GOES-R AWG Aviation Team: Volcanic Ash: Detection and Height

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Aviation Team

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  - » Shanna Sampson (Algorithm Integration)
  - » Zhaohui Zhang (Algorithm Integration)

Executive Summary

- This ABI Volcanic Ash Algorithm generates two Option 1 products: ash cloud-top height and ash mass loading (mass/area).
- Version 5 will be delivered in June. ATBD (100%) is on track for a July 1 delivery.
- The algorithm identifies volcanic ash pixels and uses infrared radiances to retrieve the ash height and mass loading.
- CALIPSO validation tools have been developed and applied to numerous volcanic ash and dust cases.
- The validation analysis indicates that all of the products meet the accuracy specification.

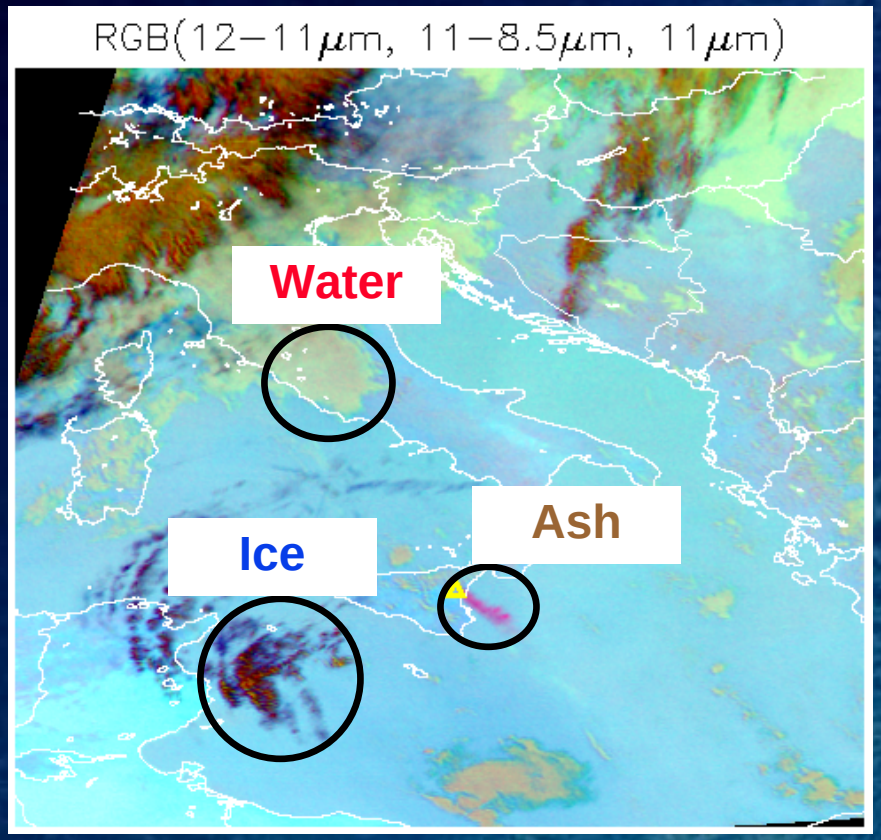
Algorithm Description

Algorithm Summary

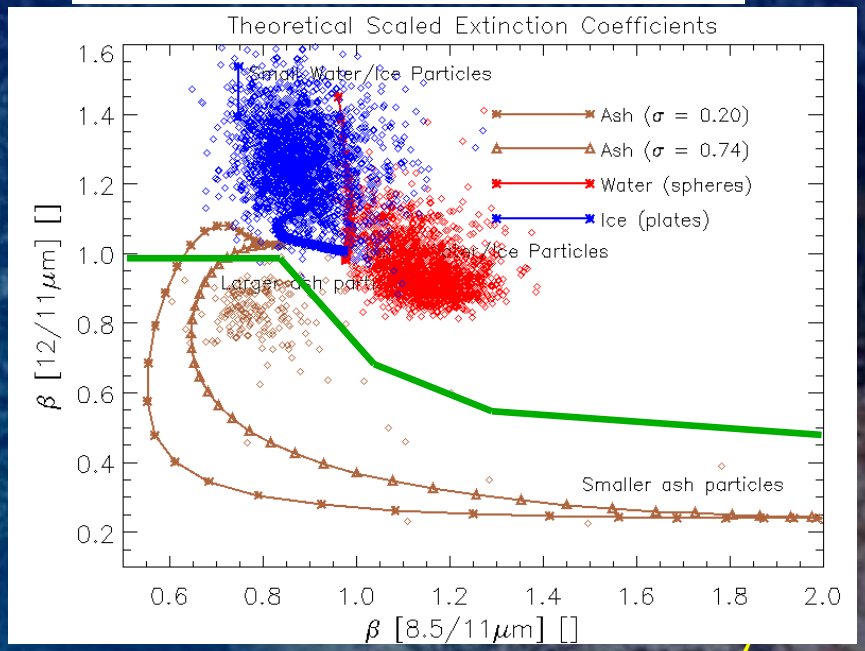
- ABI channels used: 10 (detection), 11 (detection), 14 (detection and retrieval), 15 (detection and retrieval), 16 (detection and retrieval)
- Effective absorption optical depth ratios (β-ratios) are used to identify pixels that potentially contain volcanic ash.
- An optimal estimation technique is used to retrieve the ash cloud temperature, emissivity, and a microphysical parameter. This is the same basic procedure used by the cloud team.
- Atmospheric profiles are used to convert the ash cloud temperature to an ash cloud height.
- The retrieved emissivity and microphysical parameter are used in conjunction with microphysical models to compute ash mass loading.

Ash Detection

The methodology described in Pavolonis (2010) is used to compute β-ratios, which are primarily tool used to distinguish between ash and meteorological clouds.



$$\beta_{observed} = \frac{\ln(1.0 - \varepsilon_{\lambda 1})}{\ln(1.0 - \varepsilon_{\lambda 2})}$$

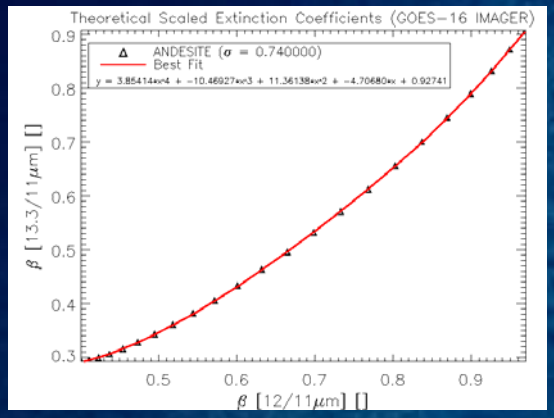


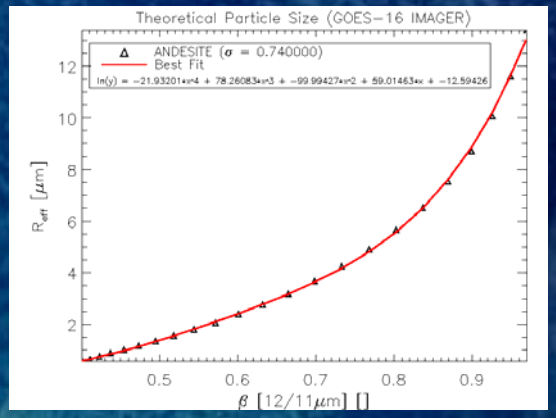
Ash Retrieval

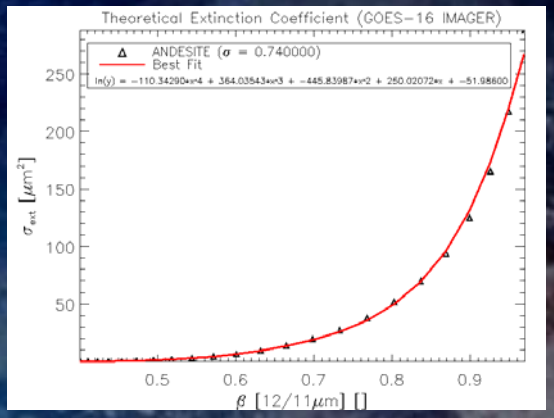
1). Optimal estimation, which propagates measurement and forward model uncertainties into the retrieved state vector, is used to determine T_{cld}, ε_{cld}, and β(12/11 μm).

$$\delta x = S_x K^T S_y^{-1}[y - f(x)] + S_a^{-1}[x_a - x]$$

2). An NWP model profile of temperature and height is used to convert T_{cld} to Z_{cld}, and microphysical models are used to convert ε_{cld} and β(12/11 μm) to mass loading and R_{eff}.







$$n(r) = \frac{N_o}{\sqrt{2\pi}} \frac{1}{r \ln\sigma} \exp\left[\frac{(\ln r - \ln r_{\mathrm{mod}})^2}{2(\ln\sigma)^2}\right]$$

$$r_{\mathrm{mod}} = \frac{r_{eff}}{\exp\left(\frac{5}{2}(\ln\sigma)^2\right)}$$

$$N_o = \frac{\tau_{cld}(\lambda)}{\sigma_{ext}(r_{eff}, \lambda)}$$

Volcanic Ash Processing Schematic

Ash Detection

INPUT: ABI channels 10, 11, 14, and 15; ancillary data; clear sky RTM parameters

↓

Compute cloud emissivities and β-ratios

↓

Apply logical tests to determine which pixels potentially contain ash

↓

Apply restoral filters

↓

OUTPUT: Ash Confidence

Ash Retrieval

INPUT: Ash Confidence, BT_{14}, BT_{14}-BT_{15}, BT_{14}-BT_{16}

↓

Retrieval Algorithm
(Forward Model, Optimal Estimation)

↓

OUTPUT: T_{cld}, ε_{cld}, β(12/11 μm)

↓

Interpolate T(z) and compute mass loading

↓

OUTPUT: Z_{cld}, Mass Loading, and QC Flags

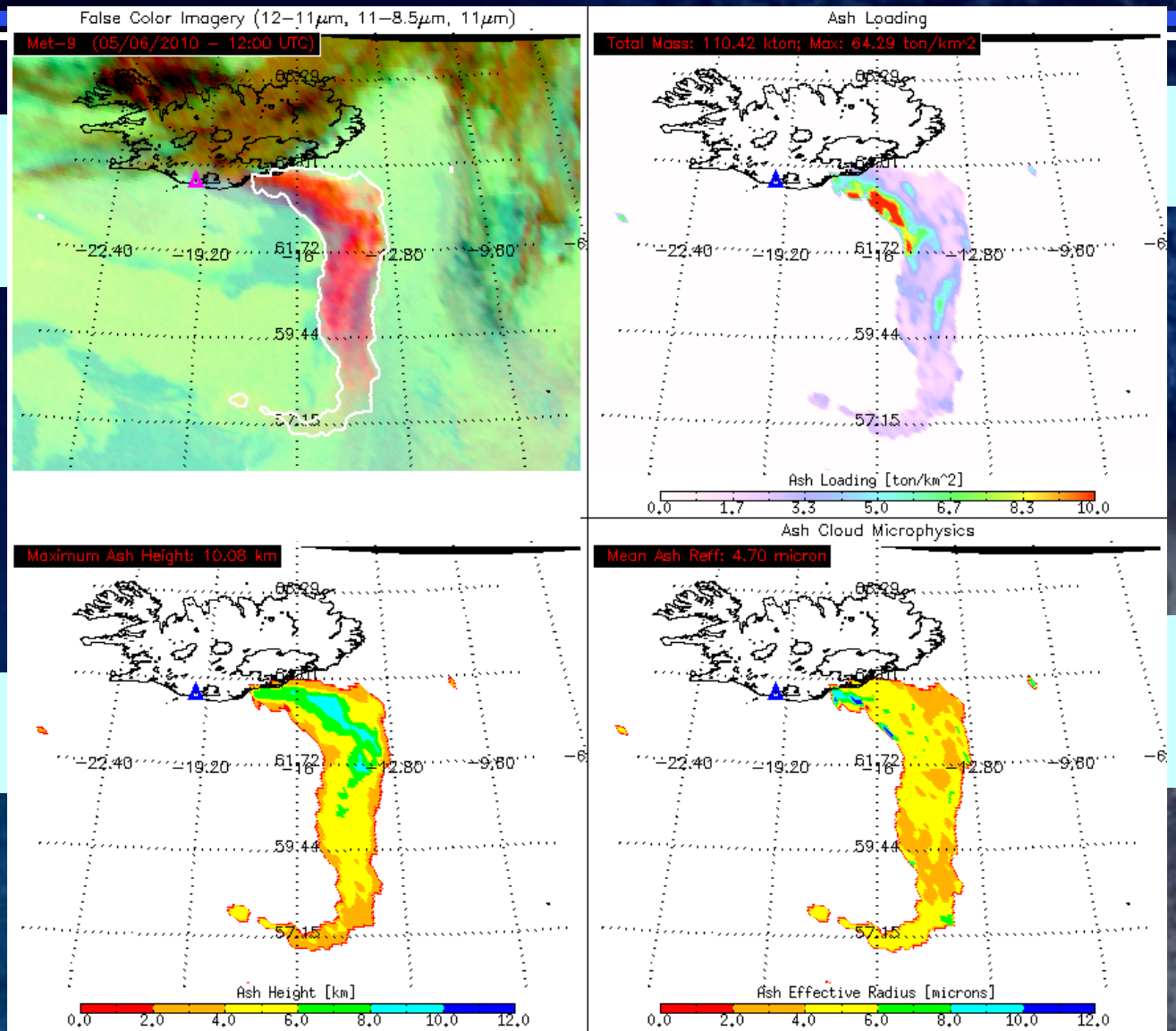
Example Volcanic Ash Output

False color for reference

Mass loading

Ash height

Effective particle radius



Algorithm Changes from 80% to 100%

- Improved ash detection component of algorithm (several changes involving the reorganization of logical tests).
- Adjusted retrieval first guess parameters and measurement error estimates
- Metadata output added
- Quality flags standardized

ADEB and IV&V Response Summary

- All ATBD errors and clarification requests have been addressed.
- No feedback required substantive modifications to the approach.

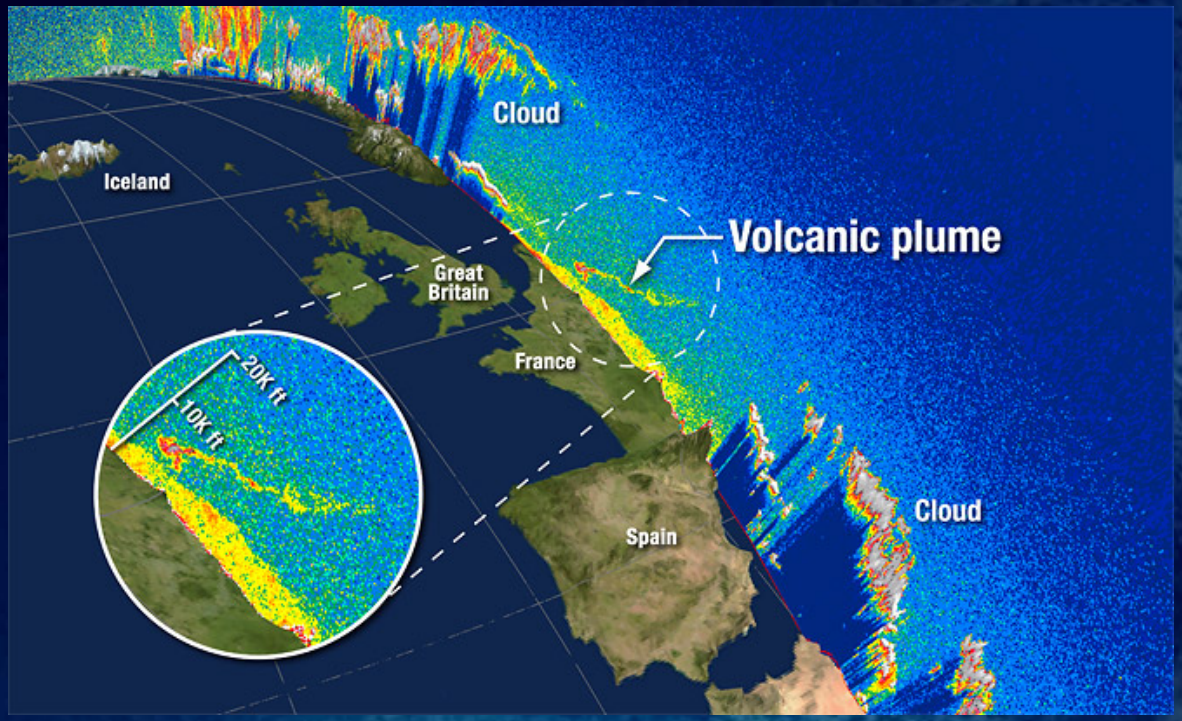
Requirements and Qualifiers

Name	User & Priority	Geographic Coverage (G, H, C, M)	Vertical Resolution	Horizontal Resolution	Mapping Accuracy	Measurement Range	Measurement Accuracy	Product Refresh Rate/Coverage Time (Mode 3)	Product Refresh Rate/Coverage Time (Mode 4)	Vendor Allocated Ground Latency	Product Measurement Precision
Volcanic Ash: Detection and Height	GOES-R	Full Disk	3 km (top height)	2 km	1 km	0 - 50 tons/km^2	2 tons/km^2	Full disk: 15 min	Full disk: 15 min	430 sec	2.5 tons/km^2

Name	User & Priority	Geographic Coverage (G, H, C, M)	Temporal Coverage Qualifiers	Product Extent Qualifier	Cloud Cover Conditions Qualifier	Product Statistics Qualifier
Volcanic Ash: Detection and Height	GOES-R	Full Disk	Day and night	Quantitative out to at least 60 degrees LZA and qualitative at larger LZA	Clear conditions down to feature of interest associated with threshold accuracy	Over volcanic ash cases

Validation Approach

Validation Approach



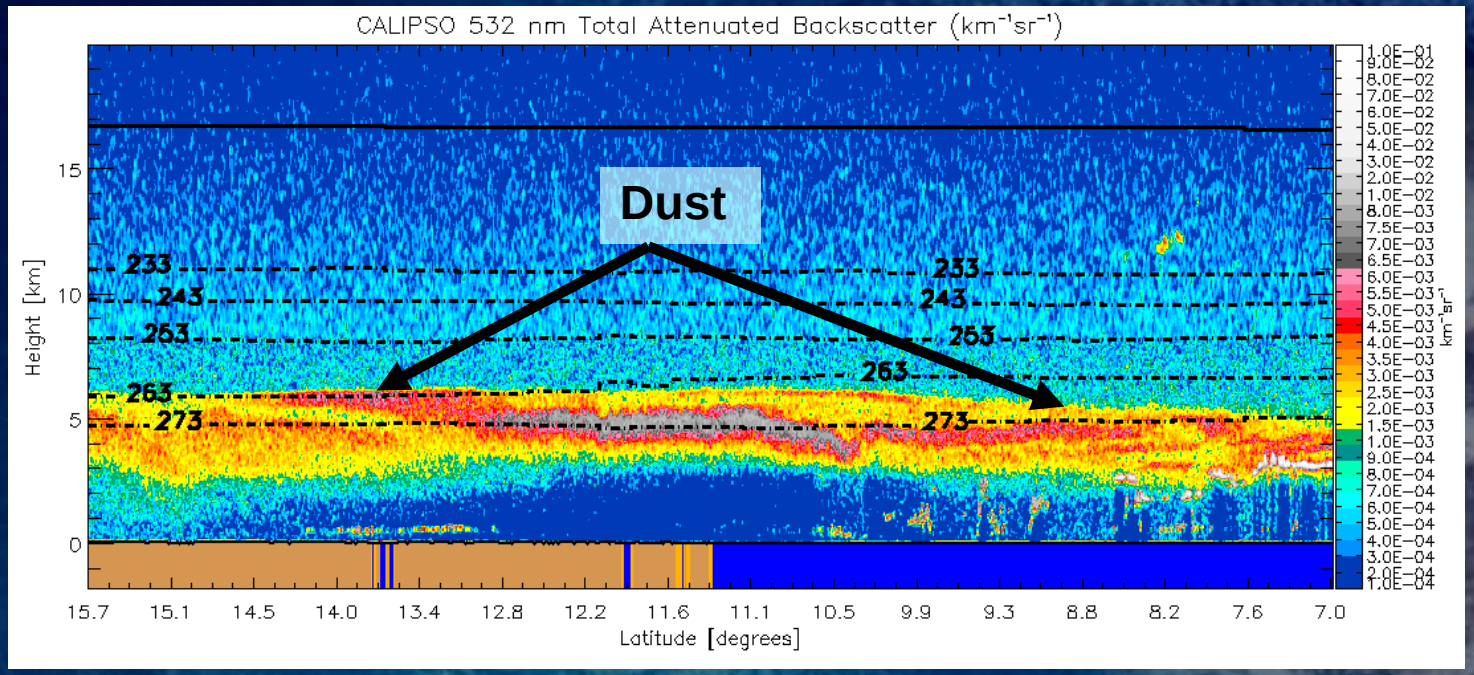
- Spaceborne lidars, like CALIOP, provide accurate information on cloud height.
- CALIOP ash cloud boundaries can be used to compute mass loading (under the same assumptions used in the ash retrieval).
- This same approach is used by the AWG Cloud Team.

- Null cases (scenes with no volcanic ash) are also identified using volcano observatory reports and manual analysis.
- In the null cases the "truth" mass loading is 0 tons/km^2

Validation Approach

- To increase the number of validation points, dust, which has a similar spectral signature as volcanic ash in the infrared, can be used to vicariously validate the ash retrieval algorithm.

- Dust clouds are commonly observed by SEVIRI and CALIOP.



Validation Results

Null Case Validation

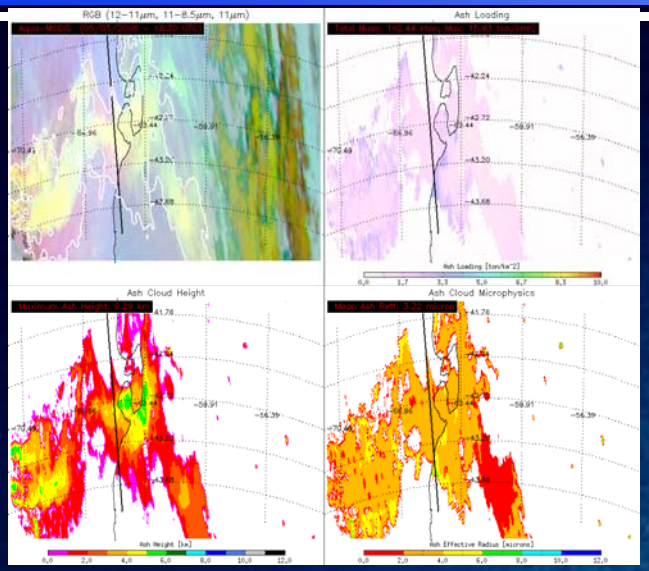
Accuracy Specification: 2 ton/km^2

Precision Specification: 2.5 ton/km^2

Using SEVIRI

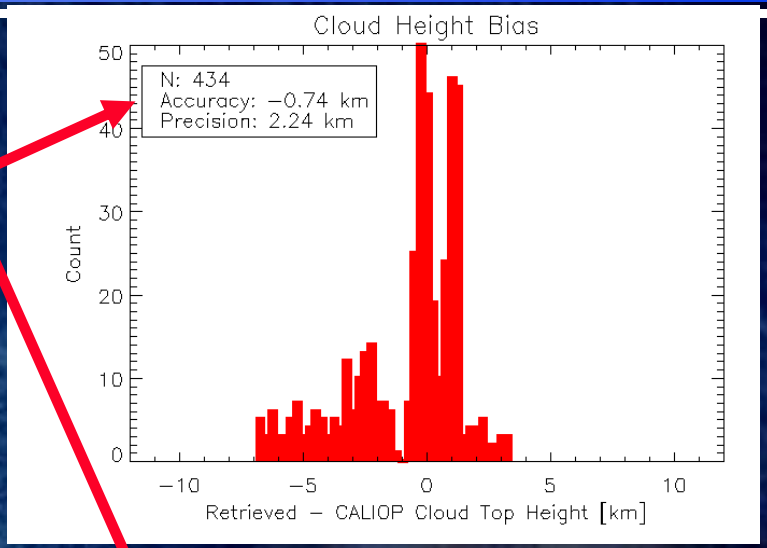
Date/Time	N	Accuracy (ton/km^2)	Precision (ton/km^2)
1/1/2008 00 UTC	61,063,208	0.027	0.340
1/1/2008 12 UTC	61,063,208	0.007	0.245
4/1/2008 00 UTC	61,063,208	0.015	0.237
4/1/2008 12 UTC	61,063,208	0.008	0.211
7/7/2008 00 UTC	61,063,208	0.074	0.510
7/7/2008 12 UTC	61,063,208	0.023	0.243
10/14/2008 00 UTC	61,063,208	0.069	0.821
10/14/2008 12 UTC	61,063,208	0.042	0.630

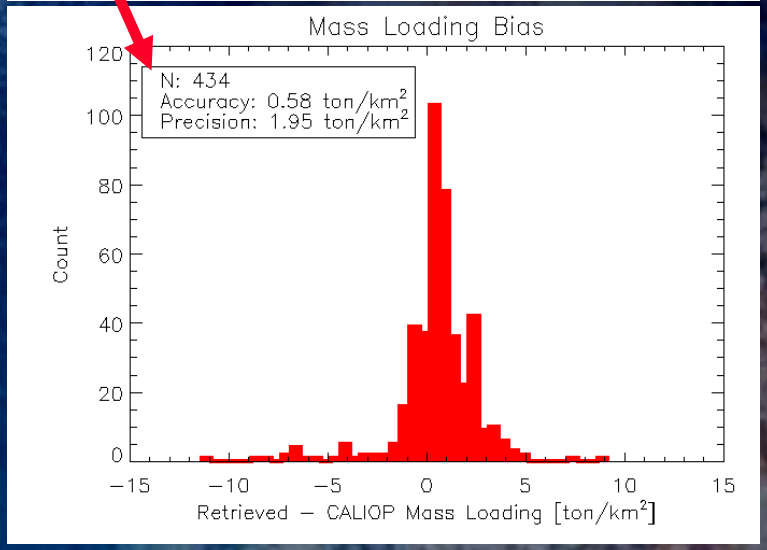
CALIPSO Ash Validation

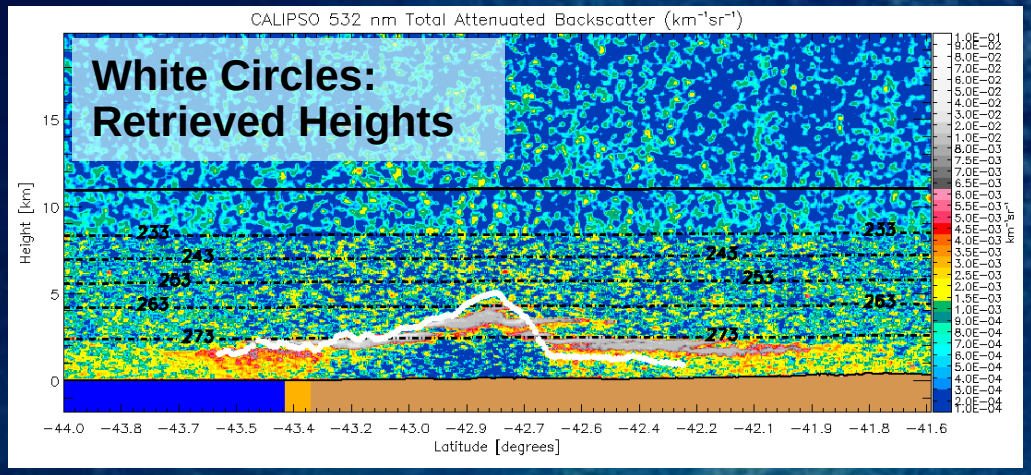


The height and mass loading are well within the specifications

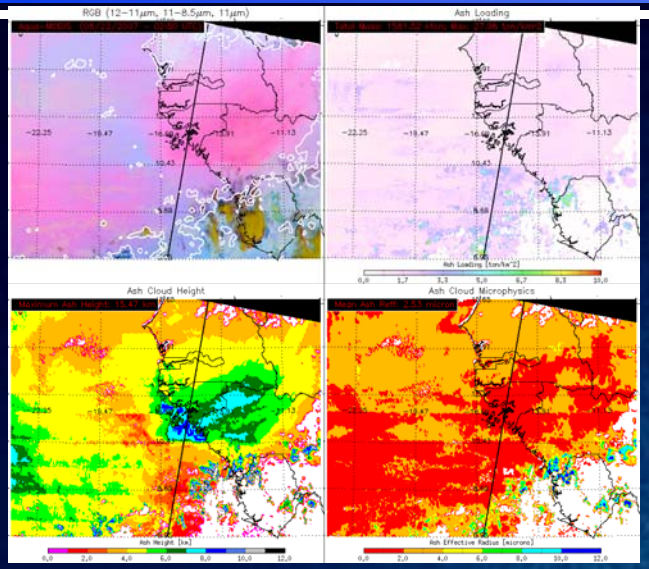
Using MODIS





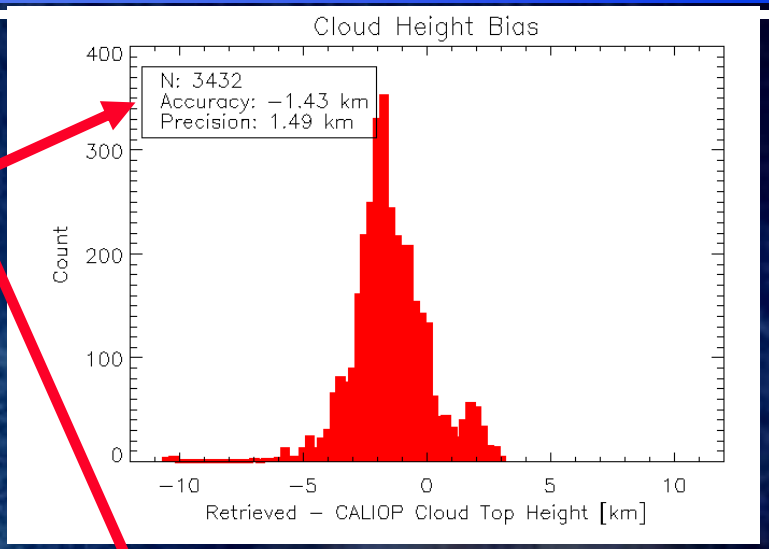


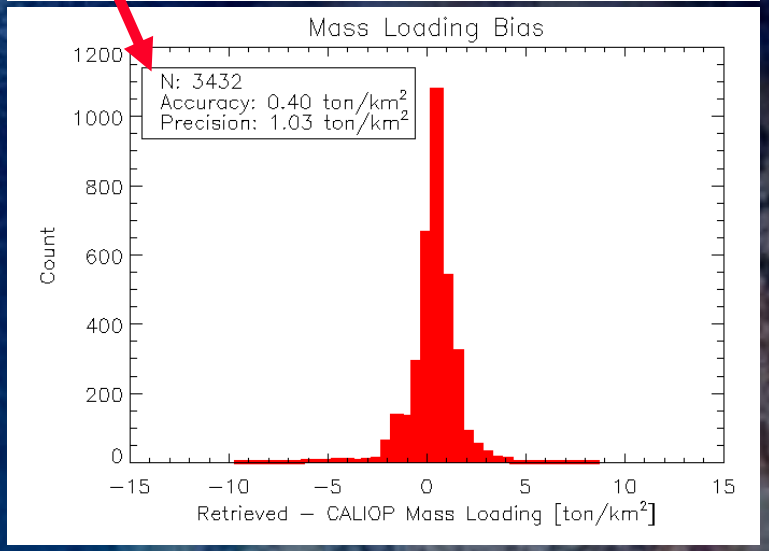
CALIPSO Dust Validation

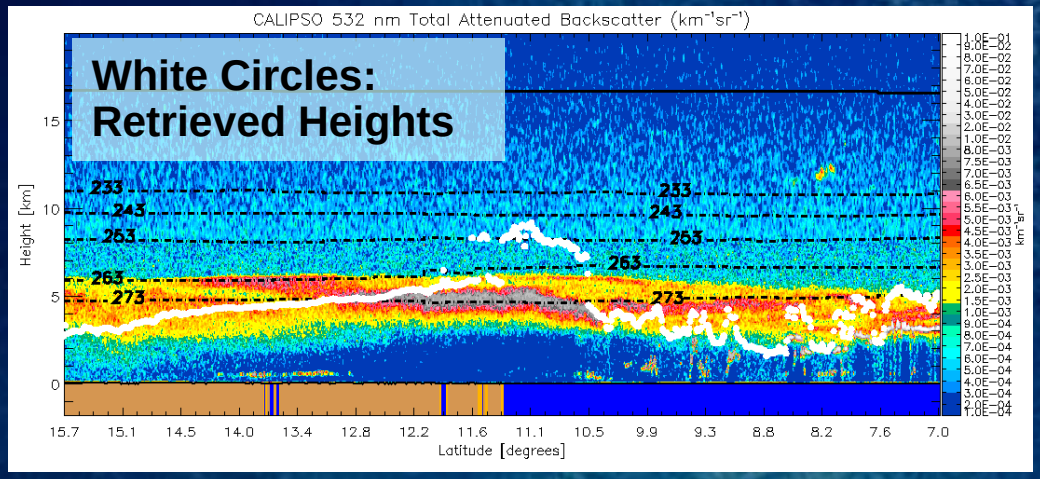


The height and mass loading are well within the specifications

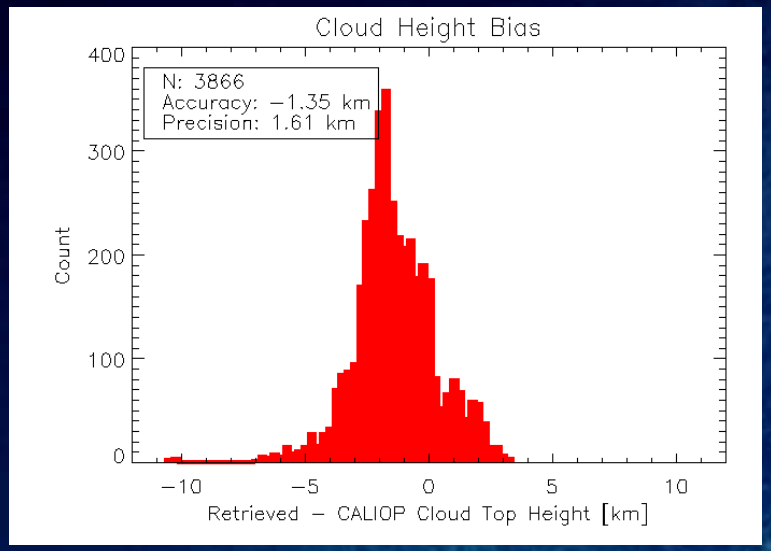
Using MODIS

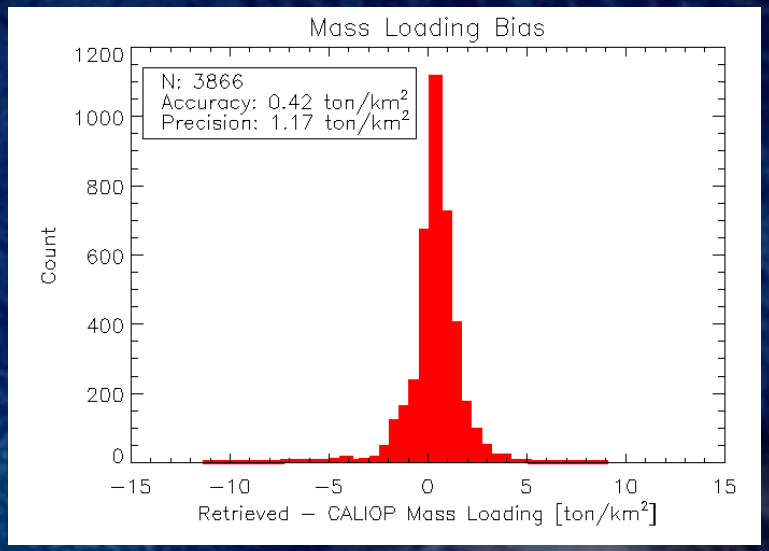






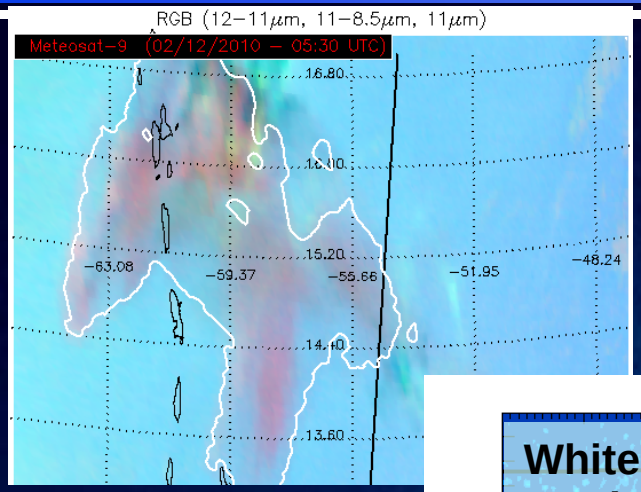
CALIPSO Validation Summary





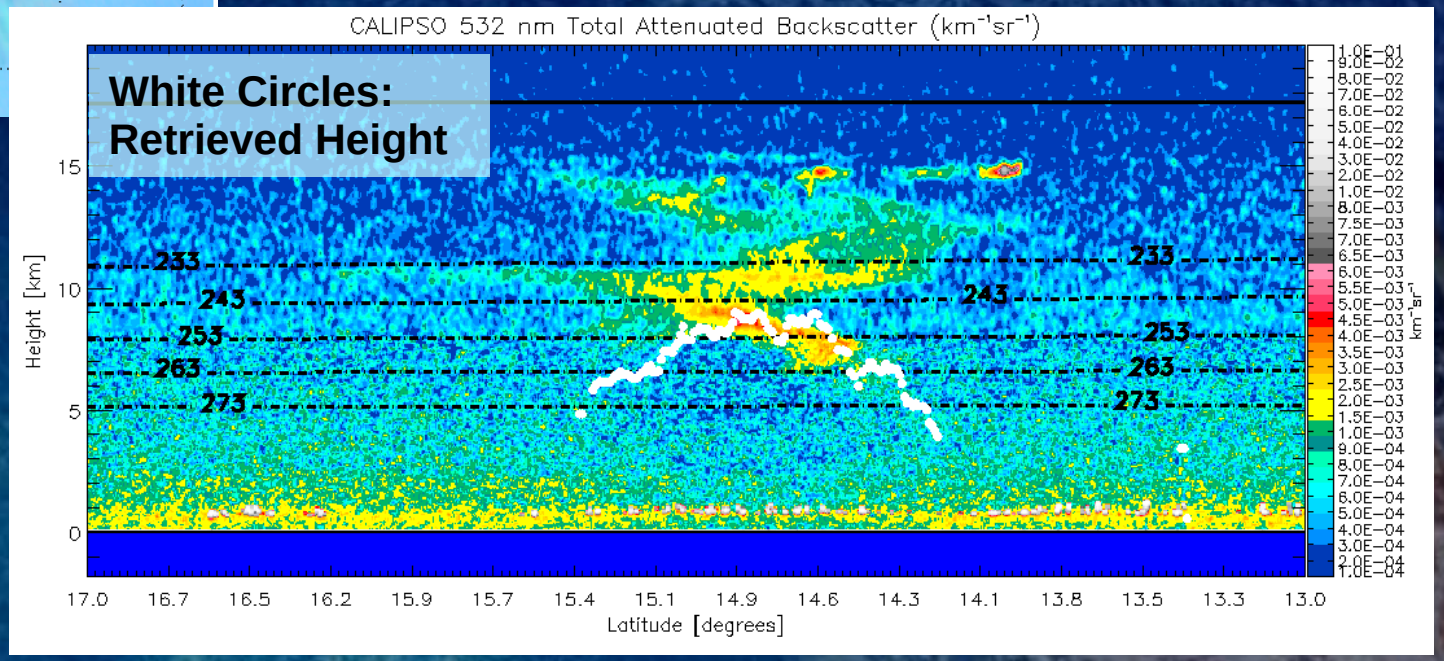
Data Set	N	*Height* Accuracy (spec = 3 km)	*Height* Precision (spec = none)	*Mass Loading* Accuracy (spec = 2.0 ton/km^2)	*Mass Loading* Precision (spec = 2.5 ton/km^2)
Ash	434	-0.74 km	2.24 km	0.58 ton/km^2	1.95 ton/km^2
Dust	3432	-1.43 km	1.49 km	0.40 ton/km^2	1.03 ton/km^2
Total	3866	-1.35 km	1.61 km	0.42 ton/km^2	1.17 ton/km^2

Impact of View Angle

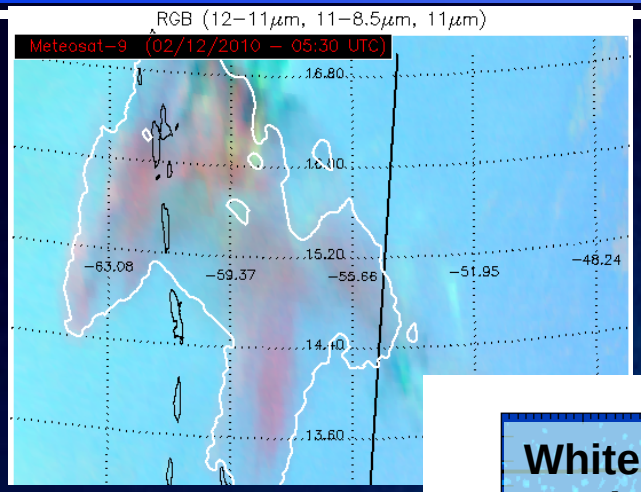


Soufriere Hills (2/12/10 - 05:30 UTC)

MODIS - $\theta_{sat} \approx 0^o$

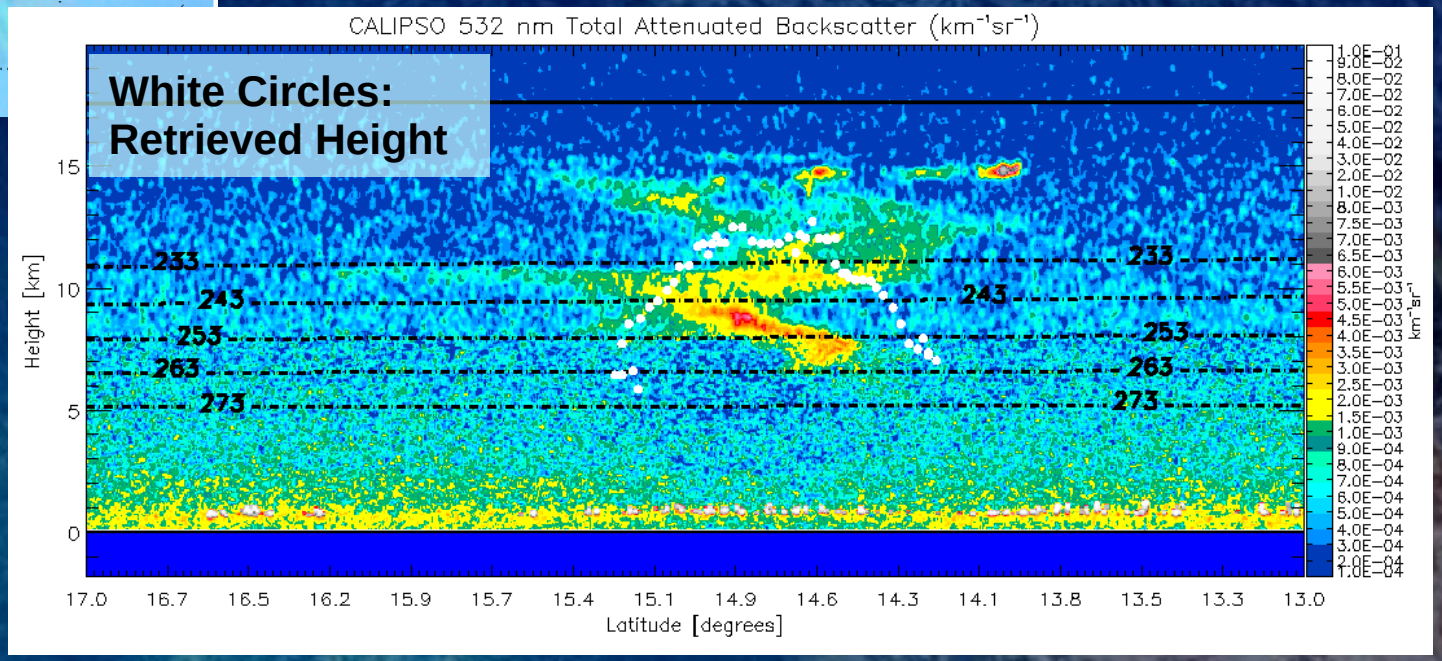


Impact of View Angle



Soufriere Hills (2/12/10 - 05:30 UTC)

SEVIRI - $\theta_{sat} \approx 75^o$



Summary

- The ABI Volcanic Ash Algorithm, which provides information that is critical to Volcanic Ash Advisory Centers (VAAC's) and the modeling community, is the first known fully automated imager-based infrared retrieval of ash height, loading, and effective particle radius.

- Version 5 of the code and the 100% ATBD will be delivered by July 1.

- These products meet the specifications and are currently being used by the international operational and user community