Combining Simultaneously Measured UV and IR Radiances from OMI and TES to Improve Tropospheric Ozone Profile Retrievals

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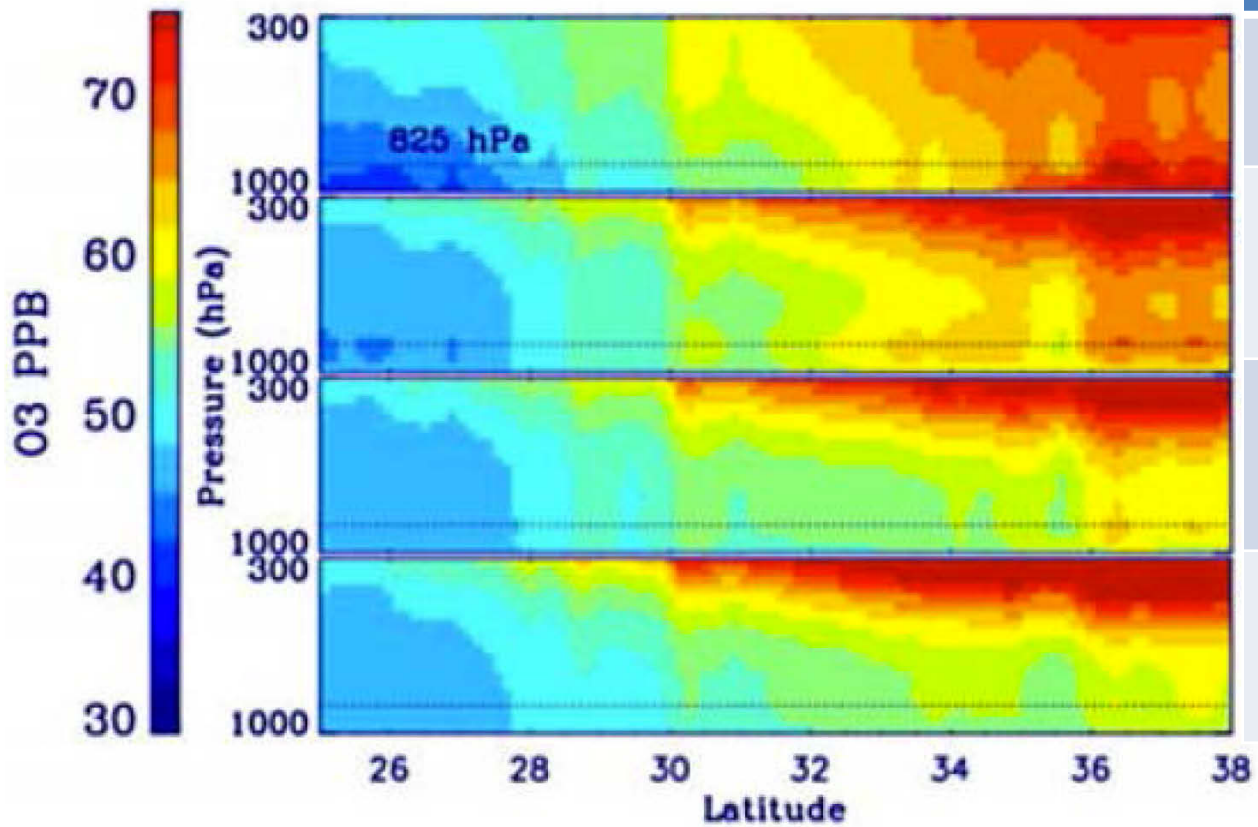
Introduction

X_ret = Xa + A (X_true - Xa)



Data Source	Vertical Resolution
GEOS – CHEM True profile	
TIR + UV	3.6 – 4.8 km
TIR	6 km
UV	12 km

Worden J., X. Liu, K. Bowman, K. Chance, R. Beer, A. Eldering, M. Gunson, and H. Worden, *Improved tropospheric ozone profile retrievals using OMI and TES radiances*, GRL, 34, 2007.

Landgraf, J., and O. P. Hasekamp, *Retrieval of tropospheric ozone: The synergistic use of thermal infrared emission and ultraviolet reflectivity measurements from space*, JGR, 112, 2007.

Tropospheric Emission Spectrometry and Ozone Monitoring Instrument

TES is a Fourier transform spectrometer

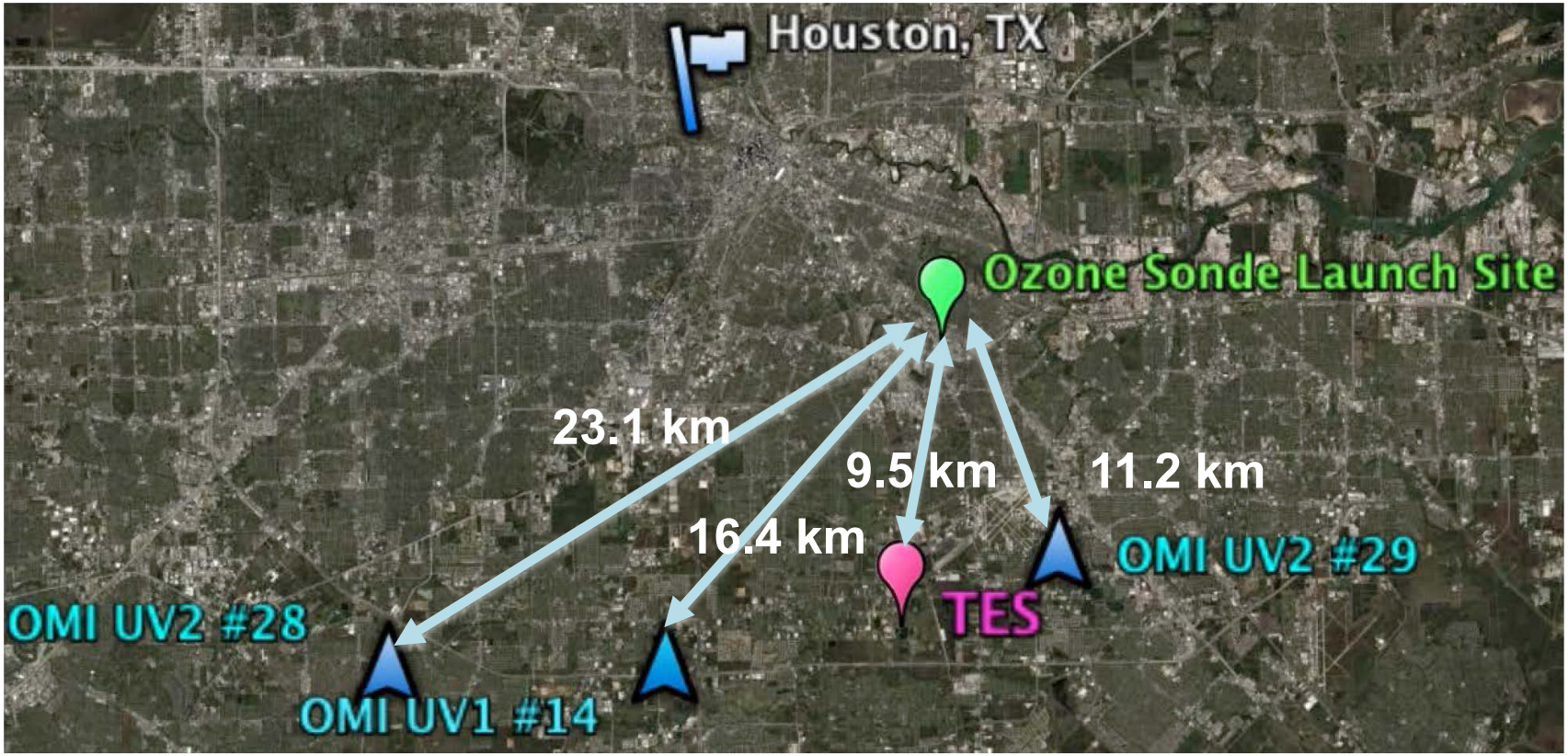
- Spectral Range: 650 – 3050 cm^{-1} (or 15.38 to 3.28 micron)
- Spectral Resolution: 0.06 cm^{-1}
- Ground Pixel Size: 8.3 by 5.3 km^2 (along track by cross track)

OMI is an imaging grating spectrometer

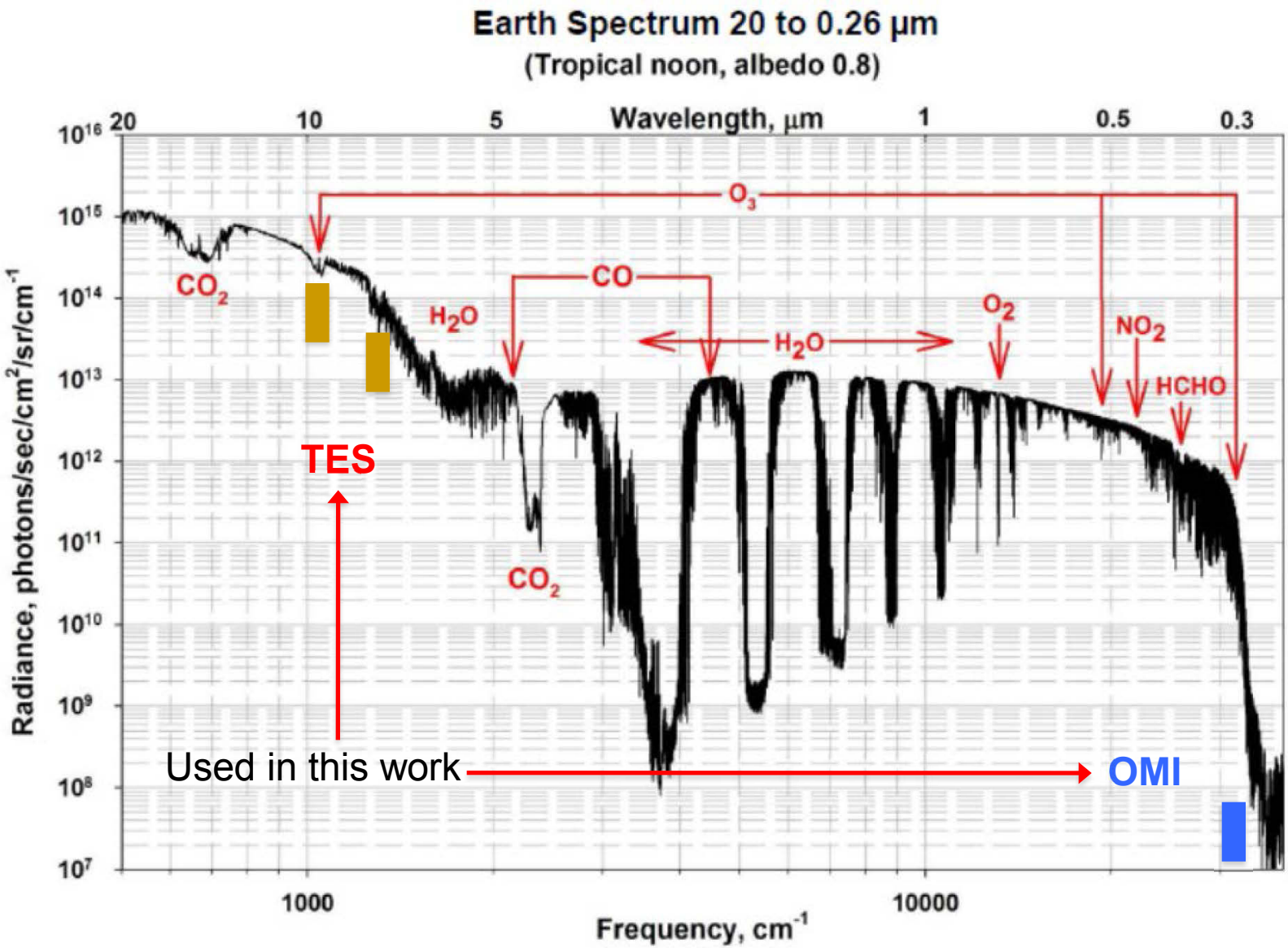
- Spectral Range 270 – 500 nm (37,037 – 20,000 cm^{-1})
  - UV1 module (264 – 311 nm): 30 pixels
  - UV2 module (307 – 383 nm): 60 pixels
  - Visible module (349 – 504 nm): 60 pixels
- Spectral Resolution: 0.42–0.63 nm
- Ground Pixel Size:
  - UV1: 13 by 48 km^2 (along track by cross track)
  - UV2: 13 by 24 km^2 (along track by cross track)
  - Visible: 13 by 24 km^2 (along track by cross track)

OMI and TES Measurements Over Houston, Texas On May 9th, 2009

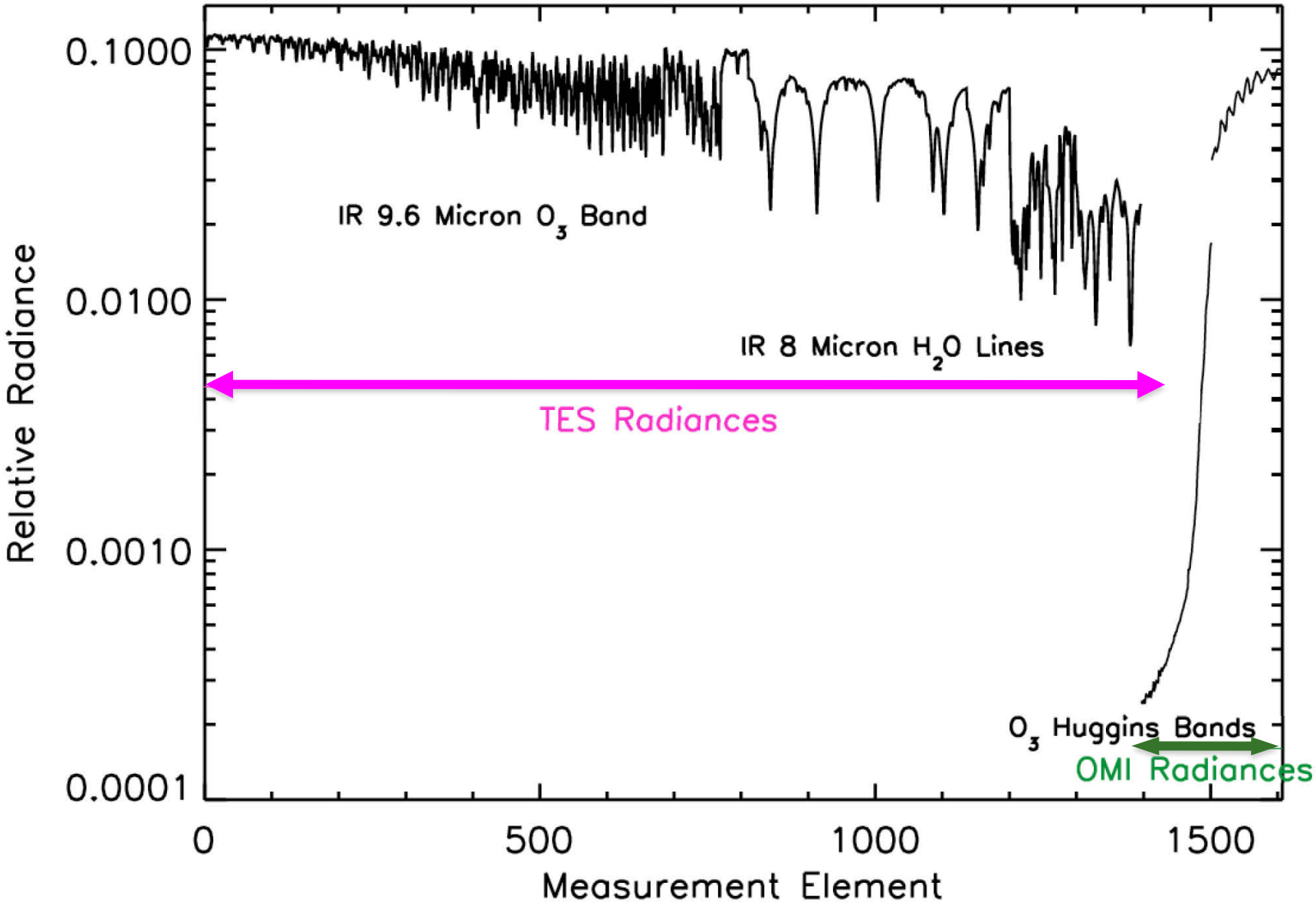
- Criteria of Coincident Measurements
  - Cloud optical depth: <= 0.005
  - Ozone sonde measurements are available for comparisons
  - Time difference of OMI and TES measurements to ozone sonde: 0.5 hours
  - Distances of OMI and TES measurements to ozone sonde site: 25 km



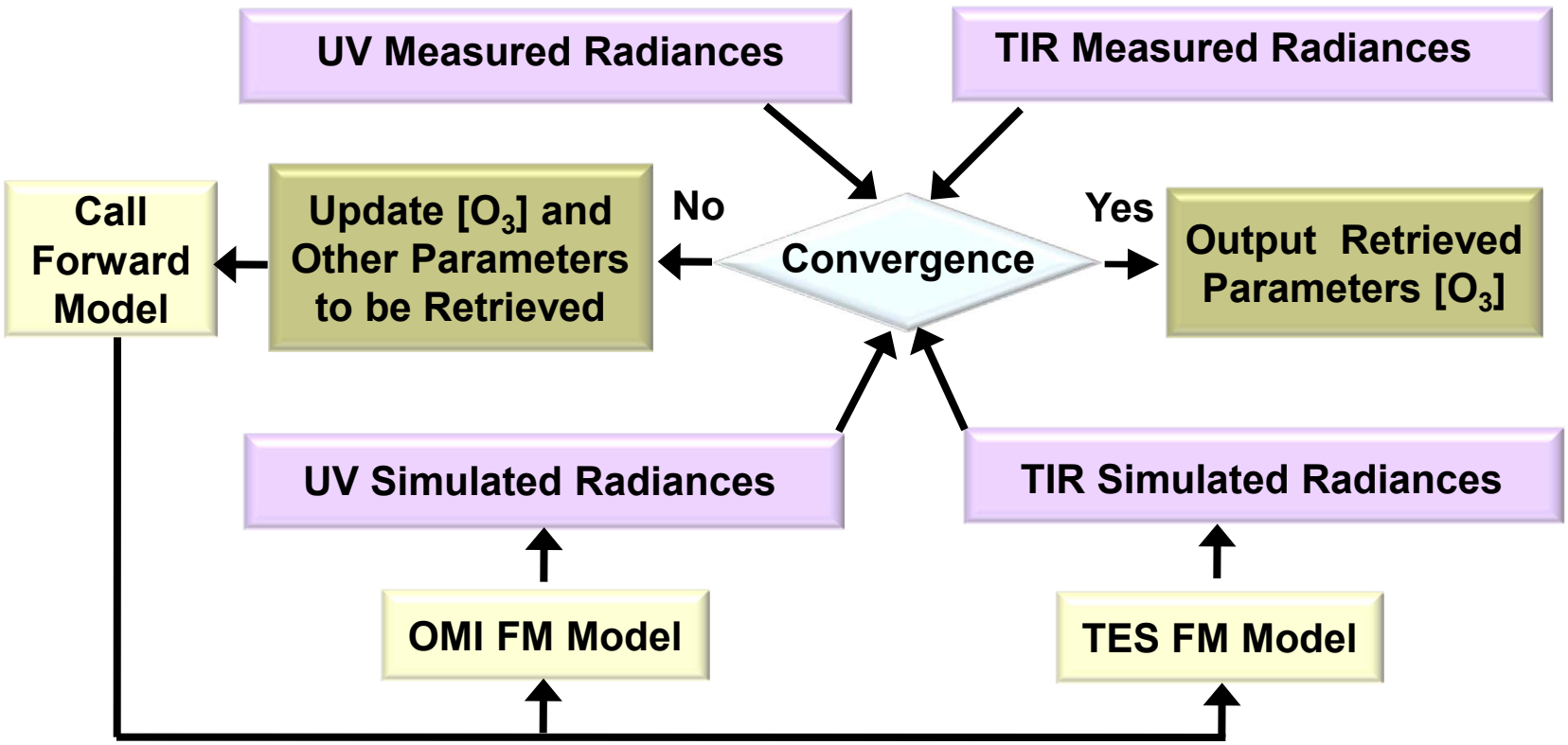
Spectral Regions Used in Joint Retrievals



TES and OMI Normalized Radiances Measured Over Houston, on May 9th, 2009



Retrievals: From Measured Spectra to O_3 Profiles



Retrievals: From Measured Spectra to O_3 Profiles

Radiative Transfer Models

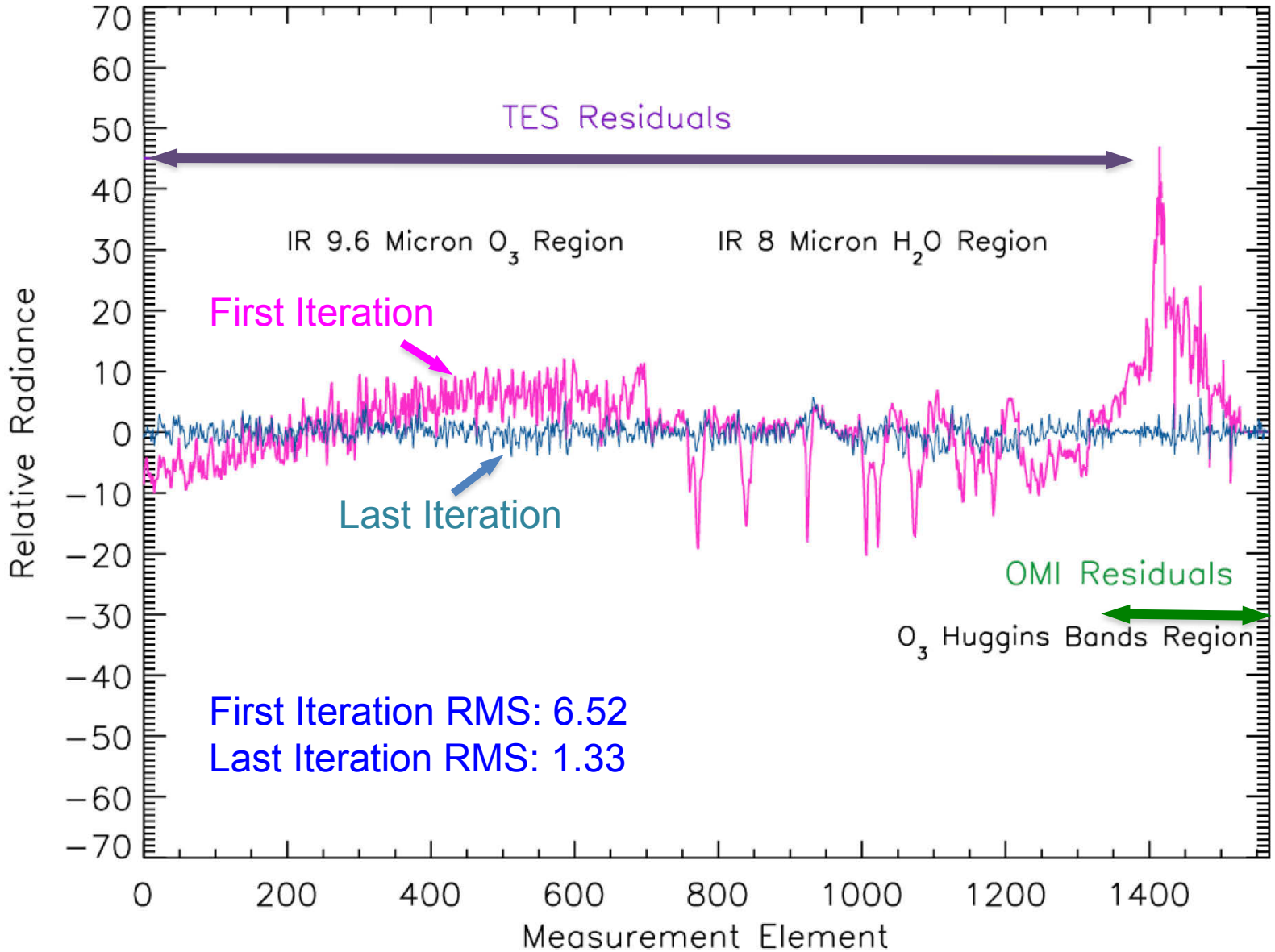
- OMI
  - Uses the linearized vector radiative transfer model VLIDORT [Spurr, 2006] for the numerical computation of the Stokes vector in a multiply-scattering multilayer medium
- TES
  - Simulates Earth radiances in the TIR spectral region, has been developed and validated by the TES retrieval team

Retrieval Methodology

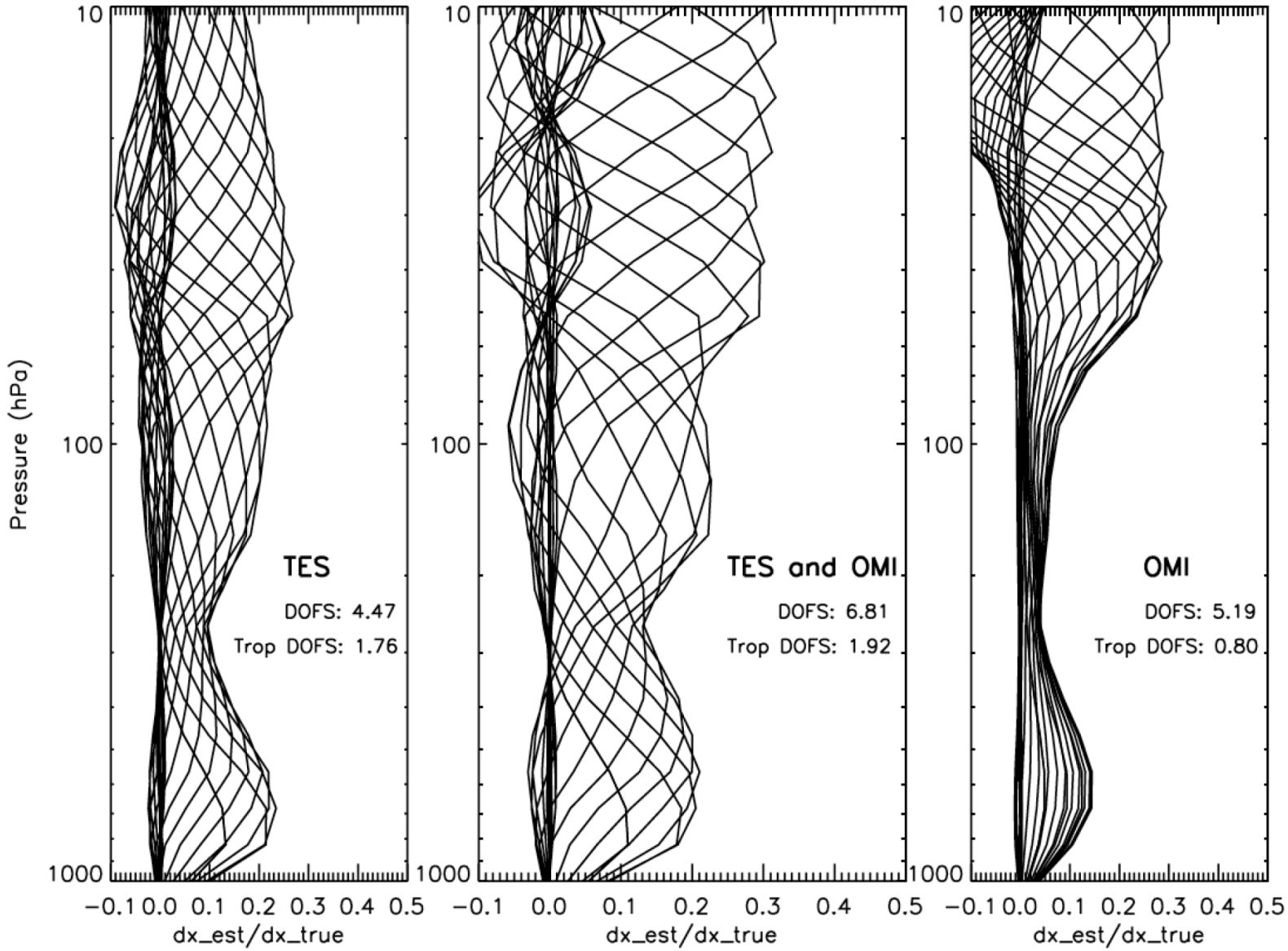
- Follows the optimal estimation method to combine a priori information and that of measurements [Rodgers 2000].
- Applies Levenberg-Marquardt algorithm [Rodgers 2000; Bowman *et al,* 2006] to the combined TES/OMI radiances

Instrument	Fitting Variables	Number Variables	A Priori	A Priori Error
TES + OMI	O_3 at each layer	25	MOZART-3	MOZART-3
TES	H_2O at each layer	16	GEOS4	NCEP ~30%
	Surface temperature	1	GEOS4	0.5K
	Surface emissivity	32	ASTER and landuse map	~0.006
	Cloud extinction	10	Initial BT difference	300%
	Cloud top pressure	1	500 mbar	100%
OMI	UV1 Surface Albedo	1	climatology	0.05
	UV2 Surface Albedo	2	climatology	0.05
	first-order wavelength-dependent term for UV2 Surface Albedo	1	0.0	0.01
	Ring scaling parameters	2	1.9	1.0
	Radiance/irradiance wavelength shifts	2	0.0	0.02 nm
	Radiance/O_3 cross section wavelength shifts (zero order)	2	0.0	0.02 nm
	Radiance/O_3 cross section wavelength shifts (first order)	2	1.0	0.004

Radiance Residuals
(Measured – Modeled) /Noise Estimate



Vertical Sensitivity and Resolution of O_3 Observations



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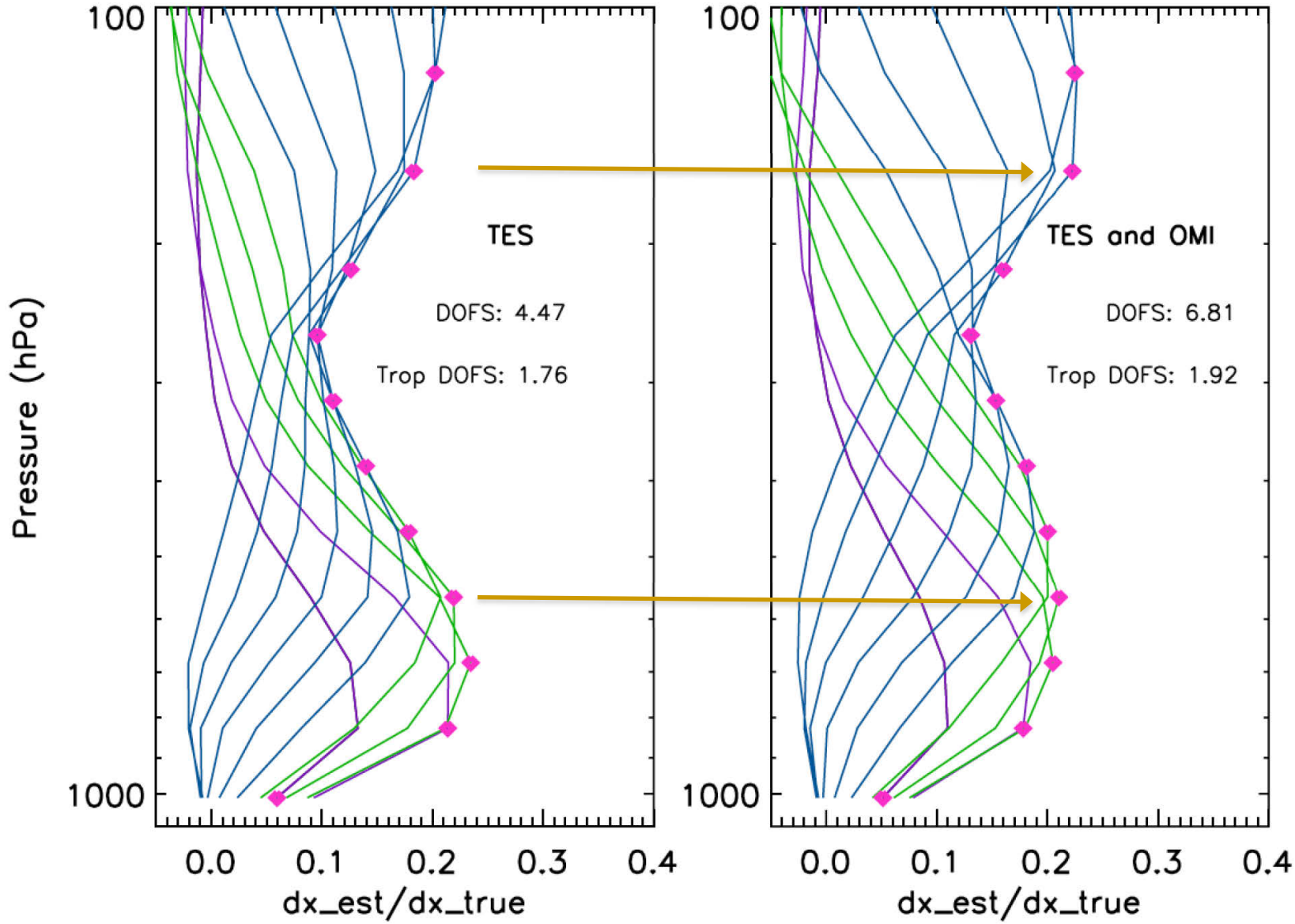
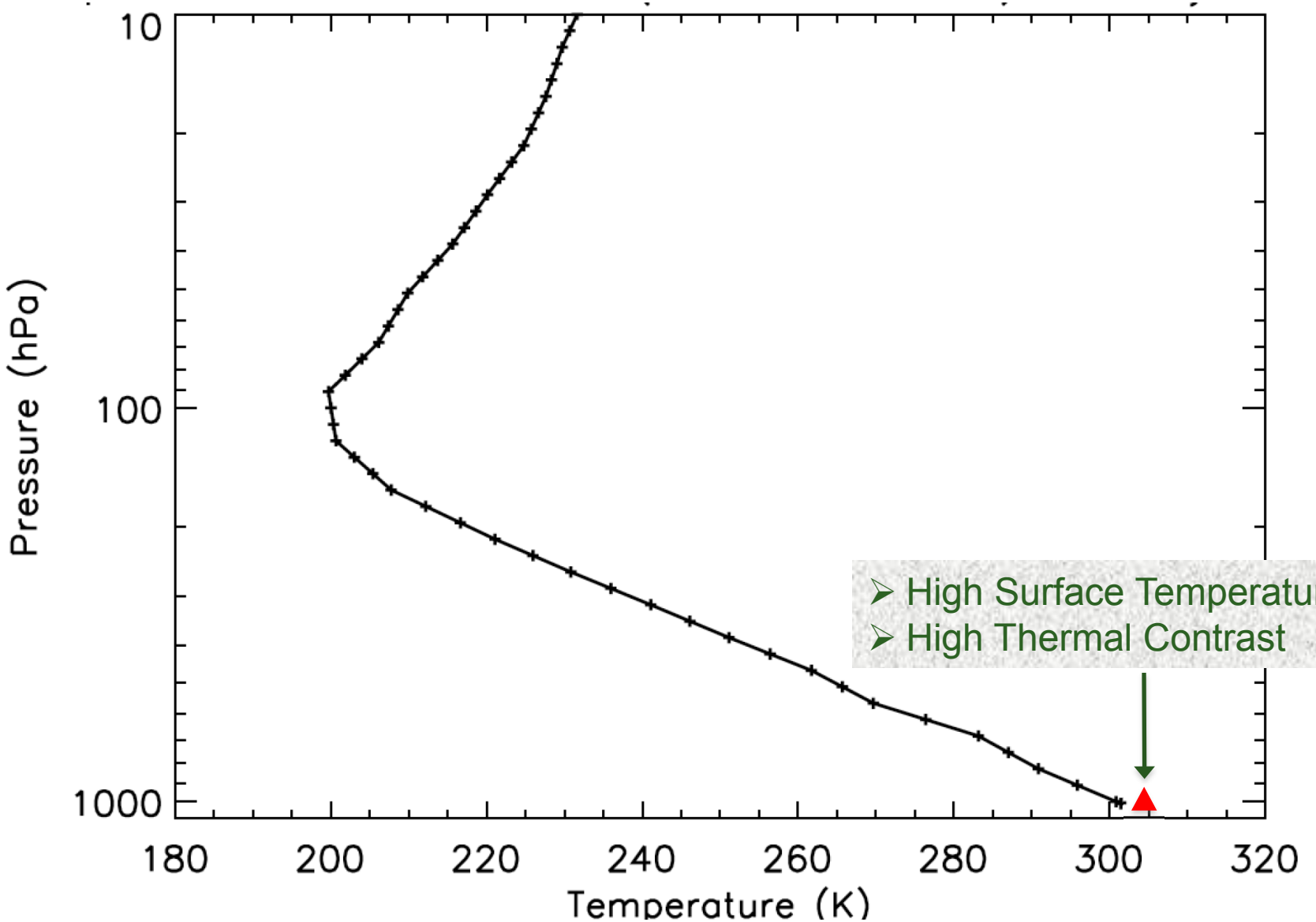
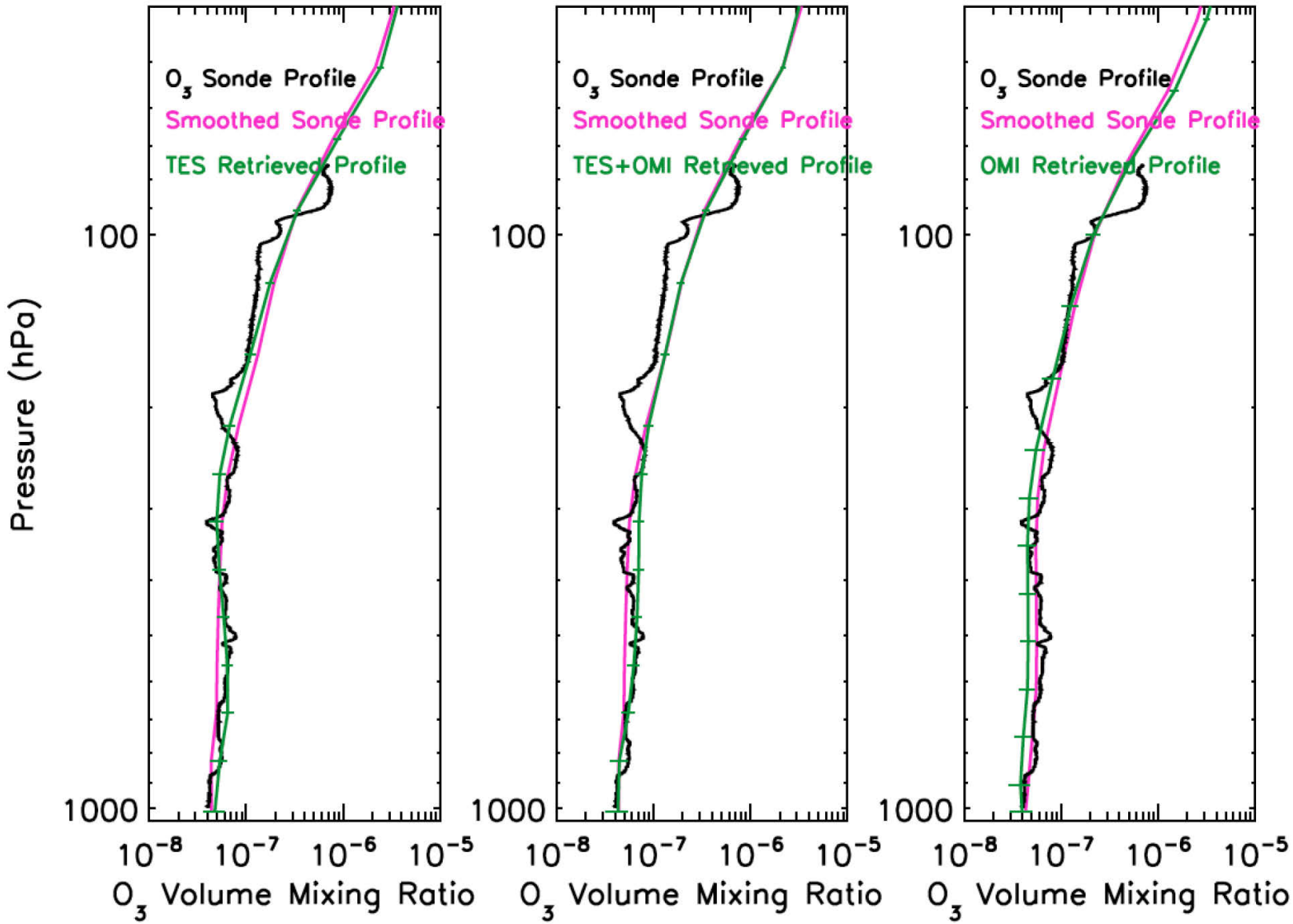


Temperature Profile over Houston, Texas, USA on May 9th, 2009

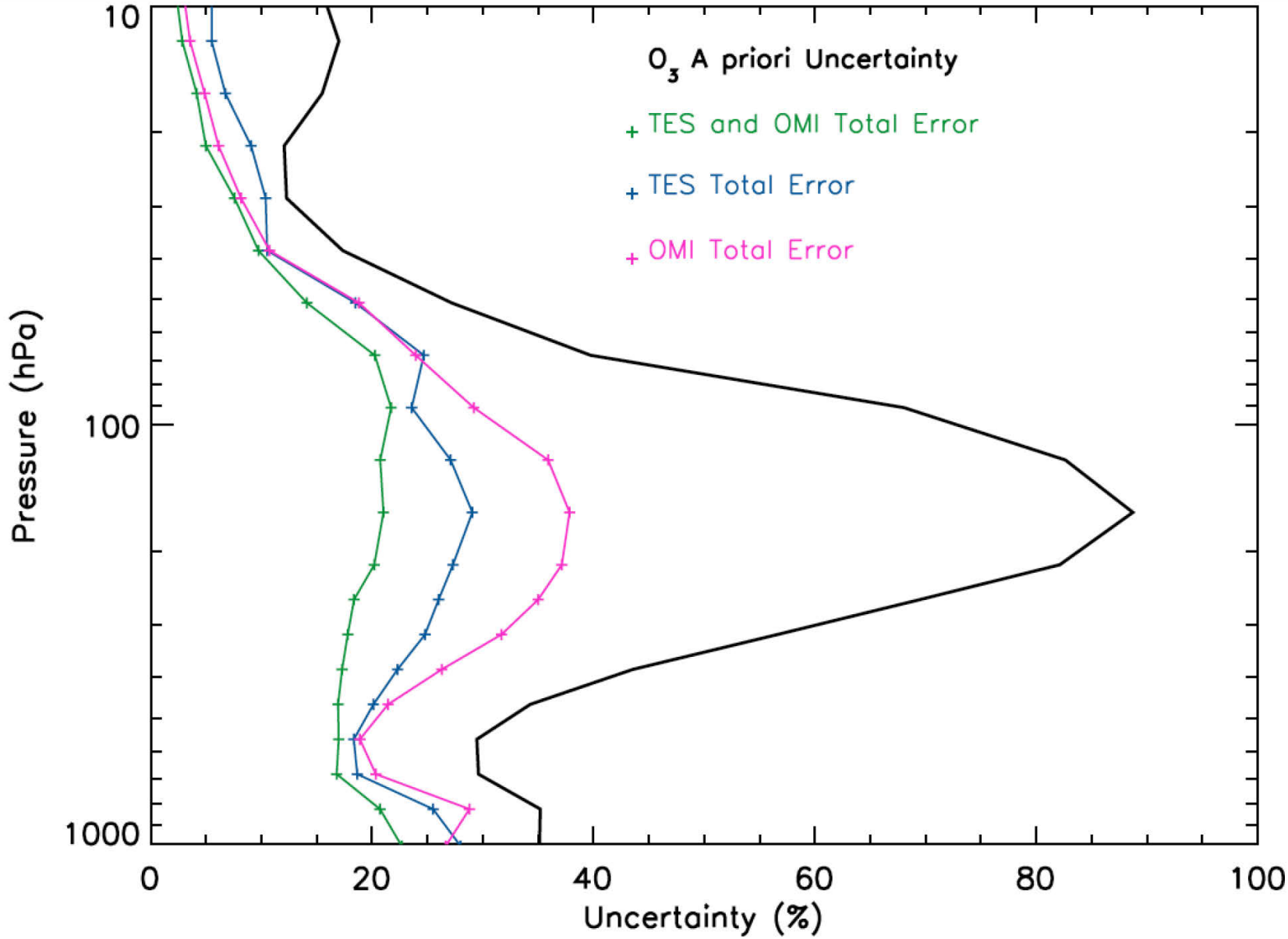


- High Surface Temperature
- High Thermal Contrast

O_3 Profiles Over Houston On May 9th, 2009



Error Analysis and Characterization



Summary and Future Work

Summary

- This work demonstrates that ozone profiles can be estimated from combined OMI and TES radiances
- Combined OMI/TES retrieval converges with chi 1.3; and ozone profile consistent with co-located sonde measurement
- Vertical resolution increases: averaging kernels are more separated in altitude for combined retrieval
- Sensitivity (DOFS) to tropospheric variability improves from 1.76 to 1.92

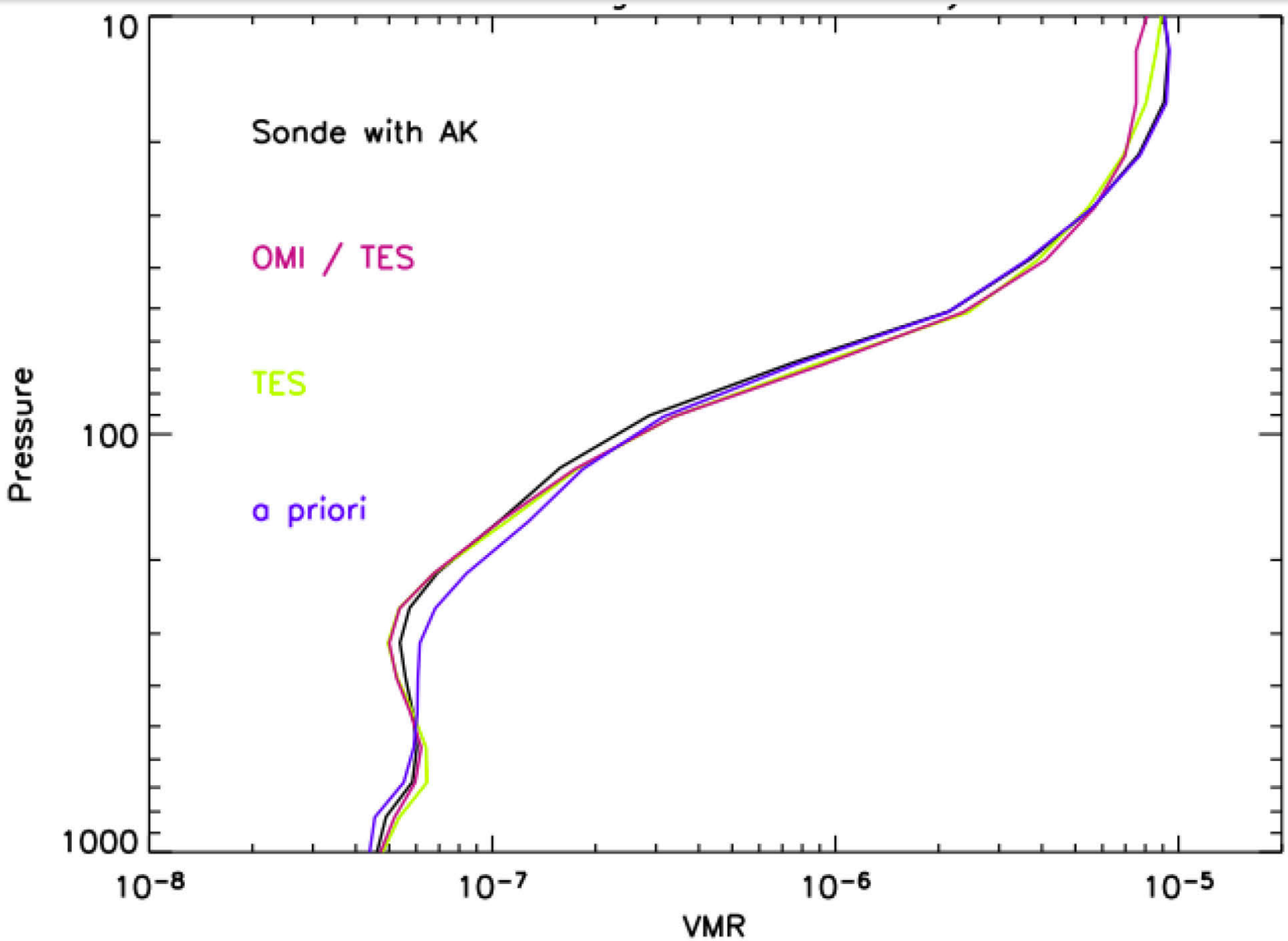
Future work

- To further improve the program package in order to do large volume of data processing
- Compare PBL ozone estimates using combined OMI/TES retrieval to in situ measurements for spring / fall conditions (lower thermal contrast / higher albedo). Under these conditions we expect larger improvements in vertical resolution for combined retrieval.

Acknowledgements

- Drs. Quitus L. Kleipool and Maarten Sneep at Royal Netherlands Meteorological Institute (KNMI)
- Drs. Alyn Lambert and Robert Herman, Vijay Natraj at JPL
- Your Attention

O_3 profile over Houston, TX on May 9th, 2009 Using Sequential Updates Technique



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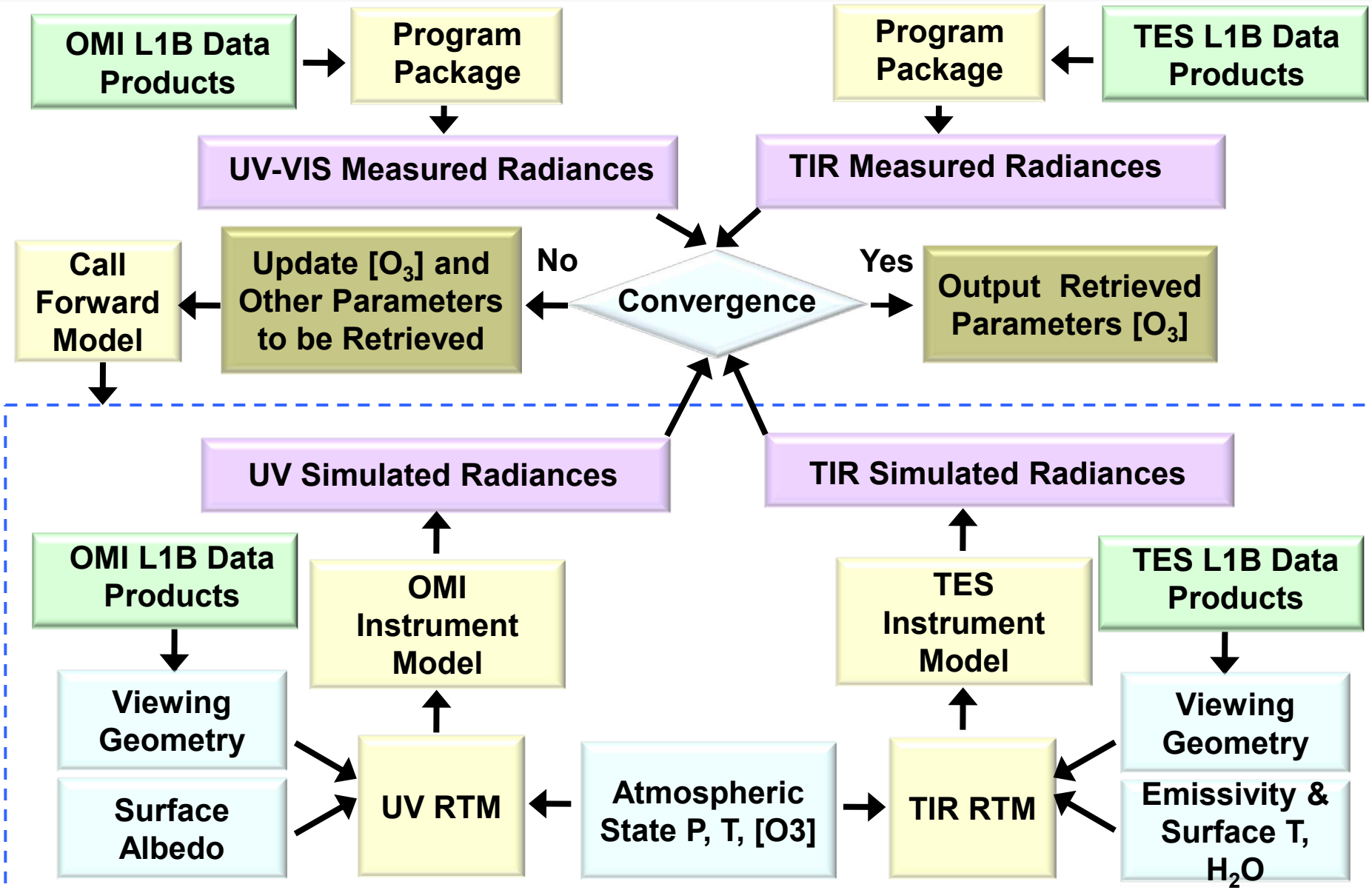
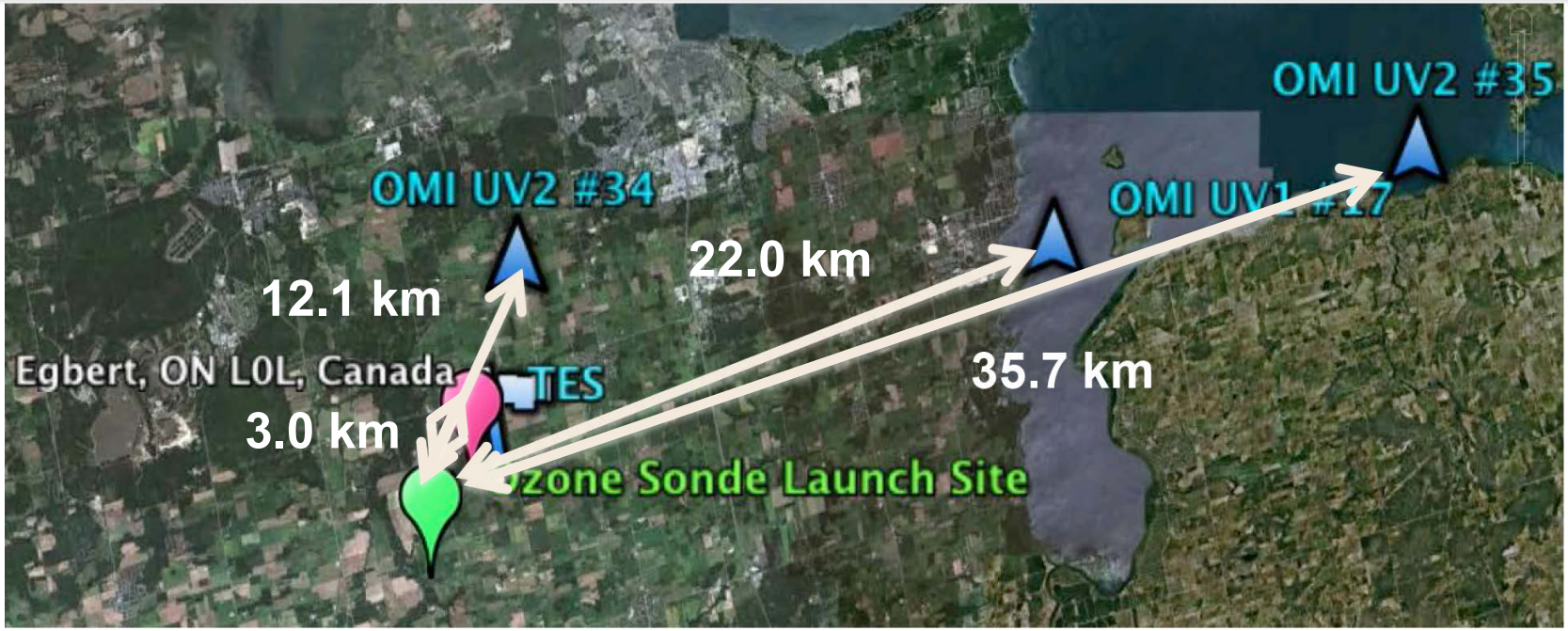


Retrievals Using TES and OMI Measurements over Egbert Canada on July 5th, 2008



- Criteria of Coincident Measurements
  - Cloud optical depth: <= 0.005
  - Ozone sonde measurements are available for comparisons
  - Time difference of OMI and TES measurements to ozone sonde: 3 hours
  - Distances of OMI and TES measurements to ozone sonde site: 50 km
  - Surface albedo was near zero over water surface