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Numerical Analysis of Shock Propagation in Eruption of Mt. Shinmoe

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The eruption of Mt. Shinmoe caused the damage of breaking windows several kilometers away from the volcano, and the word "Air vibration" came to be recognized by the general public. We can know the approximate scale of the eruption by measuring a peak pressure of air vibration. Because the pressure wave may take different profile depending on the condition of the eruption, information of the eruption is included in the waveform. Therefore, there is a possibility that the characteristics of the eruption could be understood. The objective of the present study is to simulate the shock wave propagating from the eruptive crater numerically, and to investigate the characteristics of the pressure history which is observed at far field of the volcano.

The eruption was numerically simulated with a three-dimensional flow solver. This study assumes that gases are inviscid and follow the equation of state for perfect gases. The weighted average flux (WAF) scheme is used to solve the conservation laws of mass, momentum, and energy. The scheme is one of the extended Godunov schemes with second-order accuracy both in time and space. It is constructed as a finite-volume method using the integral form of the basic equations. The HLLC approximate Riemann solver with a TVD-limiter function is utilized for inter-cell flux evaluation.

Numerical domain of 5km x 5km x 3000m around Mt. Shinmoe was given by using 10m grid of digital map published by Geospatial Information Authority of Japan. The eruptive energy is set to 7.3×10^5 MJ, which the eruptive energy is equivalent to when the peak pressure of 1500Pa is observed at 3km away from the eruptive crater. Numerical calculations are carried out with following two eruptive models.

1.Pressurized container model: An imaginary gas container filled with high pressure air is placed over the eruptive crater. Blast waves or atmospheric vibrations are simulated by suddenly removing the container wall. In this study, the diameter of the container is arbitrarily set to 50m and placed 60m above the crater. The filling pressure and the temperature are 558kPa and 1000K, respectively.

2.Shock tube model: Volcanic vent is modeled as a long tube. The bottom part of the tube is separated by a diaphragm and is filled with high pressure air. When the diaphragm is removed, the high pressure air pushes the air in the rest of the tube, generating a shock wave and high speed air flow is induced behind the wave. The shock wave and the jet flow simulate the volcanic eruption. In this study, the cross section and the length of the tube are assumed to be 100m x 100m and 150m. The diaphragm is placed at the position where the volume of the high pressure section becomes the same as that in the pressurized container model. The initial filling pressure and the temperature are also the same as that in the previous case.

Curves in Fig.1a are the pressure histories at 1km south from the crater computed using these two different eruption models. It is observed that the negative over-pressure is less pronounced and its duration time is longer in the shock tube model compared to those in the pressurized container model. Figure 1b shows a typical over pressure history actually measured at 1km from the Mt. Shinmoe's crater[1]. Although it is only qualitative at this moment, it is seen that the curve for the shock tube model in Fig1a resembles the pressure history in Fig1b.

It is expected that valuable information regarding the eruption such as how and how much of energy is released is obtained by carrying out simulations for different combinations of numerical parameters.

In this study, comparisons are made between numerical results obtained with and without taking the terrain into consideration. The effect of the terrain is also discussed.

Reference

[1] Coordinating Committee for the Prediction of Volcanic Eruption, Observation of air vibration caused by Kirishima Shinmoedake eruption, The University of Tokyo Earthquake Research Institute, 2011

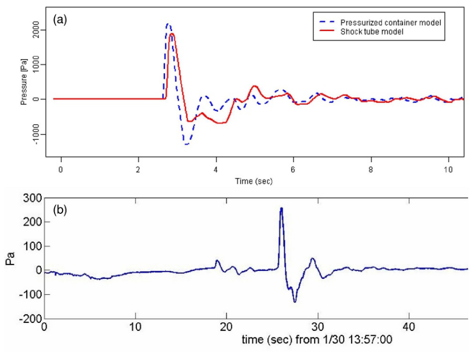

Fig. 1

Keywords: Mt. Shinmoe, CFD, Shock wave