V080-P010 Time: May 29 17:15-18:45

Turbulent Mixing between Eruption Cloud and Air in a Numerical model of Explosive Volcanic Eruption

Yujiro Suzuki[1], Takehiro Koyaguchi[1]

[1] Frontier Sciences, Univ Tokyo

http://www.gaea.k.u-tokyo.ac.jp/~yujiro/

Plinian eruptions involve the continuous discharge of a mixture of hot gas and solid fragments from volcanic vents. As the mixture rises, surrounding air is entrained; the air expands due to heating from the hot pyroclasts, and can cause the mixture in the column to become buoyant. Therefore, mixing of eruption cloud and air is one of the most important processes for eruption cloud dynamics. The efficiency of mixing depends on nature of turbulence. Previous numerical models of eruption cloud [e.g., Dobran et al., JGR, 1993] employed turbulent subgrid scale model such as the Large Eddy Simulation (LES) in order to reproduce the turbulent mixing caused by the various scales of vortex. On the other hand, most of the previous models performed simulations on an axisymmetric 2-D domain, ignoring effects of multi-dimensional and asymmetric structures of turbulence, and they employed first-order accuracy schemes. In order to assess the assumptions in the previous models, we evaluate these effects (those of multi-dimensional structure, accuracy of numerical schemes and subgrid models) on the turbulent mixing by a numerical model [Suzuki et al., JEPSJM2001].

We calculated the motion of an eruption column from a circular vent on the flat surface of the earth. We assumed that the magmatic component (the mixture of gas and pyroclasts) is treated as a homogeneous gas because relative velocity of gas and ash particles is sufficiently small. Equation of state (EOS) for the magmatic component can be reduced to the EOS for an ideal gas, because volume fraction of the gas phase is very large. The EOS for the mixture of air and the magmatic component is also expressed as the EOS for an ideal gas by changing their ratio of specific heat. The dynamics of eruption clouds is based on Euler equation of a compressible gas. The partial differential equations are solved numerically by the Roe scheme, which is a general TVD (Total Variation Diminishing) scheme.

First, we evaluate the effect of multi-dimensional structure of turbulence on the basis of numerical results of 3-D coordinates. The results show that in the gas-thrust region the eruption cloud produces a fountain that has an axisymmetric flow structure. In contrast, the central axis of the eruption cloud significantly fluctuates in the convective region, which causes the efficient turbulent mixing of the eruption cloud and the ambient air. These results suggest that axisymmetrical 2-D model can reproduce the quasi-quantitative features of turbulent mixing in the gas thrust region, whereas 3-D simulations are required in order that the turbulent mixing in the convective region is correctly calculated.

Secondly, we investigate the effects of spatial resolution on the natures of turbulent mixing in the calculations. In general, the natures of turbulent mixing depend mainly on the global features of large-scale vortices, but not on those of small-scale vortices. Hence, we attempted to find the adequate spatial resolution that makes it possible to describe the large-scale behavior of turbulent mixing. Our results show that the large-scale behavior of turbulent mixing is affected by vortices of order of 100m and that the features of those vortices can be calculated by simulations with a third-order accuracy using a mesh-size of less than 50m, whereas a first-order accuracy scheme cannot resolve such a fine scale even though a finer mesh-size (less than a few tens of meter) are used. We also compare the numerical results of the Direct Numerical Simulation (DNS) and Large Eddy Simulation (LES). The results show that the large-scale structures of column do not depend upon the subgrid model. In summary, it is suggested that it is more essential to employ a sufficiently fine mesh size and high-accuracy scheme rather than a subgrid model in order that the effect of turbulent mixing is correctly evaluated.