CrIS Sensor Data Record Quality Assessment
- Toward the Validated Product Maturity Level

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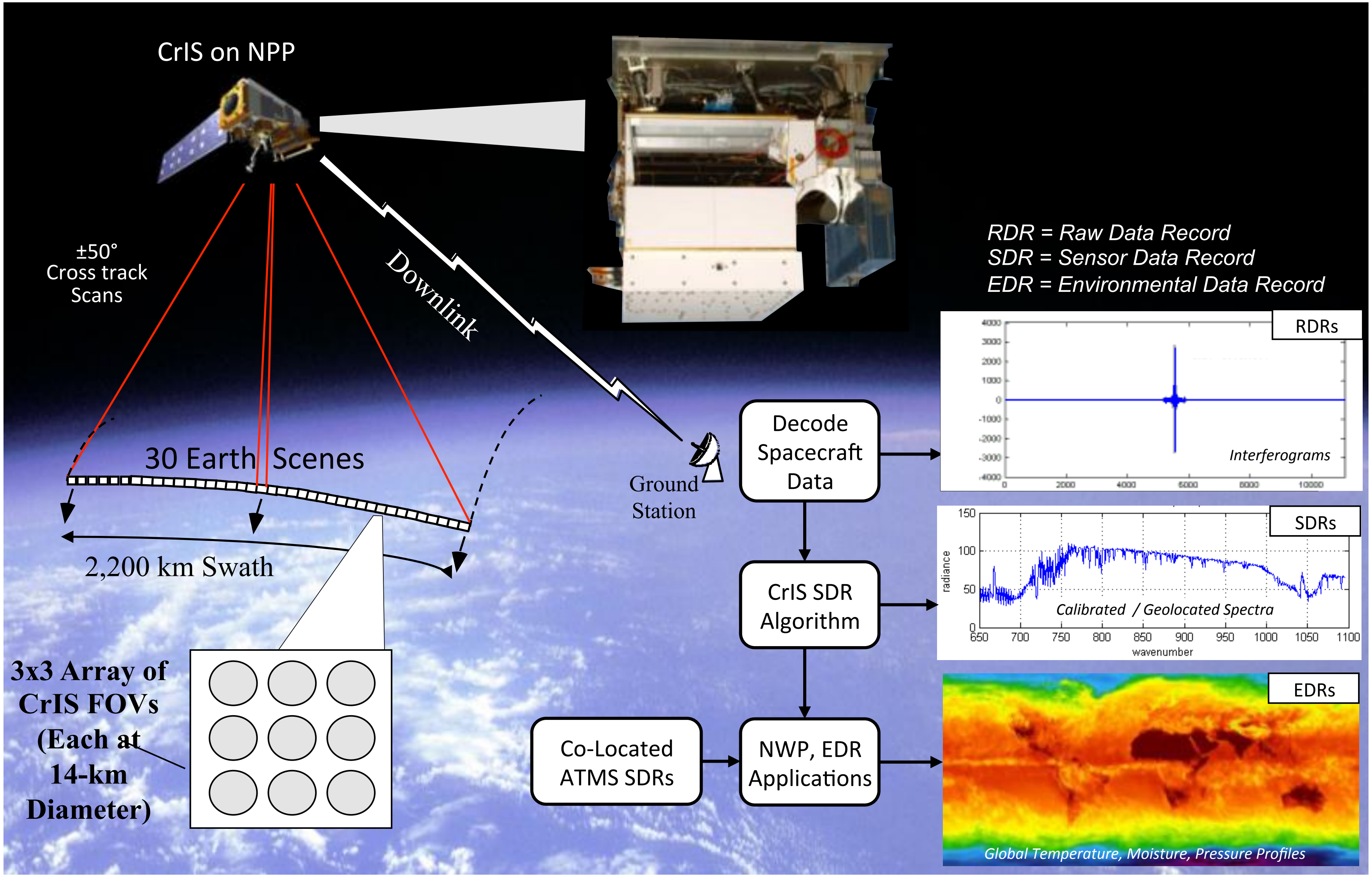
Acknowledgement goes to the CrIS SDR Team including NASA, UW/SSEC,USU/SDL, MIT, UMBC, Exelis, Ratheon, NGAS

4th AOMSUC 2013
Melbourne, Australia, October 9-11 2013

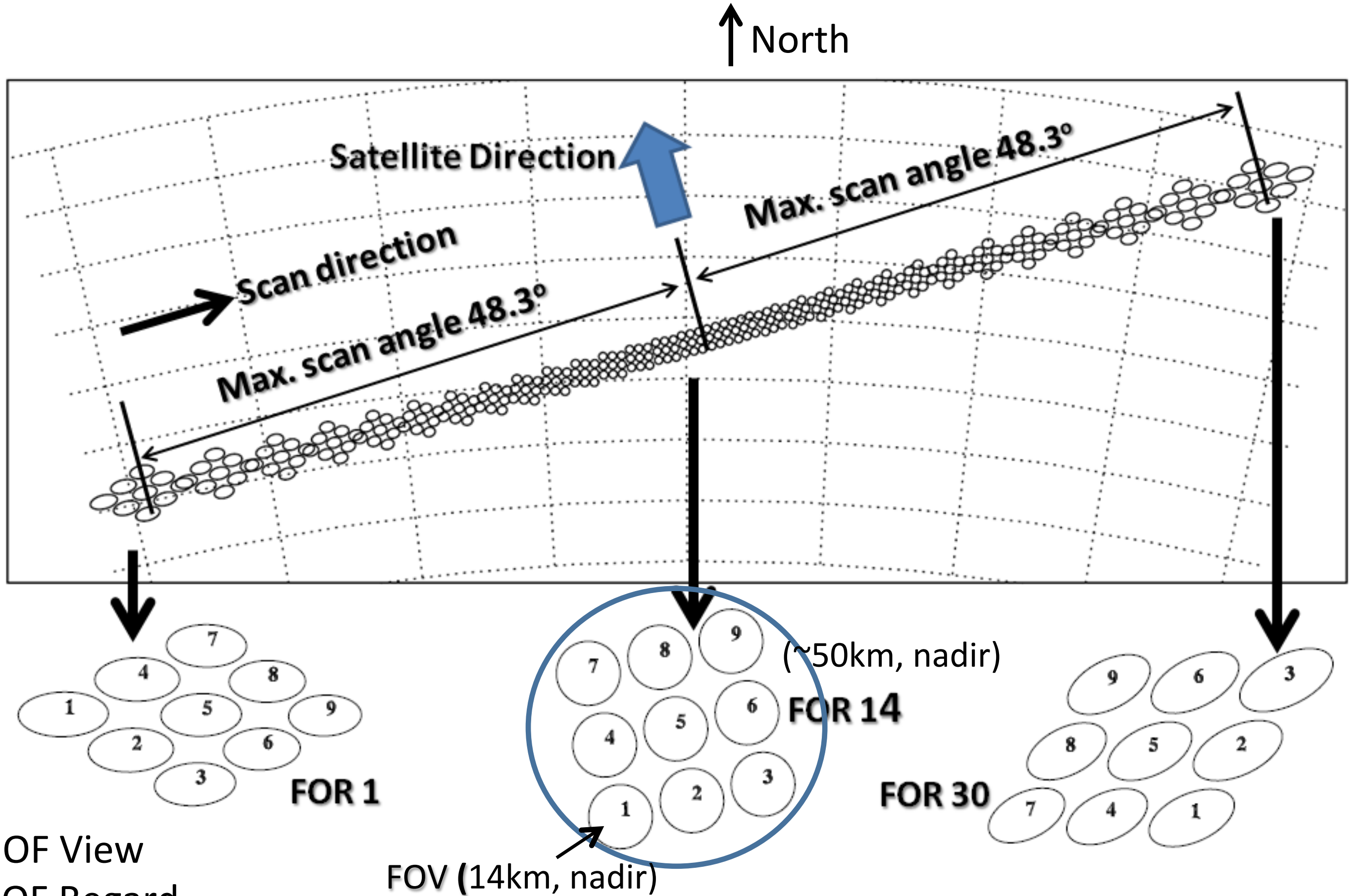
Outlines

- CrIS Instrument
- Post-launch calibration
  - Radiometric calibration
  - Spectral calibration
  - Geometric calibration
  - Instrument and SDR data quality stability
- The way moving forward
  - Full resolution CrIS SDR
  - Reprocessing CrIS SDR for long-term, consistent climate data records
- Summary

CrIS Operational Concept



CrIS Scan Pattern



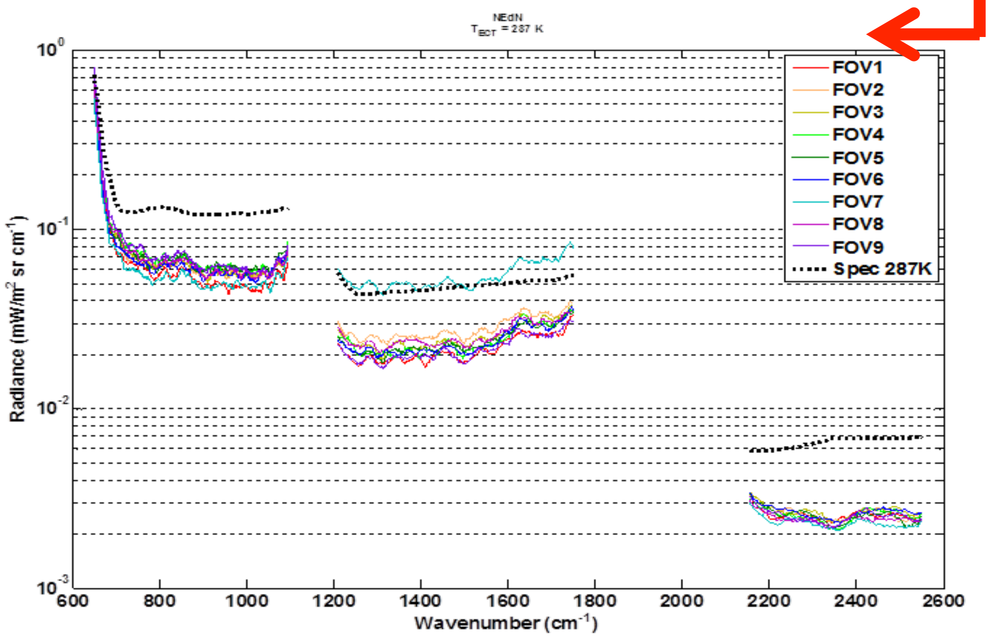
FOV – Field OF View
FOR – Field OF Regard

- Swath is 2200 Km (FOR1 to FOR 30).
- CrIS acquires 1 scan line every 8 seconds.
- CrIS measures 8.7 million spectra per day.

NPP CrIS Sensor Data Record Calibration Uncertainty Specifications

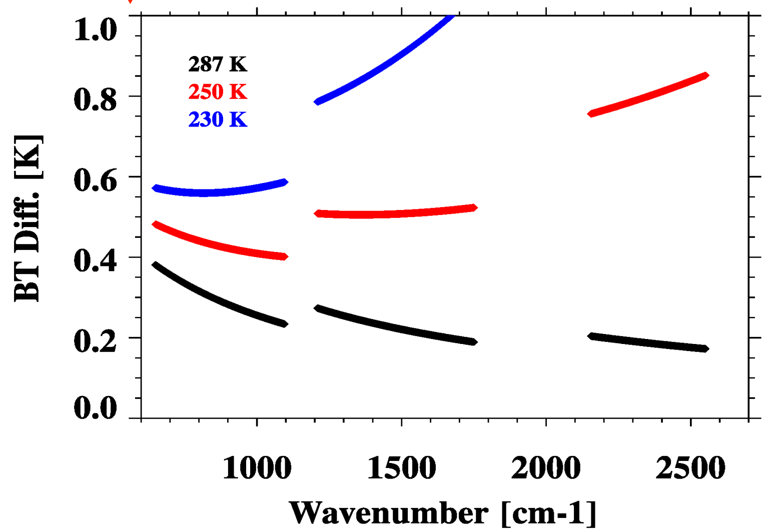
SDR Calibration Uncertainty

Band	Spectral range (cm^{-1})	N. of chan.	Resolution (cm^{-1})	FORs per Scan	FOVs per FOR	NEdN @287K BB $mW/m^2/sr/cm^{-1}$	Radiometric Uncertainty @287K BB (%)	Spectral (chan center) 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**

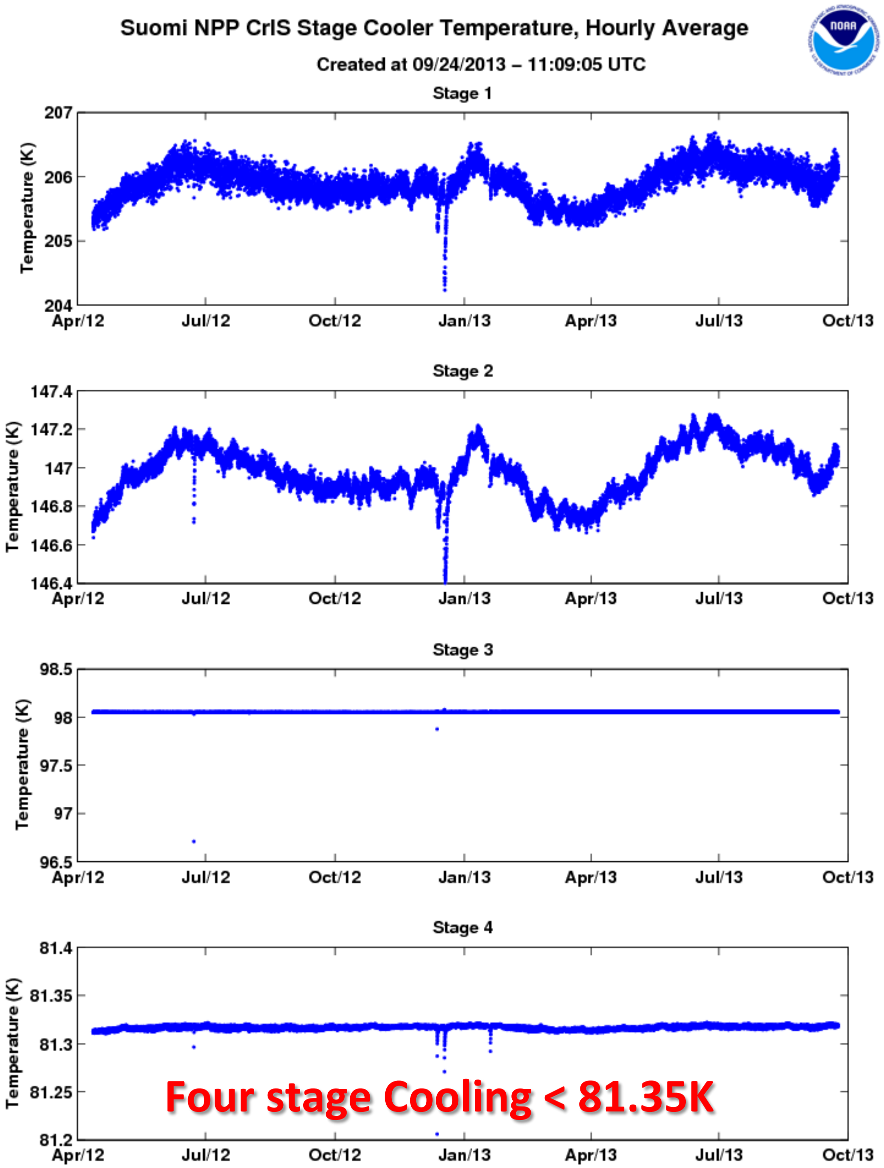


From Vladimir Zavyalov of USU/SDL

Radiometric uncertainty specification converted to that expressed in brightness temperature



CrIS Instrument Design
Noise Control



- A dynamic optical alignment system (DA) is used during the interferogram collection to reduce the noise

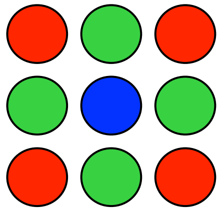
- A passive vibration-isolation system is integrated to enable CrIS to operate on the spacecraft with relatively high level of disturbances.

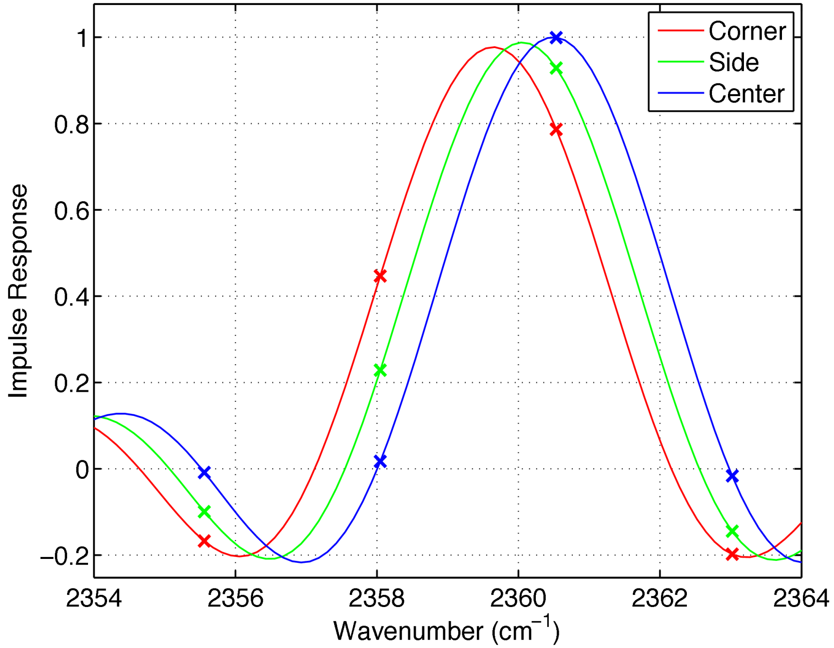
- Photovoltaic (PV) detectors are used for all three bands with controlled temperature below 81.35 K.

From Vladimir Zavyalov of USU/SDL

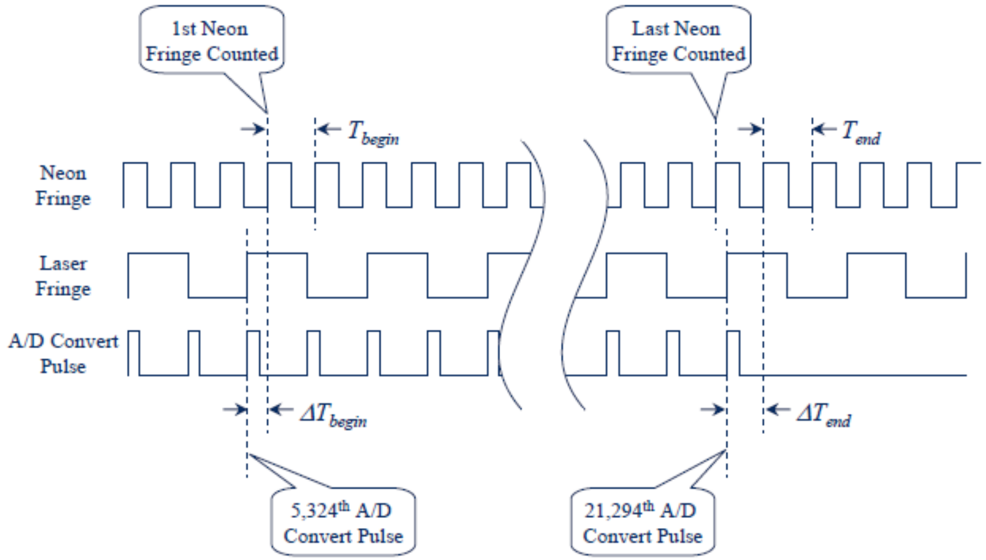
CrIS Instrument Design
Onboard Spectral Calibration

3x3 Array of CrIS FOVs (Each at 14-km Diameter at Nadir)





Neon and laser fringes are counted and rationed to Transfer neon line knowledge to metrology laser



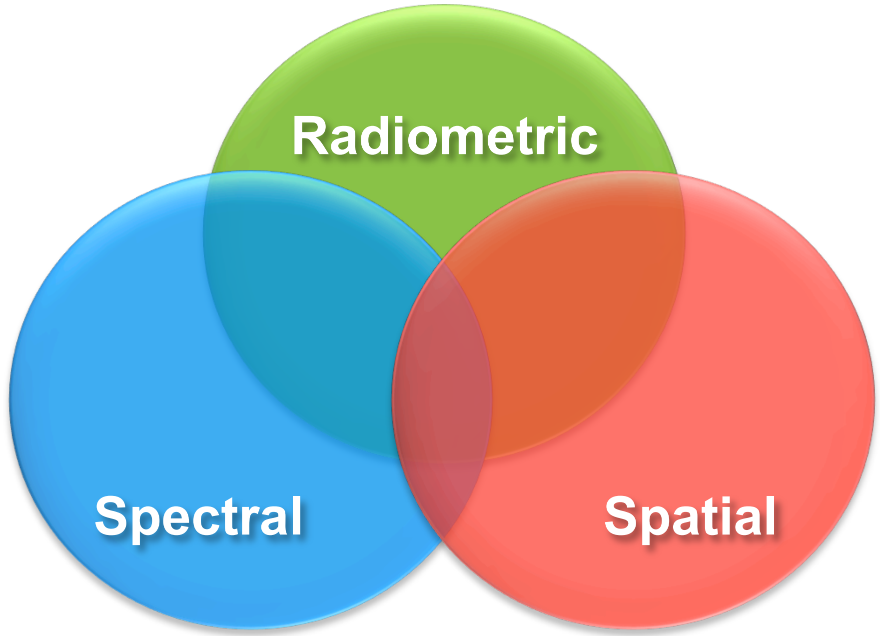
Before ILS correction, all spectra are shifted to the left

- Center : 16 ppm; Side : 282 ppm; Corner : 399 ppm

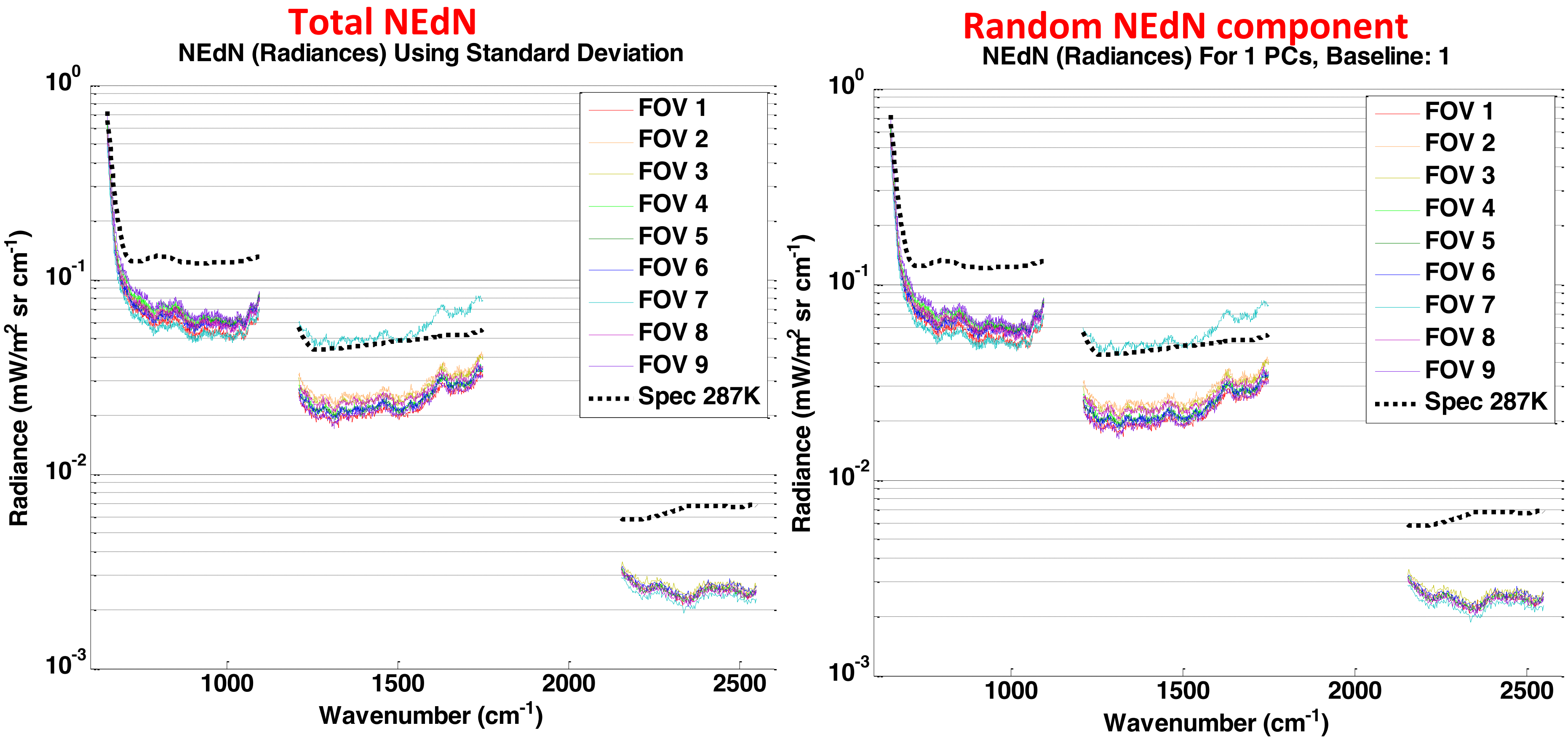
Onboard neon lamp provides long-term spectral calibration references for CrIS

CrIS Cal/Val Milestones

- **January 18th 2012:** CrIS was powered up; team started instrument checkout and optimization.
- **February 8th :** Engineering packet (EP) v32 was uploaded (PGA setting and bit trim mask updates).
- **February 22nd** : Full spectral resolution RDRs (0.8 cm maxOPD for all bands) were collected.
- **April 11th** : Engineering packet v33 was uploaded (spectral calibration parameters, nonlinearity coefficients and ICT emissivity table updates).
- **April 18th**: A new FIR digital filter was uploaded to replace the corrupted one.
- **May 15th** : CrIS SDR product reached Beta maturity level .
- **October 15th** : CrIS Gelocation errors are fixed
- **October 23rd** , CrIS SDR Provisional Review
- **February 13th , 2013** CrIS SDR Provisional
- December 18th-20th, CrIS SDR Validation Meeting
- **January 24th 2014** EP36 and Algorithm Changes



Instrument Noise
Overall Performance



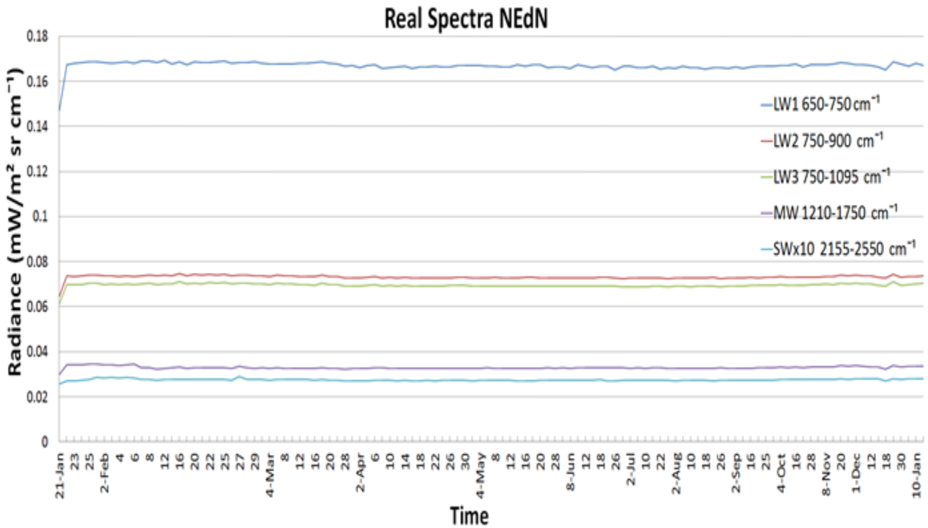
- MWIR FOV7 is out family as it was during ground TVAC4 and S/C TVAC ground tests
- NEdN is estimated over 30 ICT spectra and reports the average NEdN over 17 adjacent spectral bins
- $NEdN_{total}^2 = NEdN_{random}^2 + NEdN_{corr}^2$

From Vladimir Zavyalov of USU/SDL

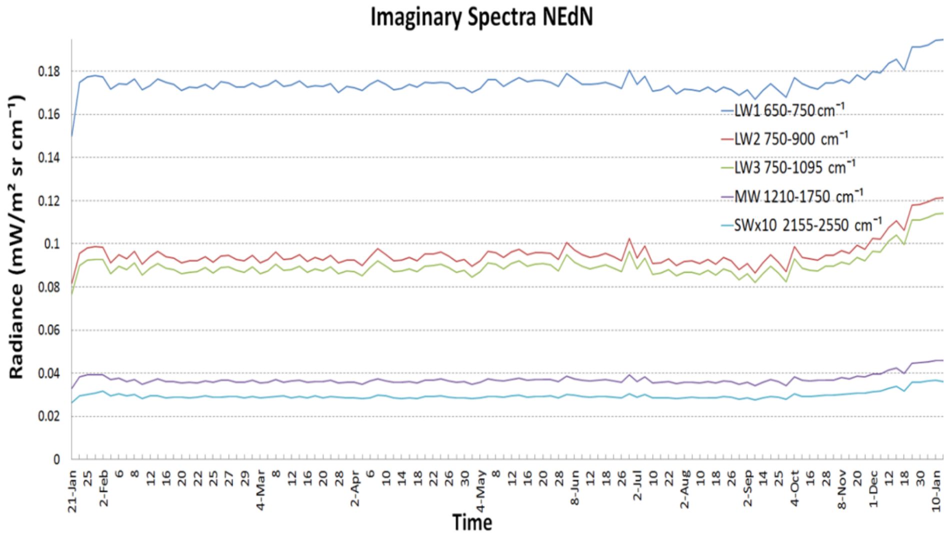
Instrument Noise NEdN Trend

Deep Space Derived Average NEDN

Real spectra NEdN



Imaginary spectra NEdN



- **NEdN is very stable in real part of the DS spectra over all spectral bands (CrIS SDR)**
- **NEdN is increasing in the imaginary part of the DS spectra over all spectral bands (~30-40%)**
- **NEdN was averaged over all FOVs and over spectral regions:**

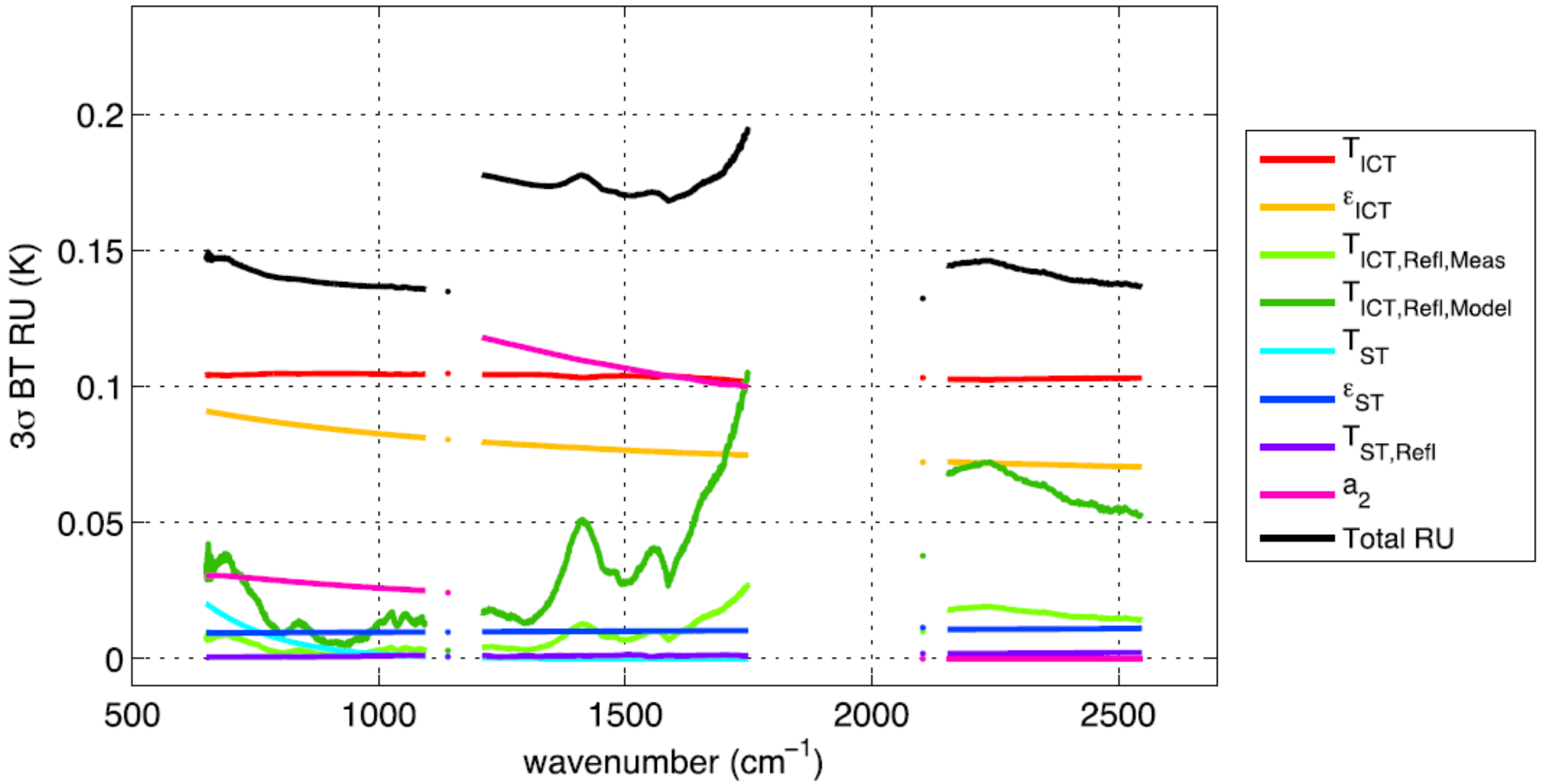
  LWIR: 650-750 ; 750-900; and 750-195 cm^{-1}

  MWIR: Entire band 1210-175 cm^{-1}

  SWIR: Entire band 2155-2550 cm^{-1}

From Vladimir Zavyalov of USU/SDL

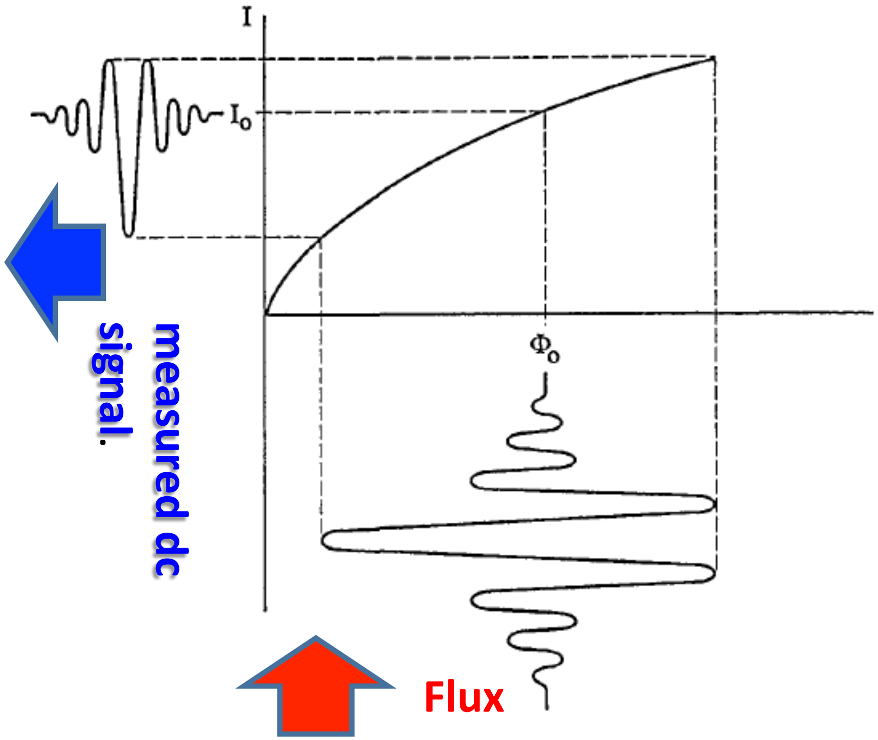
CrIS Radiometric Calibration - What you expected based on prelaunch test



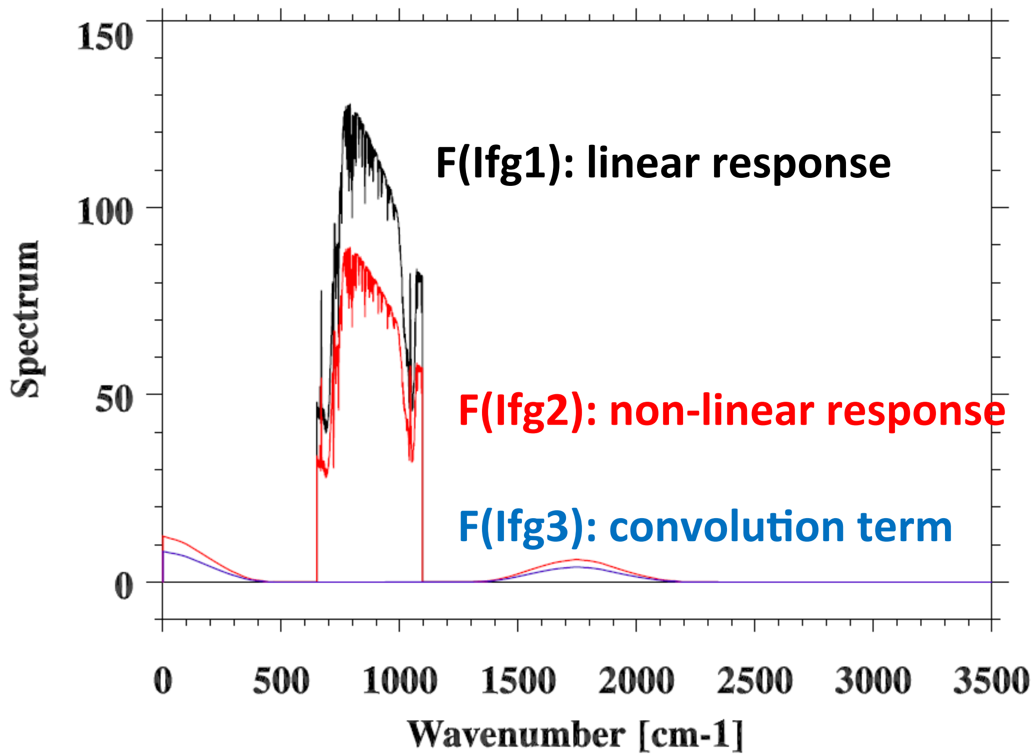
Pre-launch Radiometric Uncertainty (RU) contributions and total RU for calibrated FOV 7 ECT view spectra, for the ECT temperature of 287 K, as a function of wavenumber.

From David Tobin of UW SSEC

For a non-linear detector



Hypothetical detector-response curve exhibiting nonlinearity. The horizontal axis represents the absolute magnitude of the photon flux and the vertical axis represents the measured dc signal.



Non-linearity responses in spectral domain.

From Abrams et al. 1994

Non-linearity Coefficient Changes

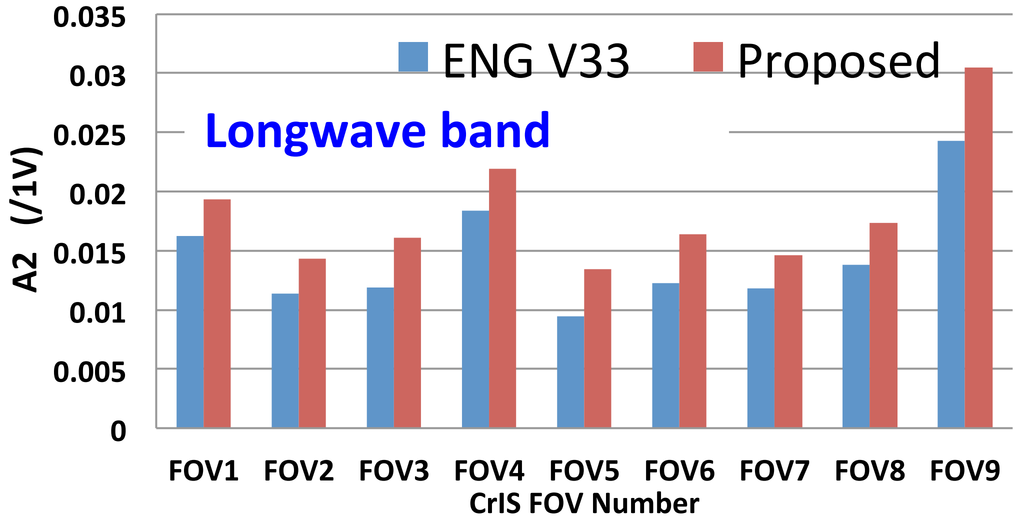
Nonlinearity parameter determination strategy:

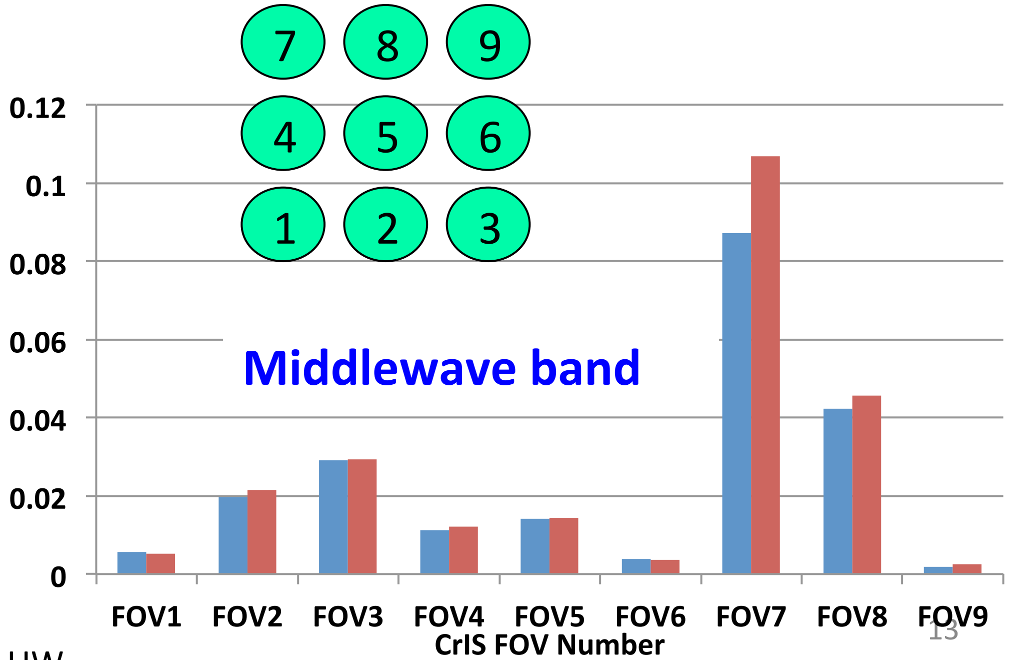
1. Initial values determined from analysis of TVAC ECT view data: $a_2^{\text{TVAC ECT}}$

2. Change from pre-launch to in-orbit estimates using DM data: $(a_2^{\text{ROP DM}} / a_2^{\text{TVAC DM}})$

3. Initial in-orbit values: $a_2^{\text{TVAC ECT}} \times (a_2^{\text{ROP DM}} / a_2^{\text{TVAC DM}})$

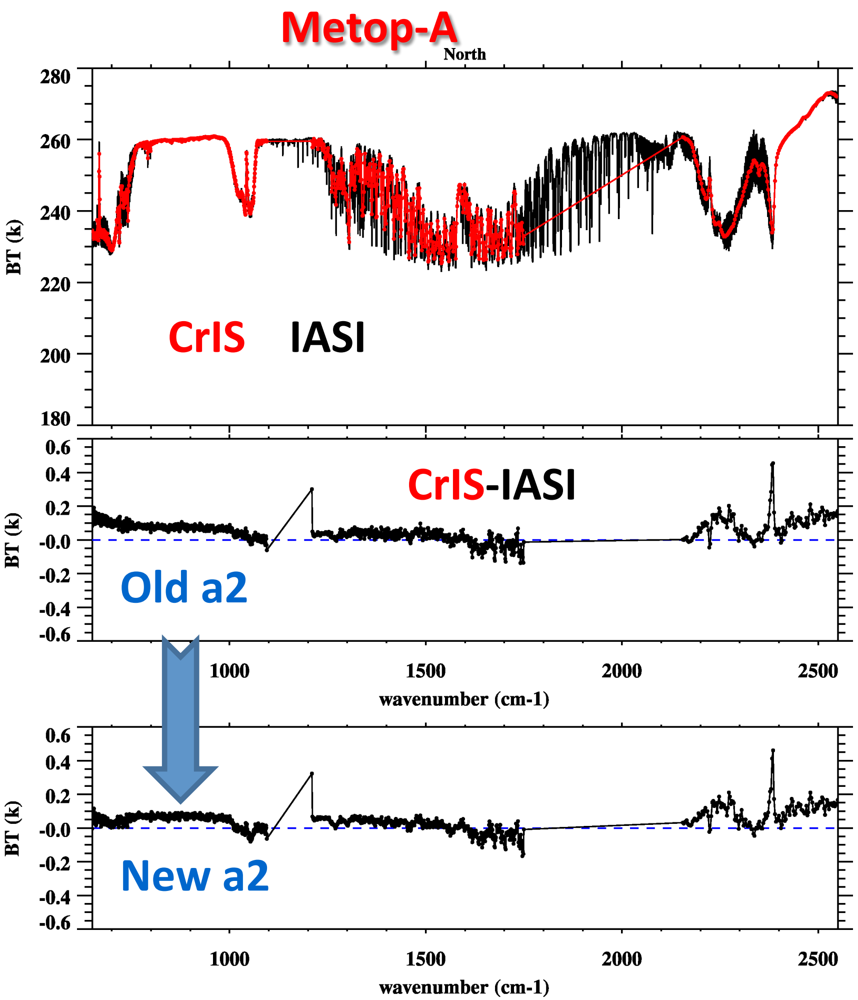
4. Followed by the selection of a reference FOV and adjustments of a_2 values for the remaining FOVs to create optimal agreement with the reference FOV using Earth view data: $a_2^{\text{FOV-2-FOV}}$

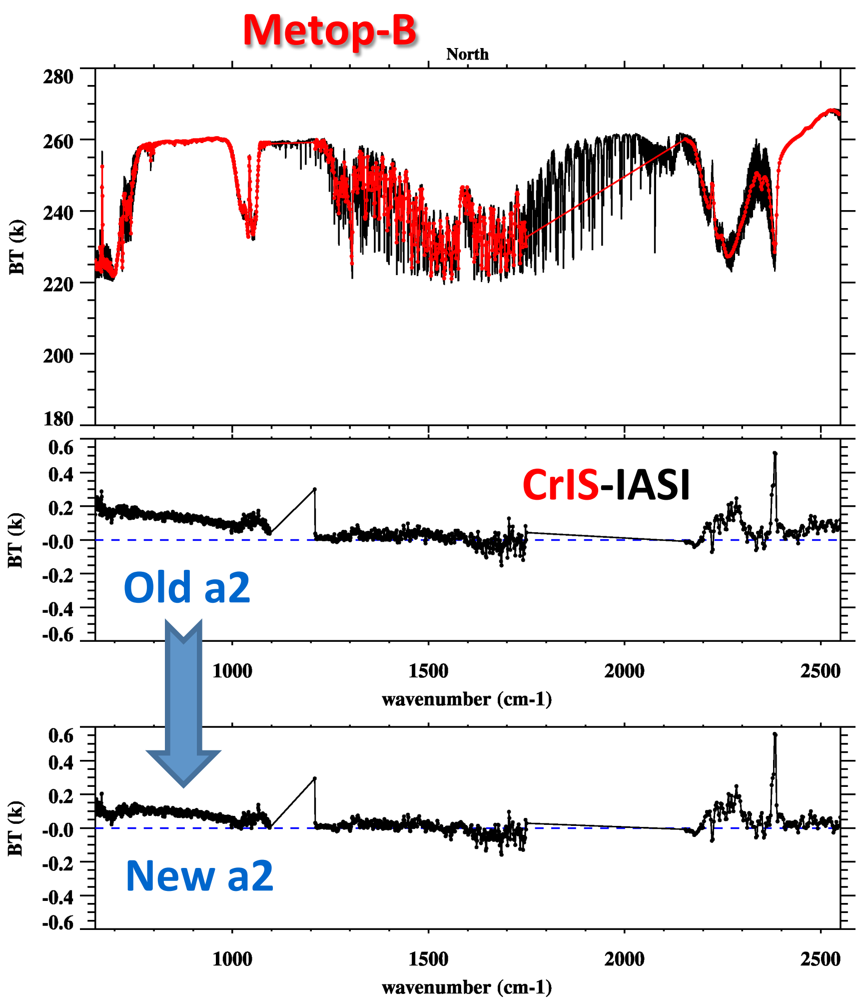




From Dave Tobin of UW

CrIS vs. IASI-A and -B

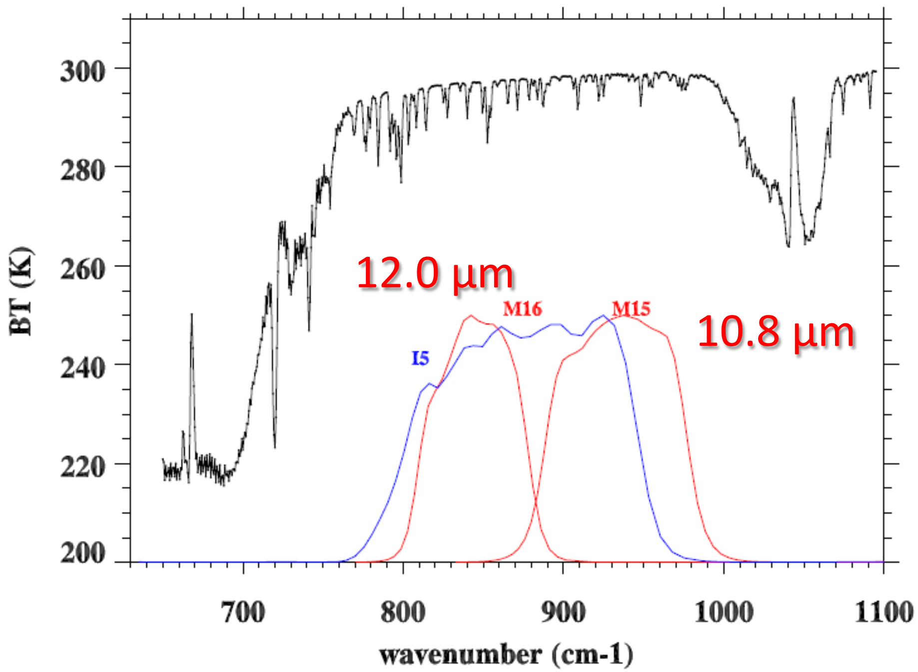


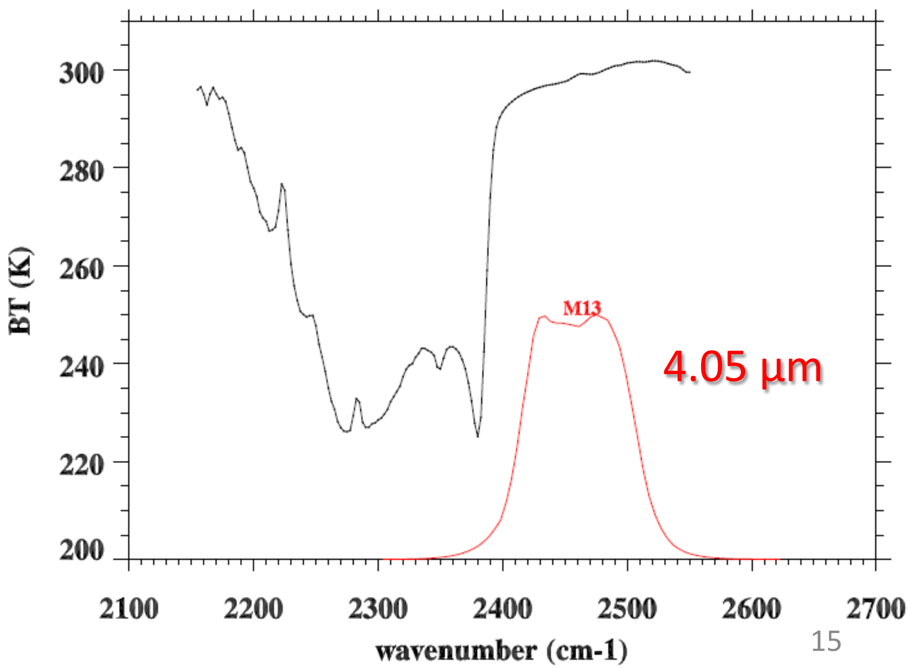


How about CrIS versus VIIRS?

CrIS spectra are overlapped with VIIRS SRFs for M13, M15, and M16, and I5

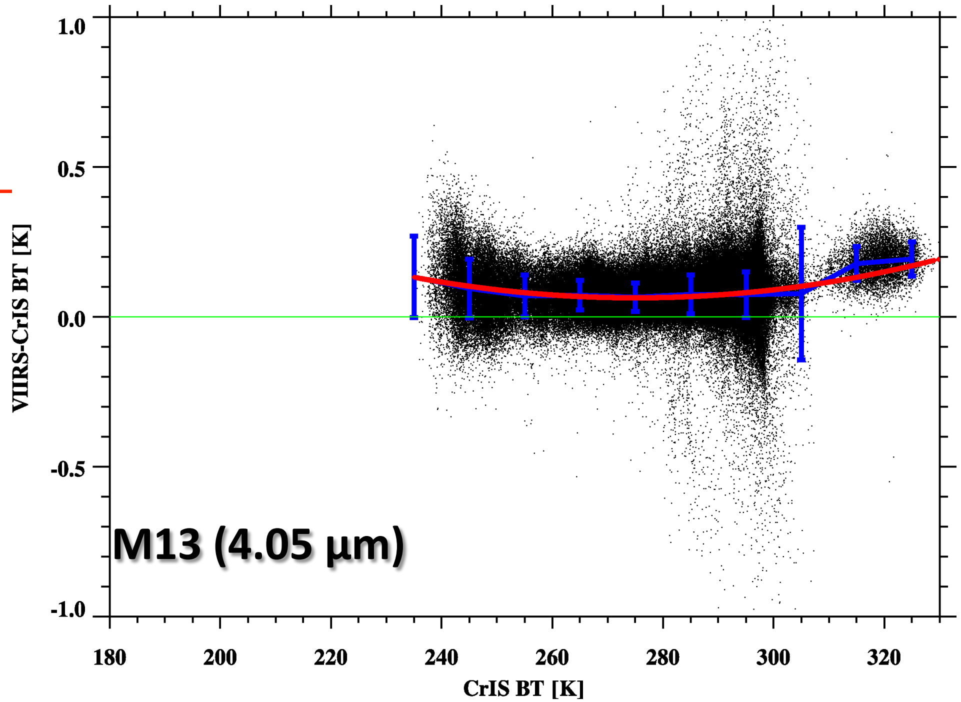
$$L_i = \frac{\int_{\nu_1}^{\nu_2} R(\nu) S_i(\nu) d\nu}{\int_{\nu_1}^{\nu_2} S_i(\nu) d\nu}$$

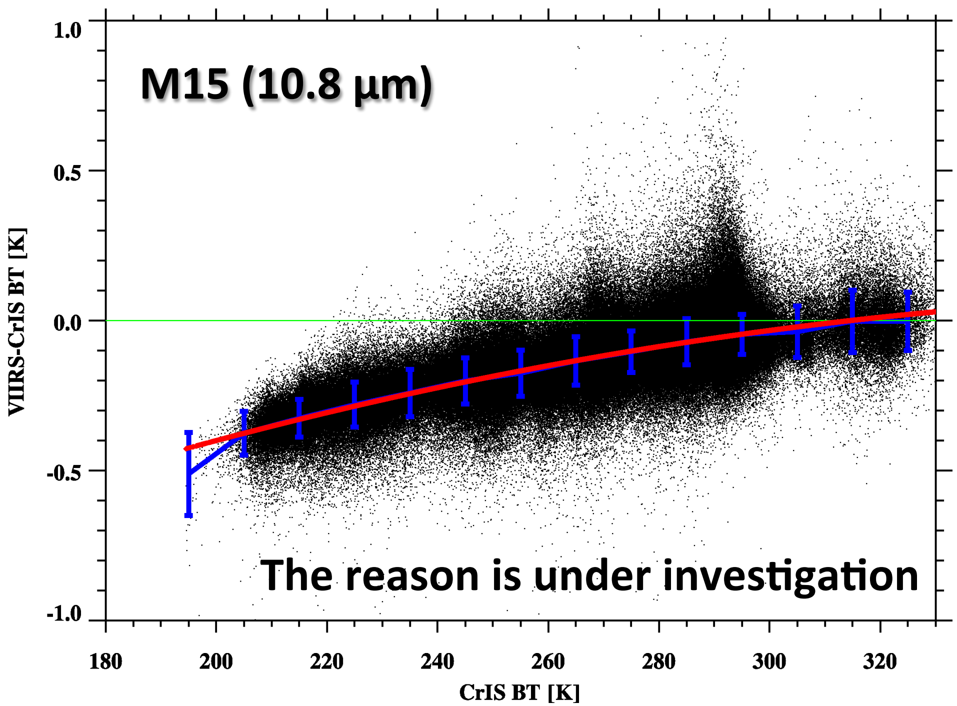


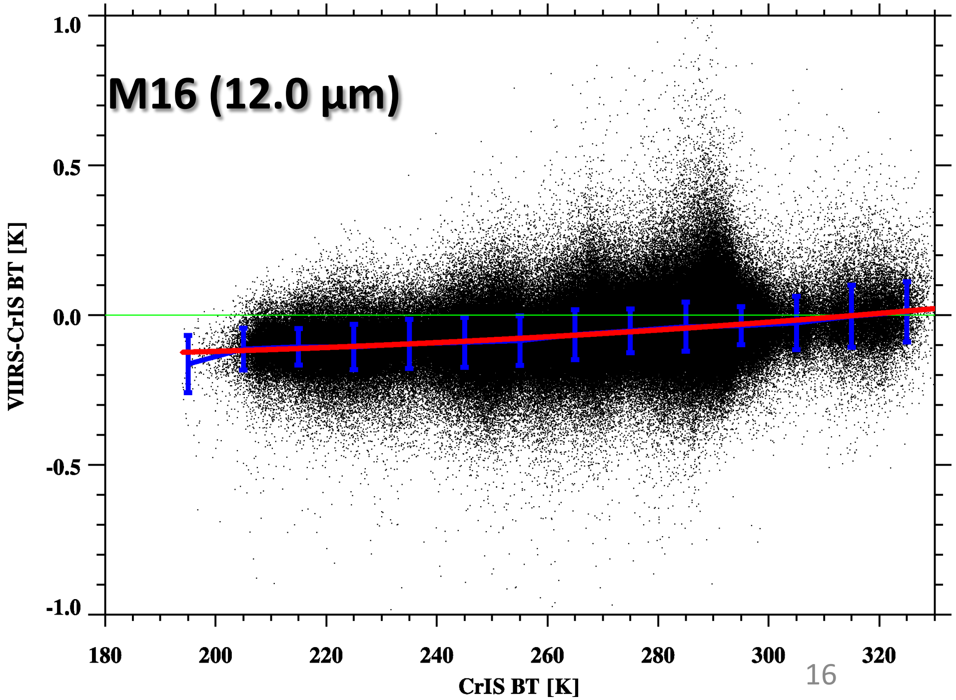


VIIRS-CrIS

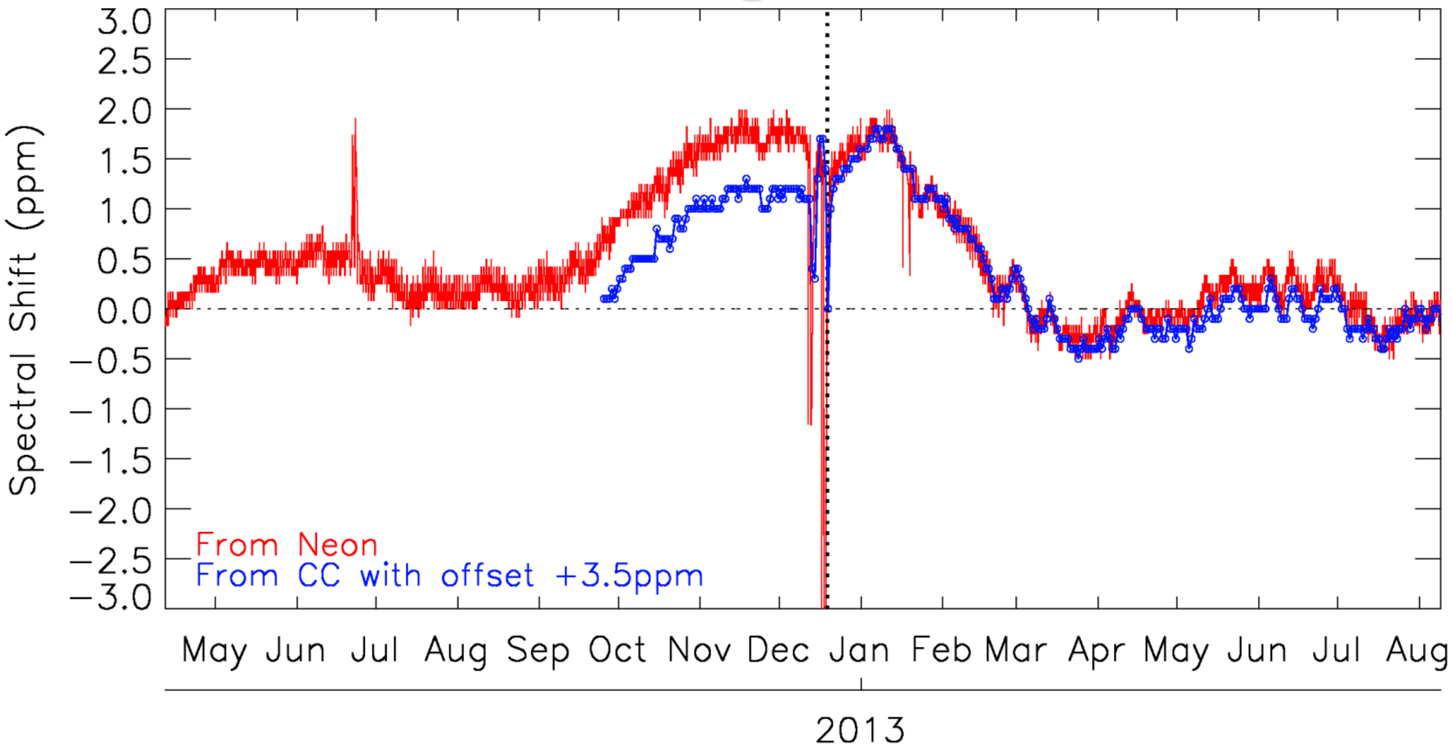
Red Line: Fitting Line
Blue Line: Bin Average







Spectral Uncertainty Long-term Monitoring
Neon Lamp vs. CRTM

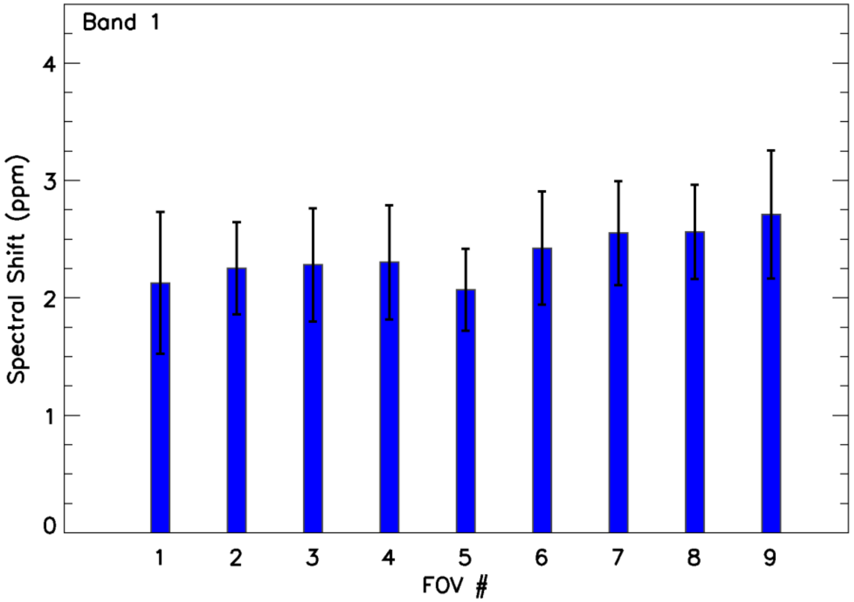


- The sharp spikes in late June and mid December 2012 are due to NPP spacecraft issues, not CrIS malfunctions.
- Band 1 FOV 5 spectral shift is determined by using cross-correlation (CC) method between CRTM simulations and observations.
- The Neon ZERO shift time is determined by the latest CMO update on Dec 19, 2012.
- An offset of +3.5 ppm from the CC results is used to match the Neon result.
- The relative spectral shift is perfectly following the Neon results after the latest CMO update.

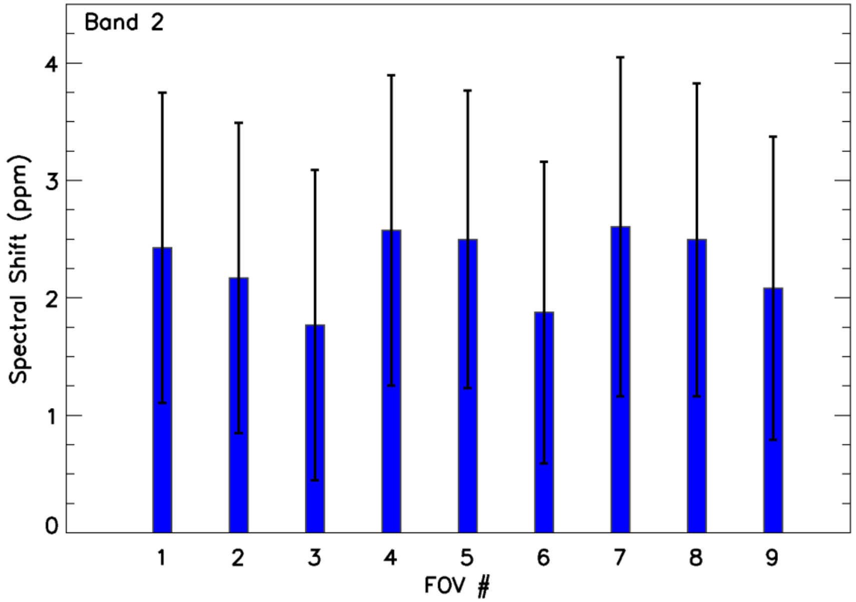
Spectral Calibration
Overall Performance relative to CRTM

Cross-correlation Method under Clear Sky between Observation and CRTM Simulation

LWIR



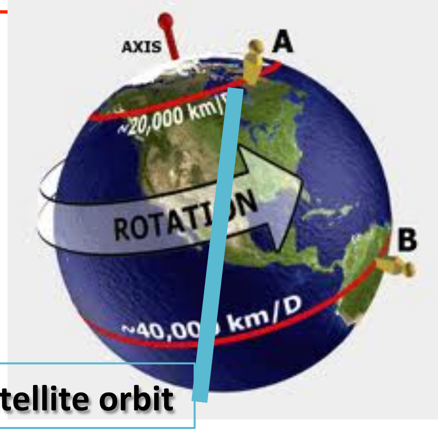
MWIR



Reprocess SDR data on 07/01/2013

- FOV spectral calibration is consistent within 1ppm
- Spectral calibration has about 2ppm offset wrt CRTM for LWIR, and MWIR (both meet requirement)

Spectral Calibration
Doppler Effects in CrIS SDR data



Spectral Shift Caused by Earth-rotation Doppler Effect

Doppler shift: $$\Delta\nu = -\frac{\nu}{c}\Omega R_s \sin(\varphi)\sqrt{\sin(i-\lambda)\sin(i+\lambda)}$$

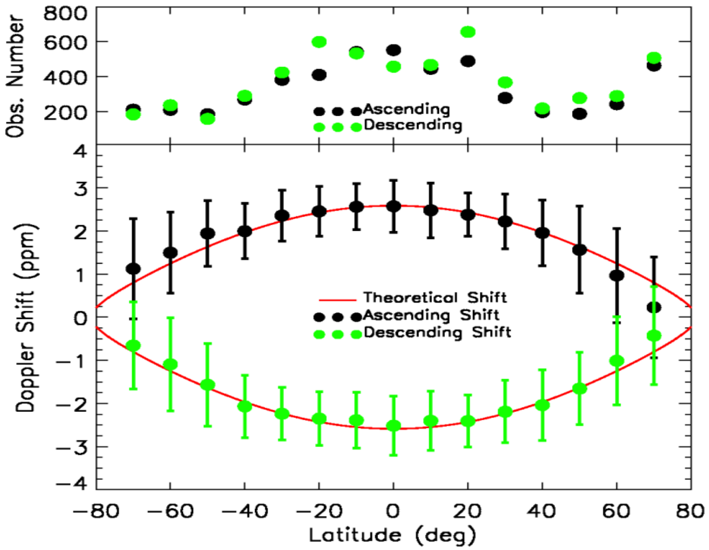
ν : channel frequency; Ω: Earth angular velocity

R_s: Distance of the satellite from the center of the Earth

i : Inclination of the orbit; λ: Latitude

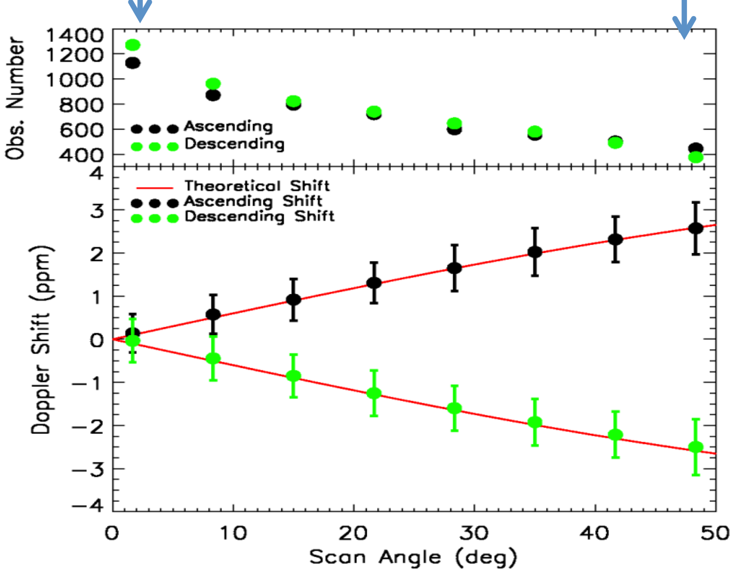
Φ: Scan angle

FOR1 frequency shift relative to FOR30



FOR15 relative to FOR16

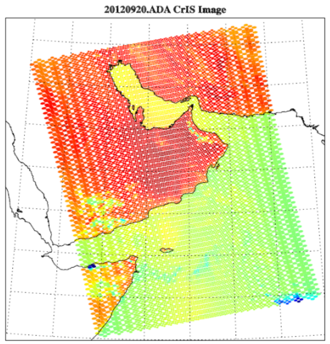
FOR1 relative to FOR30

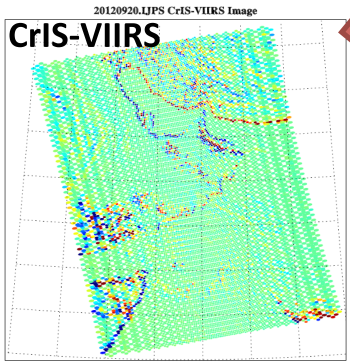


Chen, et al. 2013, Applied Optics

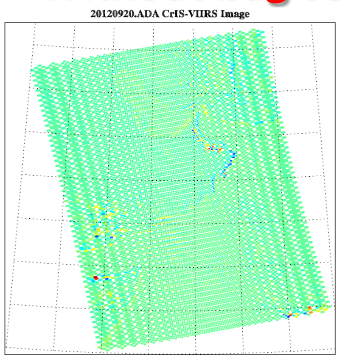
The Earth-rotation Doppler effect can cause a channel frequency bias up to 1.3 ppm, and Very stable CrIS performance allows detection of very small frequency shifts

Geolocation Assessment

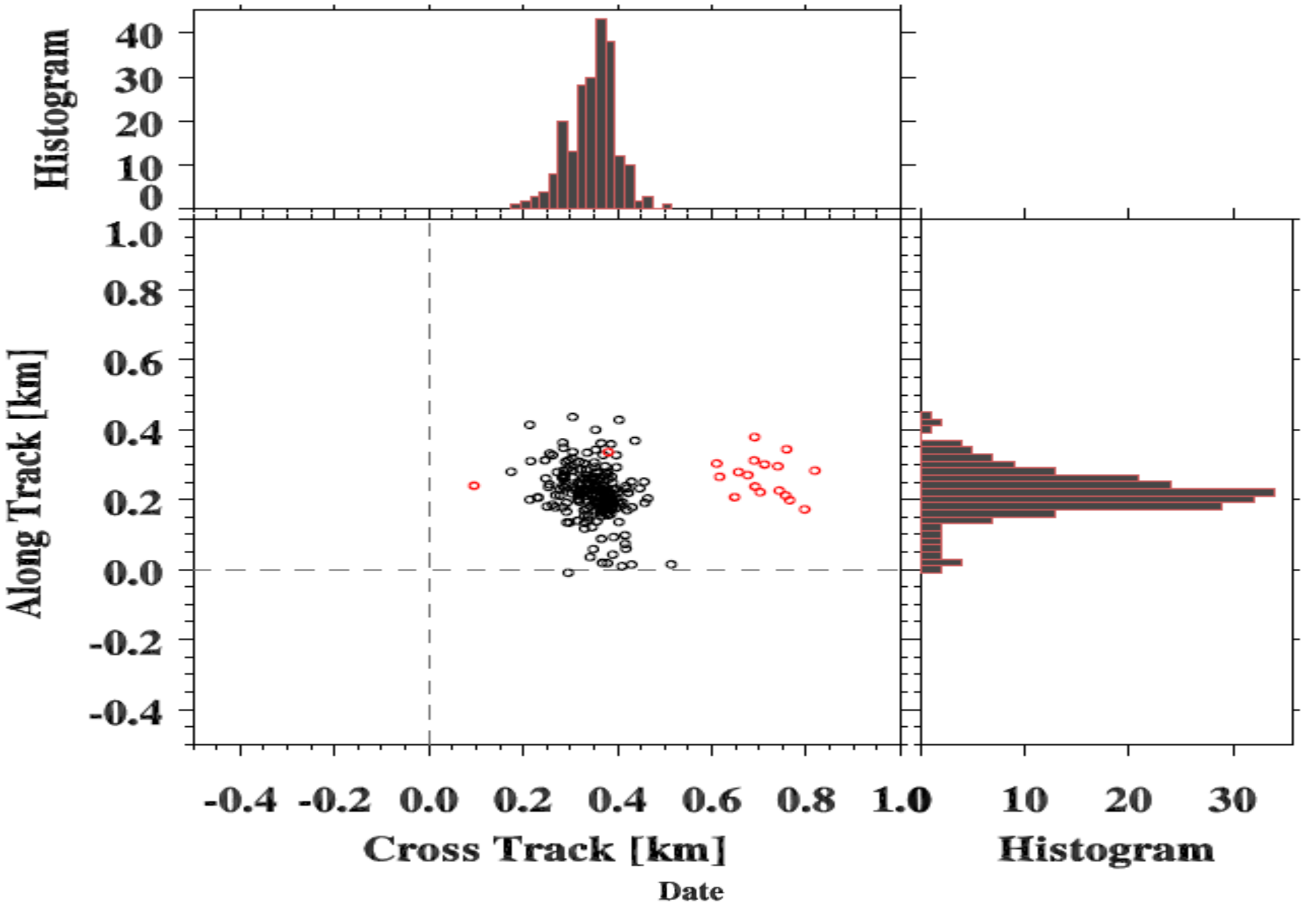




Without bug correcte

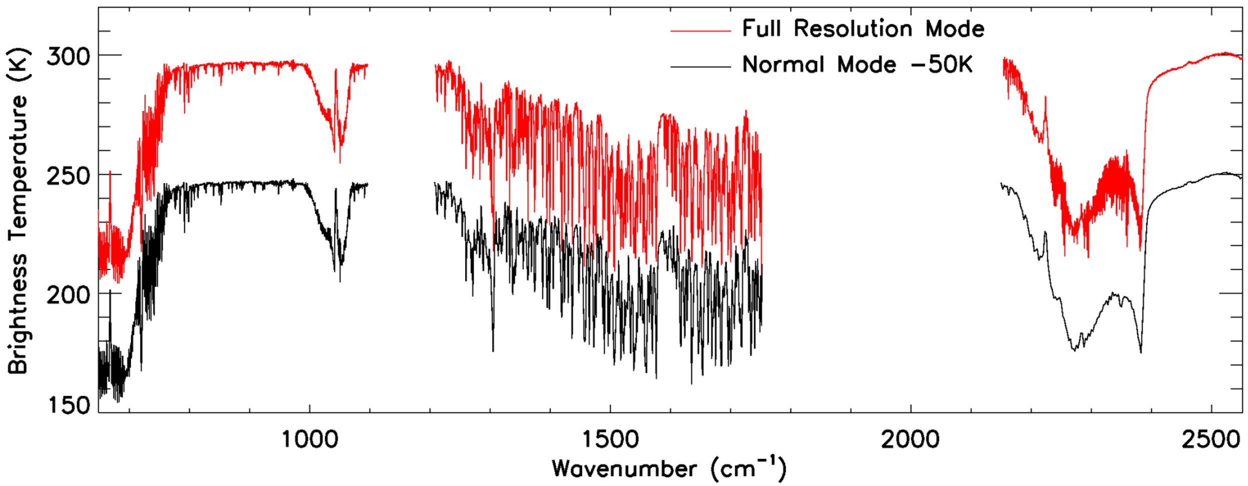


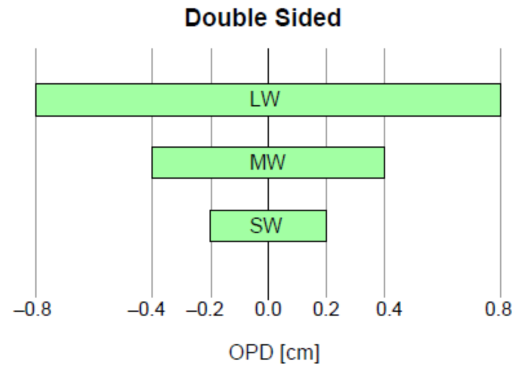
With bug corrected



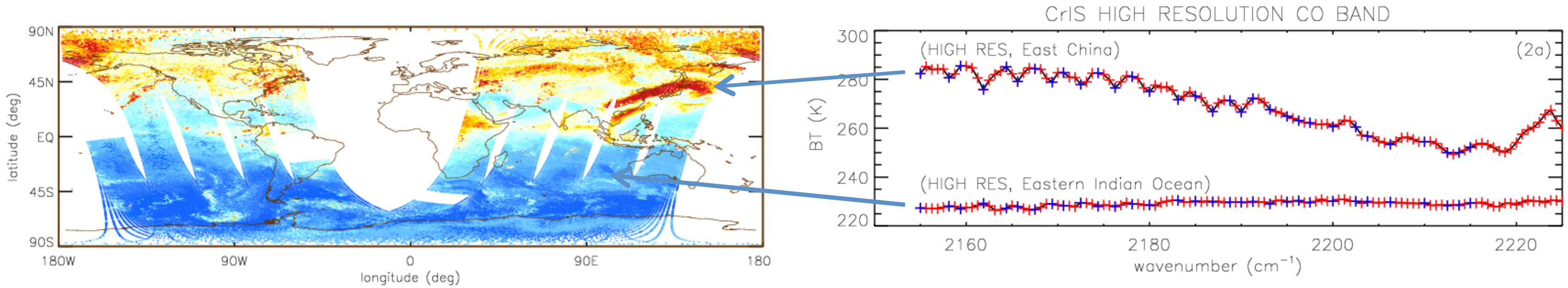
- Geolocation source code has been fixed and implemented in MX6.3 (10/16/2012).
- Geolocation accuracy is: Cross Track: 0.347±0.051 km (one sigma)
  Along Track: 0.219±0.073 km

Normal Mode *vs.* Full Resolution

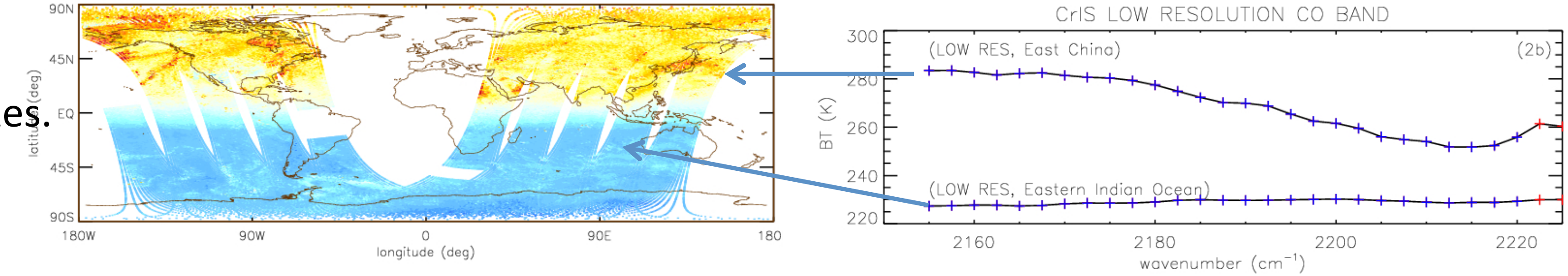




Hi Res.

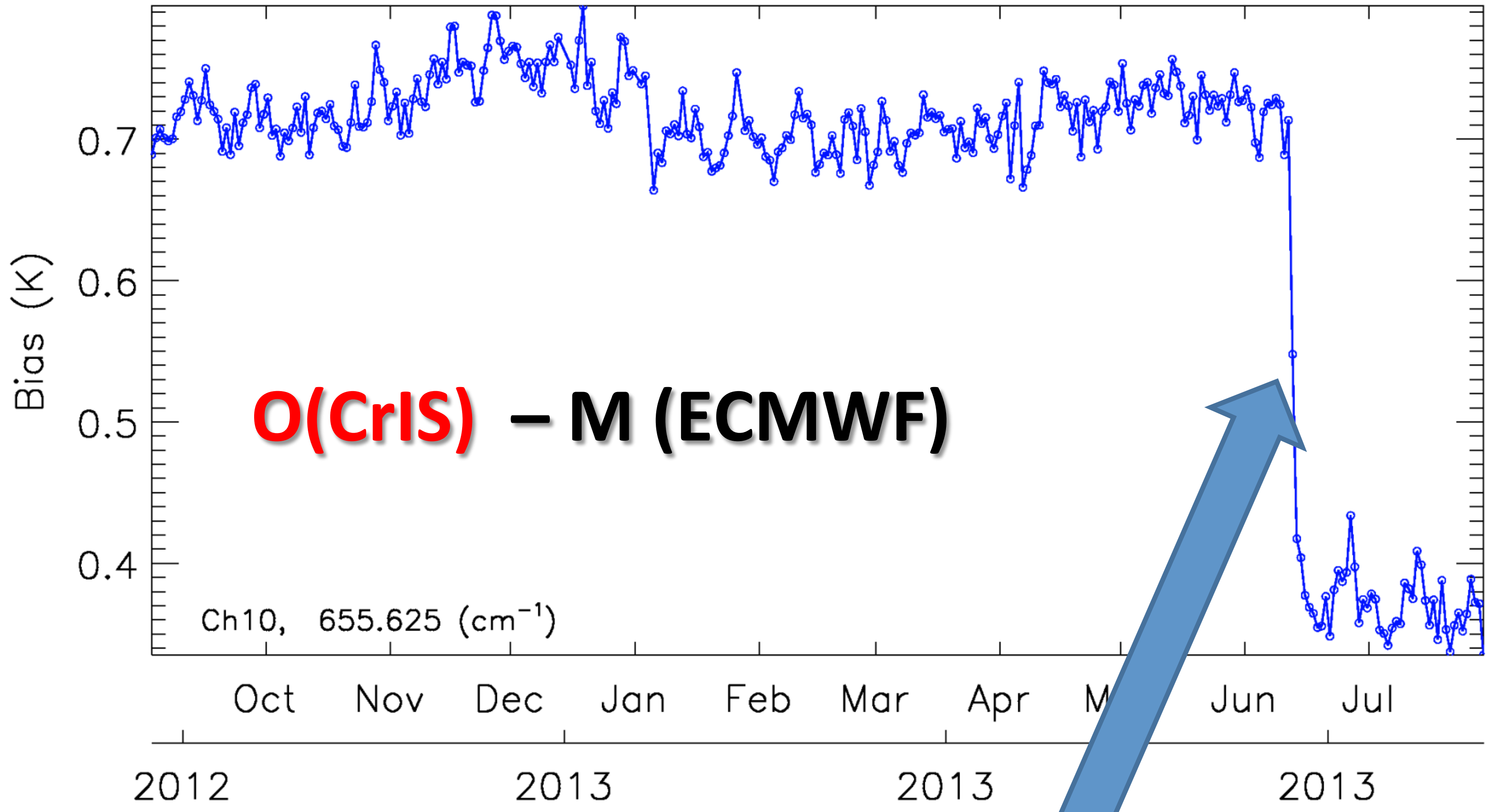


Low Res.



Courtesy of A. Gambacorta, NOAA-STAR

Re-Processing is ongoing for Long-term, Consistent SDR products



- CrIS normal mode SDR biases relative to ECMWF. Bias is mostly stable, a[illegible]mproved at this stratospheric channel after ECMWF model change on June 25, 2013. ECMWF IFS cycle 38r2 increases the vertical resolution of the model throughout the troposphere and stratosphere (from 91 levels to 137 levels).
- More detail see: http://www.ecmwf.int/products/changes/ifs_cycle_38r2

Summary

- CrIS has excellent performance since launch and meets or exceeds requirements:
  - Radiometric accuracy
  - Spectral calibration
  - Geolocation
  - Noise

- Provisional maturity level was declared on Feb 2013.

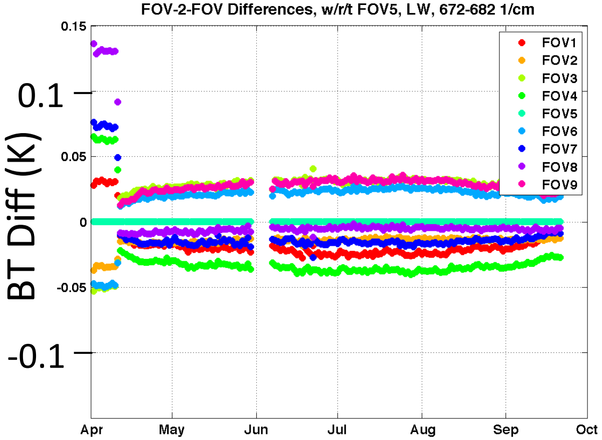
- CrIS radiance is ready for assimilation by NWP.

- The way moving foreword:
  - Full resolution data
  - Reprocessing CrIS SDR data for a long-term, consistent SDR

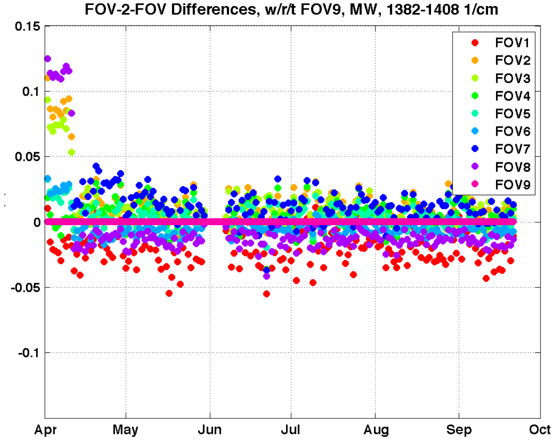
Backup

Radiometric Uncertainty Assessment
Inter-FOV difference

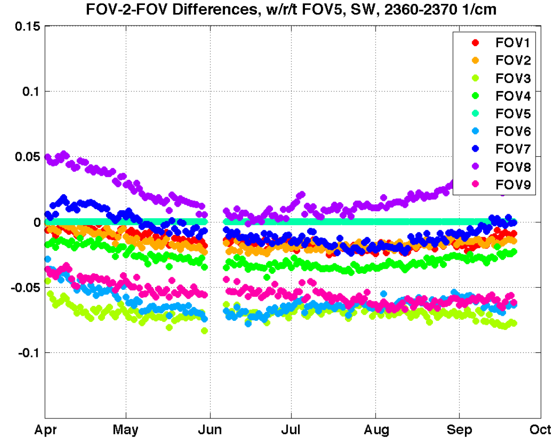
LW, 672-682 cm^{-1}, wrt FOV5



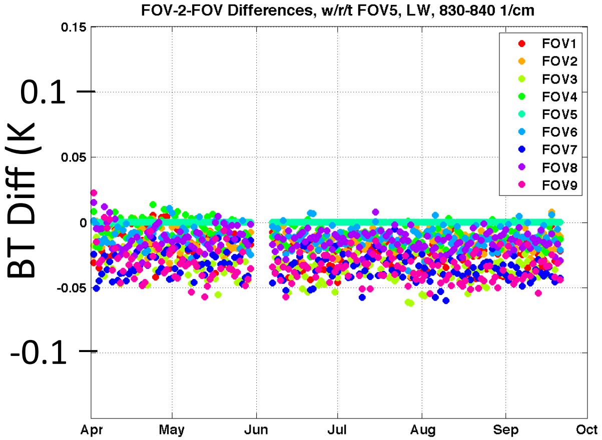
MW, 1382-1408 cm^{-1}, wrt FOV9



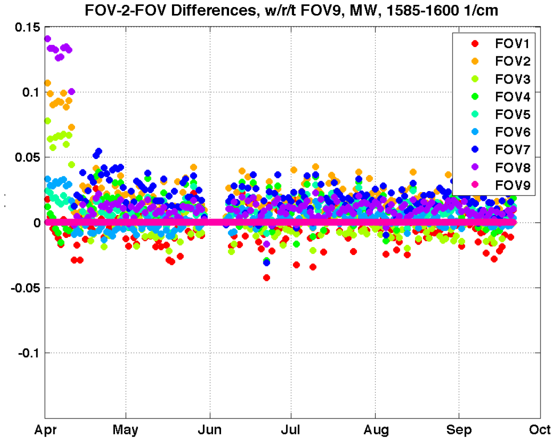
SW, 2360-2390 cm^{-1}, wrt FOV5



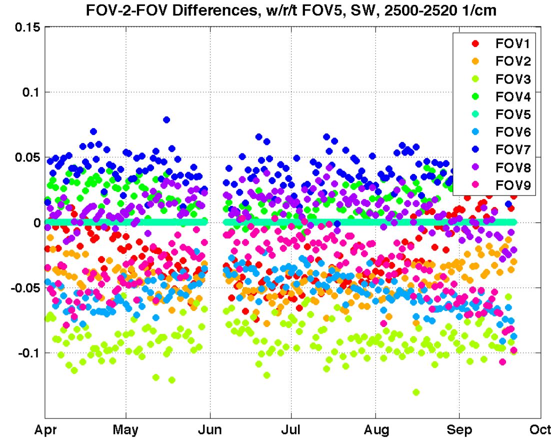
LW, 830-840 cm^{-1}, wrt FOV5



MW, 1585-1600 cm^{-1}, wrt FOV9



SW, 2500-2520 cm^{-1}, wrt FOV5



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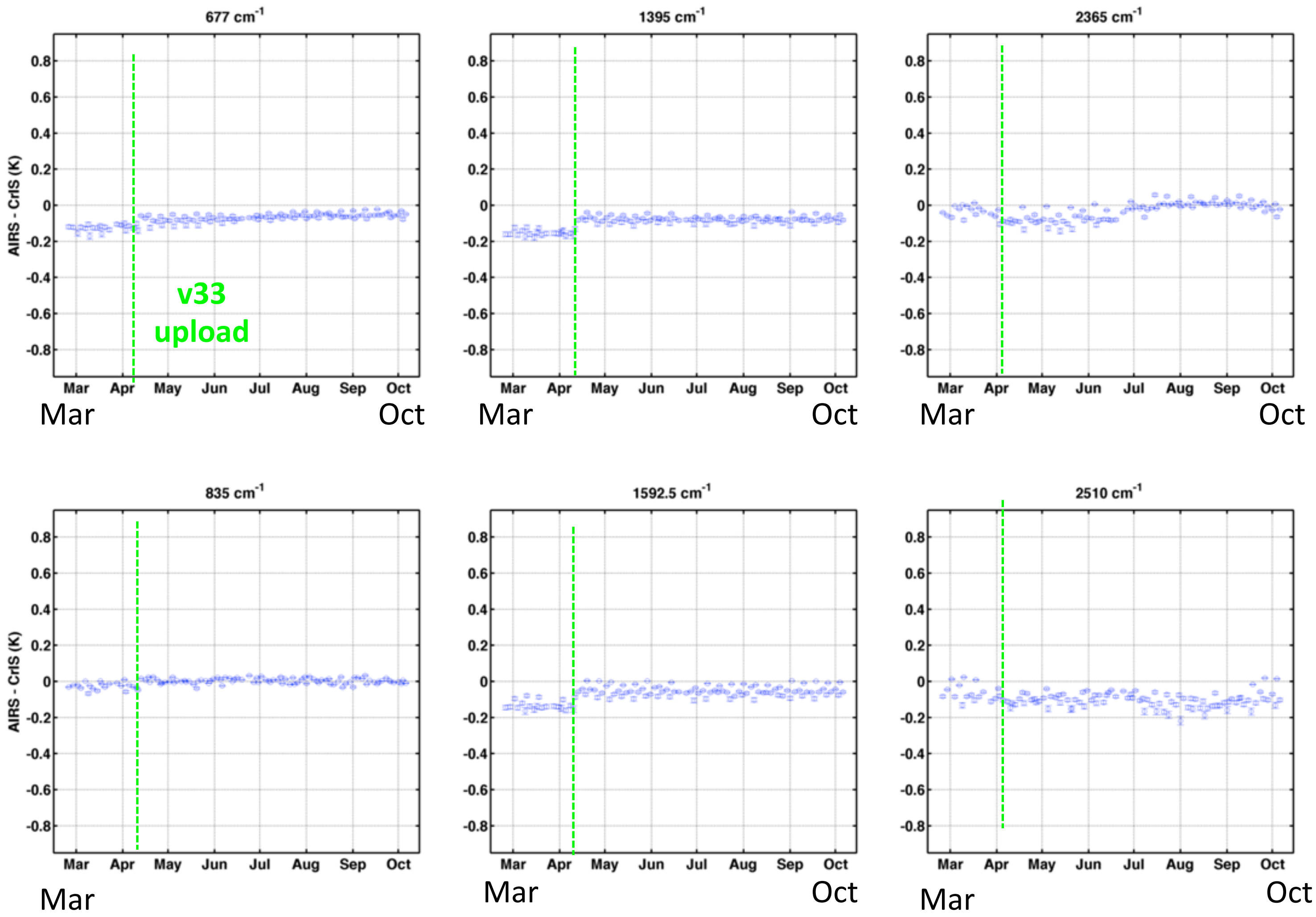
FOV-2-FOV differences are less than 0.04 K for LW and MW and less than 0.1 K for SW

Radiometric Uncertainty Assessment
Daily Mean AIRS-CrIS Differences



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Stable difference ~0.1 K