How Visible is Regional Smog Ozone from Space and How Can We Make It More Visible?

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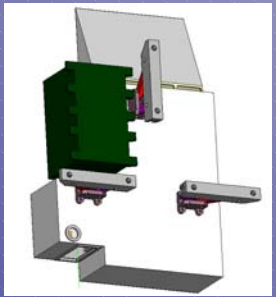
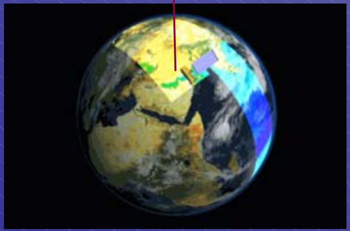


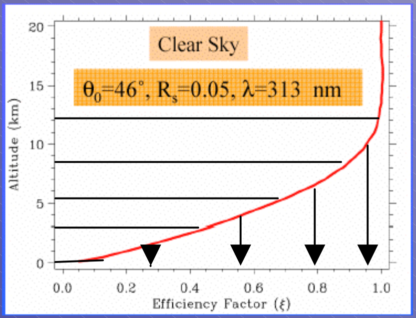


(1) Retrieval theory says that middle- and upper-tropospheric air should dominate

- *What do sonde comparisons tell us about vertical response of the tropospheric ozone estimates?*

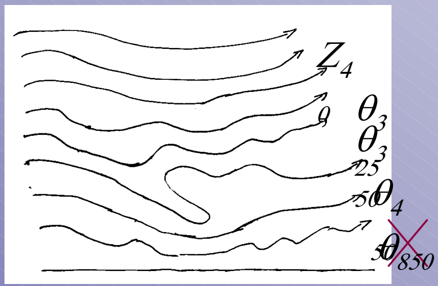
(2) We propose an ozone using AIRS depictions of stratospheric structure (T, Z, θ) and correlations/regressions, not (yet) AIRS O_3. Conceivably, this could remove low tropopause situations and even UT fronts.

- *How well do this estimate work (so far) and what is its vertical response function, based on IONS-06 sondes?*



Strat.

Trop.



Aura Science Team Meeting
Pasadena, October 2, 2007

Two Concerns We Addess:

(1) Retrieval theory says that middle- and upper-tropospheric air should dominate trpospheric column retrievals

- What do sonde comparisons tell us about vertical response of the tropospheric ozone estimates?

(2) We propose an ozone using AIRS depictions of stratospheric structure (*T, Z,* θ) and correlations/regressions, not (yet) AIRS O_3 . Conceivably, this could remove low tropopause situations and even UT fronts.

- How well do this estimate work (so far) and what is its vertical response function, based on IONS-06 sondes?

In South, OMI-MLS informs about smog, Where about tropopause and fronts

OMI–MLS tropospheric O3 as estimated for a INTEX-B Mexico City plume event. Above the orange line, the sensitivity to ozone below ~200 hPa commonly produces very high ozone features which race W to E. South of the line, features move more slowly, such as the Central-Mexico plume.

Schoberl Tropospheric Ozone Column to estimated tropopause

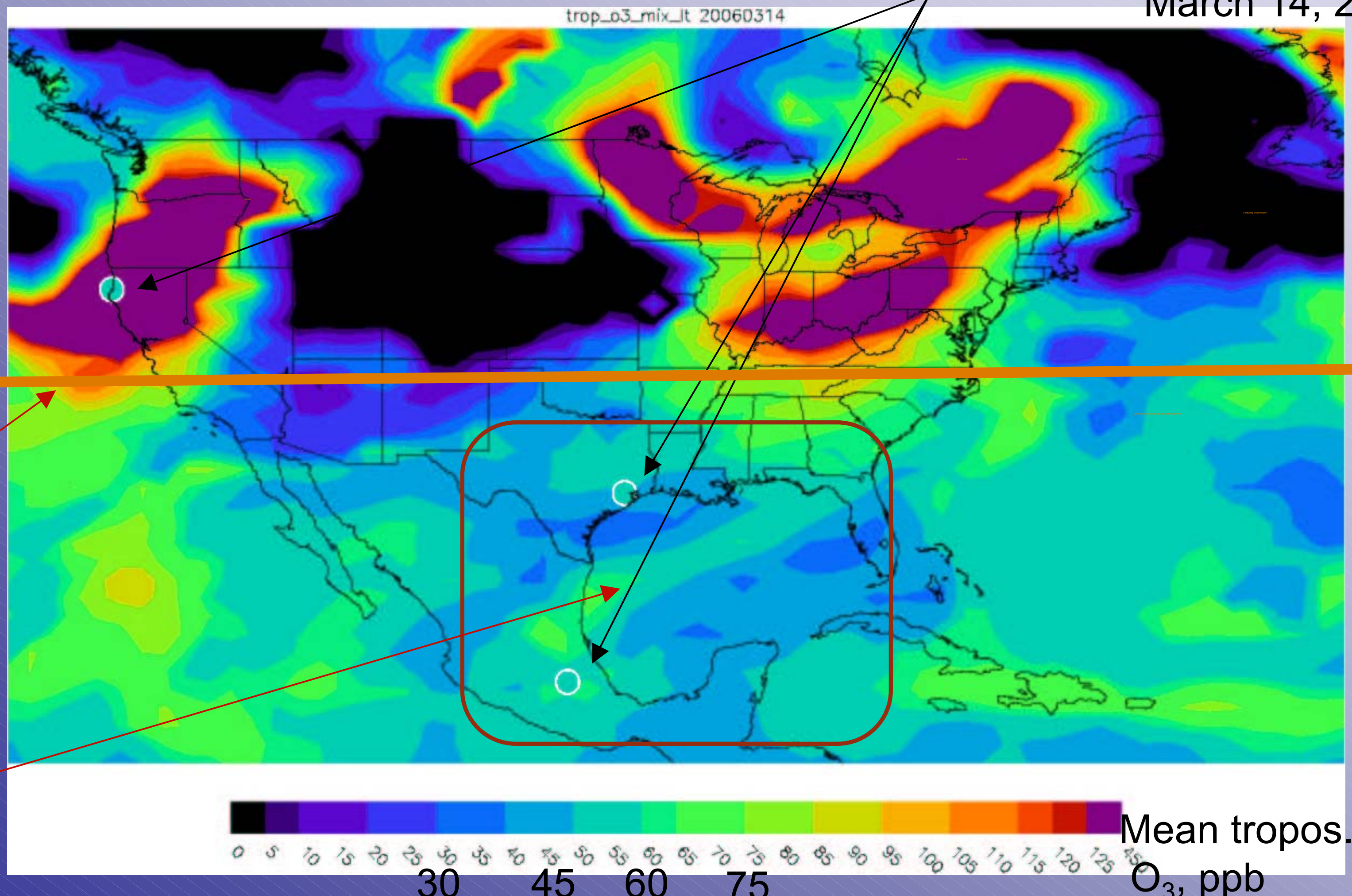
Schoeberl pre-Mar07 version

Subtropics easier to interpret, compare

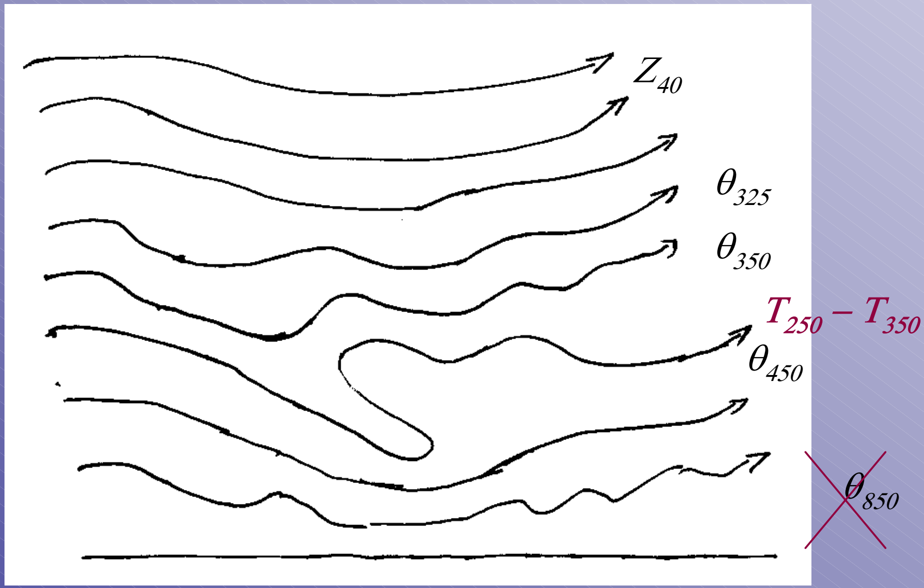
IONS Sondes comparisons

(best when collors match)

March 14, 20



OMI-AIRS(θ): Tropospheric Ozone from OMI Total Column O3 and AIRS Temperatures : Stratosphere and "Distraction" Removal:



Specific technique "projection pursuit regression" – roughly analogous to empirical orthogonal functions, but assembling combinations of those explaining variables (θ's) that have the most explanatory value for the explained variable, total ozone.

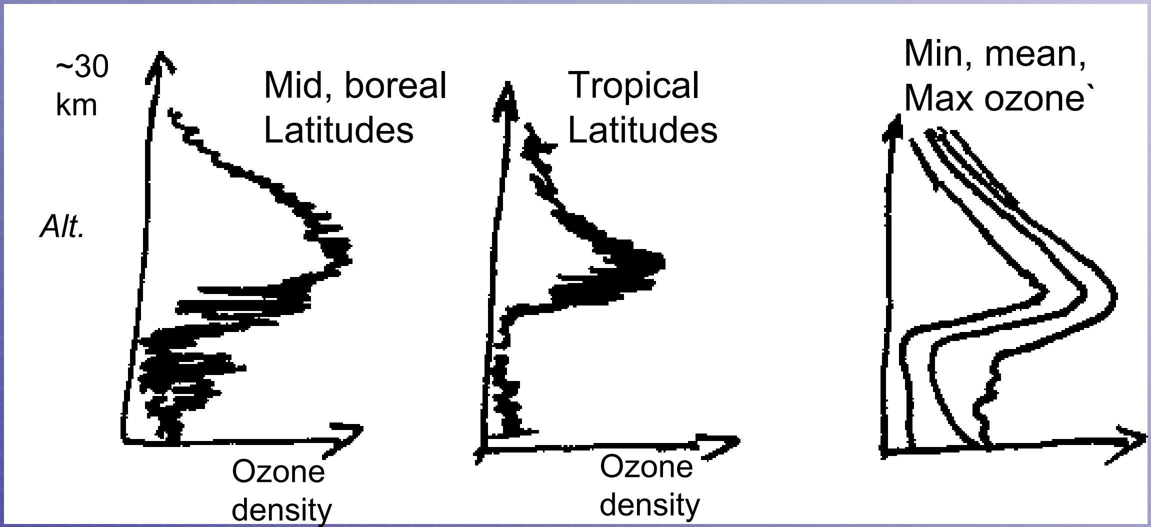
Sums: average properties of layers

Differences of *T*'s: Lapse rate

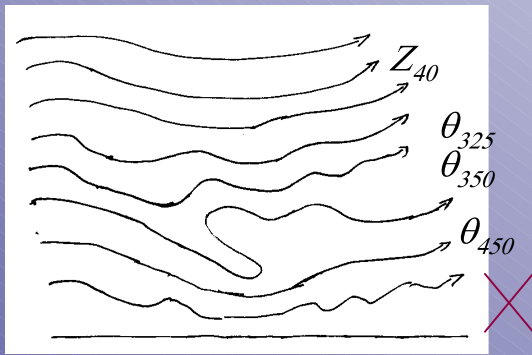
Do not include lower-tropos. variables

Some supporting rationalization is that over periods of a month or so, O_3 - θ relationships characterize the stratosphere vertically and regionally; also that local positions of the tropopause and UT fronts are *fairly well* captured by AIRS.

T's, θ's, *Z*'s (all are varied expressions of AIRS temperature structure.)



Example of Stratospheric Fit: August, 2006

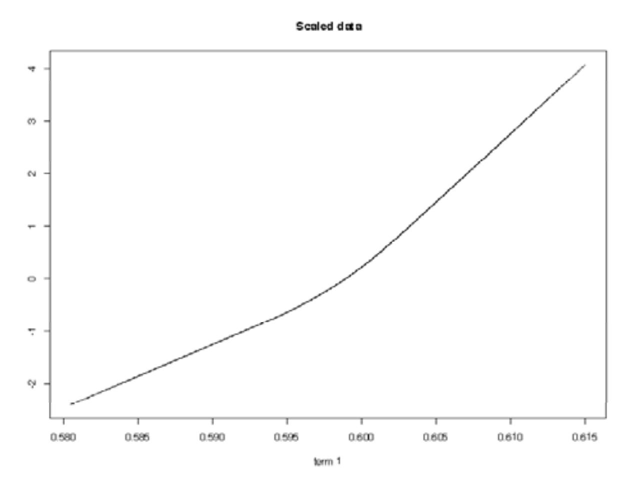


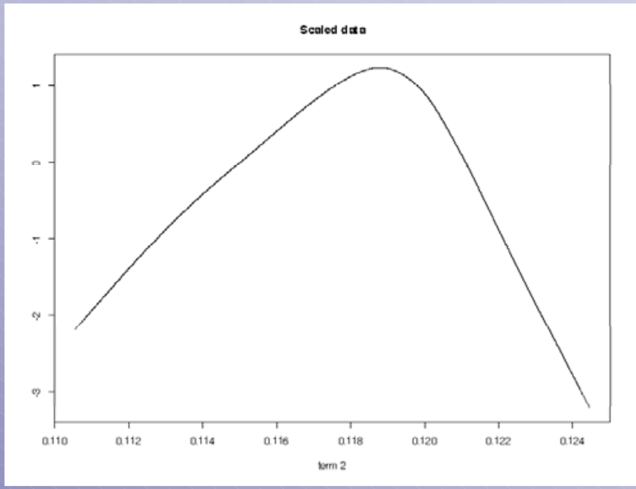
T's on a p-surface map directly to θ's; Z□'s are simply integrals of the T information. Vertical differences in T define tropapuase and front: *Limitation: limited AIRS vertical resolution for T.*

AIRS Variable	term 1	term 2	term 3	term 4	term 5	term 6
T_{450}	-0.01	-0.03	-0.01	-0.20	-0.07	0.33
T_{350}	-0.33	-0.02	0.04	0.03	0.40	-0.01
T_{275}	0.25	0.06	-0.01	-0.15	-0.59	0.40
T_{225}	-0.22	-0.06	0.04	-0.04	0.29	-0.20
Z_{175}	-0.23	-0.03	0.01	0.34	0.18	-0.53
Z_{60}	0.45	0.79	-0.73	-0.58	-0.26	0.58
Z_{40}	0.72	-0.61	0.68	0.70	-0.55	-0.28
latitude	-0.02	0.01	0.00	-0.01	0.01	0.01
Relative Contribution	0.05	0.03	0.02	0.01	0.01	.004
249317 fit points	$r = 0.92$	$r^2 = 0.84$				

- Why such a large variance explained? => Both vertical and horizontal (N/S) fit
- Any fitting of the troposphere is accidental … accdents can happen: I.e., correlations of structure between troppophere and stratosphere (particullarly UT?)

Example of Stratospheric Fit: First and second combinations



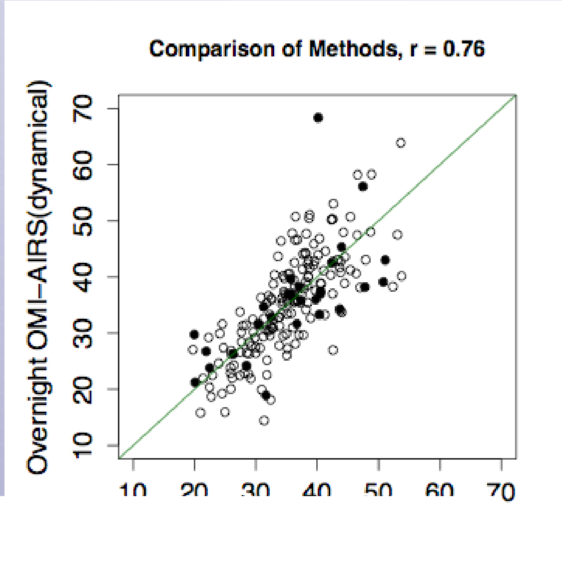


Response function for linear combinations of variables. In this situation, where we expect stratospheric ozone and stratospheric dynamical variables to exhibit simple relationships, the response curves are simple combinations of linear functions: recall that the first projection pursuit directions attempt to summarize all the most significant information, and often these are simple combinations or contrasts (differences)

PPR also allows us to organize somewhat correlated information from several levels into an informative few variable sums

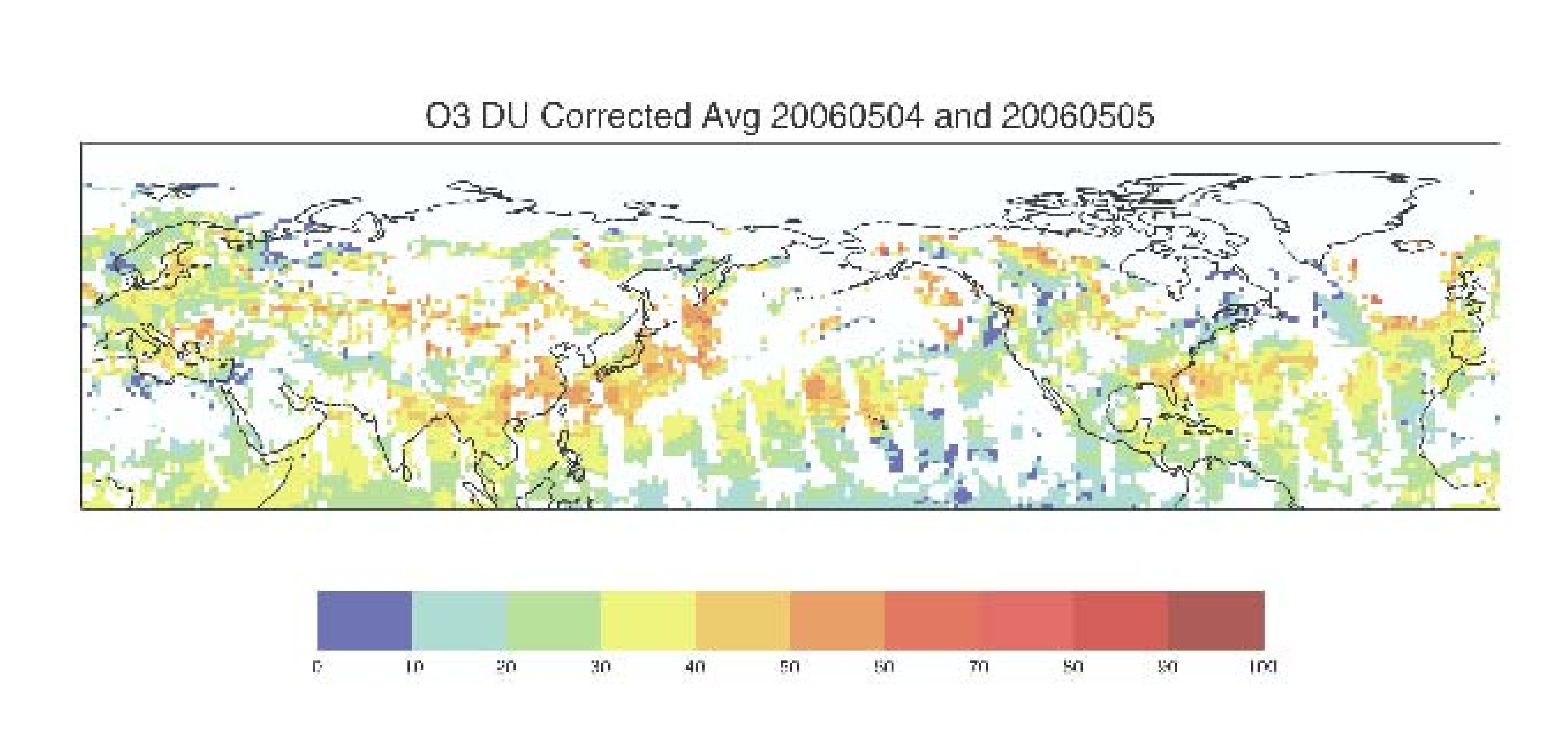
PPR gives "semi-interpretable fits" suggesting more analysis: Some other modern methods may speed interpretation.

Comparison of the "tropospheric" OMI-MLS-trajectory and the OMI-AIRS(θ) are as good as expectable

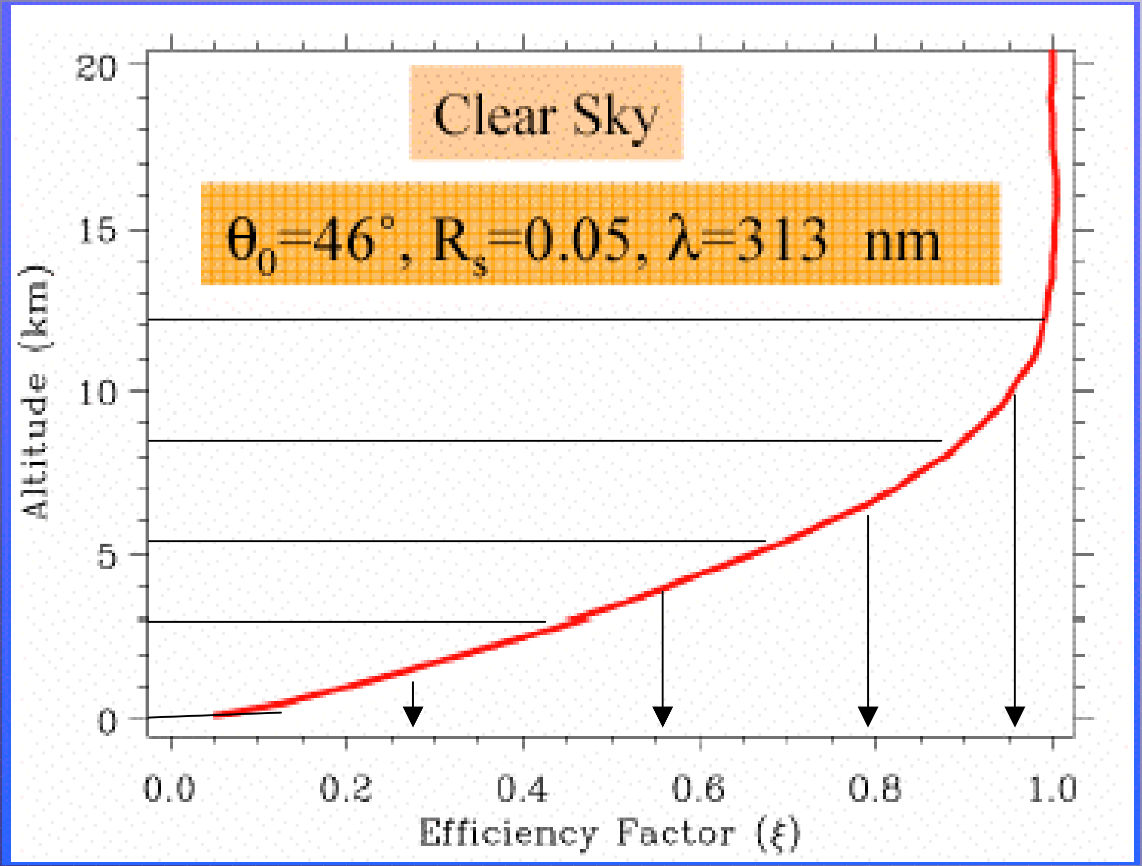


However, not all high values (UT-Strat features?) are removed. Comparisions sem better than comparisons of either with sondes!

Clouds reported by OMI and AIRS must be understood and rationalized, so that regions of the troposphere predominantly clear over 4 km can be



Theoretical clear-sky response of OMI total ozone column to lower-tropospheric ozone is low!



Theoretical sensitivity of the UV-based total ozone measurement to tropospheric ozone, decreasing greatly below 5-6 km. Reproduced from PK Bhartia, this sensitivity includes known basic scattering-absorption physics for the situation shown.

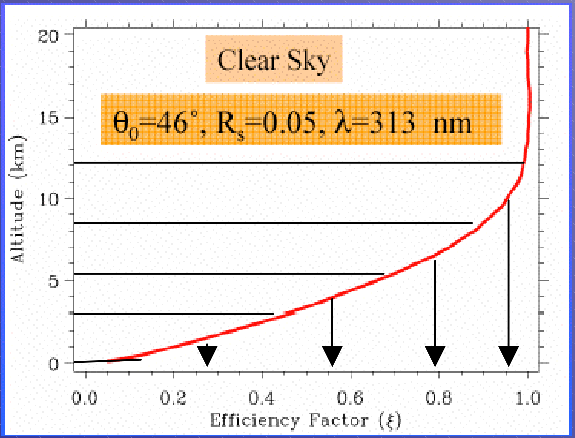
Our analysis model layers for sonde comparisons are shown: for the Sfc-700 hPa region 1 DU true ozone (e.g., estimated by sondes) should produce 0.3 DU total column ozone.

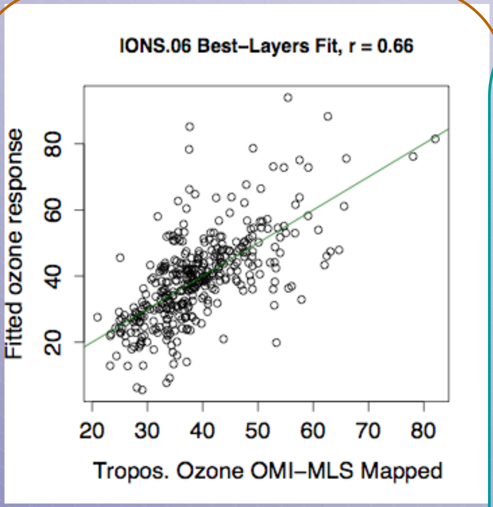
Strong covariation of 0-3 km (Sfc-700 hPa) ozone with OMI-based estimates

Comparison with layer-avereged ION2-2006 Sondes

Multiple regression analysis of OMI-based tropospheric column ozone with layer column averages gives near-1:1 contribution in lower troposphere, similar or high in UT, lower contribution in mid-tropospheric layers.

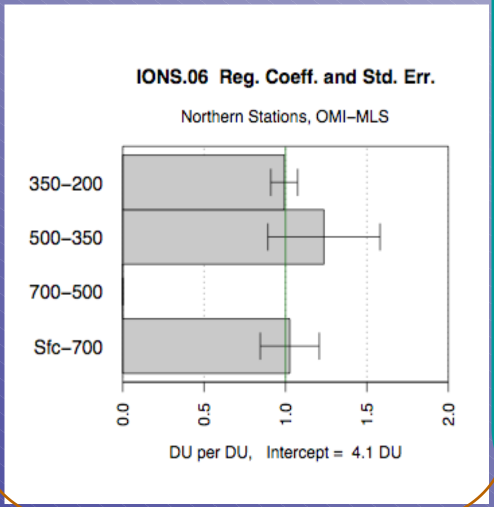
Why? Are there statistical effects connected with aerosol scattering, cloud-top scattering, or treatments of cloudiness?



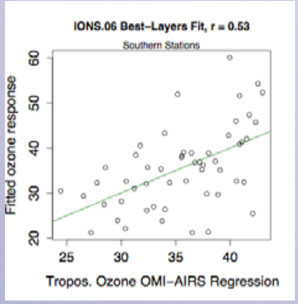


OMI–MLS (Schoeberl Estimates)

Beltsville, Boulder, Brattslake, Edmonton, Egbert, Kelowna, Narragansett, Native, Paradox, Sable, Trinidad, Valparaiso, Wallops, Walsingham, Yarmouth



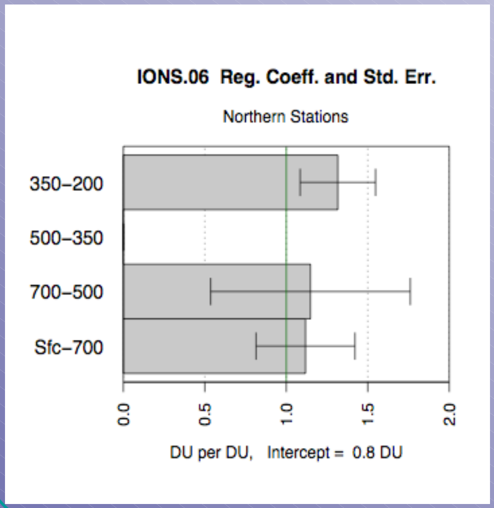
similar correlation, no very high values



OMI–AIRS(θ)

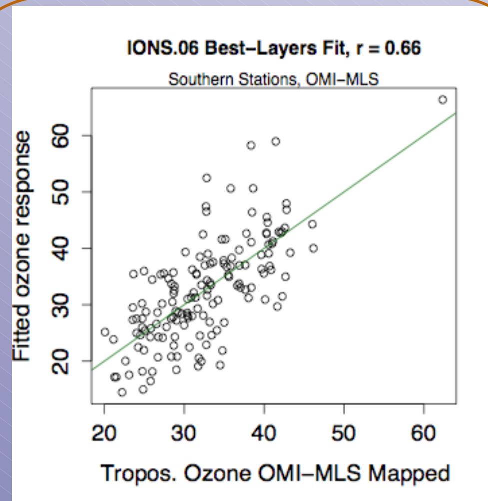
August only

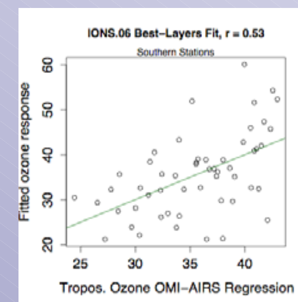
NORTHERN STATIONS



Southern IONS Ozone Soundings: Strong covariation of 0-3 km (Sfc-700 hPa) ozone with OMI-based estimate

- Best-fit regressions are shown (chosen using Mallows Cp statistic).
- Note low intercepts
- New method: August IONS (TexAQS-2006) only: more months in progress.

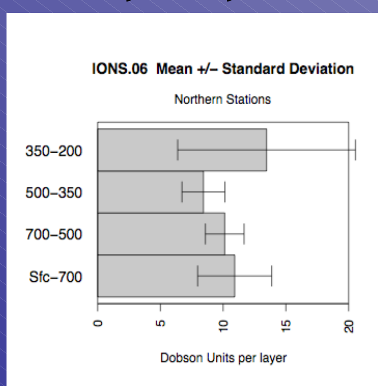


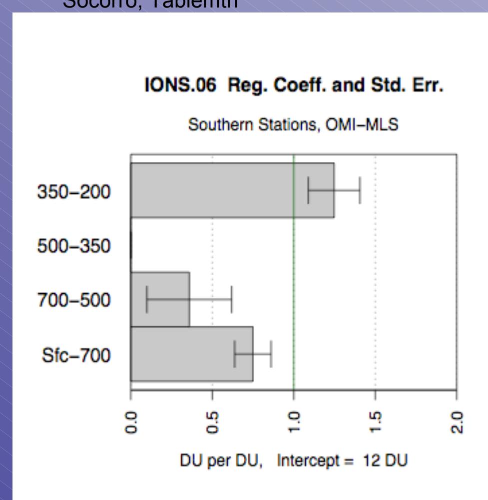


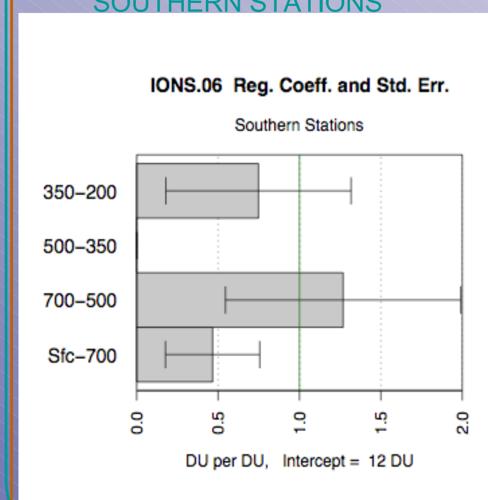
OMI–MLS (Schoeberl Estimates)
SOUTHERN STATIONS:
Holtville, Houston, Huntsville, Mexico, Socorro, Tablemtn

OMI–AIRS(θ)
August only
SOUTHERN STATIONS

- Means DU in each layer very simiilar







End

Extra slides follow

Conclusions:

“Best-regression” studies suggest that O_3 in the lower 3 km of the troposphere contributes significantly both to OMI–MLS (mapped) column estimates and a new method often with near 1:1 weighting. Air in the 350-200 hPa region contribrutes similarly, However, *mid-tropospheric ozone often contributes weakly,* insignificantly, occasionally negatively (in estimates). Other regression methods agree.

A tropospheric-ozone estimate using AIRS depictions of evolving stratospheric dynamical structure (T, Z, θ) and correlations/regressions compares well to sonde and MLS-based estimates. Some UT/LS high-ozone remains, but is reduced

- Considerable improvement is possible to this variance-based technique.

GEO Performance Data

Measurements: -- field of regard = 22° diameter and

footprint size ***at nadir*** = **2.5 km** @ 2.3 µm;

5.0 km @ 3.6 and 4.7 µm;

and **10.0 km** @ 9.6 µm

Areal coverage = 2500 km x 2500 km per 20 minutes

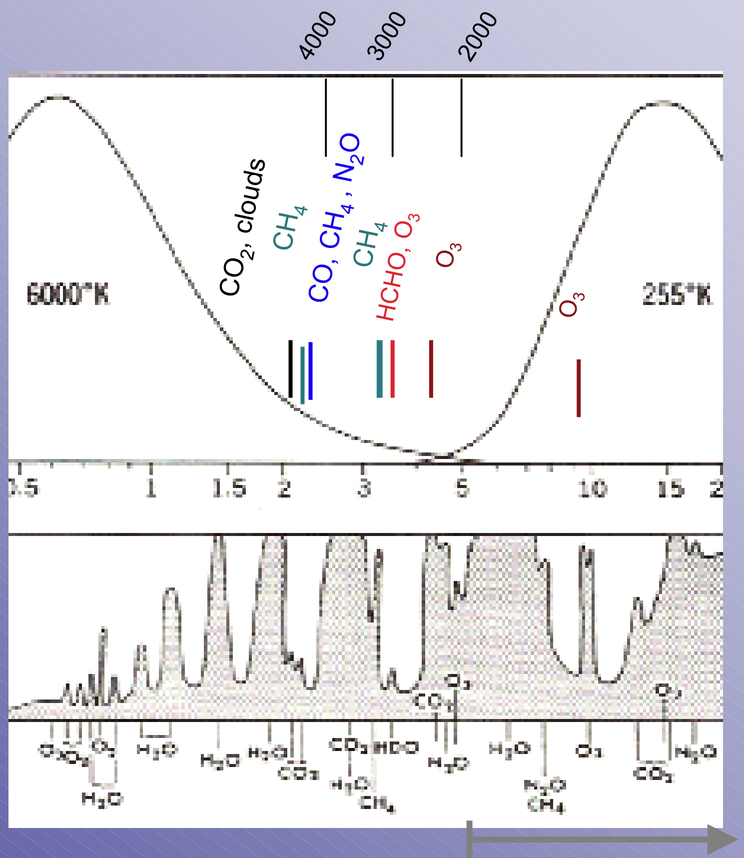
Threshold spectral range $\nu_1 \rightarrow \nu_2$, resolution ($\Delta\nu$) & NEdN characteristics

channel	$\nu_1 \rightarrow \nu_2$ (cm^{-1})	$\Delta\nu$ (cm^{-1})	NEdN ($nW/(cm^2\ sr\ cm^{-1})$)
~ 2.3 µm	4281 to 4301	0.13	1.0
~ 3.6 µm	2778 to 2791	0.13	1.0
~ 4.7 µm	2112 to 2160	0.20	1.0
~ 9.5 µm	1043 to 1075	0.10	2.0

Retrieval expectations:

- **O_3 including the BL** and 3 additional layers below 22 km with precision <5% in the latter:
  i.e., < 5% in 0 to ~3 km region: both column (3.6) and thermal (9.5) contribute
  Aggregating four 5-km footprints should
- **CO in the BL** and 2 layers above with respective precisions the order 10, 5 and 3%
- **HCHO** with column precision < 4 x 10^{15} /cm^2.
  Height information from day and night retrievals.
- Some CH_4 information should be available: this was a pollutio-oriented

Wavelengths and Species (ii)



Active cooling required
(complexity, expense, mass, lifetime?)

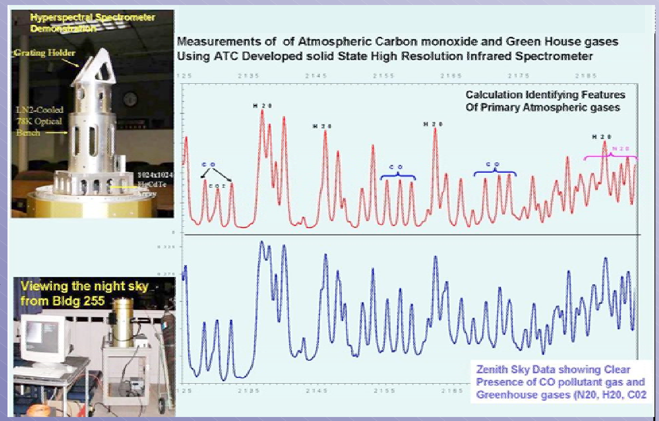
R. Chatfield, NASA Ames: TIMS: The Promise of IR Global Mapping Spectrometry

HQ Costing Study: Alternative Instrument Concepts (2/2)

GEO TIMS

Mass: est 87 kg
Power: est 160 W
Volume: 0.43 m x 0.24 m x 0.67m

TIMS = Tropospheric Infrared mapping Spectrometers



Clear sky spectral data near 4.7 um compared with a model. Data, with $\nu \sim 0.5$ cm^{-1}, were obtained with demonstration predecessor to the IIP GMS.

Features of the TIMS Measurement Concept

Employs two grating mapping spectrometers (GMS);

- Utilize separate 9 cm apertures & scan mirrors
- Each has 2 channels: 3.6 & 2.3 μm and 9.6 & 4.7 μm
- 3.6 μm channel uses solar reflective (SR) and thermal IR signal to obtain
  - Column **O_3** with sensitivity in the BL
  - **HCHO** in full and partial column
- The 9.6 μm channel provides layers of O_3 in the troposphere and above, and also
  - BL O_3 by combined retrieval with SR data
- The 2.3 and 4.7 μm channels provide **CO** in 3 layers, including the BL with precision better than 10%.
- Ancillary retrievals of BL & profile **CH_4** and **H_2O**, and **N_2O** & **CO_2** column

Performance Data

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- **CO in the BL** and 2 layers above with respective precisions the order 10, 5 and 3%
- **HCHO** with column precision < 4 x 10^{15} /cm^2.

Technology Development Needs

1. IIP demonstration (2006-2008) of the TIMS GMS will result in TRL 5+
   a. Includes GMS operating near 2.3 μm & 4.7 μm.
   - portable to facilitate field measurements
   b. CO retrieval from atmospheric measurements
   - validated by retrievals with data from Denver University FTS
2. 9.6 μm channel demonstration
   a. Large format, low noise array with cutoff ~ 10.5 μm
   b. Suitable detector array has been demonstrated on a high noise direct injection mux
   - we anticipate no problem on low noise, low light mux

➢ **Not chosen for design study owing to relatively lower TRL,~4, but should be considered for future.**