Geostationary Operational Environmental Satellite (GOES) – R Series

ABI L2+ Aerosol Detection Product (ADP) Beta, Provisional and Full Validation Readiness, Implementation and Management Plan (RIMP)

ABI L2+ Aerosol Detection Product (ADP) Beta, Provisional and Full Validation Readiness, Implementation and Management Plan (RIMP)

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Change Record

	DOCUMENT TITLE: ABI L2+ Aerosol Detection Product (ADP) Beta, Provisional and Full Validation Readiness, Implementation and Management Plan (RIMP)			
VERSION	**DATE**	**CCR #**	**PAGES AFFECTED**	**DESCRIPTION**
1.0	09/02/2016	03179	All	Initial

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Table of Contents

Table of Figures and Tables

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.

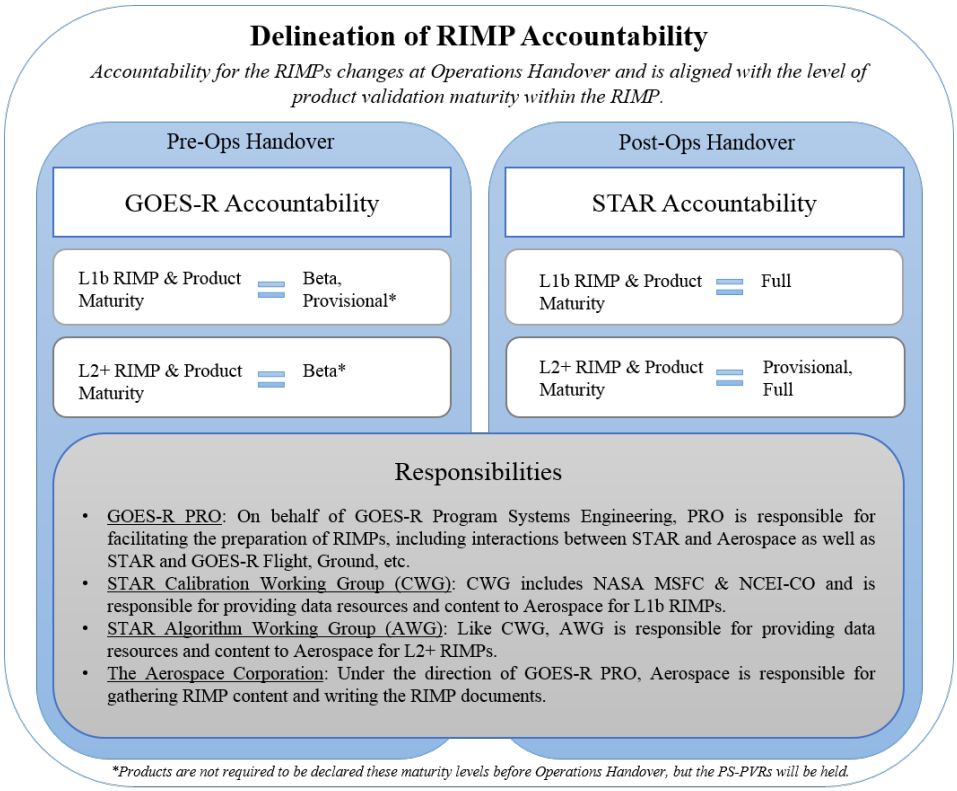

Figure 2. Delineation of accountability between GOES-R and STAR.

1. Aerosol Detection Product Validation Overview

This RIMP covers all validation stages of the GOES-R Advanced Baseline Imager (ABI) L2+ Aerosol Detection Product (ADP). 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 the ADP 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 ADP validation processes.

Eleven PLPTs have been defined to attain Beta maturity during the PLPT period[1]. Six verification events verify that when the sensor is in Mode 3, the Full Disk (FD), CONUS, and mesoscale ADP, generated every 15 minutes when an aerosol event is occurring, fall within the expected measurement ranges. These first six tests will also verify that the products are not generated if an aerosol event is not detected. Two additional PLPTs verify that the ADP falls within range when an aerosol event is occurring and that the product is not generated if an aerosol event is not detected in ABI Mode 4. The remaining three Beta PLPTs provide an initial assessment of accuracy performance of the FD, CONUS, and mesoscale products when the sensor is in Mode 3. Product accuracy is a measure of correct classification of dust over land, dust over water, smoke over land, and smoke over ocean and correct identification of absence of dust/smoke (clear pixels). Good performance is indicated by high measurement accuracy, high Probability of Correct Detection (POCD), and low Probability of False Detection (POFD).[2] The PLPTs that support Beta maturity are listed below; details are in Appendix A.

- **ABI-FD_ADP01:** verify FD products generated every 15 min of the day during aerosol event(s) are within the required measurement range.
- **ABI-CONUS_ADP02:** verify CONUS products generated every 15 min of the day during aerosol event(s) are within the required measurement range.
- **ABI-ABI-MESO_ADP03:** verify mesoscale products generated every 15 min of the day during aerosol event(s) are within the required measurement range.
- **ABI-FD_ADP04:** null test to verify that FD products are not generated when no aerosol events are occurring.
- **ABI-CONUS_ADP05:** null test to verify that CONUS products are not generated when no aerosol events are occurring.
- **ABI-MESO_ADP06:** null test to verify that mesoscale products are not generated when no aerosol event is occurring.
- **ABI-FD_ADP07:** when the sensor is in Mode 4, verify that FD products generated every 15 min of the day during aerosol event(s) are within the required measurement range.
- **ABI-CONUS_ADP08:** null test to verify that when the sensor is in Mode 4, the FD product is not generated when no aerosol events are occurring.
- **ABI-FD_ADP09:** assess accuracy, POCD, and POFD of the FD product for a very limited (i.e., not seasonally representative) number of independent measurements to convey an initial characterization to the user community.
- **ABI-CONUS_ADP10:** assess accuracy, POCD, and POFD of the CONUS product for a very limited (i.e., not seasonally representative) number of independent measurements to convey an initial characterization to the user community.
- **ABI-MESO_ADP11:** assess accuracy, POCD, and POFD of the mesoscale product for a very limited (i.e., not seasonally representative) number of independent measurements to convey an initial characterization to the user community.

Three additional PLPTs have been defined to attain Provisional maturity. These tests will quantify accuracy, POCD, and POFD for an extended period that includes some but not all seasonal variability. This extended period must be sufficient for the user to evaluate whether the product is ready for operational use. The PLPTs that support Provisional maturity are listed below; details are in Appendix A.

- **ABI-FD_ADP12:** assess accuracy, POCD, and POFD of FD product for an extended period that includes some but not all seasonal variability, to demonstrate operational readiness (a user decision).
- **ABI-CONUS_ADP13:** assess accuracy, POCD, and POFD of CONUS product for an extended period that includes some but not all seasonal variability, to demonstrate operational readiness (a user decision).
- **ABI-MESO_ADP14:** assess accuracy, POCD, and POFD of mesoscale product for an extended period that includes some but not all seasonal variability, to demonstrate operational readiness (a user decision).

Finally, three PLPTs have been defined to attain Full maturity by further extending the conditions under which ADP accuracy, POCD, and POFD performance is quantified to include a seasonally representative number of independent measurements.[1] The PLPTs that support Full maturity are listed below; details are in Appendix A.

- **ABI-FD_ADP15:** assess accuracy, POCD, and POFD of the FD product for a wide range of representative conditions (i.e., seasonal) over a period of at least one year.
- **ABI-CONUS_ADP16:** assess accuracy, POCD, and POFD of the CONUS product for a wide range of representative conditions (i.e., seasonal) over a period of at least one year.
- **ABI-MESO_ADP17:** assess accuracy, POCD, and POFD of the mesoscale product for a wide range of representative conditions (i.e., seasonal) over a period of at least one year.

Table 1 identifies the frequency of each scan type for Modes 3 and 4. It includes the required cadence of the ADP 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 frequency of that product used for verification purposes. Verification is based on each 15 min ADP product; however, the verification frequency depends on the frequency of the truth data. For qualitative verification, such as comparing with ABI RGB image and AOD products, the frequency could be 15 minutes, but for quantitative verification, i.e., generate statistics matrix, the verification frequency could range from daily to weekly.

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

Mode	Mode 3			Mode 4		
Scan Type	FD	CONUS	Meso	FD	CONUS	Meso
Freq	15 min	5 min	30 sec	5 min	5 min*	N/A
ADP Freq per F&PS	15 min	15 min	15 min	15 min	15 min	N/A
ADP Freq per PUG	15 min	15 min	15 min	15 min	15 min	N/A
ADP Verification Freq	Daily	Daily	Daily	Daily	Daily	N/A

Table 1. ADP product and verification cadences.

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. The details of any tools used in the validation process are in Appendix C.

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) key performance 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.

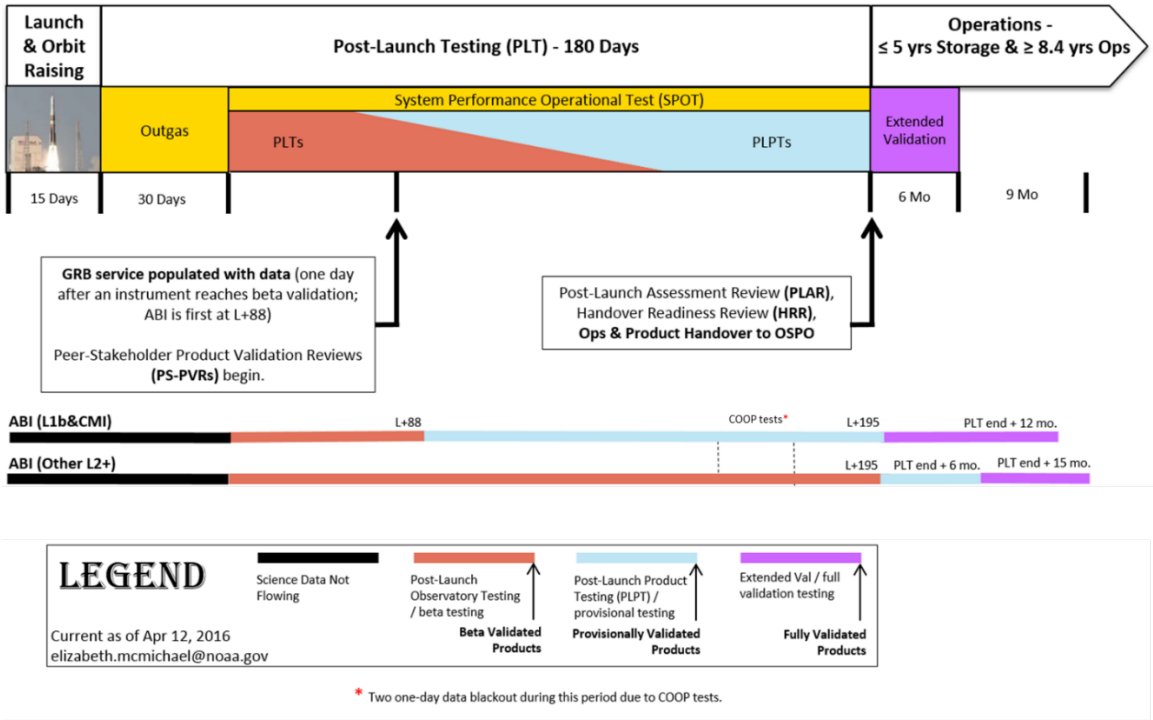

Figure 3. Schedule of events.

The first eight Beta PLPTs are one week in duration and occur in parallel. They will commence at the beginning of the PLPT period, when the ABI L1b product is declared Beta. The final three Beta PLPTs for initial performance assessments will commence at the start of the second week of the PLPT period and last for an additional 5 weeks. These PLPTs also occur in parallel.

The Provisional PLPTs will commence after the initial PLPT period has ended and the program has entered its operational phase.[1] The Provisional PLPTs are each planned for 24 weeks duration. Note that these tests are dependent upon the CSM reaching Provisional status to begin.

Finally, the three Full PLPTs will commence at the completion of the Provisional assessment and occur concurrently over another 36 week period.

3. Roles and Responsibilities

3.1 Primary Point of Contact

The ADP PLPT Lead is Shobha Kondragunta. Shobha Kondragunta is also the point of contact (POC) for the algorithm update process should any modifications be required during the PLPT or operations periods.[3] Shobha is also the POC for coordination with the other L2 leads. This coordination will be accomplished through regularly scheduled tag-ups, sharing of analysis results, and phone and email communications.

3.2 GOES-R Point of Contact

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

3.3 Test Analyst/Engineer

The analyst for all PLPTs is Pubu Ciren. Pubu Ciren is also the POC for tool preparation. To mitigate risk of personnel resource issues, Chuanyu Xu is also capable of running all the tools/software and will serve as a back up to P. Ciren.

3.4 GOES-R Feedback

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

3.5 Level of Effort

Pubu Ciren will be devoting 0.09 Full-Time Equivalent (FTE) to each of the eight one-week, concurrent Beta PLPTs that focus on measurement ranges and null checks. This is a total of 28 hours or 0.72 FTE effort in the first week. The three remaining Beta PLPTs for initial accuracy performance assessments will occur concurrently over the next five weeks and require 0.28 FTE each for a total of 0.84 FTE, or almost 34 hours per week over five weeks. The level of effort will increase to 0.33 FTE per PLPT, which is 1.0 FTE for the three concurrent performance PLPTs throughout the Provisional and Full PLPTs.[1] The additional effort is needed for more data collection and analysis needed to expand the conditions under which the product is assessed, and for potential algorithm tuning, such as adjusting thresholds.

In addition, tool preparation required 0.3 FTE. This preparation was completed by September 2015, long before the start of the PLPT activities.

4. Tools

The ADP validation effort utilizes a set of two tools: an ABI data processing and display/visualization tool for routine qualitative analysis; and a tool to support quantitative analysis by generating match-up datasets between ADP and CALIPSO Vertical Feature Mask (VFM) and between ADP and AERONET.
These tools are described in more detail in Appendix C.[4]

5. Analysis Methods

During the PLPT analysis, ADP validation will consist of statistical and case-by-case comparisons with aerosol detections from polar orbiter measurements (primarily VIIRS and MODIS) and evaluation of the spatial-temporal distribution of aerosol detections by comparison with historical data. ADP validation using high-resolution reference data (i.e., primary validation) will be initiated during the PLPT Beta testing and get fully underway with the ADP Provisional and Full PLPTs during the program operations phase, after handover to OSPO.

A detailed description of the analysis methods used throughout the ADP validation effort are as follows.[2]

5.1 Routine Analysis

- **Manual Comparison with GOES-R ABI RGB Imagery:** ABI RGB imagery has the same temporal scale as ADP. Visualizations of both will be manually compared to assess plume area consistency for diagnosing issues. Manual inspections will be conducted throughout the Beta evaluation and on a case-by-case basis during the Provisional and Full assessments after handover, such as during specific smoke/dust outbreak cases that warrant investigation. Manual visual inspection will also be used to quality control the reference data. The specific IDL routines used to support this analysis are Visual_AIT_ADP_v5.pro and Visual_ABI_RGB.pro.
- **Comparison with Ground-based Measurements:** The primary method of routine validation will be comparison to ground-based dust/smoke measurements. The analyst will use the IDL quantitative tools to generate match-ups between ABI ADP and AERONET truth data. The IDL tools will generate ADP accuracy statistics in terms of:
    - POCD: calculated as the true positives divided by the sum of true positive and false negatives.
    - POFD: calculated as false positives divided by the sum of true positives and false positives.
- Statistics that are generated on a daily or weekly time scale will be aggregated to generate time series. Time series statistics will be analyzed for systematic behavior or any sudden jumps in data quality and anomalies will be identified for deep dive analysis.
- This metric will be stratified by viewing geometry, surface type, scale of events, and time of day dependence. To the extent possible during Beta PLPTs, cloud contamination, geographic region, and aerosol conditions (boundary layer, aerosols elevated in the free troposphere, and long range transport of aerosols) will also be examined. During the Provisional analysis, the longer period of record enables the PLPTs to cover the various conditions mentioned above more thoroughly to see if the performance has dependency on those conditions. This method will continue to be used throughout the Full analysis to address seasonal variability.
- This methodology was used extensively with MODIS as proxy during algorithm development stages.
- **Comparison with Satellite Data:** during the Beta, Provisional, and Full PLPTs, secondary validation of the ABI aerosol detection product will be accomplished by inter-comparison with validated aerosol detection from other satellites. The routine quantitative validation tools will be used to make automated comparisons described below to generate the same metrics and stratifications as for the ground-based comparisons.
- **GOES-R ABI AOD Model Selection:** since ABI does not have a 0.55um green channel, synthetic ABI RGB images will first be manually compared to both the ADP and AOD product images to see if plume areas are consistent between the two. Then the ABI aerosol detection product will be automatically compared with the aerosol model that the ABI AOD algorithm selected (generic, urban, smoke, or dust) to check if both algorithms are consistent in picking

smoke/dust aerosol. The IDL routine used for this analysis is validating_adp_with_abi_aod.pro.

- **CALIPSO Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) Data:** the most useful information will come from the CALIPSO Vertical Feature Mask (VFM) product that indicates different aerosol types present in the atmosphere. VFM products provide vertical distribution of six aerosol types, including smoke and dust over its narrow (about 5 km) track. This approach was implemented for proxy ABI retrievals for 16 different cases. IDL will be used to routinely generate match up statistics and visualizations, specifically, accuracy_smoke.pro and accuracy_dust.pro.
- **Aerosol Products from MODIS and VIIRS:** the aerosol products containing aerosol type information from other satellites will be used as secondary information in the validation of ADP products. In general, smoke/dust flags from ADP will be displayed side by side with aerosol type and AOD from these satellites to visually inspect for consistency. Quantitative automated comparison will be made between ABI and MODIS and VIIRS. The IDL routines used for this analysis are validating_adp_with_viirs_aod.pro and validating_adp_with_modis_aod.pro.

5.2 Case-by-Case Deep Dive Analysis

When routine analysis indicates an anomaly, the following manual investigations may ensue:

- Identify if the anomaly coincides with an algorithm update, calibration update, or other event through coordination with any upstream product team via the Calibration Working Group (CWG) and Algorithm Working Group (AWG).
- Inspect imagery and channel reflectances/brightness temperature differences using the IDL routine Visual_AIT_ADP_V5.pro.
- Check for issues with Cloud Mask, snow/ice mask using the IDL routine Visual_AIT_ADP_v5_qualityinfor.pro.
- Use validation data to check if anomalies exist in validations. The principle validation data set includes the ABI AOD and ASP products, MODIS aerosol products, and VIIRS aerosol products. The AOD, Aerosol Type, Angstrom Exponent, and other information from those products will be used to check to see if similar anomalies exist. The validation tools related to MODIS, ABI AOD and ASP, and VIIRS data sets to support this aspect of the deep dive analysis include validating_adp_with_modis_aod.pro, validating_adp_with_abi_aod.pro and validating_adp_with_viirs_aod.pro.
- Use ancillary data sources such as aerosol model fields (if available) or human analysis (e.g., Hazard Mapping System, HMS) to see if analysts are observing similar anomalous behavior in retrievals. The IDL routine validating_ADP_with_HMS.pro supports this analysis.

5.3 Lidar Data from Field Campaign Analysis

If Lidar observations from field campaigns are available, the following manual analysis may be conducted.

- Identify the aerosol plume type and height from Lidar observations.
- Inspect imagery covering Lidar observations using the IDL routine Visual_AIT_ADP_V5.pro.
- Check for issues with cloud mask, snow/ice mask using the IDL routine Visual_AIT_ADP_v5_qualityinfor.pro.
- Comparing the smoke/dust mask from ADP with the aerosol type from Lidar observations.

6. Output Artifacts

6.1 Beta Maturity Artifacts

At the completion of the Beta analysis, a report will be prepared containing an initial quantitative assessment, based on a limited data set, of accuracy, POCD, and POFD as a function of: viewing geometry, surface type, scale of events, and time of day. 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_ADP01
- ABI-CONUS_ADP02
- ABI-ABI-MESO_ADP03
- ABI-FD_ADP04
- ABI-CONUS_ADP05
- ABI-MESO_ADP06
- ABI-FD_ADP07
- ABI-CONUS_ADP08
- ABI-FD_ADP09
- ABI-CONUS_ADP10
- ABI-MESO_ADP11

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

6.2 Provisional Maturity Artifacts

At the conclusion of the Provisional stage, results will be presented at a PS-PVR for the same performance metrics results as those provided after the Beta analysis, but based on a longer period and larger range of representative conditions. The conditions and information to be reported for the Provisional assessment include:

- Accuracy, POCD, and POFD as a function of viewing geometry, surface type, scale of events, time of day, cloud contamination, geographic region, and aerosol conditions.
- Quality of the ABI radiances in terms of percentage of good data.
- Cloudiness.
- Quality of the Clear Sky Mask (CSM), in collaboration with the cloud team.
- Internal consistency checks for CSM, snow mask, and fire locations.
- Temporal and spatial consistencies that can point to navigational errors and investigative reports on navigational errors and issues.
- Image comparisons of ABI dust/smoke with RGB images of ABI and polar-orbiting satellites.
- Image comparisons of ABI dust/smoke detections with aerosol model identified by suspended matter/optical depth algorithm.

If the product does not meet the performance specifications, the presentations will address the reason and remediation strategies. Finally, the Provisional presentations will include a summary of user feedback received during the respective validation periods.

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

- ABI-FD_ADP12
- ABI-CONUS_ADP13
- ABI-MESO_ADP14

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

6.3 Full Maturity Artifacts

Artifacts supporting Full maturity are the same as those provided for Provisional. The Full analysis will be an extension of the Provisional analysis, to include seasonally representative conditions. Accuracy, POCD, and POFD will be reported as a function of season, in addition to the other conditions listed above for Provisional.

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_ADP15
- ABI-CONUS_ADP16
- ABI-MESO_ADP17

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

6.4 Key Artifacts

The Beta report and the Provisional and Validated presentations described above constitute the artifacts.

6.5 More Output Artifacts

There are no other artifacts besides those noted in sections 6.1 through 6.4.

6.6 Delivery Schedule

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

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.

8. References

[1] PLPT_VE_List_L2_v1_0_20141022.xlsx.
[2] CV Workshop charts: Application_Team_Validation_ADP_pubu.ppt GOES-R Series Ground Segment.
[3] Project Algorithm Change Management Plan, G416-R-ALGCMP-0285.
[4] L2 Product Validation Tools_05-12-2015.xlsx.
[5] GOES-R Mission Requirements Document (MRD), 410-R-MRD-0070, Version 3.17.

A. Appendix A: Validation Events

A.1 PLPT Events that Support Beta Maturity

A.1.1 ABI-FD_ADP01

Objective: Verify FD products generated every 15 min of the day during aerosol event(s) are within required measurement range.
Start Time: Start of the PLPT period.
Duration: 1 week.
ABI Mode: Mode 3.
GOES-R Data Type(s): ABI Bands 1-7 for 15 min FD.
Beta Success Criteria: Binary yes/no detection of > 0.2 for aerosol optical thickness is qualitatively determined.
Dependencies: ABI L1b product must be Beta maturity.
PLPT Lead: Shobha Kondragunta.
PLPT Analyst: Pubu Ciren; 0.09 FTE.
Comparison/Reference Data: VIIRS, MODIS, GOES-R ABI RGB, GOES-R ABI AOD, CALIPSO, and HMS.
Monitoring & Analysis Method: Manual comparison with GOES-R ABI RGB imagery, comparison with ground-based measurements, and case-by-case deep dive analysis, as described in Section 5.

A.1.2 ABI-CONUS_ADP02

Same as ABI-FD_ADP01 except for:
Objective: Verify CONUS products generated every 15 min of the day during aerosol event(s) are within required measurement range.
GOES-R Data Type(s): ABI Bands 1-7 for 15 min CONUS.

A.1.3 ABI-MESO_ADP03

Same as ABI-FD_ADP01 except for:
Objective: Verify mesoscale products generated every 15 min of the day during aerosol event(s) are within required measurement range.
GOES-R Data Type(s): ABI Bands 1-7 for 15 min mesoscale.

A.1.4 ABI-FD_ADP04

Same as ABI-FD_ADP01 except for:
Objective: Null test to verify that the FD product is generated but smoke/dust flags are null (i.e., negative detection) when no aerosol (smoke/dust) events are occurring.
Beta Success Criteria: Product is generated but smoke/dust flags are null (i.e., negative detection).
Comparison/Reference Data: Combining ABI AOD/ASP product and MODIS/VIIRS aerosol products with NOAA HMS and NOAA Satellite Smoke Text product to ensure no smoke/dust events are occurring. CALIPSO VFM will be used if it is available.
Monitoring & Analysis Method: Routine analysis described in Section 5 in which ADP product is displayed to check if they are null.

A.1.5 ABI-CONUS_ADP05

Same as ABI-FD_ADP04 except for:
Objective: Null test to verify that the CONUS product is generated but smoke/dust flags are null (i.e., negative detection) when no aerosol (smoke/dust) events are occurring.
GOES-R Data Type(s): ABI Bands 1-7 for 15 min CONUS.

A.1.6 ABI-MESO_ADP06

Same as ABI-FD_ADP04 except for:
Objective: Null test to verify that the mesoscale product is generated but smoke/dust flags are null (i.e., negative detection) when no aerosol (smoke/dust) events are occurring.
GOES-R Data Type(s): ABI Bands 1-7 for 15 min mesoscale.

A.1.7 ABI-FD_ADP07

Same as ABI-FD_ADP01 except for:
Objective: When the sensor is in Mode 4, verify the FD product generated every 15 min of the day during aerosol event(s) is within required measurement range.
ABI Mode: Mode 4.

A.1.8 ABI-CONUS_ADP08

Same as ABI-CONUS_ADP04 null test except for:
ABI Mode: Mode 4.

A.1.9 ABI-FD_ADP09

Same as ABI-FD_ADP01 except for:
Objective: Assess performance of the FD product for a very limited number of independent measurements to convey an initial characterization to the user community. This will be a preliminary assessment of how well the GOES-R ADP product is able to generate non-null smoke/dust flags for places where aerosol events occurred in these PLPTs and null smoke/dust flags for places where aerosol event does not exist.
Start Time: At completion of previous eight Beta PLPTs.
Duration: 5 weeks.
Beta Success Criteria: Accuracy, POCD, and POFD is determined based on a limited data set, as a function of viewing geometry, surface type, scale of events, and time of day.
Issues with the product are identified.
PLPT Analyst: Pubu Ciren; 0.28 FTE.
Comparison/Reference Data: AERONET Level 1.5 (L1.5), CALIPSO VFM data, VIIRS aerosol product (daily), MODIS, GOES-R ABI AOD algorithm model selection, GOES-R ABI RGB imagery, and HMS.
Monitoring and Analysis Method: Initial QA during PLPT will include routine statistical and case-by-case comparisons with aerosol detections from polar orbiter measurements (primarily VIIRS and MODIS) and evaluation of the spatial-temporal distribution of aerosol detections by comparison with historical data. Initial validation using high-resolution reference data (i.e., primary validation) will also be carried out.[2]

A.1.10 ABI-CONUS_ADP10

Same as ABI-FD_ADP09 except for:
Objective: Assess performance of the CONUS product for a very limited number of independent measurements to convey an initial characterization to the user community. This will be a preliminary assessment of how well the GOES-R ADP product is able to generate non-null smoke/dust flags for places where aerosol events occurred in these PLPTs and null smoke/dust flags for places where aerosol event does not exist.
GOES-R Data Type(s): ABI Bands 1-7 for 15 min CONUS.

A.1.11 ABI-MESO_ADP11

Same as ABI-FD_ADP09 except for:
Objective: Assess performance of the mesoscale product for a very limited number of independent measurements to convey an initial characterization to the user community. This will be a

preliminary assessment of how well the GOES-R ADP product is able to generate non-null smoke/dust flags for places where aerosol events occurred in these PLPTs and null smoke/dust flags for places where aerosol event does not exist.
GOES-R Data Type(s): ABI Bands 1-7 for 15 min mesoscale.

A.2 PLPT Events that Support Provisional Maturity

A.2.1 ABI-FD_ADP12

Objective: Assess performance of the FD product for an extended period that includes some but not all seasonal variability, to demonstrate operational readiness.
Start Time: at completion of the Beta analysis & start of the mission operational phase.
Duration: 6 months (24 weeks).
Provisional Success Criteria:

- Accuracy, POCD, and POFD are determined as a function of: viewing geometry, surface type, scale of events, time of day, cloud contamination, geographic region, and aerosol conditions. The accuracy specifications are: 80% over land for smoke and dust detection over land, 80% for dust detection over water, and 70% for dust detection of water. The accuracy specifications apply in daytime, out to at least 60 degrees Local Zenith Angle (LZA), and in clear conditions.[5] The specifications do not have to be met to attain Provisional status, however, if they are not met, the reasons for not meeting them must be documented.
- Remediation strategies must be in place for known issues.
- Impacts from challenges with upstream dependencies and feedback from the primary user must be documented.
- Product is ready for potential operational use (user decision) and for use in scientific publications.

Dependencies: ABI L1b must be Provisional maturity.
PLPT Lead: Shobha Kondragunta
PLPT Analyst: Pubu Ciren; 0.33 FTE.
Comparison/Reference Data: AERONET Level 2 (better calibration and cloud screened), if available, otherwise AERONET L1.5, CALIPSO VFM if available, VIIRS aerosol product, MODIS, GOES-R AOD algorithm model selection, GOES-R ABI RGB imagery, and HMS. Field campaign aircraft Lidar data will be used if available.
Monitoring & Analysis Method: Routine comparisons with ground-based data (primary method) and with satellite data (secondary method) will be accomplished. Manual inspections and deep dive analyses will be conducted on a case-by-case basis. Analysis of Lidar data will be accomplished if the data are available.

A.2.2 ABI-CONUS_ADP13

Same as ABI-FD _ASD12 except for:
Objective: Assess performance of the CONUS product for an extended period that includes some but not all seasonal variability, to demonstrate operational readiness.

A.2.3 ABI-MESO_ADP14

Same as ABI-FD _ASD12 except for:
Objective: Assess performance of the mesoscale product for an extended period that includes some but not all seasonal variability, to demonstrate operational readiness.

A.3 PLPT Events that Support Full Maturity

A.3.1 ABI-FD_ADP15

Objective: Assess accuracy, POCD, and POFD of the FD product for an extended period that includes seasonal variability.

Start Time: At the completion of the ADP Provisional assessment, approximately 6 months after handover to operations.

Duration: 9 months (36 weeks).

Full Success Criteria:

- Accuracy, POCD, and POFD are determined as a function of: viewing geometry, surface type, scale of events, time of day, cloud contamination, geographic region, aerosol conditions, and season.
- Product performance meets or is close to meeting accuracy specifications[5] of 80% for smoke and dust detection over land, 80% for dust detection over water, and 70% for dust detection of water. The accuracy specifications apply in daytime, out to at least 60 degrees LZA, and in clear conditions. If the specification 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: ABI L1b must be Provisional maturity.

PLPT Lead: Shobha Kondragunta

PLPT Analyst: Pubu Ciren

Comparison/Reference Data: AERONET Level 2 (better calibration and cloud screened), if available, otherwise AERONET L1.5, CALIPSO VFM if available, VIIRS aerosol product, MODIS, GOES-R AOD algorithm model selection, GOES-R ABI RGB imagery, and HMS. Field campaign aircraft Lidar data will be used if available.

Monitoring & Analysis Method: Routine comparisons with ground-based data (primary method) and with satellite data (secondary method) will be accomplished. Manual inspections and deep dive analyses will be conducted on a case-by-case basis. Analysis of Lidar data will be accomplished if the data are available.

A.3.2 ABI-CONUS_ADP16

Same as ABI-FD _ADP15 except for:

Objective: Assess accuracy, POCD, and POFD of the CONUS product for an extended period that includes seasonal variability.

A.3.3 ABI-MESO_ADP17

Same as ABI-FD _ADP15 except for:

Objective: Assess accuracy, POCD, and POFD of the mesoscale product for an extended period that includes seasonal variability.

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

B.1 Data Set #1: AERONET

Description: Ground-based; AERONET L1.5 and L2 (Ångström Exponent data which indicates the presence of aerosol type: smoke or dust particles) used in routine analysis and L2 AOD for deep dive investigations.
Storage Location: 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. L1.5 data (3 MB) will be accessed daily; scripts are written to automatically look for updates on the availability of data for download. L2 data (3 MB) will be accessed monthly.
Spatial Coverage: 35 sites.
Temporal Coverage: Every 5 minutes.
Contingency: Impact is high, no contingency for this dataset, since no similar high quality ground-based observations are available.

B.2 Data Set #2: CALIPSO VFM

Description: Satellite based; VFM products provide vertical distribution of six aerosol types, including smoke and dust over its narrow (about 5 km) track. To be used in routine analyses.
Storage Location: https://eosweb.gsfc.nasa.gov/HORDERBIN/HTML_Start.cgi; NASA Langley Research Center (LaRC).
Access Process: Data downloaded from NASA LaRC. Scripts will be written to automatically look for updates on the availability of data for download. The daily global data set is 3.6 GB.
This dataset has been used in the validations during algorithm development stages, therefore, the access has been tested.
Spatial Coverage: 5km track, global coverage.
Temporal Coverage: Daily global coverage.
Contingency: Impact is high, as there is no contingency for this dataset, since no similar high quality observations are available.

B.3 Data Set #3: HMS Fire and Smoke Analysis

Description: Satellite based; manually generated product combines all available geostationary and polar-orbiting satellite visible imagery to create a map of fires and smoke. This data set will be used in routine analysis.
Storage Location: NOAA/NESDIS/OSPO product server (http://www.ssd.noaa.gov/).
Access Process: 12 GB file data will be downloaded from web page on a daily basis. The test of the access was done before September 2015.
Spatial & Temporal coverage: Daily.
Contingency: Impact is medium, if not available then GOES APDA and NOAA Satellite Smoke Text product has to be used.

B.4 Data Set #4: NOAA Satellite Smoke Text Product

Description: NOAA Satellite Smoke Text product is a developmental product from NOAA OSPO. It is based on human analysis of satellite images and identifies any event associated with smoke/dust output over the U.S. It is a text file to describe the areas and time of smoke dust out breaks. It will be used as a planned back-up source to check qualitatively if an event identified in the text files is also identified in the ADP product.
Storage Location: NOAA OSPO: http://www.ssd.noaa.gov/PS/FIRE/smoke.html.
Access Process: An alert is received through email. Text files can also be accessed through the website.
Spatial Coverage: On county and state level. Daily CONUS coverage.

Temporal Coverage: Daily CONUS coverage.
Contingency: Impact is low. No contingency for this dataset.

B.5 Data Set #5: SNPP VIIRS

Description: Satellite-based; aerosol product for use in both routine and deep dive statistical and case-by-case comparisons.
Storage Location: Primary source is STAR local machine in College Park. Secondary source is NOAA Comprehensive Large Array-data Stewardship System (CLASS) at http://www.nsof.class.noaa.gov/saa/products/welcome.
Access Process: 139 GB daily data set to be downloaded and stored in STAR local machine in College Park. The access has been tested routinely.
Spatial Coverage: Daily global coverage.
Temporal Coverage: Daily global coverage.
Contingency: Impact is low. If data are not available on local machines, it will have to be obtained from NOAA CLASS or the Atmosphere Science Investigator-led Processing System (SIPS) at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin.

B.6 Data Set #6: MODIS

Description: Satellite based; aerosol product for use in both routine and deep dive statistical and case-by-case comparisons.
Storage Location: http://modis-atmos.gsfc.nasa.gov/MOD04_L2/acquiring.html.
Access Process: Data is automatically downloaded daily from the NASA Distributed Active Archive Center (DAAC). The access has been tested during the algorithm development stage and routinely.
Spatial Coverage: Daily global coverage, 10 km.
Temporal Coverage: Daily global coverage, 10 km.
Contingency: Impact is low. If data are not available on this site, it will be obtained from the Atmosphere SIPS at CIMSS.

B.7 Data Set #7: GOES-R ABI AOD

Description: Satellite based; the GOES-R ABI suspended matter/optical depth algorithm is a multi-channel retrieval algorithm which derives AOD and aerosol model (size distributions) based on minimum residual between observed and calculated spectral reflectances. Four different aerosol models are used (generic, urban, smoke, and dust) to compute reflectances. The aerosol model that gives the minimum residual is picked as the most probable aerosol type present in the atmosphere for that pixel, so the aerosol model selection will be used. The selected model is in the output of the AOD/ASP product.
Storage Location: GOES-R ABI Environmental Satellite Processing and Distribution System (ESPDS) Product Distribution and Access (PDA).
Access Process: Downloaded through File Transfer Protocol (FTP) from GOES-R Access Subsystem (GAS) interface.
Spatial Coverage: FD, daily.
Temporal Coverage: Every 15 minutes, daily.
Contingency: Impact is low; no contingency for this dataset.

B.8 Data Set #8: GOES-R ABI RGB Imagery

Description: Satellite based; GOES-R RGB imagery product is developed by GOES-R Imagery working group. It will be used to visually identify smoke/dust events and compare with ADP product outputs.
Storage Location: GOES-R ABI ESPDS PDA.

Access Process: Downloaded through File Transfer Protocol (FTP) from GOES-R Access Subsystem (GAS) interface
Spatial Coverage: FD, daily.
Temporal Coverage: Every 15 minutes, daily.
Contingency: Impact is low. If this data set is not available, RGB imagery from VIIRS or MODIS can be used.

B.9 Data Set #9: Airborne Lidar Data

Description: The GOES-R field campaign will consist of measurements of aerosol backscatter vertical profile and aerosol type from a Cloud Physics Lidar (CPL) on an aircraft. These data are expected to be similar to CALIPSO.
Storage Location: TBD.
Access Process: TBD.
Spatial Coverage: TBD.
Temporal Coverage: TBD.
Contingency: None.

C. Appendix C: Tools

C.1 Tool #1: ABI Data Processing and Display - Qualitative Validation/Visualization Tools

Location: STAR computers in College Park.

Description: ABI Data Processing and Display tool suite includes the following IDL routines developed in house to process and display ABI ADP products for routine analysis:
Visual_AIT_ADP_v5.pro.
Visual_AIT_ADP_v5_confidence.pro.
These tools extract the required parameters (smoke/dust flags and confidence level flags), and display the corresponding parameters in projected maps.
To support deep dive analysis, IDL routines are used to display all ADP quality flags to identify issues with algorithm dependency variables such as cloud mask, snow/ice mask, fire mask, etc.

Developer: Pubu Ciren.

Development Schedule: Codes have been developed and were finalized in September 2015.

Data Dependencies: GOES-R ABI ADP product.

POC: Pubu Ciren.

Testing Accomplished or Planned: The developed tools have been extensively tested during the algorithm development and validation stages on ABI proxy data, such as MODIS, and simulated proxy data. Initial testing with the first delivery of DOE ABI test data, that includes diagnostic data, has been carried out. However, some information such as geolocation was missing in the first version of DOE test data. Complete testing will be carried out pre-launch when the next version of DOE test data becomes available.

C.2 Tool #2: IDL Quantitative Validation Tools

Location: STAR College Park.

Description: To support routine quantitative analysis, IDL routines perform the following functions:

- Generate match-up dataset between ADP and VFM along CALIPSO track, spatially (5 by 5 km) and temporally (coincident) and visualize vertical distribution of VFM and horizontal distribution of both ADP and VFM.
- Generate matchup data set between ADP and AERONET in both space (50 by 50 km) and time (±30 minutes), visualize the match-up dataset, and generate statistics matrices.

The specific routines used for quantitative validation are:

- For AERONET:
  - extract_adp_over_aeronet.pro.
  - combine_aeronet_detetcion.pro.
  - statistics_smoke.pro.
  - statistics_dust.pro.
- For CALIPSO:
  - adp_calipso_match_1kmbox.pro.
  - accuracy_smoke.pro.
  - accuracy_dust.pro.
- For Lidar, the match-up software will essentially be the same except the routines used to read the Lidar data will be obtained from the field campaign.

Developer: Commercial Off-The-Shelf (COTS) adapted by Pubu Ciren.

Development Schedule: N/A; COTS.

Data Dependencies: The quantitative validation tools will use ADP against CALIPSO VFM, AERONET AOD and Angstrom Exponent, and MODIS and JPSS VIIRS aerosol products to display for manual assessment and/or statistical comparison (i.e., derive accuracy, POCD, and POFD). HMS is intended to be used to compare area locations and coverage between polygons

derived from ADP smoke detection and smoke polygons from the HMS smoke product. The GOES-R field campaign will consist of measurements of aerosol backscatter vertical profile and aerosol type from a CPL on an aircraft. These data are expected to be similar to CALIPSO and will be used if available during the Provisional and Full assessments.
Testing Accomplished or Planned: The developed code has been tested on all above-mentioned datasets.
POC: Pubu Ciren.

D. Appendix D: Acronym List

Acronym	Definition
ABI	Advanced Baseline Imager
ADP	Aerosol Detection Product
AERONET	Aerosol Robotic Network
AOD	Aerosol Optical Depth
APDA	Atmospheric Pre-corrected Differential Absorption
AWG	Algorithm Working Group
Cal/Val	Calibration and Validation
CALIOP	Cloud-Aerosol Lidar with Orthogonal Polarization
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CCR	Configuration Change Request
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CLASS	Comprehensive Large Array-data Stewardship System
CMI	Cloud and Moisture Imagery
CONUS	Continental United States
COTS	Commercial Off-The-Shelf
CPL	Cloud Physics Lidar
CSM	Clear-Sky Mask
CWG	Calibration Working Group
DOE	Data Operations Exercise
ESPDS	Environmental Satellite Processing and Distribution System
FD	Full Disk
FTE	Full-Time Equivalent
FTP	File Transfer Protocol
F&PS	Functional & Performance Specification
GAS	GOES-R Access Subsystem
GOES	Geostationary Operational Environmental Satellite
GOES-R	GOES R-Series
GORWG	GOES-R Series Operational Requirements Working Group
GRB	GOES Rebroadcast
HMS	Hazard Mapping System
HRR	Handover Readiness Review
IDL	Interface Definition Language
JPSS	Joint Polar Satellite System
L1.5	Level 1.5
L1b	Level 1b
L2	Level 2
LaRC	Langley Research Center
LZA	Local Zenith Angle

Acronym	Definition
MODIS	Moderate Resolution Imaging Spectroradiometer
MOST	Mission Operations Support Team
MRD	Mission Requirements Document
MRS	Mission Requirements Specification
MSFC	Marshall Space Flight Center
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NCEI	National Centers for Environmental Information
NCEI-CO	NCEI - Colorado
NESDIS	National Environmental Satellite, Data, and Information Service
NLT	No Later Than
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
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
POCD	Probability of Correct Detection
POFD	Probability of False Detection
PRO	Product Readiness and Operations
PSE	Program System Engineering
PDA	Product Distribution and Access
PS-PVR	Peer Stakeholder-Product Validation Review
PUG	Product User's Guide
QA	Quality Assurance
RGB	Red/Green/Blue
RIMP	Readiness, Implementation and Management Plan
SIPS	Science Investigator-led Processing System
SPOT	System Performance Operational Test
STAR	Center for Satellite Applications and Research
TBD	To Be Determined
VE	Validation Events
VFM	Vertical Feature Mask
VIIRS	Visible Infrared Imaging Radiometer Suite