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

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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, and in the long term 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. The frequent activity, surrounding mountainous topography, and large amount of observational data make Sakurajima an ideal natural laboratory for the study of these effects.

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). A nested domain setting with high horizontal (12500, 2500, and 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 zero topography were carried out to show the influence of these effects.

Results

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 advect ash downwards and force deposition (Fig. 1; Poulidis *et al.*, 2017). Orographic effects were seen to increase both horizontal and vertical diffusion of volcanic ash. 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 3-5 ϕ (ie. between 0.125 and 0.03 mm).

Resolving orographic effects over the volcano leads to a "gray area" over the volcano: the initial plume height set at input can be changed due to gravity wave activity over the volcano, leading to a different simulated plume height, something that could affect similar simulations, especially for eruptions with low plume heights.

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.*

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

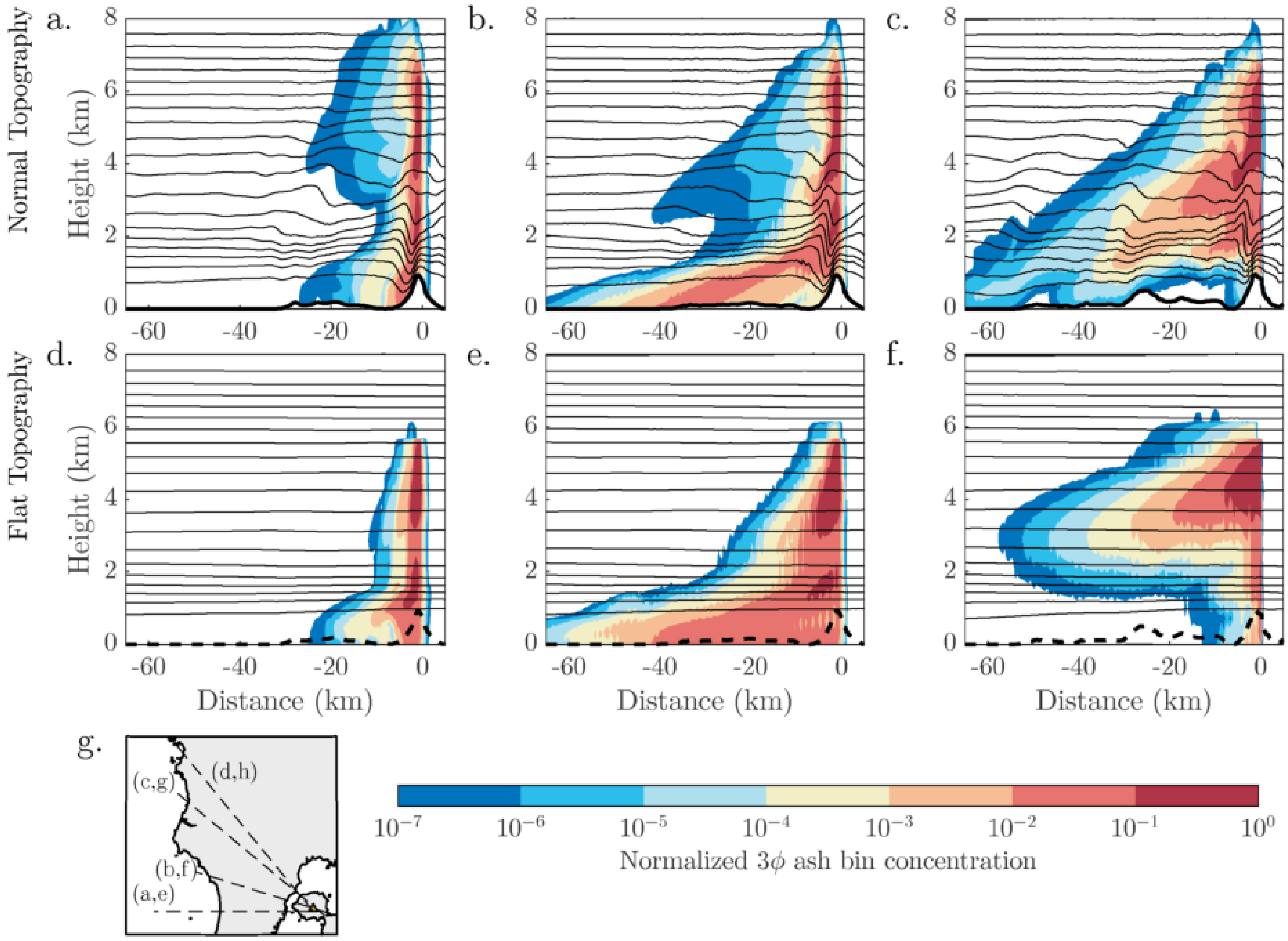
Skamarock *et al.*, (2008), *Tech. rep.*, NCAR/TN-4751STR.

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.

Keywords: Ash dispersal, Sakurajima, WRF, Orographic effects


Normal Topography
Flat Topography
a.
b.
c.
d.
e.
f.
g.
Height (km)
Distance (km)
(c,g)
(d,h)
(b,f)
(a,e)
10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0}
Normalized 3ϕ ash bin concentration