Validation Studies Using NAST-Interferometer Field Measurements

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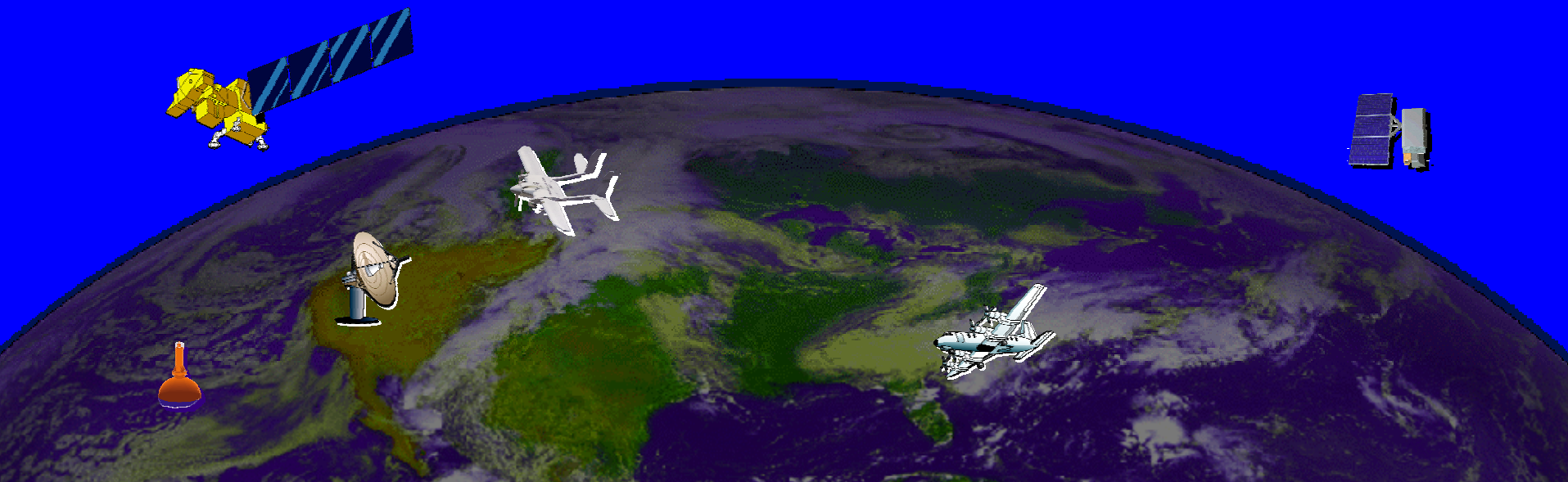

Topics

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- Motivation
- Case study & data sources
- Instrument systems
- Validation methodology
- Results
- Summary & conclusions

Motivation

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- ***Aircraft underflights fundamental to space-based sensor validation***
  - High-altitude aircraft platforms (Proteus, ER-2, DC-8, WB-57, P-3, etc.) instrumented with validation sensors (NAST-I, S-HIS, INTESA, NAST-M, LASE, MAS, etc.) provide validation data by obtaining spatially & temporally coincident observations with satellite platforms of interest (e.g. Terra (Modis), Aqua (Modis & AIRS), and future Aura (TES), Metop (IASI), EO-3 (GIFTS), and NPP/NPOESS (CrIS).

- ***Such airborne/satellite coincident data contribute toward essential cal/val activities***
  - On-orbit Sensor performance verification
  - On-orbit sensor calibration validation
  - Validate algorithms
  - Direct and derived data product validation
  - Long-term monitoring of sensor performance (radiance & geophysical)

Case Study: *PTOST*

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- **PTOST (February 18 - March 13, 2003, HAFB, Hawaii).** The 2003 ***Pacific THORPEX Observing System Test (PTOST)*** was the first in a series of Pacific and Atlantic observation campaigns in support of the WWRP/USRP THORPEX Program. THORPEX - a Global Atmospheric Research Program aimed at improving short range (up to 3 days), medium range (3-7 days) and extended range (two week) weather predictions. Flights targeted frontal boundaries and storm systems, as well as satellite sensor validation underflights (TERRA, AQUA, and ICESat)

Aircraft Payload Included:

ER-2 (NAST-I, NAST-M, S-HIS, MAS, CPL); G-IV (Dropsondes, in-situ O_3)

Satellite Platforms Included:

Terra & Aqua

The NAST & SHIS Systems

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- ✓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

Microwave Radiometer (NAST-M)

Spectral Regions: 50 - 60 GHz,
113 - 119 GHz, 183 GHz, 425GHz
A/C platforms: ER-2, Proteus

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

Characteristics of Remote Sensors Employed in Study

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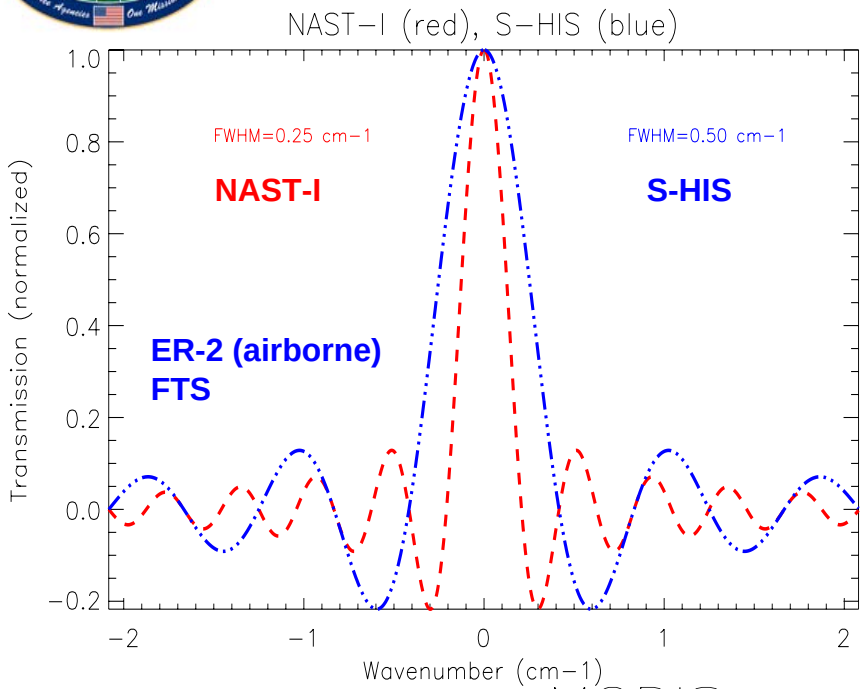
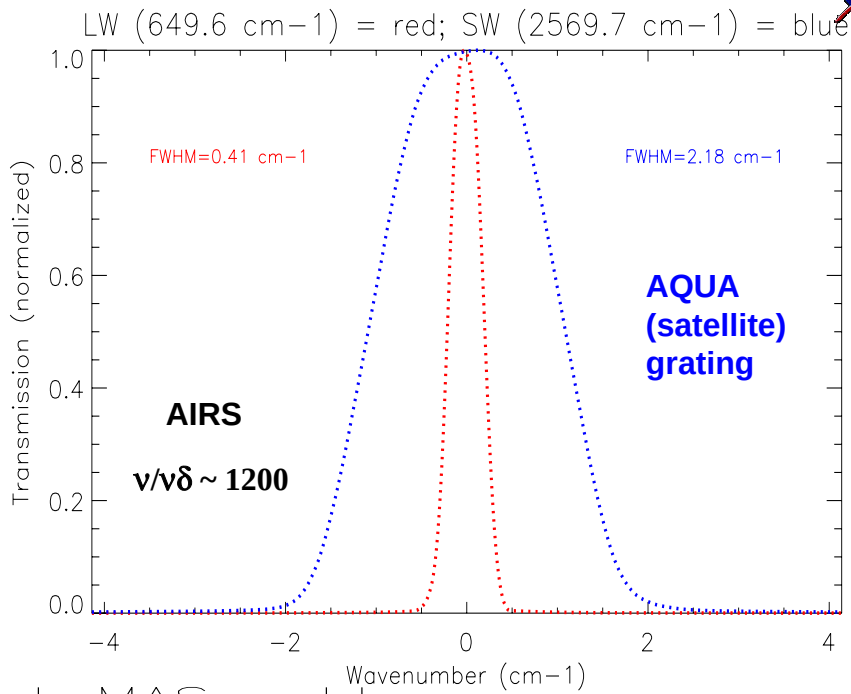
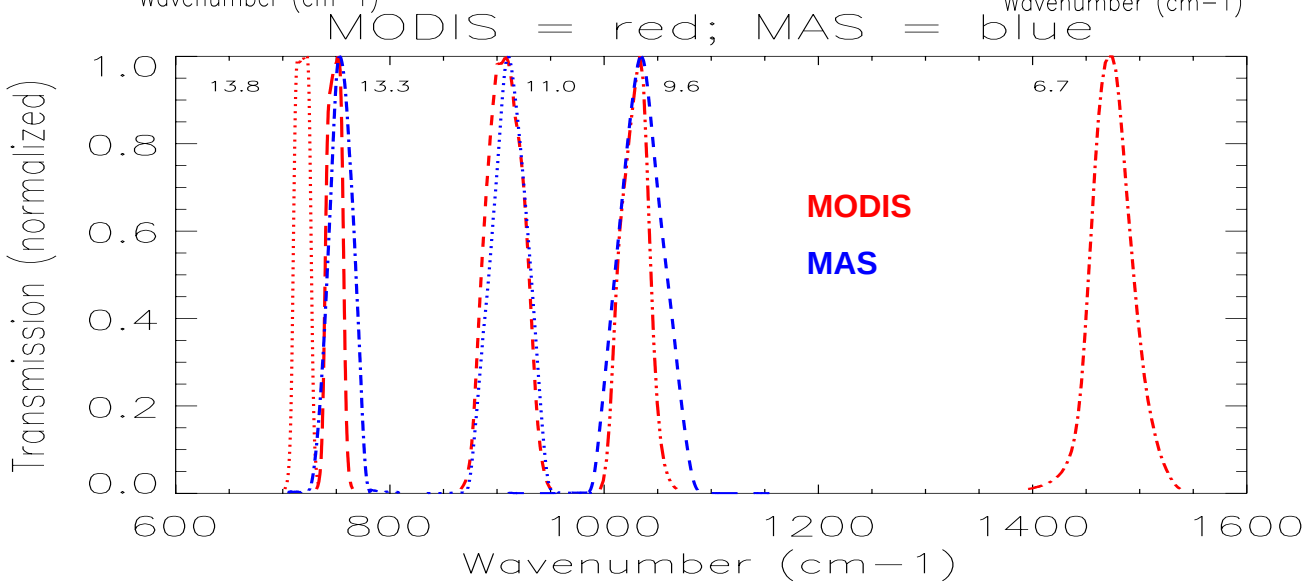
Instrument system	Sensor type	Spectral extent	Spectral resolution	Nadir IFOV	Platform
NAST-I	Michelson interferometer	3.5 – 16 μ, continuous	0.25 cm^{-1}, $\upsilon/\delta\upsilon$ > 2000	2.5 km (from ER-2)	ER-2
S-HIS	Michelson interferometer	3.0 – 17 μ, continuous	0.5 cm^{-1}, $\upsilon/\delta\upsilon$ > 1000	2.0 km (from ER-2)	ER-2
AIRS	Grating spectrometer	3.8 – 15.4 μ, discrete channels	~0.4 – 2.2 cm^{-1}, $\upsilon/\delta\upsilon$ ~ 1200	~ 13.5 km	AQUA
MODIS	Radiometer	3.6 – 14.4 μ (IR bands 20 – 36) , discrete channels	~13 – 128 cm^{-1}, broadband filters	~ 1 km	AQUA
MAS	Radiometer	3.6 – 14.4 μ (IR bands 20 – 36) , discrete channels	~13 – 128 cm^{-1}, broadband filters	~ 50 m	ER-2

Case Study Instrument SRFs







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Study Methodology

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- **Incorporate multiple, independent, temporally- & spatially-coincident data sources**
  - Satellite: AQUA AIRS & MODIS
  - ER-2: NAST-I, S-HIS, MAS, in-situ O_3
  - G-IV: dropsondes
  - HI: radiosonde
  - Buoys: ~ SST
- **Verify spatial co-registration by comparing geo-referenced images at select λ**
- **LBL- & FFM-based calculations for simulated observations**
  - SST from distant buoy & NAST-I retrieved; atmospheric profiles from vertical combination of dropsondes, NAST-I retrieved, radiosonde, in-situ O_3, NOAA-88, and standard atmosphere
- **Compare nadir-coincident observations and simulations with Modis broadband SRFs applied (or similar, i.e. MAS)**
- **For clear region, compare high resolution spectra**
  - PC-filtering applied to measured radiances & then averaged over clear FOVs
  - Measurements and simulations, on original and common spectral scales
    - Original SRFs and combined (i.e., NAST-I*S-HIS*AIRS, S-HIS*AIRS, AIRS*S-HIS)

Sat & A/C Ground Tracks

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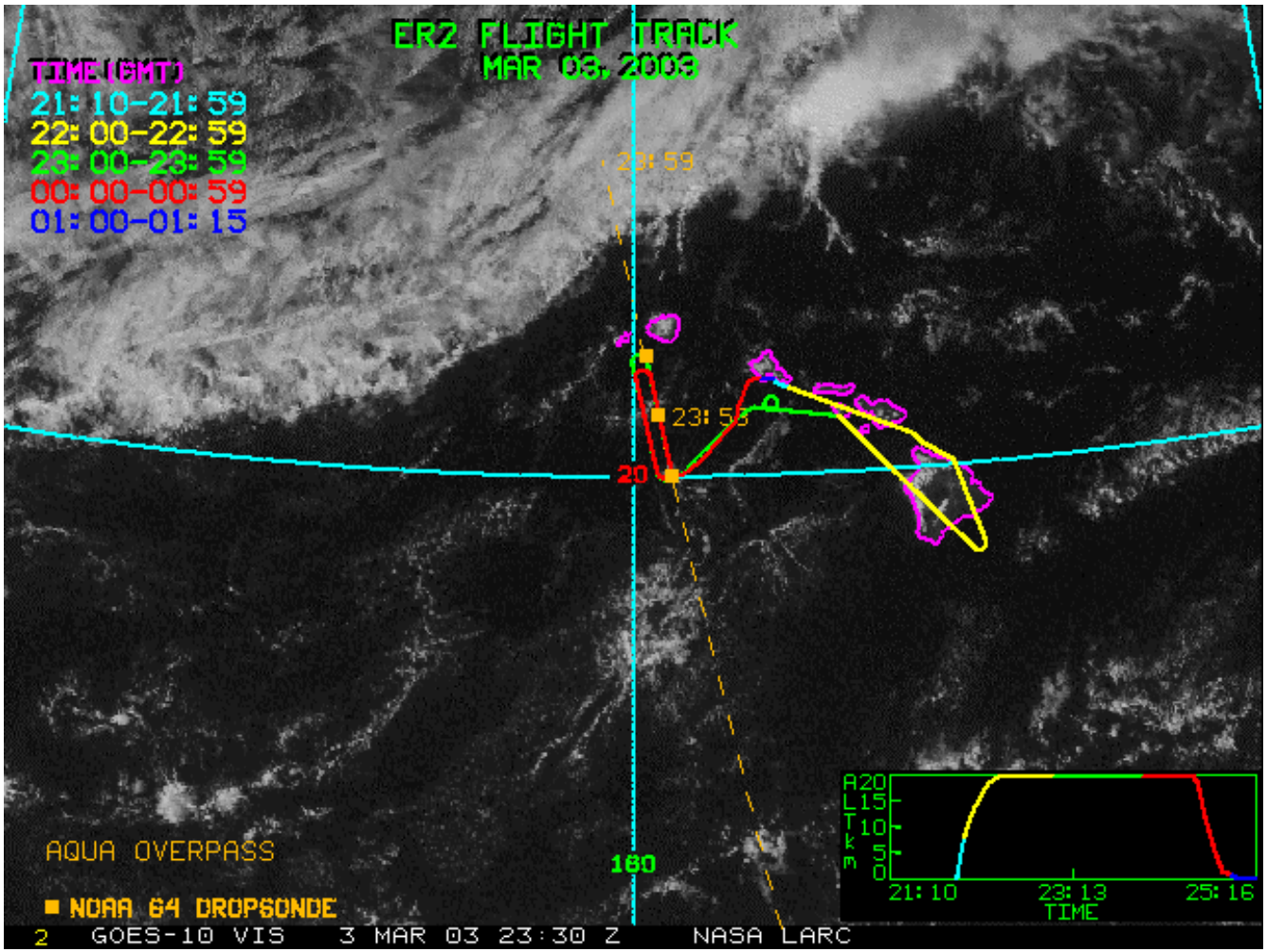

Nadir IFOV Track Overlap

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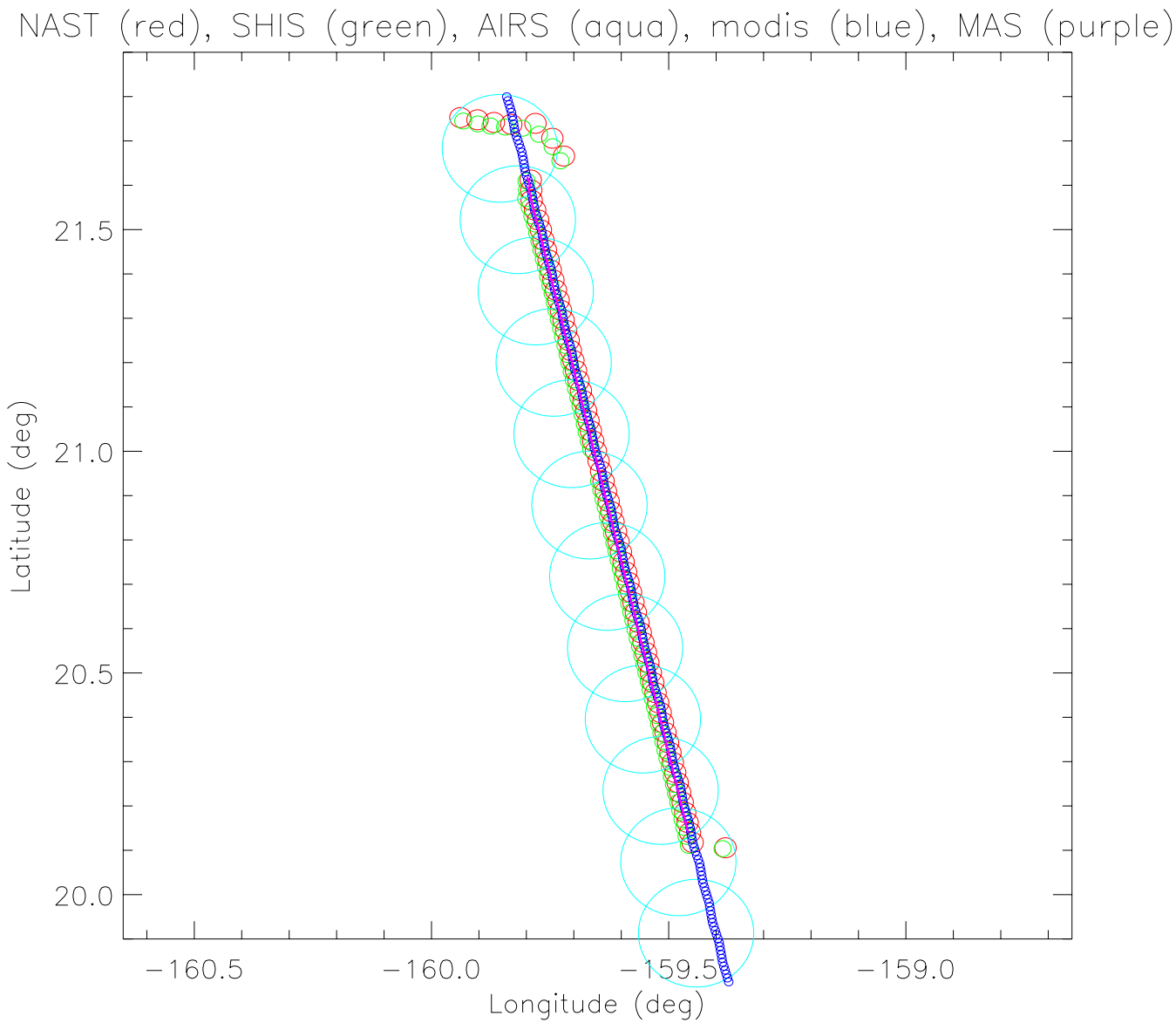

Nadir IFOV size:

AIRS ~ 14 km

NAST-I ~ 2.5 km

S-HIS ~ 2.0 km

MODIS ~ 1 km

MAS ~ 50 m

13th International TOVS Study Conference, ITSC-13, Larar et al., 31 October, 2003.

Spatially Geo-referenced Images (~ 11μ)

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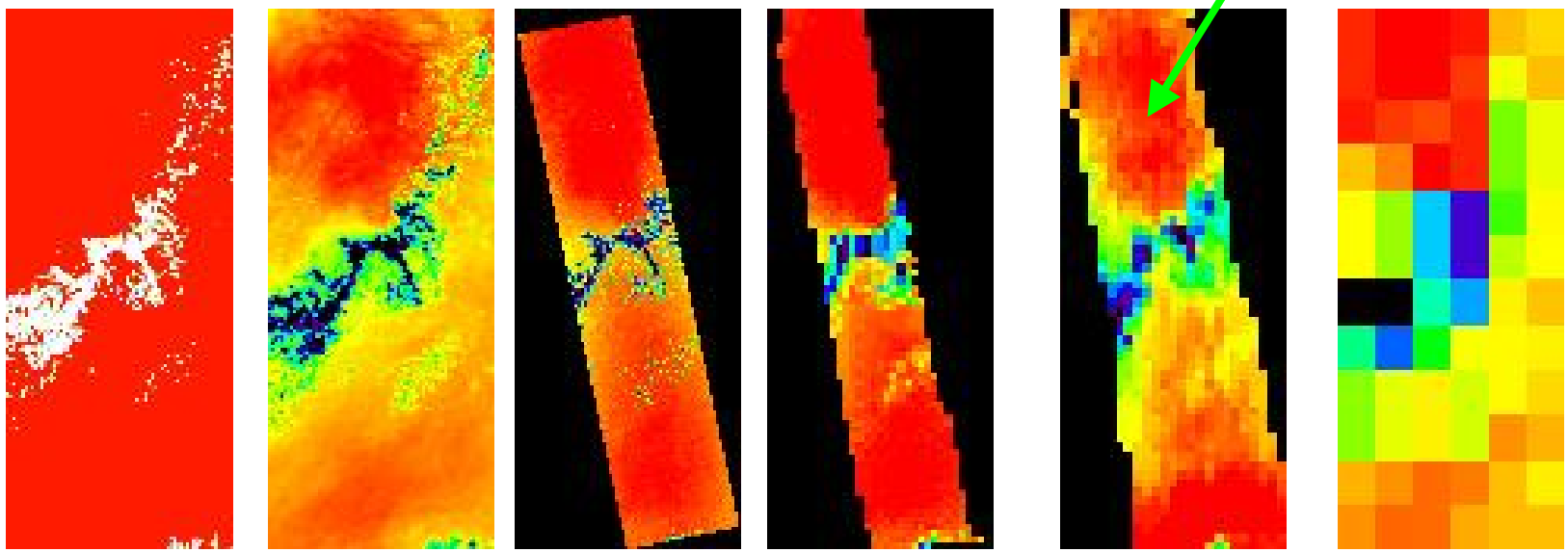
Window region

Clear region used for spectra inter-comparison



MODIS (Cld msk)	MODIS (B31)	MAS (B45)	S-HIS (*MB31)	NAST-I (*MB31)	AIRS (*MB31)
~ 1 km	~1 km	~ 50 m	~ 2.0 km	~ 2.5 km	~ 14 km

Nadir Track Coincidence with MODIS Broadband SRFs

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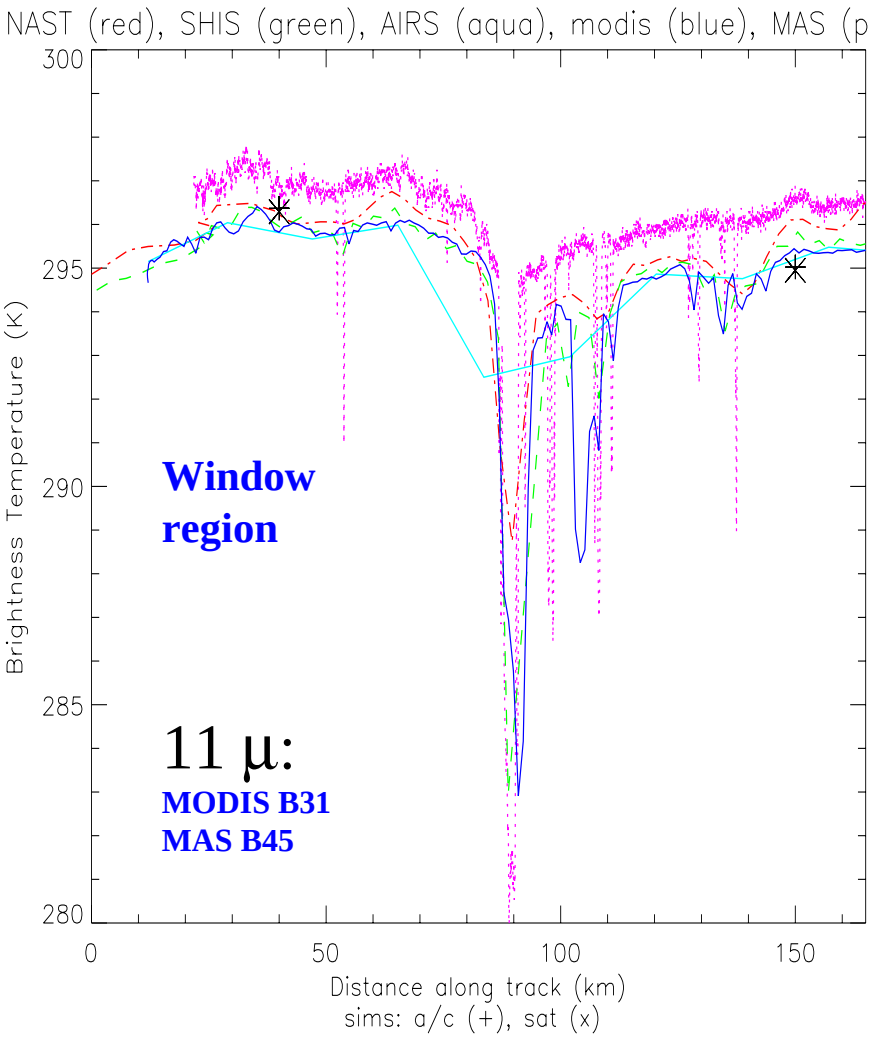

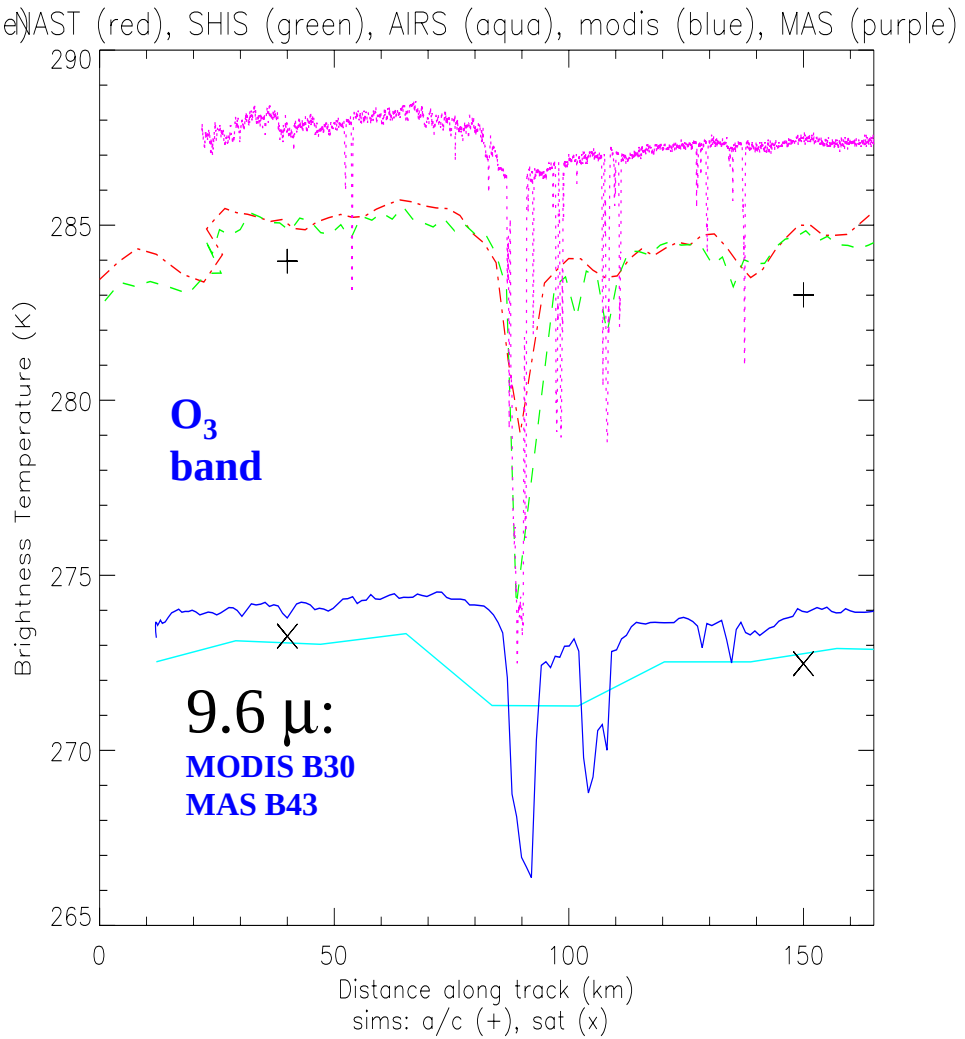

NAST-I Window Region Warm Bias?

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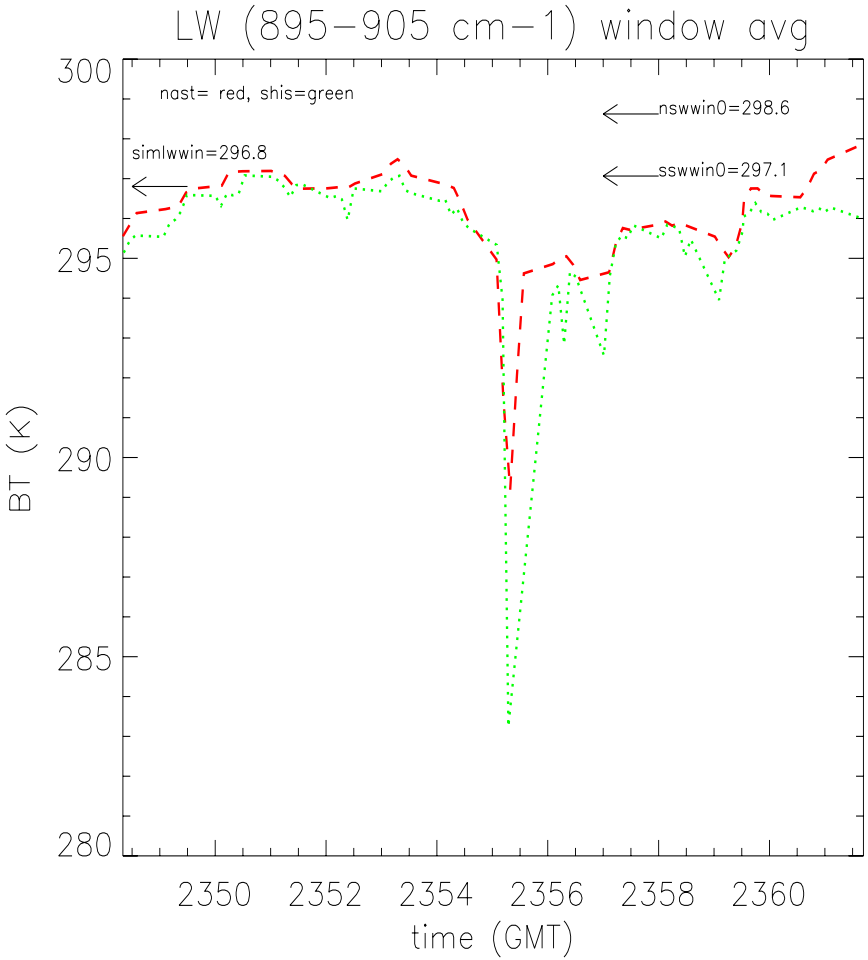

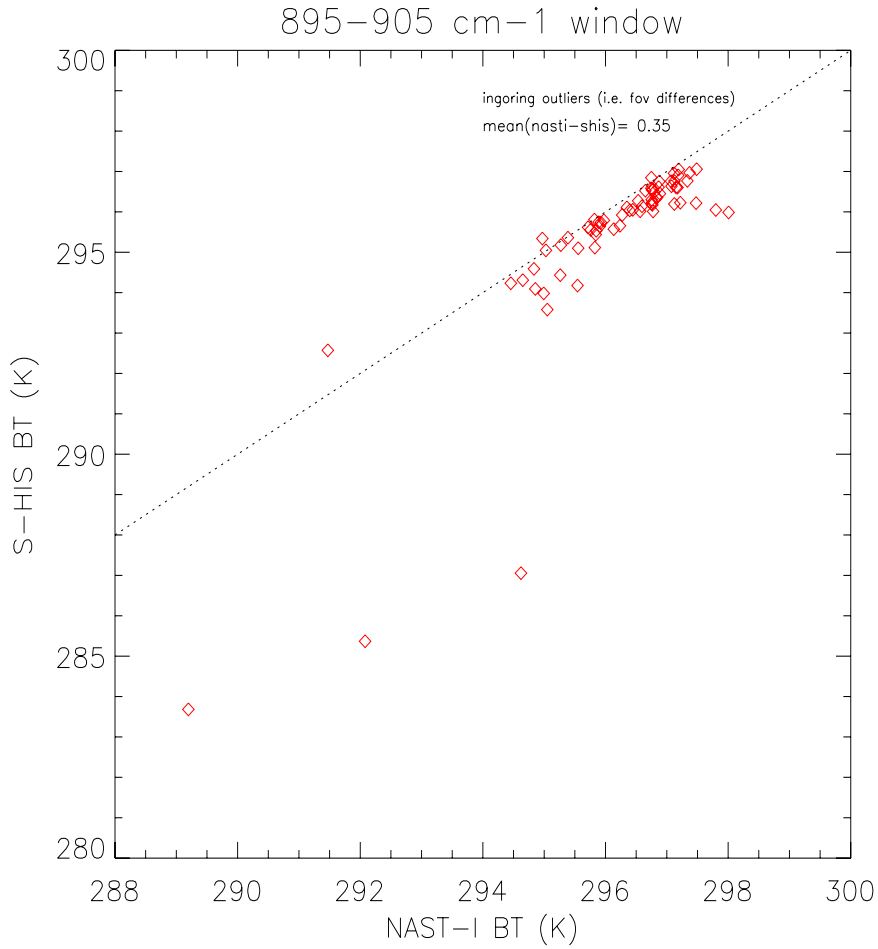

Baseline Measured Spectra w/ Original SRFs

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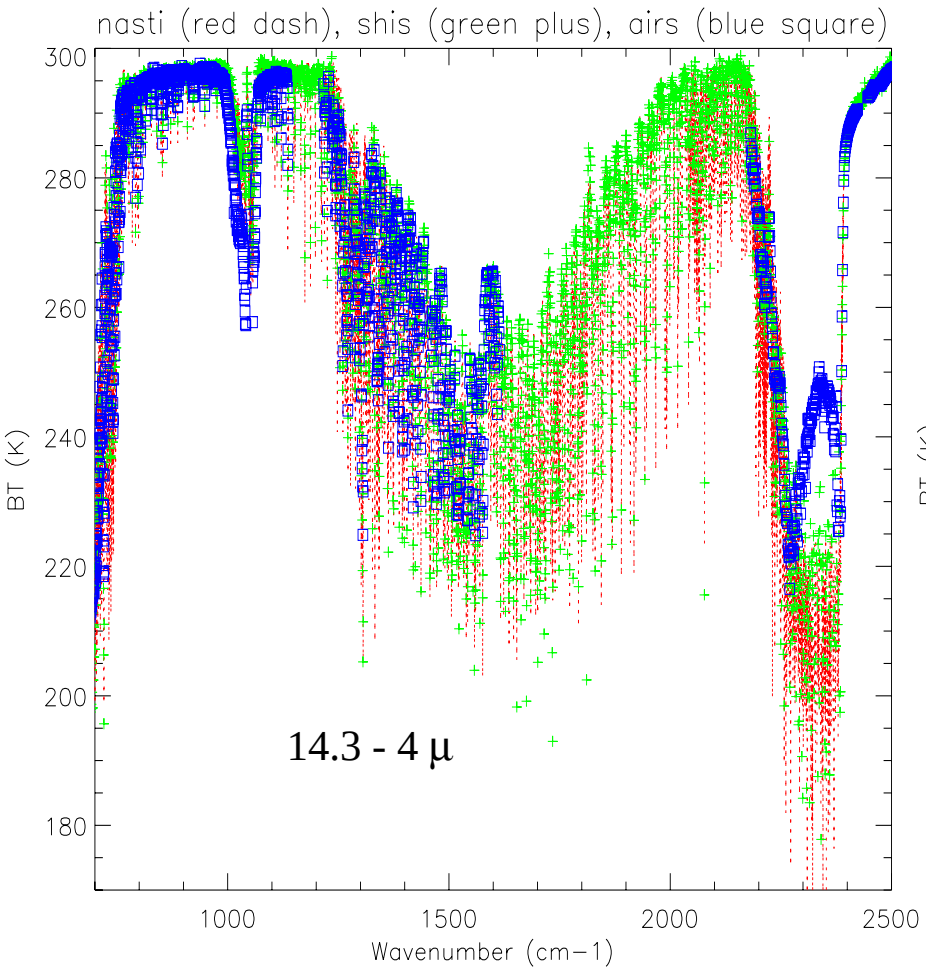

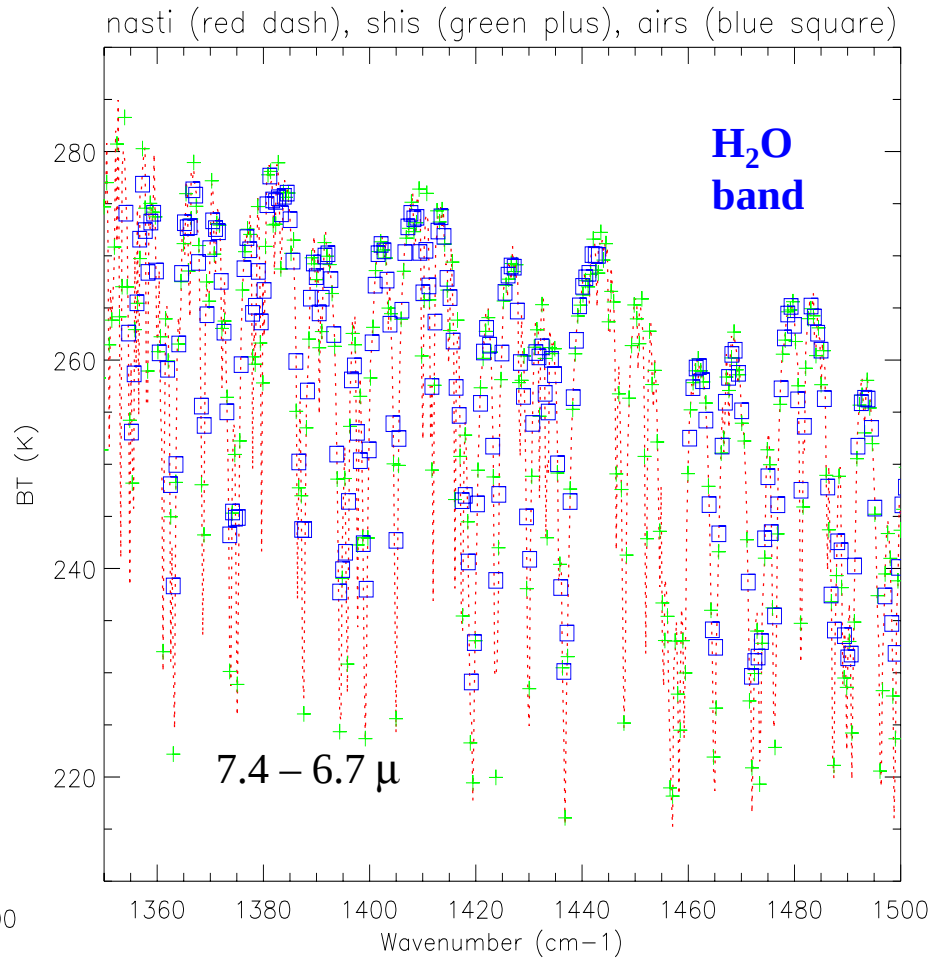

FM Simulations vs Measurements

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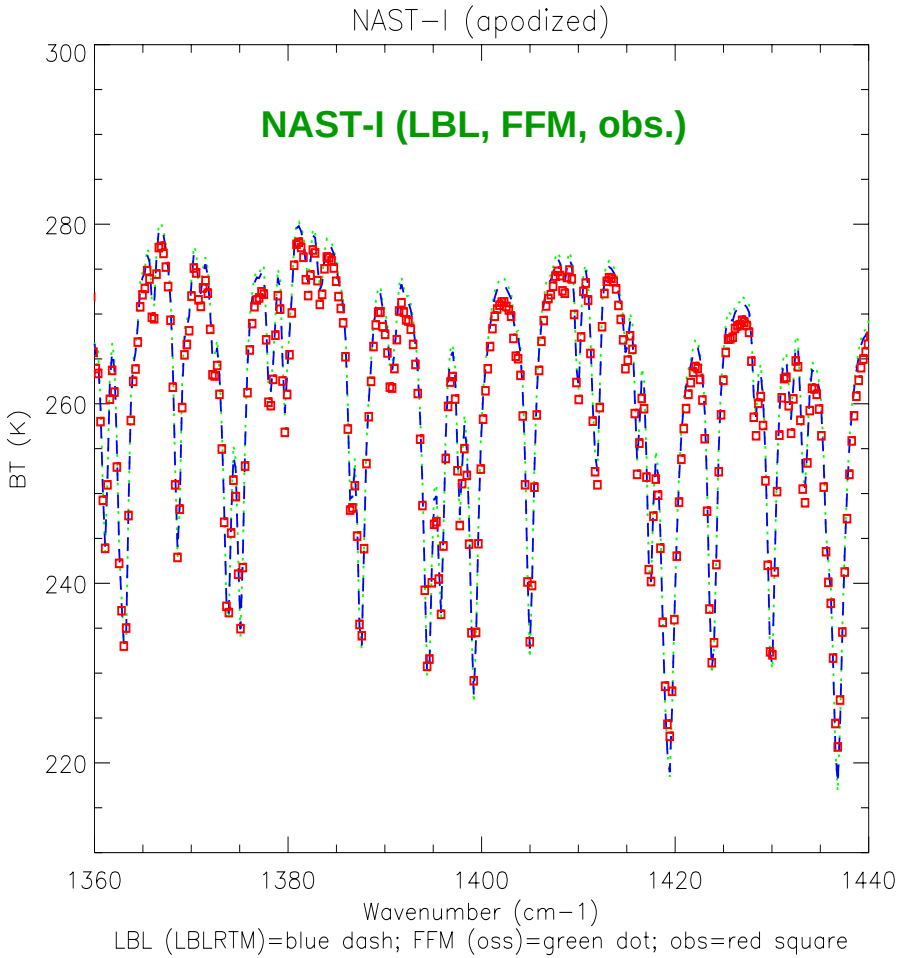
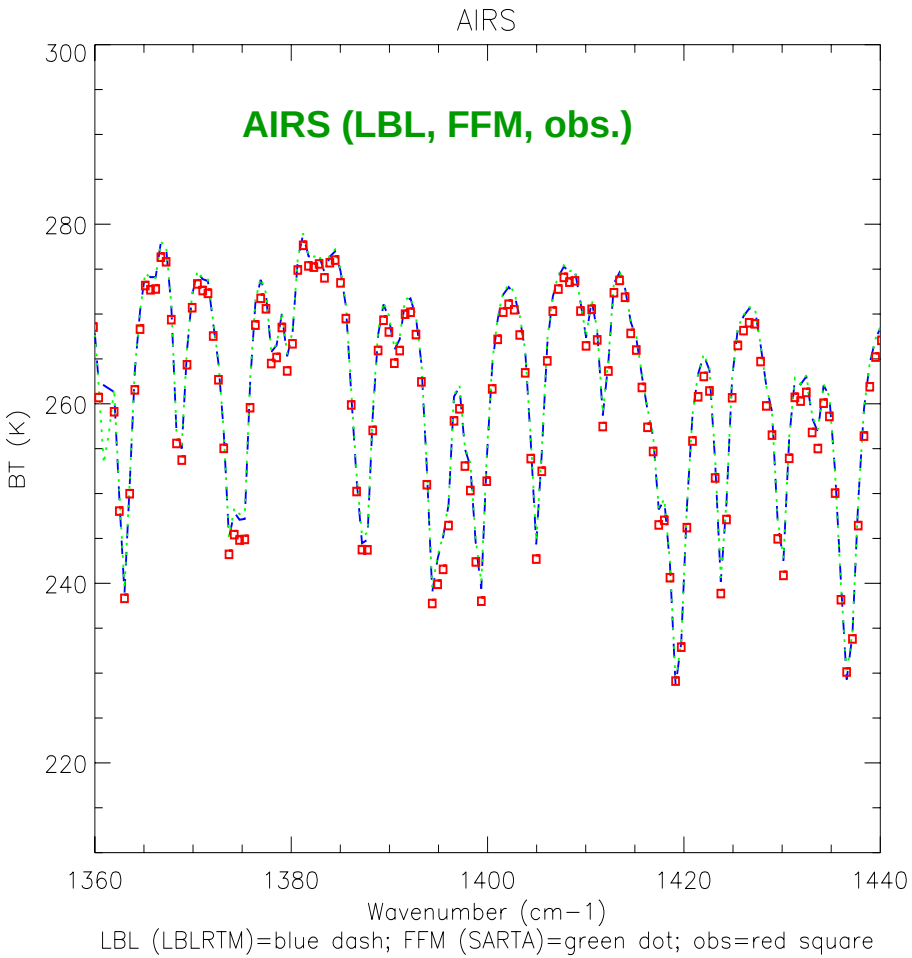
H_2O band





7.4 – 6.9 μ

Spectra Comparison with Common SRFs [NAST-I*SHIS*AIRS; SHIS*AIRS; AIRS*SHIS] (030303)

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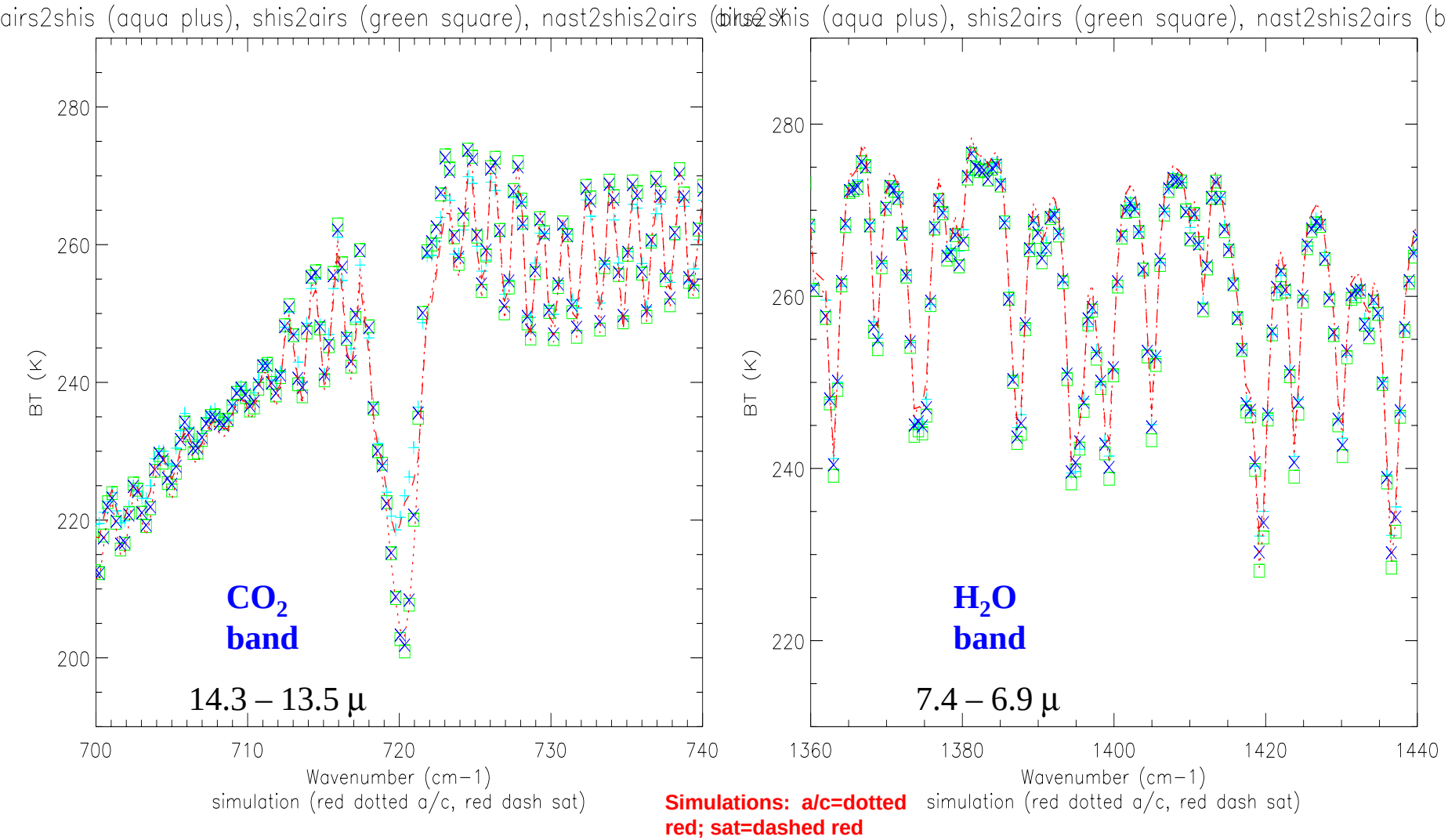

Simulations: a/c=dotted red; sat=dashed red

Spectra Comparison with Common SRFs
[NAST-I*SHIS*AIRS; SHIS*AIRS; AIRS*SHIS]

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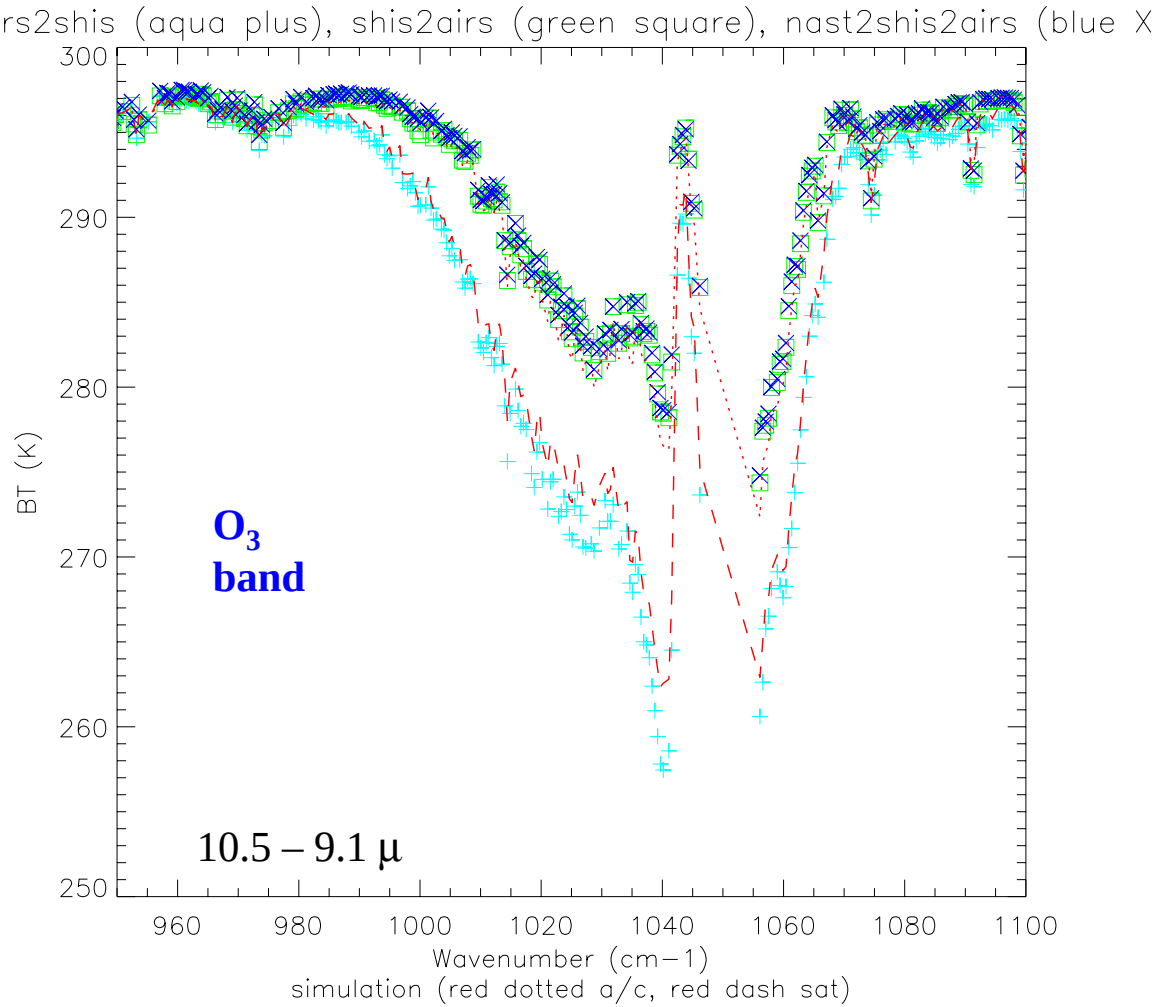

Simulations: a/c=dotted red; sat=dashed red

Summary & Conclusions

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- Instrument systems and simulation agreement shown, in general, to be within acceptable levels considering measurement and forward model uncertainties
- Offsets from Modis of similar magnitude and direction to that reported in earlier studies (e.g. Tobin et al., OSA FTS mtg., 2003; Moeller et al., SPIE SD03) and possibly due to calibration offsets or SRF spectral shifts
- Spectral fidelity easily verified via simulations, but corresponding radiometric accuracy verification from simulation is limited by vertical accuracy of ancillary data and absolute accuracy of spectroscopic parameters
- High resolution FTS systems provide continuous spectra of high radiometric and spectral fidelity enabling emulation of other high-resolution or broadband instrument systems
- NAST-I & S-HIS provide high spatial/spectral/temporal resolution radiance measurements for atmospheric state characterization; such airborne observations over calibration sites (e.g., DoE ARM CART) can be used to account for time and space variability when comparing and interpreting other measurements (e.g., ground-, balloon-, aircraft-, and space-based systems)
- Spatial and temporal coincidence between observing systems crucial to differentiate between measurement uncertainty and geophysical variability
- Aside from collocated sensor(s) on same platform, space-based sensor validation best achieved using high-altitude aircraft based sensors viewing nadir and possibly zenith; can eliminate errors from spatial and temporal mismatches and spectroscopic data uncertainties, and allows viewing most of atmospheric column