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A Climatological and Modelling Study of Ash Dispersal and Fallout over the Sakurajima Volcano

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Introduction

Volcanoes are a ubiquitous feature of the Japanese landscape. Although during periods of rest they are an object of admiration, during periods of activity they can have devastating consequences with loss of property and life. One important volcanic hazard is volcanic ash. This study deals with ash dispersal at the Sakurajima volcano, an active volcano in southern Kyushu monitored by the Sakurajima Observatory (SO) of Kyoto University.

Volcanic ash affects a range of spatial and temporal scales. It impacts lives and livelihoods: from international air traffic to the destruction of property and increased mortality (Baxter *et al.*, 1999; Ayris and Delmelle, 2012; Stuefer *et al.*, 2013). It can interact with clouds, causing acid rain and directly affecting agriculture (Whitham *et al.*, 2005) and there is an established link between volcanic emissions and the wellbeing of the communities surrounding the Sakurajima volcano (Shinkura *et al.*, 1988).

The Sakurajima volcano is a very active volcano with approximately 700 eruptions per year since the southern crater was formed in 2009. On average these are relatively weak eruptions, with an average Volcanic Explosivity Index (VEI) of 3 and a plume height of 1–1.5 km (Fig. 1). This makes the transport and deposition of volcanic ash more susceptible to localised topographical effects, unresolvable in the most commonly used Volcanic Ash Transport and Dispersion (VATD) models (Stuefer *et al.*, 2013). The Weather and Research Forecast (WRF) model, a mesoscale numerical weather prediction model capable of resolving these effects was used to provide simulations for ash dispersal at a fine horizontal resolution (down to 1 km). Results from the analysis of six years of observational data will be presented along with preliminary results from the WRF model simulations.

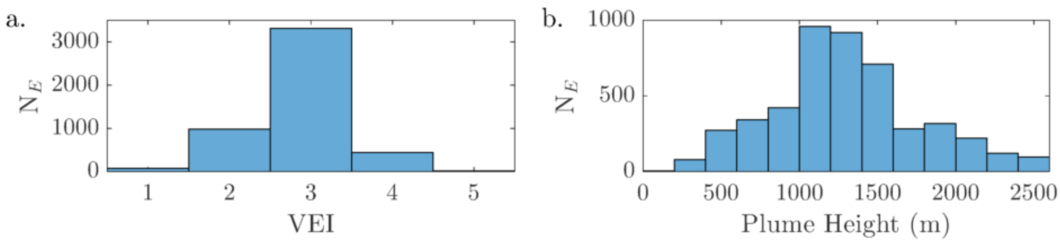

Figure 1. Eruption characteristics of the Sakurajima volcano. Histograms of number of eruptions (N_E) and: (a) VEI, and (b) Plume height, based on eruption data gathered by the Japanese Meteorological Agency (JMA).

Observations and modelling

Databases for the eruptions and ashfall are kept by the Japanese Meteorological Agency (JMA) and the SO, respectively. JMA records eruption time, VEI, plume height, and plume dispersal among other characteristics, while the SO has 59 ashfall measuring stations (mainly monthly), creating a high-resolution network in the Kagoshima prefecture. Atmospheric sounding data are available twice per day at Kagoshima (archived by the University of Wyoming), and JMA also maintains a large network of 30 rainfall measuring stations in the area. Data from all sources are synthesised to analyse the long-term ashfall patterns from the volcano.

The WRF model is used to provide high-resolution simulation data for specific months of eruptions. The WRF model is unique in VATD models as it follows an "online" approach when it comes to physics and chemistry – interactions between the plume and meteorological conditions are resolved in real time, while also resolving the fine-scale meteorological circulation, leading to more accurate predictions (Stuefer *et al.*, 2013). The setup used for the simulations presented has 4 domains, with the finest domain centred over the Kagoshima prefecture with a horizontal grid resolution of 1 km. The volcanic plume is introduced as 10 separate ash bins of varying grain sizes in the simulation with an "umbrella" shape, with 25% of the mass is contained in up to 73% of the eruptive column height, and a parabolic mass distribution with 75% of the entrained mass located on the top. Note that the volcanic plume is introduced implicitly at a selected time step and the detailed dynamics (vertical motion and thermodynamics) and phenomena such as pyrocumulus clouds as well as particle aggregation are not resolved, however wet deposition and scavenging are (Stuefer *et al.*, 2013).

Preliminary results

Analysis of the observational data reveals a strong influence of the local meteorology, with some seasonal characteristics (Fig. 2). Wind direction has the most significant role in the distribution of heavy ash close to the volcano, with the majority of ashfall over 1 kg m^2 aligned to the average wind depending on the season. However lighter ash stays airborne for longer periods of time and is more susceptible to topographic effects such as flow splitting (mainly seen over the Satsuma peninsula, SW of the volcano; Fig. 2a-c). Wet deposition due to rainfall is also suspected to have a large role in ash deposition during the wet season, resulting to an overall narrower ashfall distribution (Fig. 2c). The role of the topography and wet deposition will be further examined with numerical simulations.

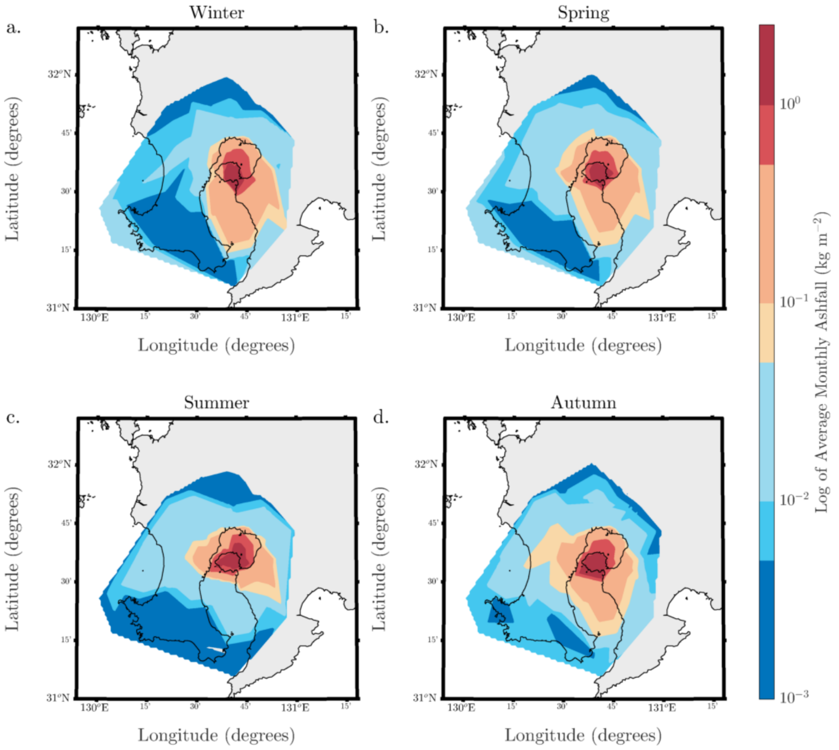

Figure 2. Seasonal distribution of average monthly ashfall on a logarithmic scale. Minimum shown at 10^{-3} kg m^{-2} with contours shown at 1 and 5 of every power up to 1 kg m^{-2}. Note, results are interpolated from monthly data from 59 stations.

Conclusions

The Sakurajima volcano is an active, closely monitored volcano located in Southern Kyushu. Due to the combination of unusually high activity and an unusually high spatial resolution of observational data it provides an excellent location for studying the role of topography in the transport and deposition of volcanic ash, a major atmospheric hazard affecting the lives and livelihoods of people living in the area. Observational data are analysed for the 6 years of eruptive activity (2009-2014), complemented with computational modelling using the WRF model, a high-resolution numerical weather prediction model.

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