ATM and Airlines’ Operations in Volcanic Ash

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22nd May 2012
ICRAT 2012, Berkeley, USA
Agenda

• Volcanic ash - what happens?
• What’s all the fuss about?
• Eyjafjallajökull eruption
• Changes in the aftermath
• VOLCEX 11/01 and Grimsvötn lessons
• Status today
Volcanic Ash – what happens?
Volcanic Ash – what happens?
The beginning of interest

• Mount St. Helens 1980 (source: USGS)
  – Caused damage to several commercial aircraft:
    • Windshield abrasions
    • The engine compressor blades abrasions
    • Plugged pitot static system
    • The wing leading edges – sandblasting effect
    • Engine oil containing high concentrations of sulfur
    • Engine flameout
      – Ash fused in turbines
      – Severe temperature stress and erosion
      – Compressor damage…
Source: Engine Damage to a NASA DC-8-72 Airplane From a High-Altitude Encounter With a Diffuse Volcanic Ash Cloud
Volcanic Ash – what happens?

• Galunggung, Redoubt, and Mount Pinatubo eruptions - the most well-known ones
• More than 100 commercial aircraft encountered volcanic ash and sustained damage from these encounters – of what is reported
Volcanic Ash – what happens?
Safety and cost

• So far none of the volcanic ash encounters resulted in the aircraft crashes or loss of life

• The consequences of an encounter can be:
  – Immediate, reducing flight safety
  – Cost inducing later on: engine change or overhaul, instrument repairs, windshield repairs, and additional aircraft downtime due to repairs
Volcanic Ash – what happens?
Safety and cost

• The volcanic-ash-related costs to aviation are estimated to be much higher than $250 million (1982-2000),
  – $80 million for Boeing 747-400 which entered the ash cloud from Redoubt Volcano, Alaska, US, in 1987

• NASA DC-8 engine damage from a high-altitude encounter with a diffuse volcanic ash cloud
  – Routine aircraft inspection after the encounter did not show the traces of ash,
  – All 4 engines were overhauled

• Volcanic ash encounters can accelerate the usual maintenance cycle, thus causing additional maintenance costs.
Volcanic Ash – what happens?

- Volcanic Ash Warnings Study Group in 1982
- International Airways Volcano Watch in 1987
- Volcanic Ash Advisory Centers (VAACs) in the 1990s
Volcanic Ash – what happens?

• When informed about eruption, the responsible VAAC provides the forecast for ash dispersion

• VAAC issues Volcanic Ash Advisory messages (VAA):
  – Meteorological Watch Offices (MWOs) produce the SIGMET (significant weather) messages for aviation
  – NOTAM Offices issue NOTAM (Notice to airmen)
Volcanic Ash – what happens?

• How does the crew recognize the ash cloud?
  – Visible ash
  – Haze
  – St. Elmo’s fire
  – Sulfuric odor in cabin
  – Smoke in cabin
What’s all the fuss about?
We have it covered,
So what’s all the fuss about?

- Ash visibility
- Satellite imagery
- Concentration levels
- Where, and how long?
- Forecasts
Ash Visibility

Source: Ólafur Sigurjónsson via Iceland Met Office
Ash Visibility

• What about the IFR or night time flights?
  – NASA
Satellite Imagery

Iceland Met Office: Ash from Eyjafjallajökull volcano, 6 May, by EUMETSAT
Satellite Imagery

Source: http://volcanoes.usgs.gov/Imgs/Jpg/Rabaul/rabshut2_large.jpg
Satellite Imagery

Source: UK Met Office
Satellite Imagery

- MSG images are monitoring for the presence of volcanic ash emission in the vicinity of Iceland using infrared data from the Meteosat Second Generation (MSG) satellite. Because cloud particles and volcanic ash particles interact with the infrared radiation in different ways, data at several different wavelengths can be combined to identify the main ash plume, which, when present, would be shown as pink, yellow and orange colours in the images. However, it should be noted that it is only the thicker parts of the plume that are able to be detected by this method. In addition, the ash plume is often masked by overlying high cloud and therefore might not appear in the satellite image.
Ash Concentration Levels

• Every eruption, and therefore ash cloud, is different
• However, still no indications exist on the concentration levels that are “safe” for airframe and/or engine
Where and how long?

• Close to airways?
  – Sometimes the only notification of eruption
• Close to dense network of airways?
• How long does it last?
  – And how much material does go into atmosphere
  – And what are the meteorological conditions
Volcanic Ash Cloud Dispersion Forecasts

• Are forecasts!
  – Based on estimation of:
    • Height of plume
    • Material composition
    • Material quantity

• NASA DC-8 flight

• Created a lot of problems during Eyjafjallajökull eruption
Eyjafjallajökull eruption
Eyjafjallajökull eruption

- 14th April – 28th April
- European coordination
- 3rd May to 23rd May
- Key areas for improvement
Eyjafjallajökull eruption
Eyjafjallajökull eruption
AIM Message

• VAAC London - First Volcanic Ash Advisory - 14th April, CFMU issues AIM:

TITLE: VOLCANIC ASH

VALID FROM: 1000 UTC TO: 2359 UTC

CFMU HAS BEEN INFORMED THAT AN ERUPTION OF VOLCANO EYJAFJOLL (ICELAND) HAS STARTED. ACCS AFFECTED MAY REQUEST CFMU TO APPLY APPROPRIATE ATFCM MEASURES, SUCH AS ZERO-RATE REGULATIONS. IN THE MEANTIME AIRCRAFT OPERATORS ARE STRONGLY RECOMMENDED TO CLOSELY MONITOR ALL RELEVANT NOTAMS.

THE HEIGHT OF THE PLUME AT THIS TIME IS FLOOO-FL220

CFMU OPS/BRUSSELS
Eyjafjallajökull eruption
From contingency to crisis

CFMU activates its volcanic ash contingency procedure

- Early warning – issue information on volcanic ash activity
- On request of national ATC providers: CFMU Applies measures
- Facilitate information exchange – organise teleconferences

Europe enters an ash aviation crisis on Thursday 15 April
VAA ZERO RATE
Regulation Duration applied on
THURSDAY 15TH APRIL 2010

- No Zero Rate
- 0 - 6 HOURS
- 6 - 12 HOURS
- 12 - 18 HOURS
- 18 - 24 HOURS

Lower Airspaces
VAA ZERO RATE
Regulation Duration applied on
FRIDAY 16TH APRIL 2010

- No Zero Rate
- 0 - 6 HOURS
- 6 - 12 HOURS
- 12 - 18 HOURS
- 18 - 24 HOURS
VAA ZERO RATE
Regulation Duration applied on SATURDAY 17TH APRIL 2010

- No Zero Rate
- 0 - 6 HOURS
- 6 - 12 HOURS
- 12 - 18 HOURS
- 18 - 24 HOURS
VAA ZERO RATE

Regulation Duration applied on
SUNDAY 18TH APRIL 2010

- No Zero Rate
- 0 - 6 HOURS
- 6 - 12 HOURS
- 12 - 18 HOURS
- 18 - 24 HOURS

Lower Airspaces

Lower Airspace
VAA ZERO RATE
Regulation Duration applied on
TUESDAY 20TH APRIL 2010

- No Zero Rate
- 0 - 6 HOURS
- 6 - 12 HOURS
- 12 - 18 HOURS
- 18 - 24 HOURS
VAA ZERO RATE
Regulation Duration applied on WEDNESDAY 21ST APRIL 2010

- No Zero Rate
- 0 - 6 HOURS
- 6 - 12 HOURS
- 12 - 18 HOURS
- 18 - 24 HOURS
Eyjafjallajökull eruption
Impact on European traffic

- 54% of flights not operated
- More than 100,000 flights
- 1% of annual traffic
- Impacted 29% of global aviation
- Affected 1.2 million passengers a day.

![Daily Traffic per Volcano Activity Week chart](chart.png)
Eyjafjallajökull eruption
Impact on Airports (traffic)

In the area directly affected by the ash - 70% reduction

Outside of the area directly affected by the ash - 23% reduction
Eyjafjallajökull eruption
Impact on Aircraft Operators (traffic)

In the area directly affected by the ash - average reduction of 67%

Outside affected areas - average reduction of 20%

Several airlines lost more than 80% of foreseen traffic.
Eyjafjallajökull eruption

- **Unlocking the crisis: 19th April:**
  - Close coordination – EC & EUROCONTROL
    - EC – political leadership
    - EUROCONTROL – network management expertise
  - EUROCONTROL proposes three options
  - Teleconference of the EUROCONTROL Provisional Council (AM) & EU Council of Ministers (PM) – option 3
**OPTION 3**

- NO FLY ZONE
- Contaminated Zone
- Ash Free Zone

**Buffer 60NM**

States to decide on NO FLY ZONE

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**Buffer Zone_24apr 2010-00h00 (issued 23apr 2010-00h00)**

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**VOLCANO:** EYJAFJALLAJökull 1702-02  
**PSN:** N6338 W01937

**VOLCANIC ASH CONCENTRATION:** BLACK PLUS BUFFER ZONE  
**MODEL RUN:** 20100423/1800  
**VALIDITY TIME:** 20100424/0000  
**FLIGHT LEVEL:** SFC/FL200  
**REMARKS:** MODEL DATA

**POLY 1**

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Eyjafjallajökull eruption

Eyjafjallajökull eruption

- 21\textsuperscript{st} May – EASA issued a Safety Information Bulletin:

  - NO FLY ZONE,
  - ENHANCED PROCEDURES ZONE: GREY AND RED,
  - NORMAL ZONE
Modelled Ash Concentration from FL000 to FL200 at 1200 UTC 18/05/2010

Issue time: 201005181200

This is a guidance product generated from model data and is supplemental to the official VAAC London Volcanic Ash Advisory and Volcanic Ash Graphic products. FIR boundaries are indicated for reference.

- **Red area**: Predicted area where volcanic ash may be encountered.
- **Grey area**: Predicted area of ash concentrations in which flights are permitted with an appropriate safety case and agreement from engine and airframe manufacturers.
- **Black area**: Predicted area of ash concentrations that exceed acceptable engine manufacturer tolerance levels.
Eyjafjallajökull eruption

- Iceland Met Office: The first winter snow proves that the new lava, at the top crater of Eyjafjallajökull, has cooled somewhat. Photo: Ólafur Sigurjónsson, 9 October 2010 at 8:10.
Eyjafjallajökull Eruption Lessons Learned

• No incidents
• Heavy economic impact on airlines
• Heavy impact on passengers
• Why such impact?
  – Ash cloud, pushed by high-altitude winds, dispersed over areas of very dense traffic flows
  – The closure of a number of airspaces, based on the forecasted cloud dispersion - zero risk approach:
    • The ICAO Manual on Volcanic Ash: “Unfortunately, at present there are no agreed values of ash concentration which constitute a hazard to jet aircraft engines... In view of this, the recommended procedure in the case of volcanic ash is exactly the same as with low-level wind shear, regardless of ash concentration — AVOID AVOID AVOID.”
  – Duration
  – Many different countries, facing such crisis for the first time
Eyjafjallajökull Eruption Lessons Learned

• Stakeholder involvement to solve the crisis resulted
  – Definition of the four zones and new graphical product (non-standard)
  – Forming of International Volcanic Ash Task Force
• Not flying, implies losses, but, what is the economic impact of flying through the ash cloud?
• Need for efficient means of communication
• Information exchange and monitoring
Eyjafjallajökull eruption
Eyjafjallajökull eruption

13.5 million hits in one day!
Eyjafjallajökull eruption

Key areas for improvement:

1. Specify thresholds for:
   – Hazardous,
   – Costly, and
   – Minor ash impact.

2. Should volcanic ash be considered an airworthiness or ATM issue?

3. Ash dispersion models harmonization and enhancement of validation of results

4. Information exchange improvement
Changes in the aftermath
Aftermath

• International Volcanic Ash Task Force (IVATF) was held in Montreal, Canada in July 2010

• New Contingency Plan for EUR/NAT regions

• Volcanic Ash Exercise (VOLCEX) boom
Changes in Europe

- Ash concentration charts
- European Aviation Crisis Coordination Cell (EACCC)
- Safety Risk Assessment approach: airlines may decide to fly or not, based on their safety risk assessment
- Aircraft Operator Crisis Cell (AOCC)
- European Crisis Visualization Interactive Tool for ATFCM (EVITA) by Eurocontrol
VOLCEX 11/01 and Grimsvötn lessons
VOLCEX 11/01

- Volcanic Ash Exercise (VOLCEX)
  - Simulated Grimswötn eruption
  - Test amended EUR/NAT contingency plan
  - Test information flow
  - Test crisis coordination by EACCC
  - Test EVITA prototype
VOLCEX 11/01 - EVITA

And this is the resulting Forecasts Map. Notice the different color hues and shades, indicating the different levels concerned (FL 060 to FL 550).
VOLCEX 11/01 Feedback

- Participation increase
  - From about 30 to over 100
- Changes in contingency plan well received
  - Gives more flexibility to airlines
- Airline Operators’ feedback:
  - Would consider operations in low-medium ash concentration areas (~77%)
  - Very different procedures for flying in or near contaminated areas
  - High level of information duplication
  - AOCC good envoy for problem resolution
VOLCEX 11/01 Feedback

• Information issues
  – Too many different sources for airlines to follow
  – Need for harmonization of content and format
    • 300 NOTAMs per day…
  – Teleconferences
    • Airlines ask for possibility of participation
    • Recommendations on nitty-gritty details, important for real crisis
VOLCEX 11/01 Feedback

- EVITA feedback
  - Appreciated graphical presentation on European level
  - Not considered very user friendly
  - Improvements from human factors point of view needed
  - Video-like visualization of forecast requested
VOLCEX 11/01 Summary

• Good practice
• Flexibility to airlines
  – Even though not all the states accepted the recommendations
• Issues regarding SRA
  – State regulators
  – Acceptance by other states/actors
• Information exchange
  – The need for one point of access
Grimsvötn Eruption

• One month after the exercise:

CFMU have been advised by Icelandic met office that there has been a volcanic eruption of volcano Grimsvötn in Iceland at 20110521 1900Z. The plume height estimated by radar 15-17 km.
ASH CLOUD IS EXPECTED TO REACH NORTH SCOTLAND ON TUESDAY 24TH MAY.
IF VOLCANIC EMISSIONS CONTINUE WITH SAME INTENSITY CLOUD MIGHT REACH WEST FRENCH AIRSPACE AND NORTH SPAIN ON THURSDAY 26TH MAY.
NO AIRSPACE CLOSURES ARE EXPECTED FOR TODAY AND TOMORROW EXCEPT IN ICELANDIC AIRSPACE/AERODROMES.
ALL ICELANDIC A/D’S ARE CLOSED FOR IFR-TRAFFIC UNTIL 1900 UTC ON 22ND MAY, AND IT IS VERY LIKELY THAT THEY WILL CONTINUE TO BE CLOSED.
NEXT TELECONFERENCE IS PLANNED AT 0800 UTC ON 23RD MAY.
IN THE MEANTIME AIRCRAFT OPERATORS ARE STRONGLY RECOMMENDED TO CLOSELY MONITOR ALL RELEVANT NOTAMS, SIGMETS AND THE ASH CONCENTRATION CHARTS ON [WWW.METOFFICE.GOV.UK](http://WWW.METOFFICE.GOV.UK) FOR FURTHER INFORMATION AND UPDATES.
AO’S CAN ASK QUESTIONS ABOUT VOLCANIC ACTIVITY AND RELEVANT AFTCM MEASURES BY EMAIL TO: CFMU.AOLO@EUROCONTROL.INT
Grimsvötn Eruption

- EVITA - European crisis Visualisation Interactive Tool for ATFCM is operational as from 08h00 UTC 25th May 2011
- Best practice: own SIGMET / NOTAM based on forecast and actual observation
Grimsvötn Eruption
Conclusions

• The biggest eruption in Iceland in last 100 years
• Why not such a big impact as Eyjafjallajökull?
  – Meteorological conditions
Modelled Ash Concentration from FL200 to FL350 at 1800 UTC 22/05/2011

Issue time: 201105221800

This is a guidance product generated from model data and is supplemental to the official VAAC London Volcanic Ash Advisory and Volcanic Ash Graphic products. FIR boundaries are indicated for reference.

200-2000 micrograms per cubic metre  2000-4000 micrograms per cubic metre  >4000 micrograms per cubic metre

All concentrations are subject to a level of uncertainty relative to errors in the estimation of the eruption strength.
Modelled Ash Concentration from FL200 to FL350 at 0000 UTC 23/05/2011

Issue time: 201105221800

This is a guidance product generated from model data and is supplemental to the official VAAC London Volcanic Ash Advisory and Volcanic Ash Graphic products. FIR boundaries are indicated for reference.

200-2000 micrograms per cubic metre  
2000-4000 micrograms per cubic metre  
>4000 micrograms per cubic metre

All concentrations are subject to a level of uncertainty relative to errors in the estimation of the eruption strength.

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Modelled Ash Concentration from FL200 to FL350 at 0600 UTC 23/05/2011

Issue time: 201105221800

This is a guidance product generated from model data and is supplemental to the official VAAC London Volcanic Ash Advisory and Volcanic Ash Graphic products. FIR boundaries are indicated for reference.

200-2000 micrograms per cubic metre

2000-4000 micrograms per cubic metre

>4000 micrograms per cubic metre

All concentrations are subject to a level of uncertainty relative to errors in the estimation of the eruption strength.
Modelled Ash Concentration from FL000 to FL200 at 1800 UTC 23/05/2011

Issue time: 201105230600

This is a guidance product generated from model data and is supplemental to the official VAAC London Volcanic Ash Advisory and Volcanic Ash Graphic products. FIR boundaries are indicated for reference.

- 200-2000 micrograms per cubic metre
- 2000-4000 micrograms per cubic metre
- >4000 micrograms per cubic metre

All concentrations are subject to a level of uncertainty relative to errors in the estimation of the eruption strength.

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Modelled Ash Concentration from FL200 to FL350 at 0000 UTC 24/05/2011

This is a guidance product generated from model data and is supplemental to the official VAAC London Volcanic Ash Advisory and Volcanic Ash Graphic products. FIR boundaries are indicated for reference.

200-2000 micrograms per cubic metre
2000-4000 micrograms per cubic metre
>4000 micrograms per cubic metre

All concentrations are subject to a level of uncertainty relative to errors in the estimation of the eruption strength.

© Crown Copyright 2011. Source: Met Office
Grimsvötn Eruption
Conclusions

• The biggest eruption in Iceland in last 100 years
• Why not such a big impact as Eyjafjallajökull?
  – Meteorological conditions
  – Coordinated action through EACCC
  – Better preparedness of all players
Status today
Status Today

• Ash concentration charts discontinued
• A standardized product to be issued by June
• Aviation colour code
• Satellite sensors need improvement
• No airspace closure
  – Not all states are endorsing
• Long term goal:
  – One set of aeronautical information for one eruptive event
Ash Concentration Charts

• Why?
  – Not reliable
  – Levels arbitrary
  – Spread of uncertainties
  – Lack of global user requirement

• Some airlines found it useful
  – Not all have their meteorologists
    • Enhanced Weather Information System (EWINS) holders
# Aviation Colour Code

- **By World Organization of Volcano Observatories**
- **Aviation colour codes**
- **Volcano Observatory Notice for Aviation (VONA)**

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<th>Description</th>
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| GREEN  | Volcano is in normal, non-eruptive state.  
  or, after a change from a higher level;  
  or, after a change from yellow level;  
  Volcanic activity has decreased significantly but continues to be closely monitored. |
| YELLOW | Volcano is experiencing signs of elevated unrest above known background levels.  
  or, after a change from higher level;  
  Volcanic activity has decreased significantly but continues to be closely monitored. |
| ORANGE | Volcano is exhibiting heightened unrest with increased likelihood of eruption.  
  or,  
  Volcanic eruption is underway with no or minor ash emission.  
  [Specify ash-plume height if possible] |
| RGD   | Eruption is forecast to be imminent with significant emission of ash into the atmosphere likely.  
  or,  
  Eruption is underway with significant emission of ash into the atmosphere.  
  [Specify ash-plume height if possible] |
Satellite Sensors

- Not always possible to discern ash from clouds
- IVATF conclusions include lobbying for satellite sensor improvements
Final Remarks

- Information exchange and monitoring important
- Forecasts + observations
- Europe vs. other parts of the world
- Intercontinental vs. regional airlines
Thank you!

Questions?
References

- ICAO Docs 9974, 9859, 9691
- IVATF Webpage: http://www.icao.int/safety/meteorology/ivatf/Pages/default.aspx
- USGS Website
- UK Met Office Website
- Iceland Met Office Website
- And many other…