GOES-R Real-Time Bias Monitoring System

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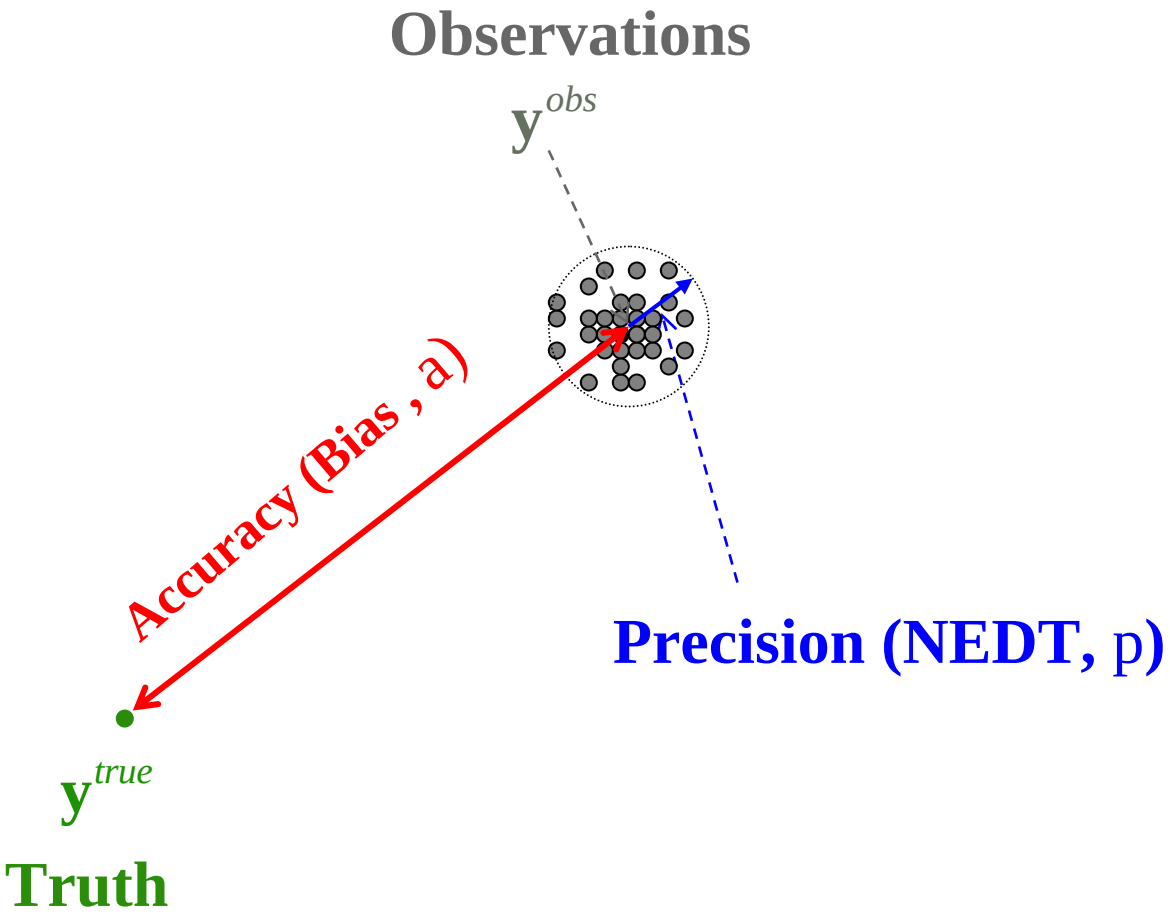
3. ERT Inc.
4. CIRA
5 IMSG Group

2009 TAC Guidance

Systematic radiance bias tuning needs to be undertaken in relation to use of the Community Radiative Transfer Model (CRTM) by the GOES AWG. Systematic LEO/GEO inter calibration particularly with AIRS, IASI and CrIS needs to be undertaken during the GOES mission

AWG Response Summary: We will use CRTM coupled with nwp models to monitor biases over large spatial domains, etc, but ideally we want to correct for ABI biases using LEO to GEO inter-calibration.

Accuracy, Precision and Uncertainty



Uncertainty

$$u = \sqrt{a^2 + p^2}$$

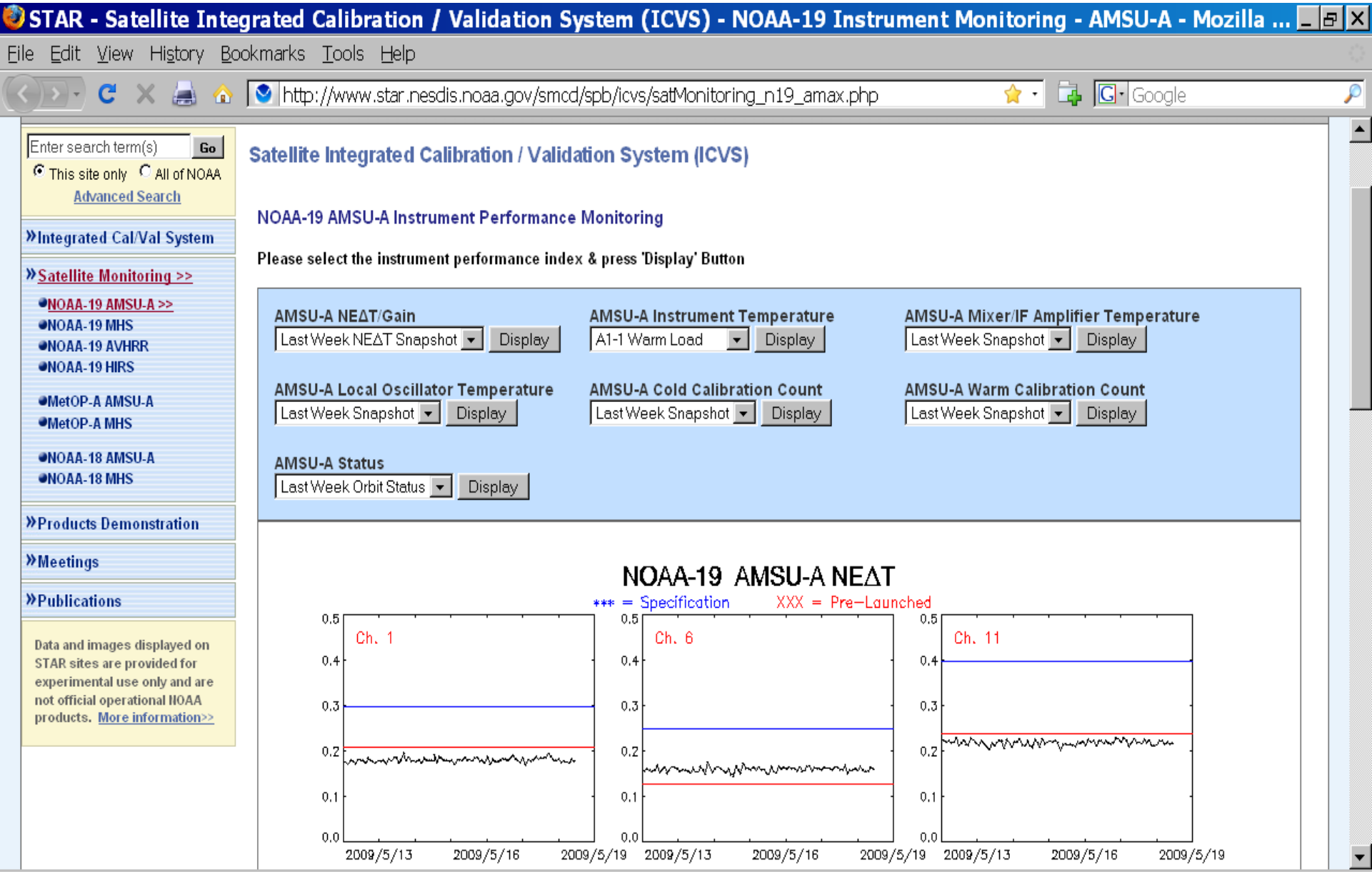
STAR Current Capabilities of Instrument Performance Monitoring

- **Real-time monitoring of in-orbit performance of all the POES/GOES instruments, providing warning to user communities when anomalies occur**

- **Bias corrections of GOES/POES instruments using WMO GSICS algorithms and demonstration of the benefit of bias correction for global and mesoscale NWP**

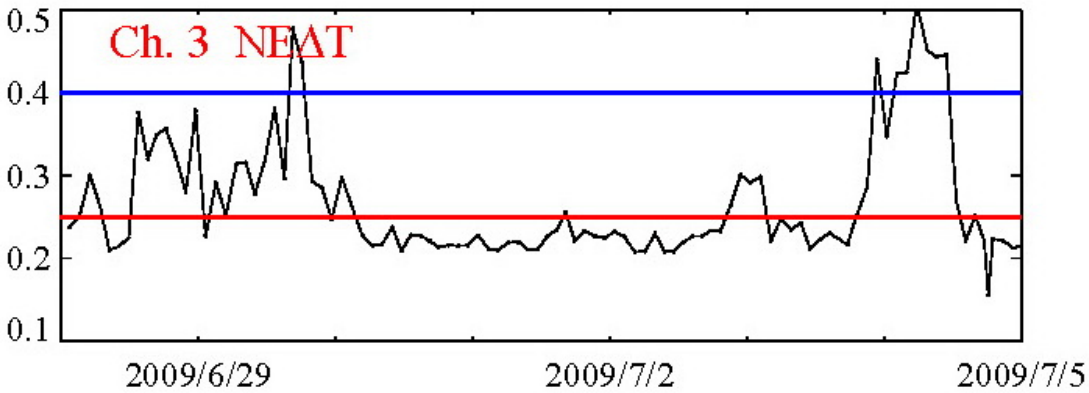
- **Global O-B distributions and O-B statistics of POES instruments using ECMWF and GFS 6 hours forecasts**

Online Capability of STAR Integrated Cal/Val System (ICVS)

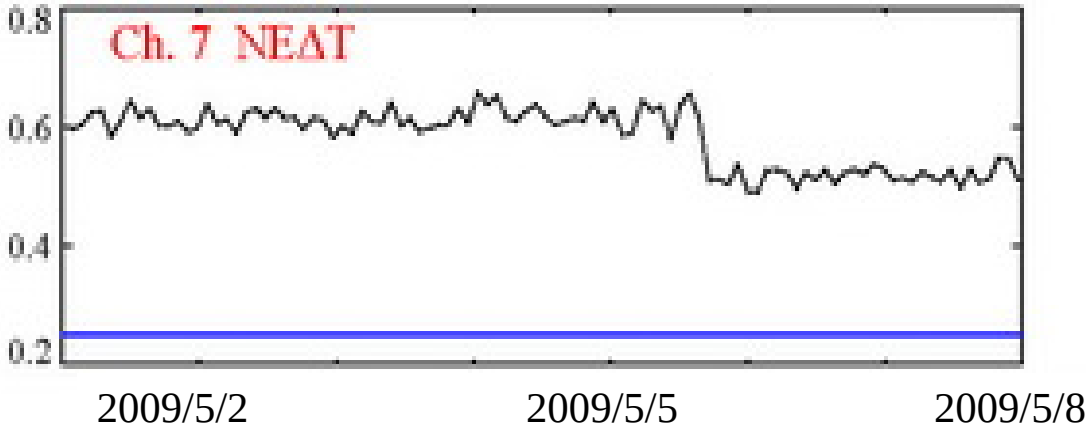


STAR ICVS
Real-Time Monitoring of POES/GOES Instrument Performance

AMSU-A



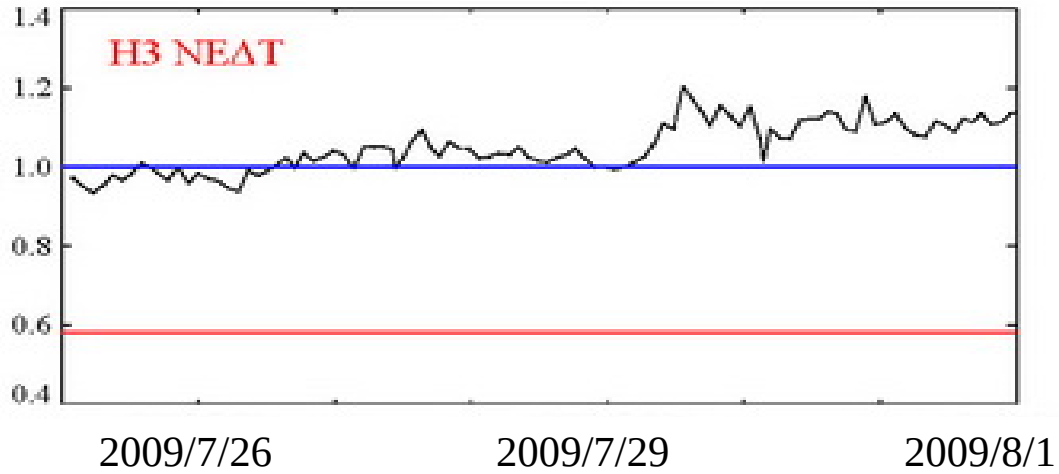
NOAA-19 Ch3
NE Δ T anomaly



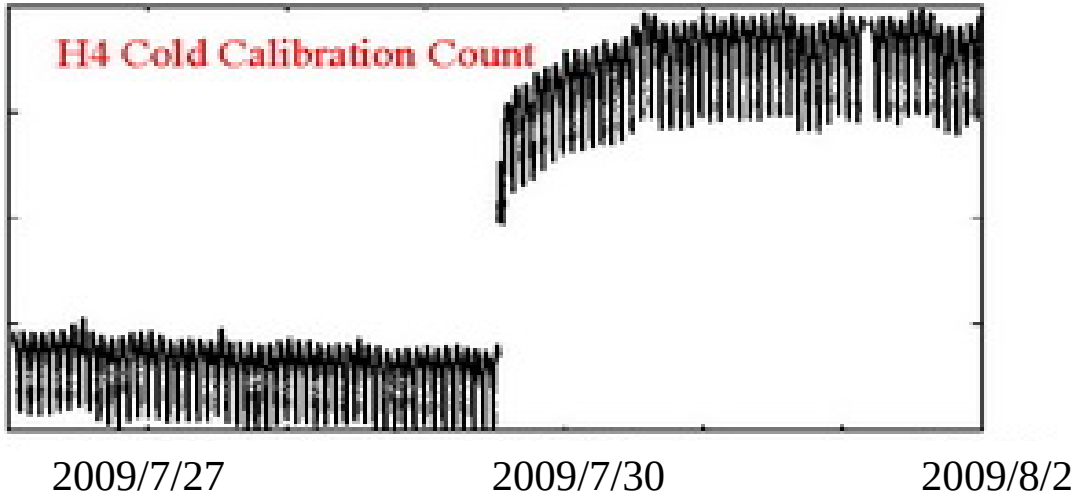
MetOP-A Ch7
NE Δ T Drop

STAR ICVS
Real-Time Monitoring of POES/GOES Instrument Performance

MHS



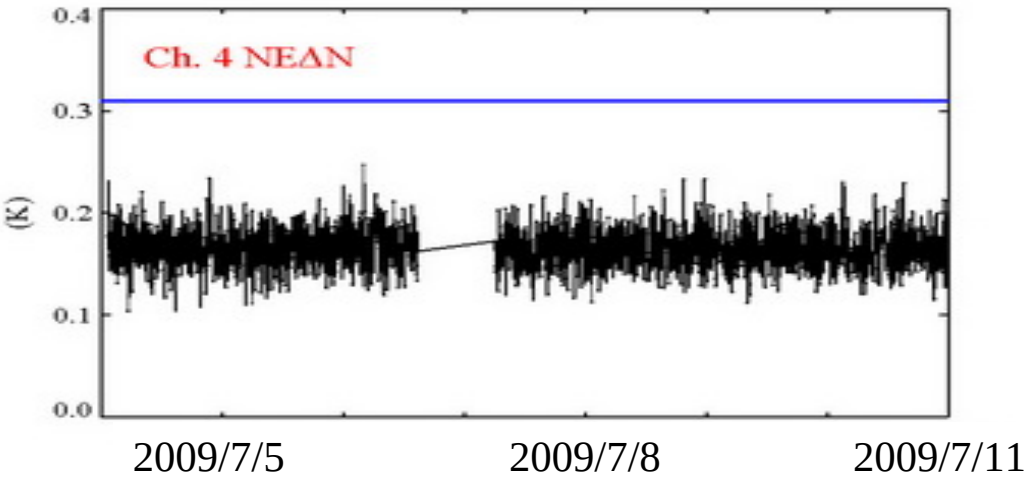
NOAA-19 H3 NEΔT is out of specification



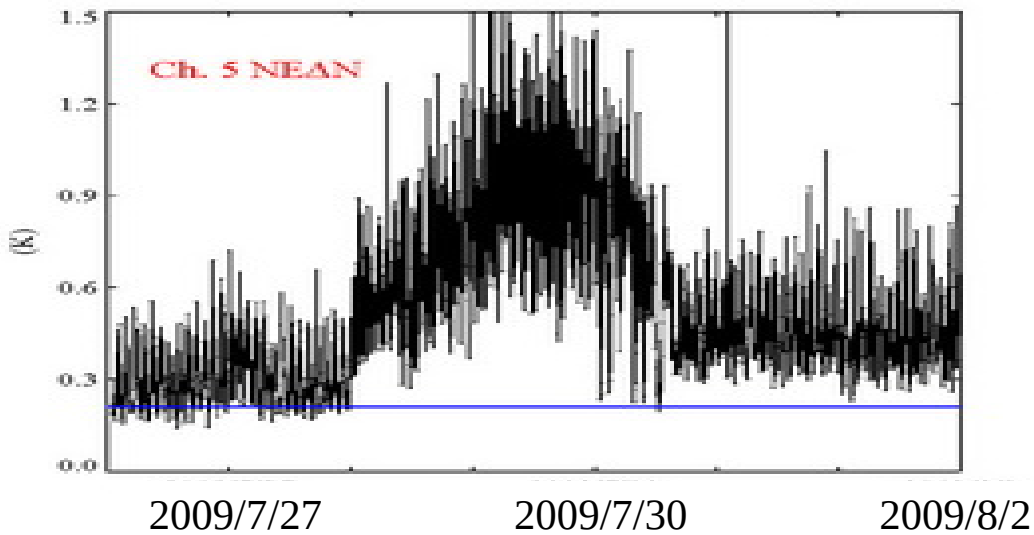
NOAA-19 H4 cold calibration count jumps

STAR ICVS
Real-Time Monitoring of POES/GOES Instrument Performance

HIRS



NOAA-19 Ch4
Data Gaps



NOAA-18 Ch5
NEΔN Anomaly

STAR ICVS
Real-Time Monitoring of POES/GOES Instrument Performance

Since its operation, STAR ICVS has captured all of the major instrument anomaly events associated with

- N18 HIRS loose lens
- N19 MHS Ch3/4 IF oscillators)

on NOAA/METOP-A satellites through

- trending noise
- telemetry and
- house-keeping information

URL: http://www.star.nesdis.noaa.gov/smcd/spb/icvs/satMonitoring_n19_amax.php

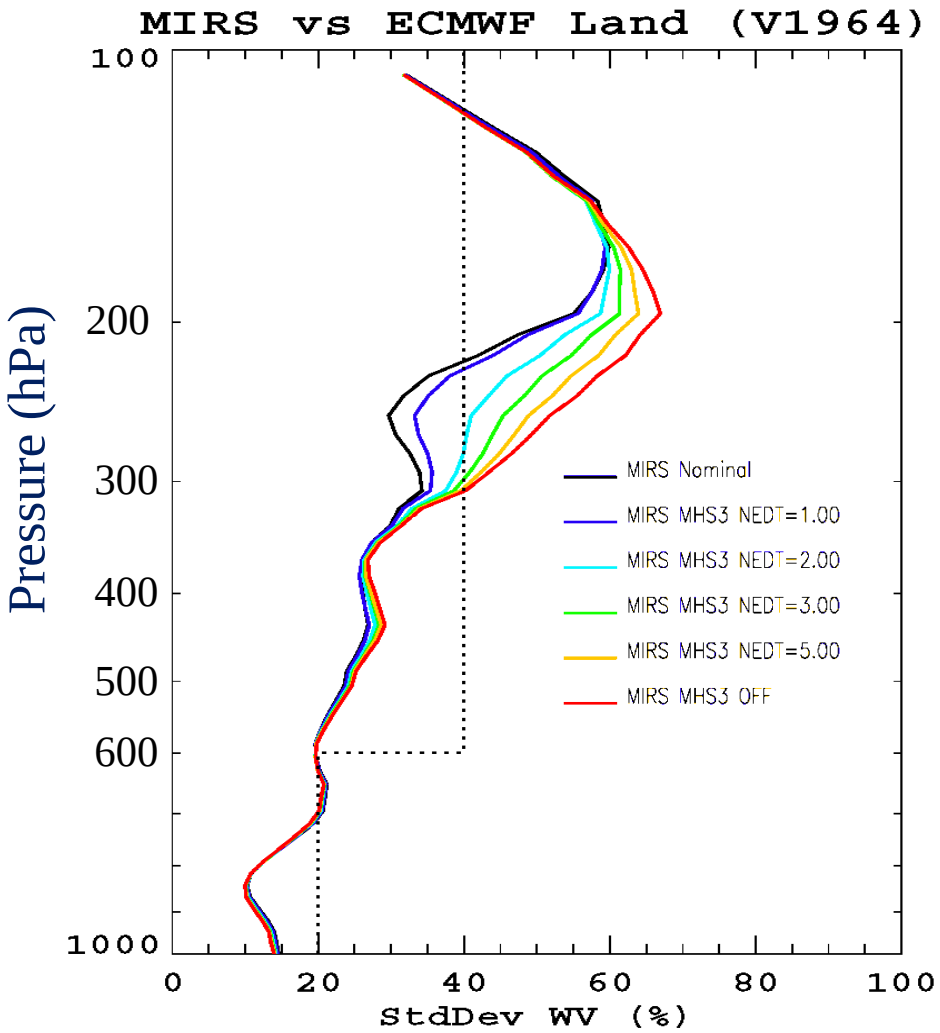
Sensitivity of Physical Retrievals to Instrument Noise (NEDT)

Experiment design:

Carry out MIRS retrievals from AMSU-/MHS radiances simulated from 60 ECMWF profiles with different NEDT for MHS Ch3

Conclusion:

When NEDT at MHS Ch3 NEDT exceeds 3K, the products exceed the IORD-II requirements.



Unknown Instrument Biases Can Seriously Degrade Application Quality

- The biased data if being assimilated into NWP system will likely mess up data assimilation results and lower the forecast scores

  All DA algorithms require biases be removed before DA

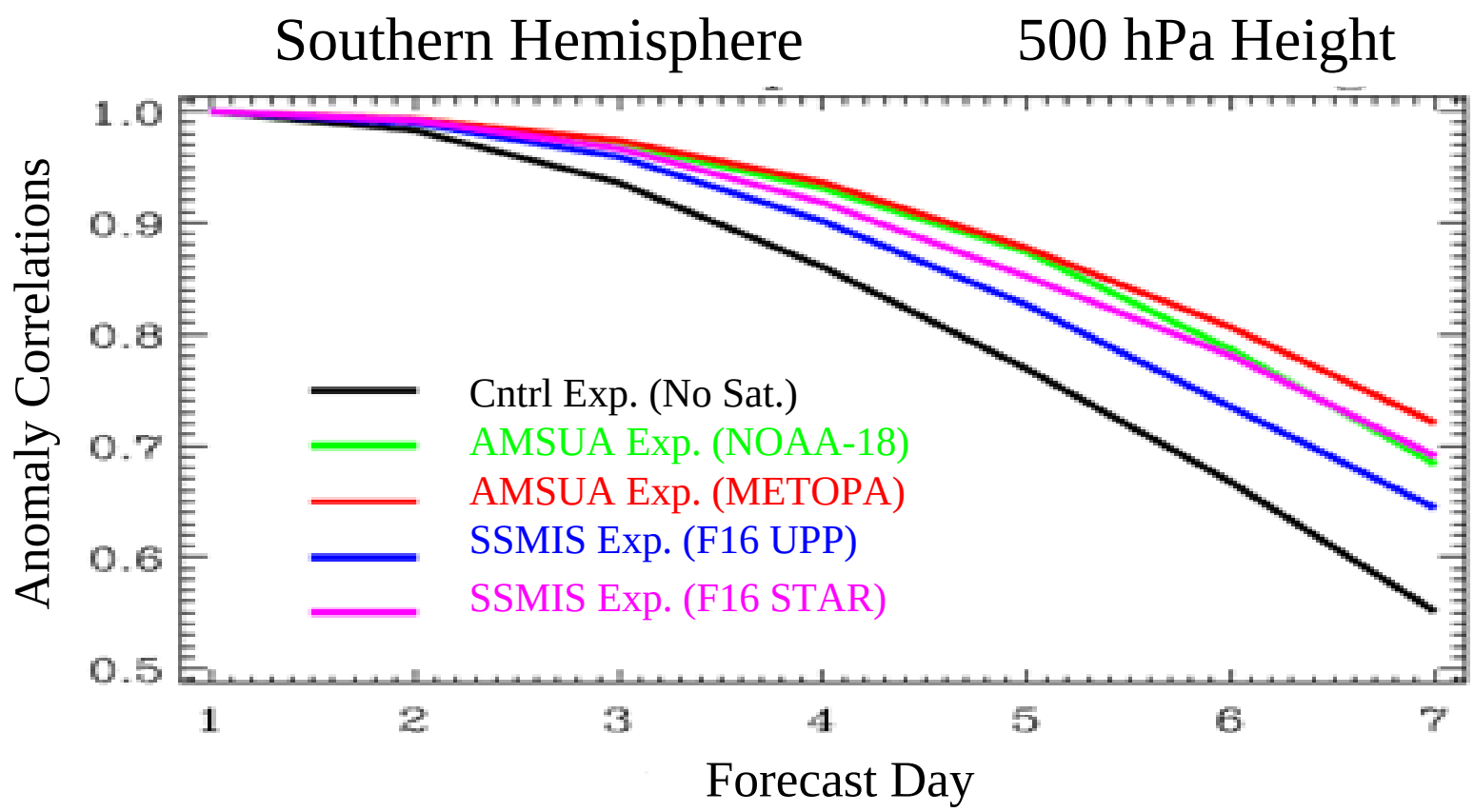
- Satellite products derived from biased data will be biased

  A dynamic bias correction is needed to avoid this from happening.

- Good data may be rejected

  The data with some large biases may be very useful.

Impacts of SSMIS Bias Correction Algorithms on Forecast Score

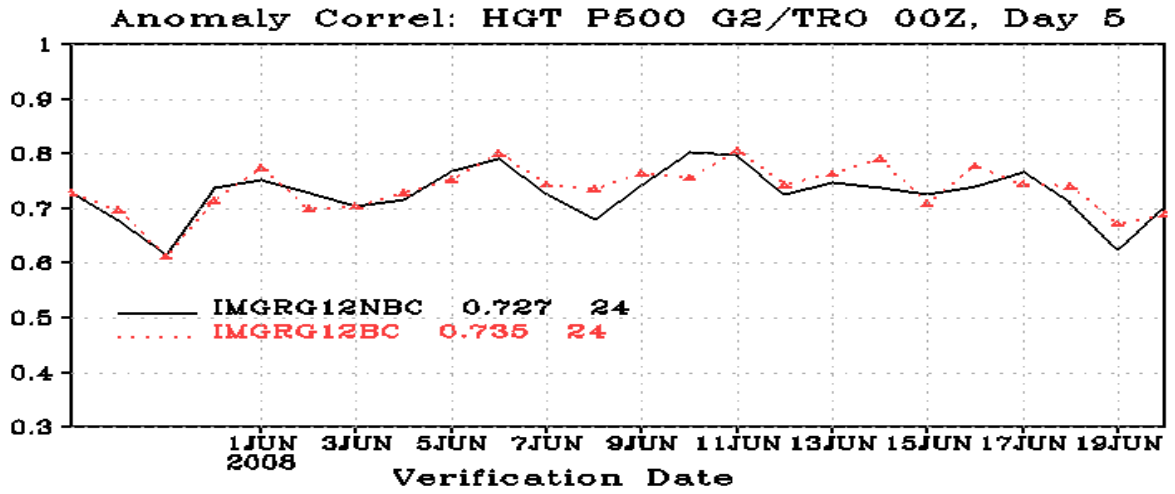


The NRL UPP bias correction algorithm (blue) results in smaller impacts, compared to the NESDIS algorithm (pink).

GOES-12 Imager Impacts with and without GSICS Calibration Correction

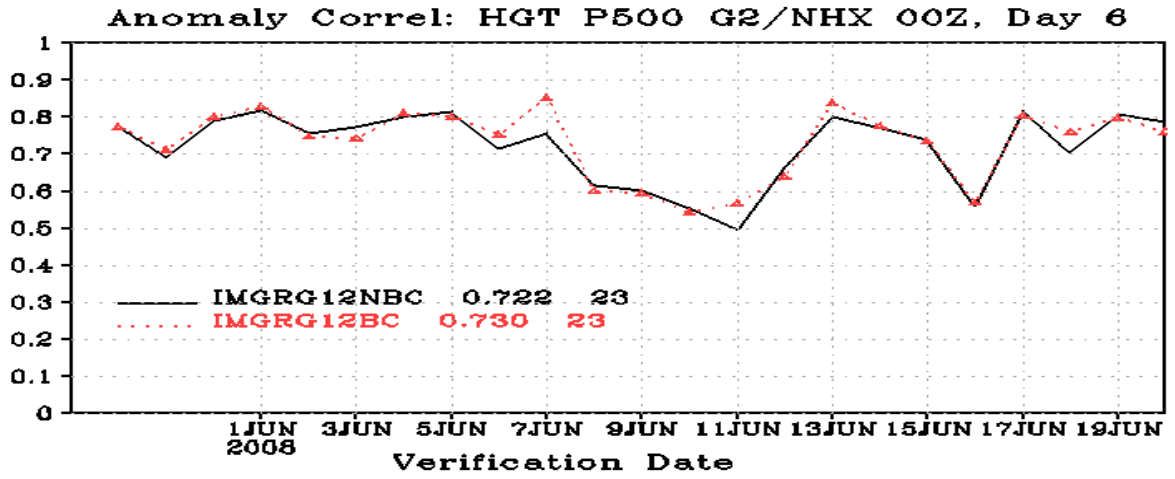
AC for 500 mb Height in Tropics

Forecast Day-5

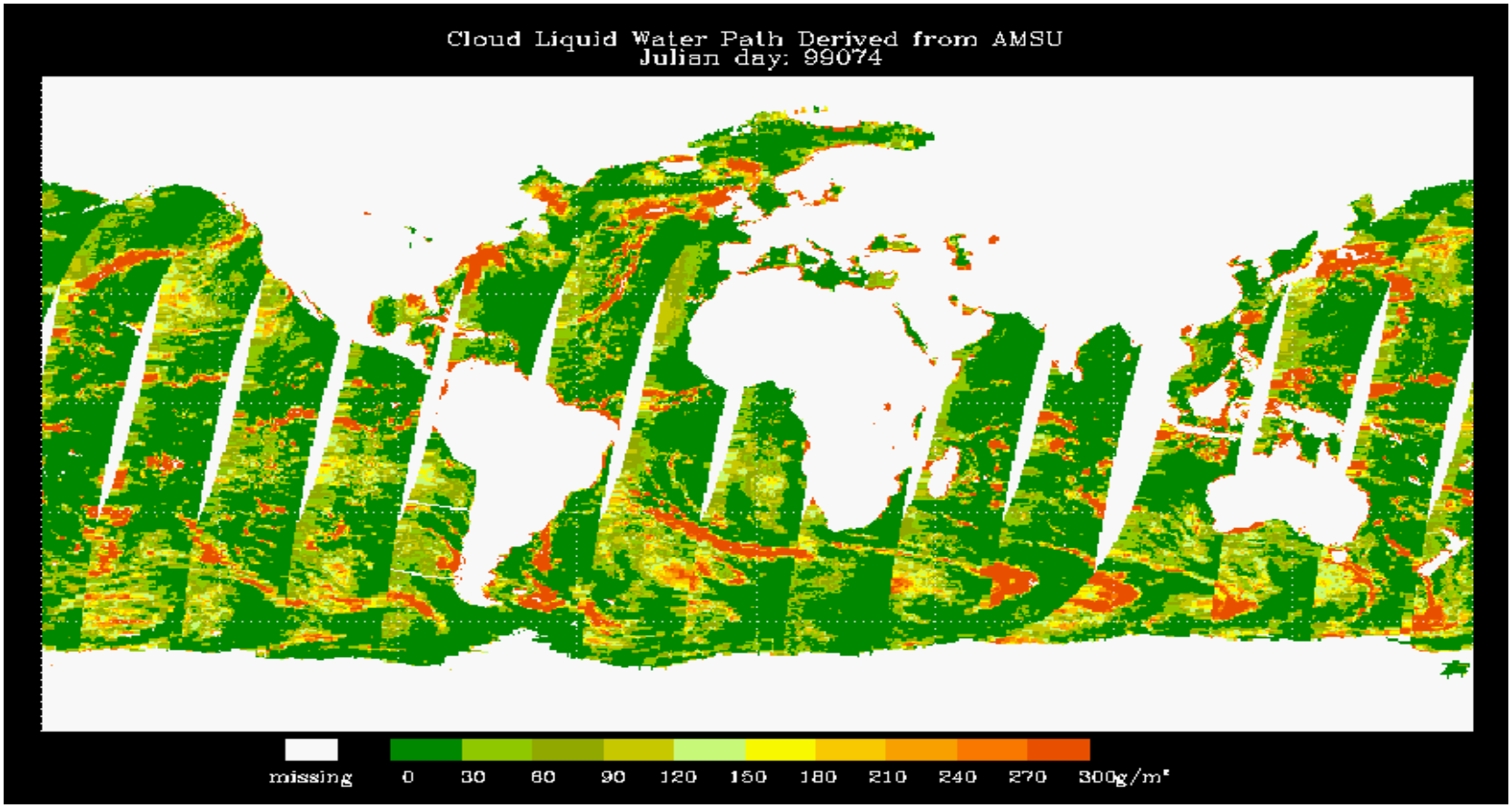


AC for 500 mb Height in NH

Forecast Day-6

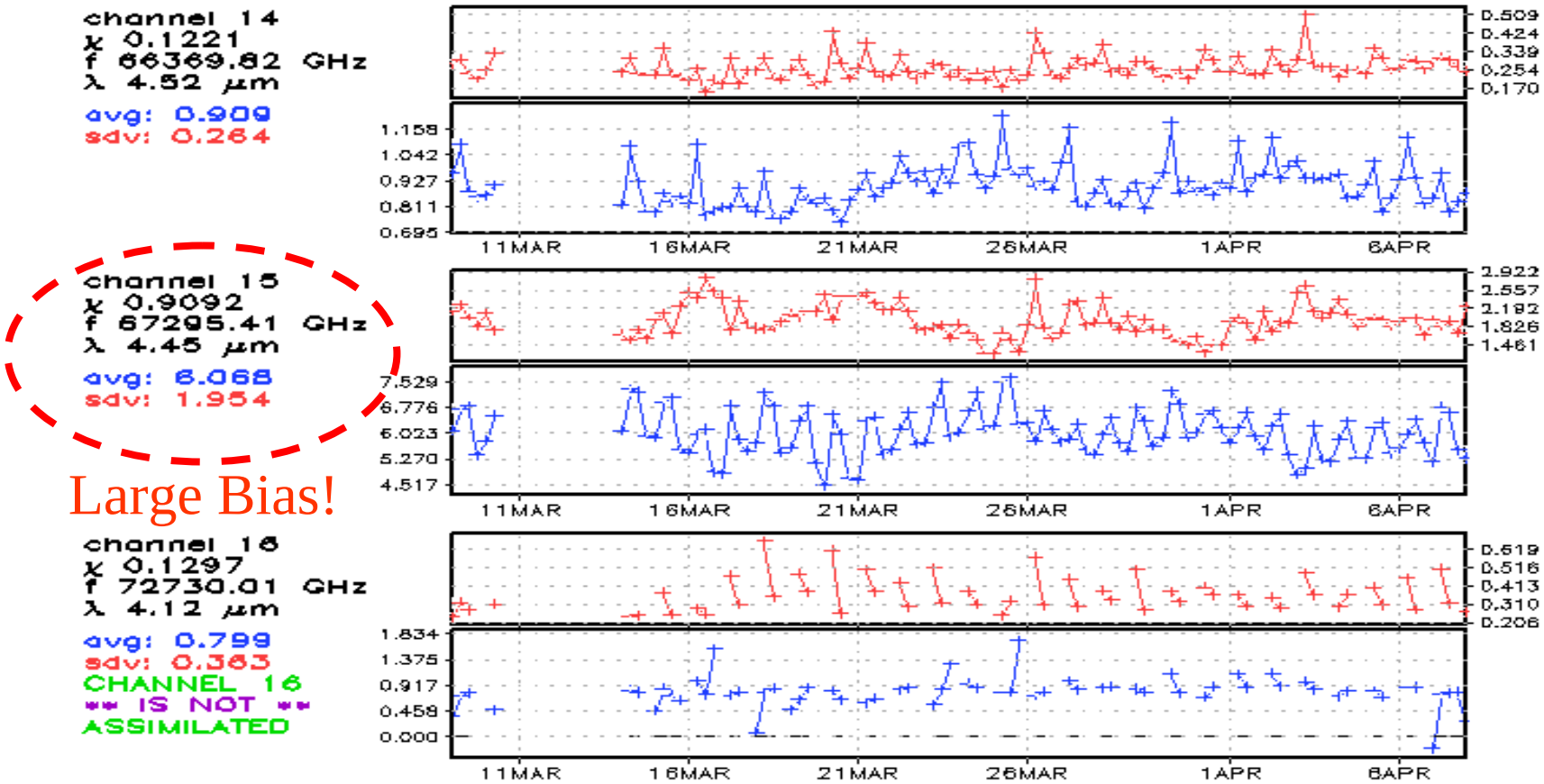


NOAA-15 AMSU Cross-Scan Bias on Cloud Liquid Water Products



Artificial cloud features are seen on the scan edge, which results in from AMSU-A Ch2 radiance biases.

GOES-11 Sounder Bias



GOES-11 Souder Ch15 displays large biases due largely to inaccurate Spectral Response Function (SRF).

Technical Approaches for Bias Monitoring

1) Radiance bias estimation using NCEP NWP model fields

Real-time calculation and display of BT differences between data and background simulated using NWP forecast fields (O-B)

2) WMO GSICS Algorithms for Radiance Bias Correction

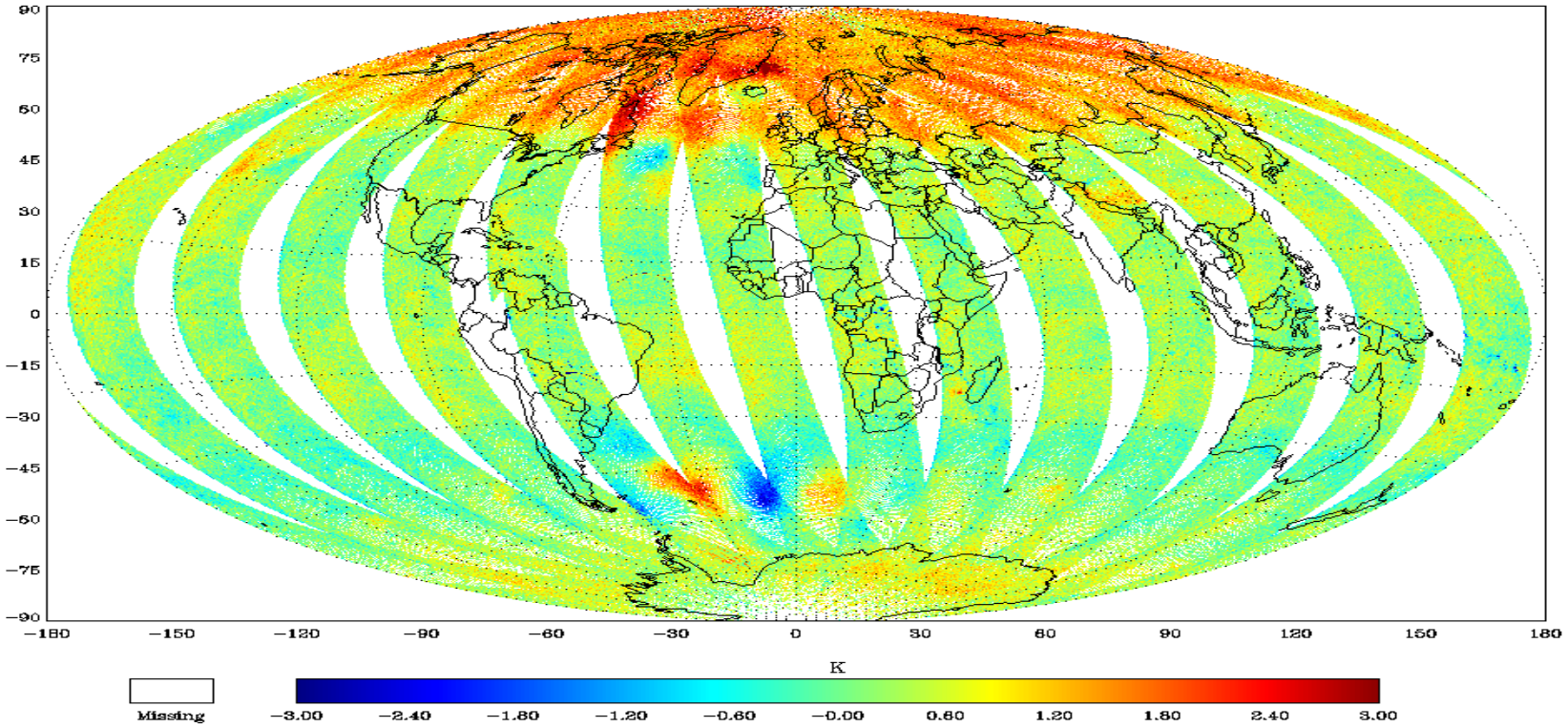
POES/GOES cross-sensor biases

3) Radiance bias estimation using in-situ data at validation sites

High quality sondes and/or GPS/RO data

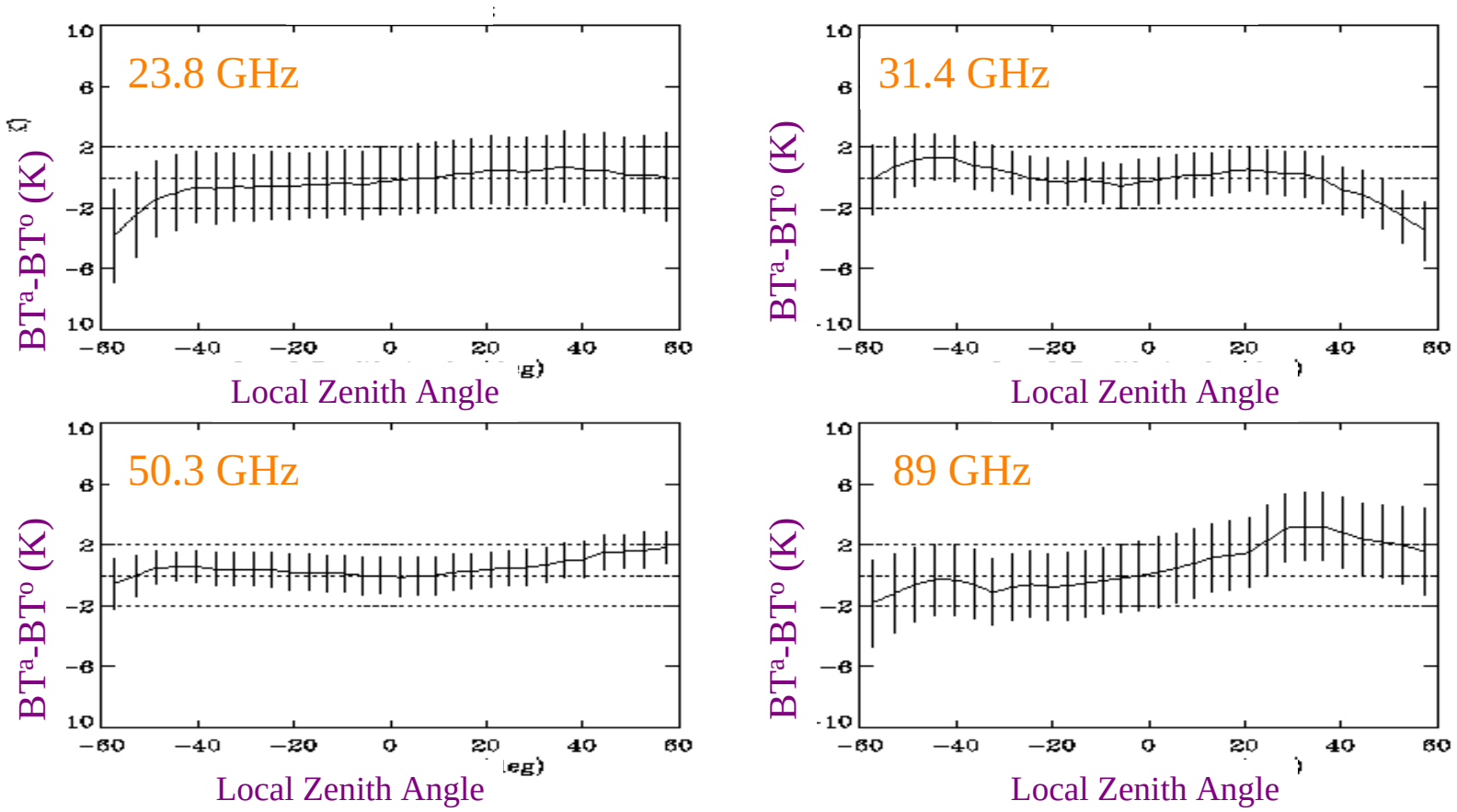
A Prototype Demonstration

SSM/IS Tb Bias (Obs-Sim) at 54.4 GHz V-Pol
2006-02-03



DMSP F16 SSMIS instrument anomalies were captured by O-B monitoring!

Characterization of AMSU-A Scan Bias (O-A) over Oceans

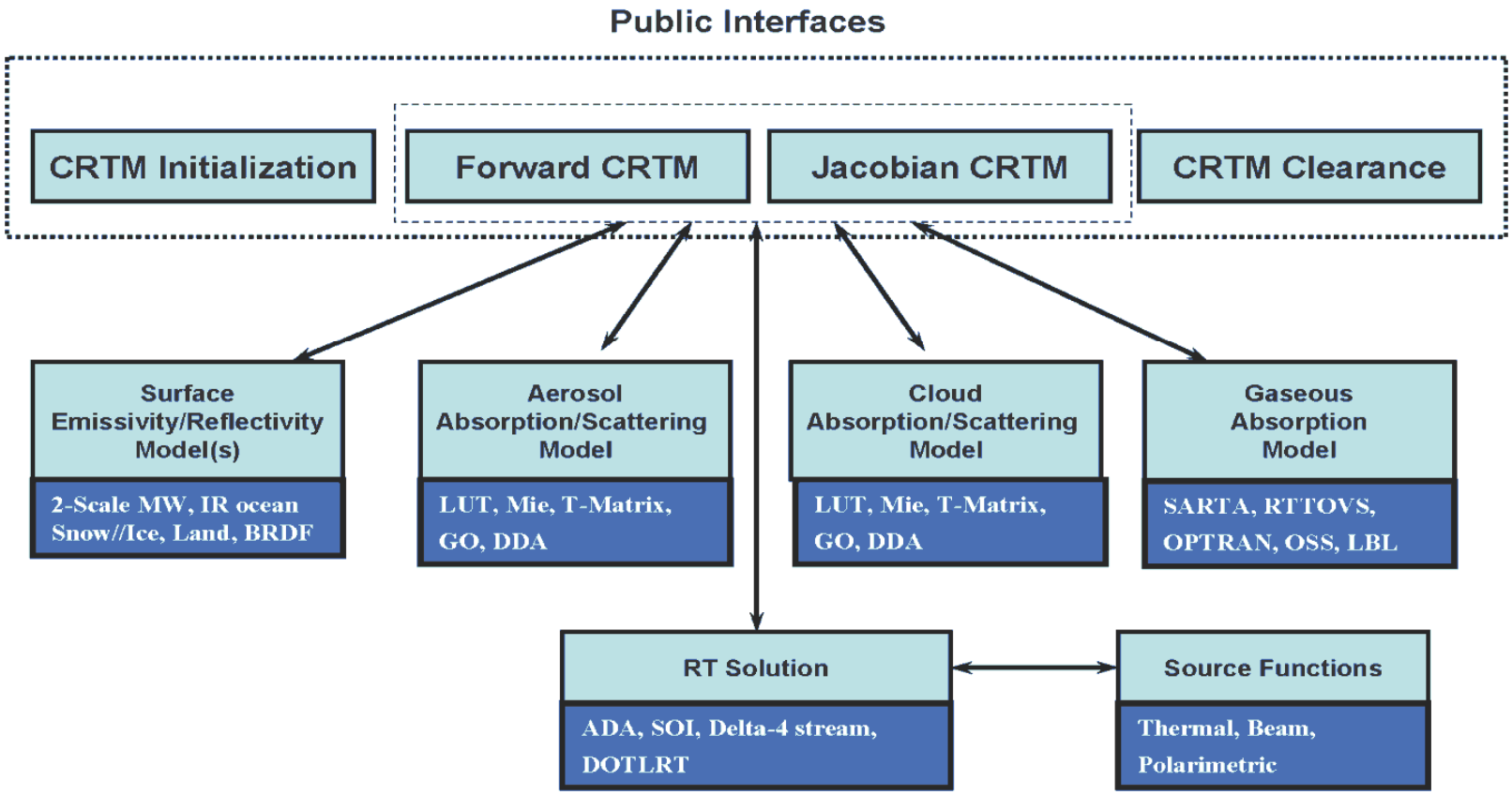


$$\overline{\Delta T_b^{\alpha}} = A_0^{\alpha} e^{-\frac{1}{2}\left(\frac{\theta - A_1^{\alpha}}{A_2^{\alpha}}\right)^2} + A_3^{\alpha} + A_4^{\alpha}\theta + A_5^{\alpha}\theta^2$$

(Weng et al., 2003)

Real-Time O-B Monitoring Requires Highly Accurate & Fast Forward RTM

Community Radiative Transfer Model (CRTM)

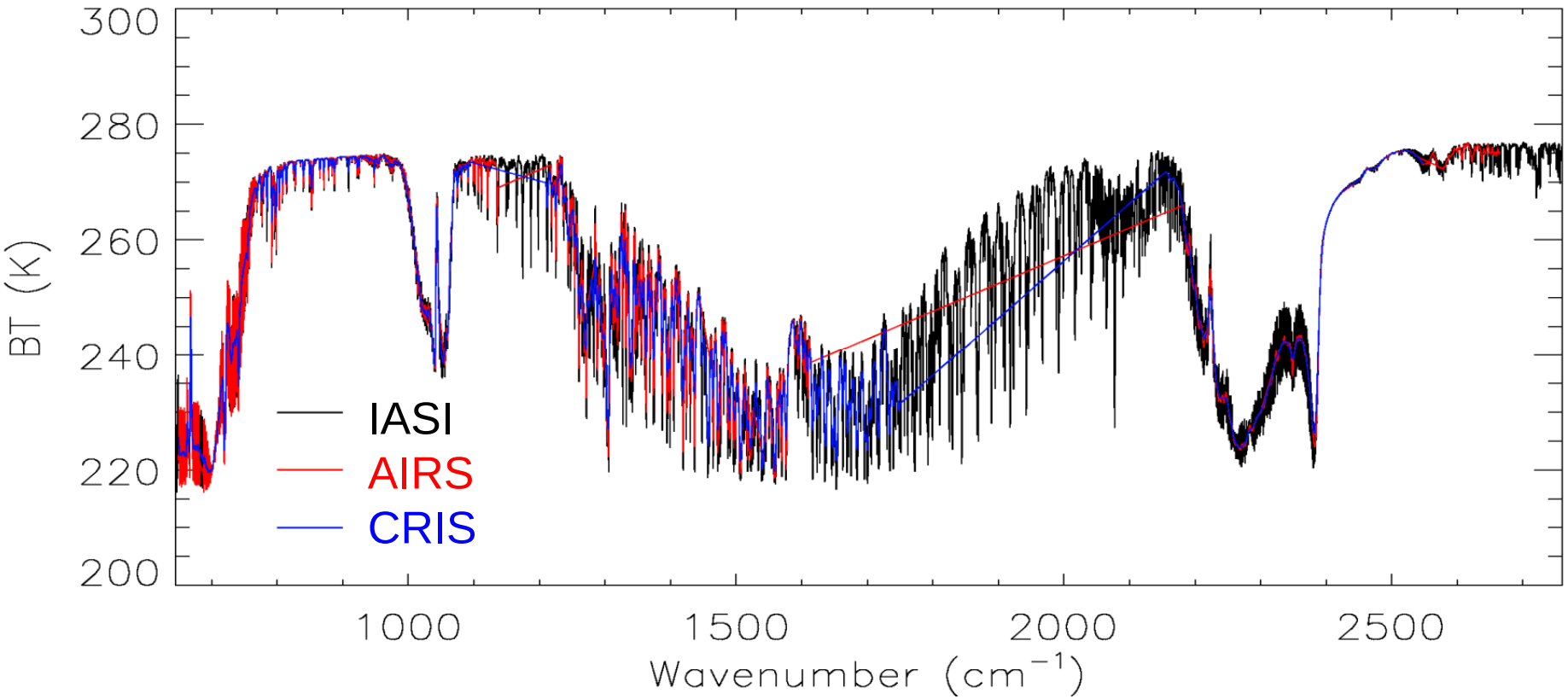


CRTM Support over 100 Sensors

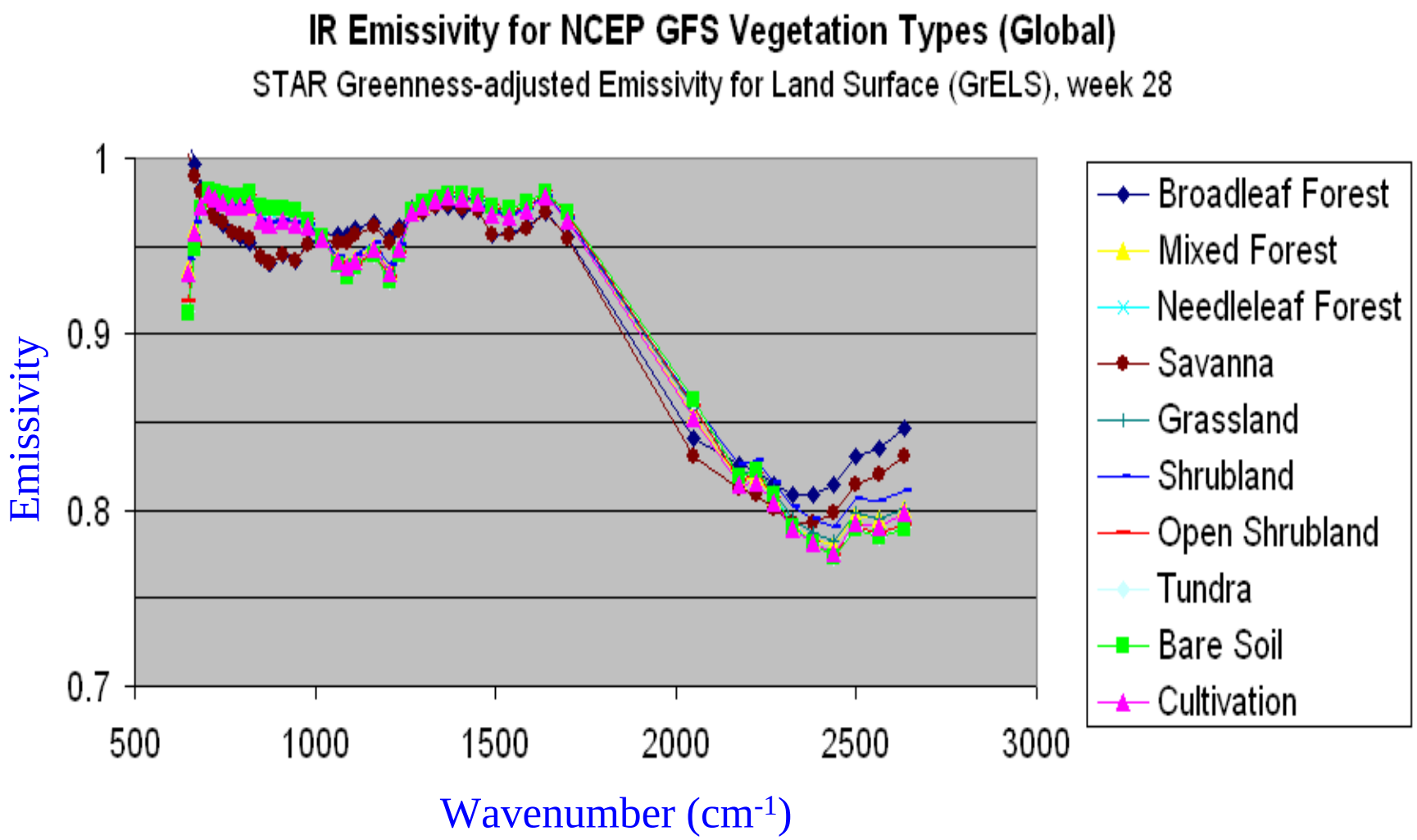
- GOES-R ABI
- Metop IASI/HIRS/AVHRR/AMSU/MHS
- TIROS-N to NOAA-18 AVHRR
- TIROS-N to NOAA-18 HIRS
- GOES-8 to 13 Imager channels
- GOES-8 to 13 sounder channels
- Terra/Aqua MODIS Channels 1-10
- METEOSAT-SG1 SEVIRI
- Aqua AIRS
- Aqua AMSR-E
- Aqua AMSU-A
- Aqua HSB
- NOAA-15 to 18 AMSU-A
- NOAA-15 to 17 AMSU-B
- NOAA-18 MHS
- TIROS-N to NOAA-14 MSU
- DMSP F13 to15 SSM/I
- DMSP F13,15 SSM/T1
- DMSP F14,15 SSM/T2
- DMSP F16-20 SSMIS
- NPP ATMS/CrIS
- Coriolis Windsat
- TiROS-NOAA-14 SSU

"Technology transfer made possible by CRTM is a shining example for collaboration among the JCSDA partners and other organizations, and has been instrumental in the JCSDA success in accelerating uses of new satellite data in operations" – Dr. Louis Uccellini, Director of National Centers for Environmental Prediction

CRTM Infrared Spectroscopy Corresponding to AIRS, IASI and CrIS

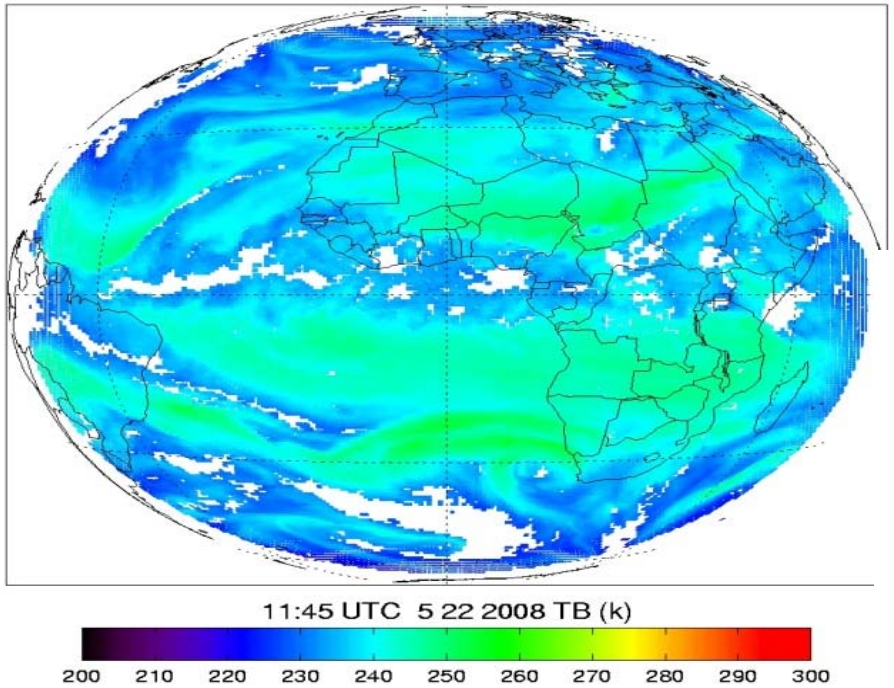


O-B Requires Visible Reflectance and IR Emissivity Information



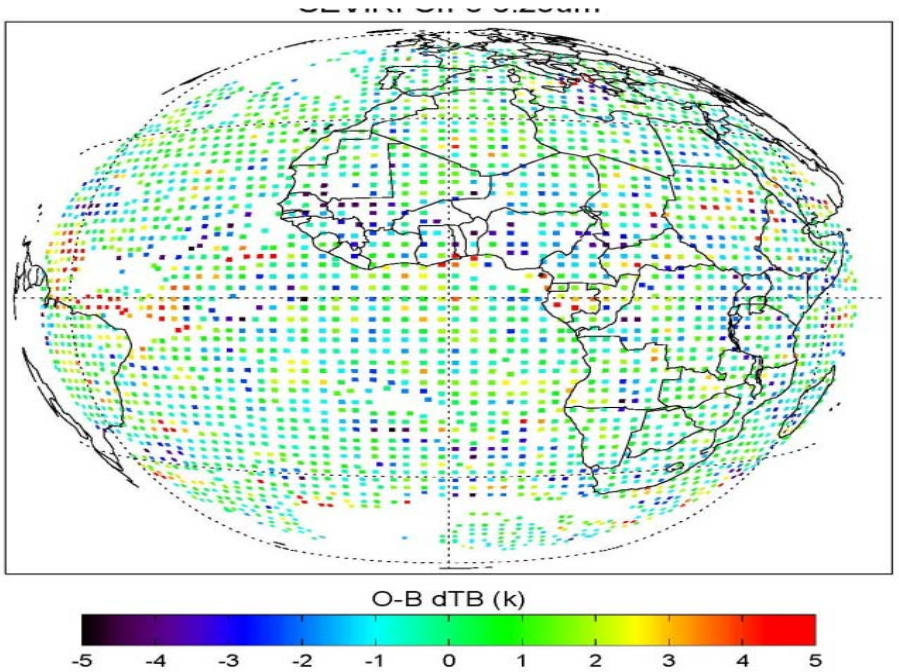
CRTM Used for MSG SEVIRI Sensor Simulations (Channel 5, 6.25 mm)

Obs.

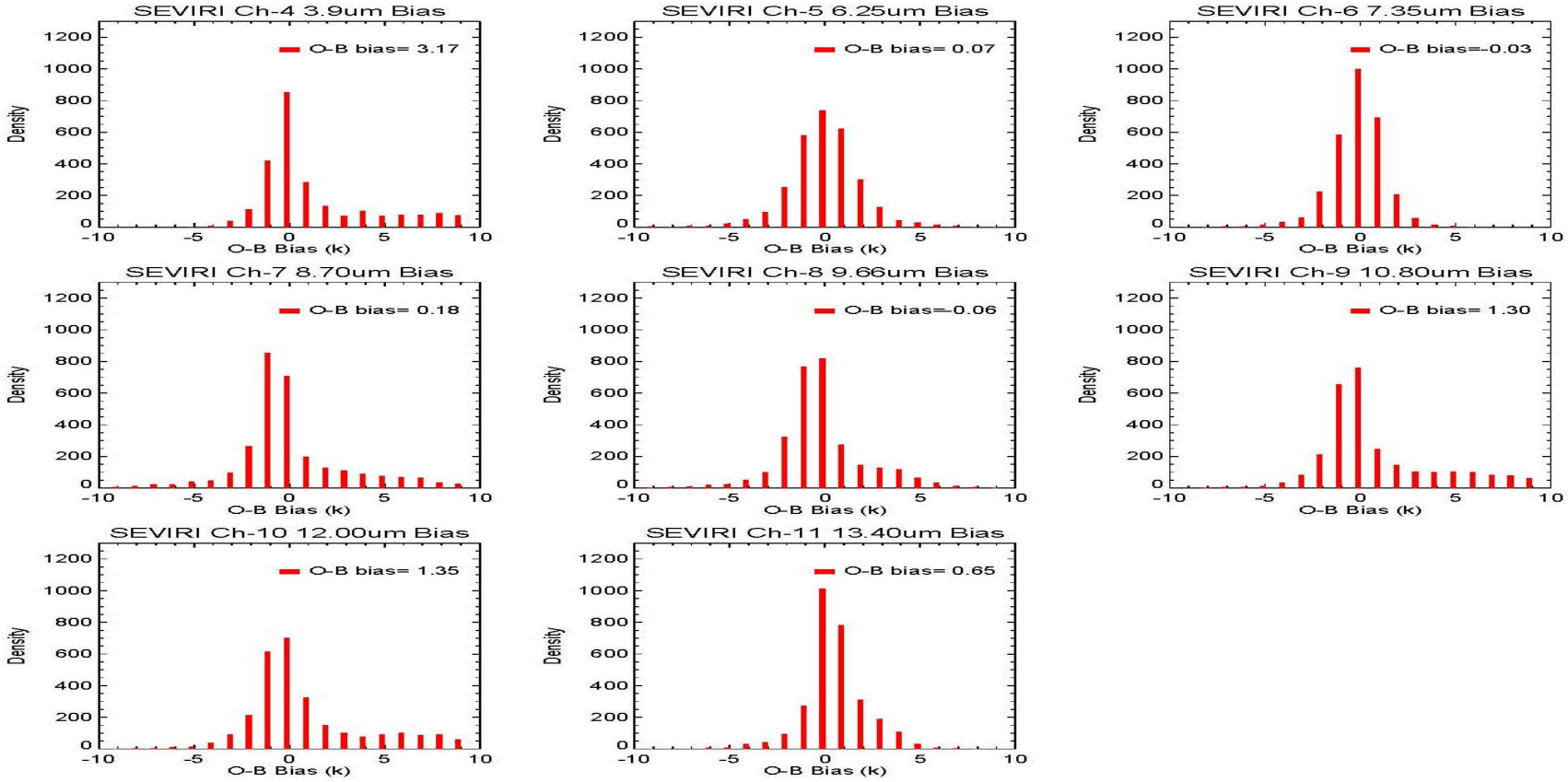


11:45 UTC May 22, 2008

O-B



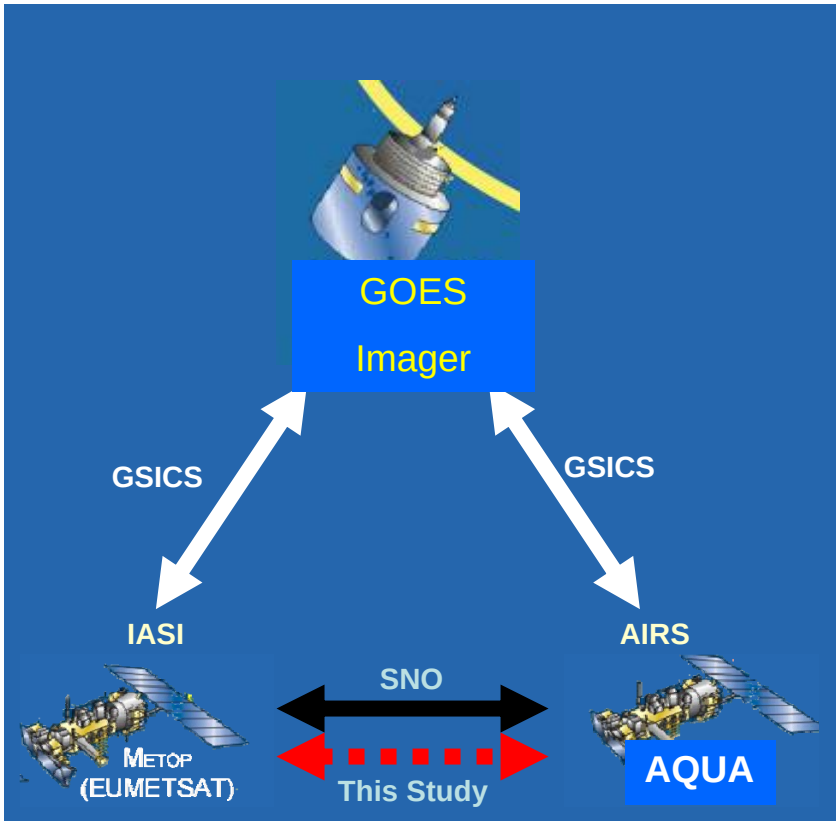
SEVIRI IR Bands (Ch4-11) Bias Distribution



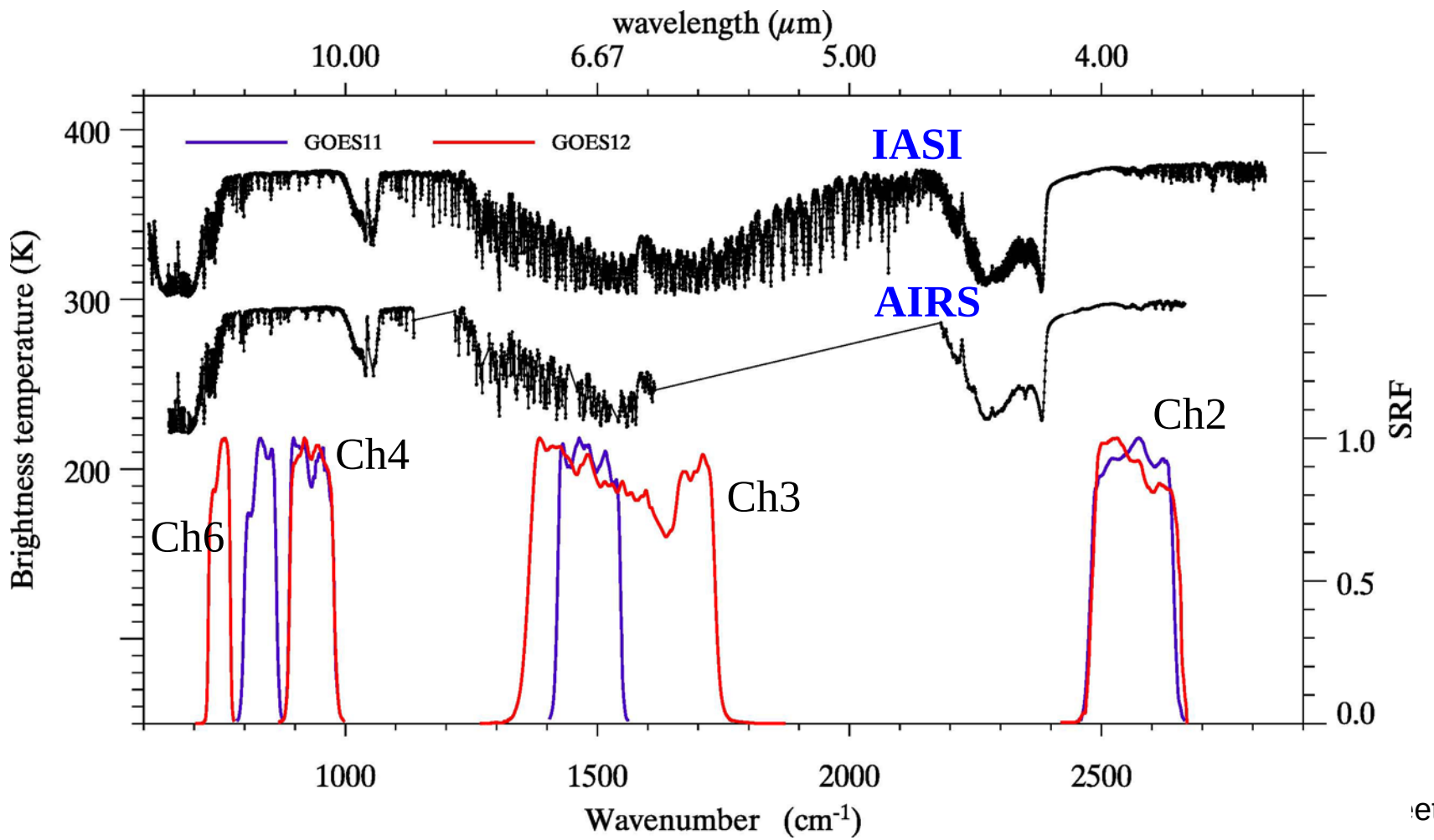
Surface sensitive channels display the distribution functions of non-Gaussian types and more related to GFS model biases in Ts, and forward model biases in emissivity

Radiance Bias Correction from WMO Global Space-based Intersatellite Calibration System (GSICS) Algorithms

- AIRS vs. IASI
  - Direct comparison using SNO
  - Double Difference Method through a transfer target
- GSICS
  - GOES-AIRS
  - GOES-IASI
  - (GOES-AIRS) vs. (GOES-IASI)



Another Prototype Demonstration
GOES-12 Imager Bias Correction



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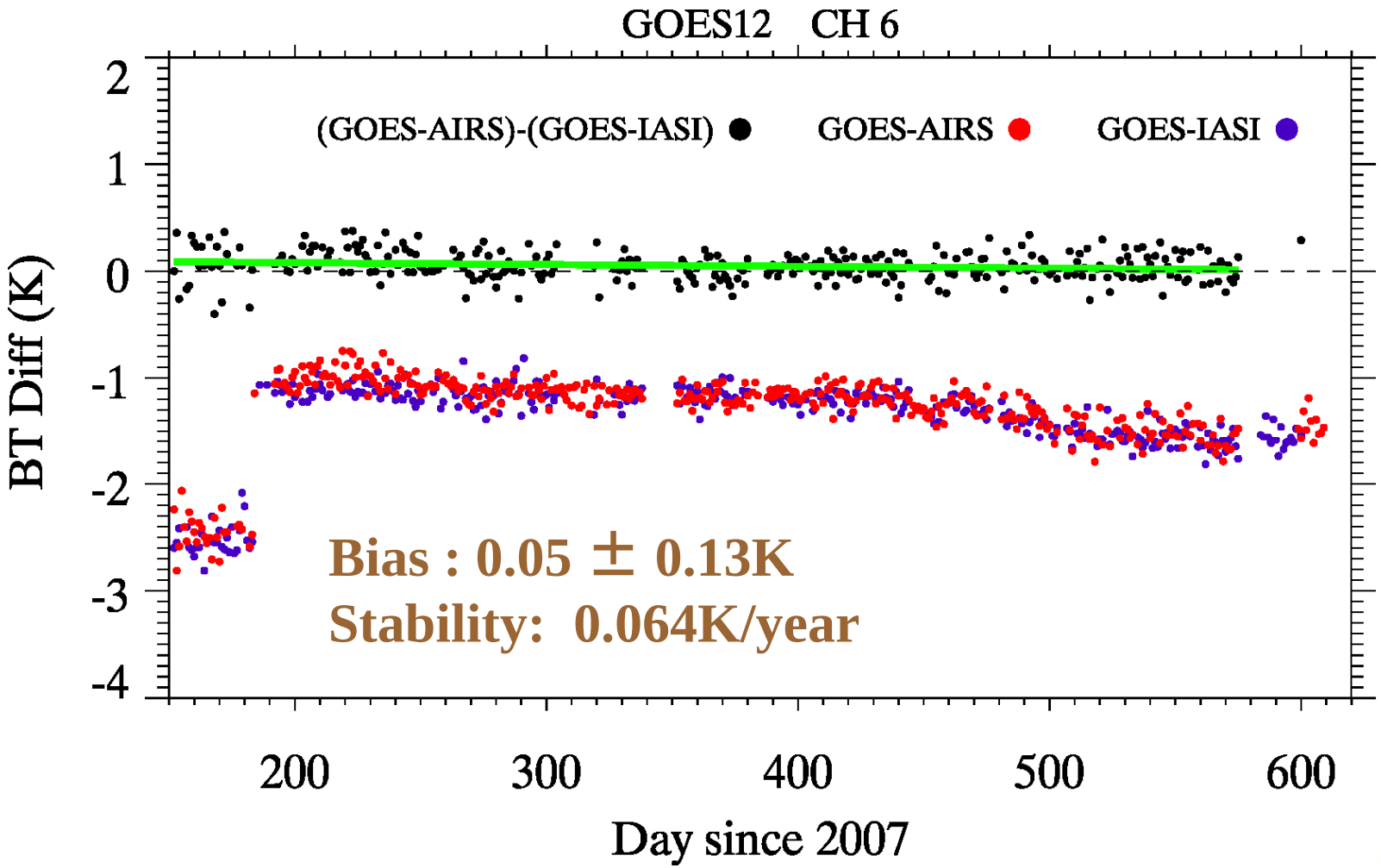
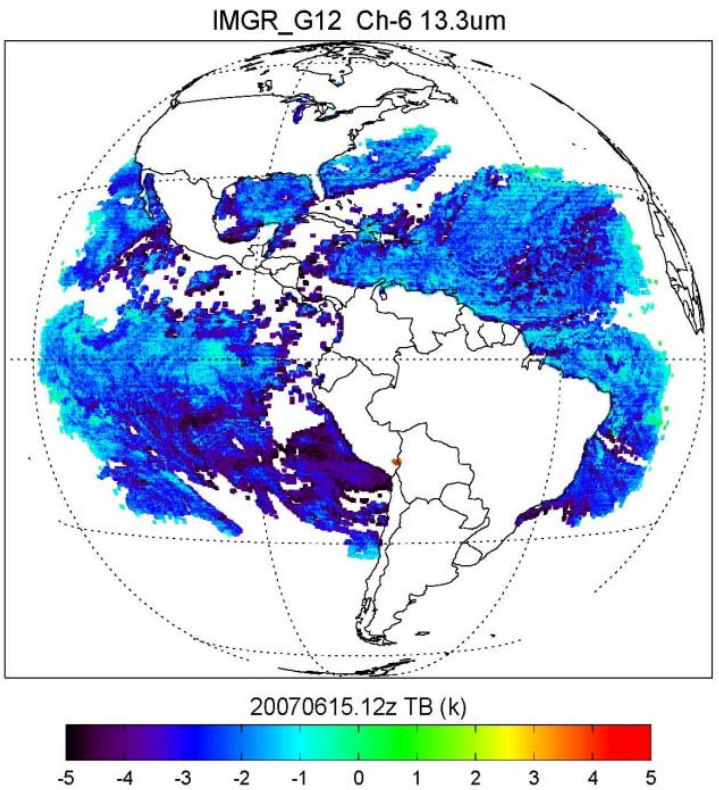
GOES-12 Channel 6 (13.3 μm) Similar to GOES-R ABI Ch16



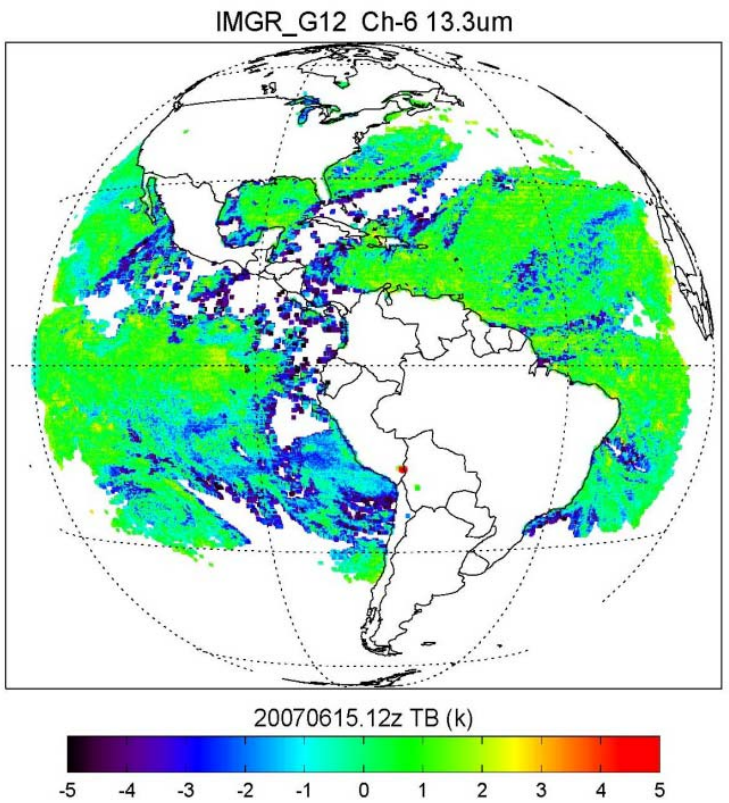
GSICS Calibration Impacts on GOES Data Assimilation

Bias correction algorithm (NOAA/NESDIS/GSICS): $Rad(c) = \frac{Rad(o) - b}{a}$



Before bias correction

GOES-CRTM bias= -2.55 K



After bias correction

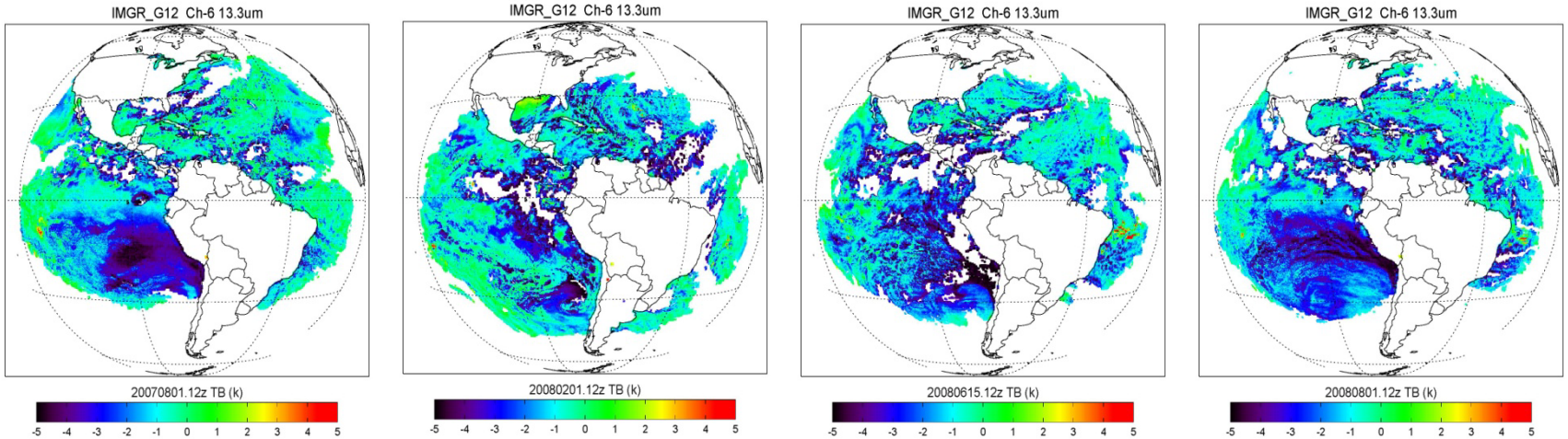
GOES-CRTM bias= -0.11 K

GOES-12 Ch6 ΔT_b(GOES-CRTM)

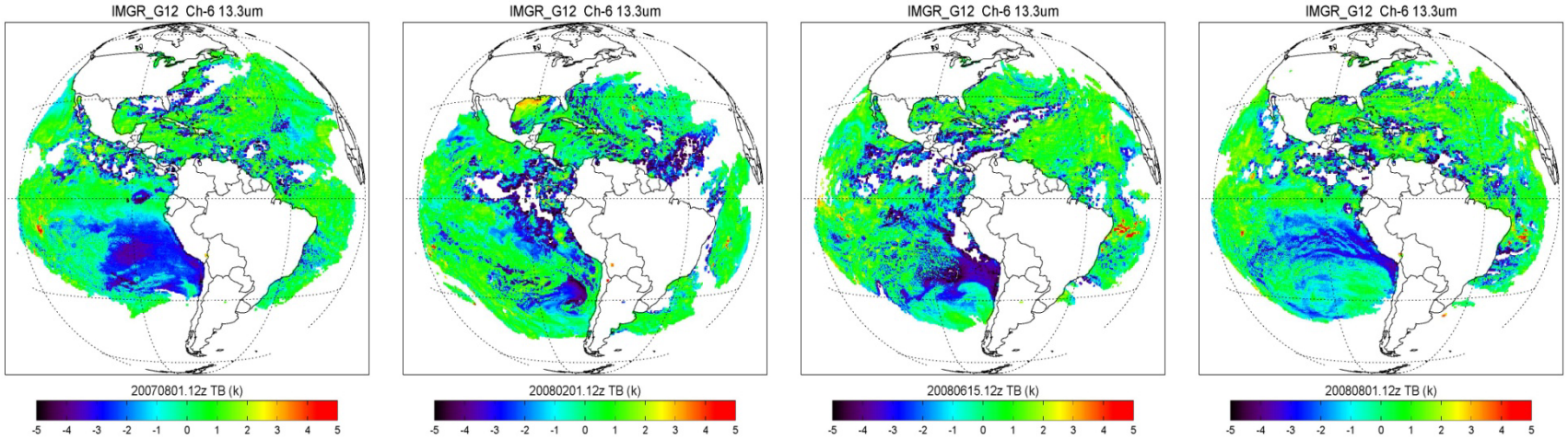
Over ocean and pixels where Tbobs > 265 K

August 1, 2007 | February 1, 2008 | June 15, 2008 | August 1, 2008

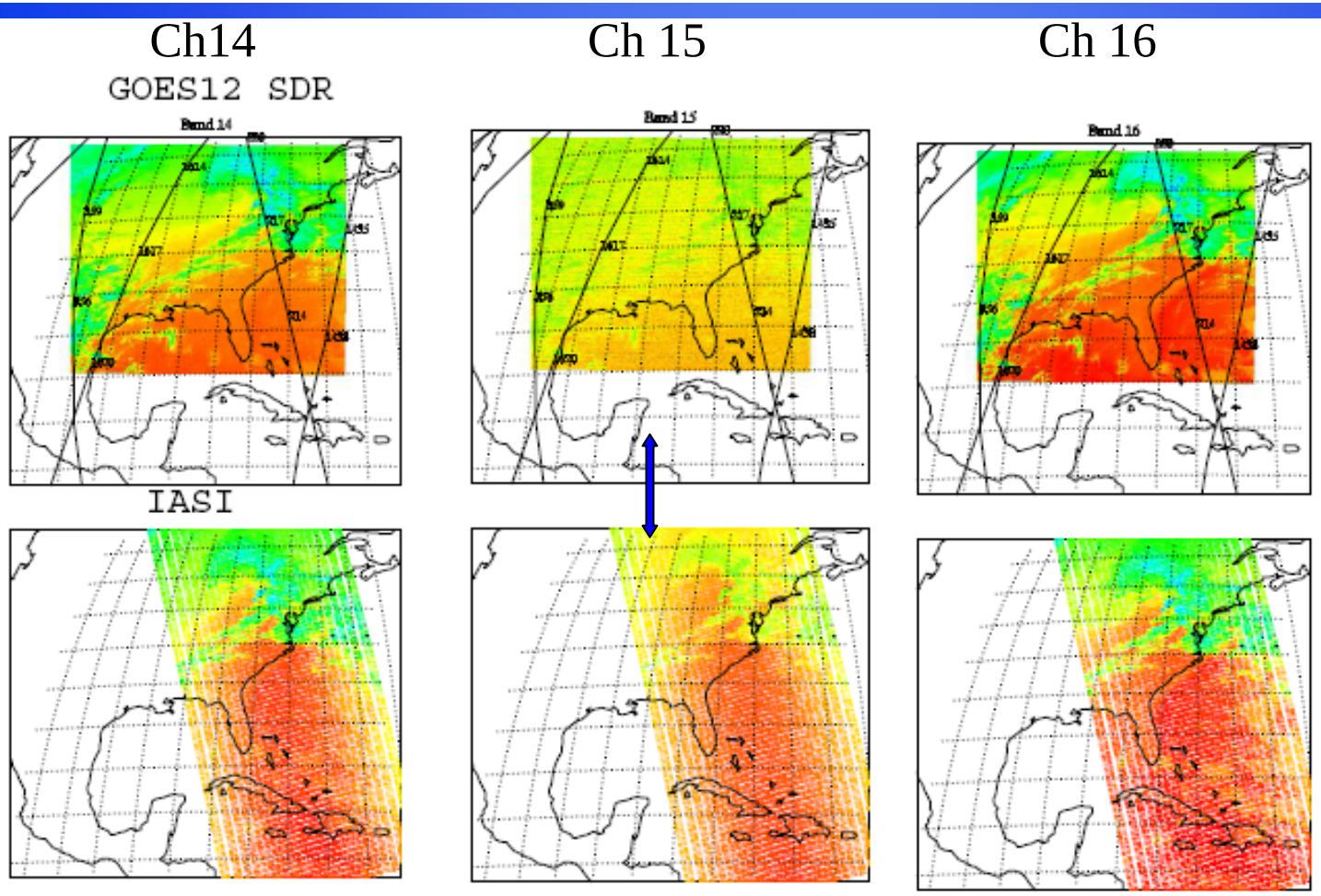
Before correction



After correction



Using IASI to Quantify GOES Sounder Errors



GOES-12 sounder observations

IASI-simulated GOES sounder

The pattern of GOES sounder is quite different from IASI simulated GOES for Ch 15.

Comparison between IASI and GOES Sounder

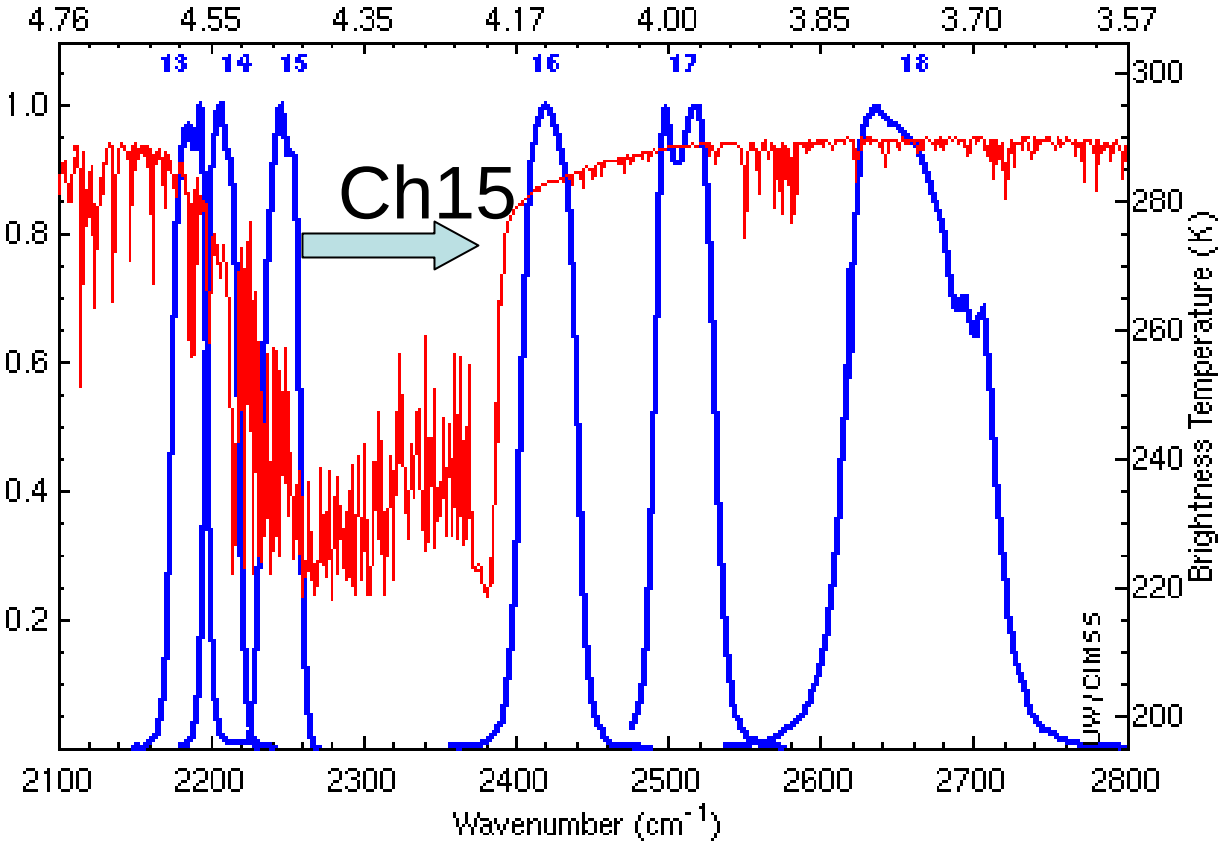
Pixel-by-pixel collocation criteria:

- Time difference: < 300 seconds
- Local zenith angle: $< 40^{\circ}$
- Pixel center distance: <5 km
- Path difference: $\left| \frac{\cos\theta_{geo}}{\cos\theta_{leo}} - 1 \right| < 0.01$

Time Period: Jan - Mar 2009

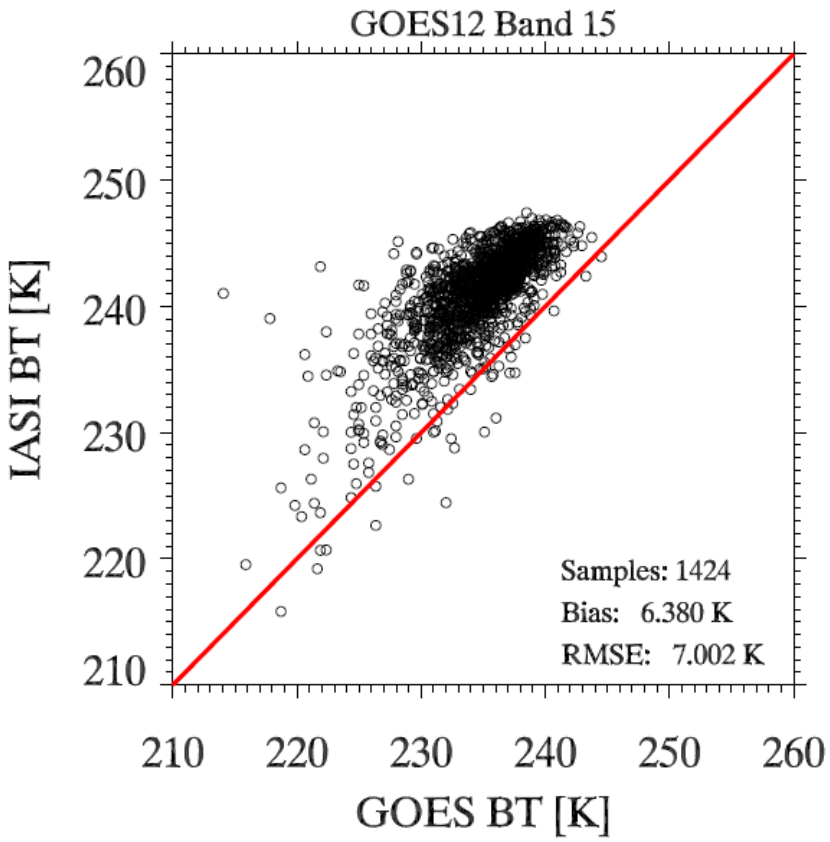
IASI FOV:13.5 km; GOES Sounder FOV:10.0km)

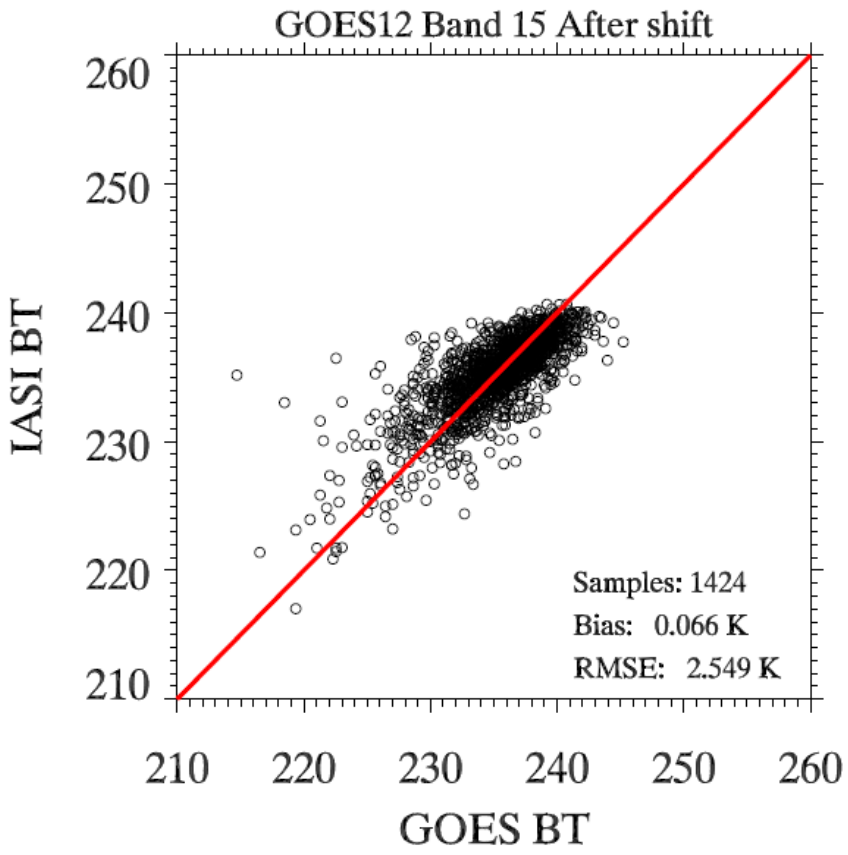
Shifting GOES-11/12 Channel 15 SFR



IASI Simulated versus GOES-12 Sounder

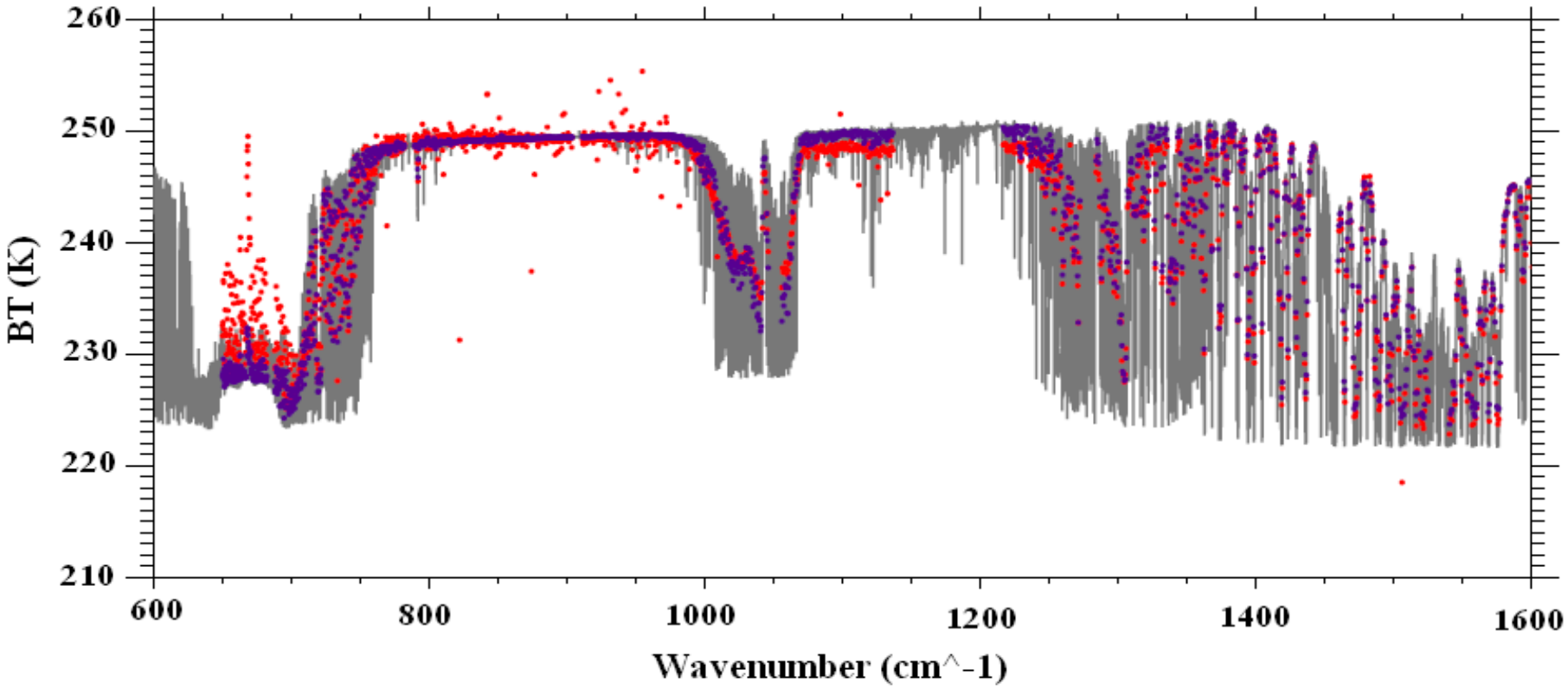
Before shift → After shift





GOES-R SRF shifted by +8.4 cm^{-1} when IASI is used to calculate GOES

AIRS Radiance for Longwave Infrared Spectra Using In-Situ Data at Validation Site



Observed, Modeled and LBLRTM

Conclusions

A User-Friendly Instrument Real-Time Bias Monitoring System

- is a powerful tool for diagnosing the forecast busts and drop-outs related to satellite data

  Correlate 500 hPa ACC with NEDT or biases

- provides real-time, root-cause analysis for any major instrument anomalies

  -- NOAA-18 HIRS filter wheel loose lens

  -- GOES 11/12 Sounder SRF uncertainties

  -- NOAA-19 MHS Ch 3 and 4 front end associated with RF/IF

- generates high quality QC metadata for establishing satellite CDR

  –Noise spikes and anomaly events associated with SDR data

  –Retrospective check of historic sensor data

  –Incorporate upgrades to Ground Processing Software

  –Reprocess SDR data as needed