Near surface ozone observation from Aura satellite using multispectral (TIR and UV) retrievals

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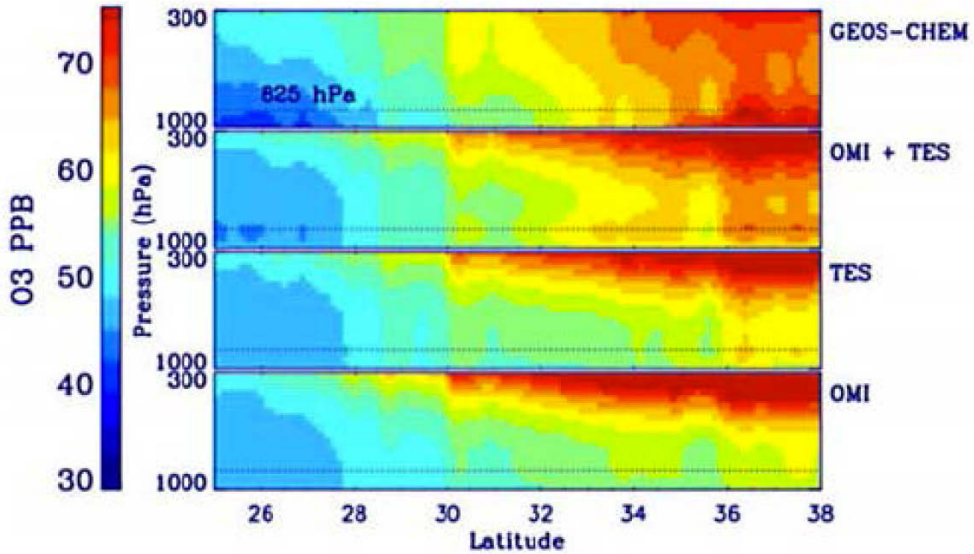
Atmospheric Ozone

- **Stratospheric ozone**
  - filters out bio-damaging UV light
- **Tropospheric ozone**
  - acts as a greenhouse gas in the upper troposphere
  - regulates the oxidation capacity of the lower atmosphere
- **Near Surface (P >= 700 hPa)**
  - affects the air quality for humans and vegetation near the Earth's surface
    - Exposure to ozone gas can harm lung function, irritate the respiratory system and increase the risk of death from respiratory causes
    - Ozone and pollution at ground level interfere with photosynthesis and stunts overall growth of plants and consequently can reduce agricultural yields

Multi-spectral Simulations and Observations

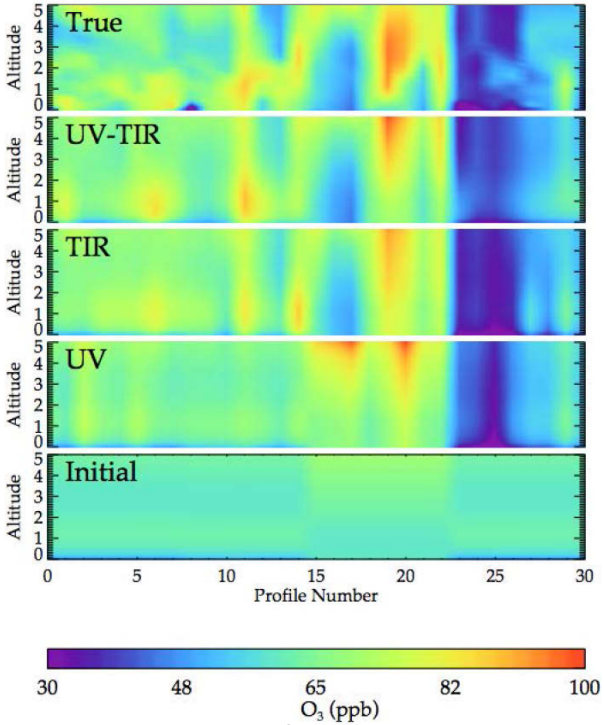
Theoretical studies

- Low earth orbit



- Figure was taken from Worden J., et al., GRL, 34, 2007.
- Landgraf J. and O.P. Hasekamp, JGR, 112, 2007.

- Geostationary orbit

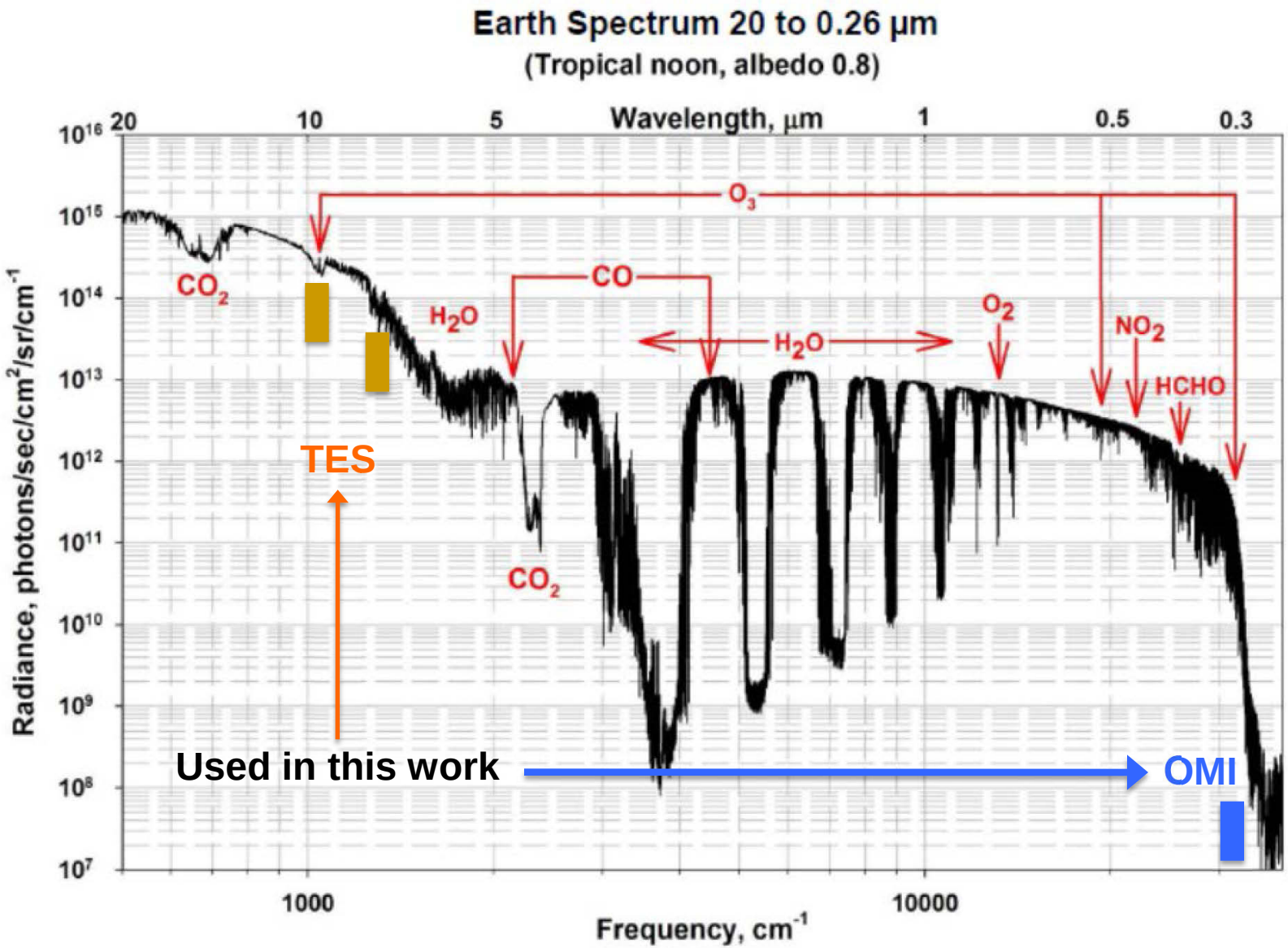


- Figure courtesy of Kulawik S.S., Natraj V., Liu X., Neu J., Luo M., S. Sander et al., 2012

Retrievals using measured radiances

- Fu D., J.R. Worden, X. Liu, S.S. Kulawik, K.W. Bowman, V. Natraj, *Characterization of Ozone Profiles Derived from Aura TES and OMI Radiances*, submitted to ACPD, August 2012.

Spectral Regions Used in Joint TES and OMI Ozone Retrievals



Retrievals: From Measured Spectra to O_3 Profiles

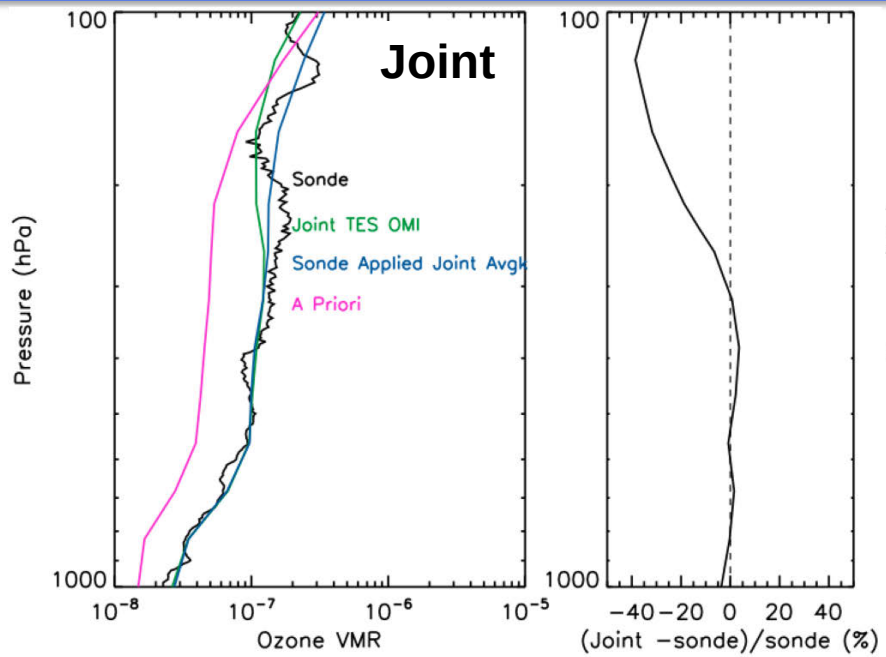
Radiative Transfer Models

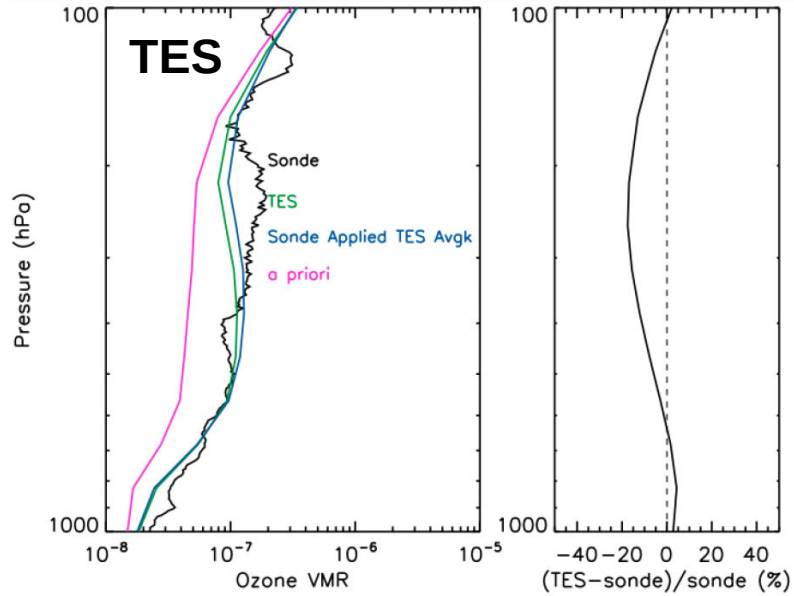
- TES
  - Simulates Earth radiances in the TIR spectral region, has been developed and validated by the TES retrieval team
- OMI
  - Uses the linearized vector radiative transfer model VLIDORT [Spurr, 2006] for the numerical computation of the Stokes vector in a multiply-scattering multilayer medium

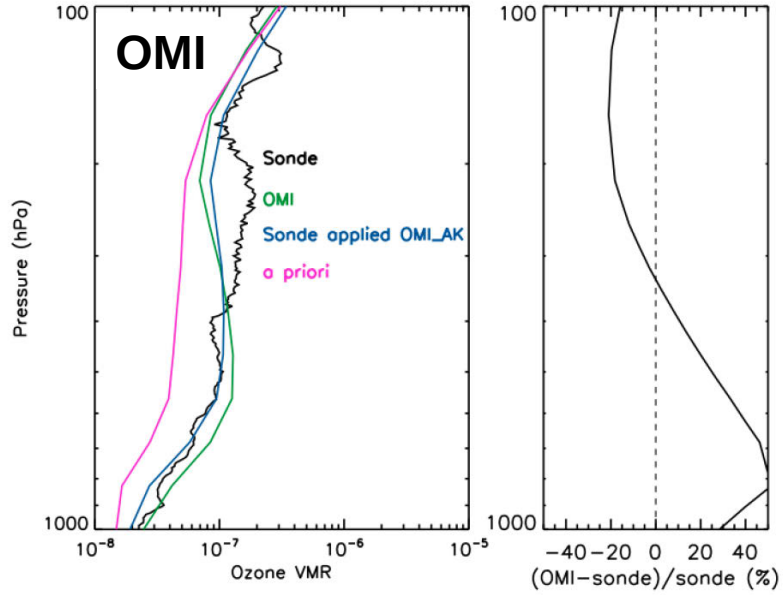
Retrieval Methodology

- Follows the optimal estimation method to combine a priori information and that of measurements [Rodgers 2000].
- Applies trust region Levenberg-Marquardt algorithm [Bowman *et al,* 2006] to the combined TES/OMI radiances

Vertical Sensitivity of O_3 Measurements over Naha, Japan on 08/01/2007







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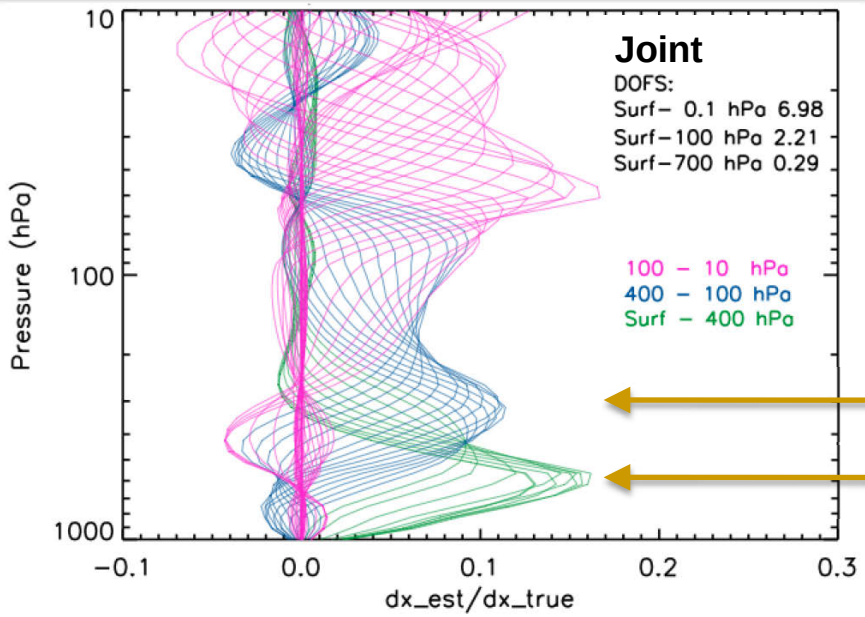
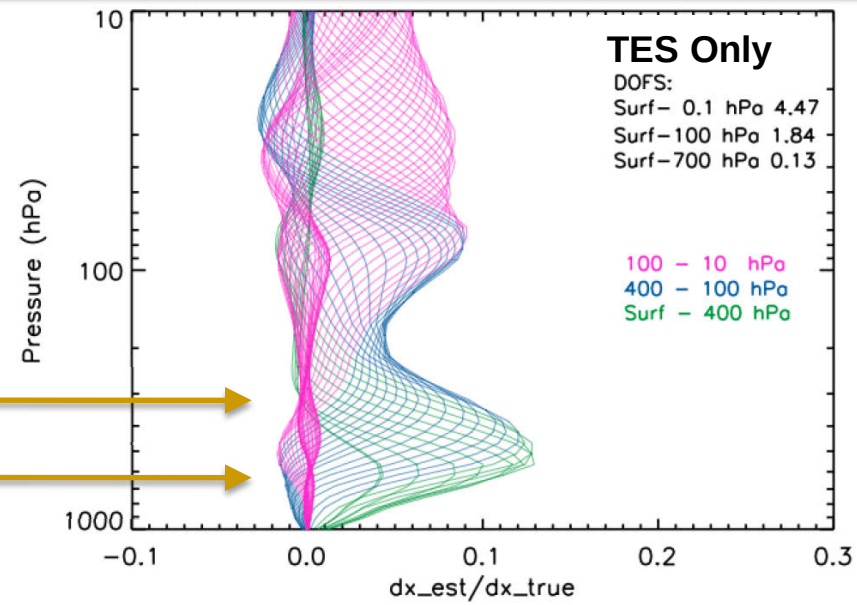
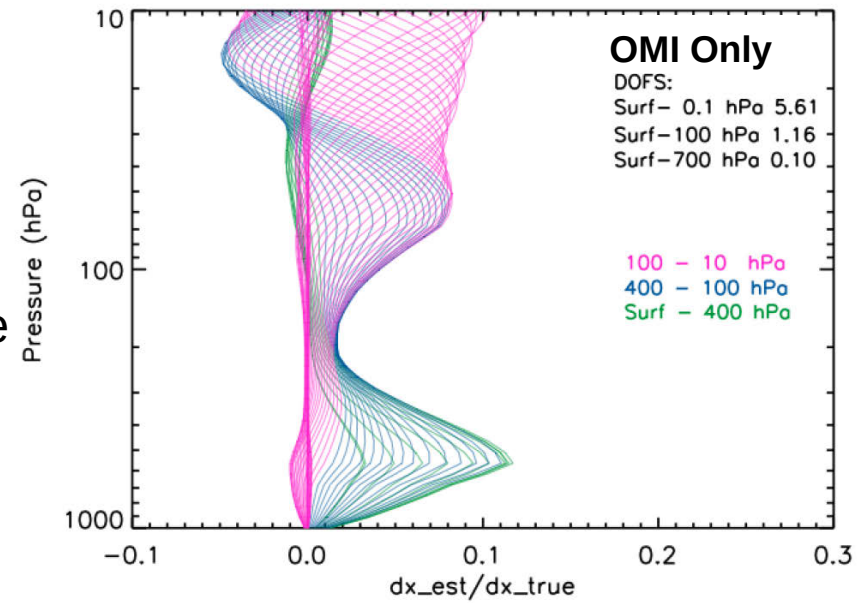


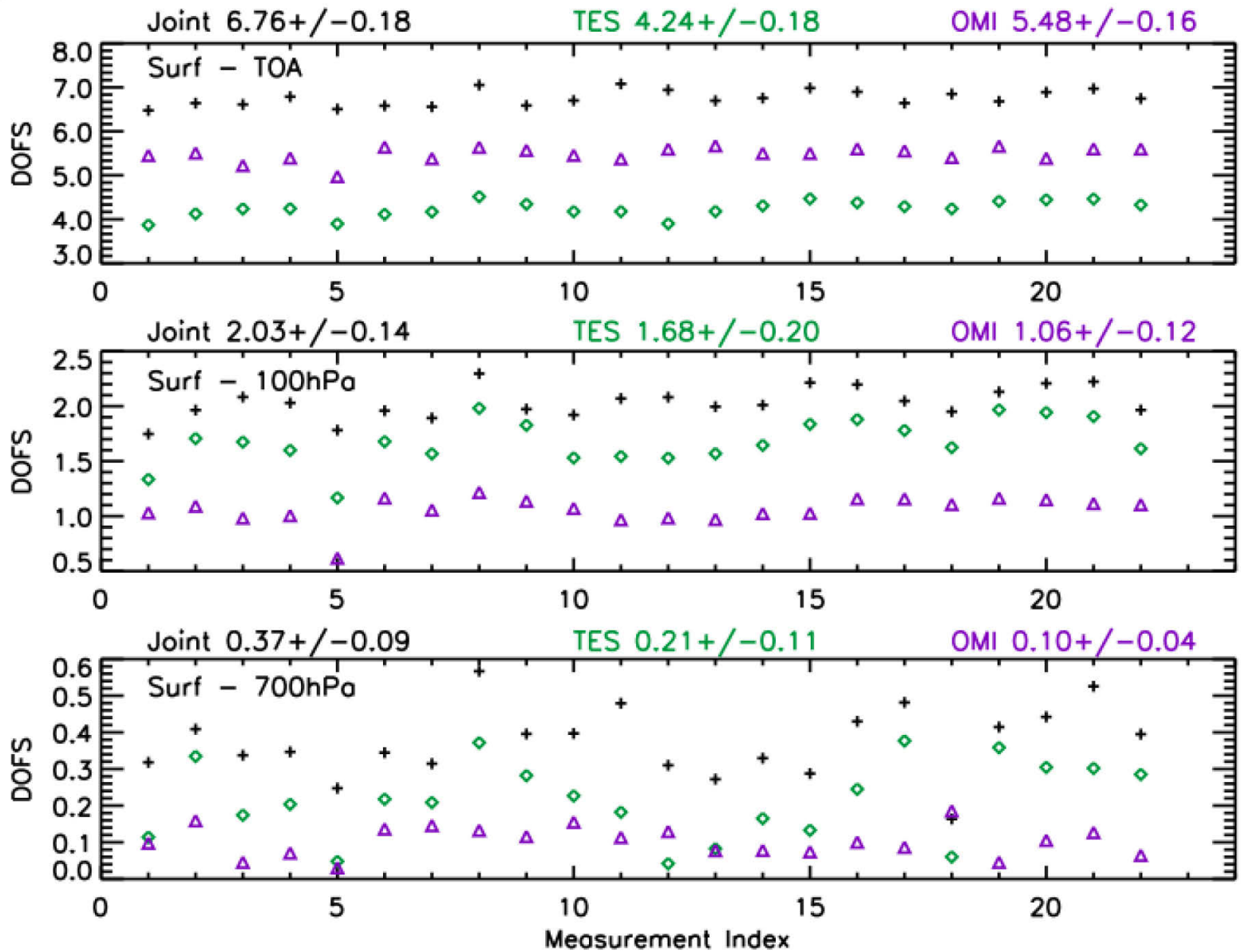




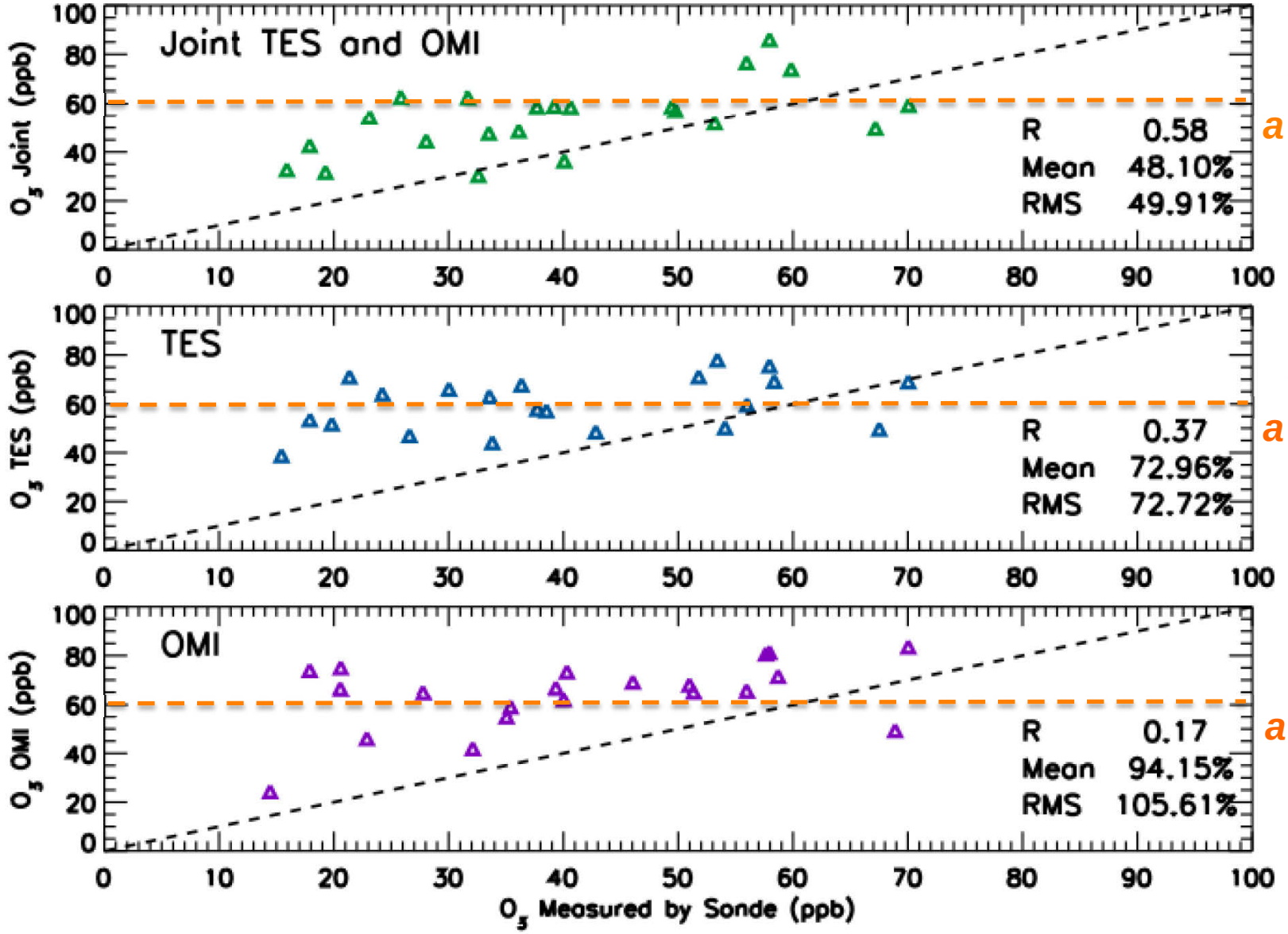
Joint TES and OMI retrievals:

- showing enhanced sensitivities in both troposphere and stratosphere
- distinguishing lower and upper troposphere
- showing sensitivities near surface

Degrees of Freedom of Signal (DOFS)



Correlations among Joint, TES only, OMI only, and Sonde Measurements (Surface – 700 hPa)

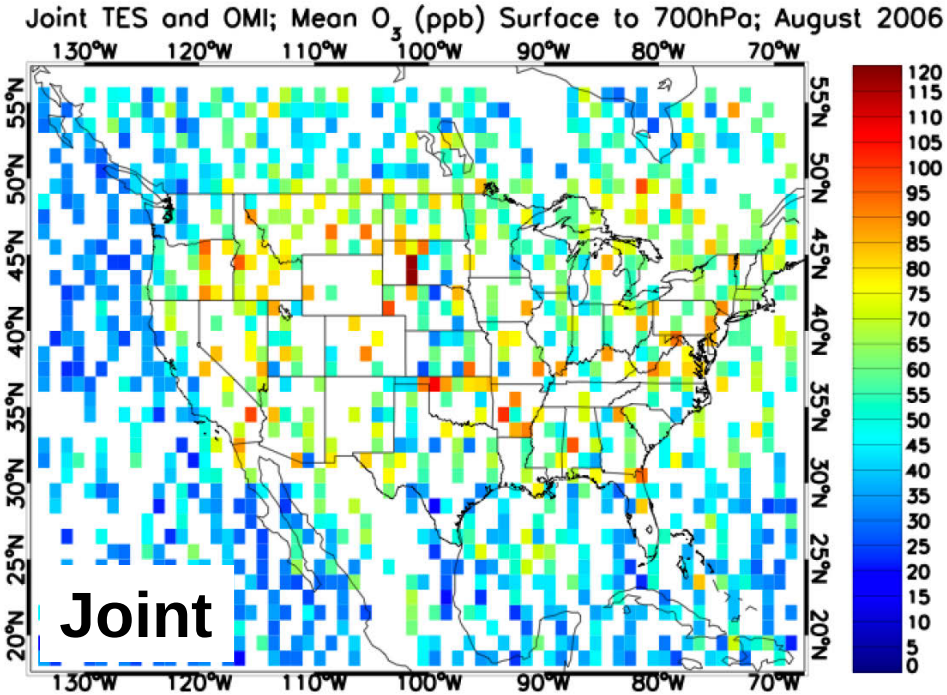


fixed *a priori*

fixed *a priori*

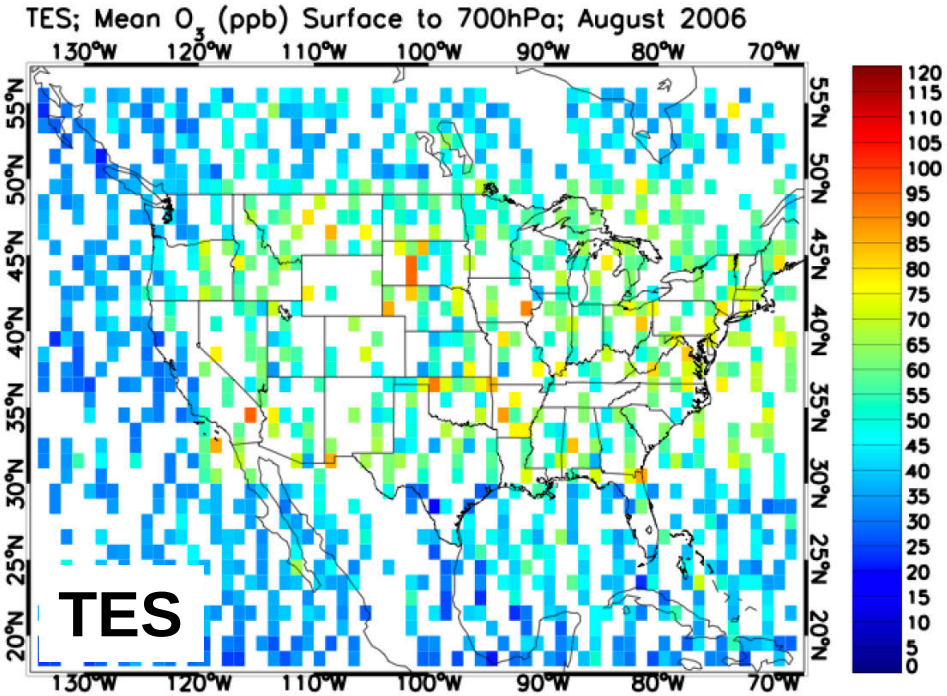
fixed *a priori*

O_3 Measurements Using Aura Satellite Instruments on August, 2006

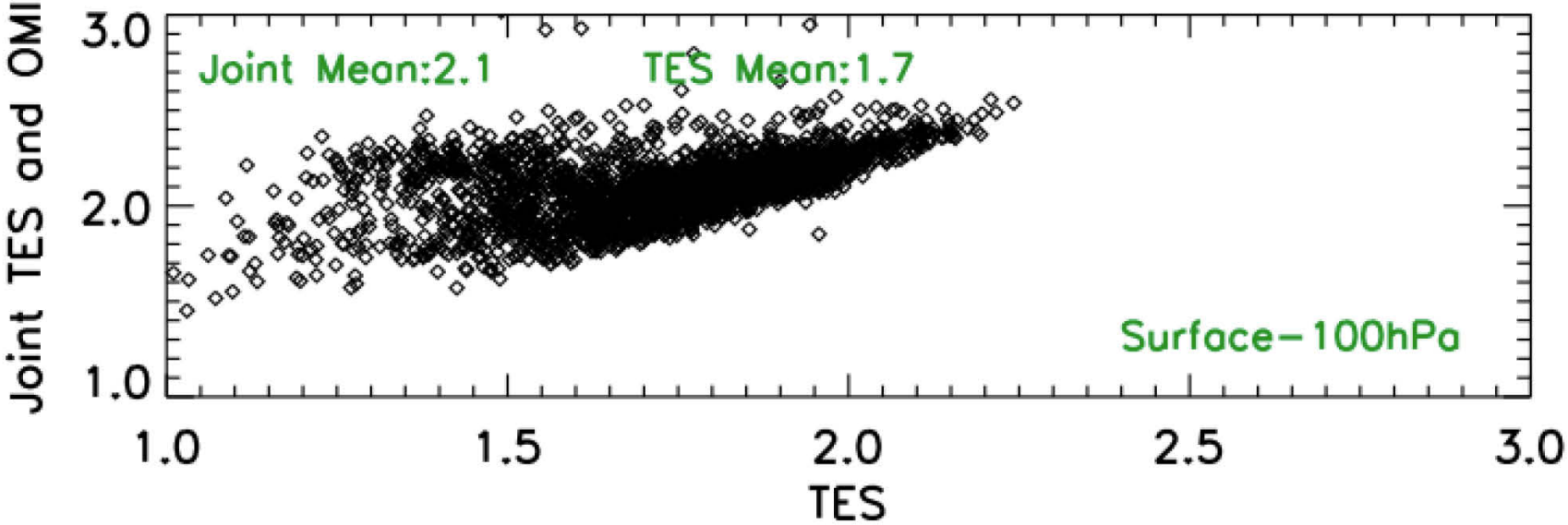


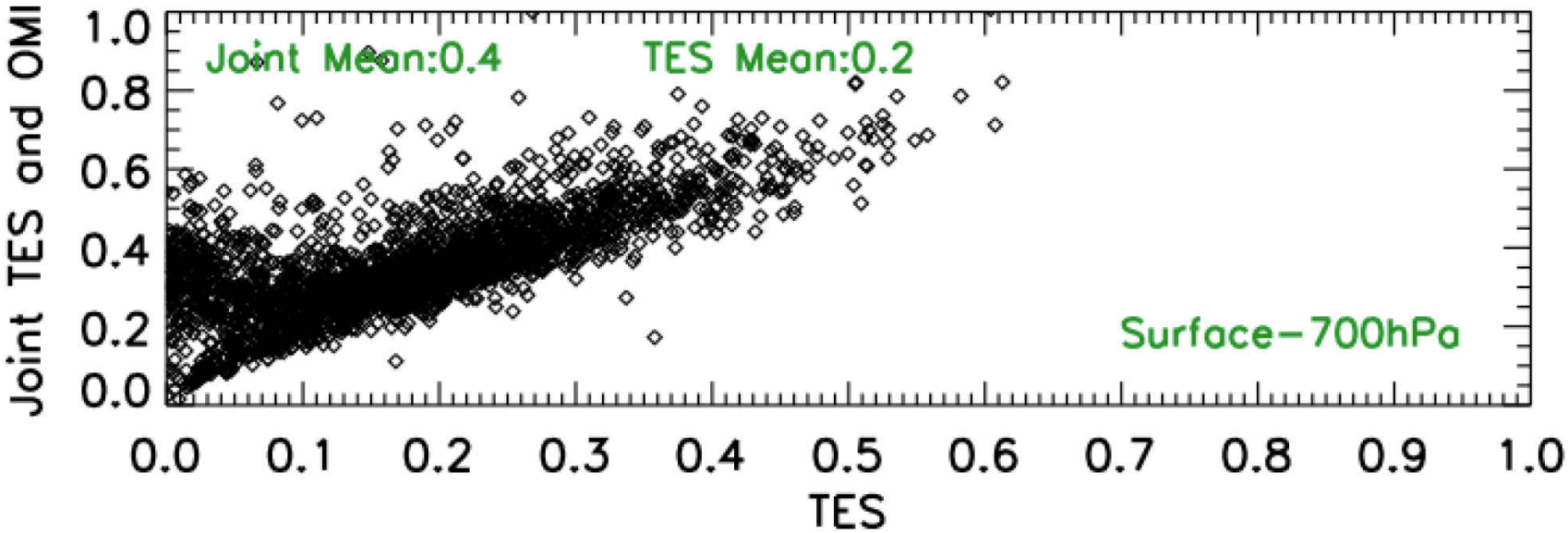
Joint TES and OMI retrievals:

- Cloud fraction <= 0.3
- Applied TES quality flags to perform quality control
- 1981 pairs daytime measurements
- Regional scale production is being evaluated



DOFS of O_3 Measurements Using Aura Satellite Instruments on August, 2006





Summary

- We have provided a demonstration of the first coincident multispectral retrievals of ozone using both UV and TIR measured radiances from space. And the manuscript on algorithm developments is submitted to ACPD.
- This technique allows for vertical ozone profiling with an average of 4.36 DOFS in the stratosphere, 2.03 DOFS in the troposphere, and with sensitivity to the planetary boundary layer (DOFS 0.37) for a wide variety of geophysical conditions.
- The typical precision for a single target near-surface estimate of ozone is approximately 26% (15.6 ppb) with a bias of approximately 9.6% (5.7 ppb).
- Comparison of the joint TES and OMI ozone near-surface ozone estimates (surface to 700 hPa) to ozone sondes show significant skill (R = 0.58(Joint), 0.37(TES), 0.17(OMI)) in quantifying near-surface ozone variations over TES or OMI estimates alone.
- To further improve the retrievals, we need to reduce correlations between ozone concentration and ancillary parameters, improve instrumental calibration, and perform more accurate radiative transfer calculations.
- Regional scale production of TES and OMI retrievals are being evaluated. We expect production of TES and OMI retrieval to begin summer 2013.

Acknowledgements

- Drs. Annmarie Eldering, Stanley Sander, Robert Herman, and Alyn Lambert at JPL
- Drs. Quitus L. Kleipool, Maarten Sneep, Braak Remco and Claas Jacques at Royal Netherlands Meteorological Institute (KNMI)
- Your Attention

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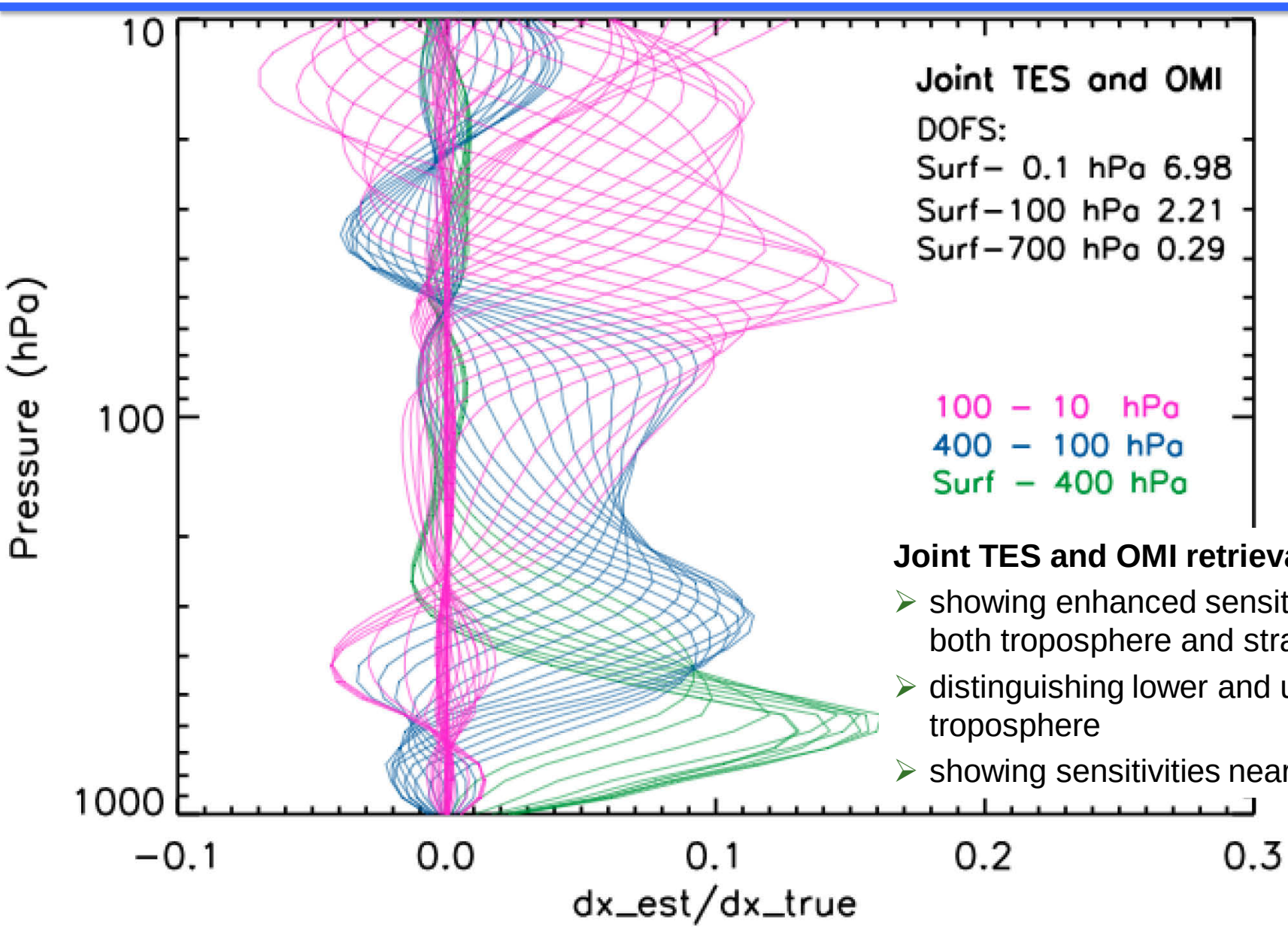

Joint TES and OMI retrievals:

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Coincident Measurements among TES, OMI, and Ozone Sonde

Profile Index	Date	TES Ground Pixel Latitude	TES Ground Pixel Longitude	Cloud Optical Depth	Delta Time[1] Minute	Distance Km	Measurement[2] TES	Ozonesonde Site
1	2005-07-18	19.86°N	154.82°W	0.10	-12.6	24.29	Global Survey	Hilo
2	2005-08-25	37.94°N	76.21°W	0.05	40.1	19.81	Global Survey	Wallops Island
3	2006-01-10	19.89°N	154.81°W	0.03	-12.1	23.31	Global Survey	Hilo
4	2006-01-12	21.32°S	55.09°E	0.03	-3.7	36.35	Global Survey	Reunion Island
5	2006-01-25	0.85°S	90.09°W	0.02	-24.9	19.92	Transect	San Cristobal
6	2006-04-06	37.88°N	76.27°W	0.03	38.9	27.45	Global Survey	Wallops Island
7	2006-05-04	21.29°S	54.85°E	0.03	-3.8	35.61	Global Survey	Reunion Island
8	2006-08-28	37.91°S	76.30°W	0.06	40.2	28.28	Global Survey	Wallops Island
9	2006-09-29	37.94°N	76.29°W	0.01	22.4	26.24	Global Survey	Wallops Island
10	2006-10-25	19.85°N	154.98°W	0.03	-18.7	16.38	Global Survey	Hilo
11	2006-12-18	37.90°N	76.09°W	0.03	39.0	14.18	Global Survey	Wallops Island
12	2007-01-03	37.91°N	76.08°W	0.03	-3.0	12.16	Global Survey	Wallops Island
13	2007-05-21	19.88°N	154.95°W	0.03	-18.3	14.13	Global Survey	Hilo
14	2007-06-06	19.89°N	154.92°W	0.02	-18.6	14.41	Global Survey	Hilo
15	2007-08-01	26.28°N	127.79°E	0.00	-33.5	37.61	Global Survey	Naha
16	2007-08-31	37.91°N	76.28°W	0.06	34.0	26.44	Global Survey	Wallops Island
17	2007-10-02	37.94°N	76.30°W	0.04	27.2	26.94	Global Survey	Wallops Island
18	2008-07-09	26.34°N	128.19°E	0.02	-34.4	42.49	Global Survey	Naha
19	2008-07-23	38.35°N	76.00°W	0.02	42.5	38.77	Step & Stare	Wallops Island
20	2008-08-08	37.95°N	75.92°W	0.03	39.7	8.99	Step & Stare	Wallops Island
21	2008-08-16	35.13°N	87.47°W	0.01	15.9	45.18	Step & Stare	Huntsville
22	2008-10-29	25.63°N	128.24°E	0.02	-32.7	47.92	Global Survey	Naha

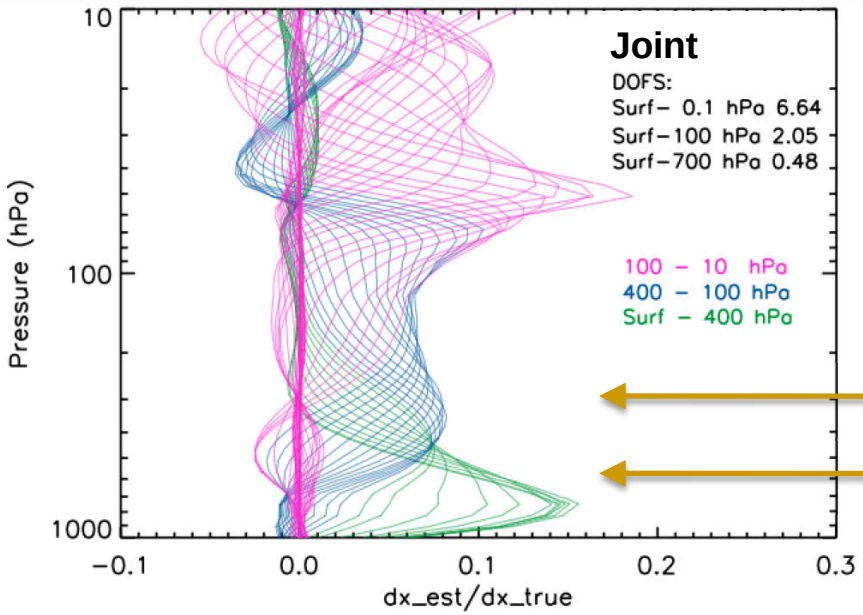
1. TES measurement time – Ozonesonde measurement time
2. All of OMI measurements used here were taken from global measurement mode.

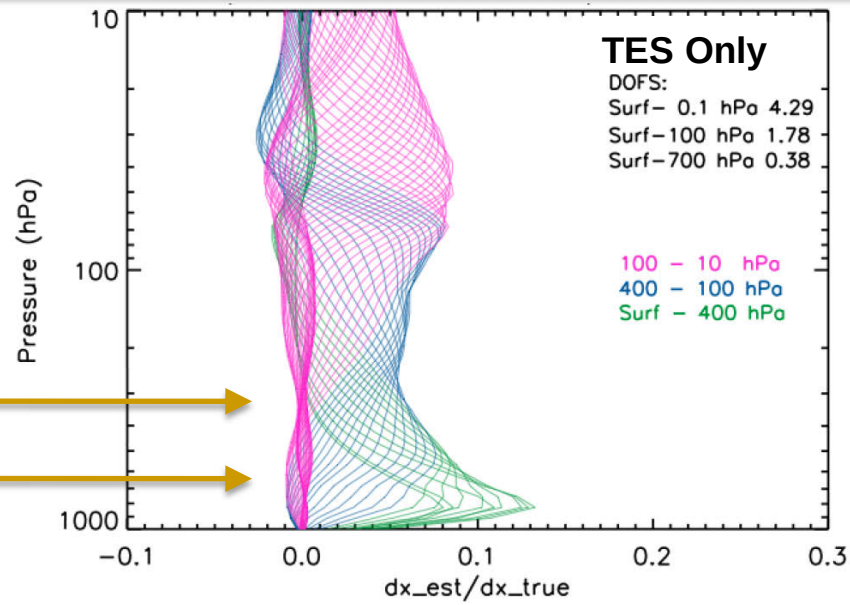
Fitting Variables, *A Priori* Values and *A Priori* Errors

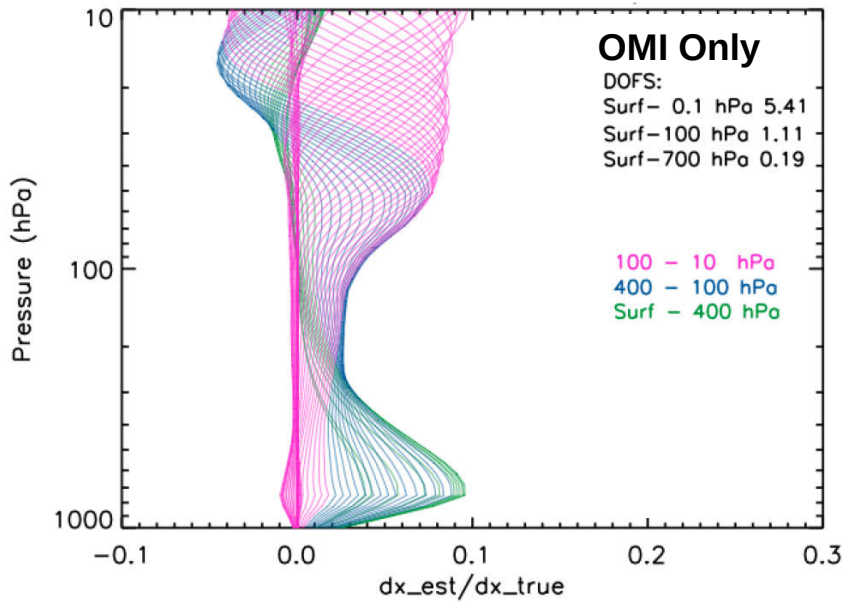
Case Selection[1]	Fitting Parameters	Number of Parameters	*A Priori*	*A Priori* Uncertainty
TES+OMI, TES, OMI	O_3 at each level	25	MOZART-3	MOZART-3
TES+OMI, TES	H_2O at each level	16	GEOS4	NCEP ~30%
TES+OMI, TES	Surface temperature[2]	1	GEOS4	0.5K
TES+OMI, TES	Surface emissivity[2]	32	ASTER and land use map	~0.006
TES+OMI, TES	Cloud extinction	10	Initial BT difference	300%
TES+OMI, TES	Cloud top pressure	1	500 mbar	100%
TES+OMI, OMI	UV-1 Surface Albedo	1	OMI climatology	0.05
TES+OMI, OMI	UV-2 Surface Albedo (zero order term)	1	OMI climatology	0.05
TES+OMI, OMI	First-order wavelength-dependent term for UV-2	1	0.0	0.01
TES+OMI, OMI	Ring scaling parameters	2	1.9	1.00
TES+OMI, OMI	Radiance/irradiance wavelength shifts	2	0.0	0.02 nm
TES+OMI, OMI	Radiance/O_3 cross section wavelength shifts (zero order)	2	0.0	0.02 nm
TES+OMI, OMI	Radiance/O_3 cross section wavelength shifts (first order)	2	0.0	0.004
TES+OMI, OMI	Cloud Fraction	1	Derived from 347 nm	0.05

1. The parameters are included in the retrievals for different cases (TES only, OMI only, and TES and OMI)
2. Retrievals over land, spectral surface emissivity and surface temperature are included.

Vertical Sensitivity of O_3 Measurements over Wallops Island, USA on 10/02/2007







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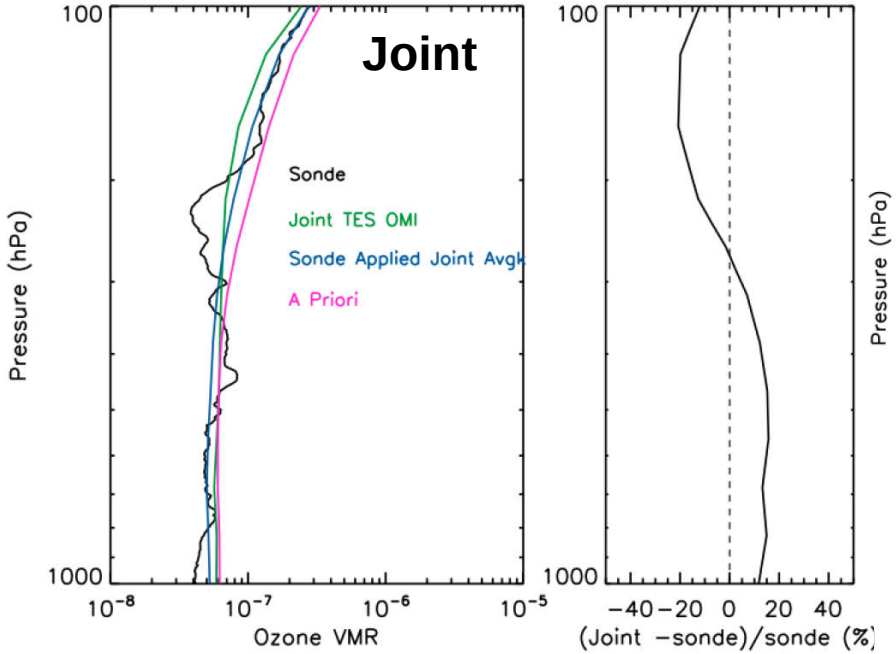

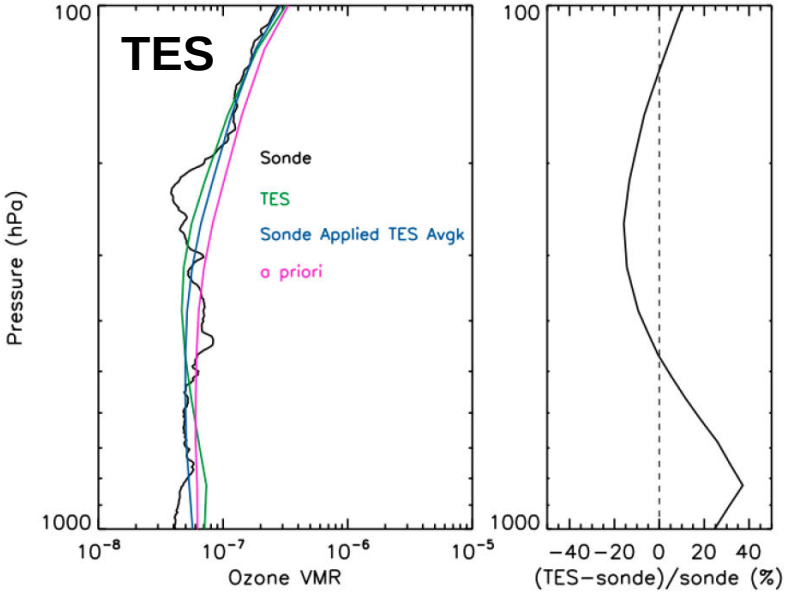

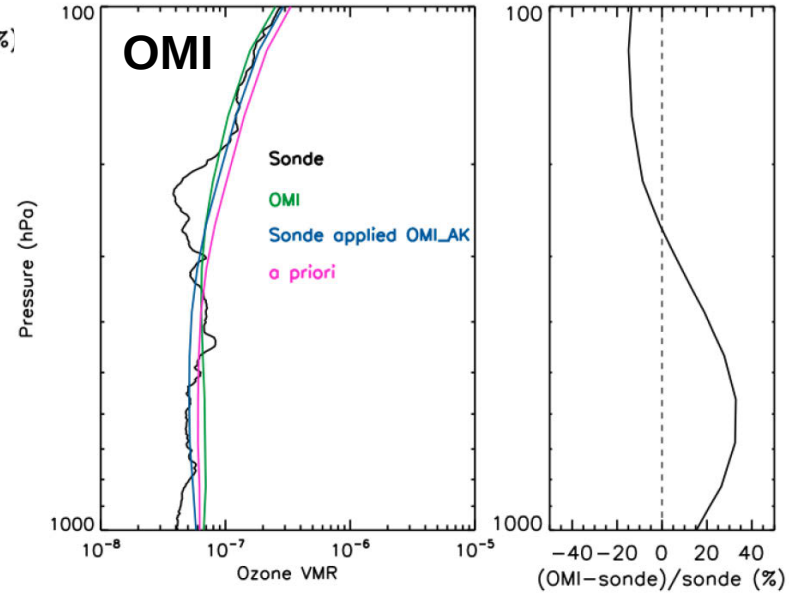

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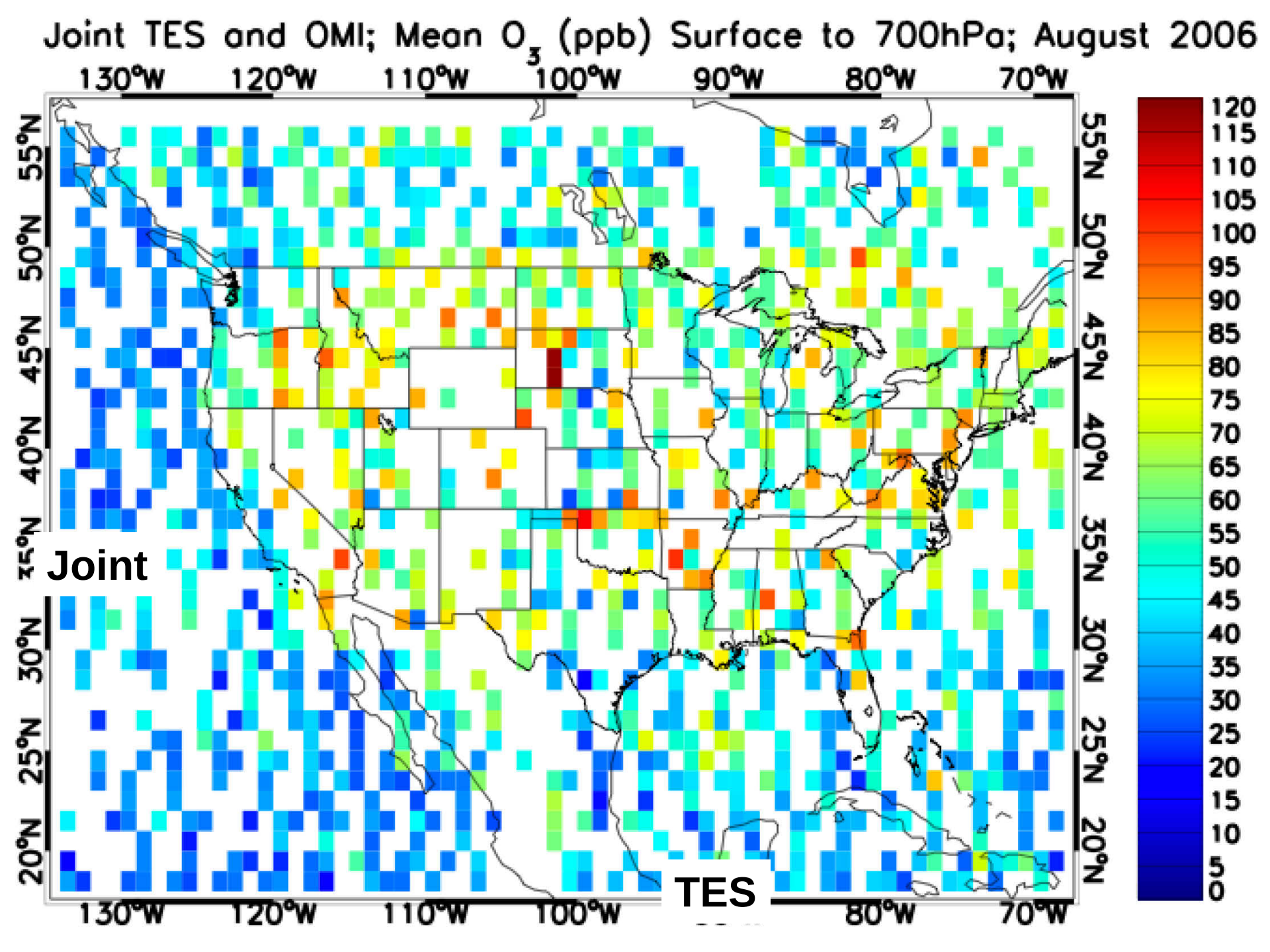
Joint TES and OMI; Mean O_3 (ppb) Surface to 700hPa; August 2006
130°W
120°W
110°W
100°W
90°W
80°W
70°W
55°N
50°N
45°N
40°N
35°N
30°N
25°N
20°N
120
115
110
105
100
95
90
85
80
75
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65
60
55
50
45
40
35
30
25
20
15
10
5
0
Joint
TES