Development of a Volcanic Ash Data Assimilation System for Atmospheric Transport Model

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In the Japan Meteorological Agency (JMA), there are two major operations related to volcanic ash forecasting: the Volcanic Ash Fall Forecast (VAFF) and the Volcanic Ash Advisory (VAA). The VAFF provides information for local governments and residents who may be affected by ash fall from volcanoes (Hasegawa et al., 2015). The VAA is issued to airline companies and aviation authorities for safe aviation services.
In these operations, the forecasts are calculated by atmospheric transport models including advection process, gravitational fall process and deposition process (wet/dry). The most important and uncertain factor of the models is the initial condition of volcanic ash. In operations, the initial condition is based on the empirical model of Suzuki (1983). Since it includes many assumptions and empirical research, it often fails to reproduce actual plumes of volcanic eruptions.
On the other hand, in recent years, research of observation techniques of volcanic ash by weather radar and satellites have advanced. The Meteorological Research Institute (MRI), one of the facilities of JMA, has started observation using two different types of weather radar. Besides, in 2015, the Himawari-8 geostationary meteorological satellite was put into operation. Himawari-8 has sixteen observation bands as against five in its predecessor, MTSAT-2. Using this abundant observation data of new-generation satellite, physical quantities of volcanic ash clouds (including top height, mass loading and particle radius) can be retrieved (Hayashi et al., JpGU2016).
In the present study, using both radar and satellite observation, we are developing a volcanic ash data assimilation system to improve initial conditions of the atmospheric transport models.
We have adopted the three-dimensional variational data assimilation scheme (3D-Var), which has low computational cost and is suitable for creating initial conditions immediately after an eruption occurs. Analysis variables are concentration of ash and size distribution parameters (median particle size and dispersion) which are mutually independent. It is assumed that observation error covariance matrix is diagonal, and background error covariance matrix has the relationship between correlation and distance and has the Gaussian form (Ishii et al., JpGU2016).
From the radar observation, it is expected that we can obtain three-dimensional ash concentration in the atmosphere and parameters of ash particle size distribution in the atmosphere. On the other hand, the satellite observation is expected to provide only two-dimensional parameters of ash clouds such as mass loading, top height and particle radius. Currently, we are trying to estimate the thickness of ash clouds using vertical wind shear.
Here, we show two case studies of data assimilation system. One is the February 14th, 2014 eruption case of Kelut in Indonesia for an experiment of data assimilation with virtual radar observation, and the other is the May 29th, 2015 eruption case of Kuchinoerabujima in Japan for an experiment of data assimilation with actual satellite observations.

References

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