Read-me for Data Users

MEMORANDUM FOR: The JPSS Program Record
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SUBJECT: NOAA-20 Volcanic Ash Product Validated maturity status
DATE: 05/16/2019
Validated maturity status declaration for Volcanic Ash Products
Maturity Review Date: **05/16/2019**
Effective Date: **05/16/2019**
Operational System: **NDE, Version 2.0**

The JPSS Algorithm Maturity Readiness Review Board approved the release of the NOAA-20 Volcanic Ash Products to the public with a Validated maturity level quality as of 05/16/2019 (effective date), based on JPSS Validation Maturity Review held on 05/16/2019 (link to review artifacts).

Maturity Definition

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

Volcanic Ash Product and Algorithm Description

The NOAA-20 Spacecraft with the Visible Infrared Imaging Radiometer Suite (VIIRS) was successfully launched on November 10, 2017. With 22 spectral bands covering wavelengths from 0.41 to 12.5 µm, VIIRS provides operational information on the land surface, atmosphere, and ocean for weather, climate and other environmental applications. The VIIRS volcanic products, which are generated at the M-band spatial resolution, consist of ash cloud height, ash mass loading, and quality flags, including a flags indicating ash detection confidence. The required volcanic ash height product has units of km and the required volcanic ash mass loading product has units of tons/km^2 (numerically equivalent to g/m^2). The ash height retrievals are for the highest ash cloud layer, although multiple layers may be present. The mass loading is a column-integrated quantity. The Volcanic Ash EDR output file format is NetCDF4.

The VIIRS volcanic ash products are generated as follows. Pixels that potentially contain volcanic ash are identified using a series of spectral and spatial tests. The detection algorithm utilizes the M14, M15, and M16 channels on VIIRS. In lieu of brightness temperature differences, effective absorption optical depth ratios are mainly used in the spectral tests. Effective absorption optical depth ratios allow for improved sensitivity to cloud microphysics, especially for optically thin clouds. An optimal estimation technique is then applied to all pixels that potentially contain ash in order to estimate the height and mass loading of ash clouds. This retrieval technique utilizes the M15 and M16 channels on VIIRS.

VIIRS Volcanic Ash product requirements are provided in the JPSS NESDIS Environmental Satellite Processing Center (ESPC) Requirements Document (JERD) Volume 2 (https://www.star.nesdis.noaa.gov/jpss/documents/Requirements/JERDV2_JPSS-REQ-1004_Version2.0.pdf). The requirements state that the ash cloud height product must achieve an accuracy of 3 km or better. The mass loading product must have an accuracy of 2 ton/km^2 and a precision of 2.5 ton/km^2. There are no requirements related to ash detection, so users must determine which pixels actually contain volcanic ash.

Product evaluation/validation

For the Full Maturity Review the quality of the NOAA-20 VIIRS Volcanic Ash EDR generated within the NDE system has been evaluated using 28 volcanic events between June 2018 and March 2019. One method of validating the ash cloud property products is to compare the movement of the cloud in geostationary satellite imagery to a nearby radiosonde. If sufficient vertical wind shear is present, the height of the ash cloud can be constrained to a narrow range. Accurate wind-based assessments of ash cloud height are limited to volcanoes located relatively close to upper air measurement sites and when the ash cloud is within a vertical layer characterized by unique wind speed and/or direction. Thus, this method cannot be applied to all cases, which is why retrieving height directly from the spectral radiances is useful.

A wind-based assessment of ash cloud height was performed for a large number of suitable cases captured by NOAA-20. The difference between the VIIRS ash cloud height and the wind-based height were analyzed. Since the wind-based analysis provides a narrow range of likely heights (1-2 km), the difference between the VIIRS height and the wind-based height can computed for the best (minimum possible difference) and worst (maximum possible difference) case scenarios. In the best-case scenario, the baseline height product is biased low, compared to the wind height, by 0.9 km. The low bias increases to 1.7 km in the worst-case scenario. For clouds that are semi-transparent to infrared radiation, a low bias is expected since the infrared measurements used to retrieve the height are sensitive to emission of radiation from the entire cloud layer, not just the top.

Validation of ash mass loading is extremely challenging and is generally done in an indirect manner by relating errors in ash cloud height to errors in mass loading via radiative closure. More specifically, there is an inverse relationship between bias in ash cloud height and loading, where a low bias in

height generally corresponds to a high bias in mass loading and vice-versa. While accurate ash height retrieval does not remove all uncertainty in the corresponding mass loading, it does significantly restrict the primary source of uncertainty. Hence, it is useful to compare the retrieved ash loading to the loading computed by placing a tight constraint on ash cloud height. The ash height constraint is taken from the wind-based analysis discussed in the previous paragraph. Similar to height, the best and worst case difference between the retrieved mass loading and the height-constrained mass loading calculation was analyzed. Since mass loading can span several orders of magnitude, the median difference is a sensible measure of accuracy and the interquartile range is a meaningful measure of precision. In the median, the VIIRS mass loading is biased high by 1.3 g/m^2 in the best case and 1.6 g/m^2 in the worst case. The high bias is physically consistent with the observed low bias in ash cloud height.

The overall performance of the VIIRS volcanic ash products is consistent with expectations and meets the established accuracy requirements of 3 km for height and 2 g/m^2 for loading (the loading precision requirement of 2.5 g/m^2 is also met), although the cases captured by NOAA-20 so far do not include long-lived high level ash clouds that are sometimes observed in the wake of a highly explosive eruption.

Product Availability/Reliability

The NOAA-20 VIIRS Volcanic Ash Product, generated within the NDE system, has been available continuously since November 2018. The collected dataset captured explosive volcanic activity ranging from low-level ash clouds to mid/upper tropospheric ash clouds at a variety of volcanoes. A long-lived upper tropospheric/stratospheric ash cloud has not yet been observed by NOAA-20.

Algorithm Performance Dependence

The VIIRS volcanic ash algorithm does not depend on any other JPSS products.

Known errors/issues/limitations

1. The VIIRS volcanic ash products are not required to accurately flag pixels that contain volcanic ash. The ash cloud height and mass loading products are generated for all pixels that have a multi-spectral infrared signal that is reasonably consistent with volcanic ash. As such, many pixels that do not contain ash will have valid ash height and loading values, especially in stratus regions and under clear sky conditions over land. It is up to users to filter out non-ash pixels with valid height and loading values. While the ash confidence flag is sometimes helpful for filtering the ash height and loading products, there is no single confidence level threshold that works consistently well.

2. The validation analysis has been significantly limited by a lack of volcanic clouds observed by NOAA-20 that are coincident with "truth" data sets such as lidars. Lessons learned so far indicate that the ash cloud height is biased low and the ash mass loading is biased high, especially in well-dispersed ash clouds.

3. The NOAA-20 VIIRS volcanic ash products are not designed to detect optically thick umbrella clouds produced by explosive events. Thus, the ash height and mass loading products will often be missing in volcanic umbrella clouds, especially in the early stages of development.

4. The core components of the VIIRS volcanic ash algorithm were finalized in 2010 and do not represent the latest state of the science. The science has evolved significantly since 2010, so users are cautioned that the VIIRS volcanic ash products were not designed for advanced applications such as eruption alerting and integration with dispersion models.

Changes since last maturity stage

None

Review board recommendations

Path Forward/Future Plans

Evaluation of the product will continue. The primary focus of evaluation in the next few month will be to analyze new eruptions that are observed by NOAA-20.

Additional Items to note

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

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