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Development of eruption cloud model incorporating water phase microphysics

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Rapid and accurate detection of phenomena is crucial to prevent and reduce a disaster with volcanic eruption. We start the research program to develop the advanced techniques monitoring volcano and the associated procedures of data analysis. In this program, we plan to apply the radar observation into the study of dynamics of eruption cloud in order to improve the prediction of volcanic ash transport. The injection of volcanic ash into the atmosphere and subsequent transport are sometimes influenced by the atmospheric moist processes. This fact motivates us to develop the eruption cloud model incorporating the phase change of water to support the observational study. The new model is now on development in the Meteorological Research Institute (MRI), based on the Japan Meteorological Agency Non-Hydrostatic Model (JMA-NHM) which is applied into the daily weather forecast.

The JMA-NHM is a Reynolds Averaged Navier-Stokes (RANS) model which is founded on the fully compressible equation system. Besides the fundamental equations for a computation of fluid dynamics, the model has the prognostic equations for the six categories of water substances (water vapor, cloud droplet, raindrop, ice crystal, snowflake, graupel) to simulate the development of cloud and precipitation. We have newly implemented the additional equations for the solid pyroclasts, volcanic gases, and the ash included into the solid and liquid water particles. Eventually, the model atmosphere is described as the mixture of moist air, volcanic gases, solid pyroclasts, and solid and liquid water. The evolution of each category of solid and liquid particles is driven with the microphysics in terms of the phase change of water, coalescence of water particles and accretion of ash by water particles, and is prognosed with the variables representing the bulk properties of the substances such as the total amounts of mixing ratio and number concentration.

In order to look over the model ability, preliminary test has been conducted with a focus on the sensitivity of the development of eruption cloud to the atmospheric condition. The detailed expression of the atmospheric moist processes in our model is advantageous in the simulations of those cases in which the latent heat released from the water vapor condensation has relatively large effect on the evolution of eruption cloud. The total discharge rate of solid pyroclasts and volcanic gases are fixed on the order of 10^4-10^5 kg s^{-1}, and the upper-air sounding data acquired in the later Baiu season (very moist), after its offset, and winter season are adopted for the initial and boundary condition of the simulations. In the first case, the top of eruption cloud tends to be raised higher than that in the second case, since larger latent heat is released in the first case. In the winter (third case), the larger potential energy is available to lift the hot air parcel due to the colder atmosphere. The top height of eruption cloud becomes higher than in the second case, although water vapor condensation is less effective. The test will be extended to the cases under precipitation.