Quantifying the uncertainty in estimation of the volcanic source mass flux from observed plume dynamics

Jeremy C Phillips[1], Mark J Woodhouse[2], Andrew J Hogg[2], Jonathan C Rougier[2], Liam J Dowson[1], Halldor Bjornsson[3]

[1]School of Earth Sciences, University of Bristol, United Kingdom, [2]School of Mathematics, University of Bristol, United Kingdom, [3]Icelandic Meteorological Office, Reykjavik, Iceland

E-mail: j.c.phillips@bristol.ac.uk

Estimates of volcanic source mass flux, currently deduced from observations of eruption plume height, are crucial for ash dispersion models for aviation and population hazard. Recent modelling studies have shown that the effect of the atmospheric wind on a volcanic plume can significantly reduce its height compared with the case of no wind, and so source mass flux can be underestimated by up to two orders of magnitude (Degruyter and Bonadonna, 2012; Woodhouse et al., 2012). Volcanic and atmospheric input parameters have associated measurement uncertainty, and the models incorporate epistemic uncertainty due to their formulation. In this study we quantify the magnitude of these uncertainties in order to identify which input parameters introduce the greatest uncertainty into estimates of volcanic source mass flux, and to identify where improvements in measurement capability would provide the greatest improvement to mass flux estimates.

The integral model of Woodhouse et al (2012) is used as a candidate model for uncertainty quantification, and it is formulated as a set of four coupled differential equations to express conservation principles for mass, momentum and enthalpy, and algebraic relationships for entrainment of atmospheric air, plume density and variation of atmospheric properties with height. Input parameters from the volcanic source include the ash mass flux, initial velocity, vent radius and ash temperature, and atmospheric properties can be taken from radiosonde, NWP or ECMWF reanalysis sources. The model can be rapidly solved numerically, so Monte Carlo methods have been used to explore the effect of parameter uncertainty. The greatest uncertainty in the source mass flux arises from the estimation of source temperature, with much weaker dependence on solid mass fraction in the initial plume. Woodhouse et al (2012) also identified a dimensional relationship between plume height, wind shear and source mass flux, which was fitted to their numerical model output. We also explore the uncertainty in this relationship, as a form of simplified model emulator, finding that variability in the wind shear has a much stronger affect that the other properties of the atmosphere.

Integral models of wind-affected volcanic plumes can also be fitted to observations of plume trajectory to provide tools to rapidly estimate the source mass flux. We use webcam imagery of the 2010 Eyjafjallajokull eruption to explore how the uncertainty in meteorological data compares with uncertainty in the parameters that are used to estimate the volcanic source mass flux. From this we are able to identify the parameters whose values have the greatest influence on the uncertainty in volcanic source term estimation.

References: Degruyter, W. and Bonadonna, C. (2012) Geophys. Res. Letts. doi:10.1029/2012GL052566; Woodhouse, M.J. et al (2012) J. Geophys. Res. doi:10.1029/2012JB009592