VOLCANOES AND VOLCANIC ASH
PART 1

By

Jeff Braun (CIRA/SHyMet/VISIT) and

Jeff Osiensky (ESSD/NWS Alaska Region)

Also Contributing:

Bernie Connell (CIRA/SHyMet), Kristine Nelson (NWS AR) ,
and Tony Hall (NWS AR)

With Additional Information from:
Scott Bachmeier (CIMSS), Ken Pryor and others at NOAA/NESDIS and
Christina Neal and others at USGS/AVO

Photo Courtesy of Chad Hults, AVO/USGS, August 13, 2008 - Okmok

Volcanic Ash

"Ash clouds are not an everyday issue and they do not provide frequent hazard. But if encountered, volcanic ash can spoil your entire day."

(Engen, 1991)

OUTLINE

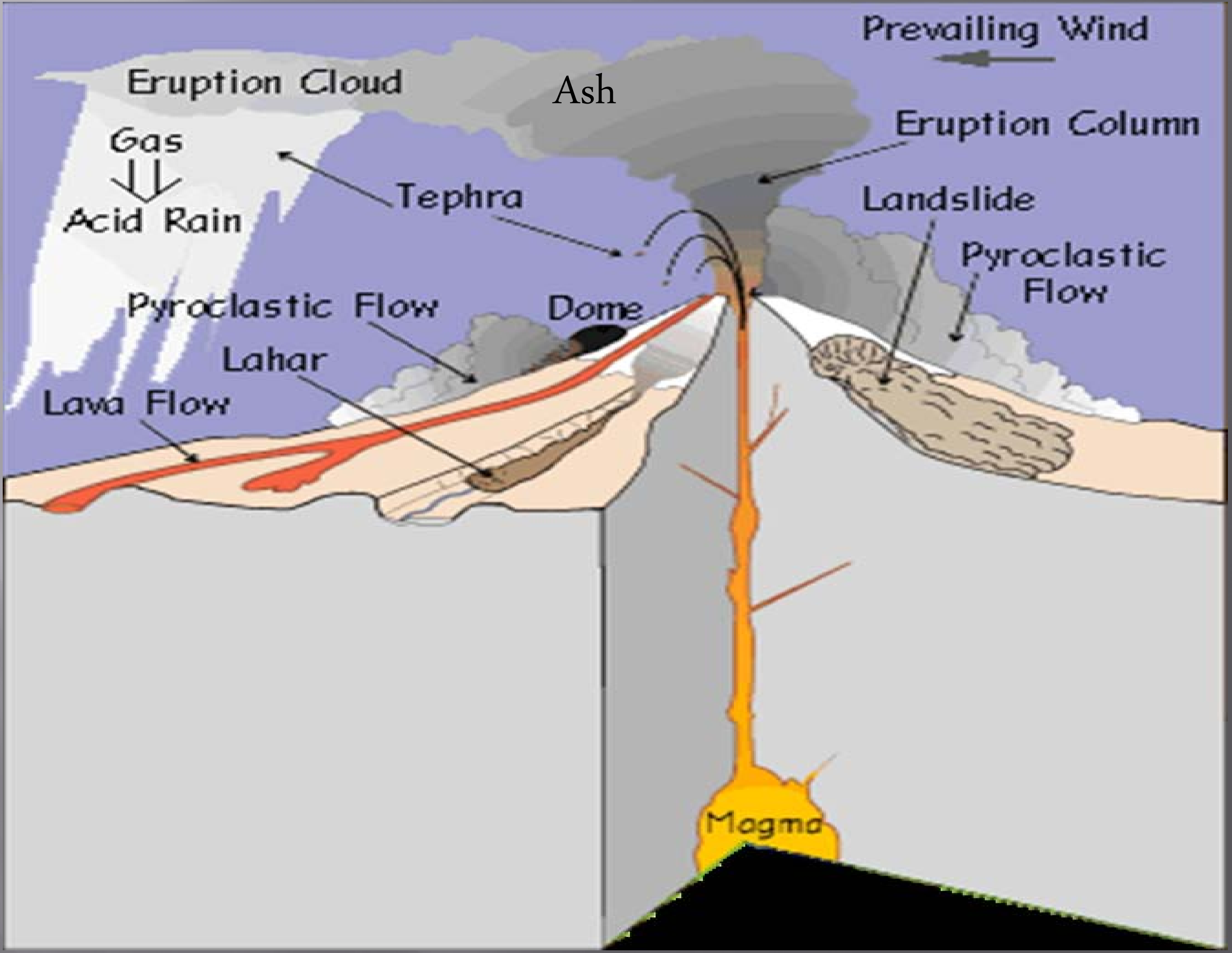
- Volcanic Activity: Effusive vs. Explosive
- Hazards on the Ground and in the Air.
  - Health hazards
  - Aviation hazards/issues
- Ash/Aerosol Detection and Observation
  - Satellite, radar, and other information
- Modeling and Plume Dispersion

Introduction to The Hazards

Eyjafjallajökull volcano, Iceland

Photo: by Marco Fulle

The Dangers



Coutesy USGS – Volcano Hazards Program

Volcanic Eruptions

Eruption of magmas and volatiles

- Effusive eruptions
  - Dominated by passive emission of lava. Kilauea Volcano in Hawaii is an example of this kind of volcano – forming row of fountains and lava flows made of basalt magma.
- Explosive eruptions
  - Dominated by the eruption of pyroclastic material that can inject large quantities of ash high into the troposphere and even the stratosphere. Okmok Volcano in Alaska (as are most of the Alaskan volcanoes) is a good example.

Eruption Mechanisms

- Gas release under decompression causing magmatic eruptions.
- Thermal contraction from chilling on contact with water causing phreatomagmatic eruptions.
- Ejection entrained particles during steam eruptions causing phreatic eruptions.

Okmok Eruption Example

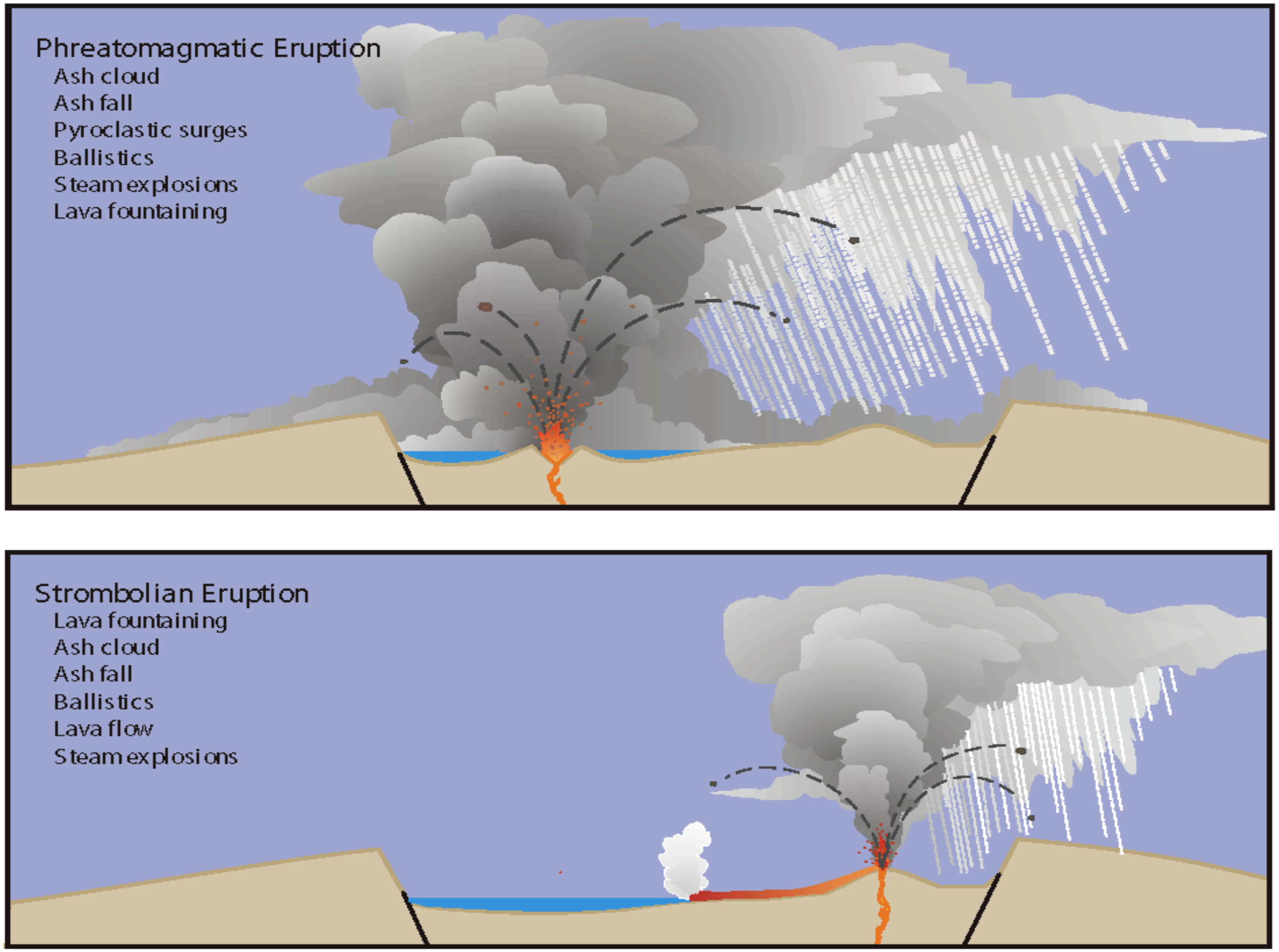


Figure 12. *Sketch of phenomena that accompany typical explosive eruptions at Okmok Volcano. Eruptions from Cone A during the 20th century were primarily Strombolian, and areas outside the caldera were affected only by ash clouds and ash falls. However, some earlier eruptions such as the 1817 event at Cone B involved magma interactions with lake water, and these hydrovolcanic explosive eruptions generated pyroclastic surges that sometimes overtopped the caldera rim and traveled down the slopes and drainages around Okmok at very high velocities.*

Okmok July 13, 2008

Hazards in the air

- Ash/sulfate aerosol can cause significant damage to airframes, and engine components
  - in-flight engine loss
  - windshield abrasion/crazing
  - instrument damage
- Ash avoidance causes substantial delays in flight operations
- Unknown health hazards associated with gases

Volcanic Plumes as Hazards to Aircraft Over the Past 35 Years

- Over the last 35 (1973-2008) years, there have been about 120 documented aircraft encounters with volcanic ash which sustained some sort of damage.
- Total repair costs of around $300 million.
- At least 9 of these encounters resulted in temporary engine failure, with 3 aircraft losing power from all engines.
- These engine failures have occurred at distances ranging from 150 to 600 miles from the erupting volcano.

Recent Example: Eyjafjallajökull and the Aviation Industry

- Eyjafjallajökull volcano, Iceland: 14 - 24 April, 2010 – $3.0 billion loss in revenue.
- 27 of the major airports in Europe were closed at one time
- Over 90,000 flights were canceled over a two week period.
- Dramatically affected: the mobility of people, transport of fresh food, medicine, machinery parts and more!
- Global impact on mobility was tremendous!

Hazards on the Ground

- Explosive eruptions can destroy vegetation and deposit volcanic rocks and ash over wide areas.
- Mud and debris flows, flash flooding, wildland fires, and hot ashflows.
- Irritant to eyes, skin and respiratory systems
  - Ash and Gases - $S0_2$, $C0_2$, and HF (acid)
- Destroys vegetation
- Collapsed roofs due to heavy ash fall
- Damage to mechanical equipment
- Impacts to ground transportation (slippery surfaces)

Volcanic Ash

Mount Redoubt – December 1989: USGS - Joyce Warren

Photo by: John Snowden, March 1944

Volcanic Ash: What is it?

- Results from an "explosive process."
- Volcanic glass, rock, or minerals
- Size: 0.001 to 2.00 millimeters
- Composition: mostly Silica (SiO_2) or other minerals rich in silica.
- It is hard, (mostly) insoluble in water, rough, and corrosive.

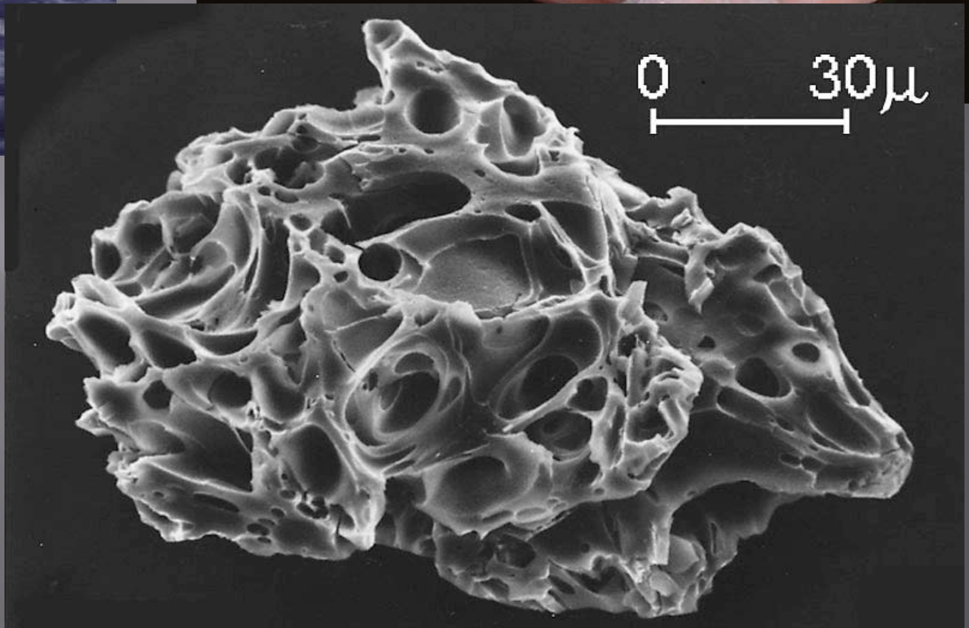
Volcanic Ash Hazards

- Volcanic Ash
  - Abrasive and dense (machinery, roof loading)
  - Conductive (electronics and power grids)
  - Small (infiltration, respiratory concern)
- Ash fallout
  - Most of the ash particles with diameter >0.5mm fall near the volcano (within 25 km) within the first hour
  - Fine grained ash typically falls out within 12-24 hours at distances of hundreds of km
- Drifting volcanic ash clouds hazardous to aviation

Close-up: The Ash of Mount St. Helens

Courtesy D. Swanson, USGS, July 1980

D. Wieprecht, USGS May 1980



SEM image provided by A.M. Sarna-Wojcicki, USGS

Ash Health Hazards

E.W. Wolfe, 1991

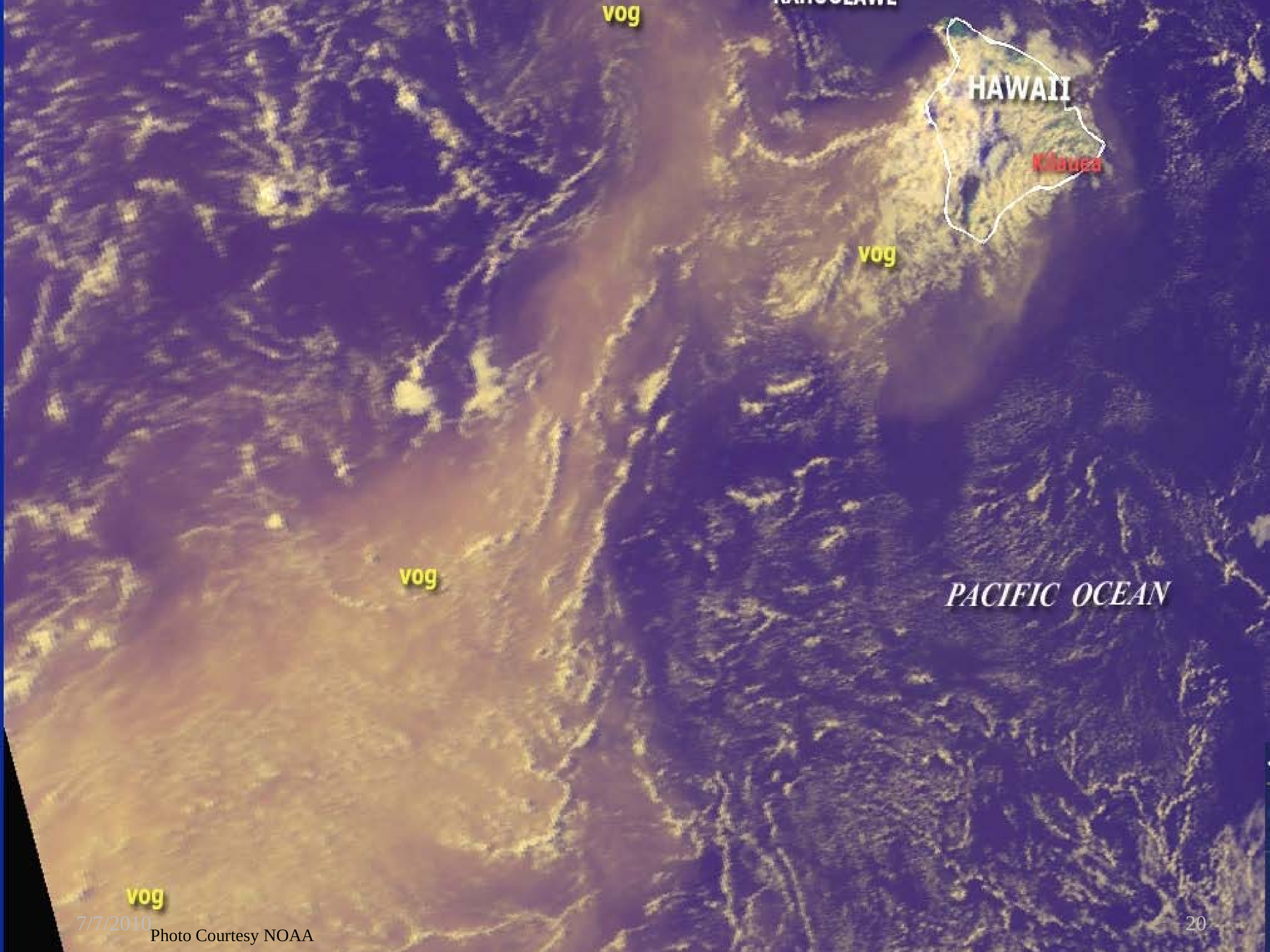


Photo Courtesy NOAA

Pyroclastic Flow

Volcanic Gases

- The most abundant volcanic gases released into the atmosphere are:

  $H_20(g)$, $C0_2$, and $S0_2$
- Small or trace amounts of others gases include:

  H_2S, $H_2(g)$, CO, HCL, HF, and HE
- The volcanic gases that pose the greatest potential hazard to people, animals, agriculture, and property are: $S0_2$, $C0_2$, and HF (acid).

Photo: S. R. Brantley (USGS)

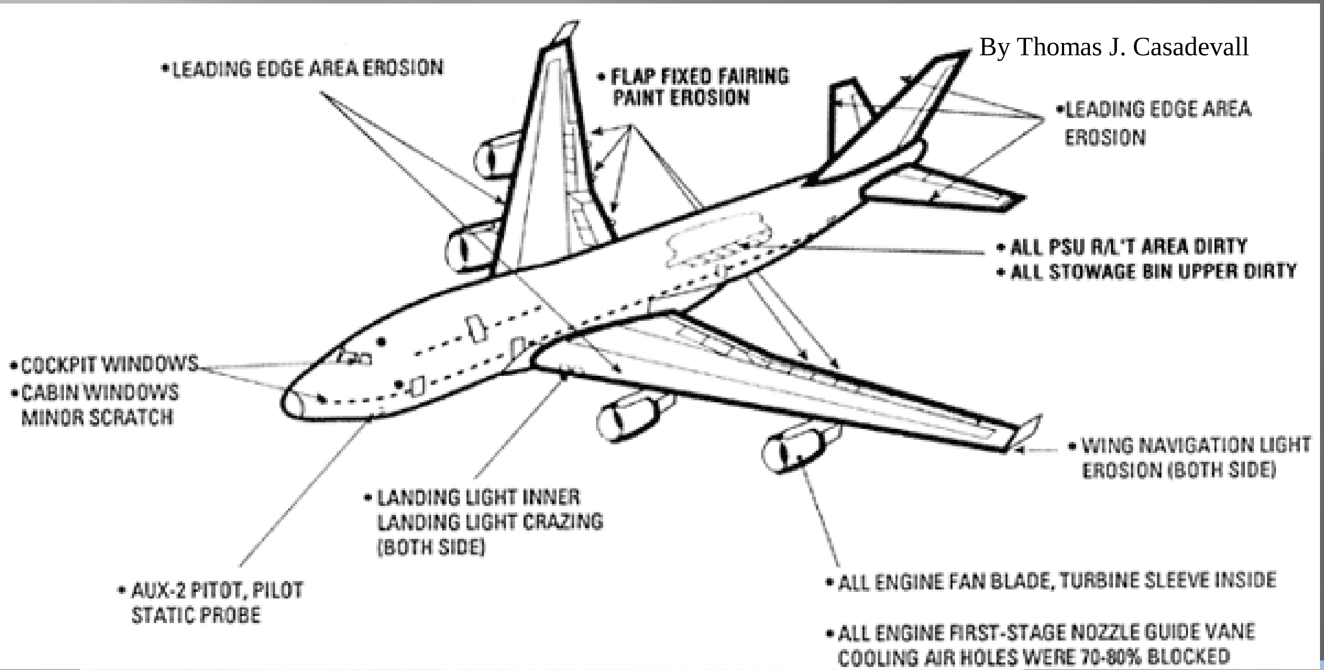
SO_2 (g) – Sulfate Aerosols

- SO_2 as a proxy for ash
- Following sulfur rich eruptions of El Chichón (1982) and Pinatubo (1991)
  - Crazing of acrylic windows, forward airframe damage, fading of polyurethane paint, accumulation of sulfate deposits in turbines
- Haze > reduced visibility (VOG)

Volcanic ash plumes as hazards to aviation

Photo: Jeff Williams, NASA

Damage to Aircraft

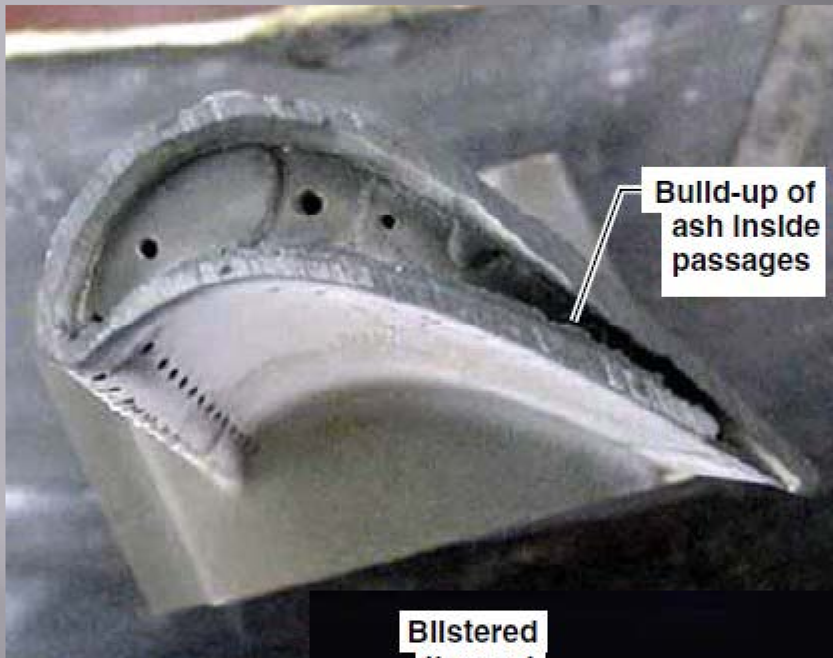


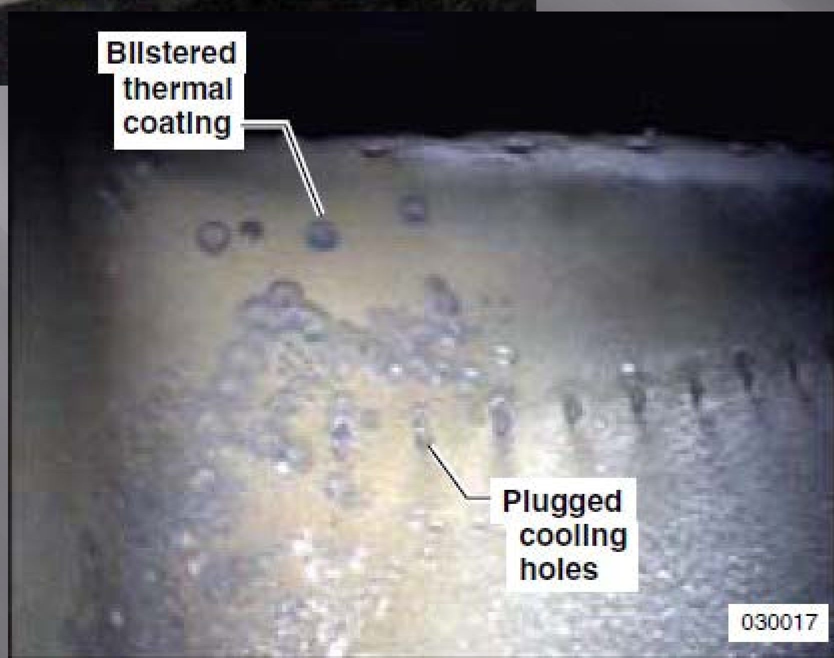
By Thomas J. Casadevall

Courtesy OFCM

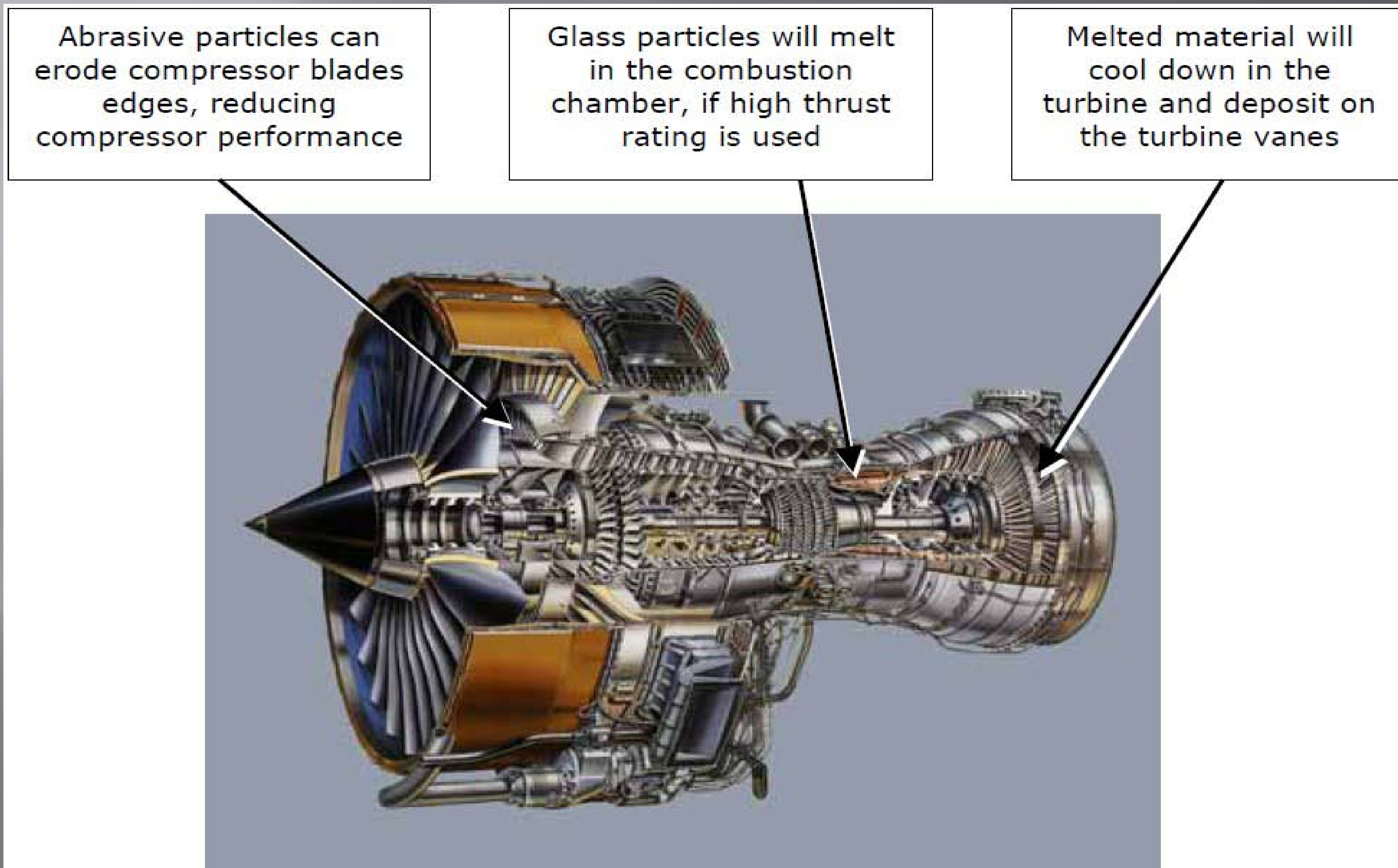

Photo: R.L. Rieger, U.S. Navy

Volcanic Ash – What is Enough?





Effect of Volcanic Ash on Jet Engines



International Civil Aviation Organization

ICAO ASH SEVERITY INDEX

- Class 0: acrid odor, electrostatic discharge, no damage reported
- Class 1: light cabin dust, EGT fluctuations
- Class 2: heavy cabin dust, external & int. abrasion damage, window frosting
- Class 3: engine vibration, erroneous instrument readings, hydraulic-fluid contamination, damage to engine and
- electrical system
- Class 4: engine failure requiring in-flight restart
- Class 5: engine failure or other damage leading to crash

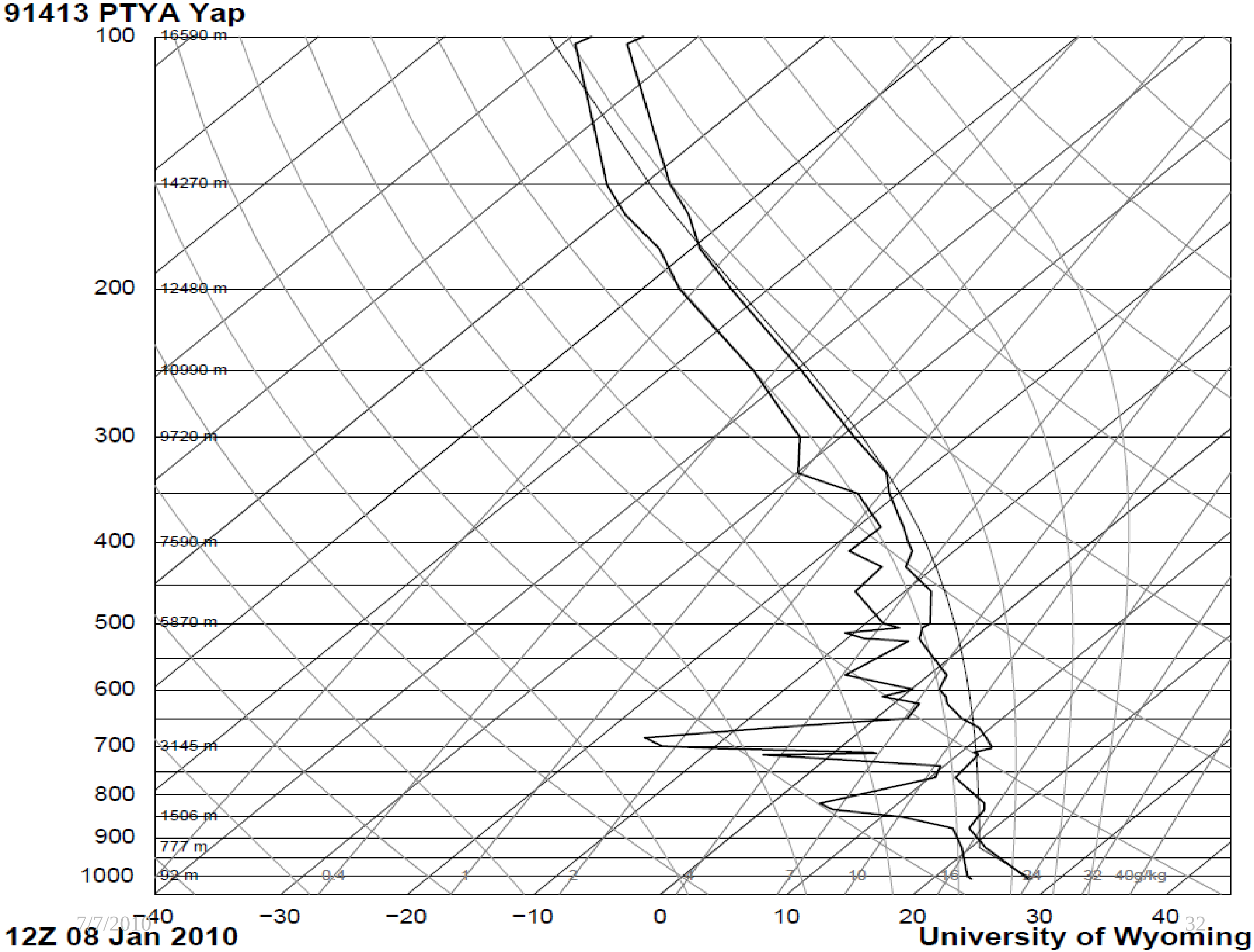
Volcanic plume characteristics

- Eruptive volcanic plumes occur in numerous forms, varying in height, intensity, duration and in style.
- A forced jet occurs at the vent surface, controlling the mass and heat flux.
- An umbrella region spreads out atop the column.
- Convective columns do not extend above the middle stratosphere.

Eruption Height and Tropospheric Instability

- Plume height is affected by wind shear and atmospheric instability.
- Even relatively weak eruptions in moist tropics can trigger deep convection columns (15-20 km).
- The same eruptive intensities will produce vastly different eruptive heights between the polar regions and the tropics (up 8 - 10 km difference at times).

From: Tupper et al. 2009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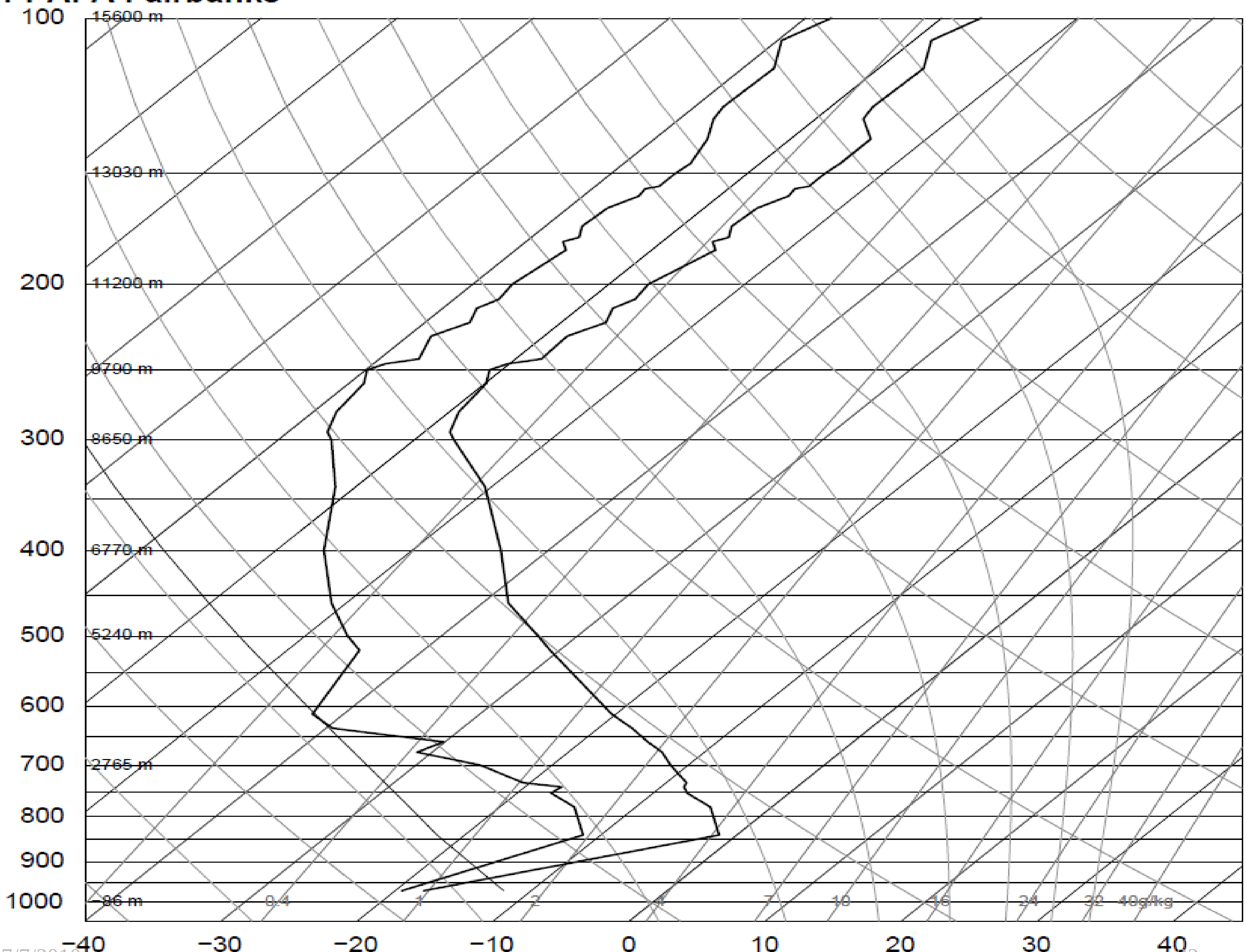
University of Wyoming

70261 PAFA Fairbanks



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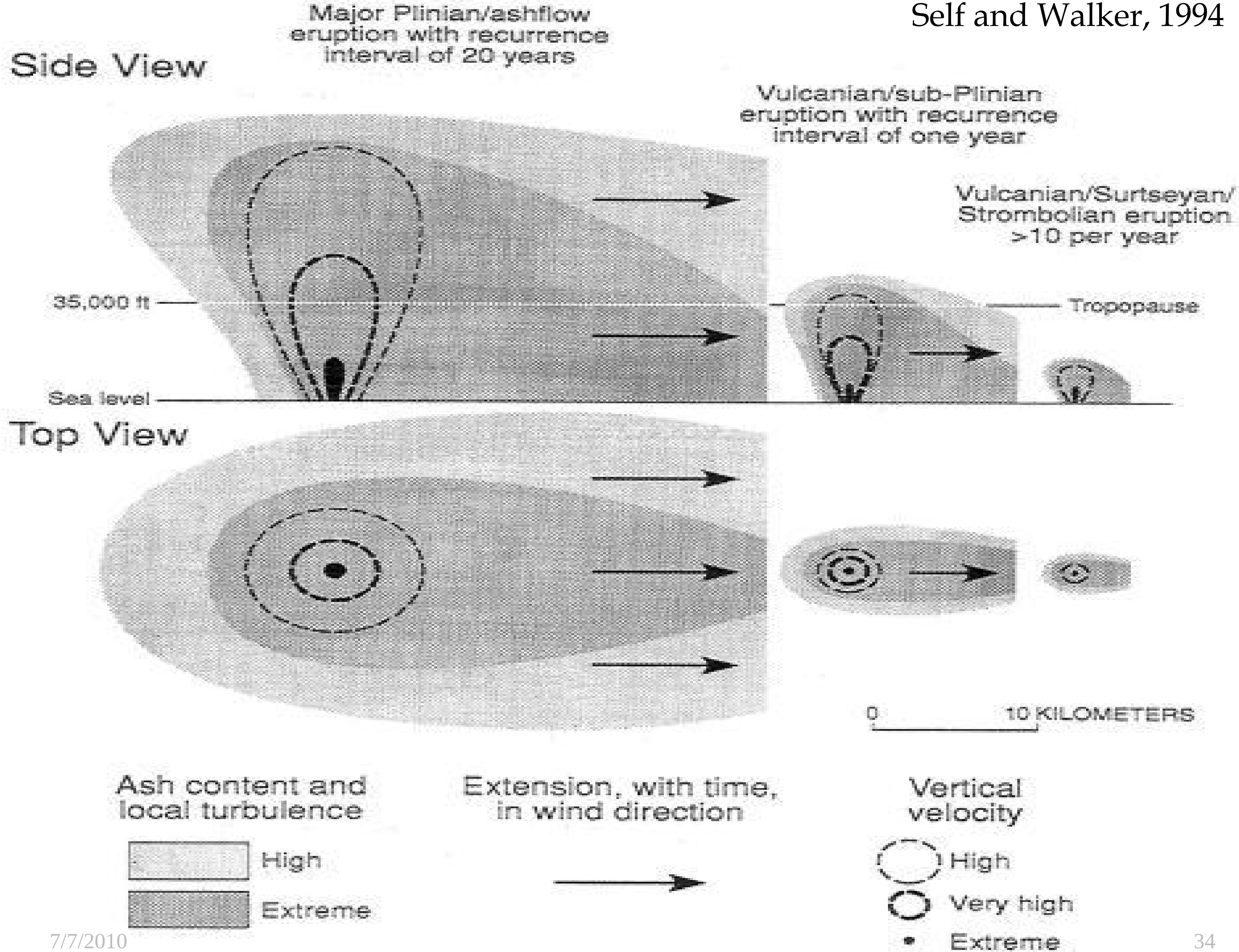
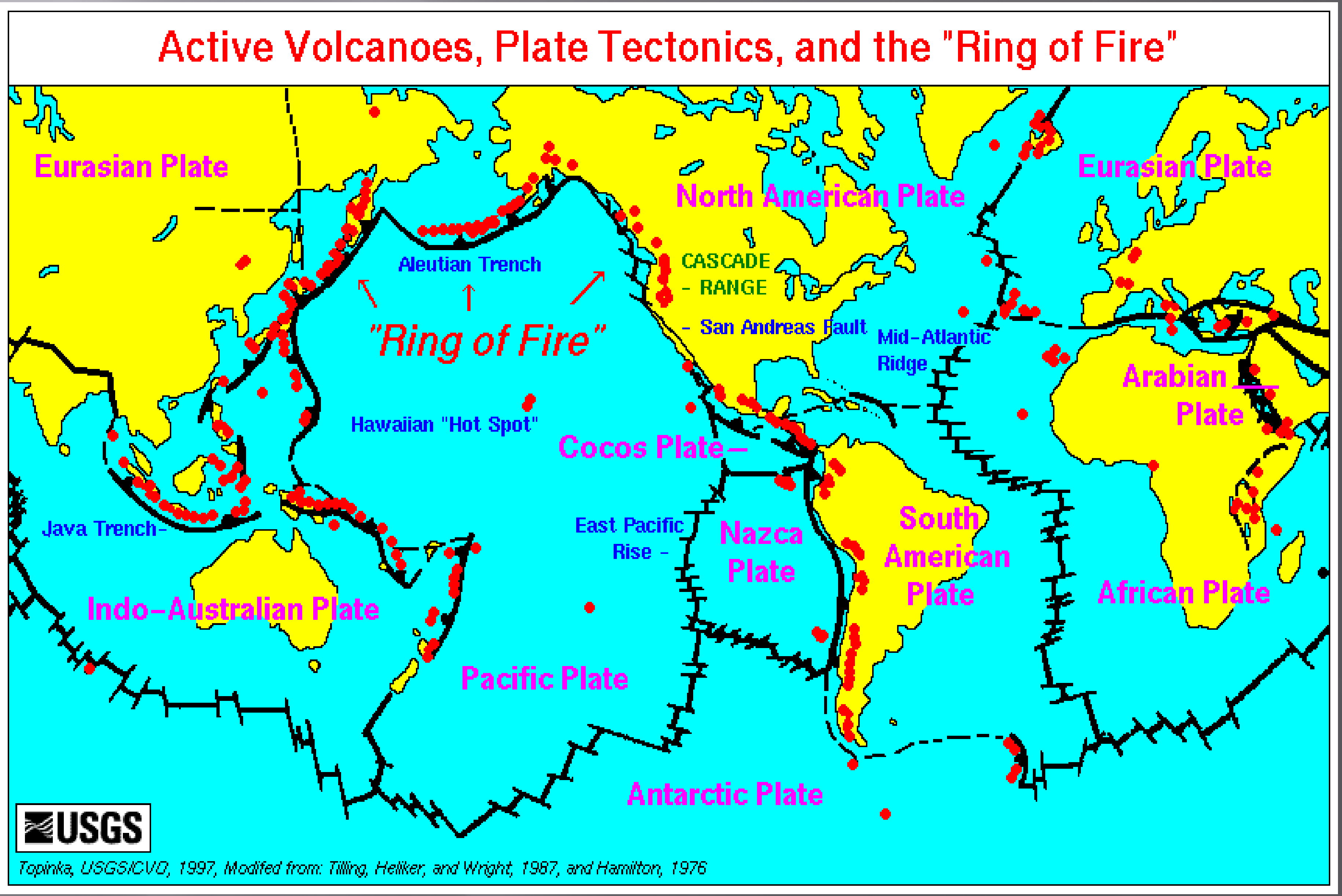
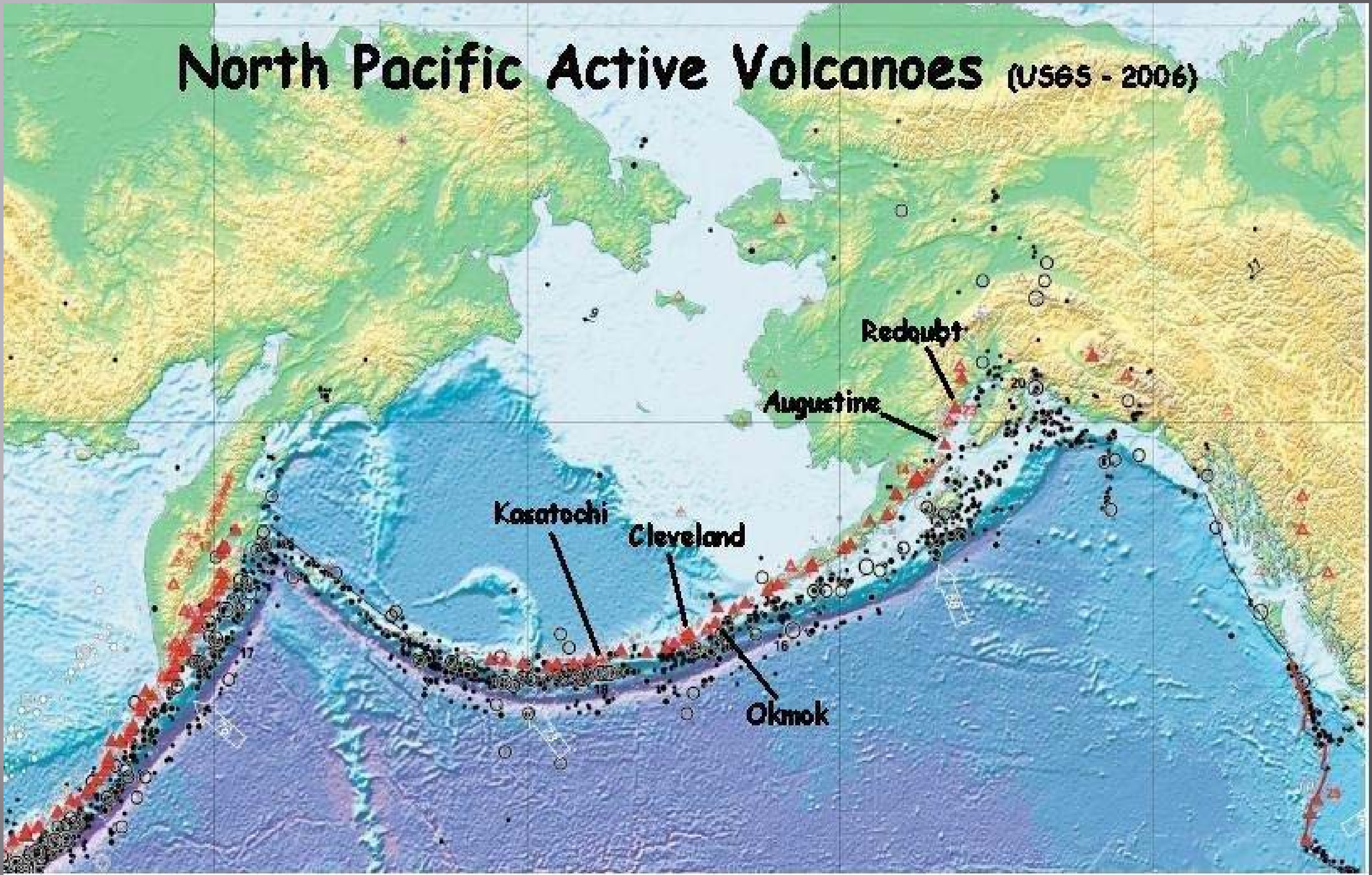
University of Wyoming

Self and Walker, 1994



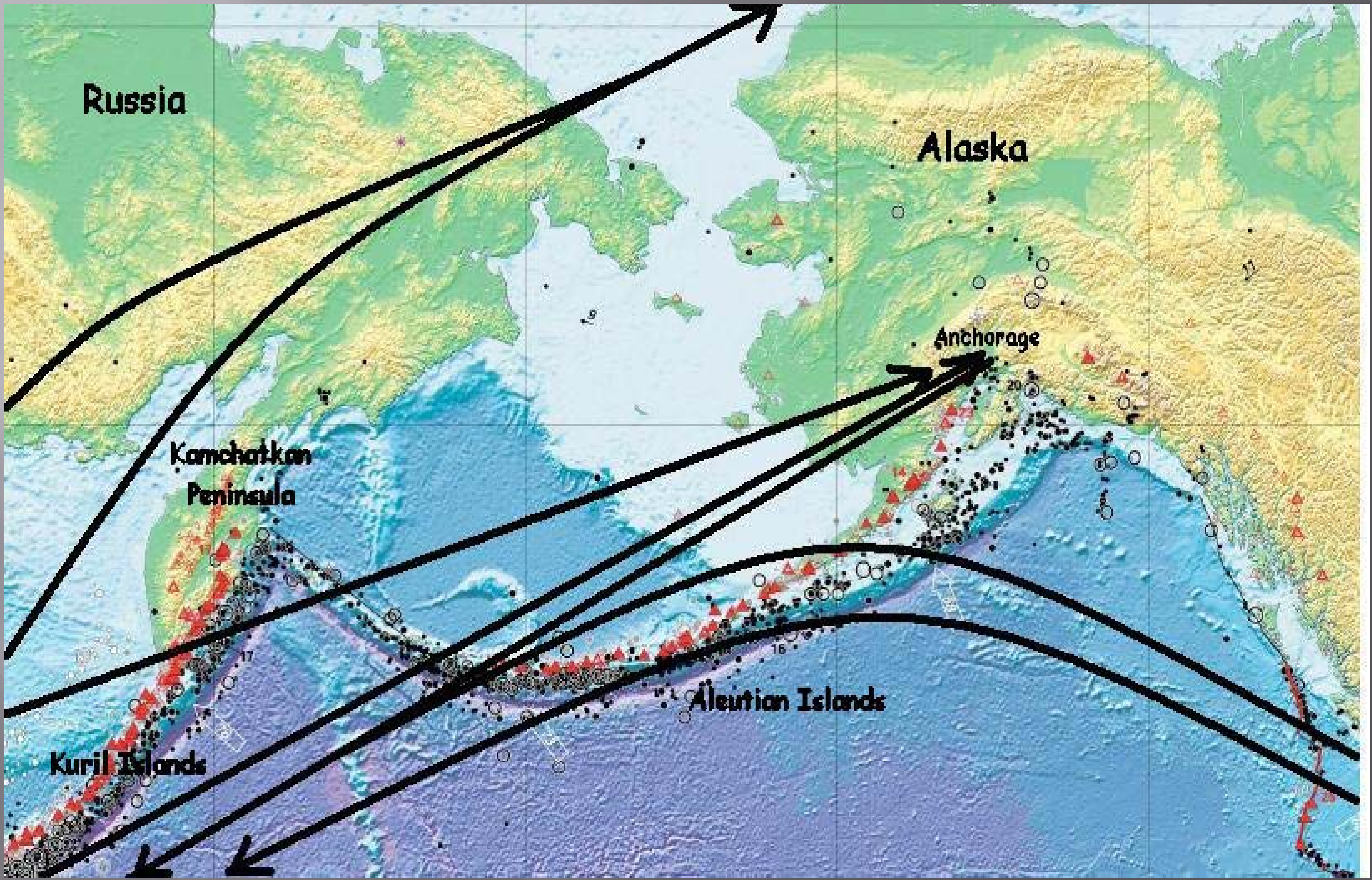


Map : Topinka, USGS 1997



From "This Dynamic Planet" World Map of Volcanoes, Earthquakes, Impact Craters, and Plate Tectonics - USGS 2006

Common Routes of some of the nearly 100,000 flights per year over the NOPAC



Volcanic Hazards to Airports

Photo: R.L. Rieger, U.S. Navy

Guatemala City, Friday May 28, 2010

Photo: Photo/Jose Luis Pos

Volcanic Hazards to Airports

- At least 101 airports in 28 countries were impacted on 171 occasions between 1944 and 2006 by the eruptions of 46 volcanoes.
- The primary hazard to airports is ashfall.
- Ash accumulation of anything more than a trace amount requires full removal of the ash in order for airports to resume full operations.
- Indonesia, the USA, and Japan have the most volcanoes (seven, five, and five, respectively) whose eruptions have impacted airports.

Guffanti et al. 2009

Reducing Impact to Airport and Aircraft Operations

Volcano Observatories

– pre-eruption, eruption and post eruption monitoring including:

- **Geodesy – look for ground deformation**
- **Seismology – listen/feel indications of ground motion**
- **Geochemical – look for changes in gas chemistry and flux**
- **Other methods: Acoustic, Gravimetric, Thermal, Electromagnetic, Visual**

Reducing Impact to Airport and Aircraft Operations

- **VAAC – Volcanic Ash Advisory Centers**
  - Develop and execute volcanic ash dispersion models in real-time.
  - Continuously use satellite information to identify volcanic ash and to discriminate volcanic ash clouds from weather clouds.
  - Issue Volcanic Ash Advisory (VAA) and Volcanic Ash Graphic (VAG), which provide guidance to MWOs for SIGMETs involving volcanic ash.
  - Provide advisory service to Regional Forecast Centers, MWOs and other VAACs.
  - Coordinate with the aviation community, the public and neighboring VAACs about volcanic episodes.

Reducing Impact to Airport and Aircraft Operations

- (Fore)warning of imminent volcanic eruptions and hazards can reduce operational disruptions at airports.
- Methods include:
  - Better real-time detection of explosive volcanic activity.
  - Forecasts modeling of ash-plume paths (PUFF and/or HYSPLIT).
  - Detection of ash plumes using ground-based Doppler Radar.

Remote Sensing and Observations

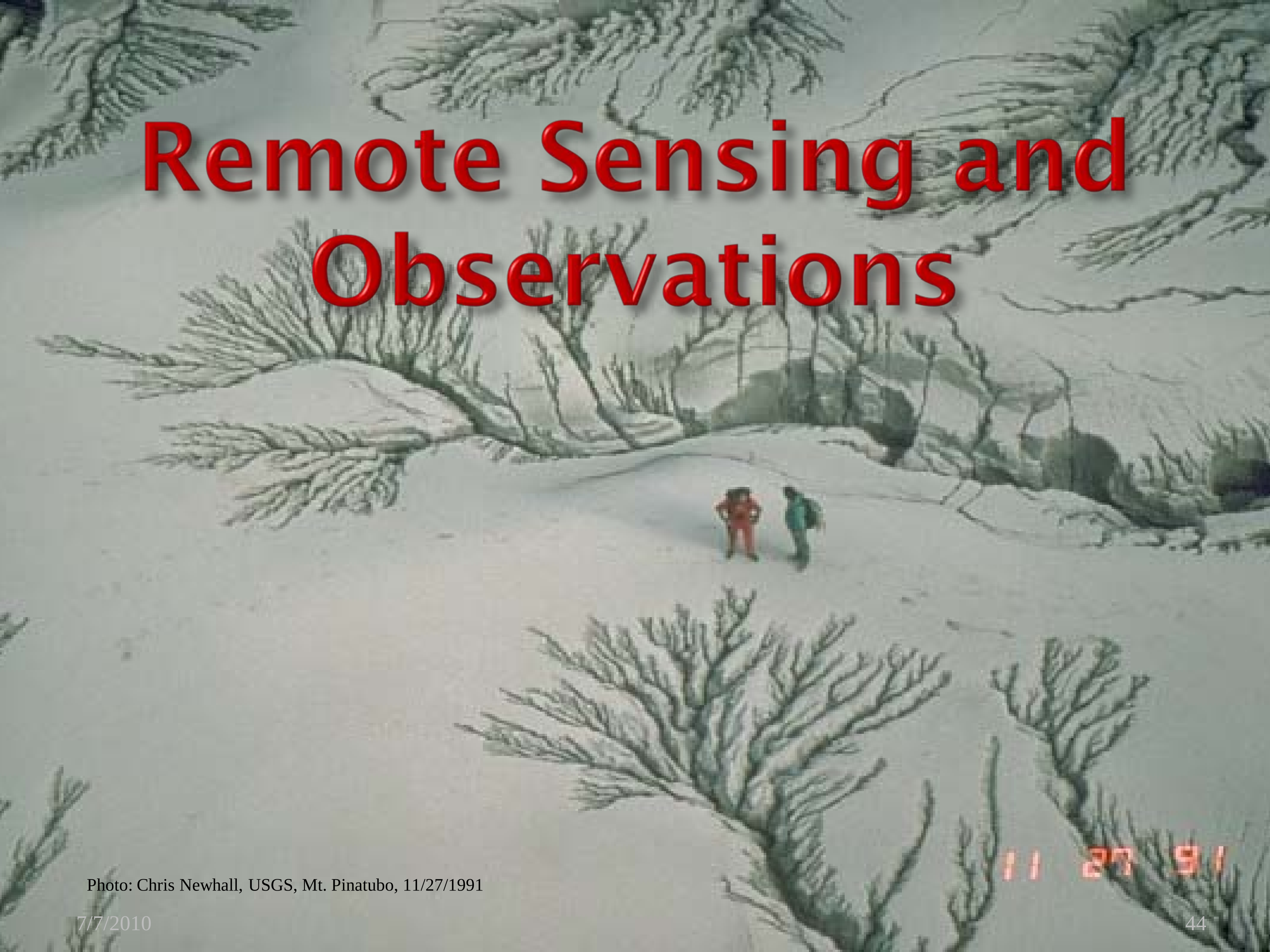


Photo: Chris Newhall, USGS, Mt. Pinatubo, 11/27/1991

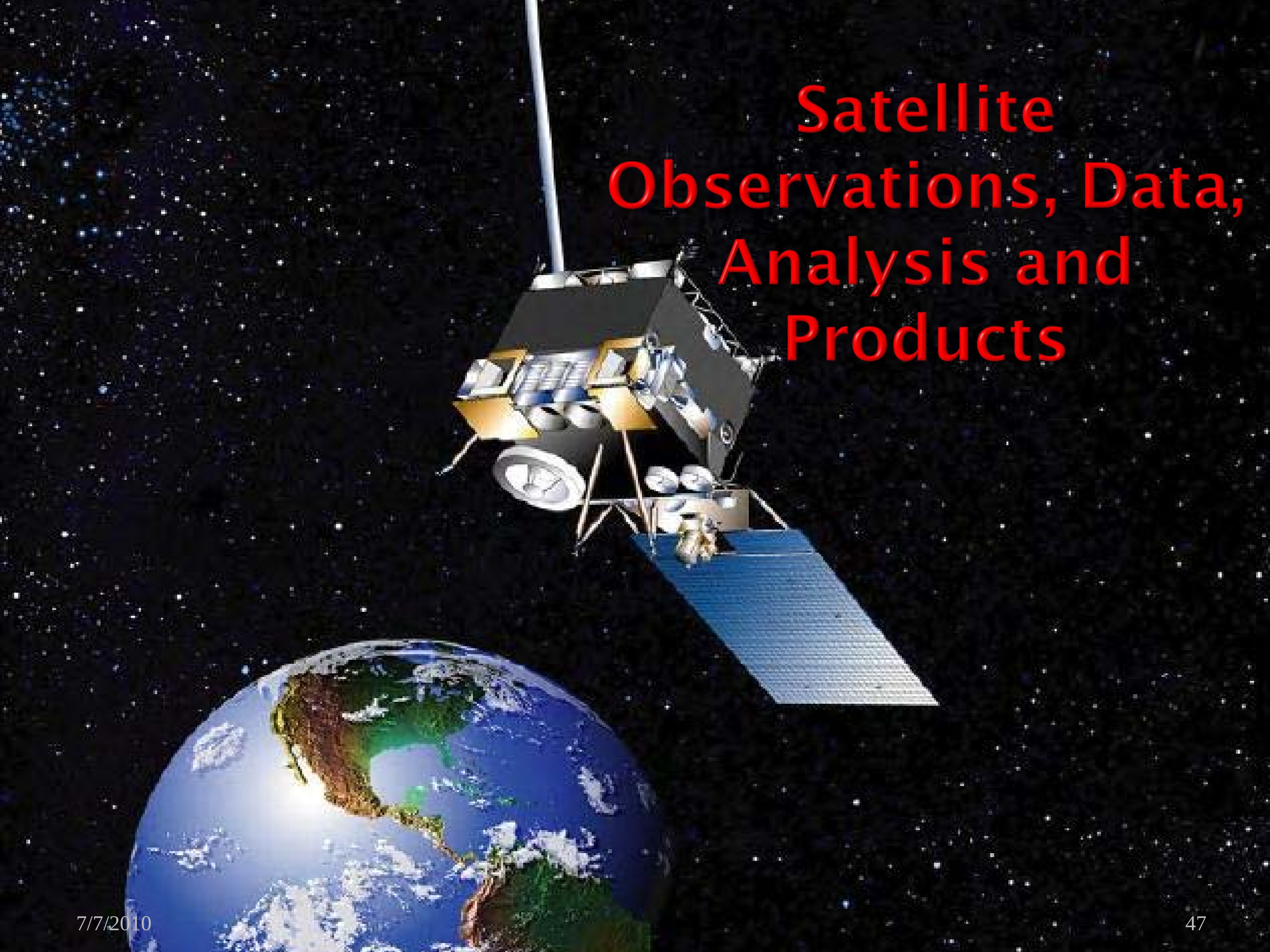
Importance of Remote Sensing

- Global coverage
- Allows for tracking of the plume both during the day and at night.
  - Provides information in remote locations
  - Can be used in conjunction with other information to determine plume height and probable plume movement.

Real-time Ash and Aerosol Detection

- Observation by Satellite
  - Visible Imagery
  - Reverse absorption: BT 10.7 µm – BT 12.0 µm
  - 3.9 µm imagery for detection hot spots/ash clouds
  - SO_2 detection using Infrared (IR) measurements in the 7 – 12 µm range
  - Image enhancement techniques
- Observation by Aircraft
  - Visual/Camera
  - Pilot Reports
- Observations from the Ground
  - Radar
  - Automatic Cameras or Video Cameras

Satellite Observations, Data, Analysis and Products



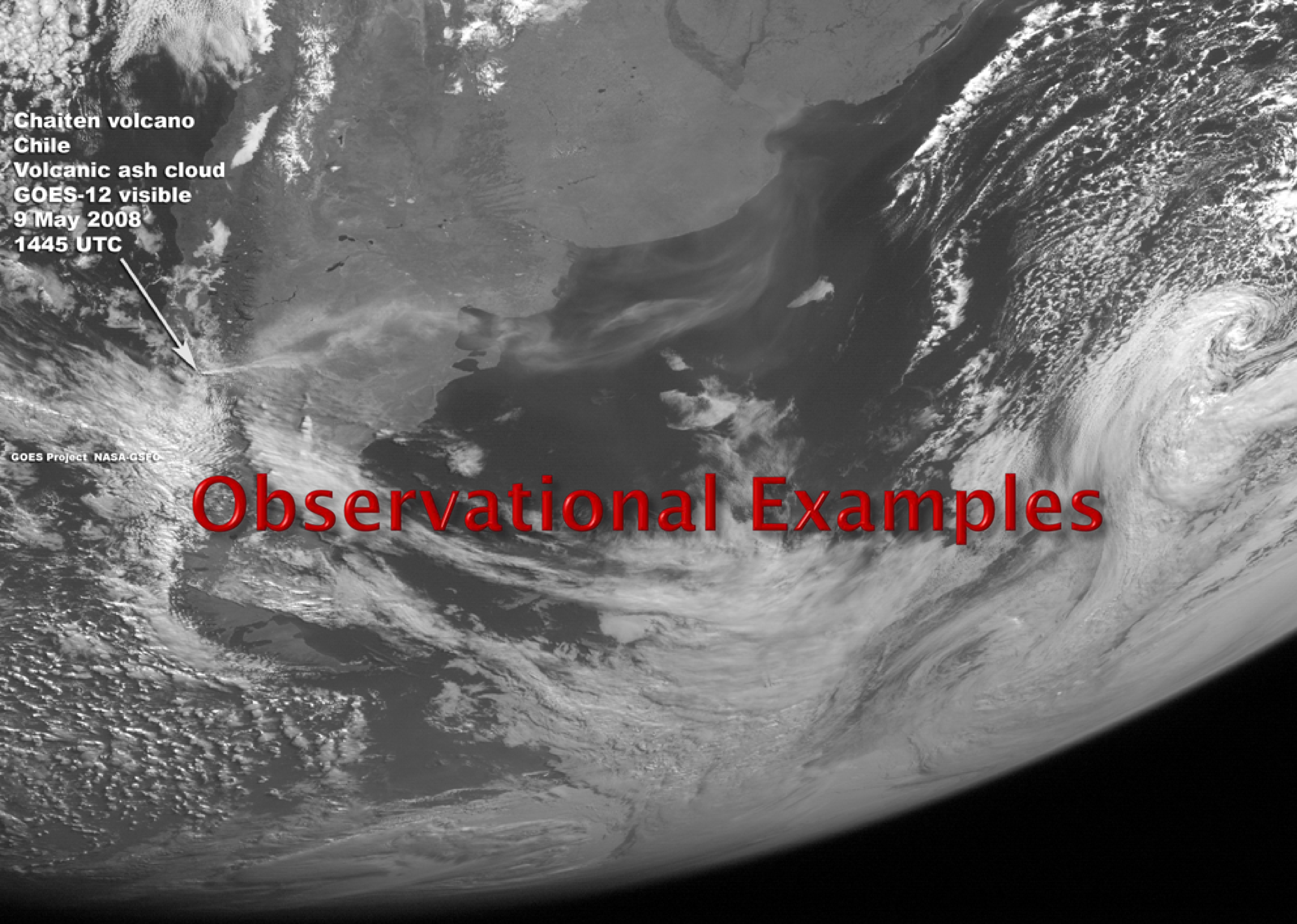
Goals of Using Satellite Data

- Quick and efficient detection of an eruption (ash) plume
- Monitoring of the thermal energy emitted from the volcano
- Mapping of the surface deformation of a volcano, including topography and topographic change
- Producing temporal and spatial distribution of ash and gases produced a volcanic eruption
- Contributing to a “baseline” data set for quantifying future changes in a give volcano
- Contributing to a “model” data set that can produce future movement of ash or gases

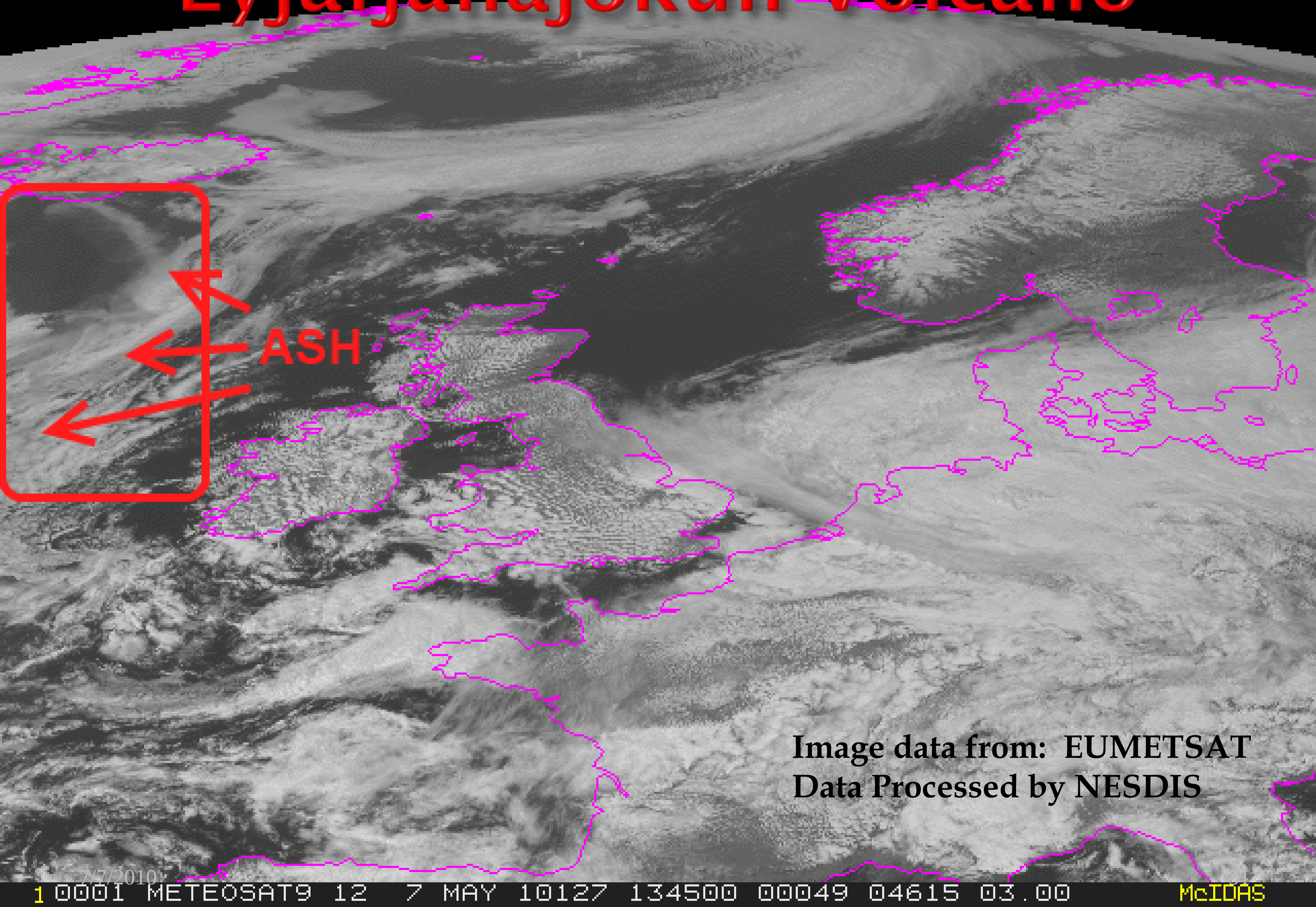
Satellite Products Used:

- NOAA's GOES and POES satellites; Japan's MTSAT series; Europe's Meteosat series.
  - Visible, Shortwave IR, Longwave IR and Differencing Products (Split Window).
- GOES and POES: (Multispectral) Principal Component Analysis and Images (PCA and PCI)
- GOES and POES: (Multispectral) Ellrod Derived Products
- Aura-OMI (Ozone Monitoring Instrument)

Observational Examples



Eyjafjallajokull Volcano



Eyjafjallajokull Volcano

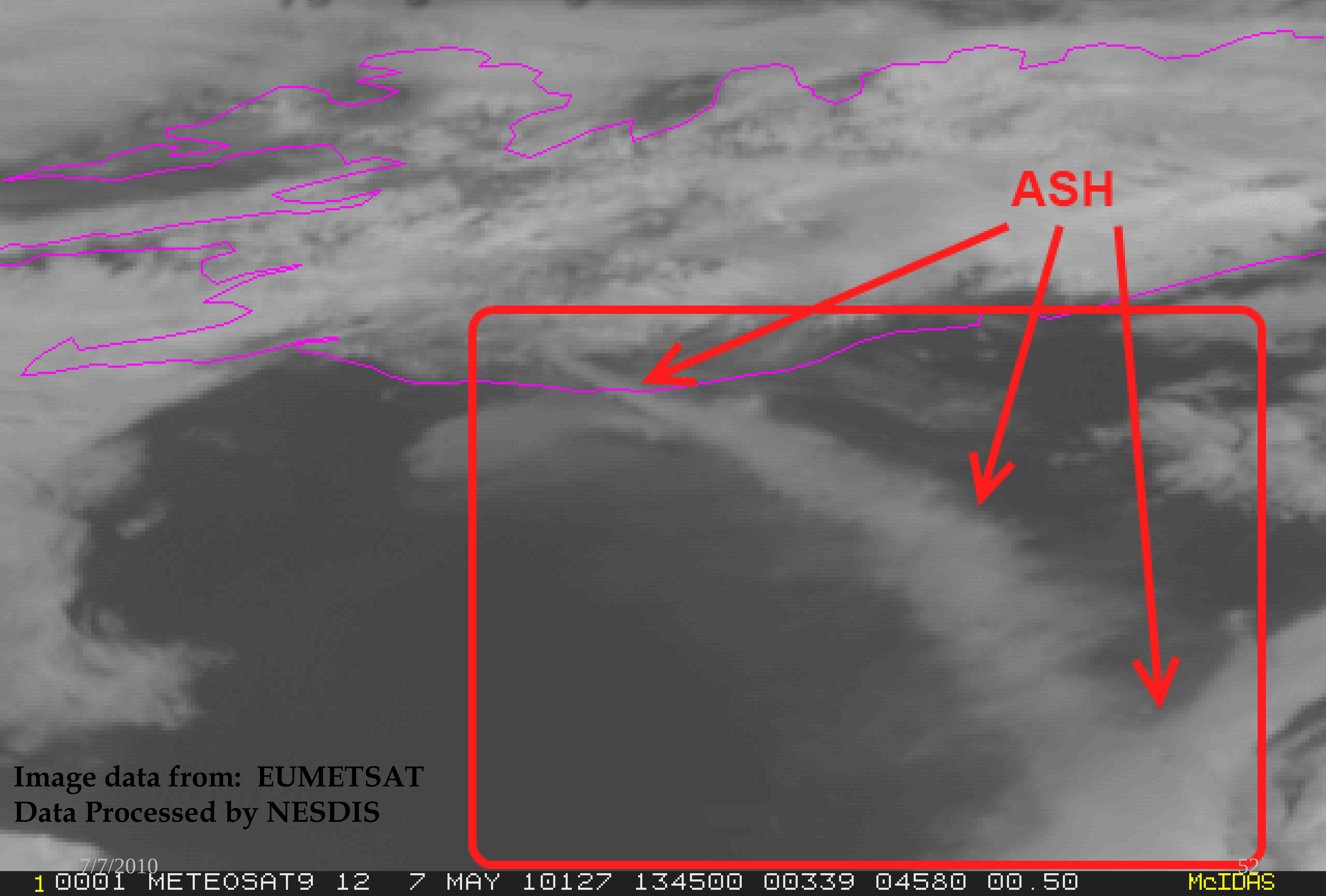
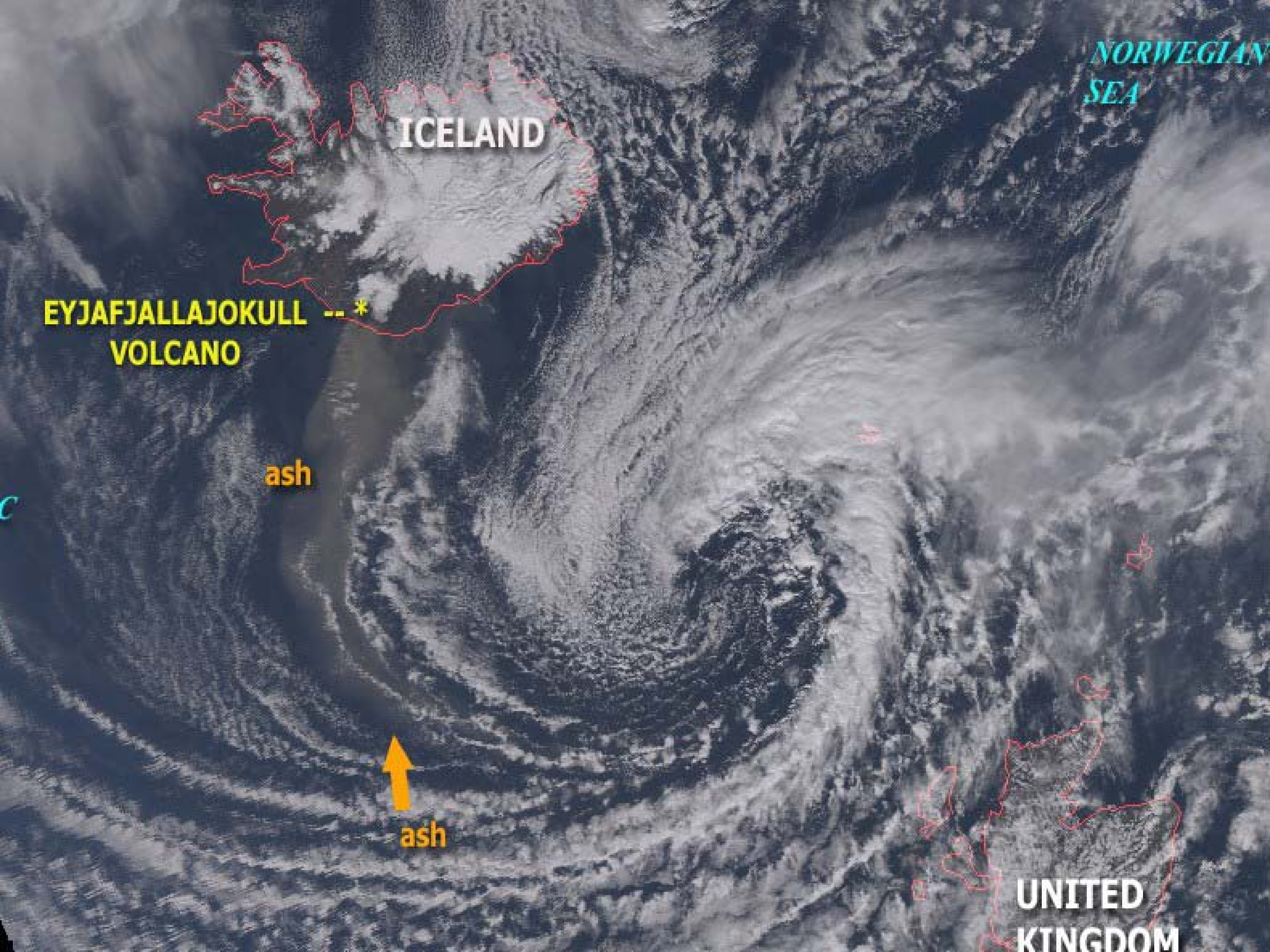


Image data from: EUMETSAT
Data Processed by NESDIS


NORWEGIAN
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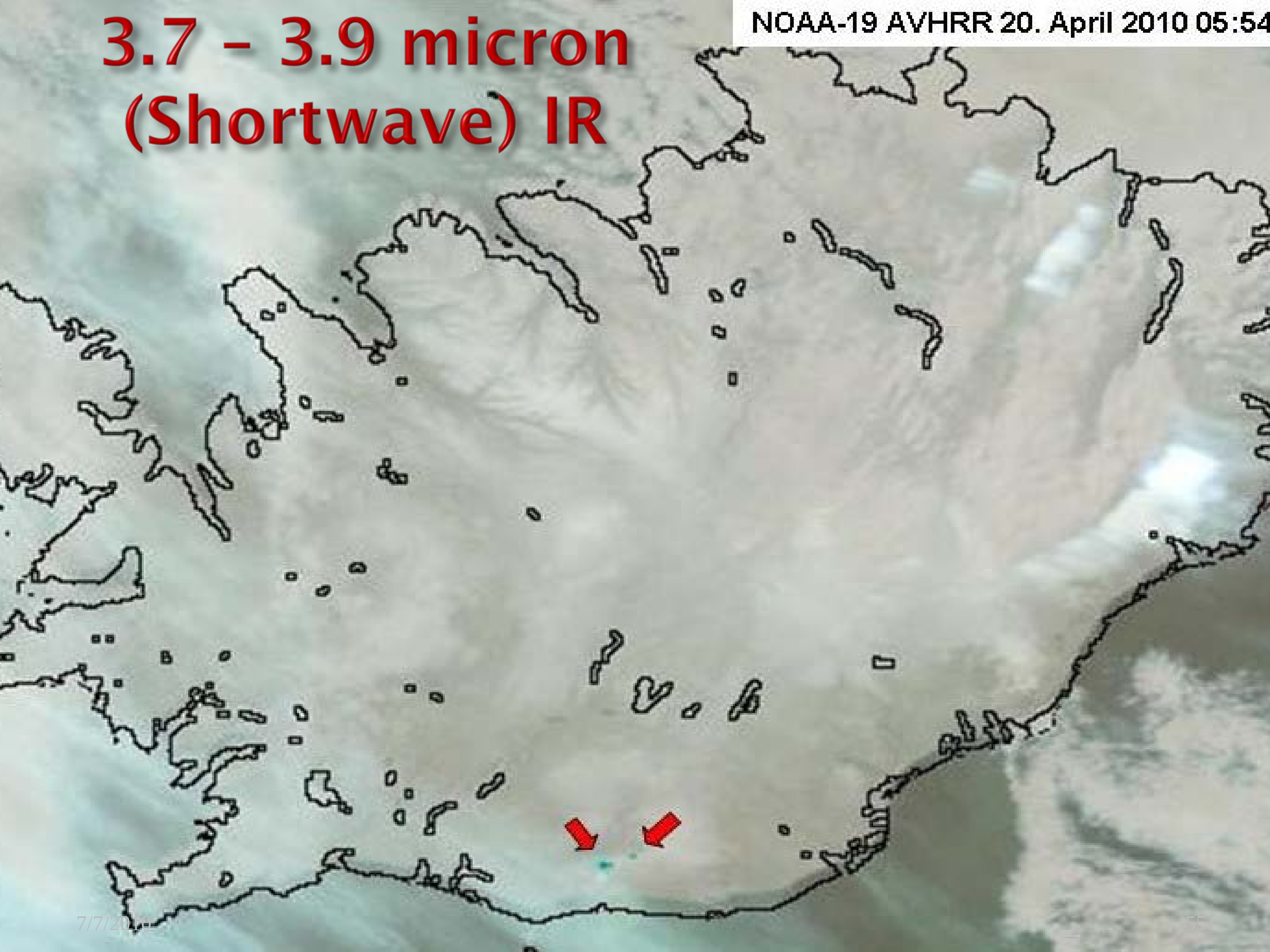
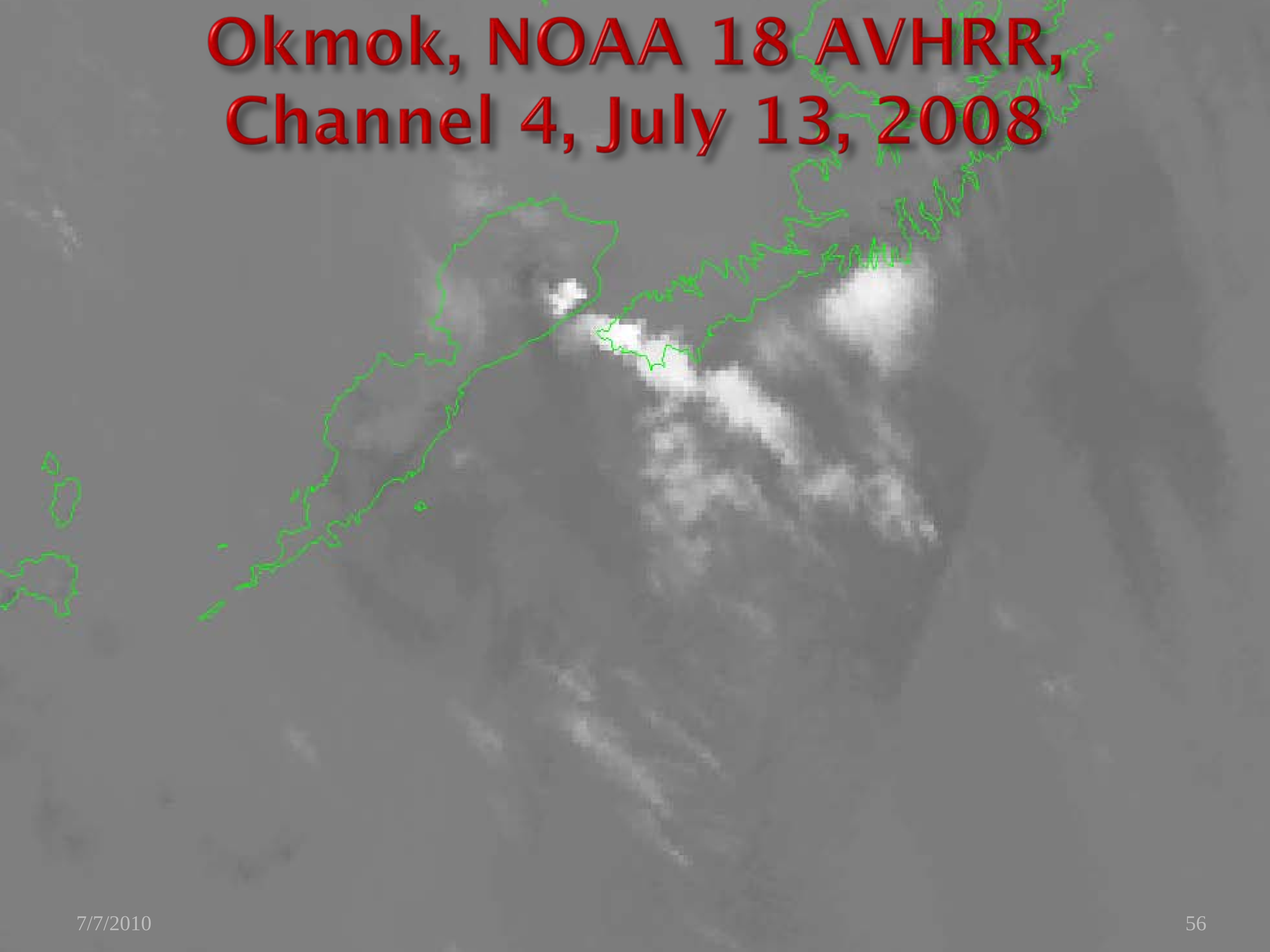
Okmok, Terra/MODIS, Visible Image July 13, 2008

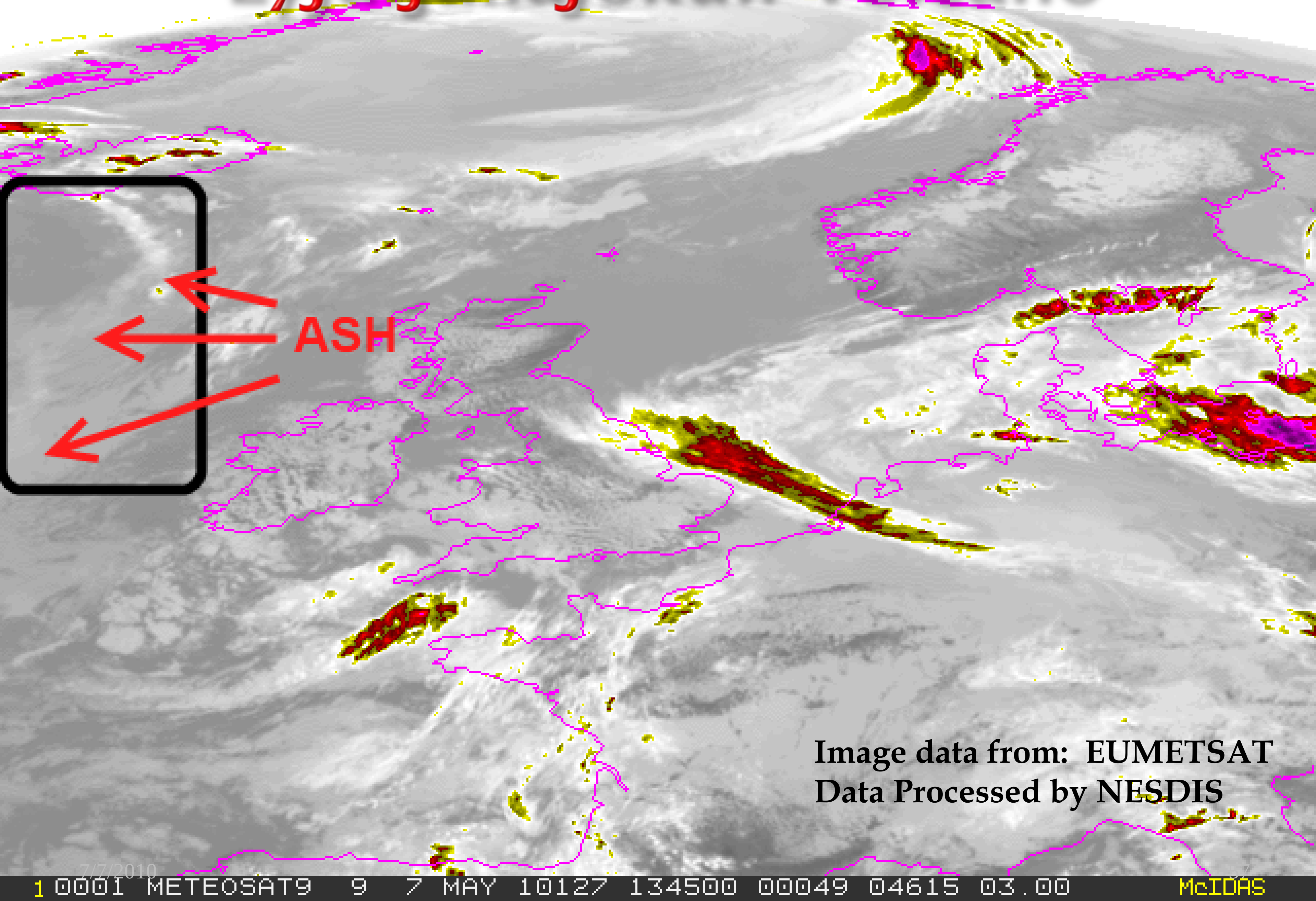
3.7 – 3.9 micron (Shortwave) IR



Okmok, NOAA 18 AVHRR, Channel 4, July 13, 2008



Eyjafjallajokull Volcano

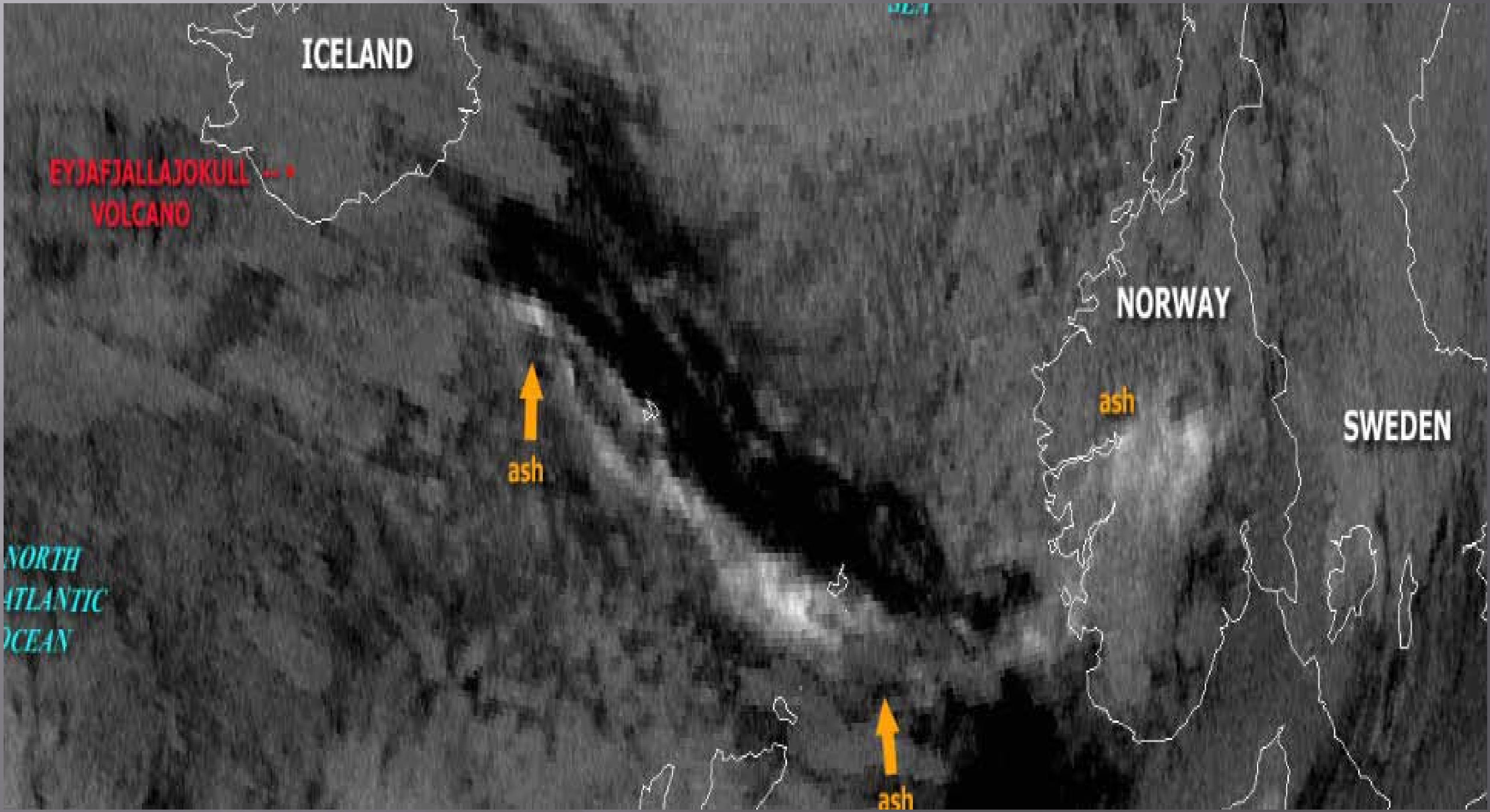


Split-window IR detection – How it Works

- Emissivity of silicate particles is lower at 11 μm than at 12 μm.
- Emissivity of water/ice particles is the opposite - higher at 11 μm and lower at 12 μm
- Therefore, ash clouds can be detected by the Brightness Temperature Difference (BTD):

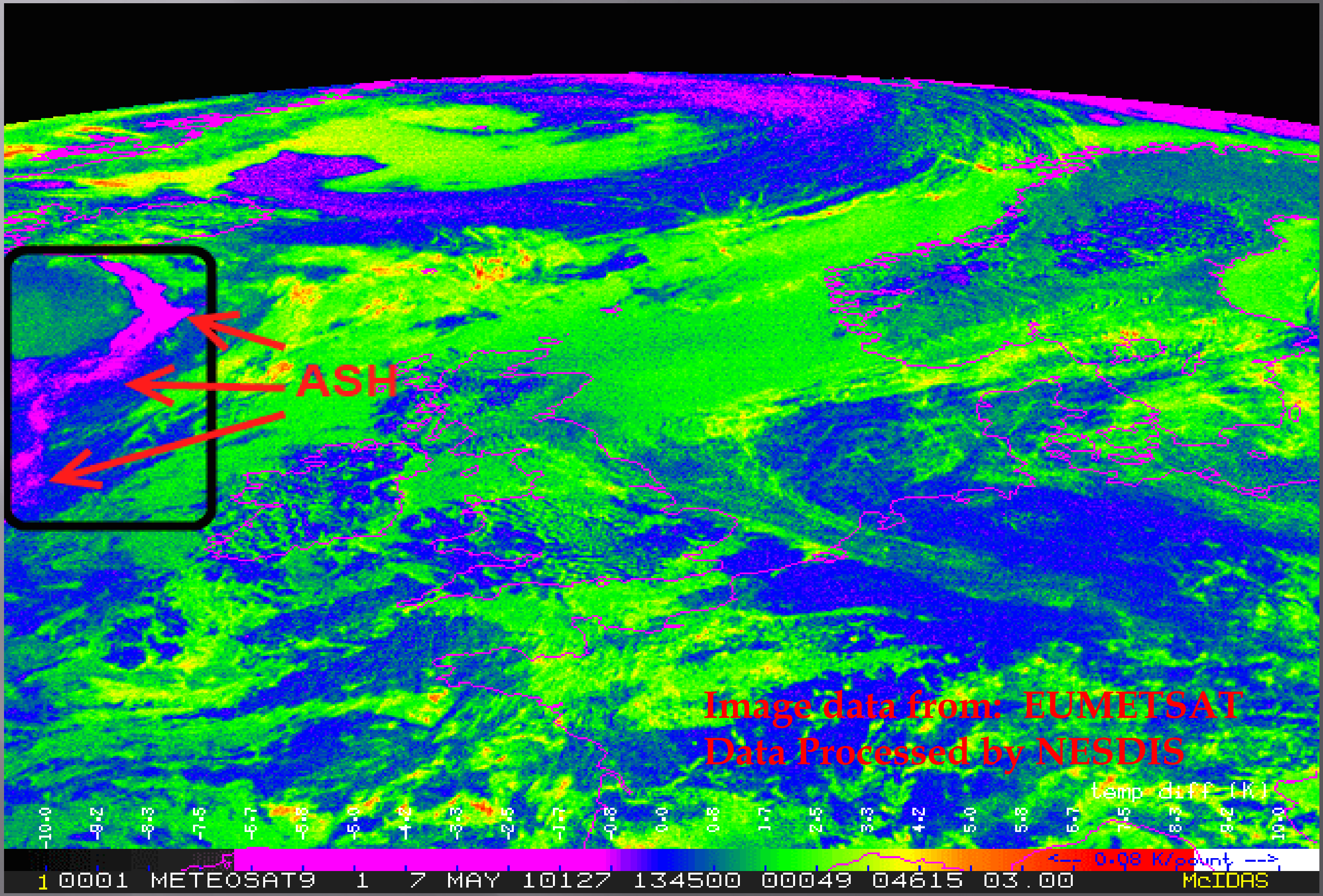
$BT_{10.7\mu m} - BT_{12\mu m}$ = **negative** for ash/dust
$BT_{10.7\mu m} - BT_{12\mu m}$ = **positive** for ice/water

Split Window IR Detection in Iceland

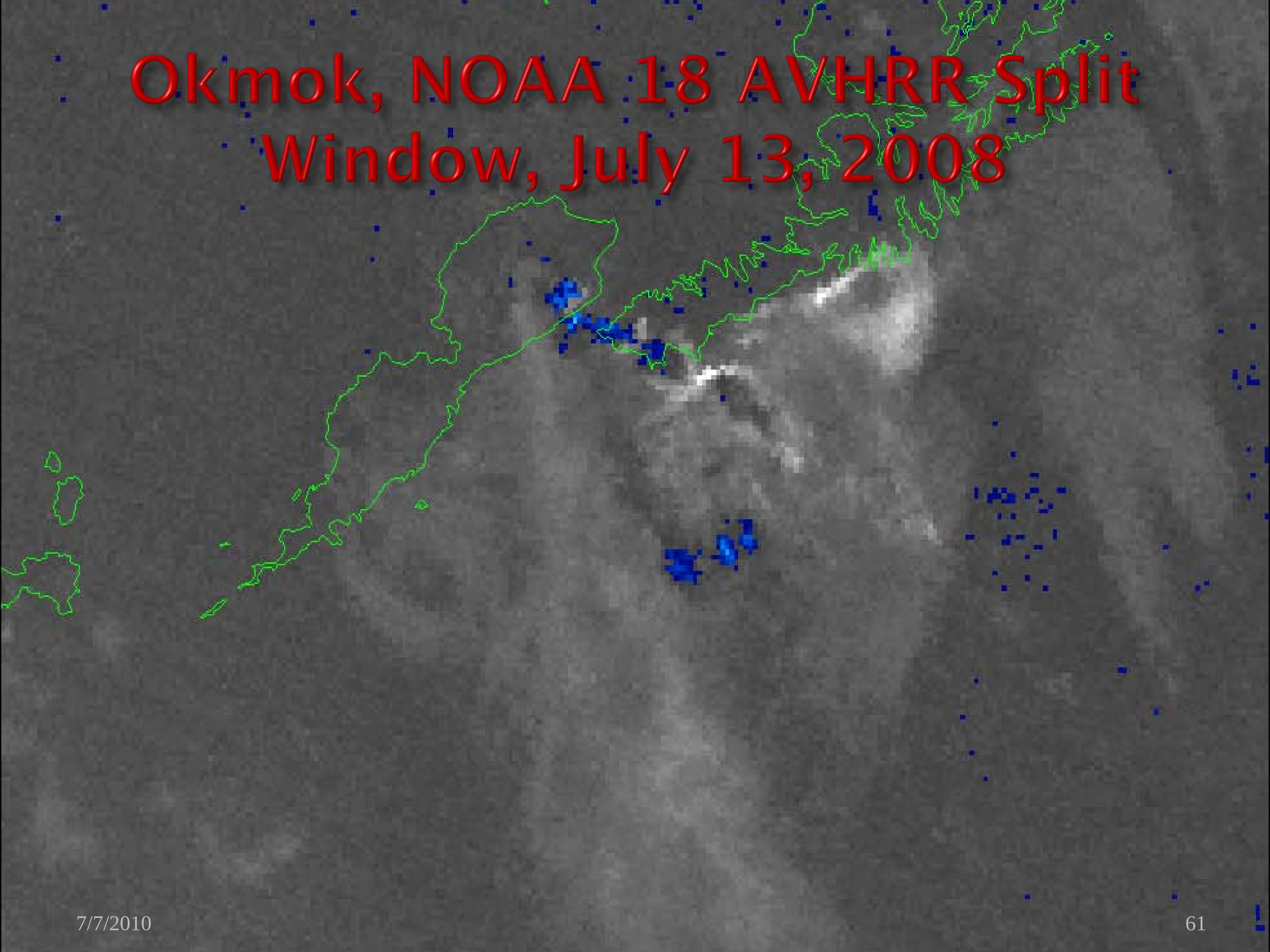


4/15/2010@15Z

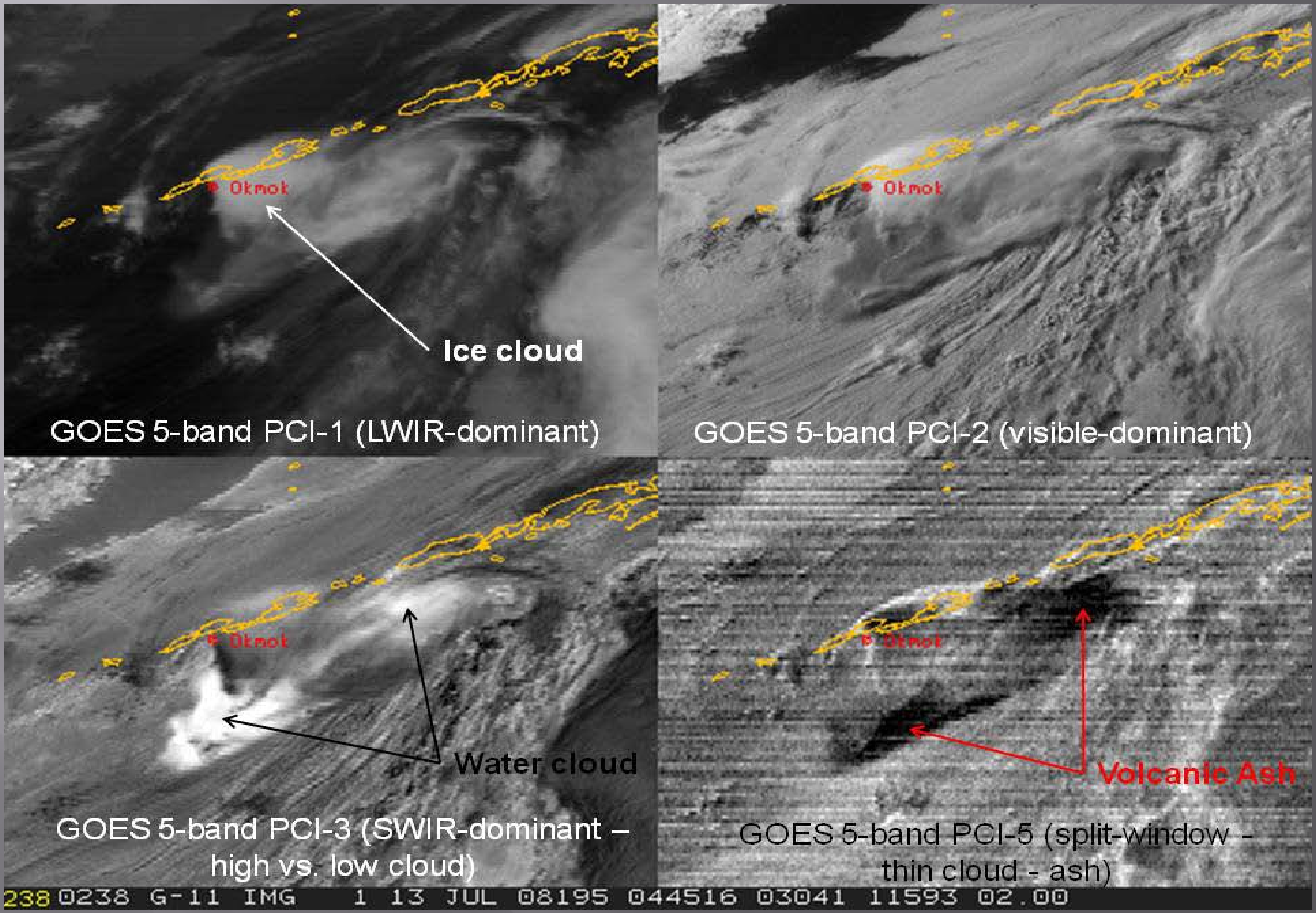
Split Window Longwave Difference



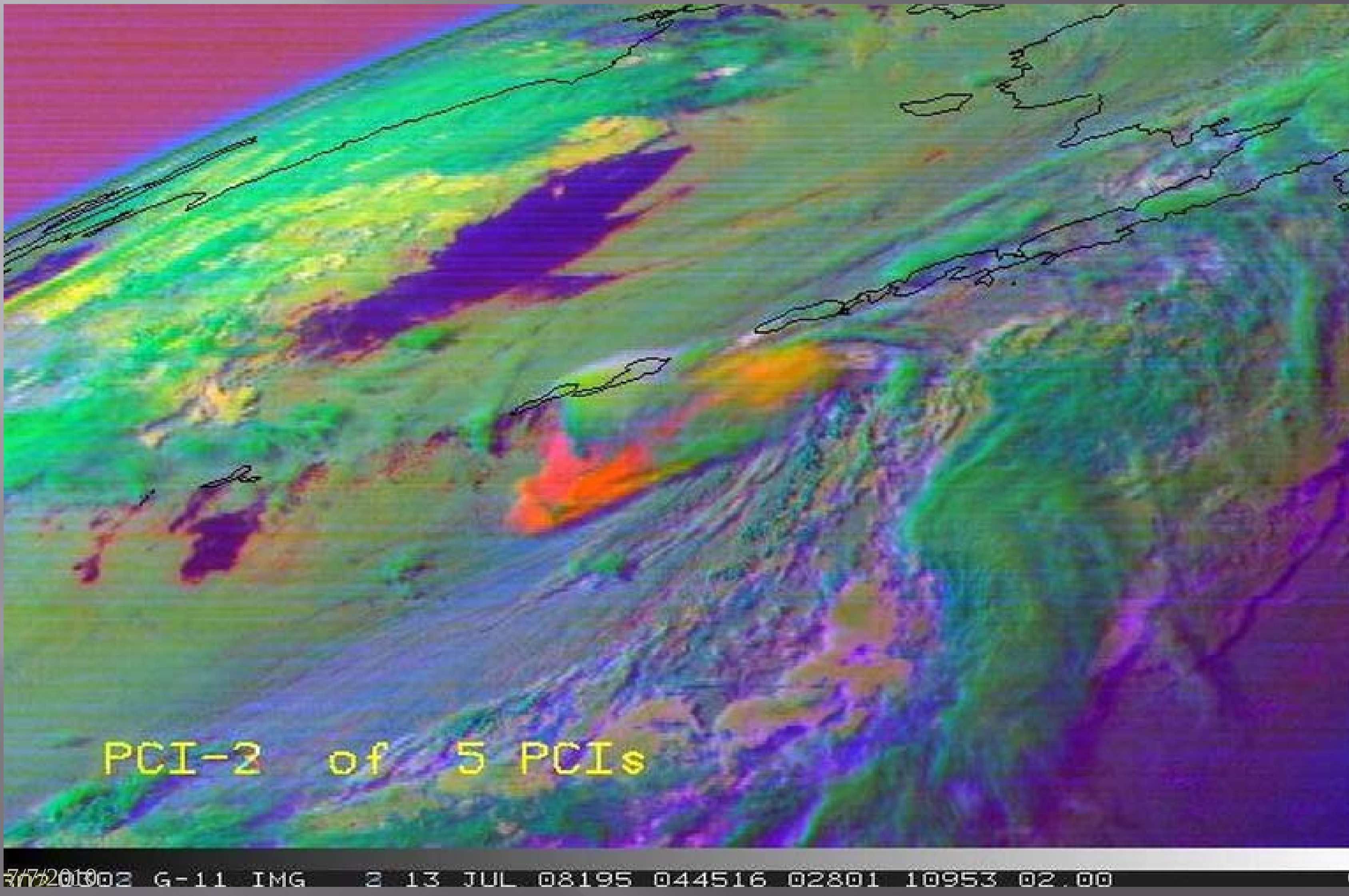
Okmok, NOAA 18 AVHRR Split Window, July 13, 2008



PCI Volcanic ash analysis



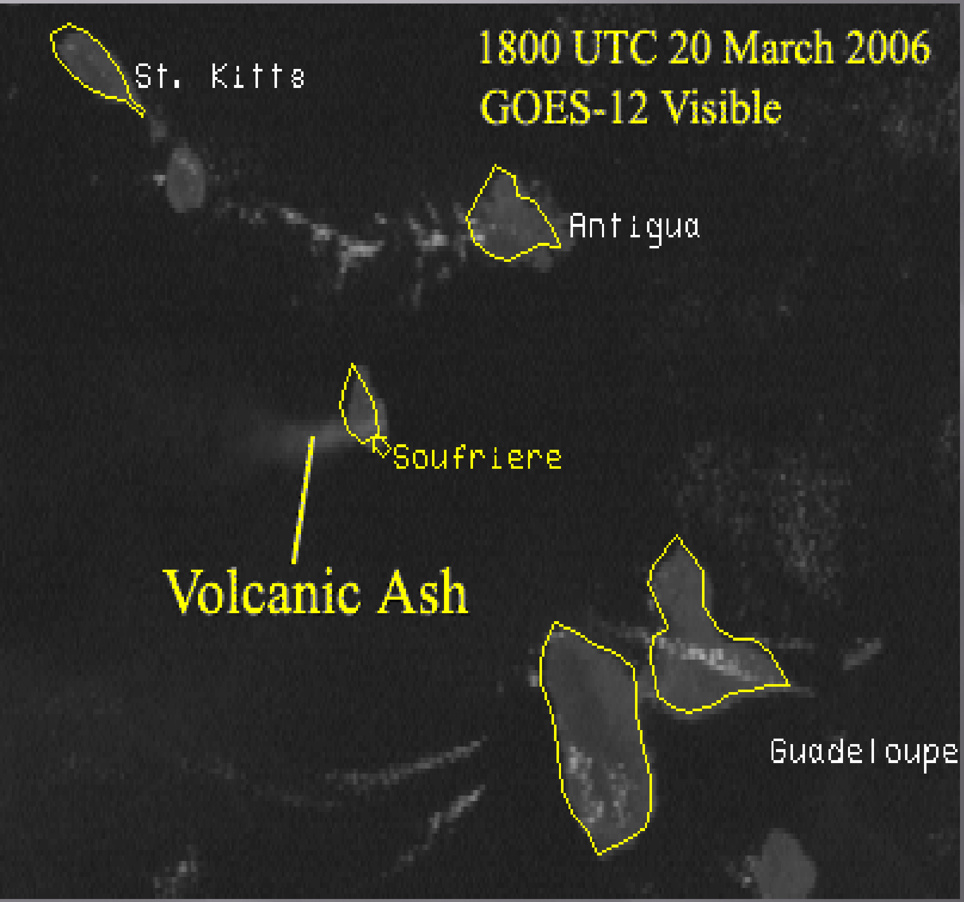
Principal Component Analysis (PCA) and Principal Component Imagery (PCI)

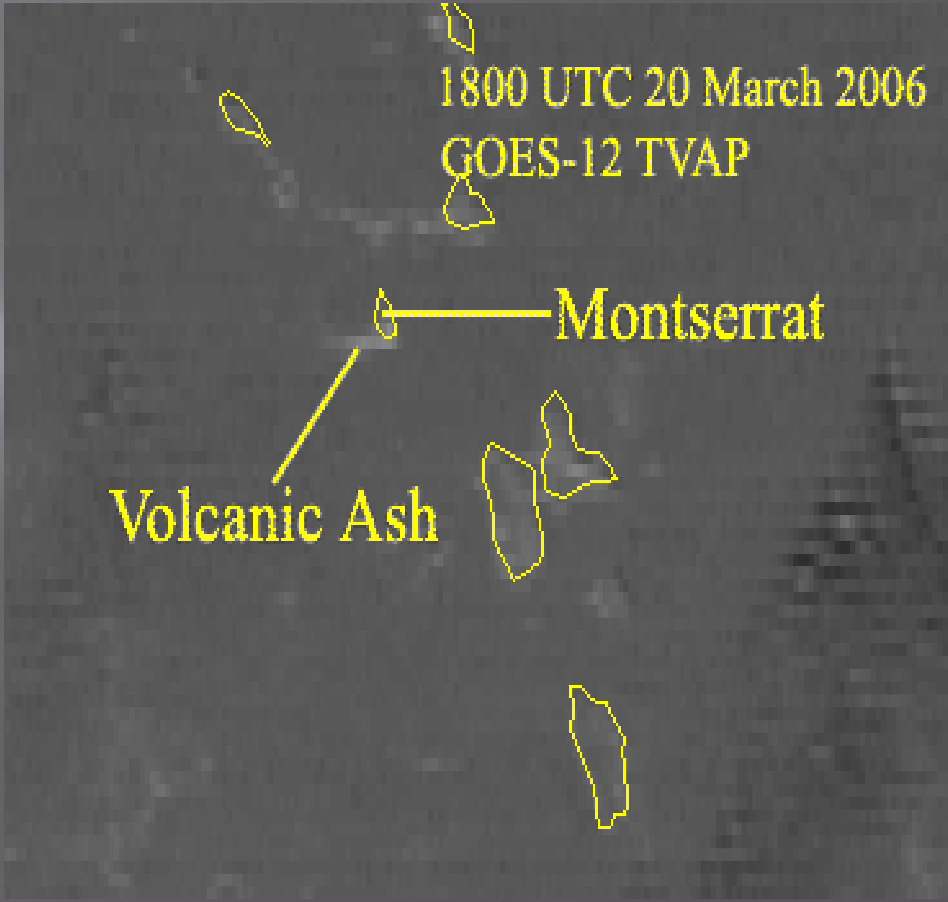


Add Iceland Volcano PCI Here

- Either still images or animations from Don Higer

Ash Detection – The 3 Channel Product





Three-channel Volcanic Ash Products (TVAP)

GOES-11 Detection Algorithm (Ellrod et al. 2003):

B = C + m1[T(12.0) – T(10.7)] + m2[T(3.9) – T(10.7)]

B = output brightness value (temperature),

C = constant; m1, m2 = scaling factors (empirical)

T = brightness temperature at (wavelength).

T(12.0) – T(10.7) results in a <u>positive</u> value for volcanic ash.

Three-channel Volcanic Ash Products (TVAP)

GOES-12+ Detection Algorithm (Ellrod and Schreiner 2004):

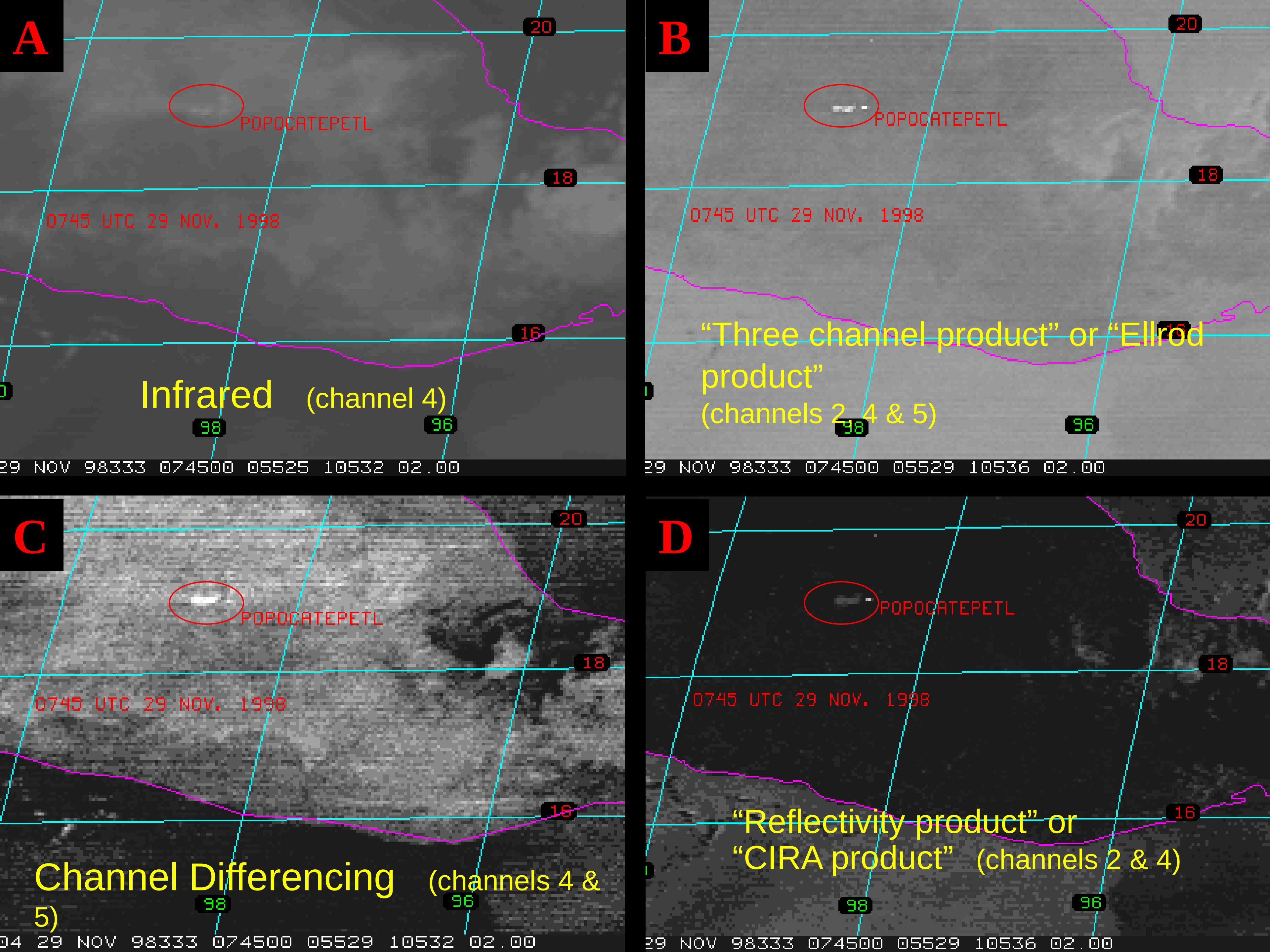
$$B = 5(DT) - 230$$

B = output brightness value,

DT = [T(3.9) – 1.5 T(10.7) +1.5 T(13.3)

T = brightness temperature at (wavelength).

Values of B that are large relative to surrounding clouds and terrain represent volcanic ash.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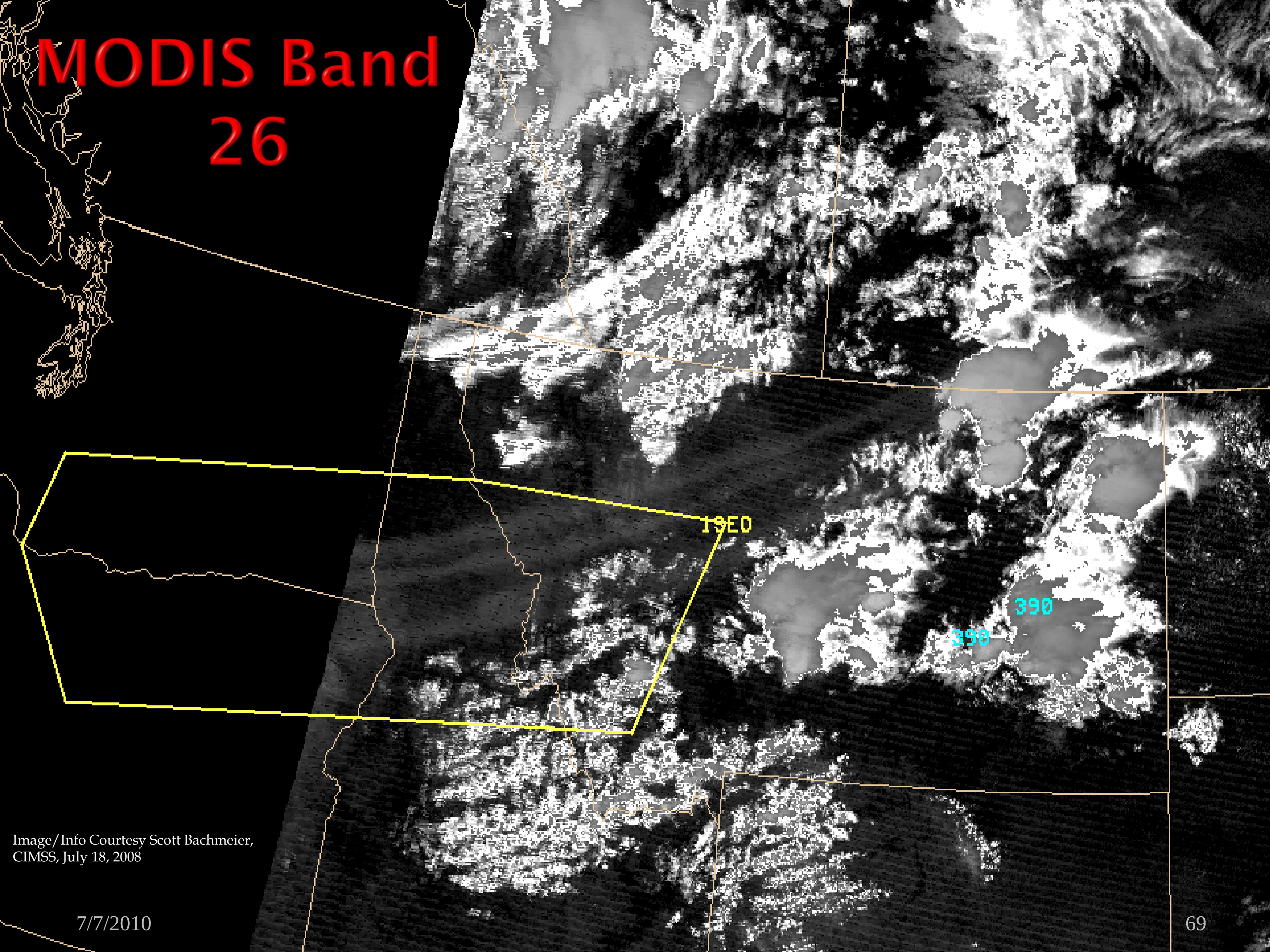
MODIS Band 26



Image/Info Courtesy Scott Bachmeier, CIMSS, July 18, 2008

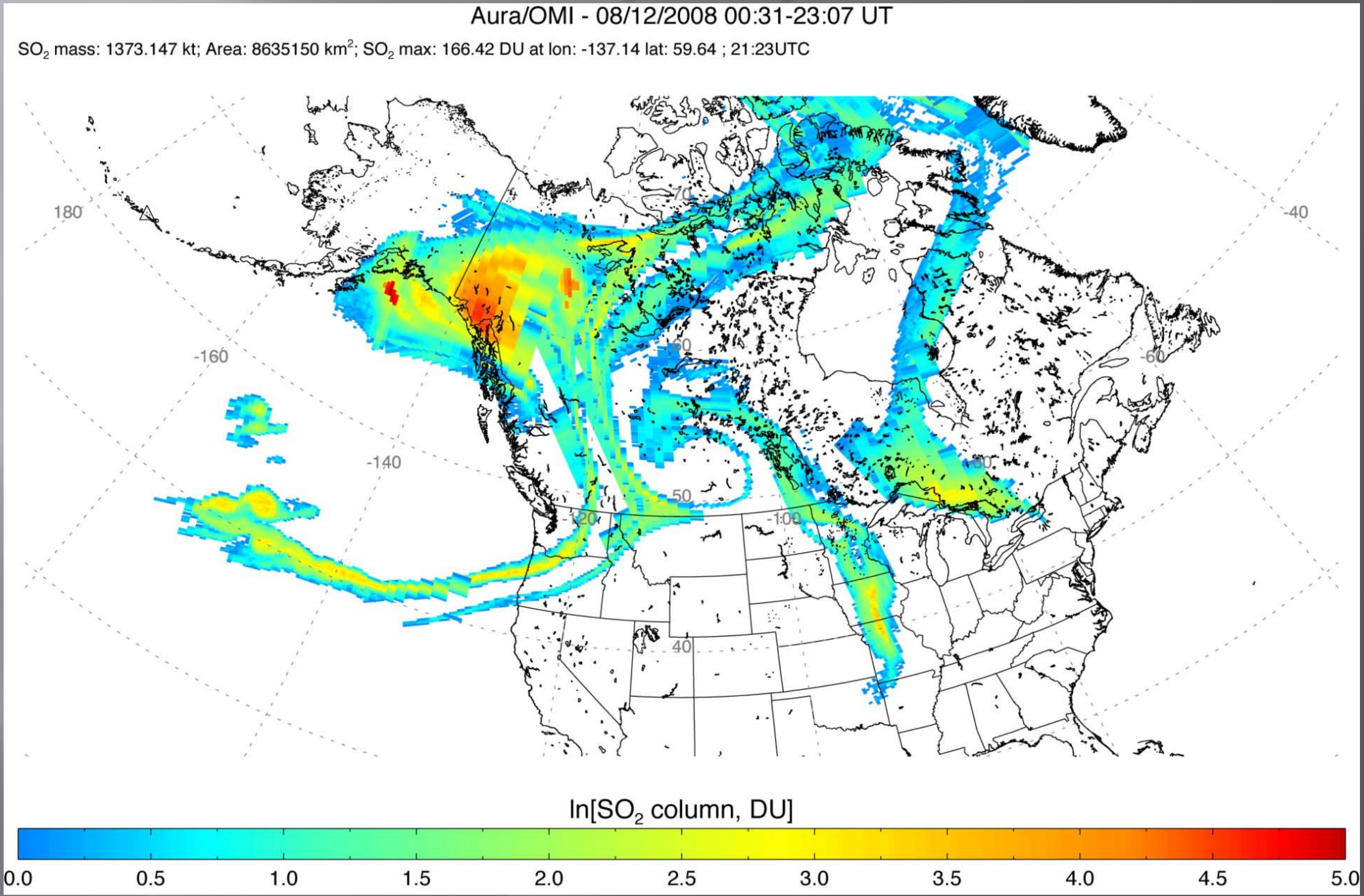
General Ash Product Limitations

- Within hours of an eruption, the presence of copious amounts of water in the volcanic eruption cloud often results in non-discrimination of ash (Ellrod and Connell 1999).
- Deep moist tropical conditions can mask the presence of volcanic ash, or prevent clear discrimination of the ash from meteorological clouds. This is especially true for eruptions of smaller volcanoes that emit ash into the lower and middle troposphere, such as the Soufriere Hills volcano.

Limitations continued…

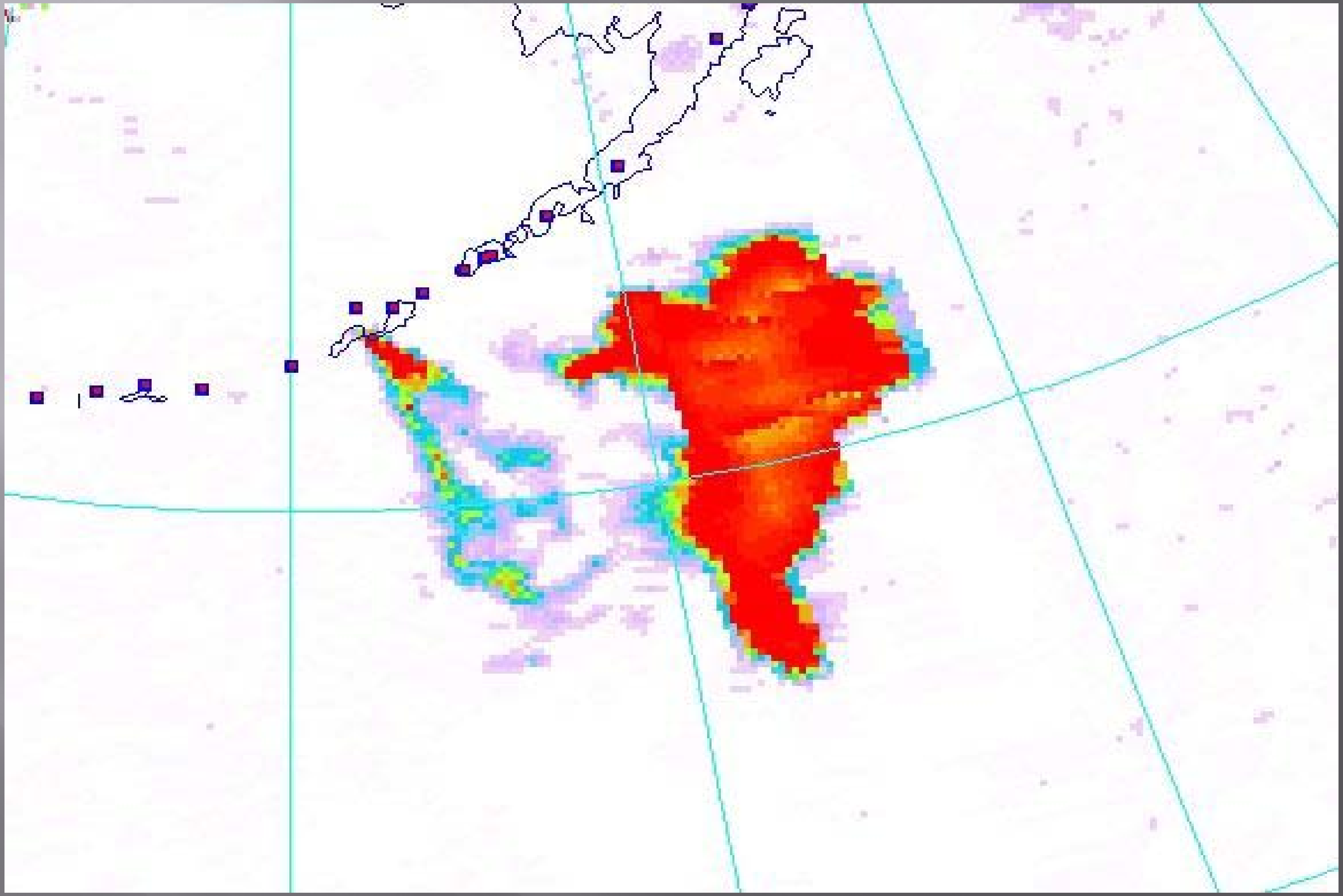
- An important modification to the GOES-12 imager was the loss of the 4 km resolution, 12 µm IR band 5 which was replaced with a lower resolution (8 km) IR band 6 centered near 13.3 µm.
- Some degradation of remote sensing of volcanic ash is likely, leading to both underdetection of thin ash, and an increase in the area of "false" ash, resulting in possible over-warning for aviation advisories.
- The 12 µm band will not be restored until GOES-R becomes operational around 2017.

The Ozone Monitoring Intrument – (OMI)



Picture Date: August 12, 2008
Image Creator: Schneider, Dave
Image courtesy of AVO/USGS. Data provided by the OMI near-real-time project funded by NASA.

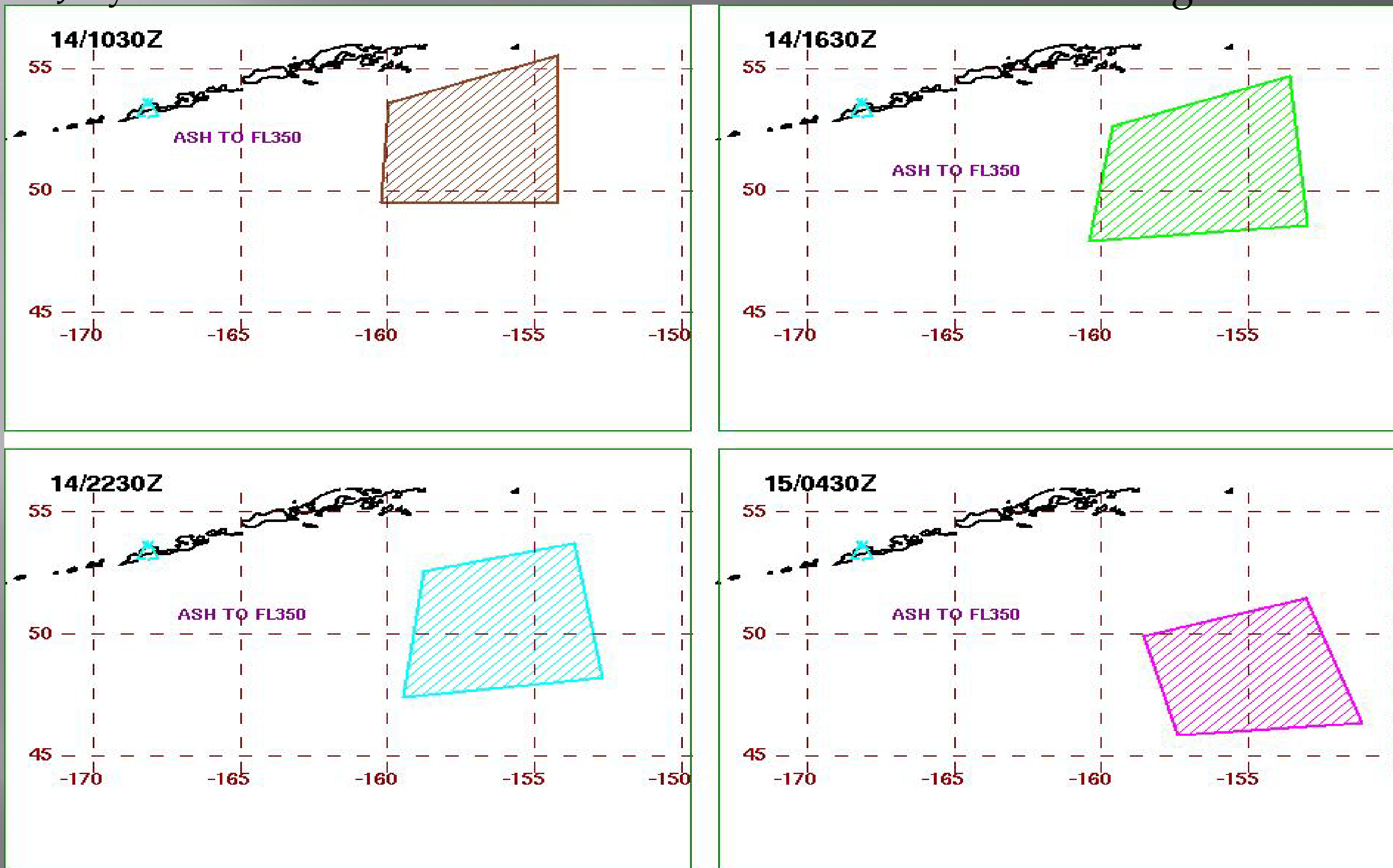
Okmok OMI (SO_2) Composite Images



Volcanic Ash Advisory analysis

14 July 2008 Okmok Volcano

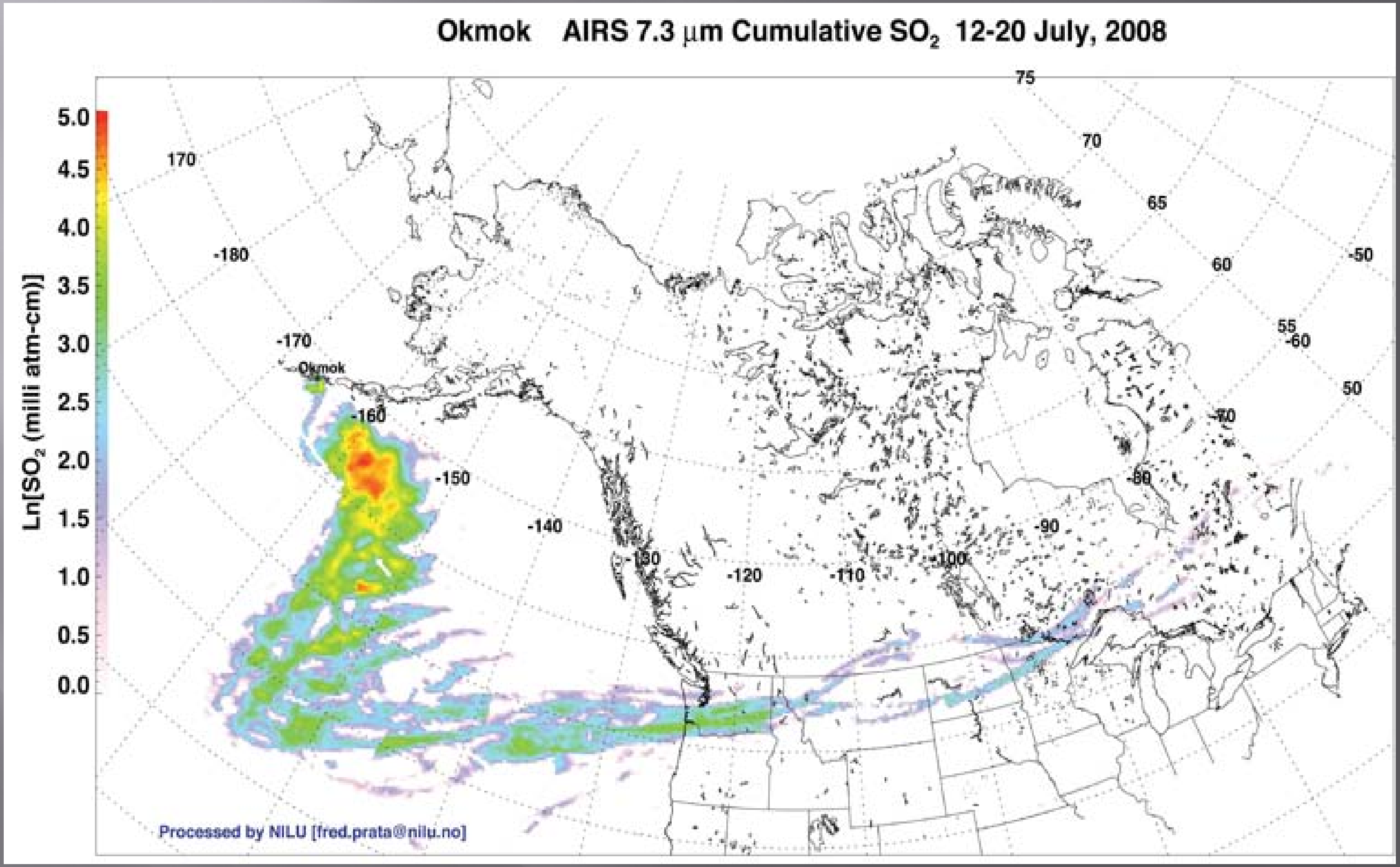
Washington VAAC



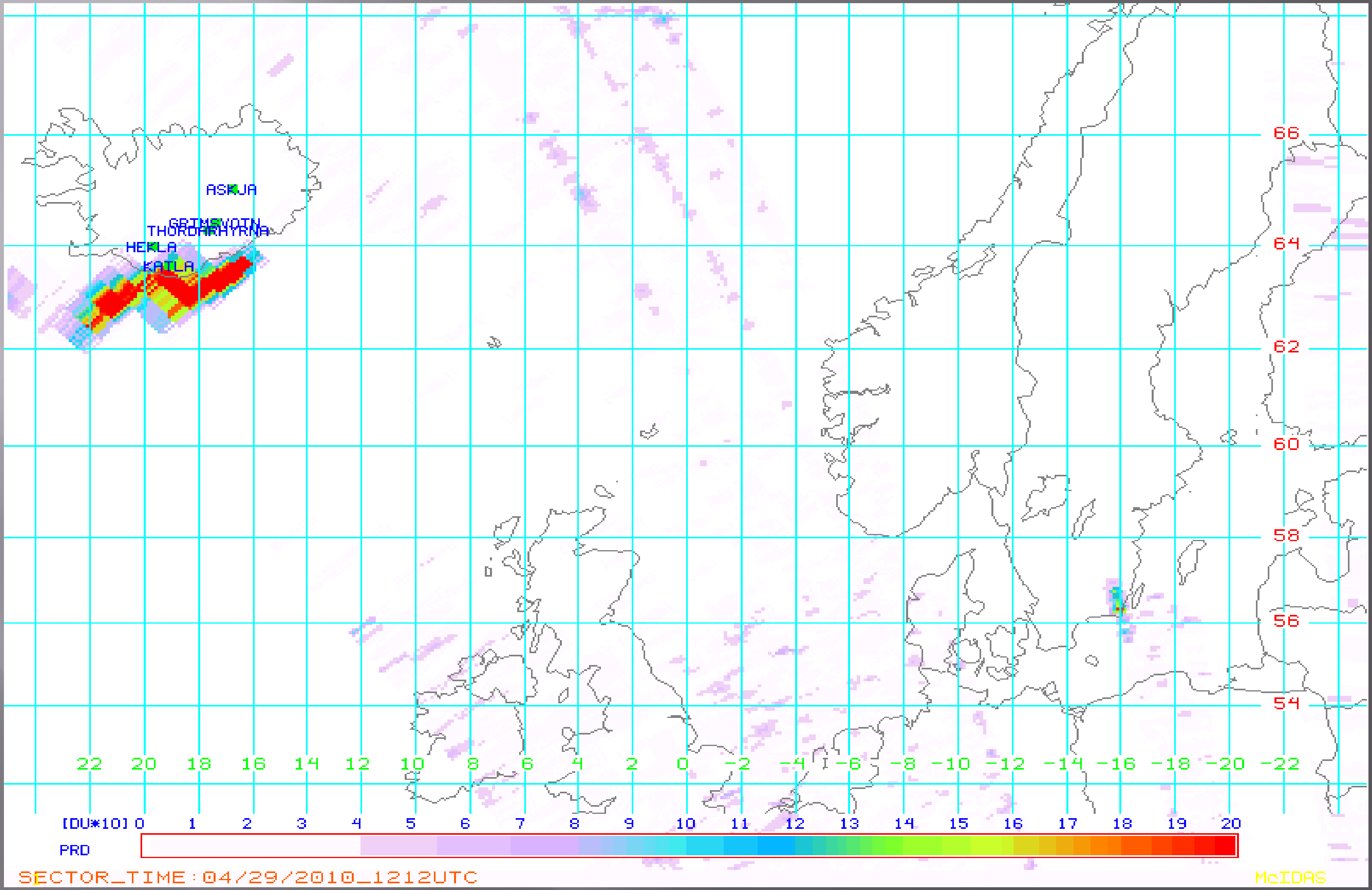
VOLCANIC ASH ADVISORY
DTG: 20080714/1058Z
VAAC: WASHINGTON
VOLCANO: OKMOK 1101-29
AREA: ALEUTIAN.IS
SUMMIT ELEV: 3520 FT (1073 M)
ADVISORY NR: 2008/007

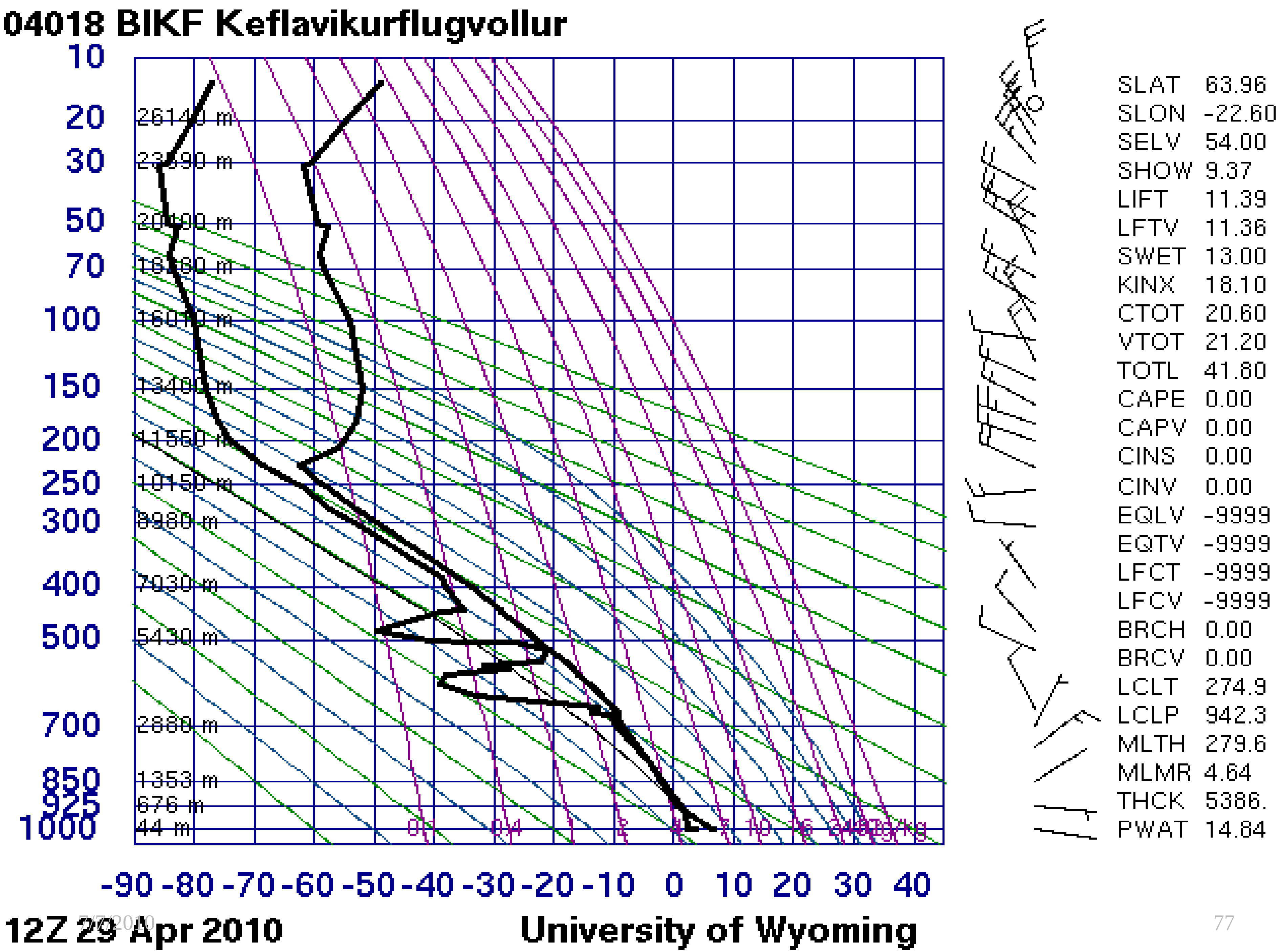
INFO SOURCE: GOES-11. GFS WINDS. S02 OMI DATA.
ERUPTION DETAILS: ONGOING EMISSIONS.
RMK: A MIXTURE OF MOSTLY SO2 AND SOME VA IS SEEN IN STLT IMAGERY. THE CONFIDENCE IN THE VA FCST IS LOW AFTER +06. LATEST MODEL RUN HAS SO2 AND VA GRADUALLY MOVING TOWARD THE SE WITH ASSOCIATED CUTOFF LOW. PLEASE ALSO SEE FVAK23 PAWU
NXT ADVISORY: WILL BE ISSUED BY 20080714/1700Z

AIRS Composite SO_2



Eyjafjallajökull SO_2 emissions (OMI)




04018 BIKF Keflavikurflugvollur
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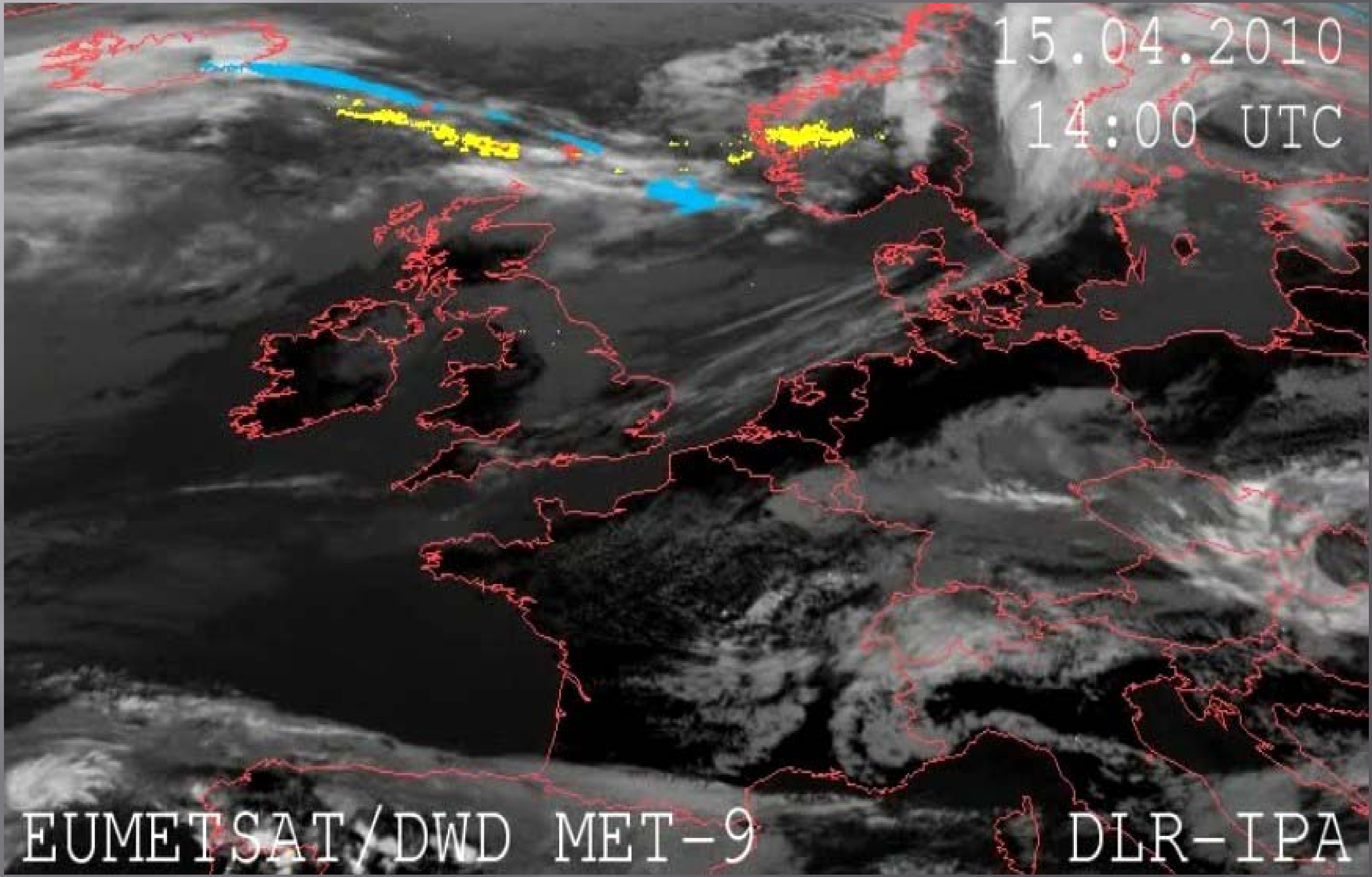
26140 m
23590 m
20400 m
18180 m
16010 m
13400 m
11550 m
10150 m
8980 m
7030 m
5430 m
2880 m
1353 m
676 m
44 m
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40
SLAT 63.96
SLON -22.60
SELV 54.00
SHOW 9.37
LIFT 11.39
LFTV 11.36
SWET 13.00
KINX 18.10
CTOT 20.60
VTOT 21.20
TOTL 41.80
CAPE 0.00
CAPV 0.00
CINS 0.00
CINV 0.00
EQLV -9999
EQTV -9999
LFCT -9999
LFCV -9999
BRCH 0.00
BRCV 0.00
LCLT 274.9
LCLP 942.3
MLTH 279.6
MLMR 4.64
THCK 5386.
PWAT 14.84
12Z 29 Apr 2010
University of Wyoming

Meteosat-9 Ash and SO_2

(Combined Multispectral Product)




GOES-R
The Future

GOES-R Aviation/Volcanic Ash Products

- GOES-R products will detect and monitor volcanic ash as well as sulfur dioxide (SO2).
- Improved spatial resolution and a large selection of spectral channels will enable the GOES-R ABI to generate more advanced quantitative volcanic cloud products.
- The **SO2 Detection Product** will automatically detect volcanic clouds during very early stages when the ash signal is generally obscured by liquid water/ice.
- The **Volcanic Ash Product** will provide objective estimates of ash cloud coverage, height, mass, and particle size, which are necessary to issue Significant Meteorological Information (SIGMET) advisories for aircraft and accurately forecast the dispersion of ash clouds.

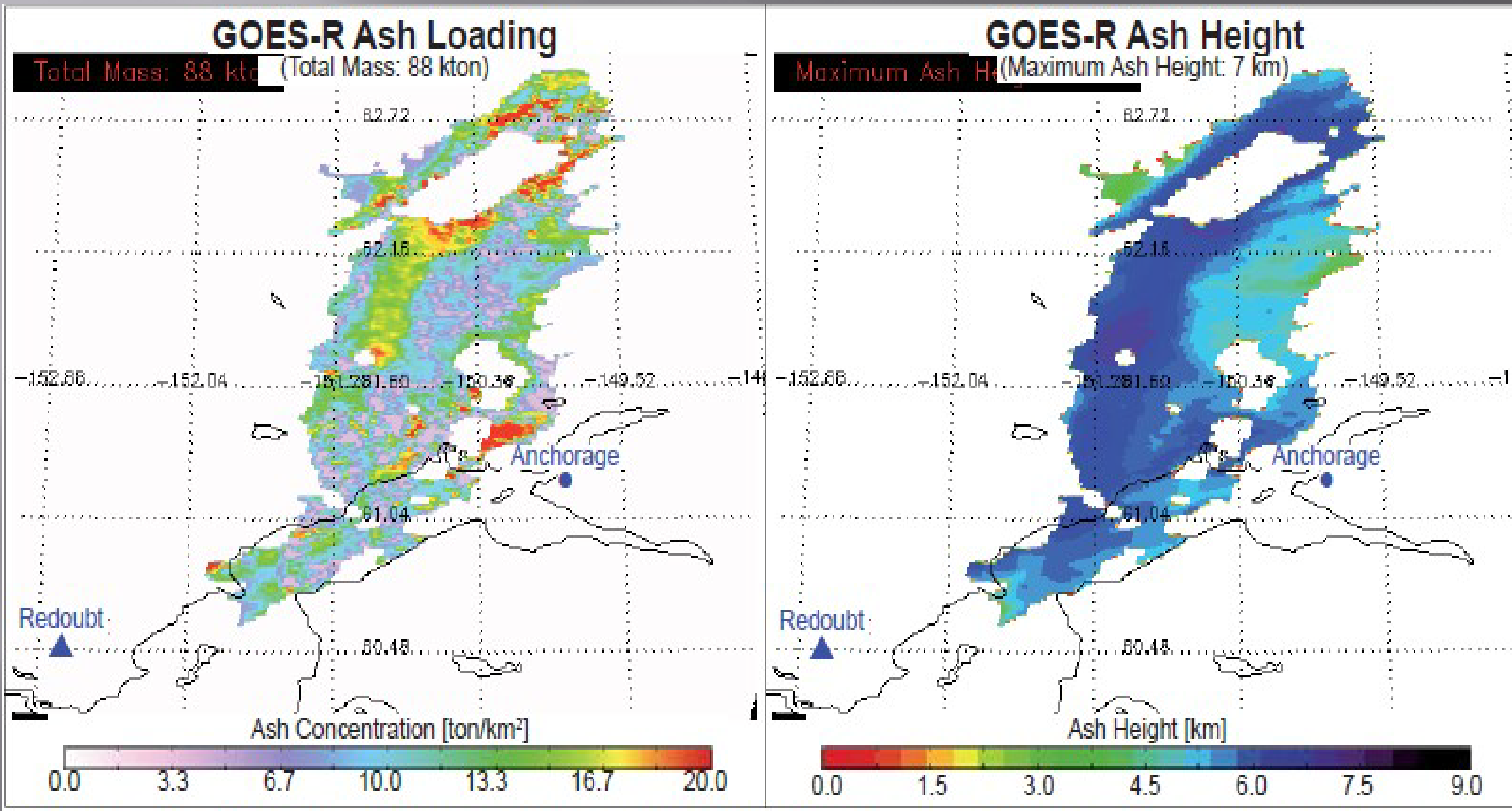
GOES-R Volcanic Ash and SO2 Detection products

- These products will be generated from infrared radiances, which are day/night independent.
- ABI channels centered at 7.3, 8.5, 11, 12, and 13.3 µm are used in the algorithms. The 8.5, 11, and 12 µm channels provide information on cloud particle size and composition, the 13.3 µm channel detects ash cloud height, and the 7.3 µm channel detects SO2 clouds.

GOES-R Volcanic Product Benefits

- The advanced spectral, spatial, and temporal resolution of the GOES-R ABI will be utilized to generate a complete set of volcanic cloud detection and monitoring products, resulting in improved air and ground safety as well as economic savings.
- The GOES-R products will also be used to improve the modeling of volcanic ash clouds, which will allow for more accurate ash cloud dispersion and ash fall forecasts.

GOES-R (Ash) Product Examples



*GOES-R-like **Volcanic Ash Loading** and **Height** products are shown for ash clouds produced by eruptions of Mount Redoubt on March 23, 2009.*

(NASA/NOAA "**GOES-R Aviation Products Volcanic Ash and SO2 Detection" – October 2009)**

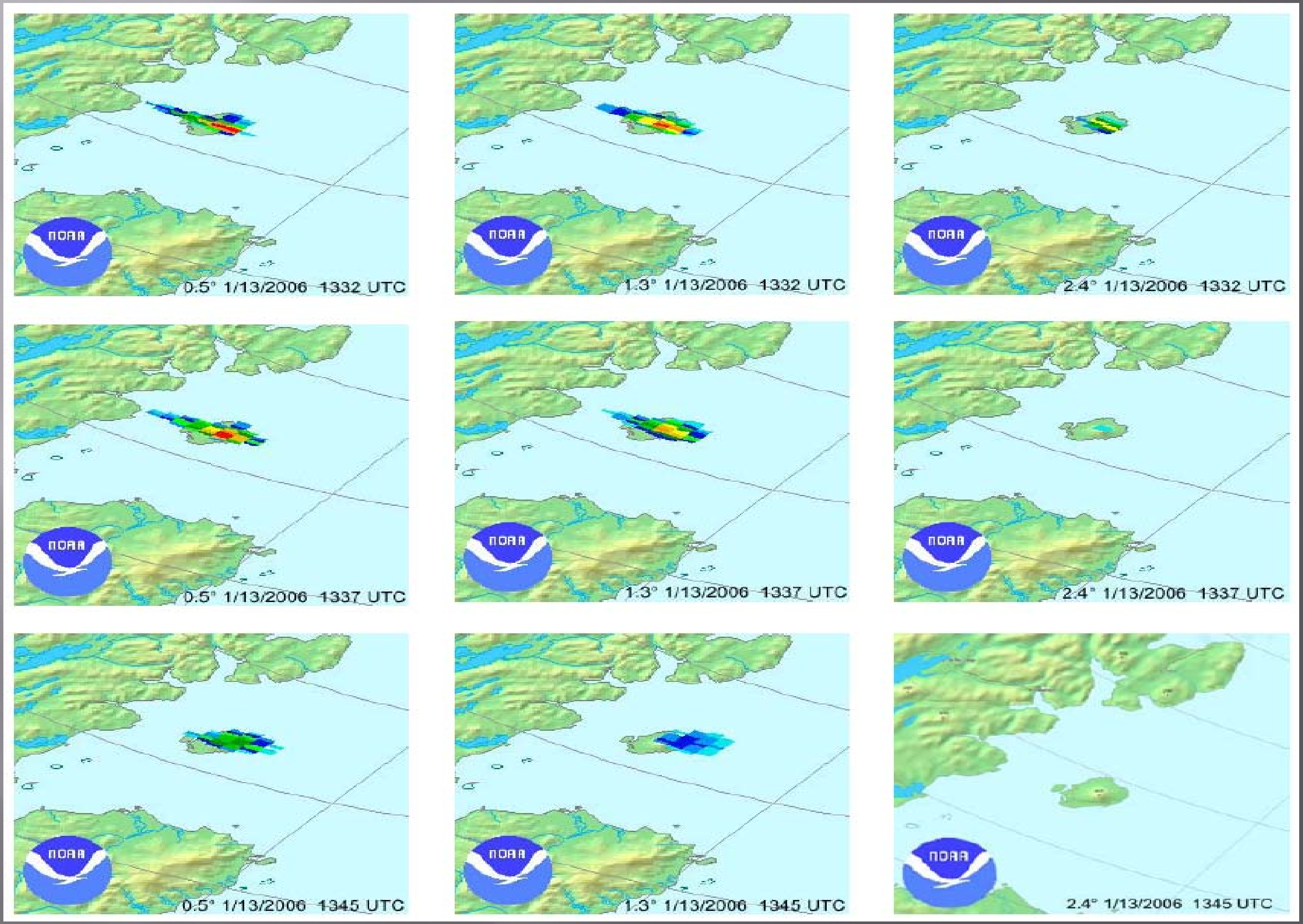
Aircraft Observations

Photo: Courtesy Burke Mees and Alaska Airlines

Ground Obs Okmok 08/03/2008

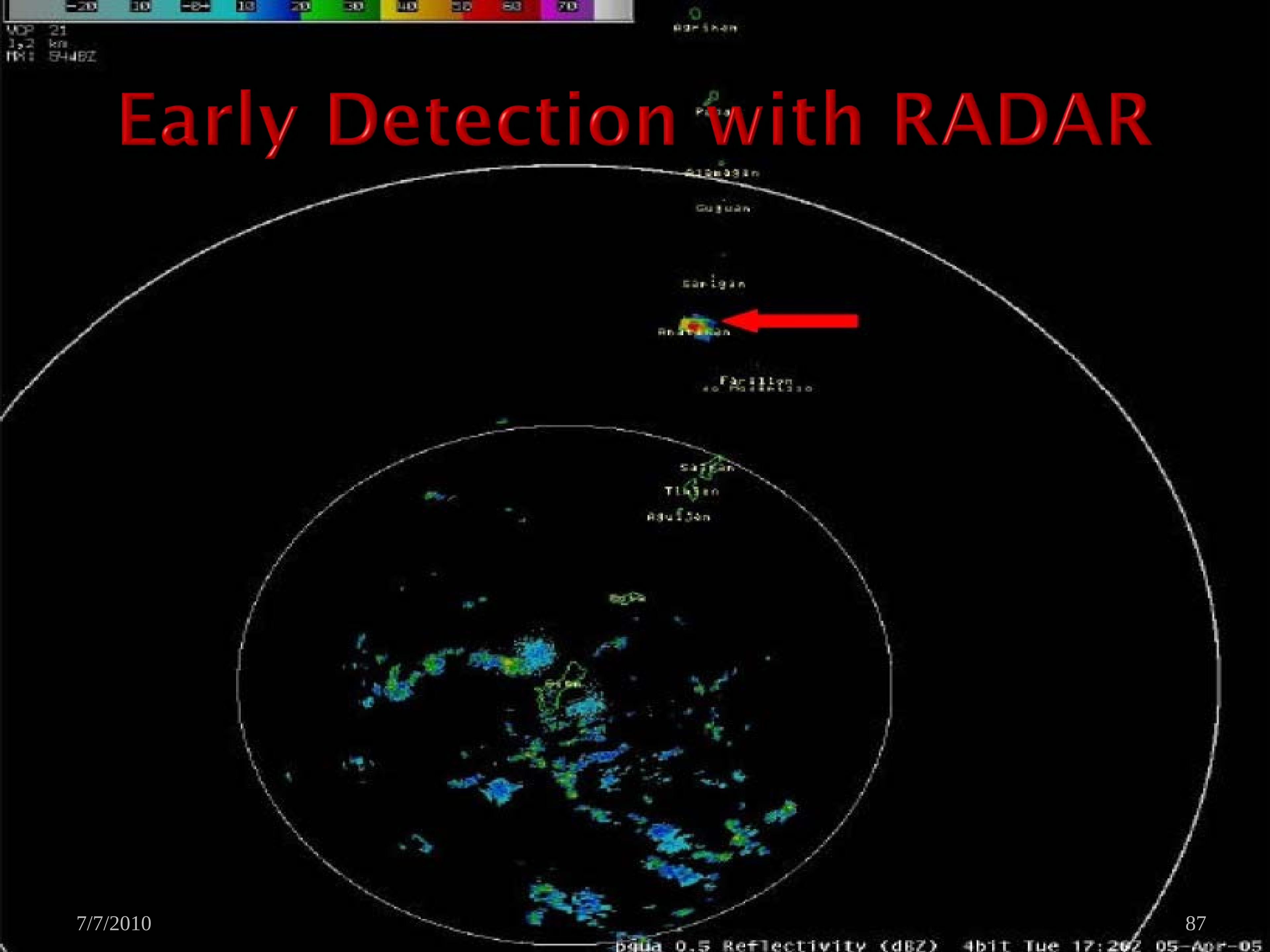
Photo: Courtesy of Jessica Larsen, AVO/UAF-GI

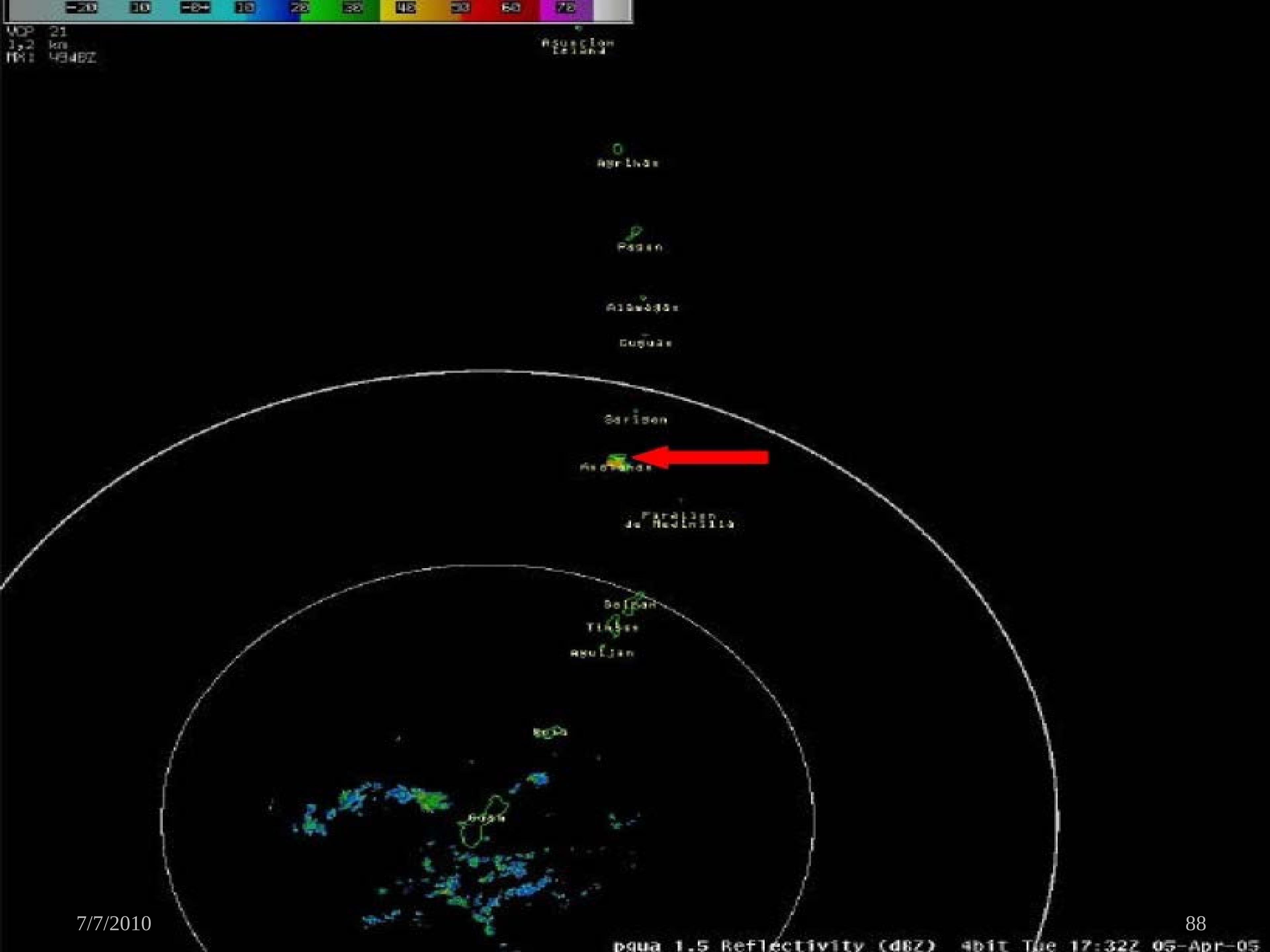
Radar Observations



From *WSR-88D OBSERVATIONS OF VOLCANIC ASH*, Jefferson Wood, Carven Scott , and David Schneider

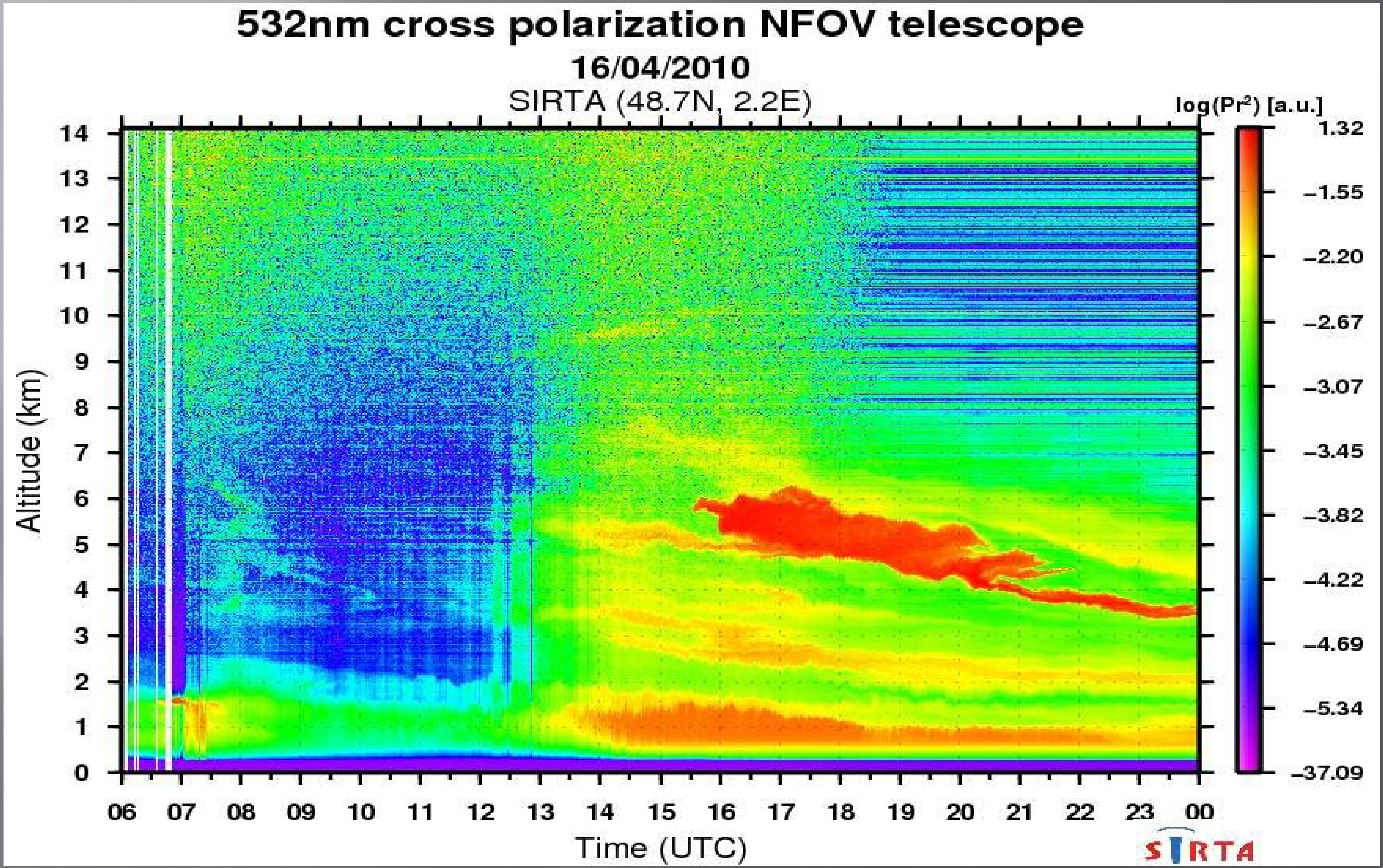
Early Detection with RADAR



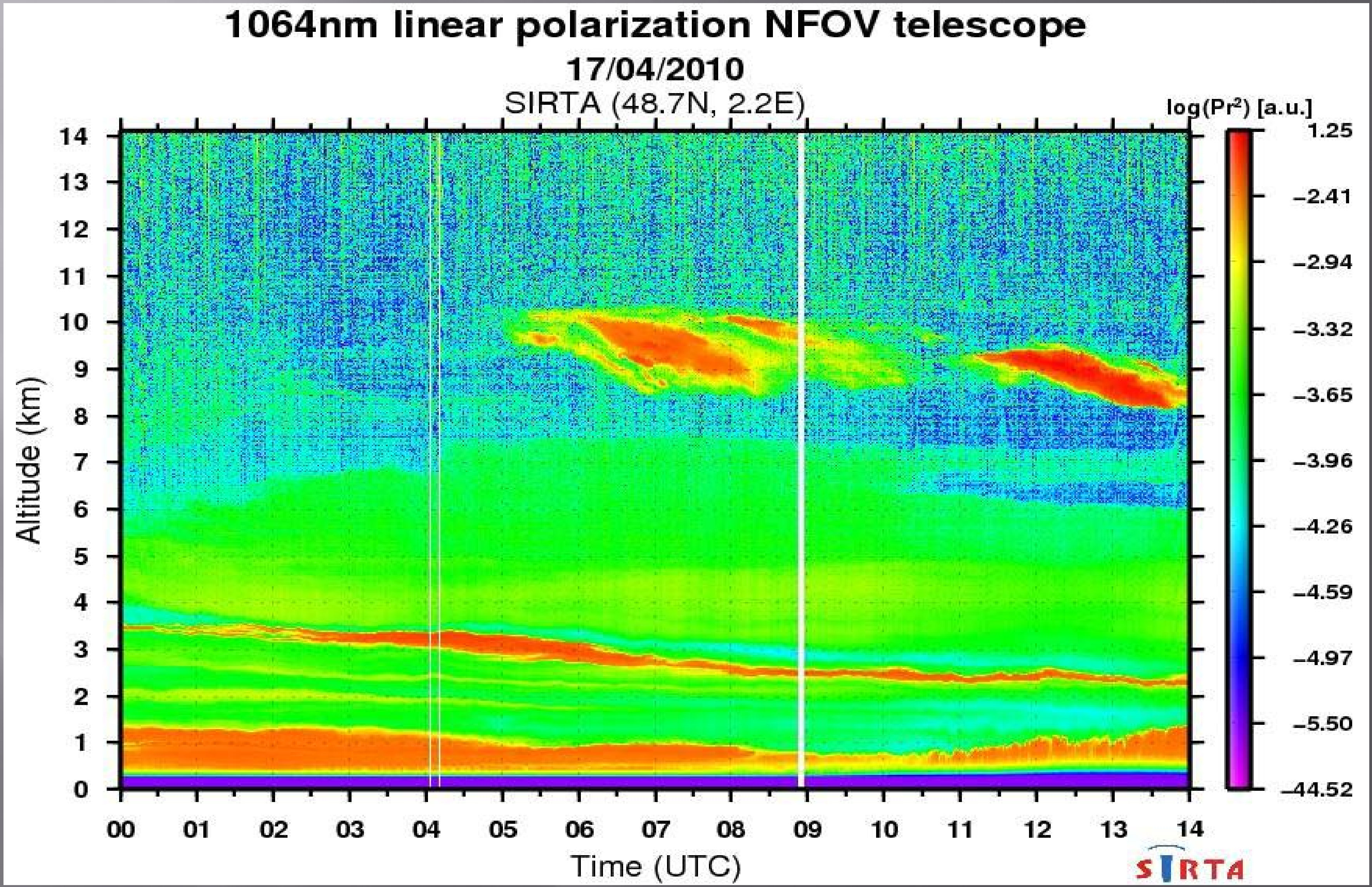

VCP 21
1,2 km
Pagan
Sarigan
Saipan
Tinian
Aguijan
Guam
pgua 1.5 Reflectivity (dBZ) 4bit Tue 17:32Z 05-Apr-05

Agrihan
Pagan
Alamagan
Guguan
Sarigan
Farallon
de Medinilla
Saipan
Tinian
Aguijan
Rota
pgua 0.5 Refl 4bit Tue 17:26Z 05-Apr-05 + MTSAT IR Tue 17:25Z 05-Apr-05

LiDAR and Volcanic Ash Detection



LiDAR continued…



Observational Strengths and Weaknesses

Observational Platform	Strength	Weakness
Visible Satellite	High resolution. Detects albedo differences. Good in "contrasty" situations.	Water/ice clouds can obscure volcanic cloud. Daytime only use. Ash may be difficult to discern if very low albedo (too diffuse or from some backgrounds).
Infrared Satellite	Temperature sensitive. Unaffected by night.	Water/ice cloud can obscure volcanic cloud. Observed temperature can be misleading.
Split-Window Infrared	Discriminates ash from cloud.	Water/ice cloud can obscure volcanic cloud. False alarms from desert areas or stratospheric cloud. Water vapor mixed with ash will 'hide' ash.

Observational Strengths and Weaknesses

Observational Platform	Strength	Weakness
Video Camera	Remote access to direct observations.	Water/ice cloud or other poor visibility can obscure volcanic cloud. Requires locally developed infrastructure and reliable communications. Prone to vandalism or theft. Daytime use only.
Thermal Infrared Camera	Heat/night-time measurement.	Water/ice cloud or other poor visibility can obscure volcanic cloud. Expensive, requires locally developed infrastructure and reliable communications, prone to vandalism or theft.
Direct human observation	Low technology, power of local/subjective interpretation. Some nighttime observations.	Meteorological cloud or poor visibility can obscure volcanic cloud.

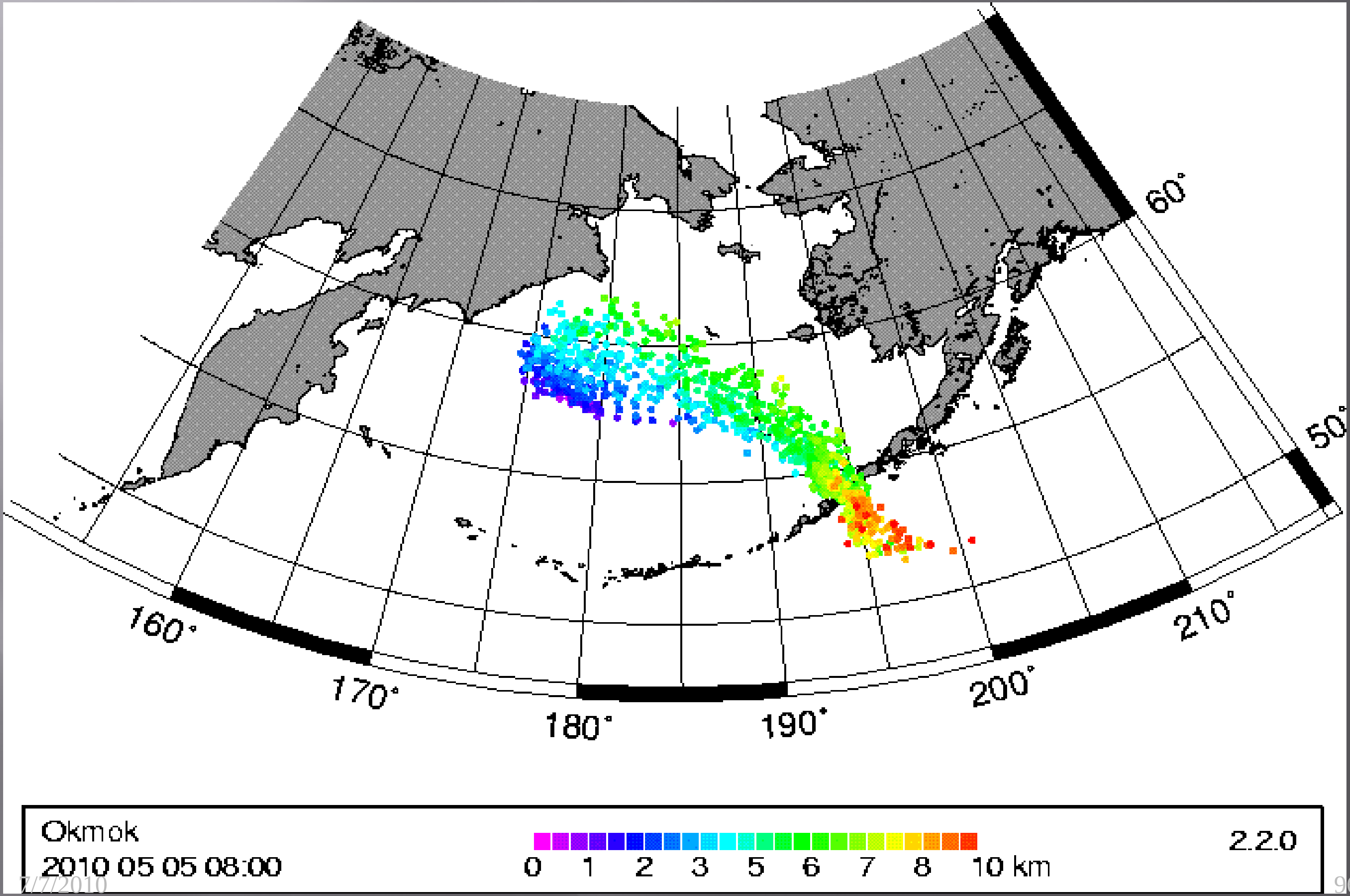
Observational Strengths and Weaknesses

Observational Platform	Strength	Weakness
Aircraft Pilot Observation (Reports)	Airborne perspective. Great viewing distance and aspect. Can also use cameras. Limited nighttime use.	Water/ice cloud or other poor visibility can obscure volcanic cloud. Requires some local infrastructure and reliable communications. Limited nighttime use. Pilot weather radar is not sensitive to volcanic ash.
Ground Based Weather Radar/Lidar	Can measure height and position of larger particles in ash cloud.	Expensive ground stations and limited range. May not detect smaller particles well. Obscured by heavy rain. Requires advanced local infrastructure/ communications and must be well staffed.

Things to Remember

- No detection technique by itself works for all cases.
- Techniques should be combined to get the best overall ash cloud detection.
- Inherent limitations for all detection methods:
  - Obstruction by meteorological cloud
  - Ambiguity in atmospheric data due to the regional conditions of the Earth's surface below
  - Low ash content plumes (or thin ash clouds)

Modeling: Volcanic Ash/Gas Movement



Model Forecasts

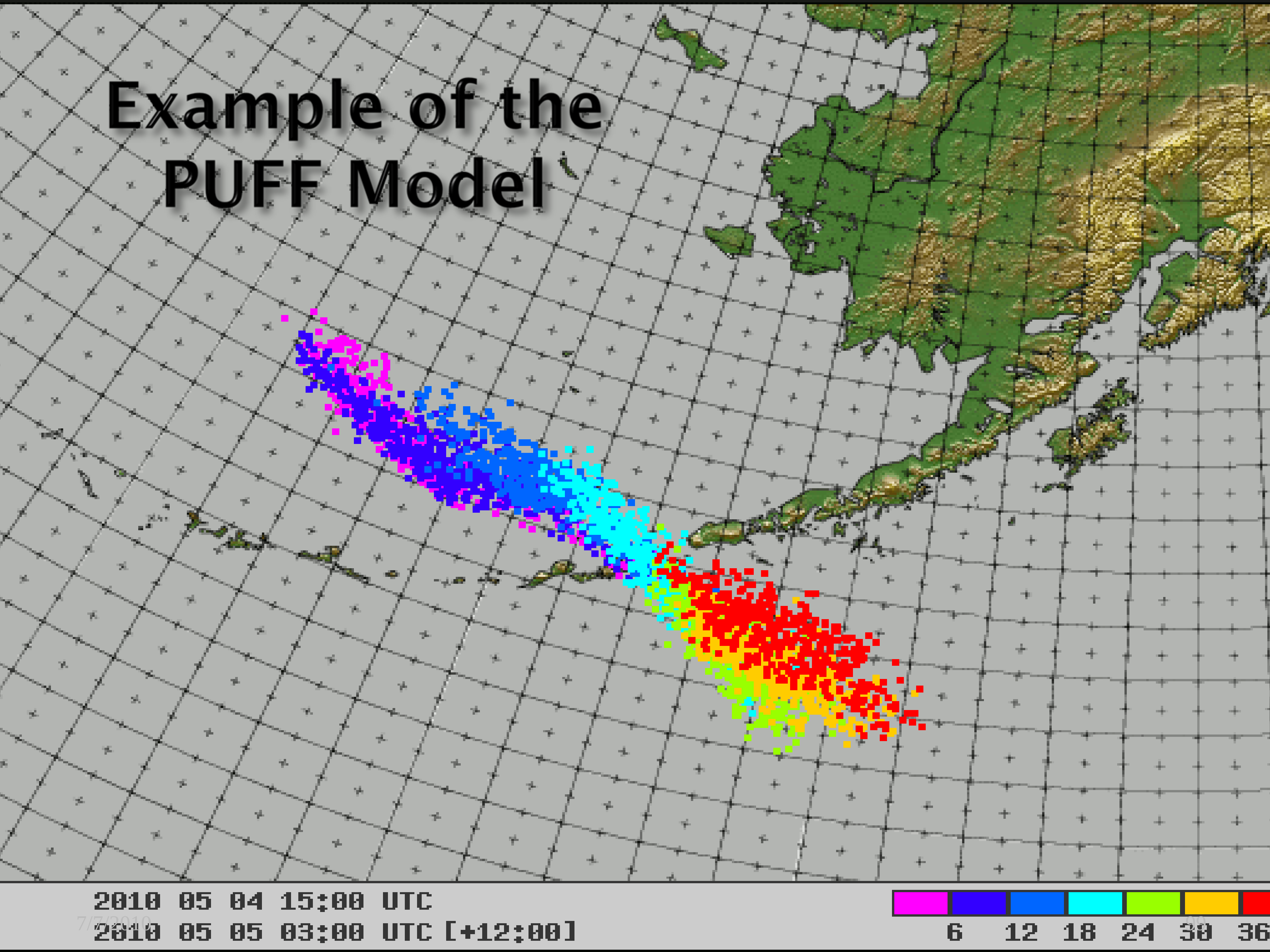
- There are two primary models used to forecast ash dispersion today:
- 1. **The PUFF model:** a volcanic ash dispersion model originally developed at the Geophysical Institute, University of Alaska Fairbanks by Dr. Hiroshi Tanaka for predicting the movement of eruption clouds (spurred on by the eruption of Mt. Redoubt in 1989).
- 2. **HYSPLIT:** A hybrid particle dispersion model, the result of a joint effort between NOAA and Australia's Bureau of Meteorology, dating back to around 1980. The current version is in its 4th major iteration and many updates are planned for the future.

Characteristics of the PUFF Model

- The PUFF model is a Lagrangian trajectory volcanic ash tracking model developed to simulate the movement of airborne ash in near real-time following a volcanic eruption. *
- The model tracks particles through a Lagrangian formulation of advection, fallout and turbulent diffusion using a random-walk technique.
- The ash source is simulated by releasing ash puffs at regular intervals (continually). Each puff contains an appropriate fraction of the ash mass and is advected according to the trajectory of its center position.
- The size of the “puff” in three dimensions expands in time to account for the dispersive nature of a dynamic atmosphere.
- Concentrations are calculated at specific points on a grid by assuming that the concentrations within the puff have a defined spatial distribution.

*Searcy, C., Dean, K., Stringer, W., 1998, PUFF: A Lagrangian Trajectory Volcanic Ash Tracking Model, Journal of Volcanology and Geothermal Research (80) 1-16

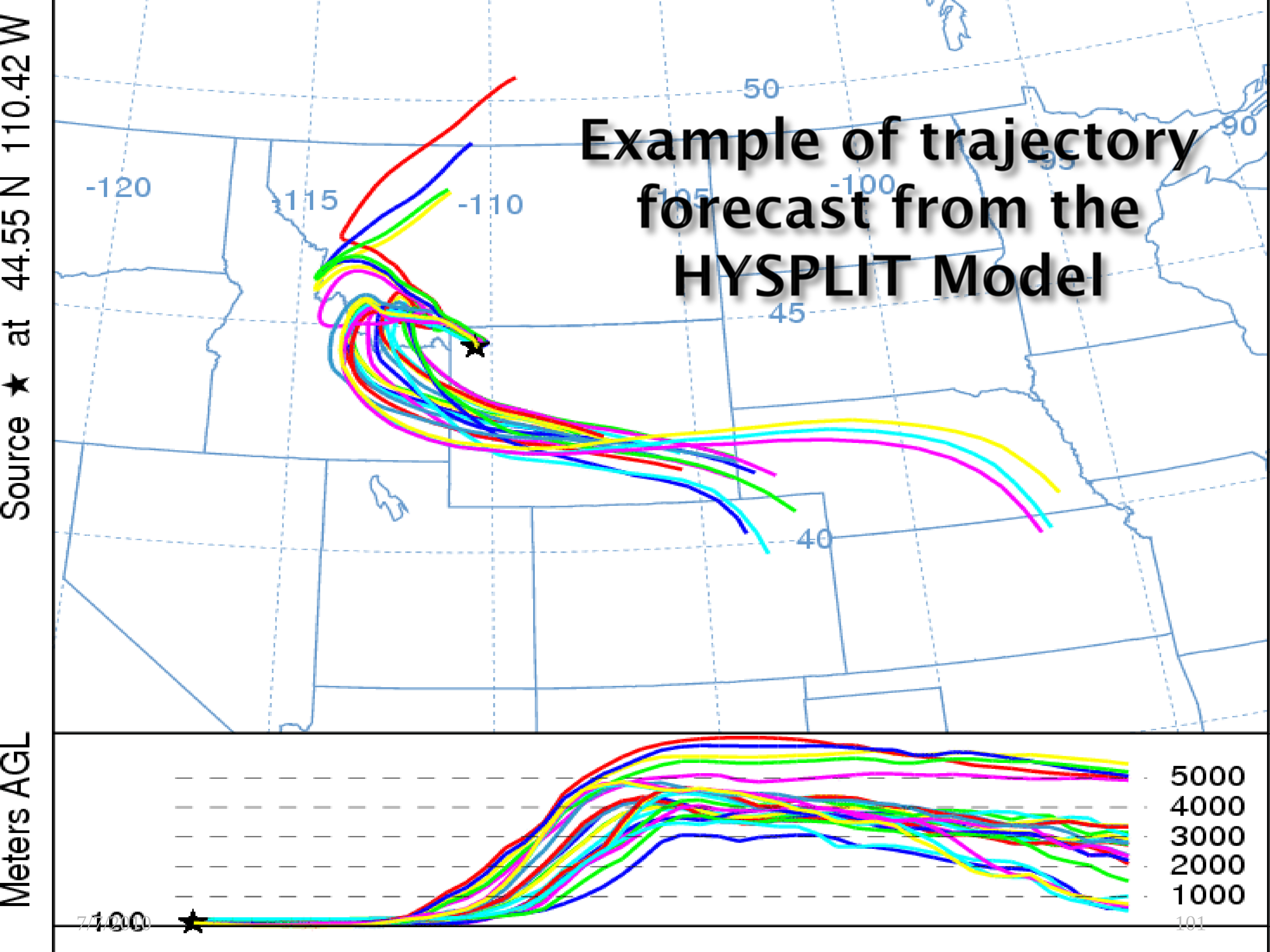
Example of the PUFF Model



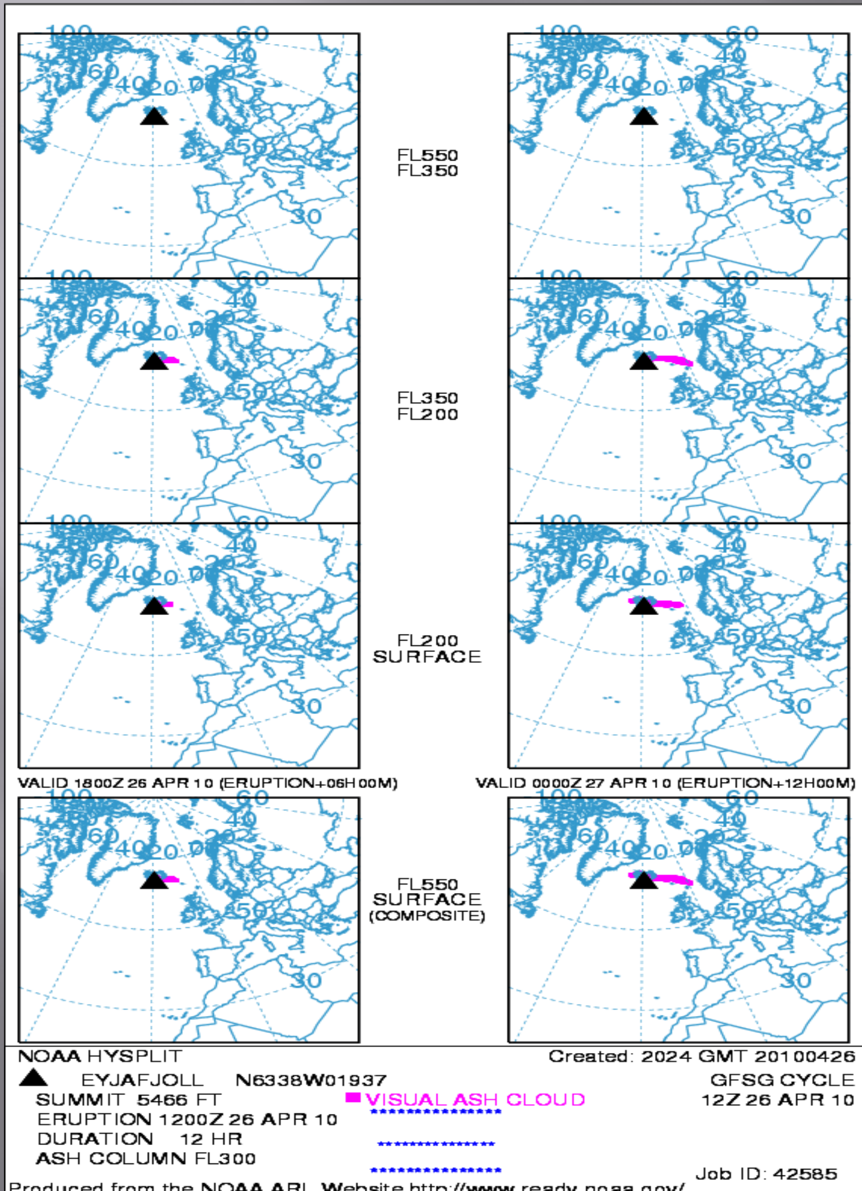
Characteristics of the HYSPLIT Model

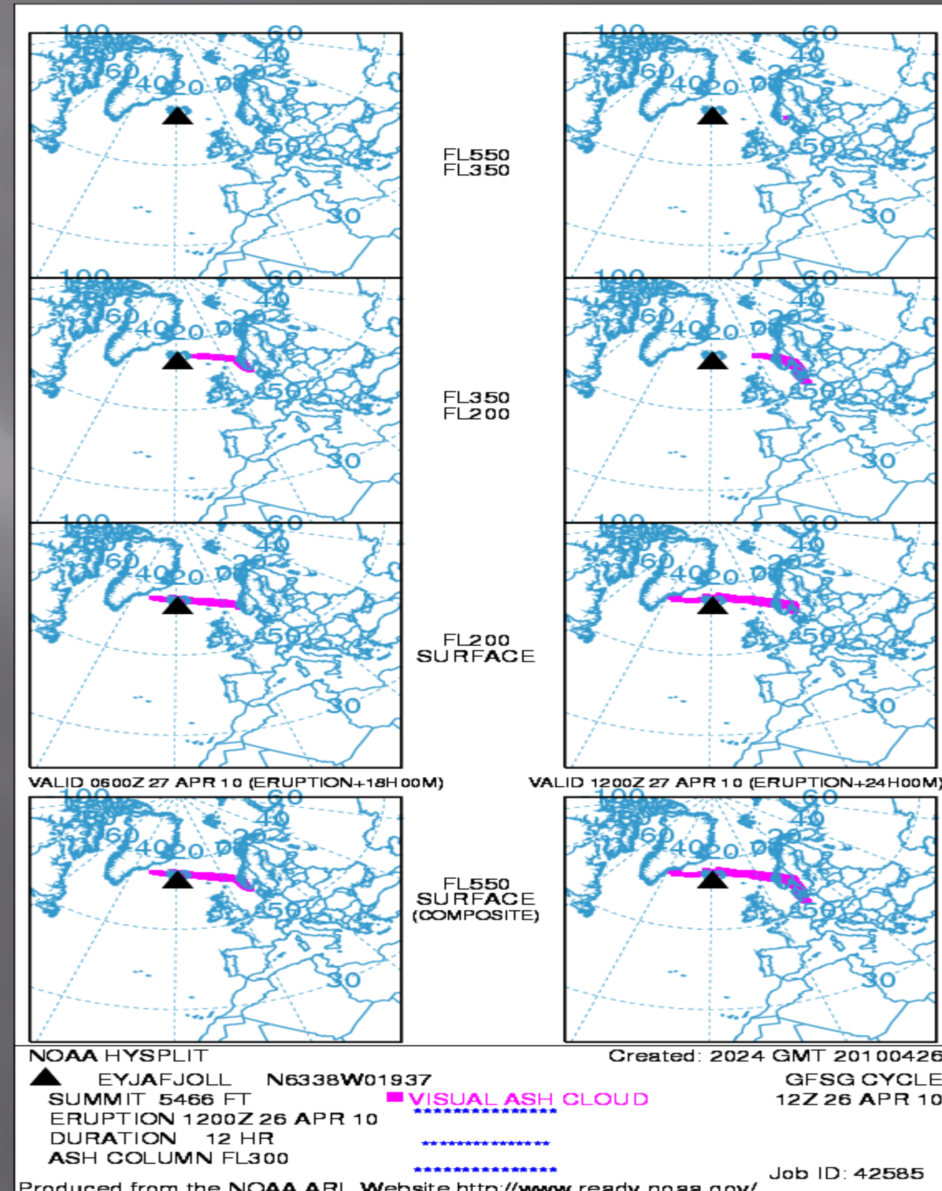
- HYSPLIT stands for "Hybrid Single-Particle Lagrangian Integrated Trajectory."
- HYSPLIT uses a mix between Eulerian and Lagrangian approaches with advection and diffusion represented in a Lagrangian framework but concentrations of ash calculated on a fixed grid.
- The transport and dispersion of the ash cloud is calculated through the release of a single puff, whereas the PUFF model releases puffs continually.
- Hysplit computes the advection of a single pollutant particle, or simply its trajectory.*

Example of trajectory forecast from the HYSPLIT Model

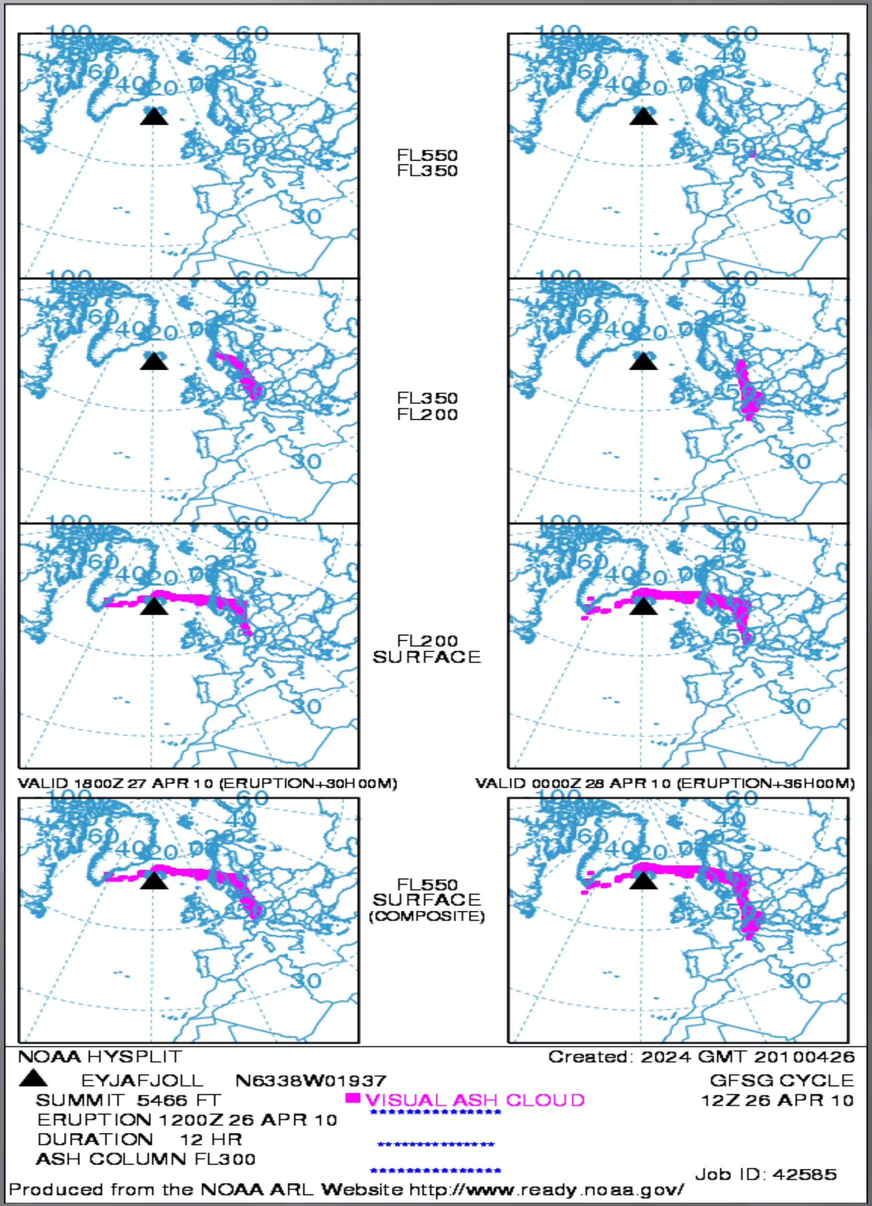


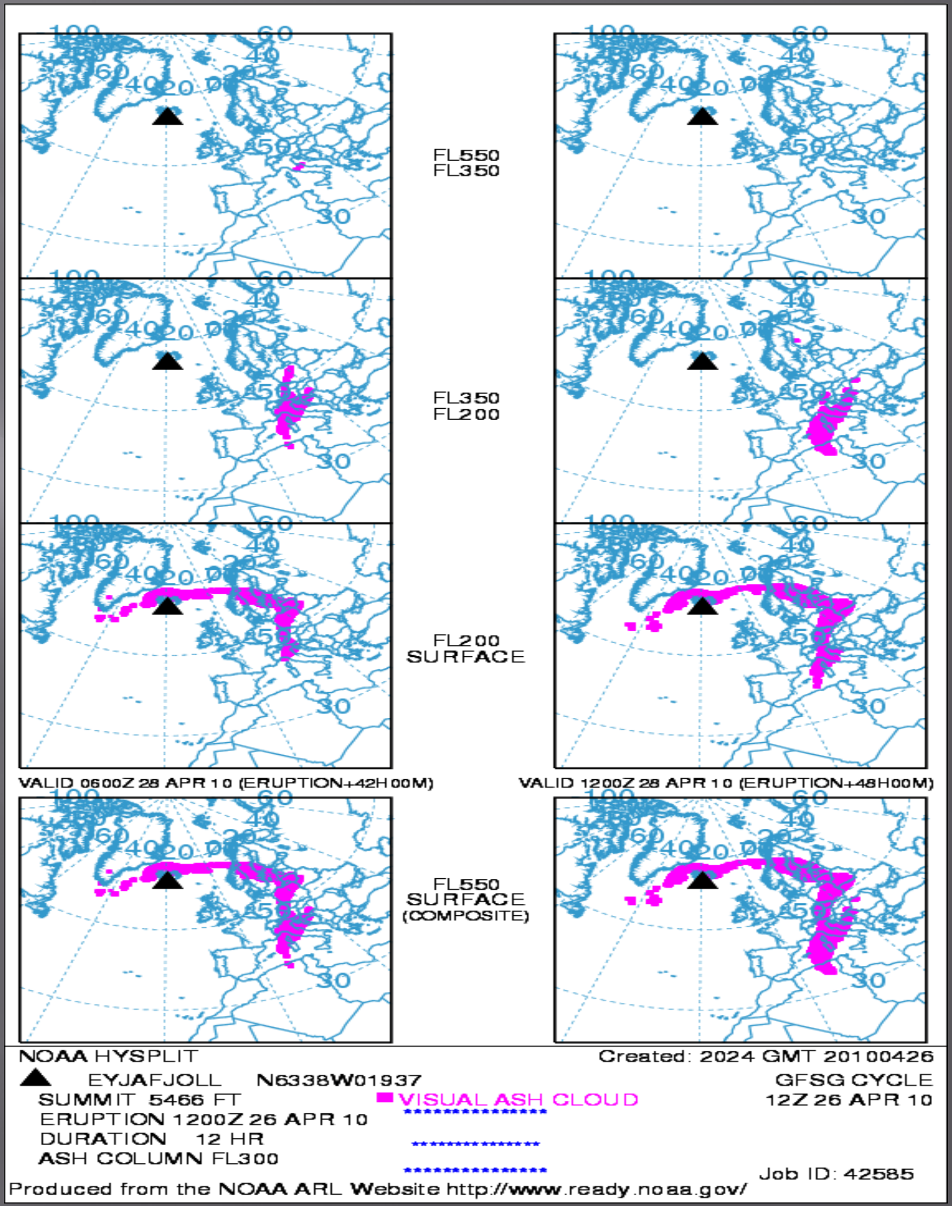
Ash Layer Dispersion Forecast HYSPLIT Model



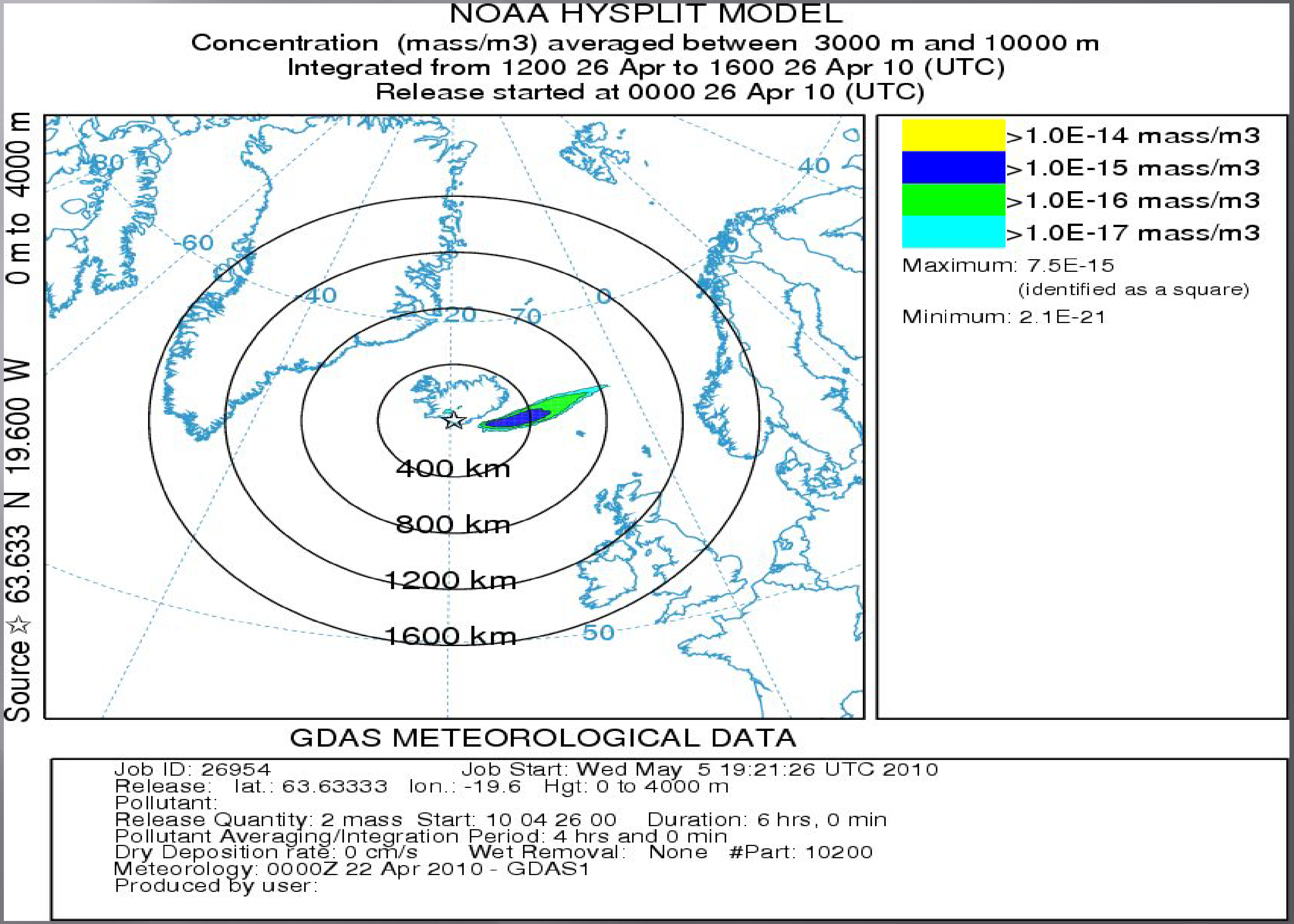


Ash Layer Dispersion Forecast HYSPLIT Model continued…

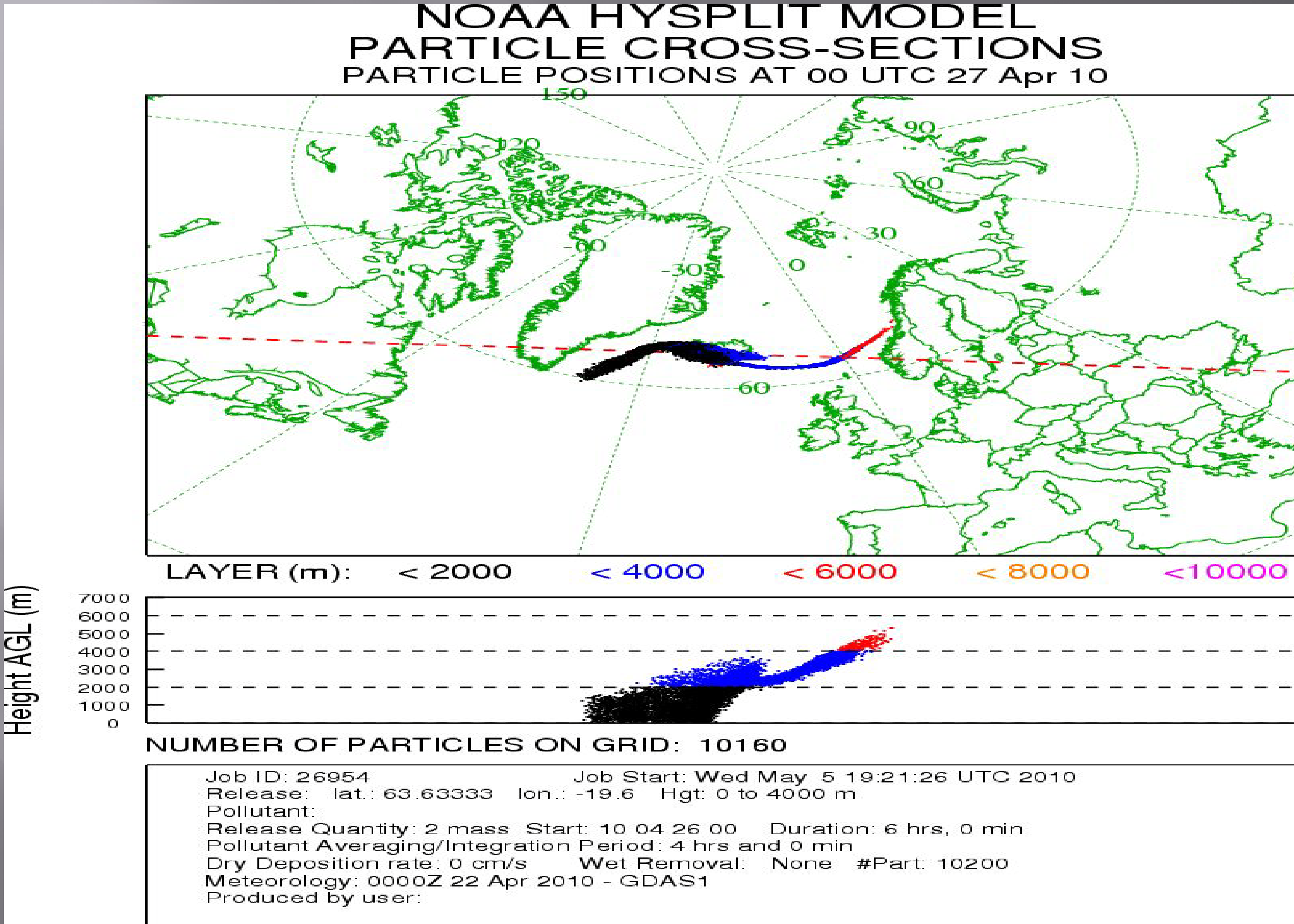




Mass Dispersion Forecast HYSPLIT Model

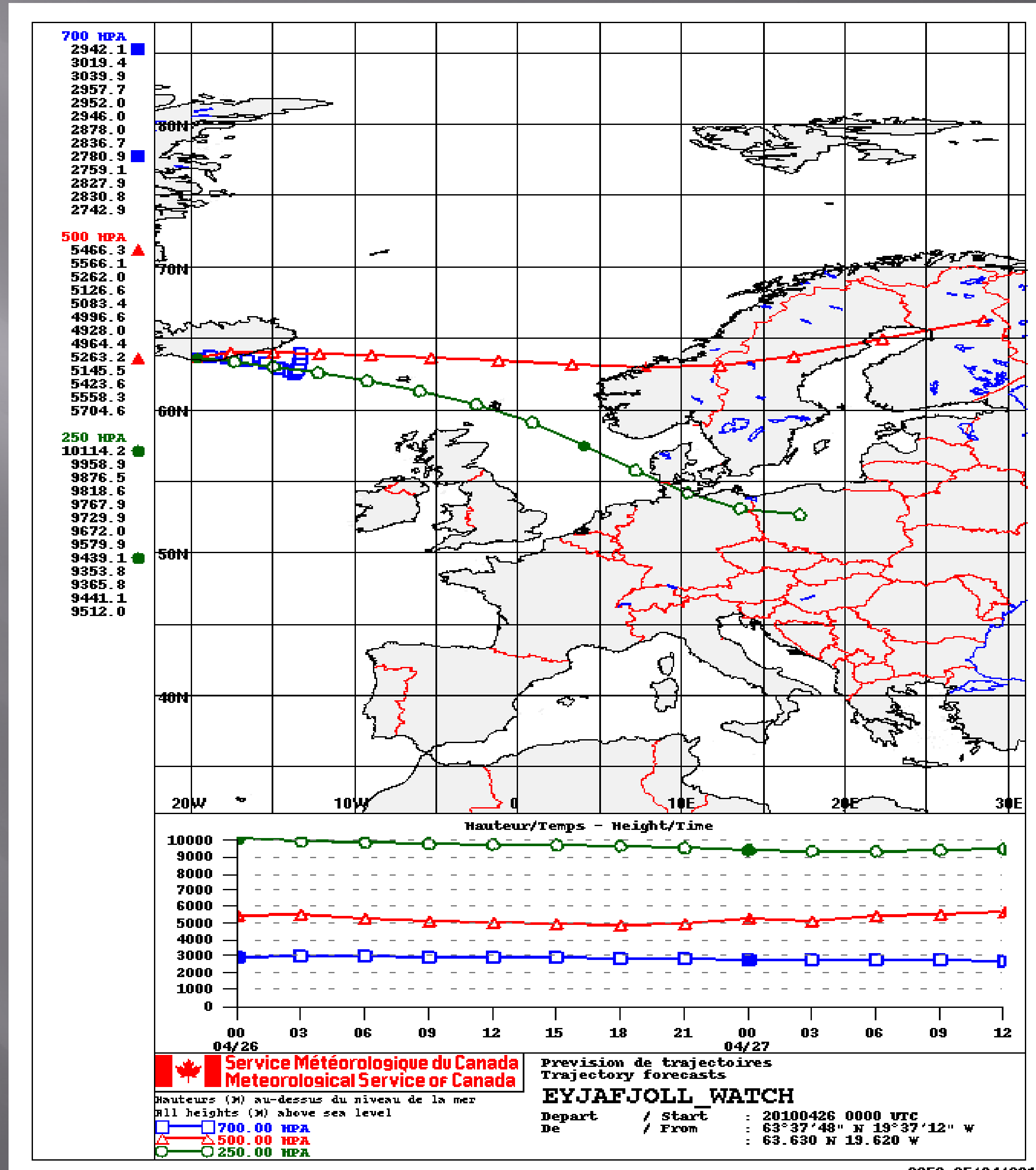


Particle Dispersion Forecast HYSPLIT Model

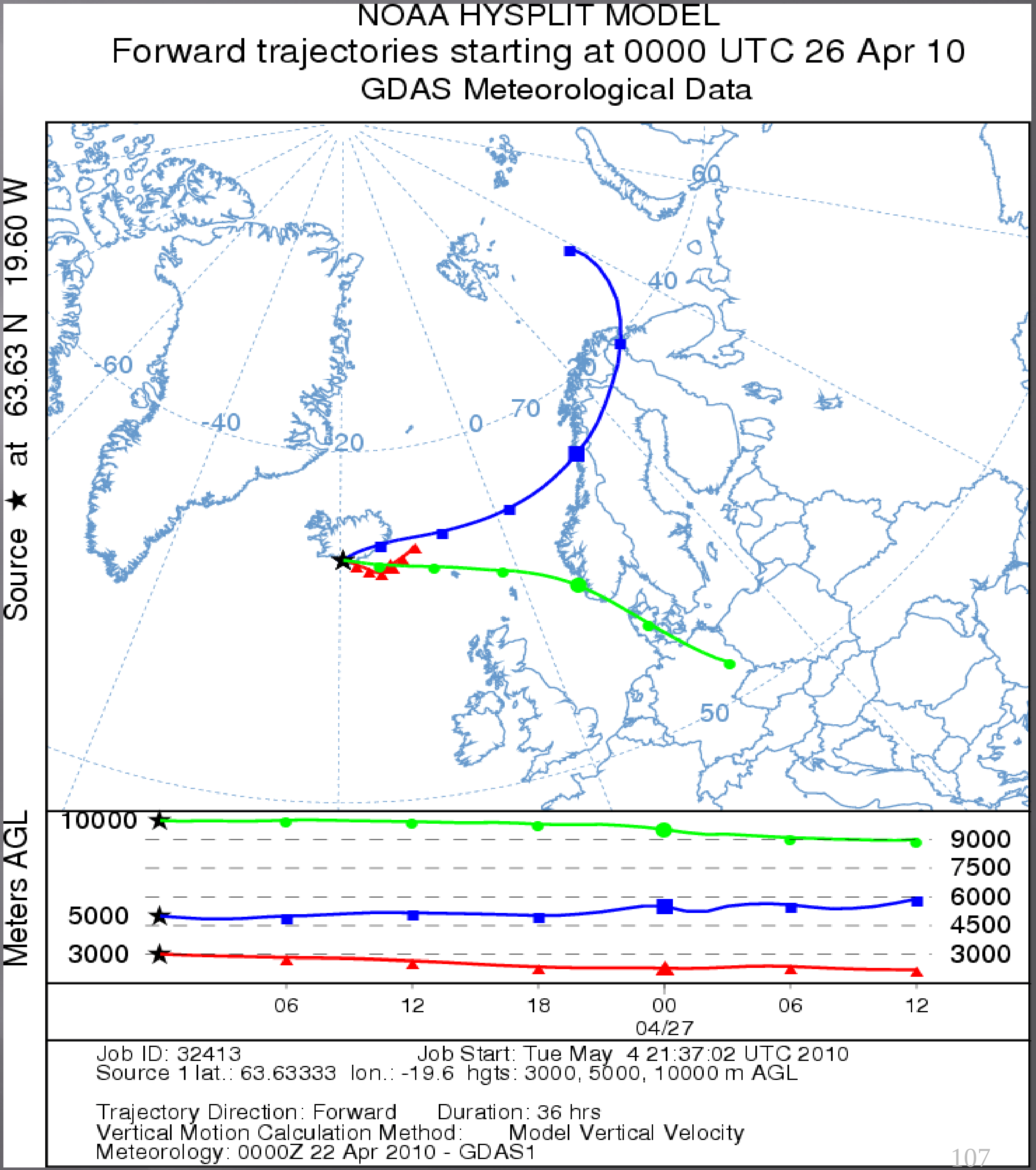


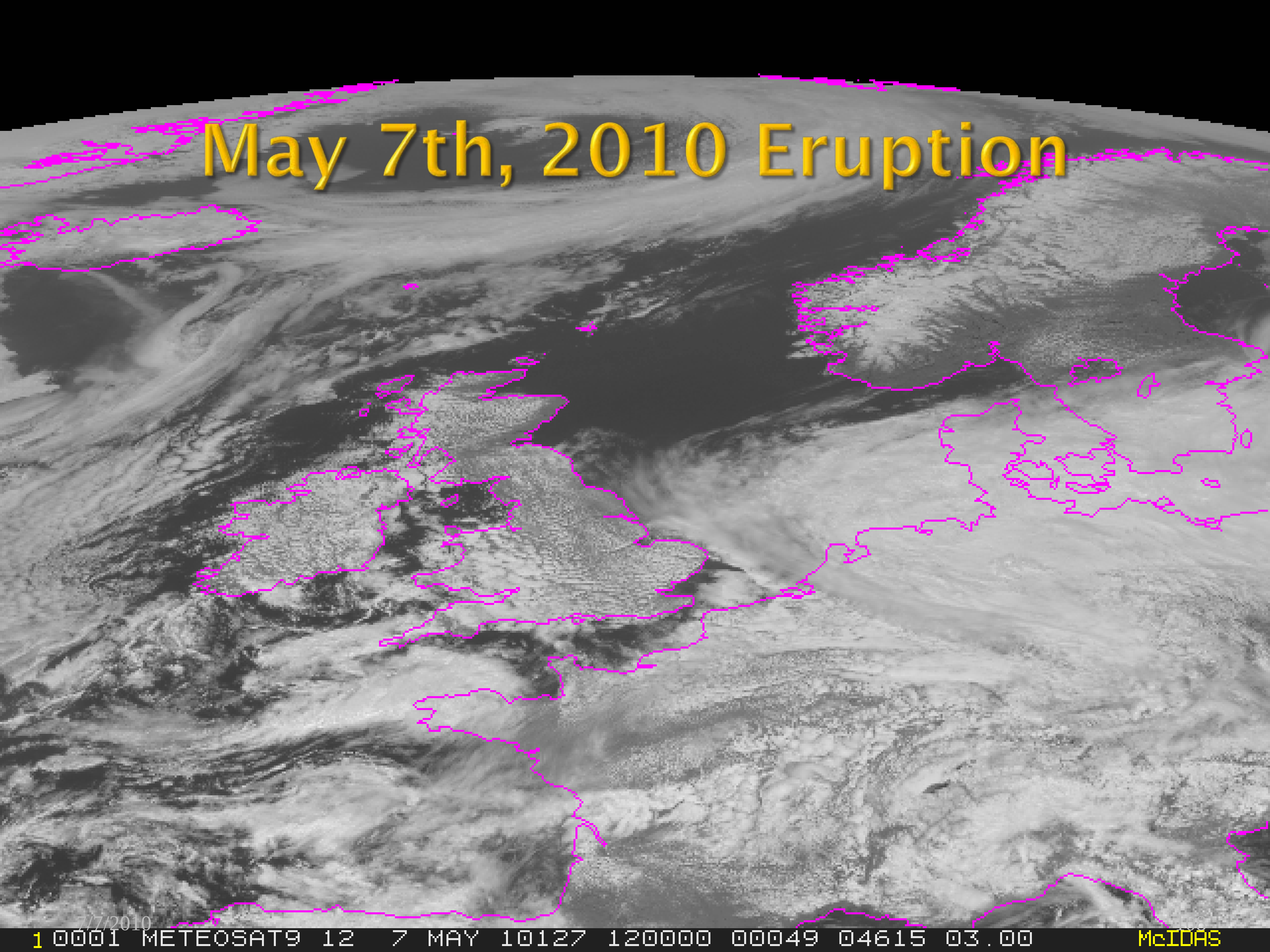
Other Models:

The CANERM - Canadian Emergency Response Model.

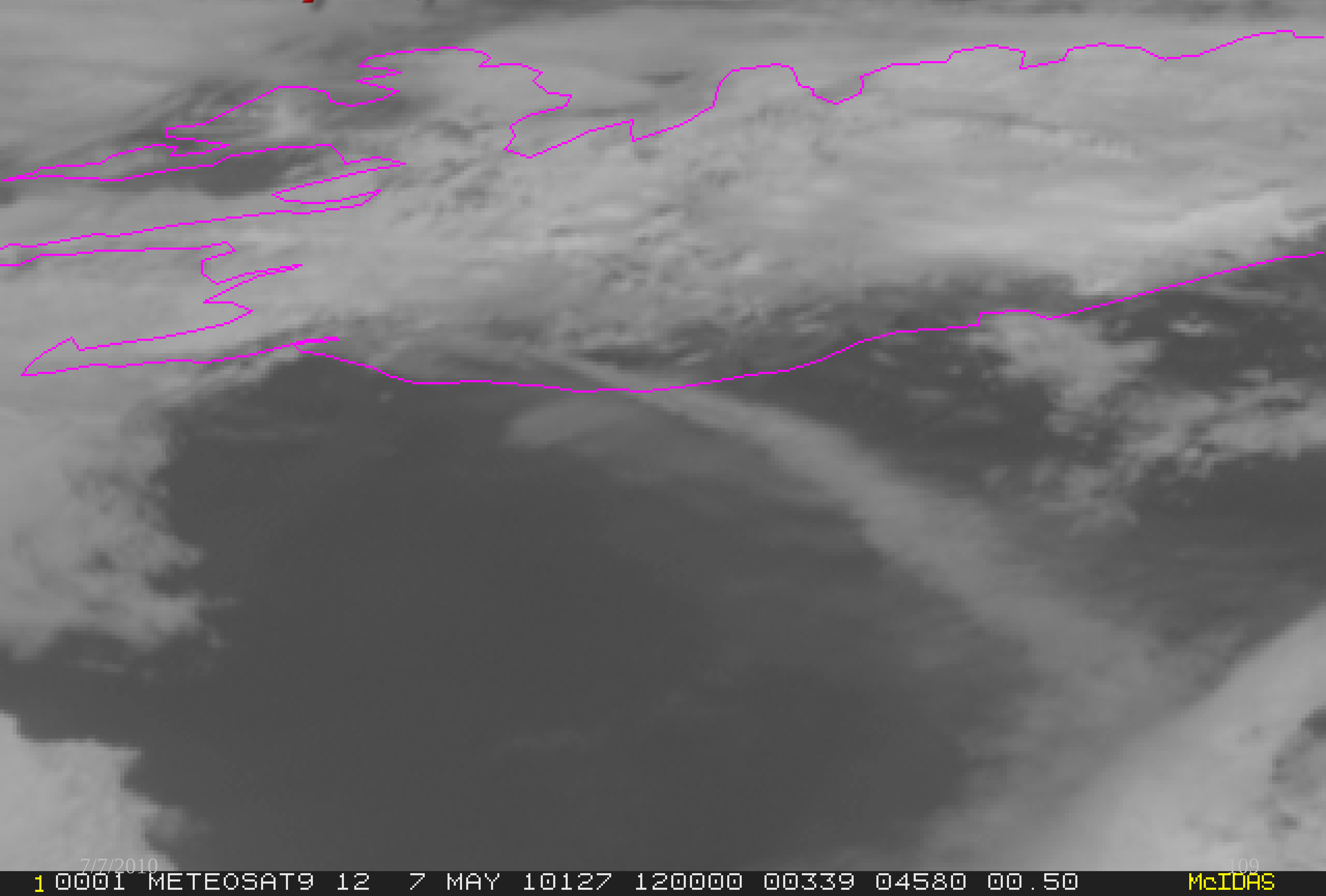


HYSPLIT model forecast same period as CANERM

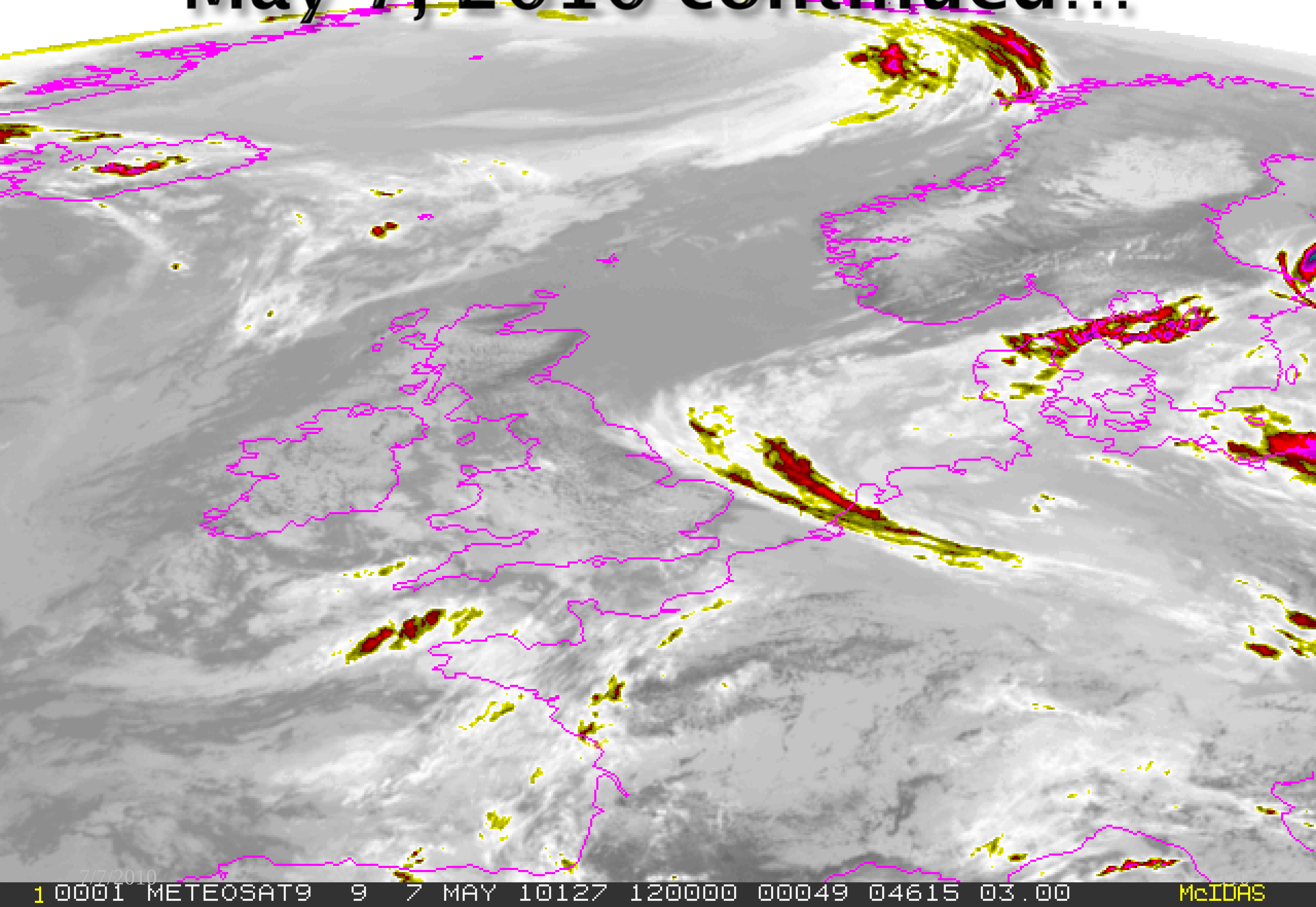



May 7th, 2010 Eruption
1 0001 METEOSAT9 12 7 MAY 10127 120000 00049 04615 03.00
McIDAS

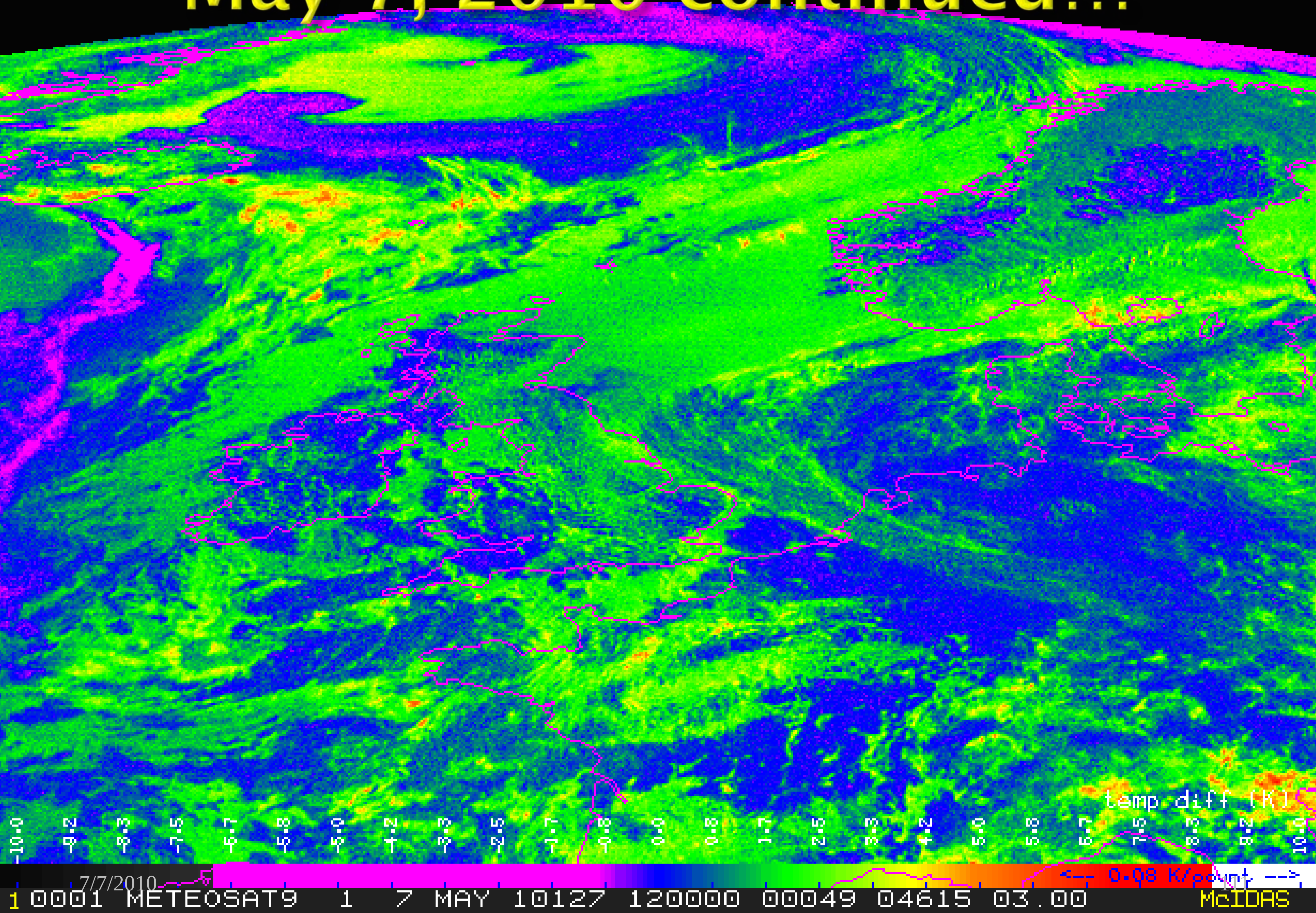
May 7, 2010 continued…



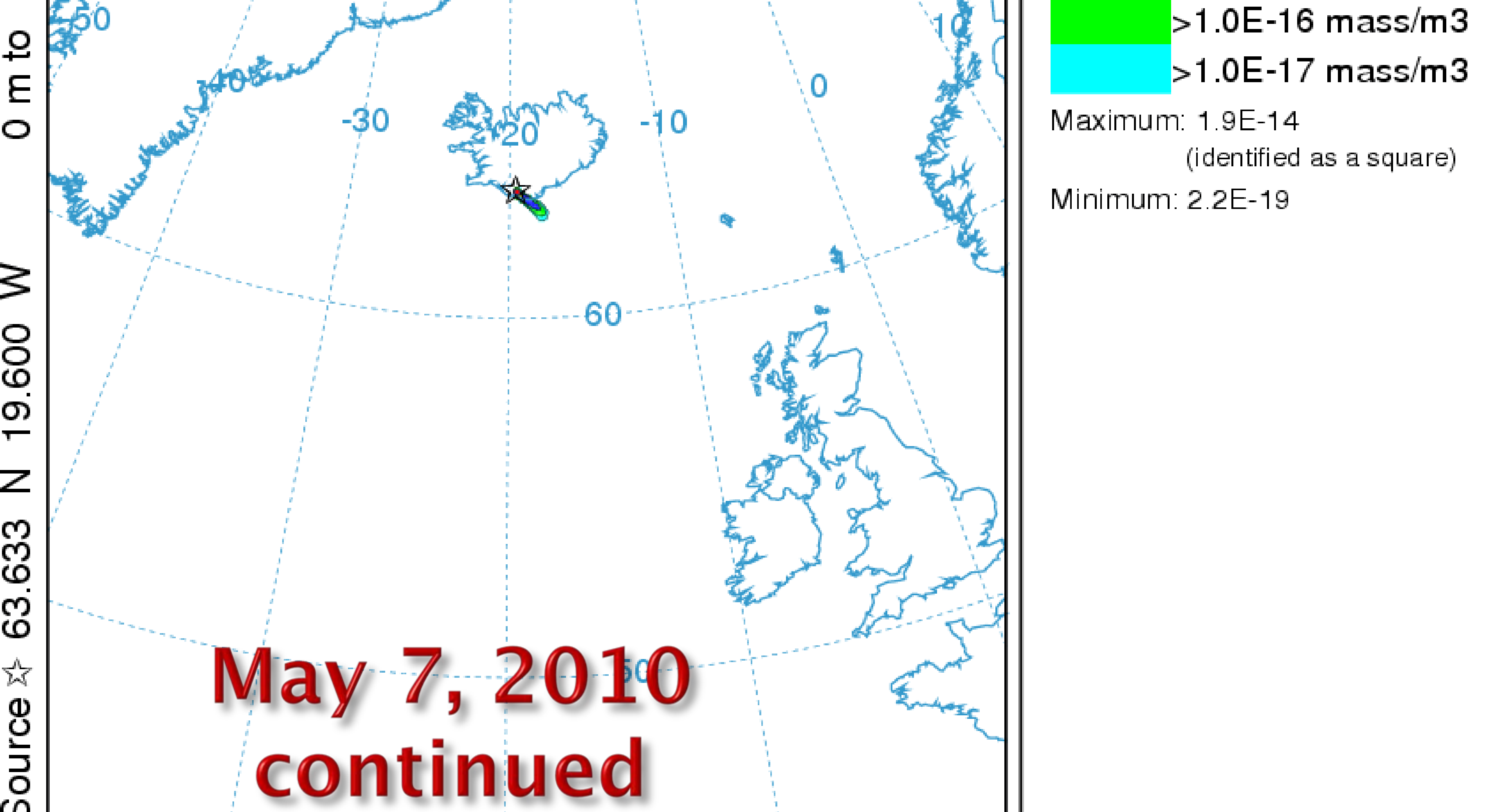
May 7, 2010 continued…



May 7, 2010 continued…



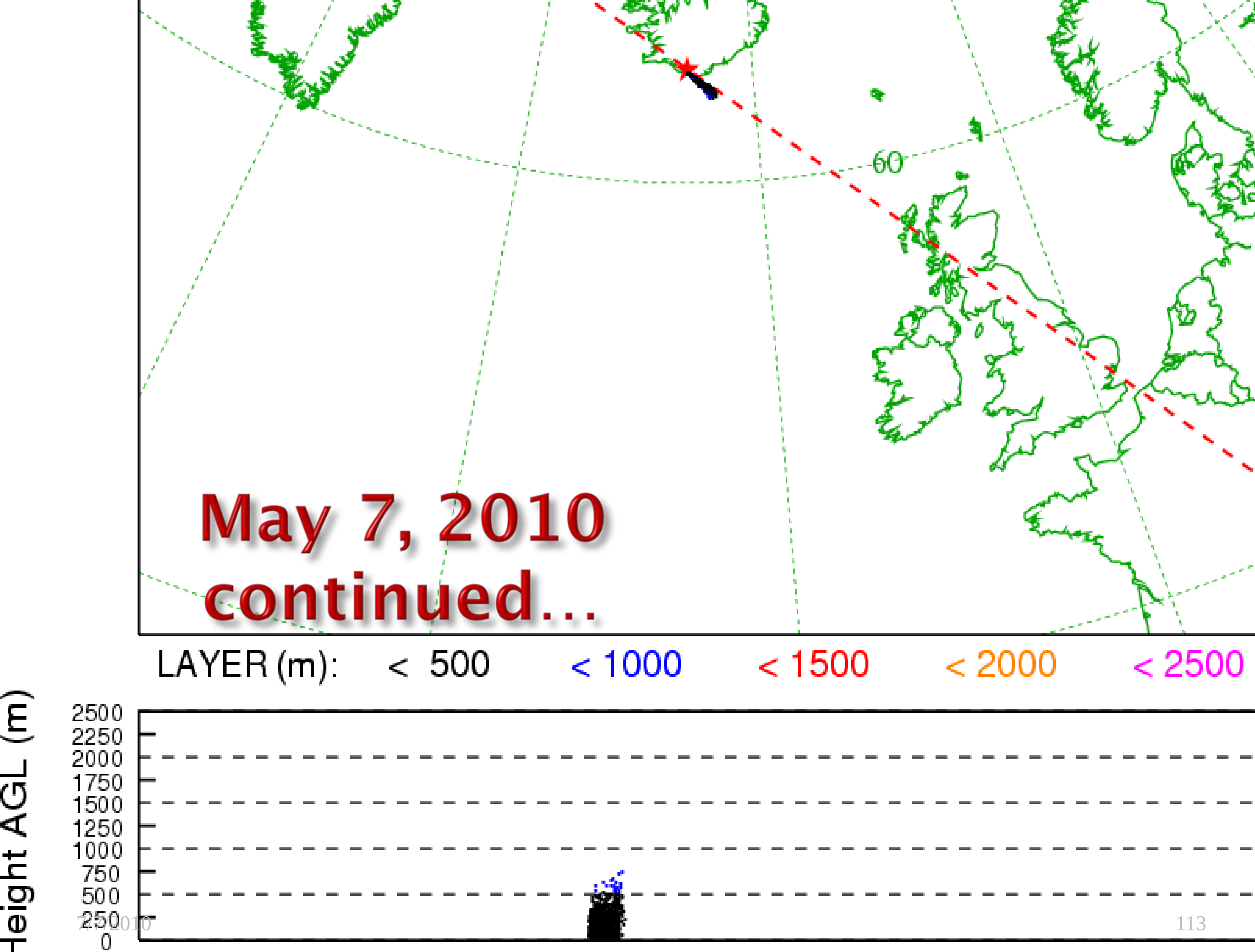
May 7, 2010 continued

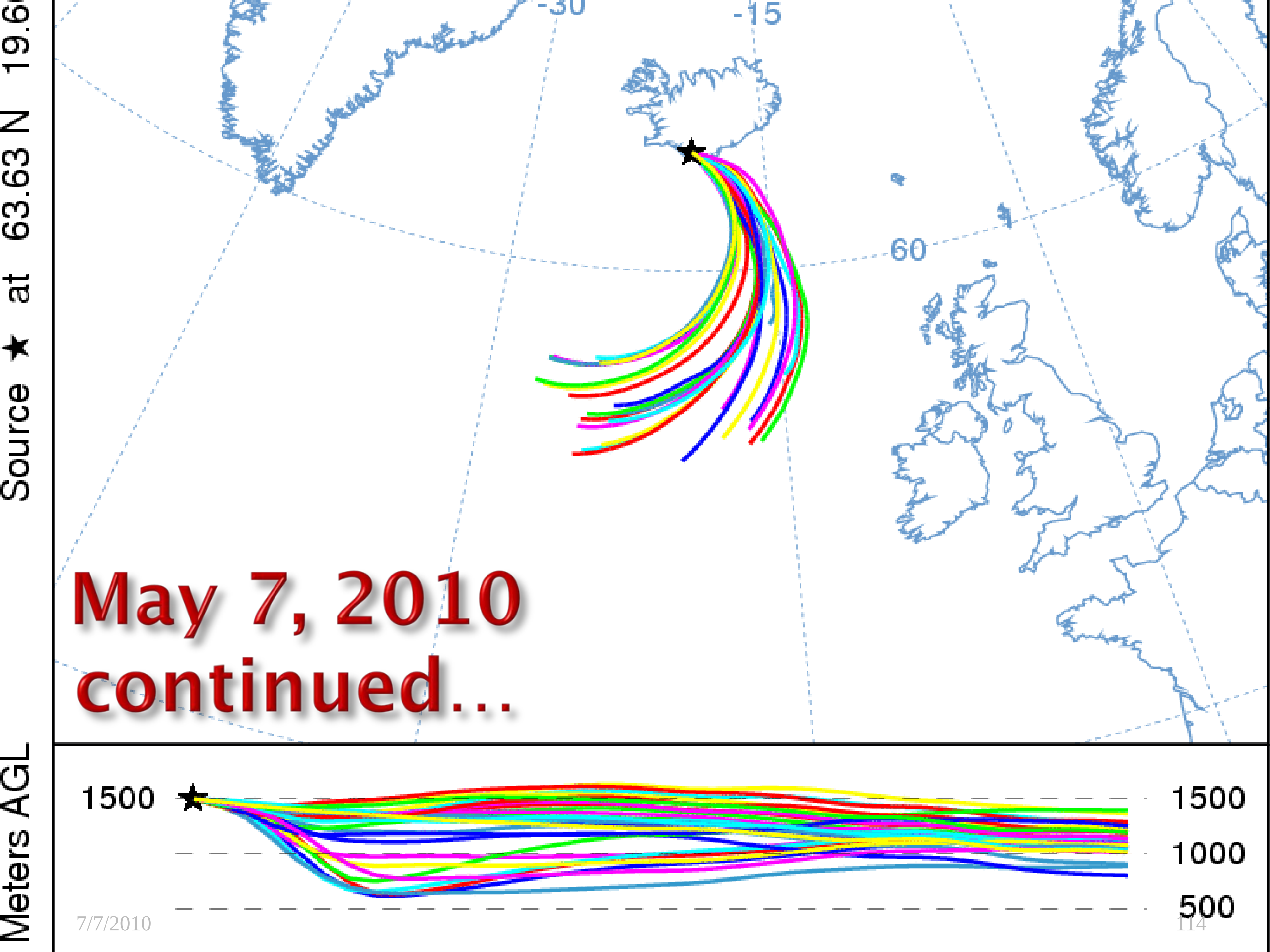


GDAS METEOROLOGICAL DATA

Job ID: 27267 Job Start: Mon May 10 16:10:54 UTC 2010
Release: lat.: 63.63333 lon.: -19.6 Hgt: 0 to 200 m
Pollutant:
Release Quantity: 2 mass Start: 10 05 06 12 Duration: 36 hrs, 0 min
Pollutant Averaging/Integration Period: 3 hrs and 0 min
Dry Deposition rate: 0 cm/s Wet Removal: None #Part: 10200
Meteorology: 0000Z 01 May 2010 - GDAS1
Produced by user:

May 7, 2010 continued…





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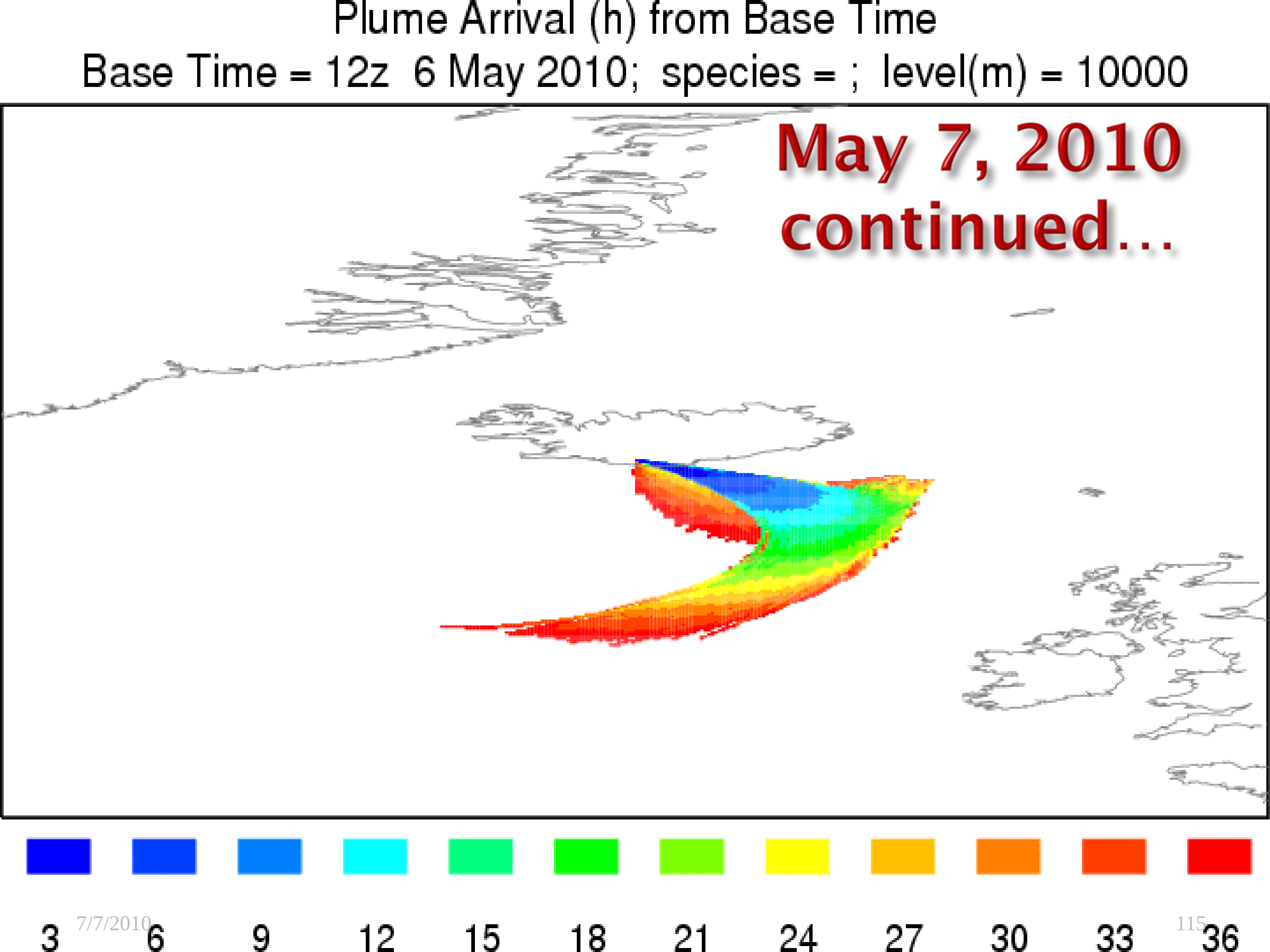
Plume Arrival (h) from Base Time
Base Time = 12z 6 May 2010; species = ; level(m) = 10000
May 7, 2010
continued…
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Volcanoes/Volcanic Ash Part II

- Case Study(s)
- The Key Players (Organizations)
- The Flow of Information
- The Volcanic Ash Advisory Centers (VAACs)
- Volcanic Ash Advisories
- Volcano Hazards Program

End of Part 1

- For more information concerning this session, please see the student guide and talking points.
  - Talking points, links and references: (list URL)

Contacts:

- CIRA/VISIT/SHyMet contact:
  - Jeff Braun: Braun@cira.colostate.edu
- NWS Alaska Region ESSD contact:
  - Jeff Osiensky: jeffrey.osiensky@noaa.gov
- NWS Anchorage CWSU contact:
  - Kristine Nelson: kristine.a.nelson@noaa.gov