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Using the GOES-R AWG Volcanic Ash Algorithm to Track Eyjafjallajökull Volcanic Ash: Impacts on Operations and Research

Michael Pavolonis (NOAA/NESDIS/STAR)

and

Justin Sieglaff (CIMSS)

Topics

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- Introduction to the GOES-R AWG volcanic ash products
- Eyjafjallajökull background
- Impact of the GOES-R volcanic ash products on volcanic ash monitoring and modeling
- Quality assessment
- Advantages of the geostationary view
- Looking ahead
- Summary

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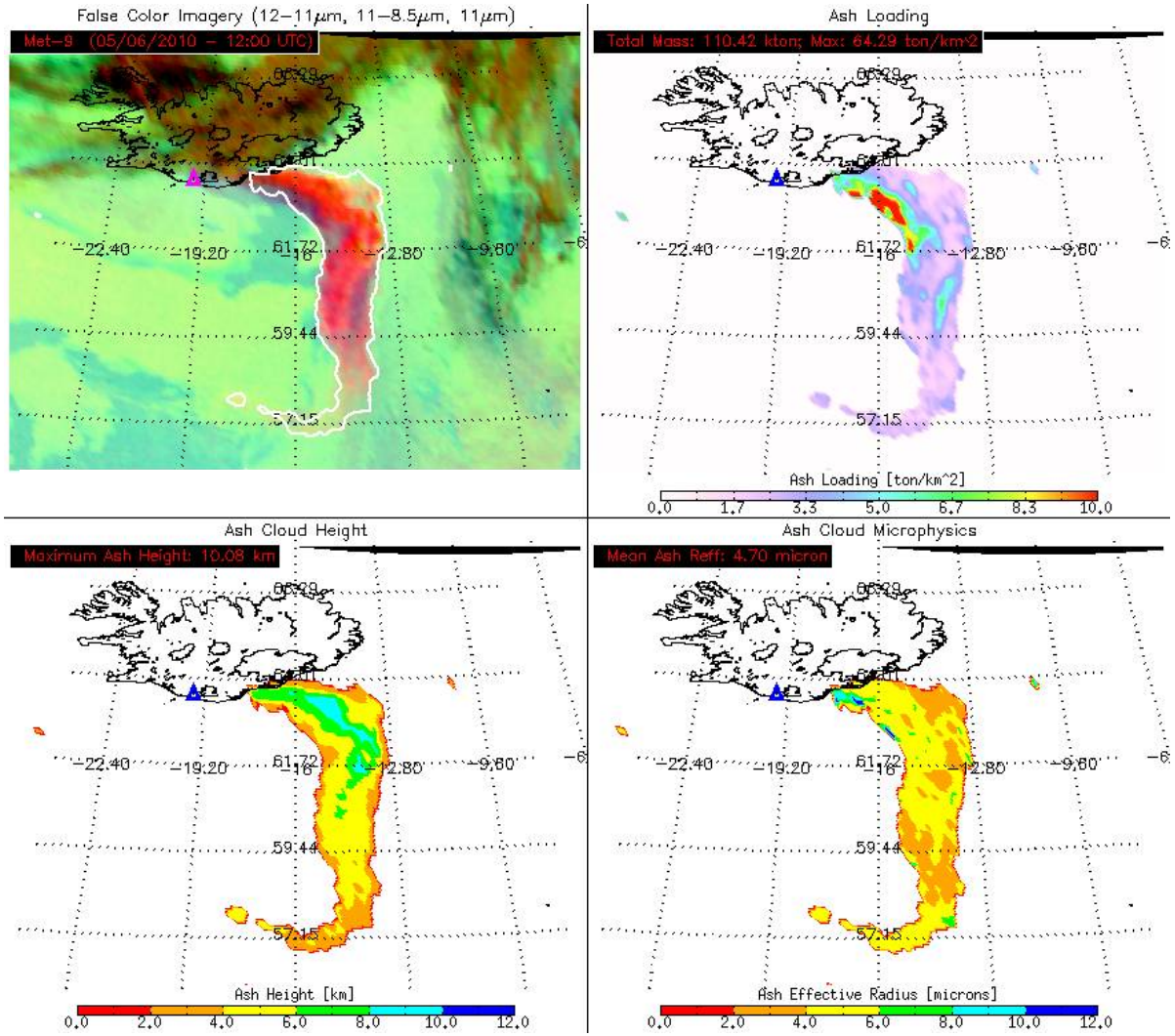
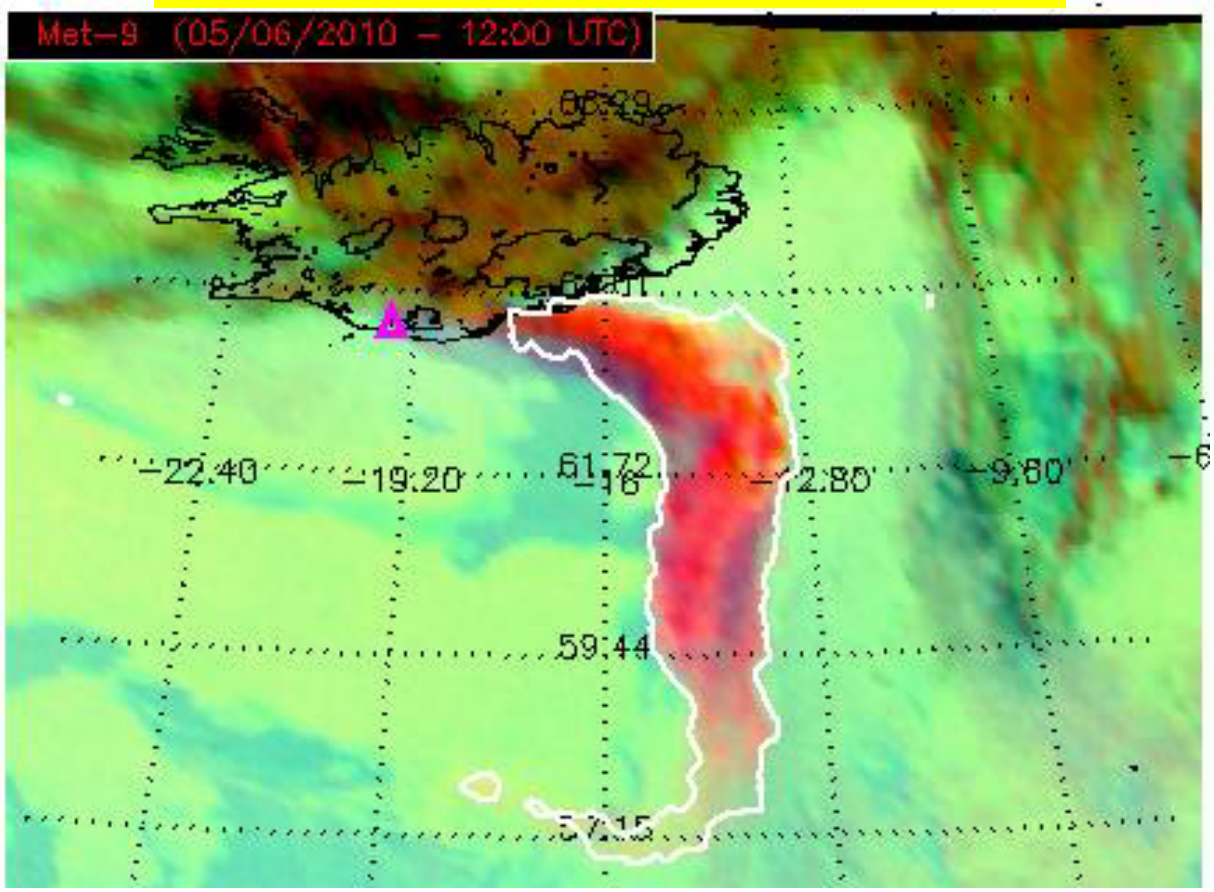
The GOES-R Volcanic Ash Products



- **SEVIRI or MODIS can be used to generate the GOES-R products.**
- **The GOES-R ash retrieval algorithm is based on the GOES-R cloud height retrieval (same IR based approach).**
- **The simultaneous retrieval of ash height, mass loading, and particle size is unique (all other ash algorithms assume a constant cloud height).**
- **These products are well suited for assimilation into models since the error estimate for each parameter is objectively determined by the algorithm.**

The GOES-R Volcanic Ash Products

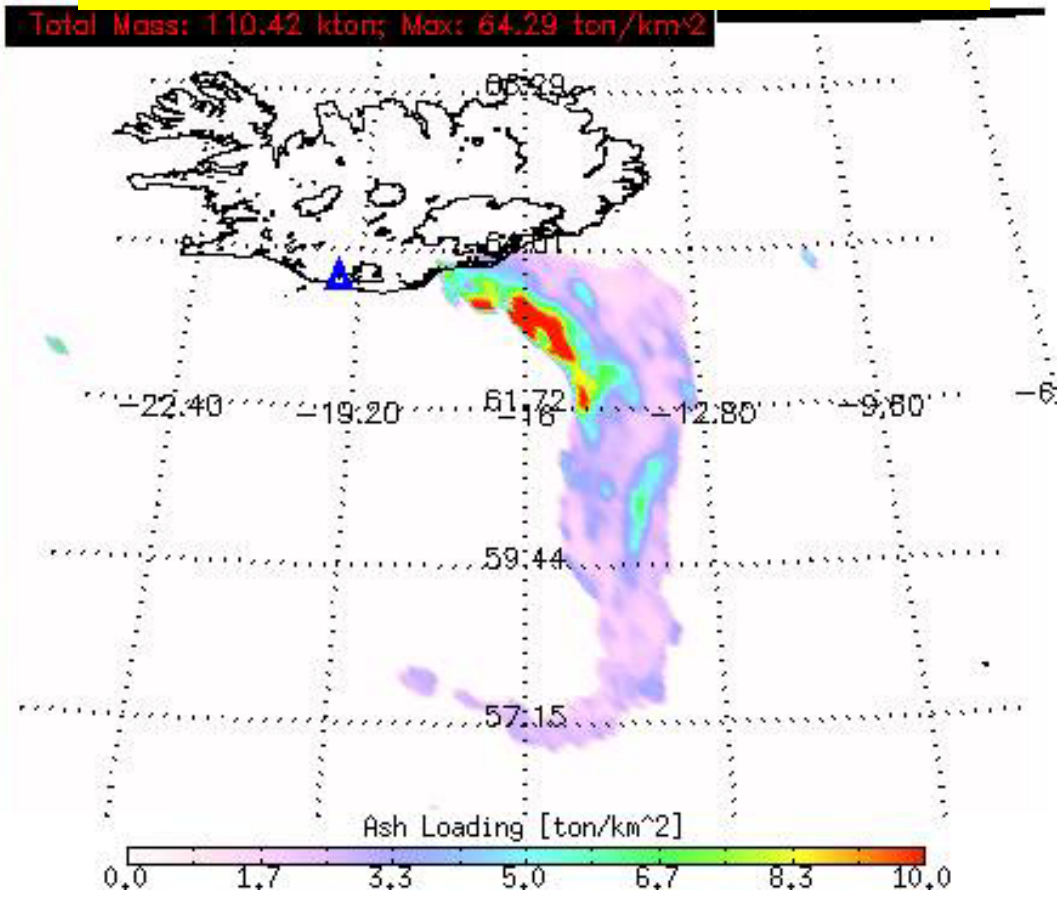
Quantitative Ash Detection



- Quantitative ash detection is expressed as an ash confidence.
- Ash detection results can be overlaid on false color imagery to give the user perspective.
- The ash detection can be used to provide automated ash alerts.

The GOES-R Volcanic Ash Products

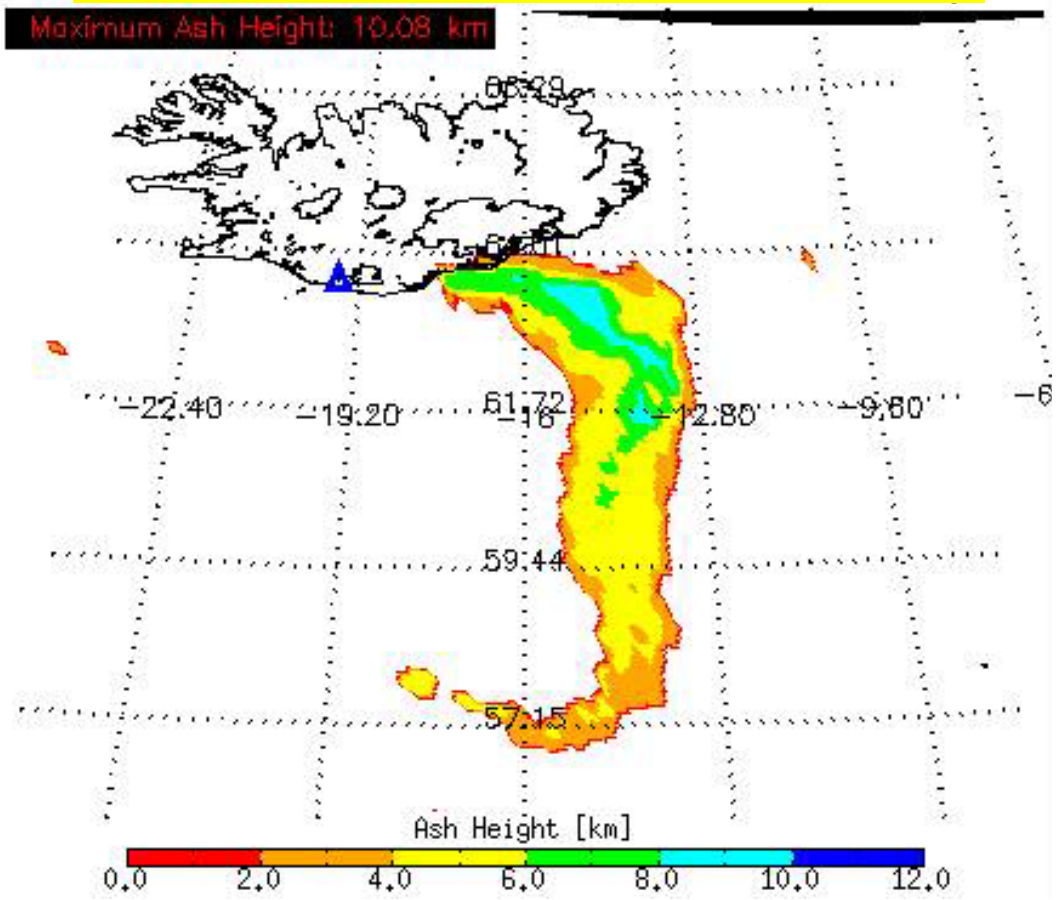
Ash Mass Loading



- Ash mass loading (ton/km^2) is needed to determine if jet engine tolerances are exceeded and to initialize models.
- If a 1 km cloud thickness is assumed, the mass loading is numerically equivalent to ash concentration in mg/m^3.

The GOES-R Volcanic Ash Products

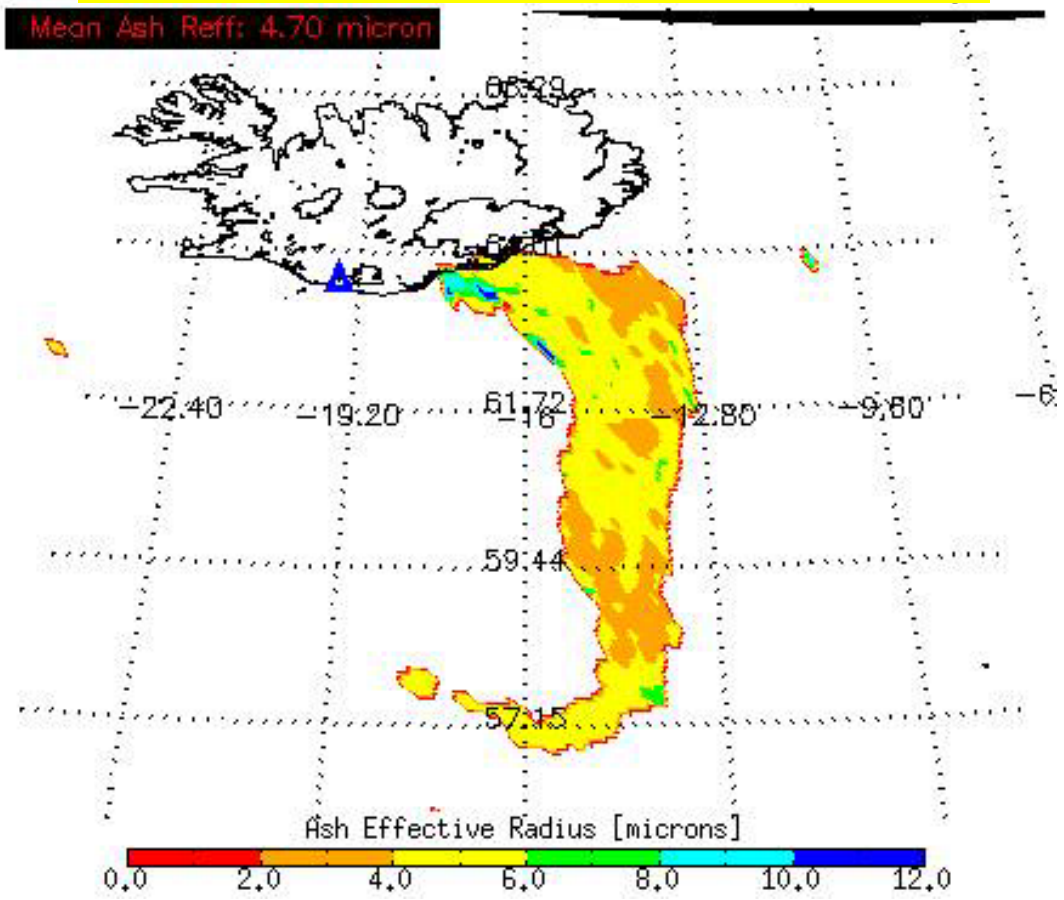
Ash Cloud Height



- The ash cloud top height is critically important for determining if ash is at jetliner cruising altitudes (nowcasting component).
- In addition, the ash cloud height is a very important parameter for initializing dispersion models (forecasting component).

The GOES-R Volcanic Ash Products

Ash Effective Radius



- The ash cloud effective particle radius is not a required product, but it is automatically generated as part of the ash retrieval.
- Since the effective particle radius is well correlated with ash residence time, we will retain this information in quality flag form.

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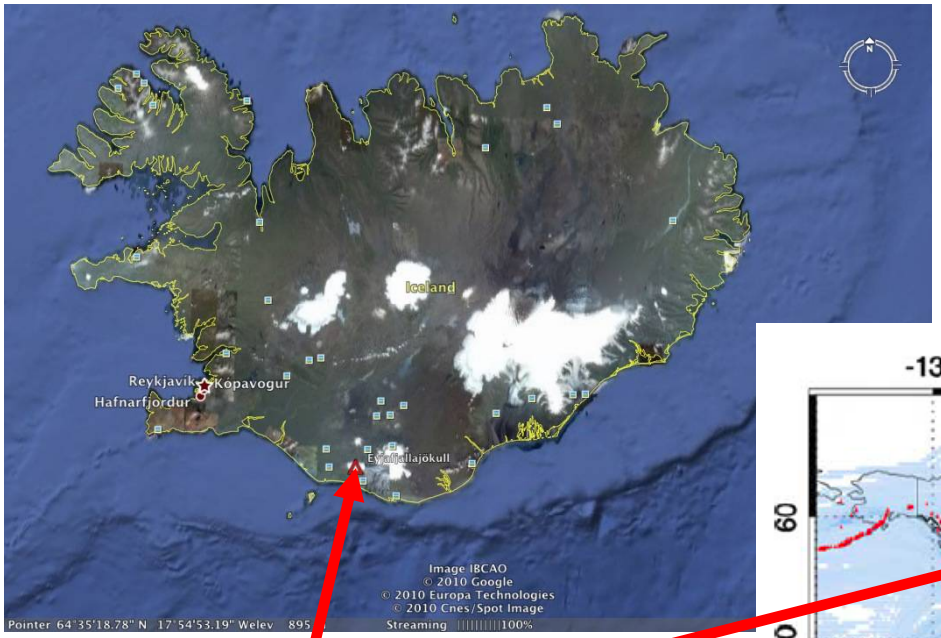
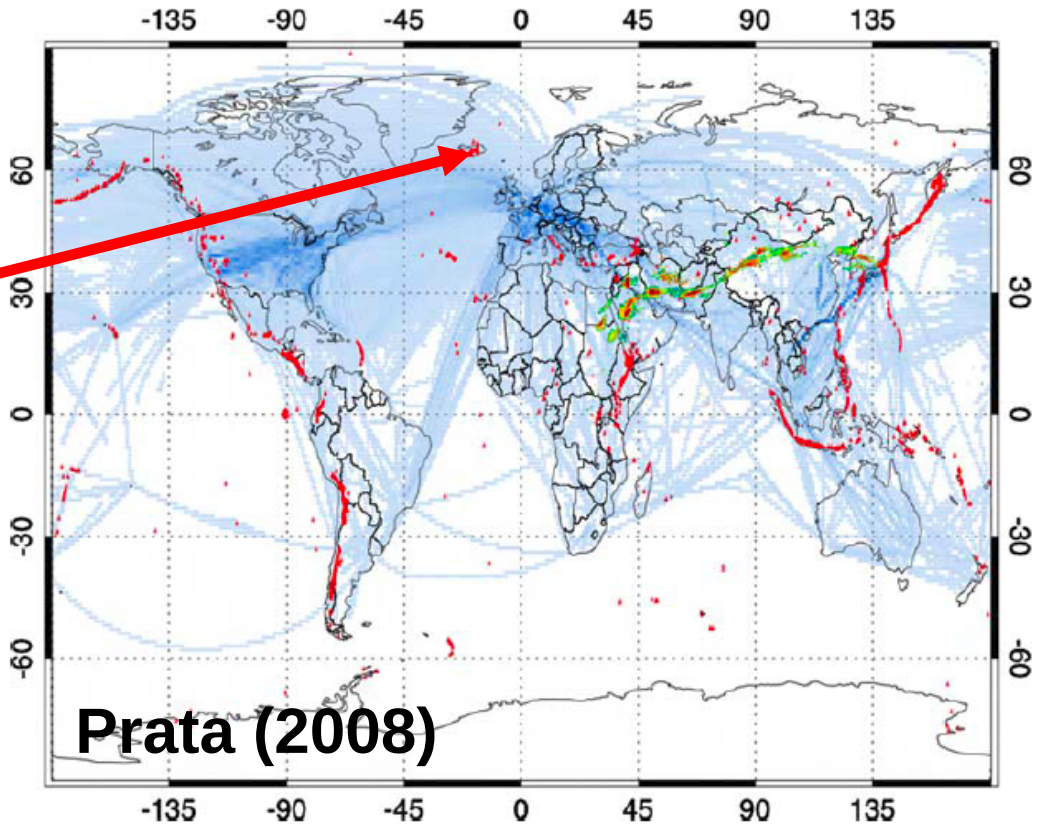
Eyjafjallajökull Background



Ash clouds from Iceland have the potential to impact very busy air routes

Eyjafjallajökull



Eruptions beginning in: 2010, 1821, 1612, ~920 AD, ~550 AD

Eyjafjallajökull Eruptions

March 20 to April 12, 2010 - non-ash eruptions, lava fountains

April 14 to May 23, 2010 - mostly explosive ash cloud producing *(ash was visible in satellite imagery 32 out of 41 days)*

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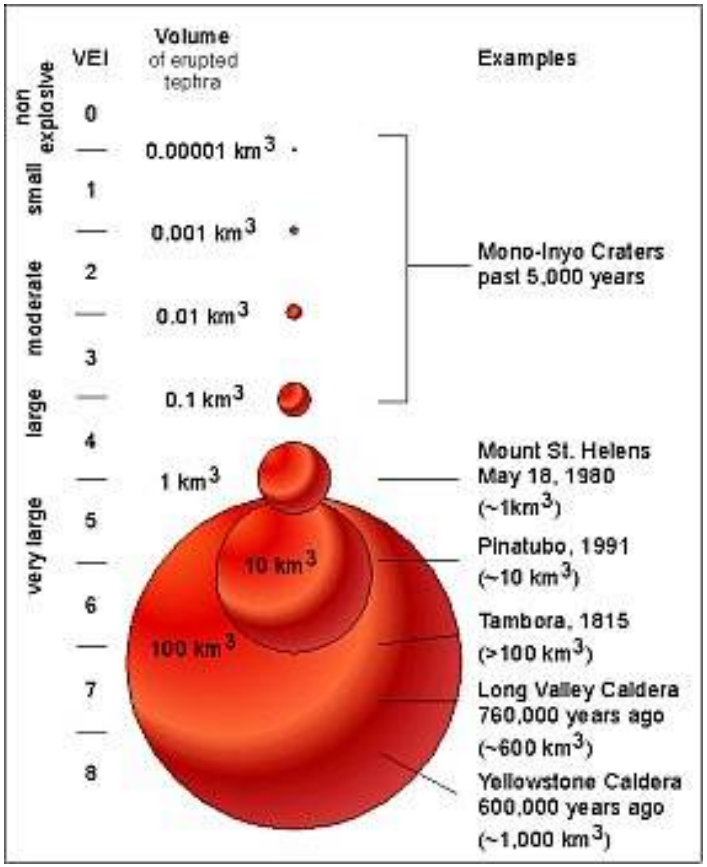
Eruption Strength

- **The Volcanic Explosivity Index (VEI) for these eruptions was in the 2 - 3 range. By comparison, Mt. St. Helens (1980) had a VEI of 5 and Pinatubo (1991) had a VEI of 6.**
- **The volcanic clouds were mainly confined to the troposphere and only small amounts of SO_2 were emitted, so these eruptions had little to no climate impact.**



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Early Role of the GOES-R Volcanic Ash Products

April 15 - April 23: Significant airspace restrictions over Europe. ***The GOES-R products show the evolution of the ash cloud and are featured on NOAA web pages.***

April 22: ***GOES-R ash products are generated in real-time and displayed on the web.***

April 20: STAR submits statement on climate impact. ***The GOES-R products played a role in the assessment.***

April 19: ***UK Met Office requests real-time GOES-R volcanic ash products (using SEVIRI).***

April 14: beginning of explosive ash producing eruption. ***We began regularly distributing the GOES-R ash products to the operational and research community via an e-mail list.***

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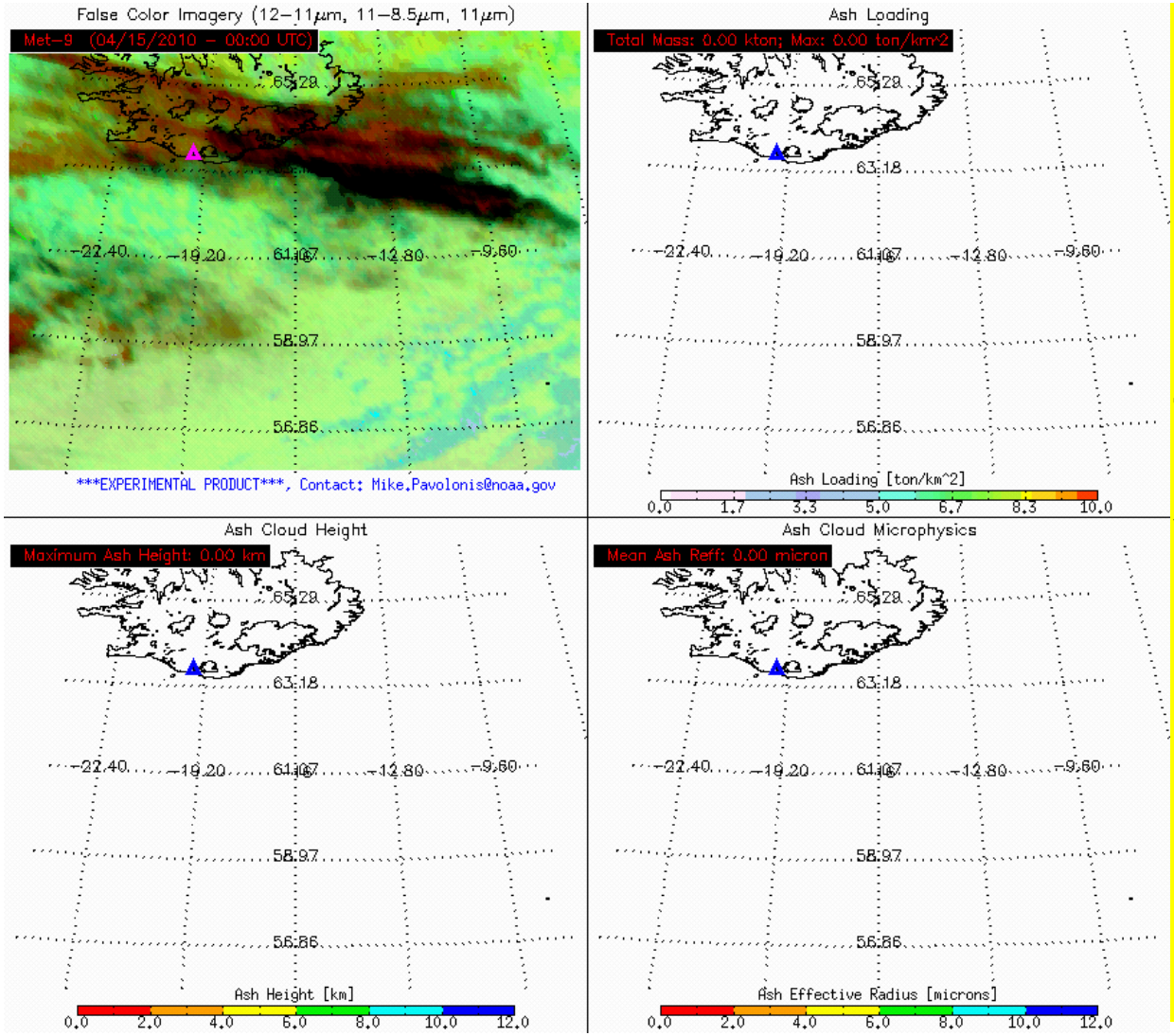
April 15 - April 20, 2010



- **We were regularly generating the GOES-R volcanic ash products using SEVIRI and MODIS and distributing them to the operational and research community via an email list.**
- **The GOES-R ash products were the only timely source of objective satellite derived ash cloud heights, loading, and particle size.**

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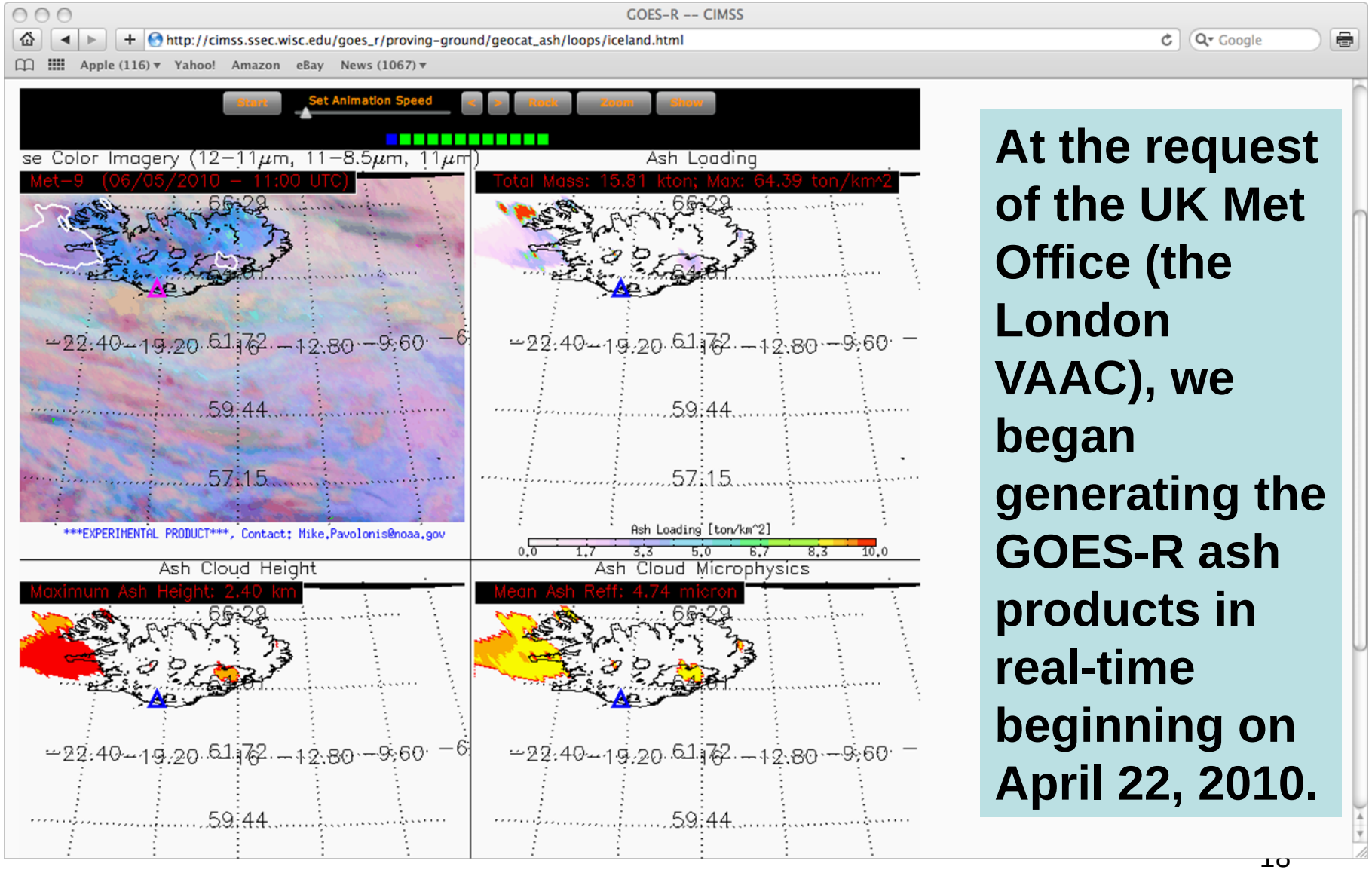
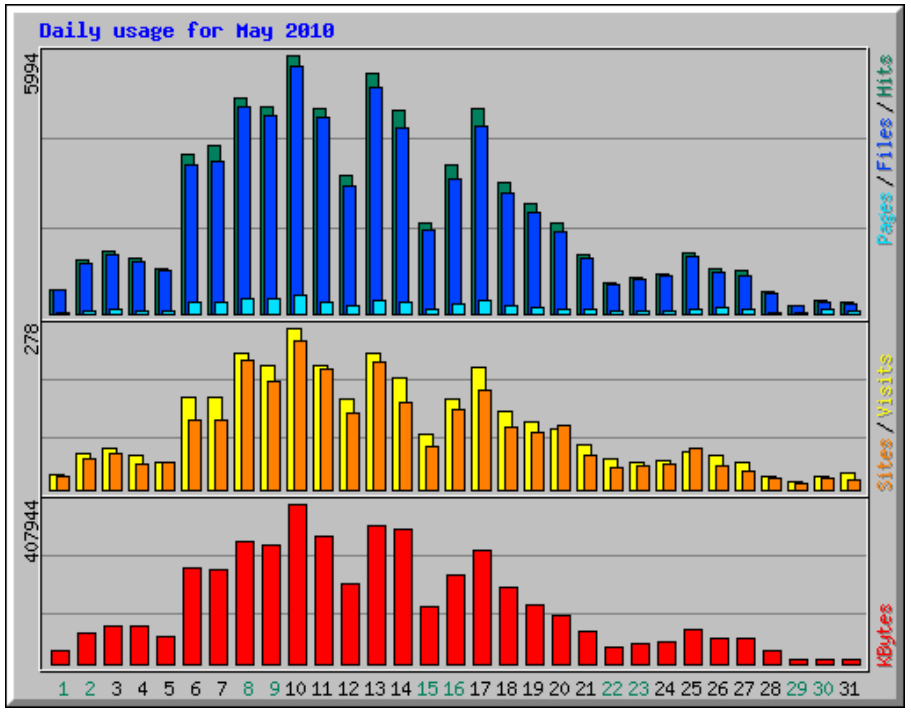
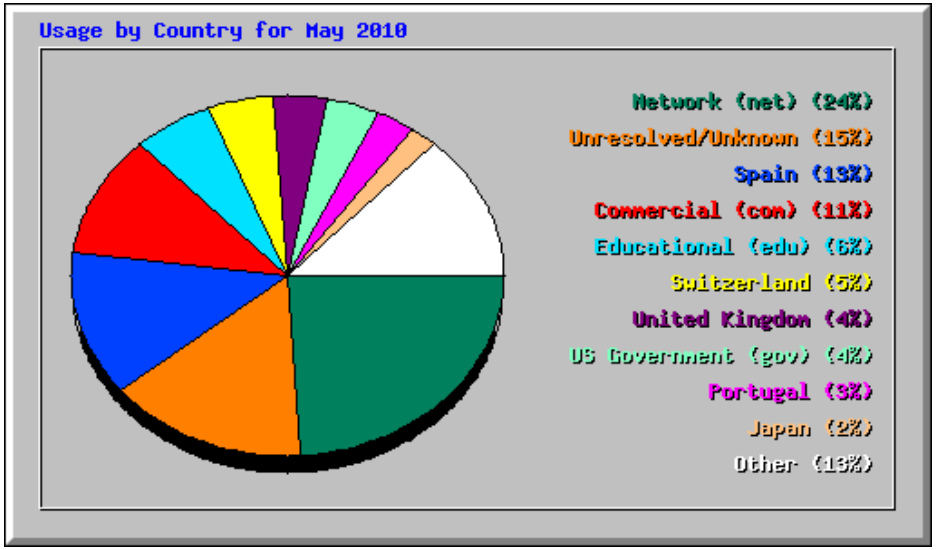
http://cimss.ssec.wisc.edu/goes_r/proving-ground/geocat_ash/



At the request of the UK Met Office (the London VAAC), we began generating the GOES-R ash products in real-time beginning on April 22, 2010.



~74,000 hits in May 2010, despite being a "hidden" site.



- **The web site attracted visitors from a wide range of countries.**
- ******The UK Met Office (London VAAC) registered the most hits out of all visitors.***
- **The UK Met Office confirmed that they use the products daily.**
- **Stan Benjamin's group has been using the ash heights to initialize the FIM.**

Known Users and Data Requests

- AFWA
- Airline Pilots Association
- Aviation Weather Testbed
- CALIPSO Science Team
- Deutscher Wetterdienst Remote Sensing Division
- ESRL (Stan Benjamin's group)
- Iceland Met Office
- Italian Civil Protection
- MISR Science Team
- Norwegian Institute for Air Research
- Norwegian Meteorological Institute
- UK Met Office
- University of Alaska - Fairbanks
- University of Buffalo
- USGS
- WMO

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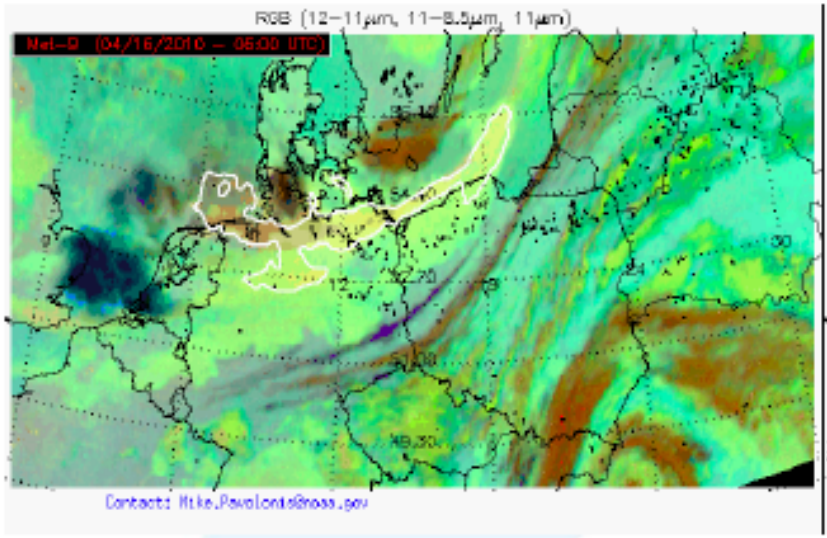
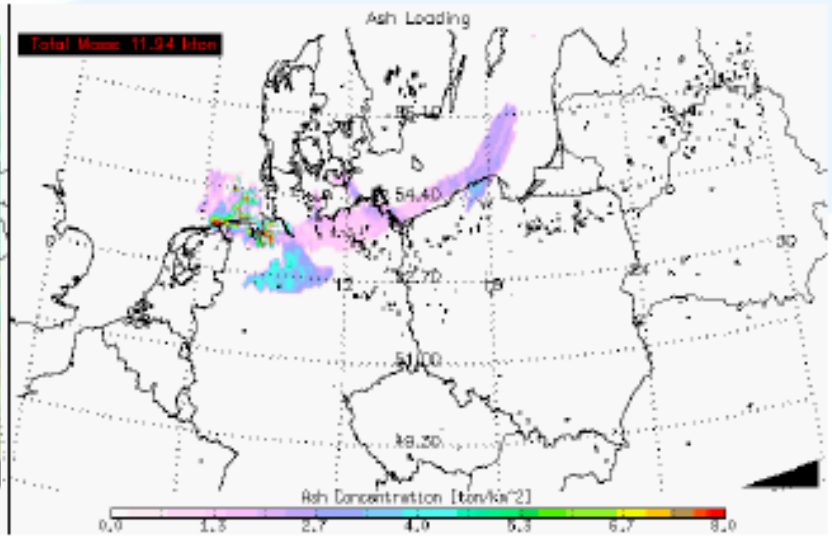
There were also features on NPR, Weather Network TV (Canada), On Wisconsin Magazine, and Physorg.com

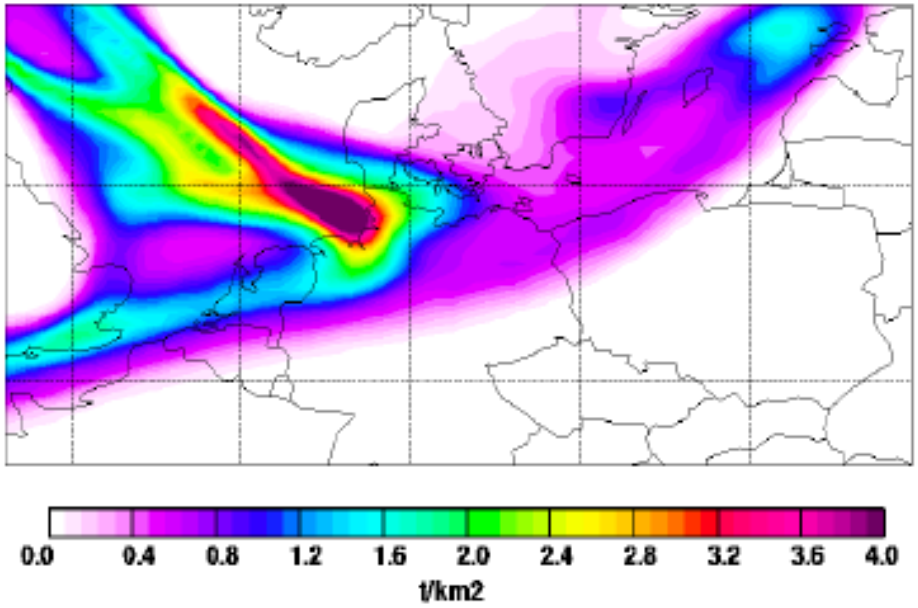
Comparison with SEVIRI ash retrievals





16 April, 6 UTC

FLEXPART total ash
16 April, 3-6 UTC



NILU

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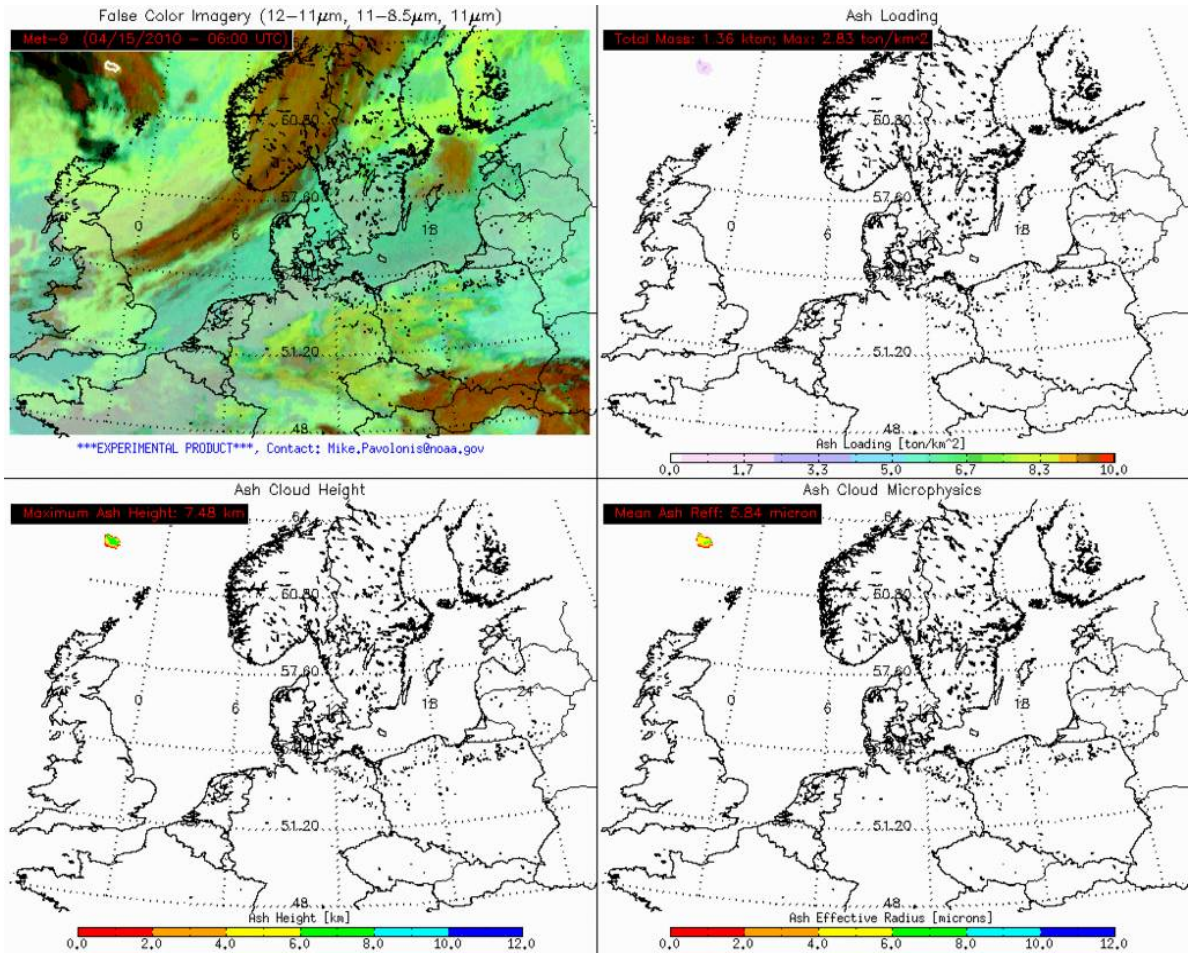
IMPACT ON AVIATION:

- **Nearly 100,000 canceled flights**
- **Airlines were losing $200 million/day**
- **Total economic impact - $2 billion**

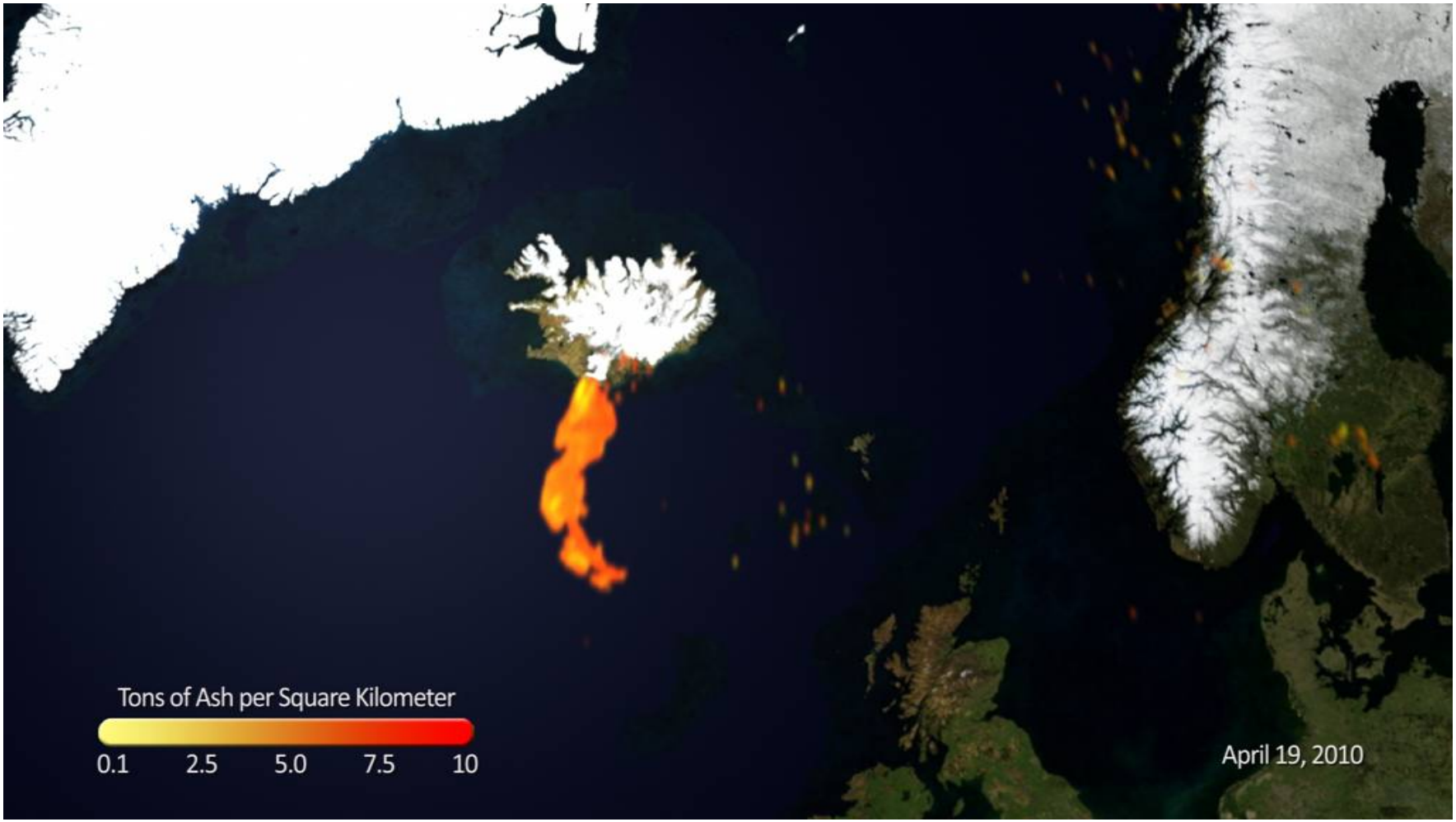


During Ash Event

After Ash Event

http://www.noaa.gov/features/03_protecting/volcanicash.html

http://www.star.nesdis.noaa.gov/star/news2010_201004_VolcAsh.php



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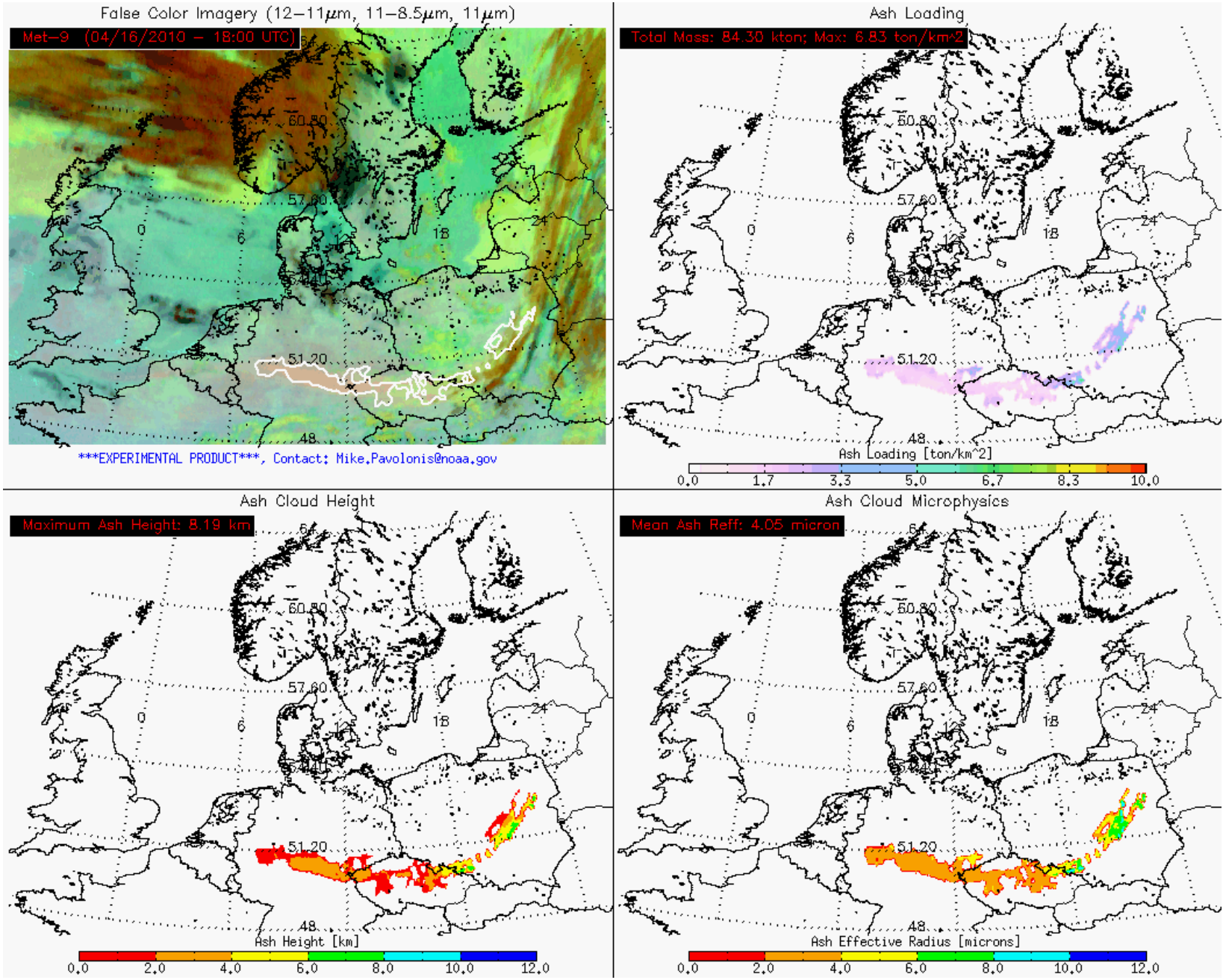
False Color Imagery (12–11μm, 11–8.5μm, 11μm)
Met–9 (04/16/2010 – 18:00 UTC)
60.80
57.60
54.40
51.20
48
0
6
12
18
24
EXPERIMENTAL PRODUCT, Contact: Mike.Pavolonis@noaa.gov
Ash Loading
Total Mass: 84.30 kton; Max: 6.83 ton/km^2
Ash Loading [ton/km^2]
0.0
1.7
3.3
5.0
6.7
8.3
10.0
Ash Cloud Height
Maximum Ash Height: 8.19 km
Ash Height [km]
0.0
2.0
4.0
6.0
8.0
10.0
12.0
Ash Cloud Microphysics
Mean Ash Reff: 4.05 micron
Ash Effective Radius [microns]
0.0
2.0
4.0
6.0
8.0
10.0
12.0

Redoubt ash from 15 Dec 1989 event

USGS

Courtesy of Dave Schneider (USGS)

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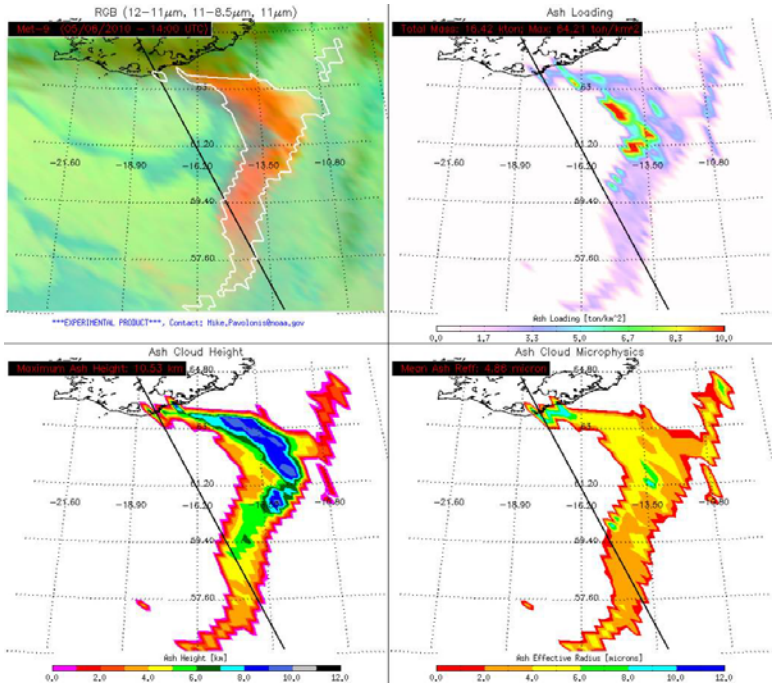
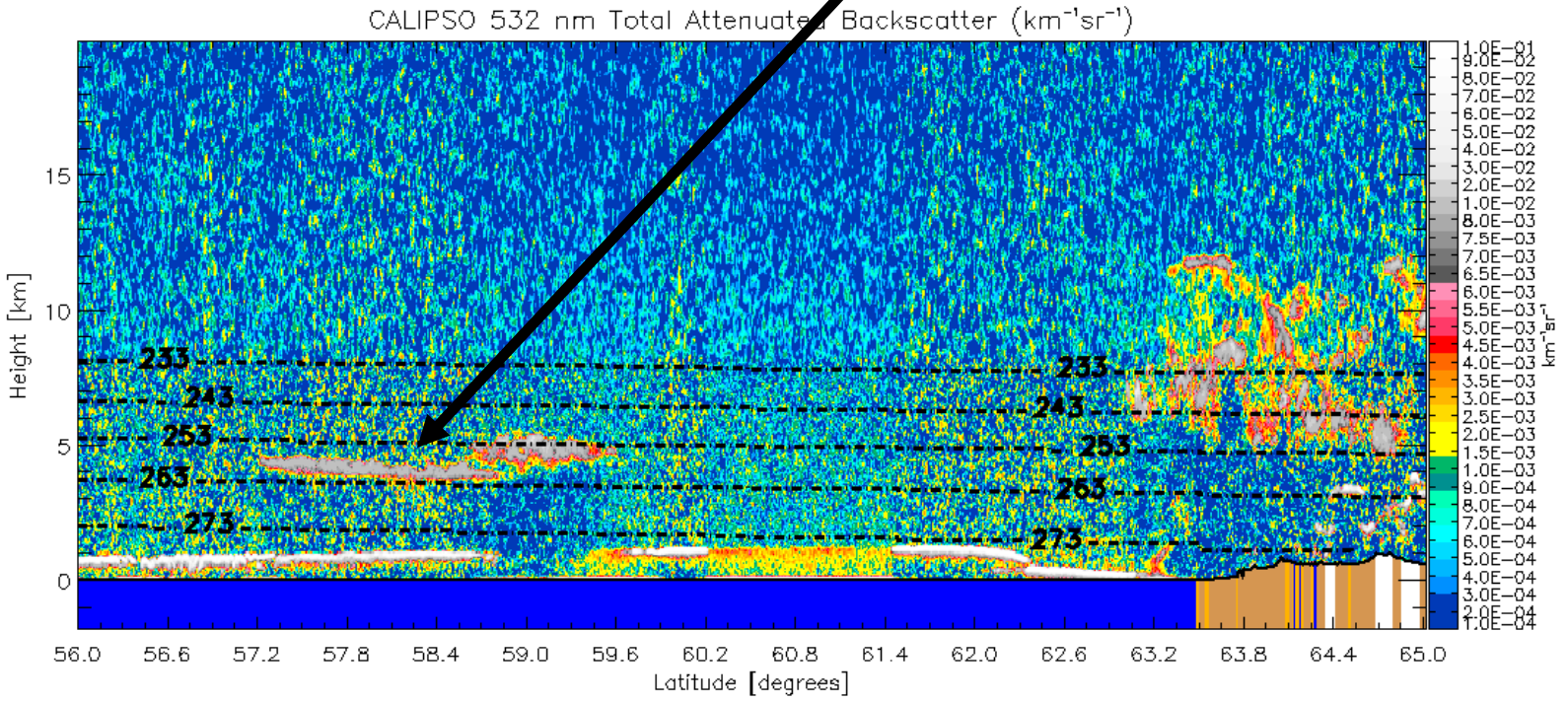
May 6, 2010 (14:00 UTC)



Ash cloud



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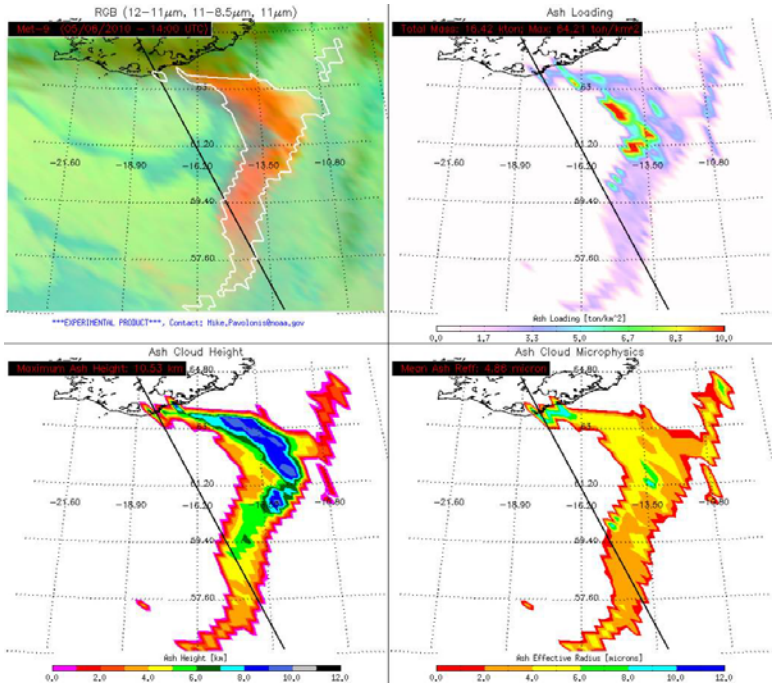
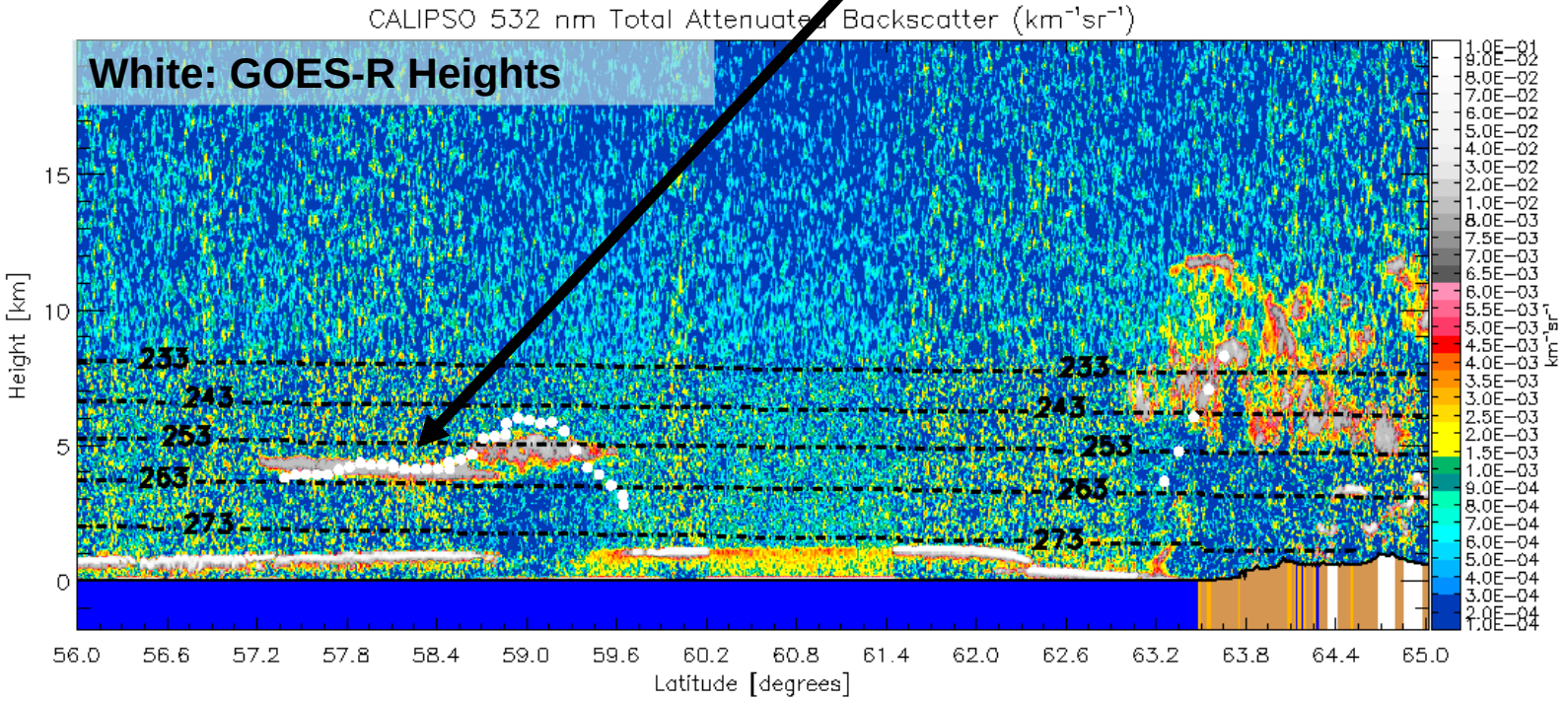
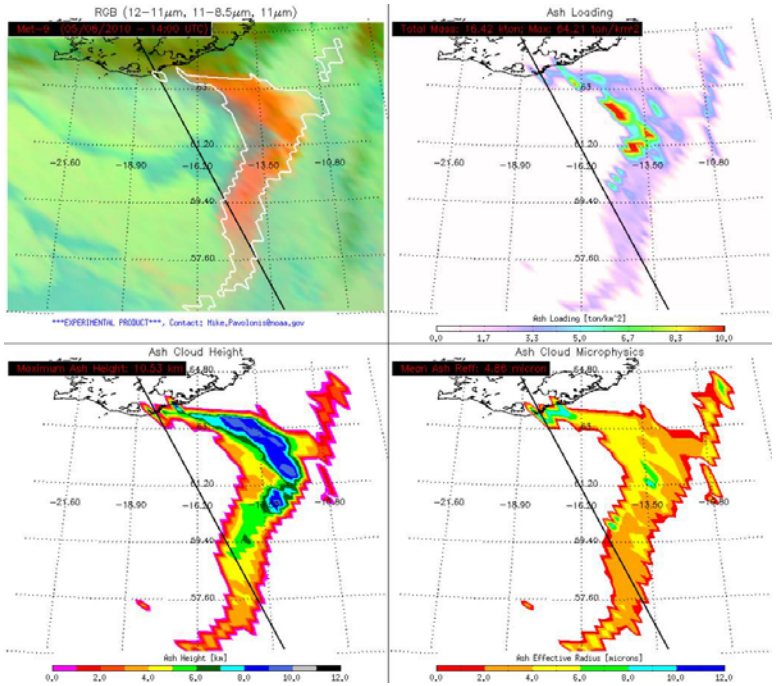


Ash cloud

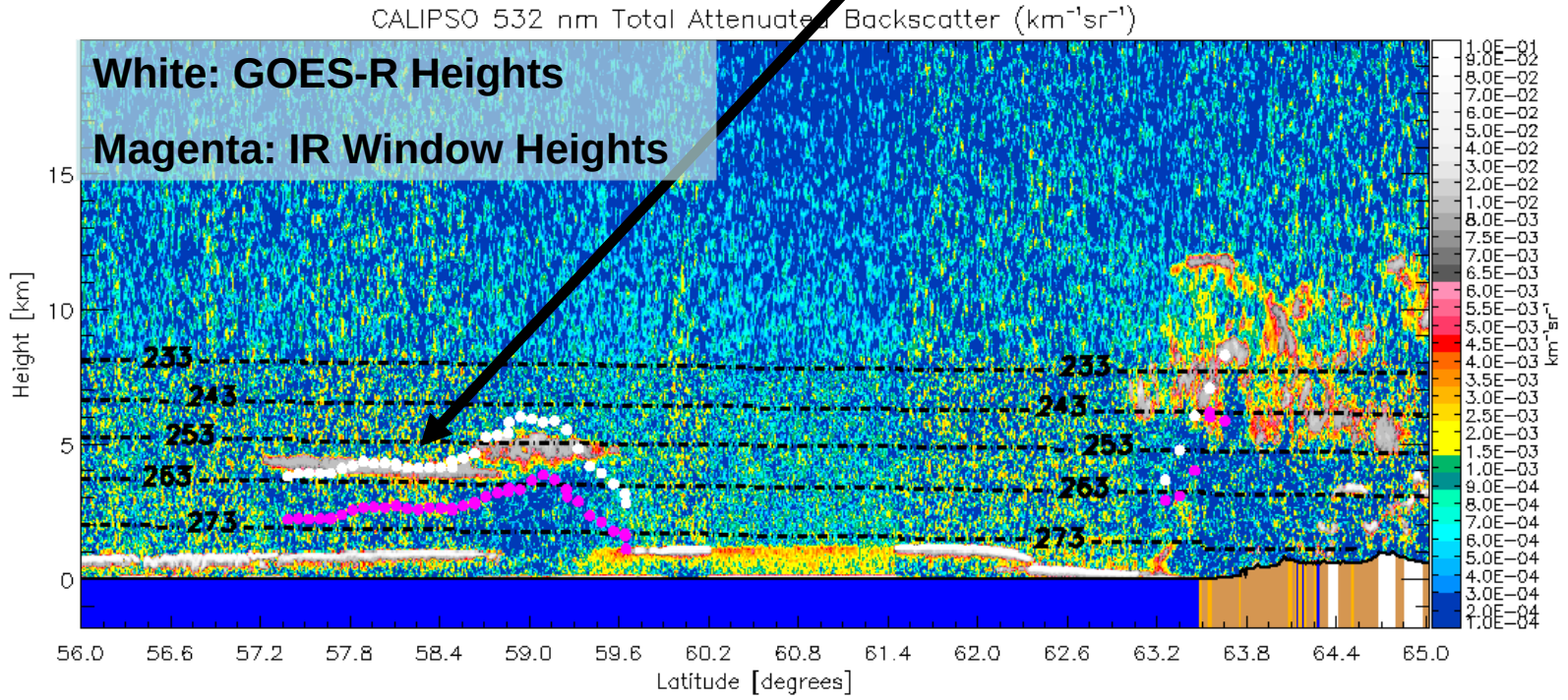




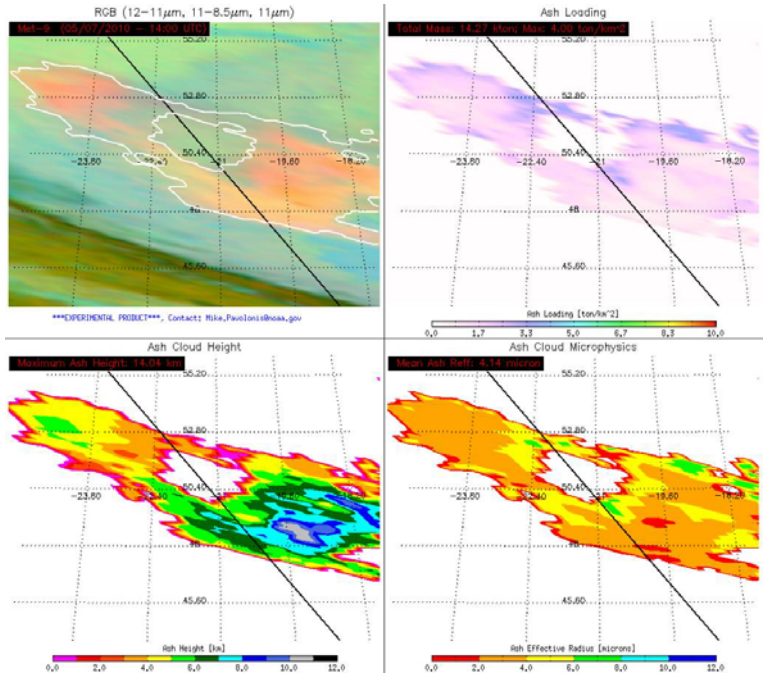
May 6, 2010 (14:00 UTC)

The GOES-R ash cloud heights closely match the CALIPSO cloud top boundary. The traditional methodology underestimates the cloud height.

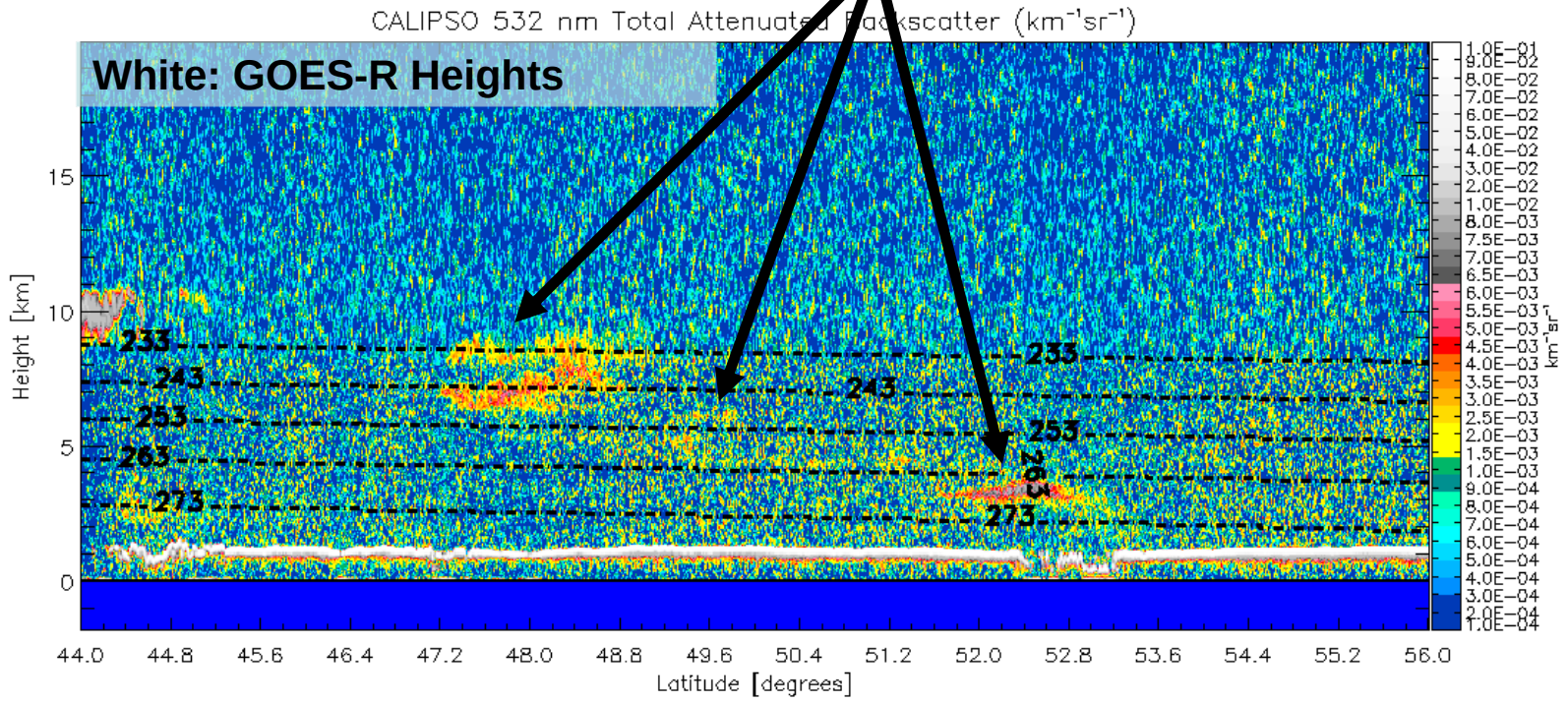
Ash cloud

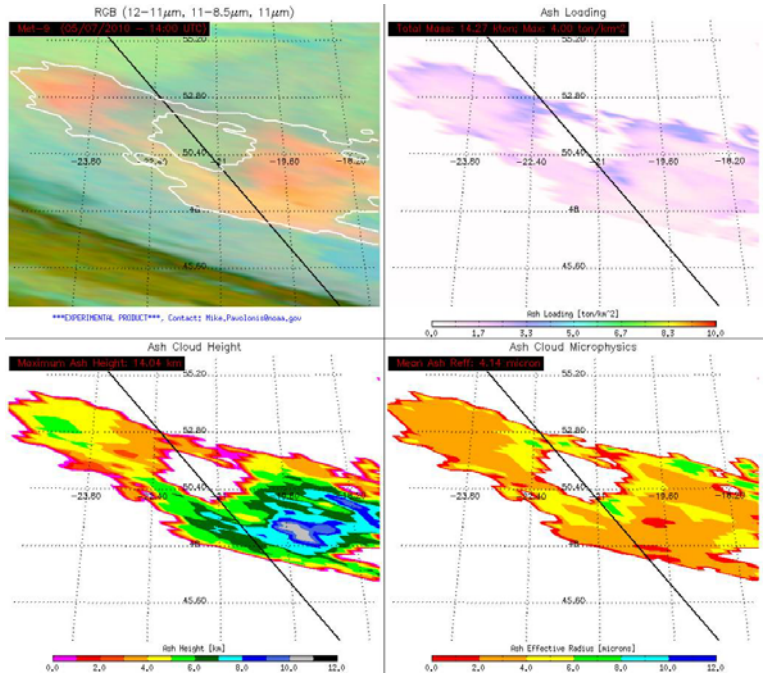


May 7, 2010 (14:00 UTC)



Ash clouds





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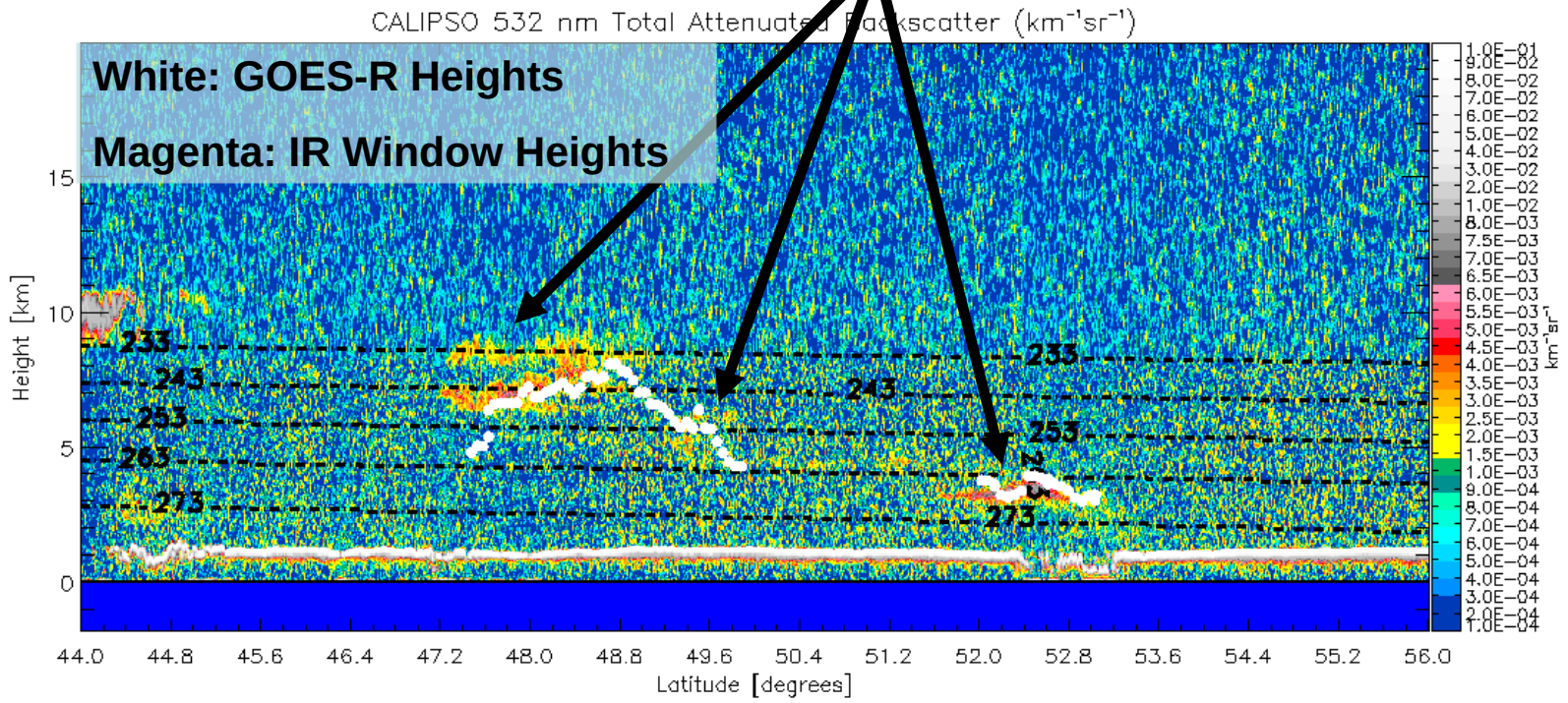
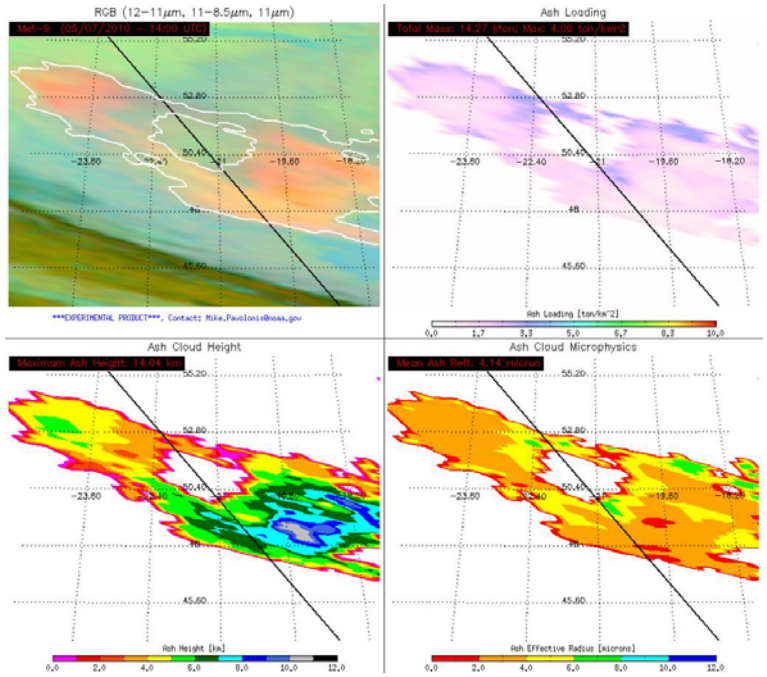
Ash clouds

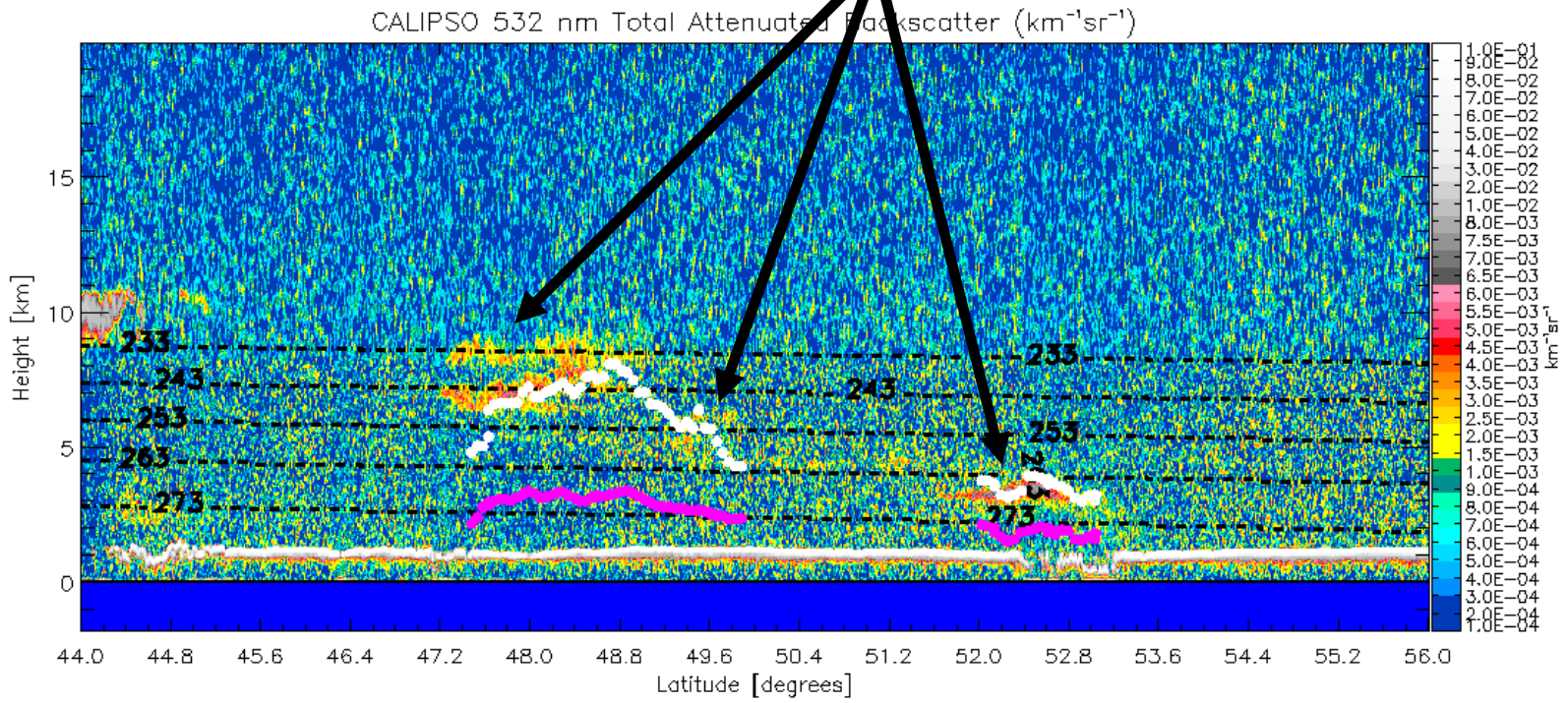




May 7, 2010 (14:00 UTC)

Even though these clouds are very optically thin, the GOES-R ash cloud heights closely match the CALIPSO cloud top boundaries, unlike the IR window based height.

Ash clouds



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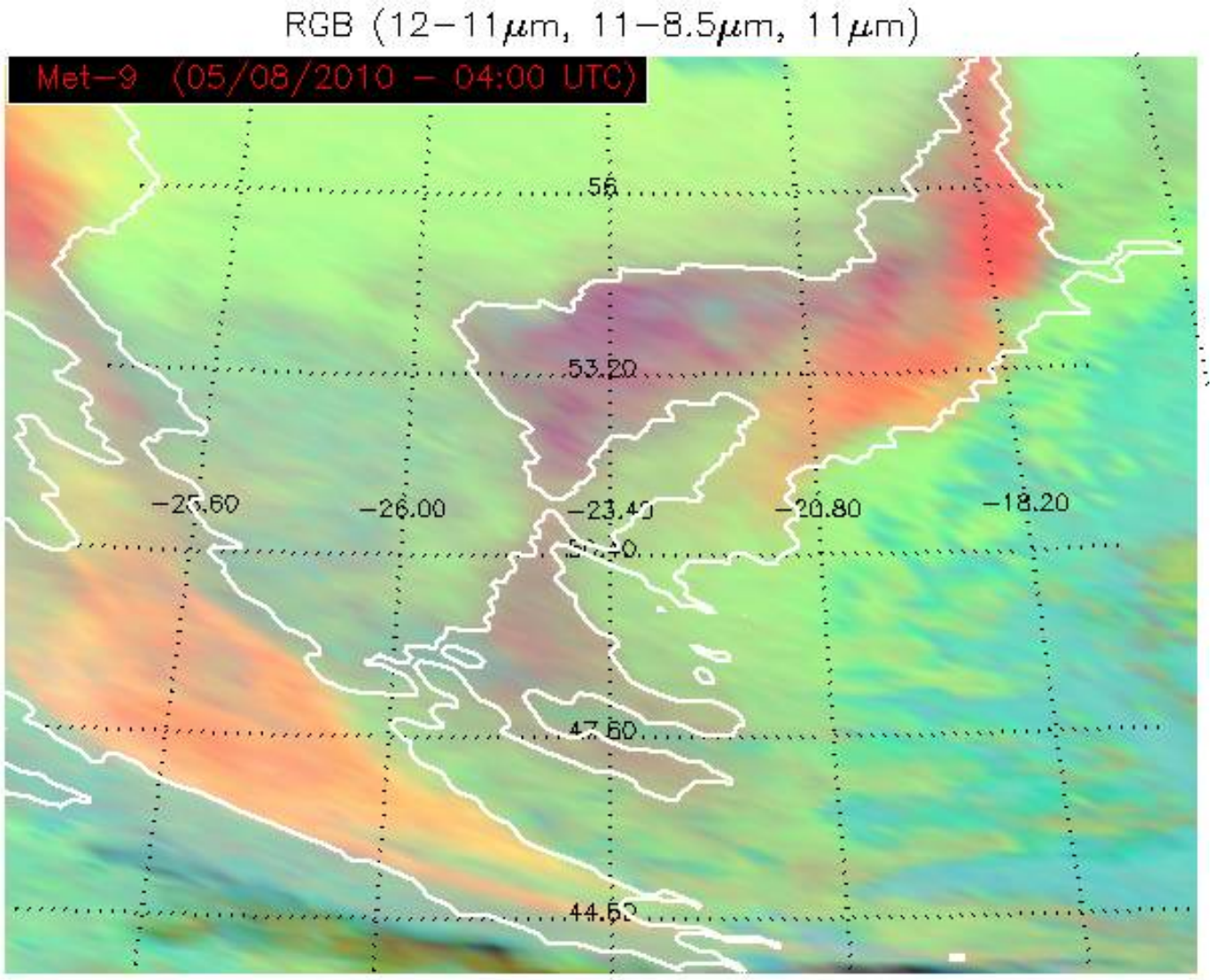
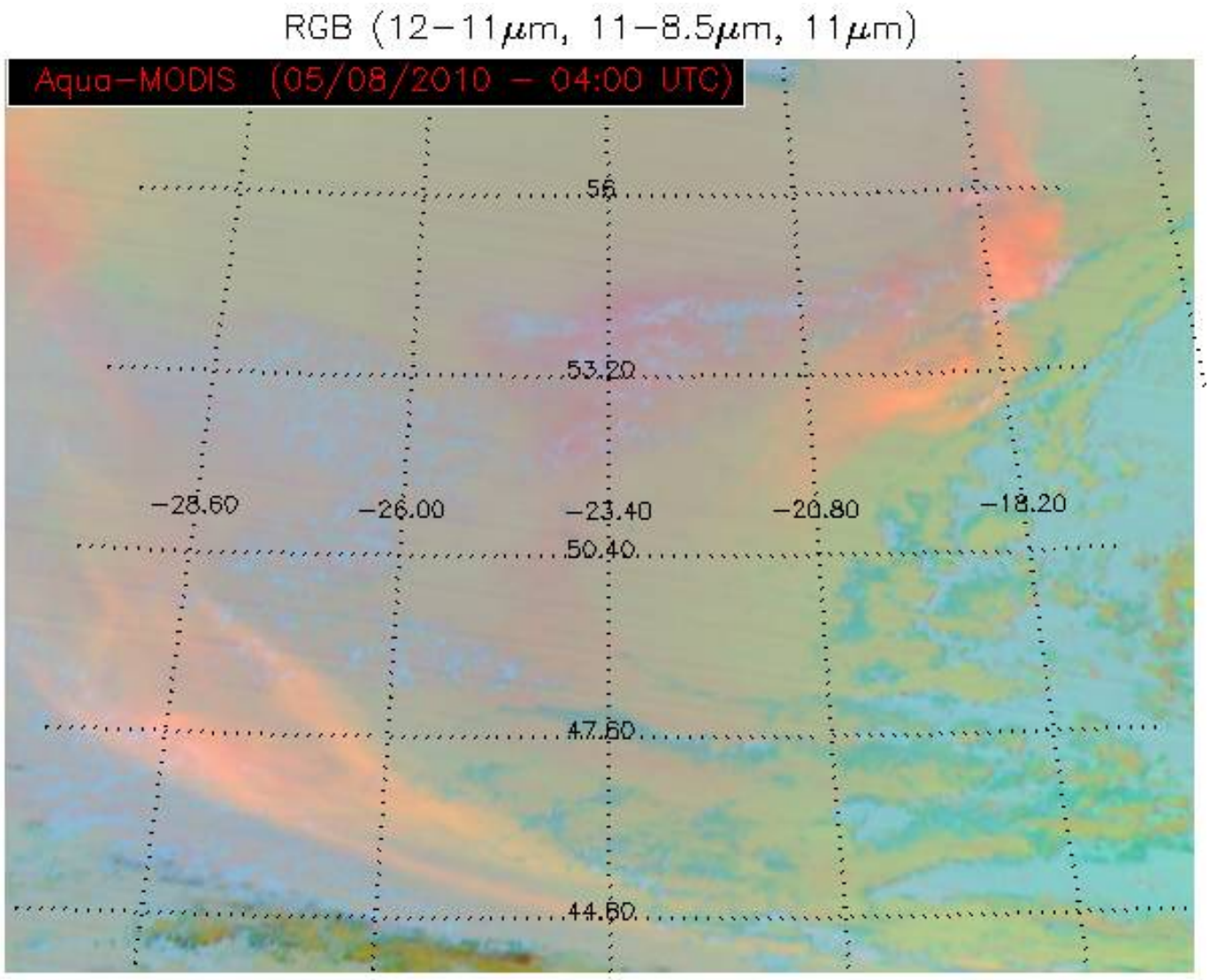
SEVIRI, θ_{sat} > 65.0°

Now you see it…

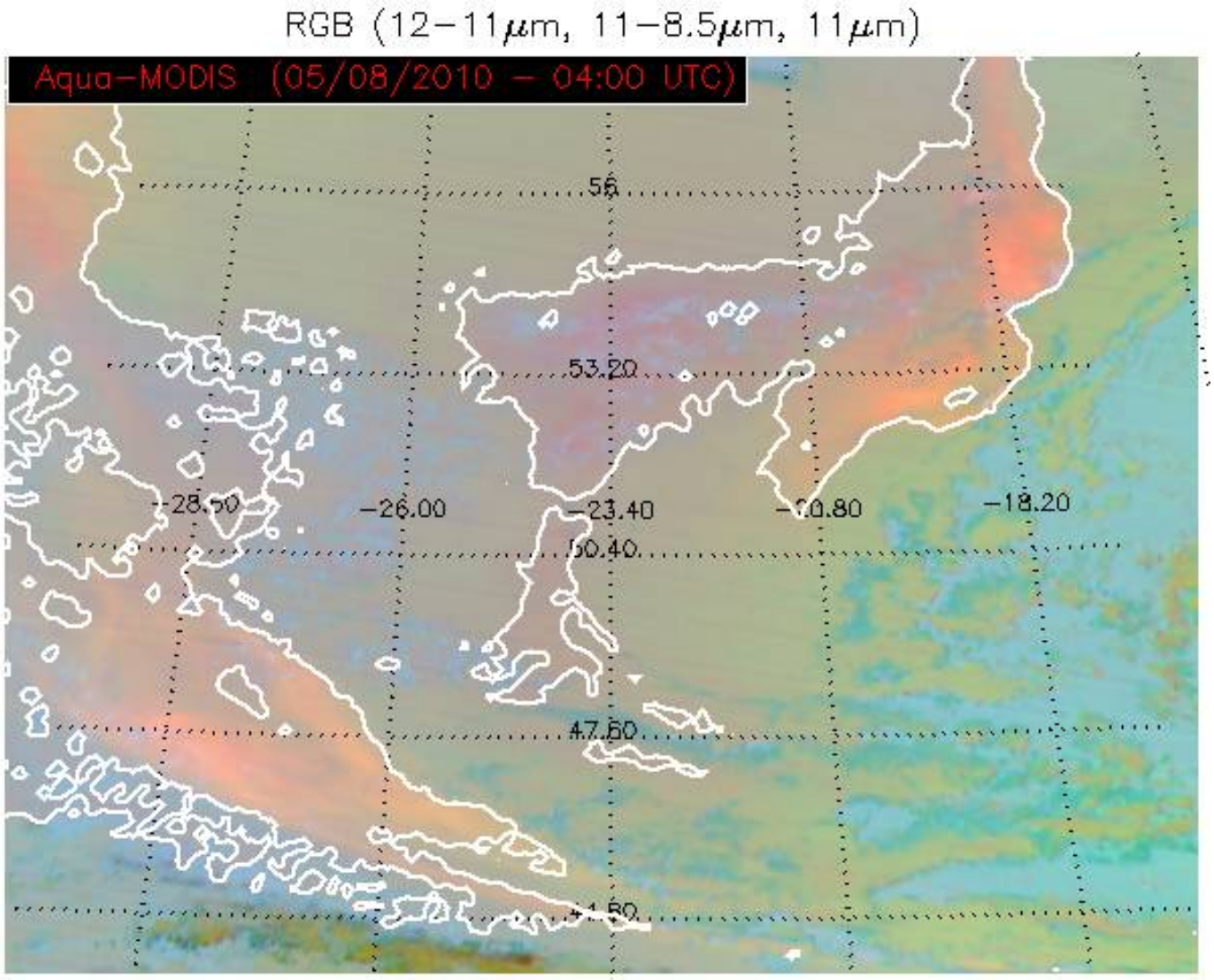


MODIS, $\theta_{sat} < 30.0^{o}$

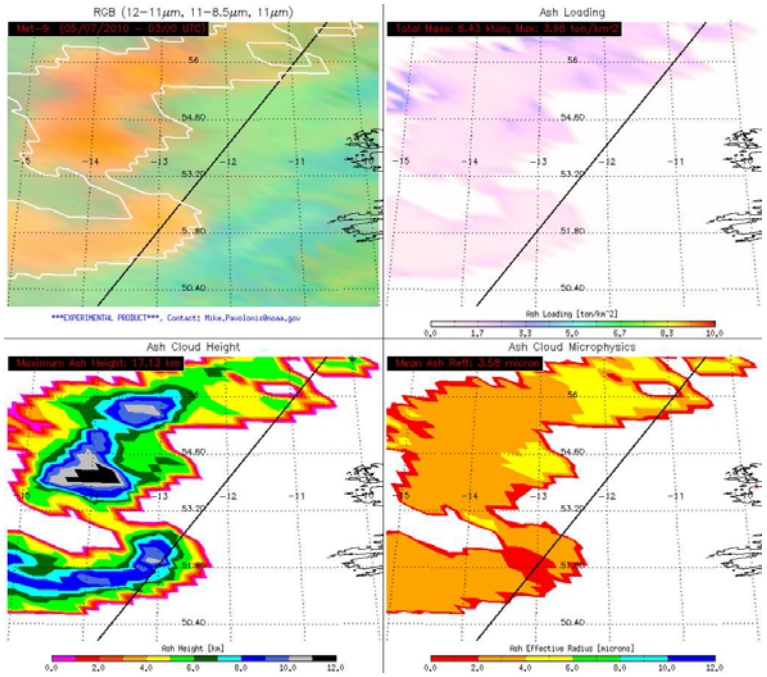
Now you don't…



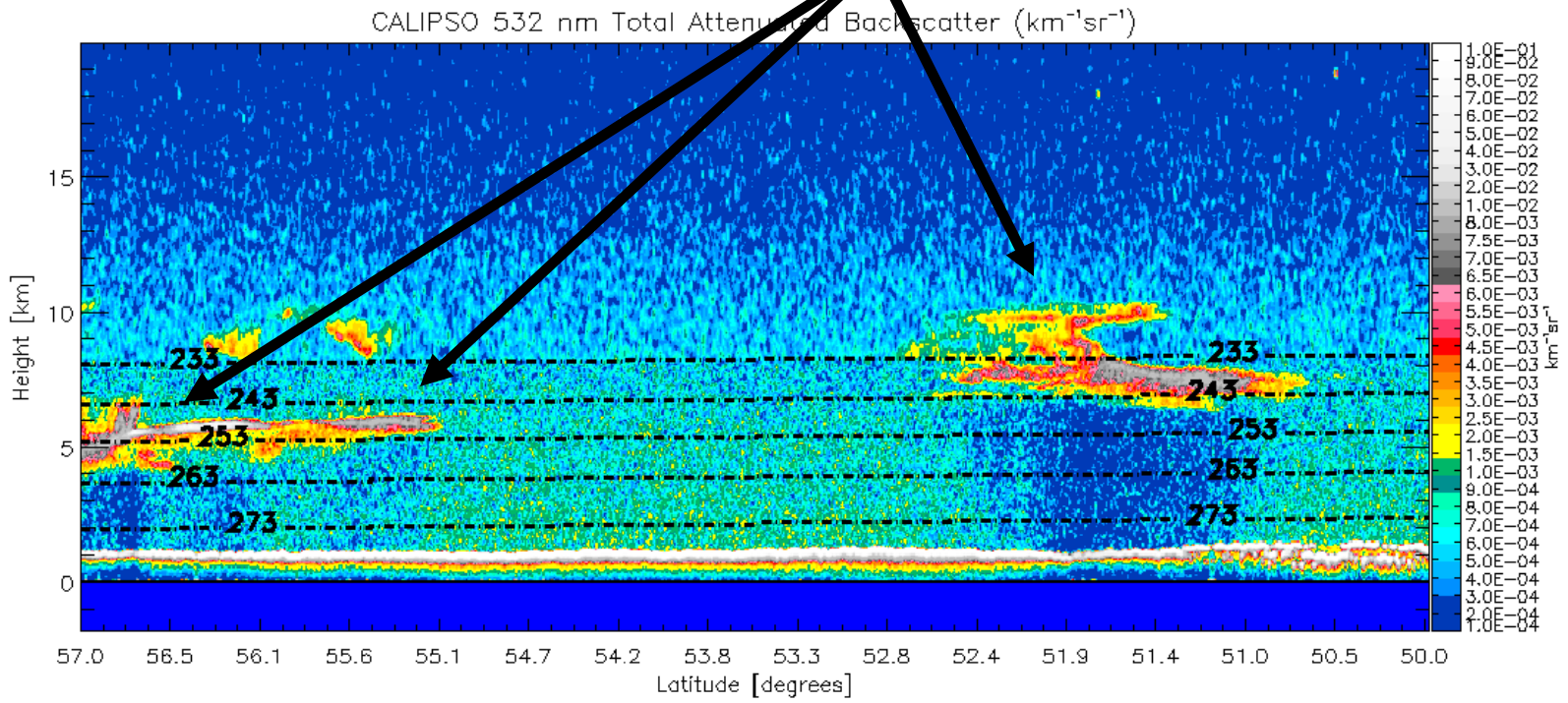
MODIS, $\theta_{sat} < 30.0^{o}$

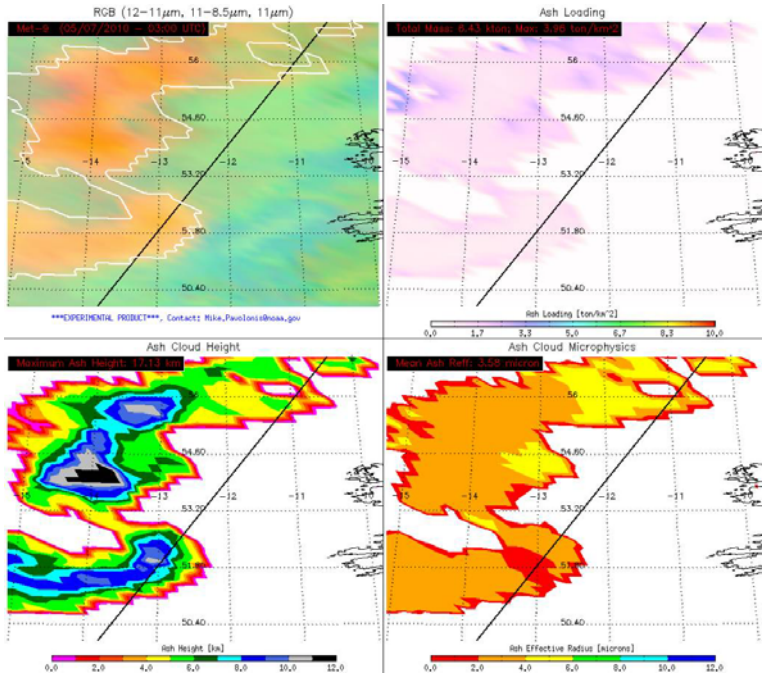


May 7, 2010 (03:00 UTC)



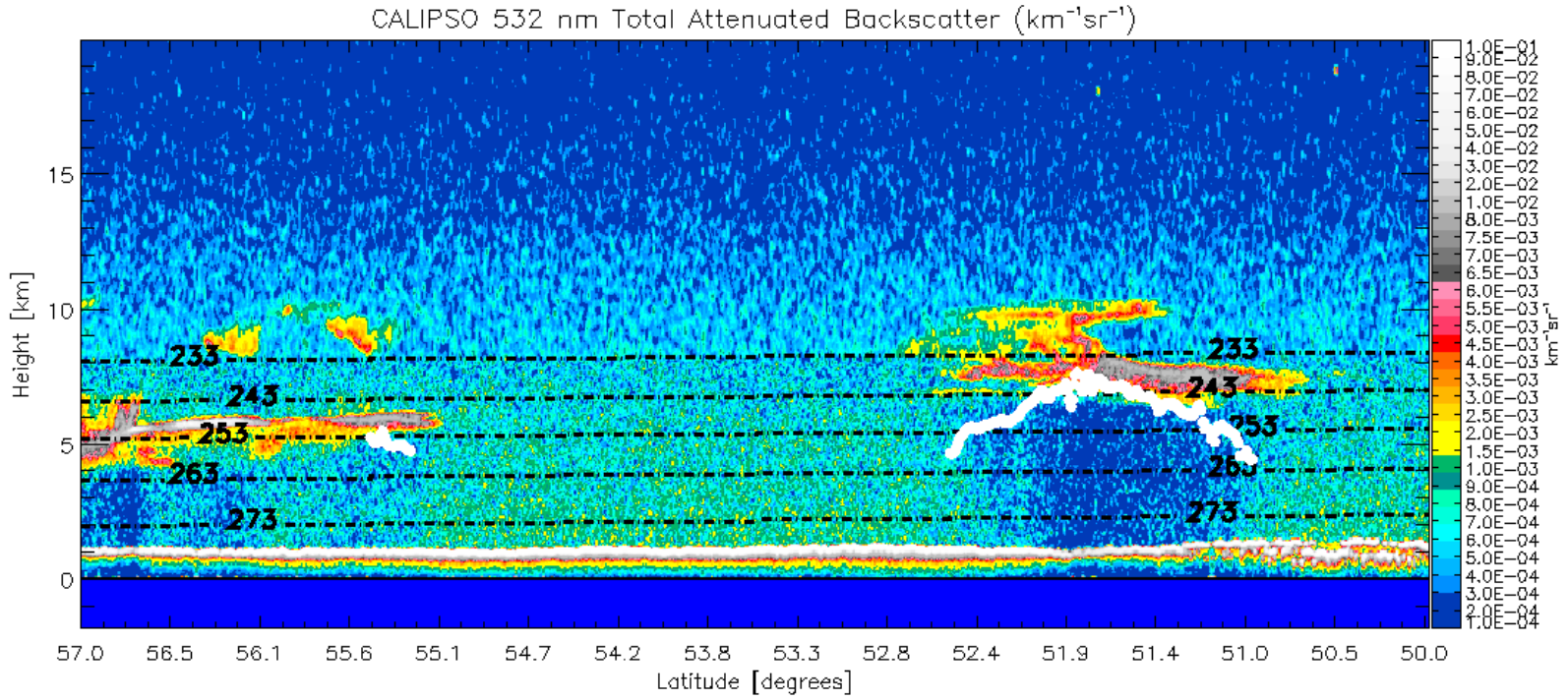
Ash clouds

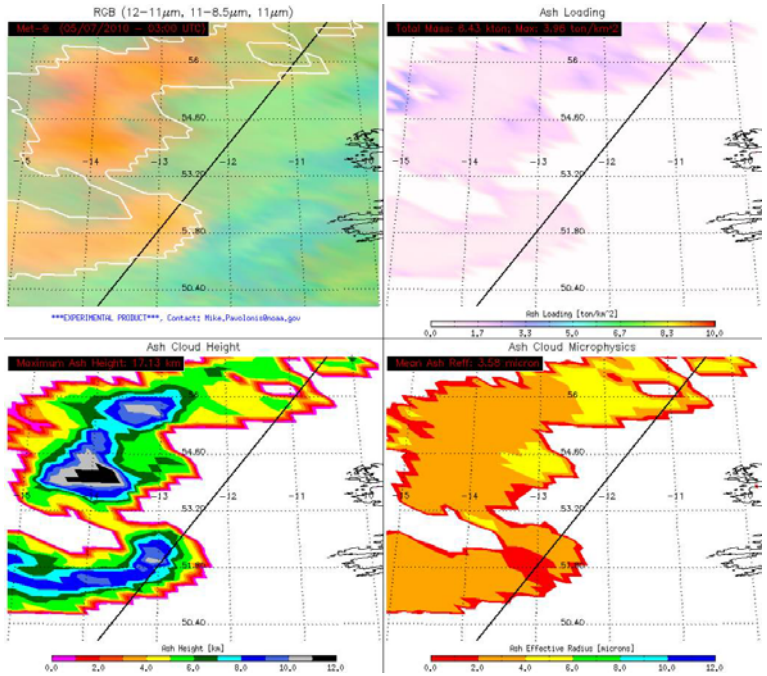




May 7, 2010 (03:00 UTC)

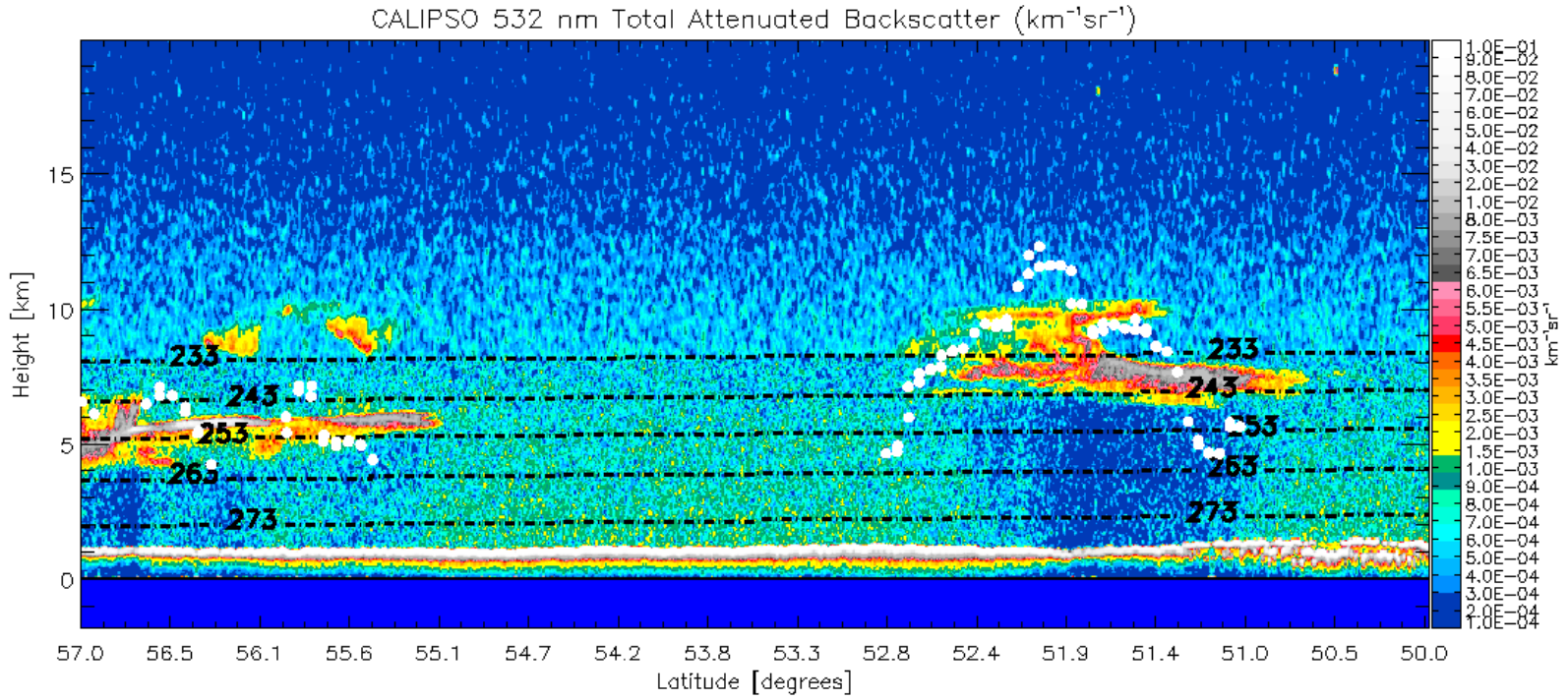
From Low Earth Orbit (MODIS)





May 7, 2010 (03:00 UTC)

From Geostationary (SEVIRI)



Topics

Marco Fulle - www.stromboli.net

- **Introduction to the GOES-R AWG volcanic ash products**
- **Eyjafjallajökull background**
- **Impact of the GOES-R volcanic ash products on volcanic ash monitoring and modeling**
- **Quality assessment**
- **Advantages of the geostationary view**
- **Looking ahead**
- **Summary**

NOAA Volcanic Ash Working Group

- In response to the major aviation disruption caused by Eyjafjallajökull, NOAA has established a Volcanic Ash Working Group (B. Pierce and M. Pavolonis represent STAR).
- Some of the goals of this group are to: examine current volcanic ash forecasting and observing tools, improve observations of volcanic ash, and work towards using satellite observations to initialize models.
- ***While the GOES-R products have been shown to be valuable, additional efforts are needed to ensure these products are addressing the goals of the VAWG***
- ***Have procedures been developed to assimilate these products into models (GOES-R RR)? Are the full capabilities of GOES-R being utilized?***

- **With an additional processing step, the ABI (and SEVIRI and MODIS) products can be used to issue automated ash cloud alerts to VAAC's.**
- **In addition, the ABI volcanic ash output can be combined with output from the SO_2 detection algorithm and lightening mapper data to build a state-of-the-art volcanic cloud alert and monitoring system.**
- **If such a decision support system is not built, the ABI's temporal resolution will not be fully utilized, as forecasters cannot possibly manually analyze every image (and the 5-minute warning criteria will not be realized).**

Text Warning

From	Subject	Date Received
Peter Webley	[volcanicclouds] Puff Automated Volcanic...	Today
mpav@ssec.wisc.edu	VOLCANIC CLOUD ALERT	Today
Mike Pavolonis	[volcanicclouds] AVHRR height and mass...	Today
Mike Pavolonis	[volcanicclouds] AVHRR height and mass...	Today

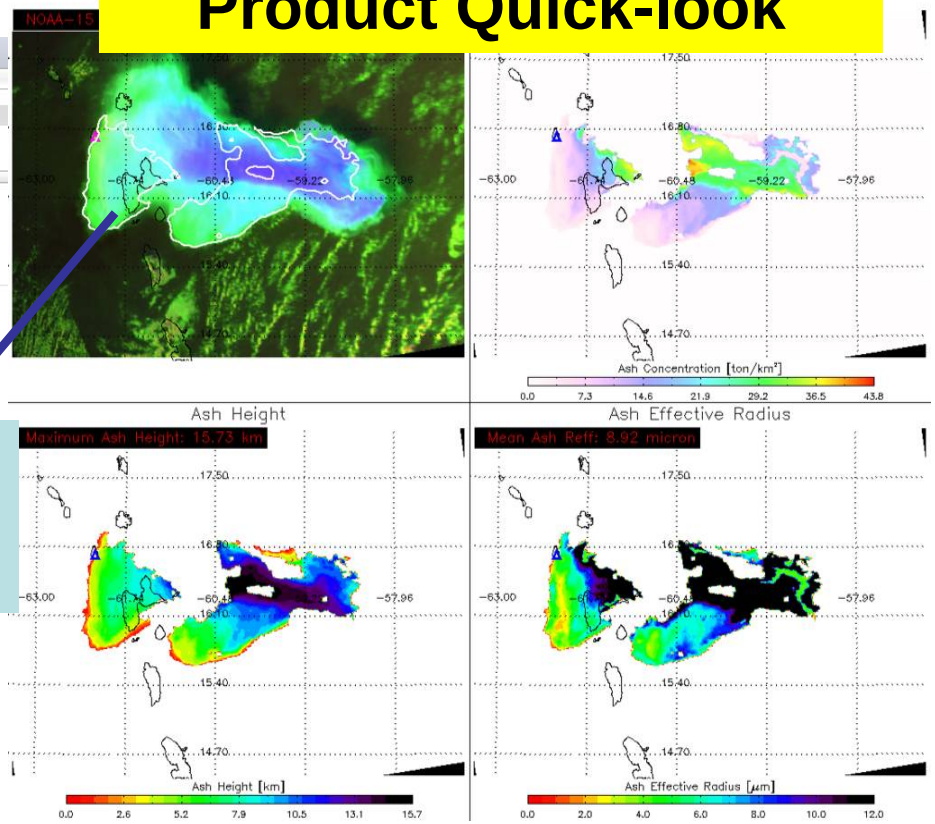
From: Mike Pavolonis
Subject: **VOLCANIC CLOUD ALERT**
Date: February 11, 2010 3:54:32 PM CST
To: Mike Pavolonis

@**********GENERATING VOLCANIC CLOUD WARNINGS**********
DATE: 02/11/2010
TIME: 20:59 UTC
SATELLITE: NOAA-15 AVHRR
L1B FILENAME: NSS.HRPT.NK.D10042.S2059.E2112.B6109191.MI
ORBIT NUMBER: 6109191
NUMBER OF ASH CLOUD WARNINGS: 1
NUMBER OF VOLCANIC Cb WARNINGS: 0
NUMBER OF VOLCANIC HOT SPOT WARNINGS: 0

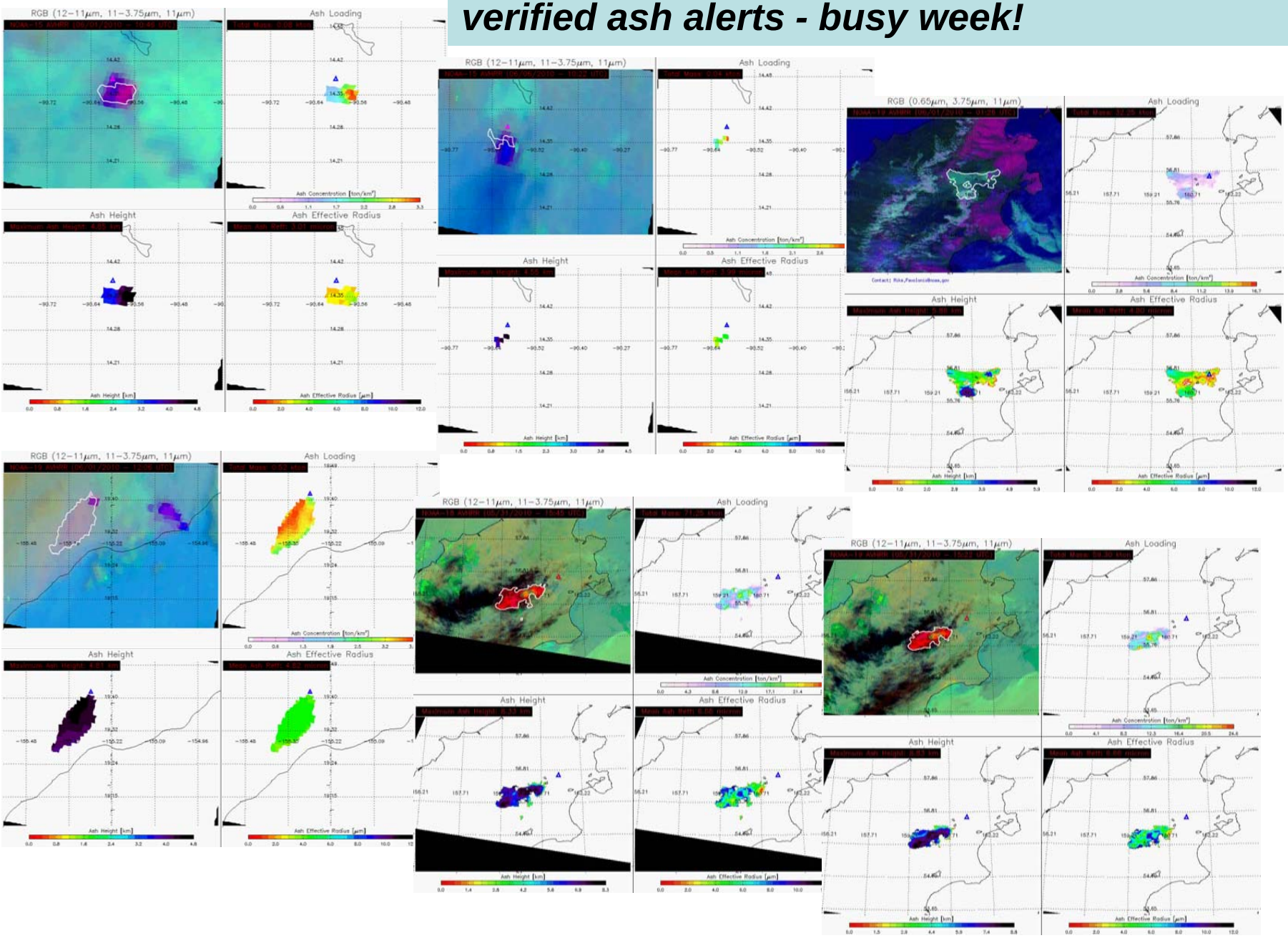
****
VOLCANIC ASH CLOUD FOUND
Radiative Center (Lat, Lon): 16.460, -61.113
Mean Viewing Angle (degrees): 43.30
Mean Solar Zenith Angle (degrees): 75.86
Nearby Volcanoes:
Soufrire Guadeloupe(75.04 km)
Diables, Morne aux(100.29 km)
False Alarm Potential: 0 out of 35515
Maximum Height: 12.4 km (40704.85 ft)
Mean Tropopause Height: 18.6 km (61069.13 ft)
Median Effective Radius: 5.54 micron
Total Mass: 72.40 ktons
Total Mass of Fine Ash: 1.16 ktons
Total Area: 6896.00 km^2
****

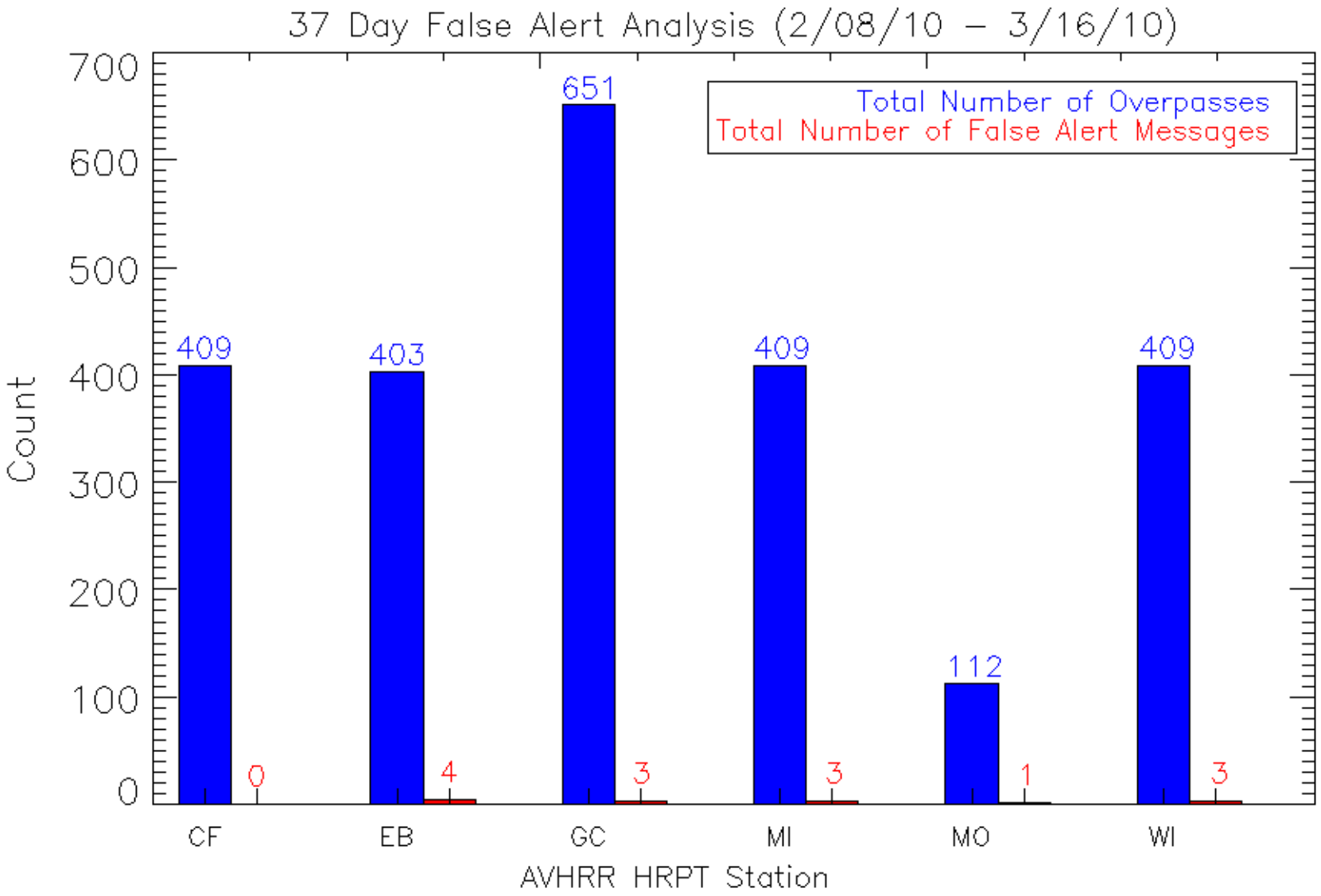
Quantitative description of ash cloud

Product Quick-look



Just in the last week or so, we received 22 verified ash alerts - busy week!




37 Day False Alert Analysis (2/08/10 – 3/16/10)
Total Number of Overpasses
Total Number of False Alert Messages
Count
700
600
500
400
300
200
100
0
409
0
403
4
651
3
409
3
112
1
409
3
CF
EB
GC
MI
MO
WI
AVHRR HRPT Station

Topics

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Summary

- **The AWG program provided the support needed to develop a sophisticated set of quantitative volcanic ash products for GOES-R (along with robust code, capable of running reliably in real-time).**

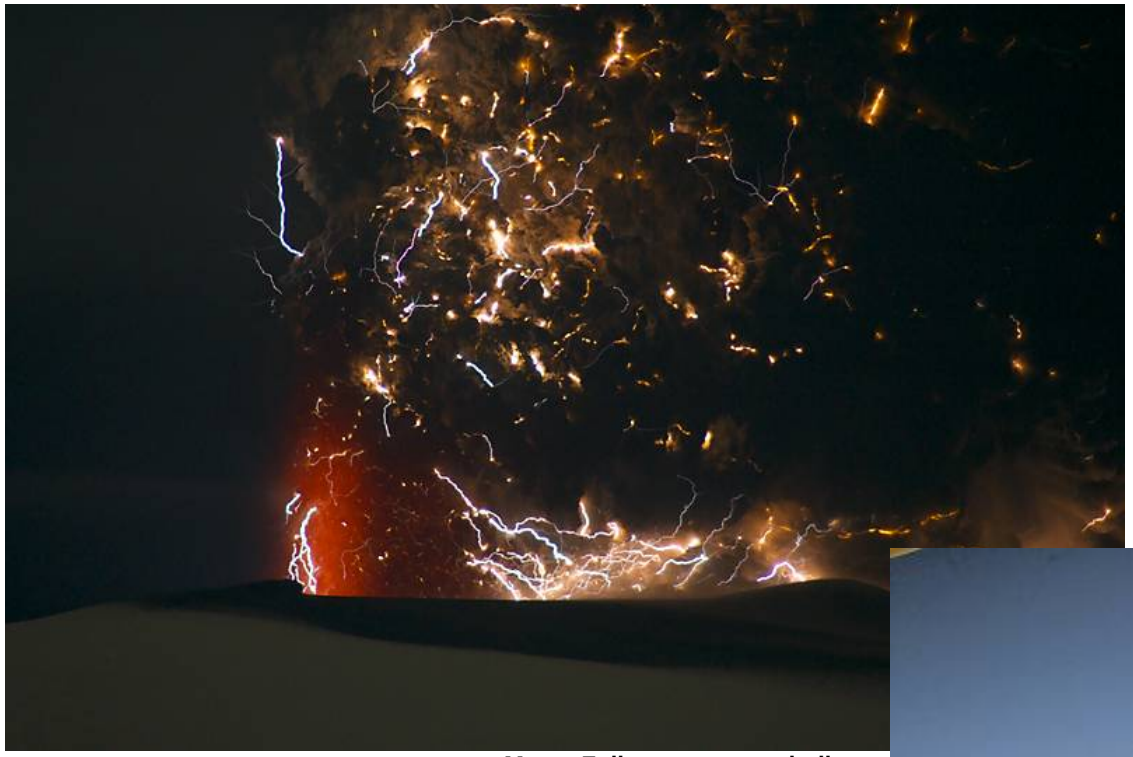
- **The eruption of Eyjafjallajökull provided an opportunity to impact operational volcanic ash forecasting and research through the generation of real-time SEVIRI products.**

- **We are now better prepared for future eruptions of Eyjafjallajökull and neighboring Katla.**

- **These products (using MODIS) will be made available to the Anchorage VAAC via the GOES-R PG.**

- **Despite the success of these products, GOES-R Risk Reduction efforts are needed to built a fully automated volcanic cloud alert system (needed to help achieve a 5-minute warning capability and take advantage of the ABI's high temporal resolution) and to develop procedures to assimilate the retrievals into models.**

Thanks!



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