Effects of subgrid-scale turbulent models on spatial structure in large-eddy simulation of an eruption column

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In the transport of volcanic ash in an explosive eruption, the turbulence is one of the important elements which determine the eruption styles such as an eruption column and a pyroclastic flow. The conventional steady one-dimensional models for an eruption column assume that the effect of turbulence is represented as a constant in a theoretical formula, although it is indicated that the assumption has measurable uncertainty (Suzuki et al. 2005, Ishimune 2006). In recent years, unsteady three-dimensional eruption column models, which represent turbulence more directly, have been developed. However, the turbulence modeling in the transports of gas and pyroclastic materials are left unclarified. For instance, subgrid-scale (SGS) turbulence stresses are differently modeled in Neri et al. (2007) and in Suzuki and Koyaguchi (2010), although the contribution of SGS models to simulations of real-scale eruption column and the consequences of different SGS models applied are not well understood. In this research, the unsteady three-dimensional simulation code for an eruption column is developed. The effects of SGS models are discussed through the comparisons between the simulation results using two kinds of the models.

In this code, the model concept of Neri et al. (2007) is adopted, which is advantageous in its applicability to various volcanic styles and to the transport of pyroclastic materials of various sizes. The large-eddy simulation (LES) technique based on a SGS model is adopted as expression of turbulence. The gas component and pyroclastic materials of various diameters are classified into two or more phases (the multi-fluid approximation). The SGS model is a part of the submodels in the stress term and the diffusion term in the basic equations. As the SGS models, the Smagorinsky model, which is generally used, and the Yuu model, in which the effect of SGS drag is considered (Yuu et al. 2001), are adopted for the gas phase, and the equation proposed by Hinze, in which the relation between the relaxation time of particles and the temporal duration of vortex is considered (Hinze 1975), for the particle phases.

The following results were obtained from the LES results for an eruption column and laboratory simple flows: (1) When fine grid systems that enable the capture of the major spectral bands in a turbulence field are used in the simulation, the LES results show general agreement with those of the existing experiments and the theoretical solution in laboratory simple flows, and qualitative agreement of cloud shapes with those of the one-dimensional model in an eruption column. (2) The SGS models for gas and particle phases cause variations in eruption cloud shape. Possible causes of the variations are the strong dependence of the whole diffusion process in the LES of an eruption column on the SGS model used and the high sensitivity of the eruption cloud shape to the strength of turbulent diffusion.