Supporting Alaska Region National Weather Service Volcanic Ash Advisory Center and Weather Forecast Offices with IMAPP Processing

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Outline

- Data processing flow/history
- GOES-R/JPSS Proving Ground (PG) Product Descriptions and Examples
- Feedback from Operations to Research
- Looking to the future

Processing Flow

Data are distributed to Anchorage, Fairbanks, and Juneau NWS WFOs and NWS Alaska Region HQ

Data latency: Processing at UW-CIMSS is complete 10-40 minutes after MODIS date/time stamp. Most of the latency is from data transfer—and it varies. Total latency is 30-60 minutes by the time data reaches NWS work stations.

Volume: 11-20 successfully geo-located Terra and Aqua granules per day.

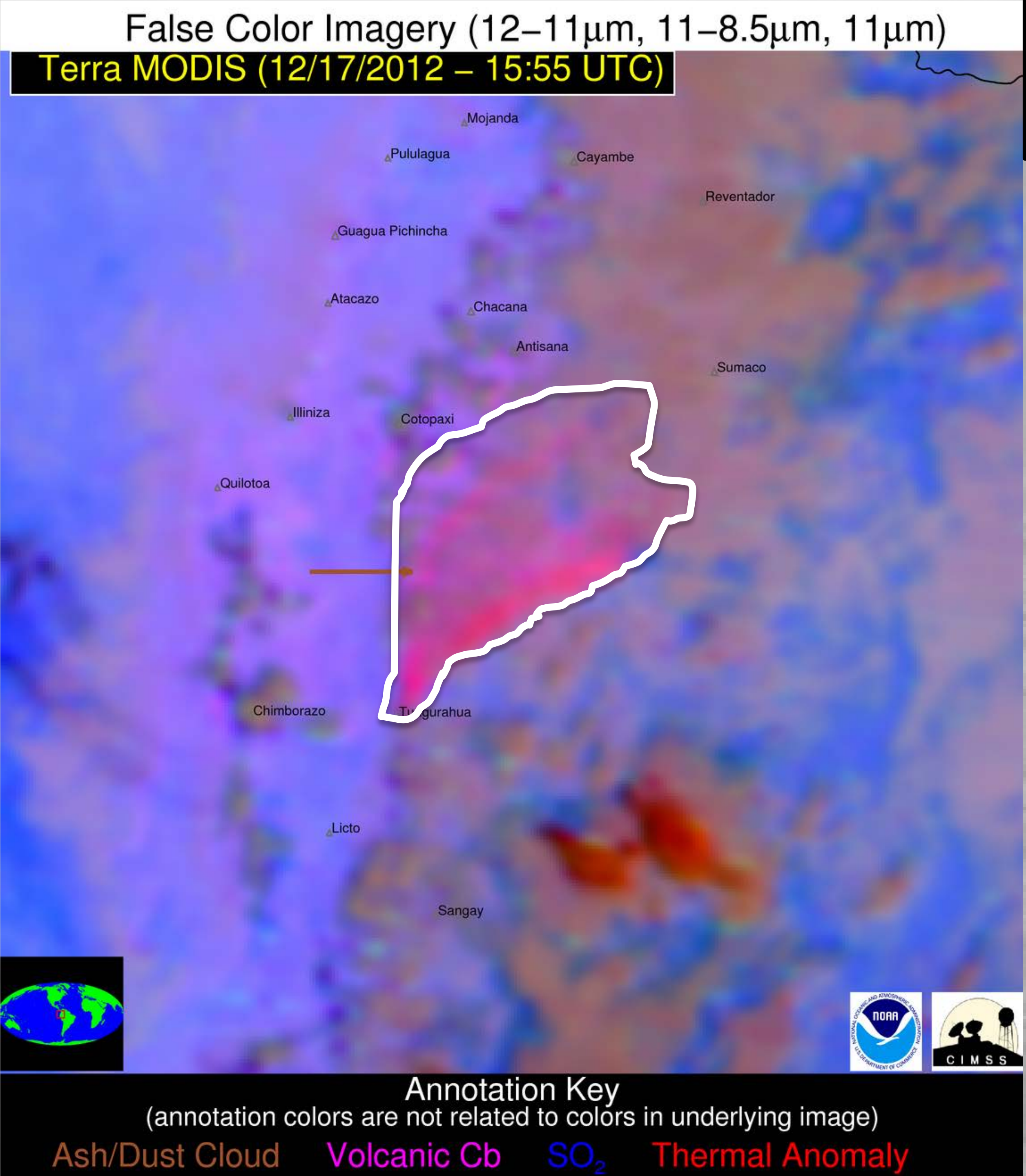
UAF-GINA processing began Fall 2010; since have added direct broadcast antennas from University of Wisconsin, US Park Service in Utah and plan on adding Hawaii antenna later in 2013.

GOES-R and JPSS Proving Ground

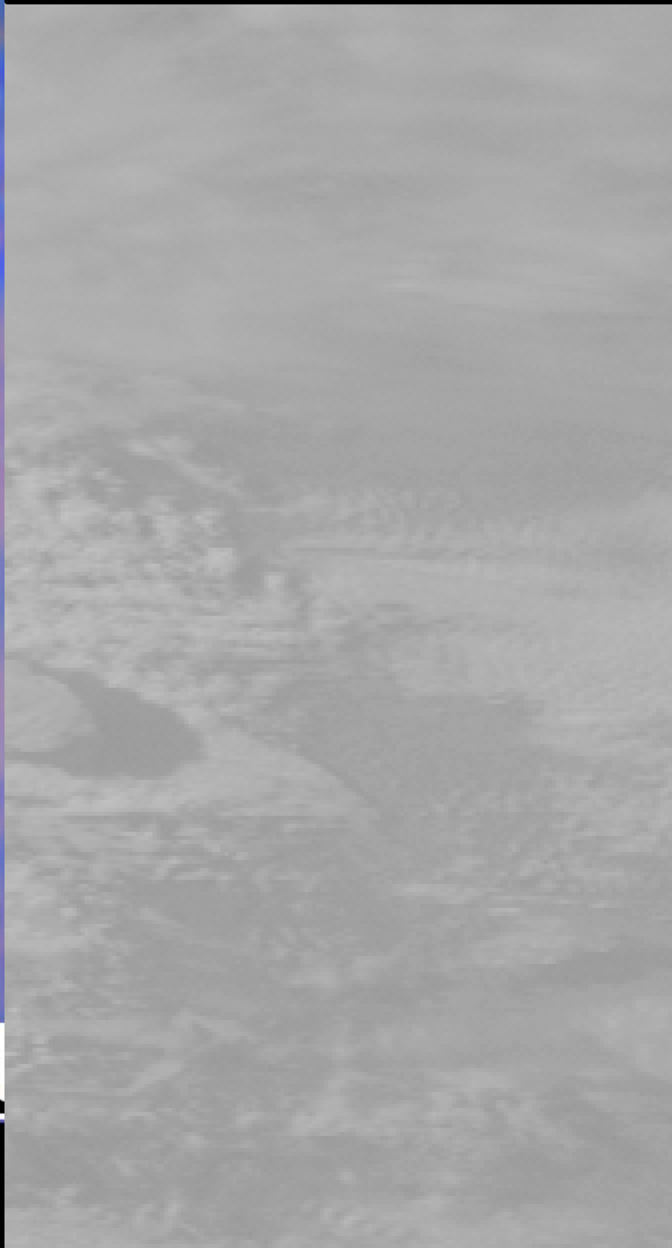
- Demonstrate new products/algorithms to National Weather Service forecasters
  - Ensure Day 1 Readiness
  - Provide iterative feedback to improve products
- Alaska region is focused on two GOES-R/JPSS product suites
  - Volcanic Ash Detection and Physical Retrievals
  - Fog / Low Stratus Detection

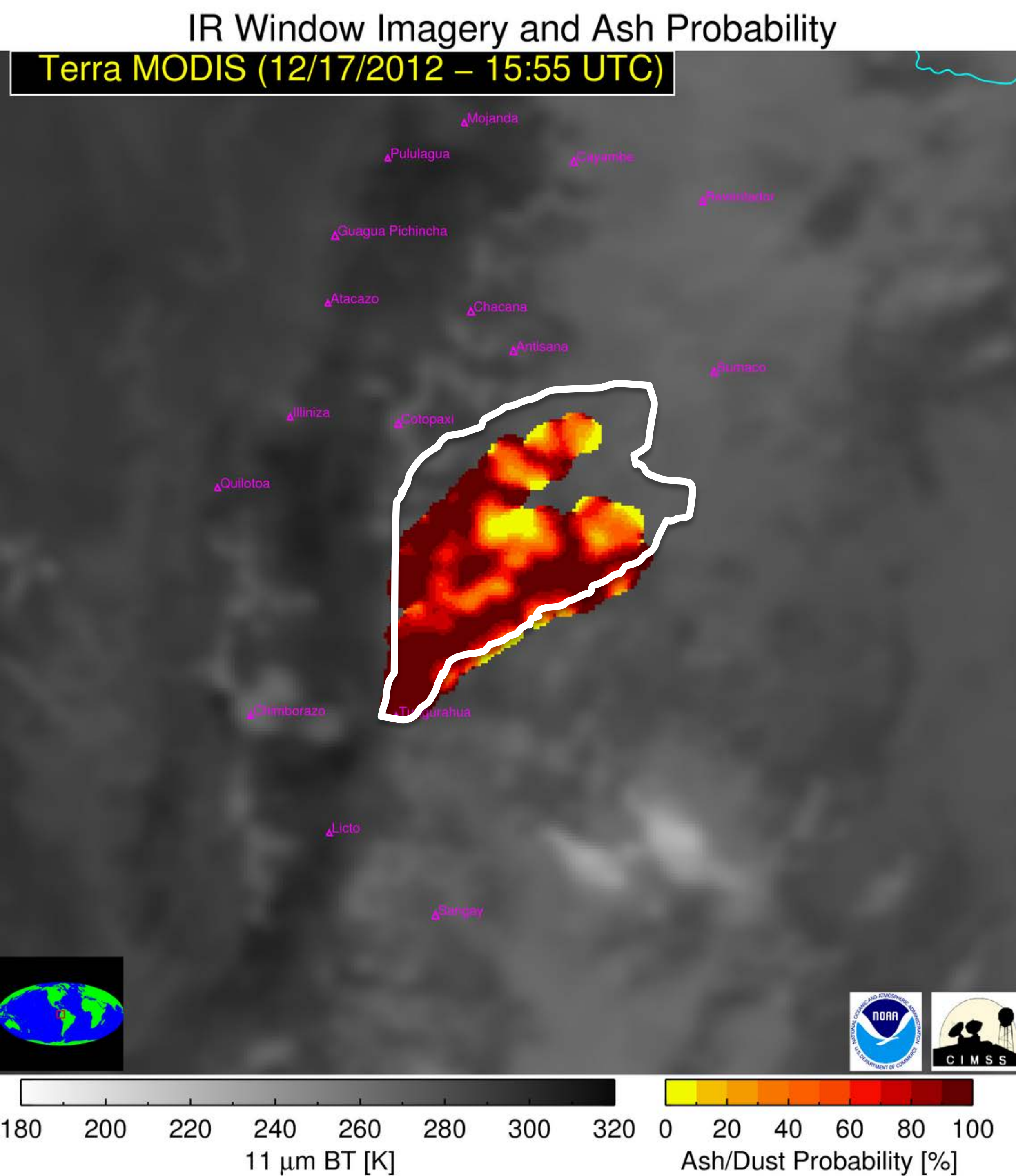
Volcanic Ash Detection and Physical Retrievals

- Automated ash cloud detection—Bayesian Model utilizes spectral and spatial quantities to mimic trained human analyst
- Retrieve physical properties of ash clouds
  - Ash cloud-top height
  - Column ash mass loading
  - Ash particle effective radius
- Ash detection and physical retrievals are input into automated ash alert system being developed by NOAA/UW-CIMSS



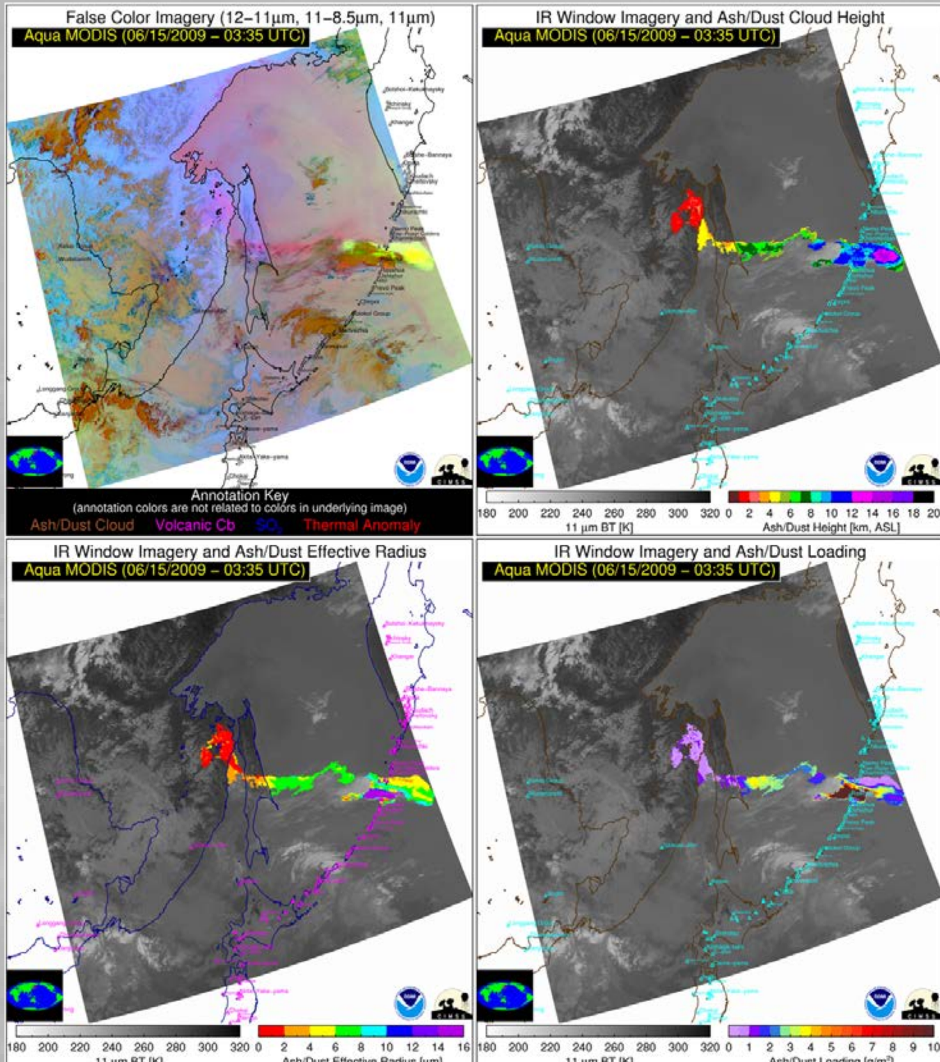
A manual analysis of this image suggests the horizontal boundary depicted in white





The horizontal extent of the ash cloud determined by GOES-R/JPSS automated computer algorithm agrees very well with the bounds derived from manual analysis of multi-spectral imagery

While a very well trained human will most often slightly out-perform the computer algorithm, the automated detection results are accurate enough to be used to issue alerts when an ash cloud is found (and eventually initialize dispersion models)



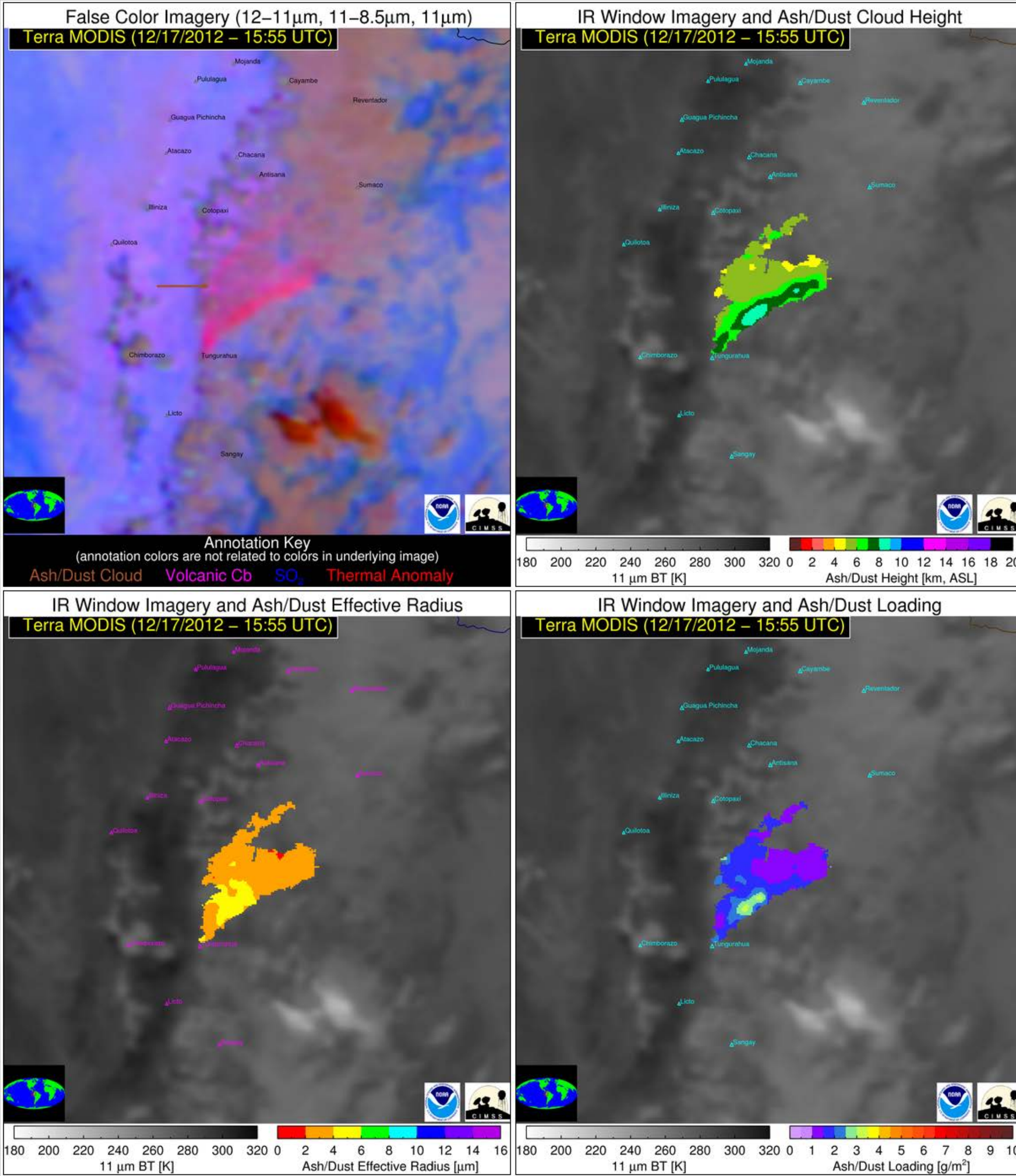
- **An optimal estimation approach is used to retrieve the ash cloud temperature, 11 µm emissivity, and β(12/11 µm)**

- **The ash cloud height can be estimated from the cloud temperature using an atmospheric profile and the mass loading and effective particle radius can be estimated from the 11 µm emissivity and β(12/11 µm)**

- **A negative split-window BTD need not be present. See Pavolonis et al. (2013) for details.**

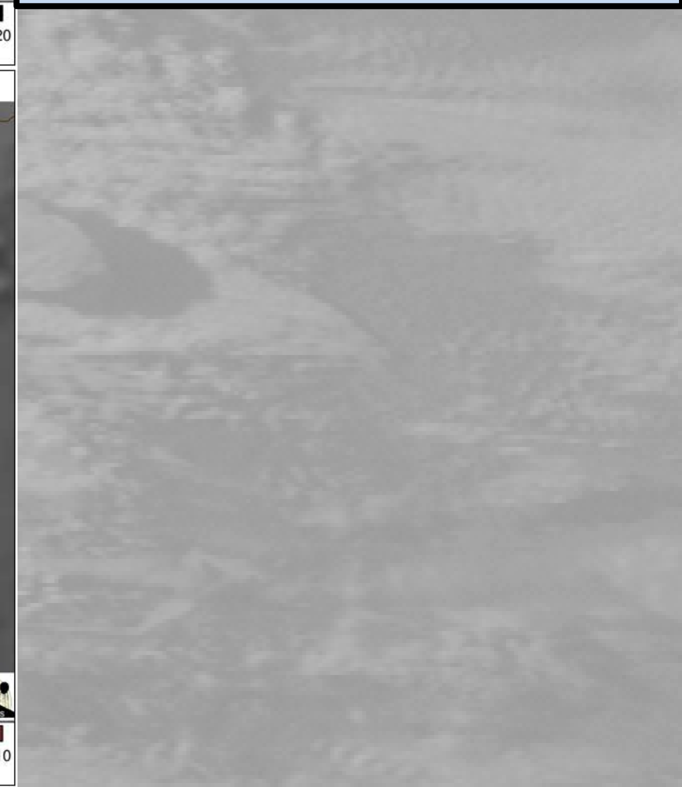
The retrieval solution is determined from a weighted combination of the difference between the measurements and forward model and the first guess

$$\delta x = S_x\{K^T S_y^{-1}[y - f(x)] + S_a^{-1}(x_a - x)\}$$



Example of physically derived quantities include ash cloud-top height (upper right), ash effective radius (lower left), and column mass loading (lower right).

Physical retrievals utilize multi-spectral optimal estimation approach using 11, 12, and 13.3 µm channels



Automated Alert Example from Pavlof Volcano Eruption 16 May 2013

Thunderbird File Edit View

Inbox | NOAA

Get Mail | Write | Chat | Reply

From Mike Pavolonis
Subject NOAA/CIMSS Volcanic Cloud Alert
To Justin Sieglaff

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@**********VOLCANIC ALERTS**********
STARTING DATE/TIME OF IMAGE: 2013-05-16
PRIMARY INSTRUMENT: Aqua MODIS
WMO SPACECRAFT ID: 784
LOCATION/ORBIT: LEO
L1 FILE: MYD021KM.A2013136.1350.005.201
VOLCANO DATABASE: /data/common//VOLCAT_
NUMBER OF ASH CLOUD ALERTS: 1
NUMBER OF VOLCANIC Cb ALERTS: 0
NUMBER OF VOLCANIC THREMAL ANOMALY ALER
NUMBER OF SO2 CLOUD ALERTS: 0

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

----------------------------------------
POSSIBLE VOLCANIC ASH CLOUD FOUND
Alert Status: Newly detected feature
Latitude of Radiative Center: 55.367 [d
Longitude of Radiative Center: -161.736
Mean Viewing Angle: 46.50 [degrees]
Mean Solar Zenith Angle: 95.30 [degrees
Nearby Volcanoes (meeting alert criteri
                Pavlof(11.07 km)  [Th
          Pavlof Sister(11.73 km)  [Th
            Emmons Lake(21.86 km)
                Dutton(40.52 km)
                  Dana(44.93 km)
Cloud Object Probability: 99.99996 [%]
Median Probability of Object Pixels: 98
Percent Unambiguous Pixels: 16.15809 [%
Maximum Height [AMSL]: 5.8 [km] (19175.
90th Percentile Height [AMSL]: 4.6 [km]
Mean Tropopause Height [AMSL]: 8.8 [km]
Total Mass: .001010 [Tg]
Median Effective Particle Radius: 4.53
Total Area: 606.44 [km^2]

Geographic Regions of Nearby Volcanoes:
VAAC Regions of Nearby Volcanoes: Ancho
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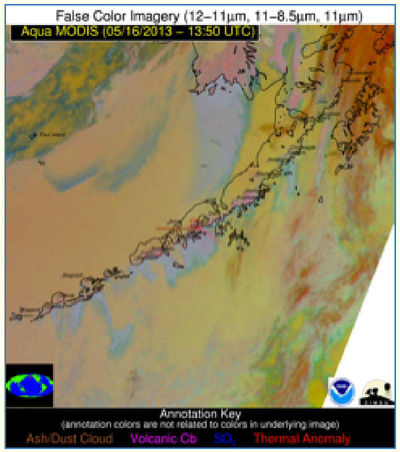
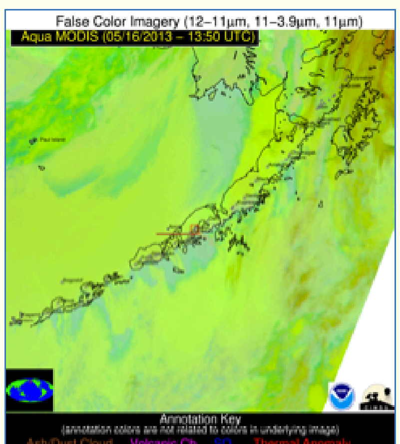
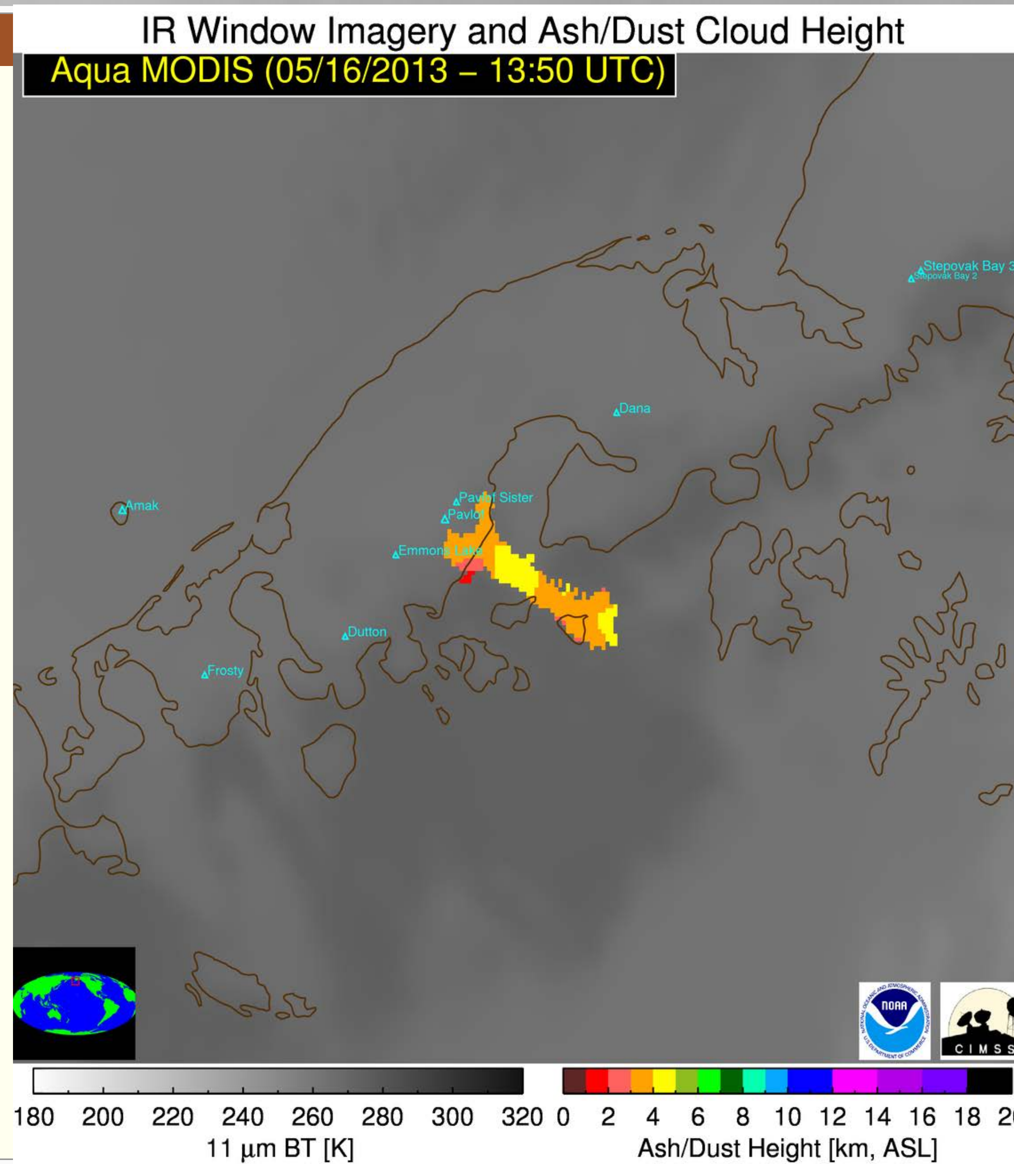
Justin's Email is up to date



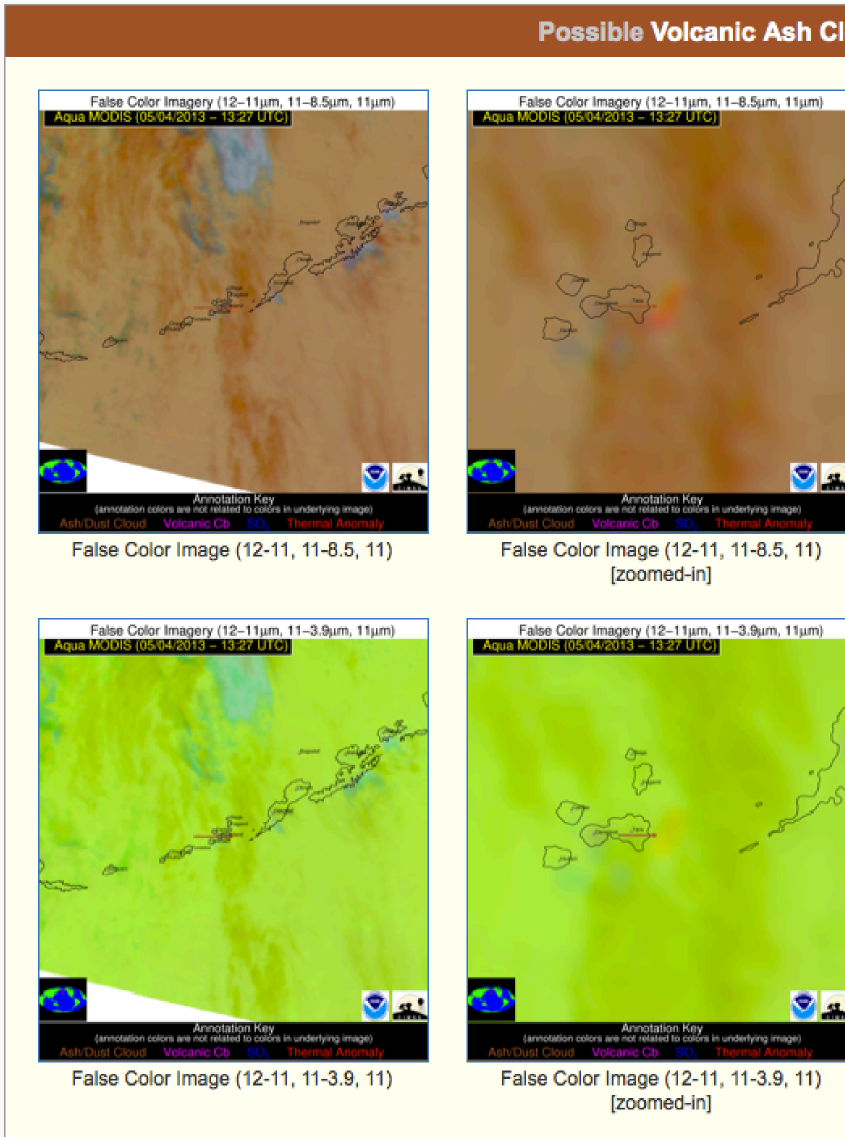
False Color Image (12-11, 11-8.5, 11)

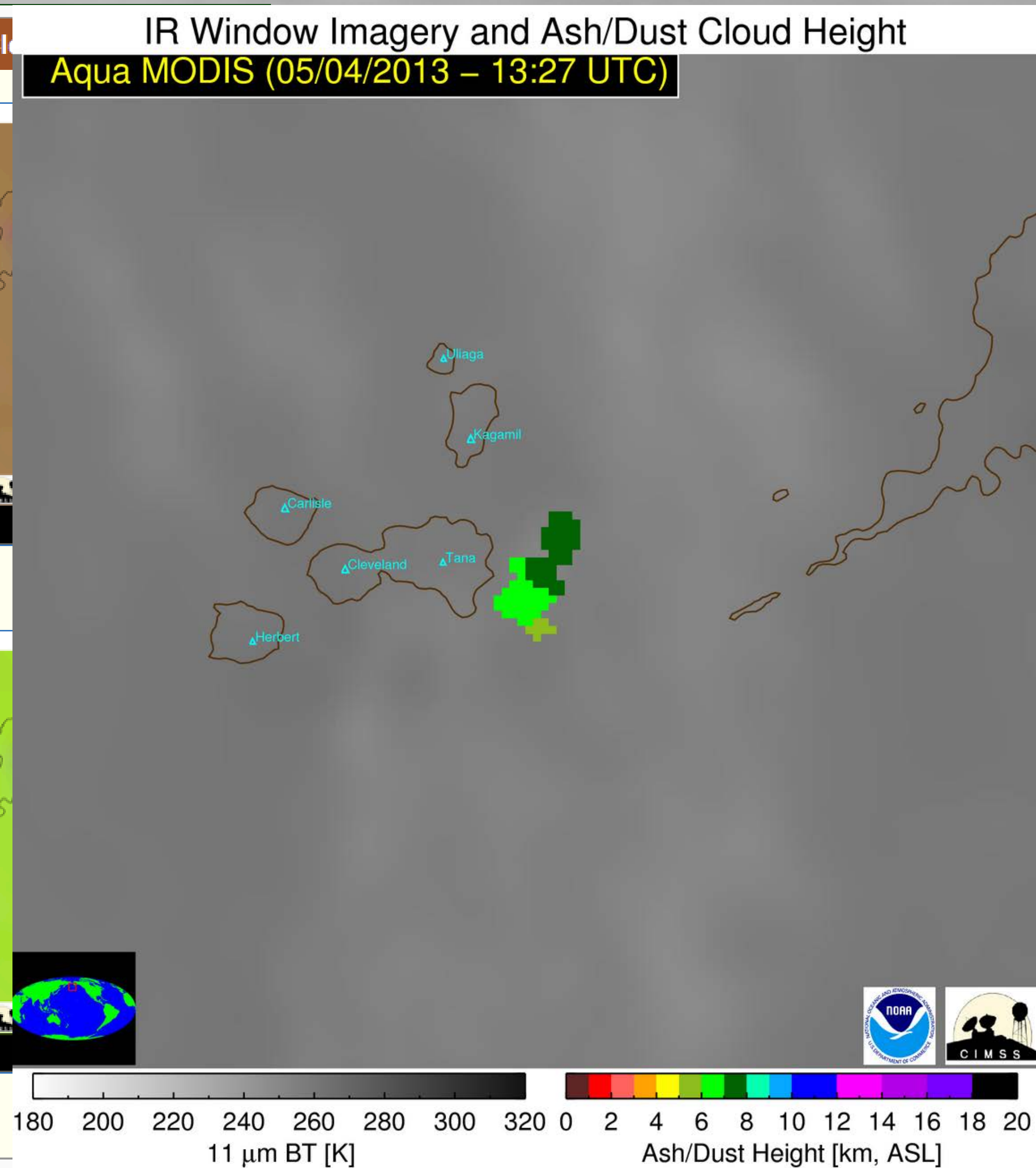


False Color Image (12-11, 11-3.9, 11)



Automated Alert Example from Cleveland Volcano Eruption 4 May 2013





Fog and Low Stratus

- Automated, probabilistic approach combines satellite observations/derived products (cloud-top phase, brightness temperature differences, etc.) and numerical weather prediction model data to determine probability of various aviation flight rules (IFR, LIFR, MVFR)
- Additionally cloud thickness (cloud top height-cloud base height) is also computed

Fused Fog/Low Cloud Detection Approach

Satellite Data

-Minimum channel requirement: 0.65, 3.9, 6.7/7.3, 11, and 12/13.3 µm
-Previous image for temporal continuity (GEO only)
-Cloud Phase

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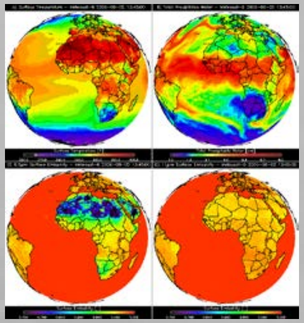
Static Ancillary Data



-DEM
-Surface Type
-Surface Emissivity

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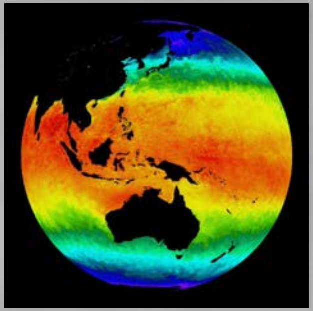
Daily SST Data



0.25 degree OISST

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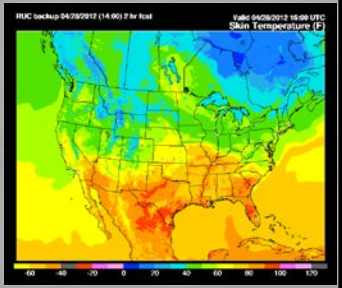
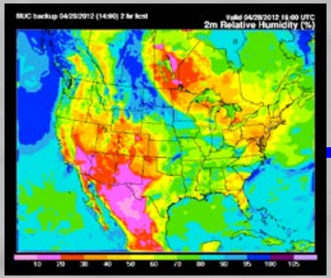
NWP



-Surface Temperature
-Profiles of T and q
-RUC/RAP (2-3 hr forecast) or GFS (12 hr forecast)

Clear Sky RTM

NWP RH Profiles

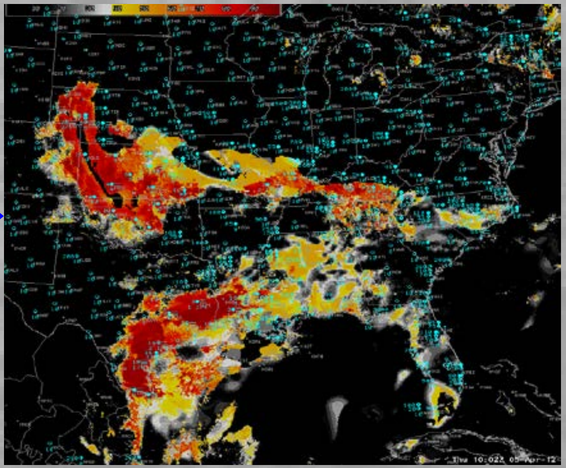


-RUC/RAP (2-3 hr forecast) or GFS (12 hr forecast)

Naïve Bayesian Model

Total run time: 2 - 3 minutes

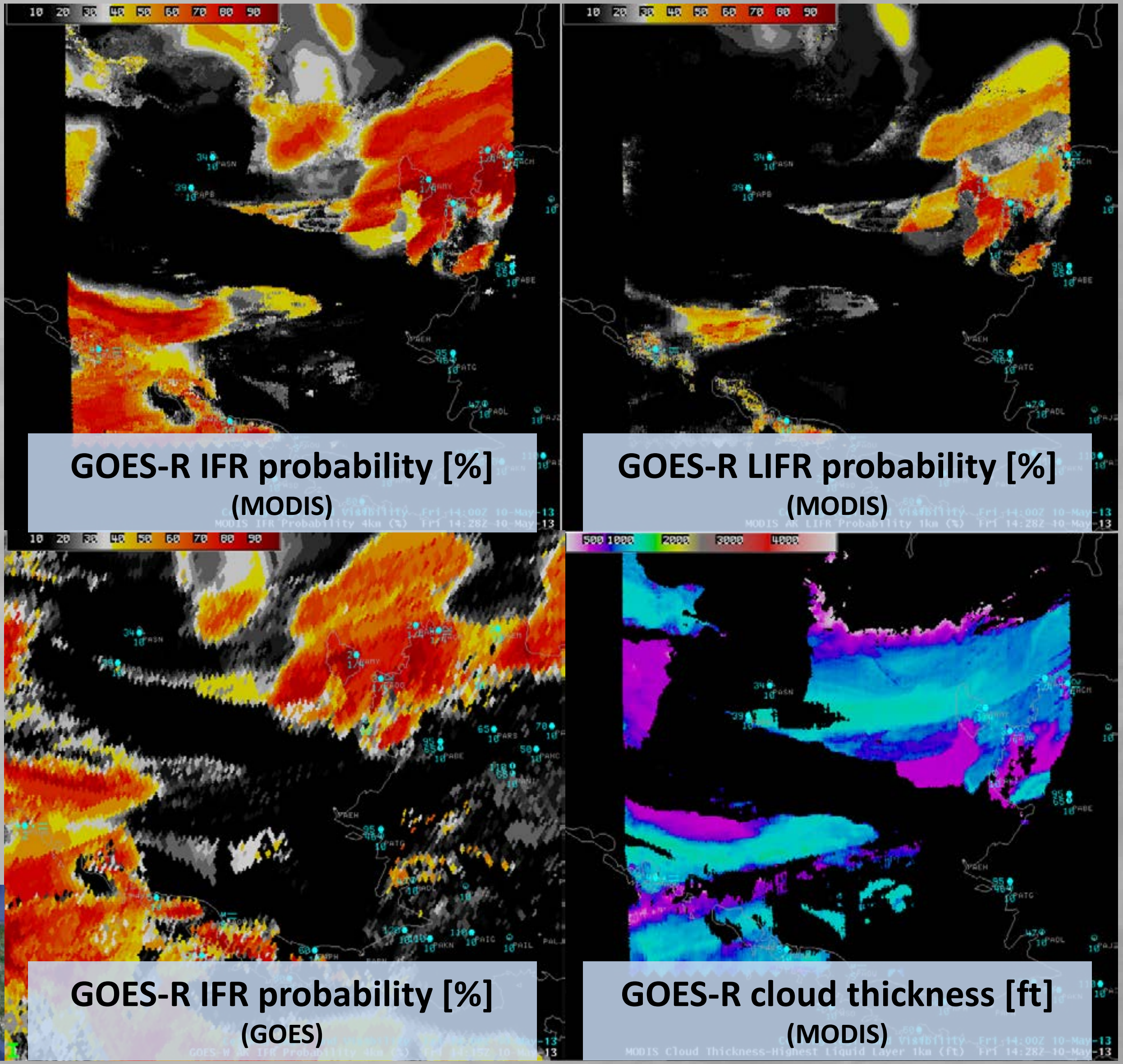
IFR and LIFR Probability



***IMPORTANT: Other sources of relevant data (e.g. sfc obs) influence results through the model fields*

GOES-R Fog/Low Stratus (FLS) Products

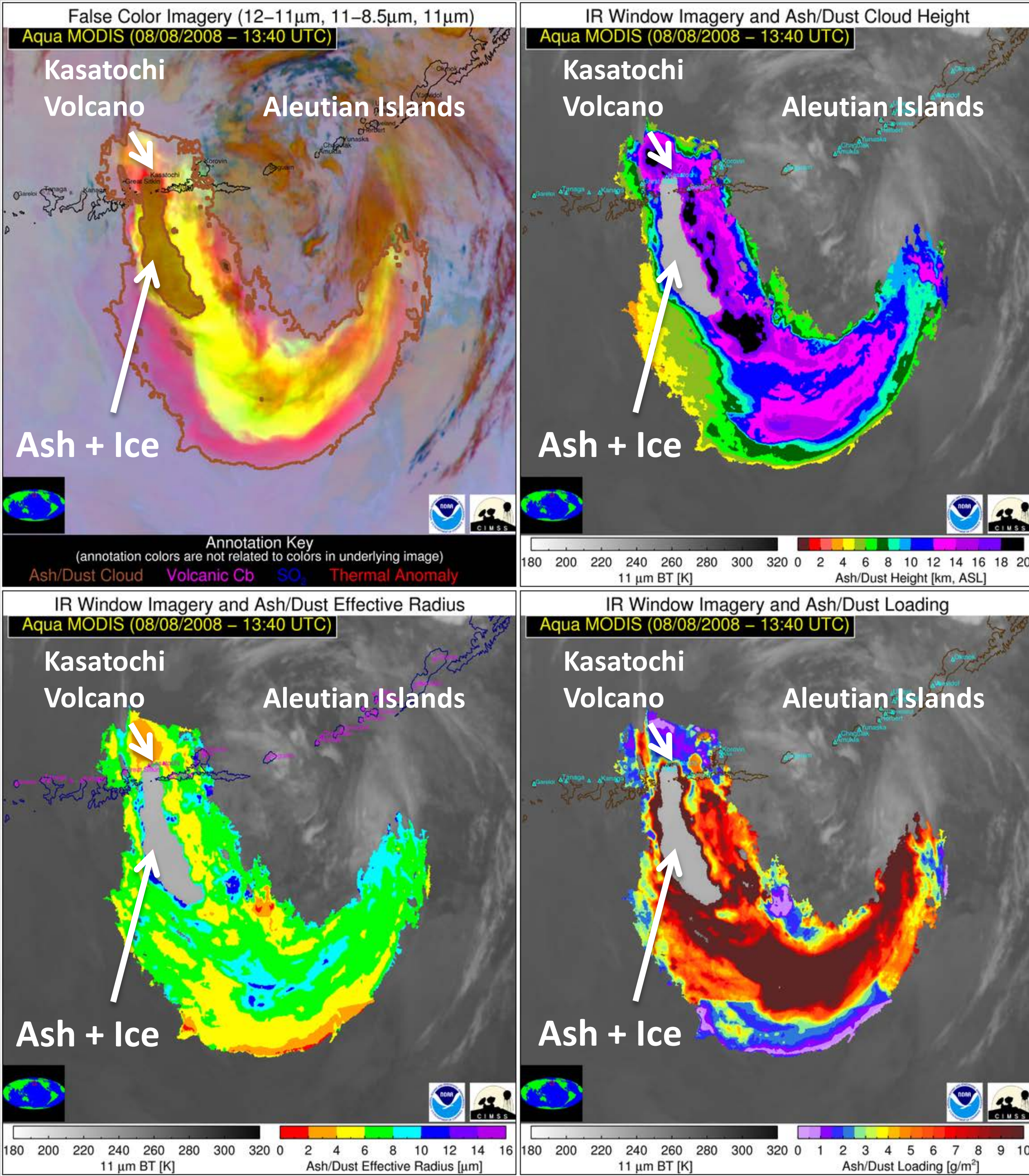
- The GOES-R FLS algorithm calculates the probability that IFR/LIFR conditions are present for a given satellite pixel and estimates the thickness of the cloud layer (cloud top – cloud base)
- MODIS data is important over Alaska because its 1 km spatial resolution provides much more detail than the larger GOES footprint (>4 km) at high latitudes
- The higher spatial resolution from MODIS makes identifying small-scale FLS possible where GOES is most useful identifying large-scale events



Feedback Improves Algorithms

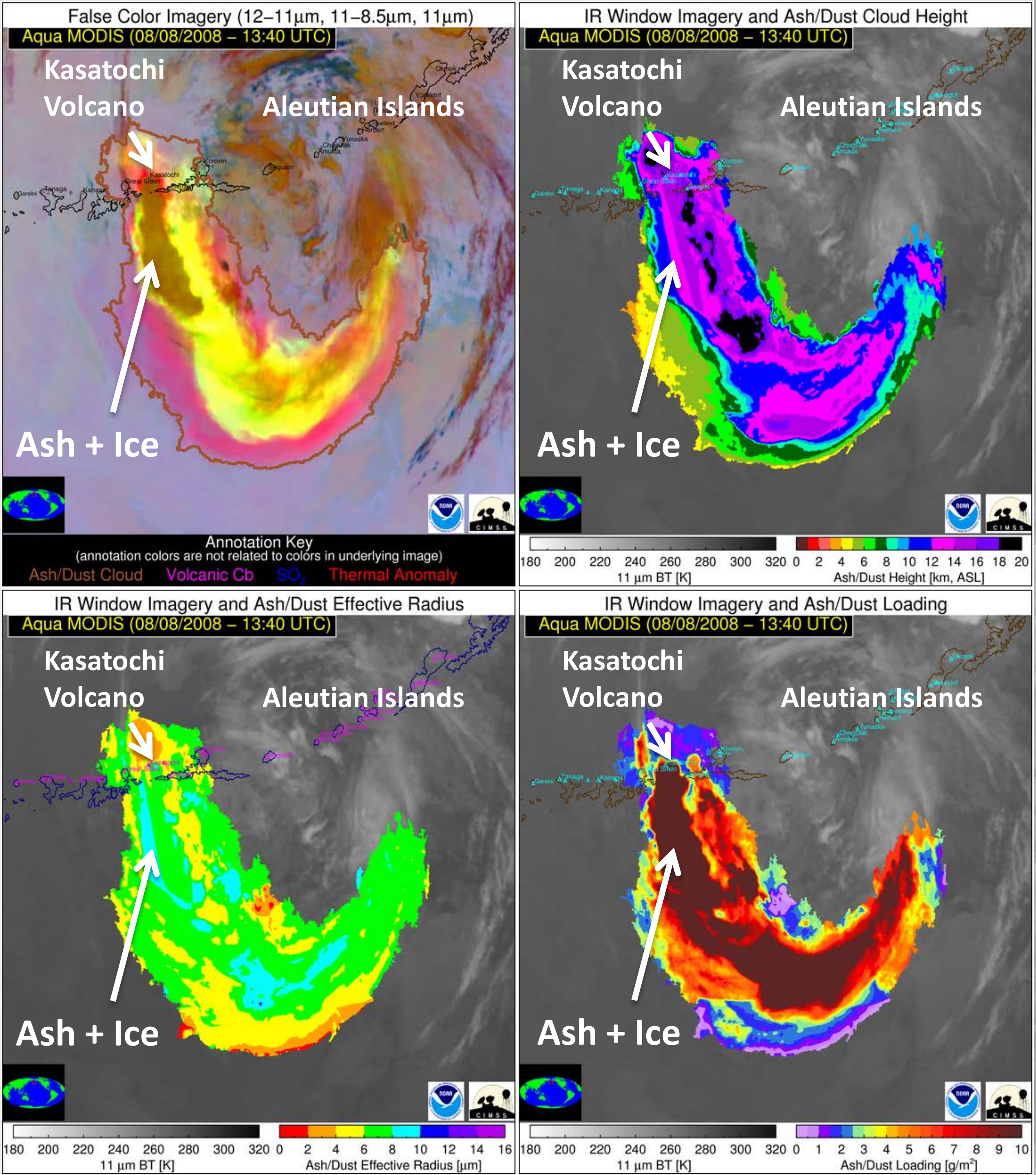
- Feedback from Anchorage VAAC identified unexpected 'holes' in volcanic ash detection and retrievals for explosive volcanic eruptions where the ash cloud was dominated by ice particles—this was addressed and these holes are now filled (next slides)

- Alaska region FLS feedback suggested the GOES display color palate wasn't ideal for Alaska given very cold backgrounds (GOES instrument noise)—so a Alaska specific FLS color display was developed—MODIS does not have this problem



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.

Future Plans

- Add Suomi NPP VIIRS to processing stream
  - Volcanic Ash Detection and Retrieval Suite
  - Fog / Low Stratus Suite
- Higher infrared resolution (750 m) of Suomi NPP VIIRS will benefit:
  - Detecting spatially small volcanic eruptions
  - Small scale terrain-induced ceiling/visibility aviation hazards
- Increased data frequency
  - Especially with Gilmore Creek DB antenna since Suomi NPP VIIRS has priority over MODIS Aqua
- Begin processing Hawaii DB antenna feed late 2013

Questions?

Thank you!

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Jordan Gerth (jordan.gerth@ssec.wisc.edu)

References

- 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., 2010: Advances in extracting cloud composition information from spaceborne infrared radiances: A robust alternative to brightness temperatures Part I: Theory, *J. Applied Meteorol. And Climatology*, **49(9)**, 1992-2012.

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