Optical disdrometer measurement of tephra fall: Constraints on radar parameters for eruption cloud observations

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A tephra fallout process during a volcanic eruption has mainly been investigated by geological method such as based on measurement of mass and grain size distribution on tephra deposits. Recently, a combination of the tephra fallout deposit data with numerical simulations of tephra dispersal and fallout contributes to understanding the detail of the eruption dynamics. In order to further promote the combination between the simulations and the observations, we need multi-parameter observations of the eruptive phenomena with high-time resolution which is comparable with the timescale of the eruption. One of the methods for the high-resolution observations is to apply techniques already used in other fields, such as precipitation measurements by weather radar and disdrometer in meteorology. In this study, we investigated the main characteristics of tephra fall from the eruptions at Sakurajima volcano in southern Kyushu, Japan by using a laser based optical disdrometer, Parsivel.

The disdrometer measurements were carried out for two years at one station located 2.5 km south of Showa crater of Sakurajima volcano, and made it possible to detect 76 tephra fall events, in which particle size and fall velocity were simultaneously measured with one-minute sampling interval. We found that the tephra fall can be easily distinguished from precipitation because of a notable feature of the tephra fall that both the particle size and the fall velocity gradually decrease with time during each event. The detected events were compared with the information about the direction of eruption cloud which is reported in eruption list by JMA, and it was found that the detection rate of the tephra fall during the eruptions with south-directed eruption cloud is about 7 times higher than that with other directions. Furthermore, the feature of the temporal changes in the size and the velocity was also most obvious in the case of south-directed eruption cloud. These indicate that the disdrometer can successfully measure the tephra fall directly reaching from the crater location to the station, and that the disdrometer measurements at multiple stations covering all directions may provide valuable information about the tephra dispersion and eruption cloud dynamics.

By using the tephra fall events, we obtained a quantitative relationship between the particle size and fall velocity. The cumulative weight of the tephra fall during one event was also measured by digital electric scale set close to the disdrometer, which enabled us to calculate the density of the particles. On the basis of the size-velocity relationship and the particle density data, we can estimate morphological parameters of volcanic particles in models of terminal fall velocity in previous studies. Furthermore, the tephra size and fall velocity data enabled us to calculate a particle size distribution per unit volume and size class, and we found that this distribution is well explained by exponential distribution. In the case of precipitation, the value of exponent is modeled as a function of the amount of rain fall. When we estimate the exponent as a function of the amount of the tephra fall using the same manner as precipitation, it was found that the exponent is smaller than that for precipitation. Because the size-velocity relationship and the particle size distribution are important parameters for radar analysis, the formulation and parametrization for its relationship and distribution in this study can be utilized for eruption cloud observations by weather radar.

Keywords: Tephra size , Tephra fall velocity, Parsivel, Particle size distribution, Vulcanian eruption

