Global Space-based Inter-Calibration System (GSICS)

Mitchell D. Goldberg

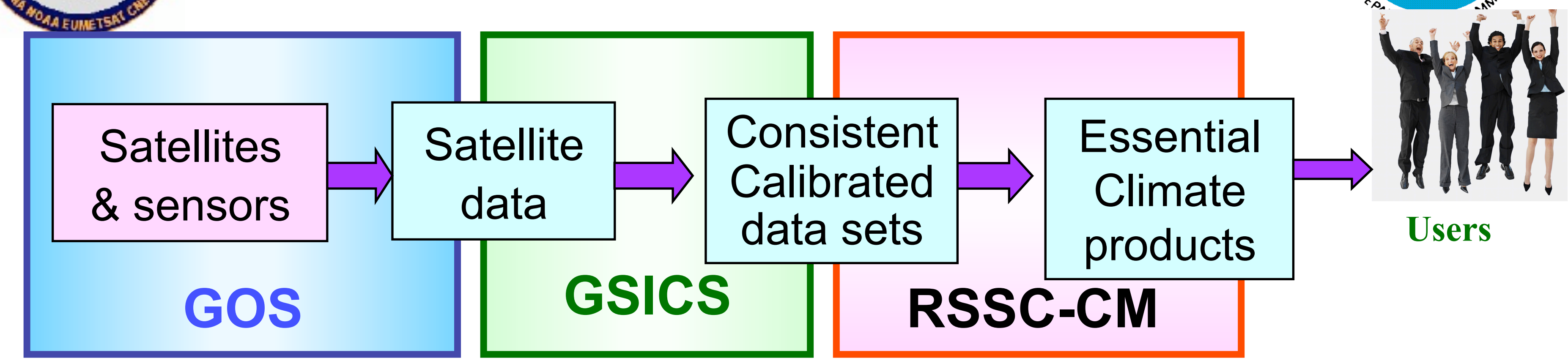
GSICS Exec Panel Chair
NOAA/NESDIS
Chief, Satellite Meteorology and Climatology Division

October 15, 2008

GSICS Objectives

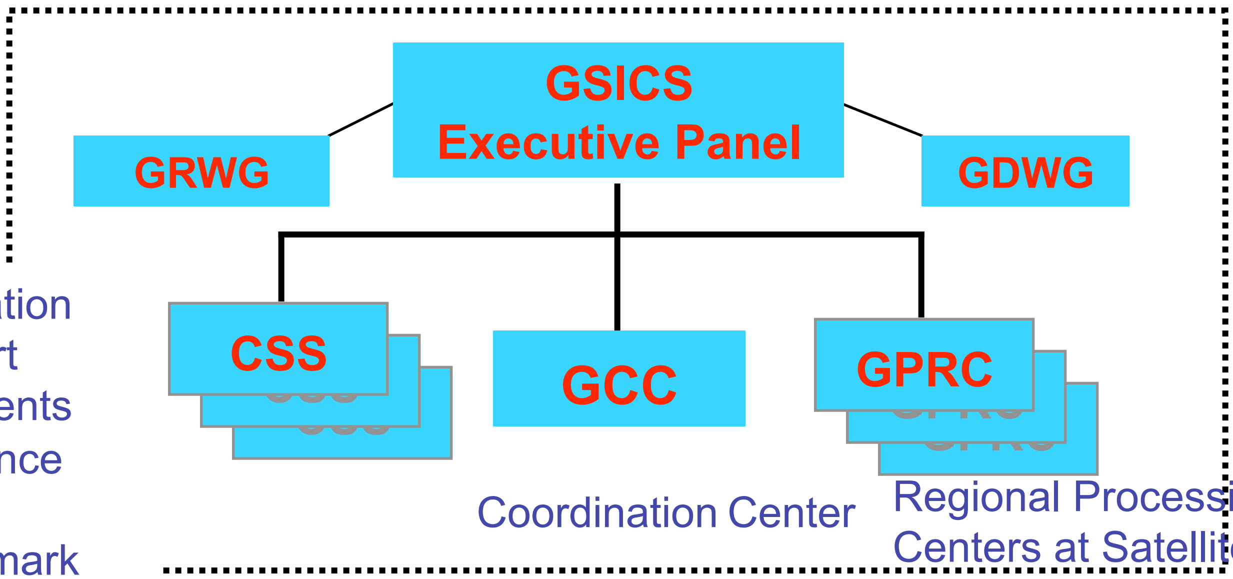
- To improve the use of space-based global observations for weather, climate and environmental applications through operational inter-calibration of satellite sensors.
  - Observations are well calibrated through operational analysis of instrument performance, satellite intercalibration, and validation over reference sites
  - Pre-launch testing is traceable to SI standards
- Provide ability to re-calibrate archived satellite data with consensus GSICS approach, leading to stable fundamental climate data records (FCDR)

RSSC to maximize data usage



- Regional/Specialized Satellite Centres
  - Address the requirements of GCOS in a cost-effective, coordinated manner, capitalising upon the existing expertise and infrastructures.
  - Continuous and sustained provision of high-quality ECVs
  - GSICS enables the generation of Fundamental Climate Data records and provides the basis for sustained climate monitoring and the generation of ECV satellite products.

GSICS Organization



Calibration Support Segments (reference sites, benchmark measurement s, aircraft, model simulations)

Coordination Center

Regional Processing Research Centers at Satellite Agencies

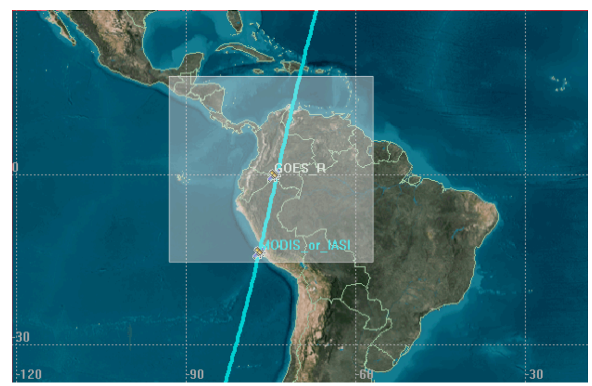
Simultaneous Nadir Overpass (SNO) Method

-a core component in the Integrated Cal/Val System

POES intercalibration

- Useful for remote sensing scientists, climatologists, as well as calibration and instrument scientists
- Support new initiatives (GEOSS and GSICS)
- Significant progress are expected in GOES/POES intercal in the near future

- Has been applied to microwave, vis/nir, and infrared radiometers for on-orbit performance trending and climate calibration support
- Capabilities of 0.1 K for sounders and 1% for vis/nir have been demonstrated in pilot studies



GOES vs. POES

Integrated Cal/Val System Architecture

Calibration Opportunity Prediction

Data Acquisition Scheduler

Calibration Opportunity Register (CORE)

Raw Data Acquisition for Calibration Analyses

Stored Raw Data for Calibration Analyses

- SNO/ SCO Rad. Bias and Spectral Analysis
- Calibration Parameter Noise/ Stability Monitoring
- RTM Model Rad. at Calibration Reference Sites
- Inter-sensor Bias and Spectral Analysis
- Earth & Lunar Calibration
- Geolocation Assessment (Coastlines, etc.)

Assessment Reports and Calibration Updates

Progress

- Annual Operating Plan
- Three GRWG meetings (chair, Fred Wu)
  - Consensus algorithms for LEO to GEO intercalibration (IR)
  - Intercalibration of VIS/NIR channels
  - Intercalibration of microwave channels.
- Two GDWG (chair, Volker Gaertner)
  - Data management issues, metadata
- Commissioned GSICS Website and routine LEO to LEO intersatellite calibration
- Intercomparisons of AIRS and IASI
- Quarterly Newsletter

GSICS Quarterly

Global Space-based Inter-Calibration System

• CMA • CNES • EUMETSAT • JMA • KMA • NOAA • WMO •

www.orbit.nesdis.noaa.gov/smcd/spb/calibration/icvs/GSICS/index.html

Vol. 1, No. 3, 2007

Robert A. Iacovazzi, Jr. and Jerry T. Sullivan, Co-Editors

GSICS LEO-LEO Inter-Calibration

In the past few years, estimation of post-launch inter-satellite calibration-related radiance biases between similar low-earth orbiting (LEO) satellite instruments has been improved substantially with the development of the Simultaneous Nadir Overpass/Simultaneous Conical Overpass (SNO/SCO) method (e.g., Cao and Heidinger 2002; Cao et al. 2004 and 2005). The essence of the SNO/SCO method is that similar space-borne radiometers flown on different LEO satellites periodically observe the same earth scene at the same time, which eliminates bias uncertainties related to meteorological evolution within the scene. The SNO/SCO method has been applied operationally to visible/near-infrared, infrared, and microwave radiometers on NOAA POES, EUMETSAT MetOp-A and NASA EOS Aqua satellites with excellent results, and is identified as an essential component of GSICS. In Figure 1, the SNO/SCO analysis is shown to be comprised of the following processes: SNO/SCO prediction; data access, subsetting, and collocation; and data analysis and plotting.

Since it is cumbersome to examine all data granules for SNO/SCO events, the Simplified General Perturbation Model Four (SGP4) and available satellite orbit ephemeris data are used to predict these events. From these predictions, it is found that the frequency of SNO/SCO events depends on the criteria of simultaneity and the nature of the orbital geometries and altitudes of a given pair of LEO satellites. Currently, a SNO/SCO is considered to occur if observations of a given scene by two satellite instruments on different polar-orbiting satellites are taken less than 30/60 seconds apart.

At the GSICS Coordination Center (GCC), access to operational satellite data is accomplished through a NOAA collaborative data environment, while research data sets are obtained through the host organization and stored locally on GCC computers for later use. Once the raw datasets are in place, data subsetting and collocation is an important next step in the process of SNO/SCO methodology.

For each SNO/SCO event, the data is subsetted near the point where the nadir tracks of the two spacecraft intersect. For the cross-track scanning instruments, data at SNO events are then collocated using either nearest-neighbor or bilinear interpolation collocation methods. The SCO observations are collocated using a new technique developed by Iacovazzi and Cao (2007) to reduce the effect of inhomogeneous surface properties on SCO observations at window channels.

After subsetting and collocation, individual SNO/SCO data analyses proceeds very quickly by finding the reflectance or brightness temperature bias between each pair of collocated data at an SNO/SCO, and then averaging these biases over the SNO/SCO region. Over time, as the population of SNO events from the two satellites increases, it becomes possible to compute SNO-ensemble average measurement biases and uncertainties, as well as other bias statistics. Currently, these statistics can be found in the "Science Pages" of the GSICS web site.

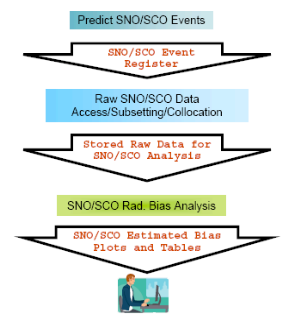


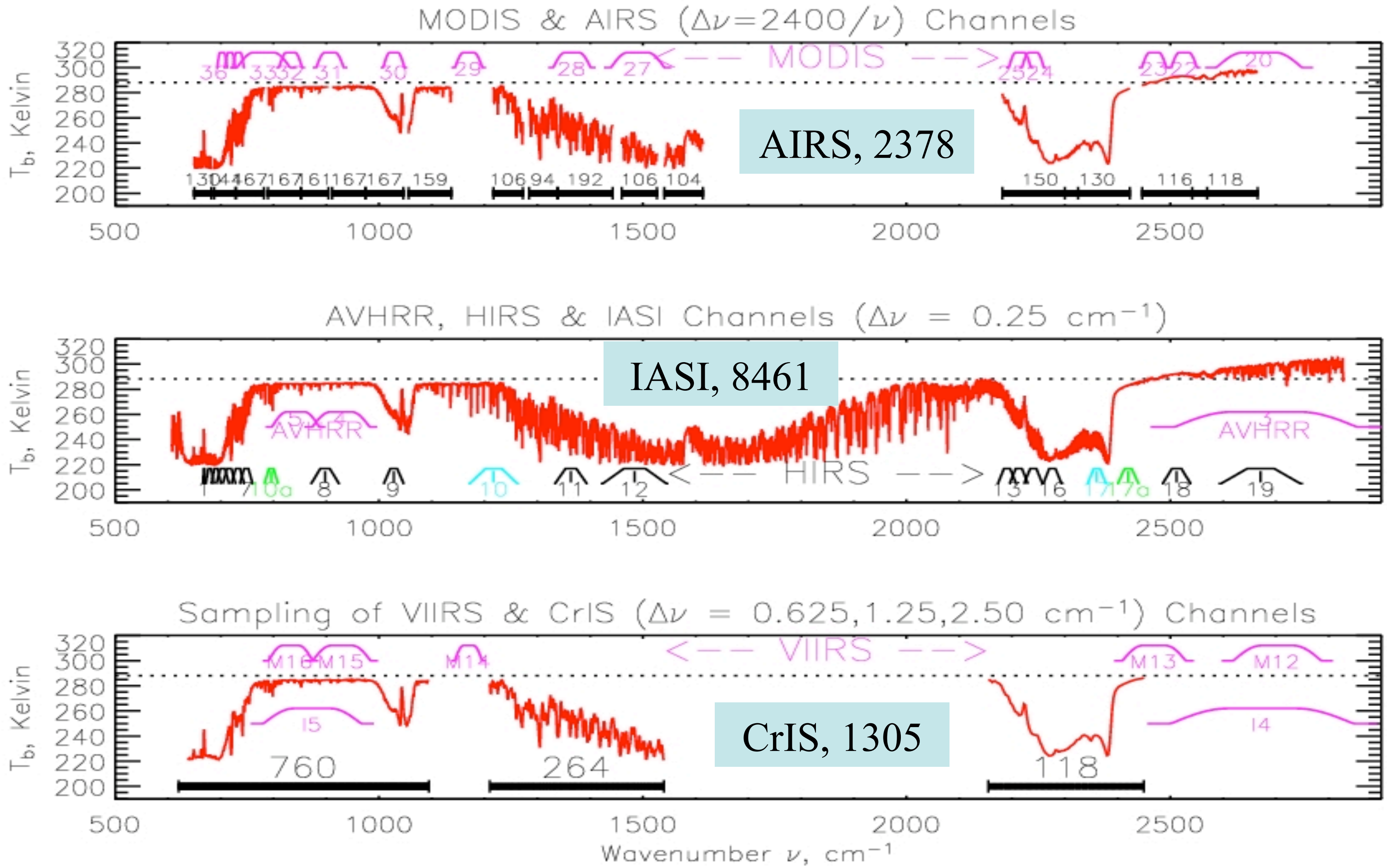
Figure 1: Process of estimating inter-satellite calibration biases using the SNO/SCO method.

Acknowledgements: GSICS LEO-LEO SNO/SCO satellite data inter-comparisons have been made possible with the help of Drs. Changyong Cao, Pubu Ciren, Sunwook Hong, Robert Iacovazzi, Jr., Yaping Li, Haibing Sun, Ninghai Sun, Likun Wang, Fuzhong Weng, and Banghua Yan.

2008 Deliverables

- Commission intercalibration of MTSAT, MSG, GOES and FY2 Infrared Imagers with IASI and AIRS.
  - Routine intercomparisons between MSG (SEVIRI) and AIRS/IASI at EUMETSAT
  - Routine intercomparisons between GOES and AIRS/IASI at NESDIS
  - Routine intercomparisons between MTSAT and AIRS/IASI at JMA
  - Routine intercomparisons between FY2 and AIRS/IASI at CMA

Routine Intercalibration of AIRS and IASI

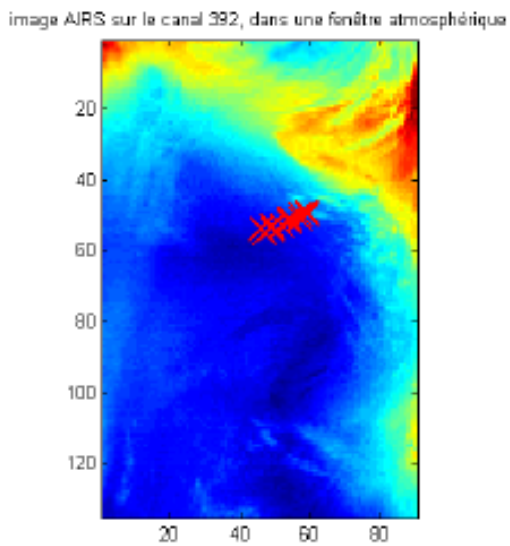


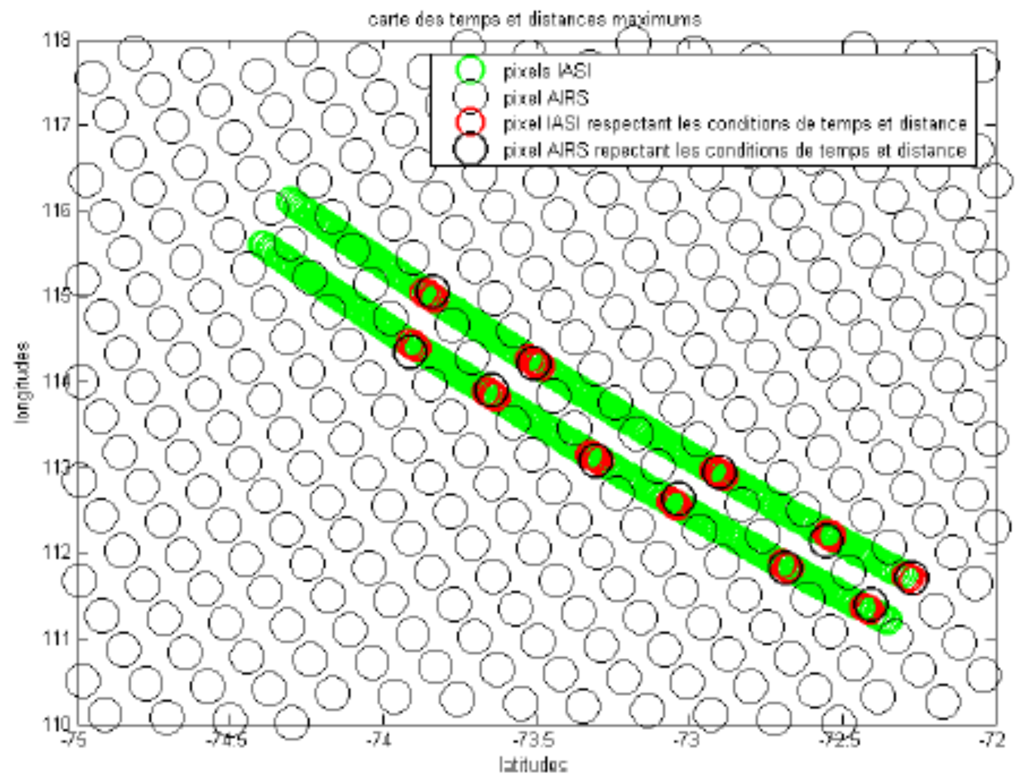
Radiometric calibration — IASI versus AIRS

Situation 16th of April

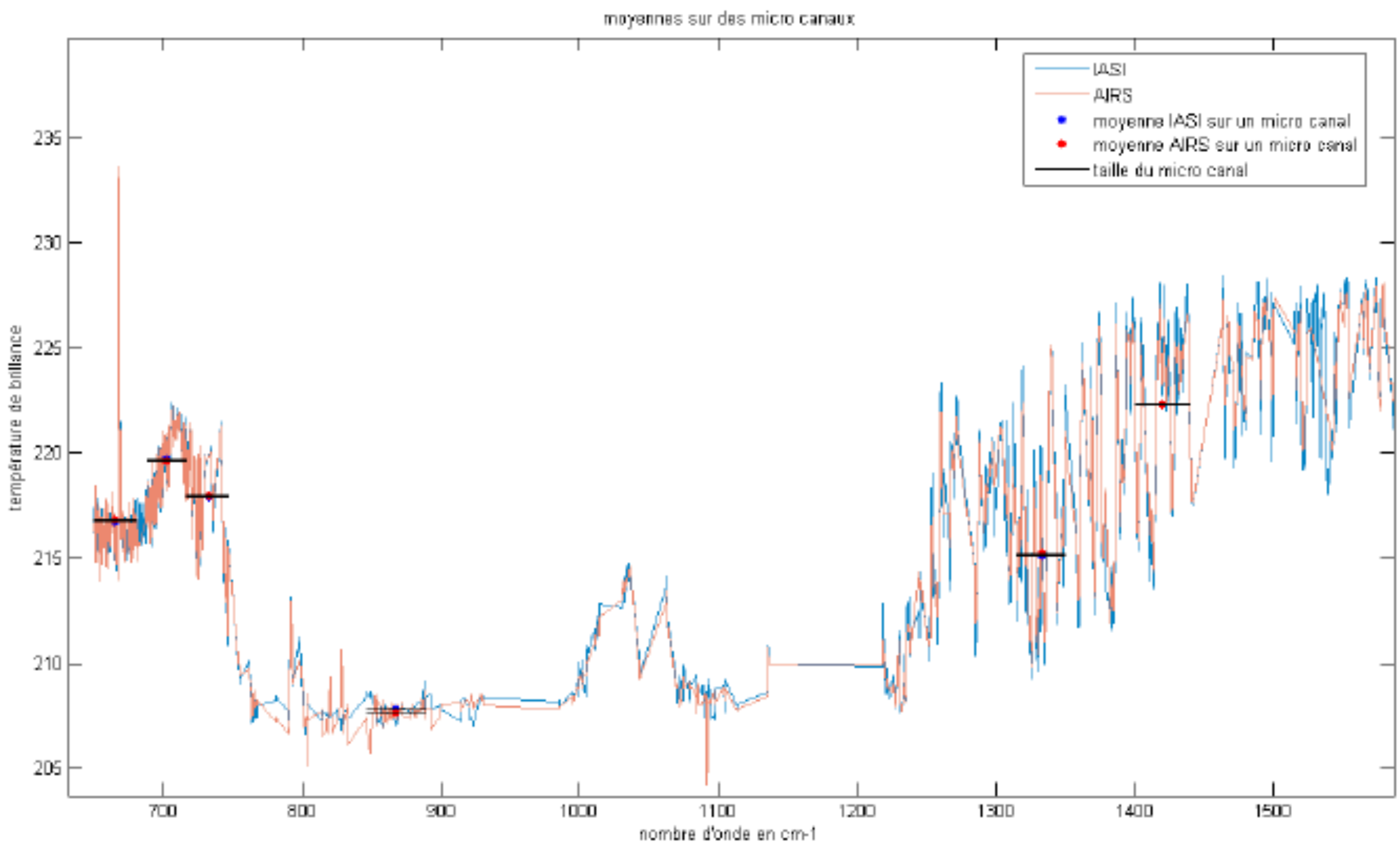
(Blumstein)

- IASI in External Cal.
  - Close to nadir
- Many comparison opportunities
  - 49 used
- Good uniformity
  - Cold scene



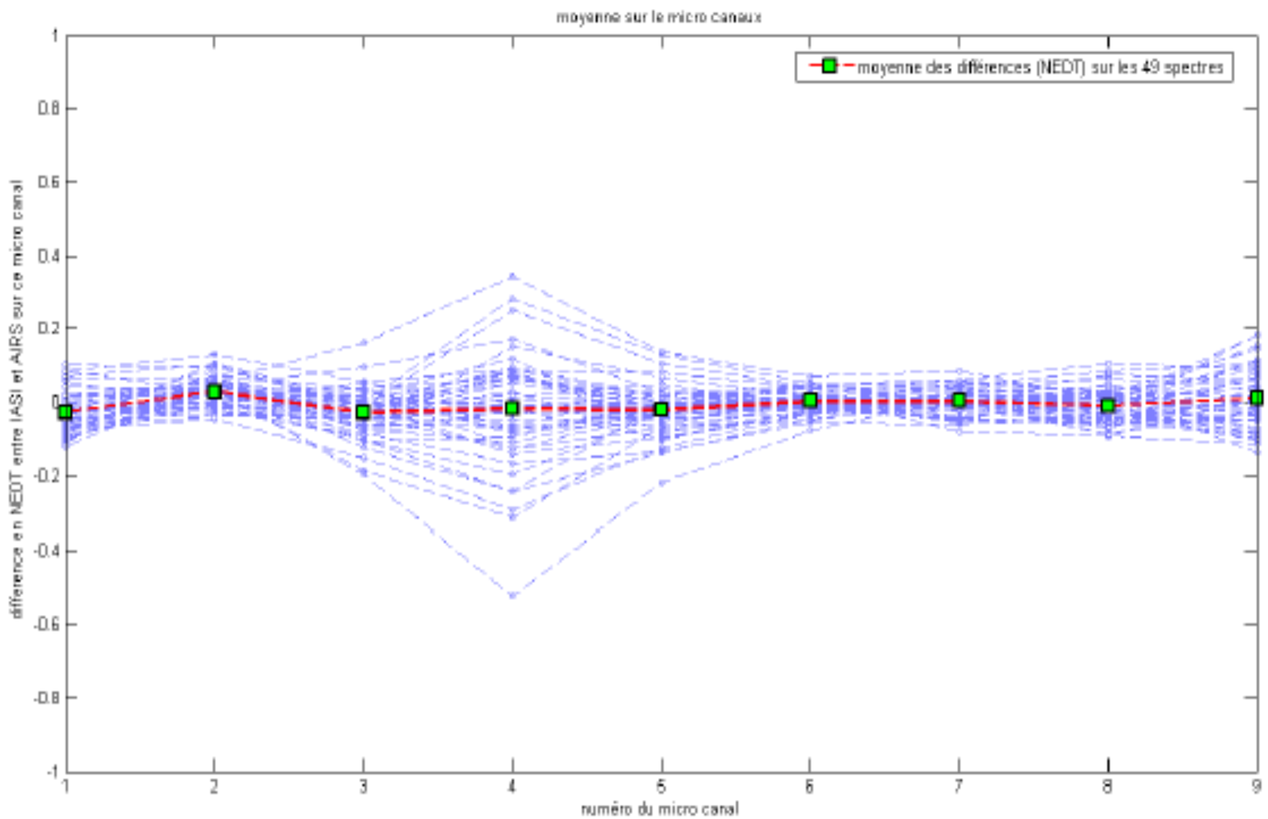


Pseudo-channels

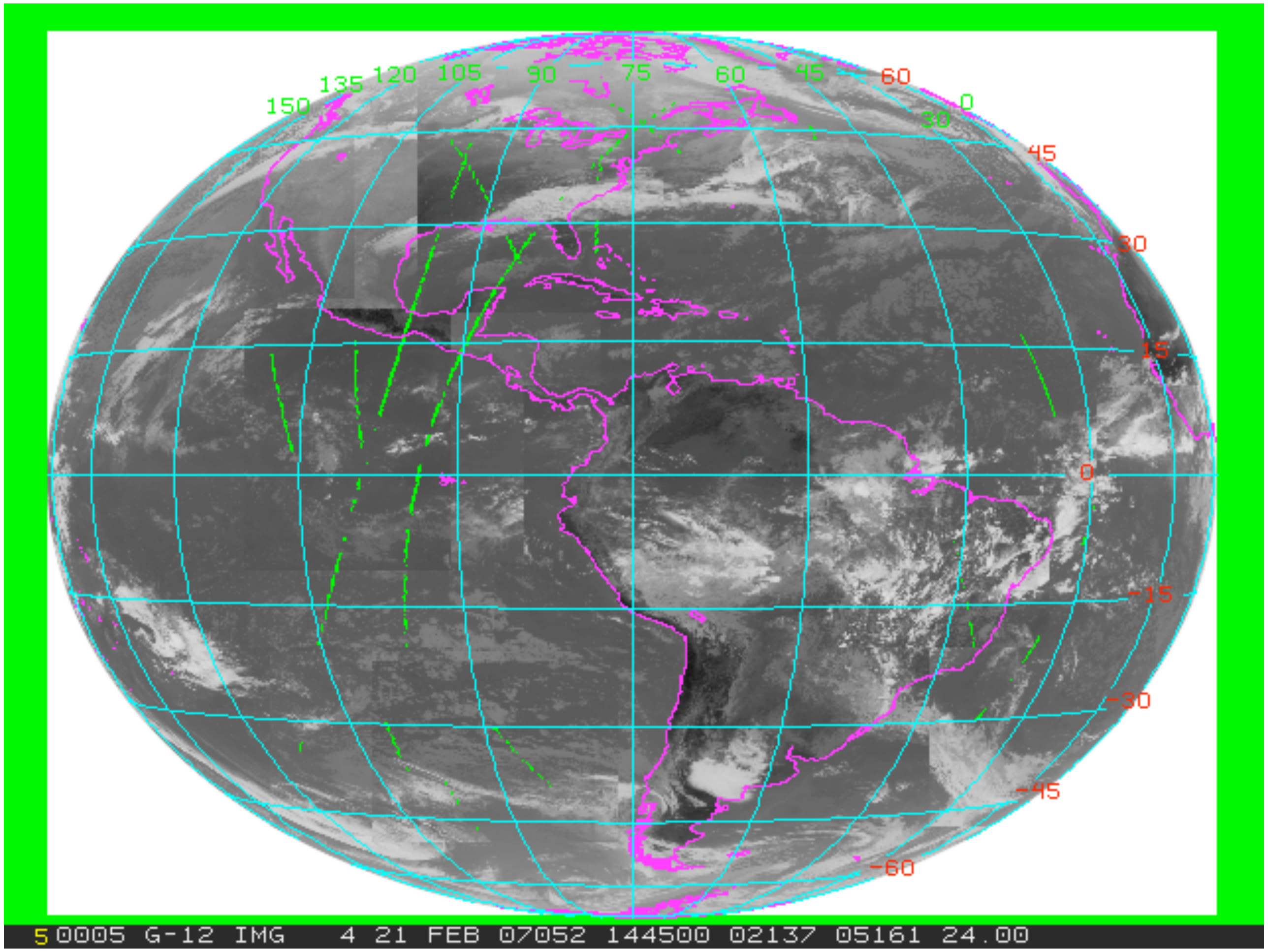


Summary results (case 16th of April 2007)

- IASI External Calibration Mode. Very uniform situation
- 9 pseudo-channels / 49 soundings / 210 K in atmospheric window
- Differences scaled to 280 K reference temperature

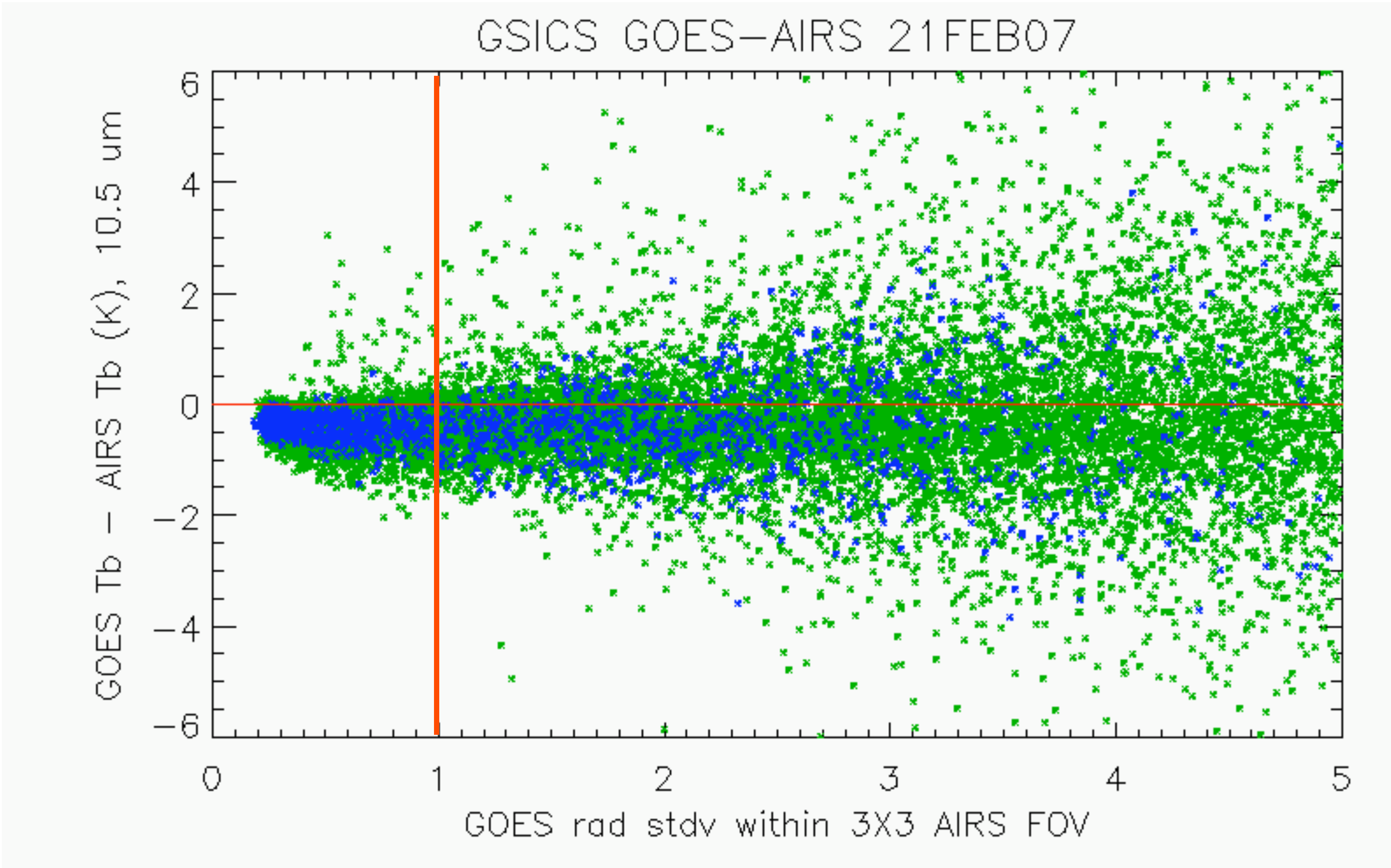


GOES 10.7 μm Co-locations with AIRS, 21feb02



1. FOV instead of large area
2. Not restricted to near nadir

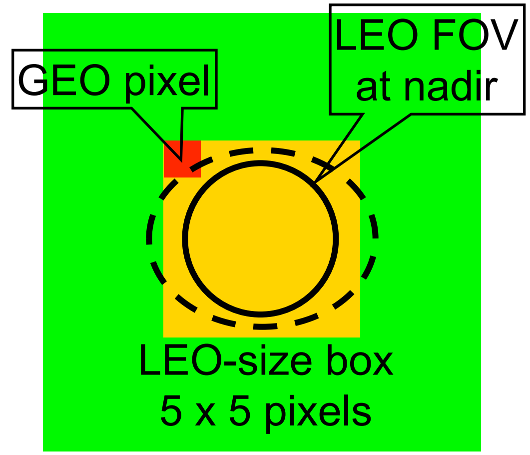
Preliminary Results from Prototype Algorithm

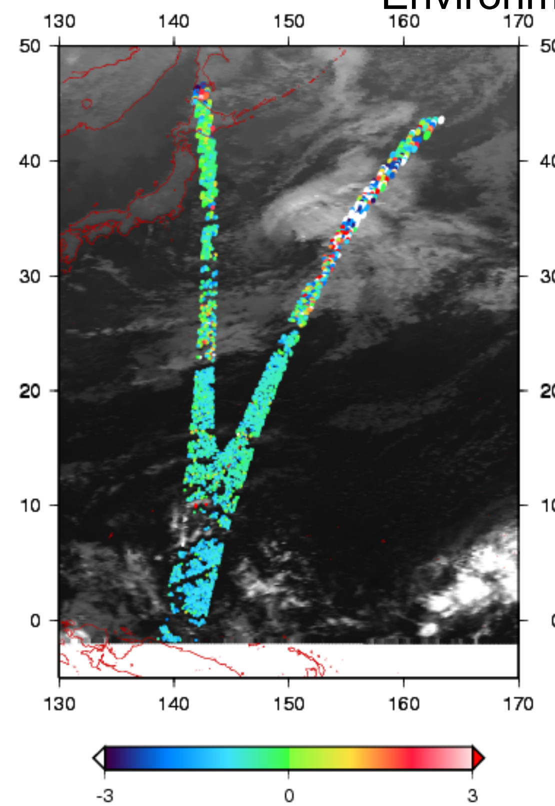


Blue: time difference < 60 seconds

Baseline GEO to LEO Collocation Algorithm

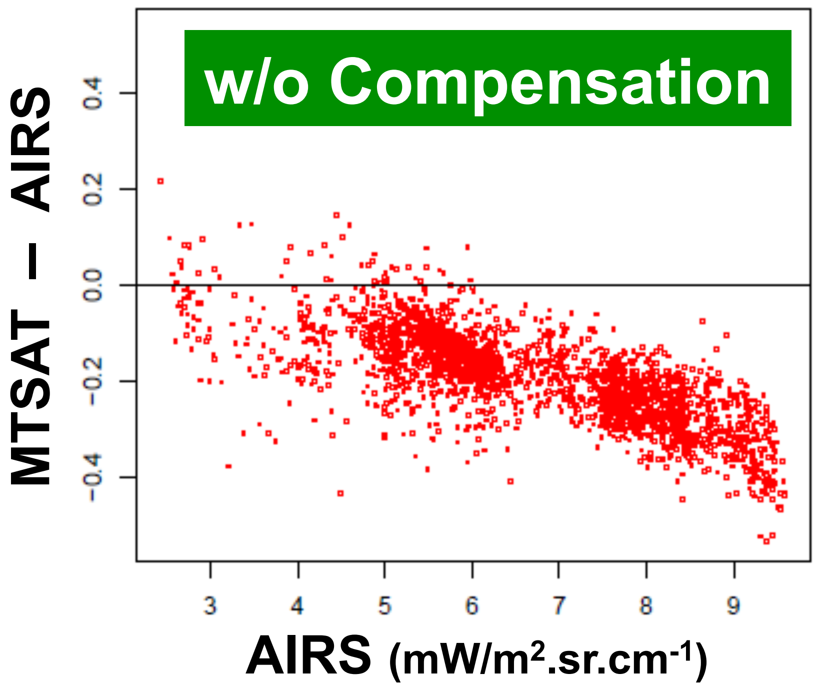
- Key match-up conditions between GEO and LEO
  - Difference of observing times < 1800 (sec)
  - Difference of 1/cos(sat. zenith angles) < 0.05
  - Environment uniformity check
    - To choose only spatially uniform area to alleviate navigation error, MTF, observing time difference, optical path difference, etc.
    - Environment domain = 11x11 IR pixel box (MTSAT-1R vs. AIRS)
    - env_stdv_tb < (TBD)
  - Representation check of LEO-size GEO pixels in the environment
    - z-test
    - LEO FOV = 5x5 IR pixel box (MTSAT-1R vs. AIRS)
    - abs(fov_mean_tb – env_mean_tb) < Gaussian x env_stdv_tb / 5

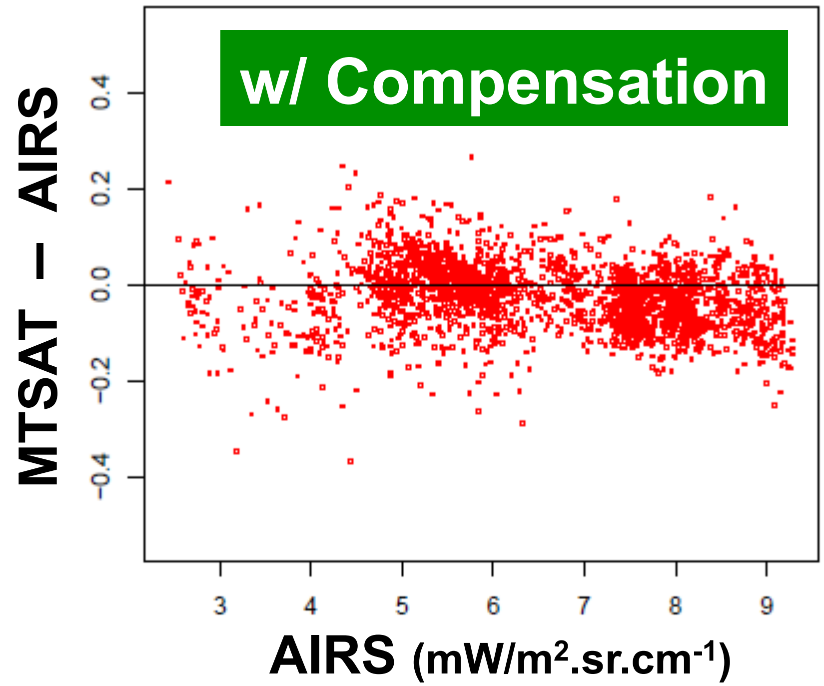


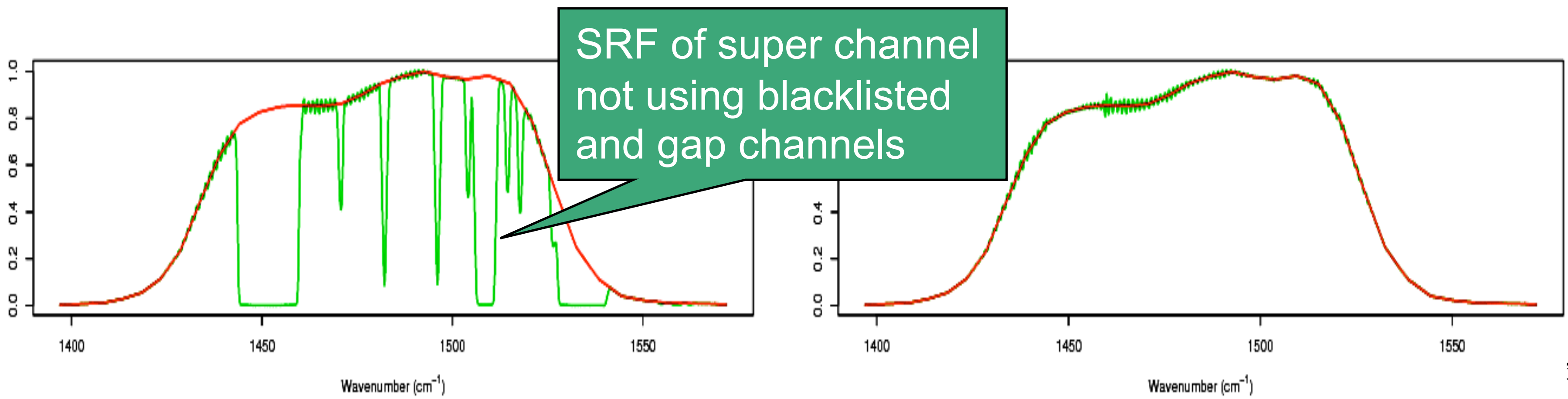


Compensation vs. No Compensation

Radiance comparison of MTSAT1R 6.8-um and AIRS

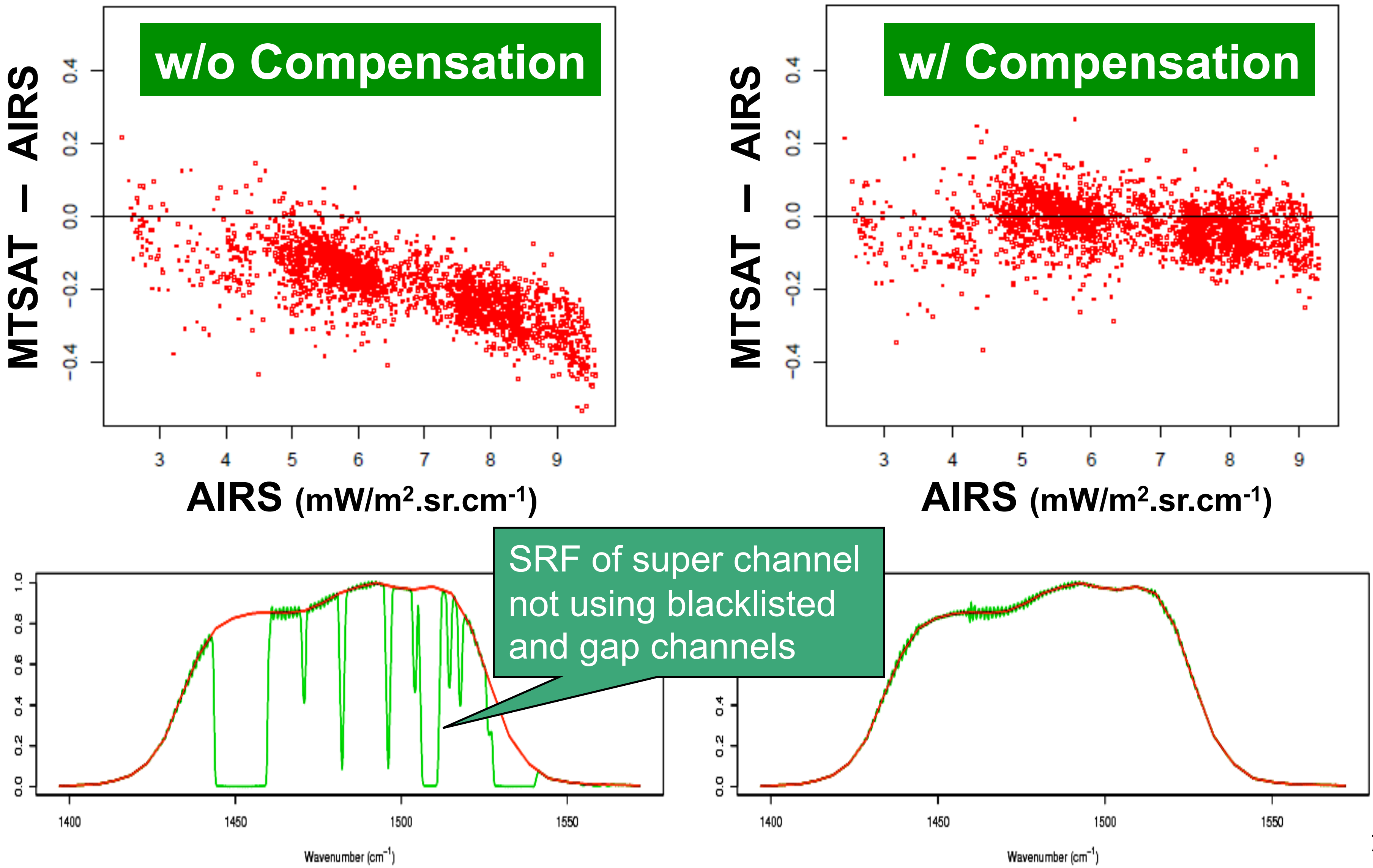






Compensation vs. No Compensation

Radiance comparison of MTSAT1R 6.8-um and AIRS



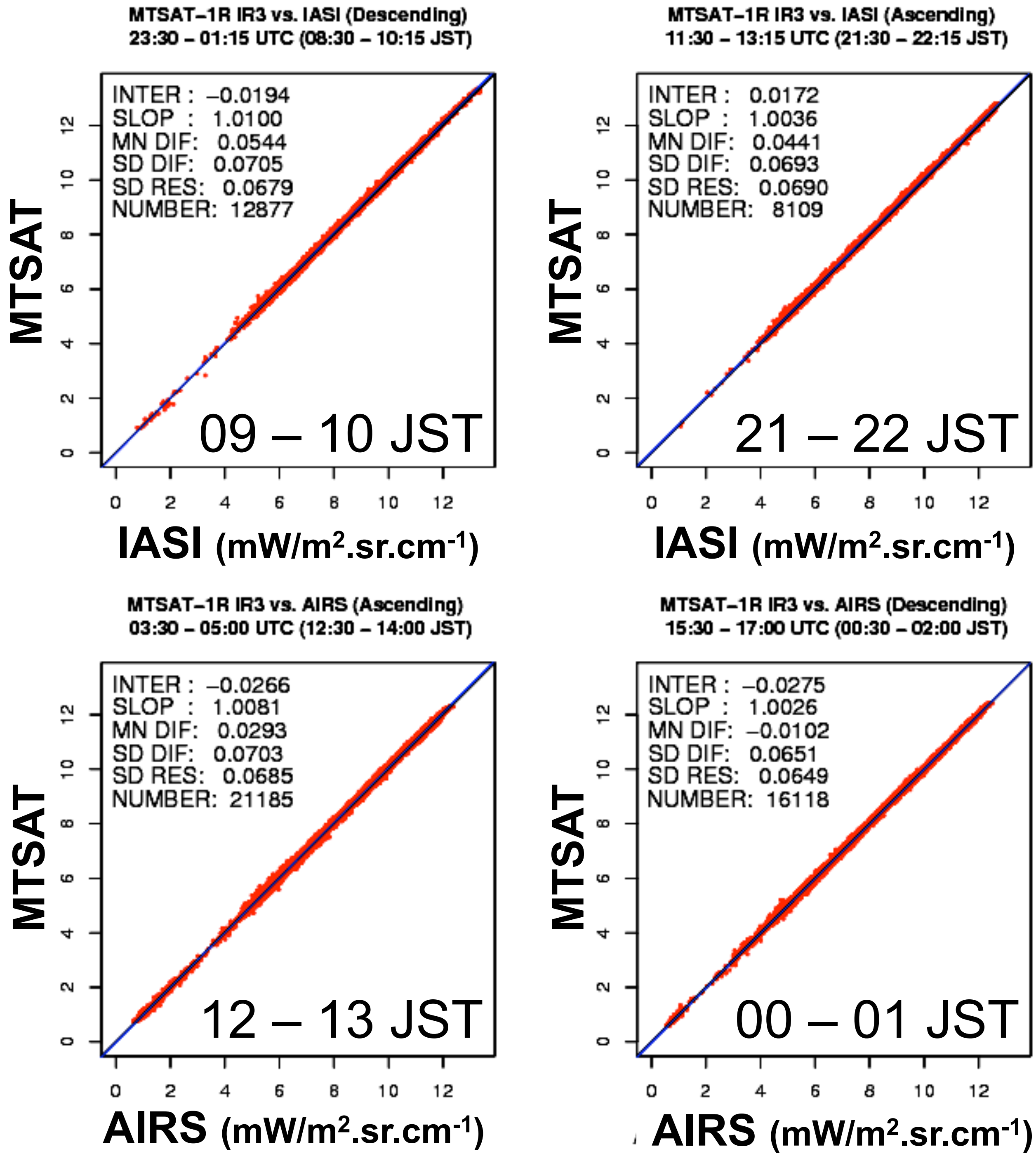
MTSAT-1R 6.8-um

vs.

AIRS/IASI

August 2008

* Compensation applied to AIRS super channel computation



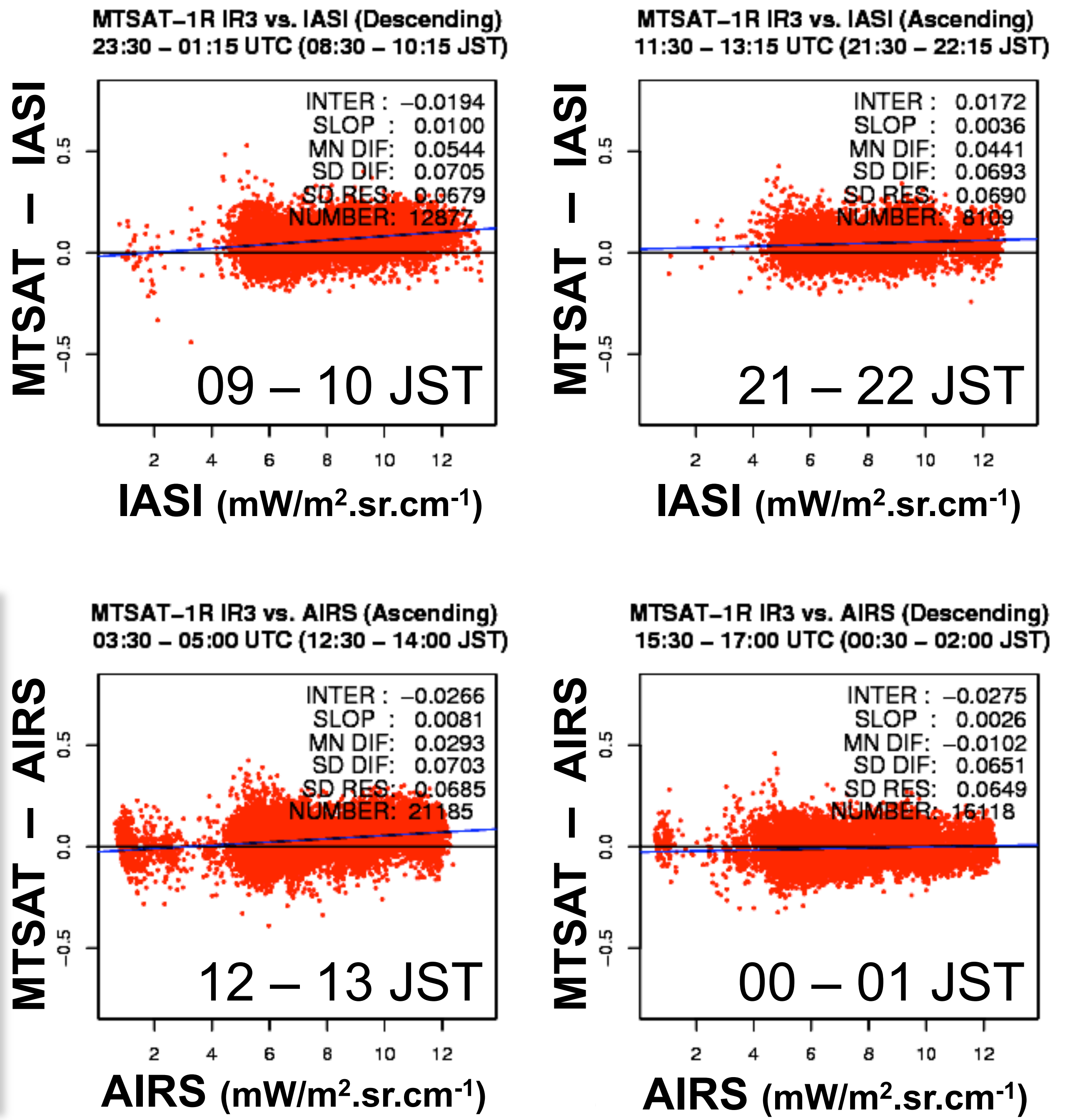
MTSAT-1R 6.8-um

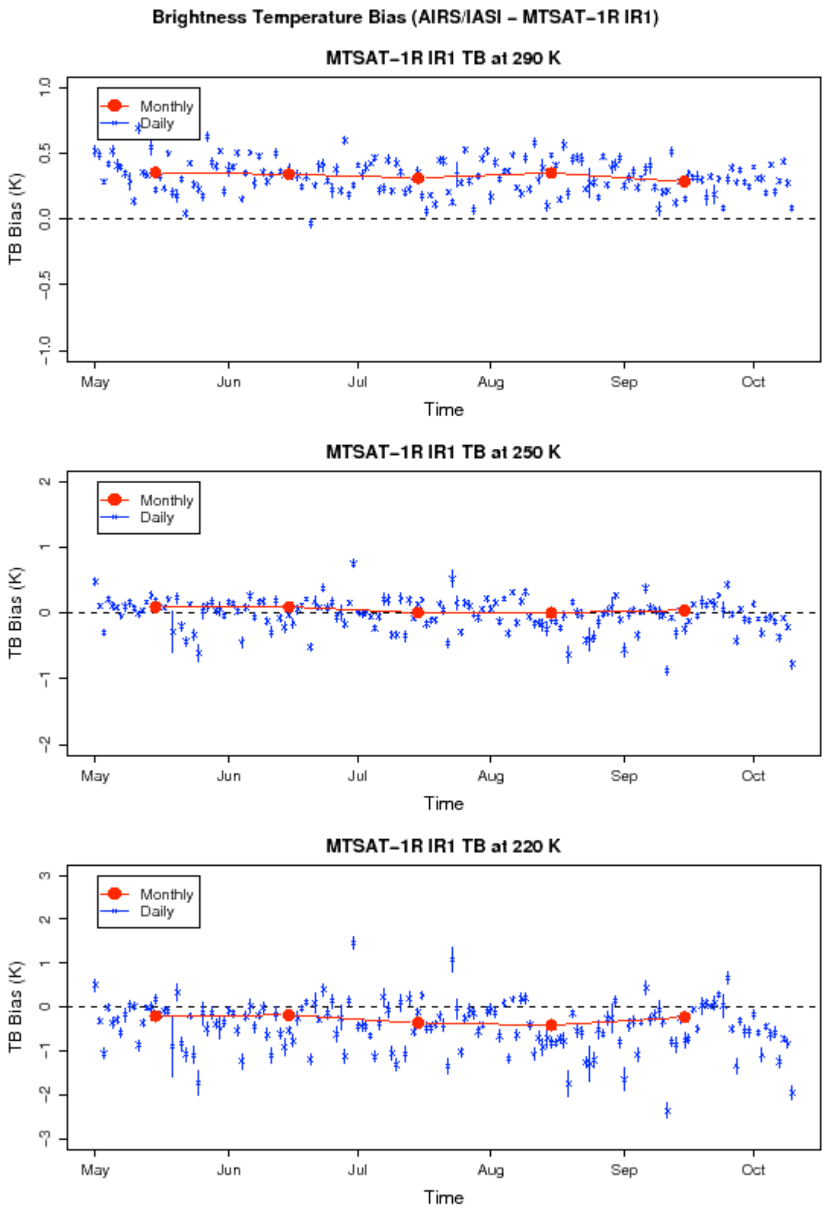
vs.

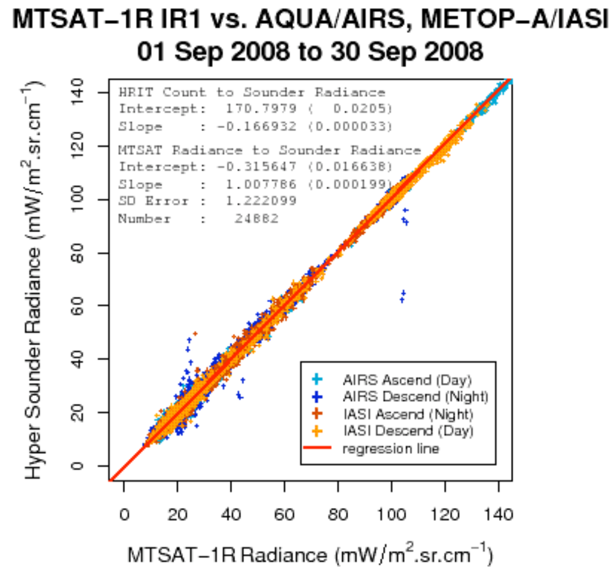
AIRS/IASI

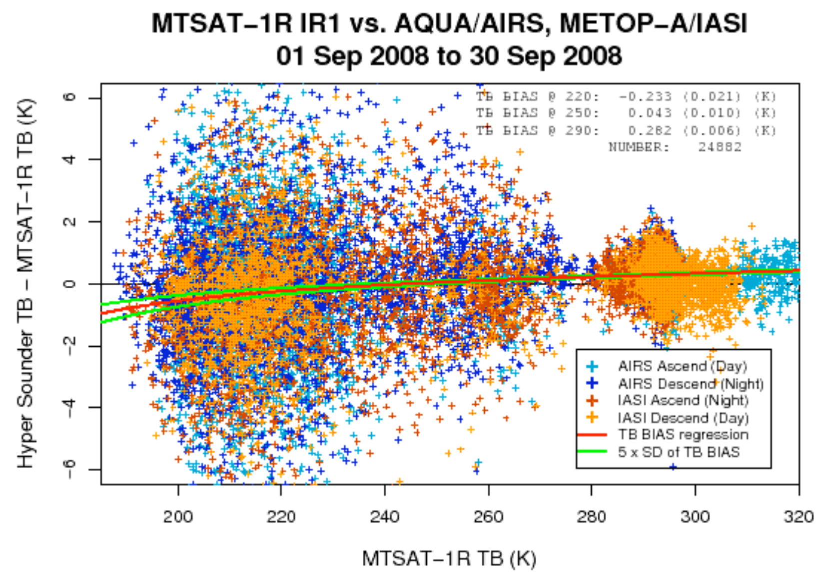
August 2008

- Daytime comparisons against AIRS & IASI show the same result
- Only midnight AIRS comparison shows different from others, that might indicate unknown solar effect on MTSAT




Brightness Temperature Bias (AIRS/IASI – MTSAT–1R IR1)
MTSAT–1R IR1 TB at 290 K
MTSAT–1R IR1 TB at 250 K
MTSAT–1R IR1 TB at 220 K
Monthly
Daily
TB Bias (K)
May
Jun
Jul
Aug
Sep
Oct
Time

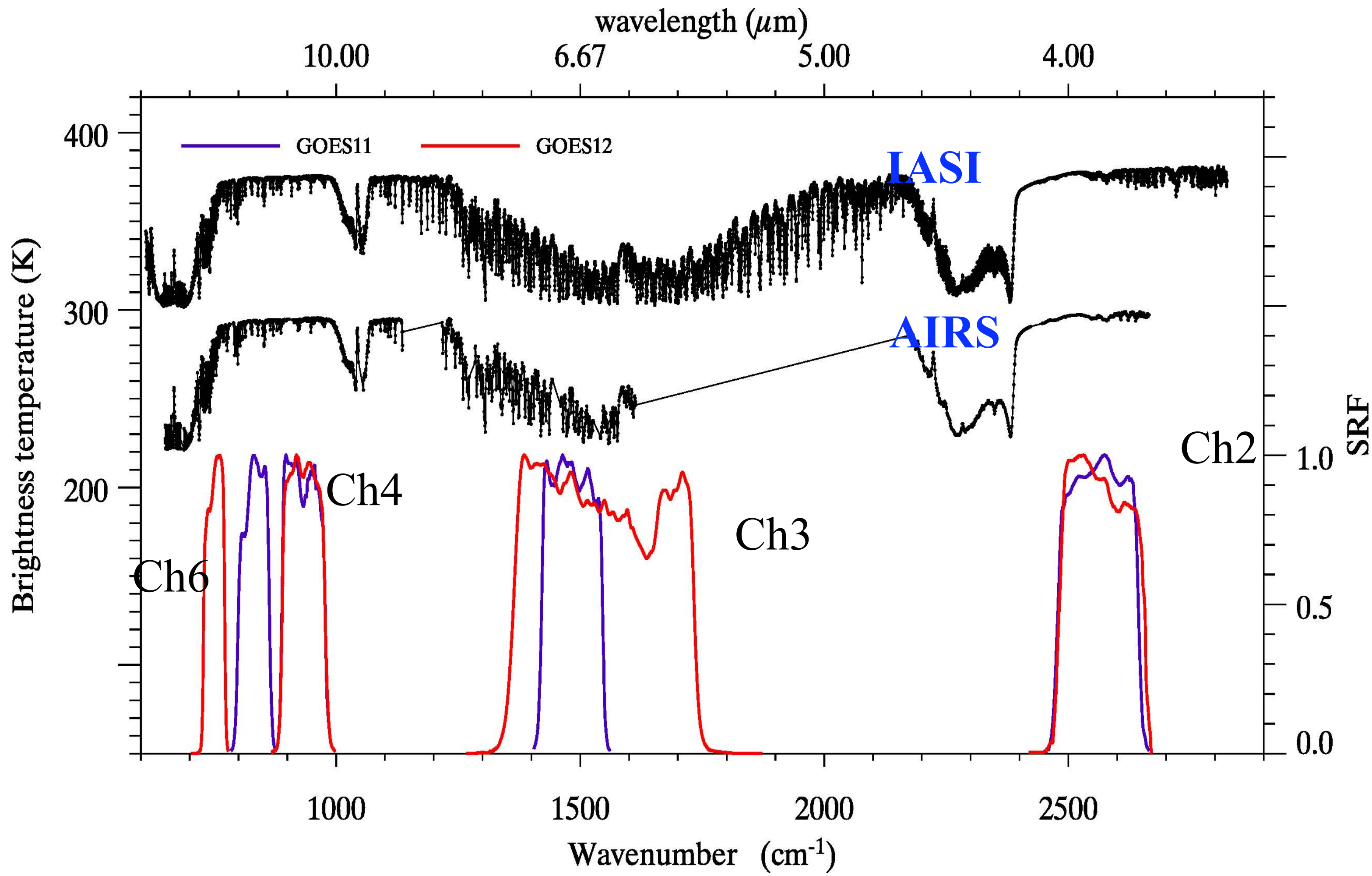

MTSAT–1R IR1 vs. AQUA/AIRS, METOP–A/IASI
01 Sep 2008 to 30 Sep 2008
HRIT Count to Sounder Radiance
Intercept: 170.7979 (0.0205)
Slope : -0.166932 (0.000033)
MTSAT Radiance to Sounder Radiance
Intercept: -0.315647 (0.016638)
Slope : 1.007786 (0.000199)
SD Error : 1.222099
Number : 24882
AIRS Ascend (Day)
AIRS Descend (Night)
IASI Ascend (Night)
IASI Descend (Day)
regression line
Hyper Sounder Radiance (mW/m2.sr.cm−1)
MTSAT−1R Radiance (mW/m2.sr.cm−1)


MTSAT–1R IR1 vs. AQUA/AIRS, METOP–A/IASI
01 Sep 2008 to 30 Sep 2008
TB BIAS @ 220: -0.233 (0.021) (K)
TB BIAS @ 250: 0.043 (0.010) (K)
TB BIAS @ 290: 0.282 (0.006) (K)
NUMBER: 24882
AIRS Ascend (Day)
AIRS Descend (Night)
IASI Ascend (Night)
IASI Descend (Day)
TB BIAS regression
5 x SD of TB BIAS
Hyper Sounder TB – MTSAT–1R TB (K)
MTSAT–1R TB (K)

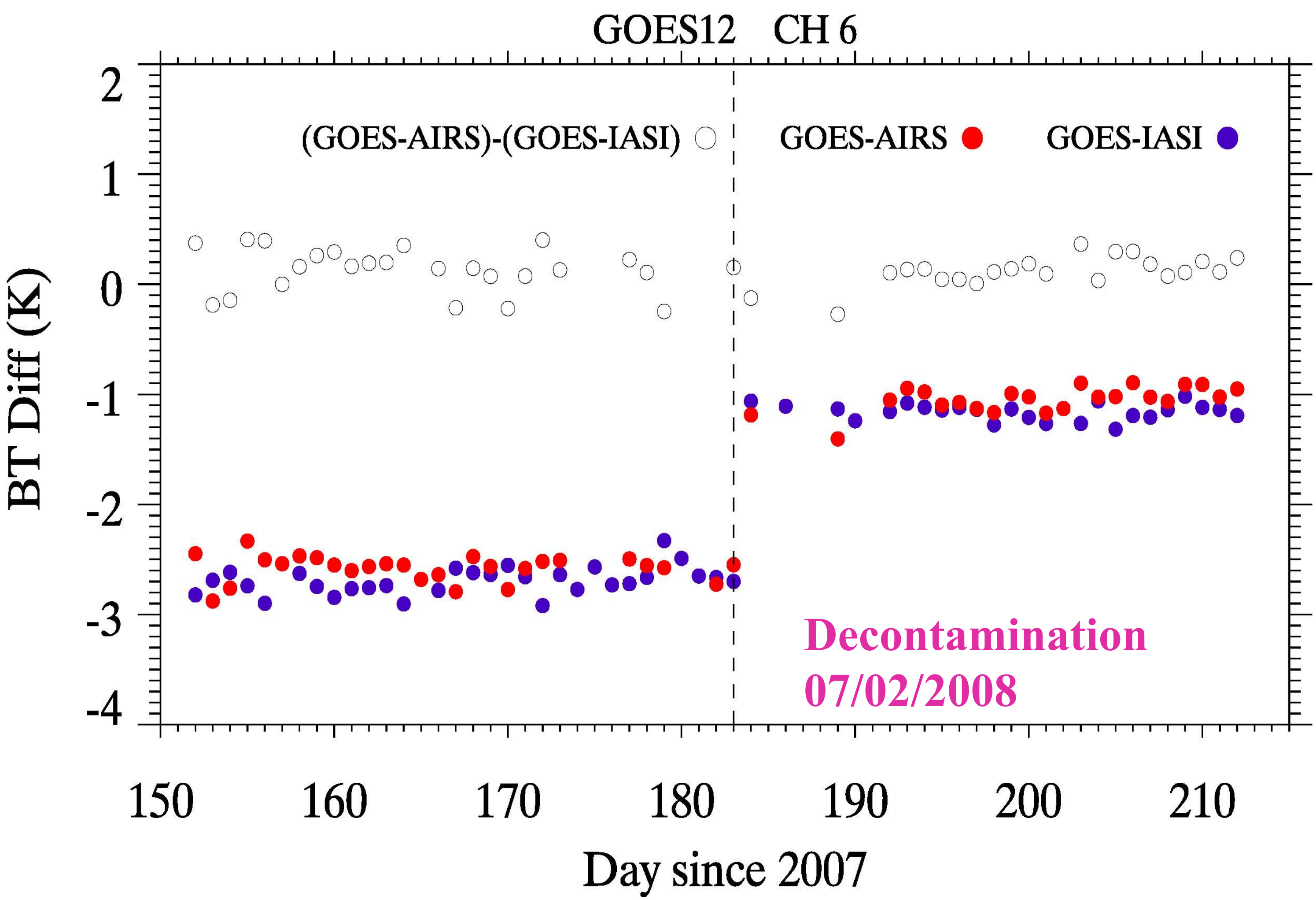
AIRS-GOES vs. IASI-GOES

- **Spectral Convolution**
  - Spectral Filling for AIRS measurements
  - Specially for water vapor channels
- **Pixel Size**
  - AIRS: 13.5 km
  - IASI: 12.0 km
  - GOES pixel: 4.0 km, 3 by 5 GOES pixels
- **Sampling Number**
  - AIRS: 6075 samples for 3 minutes
  - IASI: 2640 samples for 3 minutes
- **Diurnal Effects**
  - Aqua on afternoon orbit: 1:30pm
  - MetOp-A on morning orbit: 9:30am

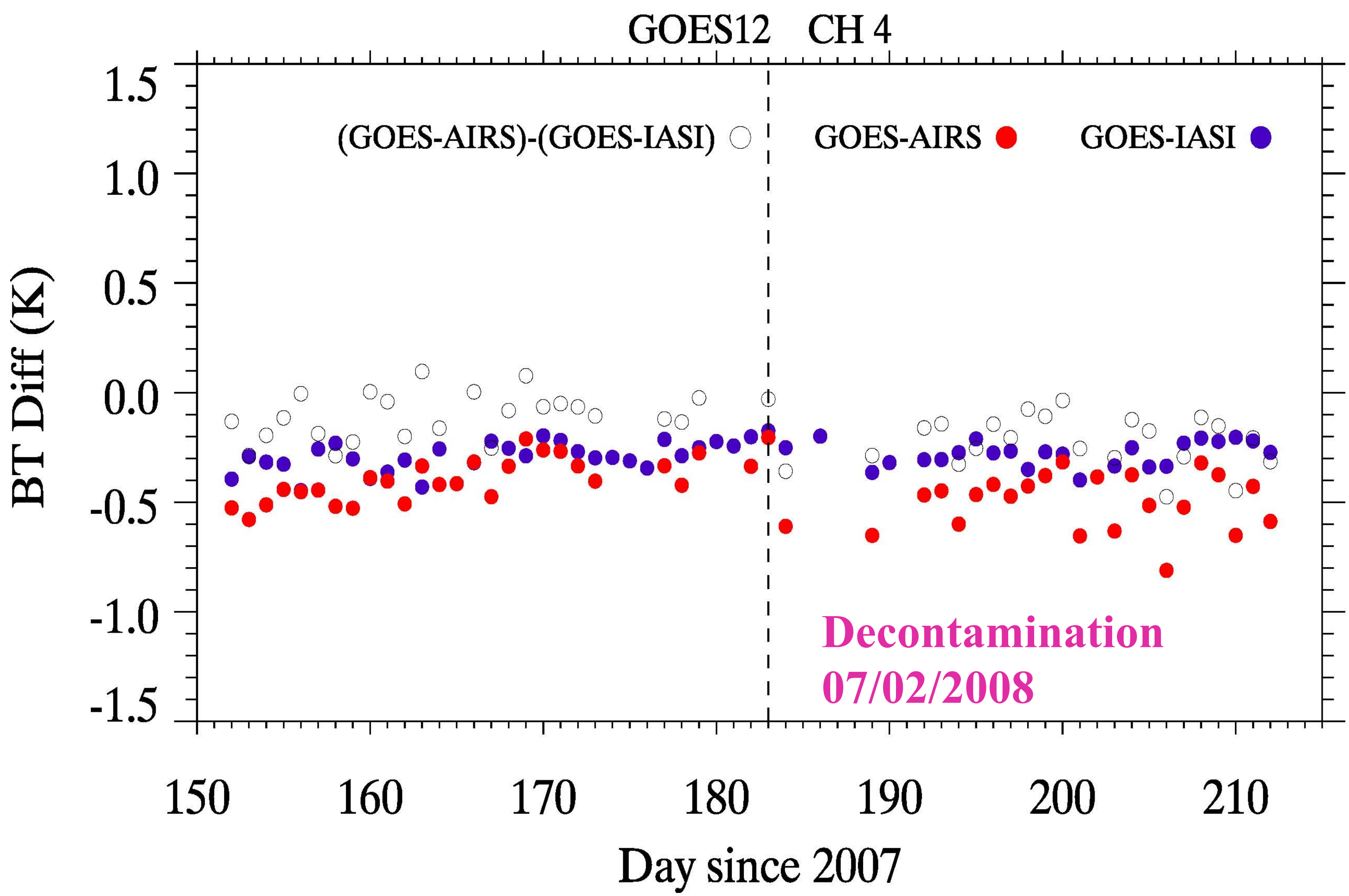
Spectral Coverage



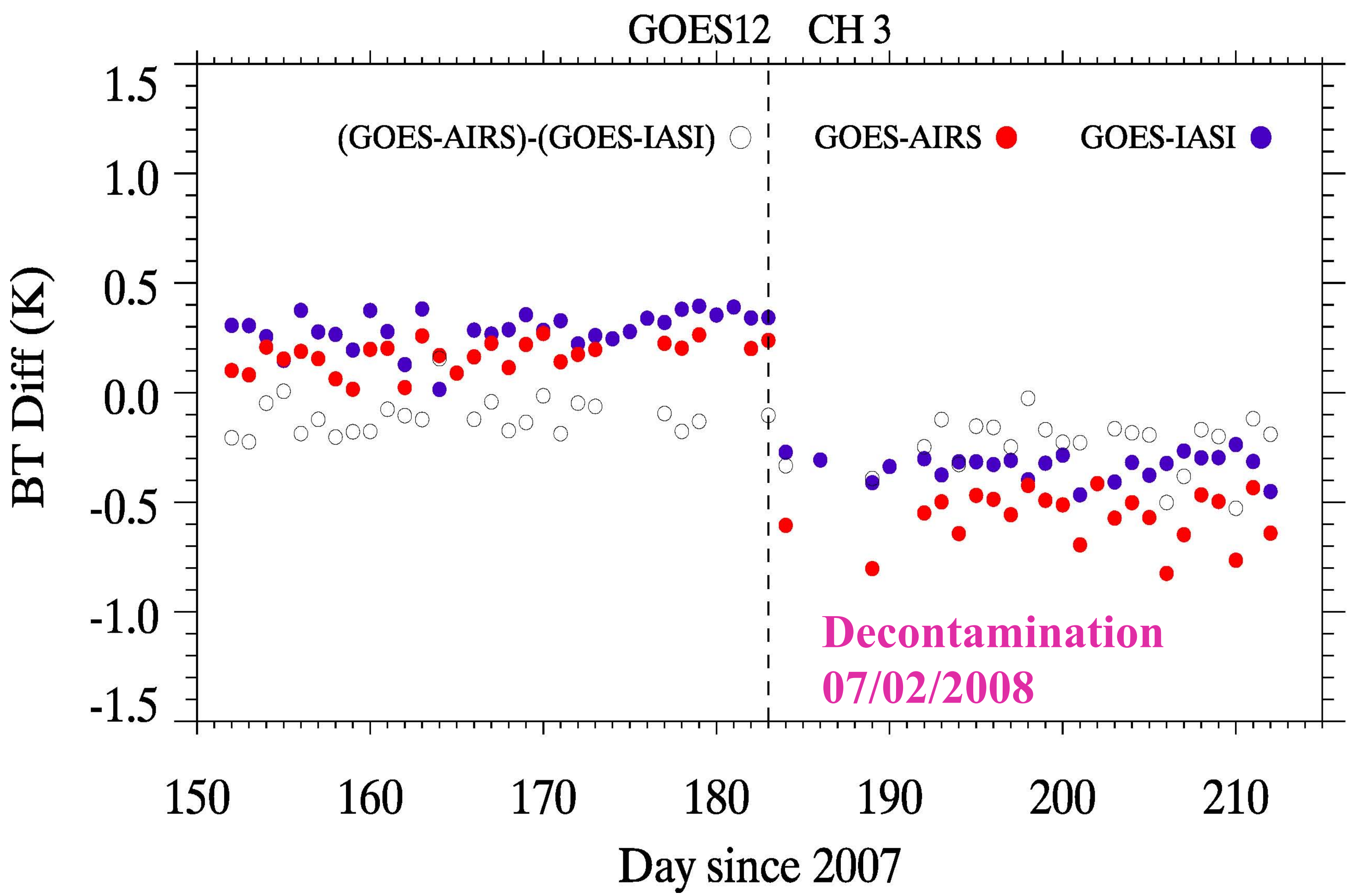
Channel 6 (13.3 µm)



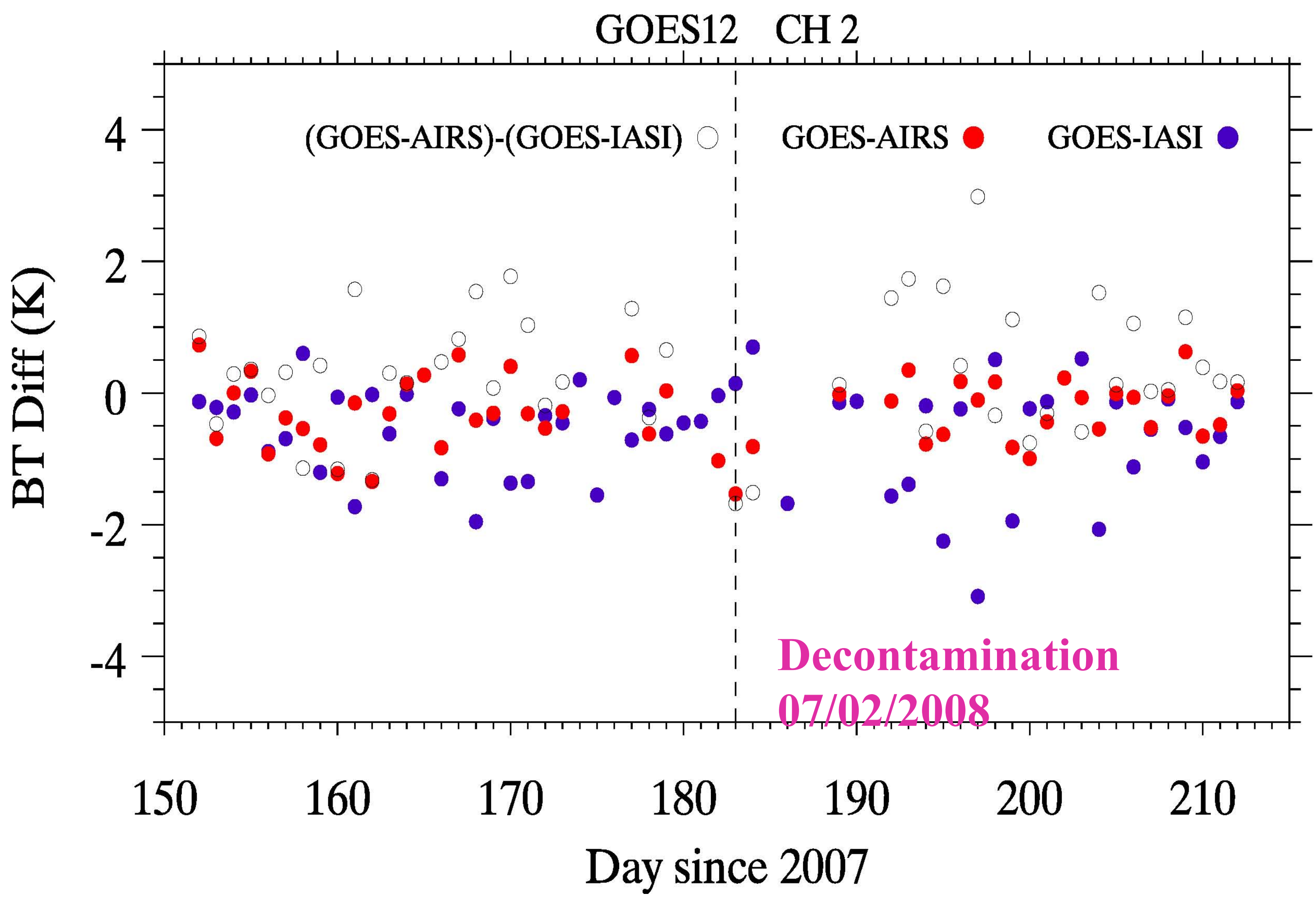
Channel 4 (10.7μm)



Channel 3 (6.5μm)



Channel 2 (3.9μm)



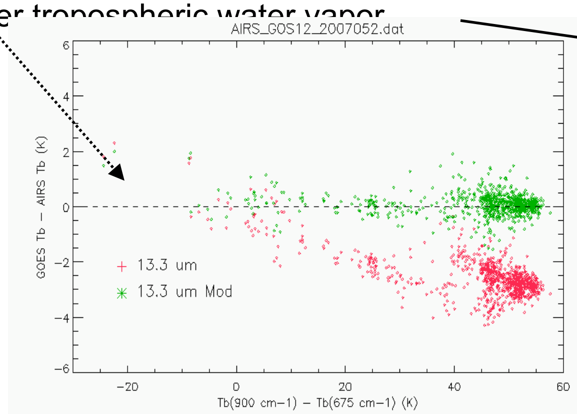
CEOS Action: CL-06-02_2
"Operational Implementation of Geostationary to Low Earth Orbit intercalibration for all geostationary IR imagers

- This action is led by the WMO Global Space-based InterCalibration System (GSICS) program

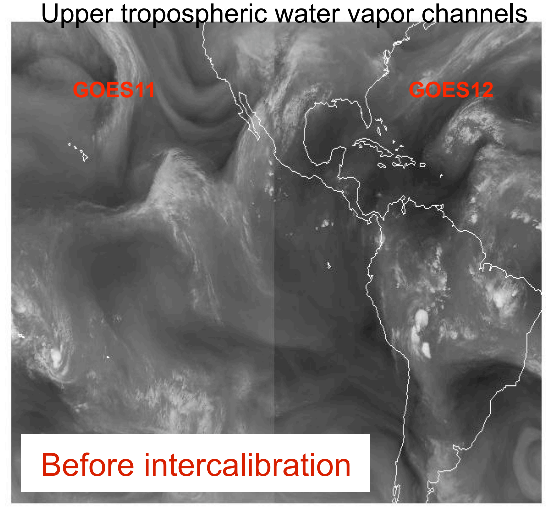
- Routine intercalibration is now performed at NOAA, JMA and EUMETSAT.

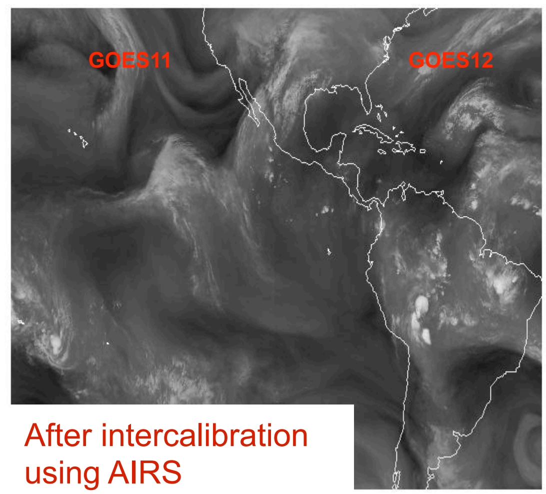
- Intercalibration with accurate and stable high spectral resolution infrared sounders (AIRS and IASI) provides:
    - improved characterization of the geostationary infrared imagers and
    - generation of seamless radiance datasets for deriving products such as upper tropospheric water vapor

Intercomparison of GOES and AIRS found the spectral response function (SRF) of GOES 13.3 micron channel is incorrect. A shift in the SRF was needed to remove the large bias (red)



Upper tropospheric water vapor channels





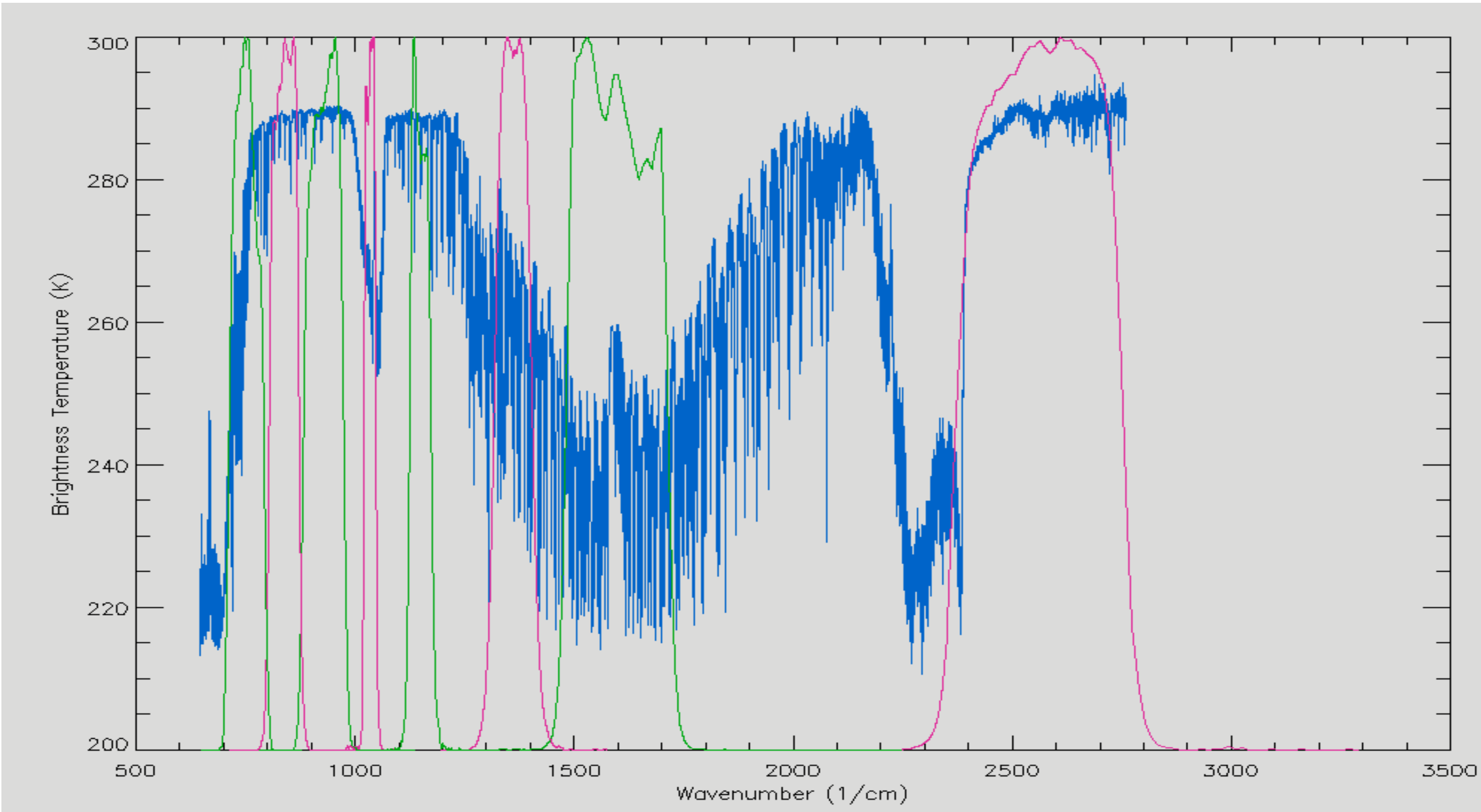
After intercalibration using AIRS

Significance: GSICS is an international coordinated effort to routinely provide instrument intercalibration and monitoring for the generation of fundamental climate data records.

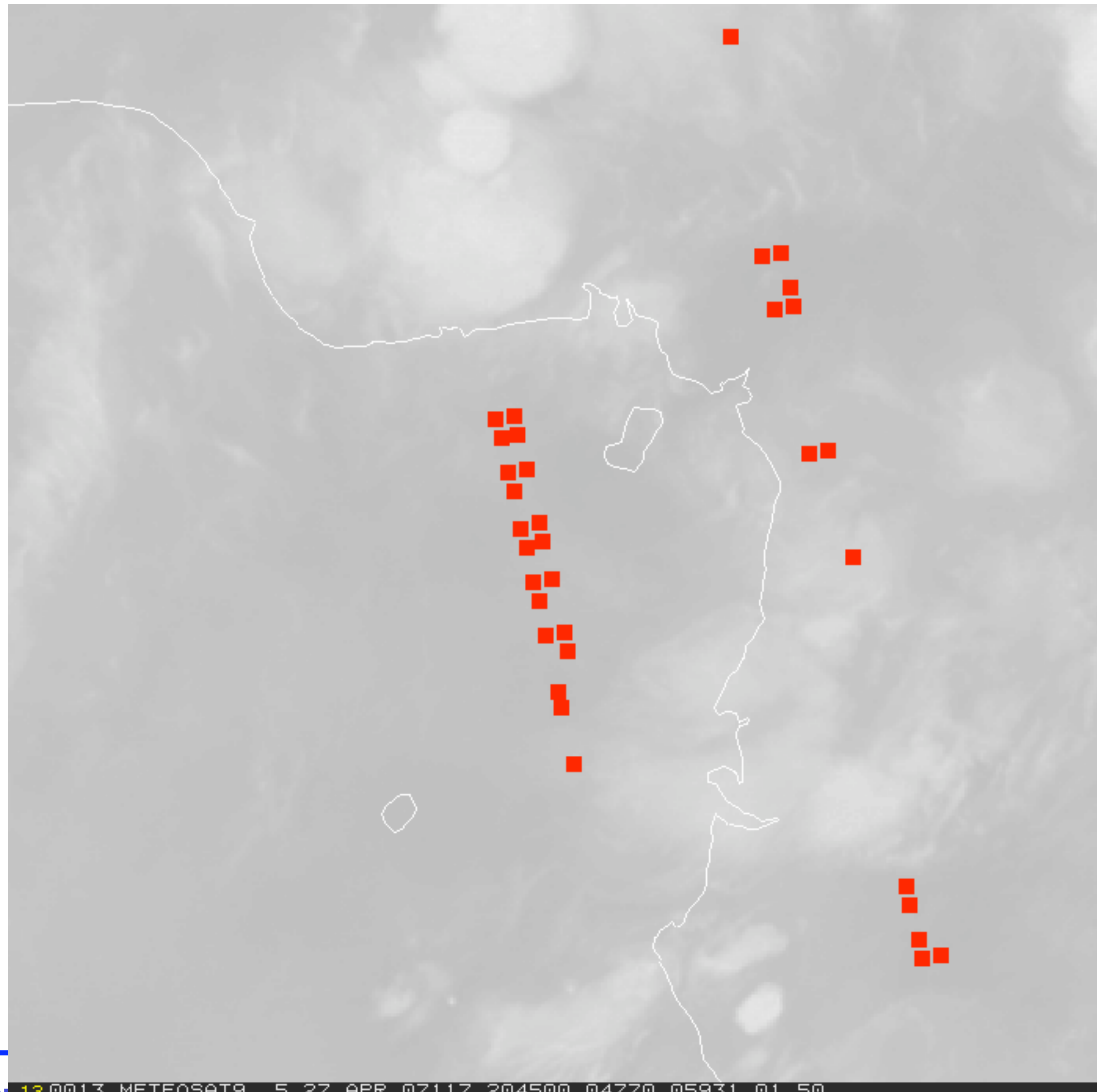
Project Lead: Mitch Goldberg

IASI Spectrum – MSG Filter

(Koenig)



"Homogeneous" Targets (WV6.2)



Meteosat-8

and

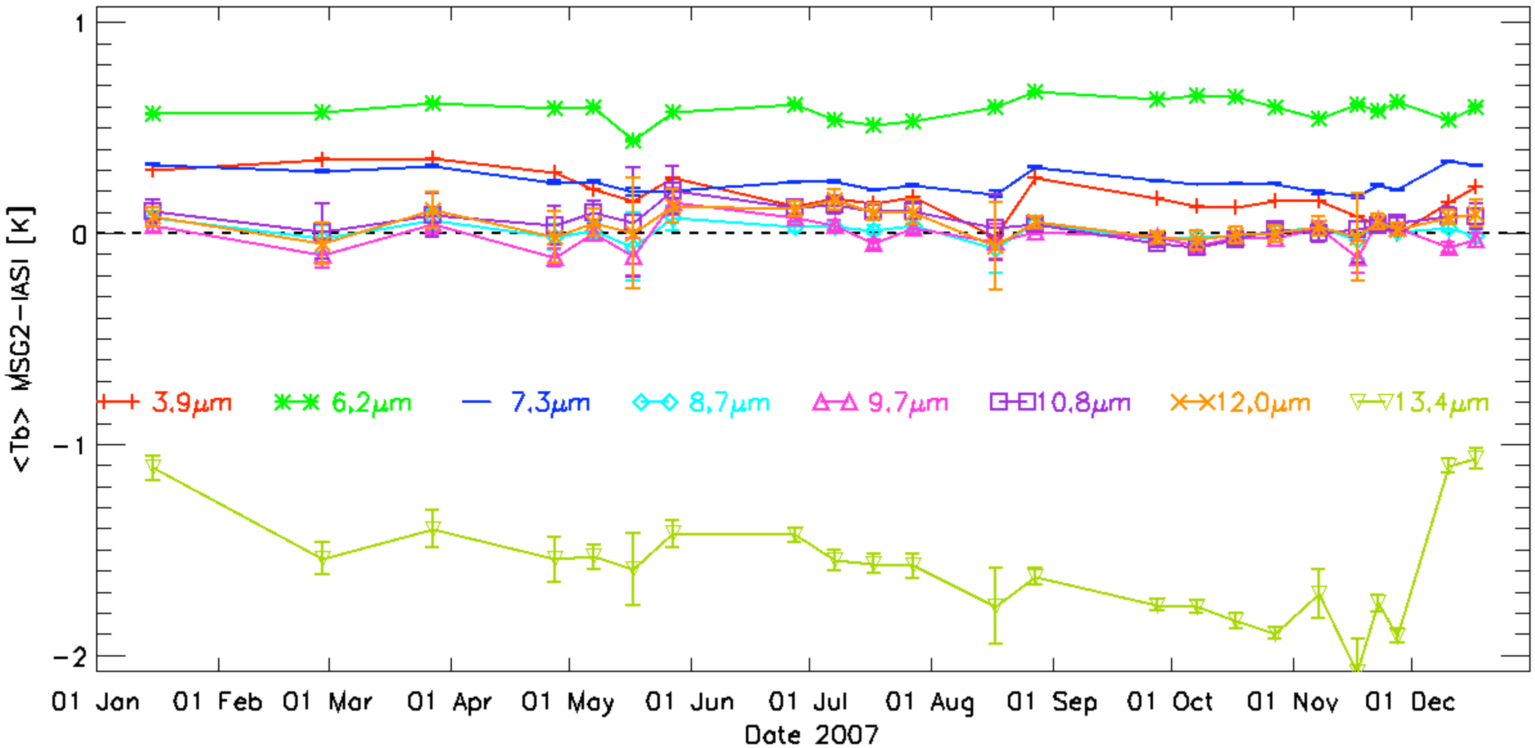
Meteosat-9

Results for 27 April 2007

Channel	ΔT IASI – Meteosat-8*	ΔT IASI – Meteosat-9 *
IR3.9	-0.17	-0.20
WV6.2	-0.24	-0.40
WV7.3	-0.51	-0.14
IR8.7	0.15	0.15
IR9.7	0.17	0.20
IR10.8	0.16	0.07
IR12.0	0.19	0.08
IR13.4	0.44	1.7

*Uncertainty 0.1 – 0.2 K

Time Series of MSG - IASI

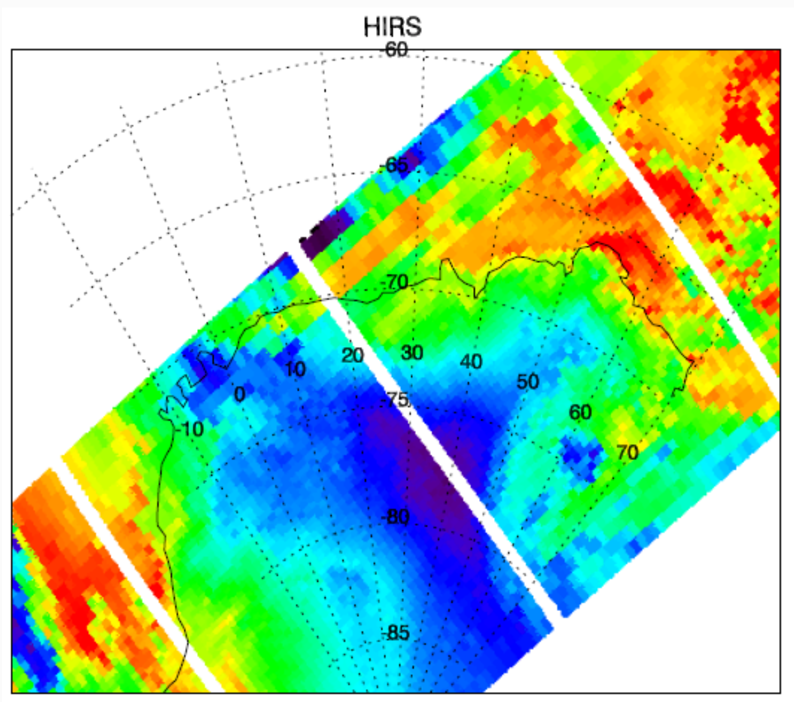


M. König &
T. Hewison

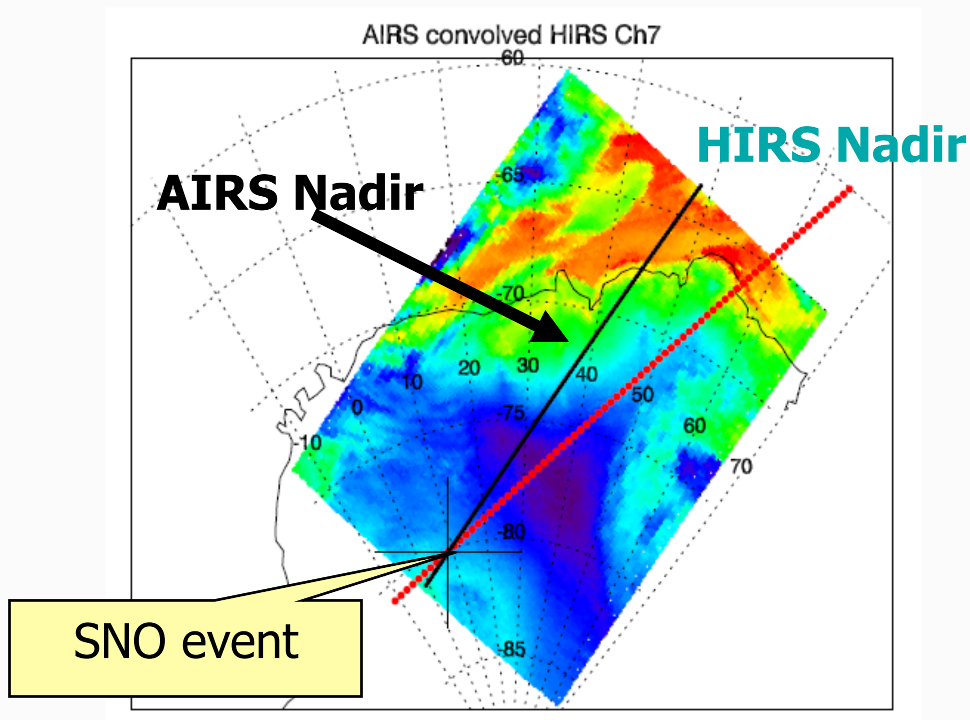
Decontamination

Example

At Intersection: Time difference: <30 Sec
Distance: < 20 km



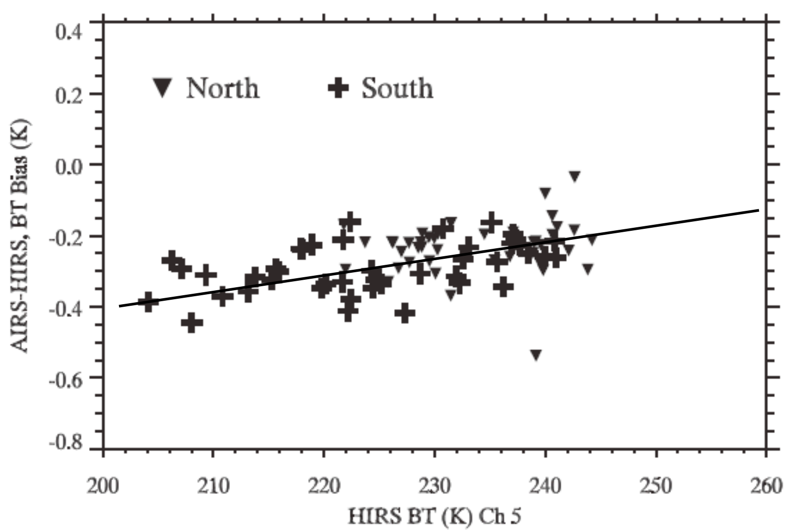
HIRS Image Channel 7



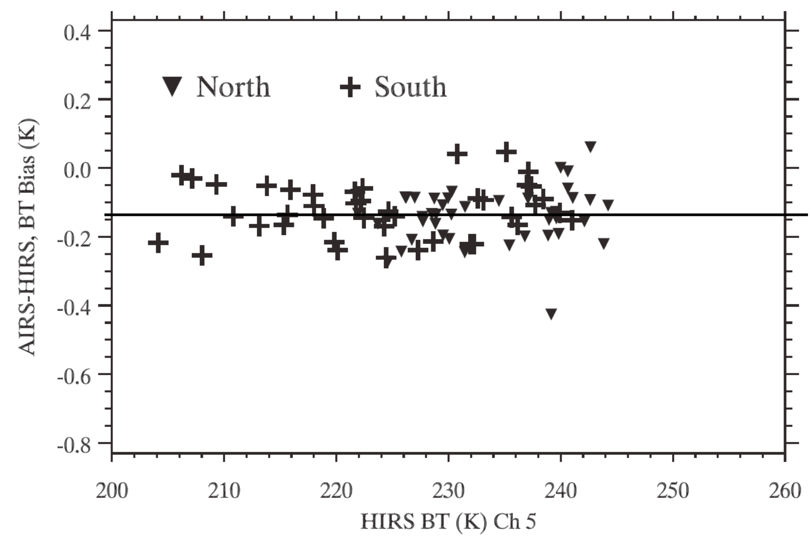
AIRS-convolved HIRS Image Channel 7

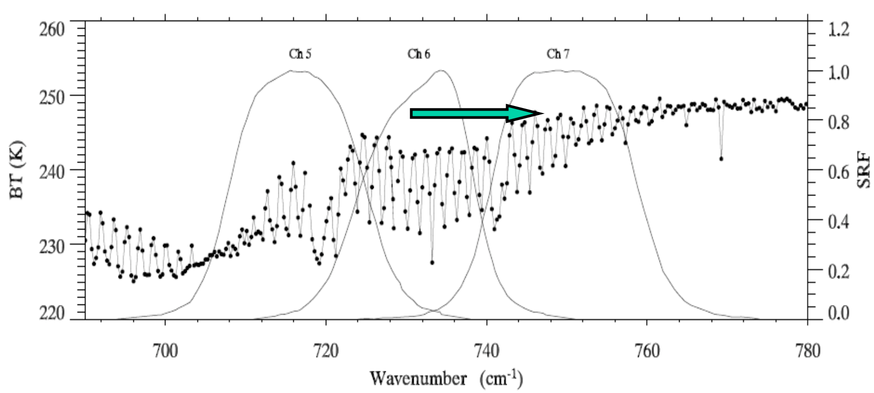
SRF Shift for HIRS Channel 6

Without SRF shift



With SRF shift 0.2 cm-1





Since the HIRS sounding channels are located at the slope region of the atmospheric spectra, a small shift of the SRF can cause biases in observed radiances.

Details can be referred to Wang et al. (manuscript for JTECH, 2006)

GSICS Outcome

- Coordinated international intersatellite calibration program
- Exchange of critical datasets for cal/val
- Best practices/requirements for monitoring observing system performance (with CEOS WGCV)
- Best practices/requirements for prelaunch characterisation (with CEOS WGCV)
- Establish requirements for cal/val (with CEOS WGCV)
- Advocate for benchmark systems
- Quarterly reports of observing system performance and recommended solutions
- <u>Improved sensor characterisation</u>
- <u>High quality radiances for NWP & Climate</u>
- <u>Close interaction with R/SSC-CM</u>