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Volcanic ash hazard climatology for an eruption of Hekla Volcano, Iceland

Susan J. Leadbetter *, Matthew C. Hort

Met Office, FitzRoy Road, Exeter, UK

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ABSTRACT

Ash produced by a volcanic eruption on Iceland can be hazardous for both the transatlantic flight paths and European airports and airspace. In order to begin to quantify the risk to aircraft, this study explored the probability of ash from a short explosive eruption of Hekla Volcano (63.98°N, 19.7°W) reaching European airspace. Transport, dispersion and deposition of the ash cloud from a three hour 'explosive' eruption with an initial plume height of 12 km was simulated using the Met Office's Numerical Atmospheric-dispersion Modelling Environment, NAME, the model used operationally by the London Volcanic Ash Advisory Centre. Eruptions were simulated over a six year period, from 2003 until 2008, and ash clouds were tracked for four days following each eruption.

Results showed that a rapid spread of volcanic ash is possible, with all countries in Europe facing the possibility of an airborne ash concentration exceeding International Civil Aviation Organization (ICAO) limits within 24 h of an eruption. An additional high impact, low probability event which could occur is the southward spread of the ash cloud which would block transatlantic flights approaching and leaving Europe. Probabilities of significant concentrations of ash are highest to the east of Iceland, with probabilities exceeding 20% in most countries north of 50°N. Deposition probabilities were highest at Scottish and Scandinavian airports. There is some seasonal variability in the probabilities; ash is more likely to reach southern Europe in winter when the mean winds across the continent are northerly. Ash concentrations usually remain higher for longer during summer when the mean wind speeds are lower.

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1. Introduction

Ash clouds produced when a volcano erupts provide a significant hazard to aircraft. In addition to the immediate issue of reduced visibility, aircraft that have encountered ash clouds have suffered surface abrasion, temporary engine failure and, in some cases, permanent engine damage (Casadevall, 1994). Volcanic ash is also hazardous to aircraft on the ground as it can cause reductions in visibility, be ingested into aircraft engines during landing, taxiing and take-off and, particularly when wet, can affect aircraft manoeuvrability (Casadevall et al., 1997). In the 1980s the International Civil Aviation Organization (ICAO) created the International Airways Volcano Watch (IAVW) (e.g. (Tupper et al., 2007)) to develop mitigation procedures against the hazards of volcanic eruptions, and in the 1990s nine Volcanic Ash Advisory Centres (VAACs) were created. VAACs are responsible for identifying volcanic ash clouds, forecasting their movement, and for issuing volcanic ash advisory messages. These are used by Met Watch Offices to issue SIGMETs within individual Flight Information Regions (FIRs). London VAAC is responsible for monitoring and forecasting the movement of volcanic ash clouds over the United Kingdom (UK), Iceland and the north-eastern region of the North Atlantic Ocean (Fig. 1). Although this is a relatively small area it covers some of the busiest airways in the world. A volcanic eruption on Iceland is potentially hazardous for both the transatlantic flight paths, and European airports and air-space located downwind of Iceland (see Fig. 2 for location of Iceland and other European regions and airports mentioned in this paper).

About 117 volcanic eruptions have occurred on Iceland in the last 300 years (Sigurdsson et al., 2000) and whilst most have been relatively small the eruption of Hekla in 2000 resulted in considerable damage to a NASA (National Aeronautics and Space Administration) aircraft (Grindle and Burcham, August 2003) and the eruption of Grimsvotn in 2004 led to the grounding of tens of aircrafts. As the volume of air traffic increases, the risk (where risk equals hazard of encounter times likelihood of encounter) to flight paths and aircraft is growing. A study of the probability of airborne ash from the 22 most active volcanoes in the North Pacific region was done by (Papp et al., 2005). However, in the European region this risk has not been quantified and so the value of any mitigation or planning measures cannot be assessed. This paper begins to address this by assessing the probability of ash clouds reaching European air space following a short explosive eruption and also by determining the probability of deposition at key airports in the Europe. This study was carried out prior to the eruption of Eyjafjallajökull in April and May 2010 and thus

* Corresponding author. Tel.: +44 (0)1392 885221; fax: +44 (0)1392 885681.
E-mail address: susan.leadbetter@metoffice.gov.uk (S.J. Leadbetter).

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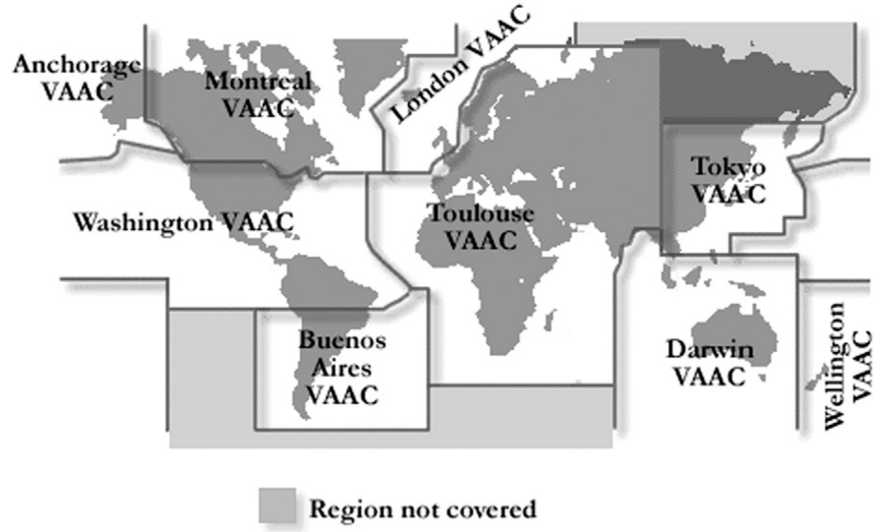

Fig. 1. Map showing regions of responsibility for the nine volcanic ash advisory centres.

the dispersion model inputs and the output interpretation was based on working practices at London VAAC prior to April 2010.

2. Method

In order to estimate the likelihood of volcanic ash clouds reaching European air space the dispersion of ash from more than 17,000 idealised volcanic eruptions was simulated using the Met Office's Numerical Atmospheric-dispersion Modelling Environment (NAME) (Jones et al., 2007). NAME is the Lagrangian particle dispersion model used operationally by the London VAAC for forecasting the transport and dispersion of volcanic ash clouds. Volcanic plumes are represented by a large number of model particles which are released into a model atmosphere. The particles are advected by the three-dimensional model winds and dispersed using random walk techniques that take into account the ambient turbulent velocity structures. Volcanic ash particles are removed from the model atmosphere by several deposition processes; i) fall out due to gravity, ii) impaction with the surface, iii) washout where ash is 'swept out' by falling precipitation and iv) rainout where ash is absorbed directly into cloud droplets as they form. NAME has been shown to compare well, both with dispersion models used by other VAACs and the limited satellite data available from an eruption of Grimsvötn in 2004 (Witham et al., 2007).

The meteorological data was extracted from the global archives of the Met Office's Unified Model (UM) (Cullen, 1993). The UM is run four times daily so the three hourly fields used in this study consist of one analysis dataset and one forecast timestep dataset from each UM run. The meteorological data has a resolution of $0.8\dot{3}^\circ$ longitude by $0.5\dot{5}^\circ$ latitude from the beginning of 2003 until November 2005 and 0.5625° longitude by 0.375° latitude from November 2005 until the end of 2008. The meteorological data has a variable vertical resolution extending up to a height of ~19 km, sufficient for modelling dispersion of the plume

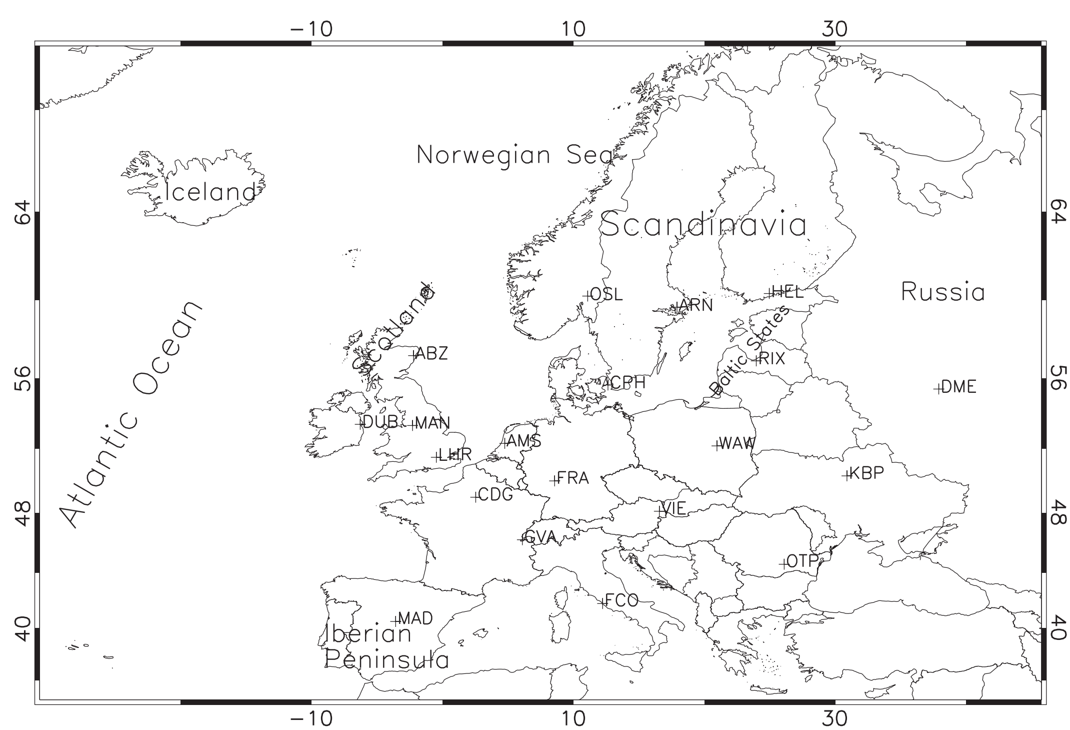

Fig. 2. Map showing location of key airports in Europe and regions mentioned in the text.

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