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Characterization of middle-distance infrasound propagation and its utility for grasping volcanic activity

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Infrasound has become an important component of observation for volcanic activity. At present, infrasound observations for volcanoes are concentrated in two distinct scales: close to the volcano in less than 10 km, or in hundreds or thousands of kilometers away. Observations and studies of infrasound in the middle-distances are very few. We have a dense network of well-calibrated infrasound sensors around Kirishima volcano, about 40 km to NNE of Sakurajima volcano. Infrasound from Sakurajima is often observed clearly at the stations, especially at high altitudes. Strengths of the infrasound at these stations relative to a station, 3.5 km from the Showa crater of Sakurajima, show a seasonal variation and large scattering from one explosion to another. The variations are considered to be caused by changes in the atmospheric structures and possibly in the radiation patterns of infrasound. This study is motivated by this observation and aims to understand the middle-distance infrasound propagation. The middle-distance observation is particularly important for monitoring a volcano in an island, including Izu-Oshima and Stromboli. When it has large eruptions, the island may become inaccessible and stations in the island may be broken. Then, the possible nearest observation sites are in the neighboring lands, which are generally in tends of km.

We analyzed signals of Sakurajima explosions in November and December, 2012, when temporal stations were installed in various distances and directions from Sakurajima. Signals recorded at a station 43 km to SSW were quite different and much weaker than those at similar distances in NNE, the stations at Kirishima. Infrasound waveforms observed in the north and east directions were sometimes very similar regardless of distances, but sometimes clear phase splitting was recognized beyond 40 km. These features were qualitatively explained by ray-tracing calculations using atmospheric data (temperature, wind speed, and wind direction) measured at Kagoshima twice a day. Sound propagation is increased by wind toward the down-wind direction and inverse layers of effective sound speed are formed. These inverse layers were frequently formed in the direction of Kirishima but rarely to the south during the analyzed period. The inverse layers prevent upward propagation of infrasound and confine waves to increase the observed amplitudes. When the phase splitting was observed, the altitude of the main reflection was higher than usual and caused the clear splitting. When the inverse layers were not clear or lower than Kirishima peaks, the wave amplitudes were distinctly reduced behind the peaks. In this way, effects of atmospheric structure and topography, and their combination, are significant in the middle-distances. In order to obtain quantitative information of the source, we need atmospheric data with better resolutions in time and space.

Next, we focus on one explosion event. Infrasound from one event consists of an initial strong pulse and gradually decaying coda lasting 5-10 minutes, sometimes accompanying small secondary explosions. The atmospheric structure is assumed to be unchanged in this short time. In fact, the relative amplitudes of the initial pulse and the secondary ones were similar among the stations. Nevertheless, the coda amplitude relative to the initial pulse were different and decayed in various ways from one station to another, and tends to be larger beyond 15 km. Because there were also cases in which coda decayed almost in the same way at all the stations, the variation is not site effects or inevitable results of scattering. We consider it as an evidence indicating that infrasound generated by an explosion and that by a following jet have different radiation pattern and/or different source heights, that is the explosion is from the crater while the jet noise is from the turbulent ash plume (cf. Matoza et al., 2009).

Keywords: infrasound, volcano, eruption, atmospheric structure, explosion, jet