Institution:

University of Leeds

Unit of Assessment:

7, Earth Systems and Environmental Sciences

Title of case study:

Case study 4: UK Government instigates contingency planning based on evidence of potential fatalities from Icelandic eruptions

1. Summary of the impact (indicative maximum 100 words)

The 2010 Eyjafjallajökull and 2011 Grímsvötn eruptions in Iceland were stark reminders that global society is increasingly vulnerable to volcanic hazards. Research at the University of Leeds has shown that volcanic gases and airborne particles could be a significant health hazard to humans – potentially more fatal than seasonal 'flu. Leeds scientists used computer models to demonstrate that a long-lasting, gas-rich eruption in Iceland could degrade air quality and lead to well over 100,000 deaths across Europe. In January 2012, the number of potential fatalities was used as evidence by the UK government for the decision to add large-magnitude effusive Icelandic eruptions to the UK National Risk Register of Civil Emergencies as a high priority risk with potentially widespread effects on health, agriculture and transport. Leeds researchers continue to advise the UK government on the mitigation of potential volcanic hazards through the Civil Contingencies Secretariat.

2. Underpinning research (indicative maximum 500 words)

Background – the effect of historical Icelandic eruptions on society

Iceland has one of the highest eruption frequencies in the world with explosive volcanic eruptions occurring once every five years on average. The geological record in Iceland also reveals that sulphur-rich and long-lasting volcanic eruptions similar to the 1783-1784 CE Laki eruption occur once every 200 to 500 years. Sulphur dioxide and sulphate particles produced by volcanic eruptions can have detrimental effects on air quality and subsequently on human health. Indeed, historical records of the 1780s reveal that the Laki eruption caused severe environmental stress and posed a health hazard far beyond the borders of Iceland.

While 'Laki-type' eruptions occur much less frequently than more typical explosive eruptions in Iceland, they are classified as 'high-impact' events. It is crucial to investigate how a similar major eruption would affect modern society. However, prior to the research conducted at Leeds it was impossible to quantify the extent to which a future Laki-type eruption would affect air quality and human health across Europe using historical records alone.

Modelling air pollution from an eruption

In 2011, Leeds researchers **Ken Carslaw**, **Anja Schmidt** and **Marjorie Wilson** led a cross-disciplinary study to quantity the impact that an eruption of the type and on the scale of the historic Laki event could have on air quality and human health in Europe today.

A sophisticated computer model was used, together with published volcanological and epidemiological datasets **[1]**. The model, called the Global Model of Aerosol Processes (GLOMAP), has been developed by several researchers at Leeds since 2005, including **Ken Carslaw**, **Dominick Spracklen** (since 2008 independent research fellow and now Associate Professor at UoL), **Kirsty Pringle** (since 2010 aerosol research and support scientist at UoL), and **Graham Mann** (since 2005 National Centre for Atmospheric Science research fellow at UoL). The model predicts the formation and distribution of particles in the atmosphere **[2]**.

Key to this research was the development of a faster modal aerosol scheme **[3]** and evaluations of the model to show that it is capable of accurately predicting the size and mass of particles in the air **[1,3]**, and extension of the model to include the necessary chemistry to simulate the feedback of high volcanic sulphur dioxide concentrations on sulphate aerosol production **[6]**.

Using GLOMAP and volcanological data, the underpinning research provided evidence that the

1783 Laki eruption is likely to have substantially altered the number and size of microscopic particles that lead to cloud formation; hence altering the climate in the Northern Hemisphere **[4,5]**.

Quantification of impacts on air quality and potential fatalities

In a follow-up study published in *Proceedings of the National Academy of Sciences* **[1]** and led by the Leeds researchers, it was demonstrated that a future Laki-type eruption would significantly degrade air quality over Europe for up to twelve months – effectively doubling the concentrations of small-sized airborne particles during the first three months of the eruption. Using concentration-response functions derived from epidemiological literature together with the increase in airborne particle concentrations predicted by GLOMAP, the study showed that about 140,000 additional cardiopulmonary fatalities could occur across Europe within twelve months of the onset of the eruption – a figure that exceeds the annual mortality from seasonal influenza.

Key researchers:

Kenneth S. Carslaw, Lecturer (1999-2006) and Professor (2006-present) of Atmospheric Science in the School of Earth and Environment, University of Leeds and Royal Society Wolfson Merit Award holder (2011-present).

Graham W. Mann, Research Fellow (1998-2005) and National Centre for Atmospheric Science Research Fellow (2005-present) in the School of Earth and Environment

Anja Schmidt, PhD Student (2007-2011) and Academic Research Fellow (2012-present) in the School of Earth and Environment, University of Leeds.

Marjorie Wilson, Lecturer (1978-1991), Senior Lecturer (1991-1998), Professor (1998-2012) and Emeritus Professor (2012-present) of Igneous Petrogenesis in the School of Earth and Environment, University of Leeds.

3. References to the research (indicative maximum of six references)

1. **Schmidt**, A., Ostro, B., **Carslaw**, K.S., **Wilson**, M., Thordarson, T., **Mann**, G.W. and Simmons, A.J. (2011). Excess mortality in Europe following a future Laki-style Icelandic eruption, *Proc. Natl. Acad. Sci. U. S. A.,* **108**(38), 15,710–15,715. DOI:10.1073/pnas.1108569108.

   Peer reviewed paper. The first study to quantify the impacts of a future Laki-type eruption on air quality and human health. This paper was subject of an editorial feature in the scientific journal "Nature Geoscience", and received international media coverage, e.g. "Der Spiegel", "Science Now", "Wired News". The research described in the paper was also covered in two scientific documentaries (NOVA PBS "Doomsday Volcanoes" and Channel 5 "Ashcloud Apocalypse").

2. **Spracklen**, D.V., **Pringle**, K.J., **Carslaw**, K.S., Chipperfield, M.P. and **Mann**, G.W. (2005). A global off-line model of size-resolved aerosol microphysics: I. Model development and prediction of aerosol properties, *Atmos. Chem. Phys*., **5**, 2227-2252. DOI:10.5194/acp-5-2227-2005.

   Peer reviewed paper. The first paper describing the GLOMAP model. Highly cited (80 citations in Web of Knowledge).

3. **Mann**, G. W., **Carslaw**, K. S., **Spracklen**, D. V., Ridley, D. A., Manktelow, P. T., Chipperfield, M. P., Pickering, S. J., and Johnson, C. E. (2010). Description and evaluation of GLOMAP-mode: a modal global aerosol microphysics model for the UKCA composition-climate model, *Geosci. Model Dev*., **3**, 519-551. DOI:10.5194/gmd-3-519-2010.

   Peer reviewed paper. The first paper describing and evaluating the faster modal version of the GLOMAP model.

4. **Schmidt**, A., **Carslaw**, K. S., **Mann**, G. W., **Wilson**, M., **Breider**, T. J., Pickering, S. J., and Thordarson, T. (2010). The impact of the 1783–1784 AD Laki eruption on global aerosol formation processes and cloud condensation nuclei, *Atmos. Chem. Phys*., **10**, 6025-6041. DOI:10.5194/acp-10-6025-2010.

   Peer reviewed paper. The first paper using the GLOMAP model to simulate an effusive, Laki-

type eruption and its potential impacts on clouds.

5. **Schmidt**, A (2013). Modelling tropospheric volcanic aerosol: from aerosol microphysical processes to Earth system impacts, Springer Theses, XV, 145 p., ISBN 978-3-642-34839-6.

   The Springer Theses series publishes outstanding PhD research around the world, selected by a panel of experts and academics in the relevant field.

6. Breider, T.J., Chipperfield, M.P., Richards, N.A.D., **Carslaw**, K.S., **Mann**, G.W. & **Spracklen**, D.V. (2010). Impact of BrO on dimethylsulfide in the remote marine boundary layer. *Geophys. Res. Lett.*, **37**, L02807. DOI: 10.1029/2009GL040868.

   Peer reviewed paper. The first paper describing the updated sulfur chemistry scheme.

Note: Key Leeds researchers are in **bold**. All journal papers are peer reviewed. Publications available on request from the HEI.

4. Details of the impact (indicative maximum 750 words)

As the first ever quantitative assessment of the impact of a future Icelandic Laki-type eruption on air quality and human health, the research conducted at the University of Leeds provided evidence (i.e., the number of potential fatalities due to a future Laki-type eruption), which resulted in policy changes by the UK Government. Specifically, Leeds research has led to the recognition of gas and aerosol particle hazards arising from Icelandic volcanism in addition to previously recognised hazards arising from volcanic ash. Government contingency planning now takes account of the high risk that a gas-rich eruption could have on society.

Volcanic gas and aerosol hazards: impact on UK contingency planning and policy

During the April to May 2010 eruption of Eyjafjallajökull in Iceland, the UK government activated the Cabinet Office Briefing Room (COBR) to ensure that the multi-sector impacts of the eruption were fully understood and that any response was effective and underpinned by scientific evidence.

During this time, COBR activated the Scientific Advisory Group for Emergencies (SAGE) chaired by the 2008-2013 Chief Scientific Adviser Sir John Beddington. **Wilson** was invited to lead the SAGE subgroup on sulphur dioxide (SO_2). In May 2010, **Schmidt** presented to this subgroup the first quantitative assessment of the potential effects that a future Laki-type eruption could have on the air quality and human health in Europe and the UK **[A]**. Consequently, SAGE advised UK government on the range of Icelandic volcanic eruption types that could impact UK society. Stemming from this scientific dissemination, in January 2012 the generic risk of volcanic hazards was added for the first time to the UK National Risk Register (NRR) **[A]**. Two types of eruptions are described: gas-rich Laki-type eruptions and explosive ash-rich eruptions. In the 2012 NRR, Laki-type eruptions were given the second highest impact score (4 out of 5) with a relative likelihood of occurring in the next five years of between 1 in 200 and 1 in 20; that is the same planning priority scenario as coastal flooding events (https://www.gov.uk/government/publications/national-risk-register-for-civil-emergencies-2013-edition; accessed 28 August 2013).

Both the inclusion of Laki-type eruptions to the UK NRR and the research published by the Leeds aerosol group [1] in September 2011 led the government's Civil Contingencies Secretariat (CCS) to request the British Geological Survey (BGS) to conduct an expert assessment of Laki-type eruptions **[A, B]**. This work was required to verify that the current state of knowledge and scientific data regarding these gas-rich eruptions are reflected in the NRR (i.e. the NRR is updated if the evidence base changes).

In May 2012, the BGS organised a workshop based at CCS in London to gather experts from various fields (volcanology, epidemiology and atmospheric science). This workshop produced a report on *"Large magnitude fissure eruptions in Iceland: source characterisation"* (with **Schmidt** as a co-author) to advise CCS about current knowledge and future research needs **[B]**. The report describes the source characteristics of a Laki-type eruption, based on expert elicitation that can be used for probabilistic risk assessment **[B]**.

Since May 2012, CCS has been in regular contact with the Leeds team to discuss recent findings and future research needs including funding, which will provide further characterisation of the risks from volcanic eruptions in Iceland. Since 2013, **Schmidt** has been member of an expert group

established by CCS and BGS that meets at regular intervals to advise CCS strategy and policy, and she is also an independent member of the CCS project board "Effusive volcanic eruption", part of the CCS High Impact Hazards programme working to increase the UK's preparedness to respond to the hazards such as a Laki-type eruption **[A]**.

Increasing public awareness

The underpinning 2011 publication **[1]** was reported in international science publications, such as Nature Geoscience, Science Now and in mainstream news publications such as Der Spiegel **[C]**. The widespread coverage (including the broadcast documentaries described below) has increased public awareness of volcanic hazards, and of their potentially serious impact on health and disruption to wider society.

In June 2012, **Schmidt** contributed to the joint production of scientific documentaries on Icelandic volcanism (NOVA "Doomsday Volcanoes" and Channel 5 "Ashcloud Apocalypse") which highlighted Laki-type eruptions; the programmes featured **Schmidt's** scientific results extensively. The January 2013 US premiere of the programme reached an audience of 4.5 million viewers **[D]**. The Channel 5 documentary premiered on 26 April 2013 in the UK **[E]**.

5. Sources to corroborate the impact (indicative maximum of 10 references)

A. Individual corroboration from Head of High Impact Hazards Team, Civil Contingencies Secretariat (CCS), regarding the involvement of **Schmidt** in the activities of CCS and providing the evidence base for the inclusion of gas-rich effusive ('Laki-type') eruptions to the National Risk Register (Dated 06/03/2013). Letter available on request.

B. Individual corroboration from Head of Volcanology, British Geological Survey, regarding the involvement of **Schmidt** and **Wilson** during SAGE 2010 SO_2 subgroup meetings and the role of Leeds research for the BGS expert elicitation and report "*Large magnitude fissure eruptions in Iceland: source characterisation*" (Dated 27/05/2013). Letter available on request. [B addendum] BGS report. *Large magnitude fissure eruptions in Iceland: source characterisation* at http://www.bgs.ac.uk/downloads/start.cfm?id=2881. Report available on request from British Geological Survey.

C. Media coverage:
   Science Now http://goo.gl/aHMss;
   Nature GeoScience http://www.nature.com/ngeo/journal/v4/n11/pdf/ngeo1304.pdf;
   Der Spiegel http://www.spiegel.de/wissenschaft/natur/0,1518,787273,00.html;
   AGU Earth Magazine http://bit.ly/Yu3MSW;

D. "Doomsday Volcanoes", NOVA PBS scientific documentary (US premier 2 January 2013); see 'Transcript' link for **Schmidt's** contribution at http://www.pbs.org/wgbh/nova/earth/doomsday-volcanoes.html Viewing figures are available on request: NOVA@wbgh.org or NOVA WGBH Educational Foundation, 1 Guest Street, Boston, MA 02135, USA.

E. "Ashcloud Apocalypse, Channel 5 scientific documentary (UK premier 26 April 2013); see http://www.channel5.com/shows/iceland-ashcloud-apocalypse/episodes/iceland-ashcloud-apocalypse