Overview of Suomi National Polar-Orbiting Partnership Satellite Instrument Calibration and SDR Validation

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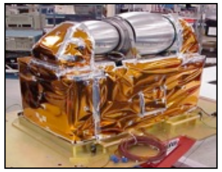
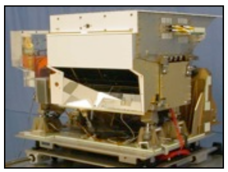
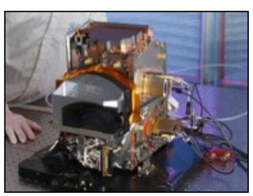
Suomi NPP and JPSS-1 Instruments

Instrument Type		Measurement
	**ATMS** - Advanced Technology Microwave Sounder	ATMS and CrIS together provide high vertical resolution **temperature** and **water vapor information needed to maintain and improve forecast skill** out to 5 to 7 days in advance for extreme weather events, including hurricanes and severe weather outbreaks
	**CrIS** - Cross-track Infrared Sounder	
	**VIIRS** – Visible Infrared Imaging Radiometer Suite	VIIRS provides many **critical imagery products** including snow/ice cover, clouds, fog, aerosols, fire, smoke plumes, vegetation health, phytoplankton abundance/chlorophyll
	**OMPS** - Ozone Mapping and Profiler Suite	Ozone spectrometers for **monitoring ozone** hole and recovery of stratospheric ozone and for UV index forecasts
	**CERES** - Clouds and the Earth's Radiant Energy System	Scanning radiometer which supports studies of Earth Radiation Budget

Suomi NPP TDR/SDR Algorithm Schedule

Sensor	Beta	Provisional	Validated
CrIS	February 10, 2012	February 6, 2013	March 18, 2014
ATMS	May 2, 2012	February 12, 2013	March 18, 2014
OMPS	March 7, 2012	March 12, 2013	September 8, 2015
VIIRS	May 2, 2012	March 13, 2013	April 16, 2014

Beta

- Early release product.
- Initial calibration applied
- Minimally validated and may still contain significant errors (rapid changes can be expected. Version changes will not be identified as errors are corrected as on-orbit baseline is not established)
- Available to allow users to gain familiarity with data formats and parameters
- Product is not appropriate as the basis for quantitative scientific publications studies and applications

Provisional

- Product quality may not be optimal
- Incremental product improvements are still occurring as calibration parameters are adjusted with sensor on-orbit characterization (versions will be tracked)
- General research community is encouraged to participate in the QA and validation of the product, but need to be aware that product validation and QA are ongoing
- Users are urged to consult the SDR product status document prior to use of the data in publications
- Ready for operational evaluation

Validated

- On-orbit sensor performance characterized and calibration parameters adjusted accordingly
- Ready for use in applications and scientific publications
- There may be later improved versions
- There will be strong versioning with documentation

ATMS SDR Requirements vs. Performance

Channel	Accuracy (K) On-Orbit/Spec	NEΔT (K) On-Orbit/Spec	Channel	Calibration (K) On-Orbit/Spec	NEΔT (K) On-Orbit/Spec
1	/1.00	0.25/0.5	**12**	0.24/0.75	0.59/1.0
2	/1.00	0.31/0.6	**13**	0.13/0.75	0.86/1.5
3	/0.75	0.37/0.7	**14**	0.02/0.75	1.23/2.2
4	/0.75	0.28/0.5	**15**	0.09/0.75	1.95/3.6
5	0.18/0.75	0.28/0.5	**16**	/1.00	0.29/0.3
6	0.09/0.75	0.29/0.5	**17**	/1.00	0.46/0.6
7	0.02/0.75	0.27/0.5	**18**	0.50/1.00	0.38/0.8
8	0.06/0.75	0.27/0.5	**19**	0.36/1.00	0.46/0.8
9	0.06/0.75	0.29/0.5	**20**	0.31/1.00	0.54/0.8
10	0.18/0.75	0.43/0.75	**21**	0.13/1.00	0.59/0.8
11	0.22/0.75	0.56/1.0	**22**	0.40/1.00	0.73/0.9

CrIS SDR Requirements vs. Performance

CrIS SDR uncertainties (**blue**) vs. specifications (black)

Band	NEdN @287K BB $mW/m^2/sr/cm^{-1}$	Radiometric Uncertainty @287K BB (%)	Frequency Uncertainty (ppm)	Geolocation Uncertainty (km) *
LW	**0.098** (0.14)	**0.12** (0.45)	**3** (10)	**1.2** (1.5)
MW	**0.036** (0.06)	**0.15**(0.58)	**3** (10)	**1.2** (1.5)
SW	**0.003** (0.007)	**0.2** (0.77)	**3** (10)	**1.2** (1.5)

VIIRS SDR Requirements vs. Performance

	Requirement (absolute uncertainty for uniform scenes)	Prelaunch and onboard calibration	Validation: Relative to MODIS/CrIS/IASI/other thru Inter-comparisons	Note
VIIRS RSB	2% typical reflectance; 0.3% stability; 0.1% desirable for Ocean Color Applications	1.2% for M1-M7; 1.5% for M8&9 1.4% for M10 1.3% for I1&I2 1.6% for I3	2% (±1%) for matching bands	Except bands with very low signal (ex. M11) Geolocation error: expectation is half I-band pixel; achieved better than quarter I-band pixel (1-s)
VIIRS TEB	M12/M13: 0.7%(0.13K) @270K M14: 0.6% (0.26K) @ 270K M15/M16: 0.4% (0.22K/0.24K) @270K I4: 5% (0.97K) @270K I5: 2.5% (1.5K) @270K	Better than 0.13K for all M bands except M13 (0.14); 0.47K for I4; 0.23K for I5	0.1K based on statistical comparison with MODIS and CrIS ER-2/SHIS Aircraft underflight shows excellent agreement M15 0.4 K bias relative to CrIS at 200K (in spec.)	M15 at 190K requirement is 2.1% radiance or 0.56K Geolocation uncertainty: expectation was half I-band pixel; achieved better than quarter I-band pixel (1-s)
VIIRS DNB	• 5%, 10%,30% L_{min} (LGS,MGS,HGS)	3.5%, 7.8%, and 11% (LGS, MGS, HGS)	• 4%, 7.7%, 11.8% (LGS, MGS, HGS)	Geolocation error is a ~10th of a pixel (1-s) on the ellipsoid earth but can exceed 1km (up to 24 km at the edges of scan) without terrain correction

OMPS SDR Requirements vs. Performance

Parameters	Specification/Prediction Value	On-Orbit Performance
Non-linearity	< 2% full well	< 0.46%
Non-linearity Accuracy	< 0.2%	< 0.2%
On-orbit Wavelength Calibration	< 0.01 nm	0.15 nm
Stray Light NM Out-of-Band + Out-of-Field Response	For NM ≤ 2	average < 2%
Intra-Orbit Wavelength Stability	Allocation (flow down from EDR error budget) = 0.02 nm	~ 0.02 nm
SNR	1000	> 1000
Inter-Orbital Thermal Wavelength Shift	Allocation (flow down from EDR error budget) = 0.02 nm	~0.02 nm
CCD Read Noise	60 –e RMS	< 25 –e RMS
Detector Gain	43 (for NP) 46 (for NM)	47 (for NP) 51 (for NM)
Absolute Irradiance Calibration Accuracy	< 7%	< 7% for majority channels
Absolute Radiance Calibration Accuracy	< 8%	< 5% for majority channels
Normalized radiance Calibration Accuracy	< 1%	< 1%

JPSS SDR 2015 Major Accomplishments

- Completed comprehensive SDR CalVal Plans for JPSS-1. The calval tasks are presented with clear role and responsibility, task objective, expected outcomes, and lessons learned from SNPP
- Developed an offline CrIS full spectral resolution (FSR) SDR processing system and made the FSR products available to user community
- Developed ATMS radiance-based radiometric calibration, replacing Rayleigh-Jeans approximation in two-point calibration system
- Developed J1 VIIRS DNB waiver mitigation and delivered pre-operational software to IDPS program on-time, and implemented the operational straylight correction in DNB band
- SNPP OMPS earth view SDR products have reached the validated maturity level after updating LUTs of wavelength scale, solar irradiance and earth view radiance coefficients
- Integrated CalVal System (ICVS) – Lite version was successfully transitioned to GRAVITE for NASA Flight and OSPO operational uses

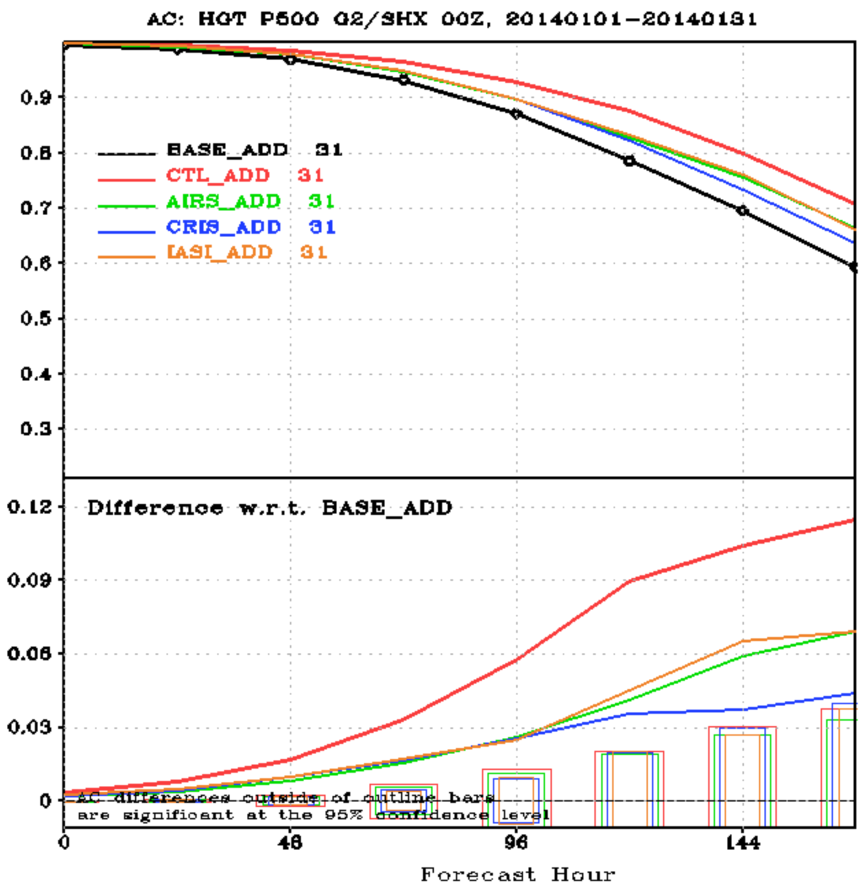
ATMS SDR Team 2015 Top Five Accomplishments

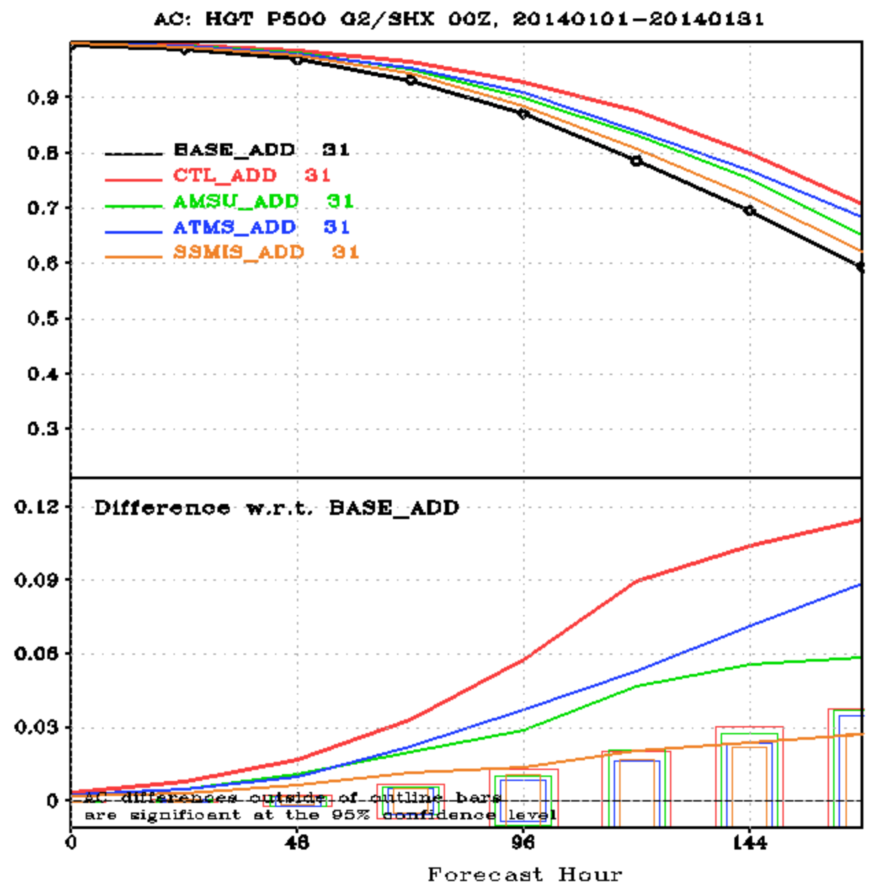
1. Developed the radiometric two-point calibration in radiance, instead of brightness temperature which is based on Rayleigh-Jeans approximation. The full radiance calibration algorithm will be in IDPS MX8.12 and IDPS Block 2
2. Standardized NEdT calculation for ATMS and other microwave sounding instruments using Allan Deviation. The new algorithm has resulted in much stable noise trending and is SI traceable
3. Optimized the ATMS de-striping algorithm for the earth scene brightness temperatures and generated 45 days of ATMS TDR data for NWP user community to experiment the impacts of ATMS on global forecast skills
4. Developed a physically based model for correcting the radiation from ATMS reflector emission contributed to the earth scene brightness temperature
5. Updated ATMS processing coefficient tables (e.g. nonlinearity coefficients, threshold for calibration counts)

NOAA Integrated CalVal System (ICVS) Online Access: http://www.star.nesdis.noaa.gov/icvs

Impacts of US Microwave Sounders in NCEP GFS

500 hPa Southern Hemisphere AC scores for
20140101 – 20140131 00Z

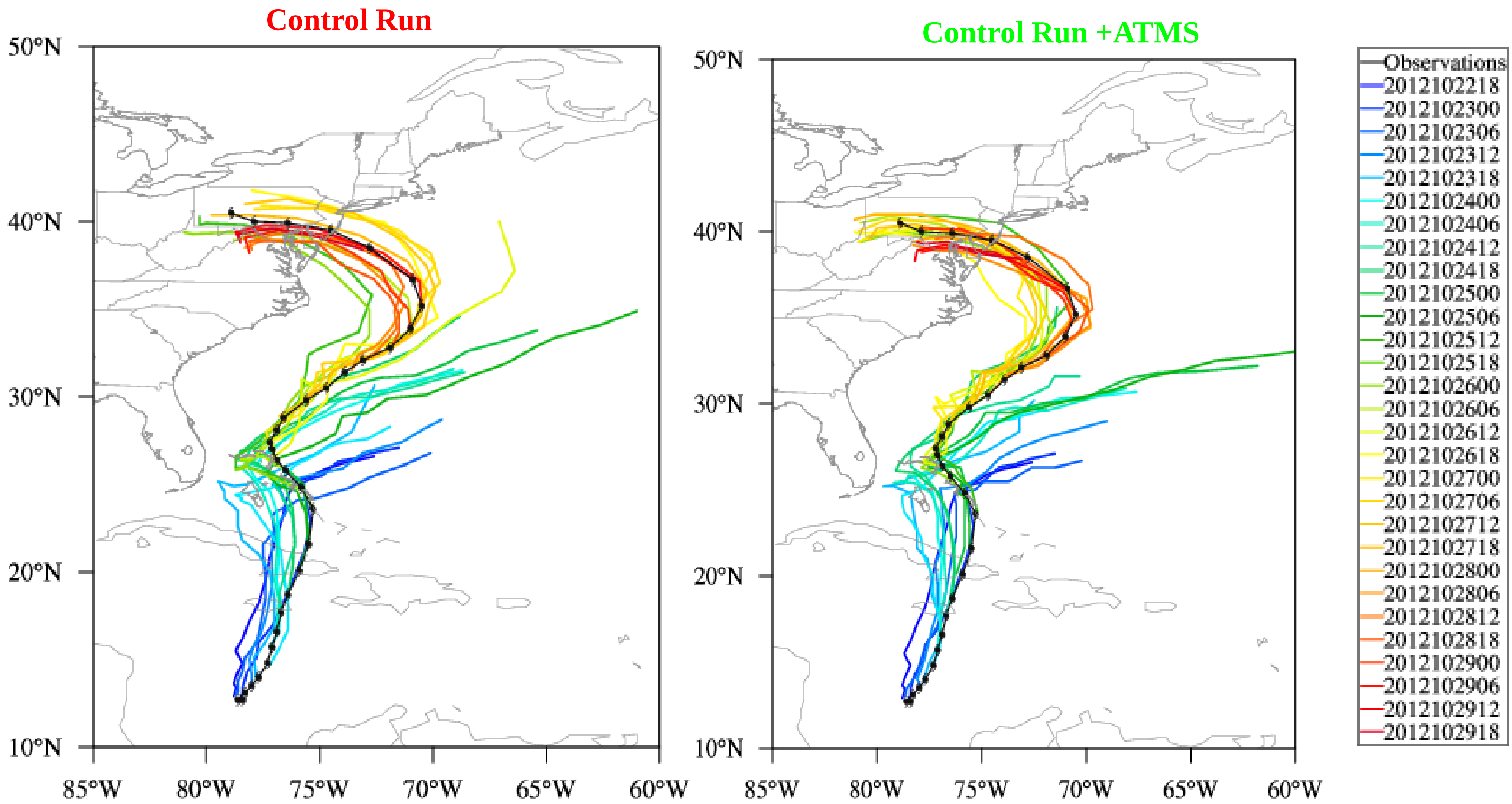




Assimilation of ATMS radiances in NCEP GFS produces a largest impact on global medium range forecast, especially over southern hemisphere. With respect to the baseline experiment that includes the conventional and GPSRO data, 75% forecast skill increase is attributed to ATMS radiance assimilation.

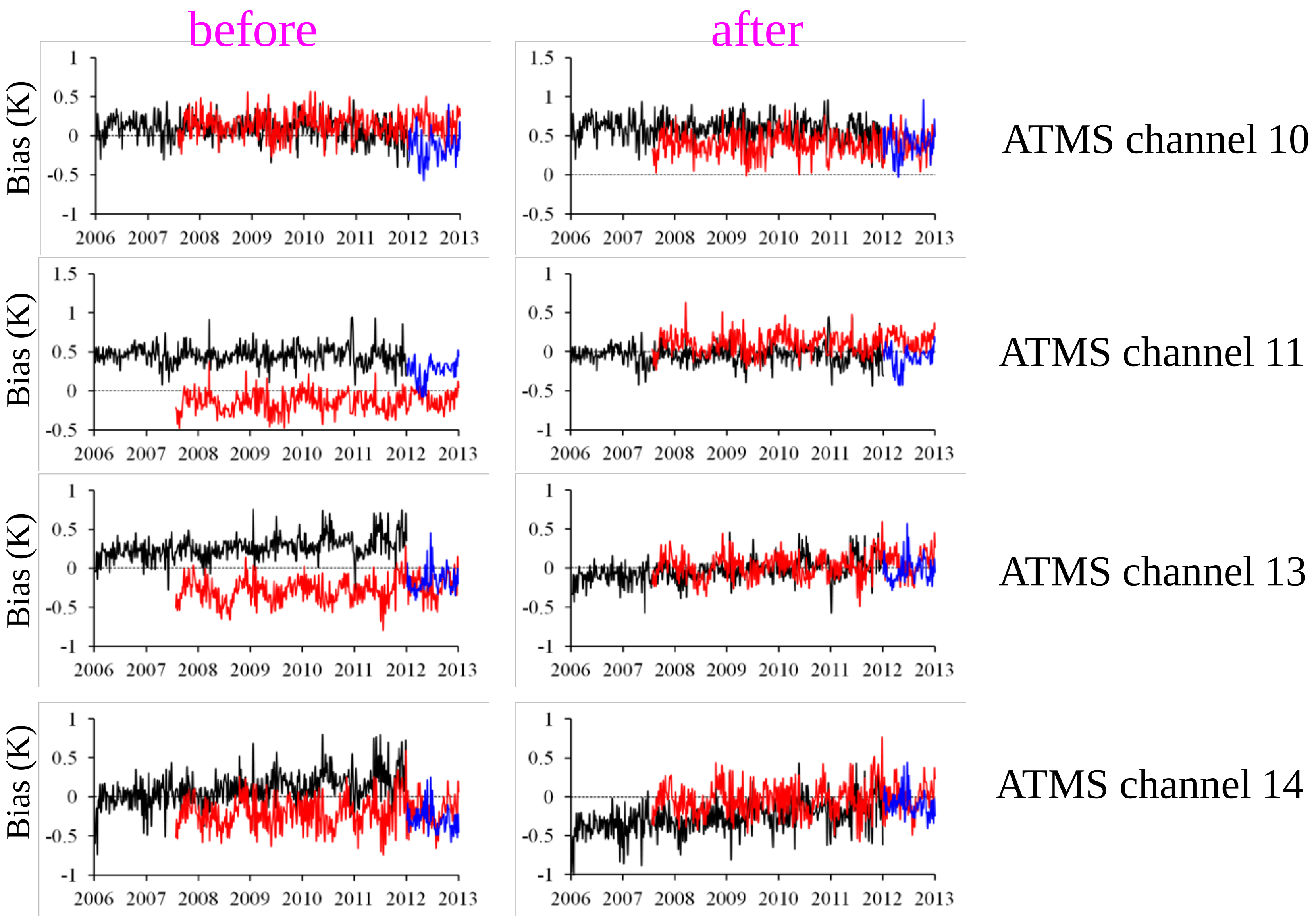
ATMS Impacts on Hurricane Sandy Forecast

2012 NCEP HWRF Version



Predicted vs. observed track for Hurricane Sandy during October 22 to 29. NCEP 2012 HWRF is revised with a high model top and is initialized with its own background 6 hour forecast for direct satellite radiance assimilation in GSI. Control Run: All conventional data and NOAA/METOP/EOS/COSMIC. It is clearly demonstrated that assimilation of Suomi NPP ATMS radiance data reduces the forecast errors of Hurricane Sandy's track

Biases in the Tropics (NOAA-15, MetOp-A, SNPP)



NOAA-18 is subtracted. The pentad data set within ±30^{o} latitudinal band.

Innovative Approaches for High-Quality SDR

- Developed an Integrated CalVal System (ICVS) for monitoring and trending the orbit performance for all the NOAA operation satellite instruments

- Developed a new SI traceable methodology for computing the instrument noises

- Established an on-orbit calibration standard through special SNPP flight operations (e.g. pitch/roll maneuvers) and special calibration targets (e.g. moon, earth targets)

- Established an SDR testbed for JPSS mission life cycle reprocessing

- Cross-calibrated the SDR using WMO GSICS and other methodology

Allan Deviation Algorithms for Computing Satellite Instrument Noise

- Allan Variance was proposed by NIST for characterizing the random noise from a time series which has a variable mean

- It was never implemented for meteorological satellite instruments . Currently, all the NOAA instrument noises are computed by the standard deviation which is only valid for the stationary mean.

- With Allan variance, all the NEDT and NEDN computed from NOAA and JPSS instruments are SI traceable

D. W. Allan, Should the classical variance be used as a basic measure in standards metrology Instrumentation and Measurement, IEEE Trans. on, IM-36, pp.646-654, 1987

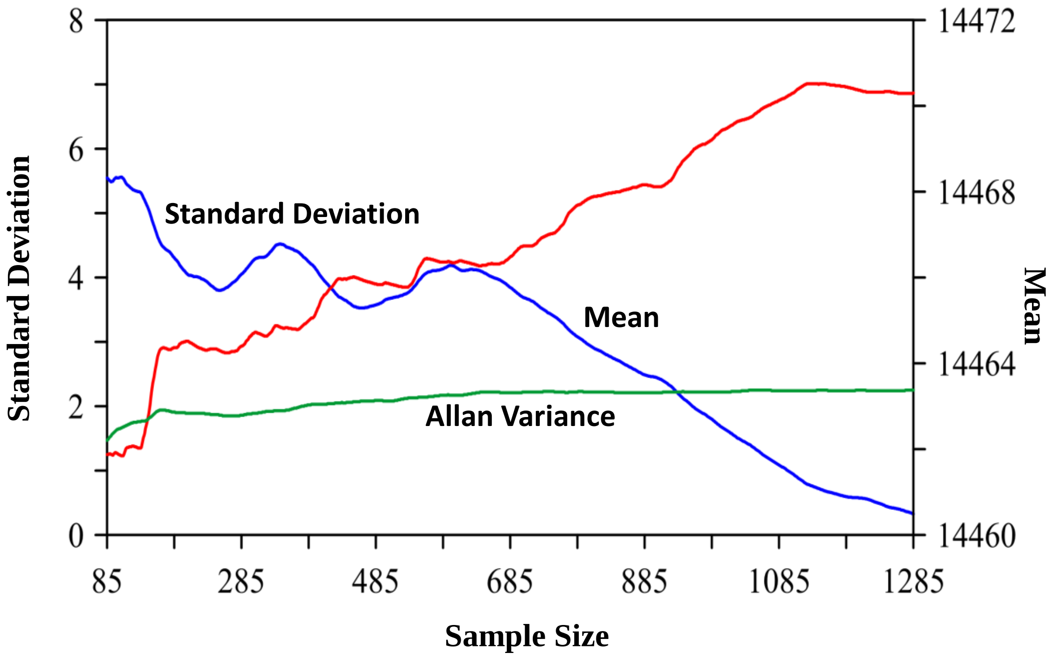
ATMS Noise Equivalent Temperature (NEDT)

For a time series with a stable mean, the standard deviation of the measurements can be used as NEDT:

$$\sigma_{ch} = \left[\frac{1}{4N} \sum_{i=1}^{N} \sum_{j=1}^{4} \left(\frac{C_{ch}^{w}(i,j) - \overline{C_{ch}^{w}(i)}}{\overline{G_{ch}(i)}} \right)^2 \right]^{1/2}$$

For a non-steady mean such as ATMS warm count from blackbody target, Allan variance works the best for NEDT:

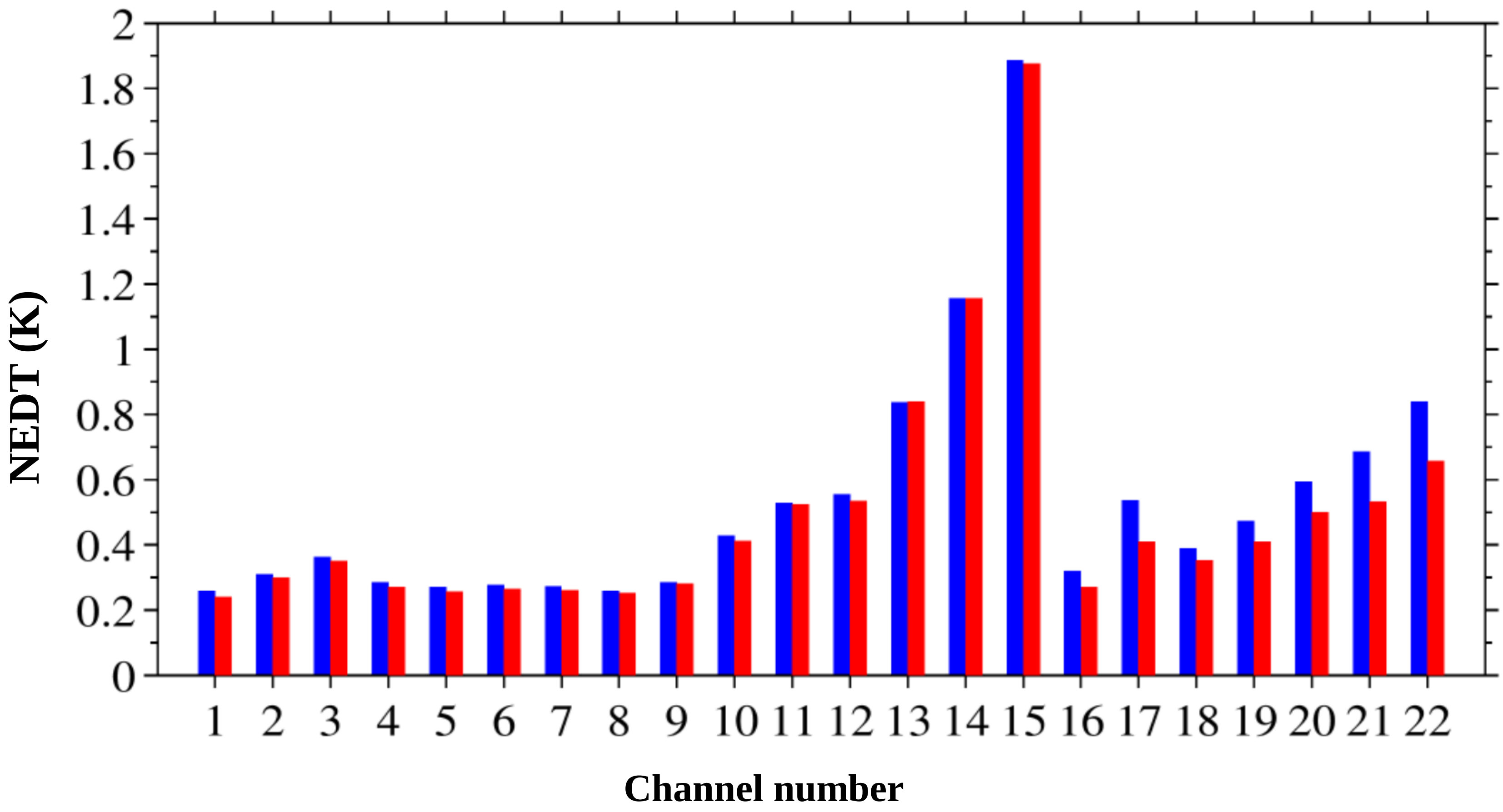
$$\sigma^{Allan}(m) = \sqrt{\frac{1}{2m^2(N-2m)} \sum_{j=1}^{N-2m} \left(\sum_{i=j}^{j+m-1} \left(C_{ch}^{w}(i+m) - C_{ch}^{w}(i) \right) \right)^2}$$



ATMS channel 1 warm count mean (blue, y-axis on the right), the standard deviation (red, y-axis on the left) and the overlapping Allan deviation (green, y-axis on the left) of the 17-scanline (m) average as a function of the total sample size (N).

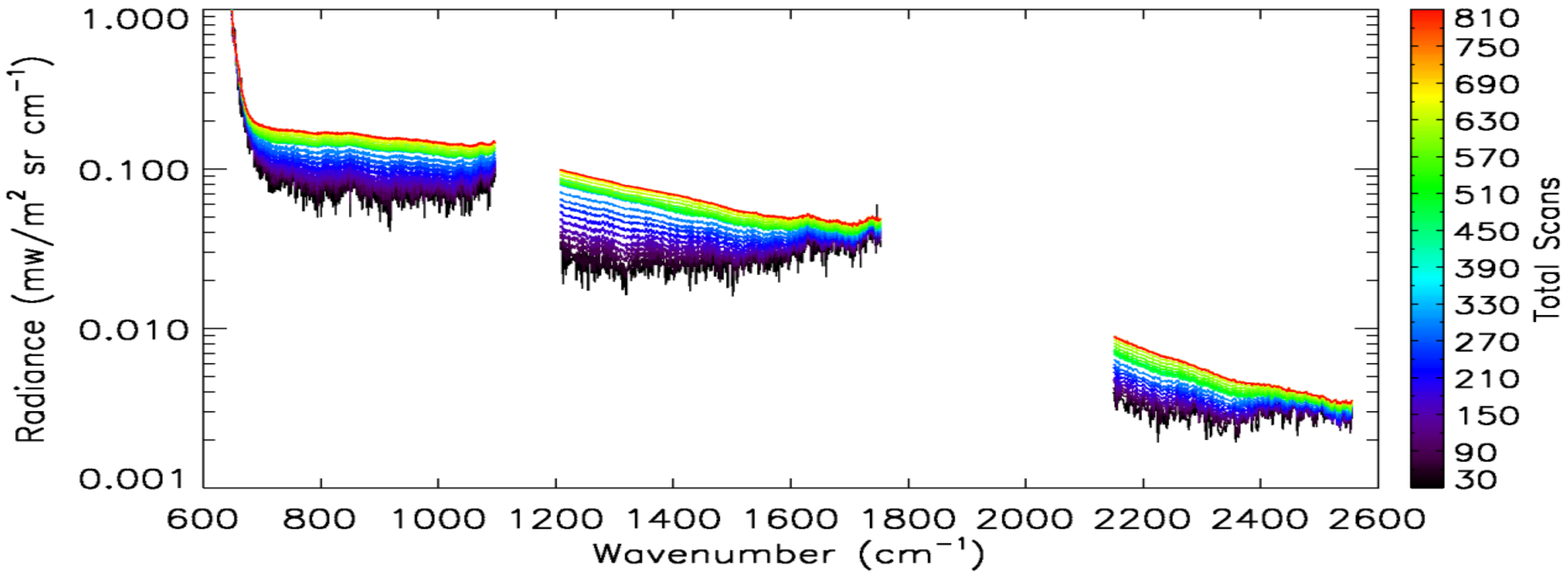
M. Tian, X. Zou and F. Weng, "Use of Allan Deviation for Characterizing Satellite Microwave Sounders Noise Equivalent Differential Temperature (NEDT)", IEEE Geosci. Remote Sens. Lett., Digital Object Identifier 10.1109/LGRS.2015.2485945

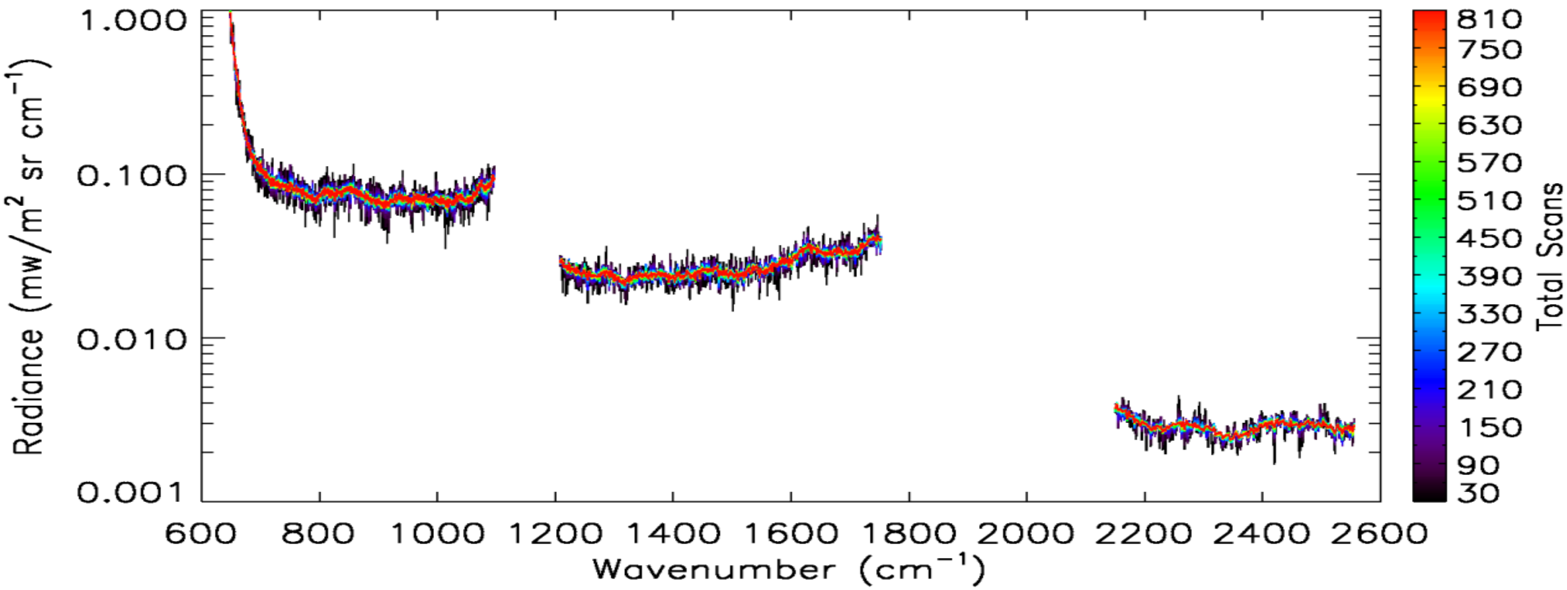
ATMS NEDT Computed from Standard and Allan Deviations



ATMS standard deviation (blue) and Allan deviation (red) with channel number. The sample size (N) is 150 and the averaging factor (m) for the warm counts is 17. The standard deviation is much higher than Allan deviation.

CrIS Noise Computed from Standard Deviation and Allan Variance





SI traceable algorithm for characterizing hyperspectral infrared sounder CrIS noise (Chen and Weng, 2015, AO, accepted)

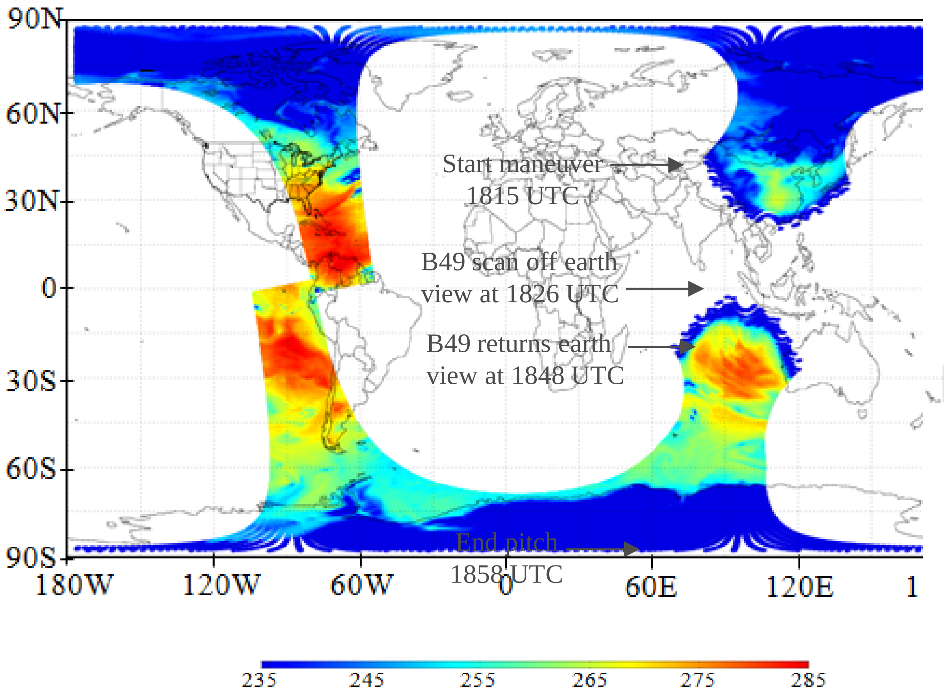
Establish an in-orbit Standard for Characterizing Instrument Calibration Accuracy

- Maneuvers Suomi NPP satellite to scan cold space and characterizes the scan angle dependent bias using physical models
- Develops the best practices for earth scene simulations using the forward models and high quality atmospheric profiles
- Uses stable earth scenes and terrestrial targets (e.g. moon and star) for monitoring the calibration stability

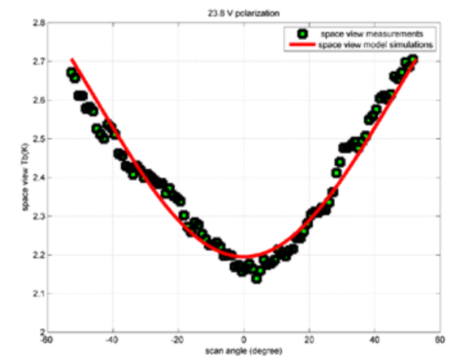
***Weng, F**., H. Yang, X. Zou, 2012: On Convertibility from Antenna to Sensor Brightness Temperature for Advanced Technology Microwave Sounder (ATMS), IEEE Geosci. Remote. Sens. Letter, 10.1109/LGRS.2012.2223193*

ATMS TDR Pitch Maneuver Data for Characterizing the Antenna Emission

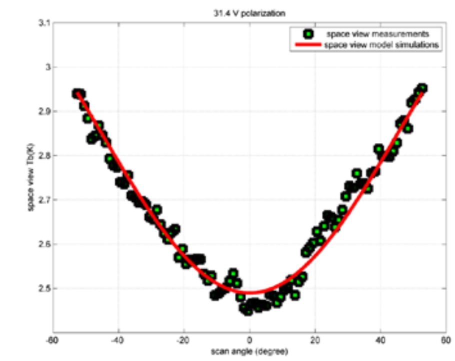
ATMS TDR at Ch18 on February 20, 2012



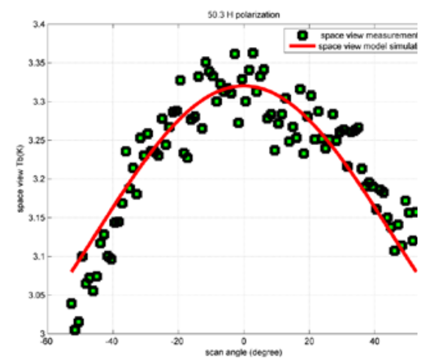
Channel 1



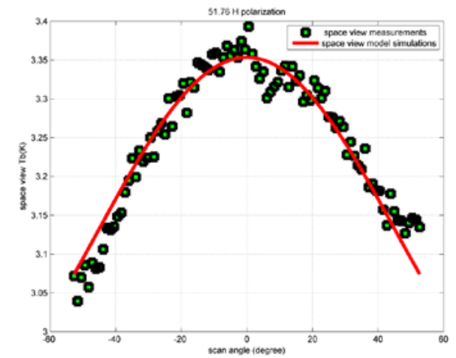
Channel 2



Channel 3

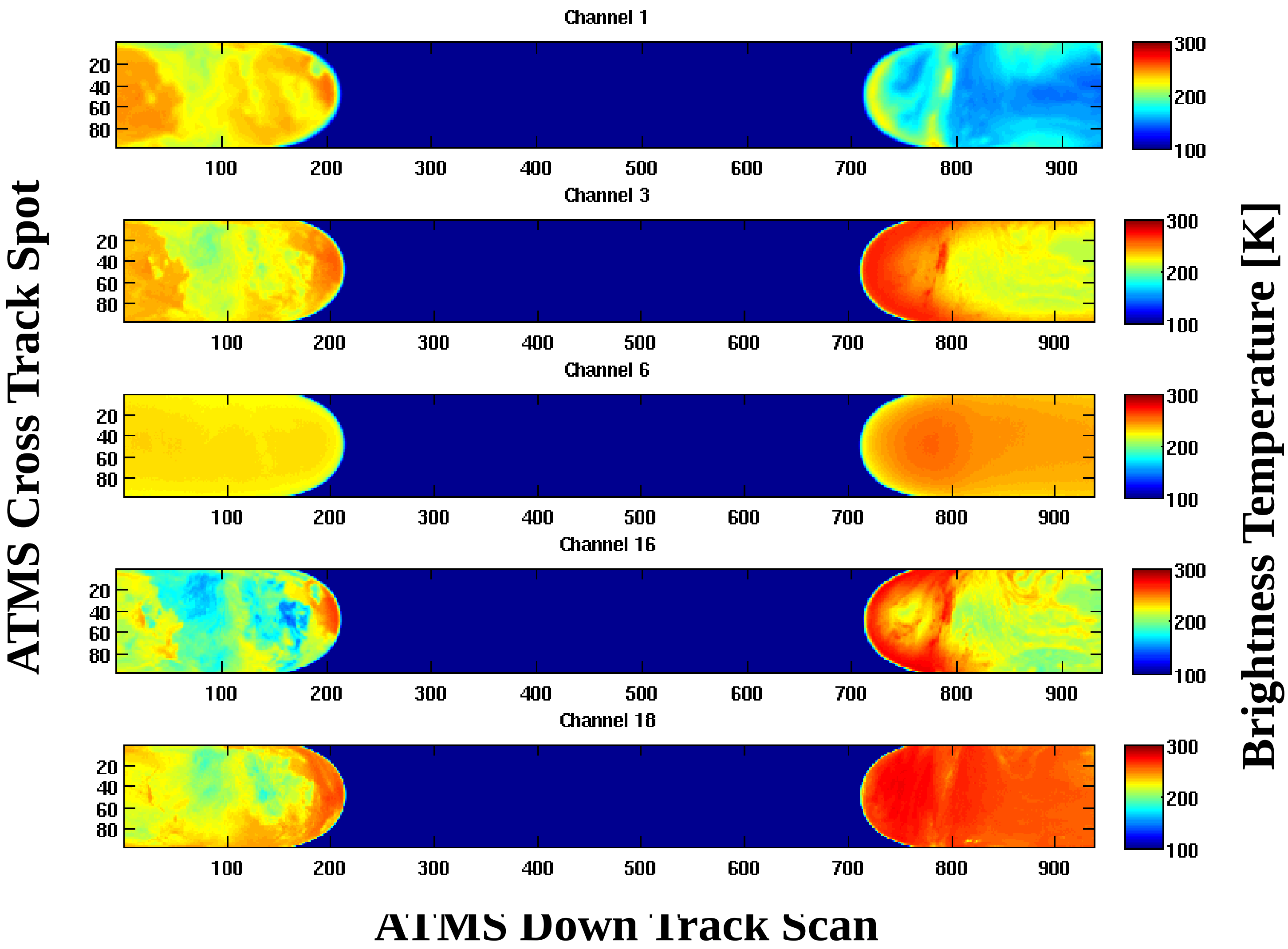


Channel 4



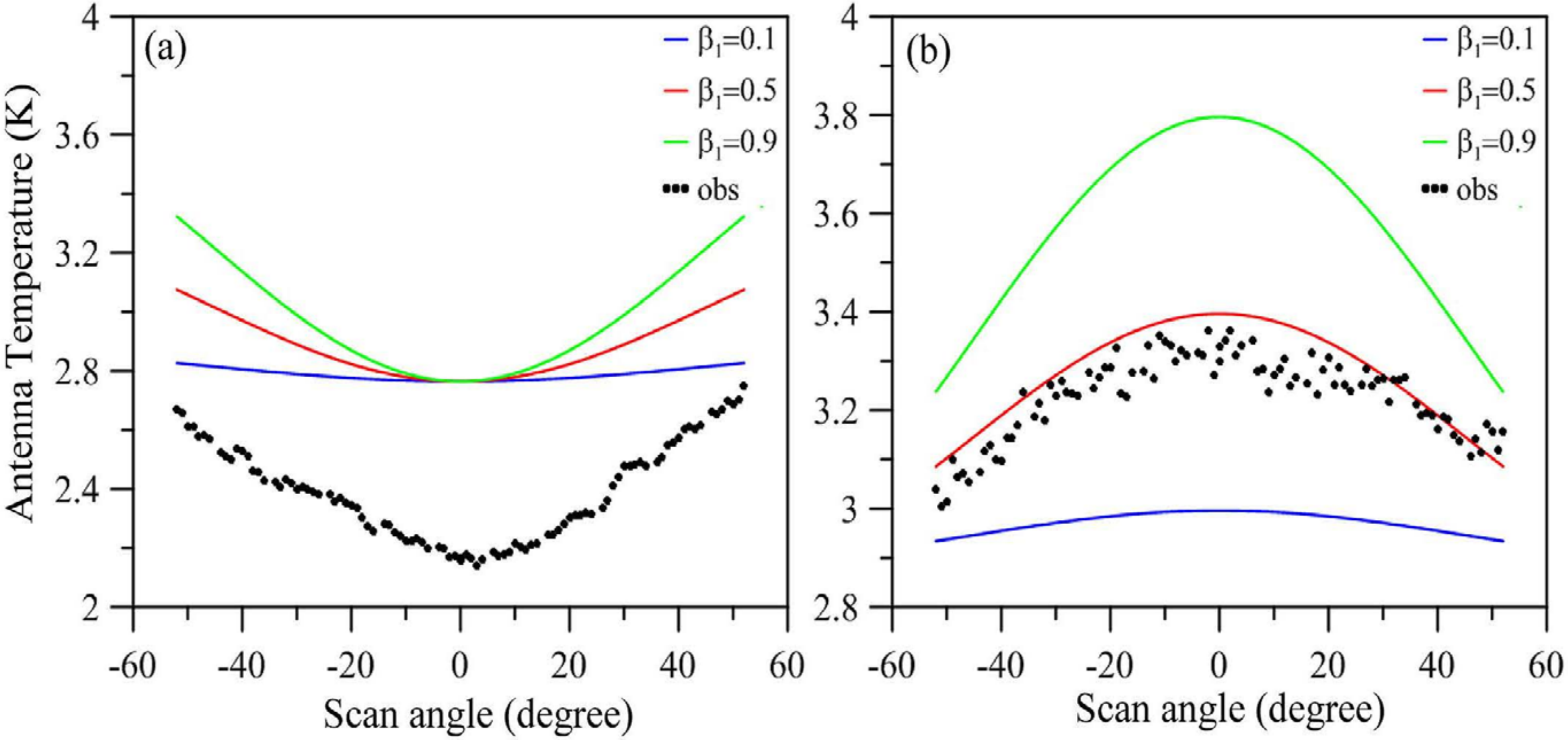
NPP ATMS pitch maneuver observations show channel related scan angle dependent feature, indicate the scan bias is not inherent feature of the scene

ATMS Pitch Maneuver February 20, 2012



Slide courtesy of Vince Leslie,
MITLL

ATMS TDR Pitch Maneuver Data for Characterizing the Antenna Emission



SNPP ATMS pitch maneuver observations show channel related scan angle dependent feature, indicate the scan bias is not inherent feature of the scene

Effects of ATMS Flat Reflector Emission on Brightness Temperature

Quasi-V (TDR) :

$$R_{qv}^{c} = R_{qv} + \varepsilon_h(R_r - R_h) + [\varepsilon_v(R_r - R_v) - \varepsilon_h(R_r - R_h)]\sin^2\theta - \frac{R_3}{2}(1-\varepsilon_h)^{3/2}\sin 2\theta$$

Quasi-H (TDR):

Bias due to the reflector emission

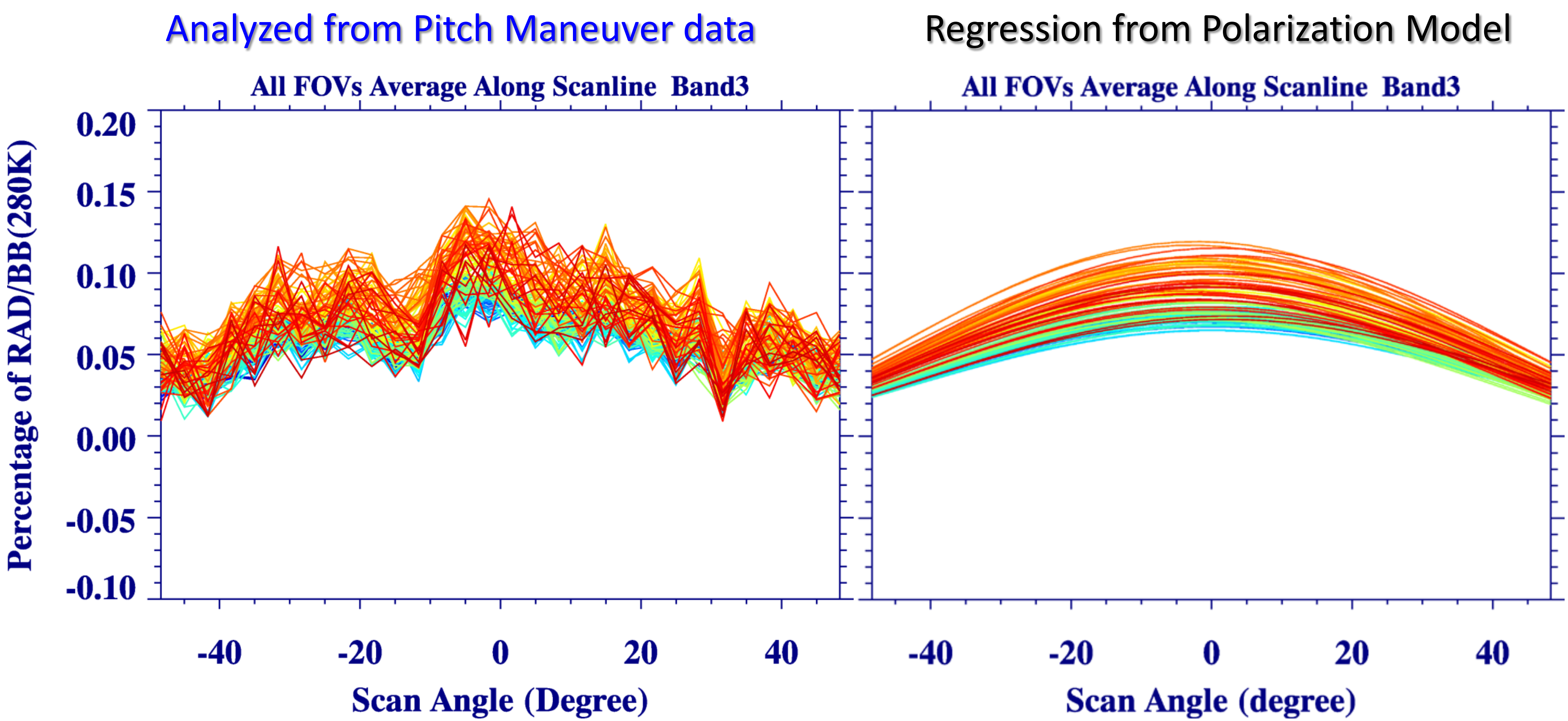
$$R_{qh}^{c} = R_{qh} + \varepsilon_h(R_r - R_h) + [\varepsilon_v(R_r - R_v) - \varepsilon_h(R_r - R_h)]\cos^2\theta + \frac{R_3}{2}(1-\varepsilon_h)^{3/2}\sin 2\theta$$

where

R_{qv} and R_{qh} are the radiances at quasi vertical and horizontal polarzation which are further related to the radiances at pure vertical and horizontal polarization, R_v and R_h. ε_v and ε_h are the reflector emissivity at the vertical and horizontal polarization. R_3 is the third Stokes radiance component of the scene. R_r is the radiance emitted from the reflector. θ is the scan angle. Note that $\varepsilon_v = 2\varepsilon_h - \varepsilon_h^2$ at an indent angle of 45 degree to reflector normal.

Yang, H. and F. Weng, 2015: Estimation of ATMS Antenna Emission from cold space observations, IEEE Geosci. Trans. Remote. Sens, in press

CrIS Shortwave IR Band 3 for All Channels



Different colors indicate different channels. The results are normalized by Planck Radiances at 287K.

Slide Courtesy of Likun Wang and Yong Han

ATMS Calibration Accuracy Assessment Using GPS RO

- **Time period of data search:**

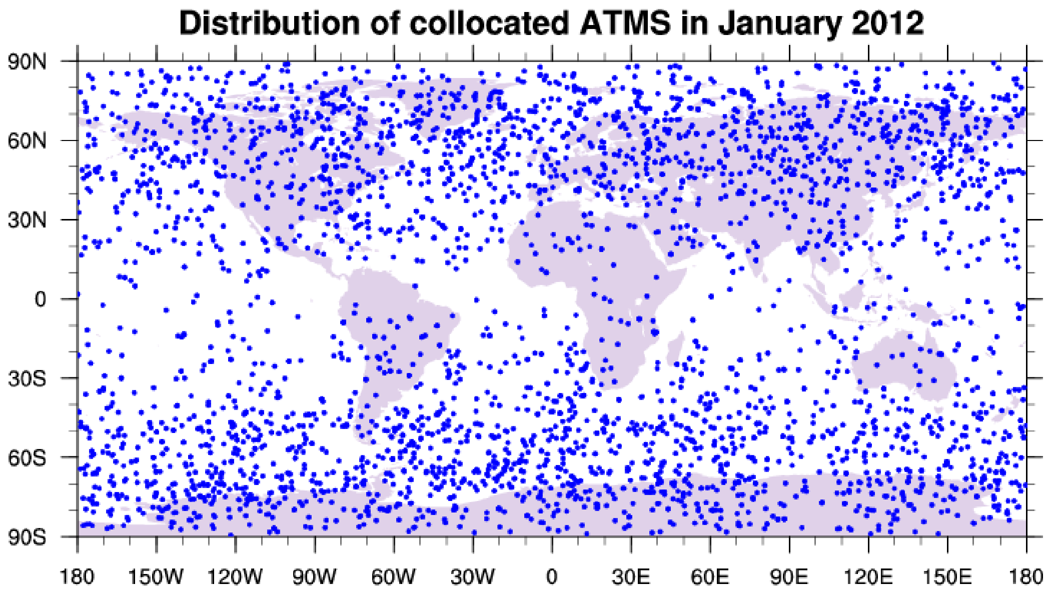
  January, 2012

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

  Time difference < 0.5 hour

  Spatial distance < 30 km

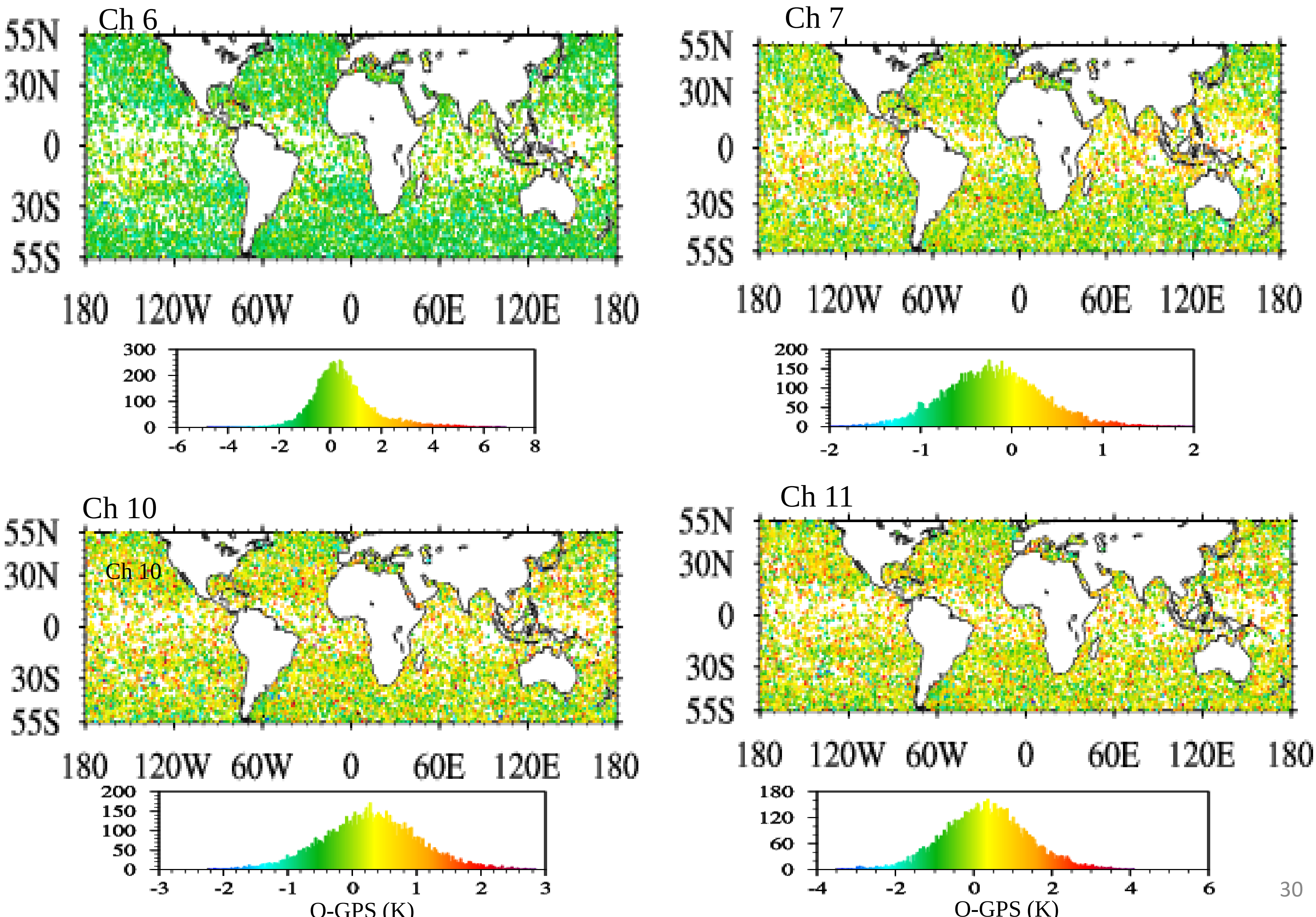
(GPS geolocation at 10km altitude is used for spatial collocation)



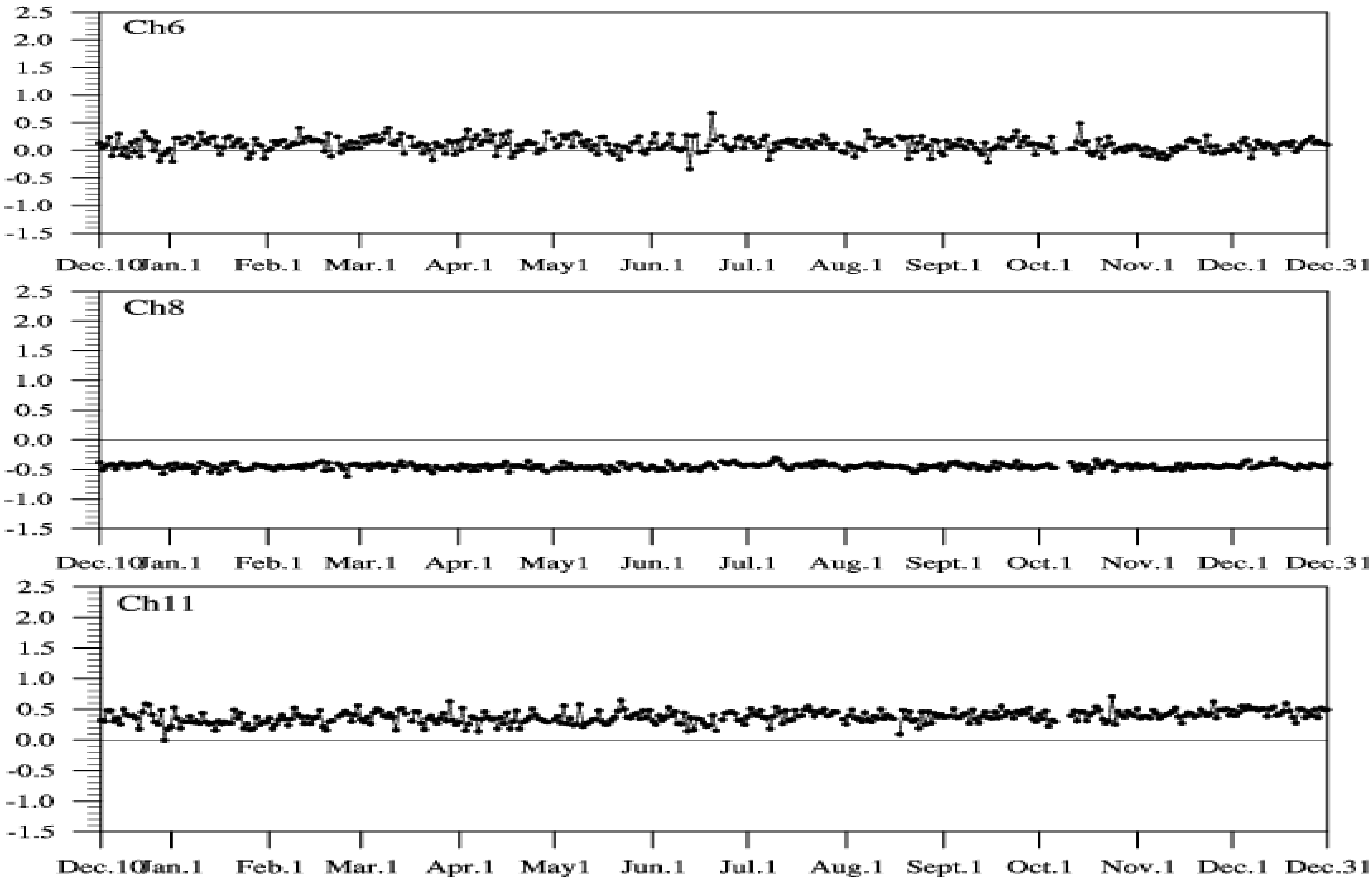
3056 collocated measurements

Slide Courtesy of Lin Lin

ATMS Bias Obs (TDR) - GPS Simulated

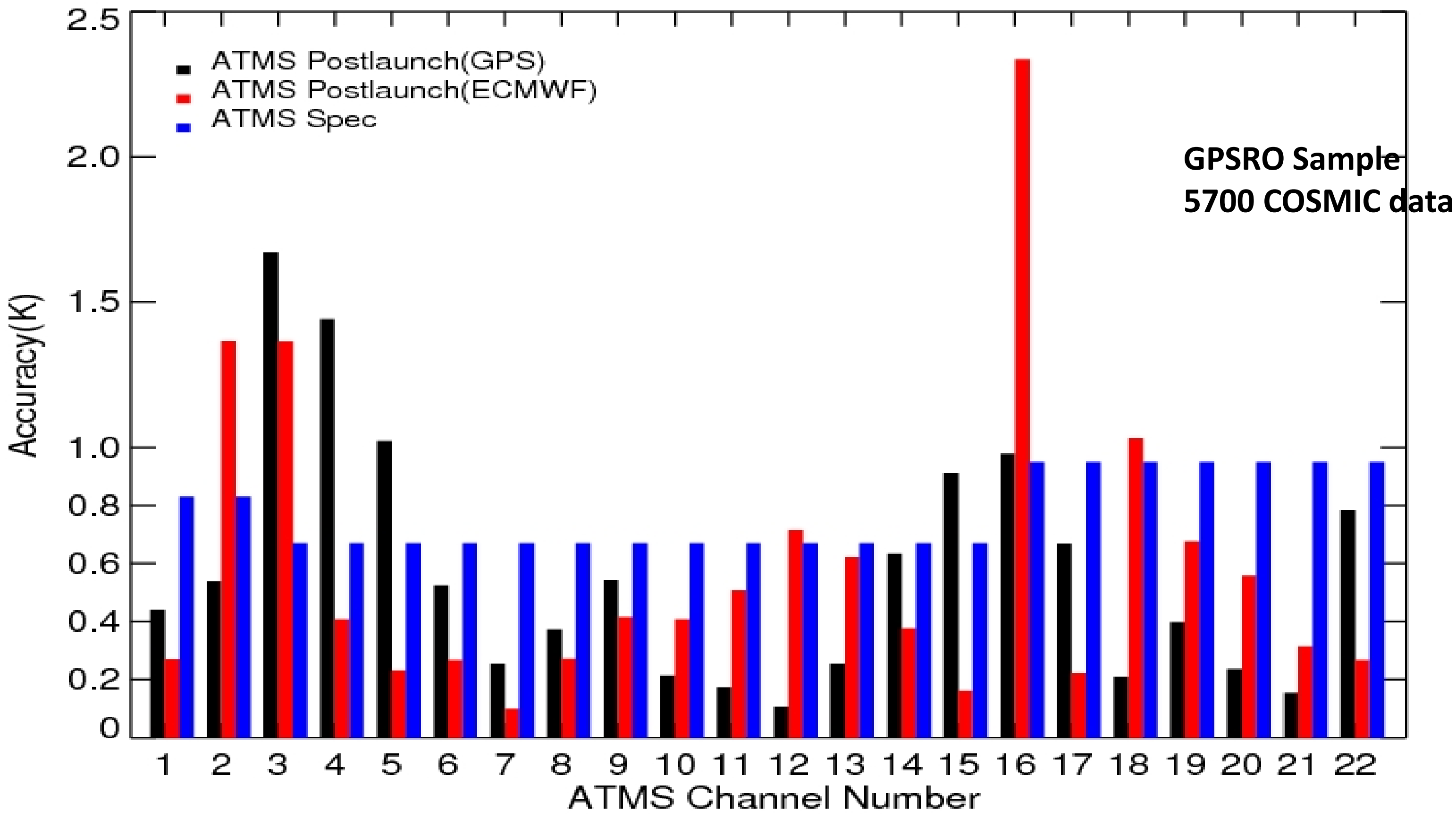


ATMS Bias Obs - Sim (GPS RO)



Slide courtesy of Lin Lin

ATMS Calibration Accuracy Using GPSRO Data

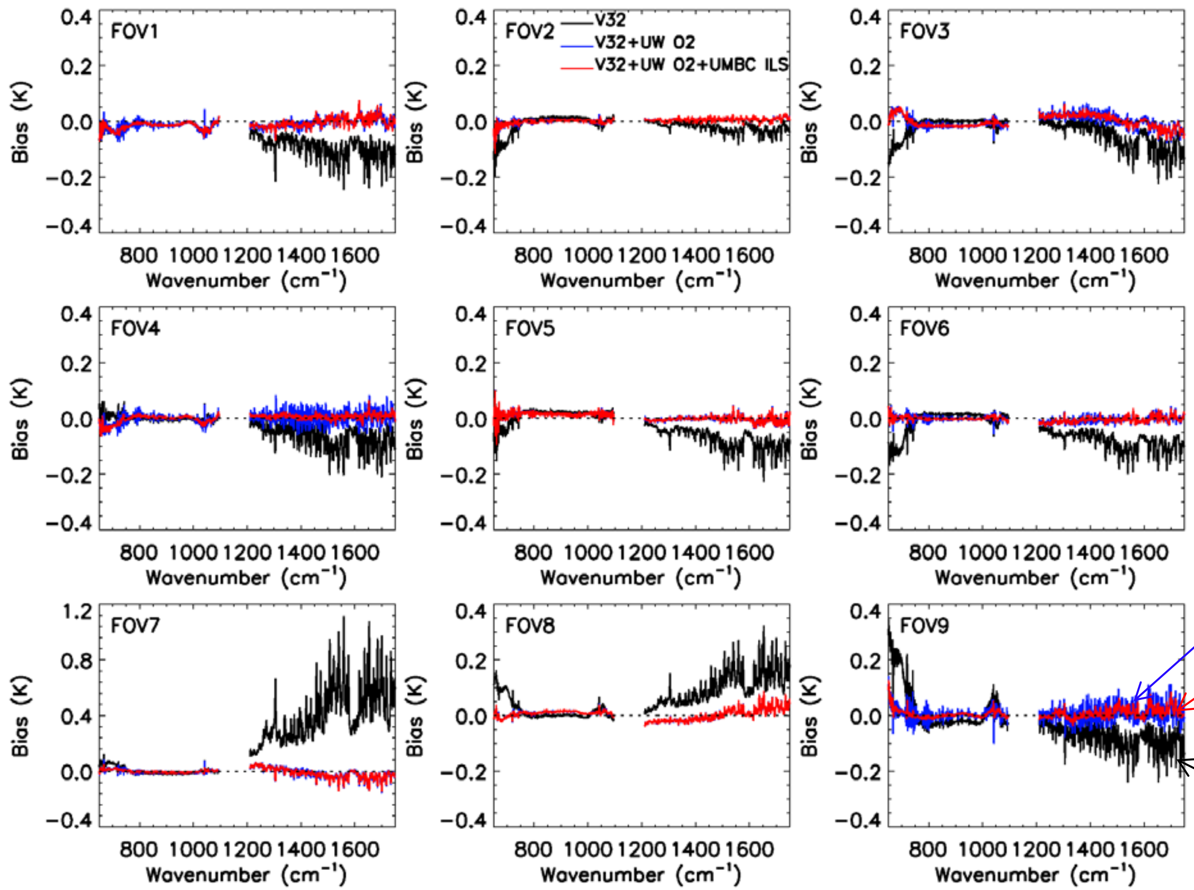


On-orbit ATMS calibration accuracy is quantified using GPSRO data as input to RT model and is better than specification for most of sounding channels.

CrIS Radiative Transfer Simulations

- Line by Line Radiative Transfer Model
  - Gaseous absorption
  - None Local Thermal Equilibrium emission correction
  - Short wave surface reflection
- Inputs to LBLRTM
  - Wavelength, solar and satellite viewing geometry, surface emissivity
  - Temperature and water vapor profile from ECMWF forecast fields
  - Climatology CO_2, CO, CH_4 profile
  - CrIS spectral response function
- Outputs from LBLRTM
  - Radiances at all 2211 channels and 9 FOVS
  - O-B at each FOV
  - Double difference of O-B between FOVs.

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

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

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

Courtesy of Yong Chen, STAR

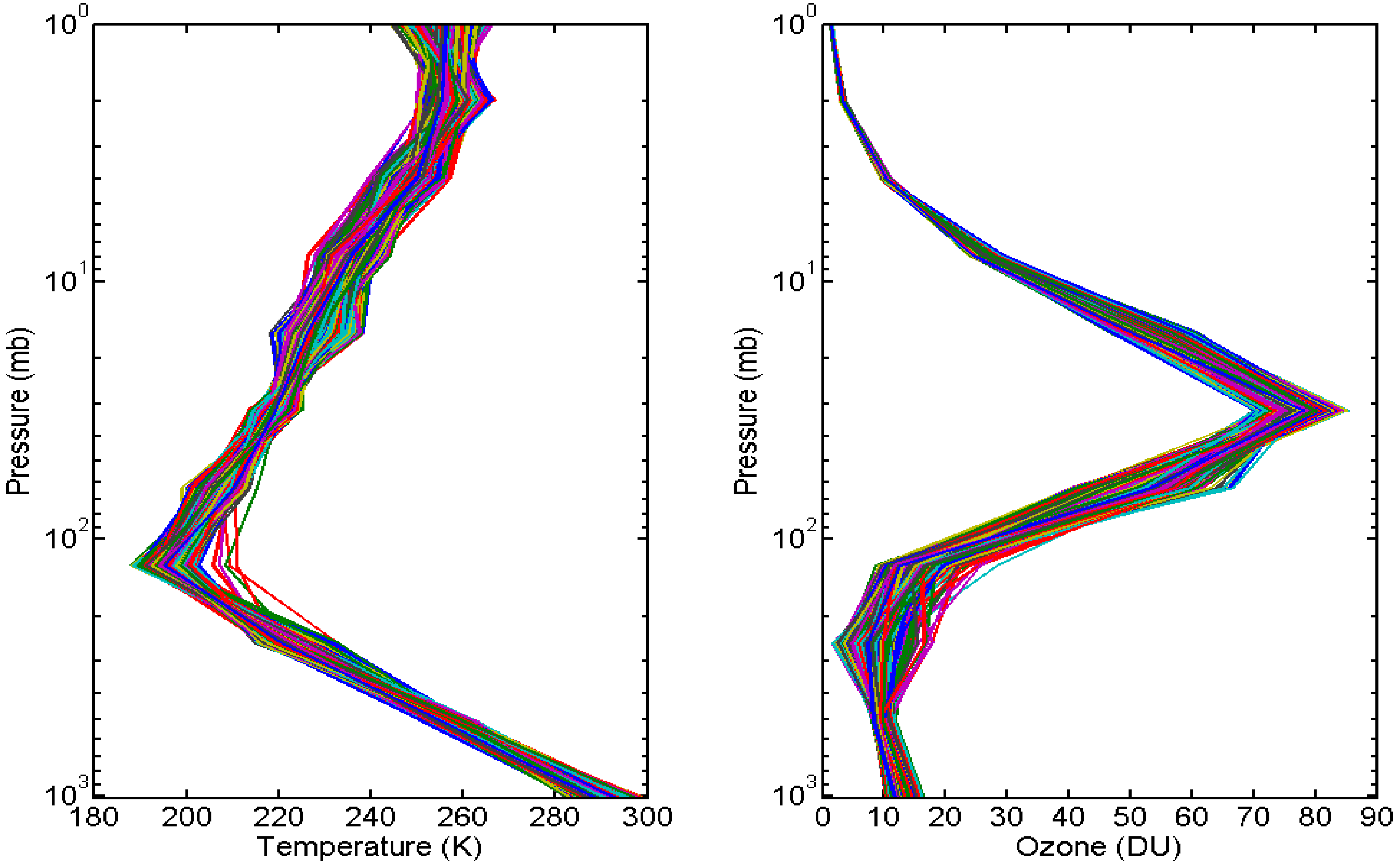
Building an on-Orbit Truth for Estimating OMPS Earth View SDR Accuracy

- Develop the “truth” simulated from the forward radiative transfer model at OMPS EV location (Macropixel)
- Radiative transfer model must include comprehensive scattering and absorption processes at UV regions
- Accurate understanding of atmospheric and surface status at OMPS EV location.
- The difference between observations and simulations is used as an estimate of on-board calibration accuracy

OMPS EV Radiative Transfer Simulations

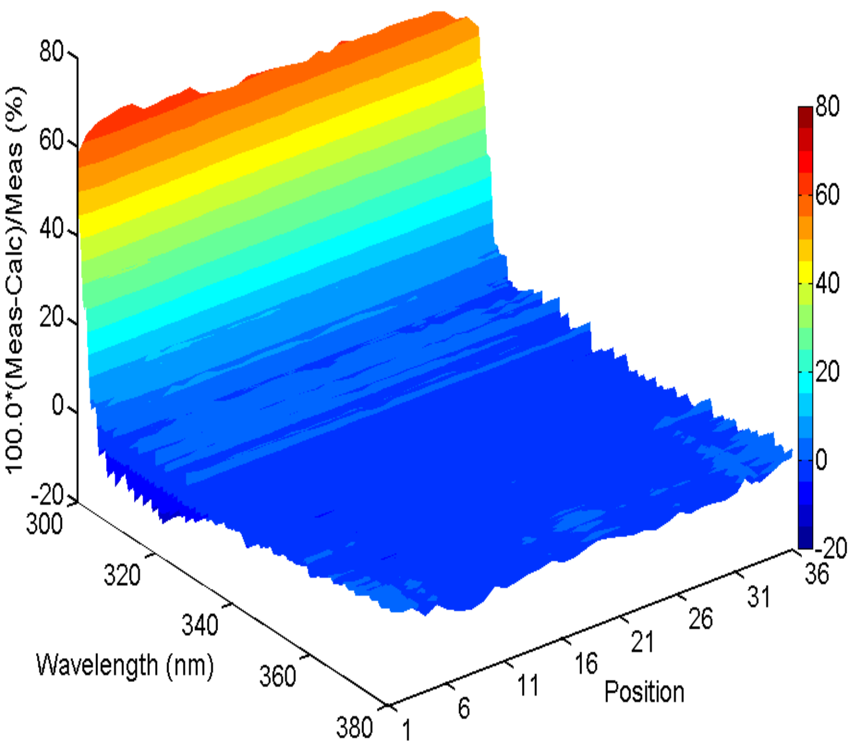
- TOMRAD-2.24: TOMS (Total Ozone Mapping Spectrometer) Radiative Transfer Model and Vector Linearized Discrete Ordinate Radiative Transfer (VLIDORT)
  - Rayleigh scattering atmosphere with ozone and other gaseous absorption
  - Spherical correction for the incident team
  - Molecular anisotropy and Raman scattering
- Inputs to TOMRAD
  - Wavelength, solar and satellite viewing geometry, surface albedo, temperature and ozone profile
  - Climatology temperature profile
  - Ozone profile from Aura Microwave Limb Sounder (MLS)
  - Collocated OMPS/MLS data generated at NASA
  - Surface reflectivity based on 331 nm
- Outputs from TOMRAD
  - Normalized radiance (NR=reflected radiance/solar flux) or N-Value (N=-100*$\log_{10}$NR)

Co-located OMPS/MLS Temperature and Ozone Profiles

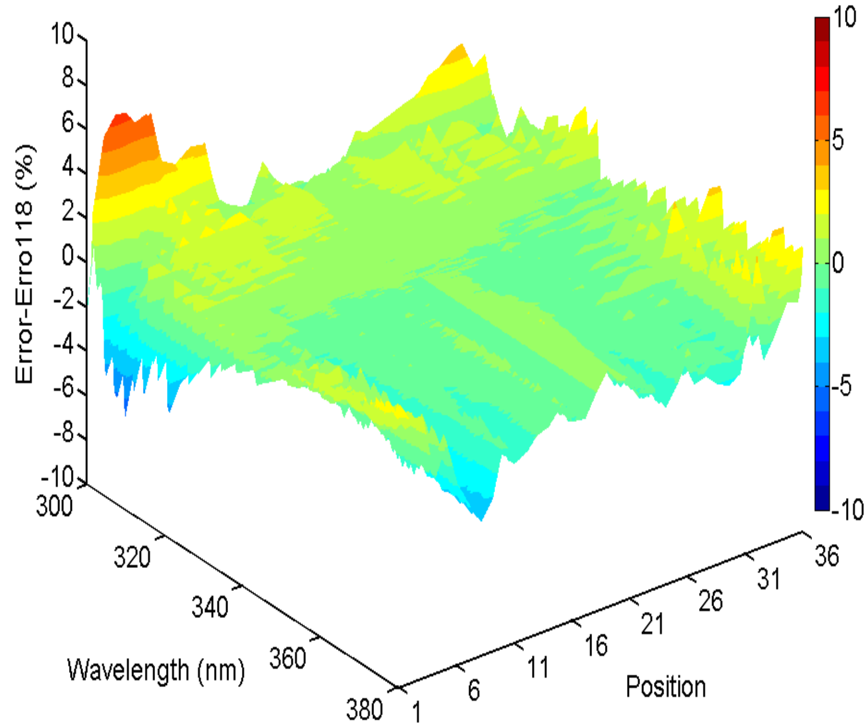


OMPS Observation minus Simulation (O-B)

Relative Error



Relative error wrt to Position 18 (nadir)



The bias in cross-track direction is generally less than 2% except at shorter wavelengths where simulations may become less accurate due to complex scattering process. The bias is also larger in side pixel locations

VIIRS Reflective Solar Band (RSB) Calibration

- F: RSB Calibration coefficient.
- H: SD degradation factor.

$$L_{EV} = \frac{F \cdot (c_0 + c_1 \cdot dn_{EV} + c_2 \cdot dn_{EV}^2)}{RVS_{EV}}$$

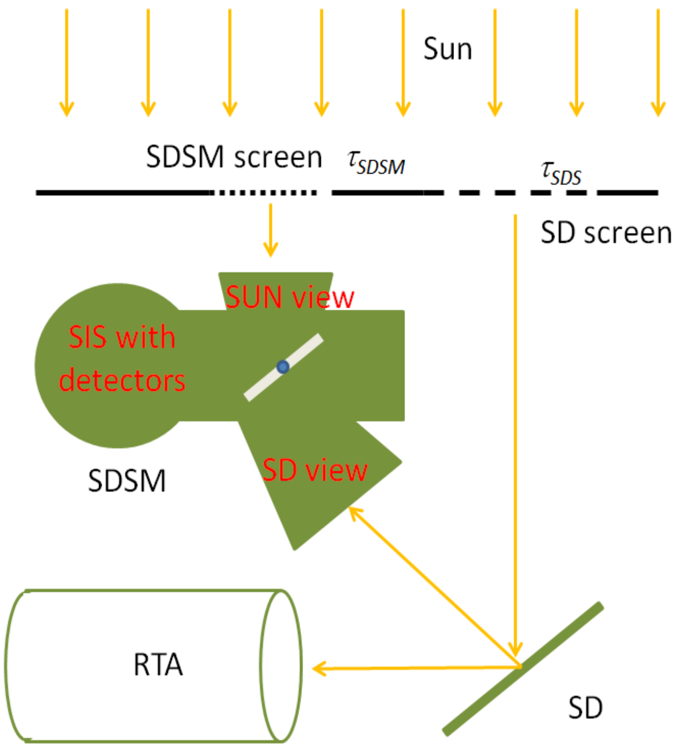
$$F = \frac{L_{Sun\_Model}}{L_{Sun\_Observation}} = \frac{Computed\_L_{Sun}}{Observed\_L_{Sun}}$$

$$F = \frac{\cos(\theta_{inc}) \cdot \left[E_{sun} \cdot \tau_{sds} \cdot BRDF(t)\right] \cdot RVS_{SD}}{c_0 + c_1 \cdot dn_{SD} + c_2 \cdot dn_{SD}^2}$$

$$BRDF(t) = H_{Norm}(t) \cdot BRDF(t_0)$$

$$H_{Norm}(t) = \frac{H(t)}{H(t_0)}$$

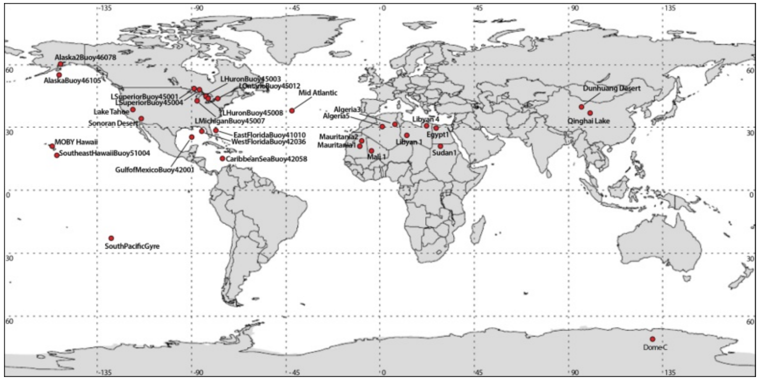
$$H(t) = \frac{dc_{SD} \cdot \tau_{SDSM}}{dc_{SUN} \cdot BRDF(t_0) \cdot \tau_{SDS} \cdot \cos(\theta_{inc}) \cdot \Omega_{SDSM}}$$



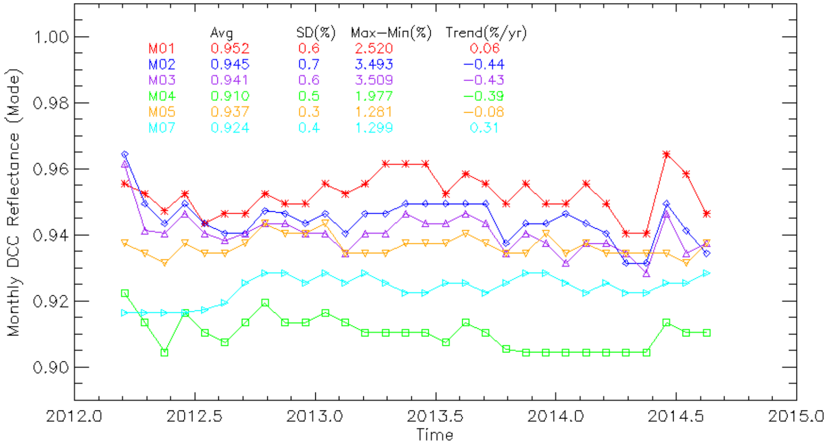
dn: VIIRS bias removed response
dc: SDSM bias removed response

VIIRS Performance at 30 Vicarious Sites Worldwide

- VIIRS calibration is monitored at 30 Vicarious sites with time series analysis for all bands
- DCC and Lunar are recognized as a unique sites and have been used to diagnose calibration anomalies
- The DCC time series are capable of detecting sub-percent calibration changes.
  - Bands M5 and M7 are stable, with calibration of stability better than 0.4% (1-sigma);
  - Bands M1-M3 show noticeable calibration changes, especially since early 2014, due to the SD anomaly
- Time series available at: https://cs.star.nesdis.noaa.gov/NCC/VSTS.



30 vicarious sites for VIIRS calibration monitoring



VIIRS DCC observation time series

STAR SDR Testbed for JPSS Reprocessing

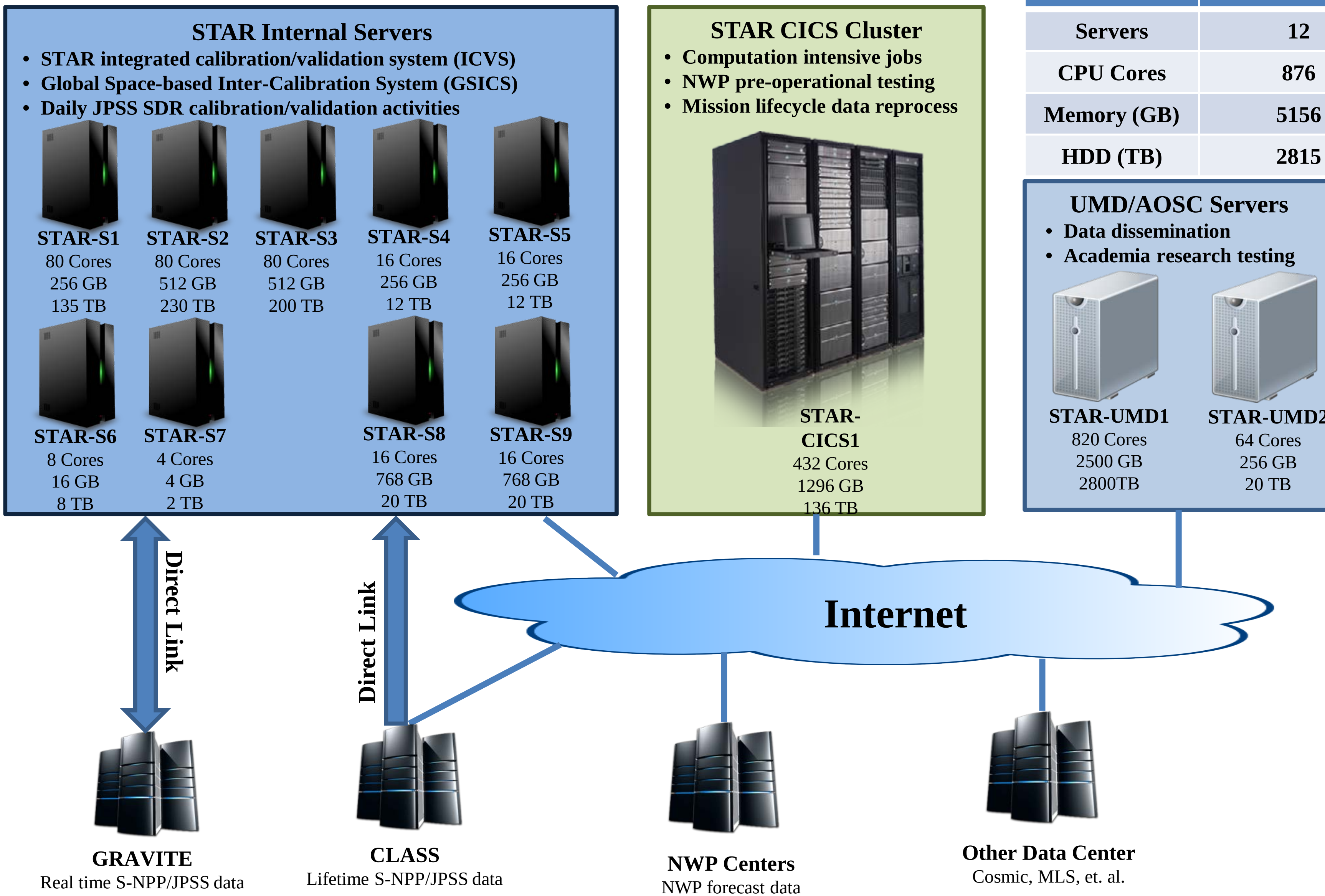
- Tests innovative sciences and algorithms to improve JPSS SDR product quality
- Transitions the new software developed from extramural community to IDPS
- Performs the NWP impact studies using improved SDR data
- Transitions the ICVS-Lite to GRAVITE for NASA and OSPO operations
- Archives anomaly reports regarding all NOAA/METOP/JPSS instruments
- Conducts new research on future JPSS and other satellite constellation
- Provides the online supports to Global Space-Based Inter-Calibration System
- Performs the JPSS SDR mission life cycle reprocessing

STAR SDR Testbed Utilities

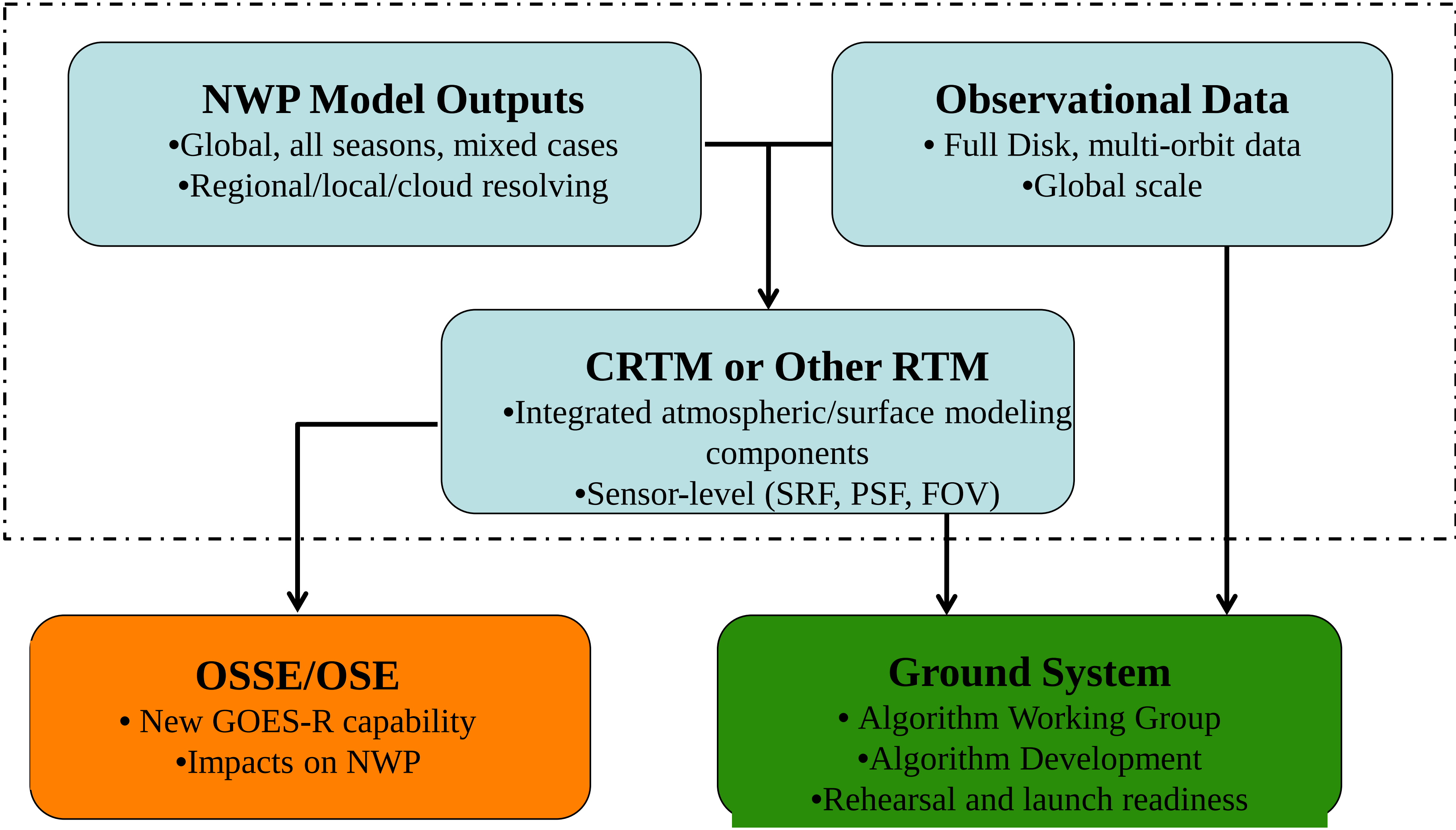
- **RDR/TDR/SDR Generation**
  - Space Sensor Simulator (S3)
  - Community Radiative Transfer Model (CRTM)
  - Line by Line RTM (LBLRTM)
  - Advanced RT models: TOMRAD, 6S, VLIDORT, VDIOSRT
- **RDR to SDR Transformation**
  - CrIS Full Spectral Resolution Processing System (CFSR)
  - Advanced Radiance Transformation System (ARTS)
  - Algorithm Dynamic Library (ADL)
- **Quality Assurance of SDR**
  - SI Traceable Noise Calculation Software (STNC)
  - NOAA Products Validation System (NPROVS)
  - Integrated Calibration and Validation System (ICVS)
- **Inversion from SDR to EDR**
  - Microwave Integrated Retrieval System (MIRS)
  - NOAA Unique CrIS and ATMS Processing System (NUCAPS)
  - Ocean coloring processing with Multi-Sensor Level 1 to Level-2 (MSL12)
  - Advanced Clear Scene Processor for Oceans (ACSPO)
  - Cloud from AVHRR-x (CLAVR-x)

STAR SDR Testbed IT Infrastructure

Parts	Total
Servers	12
CPU Cores	876
Memory (GB)	5156
HDD (TB)	2815

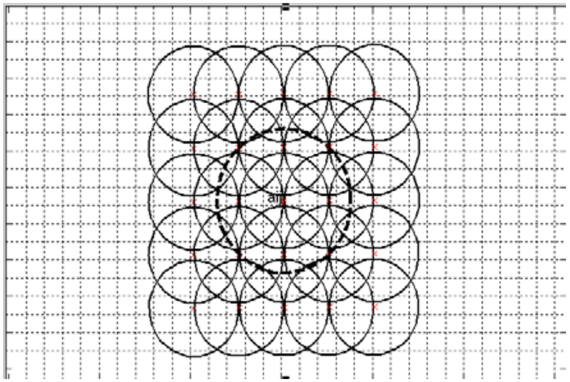


STAR Space Sensor Simulator

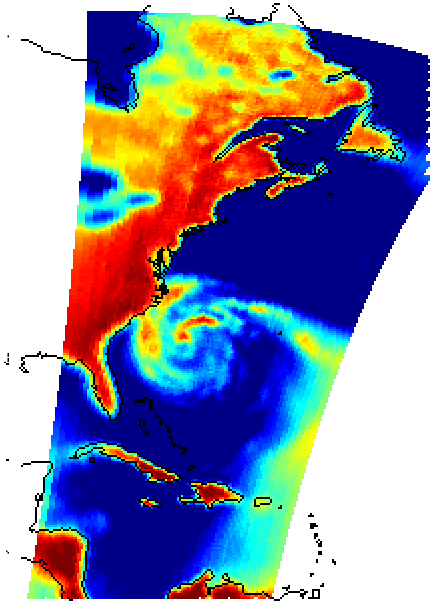


Tests on Various TDR Remapping Algorithm

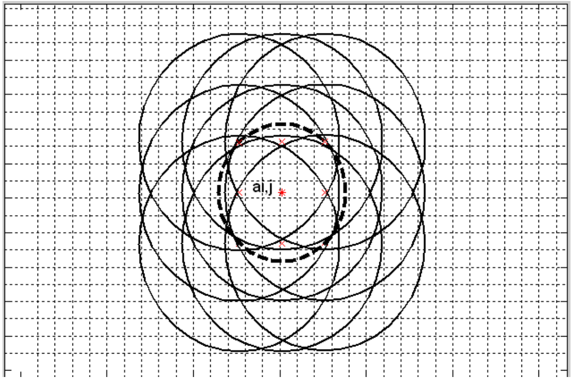
Resolution Reduction



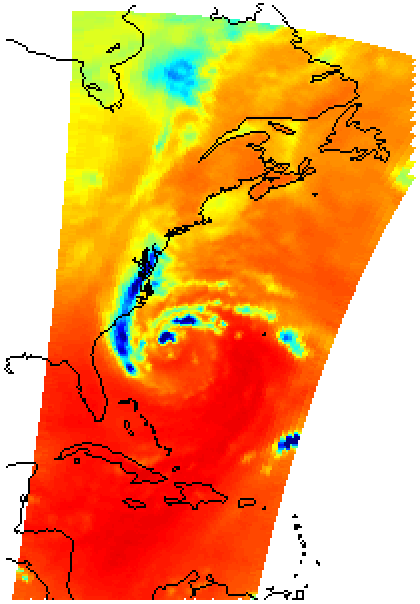
FOV 2.2°



Resolution Enhancement



FOV 2.2°



- Explore the potential of the oversampling characteristic of ATMS observations and generate observations at different frequencies with consistent FOV size

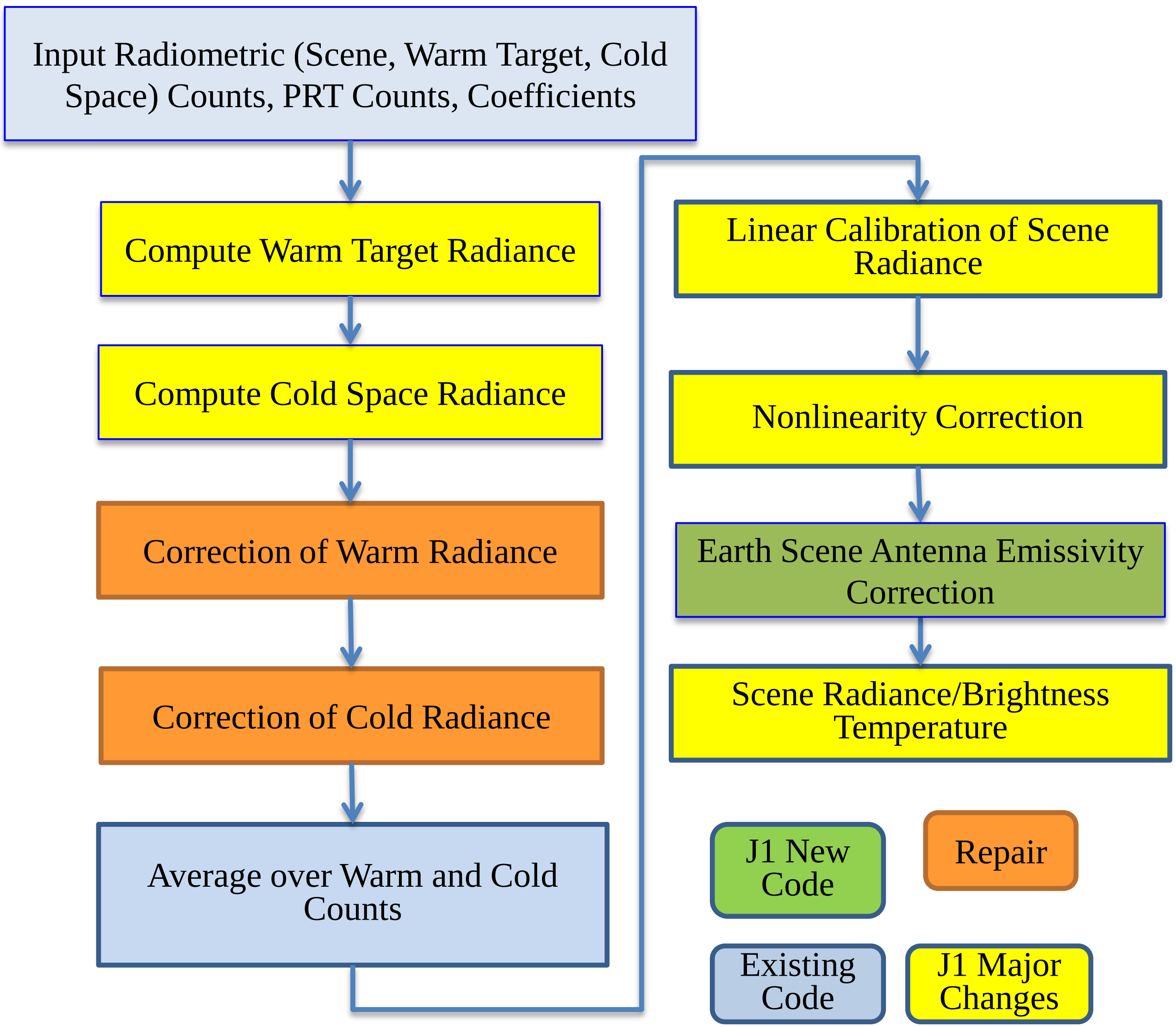
- Backus-Gilbert observation reconstruction algorithm is used for remapping TDR to expected spatial resolution

- Remapping coefficients are tuned to ensure the remapped TDR products are in best balance between noise and spatial resolution

JPSS Mission Life Cycle Reprocessing

- SNPP SDR Processing Changes since November 2011
  - CrIS SDR from normal to full spectral resolution
  - ATMS SDR from Rayleigh-Jean to full radiance
  - VIIRS SDR changes from F/H factor updates
  - Numerous discrepancy reports (DR) filed to fix the anomalies; updates in PCT, LUT, engineering packages, etc.
- Major SDR Processing Upgrades from SNPP to JPSS-1
  - CrIS FSR will implement several new modules to reduce the ring effects
  - ATMS SDR will have some new modules in correction of antenna emission, lunar correction and striping
  - OMPS will add more modules to compress and aggregate RDR, straylight and smearing
  - VIIRS DNB requires special upgrades in geolocation and aggregation
- Starting 2016, SNPP SDR products will be reprocessed every other year
  - SNPP ATMS, CrIS and OMPS - 2016
  - SNPP VIIRS – 2017

ATMS SDR Algorithm Change from SNPP to JPSS



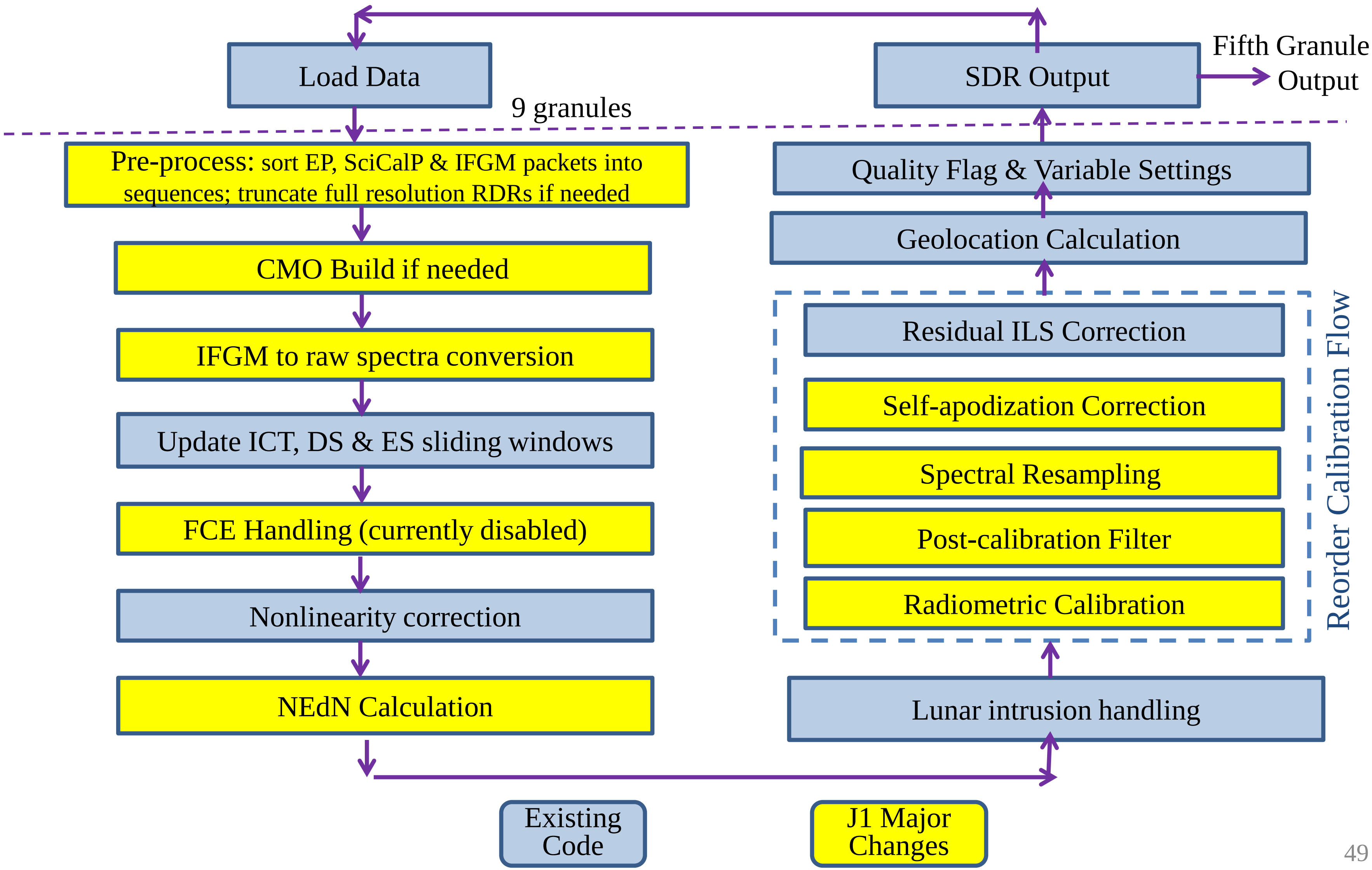
Major Changes:

- Radiance based calibration
- Model based lunar contamination correction
- Updated parameterized nonlinearity correction
- Model based antenna reflector emissivity correction

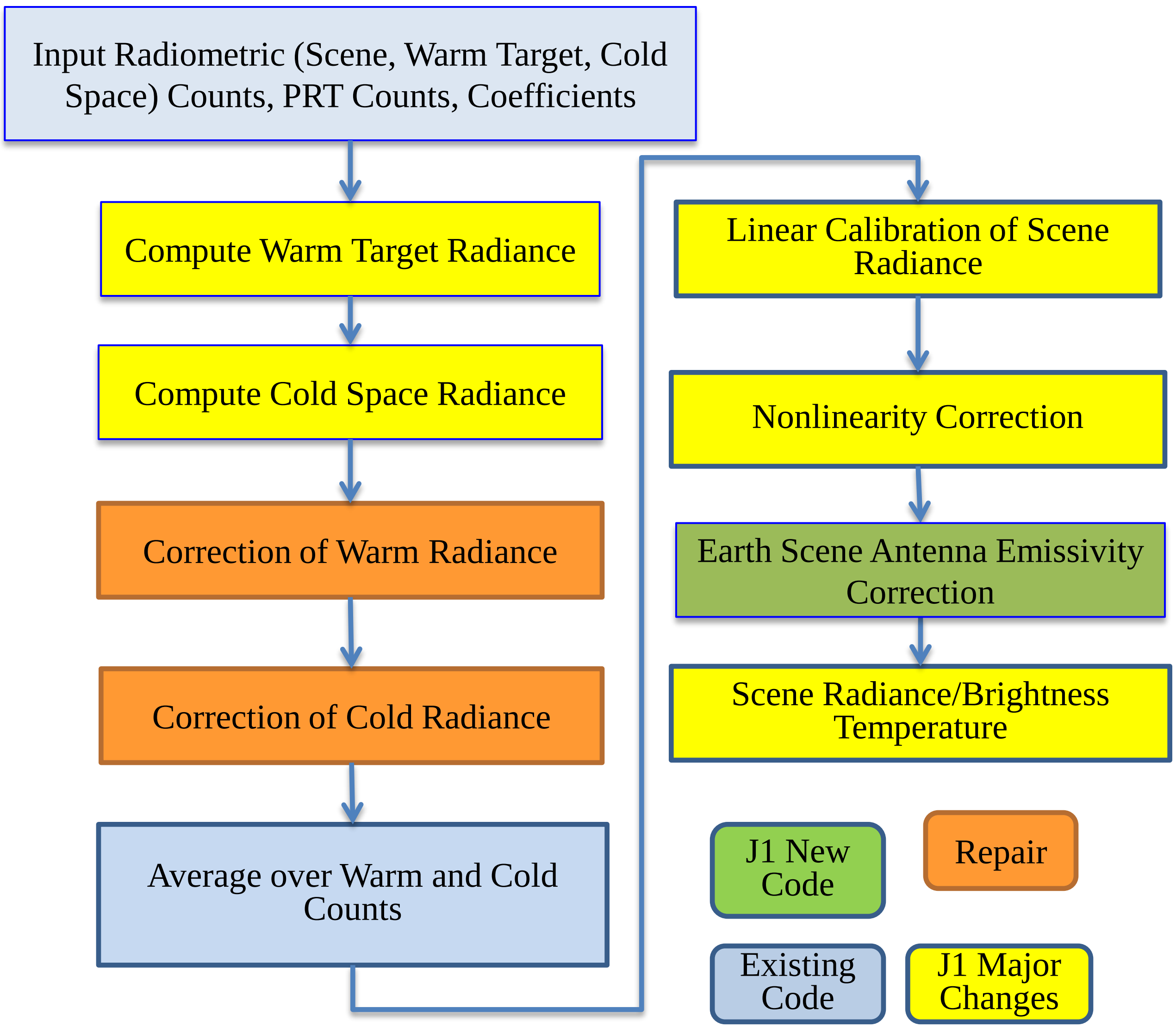
JPSS Mission Life Cycle SDR Reprocessing

- SNPP SDR Processing Changes since November 2011
  - CrIS SDR from normal to full spectral resolution
  - ATMS SDR from Rayleigh-Jean to full radiance
  - VIIRS SDR changes from F/H factor updates
  - Over 1000 discrepancy reports (DR) filed to fix the anomalies, update in PCT, LUT, engineering packages, etc.
- Major SDR Processing Upgrades from SNPP to JPSS-1
  - CrIS FSR will implement several new modules to reduce the ring effects)
  - ATMS SDR will have some new modules in correction of antenna emission
  - OMPS will add more modules to compress and aggregate the RDR
  - VIIRS DNB requires special upgrades in geolocation and aggregation
- Starting 2016, SNPP SDR products will be reprocessed every other year
  - SNPP ATMS, CrIS and OMPS - 2016
  - SNPP VIIRS – 2017

CrIS SDR Algorithm Change from SNPP to JPSS



ATMS SDR Algorithm Change from SNPP to JPSS



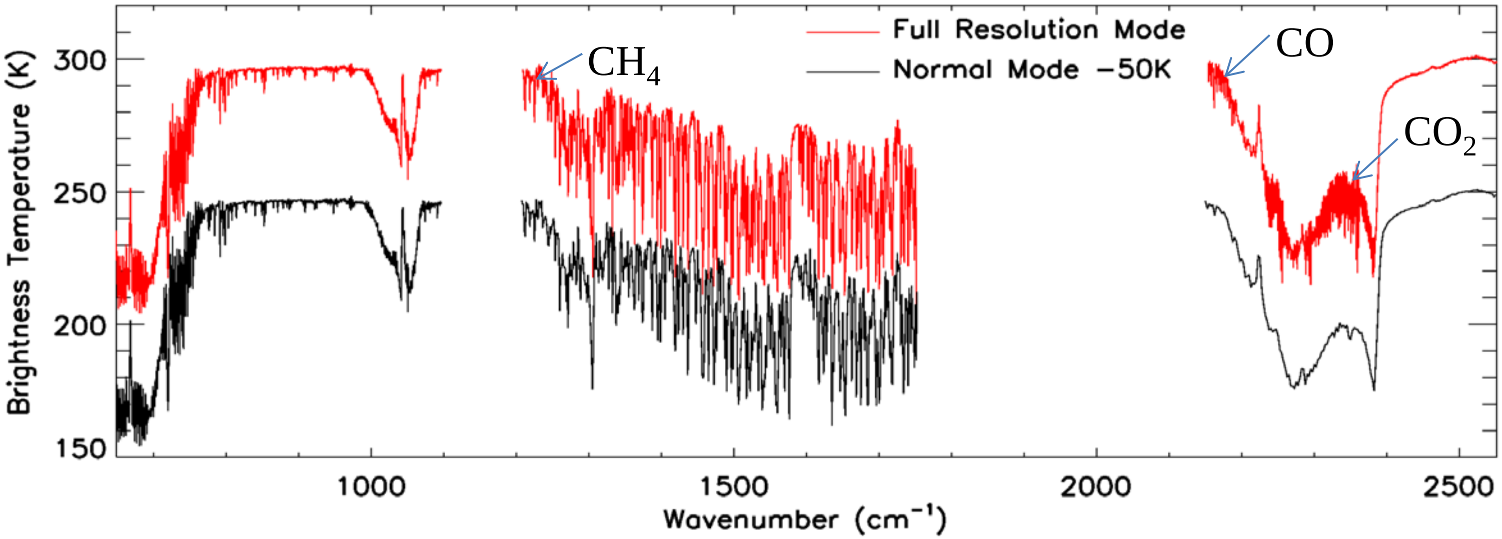
Major Changes:

- Radiance based calibration
- Model based lunar contamination correction
- Updated parameterized nonlinearity correction
- Model based antenna reflector emissivity correction

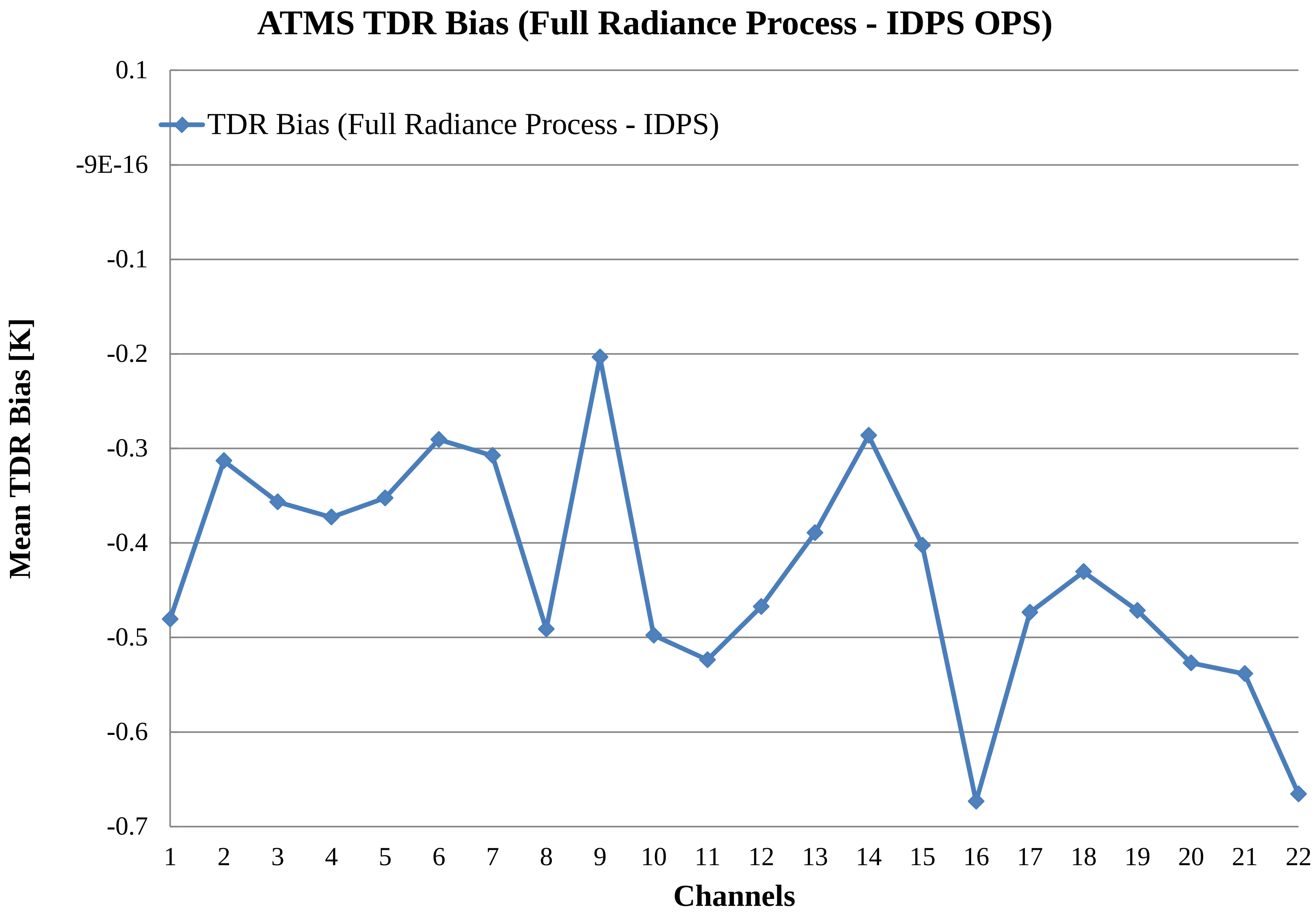
SNPP CrIS Full Spectral Resolution SDR

Frequency Band	Spectral Range (cm^{-1})	Number of Channel	Spectral Resolution (cm^{-1})
LWIR	650 to 1095	713 (713)	0.625 (0.625)
MWIR	1210 to 1750	865 (433)	0.625 (1.25)
SWIR	2155 to 2550	633 (159)	0.625 (2.5)

Red: Full resolution mode



Global Mean ATMS TDR Bias After Reprocessing



Summary and Conclusions

- ATMS, CrIS, VIIRS and OMPS onboard SNPP are well calibrated and their performances in orbit are very stable
- On-orbit calibration standards are fully vetted with SNPP pitch maneuver data and uses of the pitcher maneuver data have led to fundamental changes in calibration theory and new applications in forward modeling
- On-orbit calibration standards are also fully explored through robust O-B where B is computed with GPS RO profiles, ECMWF analysis fields and other high quality atmospheric profiles as inputs to LBLRTM, CRTM, TOMRAD, VLIDORT
- STAR SDR testbed is being established for JPSS mission life cycle reprocessing and a climate quality of SNPP SDR products will be generated in 2016 and 2017.
- SNPP SDR products have been assimilated in all NWP centers and the impacts on the forecast skills are the highest due much to the new technology, calval sciences and data assimilation sciences