

Joint Airborne IASI Validation Experiment - Use for Retrieval Technique Development

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⁷AER, Bedford, MA

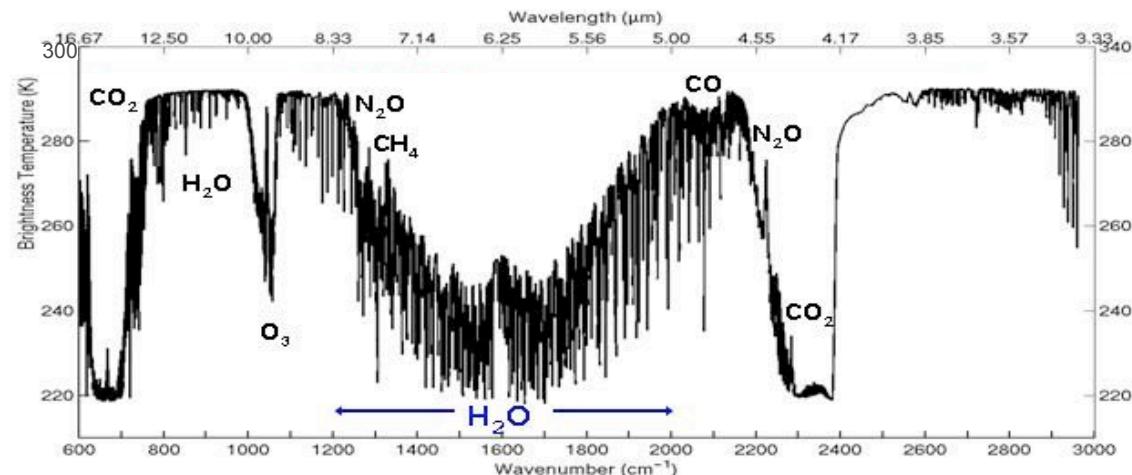
High Vertical Resolution Sounding Concept

High spectral resolution and broad spectral coverage enables high system S/N for providing accurate de-convolution of vertically smeared thermal radiance signals

High Vertical Resolution Provided by High Resolution Radiance Spectra

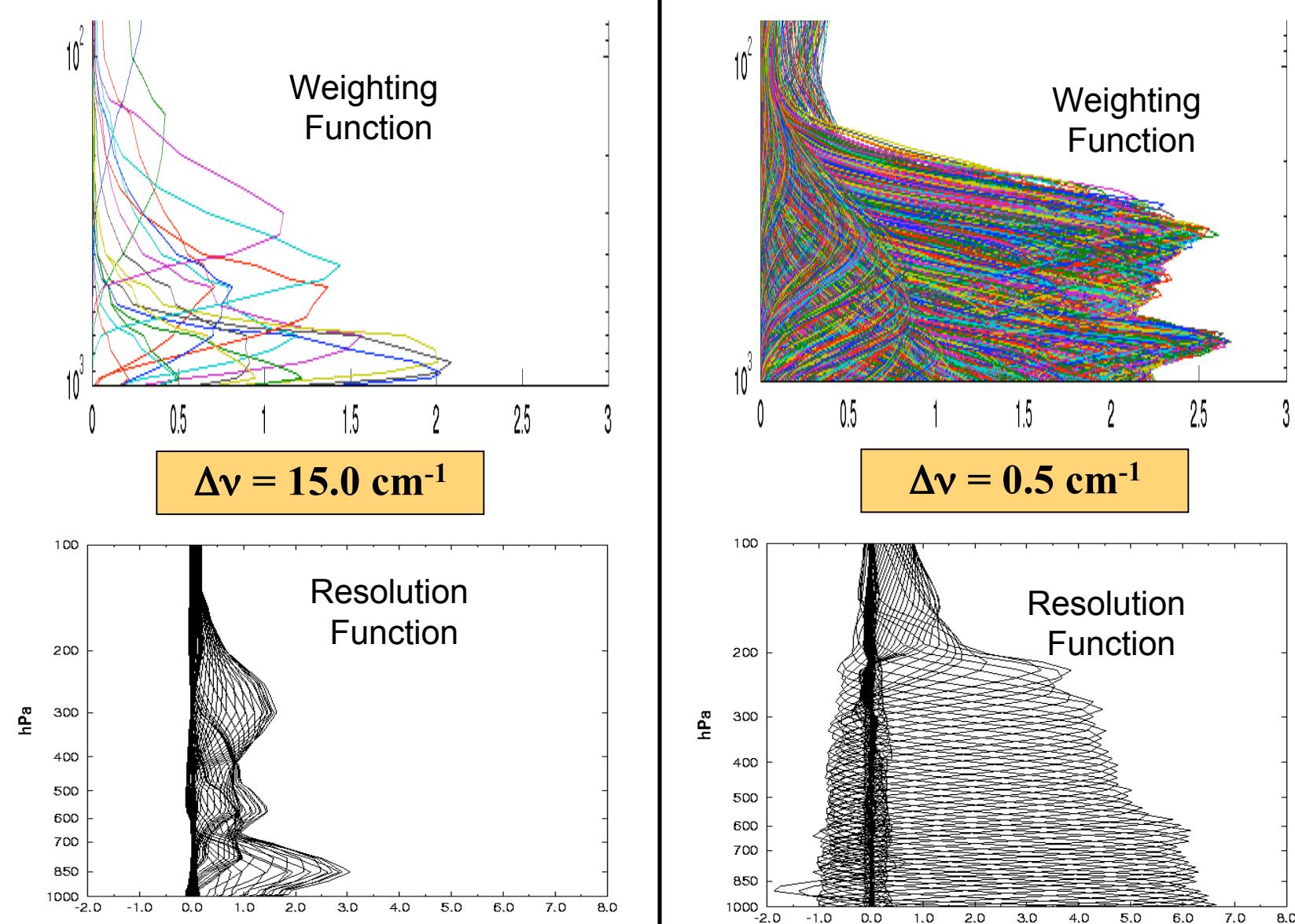
- **Spectrum**

Several thousand spectral channels are observed to profile the atmosphere with high vertical resolution

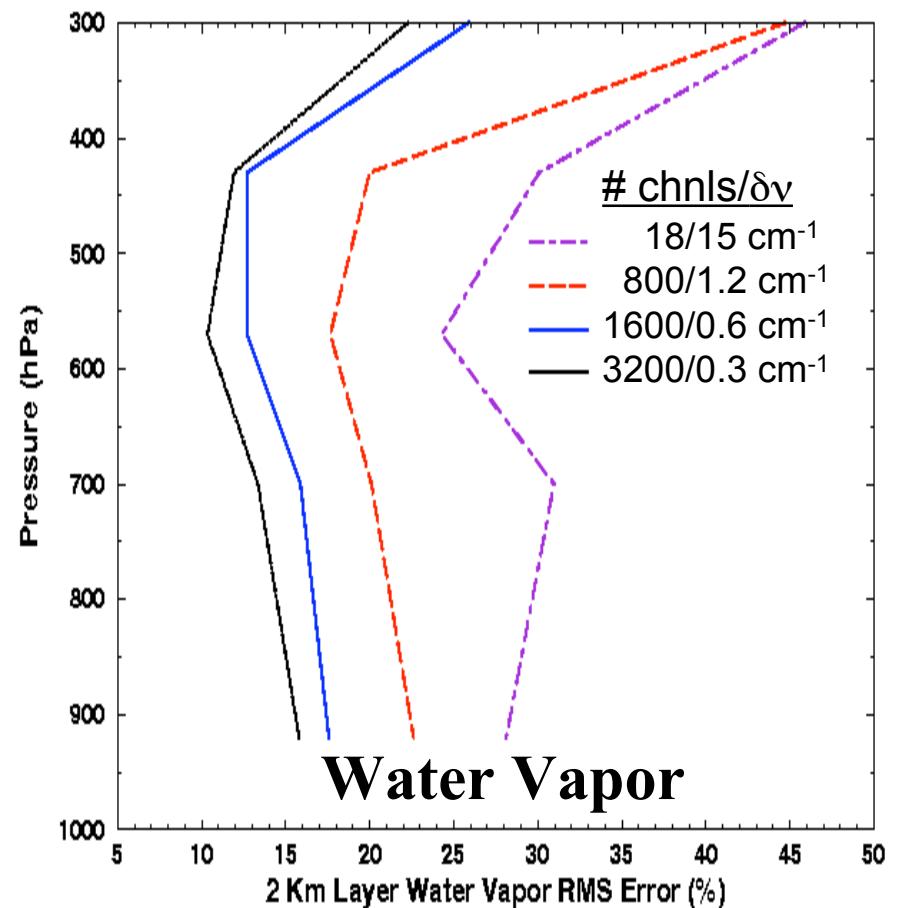
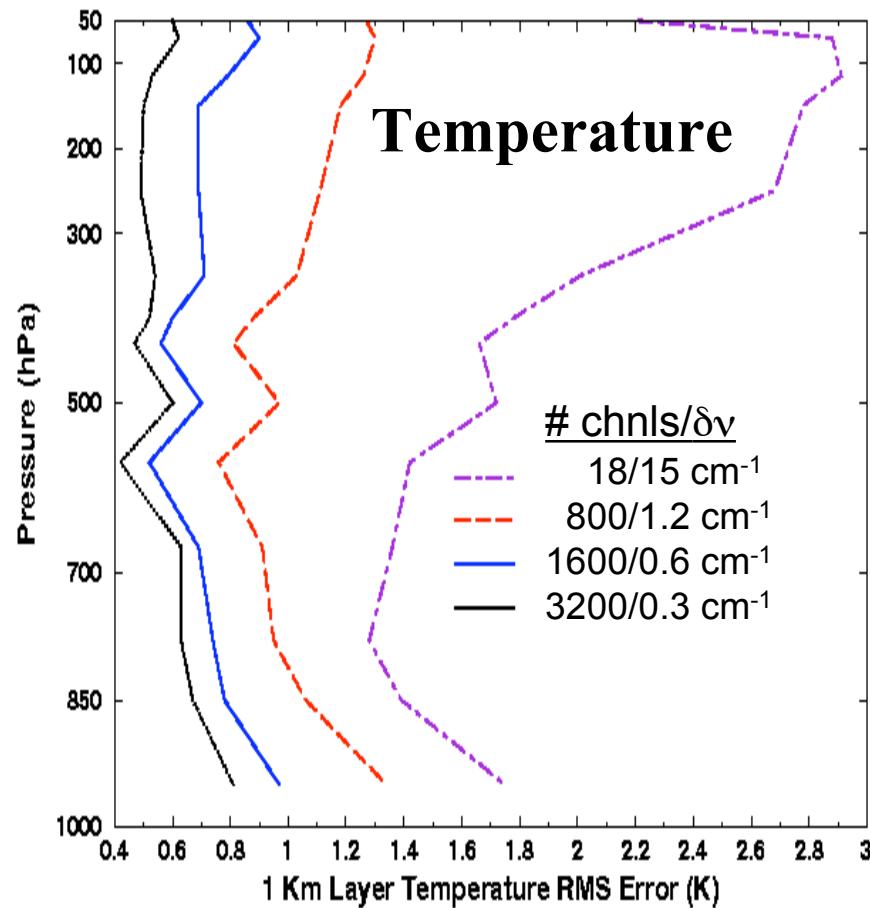


Why Does Ultraspectral Resolution Provide High Vertical Resolution ?

Slightly sharper weighting functions and much greater system S/N resulting from the very large number of radiance observations



Retrieval Accuracy Vs Spectral Resolution (i.e., number of spectral radiance observations)



The vertical resolution and accuracy increases greatly going from multi-spectral to ultra-spectral resolution. The improvement in ultra-spectral performance is proportional to the square root of the number of channels (i.e., S/N)

High-resolution Interferometer Sounder (HIS) - 1980-1998

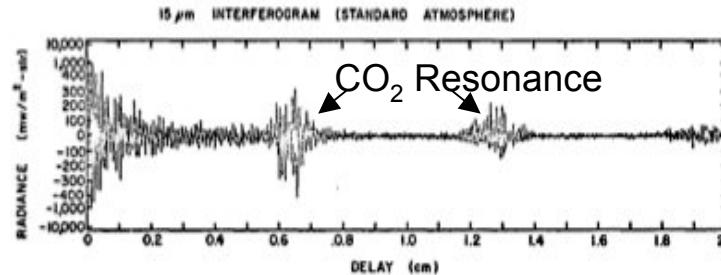
Experimental Validation of the High Vertical Resolution Sounding Concept

The Beginning

Reprinted from JOURNAL OF THE ATMOSPHERIC SCIENCES, Vol. 36, No. 4, April 1979
American Meteorological Society
Printed in U. S. A.

The Use of Interferometric Radiance Measurements for Sounding the Atmosphere

W. L. SMITH, H. B. HOWELL AND H. M. WOOLF

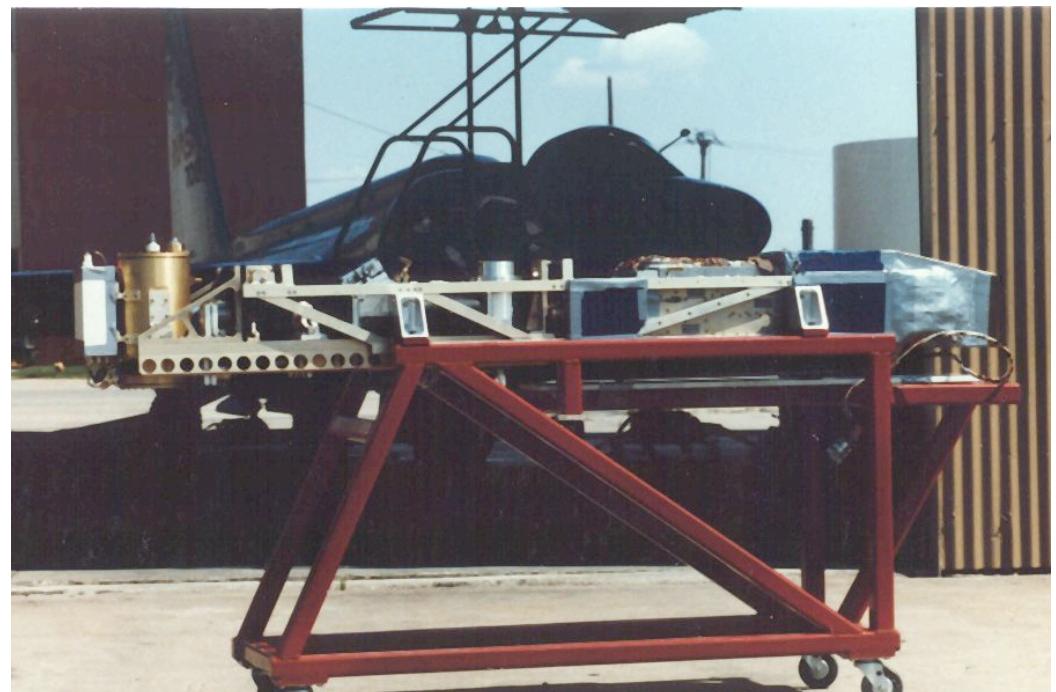


Smith, W.L., H.E. Revercomb, H.B. Howell, and H.M. Woolf, 1983: **HIS - A satellite instrument to observe temperature and moisture profiles with high vertical resolution.** Preprints Fifth Conference on Atmospheric Radiation. AMS, Boston, 9 pp.

HIS Aircraft Instrument:

U2 Shadowed in background, 1985

Three spectral bands, covering most of the region from 3.8 to 16 microns, with a spectral resolution from 0.27 - 0.42 cm^{-1}



Revercomb, H.E., H. Bujis, H.B. Howell, R.O. Knuteson, D.D. LaPorte, W.L. Smith, L.A. Sromovsky, and H.W. Woolf, 1989: **Radiometric calibration of IR interferometers: Experience from the High-Resolution Interferometer Sounder (HIS) aircraft instrument.** RSRM '87; Advances in Remote Sensing Retrieval Methods. A. Deepak, H. Fleming, and J. Theon, Eds.

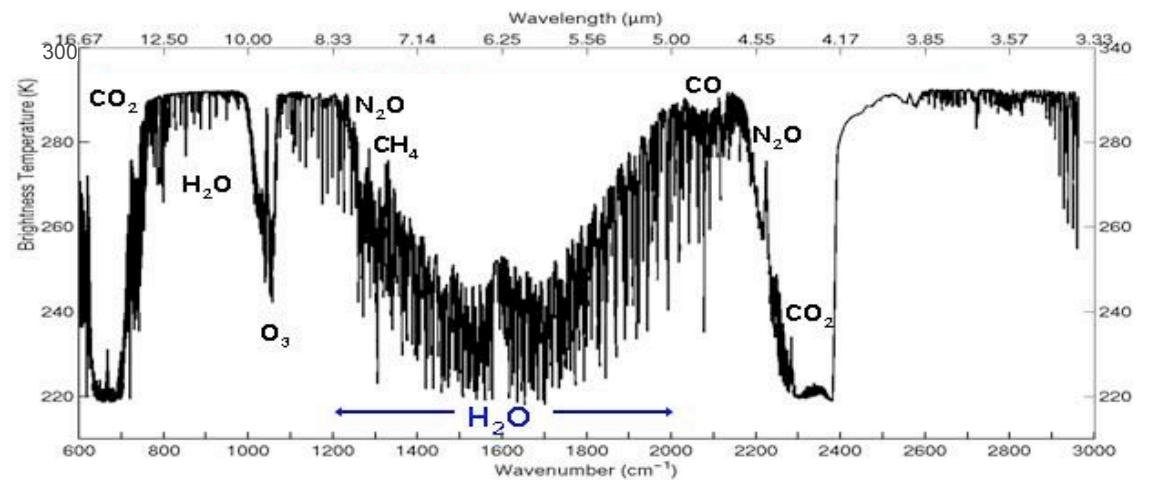
Ultraspectral Resolution

High S/N Enables Accurate De-convolution of Vertically Smeared Thermal Radiance Signals

High Vertical Resolution Provided by High Resolution Radiance Spectra

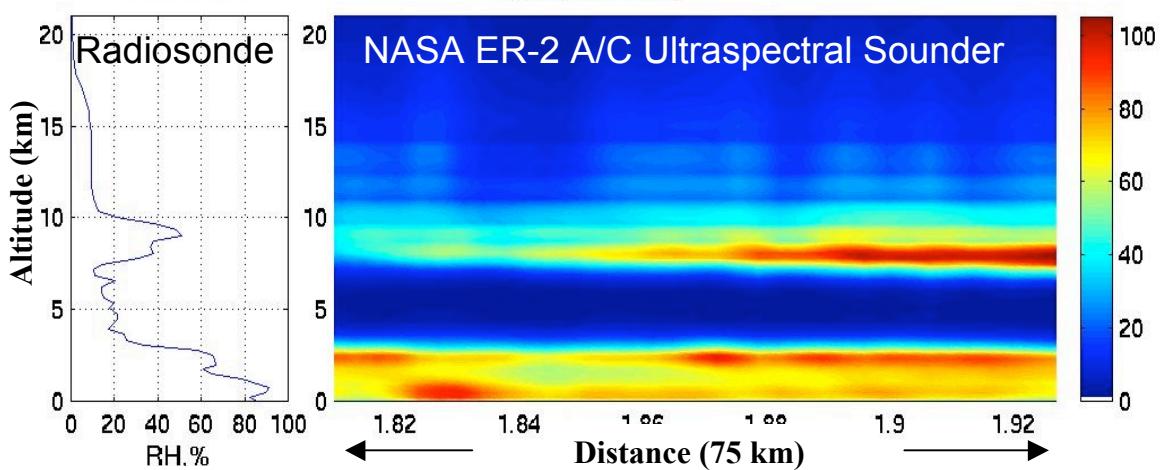
- **Spectrum**

Several thousand spectral channels are observed to profile the atmosphere with high vertical resolution

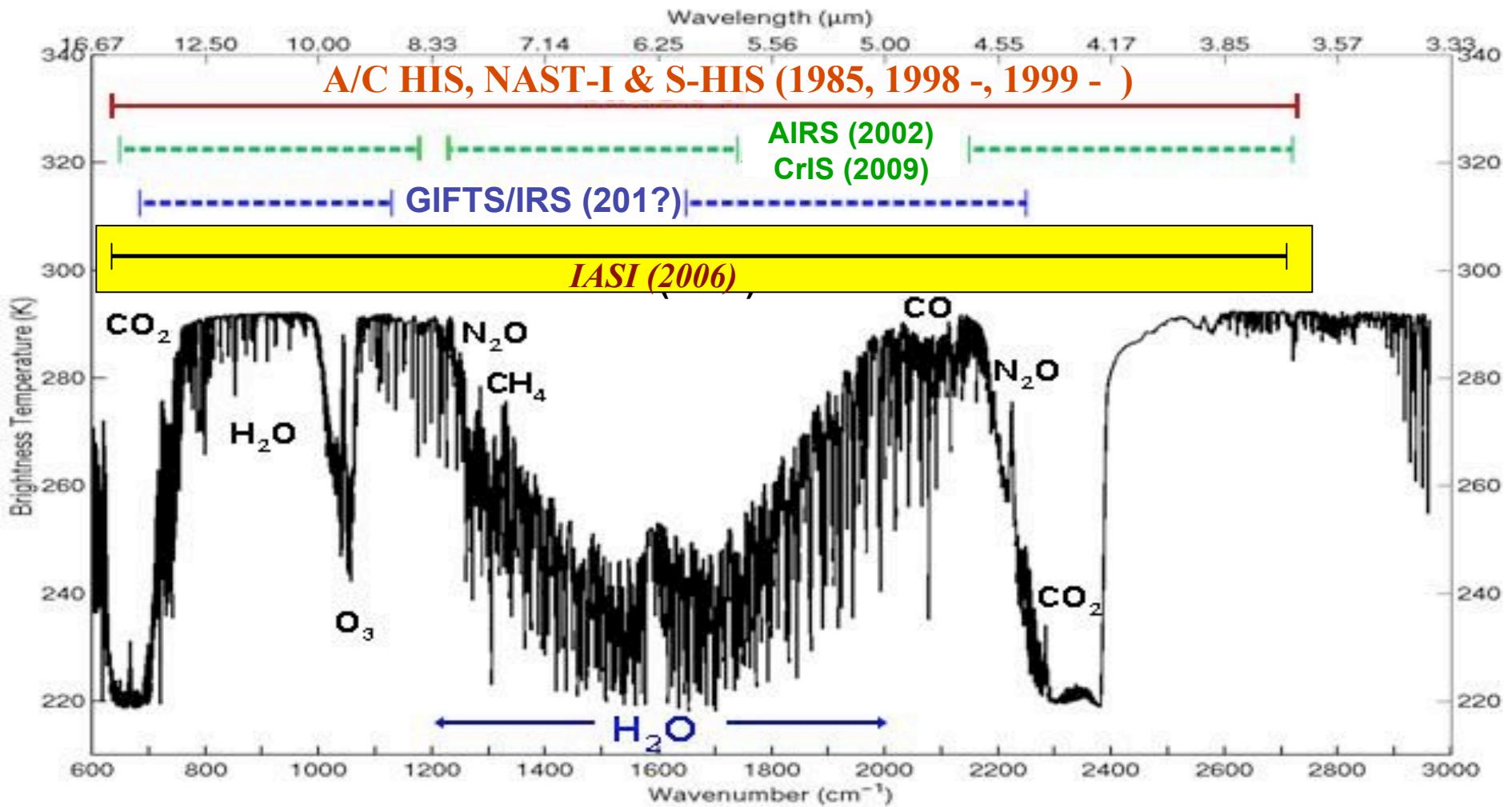


- **Soundings**

Ultraspectral resolution sounder provides 1 K / 15% temperature and moisture accuracy for 1-2 km layers



Ultraspectral Atmospheric Sounders



- Broad Spectral Coverage
- Thousands of Spectral Channels
- High Spectral Resolution
- High Information Content

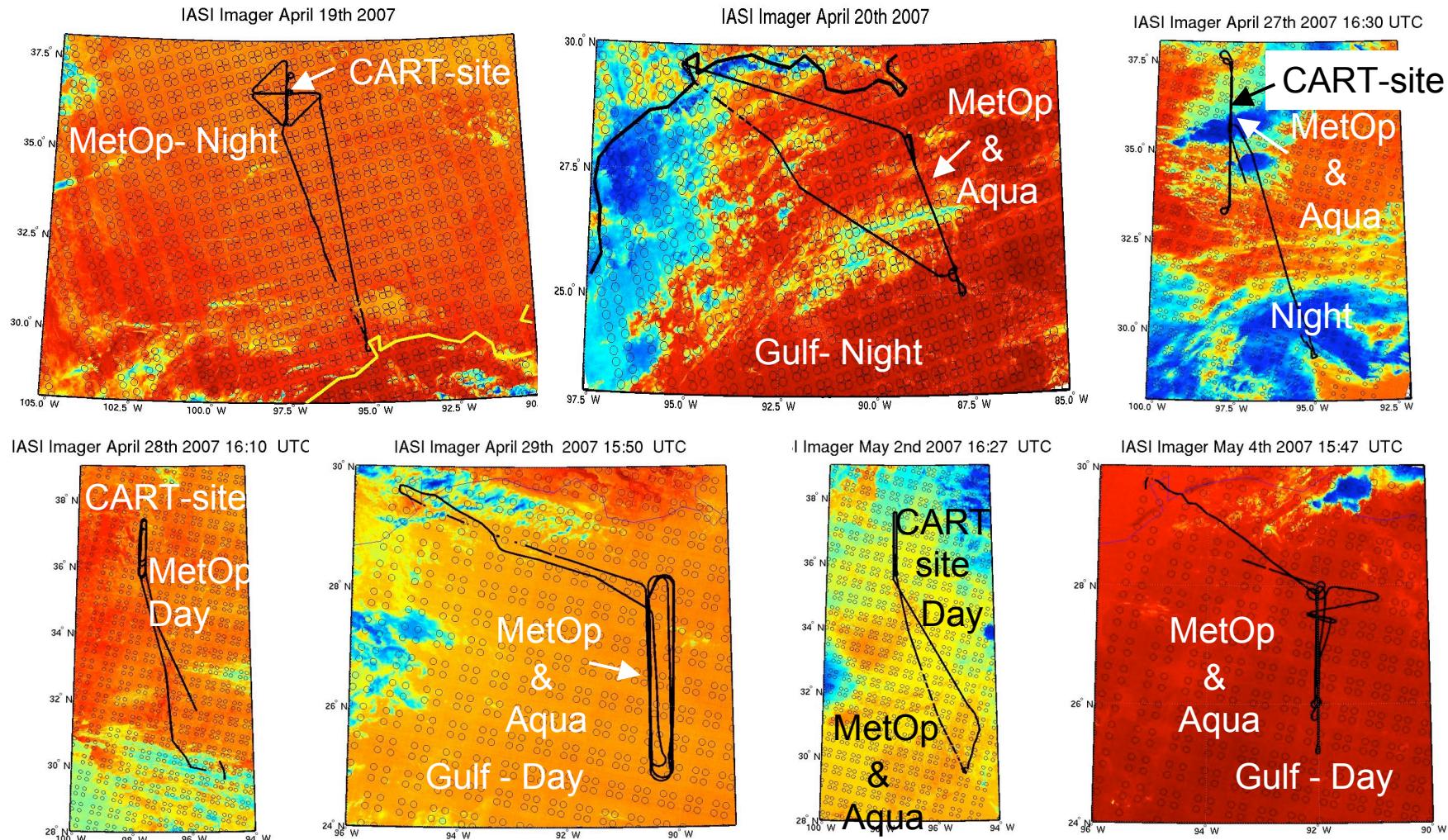
Joint Airborne IASI Validation Experiment (JAIVEx)



**First US-European collaboration in the US focusing on the validation of radiance and geophysical products from MetOp-A
(1st advanced sounder in the US/European Joint Polar System)**

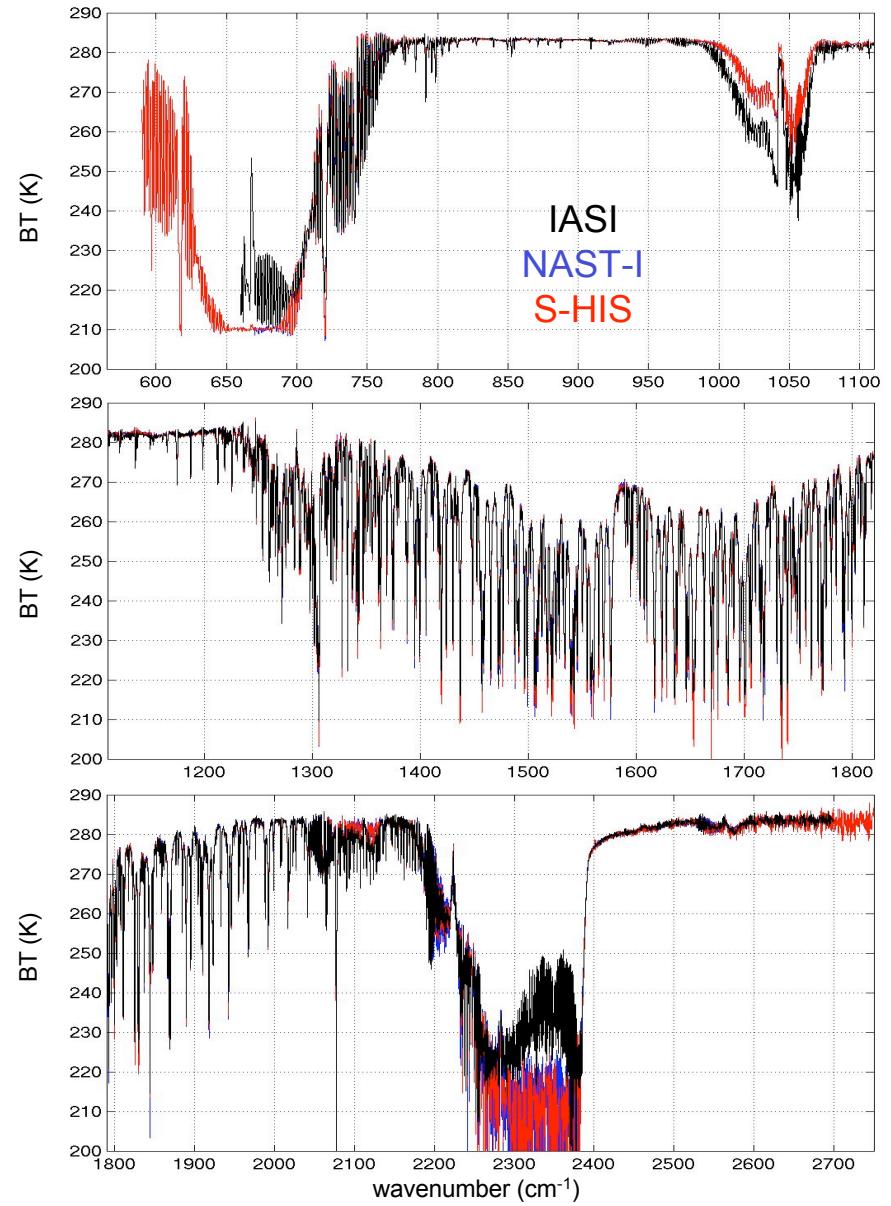
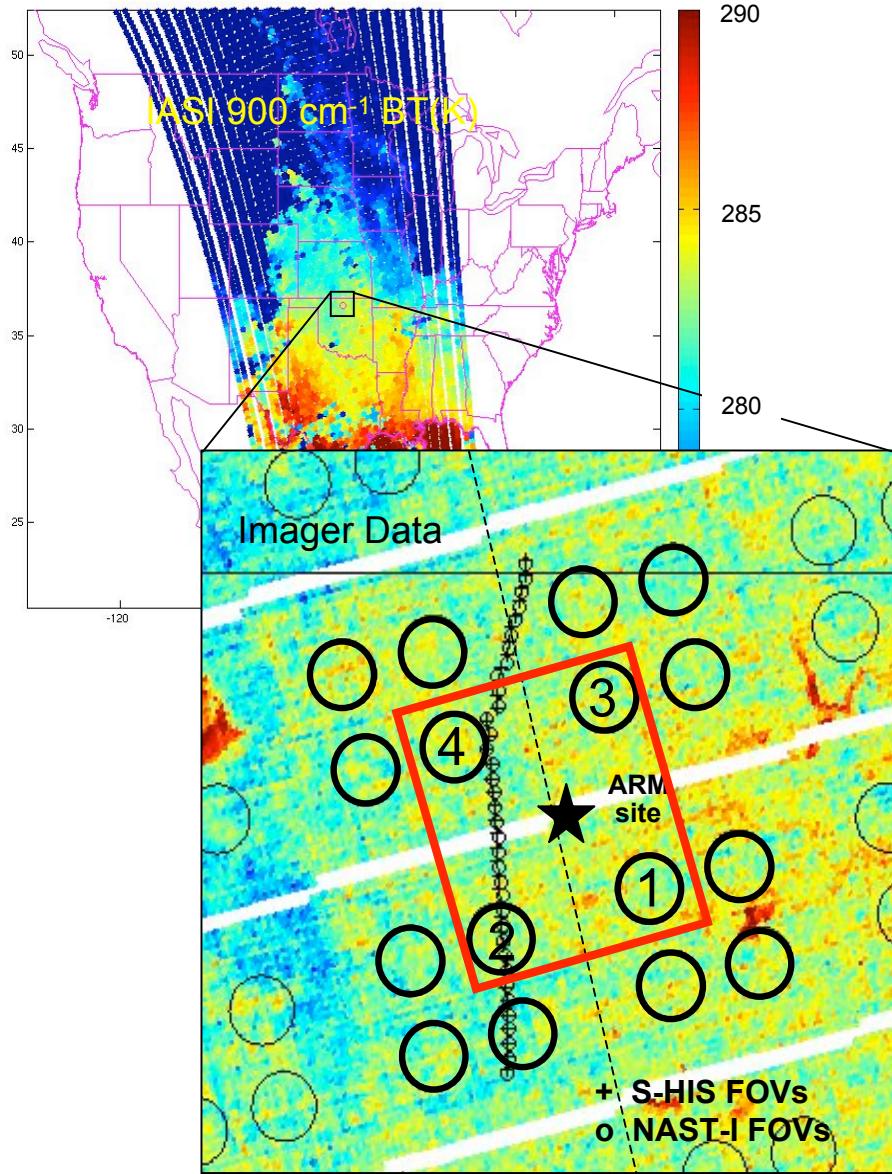
- Location/dates
 - Ellington Field (EFD), Houston, TX, 14 Apr – 4 May, 2007
- Aircraft
 - NASA WB-57 (NAST-I, NAST-M, S-HIS)
 - UK FAAM BAe146-301 (ARIES, MARSS, Deimos, SWS; dropsondes; in-situ cloud phys. & trace species; etc.)
- Ground-sites
 - DOE ARM CART ground site: RAOBS (1.5 hr apart at overpass time), Raman Lidar, AERI, etc.
- Satellites
 - MetOp-A (IASI, AMSU, MHS, AVHRR, HIRS, GOME, SBUV, ACAT)
 - A-train (Aqua AIRS, AMSU, HSB, MODIS; Aura TES; CloudSat; and Calipso)
- Participants
 - US: NASA/LaRC, NASA/JSC, UW, MIT-LL, MIT, NOAA, others
 - Europe: UKMO, FAAM, U. of Manchester, EUMETSAT, U of Bologna, ECMWF, others
- Sponsors
 - US: IPO, NASA, NOAA
 - European: FAAM, UKMO, UK-NERC, EUMETSAT

Seven JAIVEx MetOp Cal/Val Flights



Four CART-site (2 day & 2 night); Three Gulf of Mexico (2 day & 1 night);
Five joint MetOp & Aqua (3 day & 2 night)

JAIVEx 19 Apr 2007 CART-site (03:35 UTC)

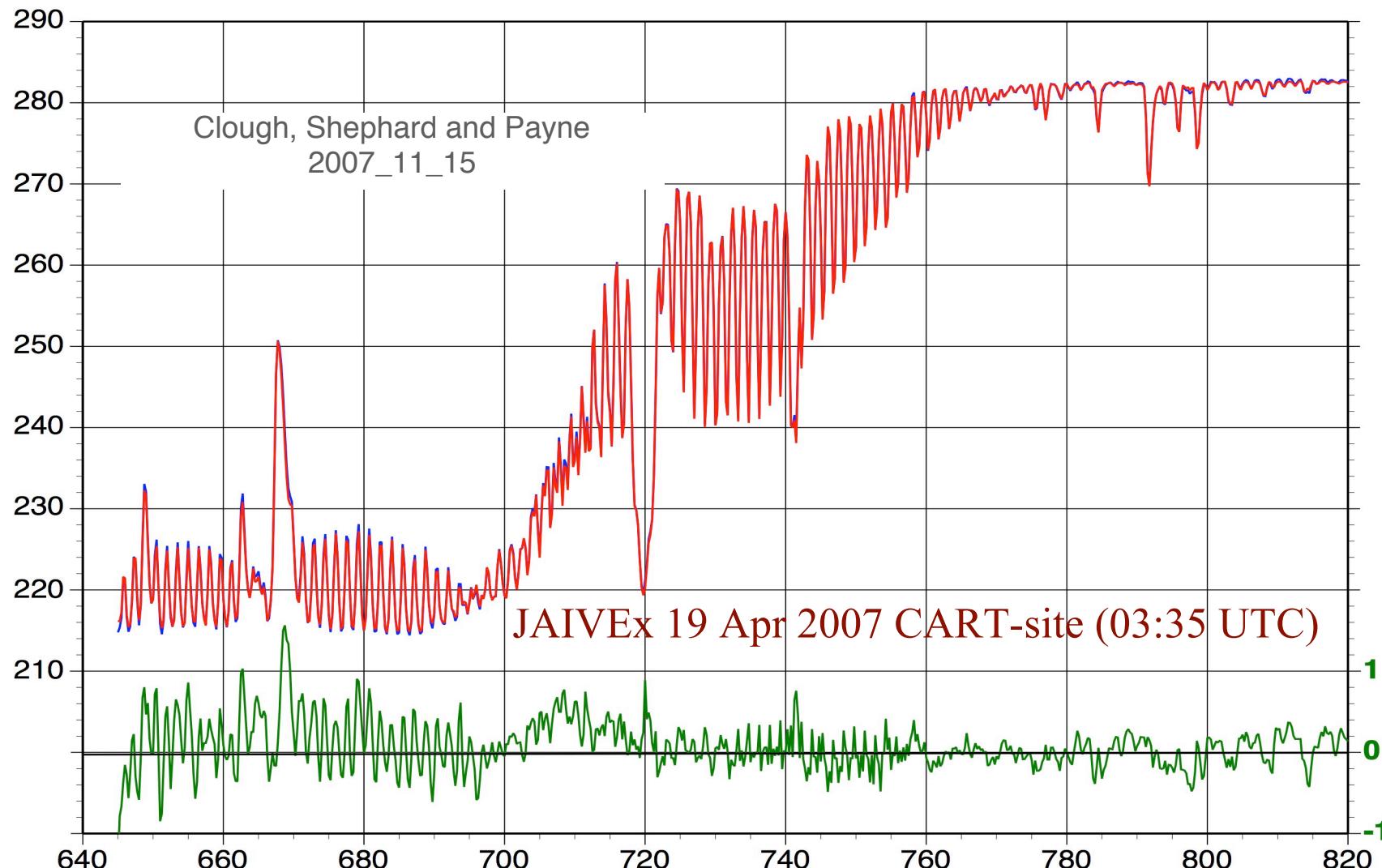


The Forward Model - LBLRTM

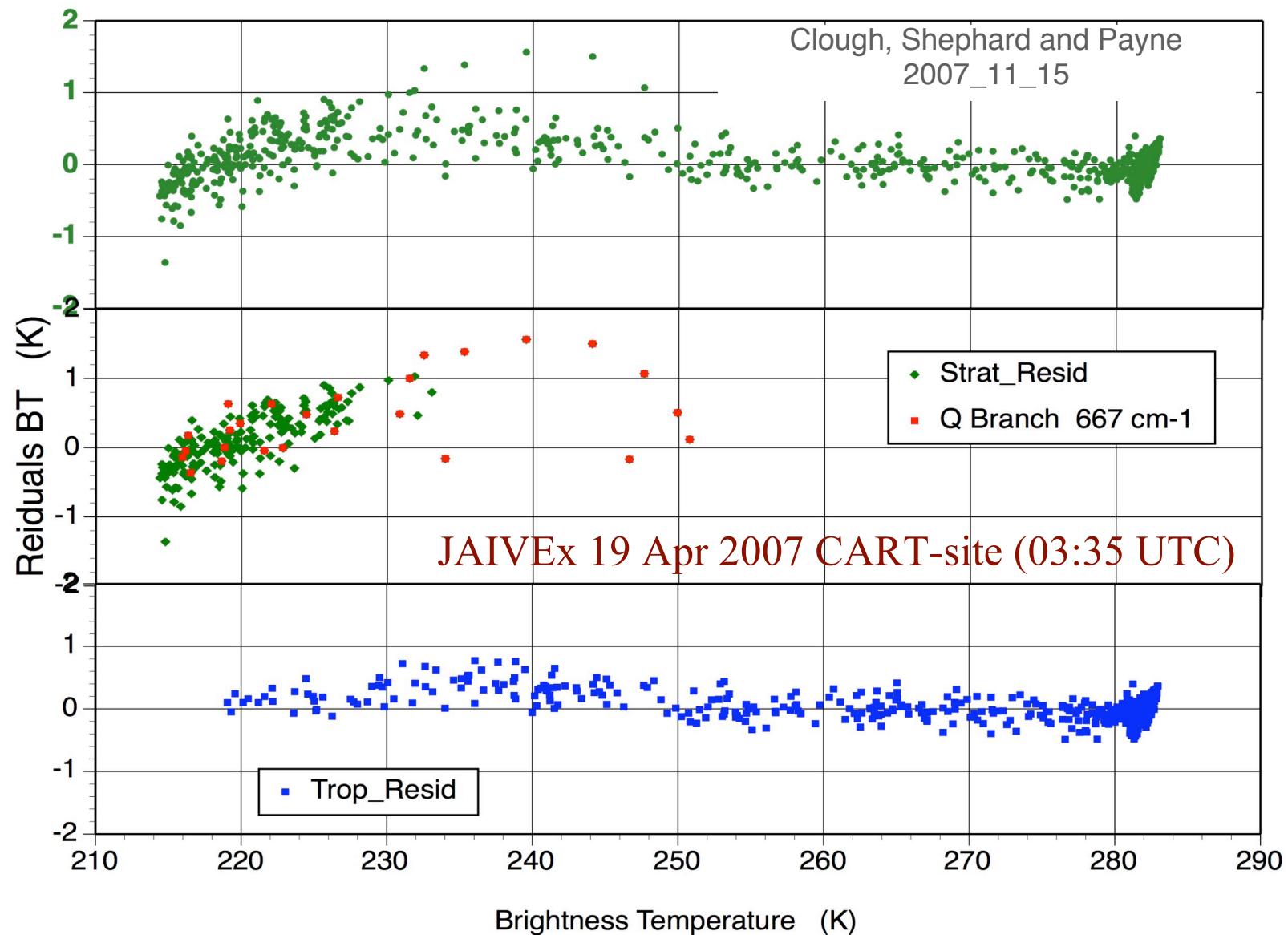
Forward Model: LBLRTM_v11.3 (Clough et. al.,)

Line Parameters: aer_v2.0, HITRAN 2006, **CO₂ Line Coupling:** (Niro et al.,)

Continuum: mt_ckd_2.3, **CO₂ Continuum** with full Line Coupling



Scatter Plot: Residuals vs Brightness Temperature



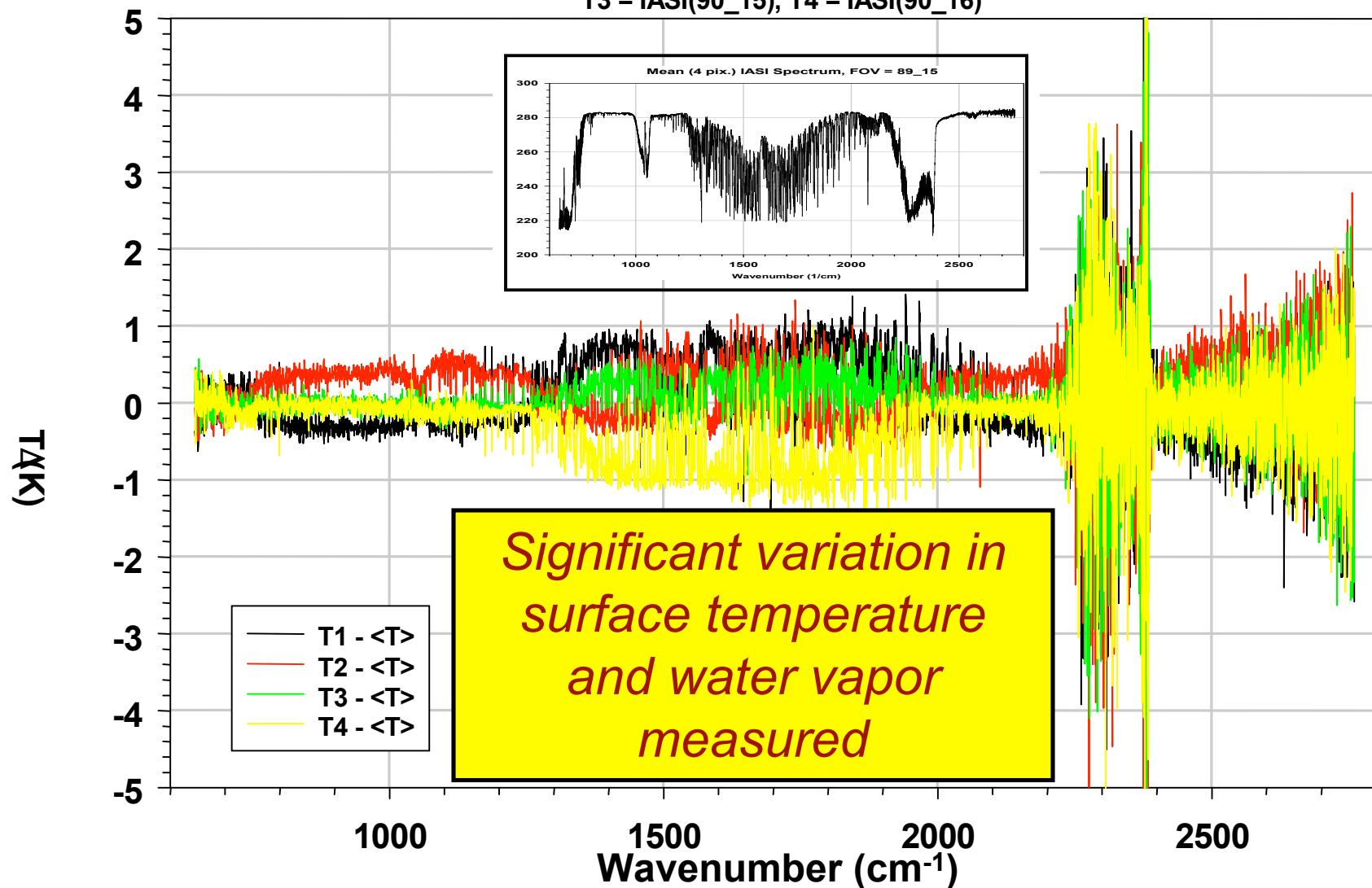
Differences Appear to be Due Mainly to Atmospheric State Errors

Local Variation of IASI Spectra

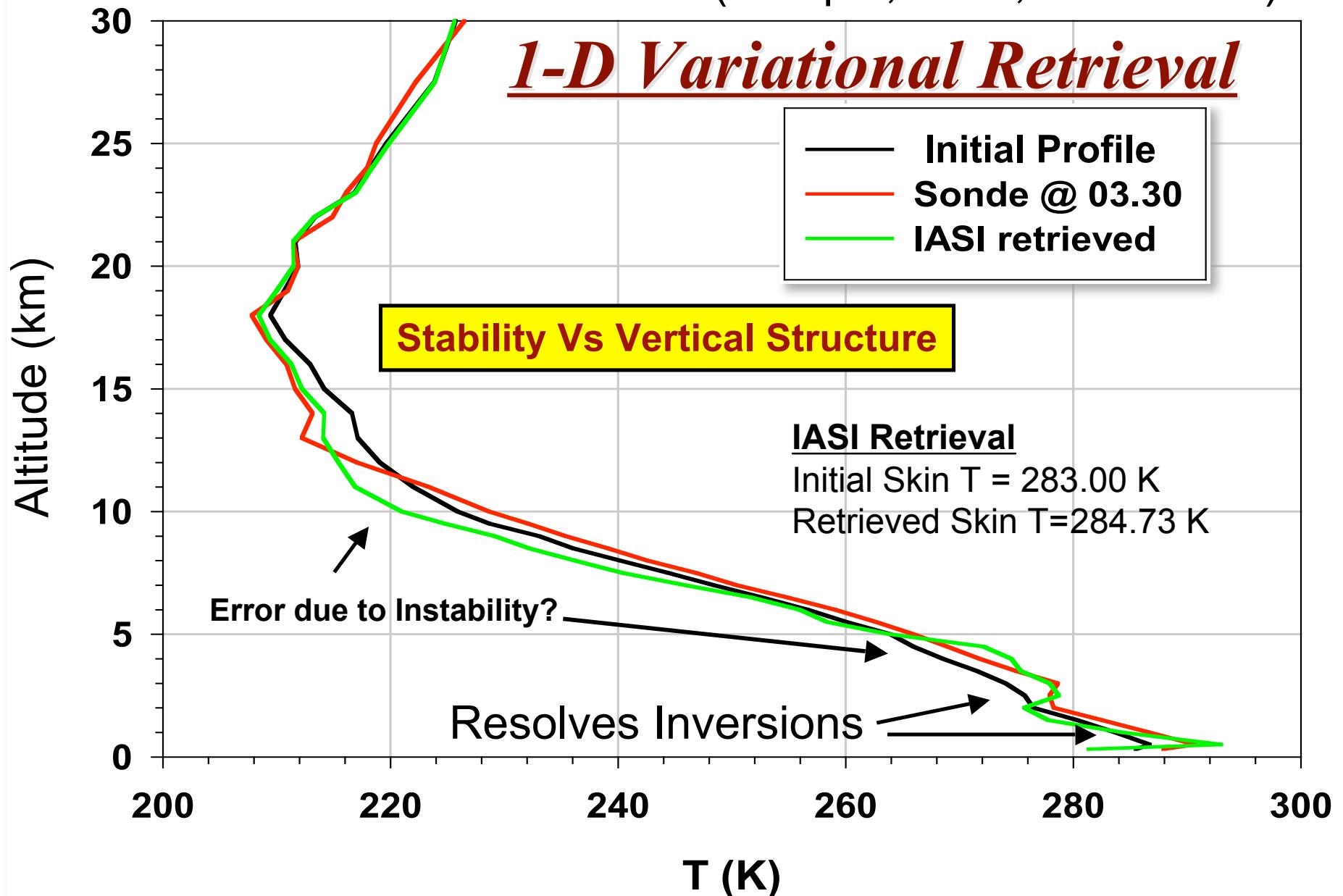
BT difference of measured spectra

T1 = IASI(89_15), T2 = IASI(89_16),

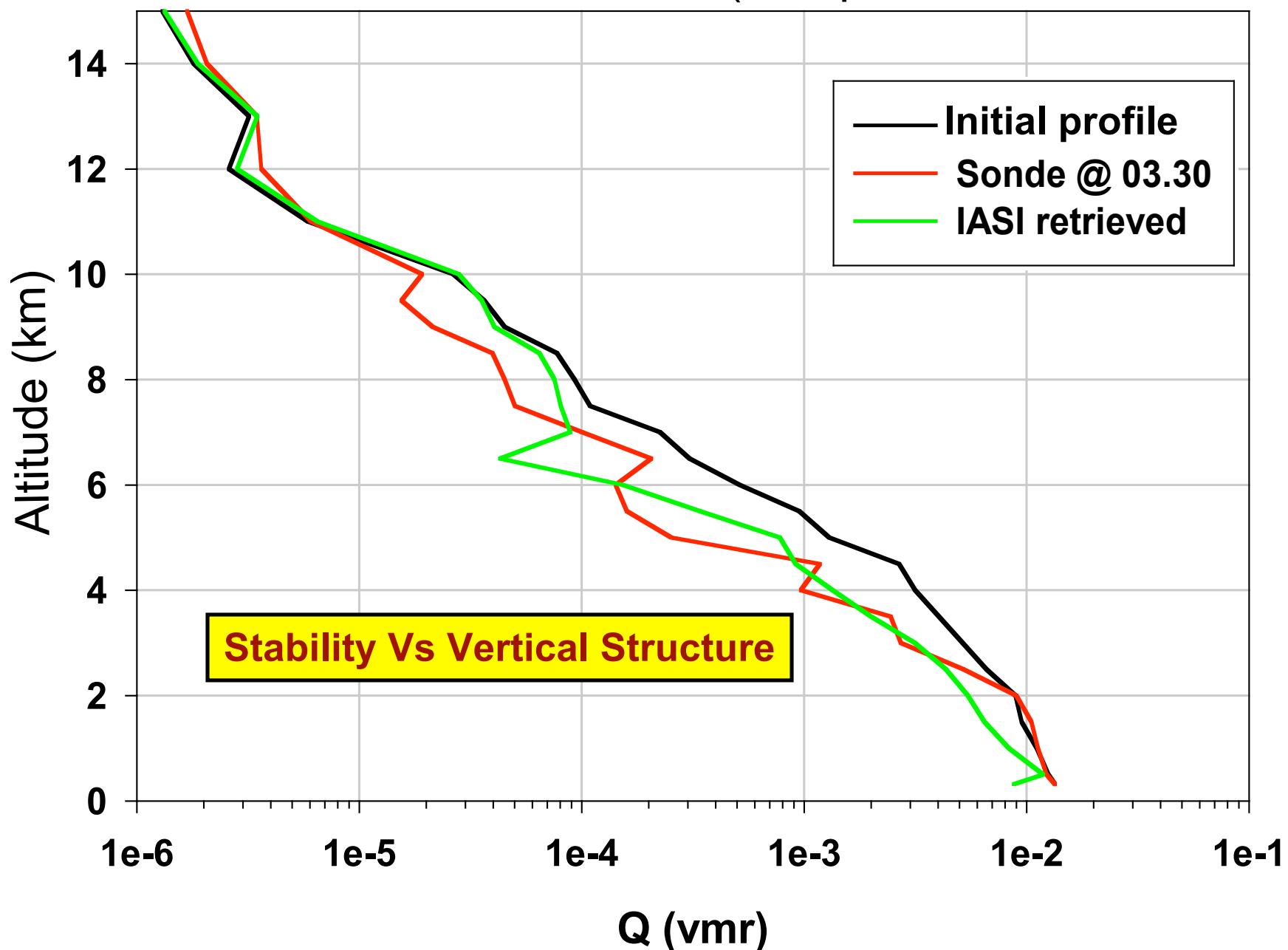
T3 = IASI(90_15), T4 = IASI(90_16)



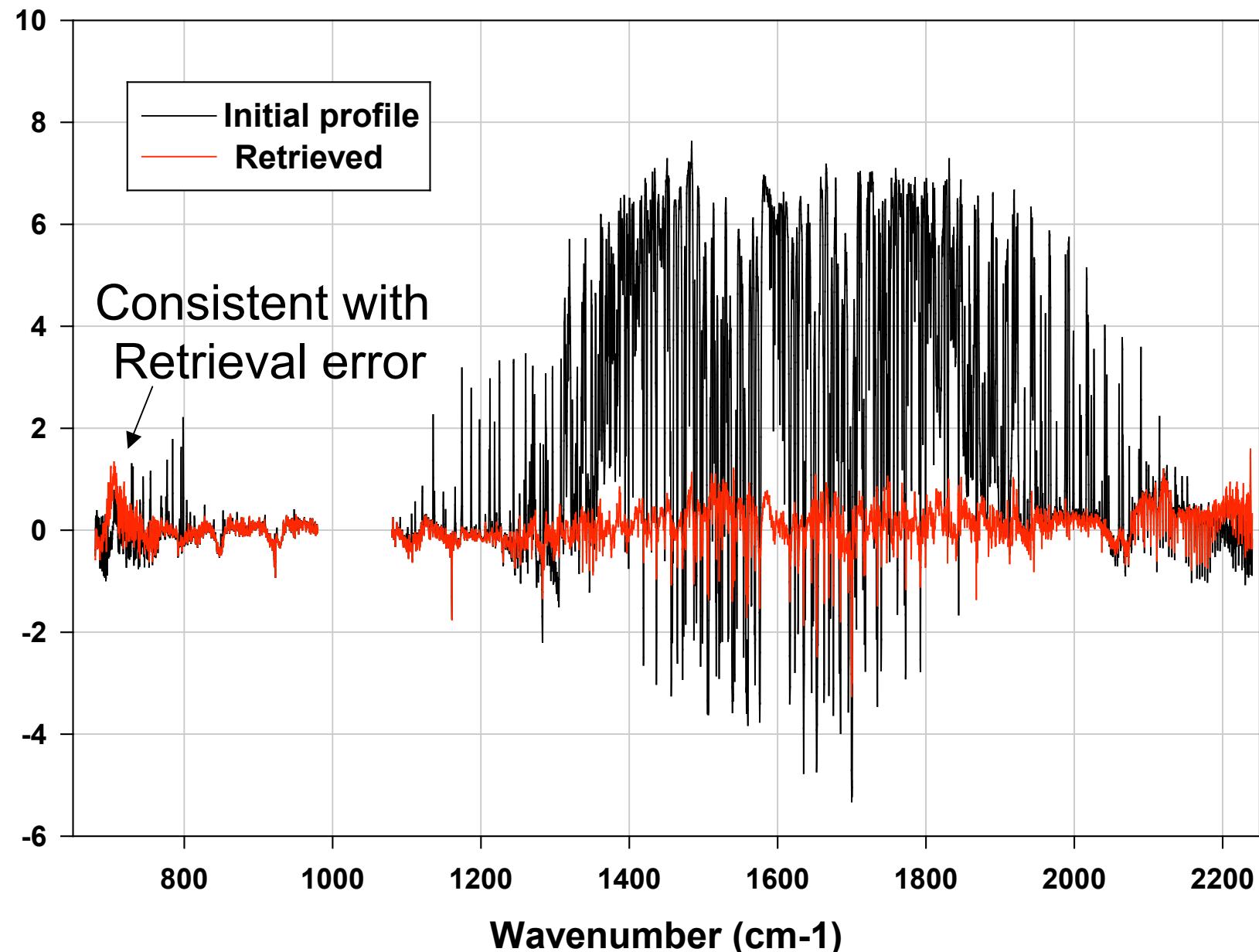
IASI Retrieval at CART-site (19 April, 2007, 03:30 UTC)



IASI Retrieval at CART-site (19 April, 2007, 03:30 UTC)



BT Residual: Observed - Calculated



PC Physical/Statistical Retrieval

Initial Profile Retrieval:

$$\mathbf{a}(T, Rh) = \mathbf{G}(A, R) \mathbf{r}(T, Rh, T_s, \varepsilon_s, \text{gases}, \dots)$$

- $\mathbf{G}(A, R)$ is a regression matrix relating atmospheric profiles (A) to LBLRTM calculated IASI radiance spectra (R) for a statistically representative set of surface and atmospheric profile conditions
- a is a vector of atmospheric state pc scores
- r is a vector of radiance pc scores

$$R = R^{*T} r_v$$

- R^* is a matrix of radiance spectra PCs, R^{*T} being the transpose of R^*
- r_v is a vector of radiances (i.e., an individual radiance spectrum)

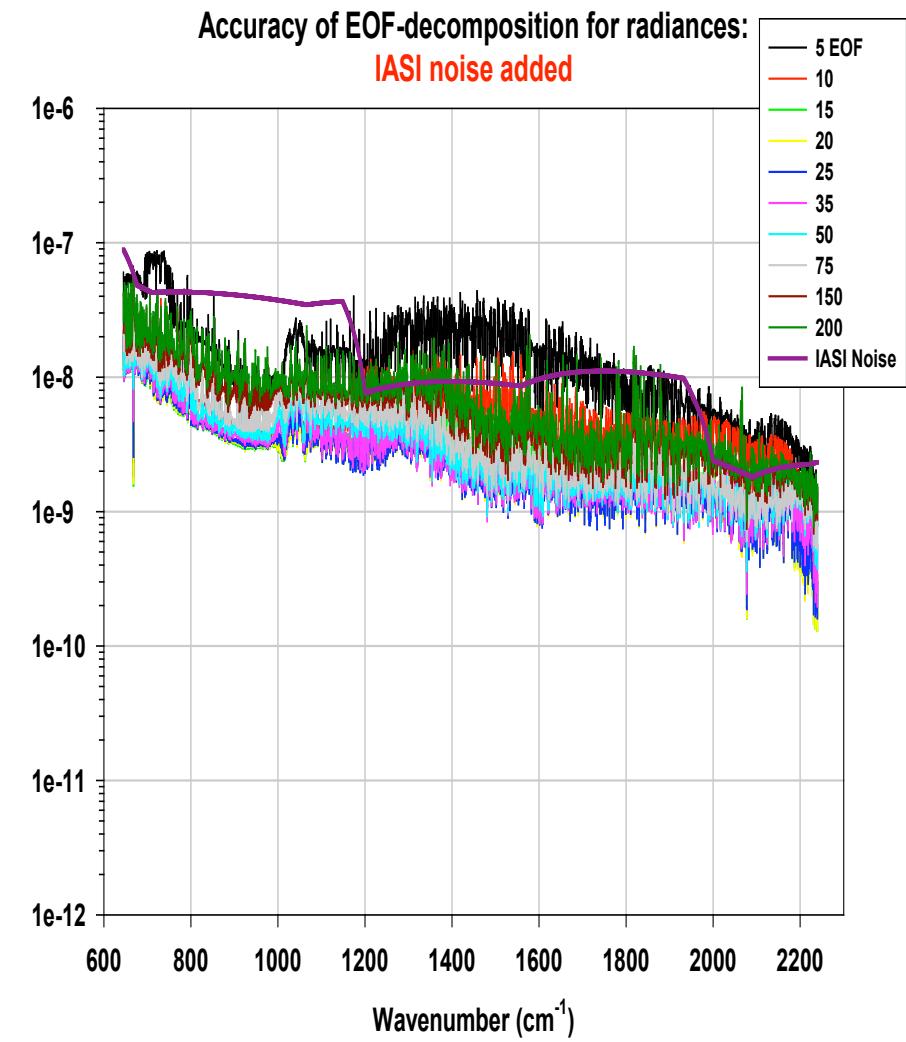
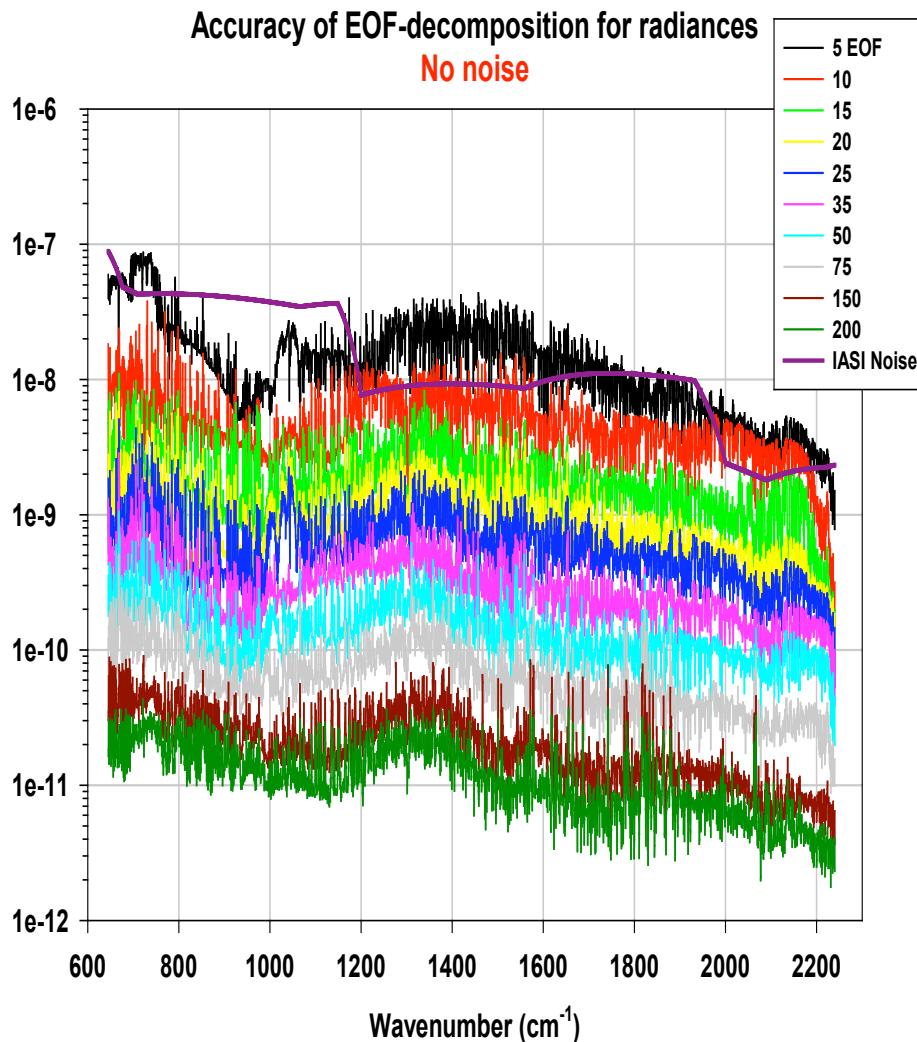
$$T/Rh = \mathbf{a}(T, Rh) \mathbf{A}^*$$

- T/Rh is a vector of the temperature (T) and humidity (Rh) profile values, plus sfc T , sfc emissivity PC scores, etc.
- A^* is a matrix of atmospheric state PCs

All LBLRTM IASI simulated radiance and atmospheric statistics defined from 236 radiosonde *10 randomly selected surface temperature/emissivity conditions per radiosonde sounding (2360 radiance spectra cases)

IASI Radiance Fit Vs Number of PCs

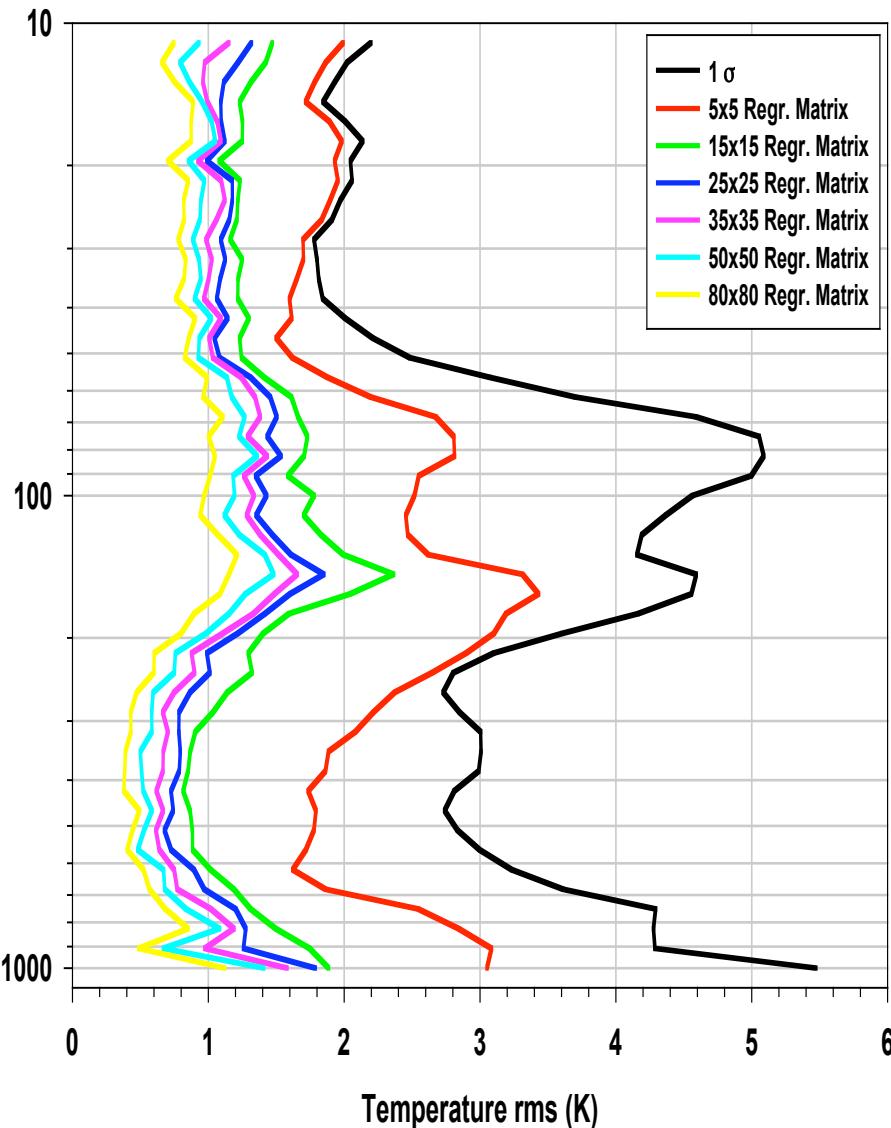
(Independent Pieces of Radiance Information For JAIVEx)



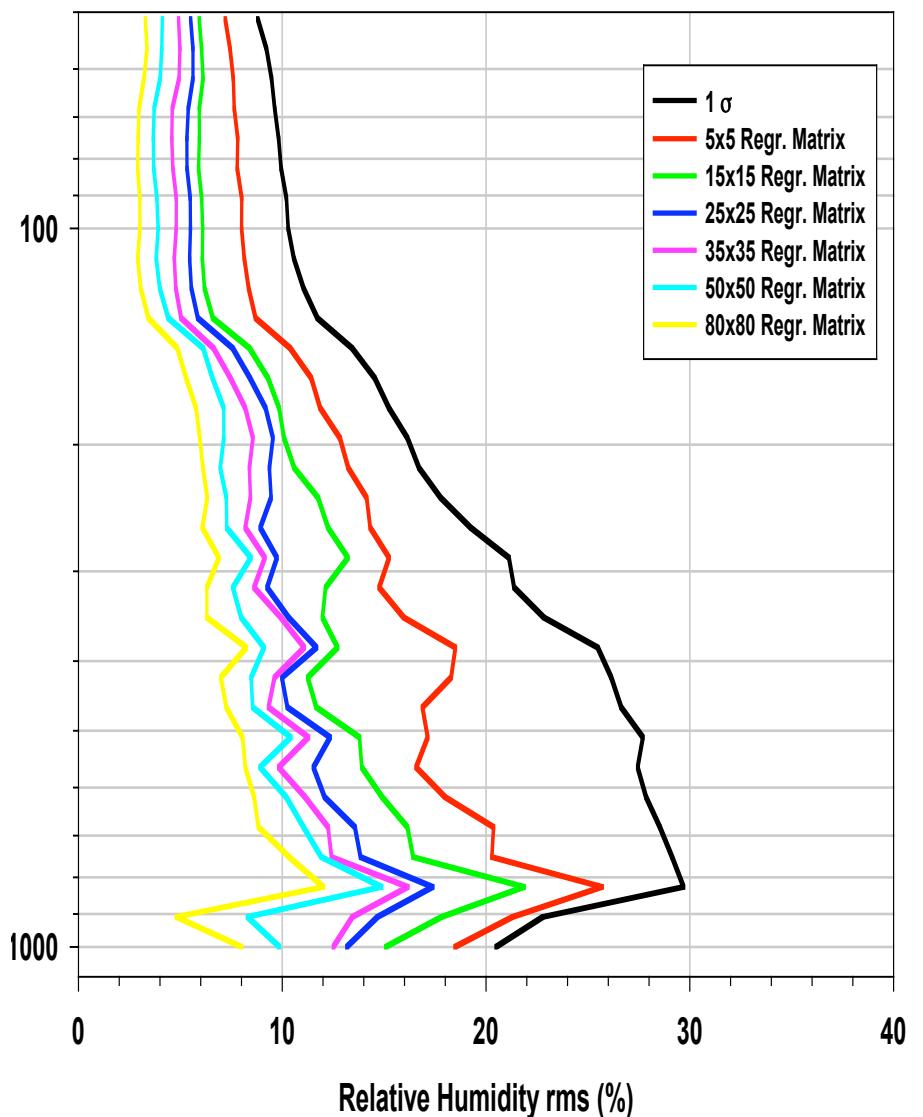
IASI Retrieval Accuracy Vs Number of PCs

(Independent Pieces of T & Q Information For JAIVEx)

T(p) regression retrieval, no noise



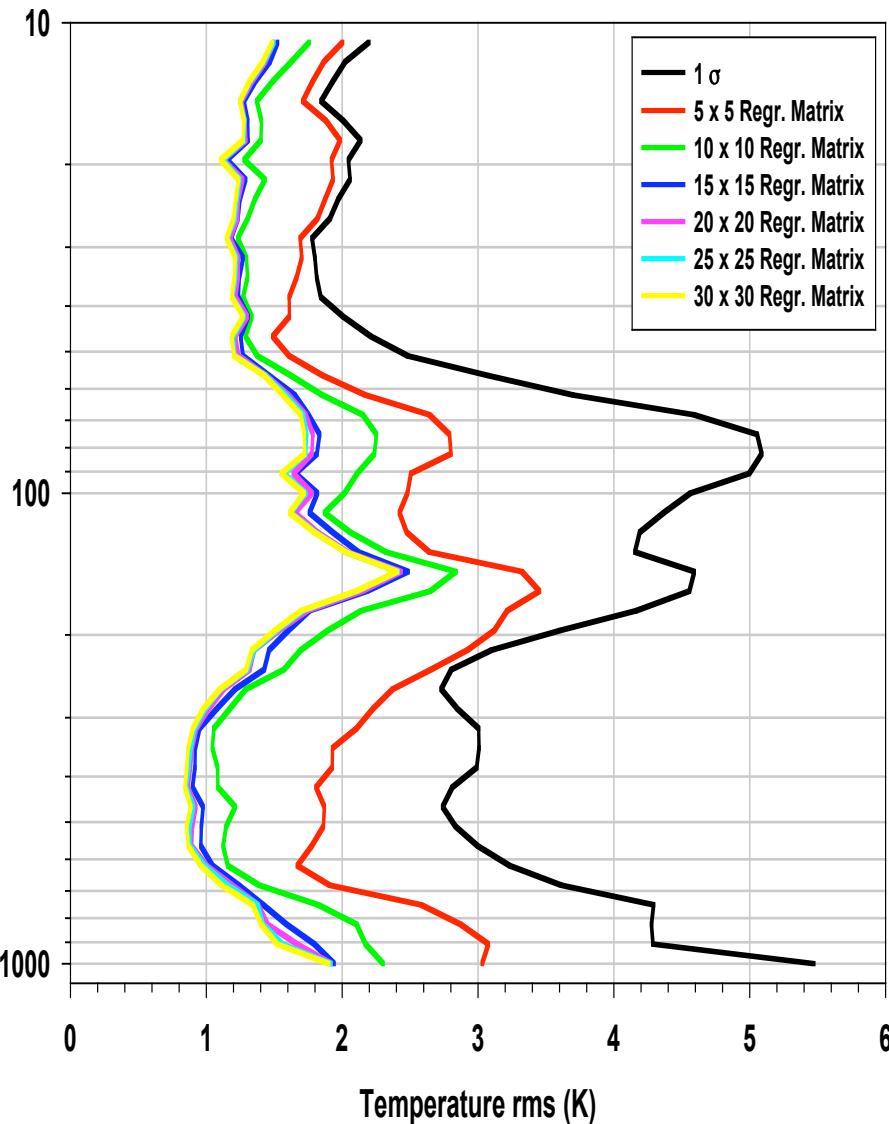
Q(p) regression retrieval, no noise



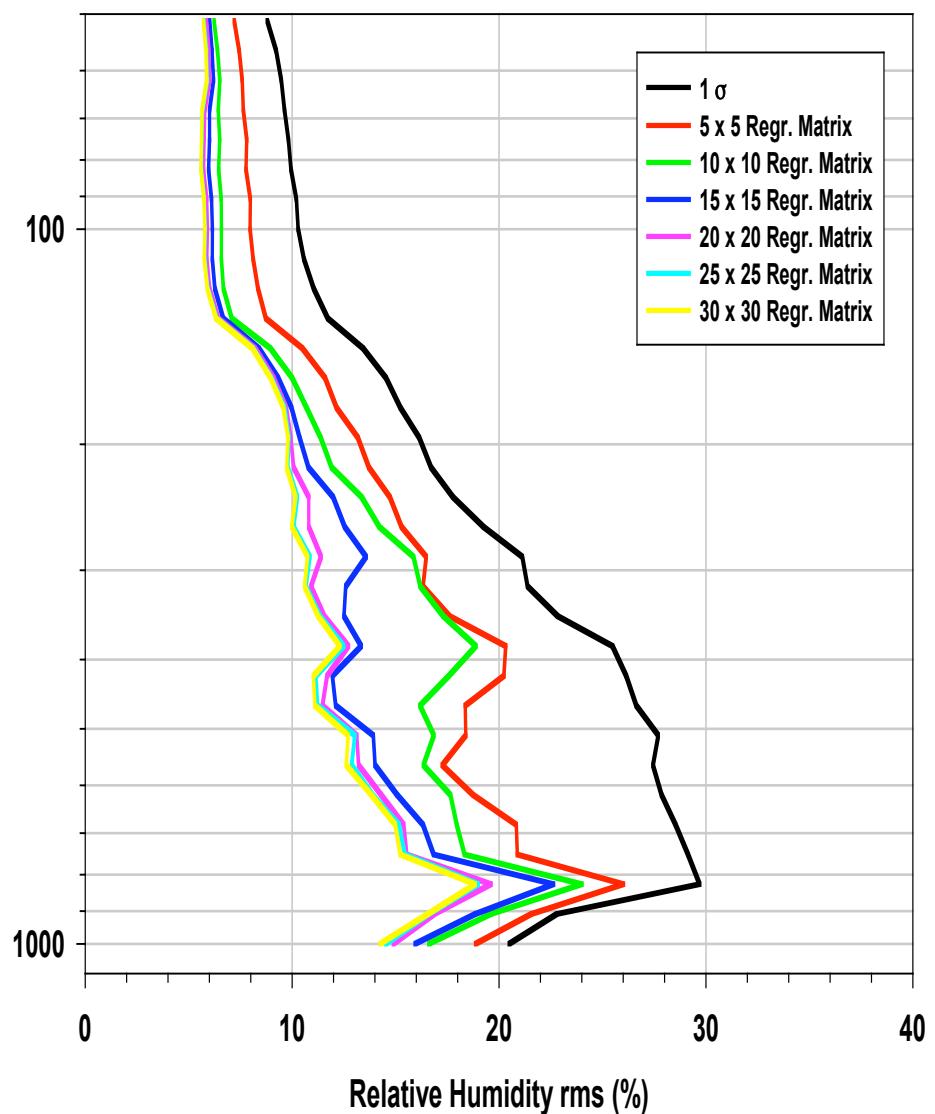
IASI Retrieval Accuracy Vs Number of PCs

(Independent Pieces of T & Q Information For JAIEx)

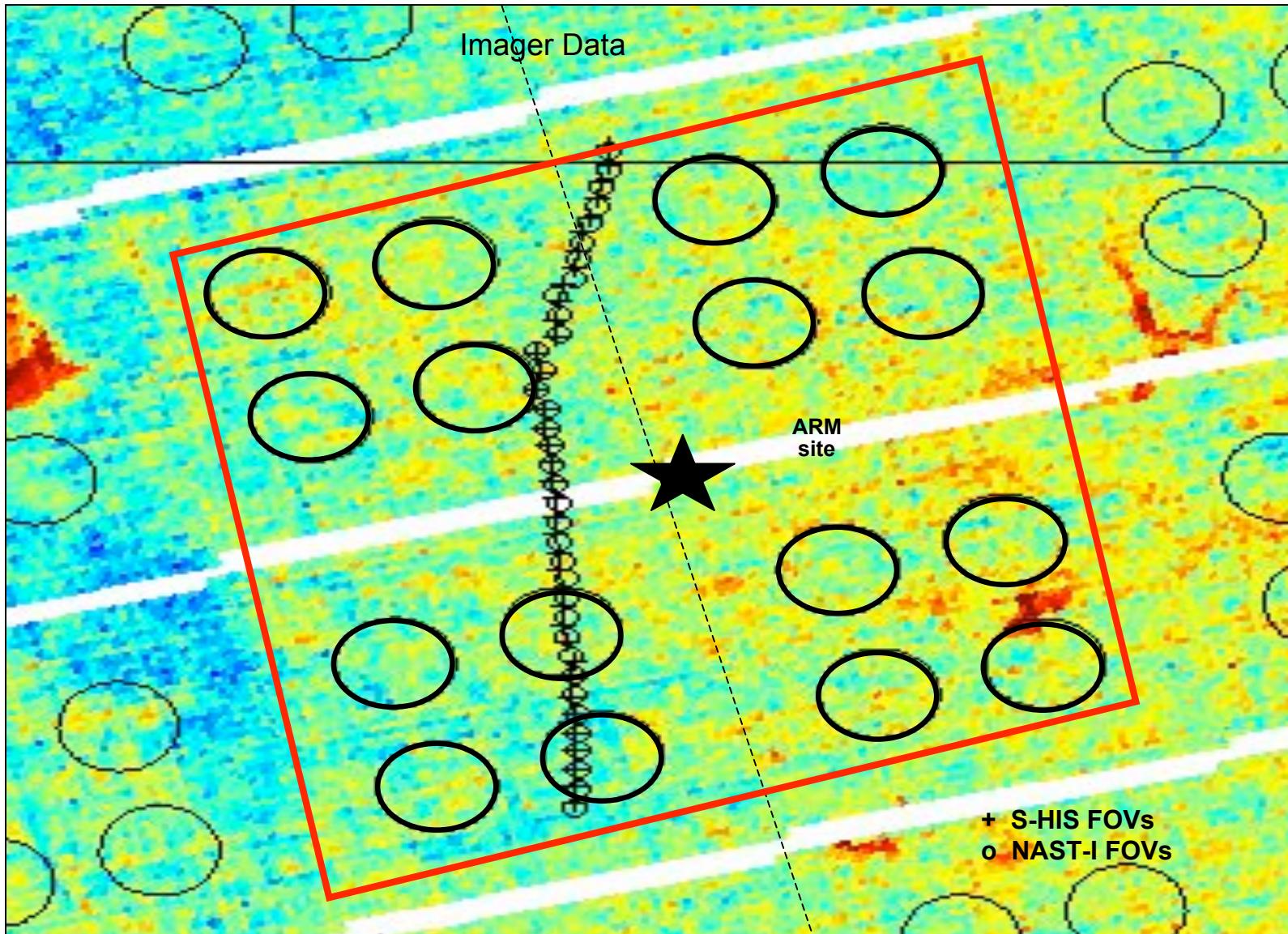
T(p) regression retrieval, noise added



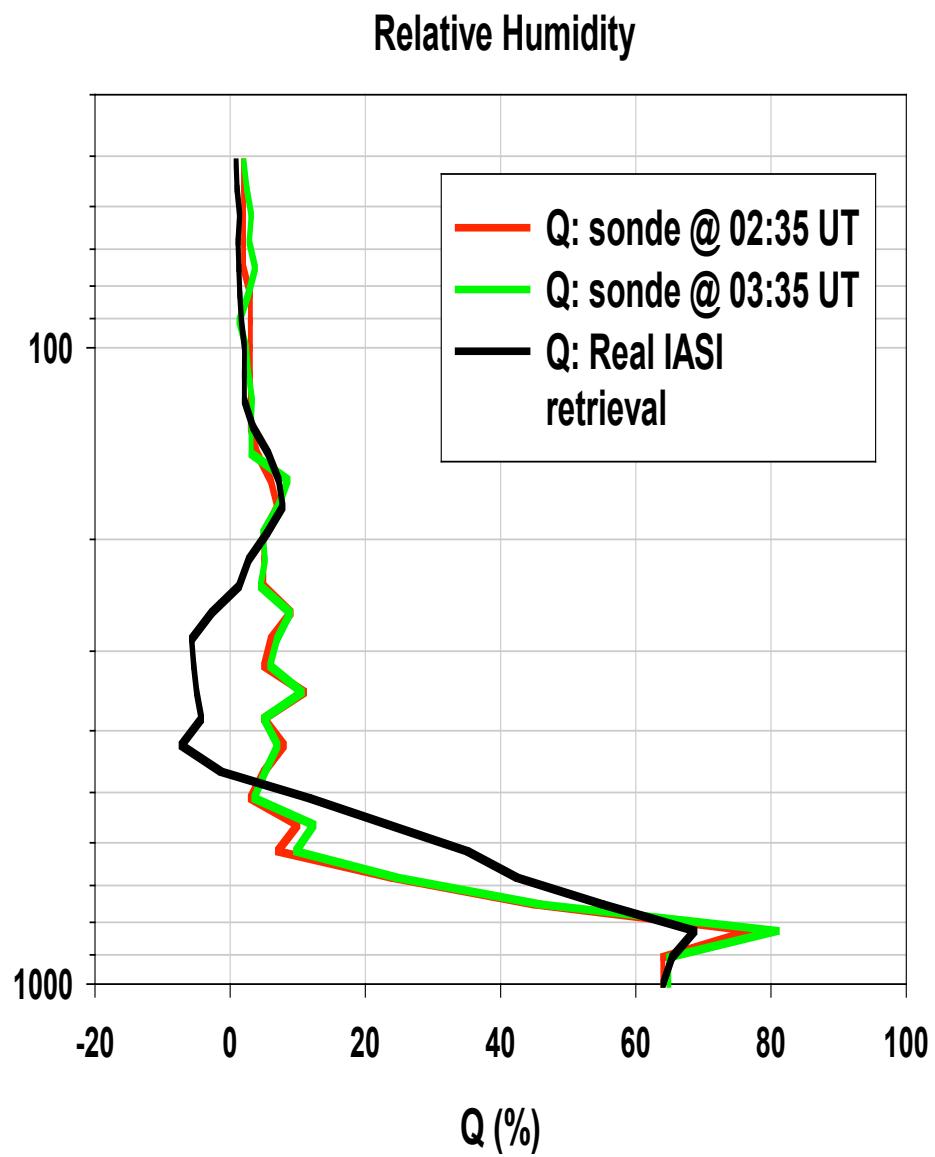
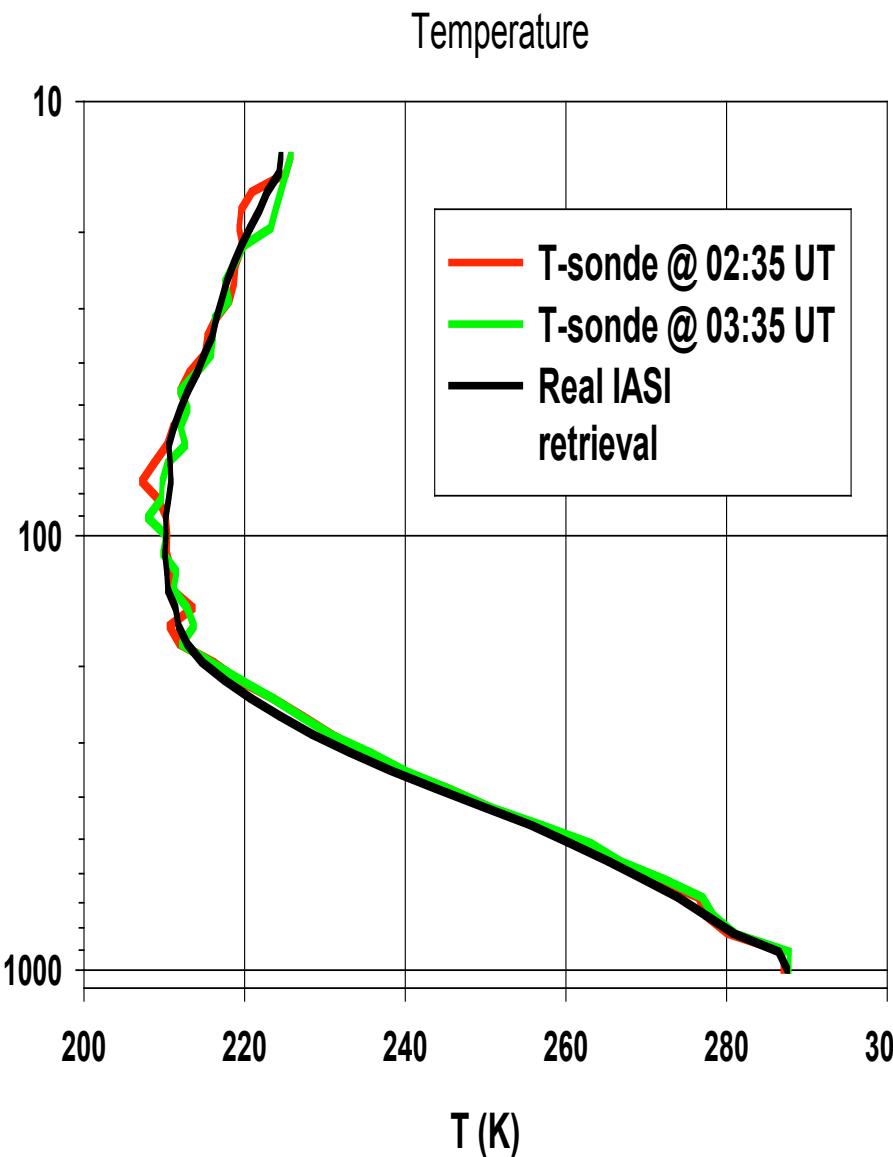
Q(p) regression retrieval, noise added



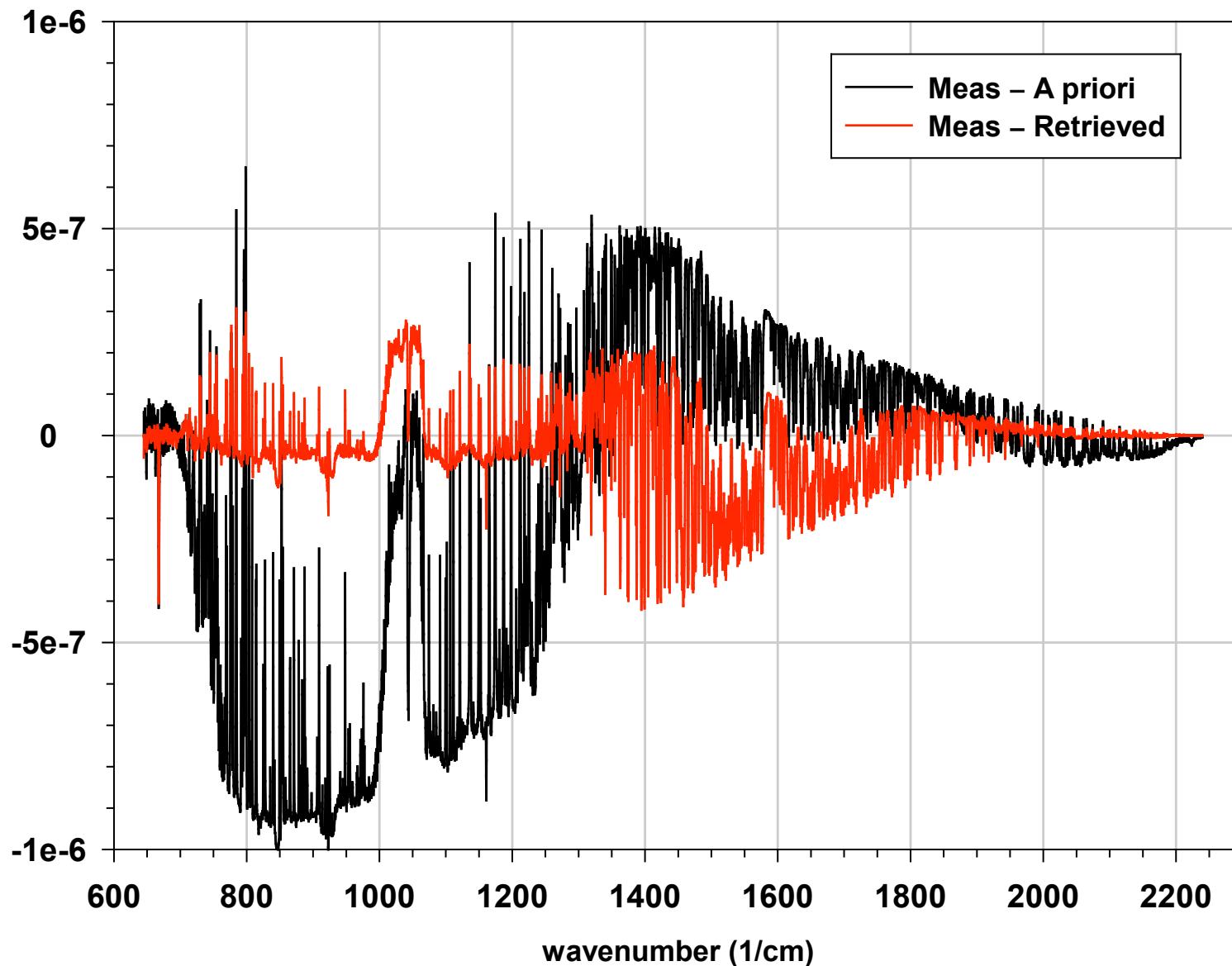
JAIVEx 19 Apr 2007 CART-site (03:35 UTC)



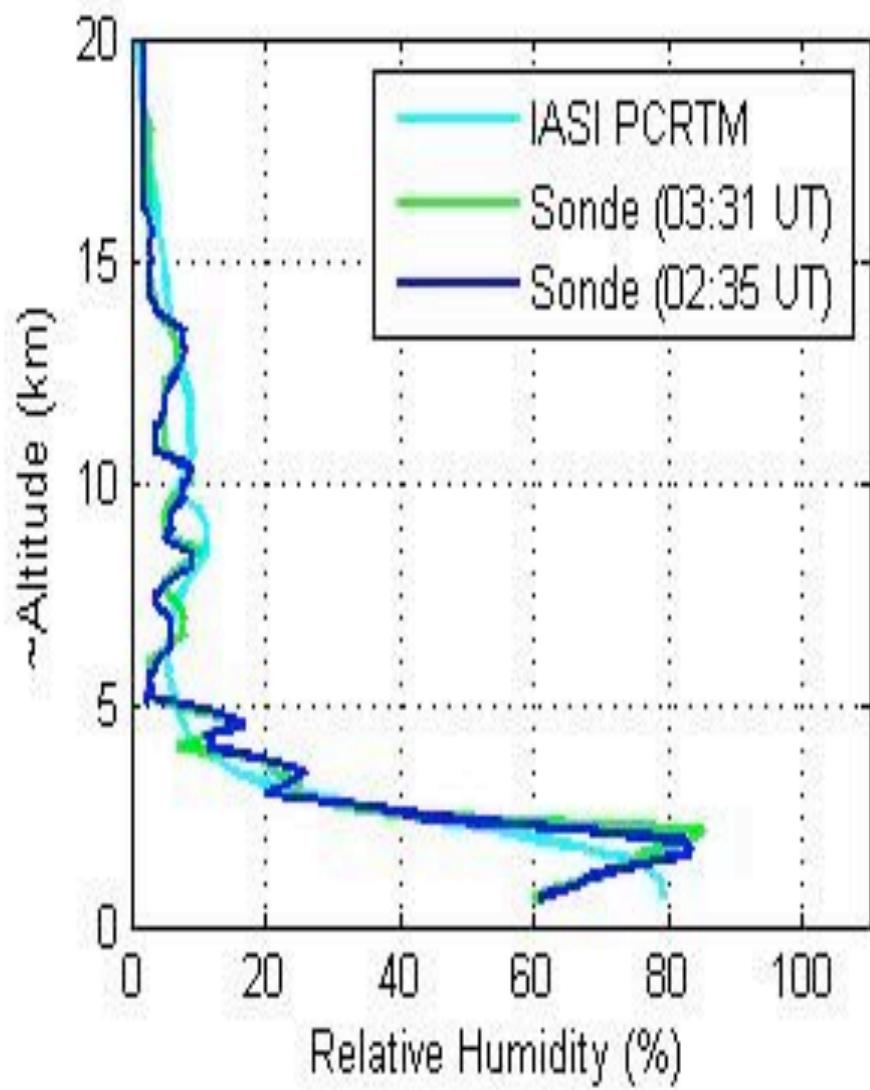
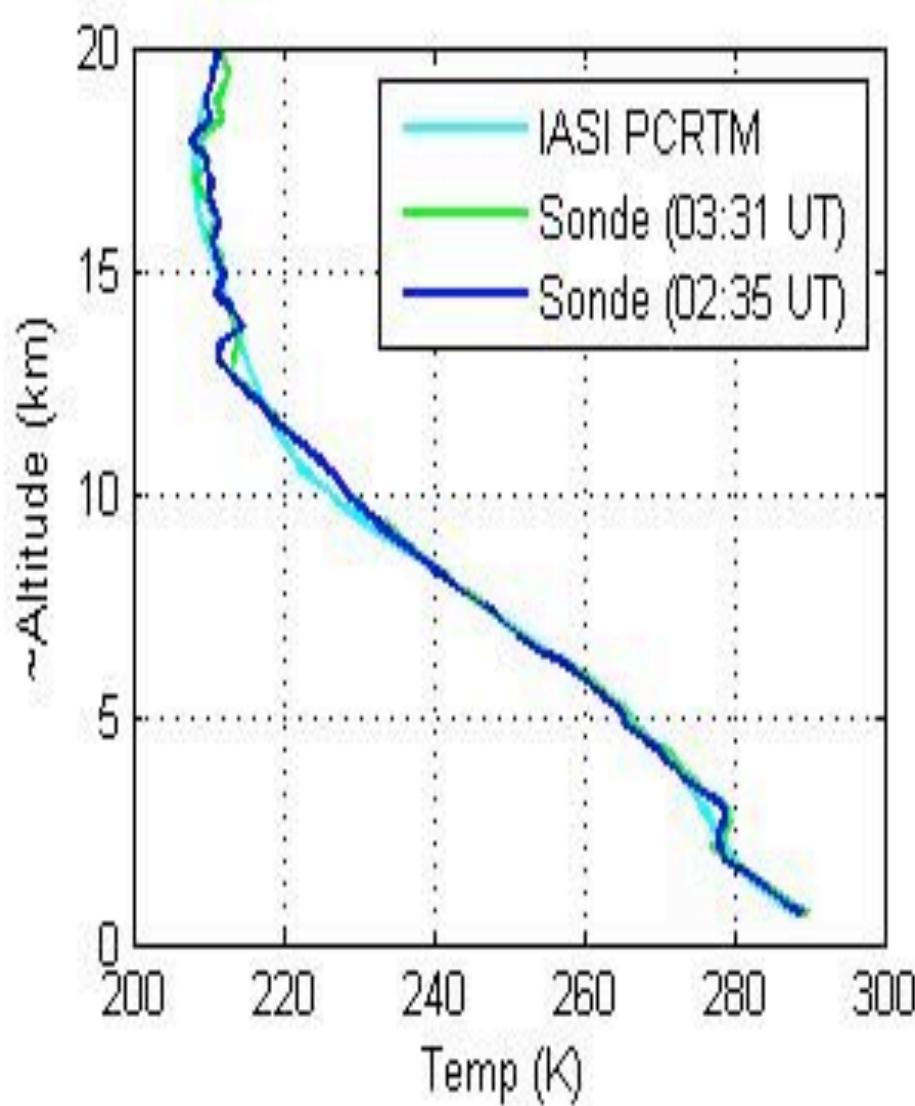
IASI Regression Retrievals



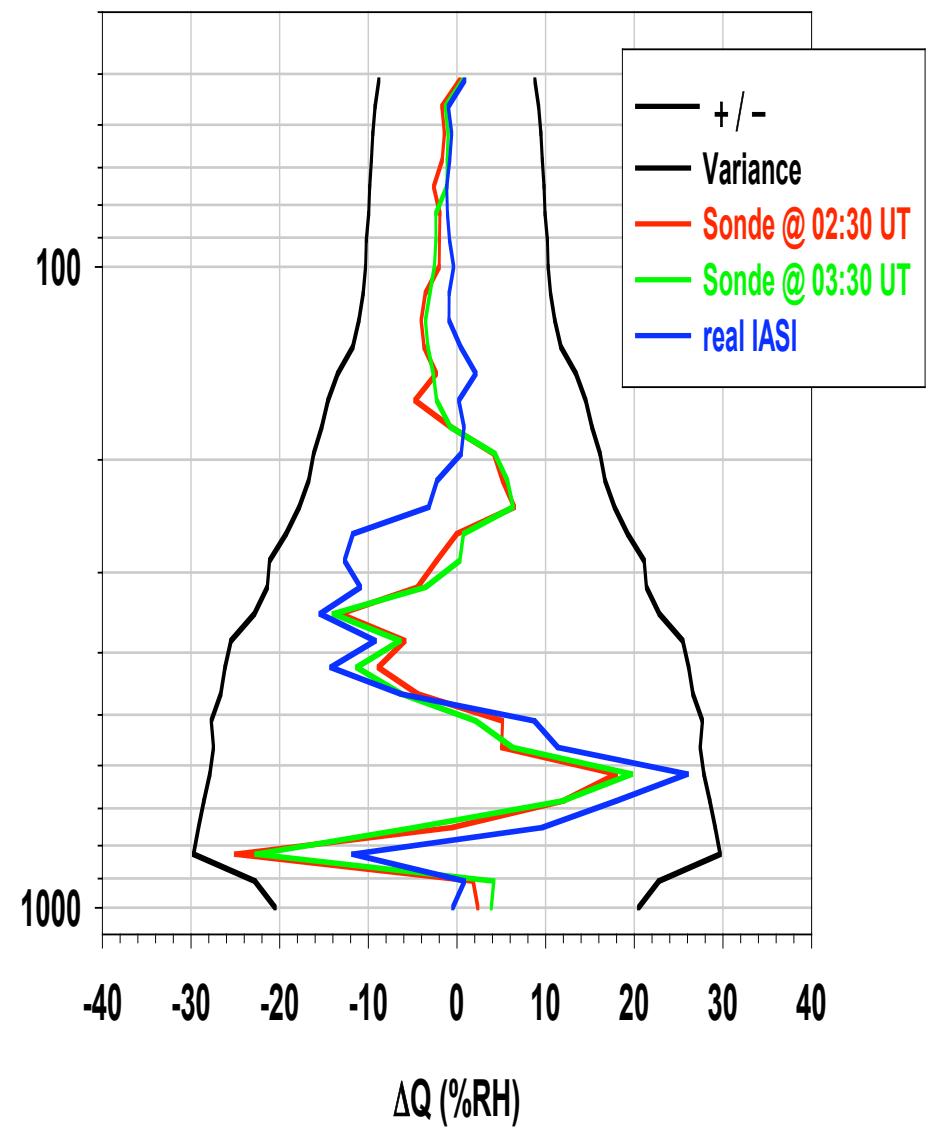
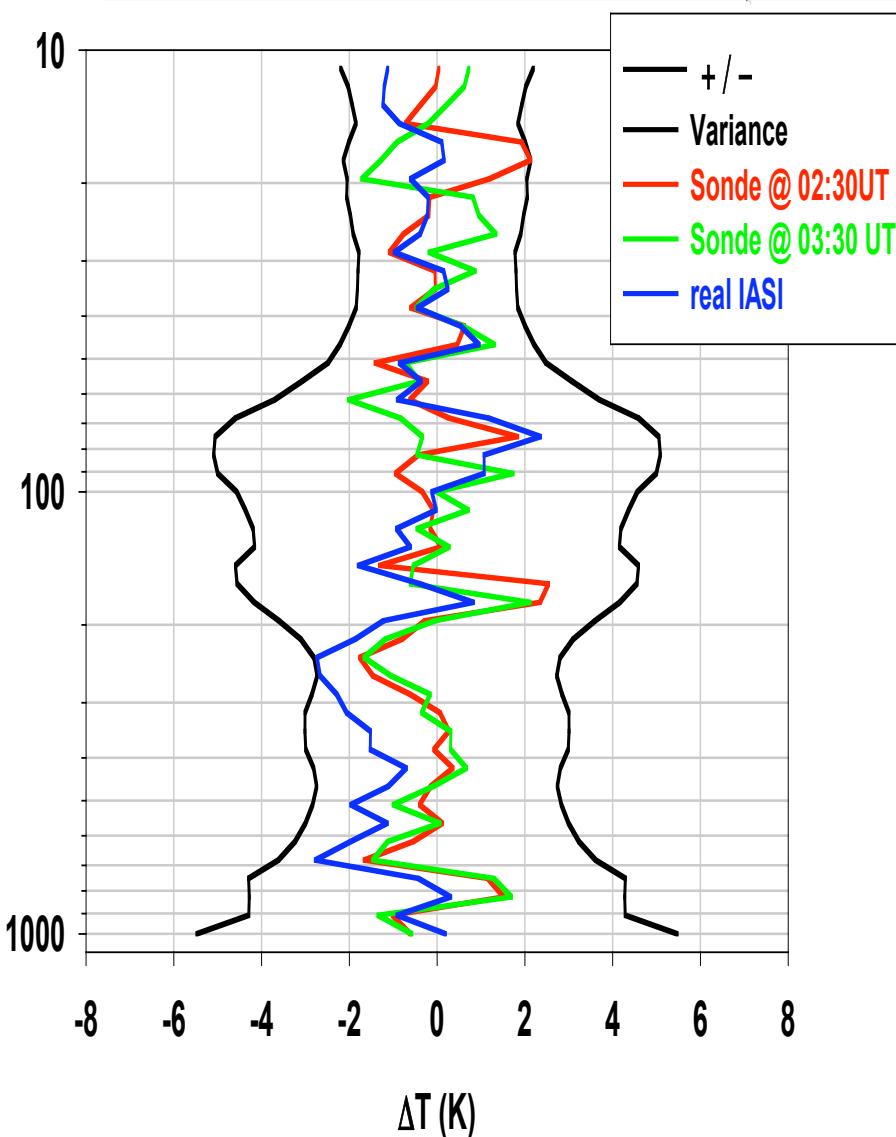
IASI Radiance Residuals



A Final Physical Retrieval Step Important For Resolving the Fine Scale Vertical Structure (Xu Liu, shown earlier)

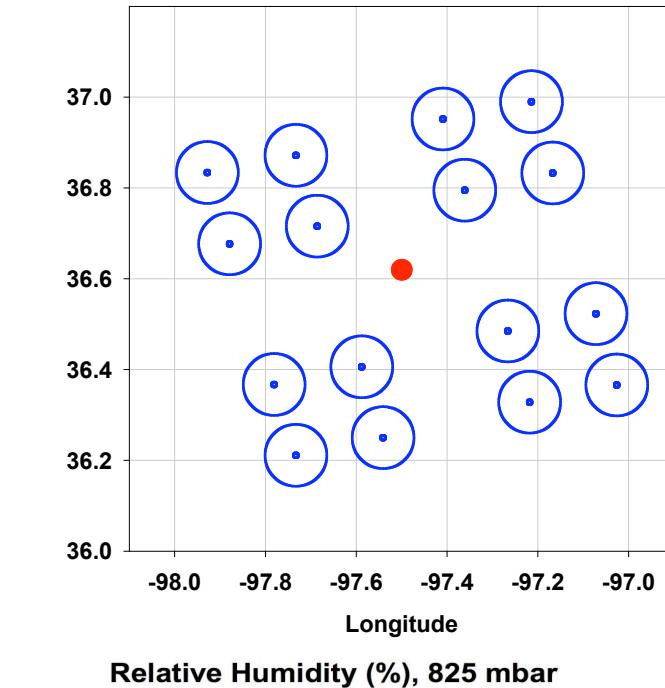


Retrieval Error (Real Vs Sonde Simulated)

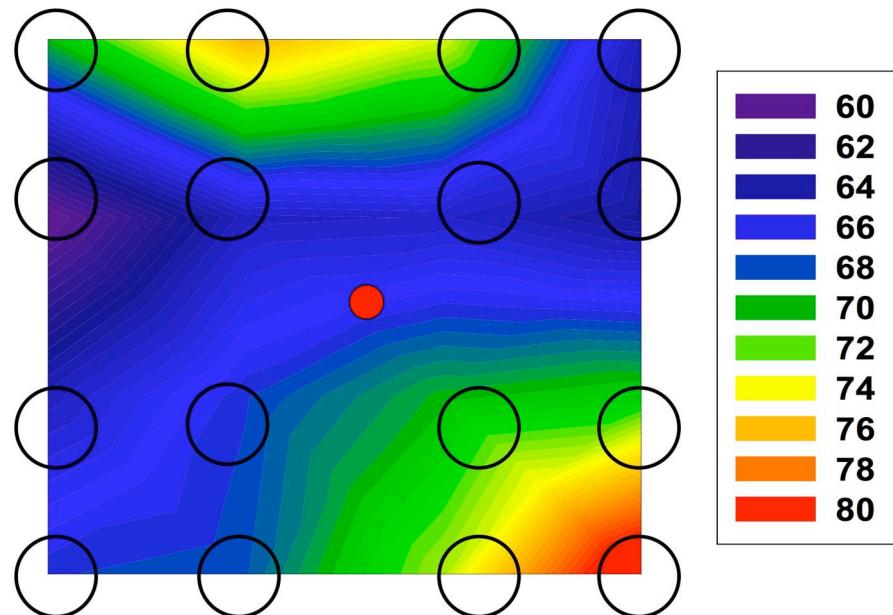


Real IASI is Very Close To Sonde Simulated Retrieval!

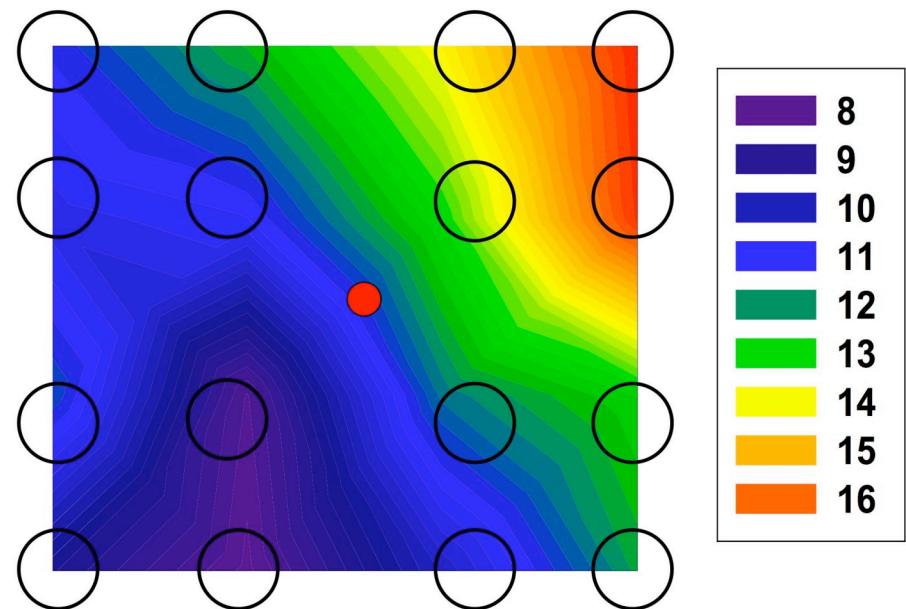
IASI over CART site, April 19, 2007, 03:35 UTC



Relative Humidity (%), 825 mbar



Relative Humidity (%), 500 mbar



*IASI Moisture Retrieval
Across the CART-Site
Showing Vertical
Independence of Moisture
Gradient Retrieval*

Net Steps Toward Very Fast Physical/Statistical Retrieval

Physical Retrieval with “optimal” γ after regression initial profile:

Step 1: regression retrieval

$$C_A = G^* C_R \quad \rightarrow \quad \gamma = K_0^T [G^T (G G^T)^{-1} - K_0]$$

Where γ yields the regression retrieval using the Jacobian for the mean profile

Step 2: “physical” retrieval

$$G_{\text{NEW}} = [\gamma + K^T K]^{-1} K^T \quad \rightarrow \quad C_A = G_{\text{NEW}}^* C_R$$

Where K is now the Jacobian for the regression retrieval

Goal: One iteration using PCRTM for efficient use of all the radiances

Stay Tuned !

Lesson Learned

- JAIVEx is a very successful cal/val field program !
- Use “All” the Channels !
- IASI is excellent !
- Lower noise will lead to even higher vertical resolution !
- Suomi’s 11th Commandment:
*“Thou Shalt Not Worship
The Radiosonde”*

Congratulations
To All The IASI Team

Well Done!