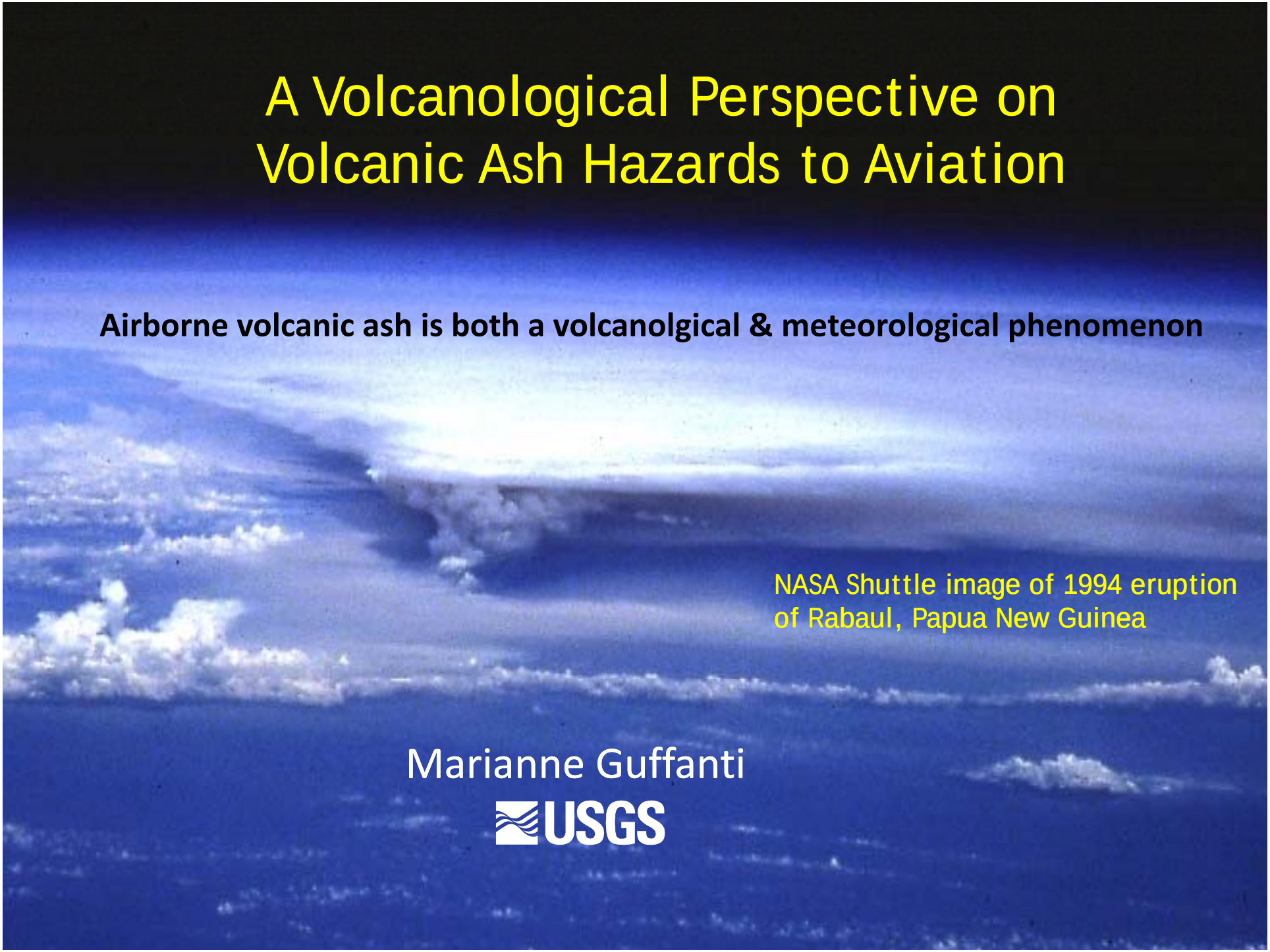
A Volcanological Perspective on Volcanic Ash Hazards to Aviation

Airborne volcanic ash is both a volcanolgical & meteorological phenomenon



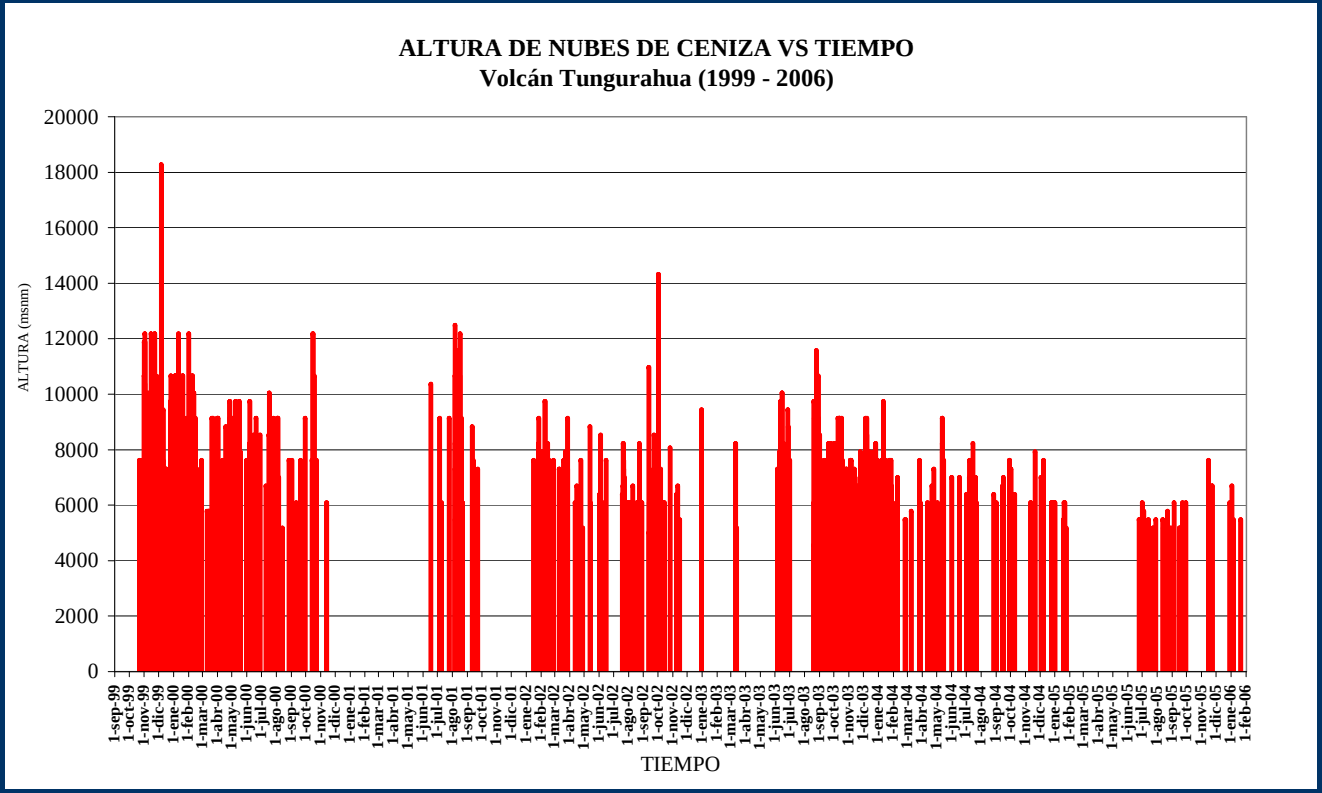
NASA Shuttle image of 1994 eruption of Rabaul, Papua New Guinea

Marianne Guffanti

USGS

Frequency of Ash-Cloud Hazard

Because of a few long-lived eruptions(e.g., Tungurahua in Ecuador & Soufriere Hills in Br. W. Indies) and many short-lived eruptions (e.g., in Alaska), volcanic ash is in the atmosphere at cruise levels ~every day, somewhere around the globe. Accepted global risk-mitigation practice has been to avoid aircraft transit through ash clouds.



(Graphic courtesy of R. Ruiz, IG, Ecuador)

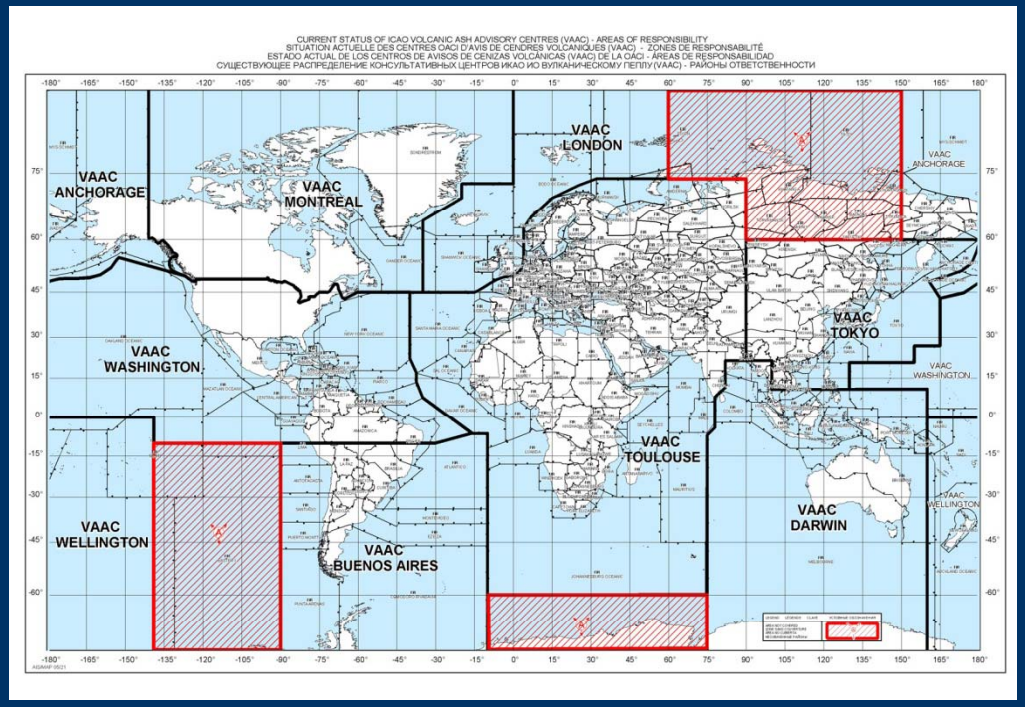
USGS

Global Ash Avoidance Program
created by the International Civil Aviation Organization

Straightforward Objective: quickly communicate warning messages about explosive eruptions & whereabouts of ash clouds to air-traffic controllers, dispatchers, & pilots so that aircraft can be routed to avoid ash-contaminated airspace.

Complex Components:

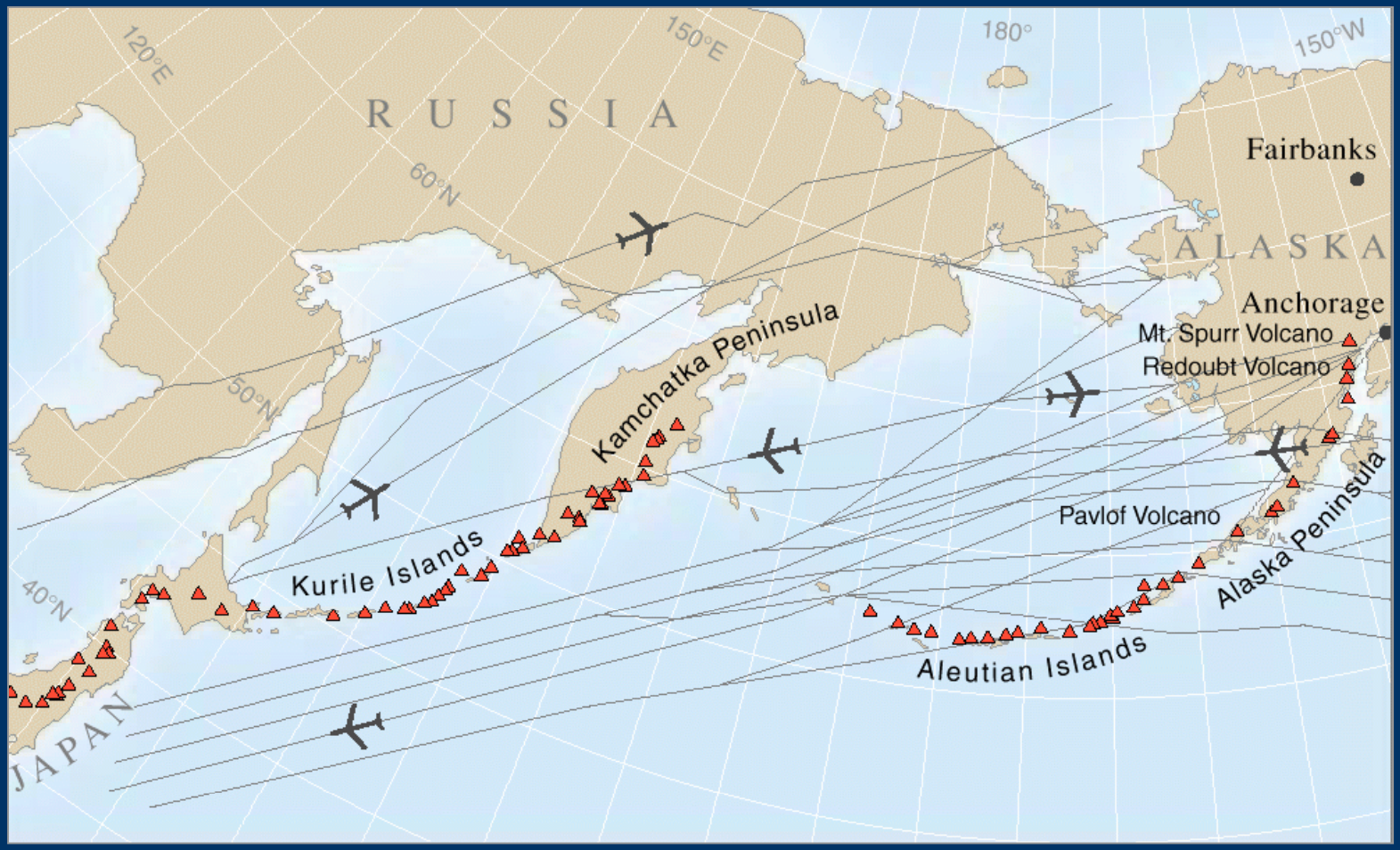
- Volcano monitoring
- Ash cloud detection
- Forecast cloud dispersion
- Warning messages
- Training & education



Worldwide system of Volcanic Ash Advisory Centers

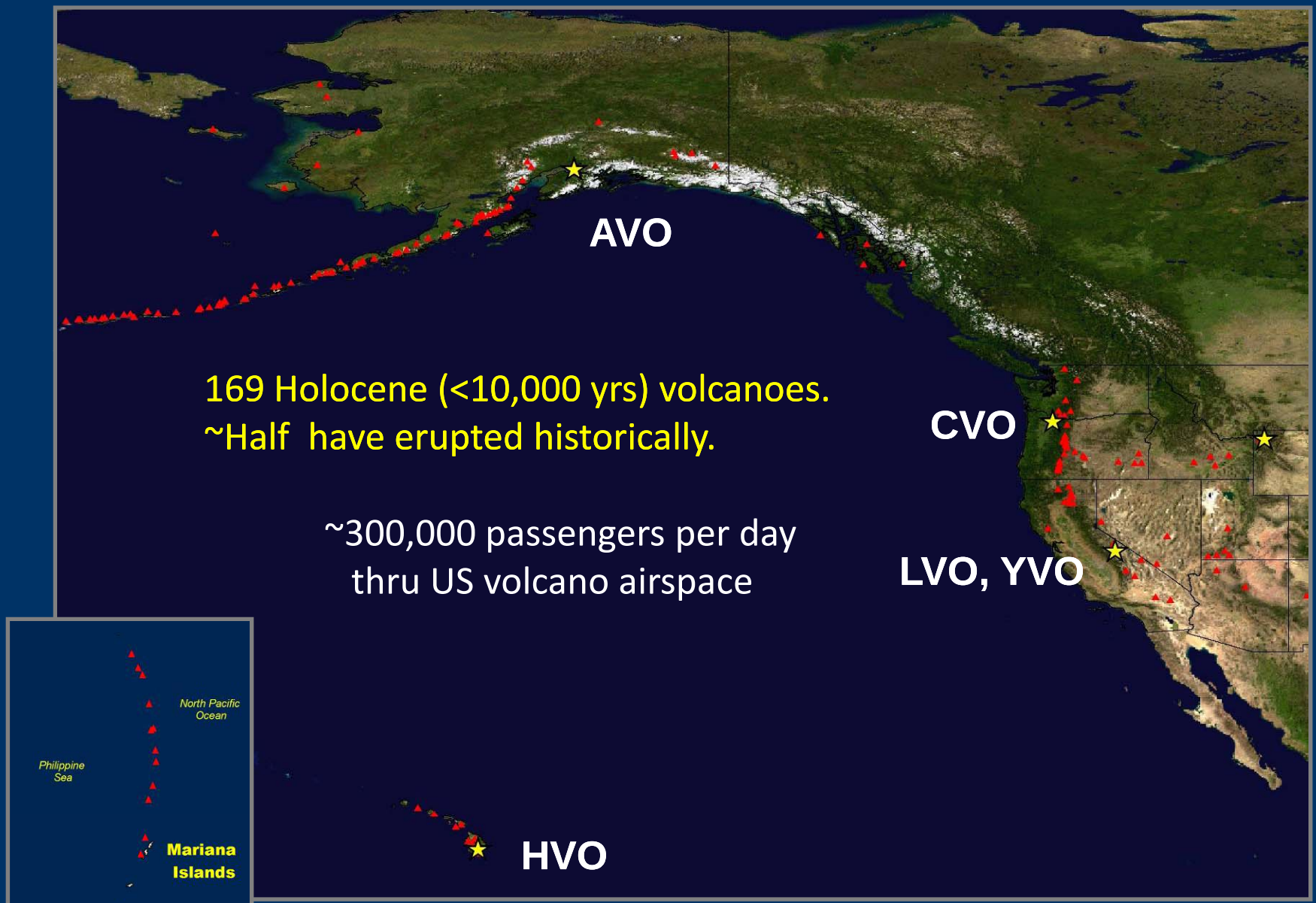
USGS

In the US, the KLM encounter (4 engine flameout) in 1989 focused the mission of the Alaska Volcano Observatory on ash hazards to aviation.



USGS

5 U.S. Volcano Observatories monitor ~60 volcanoes



USGS

USGS Volcano Observatories and Aviation

- The Observatories assign AVIATION COLOR CODES that rank the activity level at each volcano.

- The Observatories issue notifications of activity to the public and affected groups, including new specially formatted message called VONA – Volcano Observatory Notice for Aviation - aimed at aviation users.

- Immediate telephone call-down for key users when significant activity occurs.
    - 1 - FAA Air-Traffic Control Center
    - 2 - NOAA Met. Watch Office
    - 3 - NOAA Volcanic Ash Advisory Center
    - 4 - Air Force Weather Agency
    - 5 - NOAA Weather Forecast Office

USGS

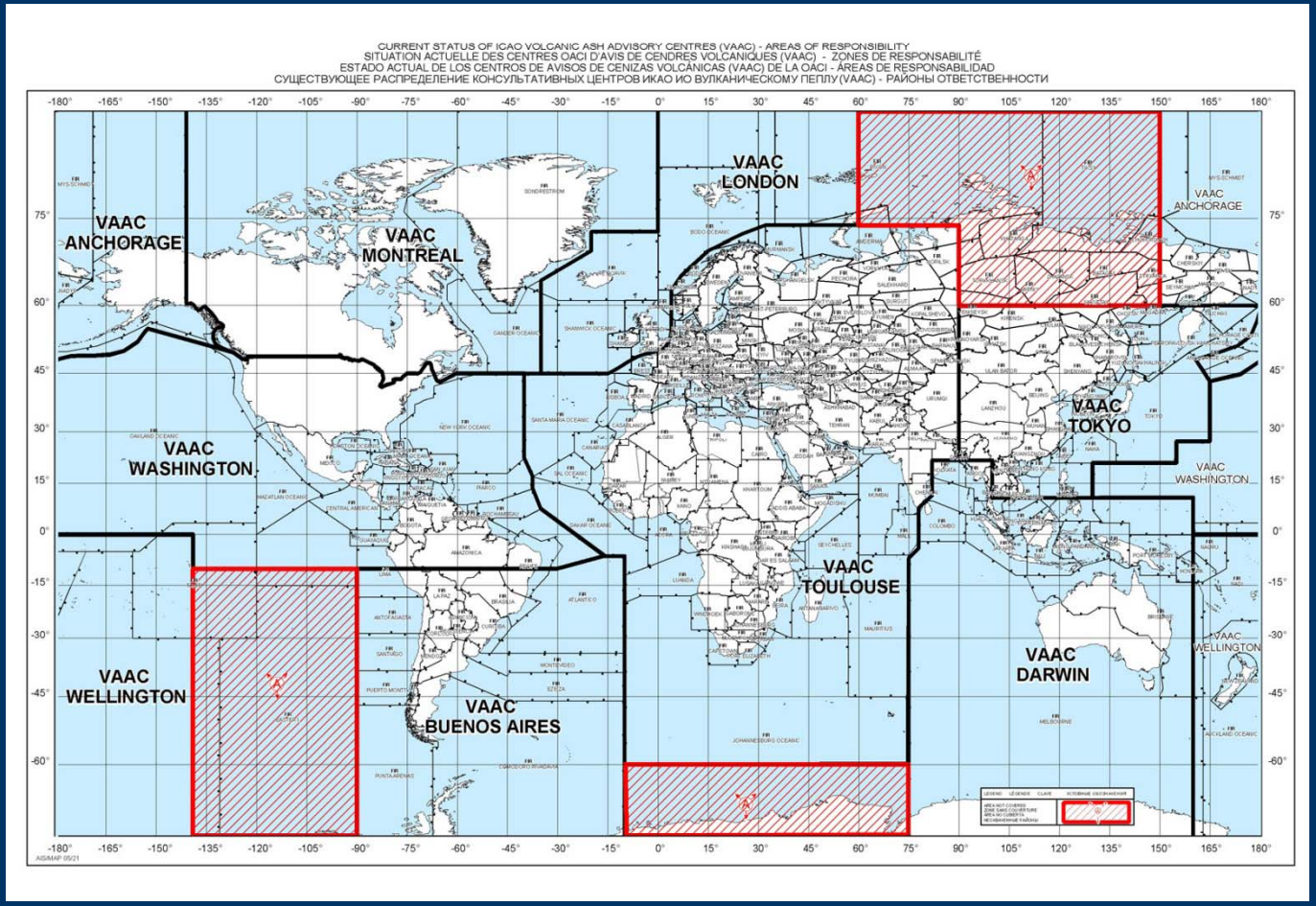
Volcano **O**bservatory **N**otice for **A**viation

Customized format for aviation users. Issued by Volcano Observatory when significant volcanic activity occurs &/or when color code is changed.

(1) **VOLCANO OBSERVATORY NOTICE FOR AVIATION (VONA)**
(2) Issued:
(3) Volcano:
(4) Current Aviation Color Code:
(5) Previous Aviation Color Code:
(6) Source:
(7) Notice Number:
(8) Volcano Location:
(9) Area:
(10) Summit Elevation:
(11) Volcanic Activity Summary: SIMPLE AND BRIEF!
(12) Volcanic cloud height:
(13) Other volcanic cloud information:
(14) Remarks:
(15) Contacts:
(16) Next Notice:

USGS

Primary responsibility for detecting ash clouds and forecasting their movement in the atmosphere is with the 9 Volcanic Ash Advisory Centers (VAACs) worldwide.



Forecasts of ash-cloud movement depend critically on the characteristics of an eruption, info that typically is provided by Volcano Observatories.

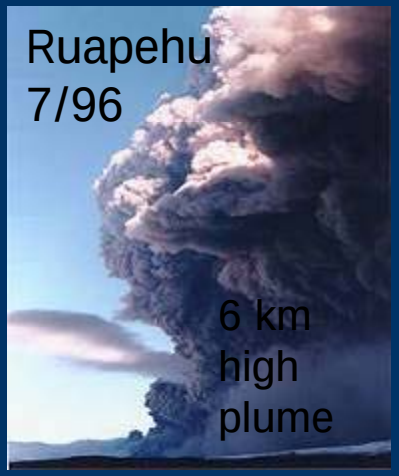
- Plume height
- Eruption rate or erupted mass
- Duration
- Grain-size distribution
- Mass distribution with altitude

- These parameters must be assigned immediately when an eruption is detected. But often there may be few data/observations to constrain these parameters.

- The better instrumented and studied the eruption – and the better the collaboration between Volcano Observatories and VAAC – the better the forecast of ash movement.

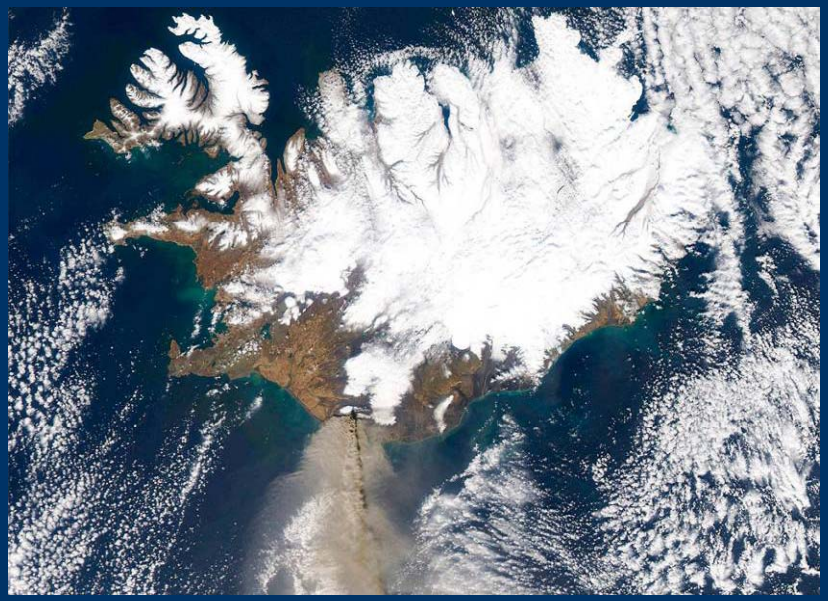
USGS

Some examples of different “eruption source parameters”

	small	medium	large
basalt	 INGV photo	 G. Soto photo	 K. Stern web photo
Explosive	 Fransje van Hoppe photo	 R. McGimsey photo	 Austin Post photo

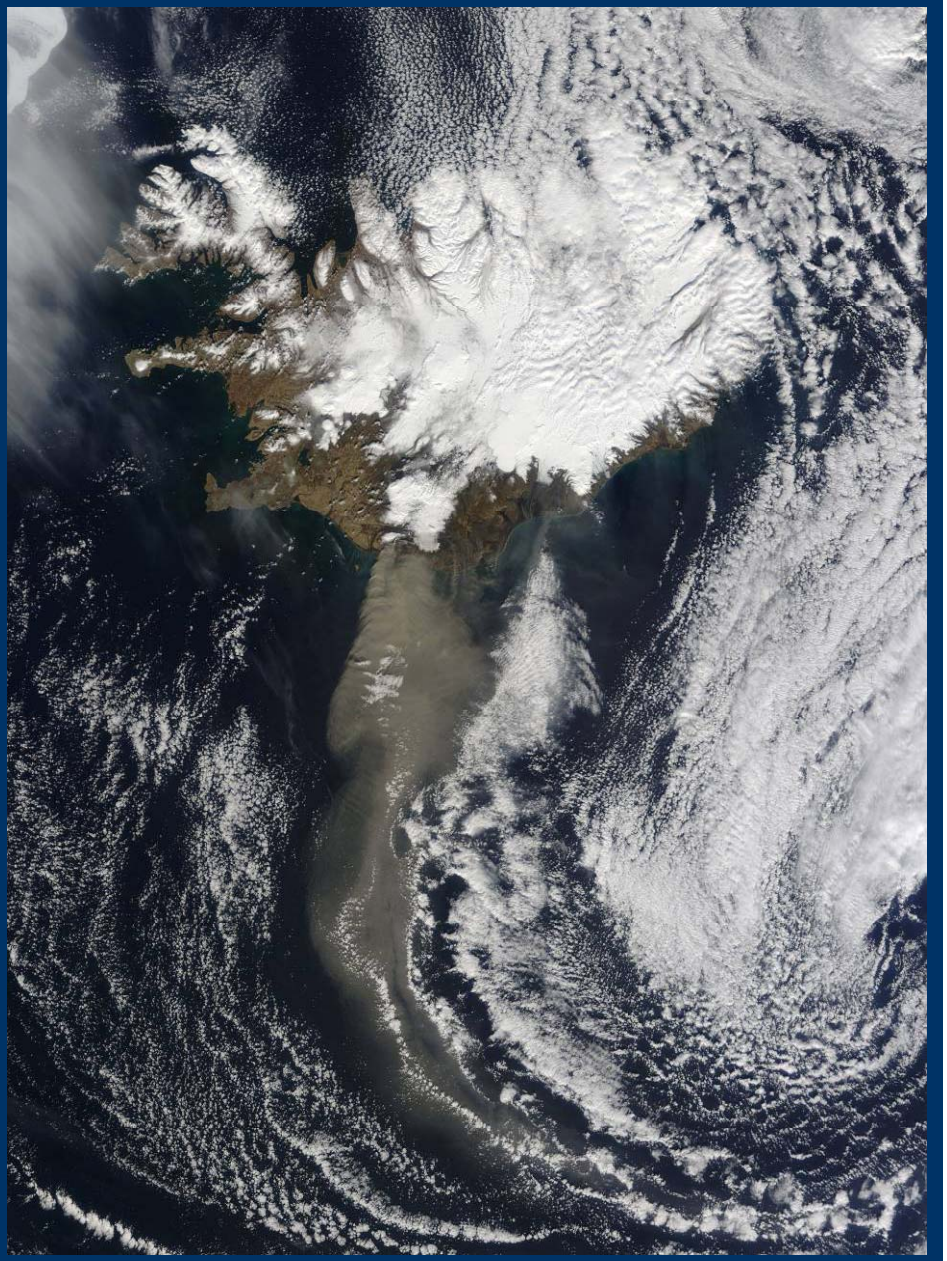
USGS

Eyjafjallajokull: moderate hazard, but enormous risk (world's busiest air routes)

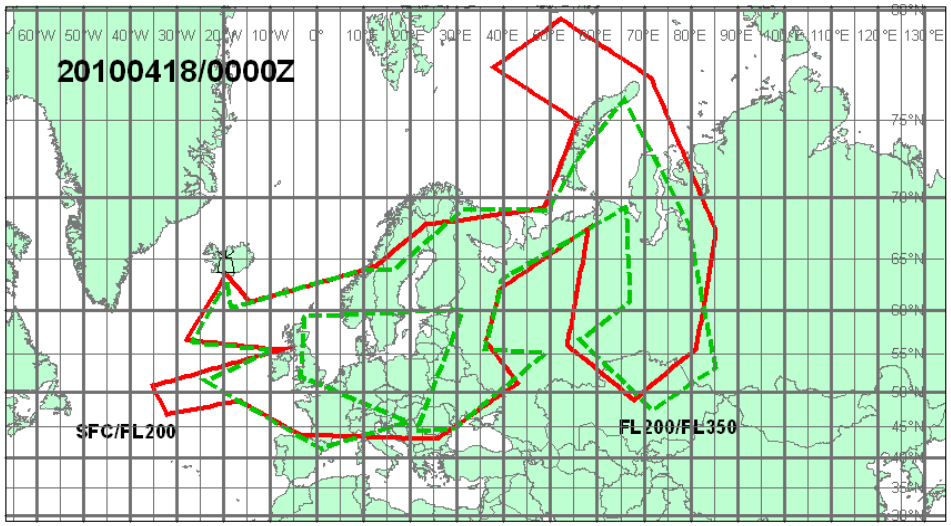


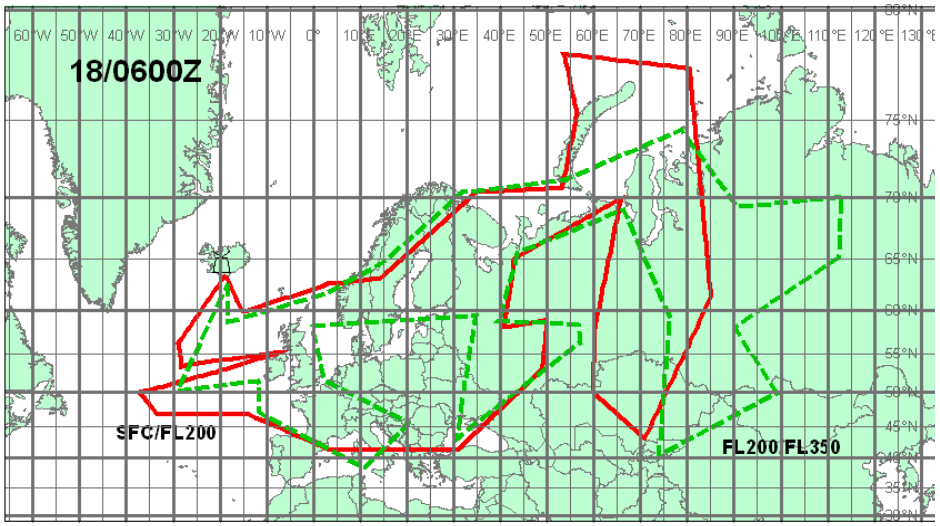
MODIS image 17 April 2010

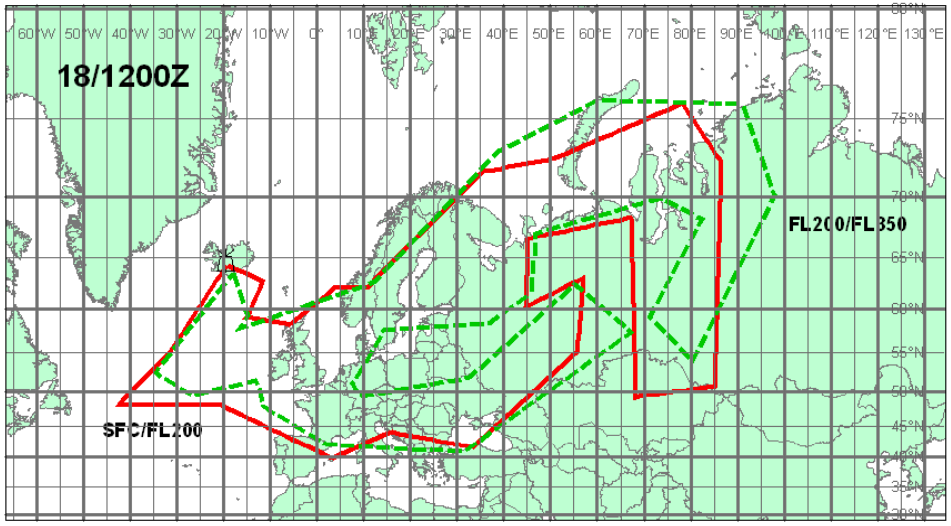
Aerial photo 17 April 2010

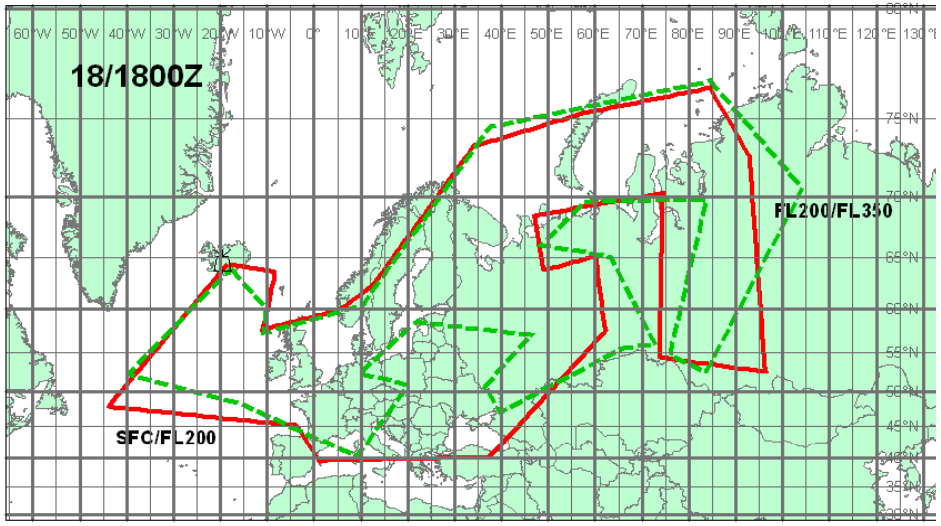


MODIS image 19 April 2010









VA ADVISORY
DTG: 20100418/0000Z
VAAC: LONDON
VOLCANO:
EYJAFJALLAJOKULL
PSN: N6338 W01937
AREA: ICELAND

SUMMIT ELEV: 1666M
ADVISORY NR: 2010/016
INFO SOURCE: ICELAND MET OFFICE
AVIATION COLOUR CODE: RED
ERUPTION DETAILS: SIGNIFICANT ERUPTION IS CONTINUING, BEST ESTIMATE OF PLUME FL280

RMK: ASH CONCNETRATIONS WITHIN INDICATED AREAS ARE UNKNOWN. NO SIGNIFICANT ASH RISK ABOVE FL350
NXT ADVISORY: 20100418/0600Z

Eruption in Eyjafjallajökull Status Report: 18:00 GMT, 05 May 2010

- Icelandic Meteorological Office and Institute of Earth Sciences, University of Iceland
- Based on: IMO seismic monitoring; IES-IMO GPS monitoring; IMO hydrological data; IMO weather radar measurements, MODIS satellite image; reports from people via phone and the IMO web site, information from the Icelandic Coast Guard flight yesterday.
- Eruption plume: Height (a.s.l.): Plume at 5.5-6.5 km height according to IMO's weather radar; reached up to 7.2 km 40 SA of eruption site at 17:45 and 8 km height just SE of eruption site at 16:55. Information from ISAVIA: 18-20,000 ft at 14:50 GMT. Information from a Boeing 757 plane at 17:50: black plume in 21,000 ft (6.5 km). Heading: East-south-east over land and then towards southeast according to a MODIS image at 12:45.
- Tephra fallout: Sólheimaheiði, Hjörleifshöfði and Álftaver (up to 70 km distance).
- Lightning: No detections today over the eruption site.
- Noises: Loud noises at farms south of the volcano troubled people during last night. Reports from people hearing loud noises in up to 200 km distance west and northwest.
- Meltwater: Due to mild weather and snowmelt, increase in discharge was noticed in Markarfljót peaking at midnight. Discharge from Gígjökull seems to be decreasing and oscillations in water temperature at the old Markarfljóts bridge relate to air temperature. Pulses of meltwater from Gígjökull are unnoticeable. At midnight electrical conductivity began to rise in Jökulsá á Sólheimasandi. Since then the conductivity has raised from 170 µS/cm up to 590 µS/cm (hr:15:00). Possible reason for this is volcanic ash from the eruption getting in to the meltwater from Sólheimajökull. Samples of the water have been collected for analysis.
- Conditions at eruption site: The eruption sight was not visible today. From the flight of the Icelandic Coast Guard (ICG) 04.05.2010: The crater continues build up in the northern most ice cauldron. Lava flows to the north and spreads at 500 m a.s.l. The lava tongue is about 200 m wide and lava


Stöðvar í nágrenni Mýrdals- og Eyjafjallajökuls
Tindfjallajökull
Markarfljót
Markarfljót
Jökulsá_Gígjökul
Steinsholtsá
STE2
Hvanná
Krossá
Básar
Markarfljótsbrú
Miðmörk
HAMR
Eyjafjallajökull
EM2
SVBH
SKOG
Þorvaldseyri
Seljavellir
Skógar
Eystri-Skógar
Sólheimajökull
Sólheimaheiði
Jökulsá_Sólheimasandi
Jökulsá á Sólheimasandi
ENTA
AUST
Goðabunga
Mýrdalsjökull
Katla
Snæbýli
Hólmsá
Þverkvísl
Kötlujökull
Blautakvísl
Lágu-Hvolar
Múlakvísl-Léreftshöfði
Múlakvísl
Múlakvísl
Vík
SIL-stöðvar
GPS-stöðvar
GPS-Jarðvísindastofnun
Vatnshæðarmælar
Vatnshæðarmælar tímabundnir
Eldstöðvakerfi
Sprungur
Hringvegur
2 4 8 12 16 20
Km
Heimildir: Kortagrunnur IS 50V © Landmælingar Íslands
Eldstöðvakerfi og sprungur © Náttúrufræðistofnun Íslands

The monitoring & community linkages that Icelanders had in place before the eruption started allowed them to successfully evacuate people & animals from the acute flood hazard zone.

Similar proactive readiness – for both ground & aviation hazards – is the goal of the NVEWS initiative (National Volcano Early Warning System) that SDR has endorsed.

USGS

As a result of the long shutdown of European airspace, there is intense interest in defining a "safe" threshold concentration of ash that an aircraft can fly through without significant damage.

<u>Very complex question with 3 types of unknowns!</u>

- What are the ash concentrations in the cloud in space & time
  a question for scientists....
- What are the tolerances of the engines under various conditions?
  a question for engine manufacturers....
- How is a particular aircraft being flown on a particular flight?
  a question for the operators (airlines)….

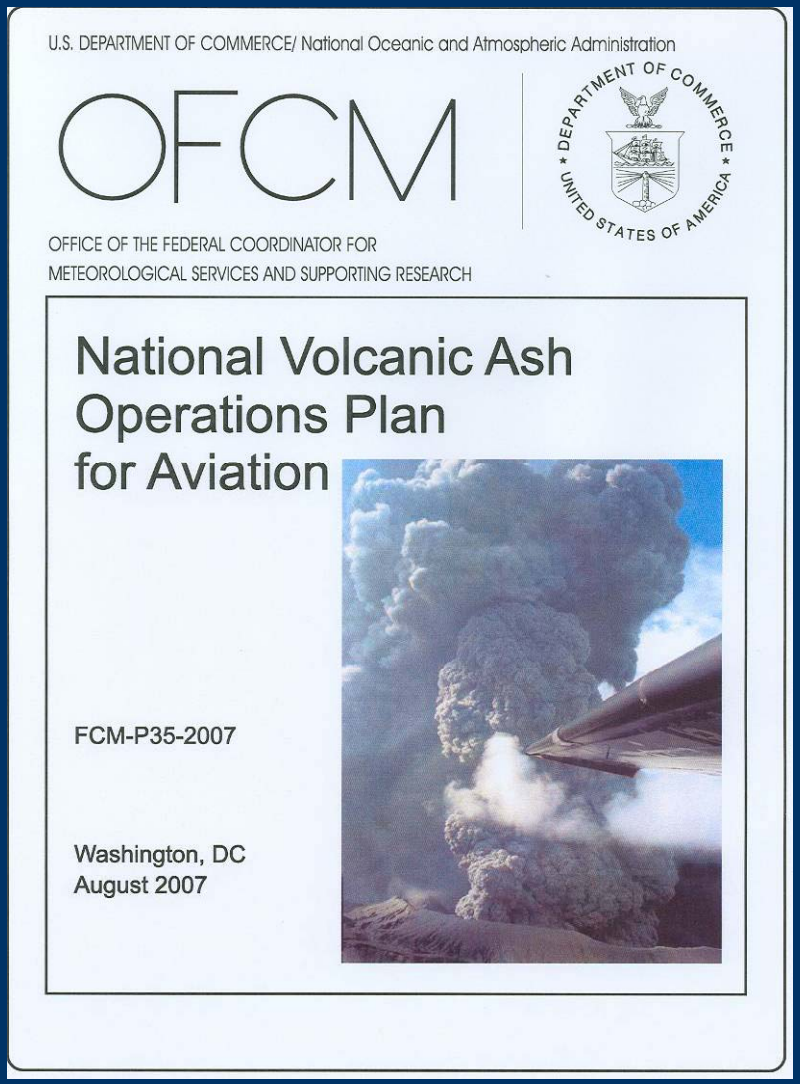
USGS

ICAO has created an International Volcanic Ash Task Force (IVATF)

The IVAFT is tasked to undertake, in close coordination with existing expert groups, the following tasks:

- evaluation of the Icelandic eruption;
- revision of guidance on volcanic ash contingency plans;
- review of operational response to volcanic ash encounter;
- development of ash concentration thresholds;
- improvement of ash detection systems;
- review of notification and warning for volcanic ash;
- improvement and harmonization of dispersion models; and
- improvement of visual volcanic ash advisory centre (VAAC) products.

USGS



National Volcanic Ash Operating Plan for Aviation

Plan involves the US Federal agencies that implement ICAO's worldwide protocols for ash warnings: FAA, NOAA, USGS, USAF.

Plan describes agency roles, inter-agency comm. protocols, & warning products issued.

COLLABORATIVE DECISION-MAKING.

http://www.ofcm.gov/p35-nvaopa/pdf/FCM-P35-2007-NVAOPA.pdf

USGS

4 May 2010: Ireland's Aviation Authority banned flights into & out of the country because of ash.

FAA – Volcanic Ash Program

Presented by: Steven R. Albersheim
U.S. member to ICAO IAVWOPSG

To: NSTC Subcommittee on Disaster Reduction

06 May 2010

Issue

- **Is the current volcanic ash program sufficient to provide information to support Air Traffic Flow Management, Dispatchers, and Flight Crews decision-making to:**
  - **Avoid ash**
  - **Mitigate impact on overall operations short of total closure of airspace**
- **Factors that need to be addressed:**
  - **Pre-eruptions, watch and warning capabilities**
  - **Alert messages/collaborative decision-making/ensemble modeling**
  - **Composition of ash cloud and its characteristics**
  - **Quality observations that define height, location, density in time and space**
  - **Engine and Air Frame tolerance to ash if ash cloud traversed**

Base Line Program

- **FAA has an active International and National program that:**
  - Defines National practices and procedures
  - Acts as International leader at ICAO and WMO
- **FAA partners with NOAA/NWS/NESDIS, USGS, DoD, NASA, and Smithsonian**
- **FAA has a research program ($1.6 M over 8 years)**
  - Focus on model enhancement
- **ICAO established special Task Force to**
  - Review existing Int'l VA program in respect to factors defined.

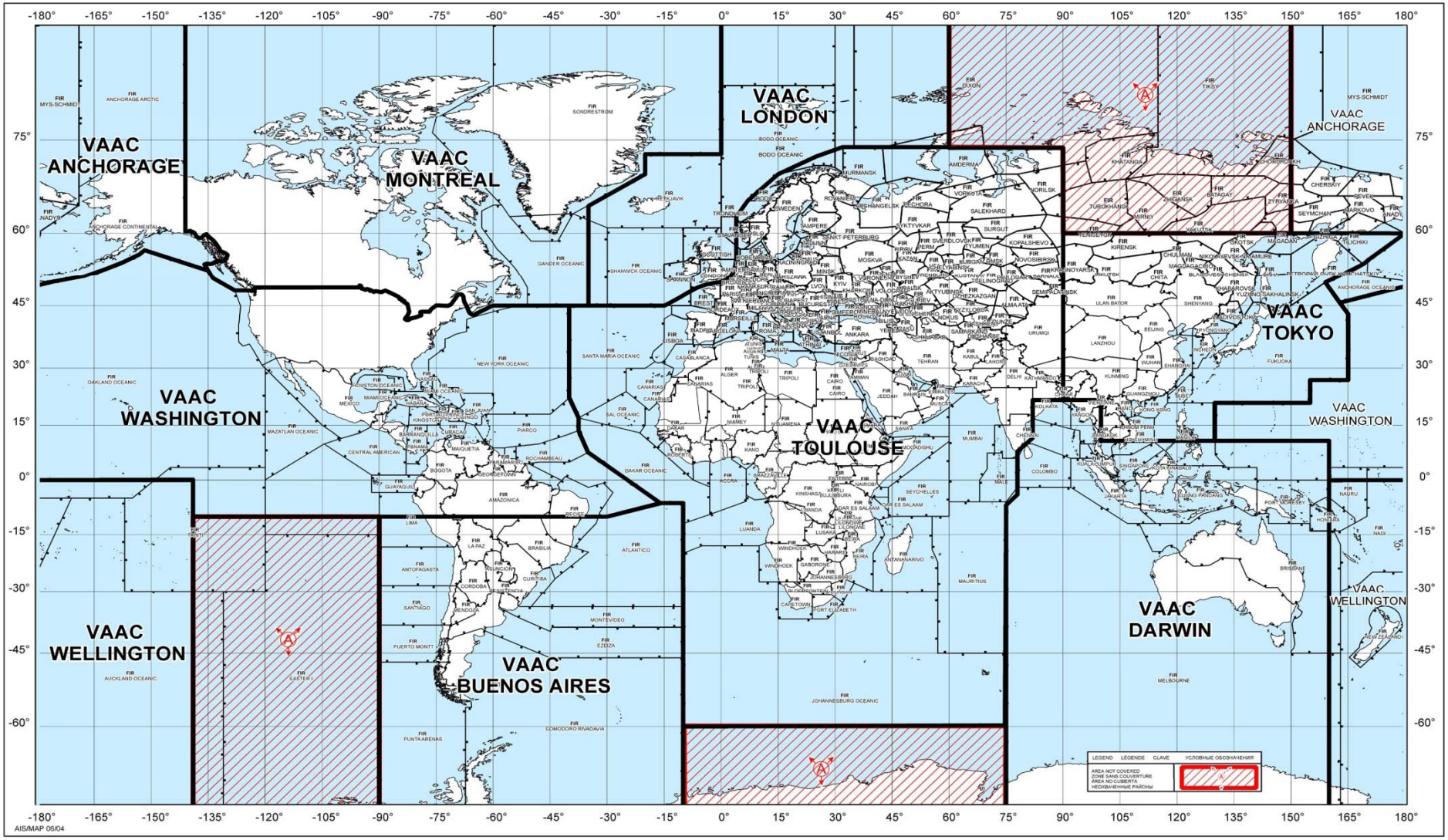
Elements of VA Program

- **Operations**
  - International
  - Domestic/National
- **Research**
  - Transport modeling
  - Detection/Monitoring
- **FAA/USGS Partnership in Alaska**
  - Early Detection in Alaska
  - Source parameters for models
- **ICAO**
  - Establishment of Task Force

International Responsibilities

- **U.S. VA program is International in breath as part of the ICAO International Airways Volcano Watch**
  - Nine Volcanic Ash Advisory Centers
  - Two VAAC in U.S. – Anchorage & Washington
    - Anchorage covers Alaska FIR
    - Washington supports Oakland & NY FIR, CONUS, Gulf of Mexico, Caribbean, Central America & 10 deg S for South America
  - Washington VAAC issues on the average 2300 messages annually over a 3 year period
  - Anchorage VAAC issues on the average 200 messages annually over a 2 year period.
  - Service provisions defined in Annex 3 & ICAO Handbook
- **There is always an eruption somewhere in the world that is a concern to international air navigation**

SITUATION ACTUELLE DES CENTRES OACI D'AVIS DE CENDRES VOLCANIQUES (VAAC) - ZONES DE RESPONSABILITÉ
ESTADO ACTUAL DE LOS CENTROS DE AVISOS DE CENIZAS VOLCÁNICAS (VAAC) DE LA OACI - ÁREAS DE RESPONSABILIDAD
СУЩЕСТВУЮЩЕЕ РАСПРЕДЕЛЕНИЕ КОНСУЛЬТАТИВНЫХ ЦЕНТРОВ ИКАО ИО ВУЛКАНИЧЕСКОМУ ПЕПЛУ (VAAC) - РАЙОНЫ ОТВЕТСТВЕННОСТИ



National Program

- **OFCM- National Volcanic Ash Operations Plan for Aviation**
  - ICAO Doc 9766 – Handbook on the International Airways Volcano Watch – Operational Procedures
- **Two Regional Plans**
  - Alaska Interagency Operating Plan for Volcanic Ash Episodes
  - Interagency Operating Plan for Volcanic Ash Hazards to Aviation in the Pacific Region of the Northern Mariana Islands

	Information/ Service	FAA	NOAA NWS/NESDIS	USGS	DoD	NASA	Smith'n
Reports	METAR	√	√				
	PIREP/VAR	√			√		
	VONA			√			
	VAA/VAG		√		√		
	SIGMET		√				
	NOTAM	√					
Functions	Modeling		√	√	√		
	Monitor & Remote Sensing		√	√	√	√	
	Source Parameters			√			
	Research	√	√	√		√	
	Archives			√			√

Information Flow and Responsibility

Actions	Who	What
Detection/Monitoring	FAA, USGS, NOAA	PIREP, Seismic, Satellite, METAR
Alerting	FAA, USGS, NOAA	VONA, VAA, VAG, PIREP, SIGMET, NOTAM
Modeling	USGS, NOAA	Hy-Split & PUFF
Post Assessment	USGS, NOAA, Smithsonian	News letters, Pubs, Database

FAA Orders

- **7900.5B**
  - Guidance on reporting volcanic eruptions and volcanic ash
- **7110.65T**
  - Terminal Operations
    - Guidance on procedures to follow
    - Guidance on reporting information on runway condition(s)
  - Reporting
    - Guidance on PIREP in support of VA
  - En Route
    - Guidance to provide emergency assistance on flight altitude changes
    - Guidance on re-routes or escape procedures with concurrence from pilot
- **7210 Facilities Order in process of being updated**
- **JO 7930.2M NOTAM**
  - Guidance on the issuance of TFR for Volcanic Eruptions
- **FMH-12 Standards for Pilot Reports**
  - Guidance on how to record and process a report for volcanic eruption/ash cloud

International Volcanic Ash Task Force (IVATF)

- **The IVAFT is tasked to undertake, in close coordination with the IAVWOPSG and the EUR/NAT Volcanic Ash Task Force, the following tasks:**
  - evaluation of the Icelandic eruption;
  - revision of guidance on volcanic ash contingency plans;
  - review of operational response to volcanic ash encounter;
  - development of ash concentration thresholds;
  - improvement of ash detection systems;
  - review of notification and warning for volcanic ash;
  - improvement and harmonization of dispersion models; and
  - improvement of visual volcanic ash advisory centre (VAAC) products.

International Volcanic Ash Task Force (IVATF)

Title	Task Description	Expected Output	Output Date
Evaluation of Iceland Eruption	Determine what occurred leading up to the eruption, the reaction to the event by the various stakeholders and identify what needs to be done next.	Report on the events that transpired, and make recommendation based on lessons learned.	1 August 2010
Improvement and harmonization of dispersion models Identify IAVWOPSG	Improve and harmonize existing ash dispersion models making use, inter alia, of the information provided by airlines including potential collaboration with other private MET, military organizations and research institutions.	Centralized VAAC outputs available on line	1 May 2011 (initial report) and ongoing
Improvement of Visual products such as VA concentration maps map.	Refine the existing PNG VAG charts with the view of mapping areas of ash contamination according to the level of ash concentration.	Updated models to include risk weighted displays of ash concentrations. •Products to be integrated with aeronautical charts. •Asses the need of harmonization of VAAC output	1 May 2011 (initial report) and ongoing

•Ash concentration thresholds	•Develop the highest acceptable level of ash for safe aircraft operation in contaminated airspace. Identify regulatory provisions required for the levels identified.	•Identify provisions required to be developed for various types of operation.	•1 November 2010 (initial report) and ongoing
•Ash detection systems	•Identify technologies and recommend system requirements for ground and airborne systems and space based systems	•Operational availability of improved detection systems	•1 November 2010 - 1 May 2013
•Guidance on volcanic ash contingency plans	•Revise existing guidance in light of Icelandic event	•Identify what needs to be updated	•1 August 2010

•Notification and warning for volcanic ash	•Review existing procedures in light of Iceland eruption experience and other eruptions	•Recommend procedures as necessary, to include enhanced in-flight information dissemination technologies to ensure notification of all affected flights.	•1 March 2011
•Operational Response to volcanic ash encounter	•Review and update related contingency procedures and establish reporting criteria to detect and mitigate risk	•1) Update operational and ATC procedures as necessary; and 2) Establish guidance for information sharing and decision making.	•1 August 2010 for initial action and then August 2011 for finalisation.

Tentative Composition of Task Force

- International Airways Volcano Watch Operations Group (IAVWOPSG) (Chairman),
- Airports Council International (ACI), Civil Air Navigation Services Organisation (CANSO),
- International Air Transport Association (IATA), International Coordinating Council of Aerospace Industries Associations (ICCAIA),
- International Federation of Air Line Pilots' Associations (IFALPA),
- International Federation of Air Traffic Controllers' Associations (IFATCA),
- International Federation of Airline Dispatchers Associations (IFALDA),
- International Union of Geodesy and Geophysics (IUGG),
- EASA (European Aviation Safety Agency) NASA, ESA (European Space Agency), World Meteorological Organization (WMO),
- World Organization of Volcano Observatories (WOVO) and
- Selected States

Questions and Discussion

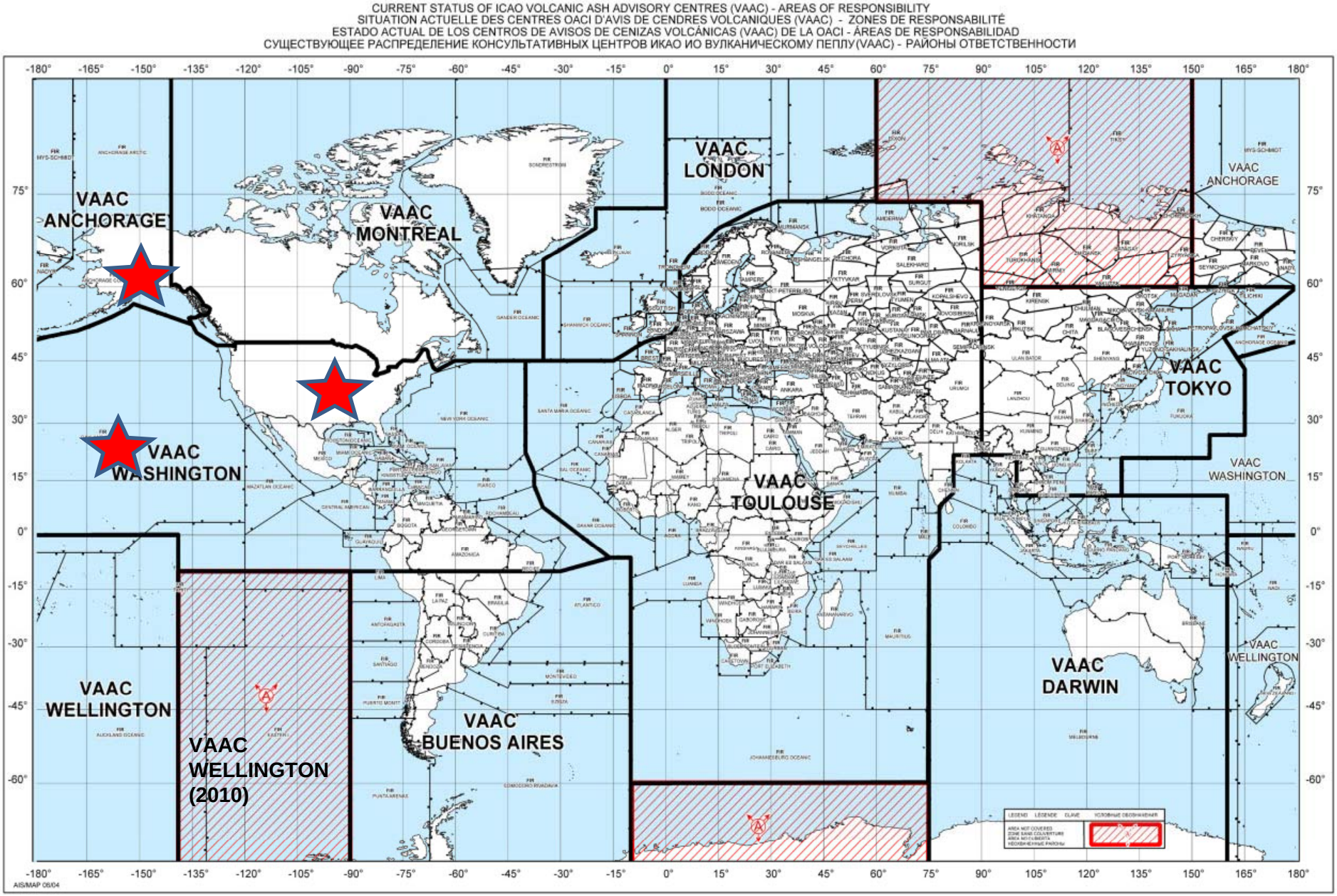
NOAA's Response to the Eruptions of Eyjafjallajokull Volcano

Jeff Osiensky
NOAA/NWS Volcanic Ash Program Manager

May 6, 2010

Outline

- Introduction of NOAA's role in volcanic ash detection and forecasting capabilities in the U.S.
- NOAA's partnership in the U.S.
- NOAA's role in the International Community
- Response to Eyjafjallajokull Volcanic eruptions
- Global issue – sharing research, modeling, and ash detection, tracking, hazard communication
- Strengthening NOAA's volcanic ash program

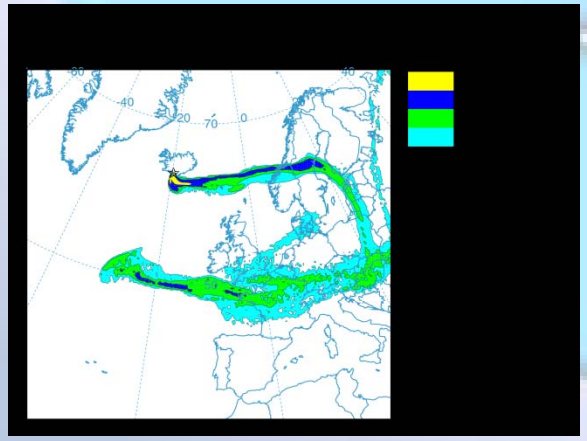


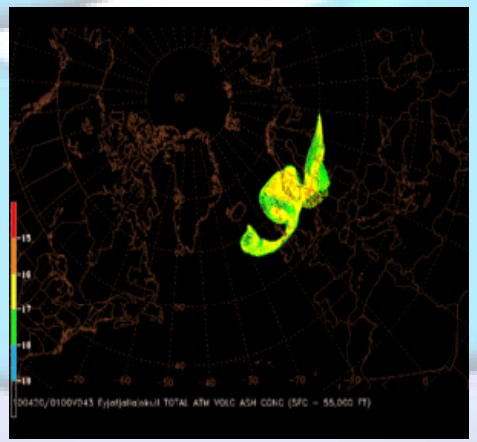
Hatched area – no VAAC coverage

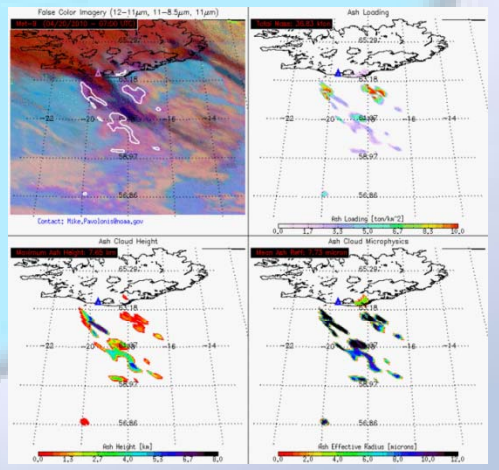
NOAA's Volcanic Ash Program

NOAA's Volcanic Ash Assets

- NESDIS (Satellite imagery resources – top and horizontal extent of cloud)
- Washington and Anchorage VAACs (detection/tracking, forecasting)
- NWS/OAR (modeling -- HYSPLIT volcanic ash dispersion)
- Meteorological Watch Offices (Aviation Warnings for Volcanic Ash – SIGMETs)
  - NWS/NCEP Aviation Weather Center
  - NWS Weather Forecast Office Honolulu
  - NWS Alaska Aviation Weather Unit







NOAA's Volcanic Ash Program

NOAA's Partnerships

- Close working relationship with partners – it can't be done alone!!!
- OFCM WG/VA
  - Interagency Volcanic Ash Plans
    - Alaska
    - Northern Marianas
    - Pacific Northwest (in process)
    - Hawaii (planned)
    - Caribbean (planned)

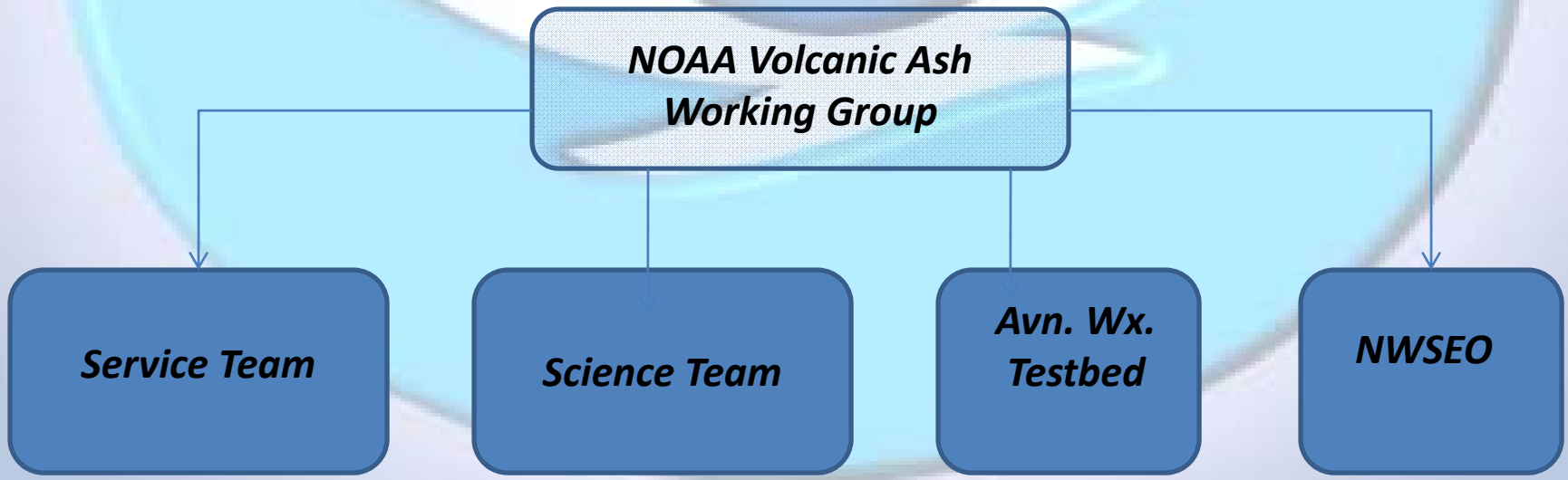
and others…

NOAA's Global Presence

- NOAA activities related to WMO through the Commission on Aeronautical Meteorology (CAeM)
  - Joint working paper to be presented in Geneva in June 2010
    - U.K. (lead) – U.S., Canada, France
      - *Purpose: Capture the event and outline issues – use to identify gaps*
- ICAO IAVWOPSG
  - Standing working group to ICAO
    - NOAA has 4 members to the IAVWOPSG
      - *Purpose: Provide guidance and advice to the operation of the International Volcano Airways Watch*
      - IAVTF (Task Force) set up as a result of Icelandic eruption (newly formed group)

NOAA's Response to Eyjafjallajokull

- Stood up NOAA Volcanic Ash Working Group (April 26, 2010)
  - Identification of gaps and provide recommendations to enhance:
    - *Ash dispersion modeling*
    - *Remote sensing*
    - *VAAC operations*



NOAA's partnership in working toward the global volcanic ash issues

- Sharing volcanic ash resources, best practices, and lessons learned with the global community
- Identifying science and services resources and sharing those with partners worldwide
- Working collaboratively with other states to strengthen the global volcanic ash program

Strengthening NOAA's VA Program

- NOAA's VA Working Group is a great start
- Assess current service and science issues
- Build a plan which addresses steps to strengthen the program
- Identify gaps and offer recommendations
- Execute the plan

Jeff Osiensky
NOAA/NWS Volcanic Ash Program Manager
Anchorage, Alaska
907.271.5132
jeffrey.osiensky@noaa.gov