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Estimating relationships between volcanic ash source term parameters using satellite data and inverse modelling

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The Australian Bureau of Meteorology monitors and issues forecasts of volcanic ash during eruption events over a region that includes Australia, Indonesia, Papua New Guinea, and the southern Philippines. This information is mainly used by the aviation industry for operational risk management purposes. Satellite based remote sensing techniques are the primary means of identifying the location of ash during eruption events. Forecasts of ash locations are obtained from dispersion models which employ prognostic meteorological fields such as wind speed and direction to predict the future locations of ash. In current operational practice, the dispersion models are initialized by a columnar source of ash, with uniform mass distribution, and with a maximum height determined by best estimates of the ash cloud height, often relying on cloud infrared brightness temperature and trajectory analysis of model wind fields at different heights. Both the remote sensing algorithms and the dispersion model contain significant uncertainties. Remote sensing of ash in tropical regions is especially challenging due to the difficulty of demarcating ash from the ice and water in convective clouds which results in frequent missed or false detections of ash. Methods for retrieving ash properties such as ash mass load have recently been developed which have the potential of enhancing the information contained in forecasts, but these are not immune to the general problems facing remote sensing of ash in tropical regions. Dispersion models also contain uncertainties. Some of these uncertainties arise from uncertainties in the meteorological fields. Other uncertainties arise from uncertainties in the ash source characteristics such the height of the ash column, the distribution of mass within the ash column, and the particle size distribution.

In this study, we seek to ameliorate these problems by making use of selected eruption case studies in which good satellite retrievals of ash are available to estimate quasi-empirical relationships between various eruption source parameters such as ash column height, fine ash fraction, and vertical mass distribution. These parameters are estimated for each case study using an inverse modelling procedure and then fitted to an assumed power-law relationship with ash column height. Meteorological uncertainties are accounted for by using an ensemble of meteorological fields to drive the dispersion model. We show that this procedure enables the mass load distribution to be crudely estimated even if no good satellite retrievals are available. In addition, even when mass load retrievals are available, the procedure enables a significant reduction in the computational cost of performing inverse modelling of source term parameters, which is particularly useful in an operational context where timely forecasts are required.