Observations of Tropospheric Ozone Profiles Using Simultaneously Measured UV and IR Radiances from OMI and TES

Dejian Fu[1], John Worden[1], Susan Kulawik[1], Kevin Bowman[1], Stanley P. Sander[1]

[1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA

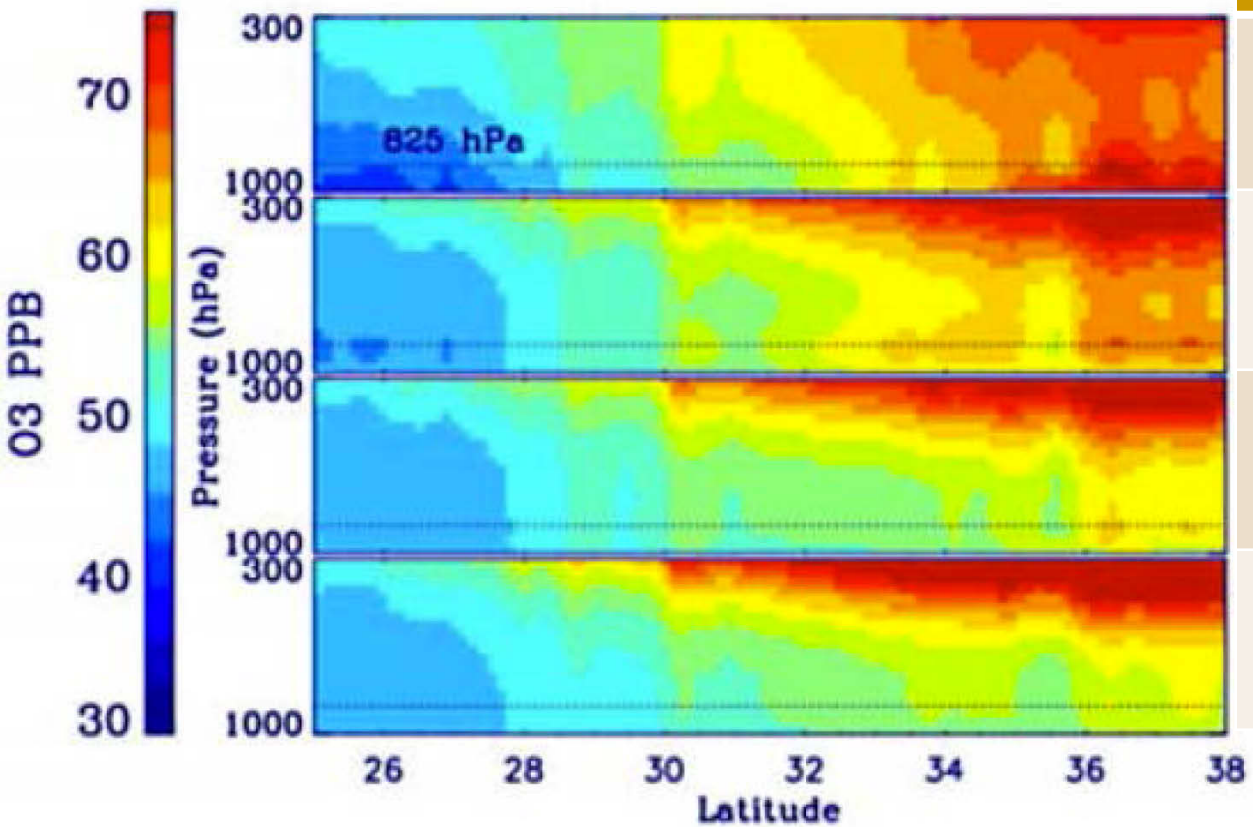
Xiong Liu[2]

[2]Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

Copyright 2011 California Institute of Technology. All rights reserved.

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

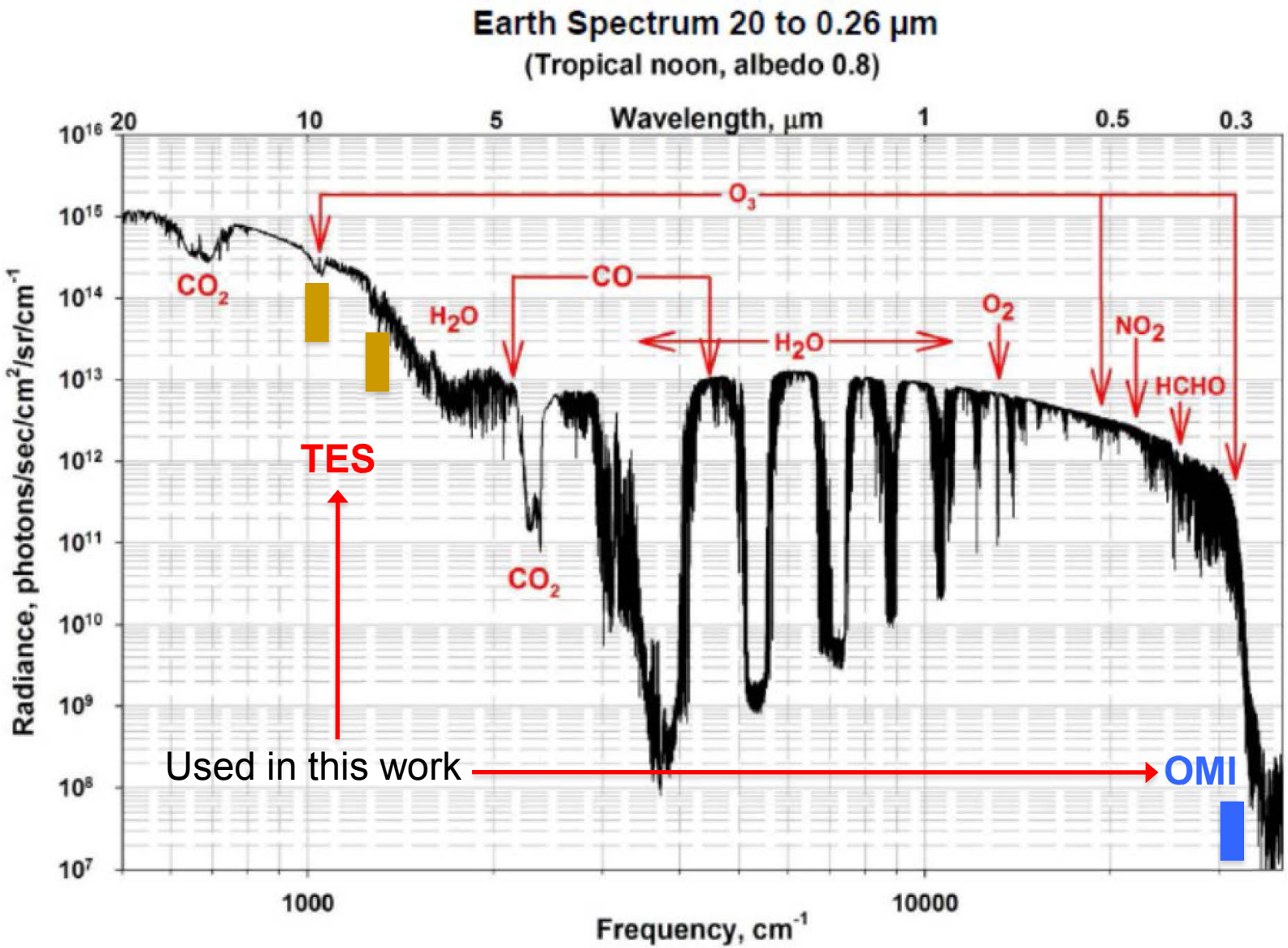
Worden J., X. Liu, K. Bowman, K. Chance, R. Beer, A. Eldering, M. Gunson, and H. Worden, *Improved tropospheric ozone profile retrievals using OMI and TES radiances*, GRL, 34, 2007.

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.

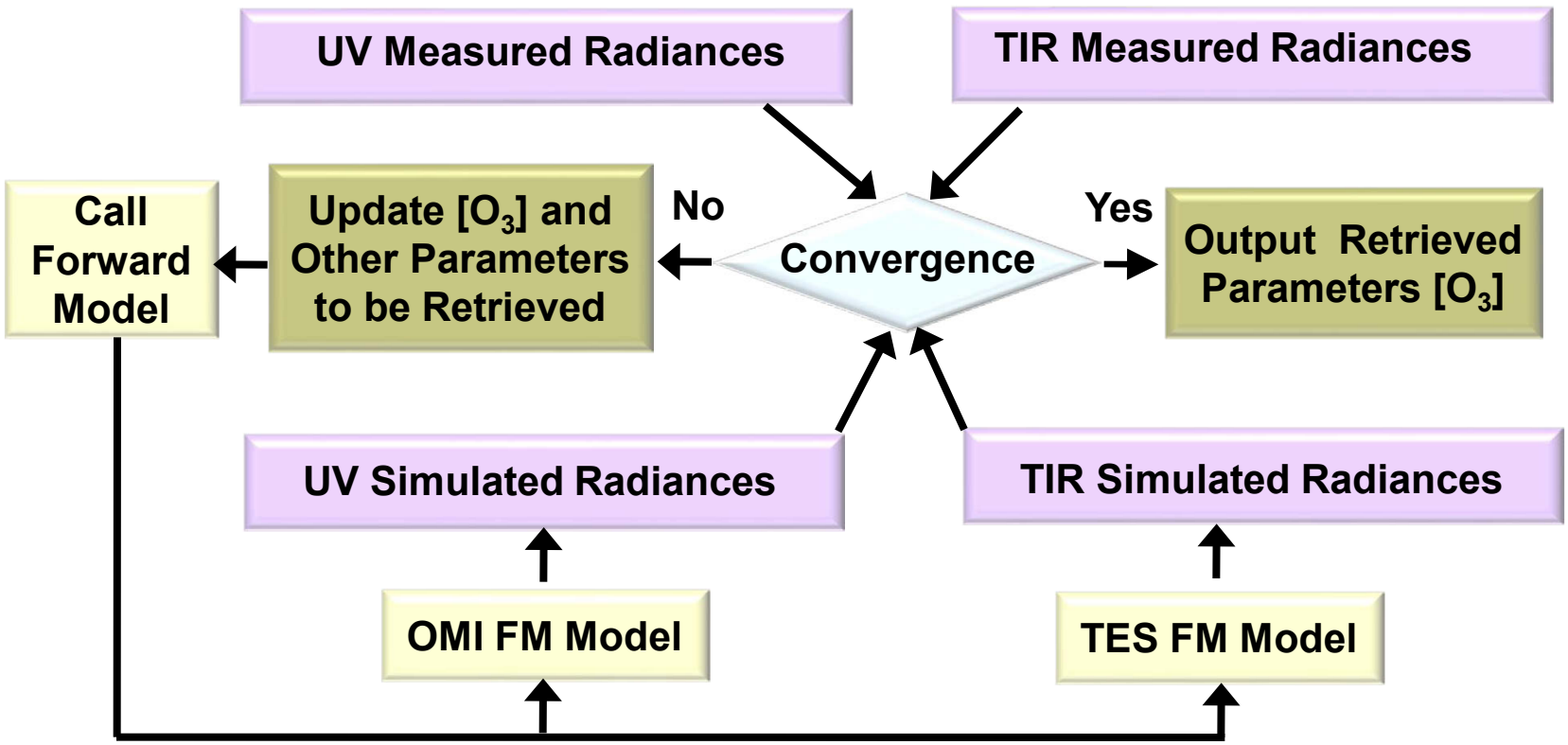
Coincident Measurements among TES, OMI, and Ozone Sonde

	TES					OMI	Sonde
Date	Lat	Long	Cloud	T_Diff	D_Diff	D_Diff	Site Name
UTC Date	degree	degree	OD	minutes	km	km	
28-Oct-05	37.9	-76.2	0.03	73	23	13	Wallops Island, USA
25-Jan-06	-0.8	-90.1	0.02	-25	20	13	San Cristobal
6-Apr-06	37.9	-76.3	0.03	39	27	13	Wallops Island, USA
10-May-06	26.2	127.7	0.01	-37	33	12	Naha, Japan
29-Sep-06	37.9	-76.3	0.01	22	26	13	Wallops Island, USA
25-Oct-06	19.9	-155.0	0.03	-19	16	12	Hilo, USA
3-Jan-07	37.9	-76.1	0.03	-3	12	14	Wallops Island, USA
10-Mar-08	-8.2	-15.0	0.01	38	21	14	Ascension, UK
10-Mar-08	39.1	-76.9	0.00	24	0	9	Beltsville, USA
29-Oct-08	25.6	128.2	0.02	-33	48	13	Naha, Japan
21-Mar-07	53.3	-113.5	0.04	-74	47	36	Edmonton, Canada
29-Jan-09	40.0	-105.2	0.03	37	18	8	Boulder, USA

Spectral Regions Used in Joint Retrievals



Retrievals: From Measured Spectra to O_3 Profiles



Retrievals: From Measured Spectra to O_3 Profiles

Radiative Transfer Models

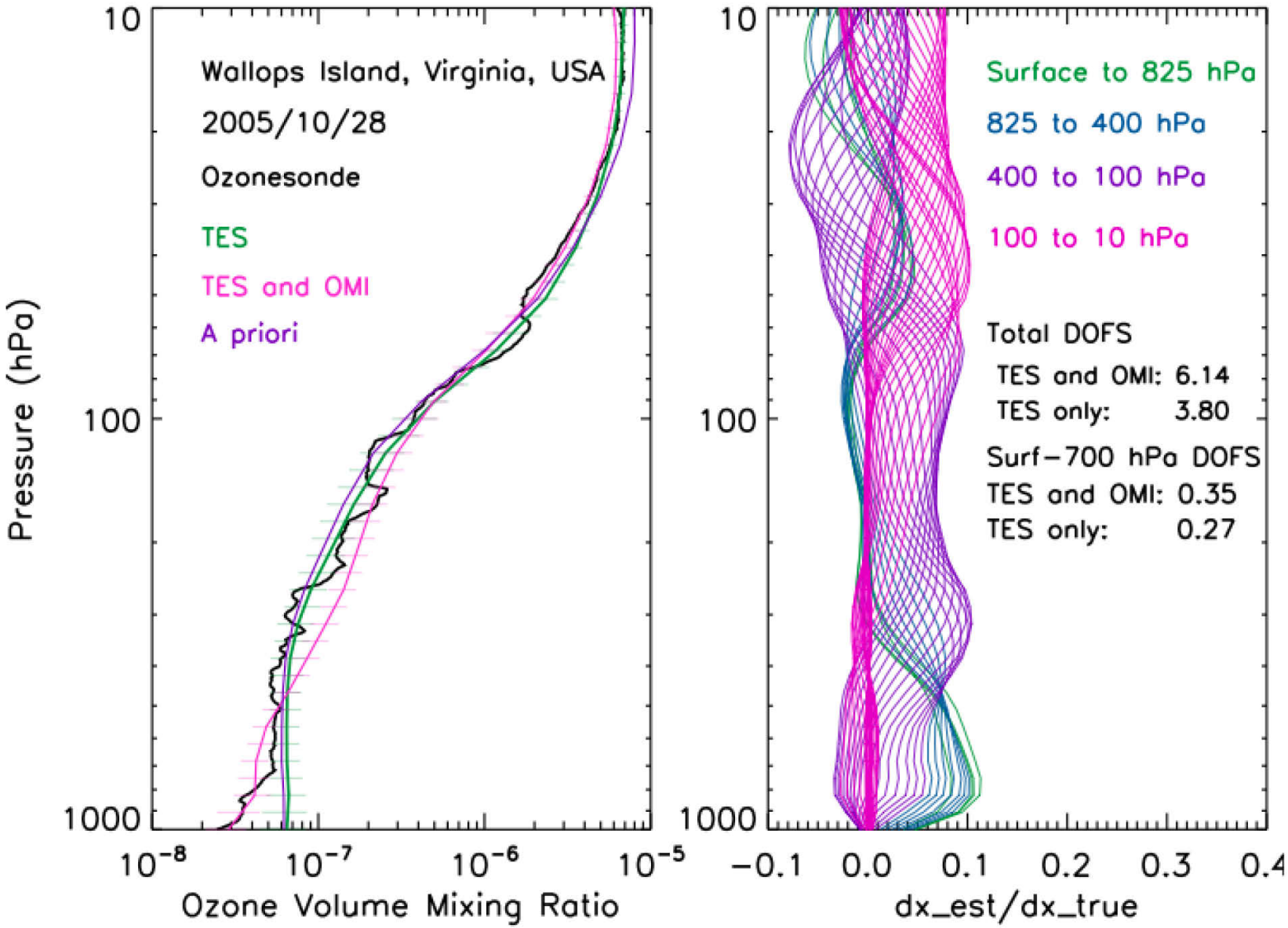
- OMI
  - Uses the linearized vector radiative transfer model VLIDORT [Spurr, 2006] for the numerical computation of the Stokes vector in a multiply-scattering multilayer medium
- TES
  - Simulates Earth radiances in the TIR spectral region, has been developed and validated by the TES retrieval team

Retrieval Methodology

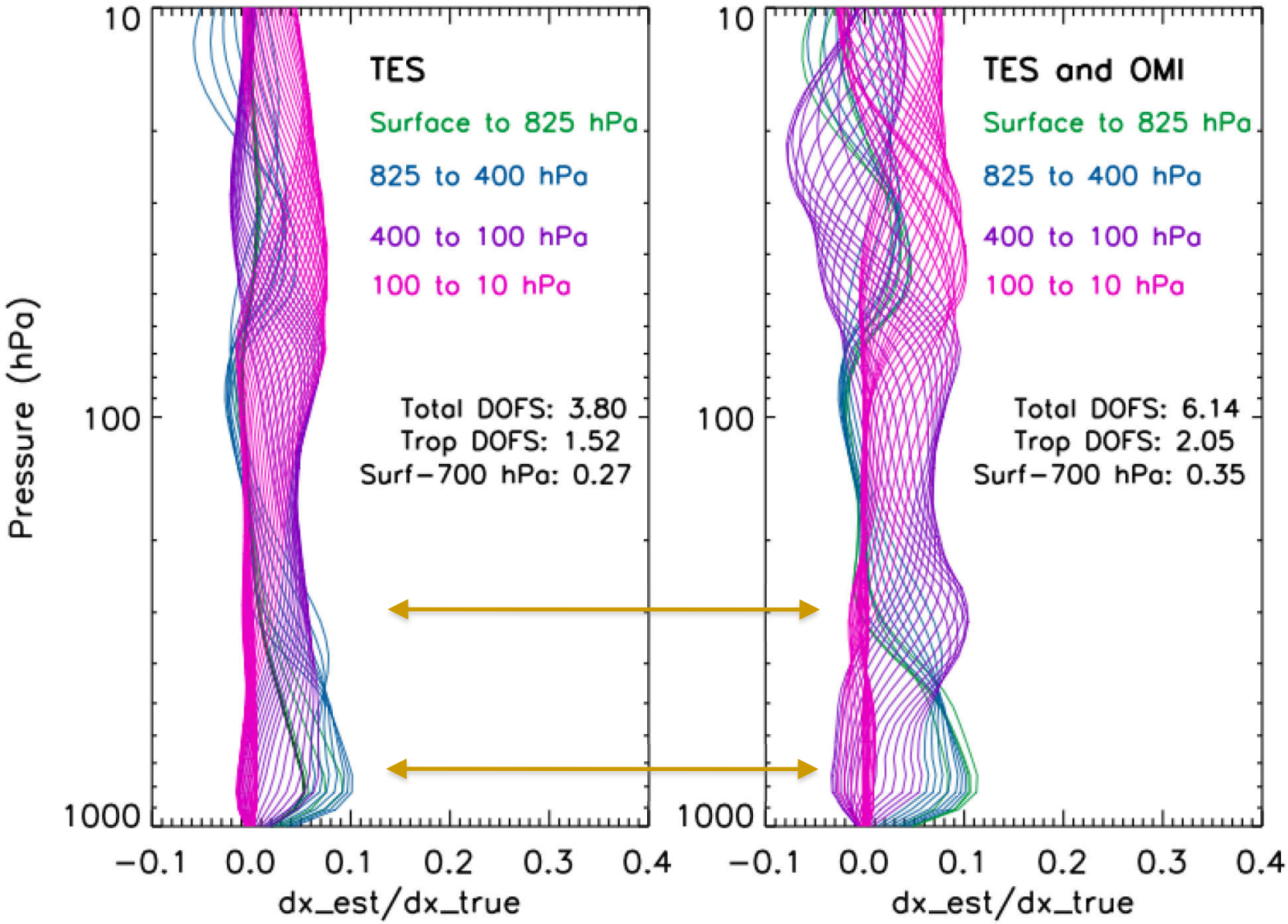
- Follows the optimal estimation method to combine a priori information and that of measurements [Rodgers 2000].
- Applies Trust region Levenberg-Marquardt algorithm [Bowman *et al,* 2006] to the combined TES/OMI radiances

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

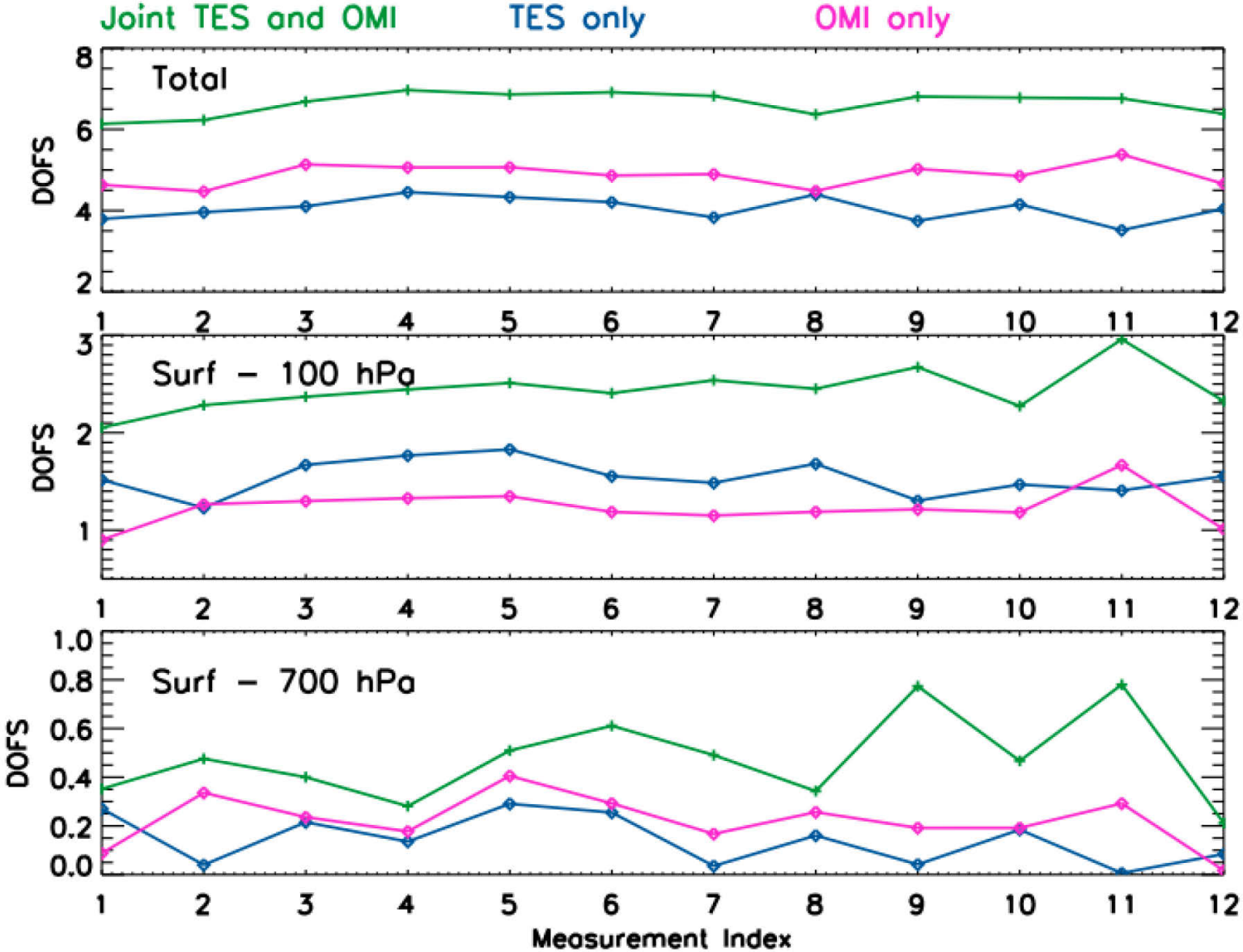
O_3 Measurements over Wallops Island, USA on 10/28/2005



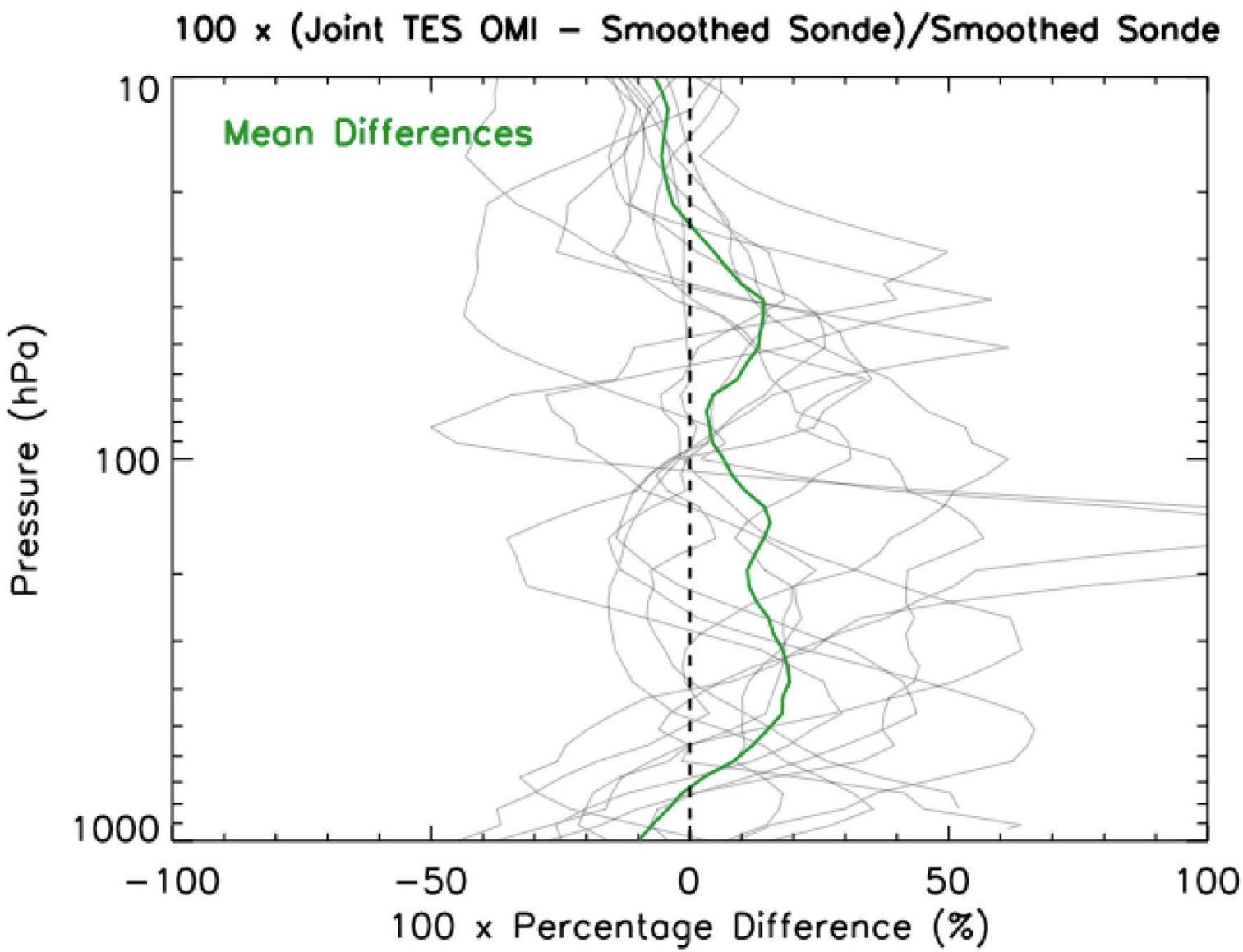
Vertical Sensitivity of O_3 Measurements over Wallops Island, USA on 10/28/2005



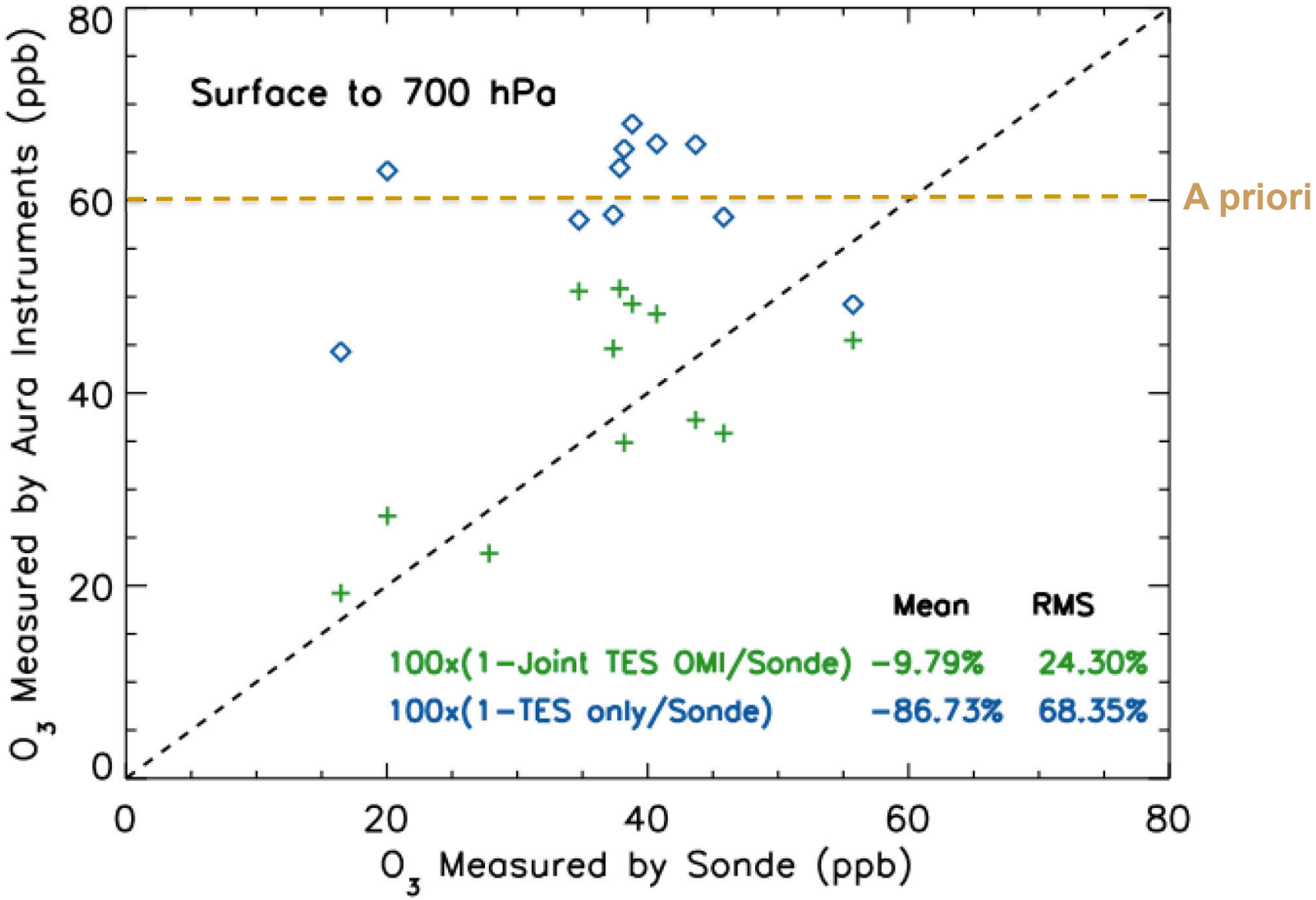
Degrees of Freedom of Signal (DOFS)



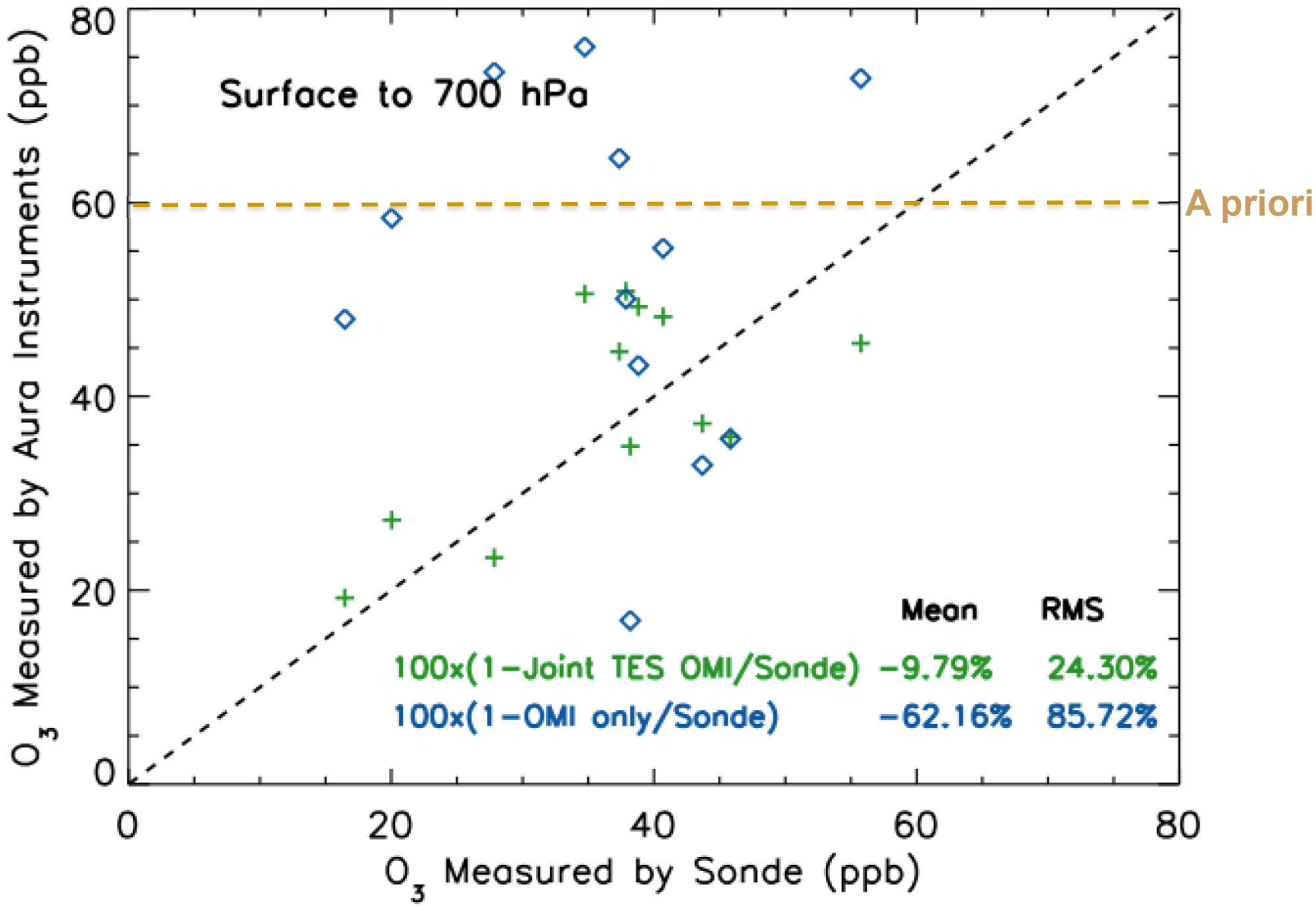
Joint TES and OMI vs. Smoothed Sonde



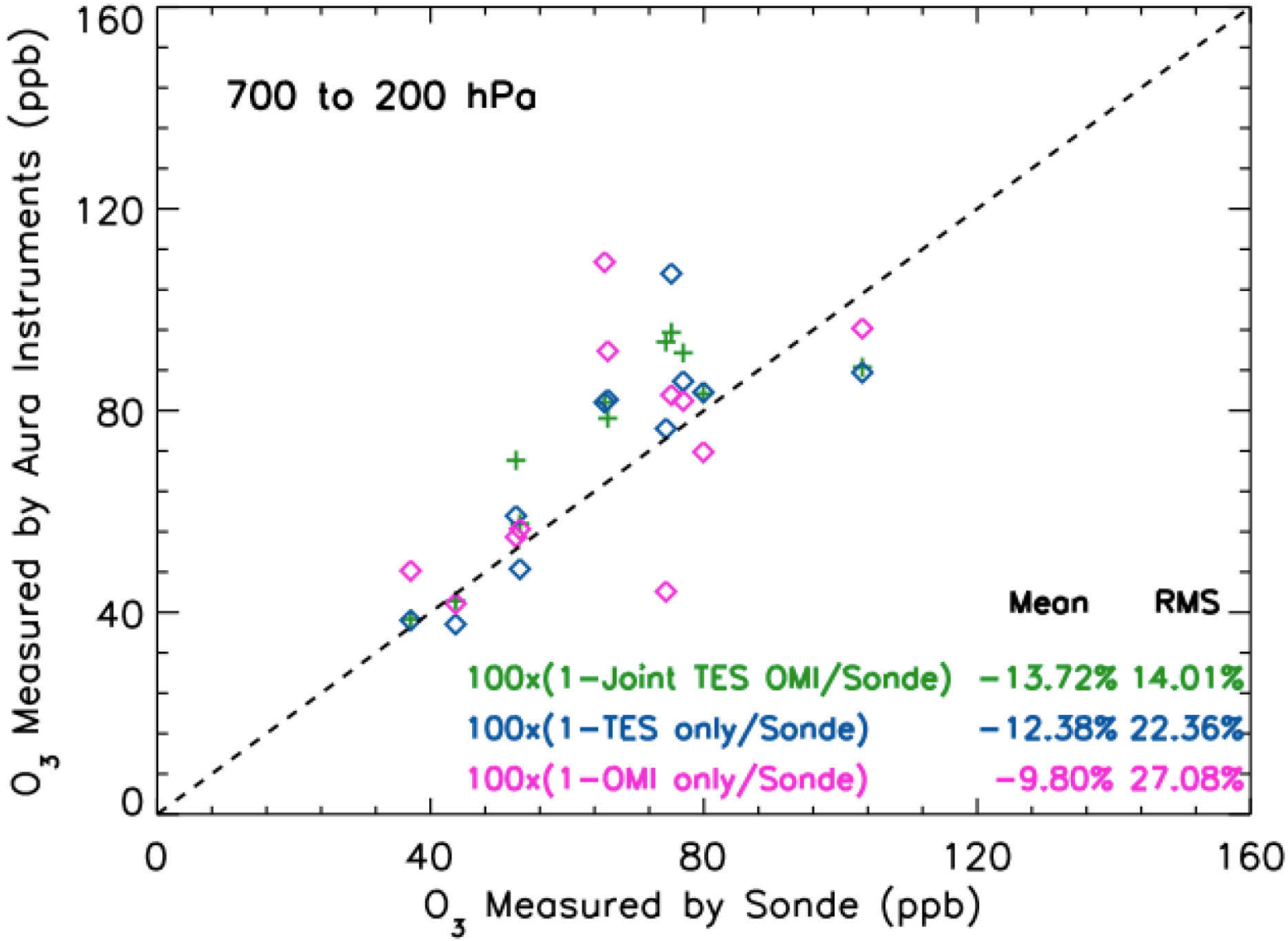
Correlations among Joint TES and OMI, TES only, and Sonde Measurements



Correlations among Joint TES and OMI, OMI only, and Sonde Measurements



Correlations among Joint TES and OMI, TES only, OMI only, and Sonde Measurements



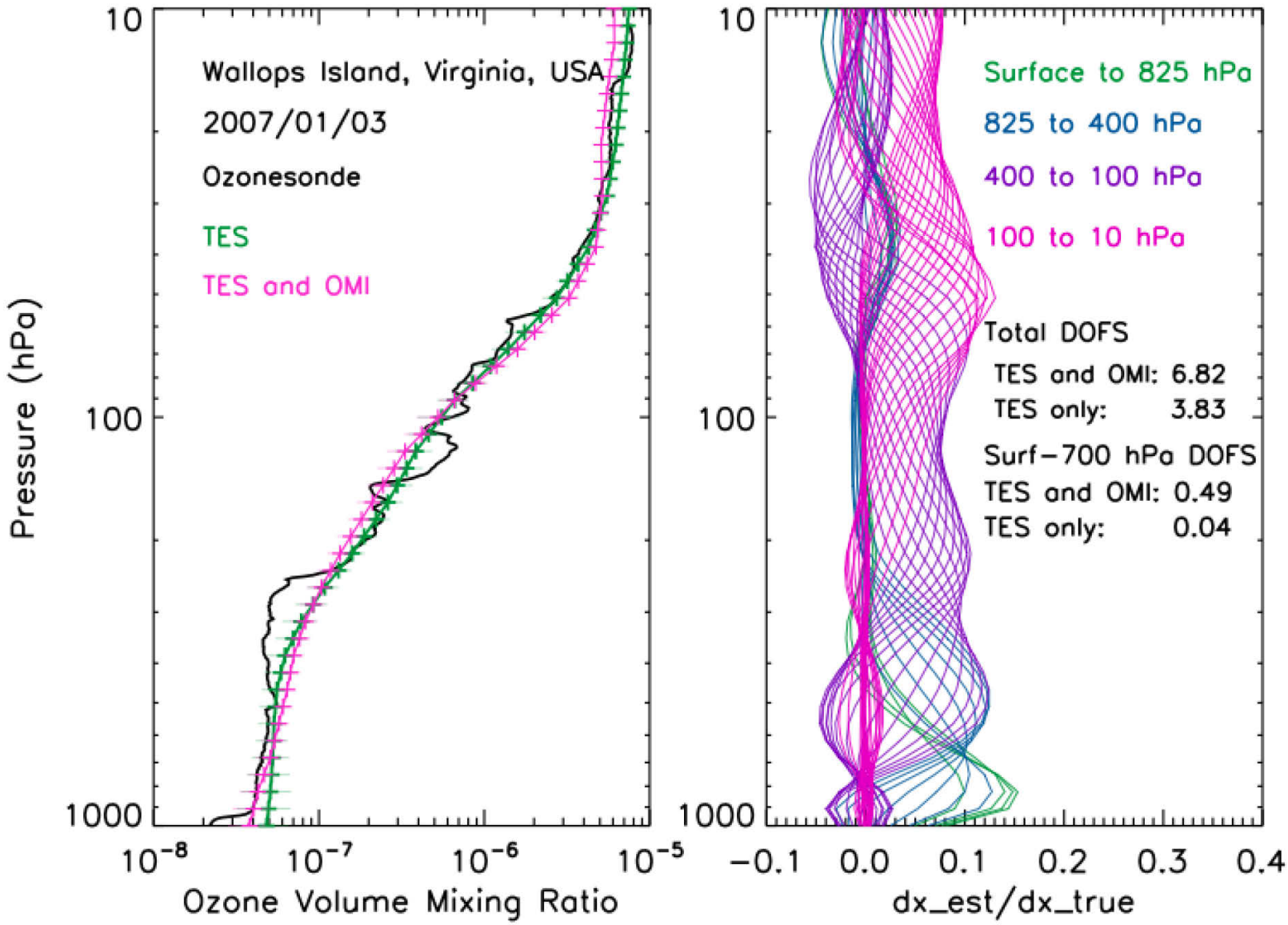
Summary

- This work demonstrates that ozone profiles can be estimated from combined OMI and TES radiances
- Ozone profiles consistent with co-located sonde measurements (differences are generally within 10%)
- Degrees of freedom of ozone signals increases:
  - Total DOFS: 6.64±0.28 (Joint), 4.05±0.28 (TES), 4.88±0.27 (OMI)
  - Trop DOFS: 2.44±0.23 (Joint), 1.53±0.18 (TES), 1.23±0.19 (OMI)
  - Surf to 700 hPa: 0.48±0.18 (Joint), 0.14±0.10 (TES), 0.22±0.10 (OMI)
- Combined TES and OMI measurements show the capability of capturing the variations of ozone volume mixing from surface to 700 hPa, neither TES nor OMI alone does for those measurements used in this study
- Joint TES and OMI measurements show most significant improvements under the low thermal contrast condition, where surface temperature is near atmospheric temperature, as compared to the TES measurements
- It is worth to note that TES provides tropospheric ozone measurements with DOFS about 1.85 in the summer and the quality of these measurements have been validated by sonde at multiple locations, e.g., Houston, Texas and Fair Hill, Maryland.

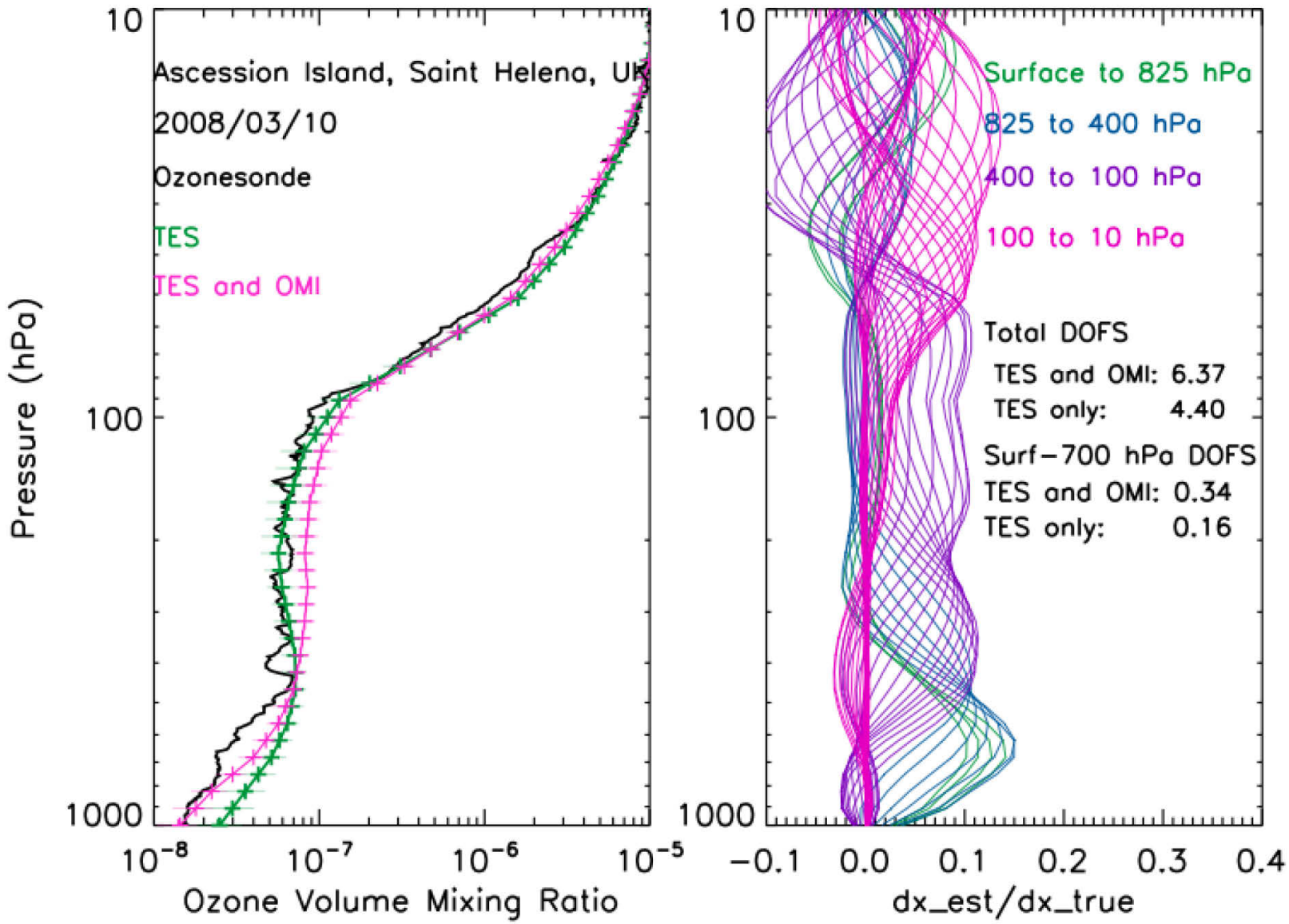
Acknowledgements

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

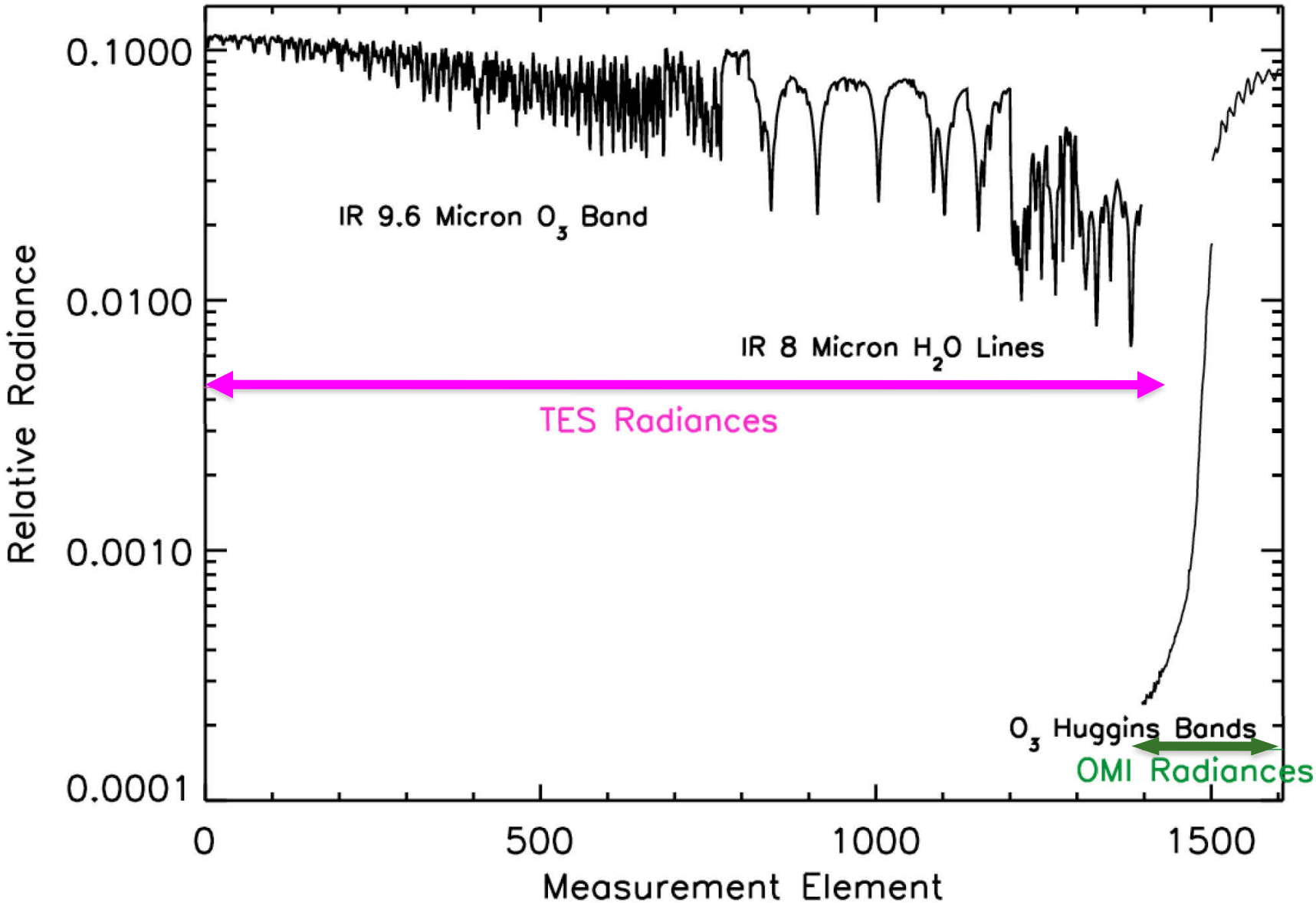
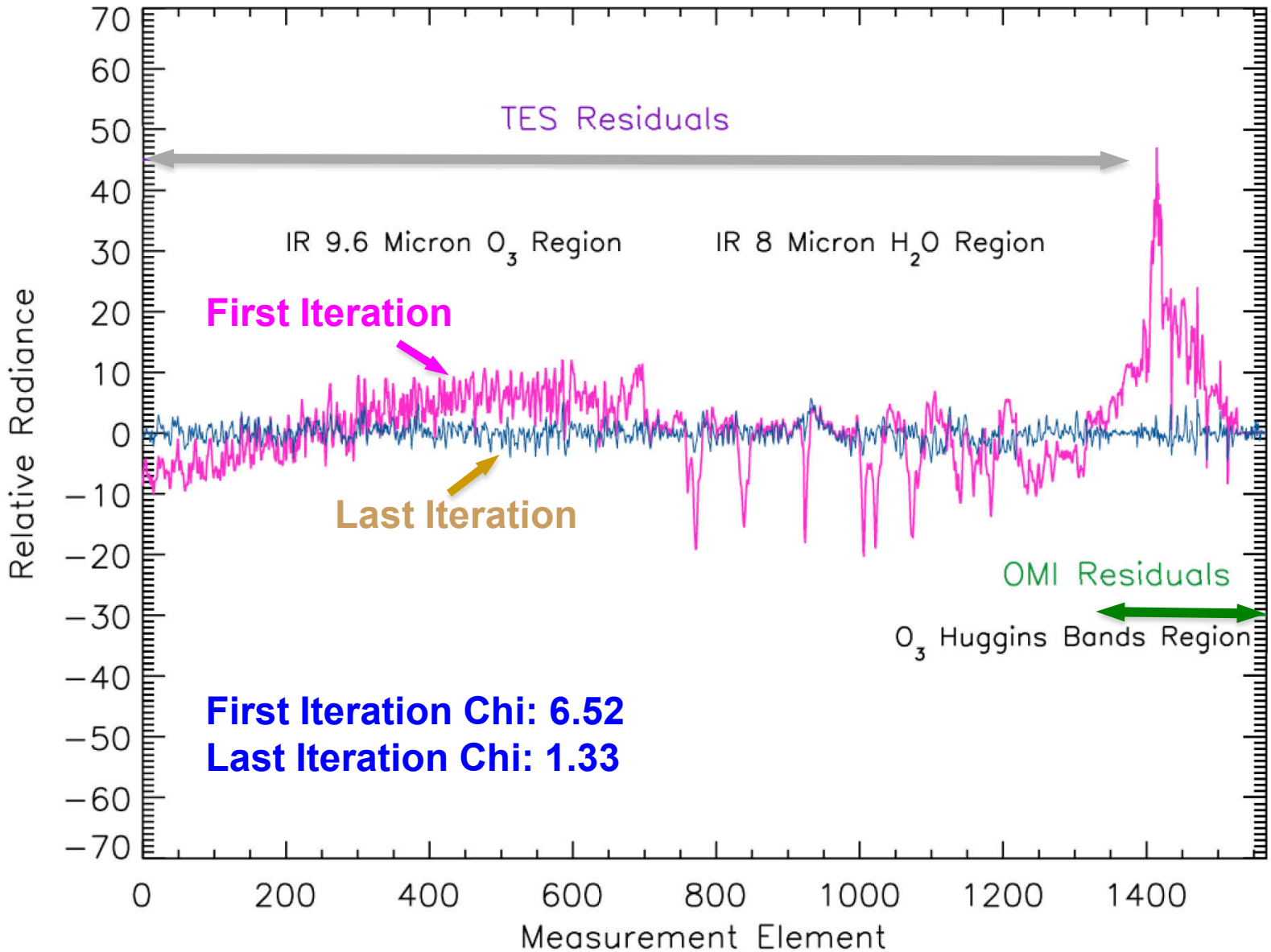
O_3 Measurements over Wallops Island, USA on 01/03/2007



O_3 Measurements over Ascension Island, Saint Helena, UK on 03/10/2008



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



Radiance Residuals
(Measured – Modeled) /Noise Estimate