Suomi NPP CrIS Reprocessed SDR Long-term Accuracy and Stability

Yong Chen¹, Yong Han², Likun Wang¹, Fuzhong Weng², Ninghai Sun², and Wanchun Chen²

¹CICS-MD, ESSIC, University of Maryland, College Park, MD, Yong.Chen@noaa.gov
²NOAA/NESDIS/STAR, College Park, MD

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)**

- **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

**Launched**

![Brightness Temperature (K) vs. Wavenumber (cm^-1)]

- **2211 channels**
- **1305 channels**
**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**
  - 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.
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)
  \[ \text{BIAS} = \frac{(\text{Obs} - \text{CRTM})}{\text{CRTM}} \]

- Assessment approach 2: Double difference between CrIS and IASI on MetOp-a/b (converted to CrIS) using CRTM simulation as a transfer tool
  \[ \text{DD} = \left( \frac{\text{Obs} - \text{CRTM}}{\text{CRTM}} \right)_{\text{CrIS}} - \left( \frac{\text{Obs} - \text{CRTM}}{\text{CRTM}} \right)_{\text{IASI2CrIS}} \]

- Assessment approach 3: SNO difference between CrIS and IASI converted to CrIS
  \[ \text{BT}_{\text{diff}} = \text{BT}_{\text{CrIS}} - \text{BT}_{\text{IASI2CrIS}} \]
CrIS Radiometric Stability: Obs-Simulation Time Series

LW 671.875 cm⁻¹

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$^{-1}$

**ECMWF analysis**

**ERA Interim**
CrIS Radiometric Stability: Obs-Simulation Time Series

SW 2500.0 cm⁻¹

ECMWF analysis

ERA Interim

Ch1285, 2500.000 (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

ΔBT (K)

11 01 03 05 07 09 11 01 03 05 07 09 11 01 03 05 07 09 11 01 03 05

2013 2014 2015 2016

Month (2012–2016)

ΔBT (K)

11 01 03 05 07 09 11 01 03 05 07 09 11 01 03 05 07 09 11 01 03 05

2013 2014 2015 2016

Month (2012–2016)

IDPS SDR

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

**SW, 2500-2520 cm⁻¹**

**IDPS SDR**

**Reprocessed SDR**
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:

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

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.
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\(^{-1}\).
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.
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.