A20

Orographic Effects on the Transport and Deposition of Volcanic Ash - A Sakurajima Case Study

〇Alexandros-Panagiotis POULIDIS, Tetsuya TAKEMI, Masato IGUCHI

Introduction

Volcanic ash is a major environmental hazard that acts over both short (hours-days) and long (months-years) timescales and, directly or indirectly, affects life, livelihoods, and infrastructure (Wilson *et al.*, 2015). After an eruption, airborne ash can cause major disruption for international aviation, while in the long term volcanic ash from eruptions and passive degassing can exacerbate existing respiratory conditions (Hillman *et al.*, 2012). Accurate prediction of the transport and deposition of volcanic ash is therefore vitally important for hazard management and mitigation.

Transport and deposition of volcanic ash are complex processes, depending heavily on the size of the particles (Bonadonna and Houghton, 2005). Heavy ash is deposited quickly within a few 10s of kilometers from the vent, while lighter ash tends to have longer flight times and is more directly influenced by local as well as regional wind fields. Atmospheric flow is heavily influenced by complex terrain creating a number of complex phenomena, such as flow spitting, gravity waves and downslope winds (Smith, 1980). These orographic effects have been seen to affect the deposition of volcanic ash (Watt *et al.*, 2015)

In the study presented we examined the impact of orographic effects on the transport and deposition of volcanic ash from the Sakurajima volcano in Kyushu, Japan. Sakurajima is one of Japan's most active and closely monitored volcanoes: since 2009 it has approximately 80 eruptions per month with volcanic plume heights ranging between a few hundred meters up to several kilometers. The Kagoshima prefectural government has installed tephrameters at 62 points to measure ashfall from the volcano in a monthly basis. The frequent activity, surrounding mountainous topography, and large amount of observational data make Sakurajima an ideal natural laboratory for the study of these effects.

Evidence of orographic effects' impact in observational data

Average ashfall around Sakurajima has been shown to decrease with distance following an inverse power law (Iguchi, 2016):

$$w_a=w_m D^{-k},$$

where w_a (in kg m^{-2}) is the weight of the ash, D (in km) is the distance, and on a logarithmic plance, w_m (in kg m^{-2}) is the intercept and k is the slope. Previous research has shown that downslope winds in the lee of mountains can force deposition of volcanic ash, creating an increase with distance (Watt *et al.*, 2015). Evidence of orographically-forced deposition of volcanic ash from Sakurajima have been found for two tephrameter groups west of the volcano while a comparison between observed and theoretical values has highlighted the impact of relative distance from the volcano (Poulidis *et al.*, 2017).

The August 2013 eruption and ash dispersal modelling

On 18th August 2013 Sakurajima erupted at 1631 JST with a plume height of 5 km - the highest plume height recorded since 2006. Ash was advected W-NW and ashfall was recorded as far as the Koshikijima islands 90 km in the west. This eruption was studied in depth using the Weather Research an Forecasting (WRF) model (Skamarock *et al.*, 2008), coupled with "online" chemistry and aerosol calculations (WRF-chem; Grell *et al.*, 2005). High horizontal (down to 500 m) and vertical (90 levels starting at 50 m height increments) resolution was used in order to resolve the orographic effects, while a series of simulations with "flat" topography were carried out to show the influence of the topography.

Simulations have shown that orographic effects can act in two ways: strong gravity wave activity close to the volcano act to keep ash afloat, while downslope winds closer to the surface can pull ash downwards and force deposition (Poulidis *et al.*, 2017). Due to its low residence time, heavy ash was seen to be relatively unaffected by orographic effects: in terms of deposition, the most readily affected size ranges for particles were of grain size between 3-5φ (ie. between 0.125 and 0.03 mm).

Conclusions

Orographic effects have a crucial role in the prediction of a large number of atmospheric disasters such as storms, floods and wildfires (Meyers and Steenburgh, 2013) and have been known to affect the deposition of volcanic ash. These effects have been studied in detail in the context of the Sakurajima volcano. Evidence of orographically-forced deposition have been found in tephrameter observations west of the volcano, marked by an increase of ashfall in the lee of the Satsuma peninsula.

The WRF model was used to study the 18 August 2013 eruption. Orographic effects were seen to influence the dispersal and deposition of volcanic ash, with gravity waves keeping ash afloat close to the volcano and forced deposition in the lee of the Satsuma peninsula. Volcanic ash with grain size between 3-5φ was seen to be the most affected range.

References

Bonadonna and Houghton, (2005), *Bull. Volcanol.*, doi:10.1007/s00445-004-0386-2

Grell *et al.*, (2005), *Atmos. Environ.*, doi:10.1016/j.atmosenv.2005.04.027.

Hillman *et al.*, (2012), *Bull. Volcanol.*, doi:10.1007/s00445-012-0575-3.

Iguchi, (2016), *J. Distaster. Res.*

Meyers and Steenburgh (2013), *Mountain Weather Research and Meteorology*, doi:10.1007/978-94-007-4098-3_1.

Poulidis *et al.*, (2017), *J. Geophys. Res.* (In preparation)

Skamarock *et al.*, (2008), *Tech. rep.*, NCAR/TN-4751STR.

Smith *et al.*, (1980), *Tellus*, doi:10.1111/j.2153-3490.1980.tb00962.x.

Watt *et al.*, (2015), *Bull. Volcanol.*, doi:10.1007/s00445-015-0927-x.

Wilson *et al.*, (2015), *Phys. Chem. Earth*, doi:10.1016/j.pce.2011.06.006.