


Automated Volcanic Cloud Identification, Tracking, and Characterization Using Next Generation Meteorological Satellites

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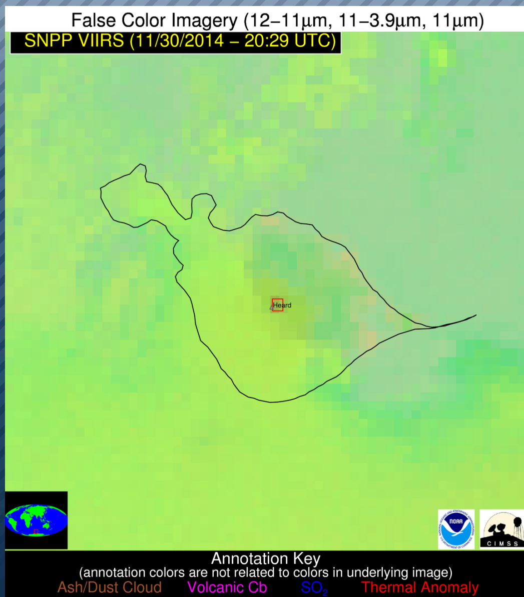
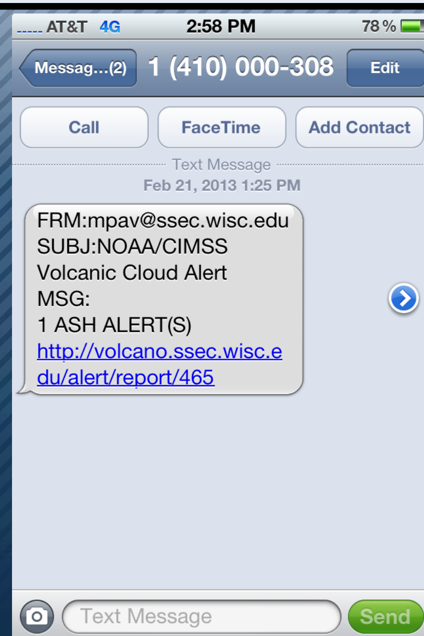
VOLcanic Cloud Analysis Toolkit (VOLCAT)

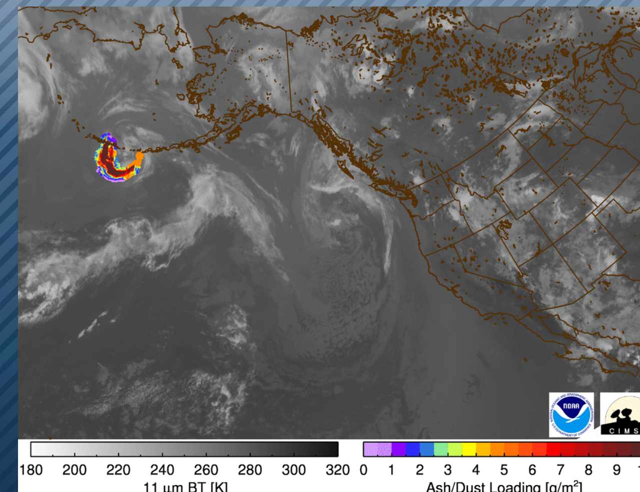
1). Unrest Alerts



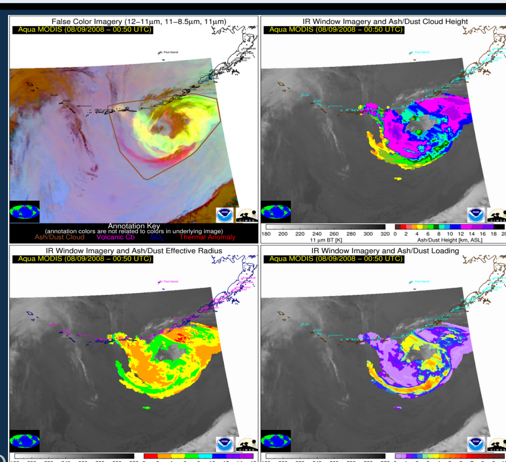
2). Eruption Alerts



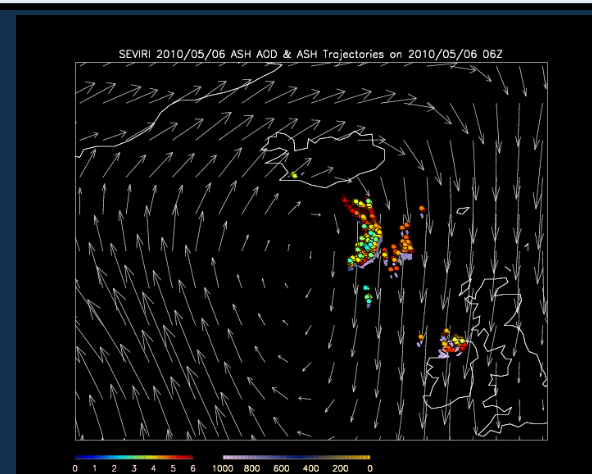
3). Volcanic Cloud Tracking



4). Volcanic Cloud Characterization



5). Dispersion Forecasting



Information Used by VOLCAT Algorithms

1. Spectral
2. Spatial
3. Temporal
4. Multi-sensor

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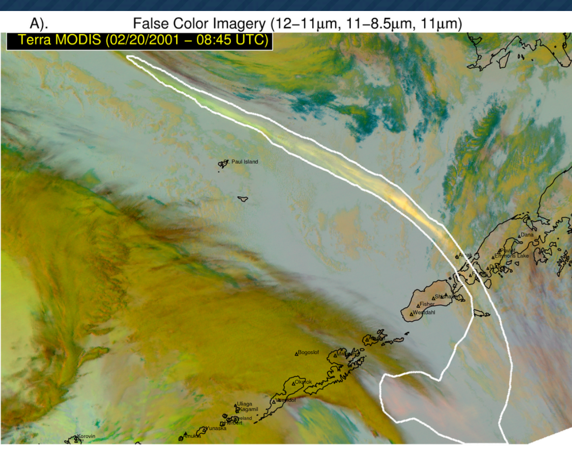
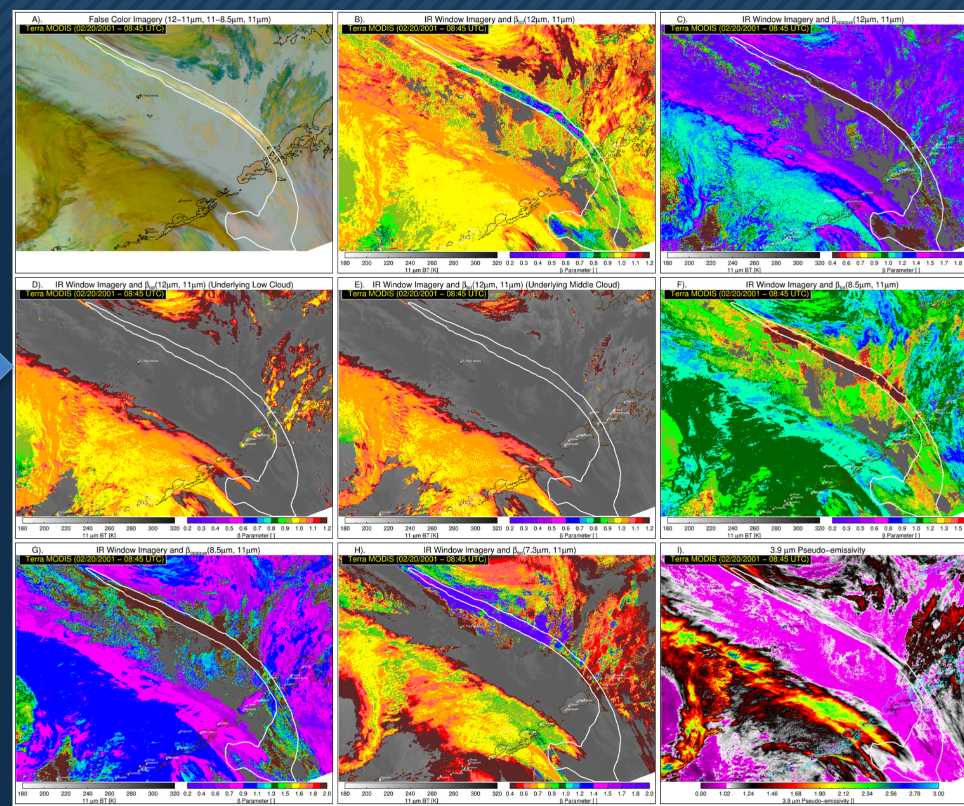
Key Science Concept: Maximize the sensitivity to volcanic ash by utilizing multi-spectral metrics that account for background conditions

Impact of NextGen Satellites: More volcanic cloud relevant spectral channels

Measured BT's, BTD's and reflectance



Robust metrics such as β-ratios



Pavolonis et al. 2015a

Information Used by VOLCAT Algorithms

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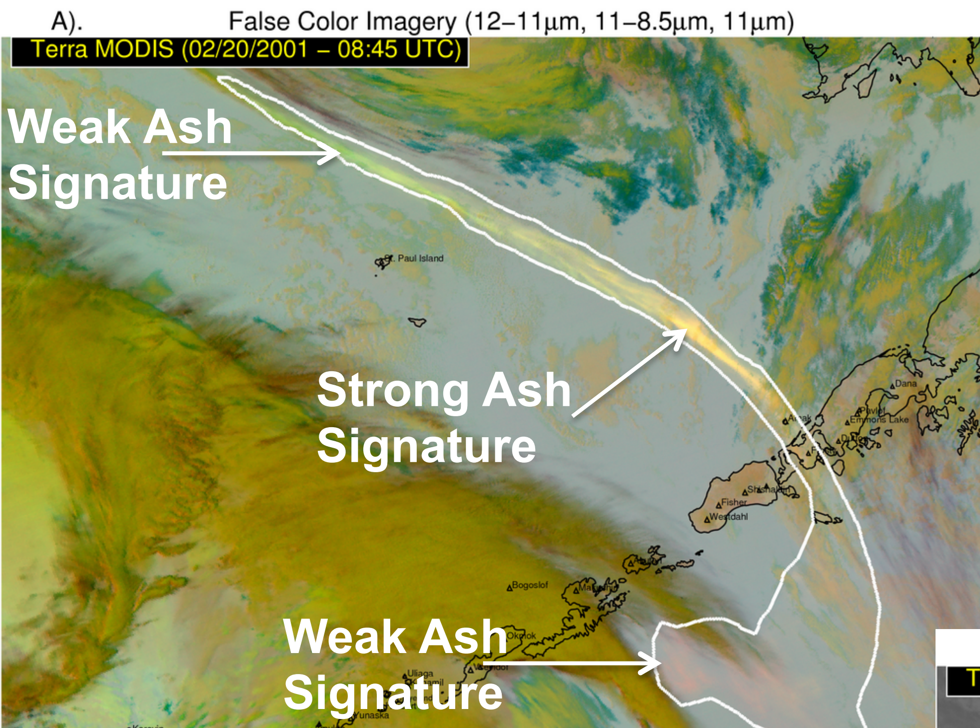


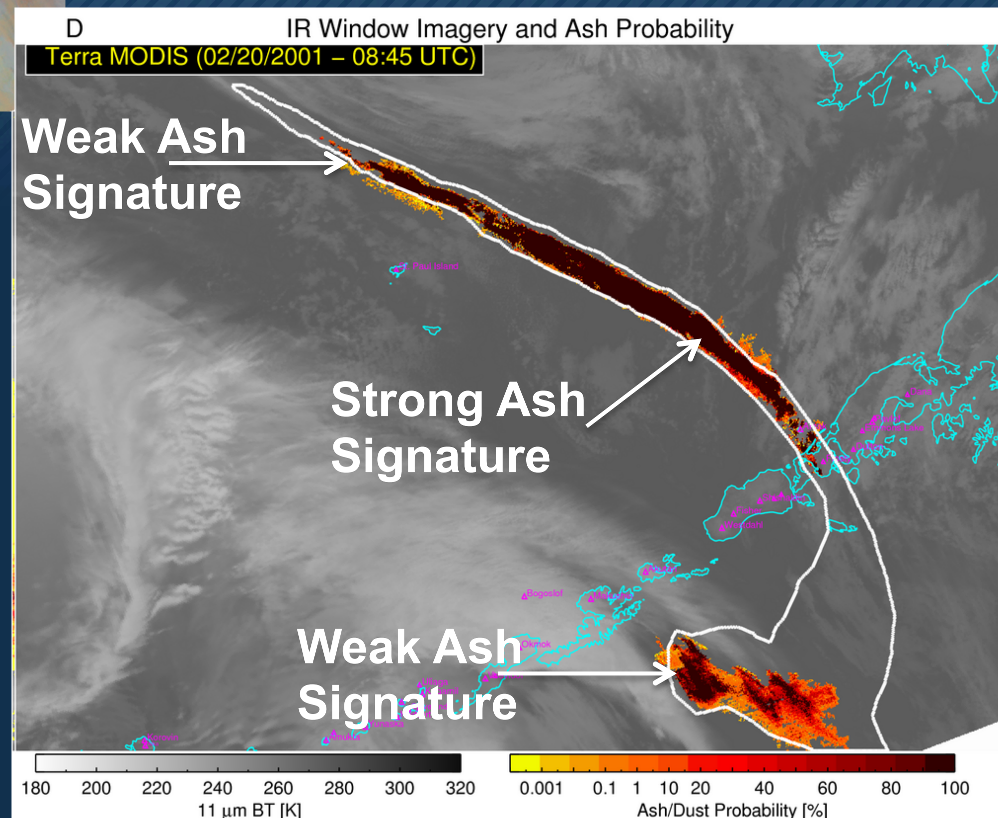
Spatial Analysis: Cloud Objects

volcanic clouds, spectral metrics are used to estimate ash probability

Pavolonis et al. (2015a);Pavolonis et al. (2015b)

Key Science Concept: Humans rely heavily on spatial pattern recognition to identify volcanic clouds, so should automated algorithms

Impact of NextGen Satellites: Higher spatial resolution aids feature recognition

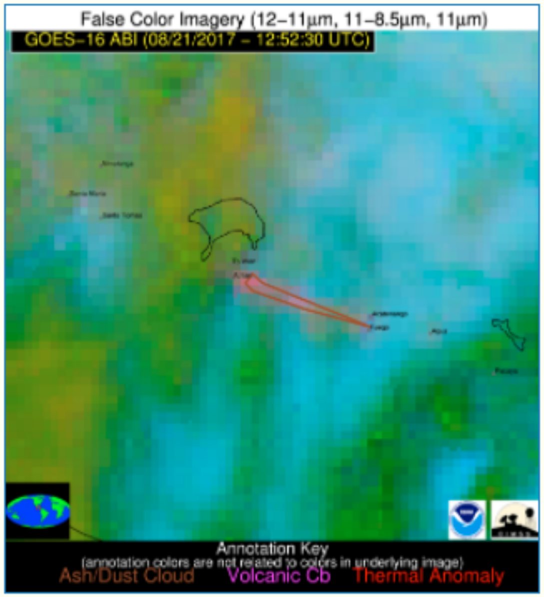


Volcanic Cloud Alert Report

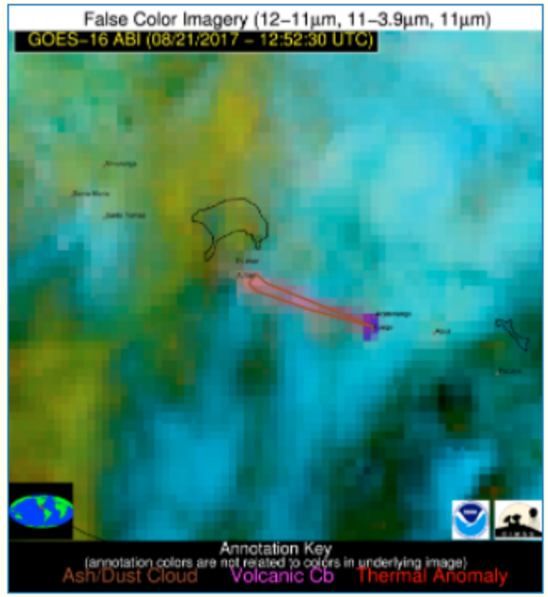
Date:	2017-08-21
Time:	12:52:30
Production Date and Time:	2017-08-21 12:58:15 UTC
Primary Instrument:	GOES-16 ABI

More details ▼

Possible Volcanic Ash Cloud



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



False Color Image (12-11, 11-3.9, 11) [zoomed-in]

Basic Information

Volcanic Region(s)	Mexico and Central America
Country/Countries	Guatemala
Volcanic Subregion(s)	Guatemala
VAAC Region(s) of Nearby Volcanoes	Washington
Identification Method	Plume
Mean Object Date/Time	2017-08-21 12:52:30UTC
Radiative Center (Lat, Lon):	14.470°, -90.880°
Nearby Volcanoes (meeting alert criteria):	Fuego (0.00 km) Acatenango (3.10 km) Agua (14.80 km) Pacaya (31.80 km) Atitlan (35.20 km)
Maximum Height [AMSL]	10.00 km ; 32808 ft
90th Percentile Height [AMSL]	9.60 km ; 31496 ft
Mean Tropopause Height [AMSL]	16.50 km ; 54134 ft

Show More ▲ View all event imagery »

Auto-detected eruption of Fugeo (Guatemala) with GOES-16

Cloud object based volcanic ash detection allows for reliable generation of eruption alerts, which is critical in an era with very large satellite data volumes

The VOLcanic Cloud Analysis Toolkit (VOLCAT)

Automated early detection of volcanic eruptions

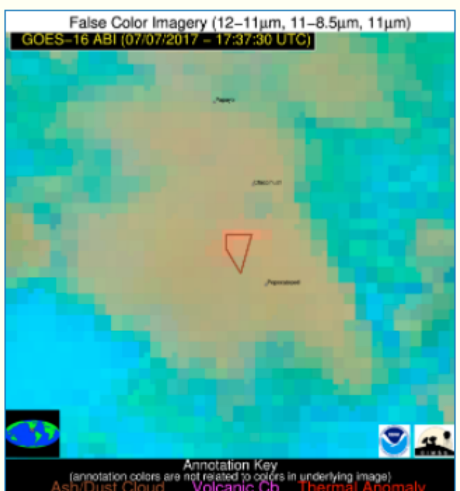
```
FVXX21 KNES 071809
VA ADVISORY
DTG: 20170707/1809Z

VAAC: WASHINGTON

VOLCANO: POPOCATEPETL 341090
PSN: N1901 W09837

AREA: MEXICO

SUMMIT ELEV: 17802 FT (5426 M)

ADVISORY NR: 2017/056

INFO SOURCE: NOAA CIMSS ALERT/CENAPRED

ERUPTION DETAILS: NEW VA EM AT 07/1719Z

RMK: WE HAVE RECEIVED INFORMATION SUGGESTING A
POSSIBLE VA EMISSION. WE WILL GATHER FURTHER
INFORMATION AND ISSUE A FULL ADVISORY AS SOON AS
POSSIBLE.

NXT ADVISORY: AS SOON AS POSSIBLE
```

Volcanic Cloud Alert Report

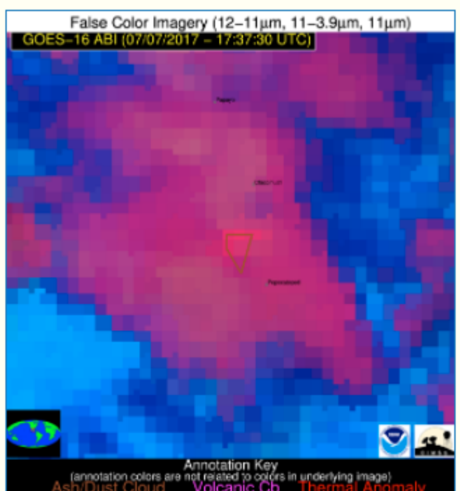
Date:	2017-07-07
Time:	17:37:30
Production Date and Time:	2017-07-07 17:44:35 UTC
Primary Instrument:	GOES-16 ABI

More details ▼

Possible Volcanic Ash Cloud



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



False Color Image (12-11, 11-3.9, 11) [zoomed-in]

Basic Information

Volcanic Region(s)	Mexico and Central America
Country/Countries	Mexico
Volcanic Subregion(s)	Mexico
VAAC Region(s) of Nearby Volcanoes	Washington
Identification Method	Puff
Mean Object Date/Time	2017-07-07 17:37:30UTC
Radiative Center (Lat, Lon):	19.100°, -98.680°
Nearby Volcanoes (meeting alert criteria):	Popocatepetl (2.80 km)
Maximum Height [AMSL]	9.20 km ; 30184 ft
90th Percentile Height [AMSL]	9.10 km ; 29856 ft
Mean Tropopause Height [AMSL]	16.50 km ; 54134 ft

Show More ▲ View all event imagery »

Information Used by VOLCAT Algorithms

1. Spectral

2. Spatial

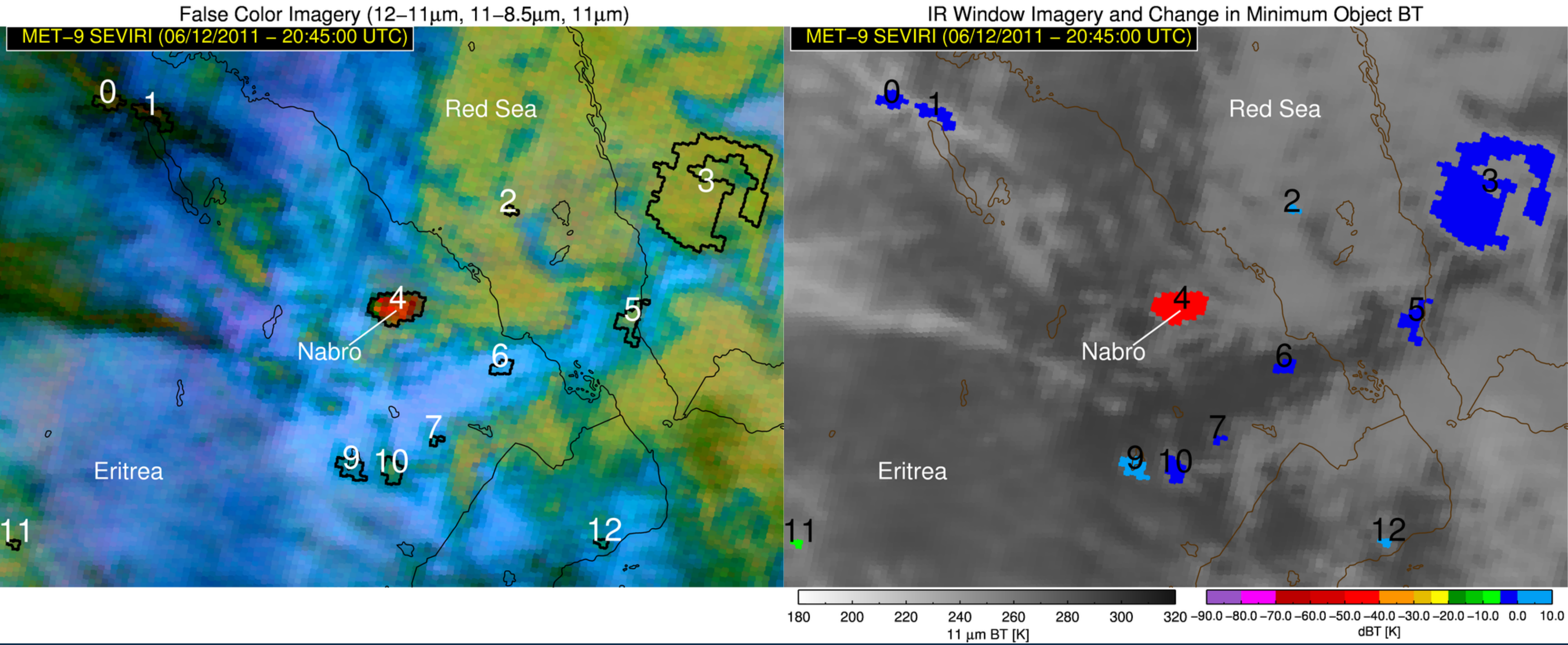
3. **Temporal**

4. Multi-sensor

Temporal – Cloud Vertical Growth

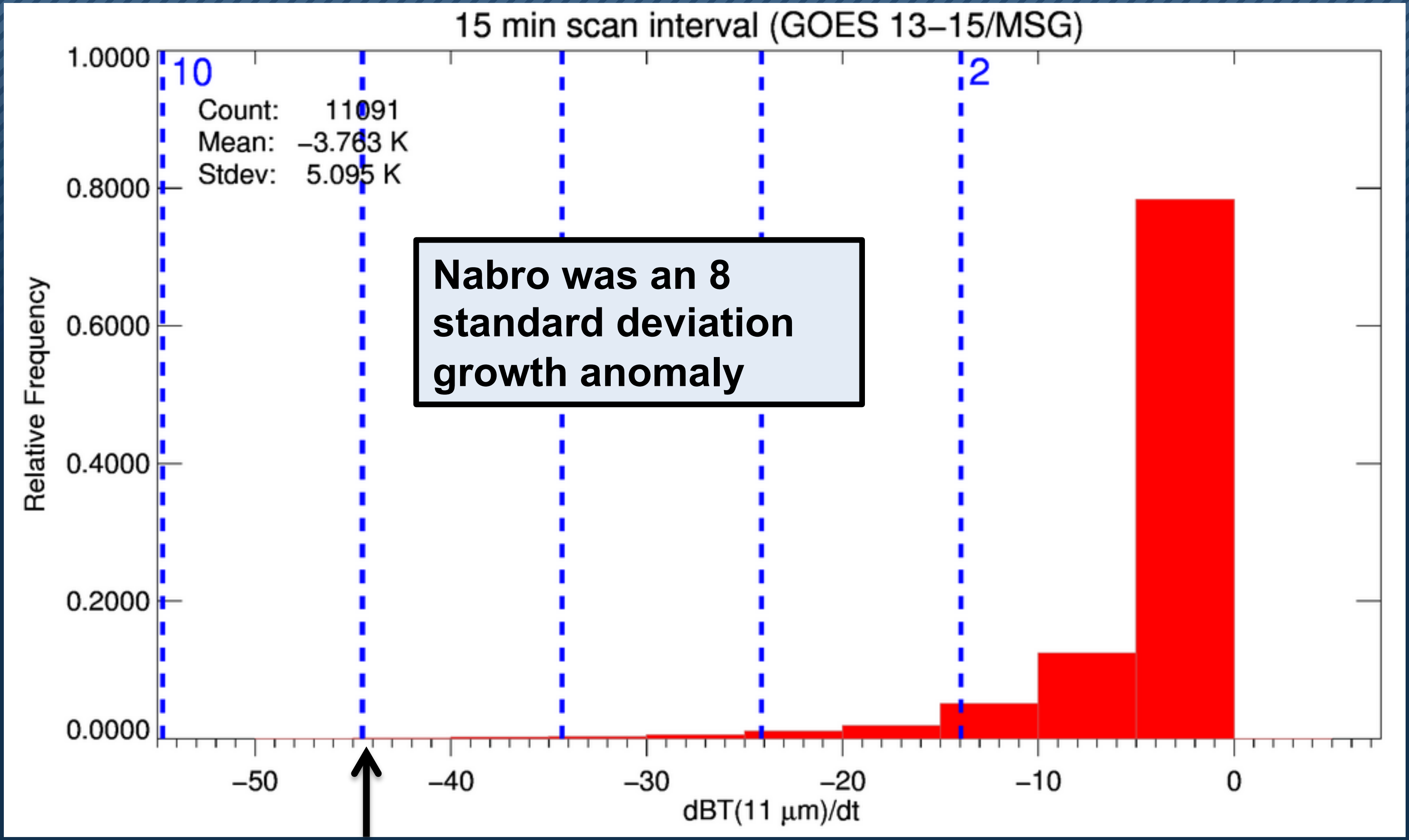
Key Science Concept: Volcanic clouds generally emerge from volcanic vents in a sudden manner

Impact of NextGen Satellites: More frequent images allows for better characterization of developing clouds



Pavolonis et al. (2017, in prep)

How anomalous is vertical growth of Nabro cloud given the pixel area, time interval between the images, and background cloudiness?



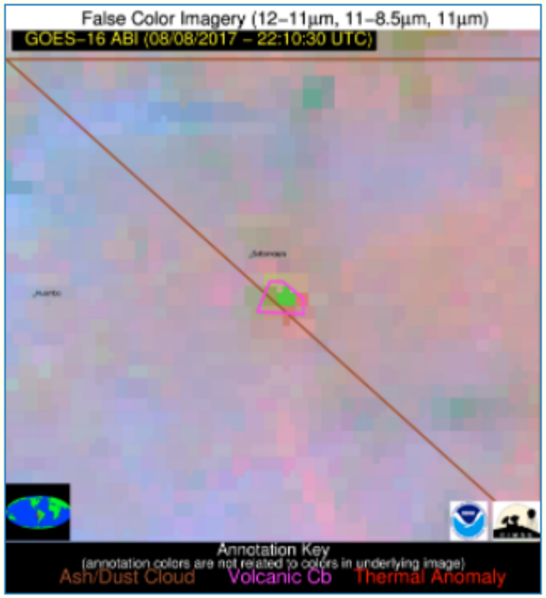
Nabro was an 8 standard deviation growth anomaly

Volcanic Cloud Alert Report

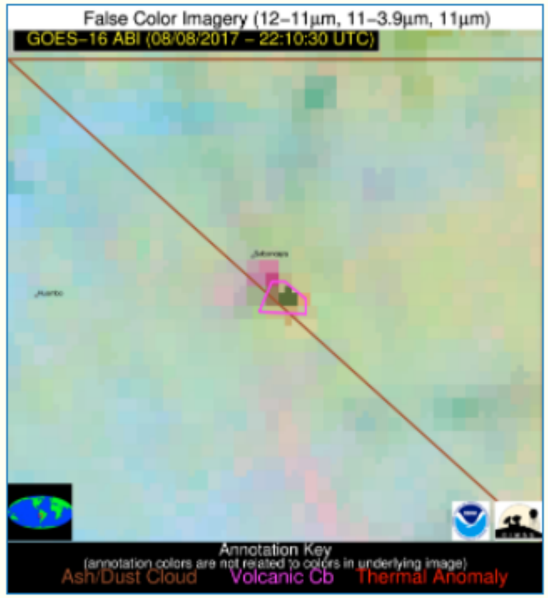
Date:	2017-08-08
Time:	22:10:30
Production Date and Time:	2017-08-08 22:20:16 UTC
Primary Instrument:	GOES-16 ABI

More details ▼

Possible Volcanic Cb



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



False Color Image (12-11, 11-3.9, 11) [zoomed-in]

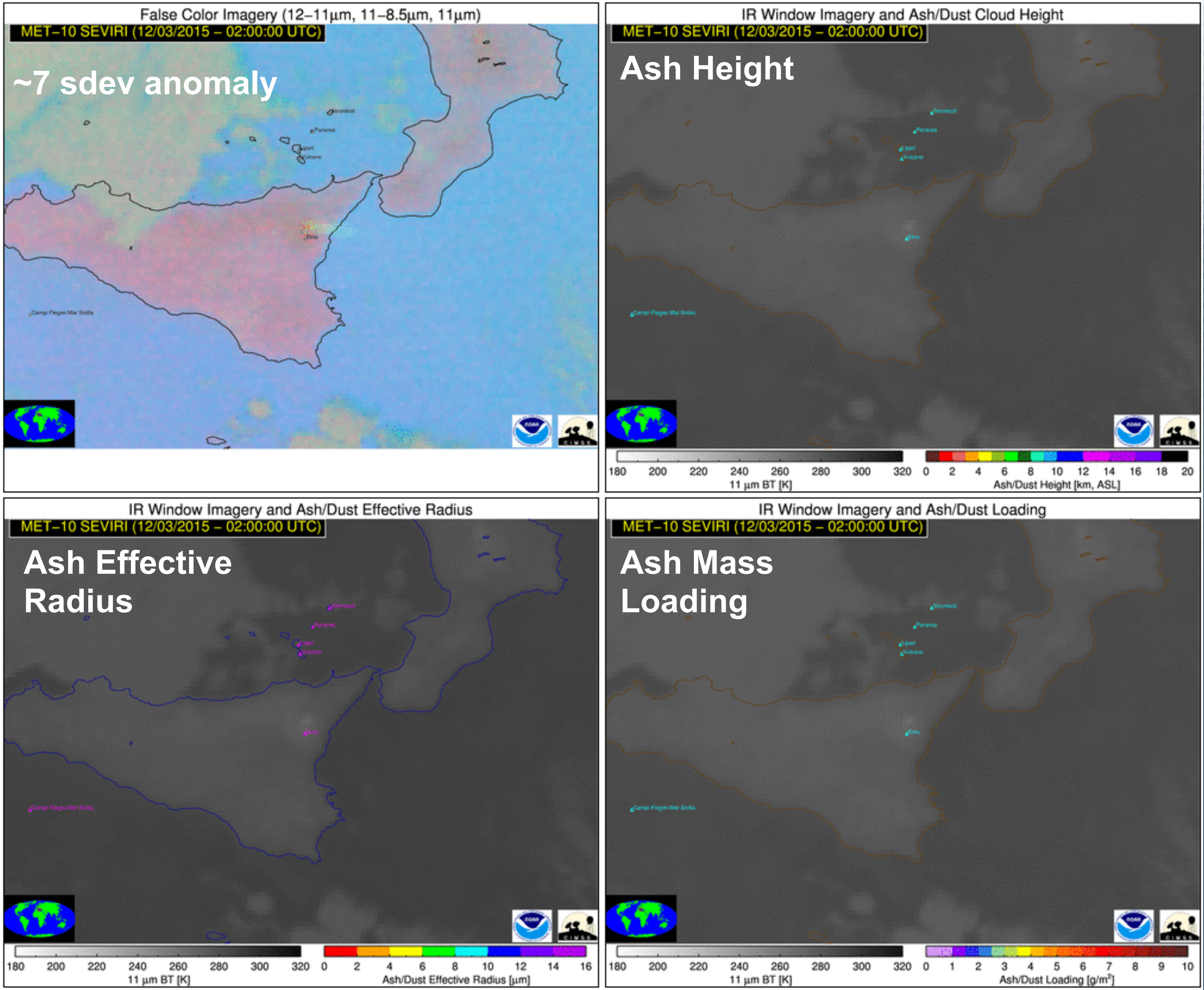
Basic Information

Volcanic Region(s)	South America
Country/Countries	Peru
Volcanic Subregion(s)	Peru
VAAC Region(s) of Nearby Volcanoes	Buenos Aires
Identification Method	Basic Growth
Mean Object Date/Time	2017-08-08 22:10:30UTC
Radiative Center (Lat, Lon):	-15.810°, -71.830°
Nearby Volcanoes (meeting alert criteria):	Sabancaya (1.10 km)
Trend in IR Brightness Temperature	-15.50 °C
Vertical Growth Rate Time Interval	5 minutes
Vertical Growth Rate Anomaly	6.10 number of stddev above mean
Maximum Height [AMSL]	6.00 km ; 19685 ft
90th Percentile Height [AMSL]	5.70 km ; 18701 ft
Mean Tropopause Height [AMSL]	16.50 km ; 54134 ft

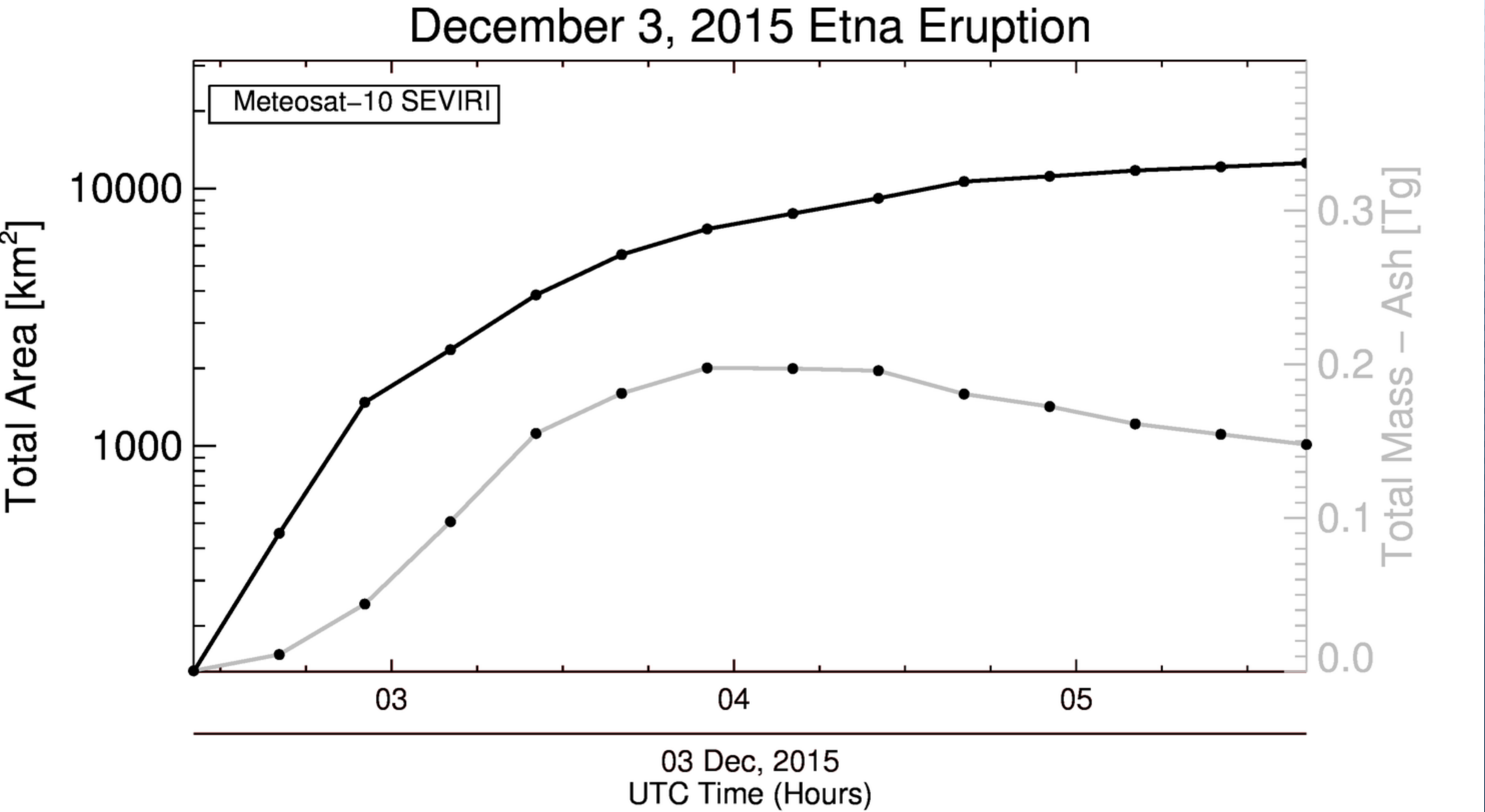
Show More ▲ View all event imagery »

Cloud growth based auto-detection of Sabancaya (Peru) eruption with 5 minute GOES-16 data

The more frequent the images, the better the detection capabilities (accuracy and timeliness)



Pavolonis et al. 2013



The time evolution of certain volcanic cloud properties (e.g. area) can be used to derive eruption source parameters required to constrain dispersion models

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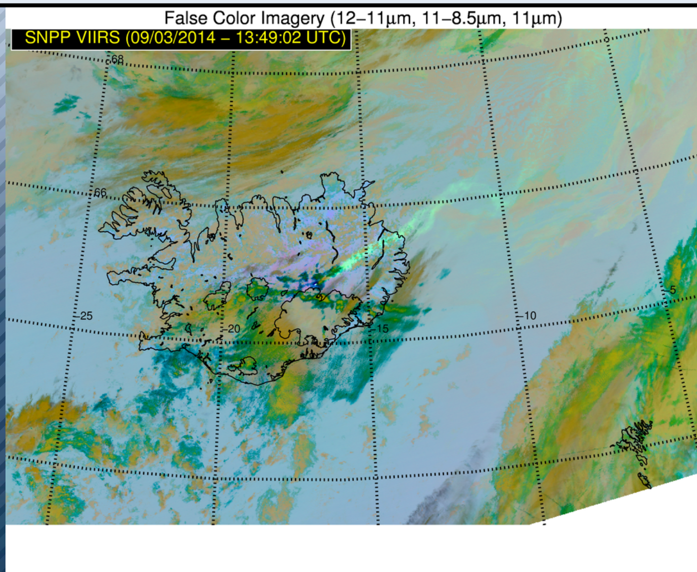
4. **Multi-sensor**

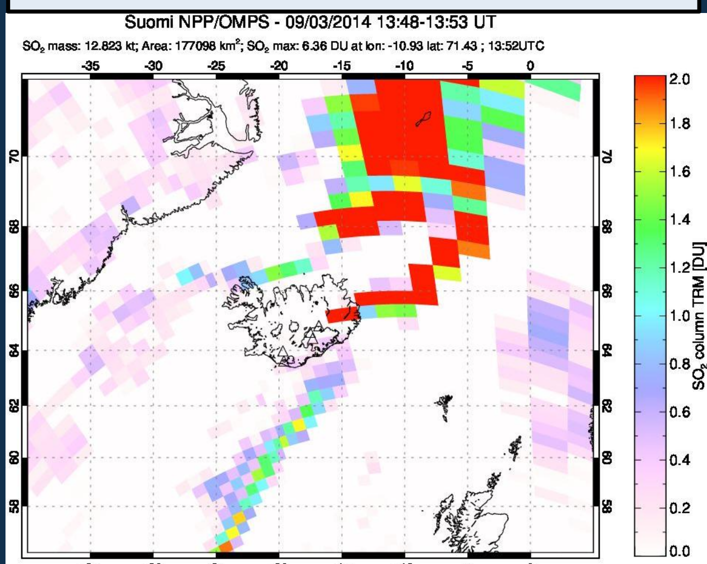
Infrared (high spectral + high spatial)

Application to SO_2



+

UV



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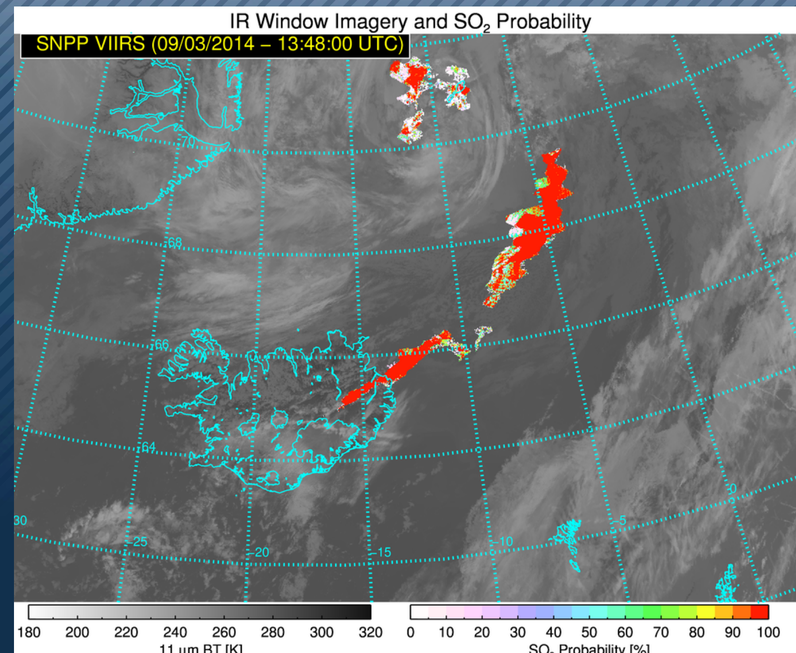
Improved SO_2 Products
SO_2 Probability, Loading, and Height



Key Science Concept: No single sensor is perfectly optimized to detect and characterize all types of volcanic clouds

Impact of NextGen Satellites: Hyperspectral UV and IR greatly aid in volcanic cloud (including SO_2) detection and characterization

Conclusions

- VOLCAT utilizes spectral, spatial, and temporal information to detect and characterize volcanic clouds captured by LEO and GEO satellites
- Much improved volcanic cloud detection and characterization is possible with next generation satellites
- Automated extraction of information is critical in this still evolving era of very large satellite data volumes
- VOLCAT products are generated at the University of Wisconsin and are not currently part of the planned operational GOES-R product suite

References

Pavolonis, M. J., W. F. Feltz, A. K. Heidinger, and G. M. Gallina, 2006: A daytime complement to the reverse absorption technique for improved automated detection of volcanic ash. J.Atmos.Ocean.Technol., **23**, 1422–1444.

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Pavolonis, M., A. Heidinger, and J. Sieglaff, 2013: Automated retrievals of volcanic ash and dust cloud properties from upwelling infrared measurements, J. Geophysical Research, **118(3)**, 1436–1458.

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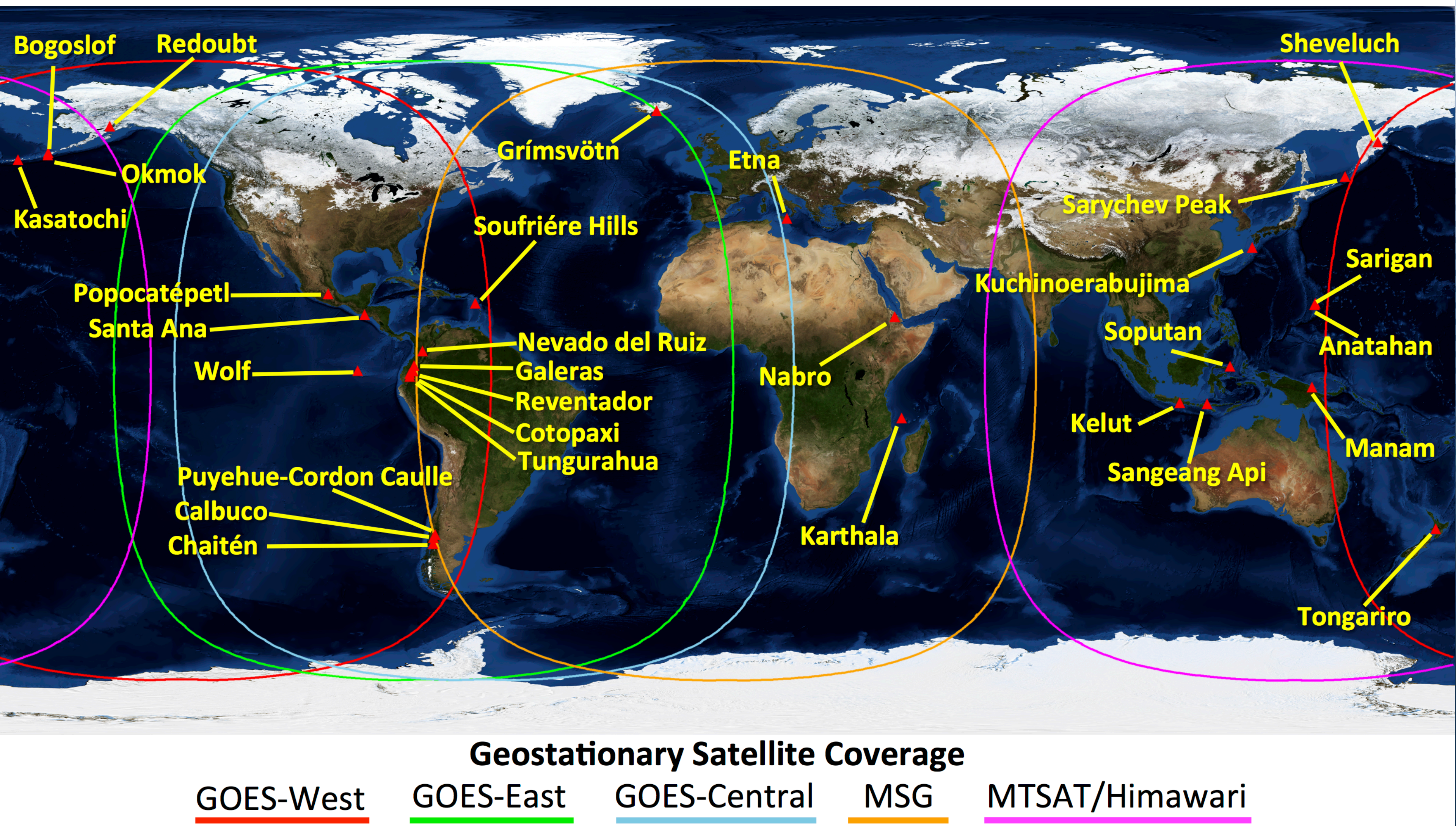
Pavolonis, M., J. Sieglaff, and J. Cintineo (2015b) Spectrally Enhanced Cloud Objects (SECO): A Generalized Framework for Automated Detection of Volcanic Ash and Dust Clouds using Passive Satellite Measurements, Part II: Cloud Object Analysis and Global Application, Journal Geophysical Research, **120**, 7842–7870.

EXTRA SLIDES



Number of cloud objects processed per day: ~3 million
Number of growing cloud objects processed per day: 1 million
Average number of false alerts per day: 3-4