Suomi NPP CrIS Reprocessed SDR Long-term Accuracy and Stability

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CICS Science Conference, November 29 - December 1, 2016

Outline

- Importance of CrIS reprocessed SDR for inter-calibration and climate applications
- Reprocessed SDR long-term radiometric accuracy and stability
- Reprocessed SDR long-term spectral accuracy and stability
- Summary

CrIS SDR CalVal Milestones

*Algorithm and software improvement
*CrIS performance characterization
*Radiometric CalVal
*Spectral CalVal
*Geolocation CalVal
*CrIS instrument and SDR trending and monitoring

Intensive Calibration & Validation (ICV)

10/28/2011
Launched

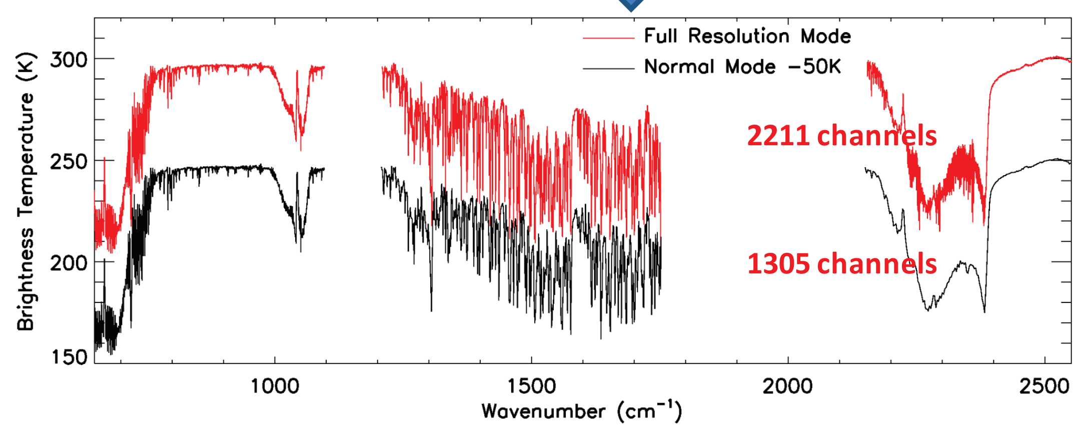
04/02/2012
First SDR product

04/19/2012
Beta status

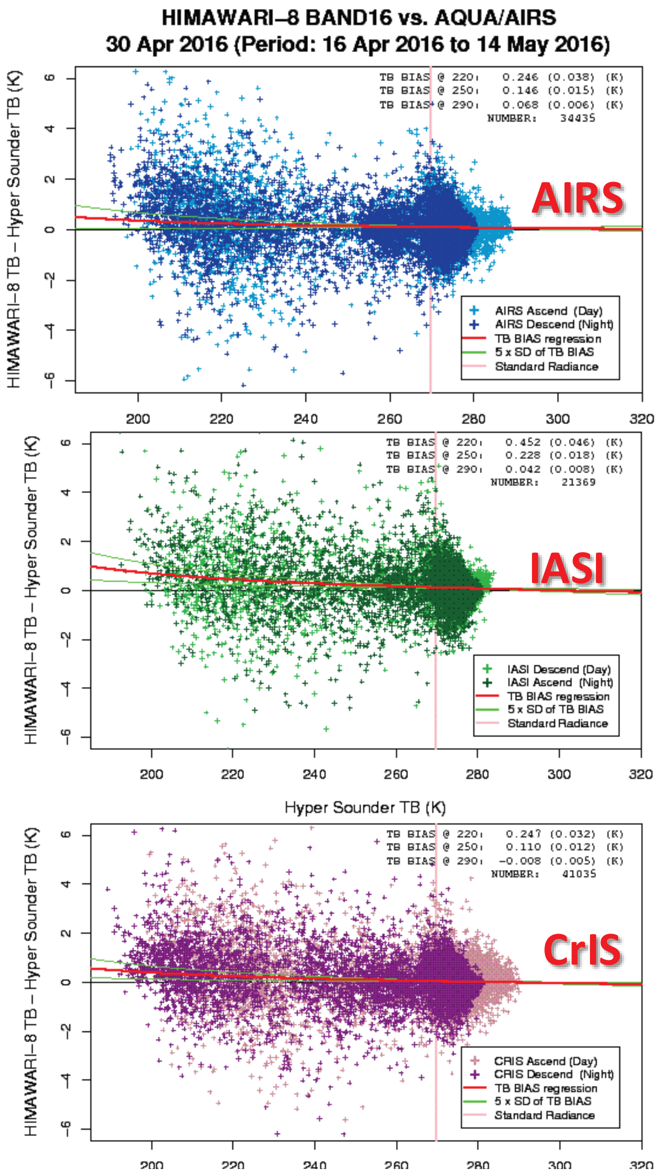
01/13/2013
Provisional status

02/20/2014
Validation status; Calibration algorithm and coefficient updates (Mx8.1)

12/04/2014
Full spectral resolution mode



GSICS IR References – AIRS, CrIS, and IASI



- AIRS
  - **10% of 2378 channels degraded or dead**
  - **No follow-on sensor since Aqua/AIRS in 2002**
  - **Spectral gaps**
  - Reprocessing capabilities
- IASI
  - MetOp-A → -MetOp B → MetOp C → EPS NG
  - **No reprocessing capabilities**
  - Fully spectral coverage
- CrIS
  - SNPP → J1 →J2 → J2 beyond
  - **Spectral gaps**
  - Reprocessing capabilities

life-long consistency of CrIS SDR spectral, radiometric, and geometric calibration is very important for inter-calibration and climate applications.

JMA GSICS website: HIMAWARI AHI band 16

Reprocessed CrIS SDR

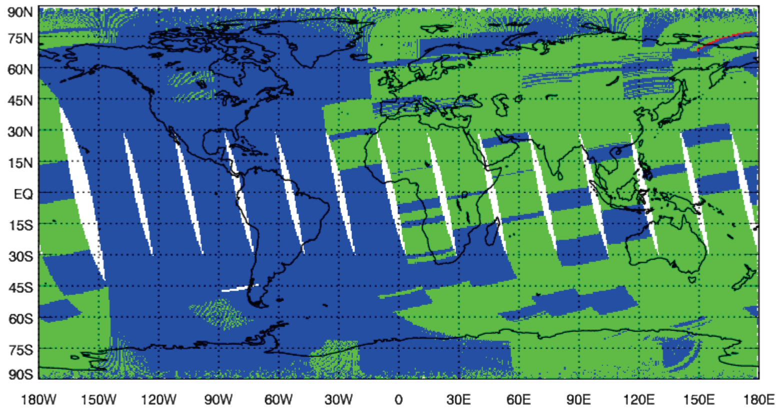
- Reprocessed CrIS SDR data quality is improved for climate applications with its fine-tuning of calibration coefficients in NOAA reprocessing project.
- One specific code for CrIS SDR reprocessing was developed. This code was based on ADL5.3.1 PSAT16 with updates for calibration algorithm, non-linearity, and geolocation to improve the scientific results.
- The calibration coefficients are refined with the latest updates based on the work from CrIS science team, and are inserted in the Engineering Packet in the Raw Data Record (RDR) data stream.
- The resampling wavelength was updated based on the metrology laser wavelength and resulting in zero sampling error in the spectral calibration.
- All the SDRs are generated with the same calibration coefficients, resulting in improved consistency during the CrIS life-time mission.

SDR Overall Quality Flag Improvement

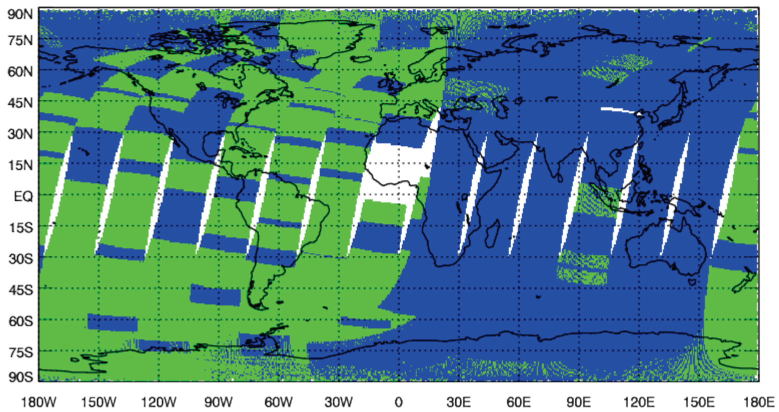
IDPS SDR

NPP CrIS Long Wave SDR Overall Quality Flag, Mapped, Ascending, 06/27/2012

(Blue: Good; Green: Degraded; Red: Invalid) Updated at Aug 10 22:48:06 2015 UTC



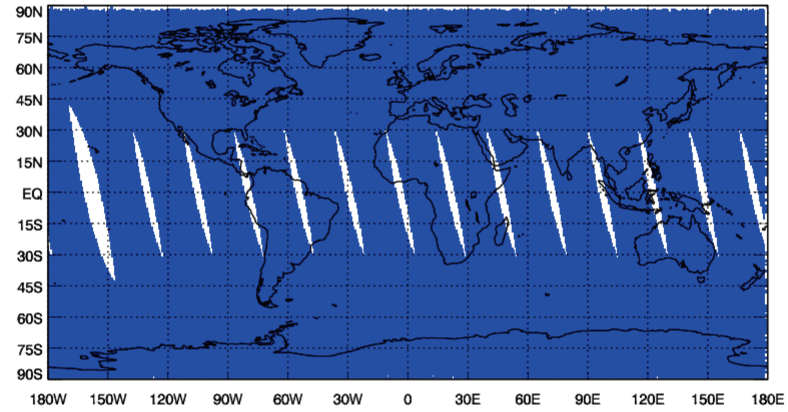
NPP CrIS Long Wave SDR Overall Quality Flag, Mapped, Descending, 06/27/2012



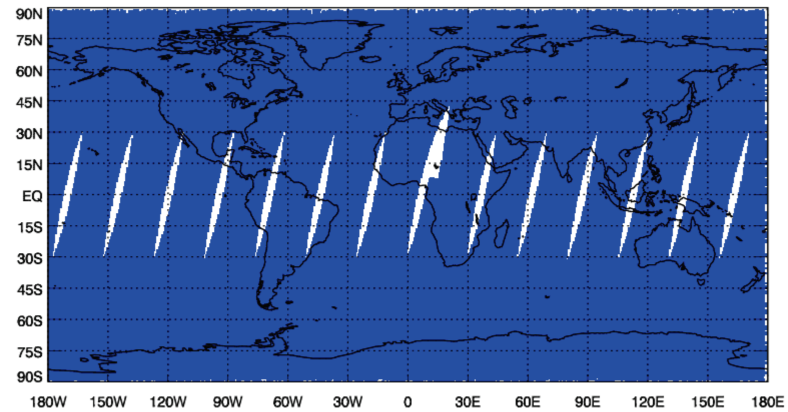
Reprocessed SDR

NPP CrIS Long Wave SDR Overall Quality Flag, Mapped, Ascending, 06/27/2012

(Blue: Good; Green: Degraded; Red: Invalid) Updated at Oct 7 17:34:09 2016 UTC



NPP CrIS Long Wave SDR Overall Quality Flag, Mapped, Descending, 06/27/2012



Overall quality flag has no degraded values after Temperature Drift Limits Updated in Eng Pkt

CrIS Radiometric Accuracy Assessment Methods

- Assessment approach 1: Biases between CrIS observations and simulations using ECMWF analysis/reanalysis fields and forward model CRTM (Community Radiative Transfer Model)

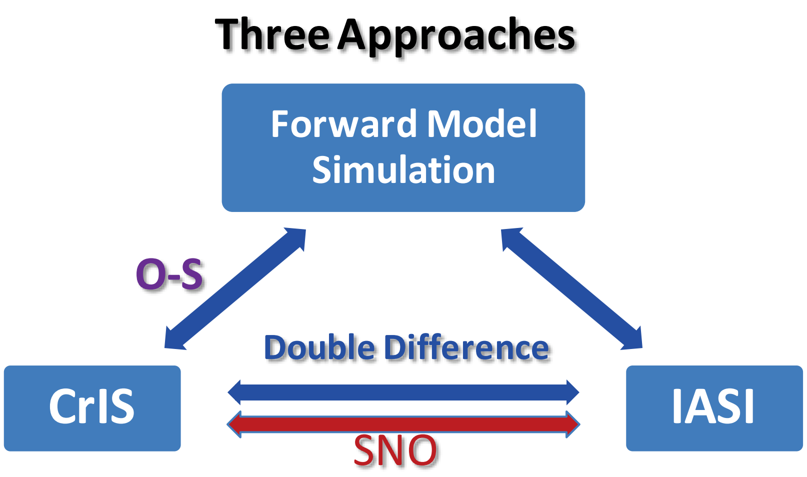
$$BIAS = \overline{(Obs - CRTM)}$$

- Assessment approach 2: Double difference between CrIS and IASI on MetOp-a/b (converted to CrIS) using CRTM simulation as a transfer tool

$$DD = \overline{(Obs - CRTM)_{CrIS}} - \overline{(Obs - CRTM)_{IASI2CrIS}}$$

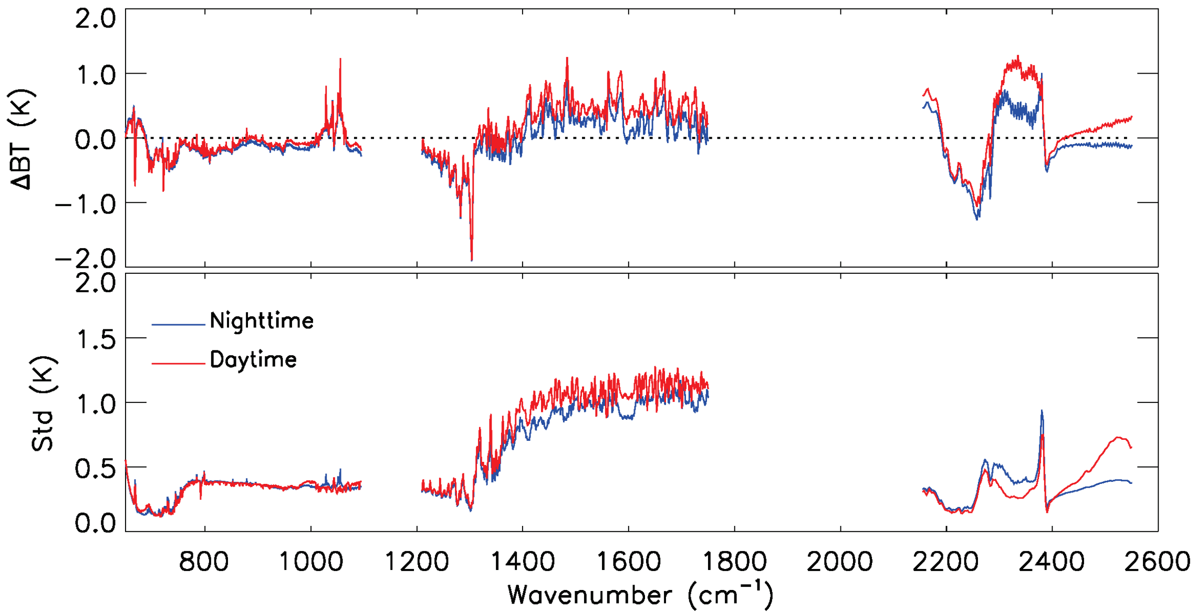
- Assessment approach 3: SNO difference between CrIS and IASI converted to CrIS

$$BT_{diff} = BT_{CrIS} - BT_{IASI2CrIS}$$

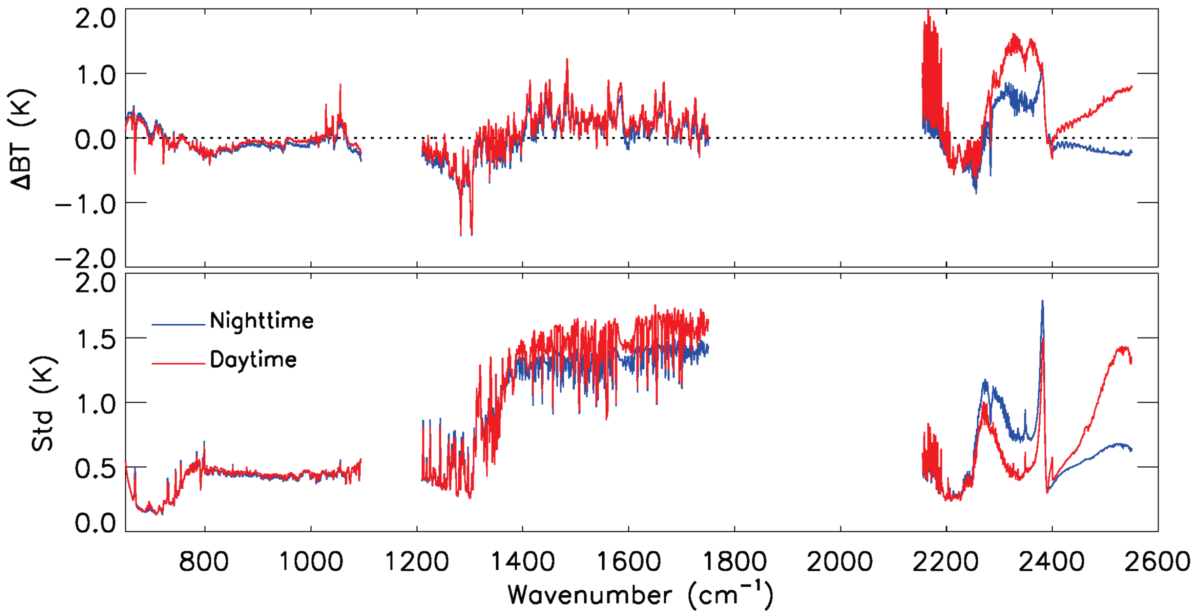


CrIS Radiometric Accuracy

Obs-Simulation
Clear scenes
Over ocean



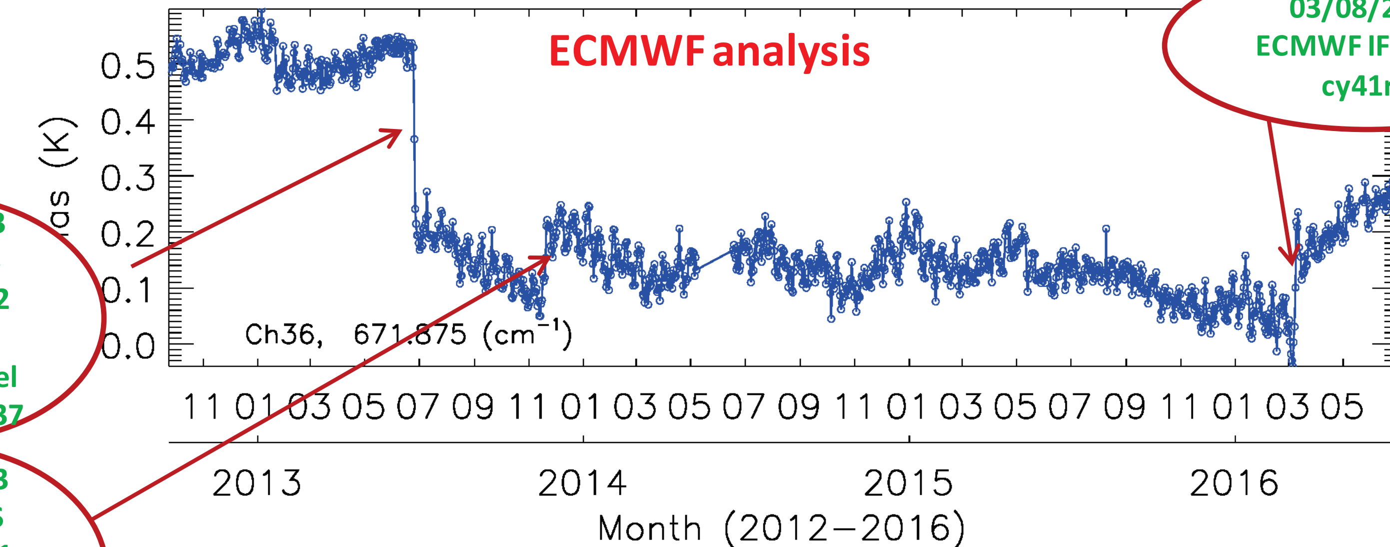
CrIS Normal Resolution



CrIS Full Spectral Resolution

CrIS Radiometric Stability: Obs-Simulation Time Series

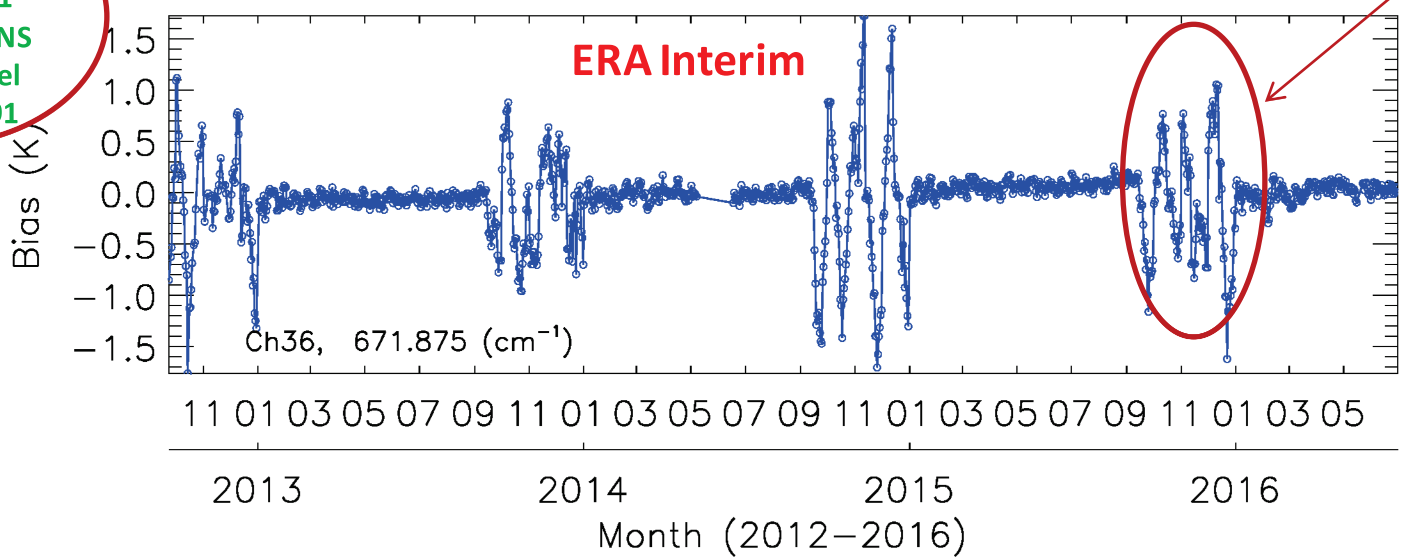
LW 671.875 cm^{-1}



06/25/2013 ECMWF IFS cycle cy38r2 Increasing vertical level from 91 to 137

11/19/2013 ECMWF IFS cycle cy40r1 Increasing ENS vertical level from 62 to 91

03/08/2016 ECMWF IFS cycle cy41r2

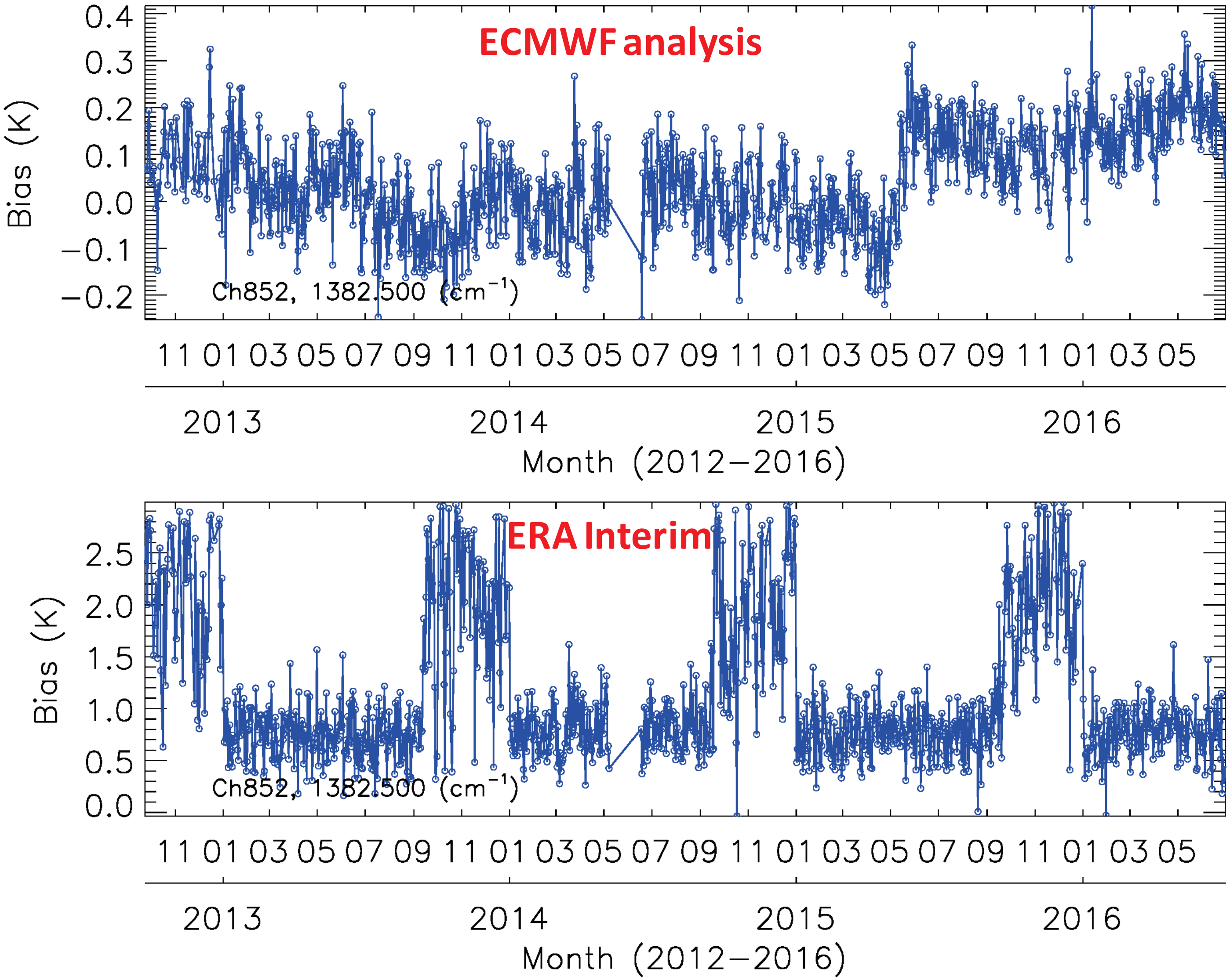


Why? Need to further investigate

The data gap from May 8, 2014 to June 16, 2014 is due to loss of ECMWF analysis data

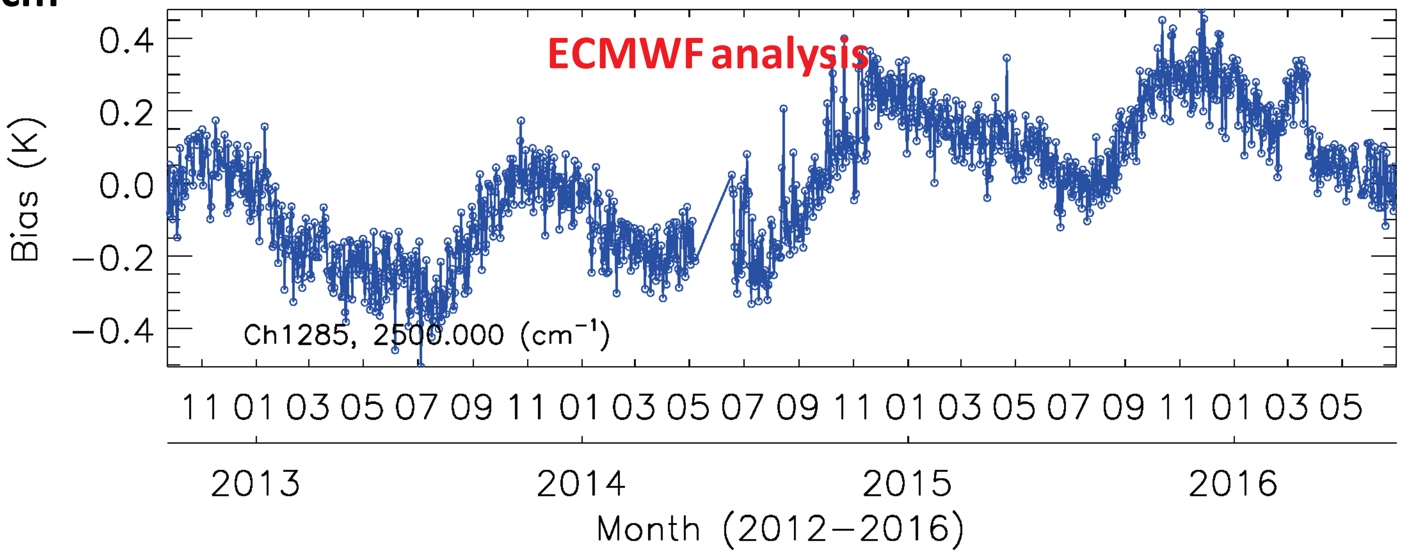
CrIS Radiometric Stability: Obs-Simulation Time Series

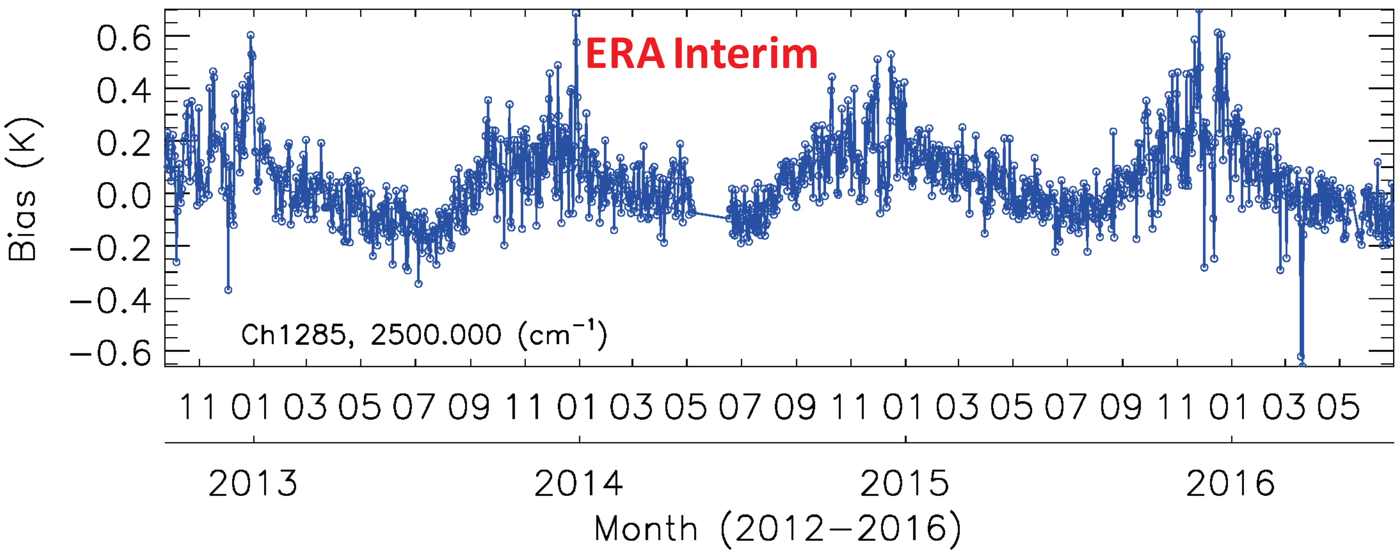
MW 1382.5 cm^{-1}



CrIS Radiometric Stability: Obs-Simulation Time Series

SW 2500.0 cm^{-1}

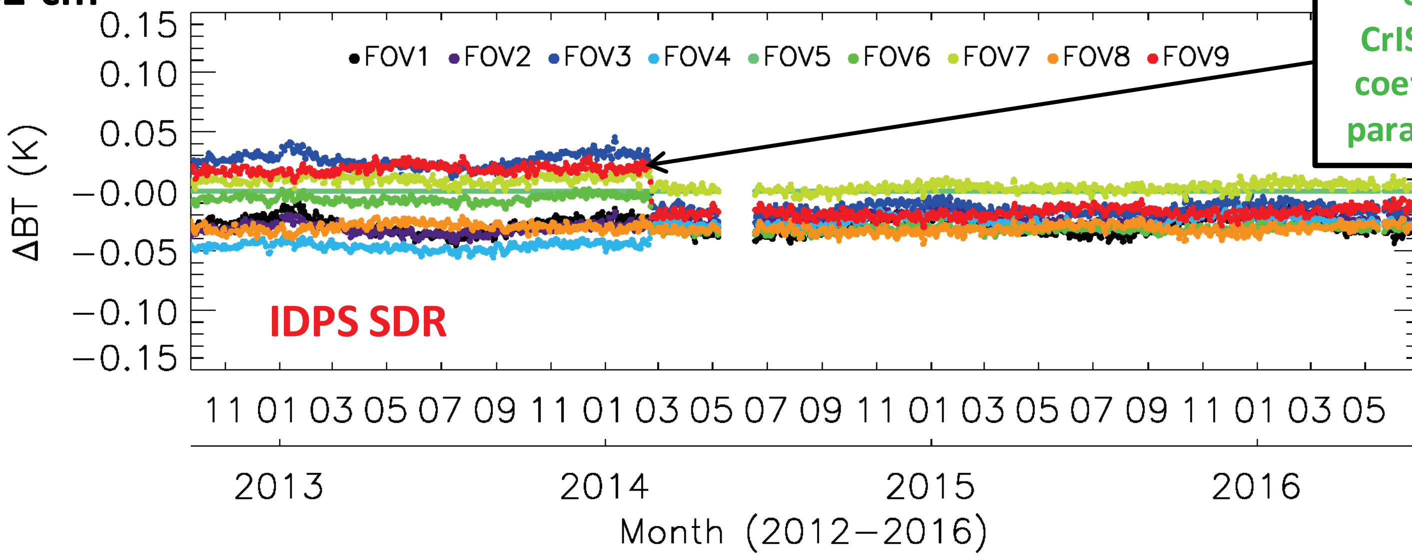


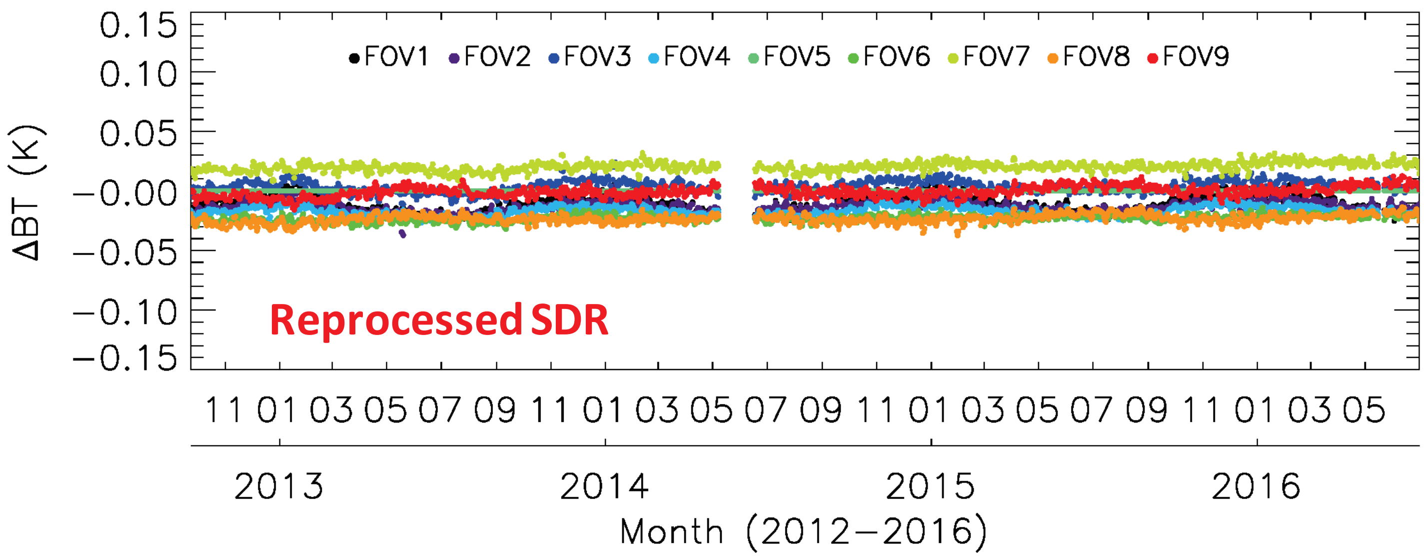


CrIS Radiometric Stability: Daily Mean FOV-2-FOV Difference wrt FOV5

LW, 672-682 cm^{-1}

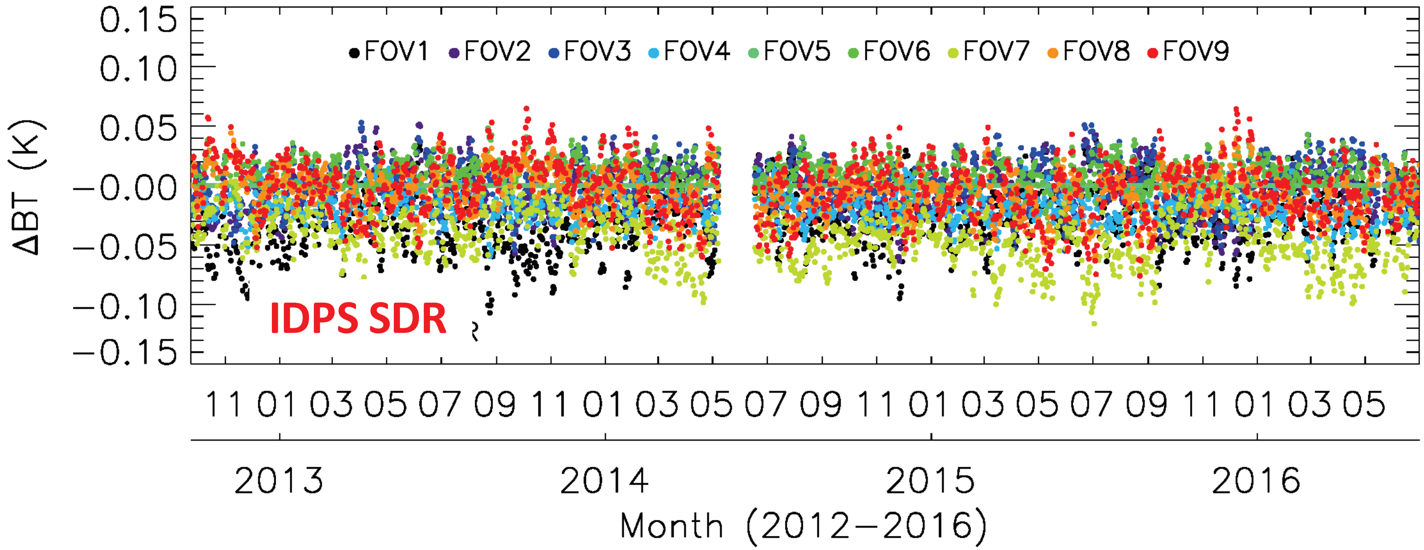
02/20/2014 CrIS non-linearity coefficient and ILS parameters update

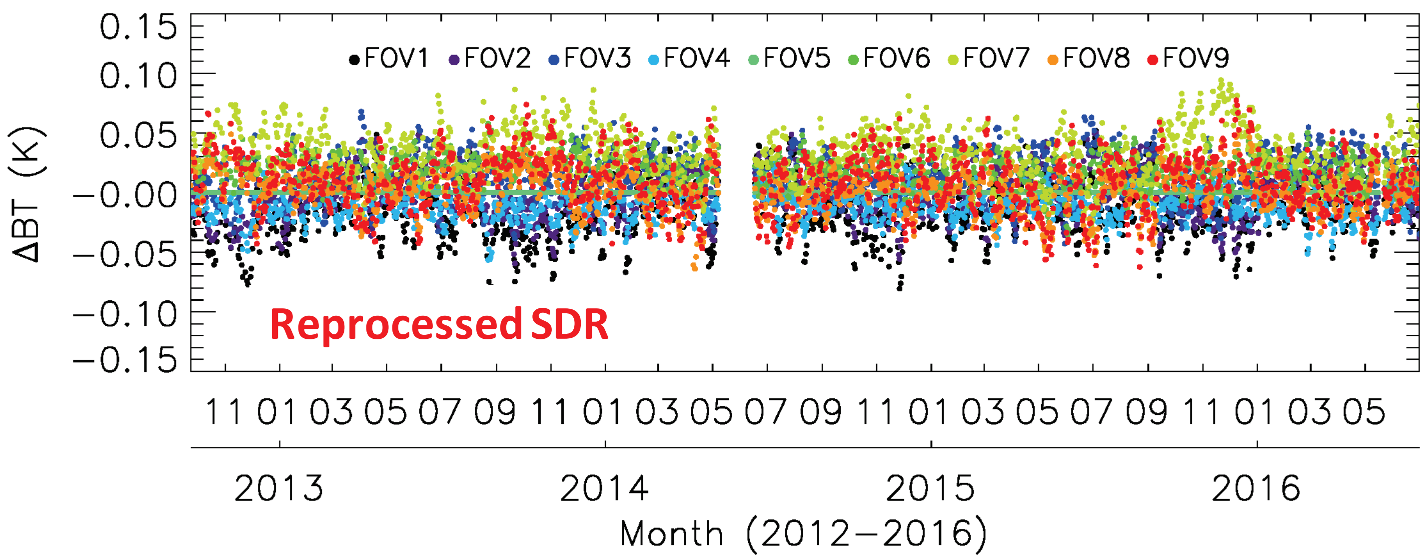




CrIS Radiometric Stability : Daily Mean FOV-2-FOV Difference wrt FOV5

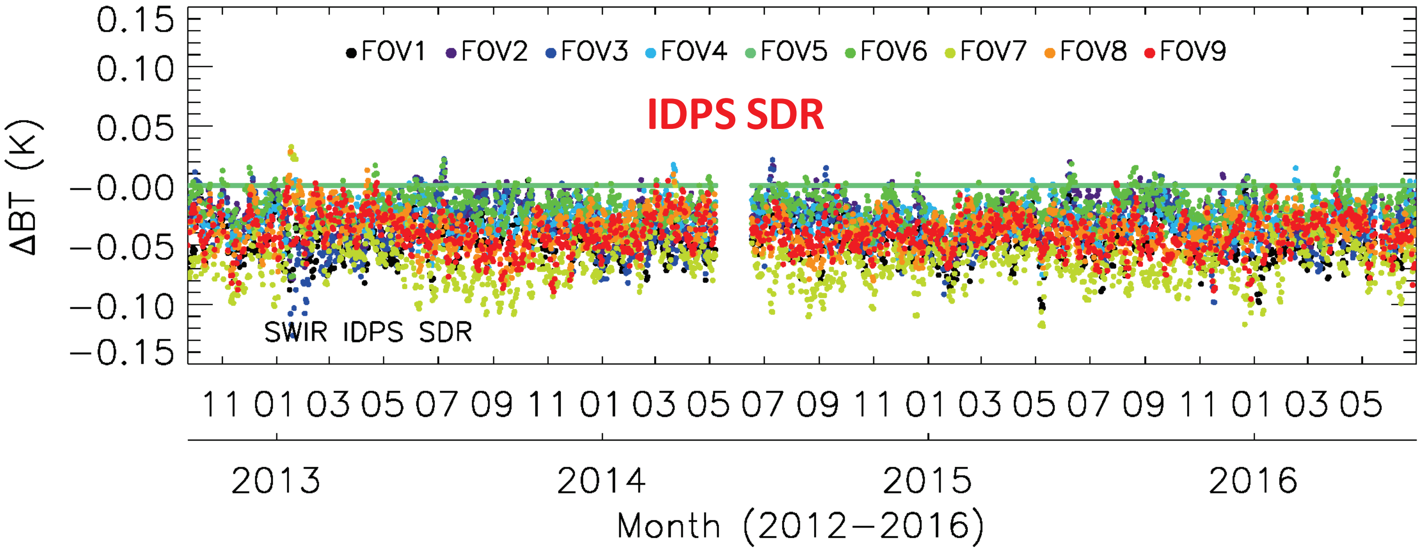
MW, 1585-1610 cm^{-1}

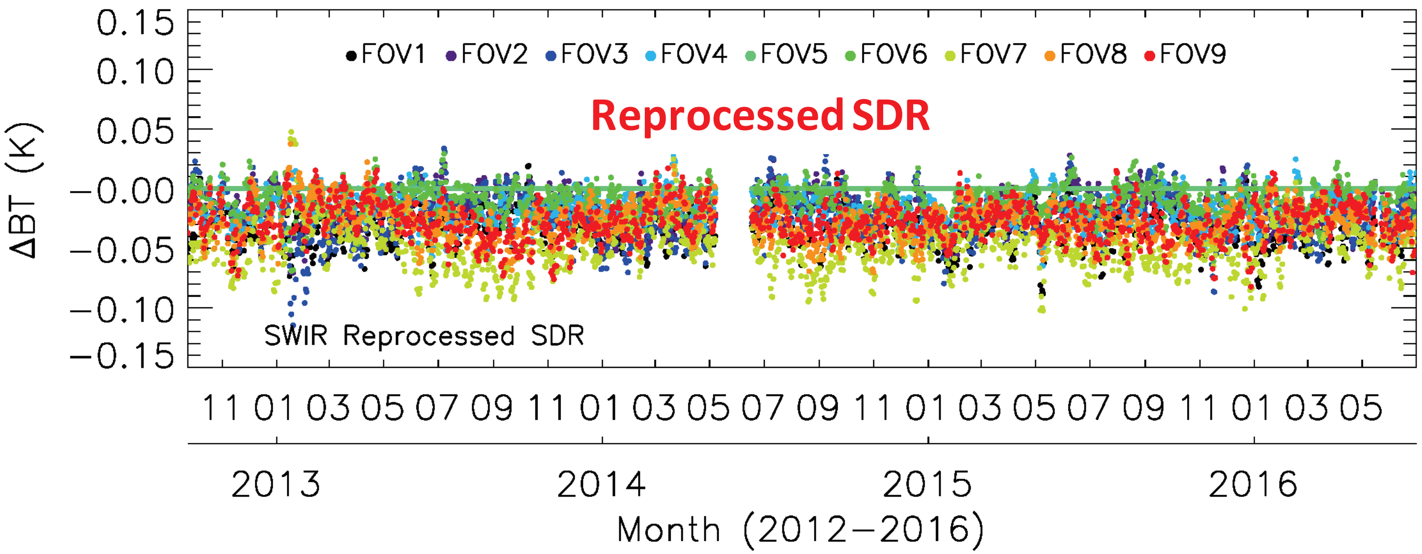




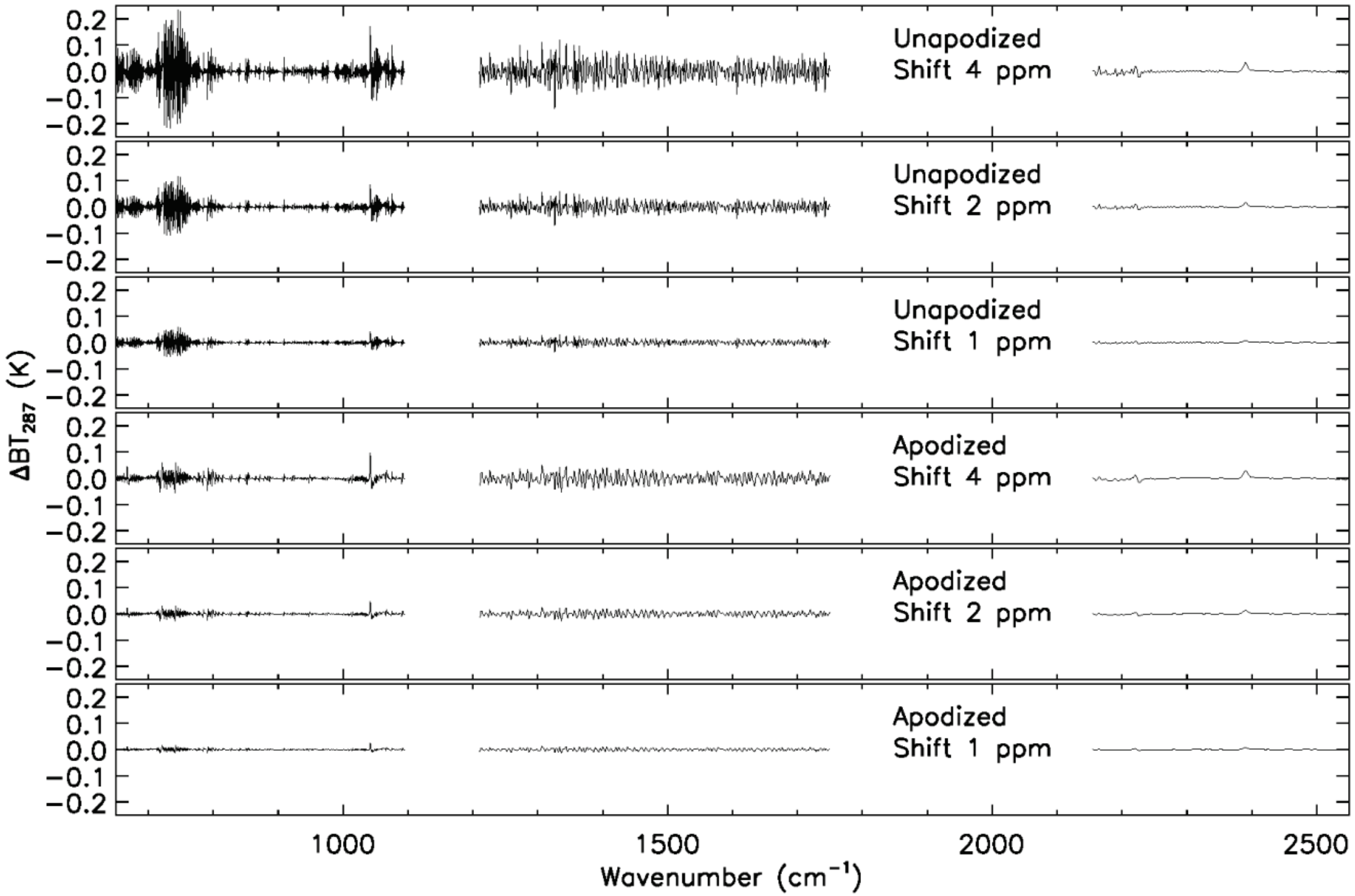
CrIS Radiometric Stability : Daily Mean FOV-2-FOV Difference wrt FOV5

SW, 2500-2520 cm^{-1}





Spectral Accuracy Impact on Radiometric Accuracy



Impact of spectral accuracy on radiometric accuracy in terms of brightness temperature difference for a typical warm scene with respect to an effective BT of 287 K for three different spectral shifts (1 ppm (parts per million), 2 ppm, and 4 ppm) at CrIS three bands for both unapodized and apodized spectra.

Spectral Validation Using Cross-Correlation Method

Two basic spectral validation methods are used to assess the spectral accuracy

- Relative spectral validation, which uses two uniform observations to determine frequency offsets relative to each other
- Absolute spectral validation, which requires an accurate forward model to simulate the top of atmosphere radiance under clear conditions and correlates the simulation with the observed radiance to find the maximum correlation

Correlation coefficient between the two spectra:

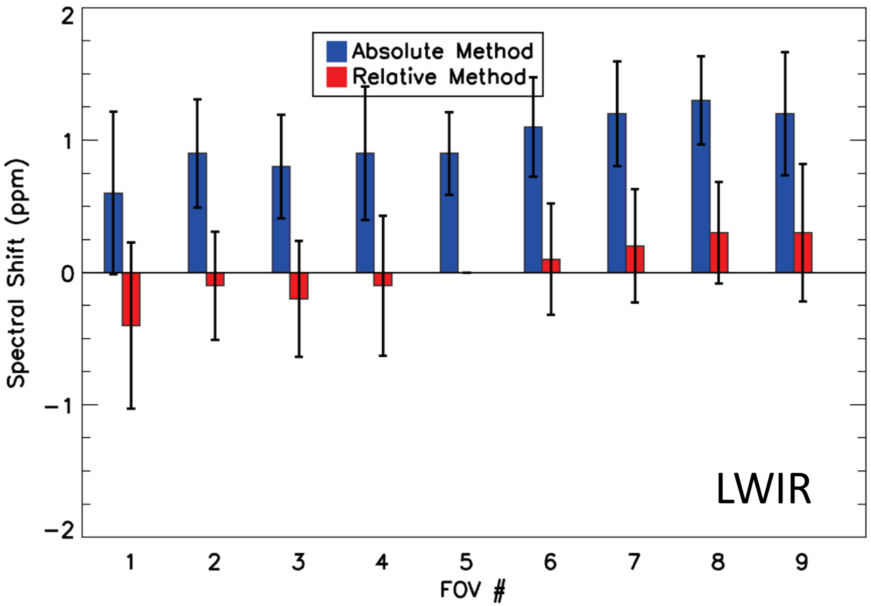
$$r_{S_1S_2} = \frac{\sum_{i=1}^{n}(S_{1,i}-\overline{S_1})(S_{2,i}-\overline{S_2})}{(n-1)D_{S_1}D_{S_2}} = \frac{\sum_{i=1}^{n}(S_{1,i}-\overline{S_1})(S_{2,i}-\overline{S_2})}{\sqrt{\sum_{i=1}^{n}(S_{1,i}-\overline{S_1})^2(S_{2,i}-\overline{S_2})^2}},$$

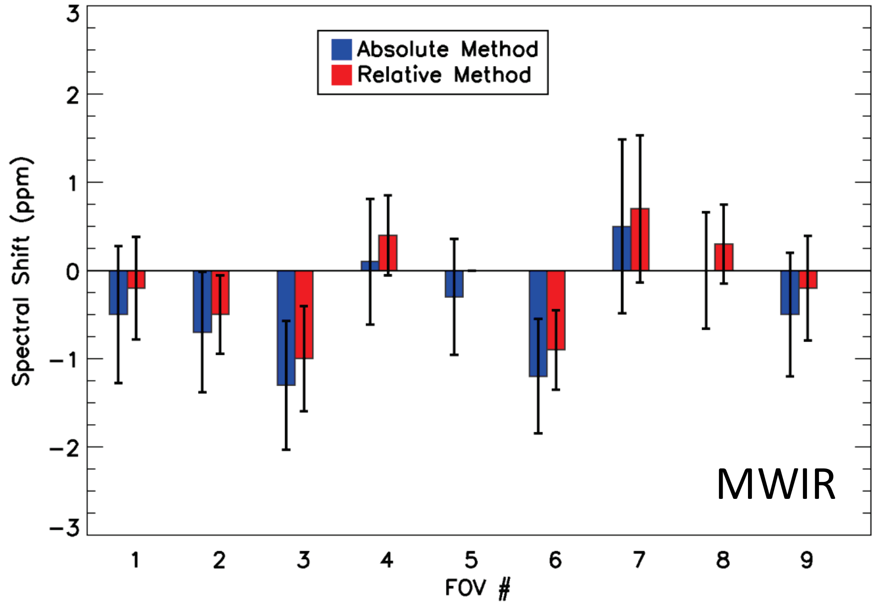
Standard deviation based on the difference of the two spectra:

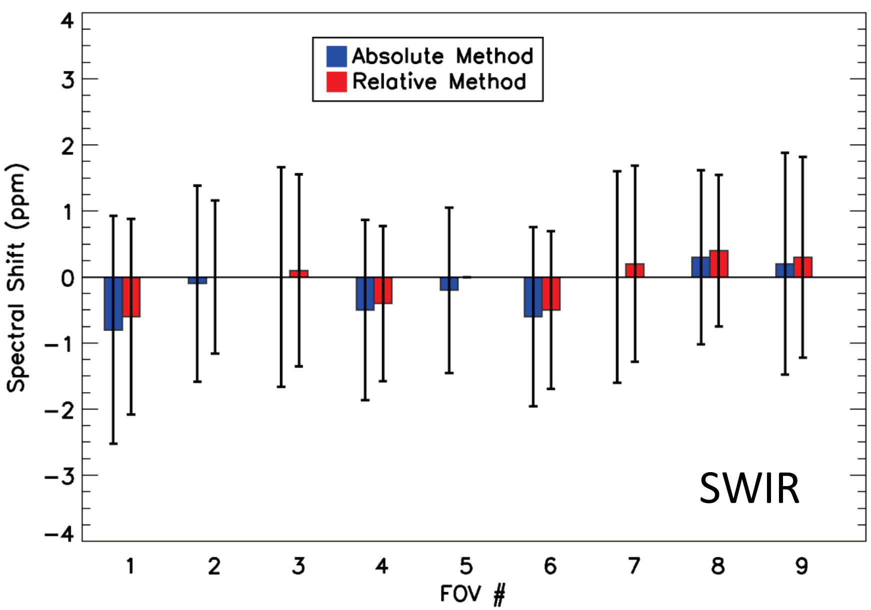
$$D_{S_1S_2} = \sqrt{\sum_{i=1}^{n}[(S_{1,i}-\overline{S_1})-(S_{2,i}-\overline{S_2})]^2 \Big/ (n-1)}.$$

The cross-correlation method is applied to a pair fine grid spectra to get the maximum correlation and minimum standard deviation by shifting one of the spectra in a given shift factor

Relative and Absolute Spectral Validation

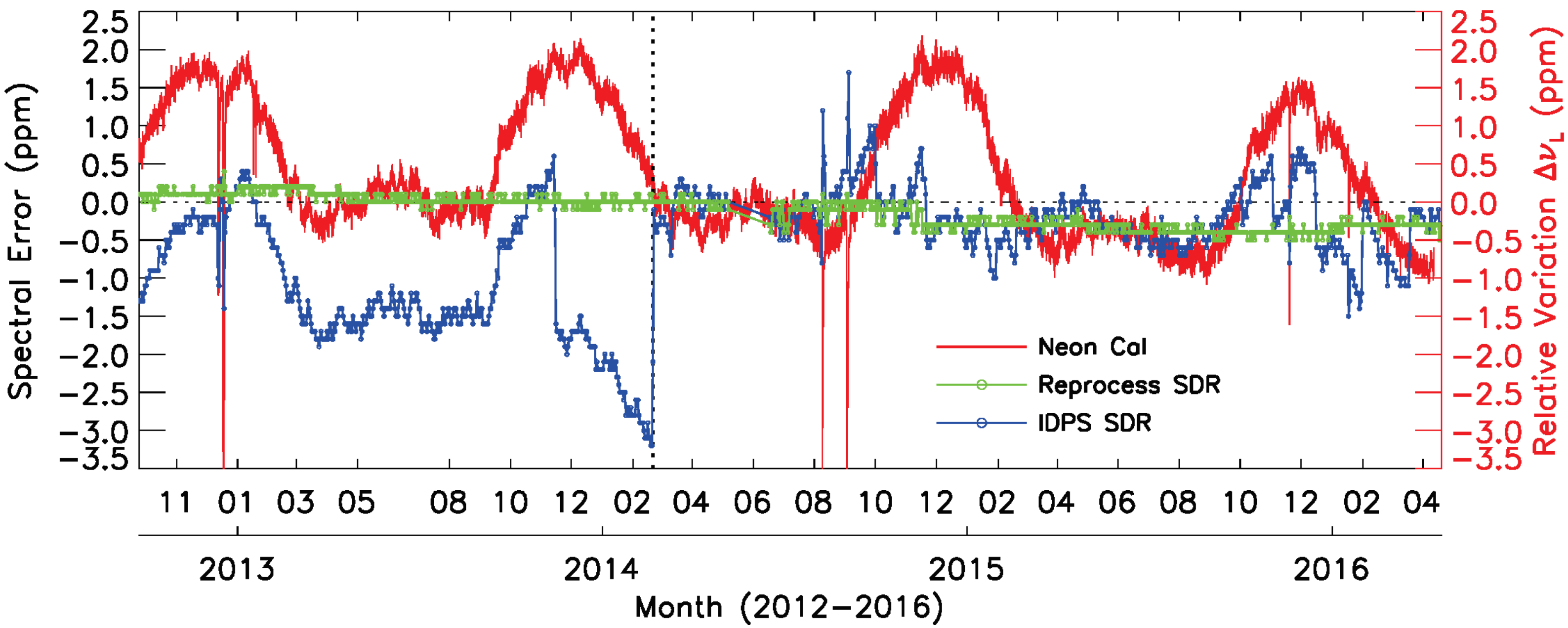






The absolute spectral shift (LBL V.S. observation) and relative spectral shift (other FOVs vs FOV 5) for all CrIS nine FOVs at band 1 spectral range 704-754 cm^{-1}, band 2 spectral range 1264-1314 cm^{-1}, and band 3 spectral range 2160-2210 cm^{-1}.

CrIS SDR Long-Term Spectral Accuracy and Stability



- Comparison of the Neon subsystem spectral calibration versus calibration using the upwelling radiances for IDPS and reprocessed SDRs from September 22, 2012 to April 19, 2016.
- The upwelling calibration has been offset by -0.6 ppm.
- The Neon zero shift time is determined by the Correction Matrix Operator (CMO) update on December 19, 2012. The several sharp spikes in the December 19, 2012, August 9, 2014, and September 2, 2014 are due to NPP spacecraft issues, not CrIS malfunctions.
- The upwelling calibration is for the daily average of FOV5 at nadir (FOR 15 or 16), descending orbit over clear tropical ocean scenes.

Summary

- In this study, the accuracy of CrIS radiometric and spectral calibration and its stability are assessed using the reprocessed SDR and compared to the operational SDR data.
- Overall radiometric biases (O-S) are small and stable over time, FOV-2-FOV differences are less than ~10 mK, and much better than that from the operational SDR.
- It is shown that CrIS metrology laser wavelength varies within 3 ppm as measured by the Neon calibration subsystem. The reprocessed SDR have spectral errors less than 0.5 ppm, is much better than the operational SDR with about 4 ppm.
- Reprocessed CrIS SDR will benefit GSICS inter-calibration capabilities and climate applications, in terms of better Radiometric and Spectral calibration accuracy, and Consistence calibration and performance based on the same software and calibration parameters