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Experimental Ash Hazard Forecasting at Sakurajima Volcano, Japan

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Introduction

The long-lasting activity from Sakurajima volcano introduces hazardous amounts of volcanic ash into the atmosphere, adversely affecting the surrounding areas (e.g. Biass *et al.* (2017), Poulidis *et al.*, (2018)), making accurate localized forecasts a necessity. The Japan Meteorological Agency (JMA) is responsible for forecasting the volcanic ash hazard for active volcanoes in Japan and operates the Volcanic Ash Fall Forecast (VAFF) system (Hasegawa *et al.*, 2015). However, at a 2 km resolution, the forecasts are too coarse to fully account for important small-scale circulations that have been shown to affect dispersal and deposition of volcanic ash (Poulidis *et al*, 2017).

Here, we present initial results from an experimental forecasting methodology carried out by the Sakurajima Volcanological Observatory (SVO), Kyoto University. Unlike the nation-wide operational nature of JMA, SVO can focus on the volcano, allowing for better defined Eruption Source Parameters (ESPs), e.g. plume height, mass discharge rate, Grain Size Distribution (GSD) among others, and the higher model resolutions that are necessary to get resolve aforementioned effects.

June 16, 2018 Eruption

Sakurajima erupted at 0719 JST (JST=UTC+9), June 16 2018, with a reported plume height of 4700 m above the vent. Deposition occurred west and southwest of the volcano, reaching the southern coast of the Satsuma peninsula. Ashfall locations were reported by the JMA, while the SVO carried out a post-eruption survey to collect samples.

Ashfall was also observed in real time by the disdrometer network operated by SVO, with ashfall detected at two locations. Exploratory modeling using the observations suggests that the original GSD – one of the most crucial ESPs for the correct simulation of ash dispersal - was mainly composed of medium to fine ash, with large aggregates produced after the eruption (e.g. Bagheri *et al.*, (2016)). For the experimental forecast modelling, a default “silicic, brief” eruption GSD (Mastin *et al.*, 2009) was modified to add: *(i)* a percentage 0.5 mm particles, and *(ii)* account for particle aggregation – the joining of airborne particles which leads to changes in the effective size and density of the new particle (Bagheri *et al.*, 2016).

Forecast Methodology

A combined modelling approach was taken: the Weather Research and Forecasting (WRF) model (Skamarock and Klemp, 2008) was used to dynamically downscale JMA forecast data down to 333 m, while the FALL3D volcanic ash transport and deposition (VATD) model (Folch *et al.*, 2009) was used for the dispersal modelling.

Ash advection and deposition calculations are usually carried out after the meteorological modelling has finished (i.e. offline coupling). As recent studies have highlighted the importance of concurrent (online) calculations (e.g. Poulidis et al., (2017)), here the data output rate from the WRF model was set at 10 minutes which is enough to represent the resolved variability in the model at the resolution used, allowing us to run the FALL3D model in a quasi-online manner.

In forecast modelling it is common practice to use the observed plume height in order to drive dispersal models (e.g. Hasegawa *et al.* (2015)). However, this means that simulations are reactive. Here, the plume height calculated by FALL3D using an estimate for the mass discharge rate based on geophysical observations carried out by SVO (Iguchi, 2016) in order to carry out forecast modelling in a proactive manner. In order to study the sensitivity of results to the timing relative to eruption, a total of 5 pseudo-forecast simulations were carried out using data up to 13 hours before the eruption.

Forecast Simulation Results

Initially, a control simulation was carried out using the final mass discharge rate output. Although qualitatively similar to the JMA ash forecast, it offered two key improvements: *(i)* ash deposition over the volcano was constrained over a narrow area, correctly reproducing the observed dispersal pattern, and *(ii)* the observed area of maximum ashfall (>1 mm deposit thickness) was reproduced correctly at a distance from the vent, over the southwestern shore of Sakurajima.

Forecast time sensitivity simulations showed surprisingly consistent ash dispersal patterns. Simulation results using forecast data up to 10 hours before the eruption time were qualitatively similar. Up to 4 hours before the eruption, the observation to estimate ratios for the two disdrometers were constrained to factor of 4, allowing for the proposed methodology to be confidently used in forecast timescales.

Conclusions

An experimental forecasting technique was designed to test the sensitivity to forecast release hour and mass discharge rate estimation. An eruption that occurred in Sakurajima in the morning hours of June 16, 2018 was used as a case study. Results showed consistent fidelity up to ~10 hours before the eruption, with little qualitative differences up to ~4 hours before the eruption. The timescales seen are favorable for using the approach for forecasting: WRF downscale simulations require 100 min and produce results that can be used for 6 hours, allowing for WRF downscaling to follow the 3 hour JMA forecast cycle. Using the current settings, FALL3D simulations required less than 30 min, a timescale similar to JMA forecast time (Hasegawa *et al.*, 2015); however, the domain can be adjusted depending on the forecasted plume height to minimize the computational time needed.

The work presented has been submitted for publication at the Journal of Disaster Research (Poulidis *et al.*, 2019).

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