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Suomi NPP/JPSS Cross-track Infrared Sounder (CrIS): Non-linearity Assessment and On-Orbit Monitoring

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Abstract

This paper presents a refinement of the CrIS pre-launch non-linearity coefficients based on on-orbit data which minimizes FOV-to-FOV radiometric errors among the nine fields of view within a 3x3 field of regard. This paper also presents a non-linearity coefficient monitoring methodology which can track the change in FOV-to-FOV radiometric differences in spectral regions sensitive to changes in non-linearity. This approach provides the JPSS CrIS Cal/Val team an approach to monitor changes in the sensor non-linearity across any potential instrument warm-up/cool-down event and assess long term trends.

Theory

The UW-Madison has developed extensive experience in the calibration of the hyperspectral radiances using a two point calibration method (*Revercomb et al., Applied Optics, 1988*). For this method to be successful, any non-linearity of the sensor response to input radiance must first be corrected. For these detectors, a non-linearity correction algorithm developed by UW-SSEC for use in aircraft and ground-based sensors was applied to CrIS T/V data to successfully meet the radiometric requirements.

- $Ifg_{meas} = (Ifg_1+V) + a_2(Ifg_1+V)^2 + a_3(Ifg_1+V)^3 + \ldots$
  $= (1+2a_2V)Ifg_1 + a_2Ifg_1^2$ if $a_{>2}=0$
  where Ifg_1 is the linear AC interferogram and V is the DC level.
- $C_{meas} = F\{Ifg_{meas}\}$
  $= (1+2a_2V)F\{Ifg_1\} + a_2 F\{Ifg_1^2\}$ + higher order terms
  $= (1+2a_2V)C_1 + a_2 C_1 \otimes C_1$
- For small corrections, assume $C_{meas}=C_1$ in-band
- In out-of-band regions, $C_1=0$ and $a_2=Re\{C_{meas}/(C_{meas}\otimes C_{meas})\}$

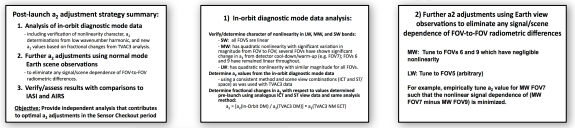
Data

The Cross-track Infrared Sounder (CrIS) is the first in a series of U.S. advanced operational sounders that will provide more accurate, detailed atmospheric temperature and moisture observations for weather and climate applications. This information will help significantly improve medium range weather forecasting. A high accuracy and good long-term stability is required for climate applications of the CrIS sensor data.

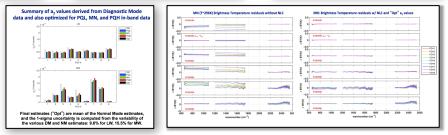
CrIS measures upwelling infrared radiance at high spectral resolution
1,305 spectral channels in three spectral bands
SWIR: 3.92-4.64um; MWIR: 5.71-8.26um; LWIR: 9.14-15.38um

A Fourier Transform Spectrometer built by ABB-Bomem and integrated by ITT/Exelis provides high resolution IR spectra:
Fields of Regard each 3 x 3 FOVs
Photovoltaic Detectors in all 3 bands
4-Stage Passive Detector Cooler
On-board internal calibration target

Calibration Methodology



Thermal/Vac quadratic nonlinearity parameters (a2) used at launch (CrIS packet V32)



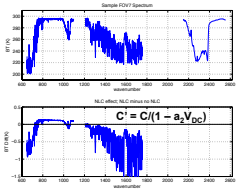
- ADL/CSPP used to compute SDR granules for two sets of "a2" coefficients for selected Golden Days.
- UW "a2" v00 – Pre-launch values from CrIS packet v32
  UW "a2" v02 – Values used in CrIS packet v33
- FOV-to-FOV relative radiance spectra computed for each granule using LW FOV5 and MW FOV9 references using selection criteria for uniform Fields of Regard.
- Jacobian perturbation method used to estimate "a2" change relative to UW a2 v02.
- Daily global mean (24 hour) of "a2" scale factor estimated
- Mean of three daily mean values used for the assessment.
- Standard deviation computed from daily mean estimates.

UW a2 version "02" Verified Using Golden Days: 2/24, 2/25, 3/2/2012
(Values represent implied change to the "UW-v02" baseline.)

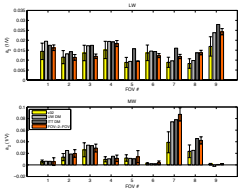
FOV	1	2	3	4	5	6	7	8	9
LW Mean	1.0038	1.0020	1.0084	0.9977	1.0000	0.9992	0.9932	0.9795	0.9915
(%)	0.4	0.2	0.8	-0.2	0	-0.1	-0.7	-2.0	-0.8
StdDev (%)	0.4	0.2	0.1	0.1	0	0.03	0.6	1.4	0.6
MW Mean	0.9987	0.9994	0.9974	1.0009	0.9967	0.9992	1.0035	1.0026	1.0000
(%)	-0.1	-0.1	-0.3	0.1	-0.3	-0.1	0.3	0.3	0
StdDev (%)	0.1	0.8	0.1	0.4	0.1	0.6	0.4	0.4	0

* UW a2 v02 determined using Golden Day 2/24/2012. Repeatability < 2%

Example Impact of Nonlinearity Correction on calibrated Earth view radiances



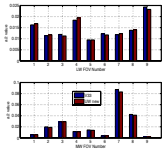
a2 values: v32 (TVAC, yellow) and v33 (In-orbit, orange)



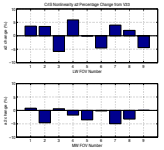
Nonlinearity Monitoring

- Create daily estimates of fractional change in detector a2 values.
- Example for FOV-2-FOV differences shown at Provisional Review.
- No conclusive evidence for a change exceeding the 10% level in CrIS V33 a2 parameter values.
- Uncertainty analysis of a2 on-orbit estimation is work-in-progress.

a2 monitored change March-October 2012



a2 percentage change March-October 2012



Acknowledgements

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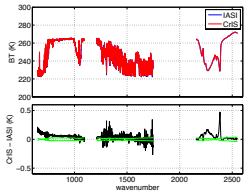
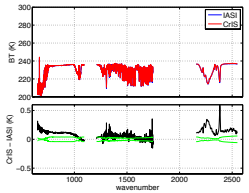
Satellite Inter-calibration Validation

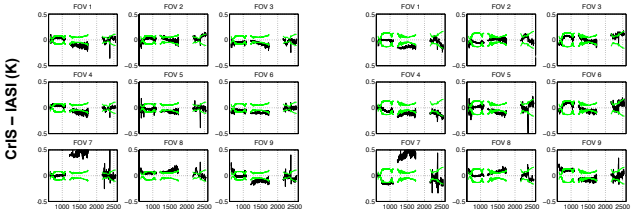
North Polar CrIS/IASI SNOs



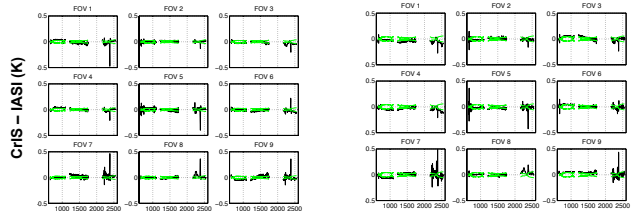
South Polar CrIS/IASI SNOs



V32 Pre-launch Parameters (based on T/V testing only)



V33+ Post-launch Parameters (T/V + On-Orbit Analysis)



The figures above show the CrIS – IASI brightness temperature differences for each CrIS FOV. The mean difference over all FOVs has been subtracted from each panel.

Conclusions

- CrIS LW and MW PV detectors exhibit a quadratic nonlinearity. CrIS SW are highly linear.
- The quadratic nonlinearity coefficients determined in Thermal/Vacuum testing (V32) were adjusted post-launch to minimize the inter-FOV radiometric error (V33).
- Since the V33 upload (April 2012) the quadratic coefficient parameter for each detector has not changed relative to the reference pixel (LW FOV5; MW FOV9) by more than 10%.
- Independent validation using METOP IASI inter-calibration demonstrates the importance of the post-launch on-orbit update of the nonlinearity parameters and provides confidence in the methodology used.