The NASA CrIS Level 1B Version 4 Software and Product

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Outline

Introduction

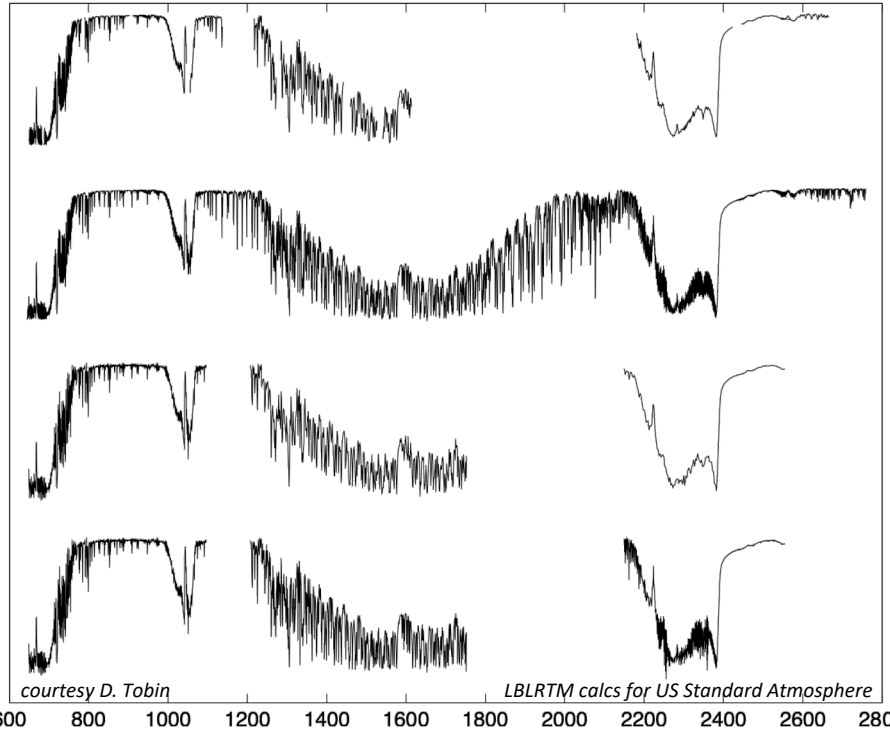
CrIS L1B Version 4

Summary

The CrIS Sensors

- CrIS is an infrared Fourier Transform Spectrometer (FTS)
- An FTS measures an interferogram as a function of optical path difference
- The spectrum and the interferogram are simply related via the Fourier Transform
- CrIS spectral coverage is split into 3 spectral bands (LW, MW, and SW)
- Each spectral band uses a 3 x 3 detector array to provide ~14 km fields of view at nadir from an 833 km orbit
- 27 detectors, 2223 spectral channels at 0.625cm^{-1} sampling, 14 km footprint at nadir

- Compact, large aperture, athermalized design
- Fully wedged / tilted with excellent image quality
- Pupil imaging system
- PV MCT detectors
- 4-stage passive cooler

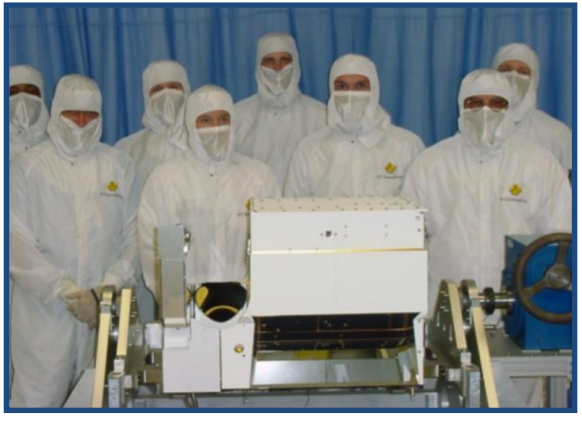


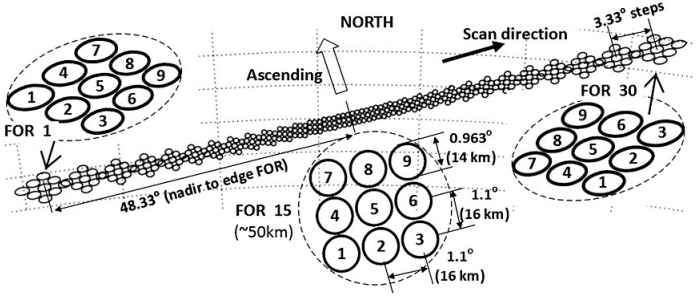
AIRS
L1B: > 1200
Resolving Power
9 FOV/50km square

IASI
L1C:±2 cm OPD
Gausian apodized
4 FOV/50km square

CrIS NSR
±0.8, 0.4, 0.2 cm
OPD unapodized
9 FOV/50km square

CrIS FSR
±0.8 cm OPD
unapodized
9 FOV/50 km square





The CrIS NASA L1B Project and Products

- **The goal of the CrIS NASA Level 1B project is to support long-term trending of our Earth by providing FCDR quality Level 1B algorithms and long-term measurement records for the five CrIS sensors (three in-orbit, two to be launched), to continue and improve on EOS-like data records.**
- These FCDR quality L1 Products enable all follow-on NASA Sounder science and product generation.
- NASA has emphasized that it is *absolutely critical* to maintain continuity of the sounder FCDR-quality L1 datasets for the entire 40-year period (AIRS through CrIS).
- This is a low-cost, small team, PI led effort, led by Joe Taylor (UW-SSEC) and Larrabee Strow (UMBC), that is tasked with efficiently producing extremely accurate, transparent, and traceable multi-sensor continuity radiance products needed for long-term trending of key climate variables.

The CrIS NASA L1B Project and Products

CrIS L1B

- Version 4 Software delivered to Sounder SIPS, product to be released in 2025

CrIS PCA RED

- Hybrid PCA representation of CrIS data with Rapid Event Detection
- Standalone product that includes critical ancillary data from the L1B file in the PCA RED file (i.e., latitude, longitude, observation time, QFs, etc).
- ~50x data compression
- Upcoming release based on the L1B version 4 product. NOAA-21 sample product currently available

CrIS RTA

CrIS/VIIRS IMG

- Provide a subset of Visible Infrared Imaging Radiometer Suite (VIIRS) products that are co-located to the CrIS footprint
- AIRS/MODIS IMG software and dataset (sample dataset in development)
- Upcoming release based on the CrIS L1B Version 4 product

CHIRP

- The Climate Hyperspectral Infrared Product converts the parent instrument's radiances to a common Spectral Response Function (SRF) and removes inter-satellite biases, providing a consistent inter-satellite radiance record
- AIRS and CrIS sounders
- Version 1 available

Product Generation and Distribution via Sounder SIPS, Atmosphere SIPS (IMG), and GES-DISC

Radiometric Uncertainty and the Radiometric Uncertainty Tool

- A critical aspect of a reference sensor and FCDR quality measurement record is the documentation of and ability to calculate the uncertainty in the sensor measurements
- The radiometric uncertainty (RU) in the calibrated radiance can be determined via a perturbation analysis of the calibration equation
- SNPP CrIS: Tobin, D., et al. (2013), Suomi-NPP CrIS radiometric calibration uncertainty, *J. Geophys. Res. Atmos.*, 118, 10,589–10,600, doi: 10.1002/jgrd.50809.
- The CrIS NASA L1B product contains the information needed to accurately calculate the radiometric uncertainty for any CrIS NASA L1B calibrated radiance
- Radiometric Uncertainty Tool documentation, sample code, and static RU parameters are now available via the GES DISC L1b landing pages

Due to this Radiometric uncertainty capability, the NASA CrIS L1B product is being used as a verification data source in the development of ERA6

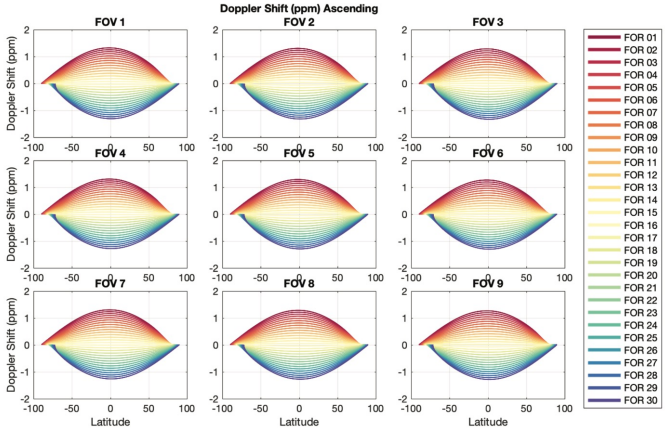
CrIS NASA L1B Version 4

- Version 4 is planned for release in in 2025
  - 4.0.0 software has been delivered to Sounder SIPS; internal product assessment is in progress
- New features for Version 4
  - Full Doppler shift correction (cross-track correction included in Version 3)
  - Improved polarization correction. V4 incorporates a spectrally dependent sensor polarization angle rather than a single value for each detector band, which was used in prior versions (primary improvement is for JPSS-2 below 750 cm^{-1})
  - Full JPSS-2 support with tuned calibration parameters
  - Updated calibration methodology that effectively addresses a **JPSS-2** CrIS calibration artifact that occurs for limited parts of the descending orbits immediately after the spacecraft exits solar eclipse
  - Physical lunar intrusion model

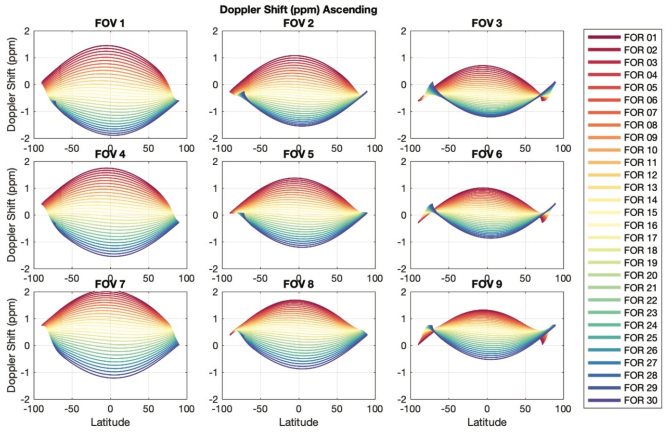
CrIS L1B Version 4: Doppler shift correction

- The correction in the v3 software only considered relative motion due to Earth rotation, which is the largest source of Doppler shift.
- A smaller but still significant shift results from satellite orbital velocity, which is a factor of 16 larger than the maximum Earth rotational velocity, in combination with the small but nonzero in-track component of the CrIS viewing geometry
- The Doppler correction for the v4 product has been extended to account for both effects.

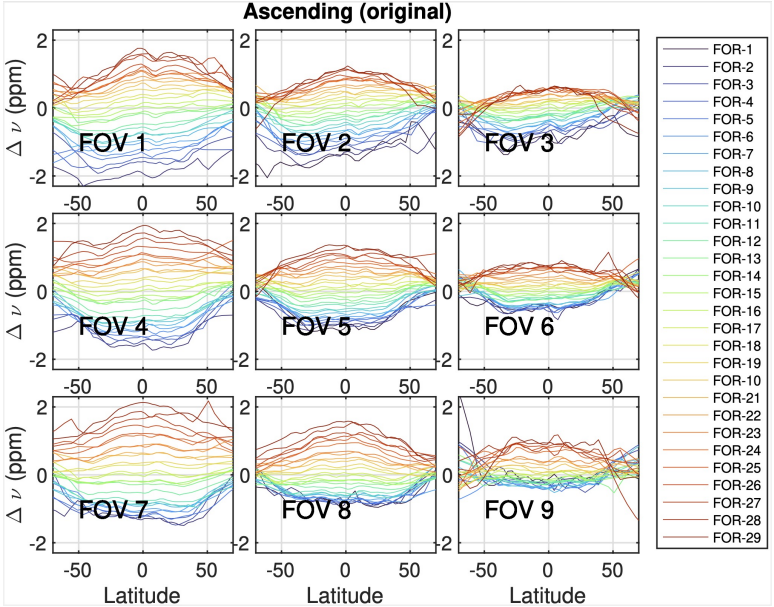
Ascending • Calculated Doppler Shift• Earth Rotation Only

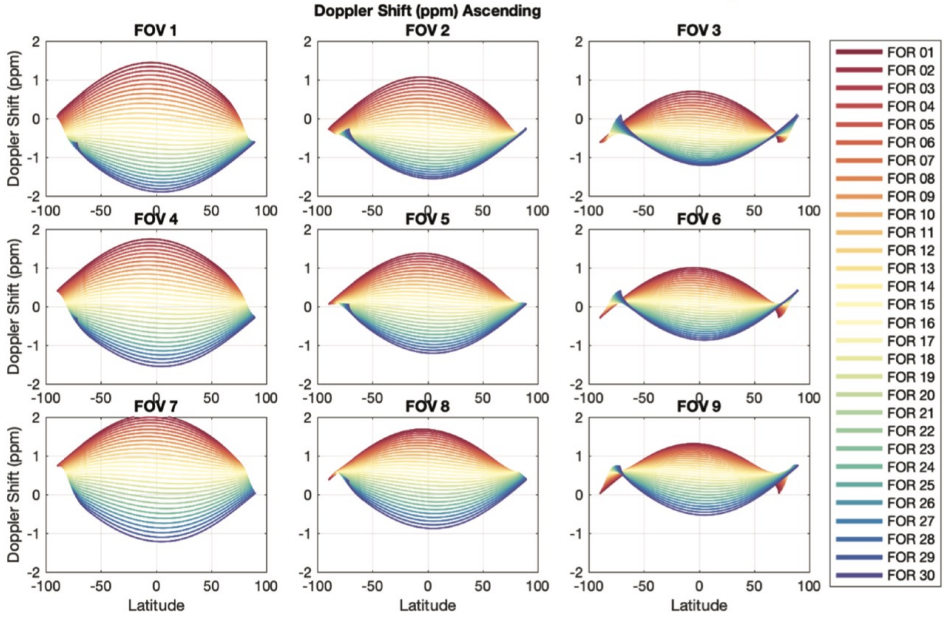


Ascending • Calculated Doppler Shift• Total



CrIS L1B Version 4: Doppler shift correction

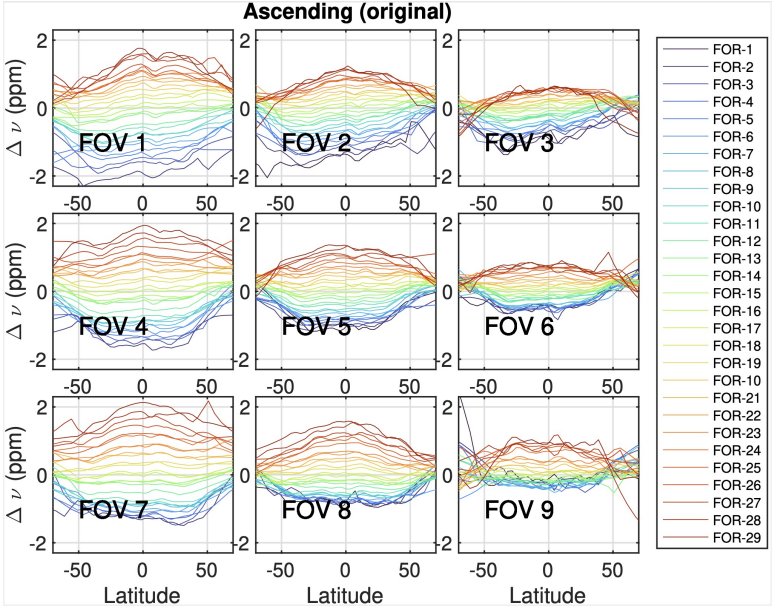




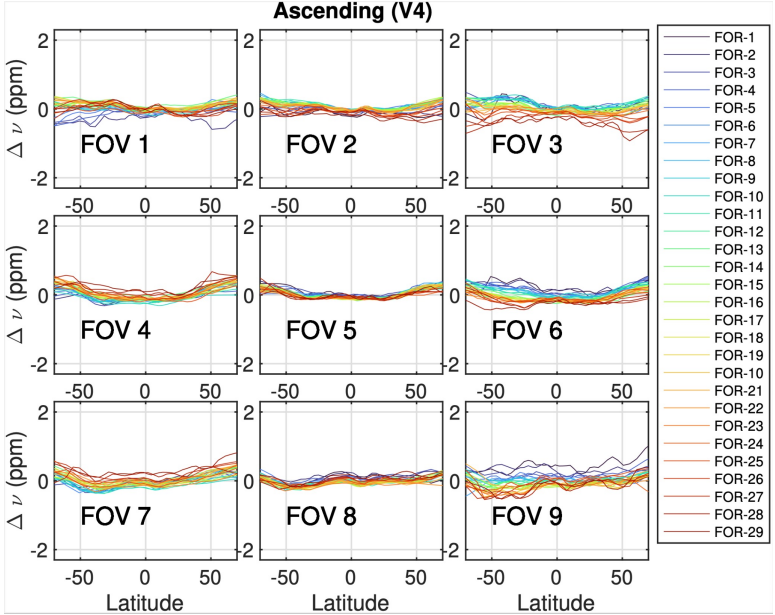
Spectral calibration frequency shifts derived from cross-correlations of observed calibrated radiances, with no Doppler correction, to ECMWF-computed radiances for JPSS-1/NOAA-20 (J1) CrIS. This analysis uses the mid-wave water vapor band, and a full year (2018) of clear scenes over ocean, binned by day in 40 equal-area latitude bins between 70°S and 70°N (courtesy Larrabee Strow).

Calculated total Doppler shift due to Earth rotation and spacecraft velocity (used in the Doppler correction) as a function of latitude, FOV, and FOR for a single ascending orbit of JPSS-1/NOAA-20 (J1) CrIS

CrIS L1B Version 4: Doppler shift correction



Spectral calibration frequency shifts derived from cross-correlations of observed calibrated radiances, with no Doppler correction, to ECMWF-computed radiances for JPSS-1/NOAA-20 (J1) CrIS. This analysis uses the mid-wave water vapor band, and a full year (2018) of clear scenes over ocean, binned by day in 40 equal-area latitude bins between 70°S and 70°N (courtesy Larrabee Strow).

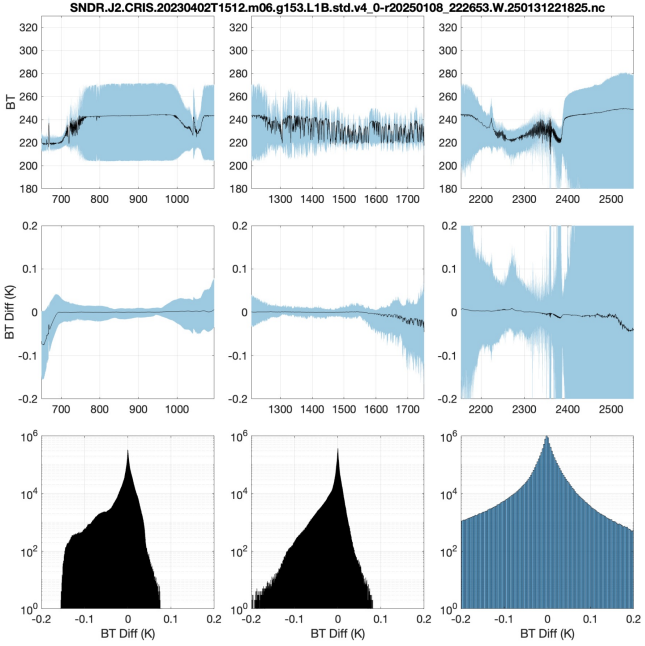


Spectral calibration frequency shifts derived from cross-correlations of observed calibrated radiances, with full Doppler correction (v4 development product), to ECMWF-computed radiances for JPSS-1/NOAA-20 (J1) CrIS. This analysis uses the mid-wave water vapor band, and a full year (2018) of clear scenes over ocean, binned by day in 40 equal-area latitude bins between 70°S and 70°N (courtesy Larrabee Strow).

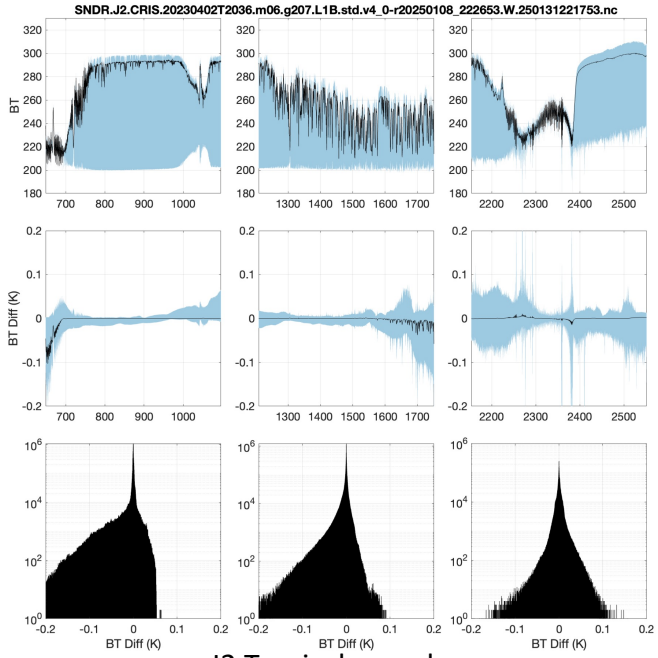
CrIS L1B Version 4: Improved Polarization Correction

- V4 incorporates a spectrally dependent sensor polarization angle rather than a single value for each detector band, which was used in prior versions
- Primary improvement is for JPSS-2 below 750 cm^{-1}

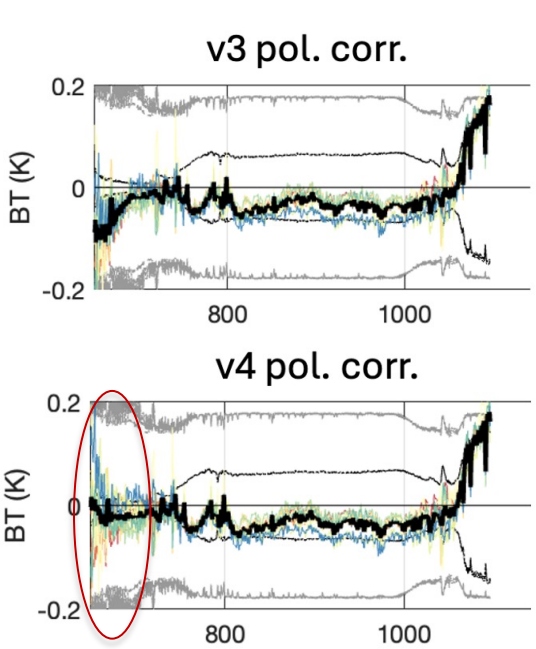
Calibrated radiance differences resulting from the change in the polarization correction algorithm for v4, compared to the v3 method



J2 Antarctic granule



J2 Tropical granule



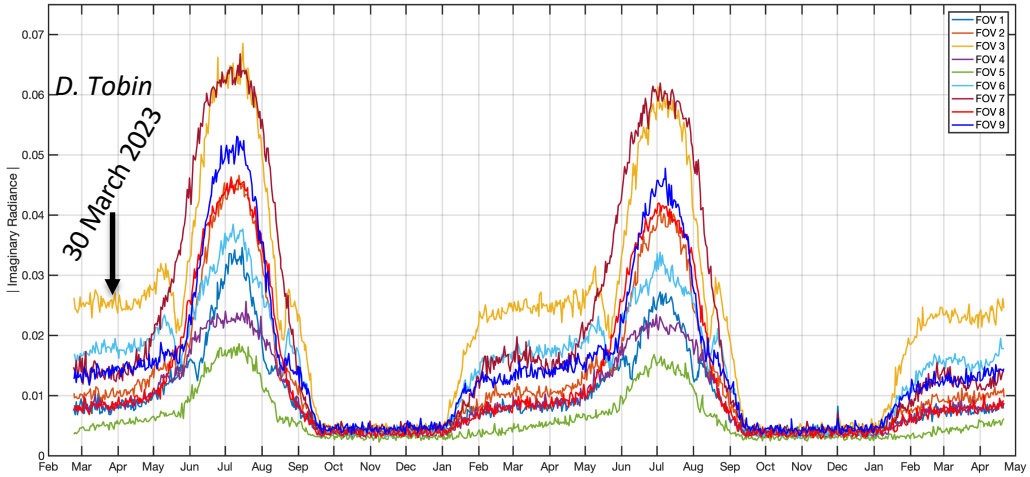
CrIS L1B Version 4: JPSS-2 Eclipse Artifact Mitigation

- For J2 CrIS, there are calibration artifacts for limited parts of the orbits (primarily descending) immediately after the spacecraft exits solar eclipse
  - Likely due to a JPSS-2 spacecraft deck geometry change
  - Scattered solar radiation that causes sudden heating of a component of the CrIS entrance optics, resulting in associated fast changes of the sensor phase and responsivity
  - Seasonal (January through September)
  - Quality flags in Version 3 Beta indicate that it impacts less than 0.1% of the total number of spectra
  - ~0.1K (LW), ~0.2K (MW), and ~2.0K (SW) impact in Version 3 Beta for extreme cases (cold scenes over Antarctica)
- Typical calibration approach uses a 29-scan line moving window, centered on the current observation scan-line, which has a relatively slow time response (232s), but which is adequate for most conditions for J2, and all conditions for J1 and SNPP
- Developed an updated calibration methodology that effectively addresses this issue
- The new approach, which produces a faster time response of the calibration views and associated phase and responsivity, uses Principal Component (PC) noise filtering of the Internal Calibration Target (ICT) and Deep Space (DS) calibration views to provide low noise with a fast single scan-line (8s) time response.

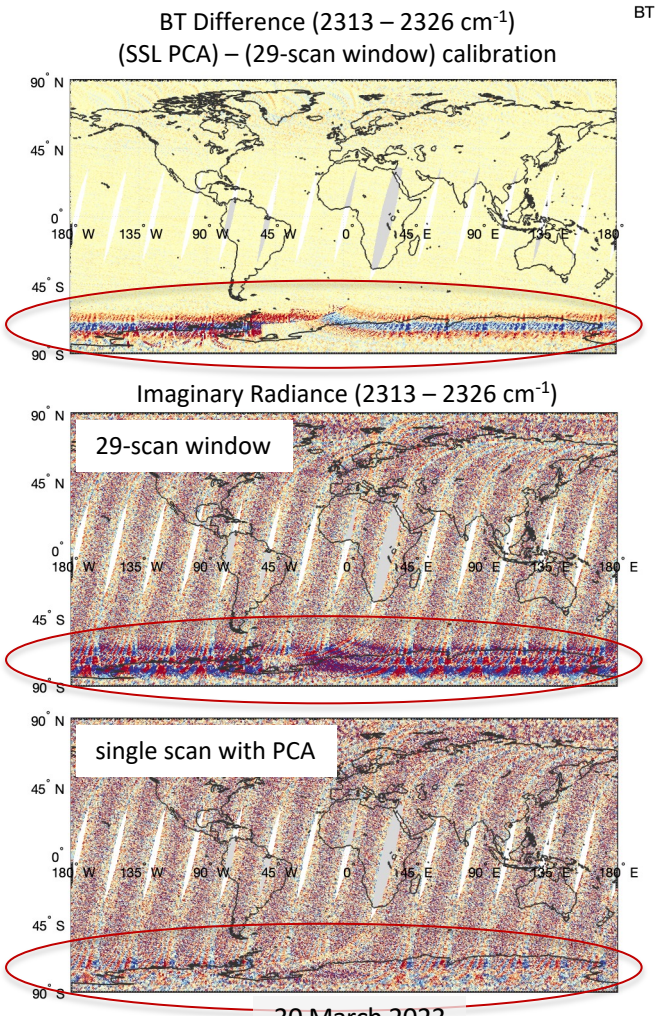
CrIS L1B Version 4: JPSS-2 Eclipse Artifact Mitigation

The imaginary component of the calibrated radiances are very useful for characterization. The effect is found to be highly correlated with solar zenith angle and solar azimuth angle with respect to the spacecraft heading, with magnitude that is field of view (FOV) dependent.

NOAA-21 Eclipse-Exit Calibration Artifact
with normal 29 scan line calibration averaging window
2320 cm^{-1} maximum
|Imaginary Radiance| per day



BT Difference (2313 – 2326 cm^{-1})
(SSL PCA) – (29-scan window) calibration



Summary

- The CrIS sensors are producing extremely high-quality calibrated radiance data records and will extend the high spectral resolution IR sounder record through 2040.
- The CrIS L1B team continues to support efforts relating to creating FCDR quality products from five CrIS sensors (three in orbit, and two to be launched).
- The CrIS NASA L1B project is responsible for providing the CrIS NASA L1B, IMG, PCA RED, CHIRP, and RTA products, and we are here to help investigators understand and use the data.
- This climate quality radiance dataset enables all follow-on NASA Sounder science and product generation, including atmospheric sounding products, trace gas products, and various long-term process and trending studies.
- NASA support is critical for production of this multi-sensor FCDR quality radiance dataset and continuation of NASA Sounder Science activities through the JPSS series.

Product contact info:

- CrIS L1B Team: cris.l1b.support@ssec.wisc.edu
- Sounder SIPS: sounder.sips@jpl.nasa.gov
- The CrIS NASA products are available via the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC) at https://www.earthdata.nasa.gov/sensors/cris

CrIS L1B Version 4 to be released later this year, and will be followed by the corresponding IMG and PCA RED Products

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Jim Gleason, NASA HQ

The NOAA CrIS Cal Val Team, led by Flavio Iturbide

Yana Williams, Dave Johnson, NASA LaRC

Sounder-SIPS and Atmosphere-SIPS Teams

GES-DISC

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The NASA Sounder Science Team