Read-me for Data Users

MEMORANDUM FOR:	The JPSS Program Record
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SUBJECT:	NOAA-21 CrIS SDR Validated Maturity Status and Public Release
DATE:	09/28/2023

Provisional maturity Status Declaration for CrIS SDR

Maturity Review Date:	**09/28/2023**
Effective Date:	**09/26/2023**
Operational System:	**IDPS with Engineering Packet (EP) v212 with PCT Update (CCR 6761)**

1. Background:

The Joint Polar Satellite System-2 (JPSS-2) was successfully launched on November 10, 2022 and renamed NOAA-21 after reaching polar orbit. Ninety-two days after launch, on February 10, 2023, the NOAA-21 Cross-track Infrared Sounder (CrIS) started collecting science data. With the same design as Suomi NPP and NOAA-20 CrIS, the NOAA-21 CrIS provides global hyperspectral infrared observations twice daily for profiling atmospheric temperature and water vapor, critically needed information for improving weather forecast accuracy out to seven days. The CrIS sensor also supplies information used to retrieve greenhouse gasses, land surface and cloud properties. The CrIS measures infrared spectra in three spectral bands: the long-wave IR (LWIR) band from 650 to 1095 cm^{-1}, mid-wave IR (MWIR) band from 1210 to 1750 cm^{-1} and short-wave IR (SWIR) band from 2155 to 2550 cm^{-1}. Full spectral resolution (FSR) operational mode provides a total of 2223 radiance channels. For each band, CrIS measures the infrared (IR) spectra from the Earth scene (ES) with a 3×3 detector array, corresponding to 9 field-of-views (FOVs) with 14-km diameter at nadir for a single field-of-regard (FOR, 30 total) .

The CrIS Calibration and Validation (Cal/Val) Science Team consists of experts from NOAA, NASA, University of Maryland/CISESS, University of Wisconsin/SSEC/CIMSS, University of Maryland Baltimore County, L3-Harris, and Logistikos. The team has performed and led pre- and post-launch calibration and validation activities and participated in the monitoring and characterization of the on-orbit CrIS sensors .

The NOAA-21 CrIS SDR data product reached effective beta maturity level on February 21, 2023 after upload of Engineering Packet Version 210, and reached effective provisional maturity level on March 23, 2023 after the upload of Engineering Packet version 211 and an extensive data quality check.

2. Validated Maturity Stage Definition:

1. Product performance has been demonstrated over a large and wide range of representative

conditions (i.e., global, seasonal).
2. Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.
3. Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.
4. Product is ready for operational use based on documented validation findings and user feedback.
5. Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument.

3. Justifications for Declaring NOAA-21 CrIS SDR Data Products Validated Maturity:

After NOAA-21 CrIS SDR provisional maturity on March 23, 2023, CrIS SDR team members continued the assessment and analysis of both CrIS on-orbit data and special post-launch tasks (PLT) data, including CrIS science RDR, SDR, and GEO data products. This includes final refinements of the Radiometric Nonlinearity using FOV2FOV radiometric comparisons, verification of the ILS parameters; and the updates made with the upload of Engineering Packet version 212 and PCT update CCR 6761 further refinement of geolocation parameters, change in the interval between neon calibration reference measurements, and derivation of polarization correction. Based on the nearly one hundred ninety days of continuous intensive evaluation and monitoring of CrIS data, the following assessments of the CrIS instrument and data products are given:

1. On-orbit NEdN: all FOVs and bands are within the specification and are comparable to S-NPP and NOAA-20 CrIS
2. Radiometric uncertainty: The radiometric uncertainty expressed as a % of the 287 K blackbody radiance, in terms of the maximum 1-sigma radiometric uncertainty for each band, is 0.15%, 0.18%, and 0.35% for the Longwave, Midwave, and Shortwave respectively. This falls well within the specification for each band.
3. The mean O-B bias over clear-sky CRTM simulations remains consistent within ± 2.0 Kelvin for LWIR, MWIR, and SWIR band since the beginning of the NOAA-21 CrIS mission (~7 months). This accounts for the systematic biases between CRTM and Observation (which has been seen with SNPP and NOAA-20 CrIS).
4. With respect to the radiometric consistency between NOAA-20 and NOAA-21 CrIS (over the 3 spectral bands), the majority of channels show radiometric differences within ± 0.2 K.
5. The radiometric FOV2FOV relative consistency is within ±0.1K for all three bands.
6. Spectral uncertainty: absolute spectral offsets for all three bands are all within ±2 ppm, and relative spectral offsets for all three bands are within ±1 ppm. This assessment accounts for changing the interval between neon lamp spectral calibration measurements to 45,864 seconds (originally 6,552 seconds).
7. Geolocation uncertainty: The total geolocation uncertainty is 760 meters 3-sigma where the specification is 5 km. Current uncertainty is comparable to S-NPP and NOAA-20 CrIS.
8. NOAA-21 CrIS SDR products have been reliably produced by IDPS since the first light data was produced on February 10, 2023.
9. Intercomparisons of NOAA-21 CrIS vs NOAA-21 VIIRS show very good agreement (mean of all scene temperature biases are within 50 mK).

10. Intercomparisons of NOAA-21 CrIS vs Metop-B IASI, Metop-C IASI, all show very good radiometric agreement (biases are within 0.5 K).
11. Double differences via calculated spectra and IASI and AIRS, show similar results and show very good agreement between NOAA-20 CrIS and NOAA-21 CrIS (double differences are within 0.5 K).
12. Intercomparisons between GOES-16 and GOES-18 ABI and NOAA-21 CrIS demonstrate consistent results across all bands over the assessment time period (bias within 0.2K).
13. NOAA NUCAPS team has generated and analyzed NOAA-21 trace gasses, temperature, water vapor and other EDR products and is comparable with operational NOAA-20 EDR's.
14. Feedback from NWP was provided by representatives of ECMWF, NCEP, OSPO, CIRA/CSU and NOAA/OAR/GSL Feedback. They provided agreement that the performance of the NOAA-21 CrIS SDR product is consistent with the NOAA-20 CrIS SDR product with respect to number of assimilated channels, as well as statistics including radiometric biases and variance.

Thus far the instrument is operating well, and the updates made to calibration parameters in EP v212 and PCT CCR 6761 has brought the SDR performance further in line with previous CrIS instruments. The comprehensive assessment for declaring NOAA-21 CrIS SDR Validated Maturity is attached in the corresponding review presentation.

4. NOAA-21 CrIS Validated Maturity SDR Data Product Caveat: Imaginary Radiance Observation

It has been observed that there are slightly elevated imaginary radiance levels in the 45 – 90 Degrees South Latitude region. We believe this results from increased heat flux in the instrument aperture when exiting eclipse at high southern latitudes, causing a thermal transient seen in the Dynamic Alignment System response and instrument temperatures. The impact of this feature has been quantified and reported. These affected scenes are captured by the Lunar Intrusion (marked as degraded) and Imaginary Radiance (marked as invalid) Quality Flags, helping to identify and reduce the impact on users.

The impact of the Imaginary Radiance has been assessed and the following observations have been made:

1. Spatial and Time Distribution: Whereas initially in February 2023 the elevated imaginary radiance observation was limited to 45-60 degree South Latitude regions, by May 2023 the elevated imaginary radiances migrated south to be between 70-90 Degrees South (in the Antarctic region).
2. The most impacted FOVs from the Imaginary Radiances is primarily the corner and Side FOVs (least affected is FOV 5), and FOV 3 and FOV 7 are the most affected, as measured by locations of high (>0.2) RMS of the Earth Scene Imaginary Radiances.
3. The radiometric impact was assessed using the offline ADL with the smallest window size (6 scanlines) as compared to the 30 scanlines used in the operational algorithm, and selecting three representative days where the Lunar Intrusion flags were at their near maximum. These findings were consistent with an approach by the University of Wisconsin (UW), where an offline research calibration algorithm was implemented using a calibration window size of 1 scanline.
    a. Using the offline ADL calibration algorithm, result show that between -75 and -85 degrees

latitude, there was a mean Brightness Temperature difference of ~50 mK for the LWIR band, 200 mK for the MWIR band, and about 5.0 K for the SWIR band (STD is more than 10 K for the SWIR band).

b. Using the UW offline research calibration algorithm with a window size of 1 scanline, it was found that the Brightness temperature differences (averaged in 2 degree latitude bins) were as large as 1K in the LWIR band, 4 K in the MWIR band, and 20 K in the SWIR band.

c. Note that the CrIS channels which are assimilated in NWP centers only include a subset of the LWIR and MWIR bands. No SWIR band channels are assimilated.

4. The CrIS SDR Team has developed and recommends the following potential paths forward (1) continue monitoring the calibrated observation while maintaining the present calibration algorithm configuration, (2) implement a shorter calibration view moving window (perhaps combined with noise filtering), (3) implement an interpolation of calibration view data to ES view times.

5. Users Feedback

Primary users of the NOAA-21 CrIS SDR product provided initial feedback in support of the Validated Maturity review. Below is a list of major observations from CrIS Data Users.

1. ECMWF: NOAA-21 CrIS is in the operational system passively since September 27, 2023 and is scheduled to assimilate at a later date in 2023. NOAA-21 CrIS has very good quality although the noise does seem elevated in the LWIR CO2 band compared to the NOAA-20 CrIS.
2. NCEP: NOAA-21 CrIS has small differences in statistics with the NOAA-20 CrIS in the assimilation test runs. The soonest implementation of the NOAA-21 CrIS SDR data in the assimilation system is November 2023.
3. NOAA/OAR/GSL: NOAA-21 CrIS FSR data quality is good and similar to the NOAA-20 CrIS. The NOAA-21 CrIS FSR data improve the fits of some channels from microwave sensors (e.g., NPP ATMS) and have neutral to slightly positive impact within the Rapid Refresh Forecast System (RRFS). There is a plan to include NOAA-21 CrIS FSR data into RRFS version 1.
4. NUCAPS Team: NOAA-21 NUCAPS EDR sounding products show excellent consistency with the NOAA-20 products. The evaluation of the NOAA-21 NUCAPS EDRs demonstrates that CrIS SDR product performs as expected and meets the Validated Maturity requirements.
5. OSPO: OSPO has been operationally running the NOAA-21 CrIS SDR and BUFR products. OSPO expects to be able to generate NOAA-21 EDR data sometime in November-December, 2023.

6. Path forward

The CrIS SDR team will work diligently as we transition to long term monitoring of the NOAA-21 CrIS SDR Product. Some highlights of the expected long-term objectives include:

1. Perform long-term inter-comparison with other sensors, including RO products.
2. Continue to monitor CrIS instrument stability and performance, as well as SDR data quality
3. Continue to monitor and investigate the 40S-90S latitude imaginary radiance behavior in order to observe the annual variation of this phenomenon. A formulation of possible mitigation strategies

will also be investigated.

4. As part of continuing operations, potential anomalies that impact the calibration of the sensor that occur during the CrIS instrument's mission will be addressed.

Additional information is available in the CrIS Algorithm Theoretical Basis Document (ATBD) and Maturity review briefings, which can be accessed at:
https://www.star.nesdis.noaa.gov/jpss/Docs.php
https://www.star.nesdis.noaa.gov/jpss/AlgorithmMaturity.php

Pre-operational NOAA-21 CrIS near real time status and performance monitoring password protected web page is available using the following URL at:
https://www.star.nesdis.noaa.gov/cris-j2/index.php
https://www.star.nesdis.noaa.gov/icvs-j2/

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