Status of the NASA CrIS Level 1B Product for Climate Applications

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The CrIS NASA L1B Project

- A low-cost, PI-led, small-team effort, tasked with efficiently producing extremely accurate, transparent, and traceable multi-sensor continuity radiance products needed for long-term trending of key climate variables
- Funded by NASA to develop calibration software to generate a climate quality CrIS L1B mission data record (SNPP, NOAA-20 through NOAA-23) to continue or improve on EOS-like data records
- This climate quality radiance dataset enables all follow-on NASA Sounder science and product generation, including for example the atmospheric sounding products, trace gas products, various climate process and trending studies

The CrIS NASA L1B Project

- Joint effort at University of Wisconsin – Madison and University of Maryland Baltimore County
- PIs: Joe Taylor and Larrabee Strow
- Current focus and available products:
  - CrIS L1B (*Version 3*) ←covered by this talk
  - CrIS/VIIRS IMG software and datasets (*Version 2*): provide a subset of Visible Infrared Imaging Radiometer Suite (VIIRS) products that are co-located to the CrIS footprint
  - Climate Hyperspectral Infrared Product (CHIRP) for the AIRS and CrIS sounders (*Version 1*). 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
  - CrIS RTA

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

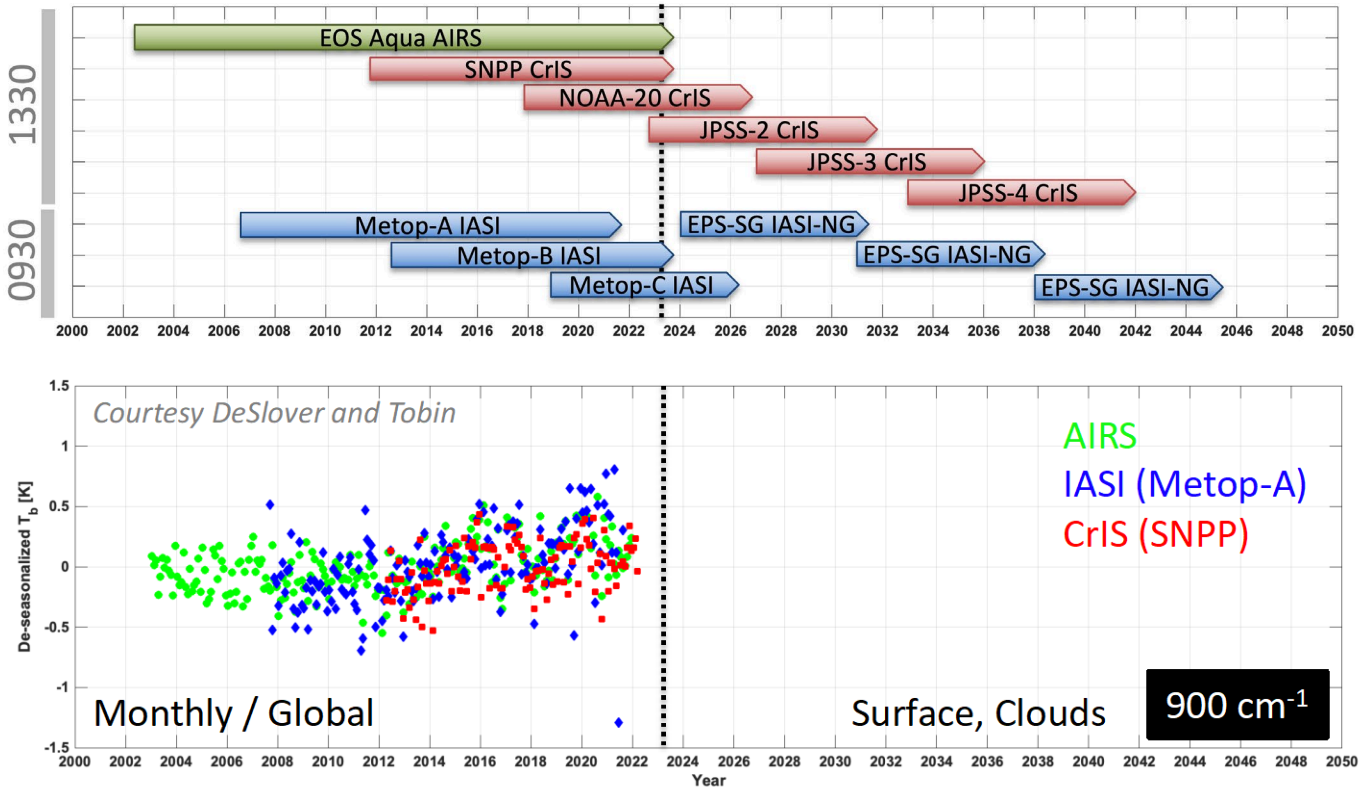
Climate Data Records

"a time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change"

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

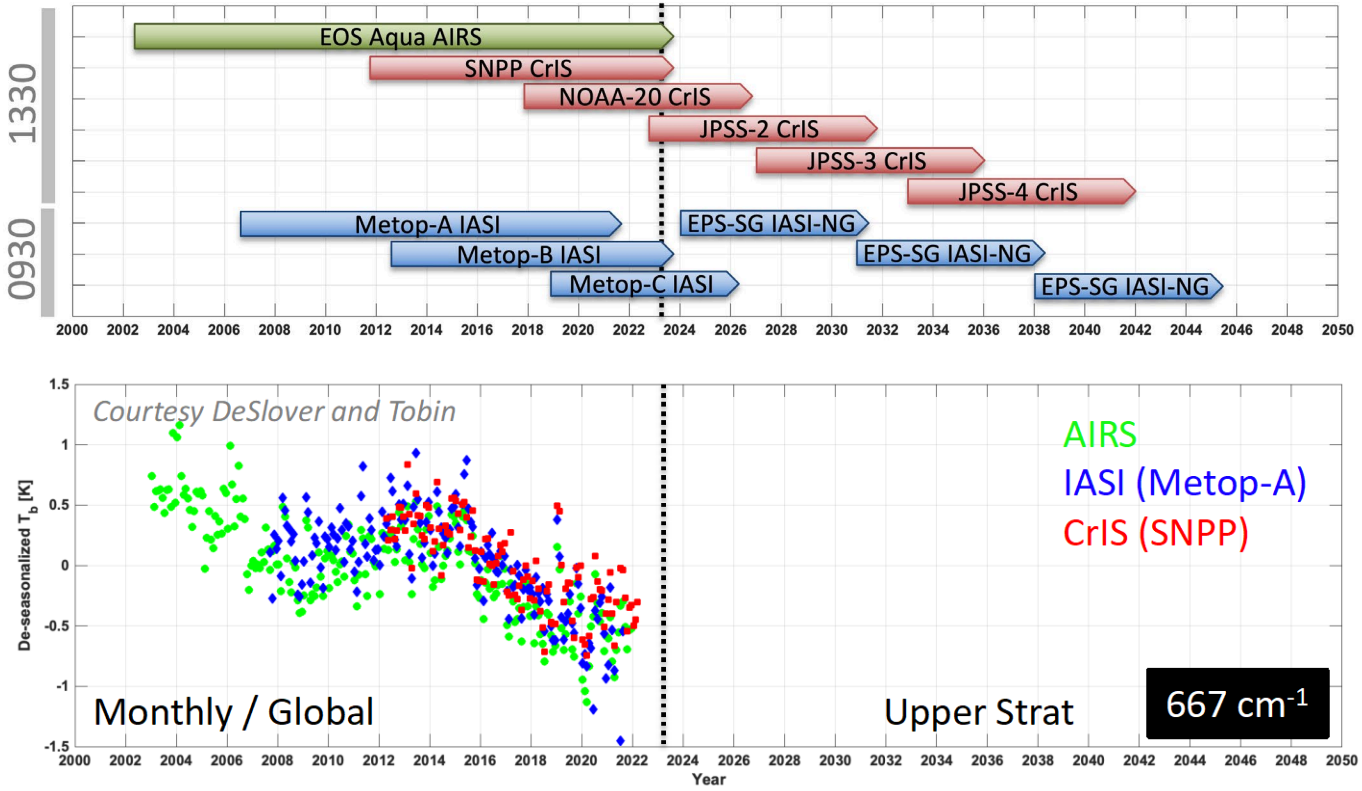
- Length: CrIS L1B product will span full SNPP / JPSS data record
- Consistency among instruments with focus on radiometric homogeneity over multiple sensors and characterized uncertainties
- Continuity with other EOS instruments
- Traceability to TVAC and first principles: uses a physical calibration with clearly defined traceability and uncertainty assessment for all calibration parameters
- Transparency: open source code base, with science code run operationally; well-documented product and methodology
- Accessibility: software and products are freely available

Multi-sensor Hyperspectral Infrared Climate Data Record



The trends from AIRS, IASI, and CrIS in overlapping time periods are very similar

Multi-sensor Hyperspectral Infrared Climate Data Record



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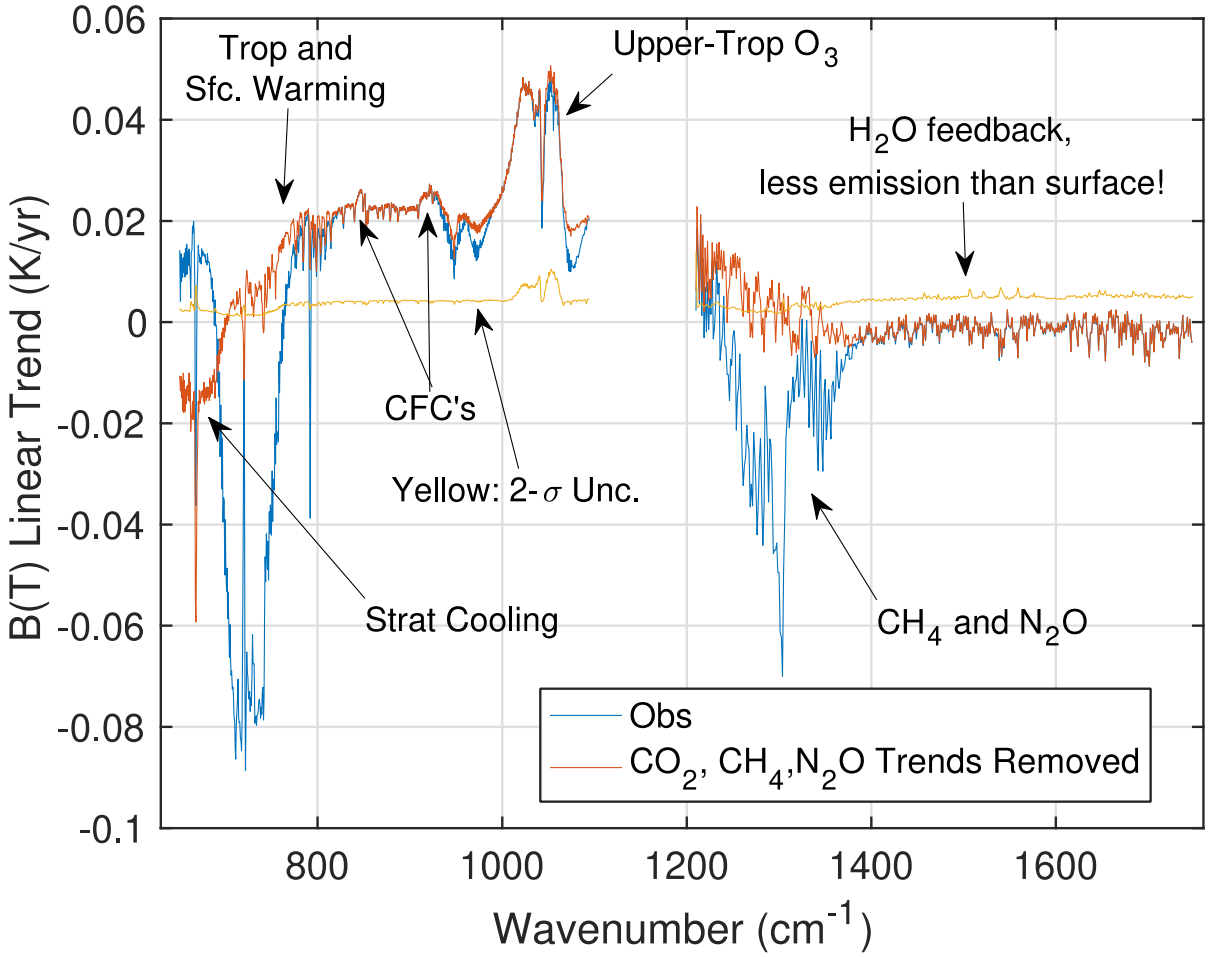


Larrabee Strow et al.

Incredibly Wide Range of Applications and Products

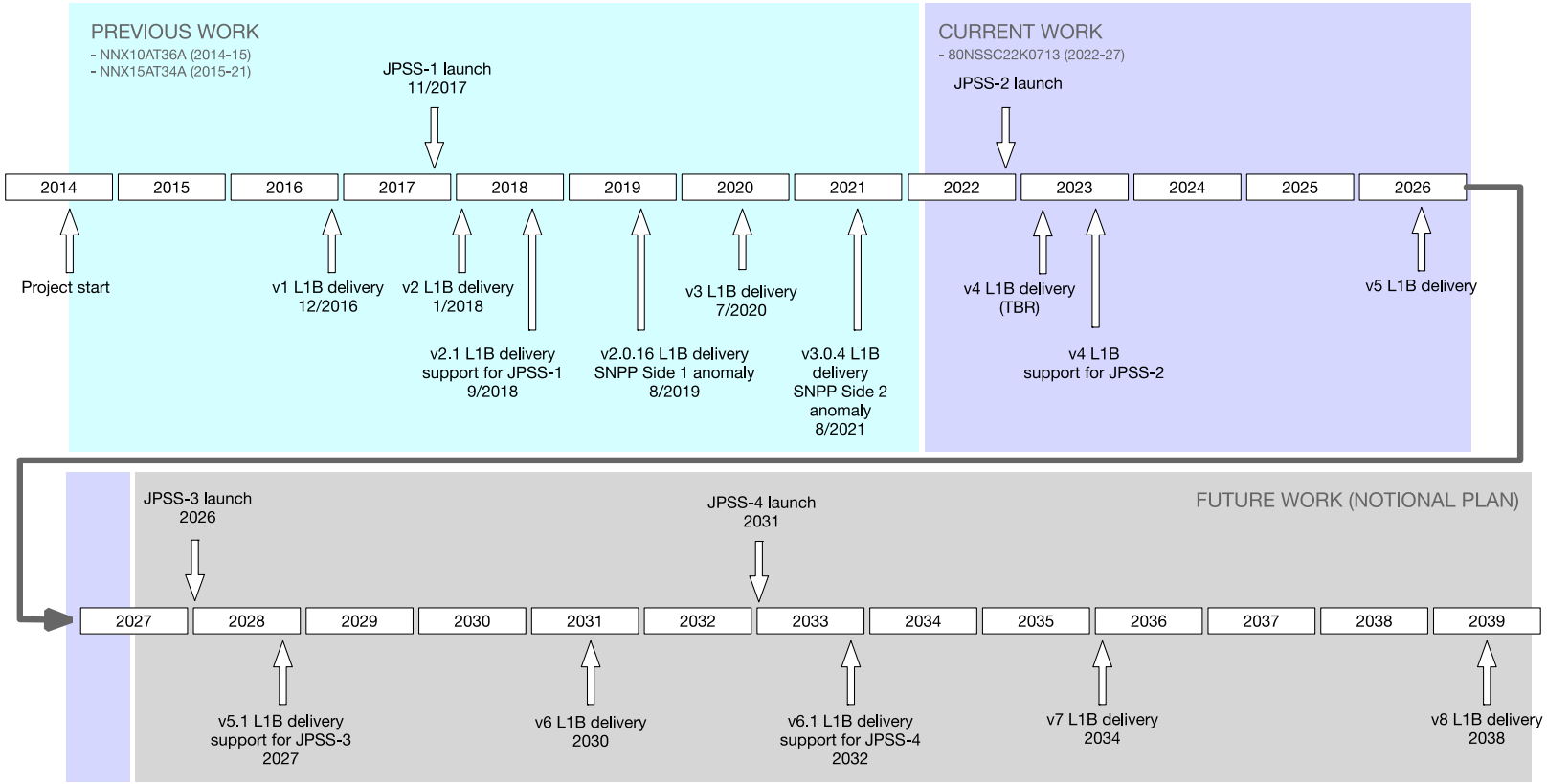
NASA ROSES A.33 and A.52

- "A Continuous Global **Cloud Thermodynamic Phase and Ice Cloud Microphysics** Record for Aqua AIRS, Suomi NPP, and JPSS", Kahn et al
- "Leveraging Multiple Observational Datasets to Advance Understanding and Simulation of **Convection Lifecycles**", Elsaesser et al.
- "Development and Analysis of New **VOC Retrievals** from the CrIS Sensors: Global Constraints on Anthropogenic, Biogenic, and Pyrogenic Emissions", Millet et al.
- "Impacts of Fires on Photochemistry: A New Long-Term Record of **Peroxyacetyl Nitrate (PAN)** from AIRS", Payne et al.
- "Using AIRS and CrIS **Radiances in Areas Affected by Clouds to Better Understand Processes Affecting Tropical Cyclone Structure** in a Global Data Assimilation and Forecasting Framework", Reale et al.
- "**Climate Anomalies and Trends** Derived from the AIRS and CrIS Infrared Radiance Time Series", Strow et al.
- "Quantifying **Tropical Ocean and Amazon Water Balance** (E – P) and Corresponding Process Controls Using AIRS and CrIS **Deuterium Observations**", Worden et al.
- "Improvements to the NASA CrIS **NH3** Product", Cady-Pereira et al.
- "Spectrally Resolved **Climate Fingerprinting** Data Products from Continuous Sounder Observations of AQUA, SNPP and JPSS", Liu et al.
- "The Continuation and Evolution of the **CLDMSK and CLDPROP** Continuity Cloud Product Suite", Meyer et al.
- "A Multi-Instrument Multi-Decadal Record of Community Long-Term Infrared Microwave Combined Atmospheric Product System (CLIMCAPS) **Atmospheric Soundings**", Smith et al.

Topics and applications

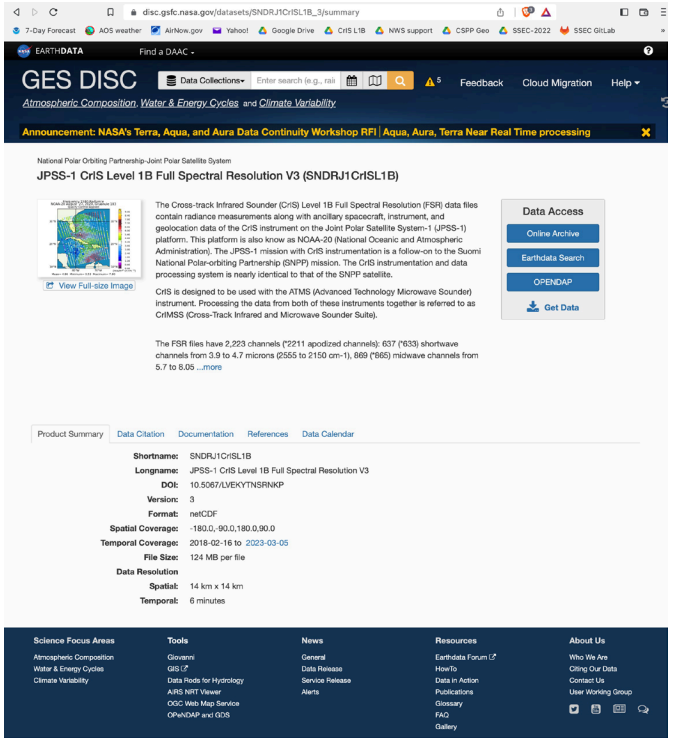
- spectral outgoing longwave radiation; cloud amount, temperature, and thermodynamic phase; water vapor feedback; climate model development; RTA and forward models; PBL; gravity waves; physical climate studies; T and q retrievals; drought monitoring; flu prediction; polar observations; atmospheric composition; PAN; Ozone; CO2, CO, NH3, CH4; ...

Level 1B Project Timeline

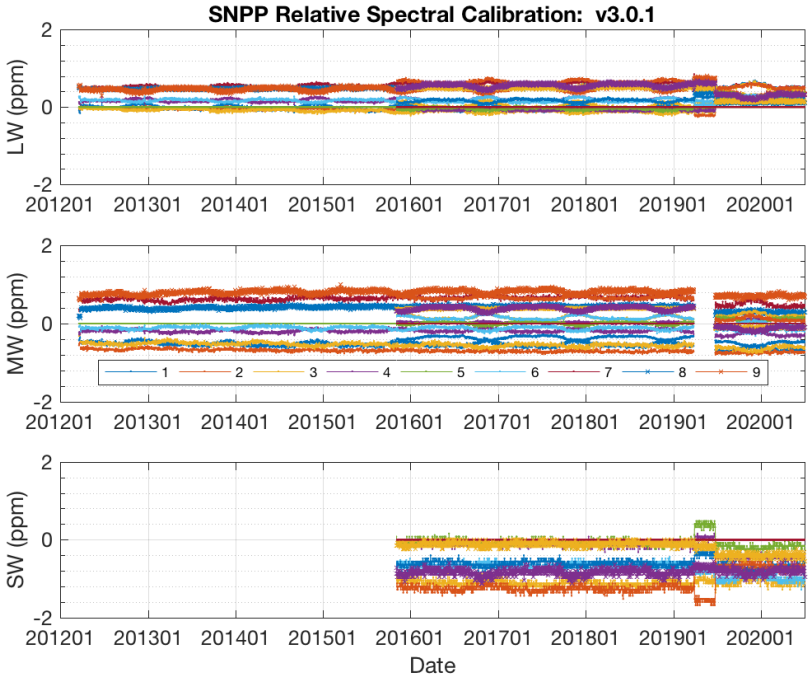


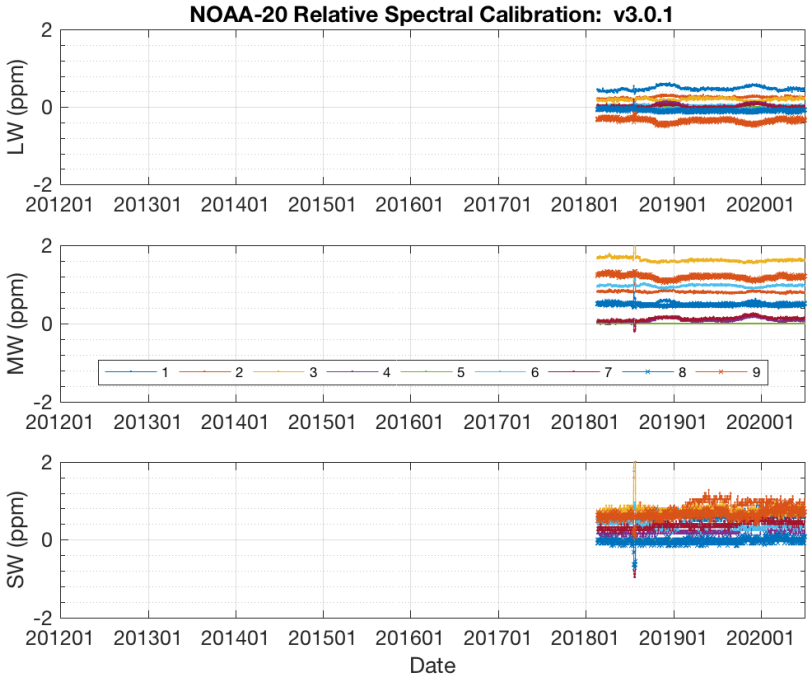
NASA CrIS Level 1B Product

- The current (v3) mission-length SNPP and NOAA-20 products are available from GES DISC
- Full Spectral Resolution (FSR) and Normal Spectral Resolution (NSR) variants of the SNPP product are available
- CrIS L1B v3 product features
  - Key components of the algorithm: FFT, nonlinearity correction, radiometric calibration, spectral calibration (including self-apodization correction), polarization correction
  - Correction of Doppler shift due to rotation of the Earth
  - Terrain corrected and uncorrected geolocation
  - “Epoch” definition to allow use optimal calibration parameters over the lifetime of the instrument
  - Auxiliary data is included to allow computation of radiometric uncertainty per observation
- A v3 test report was released in 2022, describing the methodology and results of our product assessment



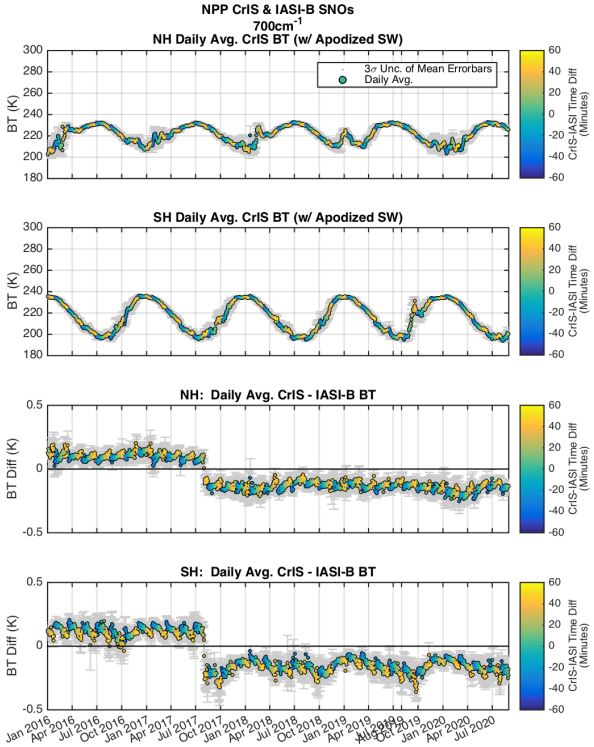
V3 Product Assessment Example: Inter-FOV Comparisons

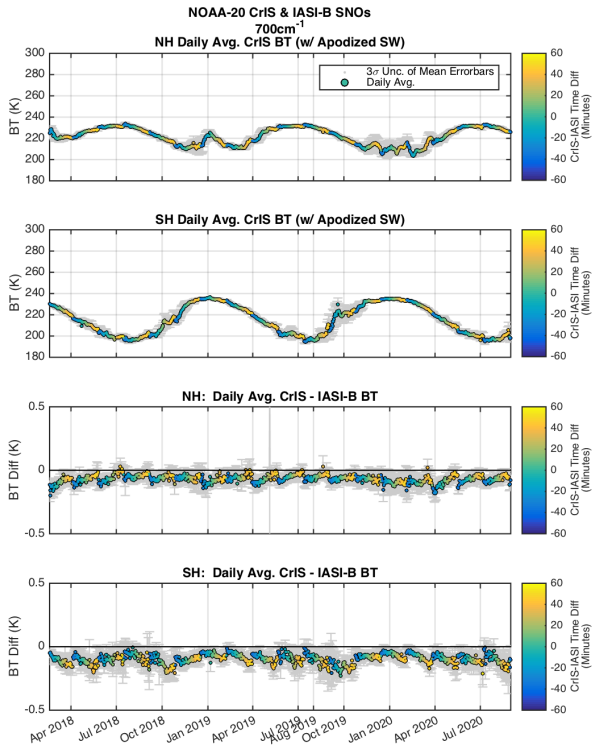




Credit: Bob Knuteson

V3 Product Assessment Example: SNOs (CrIS vs IASI-B)





Credit: Michelle Loveless

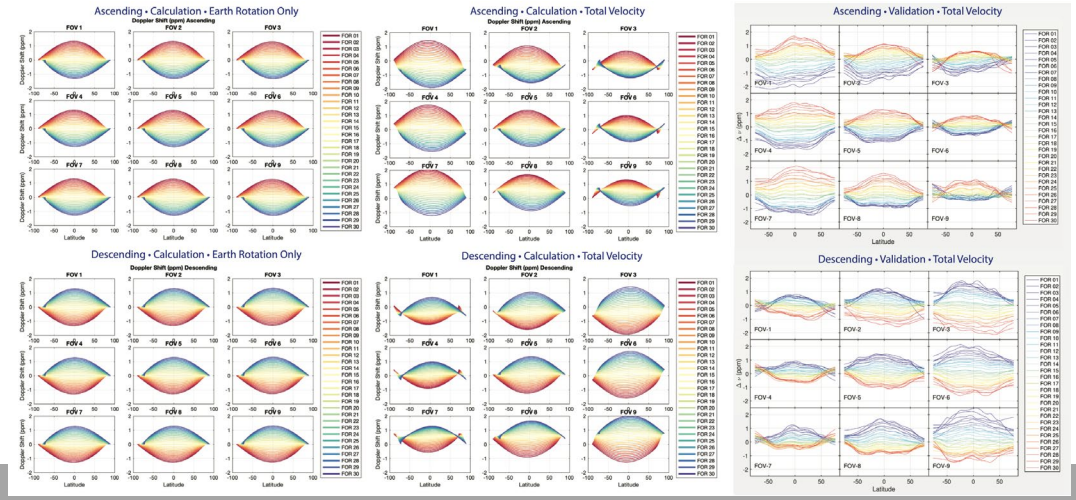
Loveless et al, 2023 [submitted for publication]. Comparison of the AIRS, IASI and CrIS Infrared Sounders Using Simultaneous Nadir Overpasses: Novel Methods Applied to Data from Oct 1st, 2019, to Oct 1st, 2020.

CrIS Level 1B Version 4

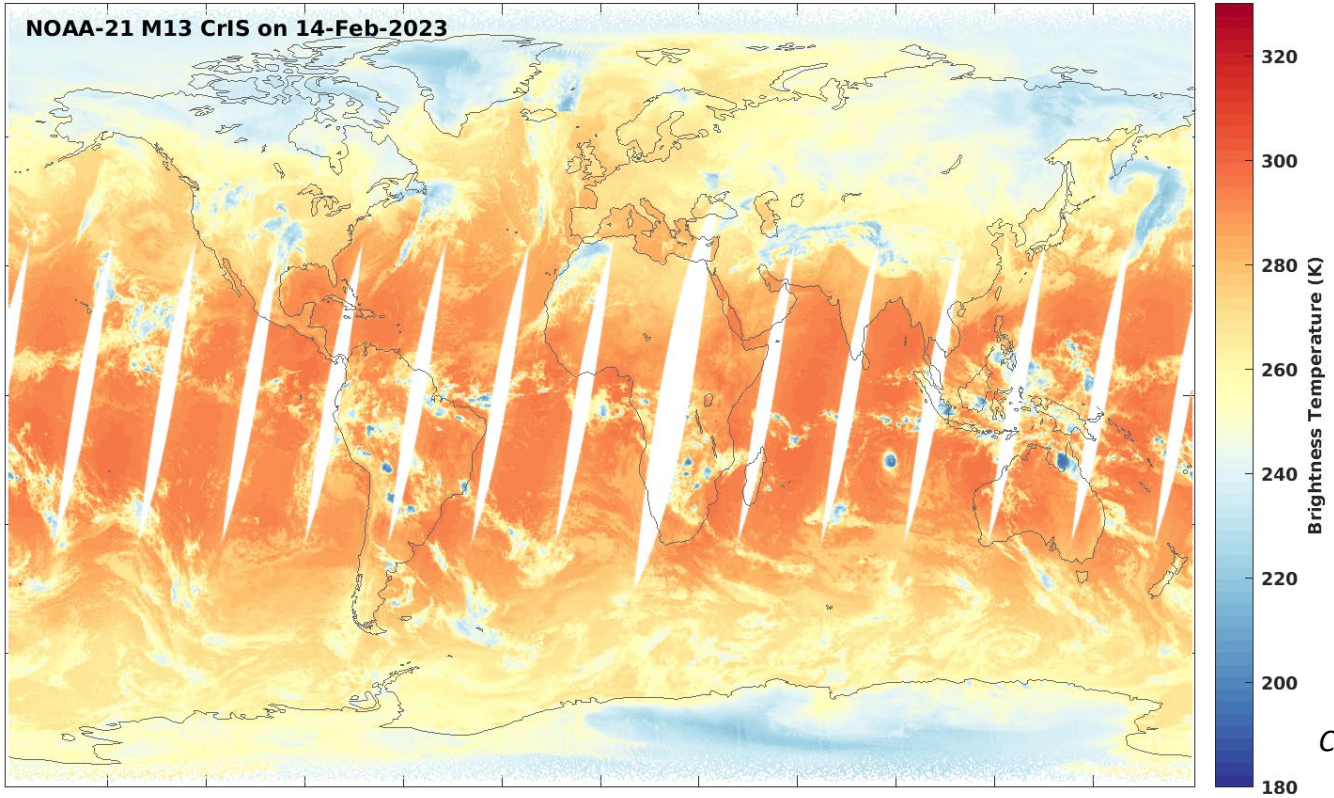
- Version 4 software is in development with product release planned in late 2023
- Planned v4 features
  - NOAA-21 support
  - Full Doppler correction (accounting for Earth rotation and satellite velocity)
  - Physical lunar intrusion model
  - Ringing correction
  - Improved spike detection
  - Improved quality checks including neon
  - Improved handling of edge cases / bad data

Doppler Correction

- The plots in the left and middle columns show the calculated Doppler shift versus latitude, FOV, and FOR for one orbit of NOAA-20 data (1) accounting for Earth rotation only, and (2) accounting for Earth velocity and Satellite velocity contributions
- The plots in the right column show the measured PPM shift between RTA generated radiances and CrIS observations without Doppler correction. Note the excellent agreement with the total calculated Doppler shift in the middle column.

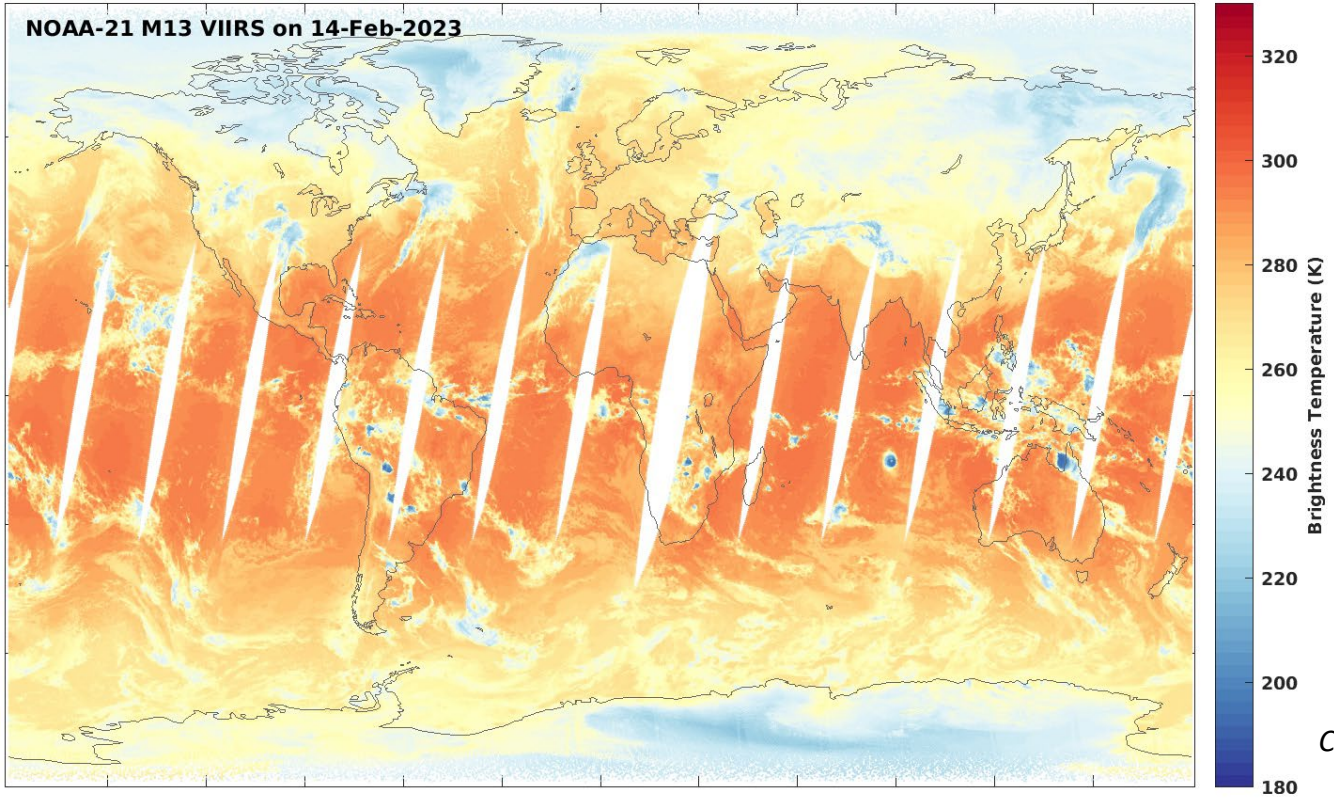


NOAA-21



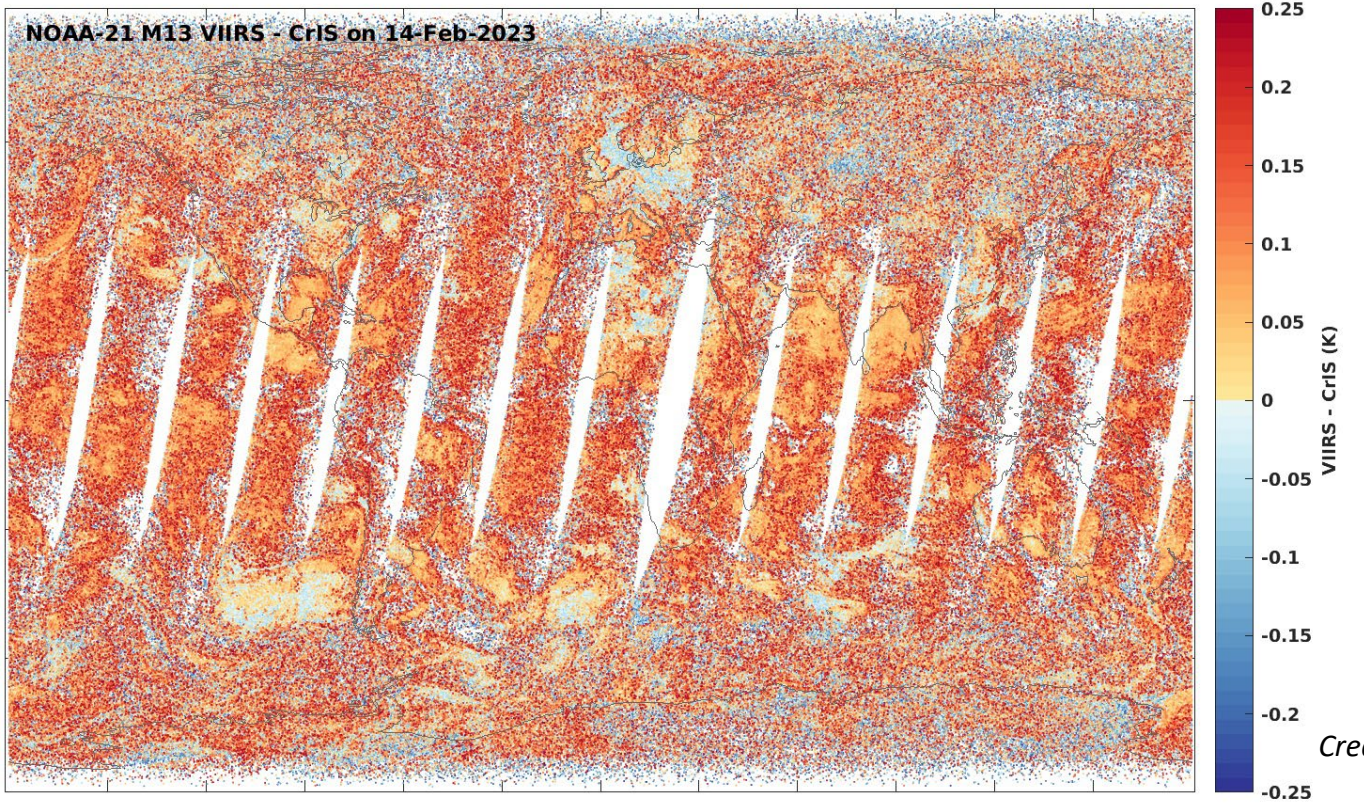
Credit: Dan Deslover

NOAA-21



Credit: Dan Deslover

NOAA-21



Credit: Dan Deslover

Summary

- The CrIS sensors are producing extremely high-quality calibrated radiance data records and will extend the record through 2040 and potentially beyond
- The CrIS L1B team continues to support efforts relating to creating climate quality products from five CrIS sensors: two in orbit and operational, one launched in November 2022 and in checkout, one just completed ground testing, and one to undergo ground testing this upcoming year
- The CrIS NASA L1B project is responsible for providing the CrIS NASA L1B, IMG, 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 climate process and trending studies
- NASA support is critical for production of this multi-sensor climate 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

The NASA CrIS L1B Version 3 products are available via the GES DISC website: https://disc.gsfc.nasa.gov

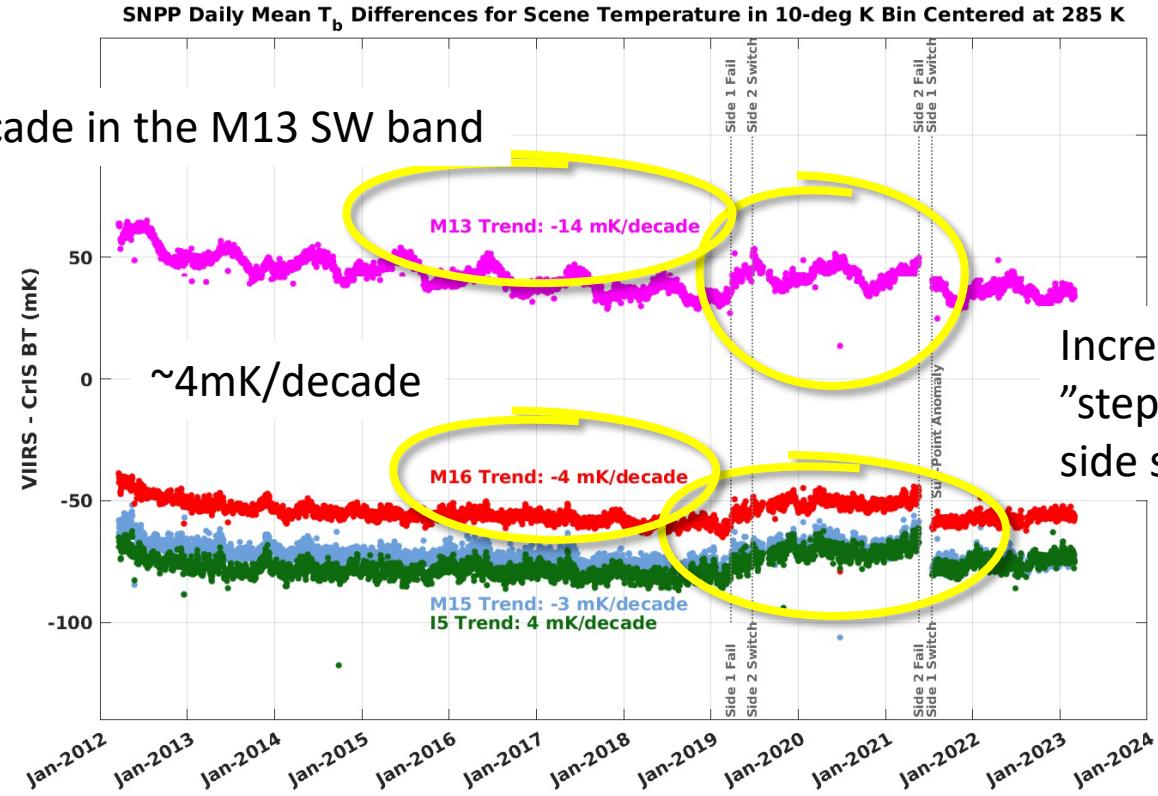
Backup

SNPP CrIS side change, 2021

- Due to a SNPP CrIS long-wave signal processor failure, the instrument was switched back to electronics Side 1 in July 2021.
- Mid-wave band data is missing after the side change due to an earlier electronics failure
- A NOAA-led effort characterized instrument performance after the side change and determined the original Side 1 calibration parameters were needed
- A new version of the CrIS L1B software was released with a new epoch definition beginning after the instrument had sufficiently stabilized following the side change

SNPP CrIS side change, 2021, VIIRS - CrIS

~14mK/decade in the M13 SW band



Incredibly small ”step” at CrIS side switches

Credit: Dan Deslover