Marco Fulle - www.stromboli.net

Development of a Multi-sensor Volcanic Cloud Monitoring System

Mike Pavolonis

(NOAA/NESDIS/STAR)

Justin Sieglaff and John Cintineo (UW-CIMSS)

Goal and Motivation

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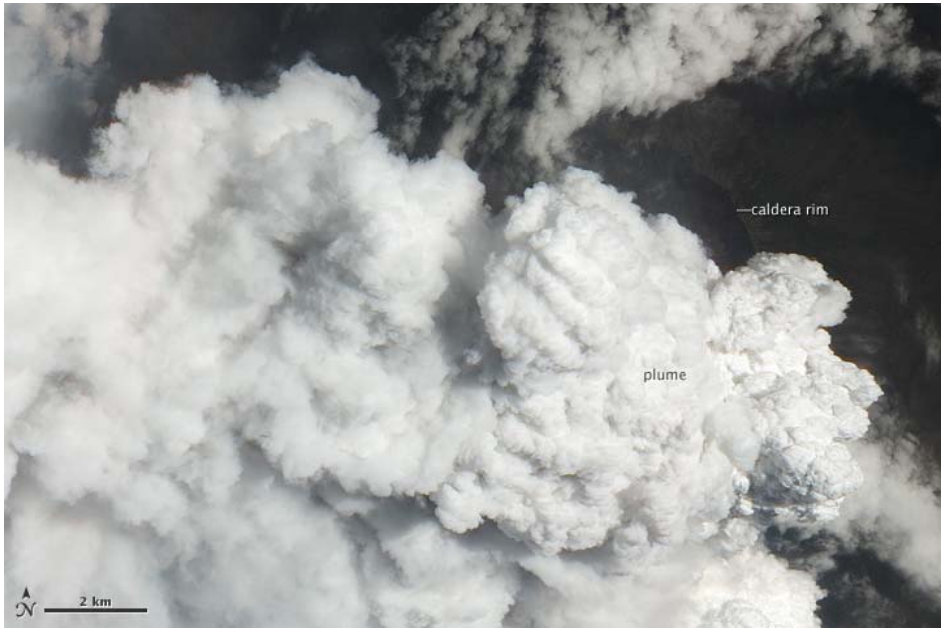
- ***Using the full capabilities of the space-based observing system (and other relevant data), develop a unique, globally applicable, automated system that can detect and characterize nearly all types of volcanic clouds***

- ***<u>Expected Operational Impacts</u>:***
  - **Increase the timeliness and quality of volcanic ash advisories issued by Volcanic Ash Advisory Centers (VAAC's) and SIGMET's issued by Meteorological Warning Offices (MWO's)**
  - **Improve operational dispersion model forecasts by providing fully automated and high quality satellite products to initialize, constrain, and validate models (model output, however, is not very useful unless you first know an eruption is happening!)**

Reliance on manual analysis of satellite images from a single sensor means that volcanic ash advisories and volcanic SIGMETS are not always timely and accurate!



Nabro volcano in Eritrea erupted for the first time in recorded history on June 12, 2011 at ~20:30 UTC, injecting volcanic ash and dangerous concentrations of SO_2 high into the atmosphere

The first VAA was issued at 04:00 UTC on June 13 (~7.5 hours after the start of the eruption!)

The height estimate for this cloud was also severely underestimated

VA ADVISORY

DTG: 20110613/0400Z

VAAC: TOULOUSE

VOLCANO: DUBBI 0201-10

PSN: N1335 E04148

AREA: ETHIOPIA

SUMMIT ELEV: 1625M

ADVISORY NR: 2011/01

INFO SOURCE: METEOSAT IMAGERY

AVIATION COLOUR CODE: UNKNOWN

ERUPTION DETAILS: ERUPTION STARTED AROUND 23UTC

OBS VA DTG: 20110613/0400Z

OBS VA CLD: FL150/300 N1330 E04145 - N1440 E03435 - N1625 E03430 - N1330 E04145

FCST VA CLD + 6H: 13/0900Z

FCST VA CLD + 12H: 13/1500Z

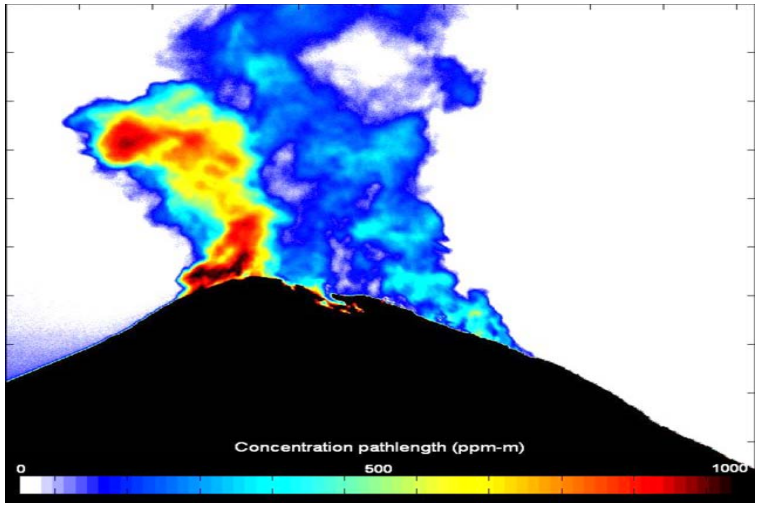
FCST VA CLD + 18H: 13/2100Z

RMK: PLEASE CHECK SIGMET FOR CURRENT WARNINGS.

Re-thinking volcanic cloud monitoring: a quantitative, multi-sensor, approach

Ash Plumes

SO_2 Clouds



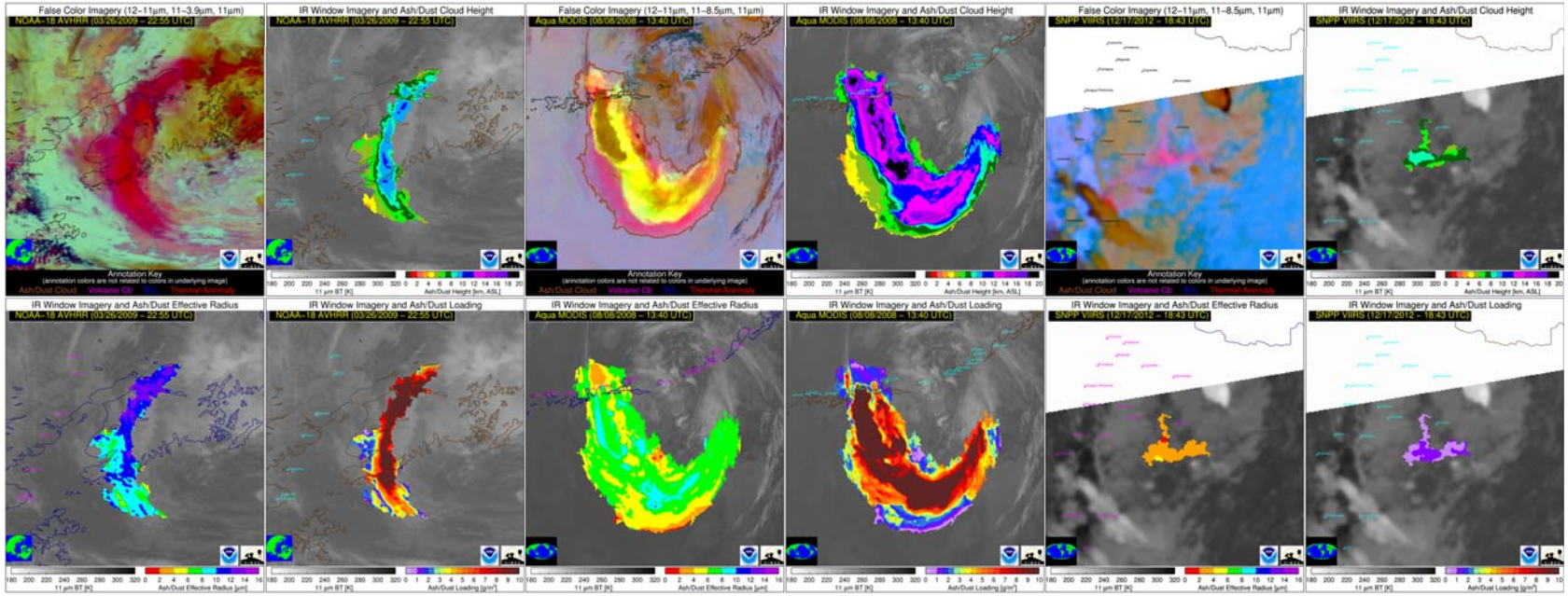
Umbrella Clouds

No single satellite sensor is ideally suited for tracking and characterizing all types of volcanic clouds

Making Full Use of the Space-based Observing System for Volcanic Cloud Monitoring

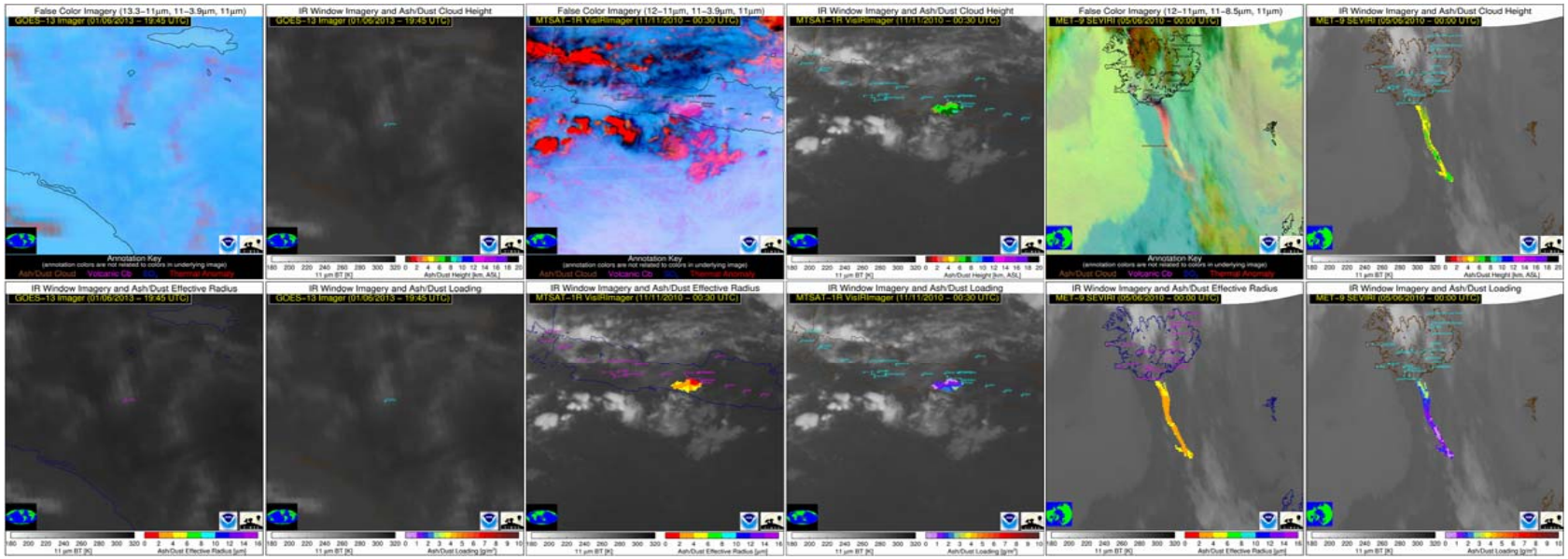
LEO

NOAA and MetOp AVHRR | **Terra and Aqua MODIS** | **SNPP-VIIRS**



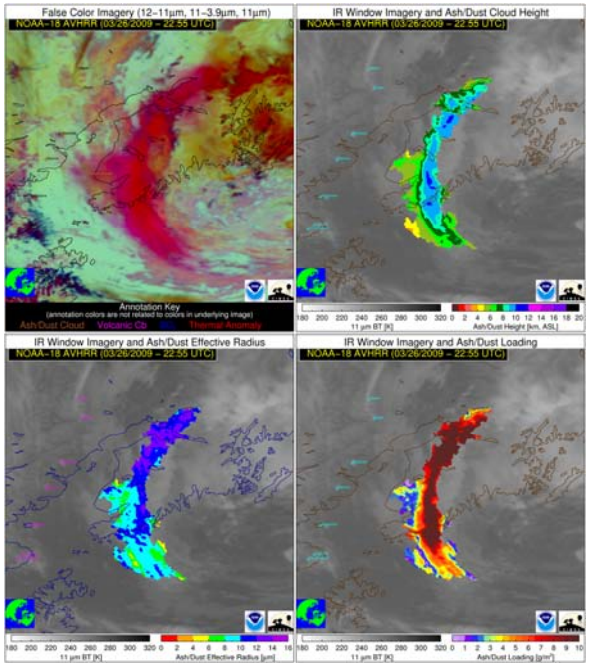
GEO

GOES-12-15 | **MTSAT-(1r and 2)** | **Met-(8,9,10) SEVIRI**

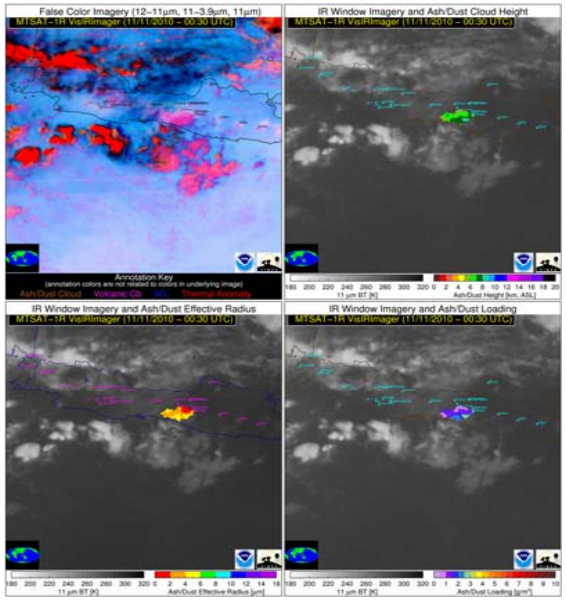


The algorithm software can be used in a variety of configurations and is designed to take full advantage of the space-based observing system

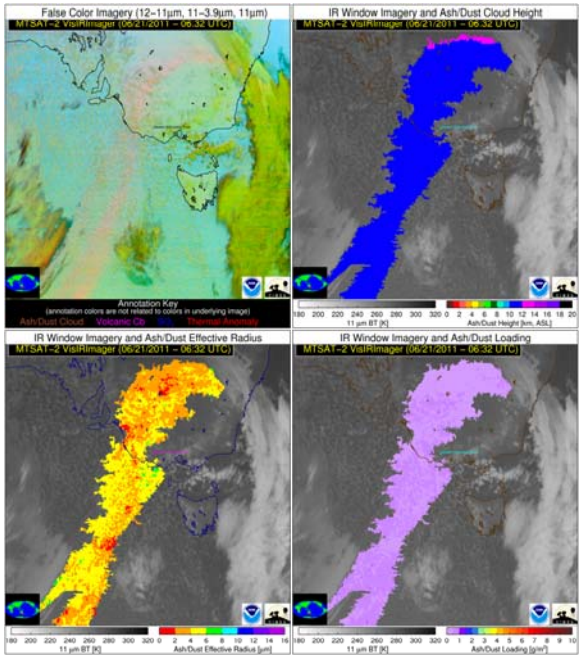
1). Use a single instrument and a single measurement time



2). Use a single instrument and multiple measurement times



3). Use measurements from a combination of instruments and measurement times (e.g. LEO + GEO)



Automated alert would have been issued after 20:45 UTC image on June 12, 2011

Subject: **NOAA/CIMSS Volcanic Cloud Alert**
Date: February 21, 2013 9:16:02 PM CST
To: Mike Pavolonis <mpav@ssec.wisc.edu>

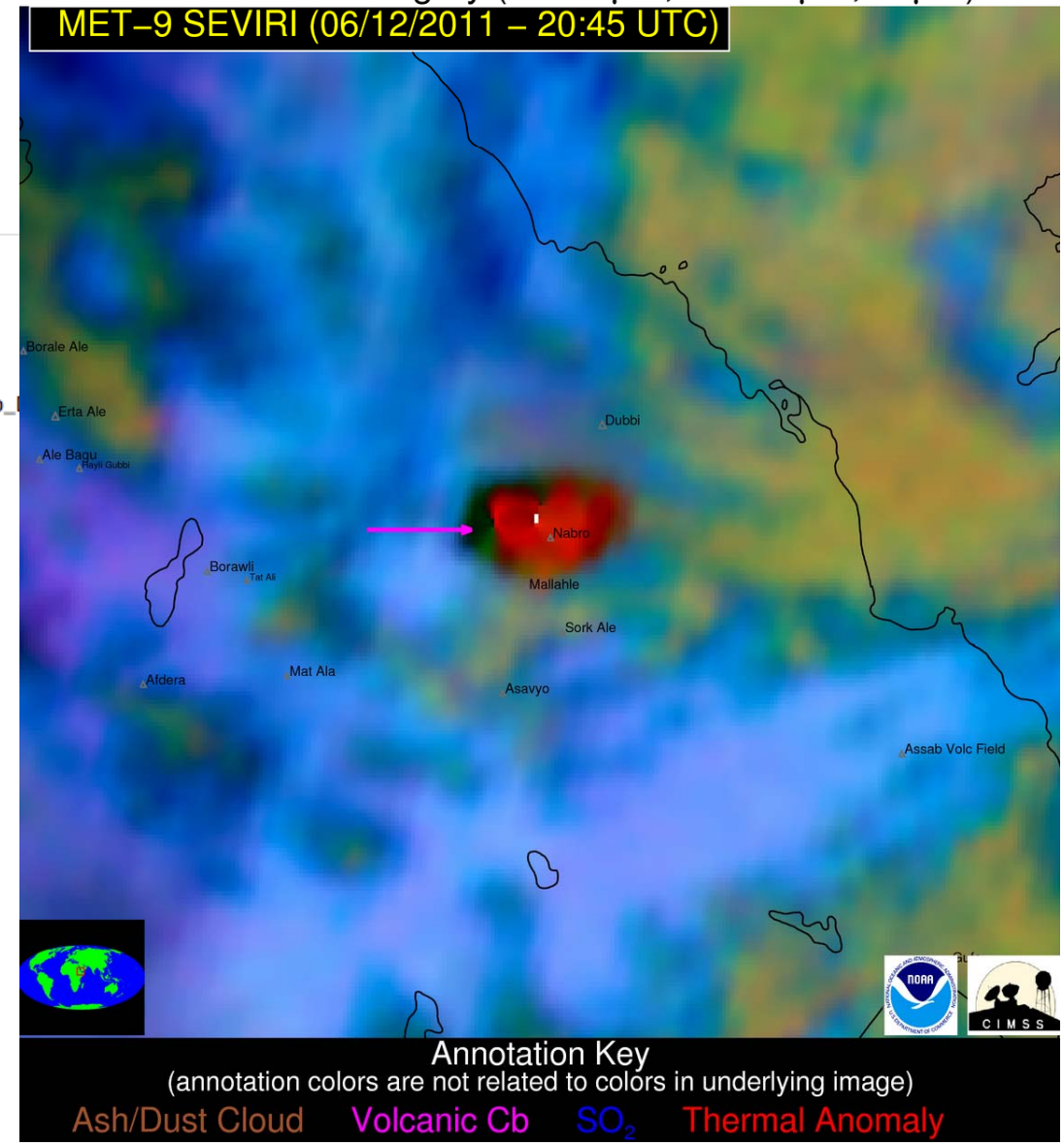
@**********VOLCANIC ALERTS**********
STARTING DATE/TIME OF IMAGE: 2011-06-12 20:45:00 [UTC]
PRIMARY INSTRUMENT: Meteosat-9 SEVIRI
WMO SPACECRAFT ID: 056
LOCATION/ORBIT: GEO
L1 FILE: met9_1_2011_163_2045.area.gz
VOLCANO DATABASE: /data/common/VOLCAT_DATA/alerts/Volcat_Alert_Volcano_
NUMBER OF ASH CLOUD ALERTS: 0
NUMBER OF VOLCANIC Cb ALERTS: 1
NUMBER OF VOLCANIC THREMAL ANOMALY ALERTS: 0
NUMBER OF SO2 CLOUD ALERTS: 0

REPORT WITH IMAGES:
http://volcano.ssec.wisc.edu/alert/report/469

POSSIBLE VOLCANIC ERUPTION DETECTED
Alert Status: Newly detected feature
Latitude of Radiative Center: 13.381 [degrees]
Longitude of Radiative Center: 41.666 [degrees]
Mean Viewing Angle: 50.48 [degrees]
Mean Solar Zenith Angle: 142.87 [degrees]
Nearby Volcanoes (meeting alert criteria):
Nabro(3.99 km)
Maximum Height [AMSL]: 20.3 [km] (66632.75 [ft])
90th Percentile Height [AMSL]: 20.4 [km] (66932.40 [ft])
Mean Tropopause Height [AMSL]: 16.5 [km] (54100.27 [ft])
Trend in IR Brightness Temperature: -45.26 [K/15 min]
Vertical Growth Rate Anomaly: 17.12 [number of stddev above mean]
Total Area: 670.77 [km^2]

Geographic Regions of Nearby Volcanoes: Ethiopia
VAAC Regions of Nearby Volcanoes: Unknown
FIR Regions of Nearby Volcanoes: Unknown

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



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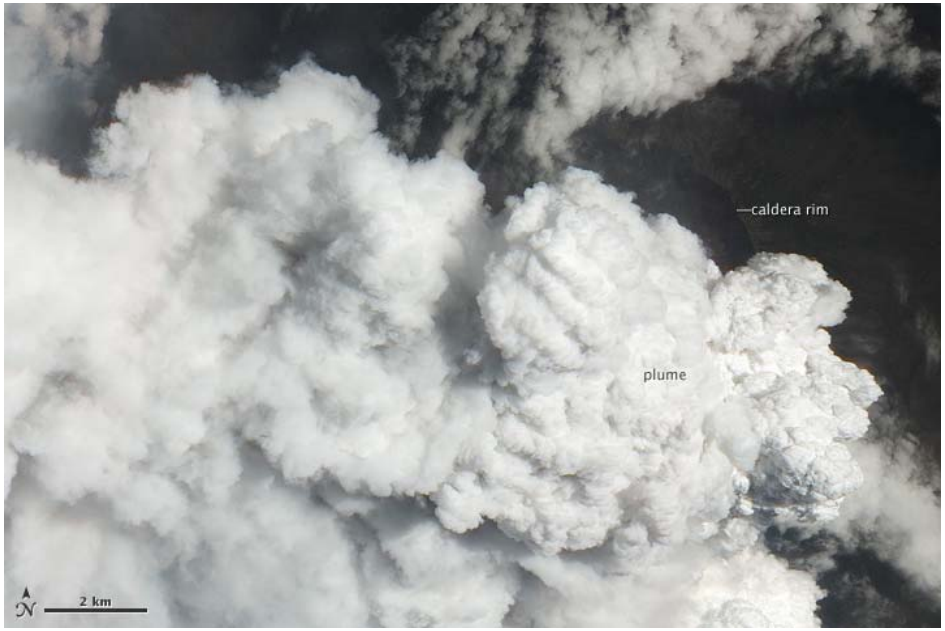

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The development of the automated alert component of the system is maturing

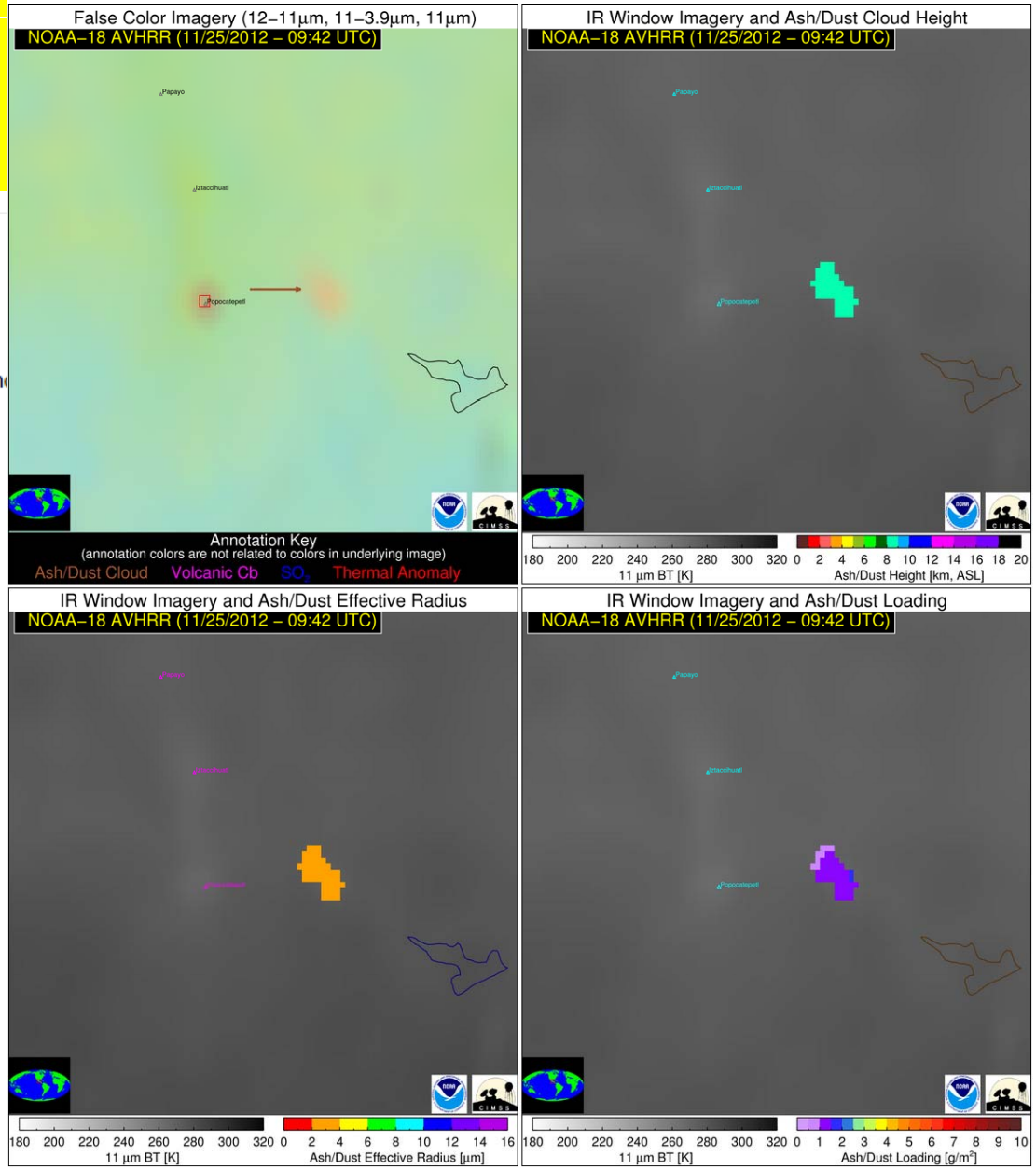
Automated detection of a Popocatepetl ash cloud. Eruption does not have to be large to be detected!

@**********VOLCANIC ALERTS**********
STARTING DATE/TIME OF IMAGE: 2012-11-25 09:42:48 [UTC]
PRIMARY INSTRUMENT: NOAA-18 AVHRR/3
WMO SPACECRAFT ID: 209
LOCATION/ORBIT: LEO
L1 FILE: NSS.HRPT.NN.D12330.S0942.E0954.B3873030.MI
VOLCANO DATABASE: /data/common/VOLCAT_DATA/alerts/Volcat_Alert_Volcan
NUMBER OF ASH CLOUD ALERTS: 1
NUMBER OF VOLCANIC Cb ALERTS: 0
NUMBER OF VOLCANIC THREMAL ANOMALY ALERTS: 0
NUMBER OF SO2 CLOUD ALERTS: 0

REPORT WITH IMAGES:
http://volcano.ssec.wisc.edu/alert/report/394

POSSIBLE VOLCANIC ASH CLOUD FOUND
Alert Status: Newly detected feature
Latitude of Radiative Center: 19.032 [degrees]
Longitude of Radiative Center: -98.414 [degrees]
Mean Viewing Angle: 8.75 [degrees]
Mean Solar Zenith Angle: 130.61 [degrees]
Nearby Volcanoes (meeting alert criteria):
Popocatepetl(21.95 km) [Thermal Anomaly Present]
Cloud Object Probability: 0.00000 [%]
Mean Probability of Object Pixels: 89.26924 [%]
Percent Unambiguous Pixels: 28.60683 [%]
Maximum Height [AMSL]: 9.6 [km] (31439.20 [ft])
90th Percentile Height [AMSL]: 8.7 [km] (28617.61 [ft])
Mean Tropopause Height [AMSL]: 16.4 [km] (53672.65 [ft])
Total Mass: 0.000045 [Tg]
Median Effective Particle Radius: 3.25 [um]
Total Area: 38.52 [km^2]

Geographic Regions of Nearby Volcanoes: Mexico
VAAC Regions of Nearby Volcanoes: Unknown
FIR Regions of Nearby Volcanoes: Unknown



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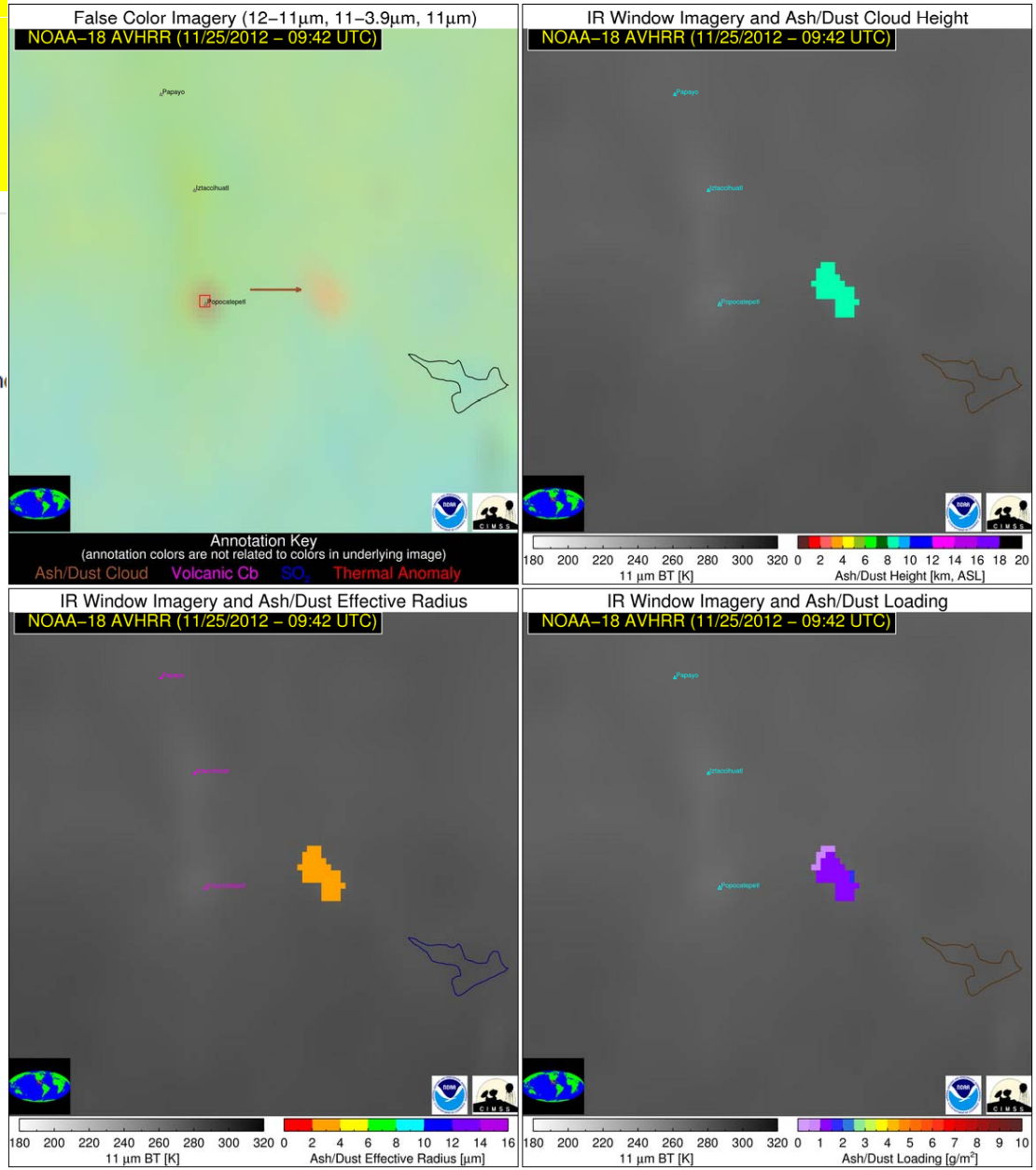


Volcanic Cloud Monitoring -- NOAA/CIMSS (DEBUG)

http://volcano.ssec.wisc.edu/alert/report/412

Apple (185) Yahoo! eBay Amazon News (1,787)

CIMSS » Volcanic Cloud Monitoring » Event Alerts » 2012-11-25

Volcanic Cloud Monitoring — NOAA/CIMSS

Home | Alerts | Logout (mpav@ssec.wisc.edu)

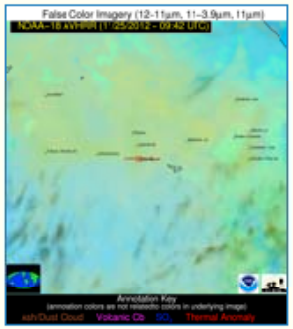
Volcanic Cloud Alert Report

DATE:	2012-11-25
TIME:	00:12:48
PRIMARY INSTRUMENT:	NOAA-18 AVHRR/3

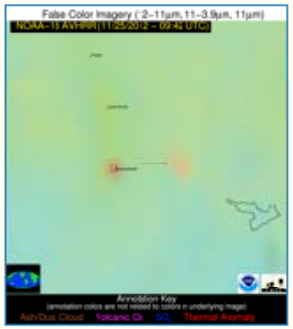
More details ▼

Possible Volcanic Ash Cloud

View event imagery ›



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



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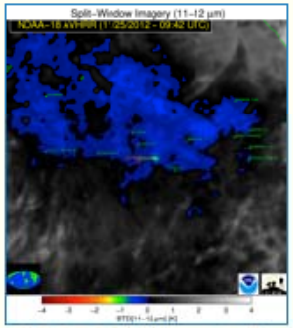
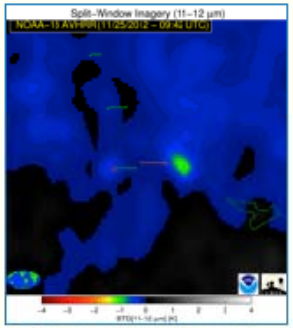


Split-window (12-11) [zoomed-out]



Split-window (12-11) [zoomed-in]

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Mean Probability of Object Pixels:	89.26924 %
Percent Unambiguous Pixels:	28.61 %
Maximum Height [AMSL]:	9.60 km
1-sigma Uncertainty of Maximum Height [AMSL]:	0.70 km
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VAAC Regions of Nearby Volcanoes:	Unknown
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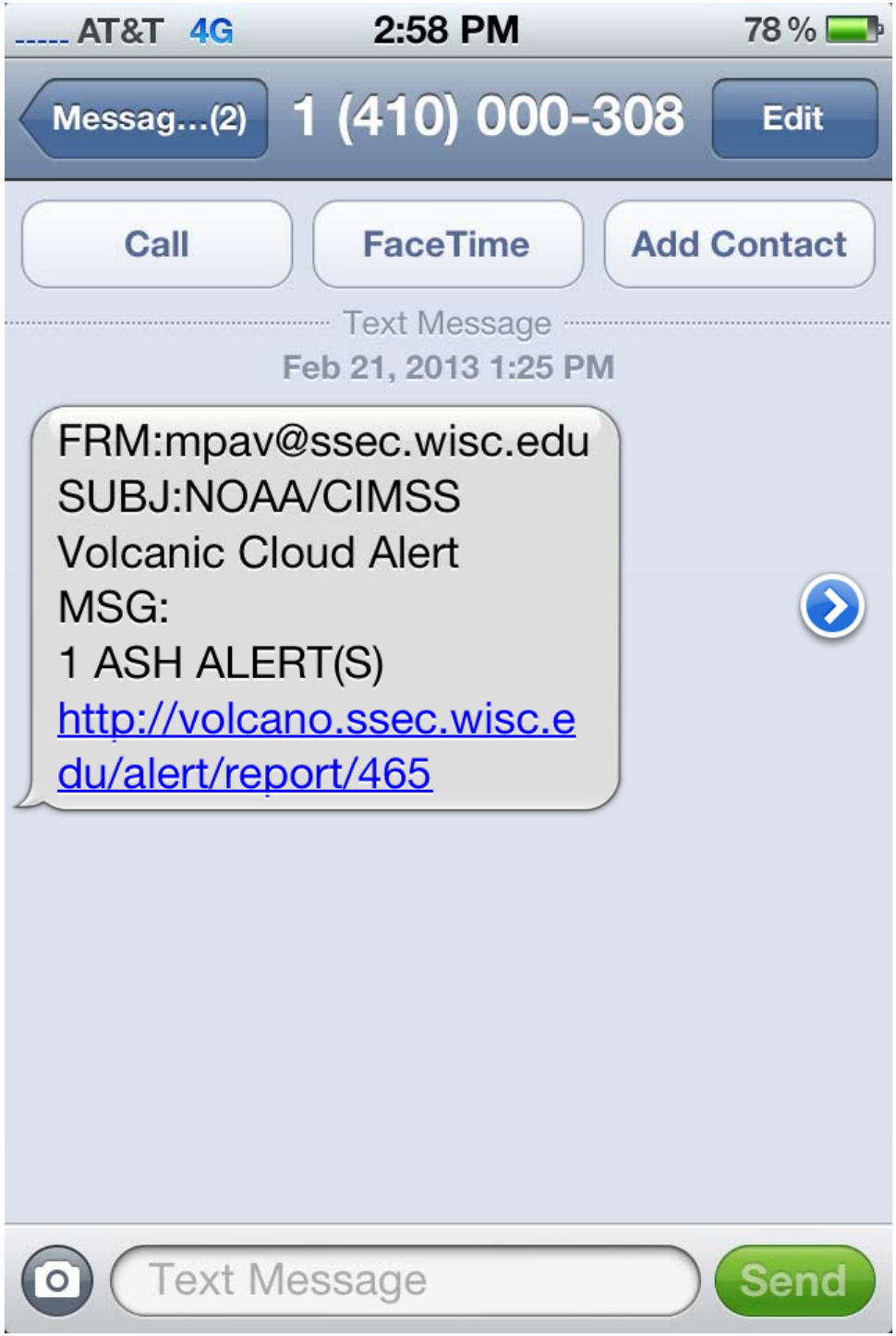
Possible Volcanic Thermal Anomaly

View event imagery ›

Alert Status:	Newly detected feature



SMS message alerts are also available

Alerts will be available for outside distribution in the next couple of months.

Summary

- **NOAA/NESDIS/STAR has developed a suite of *globally applicable* satellite remote sensing techniques for automatically identifying volcanic clouds in satellite imagery with a skill comparable to that of a well-trained human analyst**
- **The NOAA algorithms also automatically estimate relevant volcanic cloud properties (height, loading, effective particle radius)**
- **These methods can be applied to *virtually any satellite sensor*, while taking full advantage of each sensor's capabilities, and can actually *utilize combinations of satellite sensors* to help ensure that they can be used to address operational problems related to volcanic clouds**