



Operational Calibration Support to NPP/JPSS Programs

Fuzhong Weng, JPSS SDR Chair

Center for Satellite Applications and Research (STAR)

National Oceanic and Atmospheric Administration (NOAA)

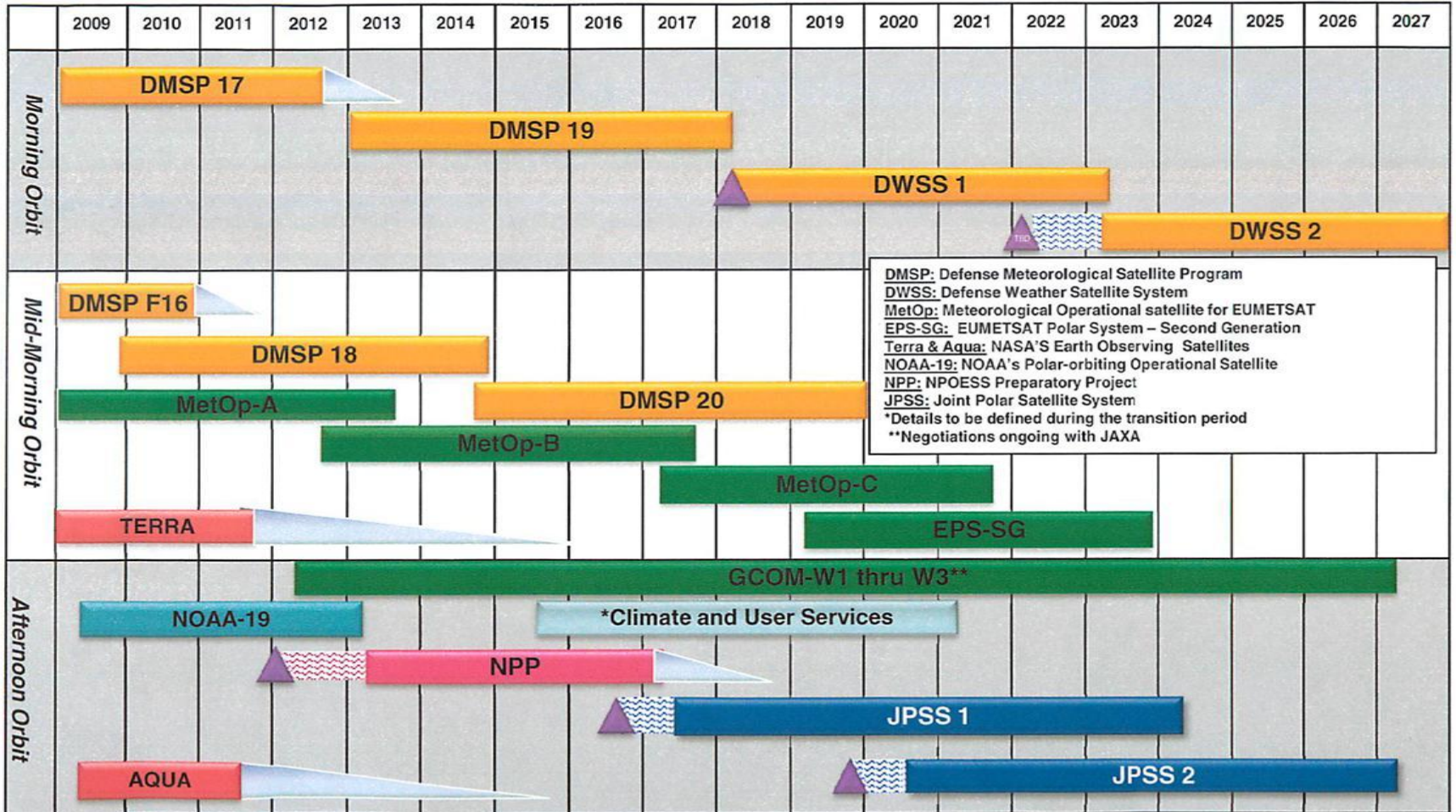
2012 CalCon Technical Conference



Continuity of Polar Operational Satellite Programs

Fiscal Year

As of January 14, 2011



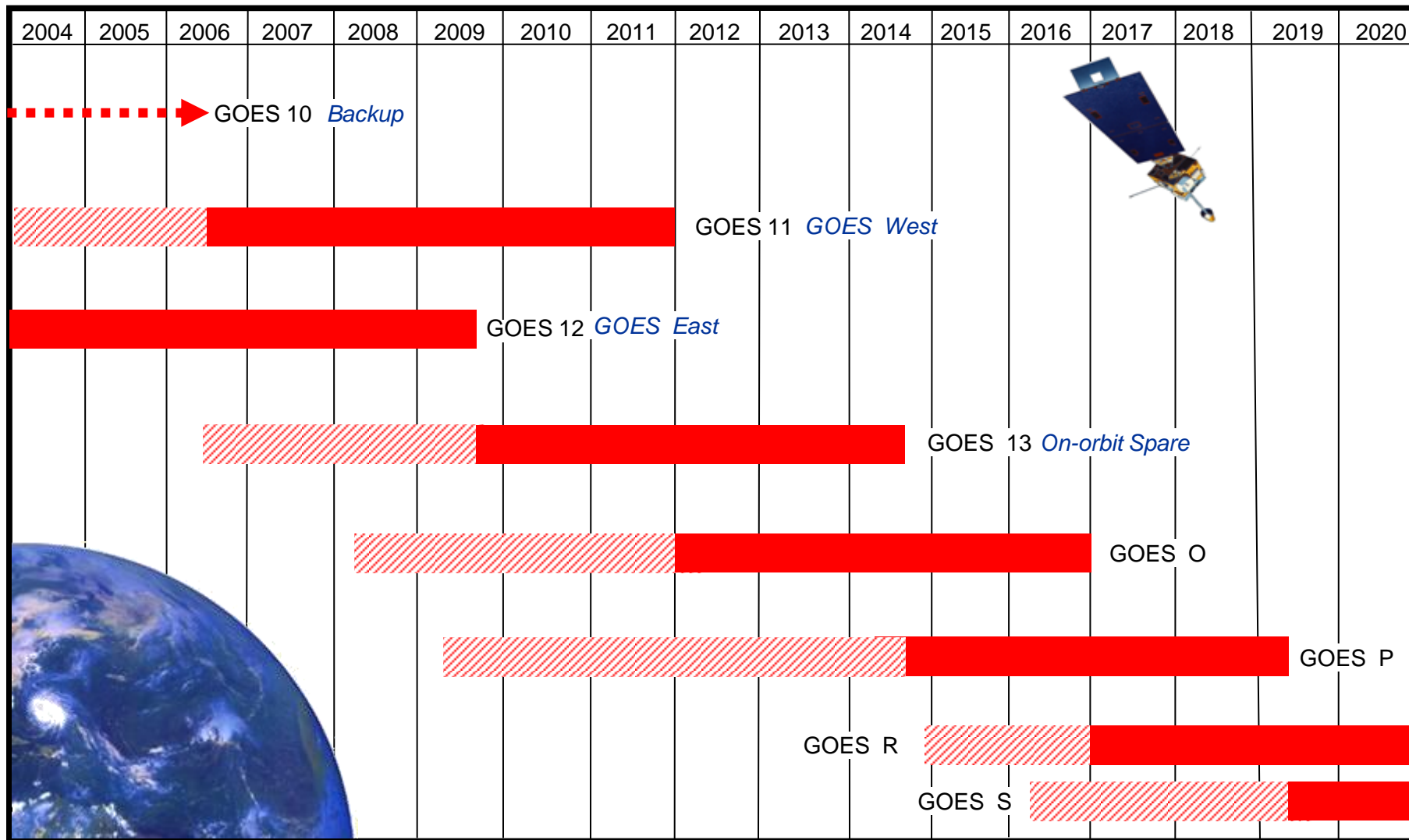
DMSP: Defense Meteorological Satellite Program
DWSS: Defense Weather Satellite System
MetOp: Meteorological Operational satellite for EUMETSAT
EPS-SG: EUMETSAT Polar System – Second Generation
Terra & Aqua: NASA'S Earth Observing Satellites
NOAA-19: NOAA's Polar-orbiting Operational Satellite
NPP: NPOESS Preparatory Project
JPSS: Joint Polar Satellite System
 *Details to be defined during the transition period
 **Negotiations ongoing with JAXA

Approved: *M. E. [Signature]*
 Assistant Administrator for
 Satellite and Information Services

Operational Satellites
 Post Launch Test
 Launch Readiness Date
 Operational beyond design life



NOAA Planned Missions - Geostationary



On-orbit GOES storage



Operational



Satellite is operational beyond design life

NOAA Operational Calibration Supports

- **Community for innovative methodology**
- **Effective and efficient process for science to operations**
- **Maintenance and improvements of CalVal algorithms**
- **Joint satellite mission (e.g. JPSS, GCOM, METOP, DMSP)**
- **Weather and climate applications (e.g. NWP, CDR, Re-analysis)**
-
- **Long-Term Monitoring (LTM) system**

LTM Objectives

1

Provide real-time satellite status, instrument performance, and data quality monitoring for operational missions

2

Provide long-term satellite and instrument stability/performance and data quality monitoring for satellite climate change study

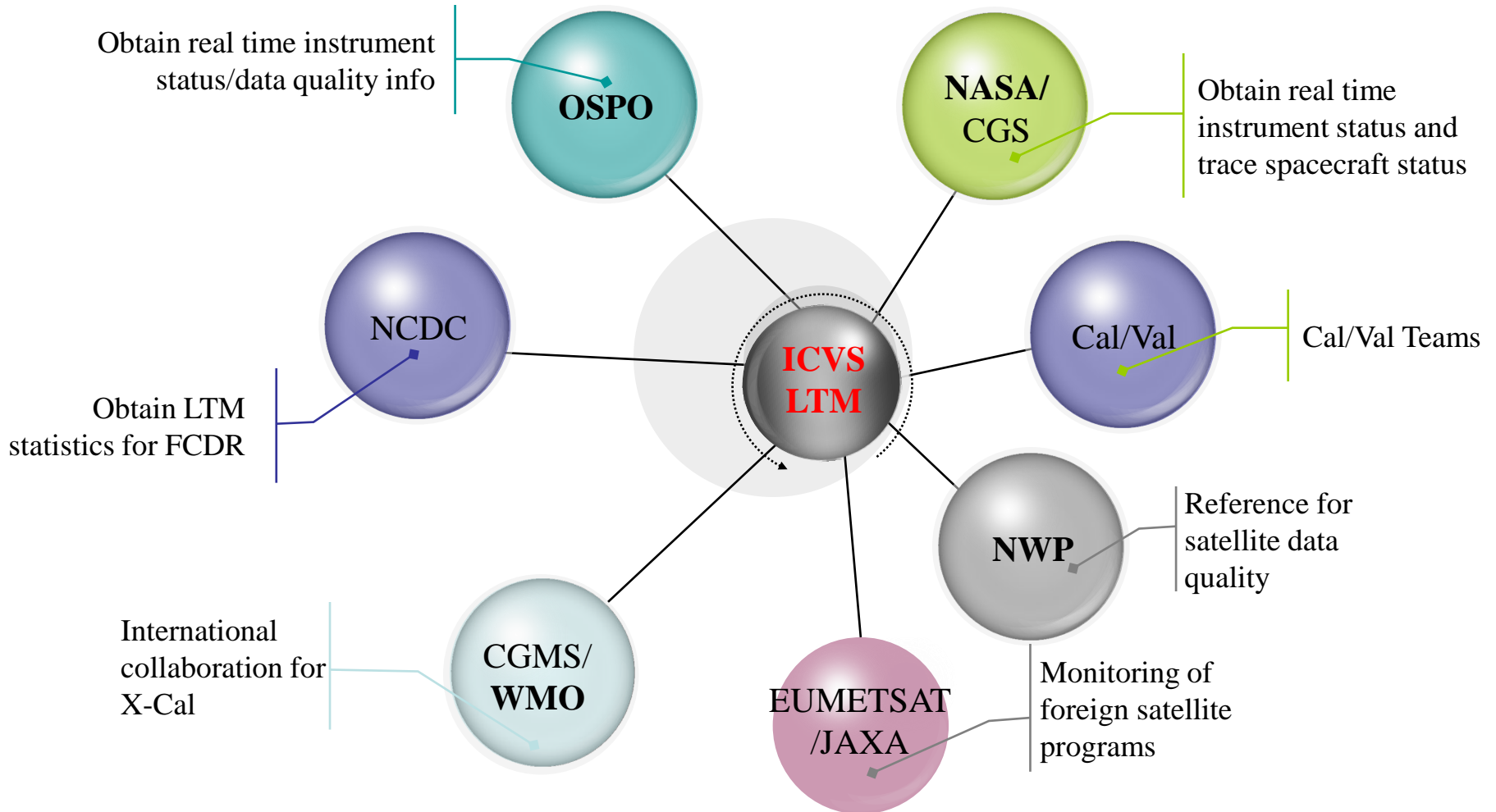
3

Provide the root-cause analysis for the instrument anomalies and the recommendation for risk mitigation

4

Generate and verify instrument calibration coefficients in NOAA operational ground processing systems such as IDPS

LTM Primary Users



NOAA Instrument Long-Term Monitoring System



STAR Center for Satellite Applications and Research
formerly ORA — Office of Research and Applications



NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)

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Search STAR websites

Satellite Integrated Calibration / Validation System (ICVS)

» Integrated Cal/Val System

» NPP Instruments

» Instrument Performance Monitoring - Telemetry >>

- IPP S/C Telemetry
- **IPP ATMS >>**
- IPP CrIS
- IPP VIIRS
- IPP OMPS

- HOAA-19 AMSU-A
- HOAA-19 MHS
- HOAA-19 AVHRR
- HOAA-19 HIRS

- MetOP-A AMSU-A
- MetOP-A MHS
- MetOP-A AVHRR
- MetOP-A HIRS

- HOAA-18 AMSU-A
- HOAA-18 MHS
- HOAA-18 AVHRR
- HOAA-18 HIRS

- DMSP F16 SSMIS
- DMSP F17 SSMIS
- DMSP F18 SSMIS

- GOES-11 Sounder
- GOES-12 Sounder
- GOES-13 Sounder
- GOES-14 Sounder
- GOES-15 Sounder

» Instrument Performance Monitoring - Bias

» Products Demonstration

Data and images displayed on STAR sites are provided for experimental use only and are not official operational HOAA products. [More information>>](#)

ATMS Channel NEdT

All Channel Snapshot

ATMS Channel Gain

All Channel Snapshot

ATMS Cold Calibration Count

All Channel Snapshot

ATMS Warm Calibration Count

All Channel Snapshot

ATMS 4-Wire PRTs

K,Ka,V-Band Sensor

ATMS Receiver Shelf 2-Wire PRTs

K-Band

ATMS 2-Wire PRT (27 PRTs)

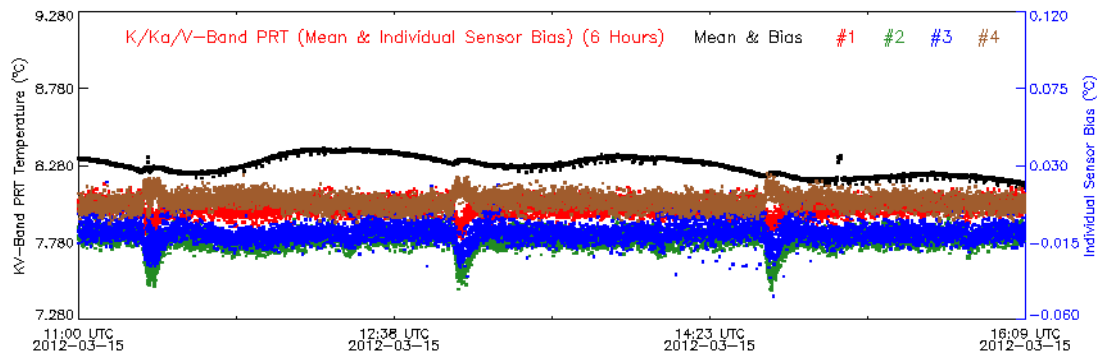
K-Band Receiver Front End Temperature

ATMS Health/Status Analog Parameters (35 Index)

Signal Processing Assembly +5V Secondary Voltage

NPP ATMS K, Ka, V-Band 4-Wire PRTs Science RDR

(Updated at Thu Mar 15 18:30:56 2012 UTC)



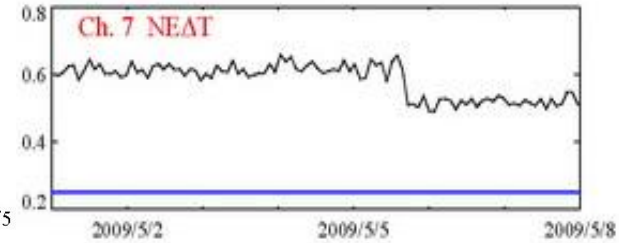
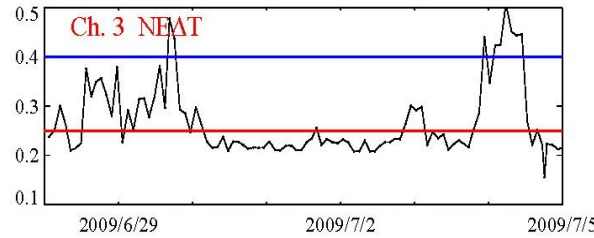
Major Benefits from Instruments LTM

- 1. Identify bugs and flaws in ground processing systems**
- 2. Characterize the instrument in-orbit performance (e.g. noise for NWP)**
- 3. Update the processing coefficient files (PCT) and lookup table (LUT)**
- 4. Detect instrument anomaly and provide the root-cause analysis**
- 5. Provide the alert and warning to user community on satellite data quality**

Example: ICVS-LTM Monitoring NOAA/METOP

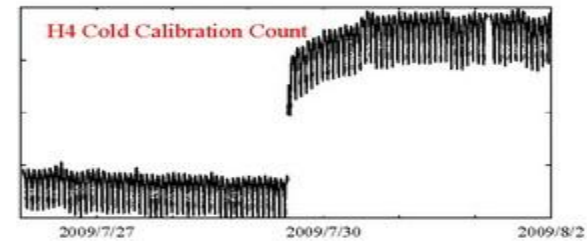
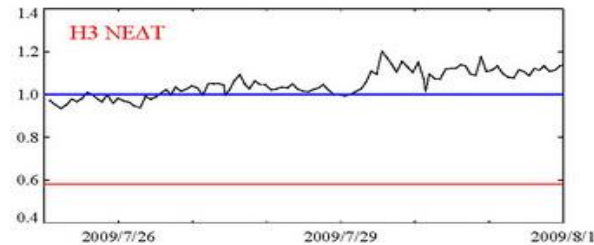
AMSU-A

- (a) NOAA-19 Ch3 NEΔT variation
- (b) MetOP-A Ch7 NEΔT Drop



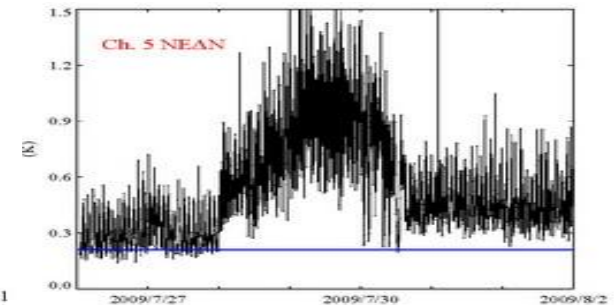
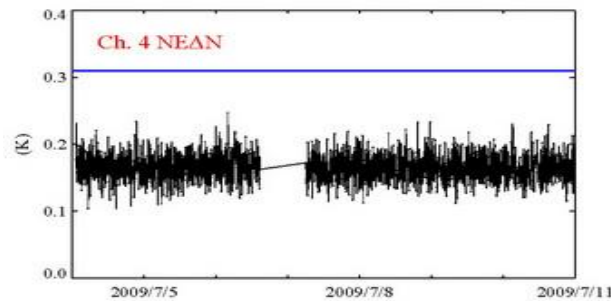
MHS

- (a) NOAA-19 H3 NEΔT is out of specification (1K)
- (b) NOAA-19 H4 Cold Calibration Count jump



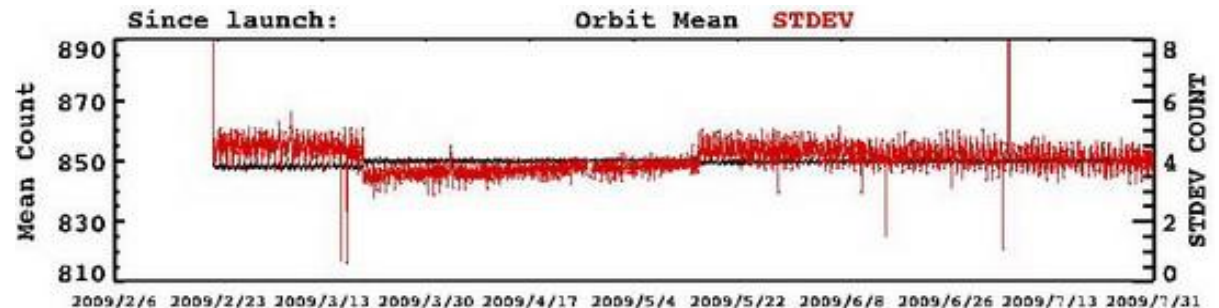
HIRS

- (a) NOAA-19 Ch4 Data Gaps
- (b) NOAA-18 Ch5 NEΔN Anomaly

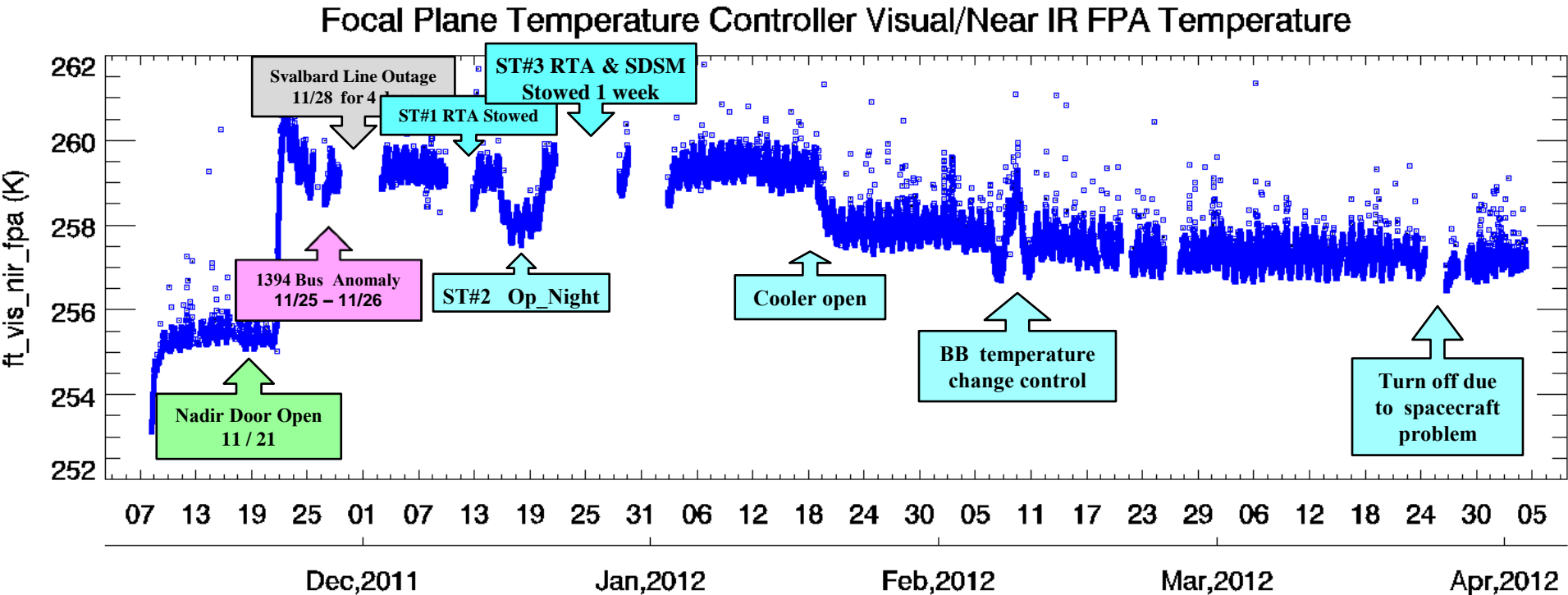


AVHRR

- (a) NOAA-19 AVHRR Ch3B Blackbody Target Counts Trend Since Launch

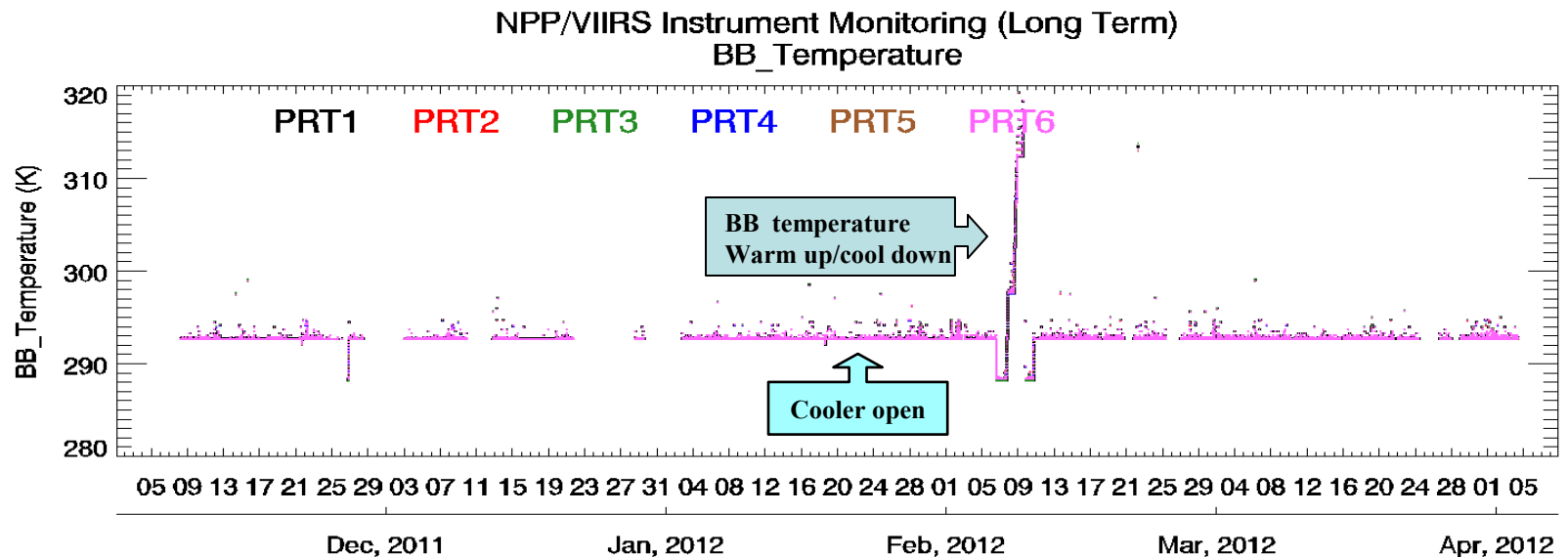
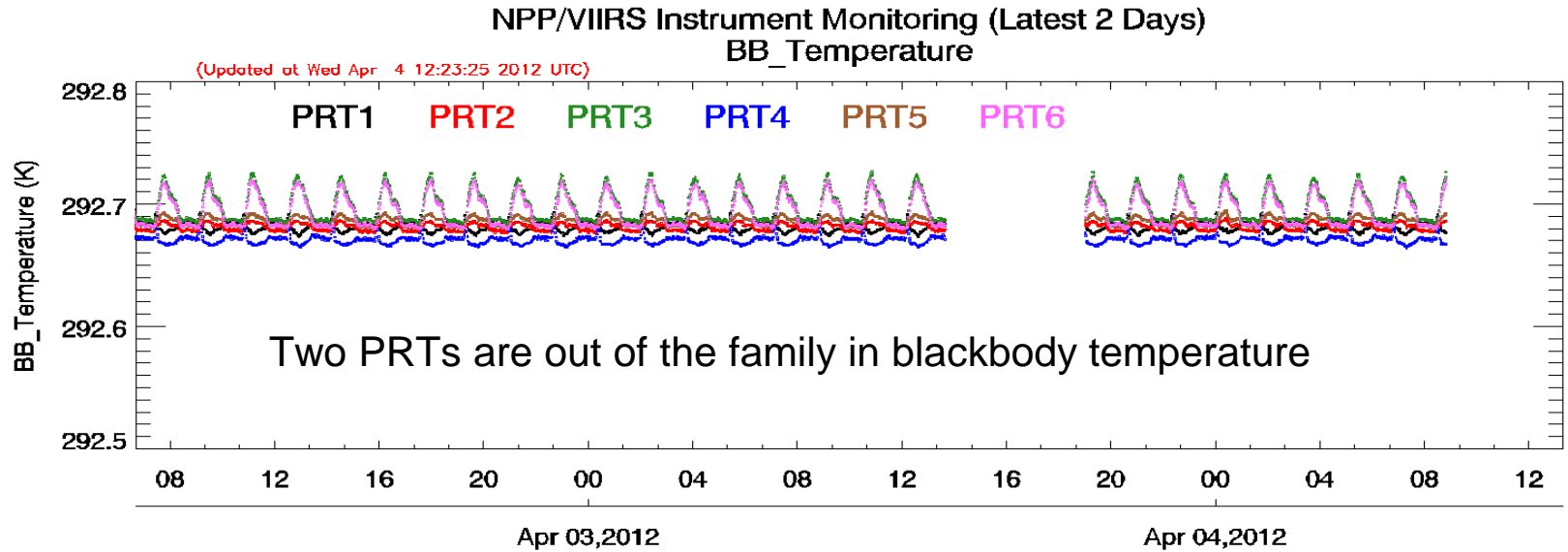


VIIRS Testing Control & Telemetry Trend



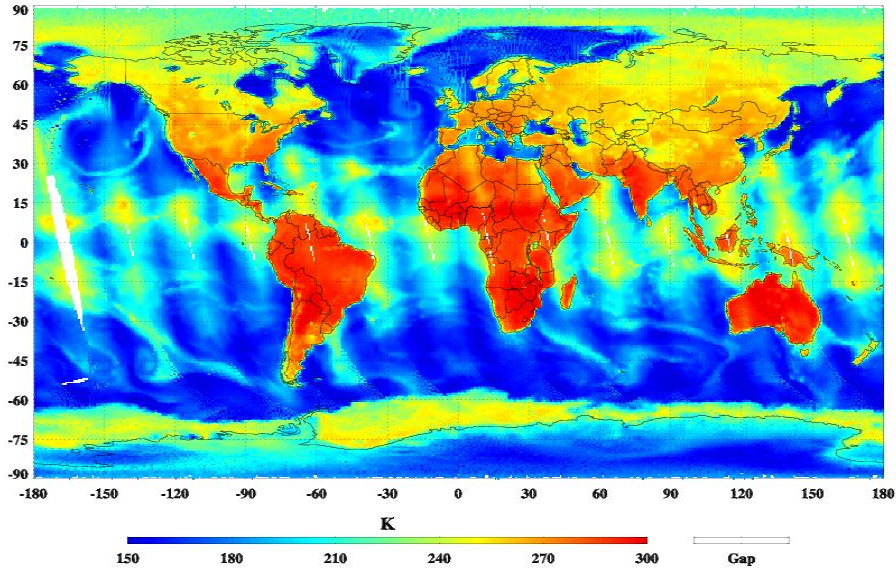
- 1) VIIRS is activated on Dec 8,
- 2) Nadir Aperture Door opening Nov 21,
- 3) After 1394 Bus anomaly Nov 25,
- 4) ST #1 RTA stowed for 3 days Dec 09–12,
- 5) ST #2 Night only observations with Solar Cals Dec 15–19,
- 6) ST #3 stow both SDSM and telescope for 1 week to evaluate the SDSM insensitivity to solar,
- 7) Cooler open on Jan 18,
- 8) Black body temperature change control,
- 9) Turn off when spacecraft problem

Example: Monitoring VIIRS Blackbody Temperature



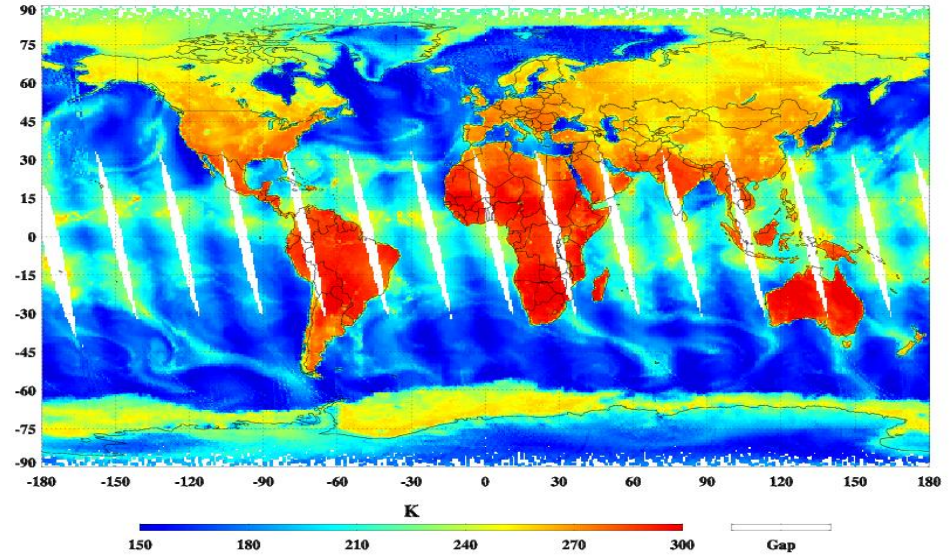
ATMS Observation Ch.1 Ascending

ATMS Observation Ch.1 23.8 GHz Scan Date: 2011-11-09



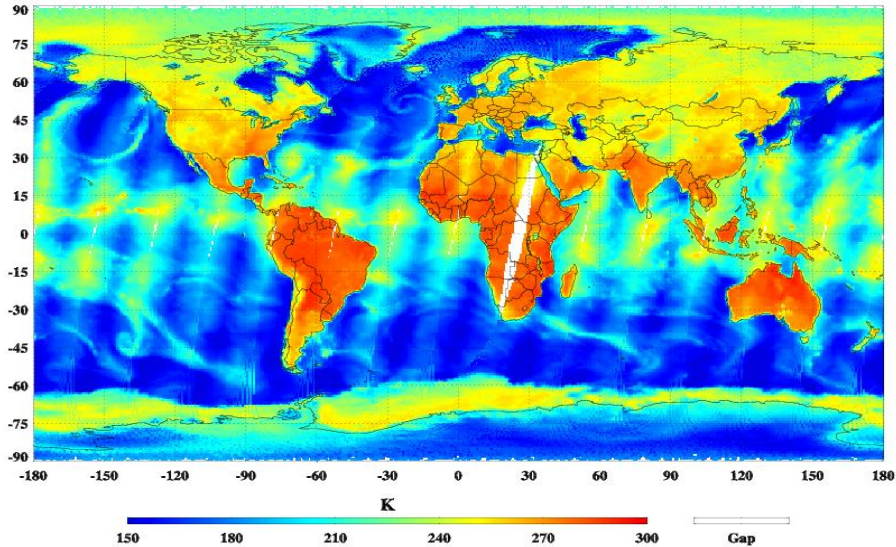
NOAA 18 AMSU-A Observation Ch.1 Ascending

NOAA 18 AMSU-A Observation Ch.1 23.8 GHz Scan Date: 2011-11-09



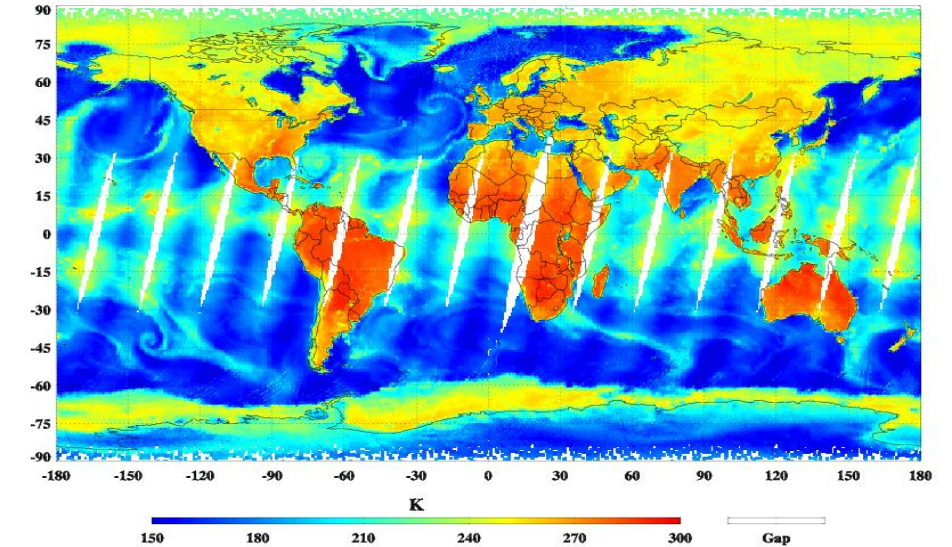
ATMS Observation Ch.1 Descending

ATMS Observation Ch.1 23.8 GHz Scan Date: 2011-11-09



NOAA 18 AMSU-A Observation Ch.1 Descending

NOAA 18 AMSU-A Observation Ch.1 23.8 GHz Scan Date: 2011-11-09

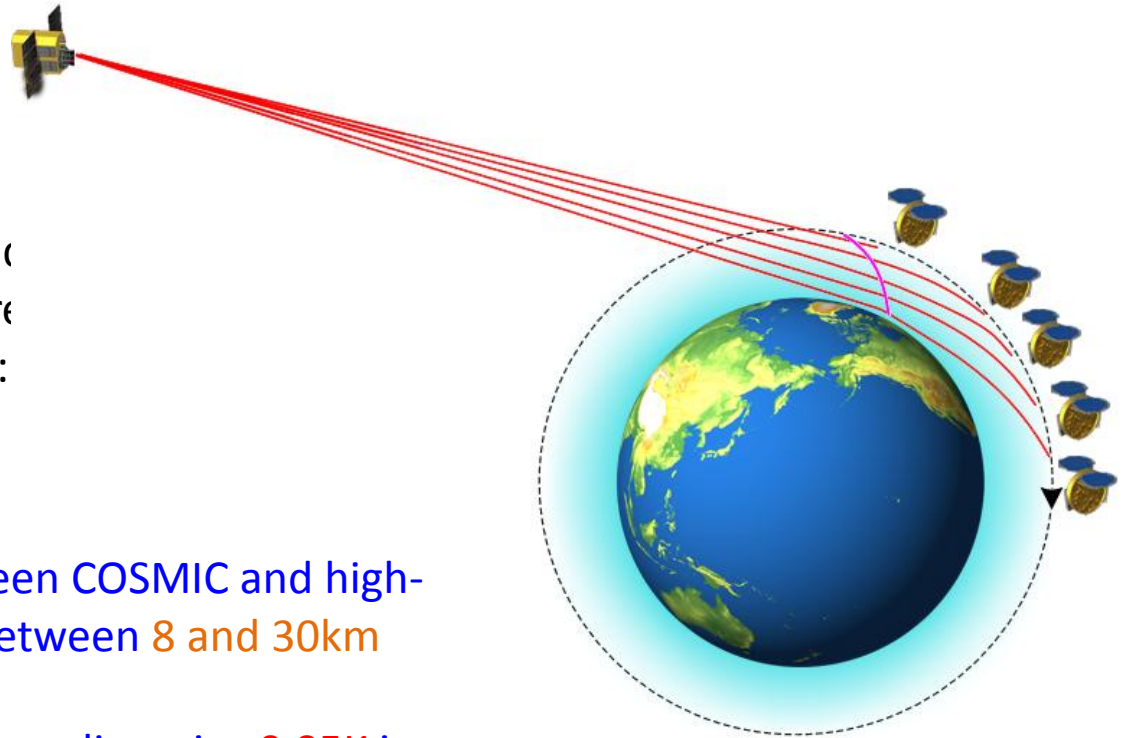


Building High Quality NPP SDR Products for Science Community: Or-Orbit ATMS Absolute Calibration Using COSMIC and LBL RT Model

1. High vertical resolution
2. No contamination from clouds
3. No system calibration required
4. High accuracy and precision:

The global mean differences between COSMIC and high-quality reanalyses is $\sim 0.65\text{K}$ between 8 and 30km (Kishore et al. 2008)

The precision of COSMIC GPS RO soundings is $\sim 0.05\text{K}$ in the upper troposphere and lower stratosphere (Anthes et al. 2008)



NPP Data Collocation with COSMIC

- **Time period of data search:**

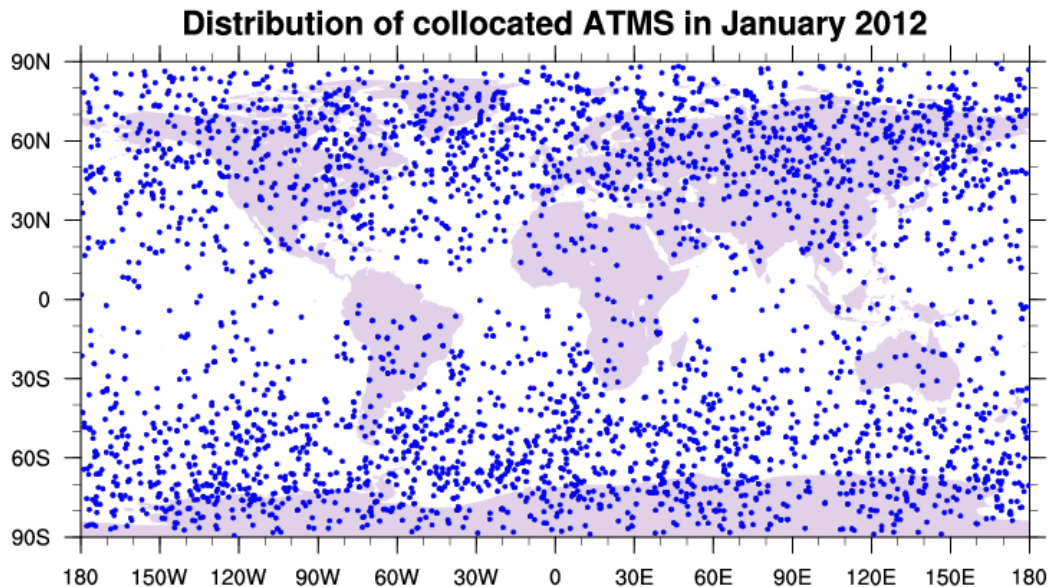
January, 2012

- **Collocation of CloudSat and COSMIC data:**

Time difference < 0.5 hour

Spatial distance < 30 km

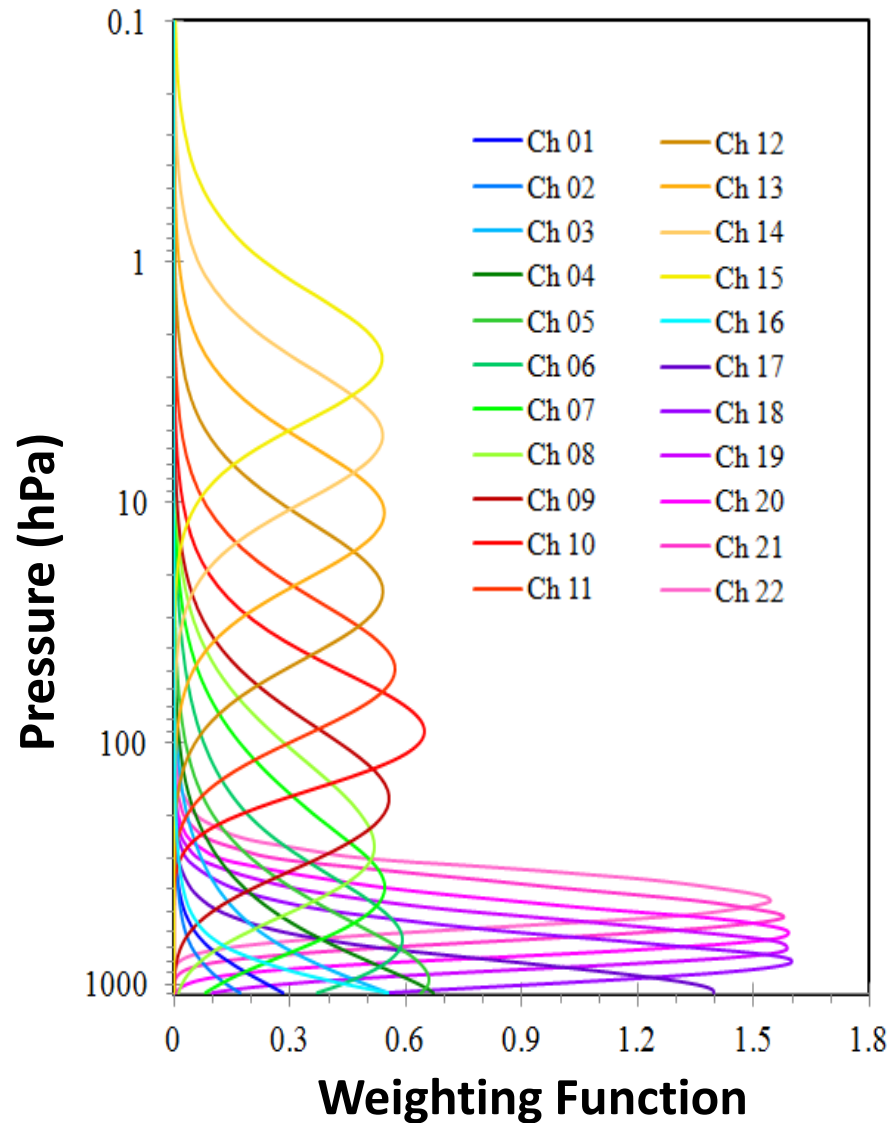
(GPS geolocation at 10km altitude is used for spatial collocation)



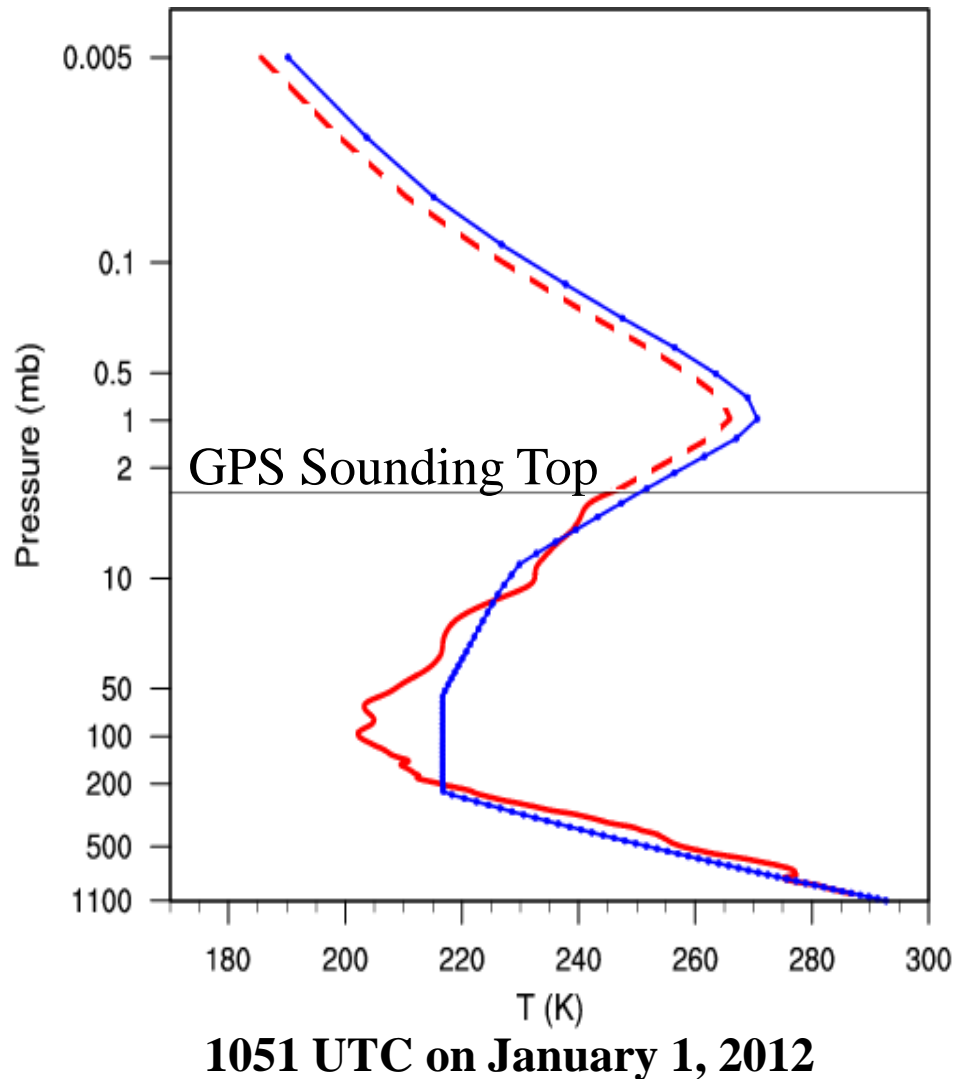
3056 collocated
measurements

Courtesy of Lin Lin, STAR

ATMS WF (U.S. Standard Atmosphere)

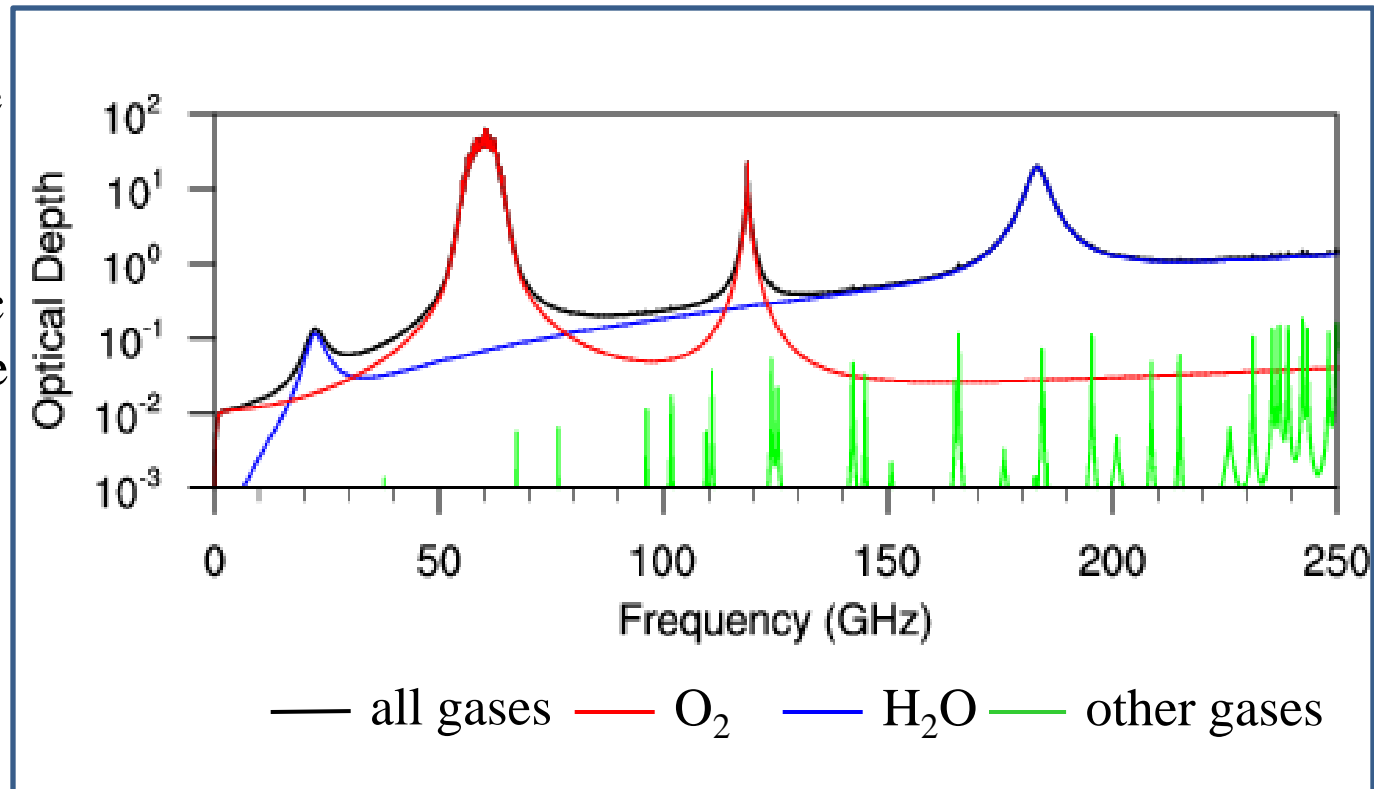


Add 1976 U.S. Standard Atmosphere State to GPS Soundings



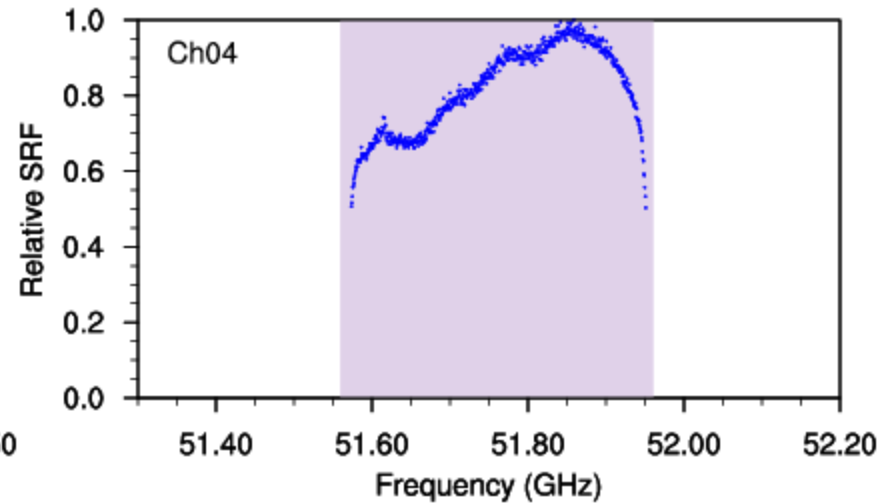
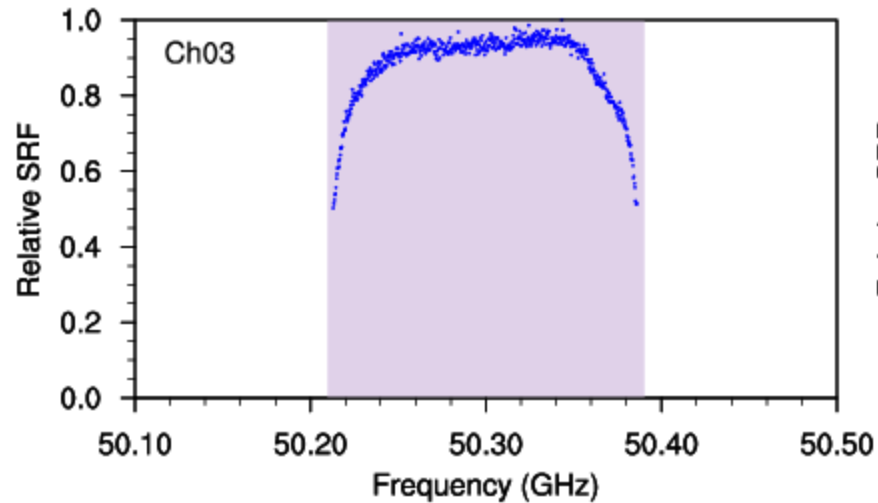
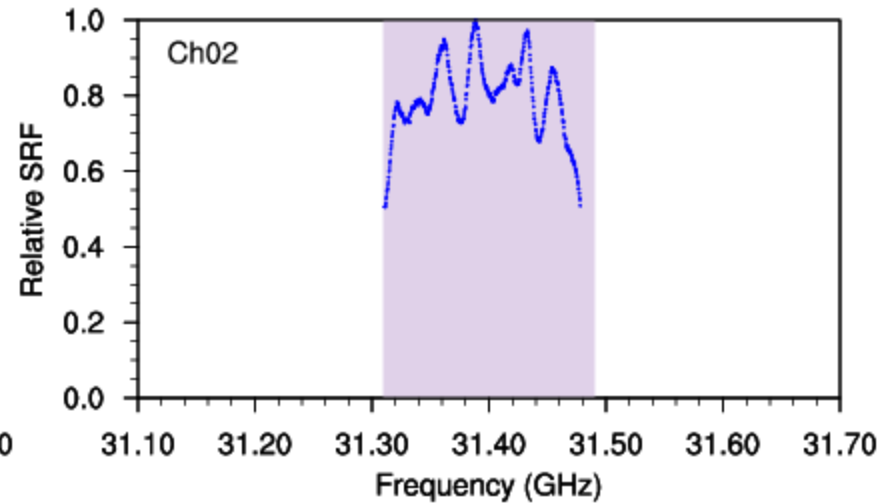
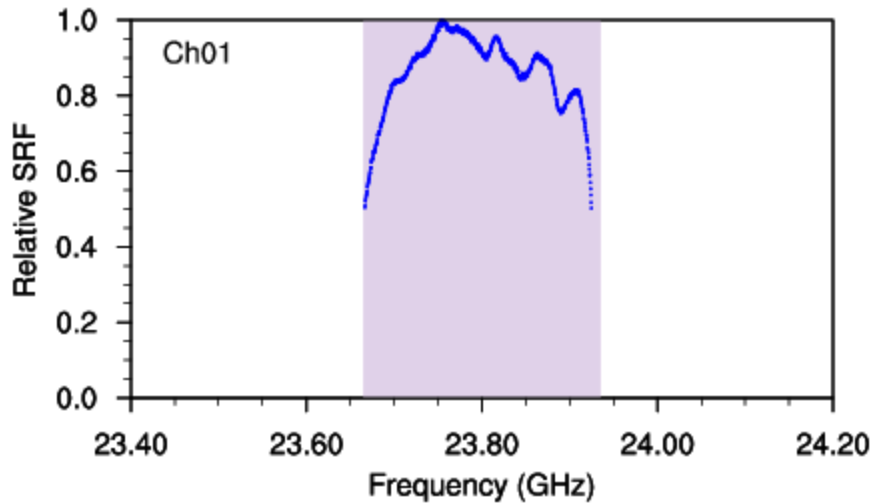
Line by Line Radiative Transfer Model

- Perform a line by line radiative transfer calculation
- Accurate atmospheric spectroscopy data base
- Only gaseous absorption
- Vertical stratification

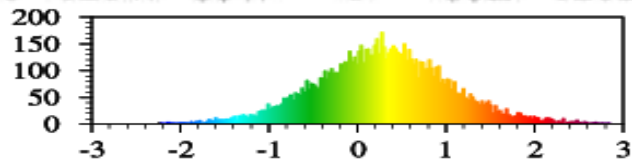
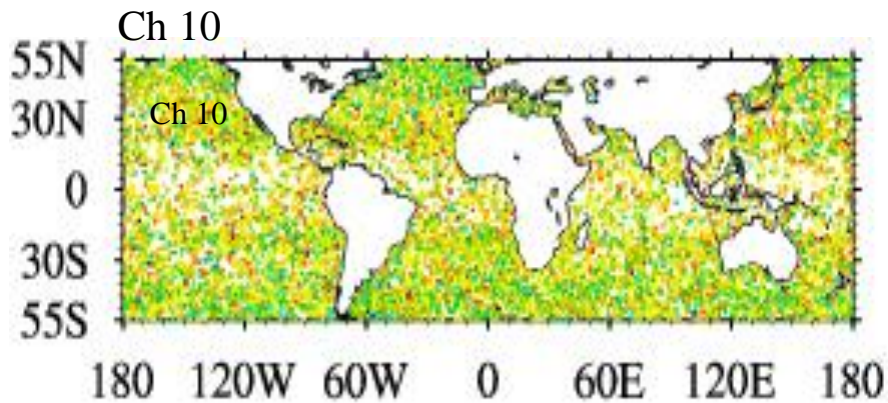
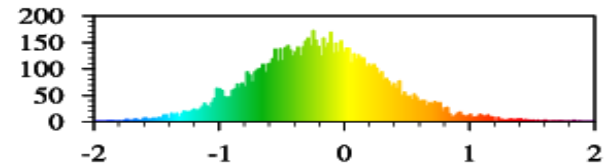
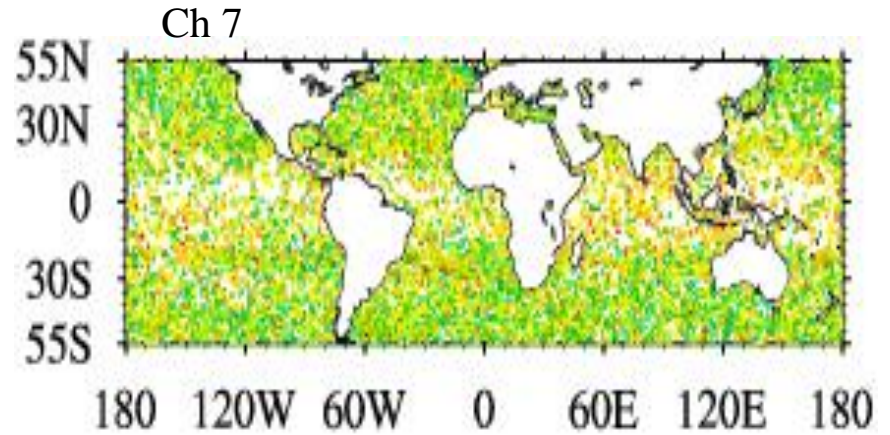
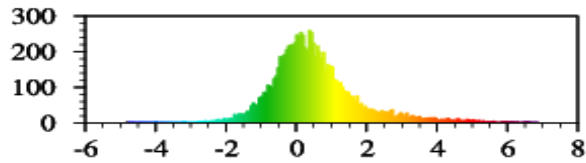
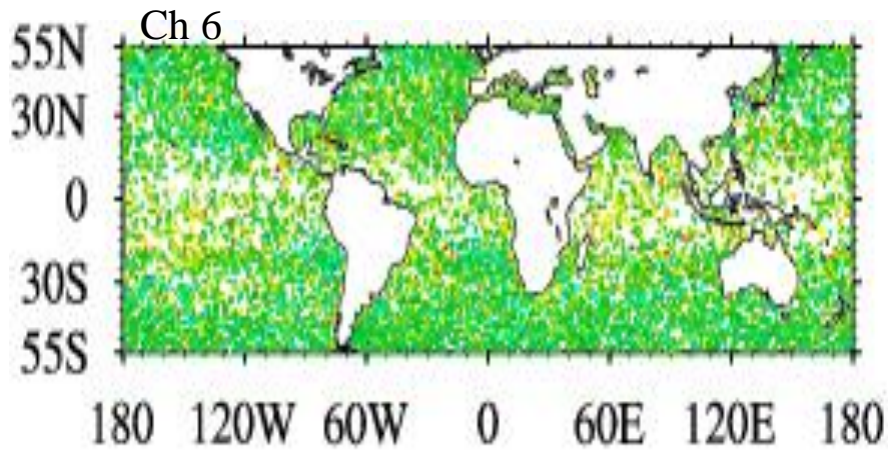


Microwave sounding channels at 50-60 GHz O₂ absorption band can be best simulated under a cloud-free atmosphere using line by line calculation

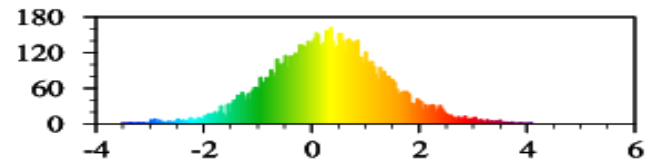
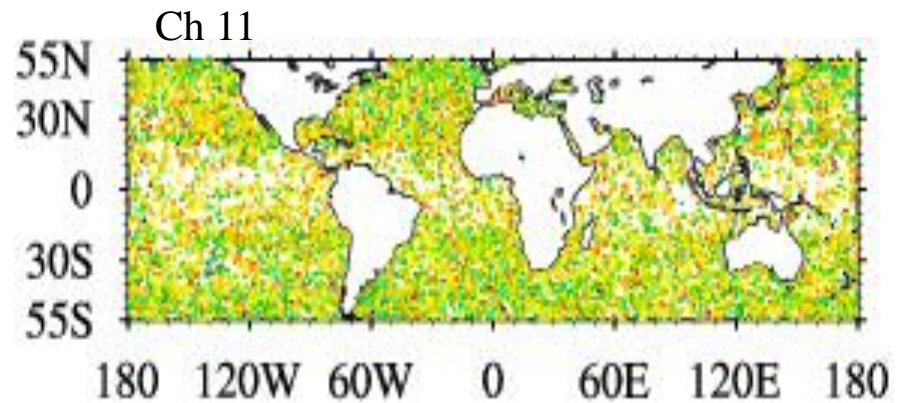
Effects of ATMS Spectral Response Function



ATMS Bias Obs (TDR) - GPS Simulated

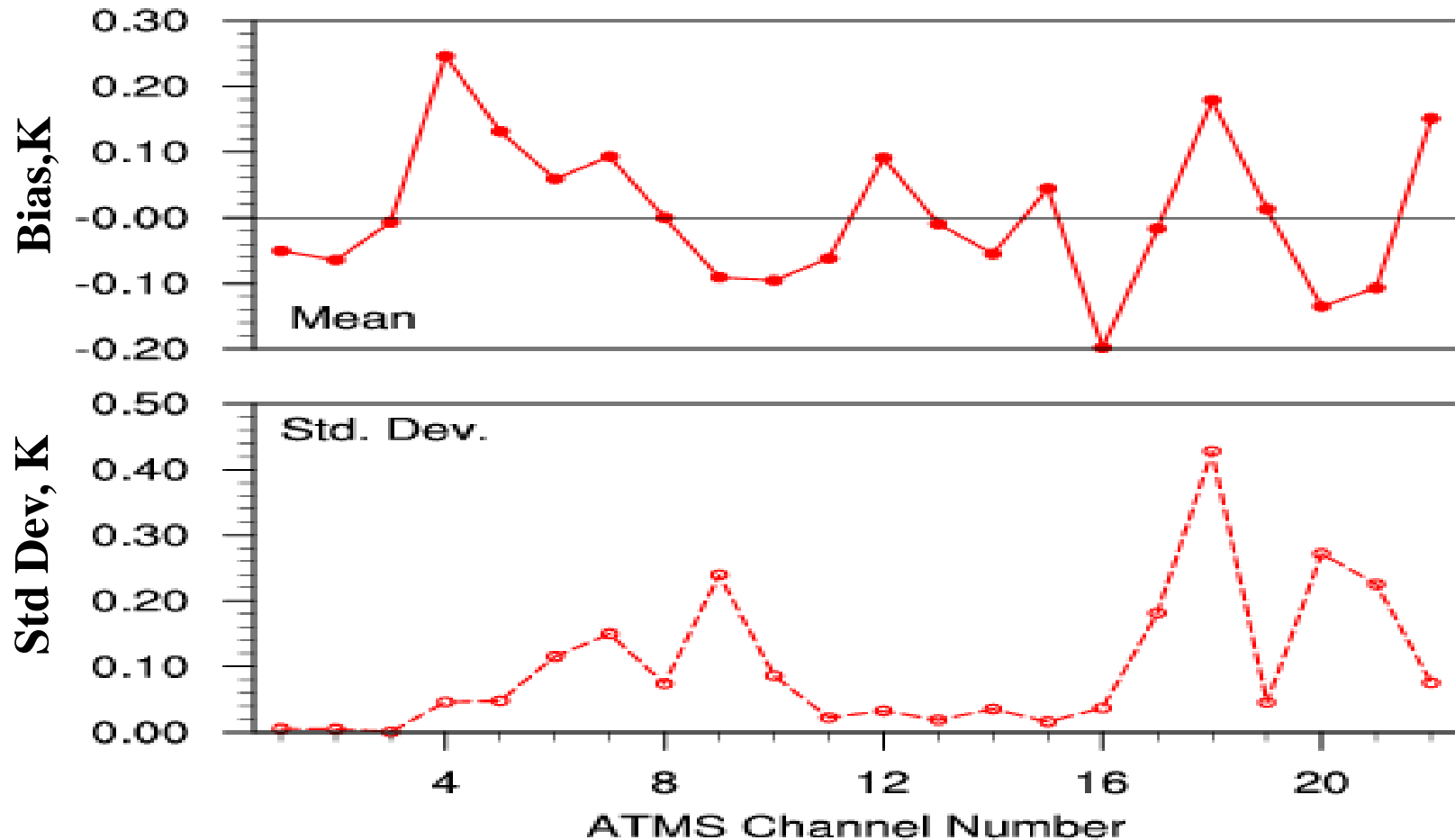


O-GPS (K)



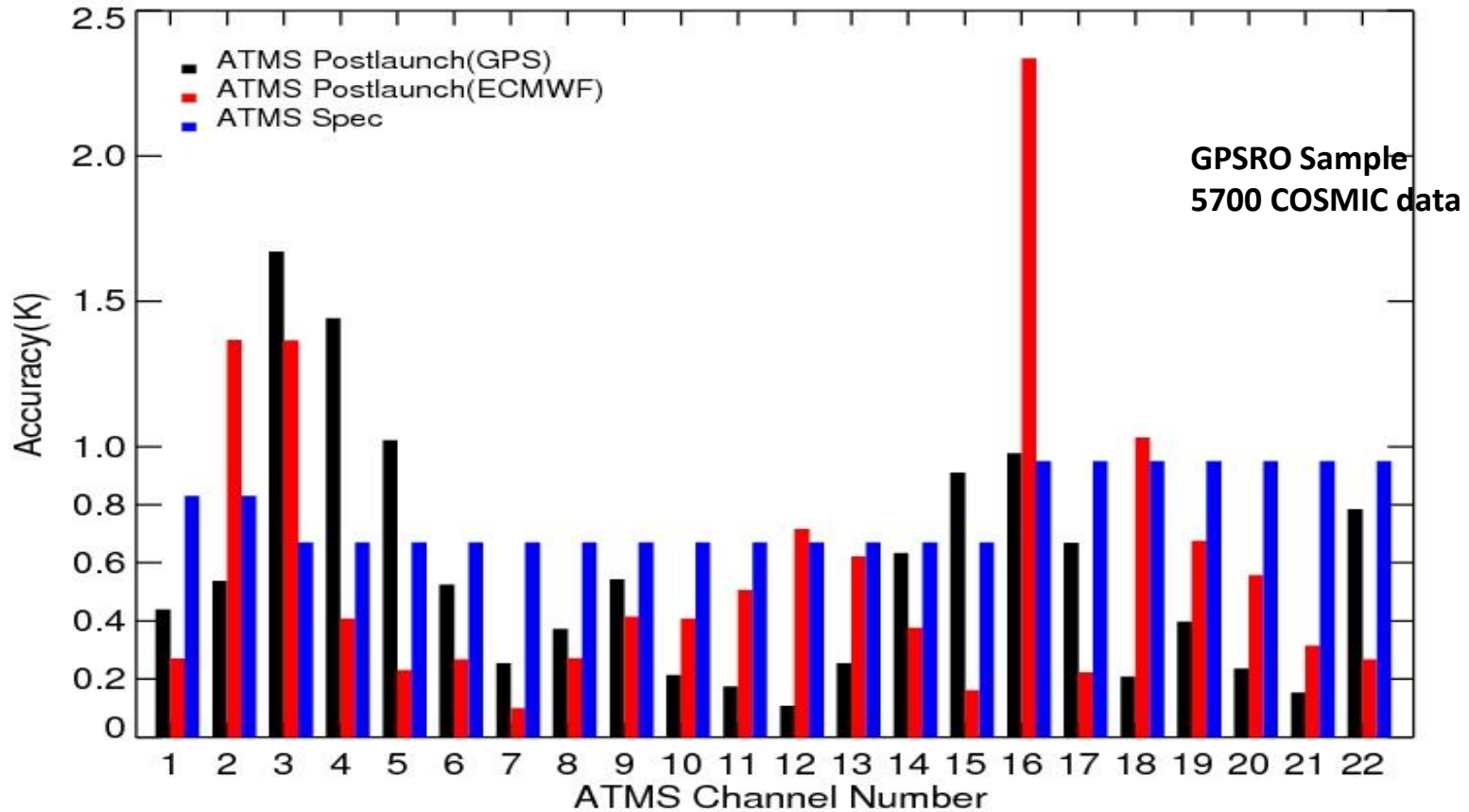
O-GPS (K)

Difference of Antenna Brightness Temperature between Measured SRF and Boxcar



Shown is the means bias of ATMS simulations using boxcar to the measured SRF and the standard deviation of the bias. The simulations are computed from GPSRO profiles and LBLRTM.

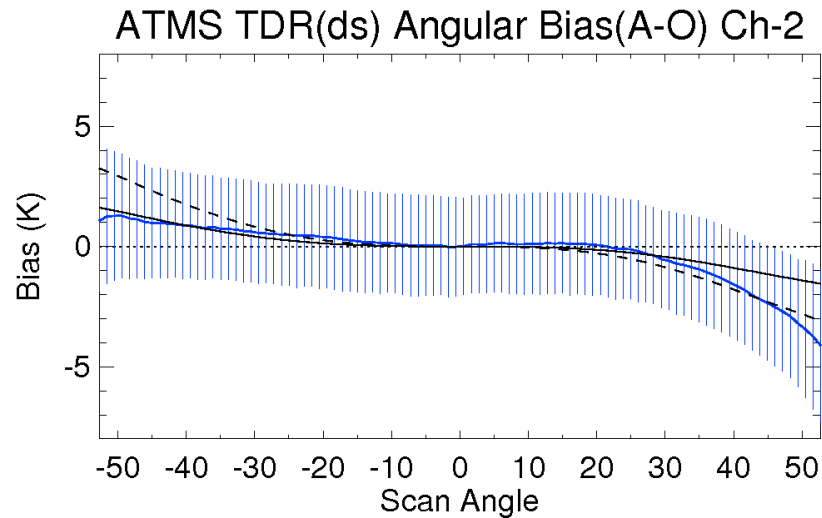
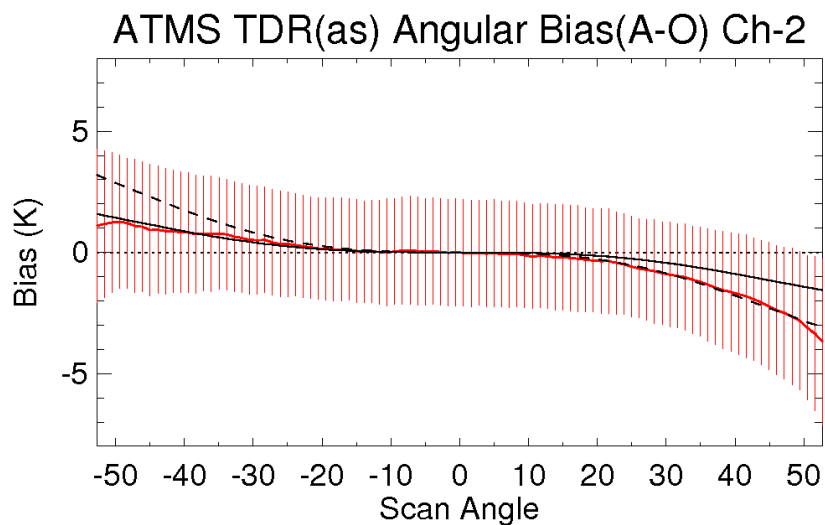
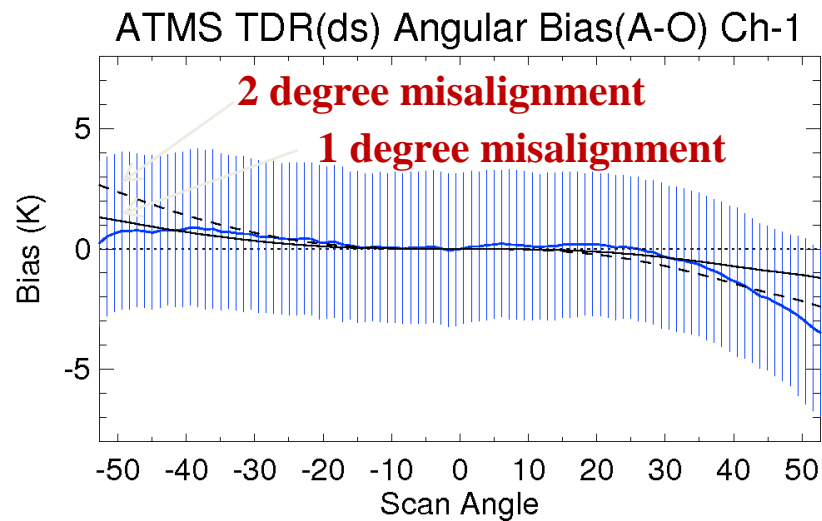
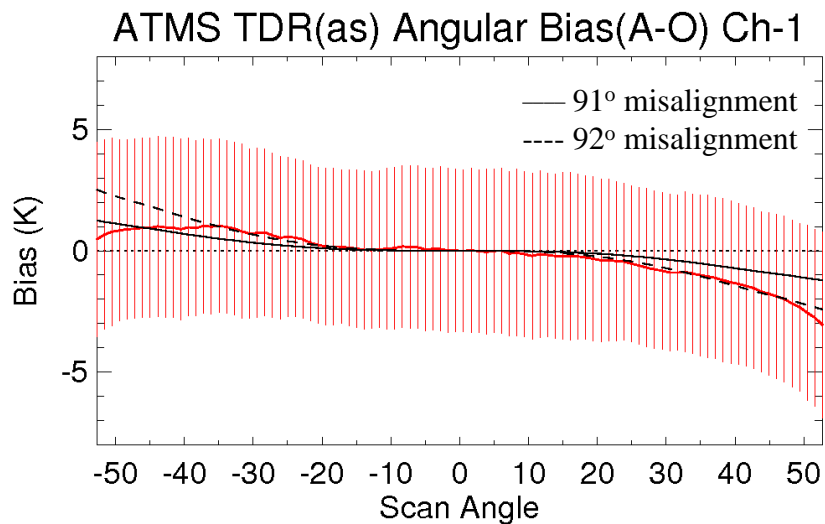
ATMS Calibration Accuracy Using GPSRO Data



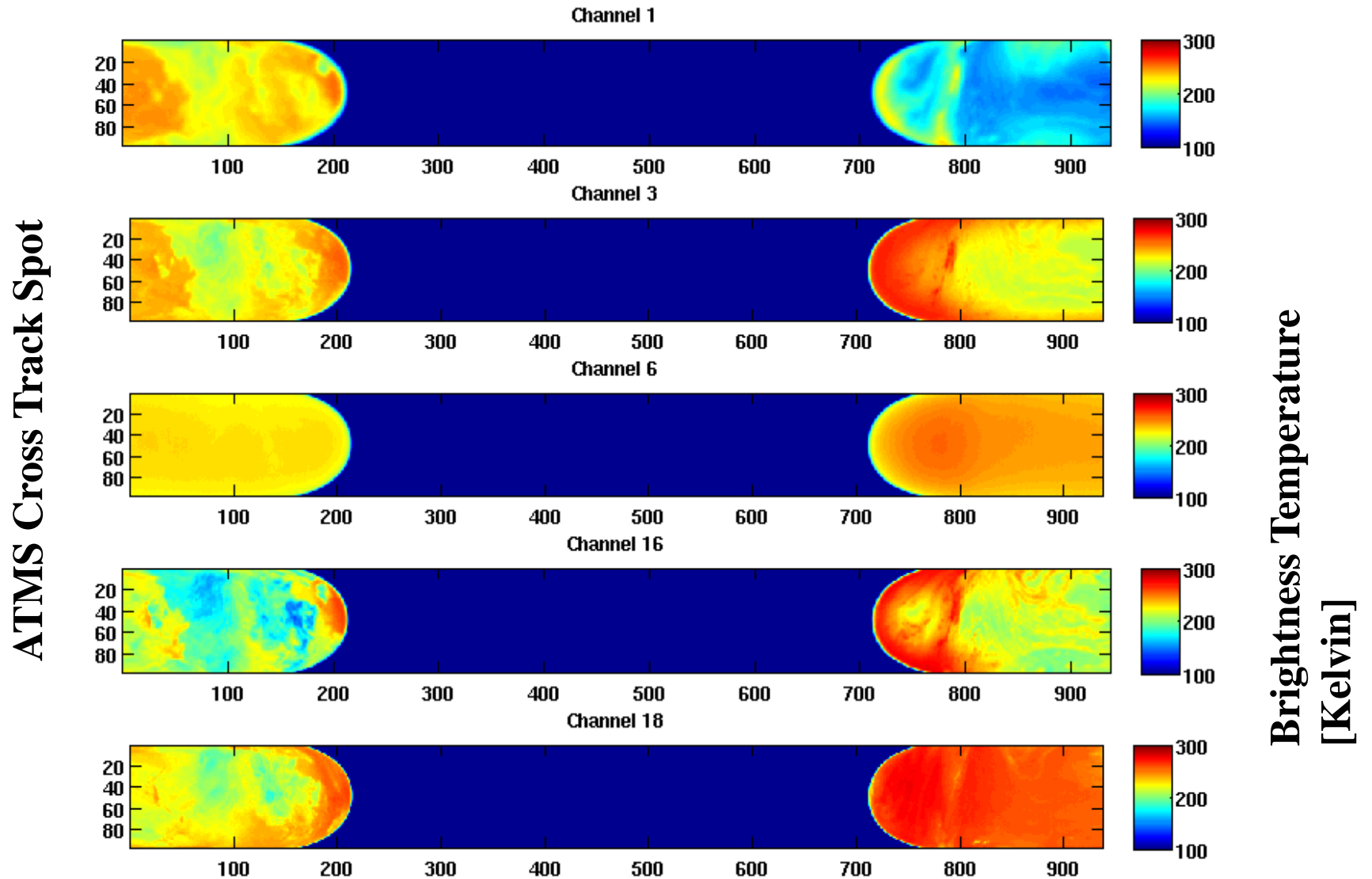
On-orbit ATMS calibration accuracy is quantified using GPSRO data as input to RT model and is better than specification for most of sounding channels.

ATMS TDR Cross-Track Asymmetry

Angular dependent bias (A-O) Dec, 16-22, 2011
CRTM Sim: GSI analysis field ; OBS: ATMS TDR



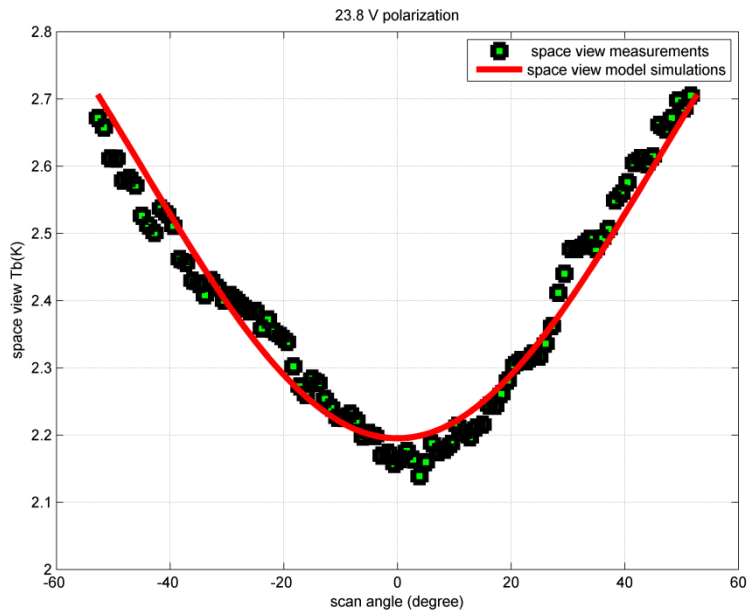
ATMS Pitch Maneuver February 20, 2012



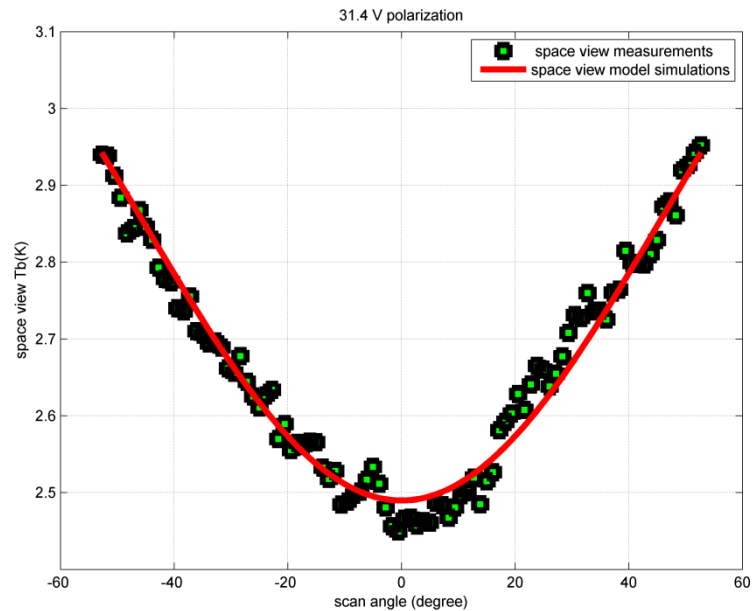
ATMS Down Track Scan

courtesy of Vince Leslie, MITLL

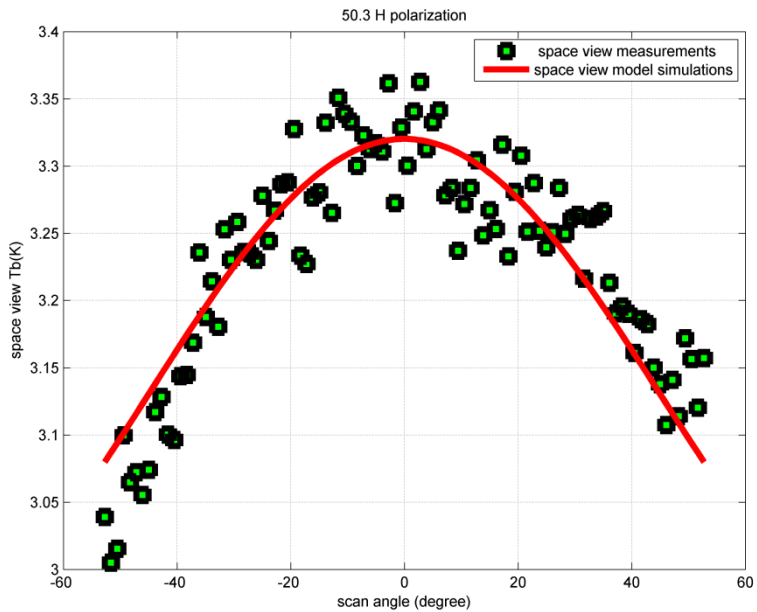
Channel 1



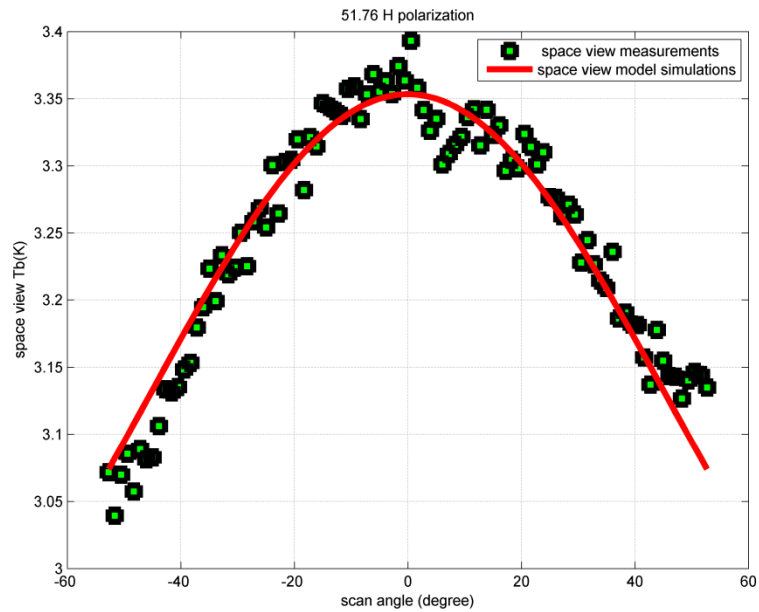
Channel 2



Channel 3



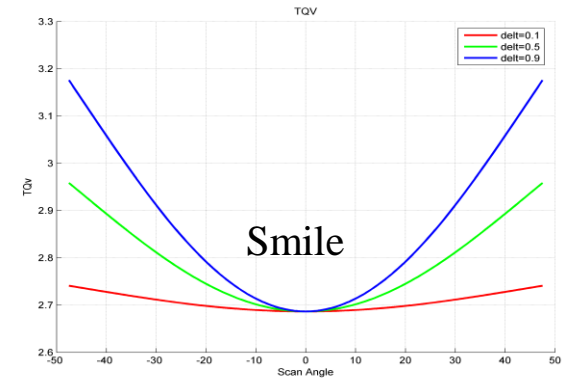
Channel 4



ATMS Pitch Maneuver Antenna Temperature Model

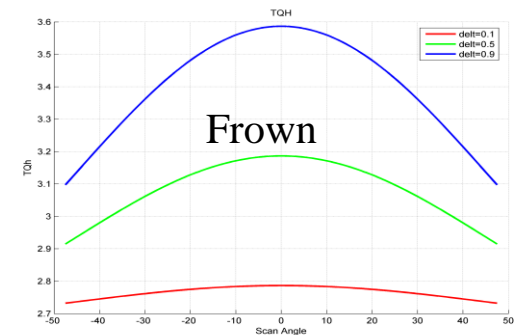
A smile pattern QV- antenna temperature:

$$T_a^{vq} = (\eta_m^{vv} + \eta_m^{hv})T_b^c + \beta_0^v + \beta_1^v \sin^2 \theta$$



A frown pattern QH- antenna temperature:

$$T_a^{hq} = (\eta_m^{hh} + \eta_m^{vh})T_b^c + \beta_0^h + \beta_1^h \cos^2 \theta$$

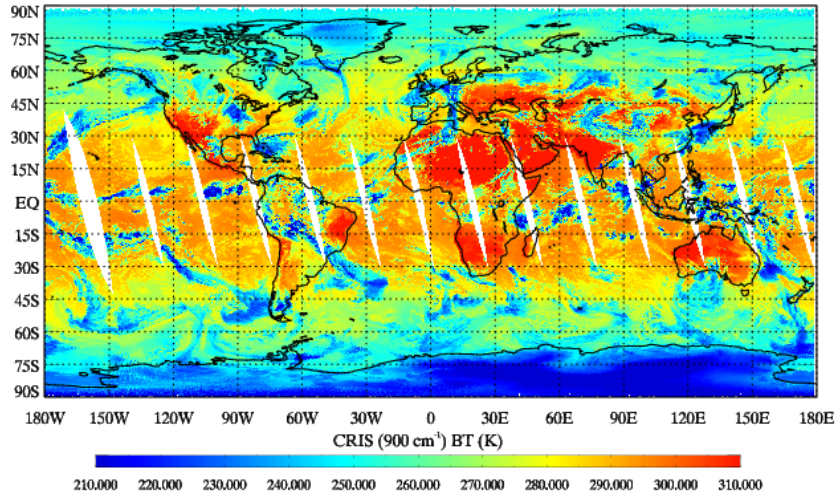


β : the slope and scale parameters related to spacecraft emission and reflection. It is not well understood in the past. NPP pitch maneuver offers a unique opportunity for us to characterize the term for better characterizations of the earth view bias along the scanline.

CrIS SDR Spectra and Global Coverage

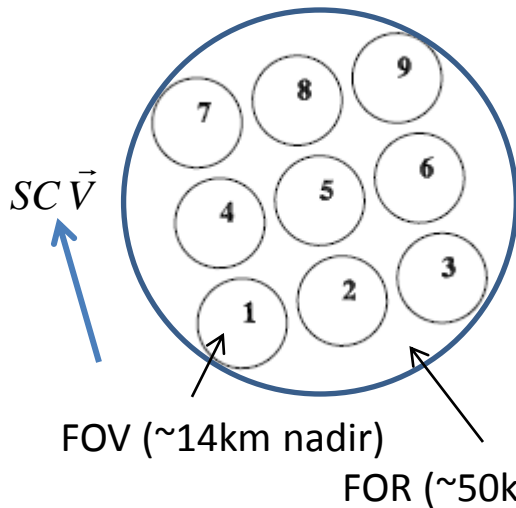
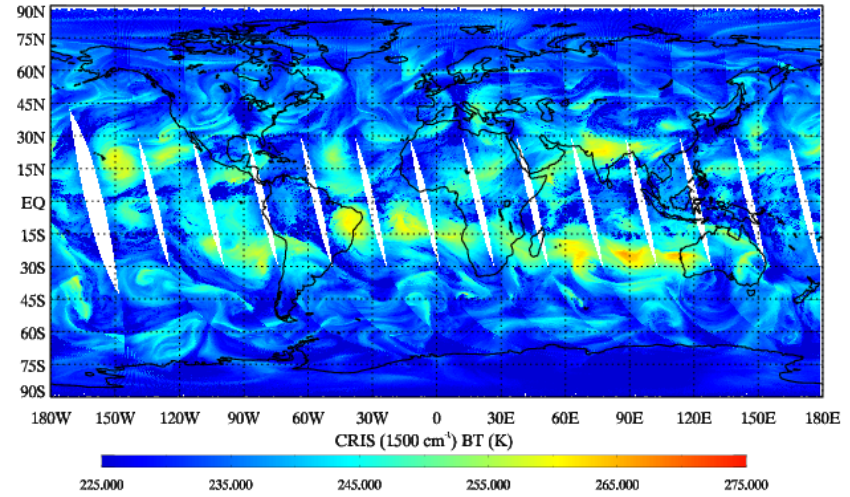
Window Channel

Ascending_orbits: CRIS (900 cm^{-1}) BT (K) Date: 2012-04-29

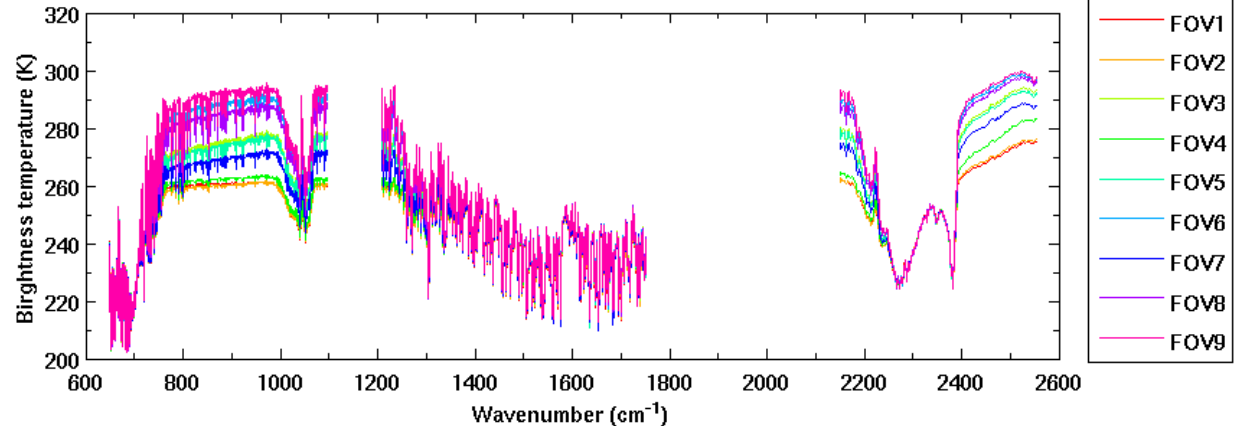


Water vapor Channel

Ascending_orbits: CRIS (1500 cm^{-1}) BT (K) Date: 2012-04-29



Brightness Temperature Lat: 0.00 Lon: -154.99 Time: 20120428 23:19:43



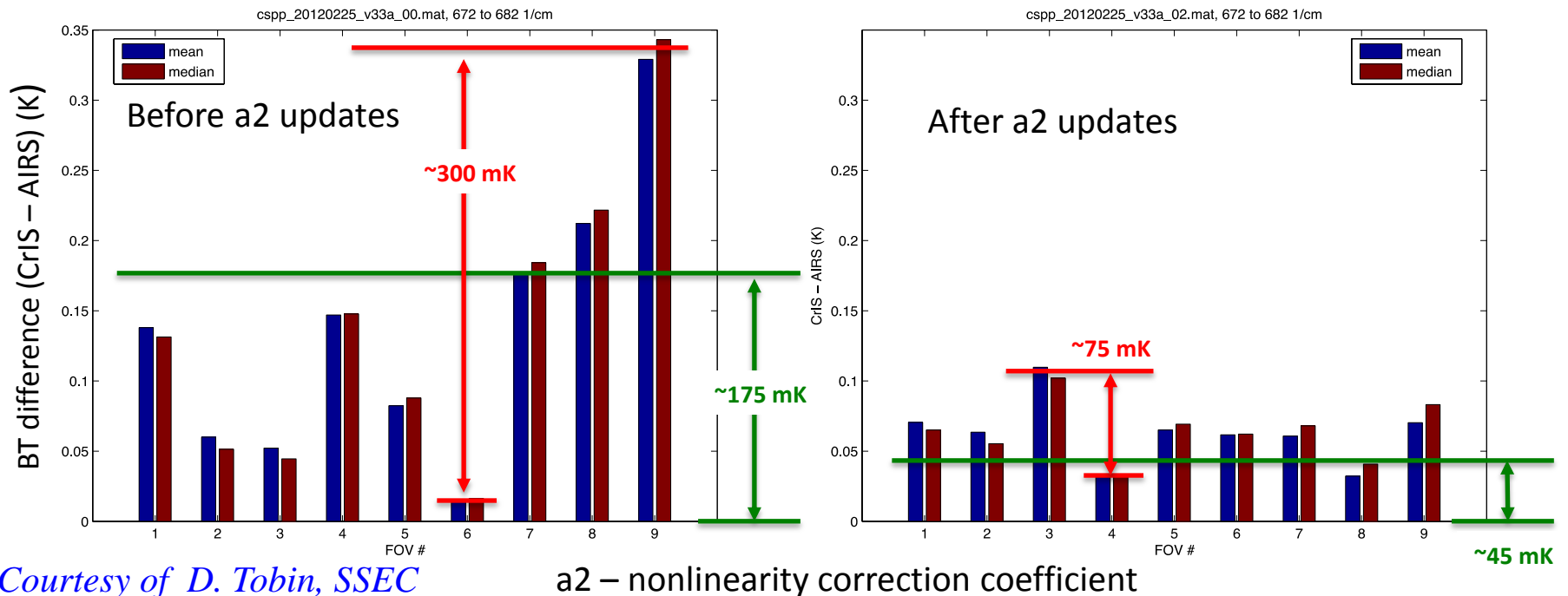
CrIS SDR Nonlinearity Correction

Method:

- Analysis of in-orbit Diagnostic Mode data
- Further a_2 adjustments using normal mode Earth scene observations
- Verify/assess results with SNO and double obs-calc comparisons with IASI and AIRS

Results:

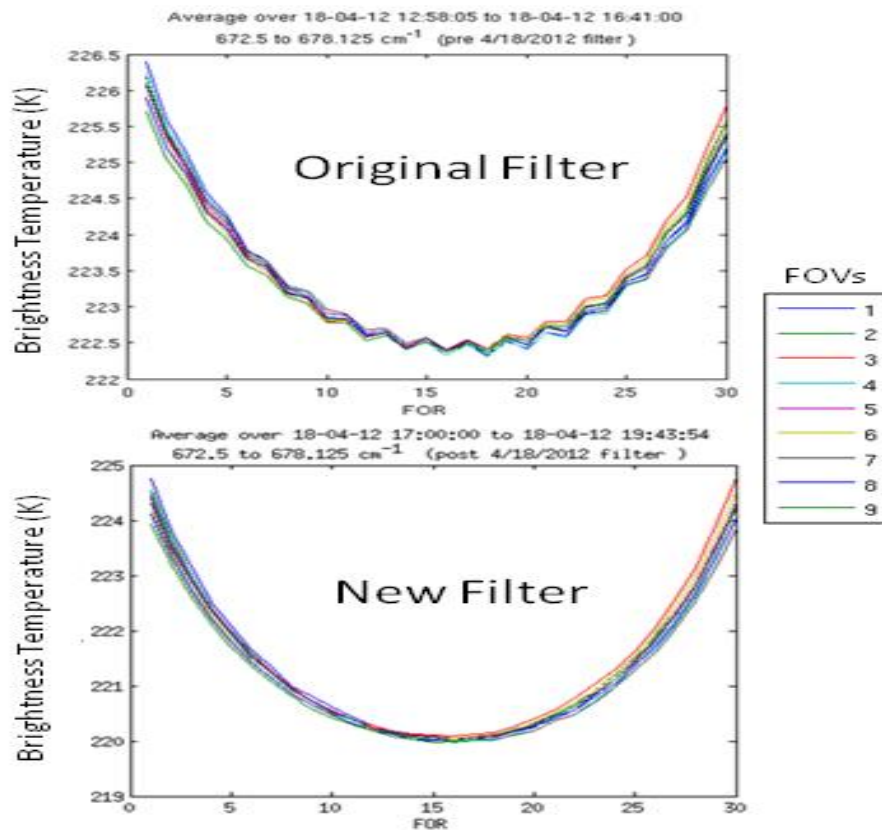
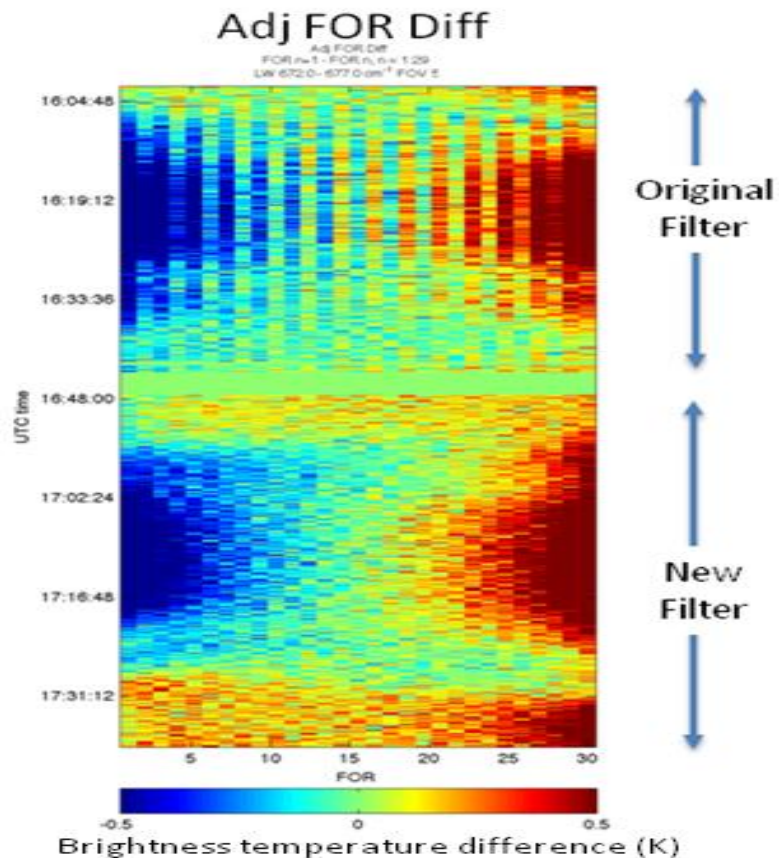
- Radiometric errors are significantly reduced (from 0.175 to 0.045K compared to AIRS)
- FOV-to-FOV differences are largely reduced



Courtesy of D. Tobin, SSEC

a_2 - nonlinearity correction coefficient

Striping Bias Removed by Changing Digital Filter

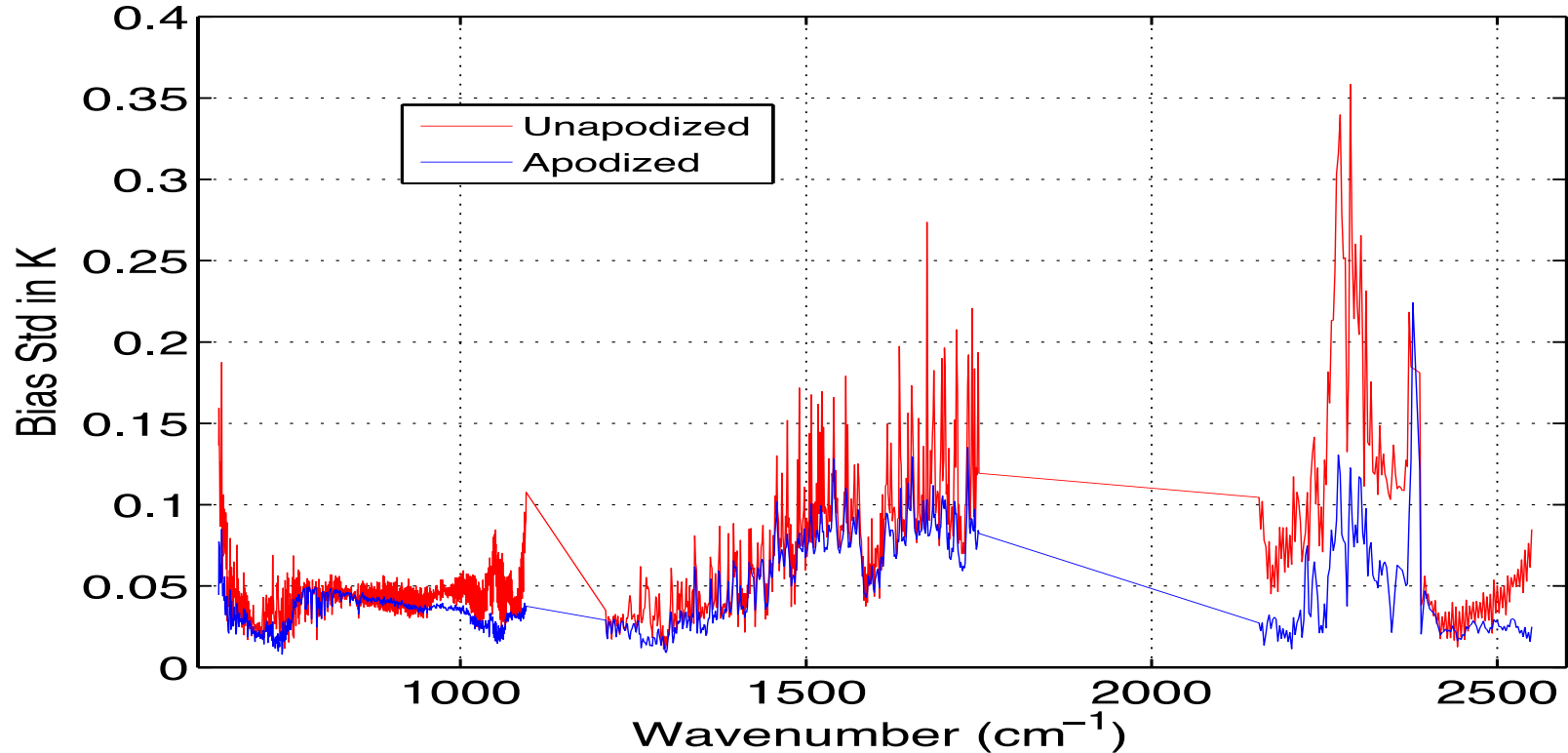


In-orbit data analysis revealed sweep direction bias (~0.1 K) and diagnostic data analysis, simulations and ground testing indicated the root cause is the defective on-board FIR digital filter. The bias was eliminated by uploading an improved filter

Courtesy of Dave Tobin (UW/SSEC) and Dan Mooney (MITLL)

CrIS SDR Apodization Effect

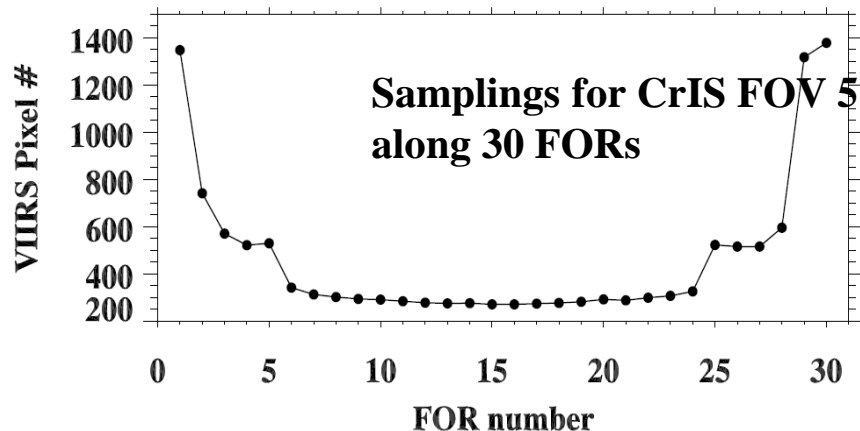
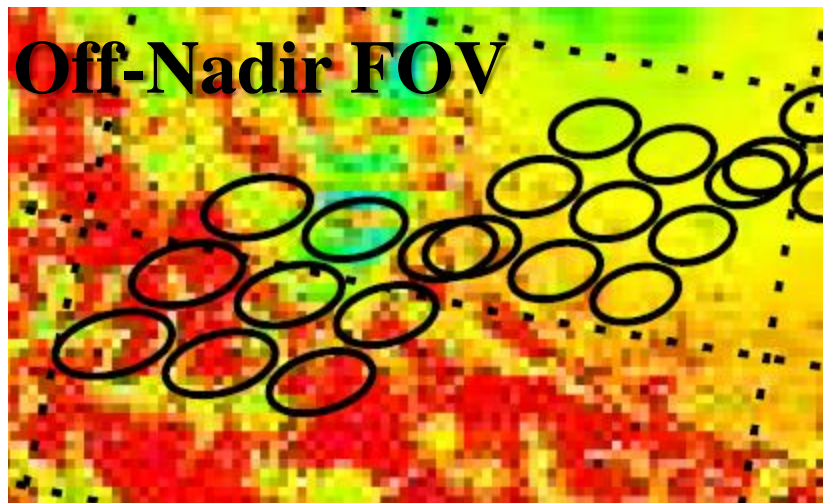
Std (over 9-FOVs) of Bias of CRIS Observed from NWP Simulated BT



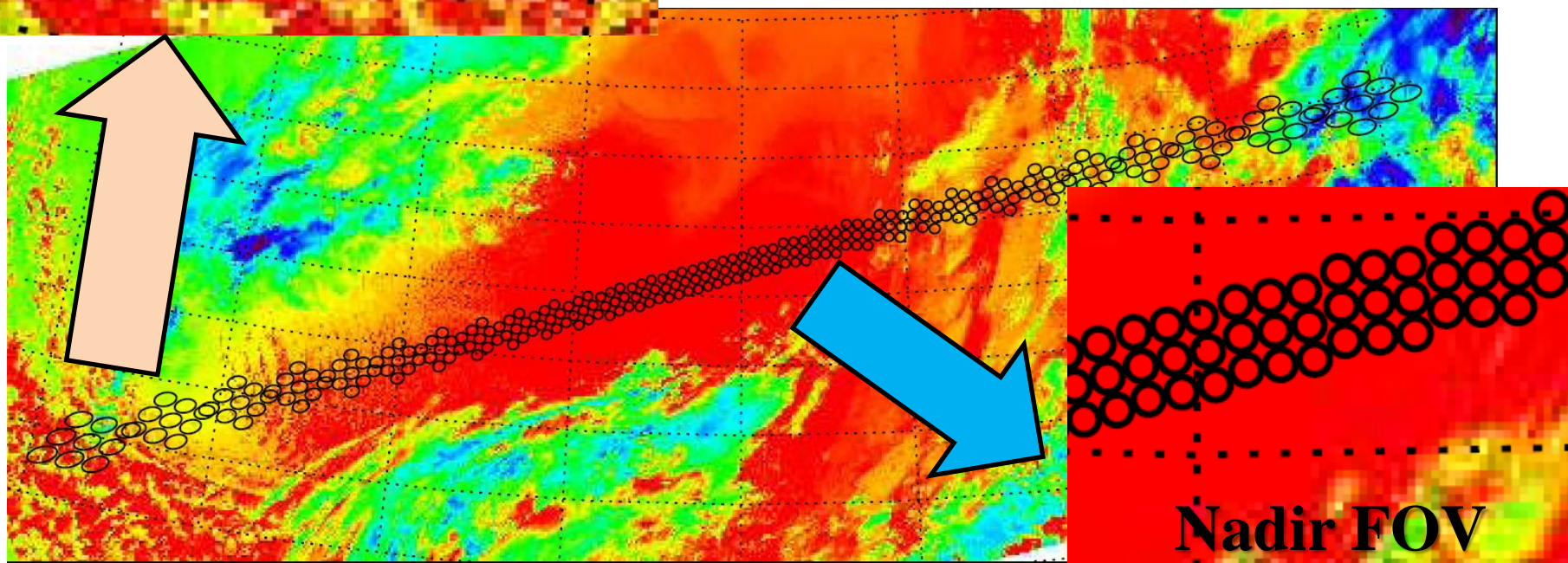
CrIS apodized SDR bias wrt NWP is about 0.03K in brightness temperature after updated nonlinearity parameter and frequency correction which is about 1 ppm in frequency uncertainty

Courtesy of Larrabee Strow, UMBC

Building High Quality NPP SDR Products for Science Community: CrIS and VIIRS Cross-Calibration

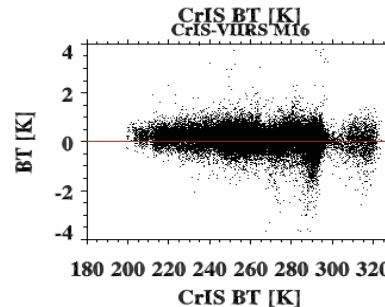
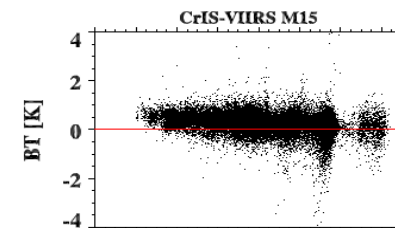
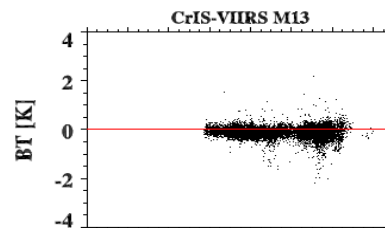
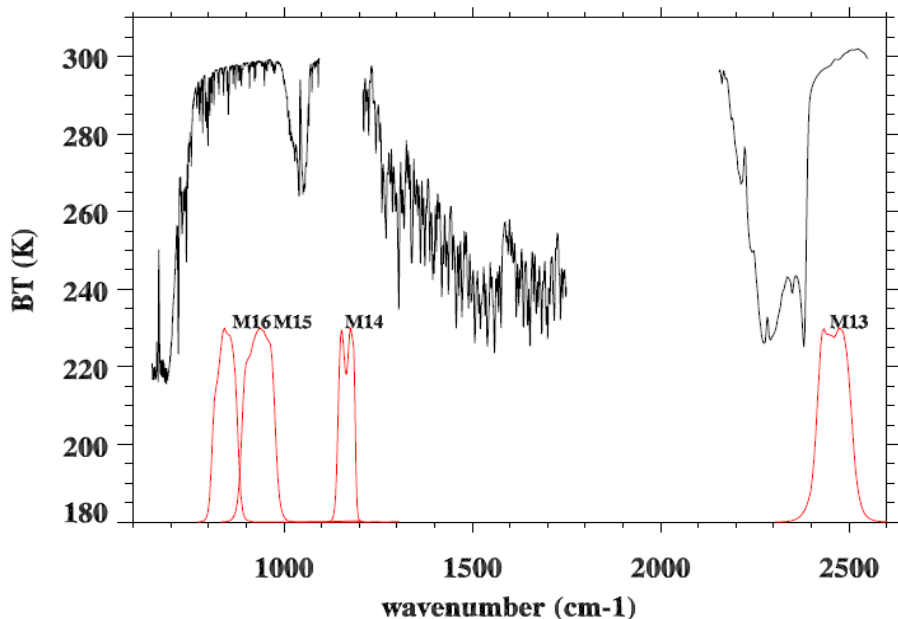


VIIRS pixels are averaged at each CrIS FOV ellipse



CrIS and VIIRS Cross-Calibration

CrIS spectrum is convolved with VIIRS SRFs for M13, M15, and M16

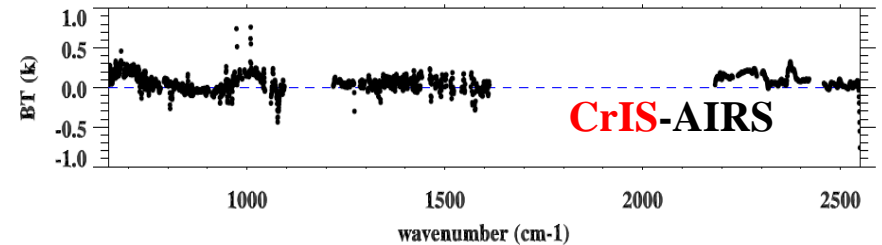
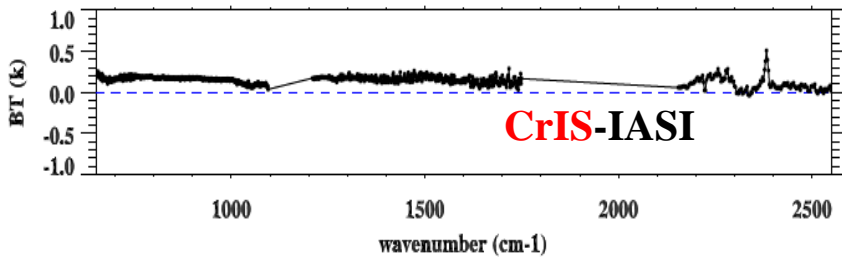
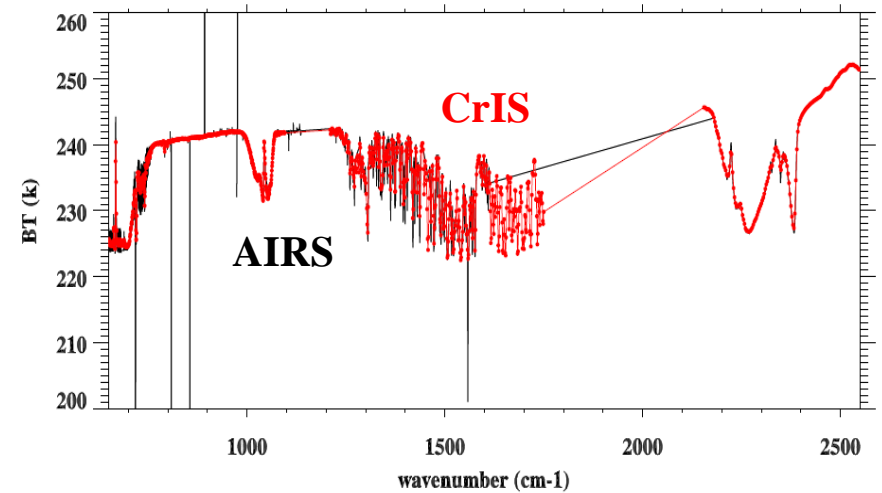
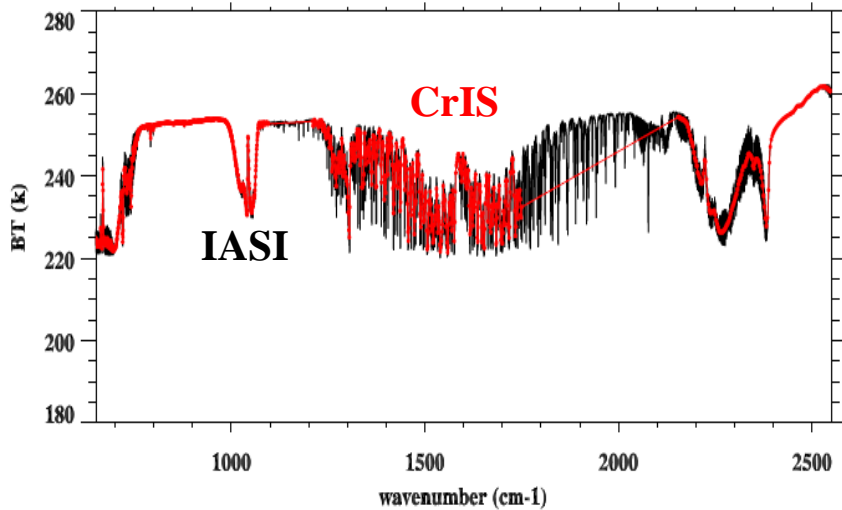


Mean Bias
M13: -0.098K
M15: 0.223K
M16: 0.122K

$$L_i = \frac{\int_{\nu_1}^{\nu_2} R(\nu) S_i(\nu) d\nu}{\int_{\nu_1}^{\nu_2} S_i(\nu) d\nu}$$

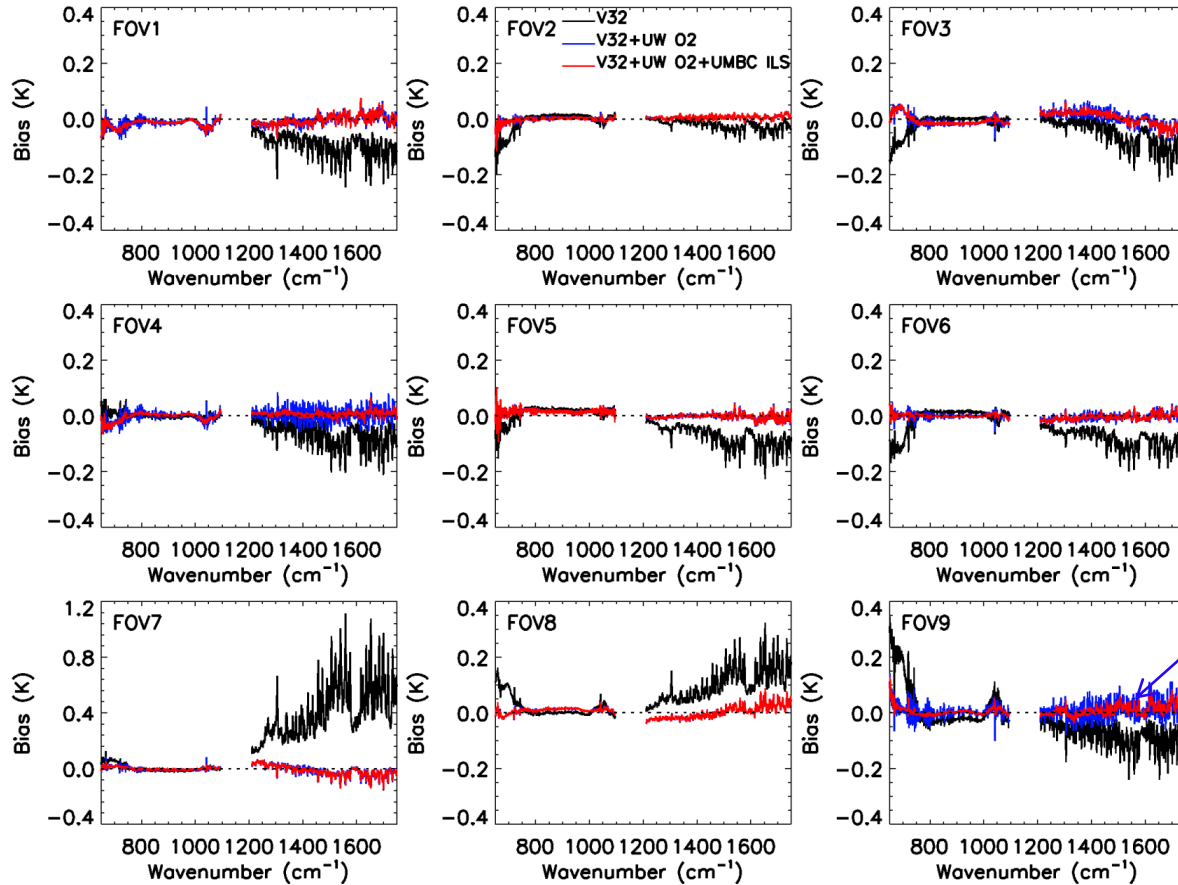
CrIS is slightly warmer than VIIRS at band M15 (10.7 μ m) and M16 (12.0 μ m). Small scene-temperature dependence can be seen at Band M15 and M16.

CrIS Radiometric Calibration: Compared to AIRS and IASI



CrIS has about 0.2K warm bias wrt IASI and no bias wrt AIRS from SNO collocated data sets. In the analysis, IASI data was de-apodized to obtain the original interferogram data and are then resampled using CrIS spectrum resolution, and FFT back to get CrIS like radiances

CrIS Individual FOV Bias wrt NWP Simulations



Total clear sky observation points ~400000

Blue: after nonlinearity coefficient change but before spectral coefficient change

Red: after nonlinearity coefficient and spectral coefficient changes

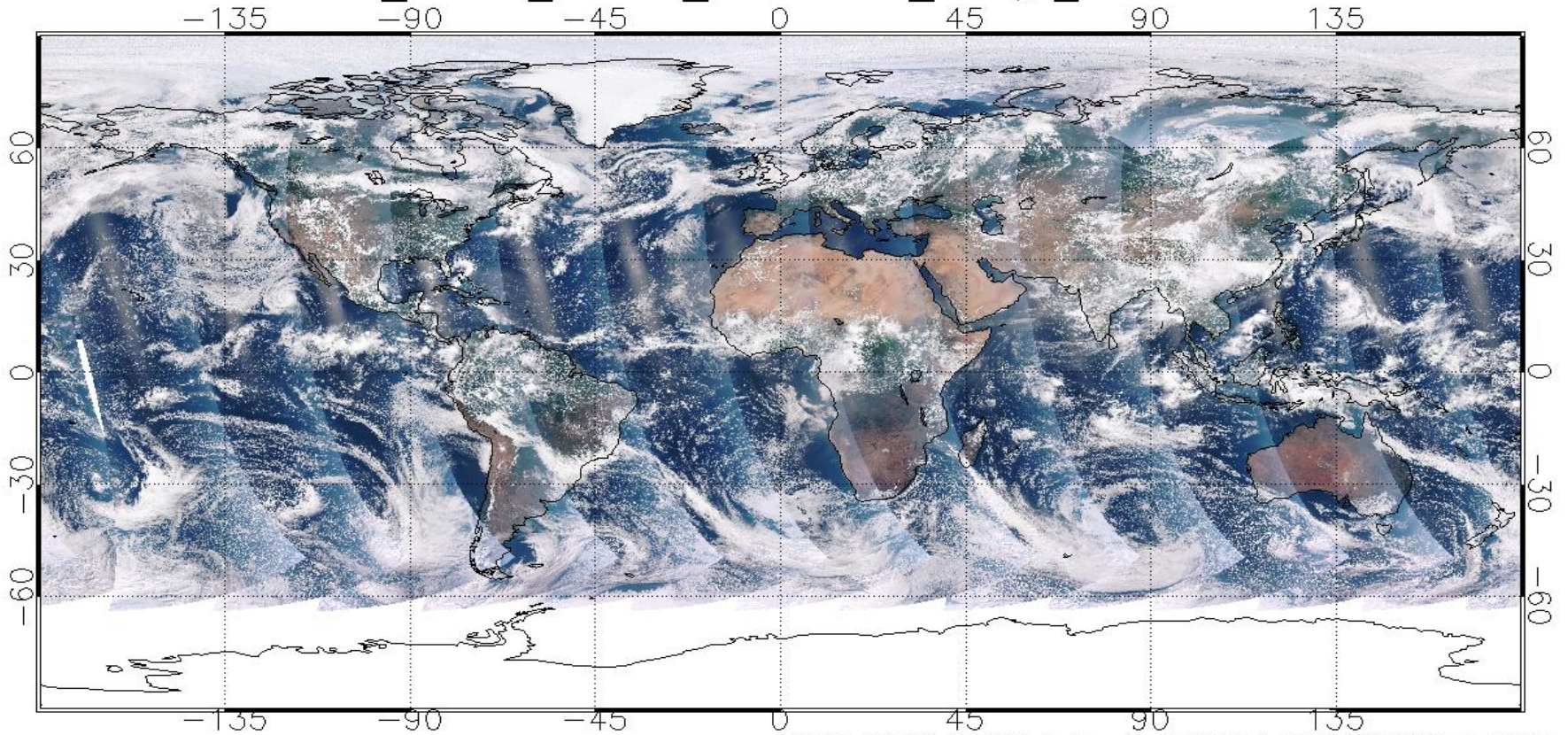
Black: before nonlinearity and spectral coefficient changes

$$BIAS_{FOVi} = \overline{(Obs - CRTM)_{FOVi}} - \overline{(Obs - CRTM)_{all}}$$

The achieved uniformity of the spectral and radiometric uncertainties cross the 9 FOVs is important for NWP to maximize the use of the radiance data

Online Browsing of VIIRS Truecolor Image

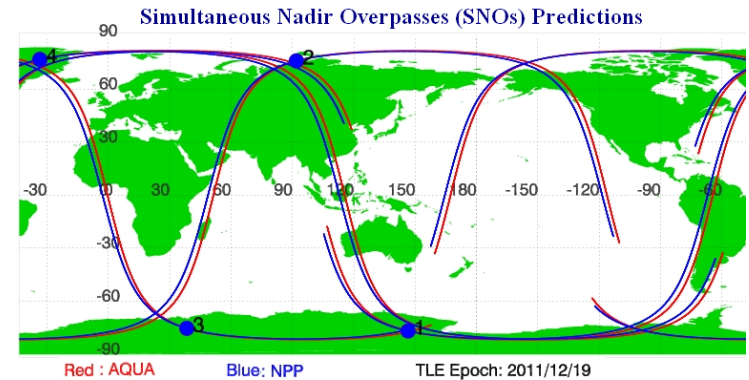
NPP_VIIRS_Global_TrueColor_Image_20120716



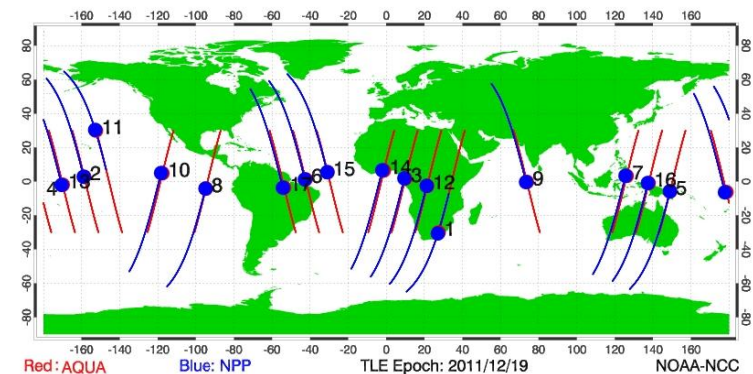
R:M5, G:M4, B:M3 (Updated at Wed Jul 18 10:27:57 2012 UTC)

Building High Quality NPP SDR Products for Science Community: VIIRS/MODIS/AVHRR Cross-Calibration

- The Simultaneous Nadir Overpass (SNO) prediction software has been upgraded with the latest version of the orbital perturbation algorithm and a graphic interface
- New capabilities developed to predict both traditional SNOs and SNOx extended to the low latitudes
- The new system has been predicting routinely since NPP launch, and predicted SNOs with Aqua/MODIS are being used for VIIRS channel responsivity diagnosis
- The SNOs as well as daily NPP orbital ground track predictions are readily available on the NCC website at: <https://cs.star.nesdis.noaa.gov/NCC/SNOPredictions>

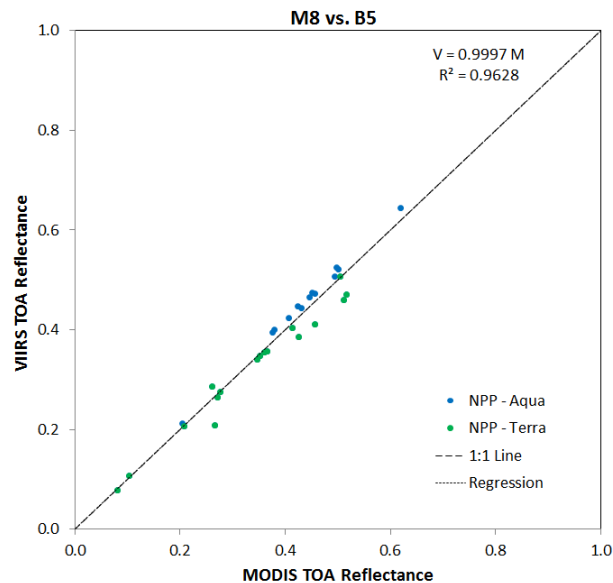
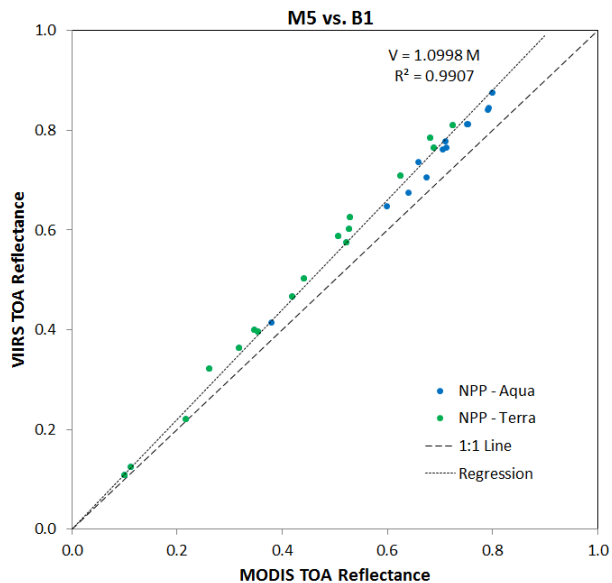
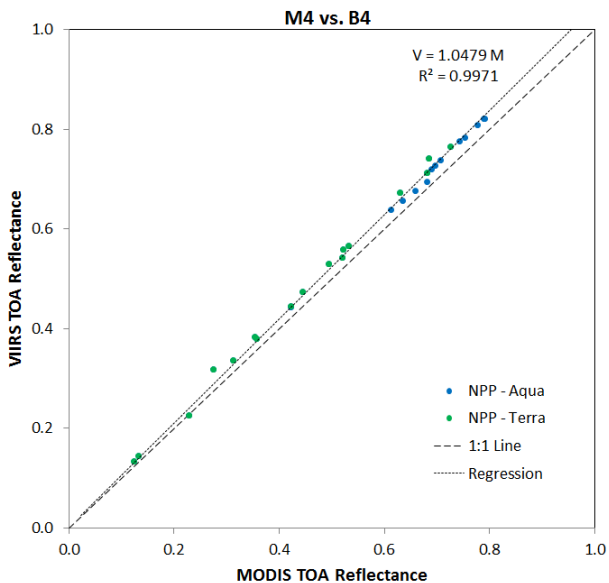
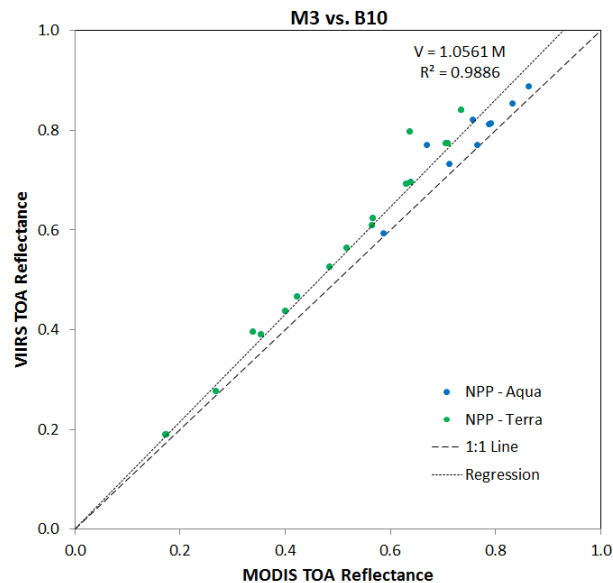
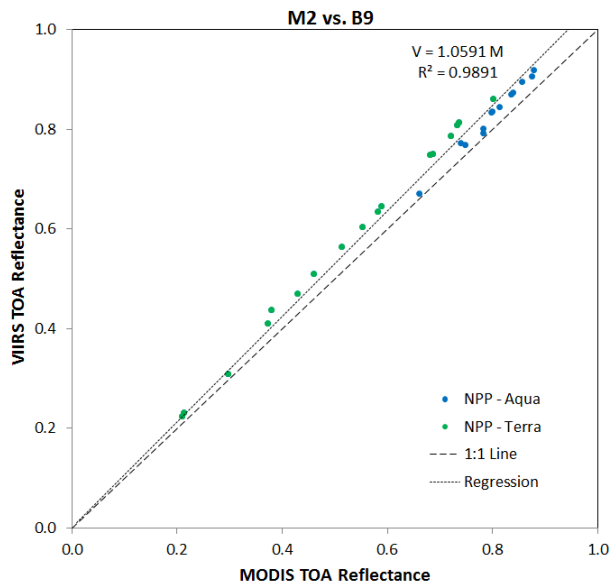
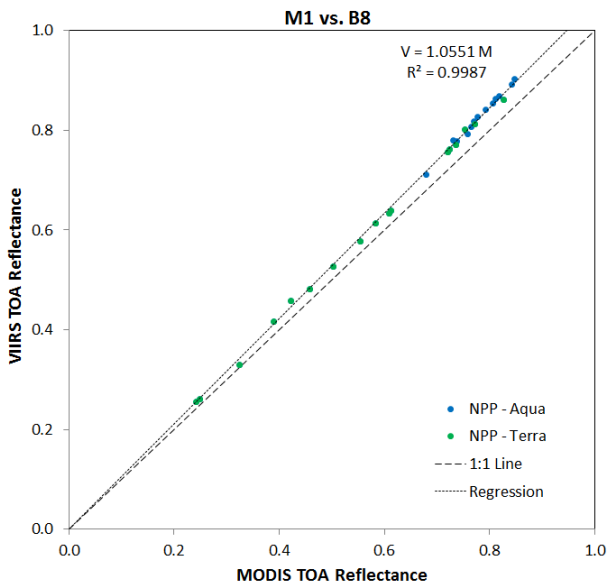


Index	Date	Time (AQUA)	AQUA Lat,Lon	NPP Lat,Lon	Distance(km)	Time Diff (sec)
1	12/21/2011	06:20:44	-76.77, 146.48	-76.77, 146.53	1.13	39
2	12/23/2011	21:47:58	75.93, 91.98	75.93, 91.93	1.46	11
3	12/26/2011	13:15:08	-75.29, 38.37	-75.29, 38.38	0.26	62
4	12/29/2011	06:20:26	76.76, -33.47	76.76, -33.49	0.67	43

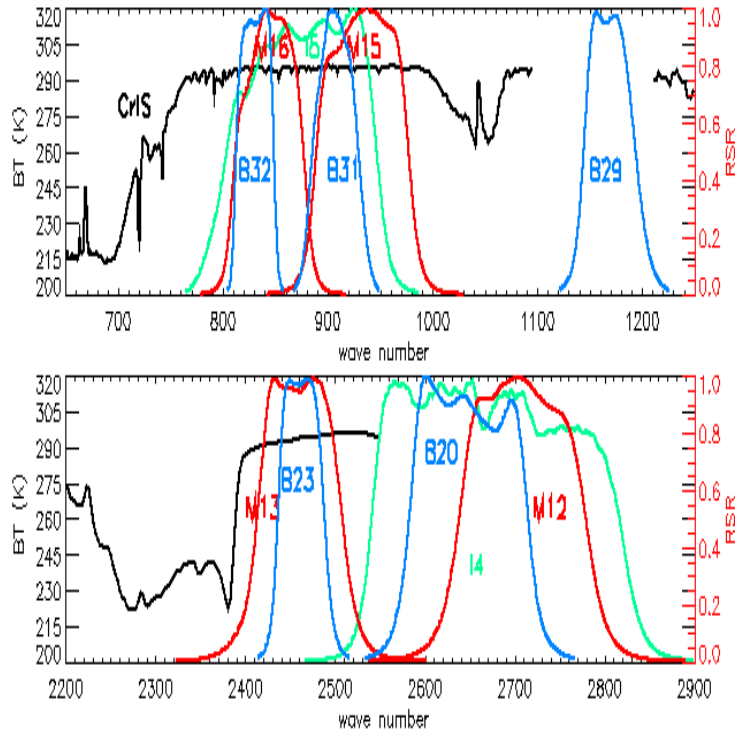


Courtesy of Changyong Cao/Mark Liu, STAR

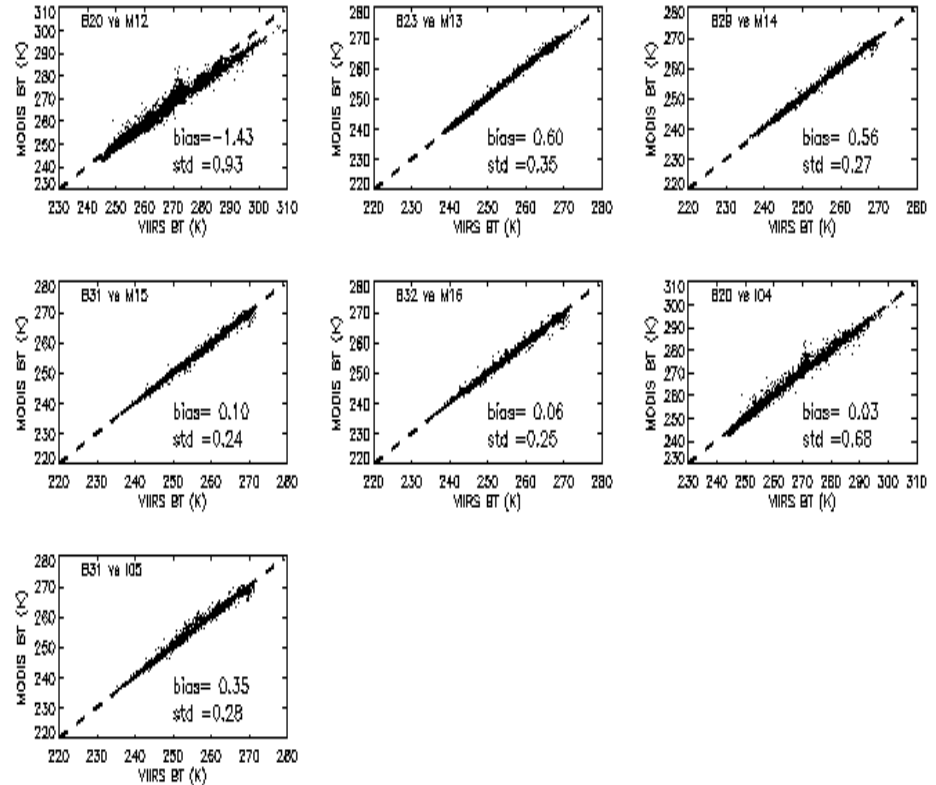
VIIRS vs. MODIS SNO Comparisons (cont.)



VIIRS and MODIS Comparison (Feb. 25)

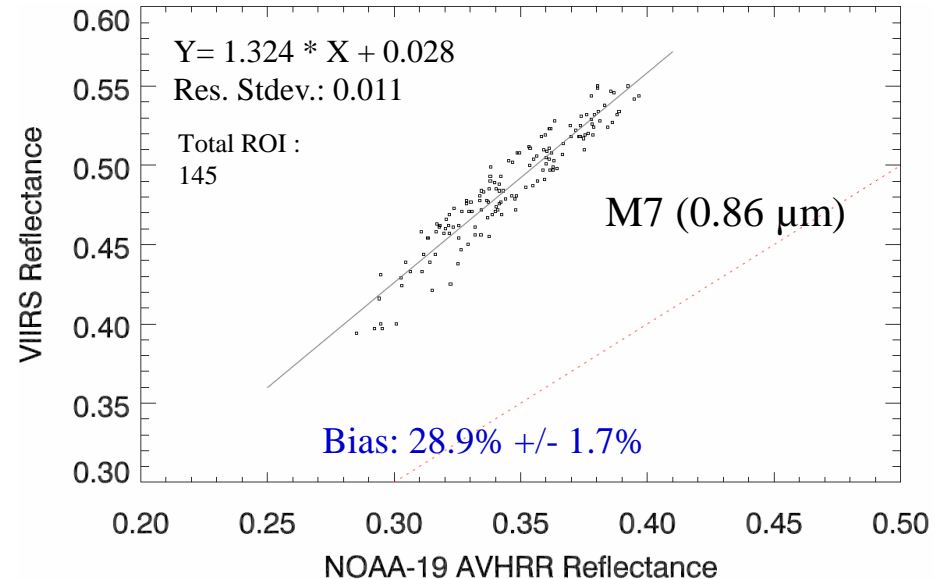
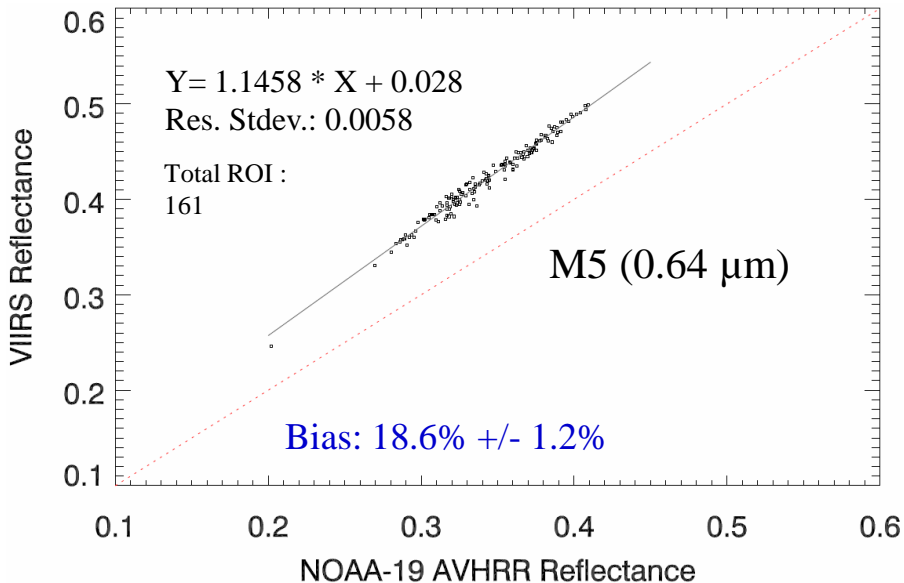


Bias = MODIS - VIIRS



Some of VIIRS and MODIS bias are caused by SRF difference between two instruments

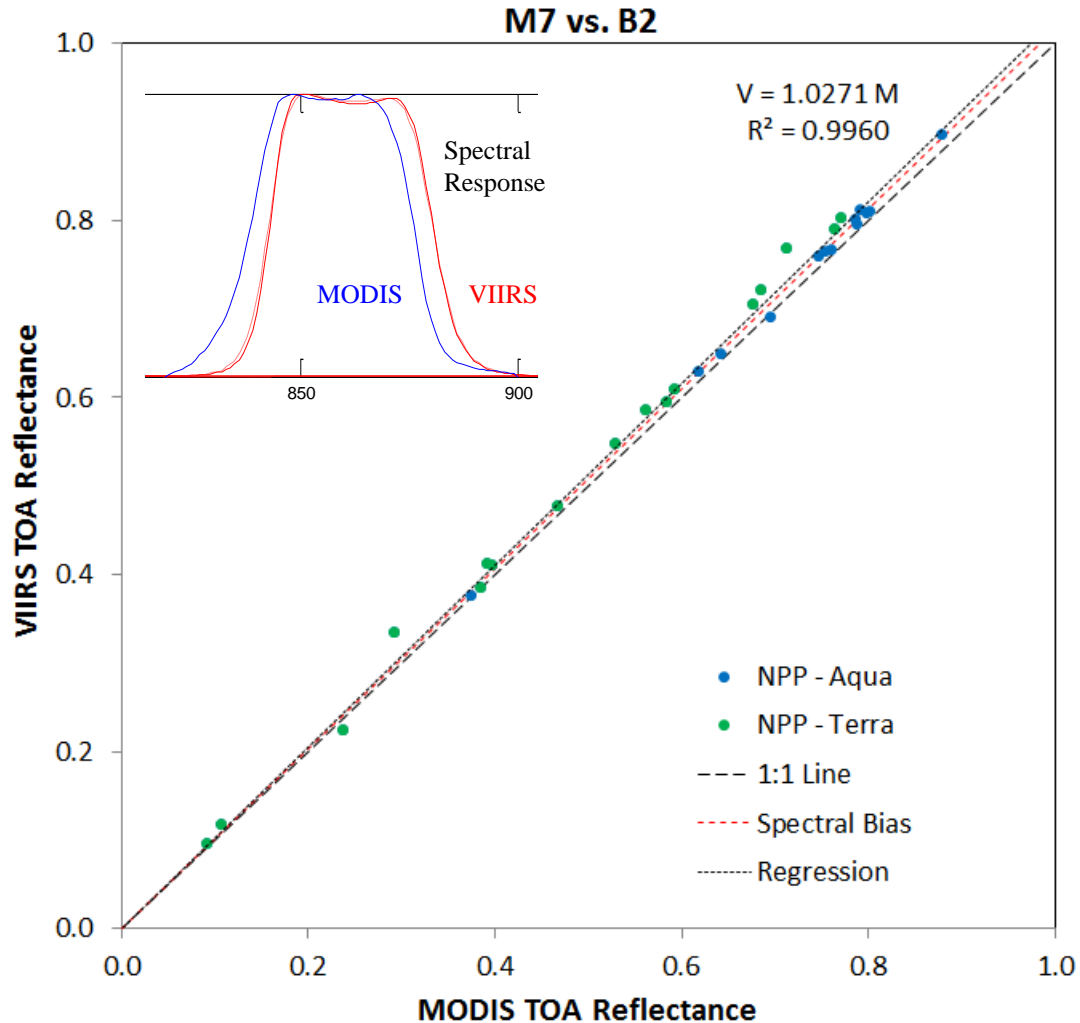
VIIRS and AVHRR SNOx Comparison



- Bias=(VIIRS-AVHRR)*100%/VIIRS
- Spectrally Induced Bias at Libya: Ch1: 9.69% +/- 0.306% Ch2: 15.14% +/- 2.37%
- *Note: the spectrally induced bias for channel 2 (given above) was calculated at NOAA-Libya site whereas this SNOx comparison is performed at different location in Africa. Thus water vapor variability might be much different.*

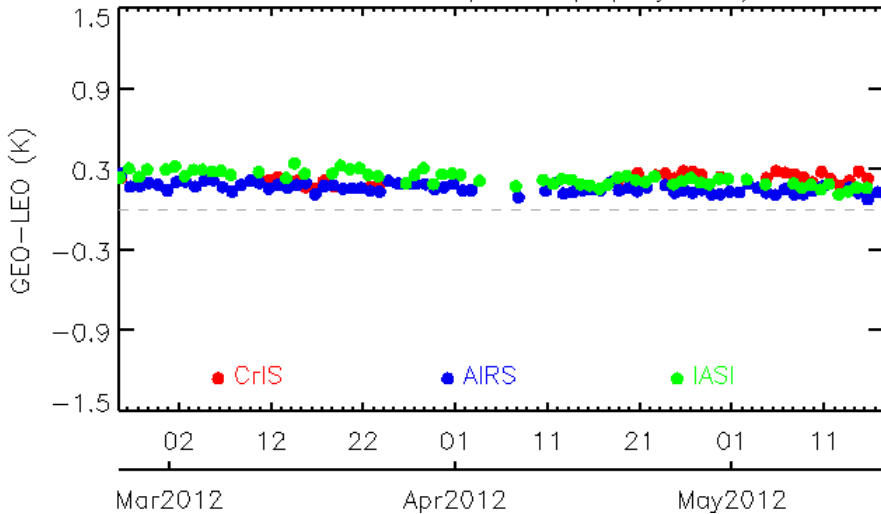
VIIRS vs. MODIS SNO Comparisons

- Compared TOA (top-of-atmosphere) reflectance measured by VIIRS and MODIS at the SNO sites (accounts for solar zenith angle differences)
- Because of differences between spectral responses of VIIRS and MODIS bands, reflectance data do not match exactly (1:1 line)
- The effect of the spectral response difference on the measured reflectance (spectral bias) was recently estimated using satellite hyperspectral data collected over the Antarctic Dome C site (Cao et al., submitted for publication)
- Ratios of the VIIRS band M7 and MODIS band 2 data agree very well with the prediction from that study (Spectral Bias line)
- This comparison confirms accuracy of the current radiometric calibration for VIIRS band M7, which is the band the most affected by the mirror degradation anomaly
- Other VIIRS bands also display high correlation with MODIS counterparts (next slide): estimates of spectral biases for these bands are ongoing
- While Terra provides so far most of the low reflectance data, a small bias between Aqua and Terra data can be seen (will investigate)

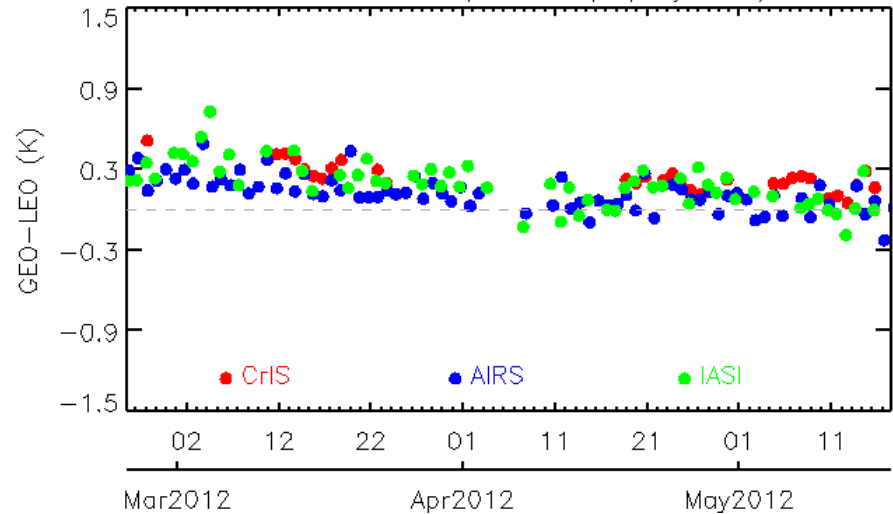


Uses of CrIS for GEO Infrared Channel Calibration

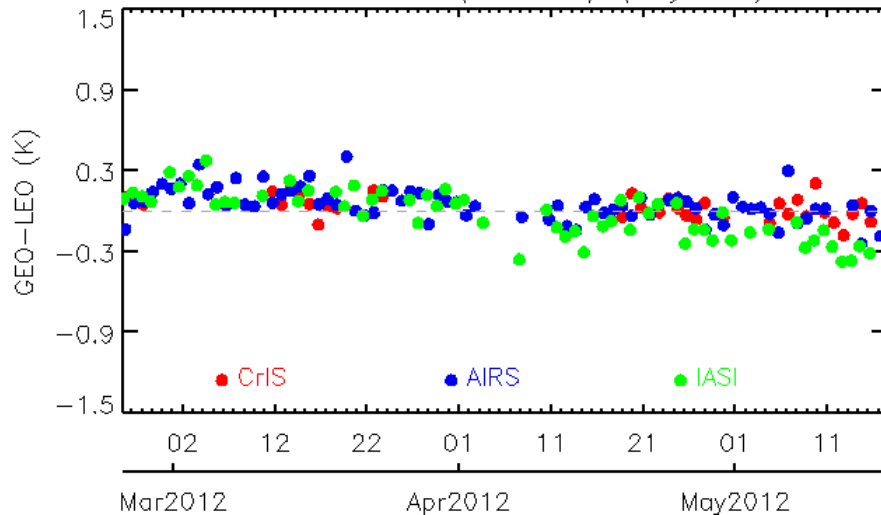
GOES13 Ch3 (6.5um) (Daytime)



GOES13 Ch4 (10.7um) (Daytime)

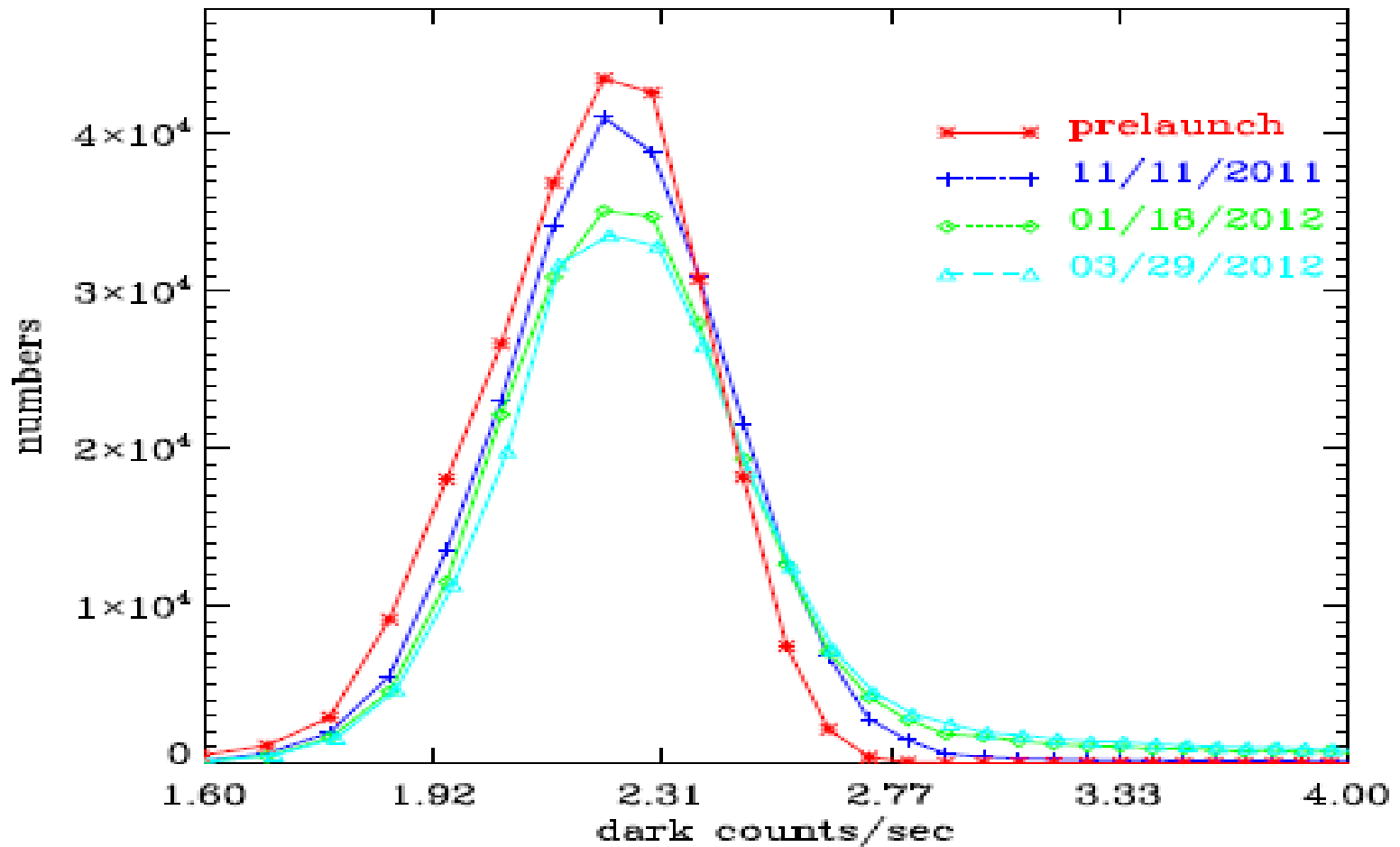


GOES13 Ch6 (13.3um) (Daytime)



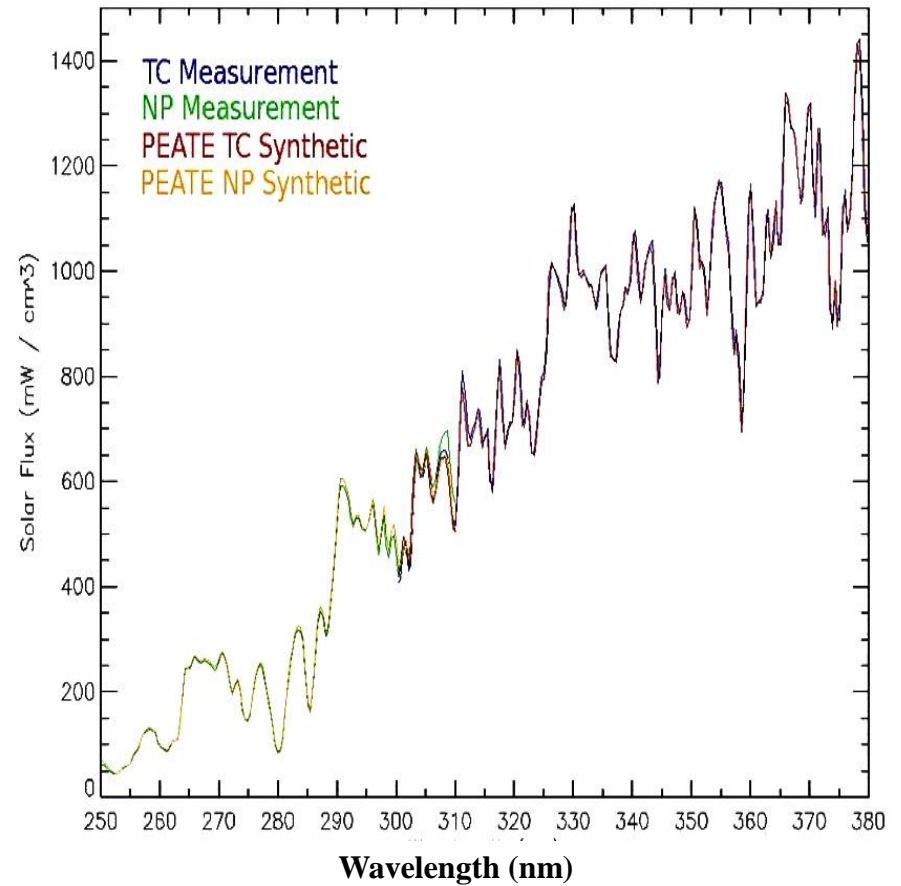
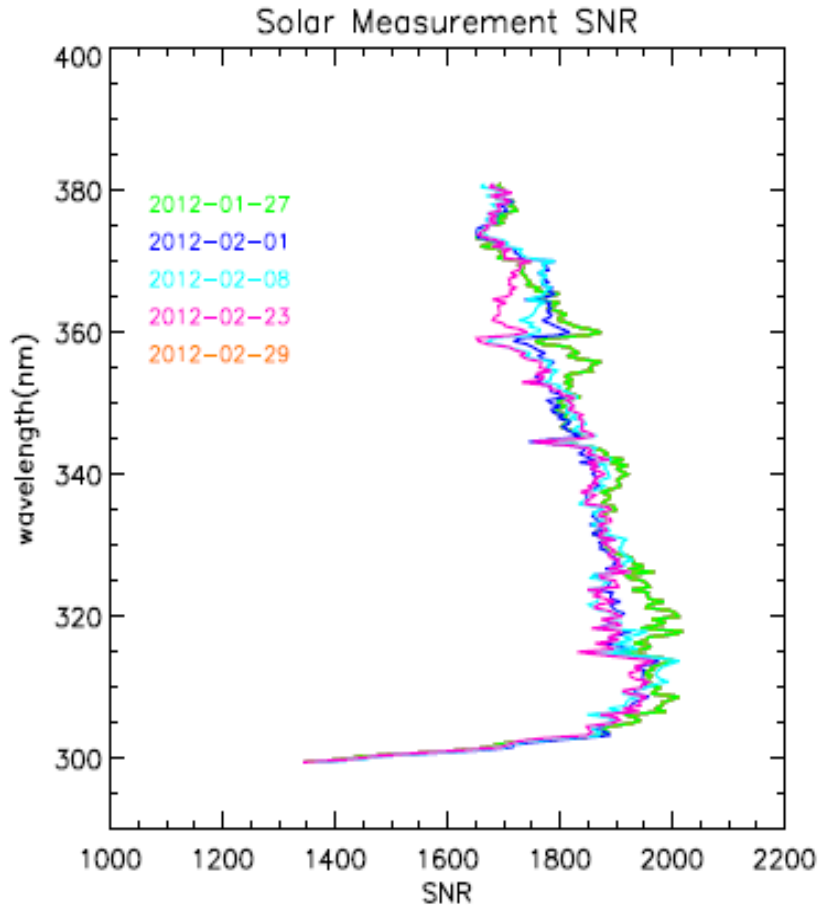
Courtesy of Fangfang Yu, STAR

OMPS On-orbit Dark Count Performance



Dark current since NPP launch is being shifted to high value in mean due to an increasing number of hot pixels and transient signal impacts

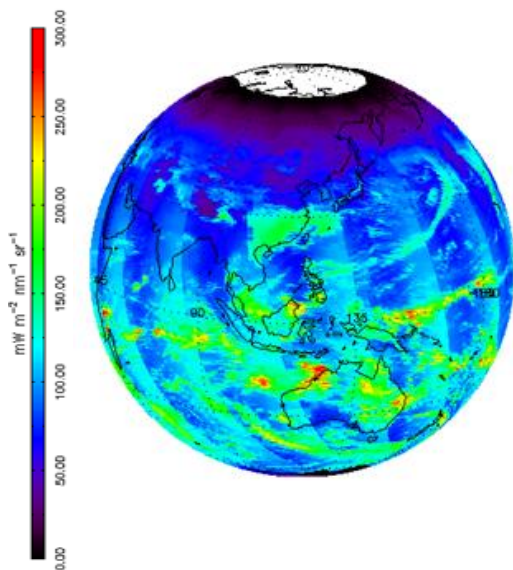
OMPS On-orbit Solar SNR and Flux



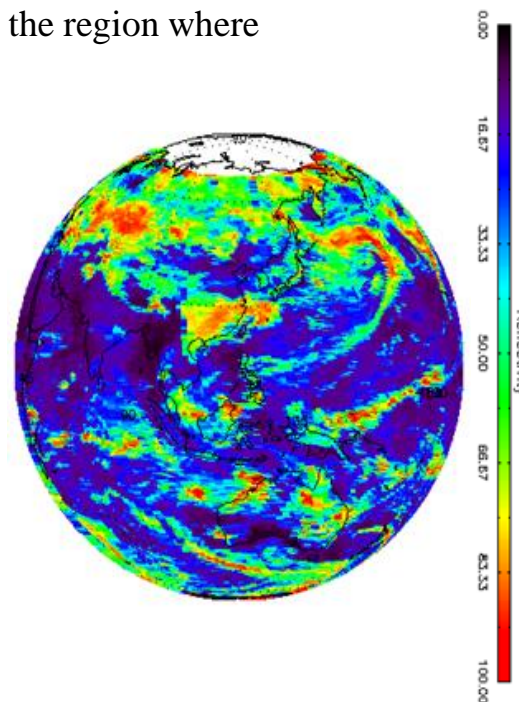
Solar SNR meets the system requirement of 1000 and on-orbit solar flux is consistent with prelaunch prediction within 1-2%

Example of IDPS SDR Application

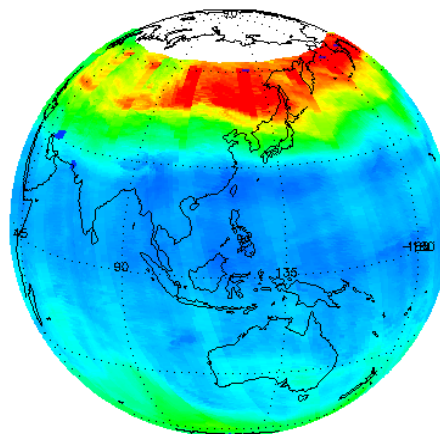
← **Radiances** at 331-nm: radiance variations across the orbital track and with solar zenith angles. The white circle around the North Pole is the region where no data is collected.



Reflectivity → Effective Reflectivity from the multiple triplet retrieval algorithm. The values vary from bright clouds to dark open ocean scenes as expected.



Total Ozone → from the multiple triplet retrieval algorithm. The values show some cross track variations and are offset approximately 5-10% from other satellite ozone products.



IDPS SDR &EDR from OMPS TC measurement (end of 1/26/2012 and start of 1/27/2012).



Summary and Conclusions

- STAR ICVS-LTM is improved for NPP/METOP/GCOM sensors with more parameters being trended. The mean and standard deviations are being used for IDPS updates in LUT, PCT and Engineering packages
- SDR teams are supporting all phases of the Suomi NPP instrument calibration and have completed all the critical tasks during ICV period.
- The teams developed some innovative techniques for on-orbit calibration. For example, uses of COSMIC GPSRO data and LBLRTM for absolute calibration of sounding channels
- Uses of the Suomi NPP mission specific data are very significant in calval. Some of data such as VIIRS maneuver data have been used for characterization of radiance vs. scan angle and SD transmission functions, and CRIS diagnostic mode data for refining nonlinearity parameter