B01

The Role of Atmospheric Vertical Velocity in the Transport and Deposition of Volcanic Ash

〇Alexandros P. POULIDIS, Tetsuya TAKEMI, Masato IGUCHI

Introduction

The transport and deposition of atmospheric pollutants over regions of complex topography is dictated by local-scale circulations enforced by the topography, mixing within the planetary boundary layer (PBL) and the physical properties of the pollutants. The successful reproduction of observed patterns hinges on the correct estimation of the involved particles' fall velocities (U_F): the sum of terminal velocity (U_T; dictated by particle morphology and height above the ground) and the atmospheric vertical velocity (*w*; based on the complex interplay of factors such as atmospheric convection, topography and large-scale weather systems). The correct estimation of U_F can be especially challenging in the case of volcanic ash that can be introduced in sizes from 2~mm down to a few microns with disparate particle characteristics (shape and density), leading to U_T values ranging between 10^{-2}-10^{1} m s^{-1}.

The simulation of VATD is especially challenging in distances of a few kilometers from the vent (proximal region) owing to a combination of unresolved volcanogenic effects and the impact of the volcano's orography. An orographic flow is the result of the atmosphere impinging on a topographic maximum (mountain, volcano, etc.) and critically depends on atmospheric stability, the kinetic energy of the incoming flow, and the characteristics of the obstacle.

Despite the relative importance of *w*, it is often neglected in VATD modelling, due to the urgency of calculations or lack of access to computational resources. In order to quantify the errors brought on by this omission, we have conducted a Large Eddy Simulation (LES) using the Weather Research and Forecasting (WRF) model, with a horizontal grid spacing down to 50 m (Fig. 1). The meteorological data were then used to carry out a combination of Eularian and Lagrangian modelling (using the FALL3D and Matlab-based trajectory calculations respectively) in order to make precise calculations along particle trajectories.

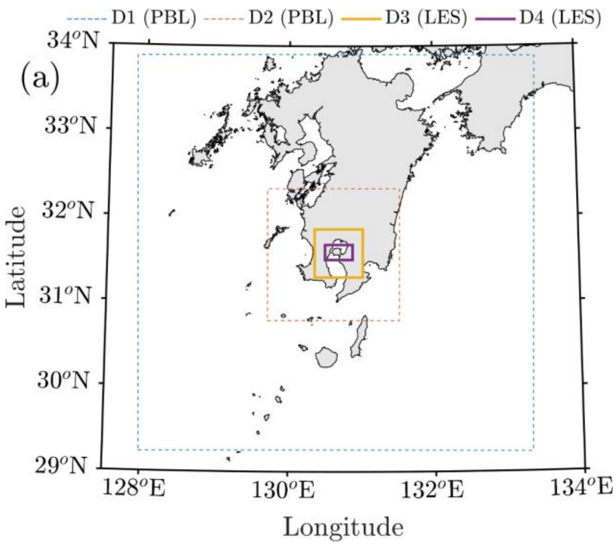

Figure 1. Placement of WRF low-resolution (PBL) and high-resolution (LES) domains. The final study area focuses over Sakurajima volcano (D4)

Case Study

Sakurajima volcano is andesitic stratovolcano located on the island of Kyushu in southern Japan (31.58N, 130.65E, peak height 1117~m). Historical eruptions occurred from the northern edifice (Kitadake), but recent activity occurs either from the southern edifice (Minamidake) or an auxiliary crater that was formed in 1939 (Showa crater). Typical activity involves ash-rich eruptions that occur as pressure build-up causes a plug of degassed, crystalline magma to fail.

Here, we focus on an eruption that occurred in the early morning hours or October 1, 2017. Close to the surface the wind direction was north-easterly, turning easterly at approximately 800 hPa and then northerly above 5 km. This led to significant fanning of the ash cloud as it neared the surface (Fig. 2). Detailed ashfall data were captured by two optical disdrometers location approximately 3 and 6 km downwind from the vent.

Figure 2. Picture taken from Kagoshima port on October 1, 2017. The initial plume position is marked with a triangle marker. Wind shear led to significant fanning of the ash cloud.

Results

Both models provided qualitatively similar results, comparing favorably against optical disdrometer observations of falling volcanic particles.

Results from trajectory modeling were used to gain detailed insight of the fall velocity of particles along individual trajectories and allowed for a statistical analysis of the total sample.

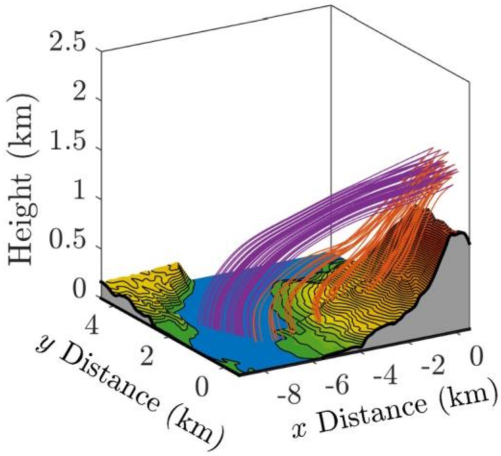

Figure 3. Comparison of modelled ash particle trajectories for particles with U_T=2 m s^{-1} for the October 1, 2017 eruption with and without accounting for *w* (red and purple lines respectively).

Accounting for atmospheric vertical velocity was shown to be a deciding factor in getting a realistic representation of observed particles. Particle fall velocities were seen to differ up to 7 m s^{-1} for instantaneous values or 5 m s^{-1} on average, with particle ascent possible over areas with a strong impact from orographic effects.

The impact of *w* is the strongest in the proximal area to the vent; however, forced deposition of low terminal velocity particles can have an impact in far-field deposition due to depletion from the ash cloud.

These effects can be expected to have an impact on volcanic ash transport and deposition for more than half the days in a year for approximately ~27% of the Holocene volcanoes.