
# Geostationary Operational Environmental Satellite (GOES) – R Series

## ABI L2+ Volcanic Ash
## Beta, Provisional and Full Validation Readiness, Implementation and Management Plan (RIMP)

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# ABI L2+ Volcanic Ash
# 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.

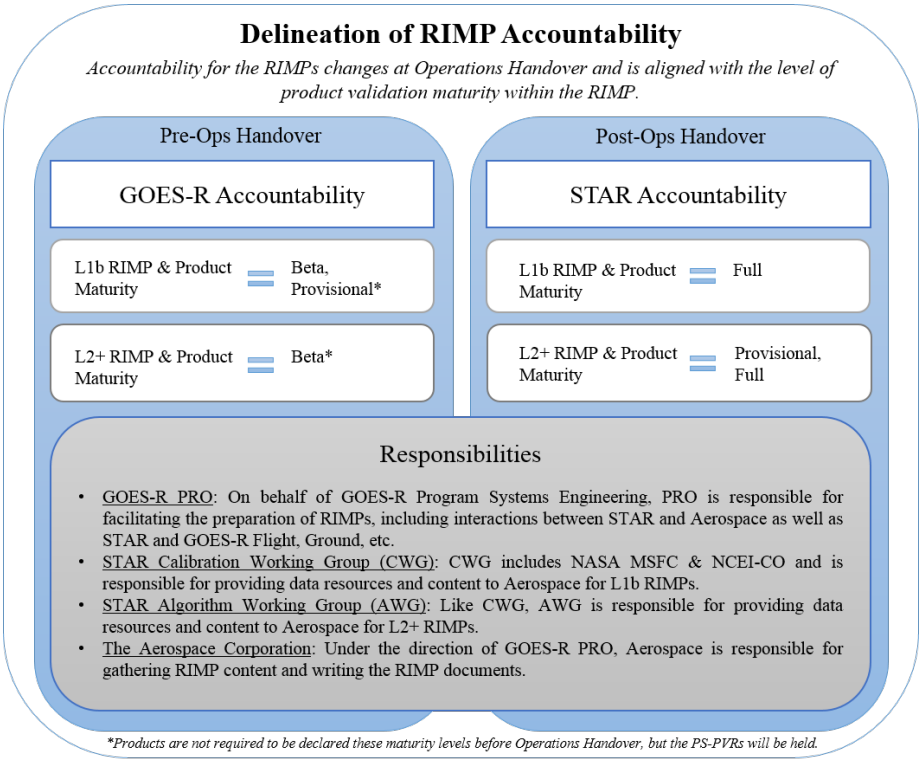


Figure 2. Delineation of accountability between GOES-R and STAR.

# 1. Volcanic Ash Validation Overview

This Readiness, Implementation, and Management Plan (RIMP) covers all validation stages for the Volcanic Ash product. There are three stages in the validation process, Beta, Provisional, and Full. Each stage is defined by tests which guide the overall validation process. This RIMP includes a summary of the methods and tools employed to prove Volcanic Ash has met a given validation stage. Appendices are included that present more detail on each applicable test and details on the different data sets employed in the Volcanic Ash validation process.

The Volcanic Ash product is only created from the Full Disk (FD) scan type. The product is created independent of any actual presence of a volcanic eruption. If there are no ongoing volcanic events of significance, the confidence is generally labeled as "low" or "medium" via quality flags. Therefore validation will occur, and indeed is necessary, whether or not a volcanic event is taking place. Feedback from users is via the Peer Stakeholder-Product Validation Review (PS-PVR) process, but there is also ongoing interactions between the volcanic ash team and Volcanic Ash Advisory Centers. The volcanic ash validation effort has no dependencies on any field campaign or the need for data from a North/South (N/S) scan.

Five PLPTs have been defined to attain Beta maturity for the Volcanic Ash product. There are two sets of two tests tied to the production and cadence of the product. The two sets are for Modes 3 and 4, while the tests themselves cover both format and output. The fifth test gets to the critical analysis of performance, which is to be assessed sufficiently to convey to the user community the capabilities of this product. The Volcanic Ash product is only produced for a FD.[1,2,11] PLPT events that support Beta maturity are listed below; details are in Appendix A: [1]

- **ABI-FD_VAH01** – Inspect the Volcanic Ash product such that all aspects of the product, including metadata and diagnostics, are formatted correctly in Mode 3.
- **ABI-FD_VAH02** – Verify the Volcanic Ash confidence is generally low (via quality flags) for every 15 minutes of the day for every Full Disk (FD) when no volcanic ash events are occurring (Mode 3).
- **ABI-FD_VAH03** – Inspect the Volcanic Ash product such that all aspects of the product, including metadata and diagnostics, are formatted correctly in Mode 4.
- **ABI-FD_VAH04** – Verify the Volcanic Ash confidence is generally low (via quality flags) for every 15 minutes of the day for every Full Disk (FD) when no volcanic ash events are occurring (Mode 4).
- **ABI-FD_VAH05** – Provide an early assessment of the Volcanic Ash product focusing on assessing and characterizing product accuracy and precision that needs to be conveyed to the user community.

The following Table identifies the frequency of each scan type for Modes 3 and 4. It includes the required cadence of the volcanic ash 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. Any validation that occurs will use the frequency of the operational output, as indicated in the Table.

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

| Mode | Mode 3 | | | Mode 4 | | |
|---|---|---|---|---|---|---|
| Scan Type | FD | CONUS | Mesoscale | FD | CONUS | Mesoscale |
| Scan Freq | 15 min | 5 min | 30 sec | 5 min | 5 min* | N/A |

| | | | | | | |
|---|---|---|---|---|---|---|
| F&PS | 15 min | N/A | N/A | 15 min | N/A | N/A |
| PUG | 15 min | N/A | N/A | 15 min | N/A | N/A |
| Verif Freq | 15 min | N/A | N/A | 15 min | N/A | N/A |

Table 1. Volcanic Ash product and verification cadence.

There is only one PLPT for Volcanic Ash to attain Provisional maturity. To declare Provisional maturity, this event must validate that the quality of the Volcanic Ash has been assessed sufficiently to characterize the product to the user community, though more cases and analysis would be expected for Provisional. The Provisional PLPT lasts approximately 34 weeks and commences immediately after Beta has been attained.[1,2] The PLPT event that supports Provisional maturity are listed below; details are in Appendix A[1]:

- **ABI-FD_VAH06 -** Assess the accuracy and precision of the Volcanic Ash product over a large and wide range of representative conditions.

The criteria by which the GOES-R Volcanic Ash product will be evaluated to determine if Provisional maturity has been met are: 1. Assess the accuracy and precision of the Volcanic Ash product over a wide range of representative conditions. 2. Document feedback from the primary user (NWS). 3. Horizontal resolution, vertical resolution, mapping accuracy, and measurement range.

Accuracy and precision do not have to be met to attain Provisional status; however, if they do not do so, the reasons behind not meeting these requirements must be documented, to include reporting of incidents/issues as an Algorithm Discrepancy Report (ADR) for discussion at the Algorithm Action Review Team (AART). Remediation strategies should be in place for known issues. Product is ready for potential operational use (user decision) and for use in scientific publications.

Moving to the final stage of validation, Full maturity, the Volcanic Ash product must now be shown to meet all requirements. Because the number of Volcanic Ash events can vary wildly from one year to the next, and have no seasonal dependence, the schedule reflects the need for Volcanic Ash to use the entire allocated cal/val period. However, even if a large scale event does not occur, moderate scale events are sufficient by themselves to validate the volcanic ash product, and these are common over Latin America. Besides those requirements proven in the Provisional stage, Full maturity must include meeting measurement accuracy and measurement precision requirements. The methods and tools necessary to prove the Full stage are the same as those for proving Provisional. The PLPT event that supports Full maturity are listed below; details are in Appendix A: [1]

- **ABI-FD_VAH07** - Assess the accuracy and precision of the Volcanic Ash product over a large and wide range of representative conditions sufficient to verify all Volcanic Ash requirements.

The conditions for achieving the Provisional hold for achieving Full, plus the conditions described below:

- The requirements for measurement accuracy and precision must be met.
- Proving the adequacy of the Volcanic Ash product must consider at least some real volcanic ash cases, and not rely solely on dust as a proxy (see method #1).

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

The Volcanic Ash product at handover is to be, at a minimum, at the Beta stage of verification. For Volcanic Ash, Beta is defined as the Volcanic Ash product being quantitatively analyzed over a limited data set with any shortfalls properly documented.[1,2]

# 2. Schedule of Events

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

The GOES-R Operations phase begins after handover, marking the start of a 12 month Extended Validation period for ABI L1B and CMI, which is coincident with the start of the 6 month L2 Provisional evaluation, followed by another nine month period for the L2 product to reach Full maturity, 15 months after Handover. Volcanic Ash validation is expected to require the entire allocated period.

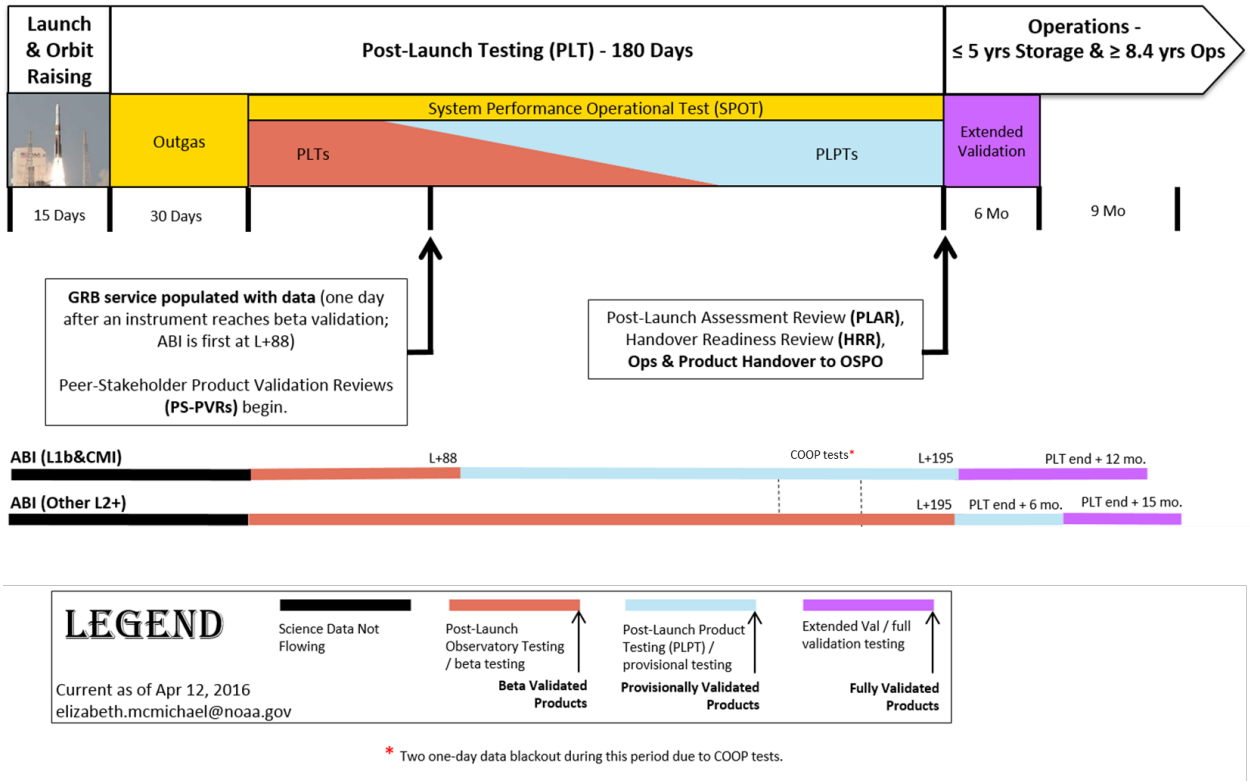


Figure 3. Schedule of events.

A schedule of specific Volcanic Ash activities includes:

- Current – Dec 2015: Finish testing all Volcanic Ash validation tools.
- Current – June 2016: Evaluate results using data from DOE 3/4.
- Dec 2015: Deliver final version of all Volcanic Ash validation tools.
- Current – Oct 2016: Test and evaluate algorithm with Himawari 8 data.
- L+70 days: Begin Volcanic Ash Beta cal/val activities.
- L+77 days: Complete verification of cadence requirements (OSPO).
- L+197 days: Complete beta validation activities.
- L+337 days: Complete Provisional phase of validation.
- L+647 days: Complete all phases of Volcanic Ash validation.

Other aspects related to schedule include:

- The initial Beta testing will focus on Volcanic Ash being produced at the proper cadence and format for the FD Volcanic Ash product in Mode 3.[1]
- The initial Beta testing includes verifying that the Volcanic Ash product is also produced at the proper cadence and format for FD in Mode 4.[1]
- There is a reasonable probability no significant volcanic ash event will occur during PLPT; however the two PLPTs that verify low confidence when there is no applicable volcanic occurrence may still be verified.[1,11]
- Because volcanic eruptions are relatively rare events, the opportunity to validate the Volcanic Ash product takes precedence over other L2 products except Imagery during PLPT.[7]
- The number of significant ash events during the Provisional phase may lead to the Provisional phase completing earlier than scheduled.
- Dust events will be used as proxy for volcanic ash during PLPT to assist in proving Beta has been achieved if no significant volcanic ash event occurs in the GOES-R coverage area during PLPT.[11]

# 3. Roles and Responsibilities

### 3.1 Primary Point of Contact

The primary point of contact for managing the Volcanic Ash product and coordinating algorithm updates is Dr. Mike Pavolonis.[1,6,7]

### 3.2 GOES-R Point of Contact

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

### 3.3 Test Analyst/Engineer

Justin Sieglaff and Jason Brunner are the primary test analysts.

### 3.4 GOES-R Feedback

Formal feedback to the GOES-R Program regarding the Volcanic Ash validation will be provided by Dr. Mike Pavolonis.

### 3.5 Level of Effort

Mike Pavolonis will work the Volcanic Ash effort at 0.25 FTE during all validation phases, while both test analysts will work at a 0.5 FTE rate.

# 4. Tools

For this product, we plan to use the tool GEOCAT ACTIVE, which is described in Appendix C. This tool encompasses all of the processes needed to validate Volcanic Ash.

# 5. Analysis Methods

The following analysis methods will be used for validation efforts:

**Method 1:** Quantitative comparisons with "truth" data.[1,6,7]

- Volcanic ash results will be compared to CALIPSO if the opportunity occurs.[1,6,7]
- This heritage method has been used with volcanic ash algorithms for many years, and is a proven technique.[2,7]
- The GEOCAT ACTIVE tool will collocate CALIPSO and GOES-R volcanic ash products and will generate the primary statistical basis to determine if Beta or Provisional status has been achieved if significant eruptions occur and related CALIPSO data is available.[6,7,10]
- The requirements for Volcanic Ash will be assessed for range, accuracy, and precision as specified in the requirements document.[1,3,11]
- Assessments of mapping accuracy, refresh, and refresh rate will be coordinated with the L1b team and the ground system, as these requirements are not science based.[3]
- If no substantial volcanic ash event occurs during PLPT, dust will be used as a proxy for volcanic ash (primarily for Beta and Provisional stages).[11]

**Method 2:** Quantitative comparisons with derived Volcanic Ash parameters based on computations combined from other sensors.[1,6,7]

- Volcanic ash parameters such as mass loading have been calculated using lidar-based boundaries.[6]
- Cloud optical depth spectra are determined from the list above, from which a "truth" mass loading may be derived.[6]
- Quantitative comparisons are made between the GOES-R Volcanic Ash parameters and the derived "truth" to provide additional quantitative validation data.[6]
- Significant differences indicate issues on a larger scale not possible with available truth data noted above.[6,7]
- Displays of the Volcanic Ash derived parameters will be placed side-by-side with the matching GOES-R locations to note if any large disparities are observed in the GOES-R Volcanic Ash product.[6,7]

**Method 3:** Qualitative comparisons with volcanic ash output derived from other weather satellites.[1,6,7]

- The same algorithm intended to produce Volcanic Ash for GOES-R is already in place to execute on other weather satellites such as SEVIRI and MODIS.[1,6,7]
- As volcanic events occur, simultaneous overpasses from polar-orbiting satellites may be used to qualitatively compare those results with the GOES-R Volcanic Ash product.[6,7]
- Since these other volcanic ash products are still undergoing some measure of quantitative verification themselves, these comparisons may only be used as a qualitative output for GOES-R.[1,6]
- This method is dependent on a significant volcanic ash occurring in the GOES-R coverage area that coincides with a simultaneous measurement from another appropriate weather satellite sensor.
- AHI assessments will be utilized to supplement ABI assessments of the accuracy of the GOES-R Volcanic Ash products.

# 6. Output Artifacts

## 6.1 Beta Maturity Artifacts

The two criteria for declaring Beta Validation are: (1) Quantitatively assess the performance of the GOES-R Volcanic Ash product with a limited set of data; and (2) Identify any issues with the Volcanic Ash product. Range, accuracy, and precision performance and product issues will be documented in a Beta test report. The primary method to evaluate Volcanic Ash is match-up data with sensors of sufficient quality to be considered "truth", via the methods in section 5.[1,6,7]

Key artifacts will be the presentation of the statistical accuracy of the Volcanic Ash output as derived from comparisons to CALIPSO.[2,7] Statistics will be derived which compare the results of the GOES-R Volcanic Ash with those derived from Low-Earth Orbiting (LEO) satellites, especially MODIS.[6,7,11] Displays of the GOES-R Volcanic Ash will be displayed side-by-side with collocated volcanic ash output from other weather satellites to show consistency in the output.[1,7] GOES-R output will also be shown with the derived "truth" output as described in section 4.[1,6,7]

If no significant events of volcanic ash occur over the GOES-R coverage area over the PLPT period, dust will be used in lieu of volcanic ash to provide appropriate insight into the Volcanic Ash product.[11]

**6.1.1** These tests of priority 1 all must pass in order to achieve Beta maturity, all tests are considered priority 1.

**6.1.2** The Volcanic Ash Beta maturity validation effort does not include any tests of priority 2.

## 6.2 Provisional Maturity Artifacts

The report covering Provisional Validation will use artifacts from all three methods described in Section 5 with additional data sets since the completion of Beta.

**6.2.1** These tests of priority 1 all must pass in order to achieve Provisional maturity, all tests are considered priority 1.

**6.2.2** The Volcanic Ash Provisional maturity validation effort does not include any tests of priority 2.

## 6.3 Full Validation Maturity Artifacts

The report covering Full Validation will use artifacts from all three methods described in Section 5, with additional data sets since the completion of Provisional.

**6.3.1** These tests of priority 1 all must pass in order to achieve Full Validations maturity, all tests are considered priority 1.

**6.3.2** The Volcanic Ash Full maturity validation effort does not include any tests of priority 2.

## 6.4 Key Artifacts

The single key artifact for the Volcanic Ash validation effort is the statistical analysis of the accuracy as derived from comparisons with CALIPSO. This will be included, with additional data sets as the validation effort progresses, in association with the PS-PVRs.

## 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 Volcanic Ash validation is tied to the schedule for completing beta, provisional, and full validation as given 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

The only pre-launch verification of the Volcanic Ash product was to ensure the format and data content is correct.[2,4] Pre-launch work has exercised the ability to recreate the Volcanic Ash algorithm using SEVIRI, MODIS, and VIIRS. [6,7] Examples based on this proxy data also gave confidence to the tools intended for GOES-R Volcanic Ash analysis.[6,7] Output from either or both of DOE 3/4 was also used to verify Imagery tools work with the appropriate outputs, including any necessary diagnostics.[11,14] Data flows in the pre-launch period were through STAR.[11]

# 8. References

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

[1] Verification Event (VE) spreadsheet. (PLPT_Validation_Event_List_L2_v0_1_20140903_with_Post-PLT_Entries)
[2] GOES-R Series Calibration/Validation Plan Volume 2: Level 2+ Product Validation.
[3] GOES-R Series Mission Requirements Document.
[4] GOES-R Series System – Level Calibration and Product Measurement Validation Concept of Operations (CONOPS) and Operational Concepts (OPSCON).
[5] GOES-R Post-Launch Product Testing Overview February 3, 2105.
[6] GOES-R AWG Product Validation Tool Development, Aviation Application Team – Volcanic Ash; 1st GOES-R Validation Workshop, May 10, 2011.
[7] AWG Volcanic Ash Products, 2nd GOES-R Validation Workshop, January 9, 2014.
[8] http://www-calipso.larc.nasa.gov/about/payload.php (CALIOP sensor).
[9] Spreadsheet containing VE Leads and VE Analysts (L2 Products POCs).
[10] Developing a Product Validation and Merged JPSS/GOES-R System Using Advanced Collocation Methods, 2nd GOES-R Validation Workshop, January 9, 2014.
[11] Interview with Mike Pavolonis, June 3, 2015.
[12] Interview with Cloud Product Team, June 2, 2015.
[13] http://www.nasa.gov/mission_pages/station/research/experiments/1037.html (CATS).
[14] Program Science Readiness Meeting 06022015.
[15] Pavolonis, M.J., A.K. Heidinger, and J. Sieglaff, 2013, Automated retrievals of volcanic ash and dust cloud properties from upwelling infrared measurements, J. of Geoph. Res. Atmos., 118, pp. 1436 – 1458.
[16] GOES-R Field Campaign, NOAA Satellite Science Week, February, 2015.
[17] GOES-R Field Campaign Preparation, October 26, 2015.

# A. Appendix A: Validation Events

## A.1 PLPT Events that Support Beta Maturity

### A.1.1 Event Name: ABI-FD_VAH01[1]

**Objective**: Inspect Volcanic Ash product such that all aspects of the product, including metadata and diagnostics, are formatted correctly in Mode 3.[1,3]
**Start Time:** Start of PLPT.[1]
**Duration:** 1 week.[1]
**ABI Mode**: 3.[1]
**GOES-R Data Type(s):** 15 minute FD Volcanic Ash.[3]
**Beta Success Criteria**: Product generated and falls within expected measurement range; for this test that means the product contains all necessary metadata and diagnostics and is produced at the proper cadence.[1,3]
**Dependencies:** The Volcanic Ash product must be created by the ground system. Delivery of such product to the validation team must be sufficient to keep up with the cadence of the FD cadence. A volcano must be active in the GOES-R field of view.[1,4]
**PLPT Lead**: PRO.[11]
**PLPT Analyst**: PRO.[11]
**Validation Data:** B.1.
**Procedural References:** None (quality assessed in a different test)[1]
**Comparison/Reference Data:** None (quality assessed in a different test)[1]
**Monitoring & Analysis Method**: Product Inspection; either the Volcanic Ash product is created at the correct cadence and in the right format or it is not.[1,3]

### A.1.2 Event Name: ABI-FD_VAH02[1]

**Objective:** Verify the Volcanic Ash product is generally evaluated as low confidence when no significant volcanic ash exists in the GOES-R coverage area.[1]
**Start Time:** Start of PLPT.[1]
**Duration:** 1 week.[1]
**ABI Mode**: 3.[1]
**GOES-R Data Type(s):** 15 minute FD Volcanic Ash.[3]
**Beta Success Criteria**: Product is low confidence while there are no significant volcanic ash events.[1,3]
**Dependencies:** There must be no significant volcanic ash events ongoing for this test to be verified.[1]
**PLPT Lead**: Mike Pavolonis.[5,6,7]
**PLPT Analyst**: Justin Sieglaff and Jason Brunner.[11]
**Validation Data:** B.1.
**Procedural References:** Section 5, method #3.
**Comparison/Reference Data:** None (quality assessed in a different test).[1]
**Monitoring & Analysis Method**: Product Inspection; either the Volcanic Ash product is properly low confidence or it is not.[1,3]

### A.1.3 Event Name: ABI-FD_VAH03

Same as for ABI-FD_VAH01 except for:
**ABI Mode:** 4.[1]

### A.1.4 Event Name: ABI-FD_VAH04

Same as for ABI-FD_VAH02 except for:

**ABI Mode:** 4.1

### A.1.5 Event Name: ABI-FD_VAH05

**Objective**: Assess the initial accuracy and precision of the Volcanic Ash product sufficient to convey an initial characterization to the user community.1 Determine the Volcanic Ash product meets the Mission Requirements Document (MRD) product specification over a very limited number of independent measurements, to generally include a low confidence result if no significant volcanic event is underway.[1]
**Start Time:** Start of PLPT.[1]
**Duration:** 30 days.[1]
**ABI Mode**: 3.[1]
**GOES-R Data Type(s):** 15 minute FD Volcanic Ash.[1]
**Beta Success Criteria**: The FD/Hemispheric Volcanic Ash product is quantitatively assessed for a limited set of independent measurements, and any shortfalls are properly documented.[1,2,6,7]
**Dependencies:** That the Volcanic Ash product is created by the ground system and delivery of such products to the validation team is sufficient to keep up with the cadence of FD/Hemispheric Volcanic Ash output, and there is a significant volcanic ash event in the GOES-R field of view.[1,3]
**PLPT Lead**: Mike Pavolonis.[6,7]
**PLPT Analyst**: Justin Sieglaff and Jason Brunner.[12]
**Validation Data:** Overlapping data from CALIPSO, comparisons with volcanic ash products derived from other weather sensors, and comparisons with derived volcanic ash parameters from lidar input.[1,6,7,11]
**Procedural References:** Section 5, methods 1, 2, and 3.
**Comparison/Reference Data:** B.1, B.2, B.3, B.4.
**Monitoring & Analysis Method**: Derive statistics using the match-up data as truth, and produce comparative statistics with volcanic ash products generated over the same area as GOES-R but derived from MODIS and VIIRS; if no significant volcanic ash event occurs than use dust as a proxy for volcanic ash.[1,6,7,11]

## A.2 PLPT Events that Support Provisional Maturity

### A.2.1 Event Name: ABI-FD _VAH06[1]

**Objective**: Assess the accuracy and precision of the Volcanic Ash product over a large and wide range of representative conditions sufficient to validate to the user community the extent to which the Volcanic Ash product are operationally applicable.[1]
**Start Time:** Immediately following PLT.[1]
**Duration:** 4 months.[1]
**ABI Mode**: 3 and 4.[1]
**GOES-R Data Type(s):** 15 minute FD Volcanic Ash.[1]
**Provisional Success Criteria**: The FD Volcanic Ash product meets its quantitative requirements for a limited/seasonal set of independent measurements. The results must be sufficient to inform users of the status and capabilities of the Volcanic Ash product.[1,2,6,7]
**Dependencies:** The Volcanic Ash product has reached the Beta level of maturity.[1,2,4]
**PLPT Lead**: Mike Pavolonis.[1,6,7]
**PLPT Analyst**: Justin Sieglaff and Jason Brunner.[11]
**Validation Data:** Overlapping data from CALIPSO, comparisons with volcanic ash products derived from other weather sensors, and comparisons with derived volcanic ash parameters from lidars.[1,6,7]
**Procedural References:** Section 5, methods 1, 2, and 3.
**Comparison/Reference Data:** B.1, B.2, B.3, B.4.

**Monitoring & Analysis Method**: Derive statistics using the match-up data as truth, and produce comparative statistics with volcanic ash products generated over the same area as GOES-R but derived from GOES and MODIS.[1,6,7]

## A.3 PLPT Events that Support Full Maturity

### A.3.1 Event Name: ABI-FD _VAH07[1]

**Objective**: Assess the accuracy and precision of the Volcanic Ash product over a large and wide range of representative conditions sufficient to validate all requirements tied to Volcanic Ash.[1]
**Start Time:** Immediately following provisional.[1]
**Duration:** 1 year.[1]
**ABI Mode**: 3 and 4.[1]
**GOES-R Data Type(s):** 15 minute FD Volcanic Ash.[1]
**Full Validation Success Criteria**: The FD Volcanic Ash product meets its quantitative requirements. The results must be sufficient to inform users of the status and capabilities of the Volcanic Ash product across a reasonable range of events.[1,2,6,7]
**Dependencies:** The Volcanic Ash product has reached the Provisional level of maturity.[1,2,4]
**PLPT Lead**: Mike Pavolonis.[1,6,7]
**PLPT Analyst**: Justin Sieglaff and Jason Brunner.[11]
**Validation Data:** Overlapping data from CALIPSO, comparisons with volcanic ash products derived from other weather sensors, and comparisons with derived volcanic ash parameters from lidars.[1,6,7]
**Procedural References:** Section 5, methods 1, 2, and 3
**Comparison/Reference Data:** B.1, B.2, B.3, B.4.
**Monitoring & Analysis Method**: Derive statistics using the match-up data as truth, and produce comparative statistics with volcanic ash products generated over the same area as GOES-R but derived from GOES and MODIS.[1,6,7]

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

**B.1 Data Set 1: Name: ABI-L2-VAAF-M3[3]**
**Storage Location**: CIMSS Data Center.[12]
**Access Process**: Product Distribution & Access (PDA) or STAR.[4,11]
**POC:** Jerald Robaidek.[12]
**Spatial Coverage:** Any volcanic ash event in the GOES-R field of view.[1,3]
**Temporal Coverage:** 15 minute FD.[1,3]
**Contingency:** None, this is the product the team must validate; there is no validation without the core product.
**Special Considerations:** None.

**B.2 Data Set 2: Name: CALIPSO[1,6,7]**
**Storage Location**: Science Investigator-led Processing System (SIPS).[12]
**Access Process**: Public internet.[12]
**POC:** Liam Gumley.[12]
**Spatial Coverage:** 333 meters horizontally, 30-60 meters vertically.[8]
**Temporal Coverage:** Not applicable.
**Contingency:** If Cloud Aerosol Transport System (CATS) data is available, then it is capable of replacing CALIPSO. Should CALIPSO become unavailable after the launch of GOES-R, then CATS data will be used instead.[2,11]
**Special Considerations:** The CALIOP sensor on CALIPSO measures clouds and aerosols via lidar, and as such also detects volcanic ash very well; CATS is currently under evaluation on the International Space Station.[8,12,13]

**B.3 Data Set 3: Name: MODIS L1B product[1]**
**Storage Location:** SIPS.[12]
**Access Process:** Public internet.[12]
**POC:** Liam Gumley.[12]
**Spatial Coverage:** GOES coverage area.[1,2]
**Temporal Coverage:** Collocated with GOES-R observations of a volcanic event.[6,7]
**Contingency:** Use the other available volcanic ash products from other weather satellites.[1,7]
**Special Considerations:** GEOCAT ACTIVE is capable of executing matching volcanic ash algorithms on a number of sensors, including MODIS. This will be the source for obtaining the input necessary to compute the MODIS-based volcanic ash product.[6,11]

**B.4 Data Set 4: Name: VIIRS SDRs[1]**
**Storage Location:** SIPS.[12]
**Access Process:** Public internet.[12]
**POC:** Liam Gumley.[12]
**Spatial Coverage:** GOES coverage area.[1,2]
**Temporal Coverage:** Collocated with GOES-R observations of a volcanic event.[6,7]
**Contingency:** Use the other available volcanic ash products from other weather satellites.[1,7]
**Special Considerations:** GEOCAT ACTIVE is capable of executing matching volcanic ash algorithms on a number of sensors, including VIIRS. This will be the source for obtaining the input necessary to compute the VIIRS-based volcanic ash product.[6,11]

**B.5 Data Set 5: Name: GOES L1B[1]**
**Storage Location:** SIPS.[12]
**Access Process:** Public internet.[12]

**POC:** Liam Gumley.[12]
**Spatial Coverage:** GOES coverage area.[1,2]
**Temporal Coverage:** Collocated with GOES-R observations of a volcanic event.[6,7]
**Contingency:** Use the other available volcanic ash products from other weather satellites.[1,7]
Special Considerations: GEOCAT ACTIVE is capable of executing matching volcanic ash algorithms on a number of sensors, including GOES. This will be the source for obtaining the input necessary to compute the GOES-based volcanic ash product.[6,11]

**B.6 Data Set 6: Name: Cloud Aerosol Transport System (CATS)[13]**
**Storage Location:** SIPS.[12]
**Access Process:** Public internet.[13]
**POC:** Mathew McGill[12]
**Spatial Coverage**: GOES coverage area.[1,2]
**Temporal Coverage:** Collocated with GOES-R observations of a volcanic event.[6,7]
**Contingency:** Use the other available volcanic ash products derived from other weather sensors.[1,7]
Special Considerations: CATS is a lidar with capabilities similar to CALIOP, but the sensor is still under evaluation. It is intended to be a mitigation if CALIOP is not available during PLPT. Access to CATS data is freely available on the web at http://cats.gsfc.nasa.gov/data/.[6,10,12]

**B.7 Field Campaign Data**
**Source:** Certain candidate instruments have the potential to measure characteristics of volcanic ash, if such an event occurred near the field campaign.[16]
**Access Process:** TBD
**POC:** Francis Padula.
**Frequency of transmission:** Not applicable, any field campaign is a finite event.[16]
**Contingency:** Although validation of the Volcanic Ash product is significantly benefitted by field campaign results, it is extremely unlikely a fortuitous volcanic ash event would occur near any field campaign supporting GOES-R. The current proposed field campaign is focused on areas where the possibility of a volcanic event is remote. Validation will proceed independent of the availability of field campaign data.[17]

# C. Appendix C: Tools

## C.1 Tool #1: GEOCAT ACTIVE (Volcanic Ash validation toolkit)[11]

**Location:** Cooperative Institute for Meteorological Satellite Studies (CIMSS).[11]

**Description:** The primary functions of the GEOCAT ACTIVE tool(s) are to: 1) Co-locate passive imager data from the data sources in Appendix B (B.3, B.4, B.5) with spaceborne lidar data. 2) Extract "truth" ash cloud properties from the combination of lidar and passive imager data (e.g. Pavolonis et al., 2013). 3) Collect validation statistics (e.g. accuracy, precision, and actual distribution of differences). 4) Generate detailed images of passive imager and lidar based results. All volcanic ash analysis and validation for the GOES-R Volcanic Ash product will be performed through this tool.[11,15]

**Developer:** Mike Pavolonis and the Volcanic Ash team.[11]

**Development Schedule:** Development has been completed.[11]

**Data Dependencies:** GOES-R, GOES, MODIS, and VIIRS L1B or SDR from which volcanic ash parameters are determined, plus CALIPSO as truth.[6,7,11]

**Testing Accomplished or Planned:** Testing is completed, other than minor additional work to ensure the ABI derived volcanic ash product related diagnostics will work with the tool; this is expected before launch through DOE test events.[11,14]

**POC:** Dr. Mike Pavolonis.[6,7]

# D. Appendix D: Acronyms

| Acronym | Definition |
|---|---|
| **AART** | Algorithm Action Review Team |
| **ABI** | Advanced Baseline Imager |
| **ADR** | Algorithm Discrepancy Report |
| **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 |
| **CATS** | Cloud Aerosol Transport System |
| **CCR** | Configuration Change Request |
| **CIMSS** | Cooperative Institute for Meteorological Satellite Studies |
| **CMI** | Cloud and Moisture Imagery |
| **CONUS** | Continental United States |
| **CWG** | Calibration Working Group |
| **DOE** | Data Operations Exercise |
| **F&PS** | Functional and Performance Specification |
| **FD** | Full Disk |
| **FTE** | Full Time Equivalent |
| **GFS** | Global Forecast System |
| **GOES** | Geostationary Operational Environmental Satellite |
| **GOES-R** | GOES R-Series |
| **GORWG** | GOES-R Series Operational Readiness Working Group |
| **GRB** | GOES Rebroadcast |
| **HRR** | Handover Readiness Review |
| **JPSS** | Joint Polar Satellite System |
| **L1b** | Level 1b |
| **L2** | Level 2 |
| **L3** | Level 3 |
| **L4** | Level 4 |
| **LZSS** | Level Zero Storage Solution |
| **MODIS** | Moderate Resolution Imaging Spectroradiometer |
| **MOST** | Mission Operations Support Team |
| **MSFC** | Marshall Space Flight Center |
| **N/S** | North/South Scan |
| **NASA** | National Aeronautics and Space Administration |
| **NCEI** | National Centers for Environmental Information |
| **NCEI-CO** | NCEI - Colorado |
| **NCEI-NC** | NCEI - North Carolina |
| **NESDIS** | National Environmental Satellite, Data, and Information Service |
| **NWS** | National Weather Service |
| **OSPO** | Office of Satellite and Product Operations |
| **PI** | Principle Investigator |
| **PLAR** | Post-Launch Assessment Review |
| **PLPT** | Post-Launch Product Test |

| Acronym | Definition |
|---|---|
| **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 |
| **SDR** | Sensor Data Records |
| **SEVIRI** | Spinning Enhanced Visible and Infrared Imager |
| **SIPS** | Science Investigator-led Processing System |
| **SPOT** | System Performance Operational Test |
| **STAR** | Center for Satellite Applications and Research |
| **TBD** | To Be Determined |
| **VIIRS** | Visible Infrared Imaging Radiometer Suite |