Forecasting of volcanic ash hazard using integrated monitoring and simulation

*Masato Iguchi[1], Haruhisa Nakamichi[1], Takeshi Tameguri[1], Kosei Takishita[1], Alexandros Poulidis[5], Tetsuya Takemi[1], Akihiko Yamaji[1], Takashi Maruyama[1], Masayuki Maki[1], Kyoka Ishii[1], Hiroshi Tanaka[2], Yusaku Ohta[3], Atsushi Shimizu[4]

1. Disaster Prevention Research Institute, Kyoto University, 2. University of Tsukuba, 3. Tohoku University, 4. National Institute for Environmental Studies, 5. Universität Bremen

Since 1955, Sakurajima volcano has experienced repeated Vulcanian-style eruptions in the summit region.In order to assess the volcanic ash hazard, we conducted a study to forecast the amount of ashfall by combining monitoring and simulation.

1)Automated ash fall observation

Twenty-one disdrometers, which measure the particle size and fall velocity of volcanic ash particles, were installed on Sakurajima to observe ash fall. By comparing the amount of ashfall with that obtained by ash sampling, we obtained an empirical formula for determining the amount of ashfall from the count of particles per particle size and falling velocity observed by the disdrometers.

2)Volcanic ash emissions detected by remote sensing

Radar, optical lidar, and GNSS were used as remote sensing observation methods to detect volcanic plumes. Lidar emits laser beams with wavelengths of 532 nm and 1064 nm to observe the backscattering of aerosols. Lidar allowed us to capture even the thin plumes that could not be seen visually. The greatest advantage of XMP radar is that it can visualize volcanic plumes even when the summit of the volcano is covered with clouds and the plumes are invisible. The radar can also monitor the advection and diffusion processes of the plume in real time. Empirical equations between plume reflection intensity and ash fall and theoretical equations for plume particle size distribution were obtained. By using the radar-based plume advection/diffusion and the equation between plume reflection intensity and ashfall amount, it is possible to determine ashfall in a nowcasting manner. The spatial distribution of carrier phase delay obtained by GNSS observation and analysis was effective for plumes with high concentrations.

3)Real-time forecasting volcanic ash dispersion

The weight distribution of ash fall is mainly determined by the volcanic ash emission rate and wind field. We used wind field data that are publicly available from meteorological institutes. We obtained an empirical formula to determine MER of ash from a linear combination of the amplitude of volcanic microtremors (2-3 Hz) and the volume change of pressure sources obtained from ground deformation associated with the eruptions of Sakurajima. Since the upper limit of the quarter power of the ejection rate obtained from the empirical equation is proportional to the volcanic plume height, consistent with Morton et al. (1956) and others, the plume height can be determined from the MER. Using these initial conditions, we developed a system to predict ash fall in real time using PUFF as a simulation engine.

4)Improving the accuracy of volcanic ash dispersion forecasting

We used WRF to improve the horizontal spatial resolution of the wind field to the order of 100 m. The obtained wind field can successfully reproduce the wind bypassing the volcanic body and the downwind flow on the leeside side beyond the summit. The wind field is also being confirmed by in situ drone observations and Doppler lider. Based on the higher-resolution wind velocity field, calculations using FALL3D have improved the reproducibility of ash fall distribution.

5)Online system for volcanic ash dispersion prediction

We treated the ash eruption rate as a continuous parameter and constructed a system that continuously operates a simulator for the advection, diffusion, and fallout of volcanic ash. FALL3D was used as the

simulation engine. The method described in 3) was used for the volcanic ash emanation rate. A high-resolution wind field database was created using the method described in 4), and wind fields similar to those announced by meteorological institutes were extracted from the database.
6)Probabilistic Ashfall Prediction before Eruption
The duration and amount of dilatational strain allow statistical prediction of the time and magnitude of subsequent eruptions. The frequency distribution of the duration of the dilatational strain and the amount of dilatation can be approximated by a log-logistic distribution, and if the time of eruption and the amount of ash emission are given probabilistically based on the log-logistic distribution and incorporated into the online simulator described in 5), the probabilistic ash fall distribution can be obtained in real time before the eruption occurs.
7)Evaluation of the impact of falling ejecta
We conducted impact experiments to evaluate the effects of falling debris, which has a larger particle size than volcanic ash, on roofs, glass, and other structures.

Keywords: Volcanic ash, Sakurajima, Vulcanian eruption