The CrIS Level 1B version 3 Product: Status and Assessment

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CrIS NASA L1b Project Overview

- Funded by NASA to create software to generate a climate quality SNPP and JPSS-1 CrIS Level 1B mission data record
  - Supports reprocessing of the full mission datasets for the CrIS sensors, with a consistent calibration algorithm and optimal calibration coefficients and parameters
  - Transparent and accessible code base (“operational science” code)
  - Software and Re-processing under NASA control
- Joint effort at Univ. of Wisconsin – Madison and Univ. of Maryland Baltimore County. PIs Taylor and Strow
- File formats, granulation and other conventions were developed in collaboration with JPL Sounder SIPS and are common with the ATMS L1B product
- Underlying calibration equation and theory for NASA CrIS L1b Version 3 processing and current IDPS processing are similar but may diverge for future releases.

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CrIS NASA L1b: Recent Focus

- CrIS L1b Version 3 product and assessment (*this talk*)
- IMG (see *D. Tobin Talk*)
- CHIRP } *See UMBC Talks*
- RTA }
- Product assessment and monitoring
- SNPP and JPSS-1 Intercomparisons
  - Potential SNPP CrIS Inter/Re-calibration using JPSS-1 CrIS
  - Quadratic nonlinearity a_2 and SNPP T_{refl} and/or e_{ICT} refinements
- CrIS Covariance Matrices
  - Sensor Noise; Hamming apodization; Calibration Uncertainty
- JPSS-2 CrIS
  - Preparation for changes in telemetry
  - TVAC testing
- Improved self-apodization correction
- Improved spectral calibration

CrIS NASA L1b Product Timeline

- Early 2015: Project start
- Mid 2015: Preliminary SNPP sample data released
- Late 2016: Version 1 software and documentation delivered
  - Supports SNPP NSR product generation
- Late 2017: Version 2 software and documentation delivered
  - Added support for FSR product generation, various improvements included additional Geo outputs
- March 2018: Preliminary JPSS-1 sample data released
- September 2018: Version 2 software update delivered with added support for JPSS-1, minor improvements
- August 2019: Version 2 software update delivered with support for SNPP Side 2 processing
- July 2020: CrIS L1b Version 3 software (SNPP, JPSS-1) delivery to Sounder SIPS

CrIS NASA L1b Version 3 Release

Version 3 software was delivered in July 2020. Key features include:

- Polarization correction
  - Mean correction is largest in SW (when expressed as brightness temperature) and approaches 0.4 – 0.5K for 220 – 230K scene temperatures
  - Mean correction in LW and MW are relatively small, but not insignificant for cold scenes
- Correction of Doppler shift due to the Earth's rotation
- Fringe count error detection and correction
  - First (& only) event on 10 Aug 2019 (SNPP)
- Earth Scene interferogram spike detection
- Improved detection and removal of calibration reference outliers
  - Improved lunar intrusion detection
  - ICT outlier detection
- Radiometric uncertainty estimate tool
- Further reduction in spectral ringing
- Common software package for SNPP and JPSS-1
  - SNPP Side 1 and Side 2 support
  - Configuration file driven
  - Instrument and epoch dependent parameter files
- L1A refinements
  - Added provenance, addition of raw telemetry values
- GEO refinements
  - geospatial bounds attribute, WGS84 ellipsoid for sun glint calculation, Doppler velocity calculation
- Other minor improvements and bug fixes

Calibration Algorithm Overview

- Primary changes for Version 3 are polarization correction and Doppler correction
- Complex calibration method (Revercomb, 1988) used for radiometric calibration
- Onboard neon source for spectral calibration
- Instrument self-apodization correction via inverse self apodization operator (Genest and Tremblay, 1999; Desbiens et al., 2006)
- Full calibration is applied to **complex** Earth scene spectra (real and imag output)
- Full calibration (without Doppler or polarization correction) is used to produce NEdN estimate

$$\tilde{L}^{es} = L^{ict} \frac{F \cdot f_{ATBD} \cdot SA_s^{-1} \cdot f_{ATBD} \cdot \left[\frac{\Delta S_1}{\Delta S_2} \left| \Delta S_2 \right| \right]}{F \cdot f_{ATBD} \cdot SA_s^{-1} \cdot f_{ATBD} \cdot \left| \Delta S_2 \right|} - E_p^{\delta}$$

$$\Delta S_1 = \tilde{S}^{es} - \left\langle \tilde{S}^{ds} \right\rangle$$

$$\Delta S_2 = \left\langle \tilde{S}^{ict} \right\rangle - \left\langle \tilde{S}^{ds} \right\rangle$$

F = *spectral resampling operator (incl. Doppler Corr.)*

f_{ATBD} = *bandguard filter*

SA_s^{-1} = *Inverse Self Apodization Operator*

L^{ict} = *predicted ICT radiance*

$\tilde{L}^{es}$ = *calibrated Earth scene radiance*

$\tilde{S}$ = *complex spectra (after NLC)*

E_p^{δ} = *polarization correction*

Radiometric Calibration: Traceability
Traceability is critical for a climate quality product

– ICT (Internal Calibration Target), T_{ICT} and e_{ICT}
  - Pre-launch PRT calibrations
  - Pre-launch emissivity characterization
  - Pre-launch L_{ICT} verification using ECT at T_{ICT}

– Nonlinearity, a_2 and V_{DC}
  - Pre-launch Out-of-band harmonic analyses
  - Pre-launch ECT views at six temperatures
  - Post-launch Out-of-band harmonic analyses
  - Post-launch FOV-2-FOV analyses

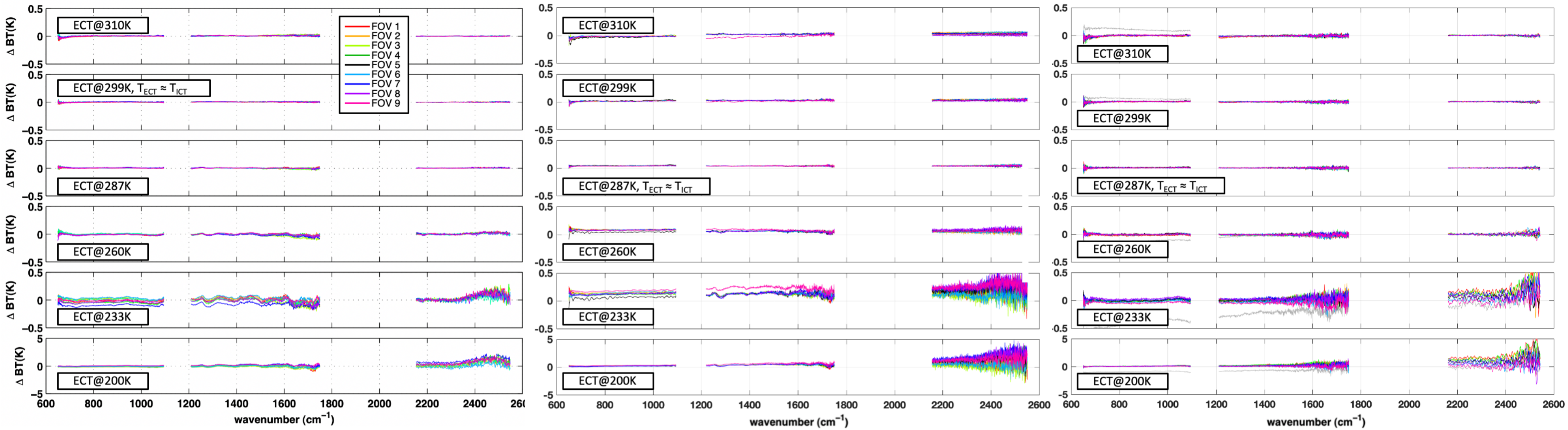
– Polarization, $p_r p_t$ and α
  - Optical design analyses
  - post-launch pitch maneuver data

$$\tilde{L}^{es} = L^{ict} \frac{F \cdot f_{ATBD} \cdot SA_s^{-1} \cdot f_{ATBD} \cdot \left[\frac{\Delta S_1}{\Delta S_2} \left| \Delta S_2 \right| \right]}{F \cdot f_{ATBD} \cdot SA_s^{-1} \cdot f_{ATBD} \cdot \left| \Delta S_2 \right|} - E_p^{\delta}$$

Pre-launch assessment of CrIS calibration using SI-traceable External Calibration Target (ECT) views

ECT view calibrated BT spectra minus ECT predicted BT, for ECT at 200K, 233K, 260K, 287K, 299K, 310K

S-NPP CrIS, 2008 | **NOAA-20 CrIS, 2014** | **JPSS-2 CrIS, 2020 (prelim)**



Courtesy D. Tobin

(JPSS-3 CrIS testing on-going now)

FOV3 (grey line) had Space Target view misalignment for the JPSS-2 data acquisition and analysis shown here. FOV3 is in family for TVAC testing in which the Space Target to FOV3 misalignment was remedied.

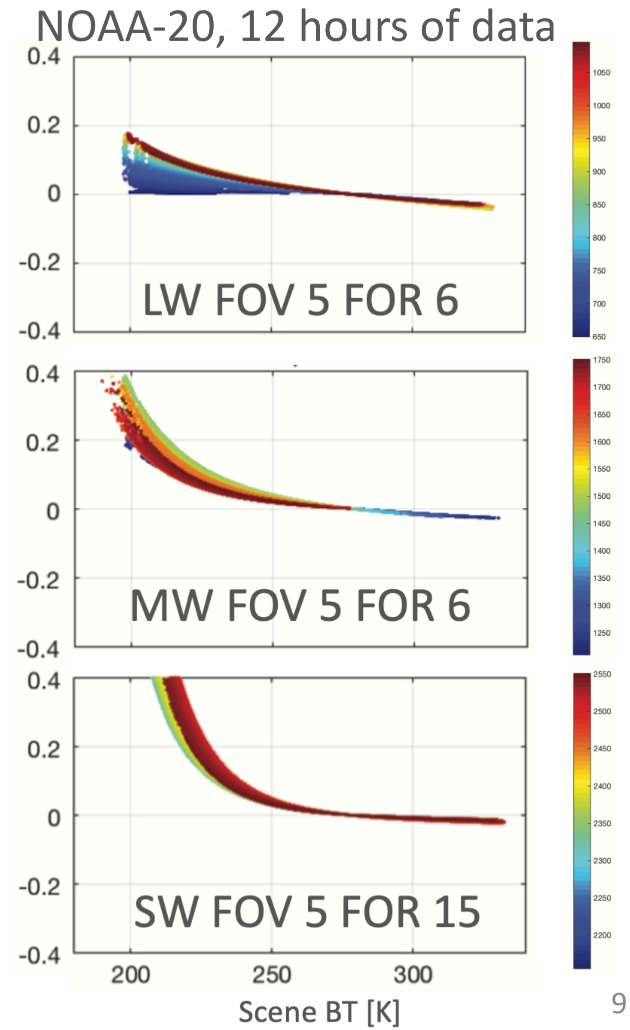
- ECT view data used to characterize the sensor radiometric nonlinearity and provide end-to-end calibration traceability to NIST via temperature sensor calibrations and NIST TXR measurements
- BT residuals are sub 0.1K for ECT temperatures of >260K, and larger as expected for 233 and 200K plateaus due to TVAC Space Target uncertainties; residuals are well within pre-launch RU
- TVAC data and analysis results to be archived and documented as part of the L1B record for traceability and on-going, future evaluations

Summary – Polarization Correction

- Details of the theory, derivation, and assessment of the CrIS polarization and polarization correction presented at 2018 SSTM
  - https://airs.jpl.nasa.gov/events/41/fall-2018-nasa-sounder-science-team-meeting
- Polarization correction parameters were derived independently for SNPP and NOAA-20 using pitch maneuver data
- The SNPP correction is slightly larger than the correction for NOAA-20
  - slightly different optical coatings for the two sensors
- The correction is scan angle dependent
  - The LW and MW correction is largest near FOR 10
  - The SW correction is largest near nadir (FOR 15, 16)
- The correction is scene temperature dependent
  - Correction increases with decreasing scene temperature
  - Correction is largest in SW when expressed as brightness temperature
  - Correction in LW and MW are relatively small, but not insignificant for cold scenes
- The correction has a small FOV dependence

V3 product assessment:

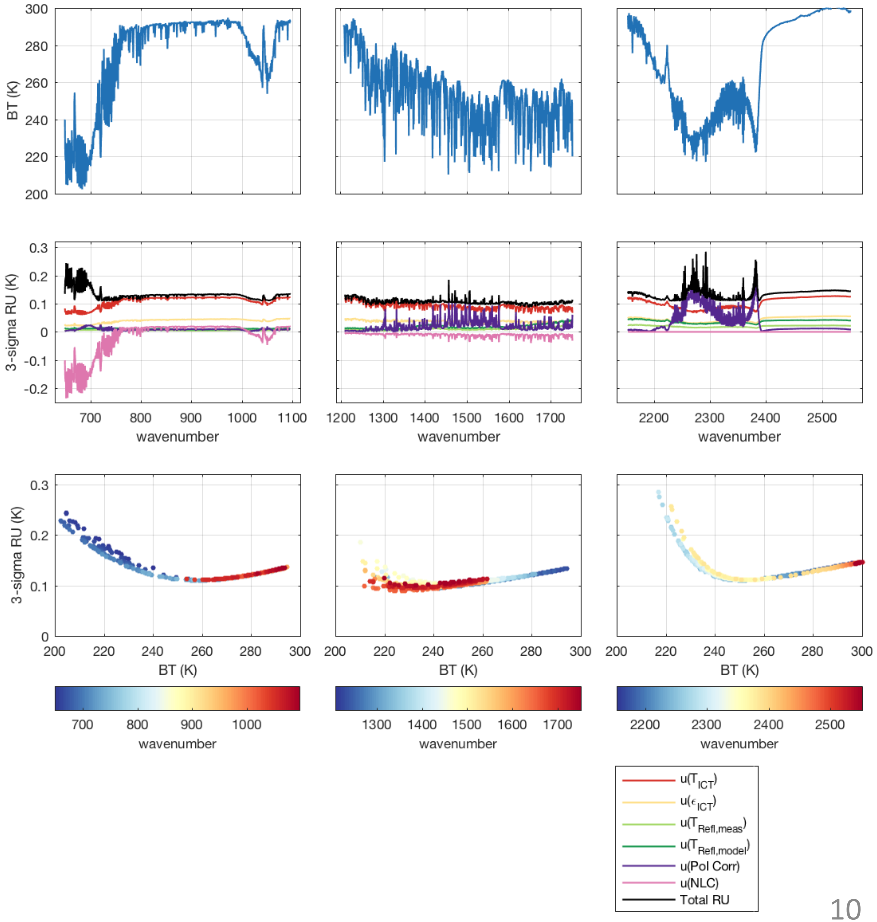
- Polarization correction reduces CrIS inter-FOV variability for NOAA-20 and SNPP
- Polarization correction improves the symmetry of the CrIS observations with respect to nadir
- Polarization correction of both CrIS sensors results in better agreement between the two sensors (using AIRS or IASI as the intermediate reference)



Radiometric Uncertainty Tool

- 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 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 will be made available for the Version 3 release

Example Warm Scene



Product Assessment

- FOV-2-FOV consistency
- CrIS to VIIRS comparisons *(see D. Tobin talk)*
- SNOs and SONOs
  - AIRS, IASI-A, IASI-B, IASI-C
- Clear sky Obs-Calc
- SNPP CrIS to JPSS-1 CrIS
  - Via calculation as transfer standard (Obs – Calc double difference)
  - Via AIRS or IASI as transfer standard (SNO double difference)
- V3 to prior release(s)
- Quality flag assessment
  - Lunar intrusion
  - Spike detection
  - Imaginary radiance threshold
- Mission length metrics

Simultaneous Nadir Overpass Satellite Intercomparison: CrIS and AIRS Example

CrIS to AIRS Big Circle SNOs Definition:

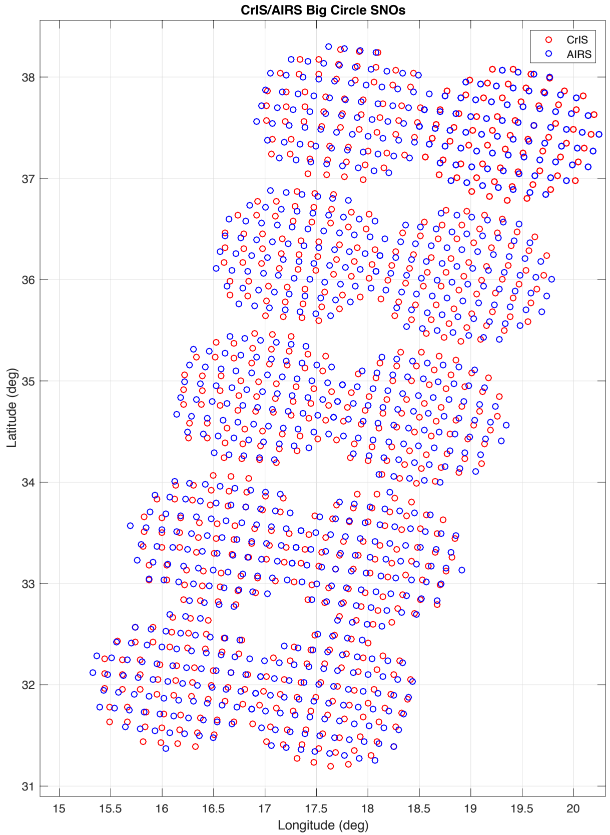
- Big Circle diameter approximately 150 km.
  (ellipse with minor axis of 75 km projected x-track)
- CrIS fields of view lat/lon retained within ellipse.
- AIRS fields of view lat/lon retained within ellipse.

Matchup Criteria Used In This Study:

- CrIS and AIRS View Angle wrt Nadir < 10 deg
- For this study CrIS restricted to near nadir FORs
  13, 14, 15 and 16, 17, 18.
- AIRS scan angles within 3 deg of CrIS mean SNO angle
- Latitude Range: [-40 deg <= Latitude <= 40 deg]
- Land/Ocean: Both included
- Day/Night: Night (Solar Zenith Angle > 95 deg)

- Time difference |CrIS-AIRS| < 12 minutes.

- Big Circle Scene Uniformity:
  AIRS radiance std dev 900 cm^{-1} < 1 $mW/(m^2\ sr\ cm^{-1})$



Courtesy R. Knuteson

SNOs Example: CrIS and AIRS (July – Dec 2019)
Provides Inter-comparison of CrIS Sensors for Low Latitudes

AIRS Mean BT

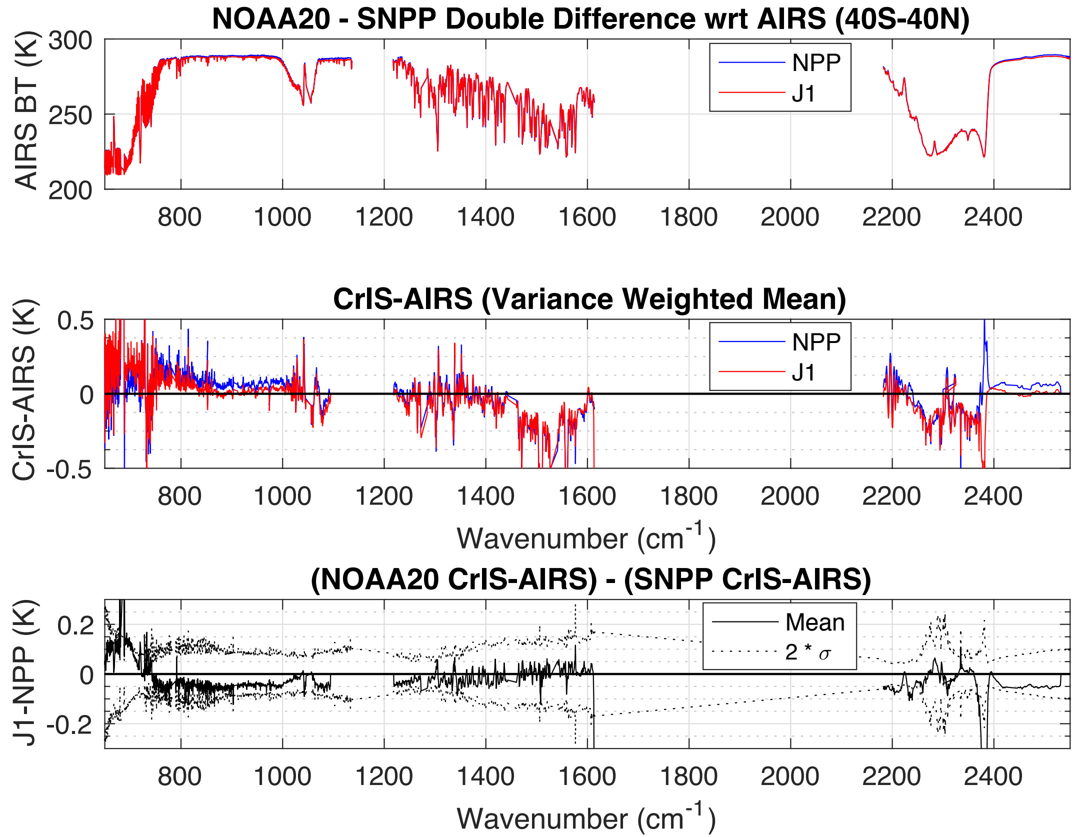
CrIS BT – AIRS BT
(smoothed)

$$\Delta = {\sigma_\Delta}^2 [\Sigma_{i=1:N} \omega_i \delta_i],$$

$$\sigma_\Delta = [\Sigma_{i=1:N} \omega_i]^{-1/2},$$

$$\omega_i = 1/({\sigma_{SPACEi}}^2)$$

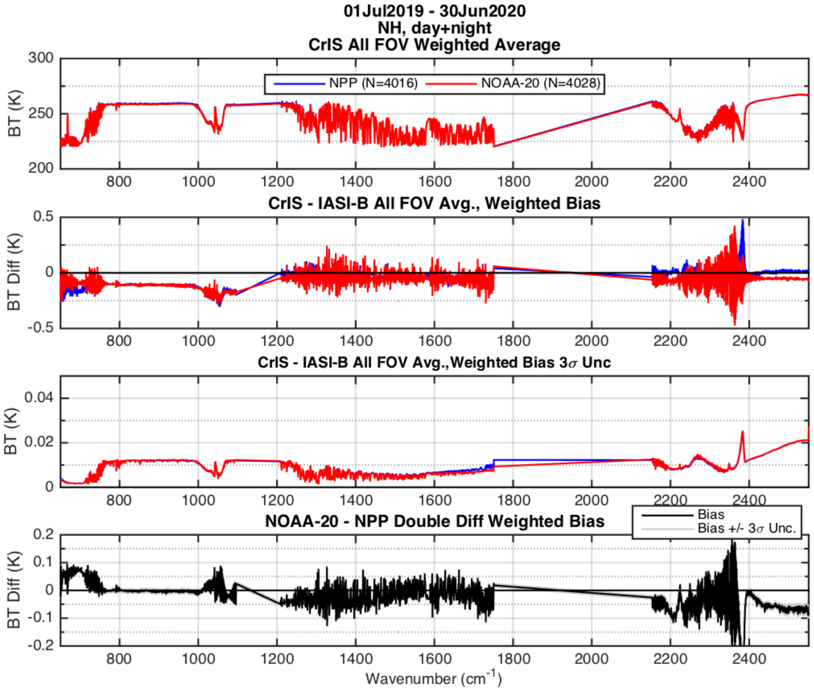
NOAA20 CrIS
minus
SNPP CrIS



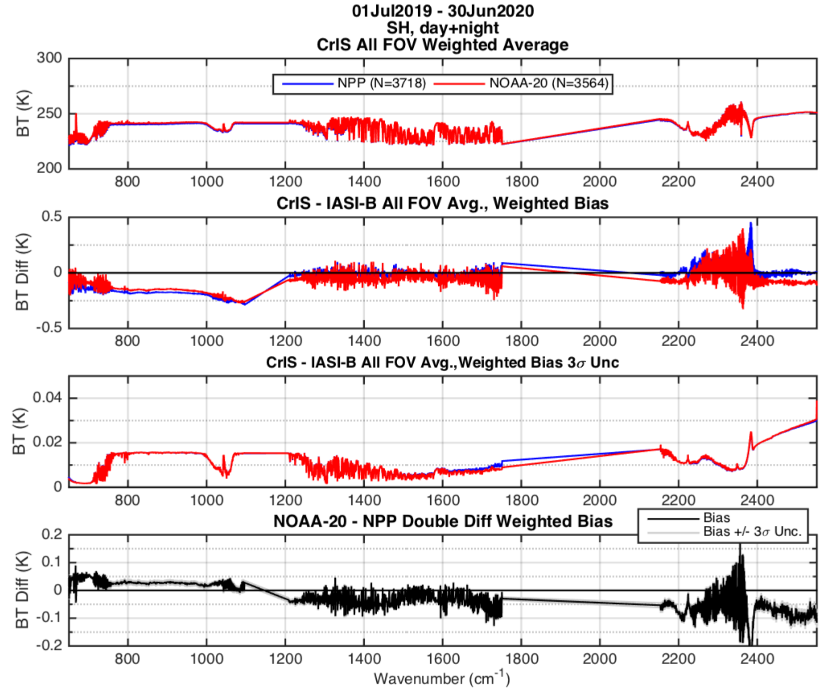
Courtesy R. Knuteson

SNOs Example: CrIS and METOP-B IASI
July 2019 – June 2020

Northern Hemisphere

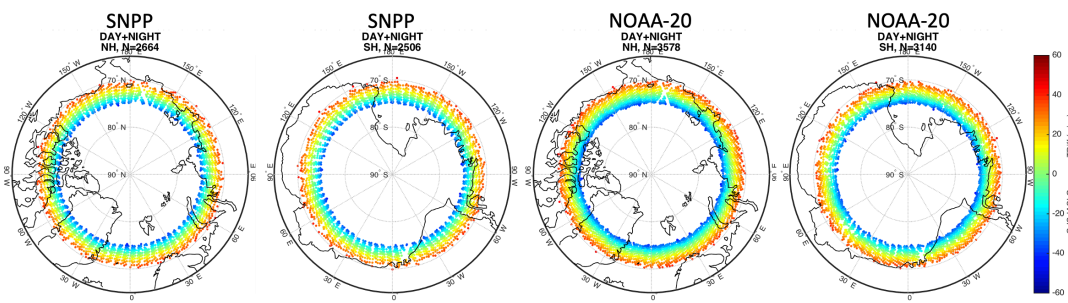


Southern Hemisphere



SNPP - IASI-B
NOAA-20 – IASI-B

NOAA-20 – NPP Double Diff

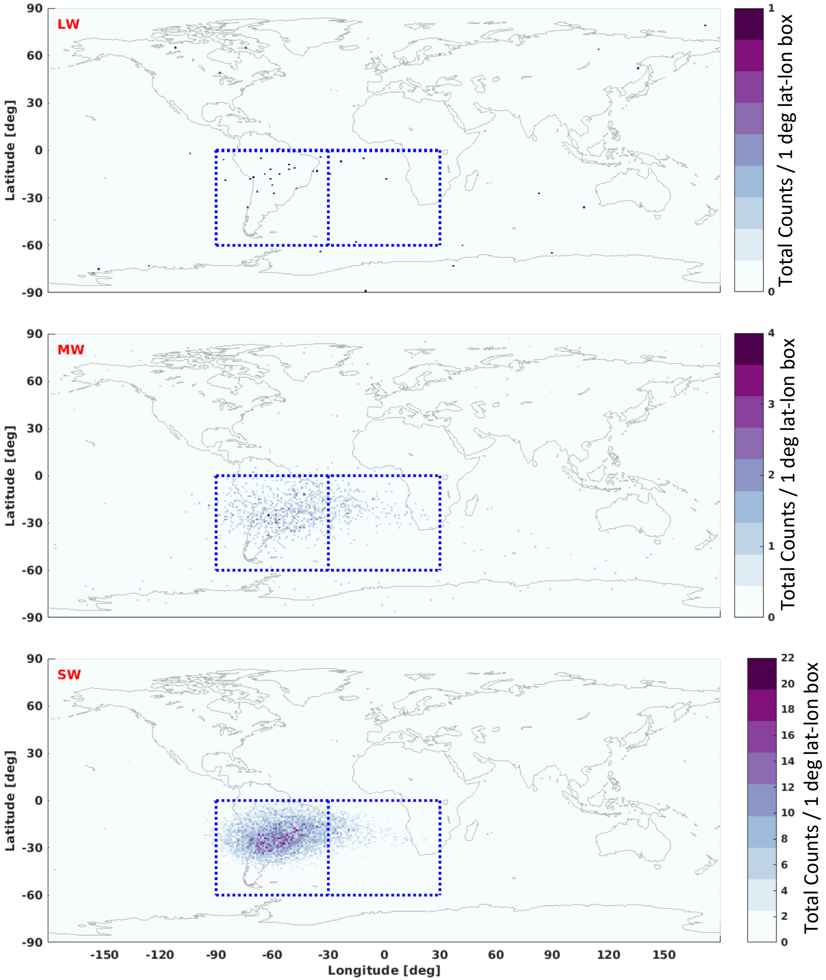


Maximum time difference: 60 minutes
Time difference histograms symmetrized
SNO Latitudes at roughly ±(70 – 75)°

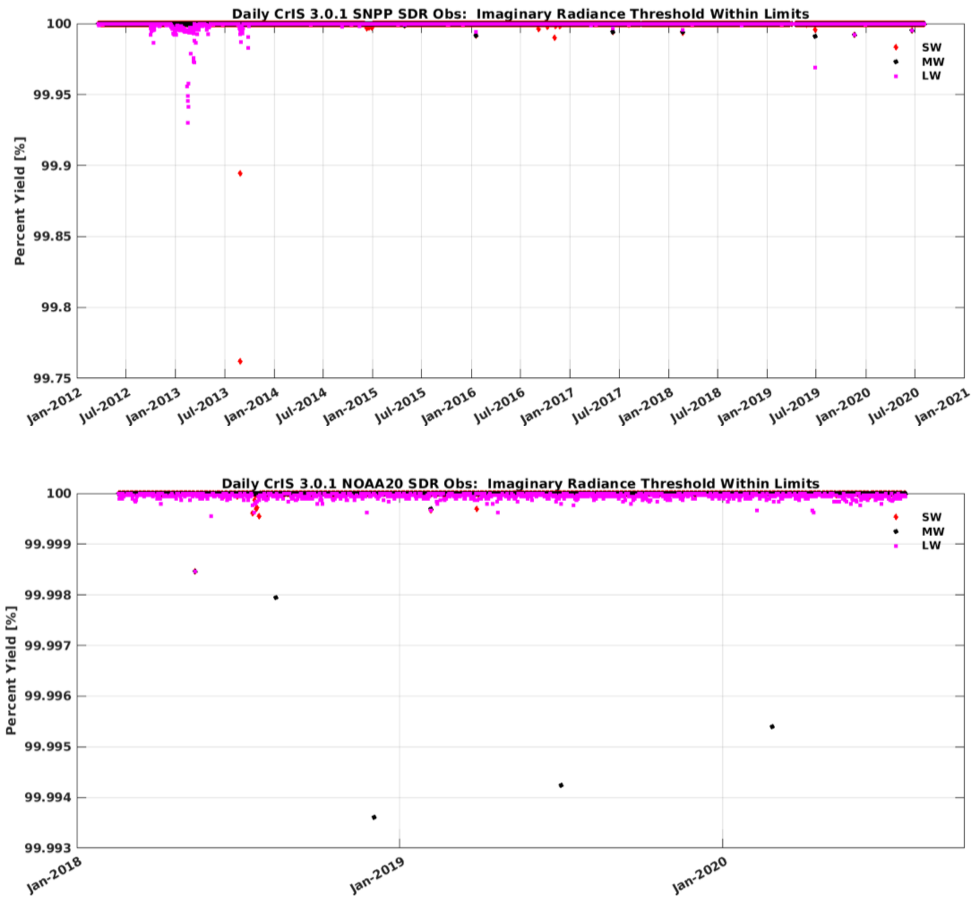
Courtesy M. Loveless

Product Assessment
Quality Flag Assessment and Mission Metrics Example

Spike Detection Flag Density Map (NOAA-20, 2020)



Imag(Radiance) Within Threshold Limits



Courtesy D. DeSlover

Products, Documentation, and Software

1. Visit GES DISC site: https://disc.gsfc.nasa.gov
2. Search “CrIS L1B”
3. Select the desired dataset
   - SNPP CrIS L1B NSR V2 (V3 expected Oct 2020)
   - SNPP CrIS L1B FSR V2 (V3 expected Oct 2020)
   - JPSS-1 CrIS L1B FSR V2 (V3 expected Oct 2020)
4. Dataset page has multiple methods of data access and links to documentation.

Direct links (V2):

- https://disc.gsfc.nasa.gov/datasets/SNPPCrISL1BNSR_2/summary
- https://disc.gsfc.nasa.gov/datasets/SNPPCrISL1B_2/summary
- https://disc.gsfc.nasa.gov/datasets/SNDRJ1CrISL1B_2/summary

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