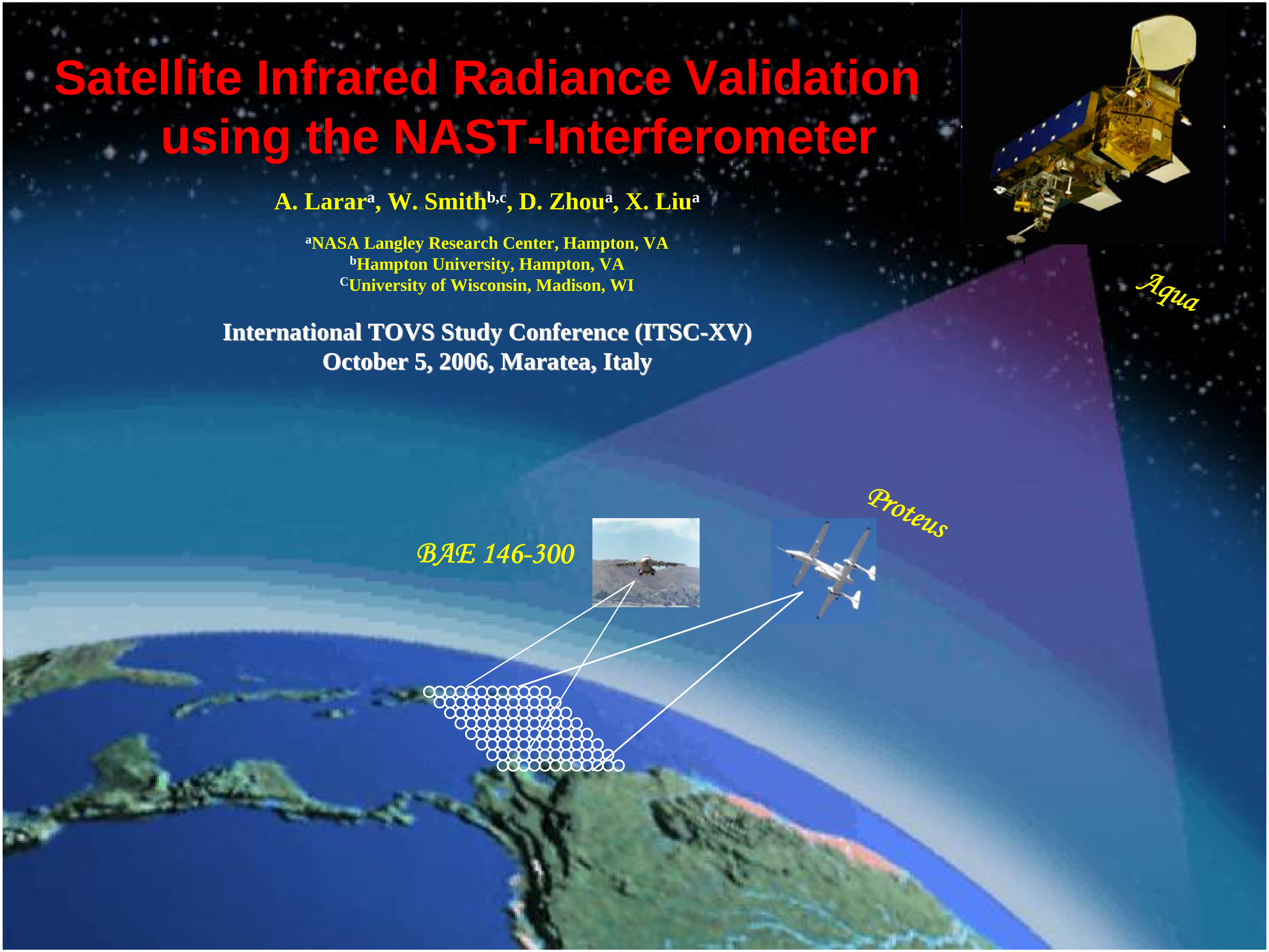
Satellite Infrared Radiance Validation using the NAST-Interferometer

A. Larar[a], W. Smith[b,c], D. Zhou[a], X. Liu[a]

[a]NASA Langley Research Center, Hampton, VA
[b]Hampton University, Hampton, VA
[c]University of Wisconsin, Madison, WI

International TOVS Study Conference (ITSC-XV)
October 5, 2006, Maratea, Italy



LaRC

SD

Topics

- **Motivation**
- **Instrument systems & datasets**
- **Validation methodology**
- **Select spectral radiance comparison results**
- **Summary & conclusions**

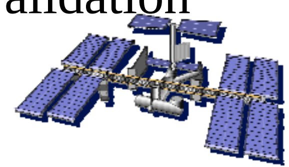
Motivation for satellite sensor cal/val and benefit from using airborne sensors

LaRC

SD

- ***Post-launch validation activities are critical to verify quality of satellite measurement system***
  - Sensor, algorithms, and direct/derived data products

- ***Resulting data contribute toward essential cal/val activities***
  - On-orbit sensor performance verification & calibration validation
  - Algorithm validation
  - Direct and derived data product validation
  - Long-term monitoring of system performance (radiance & geophysical)



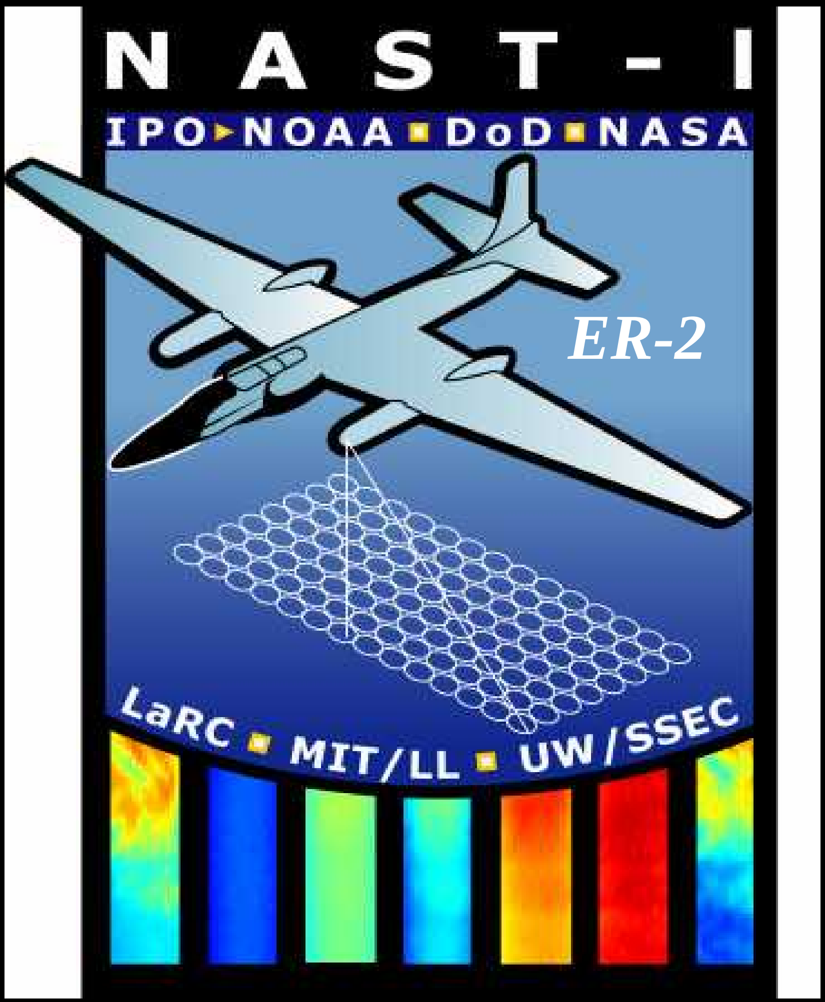
- ***Aircraft underflights fundamental to validation task***
  - High-altitude a/c instrumented with validation sensors (e.g., NAST-I, S-HIS, & ARIES) provide critical validation data spatially & temporally coincident with satellite platforms of interest (e.g. Aqua (AIRS), and future Metop (IASI), NPP/NPOESS (CrIS), and GIFTS).

The NAST & SHIS Systems

LaRC

SD

- ✓Validation tools
- ✓NPOESS risk mitigation
- ✓Airborne science
- ✓Engineering testbeds



Instruments

IR Interferometer (NAST-I)

Spectral Range: 3.5 - 16 microns
Spectral Res.: 0.25 cm-1 ($\nu/\nu\delta$ > 2000)
Spatial res.: 130m/km flight alt.
A/C platforms: ER-2, Proteus, WB-57 (soon)

Microwave Radiometer (NAST-M)

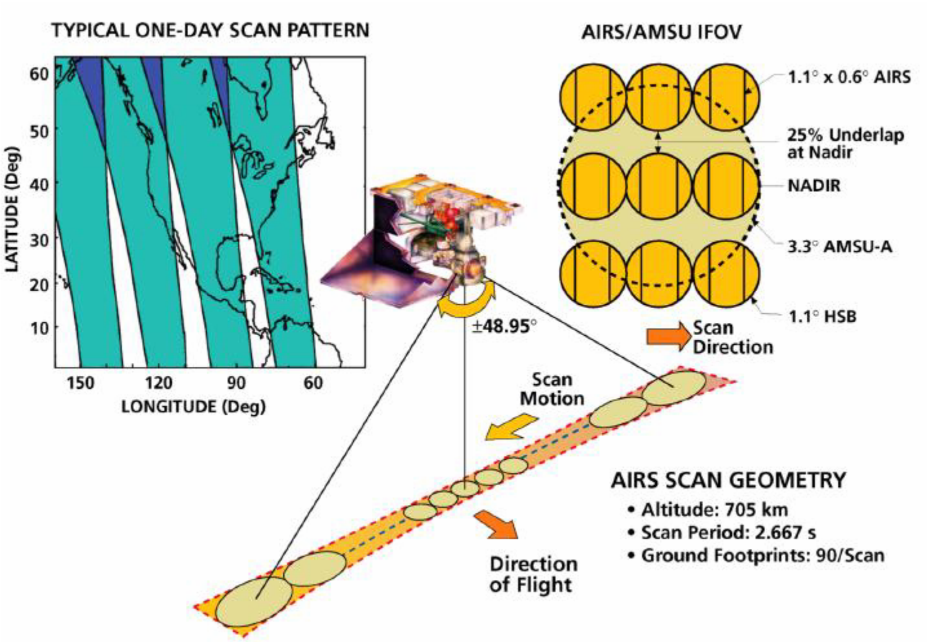
Spectral Regions: 50 - 60 GHz,
113 - 119 GHz, 183 GHz, 425GHz
A/C platforms: ER-2, Proteus, WB-57 (soon)

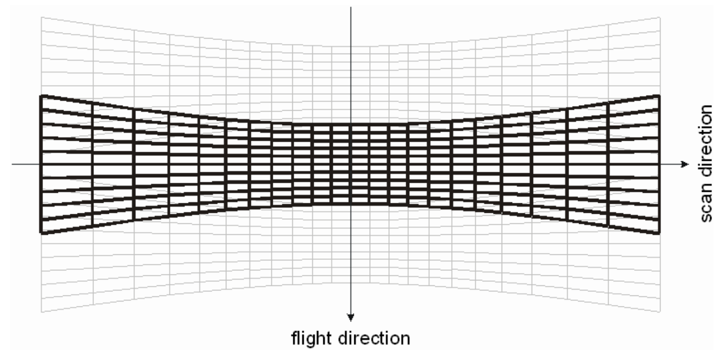
IR Interferometer (S-HIS)

Spectral Range: 3 - 17 microns
Spectral Res.: 0.5 cm-1 ($\nu/\nu\delta$ > 1000)
Spatial res.: 100m/km flight alt.
A/C platforms: ER-2, Proteus, DC-8, WB-57

Characteristics of Aqua Sensors Utilized

LaRC





Three consecutive MODIS scans, each consisting of ten 1-km lines. Partially overlapping scans at off nadir angles causes “bow tie” effect.

Instrument system	Sensor type	Spectral extent	Spectral resolution	Nadir IFOV	Platform
AIRS	Grating spectrometer	3.8 – 15.4 μ, discrete channels	~0.4 – 2.2 cm^{-1}, $\upsilon/\delta\upsilon \sim 1200$	~ 13.5 km	AQUA
MODIS	Grating spectrometer	3.6 – 14.4 μ (IR bands 20 – 36) , discrete channels	~13 – 128 cm^{-1}, broadband filters	~ 1 km	AQUA

NAST Participation in EAQUATE (European AQUA Thermodynamic Experiment):

International collaboration to validate radiance and geophysical products obtained by the Atmospheric Infrared Sounder (AIRS) aboard the Aqua satellite

LaRC

Italian Campaign (Naples, Italy, 3 – 11 Sept. 2004):

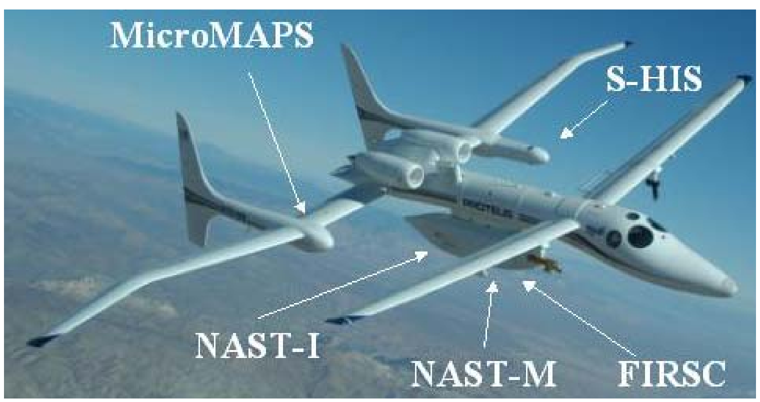
✓ **UK BAE146-300** (ARIES, TAFTS, SWS, MARSS & Deimos; dropsondes; in-situ cloud phys. & trace species)

✓ **Ground sites:** Potenza/Naples (lidar, radiosondes, aeri, m-wave)

[Note: ✓ => data used in present analysis]

United Kingdom (Cranfield UK, 11-19 Sept. 2004):

- **US *Proteus* Aircraft**



✓ ***NAST-I*:** 3.5-16 μm, 0.25 cm^{-1}
***NAST-M*:** 50-425 GHz (29 channels)
✓ ***S-HIS*:** 3.0-17 μm, 0.50 cm^{-1}
FIRSC: 225-1000 μm, 0.1cm^{-1}
μMAPS: 4.5-4.9 μm, (3 channels)

Radiance Inter-comparison Approach

LaRC

SD

- **Incorporate multiple, independent, temporally- & spatially-coincident datasets from the recent EAQUATE field campaign**
  - Satellite:
    - **AQUA (AIRS & MODIS)**
  - Aircraft:
    - **Proteus (NAST-I & S-HIS)**
    - **BaE-146 (dropsondes)**
  - Ground:
    - **Potenza** (**lidar & radiosondes**)
  - "Model":
    - **ECMWF** (**T, q, O_3**)
- **Verify spatial co-registration by comparing geo-referenced images at select λ**
- **LBL-based calculations for simulated radiance observations**
  - Using various combinations for atm state "truth" data (i.e. ECMWF, radiosondes, 2 independent Raman LIDAR systems, & dropsondes
- **For clear, uniform regions over ocean and coincidence with ground site, compare high resolution spectra (i.e. NAST-I, S-HIS, AIRS, & "simulations")**

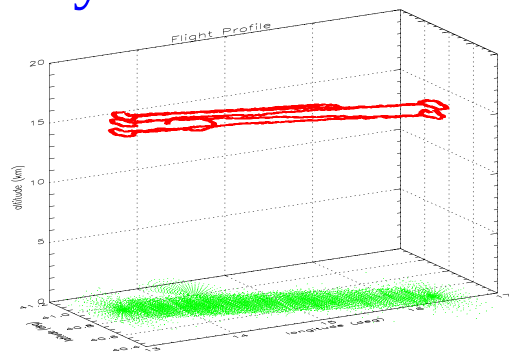
EAQUATE Proteus Mission Flight Tracks

LaRC

SD

September 6, 2004

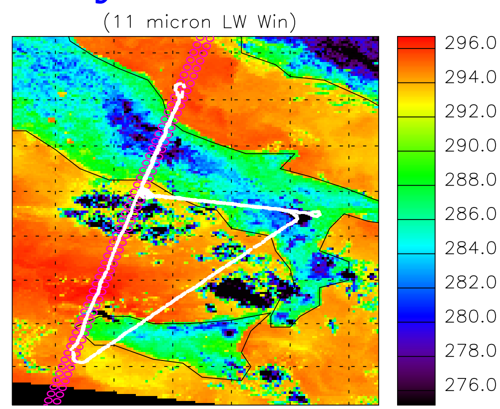
Italy



Evening; Potenza racetrack

September 7,8 2004

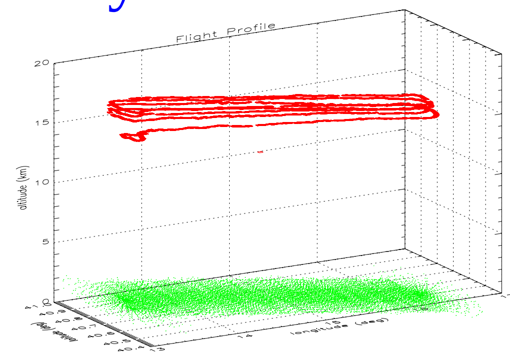
Italy ✓



Night; Aqua nadir

September 8, 2004

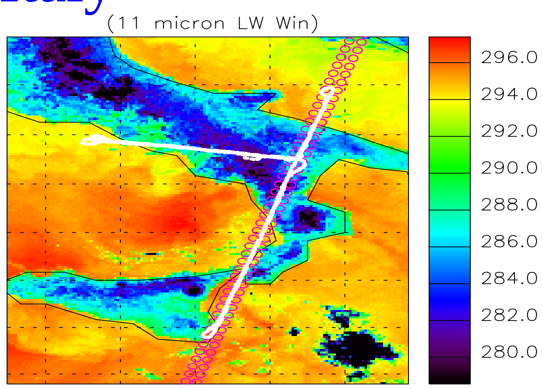
Italy



Evening; Potenza racetrack

September 9,10 2004

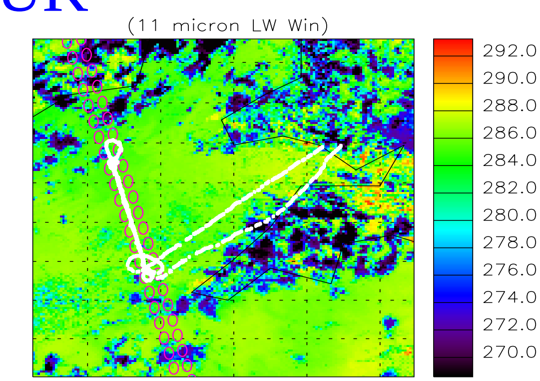
Italy ✓



Night; Aqua nadir

September 14, 2004

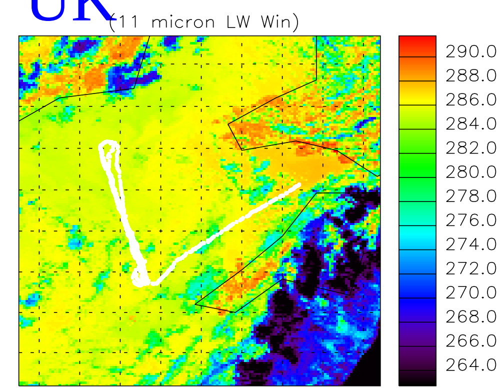
UK ✓



Day; Aqua nadir; w/ BAe-146

September 18, 2004

UK



Day; w/ BAe-146; both a/c at same z for segment

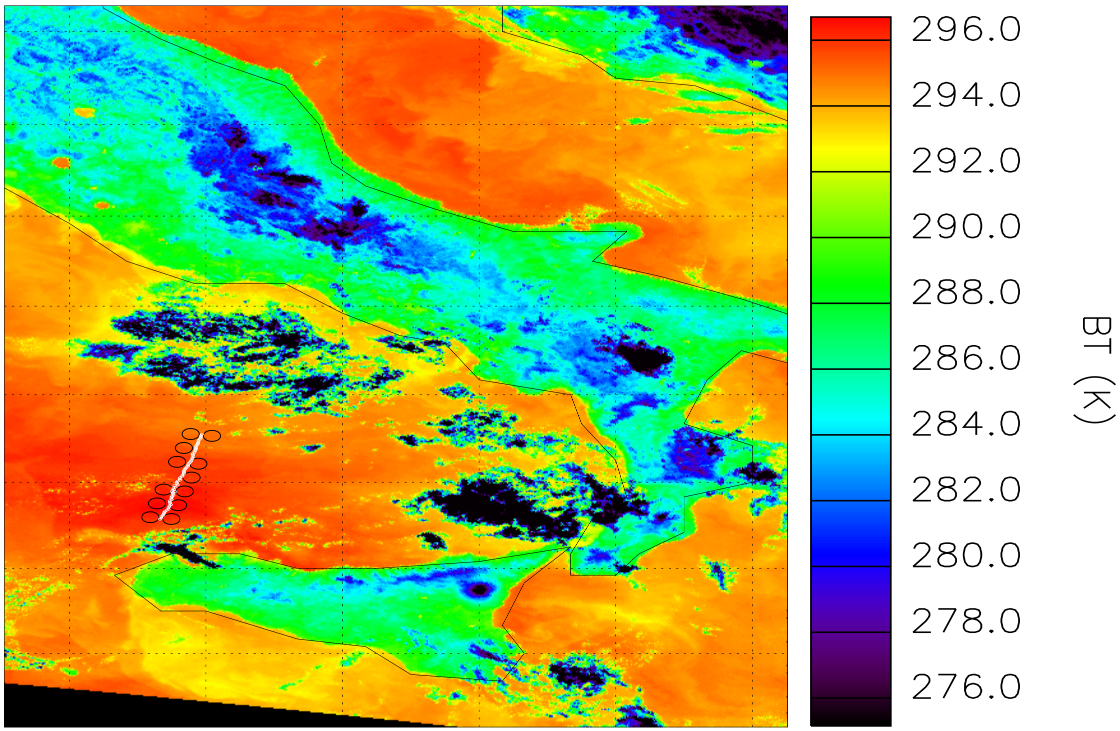
Satellite Infrared Radiance Validation using the NAST-Interferometer, Larar et al., ITSC-15, Maratea, Italy, 5 October, 2006.

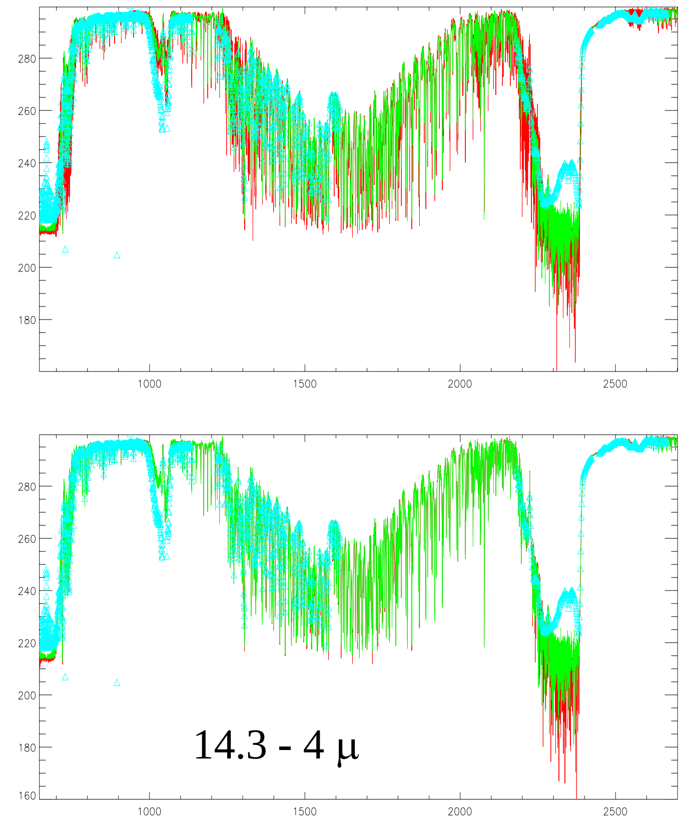
EAQUATE 090704

Spectra Comparison: NAST-I, S-HIS, AIRS

LaRC
SD

MB31





NAST-I
S-HIS
AIRS

MB31 stddev (AIRS IFOVs)

max = 0.22 K

min = 0.05 K

mean = 0.11 K

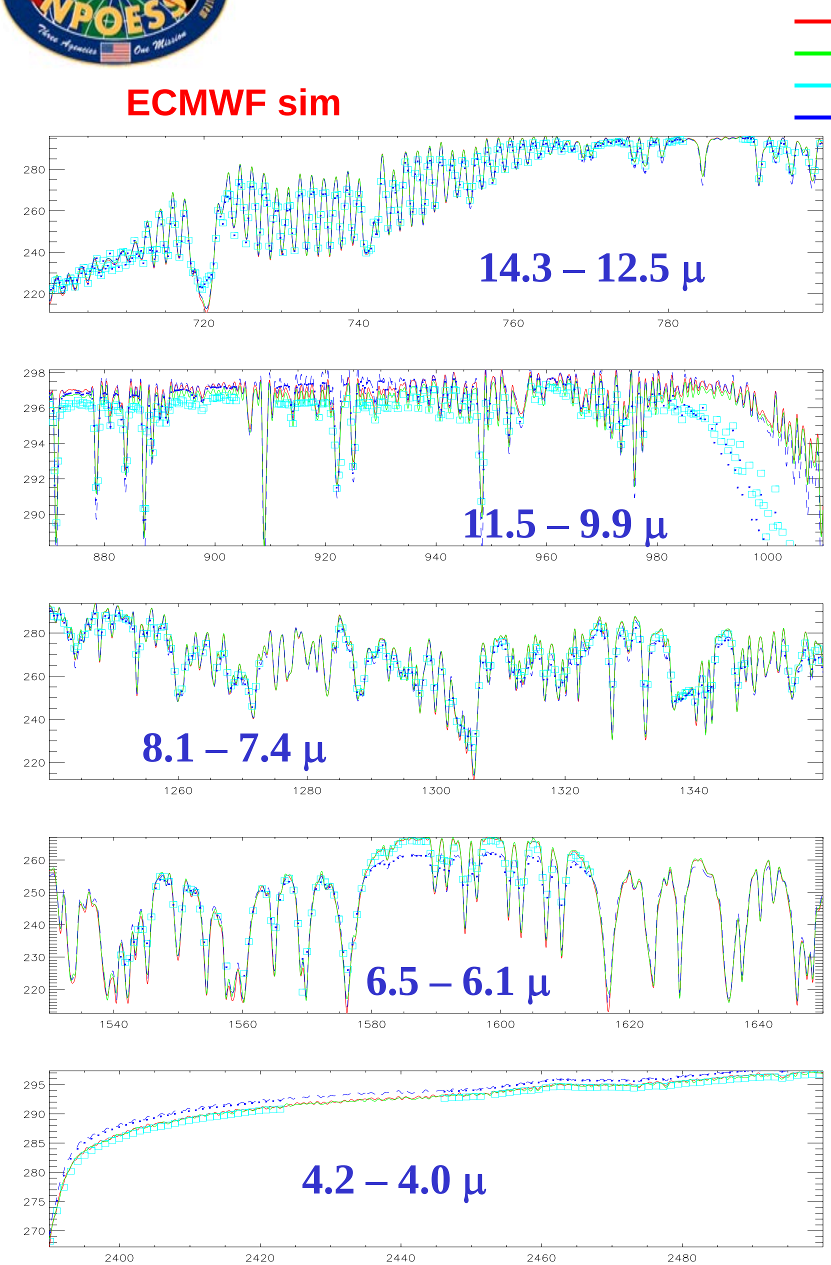
stdev = 0.05 K

Ocean Site 07Sept04

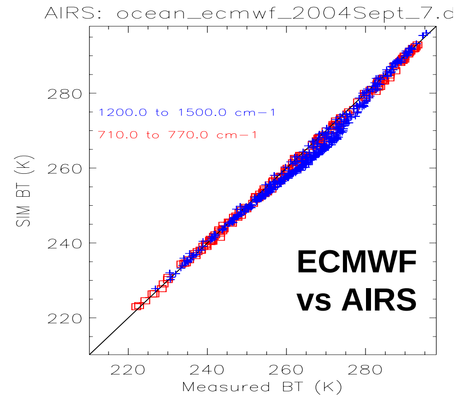
LaRC

SD

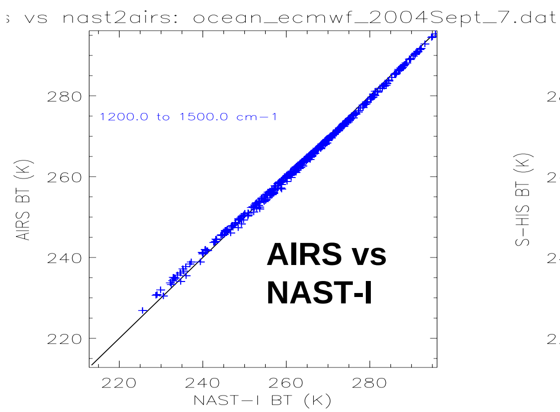
ECMWF sim

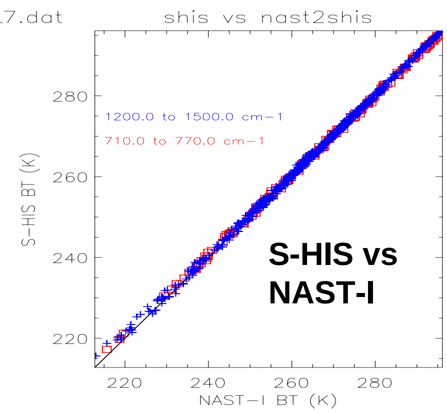


Simulation vs measured:



Measured vs measured:



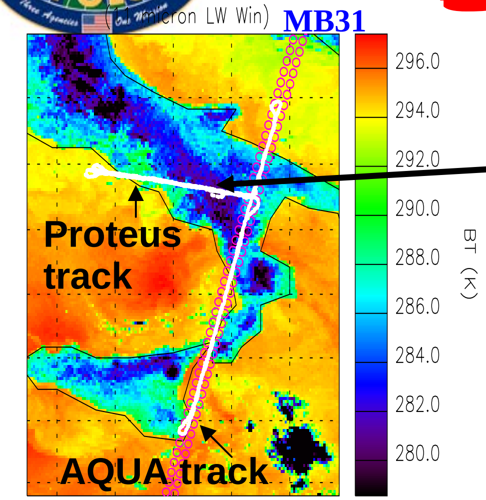


Satellite Infrared Radiance Validation using the NAST-Interferometer, Larar et al., ITSC-15, Maratea, Italy, 5 October, 2006.

EAQUATE 090904

LaRC

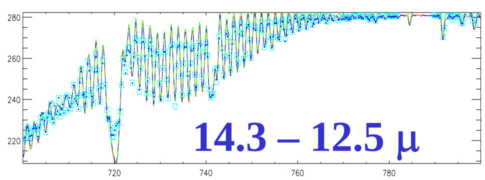
SD

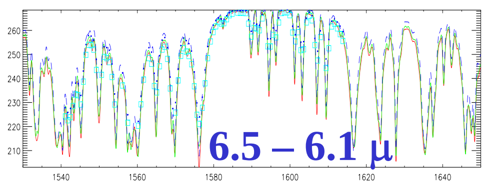


Potenza ground site

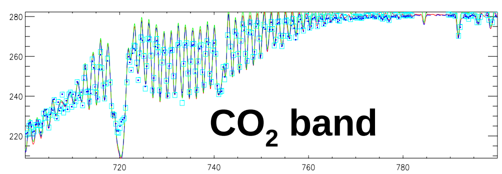
NAST-I
S-HIS
AIRS
Simulation

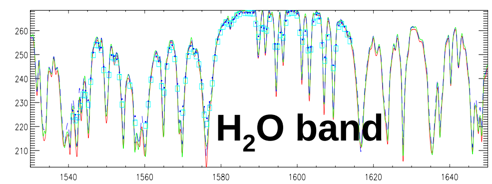
Radiosonde sim



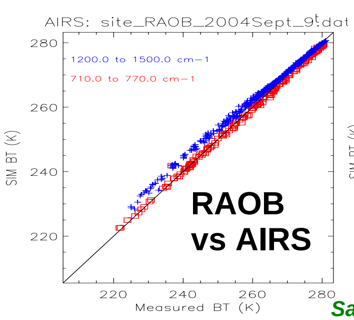


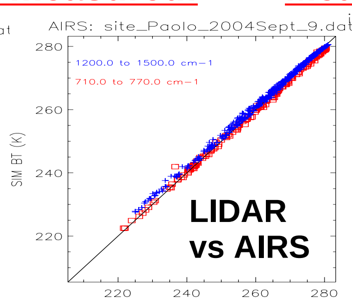
LIDAR sim



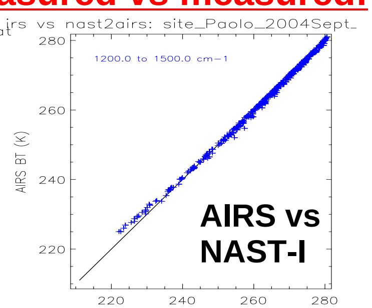


Simulation vs measured:

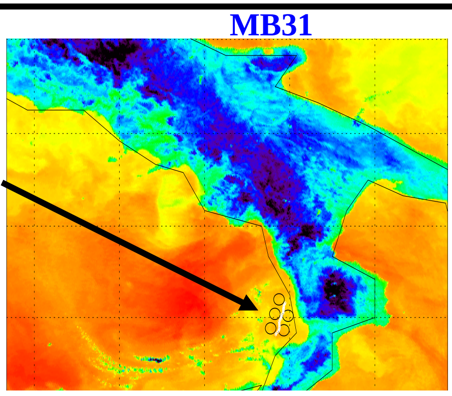




Measured vs measured:



Uniform ocean scene



MB31 stddev (AIRS IFOVs)

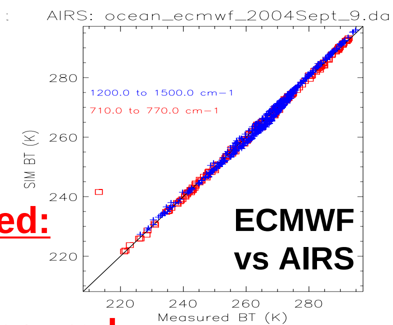
max = 0.16 K

min = 0.10 K

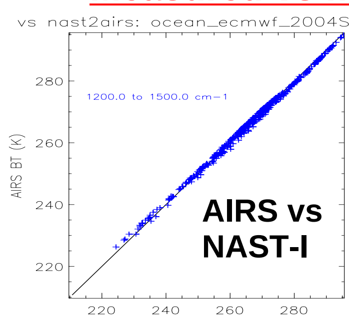
mean = 0.14 K

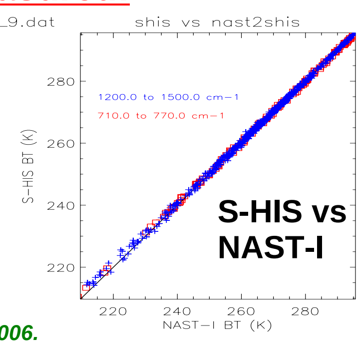
stdev = 0.02 K

Simulation vs measured:



Measured vs measured:





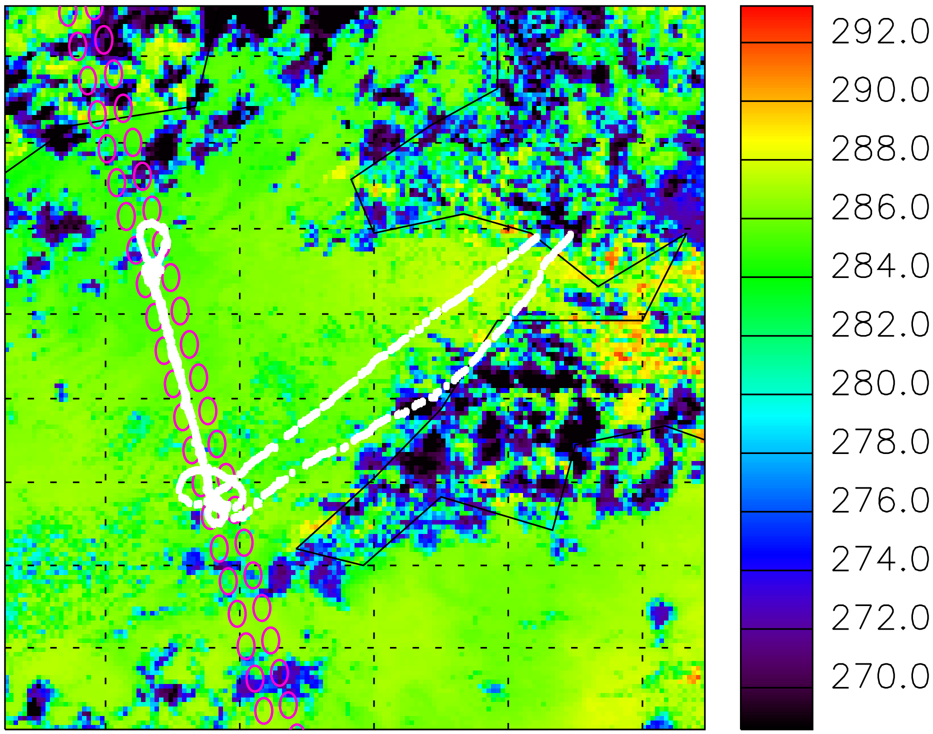
EAQUATE 091404

LaRC

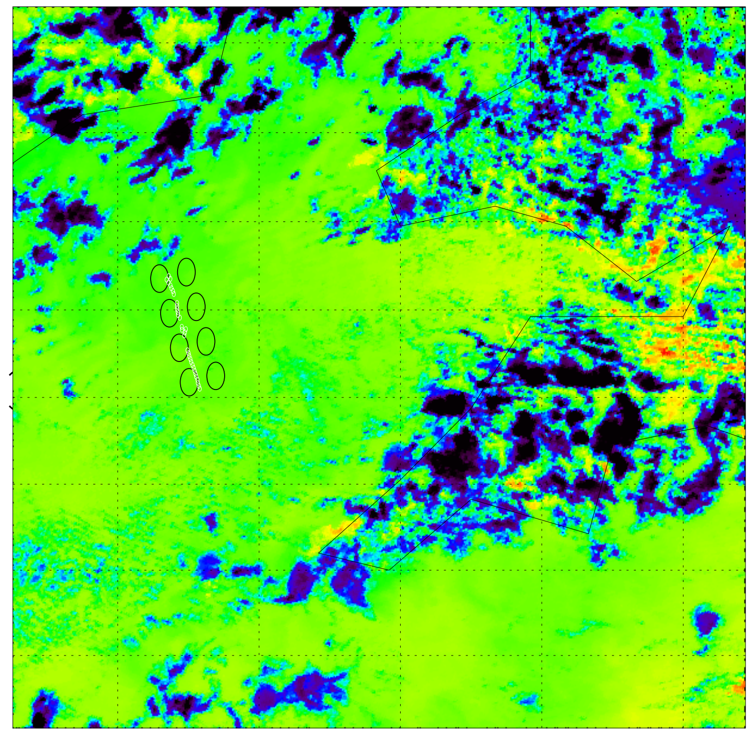
SD

Spectra Comparison: NAST-I, S-HIS, AIRS

MB31 (11 micron LW Win)



MB31



MB31 stddev (AIRS IFOVs)

max = 0.23 K

min = 0.07 K

mean = 0.16 K

stdev = 0.05 K

Region for Spectra Comparison:

NAST-I, S-HIS, AIRS

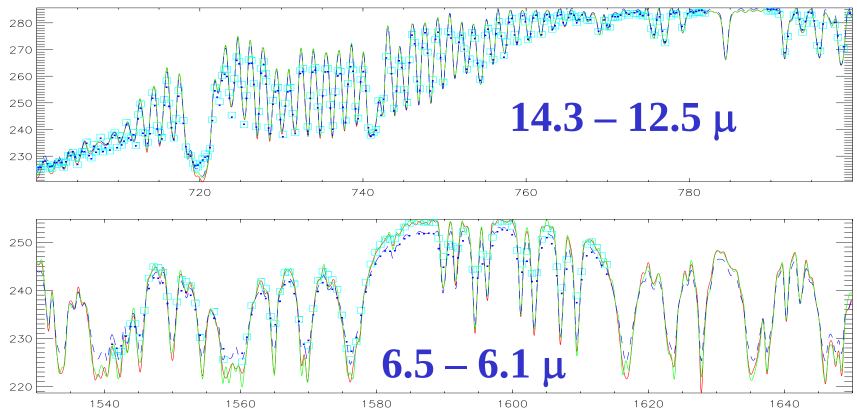
Ocean Site 14Sept04

NAST-I
S-HIS
AIRS
Simulation

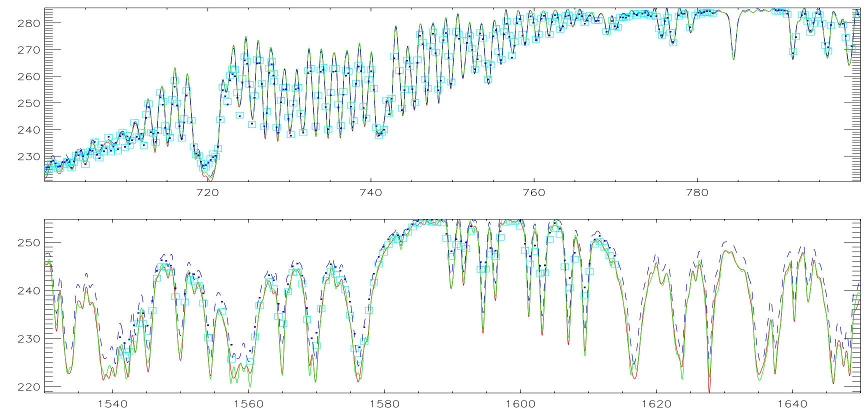
LaRC

SD

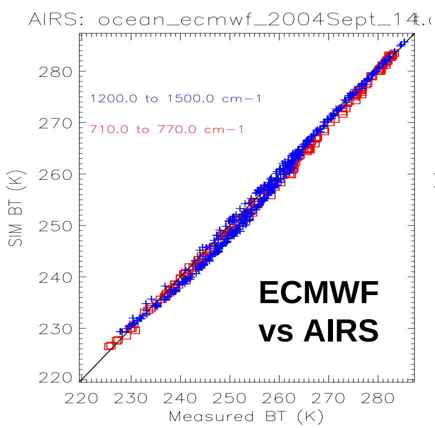
ECMWF sim

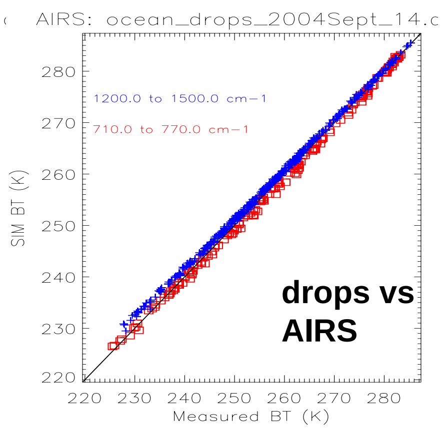


dropsonde sim

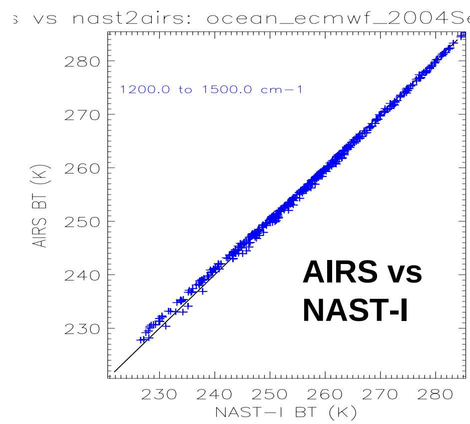


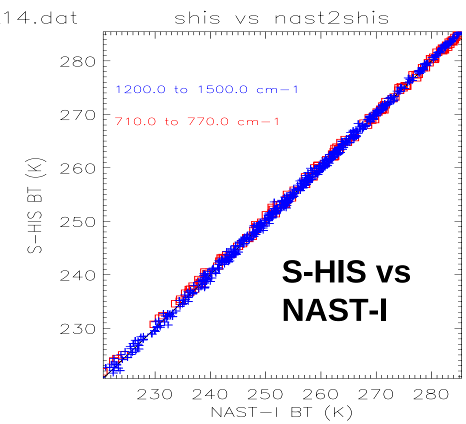
Simulation vs measured:





Measured vs measured:





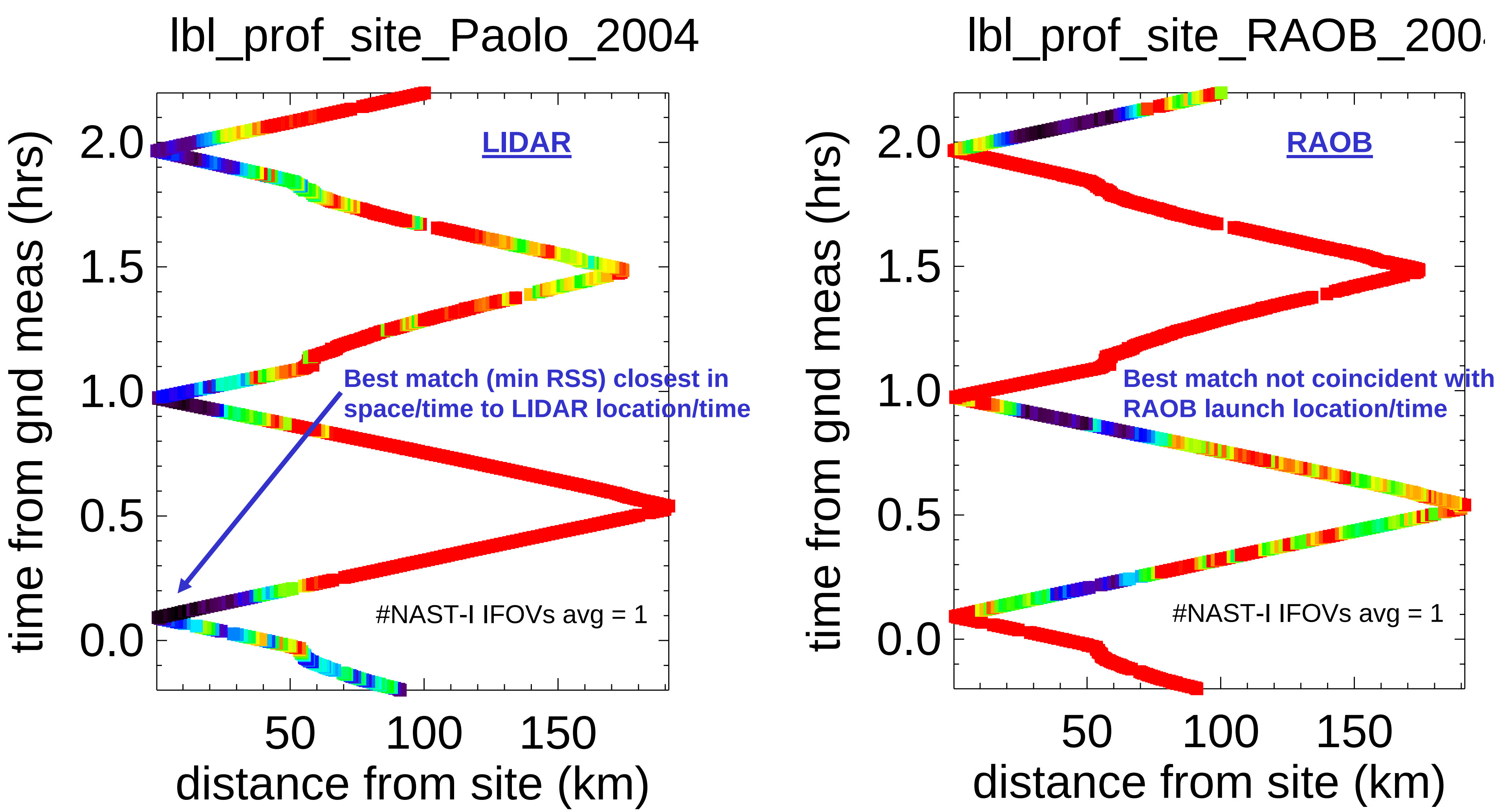
Satellite Infrared Radiance Validation using the NAST-Interferometer, Larar et al., ITSC-15, Maratea, Italy, 5 October, 2006.

Importance of space / time coincidence

LaRC

SD

RSS (meas-sim radiance residuals) shown for portion of 090904 NAST flight track



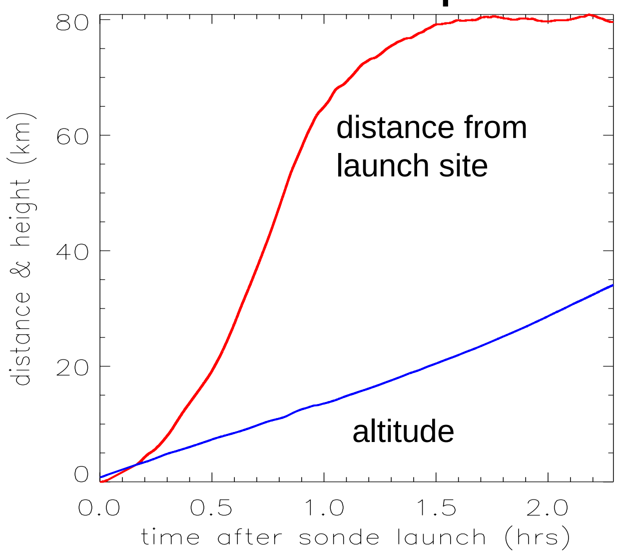
Satellite Infrared Radiance Validation using the NAST-Interferometer, Larar et al., ITSC-15, Maratea, Italy, 5 October, 2006.

RAOB motion and thermodynamic state variability (090904)

LaRC

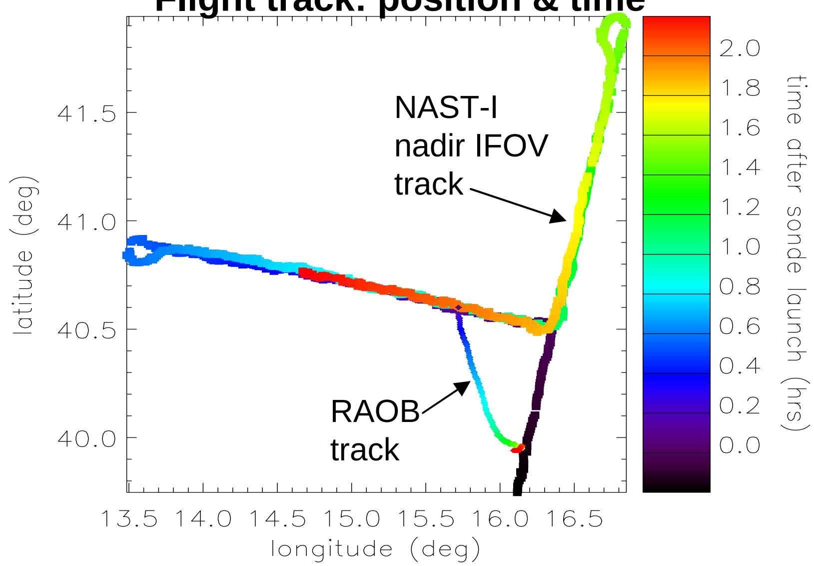
SD

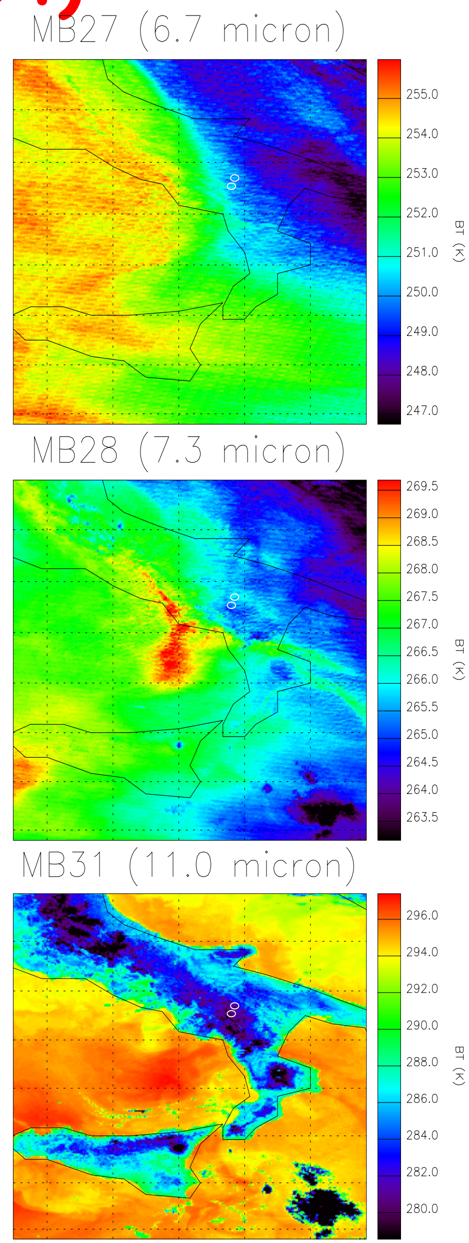
RAOB ascent profile



- **Significant geophysical field variance exists along RAOB flight profile**
- **RAOB not representative of launch site atmosphere for non-uniform fields**

Flight track: position & time





MB27 stddev (AIRS IFOVs)
max= 0.35 K
min= 0.32 K
mean= 0.34 K
stddev= 0.03 K

Modis variability within AIRS IFOVs

MB28 stddev (AIRS IFOVs)
max= 0.25 K
min= 0.19 K
mean= 0.22 K
stddev= 0.05 K

MB31 stddev (AIRS IFOVs)
max= 0.97 K
min= 0.79 K
mean= 0.88 K
stddev= 0.13 K

Satellite Infrared Radiance Validation using the NAST-Interferometer, Larar et al., ITSC-15, Maratea, Italy, 5 October, 2006.

Summary & Conclusions

LaRC
SD

- Post-launch validation activities are critical to verify quality of satellite measurement system (i.e., sensor, algorithms, and direct/derived data products)
- Very favorable spectral radiance inter-comparison results obtained between AIRS and NAST-I, S-HIS, and simulations based upon ground-based lidar, ECMWF reanalysis fields, and radiosondes
- Spatial and temporal coincidence between observing systems crucial to differentiate between measurement uncertainty and geophysical field variability
- Airborne high resolution FTS systems enable (very-well-calibrated) emulation of other high-resolution and broadband IR instrument systems, offering a unique advantage for and critical component to s/c sensor cal/val
  - coincident a/c FTS observations provide best match to s/c AIRS measurements
  - airborne assets can enable cal/val anywhere, unlike fixed-location ground sites
- EAQUATE data are proving to be very useful for current AIRS direct/derived data product validation, and should serve to further refine methodologies for future advanced sounder (e.g. IASI & CrIS) post-launch validation activities

International TOVS Study Conference, 15th, ITSC-15, Maratea,Italy, 4-10 October 2006
Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center,
Cooperative Institute for Meteorological Satellite Studies, 2006.