Suomi NPP ATMS CalVal Overview

Fuzhong Weng, ATMS SDR Team Lead

Presented at Suomi NPP SDR Science and Product Review

NOAA Center for Weather and Climate Prediction (NCWCP)

5830 University Research Park, College Park, Maryland

December 18-20, 2013

Outline

- ATMS SDR Team Membership
- Findings from 2012 Provisional Review
- CalVal Activities & Results since Provisional Review
- Discrepancy Report (DR) Status at IDPS
- Justifications for ATMS SDR at Validated Maturity Level
- Path forward
- Summary

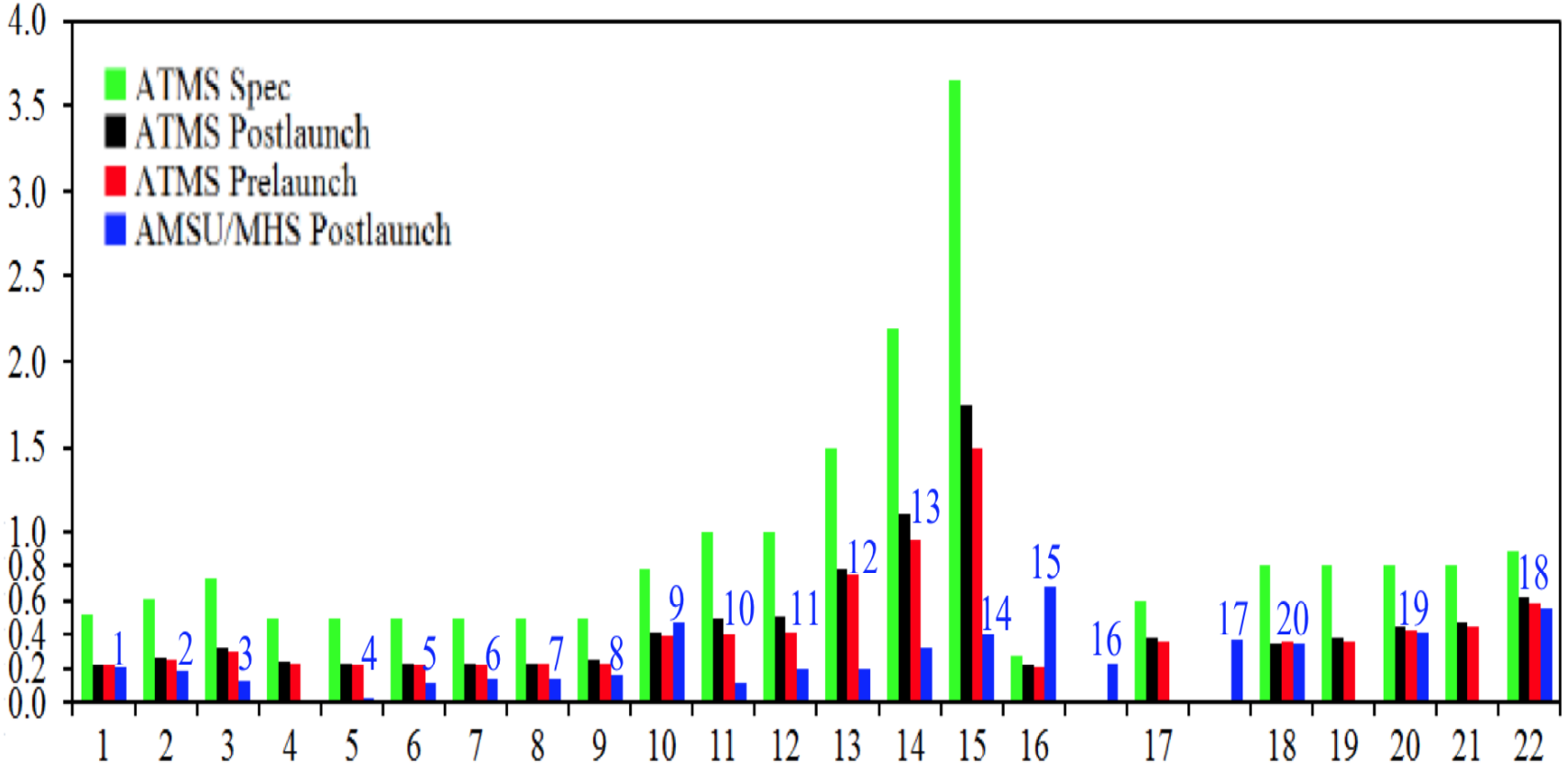
ATMS SDR Team Membership

PI Name	Organization	Team Members	Primary Role and Responsibility
Fuzhong Weng/Ninghai Sun	NOAA	T. Yang, M. Tian	Budget, Coordination, TVAC analysis, SDR sciences &algorithm, SRF, Long-term monitoring
Lin Lin	STAR/JCSDA	Y. Chen	SRF analysis, LBLRTM, bias characterization, coordination with NWP users
Edward Kim	NASA	J. Lyu	NASA ATMS instrument scientist, TVAC data, instrument anomaly investigation
William Blackwell	MIT/LL	V. Leslie	Support NPP/J1 Calval, SDR sciences, PCT/LUT, prelaunch TVAC data analysis
Xiaolei Zou	NGI/FSU	Z. Qin, Y. Ma	Striping analysis and mitigation, cross calibration
Kent Anderson	NGES	M. Landrum	NGES ATMS instrument engineer
Degui Gu	NGAS	A. Foo	Algorithm test and integration for IDPS operations
Wael Ibrahim	Raytheon		IDPS operations
Kris Robinson	USU/SDL		ATMS geolocation error characterization

Findings from 2012 Provisional Review

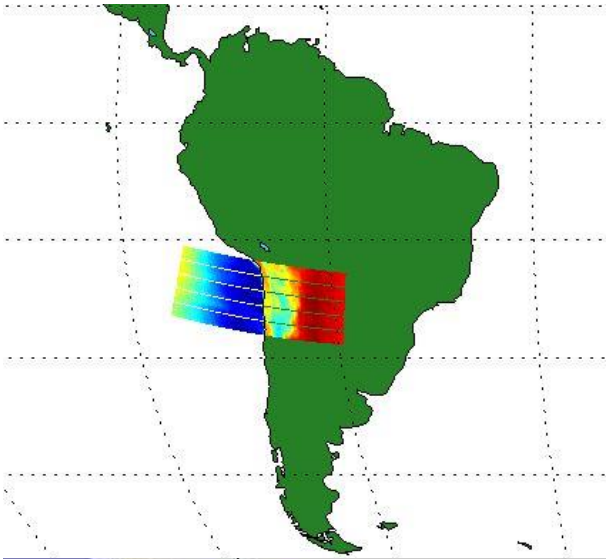
- ATMS has a stable instrument performance and calibration
- All the channels have noises much lower than specification
- ATMS processing coefficient table (PCT) were updated with nominal values
- Geolocation errors for all the channels are quantified and are smaller than specification
- On-orbit absolute calibration was explored using GPS RO data, LBLRTM and ATMS SRF. The biases at the upper-air sounding channels are characterized
- Remap SDR (RSDR) coefficients were optimally set and RSDR biases are assessed
- ***ATMS scan bias correction was not optimally updated (TDR = SDR)***
- ***ATMS striping in O-B is shown at upper-air sounding channels***

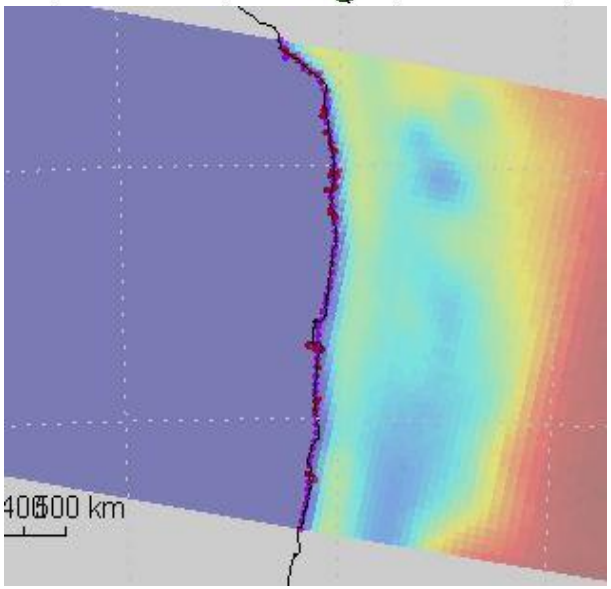
ATMS Channel Noise Characterization



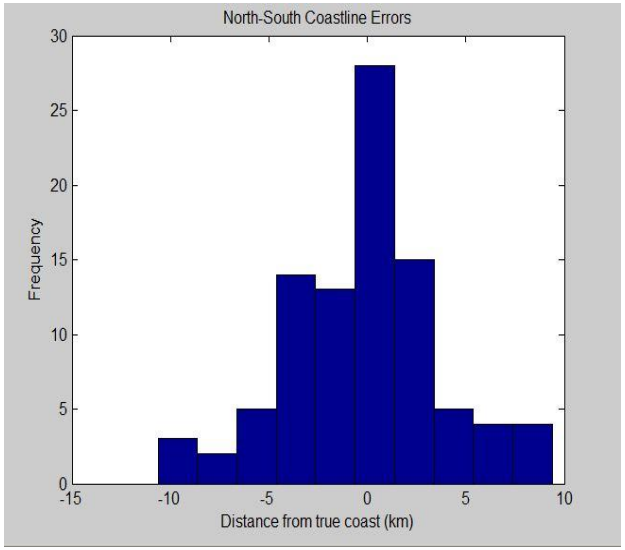
All Channels are within Specifications (Weng et al., 2012, JGR)

ATMS Geolocation Verification

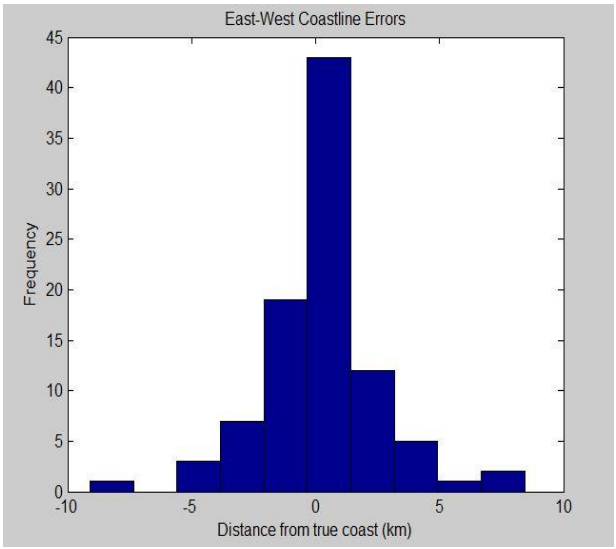




North – South
Mean -0.15km
0.01°
Std. Deviation
3.98km 0.28°

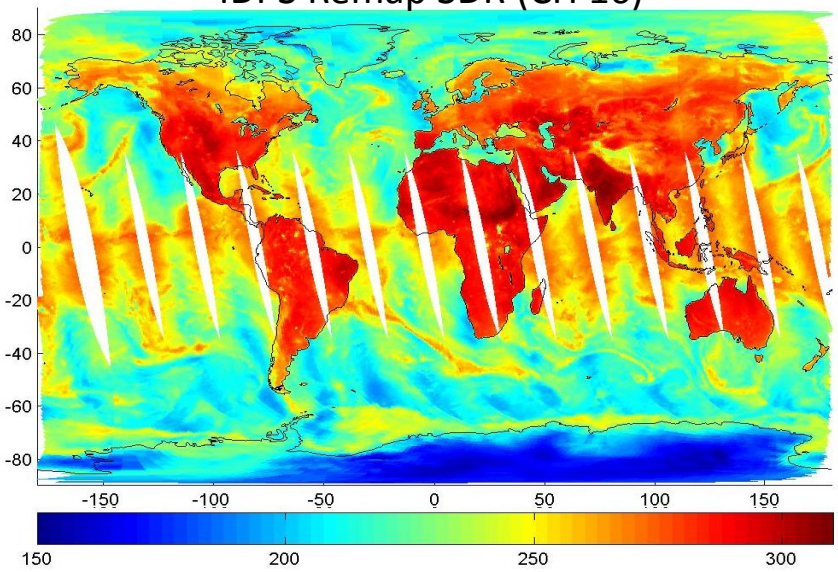


East – West
Mean -.027km
0.02°
Std. Deviation
2.34km
0.16°

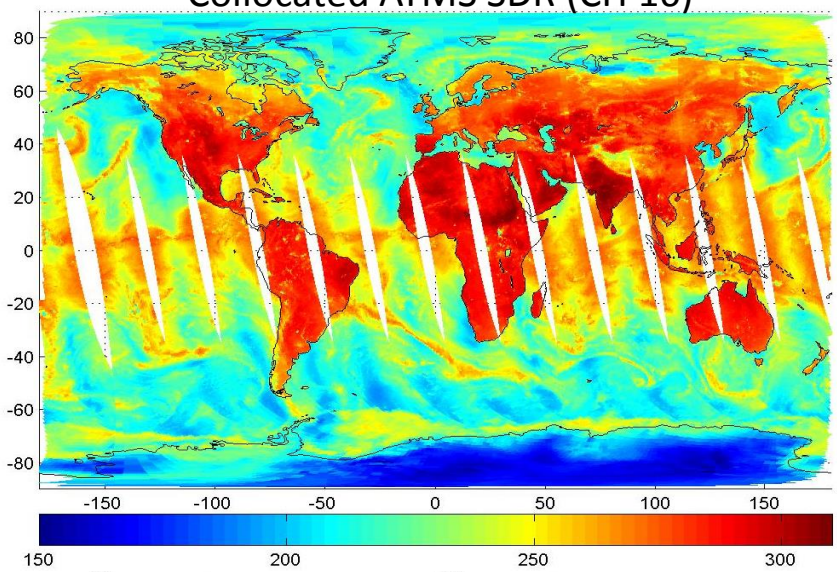


ATMS Remap SDR Evaluation

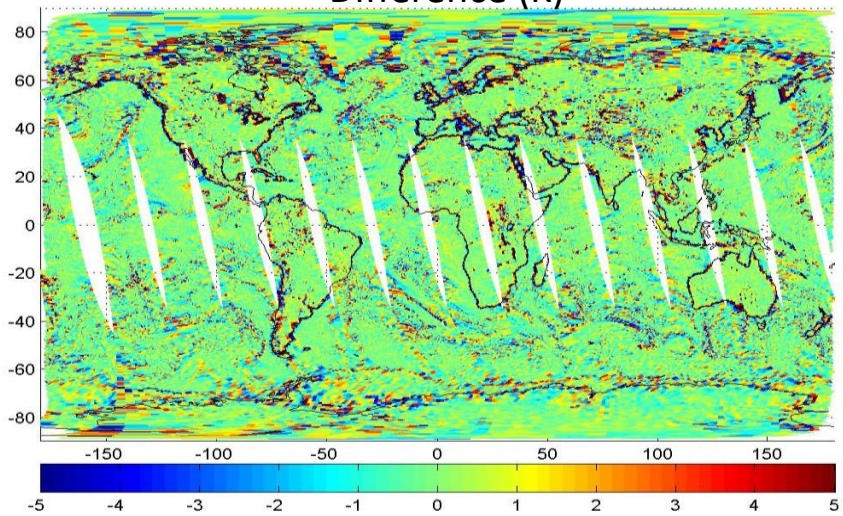
IDPS Remap SDR (CH 16)

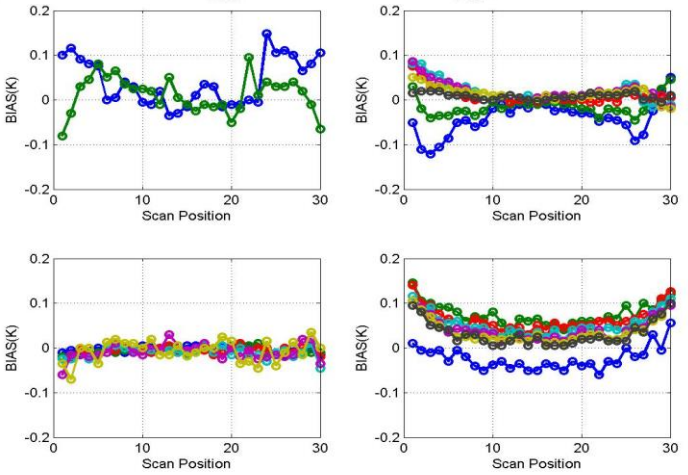


Collocated ATMS SDR (CH 16)



Difference (K)





No Significant Biases Between Remapped SDRs and Collocated ATMS SDRs

Slide courtesy of NGAS

ATMS Calibration Accuracy Assessment Using GPS RO

- **Time period of data search:**

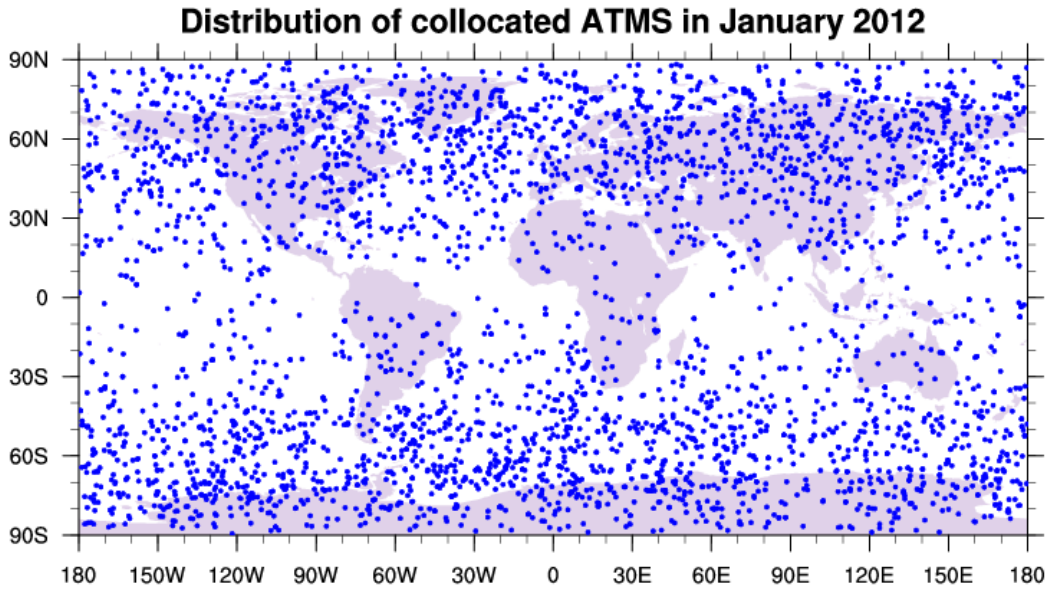
  January, 2012

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

  Time difference < 0.5 hour

  Spatial distance < 30 km

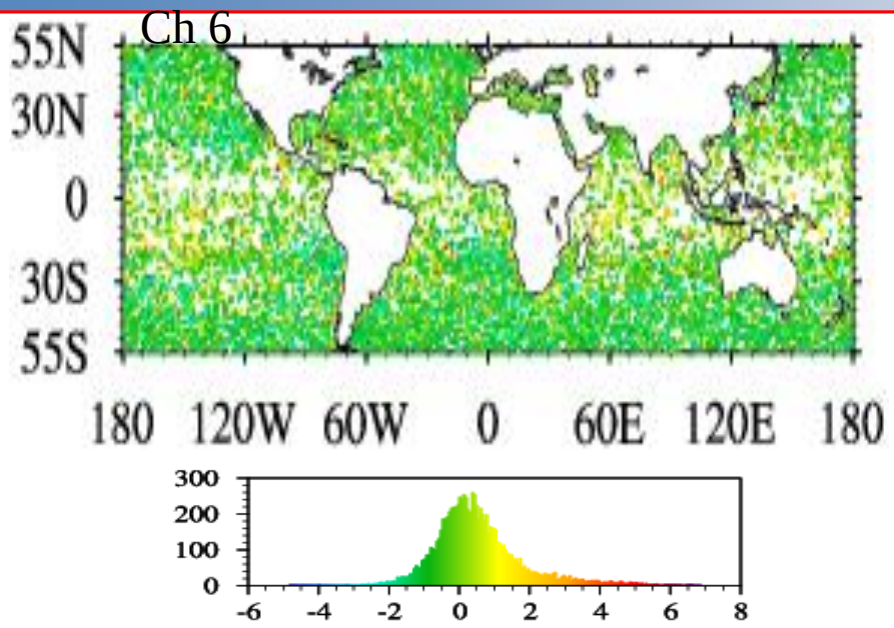
(GPS geolocation at 10km altitude is used for spatial collocation)

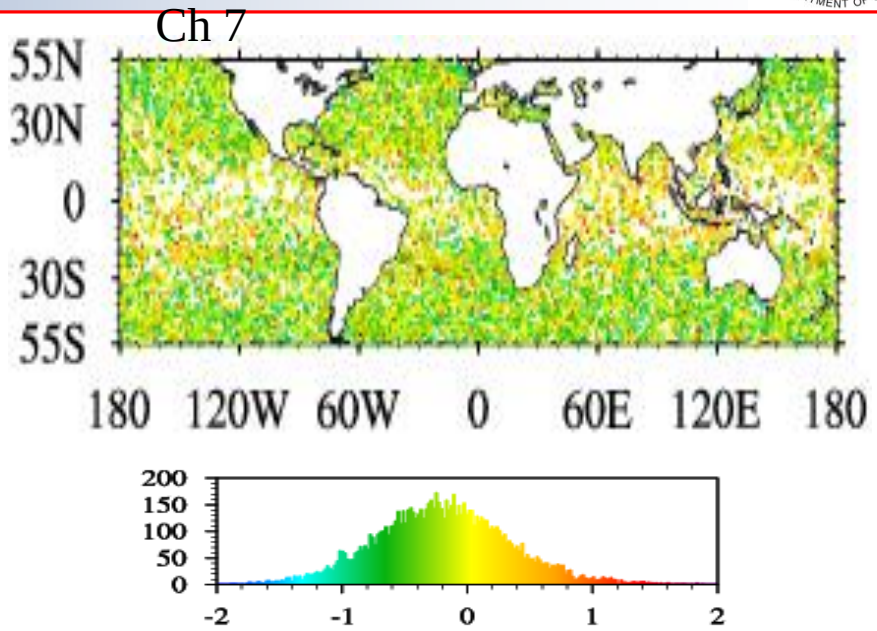


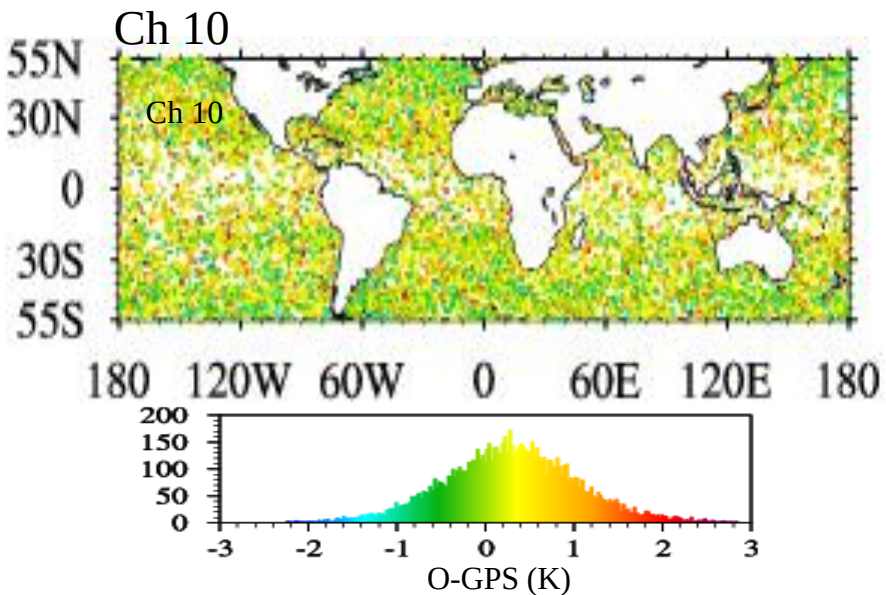
3056 collocated measurements

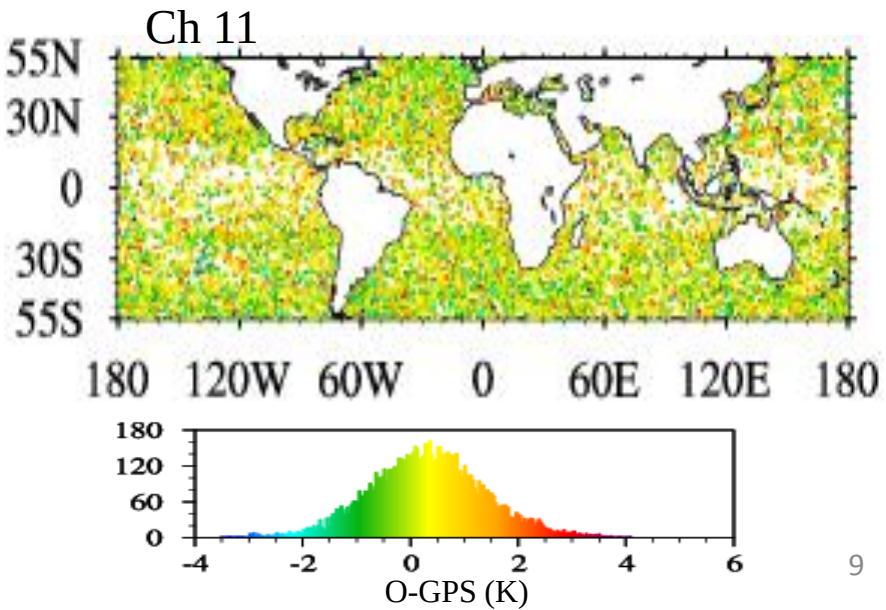
Slide Courtesy of Lin Lin

ATMS Bias Obs (TDR) - GPS Simulated

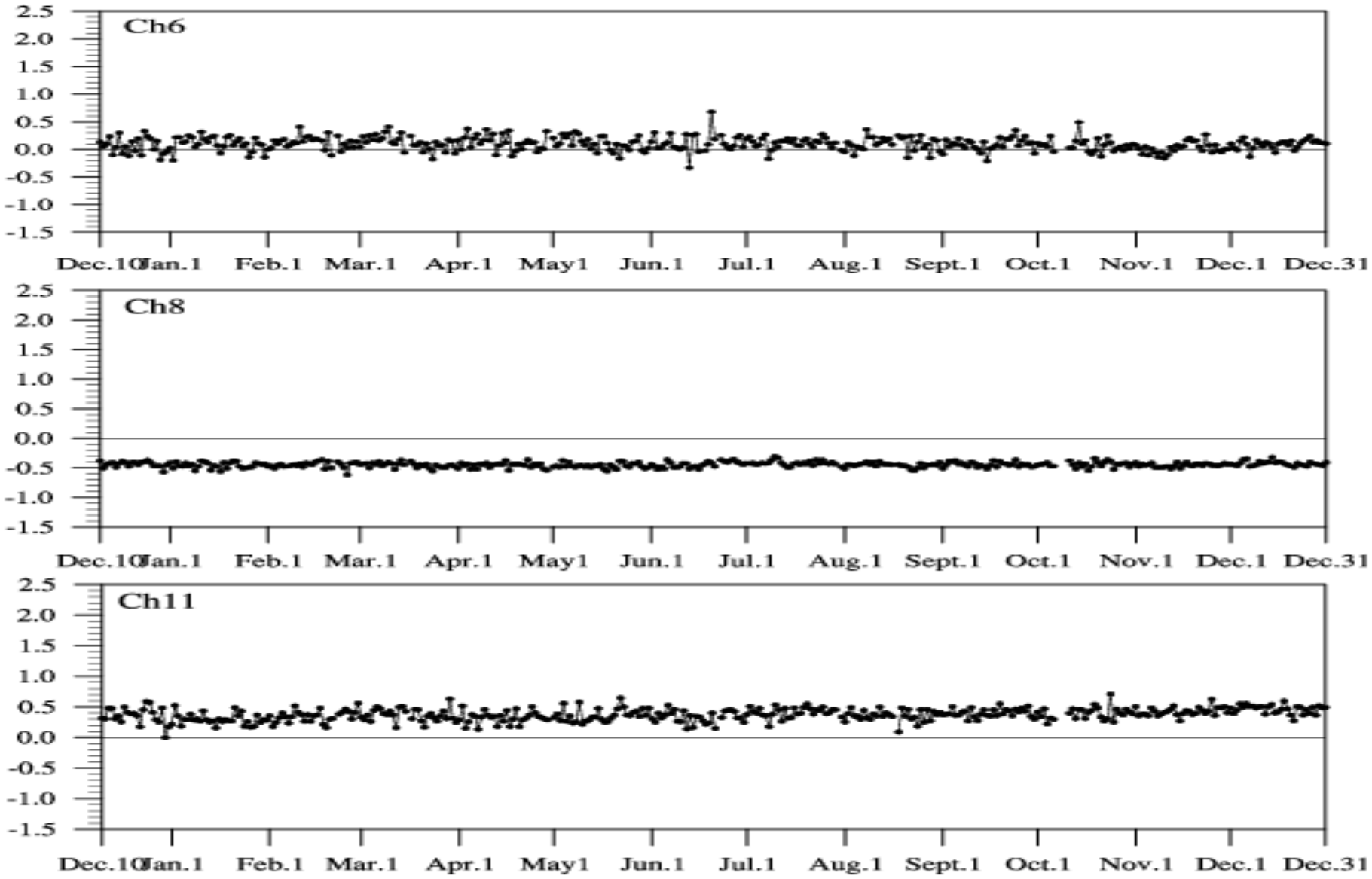








ATMS Bias Obs - Sim (GPS RO)

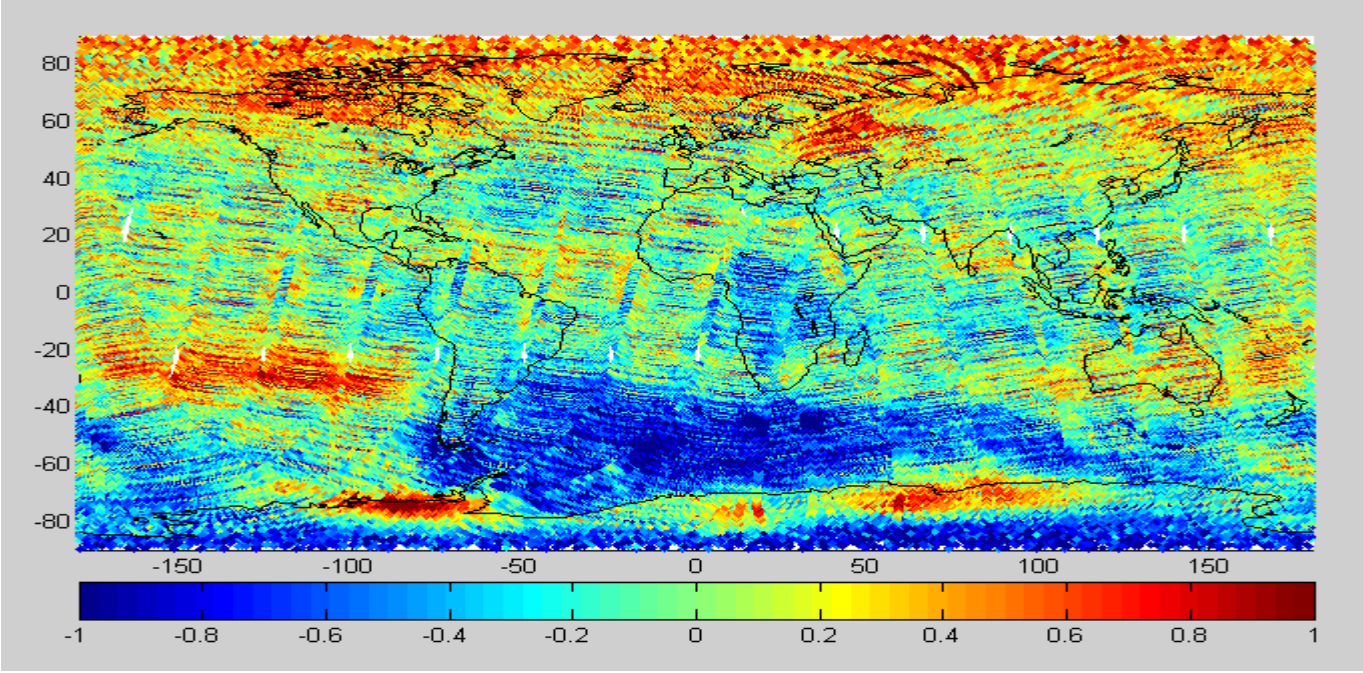


Slide courtesy of Lin Lin

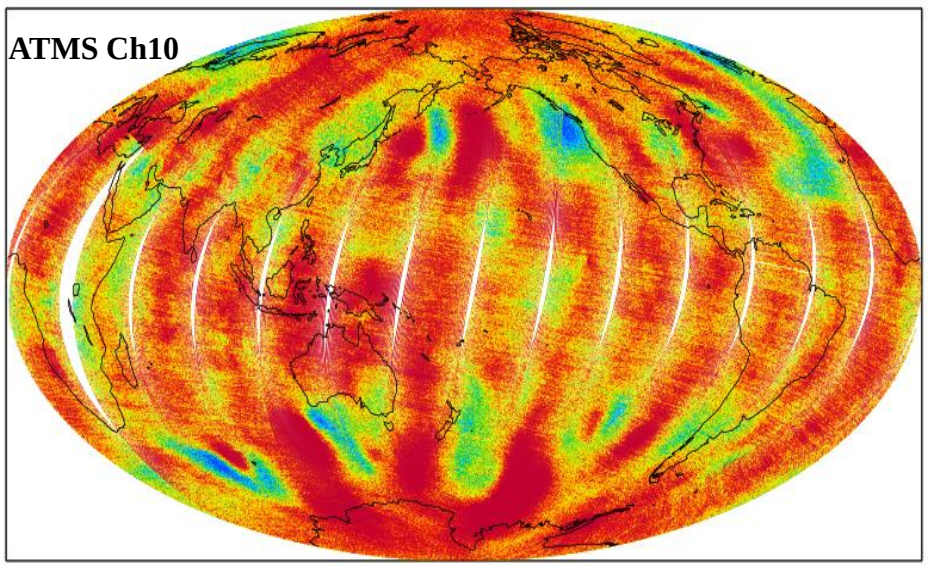
ATMS TDR Striping Noise

- Striping is caused by ATMS SDR calibration noise, specifically the noise in the warm counts. Contributions to the overall calibration noise from cold counts and PRT readings are much smaller
- The level of the striping noise is insignificant and well within ATMS SDR noise spec level

ATMS Brightness Temperature Difference: Simulated – Observed



ATMS and AMSU-A O-B



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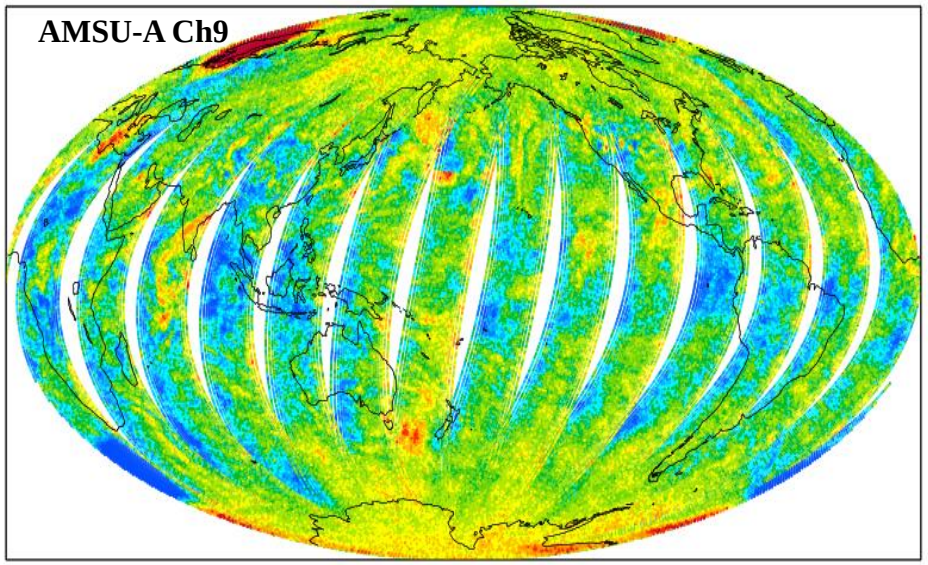
Global O-B Distributions on February 24, 2012



CalVal Tasks Performed Since Provisional Review

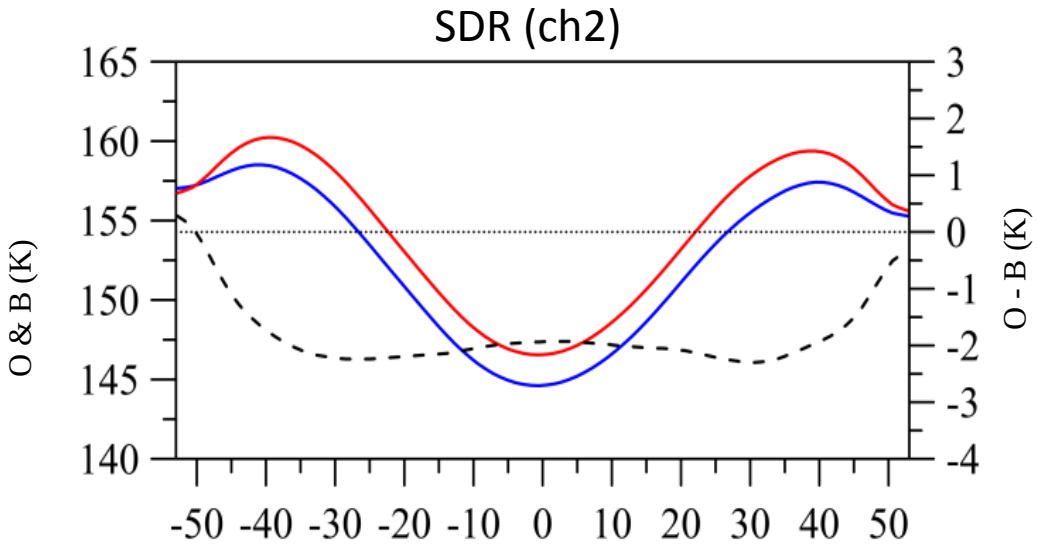
- ATMS quality flags are all thoroughly checked and updated in the MX8.1
- A full conversion from TDR to SDR is developed and implemented into IDPS system (*see Leslie's presentation*)
- TDR striping in temperature sounding channels is fully analyzed and the mitigation algorithm is being tested for IDPS implementation (*see Gu's Presentation*)
- Biases between ATMS and AMSU-A are fully characterized through SNO and double difference technique (*See Zou's presentation*)
- Lunar intrusion flag is checked and lunar contamination on TDR is corrected (*see Yang's presentation*)
- ATMS error budget analysis report is completed (*see ATMS error budget document)*
- Seven peer-reviewed articles are published in AGU, IEEE and AO etc.

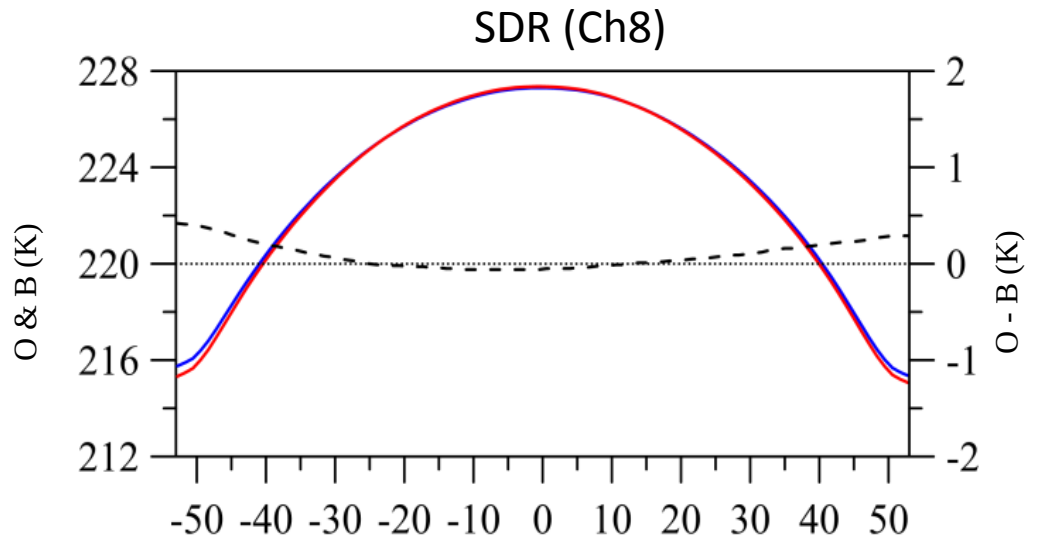
ATMS TDR-to-SDR Conversion Algorithm (1/2)

- **Activities**
  - A conversion theory was developed and tested with ATMS data
  - ATMS PCT/LUT were updated to characterize the slope and intercept
  - SDR angular dependent biases are assessed using ECMWF and CRTM simulations
  - ATMS antenna emission is investigated and a model for quantifying the emission on SDR products is being developed

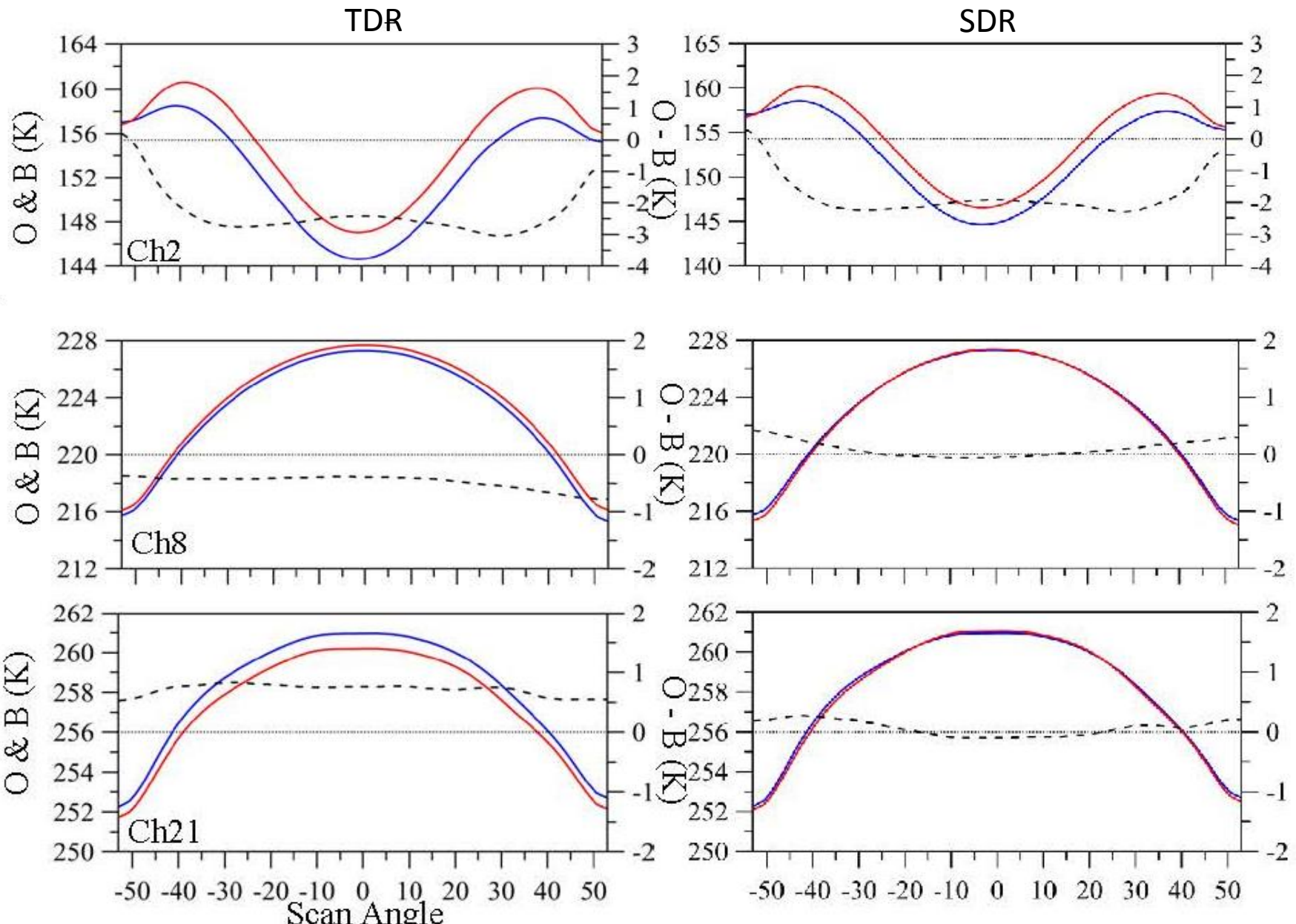
- **Results**
  - ATMS SDR products have small bias for most of channels
  - ATMS SDR at WG bands are only corrected with intercept due to an uncertainty in its antenna gain efficiency

See presentation Leslie et al.





ATMS TDR-to-SDR Conversion Algorithm (2/2)



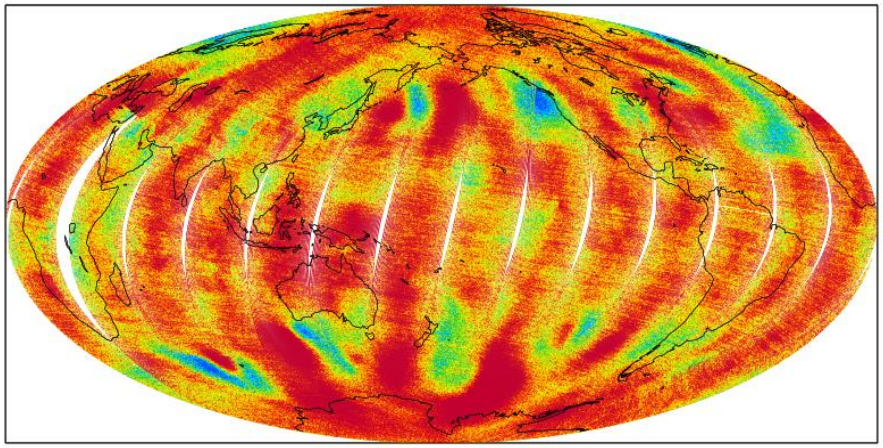
ATMS Striping Noise Investigation

- **Activities**
  - Re-analyzed TVAC and Pitch-over maneuver data to characterize striping noise and to determine the root cause
  - Applied various signal processing techniques (PCA, EMD, FFT) to isolate striping noise in operational data
  - Developed a striping index to quantify the magnitude and significance of residual striping noise
  - Optimized calibration filters to minimize residual striping noise in operational TDR/SDR data products

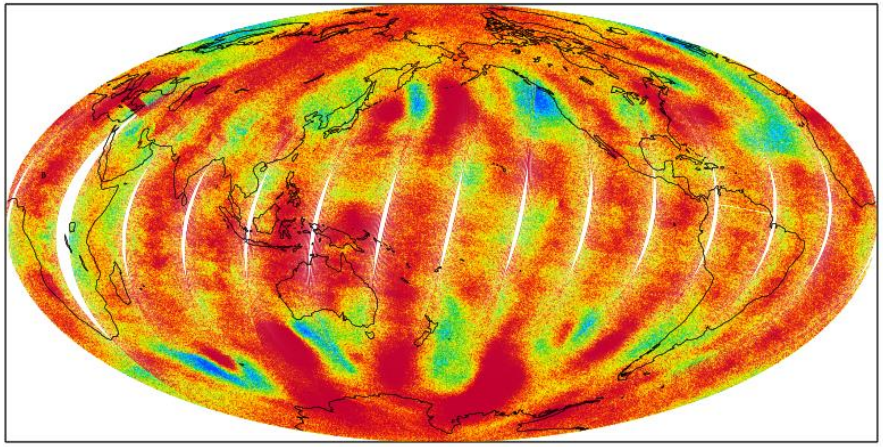
- **Results**
  - Striping noises are believed to be caused by white noise and flicker noise in the RF path
  - Optimized calibration filters are applied to effectively reduce down-track variances (striping) by ~60% for all channels
  - Residual striping is estimated to be at 5-15% of the NEdT level for the K/Ka/V bands, and 20-25% for the W/G bands

See presentation Gu et al.

O (IDPS) – B (Ch 10)

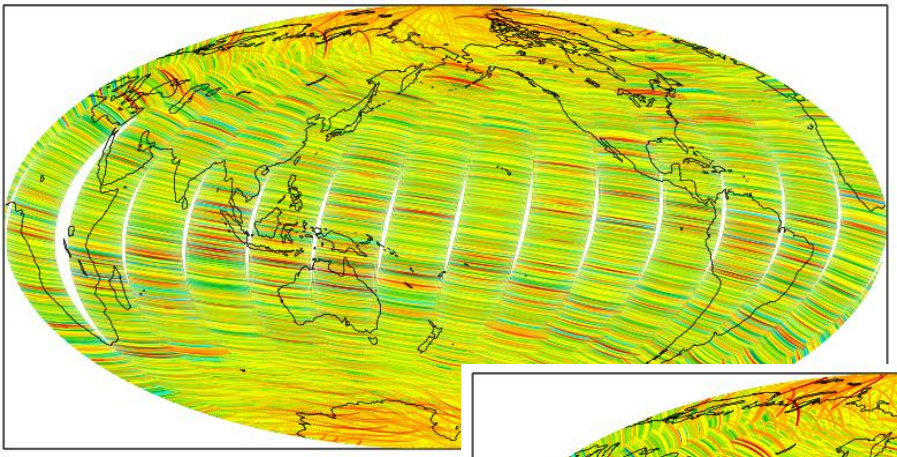


O (New) – B (Ch 10)



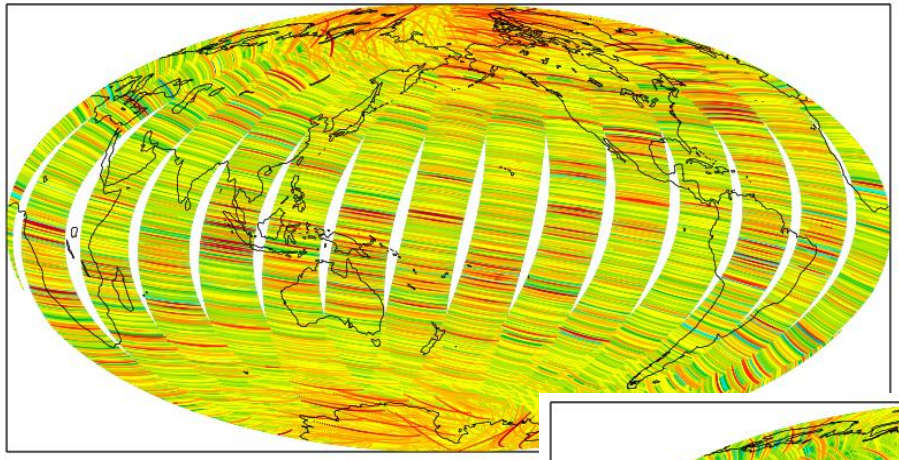
Microwave Radiometry Striping Noise

SNPP ATMS Ch 22

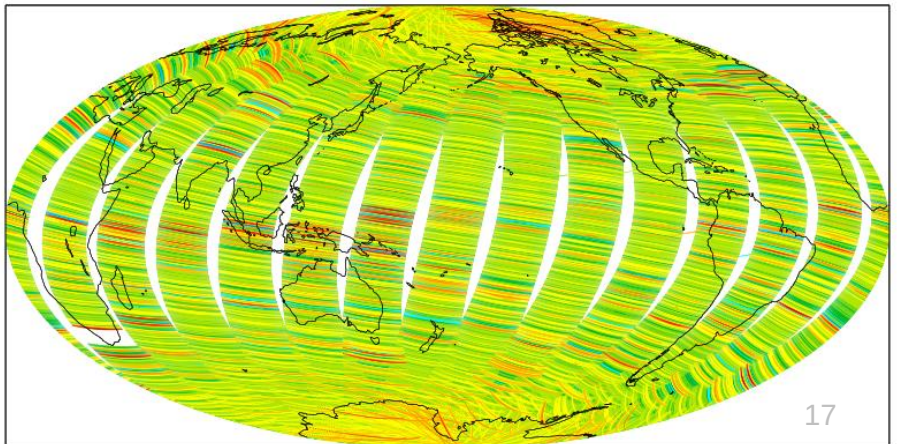


Striping noises are found in ATMS, MHS, and AMSU-B. The magnitudes of ATMS temperature and water vapor sounding channels are about ±0.3K and ±1.0K, respectively

NOAA-18 MHS Ch3



NOAA-16 AMSU-B Ch3



See Qin et al., 2013 JGR

ATMS Lunar Intrusion Correction Algorithm

Activities

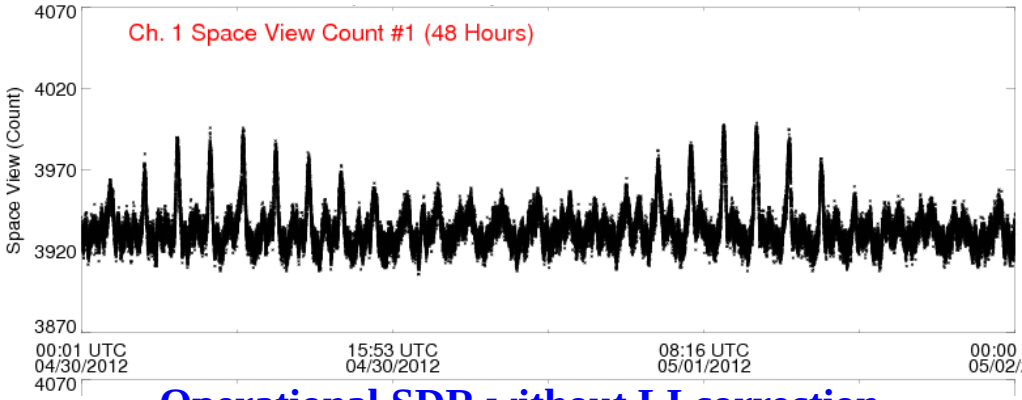
- ATMS RDR dataset was re-processed on G-ADA using the latest ATMS SDR algorithm code and PCT to evaluate lunar intrusion (LI) detection and correction performance
- The potential impact of current TDR with LI on NWP model was evaluated in GSI
- New metrics and physical model was developed for LI identification and correction
- Different approaches for LI correction was compared and tested in offline calibration system as well as in G-ADA, optimal algorithm was selected and implemented in current operational calibration system

Results

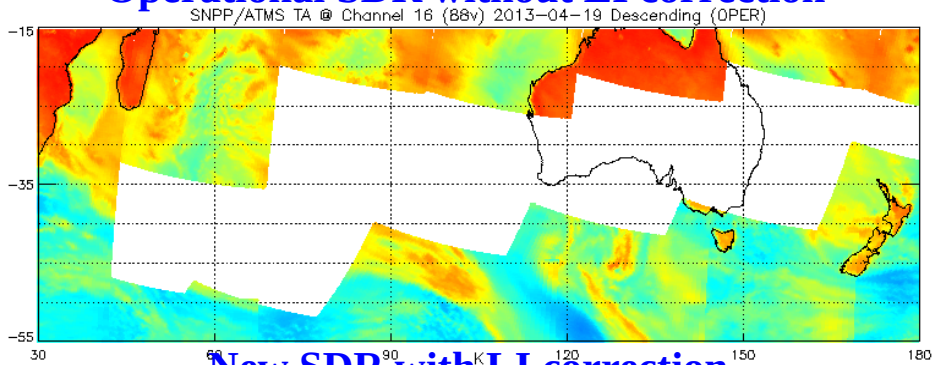
- Lunar intrusion was accurately identified and correctly flagged in SDR datasets
- Data gap was removed after LI correction, residual correction error is below the instrument noise
- New scheme for LI detection and correction was developed for future improvement of current IDPS

See presentation Yang et al.

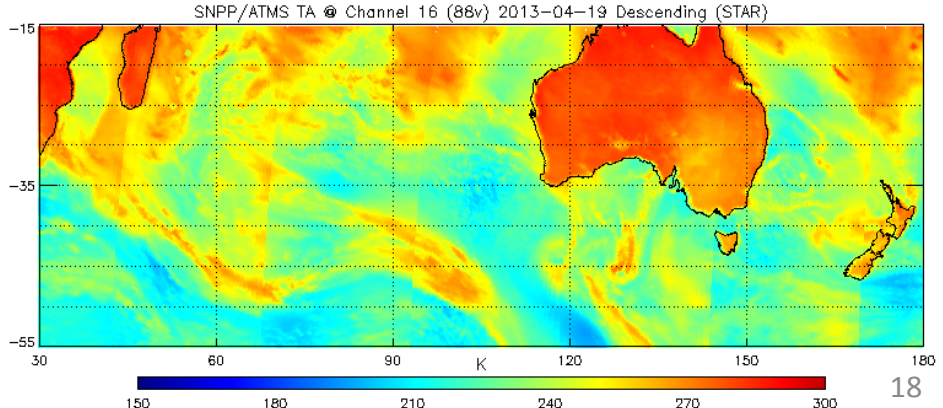
ICVS Monitoring Results of Lunar Intrusion



Operational SDR without LI correction



New SDR with LI correction



ATMS Cross Calibration for Climate Research

Activities

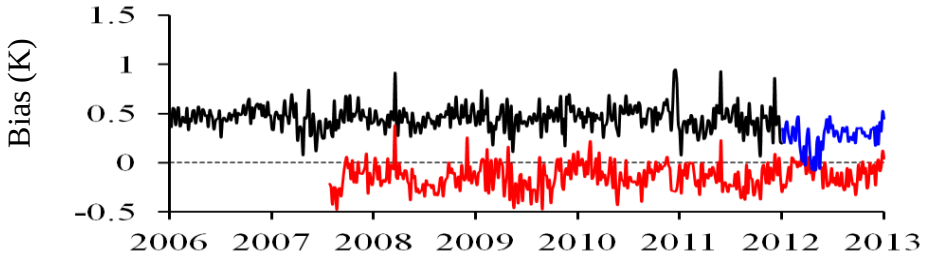
- ATMS channel 1 to 16 are remapped to AMSU-A resolution
- NOAA-15, NOAA-18 and SNPP are collocated through simultaneous nadir overpassing (SNO)
- Intersensor biases are derived from SNO locations

Results

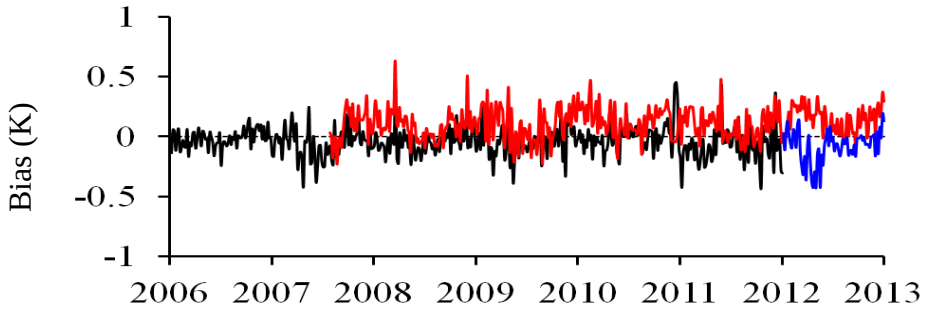
- SNO biases between NOAA-18 and SNPP are less than 1.0K
- After SNO correction, the observations among N15 AMSU-A, N18 AMSU-A and ATMS are more consistent for the selected two small regions

Before SNO Correction

AMSU-A (ATMS) channel 10 (11)



After SNO Correction



NOAA-15 - NOAA-18 MetOp-A - NOAA-18 SNPP - NOAA-18

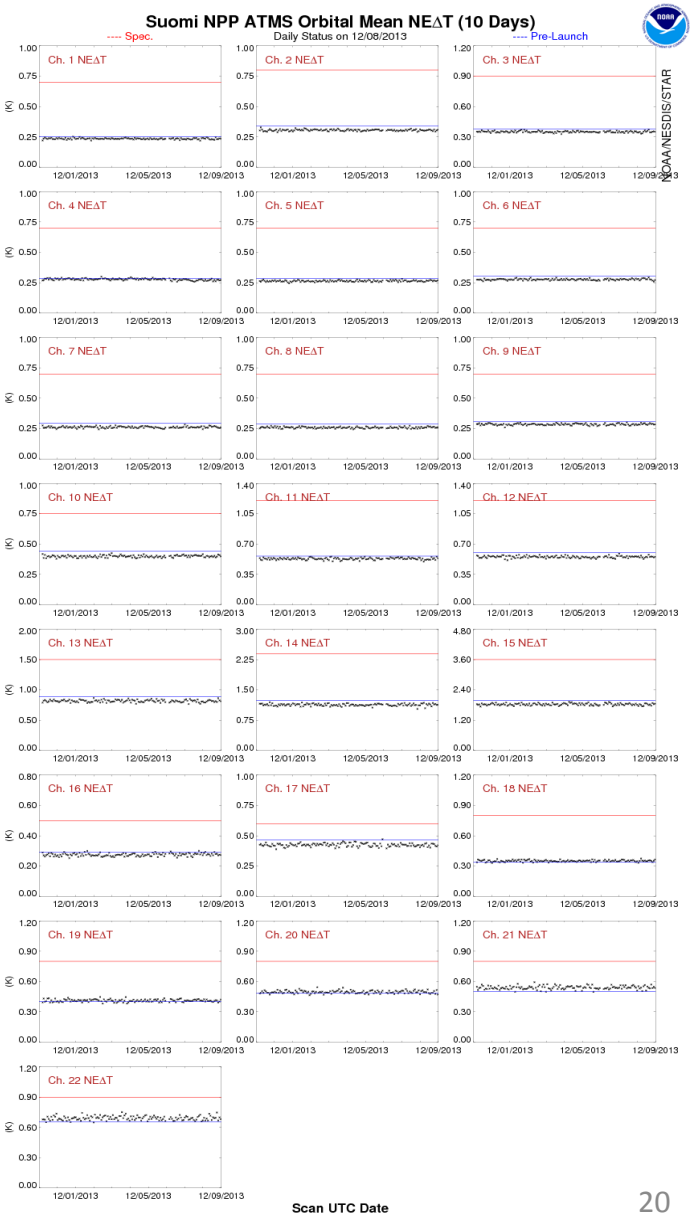
See Zou and Yang, 2013, J. Atmos. & Oceans Tech (submitted)

ICVS-LTM for ATMS

- **Activities**
  - Add daily ATMS instrument status and performance monitoring
  - Add scan drive main motor current and scan angle monitoring
  - Add SDR quality flag global distribution and time series monitoring
  - Update ATMS SDR (O-B) bias monitoring
  - Update ATMS LTM web pages

- **Results**
  - ATMS instrument channel sensitivity (NEΔT) meet specification since launch
  - ATMS SDR channel calibration accuracy meet specification since launch
  - ATMS scan drive main motor current anomaly (within engineering red line) leads to variation in scan angle (space view, hot load view, and earth scene)

- **Future Plan**
  - Reprocess ATMS RDR/TDR/SDR data to produce daily LTM plots
  - Produce monthly updated SDR bias trending monitoring using GPS-RO for sounding channels
  - Reprocess NWP simulations to produce oceanic clear-sky FOV bias trending monitoring for surface sensitive and water vapor sounding channels
  - Improve automatic instrument/data quality anomaly notification function



ATMS DR Status

Number	Status	Title
ADR00007478	New submission	ATMS Maneuver Flag incorrectly set in Mx 7.2
ADR00007456	Analysis	ATMS Striping Index
ADR00007455	Analysis	RDR flags in SDR
ADR00007454	Analysis	Land/water tag in SDR
ADR00007425	Analysis	Correct ATMS TDR for finite reflector emissivity
ADR00007337	Prepare CCR	Bug fix in ATMS SDR space view lunar calibration
ADR00007263	Analysis	ATMS IDPS Operational code should be corrected to match the OAD
ADR00007242	Analysis	JPSS-1 Algorithm Improvements: Recommended: ATMS SDR
ADR00007136	Analysis	ATMS scan profile software change prep
ADR00007129	Closed	Pad byte size correction for ATMS-SDR-CC-Int.xml
ADR00005015	Closed	RTN Sev2 PCR ATMS Remap Maneuver
ADR00004954	Closed	ATMS SDR team evaluation of two orbits of Mx6.3 data
ADR00004910	Closed	Telemetry on ICVS showing discontinuities
ADR00004847	Closed	ATMS-SDR-CC Side-B update

ATMS DR Status

Number	Status	Title
ADR00004837	Closed	ATMS stand-alone remapped SDR in error
ADR00004813	Analysis	ATMS calibration striping investigation
ADR00004811	Closed	Turn on PRT consistency check
ADR00004806	Closed	Scan bias & Beam eff.
ADR00004741	Closed	ATMS-SDR-CC PCT Update
ADR00004730	Closed	QF Correction Part 2
ADR00004729	Closed	ATMS SDR should not process fill packets
ADR00004687	Closed	New ATMS SDR/TDR DQN
ADR00004642	Closed	Geo Discrepancy between G-ADA and IDPS Ops
ADR00004601	Closed	ATMS RDR non-readable Packet
ADR00004593	Closed	Operations wants working DQN's for Provisional Status
ADR00004566	Closed	ATMS SDR Duplicate/Fill Granules
ADR00004561	Closed	QF1-QF9 Trigger Verification
ADR00004521	Closed	Maneuver Flag

ATMS Documentation (1/2)

- Presentations given in this review meeting
  - Weng : ATMS CalVal Task Overview
  - Leslie et al.: ATMS TDR to SDR Conversion Algorithm
  - Gu et al: ATMS striping analysis
  - Zou et al.: ATMS Cross Calibration
  - Yang et al.: ATMS Lunar Correction
  - Sun et al: ATMS Data Quality Monitoring
- ATMS SDR User's Guide version 1.0
- Revised ATMS SDR ATBD

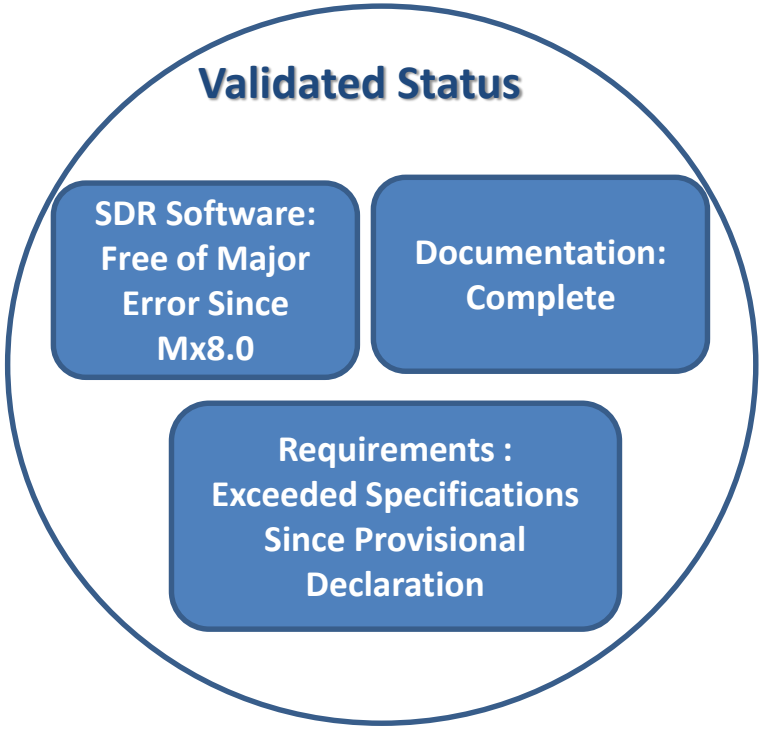
ATMS SDR Documentation (2/2)

- ATMS CalVal Results Summarized in peer review papers

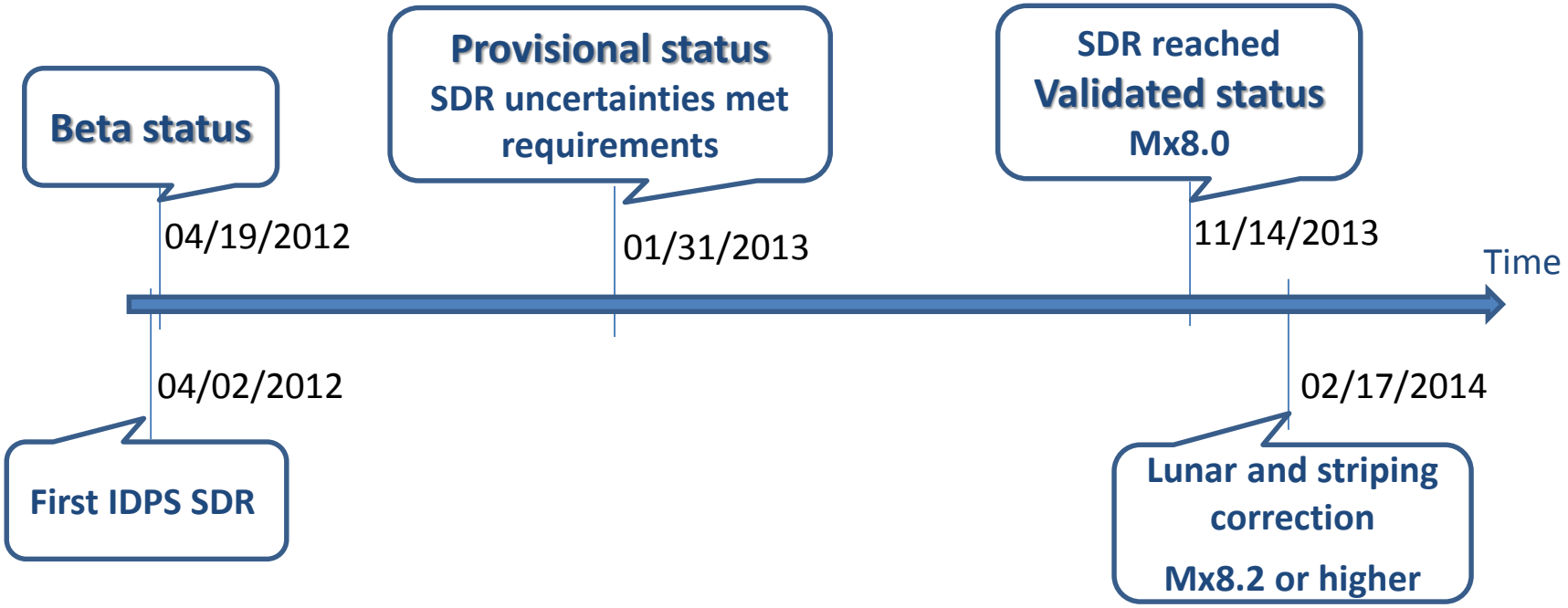
- Weng, F., X. Zou, X. Wang, S. Yang, M. Goldberg, 2012: Introduction to Suomi NPP ATMS for NWP and Tropical Cyclone Applications, *J. Geophys. Res. Atmos*, doi:10.1029/2012JD018144
- Weng, F., X. Zou, M. Tian, W.J. Blackwell, N. Sun, H. Yang, X. Wang, L. Lin, and K. Anderson, 2013, Calibration of Suomi National Polar-Orbiting Partnership (NPP) Advanced Technology Microwave Sounder (ATMS), *J. Geophys. Res.* Atmos., **118**, 1–14, doi:10.1002/jgrd.50840
- Qin, X. Zou, and F. Weng, 2013: Analysis of ATMS Striping Noise from its Earth Scene Observations Using PCA and EEMD Techniques**,** *J. Geophys. Res . Atmos.,* **118***, doi:10.1002/2013JD020399*
- Weng, F., H. Yang, and 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
- Weng, F. and X. Zou, 2013: Errors from Rayleigh–Jeans Approximation in Satellite Microwave Radiometer Calibration System, *Appl. Optics*, 12, 505-508.
- Zou, X., F. Weng, B. Zhang, L, Lin, Z. Qin, and V. Tallaparada **:**2013: Impacts of assimilation of ATMS data in HWRF on track and intensity forecasts of 2012 four landfall hurricanes, *J. Gephys. Res. Atmos*, **118**, 1-19, doi:10.1002/2013JD020405
- Bormann, N., A. Fouiloux and W. Bell, 2013: Evaluation and assimilation of ATMS data in the ECMWF system, , *J. Gephys. Res. Atmos*, **118,** doi:10.1002/2013JD020325

ATMS SDR Maturity Level – Validated

- Requirements
  - Instrument & SDR performances exceeded requirements since Provisional status declaration 1/31/2013
- SDR software
  - Stable & free of errors since 11/14/2013 (Mx8.0)
- Documentation
  - 6 presentations in this meeting
  - 7 Journal papers
  - SDR ATBD (revised)
  - SDR user guide (new)
  - SDR error budgets



IDPS ATMS SDR CalVal Milestones



ATMS SDR Data Sets

- IDPS
  - SDRs produced by IDPS with versions up to Mx8.0
  - Calibration PCT/LUT: Updated with beam efficiency and scan bias correction
  - Lunar correction DR was submitted and will be in Mx8.2 or high version
  - Striping correction DR was submitted and will be implemented in MX8.2 or high
- ARTS (ATMS Radiance Transformation System)
  - Use for reprocessing ATMS in radiance
  - Replace the current IDPS processing for J1 and J2 mission

Path Forward

- Suomi NPP
  - Refine ATMS scan bias corrections for TDR to SDR conversion with better characterization of xpol spill-over, W/G band slope (note intercept has been updated)
  - Develop ATMS radiometric calibration in full radiance to make the SDR data consistent with NOAA heritage AMSU-A/MHS
  - Refine striping mitigation algorithm for WG bands
- JPSS -1 and -2
  - Support of and participation in pre-launch testing, instrument characterization and calibration data development
  - Software update/improvement (implementations of new calibration algorithms, full resolution SDR and computation efficiency schemes), delivering the SDR code in January 2015.
  - Work with NGES to better characterize ATMS antenna (side-lobe, xpol spill-over, polarization twist angle) for J1/J2 mission
  - A comprehensive test data set derived from SNPP and J1 TVAC tests for J1 algorithm and software development and test
  - Support J1 and J2 waiver studies

Summary

- ATMS TDR/SDR data has reached a validated maturity *level (definition: on-orbit performance is characterized and calibration parameters are adjusted accordingly. The data is ready for use by the operational center and scientific publications)*
- ATMS SDR team made following major calval accomplishments:
  - STAR team also did an independent data on SNPP ATMS TVAC data and we can reproduce all the pre-launch results (e.g. calibration accuracy, calibration nonlinearity, noise)
  - On-orbit NEDT is well characterized and meets specification
  - Bias (accuracy) is well characterized
  - All the important quality flags are checked and updated
  - Calibration coefficients from TDR to SDR are updated
  - Lunar intrusion correction is tested and DR is submitted
  - ATMS and AMSU-A inter-sensor biases are well characterized and ATMS TDR data are now within AMSU-A family
  - STAR ICVS can provide long-term monitoring of ATMS instruments
  - All the calval sciences have been published through peer-reviewed process