Hybrid PCA representation of Cross-track Infrared Sounder (CrIS) data: the CrIS NASA Version 4 L1B and PCA RED Products

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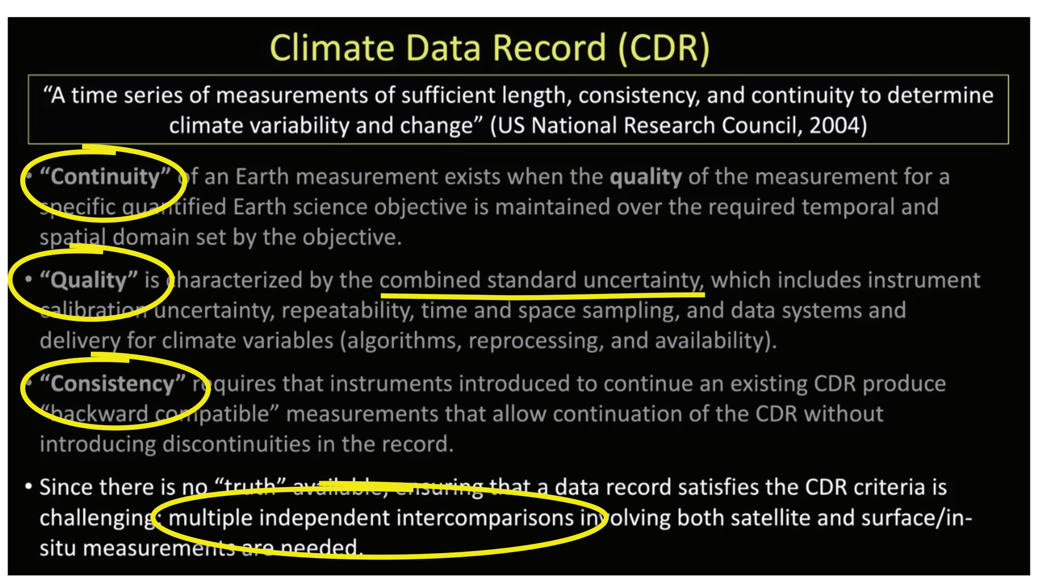
Introduction

The goal of the NASA CrIS Level 1B project is to support NASA climate research by providing a climate quality Level 1B (geolocation and calibration) algorithm and create long-term measurement records for the CrIS instruments currently on-orbit on the SNPP, JPSS-1 (NOAA-20), and JPSS-2 (NOAA-21) satellites, and for those to be launched on JPSS-3 and JPSS-4

The long-term objectives of the project include:

- Create well-documented and transparent software that produces climate quality **CrIS Level 1B** data to continue or improve on EOS-like data records, and to provide this software and associated documentation to the NASA Sounder Science Investigator-led Processing System (SIPS).
- Provide long-term monitoring and validation of the CrIS Level 1B data record from SNPP and JPSS-1 through JPSS-4, and long-term maintenance and refinement of the Level 1B software to enable full mission reprocessing as often as needed.
- Provide a homogeneous **CrIS L1B radiance product** across all CrIS sensors through the end of the CrIS series lifetime, with rigorous radiance uncertainty estimates.
- Develop and support the **CrIS/VIIRS IMG** software and datasets, which provide a subset of Visible Infrared Imaging Radiometer Suite (VIIRS) products that are co-located to the CrIS footprints.
- Develop and support the **Climate Hyperspectral Infrared Product (CHIRP)** for the AIRS and CrIS sounders. The CHIRP 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.
- Develop and support a **CrIS PCA RED (Rapid Event Detection)** product. Hybrid PCA representation of CrIS data with event detection scores. PCA RED is a standalone product that includes critical ancillary data from the L1B file and provides ~50x data compression
- Development and support of a **CrIS RTA**.

Key Features of a Climate Data Record

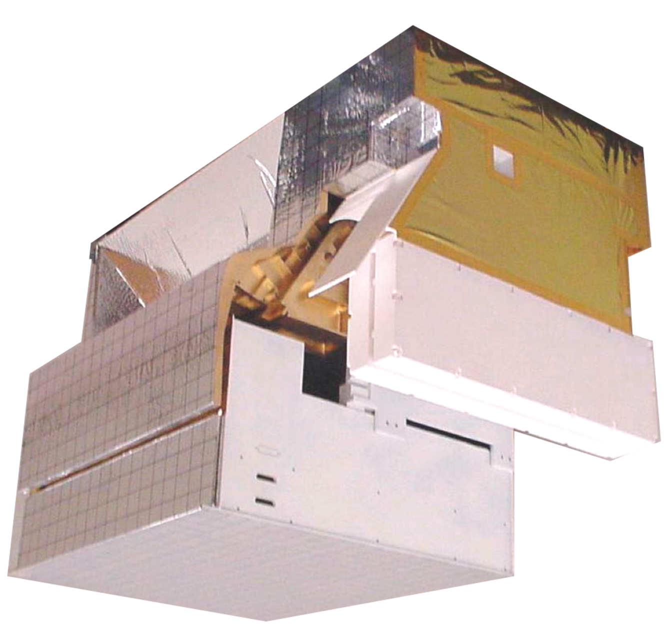


"Earth Radiation Balance", Norm Loeb, NASA LaRC; Climate and Radiation Monitoring - Mini-symposium, JPL Center for Climate Sciences

National Research Council. 2004. Climate Data Records from Environmental Satellites: Interim Report. Washington, DC: The National Academies Press. https://doi.org/10.17226/10944

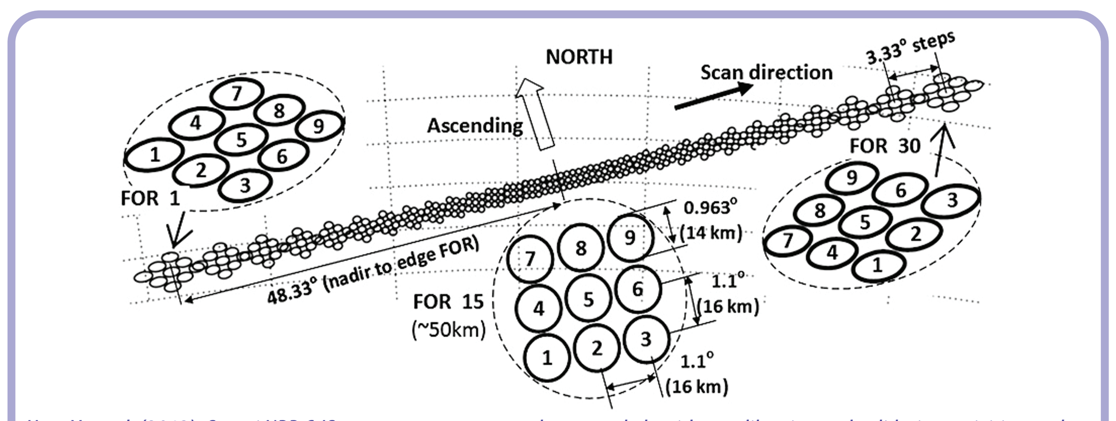
The Cross-track Infrared Sounder (CrIS)

The Cross-track Infrared Sounder is an infrared Fourier Transform Spectrometer (FTS) onboard the Suomi-NPP (SNPP) and JPSS satellites. The CrIS instrument **produces high-resolution, three-dimensional temperature, pressure, and moisture profiles** and was designed to provide an optimum combination of optical performance, radiometric accuracy, and compact packaging.



CrIS Sensor Features

- 8 cm clear aperture
- 3 spectral bands (LW, MW, SW)
- 3x3 FOVs, 14 km diameter at nadir
- 0.8 cm MOPD
- 0.625cm^{-1} unapodized spectral res.
- 4-stage passive cooler
- Plane mirror interferometer with DA
- Internal spectral calibration
- Deep-cavity calibration target
- PV MCT detectors



Han, Y., et al. (2013), Suomi NPP CrIS measurements, sensor data record algorithm, calibration and validation activities, and record data quality, J. Geophys. Res. Atmos., 118, 12,734–12,748, doi:10.1002/2013JD020344.

CrIS NASA L1b Product Version 4

New features for Version 4:

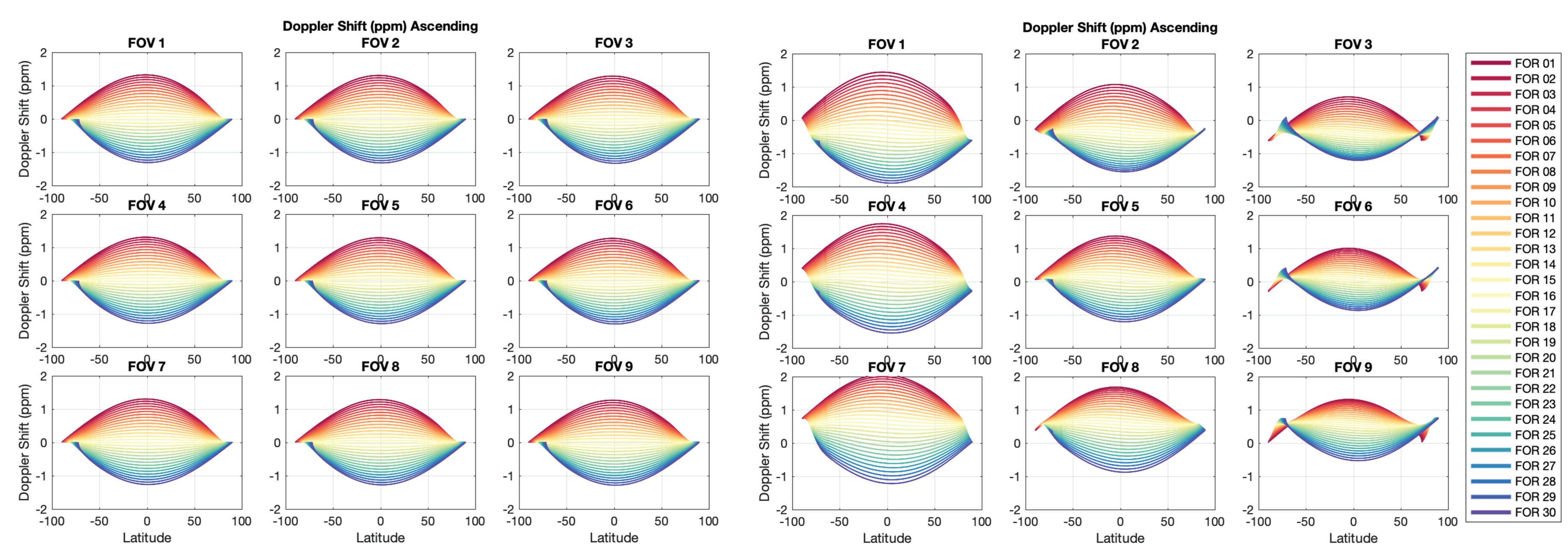
(1) Full Doppler correction (cross-track correction in Version 3).
(2) Improved polarization correction.
(3) Updated calibration methodology that will effectively address a JPSS-2 CrIS calibration artifact that occurs for limited parts of descending orbits immediately after the spacecraft exits solar eclipse.

Doppler Correction

- Both the Earth velocity and Satellite velocity contribute to the relative velocity between the Earth observation and instrument.
- The Doppler velocity is the dot product of the net velocity vector and the unit line of sight vector
- CrIS has a large cross-track swath (max sat zenith angle near equator of 59.9°) and small along-track viewing angles (~1.1° to ~1.5°, FOR dependent).
- Based on the large difference in cross-track and along-track angles, it is reasonable to expect that the Doppler shift of an observation will be primarily due to the Earth's rotation coupled with the large cross-track view angles.
- However, the satellite velocity is roughly 16x the maximum Earth velocity and the Doppler shift associated with the satellite velocity and small along-track view angles is significant.

Ascending • Calculated Doppler Shift• Earth Rotation Only

Ascending • Calculated Doppler Shift• Total



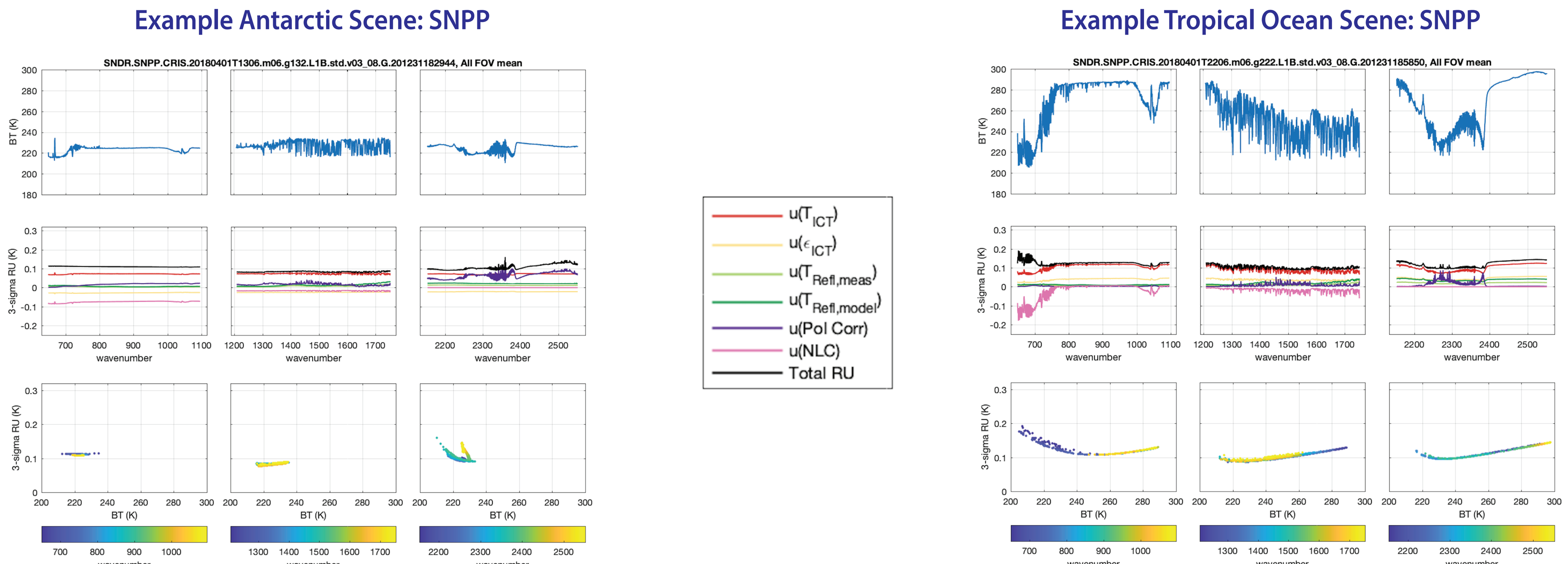
Radiometric Uncertainty

- **A critical aspect of a reference sensor and climate 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
  - *Equivalent to a differential error analysis described in the GUM (Guide to Uncertainty in Measurements)*
- 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 (V3 and later) 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 available via the GES DISC CrIS 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

Example Antarctic Scene: SNPP

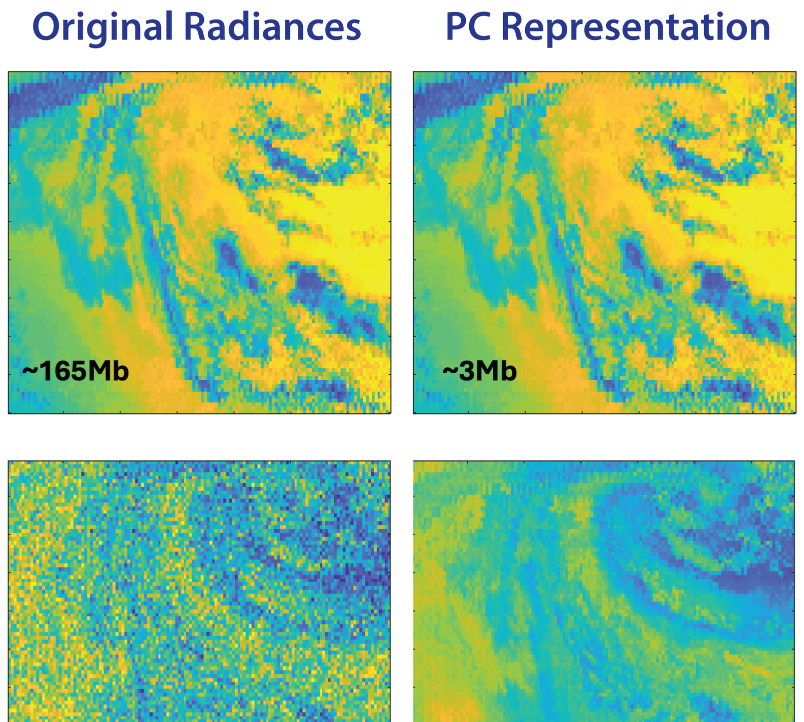
Example Tropical Ocean Scene: SNPP



CrIS PCA RED Product

- EUMETSAT developed a very useful method for Principal Component Analysis (PCA) representation of IASI and future MTG-IRS data that uses a hybrid approach (e.g., Hultberg et al. 2017). The Hybrid PCA approach efficiently represents the data using global and local level variability.
- We have adapted and applied the Hybrid PCA technique to CrIS L1B data to create the CrIS PCA RED (Rapid Event Detection) product. The CrIS PCA RED product provides ~50x data compression and ~73% random noise reduction compared to the NASA L1B CrIS FSR product and also includes Event Detection scores for 25 pre-defined spectral regions. Sample CrIS PCA RED data for JPSS-1 (NOAA-20) CrIS has been made available to users, and the Version 4 CrIS NASA L1B and corresponding CrIS L1B PCA RED products for SNPP, NOAA-20, and NOAA-21 CrIS sensors will be available in late 2024.

Original Radiances | **PC Representation**

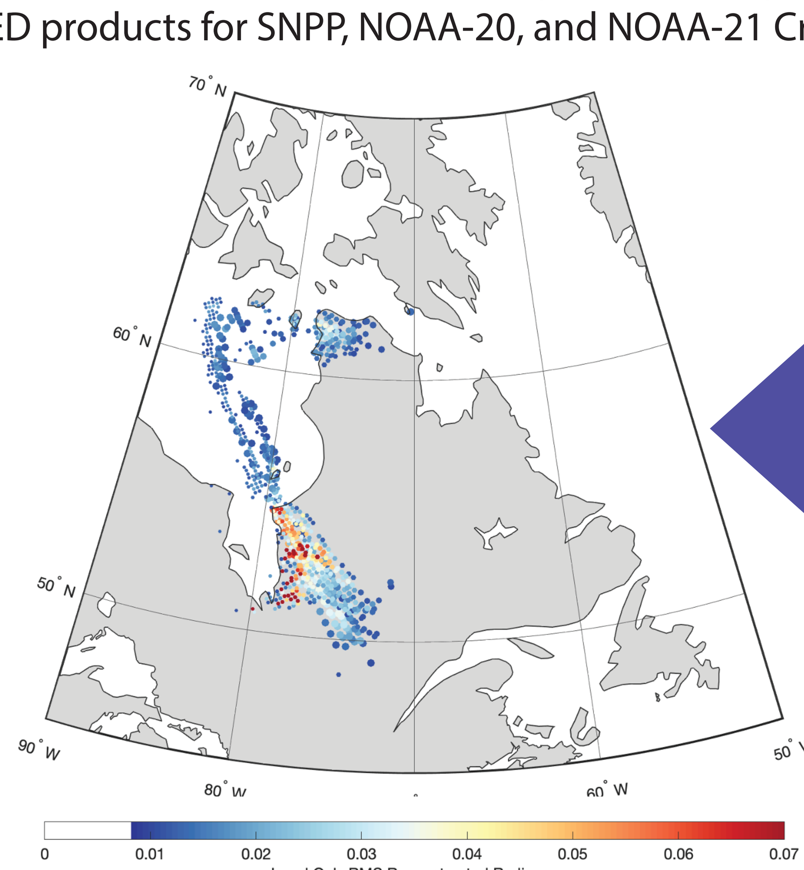


900 cm^{-1} radiance image

Color scale: 20 to 100 mW/(m^2 sr cm^{-1})

900 cm^{-1} minus 900.625 cm^{-1} radiance difference image

Color scale: -0.3 to 0.3 mW/(m^2 sr cm^{-1})



SO$_2$ RED, Post Raikoke Eruption 2019-06-25, Des. Overpasses

CO RED, Quebec Fires 2023-07-14, Asc. Overpasses