Improvement of volcanic ash cloud prediction in the Tokyo Volcanic Ash Advisory Center

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When an explosive eruption occurs, it is vital to predict volcanic ash clouds for aviation safety. The Volcanic Ash Advisory Centers are organizations to predict the ash clouds and issue the Volcanic Ash Advisories (VAAs). One of those is the Tokyo Volcanic Ash Advisory Center (Tokyo VAAC) in the Japan Meteorological Agency (JMA) which has been issuing the VAAs since April 1997.

In the Tokyo VAAC, the VAAs are issued on the basis of predictions from the atmospheric transport model (JMA-ATM; see p5-13 in this report). Generally, ash cloud predictions are governed by ash clouds in initial conditions for ash transport models, because uncertainties of the ash cloud predictions based on the ash transport models inherit uncertainties of the ash clouds in the initial conditions (Folch, 2012). Therefore, it is the key task to improve the initial conditions for the JMA-ATM from ash clouds observations such as those from meteorological satellites.

The satellite analysis by operators in the Tokyo VAAC provides two-dimensional parameters of ash clouds such as areas and top altitudes, whereas vertical profiles including bottom altitudes of ash clouds are not provided. The bottom altitude of an ash cloud is one of the most essential parameters in the initial condition, because an advection direction of the ash cloud depends on the altitude. In an old method of the Tokyo VAAC, some fixed values were used as bottom altitudes of ash clouds in the initial conditions; for example, any ash cloud with top altitude over 10 km always had a bottom altitude of 5 km in spite of a variety of horizontal wind profiles. Therefore, uncertainties of the bottom altitudes of ash clouds caused uncertainties of ash cloud predictions. In order to obtain more accurate bottom altitudes of ash clouds, we developed a new method to estimate the ash clouds thicknesses considering a vertical wind shear from the JMA numerical weather prediction. In this method, an index S which depends on the vertical wind shear is introduced as follows,

$$S = \exp\left[-\alpha C \int_{z_1}^{z_2} \left|\frac{\partial \mathbf{v}}{\partial z}\right| dz\right]$$

where z is the altitude, z_1 and z_2 are the bottom and top altitudes of the ash cloud respectively, $\alpha(= 0.01)$ is constant, $C(= \int_0^{z_{top}} \left|\frac{\partial \mathbf{v}}{\partial z}\right|^{-1} dz)$ is a scaling factor, the vector $\mathbf{v}$

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is the horizontal wind and $\frac{\partial \mathbf{v}}{\partial z}$ is the vertical wind shear. Then, the bottom altitude z_1 is obtained for $S = 0.3$. The threshold 0.3 was determined from a parameter study. The method provides thinner thicknesses of ash clouds for stronger vertical wind shear, and vice versa.

Fig.1 shows that the introduction of the new method leads to an improvement in the ash cloud prediction. A thickness of the ash cloud in the initial condition is approximately 2 km for the new method, whereas that is approximately 3 km for the old one. Although a validation for the ash clouds thicknesses from the both methods is not sufficient due to a lack of observations, the improvement of ash cloud predictions implies that the new method improves the ash cloud in the initial condition. In fact, ash cloud predictions are improved for many eruption cases not only for the case in Fig.1.

In March 2021, the new method explained above was applied to the ash cloud prediction system in the Tokyo VAAC simultaneously with the update of the JMA-ATM.

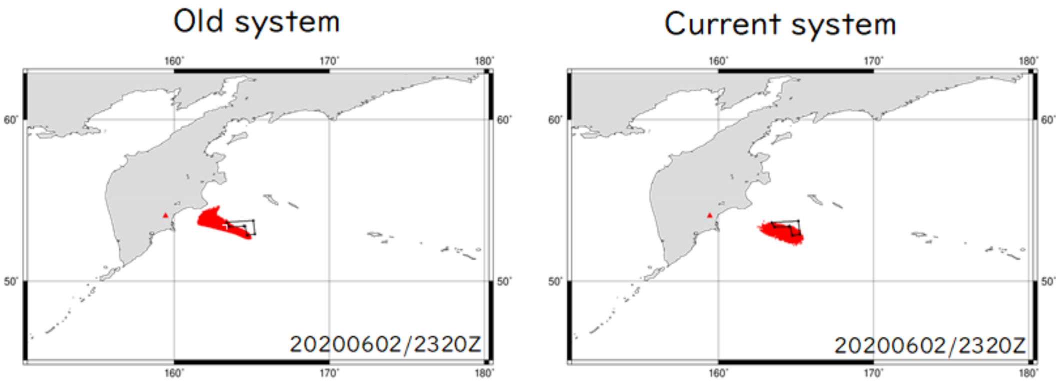

Figure 1: Six-hour ash cloud prediction for the eruption at the Karymsky volcano (▲) on 2 June 2020 (Red dot: ash cloud prediction). The black line shows ash cloud area from satellite analysis.

References

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