Coupling model of pyroclastic dispersal and eruption cloud dynamics: numerical simulation of the Pinatubo 1991 eruption

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Distribution of volcanic fall deposits reflects the eruption cloud dynamics and eruption conditions at the vent. The pyroclasts ejected from volcanic vent rise into atmosphere due to the buoyancy of volcanic plumes. When the eruption cloud reaches the neutral buoyancy level where the cloud density equals to the atmospheric density, the cloud laterally spreads as a gravity current (i.e., umbrella cloud) and transports the pyroclasts widely. As the horizontal distance from the vent increases, the driving force of the gravity current decreases and the pyroclasts are mainly transported by the atmospheric wind. Once the pyroclasts separate from the eruption cloud, they are advected by the wind and deposited on the ground. Therefore, the depositional pattern of fallout depends on the settling behavior in the cloud, the release points from the cloud, and the advections by the wind. In this study, we aim to comprehensively investigate the mechanisms of pyroclastic dispersal from vent to ground by using a numerical model.

To reproduce pyroclastic dispersal inside and outside an eruption cloud, we use a combination model of a pseudo-gas model for fluid motion (Suzuki et al., 2005) and a Lagrangian model for particle motion (Suzuki and Koyaguchi, 2013). In this model, the Lagrangian particles move depending on the drag force from surrounding fluid, whereas the pseudo-gas is not affected by particle motions. The model is designed to reproduce the continuous injection of a high-temperature mixture from a circular vent into a stratified atmosphere. The particle shape was assumed to be an ideal sphere, and 1,000 particles with the size of -8 phi to 8 phi were ejected from the vent every 10 s at the same velocity as the pseudo-gas.

We have performed three-dimensional numerical simulations of the Pinatubo 1991 eruption. Our model can reproduce 3-hours spreading of umbrella cloud and pyroclastic dispersal. The umbrella cloud expands almost axisymmetrically before 1.0 h and then it is slightly elongated by the northeasterly wind. After 2.5 h, the cloud reaches a stagnation point upwind but continues to grow leeward. The results show that the pyroclasts can be classified into at least four classes from the viewpoint of the dependency on the fluid motions inside and outside an eruption cloud. The particles which are larger than -5 phi separated from the volcanic plume and are deposited near the vent. The particles with the size of -5 to 3 phi rise up to the neutral buoyancy level and separate from the bottom of umbrella cloud, whereas those smaller than 3 phi are suspended by turbulence in the umbrella cloud. In addition, the particles larger than 0 phi develop asymmetric distribution of fallout, whereas those smaller than 0 phi show an elongated distribution. These settling behavior for each classes should be taken into account to reconstruct eruption cloud dynamics from distribution of fallout.

Keywords: eruption cloud, fallout distribution, volcanic eruption

