Geostationary Operational Environmental Satellite (GOES) – R Series

ABI L2+ Aerosol Optical Depth (AOD) 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
- Initial calibration applied (L1b).
- Rapid changes in product input tables, and possibly product algorithms, can be expected.
- Product quick looks and initial comparisons with ground truth data (if any) are not adequate to determine product quality.
- Anomalies may be found in the product and the resolution strategy may not exist.

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

Provisional Validation

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

End state
- 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.
- Product analysis are sufficient to communicate product performance to users relative to expectations.
- 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.
- Testing has been fully documented.
- Product ready for operational use and for use in comprehensive calibration/validation activities and product optimization.

Full Validation

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

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

Figure 1. GOES-R product maturity levels.

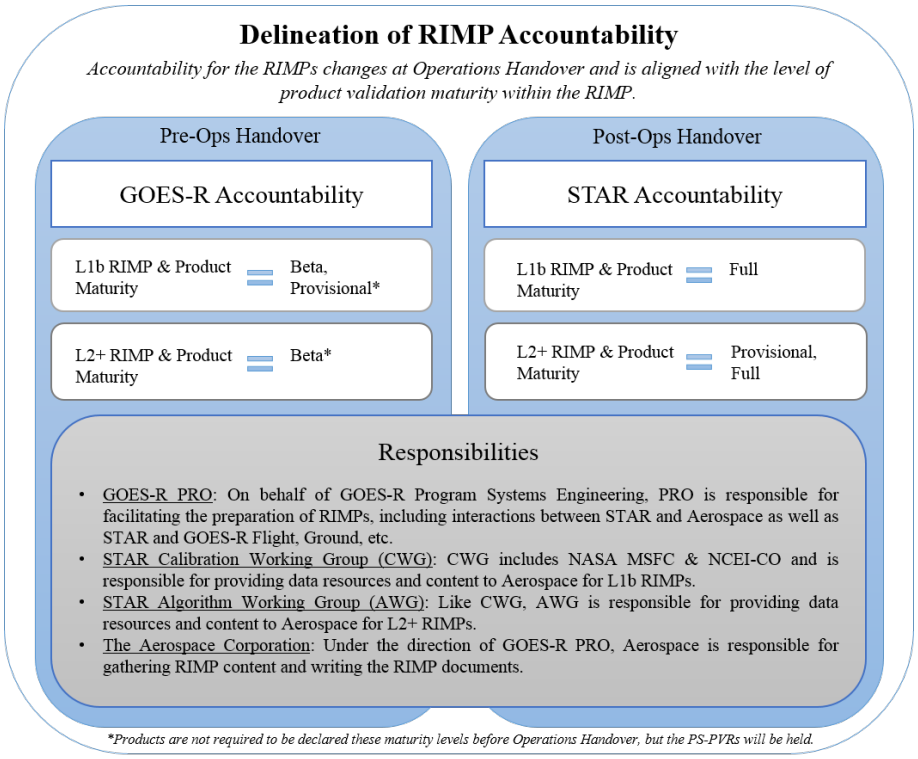

Figure 2. Delineation of accountability between GOES-R and STAR.

1. Aerosol Optical Depth Validation Overview

This RIMP covers all validation stages of the GOES-R Advanced Baseline Imager (ABI) Aerosol Optical Depth (AOD) L2+ product. The science algorithm produces both AOD and Aerosol Size Parameter (ASP). The latter is represented using two Ångström Exponents. However, the operational code only outputs AOD, which is designated a priority 1 product in the GOES-R Mission Requirements Specification (MRS).[1] Since the science code can be run offline to produce both AOD and ASP, some activities and tools described in this RIMP address both, but only AOD produced by the GOES-R operational code requires validation. There are three stages in the validation process: Beta, Provisional, and Full. Each stage is characterized by PLPTs, which guide the overall validation process. The RIMP includes a summary of the methods and tools employed to prove the AOD has met a given validation stage. Appendices are included that present more detail on each applicable PLPT and detail on the different data sets and tools employed in the AOD validation processes.

Six PLPTs have been defined to attain Beta maturity[2]. The first two events verify that when ABI is in Mode 3, the AOD 15 minute Full Disk (FD) and 5 minute CONUS products are within range. Note that there is no mesoscale AOD product. Two more events verify that AOD FD and CONUS products are within range in Mode 4. The remaining two Beta PLPTs provide an initial assessment of accuracy and precision of the FD and CONUS products when the sensor is in Mode 3. The performance assessment is dependent on L1b data reaching Beta maturity and adequate quality of the L2+ Clear Sky Mask (CSM). The performance assessment will consist of characterization of product accuracy and precision regardless of scene type or season. PLPTs that support Beta maturity are listed below; details are in Appendix A.

- **ABI-FD_AOD01:** verify 15 min FD products are within required measurement range in ABI Mode 3.
- **ABI-CONUS_AOD02:** verify 5 min CONUS products are within required measurement range in ABI Mode 3.
- **ABI-FD_AOD03:** verify 15 min FD products are within required measurement range in ABI Mode 4.
- **ABI-CONUS_AOD04:** verify CONUS products generated every 5 min are within required measurement range in ABI Mode 4.
- **ABI-FD_AOD05:** assess FD product precision and accuracy for very limited data set in ABI Mode 3.
- **ABI-CONUS_AOD06:** assess CONUS product precision and accuracy of for very limited data set in ABI Mode 3.

The following Table identifies the product refresh rate for Modes 3 and 4. It includes the required cadence of the AOD product as defined by both the GOES-R Functional and Performance Specification (F&PS) and the Product User's Guide (PUG). The bottom line reflects, for each appropriate scan type, the refresh rate of that product used for verification purposes. Routine, automated display of all products and routine evaluation of all products against "truth" is performed once per day for each day; statistics will be calculated monthly.

**There is no CONUS scan type for Mode 4, but there are required products over the CONUS that are derived from the FD output*

Mode	Mode 3			Mode 4		
Scan Type	FD	CONUS	Meso	FD	CONUS	Meso
Scan Freq	15 min	5 min	30 sec	5 min	5 min*	N/A
AOD – F&PS Freq	15 min	5 min	N/A	15 min	5 min	N/A
AOD – PUG Freq	15 min	5 min	N/A	5 min	5 min	N/A
AOD Verification Freq	once/day: all 15 min products	once/day: all 5 min products	N/A	once/day: all 5 min products	once/day: all 5 min products	N/A

Table 1. AOD product and verification cadences.

The truth or reference data to be used during the Beta maturity activities are the ground-based Aerosol Robotic Network (AERONET) Level 1.5 (L1.5) products, Visible Infrared Imaging Radiometer Suite (VIIRS) and Moderate Resolution Imaging Spectroradiometer (MODIS) satellite sensor aerosol products, and field campaign data.[3] AOD from the Surface Radiation Budget (SURFRAD) network is a contingency source in the case where AERONET is not available. Details about these data sets and preparations for their use are described in Appendix B.

Two PLPTs, one for each of the FD and CONUS AOD products, have been defined to demonstrate Provisional maturity.[2] These tests will provide an assessment of precision and accuracy for an extended period that includes some but not all seasonal variability; the period should be sufficient for the user to assess whether the product is ready for operational use. The PLPTs that support Provisional maturity are listed below; details are in Appendix A.

- **ABI-FD_AOD07:** assess precision and accuracy of FD product for an extended period that includes some but not all seasonal variability, to facilitate a user decision on operational readiness.
- **ABI-CONUS_AOD08:** assess precision and accuracy of CONUS product for an extended period that includes some but not all seasonal variability, to facilitate a user decision on operational readiness.

The same data sets used in the Beta maturity assessment will be used during the Provisional maturity assessment with the addition of AERONET L2+ data to support deep dive analyses after handover. Details about these data sets and preparations for their use are described in Appendix B.

Two additional PLPTs have been defined to attain Full maturity by further extending the conditions under which the FD and CONUS AOD product precision and accuracy performance are quantified, to include a seasonally representative number of independent measurements.2 The PLPTs that support Full maturity are listed below; details are in Appendix A.

- **ABI-FD _AOD09:** assess precision and accuracy of FD product for a wide range of representative conditions (i.e., seasonal) over a period of at least a year.
- **ABI-CONUS_AOD10:** assess precision and accuracy of CONUS product for a wide range of representative conditions (i.e., seasonal) over a period of at least a year.

The same data sets used in the Beta and Provisional maturity assessments will be used during the Full maturity assessment.

Input data used by the GOES-R AOD algorithm include Numerical Weather Prediction (NWP) data, including ocean surface wind speed and direction, surface pressure, surface height, and ozone data. ABI Total Precipitable Water (TPW) is also an input to the GOES-R AOD algorithm. While these input data are not evaluated in conjunction with routine monitoring and validation, they will be examined in deep dive analyses.

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 test are contained in Appendix A and of each reference data set in Appendix B.

2. Schedule of Events

The details of the GOES-R validation schedule are shown in Figure 3. System Performance Operation Test (SPOT) begins 44 days after launch when ABI Level 1b (L1b) and the L2+ Cloud and Moisture Imagery (CMI) Beta evaluation begins. The L1b and L2+ CMI data should be declared Beta maturity by L+87 days. One day later, the GOES Rebroadcast (GRB) will be populated with that data. The L2+ products must reach Beta maturity by handover at L+197 days, the same time that ABI L1b and CMI reach Provisional. Given that L2+ Beta tests require at least 6 weeks, L2+ Beta testing must get underway by L+155 days, but can begin as soon as the ABI L1b and CMI reach Beta (L+87 days). 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 9 month period for L2+ products to attain Full maturity, 15 months after operational handover to OSPO.

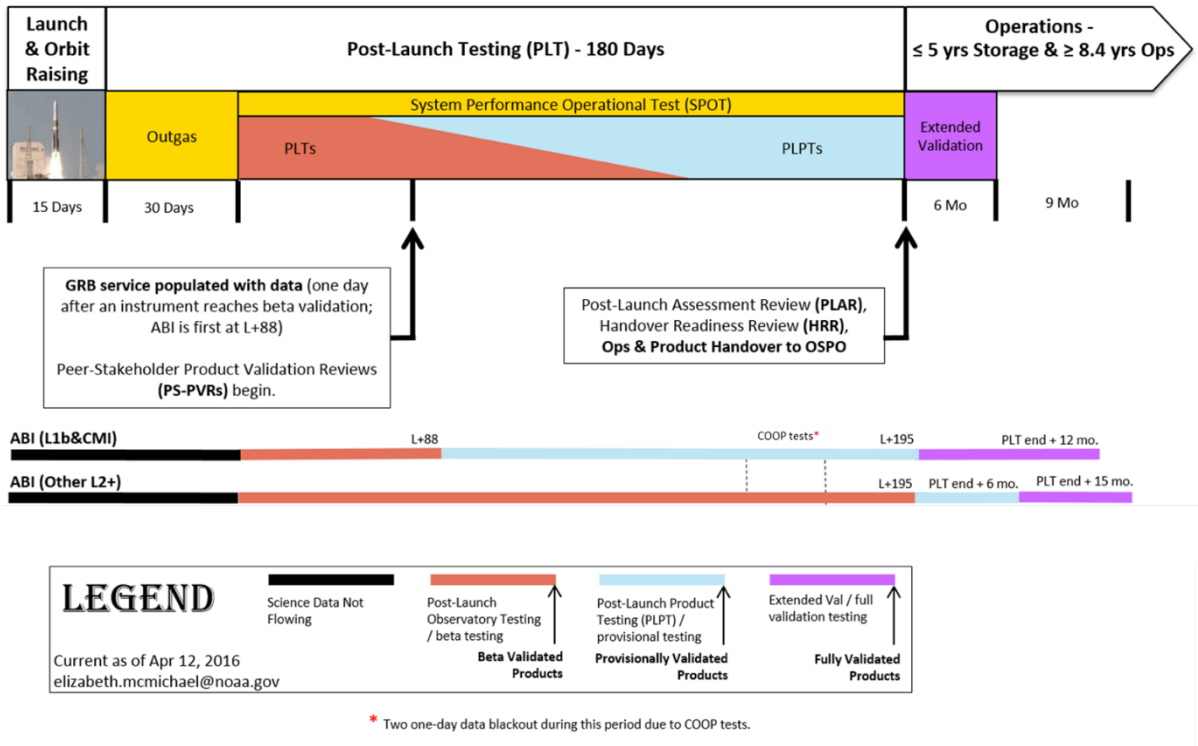

Figure 3. Schedule of events.

The first four Beta PLPTs for AOD are scheduled to begin at the start of the PLPT period. These PLPTs are a minimum of one week in duration, occur in parallel, and can begin as soon as the ABI L1b and CMI are declared Beta maturity. The final two Beta PLPTs will begin the second week of the PLPT period. These PLPTs are 5 weeks in duration and will occur concurrently.

Provisional AOD PLPT assessment will begin at the completion of the Beta maturity phase and start of the operational phase. These PLPTs occur in parallel and require at least 6 months to complete provided the L1b and L2+ CSM quality are sufficient.

Finally, the Full AOD PLPTs will begin at the completion of the Provisional assessment period, approximately 6 months after handover. These PLPTs occur in parallel over another period of at least 9 months.

3. Roles and Responsibilities

3.1 Primary Point of Contact

The AOD PLPT Lead is Istvan Laszlo. Istvan Laszlo is also the point of contact (POC) for the algorithm change responsibilities.[4]

3.2 GOES-R Point of Contact

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

3.3 Test Analyst/Engineer

Mi Zhou is the designated Analyst for all PLPTs, and Hongqing Liu will act as a back-up analyst. Mi Zhou is also the POC for tool preparation.

3.4 GOES-R Feedback

Formal feedback to the GOES-R Program regarding the AOD validation will be provided by Jaime Daniels.

3.5 Level of Effort

Each of the six one-week concurrent Beta PLPTs focusing on measurement ranges will require 0.2 Full-Time Equivalent (FTE). This is a total 1.17 FTE effort (46.8 hours) in the first week. The two remaining Beta PLPTs, intended to provide an initial performance assessment, require 0.57 FTE each and occur concurrently, totaling 1.14 FTE level of effort, or 45.6 hours a week, during the remaining five weeks of the Beta PLPT activities. This level of effort will remain approximately the same throughout the Provisional and Full PLPT efforts.[1]

Tool preparation will require 0.3 FTE/15.6 person weeks and will be completed prior to the PLPT effort.[1] The same tools will be used for field campaign data, though an additional 0.04FTE will be required to develop a data-ingest module specific to the field data.

4. Tools

The AOD validation effort utilizes a set of five tools. The first three are routine validation tools that: (1) monitor ABI L2+ aerosol products, display images of product and quality flags, and plot histograms for specified parameters; (2) collocate aerosol products with reference "truth" observations; and (3) generate time series for collocated AERONET stations and frequency scatter-plots and linear regression performance statistics in terms of MRS specifications. The last two are deep dive tools that (4) perform expanded comparisons using ABI and independent satellite (MODIS and VIIRS) data sets; and (5) display aerosol algorithm input data. These tools are described in more detail in Appendix C.[5]

5. Analysis Methods

The primary retrieval product is AOD at 550 nm (τ_{550}). However, AOD at the first six ABI channels are also calculated based on the selected/retrieved aerosol model. The aerosol size parameter product (ASP) consists of Ångström Exponents (AE) that are used as proxies for particle size. Two AEs are reported to characterize a bi-modal size distribution. They are calculated from AODs at two pairs of wavelengths, (0.47, 0.86) µm and (0.86, 2.25) µm. ASP is represented by two Ångström Exponents corresponding to these two pairs of wavelengths in order to incorporate the spectral dependence. In addition, the aerosol type is identified from the prescribed models. Due to the relatively weak aerosol signal and the large uncertainties associated with surface reflectance, the current algorithm does not attempt AOD retrieval over bright surfaces, such as sun glint over water, desert, and bare soil surface.[6]

The methods of analysis for AOD and APS fall into two general categories:

- Inspection of AOD and APS to establish their ranges.
- Comparison of ABI-retrieved AOD and APS to reference data to characterize product quality.

In the comparative methods discussed below, the ABI retrieved values are compared to the reference data and the differences are used to calculate the mean (accuracy), standard deviation (precision), and root mean square (RMS). The minimum and maximum values and probability distribution are computed for the ABI aerosol products. Metrics will be calculated as a function of region, time, and retrieved amount. A time series of validation results will be analyzed to detect any trend in the product due to algorithm or instrument issues.

5.1 Method 1 - Manual Inspection

The analyst will display the AOD fields with the Instantaneous Monitoring Tool (see Appendix C) every day for the previous day.

5.2 Method 2 - Routine Comparison with Ground-Based Measurements

Primary validation will be through comparison to ground-based measurement. Stratification of accuracy and precision on time of day, region and retrieved/measured AOD will be addressed during 5 weeks of Beta performance testing using limited ground-based data to characterize the retrieval uncertainties and identify the potential cause of any systematic errors. During Provisional analysis, the retrieval error will be stratified the same way as in the Beta phase, but using an extended set of satellite-derived and ground-measured AOD and APS. The Full analysis will provide additional stratifications including capturing seasonal variability.

Spatial and temporal match-ups with ground "truth" AERONET data are temporally averaged within a 1-hour window around the ABI overpass time and the ABI data are spatially averaged in a circle of 27.5 km radius centered on the ground station. AERONET data used are AOD at 16 wavelengths. The closest available AERONET AODs will be interpolated on logarithm scale to 550nm and ASP Ångström Exponents channels on logarithm scale. AERONET L1.5 AOD data will be used during the Beta PLPT analysis because it is available within a few days, while the L2+ fully calibrated AOD which is only updated annually will be used as available during the Provisional and Full analyses.

The overall ABI retrieval quality flag will be used to select good retrievals.

5.3 Method 3 - Comparison with Satellite Data

Cross-validation with other independent satellite products is necessary for assessment of consistency. GOES-R, MODIS, and VIIRS aerosol products will be collected in the circle of 27.5 km radius centered on AERONET stations. The MODIS aerosol products to be used for

comparative analysis (Optical_Depth_Land_And_Ocean, Angstrom_Exponent_1_Ocean, Angstrom_Exponent_2_Ocean, and Aerosol_Type_Land) have been extensively validated and cover a large variety of atmospheric and surface conditions. VIIRS aerosol products (AerosolOpticalDepth_at_550nm, AngstromExponent, and QF4_VIIRSAEROEDR) will be compared to GOES-R ABI AOD and ASP. Accuracy and precision dependence on region will be assessed.

The ABI and VIIRS retrievals are resampled to a common resolution, by averaging both over areas of ~50x50 km. The areas are centered over AERONET sites that also serve as sources of "truth" data. In the process, two sets of data (match-ups) are generated for each area: ABI vs. AERONET and VIIRS vs. AERONET. In each of the two data sets, the AERONET values represent averages for an hour centered on the satellite observation times. It's worth noting also that the difference between the two AERONET values gives us a measure of the effect of the time difference between satellite observations. For the ABI vs. VIIRS comparison, ABI-AERONET and VIIRS-AERONET match-ups are selected with times within one hour of each other.

5.4 Method 4 - Deep Dive Analyses

Deep dive validation addresses the dependence of AOD relative to reference AODs on geometry (solar zenith angle, satellite zenith angle, scattering angle, and relative azimuth), ancillary inputs (water vapor, ozone, and ocean surface wind speed/direction), intermediate data (surface reflectance and aerosol type), quality flags (clear sky masks, land surface type, and snow/ice mask), season and the magnitude of AOD. AERONET L2+ data and MODIS and VIIRS data are the primary reference data for deep dive analyses. Very limited deep dive analysis may be initiated during the Beta PLPT analysis, if needed and as resources permit, but is not required to reach Beta maturity. More extensive deep dive analyses will be conducted during the Provisional and Full efforts.

6. Output Artifacts

6.1 Beta Maturity Artifacts

The two criteria for declaring Beta maturity are to: (1) provide a quantitative performance assessment of accuracy and precision with limited set of data; and (2) identify issues with the AOD product. At the end of the first week of the PLPT period, the results from the range testing will be summarized in a report that will be made available for review by the Program. At the completion of the Beta analysis, a report will be prepared detailing the methods used and initial results of mean accuracy, precision (standard deviation), and RMS, along with minimum and maximum values and probability distributions for AOD at 550nm and APS Ångström Exponents. This evaluation will be based on a limited set of data. Metrics will be presented as a function of region, time, and retrieved amount. The report will also discuss issues identified with product.

6.1.1 These tests of priority 1 all must pass their success criteria defined in Appendix A in order to achieve Beta maturity:

- ABI-FD_AOD01
- ABI-CONUS_AOD02
- ABI-FD_AOD03
- ABI-CONUS_AOD04
- ABI-FD_AOD05
- ABI-CONUS_AOD06

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

6.2 Provisional Maturity Artifacts

The criteria for declaring Provisional maturity is that an assessment of precision and accuracy for an extended period, that includes some but not all seasonal variability, has been made. The conditions that have been assessed must be sufficient for the users to determine whether the product is ready for operational use. The precision and accuracy specifications for AOD do not have to be met to attain Provisional status. However, if they are not met, the reasons behind not meeting these specifications must be documented with remediation strategies in place. The product also must be ready for use in scientific publications and potential operational use (user decision) in order to be declared Provisional.

At the conclusion of the Provisional stage, results will be presented at a PS-PVR. In order to meet the criteria above, these results will contain a much more comprehensive assessment of performance in terms of accuracy and precision metrics, covering a larger range of representative conditions than is provided at the Beta stage. The ABI retrieval error will be stratified by measured and retrieved AOD, time of day, and region (latitude and longitude). The PS-PVR package will also address any necessary remediation strategies. Finally, the Provisional presentations will include a summary of user feedback received during this maturity phase.

6.2.1 These tests of priority 1 all must pass in their success criteria defined in Appendix A in order to achieve Provisional maturity:

- ABI-FD _AOD07
- ABI-CONUS_AOD08

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

6.3 Full Maturity Artifacts

The criteria for declaring Full maturity is that precision and accuracy specifications for the product are met or nearly met. If a specification is not met, the product can still be declared of Full maturity

if the cause is due to non-algorithm errors and the reason is documented. In addition, users must concur that Full maturity has been demonstrated.

Similar to the Provisional stage, at the conclusion of the Full stage, results will be presented at a PS-PVR. Since the Provisional PLPT duration is too short to cover full seasonal variability, the Full presentation will include seasonal results for accuracy and precision metrics. As with the Provisional stage, the Full PS-PVR package will address remediation strategies in cases where performance specifications are not met. Finally, a summary of user feedback received during the Full effort will be included.

6.3.1 These tests of priority 1 all must pass their success criteria defined in Appendix A in order to achieve Full maturity:

- ABI-FD _AOD09
- ABI-CONUS_AOD10

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

6.4 Key Artifacts

The key artifact for the AOD validation effort is the statistical analysis of accuracy and precision which will be covered in the Beta report and the Provisional and Validated presentations described above.

6.5 More Output Artifacts

N/A. The Beta report and the Provisional and Validated presentations are the only artifacts required and are described above.

6.6 Delivery Schedule

The delivery schedule of artifacts for the AOD validation coincides with the completion of the associated maturity stages as shown in Section 2. All statistical analysis necessary to prove a given validation stage will be included in a power point presentation in time for the appropriate PS-PVR.

7. Pre-launch

Tools were extensively tested during the algorithm development and validation stages on ABI proxy data, such as MODIS and simulated proxy data. Output from pre-launch Data Operations Exercises (DOEs) will also be used to verify tools work with the appropriate outputs, to include any necessary diagnostics. Web-based displays of validation tool will be ready by July (v1) and September (v2) of 2016. Output from pre-launch DOE tests will continue to be used throughout pre-launch to verify tools correctly process the GOES-R ABI OAD product formats including diagnostic data.

8. References

[1] GOES-R Mission Requirements Specification (MRS), 410-R-MRD-0070, Version 3.17.
[2] PLPT_VE_List_L2+_v1_0_20141022.xlsx.
[3] Cal/Val Workshop charts: Application_Team_Validation_LST_v1.ppt.
[4] GOES-R Series Ground Segment Project Algorithm Change Management Plan, G416-R-ALGCMP-0285.
[5] L2+ Product Validation Tools_05-12-2015.xlsx.
[6] GOES-R ABI Algorithm Theoretical Basis Document (ATBD) for Suspended Matter/Aerosol Optical Depth and Size Parameter, Version 2.

A. Appendix A: Validation Events

A.1 PLPT Events that Support Beta Maturity

A.1.1 Event Name: ABI-FD_AOD01

Objective: Verify FD products are generated every 15 min and are within measurement range.
Start Time: Start of the PLPT period.
Duration: 1 week.
ABI Mode: Mode 3.
GOES-R Data Type(s): AOD at 550 nm and at ABI Bands 1, 2, 3, 5, and 6. APS 1 and 2. 15 min FD.
Beta Success Criteria: Range assessment results reported.
Dependencies: None.
PLPT Lead: Istvan Laszlo.
PLPT Analyst: Mi Zhou and Hongqing Liu; 0.2 FTE.
Comparison/Reference Data: None.
Monitoring & Analysis Method: Product inspection.

A.1.2 Event Name: ABI-CONUS_AOD02

Same as ABI-FD_AOD01 except for:
GOES-R Data Type(s): AOD at 550 nm and at ABI Bands 1, 2, 3, 5, and 6. APS 1 and 2. 5 min CONUS.

A.1.3 Event Name: ABI-FD_AOD03

Same as ABI-FD_AOD01 except for:
Instrument Mode: Mode 4.

A.1.4 Event Name: ABI-CONUS_AOD04

Same as ABI-CONUS_AOD02 test except for:
Instrument Mode: Mode 4.

A.1.5 Event Name: ABI-FD_AOD05

Objective: Assess accuracy and precision of FD product for a very limited (i.e., not seasonally representative) number of independent measurements to convey an initial characterization of product accuracy and precision to the user community.
Start Time: start of the PLPT period week two.
Duration: 5 weeks.
ABI Mode: Mode 3.
GOES-R Data Type(s): AOD at 550 nm and at ABI Bands 1, 2, 3, 5, and 6. APS 1 and 2. 15 min FD.
Beta Success Criteria:

- Characterization of product accuracy and precision, regardless of scene type or season, based on a limited set of data.
- Issues with the product are identified.

Dependencies: L1b Beta maturity and L2+ CSM adequate quality.
PLPT Lead: Istvan Laszlo.
PLPT Analysts: Mi Zhou and Hongqing Liu; 0.57 FTE.
Comparison/Reference Data: AERONET L1.5 products, MODIS and VIIRS aerosol products.

Monitoring and Analysis Method: Manual inspection, routine comparison with ground-based measurements, and routine comparison with satellite data.

A.1.6 Event Name: ABI-CONUS_AOD06

Same as ABI-FD_ AOD05 except for:
Objective: Assess accuracy and precision of CONUS product for a very limited (i.e., not seasonally representative) number of independent measurements to convey an initial characterization of product accuracy and precision to the user community.
GOES-R Data Type(s): AOD at 550 nm and at ABI Bands 1, 2, 3, 5, and 6. APS 1 and 2. 5 min CONUS.

A.2 PLPT Events that Support Provisional Maturity

A.2.1 Event Name: ABI-FD_AOD07

Objective: Assess FD product precision and accuracy for an extended period sufficient to facilitate a user decision on operational readiness.
Start Time: Completion of Beta analysis and start of operational phase.
Duration: 6 months.
ABI Mode: Mode 3.
GOES-R Data Type(s): AOD at 550nm and at ABI Bands 1, 2, 3, 5, and 6. APS 1 and 2. 15 min FD.
Provisional Success Criteria:

- Accuracy and precision determined over a large and wide range of representative conditions with the errors stratified by measured and retrieved AOD, time of day, and region (latitude and longitude). The accuracy and precision specifications are as follows:[1]

AOD Range	Accuracy	Precision
Over Land		
< 0.04	0.06	0.13
0.04 – 0.80	0.04	0.25
> 0.80	0.12	0.35
Over Water		
< 0.40	0.02	0.15
> 0.40	0.10	0.23

  These apply in daytime at a minimum, out to at least 60 degrees Local Zenith Angle (LZA) and in clear conditions. Accuracy and precision specifications do not have to be met to attain Provisional status, however, if they do not, the reasons behind not meeting these specifications must be documented.
- Remediation strategies are in place for known issues.
- Impacts from challenges with upstream dependencies are documented.
- Feedback from the primary user (NWS) is documented.
- Product is ready for potential operational use (user decision) and for use in scientific publications.

Dependencies: L1b of Provisional maturity and L2+ CSM adequate quality.
PLPT Lead: Istvan Laszlo.
PLPT Analysts: Mi Zhou and Hongqing Liu; 0.57 FTE.
Comparison/Reference Data: AERONET L1.5 & L2+ products and MODIS and VIIRS aerosol products. AOD from SURFRAD is a contingency source in case AERONET is not available.
Monitoring & Analysis Method: Manual inspection, routine comparison with ground-based measurements, and routine comparison with satellite data.

A.2.2 Event Name: ABI-CONUS_AOD08

Same as ABI-FD_AOD 07 except for:
Objective: Assess CONUS product precision and accuracy for an extended period sufficient to facilitate a user decision on operational readiness.
GOES-R Data Type(s): AOD at 550nm and at ABI Bands 1, 2, 3, 5, and 6. APS 1 and 2. 5 min CONUS.

A.3 PLPT Events that Support Full Maturity

A.3.1 Event Name: ABI-FD_AOD09

Objective: Assess precision and accuracy of FD product for a wide range of representative conditions (i.e., seasonal) over a period of at least a year.
Start Time: Completion of Provisional assessment period, approximately six months after handover.
Duration: 9 months.
ABI Mode: Mode 3.
GOES-R Data Type(s): AOD at 550nm and at Bands 1, 2, 3, 5, and 6. APS 1 and 2. 15 min FD.
Full Success Criteria:

- Accuracy and precision determined over a period of one year to capture seasonal variability and over a wide range of representative conditions, with the errors stratified by measured and retrieved AOD, time of day, region (latitude and longitude), and season.
- Product performance meets or is close to meeting the accuracy and precision specifications. The accuracy and precision specifications are as follows:[1]

AOD Range	Accuracy	Precision
Over Land		
< 0.04	0.06	0.13
0.04 – 0.80	0.04	0.25
> 0.80	0.12	0.35
Over Water		
< 0.40	0.02	0.15
> 0.40	0.10	0.23

These apply in daytime at a minimum, out to at least 60 degrees LZA, and in clear conditions. If a requirement is not met, the product can still be declared Fully validated if the cause is due to non-algorithm errors and the reason is documented.

- User concurs with Full maturity.

Dependencies: L1b and CSM quality
PLPT Lead: Istvan Laszlo.
PLPT Analysts: Mi Zhou and Hongqing Liu; 0.57 FTE.
Comparison/Reference Data: AERONET L1.5 & L2+ products and MODIS and VIIRS aerosol products. AOD from SURFRAD is a contingency source in case AERONET is not available.
Monitoring & Analysis Method: Manual inspection, routine comparison with ground-based measurements, and routine comparison with satellite data.

A.3.2 ABI-CONUS_AOD10

Same as ABI-FD_AOD09 except for:
Objective: Assess precision and accuracy of CONUS product for a wide range of representative conditions (i.e., seasonal) over a period of at least a year.
GOES-R Data Type(s): AOD at 550nm and at Bands 1, 2, 3, 5, and 6. APS 1 and 2. 5 min CONUS.

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

B.1 Data Set #1: AERONET

Description: Ground-based AERONET L1.5 and L2 AOD. This data set consists of well-calibrated direct sun photometers that measure and derive quality-assured aerosol optical properties for a wide diversity of the aerosol regime. L1.5 AOD data are automatically cloud-cleared and, because they are available within a few days, they will be used routinely during the Beta PLPT evaluation. The L2 data, which are manually inspected with final calibration applied, are updated on a yearly basis. These will be obtained to support deep dive Provisional and Full analyses.
Storage Location: All-Points AERONET L1.5 and L2+ AOD data can be downloaded at the website http://aeronet.gsfc.nasa.gov/cgi-bin/webtool_opera_v2_new.
Access Process: Scripts are written to automatically look for updates on the availability of data for download.[6] L1.5 data (3 MB) will be downloaded daily. L2+ data will not be available during PLPT because of latency.
POC: Brent N. Holben.
Spatial Coverage: 35 sites.
Temporal Coverage: 5 minute temporal resolution.
Contingency: If AERONET data is not available, the impact would be high as no similar high-quality ground measurements are available. However, SURFRAD would be used as a backup.

B.2 Data Set #2: MODIS

Description: AOD, Ångström Exponent, fine-mode weight over ocean, surface reflectance over land, and aerosol type over land from MODIS aerosol products. This data set covers a large variety of atmospheric and surface conditions. It will be used in both routine and deep dive analyses.
Storage Location: tp://ladsweb.nascom.nasa.gov/allData/6/.
Access Process: 1.2 GB downloaded daily. IDL routine get_modis_col6.pro will run once per day and download daily MODIS MOD04 (Terra) and MYD04 (Aqua) aerosol products to local computing facility at College Park. Access has already been tested with MODIS Collection 5 Terra and Aqua aerosol products for the years 2002–2012 and Collection 6 Aqua aerosol product for the years 2002–2014. MODIS data are deleted after processing; only the MODIS-AERONET match-ups are stored. The daily data size of the match-up is ~100 KB.
Spatial Coverage: 10km resolution.
Temporal Coverage: Daily.
Contingency: The impact if this dataset is not available is medium and the alternative is the VIIRS aerosol product.

B.3 Data Set #3: SNPP VIIRS

Description: Joint Polar Satellite System (JPSS) Suomi National Polar-orbiting Partnership (SNPP) VIIRS aerosol product. This data set will be used in both routine and deep dive analyses. Note that the JPSS J1 will be on-orbit, but J1 data are unlikely to be declared Provisional or even Beta maturity in time for use in GOES-R validation activities and so is not considered a candidate reference data source.
Storage Location: Local computing facility at College Park; back up at ftp://ftp-npp.class.ngdc.noaa.gov/.
Access Process: 2 GB Environmental Data Record (EDR)/9 GB daily. IDL routine get_virrs_data.pro runs once per day to download VIIRS products (GAERO and VAOOO) to local computing facility at College Park. This routine has been running routinely since the end of March 2015. Only the VIIRS-AERONET match-ups are stored and the daily data size is approximately 300 KB.

POC: JingFeng Huang.
Spatial Coverage: 6 km at nadir and 12 km at edge of scan.
Temporal Coverage: daily.
Contingency: If this data set is not available, the impact is medium, assuming MODIS data are available.

B.4 Data Set #4: SURFRAD

Description: Ground-based SURFRAD AOD. AOD data for SURFRAD stations are generated from cloud-free measurements of Multi-Filter Rotating Shadowband Radiometers. Daily files of AOD for five spectral measurements in the visible and near-infrared have been produced since 1997.
Storage Location: ftp://aftp.cmdl.noaa.gov/data/radiation/surfrad/aod/.
Access Process: Scripts will be written to automatically download and process SURFRAD AOD data once per day. 300 KB will be downloaded daily.
POC: Kathleen Lantz (kathy.o.lantz@noaa.gov).
Spatial Coverage: Currently there are 7 stations.
Temporal Coverage: 3 minutes temporal resolution.
Contingency: None.

B.5 Data Set #5: Field Campaign Data

Description: Sun photometer measurements of AOD at ground level over land and oceanic locations together with correlative data of amount of water vapor and ozone (TBD), and surface reflectance. These are to be used with the deep dive tools.
Access Process: TBD from GOES-R Field Campaign Data Portal.
POC: Steve Goodman and Frank Padula (Frank.Padula@noaa.gov).
Frequency of transmission: TBD.
Contingency: None.

C. Appendix C: Tools

C.1 Tool #1: ABI AOD Instantaneous Monitoring Tool

Location: Local computing facility at College Park.
Description: Routine validation IDL tool that monitors ABI L2+ aerosol products, displays images of product and quality flags, and plots histograms for specified parameters. It consists of the following modules:

- instantaneous_monitoring_conus.pro
- instantaneous_monitoring_conusplot.pro
- instantaneous_monitoring_statisticsplot.pro
- instantaneous_monitoring_fulldisk.pro
- instantaneous_monitoring_fulldiskplot.pro

Developer: Mi Zhou.
Development Schedule: Development work is complete.
Data Dependencies: GOES-R ABI L2+ AOD.
Testing Accomplished or Planned: The tool has been tested with MODIS and VIIRS aerosol products. Additional testing was conducted using Himawari-8 data. ABI DOE test data will be used as-available throughout pre-launch to ensure ABI AOD product format is processed correctly.
POC: Mi Zhou.

C.2 Tool #2: ABI AOD Data Collocation Tool

Location: Local computing facility at College Park.
Description: Routine validation tool (C++, IDL, and bash script) that collocates aerosol products with reference "truth" observations. It consists of the following modules:
get_daily_aeronet_driver.sh.
get_viirs_data_pro, match_ground.pro, match_ground.sh, match-up.sh.
Developer: Hongqing Liu and Mi Zhou.
Development Schedule: Development is complete.
Data Dependencies: AERONET L1.5 & L2+ and ABI AOD product.
Testing Accomplished or Planned: The tool has been tested with AERONET L1.5 and MODIS and VIIRS aerosol products. ABI DOE test data will be used as-available throughout pre-launch to ensure ABI AOD product format is processed correctly.
POC: Mi Zhou.

C.3 Tool #3: ABI AOD Routine Validation with AERONET Tool

Location: Local computing facility at College Park.
Description: Routine IDL validation tool to compare with ground truth. This tool generates time series for collocated AERONET stations and frequency scatter-plots and linear regression performance statistics in terms of MRS specifications. The tool can display the spatial distribution map of accuracy/precision over individual AERONET stations, calculate statistical metrics as a function of region, time, and retrieved amount, automatically detect possible systematic drift, and process ABI product data format (including AOD retrieved from simulated ABI data). It consists of the following modules:

- routine_validation_over_ground.pro
- validation_over_ground_scatterplot.pro
- validation_over_ground_frequencyscatterplot.pro
- validation_over_ground_timeseriesplot.pro
- validation_over_ground_aeronetstationmap.pro

- validation_over_ground_dependence.pro

Developer: Mi Zhou.
Development Schedule: Development work is complete except for completing web-based display of results (version 1 due in July, version 2 in Sept 2016).
A data ingest module will be developed and tested for field campaign data 3 months in advance of the data collection period. Other field campaign data, like water vapor from soundings and surface reflectance data, would be used in a deep dive analysis.
Data Dependencies: AERONET L1.5 and L2+ ABI AOD product.
Testing Accomplished or Planned: The tool has been tested with AERONET-MODIS and AERONET-VIIRS collocated datasets as well as with Himawari-8 data. ABI DOE test data will be used as-available throughout pre-launch to ensure ABI AOD product format is processed correctly.
POC: Mi Zhou.

C.4 Tool #4: Deep-dive Analysis with Independent Satellite Data

Location: Local computing facility at College Park.
Description: Deep dive IDL tool that performs expanded comparisons using ABI and independent satellite (MODIS and VIIRS) data sets. This tool displays the differences of retrieved AODs as a function of input, diagnostics, intermediate parameters (e.g., surface reflectance and aerosol type over land), and aerosol product quality flags.

- deepdive_validation_with_-independent_satellite.pro
- deepdive_validation_dependence.pro
- deepdive_validation_frequencyscatterplot.pro
- deepdive_validation_scatterplot.pro
- deepdive_validation_timeseriesplot.pro
- deepdive_validation_aeronetstationmap.pro

Developer: Mi Zhou.
Development Schedule: Complete except for web-based display of results (version 1 due in July, version 2 in Sept 2016)
Data Dependencies: ABI and MODIS aerosol product at AERONET-MODIS collocations.
Testing Accomplished or Planned: The tool has been tested with a MODIS–AERONET collocated dataset and with Himawari-8 data. ABI DOE test data will be used as-available throughout pre-launch to ensure ABI AOD product format is processed correctly.
POC: Mi Zhou.

C.5 Tool #5: Deep-Dive Monitoring Tool

Location: Local computing facility at College Park.
Description: This tool displays the input data to the aerosol algorithm, including ABI channel reflectances, geometry, and ancillary data. It consists of the following modules:

- deepdive_monitoring_conus.pro
- deepdive_monitoring_-conusplot.pro
- deepdive_monitoring_statisticsplot.pro

Developer: Mi Zhou.
Development Schedule: Complete except for web-based display of results (version 1 due in July, version 2 in Sept 2016)
Data Dependencies: ABI channel reflectances; geometry and ancillary input data.
Testing Accomplished or Planned: The tool has been tested with MODIS, VIIRS and Himawari-8 data throughout October 2015–July 2016. DOE test is being used throughout pre-launch to ensure ABI AOD product format is processed correctly.
POC: Mi Zhou.

D. Appendix D: Acronym List

Acronym	Definition
ABI	Advanced Baseline Imager
AERONET	Aerosol Robotic Network
AOD	Aerosol Optical Depth
ASP	Aerosol Size Parameter
ATBD	Algorithm Theoretical Basis Document
AWG	Algorithm Working Group
Cal/Val	Calibration and Validation
CCR	Configuration Change Request
CMI	Cloud and Moisture Imagery
CONUS	Continental United States
CSM	Clear Sky Mask
CWG	Calibration Working Group
DOE	Data Operations Exercise
EDR	Environmental Data Record
FD	Full Disk
F&PS	Functional and Performance Specification
FTE	Full-Time Equivalent
GOES	Geostationary Operational Environmental Satellite
GOES-R	GOES R-Series
GORWG	GOES-R Series Operational Requirements Working Group
GRB	GOES Rebroadcast
HRR	Handover Readiness Review
IDL	Interface Definition Language
JPSS	Joint Polar Satellite System
L1.5	Level 1.5
L1b	Level 1b
L2	Level 2
LST	Land Surface Temperature
LZA	Local Zenith Angle
MODIS	Moderate Resolution Imaging Spectroradiometer
MOST	Mission Operations Support Team
MRD	Mission Requirements Document
MRS	Mission Requirements Specification
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NCEI	National Centers for Environmental Information
NCEI-CO	NCEI - Colorado

Acronym	Definition
NLT	No Later Than
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
NWS	National Weather Service
N/S	North/South scan
OSPO	Office of Satellite and Product Operations
PLAR	Post-Launch Assessment Review
PLPT	Post-Launch Product Test
PLT	Post-Launch Test
POC	Point of Contact
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
RMS	Root Mean Square
SNPP	Suomi National Polar-orbiting Partnership
SPOT	System Performance Operational Test
STAR	Center for Satellite Applications and Research
SURFRAD	Surface Radiation Budget
TBD	To Be Determined
TPW	Total Precipitable Water
VE	Validation Events
VIIRS	Visible Infrared Imaging Radiometer Suite