Seismic and acoustic waves excited by volcanic explosion: analyses of energy ratio and source spectra

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Volcanic eruptions generally accompany both seismic and acoustic signals, and these signals are used to understand volcanic fluid motions in the conduit and/or its effusion process from active vents. In the present study, we compare these two kinds of signals observed at three volcanoes in Japan, systematically examining the temporal changes of radiated energy. We further examine the basic spectral characteristics of seismic and acoustic signal radiations during large and small Vulcanian explosions at Sakurajima volcano. We use seismic and acoustic records at seismic-acoustic stations operated by Japan Meteorological Agency (JMA).

We first examine the energy ratio between seismic and acoustic signals of volcanic explosions at Sakurajima, Kirishima, and Kuchinoerabu-jima volcanoes. We calculate the time series of energy ratio of acoustic signals to three-component seismic signals by calculating their envelopes at the frequency band of 1-5 Hz. To obtain averaged characteristics, we stack the energy ratios of seismic and acoustic signals of about 900 explosions at Sakurajima and 8 explosions Shinmoe-dake (Kirishima) volcanoes, respectively. We analyze only one eruption at Kuchinoerabu-jima. The results at Sakurajima and Shinmoedake (Kirishima) show the following characteristics in the temporal changes: the ratio of seismic energies to acoustic energies rapidly decreases at the beginning and reaches the minimum in about 10 s -20 s; then the ratio gradually increases for 20 s - 40 s; the seismic signals continue after the acoustic energy decreases down to the noise level. Although we can analyze one eruption data for Kuchinoerabu-jima volcano (18 December 2018), similar characteristics are recognized. These results suggest that the volcanic fluid motions are strong in the shallow parts in the beginning, and the active zone gradually becomes deep.

Next, we investigate the source spectra of acoustic signals of volcanic explosions. Applying the spectral ratio method that has been often used for seismic signals, we clarify the difference of source spectra between large and small acoustic signals. We stack the spectral ratios of acoustic signals according to their maximum amplitudes, and classify them into Classes IV, III, II, and I from the largest to the smallest. The maximum amplitude of the largest event is about 10 Pa, while the smallest is about 2.5 Pa. Since the wind around the volcano may disturb the wave propagations, we only select the acoustic signals excited by volcanic explosions occurring during a low wind speed (< 3.3 m/s) condition, using the assimilation wind data recorded by ECMWF (European Centre for Medium-Range Weather Forecasts). We observe that the spectral ratios of acoustic signals are similar among different stations both for direct and coda waves. This means that the spectral ratio method is applicable for the acoustic signals of volcanic explosions during low wind speeds. All pair of the observed source spectral ratios of acoustic signals (Class IV/I, III/I, II/I) are characterized by almost flat amplitudes at the frequency range of about 0.2 -10 Hz. The difference between the classes is the amplitude. This characteristic is much different from the seismic signals excited by Vulcanian explosions (Hasib et al., 2018), in which a flat amplitude at low frequency range (about 0.5 - 2 Hz), a gradual decrease with frequency at an intermediate frequency range (about 2–3.5 Hz), and a flat amplitude at high frequency range (about 3.5 –10 Hz). These differences suggest the differences in the generation mechanisms between seismic and acoustic signals, which may reflect the difference of excitation region: the seismic waves are in the volcanic conduit beneath the vent, while the

acoustic waves are at the orifice of the conduit.

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