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The relationship between the eruption condition and column height during the 2011 eruptions of Shinmoe-Dake volcano

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During an explosive volcanic eruption, an eruption cloud which is ejected from volcanic vent with a high temperature becomes buoyant to generate an eruption column. The heights of eruption column are key observable data for understanding the dynamics of eruption cloud and estimating the eruption conditions at the vent. Therefore, to clarify the relationship between the column height and eruption conditions has been one of the most important issues from the viewpoint of disaster prevention as well as volcanology. In Shinmoe-Dake, Kirishima volcanic group, some eruption columns which reached a height of several kilometers have been recognized since January, 2011. During these explosive eruptions, the column heights were observed by means of the weather radar system and other eruption conditions were estimated from different observations. In this study, in order to develop a model that can quantitatively predict the relationship between the column height and eruption conditions, we compare the predictions by the existing model with the observed data.

Woods [1988] proposed a steady vertical 1-D model of eruption column in which the column is assumed to be well-mixed horizontally. This model predicts the column height when the atmospheric condition, the magma properties (temperature and water content), and the eruption conditions (mass discharge rate and exit velocity) are given. However, because this model applies the entrainment hypothesis [Morton et al., 1956] to the process of turbulent mixing in eruption clouds, the efficiency of turbulent mixing (i.e., entrainment coefficient, k) should be empirically given.

Using the steady 1-D model, we calculate the column heights for three explosive eruptions on Jan. 26 and 27. The mid-latitude atmosphere is applied to the atmospheric condition. On the basis of the petrological data, the magma temperature and water content are assumed to be 950 degrees Celsius and 3 wt.%, respectively. The average mass discharge rate can be estimated to be 10^5-10^6 kg/s from the total amount of tephra fall deposits and the durations of the eruptions; the total amount of tephra fall deposits was deduced on the basis of the field works, the durations of the eruptions were obtained from the satellite images, infrasonic observations, and seismic observations. The exit velocity and the entrainment coefficient are treated as a free parameter. The calculation results indicate that the column height is mainly dependent of the assumed value of the entrainment coefficient. When the entrainment coefficient is set to be 0.05 ? 0.13, the column height ranges 12 ? 6 km. The column height observed by means of the weather radar [MRI JMA, 2011] was about 8 km and it roughly coincides with the model prediction for k=0.1.

In order to improve the steady 1-D model and to estimate the relationship between the column height and the eruption condition with a high accuracy, the adequate value of the entrainment coefficient should be given in the model. For this purpose, the observation of column height with a high spatial resolution and the theoretical works for the turbulent mixing are required. In particular, the dependency of entrainment coefficient on the wind should be studied on the basis of the 3-D numerical simulations.

Keywords: Shinmoe-Dake, eruption cloud, numerical model