Reconstruction of volcanic plume dynamics and fallout deposits on the basis of numerical simulations

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During an explosive volcanic eruption, volcanic gas and ash are ejected from the volcanic vent. Depending on terminal velocity, the particles (i.e., volcanic ash) are carried up within a convective plume, are advected by the surrounding wind, and sediment on the ground. The fine particles are expected to have atmospheric residence, whereas the coarser particles form ash-fall deposit. Recently, particle-tracking models such as PUFF and advection-diffusion models such as TEPHRA2 and FALL3D tried to forecast both particle concentration in the atmosphere and particle loading at ground level. In these models, the source conditions (the plume height, and mass release level) should be given on the basis of a simplified model of bent-over plume (e.g., Bursik, GRL 2001) which contains an empirical constant (entrainment coefficient related to the wind-caused entrainment, β). In order to determine the value of the parameter (i.e., β) and the other source conditions for tephra dispersion, we are developing a 3-D numerical model which reproduces the dynamics of convective plume, the ash transport, and fallout deposits.

The model is designed to simulate the injection of a mixture of solid pyroclasts and volcanic gas from a circular vent above a flat surface in a stratified atmosphere, using a combination of a pseudo-gas model for fluid motion and a Lagrangian model for particle motion. During fluid dynamics calculations, we ignore the separation of solid pyroclasts from the eruption cloud, treating an eruption cloud as a single gas with a density calculated using a mixing ratio between ejected material and entrained air (Suzuki et al., JGR 2005). In order to calculate the location and movement of ash particles, we employ Lagrangian marker particles of various sizes and densities. The marker particles are ejected from the vent with the same velocity of the eruption cloud every 10 sec. The particles are accelerated or decelerated by the drag force on the spheres and fall to the ground with their terminal velocities.

We carried out a series of simulations of a small-scale eruption in various wind fields with the magma discharge rate of 2.5 x 10^6 kg/s, the initial temperature of 1000 K, and volatile content of 2.84 wt.%. The simulation results show that as the wind speed increases the mass of the entrained air increases and the plume height decreases. Through comparisons between the present results and the 1-D model predictions, we found that the preferable value of β (0.2-0.3) is substantially smaller than those suggested in previous works (0.3-1.0). The simulation results also indicate that (1) the main mass release level of particles is lower than the total height of plume, and that (2) it depends on the particle size. We confirmed that the present model correctly reproduces the plume height and ash fall area during the 2011 Shinmoe-dake eruptions (Suzuki and Koyaguchi, AGU2012).