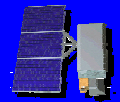
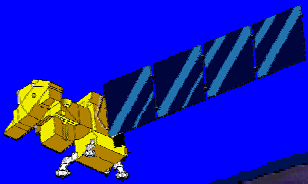
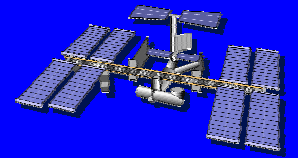


Validation Studies Using NAST- Interferometer Field Measurements

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Mango^b

^aNASA Langley Research Center, Hampton, VA

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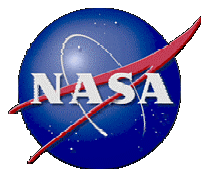
Topics



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



Motivation



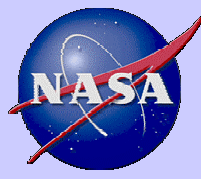
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- *Aircraft underflights fundamental to space-based sensor validation*
 - High-altitude aircraft platforms (Proteus, ER-2, DC-8, WB-57, P-3, etc.) instrumented with validation sensors (NAST-I, S-HIS, INTESA, NAST-M, LASE, MAS, etc.) provide validation 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 O₃)

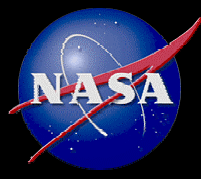


**Satellite Platforms
Included:**

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



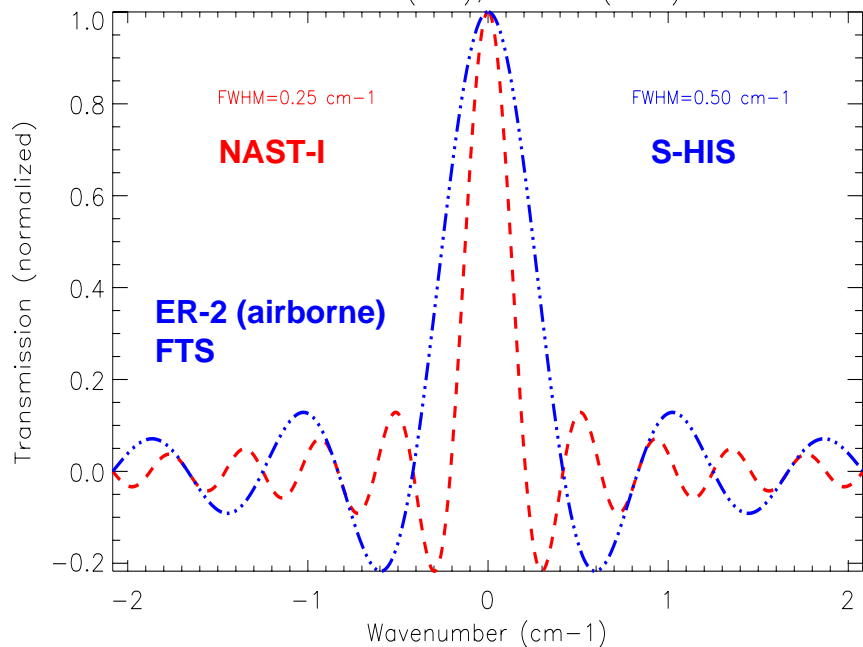
<u>Instrument system</u>	<u>Sensor type</u>	<u>Spectral extent</u>	<u>Spectral resolution</u>	<u>Nadir IFOV</u>	<u>Platform</u>
NAST-I	Michelson interferometer	3.5 – 16 μ , continuous	0.25 cm^{-1} , $\nu/\delta\nu > 2000$	2.5 km (from ER-2)	ER-2
S-HIS	Michelson interferometer	3.0 – 17 μ , continuous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



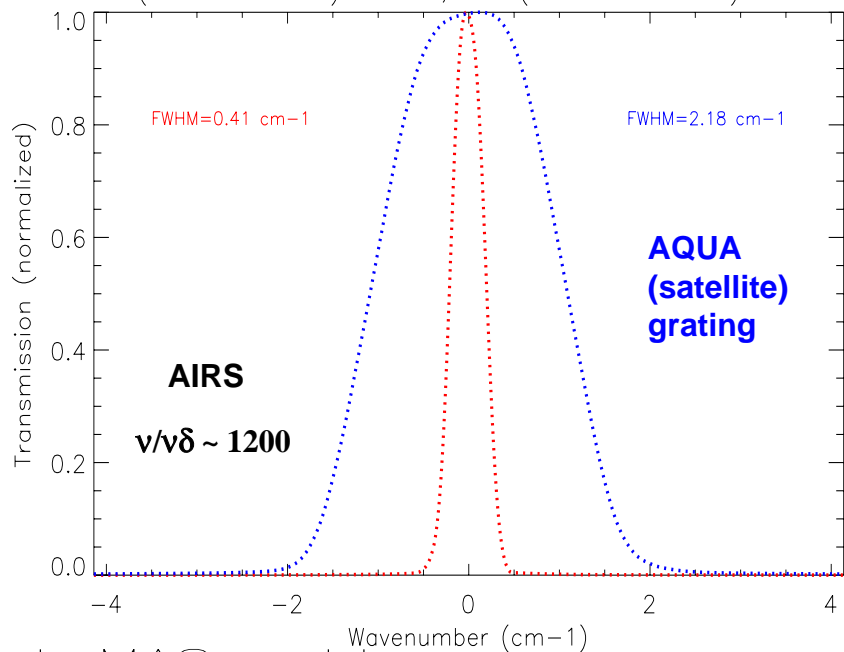
Case Study Instrument SRFs



NAST-I (red), S-HIS (blue)



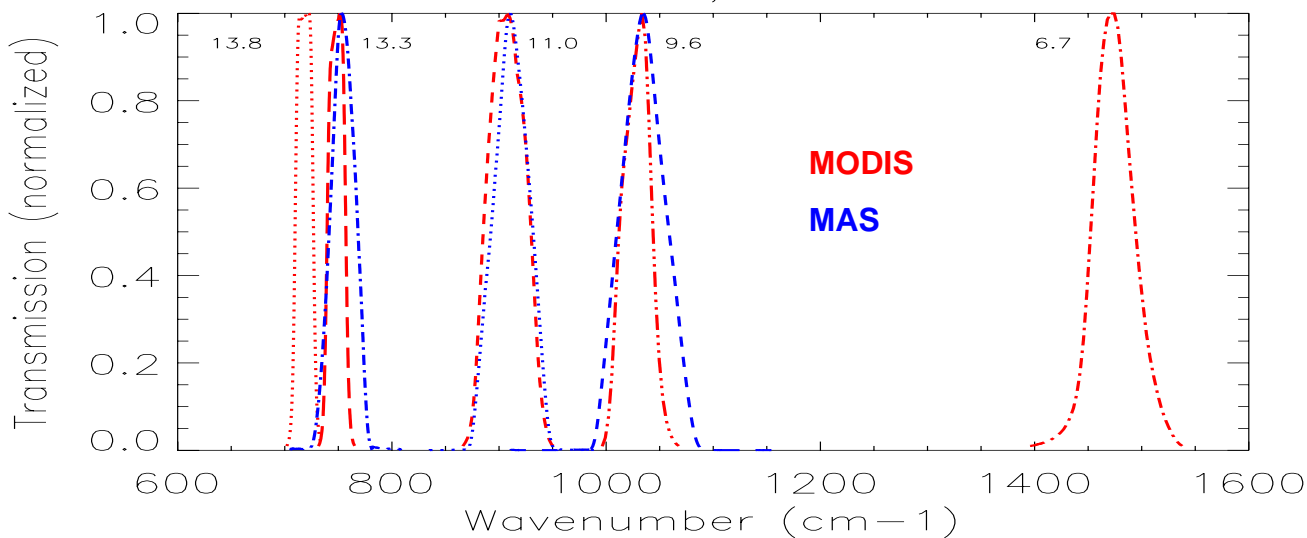
LW (649.6 cm⁻¹) = red; SW (2569.7 cm⁻¹) = blue



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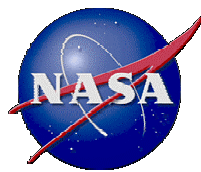
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MODIS = red; MAS = blue





Study Methodology



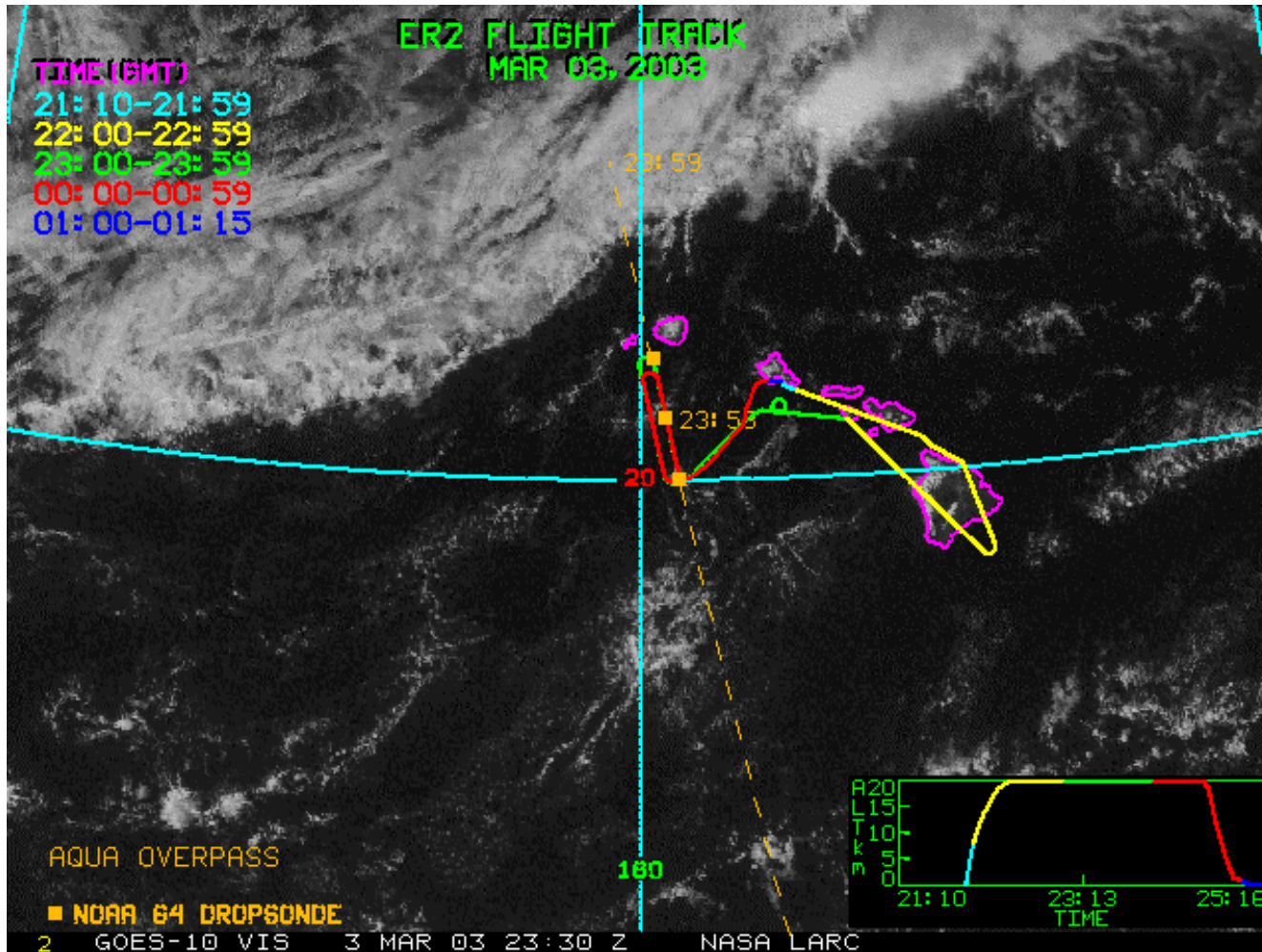
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- **Incorporate multiple, independent, temporally- & spatially-coincident data sources**
 - Satellite: AQUA AIRS & MODIS
 - ER-2: NAST-I, S-HIS, MAS, in-situ O₃
 - G-IV: dropsondes
 - HI: radiosonde
 - Buoys: ~ SST
- **Verify spatial co-registration 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 O₃, 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)



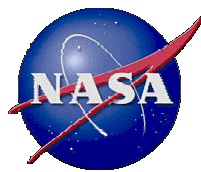
Sat & A/C Ground Tracks

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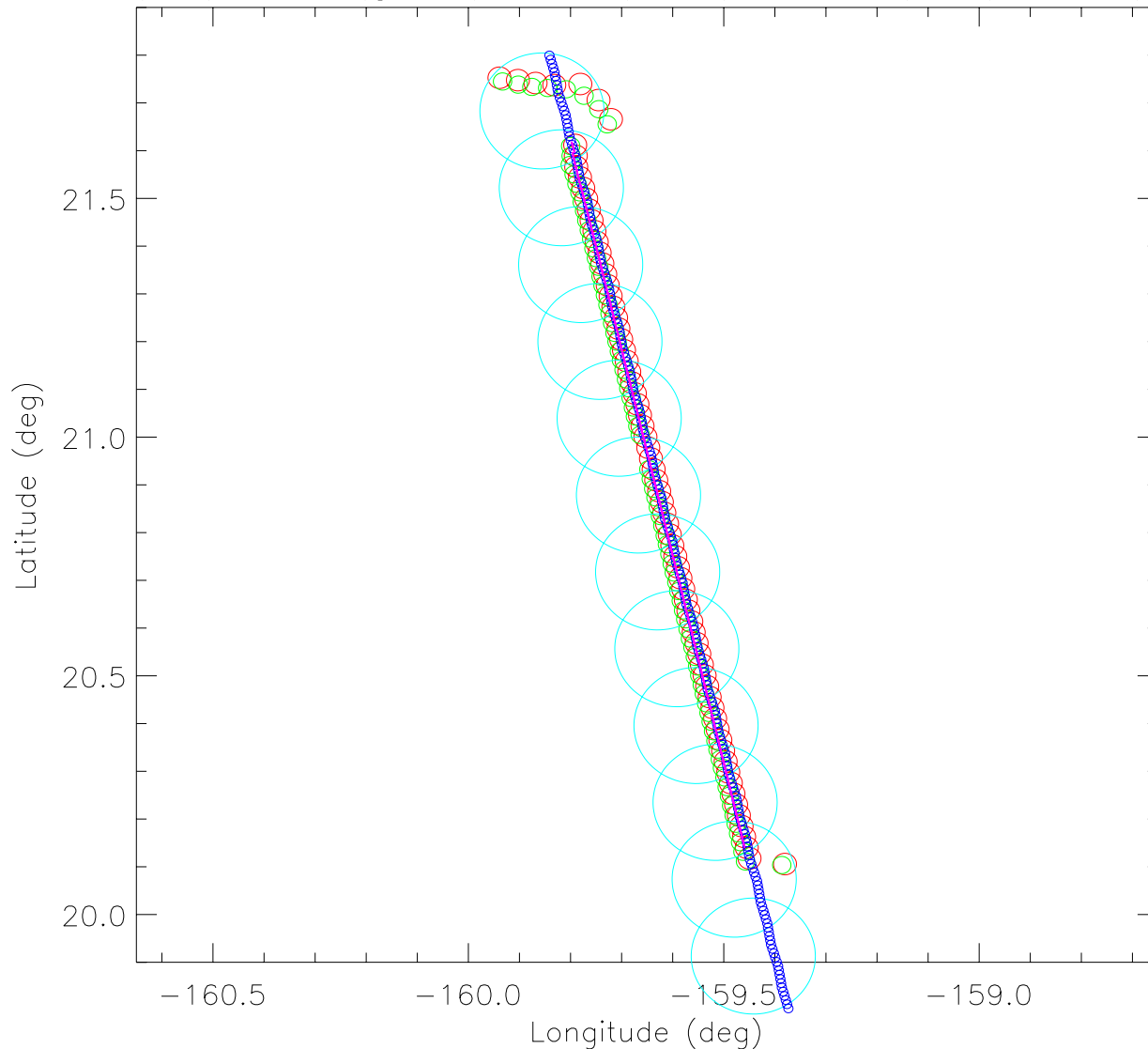
Nadir IFOV Track Overlap



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NAST (red), SHIS (green), AIRS (aqua), modis (blue), MAS (purple)



Nadir IFOV size:

AIRS ~ 14 km

NAST-I ~ 2.5 km

S-HIS ~ 2.0 km

MODIS ~ 1 km

MAS ~ 50 m

Spatially Geo-referenced Images

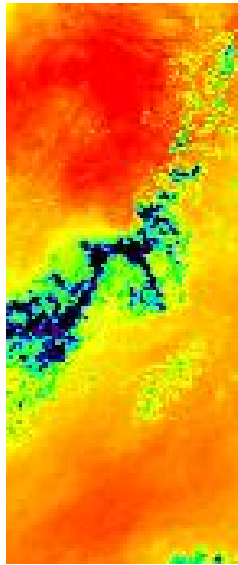
(~ 11 μ)

Window region

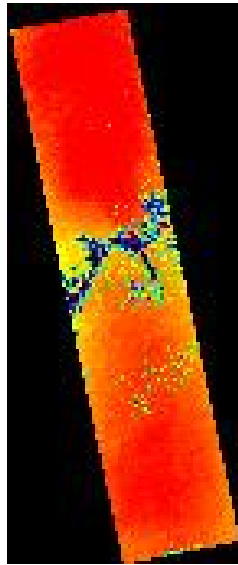
Clear region used for spectra inter-comparison



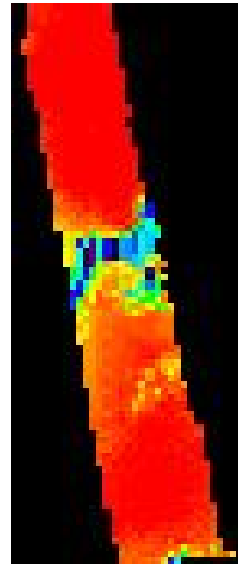
MODIS (Cld msk)
~ 1 km



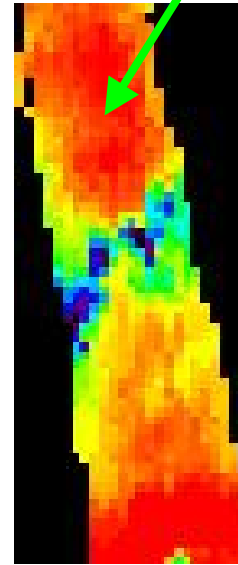
MODIS (B31)
~ 1 km



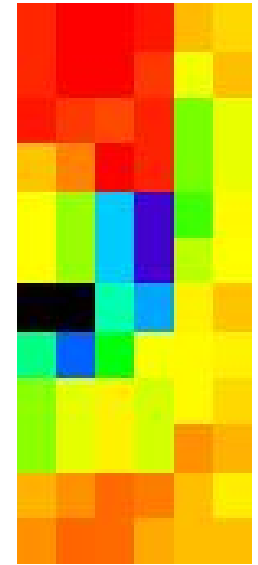
MAS (B45)
~ 50 m



S-HIS (*MB31)
~ 2.0 km



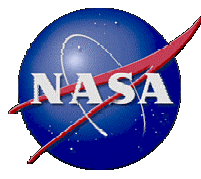
NAST-I (*MB31)
~ 2.5 km



AIRS (*MB31)
~ 14 km

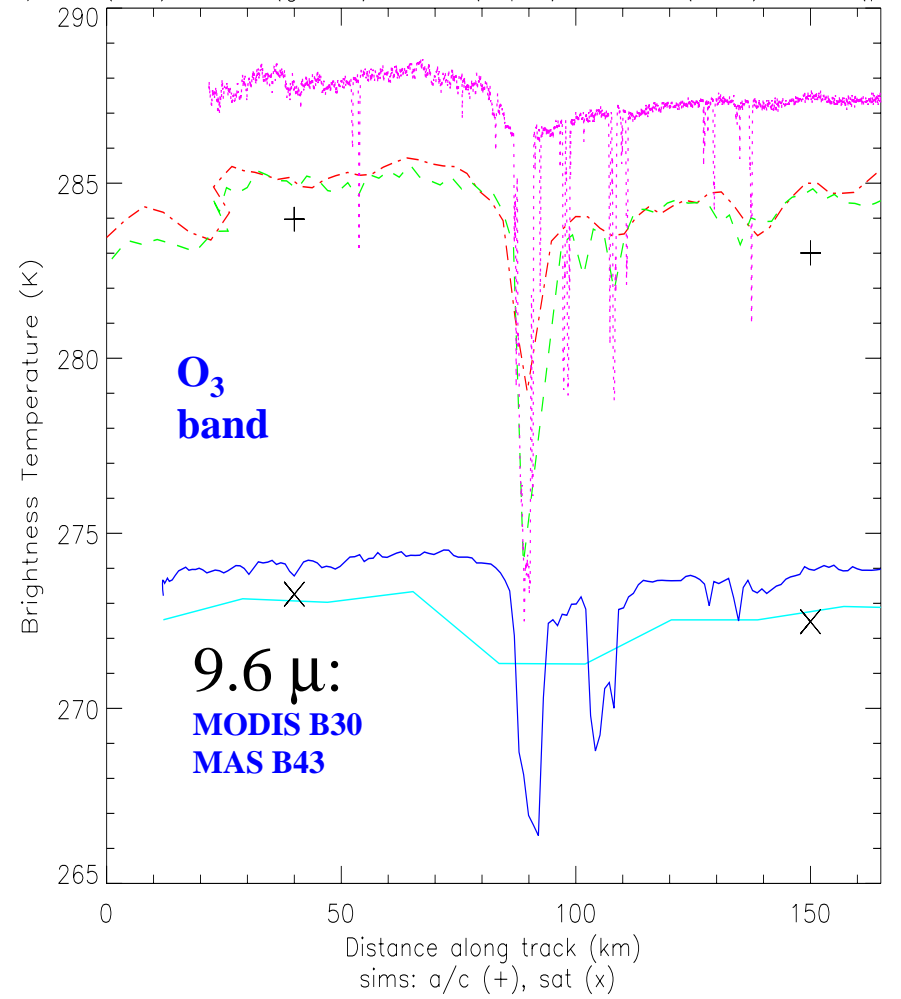
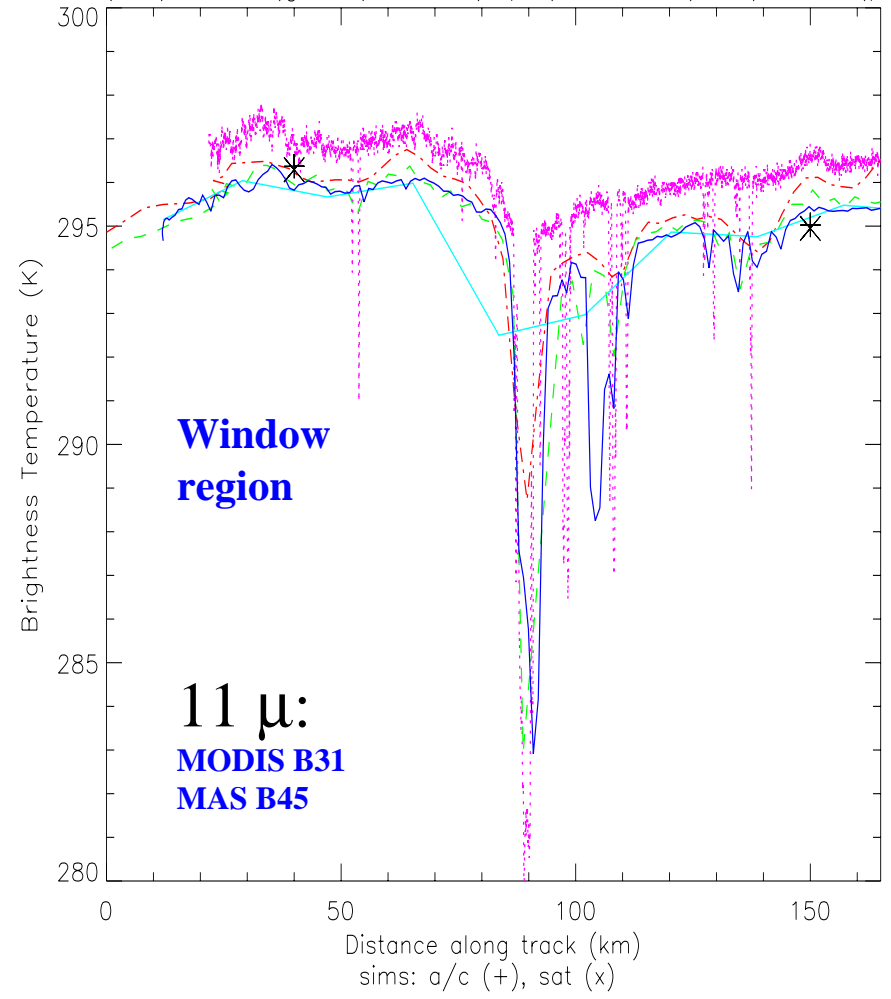


Nadir Track Coincidence with MODIS Broadband SRFs



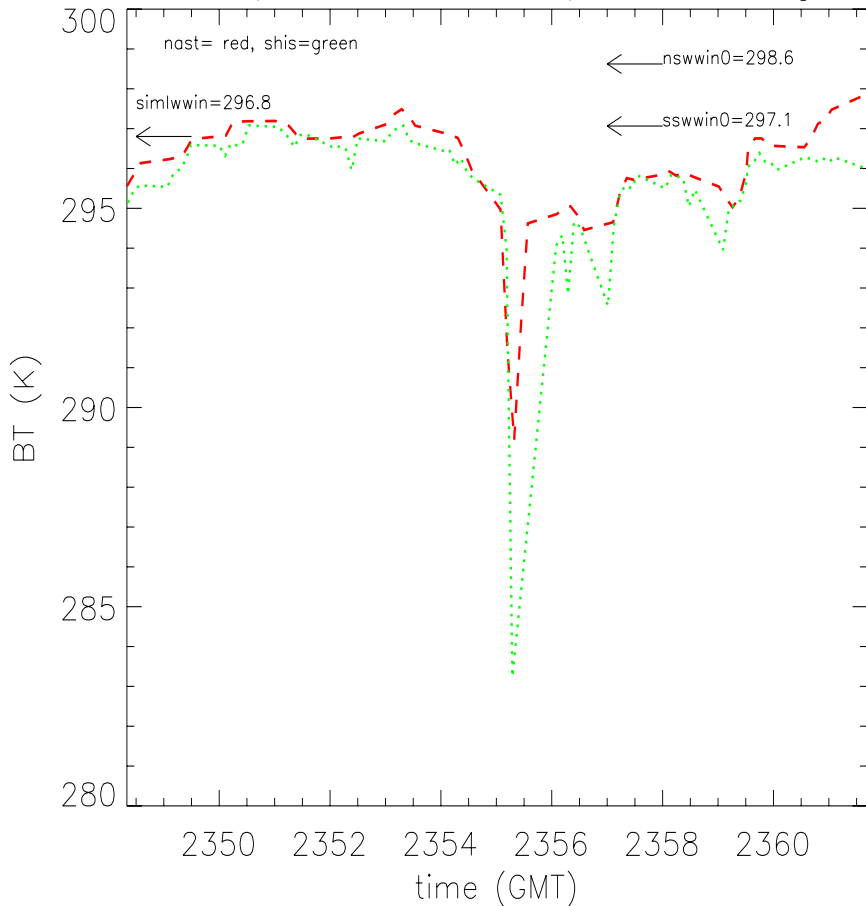
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NAOST (red), SHIS (green), AIRS (aqua), modis (blue), MAS (purple) NAOST (red), SHIS (green), AIRS (aqua), modis (blue), MAS (purple)

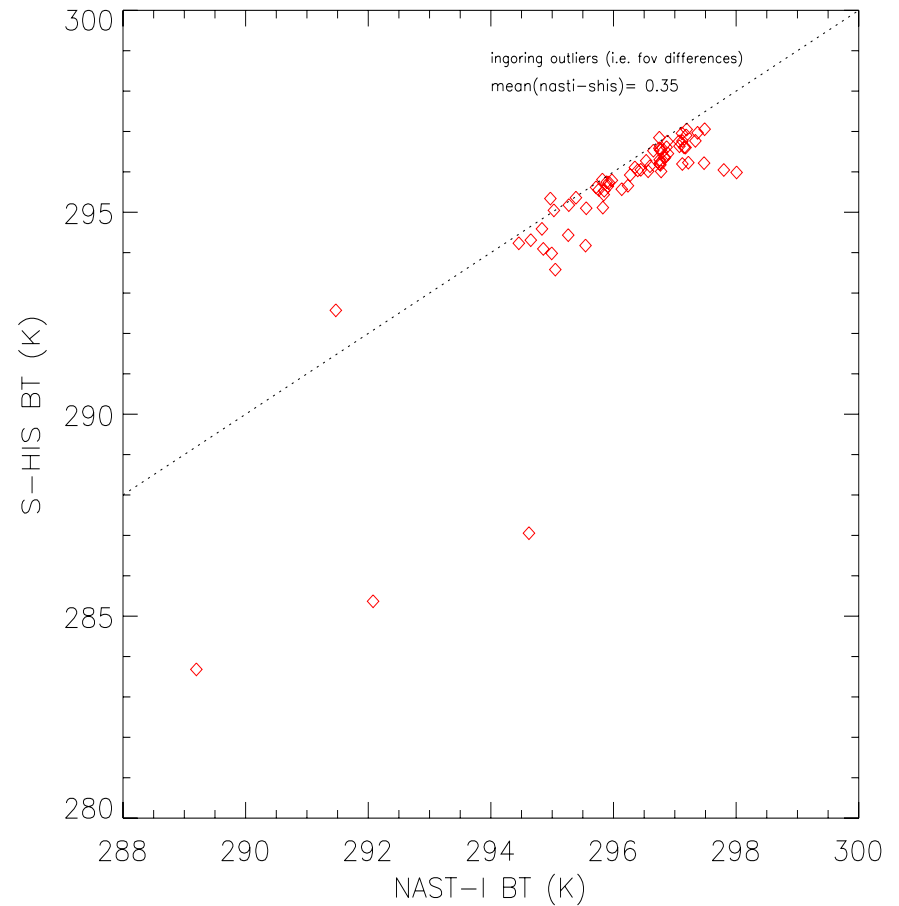


NAST-I Window Region Warm Bias?

LW (895–905 cm^{-1}) window avg

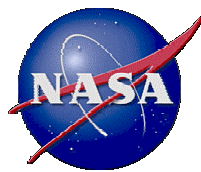


895–905 cm^{-1} window





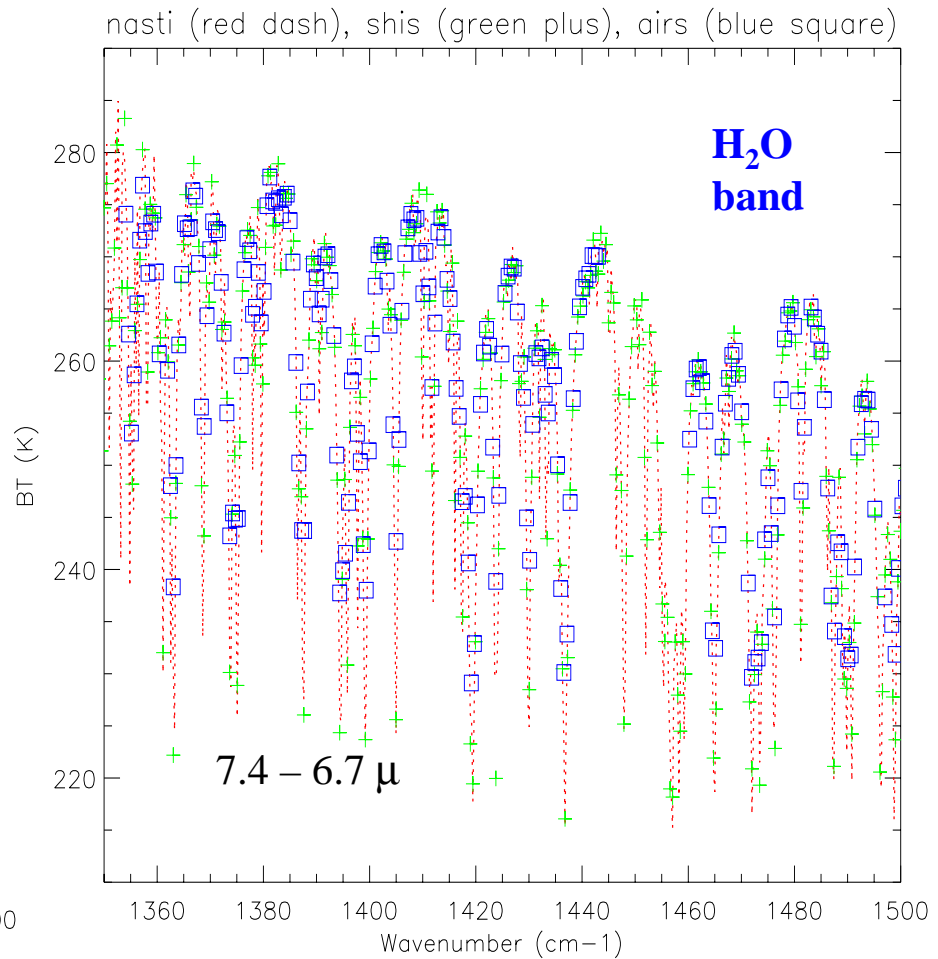
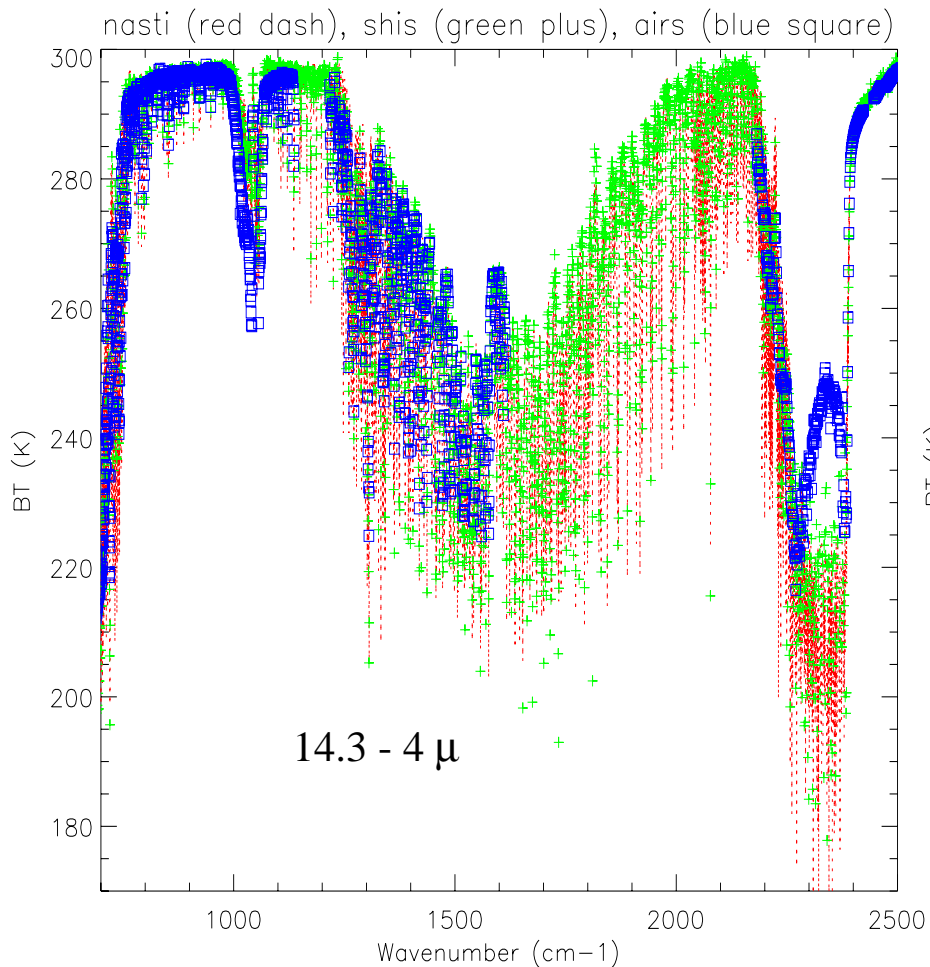
Baseline Measured Spectra w/ Original SRFs



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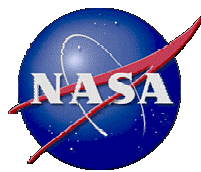
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FM Simulations vs Measurements



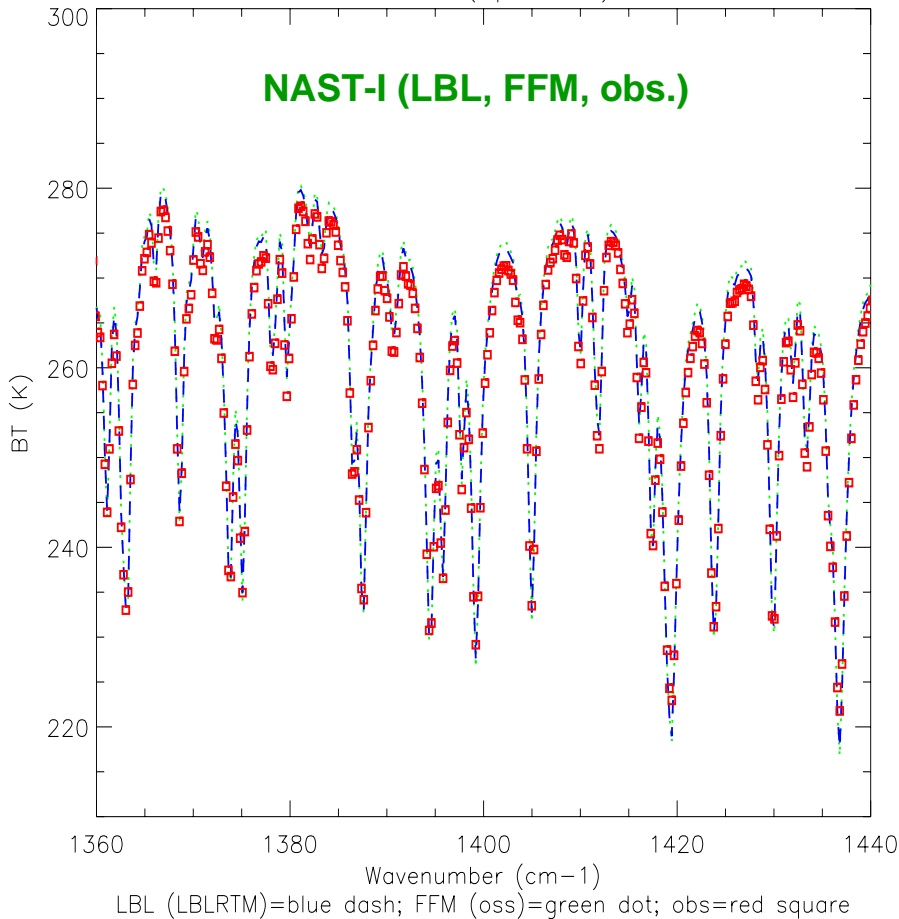
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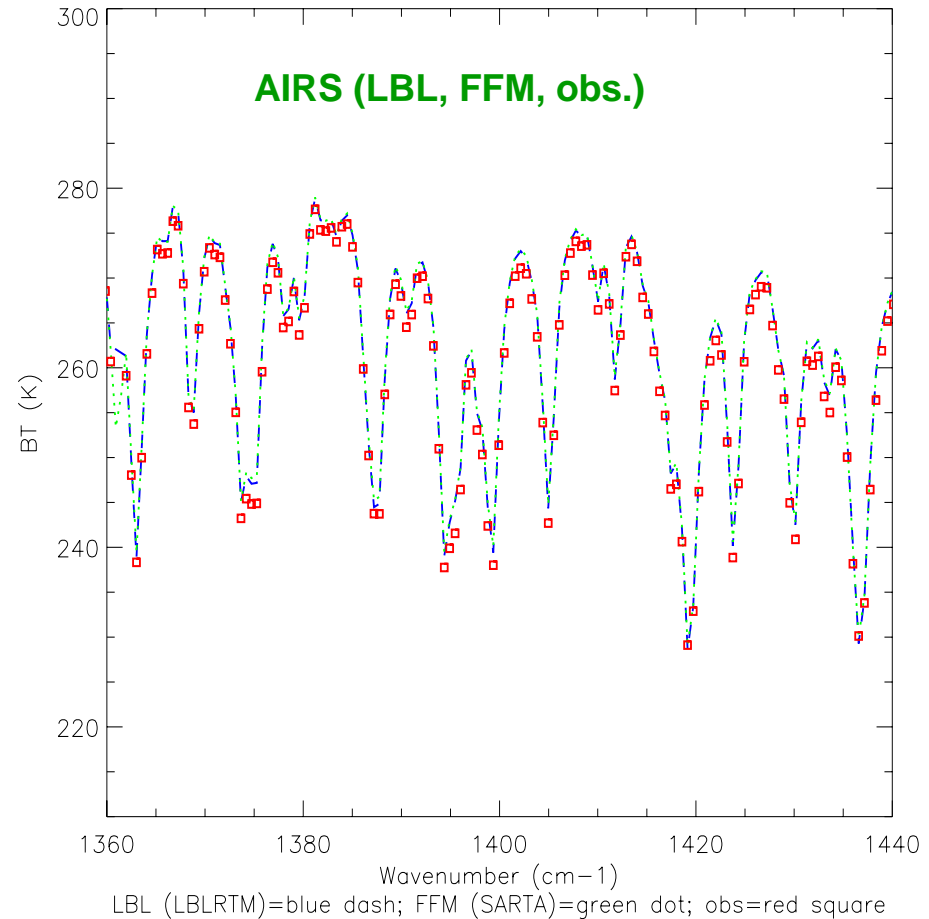
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H₂O
band

NAST-I (apodized)



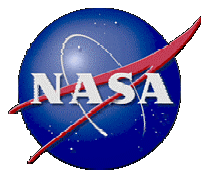
AIRS



7.4 – 6.9 μ



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

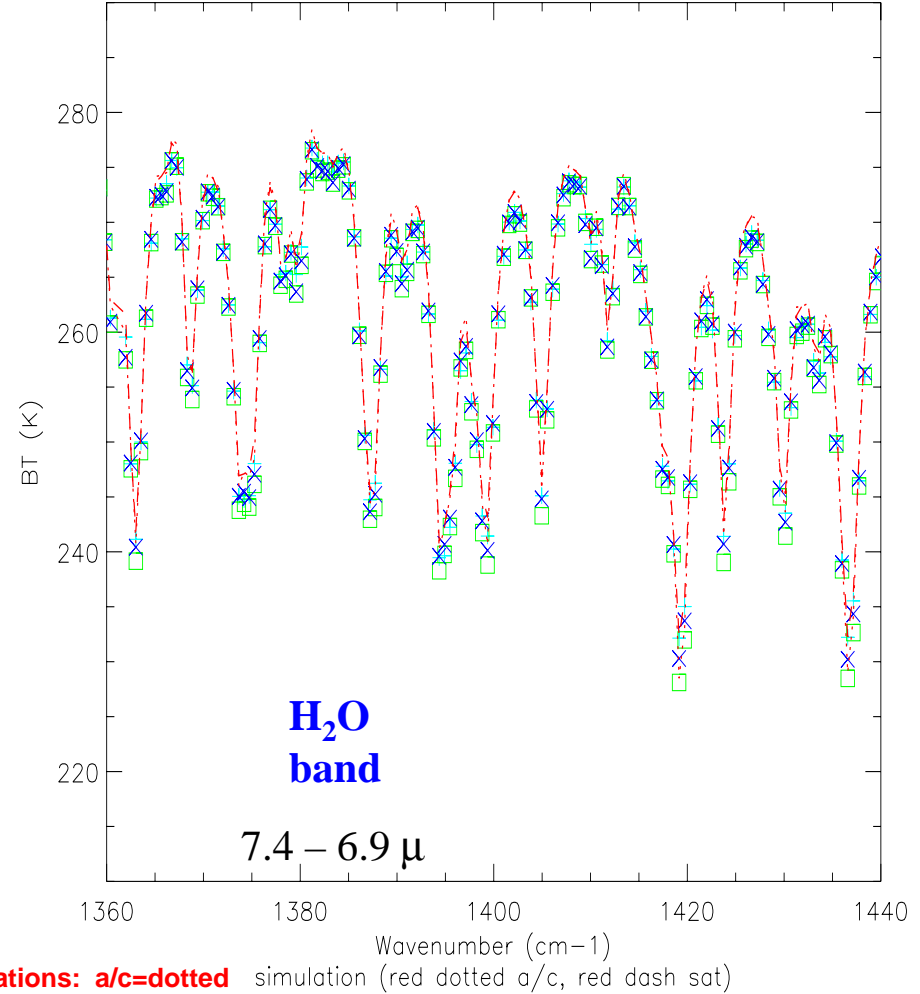
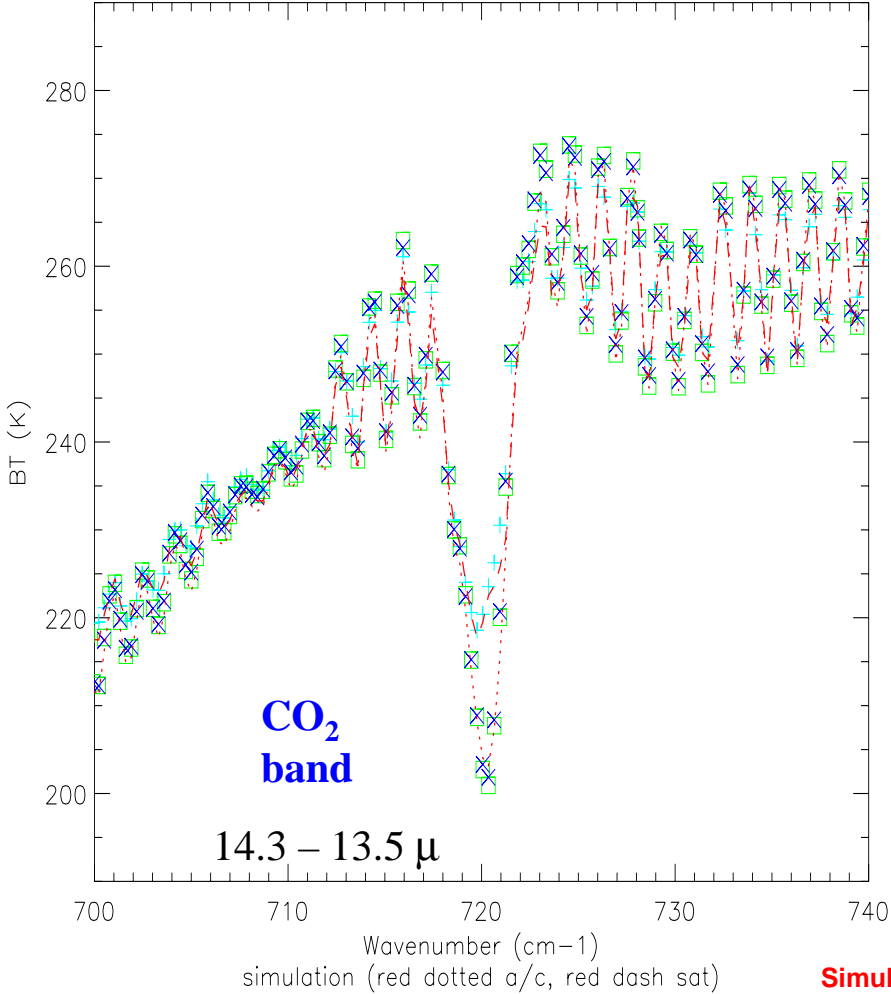


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airs2shis (aqua plus), shis2airs (green square), nast2shis2airs (blue x), shis2airs (green square), nast2shis2airs (blue x)



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

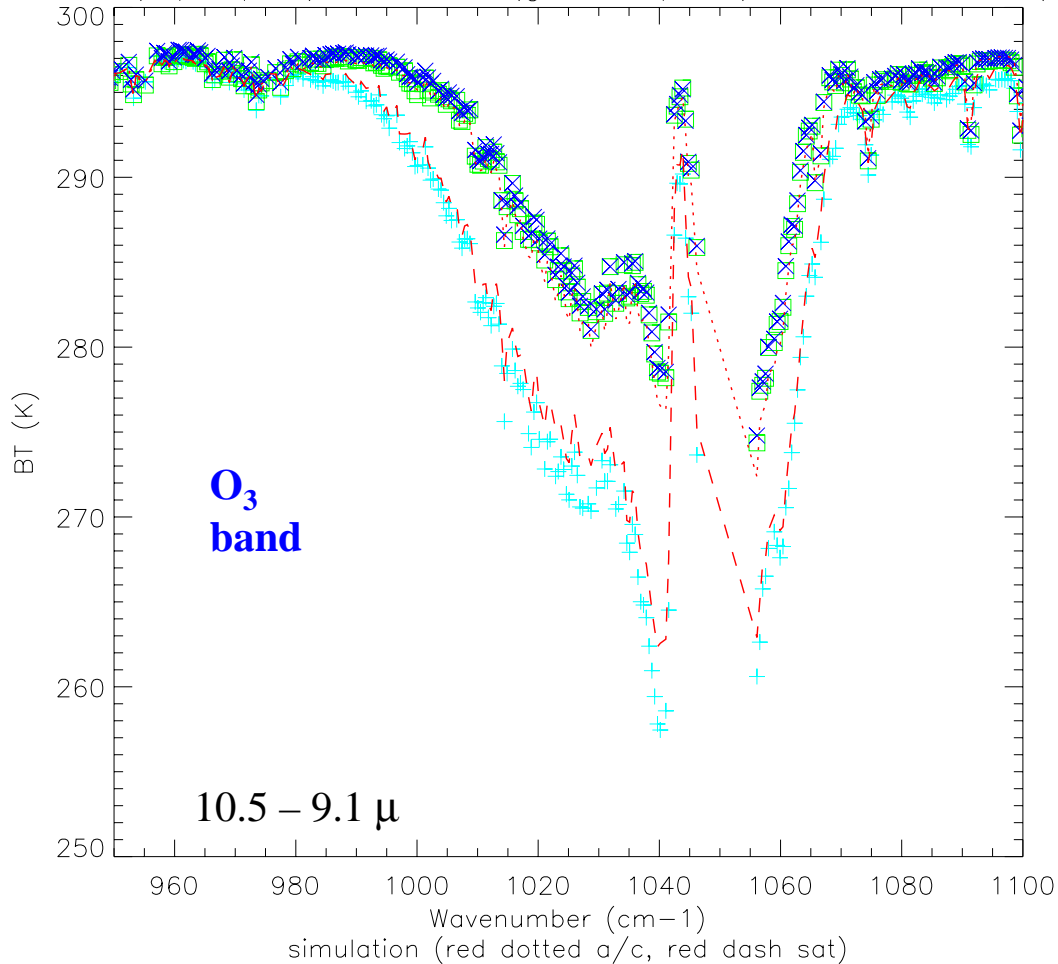


Spectra Comparison with Common SRFs [NAST-I*SHIS*AIRS; SHIS*AIRS; AIRS*SHIS]



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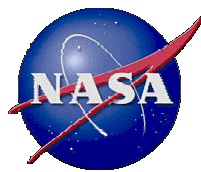
airs2shis (aqua plus), shis2airs (green square), nast2shis2airs (blue X)



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

International TOVS Study Conference, 13th, TOVS-13, Sainte Adele, Quebec, Canada, 29
October-4 November 2003. Madison, WI, University of Wisconsin-Madison, Space Science and
Engineering Center, Cooperative Institute for Meteorological Satellite Studies, 2003.