Volcanic Ash Forecasting for Aviation

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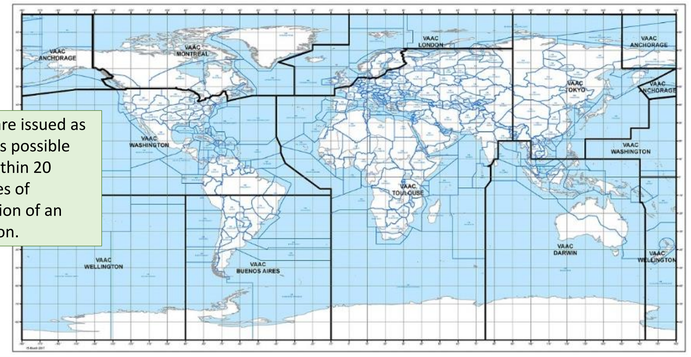
Objective

Utilize modeling and observations to develop quantitative volcanic ash concentration nowcasts and forecasts which communicate uncertainty.

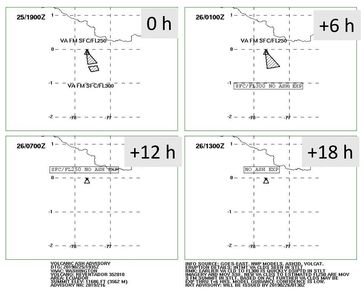
Background

Volcanic ash is a major aviation hazard which can cause engine failure. Current guidance is complete avoidance of volcanic ash by aircraft.

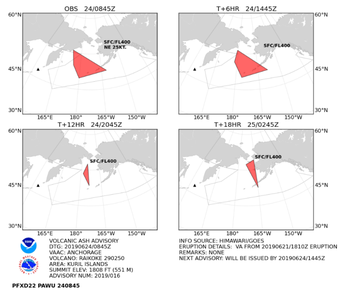


VAAs are issued as soon as possible and within 20 minutes of detection of an eruption.

Volcanic ash advisory centers (VAACs) are responsible for issuing Volcanic Ash Advisories (VAAs) for volcanic ash emissions in their area (shown above) according to International Civil Aviation Organization (ICAO) guidelines. **NOAA houses 2 of the 9 VAACs.**
Currently, the VAA is a text and graphical product. Areas of discernable ash at 0, 6, 12, 18 hours are indicated by a polygon.



VAA issued for Reventador (Ecuador) by The Washington VAAC on 25 Feb 2019. VAAs were issued for Reventador almost every day in 2019.



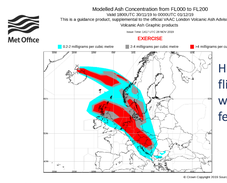
VAA issued for ash from Raikoke (Kuril Islands) by the Anchorage VAAC on 25 Feb 2019. This large eruption produced a long lived ash cloud.

Future

ICAO specifications for VAAs are likely to change significantly in the near future, including requirements for quantitative estimates of ash. Changes are in response to evolving needs of aviation stakeholders, a better understanding of the impact of ash on engines, and improved observational and modeling capabilities.

11/21/2019 Cojoint 7th WMO VAAC Best Practices Workshop 9th WMO/IUGG Volcanic Ash Scientific Advisory Group (VASAG) Meeting.
https://www.wmo.int/aemp/VAAC-BP-7-VASAG-9

Example of supplemental quantitative ash chart produced by the UK MET office.



Height of ash is in flight levels FL which is 100's of feet.

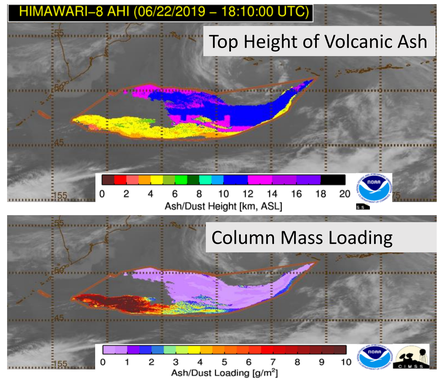
https://www.metoffice.gov.uk/services/transport/aviation/regulated/vaac/concentration-charts

Observations are critical to quantify and reduce uncertainty

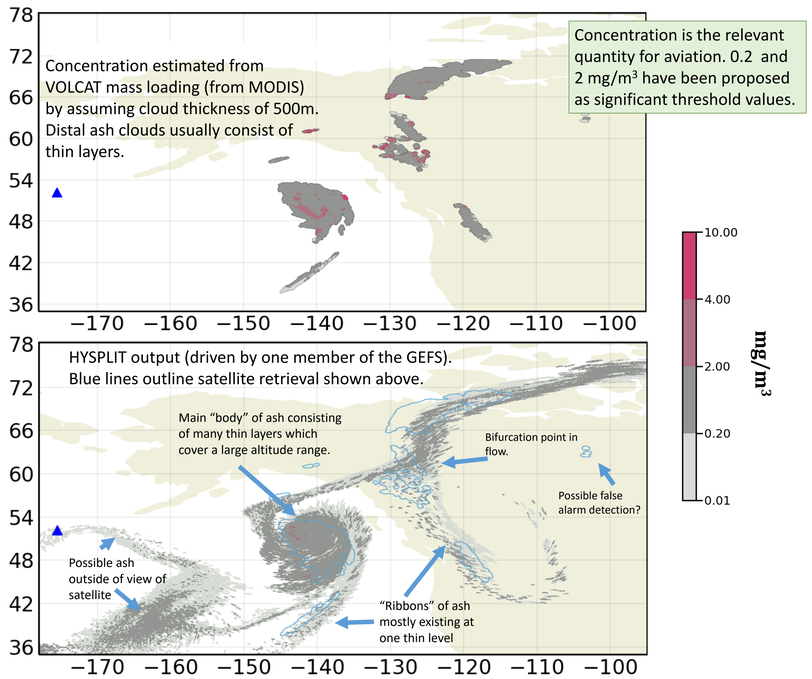
Primary source of volcanic cloud observations is satellite.

VOLcanic Cloud Analysis Toolkit (VOLCAT) is a NOAA funded project directed by Michael Pavolonis at NOAA NESDIS/CIMSS.
Multiple geostationary and low-earth orbiting satellite data are used to detect global volcanic activity. Automatic alerts are provided.
https://volcano.ssec.wisc.edu/

M. J. Pavolonis, Sieglaff, J., Cintineo, J., "Spectrally Enhanced Cloud Objects - A generalized framework for automated detection of volcanic ash and dust clouds using passive satellite measurements: 1. Multispectral analysis." *JGR: Atmospheres* (2015). https://doi.org/10.1002/2014JD022968



Modeling provides forecasts and can reduce uncertainty in nowcasting.



Ash Cloud from August 2008 Eruption of Kasatochi (blue triangle) approximately 3.5 days after end of eruption. Ash from the eruption was pulled into a passing low pressure system. The ash traveled as a fairly cohesive block within the area of low pressure for several days.

Semi-Automated Workflow

Amount of information which must be ingested as well as produced is increasing. The workflow which produces a VAA will become more automated. For instance VOLCAT alerts often reduce time to detect an eruption. Modeling tasks will be automated or semi-automated.
https://www.ready.noaa.gov/hysplitash-bin/vaac1a.py

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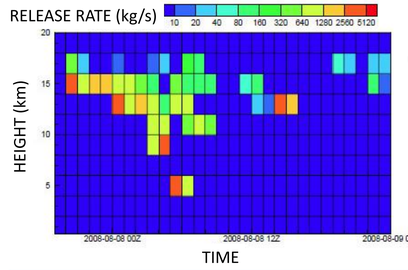
HYSPLIT Model Toolbox

HYSPLIT is NOAA's operational Lagrangian atmospheric transport and dispersion model. It can provide forecasts of concentration for emergency response quickly. https://www.ready.noaa.gov/HYSPLIT.php

Inversion Algorithms

Emission terms are obtained by searching for the emissions that would create model predictions which best match observations.

- Produce better long term forecasts by creating a more accurate initialization. Significantly less likely to over or under estimate concentrations.
- Emissions may be fed into a numerical weather prediction, NWP, model.

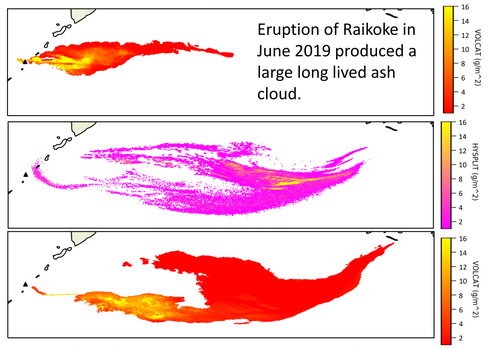


Estimated emissions from 2008 eruption of Kasatochi

Tianfeng Chai, et al., (2017) Improving volcanic ash predictions with the HYSPLIT dispersion model by assimilating MODIS satellite retrievals *Atmos. Chem. Phys., 17, p1-15* doi:10.5194/acp-17-1-2017

Data Insertion

Construct an initialization for the dispersion model at the time and location of an observation. This technique is fast and can help correct for errors in NWP winds or HYSPLIT model parameterizations.



VOLCAT mass loading (from Himawari) 12 hours after eruption start. Used to construct initialization for HYSPLIT.

Data insertion HYSPLIT forecast for 24 hours after eruption start. Model run started 12 hours after eruption with mass initialized at locations shown in observations above.

VOLCAT mass loading 24 hours after eruption start.
Compare to forecast and then create a new model initialization.

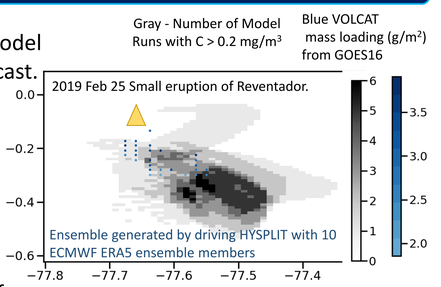
Crawford, et al., (2016) Initializing HYSPLIT with satellite observations of volcanic ash: A case study of the 2008 Kasatochi eruption *J. of Geophysical Research: Atmospheres,* 121, p 10,786, doi:10.1002/2016D024779

Dispersion model Ensembles

Combine information from multiple model runs to convey uncertainty in the forecast. Multiple runs can be constructed by

1. utilizing NWP ensemble output
2. Varying HYSPLIT parameterizations
3. Varying initializations
4. Multi-model (HYSPLIT and NWP forecasts)

There are many different kinds of products which can be constructed from the output of a dispersion model ensemble. To the right is an example which indicates the number of model runs which forecast concentrations greater than a given threshold level.



Though smaller, this eruption was difficult to forecast due to high wind shear, the placement of which was not captured well in the models.

Some of this work is part of the JPSS Initiative for Improving Volcanic Hazard Monitoring and Forecasting.