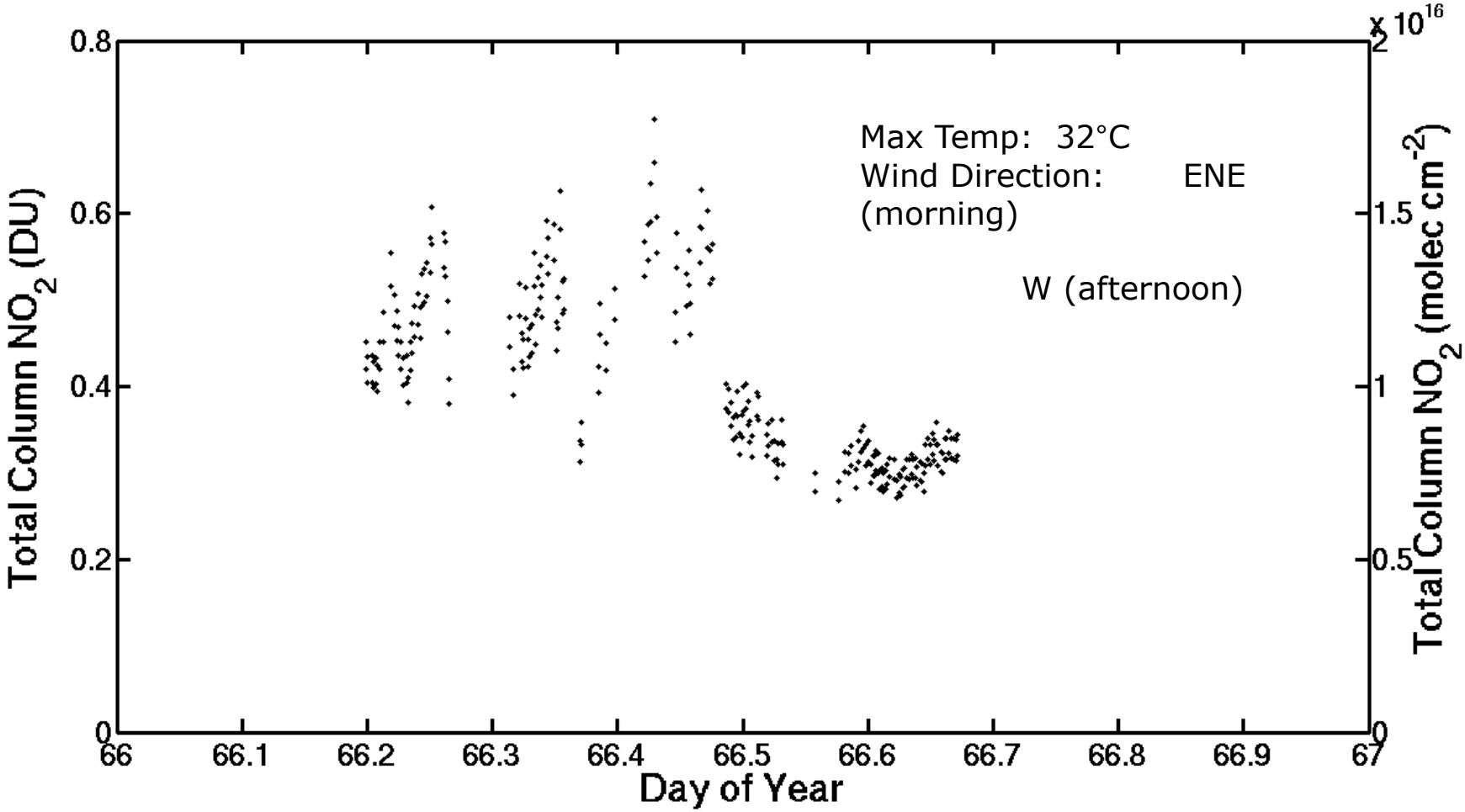
Meteorology Parameters
Trace gases: SO_2, NO_x, CO, O_3
Aerosols – Concentration, size distribution
PM_{10}, $PM_{2.5}$, PM_1
Water vapor and CO_2 fluxes
Soil temperature, moisture
Incoming, reflected radiation
VOCs

Pandora Instrument Diagram

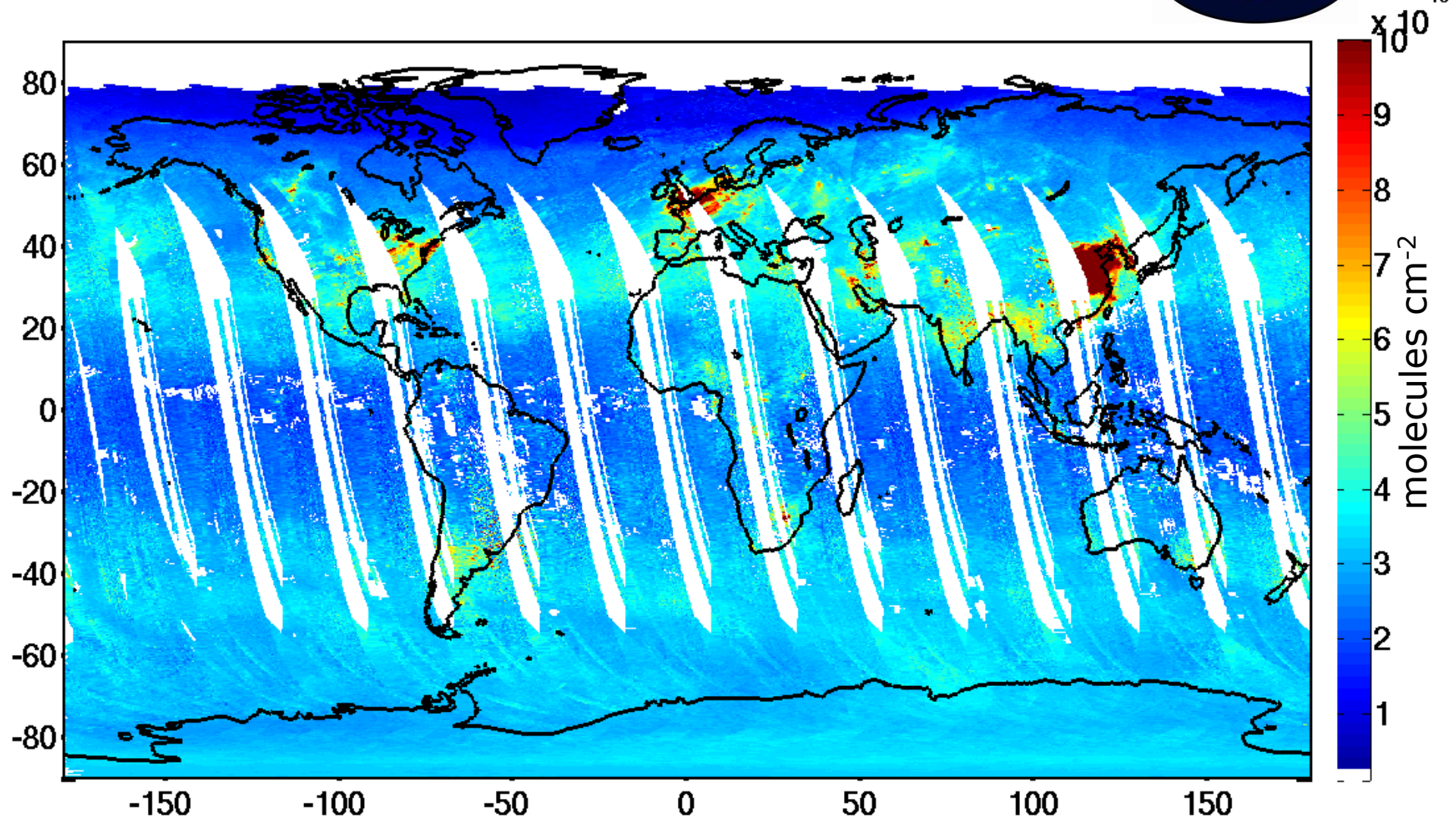


Herman et al., 2009

Pandora Total NO_2 Column – Potchefstroom 2011



OMI Total Column NO_2 – 7 March 2011



Summary

- SHADOZ dataset requires continuous interaction with intercomparison activities, NDACC sonde working group
- Major re-processing (v5) SHADOZ forthcoming
- Fulbright research
  - Demo with SANOX, Pandora going well (low sun)
  - Assembly of surface pollutant datasets +/-
  - Changing Chemistry in Changing Climate CACGP Workshop 31 May-3 June, Pretoria. Southern African region, US, European participants