**MEMORANDUM FOR:** The JPSS Program Record
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**SUBJECT:** NOAA-21 SST Provisional Maturity Status
**DATE:** 24/08/2023

**Provisional maturity status declaration for VIIRS SST**
**Maturity Review Date:** **24/08/2023**
**Effective Date:** **20/03/2023**
**Operational System:** **NDE, ACSPO V2.80**

The Joint Polar Satellite System-2 satellite (JPSS-2) was successfully launched on 10 Nov 2022 and renamed NOAA-21 (hereafter, N21) after successfully reaching its designated sun synchronous polar orbit. The N21 Visible Infrared Imaging Radiometer Suite (VIIRS; a sensor with the same design as onboard its two predecessors, the Suomi NPP and N20) is a cross-track scanning radiometer with 22 channels with wavelengths ranging from 0.41 to 12.0μm, enabling global measurements of ocean, atmosphere, and land characteristics, including sea surface temperature (SST).

On 10 Feb 2023, the N21 VIIRS started providing earth scene measurements from the mid-wave and long-wave infrared bands. By 11 Feb 2023, the IR data quality has sufficiently improved to enable the generation of the VIIRS SST. Complete time series of N21 SST from 11 Feb 2023 – on have been processed and reprocessed at STAR several times using the NOAA enterprise Advanced Clear Sky Processor for Ocean (ACSPO V2.80) SST system, and iterative improvements to the SST retrieval look up tables (LUTs) were made. The N21 SST has been continuously evaluated and re-evaluated by the NOAA SST team. Based on the evaluation presented to the NOAA JPSS program, the N21 VIIRS ACSPO SST product is now considered to have reached the Provisional Maturity.

## 1. Maturity Stage Definition

The definitions of maturity stages are available at the JPSS Algorithm Maturity Matrix webpage (www.star.nesdis.noaa.gov/jpss/AlgorithmMaturity.php). Provisional Maturity means that the product meets the following criteria:

- Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts.
- Product analyses are sufficient for qualitative and limited quantitative, determination of product fitness-for-purpose.
- Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.
- Product is recommended for potential operational use (user decision) and in scientific publications after consulting product status documents.

## 2. Algorithm Description

ACSPO is the NOAA enterprise SST system, employed to produce SST from multiple sensors onboard Low Earth Orbiting (LEO: VIIRS, AVHRR GAC/FRAC, and MODIS) and Geostationary (GEO: ABI, AHI, and FCI) US and international satellites. Two major functions of ACSPO are identifying clear-sky ocean pixels, suitable for SST retrievals, and calculation of SSTs from measured brightness temperatures in several window bands, including M12, M14, M15, and M16 centered near 3.7, 8.6, 11 and 12 μm, respectively. Two reflectance bands, M5 and M7 are also used during the daytime to improve clear-sky masking. ACSPO files report 'subskin' SST (representative of SST at depth of ~1mm) which is calculated using the Non-Linear SST Equation (NLSST), with regression coefficients empirically trained against *in-situ* SSTs separately for nighttime (solar zenith angle >90°) and daytime (solar zenith angle <90°). Error characterization information (called Single-Sensor Error Statistics, SSES) is assigned to each valid SST retrieval, with two variables providing estimates of the expected bias and standard deviation against *in-situ* SST from drifting and tropical moored buoys. Two products are produced: L2P (swath projection; ~7 GB/day) and its 0.02° gridded version, L3U ("U" meaning "uncollated", i.e., no aggregation, or collation in time is applied; 0.5 GB/day). Both are reported in netCDF4 files compliant with the Group for High Resolution SST (GHRSST) Data Specification version 2 (GDS2) standard, in 10-min granules, 144 granules per day. Quality flags are provided for each L2P/L3U pixel in the variable 'quality_level' (QL). We recommend to use only pixels with QL=5, for all applications. Other quality levels (QL=0: Missing data; QL=1: Non-SST, including cloudy, probably cloudy, land, etc.; QL=2, 3, and 4) are for information only and should not be used. More information about the algorithms and the content of the ACSPO GDS2 netCDF4 data files is available in the ACSPO SST ATBD available at https://www.star.nesdis.noaa.gov/jpss/Docs.php.

### Product Requirements/Exclusions (DPS)

VIIRS SST requirements are documented in the JPSS Ground Segment Data Product Specification (GSegDPS; available at https://www.nesdis.noaa.gov/s3/2022-03/474-01543_JPSS-GSegDPS_A.pdf). As demonstrated in the N21 SST Provisional Maturity Review presentation (available at http://www.star.nesdis.noaa.gov/jpss/Docs.php), the N21 VIIRS ACSPO SST product already meets all JPSS requirements, at the time of the provisional review.

### Product Evaluation/Validation

Global performance of ACSPO SST is routinely monitored in the NOAA SST Quality Monitor for SST system (SQUAM; https://www.star.nesdis.noaa.gov/socd/sst/squam). SQUAM includes:

- Global comparisons with several high-quality L4 SST analyses.
- Global validation vs quality-controlled drifters & tropical moorings and ARGO Floats from the NOAA in situ Quality Monitor (*i*Quam; www.star.nesdis.noaa.gov/sod/sst/iquam/).

Regional performance (quality of imagery and clear-sky mask) is monitored in the Regional Monitor for SST (ARMS; www.star.nesdis.noaa.gov/sod/sst/arms/) online system.
Performance of whole mission ACSPO VIIRS SST from NPP and N20 is documented in the journal paper "JPSS VIIRS SST Reanalysis Version 3" (doi.org/10.3390/rs14143476).

**Product Reliability**

N21 SST data has been produced at STAR since the first availability of high-quality emissive band SDR data on 11 Feb 2023. On 3 Mar 2023, the N21 VIIRS CFPA set-point temperature was changed from 82K to 80K. The effect of this change on SST is challenging to quantify due to a limited time series collected with 82K. To be on a safe side, we limited our validation on SST data starting with 4 Mar 2023. Additionally, we have identified degradation of SST retrieved during two warm-up cool-down (WUCD) exercises, on 10-13 and 16-17 Mar 2023, respectively. For this reason, SSTs during these WUCD exercises were also excluded from validation. We found that the N21 VIIRS SST after 4 Mar 2023, and excluding the two WUCD periods, is exemplarily consistent and comparable in quality to the fully validated NPP/N20 VIIRS SST products.

**Algorithm Performance Dependence**

The performance of the ACSPO VIIRS SST product largely depends on the performance of the VIIRS SDR product in the emissive bands. The SST team worked closely with the SDR team to address our concerns with instabilities in emissive bands calibration during NPP and N20 VIIRS warm-up cool-down (WUCD) exercises. The N21 VIIRS suffers from the same calibration instabilities during WUCDs. The NOAA SDR team is aware of the issue and plans to mitigate (see SDR Provisional Maturity review). ACSPO processing also employs first guess SST (currently, Canadian Met Center product, CMC L4) and GFS/MERRA atmospheric profiles, which are input into CRTM simulations of clear-sky brightness temperatures. [Note that ACSPO employs graceful degradation and uses closest in time CMC and GFS/MERRA data, if current is not available. The sensitivity to 1-2 days delayed first guess fields is relatively minor and does not result in significant degradation of SST product or clear-sky mask.]

**Known Errors/Issues/Limitations**

ACSPO reports both 'subskin' SST (temperature at depth of ~1 mm) and 'depth' SST, which is a proxy of SST at depth 20 cm. The 'depth' SST is computed using a piecewise regression algorithm that benefits from having up to a year of *in-situ* matchup data available for training. Sufficient training data has become available at the time of provisional review, and the latest SST LUTs ensure that the 'depth' SST now fully meets and exceeds JPSS requirements and users' expectations. The quality of N21 VIIRS SST products and consistency with NPP/N20 may incrementally improve when a complete year of training data becomes available, at which point in time the SST LUTs may need to be updated, depending on the ongoing evaluation.

## 3. Changes Since Last Maturity Stage

At the time of the beta maturity review, insufficient matchups with *in-situ* SSTs were available for training the ACSPO 'depth' SST algorithm coefficients. At the time of the provisional review, we demonstrate that the quality of the N21 VIIRS 'depth' SST is now comparable with those from NPP/N20 and meets JPSS requirements.

## 4. Review Board Recommendations

Declare ACSPO SST Provisional Maturity as 20 Mar 2023.

## 5. Path Forward/Future Plan

- Continue Cal/Val of N21 SST, and continuously compare its performance with NPP/N20.
- Retrain SST algorithms with a longer time series (spanning up to one year) of *in-situ* SST matchups, and adjust LUTs, if warranted.
- The NOAA VIIRS SDR team is working towards mitigation of calibration anomalies during VIIRS warm-up/cool-down (WUCD) events. We will reprocess the affected periods to validate the WUCD mitigation efforts.
- Include N21 VIIRS SST in super-collated ACSPO L3S-LEO-PM (which currently only includes SST data from the two JPSS afternoon 'PM' orbit satellites, NPP and N20.

## 6. Additional Items to Note

The VIIRS SST products are widely used at NOAA, as well as nationally and internationally. Shortly after N21 VIIRS SST Provisional Maturity is declared, we will start near-real-time production of N21 SST data at STAR and make the data publicly available on NOAA CoastWatch. We will also work with PO.DAAC to start archiving N21 L2P and L3U datasets, reprocess them back to Mar 2023 and back-fill in the PO.DAAC archives. If we receive feedback from users, we will address their recommendations and concerns as required. In the past, for NPP and N20, no negative feedback or complaints were received, with significant volume of data downloads and multiple positive feedback.

Additional information is available in the SST algorithm theoretical basis document (ATBD) and validation maturity review briefing, which can be accessed at:
http://www.star.nesdis.noaa.gov/jpss/Docs.php

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