Suomi NPP/JPSS Cross-track Infrared Sounder (CrIS): Calibration Validation With The Aircraft Based Scanning High-resolution Interferometer Sounder (S-HIS)

Joe K. Taylor[1], D.C. Tobin[1], H.E. Revercomb[1], F.A. Best[1], R. K. Garcia[1], H. Motteler[2], and M. Goldberg[3]
1. Space Science and Engineering Center, University of Wisconsin-Madison, 1225 West Dayton St., Madison, WI, 53706
2. University of Maryland Baltimore County, Baltimore, Maryland, USA
3. Joint Polar Satellite Systems Office, National Oceanic and Atmospheric Administration, Lanham, Maryland, USA

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Introduction

To better accommodate climate change monitoring and improved weather forecasting, there is an established need for higher accuracy and more refined error characterization of radiance measurements from space and the corresponding geophysical products. This need has led to emphasizing *direct tests of on-orbit performance, referred to as calibration validation*.

Currently, validation typically involves (1) collecting high quality reference data from airborne and/or ground-based instruments during the satellite overpass, and (2) a *detailed comparison between the satellite-based radiance measurements and the corresponding high quality reference data*.

Additionally, *for future missions* technology advancements at University of Wisconsin Space Science and Engineering Center (UW-SSEC) have led to the development of an *on-orbit absolute radiance reference* utilizing miniature phase change cells to provide direct on-orbit traceability to International Standards (SI) [1, 2]

The *first Suomi NPP dedicated airborne calibration validation campaign* was conducted May 2013 with *a primary objective of providing detailed validation of CrIS radiance observations*. During this calibration validation campaign, the NASA ER-2 aircraft instrument payload included the *UW-SSEC Scanning-High resolution Interferometer Sounder (S-HIS)*, the NPOESS Atmospheric Sounder Testbed-Interferometer (NAST-I) and Microwave Spectrometer (NAST-M), the NASA MODIS/ASTER airborne simulator (MASTER), and the NASA JPL Airborne Visible / Infrared Imaging Spectrometer (AVIRIS).

Detailed results for the validation of the CrIS radiance observations with the S-HIS sensor are presented here.

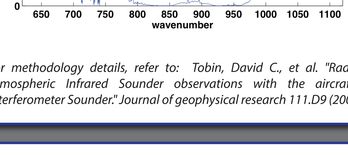
[1] Best, Fred A., et al. "On-orbit Absolute Radiance Standard (OARS) for the next generation of IR remote sensing instruments." SPIE Asia-Pacific Remote Sensing. International Society for Optics and Photonics, 2012.
[2] Best, Fred A., et al. "On-orbit absolute temperature calibration using multiple phase change materials: overview of recent technology advancements." Asia Pacific Remote Sensing. International Society for Optics and Photonics, 2010.

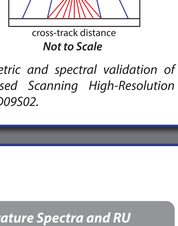
Double Obs-Calc Comparison Methodology

(1) Spatial colocation is achieved by selecting scenes with low variability and covering the selected CrIS FOVs with S-HIS observations.

(2) Compare residuals from calculations.
- S-HIS and CrIS calculations are each completed at correct altitudes, view angles, spectral resolution and sampling.
- Monochromatic calculations completed using same forward model, atmospheric state, and surface property inputs.

(3) Difference Residuals ***with Spectral Resolutions made similar***
- The full double obs-calc method accounts for altitude and view angle differences and differences in instrument lineshapes.

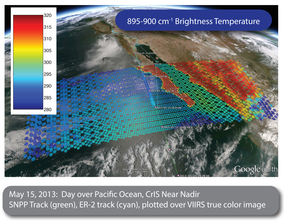




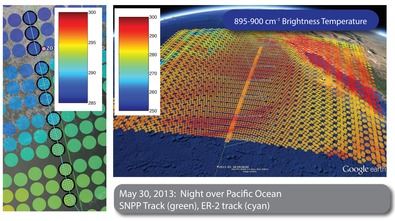
For methodology details, refer to: Tobin, David C., et al. "Radiometric and spectral validation of Atmospheric Infrared Sounder observations with the aircraft-based Scanning High-Resolution Interferometer Sounder." Journal of geophysical research 111.D9 (2006): D09S02.

Calibration Verification Results

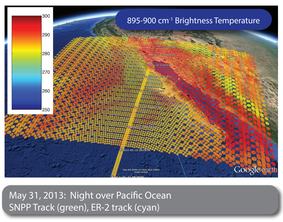
- Excellent radiance validation conditions (high scene uniformity, good spatial and temporal co-location) for 2013-05-15, 2013-05-30, 2013-05-31, and 2013-06-01 flights.
- *Brightness Temperature maps presented below approximate CrIS and S-HIS field of view footprints as circular (rather than elliptical).*



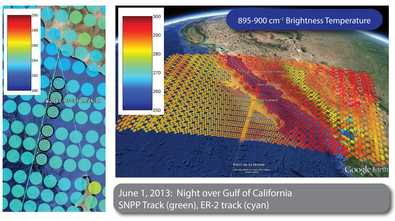
May 15, 2013: Day over Pacific Ocean, CrIS Near Nadir
SNPP Track (green), ER-2 track (cyan), plotted over VIIRS true color image



May 30, 2013: Night over Pacific Ocean
SNPP Track (green), ER-2 track (cyan)

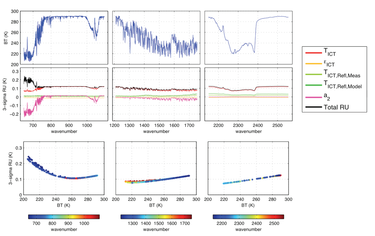


May 31, 2013: Night over Pacific Ocean
SNPP Track (green), ER-2 track (cyan)

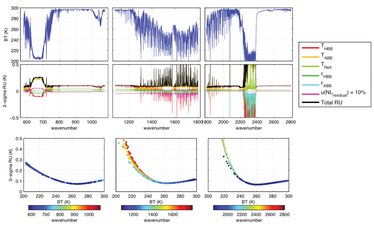


June 1, 2013: Night over Gulf of California
SNPP Track (green), ER-2 track (cyan)

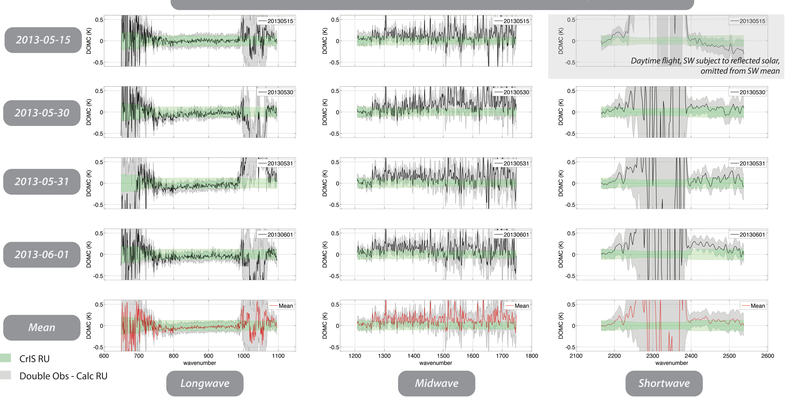
CrIS Brightness Temperature Spectra and RU
(typical clear sky Earth spectrum)



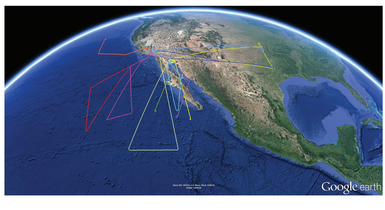
S-HIS Brightness Temperature Spectra and RU
(for flight conditions encountered during the SNPP overpass on 2013-06-01)



Double Obs - Calc Comparison Results with Radiometric Uncertainty (RU) Estimates



SNPP 2013 Cal Val Campaign Flight Paths

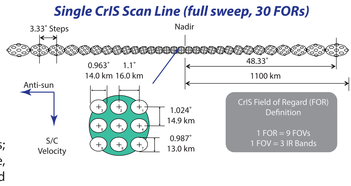


CrIS

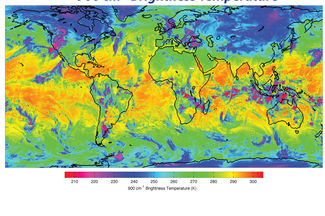
CrIS Sensor Features
- 8 cm clear aperture
- 3 spectral bands
- 3x3 FOVs, 14 km diameter at nadir
- PV MCT detectors
- 4-stage passive cooler
- Plane mirror interferometer with DA
- Internal spectral calibration
- Deep-cavity calibration target
- Modular Construction

Infrared Fourier transform spectrometer with 1305 spectral channels; produces high-resolution, three-dimensional temperature, pressure, and moisture profiles. Designed to give scientists more refined information about Earth's atmosphere and improve weather forecasts and our understanding of climate.

Single CrIS Scan Line (full sweep, 30 FORs)

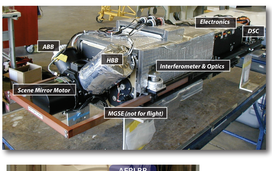


900 cm⁻¹ Brightness Temperature

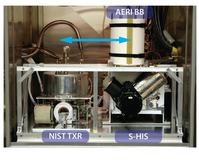


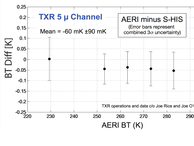
S-HIS

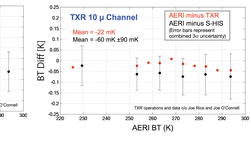
- Developed 1996 - 1998 at the UW-SSEC with the combined support of the US DOE, NASA, and the NPOESS IPO.
- 30 field experiments on 5 aircraft (NASA DC-8, ER-2, WB-57, Proteus, Global Hawk), extremely reliable (> 99.8% science data "up-time" in recent missions), excellent data quality and delivery



IFOV: 100 mrad (2km @ 20km, nadir)
FOR: Programmable 45° scene mirror nadir ± 40° typical
Spectral Coverage: 580 - 3000 cm⁻¹
Spectral Resolution: 0.5 cm⁻¹

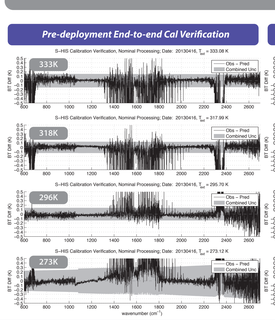




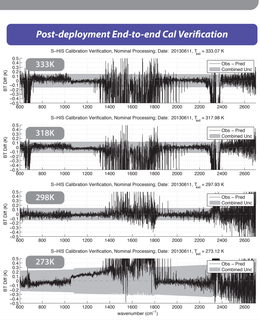


Calibration, Calibration Verification, and Traceability
- Pre-integration calibration of on-board blackbody references at subsystem level
- Pre and post deployment end-to-end calibration verification
- Instrument calibration during flight using two on-board calibration blackbodies
- Periodic end-to-end radiance evaluations under flight like conditions with NIST transfer sensors.

Pre-deployment End-to-end Cal Verification



Post-deployment End-to-end Cal Verification



joe.taylor@ssec.wisc.edu, Space Science and Engineering Center, University of Wisconsin-Madison, 1225 West Dayton Street, Madison WI 53706 USA