



The GOES-R Fog/Low Stratus Products

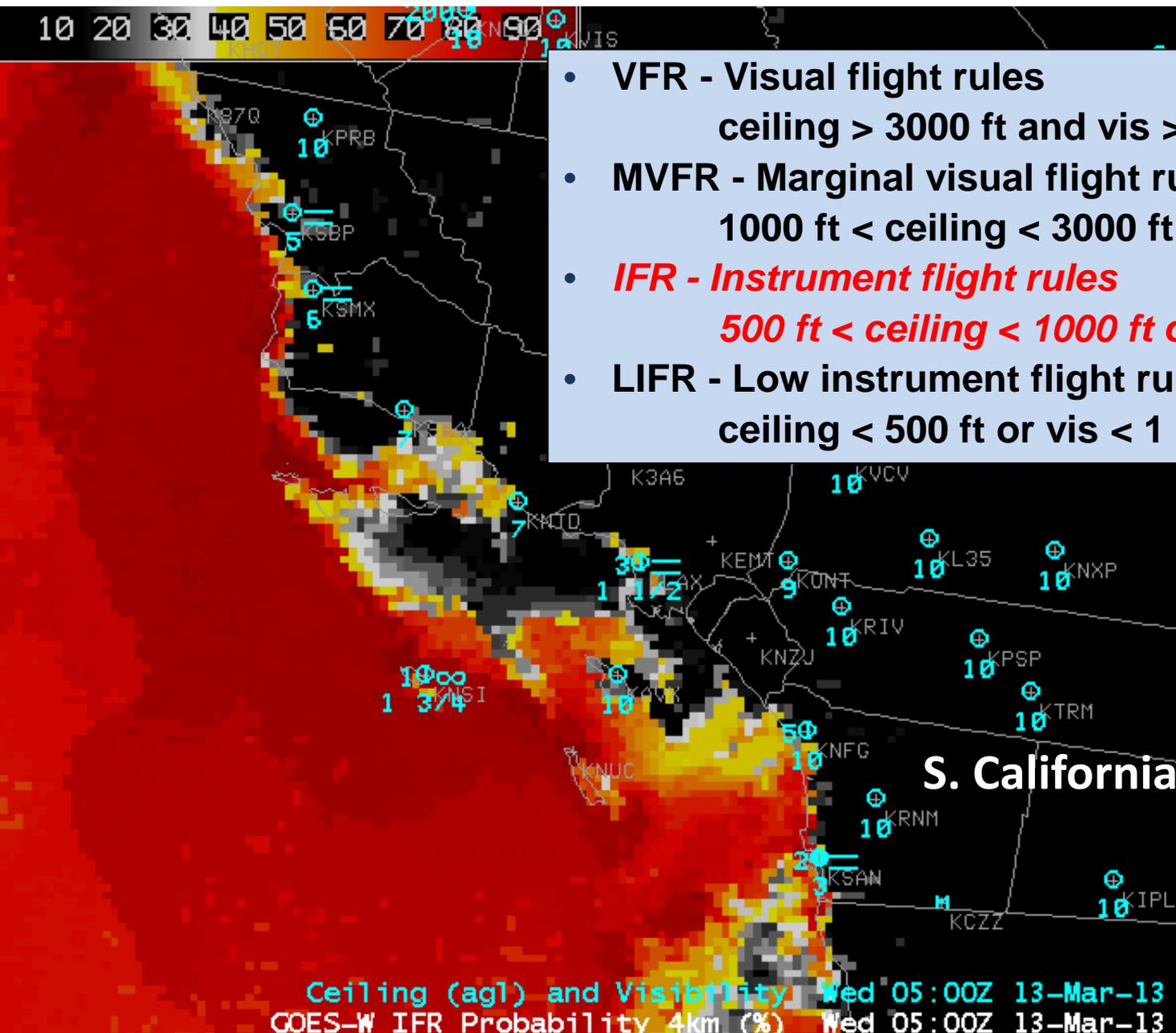
Mike Pavolonis
(NOAA/NESDIS)

Corey Calvert
(UW-CIMSS)

Chad Gravelle and Scott Lindstrom
(UW-CIMSS)



Probability of IFR

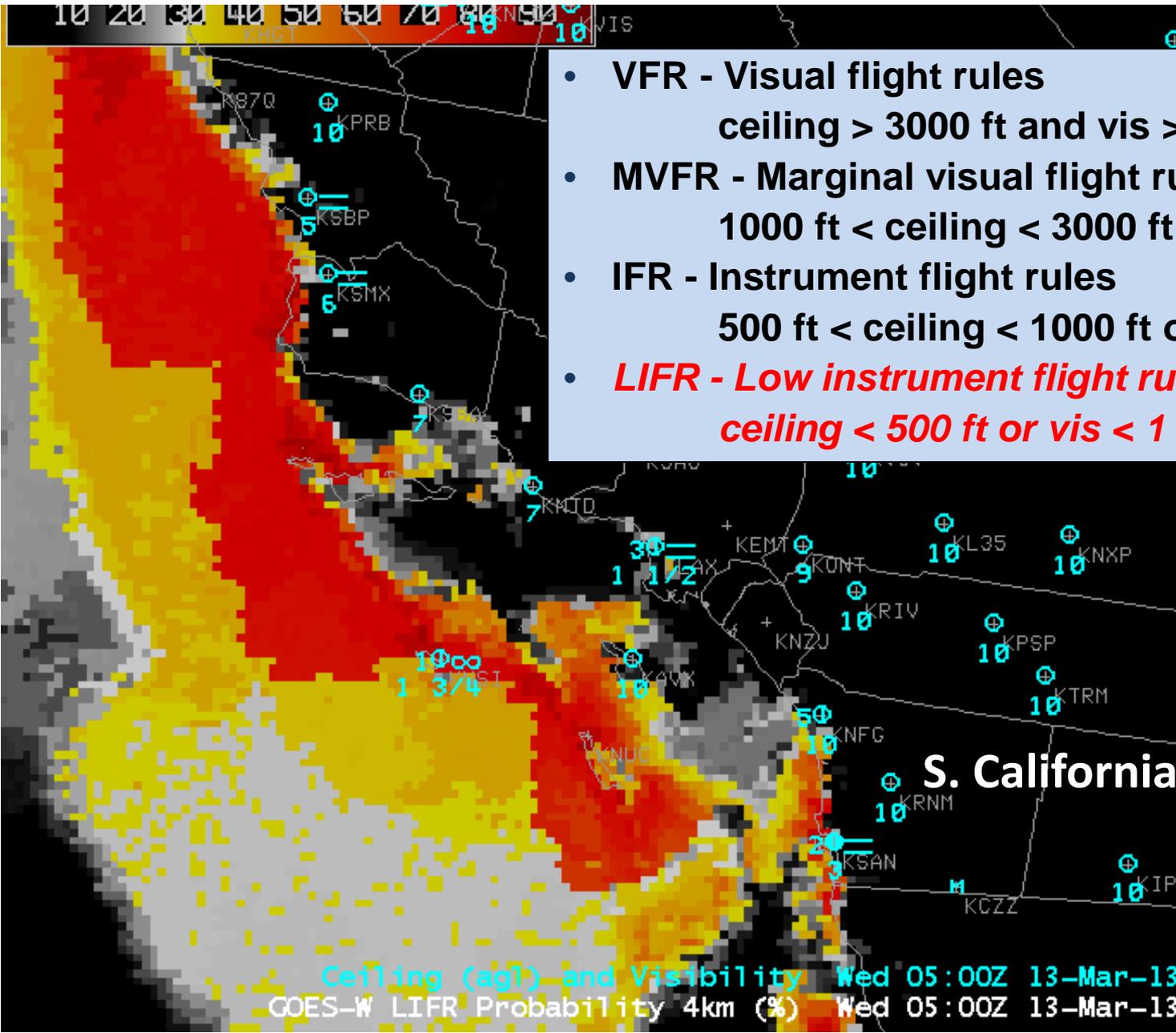


- **VFR - Visual flight rules**
ceiling > 3000 ft and vis > 5 mi
- **MVFR - Marginal visual flight rules**
1000 ft < ceiling < 3000 ft or 3 mi < vis < 5 mi
- ***IFR - Instrument flight rules***
500 ft < ceiling < 1000 ft or 1 mi < vis < 3 mi
- **LIFR - Low instrument flight rules**
ceiling < 500 ft or vis < 1 mi

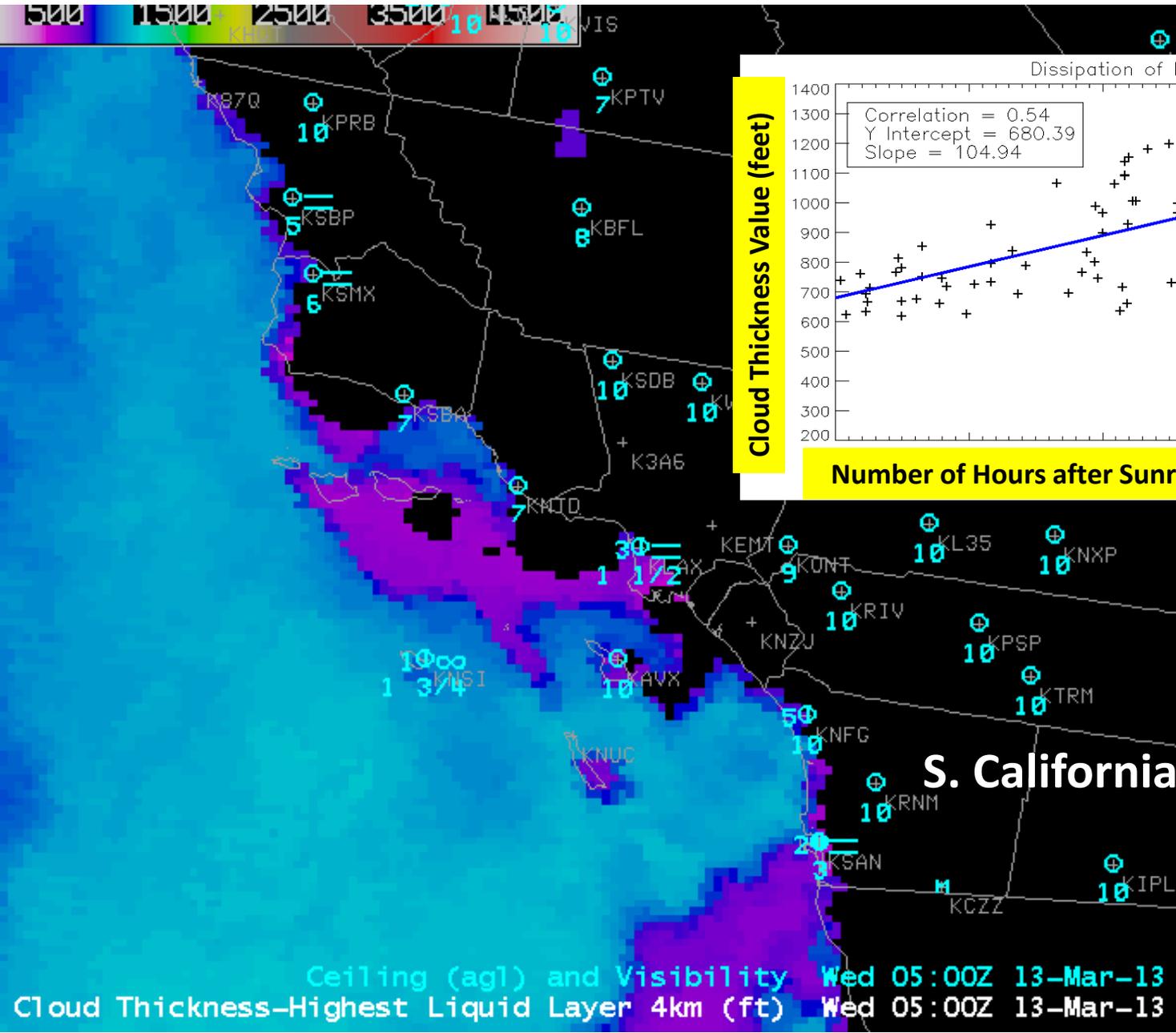
S. California

Probability of LIFR

- VFR - Visual flight rules
ceiling > 3000 ft and vis > 5 mi
- MVFR - Marginal visual flight rules
1000 ft < ceiling < 3000 ft or 3 mi < vis < 5 mi
- IFR - Instrument flight rules
500 ft < ceiling < 1000 ft or 1 mi < vis < 3 mi
- **LIFR - Low instrument flight rules**
ceiling < 500 ft or vis < 1 mi



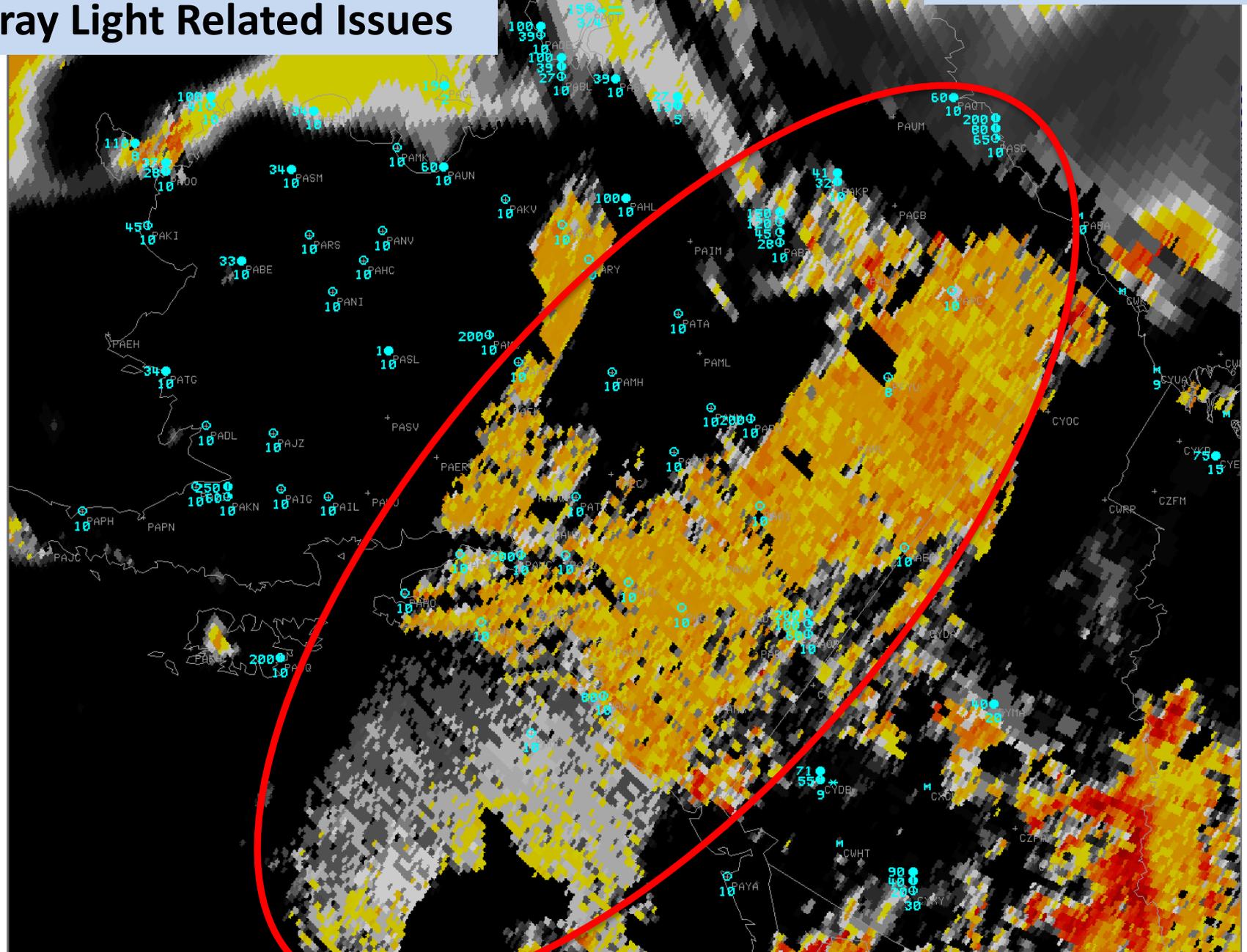
FLS Thickness



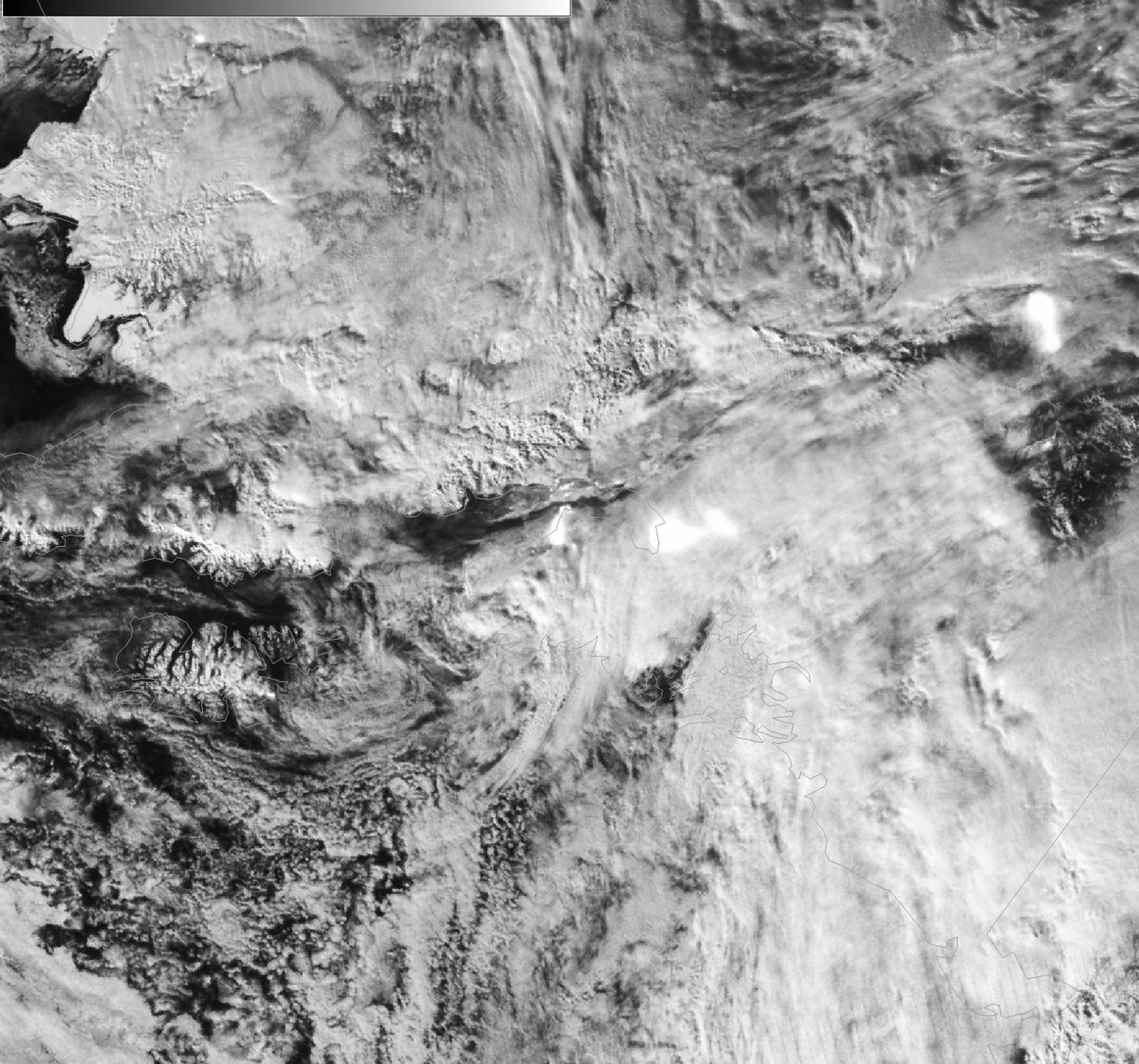


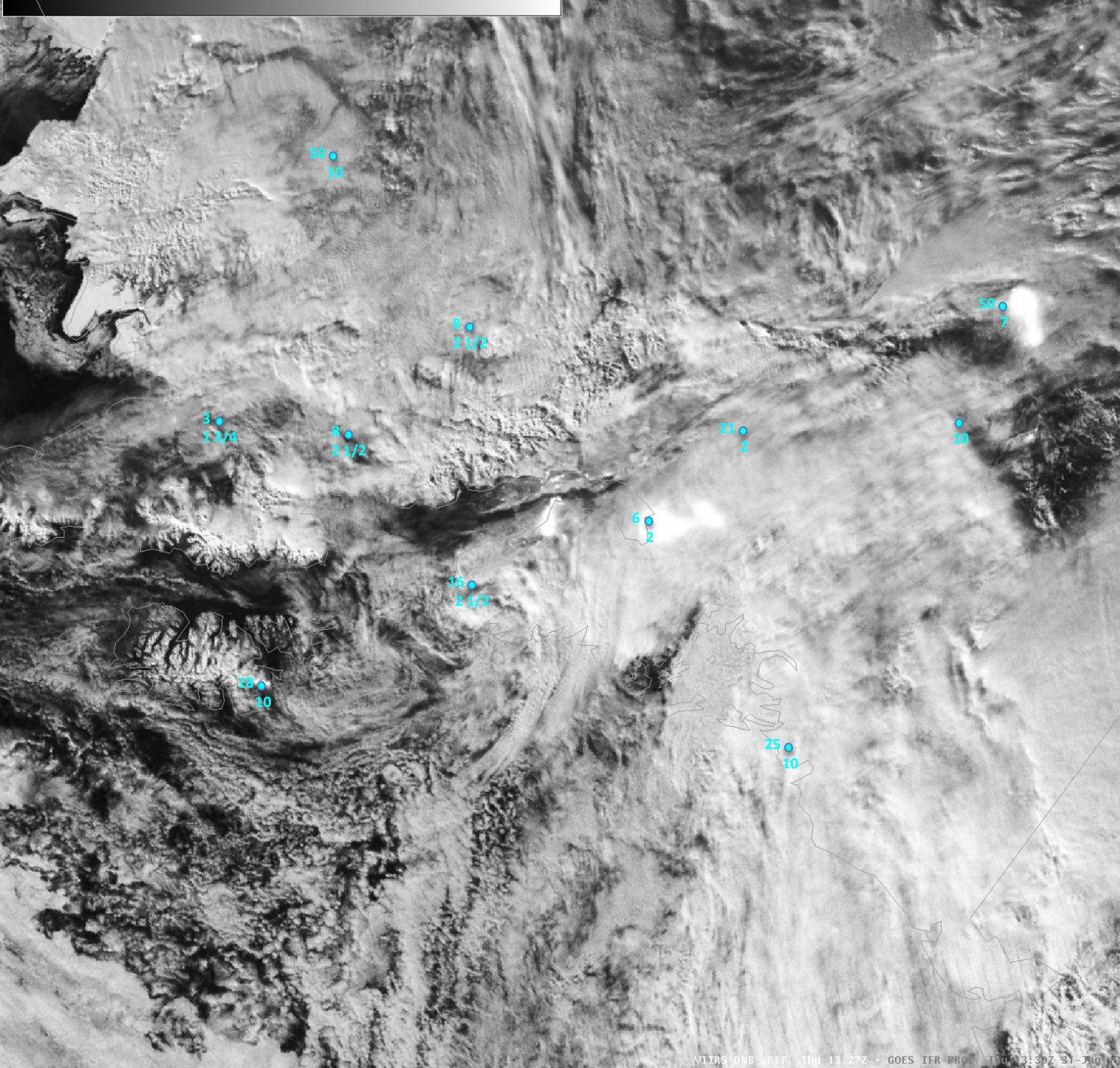
May 20, 2013 09:00 UTC

Stray Light Related Issues



Ceiling (630) and Visibility Mon 09:00Z 20-May-13
GOES-W AK IFR Probability 4km (%) Mon 09:00Z 20-May-13







Summary



- **The CWSU has found that the GOES-W version of the GOES-R FLS products are often very useful for aviation weather applications despite the poor spatial resolution**
- **We are continuing to look into what we think may be a stray light issue with the GOES-W version of the products**
- **The VIIRS version of the products will be available by the end of (lower 48) summer**
- **AK Region would benefit from a combined AVHRR + MODIS + VIIRS product stream within AWIPS (no separate product menu for each sensor)**



Marco Fulle - www.stromboli.net

The NOAA/NESDIS/STAR/CIMSS Volcanic Cloud Products

Michael Pavolonis

NOAA/NESDIS/STAR

Justin Sieglaff and John Cintineo

UW-CIMSS





Outline



- **Overview of products and product generation system**
- **Performance of near real-time system during recent AK events (Cleveland, Pavlof, etc...)**
- **Future evolution of system, next steps, collaborations**



Goal and Motivation



Marco Fulle - www.stromboli.net

- ***Using the full capabilities of the space-based observing system (and other relevant data), an automated globally applicable system that can detect and characterize nearly all types of volcanic clouds was developed***
- **Expected Operational Impacts:**
 - Increase the timeliness and quality (improved height assignment and better horizontal depiction of cloud) 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!)

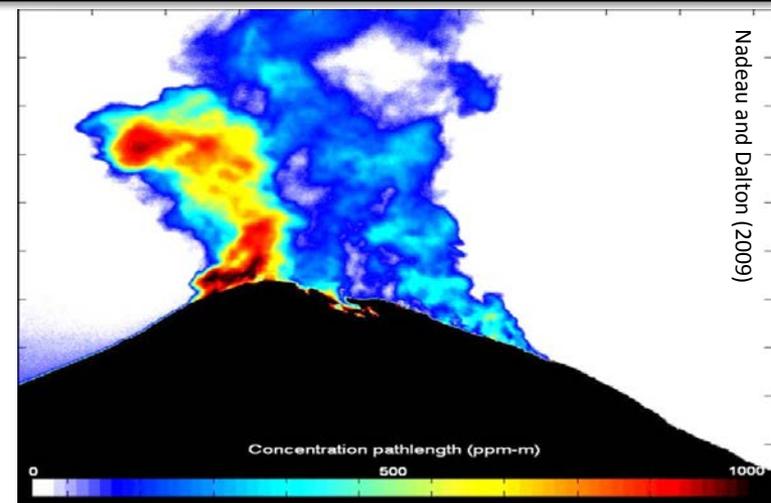
1). Ash dominated volcanic plumes – Semi-transparent clouds dominated by volcanic ash. Lightning is usually not present in these clouds.



2). Ice topped umbrella clouds – These clouds are mostly observed during a major eruption. A spectral based volcanic ash signal is usually initially absent because the ash is encased in ice and/or the cloud is opaque. Lightning is often present in these clouds.



3). SO₂ clouds – Sulfur dioxide clouds (SO₂ gas is invisible to the eye) that may or may not contain volcanic ash. Some eruptions produce large amounts of SO₂ and very little ash and vice-versa.



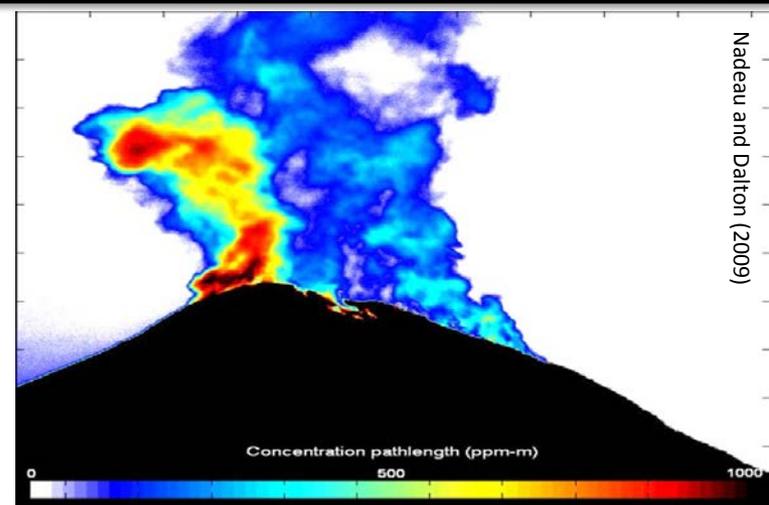
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Quantitative Products

Product	Current and Planned Distribution
Ash Probability	McIDAS**, N-AWIPS**, AWIPS-II**, and Web*
Ash Cloud Top Height	McIDAS**, N-AWIPS**, AWIPS-II**, and Web*
Ash Particle Effective Radius	McIDAS**, N-AWIPS**, AWIPS-II**, and Web*
Ash Mass Loading	McIDAS**, N-AWIPS**, AWIPS-II**, and Web*
Volcanic Ash Alerts	Email*, SMS*, and Web*
Volcanic Convection Alerts	Email*, SMS*, and Web*
Volcanic Thermal Anomaly Alerts	Email*, SMS*, and Web*

Supporting Qualitative Products

Product	Current and Planned Distribution
Split-window Imagery (excluding current GOES)	Web*
Various Multi-spectral False Color Imagery	Web*

*Current

**Planned

Quantitative Products

Product	Current and Planned Distribution
Ash Probability	McIDAS**, N-AWIPS**, AWIPS-II**, and Web*
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***Current**

****Planned**

A sophisticated set of computer algorithms utilizes the spectral, spatial, and temporal information offered by various satellites to automatically detect volcanic clouds and estimate important volcanic cloud properties (height, effective radius, and mass loading)

Channels used in volcanic cloud detection component of algorithm

Sensor	Channels used
AVHRR	0.65, 3.75, 11, and 12 μm
COMS	0.65, 3.9, 11, and 12 μm
FY2	0.65, 3.9, 11, and 12 μm
GOES	0.65, 3.9, 6.7, 11, and 13.3 μm
GOES-R ABI*	0.65, 3.9, 7.3, 8.5, 11, and 12 μm
Himawari-8/9*	0.65, 3.9, 7.3, 8.5, 11, and 12 μm
MODIS	0.65, 3.75, 7.3, 8.5, 11, and 12 μm
MTSAT	0.65, 3.9, 11, and 12 μm
SEVIRI	0.65, 3.9, 7.3, 8.5, 11, and 12 μm
VIIRS	0.65, 3.75, 8.5, 11, and 12 μm

*Future sensor

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Channels used cloud property determination portion of algorithm

Sensor	Channels used
AVHRR	11 and 12 μm
COMS	11 and 12 μm
FY2	11 and 12 μm
GOES	11 and 13.3 μm
GOES-R ABI*	11, 12, and 13.3 μm
Himawari-8/9*	11, 12, and 13.3 μm
MODIS	11, 12, and 13.3 μm
MTSAT	11 and 12 μm
SEVIRI	11, 12, and 13.3 μm
VIIRS	11 and 12 μm

*Future sensor

Our near real-time system running at UW-CIMSS has global coverage

Sensor	Daily L1 Data Volume
N15, N16, N18, N19, and MetOp-B AVHRR HRPT*	~3 GB
GOES-13/14	~14 GB
GOES-15	~14 GB
MODIS-DB (AK)	~7 GB
MODIS NASA NRT	~30 GB
MTSAT-2	~4 GB
Met-10 SEVIRI	~28 GB
VIIRS-DB (AK)*	~5 GB
Total	~105 GB

**Will be added to real-time processing stream shortly*

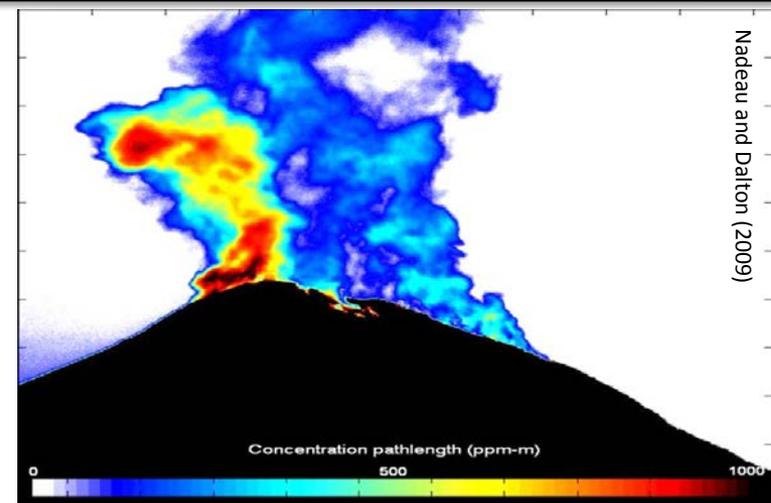
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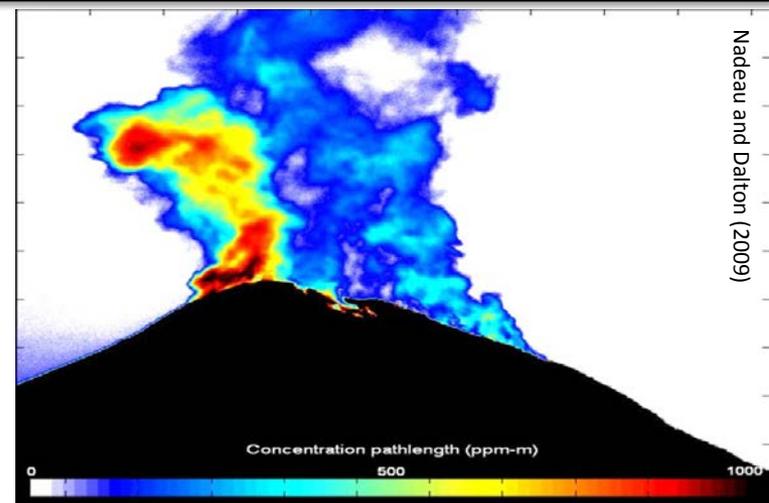
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From: Mike Pavolonis <mpav@ssec.wisc.edu>
Subject: NOAA/CIMSS Volcanic Cloud Alert
Date: May 16, 2013 12:20:24 PM CDT
To: Mike Pavolonis <mpav@ssec.wisc.edu>

When an ash cloud near a volcano is detected with confidence, an email alert is generated

The alert criteria are highly configurable such that the user can define which volcanoes can trigger any combination of ash, volcanic convection, and thermal anomaly alerts and which satellite sensors provide the alerts (and how often in the case of a long lived cloud)

@*****VOLCANIC ALERTS*****

STARTING DATE/TIME OF IMAGE: 2013-05-16 13:49:59 [UTC]
PRIMARY INSTRUMENT: Aqua MODIS
WMO SPACECRAFT ID: 784
LOCATION/ORBIT: LEO
L1 FILE: MYD021KM.A2013136.1350.005.2013136160251.NRT.hdf
VOLCANO DATABASE: /data/common/VOLCAT_DATA/alerts/Volcat_Alert_Vol
NUMBER OF ASH CLOUD ALERTS: 1
NUMBER OF VOLCANIC Cb ALERTS: 0
NUMBER OF VOLCANIC THERMAL ANOMALY ALERTS: 0
NUMBER OF SO2 CLOUD ALERTS: 0

REPORT WITH IMAGES:

<http://volcano.ssec.wisc.edu/alert/report/3017>

POSSIBLE VOLCANIC ASH CLOUD FOUND

Alert Status: Newly detected feature

Latitude of Radiative Center: 55.367 [degrees]

Longitude of Radiative Center: -161.736 [degrees]

Mean Viewing Angle: 46.50 [degrees]

Mean Solar Zenith Angle: 95.30 [degrees]

Nearby Volcanoes (meeting alert criteria):

 Pavlof(11.07 km) [Thermal Anomaly Present]

 Pavlof Sister(11.73 km) [Thermal Anomaly Present]

 Emmons Lake(21.86 km)

 Dutton(40.52 km)

 Dana(44.93 km)

Cloud Object Probability: 99.99996 [%]

Median Probability of Object Pixels: 98.71912 [%]

Percent Unambiguous Pixels: 16.15809 [%]

Maximum Height [AMSL]: 5.8 [km] (19175.99 [ft])

90th Percentile Height [AMSL]: 4.6 [km] (15037.92 [ft])

Mean Tropopause Height [AMSL]: 8.8 [km] (29026.27 [ft])

Total Mass: .001010 [Tg]

Median Effective Particle Radius: 4.53 [um]

Total Area: 606.44 [km^2]

Geographic Regions of Nearby Volcanoes: Alaska Peninsula

VAAC Regions of Nearby Volcanoes: Anchorage

FIR Regions of Nearby Volcanoes: Unknown

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**Header block of alert
-Information about the
satellite imagery that
resulted in the alert
being generated**

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Main alert body

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Lat and lon where the detected ash cloud is most dense (most optically thick)

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Satellite viewing angle and solar zenith angle (> 90.0° indicates darkness)

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Listing of nearby volcanoes
along with distance from
volcano to the radiative
center of the ash cloud

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These fields, which are used by the automated alert system to determine which clouds are truly volcanic ash, provide information on detection confidence

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The estimated maximum height of the ash cloud, the 90th percentile value of ash cloud height, and the height of the tropopause taken from an NWP model (usually the GFS) are provided here.

The smaller the difference between the maximum ash cloud height and the 90th percentile value, the greater the confidence in the maximum height estimate

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Estimates of additional properties of the detected ash cloud

Total mass of ash (terra-grams), the median value of effective particle radius, and the total horizontal area of the ash cloud

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90th Percentile Height [AMSL]: 4.6 [km] (15037.92 [ft])

Mean Tropopause Height [AMSL]: 8.8 [km] (29026.27 [ft])

Total Mass: .001010 [Tg]

Median Effective Particle Radius: 4.53 [um]

Total Area: 606.44 [km^2]

Geographic Regions of Nearby Volcanoes: Alaska Peninsula

VAAC Regions of Nearby Volcanoes: Anchorage

FIR Regions of Nearby Volcanoes: Unknown

Additional geographic information

-We are still trying to obtain shape files with FIR boundaries (this field is set to unknown for now)

From: Mike Pavolonis <mpav@ssec.wisc.edu>
Subject: NOAA/CIMSS Volcanic Cloud Alert
Date: May 16, 2013 12:20:24 PM CDT
To: Mike Pavolonis <mpav@ssec.wisc.edu>

@*****VOLCANIC ALERTS*****

STARTING DATE/TIME OF IMAGE: 2013-05-16 13:49:59 [UTC]

PRIMARY INSTRUMENT: Aqua MODIS

WMO SPACECRAFT ID: 784

LOCATION/ORBIT: LEO

L1 FILE: MYD021KM.A2013136.1350.005.2013136160251.NRT.hdf

VOLCANO DATABASE: /data/common/VOLCAT_DATA/alerts/Volcat_Alert_Volcano_Database_May14_2013_164631.txt

NUMBER OF ASH CLOUD ALERTS: 1

NUMBER OF VOLCANIC Cb ALERTS: 0

NUMBER OF VOLCANIC THERMAL ANOMALY ALERTS: 0

NUMBER OF SO2 CLOUD ALERTS: 0

REPORT WITH IMAGES:

<http://volcano.ssec.wisc.edu/alert/report/3017>

**Alert specific URL to web version of alert
and associated alert imagery**

POSSIBLE VOLCANIC ASH CLOUD FOUND

Alert Status: Newly detected feature

Latitude of Radiative Center: 55.367 [degrees]

Longitude of Radiative Center: -161.736 [degrees]

Mean Viewing Angle: 46.50 [degrees]

Mean Solar Zenith Angle: 95.30 [degrees]

Nearby Volcanoes (meeting alert criteria):

Pavlof(11.07 km) [Thermal Anomaly Present]

Pavlof Sister(11.73 km) [Thermal Anomaly Present]

Emmons Lake(21.86 km)

Dutton(40.52 km)

Dana(44.93 km)

Cloud Object Probability: 99.99996 [%]

Median Probability of Object Pixels: 98.71912 [%]

Percent Unambiguous Pixels: 16.15809 [%]

Maximum Height [AMSL]: 5.8 [km] (19175.99 [ft])

90th Percentile Height [AMSL]: 4.6 [km] (15037.92 [ft])

Mean Tropopause Height [AMSL]: 8.8 [km] (29026.27 [ft])

Total Mass: .001010 [Tg]

Median Effective Particle Radius: 4.53 [um]

Total Area: 606.44 [km^2]

Geographic Regions of Nearby Volcanoes: Alaska Peninsula

VAAC Regions of Nearby Volcanoes: Anchorage

FIR Regions of Nearby Volcanoes: Unknown

Volcanic Cloud Monitoring — NOAA/CIMSS



- [Home](#)
- [Sector Imagery](#)
- [Alerts](#)
- [Admin](#)
- [Logout \(mpav@ssec.wisc.edu\)](#)

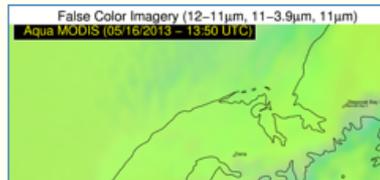
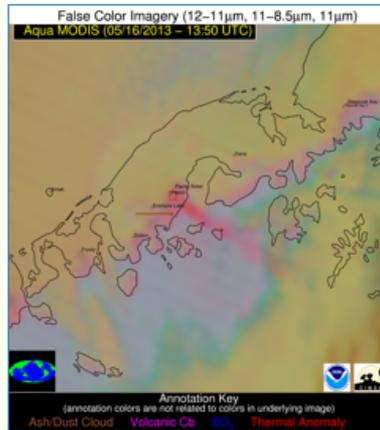
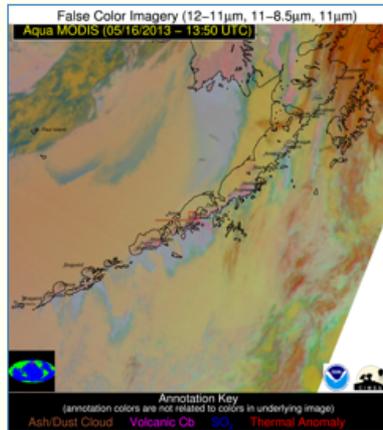
Volcanic Cloud Alert Report

Date:	2013-05-16
Time:	13:49:59
Primary Instrument:	Aqua MODIS

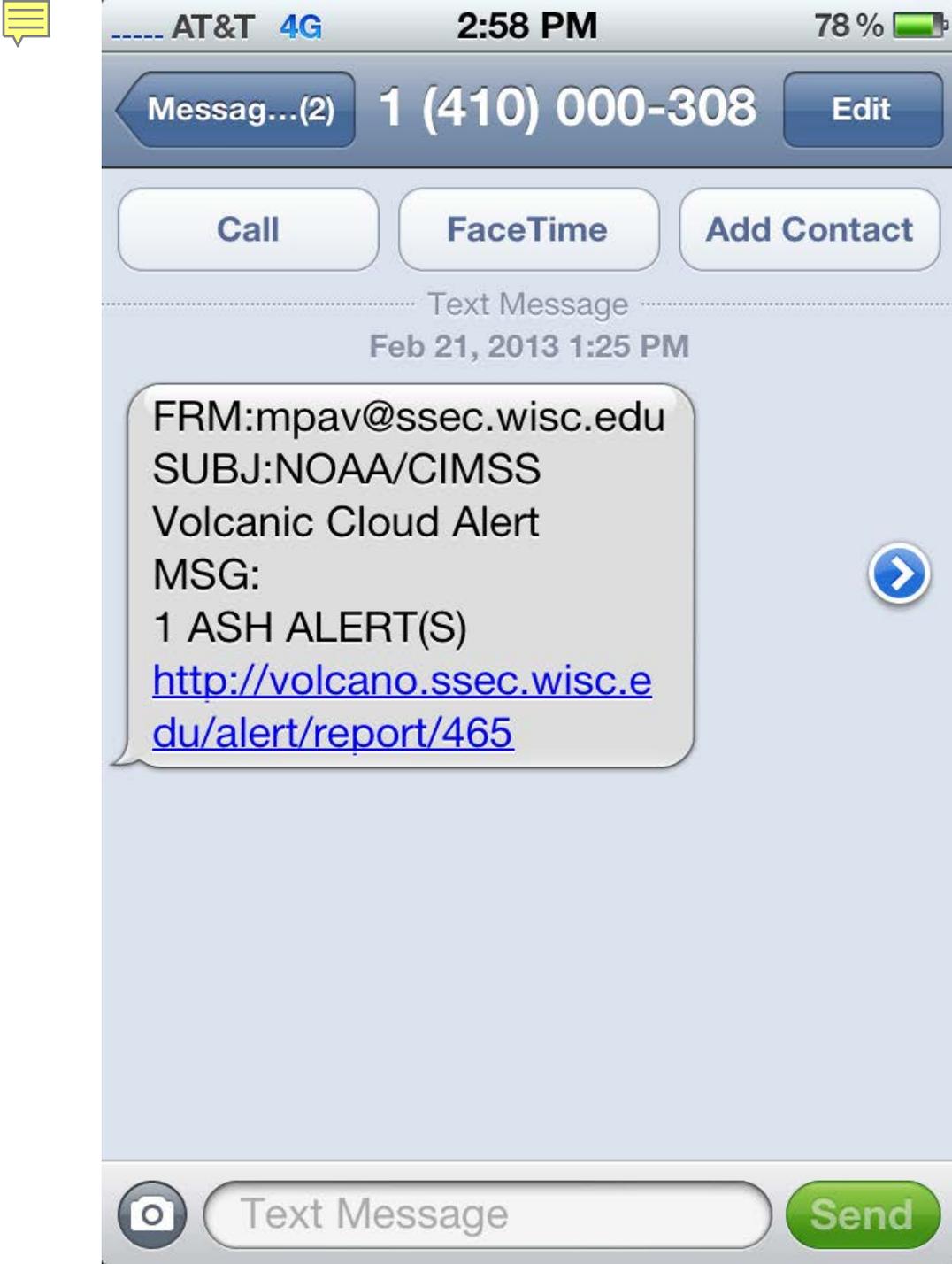
[More details ▼](#)

Possible Volcanic Ash Cloud

[View event imagery »](#)



Alert Status	Newly detected feature
Radiative Center (Lat, Lon):	55.367 °, -161.736 °
Mean Viewing Angle	46.50 °
Mean Solar Zenith Angle	95.30 °
Nearby Volcanoes (meeting alert criteria):	Dutton (40.52 km) Pavlof (11.07 km) [Thermal Anomaly Present] Pavlof Sister (11.73 km) [Thermal Anomaly Present] Emmons Lake (21.86 km) Dana (44.93 km)
Cloud Object Probability	99.99996 %
Median Probability Of Object Pixels	98.71912 %
Percent Unambiguous Pixels	16.16000 %
Maximum Height [amsl]	5.80 km
90th Percentile Height [amsl]	4.60 km
Mean Tropopause Height [amsl]	8.80 km



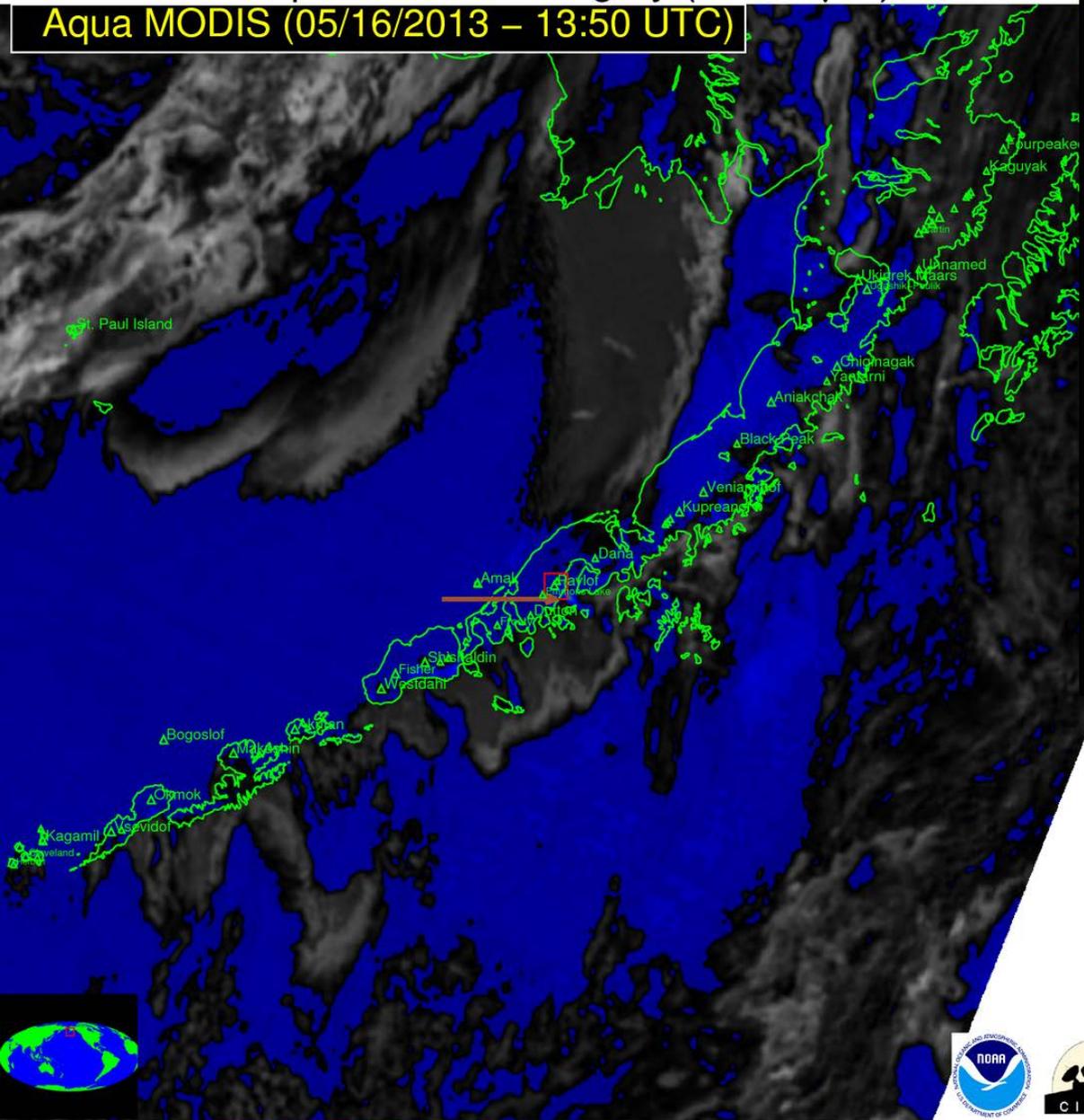
SMS message alerts are also available

The alert subscription options are very flexible and the system tracks detected clouds in time (regardless of which satellite detected them) so that multiple alerts are not issued for the same cloud (unless the user wants it)

The alerting system can also optionally be used to alert users when a LEO overpass with an ash cloud occurs

Split-Window Imagery (11–12 μm)

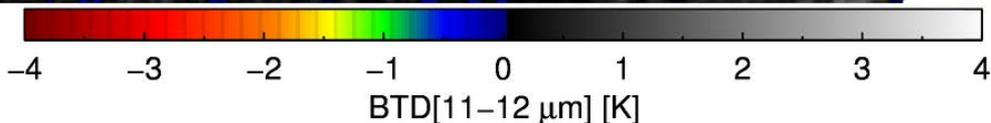
Aqua MODIS (05/16/2013 – 13:50 UTC)



“Split-window” imagery is available on the web site for all sensors except GOES-12, GOES-13, GOES-14, and GOES-15.

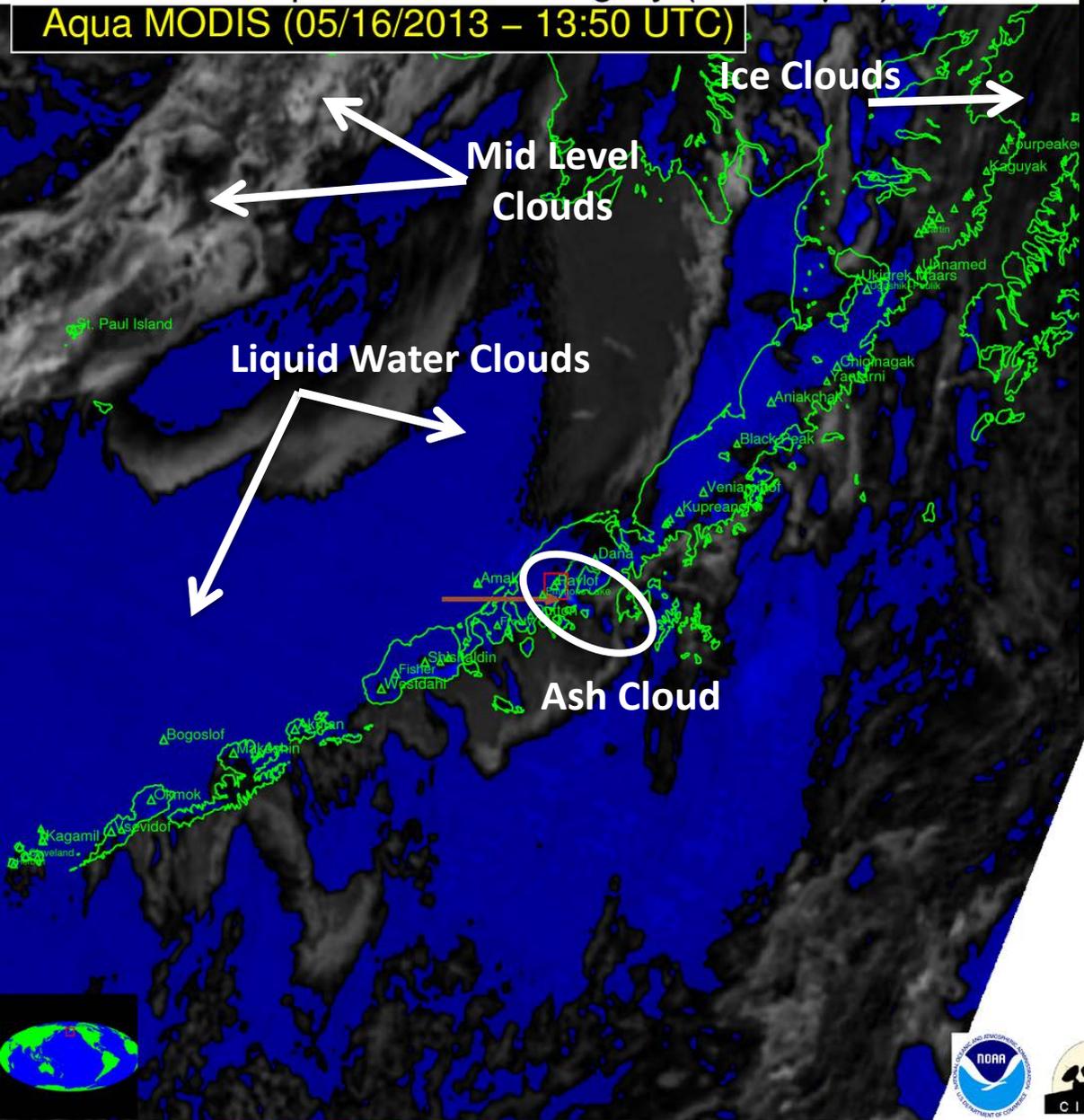
The “split-window” imagery is automatically annotated (with arrows or contours) to show where a volcanic cloud was detected by our automated algorithm.

Volcano locations are denoted on the imagery



Split-Window Imagery (11–12 μm)

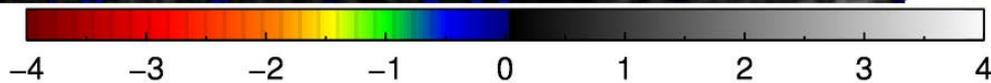
Aqua MODIS (05/16/2013 – 13:50 UTC)



“Split-window” imagery is available on the web site for all sensors except GOES-12, GOES-13, GOES-14, and GOES-15.

The “split-window” imagery is automatically annotated (with arrows or contours) to show where a volcanic cloud was detected by our automated algorithm.

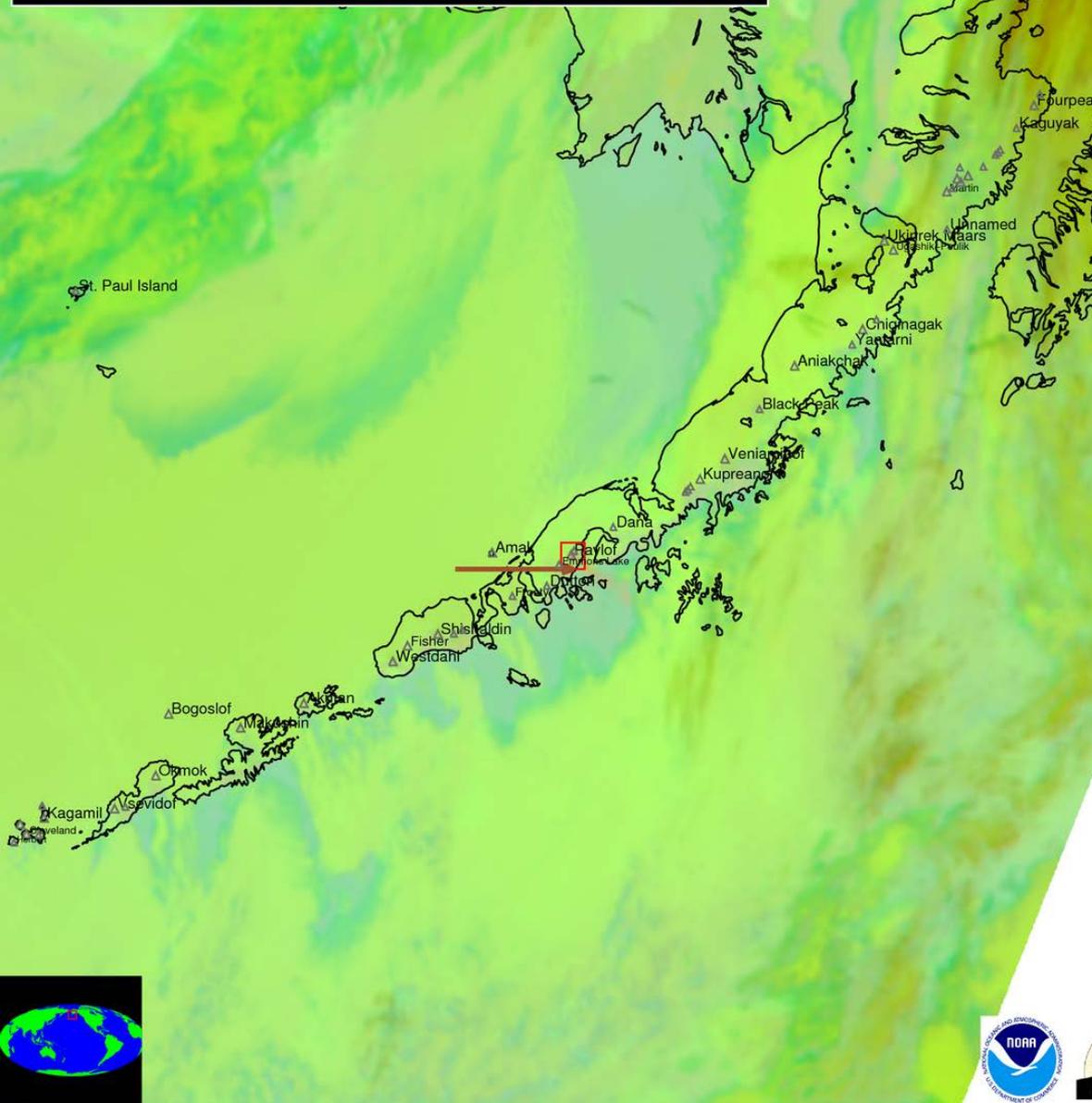
Volcano locations are denoted on the imagery



BTDR [11–12 μm] [K]

False Color Imagery (12–11 μ m, 11–3.9 μ m, 11 μ m)

Aqua MODIS (05/16/2013 – 13:50 UTC)



False color (RGB) imagery is also available on the web site. Please see:

http://www.eumetsat.int/Home/Main/DataProducts/Training/SP_2012105102052215?l=en

for detailed RGB training material.

The RGB imagery is automatically annotated (with arrows or contours) to show where a volcanic cloud was detected by our automated algorithm.

Volcano locations are denoted on the imagery

This channel combination is available on all sensors (13.3 μ m is substituted for 12 μ m on GOES)

Annotation Key

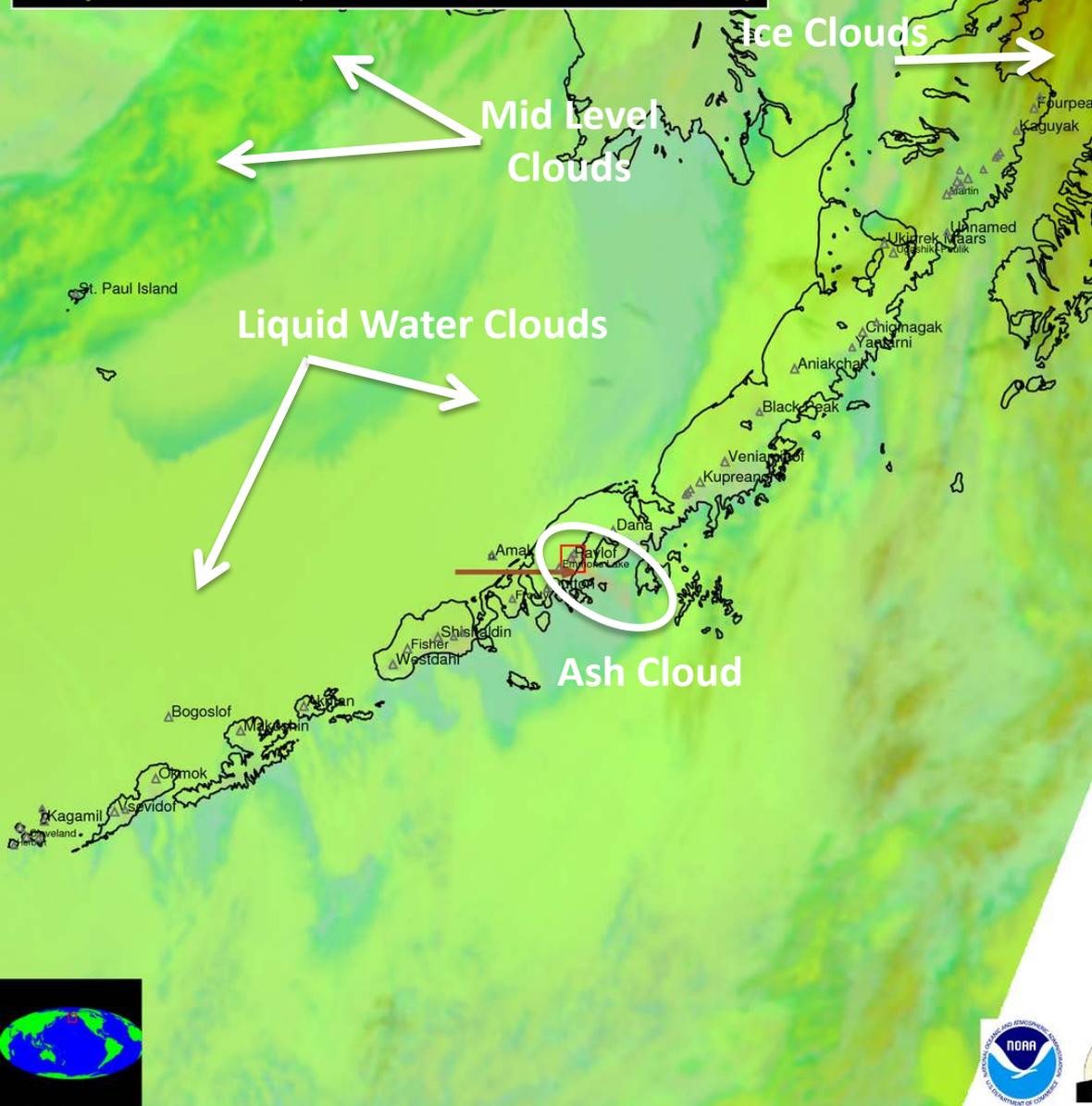
(annotation colors are not related to colors in underlying image)

Ash/Dust Cloud Volcanic Cb SO₂ Thermal Anomaly



False Color Imagery (12–11 μ m, 11–3.9 μ m, 11 μ m)

Aqua MODIS (05/16/2013 – 13:50 UTC)



False color (RGB) imagery is also available on the web site. Please see:

http://www.eumetsat.int/Home/Main/DataProducts/Training/SP_2012105102052215?l=en

for detailed RGB training material.

The RGB imagery is automatically annotated (with arrows or contours) to show where a volcanic cloud was detected by our automated algorithm.

Volcano locations are denoted on the imagery

This channel combination is available on all sensors (13.3 μ m is substituted for 12 μ m on GOES)

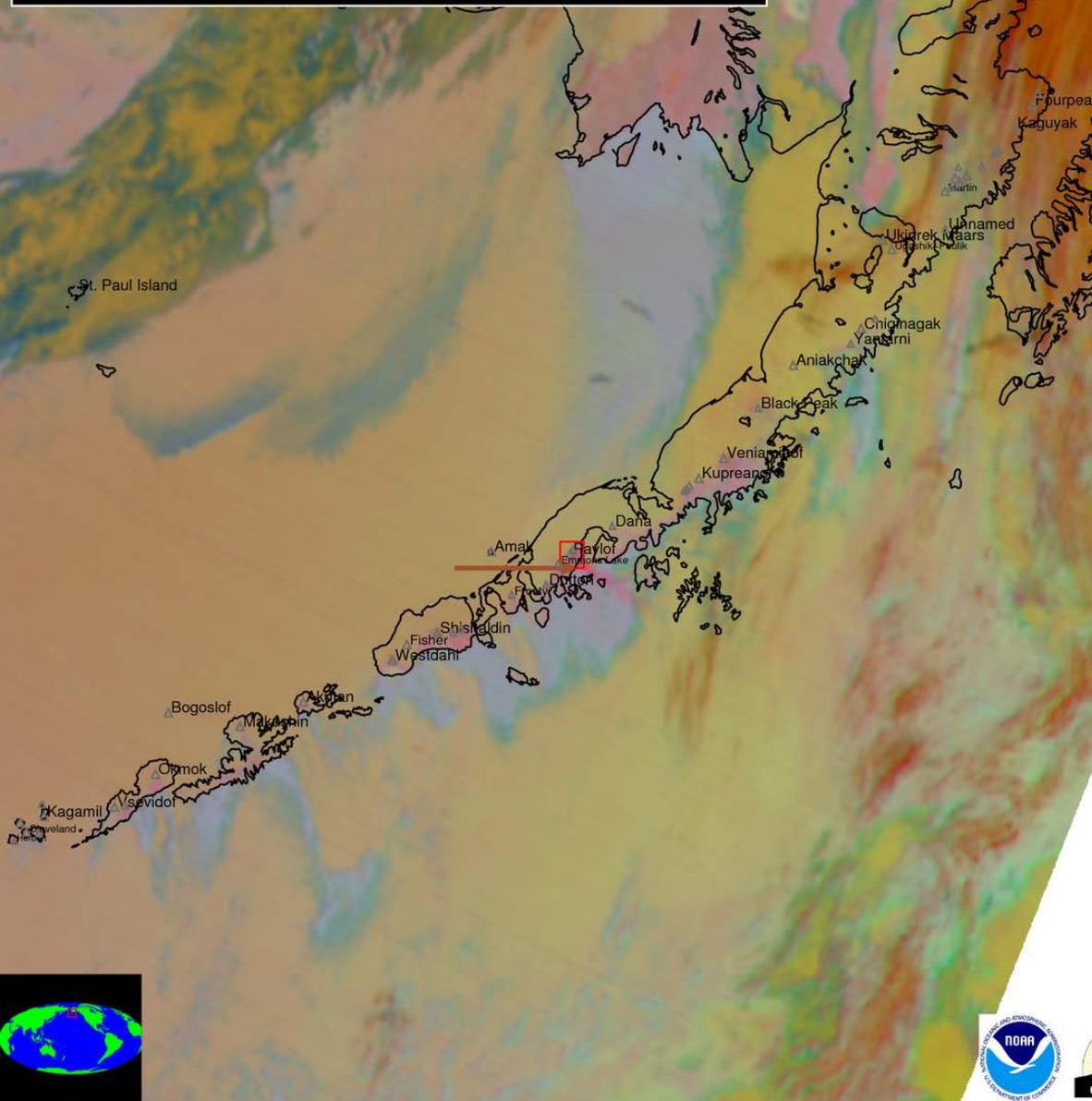
Annotation Key

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

Ash/Dust Cloud Volcanic Cb SO₂ Thermal Anomaly

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

Aqua MODIS (05/16/2013 – 13:50 UTC)



False color (RGB) imagery is also available on the web site. Please see:

http://www.eumetsat.int/Home/Main/DataProducts/Training/SP_2012105102052215?l=en

for detailed RGB training material.

The RGB imagery is automatically annotated (with arrows or contours) to show where a volcanic cloud was detected by our automated algorithm.

Volcano locations are denoted on the imagery

This channel combination is available on MODIS, SEVIRI, VIIRS, and the GOES-R ABI (future sensor)

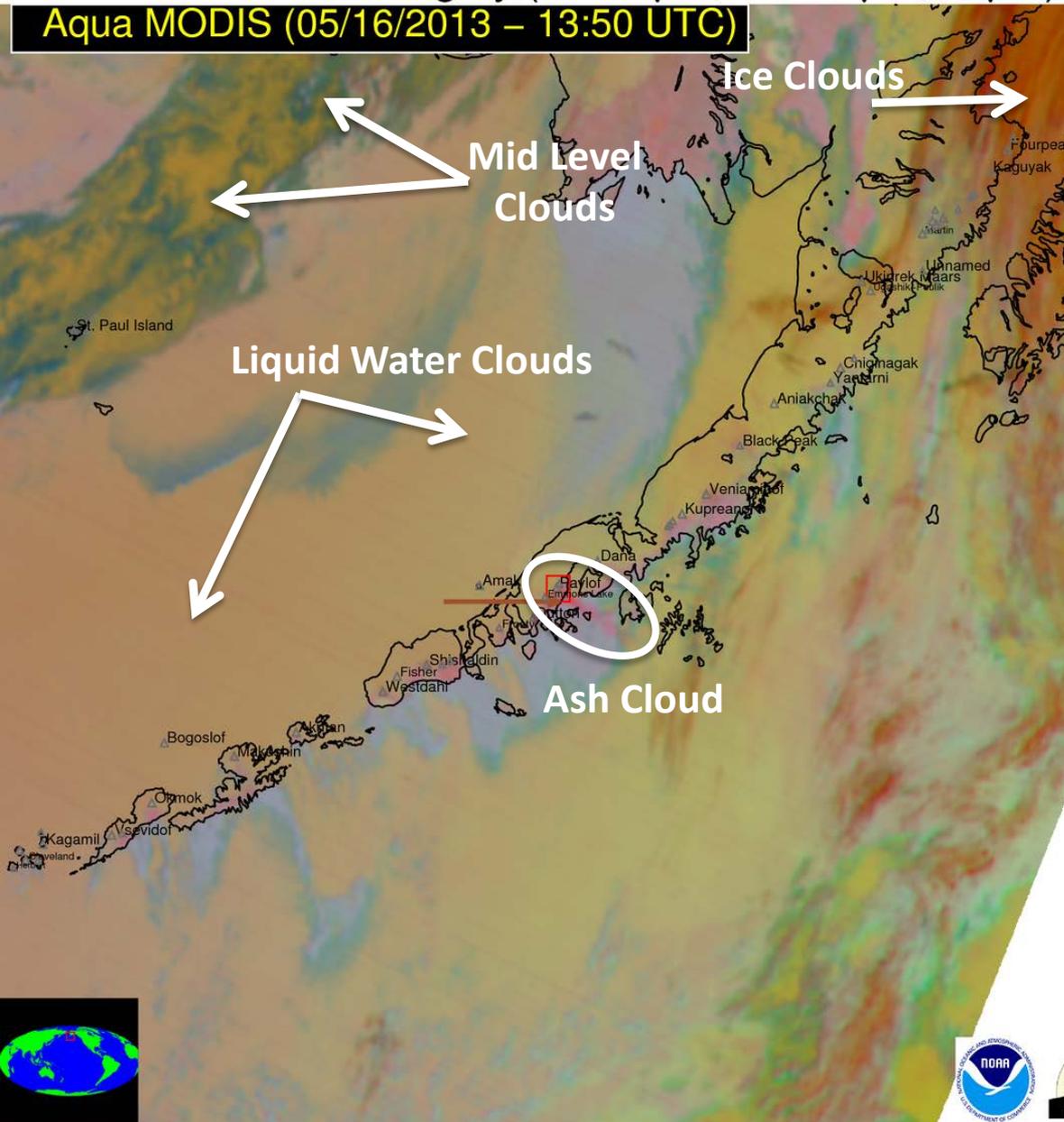
Annotation Key

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

Ash/Dust Cloud Volcanic Cb SO₂ Thermal Anomaly

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

Aqua MODIS (05/16/2013 – 13:50 UTC)



False color (RGB) imagery is also available on the web site. Please see:

http://www.eumetsat.int/Home/Main/DataProducts/Training/SP_2012105102052215?l=en

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Volcano locations are denoted on the imagery

This channel combination is available on MODIS, SEVIRI, VIIRS, and the GOES-R ABI (future sensor)

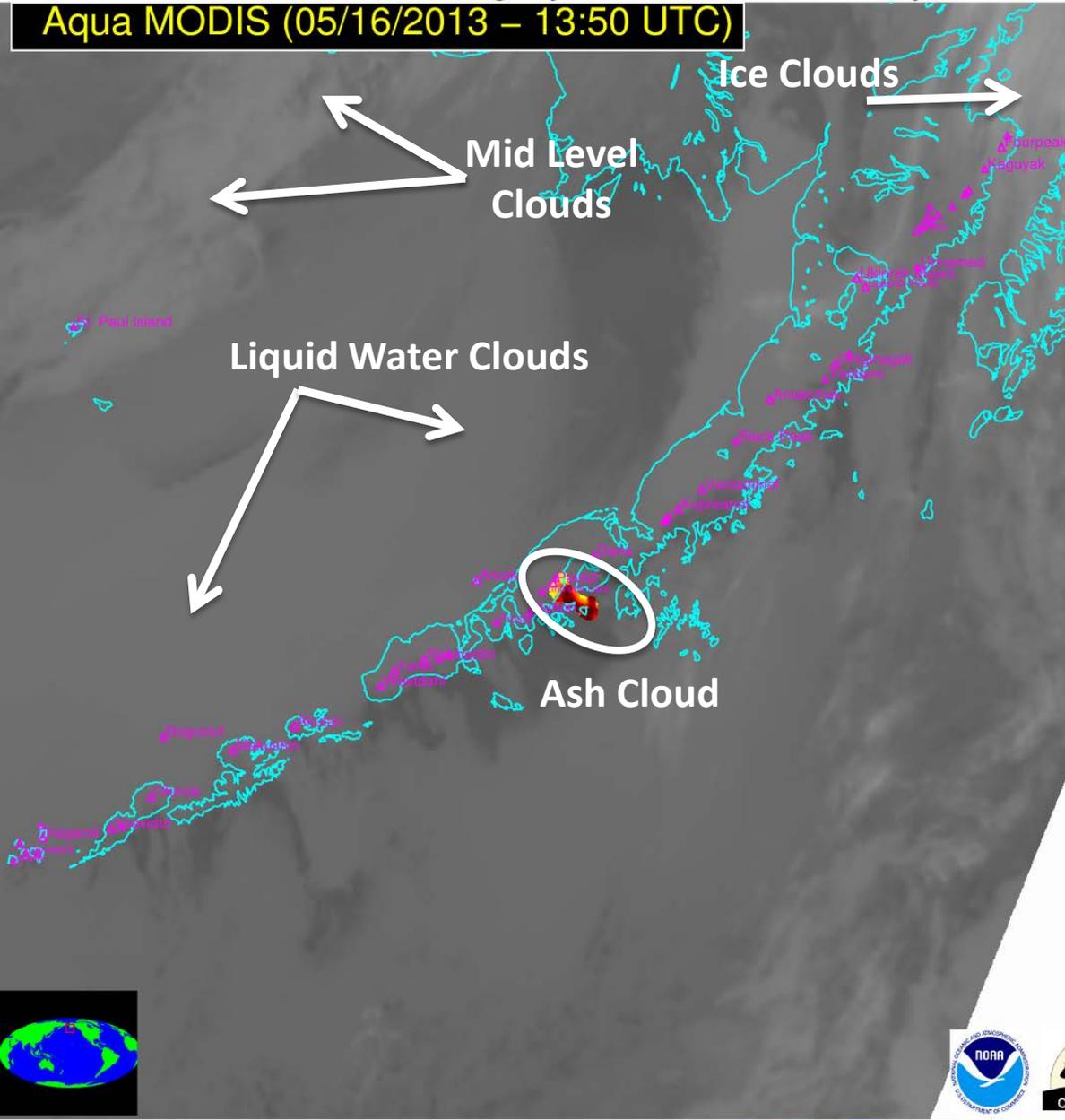
Annotation Key

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

Ash/Dust Cloud Volcanic Cb SO₂ Thermal Anomaly

IR Window Imagery and Ash Probability

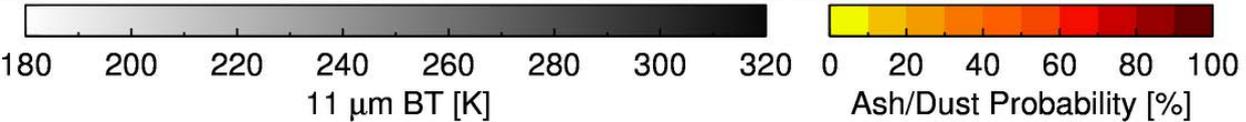
Aqua MODIS (05/16/2013 – 13:50 UTC)



The automated volcanic ash detection results quantify the horizontal extent of volcanic ash

The ash detection, which is expressed as a probability, is overlaid on standard 11 μm infrared imagery

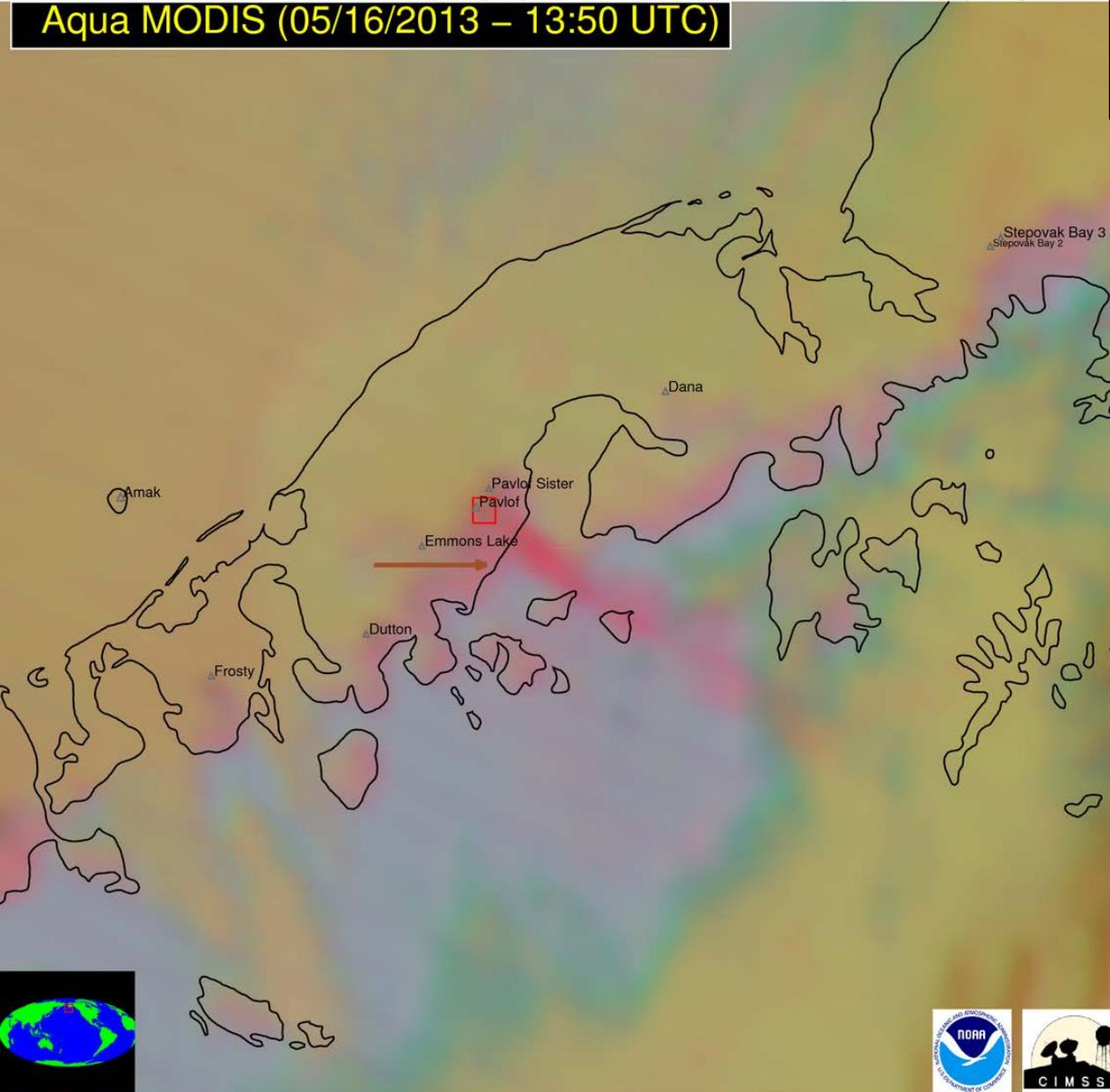
The automated ash detection algorithm is designed to mimic how a well trained human would manually analyze a multi-spectral image (high detection rate and a very low false alarm rate)



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

Aqua MODIS (05/16/2013 – 13:50 UTC)

A manual analysis of this image suggests the horizontal boundary depicted in white



Annotation Key

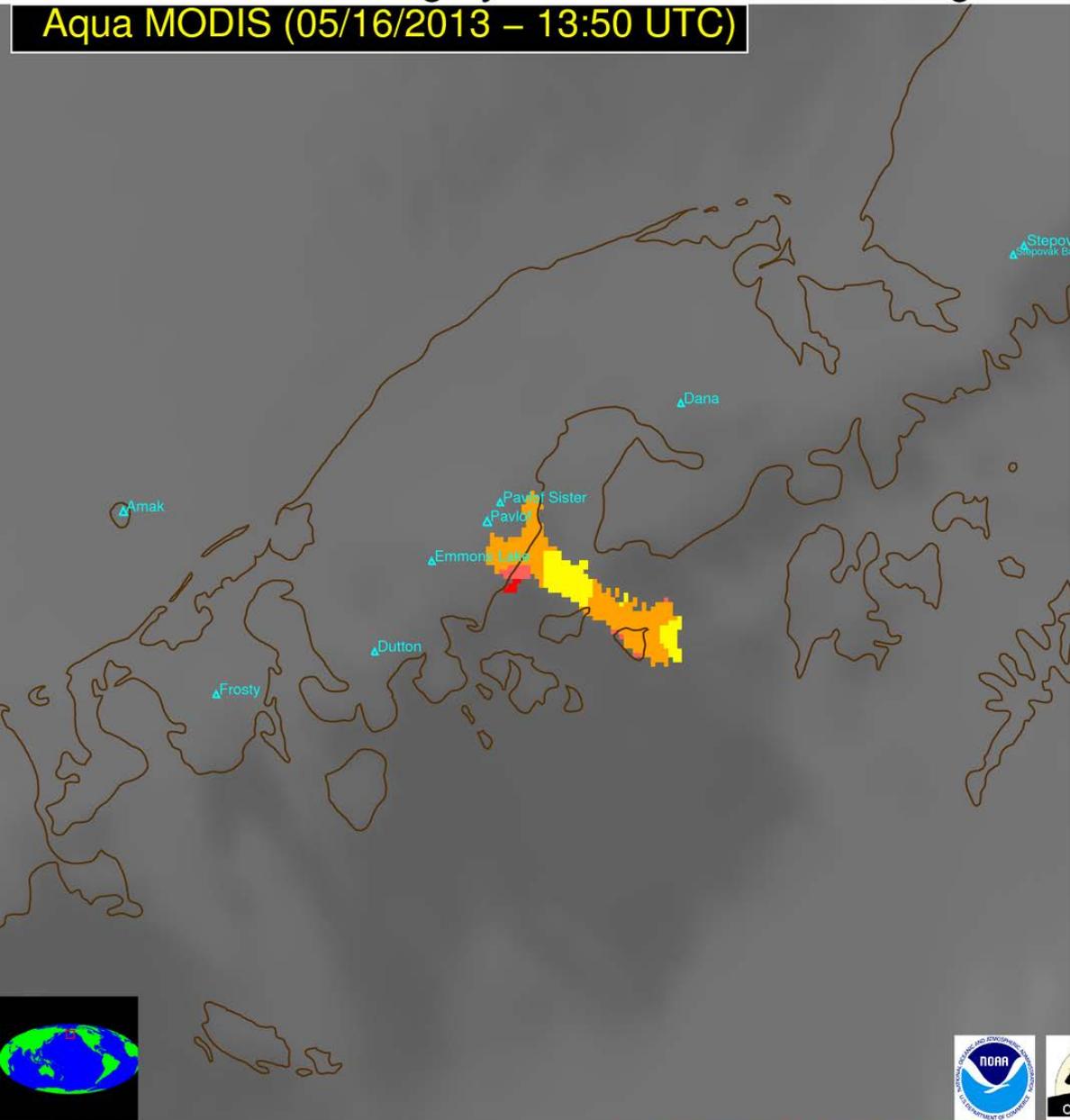
(annotation colors are not related to colors in underlying image)

Ash/Dust Cloud Volcanic Cb SO₂ Thermal Anomaly



IR Window Imagery and Ash/Dust Cloud Height

Aqua MODIS (05/16/2013 – 13:50 UTC)

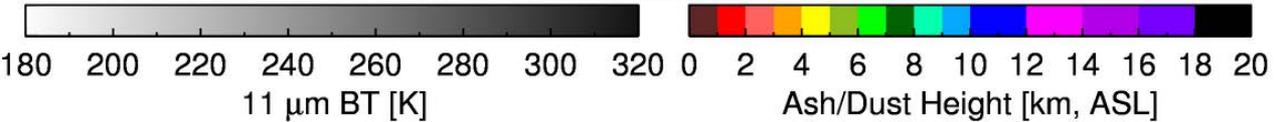


The estimated ash cloud top height (km, ASL) is also available as colors overlaid on an infrared image

The height is derived using multiple infrared channels, so no assumption regarding cloud opacity is made

The multi-spectral approach allows for accurate height estimates even when the cloud is optically thin (e.g. the 11 μm brightness temperature is a poor proxy for the true cloud top temperature)

This product can also be viewed in kilo-feet (ASL) in N-AWIPS and McIDAS

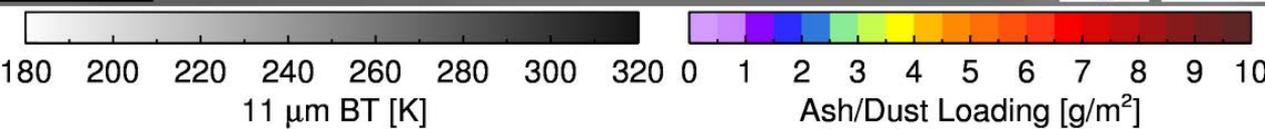
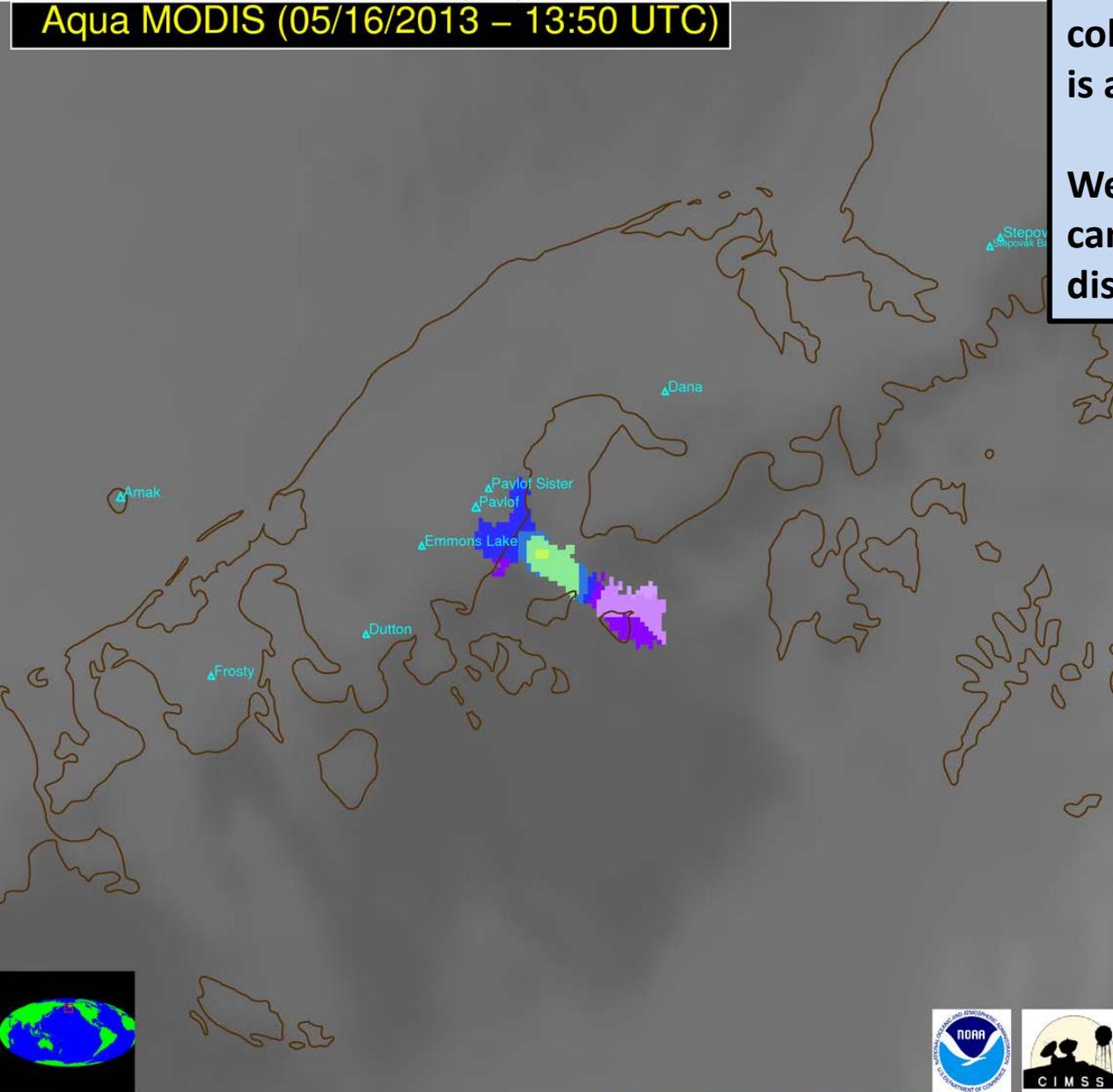


IR Window Imagery and Ash/Dust Loading

Aqua MODIS (05/16/2013 – 13:50 UTC)

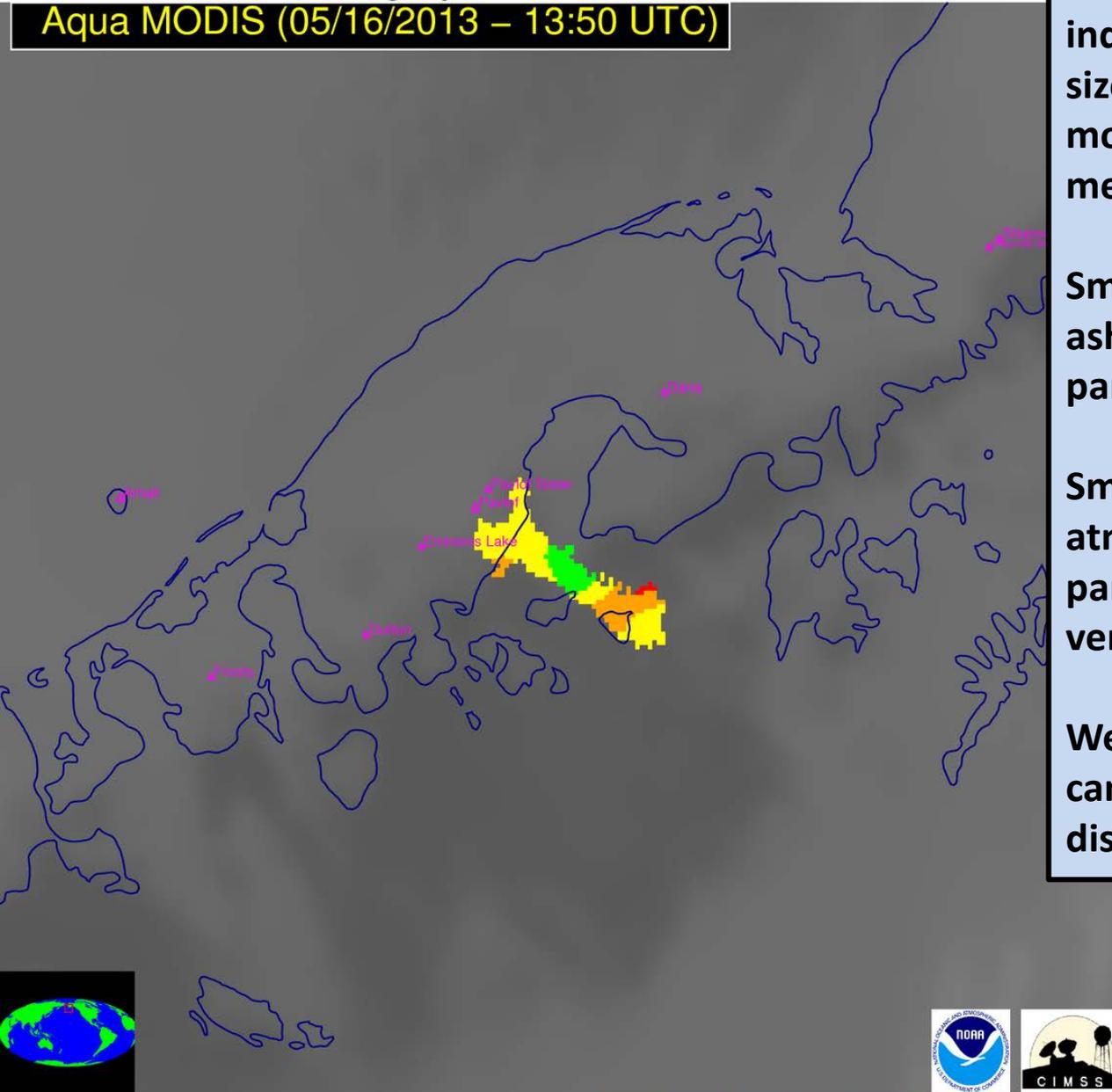
The ash mass loading (total column mass of ash per unit area) is also estimated

We are hopeful that this product can eventually be used to improve dispersion model forecasts



IR Window Imagery and Ash/Dust Effective Radius

Aqua MODIS (05/16/2013 – 13:50 UTC)

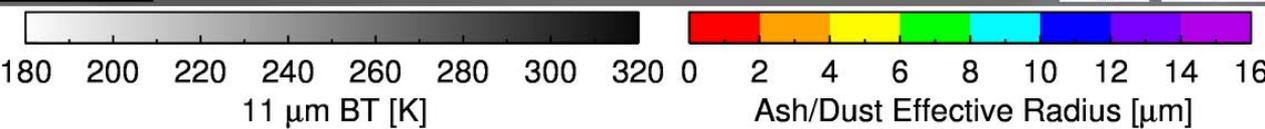


The effective ash particle radius indicates which part of the particle size distribution is contributing most to the satellites measurements

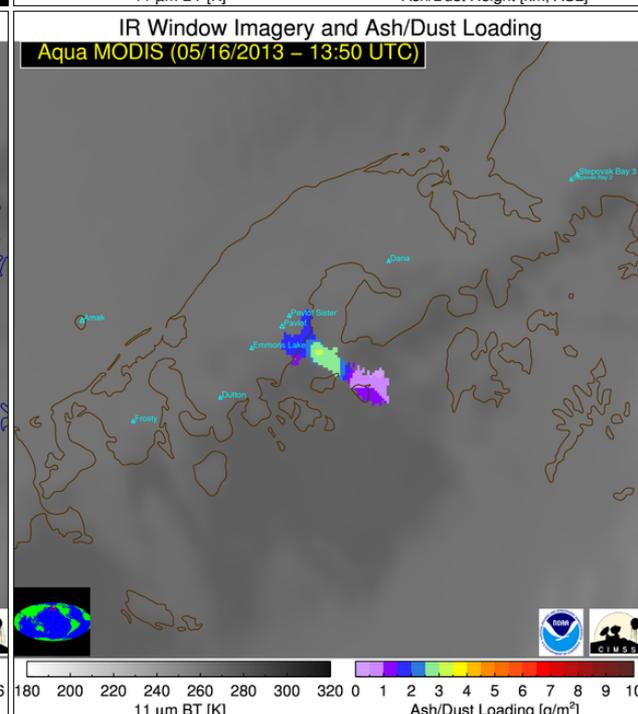
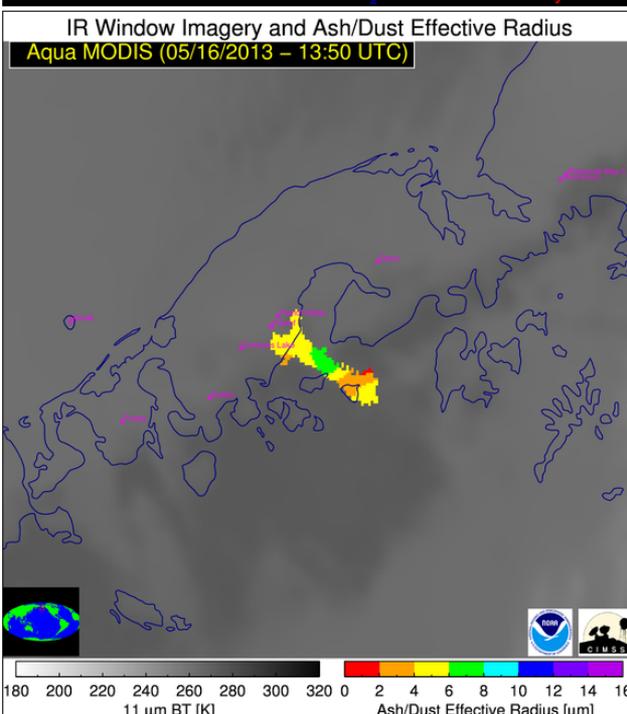
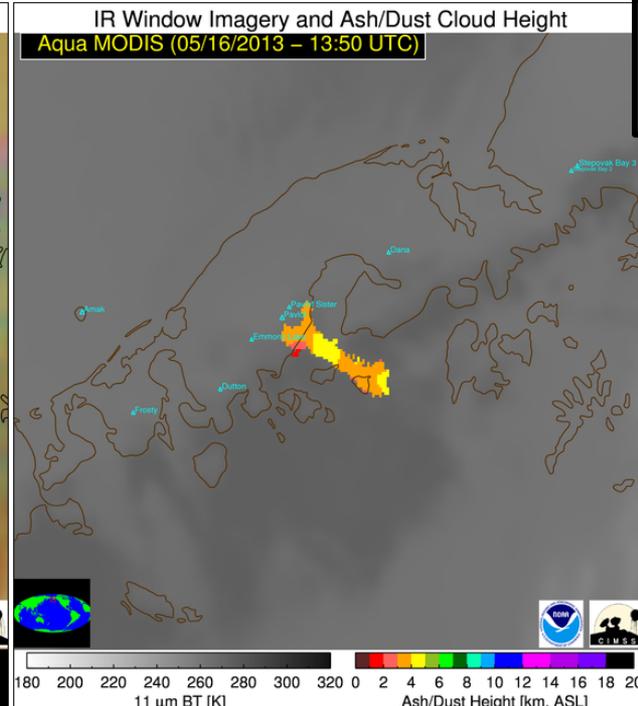
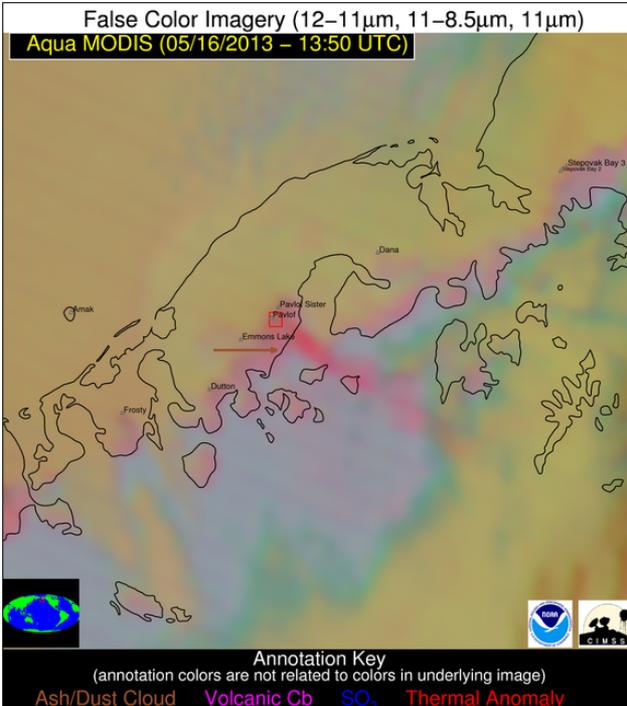
Smaller values are indicative of an ash cloud dominated by smaller particles

Smaller particles stay lofted in the atmosphere longer than larger particles (in the absence of strong vertical motions)

We are hopeful that this product can eventually be used to improve dispersion model forecasts



4-panel figures are also available on the web site



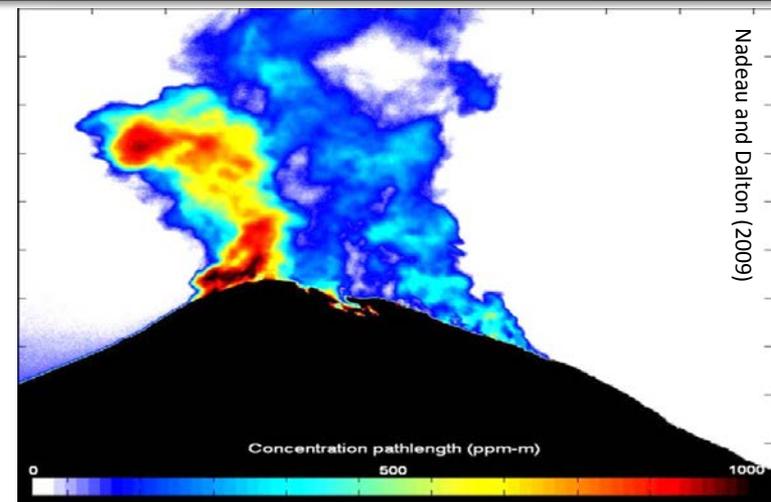
1). Ash dominated volcanic plumes – Semi-transparent clouds dominated by volcanic ash. Lightning is usually not present in these clouds.



2). Ice topped umbrella clouds – These clouds are mostly observed during a major eruption. A spectral based volcanic ash signal is usually initially absent because the ash is encased in ice and/or the cloud is opaque. Lightning is often present in these clouds.



3). SO₂ clouds – Sulfur dioxide clouds (SO₂ gas is invisible to the eye) that may or may not contain volcanic ash. Some eruptions produce large amounts of SO₂ and very little ash and vice-versa.



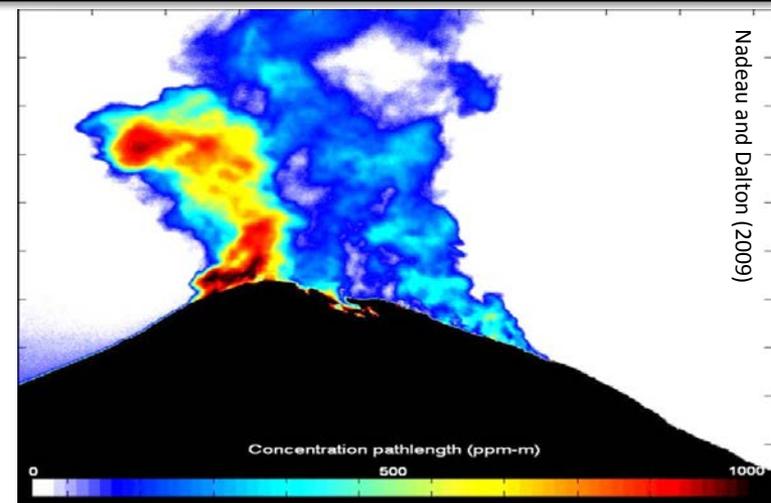
1). Ash dominated volcanic plumes – Semi-transparent clouds dominated by volcanic ash. Lightning is usually not present in these clouds.



2). Ice topped umbrella clouds – These clouds are mostly observed during a major eruption. A spectral based volcanic ash signal is usually initially absent because the ash is encased in ice and/or the cloud is opaque. Lightning is often present in these clouds.



3). SO₂ clouds – Sulfur dioxide clouds (SO₂ gas is invisible to the eye) that may or may not contain volcanic ash. Some eruptions produce large amounts of SO₂ and very little ash and vice-versa.



The time rate of change of vertical growth can be used to identify volcanic eruptions even in the absence of a spectral signature

Kasatochi (AK), August 7, 2008

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

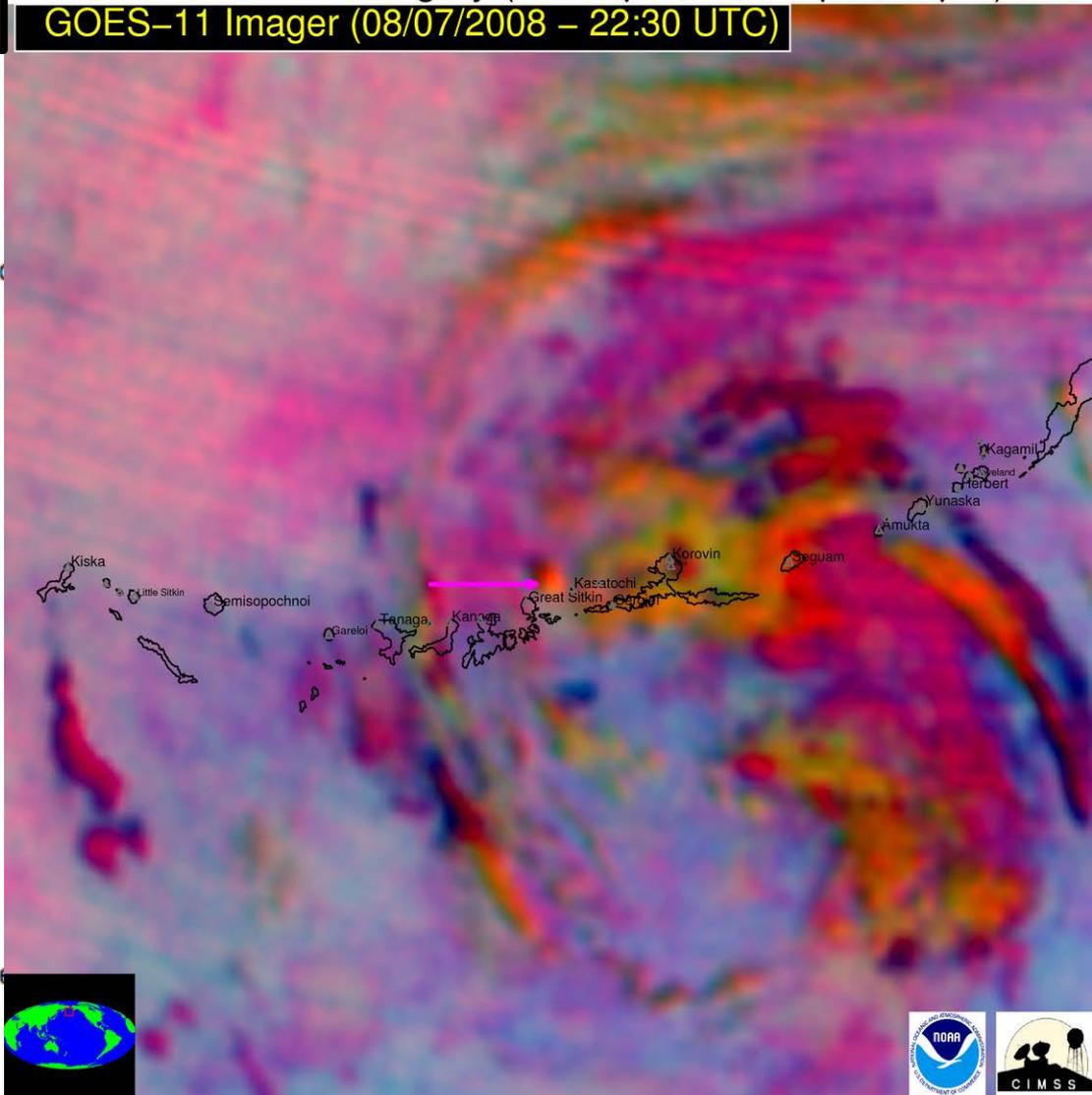
GOES-11 Imager (08/07/2008 - 22:30 UTC)

@*****VOLCANIC ALERTS*****
STARTING DATE/TIME OF IMAGE: 2008-08-07 22:30:00 [UTC]
PRIMARY INSTRUMENT: GOES-11 Imager
WMO SPACECRAFT ID: 255
LOCATION/ORBIT: GEO
L1 FILE: goes11_1_2008_220_2230.area.gz
VOLCANO DATABASE: /data/common/VOLCAT_DATA/alerts/V
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/6158>

POSSIBLE VOLCANIC ERUPTION DETECTED
Alert Status: New Alert Object
Latitude of Radiative Center: 52.163 [degrees]
Longitude of Radiative Center: -175.570 [degrees]
Mean Viewing Angle: 71.14 [degrees]
Mean Solar Zenith Angle: 38.91 [degrees]
Nearby Volcanoes (meeting alert criteria):
Kasatochi(4.53 km)
Maximum Height [AMSL]: 8.9 [km] (29271.64 [ft])
90th Percentile Height [AMSL]: 8.3 [km] (27128.11 [ft])
Mean Tropopause Height [AMSL]: 10.6 [km] (34721.60 [ft])
Trend in IR Brightness Temperature: -6.64 [K/30 min]
Vertical Growth Rate Anomaly: 1.11 [number of stddev above m
Total Area: 343.80 [km^2]

Geographic Regions of Nearby Volcanoes: Aleutian Is
VAAC Regions of Nearby Volcanoes: Anchorage
FIR Regions of Nearby Volcanoes: Unknown

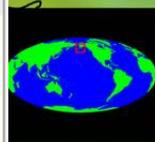
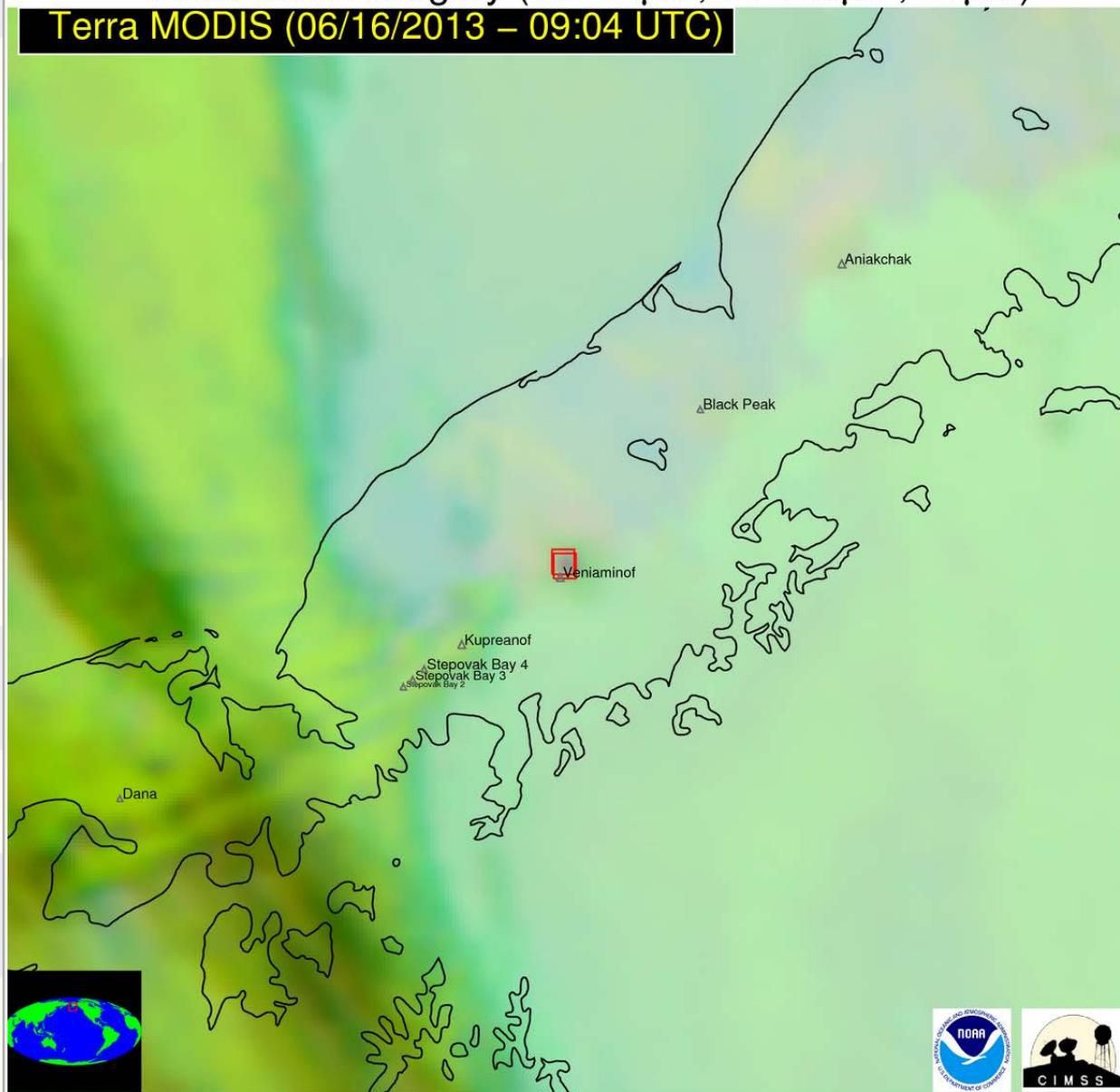


Annotation Key
(annotation colors are not related to colors in underlying image)

Ash/Dust Cloud Volcanic Cb SO₂ Thermal Anomaly

Alert Status	Newly detected feature
Radiative Center (lat, Lon):	56.193 °, -159.364 °
Mean Viewing Angle	50.26 °
Mean Solar Zenith Angle	98.05 °
Nearby Volcanoes (meeting alert criteria):	Veniaminof (3.18 km)
Maximum 3.8 Um Brightness Temperature	297.84 K
Maximum 3.8 Um Thermal Anomaly	20.22 K
Total Area	6.77 km ²
Geographic Regions Of Nearby Volcanoes	Alaska Peninsula
Vaac Regions Of Nearby Volcanoes	Anchorage
Fir Regions Of Nearby Volcanoes	Unknown

False Color Imagery (12–11μm, 11–3.9μm, 11μm) Terra MODIS (06/16/2013 – 09:04 UTC)



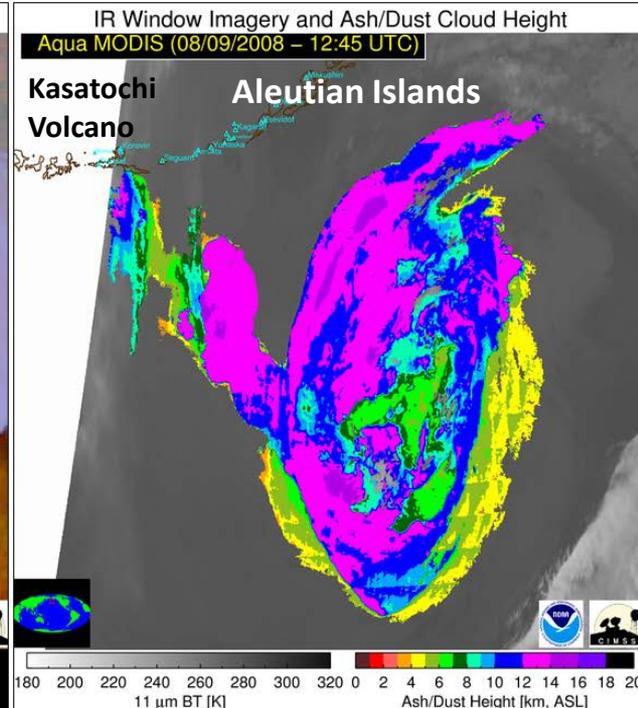
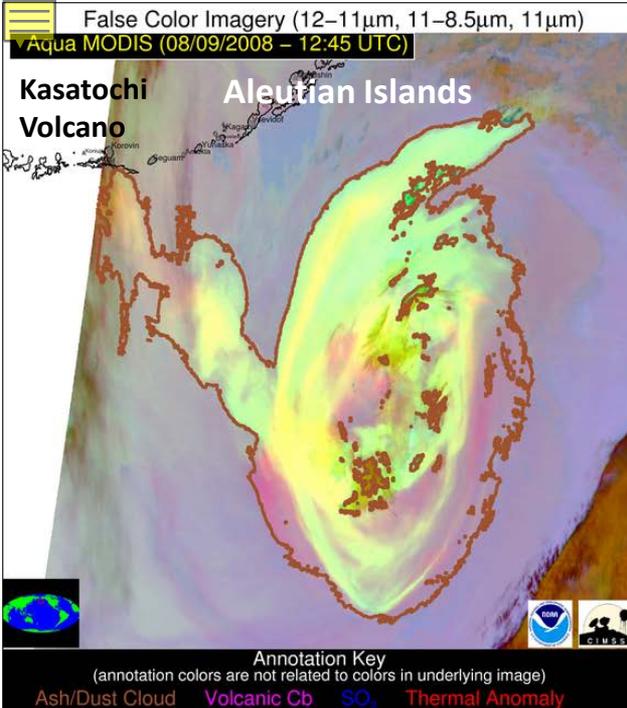
Annotation Key
 (annotation colors are not related to colors in underlying image)
 Ash/Dust Cloud Volcanic Cb SO₂ Thermal Anomaly

Primary Remote Sensing Challenges

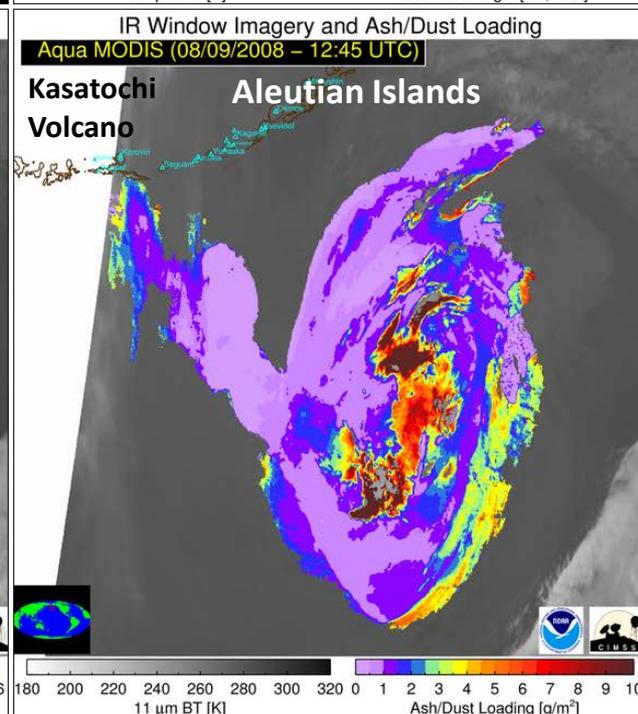
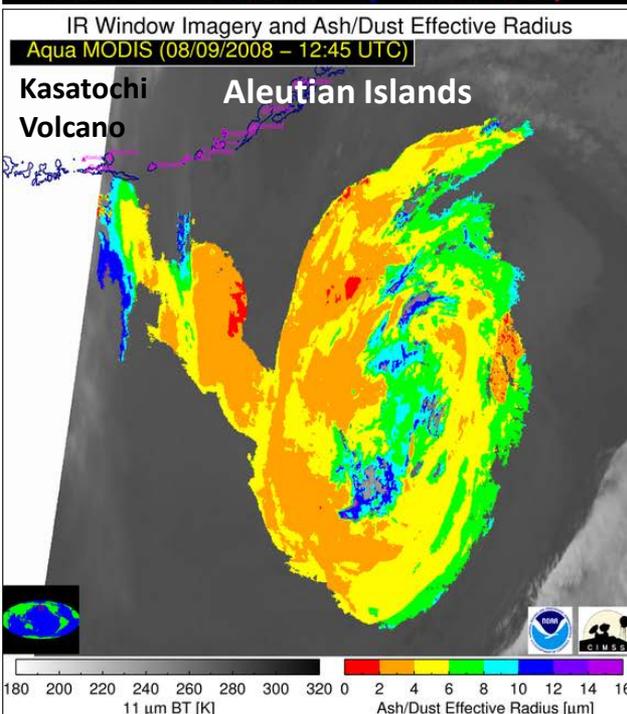
- *The following can create false volcanic ash signals in satellite data and/or dampen the ash spectral signature*
 - Background conditions (e.g. temperature, water vapor, surface emissivity, etc...), which are highly variable in time and space*
 - Multiple cloud layers**
 - Opaque volcanic clouds can easily be mistaken for meteorological convection and ash can be encased in ice**
 - Ash clouds dominated by larger particles are difficult to detect*
 - Dust and ash have a very similar spectral signature**
 - Poor signal-to-noise, calibration errors, and co-registration errors**
 - Stray light**
 - Highly variable instrument capabilities**
- *In addition there are several logistical challenges associated with real-time processing (latency, efficiency, and distribution)*

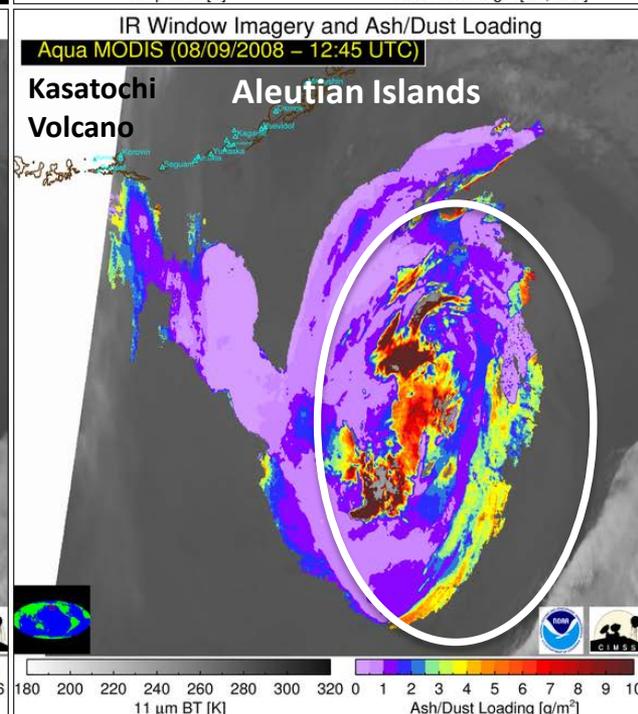
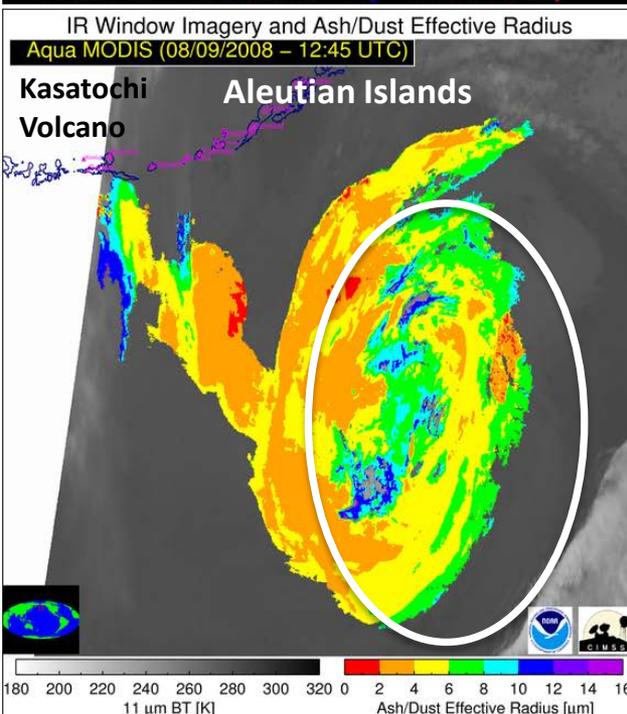
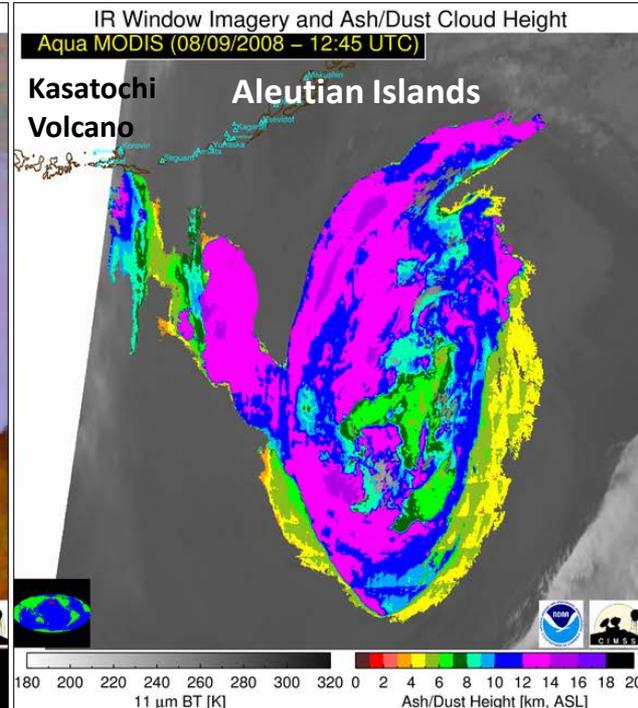
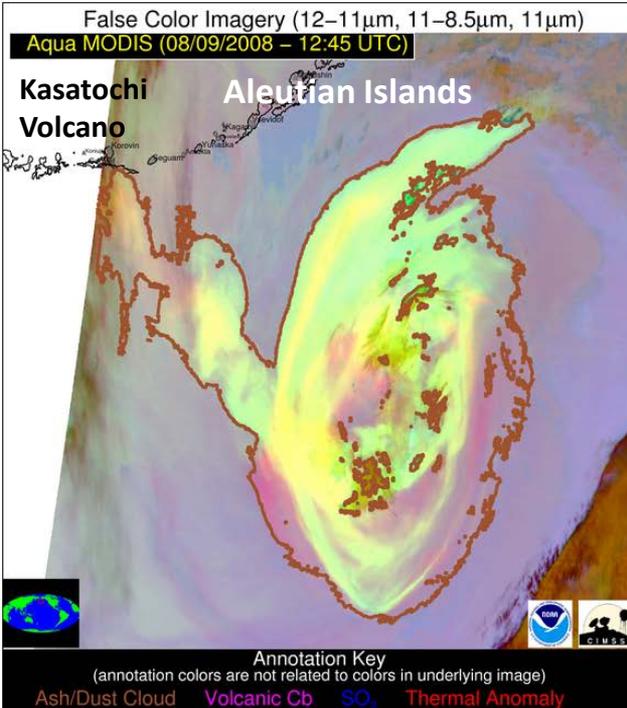
*Some improvements in past year

**Major improvements in past year



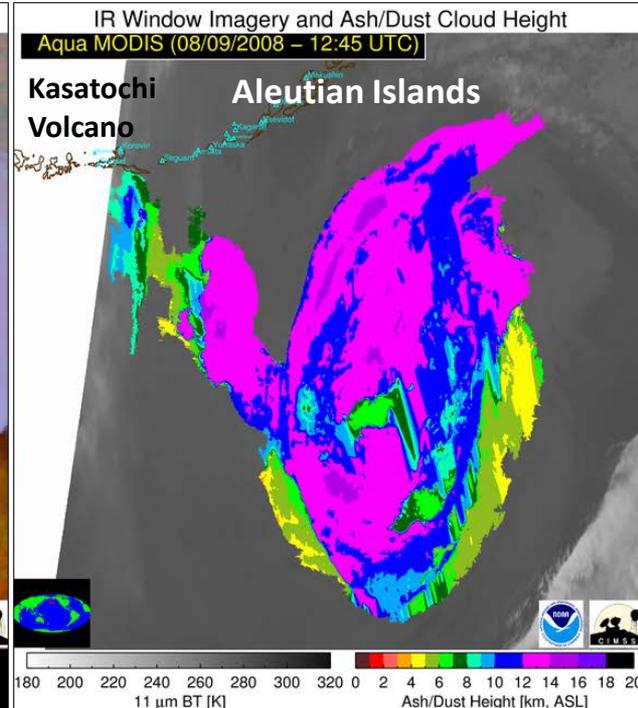
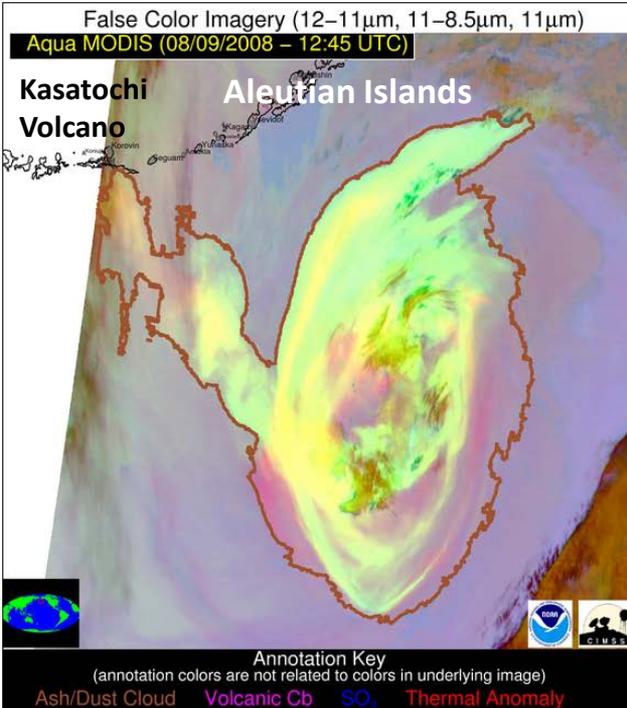
August 9, 2008 (12:45 UTC):
Kasatochi volcanic cloud





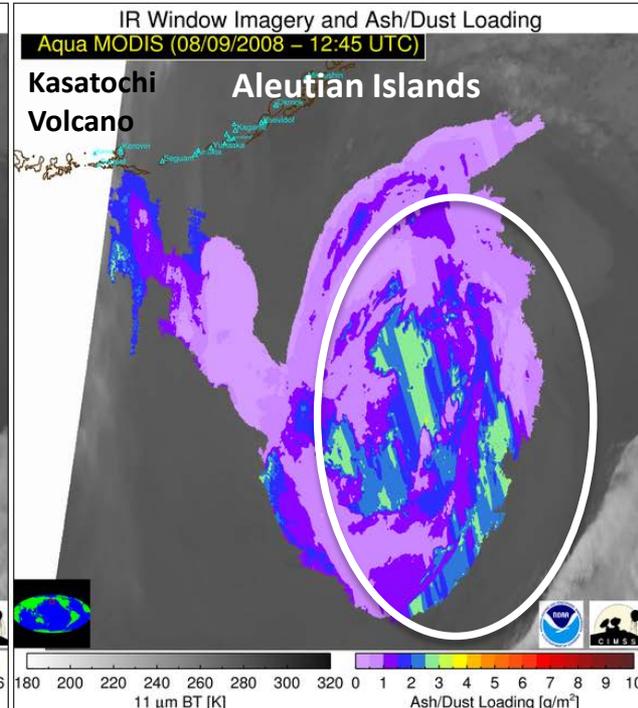
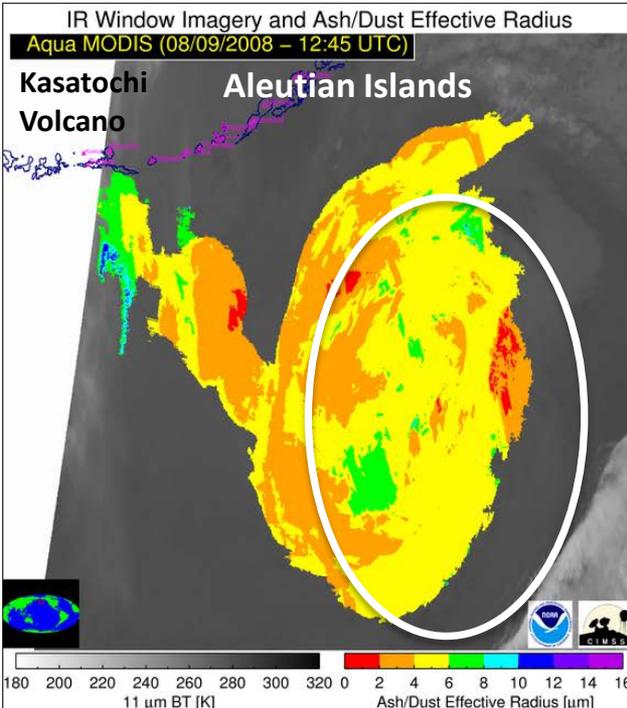
**August 9, 2008 (12:45 UTC):
Kasatochi volcanic cloud**

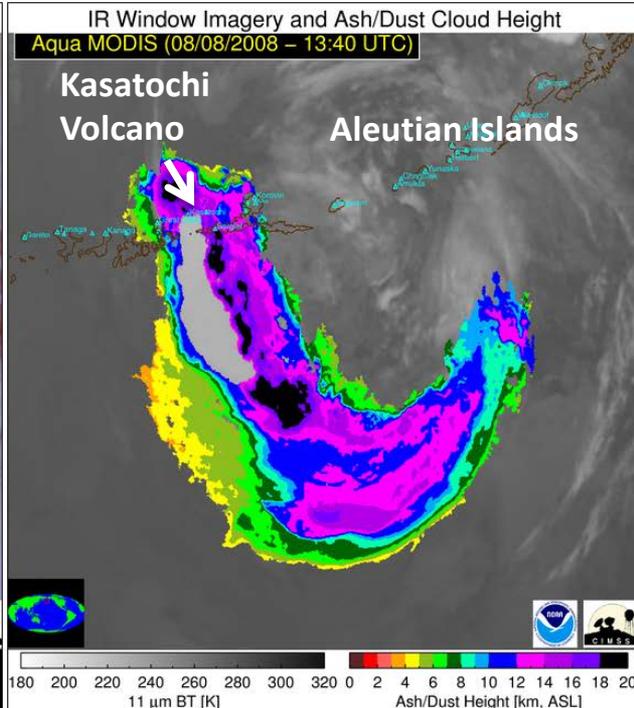
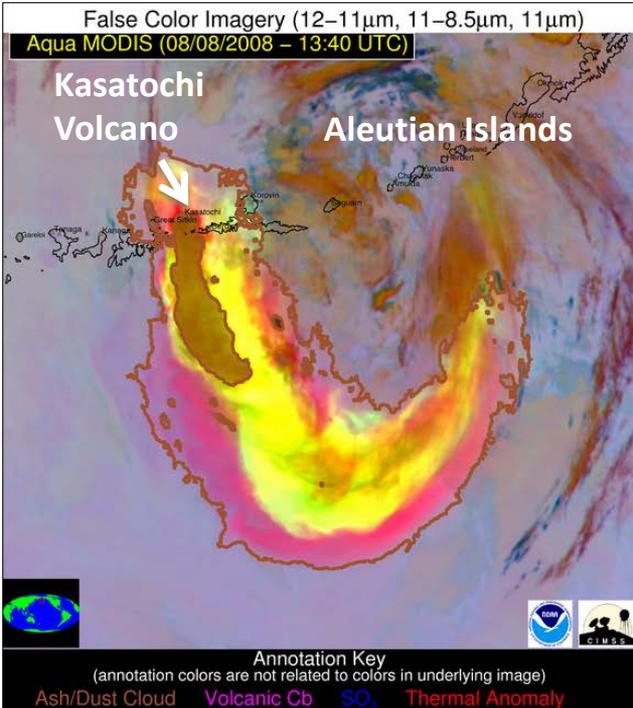
The ash mass loading and effective particle radius are greatly over-estimated in parts of this cloud due to underlying mid and high level meteorological clouds, which are very difficult to account for in the retrieval.



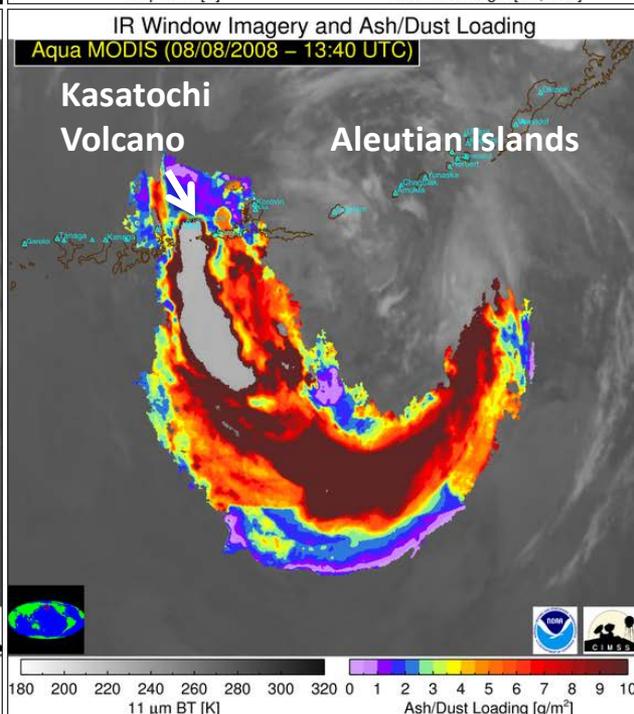
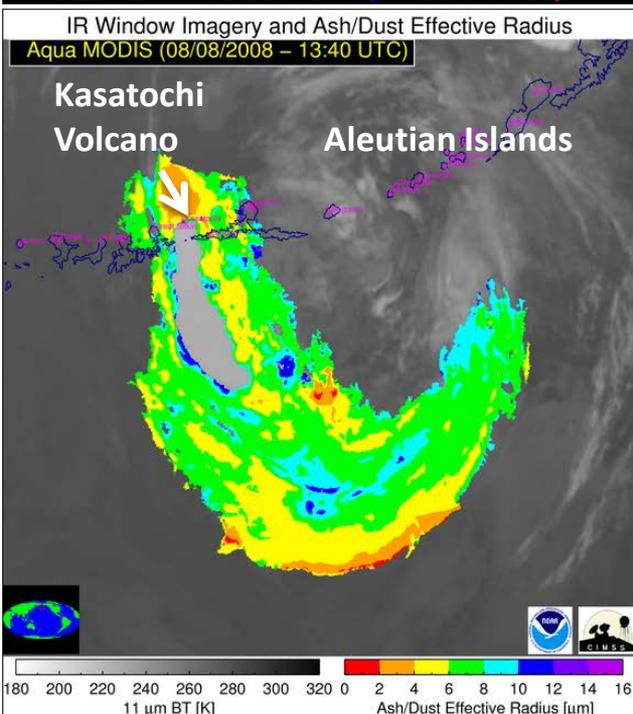
**August 9, 2008 (12:45 UTC):
Kasatochi volcanic cloud**

Any retrieved parameter that differs greatly from the median value within the cloud object is automatically identified and re-computed using a Cressman interpolation scheme.



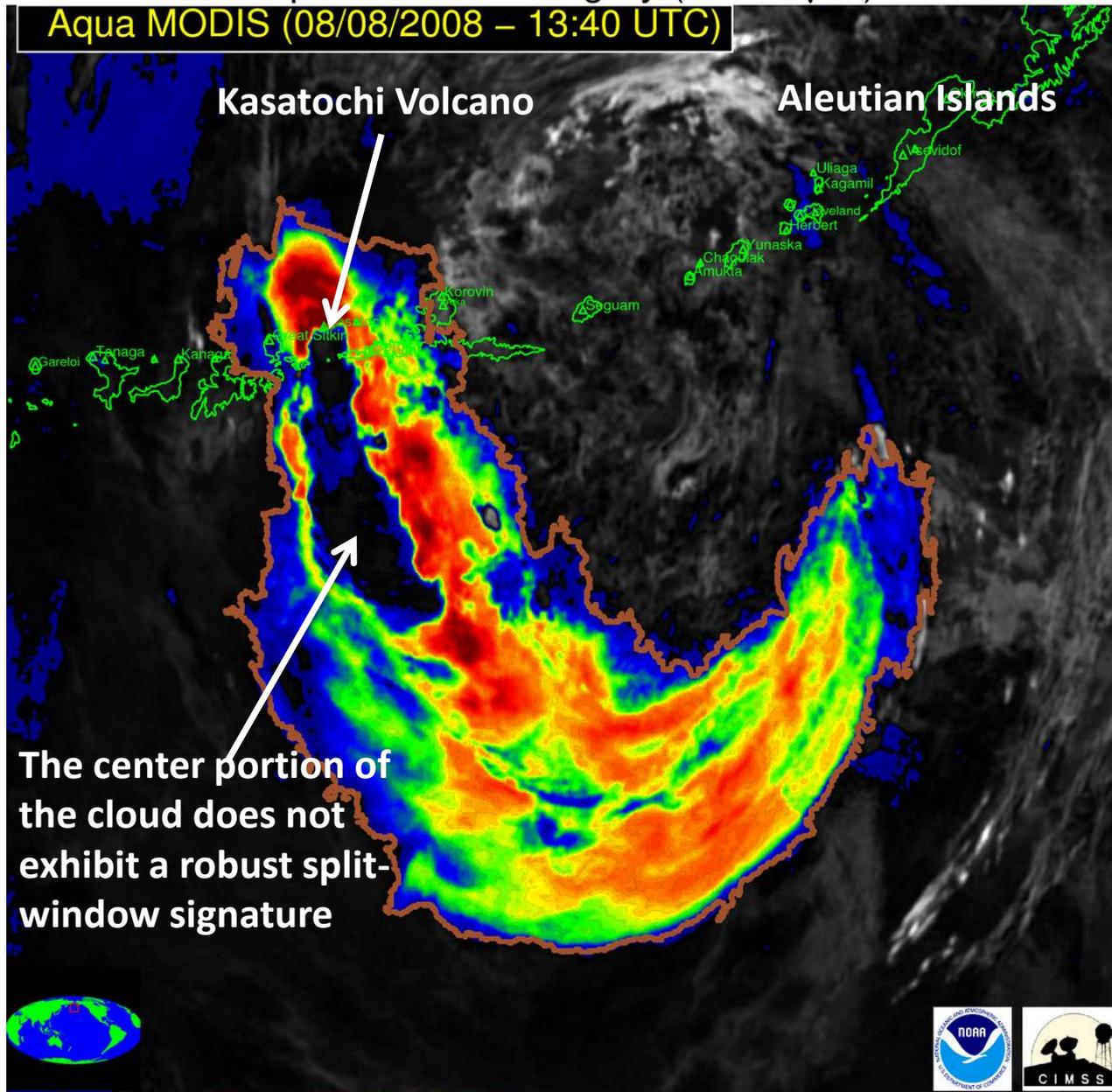


**August 8, 2008 (13:40 UTC):
Kasatochi volcanic cloud**

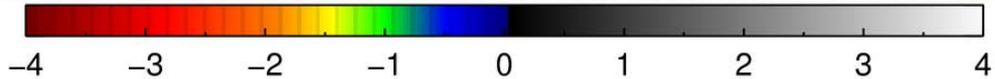


Split-Window Imagery (11–12 μm)

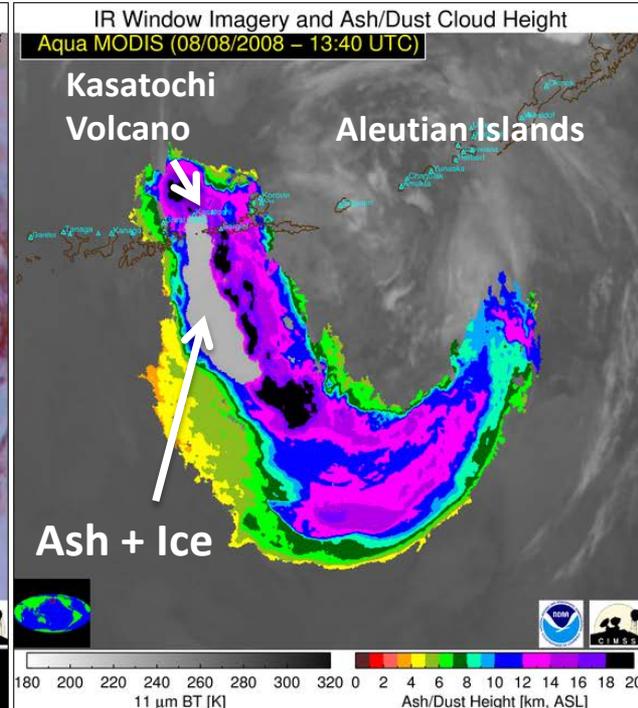
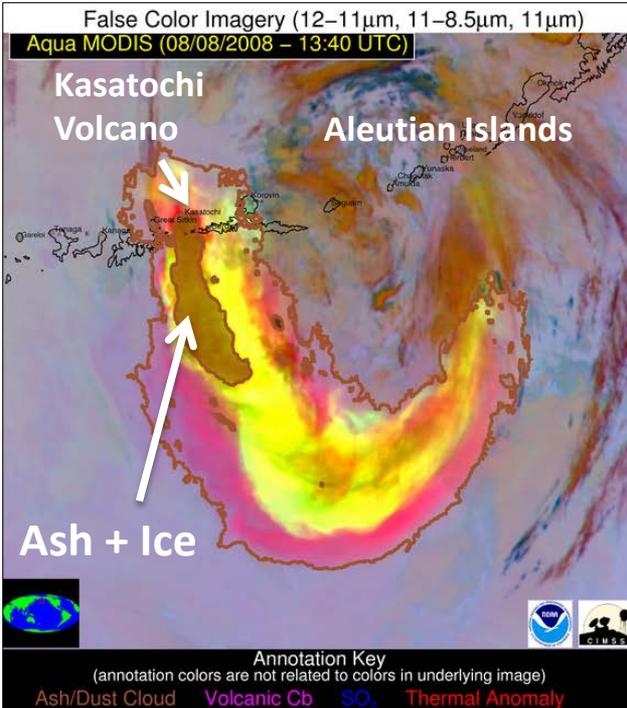
Aqua MODIS (08/08/2008 – 13:40 UTC)



The center portion of the cloud does not exhibit a robust split-window signature

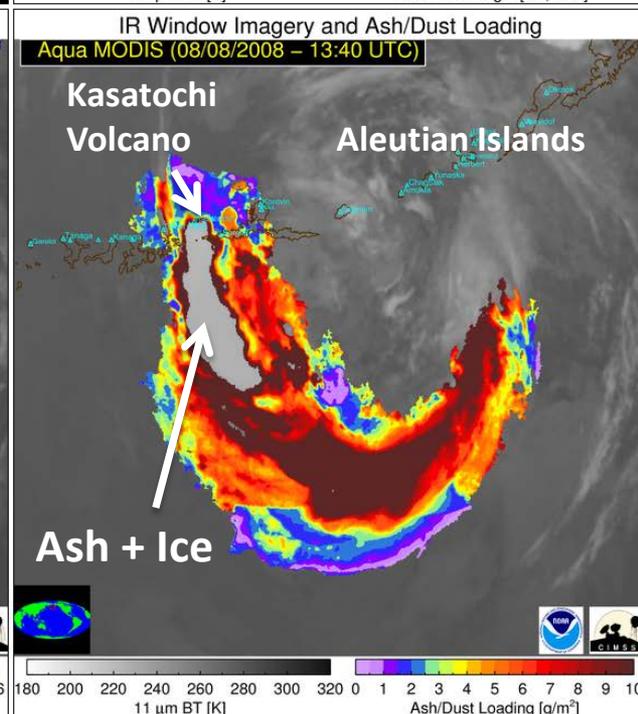
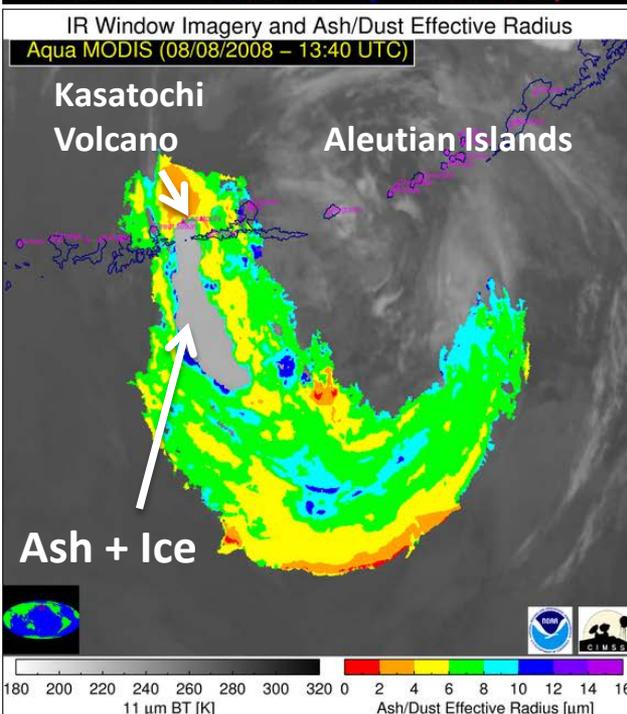


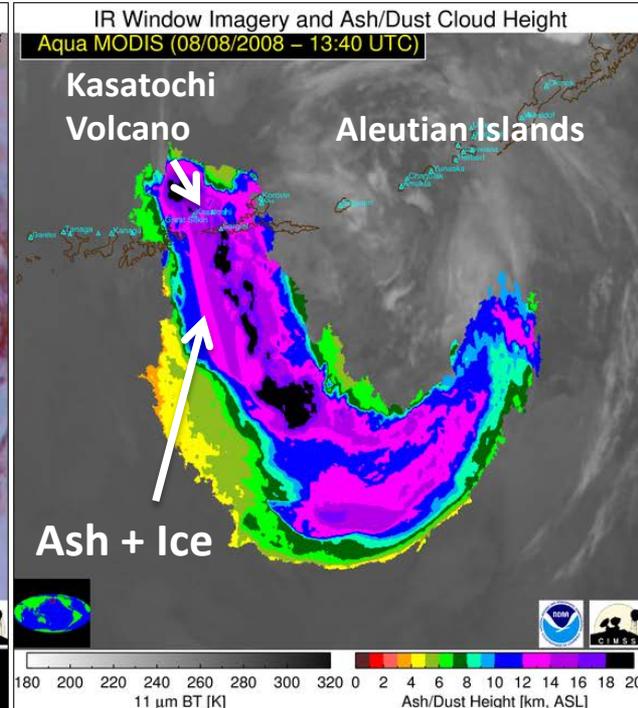
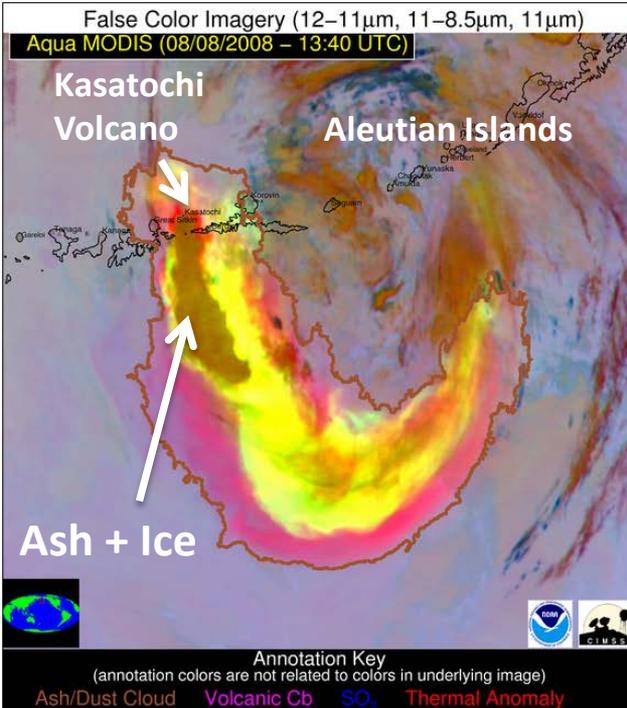
BTD[11–12 μm] [K]



**August 8, 2008 (13:40 UTC):
Kasatochi volcanic cloud**

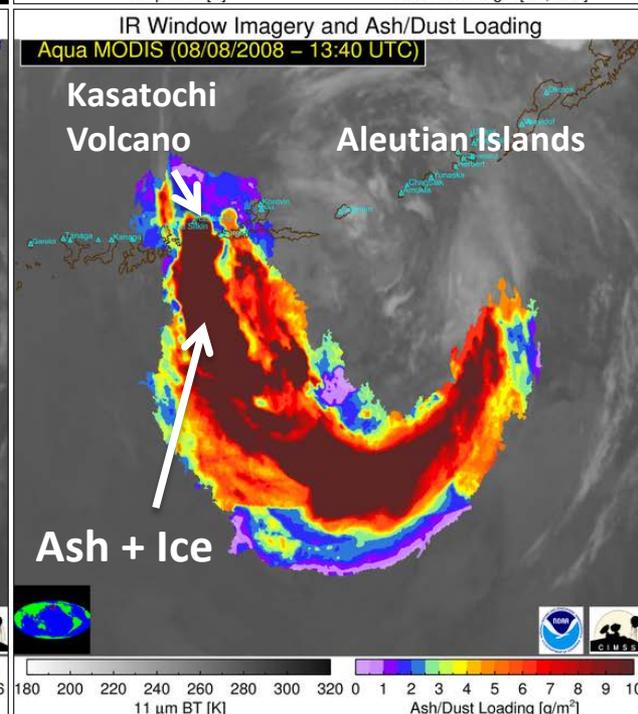
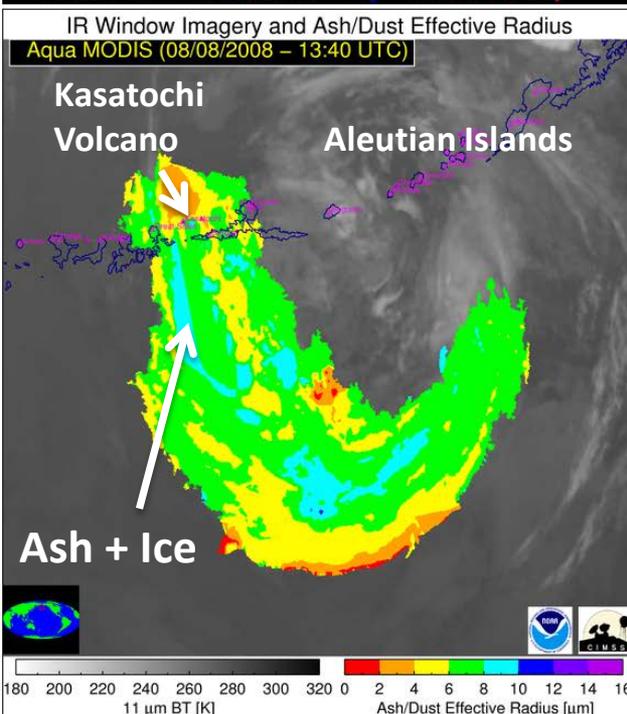
**The optically thick center
of the Kasatochi cloud
contains ice particles in
addition to volcanic ash
and thus it cannot be
distinguished from
meteorological clouds
and the ash cloud
properties are not
estimated.**





**August 8, 2008 (13:40 UTC):
Kasatochi volcanic cloud**

Artificial holes in volcanic clouds are automatically identified and a Cressman interpolation scheme is used to fill them.



From: Mike Pavolonis <mpav@ssec.wisc.edu>
 Subject: NOAA/CIMSS Volcanic Cloud Alert
 Date: May 18, 2013 8:51:33 AM CDT
 To: Mike Pavolonis <mpav@ssec.wisc.edu>

Re-suspended ash from 1912 Katmai eruption (5/18/13)

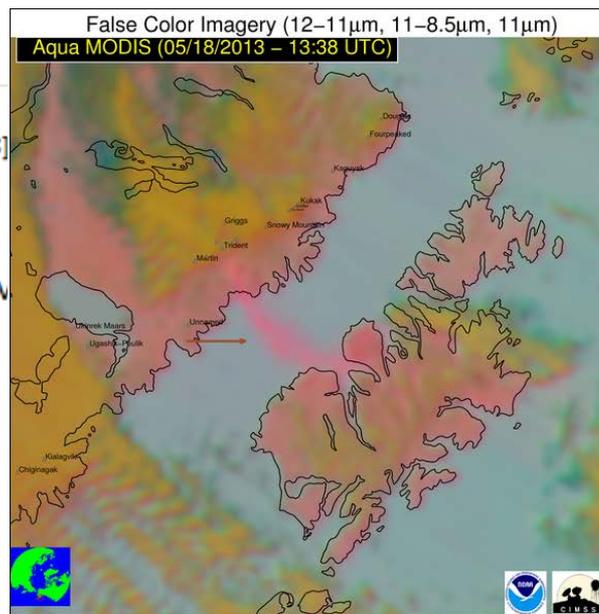
@*****VOLCANIC ALERTS*****
 STARTING DATE/TIME OF IMAGE: 2013-05-18 13:38:51 [UTC]
 PRIMARY INSTRUMENT: Aqua MODIS
 WMO SPACECRAFT ID: 784
 LOCATION/ORBIT: LEO
 L1 FILE: MYD021KM.A2013138.1338.temp.hdf
 VOLCANO DATABASE: /data/common/VOLCAT_DATA/alerts/V
 NUMBER OF ASH CLOUD ALERTS: 1
 NUMBER OF VOLCANIC Cb ALERTS: 0
 NUMBER OF VOLCANIC THERMAL ANOMALY ALERTS: 0
 NUMBER OF SO2 CLOUD ALERTS: 0

REPORT WITH IMAGES:
<http://volcano.ssec.wisc.edu/alert/report/3202>

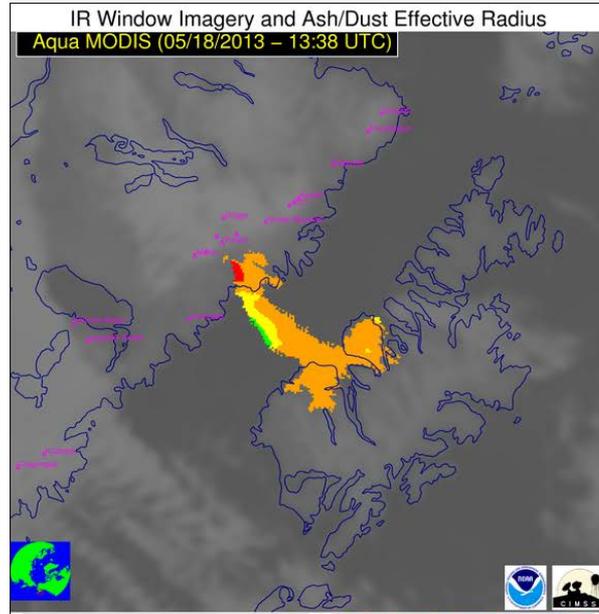
POSSIBLE VOLCANIC ASH CLOUD FOUND
 Alert Status: Newly detected feature
 Latitude of Radiative Center: 57.783 [degrees]
 Longitude of Radiative Center: -153.843 [degrees]
 Mean Viewing Angle: 51.19 [degrees]
 Mean Solar Zenith Angle: 91.59 [degrees]
 Nearby Volcanoes (meeting alert criteria):
 Snowy Mountain(78.92 km)
 Denison(79.18 km)
 Steller(79.49 km)
 Kukak(80.44 km)
 Katmai(86.13 km)

Cloud Object Probability: 100.00000 [%]
 Median Probability of Object Pixels: 71.89999 [%]
 Percent Unambiguous Pixels: 10.03266 [%]
 Maximum Height [AMSL]: 3.9 [km] (12684.28 [ft])
 90th Percentile Height [AMSL]: 2.7 [km] (8906.17 [ft])
 Mean Tropopause Height [AMSL]: 8.7 [km] (28590.08 [ft])
 Total Mass: 0.004129 [Tg]
 Median Effective Particle Radius: 3.03 [um]
 Total Area: 3508.09 [km^2]

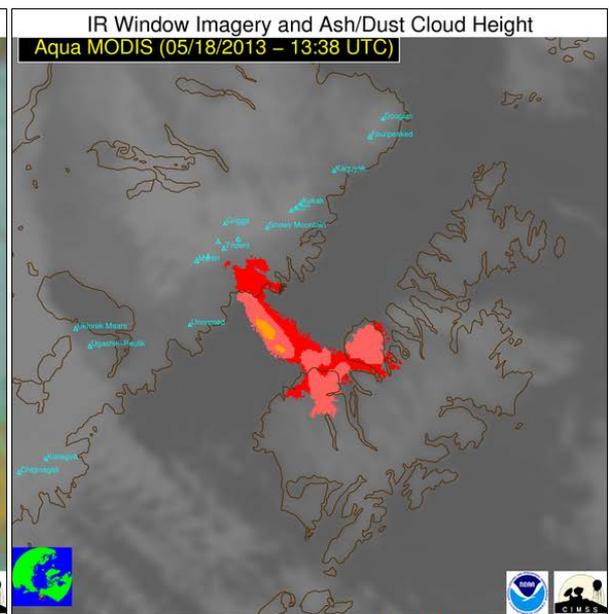
Geographic Regions of Nearby Volcanoes: Alaska Peninsula
 VAAC Regions of Nearby Volcanoes: Anchorage
 FIR Regions of Nearby Volcanoes: Unknown



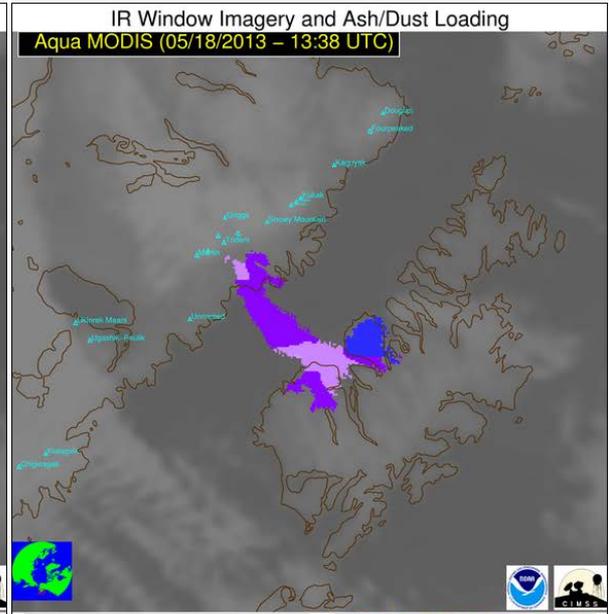
Annotation Key
 (annotation colors are not related to colors in underlying image)
 Ash/Dust Cloud Volcanic Cb SO₂ Thermal Anomaly



Ash/Dust Effective Radius [um]



Ash/Dust Height [km, ASL]



Ash/Dust Loading [g/m^2]

Difficult Pavlof case (6/6/13, 23:45 UTC)

From: Mike Pavolonis <mpav@ssec.wisc.edu>
Subject: NOAA/CIMSS Volcanic Cloud Alert
Date: June 6, 2013 9:23:32 PM CDT
To: Mike Pavolonis <mpav@ssec.wisc.edu>

@*****VOLCANIC ALERTS*****

STARTING DATE/TIME OF IMAGE: 2013-06-06 23:45:00 [U
PRIMARY INSTRUMENT: Aqua MODIS
WMO SPACECRAFT ID: 784
LOCATION/ORBIT: LEO
L1 FILE: MYD021KM.A2013157.2345.005.2013158014712
VOLCANO DATABASE: /data/common/VOLCAT_DATA/ale
NUMBER OF ASH CLOUD ALERTS: 1
NUMBER OF VOLCANIC Cb ALERTS: 0
NUMBER OF VOLCANIC THERMAL ANOMALY ALERTS: 0
NUMBER OF SO2 CLOUD ALERTS: 0

REPORT WITH IMAGES:

<http://volcano.ssec.wisc.edu/alert/report/5169>

POSSIBLE VOLCANIC ASH CLOUD FOUND

Alert Status: Newly detected feature

Latitude of Radiative Center: 55.376 [degrees]

Longitude of Radiative Center: -162.002 [degrees]

Mean Viewing Angle: 14.30 [degrees]

Mean Solar Zenith Angle: 34.45 [degrees]

Nearby Volcanoes (meeting alert criteria):

Emmons Lake(6.23 km)

Pavlof(8.55 km)

Pavlof Sister(13.21 km)

Cloud Object Probability: .00000 [%]

Percent Unambiguous Pixels: 3.97870 [%]

Maximum Height [AMSL]: 4.9 [km] (16153.74 [ft])

90th Percentile Height [AMSL]: 4.4 [km] (14600.45 [ft])

Mean Tropopause Height [AMSL]: 10.4 [km] (33992.61 [ft])

Total Mass: .001576 [Tg]

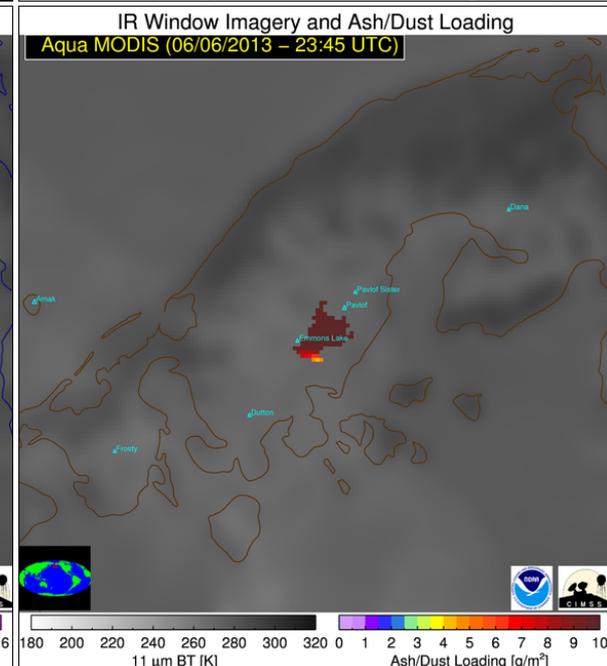
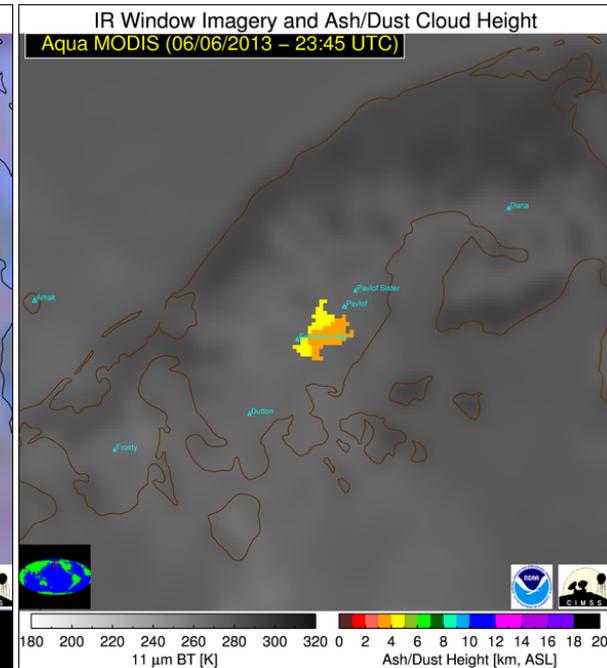
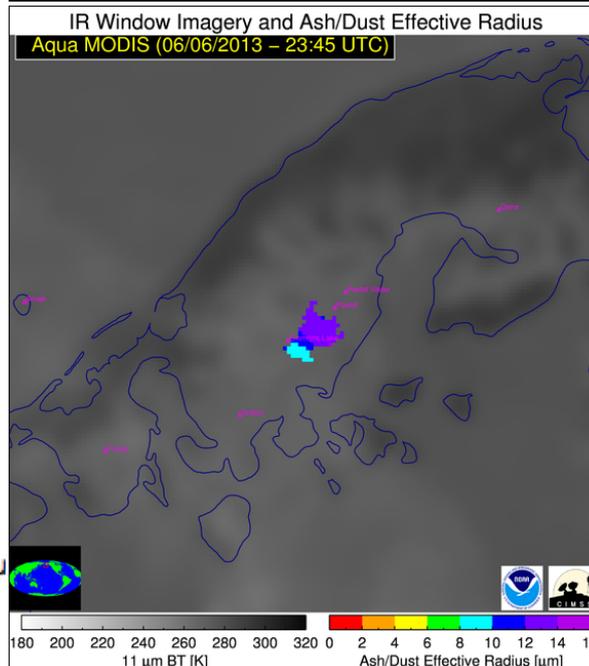
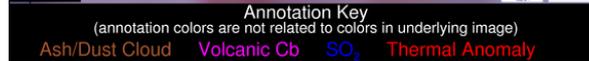
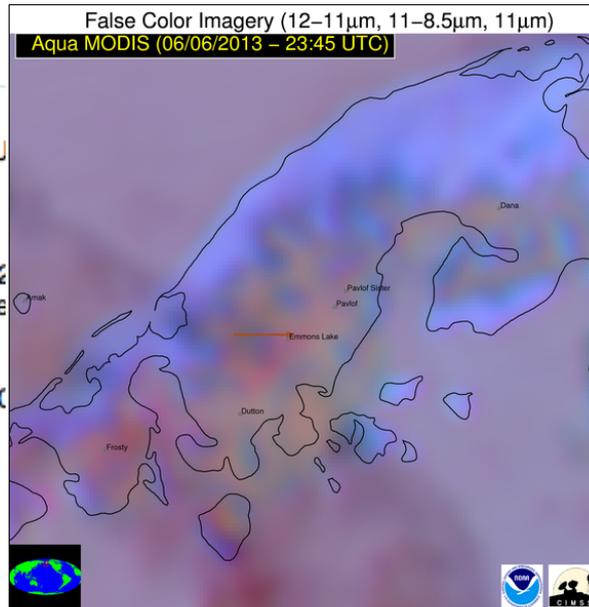
Median Effective Particle Radius: 12.55 [um]

Total Area: 110.31 [km^2]

Geographic Regions of Nearby Volcanoes: Alaska Peninsu

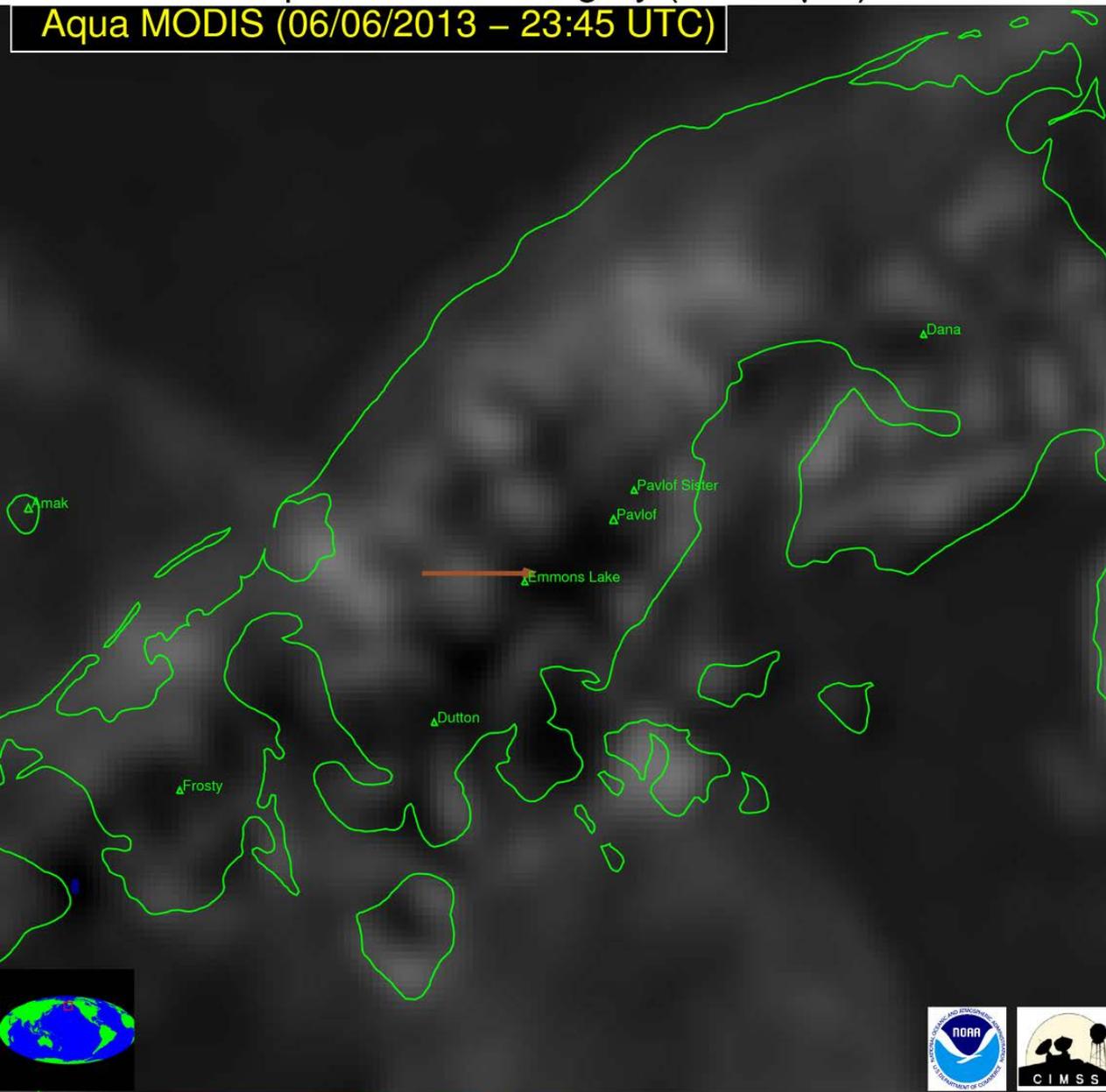
VAAC Regions of Nearby Volcanoes: Anchorage

FIR Regions of Nearby Volcanoes: Unknown

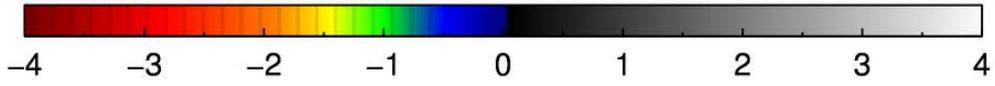


Split-Window Imagery (11–12 μm)

Aqua MODIS (06/06/2013 – 23:45 UTC)



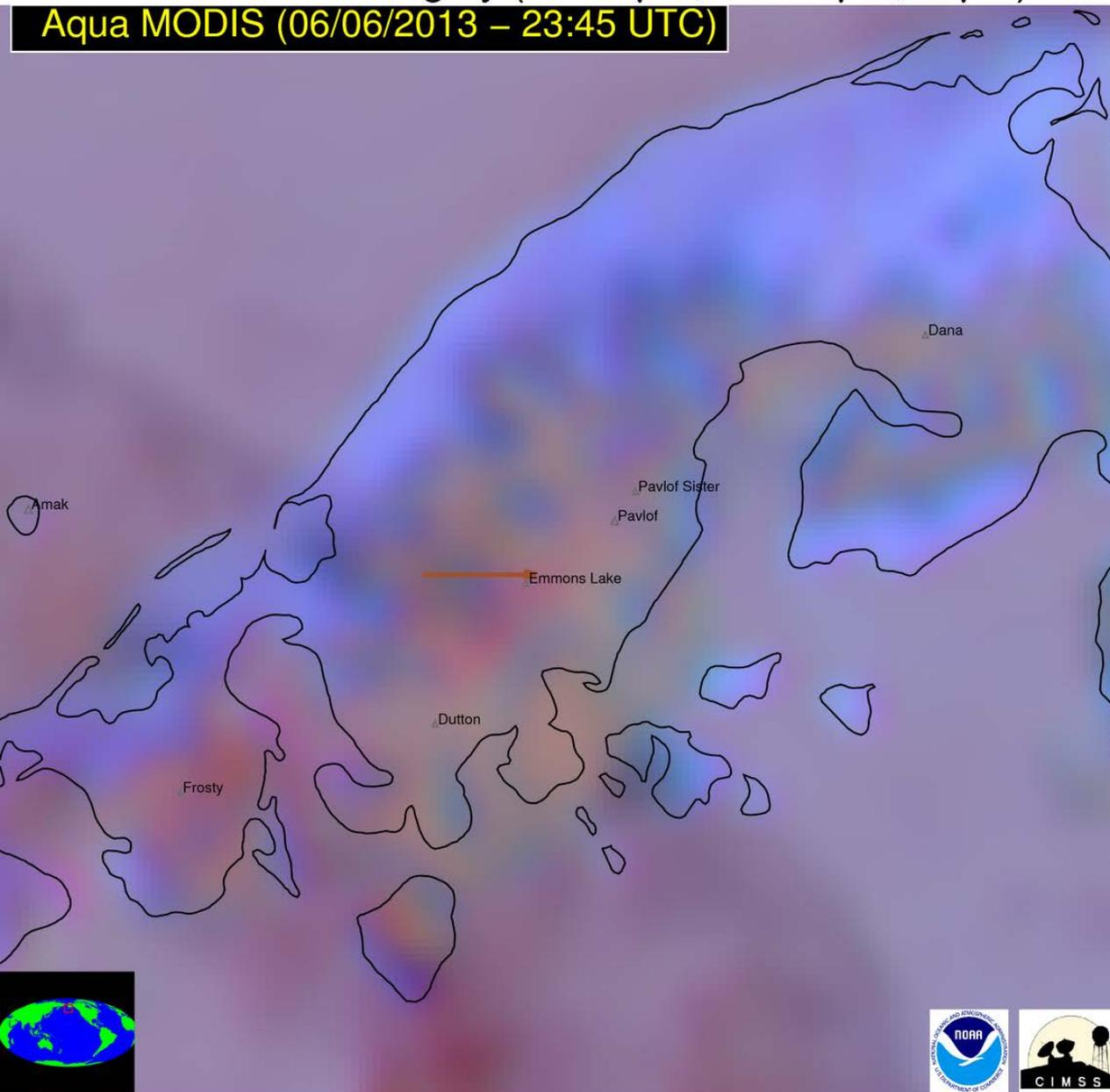
The detected cloud does not have strong traditional “split-window” signal



BTD[11–12 μm] [K]

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

Aqua MODIS (06/06/2013 - 23:45 UTC)



The detected cloud does not have strong traditional “split-window” signal

Annotation Key

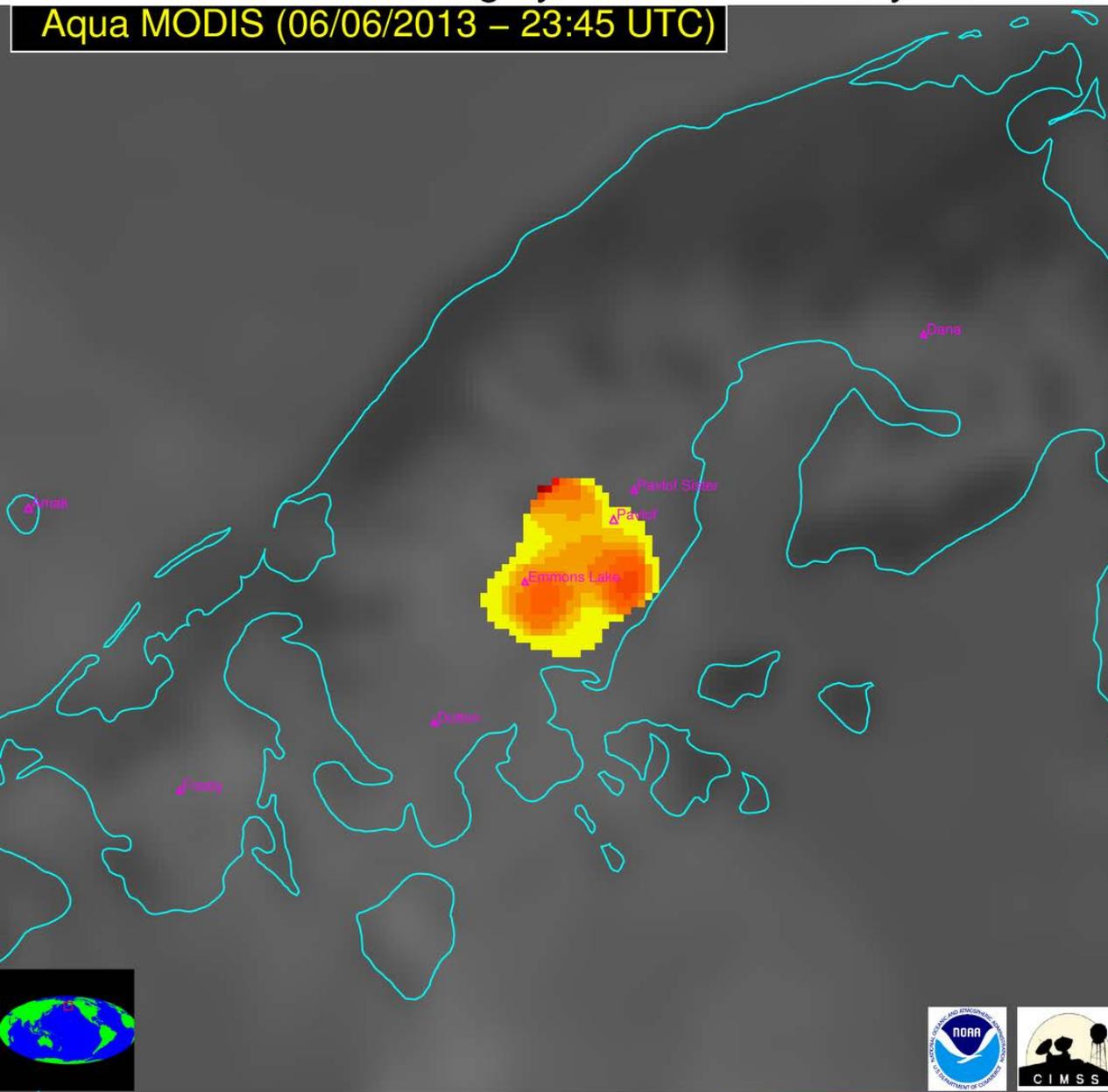
(annotation colors are not related to colors in underlying image)

Ash/Dust Cloud Volcanic Cb SO₂ Thermal Anomaly

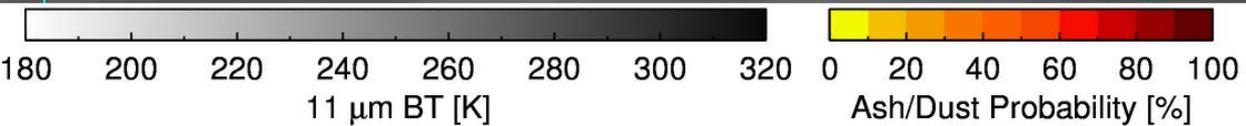


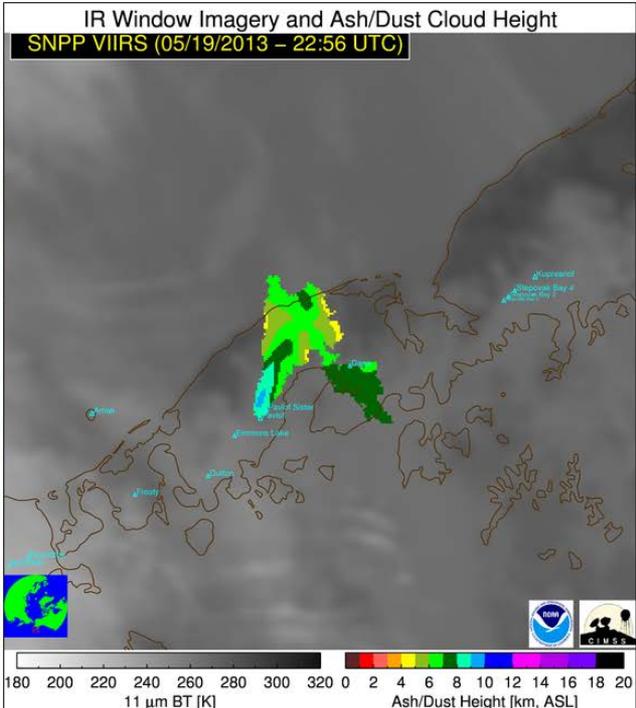
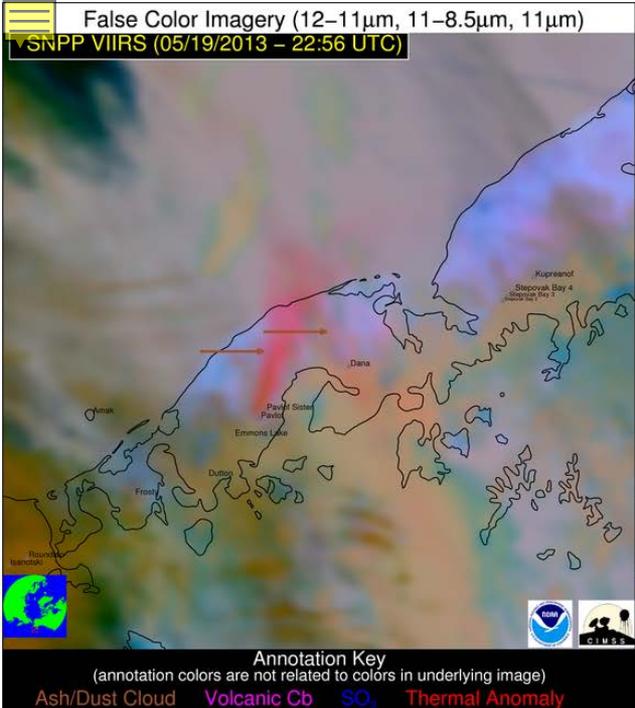
IR Window Imagery and Ash Probability

Aqua MODIS (06/06/2013 – 23:45 UTC)



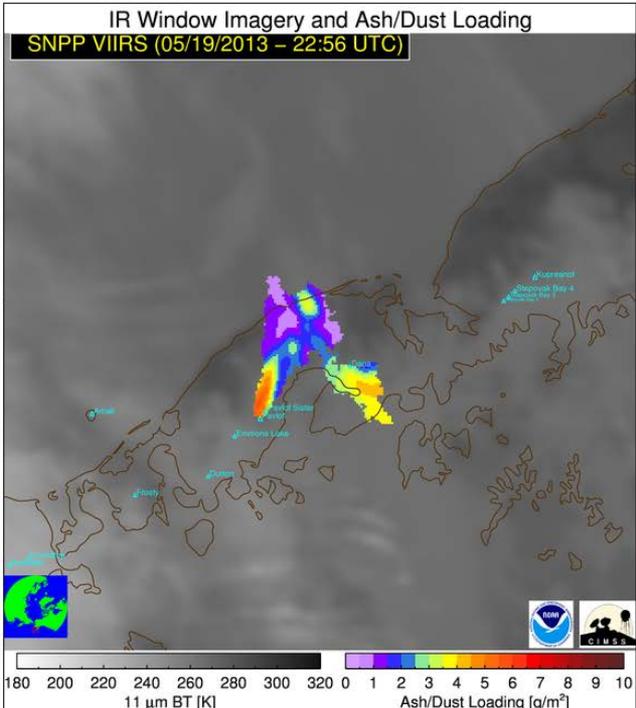
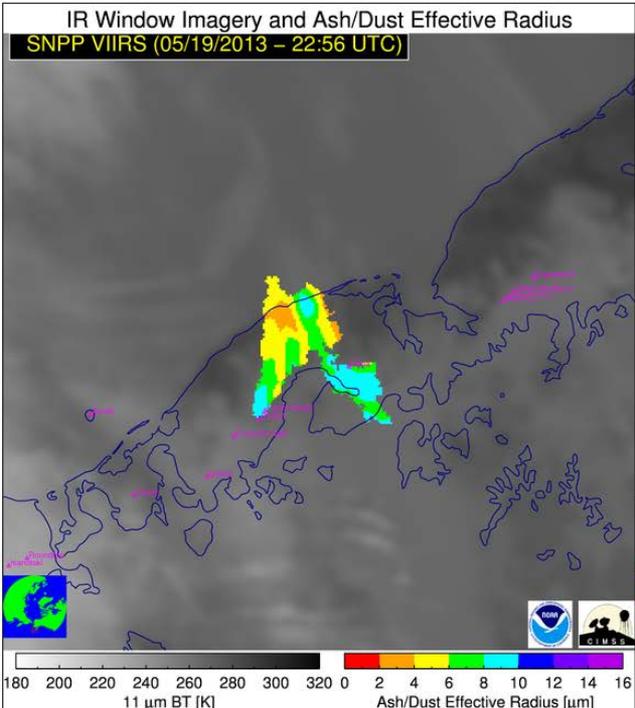
The ash probabilities are consistent with a cloud that is near the limit of detection





Pavlof ash cloud captured by SNPP-VIIRS on May 19, 2013 (22:56 UTC)

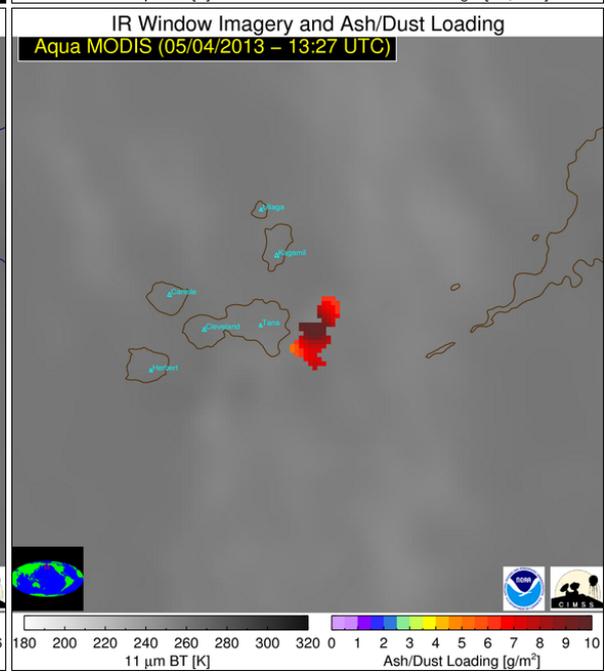
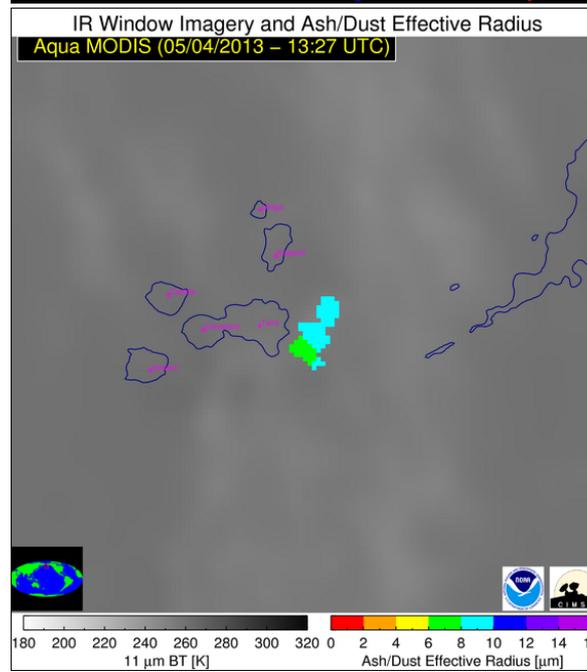
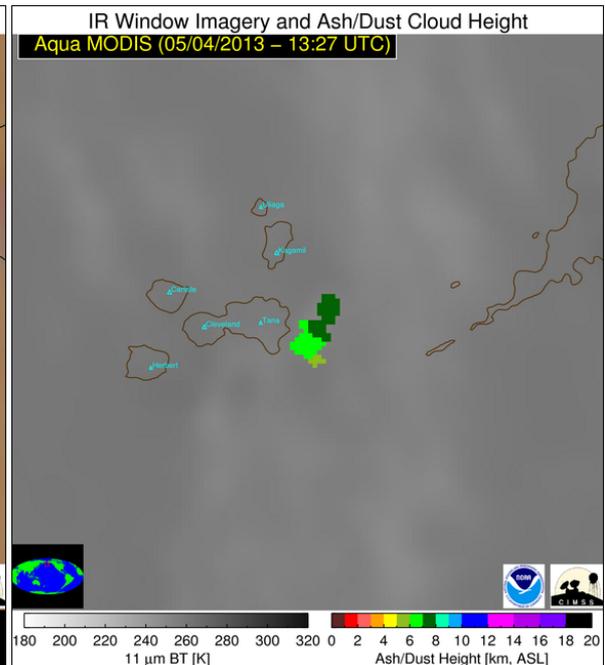
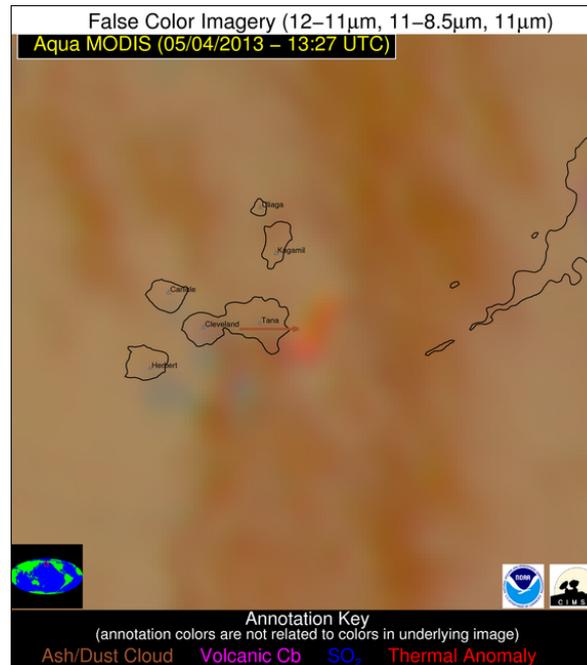
VIIRS will be added to our real-time processing in the coming weeks



The NOAA ash cloud heights agreed well with the wind profile and pilot reports throughout the event so far

Cleveland (5/4/13, 13:27 UTC)

Alert Status	Newly detected feature
Radiative Center (Lat, Lon):	52.831 °, -169.594 °
Mean Viewing Angle	11.98 °
Mean Solar Zenith Angle	105.19 °
Nearby Volcanoes (meeting alert criteria):	Tana (11.59 km)
	Kagamil (17.83 km)
	Cleveland (23.51 km)
Cloud Object Probability	0.00000 %
Median Probability Of Object Pixels	0.00000 %
Percent Unambiguous Pixels	11.13000 %
Maximum Height [amsl]	8.60 km
90th Percentile Height [amsl]	7.70 km
Mean Tropopause Height [amsl]	10.30 km
Total Mass	0.000000 Tg
Median Effective Particle Radius	8.29 μm
Total Area	87.38 km ²
Geographic Regions Of Nearby Volcanoes	Aleutian Is
Vaac Regions Of Nearby Volcanoes	Unknown
Fir Regions Of Nearby Volcanoes	Unknown



Tungurahua, Ecuador May 11, 2013 (04:15 UTC)

From: Mike Pavolonis <mpav@ssec.wisc.edu>
Subject: NOAA/CIMSS Volcanic Cloud Alert
Date: May 11, 2013 2:27:27 AM CDT
To: Mike Pavolonis <mpav@ssec.wisc.edu>

@*****VOLCANIC ALERTS*****

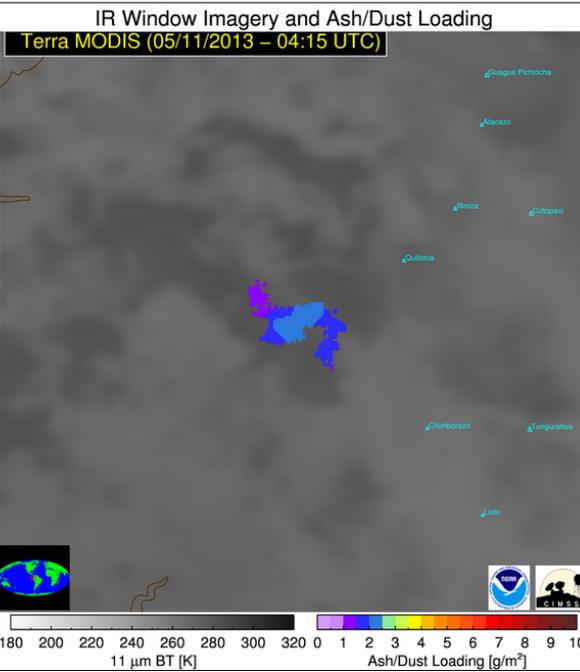
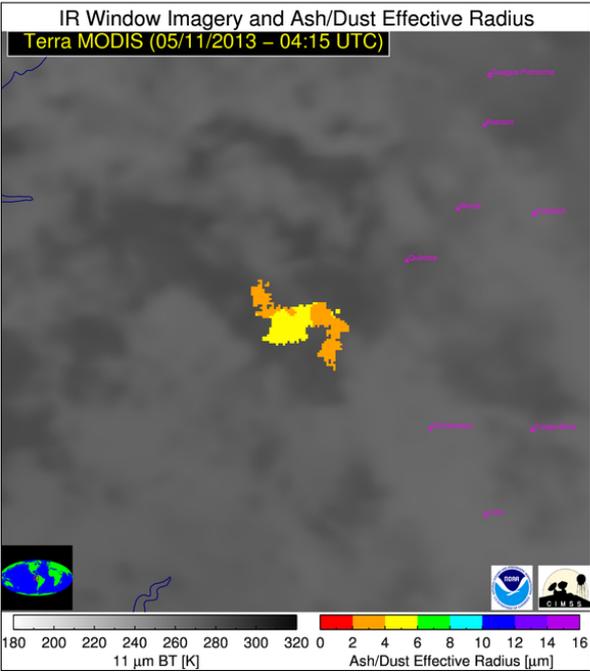
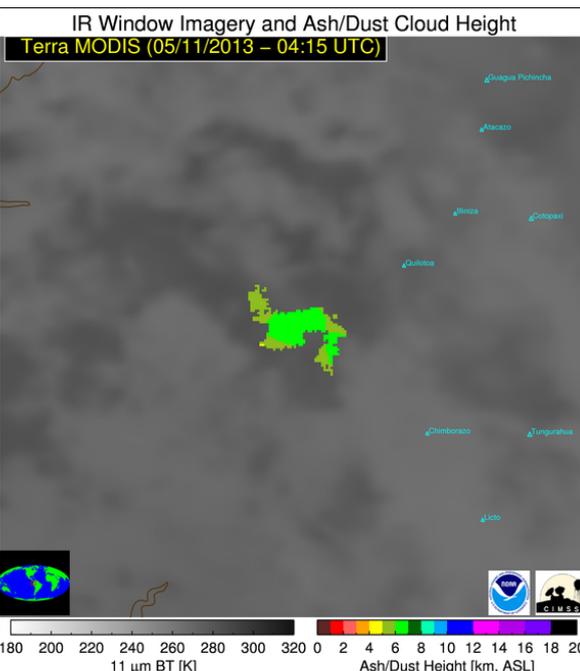
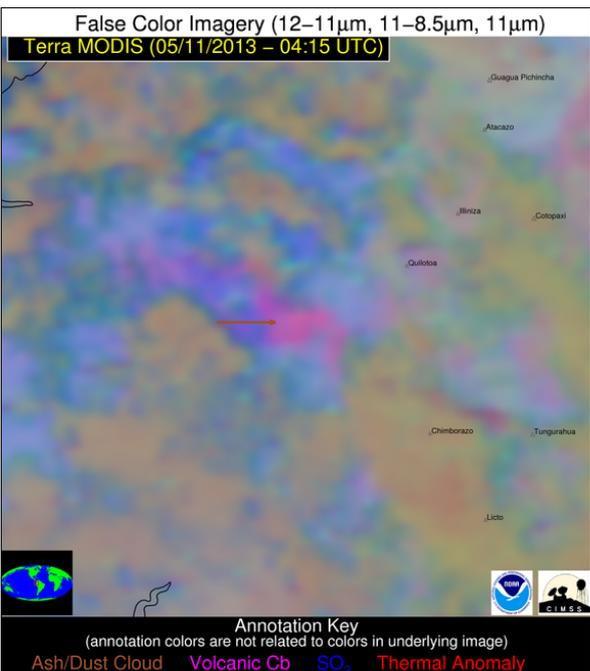
STARTING DATE/TIME OF IMAGE: 2013-05-11 04:15:00 [UTC]
PRIMARY INSTRUMENT: Terra MODIS
WMO SPACECRAFT ID: 783
LOCATION/ORBIT: LEO
L1 FILE: MOD021KM.A2013131.0415.005.2013131060106.NRT
VOLCANO DATABASE: /data/common/VOLCAT_DATA/alerts/V
NUMBER OF ASH CLOUD ALERTS: 1
NUMBER OF VOLCANIC Cb ALERTS: 0
NUMBER OF VOLCANIC THERMAL ANOMALY ALERTS: 0
NUMBER OF SO2 CLOUD ALERTS: 0

REPORT WITH IMAGES:
<http://volcano.ssec.wisc.edu/alert/report/2730>

POSSIBLE VOLCANIC ASH CLOUD FOUND

Alert Status: Newly detected feature
Latitude of Radiative Center: -1.177 [degrees]
Longitude of Radiative Center: -79.193 [degrees]
Mean Viewing Angle: 54.18 [degrees]
Mean Solar Zenith Angle: 158.24 [degrees]
Nearby Volcanoes (meeting alert criteria):
Quilotoa(48.86 km)
Chimborazo(52.77 km)
Illiniza(78.51 km)
Tungurahua(89.58 km)
Licto(93.08 km)
Cloud Object Probability: 99.98998 [%]
Median Probability of Object Pixels: 95.22222 [%]
Percent Unambiguous Pixels: 12.03986 [%]
Maximum Height [AMSL]: 7.0 [km] (22878.45 [ft])
90th Percentile Height [AMSL]: 6.4 [km] (21159.78 [ft])
Mean Tropopause Height [AMSL]: 16.9 [km] (55456.97 [ft])
Total Mass: .001352 [Tg]
Median Effective Particle Radius: 3.70 [um]
Total Area: 743.71 [km^2]

Geographic Regions of Nearby Volcanoes: Ecuador
VAAC Regions of Nearby Volcanoes: Washington
FIR Regions of Nearby Volcanoes: Unknown



Popocatepetl, Mexico May 12, 2013 (05:05 UTC)

From: Mike Pavolonis <mpav@ssec.wisc.edu>
Subject: NOAA/CIMSS Volcanic Cloud Alert
Date: May 12, 2013 2:36:31 AM CDT
To: Mike Pavolonis <mpav@ssec.wisc.edu>

@*****VOLCANIC ALERTS*****

STARTING DATE/TIME OF IMAGE: 2013-05-12 05:05:00 [UTC]
PRIMARY INSTRUMENT: Terra MODIS
WMO SPACECRAFT ID: 783
LOCATION/ORBIT: LEO
L1 FILE: MOD021KM.A2013132.0505.005.2013132063818.NF
VOLCANO DATABASE: /data/common/VOLCAT_DATA/alerts/
NUMBER OF ASH CLOUD ALERTS: 1
NUMBER OF VOLCANIC Cb ALERTS: 0
NUMBER OF VOLCANIC THERMAL ANOMALY ALERTS: 0
NUMBER OF SO2 CLOUD ALERTS: 0

REPORT WITH IMAGES:

<http://volcano.ssec.wisc.edu/alert/report/2742>

POSSIBLE VOLCANIC ASH CLOUD FOUND

Alert Status: Newly detected feature

Latitude of Radiative Center: 19.046 [degrees]

Longitude of Radiative Center: -98.600 [degrees]

Mean Viewing Angle: 30.16 [degrees]

Mean Solar Zenith Angle: 137.38 [degrees]

Nearby Volcanoes (meeting alert criteria):

Popocatepetl(3.47 km)

Iztaccihuatl(15.45 km)

Papayo(31.06 km)

Chichinautzin(56.31 km)

Malinche, La(63.14 km)

Cloud Object Probability: 100.00000 [%]

Median Probability of Object Pixels: 98.62222 [%]

Percent Unambiguous Pixels: 42.19191 [%]

Maximum Height [AMSL]: 8.7 [km] (28583.91 [ft])

90th Percentile Height [AMSL]: 7.1 [km] (23401.25 [ft])

Mean Tropopause Height [AMSL]: 18.6 [km] (61117.22 [ft])

Total Mass: .000592 [Tg]

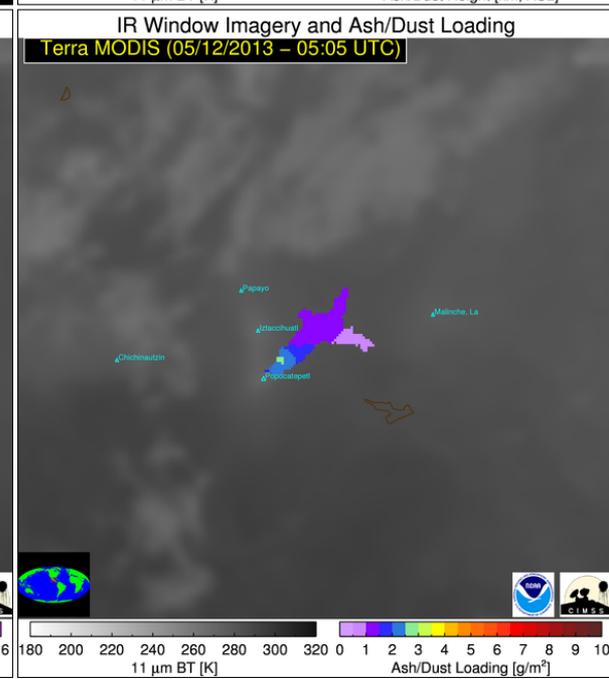
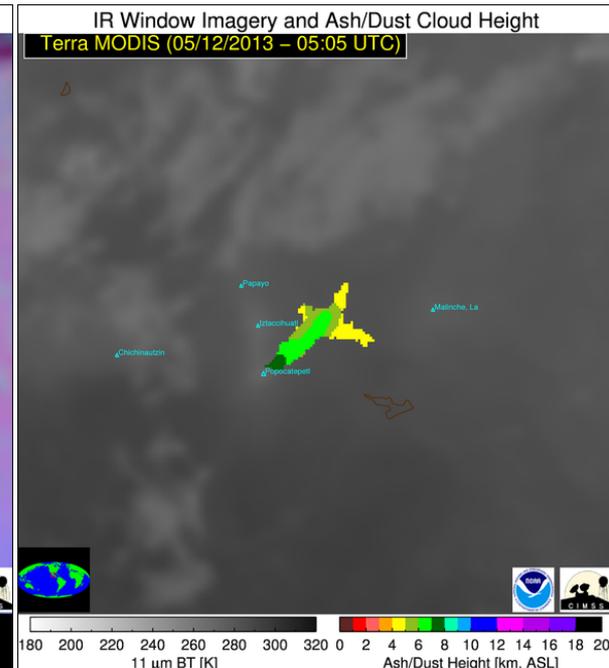
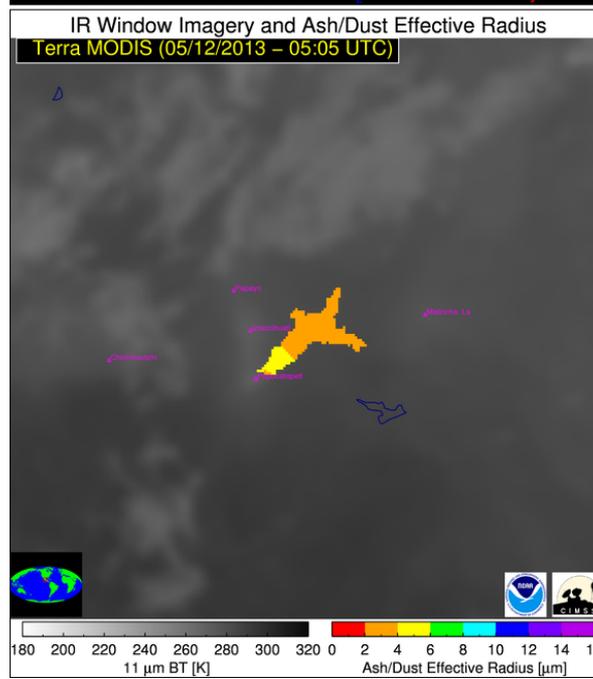
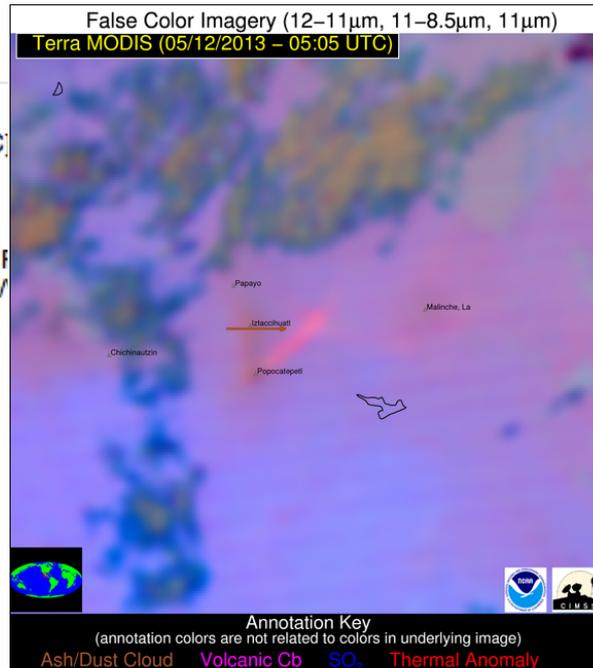
Median Effective Particle Radius: 3.11 [um]

Total Area: 414.75 [km^2]

Geographic Regions of Nearby Volcanoes: Mexico

VAAC Regions of Nearby Volcanoes: Washington

FIR Regions of Nearby Volcanoes: Unknown



Sakura-jima, Japan May 25, 2013 (05:05 UTC)

From: Mike Pavolonis <mpav@ssec.wisc.edu>
Subject: NOAA/CIMSS Volcanic Cloud Alert
Date: May 25, 2013 3:25:36 AM CDT
To: Mike Pavolonis <mpav@ssec.wisc.edu>

@*****VOLCANIC ALERTS*****

STARTING DATE/TIME OF IMAGE: 2013-05-25 05:05:00 [UTC]
PRIMARY INSTRUMENT: Aqua MODIS
WMO SPACECRAFT ID: 784
LOCATION/ORBIT: LEO
L1 FILE: MYD021KM.A2013145.0505.005.2013145071744.N
VOLCANO DATABASE: /data/common/VOLCAT_DATA/alerts
NUMBER OF ASH CLOUD ALERTS: 1
NUMBER OF VOLCANIC Cb ALERTS: 0
NUMBER OF VOLCANIC THERMAL ANOMALY ALERTS: 0
NUMBER OF SO2 CLOUD ALERTS: 0

REPORT WITH IMAGES:

<http://volcano.ssec.wisc.edu/alert/report/3750>

POSSIBLE VOLCANIC ASH CLOUD FOUND

Alert Status: Newly detected feature

Latitude of Radiative Center: 31.537 [degrees]

Longitude of Radiative Center: 130.457 [degrees]

Mean Viewing Angle: 53.18 [degrees]

Mean Solar Zenith Angle: 27.20 [degrees]

Nearby Volcanoes (meeting alert criteria):

Sakura-jima(19.72 km)

Sumiyoshi-ike(28.84 km)

Ibusuki Volc Field(37.16 km)

Kirishima(58.36 km)

Cloud Object Probability: 100.00000 [%]

Median Probability of Object Pixels: 99.63773 [%]

Percent Unambiguous Pixels: 39.48117 [%]

Maximum Height [AMSL]: 6.2 [km] (20225.15 [ft])

90th Percentile Height [AMSL]: 4.6 [km] (15122.73 [ft])

Mean Tropopause Height [AMSL]: 16.4 [km] (53729.30 [ft])

Total Mass: .001009 [Tg]

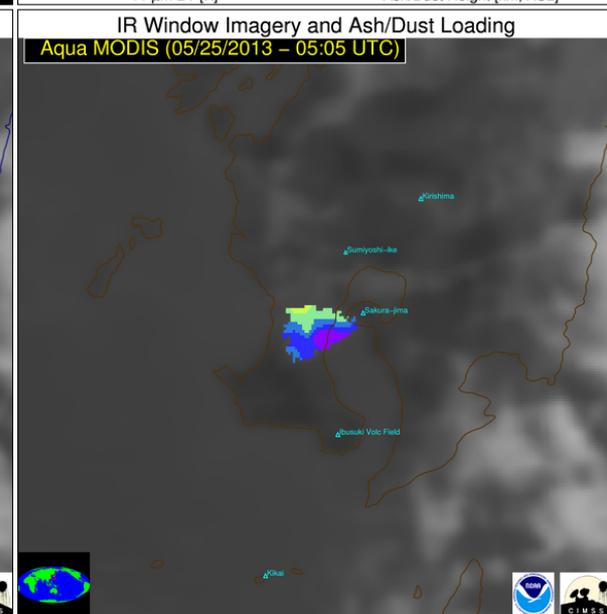
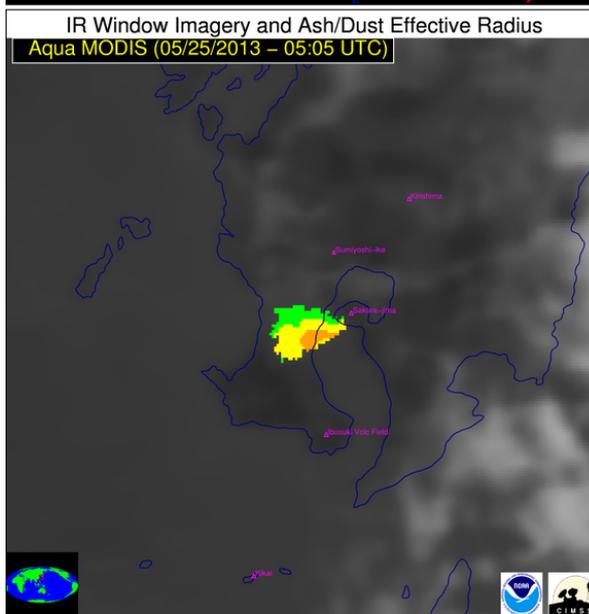
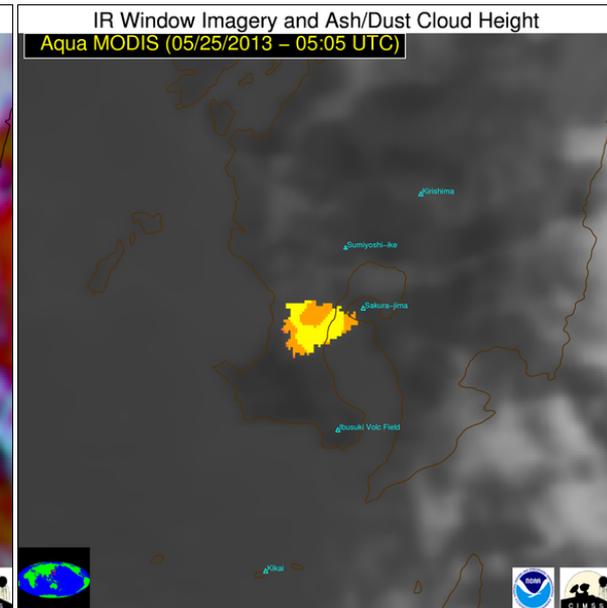
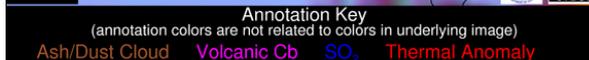
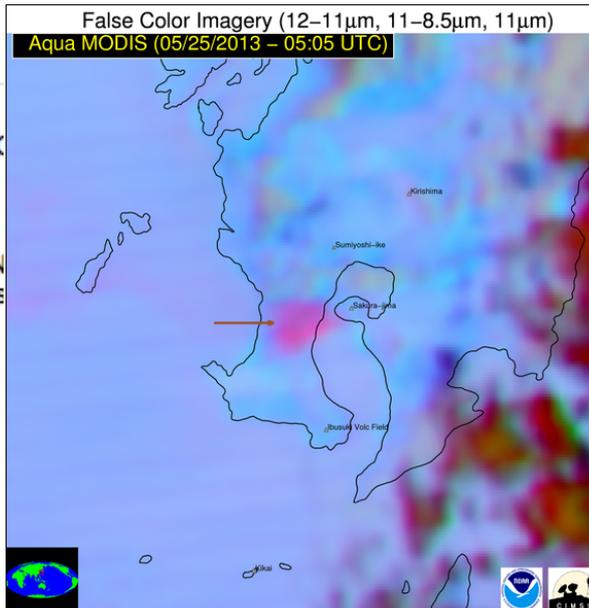
Median Effective Particle Radius: 5.43 [um]

Total Area: 471.86 [km^2]

Geographic Regions of Nearby Volcanoes: Kyushu-Japan

VAAC Regions of Nearby Volcanoes: Tokyo

FIR Regions of Nearby Volcanoes: Unknown





Short-term Work



- **Continue to fine tune system configuration for all current satellites**
- **Continue development of web portal**
- **Make sure interested users have access to products in a desirable manner**
- **Update Alaska training module**



Long-term Future Work (pending funding)

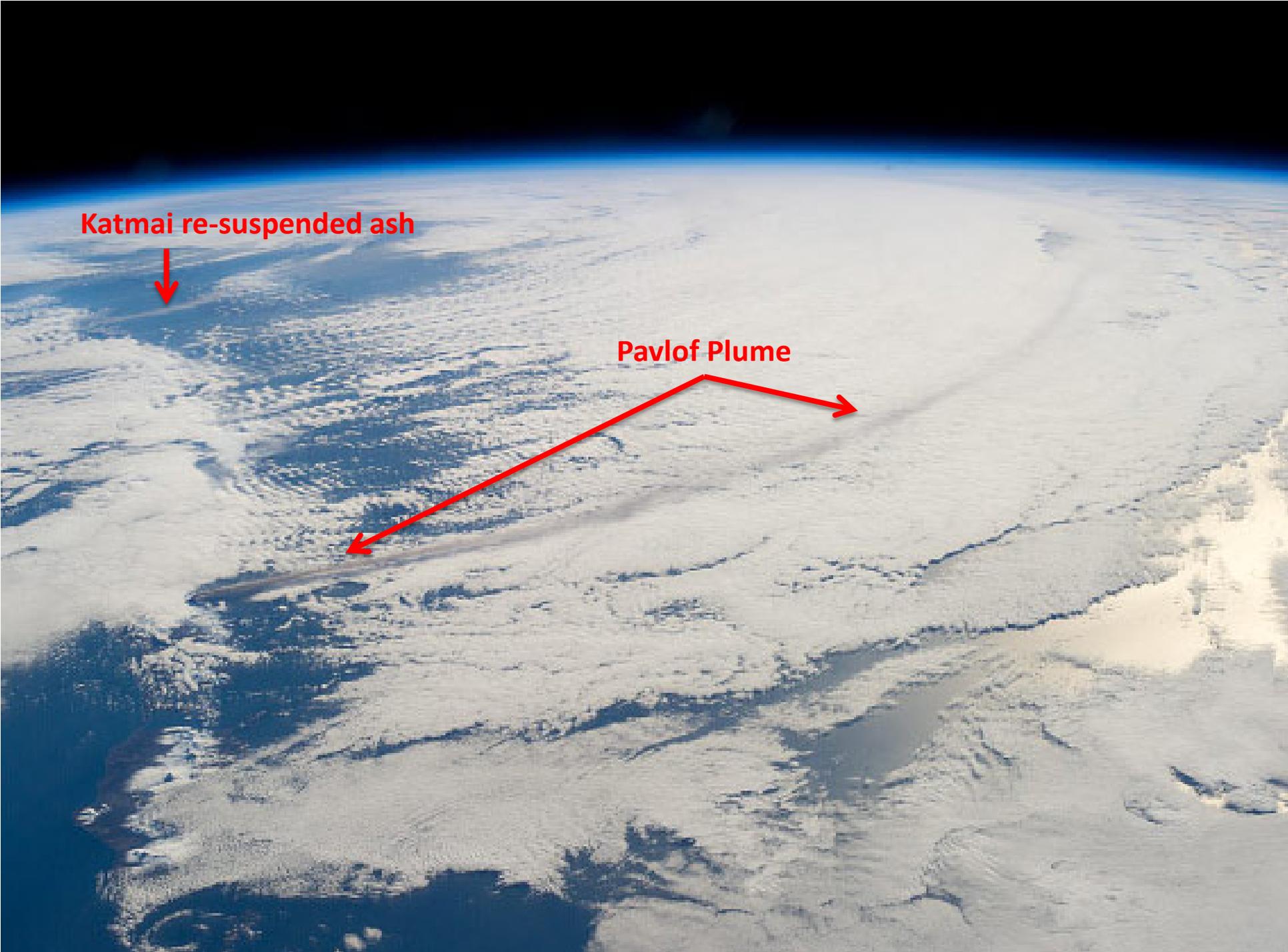


- Combine measurements from different sensors on same spacecraft (imager + sounder)
- Development of SO₂ component of system
- Integrate WWLN lightning
- Alert on spaceborne lidar overpasses through volcanic clouds
- Dispersion model applications
- Partner with USGS to incorporate other relevant data sources (e.g. seismic, infrasound, GPS, radar, web cams)
- *Working towards a complete decision support information system that synthesizes a large number of observations to generate an optimal analysis of volcanic cloud properties and improved dispersion forecasts*

Katmai re-suspended ash



Pavlof Plume



References

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