Validation of the forward/inverse physical scheme φ-IASI with NAST-I and IMG data.

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Forward/Inverse Tools

The φ-IASI package

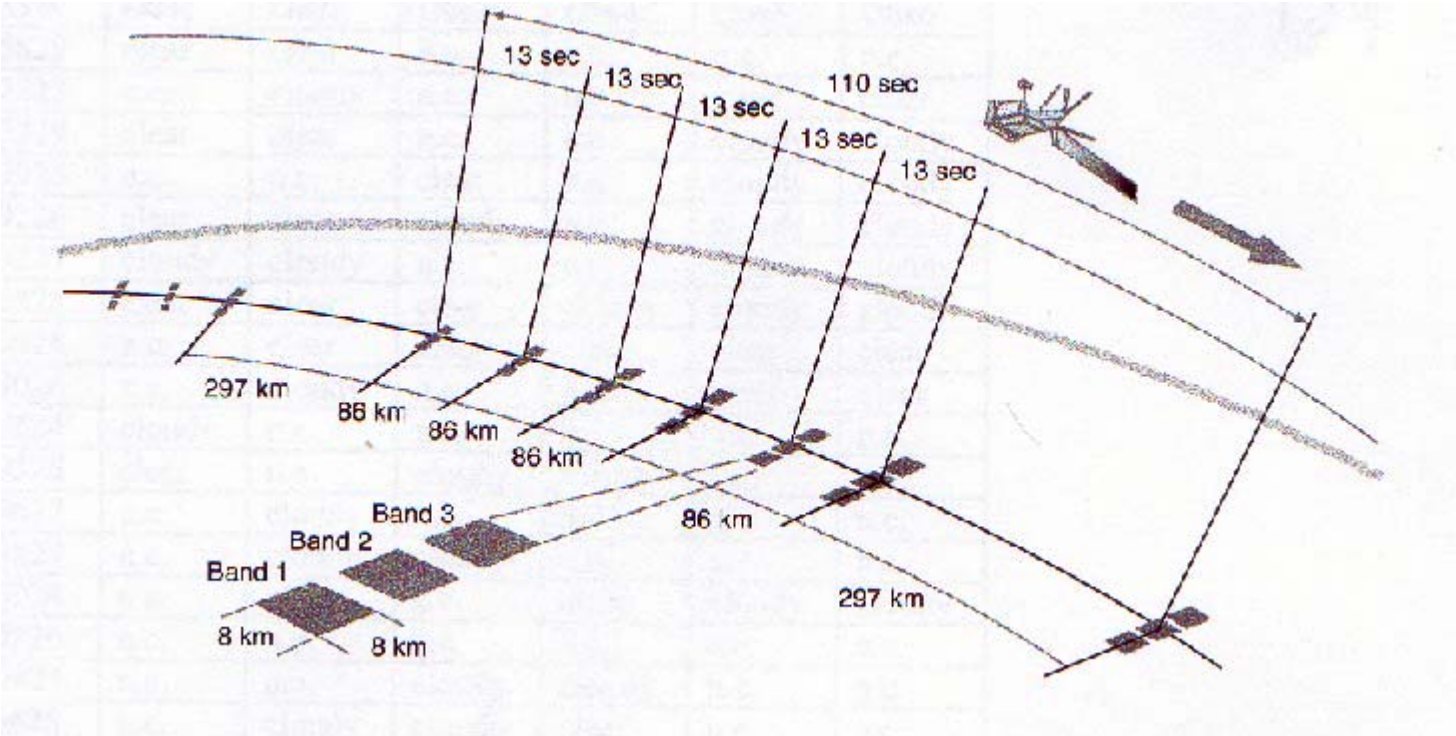
- **σ-IASI:** forward model
- **δ-IASI:** physical inverse scheme
- **ν^2-IASI:** neural network inversion scheme
- **ε-IASI:** EOF based regression scheme

- **γδσ-IASI:** Cloud Detection Scheme
- Masiello et al. JQSRT, Vol 77/2, 131-148, 2003
- *Masiello, et al. Appl. Opt.* ***43,*** *2004*

REFERENCE FRAME

- IASI project: Infrared Atmospheric Sounding Interferometer
  - Fourier Transform spectrometer with a sampling rate of 0.25 cm^{-1}
  - spectral coverage: 640 to 2760 cm^{-1}
- METOP/1, launch 7 October 2006 (?) (ESA/EUMETSAT EPS programme).

IMG: Interferometric Monitoring of Greenhouse Gases (0.05 cm^{-1} sampling rate), ADEOS/1 platform



NAST-I observations from the CAMEX/3 and EAQUATE experiments

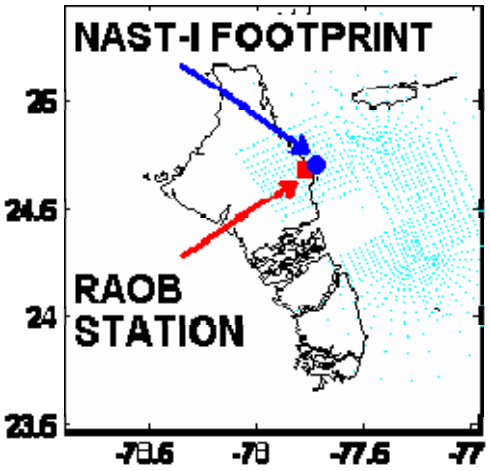
NAST-I (NPOESS Airborne Sounder Testbed, infrared interferometer)

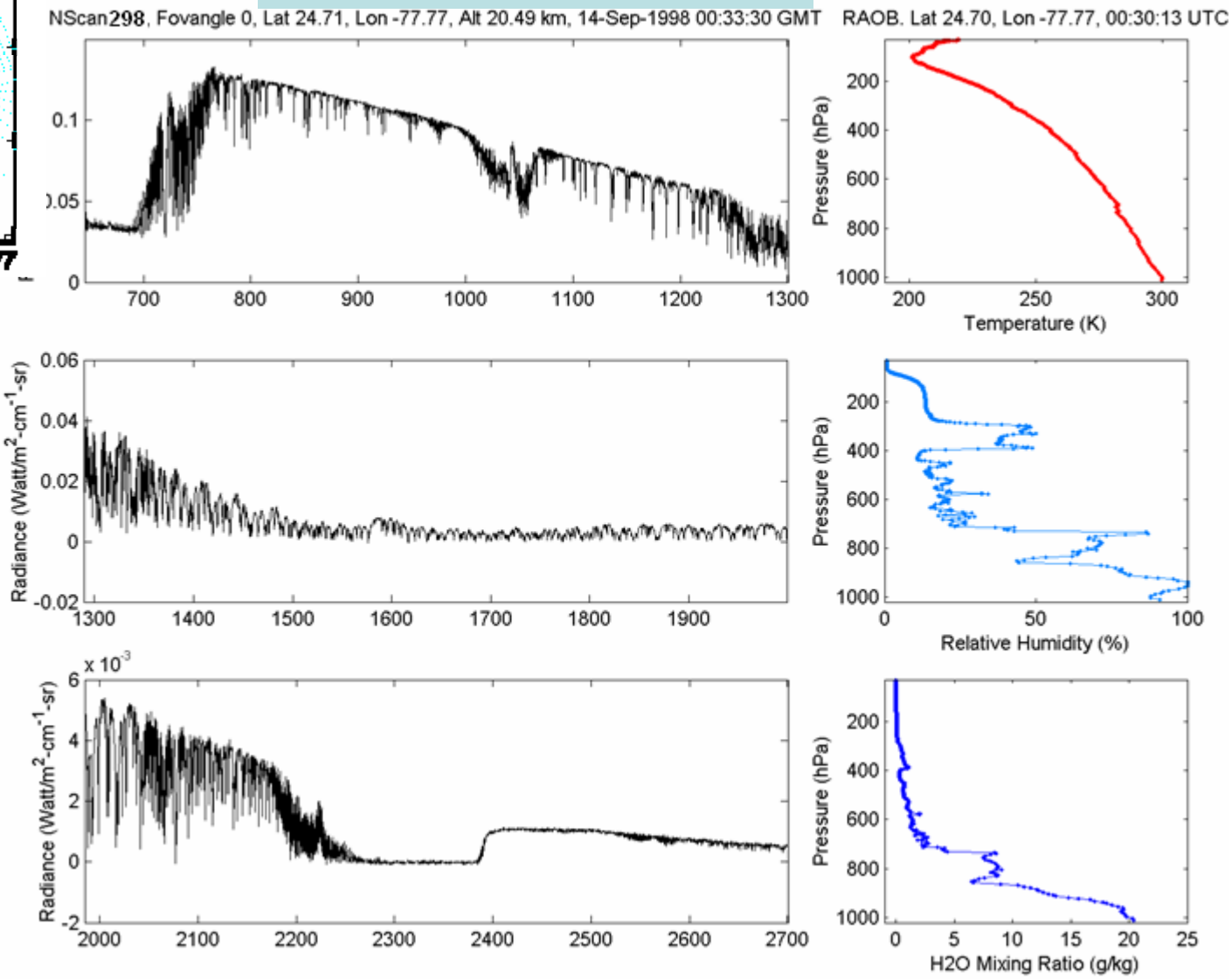
Spectral sampling of ≈ 0.24 cm-1
Spectral coverage witch matches that of IASI (645 to 2760 cm-1).

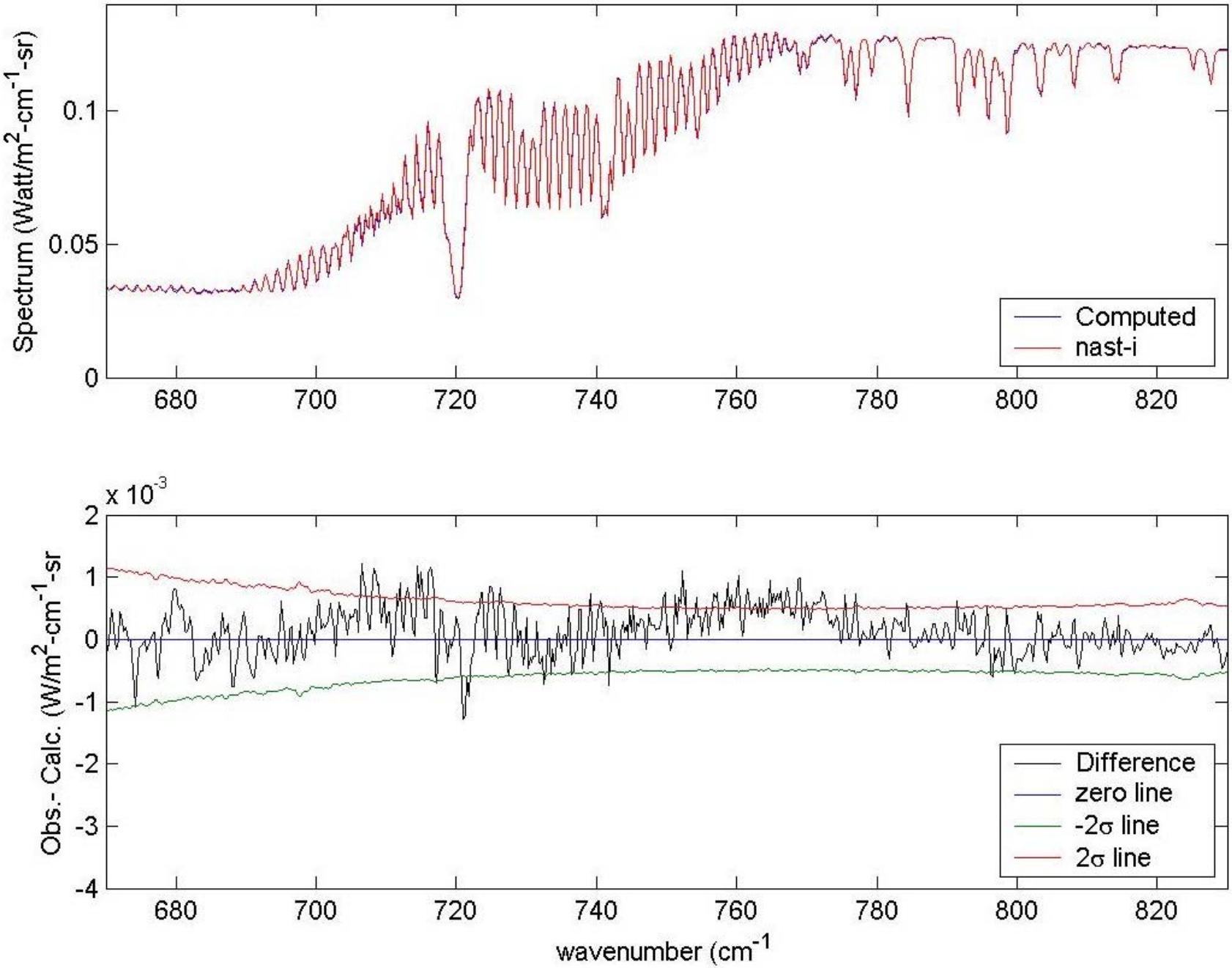
- CAMEX 3 (Convection and Moisture Experiment 3)
  - Data acquired during the Atlantic basin tropical cyclone field validation NASA ER-2 flight (during local nighttime, September 13-14, 1998) over Andros Island, Bahamas.
- EAQUATE (European AQUA Thermodynamic Experiment)
  - Data acquired during the Italian field validation Proteus flight (3-11 September, 2004)

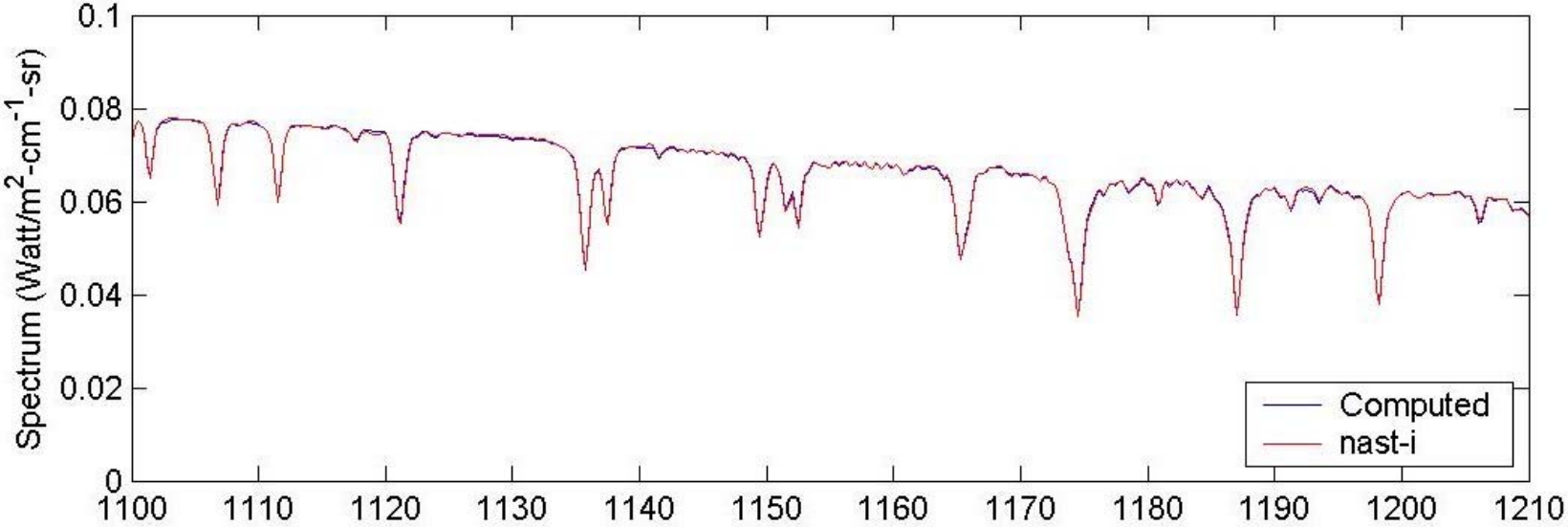
σ-IASI Consistency Check based on

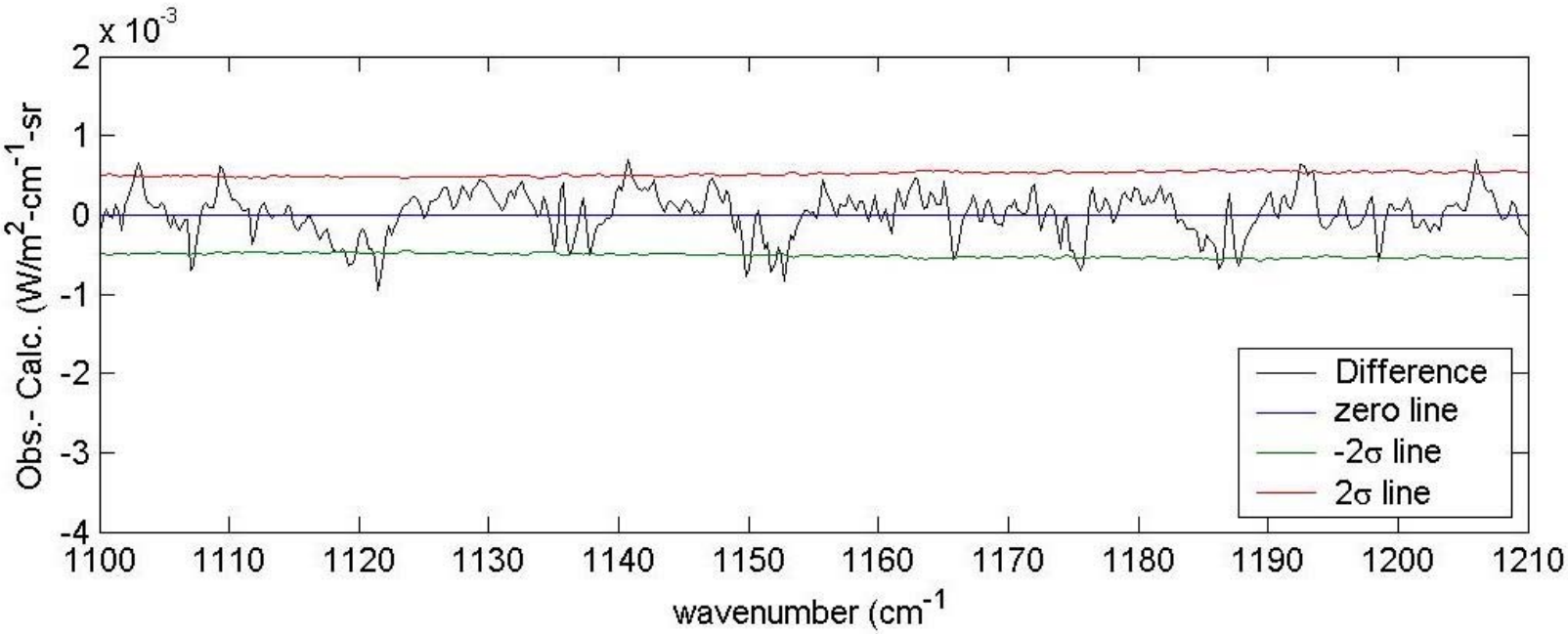
NAST-I scan #298 (Nadir)

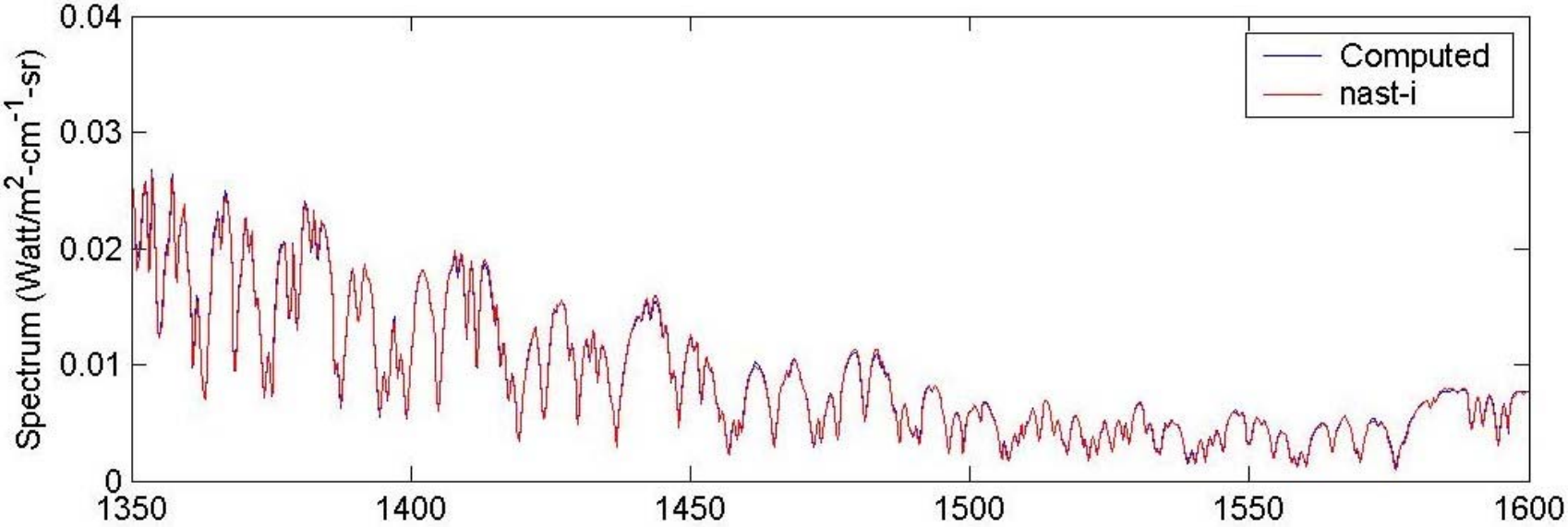


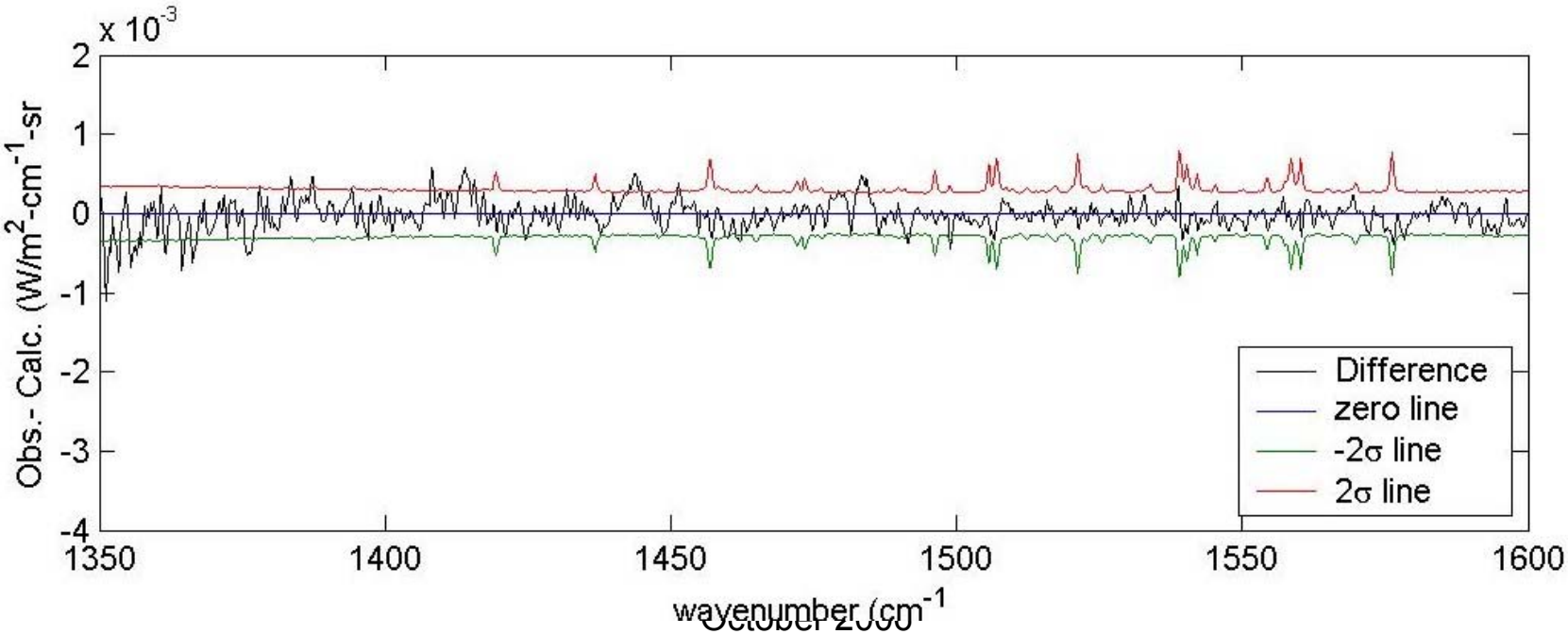


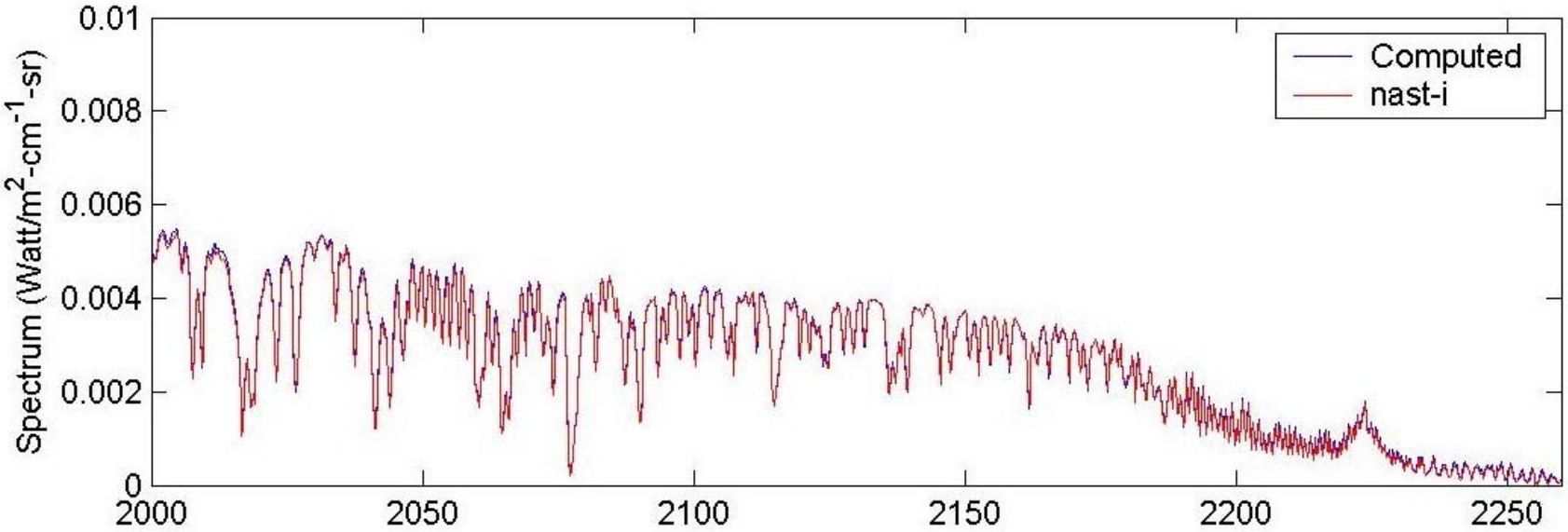

Spectrum (Watt/m^2-cm^{-1}-sr)
0
0.05
0.1
680
700
720
740
760
780
800
820
Computed
nast-i
x 10^{-3}
Obs.- Calc. (W/m^2-cm^{-1}-sr
2
1
0
-1
-2
-3
-4
Difference
zero line
-2σ line
2σ line
wavenumber (cm^{-1}

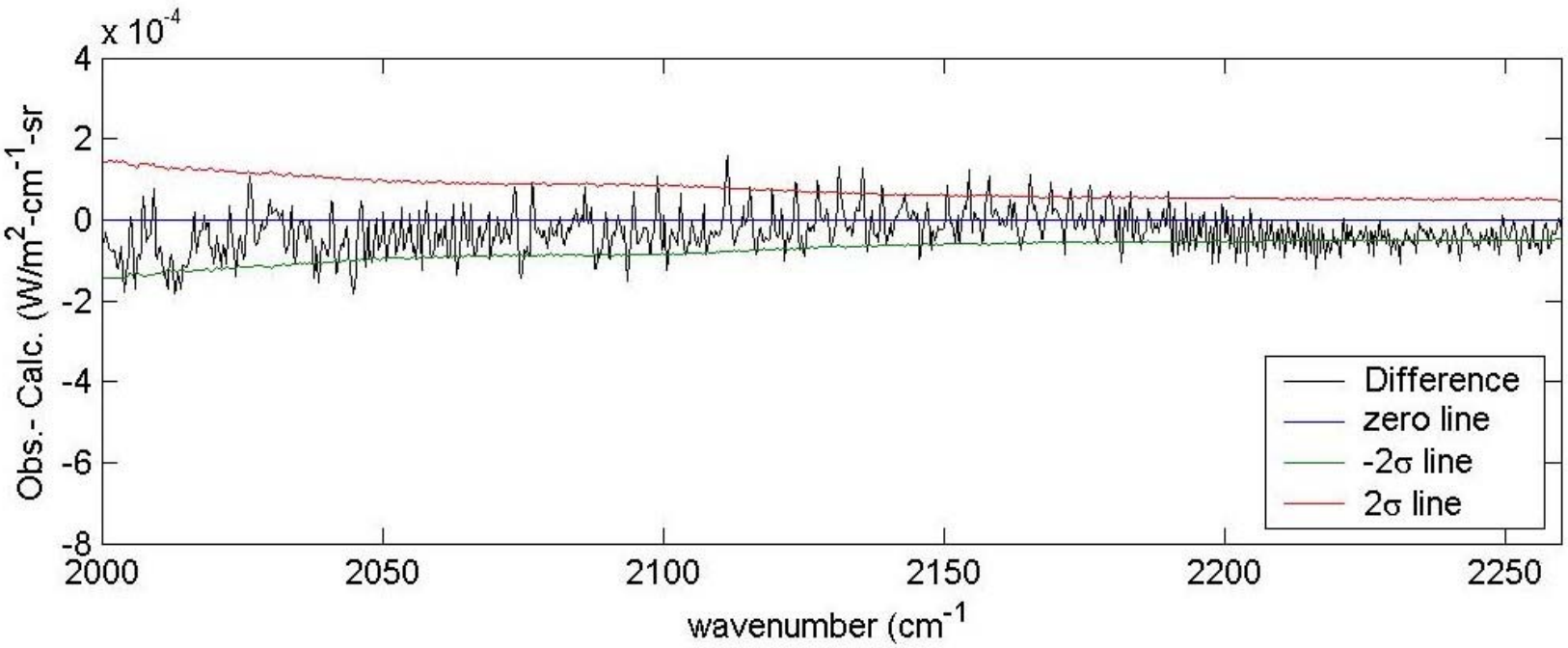

Spectrum (Watt/m^2-cm^{-1}-sr)
0.1
0.08
0.06
0.04
0.02
0
1100
1110
1120
1130
1140
1150
1160
1170
1180
1190
1200
1210
Computed
nast-i


x 10^{-3}
Obs.- Calc. (W/m^2-cm^{-1}-sr
2
1
0
-1
-2
-3
-4
1100
1110
1120
1130
1140
1150
1160
1170
1180
1190
1200
1210
wavenumber (cm^{-1}
Difference
zero line
-2σ line
2σ line


Computed
nast-i
Spectrum (Watt/m^2-cm^{-1}-sr)
0.04
0.03
0.02
0.01
0
1350
1400
1450
1500
1550
1600

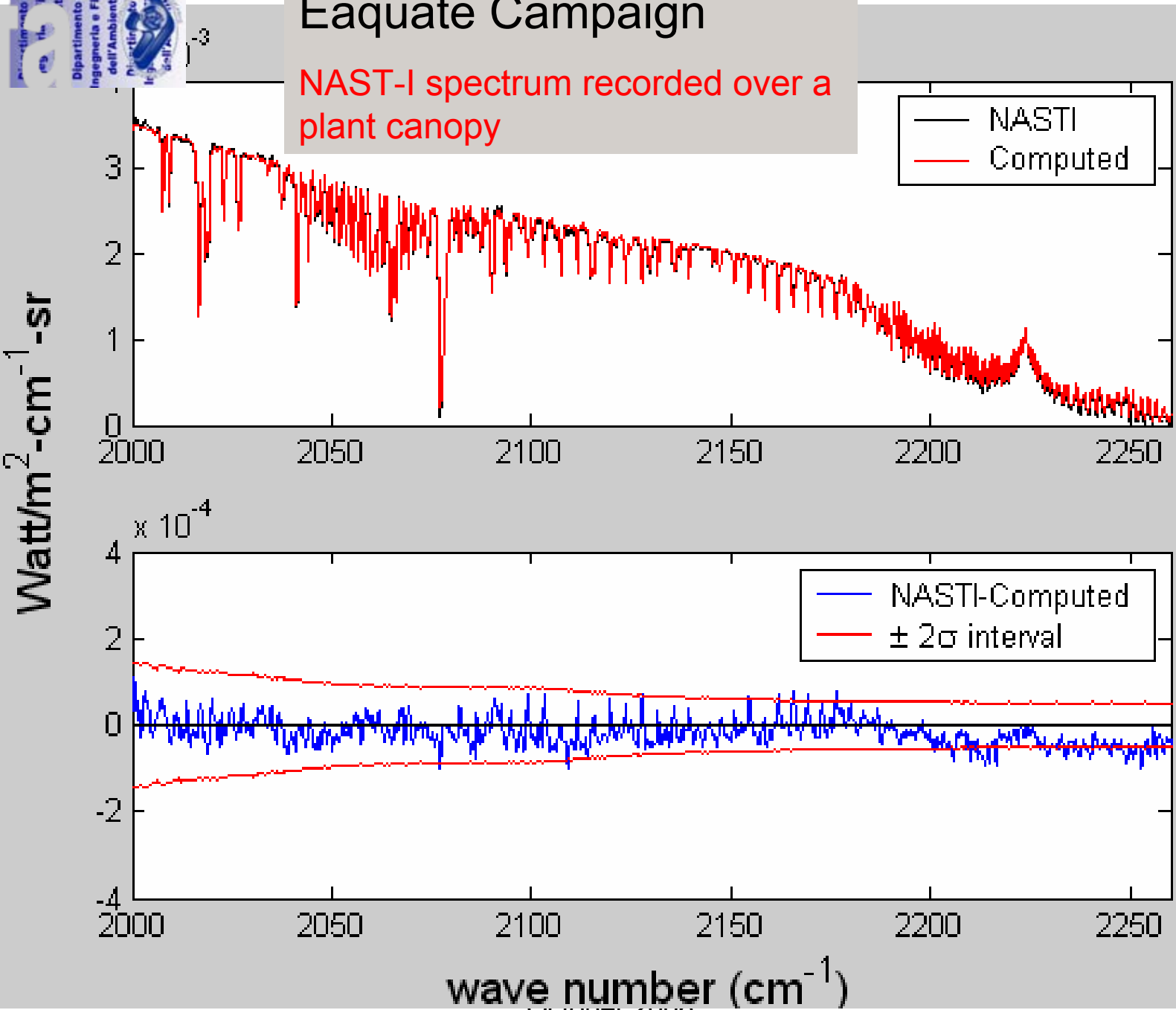

x 10^{-3}
Difference
zero line
-2σ line
2σ line
Obs.- Calc. (W/m^2-cm^{-1}-sr
2
1
0
-1
-2
-3
-4
1350
1400
1450
1500
1550
1600
wavenumber /cm^{-1}


Computed
nast-i
Spectrum (Watt/m^2-cm^{-1}-sr)
0.01
0.008
0.006
0.004
0.002
0
2000
2050
2100
2150
2200
2250


x 10^{-4}
Difference
zero line
-2σ line
2σ line
Obs.- Calc. (W/m^2-cm^{-1}-sr
4
2
0
-2
-4
-6
-8
2000
2050
2100
2150
2200
2250
wavenumber (cm^{-1}

Eaquate Campaign

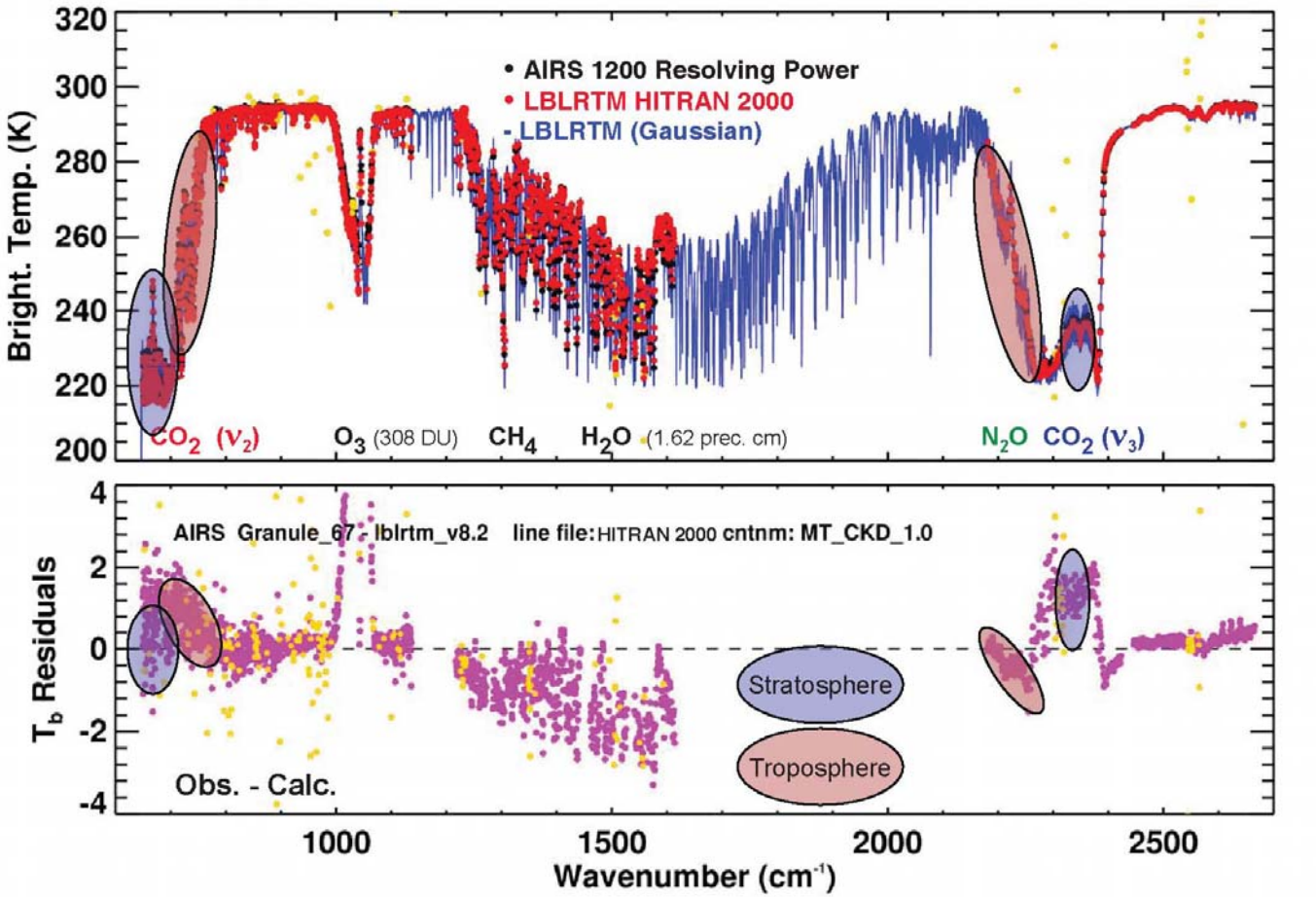
NAST-I spectrum recorded over a plant canopy



AFTER: Mark Shephard, Tony Clough, Jennifer Delamere, Karen Cady-Pereira, and Eli Mlawer, *Atmospheric and Environmental Research (AER), Inc.,*

http://bernath.uwaterloo.ca/ASSFTS/Media/ASSFTS%20Presentations/pdfPres/Shephard.pdf

AIRS : Chesapeake Bay Case Study : Sept. 13, 2002 6:43 Z



The inverse scheme

$$(\mathbf{v}-\mathbf{v}_g)^t\mathbf{L}(\mathbf{v}-\mathbf{v}_g) \qquad \text{Min!}$$

Subject to :

$$(\mathbf{R}-F(\mathbf{v}))^t\mathbf{S}^{-1}(\mathbf{R}-F(\mathbf{v})) \le \chi^2_\alpha$$

$$\mathbf{L} = \mathbf{B}^{-1}$$

$$Q(\mathbf{v}) = (\mathbf{R}-F(\mathbf{v}))^t\mathbf{S}^{-1}(\mathbf{R}-F(\mathbf{v})) + \gamma\left[(\mathbf{v}-\mathbf{v}_g)^t\mathbf{B}^{-1}(\mathbf{v}-\mathbf{v}_g)\right]$$

$$\hat{\mathbf{v}}_{n+1} = \hat{\mathbf{v}}_n - (\nabla_v \nabla_v Q)^{-1}(\nabla_v Q)$$

Rodgers-like Approach

Tikhonov-like Approach

$$\hat{\mathbf{v}} - \mathbf{v}_0 = (\gamma \mathbf{B}^{-1} + \mathbf{K}^t \mathbf{S}^{-1} \mathbf{K})^{-1} (\mathbf{K}^t \mathbf{S}^{-1} \mathbf{d} - \gamma \mathbf{B}^{-1} \mathbf{q}_0)$$

$$\mathbf{q}_0 = \mathbf{v}_0 - \mathbf{v}_g$$

$$\mathbf{S}_{\mathrm{v}} = (\gamma \mathbf{B}^{-1} + \mathbf{K}^t \mathbf{S}^{-1} \mathbf{K})^{-1} (\gamma^2 \mathbf{B}^{-1} + \mathbf{K}^t \mathbf{S}^{-1} \mathbf{K}) (\gamma \mathbf{B}^{-1} + \mathbf{K}^t \mathbf{S}^{-1} \mathbf{K})^{-1}$$

Transform the inverse solution to PC space trough SVD of the resolving kernel:

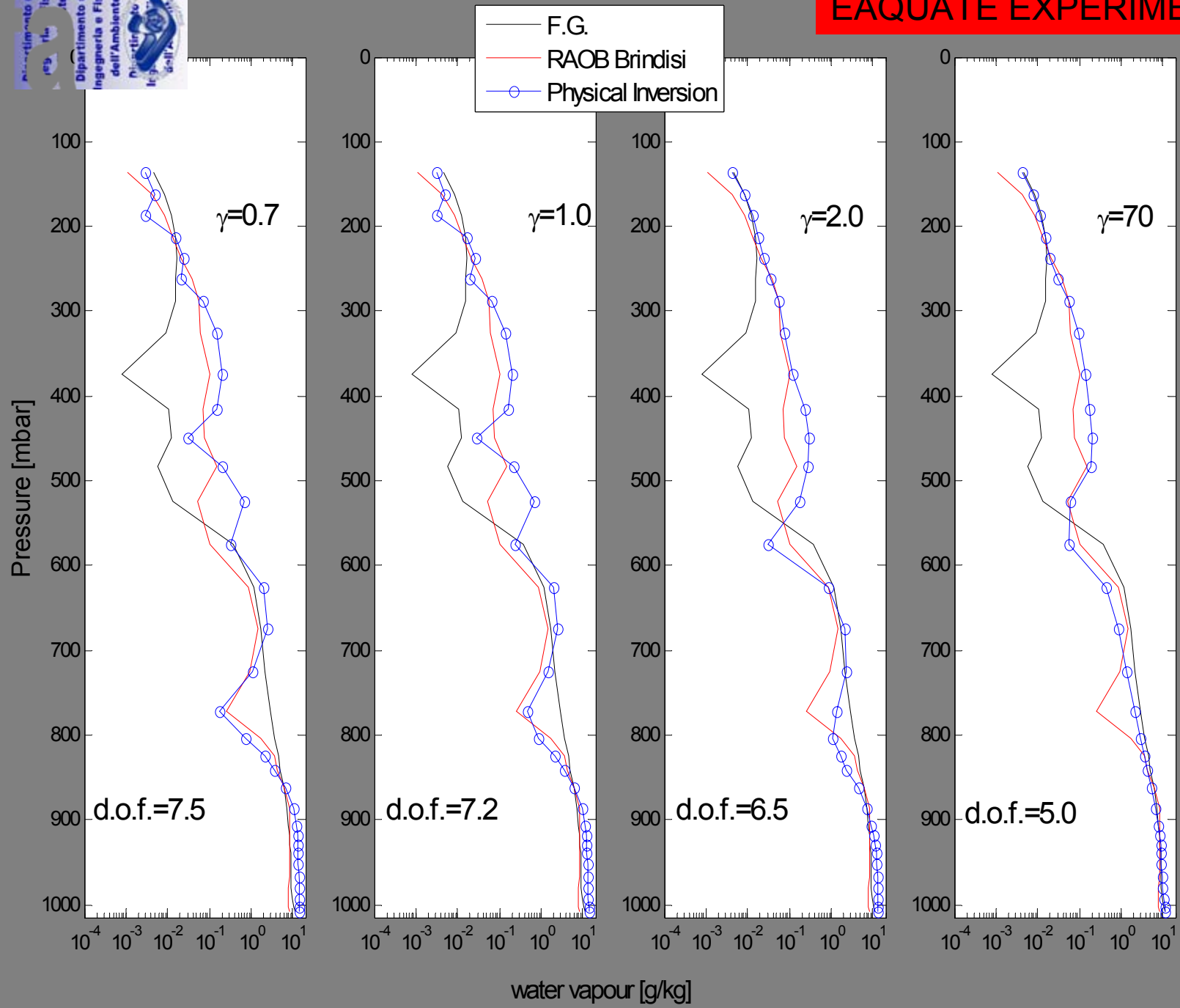
(details in:
Carissimo et al, 2005, EMS, *Vol. 20, 1111-1126*
and
EUMETSAT Tech. Rep. EUM/CO/04/1285/RST, Final report, 2004)

$$\mathbf{G} = \mathbf{S}^{-\frac{1}{2}}\mathbf{K}\mathbf{B}^{\frac{1}{2}}; \quad [\mathbf{U}, \mathrm{A}, \mathbf{V}] = svd(\mathbf{G})$$

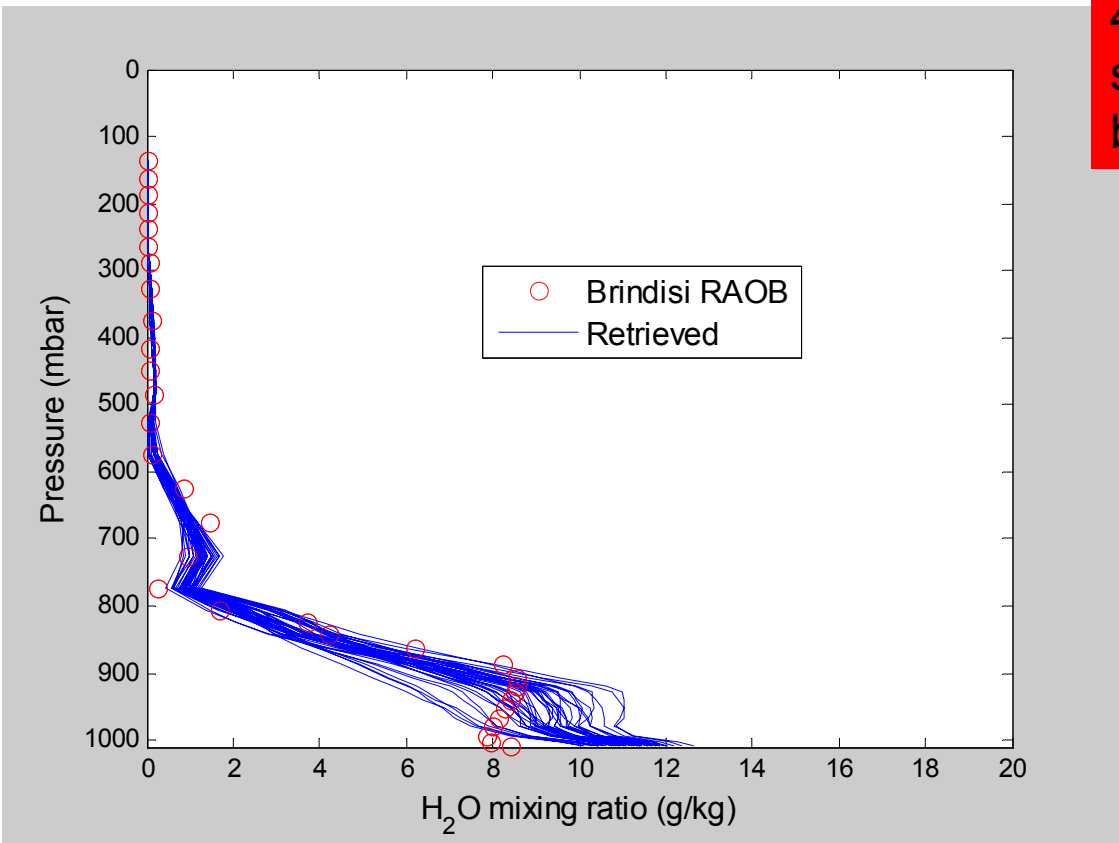
Component-wise form:

$$\hat{c}(i) = \frac{\alpha_i^{\,2}}{\gamma + \alpha_i^{\,2}} c_{true}(i) + \frac{\alpha_i}{\gamma + \alpha_i^{\,2}} c_{\varepsilon}(i) + \frac{\gamma}{\gamma + \alpha_i^{\,2}} c_b(i); \text{ Rodgers-like}$$

EAQUATE EXPERIMENT

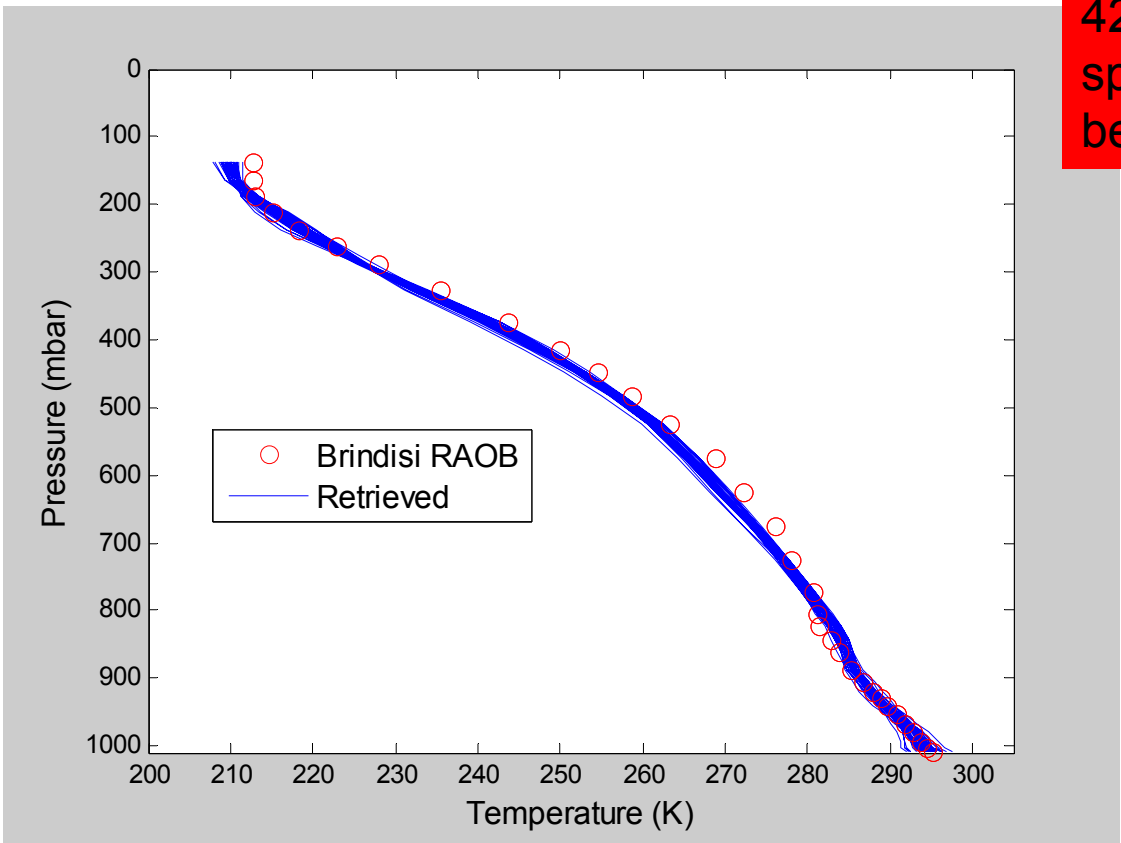


Physical retrieval, H_2O (Initialization by EOF Regression) EAQUATE experiment



42 NAST-I spectra have been inverted

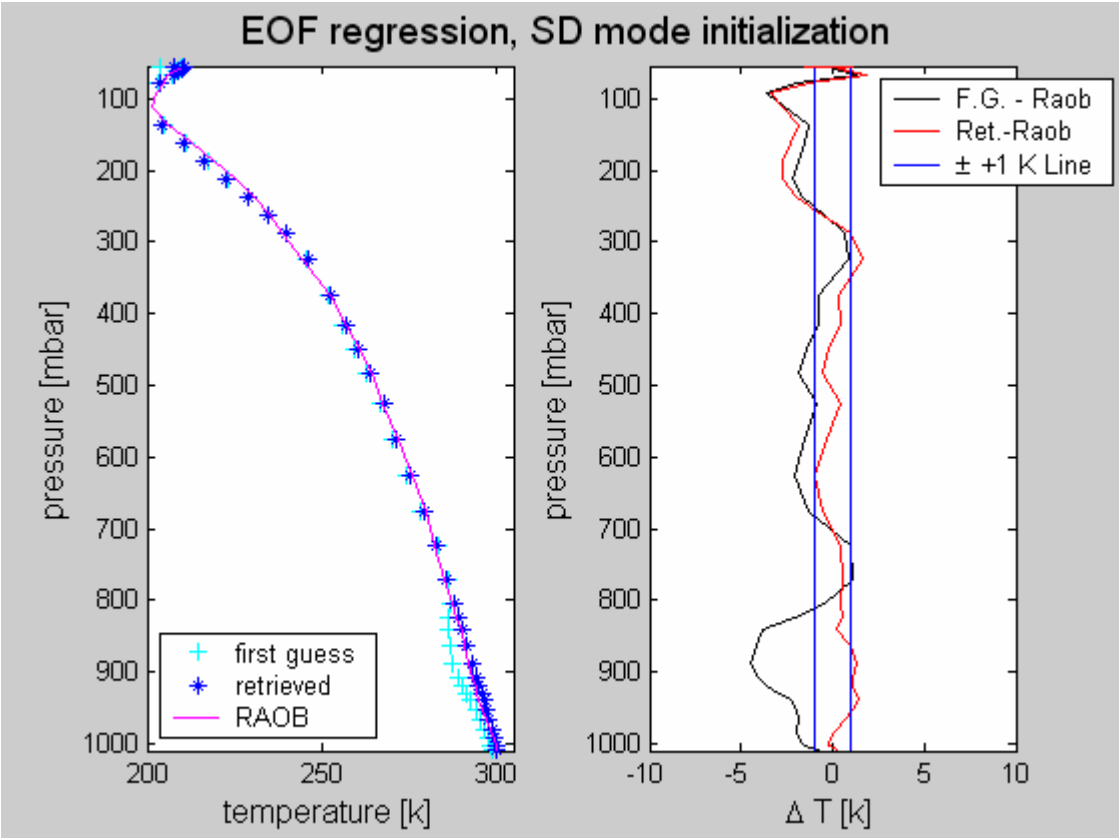
Physical retrieval, Temperature (Initialization by EOF Regression) EAQUATE experiment



42 NAST-I spectra have been inverted

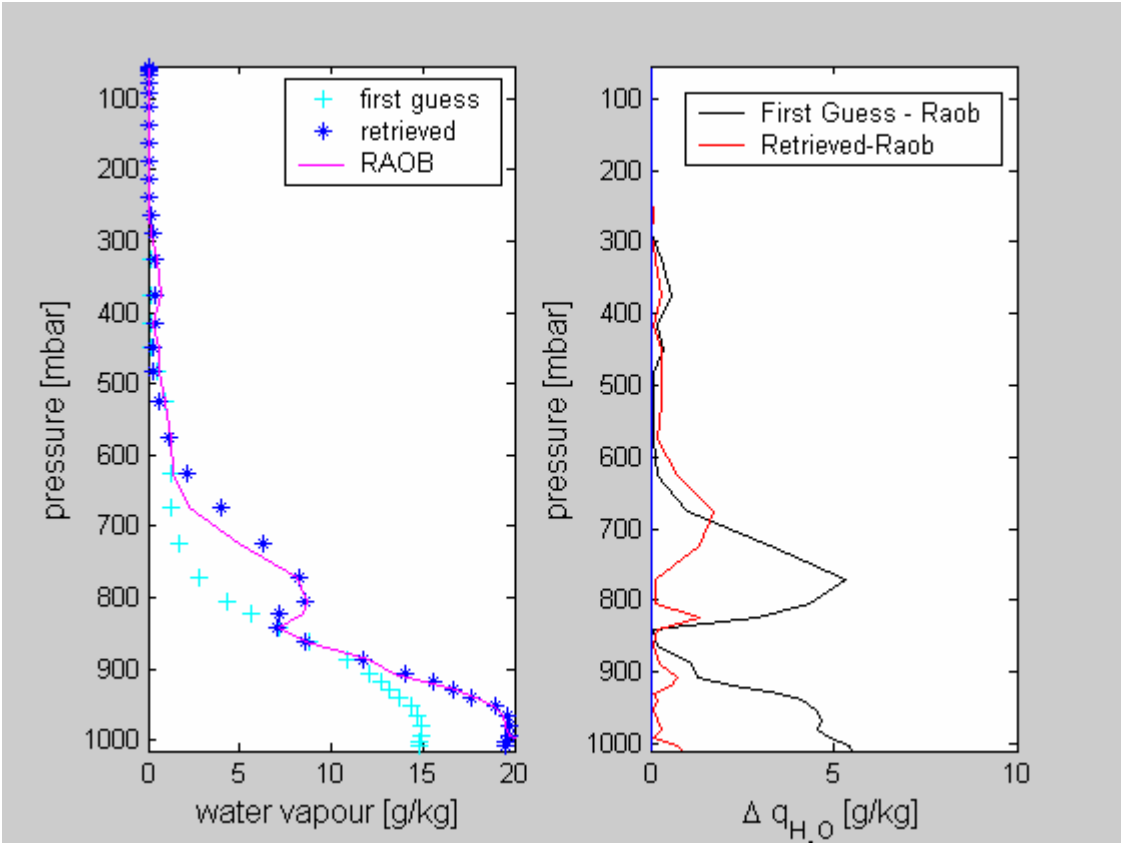
Retrieval Exercise based on NAST-I scan #298 spectrum

FG: from EOF Regression; Truth: RAOB2

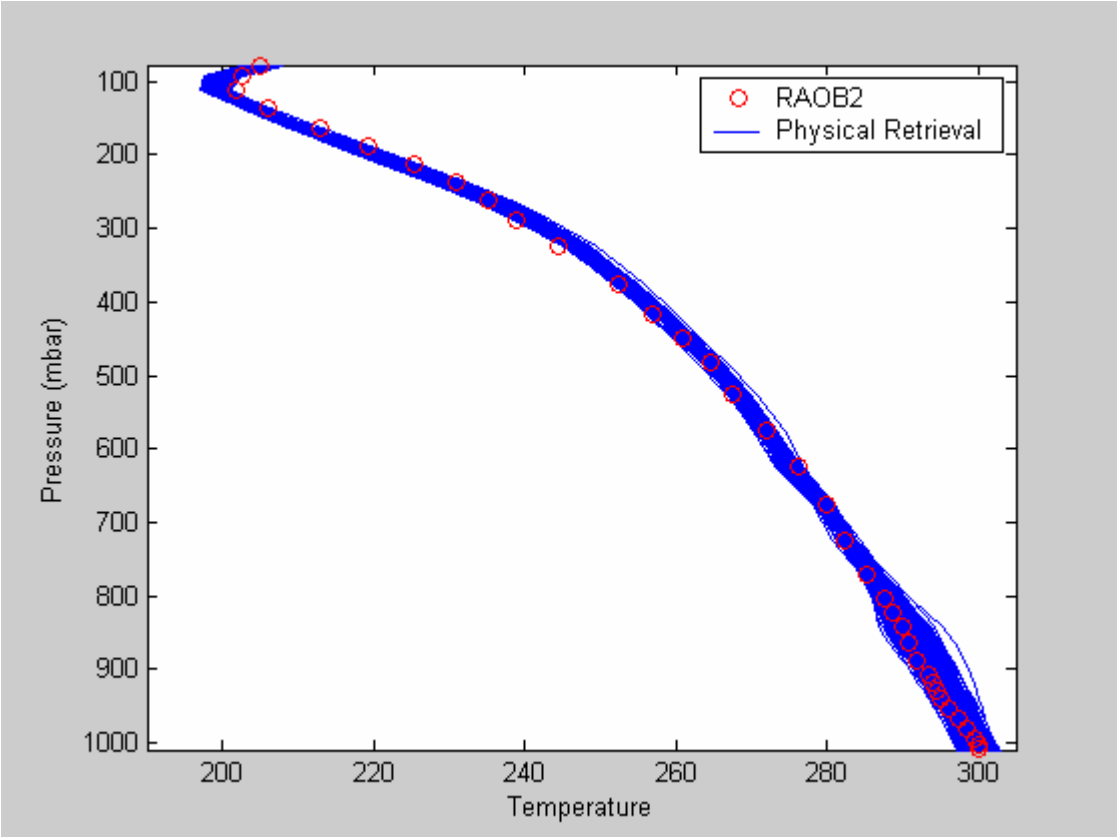


Retrieval Exercise based on NAST-I scan #298 spectrum

FG: from EOF Regression; Truth: RAOB2

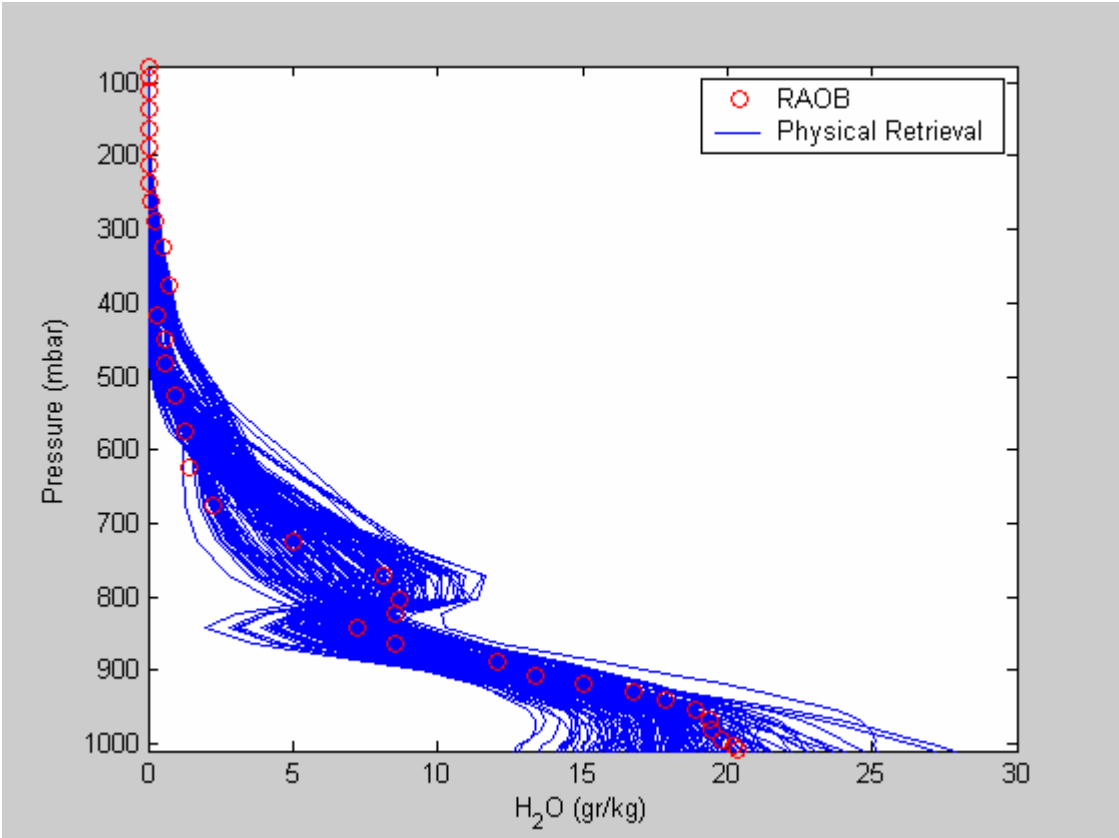


Physical retrieval, Temperature (Initialization by EOF Regression) CAMEX/3



294 NAST-I spectra have been inverted

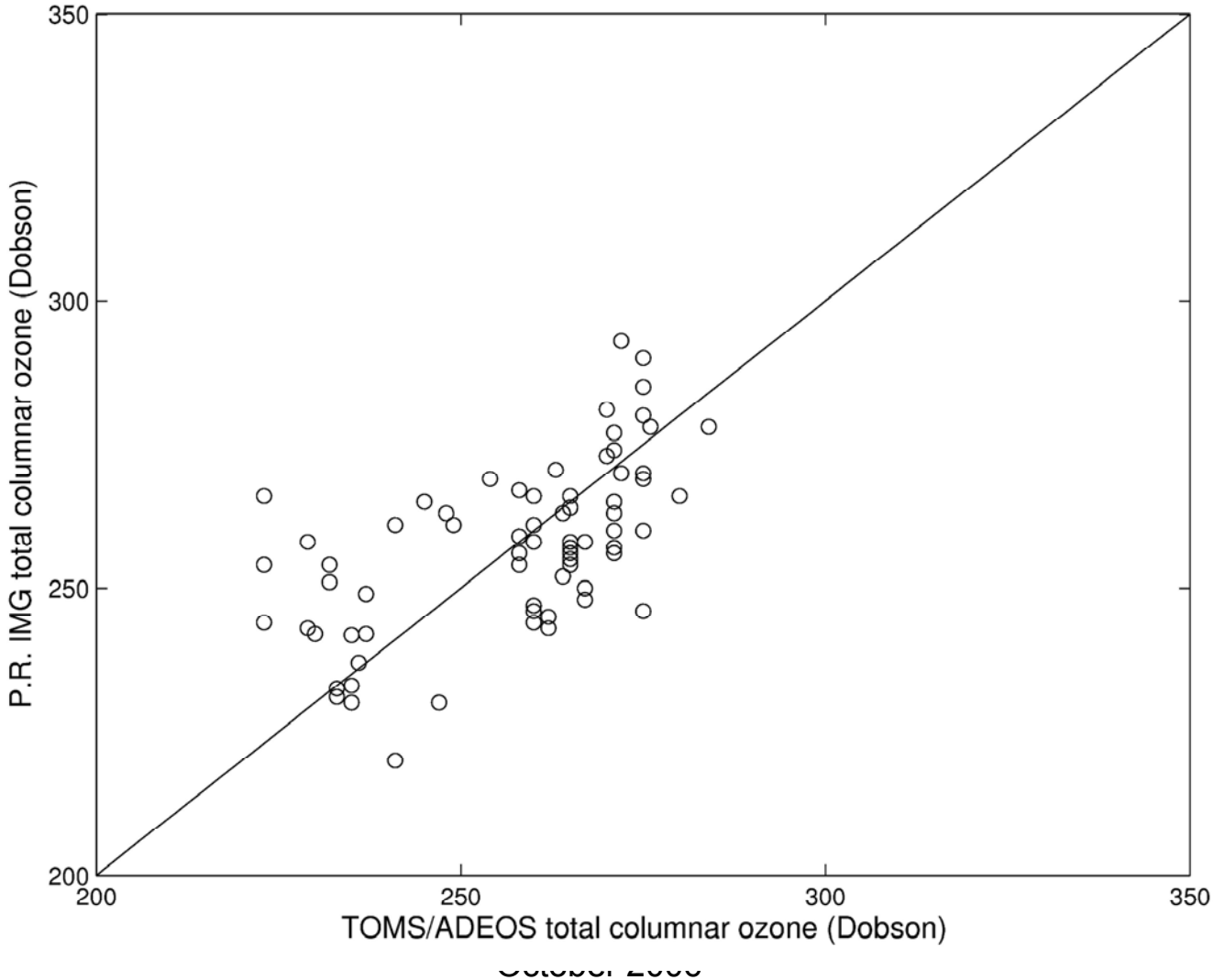
Physical retrieval, H_2O (Initialization by EOF Regression) CAMEX/3



294 NAST-I spectra have been inverted

Ozone Retrieval from IMG tropical soundings

(details in: *Grieco et al JQSRT, Volume 95, Issue 3 (2005) 331-348*)



Main Conclusions

- ***φ-IASI does work***
- The quality of state-of-art radiative transfer seems to be good enough to meet Temperature and H_2O IASI mission objective.
  - In particular no radiosonde tuning was needed to yield accurate retrieval
  - Some problems do exist and are mostly confined to the short wave side of the spectrum (forward modeling?, spectroscopy?, N_2O climatology?)
- The Physical inverse scheme improves T and H_2O retrieval independently of the initialization scheme.