JPSS DPA Program Planning Meeting
CrIS SDR Team

September 18, 2012

Outlines

- Team Membership
- FY-12 Accomplishments
- Scientific Advancements
- Issues, Challenges, Setbacks
- Changes in Strategy due to funding constraints
- FY-13 Schedule and Milestones
- Path Forward (FY-13 thru FY-17)
- Budgetary Needs (FY-13 thru FY-17)
- Summary

Team Members' Roles & Responsibilities

PI Name	Organization	Funding Agency	FY13 Task
Yong Han	NOAA/NESDIS/STAR	NJO	Team lead; support NPP/J1 Calval
Deron Scott	SDL	NJO	Support NPP/J1 Calval
Hank Revercomb	UW	NJO	Support NPP/J1 Calval
Larrabee Strow	UMBC	NJO	Support NPP/J1 Calval
Dan Mooney	MIT/LL	NJO	Support NPP/J1 Calval

- STAR tasks are listed in the next slide
- Tasks of non-STAR members will be submitted through grant proposals and annual contract awards

Exelis(ITT), NGAS, Raytheon and NASA are team members; due to different funding paths, they are not listed in the table.

FY13 STAR Tasks

Task	Task Description
1	CRIS Team Management and Coordination
2	Update CRIS Algorithm Theoretical Basis Algorithm Document (ATBD)
3	CrIS SDR Algorithm Development, Refinement and Maintenance
4	Radiometric Accuracy Assessment and Monitoring
5	Spectral Accuracy Assessment and Monitoring
6	Radiance Residual Examination of CrIMSS Retrieval Algorithm
7	Geolocation Accuracy Assessment and Monitoring
8	J1 Calibration of the CrIS FM-2 Unit
9	Software Development for Processing Full Resolution Data
10	STAR Science CrIS SDR Software Development
11	CrIS SDR Backproduction (or RDR Generator)
12	SDR Product Reprocessing at SNO Locations
13	Create the CrIS SDR Product User's Guide
14	Engineering packet preparation and upload
15	NGAS CRIS SDR Science Transition

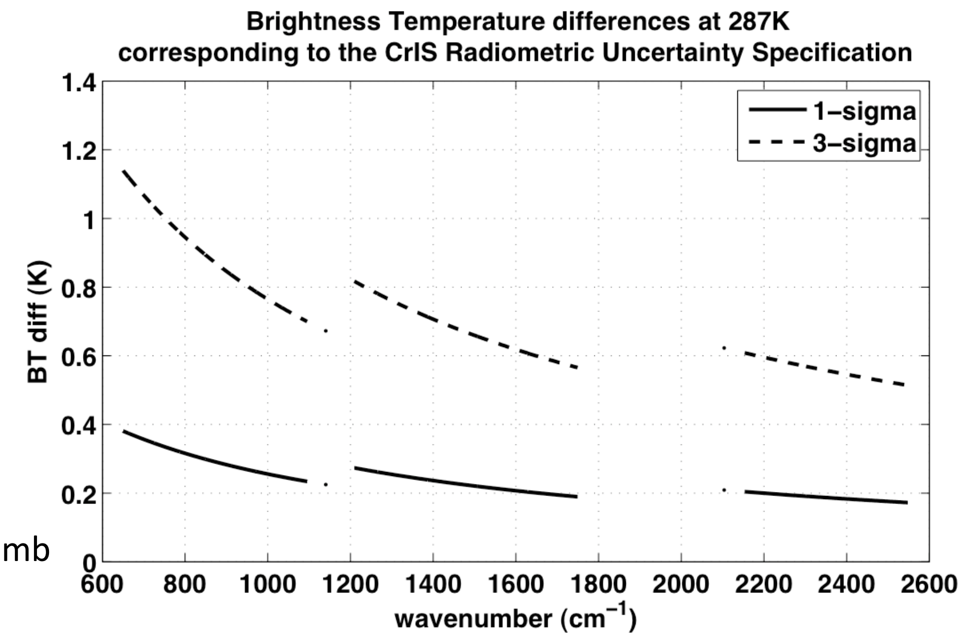
FY12 Accomplishment

NPP CrIS Sensor Data Record (SDR) Requirements

Requirements

Band	Spectral range (cm^{-1})	N. of chan.	Resolution (cm^{-1})	FORs per Scan	FOVs per FOR	NEdN@287K $mW/m^2/sr/cm^{-1}$	Radiance Uncertainty (%)	Spectral uncertainty ppm	Geolocation uncertainty km
LW	650-1095	713	0.625	30	9	0.14	0.45	10	1.5
MW	1210-1750	433	1.25	30	9	0.06	0.58	10	1.5
SW	2155-2550	159	2.5	30	9	0.007	0.77	10	1.5

CrIS SDR spectra are un-apodized



CrIS Radiometric Uncertainty spec, expressed as 1 and 3 sigma brightness temperature differences

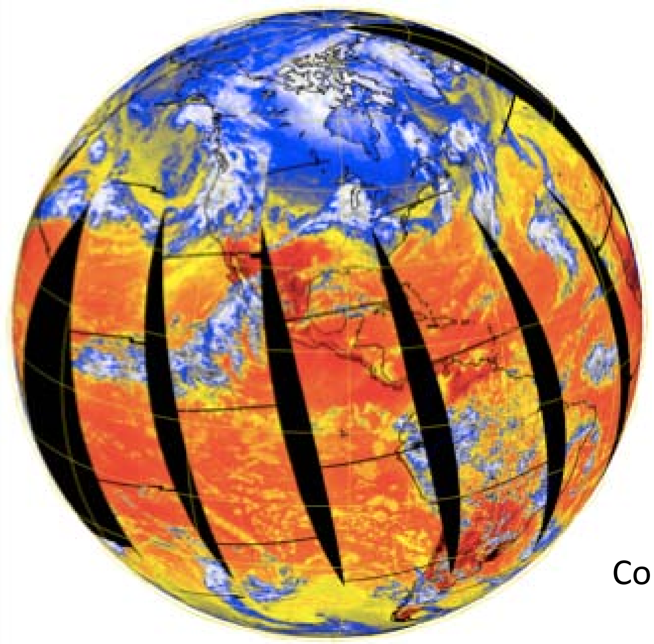
Courtesy of Hank Revercomb

FY-12 Accomplishments (1/5)

- First light image and IDPS code fix
  - CrIS was powered up on Jan. 18. First light CrIS SDR image was created by UW/UMBC CCAST on Jan, 25th, at the time when there was no valid Ops SDR produced by IDPS; it indicated problems in the IDPS code
  - IDPS code bugs were found and fixed; IDPS started producing SDR product on April 2 (Build MX5.3)
- Completion of Early-Orbit-Checkout (EOC)
  - The team actively supported and participated in the EOC activities
  - Results: calibration parameter updates in Engineering packet V32, including PGA gain settings and bit trim masks, which was uploaded on Feb. 8.
- Full spectral resolution RDRs (0.8 cm maxOPD for all bands) were collected on February 22nd (~18 hours). This allowed spectral calibration of MW and SW bands and retrievals of trace gases such as CO.
- Sweep direction bias (striping) was found and fixed. The root cause is the corrupted on-board FIR digital filter. It is replaced by a new filter uploaded on April 18th.

First Light Image

CCAST first light image indicates the IDPS CrIS software problem



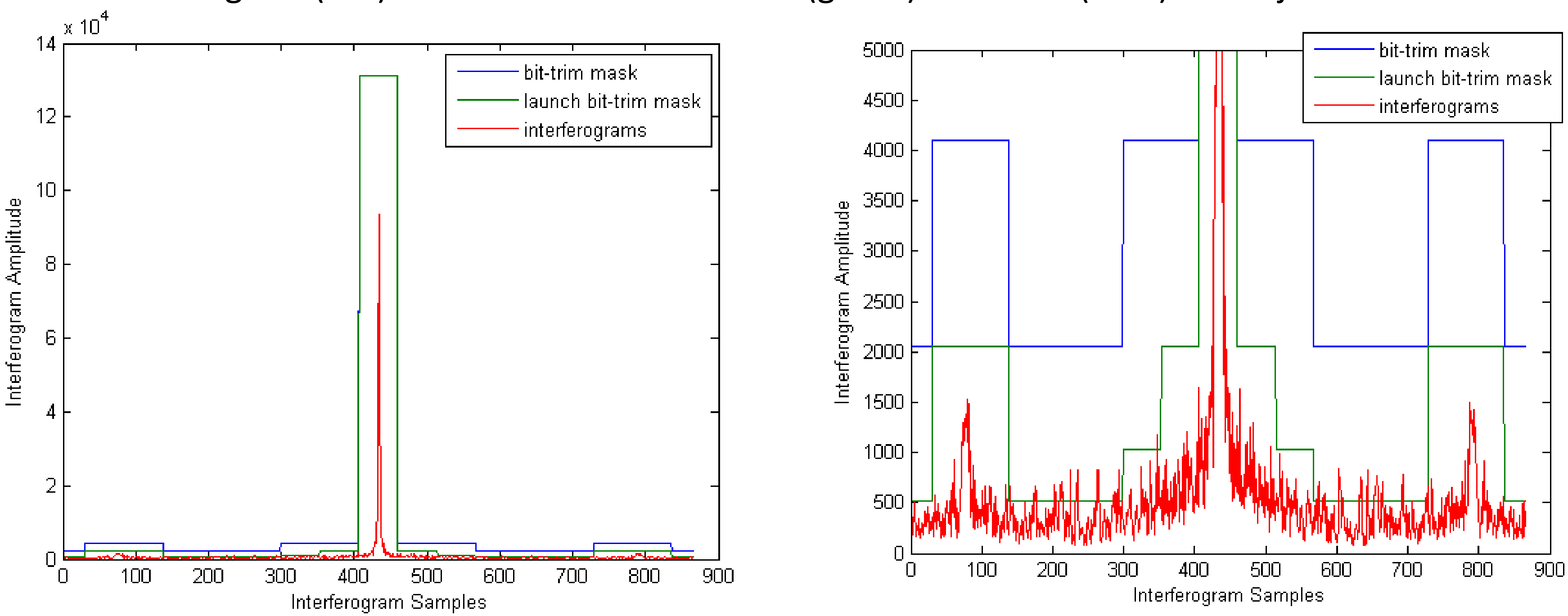
Courtesy of Hank Revercomb

First light image, 900 cm^{-1} BT
20-Jan-2012 12:54 to 23:57 UTC
From CCAST SDR processing system, UW/UMBC

Bit-Trim Mask Adjustment

Bit trim masks are used to compress the raw data rates saving 30% of downlinked data volume.

LW interferogram (red) and bit trim masks before (green) and after (blue) the adjustment



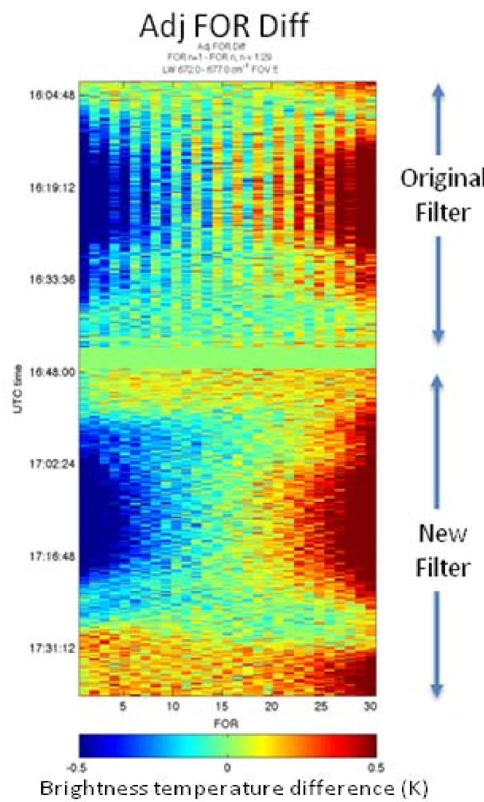
Courtesy of Deron Scott

The bit trim mask tables, as well as electrical gain, were adjusted to avoid signal saturation

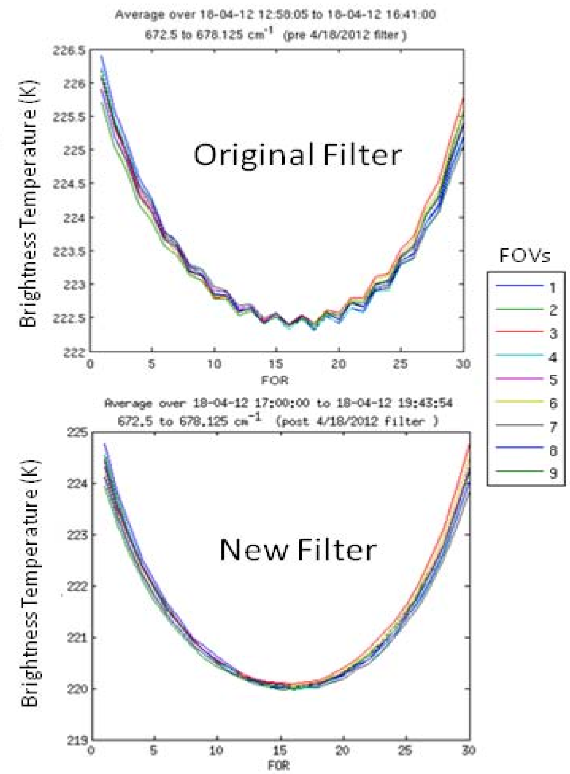
On-board FIR Digital Filter Change

- In-orbit data analysis revealed sweep direction bias (~0.1 K).
- Diagnostic data analysis, simulations and ground testing indicated the root cause is the defective on-board FIR digital filter.

The bias was eliminated by uploading an improved filter.



Courtesy of Han Revercomb



Courtesy of Dan Mooney

FY-12 Accomplishments (2/5)

- Spectral (frequency) calibration and validation
  - Work was performed to evaluate the stability of the metrology laser and Neon lamp and tune the spectral calibration modules of the SDR algorithm and code
  - As a result of the efforts, spectral accuracy was significantly improved after the ILS parameters were updated and included in EngPkt V33
- Radiometric calibration and validation
  - Work was performed to evaluate and tune the radiometric calibration modules of the SDR algorithm and code, including the nonlinearity correction module
  - As a result of the efforts, radiometric accuracy was significantly improved after the nonlinearity correction coefficients were updated and included in EngPkt V33

Engineering packet V33 with updated ILS parameters and nonlinearity correction coefficients was uploaded on April 11th

ILS Parameter Adjustment for Spectral Calibration

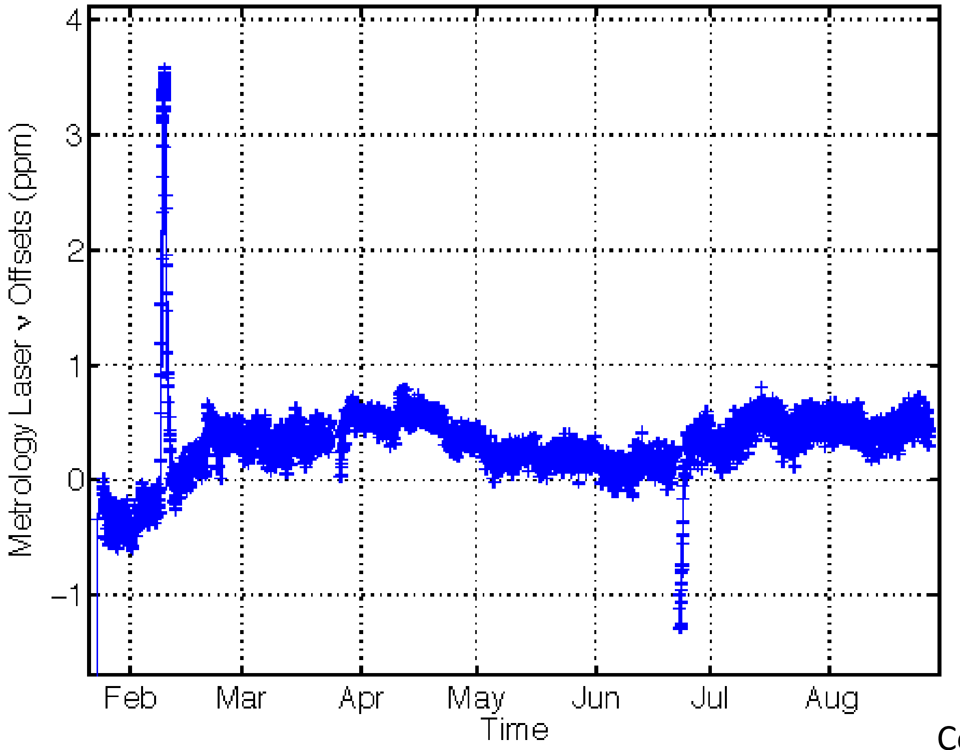
- Neon bulb wavelength and detector focal plane position parameters are key Instrument-Line-Shape (ILS) parameters for spectral calibration.
- Methods
  - Adjust detector positions until all 9 detectors on each focal plane exhibit the same frequencies in observed radiance (FOV overlay).
  - Adjust Neon bulb frequency until observed upwelling radiances agree with computed radiances via cross-correlation of Observation with Calculations.

Results:

On-orbit spectral accuracy achieved: ~1ppm

Specification: 10 ppm.

Excellent Neon/Metrology Laser Stability



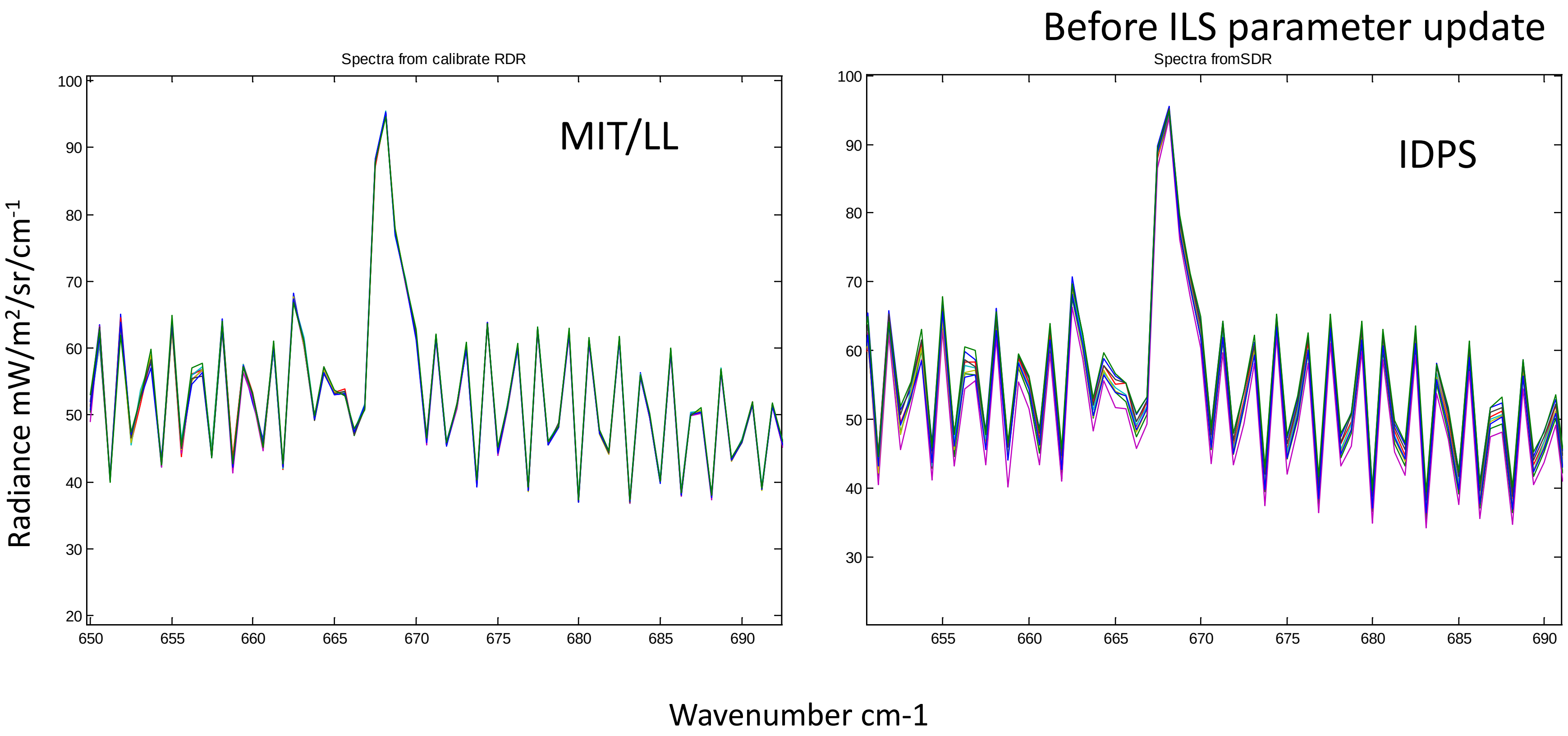
Courtesy of Larrabee Strow

Spikes are due to known instrument testing or spacecraft shutdowns

5 month Metrology laser stability: 1 ppm

SDR comparisons between IDPS and Science Codes Indicated IDPS ILS Correction Was Not Optimal

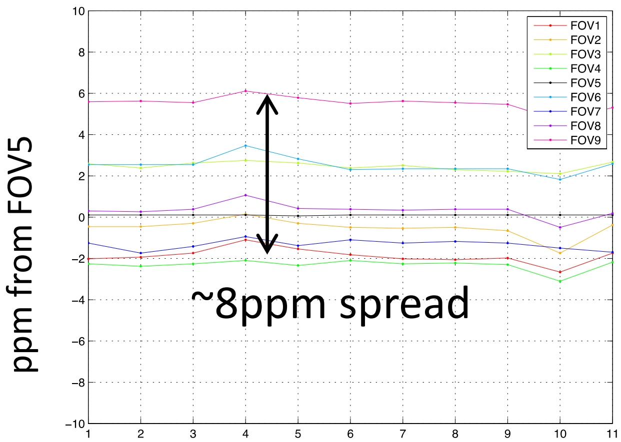
ILS corrected in both cases
9 FOVs are represented by different colored curves



Courtesy of Dan Mooney

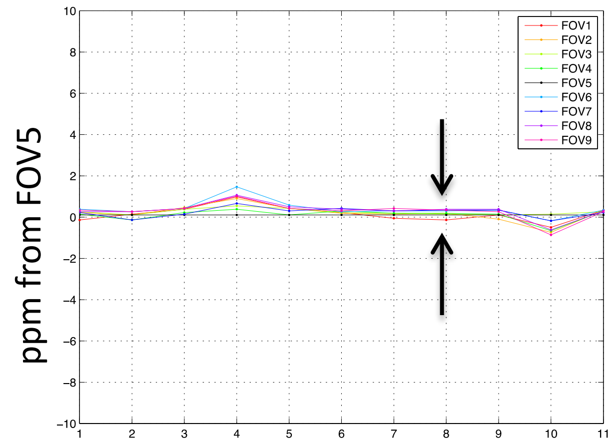
LW Inter-FOV Spectral Calibration Analysis

ADL with pre-launch ILS parameters



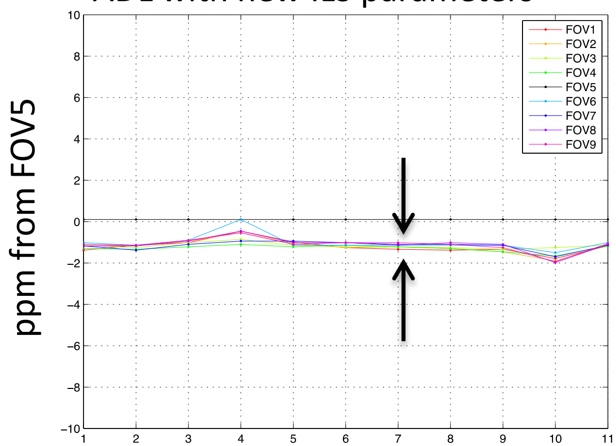
Before

CCAST with new ILS parameters, derived using CCAST



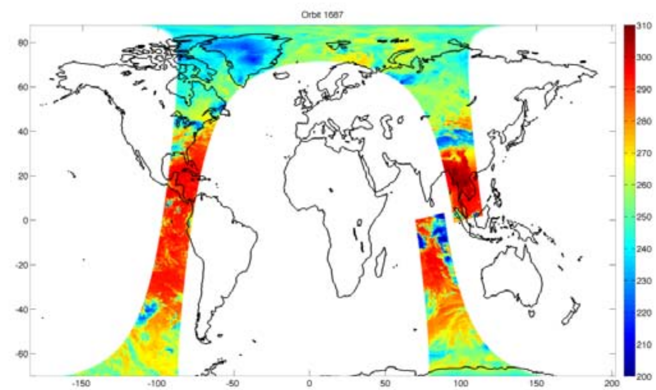
After

ADL with new ILS parameters



After

Orbit 01687
Feb 24th 2012



Courtesy of Han Revercomb

Main spread removed, but
all FOVs ~1.5 ppm off from FOV5

The new ILS parameters have greatly improved the spectral calibration.

Nonlinearity Correction Coefficient Adjustment for Radiometric Calibration

Nonlinearity correction coefficient (a_2) is used in the factor ($1-2a_2V_{int}$) to scale the spectrum for nonlinearity correction for each detector.

Some LW and MW detectors have significant nonlinearity.

Method:

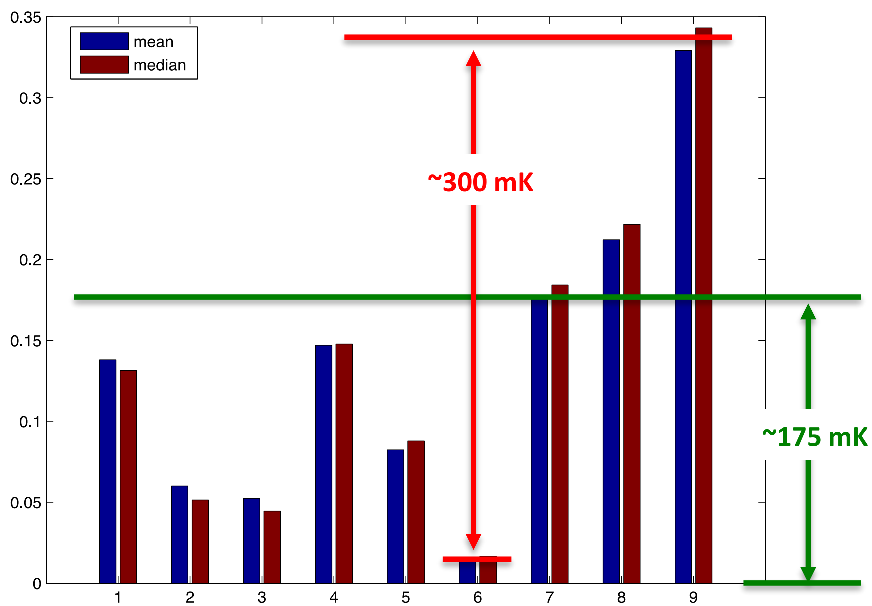
- Analysis of in-orbit Diagnostic Mode data.
- Further a_2 adjustments using normal mode Earth scene observations.
- Verify/assess results with SNO and double obs-calc comparisons with IASI and AIRS

Results:

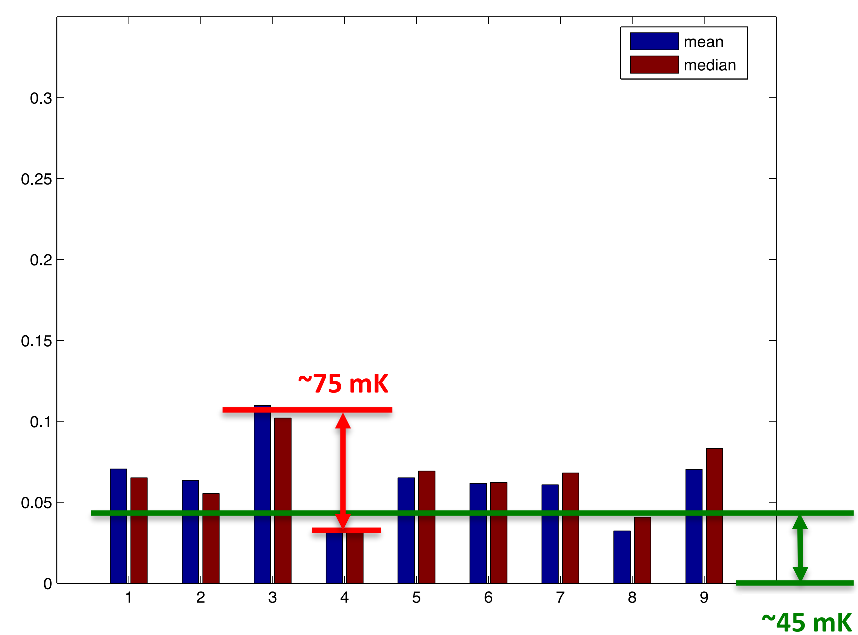
- FOV-to-FOV radiometric performances approach uniformity.
- Radiometric uncertainties are significantly reduced.

CrIS-AIRS before and after a_2 Updates
LW Band

Before a_2 updates



After a_2 updates



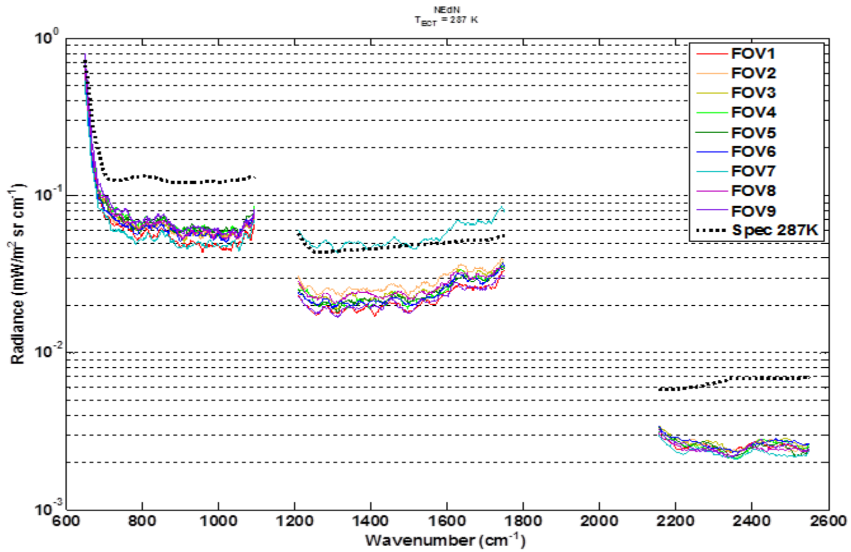
Courtesy of Han Revercomb

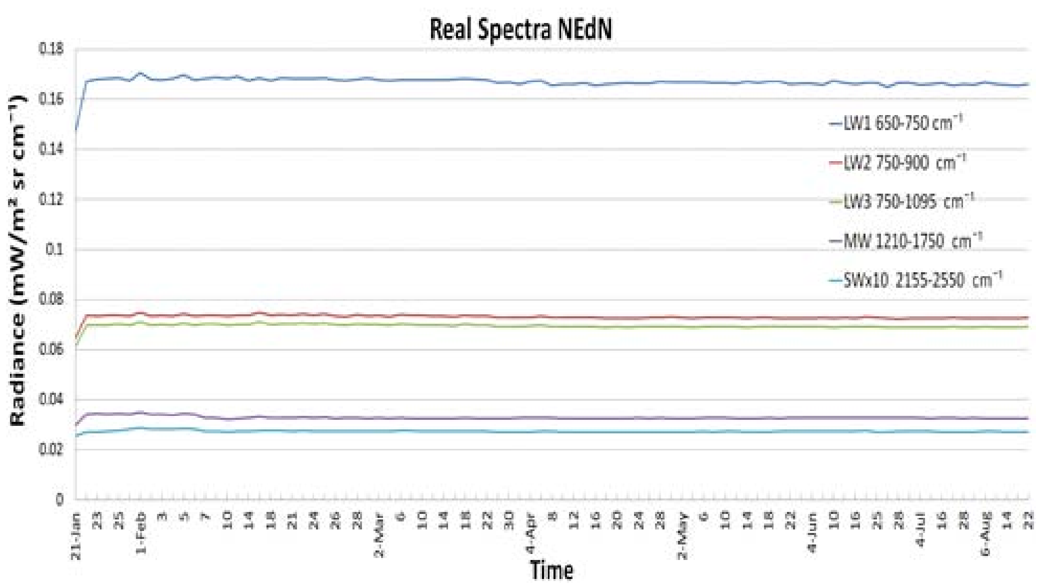
FOV-to-FOV difference is reduced from 300 mK to 75 mK.
Radiometric uncertainty is reduced from 175 mK to 45 mK .

FY-12 Accomplishments (3/5)

- Instrument noise characterization
  - NEDN analysis on ICT, DS and ES spectra
  - PCA analysis of correlated and uncorrelated noise
  - Results: demostrate much better instrument noise than the specification
- SDR uncertainty assessed with inter-satellite/sensor comparison
  - CrIS compared with IASI and AIRS (SNO, DD using RTM or GEO as transition agency)
  - CrIS compared with VIIRS and GEO-sensors
  - Results: ~0.1-0.2 K differences between these sensors (Hamming apodized CrIS spectra)
- SDR uncertainty assessed with RT models
  - Bias between CrIS observed and RTM simulated radiances
  - FOV-to-FOV radiometric uniformity analysis
  - Results: CrIS vs RTM biases are similar to AIRS and IASI; the biases are dominated by the uncertainties from RTM and its input profiles describing the atmospheric and Earth surface state

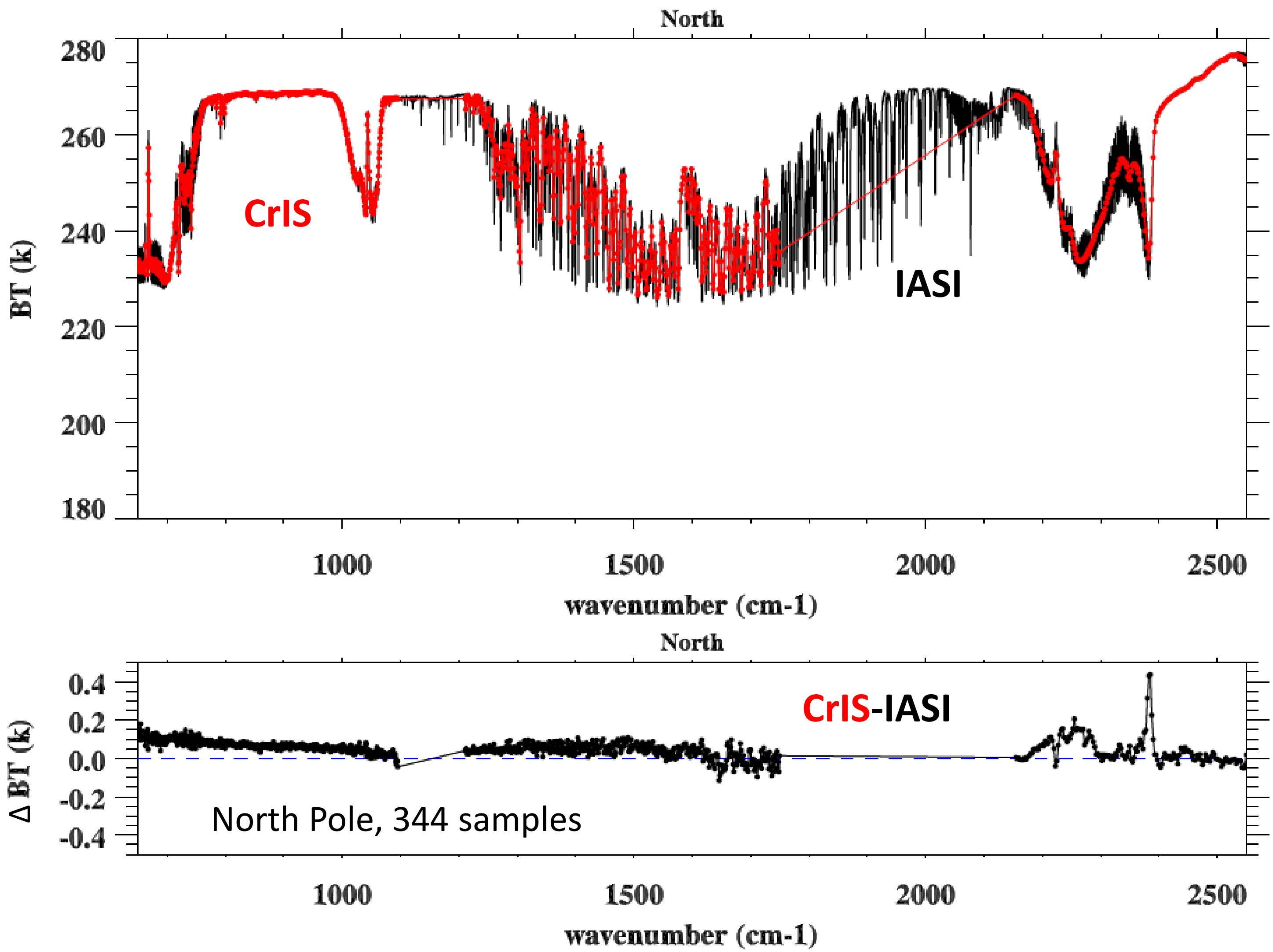
NEdN and Its Stability



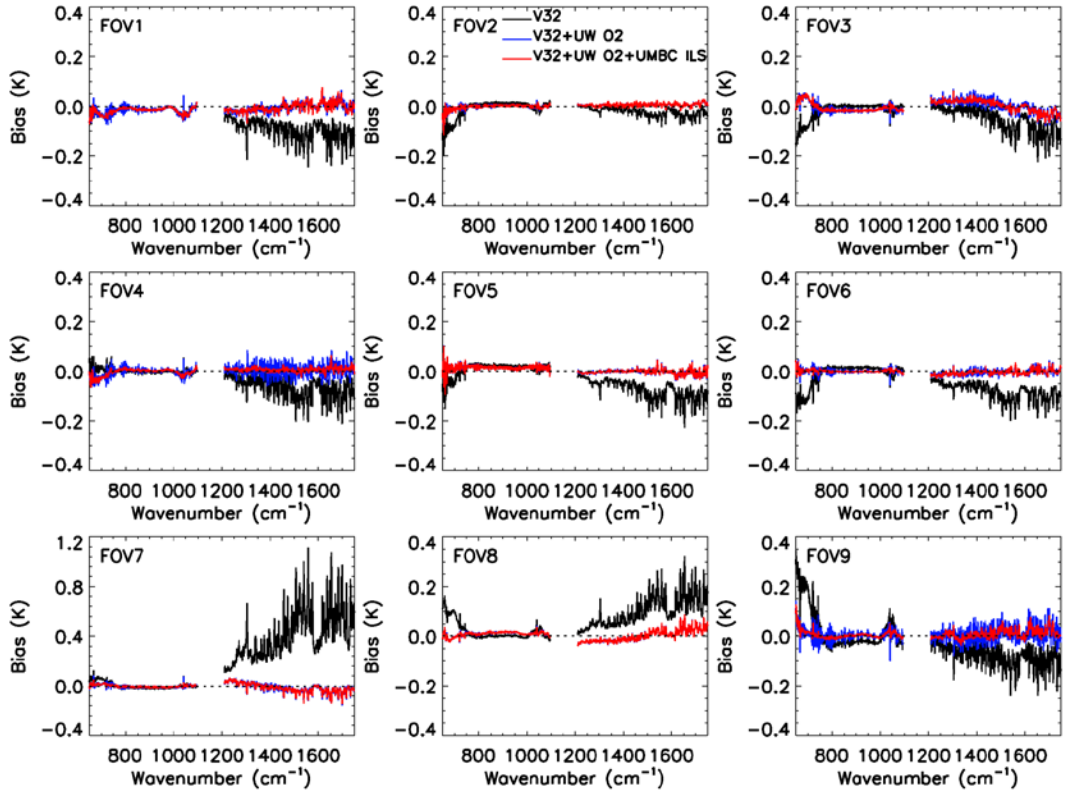


Courtesy of Deron Scott

SNO Radiance Difference between CrIS and IASI



Radiance Bias Assessed with RTM after Nonlinearity and ILS Parameter Adjustments



Black: before a2 and ILS parameter updates

Blue: after a2 updates but before ILS parameter change

Red: after both a2 and ILS parameter updates

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

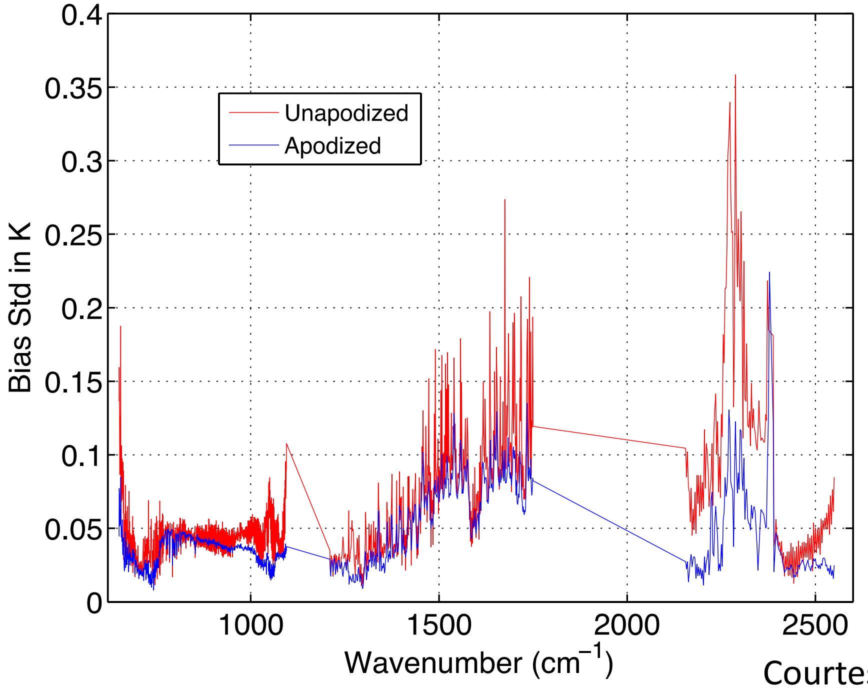
CRTM – Community Radiative Transfer Model used at Numerical Weather Prediction (NWP) centers

Total clear sky observation points ~400000

The achieved uniformity of the spectral and radiometric calibration cross the 9 FOVs allows the NWP centers to assimilate more radiance data

Radiance Bias Assessed with RTM after Nonlinearity and ILS Parameter Adjustments

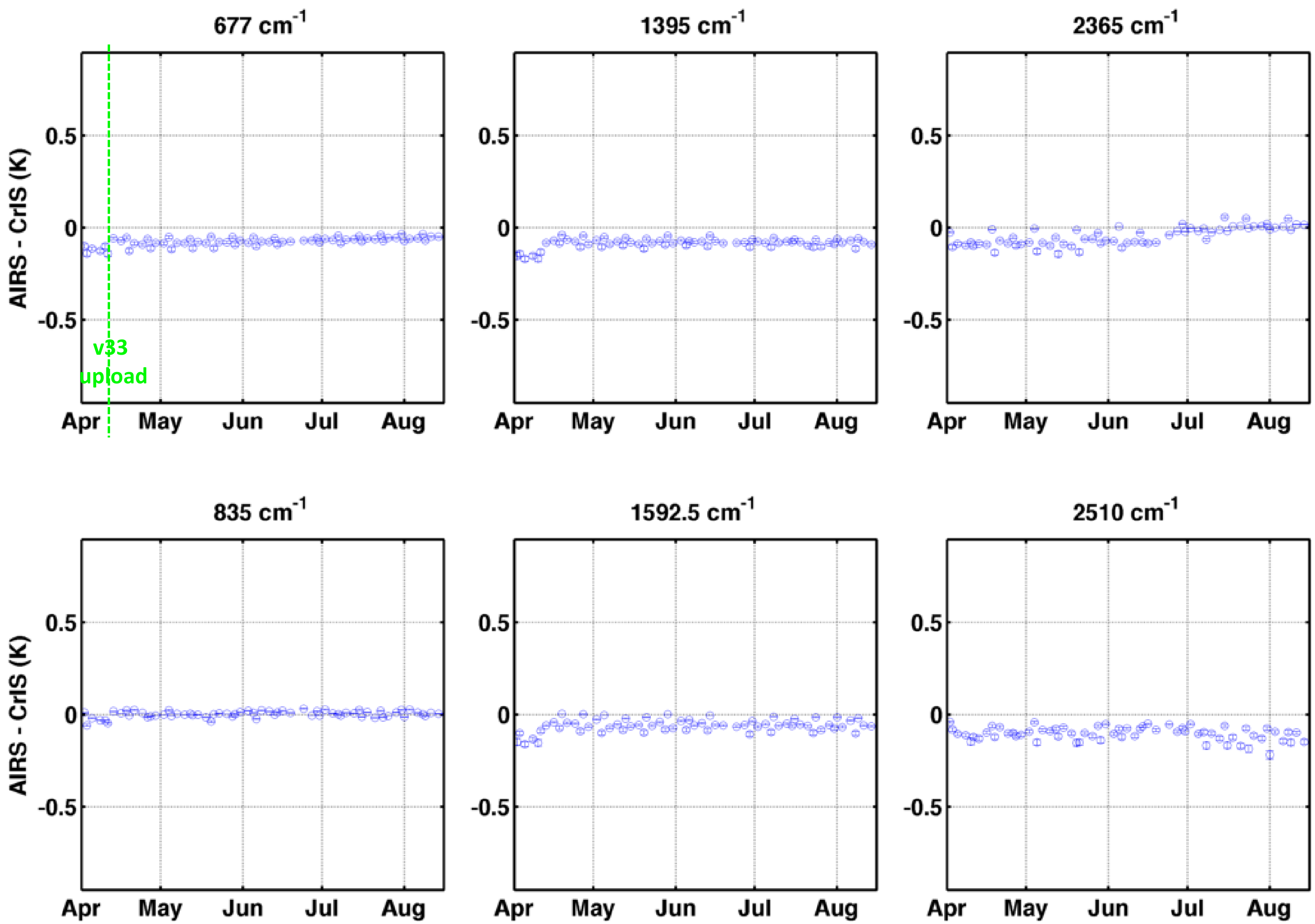
Standard deviation (over 9-FOVs) of Bias vs Radiative Transfer Model (RTM) simulated radiances after a2 and ILS parameter adjustment



Courtesy of Larrabee Strow

Overall bias < 0.1 K

Stable Daily CrIS – AIRS

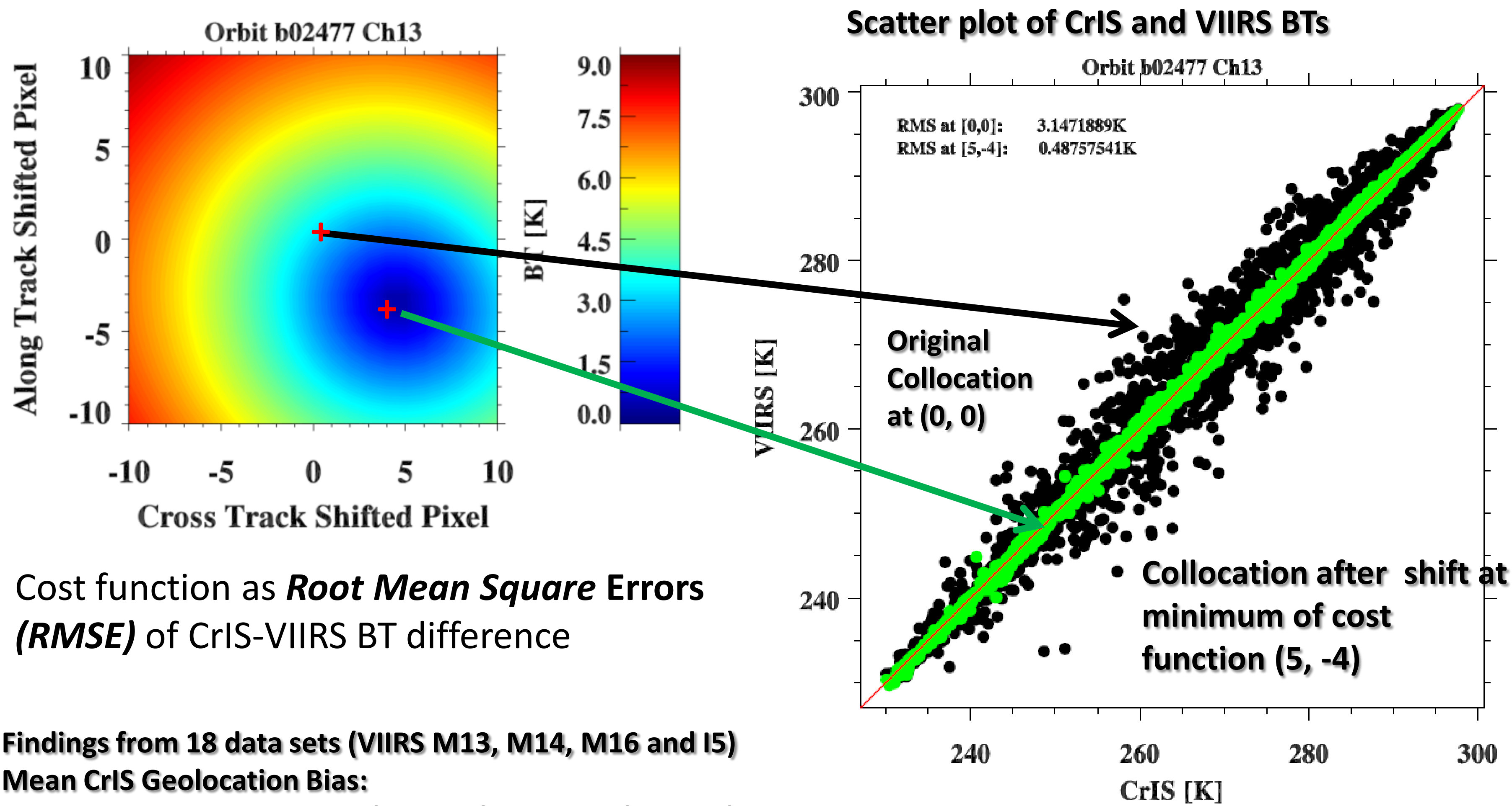


Courtesy of Han Revercomb

FY-12 Accomplishments (4/5)

- Geolocation uncertainty assessment and error correction
  - Geolocation uncertainty estimated by analyzing the CrIS SDR at the coastlines
  - Geolocation uncertainty estimated by comparing CrIS with VIIRS geolocation data
  - 4.5 km CrIS geolocation error and the root-cause was found and fixed
  - Results: CrIS geolocation uncertainty < 1 km
- Orbital dependence of CrIS responsivity observed and explained
  - Orbital variations of the CrIS responsivity were observed (0.3% peak to peak)
  - Channeling explains the 1st order of the variations
  - Conclusion: the dominant responsivity changes are not causing radiometric errors

Geolocation Errors Estimated Using Co-located VIIRS (1/2)



Cost function as ***Root Mean Square*** **Errors** ***(RMSE)*** of CrIS-VIIRS BT difference

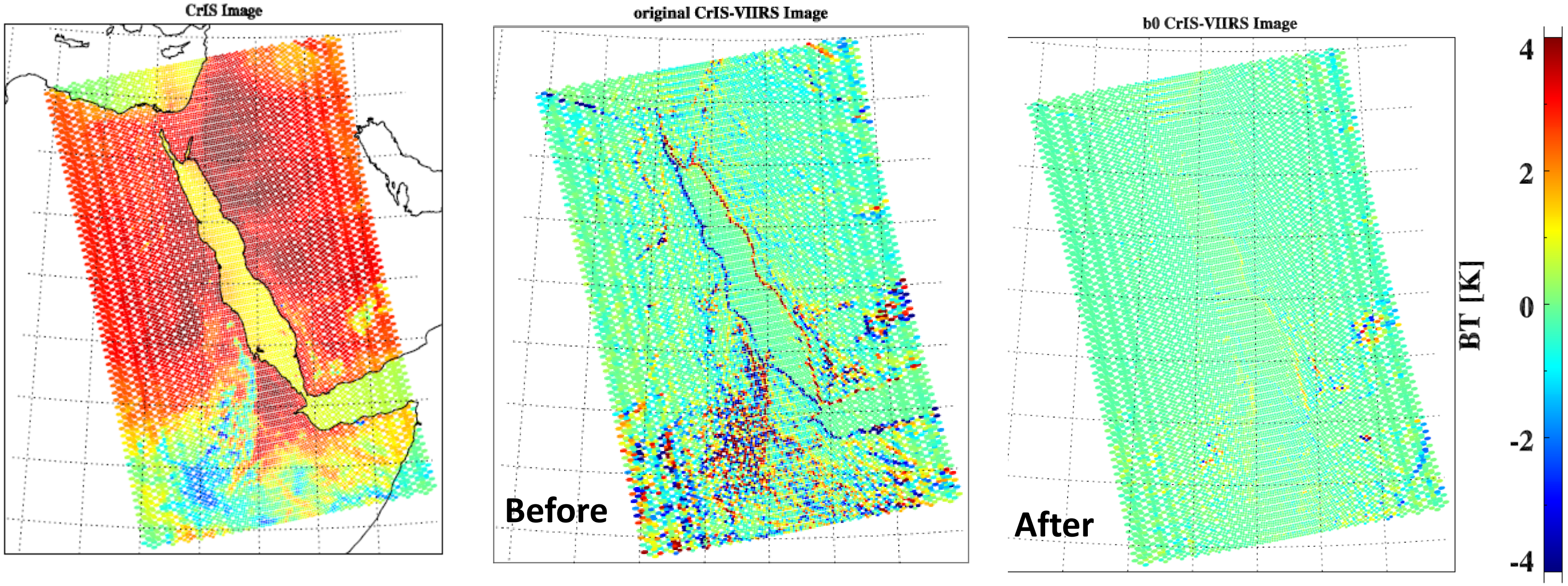
Findings from 18 data sets (VIIRS M13, M14, M16 and I5)
Mean CrIS Geolocation Bias:

- **Crosstrack: 4.5 pixels (±1 pixel) ~ 3.5 km (± 776m)**
- **Alongtrack: -3.6 pixels (±1 pixel) ~ -2.7 km (± 742 m)**

Geolocation Error Root-cause and Correction (2/2)

A coding error was found that caused the geolocation error

Before and after the coding error correction

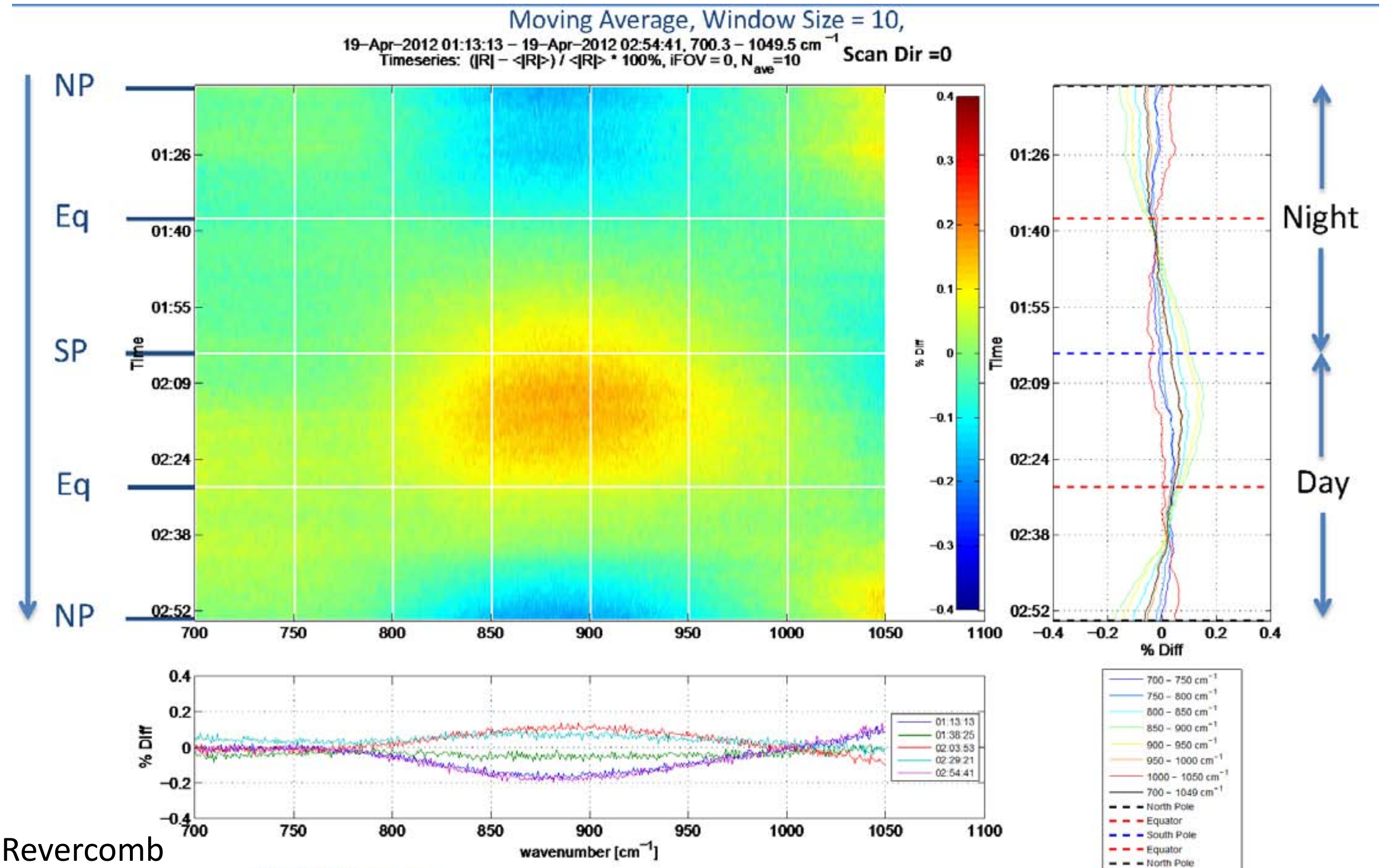


Geolocation uncertainty after the correction: < 1 km

Channeling Cause Responsivity Orbital Variations

Responsivity % difference from orbital mean, LW mean over all FOVs

$(|R|-<|R\}>_t)/<|R|_t *100\%$



Courtesy of Han Revercomb

0.3% p-p

The two-target calibration process is able to calibrate out the effect

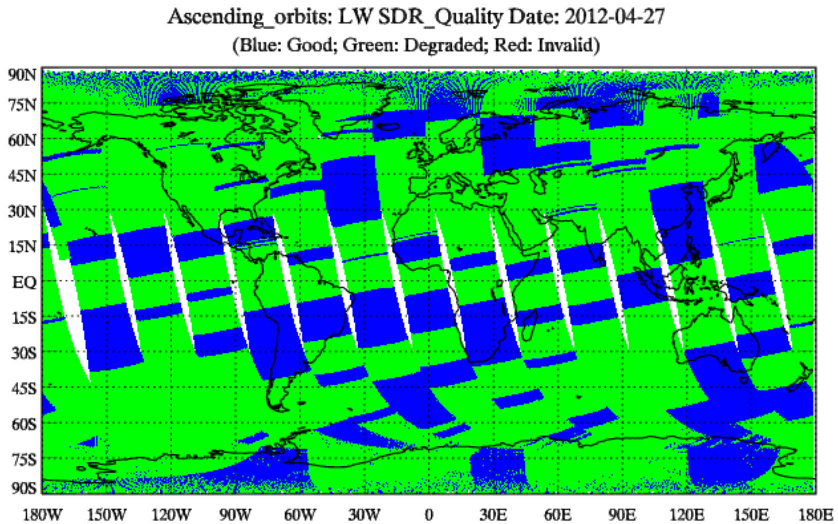
FY-12 Accomplishments (5/5)

- SDR processing algorithm/software fixes and improvement
  - A number of algorithm issues and software bugs were discovered, some of them are critical to the NPP mission
  - Critical problems include
    - Software bugs in geolocation module (fixed in MX5.2 and MX6.3)
    - Handling filled RDR packets (fixed in MX6.2)
    - Wrong temperature drift limits in the EngPkt, which cause 60% of valid SDRs flagged as Degraded (fixed in MX6.3)
    - EngPkt is not updated in the ADL code
    - Bugs and issues in the Fringe Count Error (FCE) detection/correction module (turned off)
  - Added new quality flag based on the imaginary radiance spectra (implemented in Mx6.3)
  - A prototype of interferogram truncation module for preprocessing the full spectral resolution RDRs

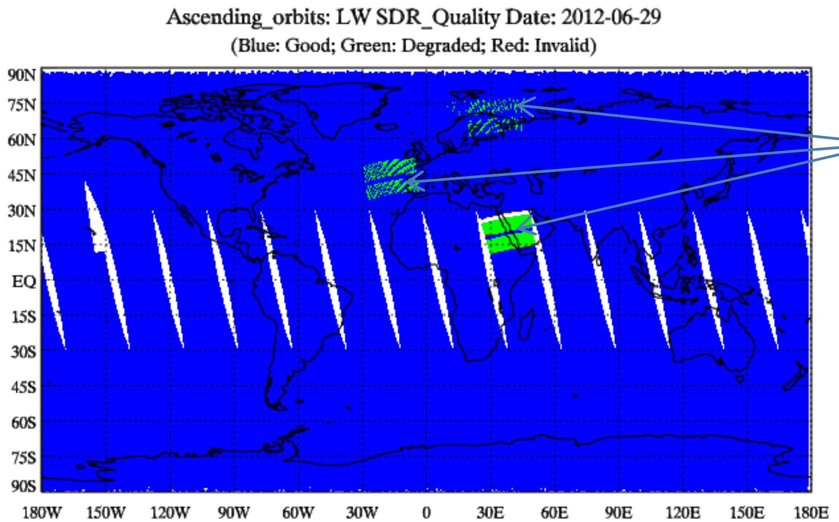
False Overall Quality Flags: Fixed

Blue color – GOOD

Green color - DEGRADED



Before



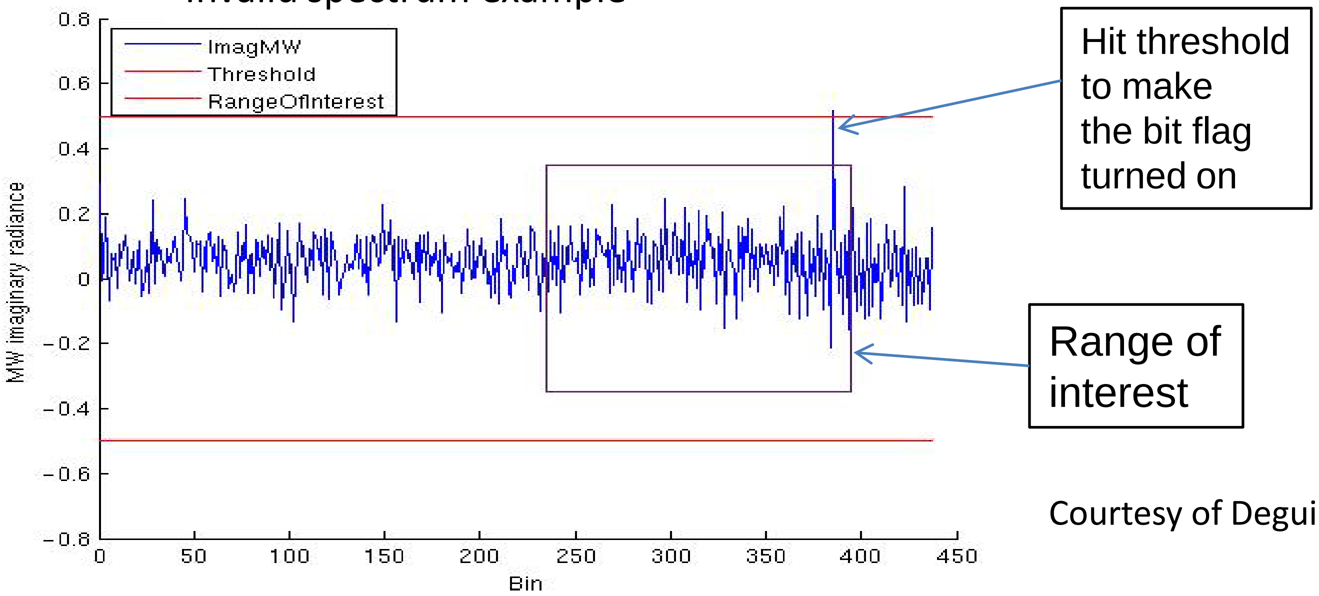
Should be fixed in Mx6.3

After

New Quality Flag Based on the Imaginary Radiance

- The SDR product includes both real and imaginary parts of the spectra
- Good radiance spectra have near zero imaginary radiances
- Add a bit flag to indicate the spectrum is Invalid if any imaginary channel in the range exceeds the thresholds:
  - LW: upper limit 1.5, lower limit -1.5, in the range 800 – 980 cm^{-1}
  - MW: upper limit 0.5, lower limit -0.5, in the range 1500 – 1700 cm^{-1}
  - SW: upper limit 0.05, lower limit -0.05, in the range 2250 – 2350 cm^{-1}

Invalid spectrum example



Courtesy of Degui Gu

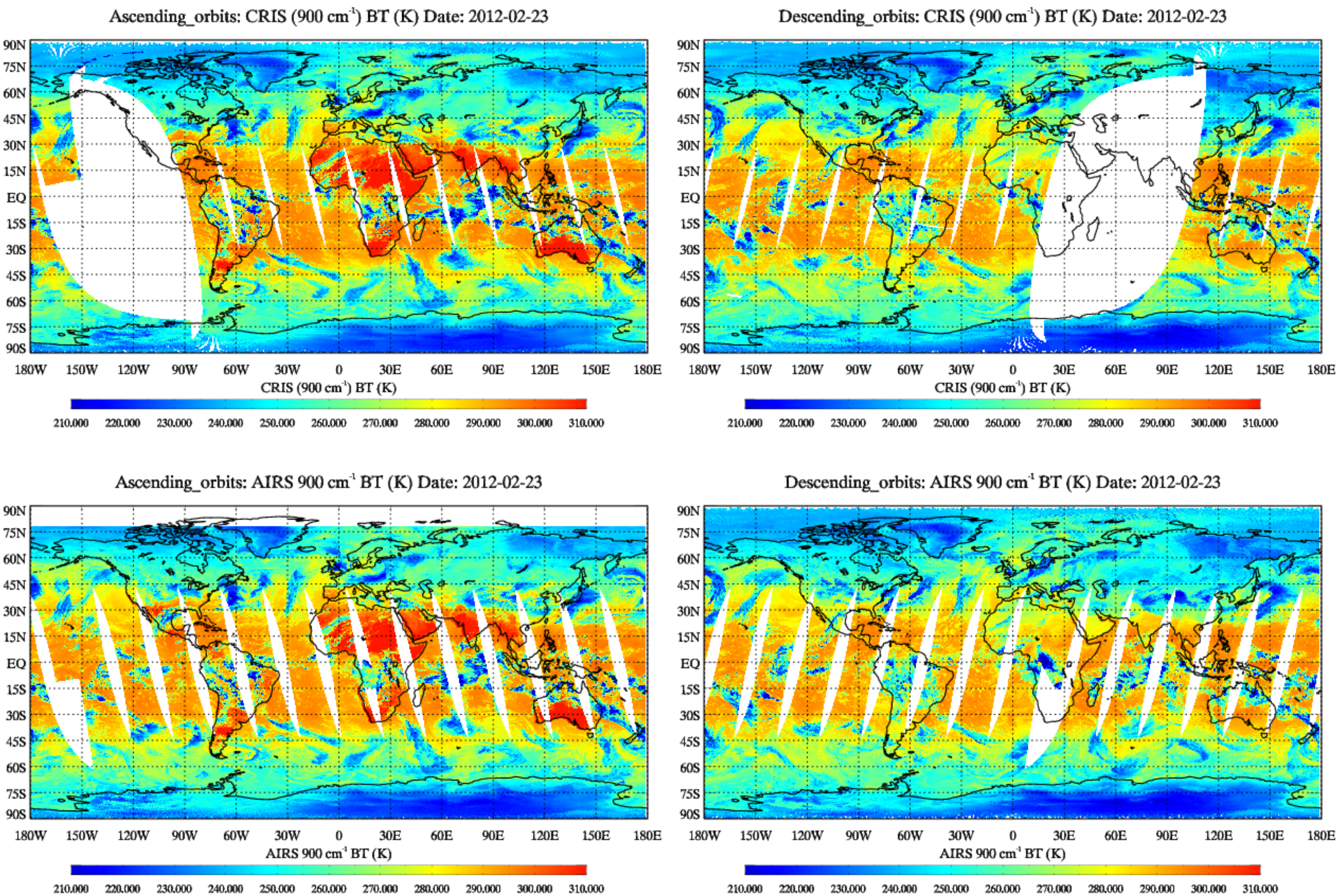
New ADL module: High Spectral Resolution RDR preprocessor

A new module added to the Ops code to preprocess the HR RDR data

CrIS

SDR from high spectral resolution RDRs

AIRS



Good match of CrIS and AIRS BT at LWIR 900cm^{-1}.

FY12 Accomplishments: DRs (1/3) (Partial list)

DR #	Short Description	Status
4373	Incorrect reported value of the laser wavelength	closed
4375	SDR errors when Engineering Packet get updated	closed
4433	Update EngPkt version 32	closed
4477	CrIS ATBD quality flag definitions into current with code	closed
4502	Erroneous non-setting of instrument wave number	closed
4529	Lack of SDR product (bugs in geolocation module)	closed
4530	Warm load values high (bad range settings)	closed
4548	Bit trim changes	closed
4611	Incorrect time stamp in CrIS RDR filename	closed
4634	Bad radiance values for orbit b01715	closed
4646	Radiometric bias with sweep direction dependency	closed
4647	Update of EngPkt version 33	closed
4731	New EngPkt version 34	closed
4796	Incorrect packet time stamp	closed

FY12 Accomplishments: DRs (2/3)

DR #	Short Description	Status
4478	CrIS Overall data quality flag set to invalid for cold Earth scenes; will be fixed in Mx6.3	PCR in work
4661	CrIS overall DQF incorrectly set to value 3; will be fixed in Mx6.3	PCR in work
4680	CrIS overall DQF set to degraded; will be fixed in Mx6.3	PCR in work
4821	Incorrect geolocation calculation; will be fixed in Mx6.3	PCR in work
4378	CrIS ephemeral tuning file baseline	open
4389	Earth scene ZPD magnitude data type field inconsistencies	Open, on track
4391	Some interferogram.cpp operators need to be updated; Check value of 1u is incorrect, should check for 0	Open
4407	Inconsistency in Serialization; Might be related to code instability and May30-June7 2012 anomaly.	Open
4481	Fringe count error correction algorithm does not work for cold Earth scenes; major algorithm and software work	Open
4491	Review CrIS OAD for updates	Open
4758	Incorrect radiance values for a repaired granule observed in ADA	Open

FY12 Accomplishments: DRs (3/3)

DR #	Short Description	Status
4774	Corrupted CMO matrix leading to radiance with zero values; approved for future evaluation	Open
4794	Make the CMO-EngPkt binary file available to end user	Open
4812	Add a flag indicating the CMO values have changed	Open
4848	CDFCB volume III, VIII, 4478; document update	Open
4849	CrIS DR4478, 4680 AOD documentation; document update	Open
4855	4478_4680 Request for PCT and documentation; document update	Open
4868	Scan with filled values in short granule set to valid; NASA request to have a user guide describing this situation	Open
4878	Processing of full spectral resolution RDR	Open

Scientific Advancements (1/2)

- In-orbit spectral (frequency) calibration and validation methods
  - Spectral error and ILS parameter adjustments determined using the technique that maximizes the correlation of the RTM simulated and CrIS observed spectra
  - Determination of ILS parameters relative to FOV5 using Earth scene data by the technique that maximizes the correlation between any of the FOVs and FOV5, which has a small self-apodization
- Nonlinearity correction methods
  - Technique to derive the NLC coefficient a2 from in-orbit diagnostic mode data
  - Technique to determine as values using in-orbit normal mode data
- Geolocation calibration methods
  - Method to determine geolocation errors by minimizing the cost function that is the RMS difference of the CrIS and VIIRS radiances
  - Method to determine geolocation errors by comparing CrIS window channel image with the coastline geolocations

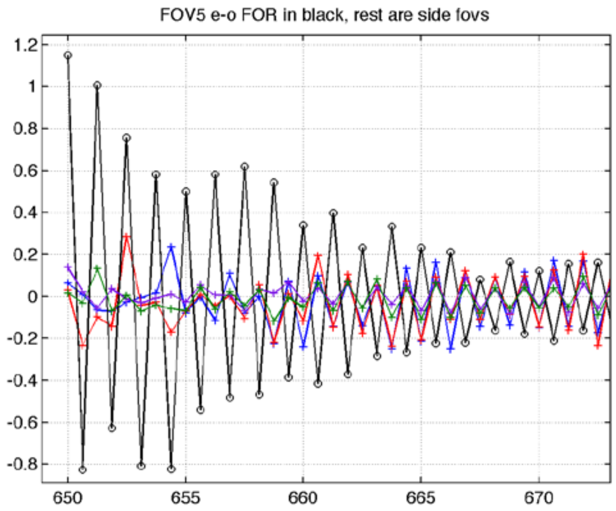
Scientific Advancements (2/2)

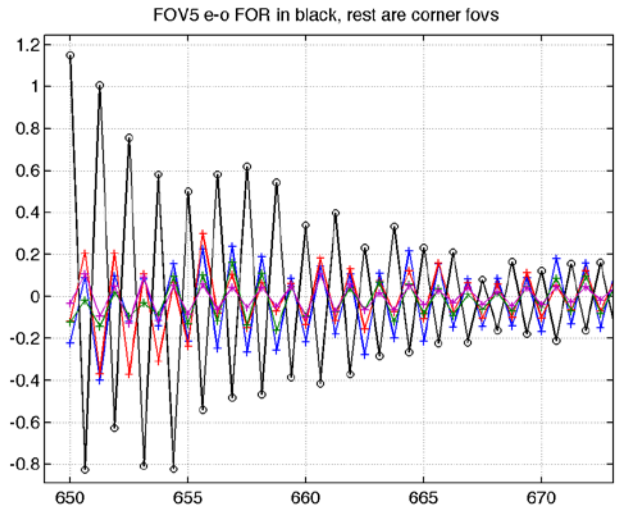
- Method to assess the ICT model by checking a pair of channels (Buddy channels) that have similar weighting function
- Theoretical basis for lower error bound on ILS corrections and the significance of the order of the ILS correction model in SDR processing chain
- Method analyzing the orbital variations of the instrument responsivity that is able to detect small variations such as that caused by channeling
- Improved ILS correction algorithm implemented in the UW/UMBC CrIS Calibration Algorithm and Sensor Testbed (CCAST) and the MIT/LL SDR code

Issues, Challenges, Setbacks

- FOV 5 scan bias in LW unapodized spectra
- SW cold scene FOV-to-FOV difference
- Spectral (un-apodized) ringing
- Operational ground data system instability causing one week of bad radiance product (May 30^{th} to June 7^{th}). Problem was not replicated and root cause is unknown.
- FCE detection/correction module was turned off
  - Although, currently missing the component in the Ops code does not pose a significant problem as the FCE is a rare event up to now, but there is no guarantee that it will not be a problem in the future
  - Software bug fixes and possibly algorithm fixe are needed, which require a large team effort
- The Ops code can not process the upcoming J1 TVAC data
- Lack of diagnostic data output from the SDR code
- Inefficient and ineffective code changing process, causing delays and uncertainties of algorithm and software fixes and updates
- No aircraft campaign has been conducted. Future campaign is uncertain.

Issue: FOV 5 Scan Bias



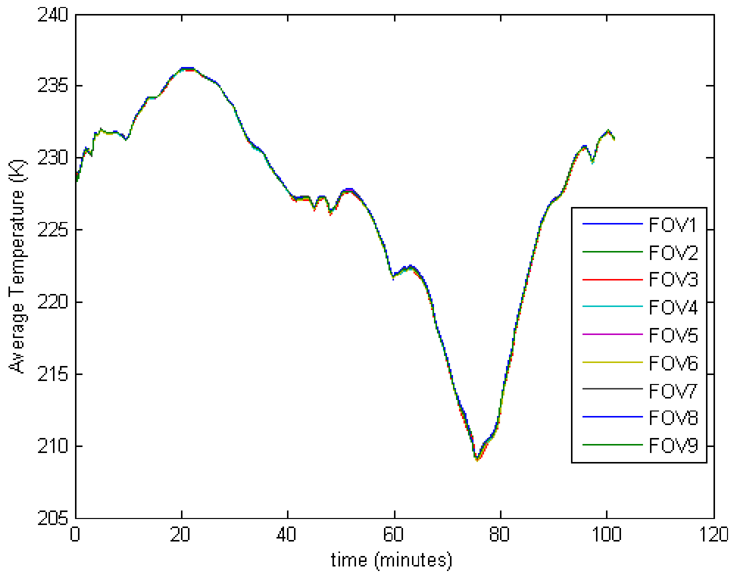


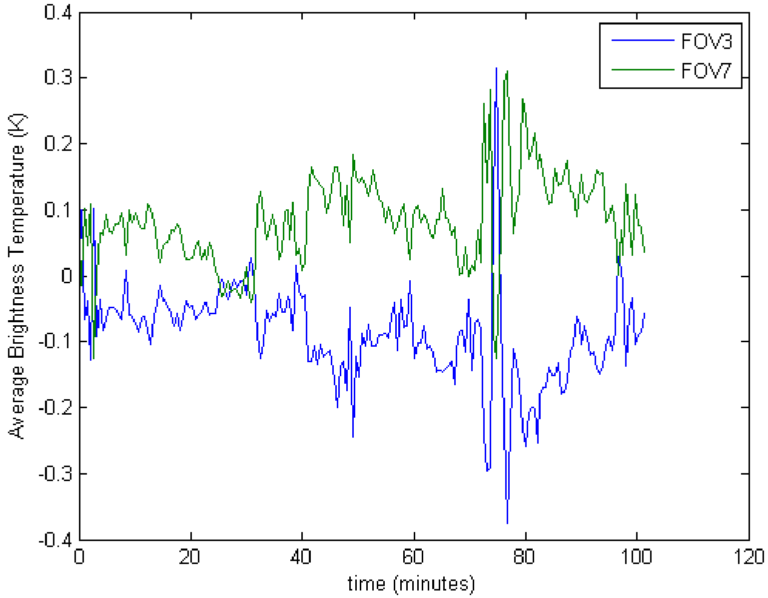
Courtesy of Larrabee Strow

Differences in NWP biases with interferometer scan direction.
Note that FOV5 stands out

Issue: SW Cold Scene FOV Differences

Brightness temperature averaged over the range from 2256 to 2302 cm^{-1} ; the scene is very cold

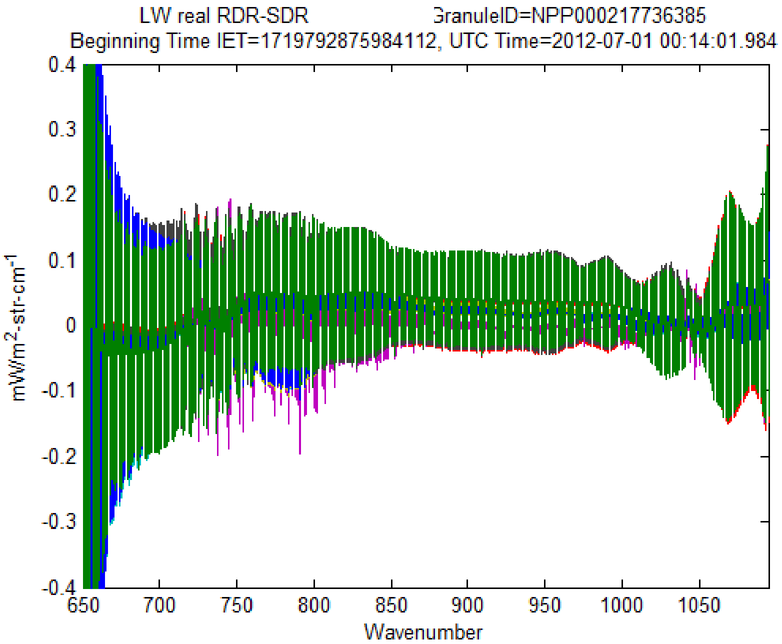




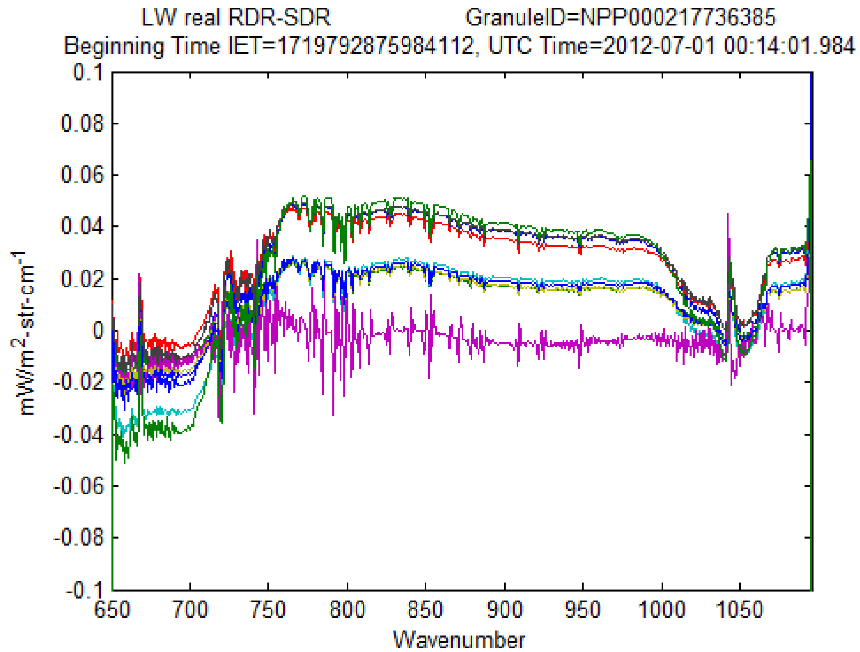
Courtesy of Deron Scott

Issue: Ripple in IDPS SDRs

Difference between IDPS and MIT/LL SDRs



Before spectral averaging



After 2 point averaging

Courtesy of Dan Mooney

Changes in Strategy (due to funding constraints)

- ITT-Exelis ran out of funding in May for supporting the team CalVal activities
  - A special SOW was sent to DPA and was approved to provide funding for selected activities up to the end of this year
  - The team needs Exelis to continue the support

FY-13 Schedule and Milestones

- Provision product review meeting, October 24-26, 2012
- Validated product review meeting, mid 2013
- STAR's responsibility for changing EngPkt parameters and its upload, December 2012
- CrIS SDR user guide, December 2012
- Tools for trending and monitoring radiance differences between CrIS and IASI/AIRS/VIIRS, March 2013
- Geolocation uncertainty trending and monitoring tool, March 2013
- STAR CrIS SDR processor (IDL code): CrIS Interferometry Transformation System (CITS), March 2013
- Spectral uncertainty trending and monitoring tool, June 2013
- RDR generator, September 2013

Path Forward (FY-13 thru FY-17)
(assume "FY13" runs from April 1, 2013 to March 31, 2018)

	Suomi NPP	JPSS J1
FY13	(1) Continuation of CrIS on-orbit calibration and validation as planned. (2) Algorithm and software improvement. (3) Address DR backlog. (4) Improve code testing. (5) Aircraft campaigns	(1) Participate in and support re-launch tests and instrument characterization (2) Improve Algorithm and software: Improve FCE handling module; Improve ILS correction algorithm; Upgrade algorithm and code for handling full spectral resolution; Compare Ops code with science codes (Exelis, UW/UMBC and MIT/LL) (3) Add CrIS SDR processing capability of TVAC data.
FY14	(1) Instrument parameters trending and monitoring (2) Calibration/validation on key parameters such as Neon wavelength and nonlinearity on a regular basis (3) Updates of calibration coefficients (EngPkt update and uploads) (4) Performance characterization and documentation on a regular basis	(1) Same as above (2) Proxy data preparation. Need to have RDR generator. (3) Post CalVal planning
FY15	Same as above	(1) Participate in and support re-launch tests and instrument characterization (2) Improve algorithm and software (3) Support for mission integration and test
FY16	Same as above	Prepare for J1 launch and post-launch Calval
FY17	Save as above	Post-launch Calval

Summary

- The team has addressed all critical issues and problems, many of which are unexpected and challenging.
- The SDR product reached Beta level in May and will reach the Provisional level in October 2012.
- The team is confident that weather requirements for NWP have been achieved. Establishing a climate record is achievable and will require a greater level of effort.
- The team has a plan for the future NPP and J1 work and is confident that the projects will be successfully executed.