

NOAA
National Satellite and
Information Service

30 June 2022

10 Years of SNPP in Support of Volcanic Ash Advisory Center Operations

Mike Pavolonis
NOAA/NESDIS/STAR

Volcanic Cloud Applications

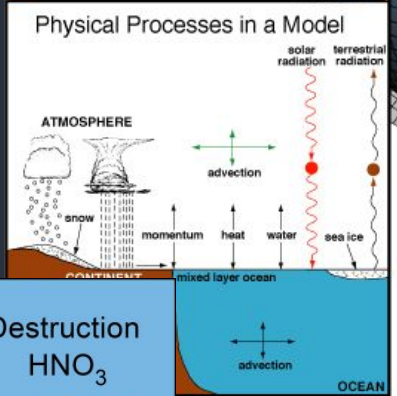
Climate

Weather

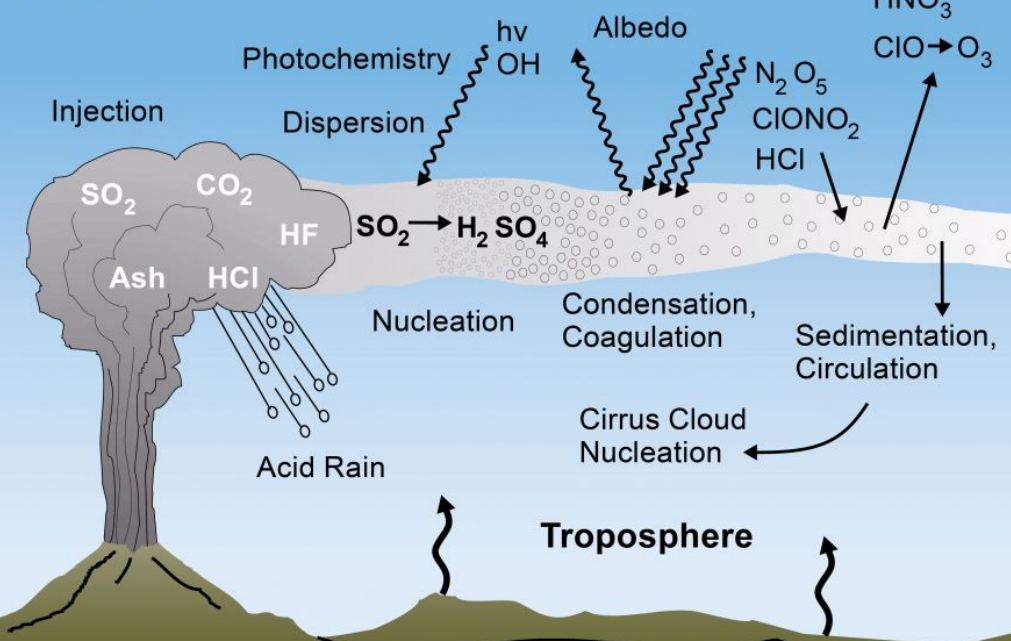
Aviation

Horizontal Grid
(Latitude-Longitude)

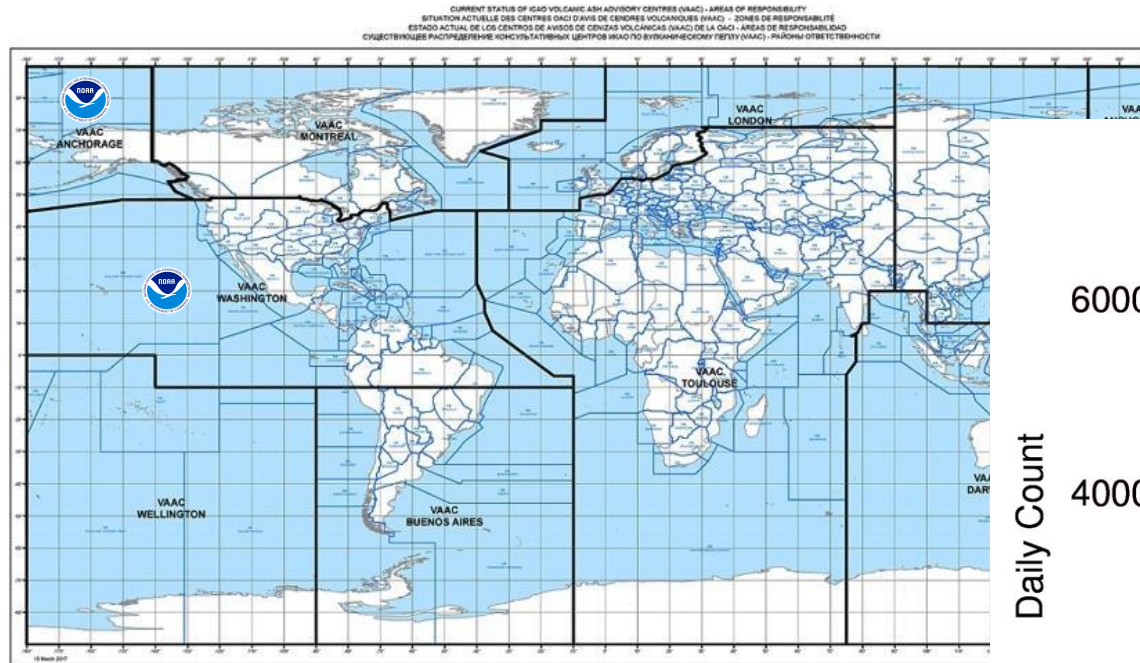
Vertical Grid
(Height or Pressure)



Stratosphere

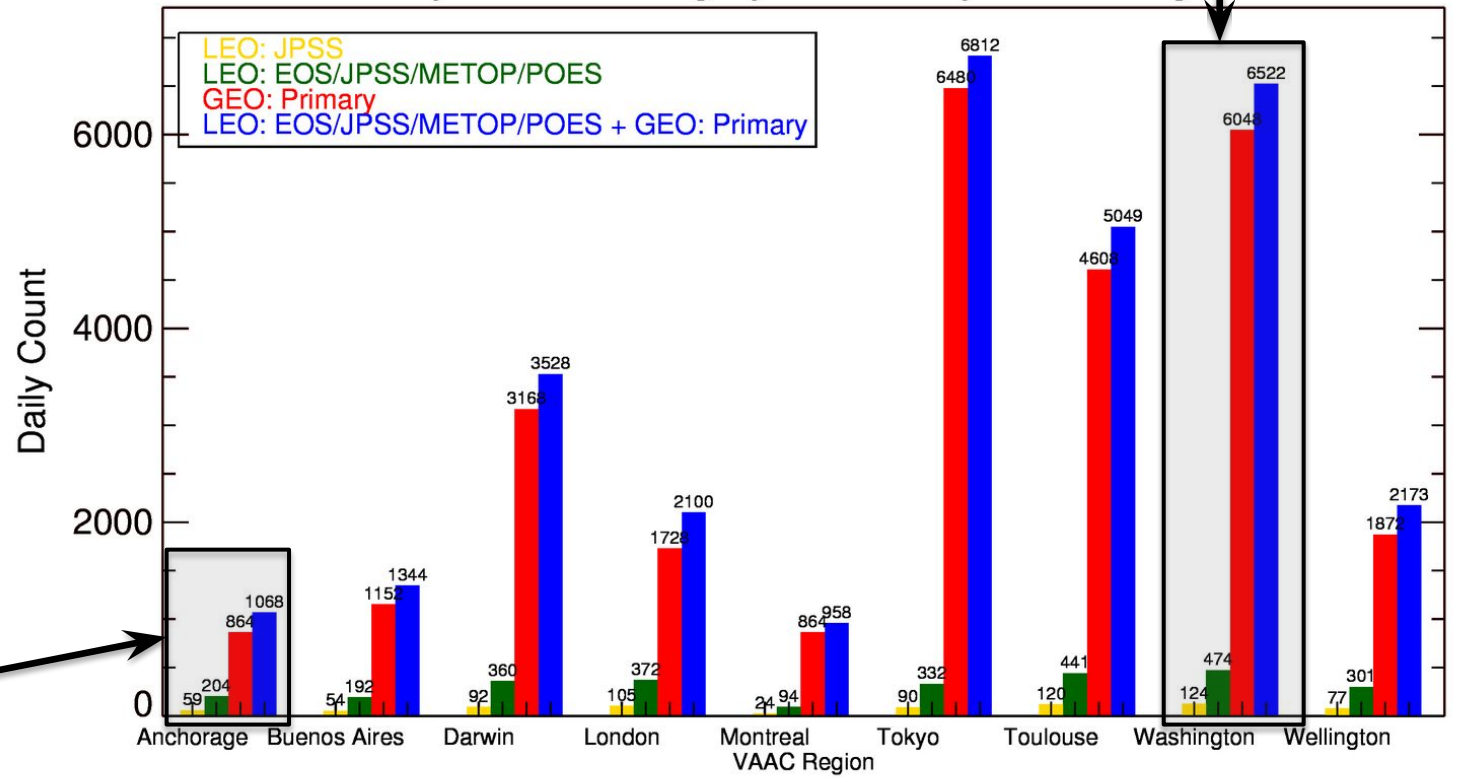


Volcanic Ash Advisory Centers



Minimum human work load (@W-VAAC) for “complete” monitoring: 1 satellite image every 15 seconds

Daily Satellite Imagery Refresh by VAAC Region



Minimum human work load (@A-VAAC) for “complete” monitoring: 1 satellite image every 1 minute



Volcanic Ash Advisory Workflow

**Standards and
Practices: ICAO
Annex 3**

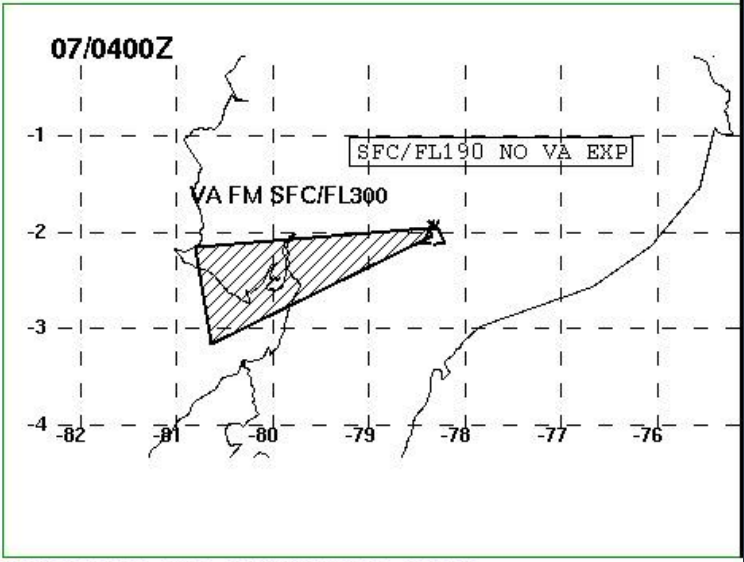
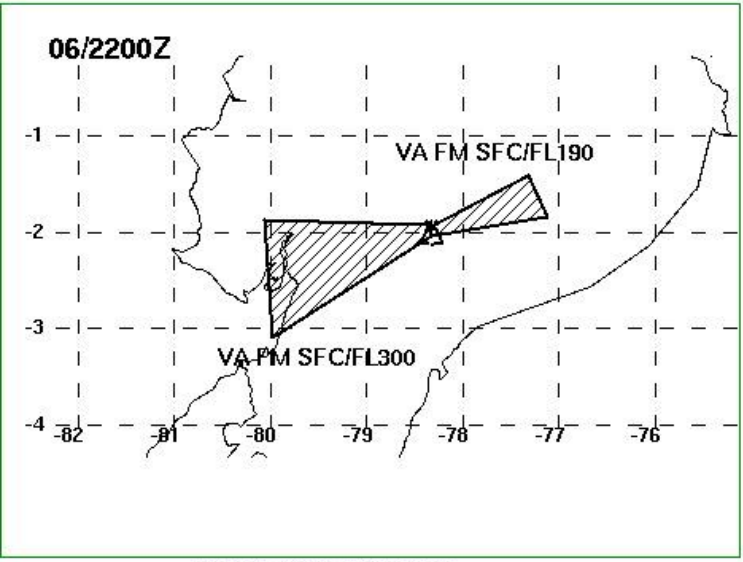
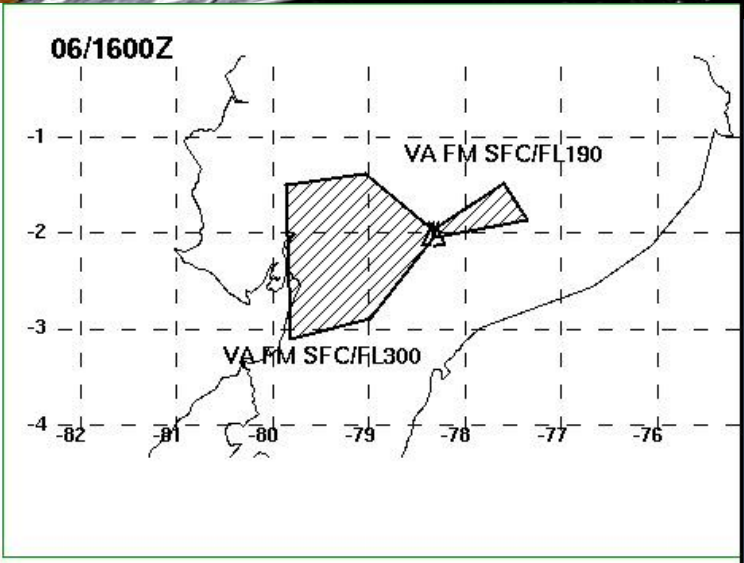
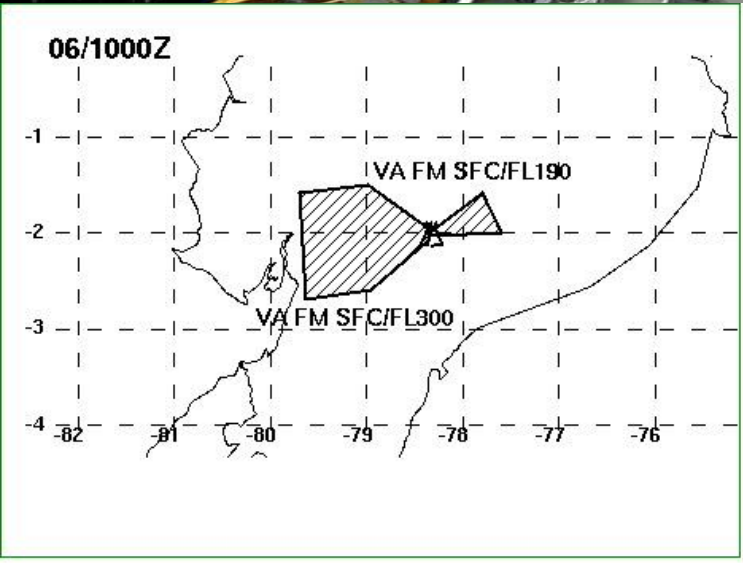
**1. Timely
detection of
new volcanic
event**

**2. Properties of
volcanic cloud**

**3. Future state
of volcanic
cloud**

**Volcanic Ash
Advisory (VAA)
and customer
support**





Current Volcanic Ash Advisory format: polygon denoting discernible ash with a single flight level range assigned to each polygon

VOLCANIC ASH ADVISORY
 DTG: 20210306/1027Z
 VAAC: WASHINGTON
 VOLCANO: SANGAY 352090
 AREA: ECUADOR
 SUMMIT ELEV: 17159 FT (5230 M)
 ADVISORY NR: 2021/246

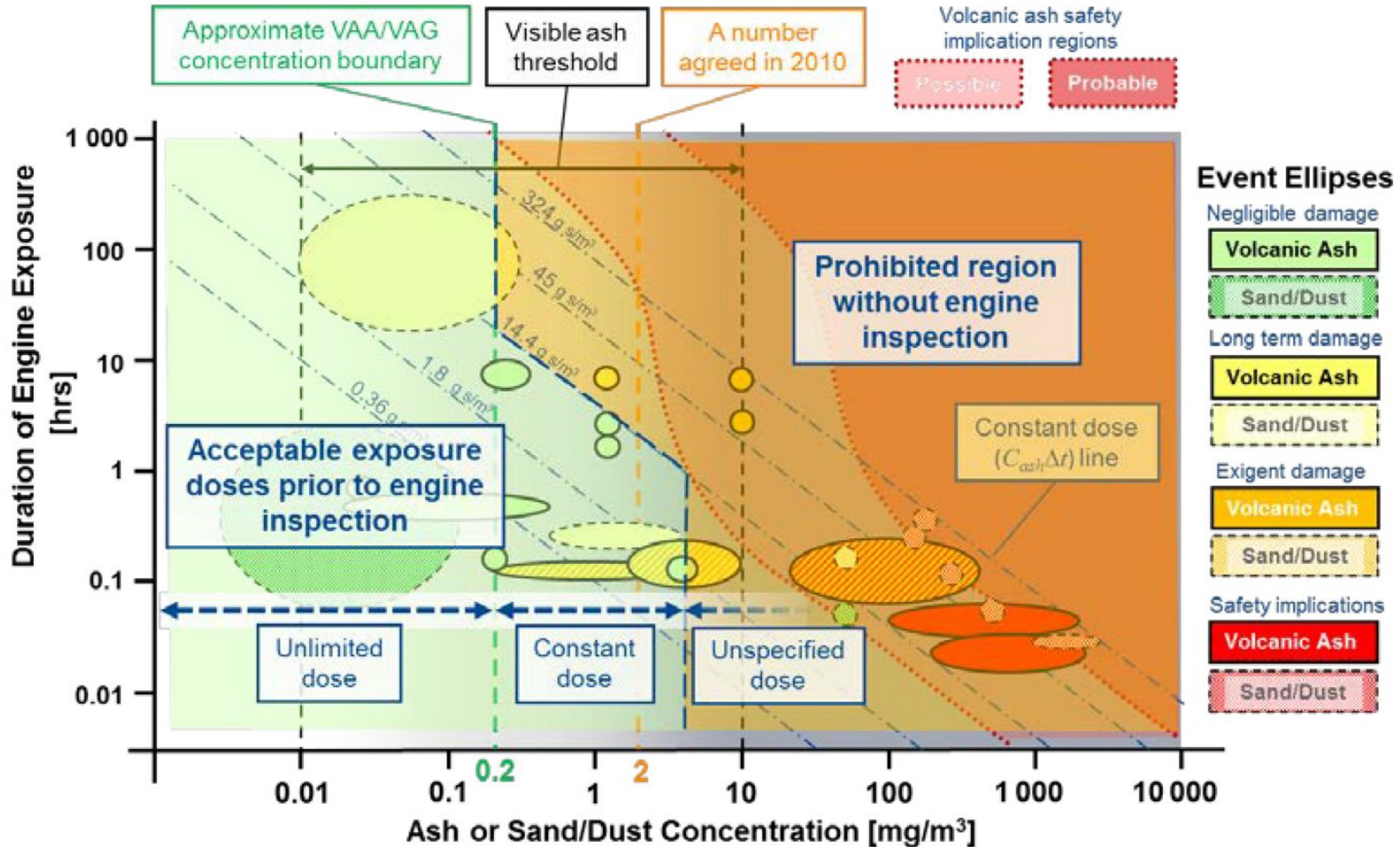
INFO SOURCE: GOES-16, NWP MODELS, ASH3D.
 ERUPTION DETAILS: LARGE VA CLDS.
 RMK: VA OBS FANNING OUT NW TO SW UP TO 90 NM FM SUMMIT AT FL300. ADDL VA OBS MOV E FM SUMMIT BELOW FL190. OBS FLS ESTD FM NWP MDLS WITH LOW CONFIDENCE AND COULD BE HIGHER. FL MVMT EXP TO PERSIST THRU T+16 HRS. ... CLARK
 NXT ADVISORY: WILL BE ISSUED BY 20210306/1630Z



Emerging ICAO Requirements

Risk = F(C, E)

Rory Clarkson, Rolls Royce

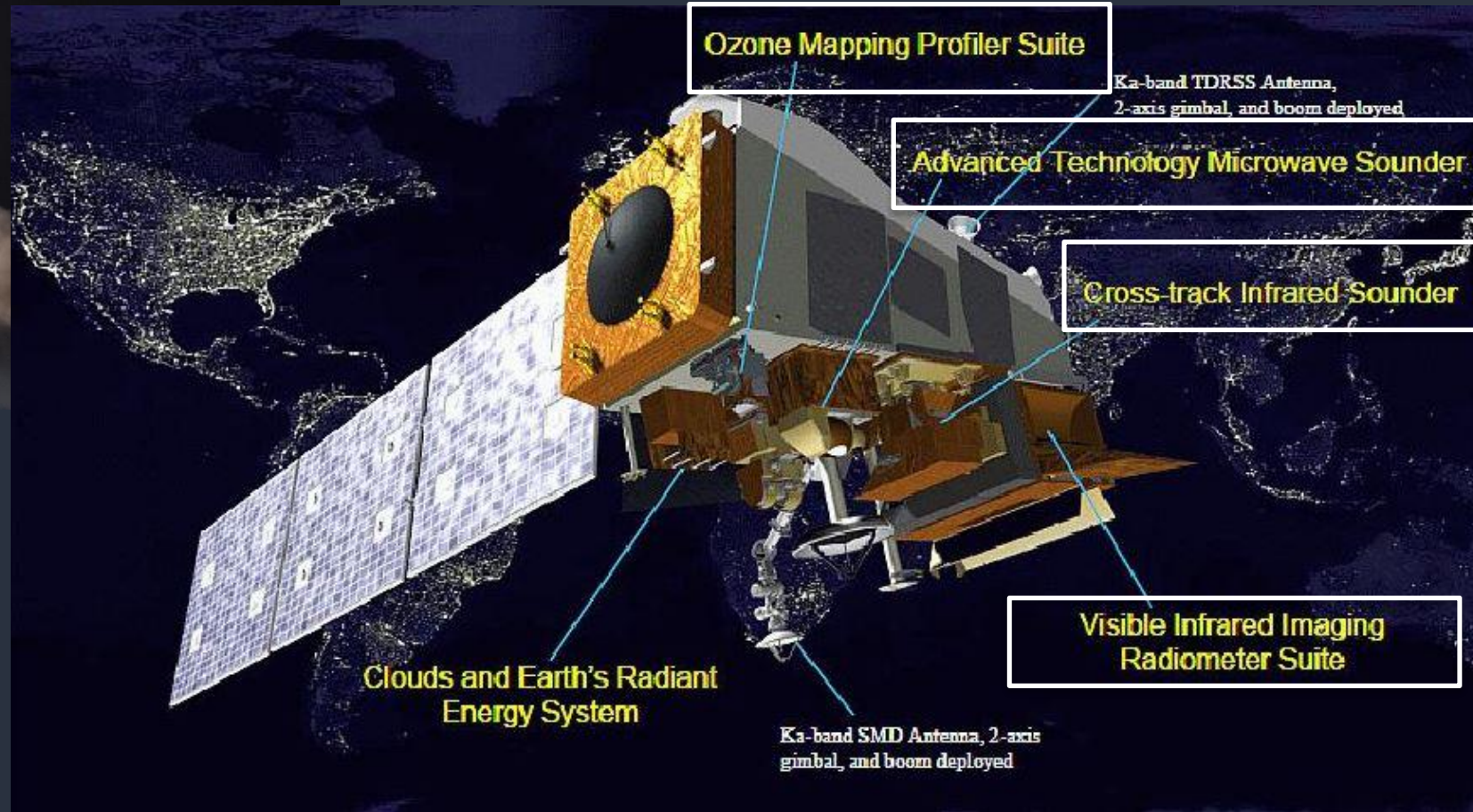


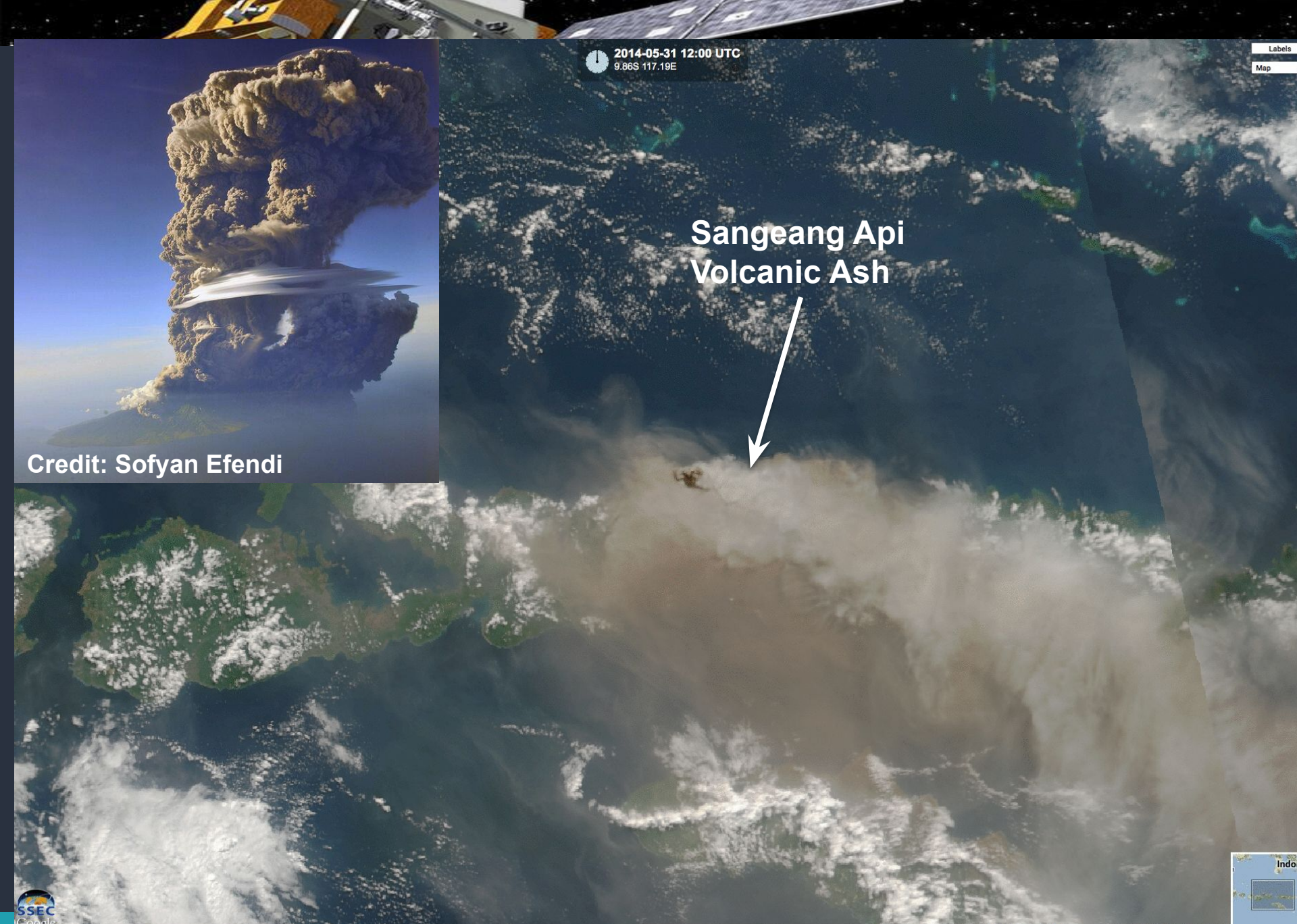
LEO Satellite Capabilities - JPSS



S-NPP was launched on 28 October 2011 and entered operational mode on 1 May 2014

NOAA-20 was launched on 18 November 2017 and entered operational mode on 30 May 2018





2014-05-31 12:00 UTC
9.86S 117.19E

Labels
Map

Sangeang Api
Volcanic Ash

Credit: Sofyan Efendi

VIIRS True Color Imagery



VIIRS Day Night Band Imagery

**Kelut Eruptive
Cloud**



CIMSS Satellite Blog

VIIRS 2014-02-13 17:28:12 GMT,... - Day Night Band

NOAA National Environmental Satellite, Data, and Information Service

30 June 2022



At 375 m resolution, the minimum 11 μm brightness temperature is -101°C

VIIRS I-bands

April 23, 2015 (05:09 UTC)

CIMSS Satellite Blog

VIIRS 2015-04-23 05:09:38 GMT, ... - I05 (11 μm) BT



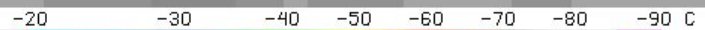
April 23, 2015 (05:08 UTC)

At 4+ km resolution, the minimum 11 μm brightness temperature is -66°C



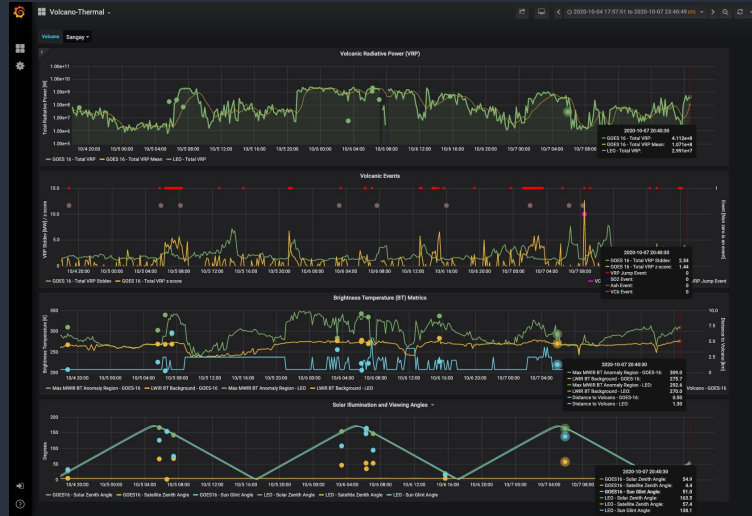
GOES-13

CIMSS Satellite Blog

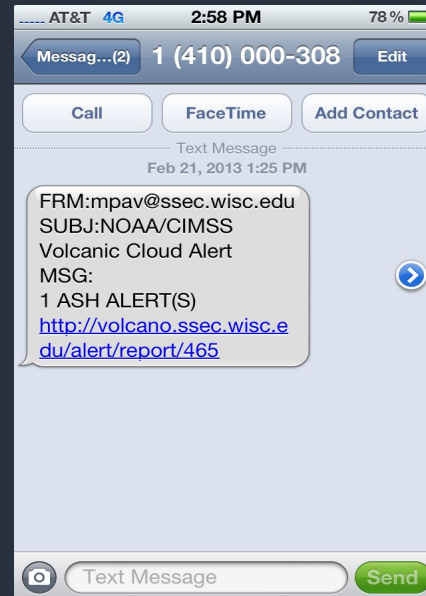


The VOLcanic Cloud Analysis Toolkit (VOLCAT)

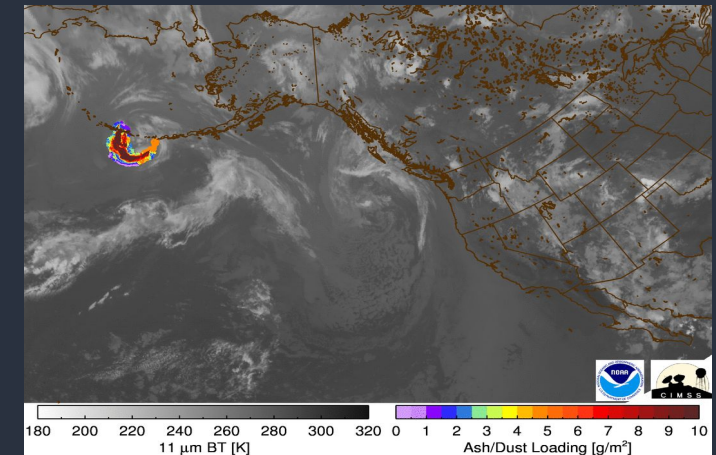
Thermal Monitoring



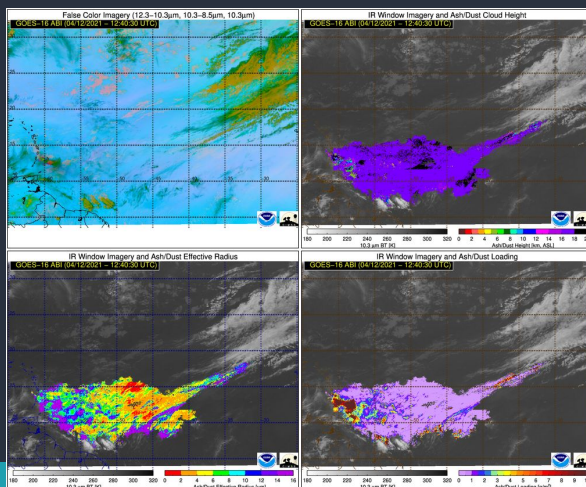
Eruption Alerts



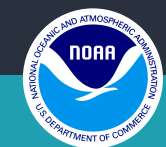
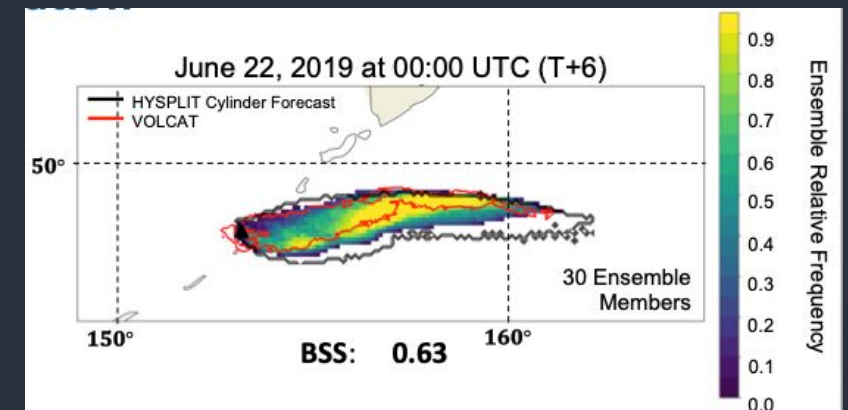
Volcanic Cloud Tracking



Volcanic Cloud Characterization



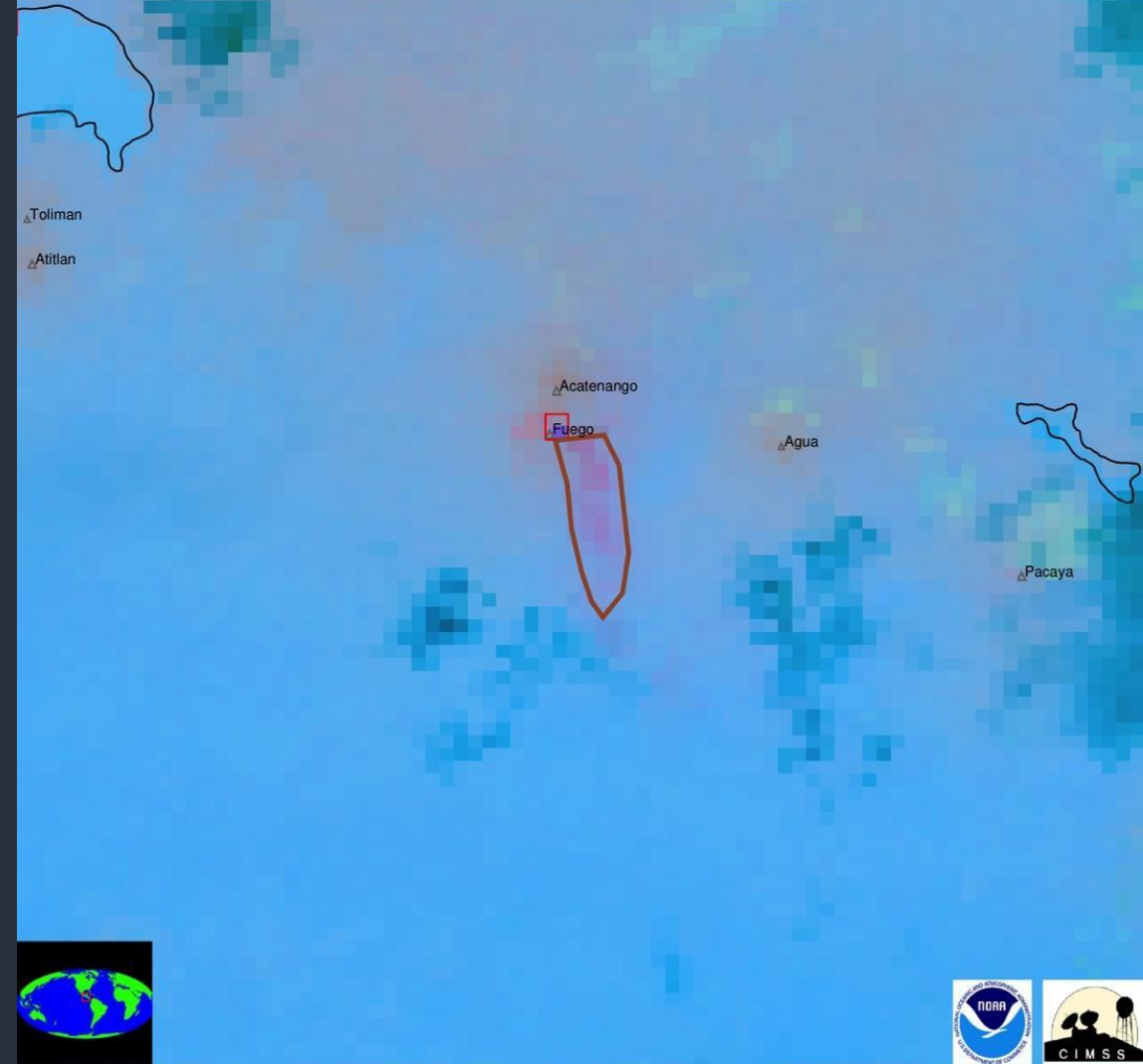
Dispersion & Transport Forecasting



Quantitative Ash Detection



False Color Imagery (12–11 μm , 11–8.5 μm , 11 μm)
NOAA-20 VIIRS (05/04/2020 – 08:00:00 UTC)



Major Science Challenges:

- Very wide range of cloud properties
- Highly variable background/foreground
- Source attribution
- Requires general AI solution that can be applied to many sensors

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

h/Dust Cloud	Volcanic Cb	SO ₂	Thermal Anomaly
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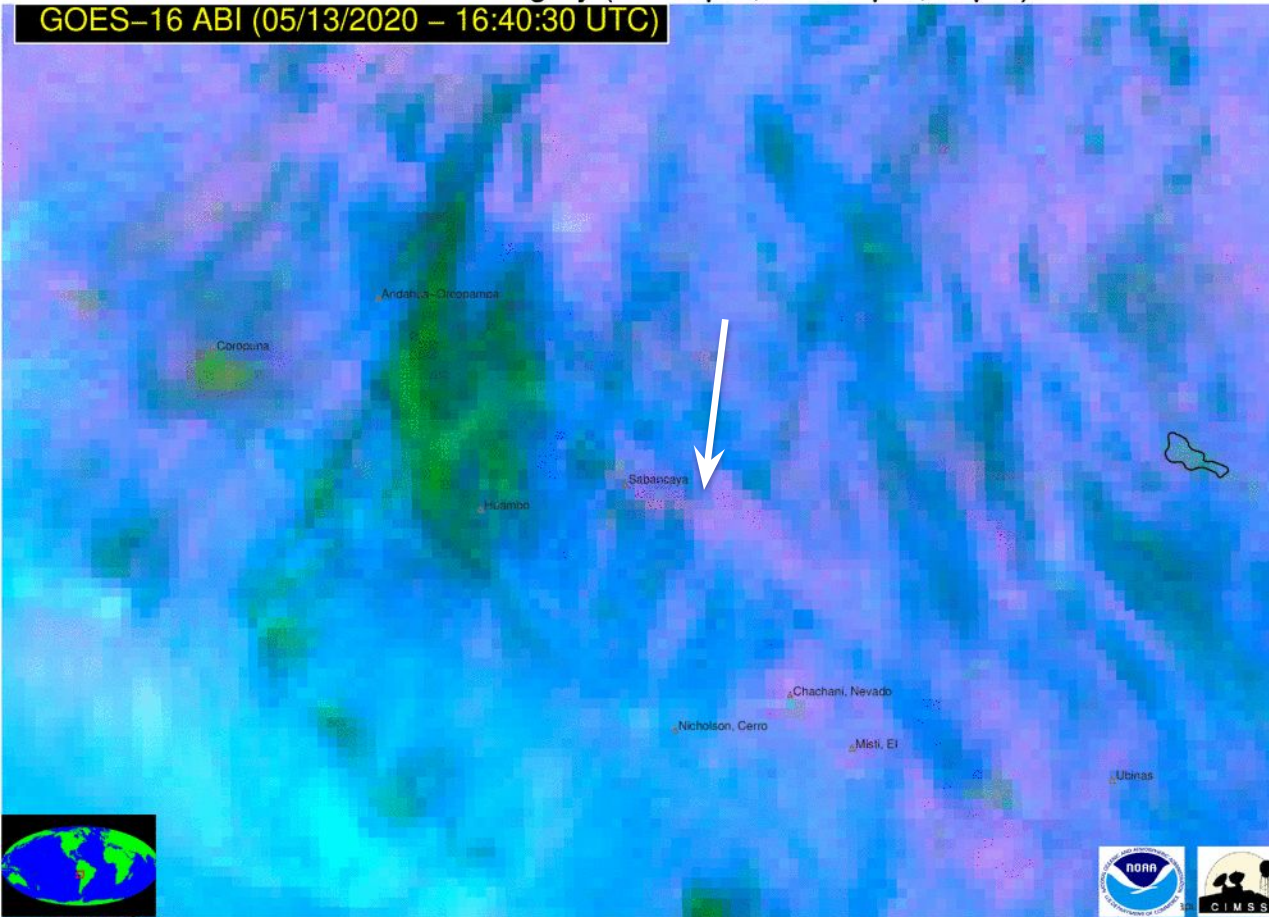
Auto Detection of New Ash Emissions

GOES-16 ABI

NOAA-20 VIIRS

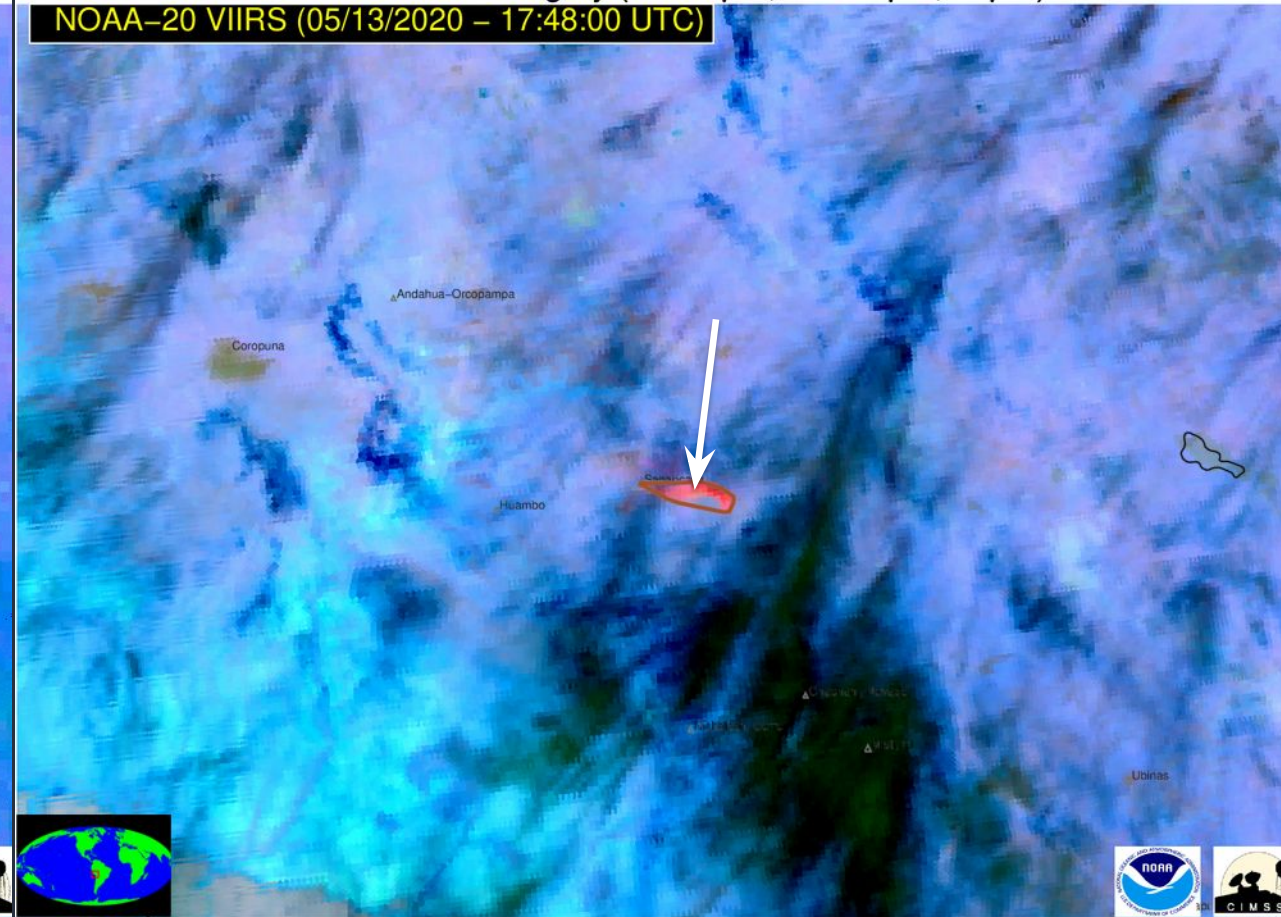
False Color Imagery (12–11 μ m, 11–8.5 μ m, 11 μ m)

GOES-16 ABI (05/13/2020 – 16:40:30 UTC)



False Color Imagery (12–11 μ m, 11–8.5 μ m, 11 μ m)

NOAA-20 VIIRS (05/13/2020 – 17:48:00 UTC)



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

Spectral, spatial, and temporal

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

Spectral and spatial





1 (410) 100-488 >

Text Message
Today 4:29 PM

FRM: volcano.alerts-noreply@ssec.wisc.edu
SUBJ: NOAA/CIMSS VOLCAT Alert
MSG:
1 ASH ALERT(S)
<https://volcano.ssec.wisc.edu/alert/report/112468>

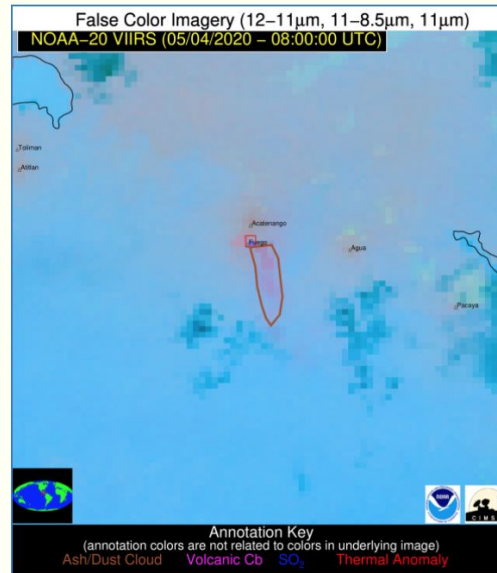
Volcanic Cloud Alerting

Volcanic Cloud Alert Report

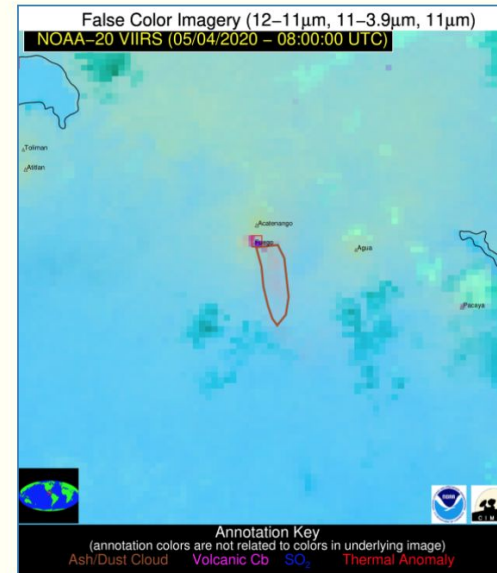
Date:	2020-05-04
Time:	08:00:00
Production Date and Time:	2020-05-04 09:40:14 UTC
Primary Instrument:	NOAA-20 VIIRS

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/Puff Extraction (SECO+)
Mean Object Date/Time	2020-05-04 08:02:32UTC
Radiative Center (Lat, Lon):	14.470°, -90.880°
Nearby Volcanoes (meeting alert criteria):	Fuego (0.00 km) [Thermal Anomaly Present] Acaterango (3.10 km) [Thermal Anomaly Present] Agua (14.80 km) Pacaya (31.80 km) [Thermal Anomaly Present] Atitlan (35.20 km)
Maximum Height [AMSL]	4.70 km ; 15420 ft
Maximum Height (opaque assumption) [AMSL]	3.70 km ; 12139 ft
Minimum IR Window BT	281.00 K

Show More ▲

View all event imagery »

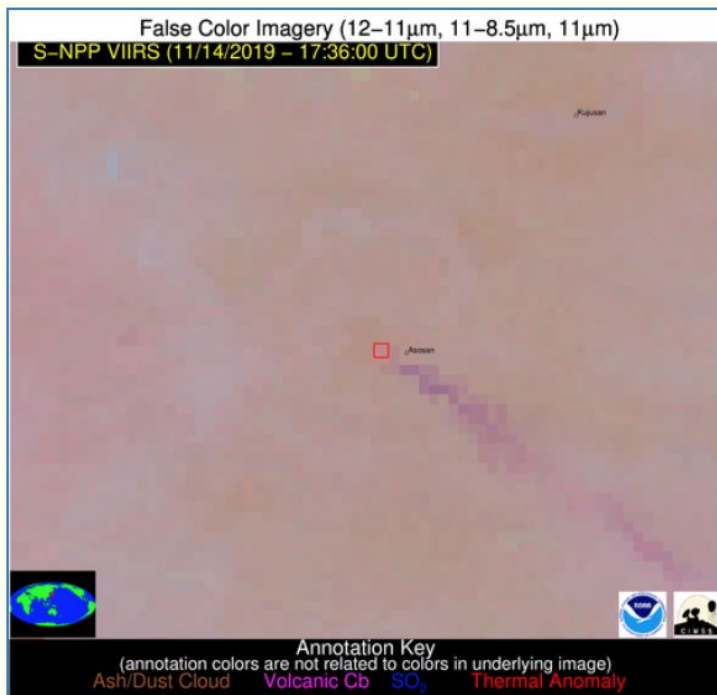
Volcanic Thermal Anomaly Alerts

Volcanic Cloud Alert Report

Date:	2019-11-14
Time:	17:36:00
Production Date and Time:	2019-11-14 21:22:00 UTC
Primary Instrument:	NPP VIIRS

[More details ▼](#)

Possible Volcanic Thermal Anomaly



[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)	Japan, Taiwan, Marianas
Country/Countries	Japan
Volcanic Subregion(s)	Ryukyu Islands and Kyushu
VAAC Region(s) of Nearby Volcanoes	Tokyo
Identification Method	Enhanced Contextual (Clear)
Mean Object Date/Time	2019-11-14 17:40:20UTC
Radiative Center (Lat, Lon):	32.890°, 131.080°
Nearby Volcanoes (meeting alert criteria):	Asosan (2.00 km)
Total Radiative Power Anomaly	n/a
Total Radiative Power	5.72 MW

[Show More ▲](#)

[View all event imagery »](#)

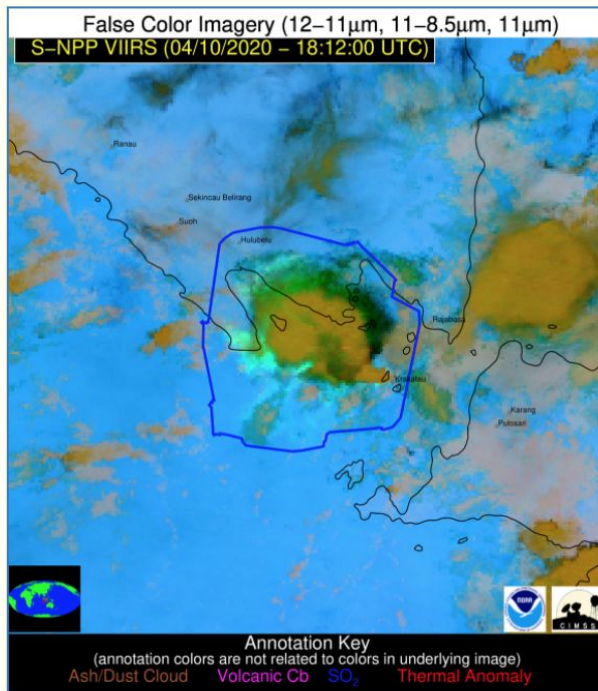
Volcanic SO₂ Alerting (CrIS + VIIRS)

Volcanic Cloud Alert Report

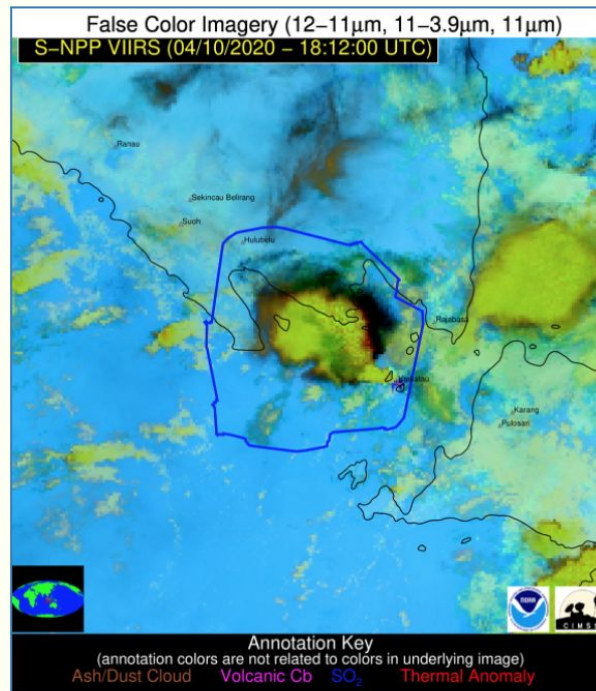
Date:	2020-04-10
Time:	18:12:00
Production Date and Time:	2020-04-10 21:13:17 UTC
Primary Instrument:	NPP VIIRS/CrIS

More details ▼

Possible Sulfur Dioxide 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)	Indonesia
Country/Countries	Indonesia
Volcanic Subregion(s)	Krakatau, Sumatra, Java
VAAC Region(s) of Nearby Volcanoes	Darwin
Identification Method	Feature Extraction (Basic SECO)
Mean Object Date/Time	2020-04-10 18:16:51UTC
Radiative Center (Lat, Lon):	-5.920°, 105.160°
Nearby Volcanoes (meeting alert criteria):	Krakatau (35.30 km) Rajabasa (53.30 km) Hulubelu (88.80 km) Pulosari (101.40 km) Karang_(104.80 km)
Maximum Height [AMSL]	16.50 km ; 54134 ft
90th Percentile Height [AMSL]	15.00 km ; 49213 ft
Mean Tropopause Height [AMSL]	16.90 km ; 55446 ft

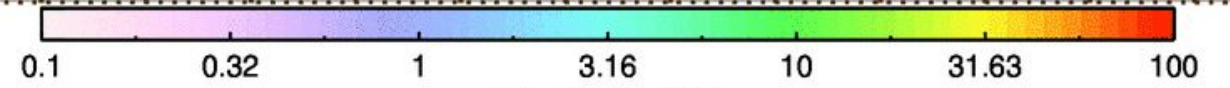
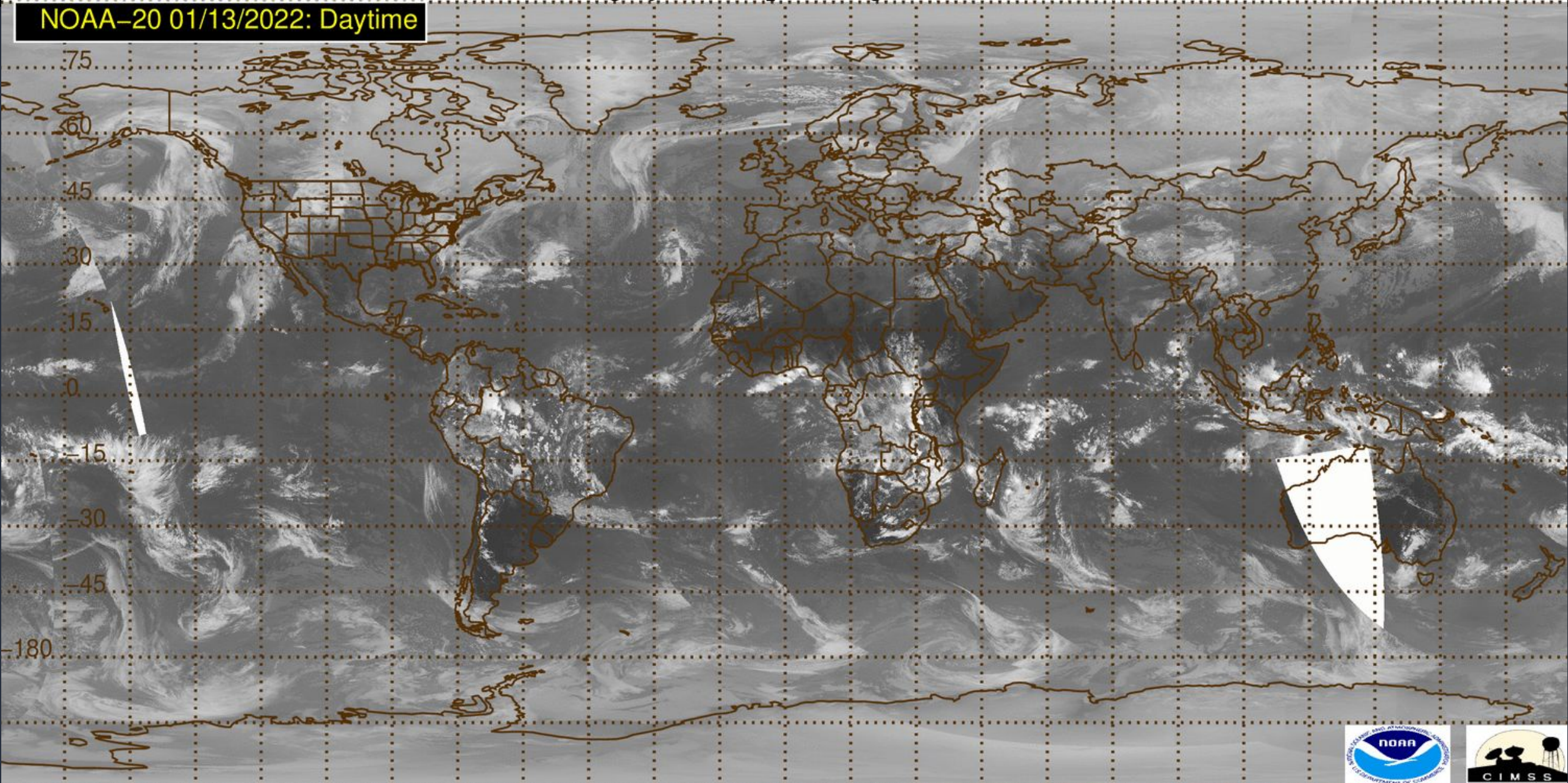
Show More ▲

View all event imagery »

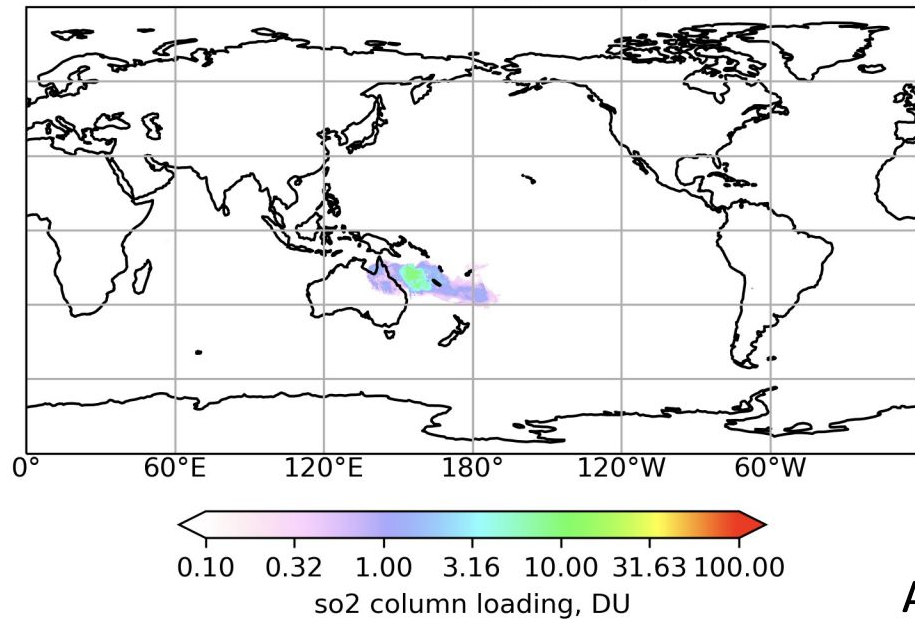


IR Window Imagery and SO₂ Loading – Total Mass: 0.75 kt

NOAA-20 01/13/2022: Daytime

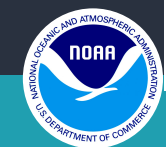
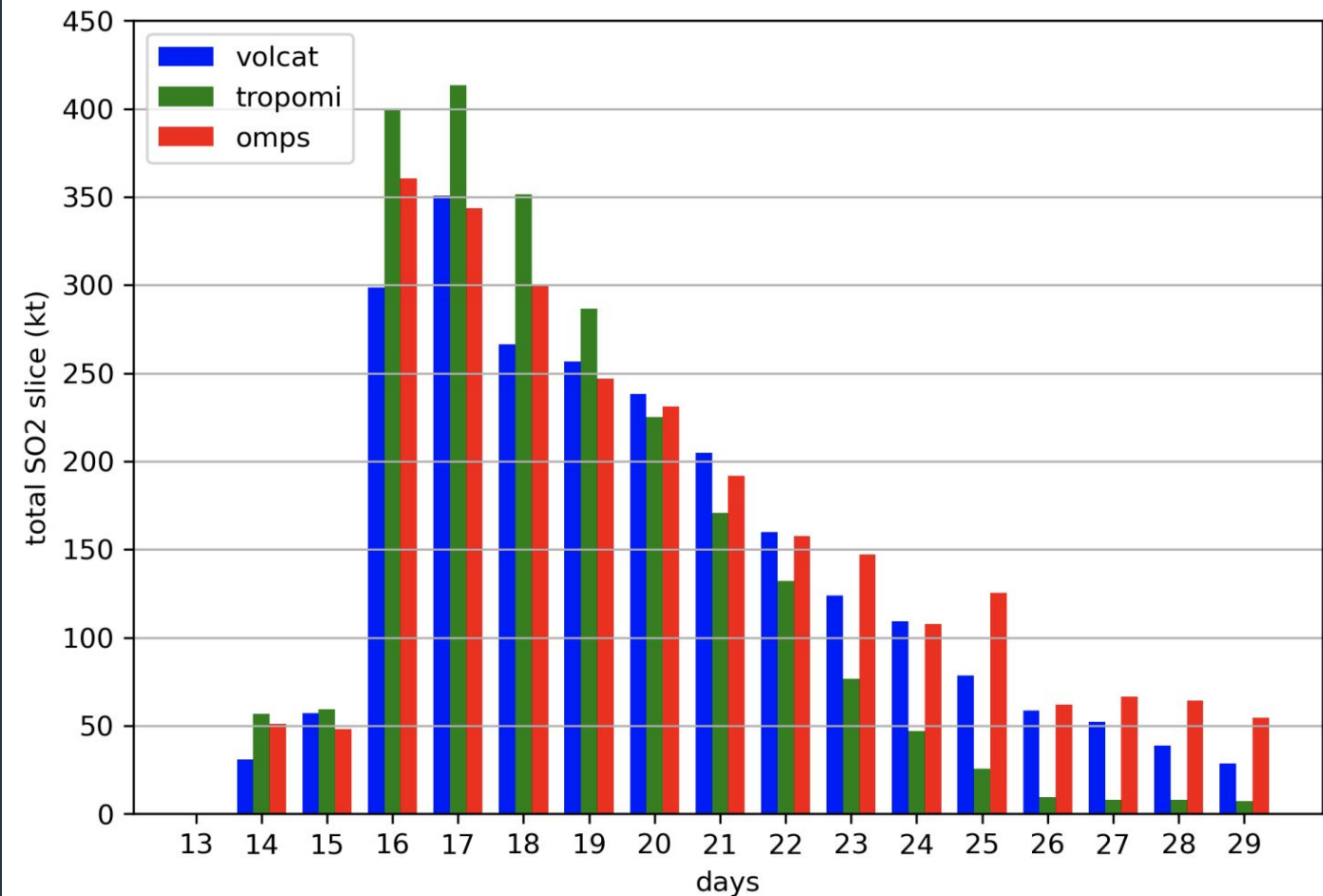
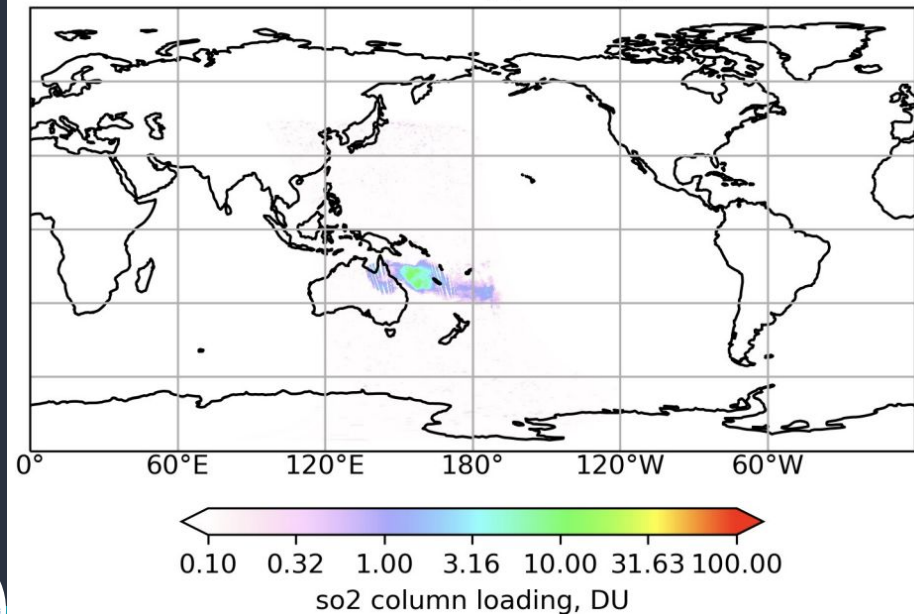


VOLCAT SO2 map January 17

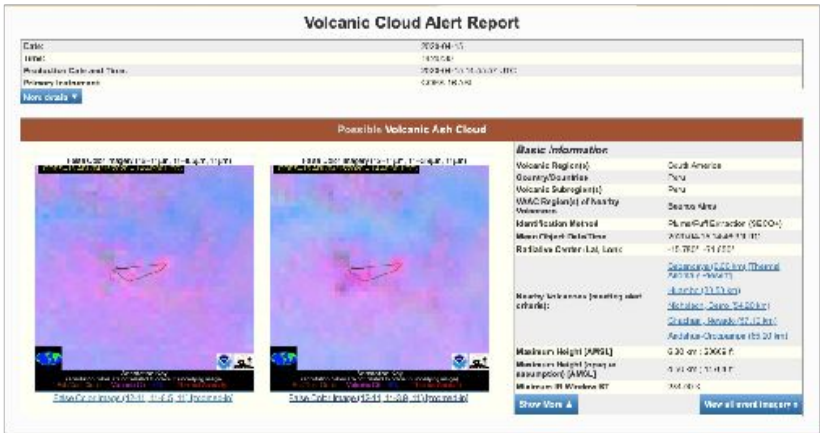


JPSS allows SO₂ loading to be estimated in two completely independent manners (UV and IR)

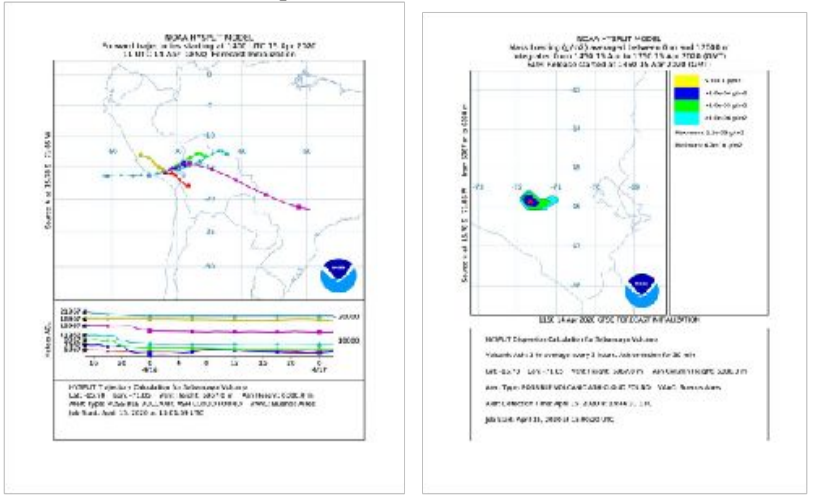
OMPS SO2 map January 17



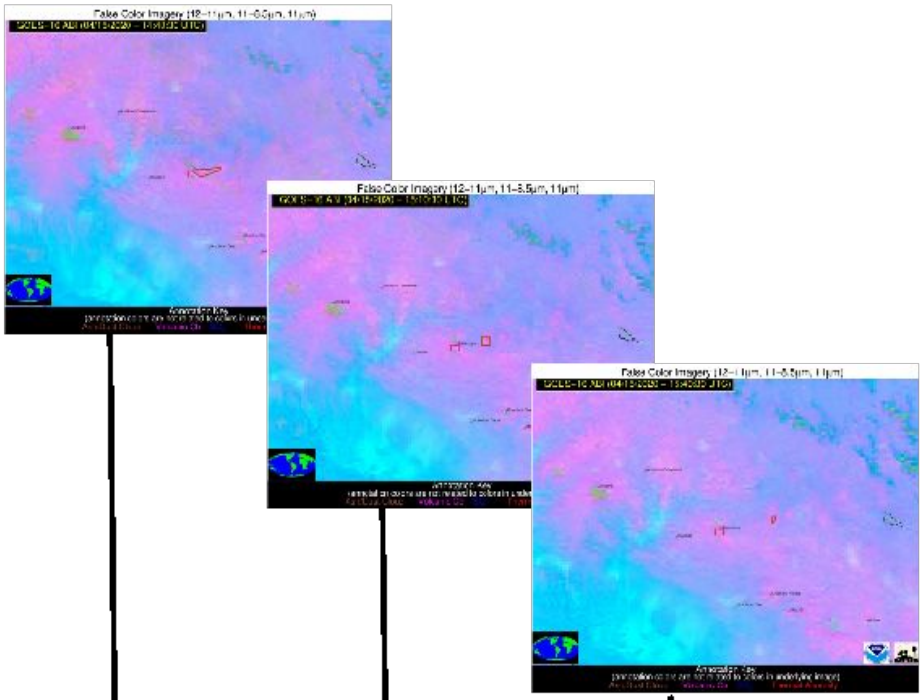
VOLCAT Alerting



Initial HYSPLIT Trajectory and Dispersion Forecasts



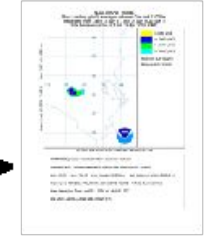
Automated VOLCAT Feature Tracking



Notification of availability of limited domain netCDF file for each unique instance of volcanic cloud feature (users download instances of choice)

Refined HYSPLIT Forecasts

HYSPLIT data insertion, inverse modeling, and verification tools



OAR/ARL Science Team: Alice Crawford, Allison Ring, and Barbara Stunder



FVXX20 KNES 142333
VA ADVISORY
DTG: 20200514/2333Z

Volcanic ash advisory

VAAC: WASHINGTON

VOLCANO: SANGAY 352090
PSN: S0200 W07820

AREA: ECUADOR

SUMMIT ELEV: 17159 FT (5230 M)

ADVISORY NR: 2020/486

INFO SOURCE: GOES-EAST. NWP MODELS. **VOLCAT.**

ERUPTION DETAILS: CONT LGT VA EMS

OBS VA DTG: 14/2300Z

OBS VA CLD: SFC/FL210 S0159 W07820 - S0213 W07838
- S0202 W07844 - S0159 W07820 MOV SW 10-15KT

FCST VA CLD +6HR: 15/0500Z SFC/FL210 S0159 W07820
- S0213 W07838 - S0202 W07844 - S0159 W07820

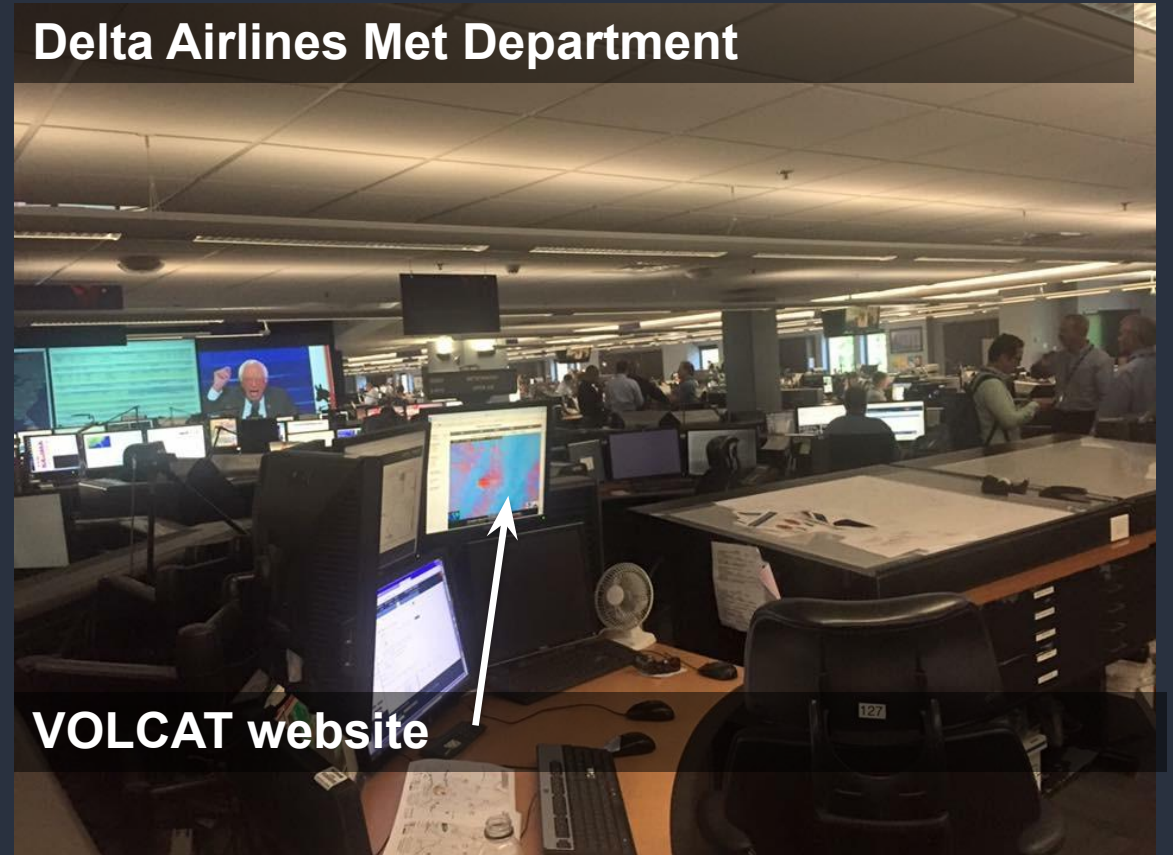
FCST VA CLD +12HR: 15/1100Z NO ASH EXP

FCST VA CLD +18HR: 15/1700Z NO ASH EXP

RMK: CONT LGT VA EMS OBS MOV SW FM SUMMIT IN STL
IMAGERY. VA FCST TO CONT SW MOV THRU T+6HRS

SNPP imagery and products (including from VOLCAT) have positively impacted operational decision-making at VAACs and other operational centers. Greater impact from JPSS is achievable.

Delta Airlines Met Department

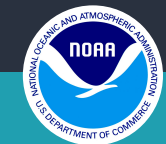


VOLCAT website





Backup Slides



VOLCAT Related Papers

- 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.
- Pavolonis, M. J., 2010: Advances in Extracting Cloud Composition Information from Spaceborne Infrared Radiances–A Robust Alternative to Brightness Temperatures. Part I: Theory. *Journal of Applied Meteorology and Climatology*, **49**, 1992–2012, doi:10.1175/2010JAMC2433.1 ER.
- 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.
- Pavolonis, M., J. Sieglaff, and J. Cintineo (2015a), Spectrally Enhanced Cloud Objects (SECO): A Generalized Framework for Automated Detection of Volcanic Ash and Dust Clouds using Passive Satellite Measurements, Part I: Multispectral Analysis, *Journal Geophysical Research*, **120**, 7813–7841.
- 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.
- Crawford, A. M., B. J. B. Stunder, F. Ngan, and M. J. Pavolonis (2016), Initializing HYSPLIT with satellite observations of volcanic ash: A case study of the 2008 Kasatochi eruption, *Journal of Geophysical Research–Atmospheres*, **121(18)**, 10786–10803, doi:10.1002/2016jd024779.
- Chai, T.F., Crawford, A., Stunder, B., Pavolonis, M.J., Draxler, R. and Stein, A., 2017. Improving volcanic ash predictions with the HYSPLIT dispersion model by assimilating MODIS satellite retrievals. *Atmospheric Chemistry and Physics*, **17(4)**: 2865–2879.
- Pavolonis, M.J., J. Cintineo, and J. Sieglaff, 2018: Automated Detection of Explosive Volcanic Eruptions Using Satellite–derived Cloud Vertical Growth Rates, *Journal Geophysical Research*, **5(2)**, 903–928.
- Poland, M., Lopez, T., Wright, R., and Pavolonis, M., 2020: Detecting, monitoring, and forecasting volcanic eruptions from space, *Remote Sensing in Earth Systems Science*, **3**, 55–94.
- Pavolonis, M.J., Sieglaff, J., and Cintineo, J.L., Chapter 10 – Remote Sensing of Volcanic Ash with the GOES–R Series, Editor(s): Steven J. Goodman, Timothy J. Schmit, Jaime Daniels, Robert J. Redmon, *The GOES–R Series*, Elsevier, 2020, Pages 103–124.

Hyman, D., Pavolonis, M.J., 2020: Probabilistic retrieval of volcanic SO₂ layer height and cumulative mass loading using the Cross-track Infrared Sounder (CrIS), *Atmospheric Measurement Techniques*, **13(11)**, 5891–5921.

NOAA National Environmental Satellite, Data, and Information Service
Hyman, D., Pavolonis, M.J., Sieglaff, J.M., 2021: A novel approach to estimating time-averaged volcanic SO₂ fluxes from infrared satellite measurements using computer vision and



Initial Z-score // 1x WHO Exceedance Prob Contours: L~Unif(0.1,1.0): 20190621T2354-20190622T1018

95°E 100°E 105°E 110°E 115°E 120°E 125°E 130°E 135°E 140°E 145°E 150°E 155°E 160°E 165°E 170°E 175°E 180° 175°W 170°W 165°W 160°W 155°W 95°W

