multi-sensor data-fusion approach

IASI Radiance Validation Analysis for JAIVEx

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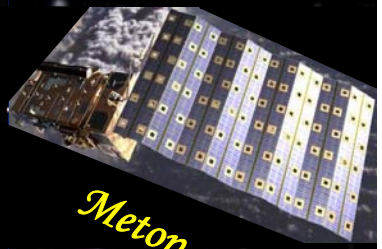
1st IASI Workshop, Anglet, France
November 14, 2007

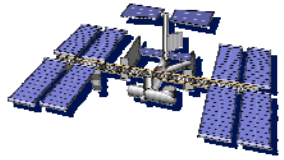


Topics

- **Motivation**
- **NAST-I background**
- **Validation methodology**
- **Radiance validation examples using JAIVEx data**
  - **Radiometric accuracy**
  - **Spatial registration**
  - **Spectral fidelity**
- **Summary & conclusions**

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

- ***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



- ***Aircraft underflights fundamental to validation task***
  - High-altitude aircraft instrumented with validation sensors (e.g., high-res FTS) provide critical validation data spatially & temporally coincident with satellite platforms of interest
    - Observations + retrievals enable independent assessment of sensor performance, L1/L2 algorithms, and data products
    - Higher spatial resolution enables sub-pixel assessments

Langley Research Center

The NAST-I & SHIS Systems

NAST has flown ~ 162 mission sorties accumulating over 900 hours of flight data in 18 field experiments

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

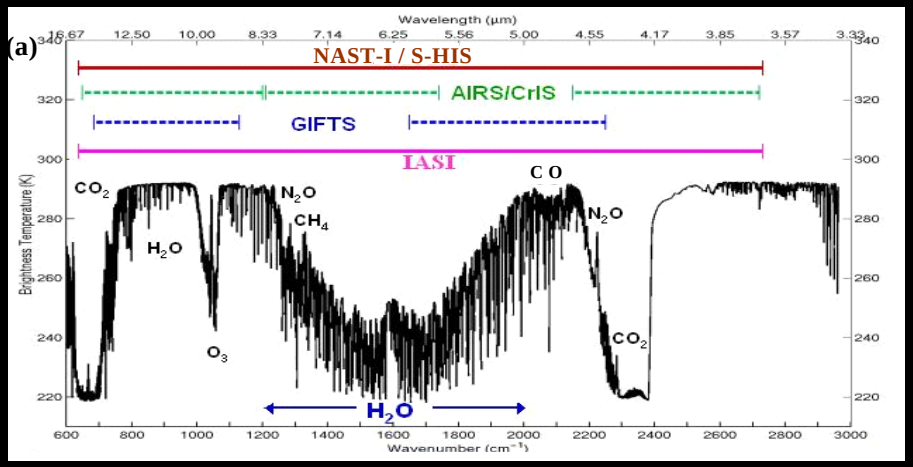
IR Interferometers

(NAST-I)

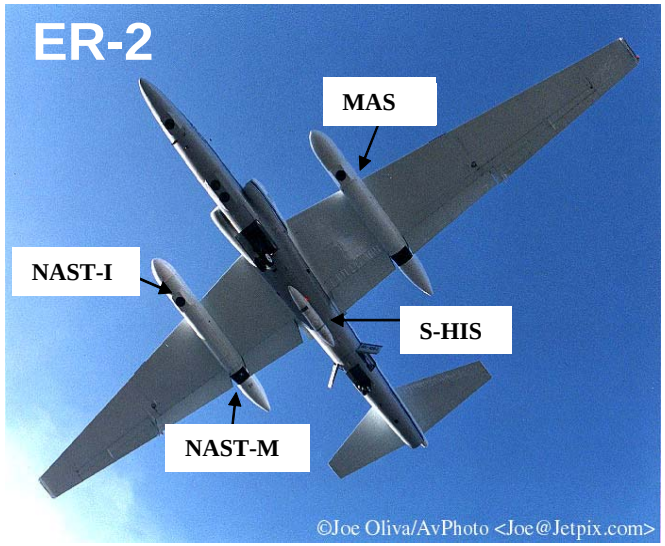
Spectral Range: 3.5 - 16 microns
Spectral Res.: 0.25 cm-1 ($\nu/\nu\delta$ > 2000)
Spatial res.: 130m/km flight alt.
A/C platforms: ER-2, Proteus, WB-57

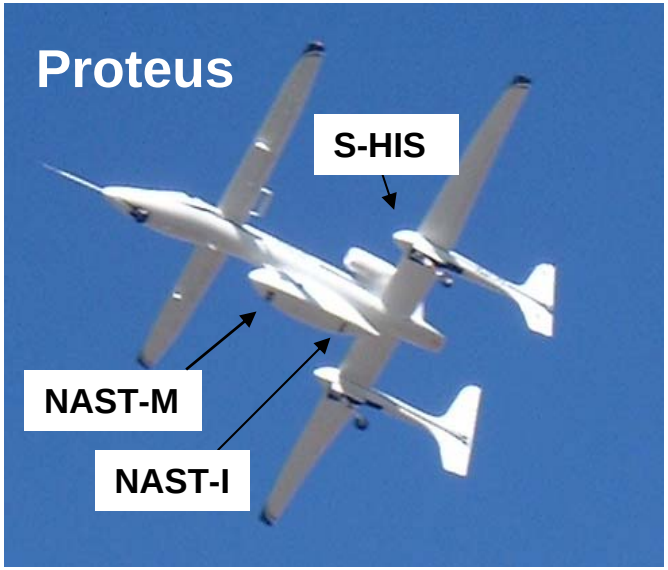
(S-HIS)

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



NAST Flight History

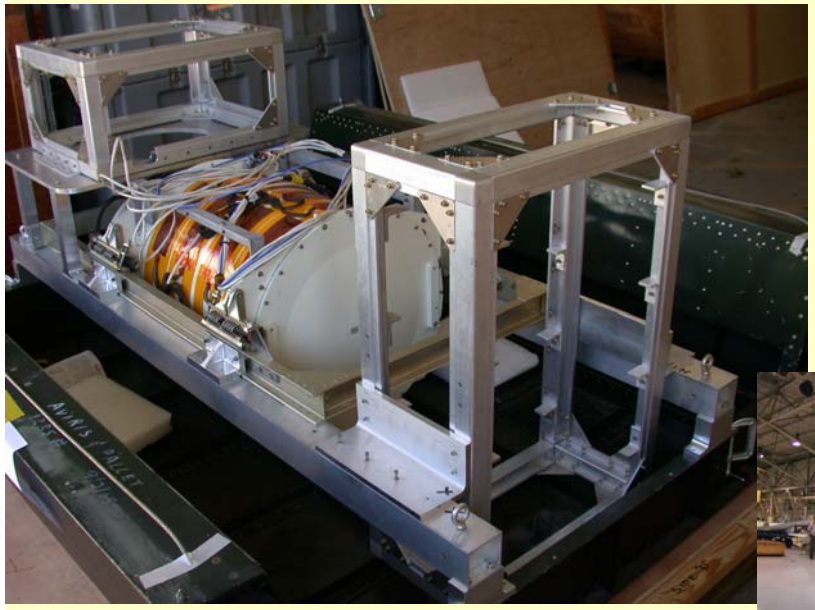




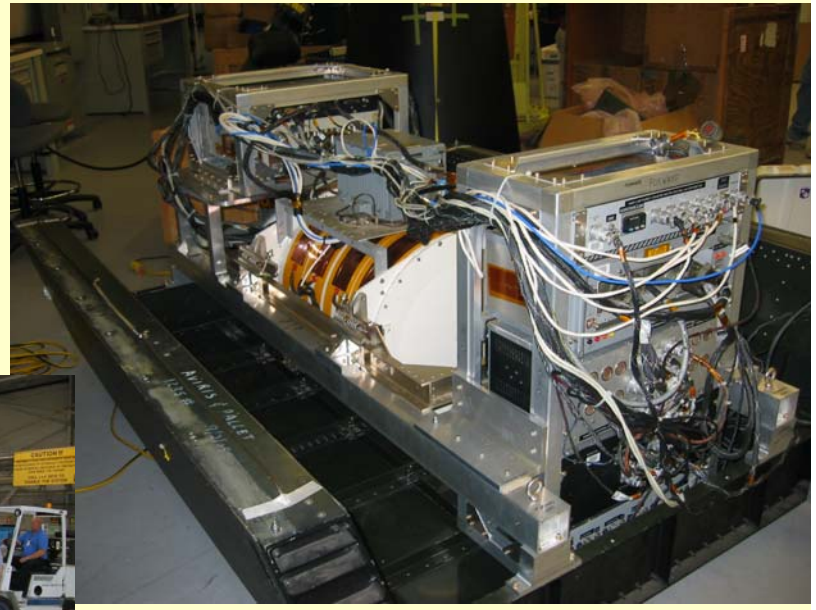
- 1998-2007: 18 Missions
- 162 Mission sorties

Mission	Location	Platform	Year
Wallops 98	Virginia	ER-2	1998
Camex-3	Florida	ER-2	1998
WINTEX	Wisconsin	ER-2	1999
Wallops 99	Virginia	ER-2	1999
C-IOP	Oklahoma	Proteus	2000
WV-IOP	Oklahoma	Proteus	2000
AFWEX	Oklahoma	Proteus	2000
A-P	CA/HI/Japan/AK	Proteus	2001
CLAMS	Virginia	Proteus	2001
IHOP	Oklahoma	Proteus	2002
CRYSTAL-FACE	Florida	Proteus	2002
TX2002	Texas	ER-2	2002
THORPEX	Hawaii	ER-2	2003
ATOST	Maine	ER-2	2003
INTEX	Virginia	Proteus	2004
EAQUATE-IT	Italy	Proteus	2004
EAQUATE-UK	United Kingdom	Proteus	2004
JAIVEx	Houston	WB-57	2007

NAST-I WB-57 Integration & Test

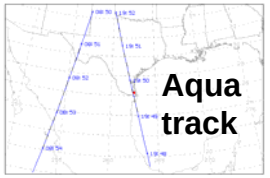


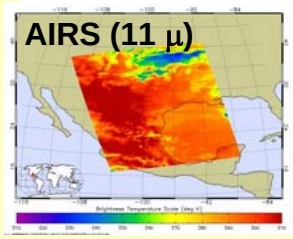
Ellington Field (EFD) Nov 2006



NAST-I checkout flights on NASA WB-57

- **Flight #1: 29 Nov 2006 (926)**
- **Engineering qualification achieved**
- **Flight #2: 15 Mar 2007 (928)**
- **Scientifically sound NAST-I on WB-57 demonstrated!**





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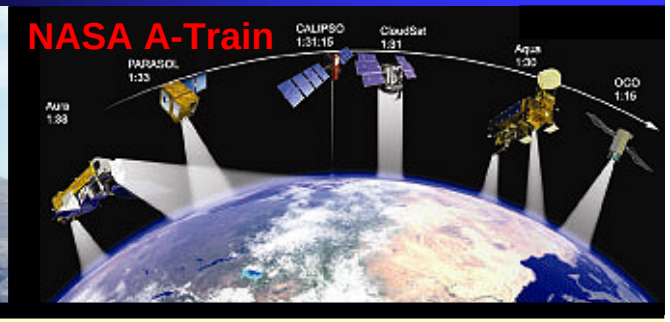
Joint Airborne IASI Validation Experiment (JAIVEx)



US-European collaboration focusing on validation of radiance and geophysical products from MetOp (IASI/AMSU) and Aqua (AIRS/AMSU) to provide data and experience for NPP & NPOESS (CrIS/ATMS) Cal/Val and program risk mitigation

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, SWS; dropsondes; in-situ cloud phys. & trace species)**

Satellites

- **Metop (IASI, AMSU, MHS, AVHRR, HIRS, ASCAT)**
- **A-train (Aqua AIRS, AMSU, HSB, MODIS; Aura TES; CloudSat; and Calipso)**

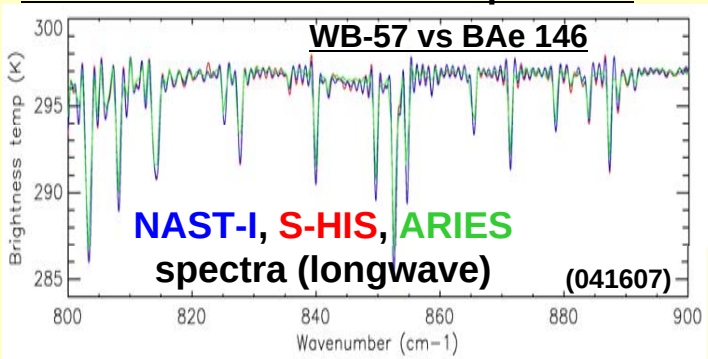
Ground-sites

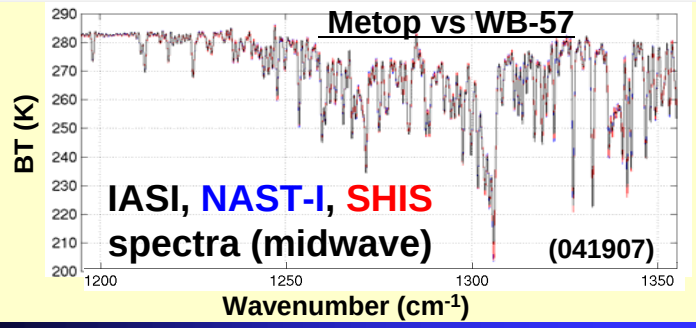
- **DOE ARM CART site (RAOBS, Raman Lidar, AERI, etc.) & GOM (scene uniformity—radiometric, spatial, & spectral)**

Participants

- **LaRC, UKMO, UW, MIT, MIT-LL, NASA, IPO, EUMETSAT, ECMWF, + …**

In-field radiance inter-comparison:





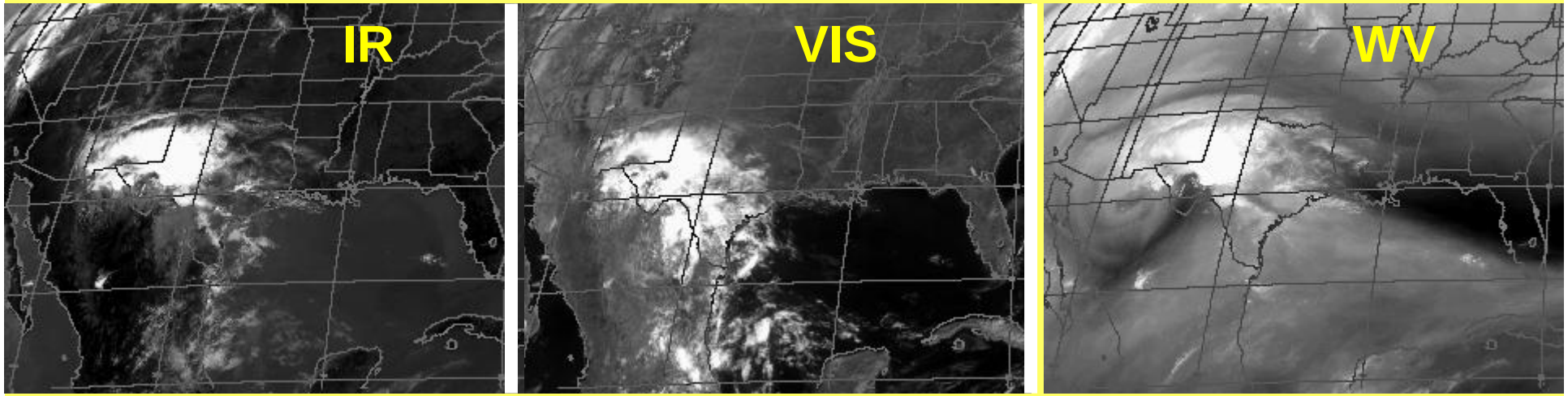
Calibration validation approach *

- **Spatial**
  - **Landmark navigation**
    - compare observations to databases for known, time invariant distinct features (e.g., coastlines)
  - **Comparison with coincident observations**
    - spatial feature variability (coastlines, thermal gradients, clouds, hot lava, fires, etc.)
- **Spectral**
  - **Comparison with simulations**
    - obs vs LBL RTA calculations; vary simulated instrument spectral response to minimize residuals (e.g., effective metrology laser wavenumber for FTS or channel SRFs for grating)
  - **Comparison with coincident observations**
    - compare obs to same-scene view high-spectral resolution measurements (i.e., a/c- or s/c-based FTS)
- **Radiometric**
  - **Comparison with other coincident observations and simulations**
    - compare varying scene temp, uniform scenes with other (a/c & s/c) observations/calculations
      - High-spectral resolution & broadband measurements
      - RTA calculations (using, e.g., lidar, radiosondes, dropsondes, a/c in-situ, NWP)

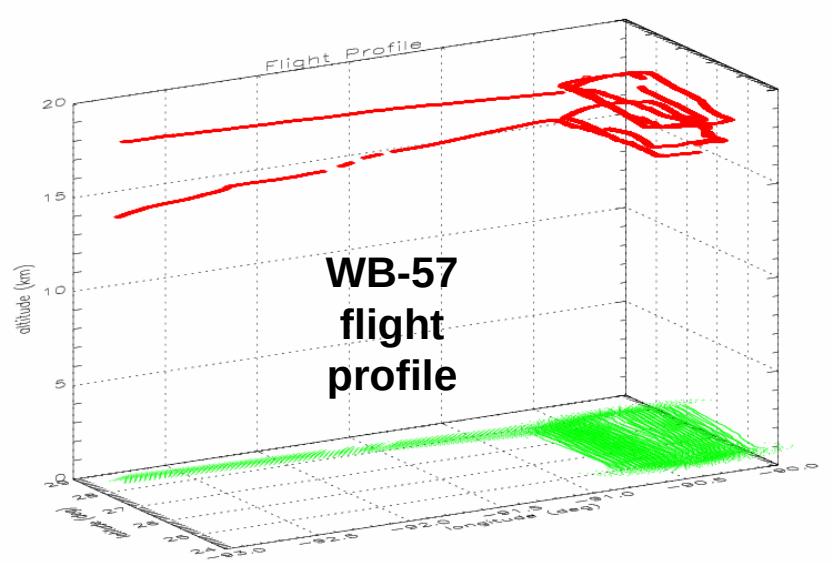
* ***Applied to each detector, i.e. FTS band, grating channel, etc.***

29 April 2007: JAIVEx

GOES images of extended scene (1602 GMT)



- **Flight mission objective**
  - Coordinated WB-57 and BAe-146 aircraft under-flight of Metop (1550 GMT) and Aqua (1919 GMT) satellites over northern Gulf of Mexico
- **Aircraft flight profiles**
  - WB-57 flew north-south-oriented oval racetrack pattern (@ ~ 17 km) in between satellite overpass events; BAe-146 characterized atmosphere and surface, from a range of altitudes below the WB-57
  - WB-57 arrived on-station 20 min prior to Metop, and remained until 10 seconds after Aqua (for a 3 hr & 50 min on-station duration). Conditions ranged from very clear on northern part of race track, to low, puffy cumulus sparsely populating southern extent of flight profile

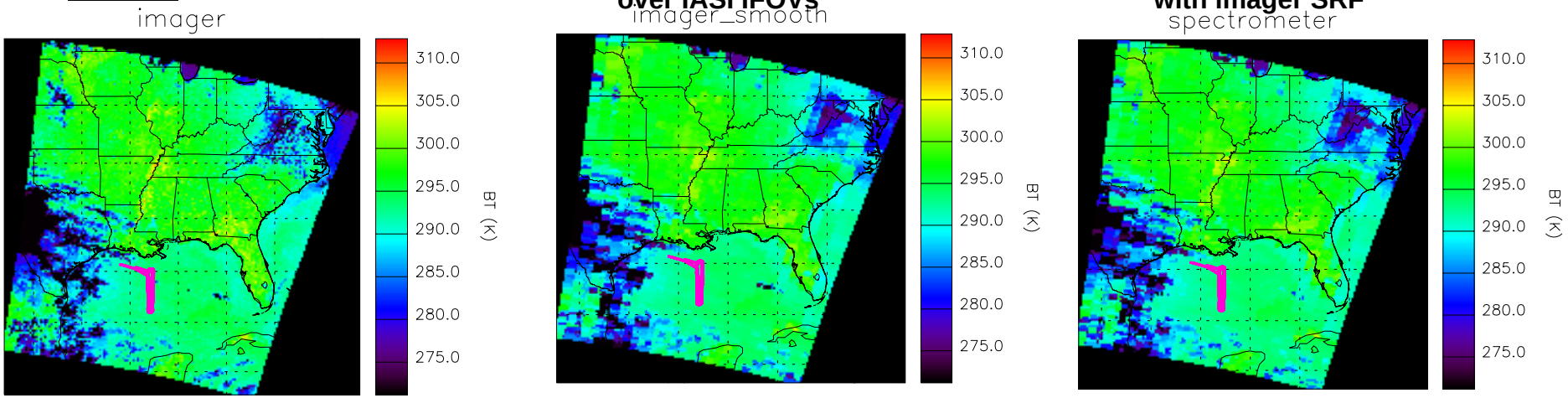


IASI vs IASI imager

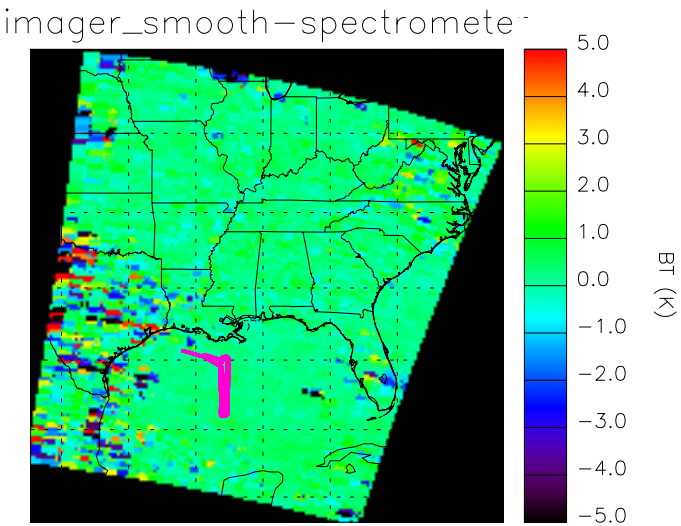
29 April 2007 (JAIVEx)

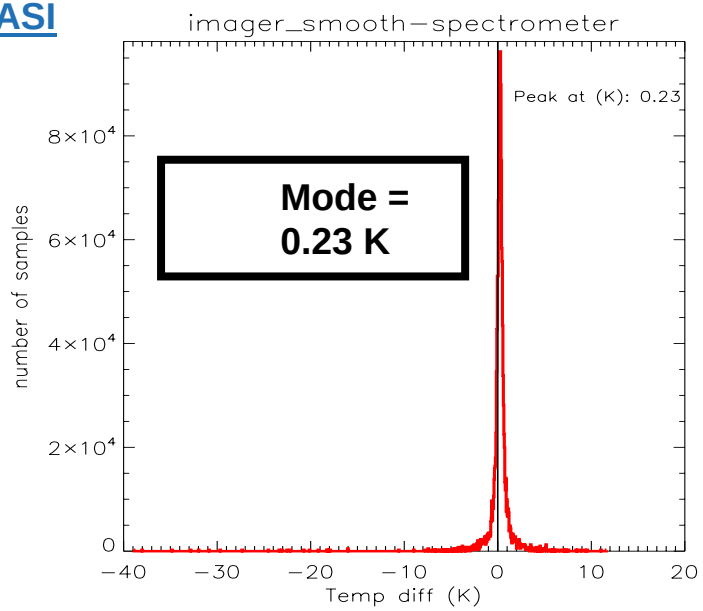
imager integrated spatially over IASI IFOVs

IASI spectrally-convolved with imager SRF



Imager - IASI



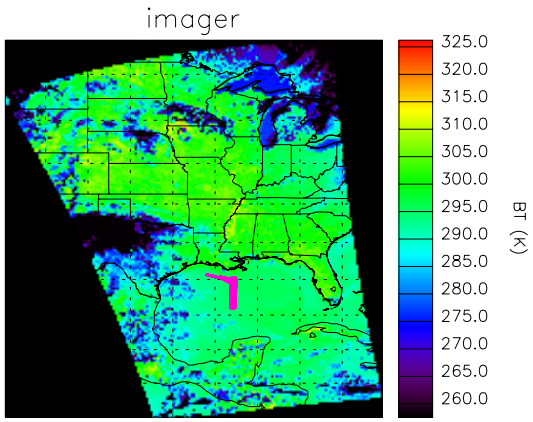


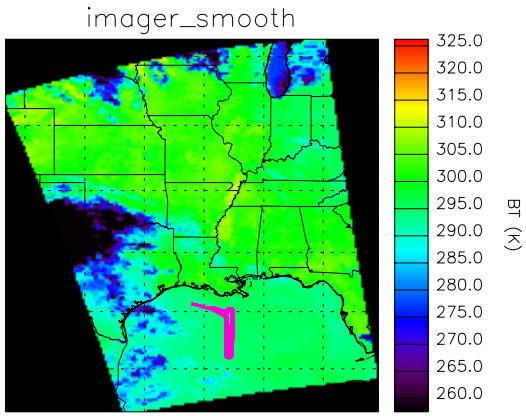
AIRS vs MODIS B31

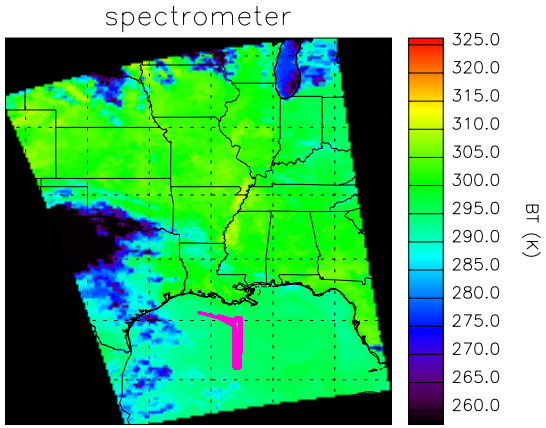
29 April 2007 (JAIVEx)

MB31 integrated spatially over AIRS IFOVs

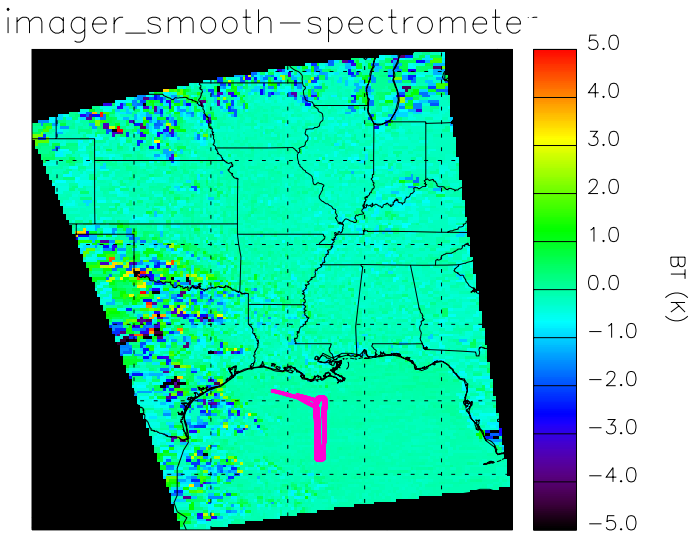
AIRS spectrally-convolved with MB31 SRF

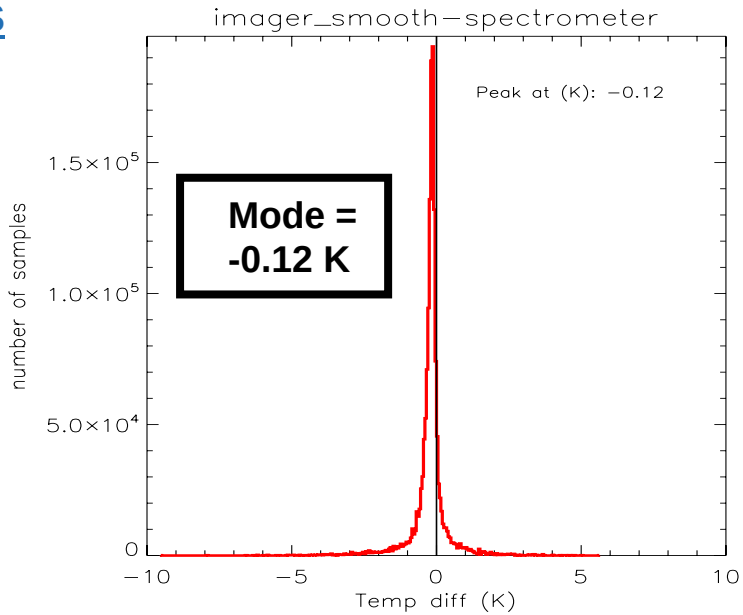






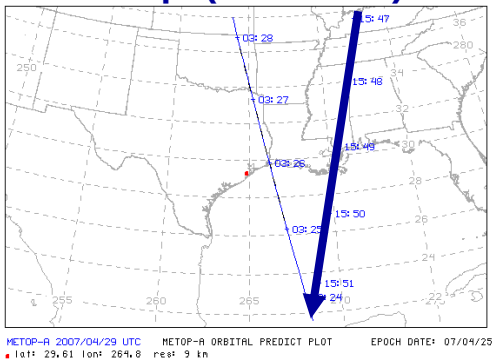
MB31 - AIRS



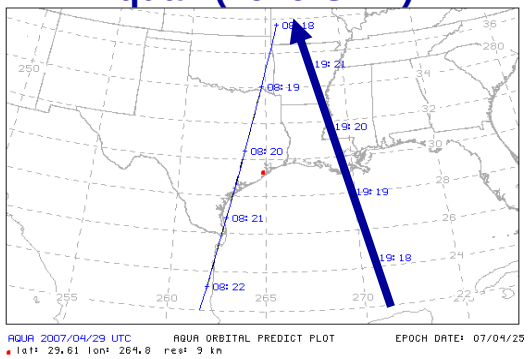


IASI vs AIRS: 29 April 2007

Metop (1550 GMT)



Aqua (1919 GMT)



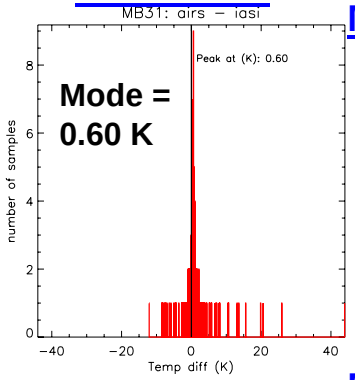
Broadband comparisons done to minimize comparison scene evolution between satellite overpass events

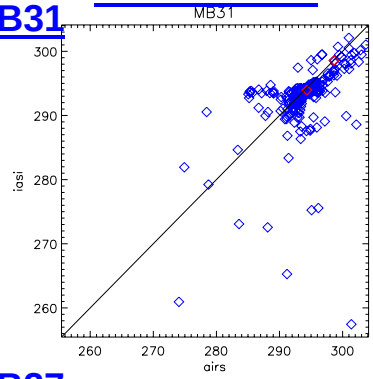
IFOV selection criteria

- 374 IFOVs overlap spatially in JAIVEx "study region"
- 2 IFOVs satisfy minimum scene variance criteria:
  - ΔMB31 <= .7 K
  - ΔMB27 <= .75 K
  - ΔMB28 <= .7 K

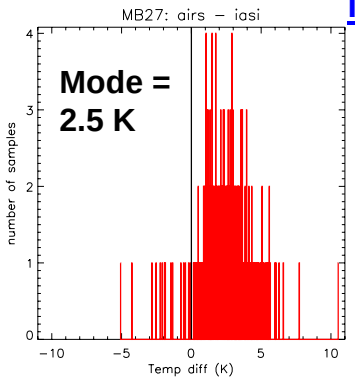
AIRS - IASI | **IASI vs AIRS**

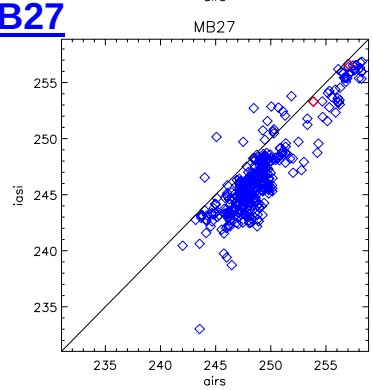
MB31



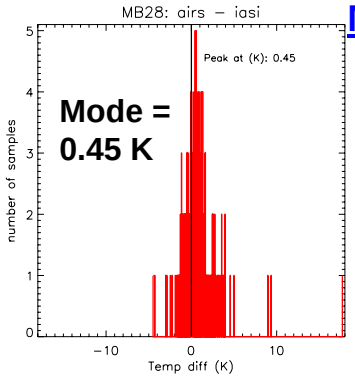


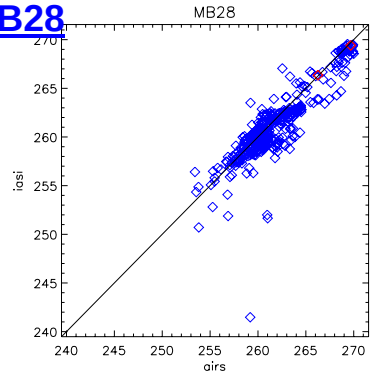
MB27





MB28





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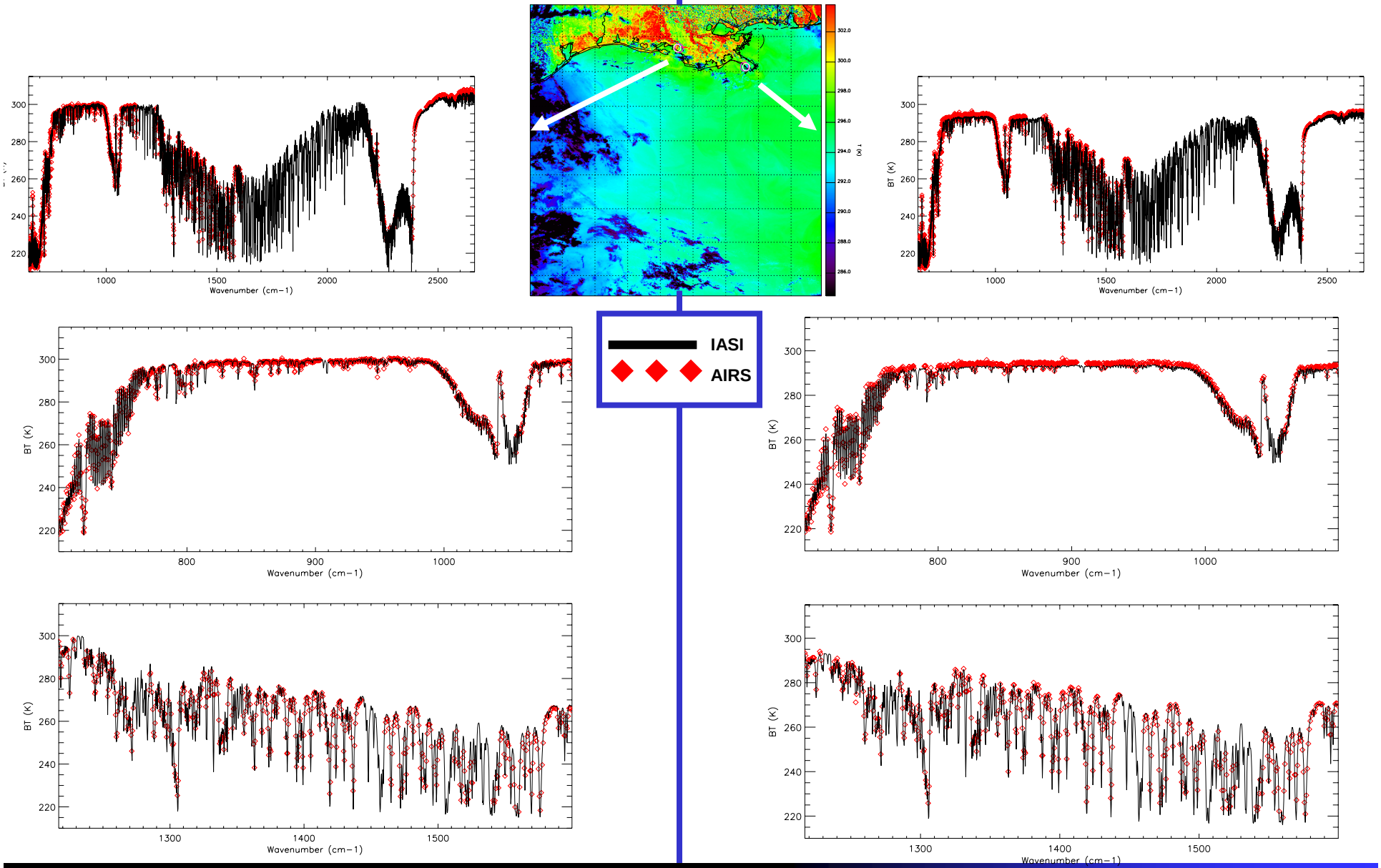
IASI vs AIRS: direct as-measured spectra comparison (29 April 2007)



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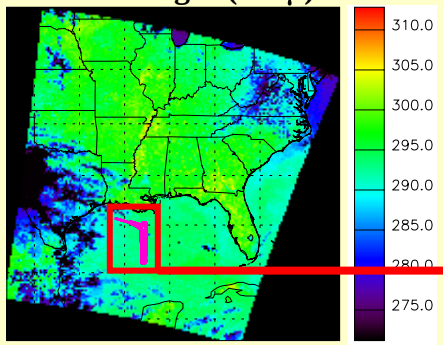
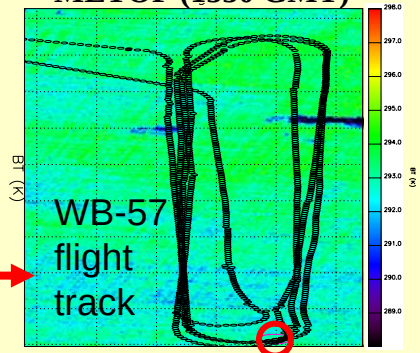
NAST-I vs IASI & AIRS (JAIVEx, 29 April 2007)

JAIVEx aircraft underfly both Metop (1550 GMT) & Aqua (1919 GMT) within single flight mission (042907) enabling a/c sensors to obtain space/time coincident observations with both satellites

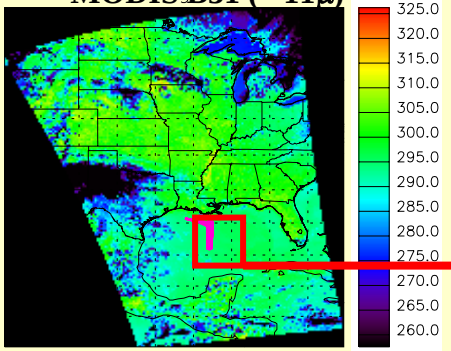
IASI imager (~11μ)



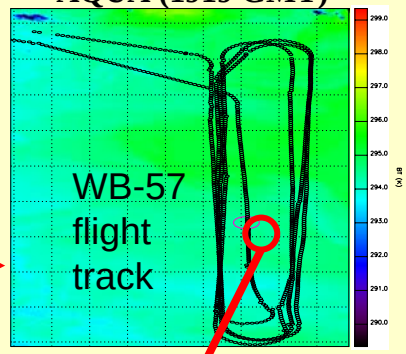
METOP (1550 GMT)



MODIS B31 (~ 11μ)

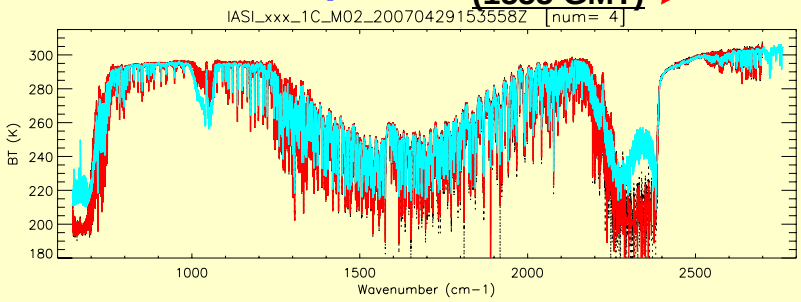


AQUA (1919 GMT)



NAST-I vs IASI spectra

NAST-I (1555 GMT)



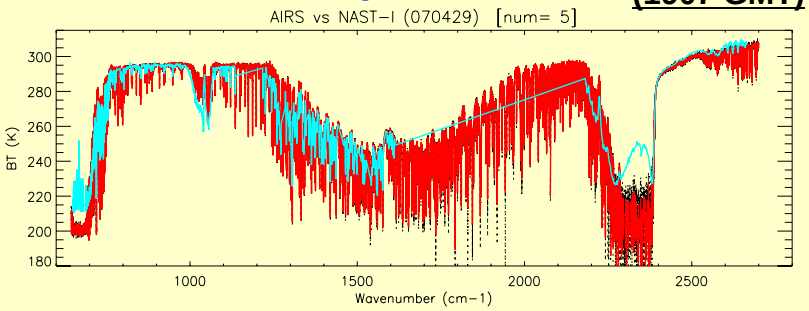
IASI or AIRS

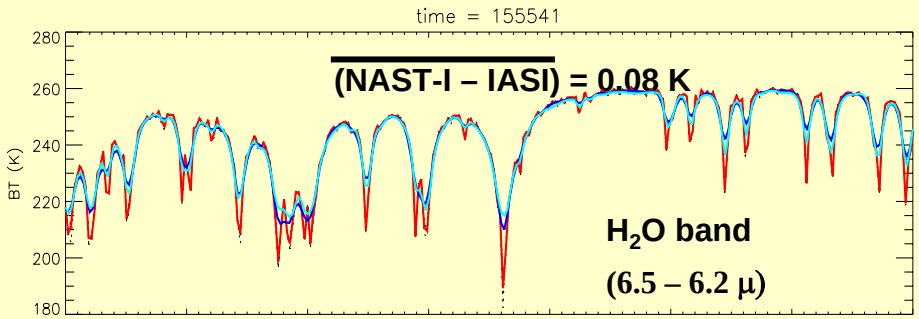
NAST-I

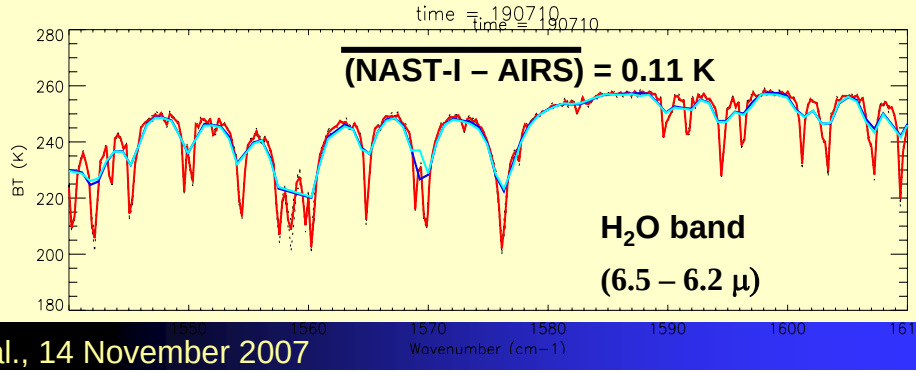
NAST-I * SRF (IASI or AIRS)

NAST-I vs AIRS spectra

NAST-I (1907 GMT)

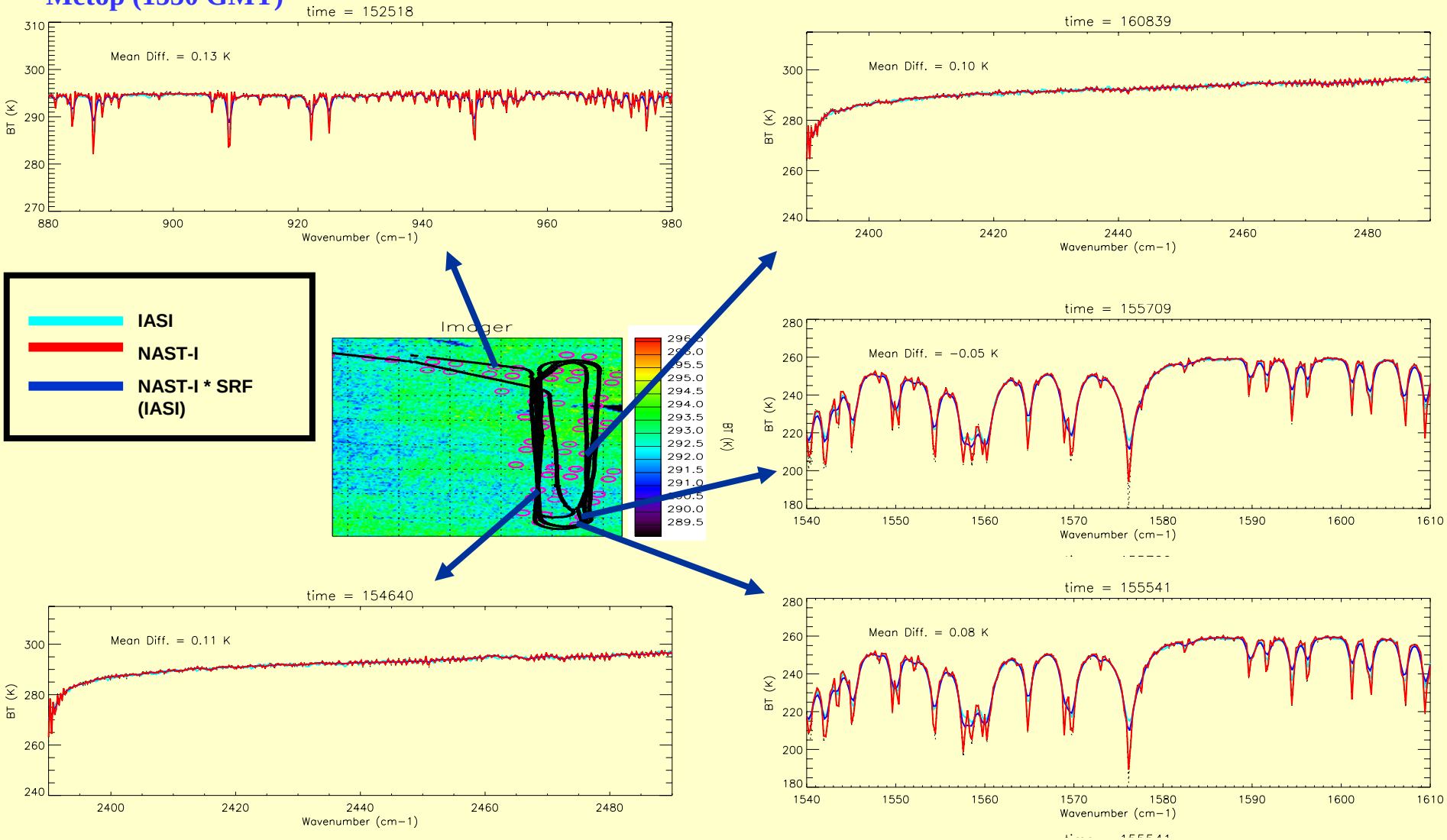






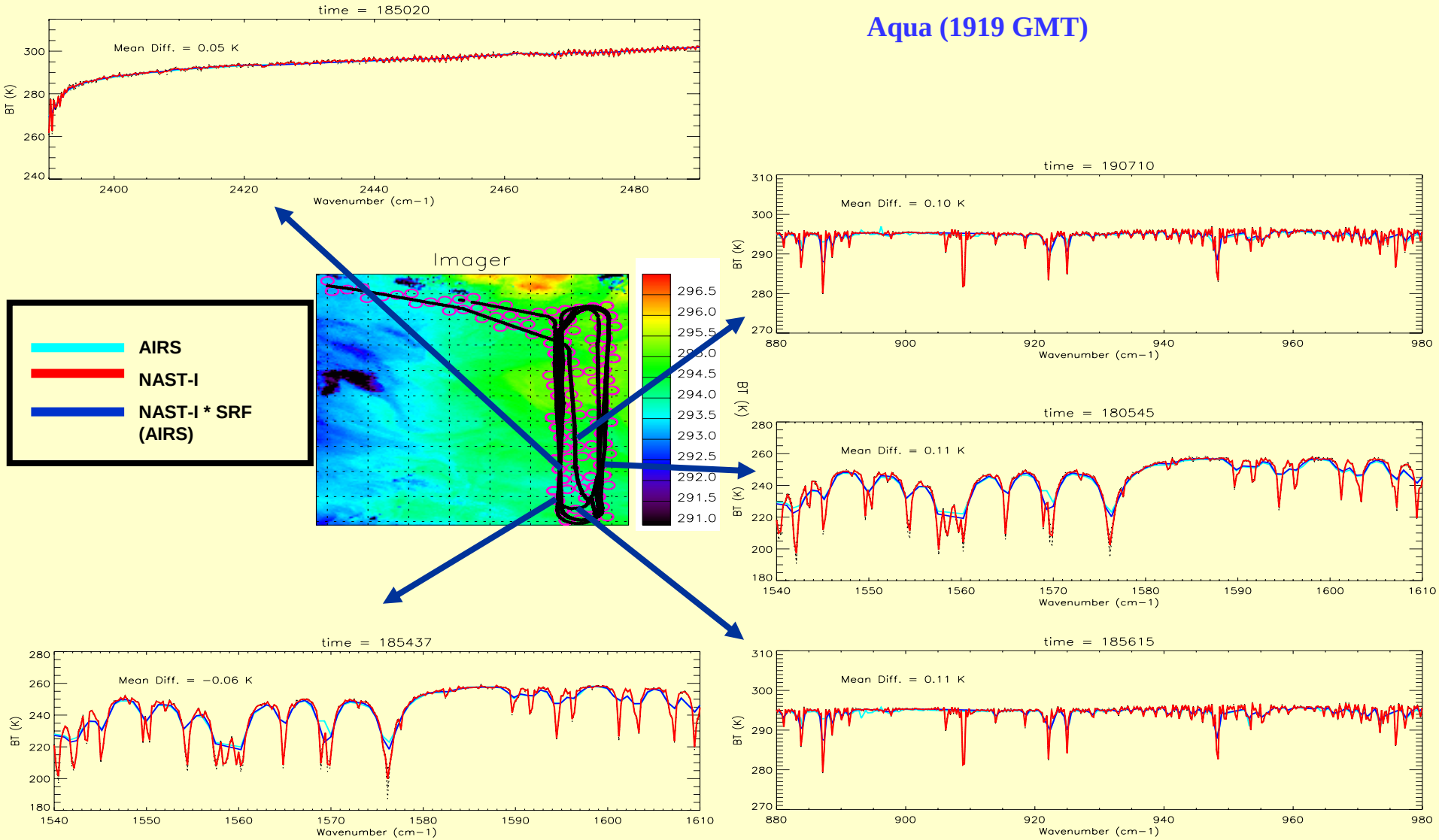
NAST-I vs IASI spectra

Metop (1550 GMT)



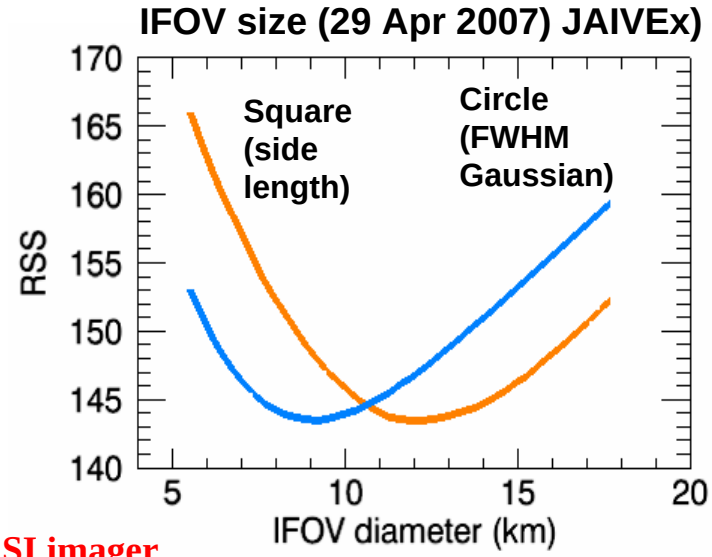
NAST-I vs AIRS spectra

Aqua (1919 GMT)

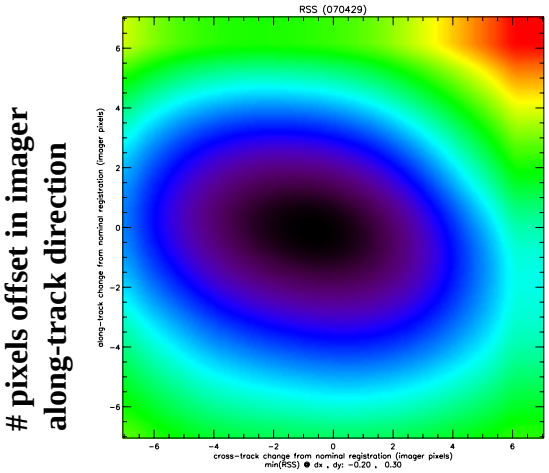


Spatial calibration validation example

- Comparison of IASI and IASI imager relative spatial registration
  - IASI spectrally-convolved with IASI imager SRF
  - IASI imager integrated spatially over IASI IFOVs
  - RSS differences calculated for varying relative offsets in spatial co-registration
  - Coincident portions of scenes with high spatial variability examined for select JAIVEx flight days



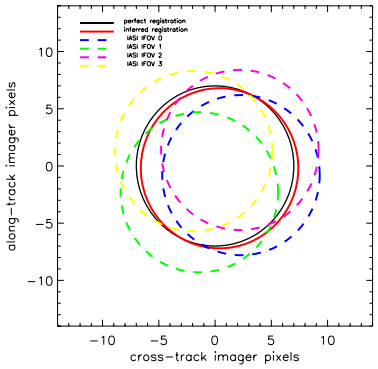
IASI offsets from IASI imager

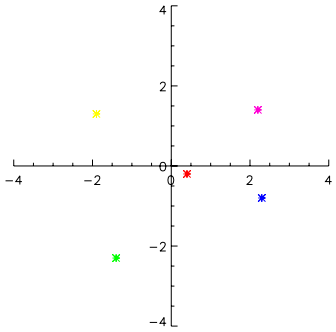


 # pixels offset in imager cross-track direction

Spatial co-registration example

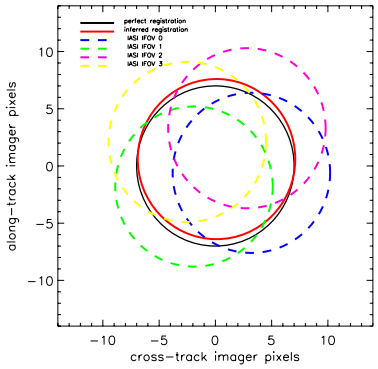
4 May 2007

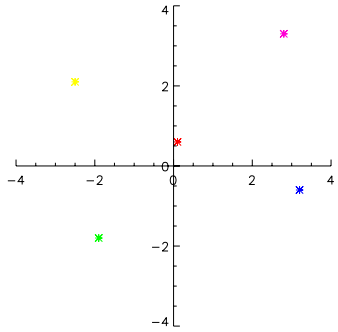




radial distance = 0.4 imager pixels

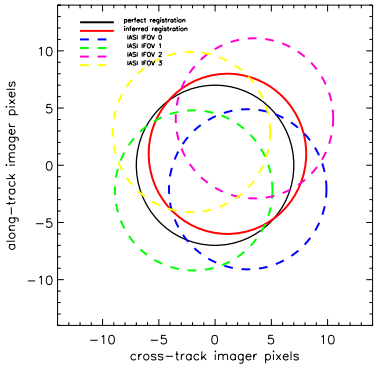
27 April 2007

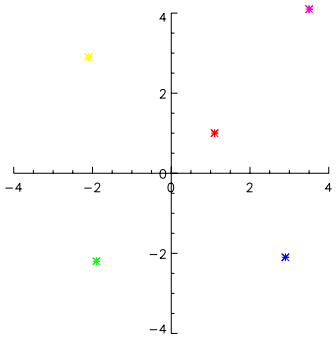




radial distance = 0.6 imager pixels

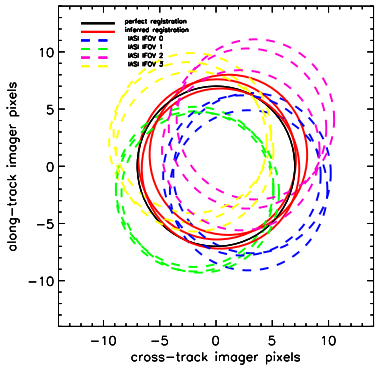
29 April 2007

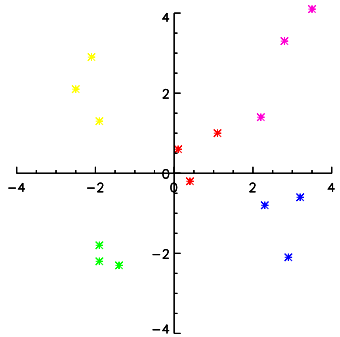




radial distance = 1.5 imager pixels

27, 29 Apr & 4 May 2007

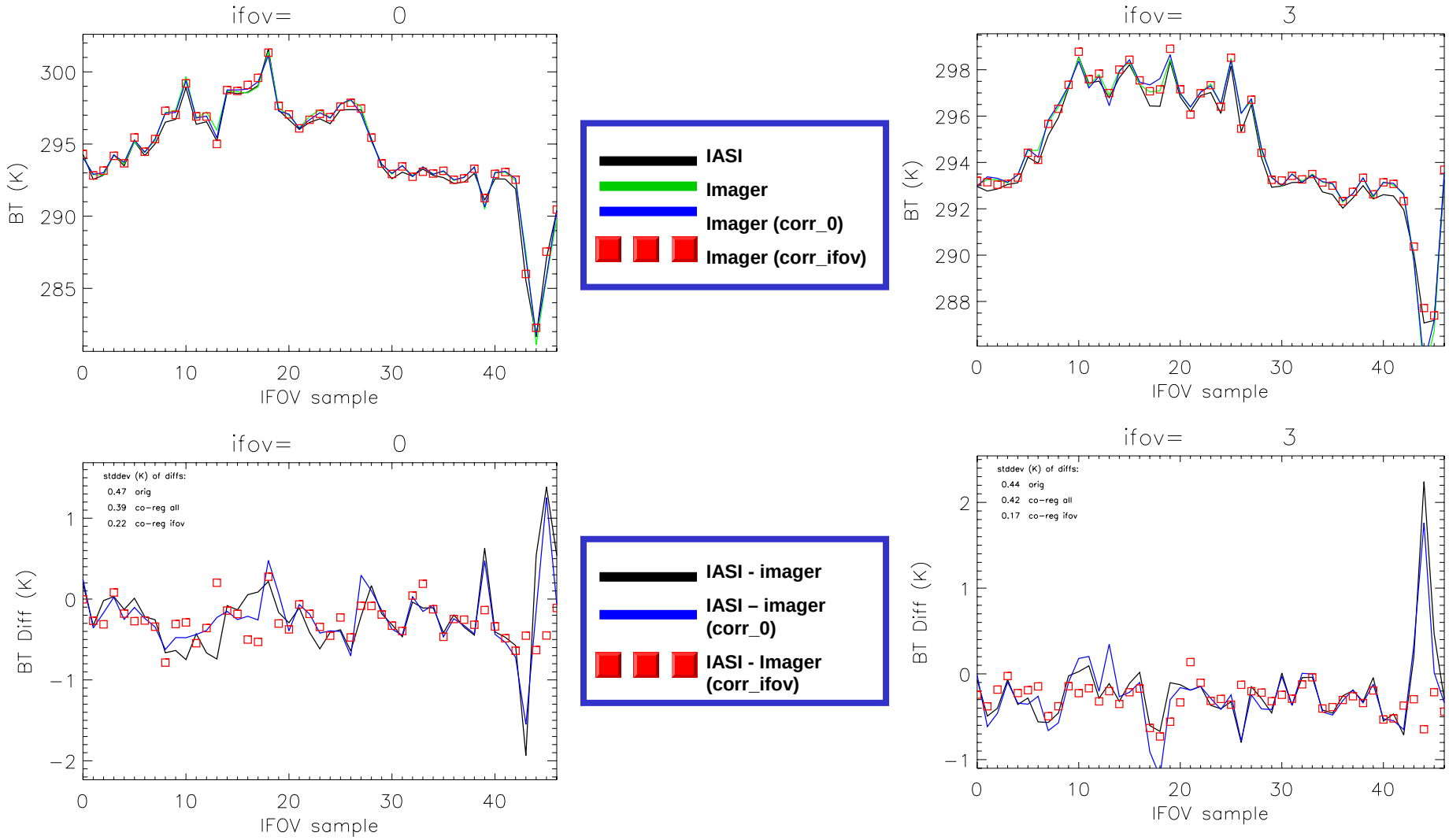




radial distance = 0.8 imager pixels

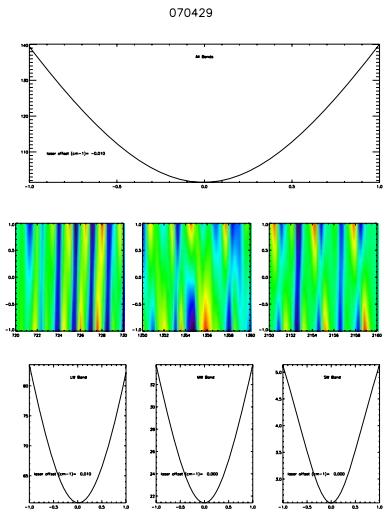
Spatial co-registration example

IFOV x-sections: IASI vs IASI imager—JAIVEx 29 Apr 2007



Spectral Calibration Validation Example

- **IASI laser cm^{-1} stability**
  - **Spectral calibration fidelity assessed by varying laser wavenumber in simulations to best match measured (calibrated) radiance spectra (i.e. minimizing RSS of obs-calc residual)**



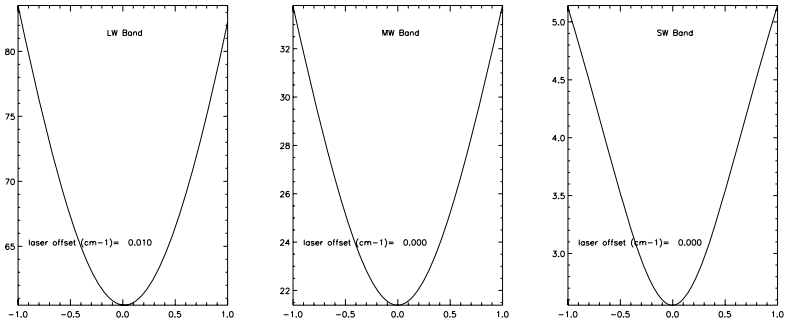
- **Select days examined from JAIVEx**
  - **27, 29 April & 4 May 2007**
- **Simulation assumptions**
  - **υ_0=6503.2 cm^{-1} (1.5377 micron) used as baseline for sims**

LW = 705. < ν < 755. cm^{-1}
MW = 1340. < ν < 1440. cm^{-1}
SW = 2150. < ν < 2260 cm^{-1}
All = 705. < ν < 2260 cm^{-1}

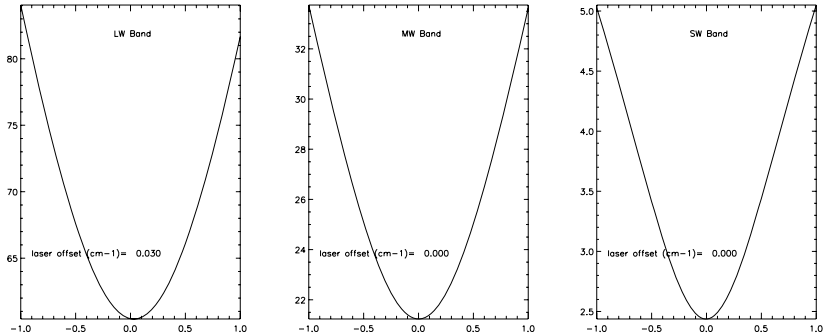
IASI Spectral Bands

Band	Range (cm^{-1})	Range (μm)
1	645 to 1210	15.5 to 8.26
2	1210 to 2000	8.26 to 5
3	2000 to 2760	5 to 3.62

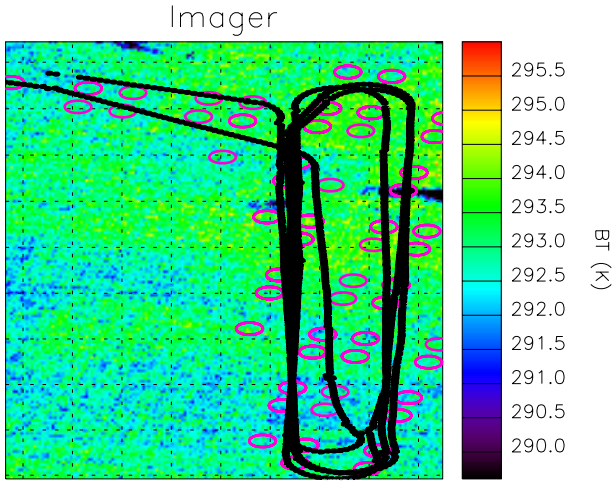
Spectral calibration example (04/29/07)



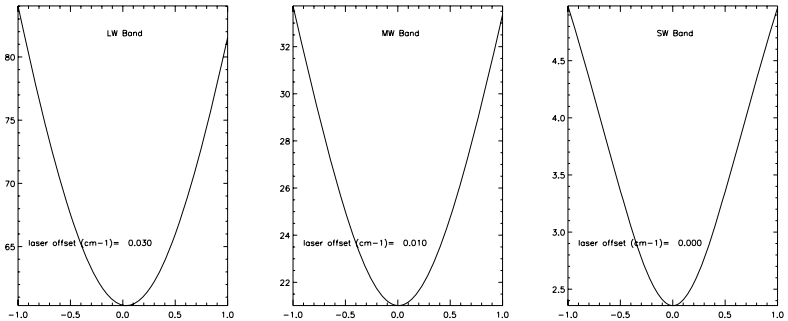
IFOV 1



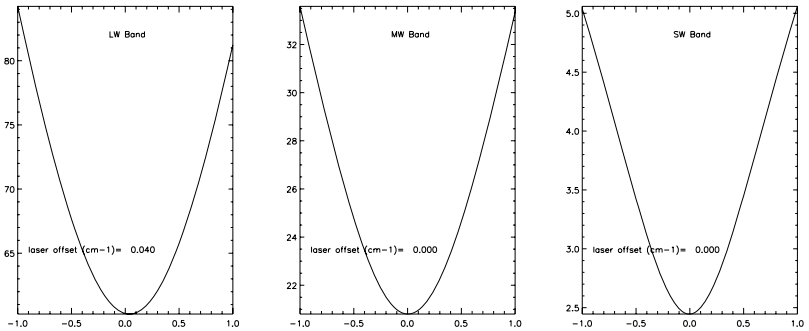
IFOV 2



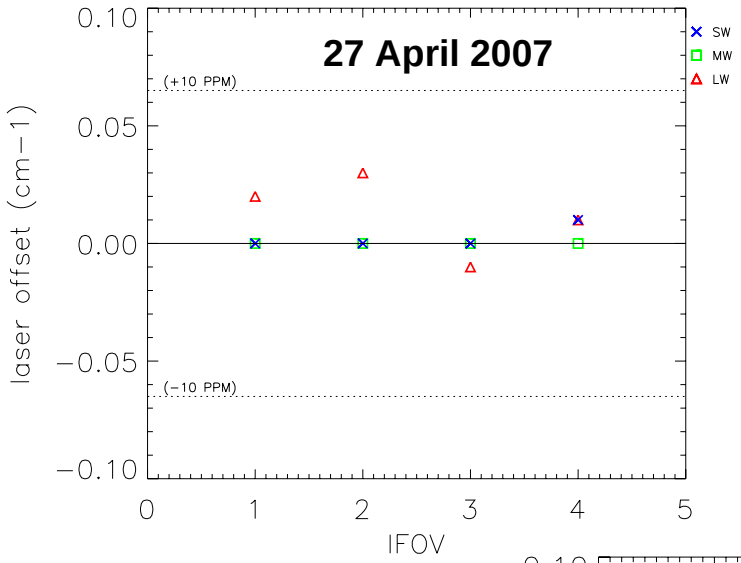
IFOV 3

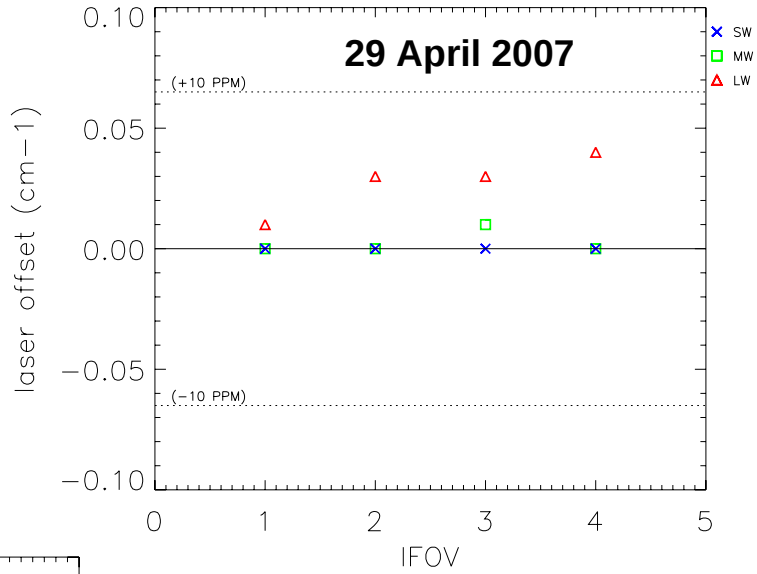


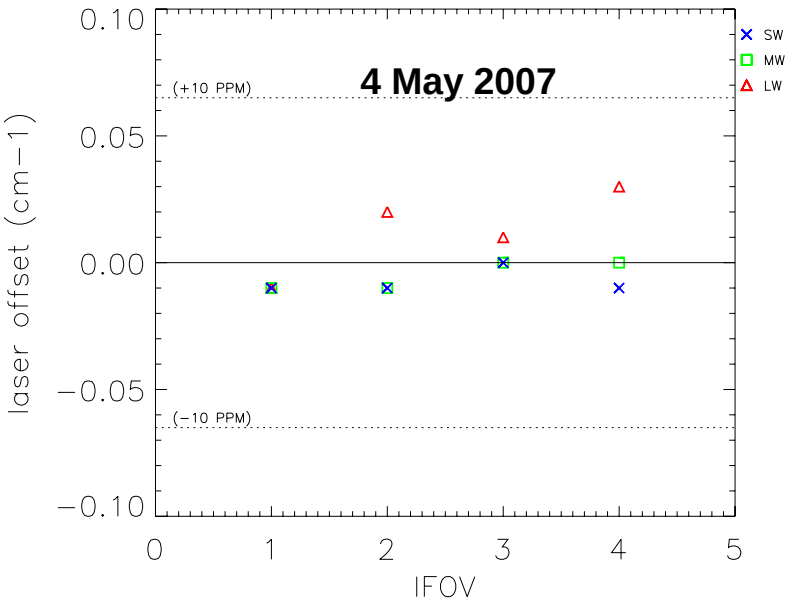
IFOV 4



Spectral calibration example







Summary & Conclusions

- **Post-launch validation activities are critical to verify quality of satellite measurement system (i.e., sensor, algorithms, and direct/derived data products)**
- **High-altitude, airborne FTS systems enable NIST-traceable high-spectral-resolution comparisons with space/time coincident spaceborne measurements**
  - **coincident a/c FTS observations provide best match to IASI & AIRS measurements**
  - **airborne assets can enable cal/val <u>anywhere</u>, unlike fixed-location ground sites**
- **The need for exact spatial/temporal coincidence increases with the degree of scene non-uniformity/variability**
- **JAIVEx was a great success!**
  - 10 coordinated flight missions implemented under MetOp and Aqua overpasses
  - Campaign data are proving to be very useful for IASI and AIRS product validation, and are serving to further refine methodologies for future advanced sounder validation activities (e.g., NPP & NPOESS CrIS)