Introduction

With increasing interconnectedness, a disturbance of air traffic in one part of the world can have long-ranging financial and social effects on other parts. The eruption of the Eyjafjallajökull volcano in April 2010 illustrated this memorably. The eruption prevented millions of passengers, as well as goods, from reaching their destination, as air traffic was halted in Europe for several days (Ulfarsson and Unger, 2011). It led to what is known to be the greatest disruption of air traffic since World War II and caused an estimated worldwide loss of US$5 billion with more than 100.000 flights cancelled (Oxford Economics, 2010).

Historic records (see Gudmundsson, 1987; Haraldsson, 2012; Höskuldsson et al., 2013) suggest a volcanic eruption in Iceland approximately once every five years. **Since such an event cannot be prevented from happening, cooperation and preparation are key in mitigating its impact**. With the certainty of a new volcanic ash eruption at some point in the future, the question is, however, whether the aviation industry is prepared for the next eruption?

As part of the EU project ENHANCE on stakeholder partnerships, this case study has sought to obtain insights into how the European aviation sector has advanced its risk management with regard to volcanic ash since the eruption in 2010. The case study focused on the cooperation and information exchange of the stakeholders involved in the post-disaster process of reducing impact from ash outburst to the air industry. The study has conducted expert interviews and used the method of scenario narratives and visualisation in an alternation participatory stakeholder workshop to facilitate the discussion and jointly develop improvement measures. This chapter draws on the reports developed in the course of the project (Ulfarsson et al., 2013; Ulfarsson et al., 2014; Reichardt et al., 2015a; Reichardt et al., 2015b).

Ash plume of the Eyjafjallajökull volcano eruption on April 22, 2010. Photo by G. F. Ulfarsson.

“Eyjafjallajokull led to the greatest disruption in air traffic since World war II.”

The multi-sector-partnership

The management of volcanic ash risk to aviation is complex and requires the efforts of a number of stakeholders from different sectors. According to their position in the process, the stakeholders can be grouped into information providers, crisis coordination and network management, air navigation service providers, global/international and national regulators and aircraft operators.

An overview of the sectors, roles, and associated institutions involved in the Multi-Sector Partnership (MSP) of this case study can be found in Table 9.1. The MSP's main aim is to prepare an aligned strategic response to volcanic eruptions, which (1) should guarantee flight safety and prevent harm to humans or machines, and (2) should minimise interruption of air traffic and thereby economic losses.

In the MSP, roles and responsibilities are roughly divided as follows: global and national regulators provide the legal framework for aircraft operations. In case of a volcanic eruption, the information providers collect information on the eruption and create 'ash forecast maps' on predicted ash concentration. These maps facilitate the decision-making-process of the aircraft operators on whether to proceed, divert or cancel flights. Air navigation service providers coordinate the air traffic. To ensure a smooth transition of flight plans the network manager facilitates on a European level and acts as crisis coordinator if needed.

This study used the Eyjafjallajökull volcanic eruption in 2010 as a reference for the analysis of the MSP, the MSP's responses to the volcanic eruption, and the effects of the volcanic ash on air traffic.

Table 9.1.
The MSP - Overview of sectors, roles, and institutions.

Sector	Role	Institutions
Global air regulator	Development of global standards and recommended practices	ICAO (International Civil Aviation Organisation)
International regulator	Limit setting for shared air transport zones	EU Directorate General for Mobility and Transport
National regulator	Responsible for state's Volcanic Ash Contingency Plan, approval of Self Risk Assessment procedures, airspace closure	ICETRA (Icelandic Transport Authority)
Crisis coordination and network management	Coordination and planning of air traffic control in Europe	EUROCONTROL (European Organisation for the Safety of Air Navigation)
Information provider	Issue weather observations and forecasting. Monitoring of volcanic eruption, detection of seismic activity, ash measurements, issue warnings	IMO (Icelandic Meteorological Office)
Information provider	Tracks volcanic activity and issues ash distribution forecasts	London VAAC (Volcanic Ash Advisory Centre)
Air navigation service provider	Management of airport operations and air traffic in control area	ISAVIA (Icelandic Air Traffic Management)
Aircraft operators	Air transport and service providers to passengers and cargo	Icelandair (Icelandic Aircraft operator)

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Risk assessment and extreme-case scenarios

To evaluate the functioning of the MSP, two extreme volcanic ash scenarios were developed using expert judgement and historic data:

1) One scenario describes a volcanic eruption of medium ash concentration over a long period of time ('Eyjafjallajökull times Four scenario') to test MSP decision-making when facing a long period of continuous risk assessment and maintenance (Figure 9.1).

2) In order to assess the reactions of the stakeholders to an extreme large-scale severe interruption of air traffic, a second scenario contains a volcanic eruption with a large ash emission but in a rather short period of time (´Öræfajökull scenario´, Figure 9.2).

Although the uncertainties are considered too large to perform a detailed economic risk assessment, the financial consequences in both scenarios are expected to be in the order of billions of euros. The **NAME model**, the ash dispersion model used by the London Volcanic Ash Advisory Centre (VAAC), is used to simulate the ash cloud from the scenarios. Both scenarios are modelled under the meteorological conditions that were prevalent during the Eyjafjallajökull eruption from the 15-19th of April 2010 (Petersen, 2010).

The reason the ash cloud is shown as a discrete area, separate from Iceland, is due to the modelling input. The duration of the modelled eruption was set to 24 h as this is assumed to be the timeframe for the main ash emission during an eruption phase, but repeated bouts of ash eruption phases are possible. Once the pressure of the eruption declines, the plume height changes and the model needs to be adjusted (discussion with the IMO, 2015). The maps display different concentrations of ash, low (blue), medium (grey) and high (red) over a period of up to 5 days into the eruption.

The risk of volcanic eruptions is a natural phenomenon (Gudmundsson, 2008; Thordarson and Hökuldsson, 2008) and research indicates that it may be increasing due to climate change (Compton et al., 2015) with an event like the Eyjafjallajökull eruption even possible up to every 7 years (Schmidt et al., 2013). It is however not possible to derive meaningful probabilities about the likelihood of the proposed scenarios of volcanic eruptions because of the complex characteristics of the hazard and limited data available.

Figure 9.1.

Eyjafjallajökull scenario. Example of modelled ash distribution for one of the eruptions in the scenario, at day 5 after the eruption. While high ash concentrations slowly decrease, a broad band of air with low ash concentration between 200 – 2000 µg/m³ is forecasted 5 days into the eruption up to flight level 200 (denotes 20,000 feet).

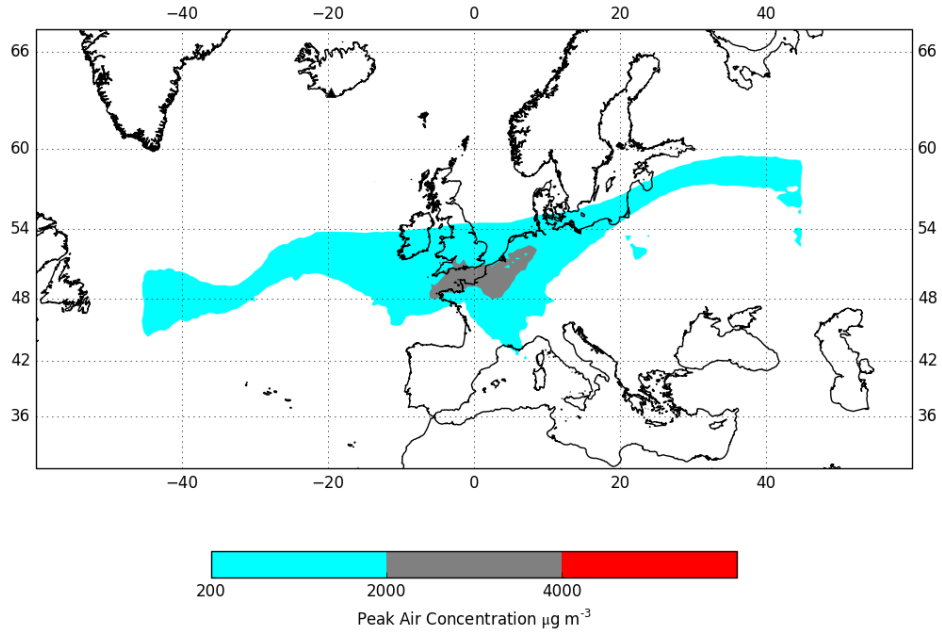
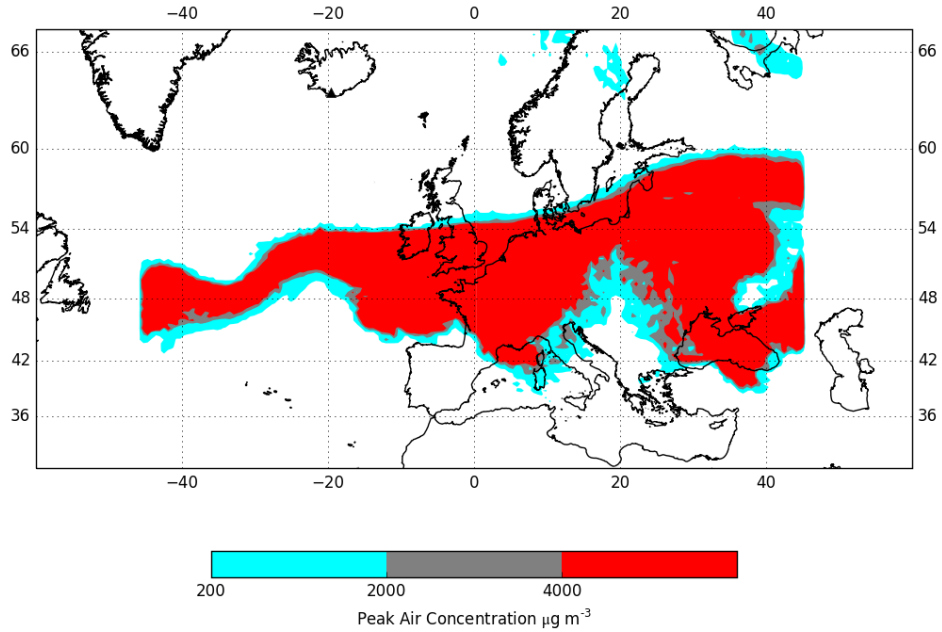


Figure 9.2.

Öræfajökull scenario. Example of modelled ash distribution, at day 5 after the eruption. High ash concentrations of more than 4000 µg/m³ are predominant throughout the whole forecast period up to flight level 200 (denotes 20,000 feet).



MSP performance

To gain insight into the stakeholder partnership's reaction to the scenarios, the stakeholders were invited to participate in a workshop to meet face-to-face and work through the scenarios. The workshop day was set up as an alternation between short presentations from research team mediators and the stakeholders, plenum discussions, scenario group discussions and opportunities for the participants to discuss in smaller groups. The scenarios were presented as a narrative in fictitious newspaper articles to support the group in imagining the real-life event and to discuss real-life implications.

The MSP performance under normal conditions

The Disaster Risk Management (DRM) of the MSP takes place on two levels: the stakeholders' individual management; and the overall joint stakeholder partnership. The individual stakeholders' responses and their interplay present the basis for the partnership's response as a whole with major improvements done since 2010. The **VOLCEX exercise** rehearses the initial mutual response to a volcanic eruption, often in Iceland, and is conducted roughly on an annual basis. In a preparatory meeting the stakeholders agree on a scenario to be tested. The VAAC runs the NAME model for the eruption scenario using agreed weather conditions (Interview with representatives from UK Met Office, October 2014). These exercises are under the supervision of the International Civil Aviation Organisation (ICAO). VOLCEX involves air navigation service providers, air traffic control centres, civil aviation administrations, meteorological offices, London and Toulouse VAAC, EUROCONTROL, and aircraft operators.

MSP performance assuming extreme scenarios

The stakeholder workshop helped to analyse the performance of the MSP under extreme case scenarios and the new regulation that gives decision-making for take-off to aircraft operators who provide an approved Self Risk Assessment (ICAO 2012a, 2013). The Eyjafjallajökull scenario would mostly impact air traffic at low altitudes, affecting take-offs and landings. A representative of Rolls-Royce estimated that ´even under the new regulations, by day two flights would be limited, approximately up to 50%´, a significant reduction in air traffic.

An extreme scenario like Öræfajökull is likely to impact air traffic at all flight altitudes. A representative from EUROCONTROL stated that even though the airspace would most likely not be closed by national authorities, there would be no flying within one or two days of the eruption onset.

The stakeholders emphasised that large uncertainties exist, related to understanding the risk that ash posesto engines, modelling uncertainties, regulations and staff capacity. The MSP is focused on the management at the onset of an eruption. The MSP's performance with regard to extreme case scenarios of long or high impact is mixed and exercises to practice extreme conditions are not yet in place.

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