Read-me for Data Users

MEMORANDUM FOR: The JPSS Program Record

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SUBJECT: Suomi NPP CrIS SDR Validated Maturity Status and Public Release

DATE: 02/06/2019

Validated maturity status declaration for CrIS SDR

Maturity Review Date: **02/06/2020**

Effective Date:

Operational System: **IDPS with Engineering Packet (EP) v40**

1. Background:

The Suomi National Partnership Program (NPP) spacecraft was successfully launched on October 28, 2011. The Suomi NPP Cross-track Infrared Sounder (CrIS) Sensor Data Record (SDR) was declared to have reached validated maturity in December 2013. For more than seven years, Suomi NPP (SNPP)/CrIS has provided global hyperspectral infrared (IR) observations twice daily for profiling atmospheric temperature and water vapor, critically needed information for improving weather forecast accuracy out to seven days. The CrIS observations also supply information to retrieve greenhouse gases, land surface and cloud properties. 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}. Nominal spectral resolution (NSR) and full spectral resolution (FSR) operational modes provide a total of 1305 and 2211 radiance channels, respectively.

On March 23, 2019, the first instance of missing SNPP/CrIS MWIR Interferograms in the Raw Data Record (RDR) associated with the MWIR band anomaly was detected. Invalid SNPP/CrIS MWIR SDR data was observed in 1 scan on March 23, in 4 scans on March 24, and in 33 scans on March 25, 2016. On March 26, 2019 the Interface Data Processing Segment (IDPS) stopped producing SNPP/CrIS SDR data. Root cause analysis identified a potential point of failure in the MWIR signal processor field programmable gate array (FPGA) and associated circuitry. While production of operational LWIR and SWIR SNPP/CrIS SDR data resumed on April 16, 2019, the MWIR SDR data remained unavailable. To rectify the instrument anomaly and recover the full capabilities of the SNPP/CrIS instrument, a formal decision to switch from the Side-1 to the Side-2 electronics was made on June 21, 2019. One June 24, 2019 the switch to Side-2 electronics was initiated and the three instrument spectral bands were recovered. The SNPP/CrIS SDR data became available in GRAVITE and the instrument was transitioned from Nominal Mode to Operational Mode producing FSR data on June 24, 2019. Following the instrument tuning, the CrIS SDR team began an intensive period of review and monitoring to quickly restore the CrIS SDR data to operational quality.

Evaluation of the first two weeks of SNPP/CrIS SDR Side-2 data, following the switch to Side-2 electronics, demonstrated that it held Beta Level quality. The SNPP/CrIS SDR Side-2 data products were declared provisional with the upload of Engineering Packet v40 on August 1, 2019, at 16:49:40 UTC/12:49:40EST, following an intensive calibration and validation period. This engineering packet provided corrected mapping angles that brought the geolocation within specification and updated ILS parameters that matched the Side-1 performance for continuity of the mission data.

The CrIS SDR team consists of experts from NOAA, NASA, University of Maryland/CICS, University of Wisconsin/SSEC, University of Maryland at Baltimore County, Harris, and Logistikos. The team has been working intensively on instrument performance optimization and CrIS SDR calibration and validation following the switch to Side-2 electronics. This document contains the justification to transition the SNPP/CrIS SDR product to the Validated Maturity Level, the path forward toward the Validated level, and the lessons learned after the successful recovery of the first CrIS instrument on-orbit, using redundant electronics.

2. Maturity Stage Definitions:

Validated Maturity

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 Validated Maturity for Suomi NPP CrIS SDR Data Products:

After the switch to the SNPP/CrIS Side-2 electronics on June 24, 2019, the CrIS SDR team members began the assessment and analysis of CrIS on-orbit data, including CrIS science RDR, telemetry RDR, SDR, and GEO data products. Calibration parameters were adjusted to maintain SDR data continuity between Side-1 and Side-2 rather than to minimize calibration errors; however, the difference between optimizing continuity versus absolute accuracy is very small. The only instrument calibration parameter that changed with the switch to Side-2 was the Neon bulb wavelength (Side-2 uses a different Neon bulb). Small changes to the focal plane positions (x,y offsets) for all three bands were also observed. As expected, no other changes to optical parameters were identified during the side switch. This work resulted in the transition of the SNPP/CrIS SDR data product to the JPSS Provisional Maturity Level on August 1, 2019. After successfully reaching the provisional level, the CrIS SDR Team was focused on demonstrating that the long-term stability of the SNPP/CrIS instrument and the SDR data product over a large and wide range of representative conditions (i.e., global, seasonal) and that the SDR data product was ready for operational use based on documented validation findings and user feedback. The long-term assessment of the SNPP/CrIS SDR data product included radiometric inter-comparisons against SNPP/VIIRS, Metop-B/IASI, NOAA-20/CrIS observations, and simulated radiances over nearly six months. The evaluation of the spectral quality of the SDR products was mainly based simulated observations, while the geolocation was assessed using the high spatial resolution and accurate geolocation of the SNPP/VIIRS observations. Derived from this intensive evaluation and monitoring, following assessments of the SNPP/CrIS instrument and SDR data product are given:

1. The performance of the SNPP/CrIS SDR data product has been demonstrated globally over nearly six months after successfully switching to Side-2 electronics and updating calibration parameters;
2. On-orbit NEdN: all FOVs and bands are within the specification (MW FOV7 is out of family as before side switch) and comparable to SNPP/CrIS Side-1;
3. Radiometric uncertainty: radiometric FOV2FOV consistency within 0.1 K;
4. Spectral uncertainty: spectral offsets for relative and absolute for all three bands are all within ±2ppm;
5. Geolocation uncertainty: in-track geolocation meets specification after updating the mapping angles with Engineering Packet v40 (Side-2) to match those in Engineering Packet v37 (Side-1). The SNPP/CrIS geolocation is within 250 meters, relative to VIIRS, for all FORs;
6. Radiometric differences between SNPP and NOAA-20 are within ±0.1 K for the majority channels. The estimated differences were derived from the double-difference from radiative transfer calculations.
7. The SNPP/CrIS SDR products have been reliably produced by IDPS since the transition to Provisional Maturity on August 1st, 2019.

User Feedback was received and presented during the Validated review from NOAA/NCEP, ECMWF, NRL, the NUCAPS Team and the NPROVS Team. A summary of major observations from CrIS Users is as follows:

1. The long-term statistical performance of the difference between observations and background, monitored at NWP centers, confirmed the consistent and stable quality of the SNPP/CrIS SDR data before and after the side switch.
2. No identifiable changes were observed in the standard deviation of observation minus background over the assimilated SNPP CrIS Side-2 observations. The standard deviation is within the expected NWP error.
3. At NRL, the overall observed impact for SNPP CrIS is still consistently positive, with no issues of concern. No adjustments to the quality control or observation error were needed to accommodate the impact of the side switch. The SNPP CrIS sensor continues to provide substantial benefit to the NWP skill, and efforts to increase the uptake and impact of the CrIS sensors is ongoing.
4. At ECMWF, higher impact of the CrIS observations is expected after increasing the number of assimilated MWIR band channels from 7 to 37.
5. The NUCAPS/SNPP Side-2 Environmental Data Record (EDR) products are meeting the JPSS requirements with similar performance as before the SNPP/CrIS side switch.
6. The quality of the SNPP/CrIS SDR data product is sufficient to be used in operational

environments as confirmed by inputs from NOAA/NCEP, NRL, NUCAPS Team and NPROVS Team. The rate of good data quality after instrument side switch is greater than 99.7%, which is similar to Side-1 data quality rate.

Detailed justifications for declaring SNPP/CrIS SDR Validated Maturity are included in the Validated Review presentations.

4. Suomi NPP CrIS Validated Maturity SDR Data Product Caveats:

No caveats have been identified. No discrepancy reports (DRs) have been submitted after the side switch.

5. Path forward

The team will work diligently to continue with the following planned Cal/Val tasks after the Validated Maturity of the SNPP/CrIS SDR data product:

1. Continue monitoring the instrument long-term stability and performance, as well as the SDR data quality;
2. Continue to inter-compare the instrument against other sensors (including the NOAA-20 CrIS, IASI, VIIRS, and ABI) ;
3. Continue assessing the instrument noise, spectral and geolocation calibration, as well as the instrument yield rate;
4. Continue monitoring the instrument long-term stability and performance, as well as the SDR data quality.
5. Planning to Reprocess SNPP CrIS data around April 2020, using the same calibration coefficients and the latest IDPS software to improve the data consistency for the whole mission.

6. Lessons Learned

The following lessons were learned during the switch to Side-2 electronics:

1. The JPSS Missions Operations Team (MOT) successfully switched SNPP/CrIS from primary to redundant side electronics without major issues. Full performance was restored following the side switch, with redundant side performance being comparable to that on the primary side. Even though critical calibration electronics, including the internal calibration target temperature sensors, reside in the redundant circuitry, both sides had been thoroughly checked out during ground testing and calibration constants for both sides were available at launch.
2. Engineering packet parameters for the redundant side were adjusted after the switch to optimize SDR continuity over absolute accuracy. Note that the difference between optimizing continuity versus accuracy is very small.
3. Improvements are needed to the process for transferring updates to the initial geolocation parameters from the primary to the redundant side. The first guess for the on-orbit redundant side geolocation parameters was not optimal, and the subsequent update for the in-track torque null position made geolocation worse instead of better.
4. The time from the loss of the SNPP/CrIS MWIR band to the start of the side switch was about 3 months. The Science Team recommends a careful assessment of the timeline to see if it is possible to reduce the time required to initiate a side switch. It seems possible that some time

could be saved by 1) maintaining up to date configuration files for both primary and redundant sides; 2) maintaining up to date instrument activation procedures for the redundant side; note that these may differ slightly from the procedures for simply restoring power to the primary side due to memory persistence; 3) optimizing the redundant side cal/val plan; 4) documenting the reliability analysis over the life of the mission so that it does not have to be repeated after an on-orbit failure prior to a decision to switch to the redundant side.

7. Acknowledgements

Thanks are extended to all individuals and organizations participating in the Recovery Activities of the SNPP/CrIS Instrument for their team effort, hard work, dedication and professionalism: NOAA, NASA, HARRIS, University of Wisconsin, University of Maryland Baltimore County, MIT, Logistikos, NRL, ECMWF.

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
SNPP/CrIS near real time status and performance monitoring web page is available using the following URL at: https://www.star.nesdis.noaa.gov/icvs/status_NPP_CrIS.php

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