Using the GOES-R AWG Volcanic Ash Algorithm to Track Eyjafjallajökull Volcanic Ash: Impacts on Operations and Research

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and

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Topics

• Introduction to the GOES-R AWG volcanic ash products
• Eyjafjallajökull background
• Impact of the GOES-R volcanic ash products on volcanic ash monitoring and modeling
• Quality assessment
• Advantages of the geostationary view
• Looking ahead
• Summary
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The GOES-R Volcanic Ash Products

- SEVIRI or MODIS can be used to generate the GOES-R products.
- The GOES-R ash retrieval algorithm is based on the GOES-R cloud height retrieval (same IR based approach).
- The simultaneous retrieval of ash height, mass loading, and particle size is unique (all other ash algorithms assume a constant cloud height).
- These products are well suited for assimilation into models since the error estimate for each parameter is objectively determined by the algorithm.
The GOES-R Volcanic Ash Products

Quantitative Ash Detection

- Quantitative ash detection is expressed as an ash confidence.
- Ash detection results can be overlaid on false color imagery to give the user perspective.
- The ash detection can be used to provide automated ash alerts.
The GOES-R Volcanic Ash Products

- Ash mass loading (ton/km²) is needed to determine if jet engine tolerances are exceeded and to initialize models.
- If a 1 km cloud thickness is assumed, the mass loading is numerically equivalent to ash concentration in mg/m³.
The GOES-R Volcanic Ash Products

• The ash cloud top height is critically important for determining if ash is at jetliner cruising altitudes (nowcasting component).

• In addition, the ash cloud height is a very important parameter for initializing dispersion models (forecasting component).
The GOES-R Volcanic Ash Products

• The ash cloud effective particle radius is not a required product, but it is automatically generated as part of the ash retrieval.

• Since the effective particle radius is well correlated with ash residence time, we will retain this information in quality flag form.
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Eyjafjallajökull Background

Ash clouds from Iceland have the potential to impact very busy air routes

Eruptions beginning in:
2010, 1821, 1612, ~920 AD, ~550 AD
Eyjafjallajökull Eruptions

March 20 to April 12, 2010 - non-ash eruptions, lava fountains

April 14 to May 23, 2010 - mostly explosive ash cloud producing (ash was visible in satellite imagery 32 out of 41 days)

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The Volcanic Explosivity Index (VEI) for these eruptions was in the 2 - 3 range. By comparison, Mt. St. Helens (1980) had a VEI of 5 and Pinatubo (1991) had a VEI of 6.

The volcanic clouds were mainly confined to the troposphere and only small amounts of SO$_2$ were emitted, so these eruptions had little to no climate impact.
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Early Role of the GOES-R Volcanic Ash Products

April 14: beginning of explosive ash producing eruption. *We began regularly distributing the GOES-R ash products to the operational and research community via an e-mail list.*

April 15 - April 23: Significant airspace restrictions over Europe. *The GOES-R products show the evolution of the ash cloud and are featured on NOAA web pages.*

April 19: *UK Met Office requests real-time GOES-R volcanic ash products (using SEVIRI).*

April 20: *STAR submits statement on climate impact. The GOES-R products played a role in the assessment.*

April 21: *GE Aviation releases preliminary safe operating threshold. The 2 mg/m³ threshold is within the GOES-R algorithm sensitivity range.*

April 22: *GOES-R ash products are generated in real-time and displayed on the web.*
April 14: beginning of explosive ash producing eruption. *We began regularly distributing the GOES-R volcanic ash products to the operational and research community via an e-mail list.*

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April 22: *GOES-R ash products are generated in real-time and displayed on the web.*
April 15 - April 20, 2010

• We were regularly generating the GOES-R volcanic ash products using SEVIRI and MODIS and distributing them to the operational and research community via an email list.

• The GOES-R ash products were the only timely source of objective satellite derived ash cloud heights, loading, and particle size.
April 14: beginning of explosive ash producing eruption. *We began regularly distributing the GOES-R ash products to the operational and research community via an e-mail list.*

April 17: beginning of explosive ash producing eruption.

We began regularly distributing the GOES-R ash products to the operational and research community via an e-mail list.

April 18: GOES-R ash products are generated in real-time and displayed on the web.

April 19: UK Met Office requests real-time GOES-R volcanic ash products (using SEVIRI).

April 20: STAR submits statement on climate impact. *The GOES-R products played a role in the assessment.*

April 21: GE Aviation releases preliminary safe operating threshold. *The 2 mg/m³ threshold is within the GOES-R algorithm sensitivity range.*

April 22: GOES-R ash products are generated in real-time and displayed on the web.
At the request of the UK Met Office (the London VAAC), we began generating the GOES-R ash products in real-time beginning on April 22, 2010.
The web site attracted visitors from a wide range of countries.

The UK Met Office (London VAAC) registered the most hits out of all visitors.

The UK Met Office confirmed that they use the products daily.

Stan Benjamin’s group has been using the ash heights to initialize the FIM.
Known Users and Data Requests

- AFWA
- Airline Pilots Association
- Aviation Weather Testbed
- CALIPSO Science Team
- Deutscher Wetterdienst Remote Sensing Division
- ESRL (Stan Benjamin’s group)
- Iceland Met Office
- Italian Civil Protection
- MISR Science Team
- Norwegian Institute for Air Research
- Norwegian Meteorological Institute
- UK Met Office
- University of Alaska - Fairbanks
- University of Buffalo
- USGS
- WMO

There were also features on NPR, Weather Network TV (Canada), On Wisconsin Magazine, and Physorg.com
Comparison with SEVIRI ash retrievals

16 April, 6 UTC

FLEXPART total ash
16 April, 3-6 UTC
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IMPACT ON AVIATION:
• Nearly 100,000 canceled flights
• Airlines were losing $200 million/day
• Total economic impact - $2 billion
http://www.noaa.gov/features/03_protecting/volcanicash.html

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Redoubt ash from 15 Dec 1989 event

2 g

2 mg
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May 6, 2010 (14:00 UTC)

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CALIPSO 532 nm Total Attenuated Backscatter (km$^{-1}$sr$^{-1}$)

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Ash cloud
May 6, 2010 (14:00 UTC)

White: GOES-R Heights

Ash cloud

CALIPSO 532 nm Total Attenuated Backscatter (km$^{-1}$sr$^{-1}$)
May 6, 2010 (14:00 UTC)

The GOES-R ash cloud heights closely match the CALIPSO cloud top boundary. The traditional methodology underestimates the cloud height.
May 7, 2010 (14:00 UTC)

Ash clouds

CAMPSO 532 nm Total Attenuated Backscatter ($\text{km}^{-1}\text{sr}^{-1}$)

White: GOES-R Heights
May 7, 2010 (14:00 UTC)

Ash clouds

White: GOES-R Heights
Magenta: IR Window Heights

CALIPSO 532 nm Total Attenuated Backscatter (km^{-1}sr^{-1})
Even though these clouds are very optically thin, the GOES-R ash cloud heights closely match the CALIPSO cloud top boundaries, unlike the IR window based height.
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SEVIRI, $\theta_{\text{sat}} > 65.0^\circ$

Now you see it...
MODIS, $\theta_{\text{sat}} < 30.0^\circ$

Now you don’t…

RGB (12–11 $\mu$m, 11–8.5 $\mu$m, 11 $\mu$m)
Aqua–MODIS (05/08/2010 – 04:00 UTC)
MODIS, $\theta_{\text{sat}} < 30.0^\circ$

RGB (12–11 µm, 11–8.5 µm, 11 µm)

Aqua-MODIS (05/08/2010 - 04:00 UTC)
May 7, 2010 (03:00 UTC)

Ash clouds
May 7, 2010 (03:00 UTC)

From Low Earth Orbit (MODIS)
May 7, 2010 (03:00 UTC)

From Geostationary (SEVIRI)
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NOAA Volcanic Ash Working Group

• In response to the major aviation disruption caused by Eyjafjallajökull, NOAA has established a Volcanic Ash Working Group (B. Pierce and M. Pavolonis represent STAR).

• Some of the goals of this group are to: examine current volcanic ash forecasting and observing tools, improve observations of volcanic ash, and work towards using satellite observations to initialize models.

• While the GOES-R products have been shown to be valuable, additional efforts are needed to ensure these products are addressing the goals of the VAWG.

• Have procedures been developed to assimilate these products into models (GOES-R RR)? Are the full capabilities of GOES-R being utilized?
• With an additional processing step, the ABI (and SEVIRI and MODIS) products can be used to issue automated ash cloud alerts to VAAC's.

• In addition, the ABI volcanic ash output can be combined with output from the SO2 detection algorithm and lightening mapper data to build a state-of-the-art volcanic cloud alert and monitoring system.

• If such a decision support system is not built, the ABI’s temporal resolution will not be fully utilized, as forecasters cannot possibly manually analyze every image (and the 5-minute warning criteria will not be realized).
Just in the last week or so, we received 22 verified ash alerts - busy week!
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- The AWG program provided the support needed to develop a sophisticated set of quantitative volcanic ash products for GOES-R (along with robust code, capable of running reliably in real-time).

- The eruption of Eyjafjallajökull provided an opportunity to impact operational volcanic ash forecasting and research through the generation of real-time SEVIRI products.

- We are now better prepared for future eruptions of Eyjafjallajökull and neighboring Katla.

- These products (using MODIS) will be made available to the Anchorage VAAC via the GOES-R PG.

- Despite the success of these products, GOES-R Risk Reduction efforts are needed to built a fully automated volcanic cloud alert system (needed to help achieve a 5-minute warning capability and take advantage of the ABI’s high temporal resolution) and to develop procedures to assimilate the retrievals into models.
Thanks!

Marco Fulle - www.stromboli.net