Development of the plume source model for inversion of tephra fallout

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During an explosive volcanic eruption, tephra falls out from eruption cloud to ground surface and forms tephra deposits. The characteristics of tephra deposits (e.g. their thickness and spatial distribution) reflect the eruption source conditions. When an eruption source condition is specified by parameters, tephra transport and deposition can be calculated using the advection-diffusion model. Based on this forward model, we can inversely search for an optimal set of parameters that explain the observed characteristics of tephra deposits (e.g. Conner & Conner 2006). In practice, we estimate the supply rate of tephra particles from the eruption cloud into the atmosphere as a function of height and grain size (referred to as “supply rate function”) from the inversion analysis. The form of supply rate function is determined by the physical processes of particle separation from the eruption cloud, and hence it must depend on the dynamics of eruption column. In previous studies, however, the form of supply rate function was assumed to be a certain mathematical function without physical considerations (White et al 2017). In this study, we developed a physical model to obtain the supply rate function.
The physical model is a combination of a particle sedimentation model and a cloud dynamics model. The sedimentation model describes the process of particle fallout from the cloud. The cloud dynamics model is subdivided into 2 models: the 1-D plume model and the gravity current model. The 1-D plume model describes the dynamics of eruption columns below the neutral buoyancy level (NBL), and the gravity current model describes the dynamics of spreading cloud around NBL. We used the 1-D plume model of Bursik (2001), which considers bending by windy air and the effects of particle sedimentation. We also take into account the geometrical effects of plume bending on the sedimentation model.
From a parametric study using the above physical model, we obtained the supply rate function for each grain size. The supply rate function is composed of two functions: “plume supply rate function” and “gravity-current supply rate function”. The plume supply rate function represents the mass loss of particles from the edge of a rising plume below NBL. It is convex downward and monotonically decreasing against height regardless of grain size. The gravity-current supply rate function describes the mass flux of particles at NBL in the cloud (i.e., at the top of the rising plume), and it is used as the source term for the gravity current model. The characteristics of the supply rate function depend on grain size. Because most of coarse particles (>10 mm) fallout from the lower part of rising plume, their plume supply rate function decreases rapidly with height, and the value of their gravity-current supply rate function is nearly zero. Because most of fine particles (< 1 mm) carried by rising plume up to NBL, their plume supply rate function has small values throughout the plume, and their gravity-current supply rate function is approximately equal to the supply rate at the vent. The plume supply rate function of intermediate particles (1~10 mm) is a mildly decreasing function, and it has larger values than that of fine particles; therefore, it has greater values than those of coarse or fine particles for the upper part of the plume. The value of the gravity-current supply rate function for intermediate particles remarkably decreases with the increasing grain size. In the presentation, we compare these results based on our plume source model with the mathematical functions used in previous inversion analyses.

Keywords: explosive volcanic eruption, inversion of tephra fallout, 1-D eruption model, particle sedimentation, advection-diffusion model

