Joint Airborne IASI Validation Experiment (JAIVEx) - An Overview

W. Smith[1,2], A. Larar[3], J.Taylor[4], H. Revercomb[2] , S. Kireev[1], D. Zhou[3], X. Liu[3], D. Tobin[2], S. Newman[4], P. Schluessel[5], X. Calbet[5], A. Clough[6], S. Mango[7], K. St. Germain[7]

[1]Hampton University, Hampton, US
[2]University of Wisconsin, Madison, US
[3]NASA Langley Research Center, Hampton, US
[4]Met Office, Exeter, UK
[5]EUMETSAT, Darmstadt, DE
[6]AER, Bedford, MA, US
[7]Integrated Program Office for NPOESS, Silver Spring, US

ITSC –XVI Angra dos Reis, Brazil (7 – 13 May 2008)

Objectives of Airborne Field Campaigns

- ***Radiometric and spectral calibration*** of satellite sensors
- ***Cross-validation*** of sensors in different orbits
- ***Validation of forward radiative transfe***r models used for retrieval of geophysical variables
- Provision of accurate in-situ and well calibrated ground-based, airborne and satellite radiance ***data sets*** for:
  - Cal/Val of satellite radiance sensors in orbit
  - Conducting studies to define limitations of current sensing techniques and to define more optimal sensing approaches
  - Simulating instrument measurements and validating processing algorithms intended for future satellite systems
  - Performing regional Observing System Experiments (OSEs) to define NWP impact of current and simulated future satellite systems

Unique Contribution of the Airborne Component

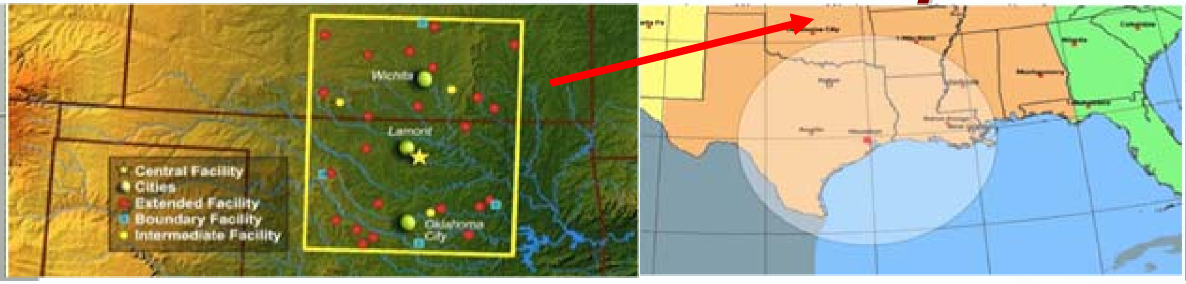
- Simultaneous independent***, SI traceable radiance measurements*** for absolute radiometric and spectral cal/val of satellite sensors

- ***Transfer standard*** for cross-validation of sensors in different orbits at more than a very limited number of polar latitudes

- Provides simultaneous ***accurate in-situ and remotely sensed geophysical variables*** that characterize the entire footprint of the satellite sounder for validation of satellite products and forward radiative transfer models used for their derivation

- Provides the ***high spatial resolution coupled with the high spectral resolution radiance measuremen***ts needed to determine the impact of satellite measurement characteristics on the accuracy of the derived products

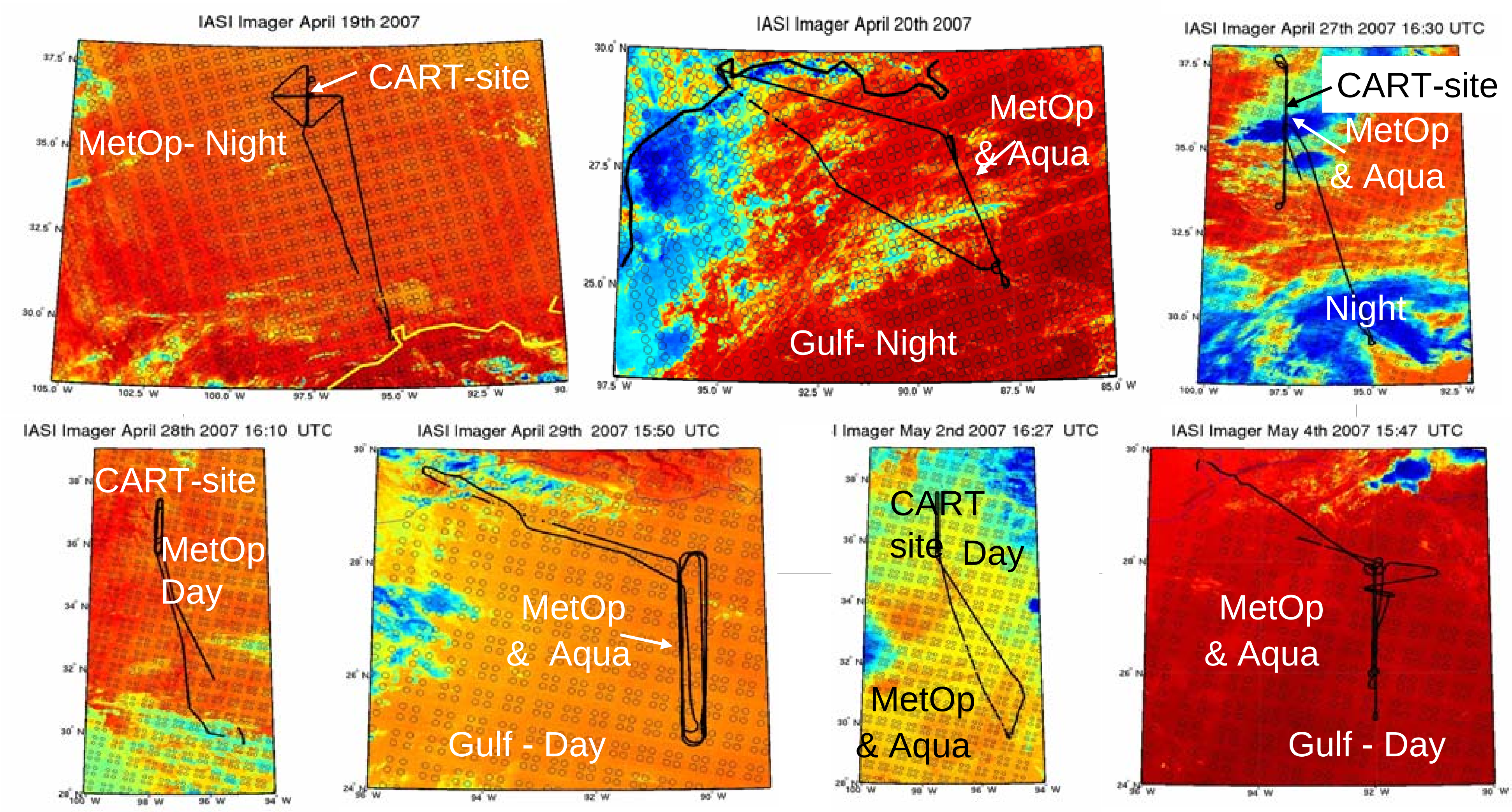
Joint Airborne IASI Validation Experiment (JAIVEx)



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

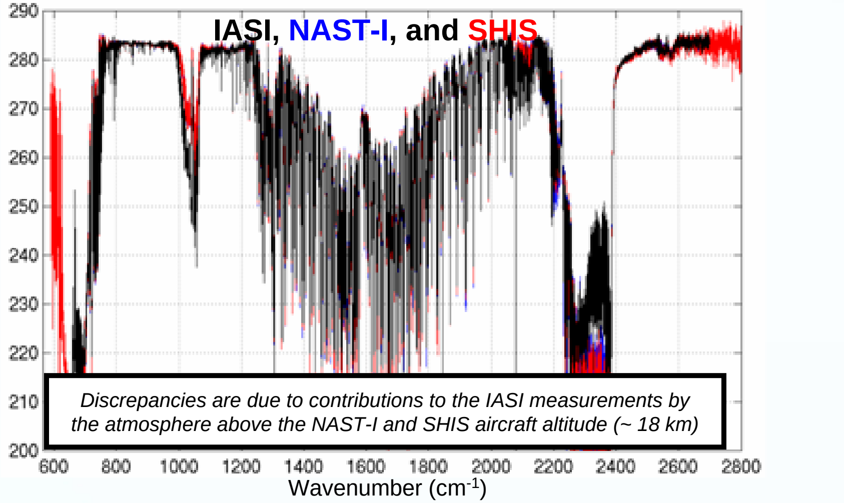
- **Location/dates**
  - **Ellington Field (EFD), Houston, TX, 14 Apr – 4 May, 2007**
- **Aircraft**
  - **NASA WB-57 (NAST-I, NAST-M, S-HIS)**
  - **UK FAAM BAe146-301 (ARIES, MARSS, Deimos, SWS; dropsondes; in-situ cloud phys. & trace species; etc.)**
- **Ground-sites**
  - **DOE ARM CART ground site: 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

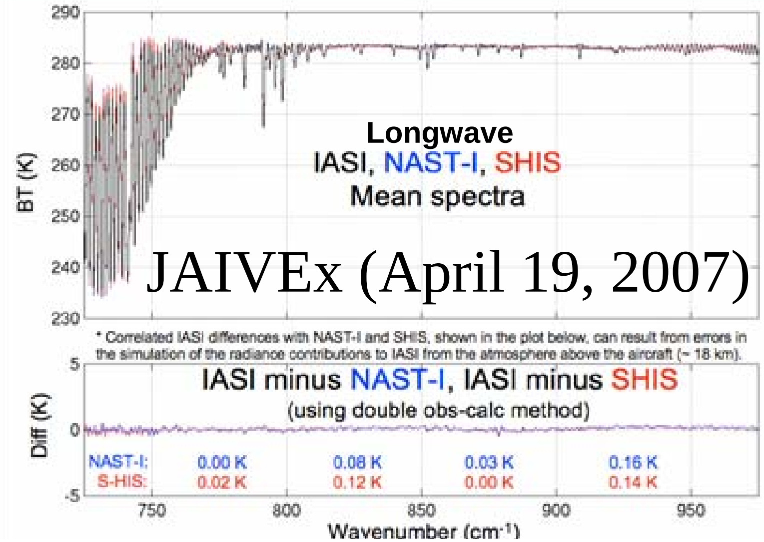


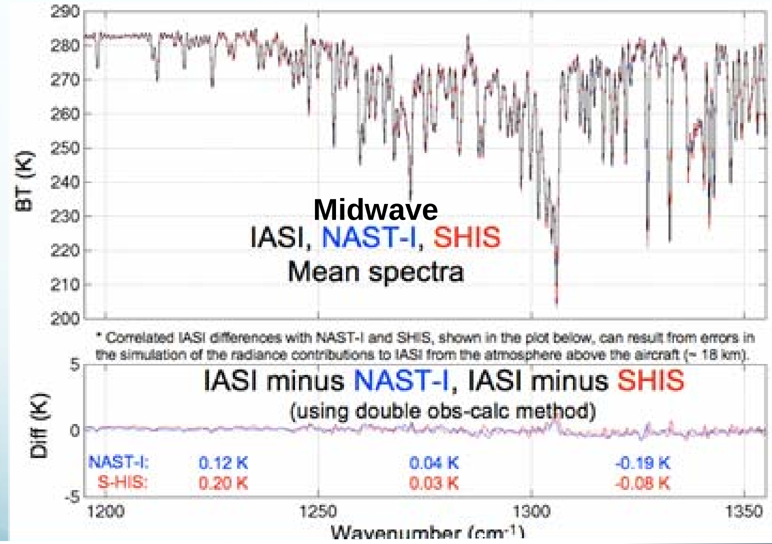
Four CART-site (2 day & 2 night); Three Gulf of Mexico (2 day & 1 night); Five joint MetOp & Aqua (3 day & 2 night)

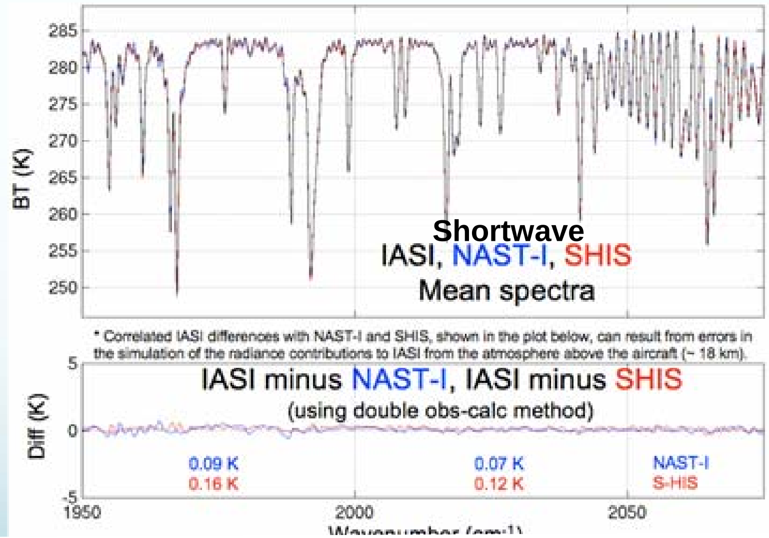
Simultaneous Independent SI Traceable Radiance Measurements for Absolute Radiometric and Spectral Cal/Val of Satellite Sensors



(IASI L1C and NAST-I spectra processed to match SHIS spectral resolution)



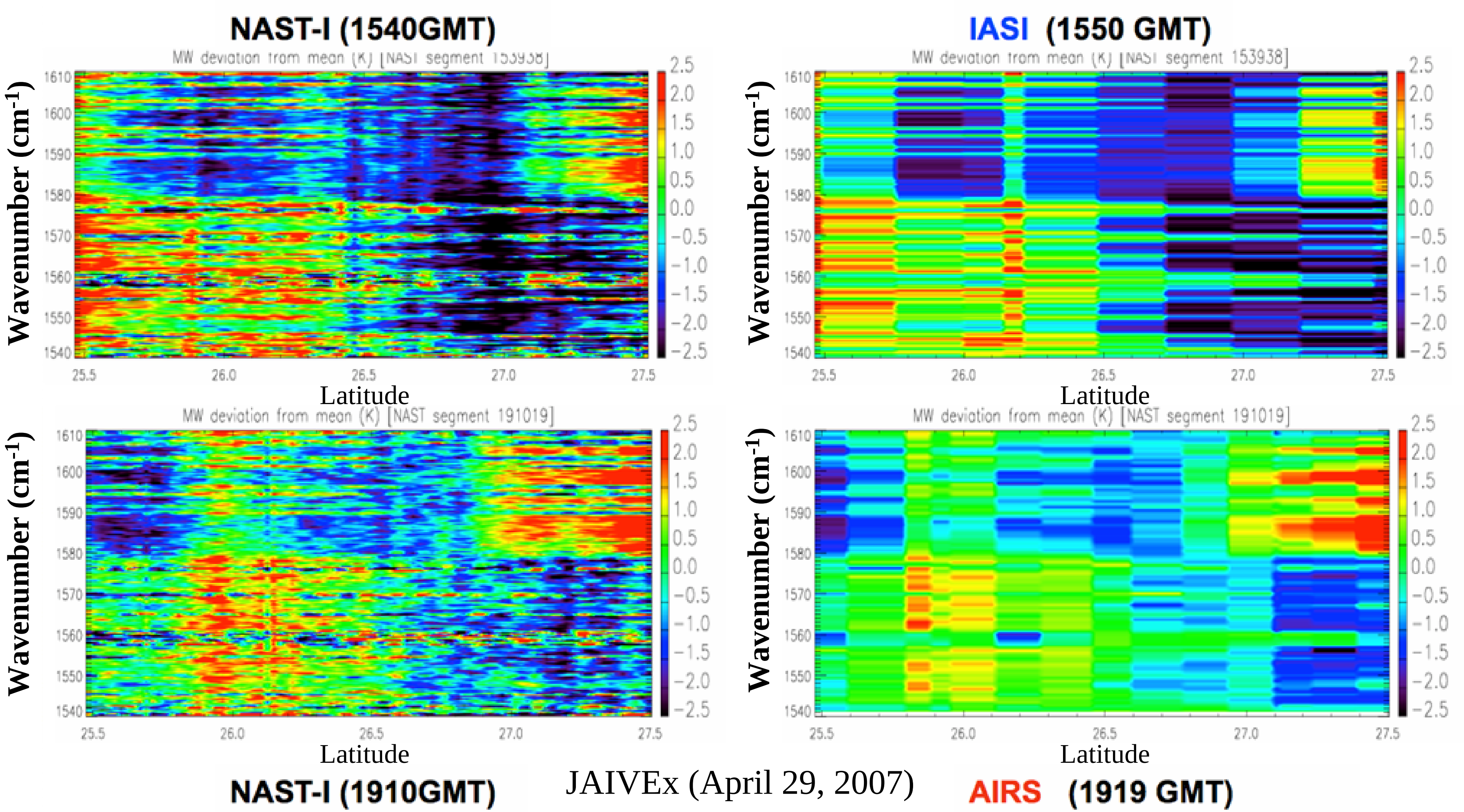




Multiple Airborne Sensors Provides an Internally Verified Assessment of Satellite Sensor Performance Thereby Enabling More Immediate Use of the Data

Transfer Standard for Cross-Validation of Sensors in Different Orbits

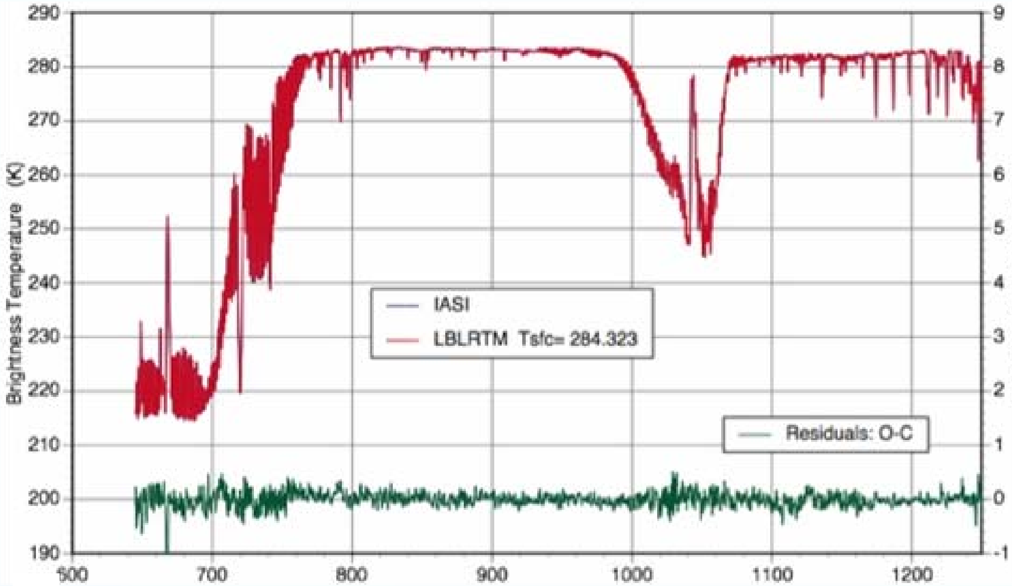
Midwave Radiance Spectra (deviation from latitudinal mean) Vs Latitude for two NAST-I Nadir Track Legs Under the MetOp IASI and Aqua AIRS Satellite Instruments at Their Individual Overpass Times

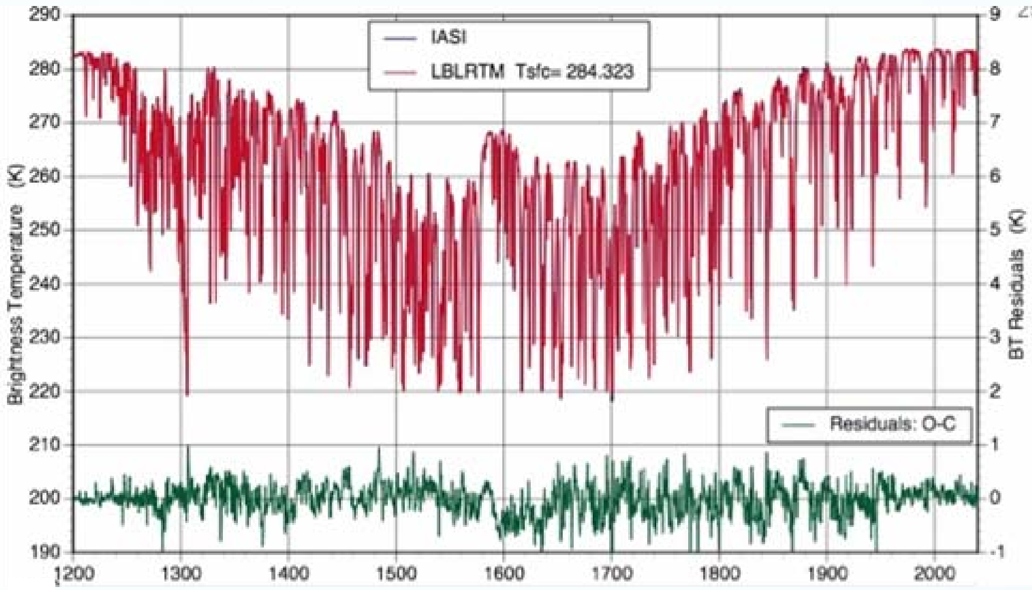


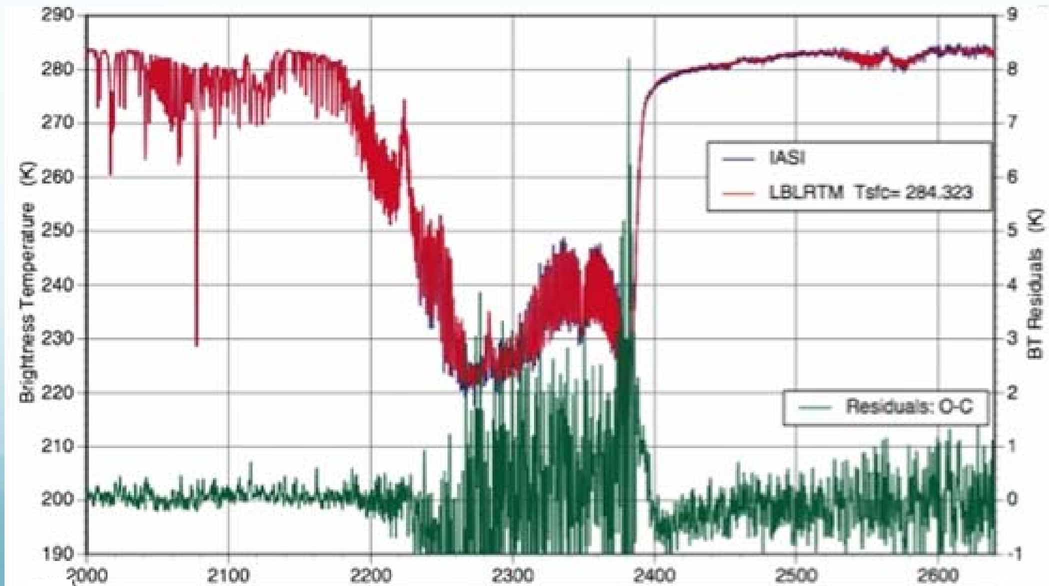
JAIVEx (April 29, 2007)

Airborne Radiance Spectra Enables Cross-Validation of Satellite Instruments in Different Orbits

Simultaneous Accurate In-situ and Remotely Sensed Geophysical Variables for Validation of Satellite Products and Forward Radiative Transfer Models Used for Their Derivation







Aircraft Dropsondes & Science Quality Radiosondes Used to Validate Radiative Transfer Models and Satellite Retrieval Products

JAIVEx (April 19/29, 2007)

Example Use of the JAIVEx Data Set For Atmospheric Retrieval and Associated Radiance Assimilation Problem Studies

The Problem: Due to the strong non-linearity of atmospheric water radiance, with respect to the water vapor and temperature profile, and due to the strong water vapor radiance Jacobians for atmospheric temperature [i.e., (dR(ν)/dT(p) where water vapor is the primary emitter], the 1-d variational physical retrieval of atmospheric temperature profiles can be compromised by the direct use of water vapor radiances when the initial water vapor profile (or background state) deviates greatly from the true profile. This problem is particularly acute for the hyperspectral sounder where the measured radiance spectrum is dominated by water radiance contributions.

Potential solution: (1) Solve for an initial temperature and moisture profile using linear regression, which generally yields good temperature profile solution due to the near linear relation between radiance and atmospheric temperature for invariant atmospheric constituents. (2) Obtain a non-linear 1-d variational solution (by iteration of the linear solution) for the atmospheric water vapor profile assuming that the regression temperature retrieval represents the true atmospheric state. (3) Obtain the final temperature and water vapor profile retrievals through the iteration of the full 1-d variational simultaneous solution of the radiative transfer equation.

PC Statistical Retrieval

Initial Profile PC Regression Retrieval:

a(T,Rh) = **G**(A,R) **r**(T,Rh,T_s,ε_s, gases,,)

- **a** is a vector of atmospheric state pc scores
- **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
- **r** is a vector of radiance pc scores

R = R* ^{T} **r** $_\nu$

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

T/Rh = a(T,Rh) **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

LBLRTM IASI simulated radiance and atmospheric statistics defined from statistical sample of radiosondes *10 randomly selected surface temperature/emissivity conditions per radiosonde sounding

PC Physical Retrieval

1-d Variational Physical PC-score Retrieval:

Given: $R = R^{*T} r_\nu$
$T/Rh = aA^*$

The Physical Solution is:

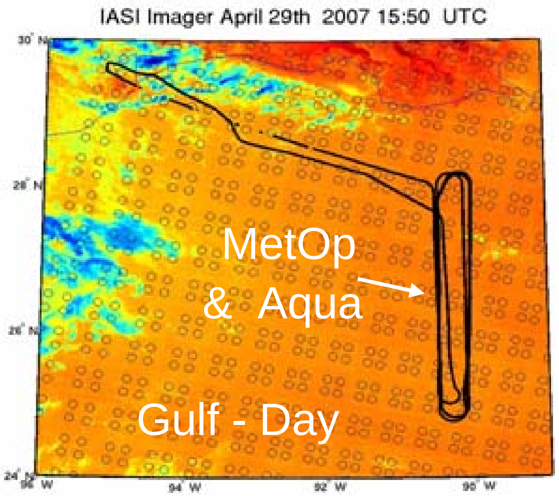
$$a_{n+1} = a_0 + (K_n^T S_{\varepsilon(R)}^{-1} K_n + \lambda S_a^{-1})^{-1} S_{\varepsilon(R)}^{-1} [R_m - R(a_n) + K_n(a_n - a_0)]$$

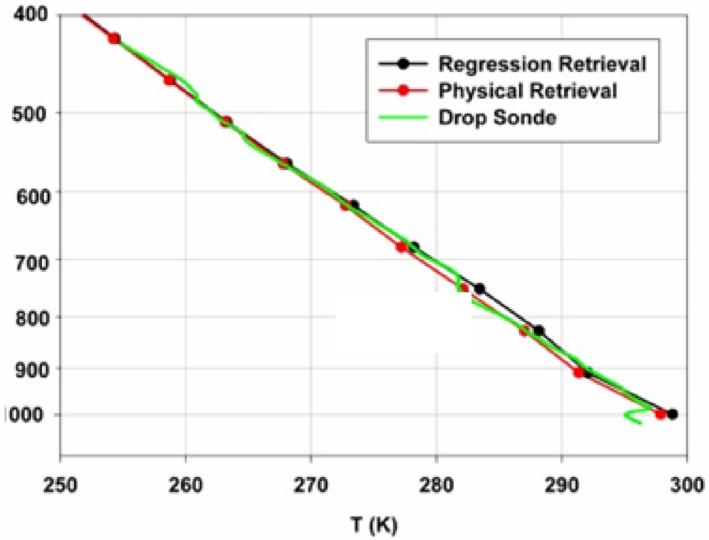
Where:

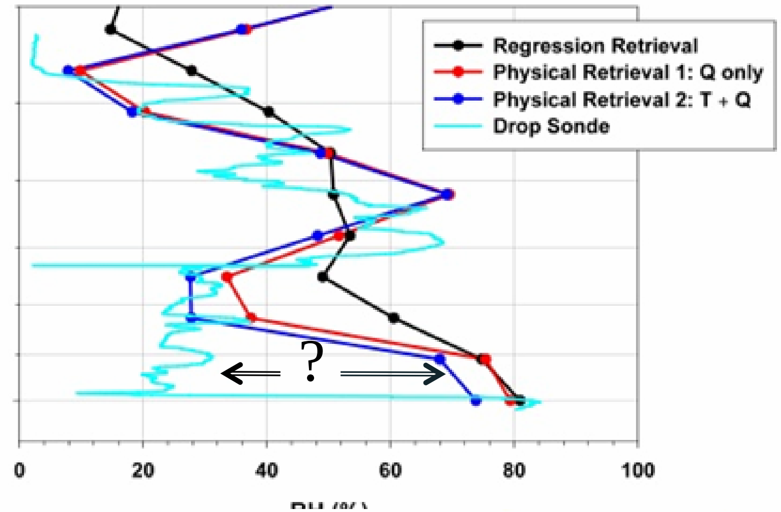
$S_{\varepsilon(R)} = R^{*T} E(r_\nu)$
$S_a = A^{*T} S(T/Rh)$
$K_n = [\delta R(a)/\delta a]_n$
λ=Lagrangian multiplier

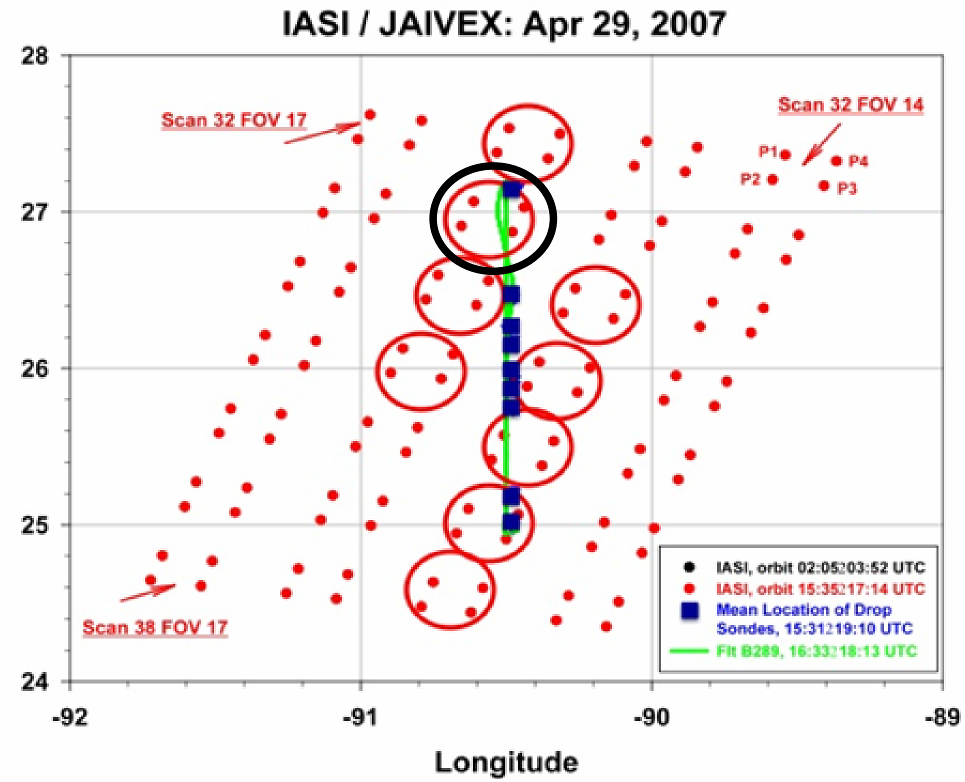
Two step physical retrieval: (1) solve for an improved relative humidity profile, assuming all the temperature profile PC score Jacobians are zero (i.e. temperature fixed to initial regression solution), (2) simultaneous solution for the final T and Rh PC scores.

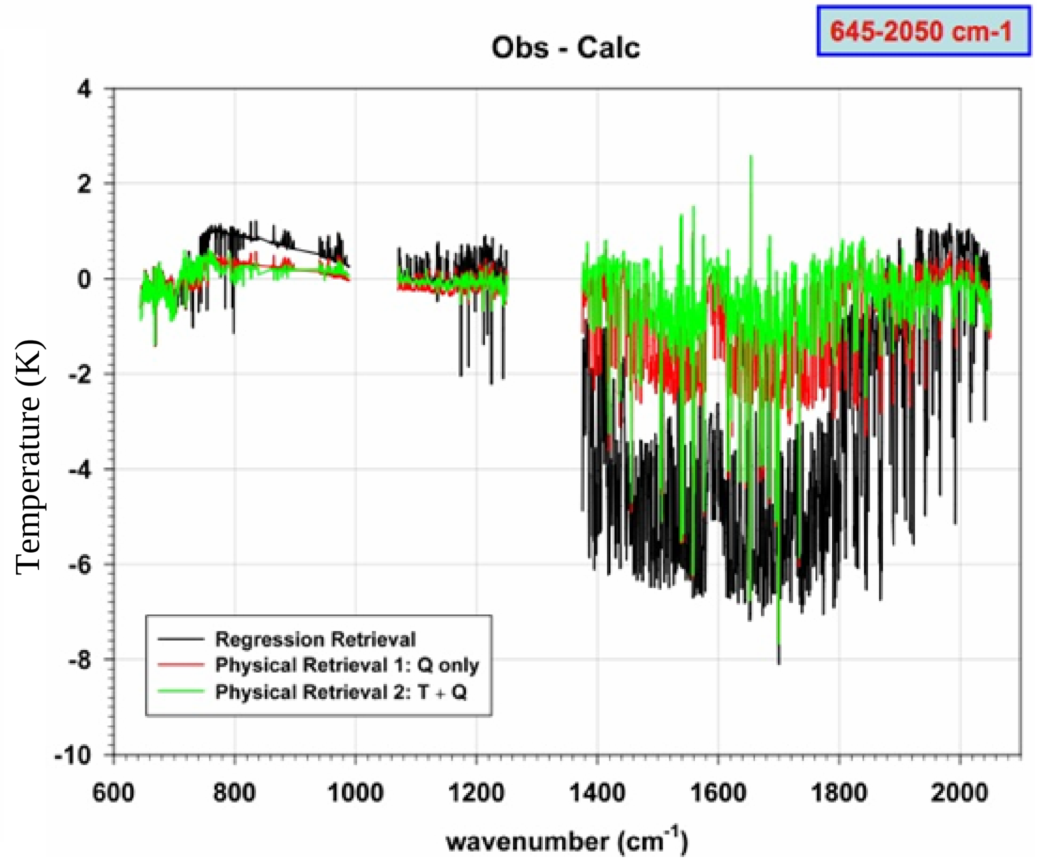
- **LBLRTM used for background radiance and Jacobian calculation**
- **~ 4000 spectral channels (0.5 cm^{-1} spacing)**
- **No Bias Correction**


IASI Imager April 29th 2007 15:50 UTC
MetOp
& Aqua
Gulf - Day

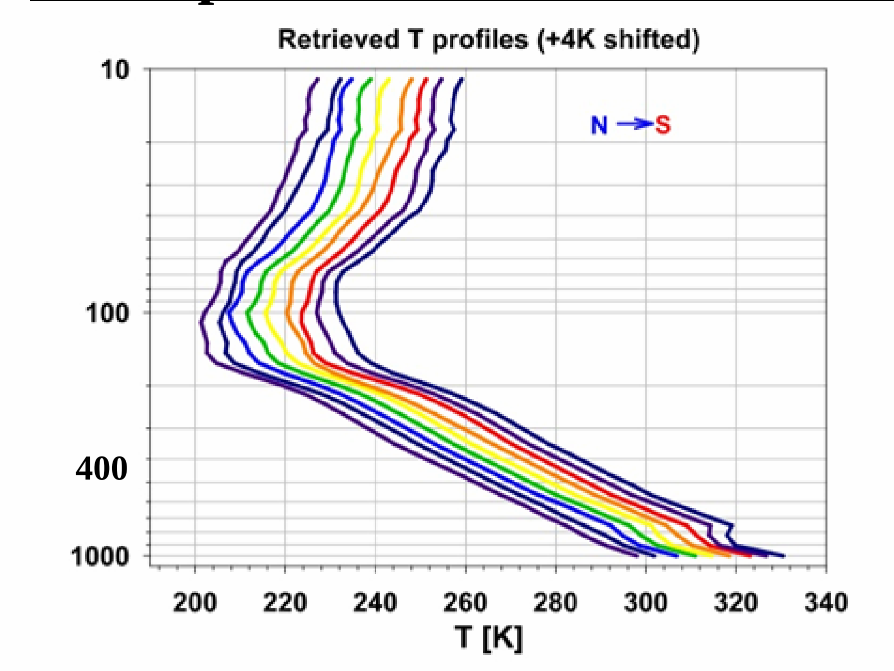

Regression Retrieval
Physical Retrieval
Drop Sonde
400
500
600
700
800
900
1000
250
260
270
280
290
300
T (K)

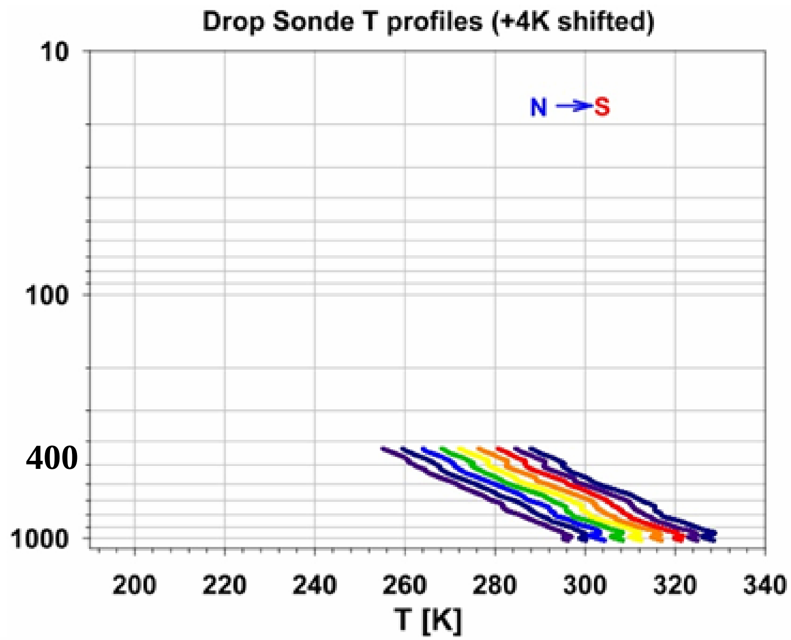

Regression Retrieval
Physical Retrieval 1: Q only
Physical Retrieval 2: T + Q
Drop Sonde
?
0
20
40
60
80
100

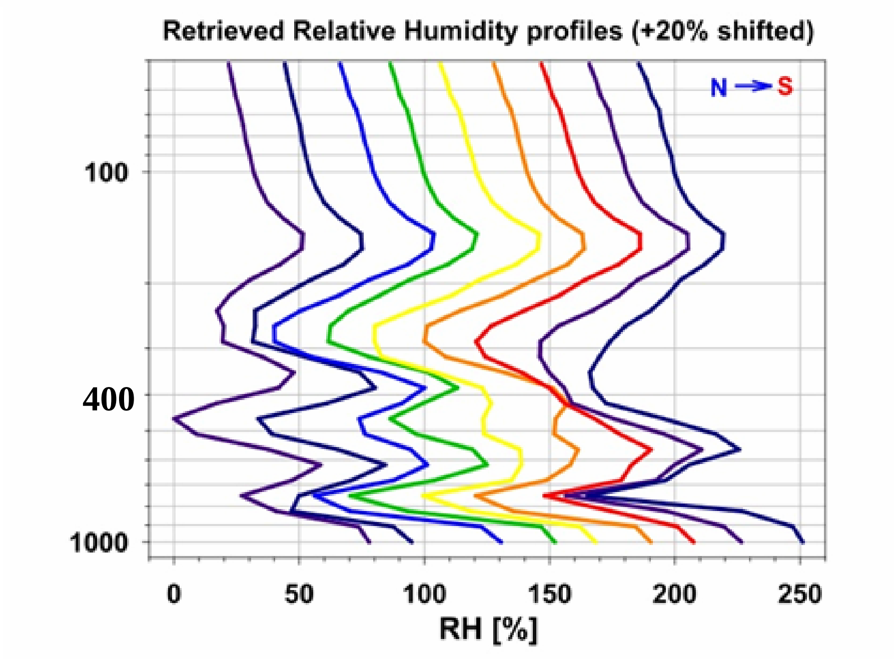

IASI / JAIVEX: Apr 29, 2007
Scan 32 FOV 17
Scan 32 FOV 14
Scan 38 FOV 17
P1
P2
P3
P4
IASI, orbit 02:05:03:52 UTC
IASI, orbit 15:35:17:14 UTC
Mean Location of Drop Sondes, 15:31:19:10 UTC
Fit B289, 16:33:18:13 UTC
28
27
26
25
24
-92
-91
-90
-89
Longitude

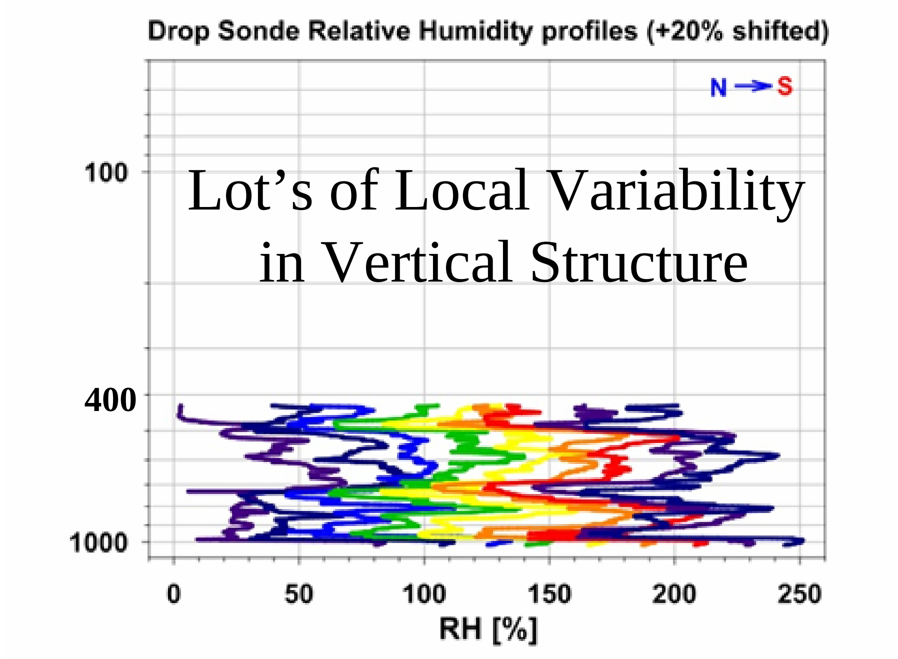

645-2050 cm-1
Obs - Calc
Temperature (K)
Regression Retrieval
Physical Retrieval 1: Q only
Physical Retrieval 2: T + Q
4
2
0
-2
-4
-6
-8
-10
600
800
1000
1200
1400
1600
1800
2000
wavenumber (cm-1)

Atmospheric Profiles Retrieved with IASI and Observed by Dropsondes

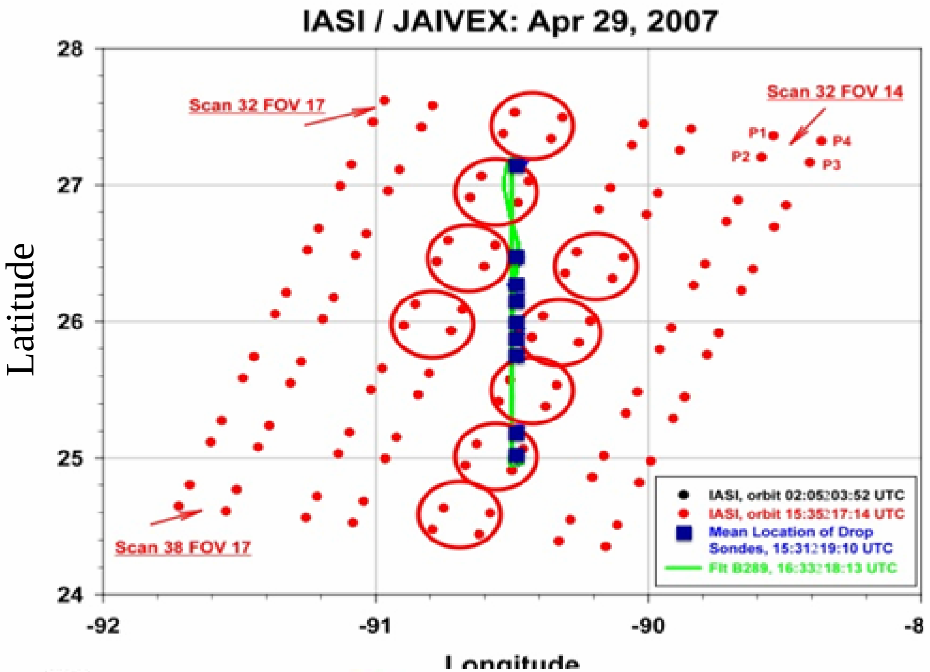


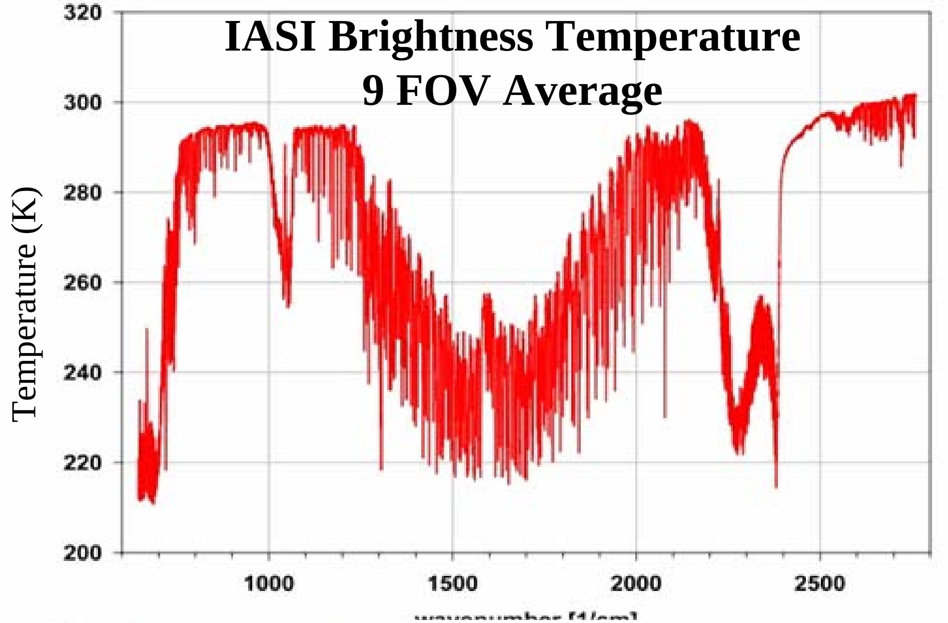


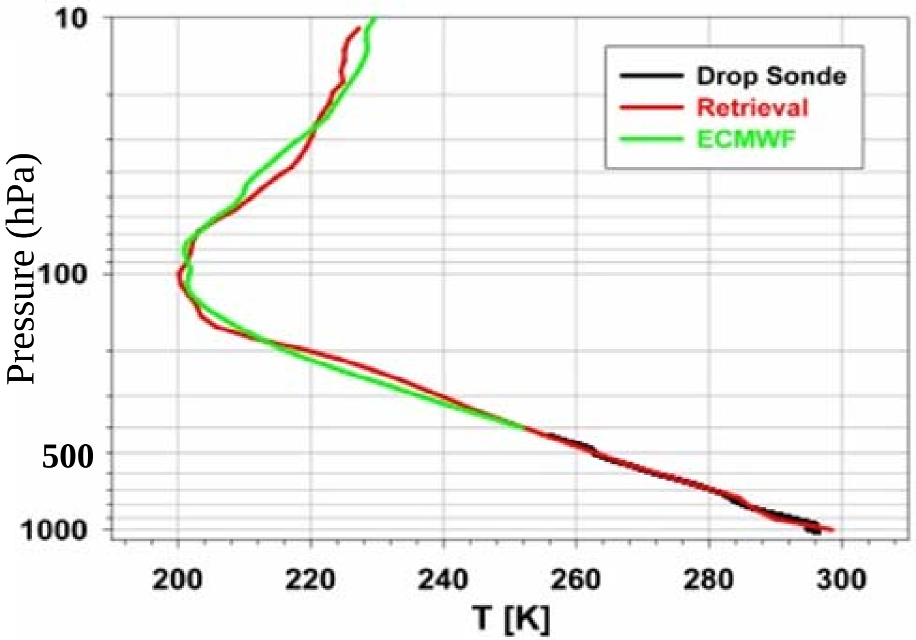


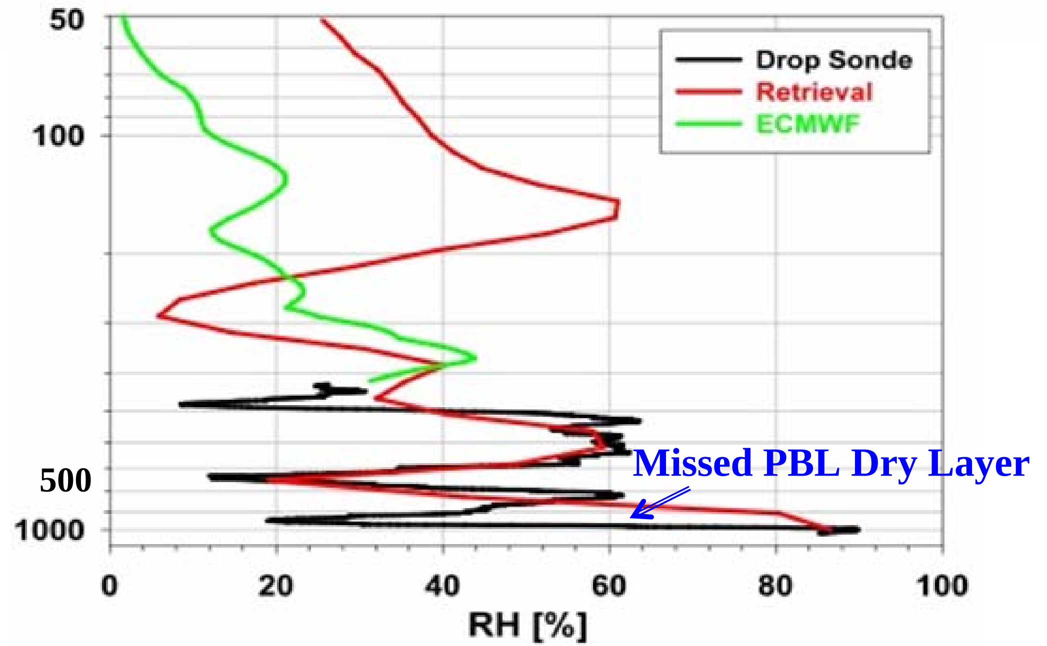


Mesoscale Atmospheric Variability Sensitivity Analysis (Local Mean State)

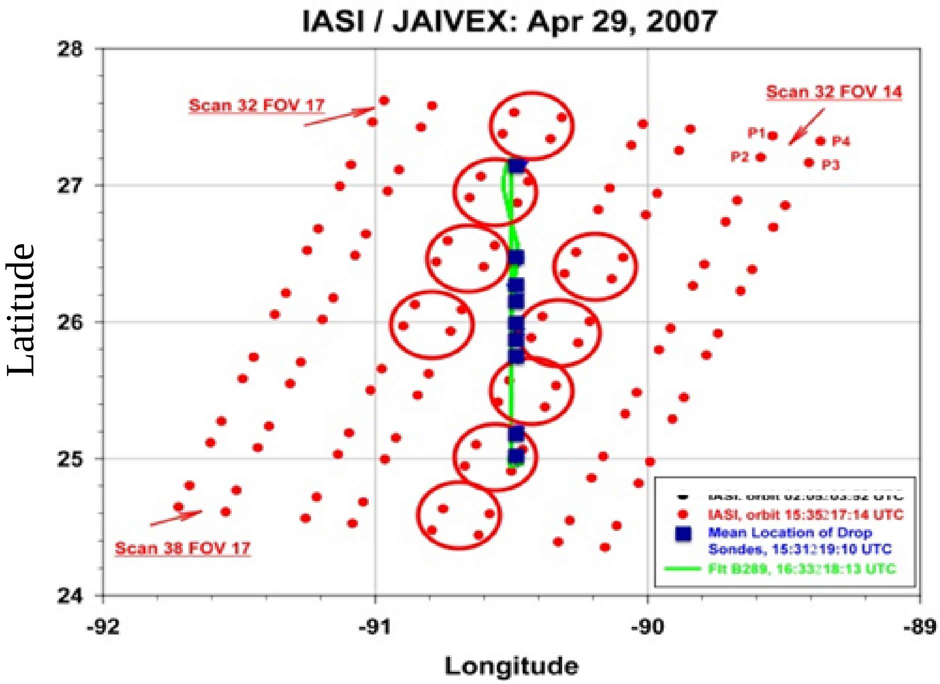


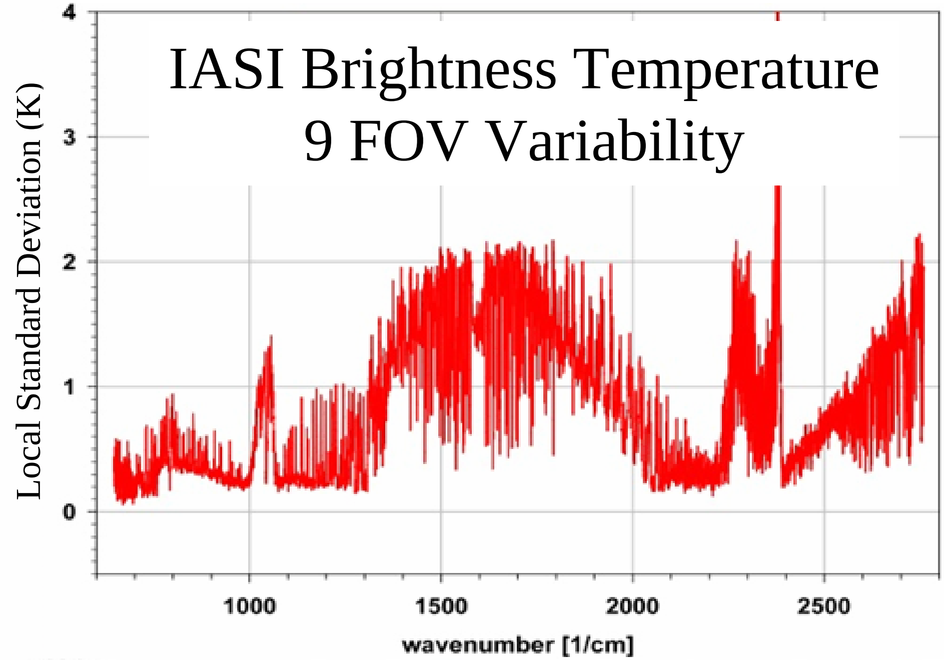


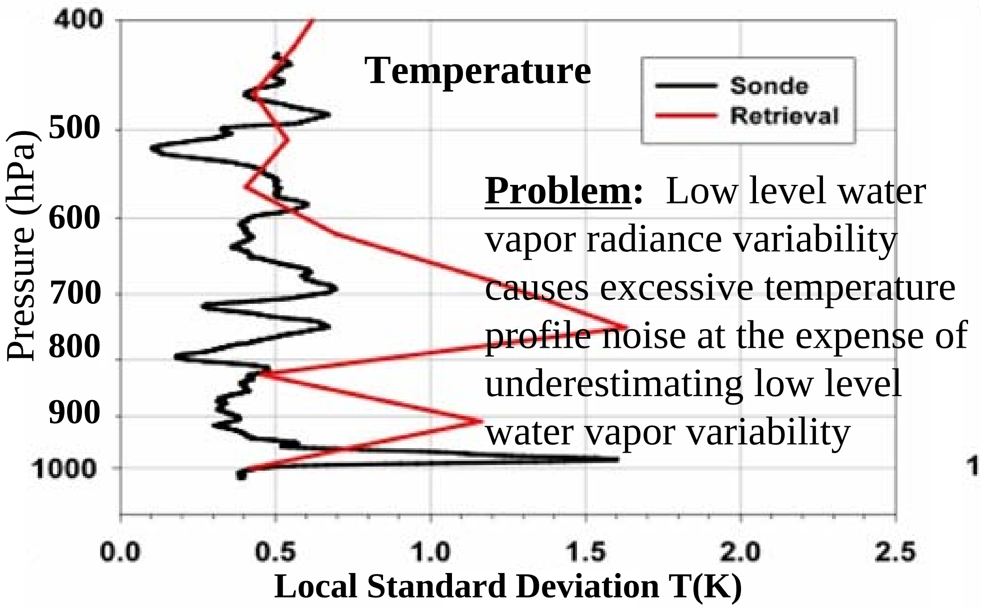




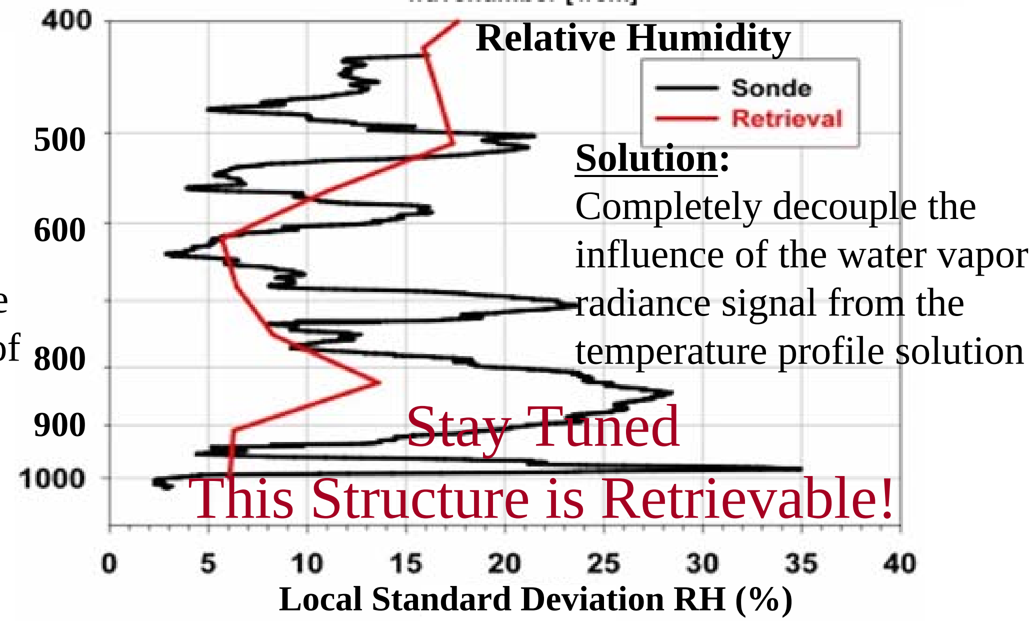
Mesoscale Atmospheric Variability Sensitivity Analysis (Local Std. Deviation)







Problem: Low level water vapor radiance variability causes excessive temperature profile noise at the expense of underestimating low level water vapor variability



Solution:
Completely decouple the influence of the water vapor radiance signal from the temperature profile solution

Stay Tuned
This Structure is Retrievable!

Summary and Conclusions

- JAIVEx was a very successful airborne field program for the cal/val of MetOp and Aqua Radiances and Retrieval Products. (Presentations that follow show more detailed results.)

- Simultaneous independent, SI traceable high spectral resolution radiance measurements enable immediate absolute radiometric cal/val of satellite sensors

- Airborne interferometers can be used as a transfer standard for the cross-validation of sensors in different sun-synchronous orbits (e.g., Aqua AIRS and MetOp IASI radiances and derived products)

- The extensive JAIVEx data set, including ground-based (i.e., CART-site) and airborne (e.g., dropsonde) validation measurement assets, make it ideal for solving peculiar sounding retrieval and radiance data assimilation problems. (For example, the influence of strong localized water vapor radiance variance on the retrieval of small scale variations of atmospheric temperature.)

Thank you to my co-authors and all those who made the JAIVEx a very successful Satellite Cal/Val Program