Geostationary Operational Environmental Satellite (GOES) – R Series

ABI L2+ Sea Surface Temperature (SST) Beta, Provisional and Full Validation Readiness, Implementation and Management Plan (RIMP)

ABI L2+ Sea Surface Temperature (SST)
Beta, Provisional and Full Validation
Readiness, Implementation and Management Plan (RIMP)

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Preface

The evolving calibration and validation (cal/val) maturity of Geostationary Operational Environmental Satellite R-Series (GOES-R) products throughout the beginning of the mission is described by three levels: Beta, Provisional, and Full validation. The Flight Project is responsible for producing the Level 1b (L1b) products according to the Level III requirement documents. Once Beta Maturity of the L1b products is achieved, the Level 2+ (L2+) will begin analysis towards Beta maturity. Further levels of maturity (Provisional and Full validation) require additional and often long-term activities. A detailed description of the three product maturity levels is given in Figure 1, but brief descriptions of the three maturity levels are:

Beta: the product is minimally validated and may still contain significant errors; based on product quick looks using the initial calibration parameters.

Provisional: product performance has been demonstrated through a large, but still (seasonally or otherwise) limited, number of independent measurements. The analysis is sufficient for limited qualitative determinations of product fitness-for-purpose, and the product is potentially ready for testing operational use.

Full: product performance has been demonstrated over a large and wide range of representative conditions, with comprehensive documentation of product performance, including known anomalies and their remediation strategies. Products are ready for operational use.

Assessment and declaration of maturity levels is performed during Peer Stakeholder–Product Validation Reviews (PS-PVRs). At each PS-PVR, the status of products will be presented by members of the cal/val science teams. For L2+ products, Beta maturity PS-PVRs are held in close proximity with and prior to Operations Handover. The review panel at the PS-PVRs will include the GOES-R Operational Readiness Working Group (GORWG), GOES-R Program System Engineering (PSE), NOAA Office of Satellite and Product Operations (OSPO), and GOES-R Product Readiness and Operations (PRO). The Readiness, Implementation, and Management Plans (RIMPs) have been created to document the analysis techniques, methodology, duration, tools, data, resources, staffing, and schedule of the Post-Launch Product Tests (PLPTs) to be used by the cal/val science teams to demonstrate the different levels of product maturity. The primary purpose of the RIMPs is to act as a planning resource for the cal/val teams as they prepare for Launch. Additionally, the RIMPs can be used by other members of the GOES-R Program to prepare for cal/val activities, to assess the suitability of the cal/val test plans, and to understand the data and resource requirements the science teams have. Cal/val testing is likely to reveal necessary algorithm changes to evolve the product quality through the maturity levels. The Algorithm Change Management Plan (ACMP) will be used to track and implement these algorithm changes.

The introspection necessary to create these RIMPs has led to extensive consultations between the cal/val teams and other groups within the GOES-R Program, including the Flight Project, the Ground Segment, and a team of experts from The Aerospace Corporation under contract from GOES-R PSE to help improve the cal/val mission. Figure 2 below describes the responsibilities and accountability of each of the main parties involved in the creation of the RIMPs. This delineation is required because GOES-R operations are to be handed over from the GOES-R Program to NOAA OSPO at the end of the PLT period, yet the process of validating product maturity will continue. This changing nature of accountability during the process must be acknowledged. Accountability of the RIMPs changes at Operations Handover from NASA to NOAA and is aligned with the level of each RIMPs' validation maturity objective. Accountability determines which organization owns documentation, process, and procedures. Responsibility determines which organization creates, executes, and maintains specific activities.

GOES-R Product (L1b and L2+) Maturity Levels

Beta Validation

Preparation Activities
- o Initial calibration applied (L1b).
- o Rapid changes in product input tables, and possibly product algorithms, can be expected.
- o Product quick looks and initial comparisons with ground truth data (if any) are not adequate to determine product quality.
- o Anomalies may be found in the product and the resolution strategy may not exist.

End state
- o Products are made available to users to gain familiarity with data formats and parameters.
- o Product has been minimally validated and may still contain significant errors.
- o Product is not optimized for operational use.

Provisional Validation

Preparation Activities
- o Validation and quality assurance (QA) activities are ongoing, and the general research community is now encouraged to participate.
- o Severe algorithm anomalies are identified and under analysis. Solutions to anomalies are in development and testing.
- o Incremental product improvements may still be occurring.
- o Users are engaged in the Customer Forums (L2+ products only), and user feedback is assessed.

End state
- o Product performance (L1b or L2) has been demonstrated through analysis of a small number of independent measurements obtained from selected locations, periods, and associated ground-truth/field program efforts.
- o Product analysis are sufficient to communicate product performance to users relative to expectations.
- o Documentation of product performance exists that includes recommended remediation strategies for all anomalies and weaknesses. Any algorithm changes associated with severe anomalies have been documented, implemented, tested, and shared with the user community.
- o Testing has been fully documented.
- o Product ready for operational use and for use in comprehensive calibration/validation activities and product optimization.

Full Validation

Preparation Activities
- o Validation, QA, and anomaly resolution activities are ongoing.
- o Incremental product improvements may still be occurring.
- o Users are engaged and user feedback is assessed.

End state
- o Product performance for all products is defined and documented over a wide range of representative conditions via ongoing ground-truth and validation efforts.
- o Products are operationally optimized, as necessary, considering mission parameters of cost, schedule, and technical competence as compared to user expectations.
- o All known product anomalies are documented and shared with the user community.
- o Product is operational.

Figure 1. GOES-R product maturity levels.

Delineation of RIMP Accountability

Accountability for the RIMPs changes at Operations Handover and is aligned with the level of product validation maturity within the RIMP.

Pre-Ops Handover

GOES-R Accountability

| L1b RIMP & Product Maturity | = | Beta, Provisional* |

| L2+ RIMP & Product Maturity | = | Beta* |

Post-Ops Handover

STAR Accountability

| L1b RIMP & Product Maturity | = | Full |

| L2+ RIMP & Product Maturity | = | Provisional, Full |

Responsibilities

- • GOES-R PRO: On behalf of GOES-R Program Systems Engineering, PRO is responsible for facilitating the preparation of RIMPs, including interactions between STAR and Aerospace as well as STAR and GOES-R Flight, Ground, etc.
- • STAR Calibration Working Group (CWG): CWG includes NASA MSFC & NCEI-CO and is responsible for providing data resources and content to Aerospace for L1b RIMPs.
- • STAR Algorithm Working Group (AWG): Like CWG, AWG is responsible for providing data resources and content to Aerospace for L2+ RIMPs.
- • The Aerospace Corporation: Under the direction of GOES-R PRO, Aerospace is responsible for gathering RIMP content and writing the RIMP documents.

Products are not required to be declared these maturity levels before Operations Handover, but the PS-PVRs will be held.
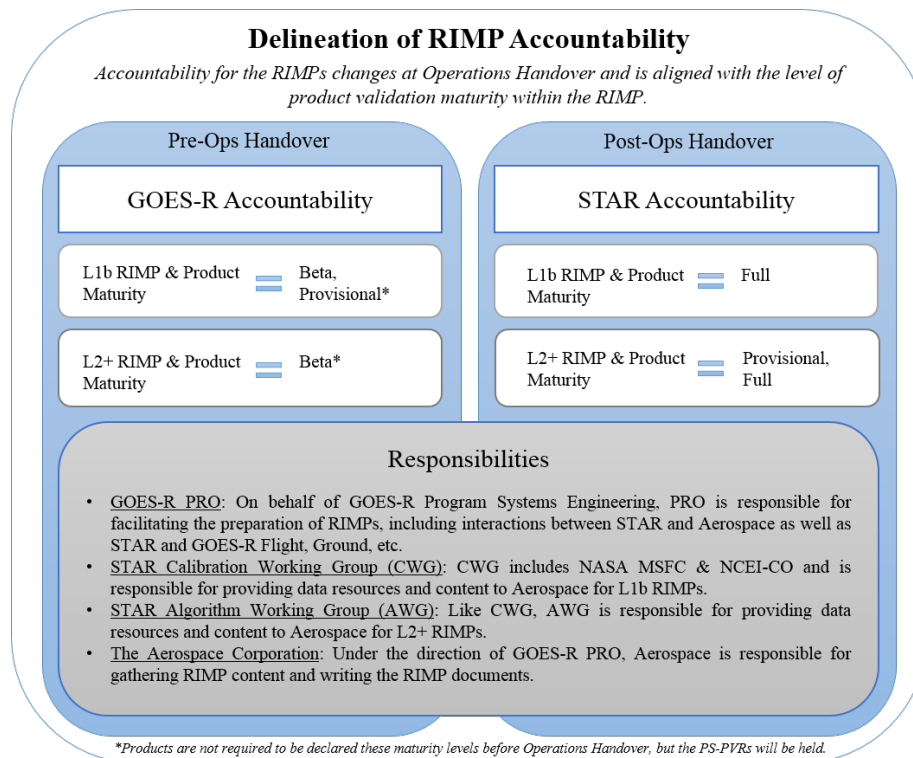
Figure 2. Delineation of accountability between GOES-R and STAR.

1. Sea Surface Temperature Validation Overview

This RIMP covers all validation stages of the GOES-R Advanced Baseline Imager (ABI) Sea Surface Temperature (SST) L2 product. There are three stages in the validation process: Beta, Provisional, and Full. Each stage is characterized by PLPTs, which guide the overall validation process. This RIMP includes a summary of the methods and tools employed to prove SST has met a given validation stage. Feedback from the NWS will be provided through the PS-PVR process. Other forums are being considered, but are TBD at this time. Appendices are included that present more detail on each test method and detail on the different data sets employed in the validation of the SST product. Note that the verification of product generation is the responsibility of OSPO, whereas the verification of the product completeness, quality and performance is the responsibility of the STAR cal/val team. The SST validation effort has no identified need for data from a North/South (N/S) scan, but are interested in exploring the utility of such scans if they become available. Data from field campaigns is not required for SST validation, but all additional in situ data could be used if available. SST validation has no specific mesoscale requirements.

The SST team has identified three PLPTs with success criteria to achieve Beta maturity – ABI-FD_SST01, ABI-FD_SST02, and ABI-FD_SST03. There is one additional PLPT defined to attain Provisional maturity (ABI-FD_SST04) and one more to attain Full maturity (ABI-FD_SST05) with appropriate success criteria. ABI-FD_SST01 and ABI-FD_SST02 will verify that the product is generated at the required frequency (see Table 1) and completeness. The analyses of these events are scheduled to be carried out in parallel during the first week of the PLPT period. ABI-FD_SST03 is planned to assess the accuracy and precision of the product in Mode 3[1] and/or Mode 4 if possible. The analysis for this third event is planned to be carried out during a five-week period following completion of the ABI-FD_SST01 and ABI-FD_SST02. Each PLPT event that supports Beta maturity is also listed below; details are in Appendix A.

- **ABI-FD_SST01:** verify that the SST product is generated for every hour of the day for cloud-free areas while in ABI Mode 3 and that the SST is retrieved within the full expected domain and falls within the expected measurement range.
- **ABI-FD_SST02:** verify that the SST product is generated for every hour of the day for cloud-free areas while in ABI Mode 4 and that the SST is retrieved within the full expected domain and falls within the expected measurement range.
- **ABI-FD_SST03:** determine the extent to which the SST product generated for every hour in cloud-free areas, in ABI Mode 3 and/or 4, meets the Mission Requirements Document[3] (MRD) specifications for accuracy and precision (for a limited and not seasonally representative number of independent measurements, covered by the PLPT period).

The following Table identifies the frequency of each scan type for Modes 3 and 4. It includes the required cadence of the SST products as defined by both the GOES-R Functional and Performance Specification (F&PS)[8] and the Product User's Guide (PUG)[4].

Mode	Mode 3			Mode 4		
Scan Type	FD	CONUS	Mesoscale	FD	CONUS	Mesoscale
Scan Freq	15 min	5 min	30 sec	5 min	5 min	N/A
SST - F&PS	60 min	N/A	N/A	60 min	N/A	N/A
SST - PUG	60 min	N/A	N/A	60 min	N/A	N/A

Table 1. Sea Surface Temperature documented product and verification cadences

ABI-FD_SST04 will assess the accuracy and precision of the SST generated in ABI Mode 3 under clear-sky conditions against the threshold accuracy, as documented in the MRD. The ABI-FD_SST04 is planned to begin at the end of the PLPT period, immediately after completion of the Beta maturity validation events,

and last 24 weeks. The PLPT event that supports Provisional maturity is also listed below; details are in Appendix A.

- **ABI-FD_SST04:** assess the accuracy and precision of the SST product generated in ABI Mode 3 and verify if it meets MRD specifications for a limited (i.e., not seasonally representative) number of independent measurements and if the product is ready for operational use, or identify fixes to the ABI sensor performance, clear-sky mask (CSM) or SST algorithm to make the SST product ready for operational use.

ABI-FD_SST05 will continue to assess the accuracy and precision of the SST generated in the ABI Mode 3 under clear-sky conditions. ABI-FD_SST05 is planned to begin immediately after the completion of the Provisional maturity validation event, and last 36 weeks. It assumes that the ABI sensor and the CSM are working properly and/or they have been validated. The PLPT event that supports Full maturity is also listed below; details are in Appendix A.

- **ABI-FD_SST05:** assess the accuracy and precision of the SST generated in ABI Mode 3 and verify if it meets MRD specifications for a full range of retrieval conditions, including a full seasonal cycle, verify that the product is fully operational, and identify any limitations for the SST product.

The ABI L2 SST cal/val will be performed in a similar fashion to the Joint Polar Satellite System (JPSS) program and Himawari-8 SST Project, since Alexander Ignatov, the GOES-R SST Principle Investigator (PI) is also the JPSS and Himawari-8 SST lead.

During all SST PLPTs, the following analyses will be performed:

- Collocations of ABI SSTs and Brightness Temperatures (BTs) with global Level 4 (L4) fields, including Reynolds Optimum Interpolation Sea Surface Temperature (OISST), Canadian Meteorological Center (CMC), and the Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA)[2, 7].
- Collocations with the in situ SST Quality Monitor (iQuam) data.
- Visualization in the NOAA SST Quality Monitor (SQUAM) and Monitoring of Infrared Clear-sky Radiances over Ocean for SST (MICROS) statistical analysis tools.
- Visualization in the Advanced Clear-Sky Processing over Ocean (ACSPO) Regional Monitor for SST (ARMS).

Development of validation tools is complete pending the results of full testing with data from DOE-4 and will be ready for launch by September 2016[1, 7].

The initial assessment of SST accuracy will be performed against global reference L4 SST fields (daily Reynolds OISST, OSTIA and CMC[2,7]) that are computed by blending polar and geostationary L2 and Level 3 (L3) SST and in situ data sets, as well as against in situ SST data[7]. ARMS and other customary graphics and animations will be generated at the Provisional and Full maturity stages for improved diagnostics.

The validation processes and procedures, monitoring and analysis methods, tools, and expected output artifacts are described in the following sections. The details of each PLPT are contained in Appendix A and of each reference data set in Appendix B. The details of any tools used in the validation process are in Appendix C.

2. Schedule of Events

Figure 3 shows the GOES-R validation schedule. System Performance Operation Test (SPOT) begins 44 days after launch when ABI L1B and the L2 Cloud and Moisture Imagery (CMI) Key Performance Beta evaluation begins and should be declared Beta maturity by L+87. One day later, the GOES Rebroadcast (GRB) will be populated with that data. The L2 product must reach Beta maturity by Handover at L+197, the same time that ABI L1B and CMI must reach Provisional. Given that L2 Beta tests require at least 6 weeks, L2 Beta testing must get underway by L+155, but can begin as soon as the ABI L1B and CMI reach Beta (L+87). For SST it is also necessary to have open cryoradiator doors, as it needs the data in the thermal bands.

The GOES-R Operations phase begins after handover, marking the start of a 12 month Extended Validation period for ABI L1B and CMI, which is coincident with the start of the 6 month L2 Provisional evaluation, followed by another nine month period for the L2 products to reach Full maturity, 15 months after Handover. This schedule assumes that the ABI sensor and the CSM are working properly and/or they have met validation milestones. SST validations are expected to require the entire allocated period.
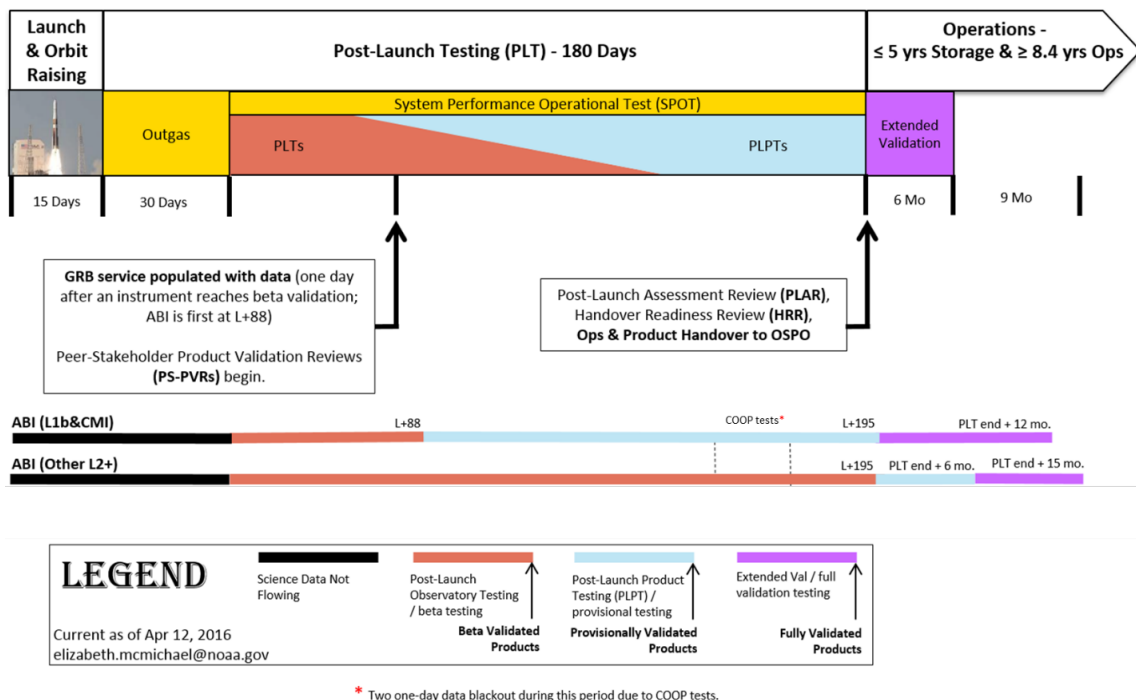

Figure 3. Schedule of events.

A schedule of activities supporting the SST validation effort includes the following:

- Current – September 2016: evaluate results using data from GOES-R Data Operations Exercise (DOE) 3/4.
- Current – October 2016: test and evaluate algorithm with Himawari-8 data.
- December 2016: final version of the SST tools ready for GOES-R cal/val. Tools ready by December 2015 will be further tested and updated as needed with Himawari and DOE data.
- L+197 days: Complete Beta phase of validation.
- L+337 days: Complete Provisional phase of validation.
- L+647 days: Complete all phases of SST validation effort.

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3. Roles and Responsibilities

3.1 Primary Point of Contact

The primary point of contact (POC) for leading the SST validation effort is Dr. Alexander Ignatov (NOAA STAR). Dr. Ignatov is also the POC for the algorithm update process[5], should any modifications be required during the PLPT. Dr. Maxim Kramar (NOAA STAR, GST Inc.) is the back-up POC for the algorithm update process.

3.2 GOES-R Point of Contact

The primary POC at GOES-R for the SST validation effort is Wayne MacKenzie.

3.3 Test Analyst/Engineer

Dr. Maxim Kramar is the primary test analyst/engineer and will carry out the technical oversight and analysis of the tests. Additional support and backup will be provided by the current SST team working on similar efforts for other programs (e.g., JPSS).

3.4 GOES-R Feedback

Formal feedback to the GOES-R Program regarding the SST validation will be provided by Dr. Alexander Ignatov.

3.5 Level of Effort

The total analyst level-of-effort to complete these tests is anticipated to be 0.8 FTE per week for the duration of PLPT.

4. Tools

The SST validation effort utilizes a set of four tools to collocate, visualize, obtain QC for, match-up, and monitor SST. These tools present results in the form of histograms, time-series plots, maps, scatter plots and tables. An identical set of tools will be utilized during the Beta, Provisional and Full assessments. Each of these tools is detailed in Appendix C.

5. Analysis Methods

In the thermal IR (TIR), SST can only be retrieved under clear skies. Accuracy of the satellite SST measurement is limited by the quality of the cloud screening, correction for the effects of atmospheric absorption and scattering, surface emission and reflection, sensor performance, and accuracy of the model (physical or statistical) employed to simulate SST variability in the range of temporal (from diurnal to seasonal cycles) and spatial (hemispheric or global) scales.

During the pre-launch period, the data of the following sensors will be used as ABI proxy for the development of SST retrieval algorithms and validation methodologies:
- Advanced Himawari Imager (AHI) onboard Himawari-8.
- Visible Infrared Imaging Radiometer Suite (VIIRS) sensor onboard the Suomi National Polar-orbiting Partnership (SNPP).
- Moderate Resolution Imaging Spectroradiometer (MODIS) onboard Terra and Aqua platforms.
- Advanced Very High Resolution Radiometer (AVHRR) onboard multiple NOAA and Metop platforms.

Post-launch, the two initial tests, ABI-FD_SST01 and ABI-FD_SST02, will:
- Analyze the retrieved ABI L2 SST itself, in terms of frequency of availability, completeness and whether it is within expected ranges.
- Match-up L2 SST with L4 analyses (CMC, OSTIA and Reynolds), check for availability and completeness, and assess with SQUAM at www.star.nesdis.noaa.gov/sod/sst/squam/.
- Preliminarily assess the accuracy and precision using the matchups with QCed in situ SST available from iQuam at www.star.nesdis.noaa.gov/sod/sst/iquam/.
- Compare ABI L2 SSTs and clear-sky radiances with corresponding L2 products from polar - VIIRS, AVHRR, and MODIS - and geostationary - Multifunctional Transport Satellite-2 (MTSAT-2) and Himawari-8 - platforms and sensors available from the NOAA Comprehensive Large Array-data Stewardship System (CLASS) at www.class.ngdc.noaa.gov/saa/products, the Physical Oceanography Distributed Active Archive Center (PO.DAAC) at https://podaac.jpl.nasa.gov/, NOAA National Centers for Environmental Information (NCEI) at https://www.nodc.noaa.gov/, and MICROS at www.star.nesdis.noaa.gov/sod/sst/micros.

ABI-FD_SST03 and ABI-FD_SST04 that need to be completed for Beta and Provisional maturity, respectively, will continue the preliminary assessments through the use of ABI L2 SST matchups with L4 SSTs, QCed in situ SSTs, and corresponding L2 products from geostationary and polar platforms, and they will extend analyses to a larger number of retrieval conditions. Along with the SST product evaluation, the validation activity will include monitoring of the clear-sky BTs associated with SSTs and the algorithm accuracy. The Full effort (comprised of ABI-FD_SST05) will continue the Provisional validation with the same methods and extend the analysis to a full seasonal cycle.

The general methods associated with the SST validation effort are described below.
- **Method 1:** the initial assessment of ABI L2 SST will be performed to ensure regular generation, complete coverage of the retrieval domain, and falling within the measurement range.
- **Method 2:** after the initial assessment, ABI L2 SST will be matched up with global L4 reference SST fields, including Reynolds, OSTIA and CMC. These products are produced daily using blended satellite and in situ SSTs, and are available in near real-time (NRT). They use satellite SSTs from different platforms, tuned against in situ data and optimally interpolated to

compensate for satellite biases, and thus represent a global reference daily SST field. These gridded, gap-free, and global SST fields, produced daily in different spatial resolutions, are convenient for quick operational diagnosis of the retrieved ABI L2 SST to identify residual cloud, limitations of the SST algorithm, and sensor malfunctions. The current L4 products, however, do not resolve the diurnal cycle, which is critically important for the geostationary data analyses. Using several L4 products compensates for their potential individual specifics and deficiencies.

- **Method 3:** SST validation will be performed against QCed in situ SSTs from iQuam. This analysis will provide a measure of algorithm true (absolute) uncertainty, with respect to the "gold standard", in situ SST. QC in iQuam is applied to in situ data including basic checks such as geolocation check, track check, and duplicate check. A Bayesian check against background SST fields (e.g., averaged daily Reynolds SST in past week) and 'buddy checks' are applied, which evaluate the probability that errors occurred in the in situ measurements with respect to a priori background SST and nearby in situ measurements. The expected accuracy of in situ data after quality control is standard deviation ~0.3 K.

- **Method 4:** along with SST product evaluation, the validation effort will include monitoring of clear-sky BTs associated with SSTs in MICROS, against BTs simulated with the Community Radiative Transfer Model (CRTM).

- **Method 5:** finally, ABI SST will be evaluated against other satellite products from polar and geostationary satellites, all of which are currently monitored in SQUAM and MICROS.

Algorithm accuracy will be monitored using the following metrics: mean bias, standard deviation, and higher-order moments of the "retrieved SST minus reference SST" statistical distribution. The global reference L4 SST fields, such as CMC, Reynolds OISST and OSTIA SST will be used as reference fields, primarily for monitoring and quick-look analyses. Experience of the SST cal/val team suggests that these statistics are fairly representative of satellite SST performance against in situ data (especially at night), which is the required specification.

Ultimate evaluation of ABI SST will be done against in situ data, which account for the diurnal cycle in SST. Since available reference SST fields are produced on a daily basis, they cannot be used as a reference for SST diurnal cycle validation. This type of validation activity will require a thorough evaluation against timely and QCed in situ data.

The current version of the daytime regression retrieval algorithm, the Non-Linear SST (NLSST), requires first-guess SST as one of the predictors in the SST equation. It is necessary to ensure that the retrieved SST provides an essential accuracy improvement over the first-guess reference SST field. The relationship of accuracies of the first-guess and retrieved SST will be evaluated.

6. Output Artifacts

The performance statistics of "retrieved-reference SST" and "model-observed BT" will be stratified by retrieval conditions (view zenith angle, water vapor, ambient cloud, etc.). Long-term stability of the ABI BTs and SSTs and their consistency with the heritage polar and geostationary BT and SST products will be continuously monitored and evaluated.

The validation tools enable routine monitoring of the product performance. Throughout all maturity validation phase, the diagnostics will be posted, in NRT, on the web using the tools developed by the SST team. The SST retrieval quality will be estimated and recorded in the output file with a set of quality flags and indicators, which are either passed from the input data or generated in the SST retrieval process. The quality flags and indicators will be assigned to the SST product, in each pixel. The generation of a minimum of ~1,000 matchups/day will be necessary to carry out an appropriate statistics of the retrievals. The longer duration of the event for Provisional maturity validation will improve the statistics and allow the product assessment under an expanded set of conditions. Further improvements will be possible for the Full maturity validation effort that includes not only a longer duration but a seasonal representative range of conditions. Performance assessment and product issues will be documented at the conclusion of each maturity assessment phase.

6.1 Beta Maturity Artifacts

The criteria for declaring Beta maturity are that the SST product is generated in the full-expected domain, at the required frequency, and corresponding BTs in cloud-free areas fall within the expected measurement range comparable to heritage sensors such as Himawari-8 AHI, as well as polar AVHRR, MODIS, and VIIRS sensors. Further, it must be shown that the product meets the level of performance in the MRD, but only for all independent measurements covered by the PLPT period. At the completion of the Beta maturity validation effort, a report will be prepared containing an initial quantitative assessment, based on a limited dataset, of accuracy and precision of the SST product as a function of: characteristic parameters (e.g., view zenith angle, total precipitable water content, clear-sky conditions, BT, L1b inputs, etc.). The report will also discuss issues identified with the product.

6.1.1   These tests of priority 1 all must pass in order to achieve Beta maturity: ABI-FD_SST01, ABI-FD_SST02, and ABI-FD_SST03.

6.1.2   The SST Beta maturity validation effort does not include any tests of priority 2.

6.2 Provisional Maturity Artifacts

The criteria for declaring Provisional maturity are that the product, generated over a large and wide range of representative (except seasonally representative) conditions for Mode 3 (FD, every hour), has been assessed sufficiently to characterize its accuracy and precision, as well as the product limitations, potential fixes and improvements needed to satisfy the MRD specifications (Appendix A). Further, necessary fixes to the ABI sensor performance for the SST product to be ready for operational use must be established. Finally, necessary fixes to the SST algorithm and/or CSM for the product to be ready for operational use must also be established.

At the conclusion of the Provisional maturity validation effort, results will be presented at PS-PVRs for the same performance metrics results, but based on a longer period and larger range of representative conditions. The conditions and information to be reported for the Provisional assessment includes the accuracy and precision as a function of input parameters (e.g., viewing geometry, total precipitable water content, BT, ABI L1b Bands, general parameter settings used for calculations, test thresholds, regression coefficients, etc.).

The product limitations, areas where it does not satisfy the MRD specifications, and the remediation strategies will be documented. The feedback from the primary user (NWS) will be requested and documented if available. International partners will receive test data and results of validation and asked to comment. The Provisional presentation will include a summary of user feedback received during the respective validation periods. The Provisional maturity can be assigned even if this product evaluation by the user is not available.

6.2.1 The following test of priority 1 must pass in order to achieve Provisional maturity: ABI-FD_SST04.

6.2.2 The SST Provisional maturity validation effort does not include any tests of priority 2.

6.3 Full Maturity Artifacts

The criteria for declaring Full maturity are that the product generated over a full range of retrieval conditions, including a full seasonal cycle, satisfies the accuracy and precision specified in the MRD or in case the performance is not met, the SST algorithm limitations and/or the necessary SST algorithm or ABI sensor performance remediation strategies have been identified. While specifications do not have to be met for the product to be declared of Full maturity, if they are not, the reason must be documented along with further remediation strategy recommendations, and users must concur that the product is sufficient. Output artifacts for the Full maturity validation effort will be analogous to those prepared for the Provisional effort. Further, the Full stage will include results over a seasonal representative set of cloud-free conditions for Mode 3.

The Full presentation will include a summary of user feedback received during the validation period. The Full maturity cannot be assigned if this product evaluation by the user is not available.

6.3.1 The following test of priority 1 must pass in order to achieve Full maturity: ABI-FD_SST05.

6.3.2 The SST Full maturity validation effort does not include any tests of priority 2.

6.4 Key Artifacts

Key artifacts for the SST validation effort are reports generated at the end of each validation stage, as described above.

6.5 More Output Artifacts

None.

6.6 Delivery Schedule

The delivery schedule of artifacts for the SST validation effort is tied to the schedule for completing Beta, Provisional, and Full validation as given in section 2. The generation of reports will the responsibility of the Test Lead, working in conjunction with the Test Analyst.

7. Pre-launch

The following activities have been completed during pre-launch.

- Secured availability of resources (compute servers, local storage).
- Verified tool readiness: developed and tested collocation and visualization tools.
- Verified accessibility to L1b data sets, L2+ product datasets and L2+ diagnostic datasets.
- L2 SST products from polar (VIIRS, AVHRR, and MODIS) and geostationary (MTSAT, Himawari-8) sensors were used as proxies for the ABI L2 SST. The *in situ* SST data and L4 SST analyses (CMC, OSTIA, and Reynolds), Global Forecasting System (GFS) analyses (00, 06, 12, and 18 UTC) were used to validate the satellite products.
- Identified validation reference data corresponding to days of image triplet data at 75W, 89.5W, and 137W (November 2014). Corresponds to days of continuous NRT imagery.
- During DOE 1/2/3, Metadata was inspected to ensure that they match the Product Users Guide (PUG). Found discrepancies and reported back. Checked simple statistics of the data product (min/max/mean/std) using online validation tools. Observed inconsistencies and reported back. Checked for data outliers (didn't find any). Checked the Quality Flags (QF) and verified consistency with the PUG. Checked validation tools to make sure that they can read the data. Visualized in offline tools (Panoply).
- The DOE 1/2/3 data have been small to fully exercise the SST validation tools. Full exercise of the tools is planned for DOE 4, for which one full day of simulated data was requested.

8. References

The references listed below were used to generate this document, augmented with written and/or verbal feedback with the STAR product team. Superscripts are invoked within the text of this document to indicate a reference that can provide additional detail for the reader.

[1] PLPT_VE_List_L2_v1_0_20141022.xlsx.
[2] CalValPlan_Vol2_L2_v1-1-draft-redlines_inc-ERB_comments_v2a - Clean - BobEdits.docx.
[3] MRD_v3_17.pdf
[4] SE-16_CGS_7035538_PUG_V5_L2_RevD.pdf.
[5] GOES-R Series Ground Segment Project Algorithm Change Management Plan.
[6] GOESR-CVCT-PLPT_BriefingToNOAA-IAC_2015-02-03_FINAL.pptx – Shortcut.
[7] SST_Validation_Table_v2_rico.docx.
[8] GOES-R_GS_FPS.pdf.

A. Appendix A: Validation Events

A.1   PLPT Events that Support Beta Maturity

A.1.1   Event Name: ABI-FD_SST01
Objective: Verify that product is generated at the required cadence (60 min) for FD.
Start Time: Start of PLPT period.
Duration: 1 week.
ABI Mode: Mode 3.
GOES-R Data Type(s): 60 minute FD.
Beta Success Criteria: Product is generated in cloud-free areas and falls within expected measurement range; that is, within range of comparable heritage sensors (e.g., SEVIRI and VIIRS). Product must be received at the validation site every hour of the day for every FD.
Dependencies: ABI L1b Bands 7, 11, 13, 14, and 15 generated. L1b products generated by the ground system and delivered to the cal/val team within the FD cadence.
PLPT Lead: Dr. Alexander Ignatov
PLPT Analyst: Dr. Maxim Kramar
Monitoring & Analysis Method: Product inspection; compare to reference/ground truth data[2].

A.1.2   Event Name: ABI-FD_SST02
Same as ABI-FD_SST01 except for:
ABI Mode: Mode 4.

A.1.3   Event Name: ABI-FD_SST03
Objective: Assess initial accuracy and precision of product.
Start Time: Completion of ABI-FD_SST01 and ABI-FD_SST02 (PLPT period start + 1 week).
Duration: 5 weeks.
ABI Mode: Mode 3 and/or Mode 4.
GOES-R Data Type(s): 60 minute FD.
Beta Success Criteria: Quantitatively assess performance with limited set of data in cloud free areas. Identify issues with SST product. Document performance and issues in the Beta report.
Dependencies: Completion of ABI-FD_SST01 and ABI-FD_SST02. ABI L1b Bands 7, 11, 13, 14, and 15 generated. L1b products generated by the ground system and delivered to the cal/val team within the FD cadence.
PLPT Lead: Dr. Alexander Ignatov
PLPT Analyst: Dr. Maxim Kramar
Comparison / Reference Data: In situ SST data, L4 SST analyses (CMC, OSTIA, and Reynolds), GFS analyses (00, 06, 12, and 18 UTC), L2 SST products from polar (VIIRS, AVHRR, and MODIS) and geostationary (GOES, MSG, and MTSAT).
Monitoring & Analysis Method: Comparison with controlled in situ SST and measurement from other satellite platforms.

A.2   PLPT Events that Support Provisional Maturity

A.2.1   Event Name: ABI-FD_SST04
Objective: Assess accuracy and precision of product.
Start Time: Completion of ABI-FD_SST03 (PLPT period start + 6 weeks).
Duration: 24 weeks.
ABI Mode: Mode 3.
GOES-R Data Type(s): 60 minute FD.

Provisional Success Criteria: Product meets MRD specifications over a large and wide but limited range of representative (except seasonally representative) conditions for Mode 3 (FD, every hour). Accuracy and precision do not have to be met to attain Provisional status, however, if they do not, the reasons behind not meeting these requirements must be documented. The following requirements will be evaluated.[4,8]

- Product Measurement Range: 271-313 K.
- Product measurement Accuracy: 2.1 K with known emissivity, known atmospheric correction and 80% channel correlation; 3.1 K otherwise.
- Product Refresh Rate/Coverage Time: 60 min.
- Product Measurement Precision: 1.0 K.
- Temporal Coverage Qualifier: day and night.
- Product Extent Qualifier: quantitative out to at least 67 degrees Local Zenith Angle (LZA) and qualitative at larger LZA.
- Cloud Cover Conditions Qualifier: clear conditions associated with threshold accuracy.
- Product limitations or areas where it doesn't meet are identified.
- Have remediation strategies in place for known issues.
- Product is ready for potential operational use (user decision) and for use in scientific publications.

Dependencies: Completion of ABI-FD_SST03. ABI L1b Bands 7, 11, 13, 14, and 15 generated by the ground system and delivered to the cal/val team within the FD cadence. CSM product available.
PLPT Lead: Dr. Alexander Ignatov
PLPT Analyst: Dr. Maxim Kramar
Comparison / Reference Data: In situ SST data, L4 SST analyses (CMC, OSTIA, and Reynolds), GFS analyses (00, 06, 12, and 18 UTC), L2 SST products from polar (VIIRS, AVHRR, and MODIS) and geostationary (GOES, MSG, and MTSAT) sensors.

A.3   PLPT Events that Support Full Maturity

A.3.1   Event Name: ABI-FD_SST05

Objective: Assess accuracy and precision of product.
Start Time: Completion of ABI-FD_SST04 (PLPT period start + 30 weeks).
Duration: 36 weeks.
ABI Mode: Mode 3.
GOES-R Data Type(s): 60 minute FD.
Full Success Criteria: Product meets MRD specifications over seasonal representative set of conditions for Mode 3 (FD, every hour). Accuracy and precision do not have to be met to attain Full maturity status, however, if they do not, the reasons behind not meeting these requirements must be documented and user agreement must be obtained. Accuracy and precision specifications are the same as those listed above for Provisional maturity. Additional artifacts to meet the success criteria include:

- Cloud Cover Conditions Qualifier: clear conditions associated with threshold accuracy.
- Product limitations or areas where it does not meet specification in the MRD are identified.
- Remediation strategies are in place for known issues.
- Product is ready for operational use. Requires user feedback if product does not meet specifications.

Dependencies: Completion of ABI-FD_SST04. ABI L1b Bands 7, 11, 13, 14, and 15 generated by the ground system and delivered to the cal/val team within the FD cadence. CSM product available.
PLPT Lead: Dr. Alexander Ignatov
PLPT Analyst: Dr. Maxim Kramar

Comparison / Reference Data: In situ SST data, L4 SST analyses (CMC, OSTIA, and Reynolds), GFS analyses (00, 06, 12, and 18 UTC), L2 SST products from polar (VIIRS, AVHRR, and MODIS) and geostationary (GOES, MSG, and MTSAT) sensors.

B. Appendix B: GOES-R and Validation Reference Data

B.1   **Data Set #1: Visualization in iQuam**
Description: In situ SST data and L4 SST analyses (CMC, OSTIA, and Reynolds SST). Routine.
Storage Location: iQUAM at www.star.nesdis.noaa.gov/sod/sst/iquam/.
Access Process: Web download from site to NOAA local machines. Data volume is 403KB/day.
POC: X. Zhou.
Spatial Coverage: Global.
Temporal Coverage: Global.
Contingency: Impact is high as there is no contingency for this dataset. No similar high quality observations are available.

B.2   **Data Set #2: Geolocation Analysis – Visualization in SQUAM**
Description: L4 SST analyses (CMC, OSTIA, and Reynolds SST), L2 SST products from polar (VIIRS, AVHRR, and MODIS) and geostationary (GOES, MTSAT, and Himawari-8) sensors, and in situ SSTs[1]. Routine.
Storage Location: CMC, United Kingdom Meteorological Office (UKMO), NCEI-NC (NCEI-North Carolina).
Access Process: Web download from site to NOAA local machines. Data volume is 171MB/day. http://www.star.nesdis.noaa.gov/sod/sst/squam/L4.
Spatial Coverage: Global.
Temporal Coverage: Global.
Contingency: Impact is high as there is no contingency for this dataset. No similar high quality observations are available.

B.3   **Data Set #3: L2 SST products from Polar Sensors**
Description: L2 SST products from polar (VIIRS, AVHRR, and MODIS) and geostationary (GOES, MSG, and MTSAT) sensors. Routine.
Storage Location: NOAA CLASS.
Access Process: Data downloaded from http://www.class.ngdc.noaa.gov/saa/products and other national and international agencies. Data volume is 35GB/day.
Spatial Coverage: Global.
Temporal Coverage: Global.
Contingency: Impact is high as there is no contingency for this dataset. No similar high quality observations are available.

B.4   **Data Set #4: Clear-sky Radiances from Polar and Geostationary Sensors**
Description: Clear-sky radiances from polar (VIIRS, AVHRR, and MODIS) and geostationary (GOES, MSG, and MTSAT) sensors, L4 SST analysis (CMC), and GFS analysis (00, 06, 12, and 18 UTC). Routine.
Storage Location: NOAA/NESDIS ACSPO L2.
Access Process: Data downloaded from star.nesdis.noaa.gov/sod/sst/micros. Data volume is 35 GB/day.
Spatial Coverage: Global.
Temporal Coverage: Global.
Contingency: Impact is high as there is no contingency for this dataset. No similar high quality observations are available.

C. Appendix C: Tools

C.1   Tool #1: Collocation and Visualization in SQUAM

Location: NOAA in-house computers.

Description: Tool is used to inspect the ABI SST. It uses the NOAA SQUAM system that monitors in real-time global L2 and L3 SST products with respect to L4 fields and in situ data, as well as inter-compares and validates with similar products generated by NOAA (from Himawari-8/AHI, JPSS, MODIS, and AVHRR) and by other national and international partners, against two types of reference SSTs: several L4 global analyses (e.g., CMC, CMC L4 SST; UKMO OSTIA, and NCEI Reynolds SST) and QCed in situ SSTs (from iQuam). The following results of delta SST (dSST, equivalent to retrieved minus reference SST) are presented in SQUAM: maps, histograms, time series, dependencies (on view zenith angle, latitude, etc), and Hovmoller diagrams. SQUAM is run within an in-house Fortran wrapper and requires IDL, HTML, JavaScript, JQuerry, and JQplot.

Developer(s): Maxim Kramar, Kai He.

Development Schedule: 90% complete.

Data Dependencies: GOES-R ABI L1b Bands 7,11,13,14, and15[1] and GOES-R CSM.

Testing Accomplished or Planned: SQUAM has been extensively tested for previous programs (JPSS, Himawari-8), with proxy data from AVHRR, SEVIRI, MODIS and VIIRS, AHI (see Analysis Methods below). This tool was tested with data from DOE 1/2/3. A full exercise using a full day of simulated data is planned for DOE 4.

POC: Maxim Kramar[6, 7].

C.2   Tool #2: Collocation and Visualization in MICROS

Location: Local NOAA computers.

Description: Tool to collocate and visualize clear-sky brightness temperatures (BTs) associated with SSTs. It makes use of the CRTM. It is run within an in-house Fortran wrapper and requires IDL, html, JavaScript, JQuery, and JQplot. The MICROS tool monitors radiances in SST Bands, from which NOAA L2 SSTs are derived, against CRTM simulations (using Reference L4 SST, and GFS/ECMWF profiles). The following results of delta BTs (=Model minus Observation BT) are presented in MICROS: (1) Maps; (b) Histograms; (c) Time series; (c) Dependencies (on view zenith angle, latitude, etc.).

Developer: Xingming Liang.

Development Schedule: 90% complete.

Data Dependencies: GOES-R ABI L1b Bands 7,11,13,14, and 15[1].

Testing Accomplished or Planned: MICROS has been extensively tested for previous programs (e.g., JPSS) and is now being updated for Himawari-8. It was extensively tested with proxy data from AVHRR, SEVIRI, MODIS, VIIRS and AHI (see Section 5, Analysis Methods). This tool was tested with data from DOE 1/2/3. A full exercise using a full day of simulated data is planned for DOE 4.

POC: Maxim Kramar[6, 7].

C.3   Tool #3: In Situ Quality Control and Visualization in iQuam

Location: NOAA local computers.

Description: QC and visualization tool that is run in-house with Linux, crons/scripts, IDL, HTML, and Java Script. Uses iQuam: QCs in-situ data, monitors online, and serves QCed data to users. The following results of dSST (equivalent to in situ minus reference SST) are presented in iQuam:

maps, histograms, time series, and trending of individual in situ platforms. In situ data are used to created match-ups with satellite data, which are subsequently displayed in SQUAM.

Developer: Xinjia Zhou.

Development Schedule: 90% complete.

Data Dependencies: GOES-R ABI L1b Bands 7,11,13,14, and 15[1].

Testing Accomplished or Planned: iQuam has been extensively tested for previous programs (JPSS, POES, and Himawari-8). Matchups with proxy data from AVHRR, SEVIRI, MODIS, VIIRS, and AHI have been generated and analyzed (see Section 5, Analysis Methods). This tool was tested with data from DOE 1/2/3. A full exercise using a full day of simulated data is planned for DOE 4.

POC: Maxim Kramar[6, 7].

C.4 **Tool #4: Match-up Tool**

Location: NOAA local computers.

Description: Performs spatial and temporal match-ups of NOAA and partners' L2/3 SSTs with in situ iQuam SSTs.

Developer: Yury Kihai.

Development Schedule: 90% complete.

Data Dependencies: GOES-R ABI L1b Bands 7,11,13,14, and 15[1] and in situ SST data.

Testing Accomplished or Planned: This tool has been extensively tested for previous programs (JPSS and Himawari-8), with proxy data from AVHRR, SEVIRI, MODIS, VIIRS, and AHI (see Section 5, Analysis Methods). This tool was tested with data from DOE 1/2/3. A full exercise using a full day of simulated data is planned for DOE 4.

POC: Maxim Kramar[6, 7].

D. Appendix D: Acronym List

Acronym	Definition
ABI	Advanced Baseline Imager
ACMP	Algorithm Change Management Plan
ACSPO	Advanced Clear-Sky Processing over Ocean
AHI	Advanced Himawari Imager
ARMS	ACSPO Regional Monitor for SST
AVHRR	Advanced Very High Resolution Radiometer
AWG	Algorithm Working Group
BTs	Brightness Temperatures
Cal/Val	Calibration and Validation
CCR	Configuration Change Request
CLASS	Comprehensive Large Array-data Stewardship System
CMC	Canadian Meteorological Center
CMI	Cloud and Moisture Imagery
CONUS	Continental United States
CRTM	Community Radiative Transfer Model
CSM	Clear-Sky Mask
CWG	Calibration Working Group
DOE	Data Operations Exercise
dSST	Delta SST
F&PS	Functional and Performance Specification
FD	Full Disk
GFS	Global Forecast System
GOES	Geostationary Operational Environmental Satellite
GOES-R	GOES R-Series
GORWG	GOES-R Operational Readiness Working Group
GRB	GOES Rebroadcast
HTML	HyperText Markup Language
IDL	Interactive Data Language
iQuam	in situ SST Quality Monitor
JPSS	Joint Polar Satellite System
L1b	Level 1b
L2	Level 2
L3	Level 3
L4	Level 4
LZA	Local Zenith Angle
MICROS	Monitoring of Infrared Clear-sky Radiances over Ocean for SST
MODIS	Moderate Resolution Imaging Spectroradiometer
MOST	Mission Operations Support Team
MRD	Mission Requirements Document
MSFC	Marshall Space Flight Center
MSG	Meteosat Second Generation
MTSAT-2	Multifunctional Transport Satellite-2
NASA	National Aeronautics and Space Administration

Acronym	Definition
NCEI	National Centers for Environmental Information
NCEI-CO	NCEI - Colorado
NCEI-NC	NCEI - North Carolina
NESDIS	National Environmental Satellite, Data, and Information Service
NLSST	Non-Linear SST
NRT	Near Real-time
NWS	National Weather Service
OISST	Optimum Interpolation SST
OSPO	Office of Satellite and Product Operations
OSTIA	Operational Sea Surface Temperature and Sea Ice Analysis
PI	Principle Investigator
PLAR	Post-Launch Assessment Review
PLPT	Post-Launch Product Test
PLT	Post-Launch Test
PO.DAAC	Physical Oceanography Distributed Active Archive Center
POC	Point of Contact
POES	Polar Operational Environmental Satellite
PRO	Product Readiness and Operations
PSE	Program System Engineering
PS-PVR	Peer Stakeholder-Product Validation Review
PUG	Product User's Guide
QA	Quality Assurance
RIMP	Readiness, Implementation and Management Plan
SNPP	Suomi National Polar-orbiting Partnership
SPOT	System Performance Operational Test
SQUAM	SST Quality Monitor
SST	Sea Surface Temperature
STAR	Center for Satellite Applications and Research
TBD	To Be Determined
TIR	Thermal Infrared
UKMO	United Kingdom Meteorological Office
UTC	Universal Time Coordinated
VIIRS	Visible Infrared Imaging Radiometer Suite