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A Bayesian inversion method for estimating ash emissions: accounting for meteorological uncertainty & quantifying uncertainty in the estimated emissions.

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Atmospheric dispersion models are employed during volcanic eruptions to forecast the atmospheric transport and dispersion of the ash cloud. Uncertainties exist in the predicted ash cloud due to uncertainties in the ash emissions, in the atmospheric dispersion model and its parameterisations, and in the driving input meteorological data. A Bayesian inversion method has been developed for estimating the height- and time-varying profile of ash emissions using satellite retrievals of ash column load, atmospheric dispersion modelling and a prior estimate of emissions (Pelley et al., 2021). Gaussian distributions are assumed for the prior distribution of the emissions and for the errors in the satellite retrievals. An optimal emission estimate is obtained by finding the peak of the posterior probability density, subject to an imposed non-negative constraint on the emissions. The method is computationally efficient and suited for operational use.

In the original design of the Bayesian inversion method, uncertainties in the atmospheric dispersion model and its input meteorological data are not considered. Errors in the input meteorological data can lead to discrepancies between the modelled and observed ash cloud locations and can affect the performance of the Bayesian inversion method. We employ ensemble NWP (Numerical Weather Prediction) data sets to overcome issues with meteorological errors. The Bayesian framework enables a model selection approach to be adopted, where a 'best' meteorological data set is chosen from within the ensemble. Using the eruption of the Icelandic volcano Grímsvötn in 2011 as a case study, we illustrate the impact meteorological errors can have on ash emission estimates and show how the 'best' meteorological data set leads to improvements in ash cloud forecasts.

The posterior probability density is a multi-dimensional Gaussian distribution which contains information on the uncertainty in the estimated emissions. If time permits, I will describe recent attempts to obtain an ensemble of emission estimates by sampling from the posterior distribution. This is challenging because of the high dimensionality and the non-negative emissions constraint. Nonetheless, an ensemble of emission estimates from the posterior distribution would enable the uncertainty in the emissions estimate, and the associated uncertainty in the ash concentrations in the predicted ash cloud, to be quantified.