NOAA-20 VIIRS Enterprise Volcanic Ash (VA) Provisional Maturity

November 27, 2018

VIIRS Volcanic Ash Team

Michael Pavolonis (STAR), Justin Sieglaff (CIMSS), Jason Brunner (CIMSS)

Outline

- Description
- Status in NDE
- SDR Issues
- Evaluation
- Provisional Maturity Conclusions
- Path Forward to Full Validation Maturity
- Future Plans

STAR ECP Cal/Val Team

Name	Organization	Major Task
Michael Pavolonis	NESDIS/STAR	Volcanic Ash PI
Justin Sieglaff	CIMSS	Algorithm development and validation
Jason Brunner	CIMSS	Algorithm development and validation
William Straka	CIMSS	ASSISTT integration
Shuang Qiu	OSPO	Product Area Lead

Enterprise Volcanic Ash Review

Enterprise Volcanic Ash EDR

- **The fundamental outputs of the VA are the ash cloud top height and ash mass loading products. Ash detection confidence can be found in the quality flag (QF).**
  - **The ash cloud top height provides the height (km; above mean sea level) of the highest ash cloud layer.**
  - **The ash mass loading is the column integrated total mass of ash in tons/km^2 (numerically equivalent to g/m^2)**
  - **Ash detection confidence: 0: high confidence; 1: moderate confidence; 2: low confidence; 3: very low confidence; 4: ash likely not present**

VA Channels

- VA uses the following channels
  - M14
  - M15
  - M16

		Band No.	Driving EDR(s)	Spectral Range (um)	Horiz Sample Interval (km) (track x Scan) Nadir	End of Scan
Reflective Bands	VisNIR	M1	Ocean Color Aerosol	0.402 - 0.422	0.742 x 0.259	1.60 x 1.58
		M2	Ocean Color Aerosol	0.436 - 0.454	0.742 x 0.259	1.60 x 1.58
		M3	Ocean Color Aerosol	0.478 - 0.498	0.742 x 0.259	1.60 x 1.58
		M4	Ocean Color Aerosol	0.545 - 0.565	0.742 x 0.259	1.60 x 1.58
		I1	Imagery EDR	0.600 - 0.680	0.371 x 0.387	0.80 x 0.789
		M5	Ocean Color Aerosol	0.662 - 0.682	0.742 x 0.259	1.60 x 1.58
		M6	Atmosph. Correct.	0.739 - 0.754	0.742 x 0.776	1.60 x 1.58
		I2	NDVI	0.846 - 0.885	0.371 x 0.387	0.80 x 0.789
		M7	Ocean Color Aerosol	0.846 - 0.885	0.742 x 0.259	1.60 x 1.58
	S/MWIR	M8	Cloud Particle Size	1.230 - 1.250	0.742 x 0.776	1.60 x 1.58
		M9	Cirrius/Cloud Cover	1.371 - 1.386	0.742 x 0.776	1.60 x 1.58
		I3	Binary Snow Map	1.580 - 1.640	0.371 x 0.387	0.80 x 0.789
		M10	Snow Fraction	1.580 - 1.640	0.742 x 0.776	1.60 x 1.58
		M11	Clouds	2.225 - 2.275	0.742 x 0.776	1.60 x 1.58
Emissive Bands		I4	Imagery Clouds	3.550 - 3.930	0.371 x 0.387	0.80 x 0.789
		M12	SST	3.660 - 3.840	0.742 x 0.776	1.60 x 1.58
		M13	SST Fires	3.973 - 4.128	0.742 x 0.259	1.60 x 1.58
	LWIR	M14	Cloud Top Properties	8.400 - 8.700	0.742 x 0.776	1.60 x 1.58
		M15	SST	10.263 - 11.263	0.742 x 0.776	1.60 x 1.58
		I5	Cloud Imagery	10.500 - 12.400	0.371 x 0.387	0.80 x 0.789
		M16	SST	11.538 - 12.488	0.742 x 0.776	1.60 x 1.58

Enterprise Volcanic Ash NDE Status

NDE/STAR VIIRS ECP Production Status

Algorithm	Suomi NPP	NOAA-20
February 2018 DAP **w/o April patch (missing granules)** August 2017 Science Code delivery (**v1r2**)	**NDE** **Currently in Operations since 1200 UTC on 13 August 2018**	**NDE** **Currently in I&T since 28 March, 2018**
August 2018 DAP February 2018 Science Code delivery (**v2r0**)	**STAR** Systematic production since June, 2018 **NDE** I&T on as of 28 September, 2018	**STAR** Systematic production since June, 2018 **NDE** I&T on as of 28 September, 2018
Jan/Feb 2019 DAP August 2018 Science Code delivery (**v2r1**)	**Delivery and development in progress** Delivery schedule provided by ASSISTT	**Delivery and development in progress** Delivery schedule provided by ASSISTT

SDR Issues

SDR Issues

- **No known issues.**

Evaluation of the NDE VA

Requirement Check List – Volcanic Ash

JERD	Requirement	Meet Requirement (Y/N)?
	Applicable Conditions: 1. Clear, AOD > 0.15	
JERD-2444	The algorithm shall produce a volcanic ash detection and height product that has a horizontal cell size of 0.8 km	Y
JERD-2544	The algorithm shall produce a volcanic ash detection and height product that has a vertical coverage of the total column	Y
JERD-2545	The algorithm shall produce a volcanic ash detection and height product that has a mapping uncertainty (3 sigma) of 3 km	Y
JERD-2546	The algorithm shall produce a volcanic ash detection and height product that has a measurement accuracy of 2 tons/km^2, 3 km height (Note 1)	Y
JERD-2547	The algorithm shall produce a volcanic ash detection and height product that has a measurement precision of 2.5 tons/km^2 (Note 1)	Y

Notes:

1. Accuracy and precision requirements only apply to actual pixels that contain volcanic ash as the highest cloud layer

Evaluation Methodology

Our Specific Evaluation Methodology applied here:

1. **Manual analysis of ash detection**

1. **Advection vs. ash height and loading EDRs**

1. **S-NPP vs NOAA-20 NDE comparisons**

We have chosen volcanic eruptions for validation that the following conditions:

1. **Volcanic ash is the highest cloud layer**
2. **Sufficient vertical wind shear for wind-height analysis and representative radiosonde (for wind-height cases)**
3. **Sufficient pixel count (many eruptions occupy an extremely small number of pixels and suffer from sub-pixel effects)**

Thus far, there have been no coincident CALIPSO/NOAA-20 overpasses of volcanic ash

Identifying Ash Contaminated VIIRS Pixels

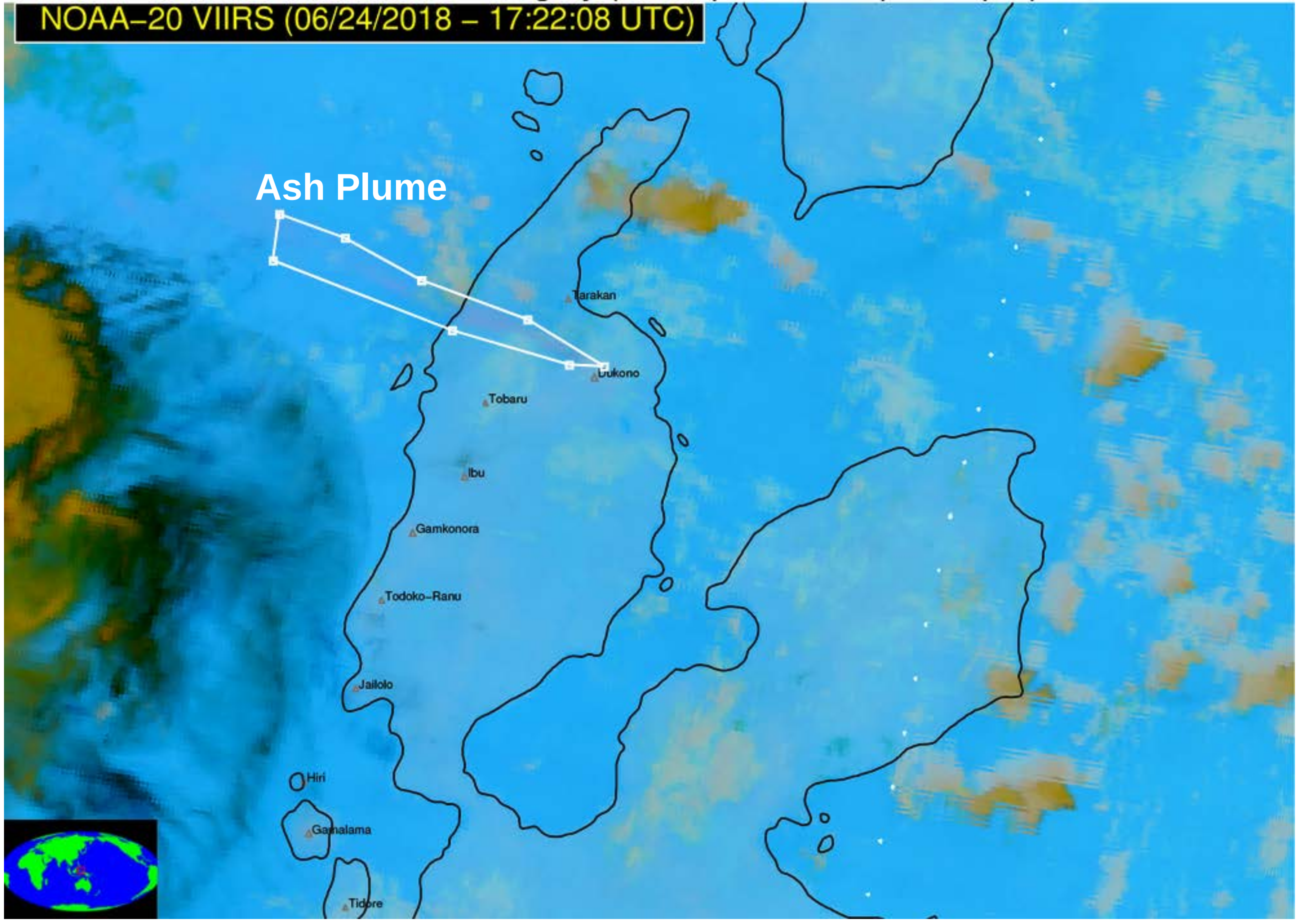
NOAA-20 Volcanic Ash Cases

- 9 volcanic ash cases were identified and analyzed, totaling over 5,000 NOAA-20 VIIRS M-band pixels

- Ash clouds from the following volcanoes were included:
  - 1 Popocatepetl (Mexico)
  - 2 Dukono (Indonesia)
  - 3 Sabancaya (Peru)
  - 2 Krakatau (Indonesia)
  - 1 Merapi (Indonesia)

- Land and water pixels are well represented

False Color Imagery (12–11µm, 11–8.5µm, 11µm)



Dukono, Indonesia

A web-based tool allows us to extract ash contaminated pixels using manual analysis of false color imagery

Ash Detection: “a needle in a haystack”

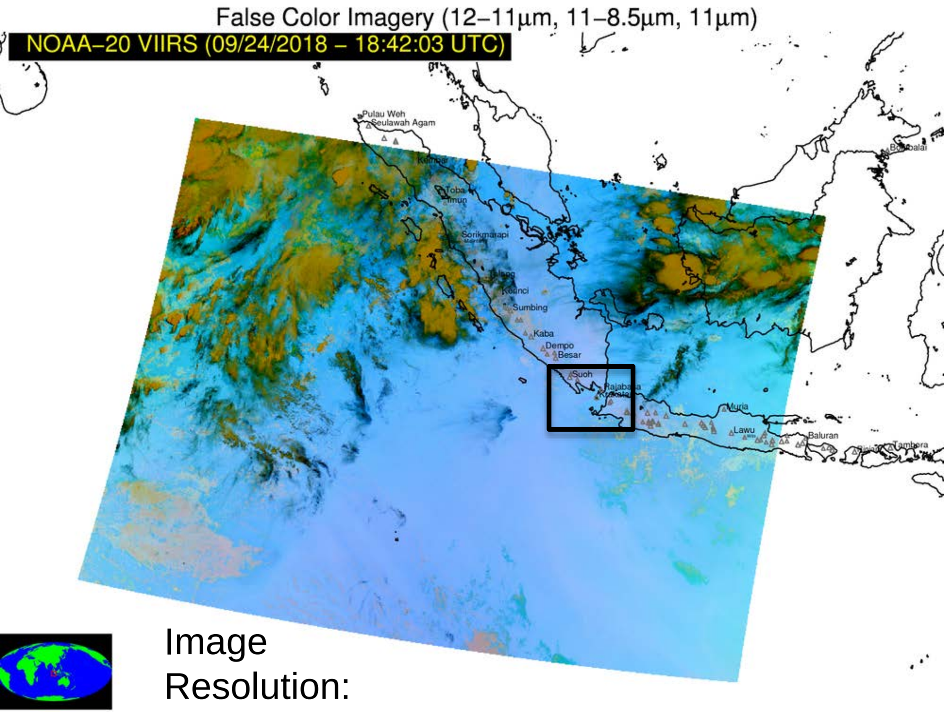
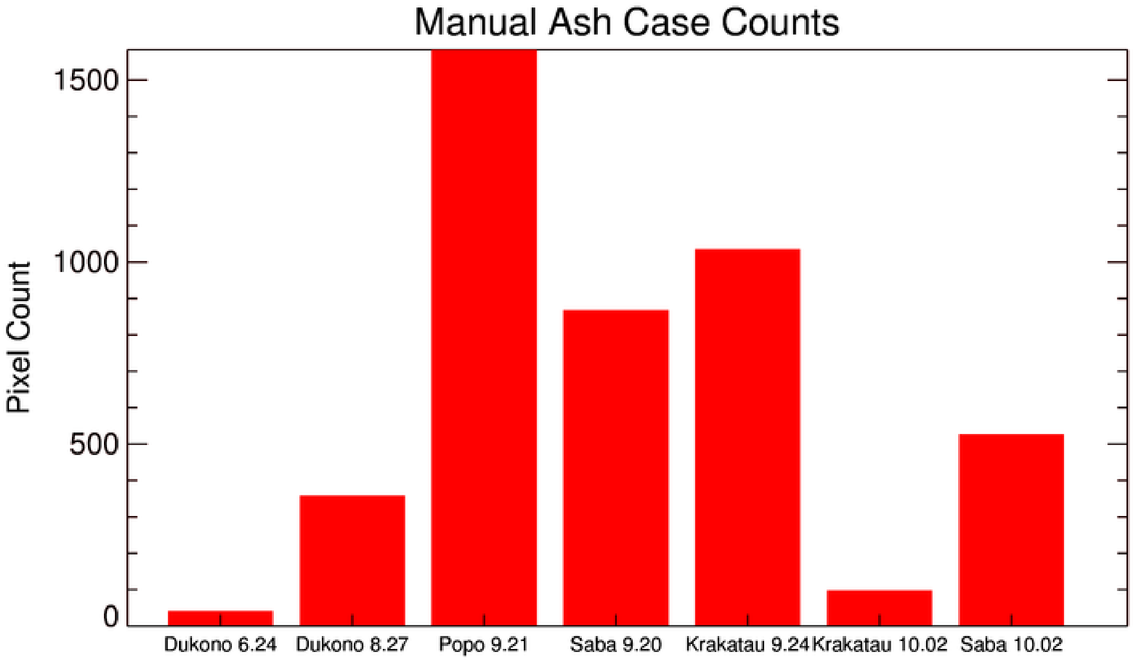


Image Resolution: Native/5

Image Resolution: Native * 1.5

Ash Detection: "a needle in a haystack"

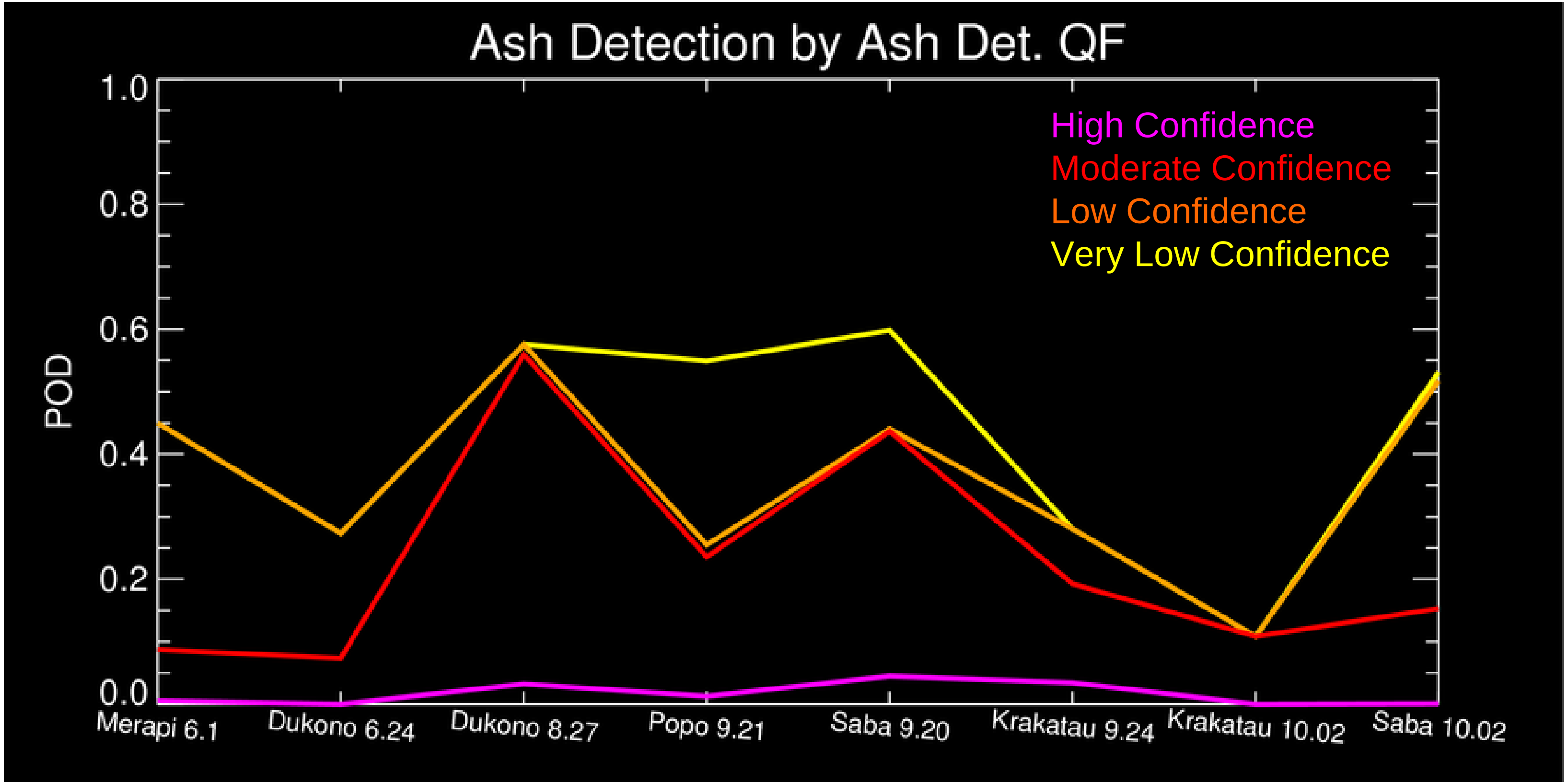


Pixel counts for a sampling of ash clouds observed by NOAA-20

- **The most commonly occurring ash clouds encompass 1000 pixels or less at a given time (see bar chart to the left)**
- **On a typical day there will be 1000-10,000 ash contaminated VIIRS M-band pixels out of the ~2.5 billion M-band pixels collected each day**
- **Thus, ash comprises fewer than 0.0004% of VIIRS M-band pixels**

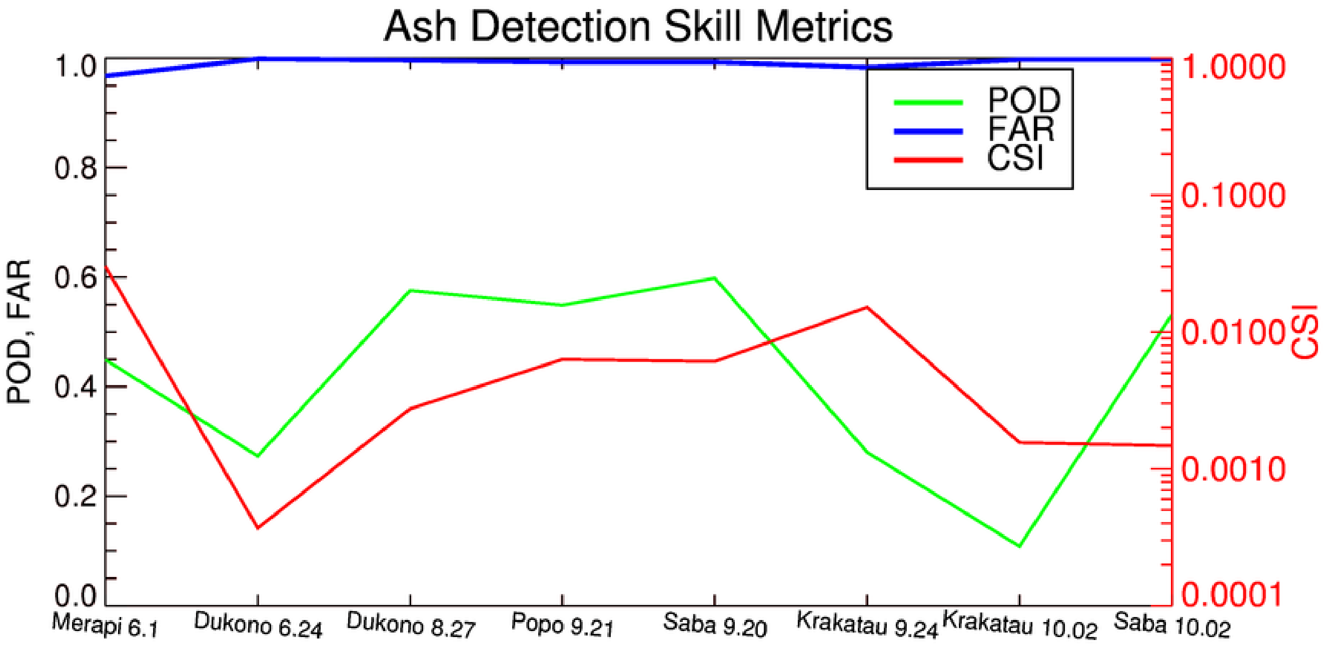
Assessment of Volcanic Ash Detection Flag

Ash Detection Assessment



- Ash clouds encompasses all ash detection categories (simple filtering by confidence is generally not effective)

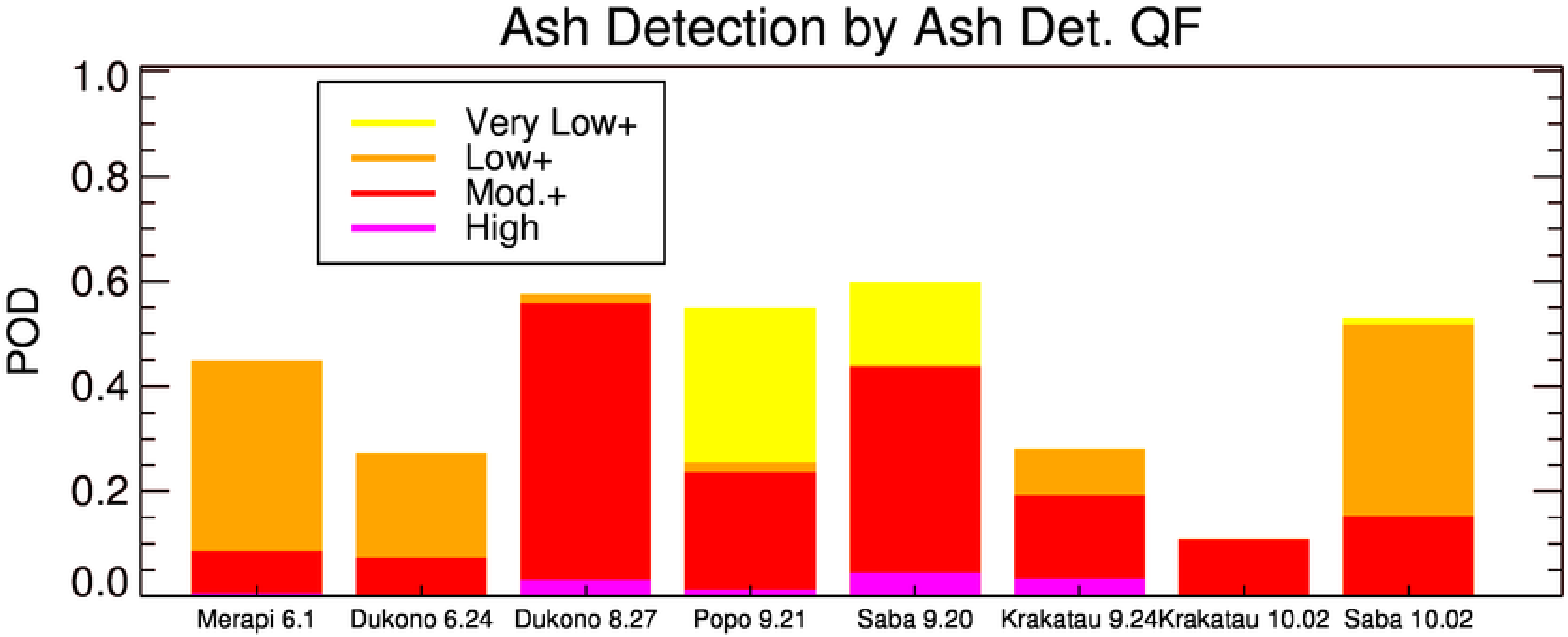
Ash Detection Assessment



Ash detection skill is computed using very low confidence, low confidence, moderate confidence, and high confidence pixels

The ash detection algorithm was not designed for advanced applications (e.g. alerting and dispersion modeling) due to lack of requirements and technical challenges

Ash Detection Assessment



When EDR data are available, NOAA-20 has only observed minor ash emissions, so the probability of the pixel being flagged as very low confidence or higher is less than it would be with a more significant event.

Validation of Ash Cloud Height and Loading

Advection Analysis

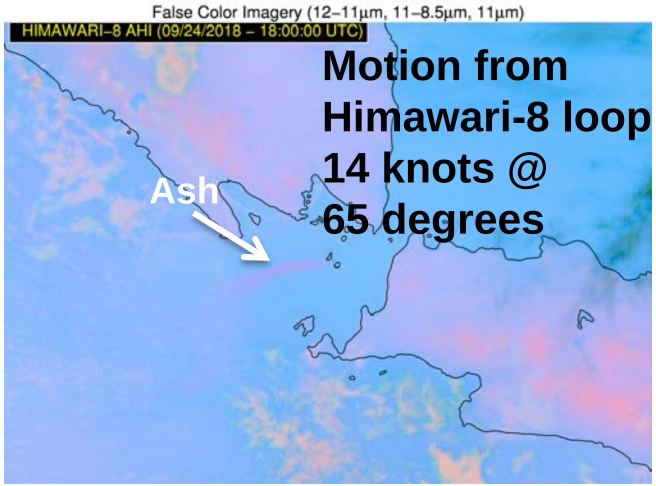
As outlined in validation plan, given rare CALIPSO observations of volcanic ash co-located with NOAA-20, alternative validation methods are necessary to compliment any CALIOP/NOAA-20 analysis (currently no CALIOP/NOAA-20 ash matchups exist).

- Detection: manual analysis using RGB imagery loops. Used to assess detection and constrain height and mass loading validation statistics.

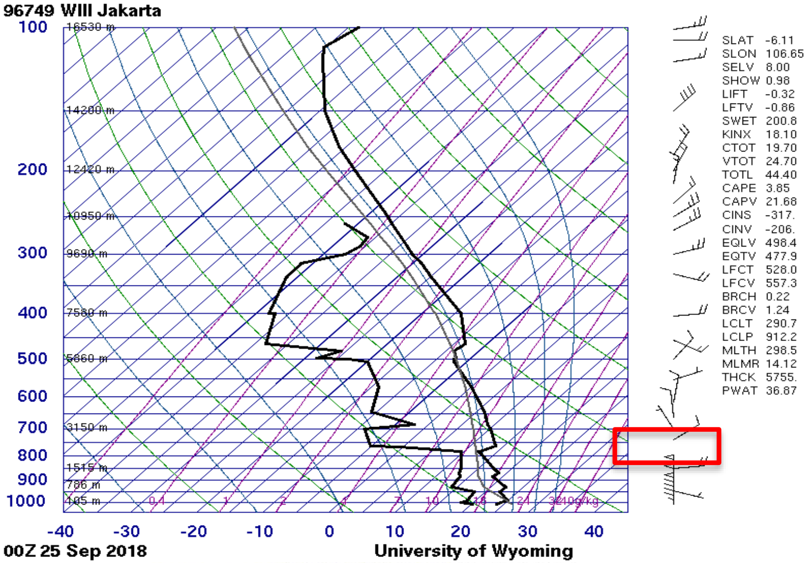
- Height: Use false color image movies (from GOES-16 and Himawari-8) to extract ash cloud motion (speed and direction). Use radiosondes to assign the satellite derived motion a height range (only cases where vertical shear is sufficient to constrain height to a ~1 km layer were used)

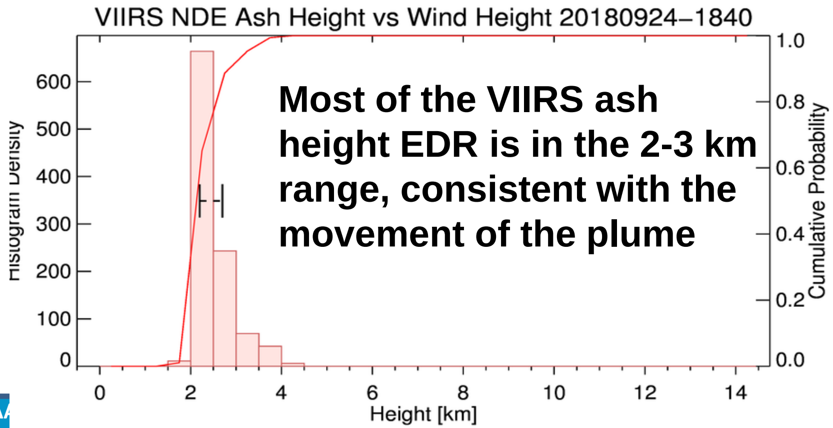
- Mass Loading: Satellite-derived mass loading is a strong function of the assigned cloud height. Thus, the cloud motion derived height range can be used to compute a highly representative range of “truth” mass loading.

Advection Analysis

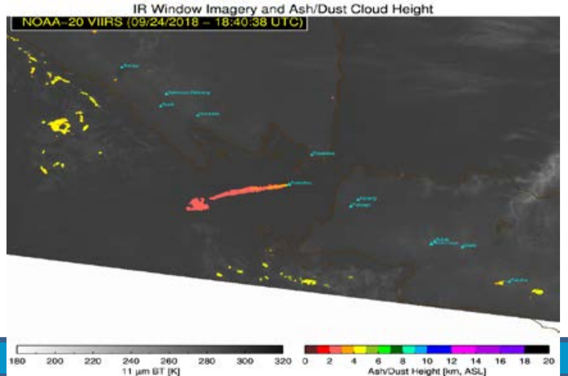


Motion from Himawari-8 loop: 14 knots @ 65 degrees

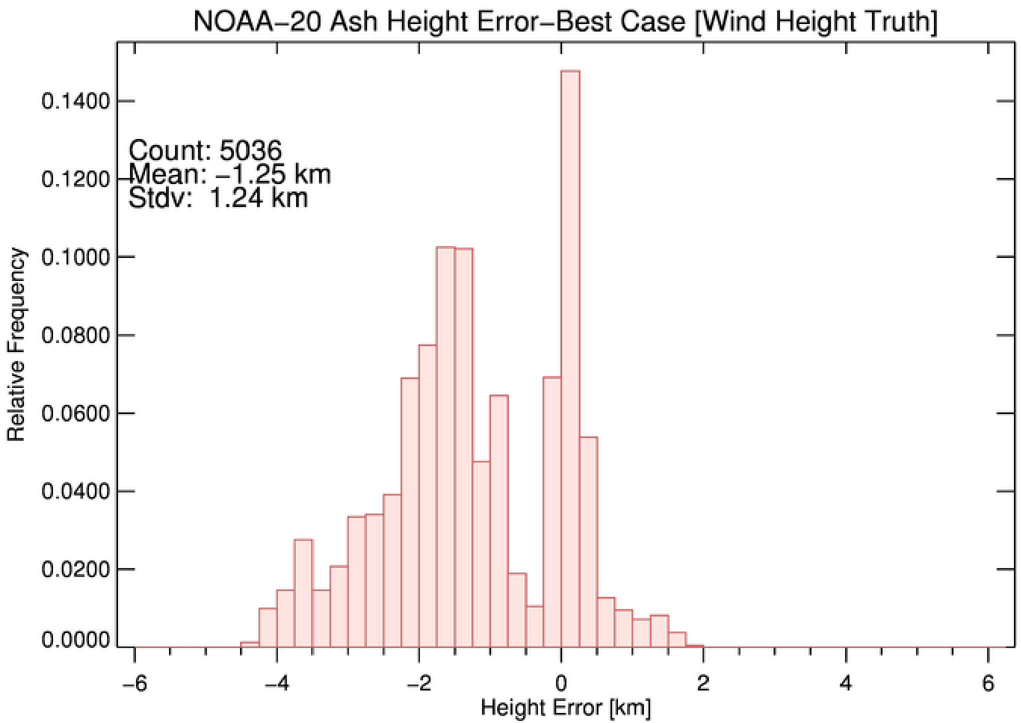




Most of the VIIRS ash height EDR is in the 2-3 km range, consistent with the movement of the plume

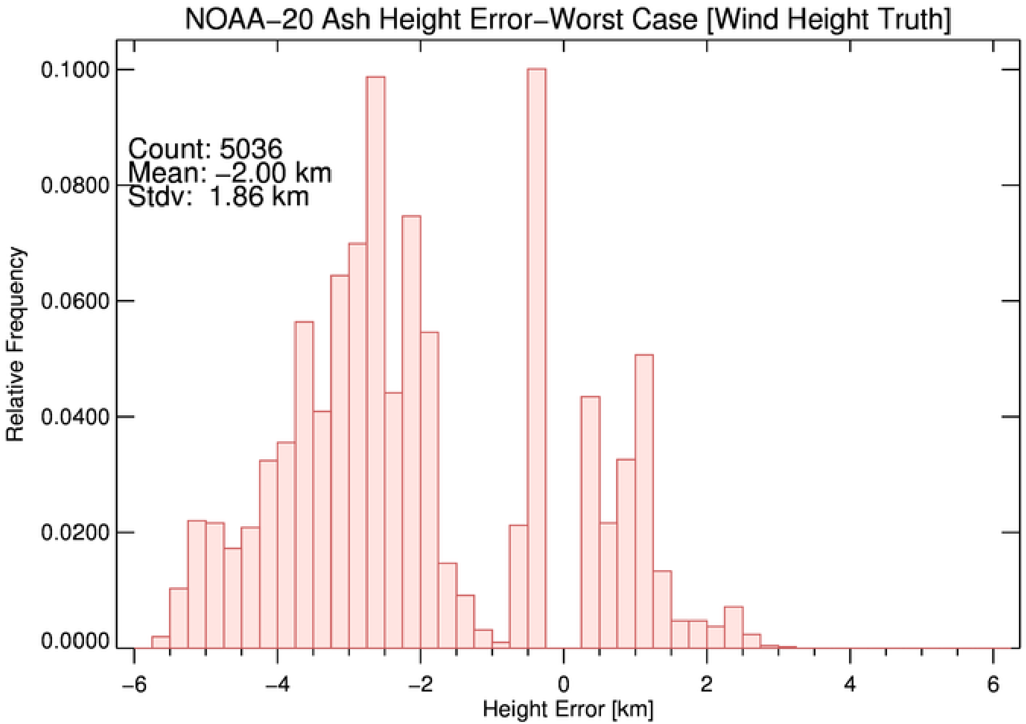


Advection Analysis - Height



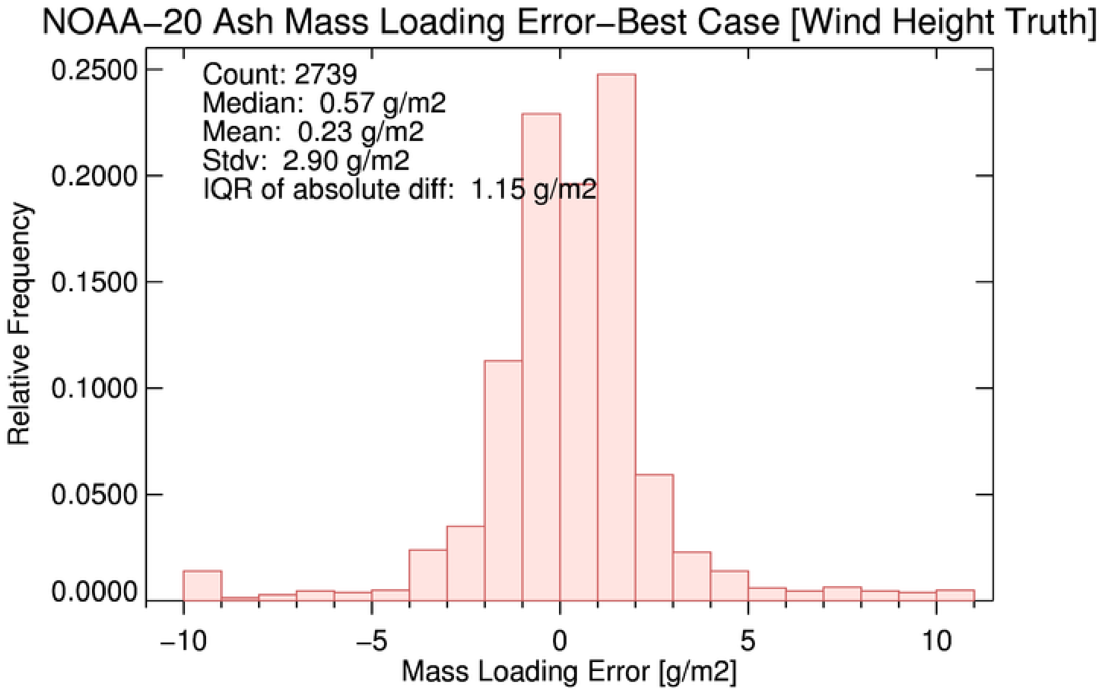
Mean Difference (accuracy): -1.25 km (within 3 km spec)

Advection Analysis - Height



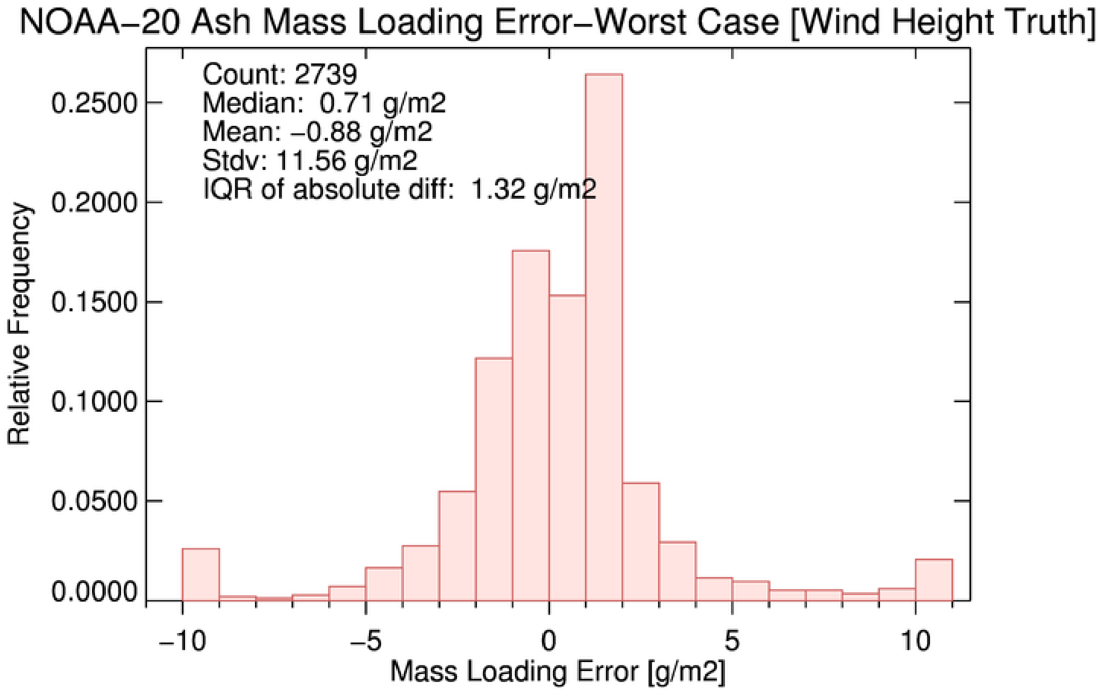
Mean Difference (accuracy): -2.00 km (within 3 km spec)

Advection Analysis - Loading



Median Difference (accuracy): 0.57 g/m^2 (within 2 g/m^2 spec)
Interquartile range (precision): 1.15 g/m^2 (within 2.5 g/m^2 spec)

Advection Analysis - Loading



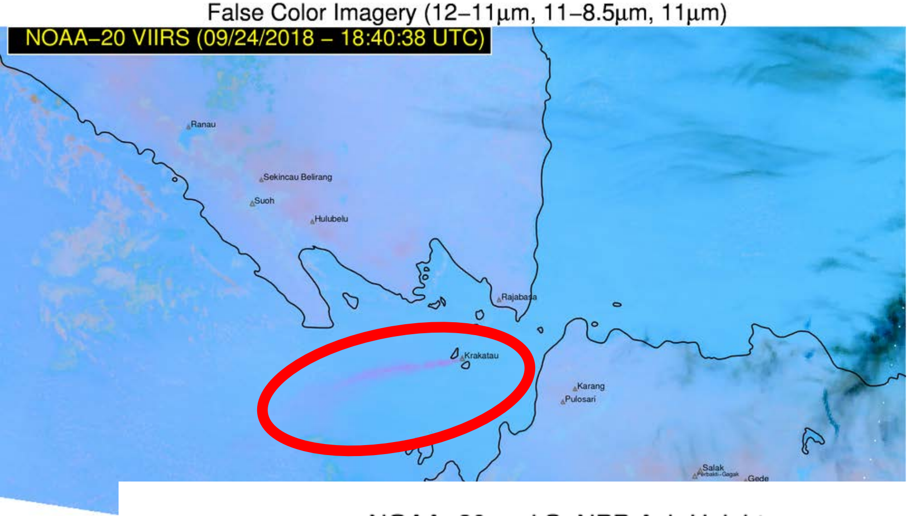
Median Difference (accuracy): 0.71 g/m^2 (within 2 g/m^2 spec)
Interquartile range (precision): 1.32 g/m^2 (within 2.5 g/m^2 spec)

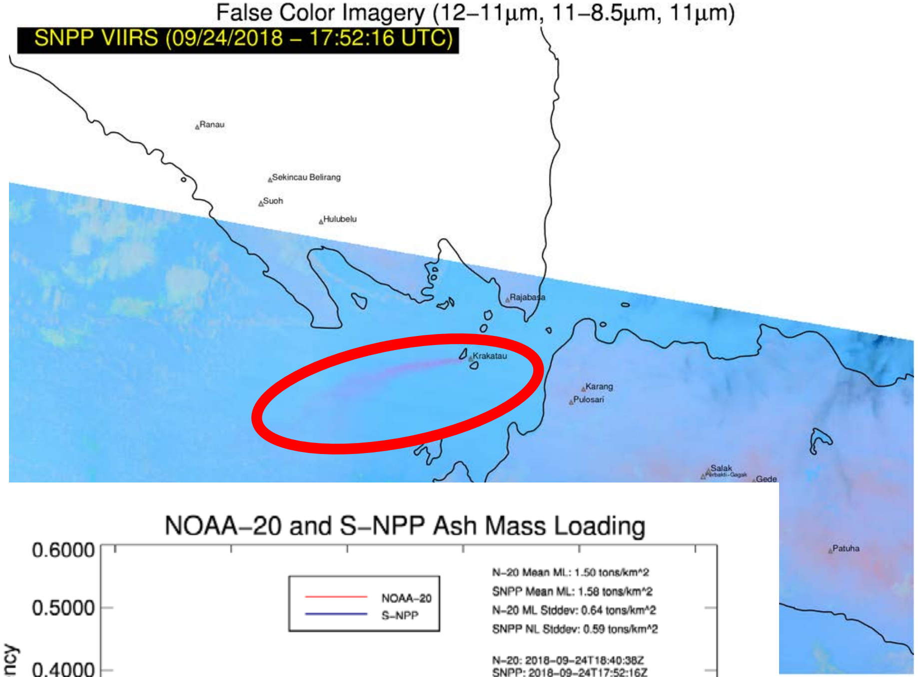
S-NPP and NOAA-20 Comparisons

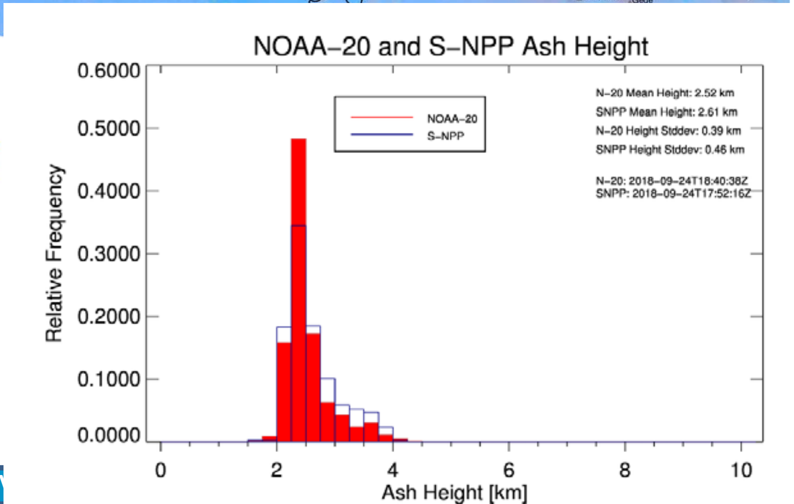
S-NPP vs NOAA-20 NDE Comparisons

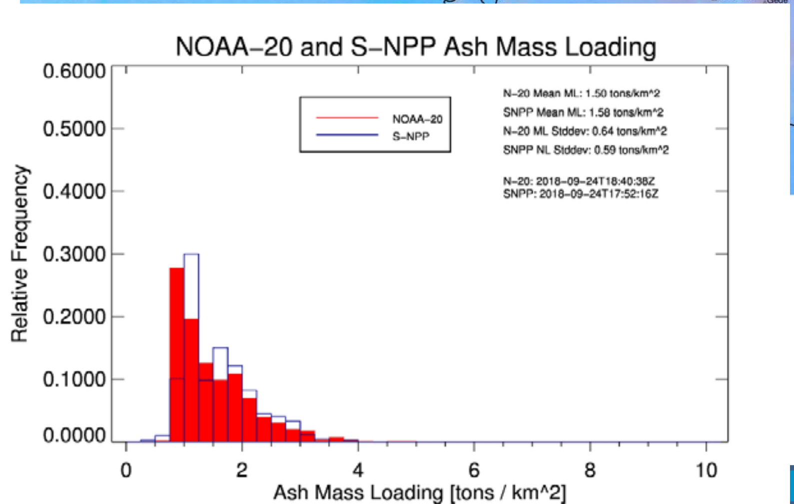
- S-NPP and NOAA-20 orbits are separated by approximately 50 minutes
- 7 cases were chosen for comparisons where both datasets were available and not at the extreme limb of the imager
- Results should be consistent, but not identical due to actual changes in cloud properties and viewing angle differences between S-NPP and NOAA-20

S-NPP vs NOAA-20 NDE Comparison Example

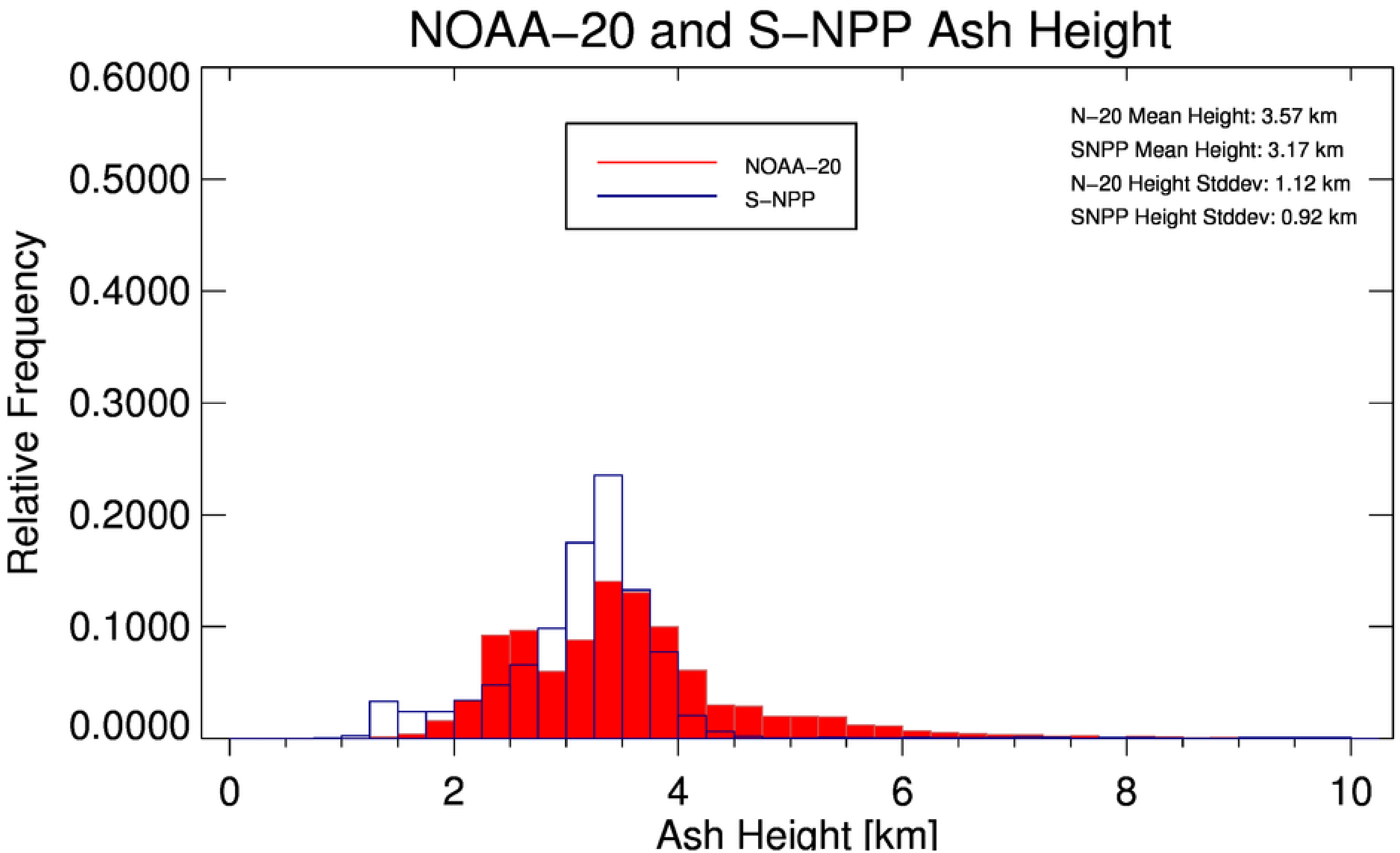




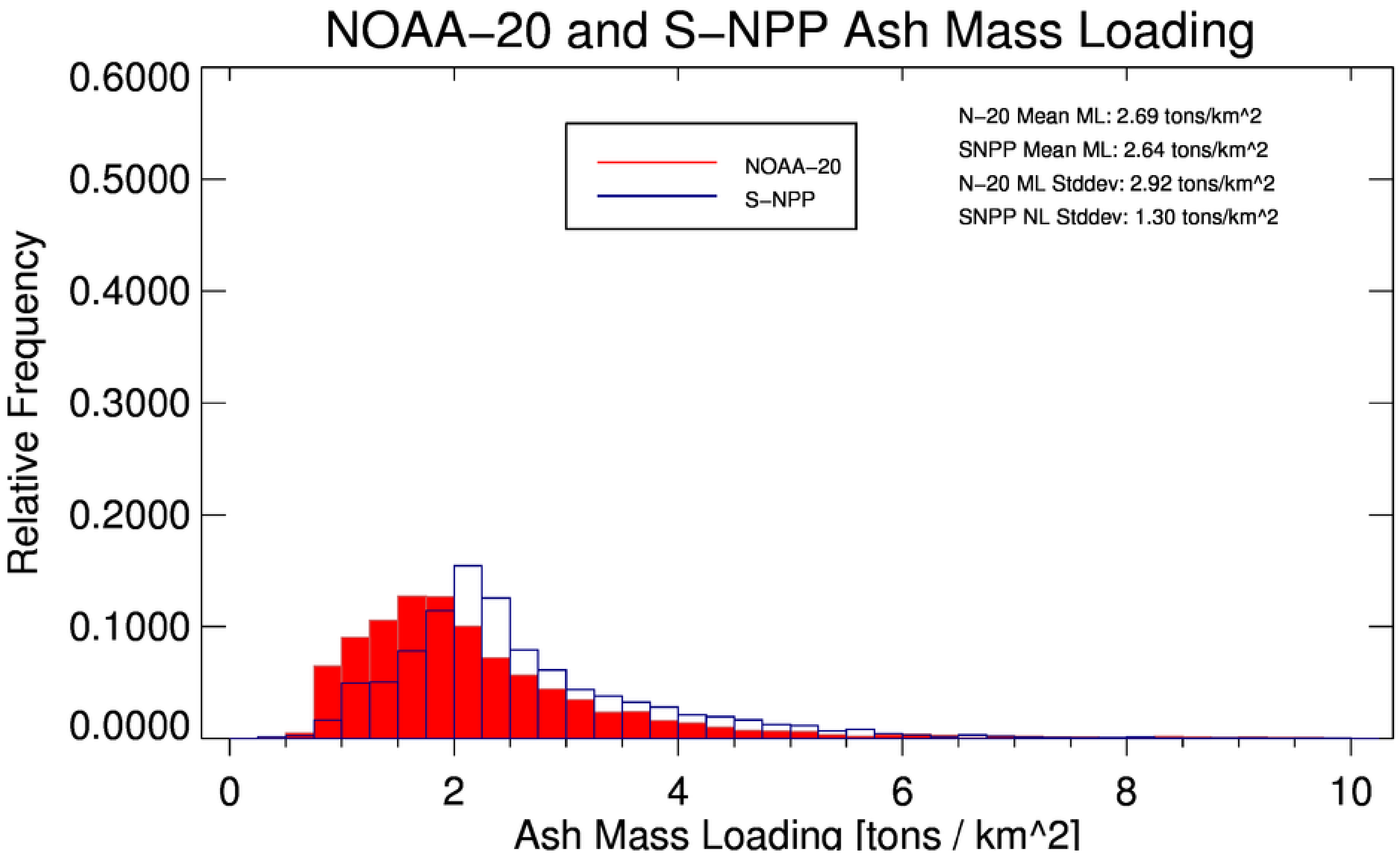




S-NPP vs NOAA-20 NDE Comparison Bulk Stats



S-NPP vs NOAA-20 NDE Comparison Bulk Stats



Provisional Maturity Conclusions

- **An advection based validation analysis and comparisons to S-NPP indicate that the NOAA-20 volcanic ash products meet the accuracy specifications**

- **The Volcanic Ash Team recommends Provisional Maturity at this time**

Pathway to Full Validation

- Additional volcanic eruptions will be used to increase the advection based validation analysis
- NOAA-20 vs. S-NPP comparisons will continue
- Any NOAA-20 and CALIOP coincident volcanic ash observations will be compared, should they occur.

Risks for Full Validation

Currently outstanding issues, unless fixed by handover, may prevent declaration of Full Validation Maturity:

- **Lack of CALIOP validation data (Low)**
  - **CALIOP observations of volcanic ash coincident with NOAA-20 have been elusive. We plan to continue to leverage advection based validation and compare S-NPP and NOAA-20 products.**
- **NDE processing issues (Low)**
  - **I&T string feed of volcanic ash data files has become considerably more stable during Fall 2018 and processing issues are now only considered low risk.**
- **Situational performance issues (Low)**
  - **Every volcanic cloud is different; a larger eruption would enhance validation**

Future Outlook (2020 and beyond)

- The VIIRS volcanic ash EDR was introduced to ensure continuity with GOES-R product requirements
- The Enterprise Algorithm is very similar to the GOES-R baseline algorithm, which was the first automated algorithm of its kind when it was first developed in 2007-2010
- Since 2010, far more sophisticated algorithms have been developed within the VOLcanic Cloud Analysis Toolkit (VOLCAT)
- VOLCAT is a stand-alone multi-sensor application that not only addresses the GOES-R and JPSS ash product requirements, but also introduces new capabilities such as eruption alerting
- We continue to seek an R2O path for VOLCAT that overcomes issues associated with mission stove piping and can accommodate its unique processing requirements. VOLCAT, as is, can be implemented into operations, as the Japanese Meteorological Agency, the Australian Bureau of Meteorology, and the New Zealand Met Service have successfully transitioned VOLCAT to operations