The Ash Spring: How an Icelandic Volcanic Eruption Brought Europe to a Standstill

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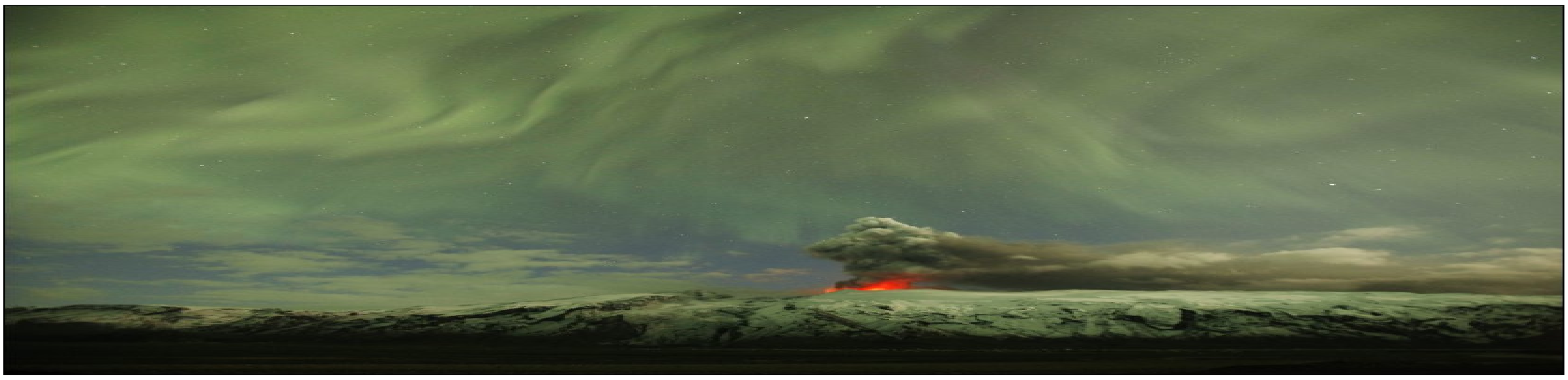

Figure 1. Photograph of an eruption of Eyjafjallajökull during April 2010. *Picture credit: REUTERS/Ingolfur Juliusson*

Background

In the spring of 2010 a little known volcano in southern Iceland alerted the world to the aviation hazard of volcanic ash. This was not some impending climate catastrophe nor an immediate threat to human health, but a clash of one of the most powerful and ancient forces of nature, an erupting volcano, with one of mankind's greatest technological achievements, the jet aircraft transport system. The chaos, reaction and effects related to the spread of the Eyjafjallajökull ash clouds over continental Europe have been widely discussed in the media and in learned journals. Ironically, the International Civil Aviation Organisation (ICAO) had been making great progress on the problem of ash and aviation for many years by convening regular meetings between the science community, aviation stakeholders and regulators. Major agencies, including the UK Civil Aviation Authority (CAA), the European Aviation Safety Agency (EASA), ICAO and the World Meteorological Organisation (WMO) have been galvanised into setting new policies and procedures for jet aircraft flights in ash affected airspace. At the same time science has been challenged to improve both quantitative forecasting of volcanic ash concentrations and enhance observation networks.

Volcanic ash can damage jet turbine engines as it melts and is deposited on the hot-sections of the engine, blocks fuel nozzles and erodes the compressor blades [1]. In the worst case scenario, the power plant will stall and shut down, resulting in a dramatic loss of power to the aircraft and potentially causing an air crash. These issues have been known since at least 1980 following the eruptions of Mt. St. Helens. Air-traffic is increasing and volcanic activity remains undiminished.

The lack of reliable observational data led to under-constrained dispersion model forecasts at the time of the Eyjafjallajökull eruption resulting in a very cautious response to the event, and a complete shutdown of air transport systems across Europe for several days. The Eyjafjallajökull, Grímsvötn, and to a certain extent, the long-lived and ash-rich Puyehue Cordón-Caulle eruptions over the past two years have now provided researchers with a wealth of new data on the behaviour and fate of volcanic ash in the atmosphere. For the first time it has been possible to independently validate satellite retrievals of volcanic ash [4]. These new results suggest that dispersed ash plumes can be highly inhomogeneous, exist in thin layers of $\sim$500–2000 m thickness and undergo transport over 1000s of km, staying aloft for days to weeks. The infrared sensors on operational, geosynchronous and polar orbiting satellites can measure mass loadings as low as 0.2 g m^{-2} with rms accuracies of $\pm$0.15 g m^{-2} and, when combined with inversion schemes [3,5], give dispersion models the opportunity to meet regulatory requirements and the demands of the aviation industry.

Effects

During the period 15–23 April, 2010 large parts of European airspace were closed to instrument flight rules traffic (IFR). Due to aircraft groundings, many European carriers lost large sums of money. Figure 2 shows the losses suffered (in millions of passenger numbers) by national carriers after adjusting for seasonal effects. While the economic impact was large, there were also significant repercussions on operational centres (Volcanic Ash Advisory Centres–VAACs) tasked with providing advisories for volcanic ash.

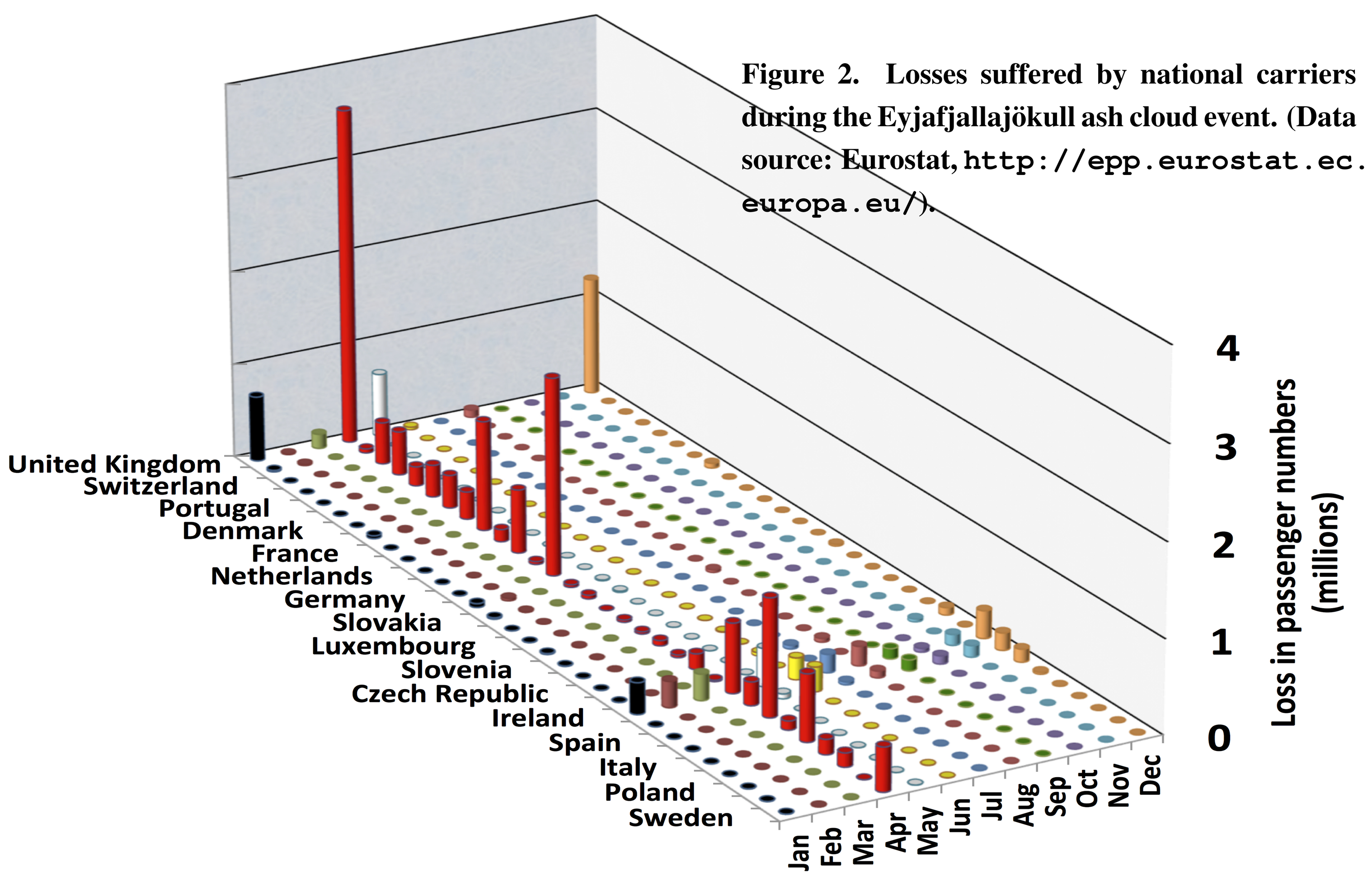

Figure 2. Losses suffered by national carriers during the Eyjafjallajökull ash cloud event. (Data source: Eurostat, `http://epp.eurostat.ec.europa.eu/`).

New regulatory procedures have been established and the "ash spring" has galvanised the scientific community into improving the knowledge base, observational capabilities and forecasting of volcanic ash. There has been a recognition of the need to better specify the volcanic eruption source term, notably the mass eruption rate, particle size distribution and removal processes (e.g. aggregation and subsequent fall-out). Just over one year after the Eyjafjalljökull eruption, Grímsvötn erupted sending a small amount of ash towards Europe and a large quantity of SO_2 gas at high-altitude northwards. The London VAAC mistakenly forecast this emission as potentially containing high ash concentrations, further demonstrating the need to better monitor and understand emissions from Icelandic volcanoes. The April and May, 2010 eruptions of Eyjfjallajökull were relatively small [2] but the confluence of copious ash emissions into the middle troposphere and the winds that drove the ash towards Europe has caused a revolution in the science surrounding the hazard that it presents to commercial jet aircraft.

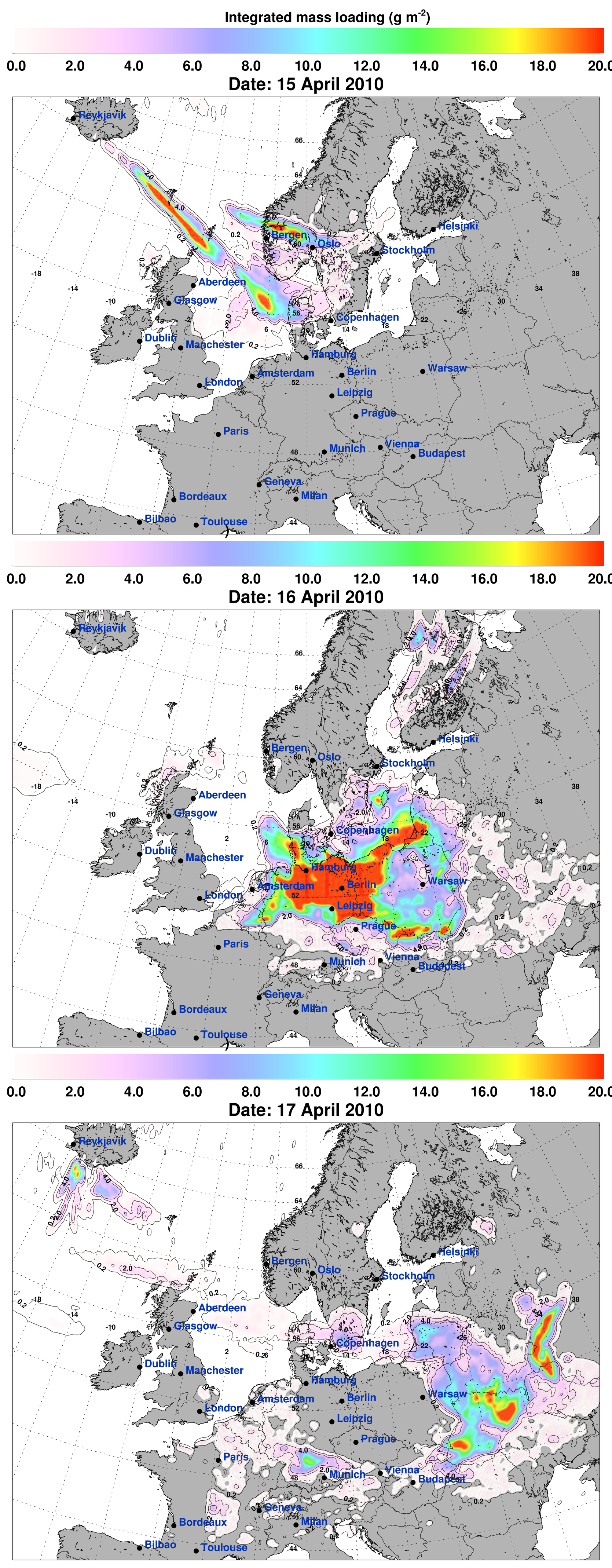

Figure 3. The three panels show volcanic ash mass loading (g m^{-2}) determined from the infrared channels of the MSG-2 SEVIRI instrument in geostationary orbit at 0° longitude. Data are obtained every 15 minutes providing excellent temporal coverage of volcanic activity and the movement of dispersing volcanic clouds in a region from 70°W–70°E and 70°S–70°N. The plots show mass loading integrated over the European region.

15 April, 2010 Ash emitted from Eyjafjallajökull travels over 1000 km across the North Sea entering Norwegian airspace, covering southern Norway, Denmark and parts of Sweden. The ash arrives with ice-laden cloud, which partly conceals its presence from satellites.

16 April, 2010 The ash cloud enters northern Germany, Poland and Hungary, slows and spreads laterally eastwards and westwards. Large parts of central and eastern Europe are now covered by ash in parts of the atmosphere used by commercial aircraft. Airspace over Europe is closed causing travel chaos and grounding aircraft, leaving people stranded at airports from Turkey to Ireland. Emergency discussions are held to establish a new protocol for specifying "safe" ash concentration limits in an effort to re-open the skies for aviation amid strong protests from several major airlines.

17 April, 2010 The ash cloud continues its movement south, entering France, Austria, the Czech Republic, Slovakia, Switzerland, and northern Italy (see [5] for dispersion model results). Its southward progression is largely halted by the Alps, where the research station at Jungfraujoch, at an elevation of 3471 m, records elevated levels of particulates. Ash is measured by the EARLINET lidar network from northern Germany to northern Italy. Aircraft remain grounded as regulators struggle to set safety limits for operation in ash-affected aviation corridors.

Aftermath Oxford Economics estimates the global cost to the world economy at $\sim$€5bn. New ash concentration limits are announced.

Conclusions

More than 100 peer reviewed papers (e.g [2–6]) have been published on various aspects of the Eyjafjallajökull eruption and its after effects. A good summary of recommendations for the way Earth Observation can be used for this problem may be found in Zehner [6]. The regulatory environment in Europe has changed, with new ash concentration limits: $<$200 μg m^{-3} ("White zone"–normal procedures), 200–2000 μg m^{-3} ("Red zone"–enhanced procedures), 2000–4000 μg m^{-3} ("Grey zone"–enhanced procedures), and $>$4000 μg m^{-3} ("Black zone"–no-fly zone). After the eruption of Pinatubo in June 1991, a Volcanic Ash Symposium was convened in Seattle, Washington. The proceedings [1] of that Symposium included a summary of the issues and needs that the participants felt were urgently required. Many of those recommendations have been implemented and progress has been made, however there is one need that still remains and has been reinforced following the Eyjafjallajökull eruption–the need to determine the minimum ash concentration that can damage jet engines. Almost no progress has been made on this matter and until a full suite of engine tests have been performed and the results studied, the best advice to aviation in ash-affected airspace is complete avoidance.

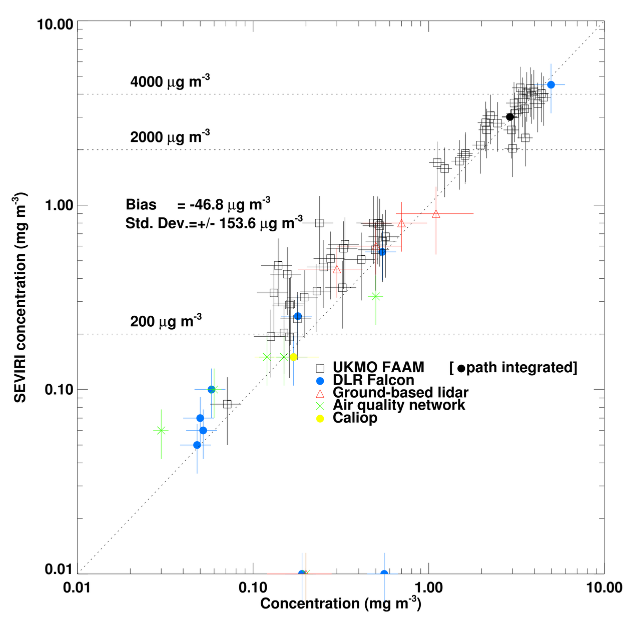

Figure 3. Validation plot for SEVIRI ash concentrations and four kinds of independent data sets, plotted on a log-log scale to identify detail at low and high concentrations. (See [4] for a full description of the data sources used in this plot).

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