The Cross-track Infrared Sounder Level 1B Product: NASA's Accurate and Stable Infrared Hyperspectral Radiance Record

David Tobin[1], Joe Taylor[1], Larrabee Strow[2], Hank Revercomb[1], Graeme Martin[1], Sergio DeSouza- Machado[2], Jess Braun[1], Daniel DeSlover[1], Ray Garcia[1], Michelle Loveless[1], Robert Knuteson[1], Howard Motteler[2], Greg Quinn[1], and William Roberts[1]
(1) University of Wisconsin-Madison, Space Science and Engineering Center (SSEC), Madison, USA (2) University of Maryland Baltimore County, Atmospheric Spectroscopy Lab (ASL), Baltimore, USA

Monday, 15 Apr, 08:30–12:30 X4.136 | EGU24-12167

The CrIS NASA L1B Project and Products

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 radiance product across all CrIS sensors through the end of the CrIS series lifetime, with rigorous radiance uncertainty estimates.
- Develop and support of 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 of 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.

The NASA CrIS products are available via the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC) at https://www.earthdata.nasa.gov/sensors/cris

Key Features of a Climate Data Record

Climate Data Record (CDR)

"A time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change" (US National Research Council, 2004)

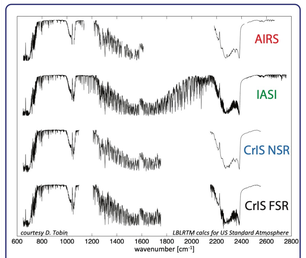
- "Continuity" of an Earth measurement exists when the **quality** of the measurement for a specific quantified Earth science objective is maintained over the required temporal and spatial domain set by the objective.
- "Quality" is characterized by the combined standard uncertainty, which includes instrument calibration uncertainty, repeatability, time and space sampling, and data systems and delivery for climate variables (algorithms, reprocessing, and availability).
- "Consistency" requires that instruments introduced to continue an existing CDR produce backward compatible" measurements that allow continuation of the CDR without introducing discontinuities in the record.
- Since there is no "truth", establishing a metric that a data record satisfies the CDR criteria is challenging. multiple independent intercomparisons involving both satellite and surface/in-situ measurements are needed.

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

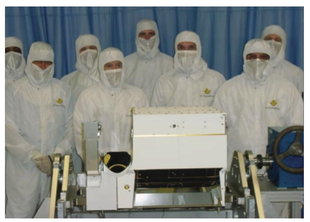
National Research Council. 2004. Climate Data Records from Environmental Satellites: Interim Report. Washington, DC: The National Academies Press. https://doi.org/10.17226/10944

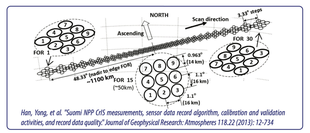
The Cross-track Infrared Sounder (CrIS)

The Cross-track Infrared Sounder (CrIS) is an infrared Fourier Transform Spectrometer onboard the Suomi-NPP (SNPP), JPSS-1, and JPSS-2 satellites (and on the to be launched JPSS-3 and JPSS-4 satellites). The CrIS instrument was designed to provide an optimum combination of optical performance, high radiometric accuracy, and compact packaging. While CrIS was developed primarily as a temperature and water vapor profiling instrument for weather forecasting, its high accuracy and extensive information about trace gases, clouds, dust, and surface properties make it a powerful tool for climate applications.



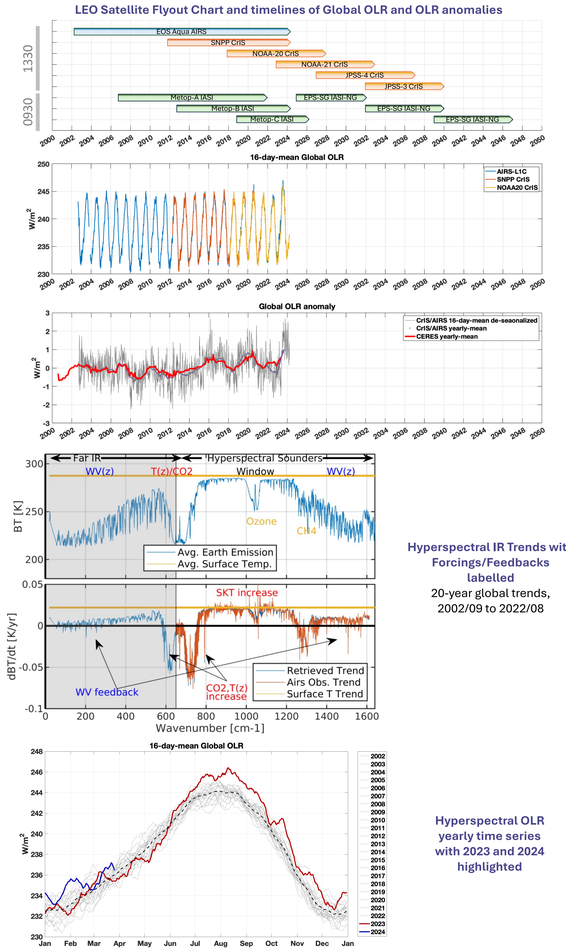
AIRS	IASI
L1B: > 1200 Resolving Power 9 FOV/50km square	L1C:±2 cm OPD Gausian apodized 4 FOV/50km square
CrIS NSR	**CrIS FSR**
±0.8, 0.4, 0.2 cm OPD unapodized 9 FOV/50km square	±0.8 cm OPD unapodized 9 FOV/50 km square





Han, Yong, et al. "Suomi NPP CrIS measurements, sensor data record algorithm, calibration and validation activities, and record data quality." Journal of Geophysical Research: Atmospheres 118.22 (2013): 12-734

Climate: OLR, INR, and Spectral Radiance Trending



Hyperspectral IR Trends with Forcings/Feedbacks labelled
20-year global trends, 2002/09 to 2022/08

Hyperspectral OLR yearly time series with 2023 and 2024 highlighted

Climate Hyperspectral Infrared Product (CHIRP)

- **Level 1b Hyperspectral Data Continuity Product**
- **Will allow inter-instrument radiance trending and a common input for climate-oriented Level 2 retrieval algorithms**
- Goal: Hyperspectral radiances that span AIRS, CrIS, (and potentially IASI and HIRAS) with common:
  - Spectral sampling and spectral shape (ILS/SRF)
  - Radiometric calibration
  - Radiative Transfer Model
  - File format (based on CrIS NASA L1b file format)
- **Essential for providing a long-term Level-3 radiance data set of climate quality**
- **A simpler dataset for users in 20+ years**
- Spectral Sampling: LW: 0.625, MW: 0.833, SW: 1.250 cm−1 (MOPD: 0.8, 0.6, 0.4 cm)

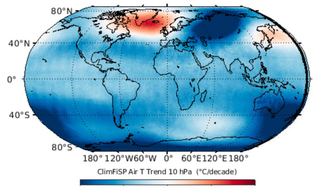
A Climate Hyperspectral Infrared Radiance Product (CHIRP) Combining the AIRS and CrIS Satellite Sounding Record, Strow et al, https://doi.org/10.3390/rs13030418

AIRS Deconvolution and the Translation of AIRS-to-CrIS Radiances With Applications for the IR Climate Record, Motteler et al, https://doi.org/10.1109/TGRS.2018.2869170

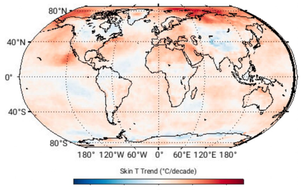
Example Applications and Related Products

Climate Fingerprinting Sounder Products (ClimFiSP)

- **Remote Sensing of Atmospheric Temperature, Water Vapor, Trace Gases, Cloud, and Surface Properties on Daily and Decadal Time Scales, Xu Liu et al.** (Thu, 18 Apr | EGU24-2925 | AS3.29)
- Works on spatiotemporally averaged radiance spectra
- The ClimFiSP algorithm has been applied to CHIRP data from 2003-2022



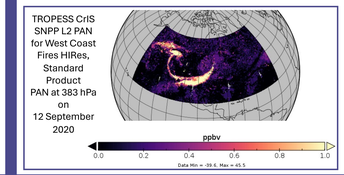
Example of ClimFiSP derived global Stratospheric (10 hPa) temperature trend from 20 years of sounder data



Example of ClimFiSP derived global surface temperature trend from 20 years of sounder data

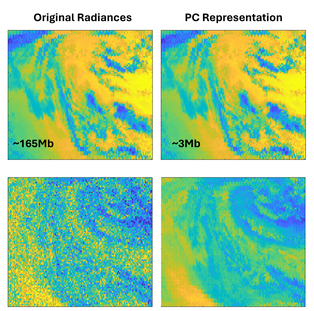
TRoposheric Ozone and its Precursors from Earth System Sounding (TROPESS)

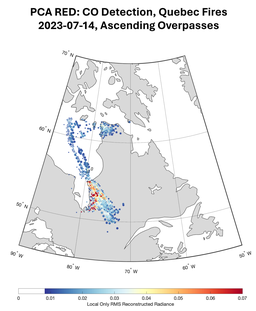
- **Quantification and evaluation of TROPESS ozone trends, Pennington et al.** (Wed, 17 Apr | EGU24-13520 | AS3.15)
- **Using Machine Learning to Predict Column Concentrations and Retrieval Diagnostics of the TROPESS Atmospheric Composition Profiles, Werner et al.** (Wed, 17 Apr | EGU24-21179 | AS3.30)
- *https://disc.gsfc.nasa.gov/information/mission-project?title=TROPESS*

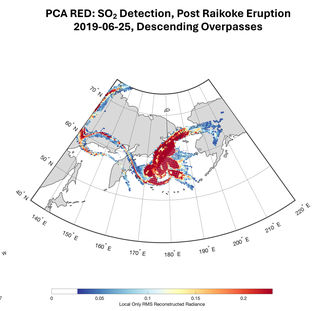


CrIS PCA RED (Rapid Event Detection)

- **Adapted the EUMETSAT Hybrid PCA technique to CrIS**
  - e.g.: Hultberg et al. 2017
  - Currently available for IASI, and will be used for IASI-NG and MTG-IRS
  - Sample data for JPSS-1 (NOAA-20) CrIS now available via GES-DISC (including forward processing)
- **Benefits**
  - Data compression (52x)
    - Data accessibility
    - Preparing for future sensors
  - Random Noise Filtering (~78%)
  - Rare/Rapid Event Detection (25 species/spectral regions)

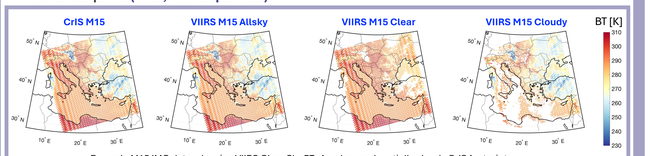




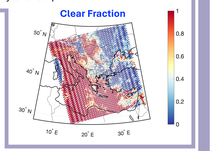


CrIS/VIIRS IMG

- A "value added" product, that provides VIIRS to CrIS footprint collocation information in small, easy to use files with common file granulation to the NASA VIIRS and CrIS L1b products
- Collocate CrIS FOVs with VIIRS Cloud Mask and Radiances/Reflectances
- For each CrIS and corresponding VIIRS L1B granule, CrIS/VIIRS collocation is performed, and the indices of VIIRS pixels within each CrIS footprint are written to an imager to sounder collocation file **(IMG_COL, 12-15 MB per file)**
- A corresponding IMG file is also produced, containing statistics of the VIIRS (MVCM) cloud mask and VIIRS radiances and reflectances that have been collocated within each CrIS footprint **(IMG, ~6 MB per file)**



Example M15 IMG data, showing VIIRS Clear Sky BTs for clear and partially cloudy CrIS footprints



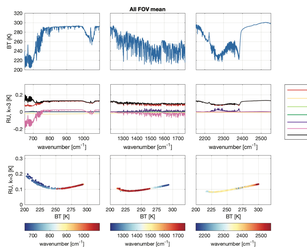
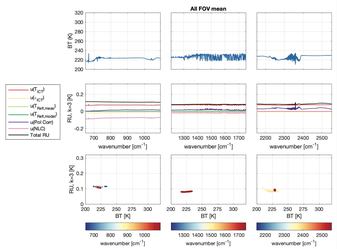
- One-to-one relation to the [9 x 30 x 45] CrIS footprints in the L1b files
- Data processed at the Atmospheres SIPS and mission length products delivered to and available at GES-DISC
- Recent applications: Ammonia "non-detects" paper (Evans et al.); Single sounder footprint retrievals; clear sky determination for climate studies
- Potential future work, pending priorities and resources, to add additional collocated variables:
  - VIIRS cloud height, aerosols, etc.
  - Surface temperature and emissivity (CAMEL), re-analysis fields, carbon tracker, etc.
  - Create the same product for AIRS/MODIS

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 measurement.
  - *A complete measurement includes the best estimate and its uncertainty*
- 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 V3 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 available via the GES DISC L1b landing pages ('NASA Cross-track Infrared Sounder (CrIS) Level 1B Radiometric Uncertainty Description Document, v3')

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 Tropical Ocean Scene: NOAA-20



Example Antarctic Scene: NOAA-20