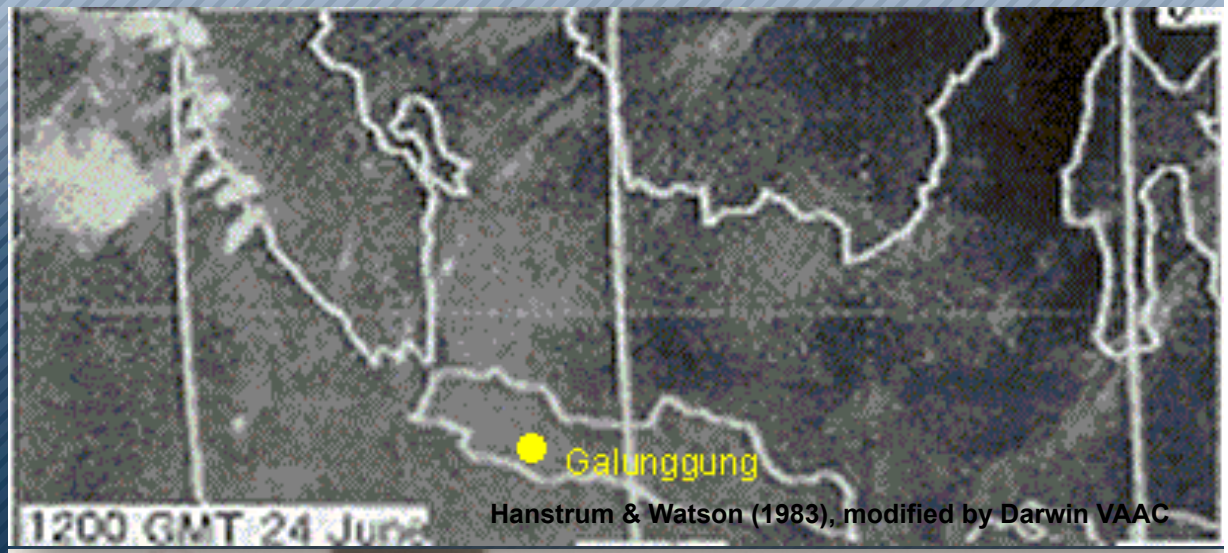
How GOES-R Will Help Mitigate Aviation-related Volcanic Hazards

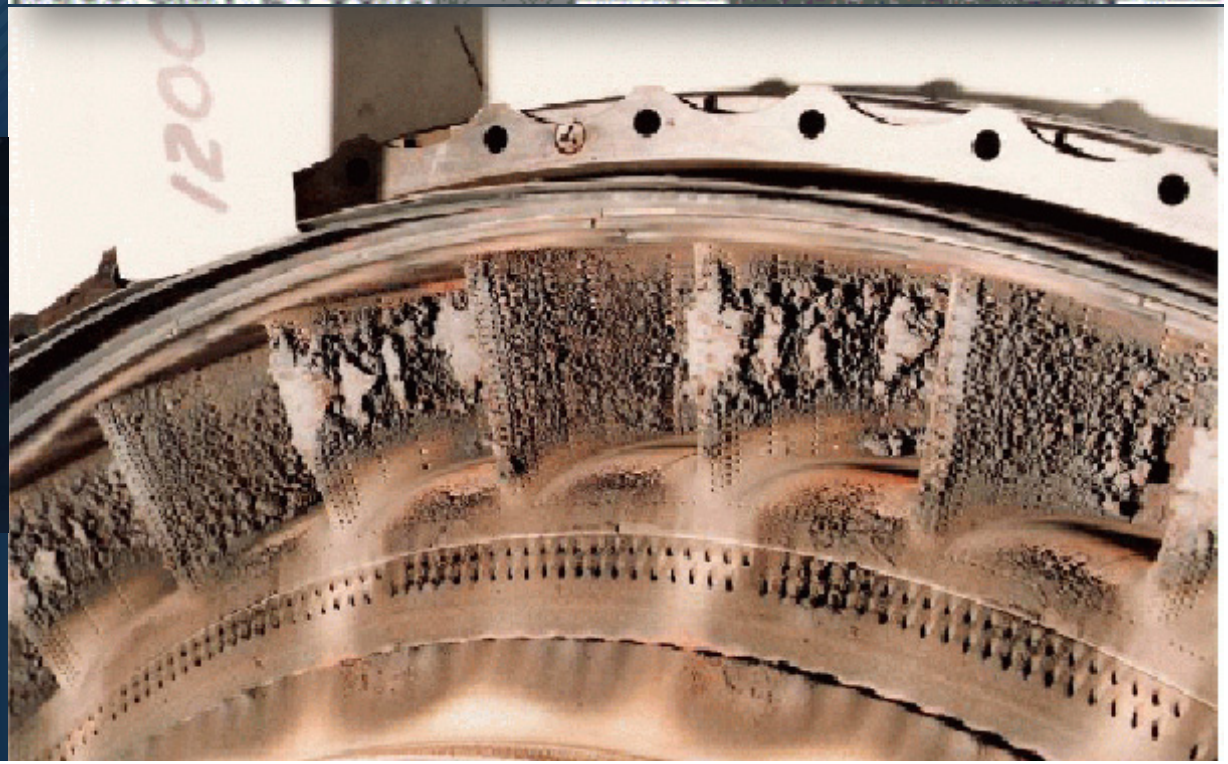
Michael J. Pavolonis
Physical Scientist
National Environmental Satellite, Data, and Information Service
Center for Satellite Applications and Research

British Airways Flight 9, June 24, 1982

"Ladies and gentlemen, this is your captain speaking. We have a small problem. All four engines have stopped"
-Captain Eric Moody



Hanstrum & Watson (1983), modified by Darwin VAAC



KLM Flight-867, December 15, 1989


Credit: Gary Hufford

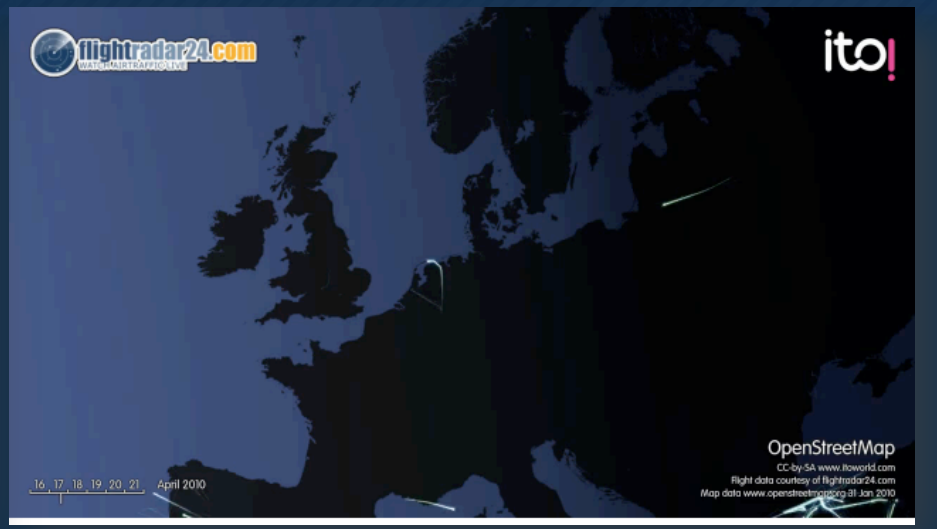

Joyce M. Warren

Economic Impacts of Volcanic Ash

The Eyjafjallajökull Eruption:

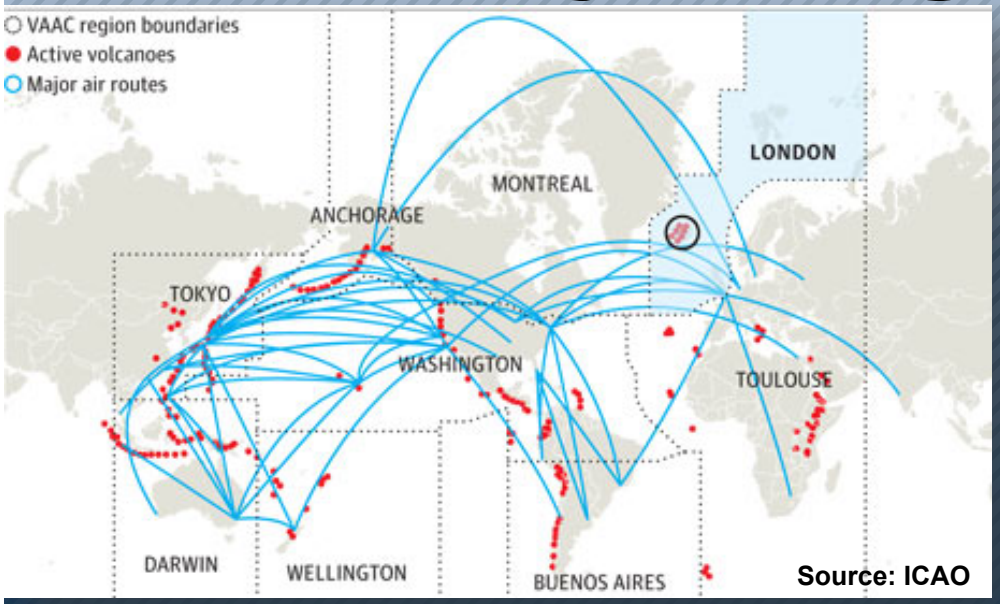
- Nearly 100,000 canceled flights (50% of world's air traffic!)
- Airlines were losing $200 million/ day
- Total economic impact - $2 billion

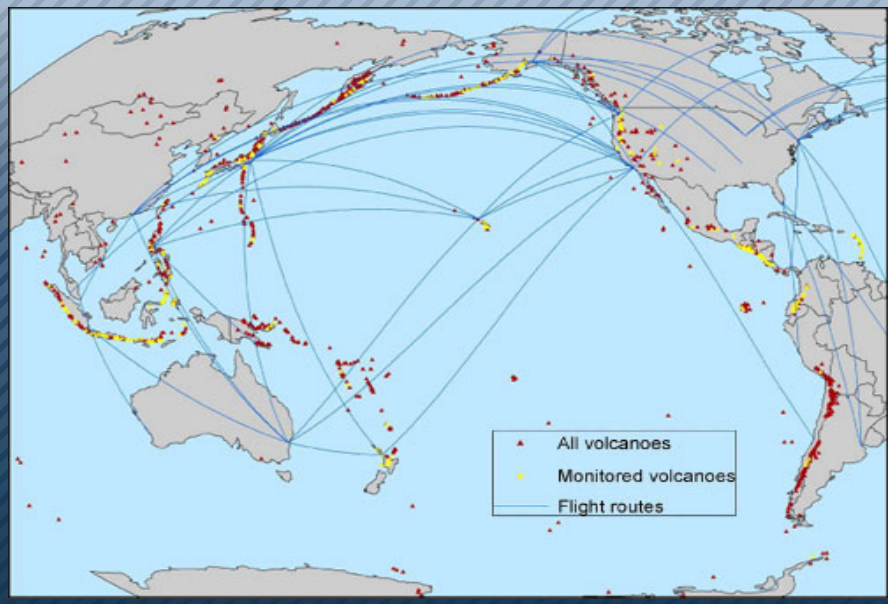
Before Ash Event

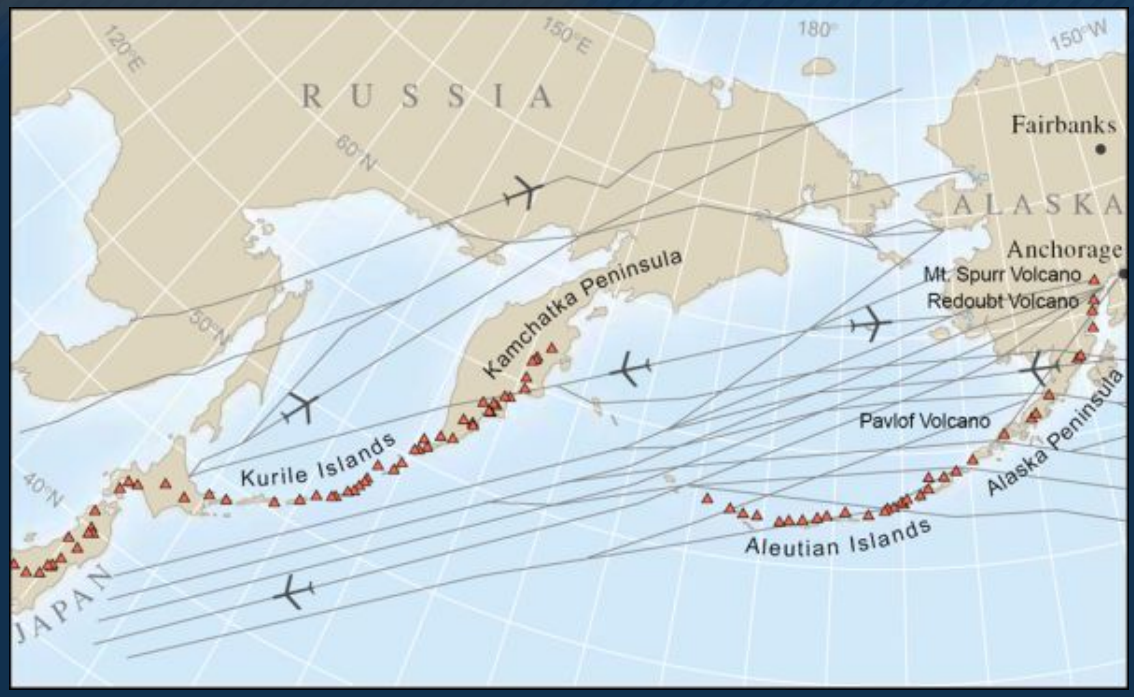


During Ash Event

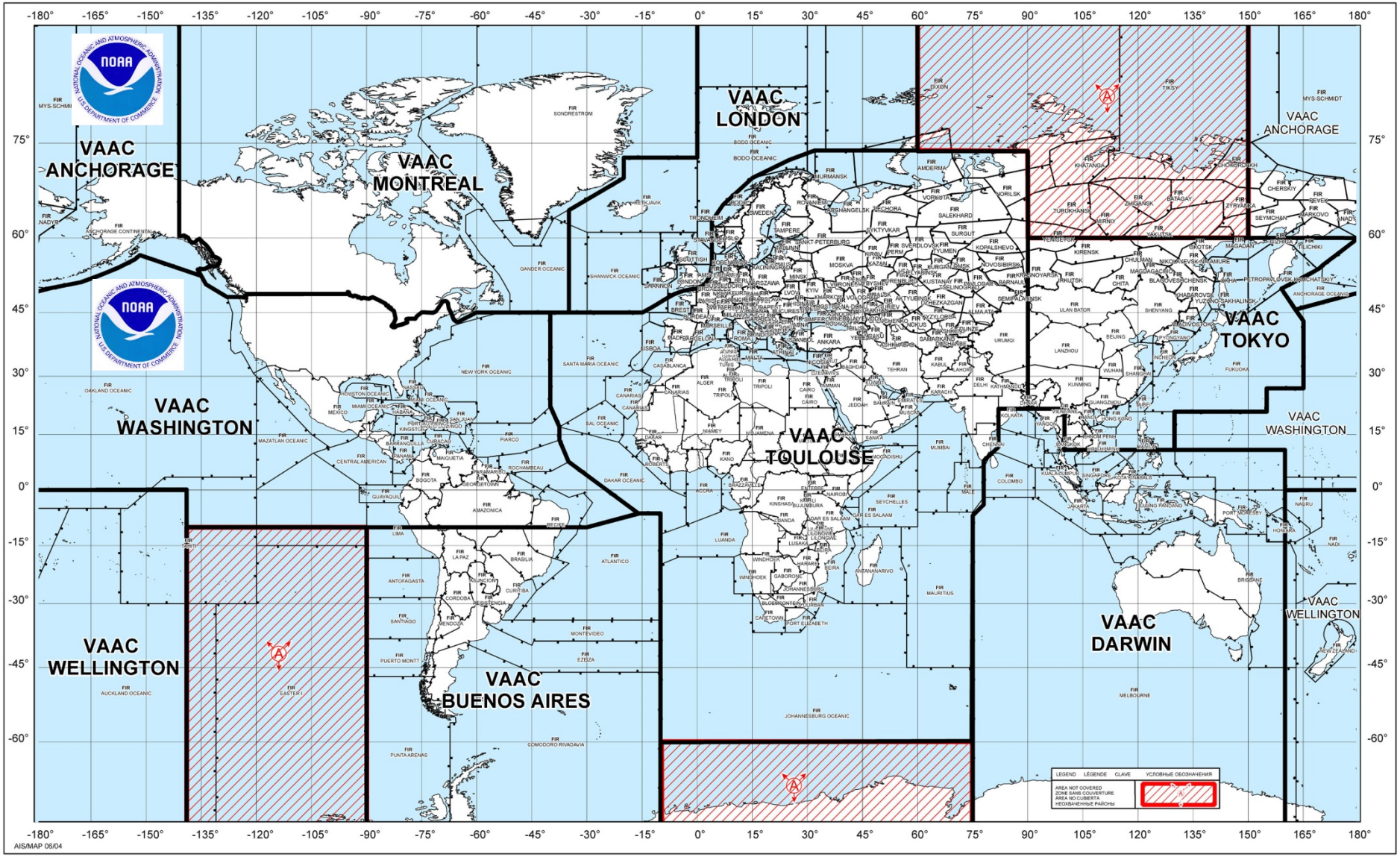
Major Flight Routes

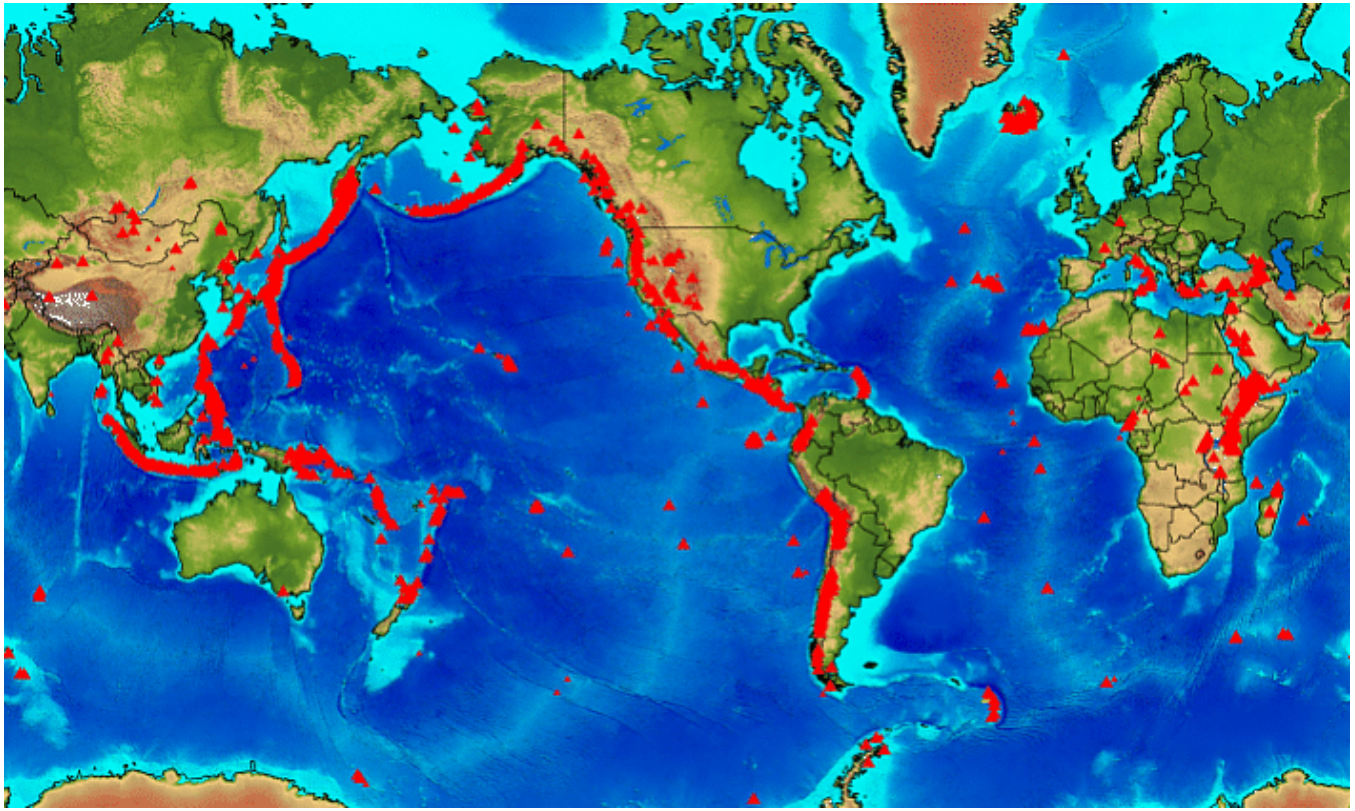






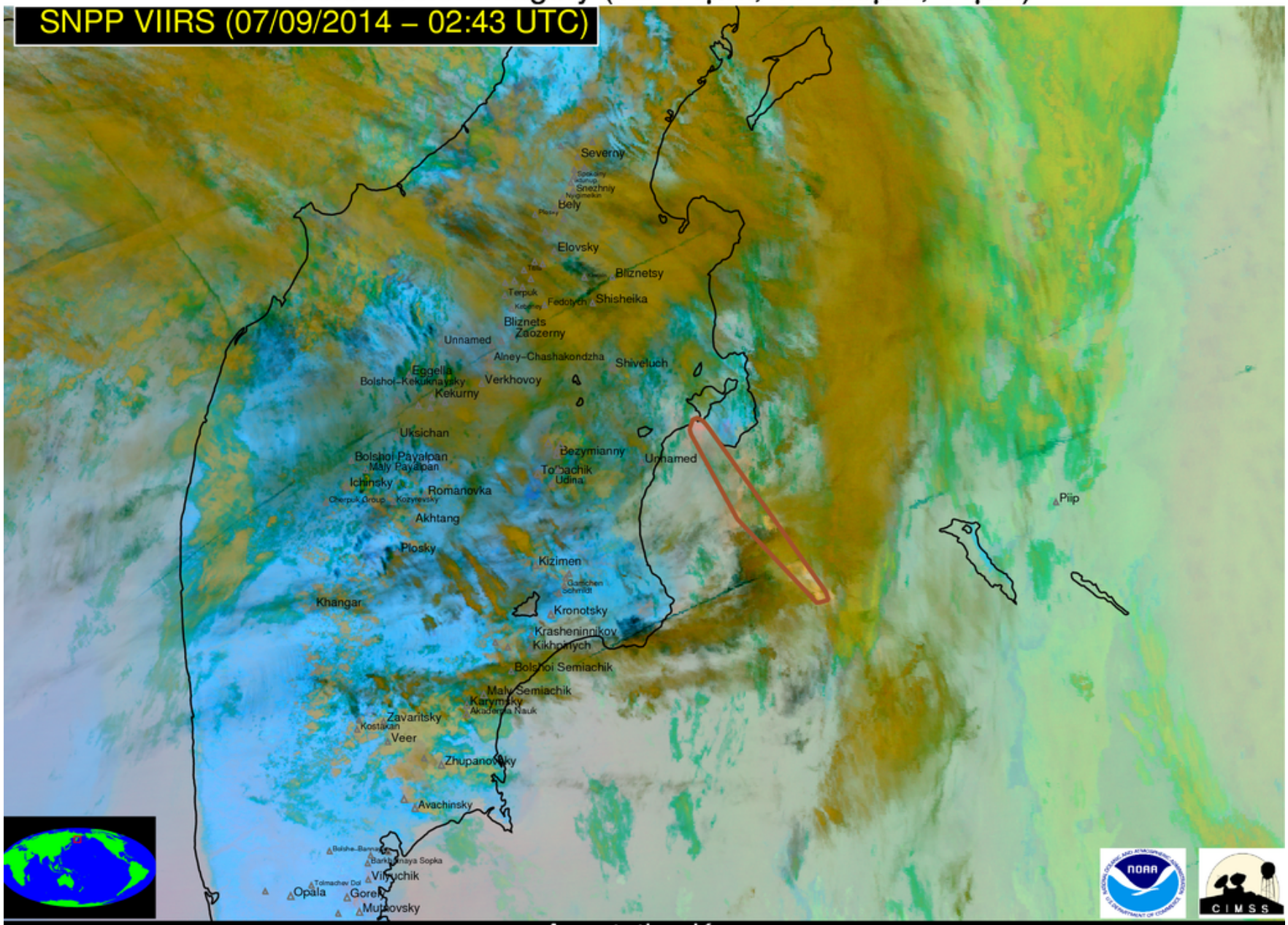
CURRENT STATUS OF ICAO VOLCANIC ASH ADVISORY CENTRES (VAAC) - AREAS OF RESPONSIBILITY
SITUATION ACTUELLE DES CENTRES OACI D'AVIS DE CENDRES VOLCANIQUES (VAAC) - ZONES DE RESPONSABILITÉ
ESTADO ACTUAL DE LOS CENTROS DE AVISOS DE CENIZAS VOLCÁNICAS (VAAC) DE LA OACI - ÁREAS DE RESPONSABILIDAD
СУЩЕСТВУЮЩЕЕ РАСПРЕДЕЛЕНИЕ КОНСУЛЬТАТИВНЫХ ЦЕНТРОВ ИКАО ИО ВУЛКАНИЧЕСКОМУ ПЕПЛУ (VAAC) - РАЙОНЫ ОТВЕТСТВЕННОСТИ





- **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**

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

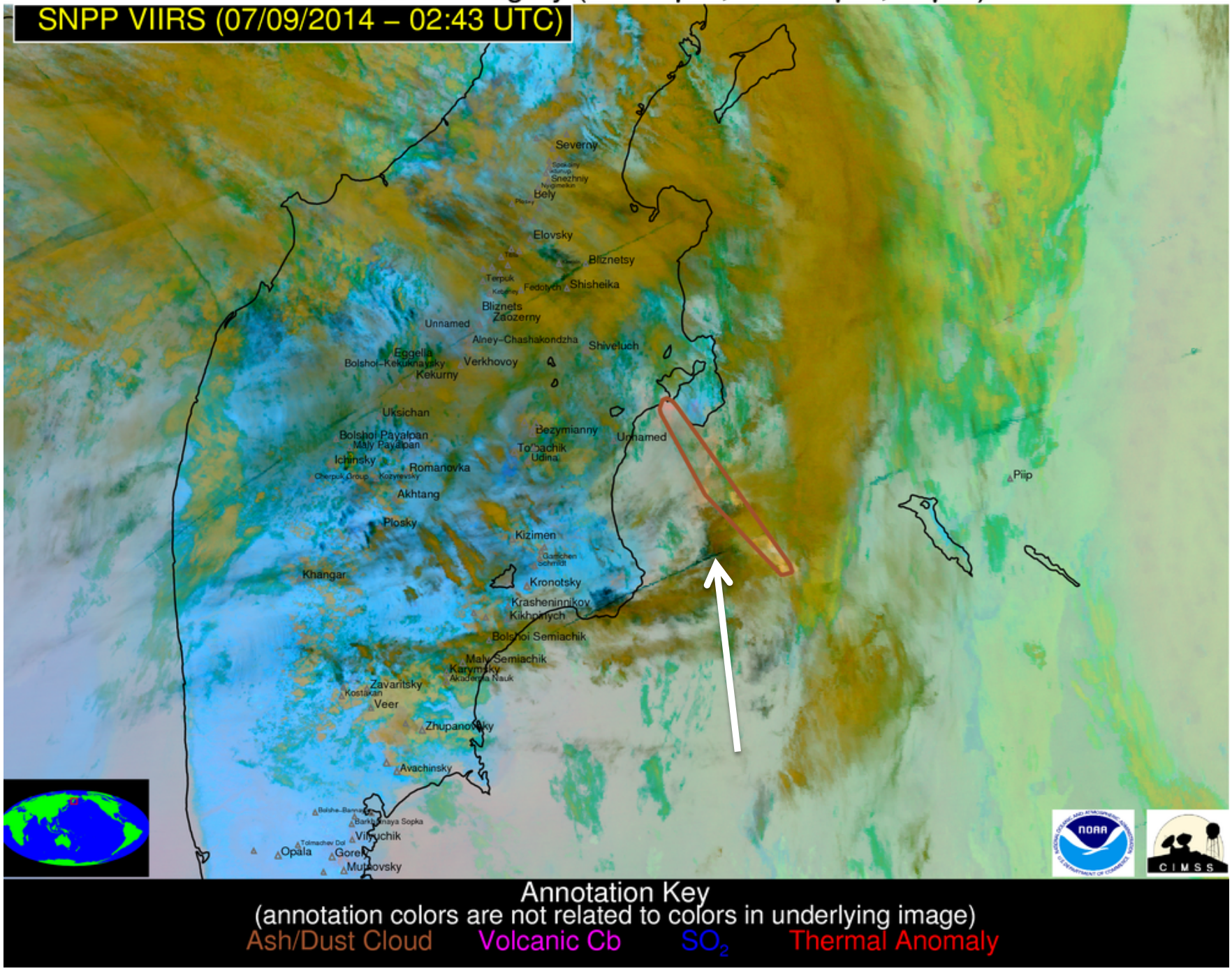


Annotation Key

(annotation colors are not related to colors in underlying image)

Ash/Dust Cloud Volcanic Cb SO_2 Thermal Anomaly

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



Annotation Key

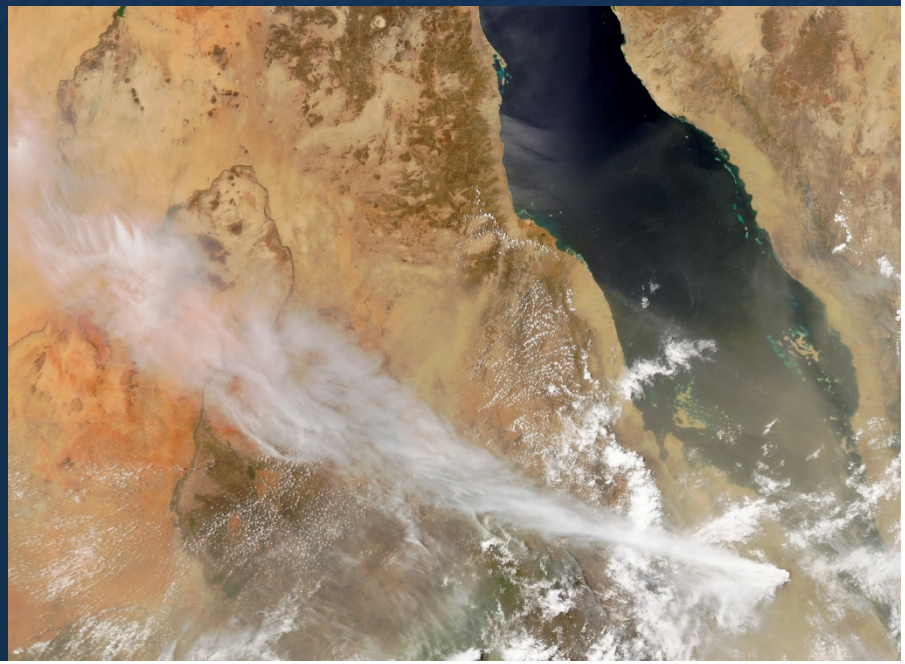
(annotation colors are not related to colors in underlying image)

Ash/Dust Cloud Volcanic Cb SO_2 Thermal Anomaly

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!



14 June 2011 Last updated at 09:35 ET

Share

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.

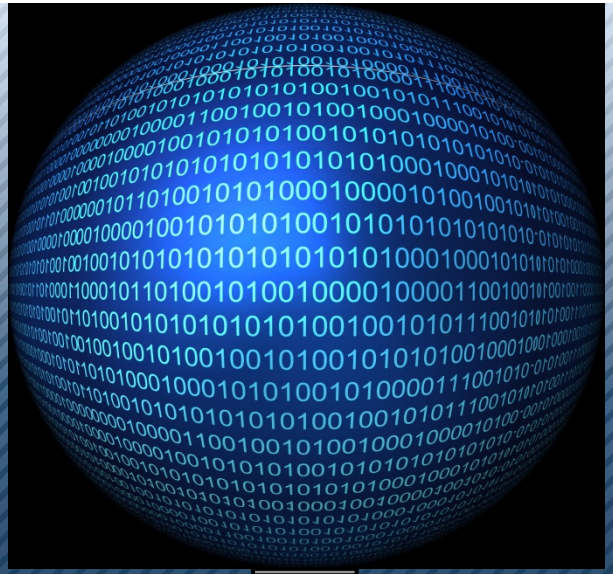
US officials said the decision was taken because the cloud was due to move towards Addis Ababa.

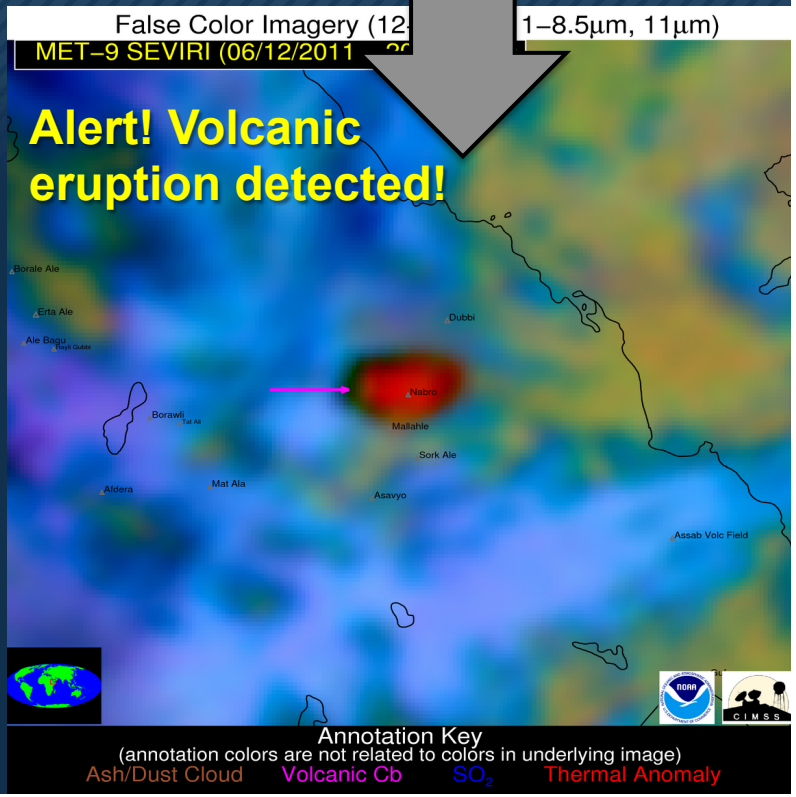
The cloud, triggered by an eruption in Eritrea, has led to the cancellation of some flights to East Africa.

The German airline Lufthansa cancelled flights to both Eritrea and neighbouring Ethiopia.

BBC NEWS AFRICA

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

Satellite measurements

↓

Scientific computer algorithm

↓

Identification of volcanoes that are most likely to erupt

↓

Automated alert to users

Using weather satellite data, an unusually large ground temperature was identified at Kelut volcano and an alert was automatically generated

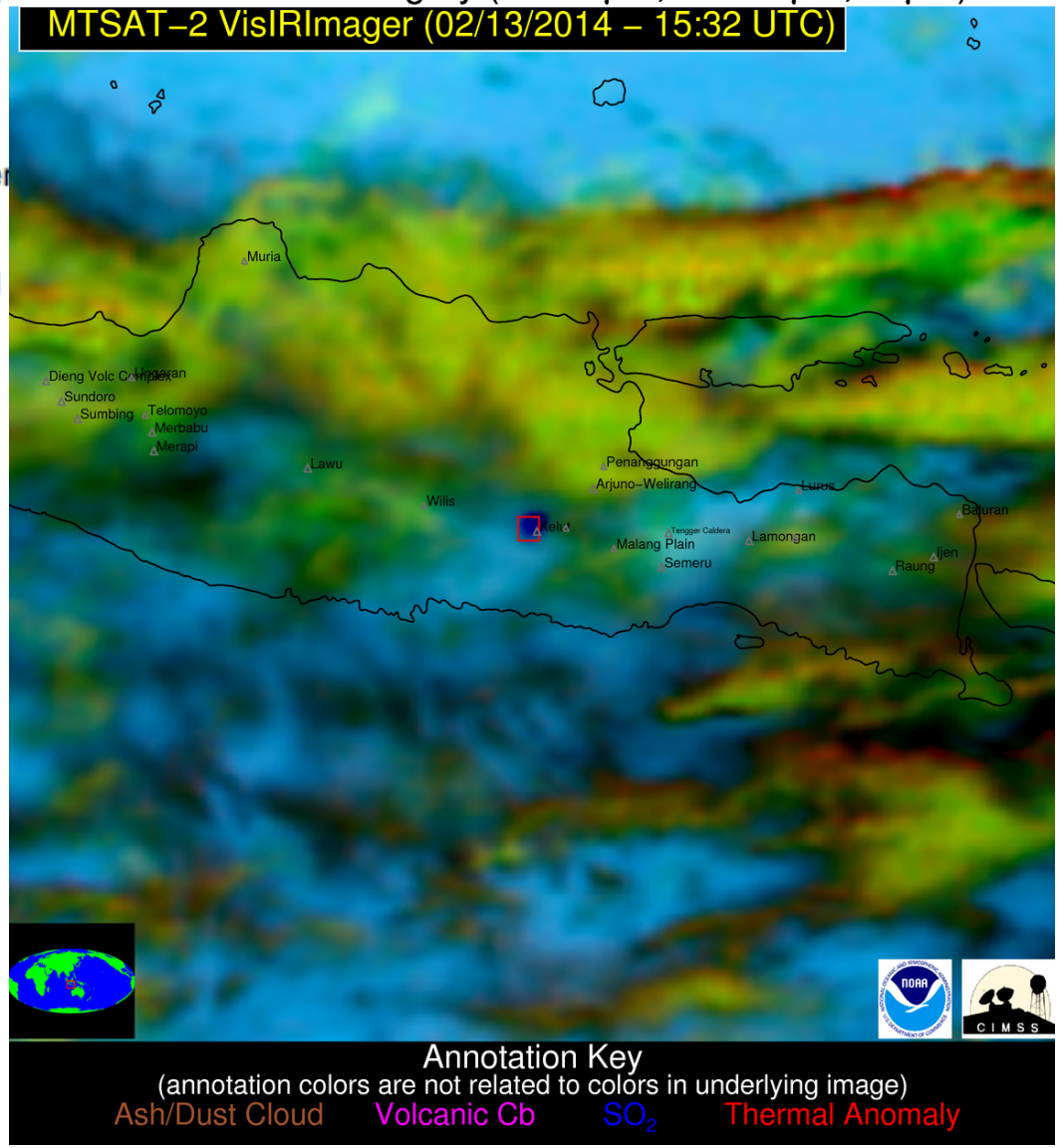
From: Mike Pavolonis NOAA Federal
Subject: **NOAA/CIMSS Volcanic Cloud Alert**
Date: February 13, 2014 10:09:05 AM CST
To: Mike Pavolonis NOAA Federal

@**********VOLCANIC ALERTS**********
STARTING DATE/TIME OF IMAGE: 2014-02-13 15:32:00 [U
PRIMARY INSTRUMENT: MTSAT-2 Vis/IR_Imager
WMO SPACECRAFT ID: 172
LOCATION/ORBIT: GEO
L1 FILE: mtsat02_1_2014_044_1532.area.gz
VOLCANO DATABASE: /data/common//VOLCAT_DATA/aler
NUMBER OF ASH CLOUD ALERTS: 0
NUMBER OF VOLCANIC Cb ALERTS: 0
NUMBER OF VOLCANIC THERMAL ANOMALY ALERTS: 1
NUMBER OF SO2 CLOUD ALERTS: 0

REPORT WITH IMAGES:
http://volcano.ssec.wisc.edu/alert/report/12211

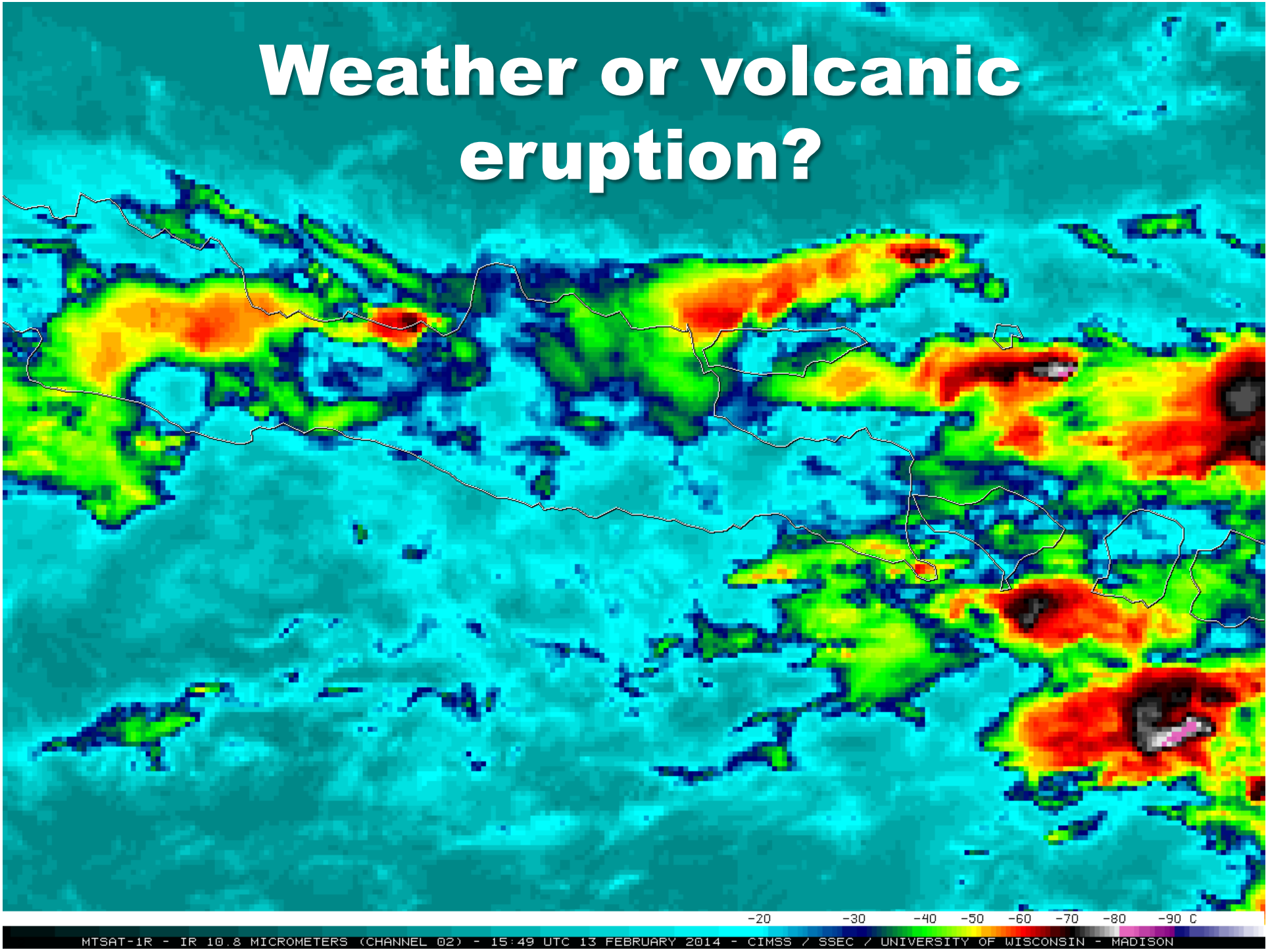
POSSIBLE VOLCANIC THERMAL ANOMALY FOUND
Alert Status: New Alert Object
Latitude of Radiative Center: -7.920 [degrees]
Longitude of Radiative Center: 112.268 [degrees]
Mean Viewing Angle: 39.18 [degrees]
Mean Solar Zenith Angle: 151.86 [degrees]
Nearby Volcanoes (meeting alert criteria):
Kelut(4.67 km)
Maximum 3.8 um Brightness Temperature: 310.37 [K]
Maximum 3.8 um Thermal Anomaly: 20.80 [K]
Total Area: 89.30 [km^2]

Geographic Regions of Nearby Volcanoes: Java
VAAC Regions of Nearby Volcanoes: Darwin
FIR Regions of Nearby Volcanoes: Unknown



30 minutes later...

Weather or volcanic eruption?




Erupsi Kelud
@hilmi_dzi | 00:30 am
Nglegok, Blitar

@**********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/al
NUMBER OF ASH CLOUD ALERTS: 0
NUMBER OF VOLCANIC Cb ALERTS: 1
NUMBER OF VOLCANIC THERMAL ANOMALY ALERTS:
NUMBER OF SO2 CLOUD ALERTS: 0

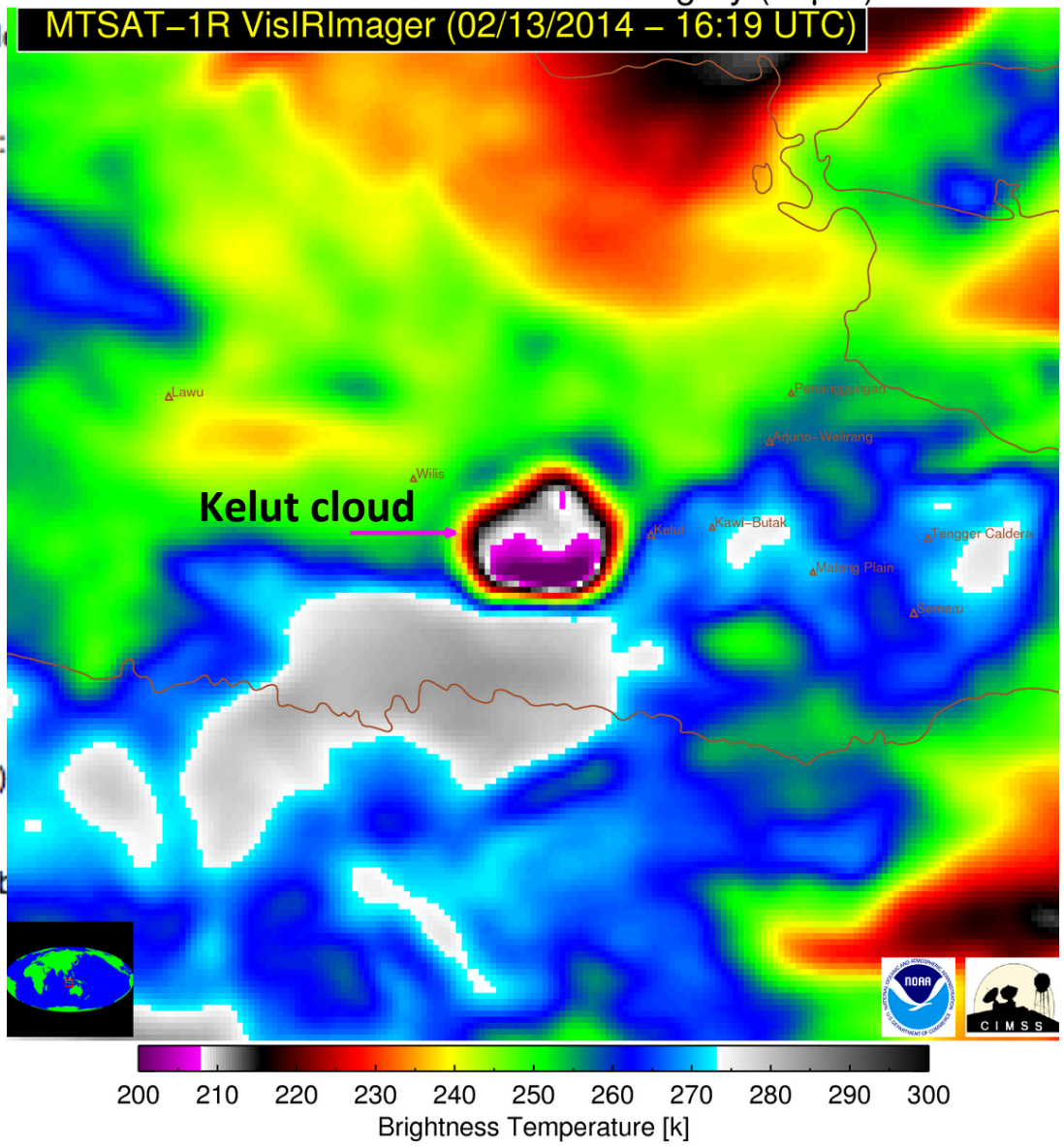
REPORT WITH IMAGES:
http://volcano.ssec.wisc.edu/alert/report/12238

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 ab
Total Area: 1270.01 [km^2]

Geographic Regions of Nearby Volcanoes: Java
VAAC Regions of Nearby Volcanoes: Darwin
FIR Regions of Nearby Volcanoes: Unknown

Kelut eruption is detected in a timely manner

Color Enhanced Infrared Imagery (11μm)



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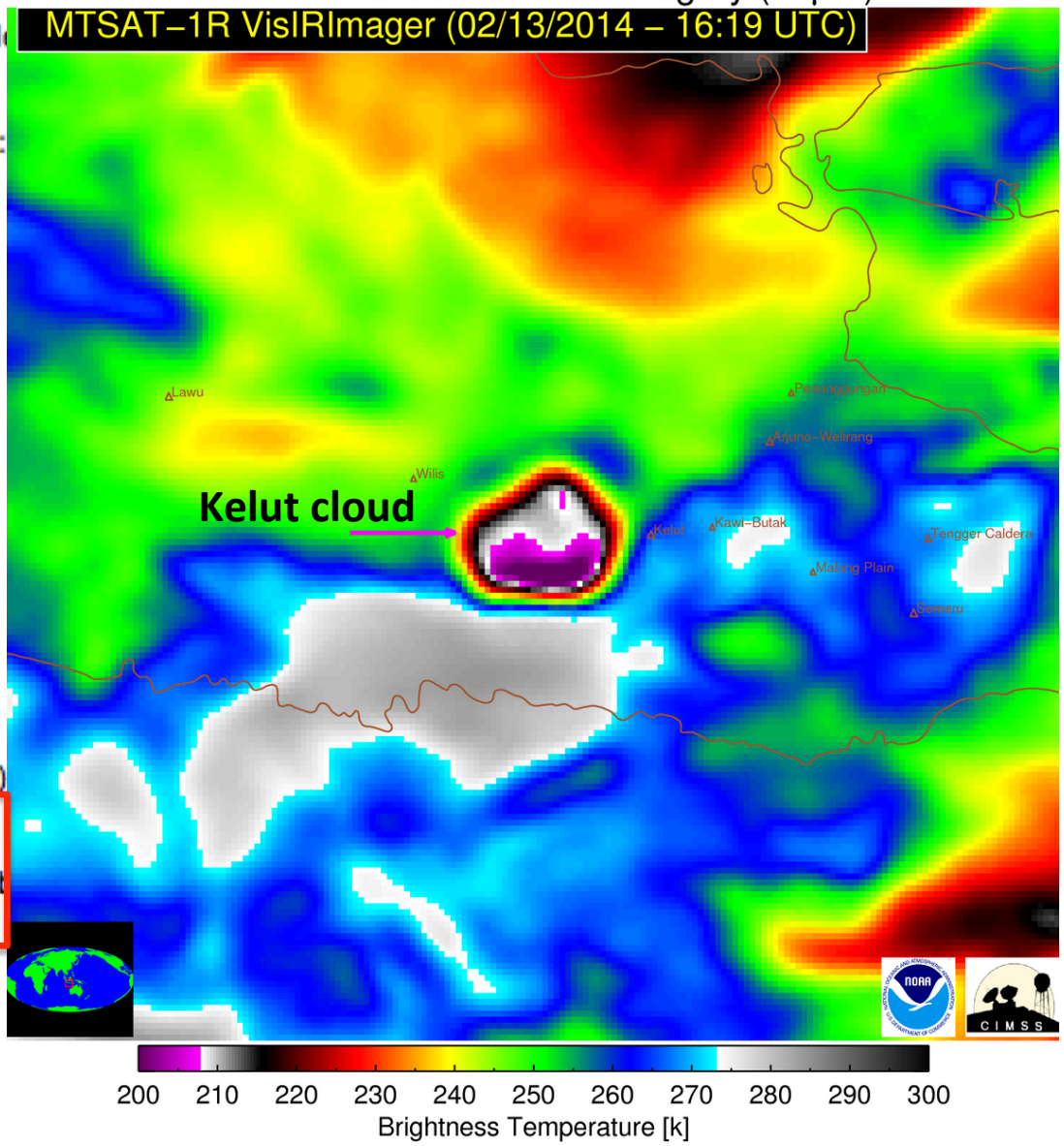

The next generation of GEO satellites are very well suited for automated detection of volcanic eruption through cloud object growth rate analysis!

NUMBER OF VOLCANIC Cb ALERTS: 1
NUMBER OF VOLCANIC THERMAL ANOMALY ALERTS:
NUMBER OF SO2 CLOUD ALERTS: 0

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

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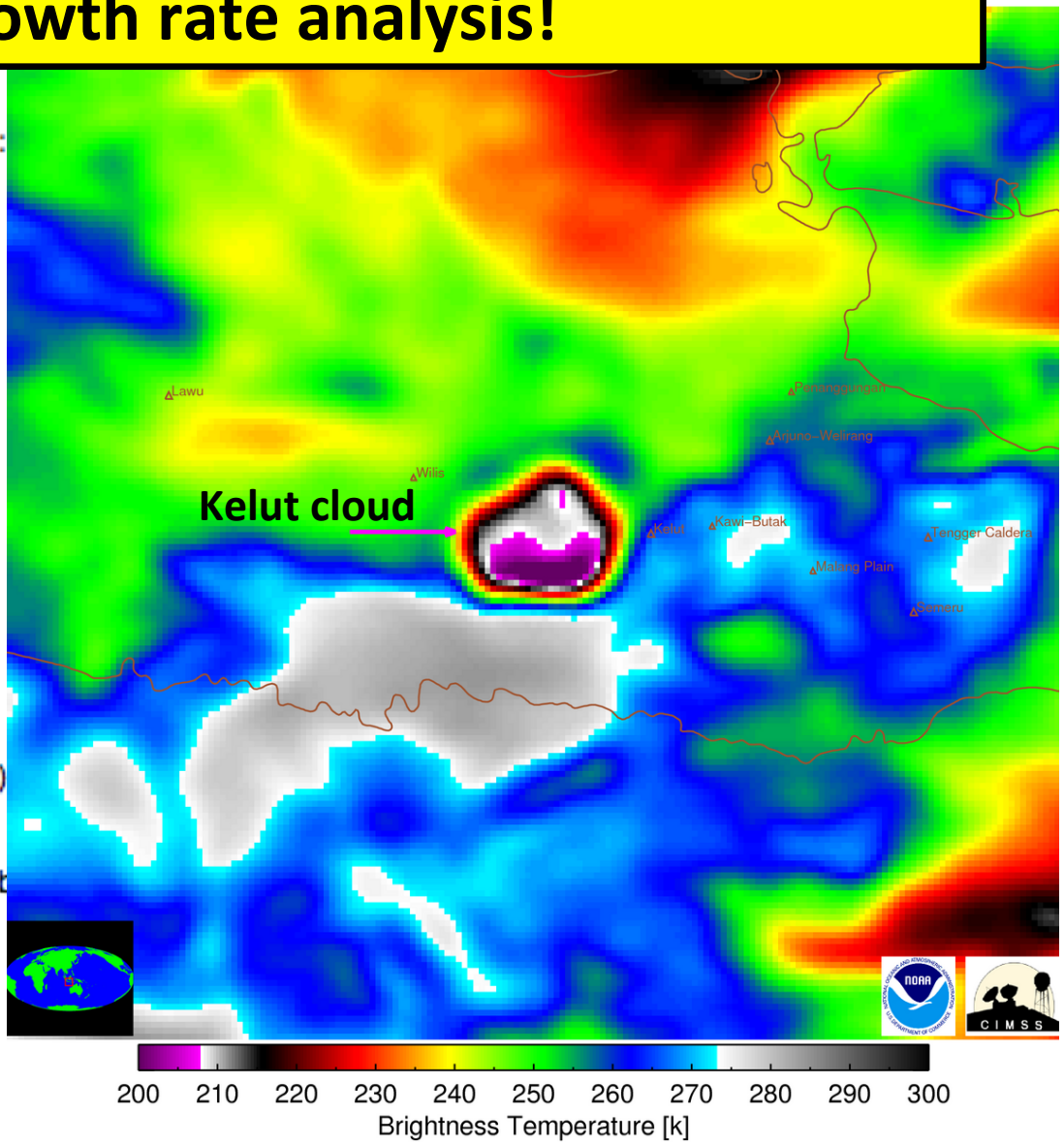


http://volcano.ssec.wisc.edu

Volcanic Cloud Monitoring -- NOAA/CIMSS (BETA)

http://volcano.ssec.wisc.edu/alert/report/14713

Amazon Apple (113) Yahoo! eBay News (1,455)

CIMSS » Volcanic Cloud Monitoring » Event Alerts » 2014-06-19

Volcanic Cloud Monitoring — NOAA/CIMSS (BETA)

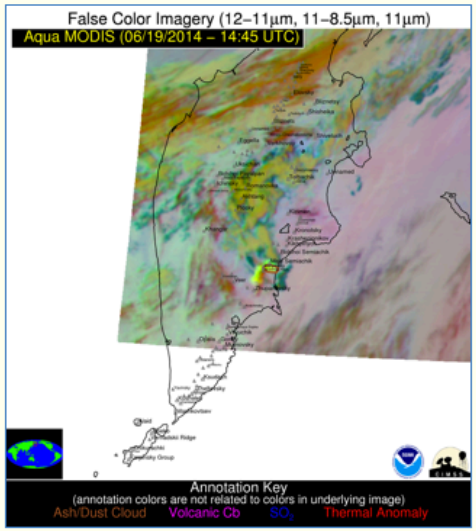
Home | Satellite Imagery | Alerts | Tutorials | Admin | Logout (mpav@ssec.wisc.edu)

Volcanic Cloud Alert Report

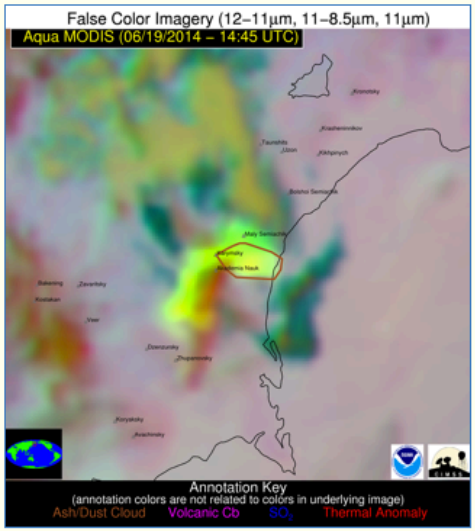
Date:	2014-06-19
Time:	14:45:00
Production Date And Time:	2014-06-19 18:17:34 UTC
Primary Instrument:	Aqua MODIS

More details ▼

Possible Volcanic Ash Cloud — View event imagery »

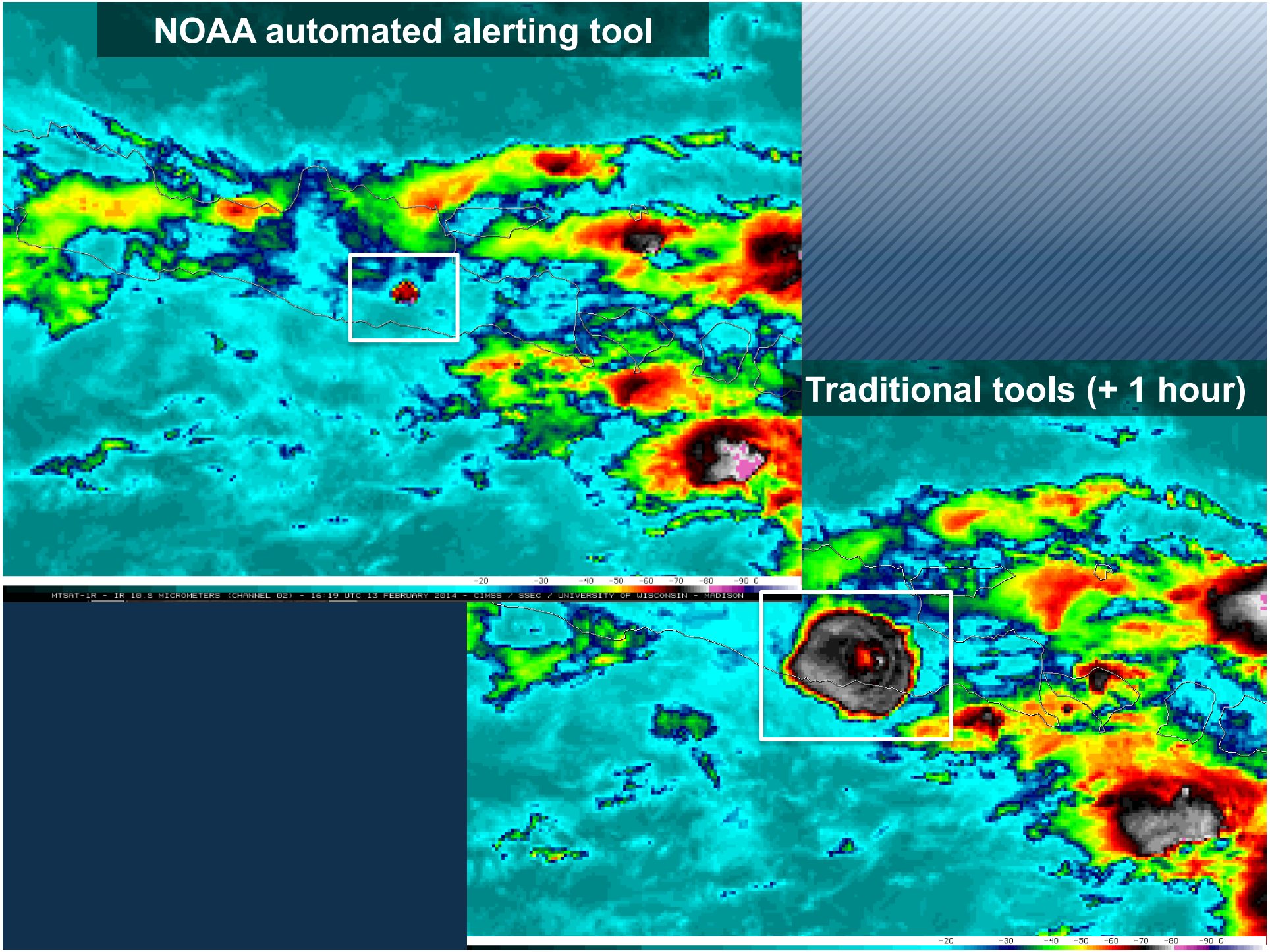


False Color Image (12-11, 11-8.5, 11)



False Color Image (12-11, 11-8.5, 11) [zoomed-in]

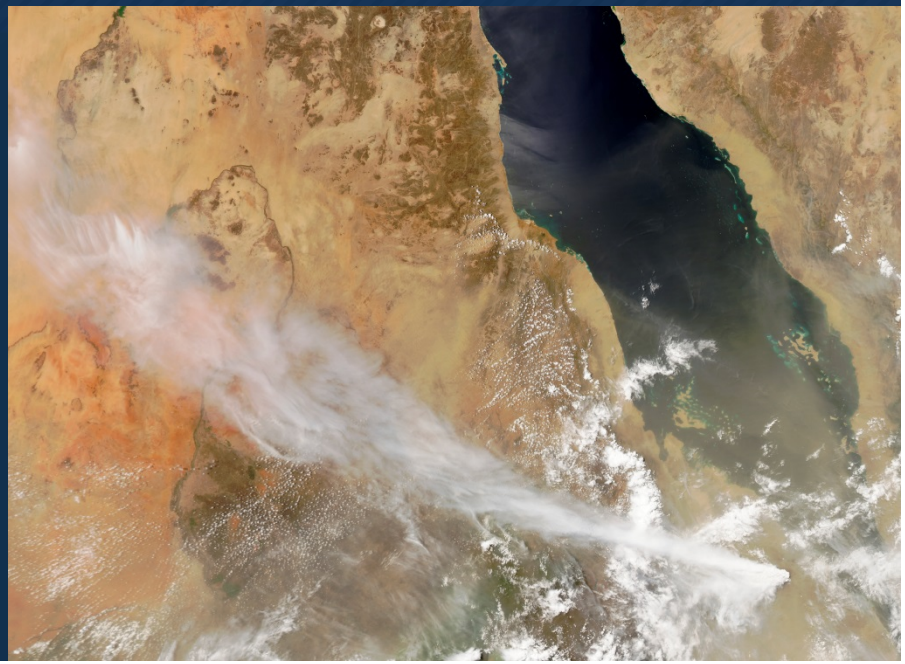
Alert Status	New Alert Object
Radiative Center (Lat, Lon):	54.032 °, 159.487 °
Mean Viewing Angle	55.75 °
Mean Solar Zenith Angle	100.31 °
Nearby Volcanoes (meeting alert criteria):	Karymsky (3.13 km) Akademia Nauk (5.92 km) Maly Semiachik (16.30 km) Bolshoi Semiachik (46.88 km) Zhupanovsky (54.03 km)
Cloud Object Probability	100.00000 %
Median Probability Of Object Pixels	98.80333 %
Percent Unambiguous Pixels	27.86300 %


NOAA automated alerting tool
Traditional tools (+ 1 hour)
-20 -30 -40 -50 -60 -70 -80 -90 C
MTSAT-1R - IR 10.8 MICROMETERS (CHANNEL 02) - 16:19 UTC 13 FEBRUARY 2014 - CIMSS / SSEC / UNIVERSITY OF WISCONSIN - MADISON
-20 -30 -40 -50 -60 -70 -80 -90 C

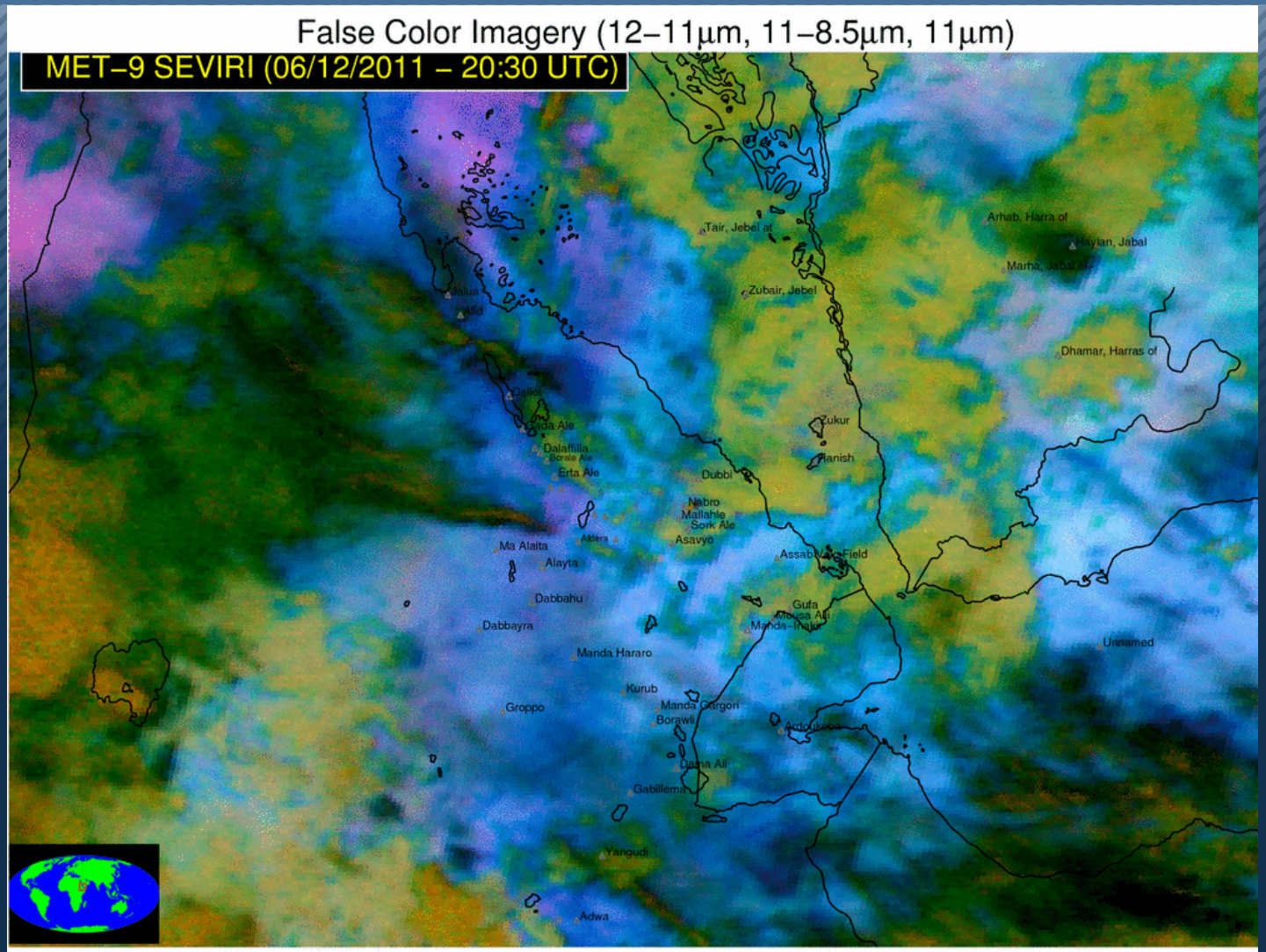
First detection of volcanic eruptions

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

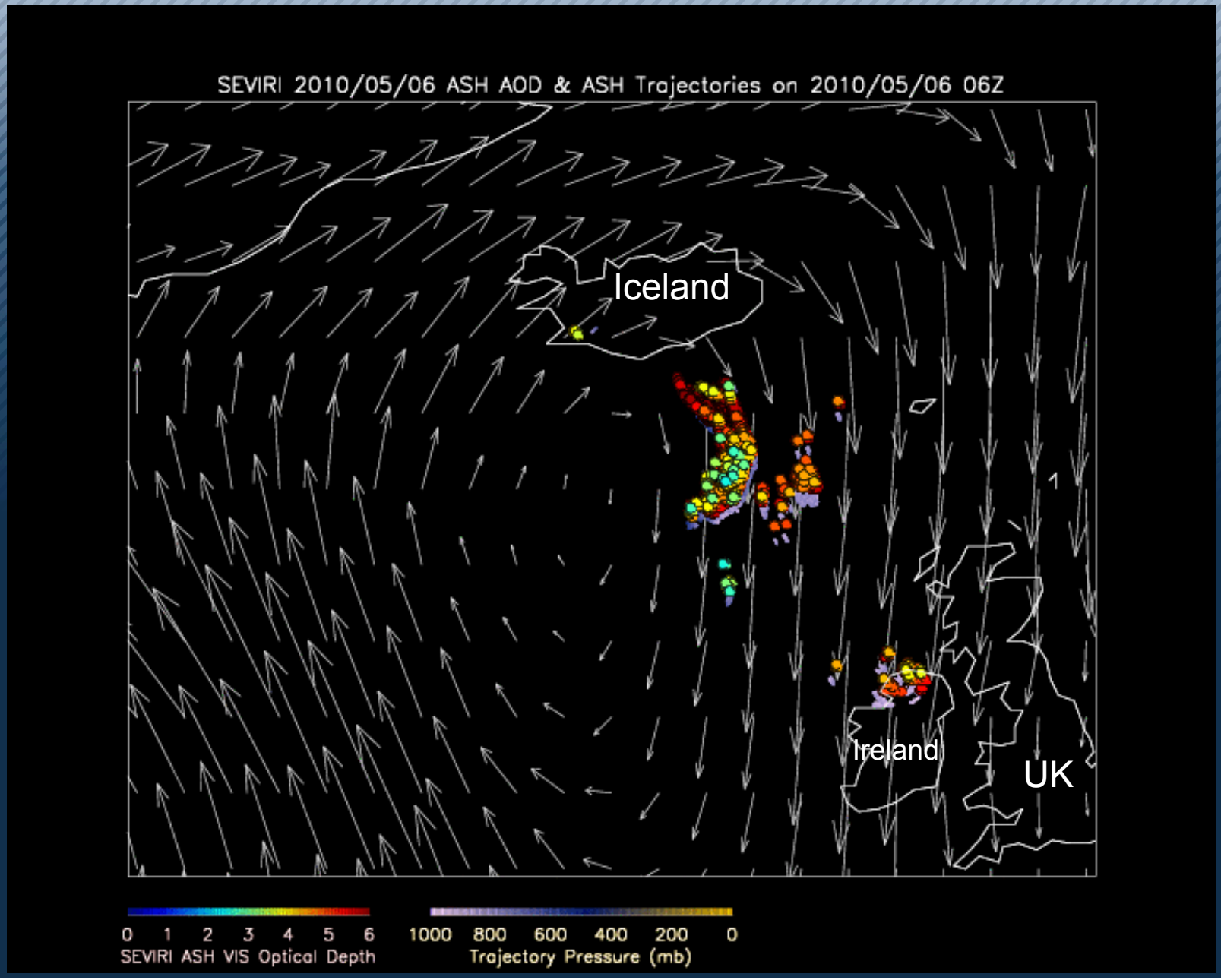
The eruption went undetected for 7.5 hours!



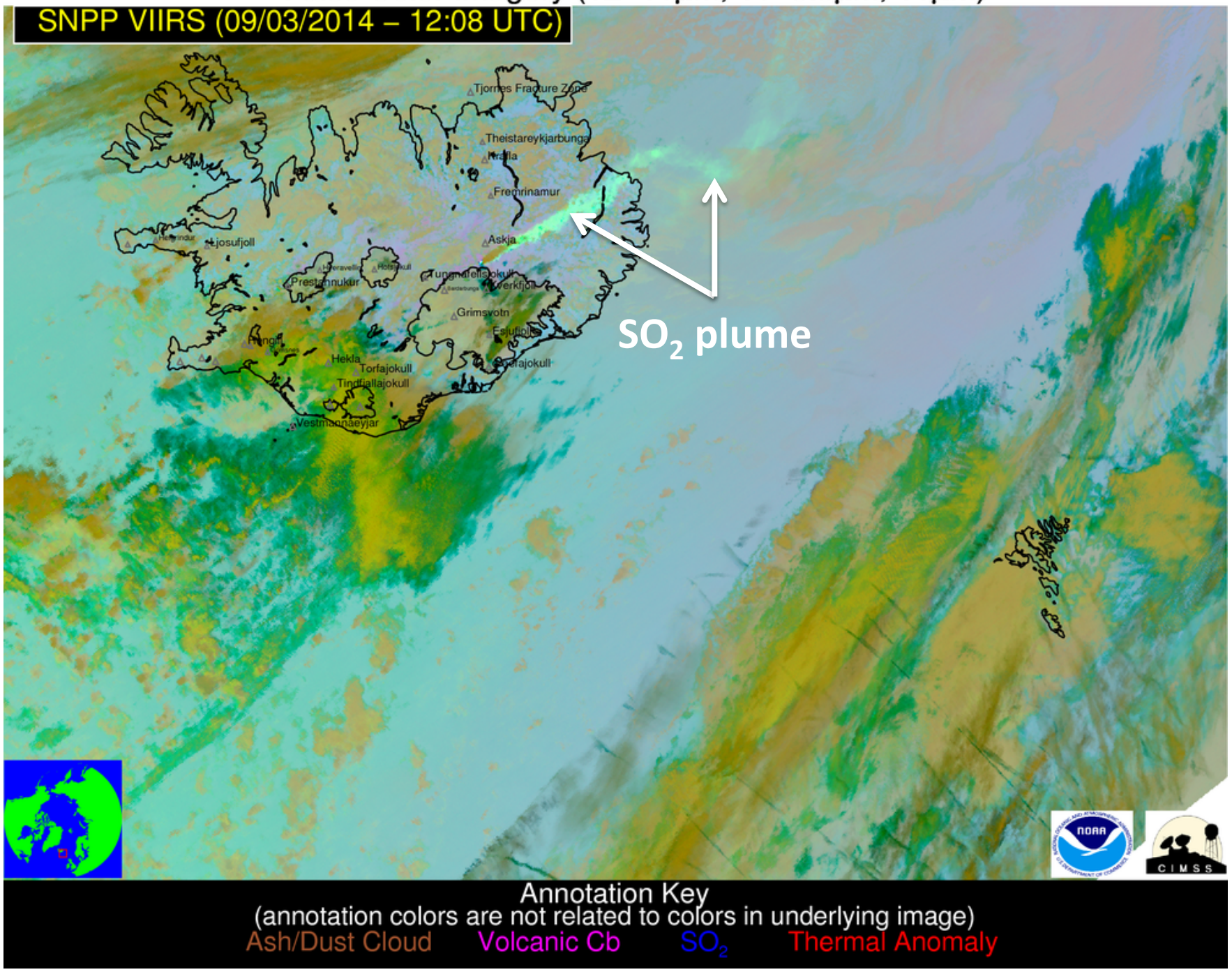
The NOAA volcanic eruption alerting tool was able to detect the eruption within 15 minutes of the start time and generate an alert



Improving ash cloud forecasts

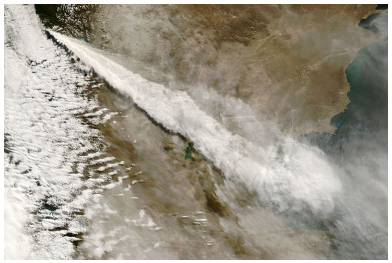


False Color Imagery (12–11μm, 11–8.5μm, 11μm)



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!

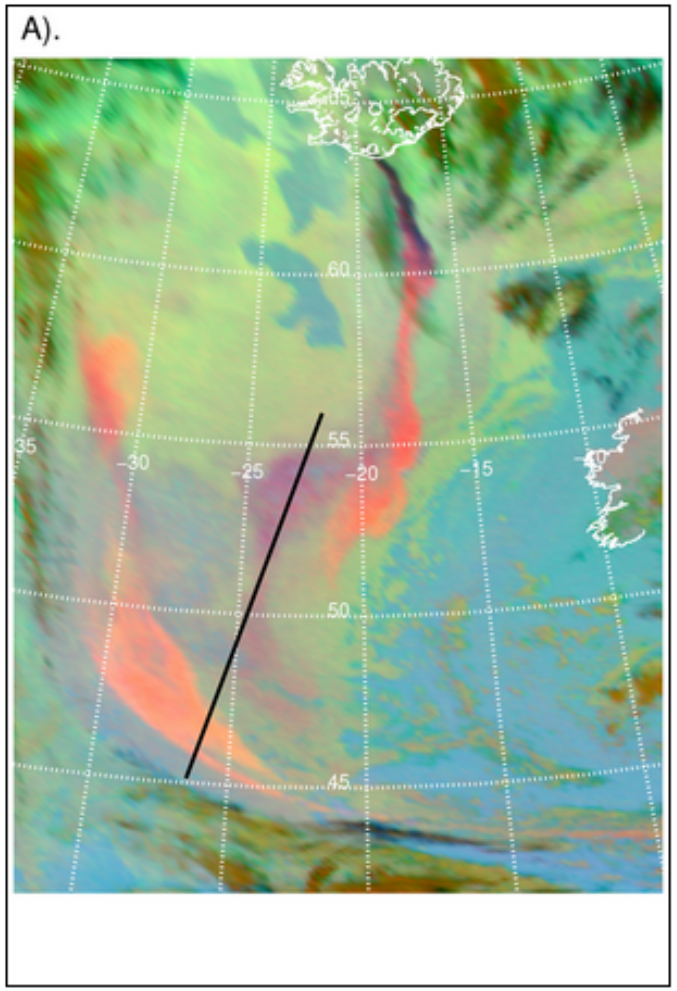
Questions?

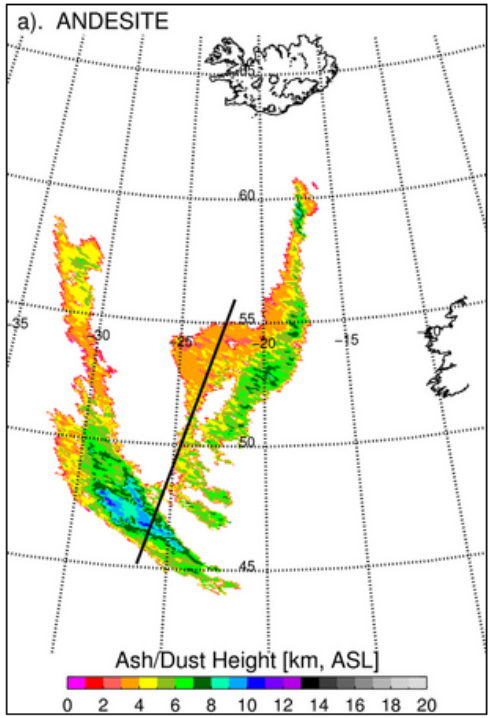


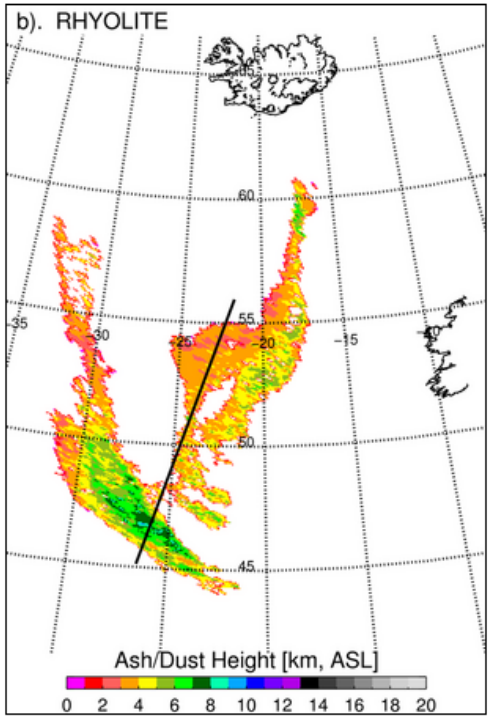

Marco Fulle - www.stromboli.net

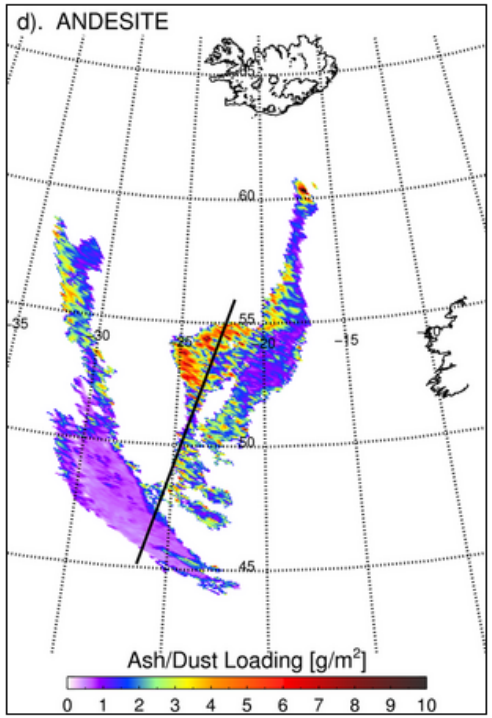
Back-up slides

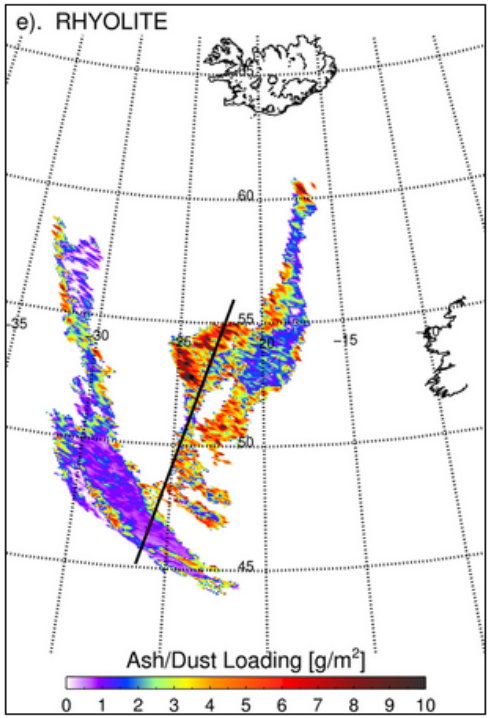




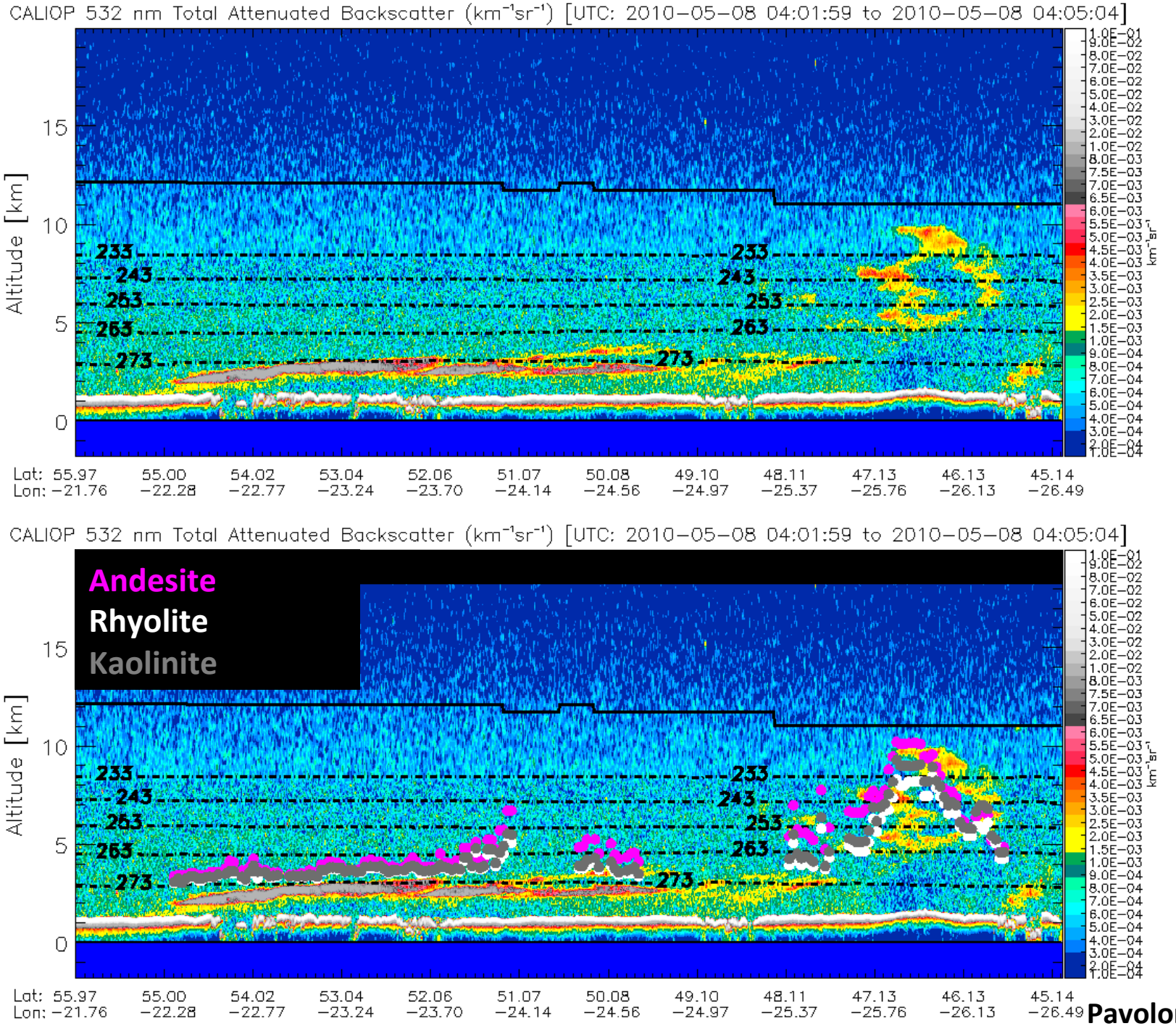




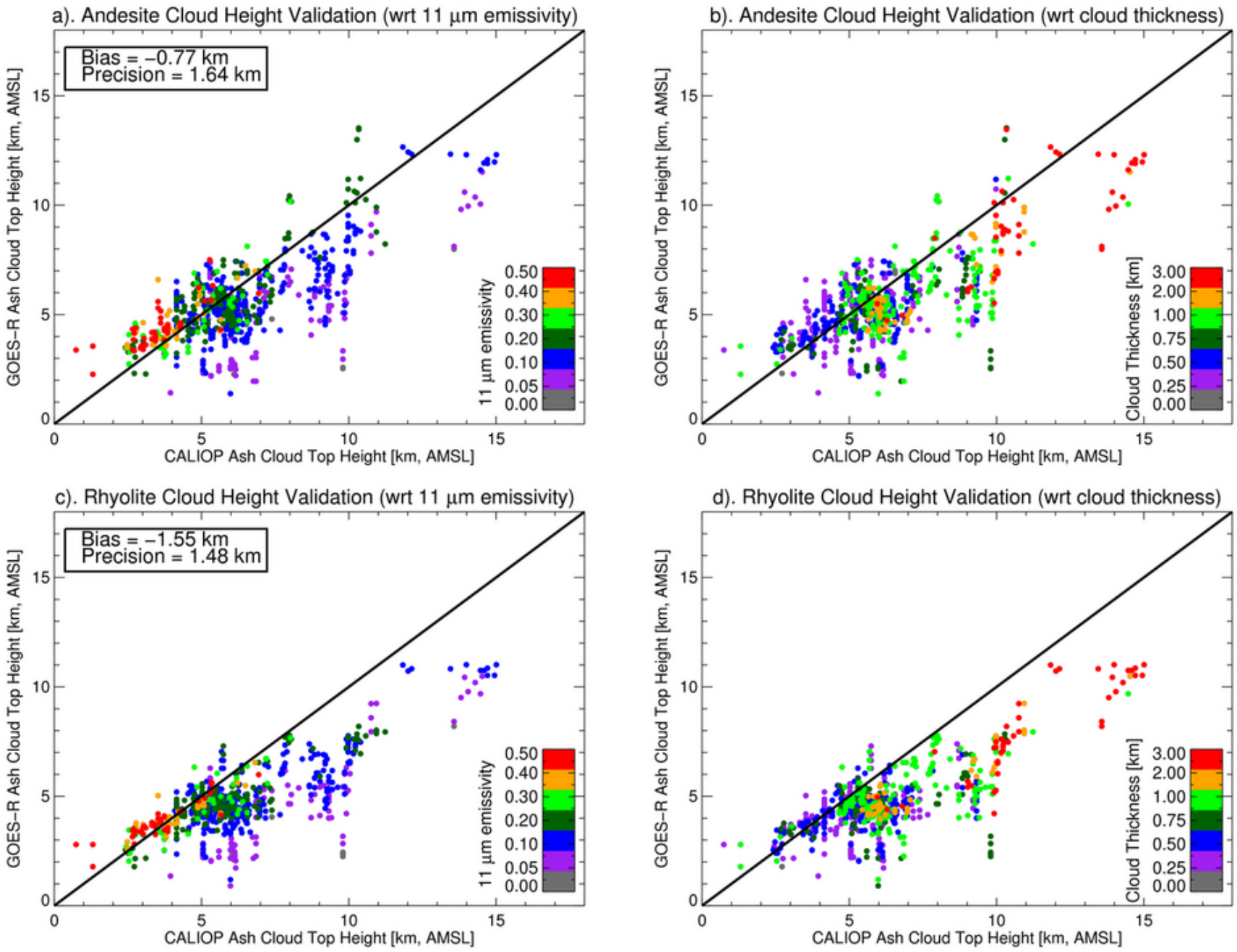




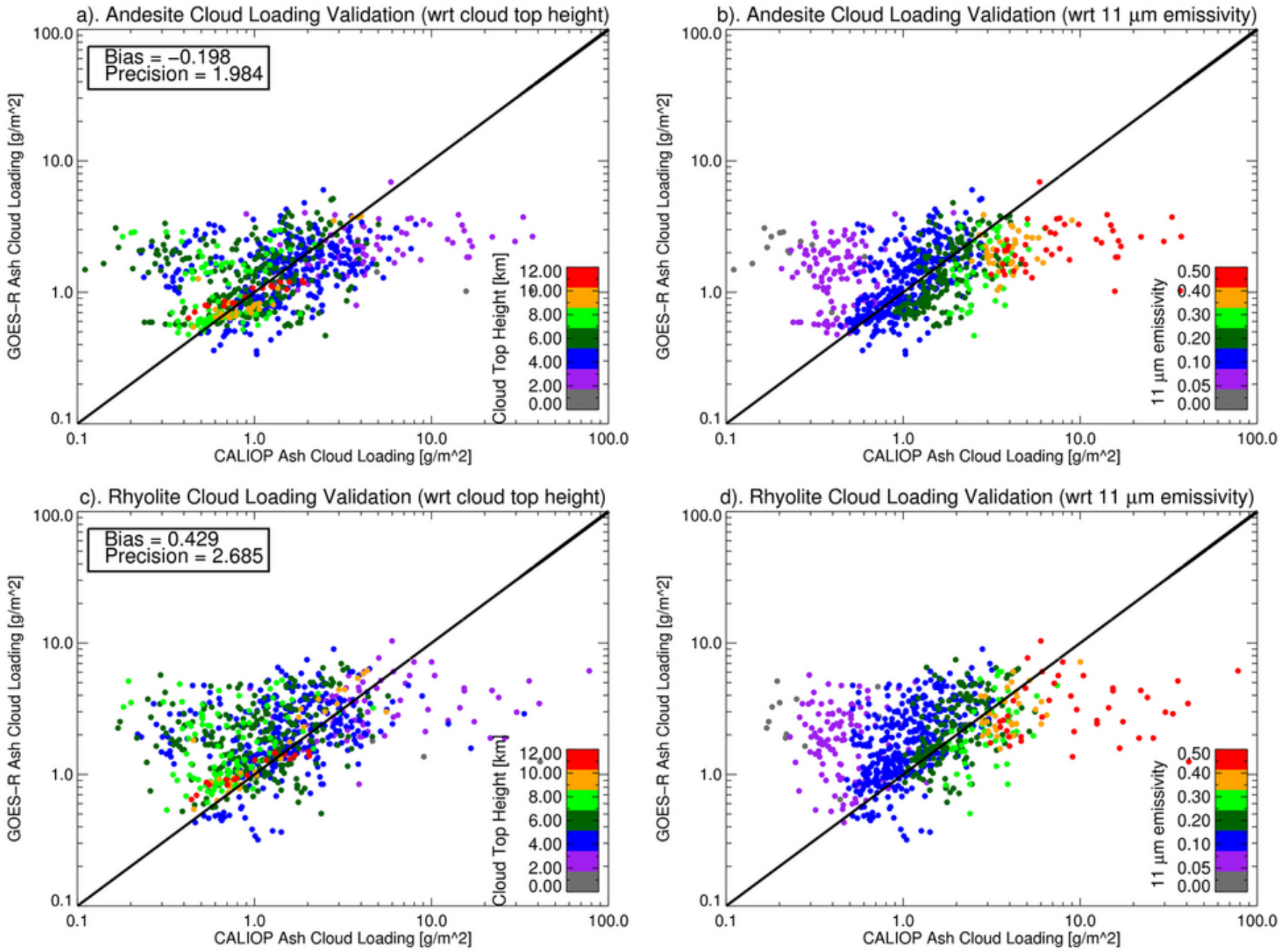
The assumed mineral composition has a larger impact on mass loading compared to cloud height



Pavolonis et al., 2013



Pavolonis et al., 2013



Pavolonis et al., 2013