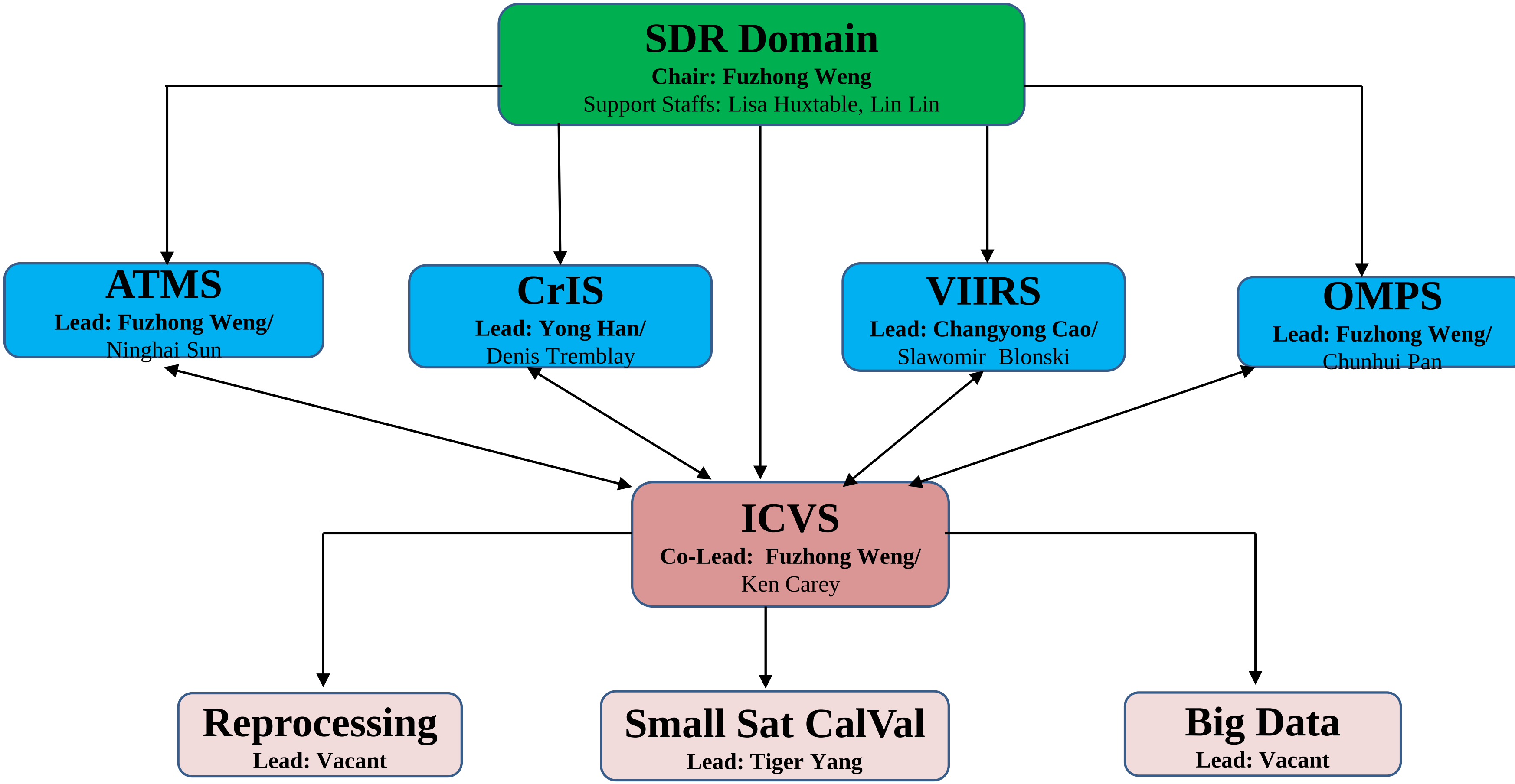
Joint Polar Satellite System (JPSS) SDR Highlights

Fuzhong Weng, JPSS SDR Chair
Center for Satellite Applications and Research (STAR)
National Oceanic and Atmospheric Administration (NOAA)

STAR JPSS 2015 Annual Science Team Meeting
August 24-28, 2015
5830 University Research Court, College Park, MD 20740

STAR JPSS SDR Teams/Management Structures



Scientific and Engineering Interactions among NOAA /NASA/Vendor Instrument Scientists

NOAA	NASA	Vendor
ATMS Hu (Tiger)Yang	ATMS Ed Kim	ATMS NGES: Kent Anderson
CrIS Yong Chen	CrIS Dave Johnson	CrIS Exellis: Lawrence Suwinski
OMPS Trever Beck	OMPS Glen Jaross	OMPS BATC: Sara Lipscy
VIIRS Slawomir Blonski	VIIRS Kurt Thome	VIIRS Raytheon: Eric Johnson

JPSS SDR 2015 Major Accomplishments

1. 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
2. Developed an offline CrIS full spectral resolution (FSR) SDR processing system and made the FSR products available to user community
3. Developed ATMS radiance-based radiometric calibration, replacing Rayleigh-Jeans approximation in two-point calibration system
4. 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
5. 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
6. Integrated CalVal System (ICVS) – Lite version was successfully transitioned to GRAVITE for NASA Flight and OSPO operational uses

2015 NOAA Administrator's Award to CrIS SDR Science Team Lead: Dr. Yong Han

The Administrator's Award is a combination honorary and monetary award designed to recognize NOAA-specific contributions

Citation Title: For developing state-of-the-art processing, calibration, and monitoring of Cross-track Infrared Souder full spectral resolution data for weather and climate applications

" ….Yong had to wade into an existing program at a critical time, and he has done a superlative job. He is a natural at management, although I suspect he denies that. His willingness and ability to delve very deeply into mathematical, instrument, science, and code issues while serving as the team leader is even more impressive and I suspect is the one of the main reasons he is such a good leader!…." – Professor Larrabee Strow, UMBC

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	August 20, 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

JPSS-1 SDR Algorithm Schedule

Sensor	Beta	Provisional	Validated
CrIS	L+3M	L+6M	L+12M
ATMS	L+1M	L+3M	L+12M
OMPS	L+3M	L+6M	L+12M
VIIRS	L+3M	L+6M	L+12M

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Backup Slides:
Summary of 2015 Top Five Accomplishments for Five SDR Teams

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)

CrIS SDR Team 2015 Top Five Accomplishments

1. Developed an offline CrIS full spectral resolution (FSR) SDR processing system and made available to user community the FSR SDR product since December 4, 2015

2. Completed and delivered J1 CrIS SDR software with backward compatibility for S-NPP data processing

3. Characterized J1 CrIS instrument performances and derived calibration LUTs from pre-launch test data

4. Significantly improved CrIS SDR calibration algorithm to reduce radiance ringing artifacts by a factor 3 in certain unapodized spectral regions

5. Developed and delivered a new Fringe Count Error detection and correction SDR software module

VIIRS SDR Team 2015 Top Five Accomplishments

1. Developed J1 VIIRS DNB waiver mitigation and delivered pre-operational software to the program on-time, which greatly reduced program schedule and cost risks, in addition to operational straylight correction

2. Prepared all 47 J1 VIIRS LUTs (ver1.0) based on analysis of prelaunch test data, tested using ADL and simulated J1 data, and delivered to the program

3. Developed and demonstrated VIIRS DNB radiometric and geolocation monitoring/characterization capabilities using nightlight point sources, which is critically needed for J1 postlaunch validation of the waivers

4. Expanded validation time series with the 30+ validation sites worldwide, with added capabilities in the SWIR bands, as well as comparing with GOSAT FTS hyperspectral observations

5. Generated recalibration coefficients since launch with the latest corrections and RSB Autocal

OMPS SDR Team 2015 Top Five Accomplishments

1. LUTs of wavelength, day one solar and radiance coefficients were updated for both NP (CCR 15-2548) and NM (CCR 15-2547). These LUTs reduced NM radiance error in the cross-track direction. The SDR products now meet the requirement of wavelength dependent albedo (normalized radiance) <2.0%. Additional improvements have been made for the NM and NP consistency in 300-310 nm by 2-10%.
2. Completed NM SDR J1upper modifications. 1) Implemented NM decompression algorithms to process/convert compressed RDR input and aggregation algorithm to convert RDR to the required resolution. Enhanced NM SDR algorithms to process medium-resolution 17x17 km, sparse-spectral RDR products, provide data with current NM SDR product content (CCR 15-2283) 2) performed algorithm validation test using J1 proxy data (CCR 15-2432).
3. Completed NP SDR medium resolution code updates. 1) Implemented NP decompression algorithms to process/convert compressed RDR input. Enhance NP SDR algorithms to process medium-resolution 50x50 km RDR products, provide data with current NP SDR product content (CCR 15-2388) and 2) performed algorithm validation test using J1 proxy data (CCR 15-2469).
   J1 proxy data: use SNPP earth view data processed by J1 MEB (Main Electronic Box) with J1 timing pattern and sample tables.
4. Updated NM stray light LUT (CCR 14-2100) and added the NM out of band response from 417 nm to the stray light correction.
5. Evaluated, converted and formatted OMPS SCDBs contents to J1 algorithm LUTs for both NM and NP.
   - Spectrometric LUTs: Spectral Response, Spectral Registration, Wavelengths
   - Radiometric LUTS: Calibration Coefficients, CF-Earth(contains radiometric calibration factors for the Earth scene spatial cells) , Darks, Linearity, Stray Light, Solar Irradiance, Observed Solar, Predicted Solar
   - Geolocation LUT: Mounting Matrix and Field Angle Map

ICVS Team 2015 Top Five Accomplishments

1. Transitioned ICVS-Lite to GRAVITE for OSPO operational uses. The ICVS-Lite is running at GRAVITE and is being used by OSPO engineers.

2. Detected 3 major ATMS scan motor current anomalies with timely reports to NASA flight and NOAA JPSS senior managements

3. Standardized ICVS codes and eliminated the IDL language in graphics and optimized software structures through version control and central repository

4. Upgraded ICVS storage through OSGS ground system fund for storing the metadata from all the instrument house keeping and anomaly events

5. Began a prototype design of ICVS Big Data structure for more applications of ICVS data

ATMS SDR Overview

Fuzhong Weng

ATMS SDR Team

August 24, 2015

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Outline

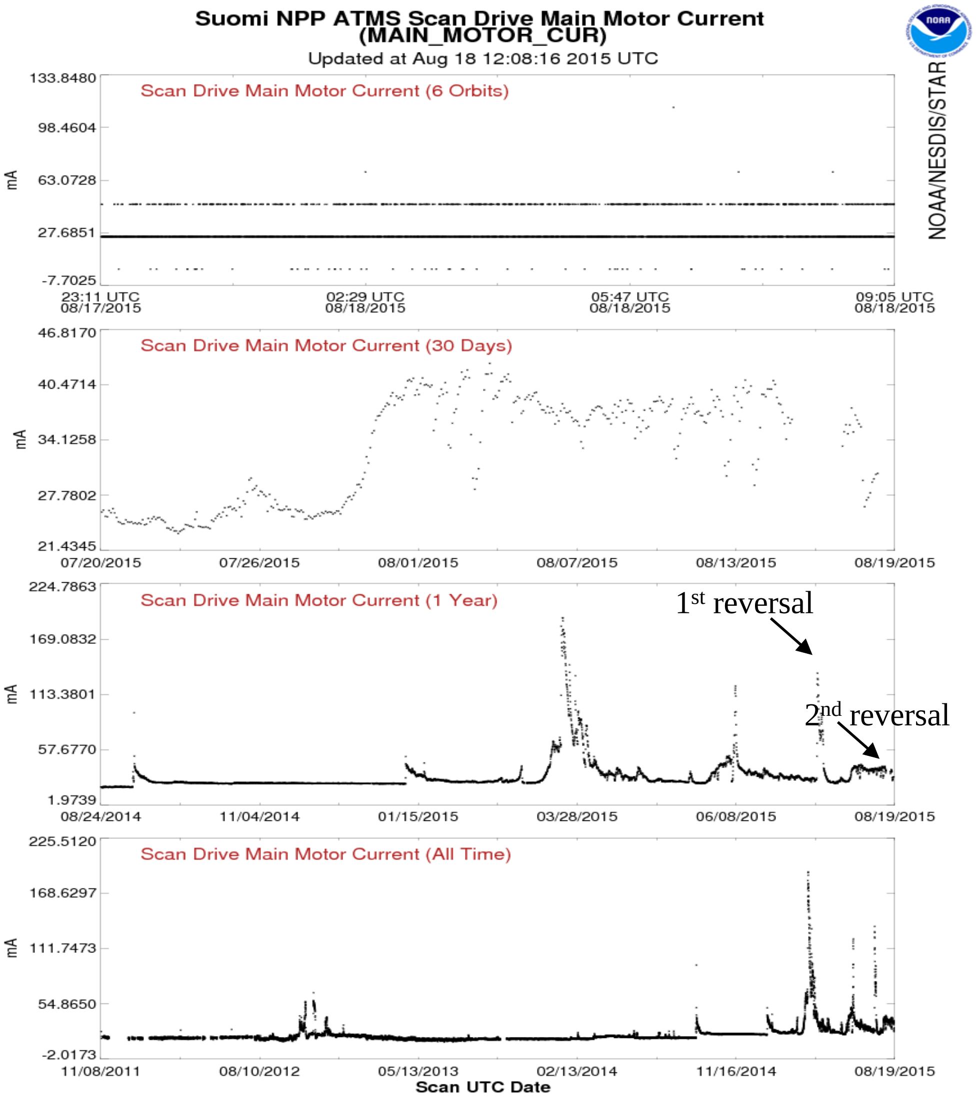
- ATMS SDR Team Members
- ATMS Instrument Overview
- ATMS SNPP Product Overview
- ATMS JPSS-1 Readiness
- Summary and Path Forward

ATMS SDR Team Members

PI Name	Organization	Primary Role and Responsibility
Fuzhong Weng	NOAA	Budget execution, calval task planning, and ATMS SDR sciences and algorithms
Ninghai Sun	ERT	Technical coordination, ATMS SDR processing in ADL, ATMS monitoring, anomaly investigation
Edward Kim	NASA	NASA ATMS instrument scientist, TVAC data, instrument anomaly investigation
Vince Leslie	MIT/LL	Calval support, SDR sciences, PCT/LUT, prelaunch TVAC data analysis, RDR generation
Xiaolei Zou	ESSIC/UMD	Striping analysis and mitigation, RFI analysis, xcal (ATMS vs. AMSU)
Kent Anderson	NGES	NGES ATMS instrument and engineering sciences, TVAC data
Wes Berg	CIRA	Xcal ATMS with GPM microwave imager, other WG band instruemnts
Wael Ibrahim	Raytheon	IDPS operational feedbacks and code implemention
Hu(Tiger) Yang	ESSIC/UMD	ATMS SDR algorithm sciences, full radiance calibration, lunar correction, antenna spill-over

ATMS Instrument Review

- SNPP and JPSS-1 ATMS instruments are identical in channel and spatial resolution. J1 ATMS design life should be longer than SNPP ATMS (e.g. better bearing system)
- SNPP ATMS has been commanded for daily scan reversal to extend the life time performance beyond 5 years. The motor current shows significant drops after the August 17 reversal.
  - The reversal was initiated above 75 degrees latitude North and repeats every 15 orbits after the previous reversal. The 15 orbits will "walk" the longitude across the earth in 14-15 days, with steps about 20 degrees longitude between successive orbits. Each reversal last no more than 1 minute
- Rework of JPSS-1 ATMS is nearly completed. The new TVAC data will be soon released. The sensor will be delivered on November 7
  - Team has evaluated the proposal of TVAC with less scene measurements from 11 to 6.
  - All the software for anlayzing TVAC data is ready at STAR



ATMS Instrument Characterization

Ch	Channel Central Freq.(MHz)	Polarization	Bandwidth Max. (MHz)	Frequency Stability (MHz)	Calibration Accuracy (K)	Nonlinearity Max. (K)	NEΔT (K)	3-dB Bandwidth (deg)	Remarks	Characterization at Nadir
1	23800	QV	270	10	1.0	0.3	0.5	5.2	AMSU-A2	Window-water vapor 100 mm
2	31400	QV	180	10	1.0	0.4	0.6	5.2	AMSU-A2	Window-water vapor 500 mm
3	50300	QH	180	10	0.75	0.4	0.7	2.2	AMSU-A1-2	Window-surface emissivity
4	51760	QH	400	5	0.75	0.4	0.5	2.2		Window-surface emissivity
5	52800	QH	400	5	0.75	0.4	0.5	2.2	AMSU-A1-2	Surface air
6	53596±115	QH	170	5	0.75	0.4	0.5	2.2	AMSU-A1-2	4 km ~ 700 mb
7	54400	QH	400	5	0.75	0.4	0.5	2.2	AMSU-A1-1	9 km ~ 400 mb
8	54940	QH	400	10	0.75	0.4	0.5	2.2	AMSU-A1-1	11 km ~ 250 mb
9	55500	QH	330	10	0.75	0.4	0.5	2.2	AMSU-A1-2	13 km ~ 180 mb
10	57290.344(f_o)	QH	330	0.5	0.75	0.4	0.75	2.2	AMSU-A1-1	17 km ~ 90 mb
11	f_o± 217	QH	78	0.5	0.75	0.4	1.0	2.2	AMSU-A1-1	19 km ~ 50 mb
12	f_o±322.2±48	QH	36	1.2	0.75	0.4	1.0	2.2	AMSU-A1-1	25 km ~ 25 mb
13	f_o±322.2±22	QH	16	1.6	0.75	0.4	1.5	2.2	AMSU-A1-1	29 km ~ 10 mb
14	f_o±322.2±10	QH	8	0.5	0.75	0.4	2.2	2.2	AMSU-A1-1	32 km ~ 6 mb
15	f_o±322.2±4.5	QH	3	0.5	0.75	0.4	3.6	2.2	AMSU-A1-1	37 km ~ 3 mb
16	88200	QV	2000	200	1.0	0.4	0.3	2.2	89000	Window H_2O 150 mm
17	165500	QH	3000	200	1.0	0.4	0.6	1.1	157000	H_2O 18 mm
18	183310±7000	QH	2000	30	1.0	0.4	0.8	1.1	AMSU-B	H_2O 8 mm
19	183310±4500	QH	2000	30	1.0	0.4	0.8	1.1		H_2O 4.5 mm
20	183310±3000	QH	1000	30	1.0	0.4	0.8	1.1	AMSU-B/MHS	H_2O 2.5 mm
21	183310±1800	QH	1000	30	1.0	0.4	0.8	1.1		H_2O 1.2 mm
22	183310±1000	QH	500	30	1.0	0.4	0.9	1.1	AMSU-B/MHS	H_2O 0.5 mm

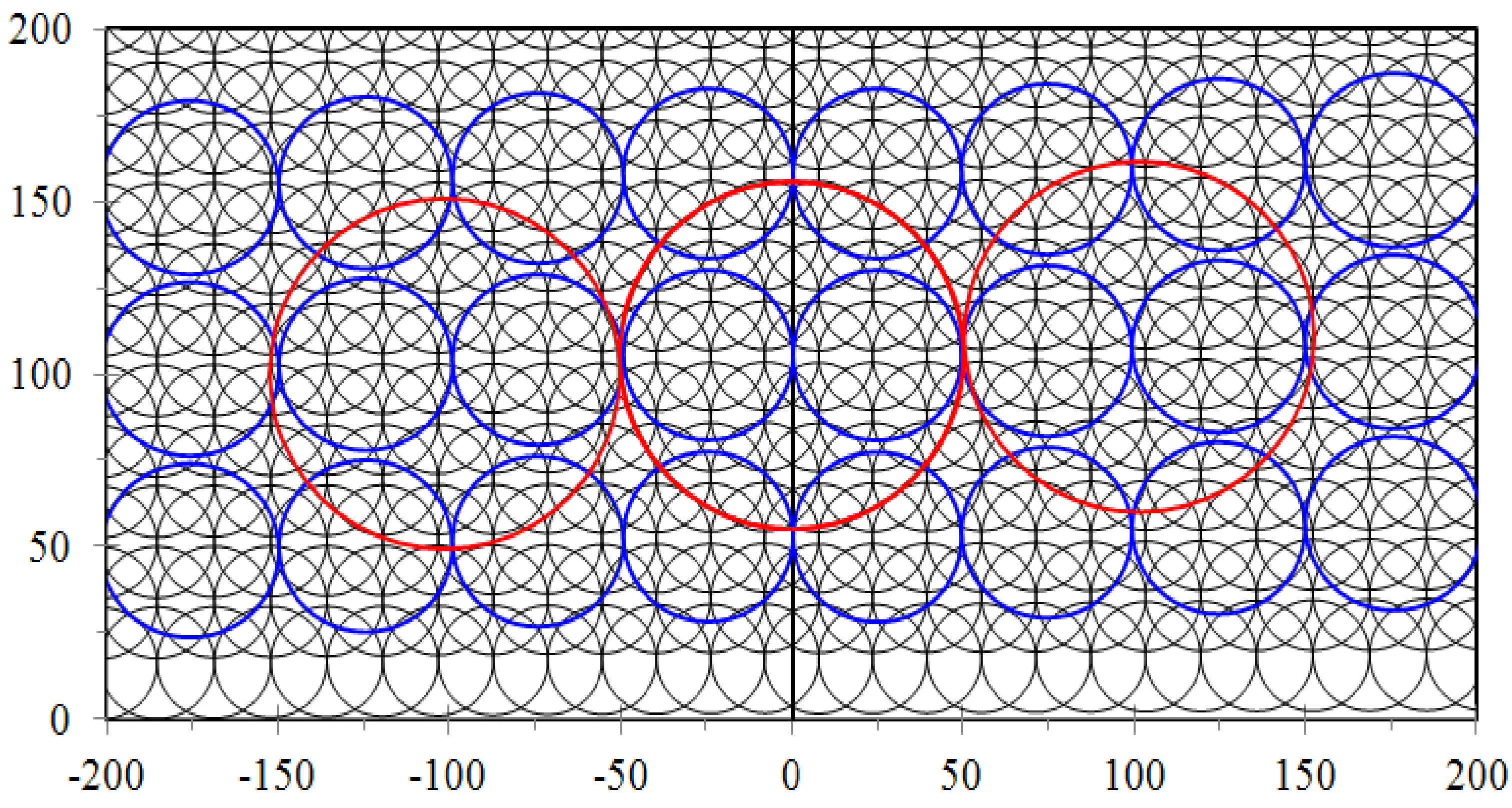
MSU			AMSU/MHS			ATMS		
Ch	GHz	Pol	Ch	GHz	Pol	Ch	GHz	Pol
			1	23.8	QV	1	23.8	QV
			2	31.399	QV	2	31.4	QV
1	50.299	QV	3	50.299	QV	3	50.3	QH
						4	51.76	QH
			4	52.8	QV	5	52.8	QH
2	53.74	QH	5	53.595 ± 0.115	QH	6	53.596 ± 0.115	QH
			6	54.4	QH	7	54.4	QH
3	54.96	QH	7	54.94	QV	8	54.94	QH
			8	55.5	QH	9	55.5	QH
4	57.95	QH	9	fo = 57.29	QH	10	fo = 57.29	QH
			10	fo ± 0.217	QH	11	fo±0.3222±0.217	QH
			11	fo±0.3222±0.048	QH	12	fo± 0.3222±0.048	QH
			12	fo ±0.3222±0.022	QH	13	fo±0.3222±0.022	QH
			13	fo± 0.3222±0.010	QH	14	fo±0.3222 ±0.010	QH
			14	fo±0.3222±0.0045	QH	15	fo± 0.3222±0.0045	QH
			15	89.0	QV			
			16	89.0	QV	16	88.2	QV
			17	157.0	QV	17	165.5	QH
						18	183.31 ± 7	QH
						19	183.31 ± 4.5	QH
			19	183.31 ± 3	QH	20	183.31 ± 3	QH
			20	191.31	QV	21	183.31 ± 1.8	QH
			18	183.31 ± 1	QH	22	183.31 ± 1	QH

- Exact match to AMSU/MHS
- Only Polarization different
- Unique Passband
- Unique Passband, and Pol. different from closest AMSU/MHS channels

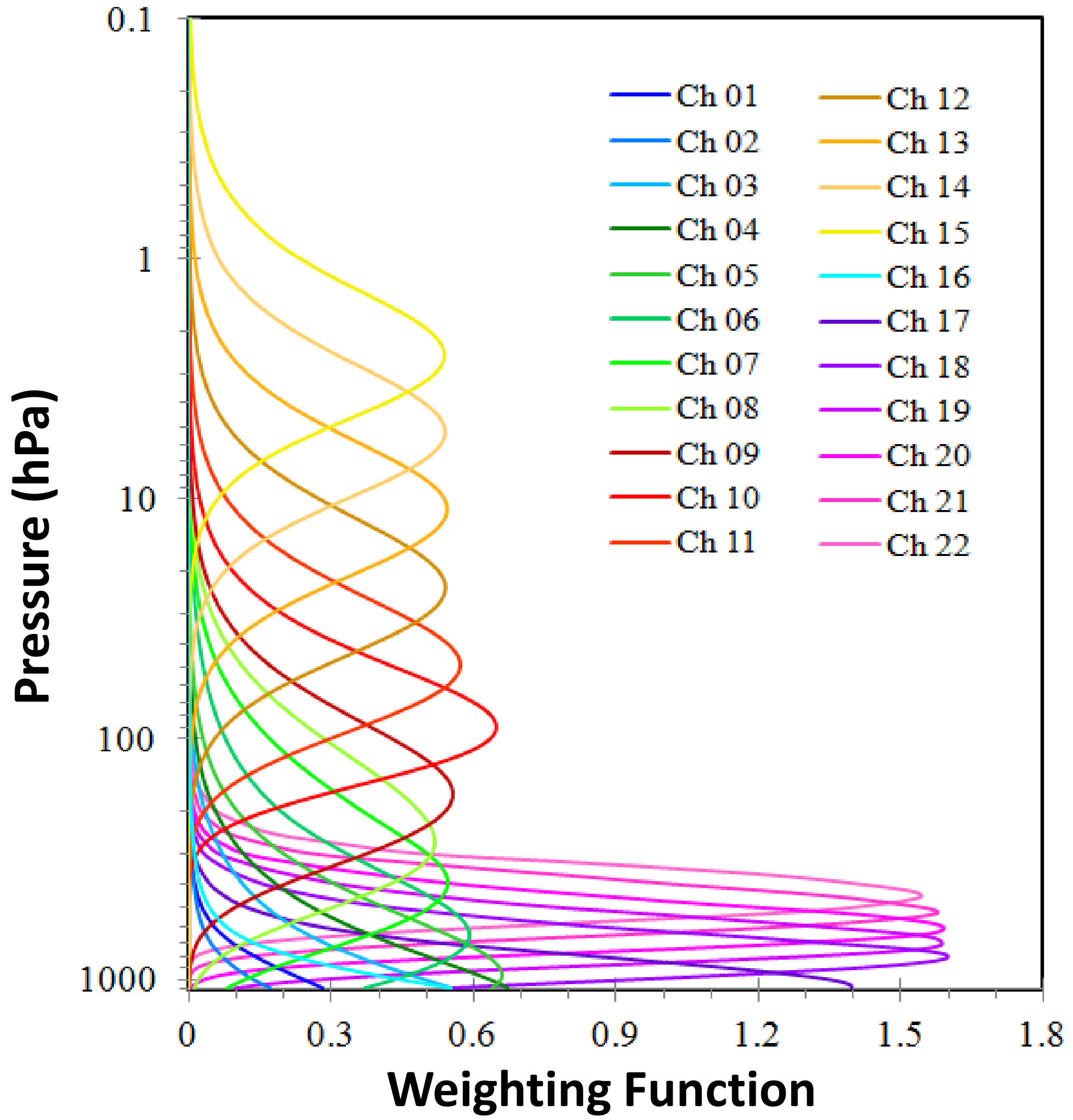
Microwave Sounding Instruments from MSU to AMSU/MHS to ATMS

ATMS Field of View Size for the beam width of 2.2° – black line

ATMS Resample to the Field of View Size for the beam width of 3.3°- blue line



ATMS Channel Weighting Functions



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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

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4. Developed a physically based model for correcting the radiation from ATMS reflector emission contributed to the earth scene brightness temperature

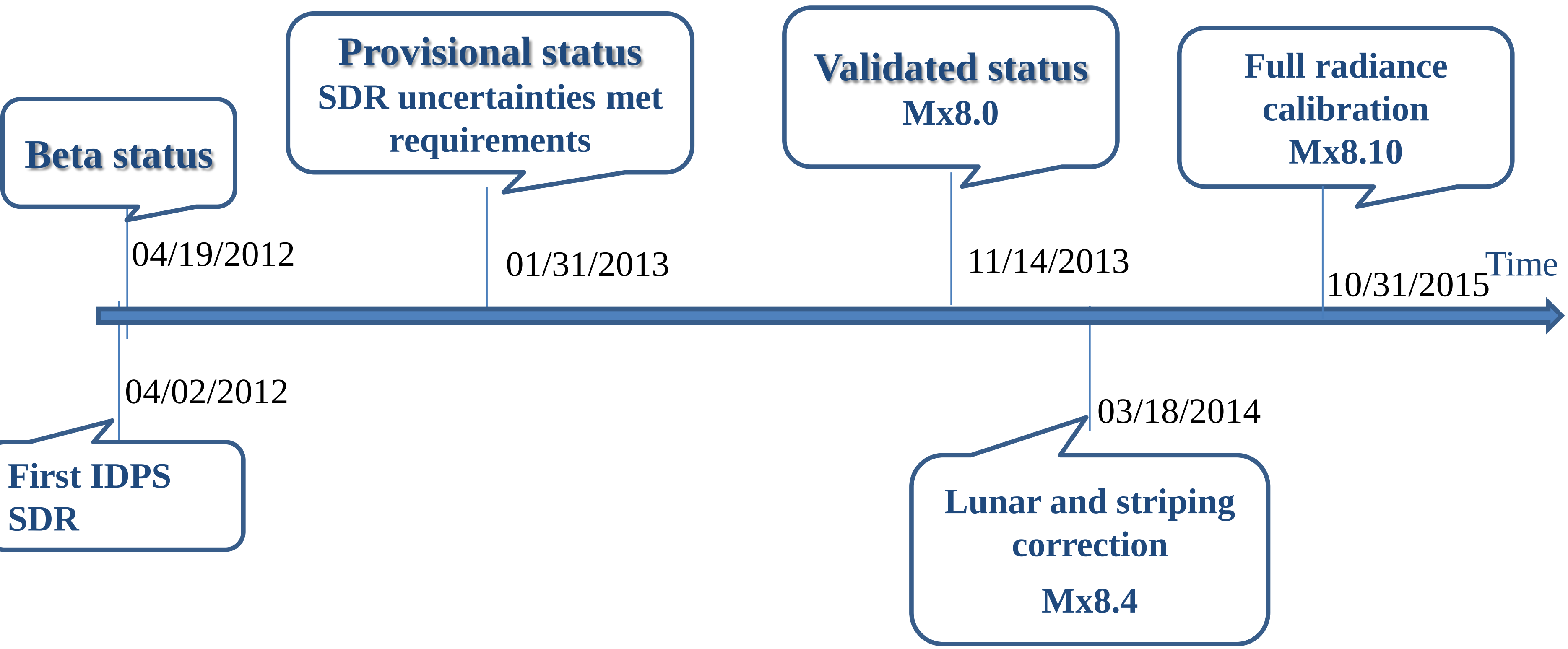
5. Updated ATMS processing coefficient tables (e.g. nonlinearity coefficients, threshold for calibration counts)

S-NPP ATMS On-orbit 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

Note: On-orbit calibration accuracy for ATMS antenna brightness temperatures at upper air sounding channels is derived from the forward model (*see Zou, X., Lin Lin and F. Weng, 2013: Absolute Calibration of ATMS Upper Level Temperature Sounding Channels Using GPS RO Observations , IEEE Trans. Geosci. and Remote Sens., 10.1109/TGRS.2013.2250981*)

SNPP ATMS SDR CalVal Major Milestones

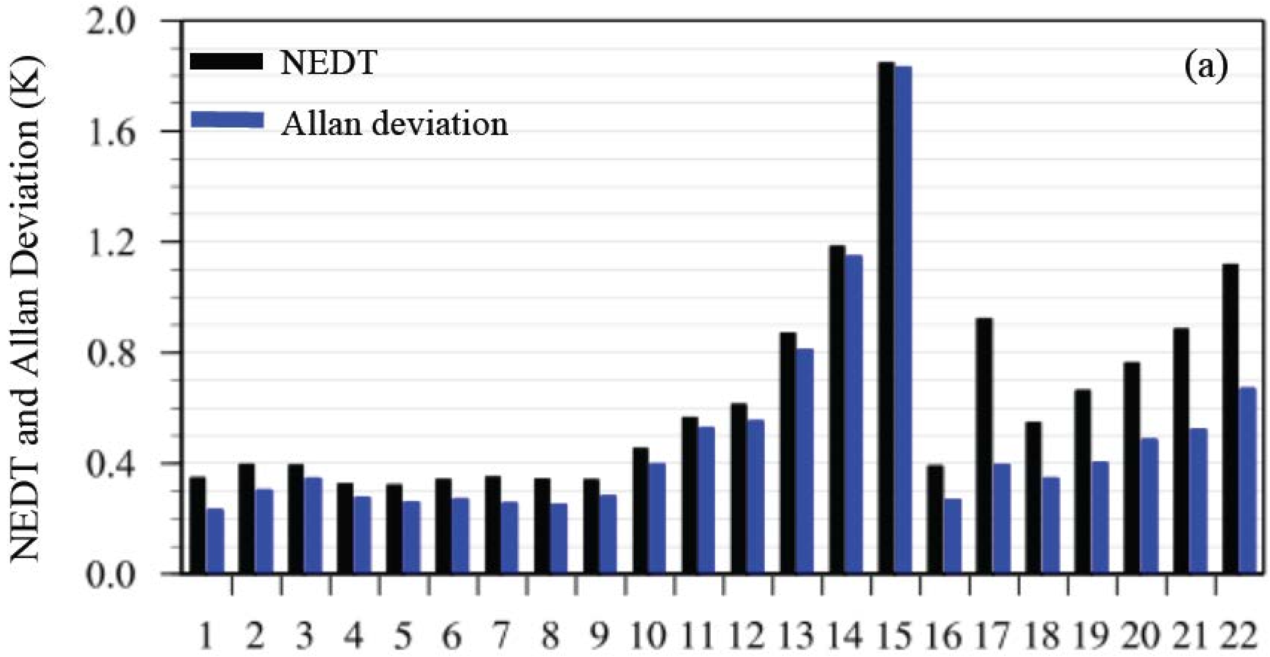


ATMS SDR Science Advances

- Radiometric Calibration
  - ✓ *Non-linearity correction*
  - ✓ *Calibration accuracy*
  - ✓ *Lunar intrusion correction*
- Noise Characterization
  - ✓ *Standard deviation*
  - ✓ *Allan deviation*
- SDR Algorithm
  - ✓ *TDR to SDR conversion*
  - ✓ *Resampling SDR through Back-Gilbert theory*
  - ✓ *Xcal with respect to AMSU for climate applications*
  - ✓ *Striping and characterization*
- Advanced Developments
  - ✓ *TDR correction from antenna emission*
  - ✓ *Full radiance calibration*

ATMS Noise Equivalent Temperature (NEDT)

- Define SI-traceable noise evaluation algorithm using Allan deviation method*
- Channel noise by Allan deviation based algorithm is lower than that provided by heritage standard deviation based algorithm
- Annual oscillation of channel noise is removed
- Long term trending of S-NPP ATMS channel noise by Allan deviation algorithm started to be provided in STAR ICVS-LTM from June 17, 2015

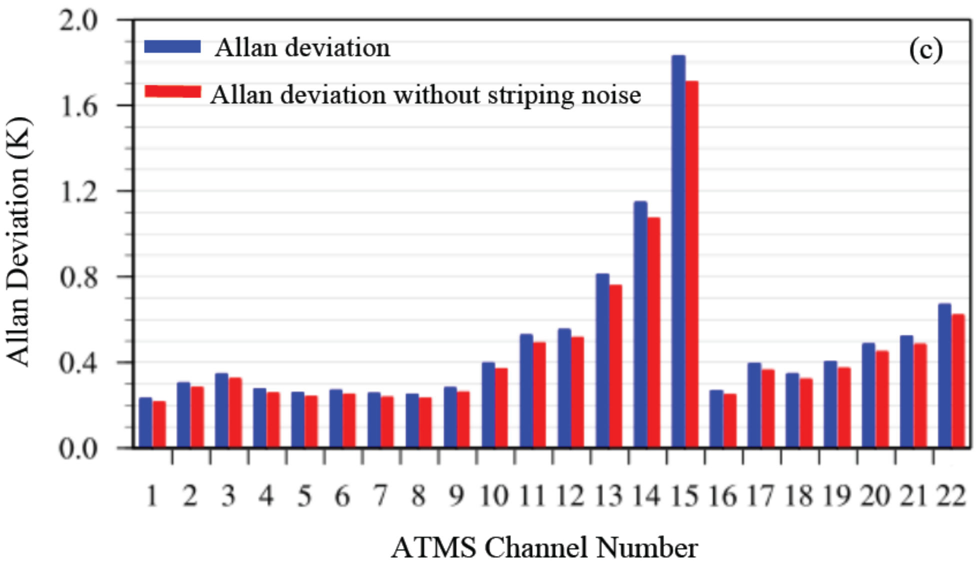


Tian, M., X. Zou and F. Weng, "*Use of Allan Deviation for Characterizing Satellite Microwave Sounders Noise Equivalent Differential Temperature (NEDT)*", *IEEE Geosci. Remote Sens. Lett., (Accepted).*

Impacts of ATMS Striping Effects on Channel Noise Characterization

Channel	NEDT (K)		Allan Deviation (K)	
	Before	After	Before	After
1	0.3490	0.3256	0.2324	0.2171
2	0.3977	0.3593	0.3052	0.2843
3	0.3945	0.3464	0.3473	0.3248
4	0.3279	0.2883	0.2772	0.2581
5	0.3232	0.2871	0.2603	0.2422
6	0.3433	0.3069	0.2714	0.2526
7	0.3518	0.3201	0.2559	0.2382
8	0.3453	0.3138	0.2518	0.2345
9	0.3421	0.3046	0.2816	0.2628
10	0.4542	0.3968	0.3981	0.3716
11	0.5675	0.4900	0.5277	0.4922
12	0.6140	0.5365	0.5534	0.5174
13	0.8718	0.7527	0.8123	0.7593
14	1.1849	1.0179	1.1479	1.0727
15	1.8476	1.5651	1.8319	1.7110
16	0.3914	0.3578	0.2692	0.2501
17	0.9237	0.8865	0.3954	0.3650
18	0.5496	0.5103	0.3479	0.3230
19	0.6637	0.6149	0.4041	0.3740
20	0.7636	0.7039	0.4859	0.4508
21	0.8862	0.8202	0.5239	0.4848
22	1.1194	1.0337	0.6712	0.6217

- Channel noise reduced after applying striping mitigation algorithm
- 45-day de-striping BUFR data generated for NWP impact study



Qin, Z., X. Zou and F. Weng, 2013: Analysis of ATMS and AMSU striping noise from their earth scene observations. J. Geophy. Res., 118, 13,214-13,229, doi: 10.1002/ 2013JD020399

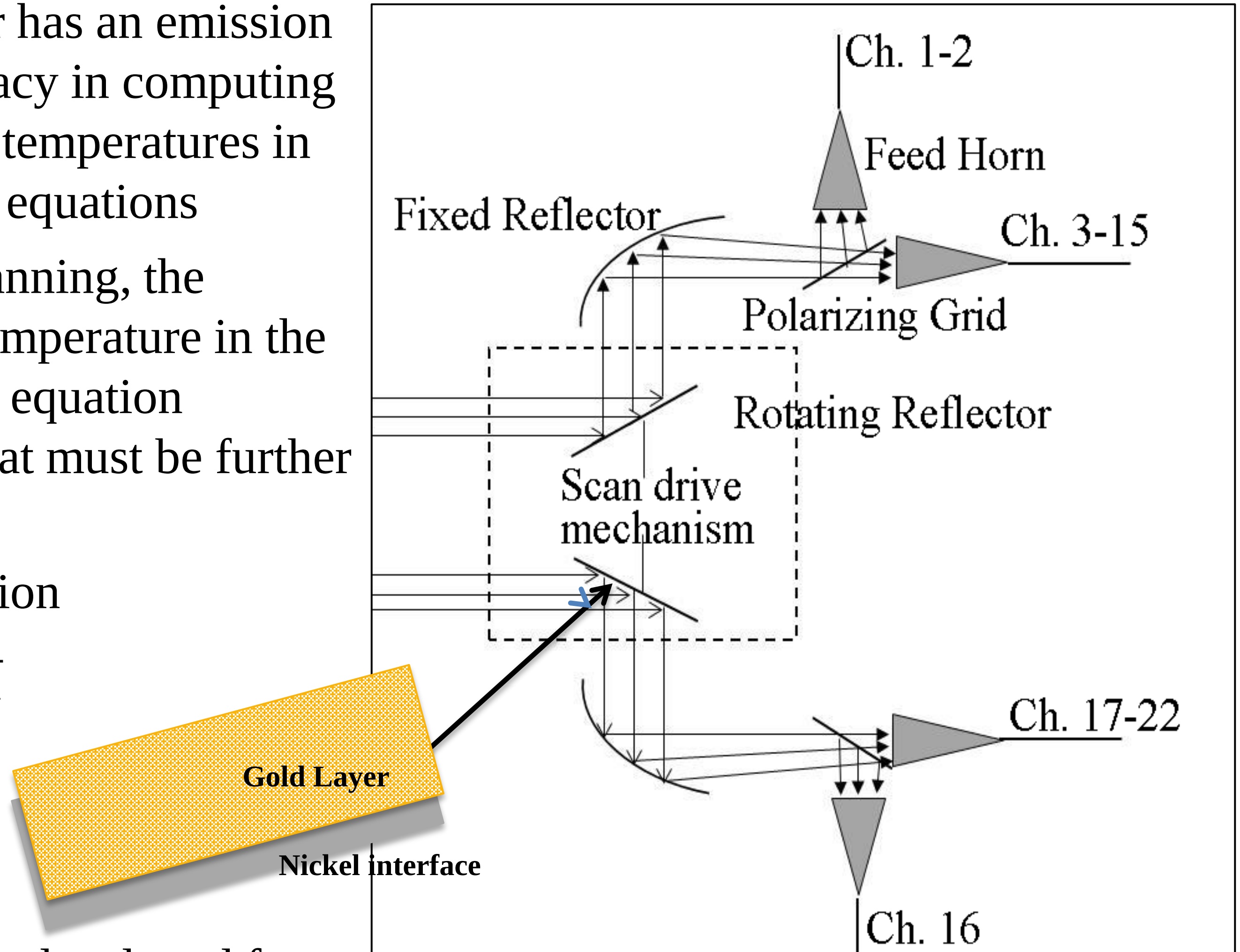
Ma, Y. and X. Zou, 2015: Optimal filters for striping noise mitigation within ATMS calibration counts. IEEE Trans. Geo. Remote Sensing, (in revision)

ATMS Reflector Emission and Its Effects on TDR

- Flat rotating reflector has an emission and affects the accuracy in computing the calibration target temperatures in two point calibration equations
- In the earth scene scanning, the antenna brightness temperature in the two-point calibration equation contains emission that must be further corrected
- Hagen-Rubens equation

$$\varepsilon_N = \sqrt{16\pi e_0 f / \sigma}$$

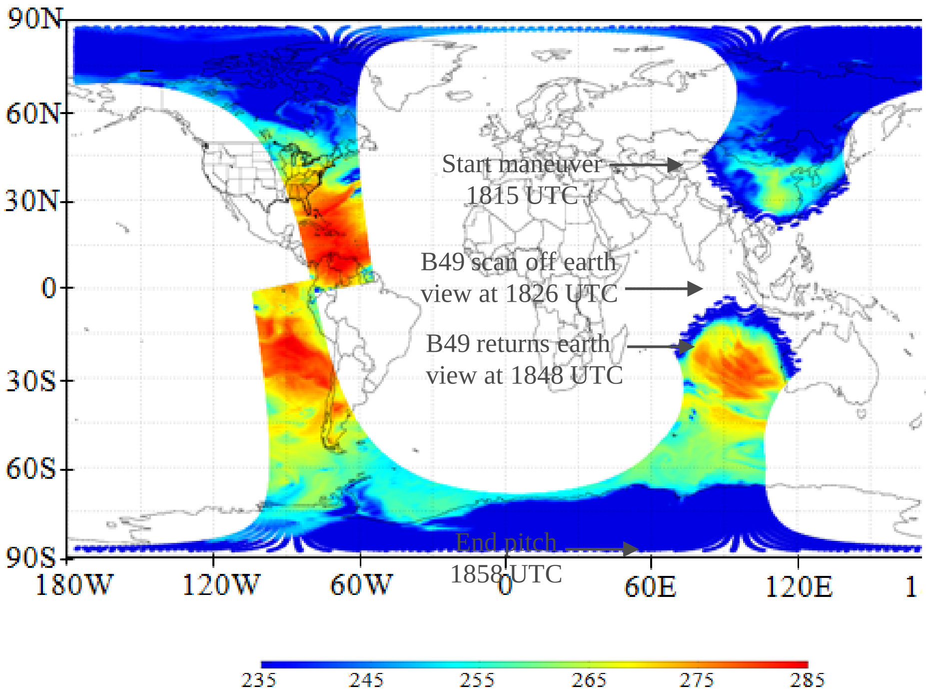
0.0025 to 0.0065



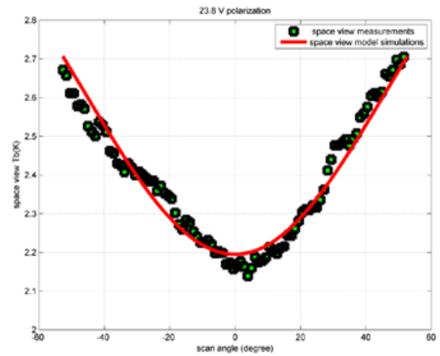
- An algorithm is being developed for ATMS TDR correction

ATMS TDR Scan Bias from Pitch-Over Maneuver Data

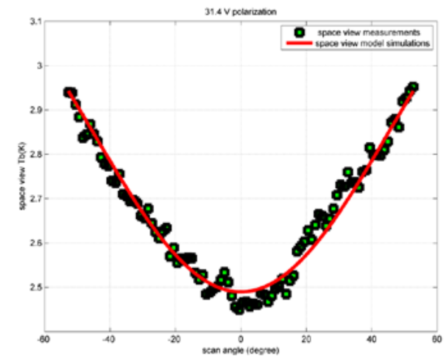
ATMS TDR at Ch18 on February 20, 2012



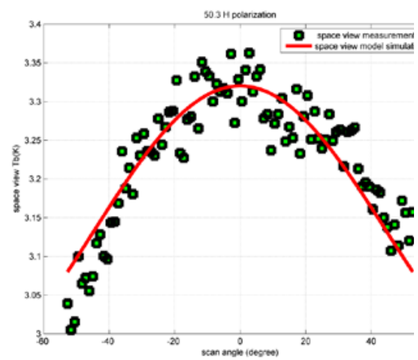
Channel 1



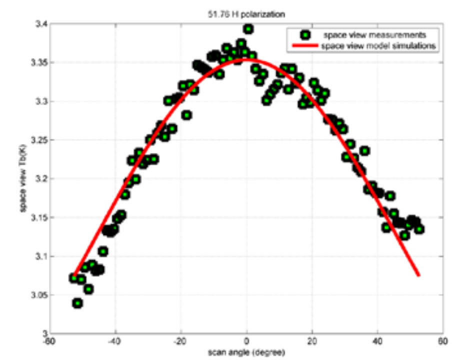
Channel 2



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

Effects of ATMS Plane Reflector Emission on Brightness Temperature

For Quasi-V (TDR) :

$$T_{b,r}^{Qv} = T_b^{Qv} + \varepsilon_h (T_r - T_b^h) + [\varepsilon_v (T_r - T_b^v) - \varepsilon_h (T_r - T_b^h)] \sin^2 \theta$$

For Quasi-H (TDR)

$$T_{b,r}^{Qh} = T_b^{Qh} + \varepsilon_h (T_r - T_b^h) + [\varepsilon_v (T_r - T_b^v) - \varepsilon_h (T_r - T_b^h)] \cos^2 \theta$$

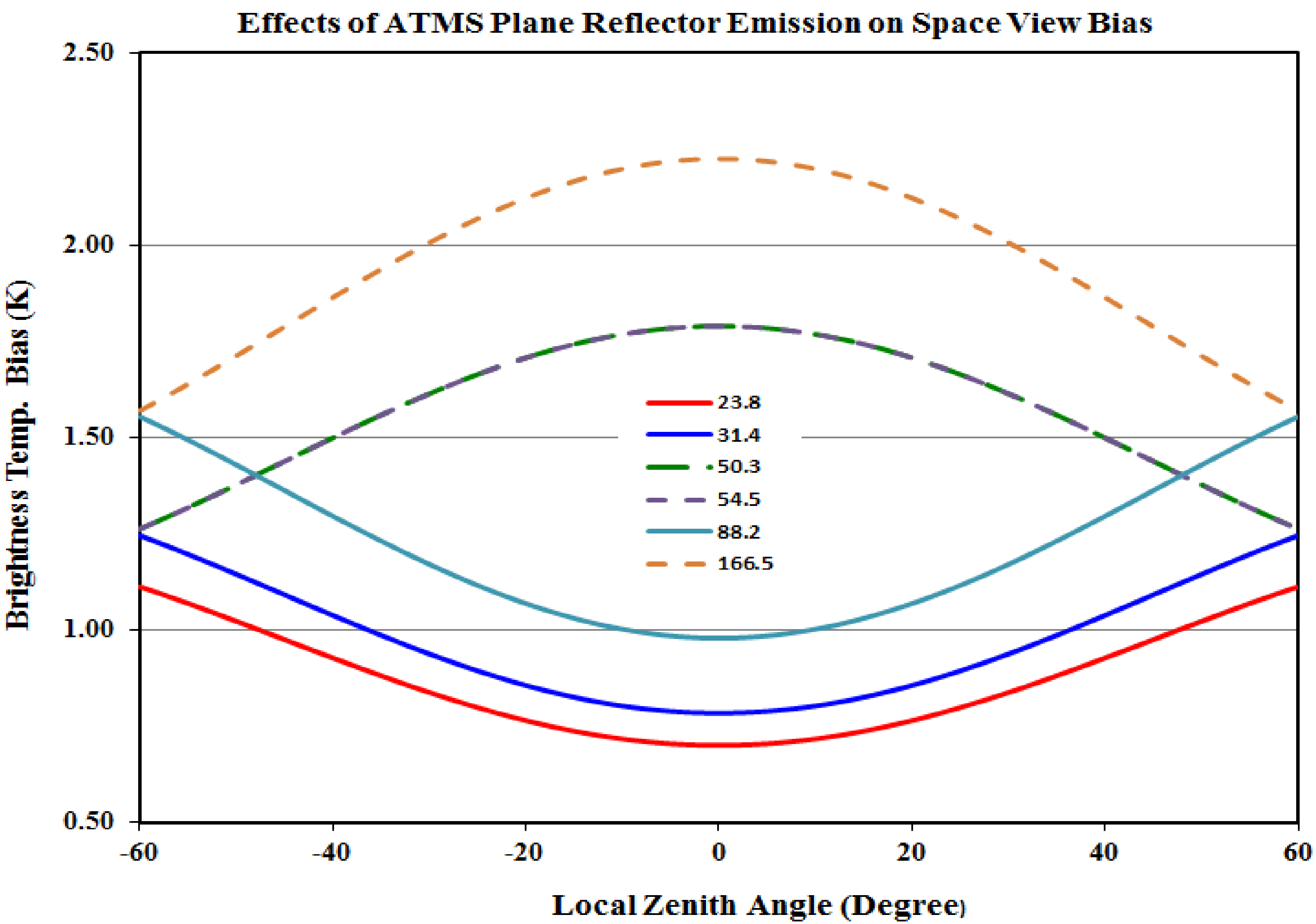
The second and third terms are the biases related to the reflector emission

At an incident angle of 45 degree to the plane reflector, the Fresnel equation becomes

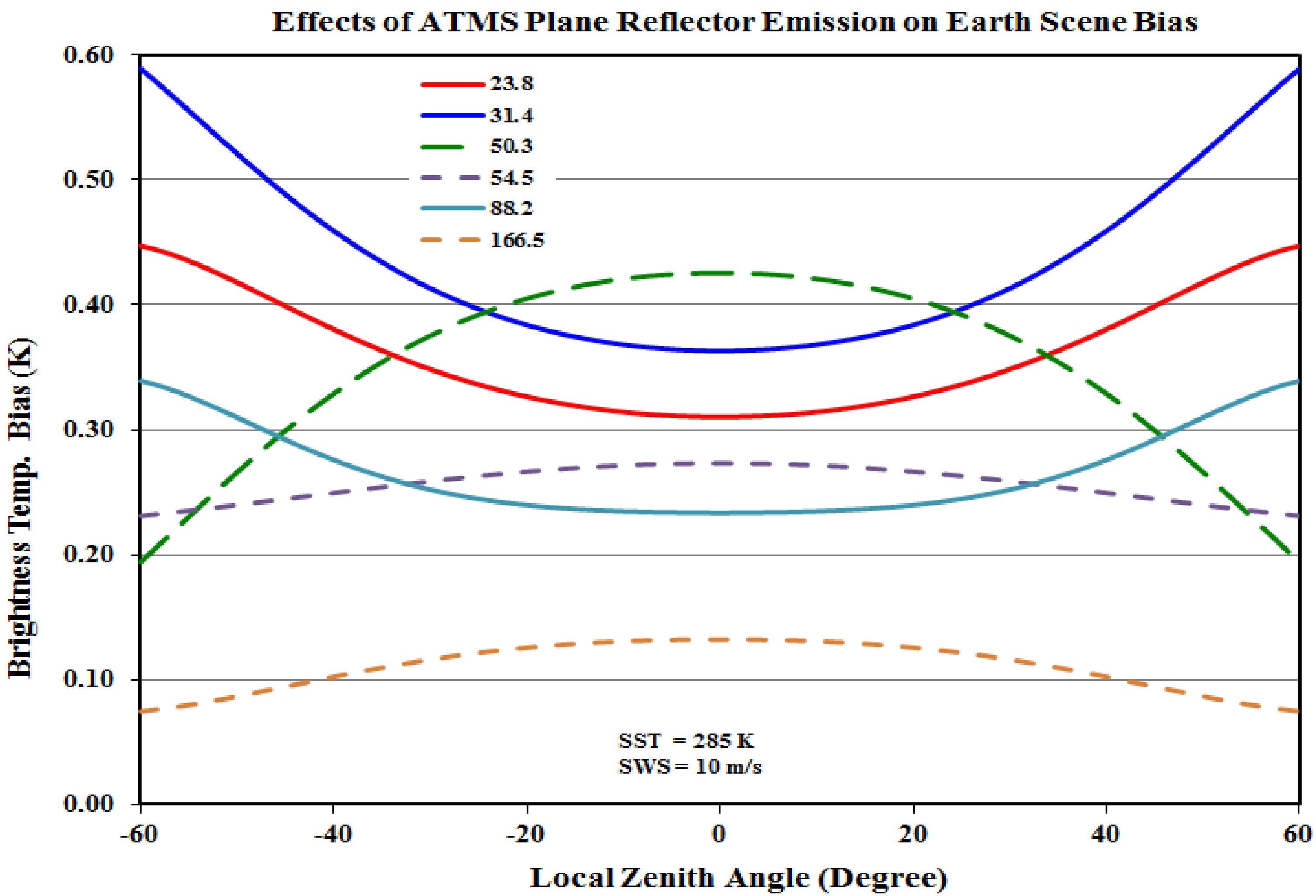
$$\varepsilon_v = 2\varepsilon_h - \varepsilon_h^2$$

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

The Reflector-Emission Bias for Space View



The Reflector-Emission Bias for Earth Scenes



ATMS Full Radiance Calibration (FRC) Tested in ADL Environment

Package:

ADL 4.2 with MX 8.8

Data Ingested:

6 orbits S-NPP RDR data (17829 – 17834 from GRAVITE) on April 7, 2015

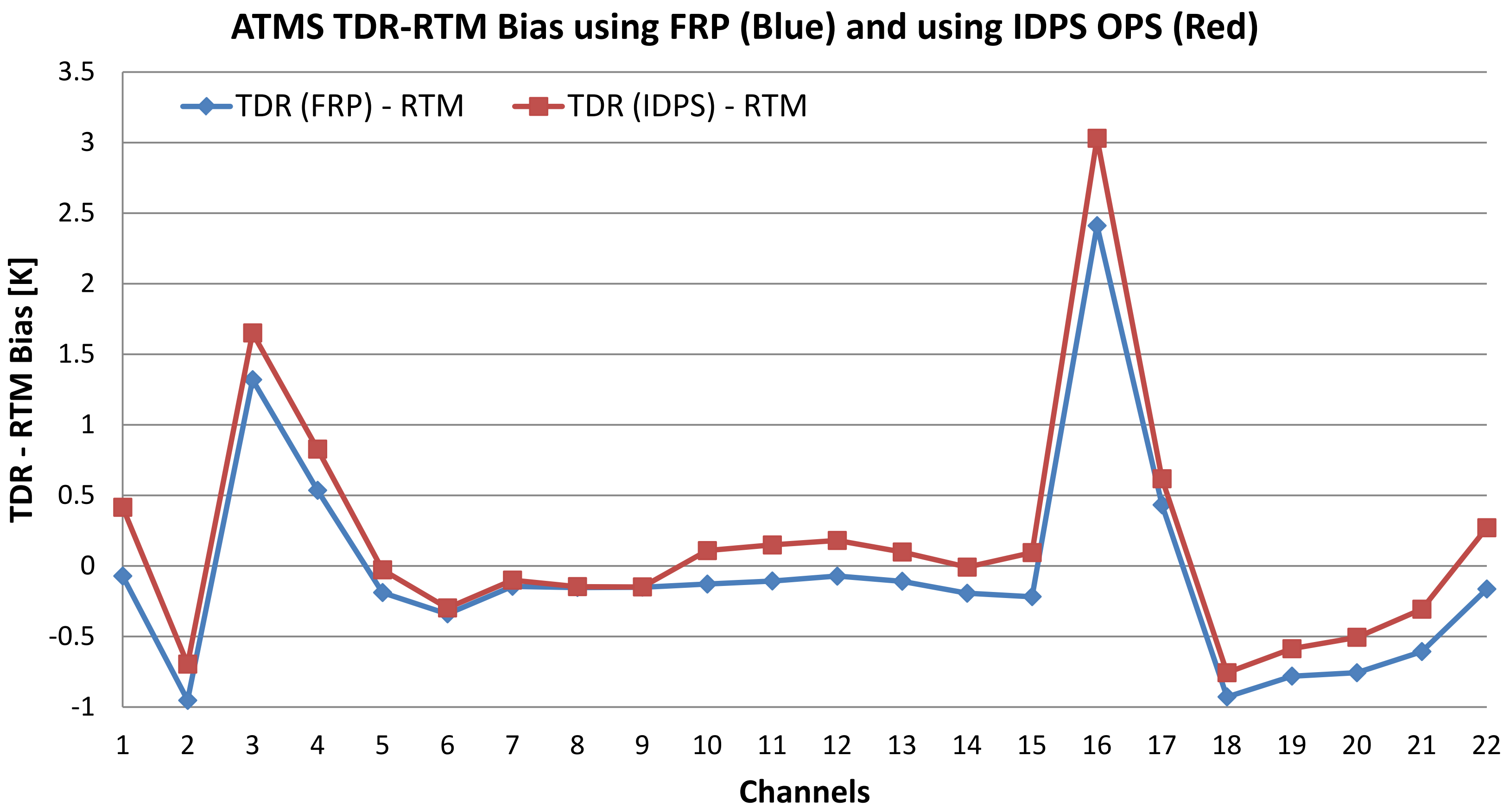
Output Data:

- TDR/SDR/GEO using full radiance calibration (FRC) algorithm

Analysis Provided:

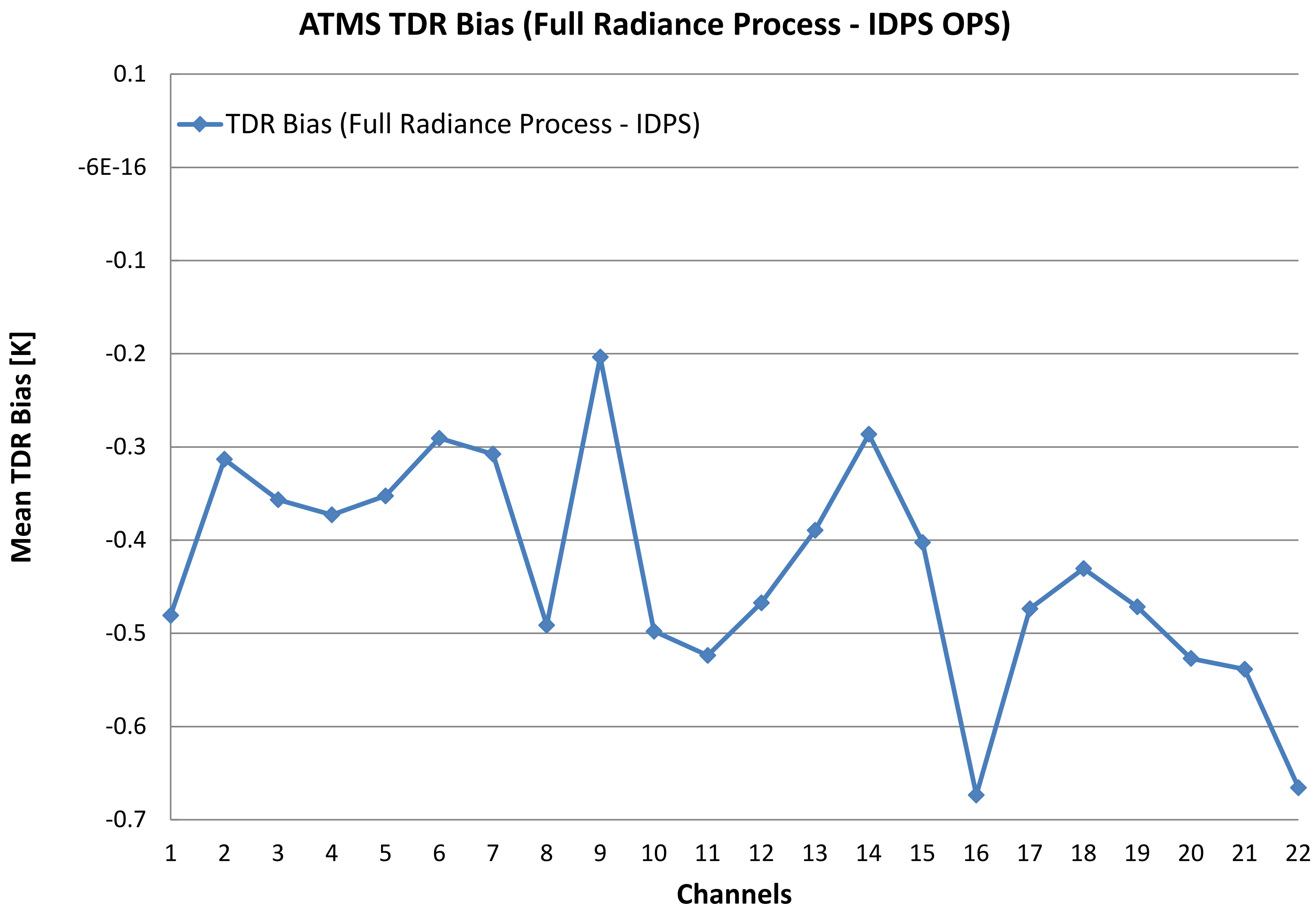
- Global mean TDR-RTM bias (ADL-FRC vs IDPS) by channels based on 6 orbits data
- Global mean TDR bias (ADL-FPC vs IDPS) by channels based on 6 orbits data

Global Mean TDR-RTM Bias



ATMS full radiance calibration (FRC) performs two corrections: 1) replacing the brightness temperatures (R-J approximation) with Plank function radiance and 2) reversing the sign in nonlinearity term. WG bands are affected by two corrections where the rest bands are mainly affected by the nonlinearity term.

Global Mean TDR Bias



JPSS-1 ATMS SDR Algorithm Readiness

Radiance calibration algorithm

– A full radiance calibration is adopted as the standard calibration method for both the two-point linear calibration and non-linear correction

Nonlinearity correction algorithm consistent with NOAA/METOP AMSU-A/MHS

– Maximum nonlinearity was expressed as a function of μ parameter

– Nonlinear parameter was expressed as a function of instrument temperature

Reflector emissivity correction

– Physical model for antenna reflector emissivity correction

Lunar intrusion correction algorithm

– LI is modeled as a function of antenna response, solid angle of the Moon and the microwave emission from the Moon

– The new correction model with best fitted parameters from ATMS observations can effectively reduce the calibration error due to lunar contamination on cold counts

De-stripping algorithm

– Based on power spectrum analysis, stripping index and de-striping algorithm was developed to reduce the flicker noise in calibration data and TDR products

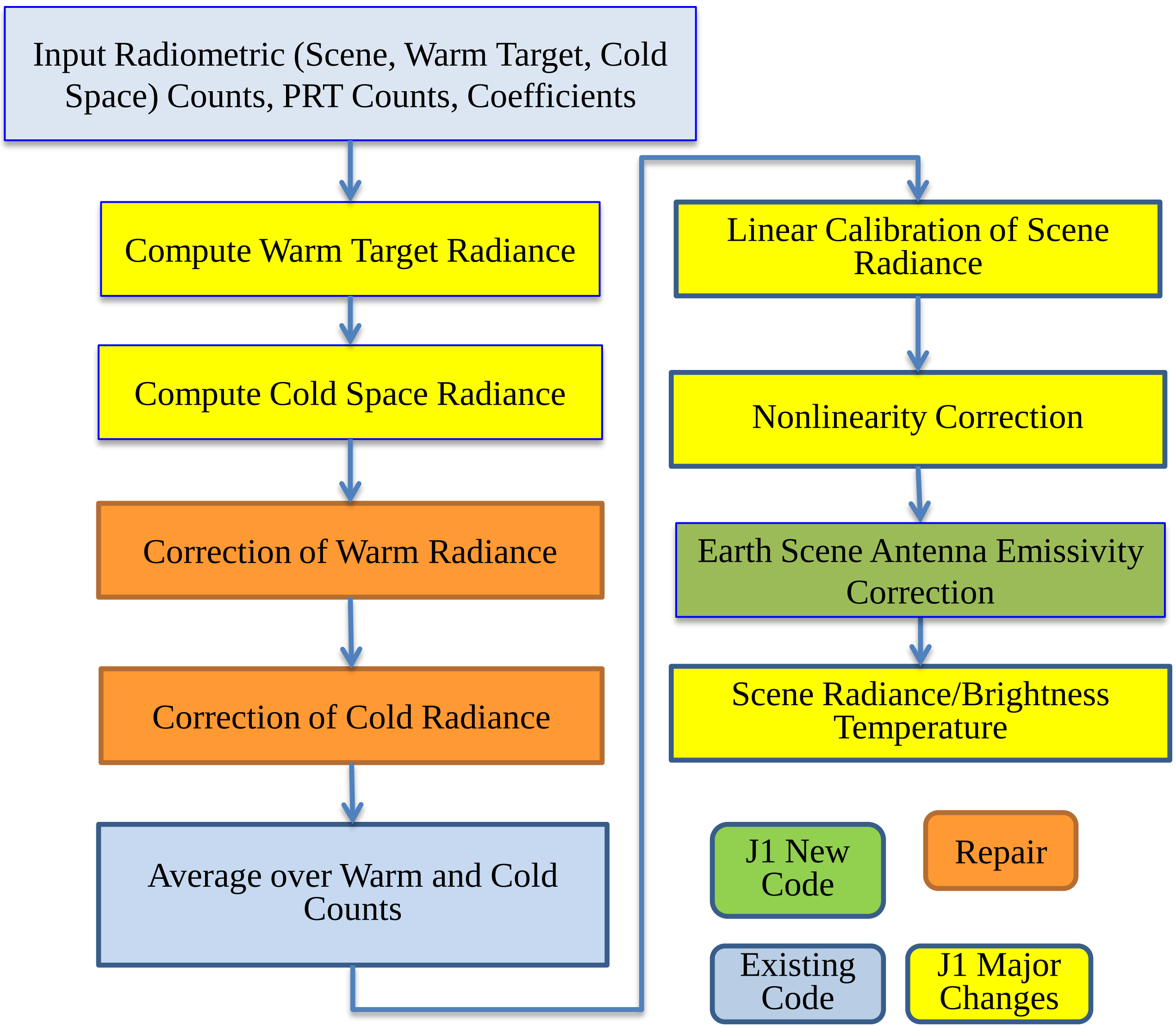
– The flicker noise and correlation on the JPSS1 ATMS is much lower than S-NPP ATMS

TDR Remapping algorithm

– B-G algorithm was developed to explore the advantage of ATMS oversampling feature

– By using B-G algorithm, remapping coefficients were generated offline, to remap ATMS observation to different FOV size

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-1 Readiness

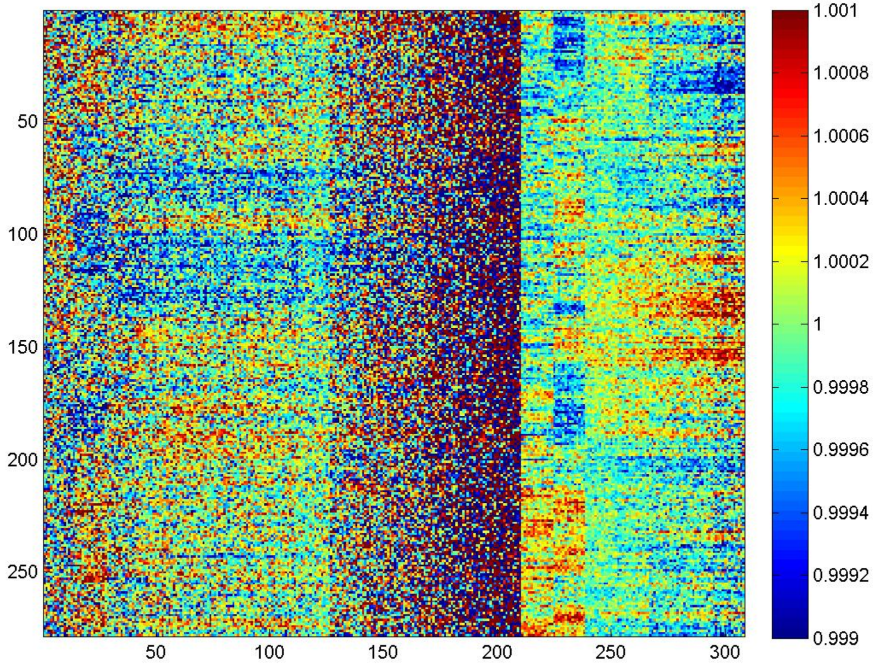
- J1 Cal/Val Overview
  - Beta Maturity: L+1 Month
  - Provisional Maturity: L+3 Months
  - Validated Maturity: L+12 Months
  - Pre-Launch Calibration/Validation Plans
    - Analyze J1 ATMS TVAC regression test data
    - Derive coefficients for SDR algorithm and deliver JPSS-1 ATMS SDR PCT
    - Test JPSS-1 proxy data for SDR algorithm functional testing
    - Use JPSS-1 proxy data (from TVAC) to verify delivered PCT
    - Analyze spectral response function datasets
    - Verify instrument mounting matrix for geolocation accuracy assessment
  - Post-Launch Calibration/Validation Plans
    - Conduct 30+ post-launch cal/val activities following JPSS ATMS Cal/Val plan

JPSS-1 ATMS SDR Algorithm Tests with Proxy Data

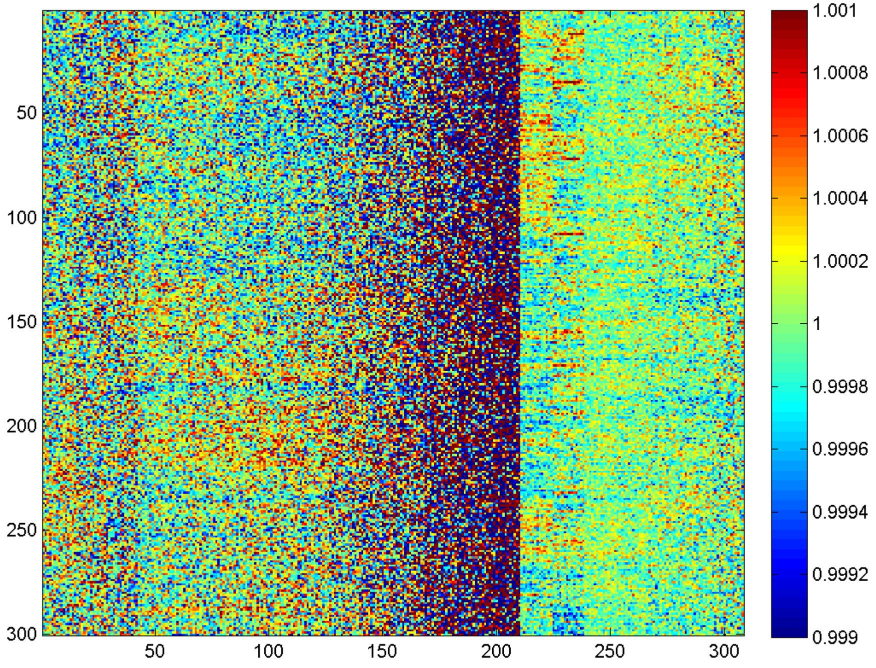
- **Proxy data**
  - JPSS-1 ATMS RDR from S-NPP mission data
  - JPSS-1 ATMS RDR from JPSS-1 ATMS TVAC data
  - JPSS-1 ATMS spacecraft level RDR
- **Test Results**
  - Test results using JPSS-1 ATMS RDR from S-NPP mission data have been compared with those from SNPP.
    - IDPS code was updated to handle JPSS-1 granule ID (J01)
    - Geolocation is not accurate. Updated data will be delivered for additional testing.
  - JPSS-1 ATMS PCT will be verified using RDR from JPSS-1 ATMS TVAC data
  - Validation system readiness:
    - The additional validation capabilities is currently being developed at STAR and will be ready well before J1 launch.

JPSS-1 ATMS TVAC Data Analysis Prior to Rework (1/2)

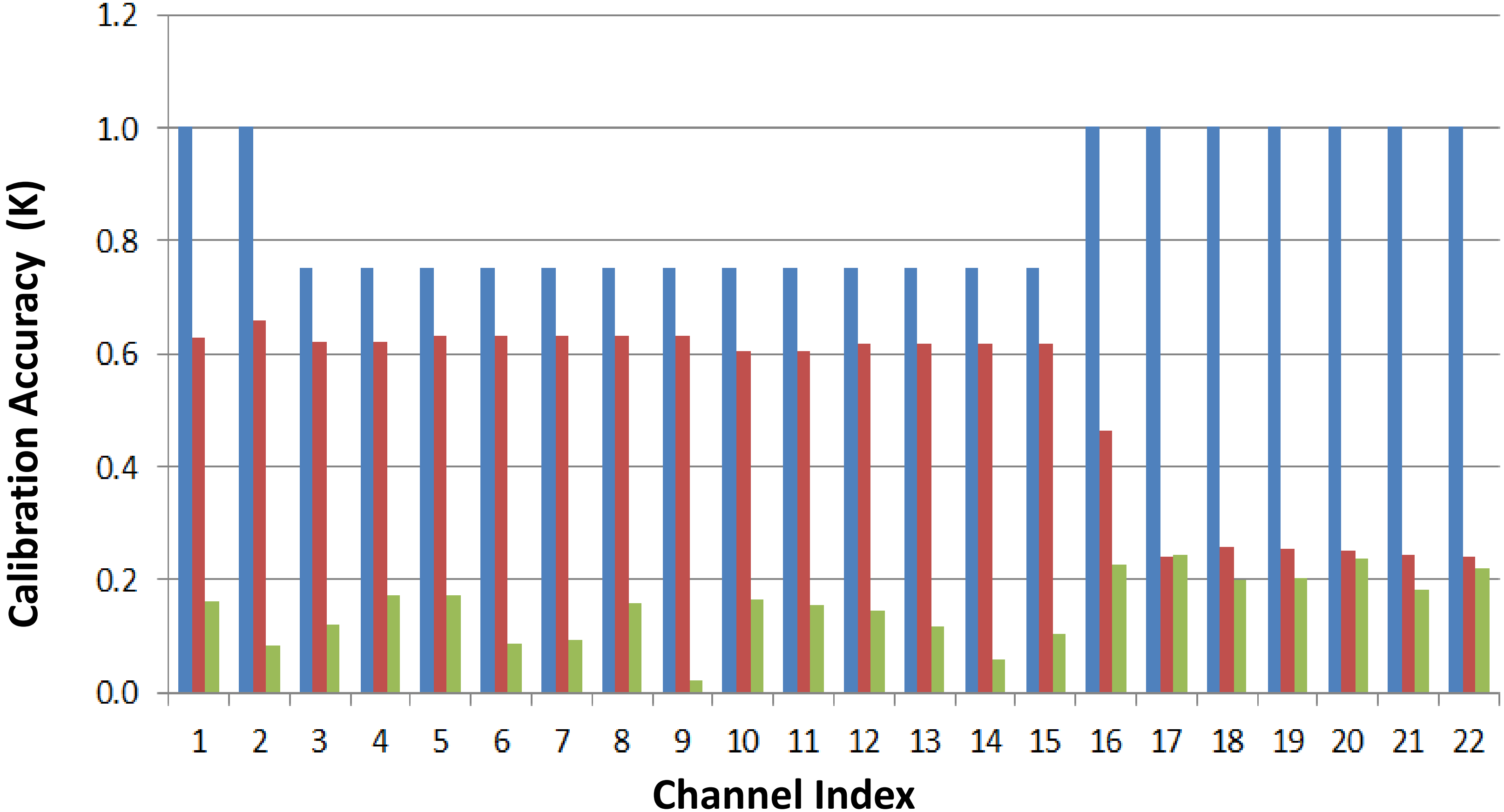
SNPP TVAC Data (RC1 230K)



J-1 TVAC Data (1/10/14)



JPSS-1 ATMS TVAC Data Analysis Prior to Rework (2/2)



Red – Calibration accuracy from nominal Thermal Vacuum (TVAC) data, Green – values obtained from the best TVAC data and Blue – specification

Summary

- JPSS-1 ATMS CalVal Plan has been developed, including task networks, role and responsibility, caval methodology, expected outcomes
- ATMS on-orbit NEDT is well characterized in new Allan deviation method. The performance meets specification
- ATMS house-keeping parameters are being monitored through ICVS to support NASA commanding operations of scan reversal.
- Antenna reflector emission is fully characterized and the algorithm for correcting the emission from the reflector is ready for implementation
- All the calval sciences are well documented and published through peer-reviewed process

Path Forward

- For Suomi NPP ATMS, we will continue refining the SDR processing system
  - Begin ATMS mission-cycle reprocessing
  - Closely monitor S-NPP ATMS health status after implementing scan drive daily reversal
  - Improve radiative transfer (RT) model for more accurate simulation of window channels and cloud radiance measurements for validation
  - Refine SDR algorithm modules, including lunar correction, antenna emission, TDR to SDR conversion at window channels, and de-striping algorithm
- For JPSS -1 ATMS, we continue supporting pre-launch testing, instrument characterization and calibration data development
  - Complete the analyze J1 ATMS TVAC regression data after rework
  - Characterize the ATMS side lobe and cross-pol from antenna pattern data
  - Study the impacts of J1 spectral response function on forward model
- For the JPSS polar follow-on mission
  - Support the waiver studies in future instruments
  - Support the new instrumentation

CrIS SDR Overview

Yong Han

CrIS SDR Science Team

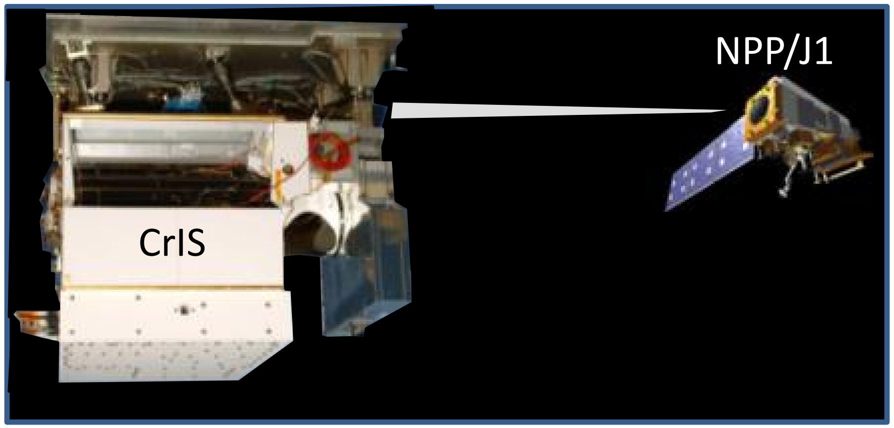
STAR JPSS Science Team Annual Meeting
August 24-28, 2015

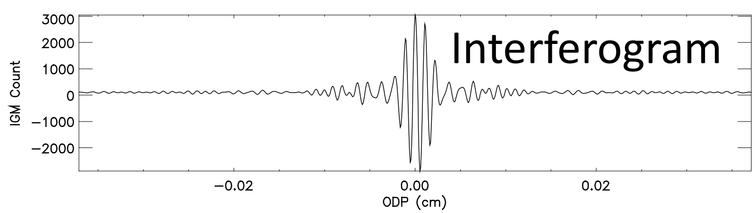
Outline

- SNPP/JPSS-1 Instrument and SDR Spec Overview
- Team Members
- S-NPP Product Overview
- JPSS-1 Readiness
- Summary
- Path Forward

CrIS System

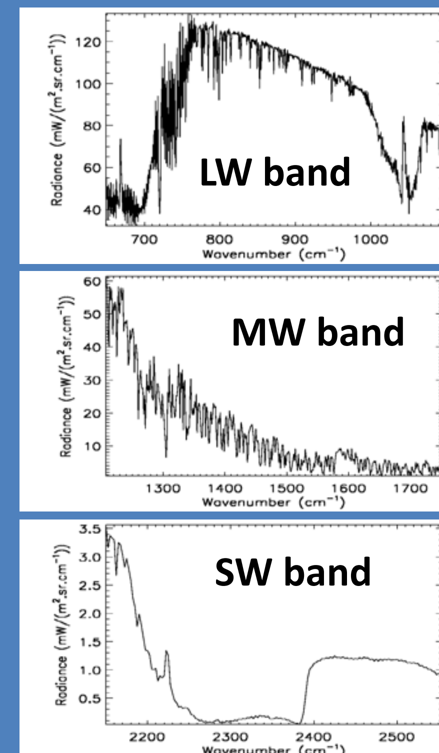
CrIS instrument provides interferograms & calibration data





SDR Product

Radiance Spectra



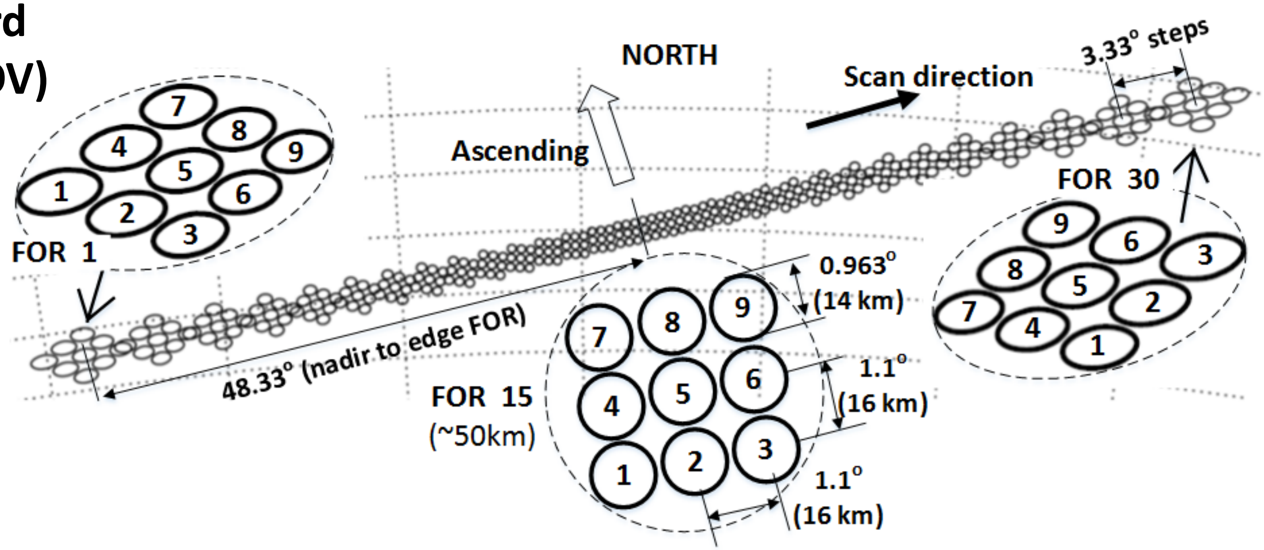
Science RDRs

SDR product

Ground SDR Processing

S-NPP/JPSS1 CrIS SDR Specifications

CrIS scan, field-of-regard (FOR), field-of-view (FOV)



CrIS SDR specifications. Black – normal spectral resolution (NSR); blue – full spectral resolution (FSR)

Band	Spectral Range (cm^{-1})	# of Chan.	Spectral Res. (cm^{-1})	NEdN @287K BB ($mW/m^2/sr/cm^{-1}$)	Radiometric Uncertainty @287K (%)	Frequency Uncertainty (ppm)	Geolocation Uncertainty (km)
LWIR	650-1095 650-1095	713 713	0.625 0.625	0.14 0.14	0.45 0.45	10 10	1.5 1.5
MWIR	1210-1750 1210-1750	433 865	1.25 0.625	0.06 0.085	0.58 0.58	10 10	1.5 1.5
SWIR	2155-2550 2155-2550	159 633	2.50 0.625	0.007 0.014	0.77 0.77	10 10	1.5 1.5

Number of FSR channels: 2211; Number of NSR channels: 1305

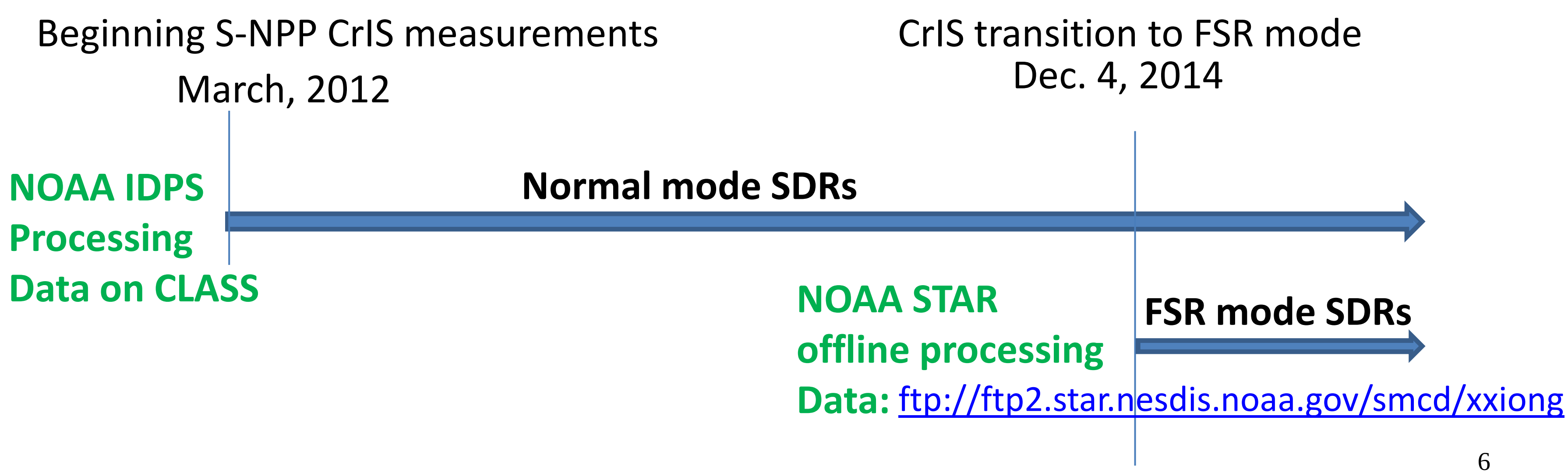
CrIS SDR Team Members

PI	Organization
Yong Han	NOAA/STAR
Hank Revercomb	U. of Wisconsin (UW)
Larrabee Strow	U. of Maryland Baltimore County (UMBC)
Deron Scott	Space Dynamic Lab (SDL)
Dan Mooney	MIT/LL
Degui Gu	NGAS
Dave Jonson	NASA Langley
Lawrence Suwinski	Exelis
Joe Predina	Logistikos
Carrie Root	JPSS/DPA
Wael Ibrahim	Raytheon

S-NPP CrIS SDR Product Overview 1/3

- Excellent instrument performances since the beginning of the mission
- Stable SDR product with radiometric and spectral calibration accuracies and noise performance exceeding requirements with large margins
- Successful transition normal spectral resolution (NSR) mode to full spectral resolution (FSR) mode on 12/4/2014
- Both NSR and FSR SDRs are routinely generated
- Both NSR and FSR SDRs are monitored with web-based ICVS

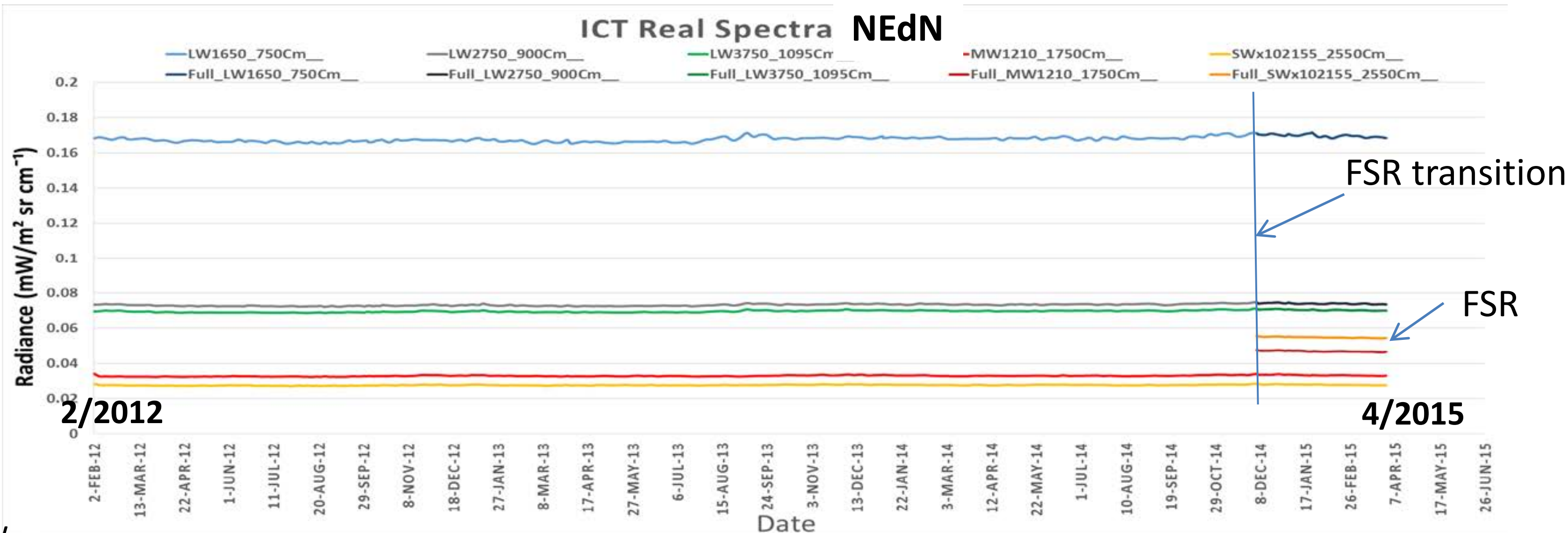
SDR Processing Time Line



S-NPP CrIS SDR Overview 2/3 (Performance Stability)

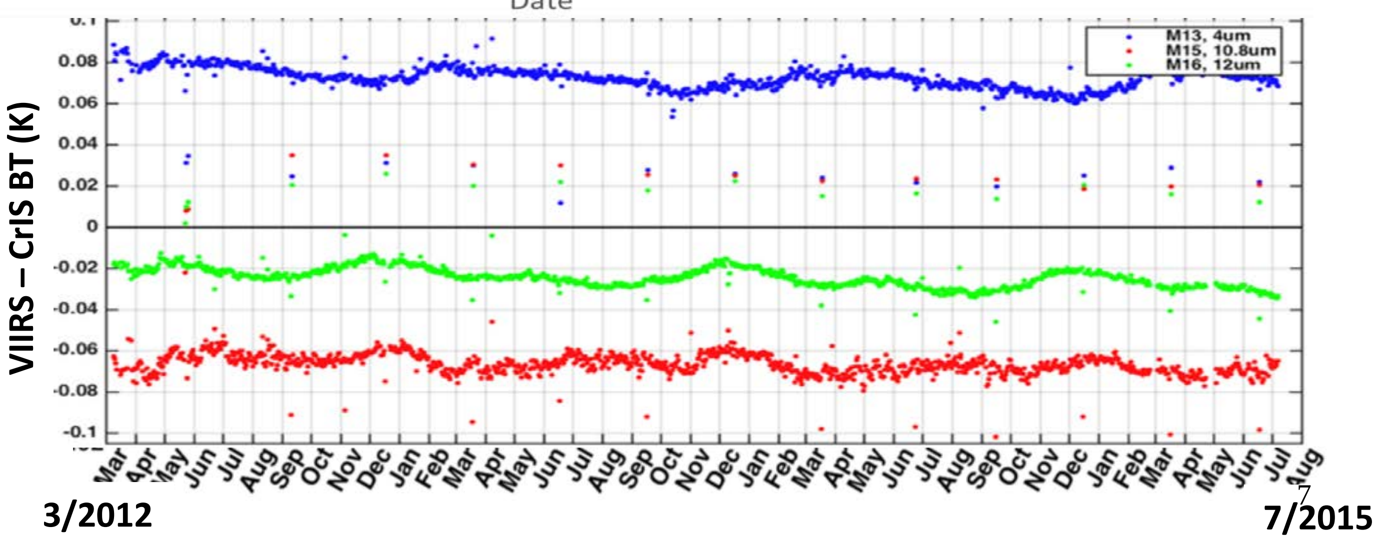
- **Excellent instrument performances since the beginning of the mission**

From SDL



From UW

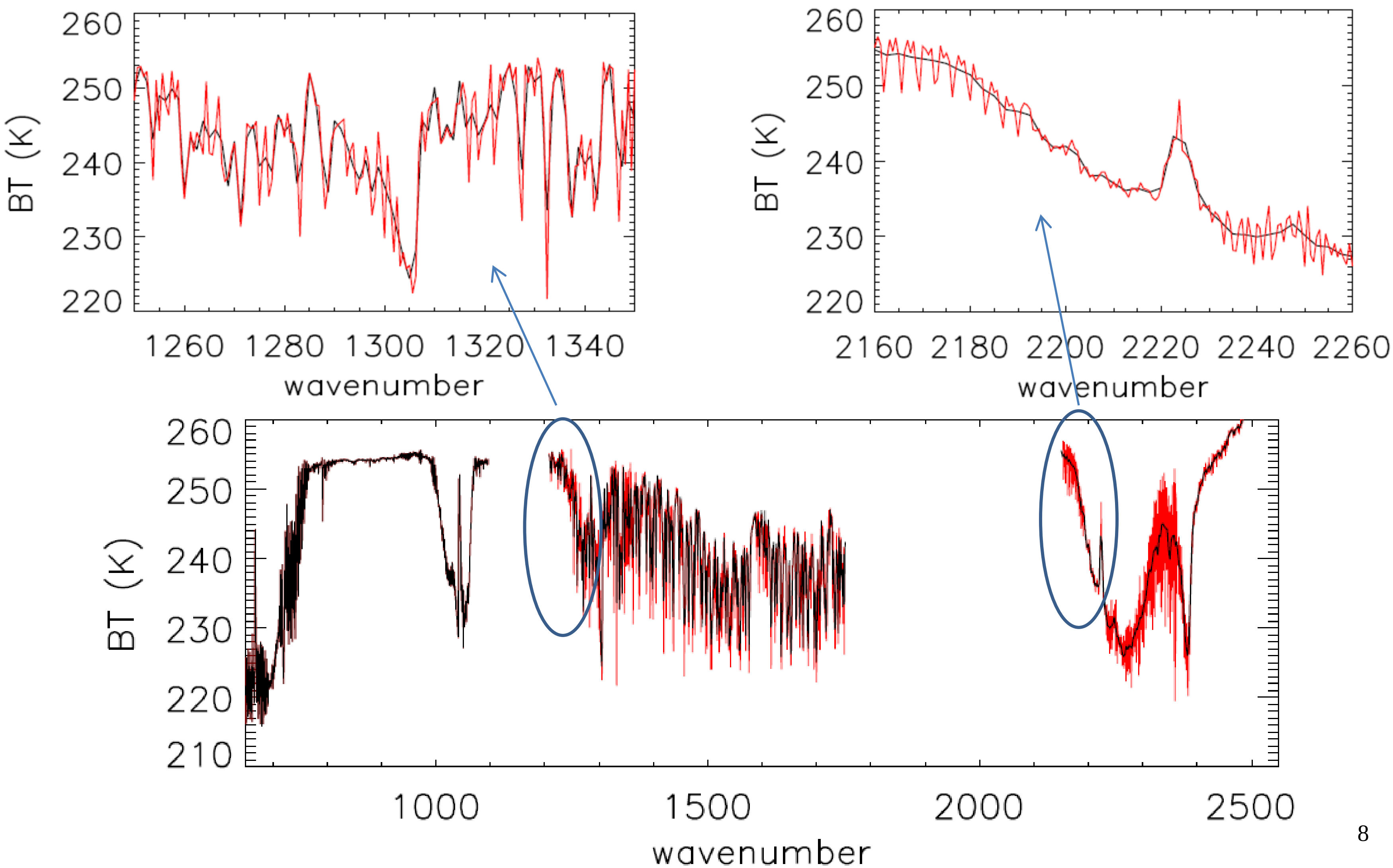
- Variation of the difference is less than ±0.01
- Large outliers are due to VIIRS quarterly nonlinearity tests



S-NPP CrIS SDR Overview 3/3 (NSR and FSR SDR Products)

From STAR

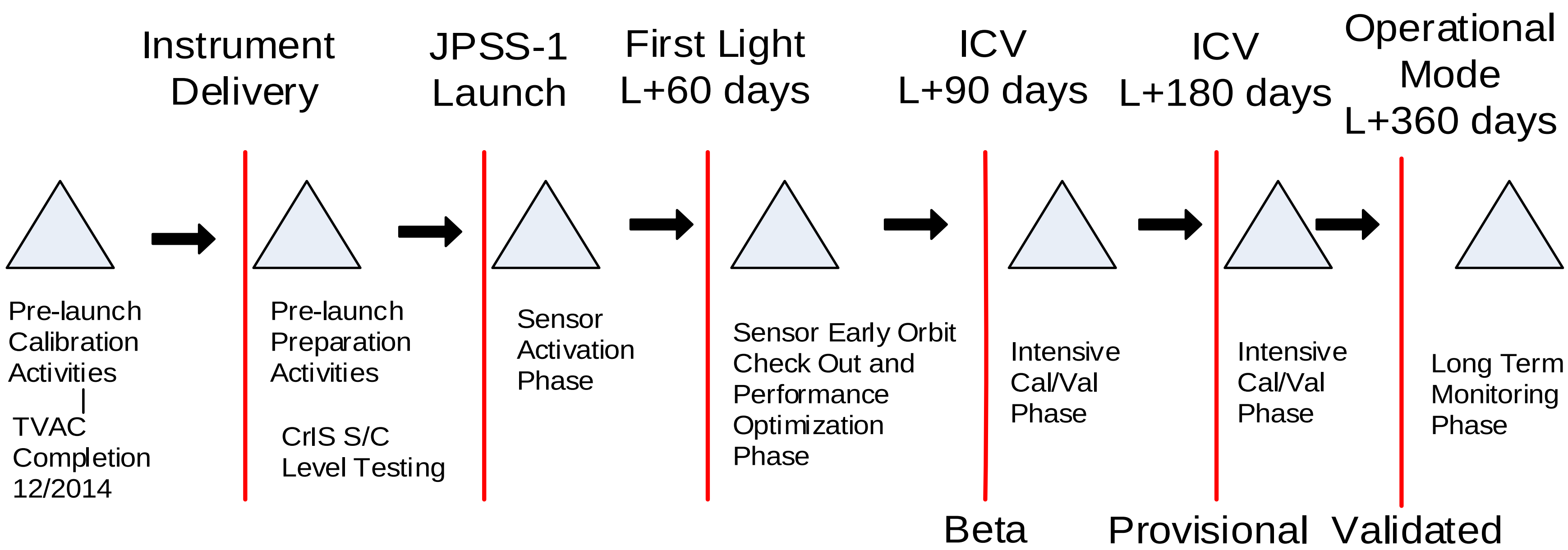
Red lines – FSR spectrum; black lines – IDPS NSR spectrum



J1 CrIS Pre-launch CalVal Status

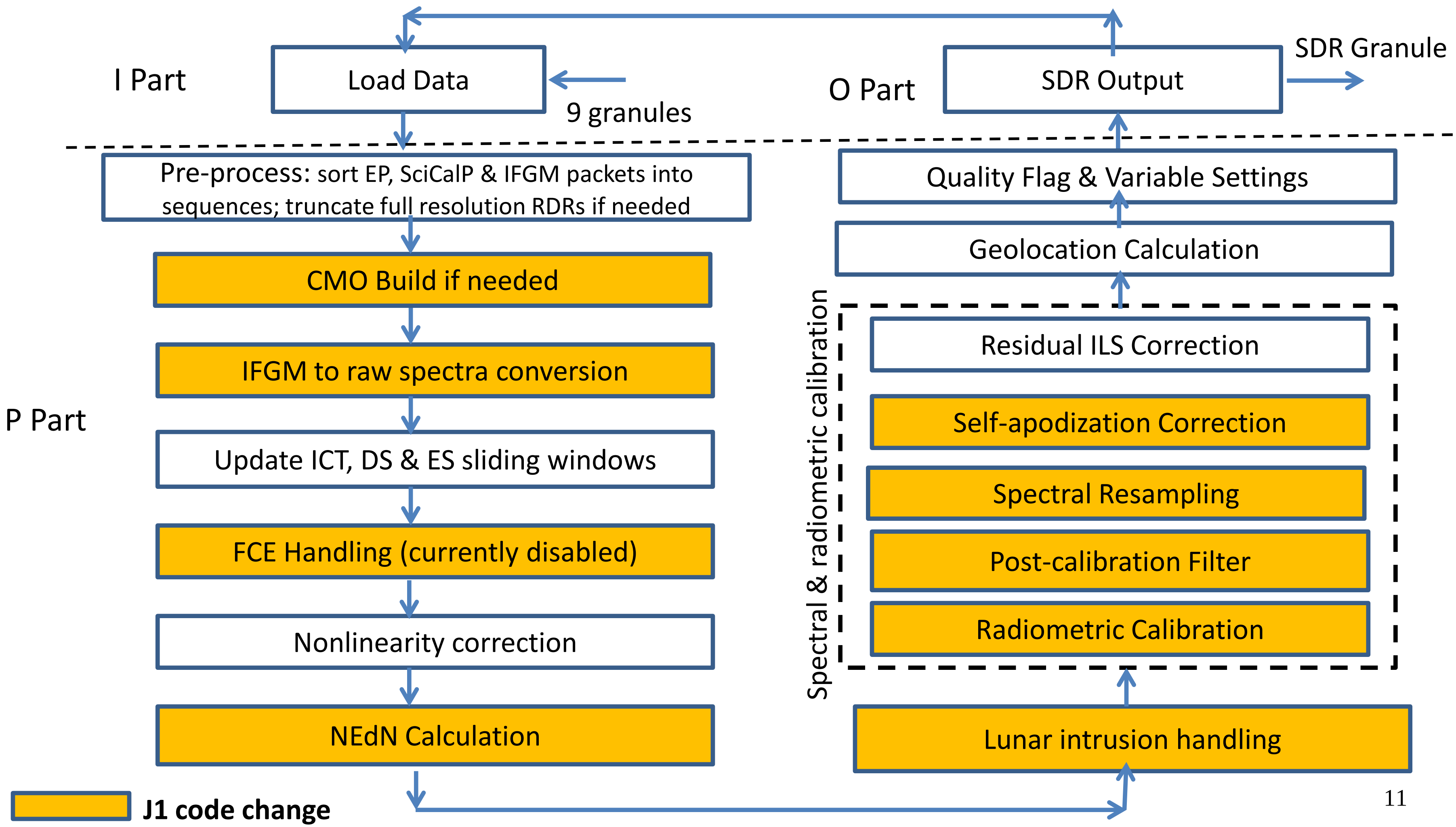
- Successfully completed environmental test campaign (instrument currently at BATC for spacecraft level testing)
- Determined the pre-launch version of the calibration coefficients and parameters
- Developed and delivered the first version of the J1 CrIS SDR algorithm/software
- Characterized the instrument performances with the pre-launch test data
- Addressed the only instrument science waiver for the LW FOV8 partial obscuration
- Made significant progress in improving SDR algorithm to reduce radiance ringing artifacts (updates to be delivered in December 2015)
- Completed initial version of J1 CalVal plan

J1 CrIS Pre- & Post-launch CalVal Schedule



J1 CrIS SDR Algorithm/Software Changes

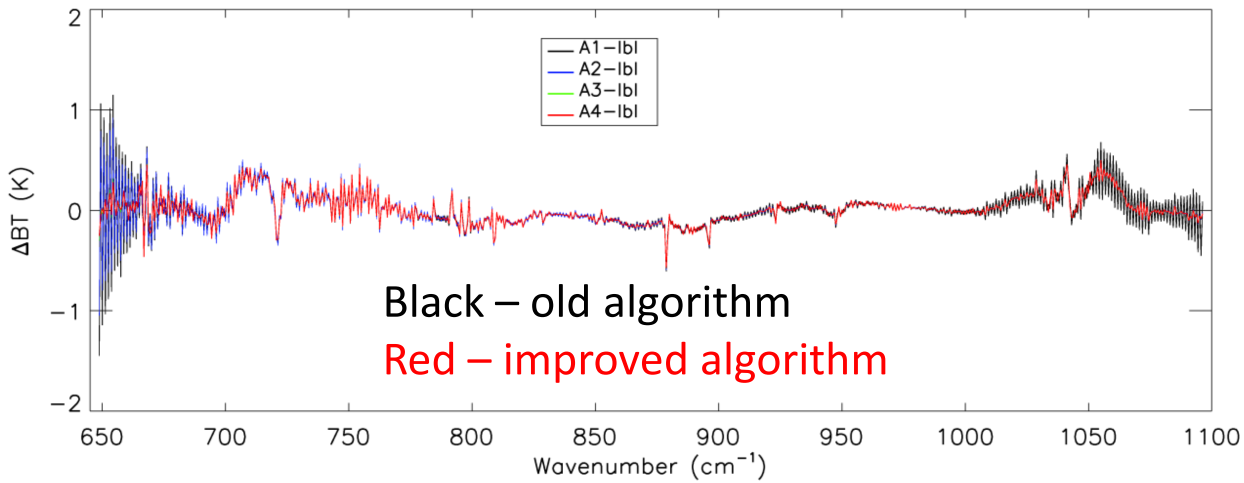
- J1 SDR code & LUTs delivered in January, 2015, able to process both NSR and FSR SDRs
- An update will be delivered in December 2015



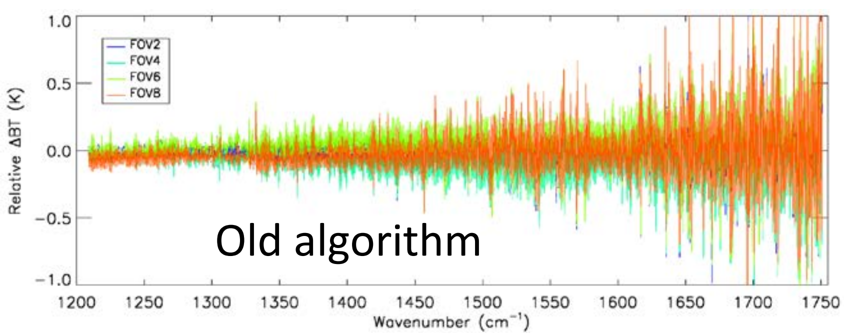
J1 Algorithm Improves Calibration Uncertainty

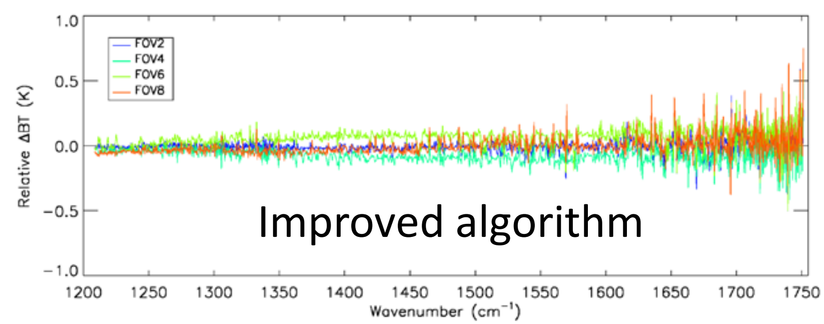
From STAR

Observed - simulated



FOV-to-FOV difference



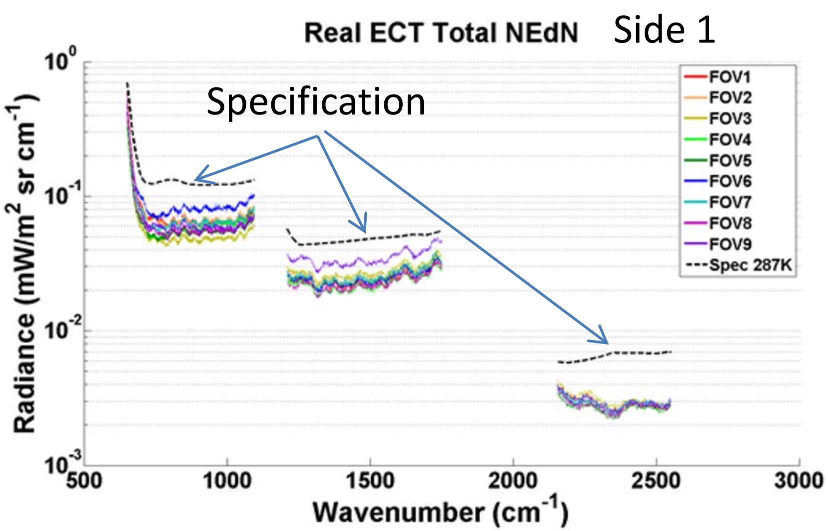


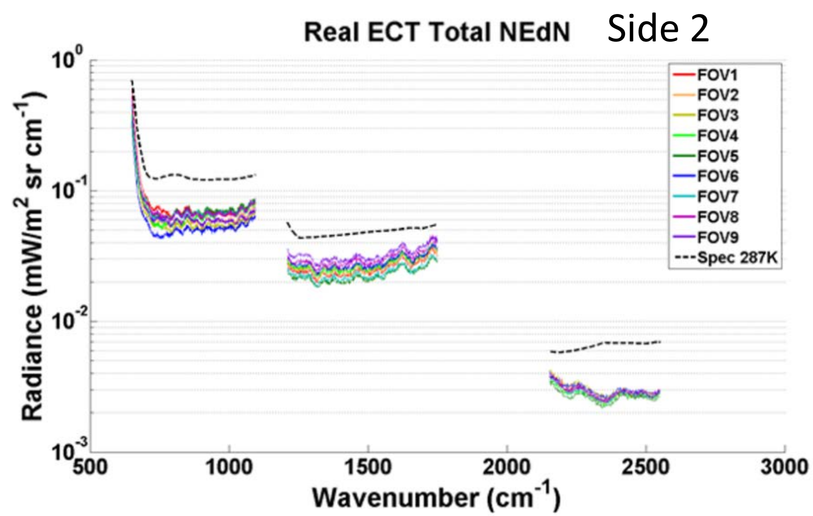
Ringing artifacts are significantly reduced

J1 CrIS Noise Performance

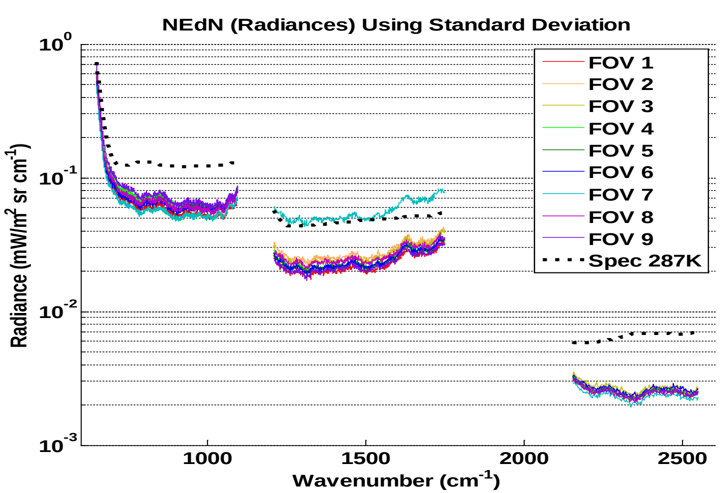
From SDL

J1





S-NPP

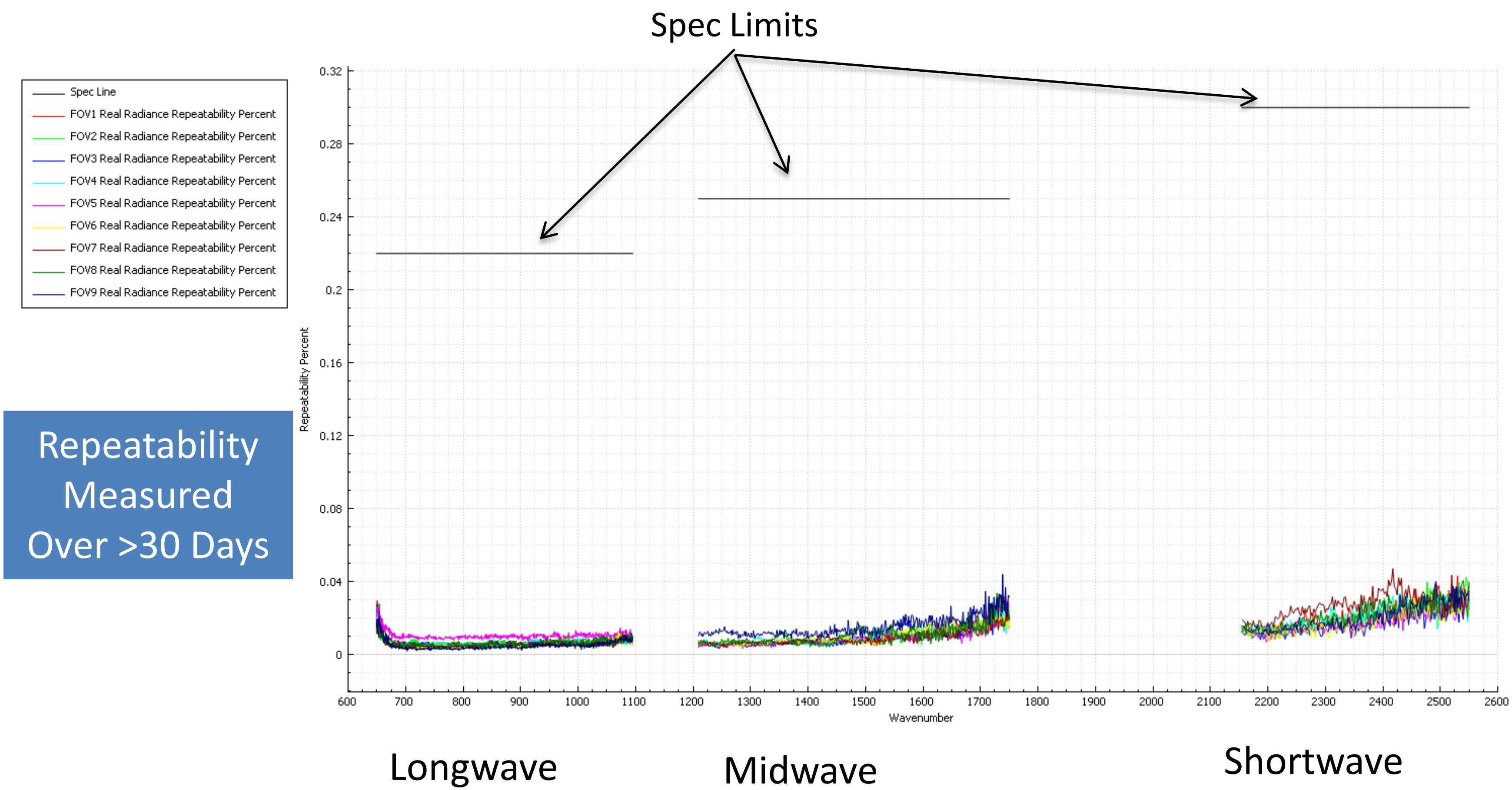


Similar to S-NPP:

noise performance significantly better than specification

Long Term Repeatability Performance

From Exelis

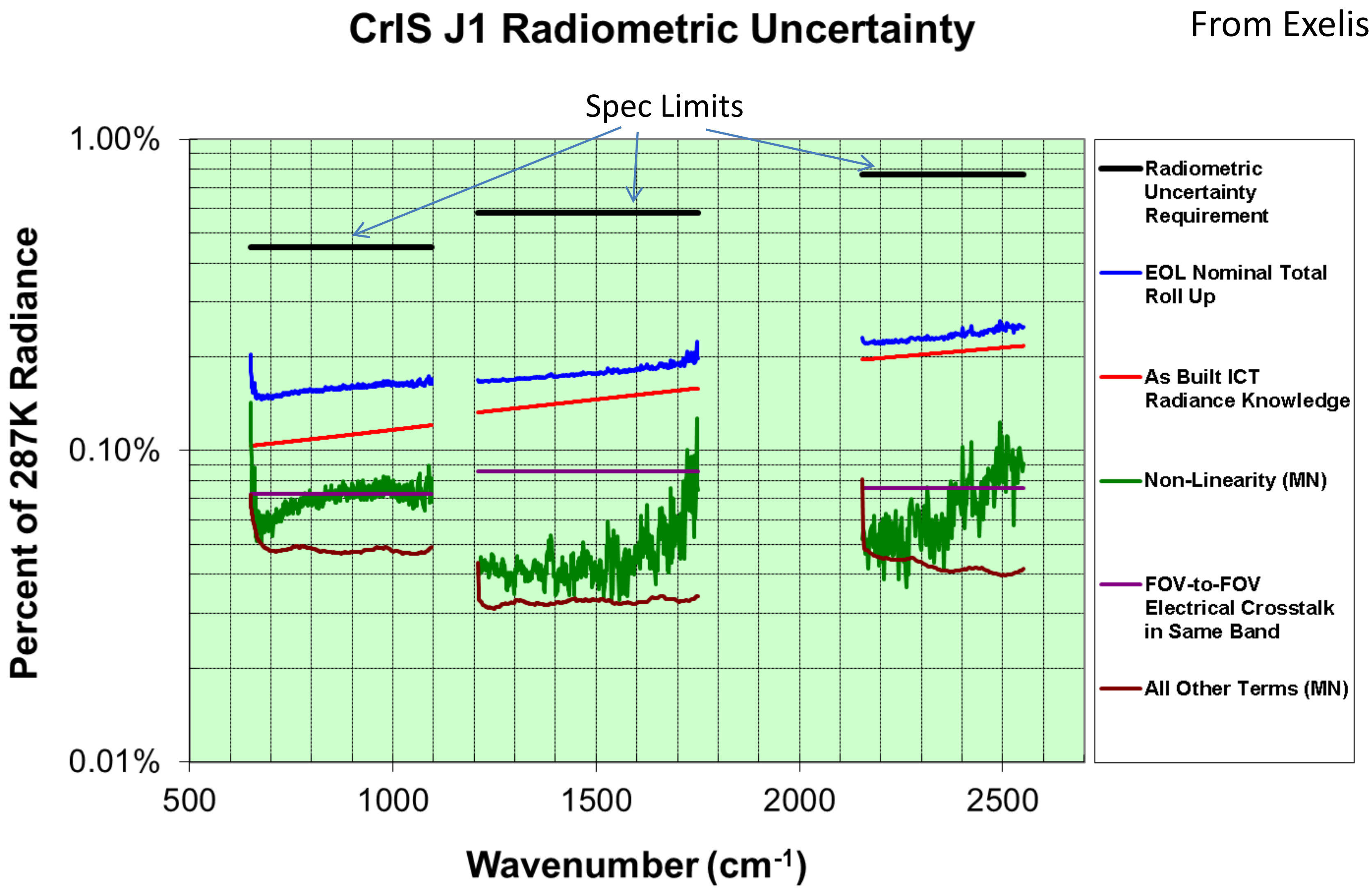


Repeatability Measured Over >30 Days

Excellent long term repeatability

Radiometric Uncertainty Performance

From Exelis



Excellent Radiometric Uncertainty Performance

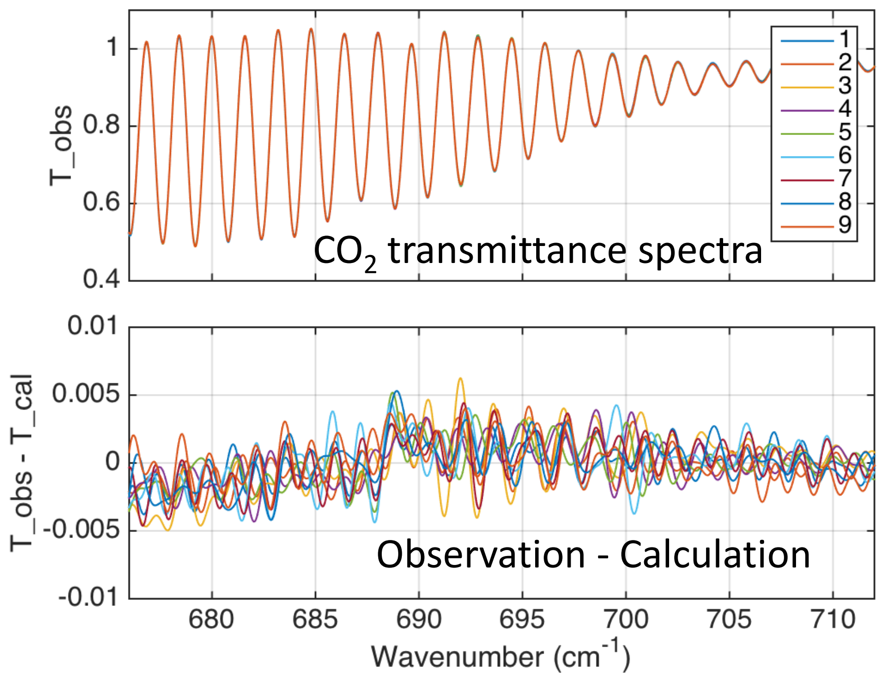
Instrument Line Shape Parameters Derived for Spectral Calibration

Instrument Line Shape parameters derived from TVAC data (UMBC):

	LW Y	LW X	MW Y	MW X	SW Y	SW X
FOV 1	19266	19266	19173	19173	19125	19125
FOV 2	0	19313	0	19205	0	19209
FOV 3	-19209	19209	-19181	19181	-19141	19141
FOV 4	19261	0	19174	0	19177	0
FOV 5	0	0	0	0	0	0
FOV 6	-19219	0	-19142	0	-19167	0
FOV 7	19282	-19282	19184	-19184	19149	-19149
FOV 8	0	-19084	0	-19168	0	-19172
FOV 9	-19287	-19287	-19189	-19189	-19136	-19136

Neon Calibration: 703.45036

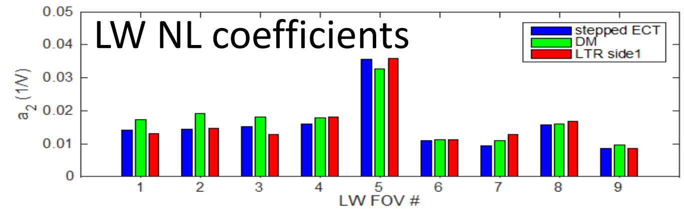
Band	Y offset	X offset	dR
LW	-601	-22	99
MW	-658	-10	-25
SW	-605	6	-63

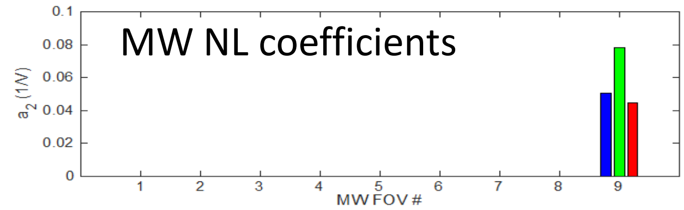


The ILS parameters minimize the difference between observed and calculated spectra

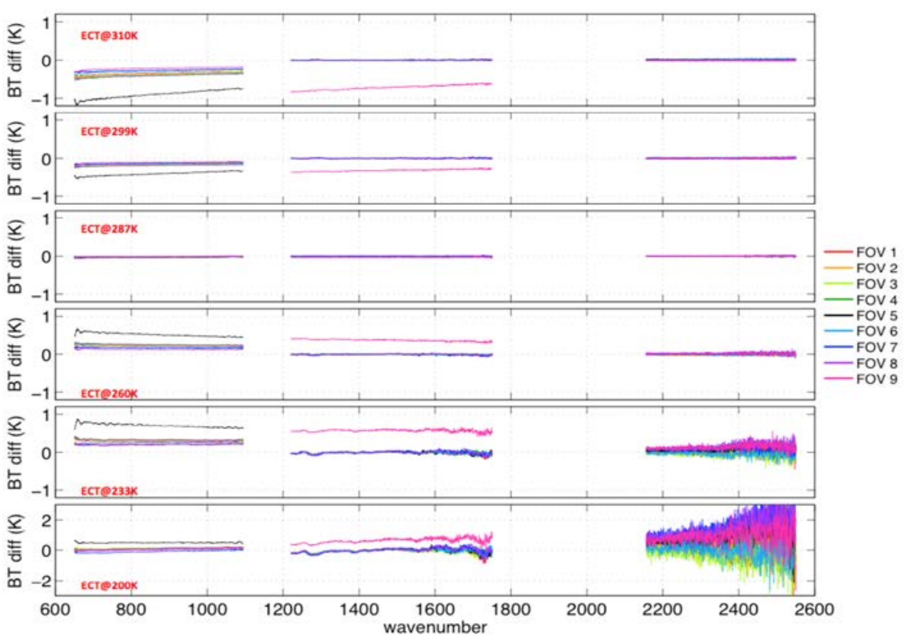
Non-linearity (NL) Correction Coefficients Derived for Radiometric Calibration

- NL correction coefficients derived from different methods (UW)
- NL correction is a critical step to reduce radiance errors and FOV-to-FOV difference

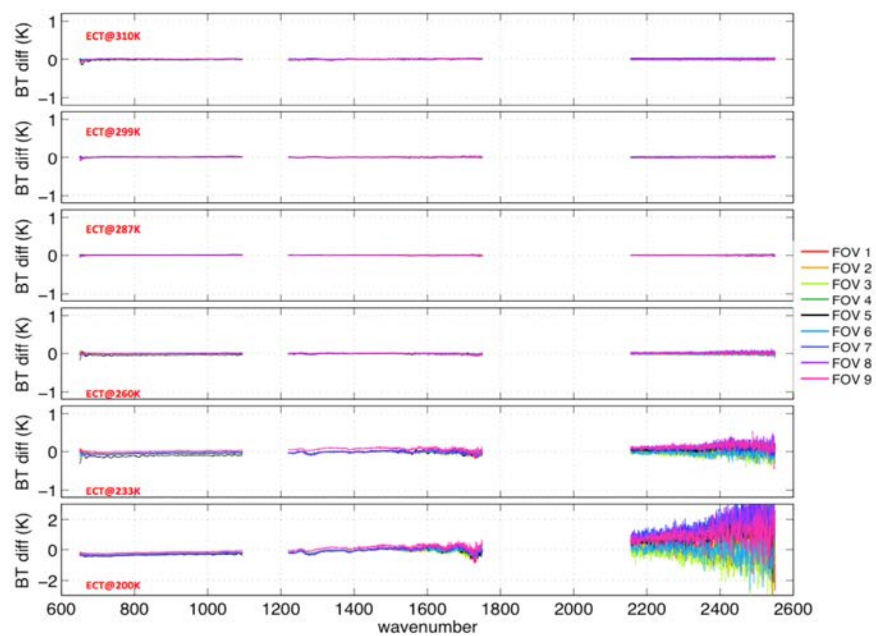




ECT view residuals without NL correction



ECT view residuals with NL correction



Summary

- S-NPP CrIS instrument and SDR performances have been in excellent status; no significant degradations have been detected so far
- Both normal and full spectral resolution SDR products are routinely generated, available to public
- J1 CrIS pre-launch performance exceeds specifications
- J1 SDR algorithm/software is a significant improvement over S-NPP's
- There is no critical unresolved issue in both S-NPP and J1 CrIS missions

Path Forward

- S-NPP
  - Continuation of S-NPP CrIS FSR SDR processing
  - Continuation of CalVal; assessment of 5 years of CrIS instrument and SDR performances
  - SDR reprocessing
- JPSS-1
  - Algorithm improvement updates (to be delivered in Dec. 2015)
  - Further TVAC data analysis; ECT characterization (2015-2016)
  - Preparation of post-launch CalVal activities (2015-2016)
- JPSS-2 and beyond
  - Full spectral coverage (650 – 2760 cm^{-1}; no gaps)
  - Smaller FOV size and larger FOV grid (e.g. 8 km FOV size and 5 x 5 FOV grid)

VIIRS SDR Overview

Name of the Product: VIIRS SDR
Contributors: VIIRS SDR Team

Changyong Cao
VIIRS SDR Team Lead

Date: August 24, 2015

VIIRS Instrument Overview

•VIIRS is a scanning imaging radiometer onbaord the Suomi NPP, and JPSS satellites in the afternoon orbits with a nominal altitude of 829km at the equator, and swath width of ~3000km;

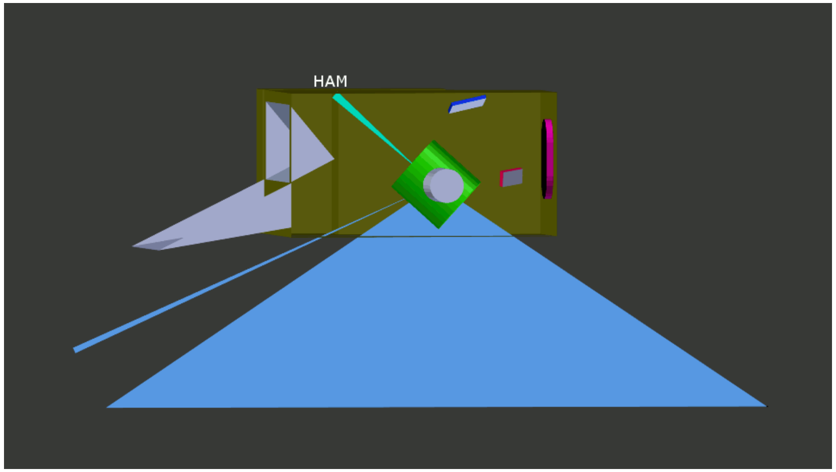
VIIRS has 22 types of SDRs:

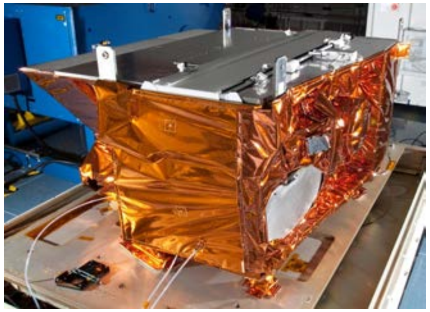
- *•16 moderate resolution (750m), narrow spectral bands (11 Reflective Solar Bands (RSB); 5 Thermal Emissive Bands (TEB))*
- *•5 imaging resolution(375m), narrow spectral bands (3 RSB; 2 TEB)*
- *•1 Day Night Band (DNB) imaging (750m), broadband*

•VIIRS Onboard calibration relies on the solar diffuser (SD), solar diffuser stability monitor (SDSM), space view (SV), and the blackbody (BB);

•Vicarious calibration also used (lunar, dark ocean for DNB, and cal/val sites);

•Calibration is performed per band, per scan, per half angle mirror side (HAM), and per detector.





VIIRS instrument

Smoke & fire in Tianjin explosion last week

Algorithm Cal/Val Team Members

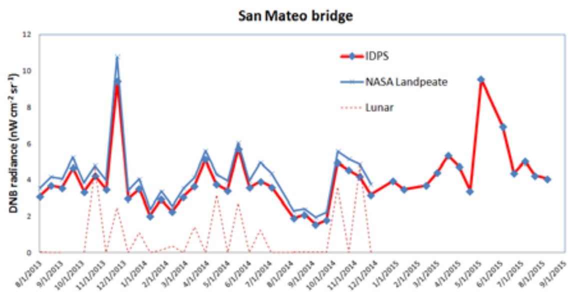
PI	Organization	Team Members	Roles and Responsibilities
C. Cao	STAR	W. Wang, S. Blonski, S. Uprety, Z. Wang, S. Shao, Y. Bai, B. Zhang, J. Choi, M. Schull, Y. Gu, C. Moeller.	VIIRS SDR calibration/validation for S-NPP, J1, and beyond. - Prelaunch calibration LUT development - Software code changes - ADL test - Vicarious calibration - Postlaunch monitoring and LUT update
F. DeLuccia	Aerospace	G. Moy, E. Haas, C. Fink, D. Moyer	VIIRS operational calibration update; RSB autocal; prelaunch TV data analysis;
J. Xiong	VCST	J. McIntire, G. Li, N. Lei, T. Schwarting	VIIRS TV data analysis; prelaunch characterization; LUT development

VIIRS SDR Product Requirements from JPSS L1RD

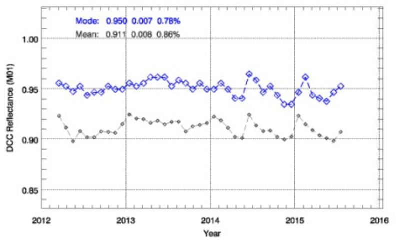
Attribute	Threshold	Objective
Center Wavelength	412 to 12,013 nm	412 to 12,013 nm
Bandpass	15 to 1,900 nm	15 to 1,900 nm
Max. Polarization Sensitivity	2.5 to 3.0 %	2.5 to 3.0 %
Accuracy @ Ltyp	0.4 to 30 %	0.4 to 30 %
SNR @ Ltyp or NEdT @ 270 K	6 to 416 or 0.07 to 2.5 K	6 to 416 or 0.07 to 2.5 K
FOV @ Nadir	0.4 to 0.8 km	0.4 to 0.8 km
FOV @ Edge-of-Scan	0.8 to 1.6 km	0.8 to 1.6 km
Ltyp or Ttyp	0.12 to 155 $W \cdot m^{-2} \cdot sr^{-1} \cdot mm^{-1}$ or 210 to 380 K	0.12 to 155 $W \cdot m^{-2} \cdot sr^{-1} \cdot mm^{-1}$ or 210 to 380 K
Dynamic Range	0.12 to 702 $W \cdot m^{-2} \cdot sr^{-1} \cdot mm^{-1}$ or 190 to 634 K	0.12 to 702 $W \cdot m^{-2} \cdot sr^{-1} \cdot mm^{-1}$ or 190 to 634 K

S-NPP Product Overview

- S-NPP Cal/Val Accomplishments
  - Developed validation time series at 30+ vacarious sites and at SNOs , DCC and Lunar;
  - Developed VIIRS DNB radiometric stability monitoring and geolocation validation using point sources;
  - Developed common geo processing capabilities;
  - Successfully transitioned DNB stray light correction LUT from NG to STAR. LUTs are being delivered monthly for IDPS operational processing since January 2015;



- Known Product Deficiencies:
  - Calibration uncertainty for reflective solar bands is within 2% for most bands;
  - SWIR bands such as M11 has large uncertainties due to lack of traceable source;
  - Bowtie deletion may cause discontinuities in imagery with satellite projection, although not an issue with earth projection;
  - M15 bias at 200k can be upto 0.5k, although meeting the spec.
  - Striping may be apparent in both RSB and TEB bands, although below noise level.
- LTM: Monitoring Tools/Website
  - VIIRS SDR home page: http://ncc.nesdis.noaa.gov
  - ICVS: http://www.star.nesdis.noaa.gov/icvs/ status_NPP_VIIRS.php



Deep Convective Clouds (M1)

JPSS-1 Readiness

- J1 Algorithm Summary

Major changes to the product algorithm(s)/Improvements:

- J1 VIIRS DNB nonlinear response at high scan angles required a performance waiver with the implementation of Agg mode 21 and 21/26:

- VIIRS DNB GEO code analysis shows that J1 DNB GEO product cannot be generated correctly without code change.
- Block 2 ADL VIIRS GEO code was modified to support J1 DNB agg mode change.
- J1 GEO code change was verified using MDR 28 and MDR 39 J1 RDRs
- The Modified code can support Agg21, Agg21/26 correctly
- Backward compatible with SNPP.

J1 VIIRS DNB Geo code changes

GEO_determine_DNB_sample_time_offsets.cpp — 1. Determine DNB sample time offsets

GEO_interpolate_mirror_encoder.cpp
GEO_interpolate_telescope_encoder.cpp — 2. Extrapolating of encoder data

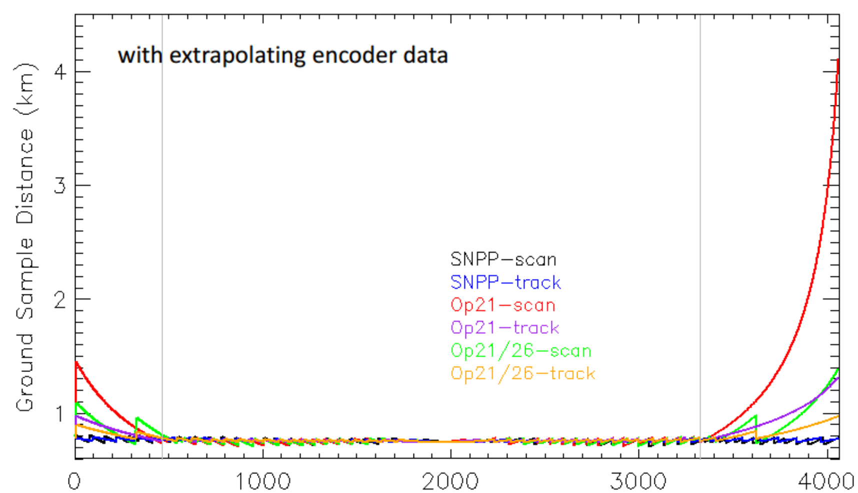
ProSdrViirsGeoDataStructs.h
GEO_process_parameters.cpp
fixSatAngles.cpp
ProSdrViirsGeo.cpp
geolocateDecim.cpp
geolocateAllRecPix.cpp — 3. Hard-coded nadir frame #

Files with red color have relatively more changes.

GEO_parameters.h
ProViirsGeoRectangle.h
ProGeoloc_createInterpRectangles.cpp
calcModFromImg.cpp
geolocateGranule.cpp — 4. Interpolation rectangles

Totally 14 files were modified
All files are located at ${ADL_HOME}/SDR/VIIRS/Geo, except for *ProViirsGeoRectangle.h & ProGeoloc_createInterpRectangles.cpp are located at* ${ADL_HOME}/include & ${ADL_HOME}/Geolocation/Util/src, respectively.

7



JPSS-1 Readiness

- J1 Cal/Val Overview
  - Timelines for Beta, Provisional and Validated Maturity
    - Beta: L+10/40 days to L+60?
      - Initial power on: L+10
      - Outgassing: L+10 to L+39
      - Door deploy: L+40: ?
    - Provisional: L+60 to L+90?
    - Validated: L+180
  - Pre-Launch Calibration/Validation Plans
    - Cal/val plan developed, currently under review by external team members
  - Post-Launch Calibration/Validation Plans
    - Cal/val plan developed, currently under review by external team members

JPSS VIIRS Calibration and Validation Plan

Table of Contents

JPSS-1 Readiness

- Major Accomplishments and Highlights Moving Towards J1
  - Developed J1 VIIRS DNB waiver mitigation and delivered pre-operational software to the program on-time, which greatly reduced program schedule and cost risks (Wang & Lee), in addition to operational straylight correction.
  - Prepared all 47 J1 VIIRS LUTs (ver1.0) based on analysis of prelaunch test data, tested using ADL and simulated J1 data, and delivered to the program(Aerospace/VCST/STAR);
  - Developed and demonstrated VIIRS DNB radiometric and geolocation monitoring/characterization capabilities using nightlight point sources (Cao & Bai, 2014,RS.), which is critically needed for J1 postlaunch validation of the waivers;
  - Expanded validation time series with the 30+ validation sites worldwide, with added capabilities in the SWIR bands, as well as comparing with GOSAT FTS hyperspectral observations (Uprety & Cao, 2015, RSE);
  - Completed J1 VIIRS prelaunch test data analysis (VCST/Aerospace/STAR)
  - Improved RSB autocal maturity;
  - Geolocation thermal chip development for the infrared bands;
  - Modeled VIIRS solar diffuser degradation using surface roughness and metrology;
  - Active nightlight SBIR project feasibility study in support of VIIRS DNB cal/val.

JPSS-1 Readiness

- Issues/Mitigation
  - Need to work closely with flight to test DNB op21 and op21/26 postlaunch
  - Other waivers still need to be addressed:
    - SWIR nonlinearity
    - Bad detector
    - Saturation
- Stake Holder Interactions, Users and Impact Assessment Plans
  - List of Users/Stake Holders
    - SST, Ocean Color, Imagery, Aerosols, Ice temperature, and other products
    - User Impact Assessment (examples)

      Work with SST team to address bow-tie, striping, and other issues.

      Work with imagery team to address bad detector issue.

      Work with Ocean color team to address polarization sensitivity issues.

      Work with Cryosphere team to assess impact of M15 bias.

FY16 Milestones/Deliverables

Task Category	Task/Description	Start	Finish	Deliverable
Development (D)	• DNB&SWIR band dual calibration; • Improve straylight correction; • RDR toolkit; • Geolocation control points; • SD degradation model	10/2015	09/2016	Science code & LUTs & data
Integration & Testing (I)	J1 prelaunch LUT and code change testing support	10/2015	09/2016	Code & LUT updates
Calibration & Validation (C)	• Support the RSB autocal (operational); • Offline RSB/DNB/TEB cal/val analysis; • Quantify striping & develop mitigation; • Common geo validation; • Prepare field campaign validation for J1	10/2015	09/2016	Improved radiometric & geolocation accuracy; LUT; publications
Maintenance	• Maintain the performance trending at 30 sites • Update documentation	10/2015	09/2016	Continuity
LTM & Anomaly Resolution (L)	LTM for all RSB bands using DCC, lunar, SNOs, and other vicarious targets	10/2015	09/2016	Continuity

Summary & Path Forward

The VIIRS SDR team has made great progress:

- Supported J1 VIIRS waiver studies
- Developed and enhanced vicarious validation site time series at 30+ sites
- Developed geolocation software code modifications for J1
- Developed and delivered J1 VIIRS LUTs
- Developing common geo and geolocation validation capabilities

- **The VIIRS SDR team will continue to support SNPP, J1, J2 & beyond**
  - Refine J1 VIIRS LUTs, and expand validation capabilities
  - Feasibility study developing value-added SDR L1.5 product
  - Reprocessing
  - Support J2 enhancements

OMPS SDR Overview

Chunhui Pan and Fuzhong Weng

SDR Products
OMPS SDR Team
August 24, 2015

Outline

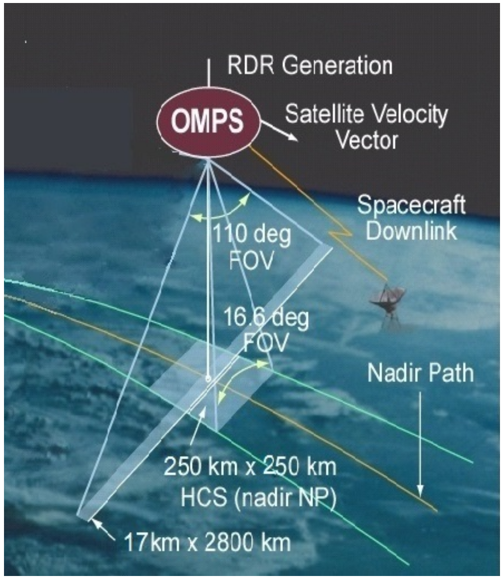
- OMPS Algorithm Cal/Val Team PIs
- OMPS SNPP/JPSS-1 Instrument Overview
- OMPS S-NPP Product Overview
- OMPS JPSS-1 Readiness
- Summary and Path Forward

OMPS Algorithm Cal/Val Team PIs

PI Name	Organization	Primary Roles
Fuzhong Weng	NOAA/STAR	Budget and coordination; instrument and product performance monitoring; TOMRAD/VLIDORT modeling
Glen Jaross	NASA	Instrument scientist; TVAC data acquisition and analysis; SDR algorithm.
Chunhui Pan	NOAA/STAR	NOAA Technical Lead; OMPS SDR cal/val science, code development, TVAC data analysis; SDR algorithm.
Maria Caponi	Aerospace	Algorithm changes coordination; DR and issues tracking
Sarah Lipscy	BATC	Instrument scientist; prelaunch test; …
Wael Ibrahim	Raytheon	IDPS operations

OMPS J1 Instrument Overview

- **Enhanced spatial resolution with new timing patterns**
  - Provides Total Column ozone data w/ 17x17 km^2 IFOV at nadir
  - Provides ozone profiles in 5 ground pixels of 50x50 km^2 at nadir
- **Configuration**
  - Push-broom 110 deg. cross-track FOV telescope
  - Two grating spectrometers
    - » NM covers 300 – 420 nm
    - » NP covers 250 nm to 310 nm
  - CCD optical detector for each spectrometer
- **Onboard Calibrators**
  - Light-emitting diode provides linearity calibration
  - Reflective quasi-volume diffusers (QVD) maintains calibration stability
- **Products**
  - Provide globe maps every 24 hours of amount of ozone and volumetric concentration in a vertical column of atmosphere with a 4- days revisit



Spatial resolution will be altered to provide low, medium and high spatial resolution data

- The LP will not be present for J-1
- NM slit redesigned to reduce "puckering"
- Optical mounts redesigned to improve boresight stability
- Modified optical alignment permits wavelengths up to ~420nm to be measured -- potentially enhances science products and help to correct nadir geolocation and stray light OOB.
- Generation of three SDR products: EV SDRs, Cal. SDRs (offline), and GEOs

Instrument Specification

Dominant contribution to accuracy

Spatial Properties

- Cross-track MTF at nadir >.5 at .01cycles/Km
- Cross-track NP FOV >16.7 degrees
- Cross-track NM FOV >110 degrees

Radiometric Accuracy

- Pixel-pixel radiometric calibration <.5%
- Non linearity 2% full well
- NL knowledge <.5%
- On-orbit wavelength calibration .01 nm
- Stray Light signal <1%
- Intra-orbit wavelength stability .02 nm
- Band Pass Shape Knowledge 2%
- Solar Irradiance < 7%
- λ - normalized radiance <2%

Dominant contribution to precision

Radiometric Precision Terms

- SNR 1000 for TC, varies for NP
- Inter-orbital Thermal Wavelength Shift .02 nm

Geolocation Error Terms

- Boresight alignment knowledge uncertainty between nadir instrument interface and nadir alignment reference <160 arcsec
- Total cumulative boresight alignment shift (between final ground calibration and on-orbit operations <500 arcsec

Prelaunch calibration has verified that instrument characteristics match the sensor performance needed to meet the products requirements.

OMPS J1 Accuracy Meets Science requirements

Prelaunch lab test shows that J1 OMPS calibration stability and accuracy meets science requirements

Source of Uncertainty	Absolute 1σ Fractional Uncertainty (%)				Albedo 1σ Fractional Uncertainty (%)			
	Radiance		Irradiance		λ - independent		λ - dependent	
	NP	TC	NP	TC	NP	TC	NP	TC
SNPP Goniometry	0	0	0.38	0.41	0.38	0.41	0.15	0.36
J1 Goniometry	0	0	0.21	0.21	0.21	0.21	0.1	0.11
OMPS NPP RSS Total	3.383	3.067	3.499	3.194	1.653	1.717	0.426	0.497
OMPS J1 RSS Total	2.637	1.646	2.731	1.8	1.587	1.389	0.405	0.437
Requirement	8.0	8.0	7.0	7.0	2.0	2.0	0.5	0.5

S-NPP OMPS SDR Product Overview

- OMPS EV SDR products maturity milestone
  - Beta maturity since March 2012
  - Provisional maturity since March 2013
  - Validated maturity since August 2015
- SNPP OMPS orbital performance is stable and SDRs meet validated maturity requirement
- A CCR is in preparation to move forward with an upgrade of the S-NPP OMPS FSW to v6.0. This upgrade improves capabilities for better products with the S-NPP OMPS measurements.
- OMPS long term monitoring via. STAR ICVS provides much of the information to characterize the S-NPP OMPS NM, NP and LP in their cal/val studies.

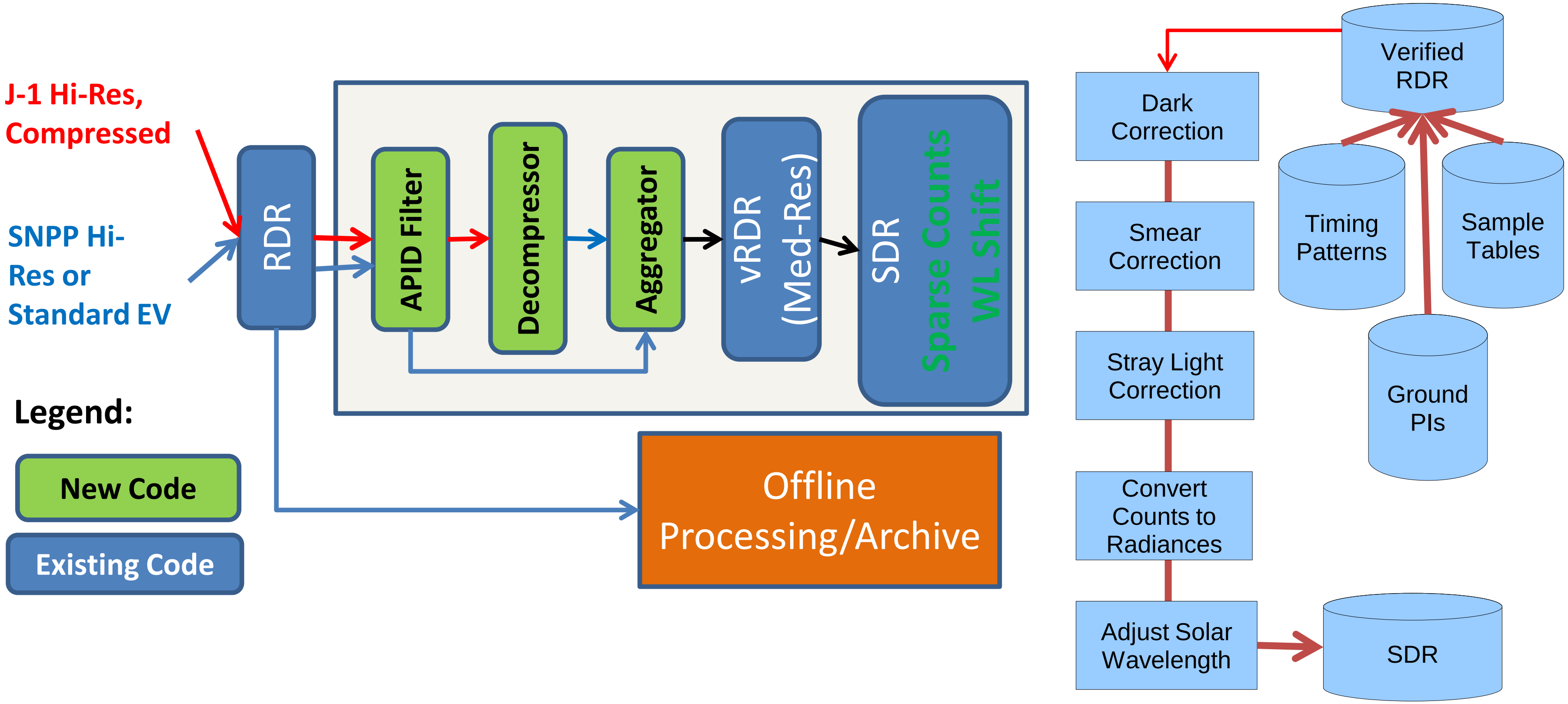
  http://www.star.nesdis.noaa.gov/icvs/status_NPP_OMPS_NM.php

  http://www.star.nesdis.noaa.gov/icvs/status_NPP_OMPS_NP.php

  http://www.star.nesdis.noaa.gov/icvs/status_NPP_OMPS_LP.php

OMPS J1 NM Algorithm Summary

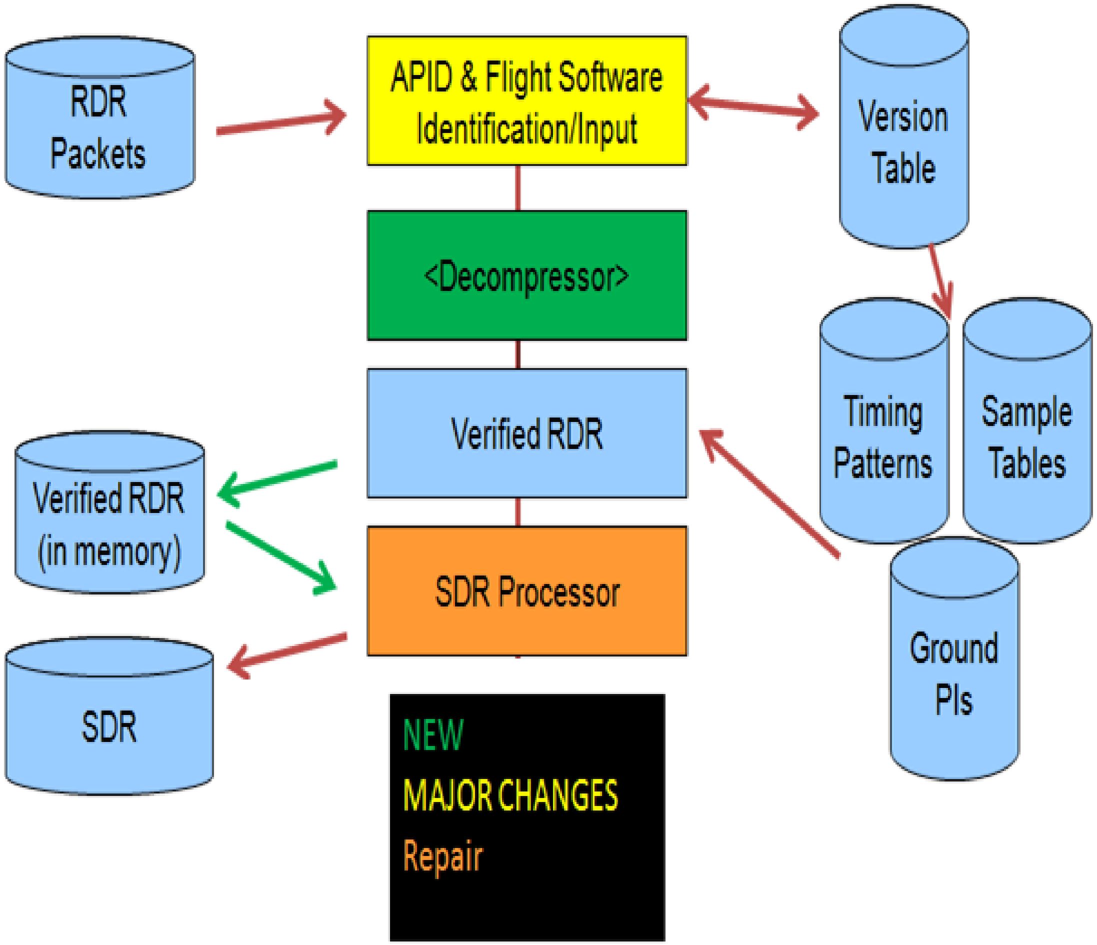
OMPS J1 SDR algorithm is enhanced to process current SDR product content for medium spatial resolution. Additional capabilities include: FSW6 engineering headers, Rice decompression, APID filter capable to process new APIDs (four new APID values), J01 spacecraft ID, aggregation, sparse spectral data and new wavelength format table.



OMPS J1 NP Algorithm Summary

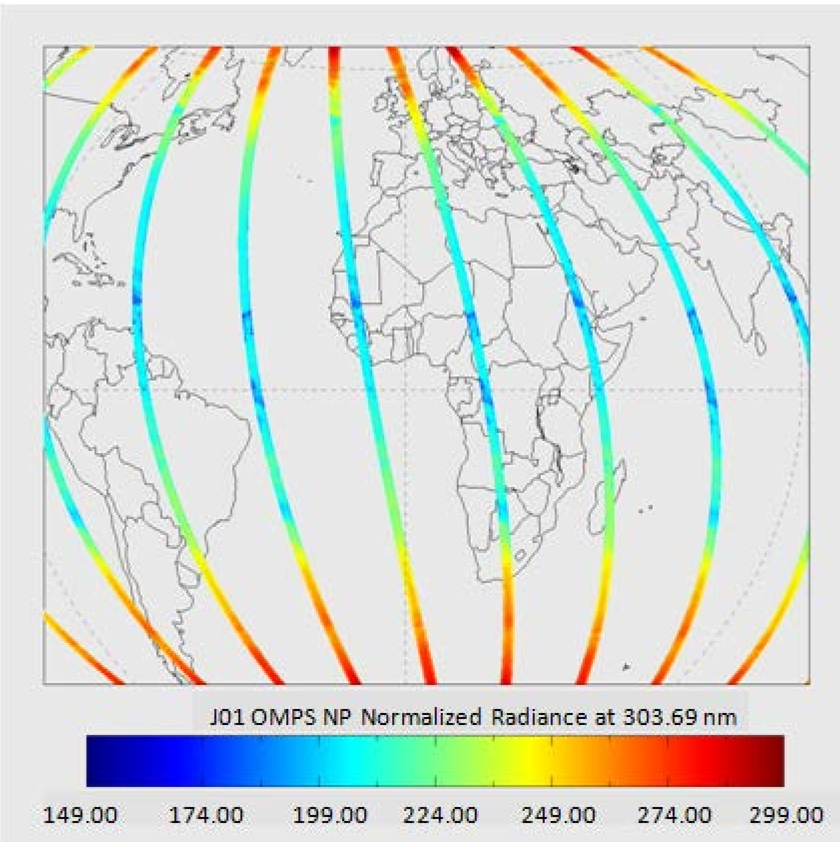
The J1 NP SDR required the following major changes:

- FSW6 engineering headers
- Rice decompression
- Four new APID values
- J01 spacecraft ID
- J1 algorithm LUTs

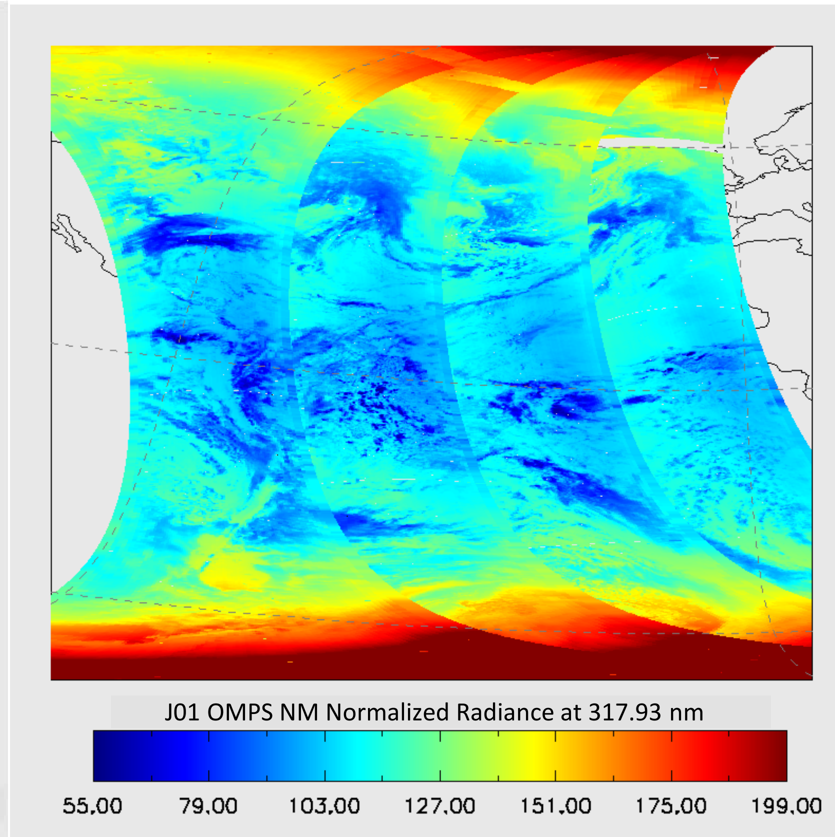


Example of Proxy SDR products from J1 Algorithm

50x50 km resolution for NP



16.7x50 km resolution for NM



J1 algorithm was tested for software validation and geophysical validation. SNPP derived RDRs were used as inputs. Results were verified to have the correct data structure, engineering data, and science data

OMPS J1 Cal/Val Overview (1)

- SDR Maturity Timeline
  - "Beta" L+ 3M
  - "Provisional" around L+6M.
  - "Validated/calibrated" around L+12M
- Pre-Launch Calibration/Validation Plans

Year	Tasks/Activities	Deliverables
2015	• SDR Algorithm development and enhancement to meet required performance • Ground test data analysis and software development.	• Initial Pre-launch LUTs • Software code packages • Cal/Val documentation
2016	• Further analysis on pre-launch test data and refinement of LUTs. Establish sensor initial settings and parameters • Sensor and Algorithm Parameter Updates • SDR software tool develop to handle diagnostic data	• Improved version of Pre-launch LUTs • Revised Cal/Val documentation

J1 OMPS Cal/Val Overview (2)

- Post-Launch Calibration/Validation Plans

Year, Phase	Tasks/Activities	Deliverables
2017, PLT to ICV	• Execute the Cal/Val tasks described in the Calval. Plan • Baseline instrument parameters for nominal operation • Adjust instrument settings when necessary • Modify measurement sequences when needed • Update appropriate SDR LUTs and coefficients that optimize the sensor's performance. • Make the instrument and software properly staged for Intensive Cal/Val (ICV) activities.	Provisional SDR products
2018, ICV to LTM	• Improve the calibration; establish long term monitoring. • Validate the SDR products through verification and cross-comparison with external independent measurements and models. • Provide radiances that are stable and accurate to support EDR retrievals.	Validated SDR products

Major Accomplishments and Moving Towards J1

Major Accomplishments

19 CCRs were implemented into operation since May 2014.

- Updated 6 LUTs wavelength, solar flux and radiance coefficients for both NM and NP (CCR 15-2547/2548). SNPP NP and NM SDRs reach validated maturity requirement.
- OMPS J1 SDR algorithm has been implemented and tested and delivered to DPES for further testing and integration (CCRs 15-2482/2483, 15-2469, 2388).
- Updated SNPP NM stray light LUT (CCR 14-2100) to account for the OOB response.
- Completed transition of Dark Cal. SDRs to STAR and GRAVITE
- Evaluated, converted and formatted J1 SCDBs contents to J1 algorithm LUTs for both NM and NP.

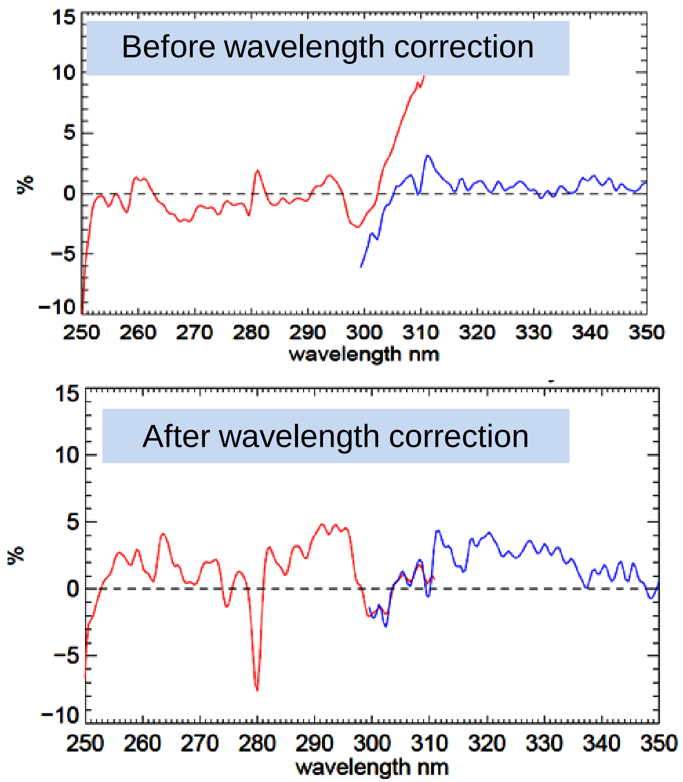
Highlights Moving Towards J1

- Refinement and verification of J1 SDR algorithm LUTs and operation tables
- Test of integrated chain for J1 algorithm LUTs through RDR, SDR and EDR.
- Transition SNPP Solar Cal. SDRs to STAR and GRAVITE

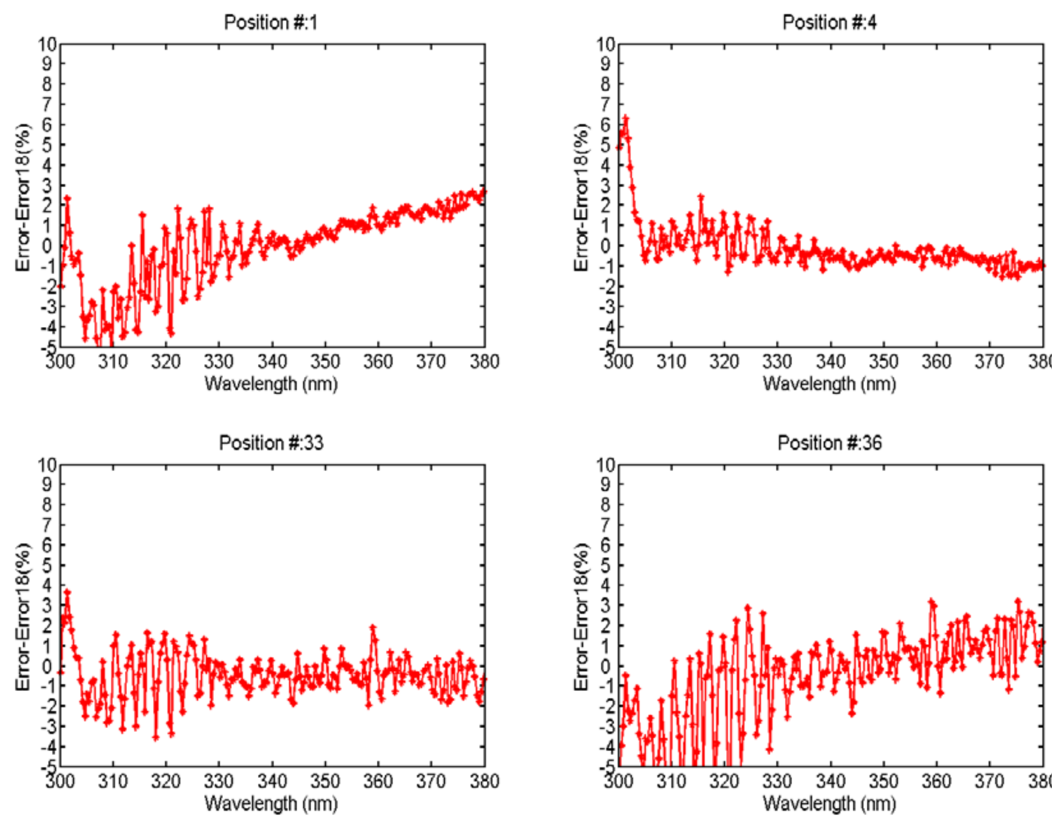
Issues/Mitigation Cal/Val challenges

From S-NPP experiences and initial evaluation of the J1 OMPS prelaunch data, the major challenges are sensor spectral wavelength calibration and bandpass calibration

Wavelength shifted ~ 0.15 nm from ground to orbit. The figure shows percent difference between observed and synthetic solar flux



Wavelength dependent accuracy in cross-track scan direction exceed our expectation but can be corrected. The figure shows relative difference between measured and calculated NR



Stake Holder Interactions, Users and Impact Assessment Plans

- OMPS SDR users/stake holders
  - CPC Climate Prediction Center
  - NCEP National Centers for Environmental Prediction
  - NRL Naval Research Laboratory
  - USGS United States Geological Survey
  - EPA Environmental Protection Agency
  - NOAA ARL Air Resources Laboratory
  - NOAA VAAC Volcanic Ash Advisory Center
  - STAR Center for Satellite Applications and Research
  - CLASS Comprehensive Large Array-data Stewardship System
- The J1 OMPS products will be used by the users the same way as they use SNPP data.
- Users won't be negatively impacted with the J1 data that is of comparable quality as SNPP SDR and EDR products.
- The Version 8 Algorithms are in transition to become the operational EDR algorithms. The SDR and EDR team have significant interaction and cooperative planning and development at these algorithms move forward.

Summary & Path Forward

- OMPS SNPP NP and NM EV SDR products meet the validated maturity requirement. SDRs products are stable.
  - Our current strategy is to stabilize and monitor SDR products quality conditions at the already established product maturity that represent sensor attainable levels.
  - Utilize ADL and GADA for testing and validation of calibration tables and data anomaly analysis.
  - Deploy already established radio transfer model for cross-sensor calibration.
  - SNPP dark Cal. SDR has been transitioned to STAR and GRAVITE. The transition of solar Cal. SDR will be completed in FY2016.
- OMPS J1tasks and schedule are well defined and on schedule. Risk is low for SDR. performance.
  - Prelaunch calibration analysis shows OMPS J1 meets system requirement.
  - J1 algorithm LUTs were derived from SCDBs and will be refined and verified through a integrated test from RDR, SDR to EDR.
  - J1 algorithm is being implemented into IDPS Block 2.0. Results will be evaluated and reviewed by OMPS science team.

FY16 Milestones

- Establish sensor initial settings and parameters for J1 launch preparation
  - Further analysis on pre-launch test data and refinement of SDR algorithm LUTs
  - Sensor and Algorithm Parameter Updates
- Refine and verify SDR algorithm LUTs
  - Measurement: Sample Tables, Macrotable, Timing Pattern
  - Spectrometric LUTs: Spectral Response, Spectral Registration, Wavelengths
  - Radiometric LUTS: Calibration Coefficients, CF-Earth, Darks, Linearity, Stray Light, Solar Irradiance, Observed Solar, Predicted Solar
  - Geolocation LUT: Mounting Matrix and Field Angle Map
  - Table version LUT
- Complete integration test of J1 algorithm chain of RDR-SDR-EDR
  - Synthetic datasets will be used to test full range of spatial and spectral domain of J1 sensor beyond NPP sensor capabilities
- Develop SDR software tools to process diagnostic data and perform offline calibration
- Complete SNPP solar Cal. SDR transition to STAR and GRAVITE
- Revise and finalize Cal/Val documentations
- Outreach to Community: AMS, EUMETSAT, IGARSS, and CALCON.
- J2 and Beyond: OMPS Limb Profiler SDR algorithm preparation is on scheduled
  - Gridded measurements of atmospheric limb Earth-view for three Nadir orbital track.
  - Spectral coverage from 290 to 1000 nm at 1-km tangent height spacing.

Integrated Calibration/Validation System (ICVS) Overview

Name of the Product: ICVS
Contributors: ICVS Team
Presenter: Ninghai Sun
Date: August 24, 2015

STAR ICVS Overview

Suomi NPP
- Spacecraft
- ATMS >>
- CrIS
- CrIS FSR
- VIIRS
- OMPS Nadir Mapper
- OMPS Nadir Profiler
- OMPS Limb Profiler

MetOp-B
- AMSU-A
- MHS
- AVHRR
- HIRS

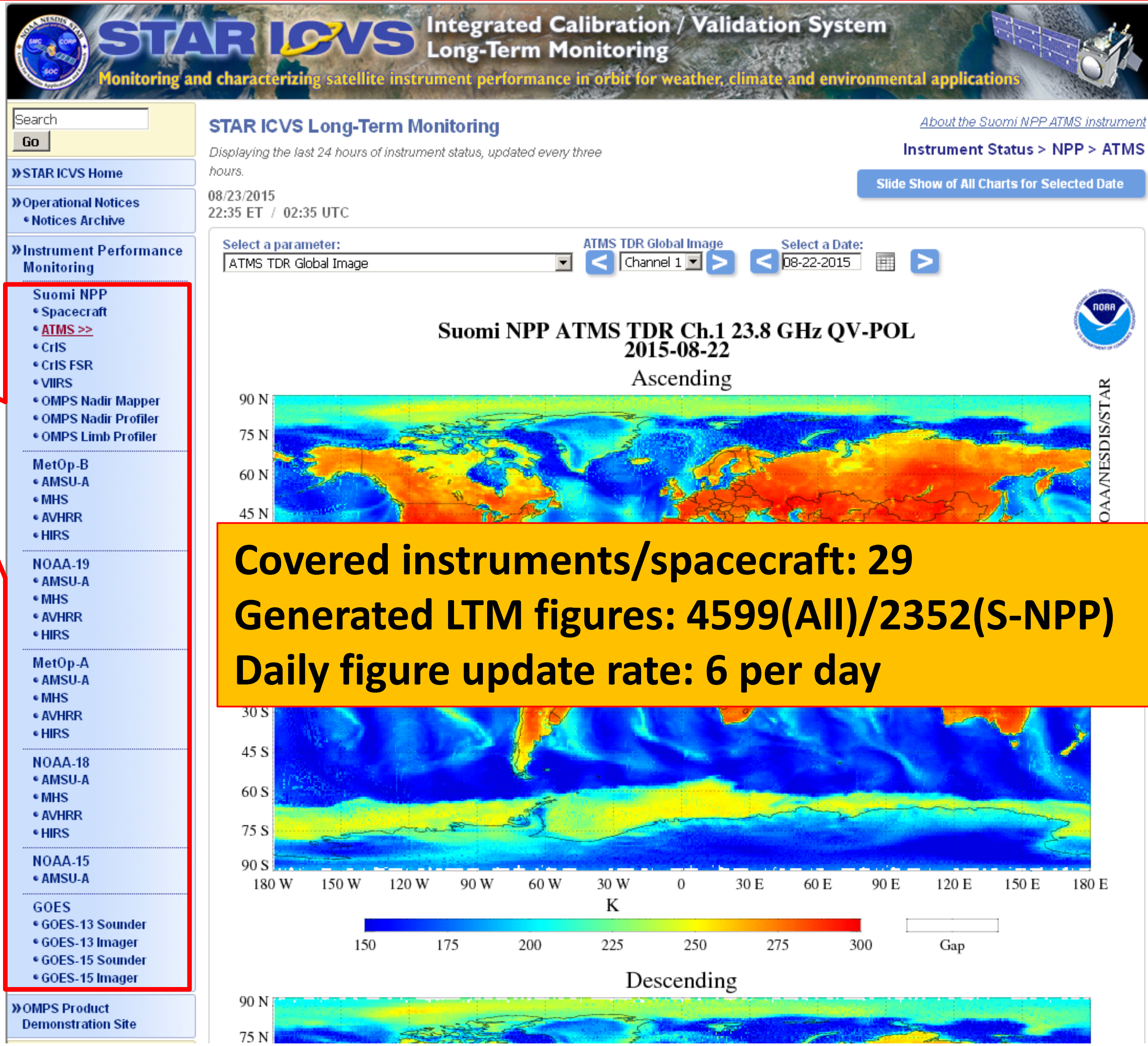
NOAA-19
- AMSU-A
- MHS
- AVHRR
- HIRS

MetOp-A
- AMSU-A
- MHS
- AVHRR
- HIRS

NOAA-18
- AMSU-A
- MHS
- AVHRR
- HIRS

NOAA-15
- AMSU-A

GOES
- GOES-13 Sounder
- GOES-13 Imager
- GOES-15 Sounder
- GOES-15 Imager

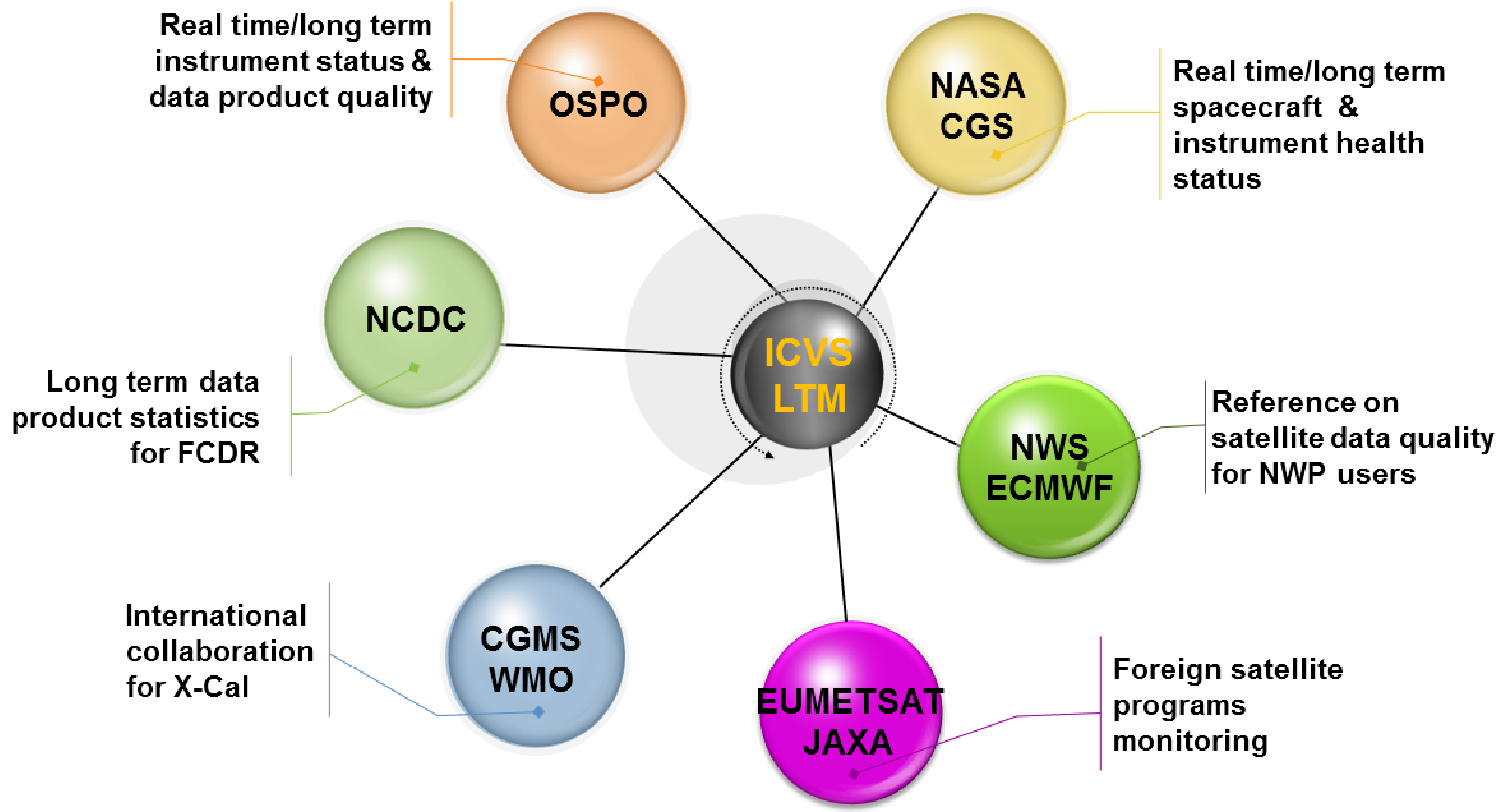


Covered instruments/spacecraft: 29

Generated LTM figures: 4599(All)/2352(S-NPP)

Daily figure update rate: 6 per day

STAR ICVS Overview



NOAA STAR ICVS are now providing more parameters for applications by broader communities including NWP. It is a very powerful tool and should be set up as a gold standard for all the space agencies to follow in satellite instrument monitoring and trending ***- Stephen English (ECMWF DA Head)***

STAR ICVS Team Members

Name	Organization	Major Task
Fuzhong Weng	NOAA/STAR	Team lead, technical oversight, budget and schedule
Ninghai Sun	ERT Inc.	System designer and Spacecraft/ATMS/AMSU/MHS LTM developer; Big data analysis lead
Ken Carey	ERT Inc.	ICVS outreach
Xin Jin	ERT Inc.	CrIS SDR LTM developer
Jason Choi	ERT Inc.	VIIRS SDR LTM developer
Ding Liang	ERT Inc.	OMPS SDR LTM developer
Wanchun Chen	ERT Inc.	System developer
Haifeng Qian	ERT Inc.	POES AVHRR/HIRS LTM developer
Miao Tian	ERT Inc.	Microwave trending analyst; Big data statistic analyst
Jian Li/Emily Duff	ERT Inc.	Multiple sensor imaging visualization developer

STAR ICVS Accomplishments

1. Transitioned S-NPP instrument health status and data product quality monitoring package (ICVS-Lite) to GRAVITE for OSPO 24/7 operational uses
2. Supported S-NPP ATMS scan drive main motor current anomaly analysis and scan reversal activities
3. Defined SI traceable channel noise evaluation algorithm using Allan deviation method for both ATMS and CrIS
4. Explored Big Data applications in database construction, statistic analysis, prediction model construction, data mining algorithm development for ICVS
5. Held the first STAR ICVS annual meeting and published STAR ICVS instrument status annual technical report
6. Updated ICVS to improve the instrument status and data quality monitoring capability
   - Added VIIRS band averaged and detector level F/H-factor trending
   - Added ATMS dwell telemetry RDR trending
   - Added CrIS full spectral resolution (FSR) SDR trending
   - Added ATMS/CrIS TDR/SDR bias characterization trending
   - Added VIIRS Imagery over Alaska real time monitoring
   - Rejuvenated OMPS NP/NM/LP SDR trending packages
   - Updated STAR ICVS website to improve user experience

ICVS-Lite Transition to GRAVITE

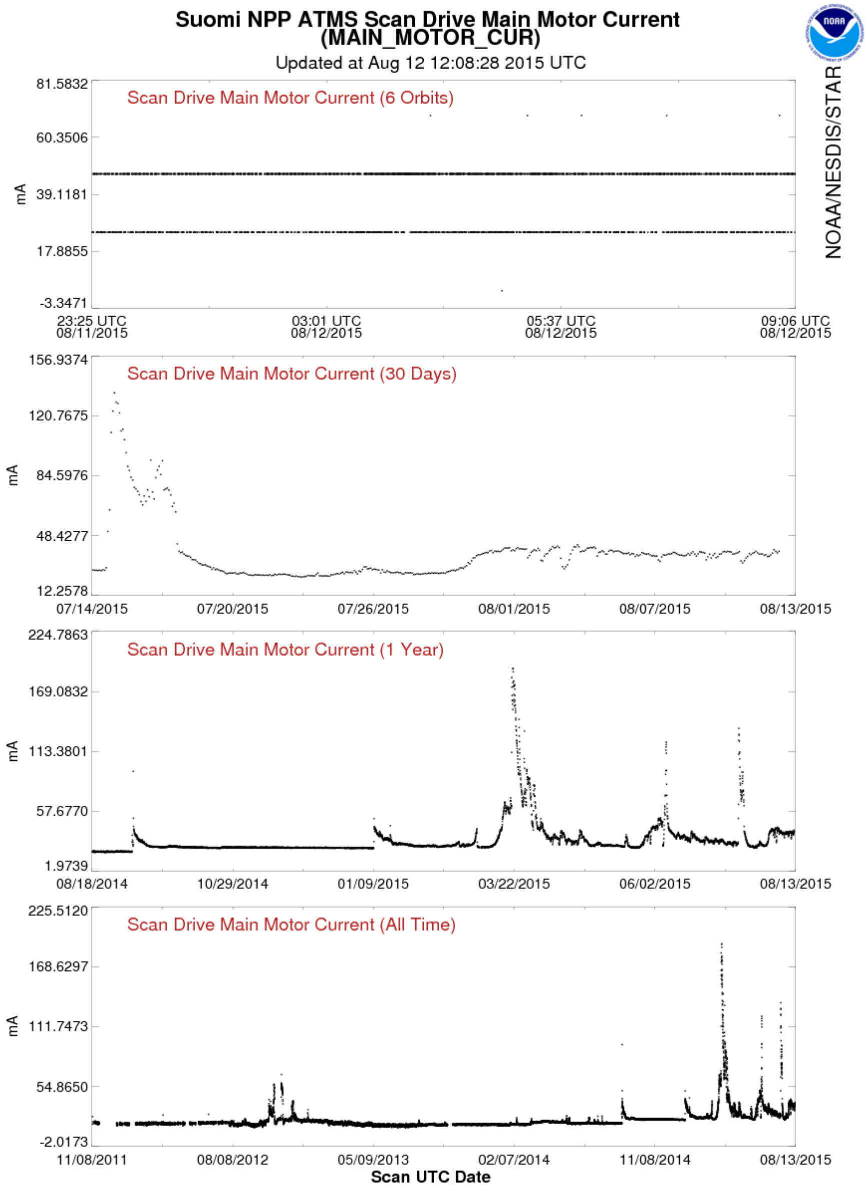
S-NPP Spacecraft and onboard instruments health status, performance, and SDR data quality long term monitoring (LTM) from STAR ICVS has been transitioned to GRAVITE

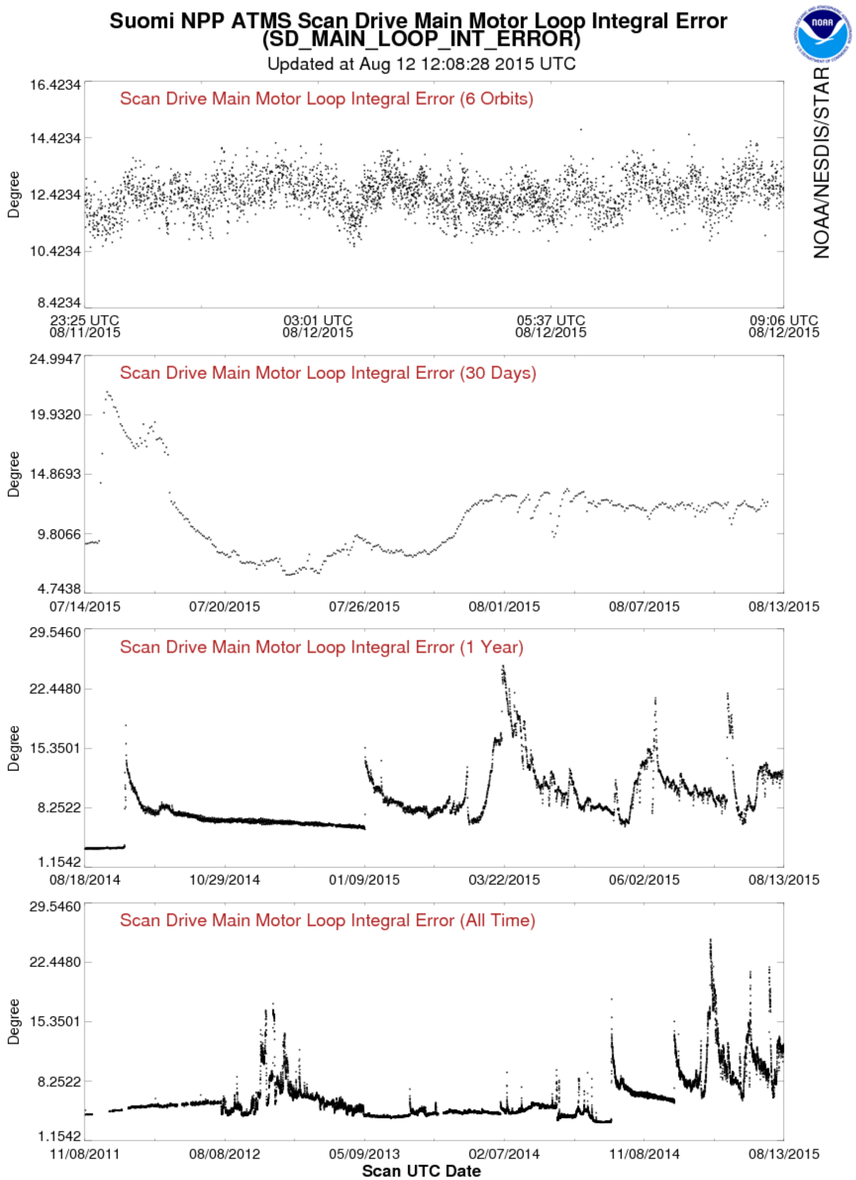
Modules includes,

1. S-NPP Spacecraft health status LTM
2. S-NPP ATMS instrument health status/performance and TDR data quality LTM
3. S-NPP CrIS instrument health status/performance and SDR data quality LTM
4. S-NPP VIIRS instrument health status and key calibration parameters LTM
5. S-NPP OMPS instrument health status LTM
6. S-NPP VIIRS Imagery real time monitoring

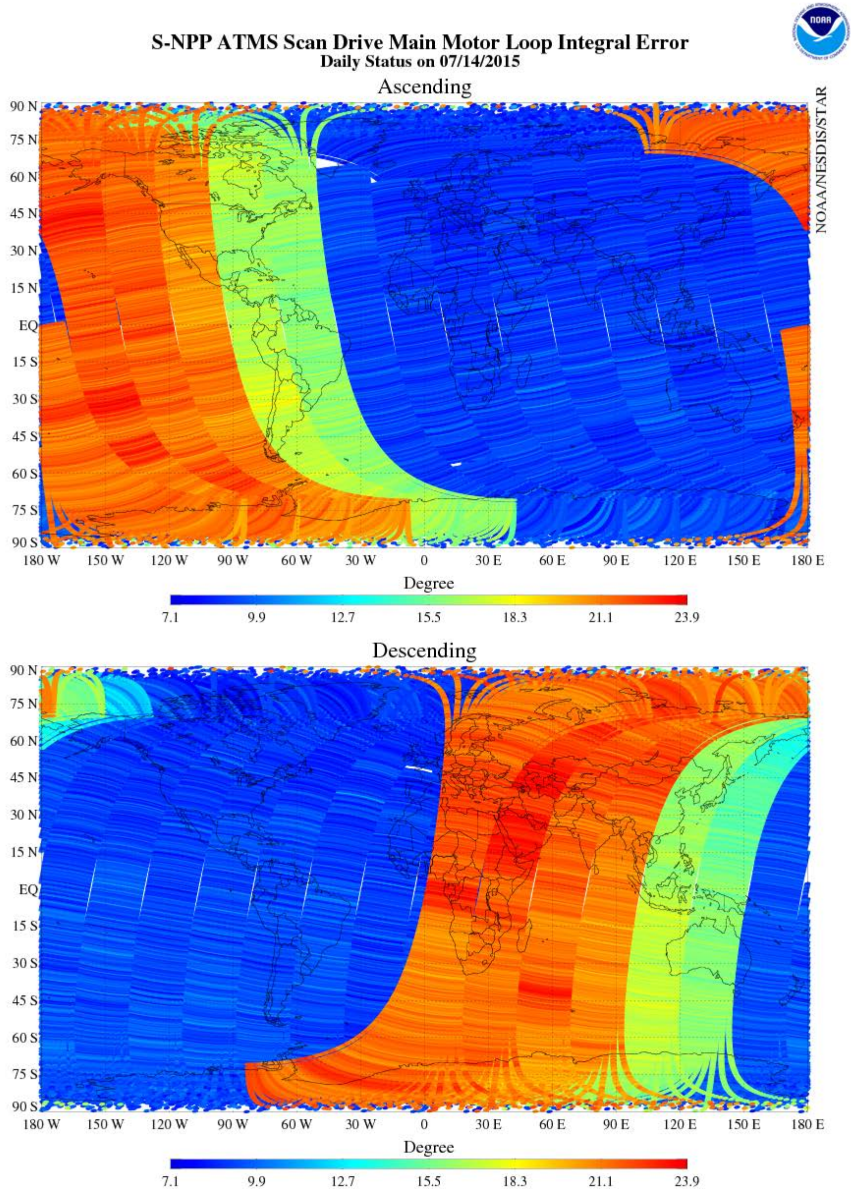
STAR ICVS team and GRAVITE data quality monitoring team work closely to make ICVS-Lite work stable for OSPO 24/7 operational missions

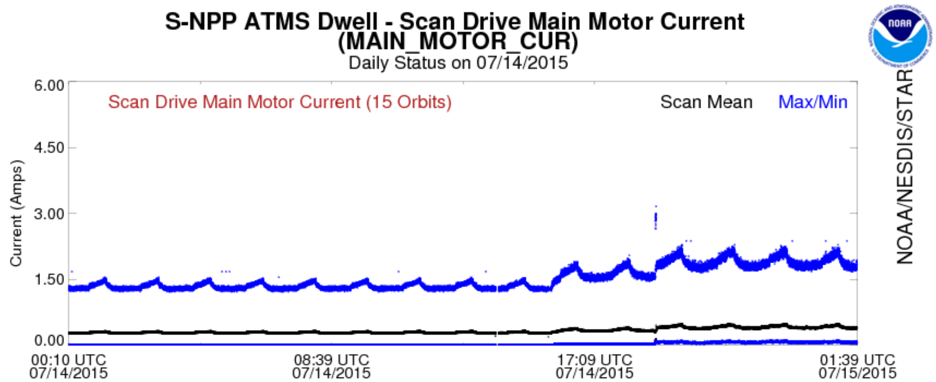
ATMS Scan Drive Main Motor Monitoring

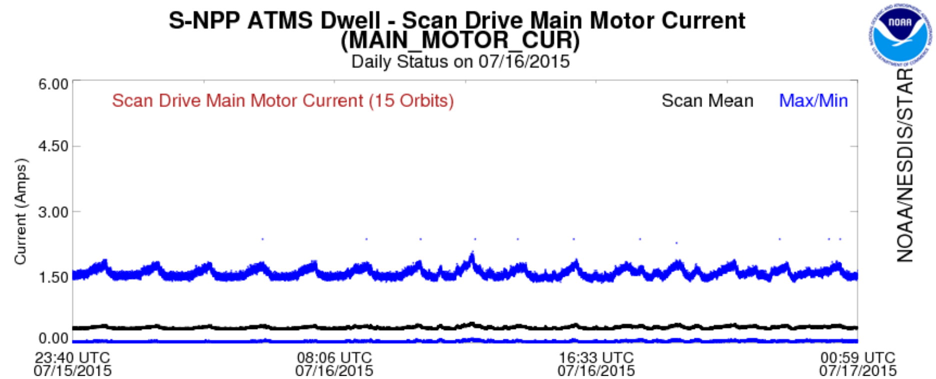


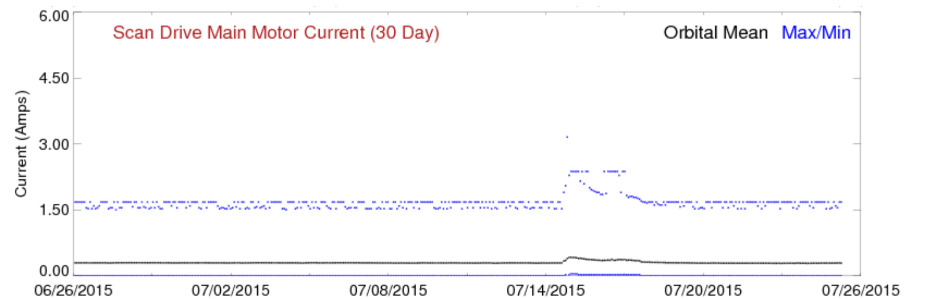


ATMS Scan Drive Main Motor Monitoring

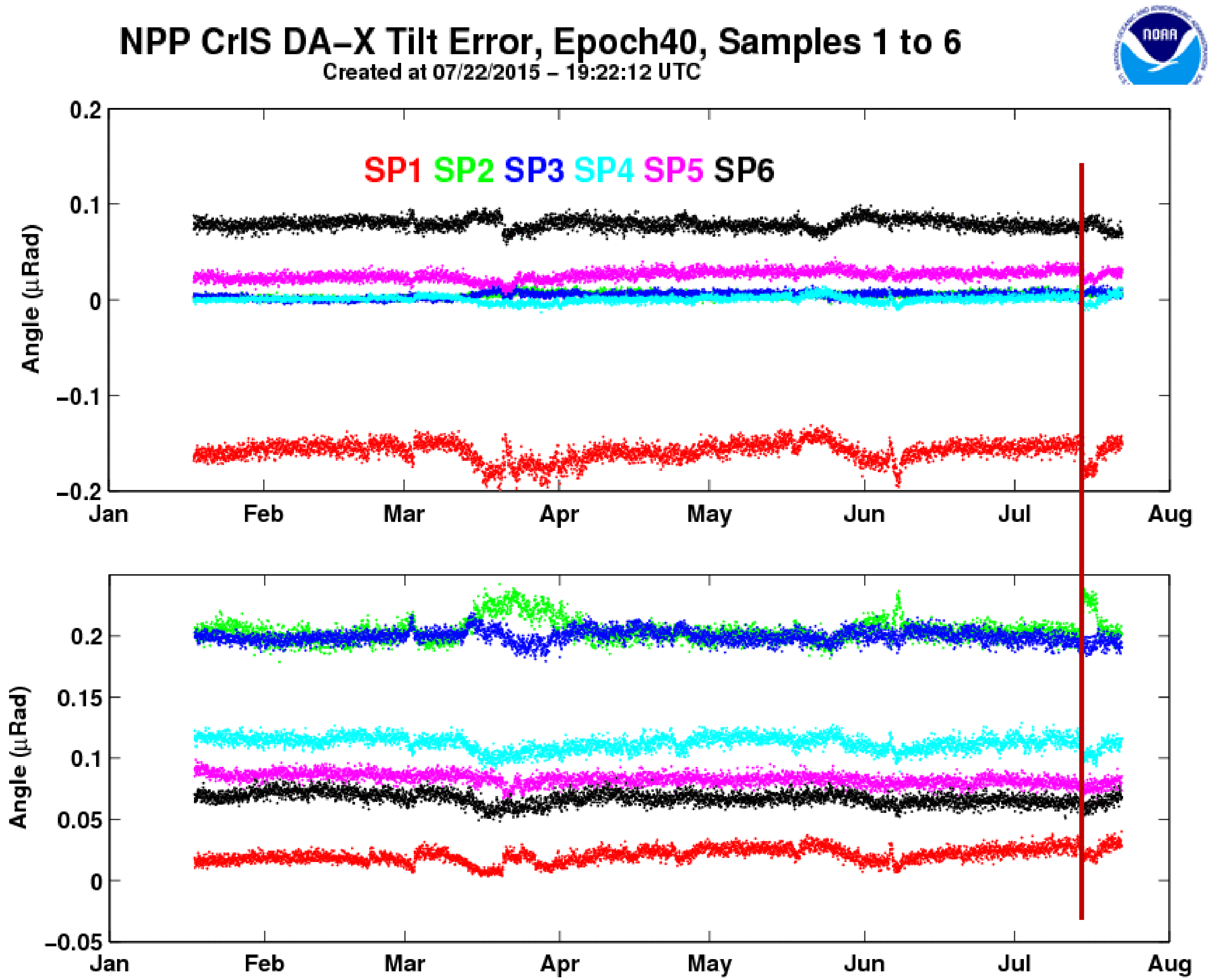








ATMS Scan Drive Main Motor Monitoring



SI Traceable Noise Evaluation Method

Current operational NEΔT calculation method,

$$NE\Delta T_{ch} = \sqrt{\frac{1}{NM}\sum_{i=1}^{N}\sum_{j=1}^{M}\left(\frac{C_{ch}^{w}(i,j)-\overline{C_{ch}^{w}}(i)}{\overline{G_{ch}}(i)}\right)}$$

where C_{ch}^{w} represents the warm count readings at each scan, $\overline{G_{ch}}$ is the averaged calibration gain.

By using overlapping Allan deviation, NEΔT can be calculated via

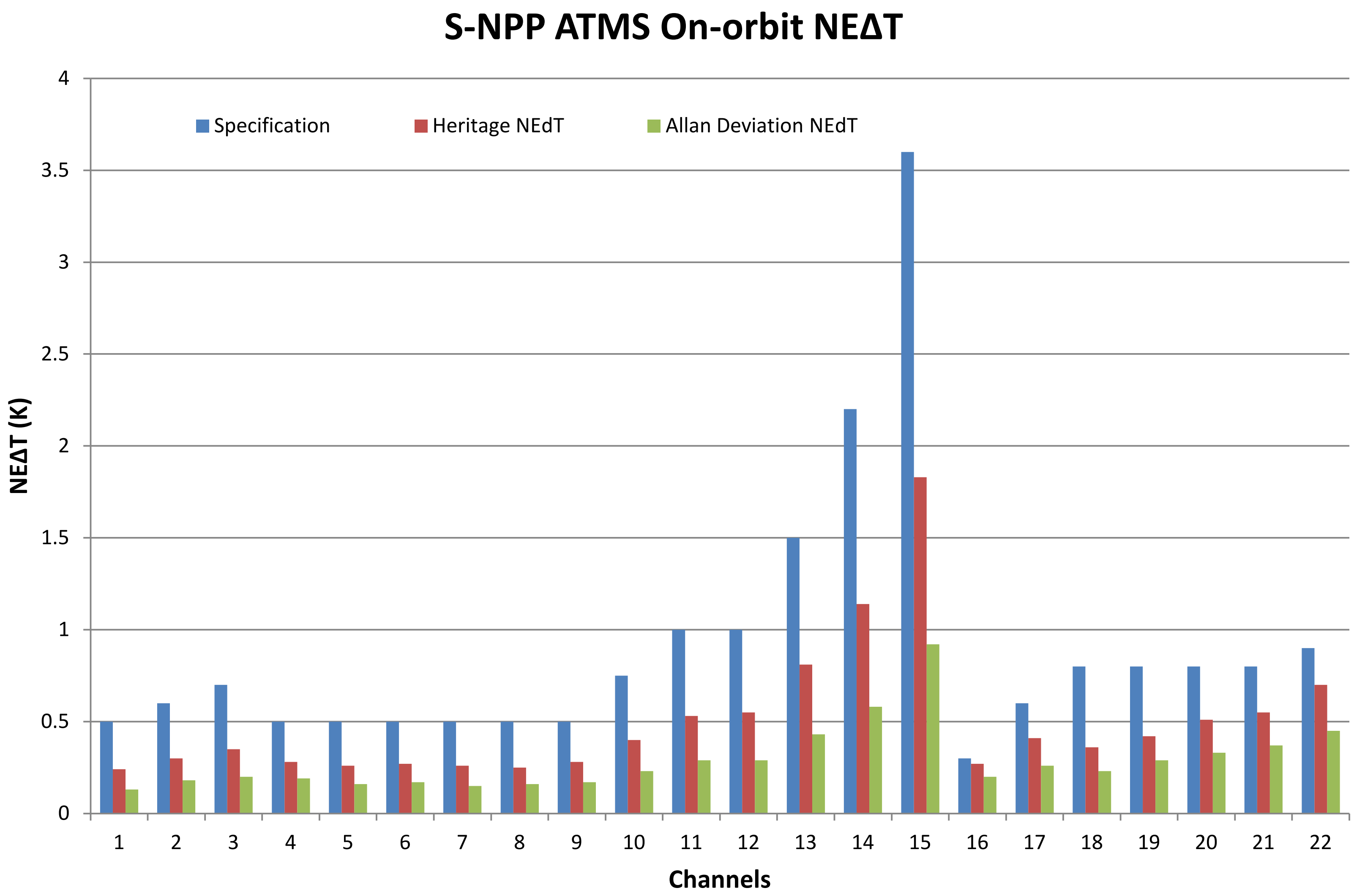
$$NE\Delta T_{ch}^{Allan}(M,m) = \sqrt{\frac{1}{2m^2(M-2m+1)}\sum_{i=1}^{M-2m+1}\sum_{k=i}^{i+m-1}\left[\frac{C_{ch}^{w}(k+m)-C_{ch}^{w}(k)}{\overline{G_{ch}}}\right]^2}$$

when $m = 1$, NEΔT can be calculated using neighborhood Allan deviation

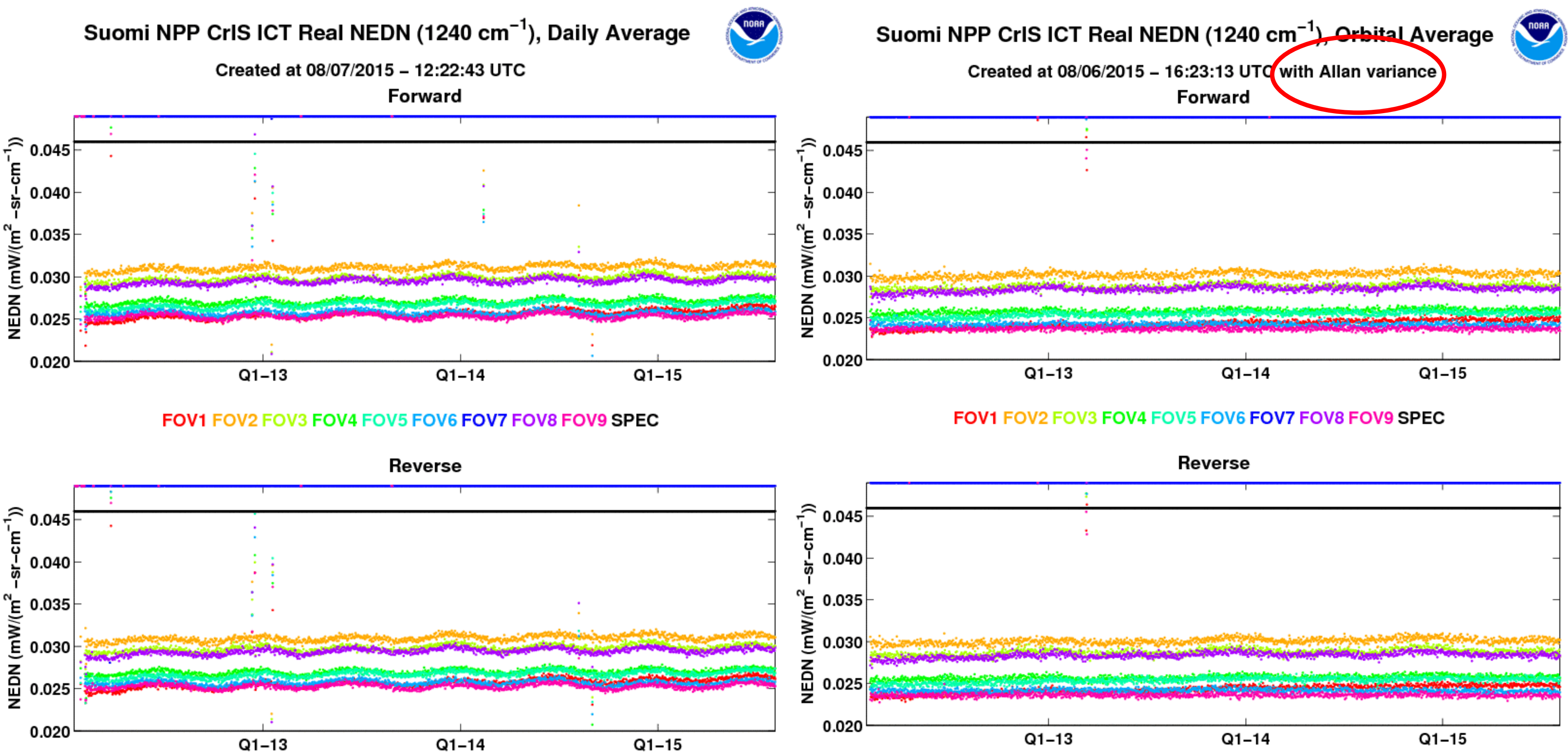
$$NE\Delta T_{ch}^{Allan} = \sqrt{\frac{1}{2(M-1)}\sum_{i=1}^{M-1}\left[\frac{C_{ch}^{w}(i+1)-C_{ch}^{w}(i)}{\overline{G_{ch}}}\right]^2}$$

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., (Accepted).

SI Traceable Noise Evaluation Method



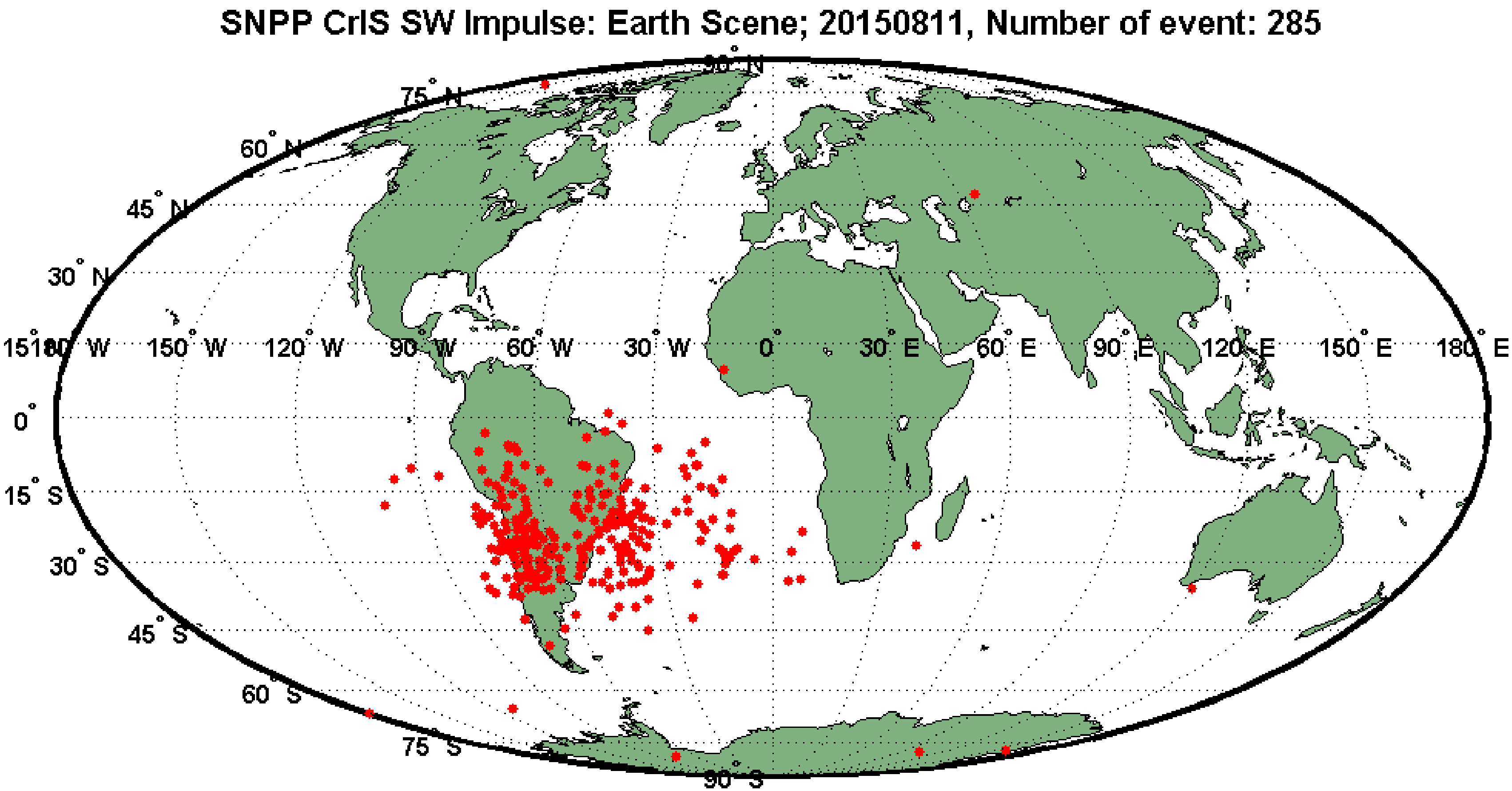
SI Traceable Noise Evaluation Method



Y. Chen, F. Weng and Y. Han, "*SI Traceable Algorithm for Characterizing Hyperspectral Infrared Sounder CrIS Noise*", Applied Optics, (Accepted).

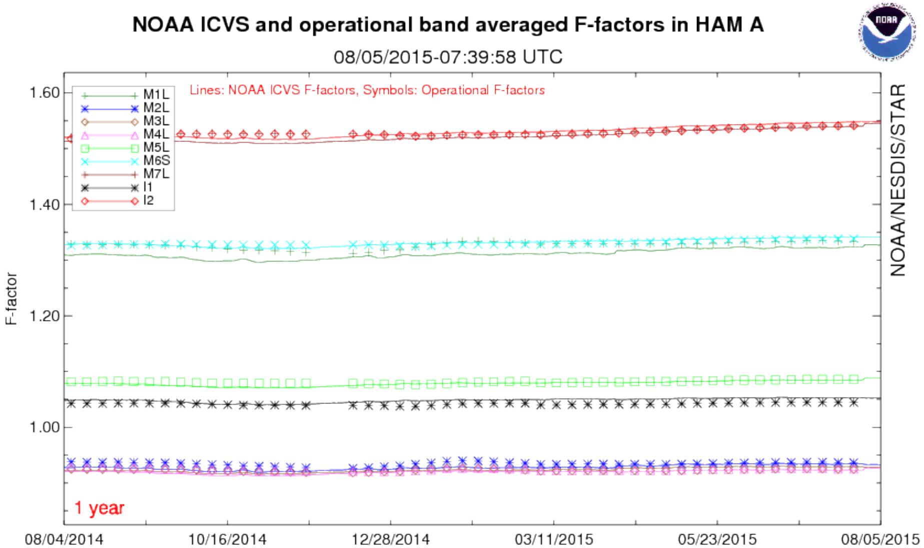
CrIS Full Spectral Resolution (FSR) Trending

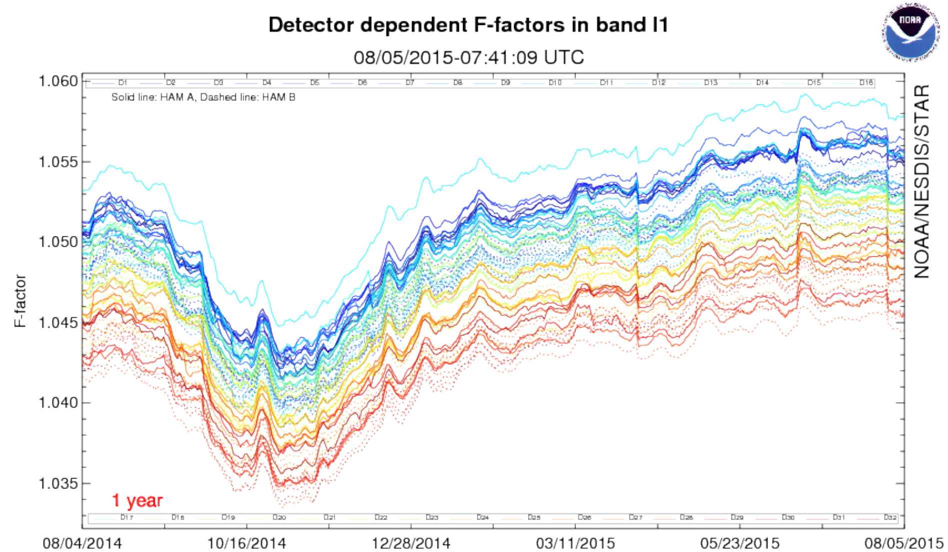
Detect CrIS Shortwave (SW) impulse noise events automatically through long term statistic results

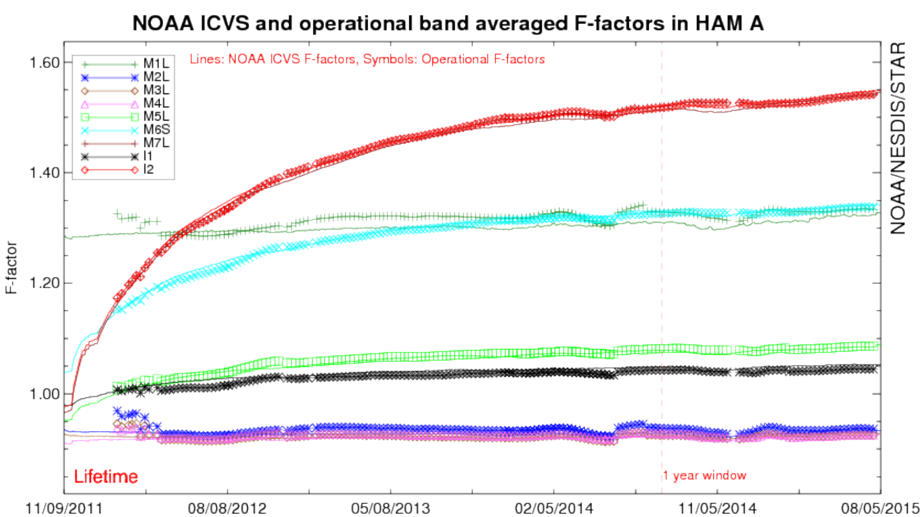


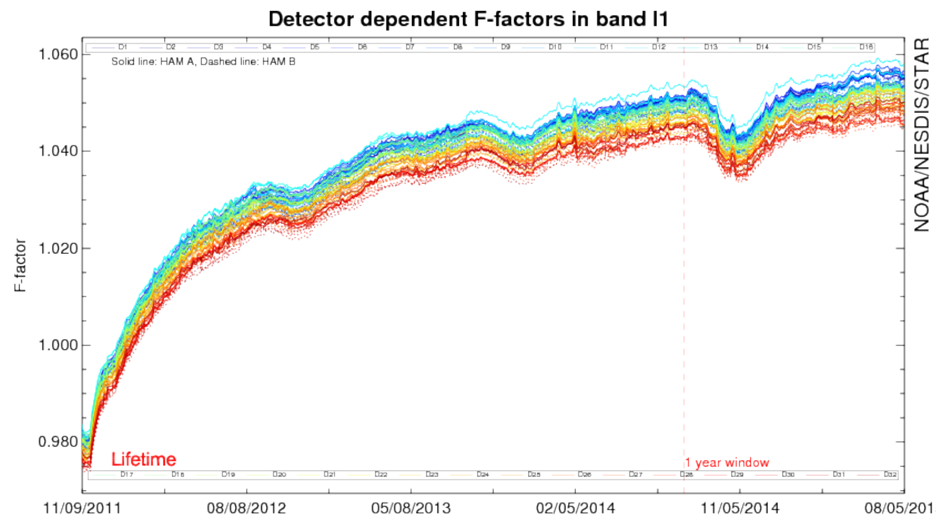
S-NPP VIIRS F-factor Trending

Detector Dependent F-factor plots added to ICVS

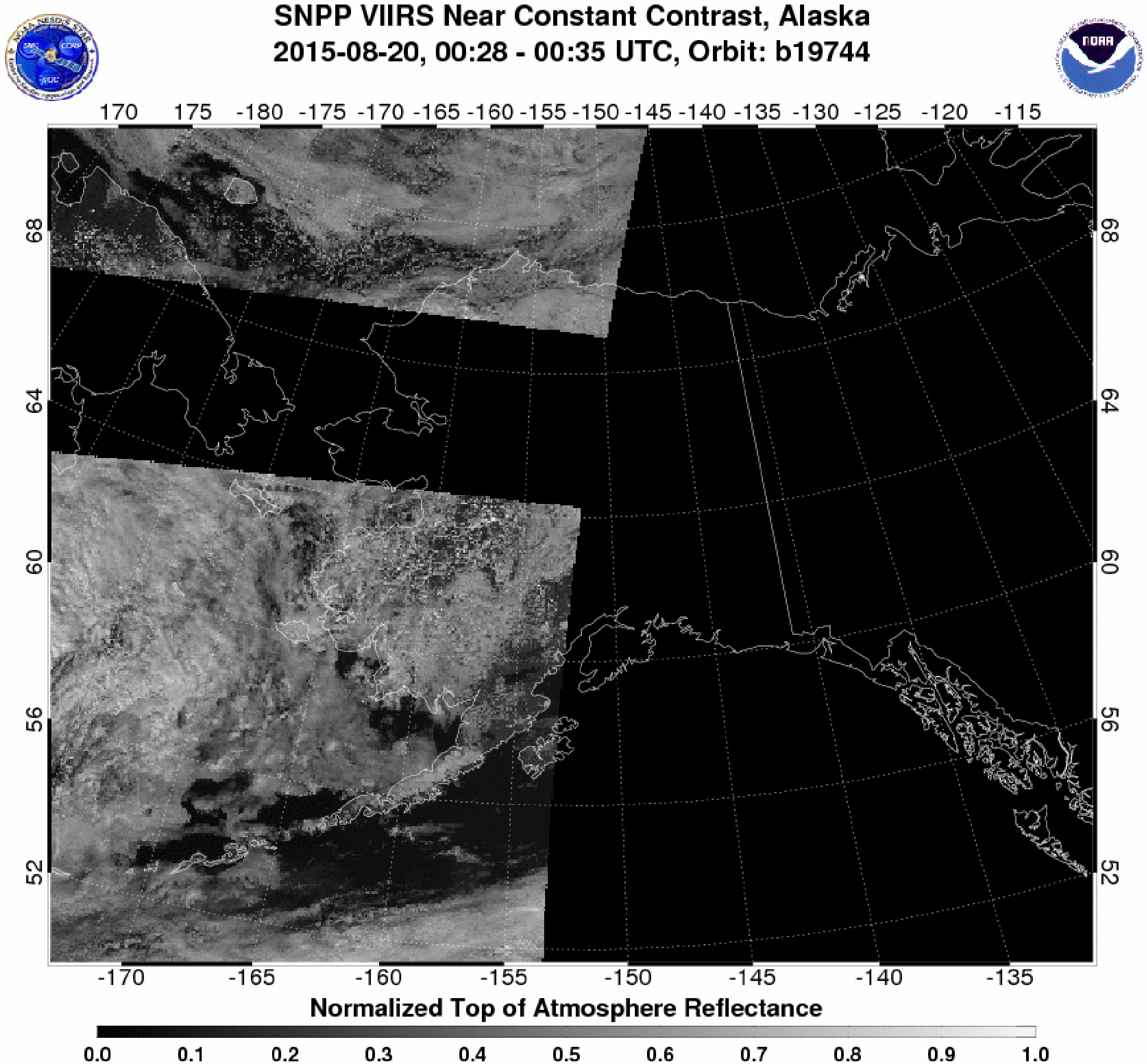








S-NPP VIIRS Imagery Monitoring



STAR ICVS Annual Report

NOAA Technical Report NESDIS XXX

2014-2015 Annual Instrument Performance Review as Monitored by the NESDIS/STAR Integrated Calibration/Validation System

Ninghai Sun, Xin Jin, Taeyoung Choi, Lawrence E. Flynn, Ding Liang, Chengzhi Zou, Greg Krasowski, and Fuzhong Weng

Washington, DC
August 2015,

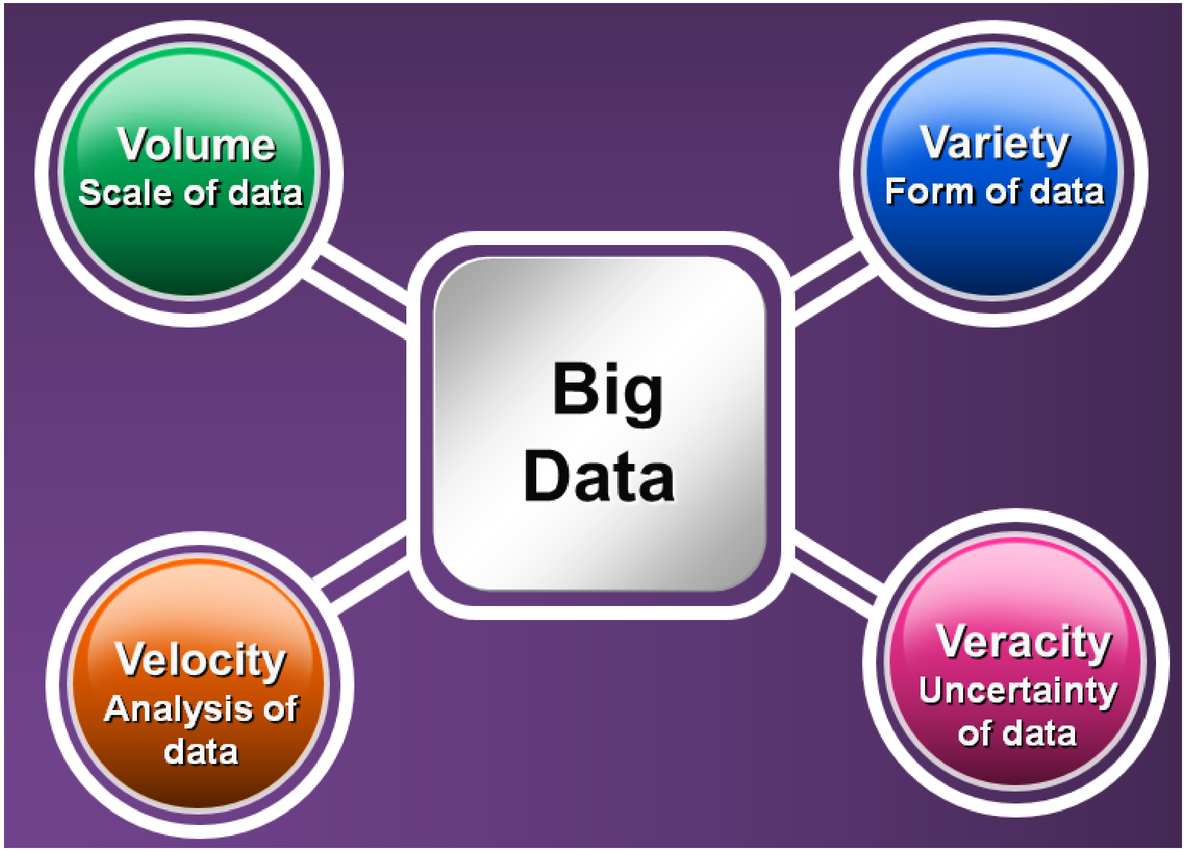
U.S. DEPARTMENT OF COMMERCE
Penny Pritzker, Secretary
National Oceanic and Atmospheric Administration
Dr. Kathryn Sullivan, NOAA Administrator
National Environmental Satellite, Data, and Information Service
Stephen Volz, Assistant Administrator

- Instrument overview including scan geometry
- Instrument health status summary
- Annual instrument anomaly event record
- Include NOAA-19/NOAA-18/Metop-A/Metop-B AMSU-A and MHS, S-NPP ATMS, CrIS, VIIRS, OMPS

Big Data Analysis on ICVS

Big data exceeds the reach of commonly used hardware environments and software tools to capture, manage, and process it within a tolerable elapsed time for its user population (*Merv Adrian, Teradata Magazine, 2011*)

Big data refers to data sets whose size is beyond the ability of typical database software tools to capture, store, manage and analyze (*McKinsey Global Institute, 2011*)



Big Data Analysis on ICVS

1. **Data collection and storage**
   - Collect data from different sources
   - Store data in DB system
   - Verify datasets

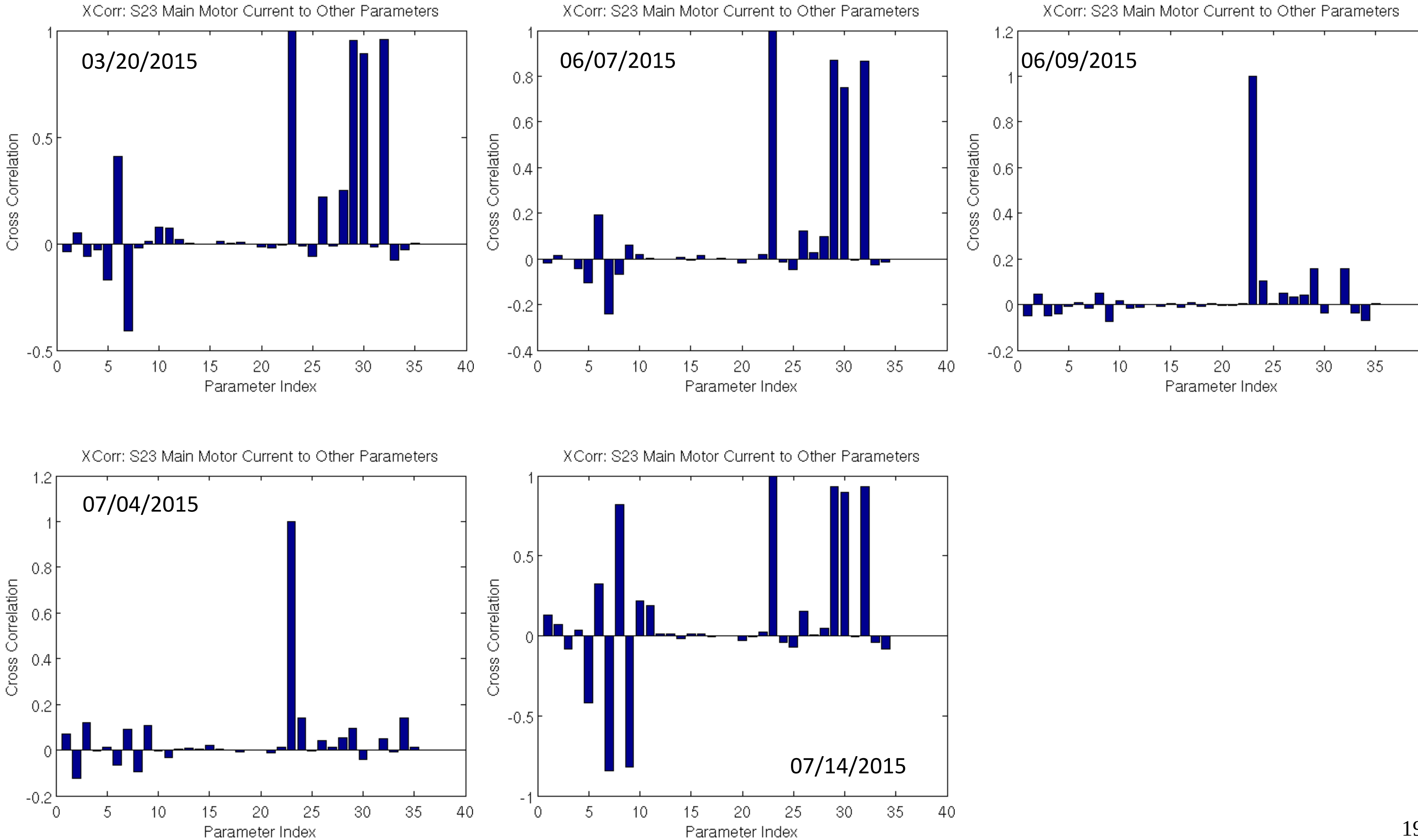
2. **Data import/Pre-processing**
   - Import different DB to centralized cloud storage
   - Data clean, conversion, and pre-processing

3. **Data statistic analysis**
   - Perform simple statistic analysis
   - Extensive computation & I/O requirements

4. **Data mining/prediction**
   - Apply data mining methods for advanced analysis
   - Build prediction model

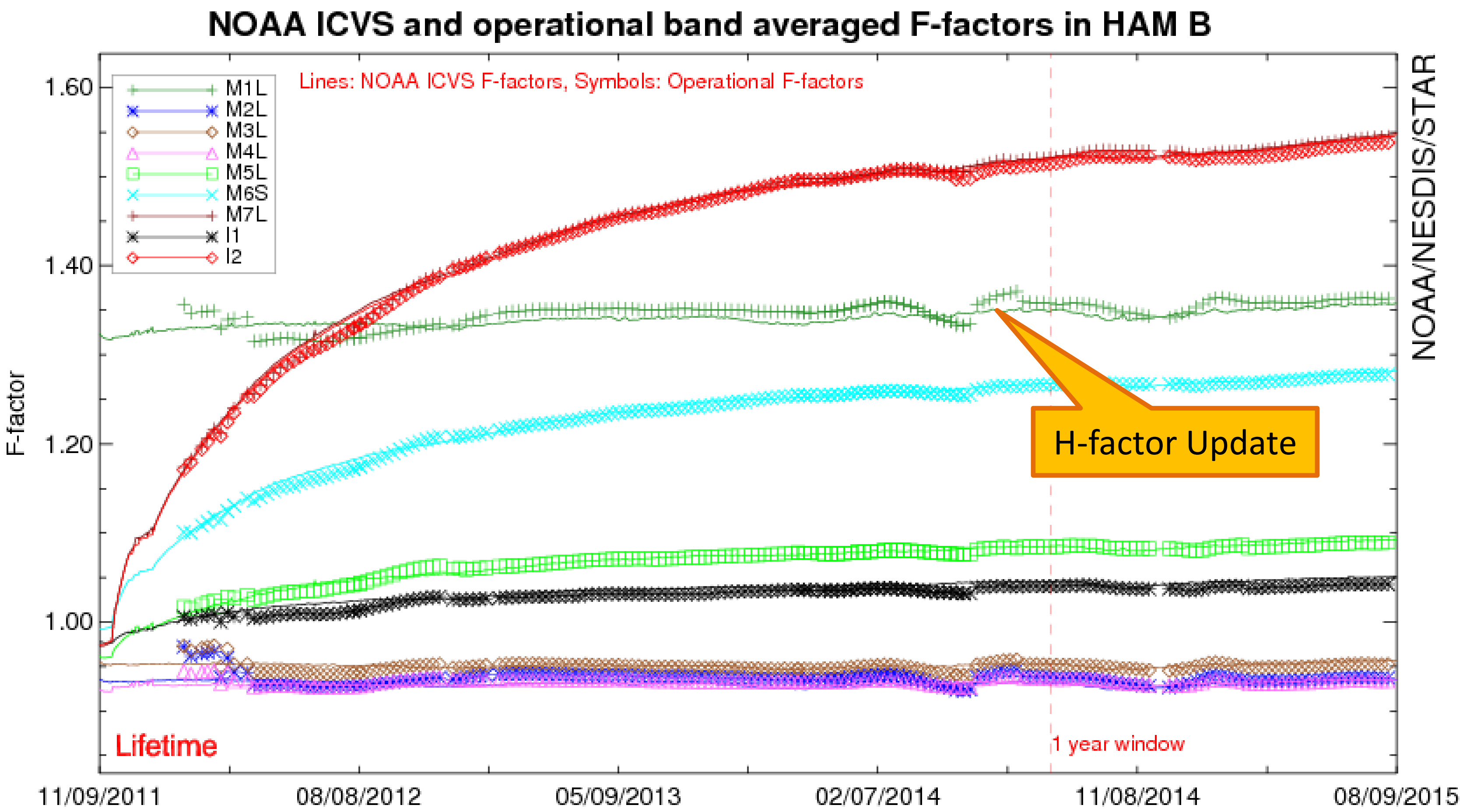
Big Data Analysis on ICVS

Data Statistic and Analysis for ATMS scan drive main motor current anomaly

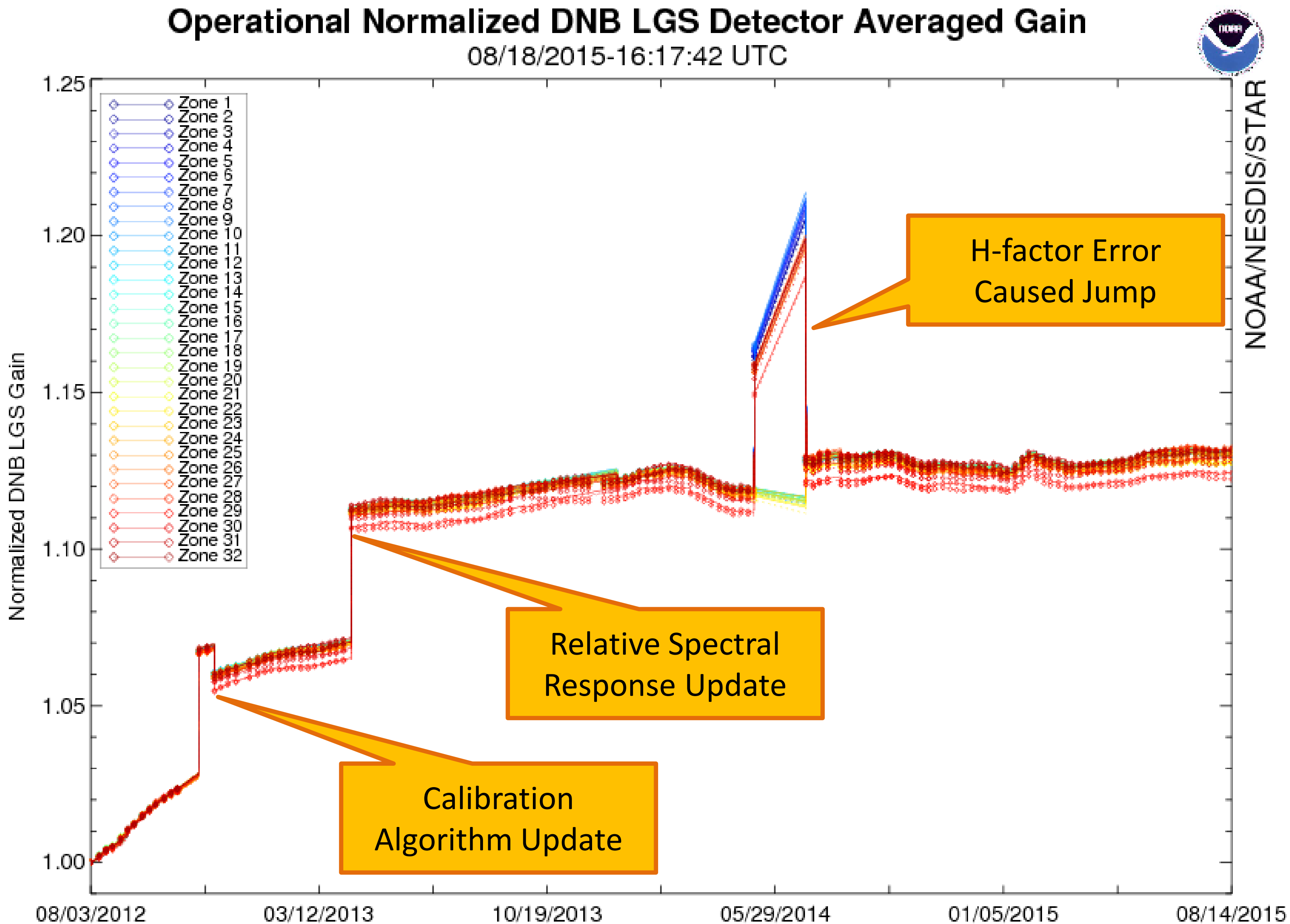


Mission Life-cycle Reprocessing

- Ensure the consistence of data quality with improved calibration algorithm
- Fundamental for reference environmental data record generation



Mission Life-cycle Reprocessing



Summary

- STAR ICVS is not only just instrument status monitoring system but also a calibration testing and quality evaluation system
- STAR ICVS keeps providing near real time and long term trending of NOAA instrument and automatically sending warning messages when anomaly is detected
- STAR ICVS will keep supporting GRAVITE ICVS-Lite 24/7 operational missions
- New functions and parameters are being added to ICVS to provide users better understanding of NOAA satellites/instruments operational status and support on calibration activities, as well as improving user experience by updating STAR ICVS website
- STAR ICVS has supported JPSS-1 pre-launch calibration activities and is ready for JPSS-1 post-launch instrument monitoring and calibration activities

Path Forward

- Keep developing STAR ICVS Big Data analysis enterprise system
  - Collect satellite observation and derived environmental data to increase ICVS Big Data analysis database volume
  - Start data importing and pre-processing to improve Big Data analysis efficiency
  - Begin initial statistic analysis on multi-dimensional database
  - Attempt to apply different data mining technical for advanced data analysis for different users
- Plan on S-NPP mission life-cycle reprocessing for reference environmental data record generation
- VIIRS DNB parameter trending
- Instrument geolocation accuracy trending