AIRS Radiance Validation

Bob Knuteson
Hank Revercomb, Dave Tobin, Ken Vinson
And the Whole S-HIS Team
With help from Paul Van Delst
Space Science and Engineering Center,
University of Wisconsin-Madison

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Hyperspectral Workshop Meeting
Madison

Topics

1. **Airborne Validation (Scanning-HIS)**
2. **Radiometric Calibration Expectations**
3. **AIRS Radiance Validation with S-HIS**
   5 cases cover Tropics to Arctic,
   Day and Night, Land and Sea
4. **AIRS Radiance Validation with Forward Model using In Situ Observations**

1. UW-Madison Scanning-High-resolution Interferometer Sounder (S-HIS)

Airborne Validation
Using High Altitude
NASA Aircraft

UW Scanning HIS: 1998-Present

HIS: High Resolution Interferometer Sounder (1985-1998)

Characteristics

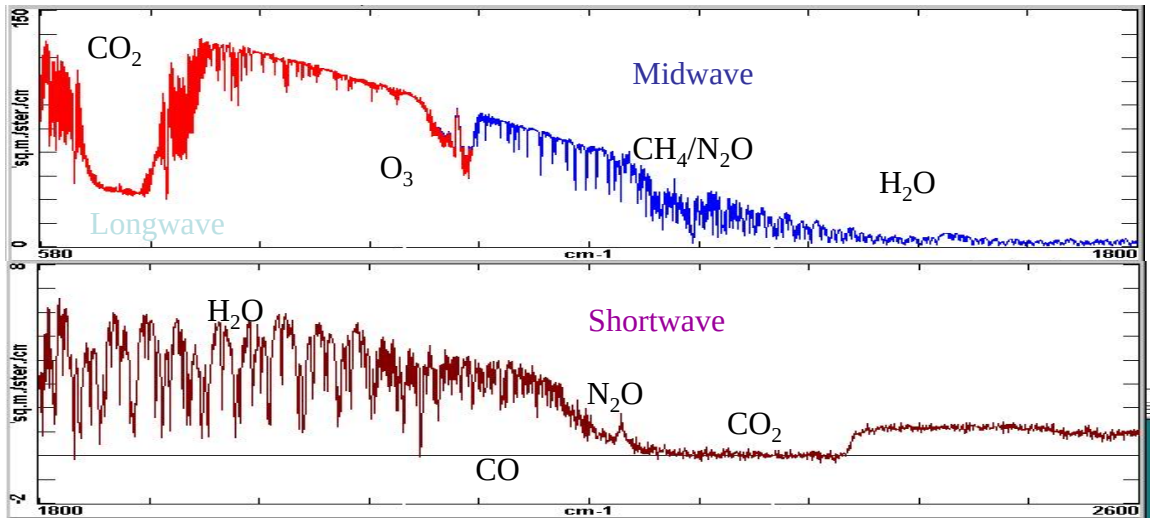
Spectral Coverage: 3-17 microns

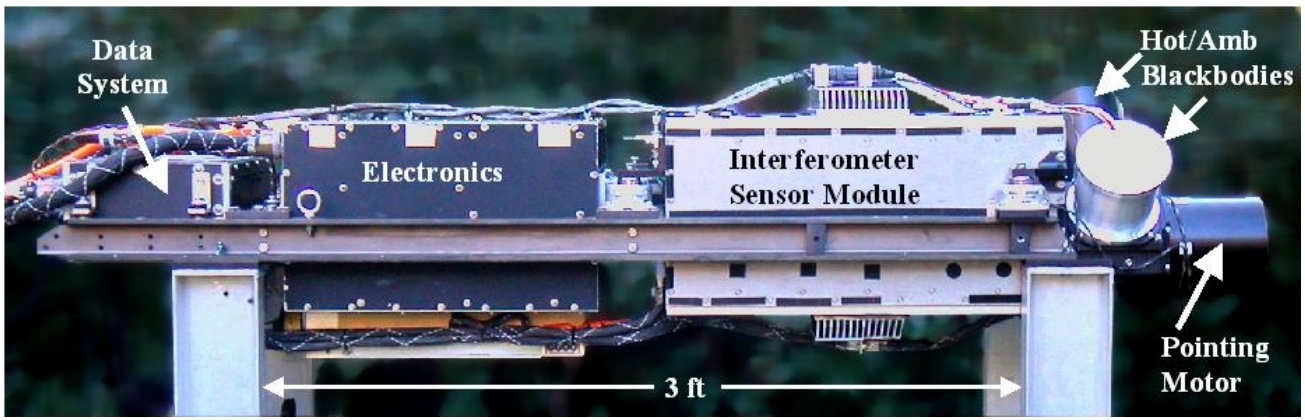
Spectral Resolution: 0.5 cm^{-1}

Resolving power: 1000-6000

Footprint Diam: 1.5 km @ 15 km

Cross-Track Scan: Programmable including uplooking zenith view

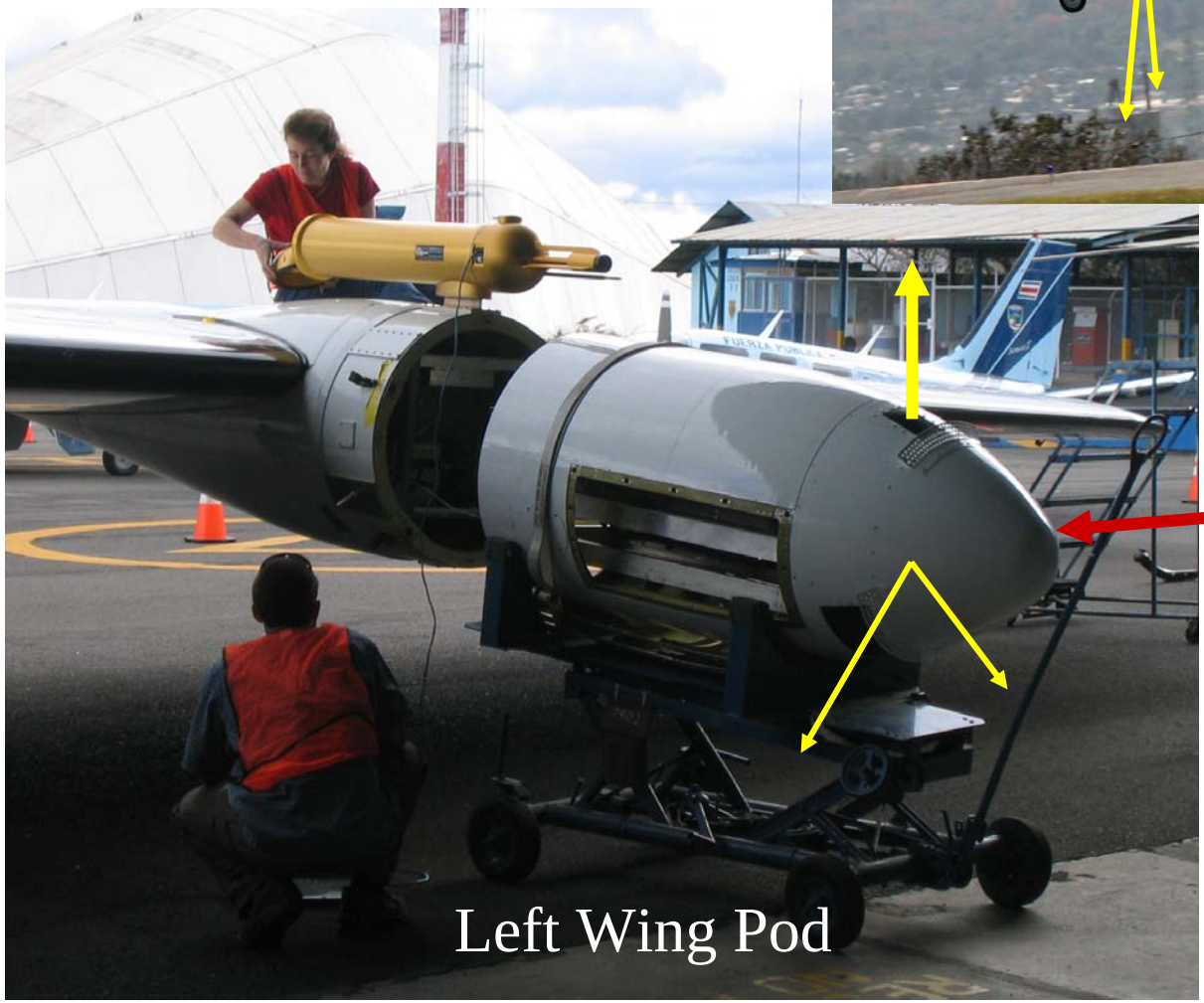




Applications:

- Radiances for Radiative Transfer
- Temp & Water Vapor Retrievals
- Cloud Radiative Prop.
- Surface Emissivity & T
- Trace Gas Retrievals

S-HIS for CRAVE
January 2006



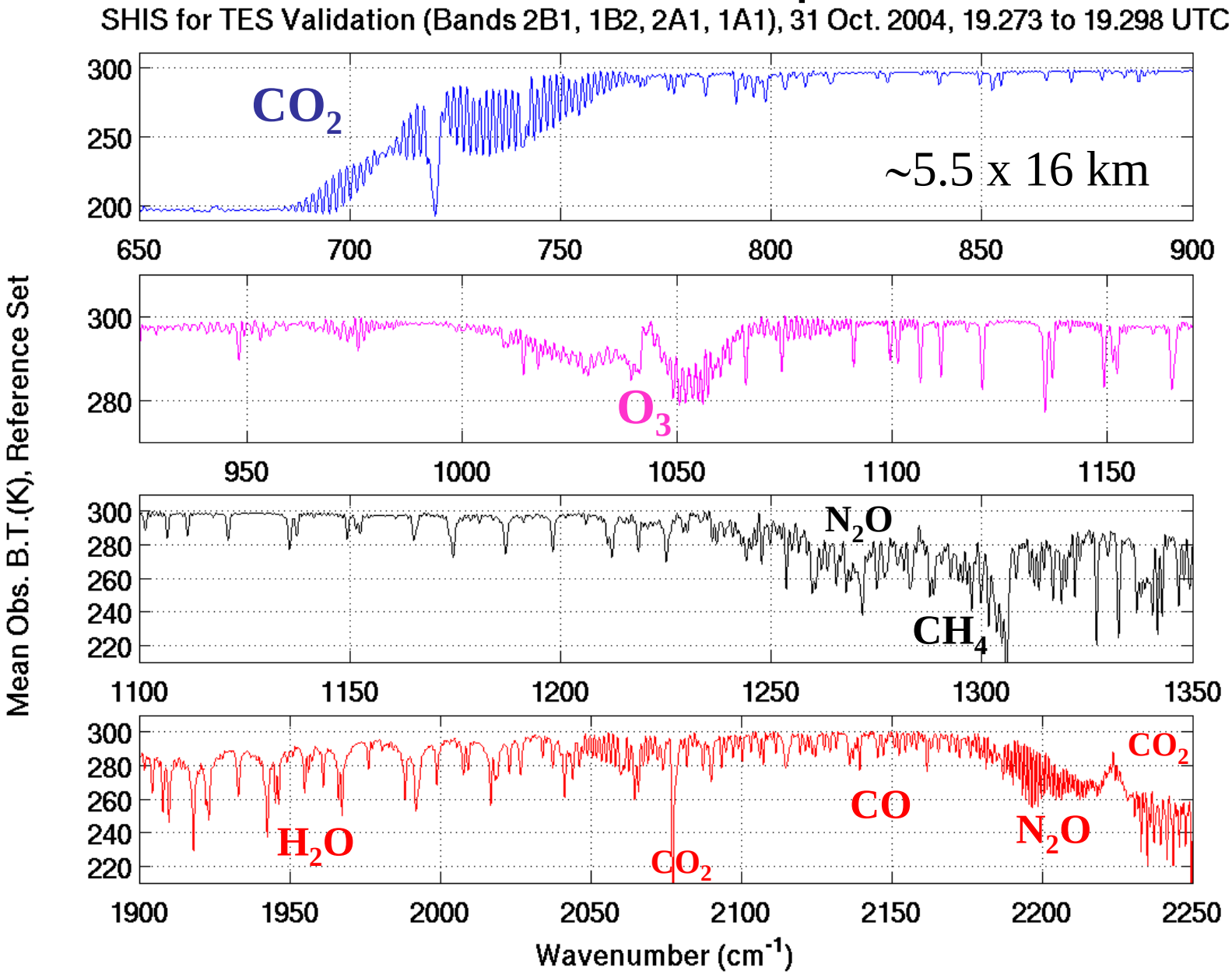
AURA Validation Experiment-Costa Rica

S-HIS

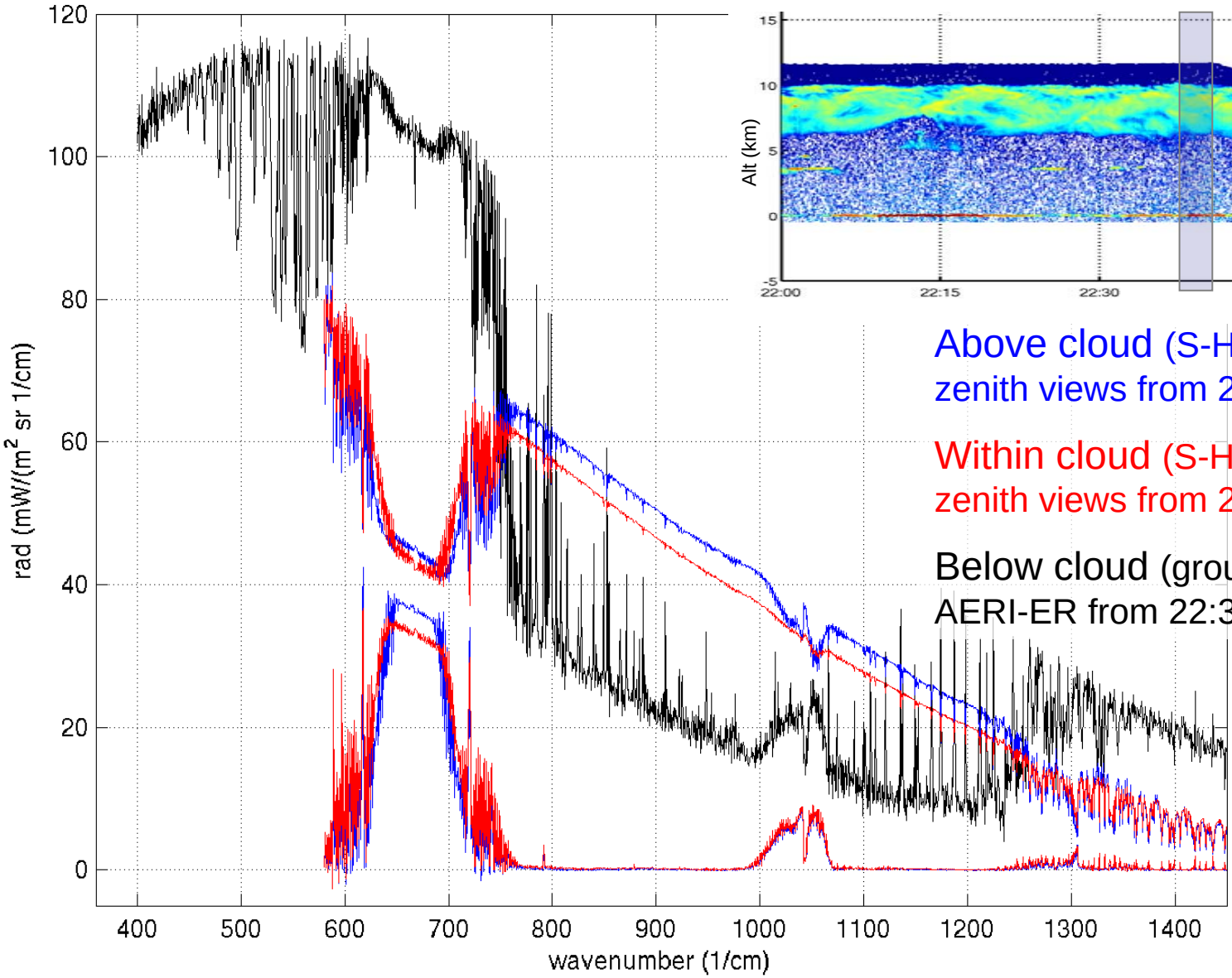
scans cross-track downward & looks upward

S-HIS –Tropospheric Emission Spectrometer (TES) Bands

near 31 Oct 2004 overpass



Uplooking: MPACE Example 10/17/04 with SHIS & AERI-ER



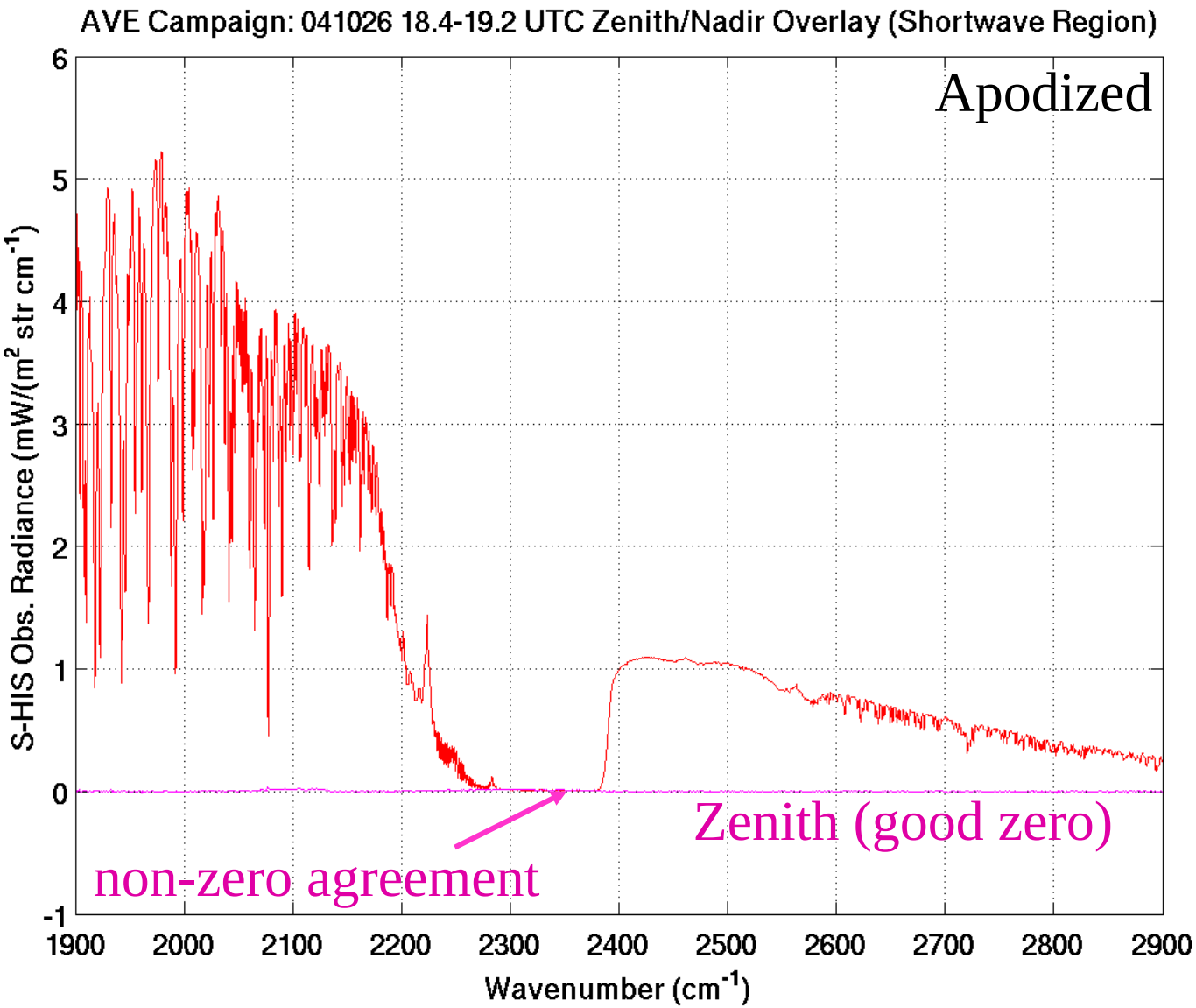
Above cloud (S-HIS nadir and zenith views from 22:35 to 22:40)

Within cloud (S-HIS nadir and zenith views from 22:55 to 23:00)

Below cloud (ground based AERI-ER from 22:35 to 23:00)

S-HIS Spectra, SW/4.3 μm CO_2

AVE, 26 October 2004



2. Radiometric Calibration Expectations

Scanning-HIS Radiometric Calibration Budget

TABB= 227, THBB=310, 11/16/02 Proteus

Similar to AERI description in Best, et al., CALCON 2003

3-sigma Tb error mostly < 0.2 K for Tb >220 K

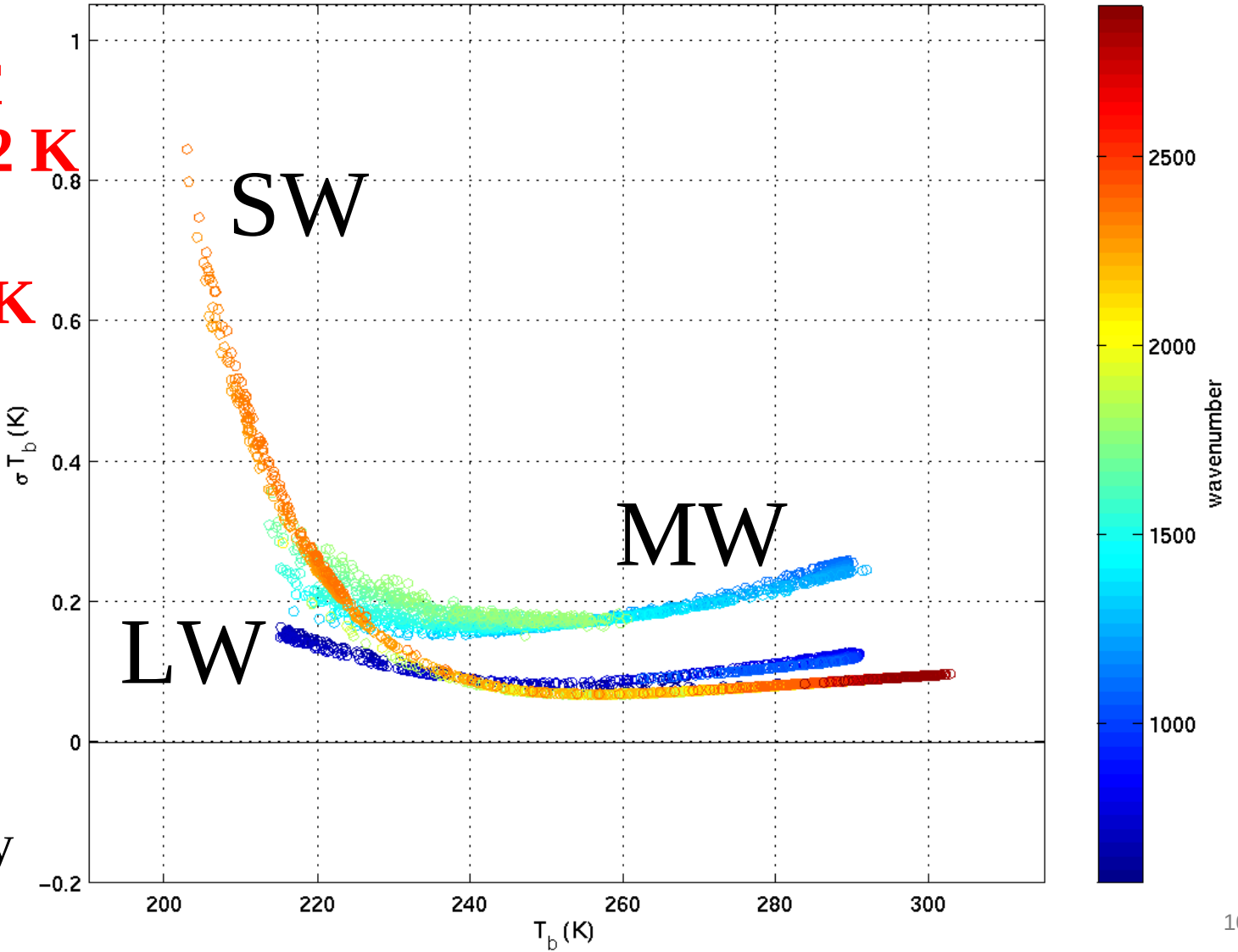
RSS of Errors in

T_{HBB}, T_{ABB}

T_{Rfl}

$\varepsilon_{HBB}, \varepsilon_{ABB}$

+ 10% of non-linearity correction

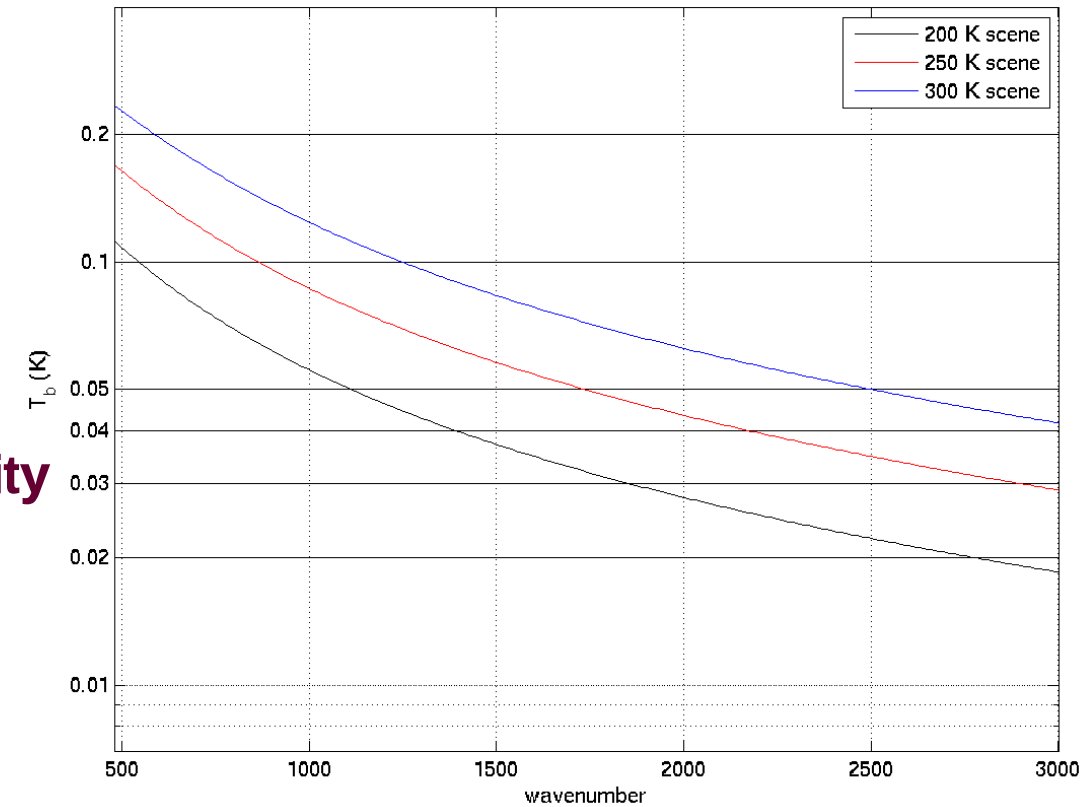


AIRS Radiometric Calibration: A better error estimate is needed

The statement of an AIRS Radiometric Calibration of <0.2% absolute error in the AIRS Technical Fact Sheet* is indicative of the problem

The difference between absolute error (3-sigma or at least 2-sigma) and reproducibility or repeatability needs to be clarified

Brightness temperature errors for 0.2% radiance errors are unrealistic in the SW band; 0.2 K is entirely different



*http://www-airs.jpl.nasa.gov/press/AIRS_tech_factsheet.pdf

The NIST Connection

- NIST traceable standards are used in the AERI blackbody calibration. S-HIS employs the same calibration.

Max Difference
< 0.055°C Longwave
< 0.035°C Shortwave
between 293 & 333 K

- Direct test of S-HIS planned for 2006 using NIST Transfer Radiometer (TXR) at aircraft flight temperatures

3. DIRECT Radiance Validation of AIRS using Scanning-HIS

- 4 Daytime Cases
- 1 Nightime Case

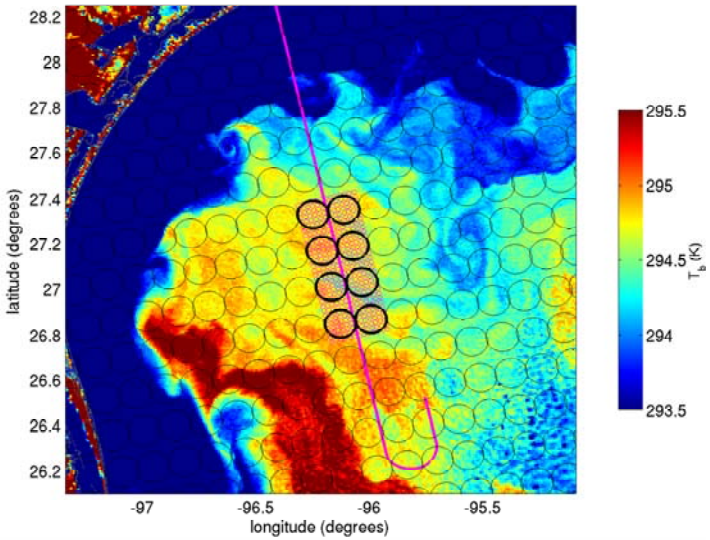
AIRS / S-HIS Comparison Methodology

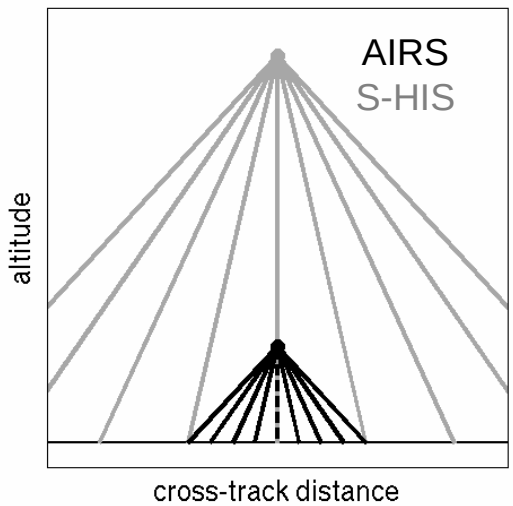
$$(Obs_{AIRS}\text{-}Calc_{AIRS}) \otimes SRF_{SHIS} - (Obs_{SHIS}\text{-}Calc_{SHIS}) \otimes SRF_{AIRS}$$

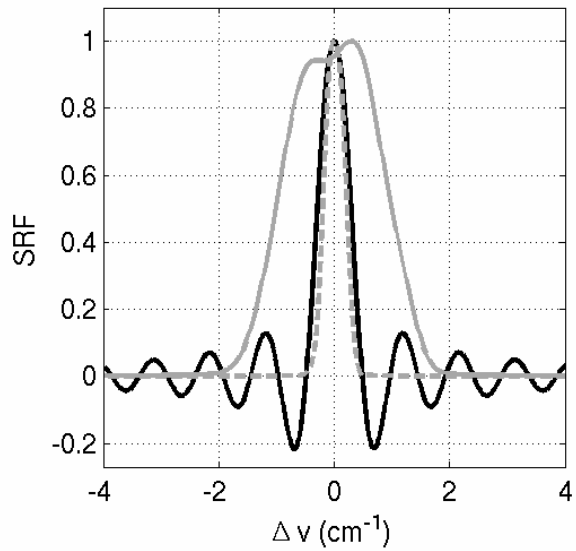
Spatial colocation is achieved by selecting scenes with low variability and covering the full AIRS FOVs with SHIS observations

The double obs-calc method accounts for altitude and view angle differences and differences in instrument lineshapes

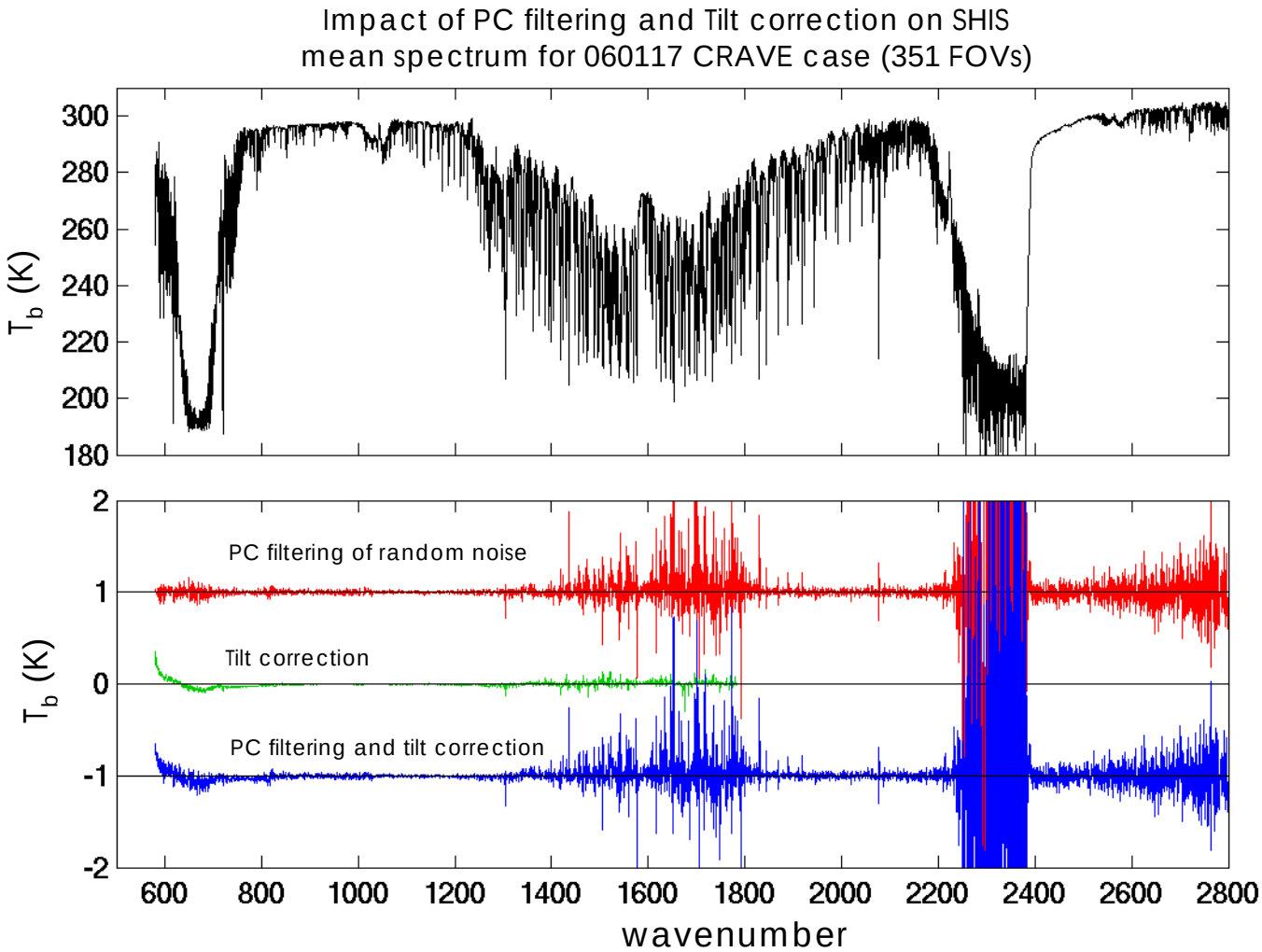
Channels with high sensitivity above the aircraft altitude are excluded from the final comparisons







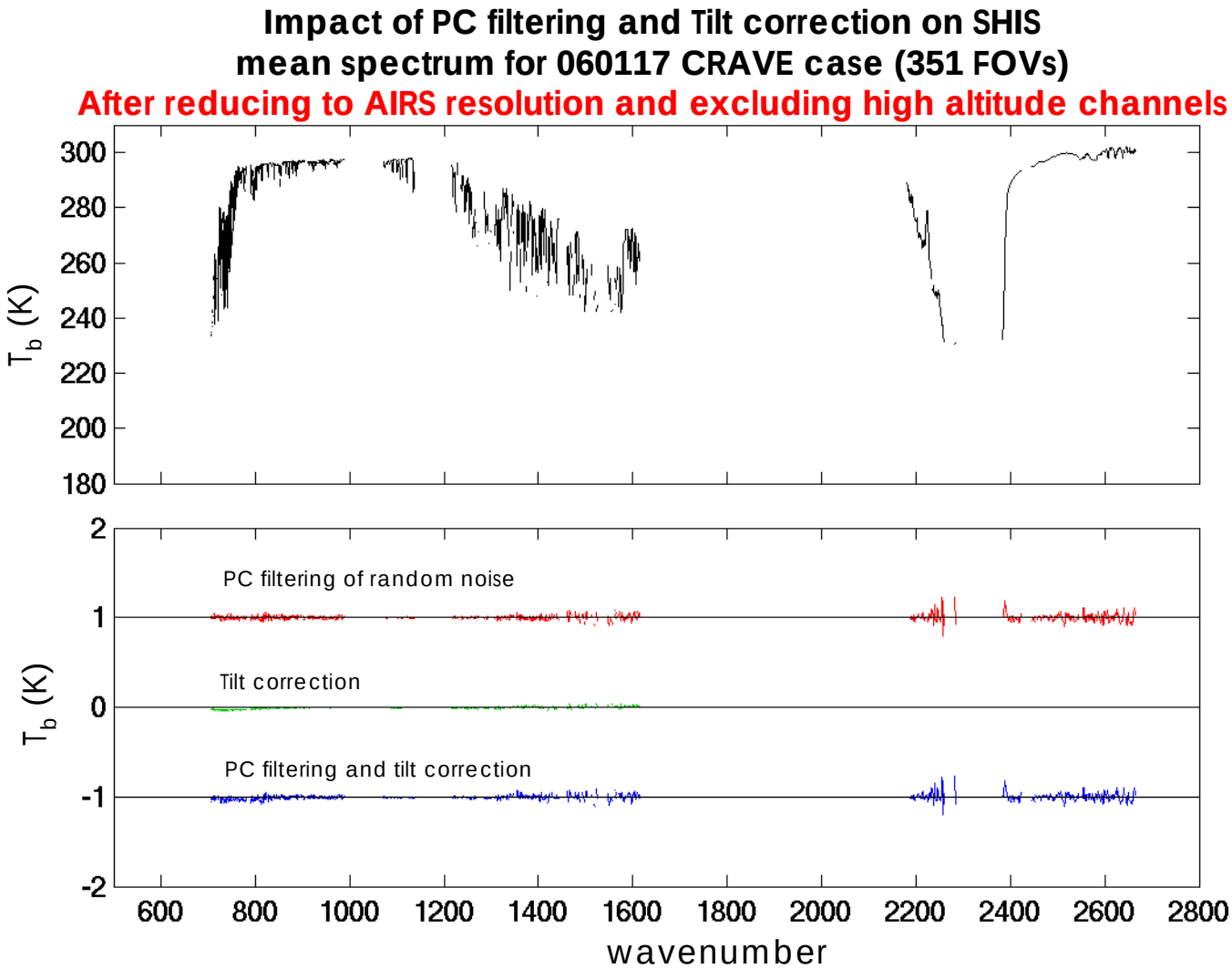
Full S-HIS Spectral Coverage



Full S-HIS spectral coverage & resolution:

Mainly noise reduction (bias for only LW < 650 cm^{-1} tilt correction)

S-HIS After PC Filtering and Tilt Correction

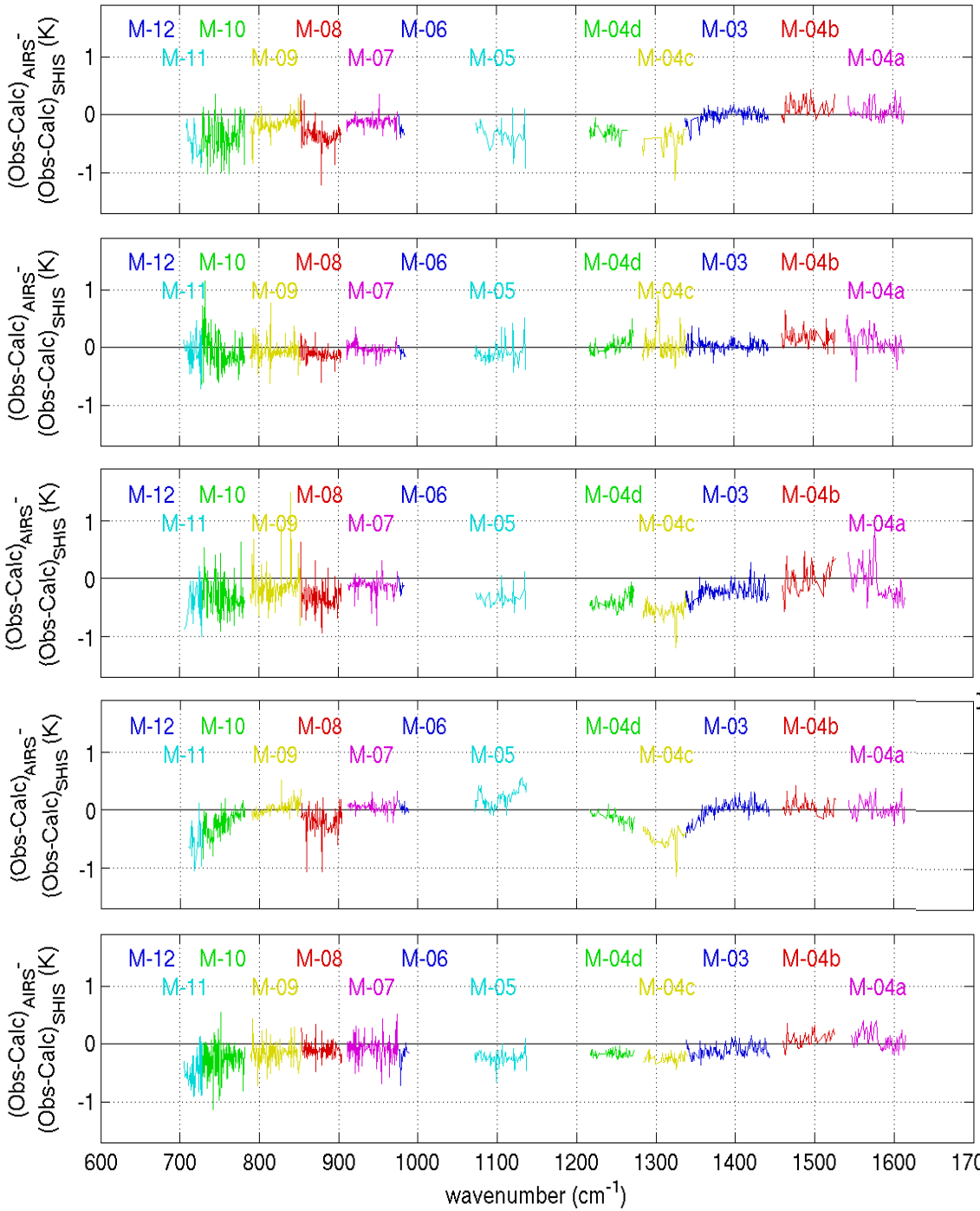


For final comparison conditions:

No biases, just noise reduction

AIRS-SHIS Summary

- **Direct Radiance validation with S-HIS is remarkably good**
- **What details go into these comparisons?**



2002.11.16 ARM-SGP (Day/Land)

2002.11.21 Gulf of Mex (Day/ Ocean)

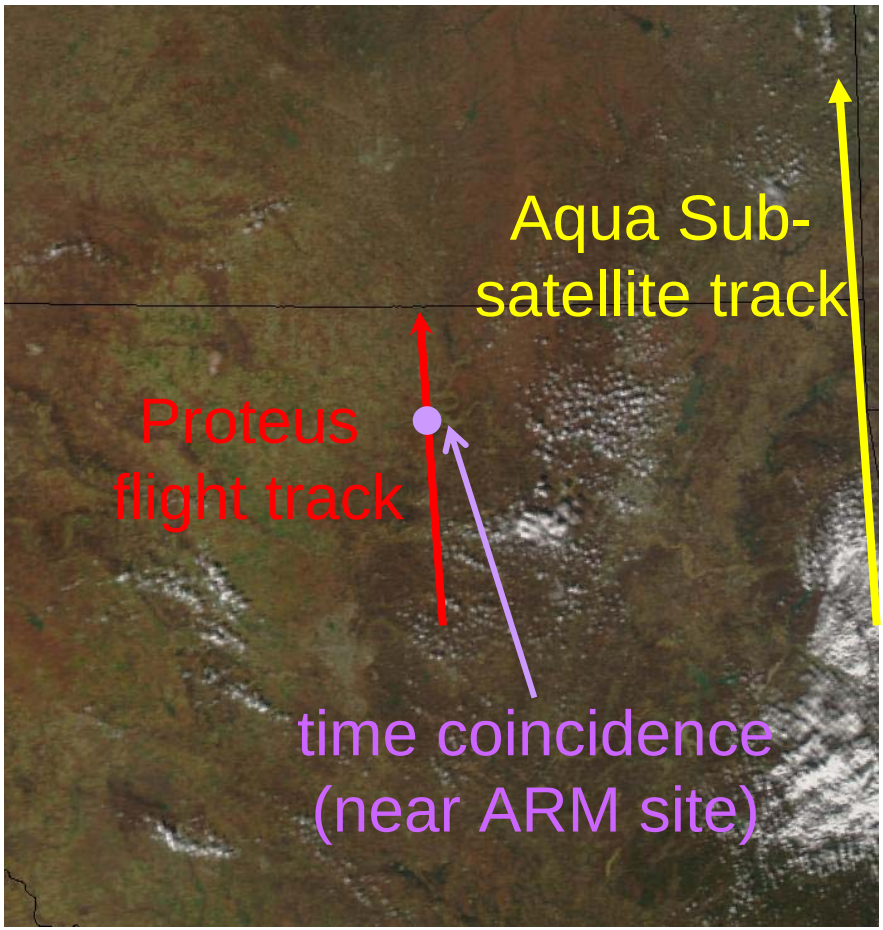
2004.09.07 Italy (Night/ Ocean)

2004.10.21 Arctic (Day/Ice)

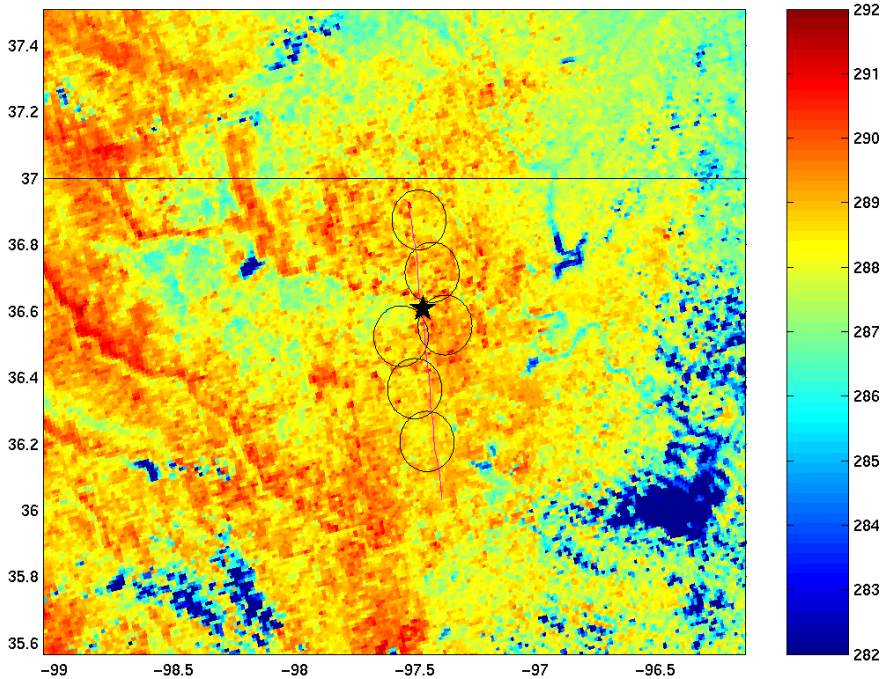
2006.01.17 Tropical (Day/ Ocean)

ARM-SGP Validation case: 2002.11.16

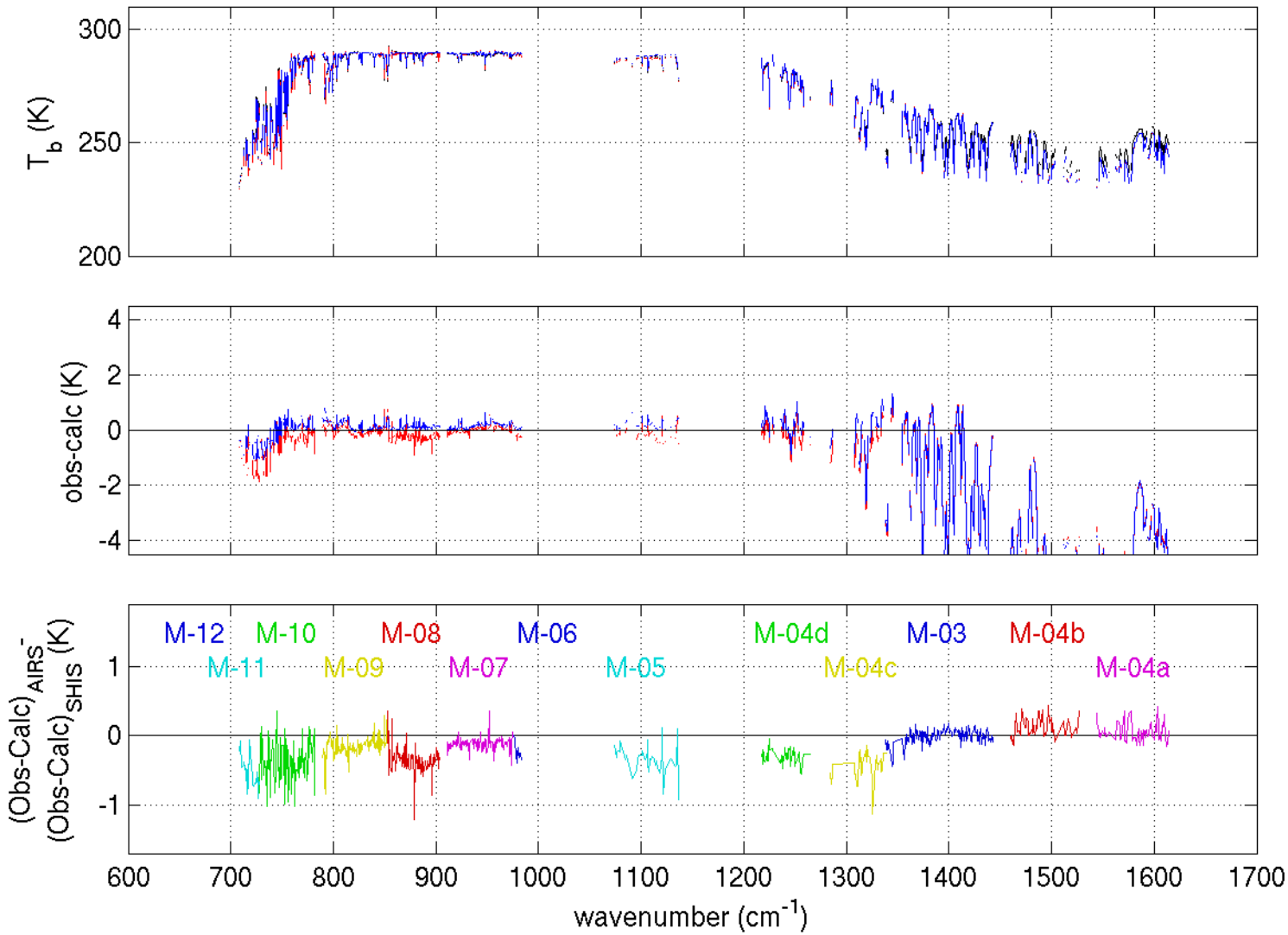
ARM UAV Campaign, S-HIS on Proteus
@ ~14km near ARM SGP CF, 19:24 UTC



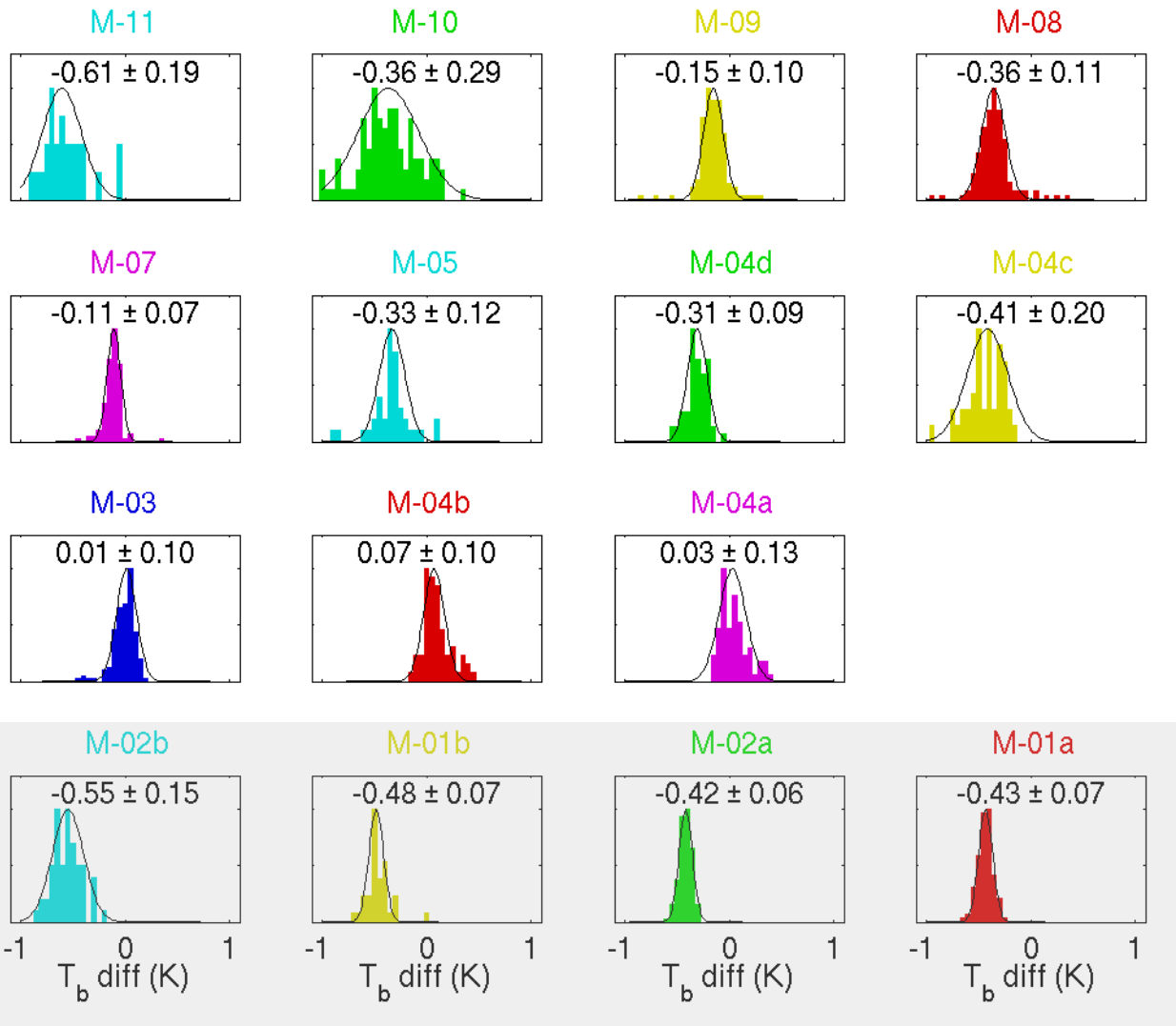
MODIS 12 μm brightness temperatures and AIRS FOV locations:



ARM-SGP Validation case: 2002.11.16



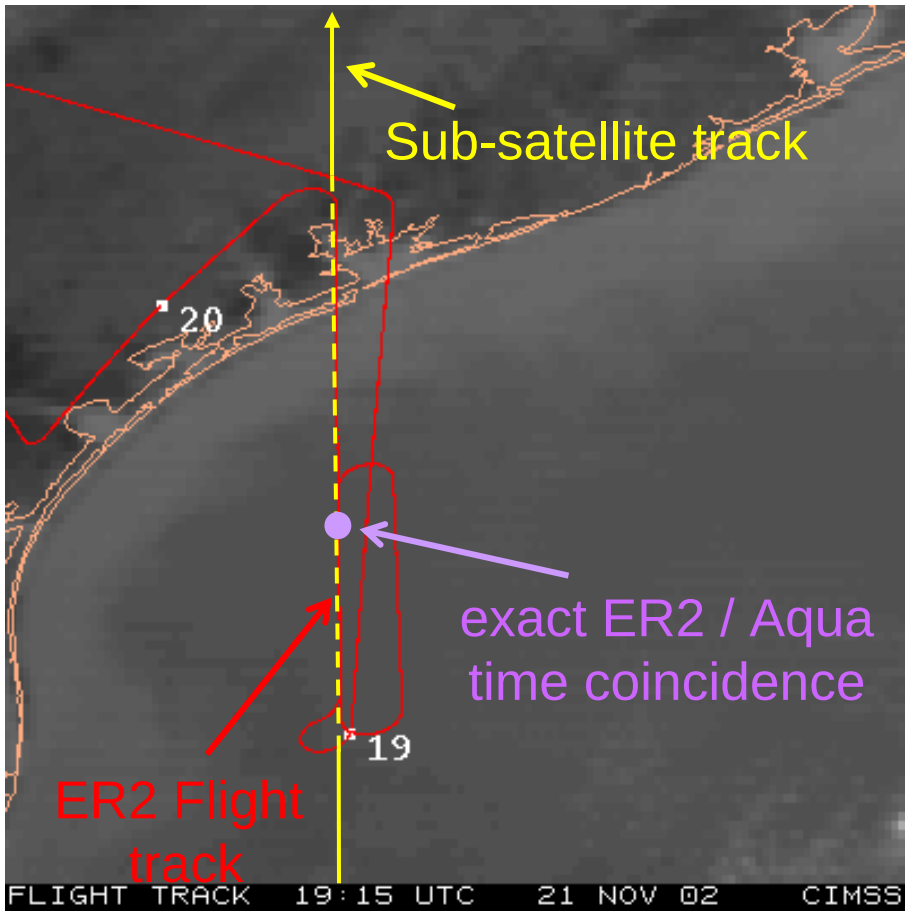
ARM-SGP Validation case: 2002.11.16



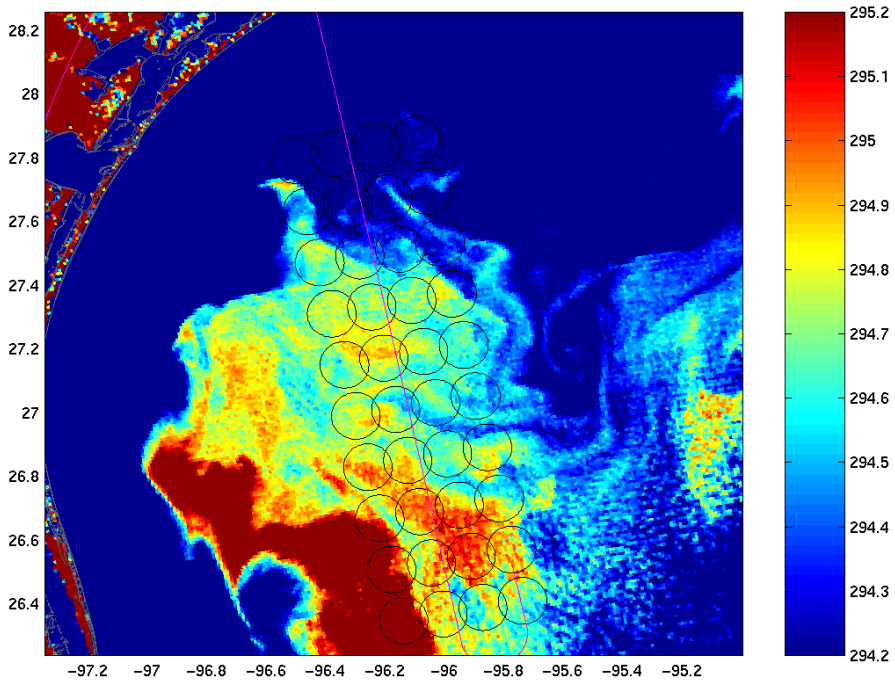
SW Modules

Gulf of Mexico Validation case: 2002.11.21

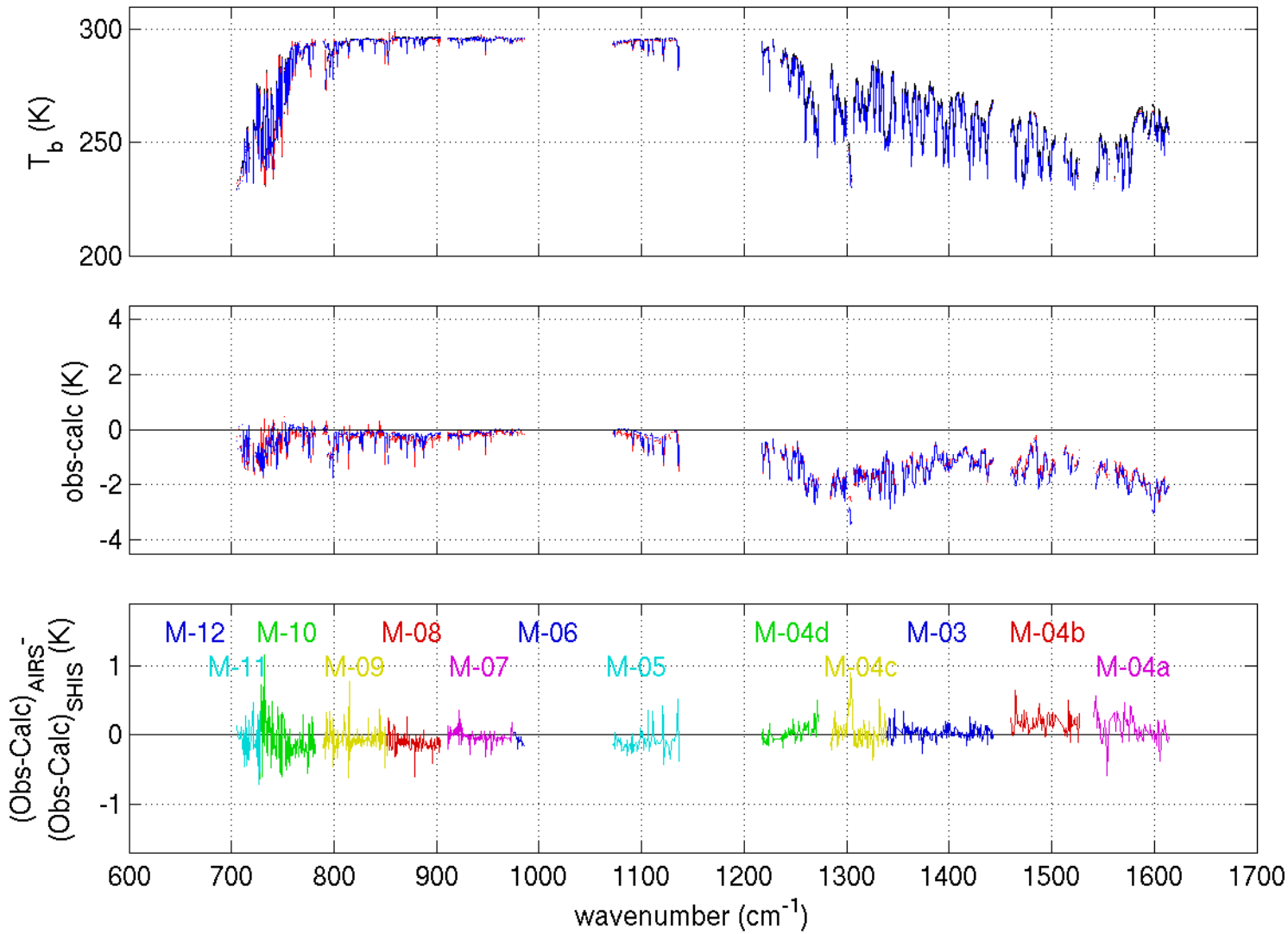
Texas 2002 Aqua Validation Campaign
S-HIS on ER-2 @ ~20km over Gulf of Mexico
at 19:40 UTC



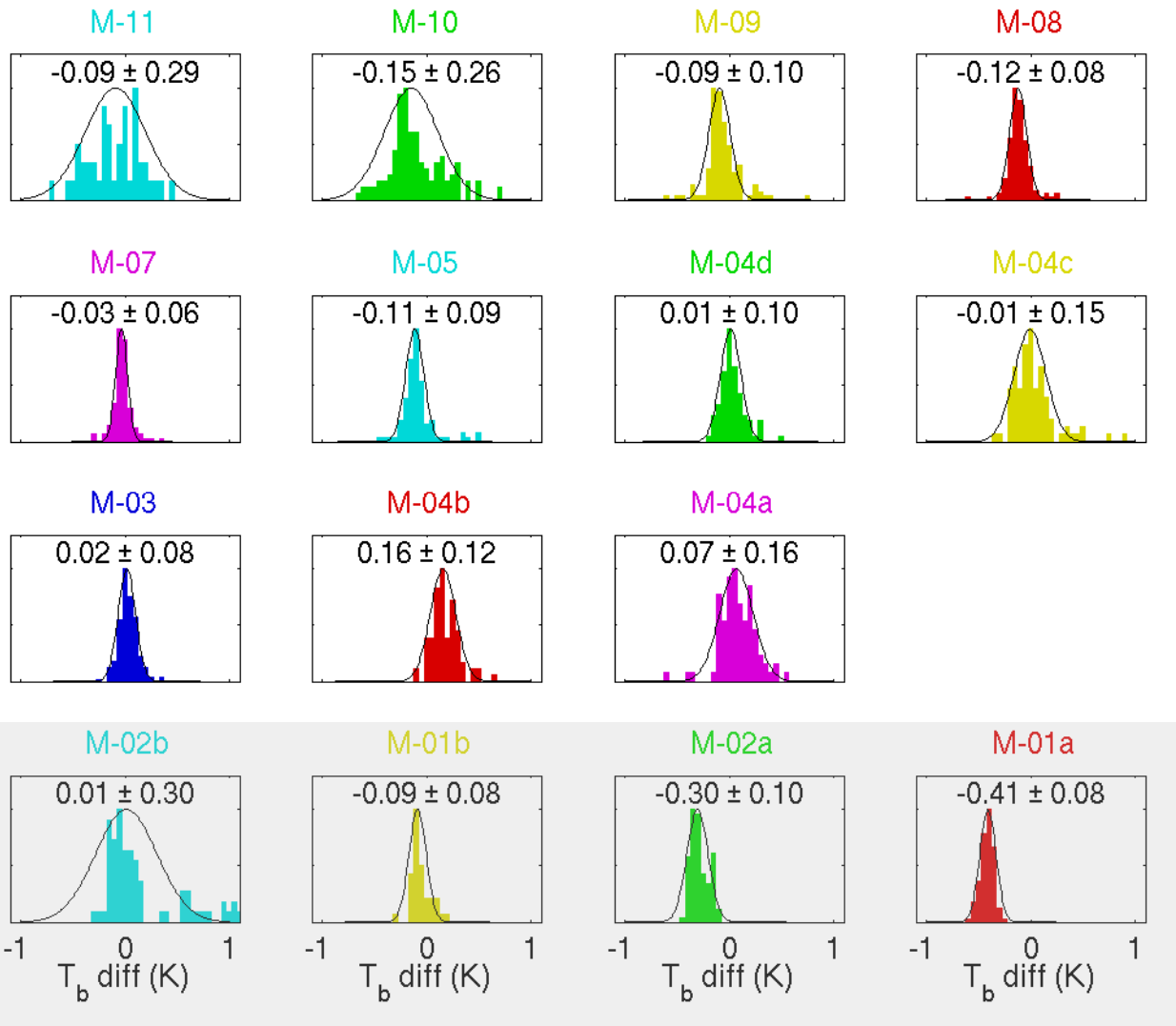
MODIS 12 μm brightness
temperatures and AIRS FOV locations:



Gulf of Mexico Validation case: 2002.11.21



Gulf of Mexico Validation case: 2002.11.21

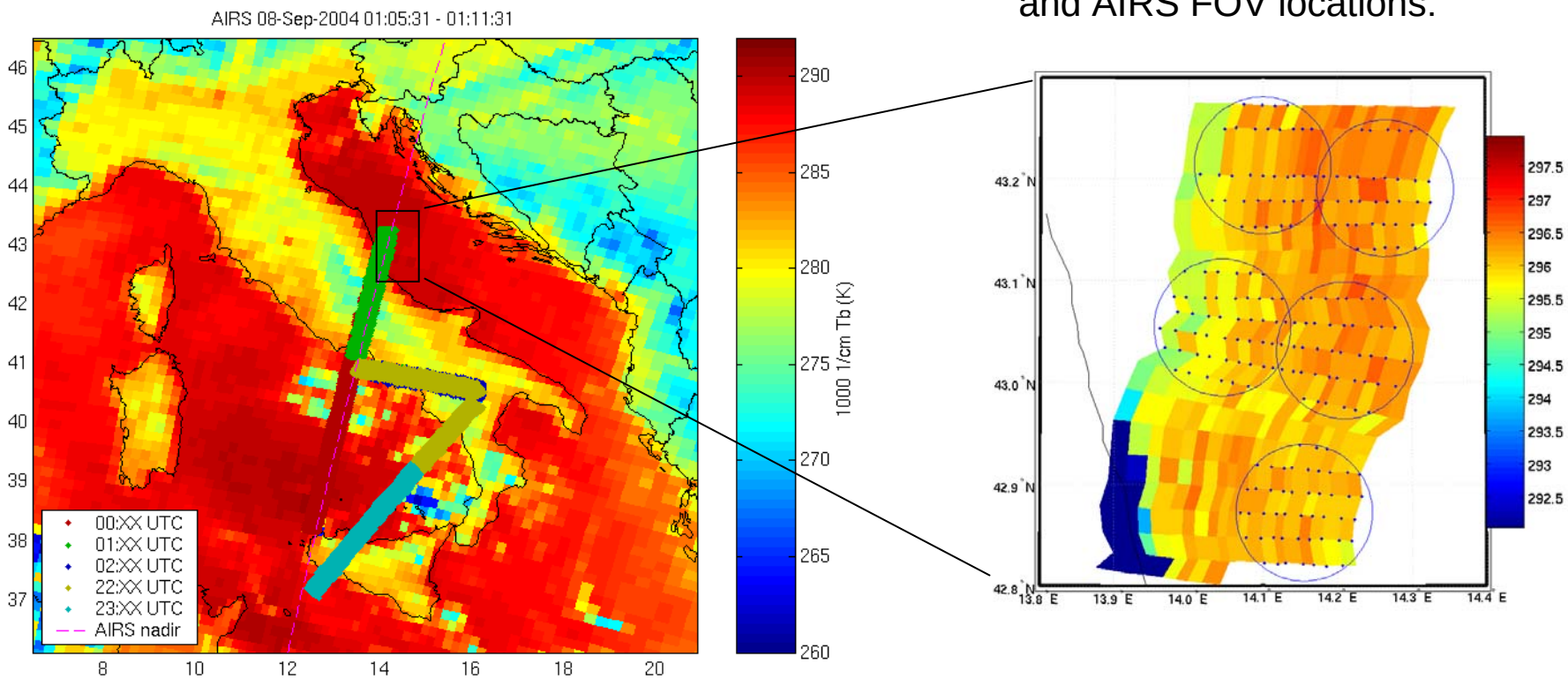


SW Modules

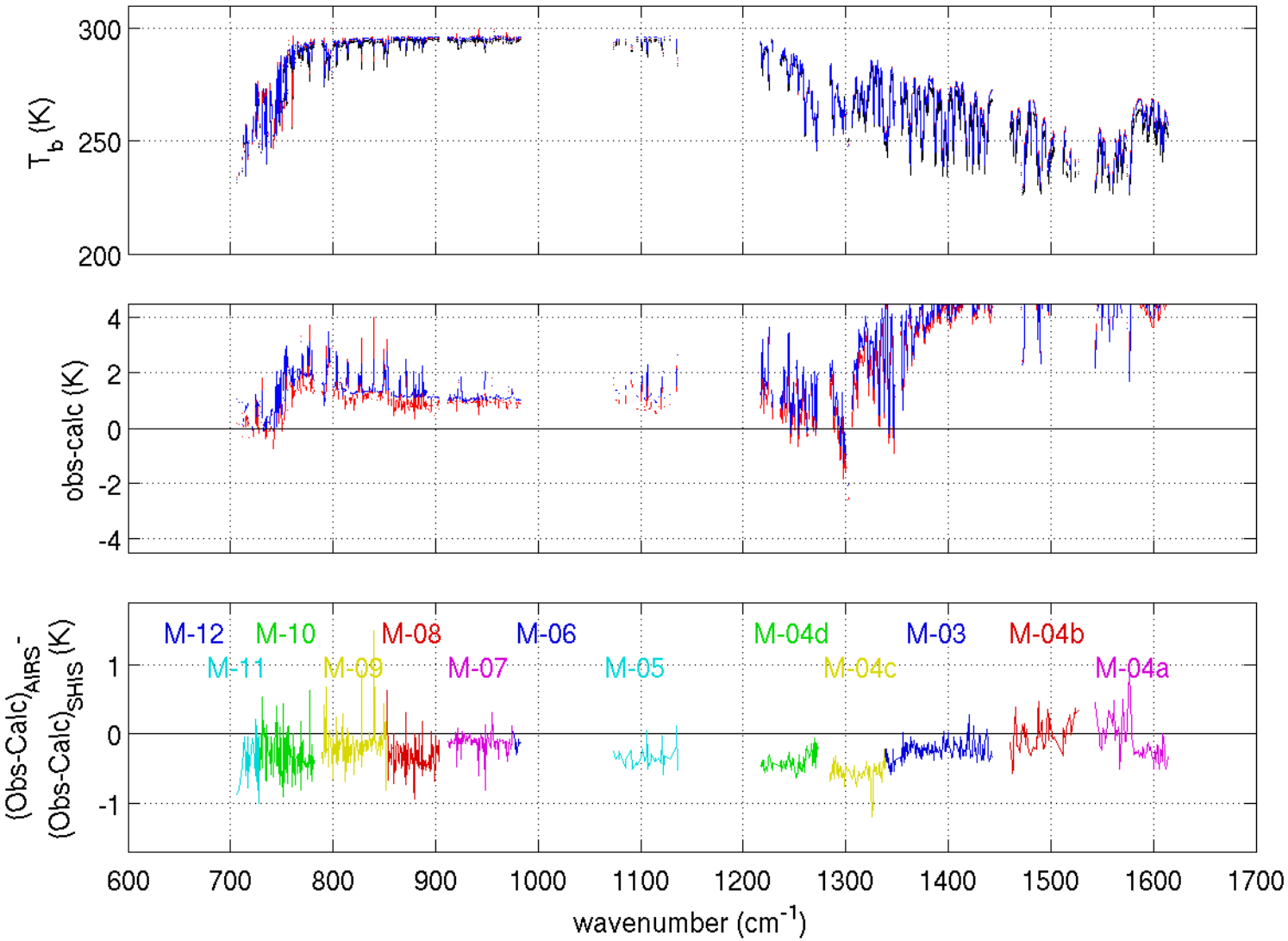
Italy Validation case: 2004.09.07

ADRIEX (EAQUATE) Campaign
S-HIS on Proteus @ ~16km over Adriatic Sea
2004.09.08, 01:10 UTC (Nighttime)

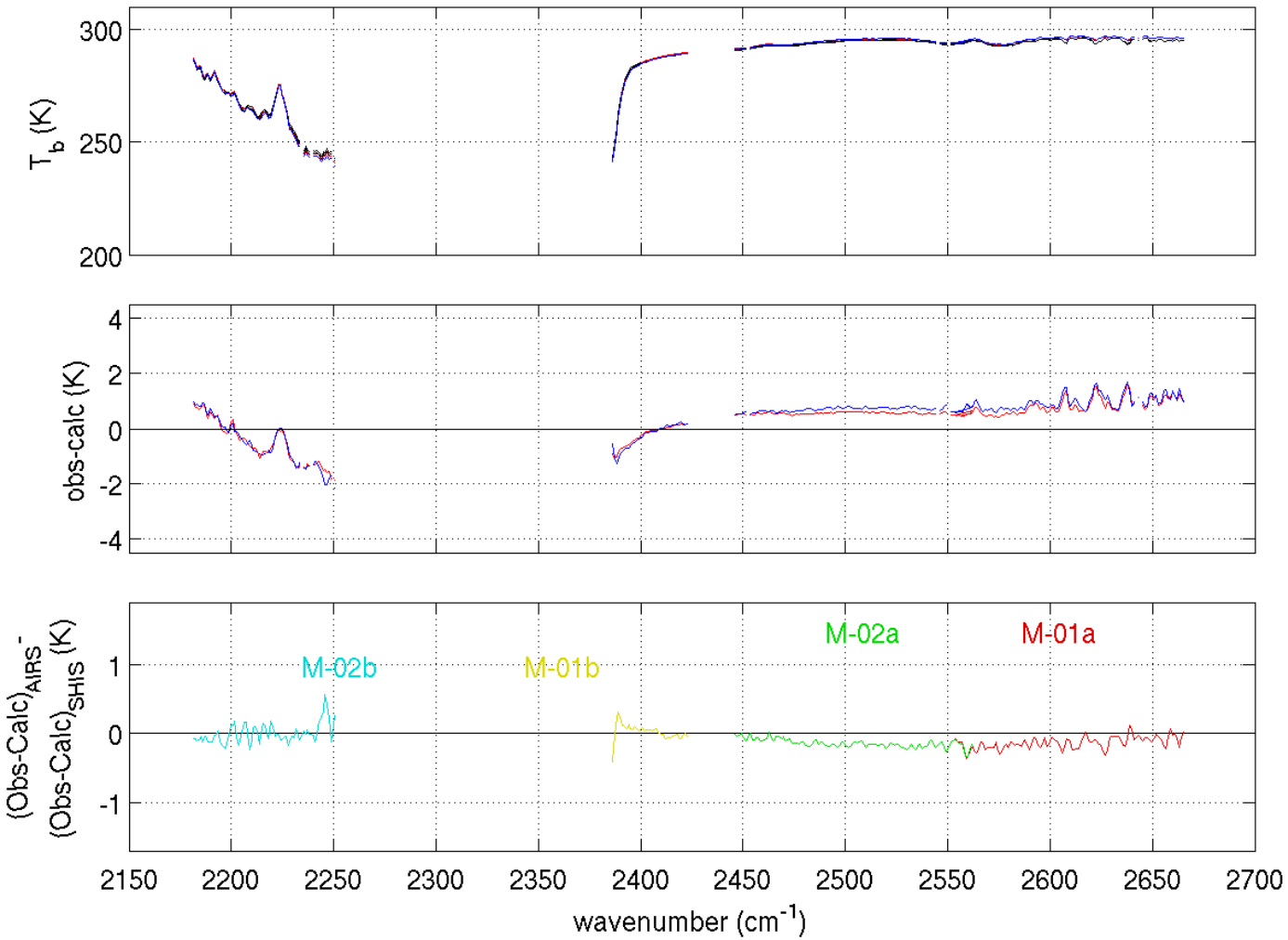
S-HIS 12 μm brightness temperatures and AIRS FOV locations:



Italy Validation case: 2004.09.07

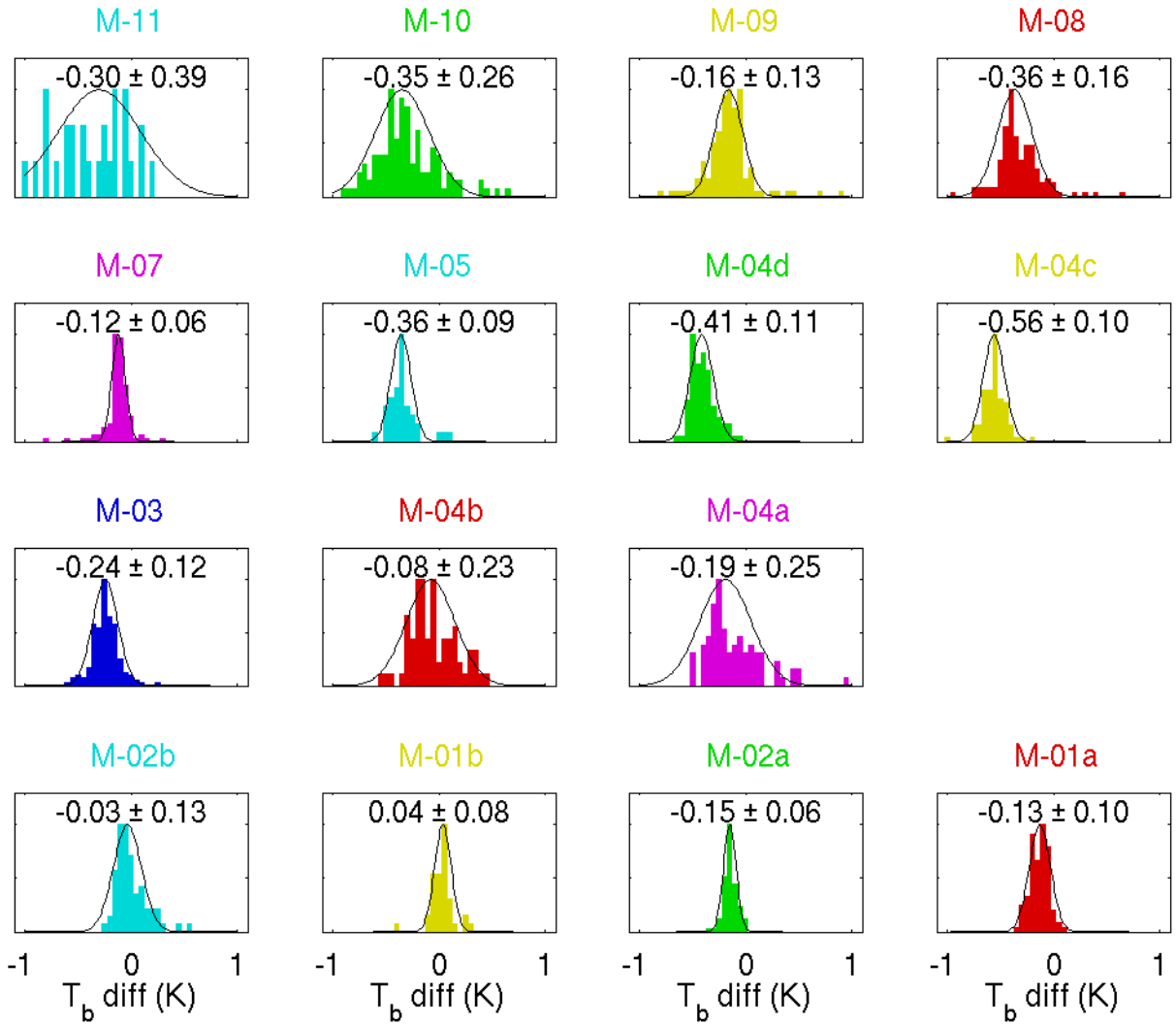


Italy Validation case: 2004.09.07



Night Flight Shortwave validation is Excellent

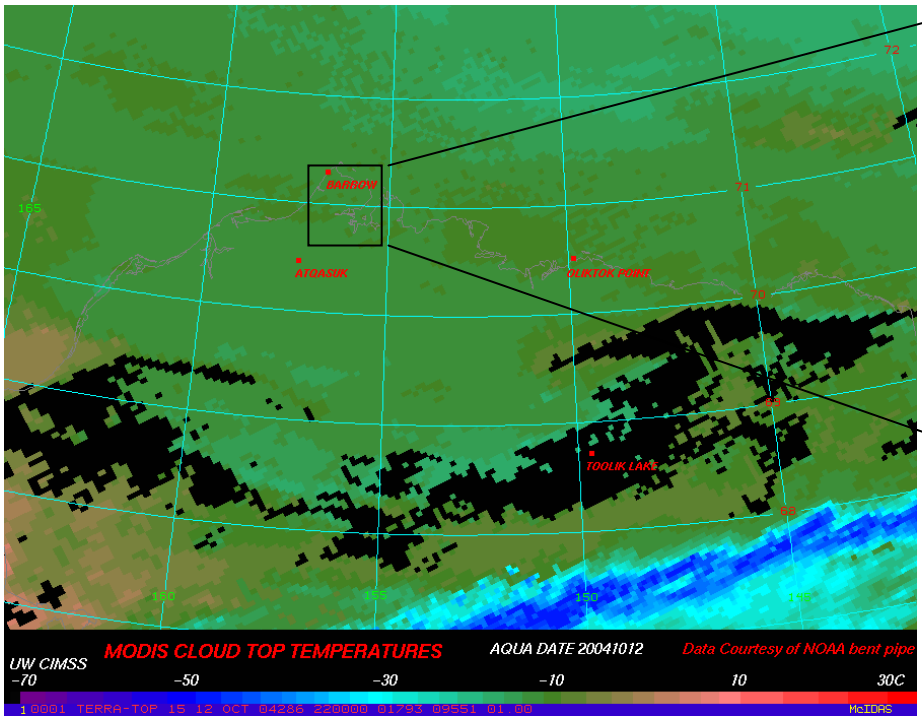
Italy Validation case: 2004.09.07



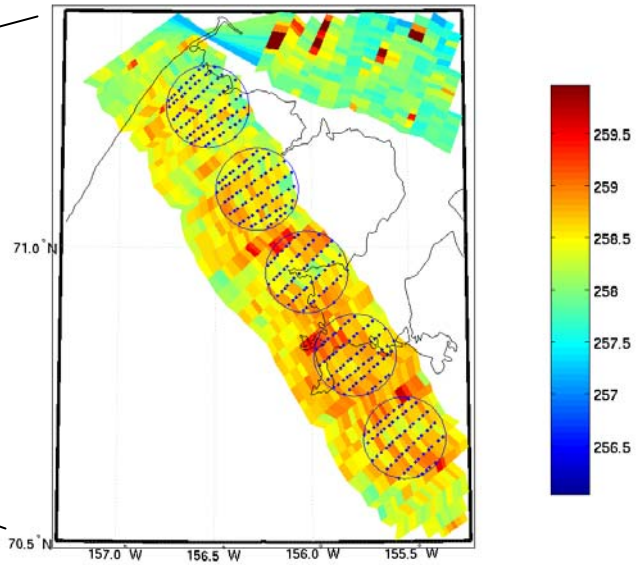
SW Modules

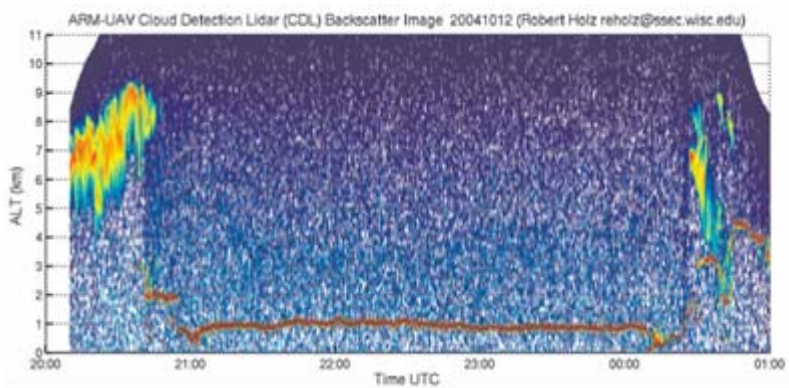
Arctic Validation case: 2004.10.21

MPACE Campaign
S-HIS on Proteus @ ~16km over low stratus clouds near Barrow, AK at 22:00 UTC

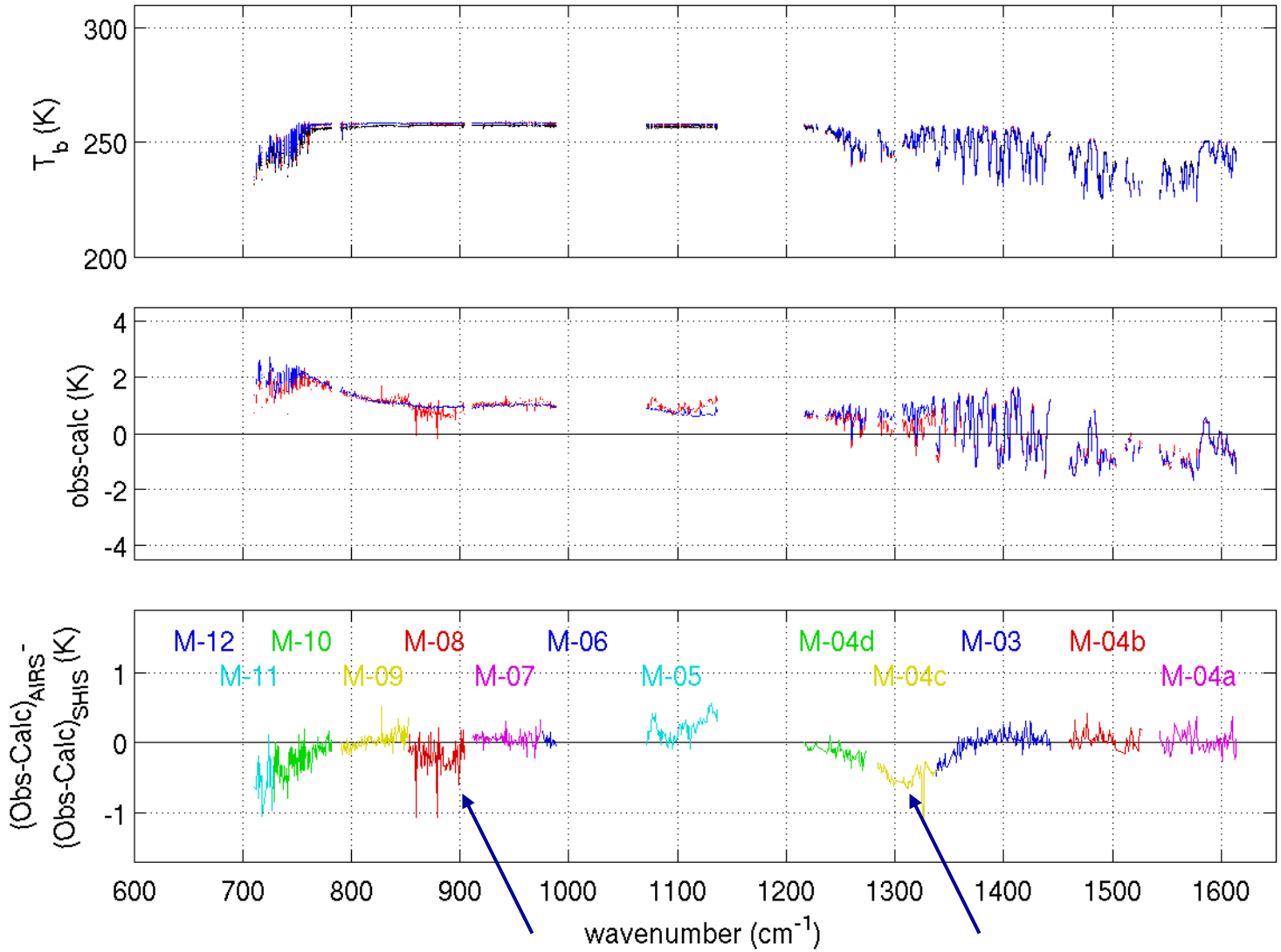


S-HIS 12 μm brightness temperatures and AIRS FOV locations:



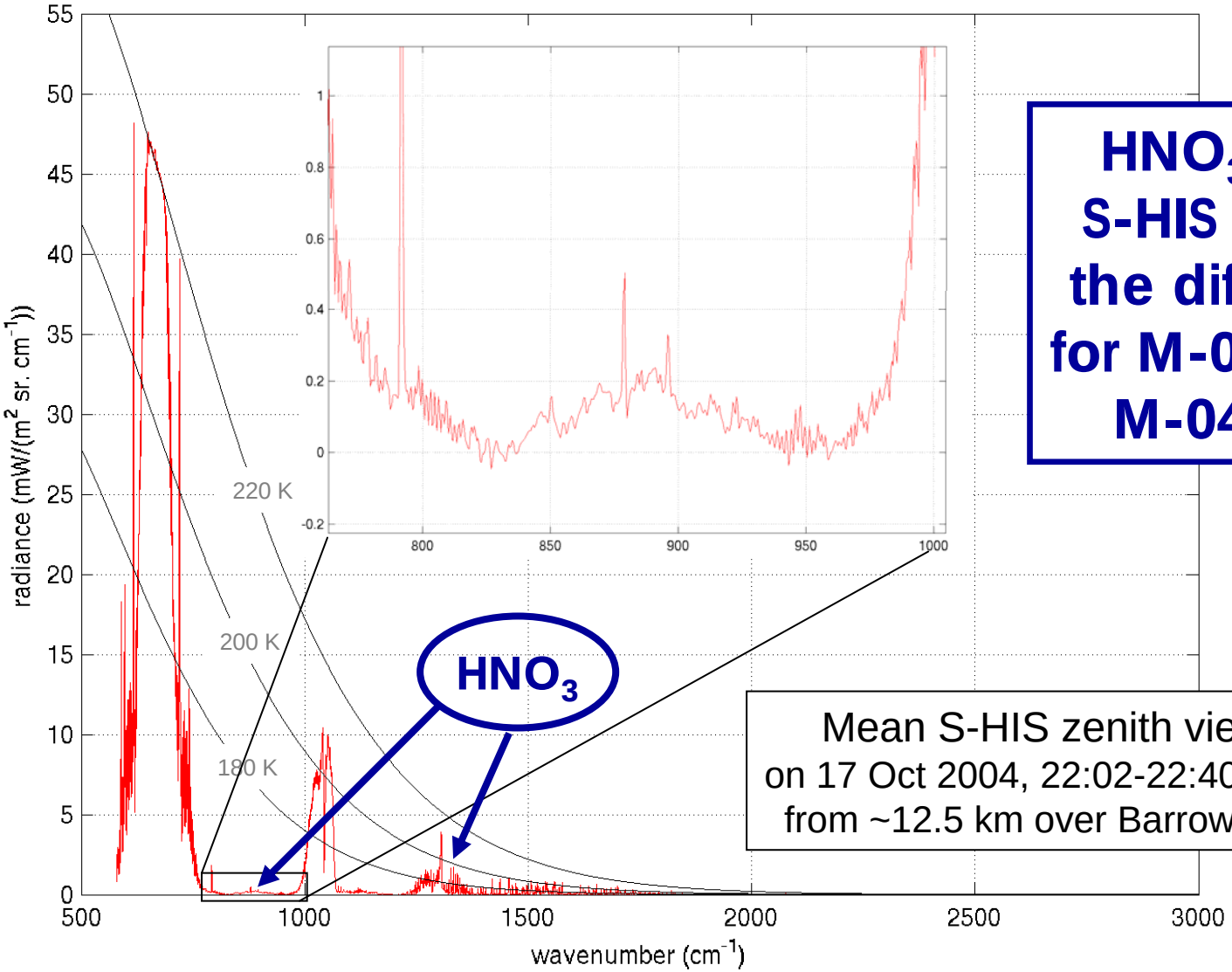


Arctic Validation case: 2004.10.21



How do we explain these differences?

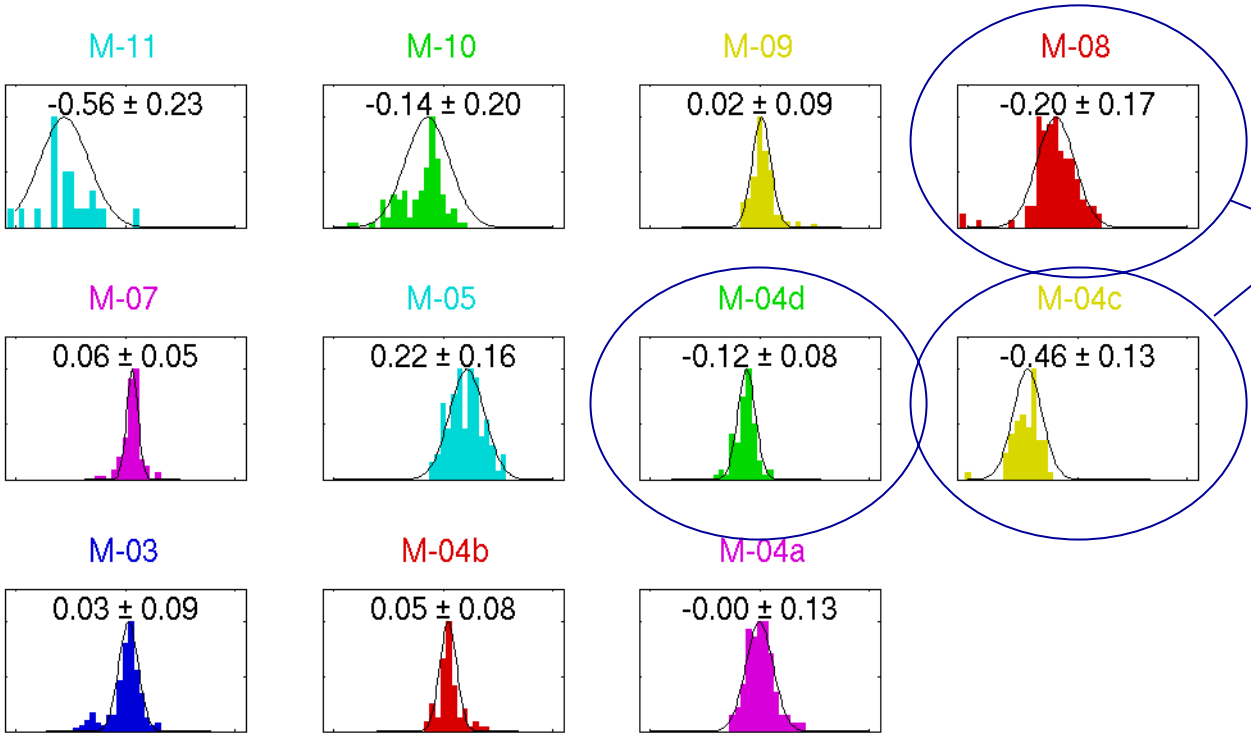
HNO_3 in S-HIS zenith views

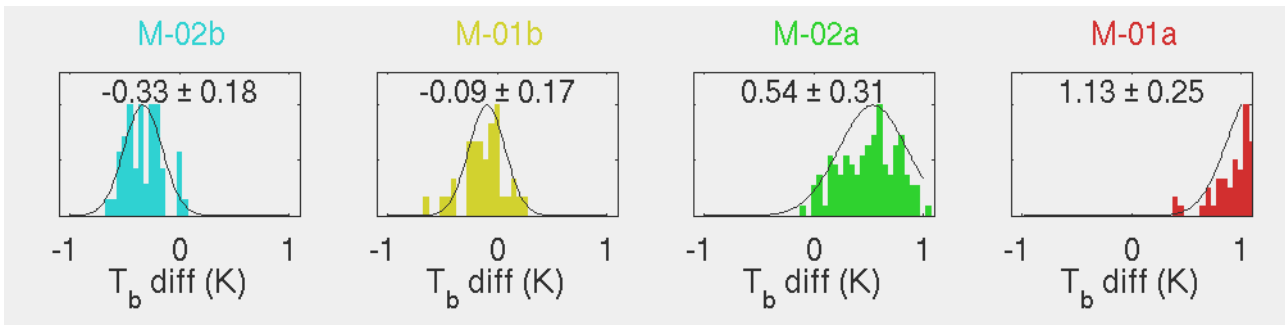


HNO_3 above S-HIS explains the differences for M-08, M-04c, M-04d, M03

Mean S-HIS zenith view
on 17 Oct 2004, 22:02-22:40 UTC
from ~12.5 km over Barrow, AK

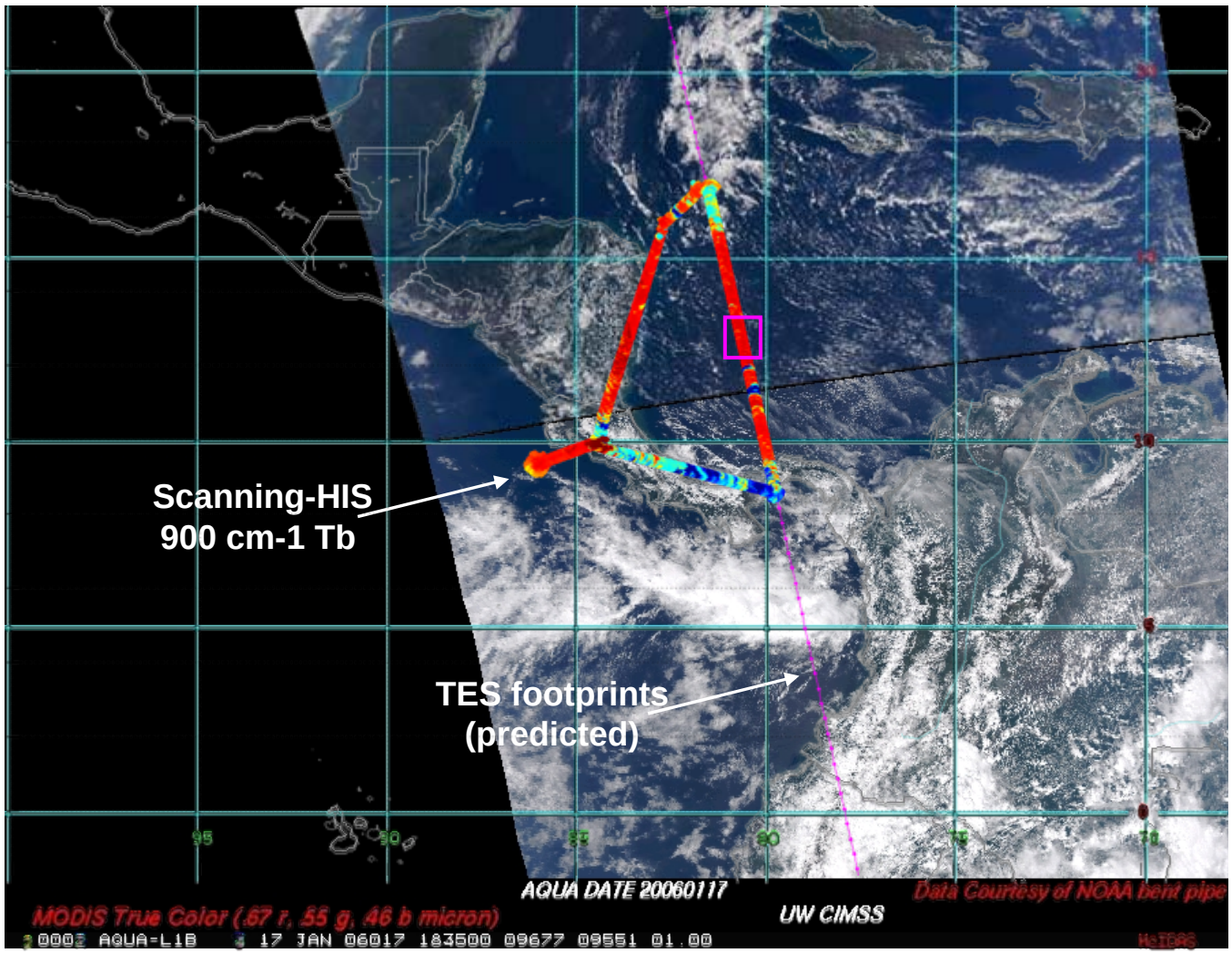
Arctic Validation case: 2004.10.21



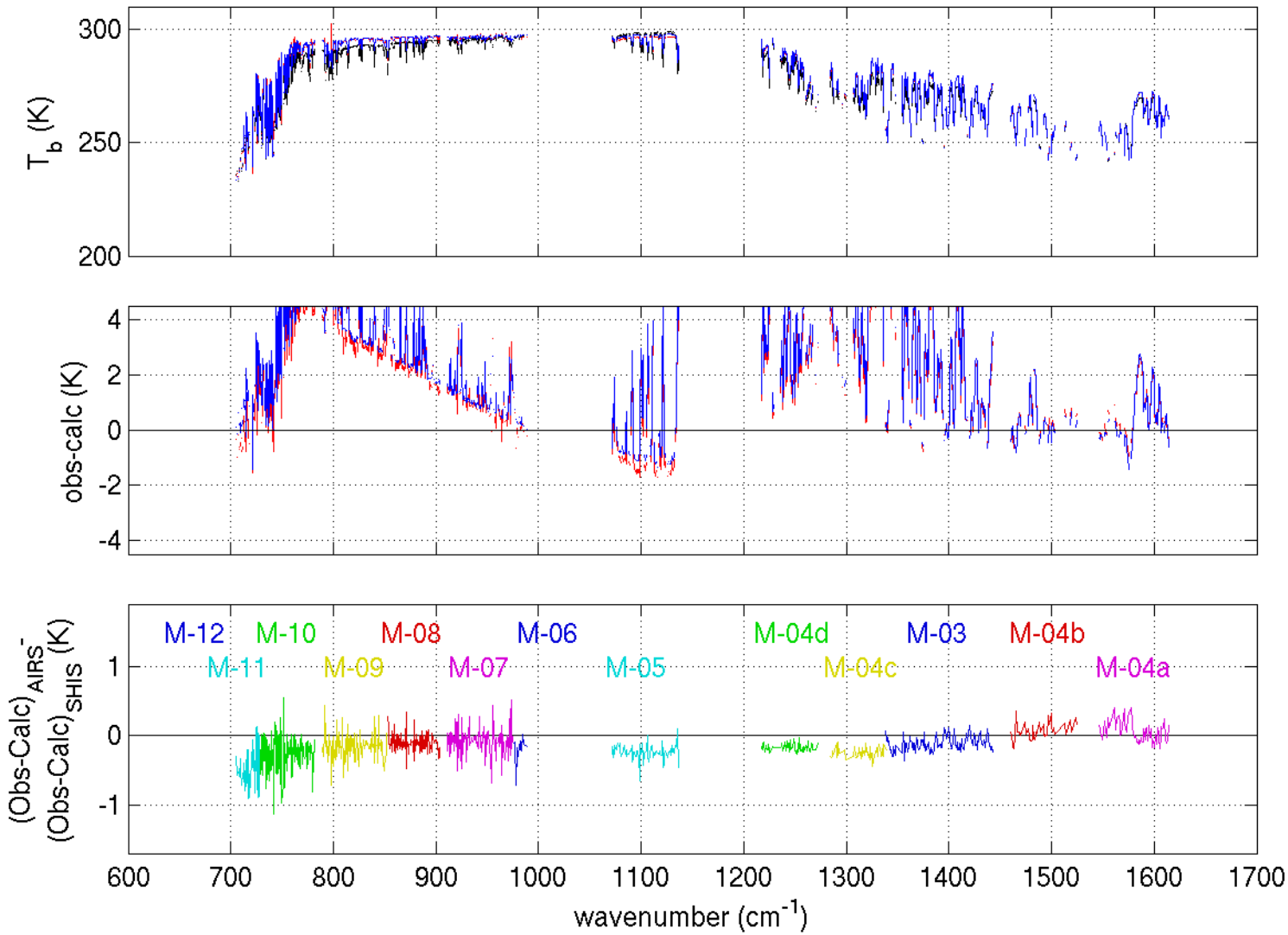


Tropical Validation case: 2006.01.17

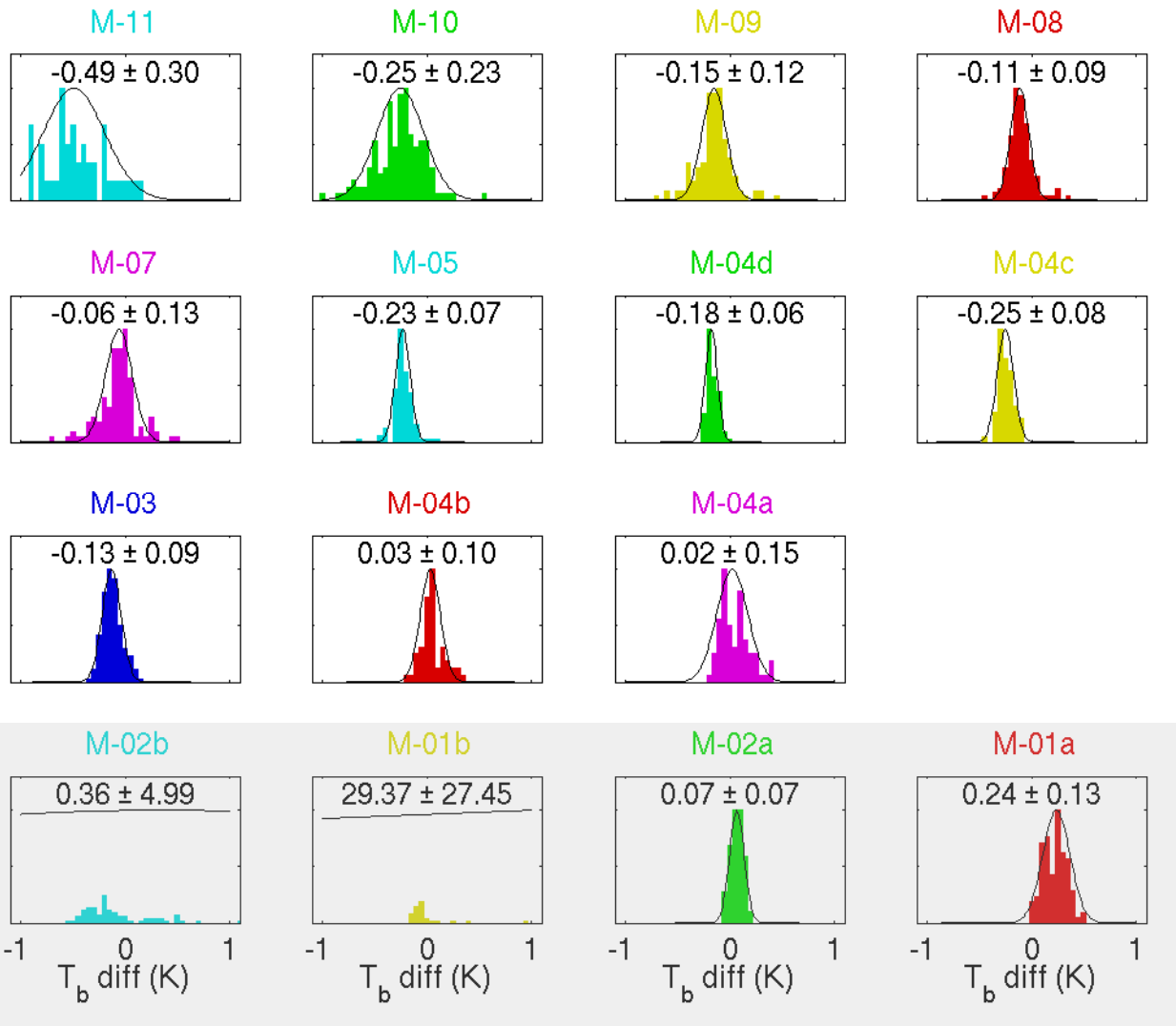
CRAVE Campaign, S-HIS on WB-57 at ~17 km over the Caribbean



Tropical Validation case: 2006.01.17



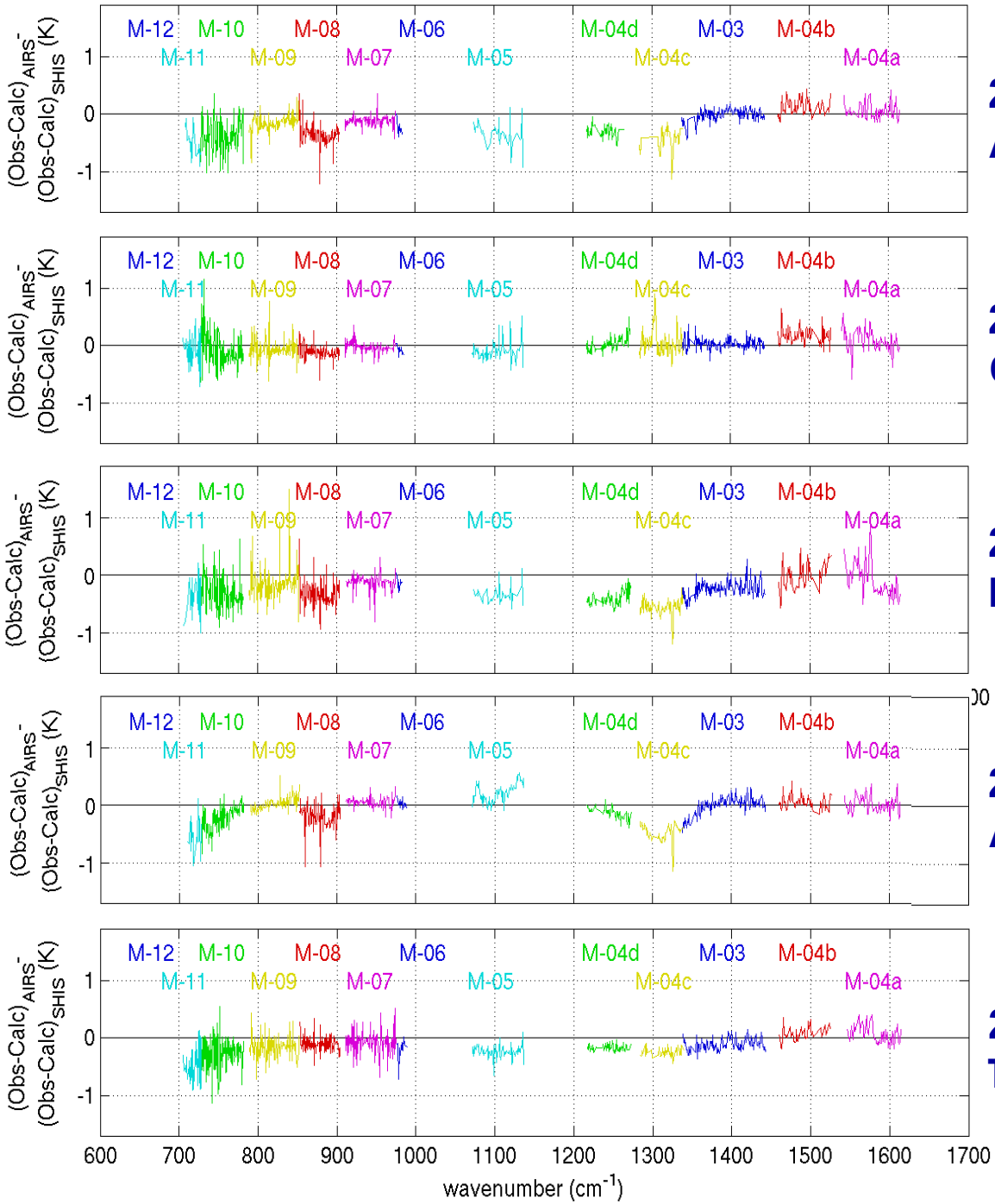
Tropical Validation case: 2006.01.17



SW Modules

AIRS-SHIS Summary

- Radiance validation is remarkably good
- Includes Tropical to Arctic atm.
- Extends over > 3 years
- HNO_3 creates 08, 04c, 04d biases
- Small 05=O_3?
- Small LW CO_2 diffs: above plane contributions?



2002.11.16
ARM-SGP

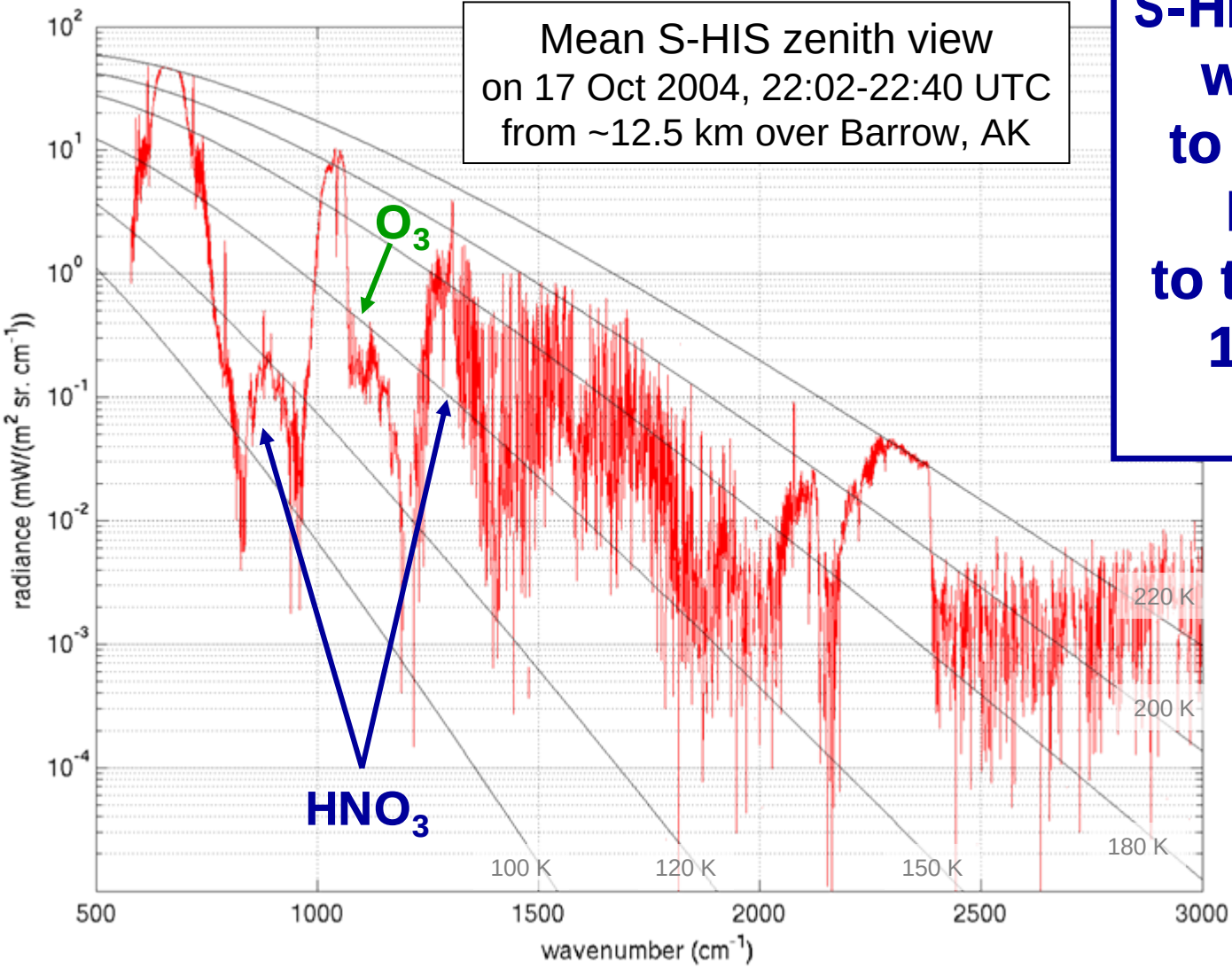
2002.11.21
Gulf of Mex

2004.09.07
Italy

2004.10.21
Arctic

2006.01.17
Tropical

S-HIS zenith views are very revealing

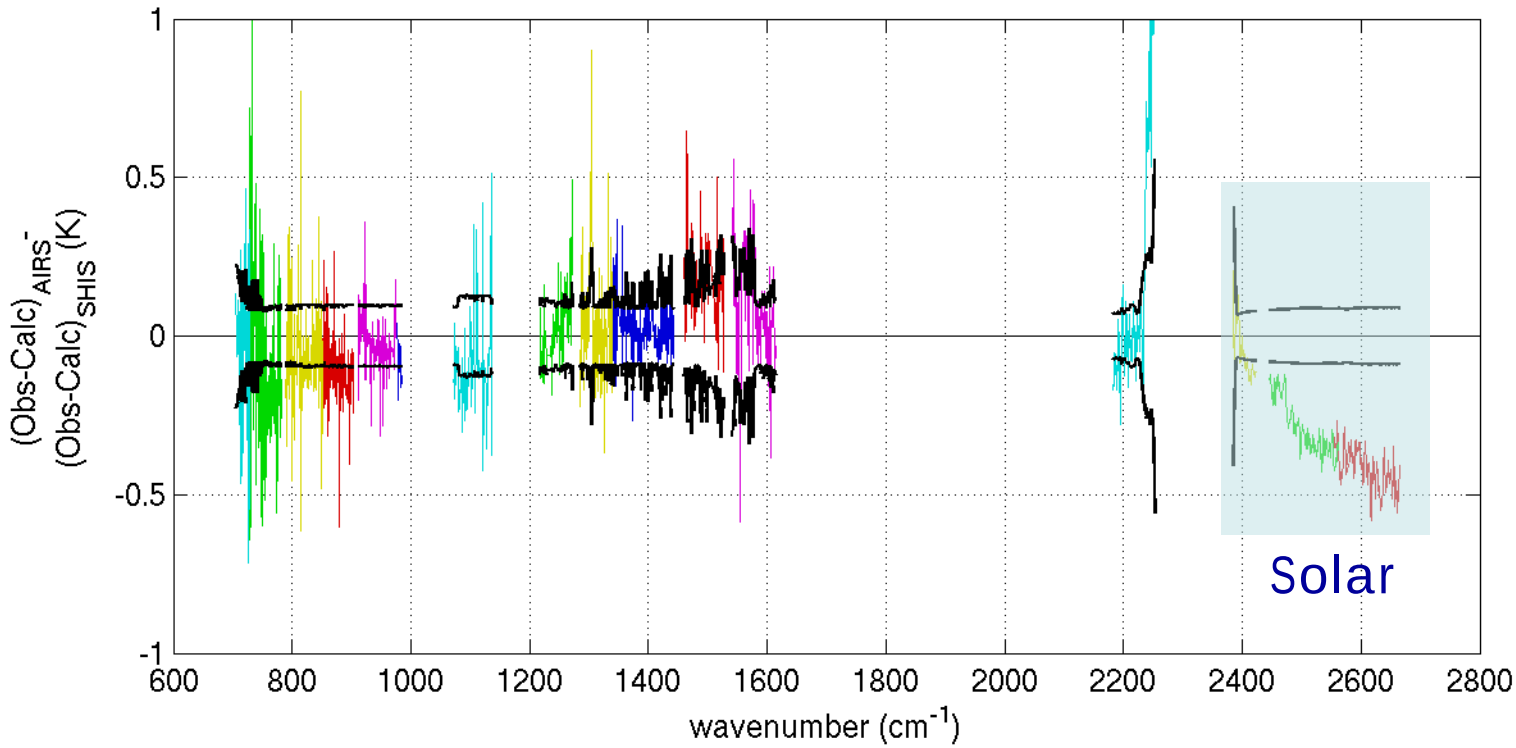


S-HIS zenith view will be used to account for HNO_3 and to test the O_3 & 15 μm CO_2 regions

Summary of AIRS/SHIS case (21 Nov 2002)

DAYTIME CASE:

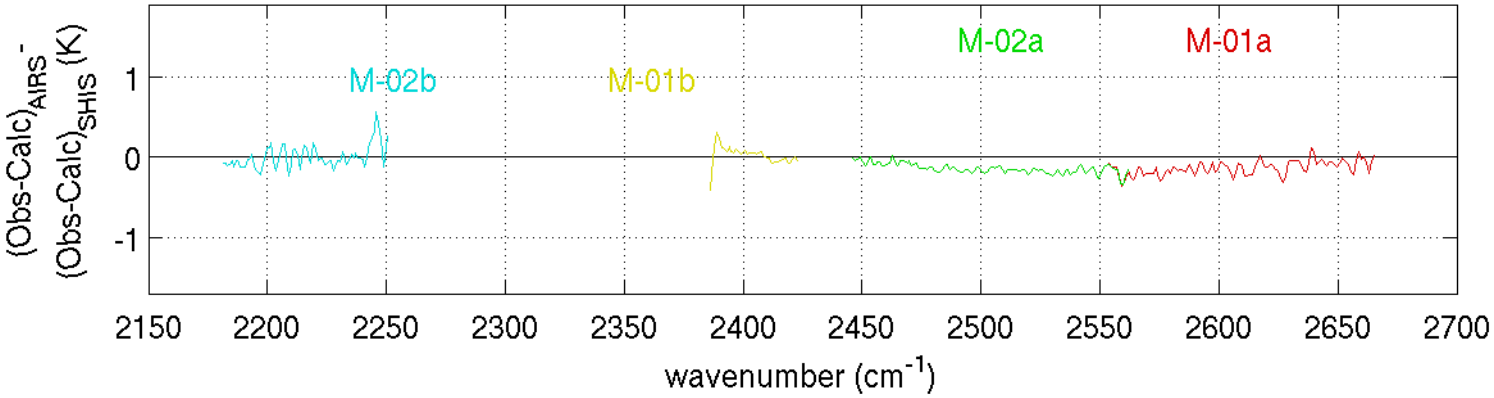
2002.11.21 Differences and S-HIS 3-sigma calibration uncertainty

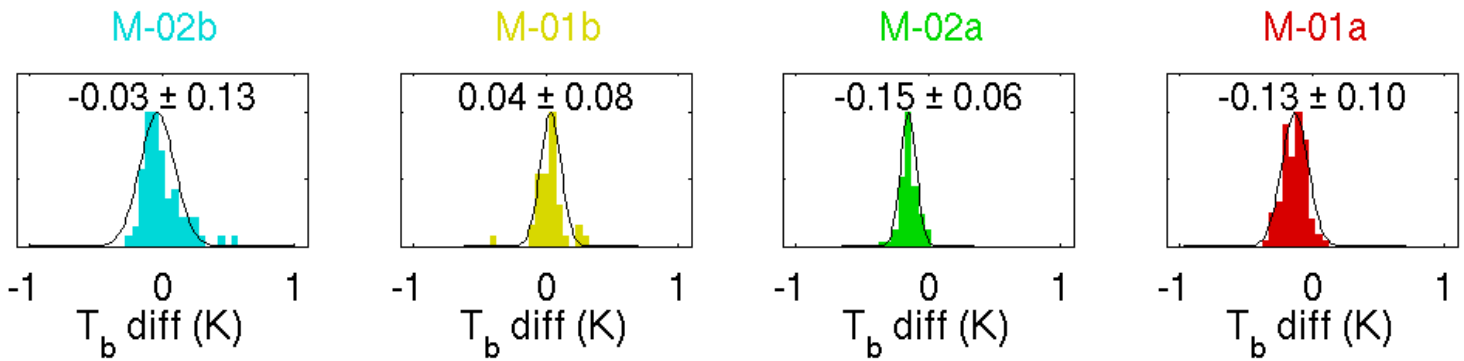


- Differences are generally within the S-HIS "not to exceed" error.

AIRS-SHIS Summary: SW (7 Sept 2004)

NIGHTTIME CASE:





1st Direct SW Radiance Validation

Excellent agreement for night-time comparison at 4 microns < -0.15 K +- 0.10 K

4. Radiance Validation of AIRS using In Situ Observations at Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site

DOE ARM SGP SITE

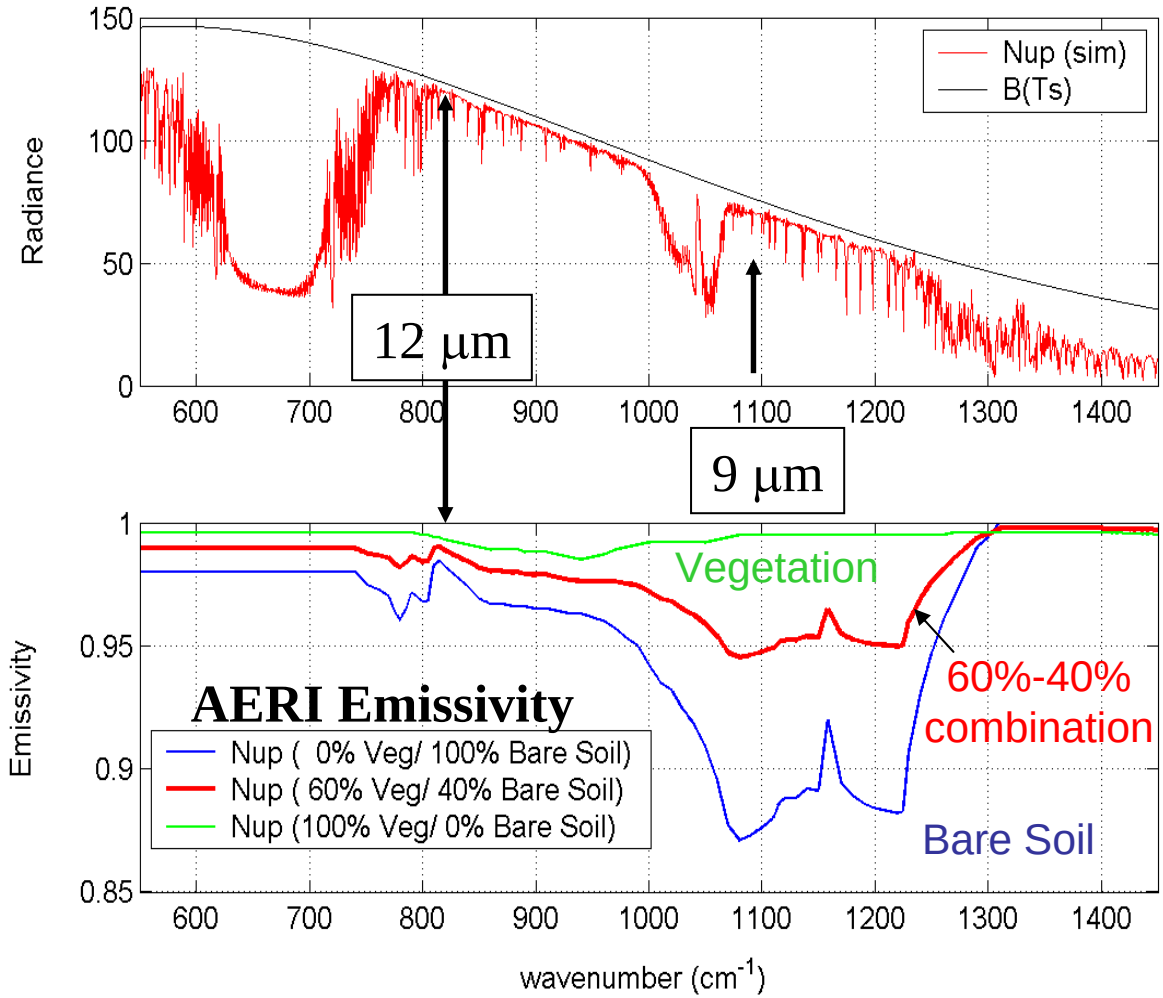
Sept 2002-March 2005

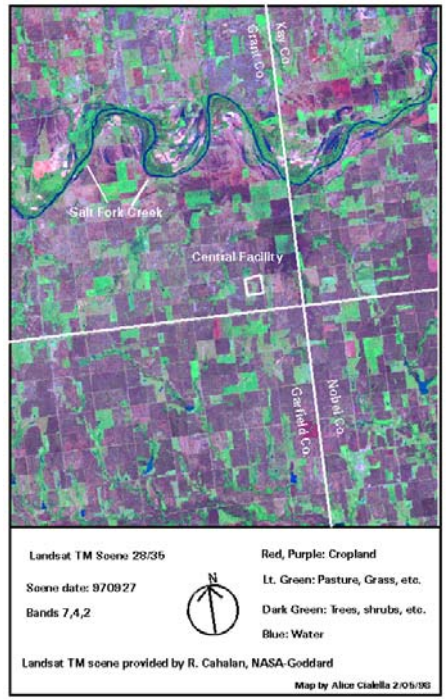
Clear sky

[identified with ARM Active Remotely Sensed Cloud Location (ARSCL product), AERI & microwave standard deviations, and AIRS surface properties]

- **Surface Properties from AIRS**
- **AIRS-LBLRTM (Obs minus Calc)**

Surface properties from AIRS using AERI-observed surface emissivity



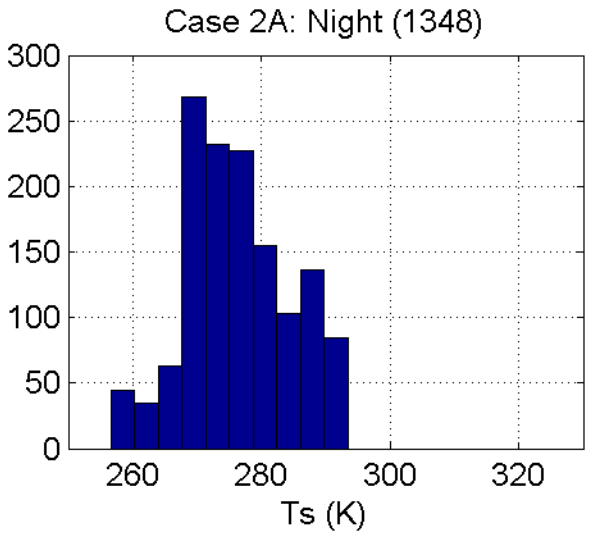


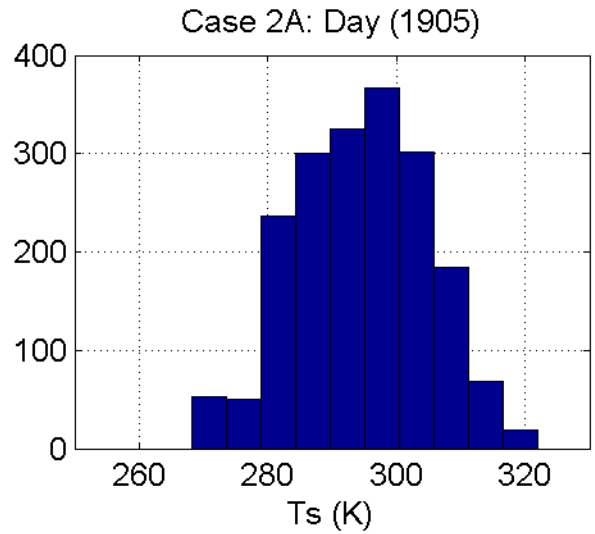
Technique

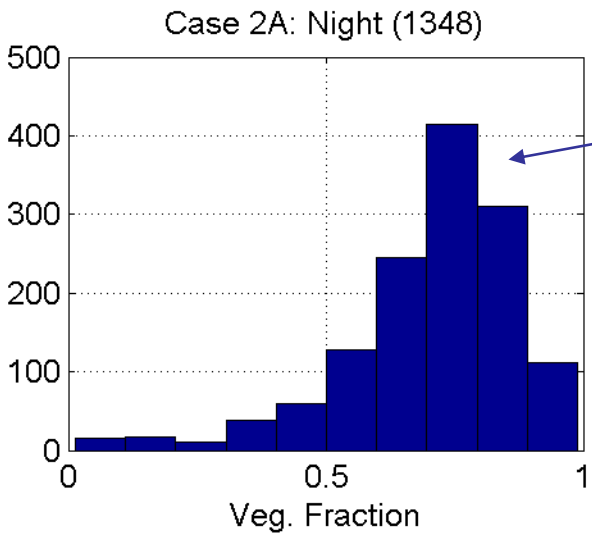
Surface Temperature from assuming emissivity
ε (12 μm) = 0.985

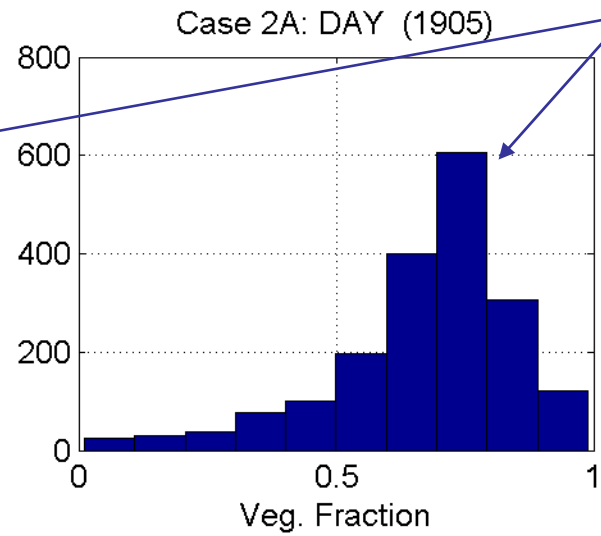
Vegetation Fraction from fitting linear combination of Bare Soil and Vegetation 9 μm radiance

Surface temperature and Vegetation Fraction Distributions



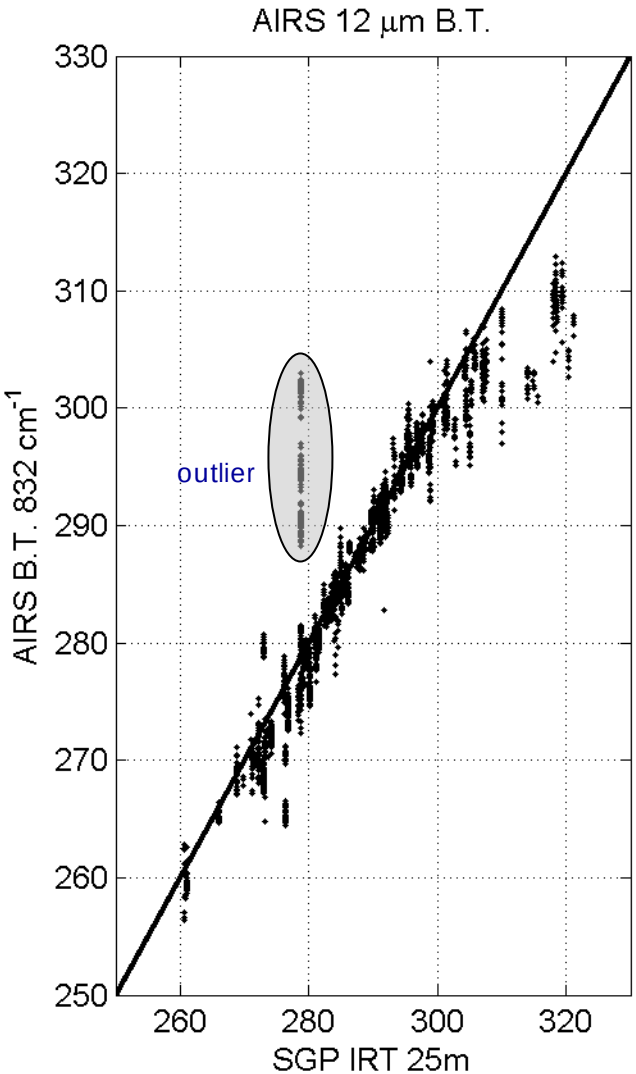




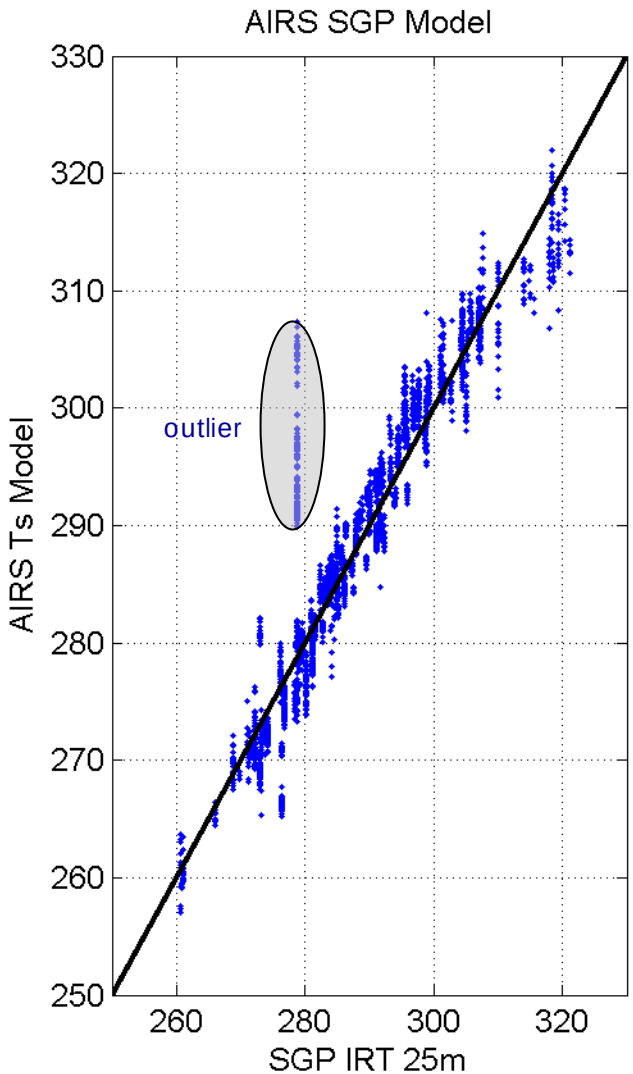


Note similar Day & Night Vegetation Fraction from very different T_s distributions

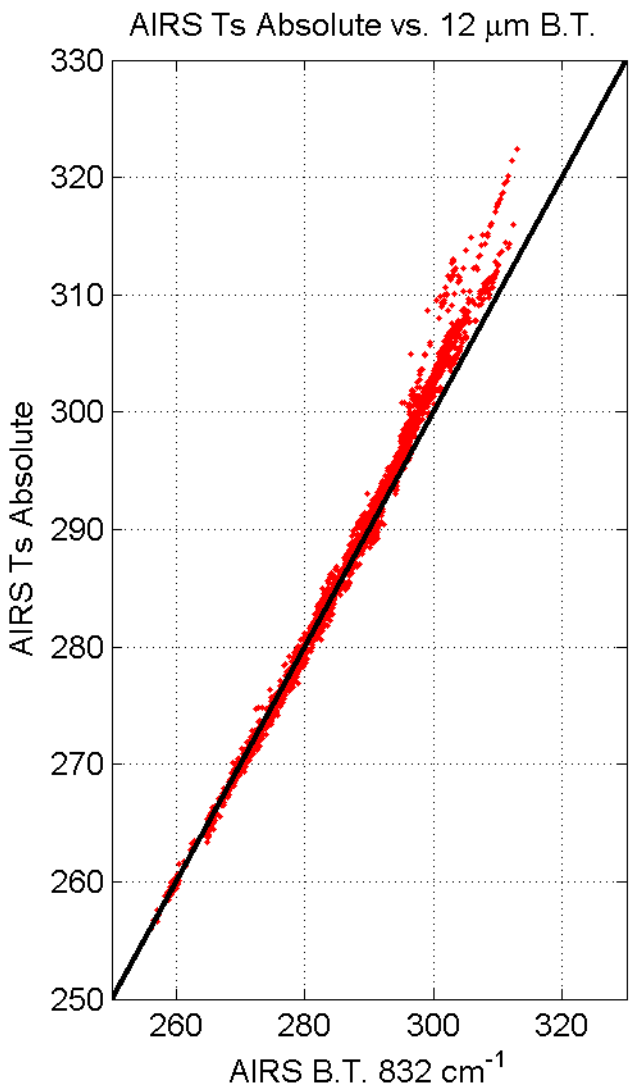
Uncorrected 12 μm B.T. Vs. Truth (25 meter IRT)



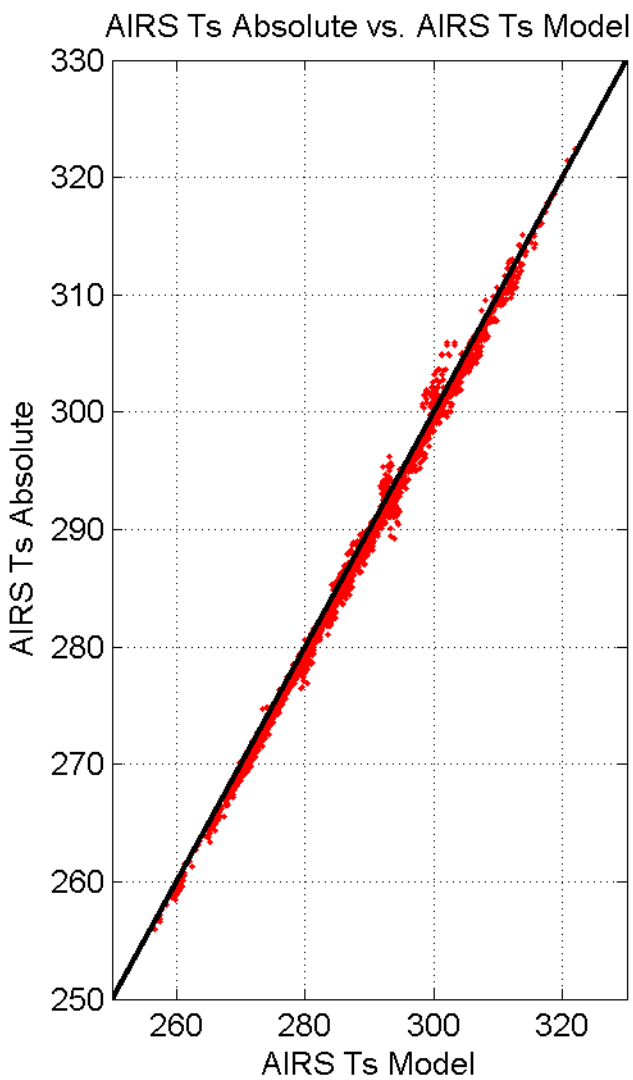
Land Surface Model Vs. Truth (25 meter IRT)



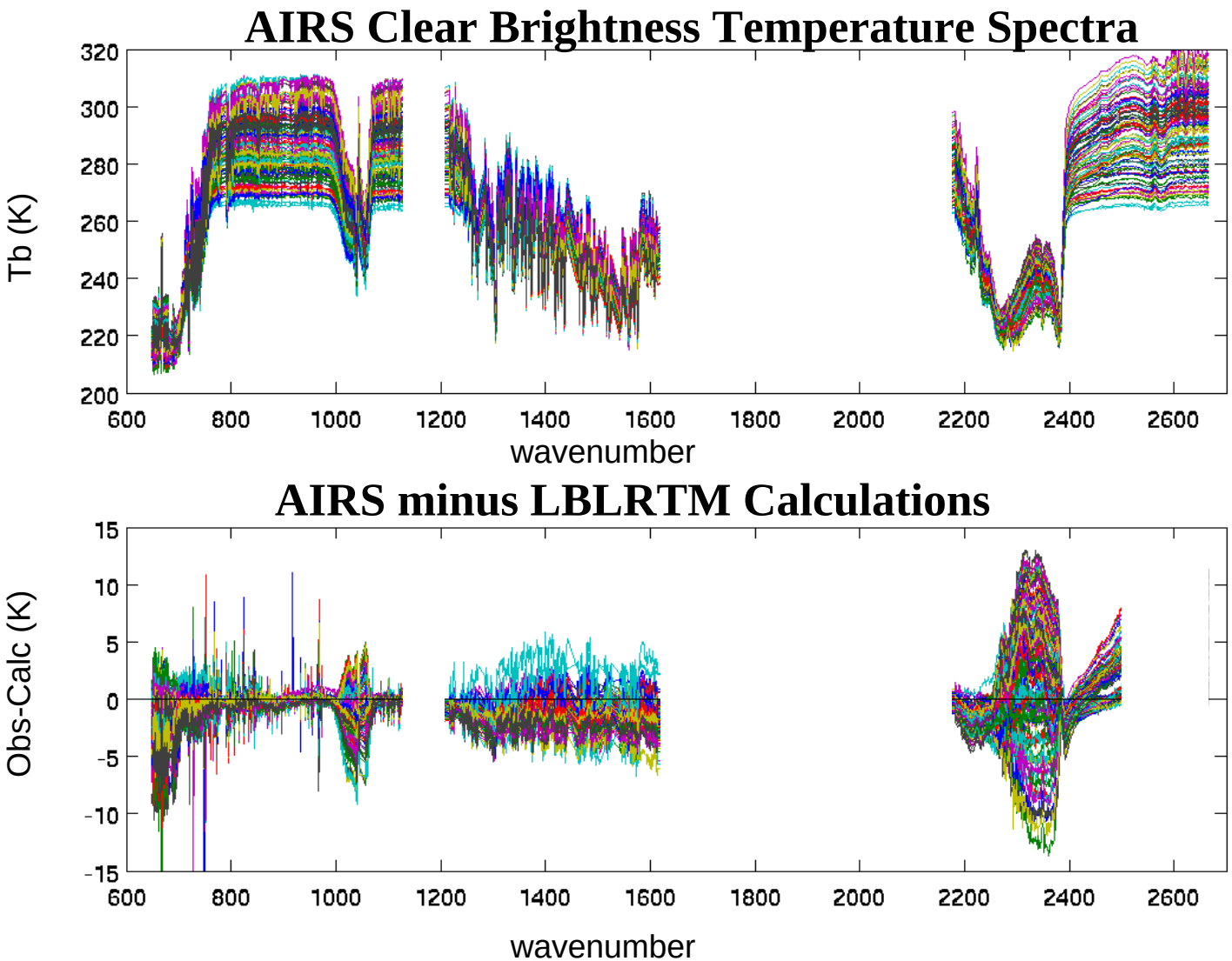
Spectral Variance Method Vs. 12 micron B.T.



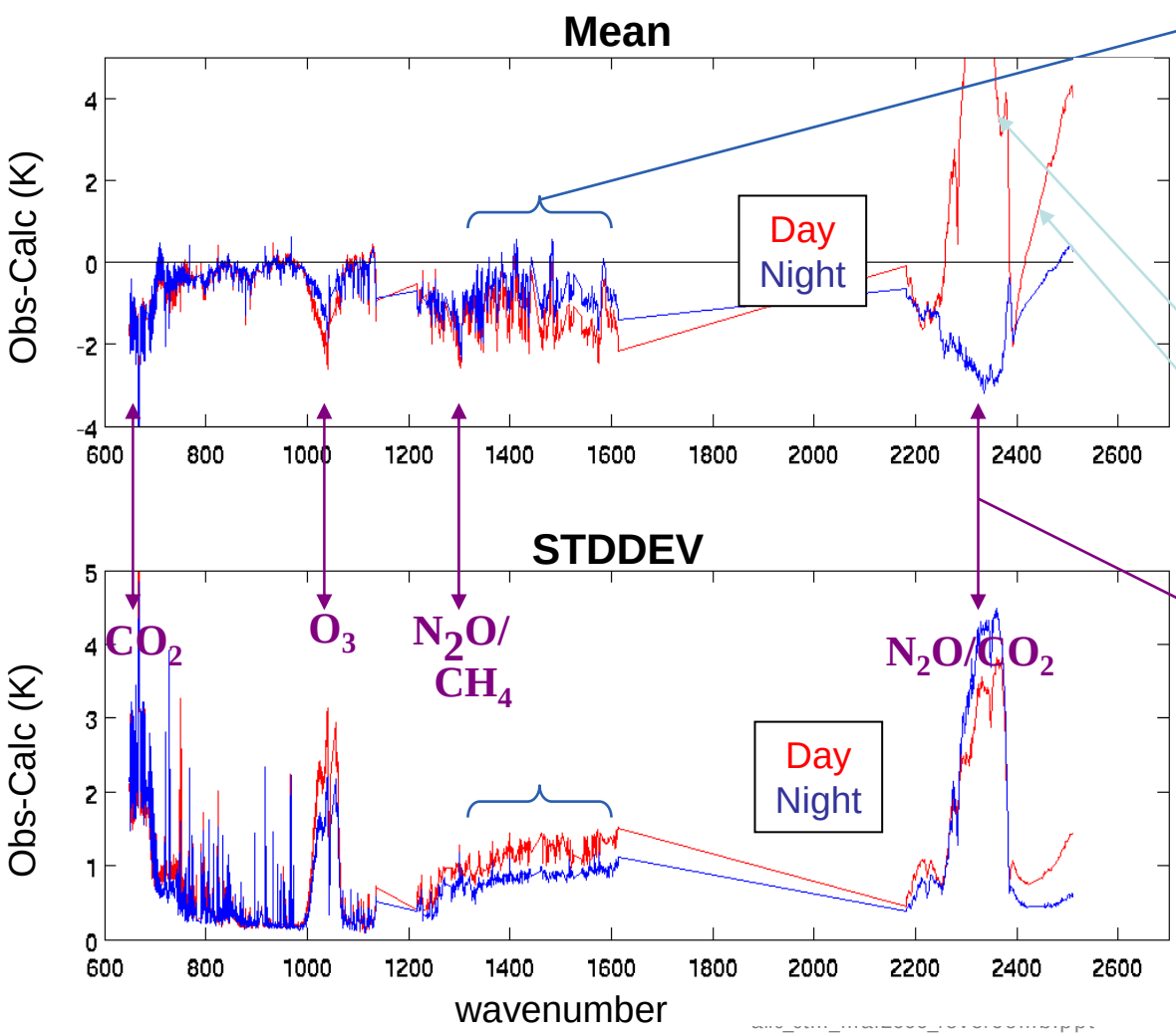
Spectral Variance Method Vs. Land Surface Model



Clear Sky AIRS minus LBLRTM



AIRS minus LBLRTM, Mean & SD



Upper level H_2O vapor

+1 K T_b is order

15% dry above 7 km

~ +1 W/m^2

Daytime

Non-thermo. Equilib &

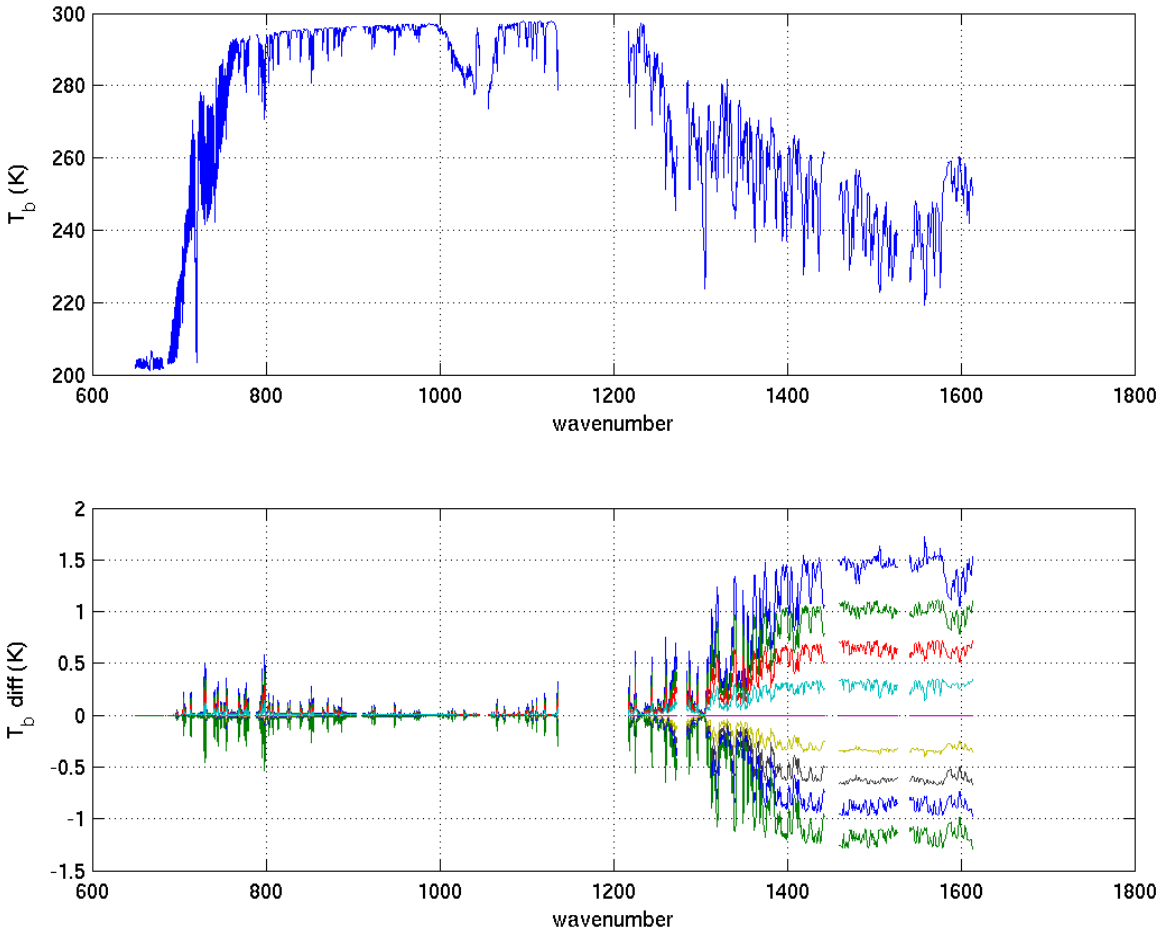
Reflected solar

Temperature above sondes

uses Climatology-

Plan to test with AIRS retrievals

Upper Level Water Vapor:
Interpretation of Radiance Residuals



+ 20% H_2O above 7km
+15% H_2O above 7km
+10% H_2O above 7km
+ 5% H_2O above 7km
0 % H_2O above 7km
- 5 % H_2O above 7km
-10 % H_2O above 7km
-15 % H_2O above 7km
-20 % H_2O above 7km

Calibration Emphasis

Make full use of the fundamental advantage of high resolution infrared spectra to provide a new standard of accuracy for weather and climate applications

- High spectral resolution does offer inherent advantages for calibration accuracy (Goody and Haskins, 1998)
- S-HIS verifies highly accurate AIRS radiometric calibration- better than originally specified
- Characterizing the nature of small differences should lead to improvements in remote sensing
- The high resolution calibration advantage has also been transferred to lower resolution IR instruments, like MODIS

Now concerned with tenths of K, not 1 K!