How GOES-R Will Help Mitigate Aviation-related Volcanic Hazards

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“Ladies and gentlemen, this is your captain speaking. We have a small problem. All four engines have stopped”
-Captain Eric Moody
KLM Flight-867, December 15, 1989
Economic Impacts of Volcanic Ash

The Eyjafjallajökull Eruption:

- Nearly 100,000 canceled flights (50% of world’s air traffic!)
- Airlines were losing $200 million/day
- Total economic impact - $2 billion

Before Ash Event

During Ash Event
• Only about 10% of the world’s volcanoes are regularly monitored by volcano observatories!

• Meteorological satellites are often the only means of detecting explosive (and non-explosive) volcanic eruptions
Even explosive eruptions can be missed!

Nabro volcano in Eritrea erupted explosively for the first time in recorded history on June 12, 2011.

The eruption went undetected for 7.5 hours!
Eritrea eruption: **Clinton cuts short African tour**

A plume of smoke from an erupting volcano in southern Eritrea, seen at top, centre, is carried by winds blowing across northern Ethiopia on Monday.

The US secretary of state has cut short a three-nation tour of Africa following a volcano eruption that has created an ash cloud over parts of East Africa.

Hillary Clinton arrived in the Ethiopian capital on Monday for an address to the African Union.

US officials said the decision was taken because the cloud was due to move towards Addis Ababa.

The cloud, triggered by an eruption in Eritrea, has led to the cancellation of some flights to East Africa.

The German airline Lufthansa cancelled flights to both Eritrea and neighbouring Ethiopia.
Collecting large volumes of satellite data alone does not directly address any natural hazard problem, the satellite data must be converted into actionable information using science and computers.
Identifying “restless” volcanoes

Alert: Restless Volcano Detected

False Color Imagery (12–11 µm, 11–3.9 µm, 11 µm)

Satellite measurements

Scientific computer algorithm

Identification of volcanoes that are most likely to erupt

Automated alert to users

Annotation Key
(Annotation colors are not related to colors in underlying image)
Ash/Dust Cloud Volcanic Ob SO₂ Thermal Anomaly

Aqua MODIS (05/09/2014 – 13:14 UTC)
Using weather satellite data, an unusually large ground temperature was identified at Kelut volcano and an alert was automatically generated.
30 minutes later...

Erupsi Kelud
@hilmi_dzi | 00:30 am
Nglegok, Blitar
Weather or volcanic eruption?
Erupsi Kelud
@hilmi_dzi | 00:30 am
Nglegok, Blitar
Kelut eruption is detected in a timely manner

Color Enhanced Infrared Imagery (11µm)
Kelut eruption is detected in a timely manner

Color Enhanced Infrared Imagery (11μm)

MTSAT–1R VisIRImager (02/13/2014 – 16:19 UTC)

Kelut cloud

@**********VOLCANIC ALERTS**********
STARTING DATE/TIME OF IMAGE: 2014-02-13 16:19:00 [UTC]
PRODUCTION DATE/TIME OF ALERT: 2014-02-14 16:49:44 [UTC]
PRIMARY INSTRUMENT: MTSAT-1R Vis/IR_Imager
WMO SPACECRAFT ID: 171
LOCATION/ORBIT: GEO
L1 FILE: mtsat01_1_2014_044_1619.area.gz
VOLCANO DATABASE: /data/common/VOLCAT_DATA/alert
NUMBER OF ASH CLOUD ALERTS: 0
NUMBER OF VOLCANIC Cb ALERTS: 1
NUMBER OF VOLCANIC THERMAL ANOMALY ALERTS: 0
NUMBER OF SO2 CLOUD ALERTS: 0

REPORT WITH IMAGES:
http://volcano.ssec.wisc.edu/alert/report/12238

POSSIBLE VOLCANIC ERUPTION DETECTED
Alert Status: New Alert Object
Latitude of Radiative Center: -8.012 [degrees]
Longitude of Radiative Center: 112.265 [degrees]
Mean Viewing Angle: 33.92 [degrees]
Mean Solar Zenith Angle: 157.44 [degrees]
Nearby Volcanoes (meeting alert criteria):
Kelut (9.99 km)
Kawi-Butak (23.00 km)
Maximum Height [AMSL]: 21.2 [km] (69649.79 [ft])
90th Percentile Height [AMSL]: 19.2 [km] (62995.20 [ft])
Mean Tropopause Height [AMSL]: 16.4 [km] (53783.42 [ft])

Trend in IR Brightness Temperature: -53.16 [K]
Vertical Growth Rate Time Interval: 10 [minutes]
Vertical Growth Rate Anomaly: 24.75 [number of stddev at]
Total Area: 1270.01 [km^2]

Geographic Regions of Nearby Volcanoes: Java
VAAC Regions of Nearby Volcanoes: Darwin
FIR Regions of Nearby Volcanoes: Unknown
The next generation of GEO satellites are very well suited for automated detection of volcanic eruption through cloud object growth rate analysis!
http://volcano.ssec.wisc.edu
Nabro volcano in Eritrea erupted explosively for the first time in recorded history on June 12, 2011. The eruption went undetected for 7.5 hours!
The NOAA volcanic eruption alerting tool was able to detect the eruption within 15 minutes of the start time and generate an alert.
Improving ash cloud forecasts
Concluding Thoughts

• GOES-R will greatly improve volcanic hazard monitoring, but only when combined with sophisticated scientific algorithms

• Automated volcanic cloud alerting service will be more broadly available within a year

• The integration of satellite-derived parameters and models holds great promise for improving volcanic cloud dispersion forecasts and our understanding of how ash is dispersed within and removed from the atmosphere

• We are working with the USGS to integrate satellite and non-satellite data sources (lightning, infrasound, seismic, etc...) for operational and research applications
Many factors dictate the impact on aviation. The properties of the magma, external water sources, and eruption duration matter!
Questions?
Back-up slides
The assumed mineral composition has a larger impact on mass loading compared to cloud height.
CALIPSO 532 nm Total Attenuated Backscatter (km^-1sr^-1) [UTC: 2010-05-08 04:01:59 to 2010-05-08 04:05:04]

Andesite
Rhyolite
Kaolinite

Pavolonis et al., 2013
a. Andesite Cloud Loading Validation (wrt cloud top height)

Bias = -0.196
Precision = 1.984

b. Andesite Cloud Loading Validation (wrt 11 μm emissivity)

c. Rhyolite Cloud Loading Validation (wrt cloud top height)

Bias = 0.429
Precision = 2.685

d. Rhyolite Cloud Loading Validation (wrt 11 μm emissivity)

Pavolonis et al., 2013