# A ray-tracing study for wind effects in middle-distance infrasound propagation

Makiko Iwakuni[1], Mie Ichihara[2], Giorgio Lacanna[3], Minoru Takeo[2], Masato Iguchi[4], Maurizio Ripepe[3]

[1]Japan Weather Association, Japan, [2]Earthquake Research Institute, University of Tokyo, Japan, [3]Earth Science Department, University of Florence, Republic of Italy, [4]Disaster Prevention Research Institute, Kyoto University, Japan

E-mail: iwakuni_01@jwa.or.jp

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. Infrasound signals induced by explosive eruptions of Sakurajima are often observed clearly at the dense network of well-calibrated infrasound sensors, which Earthquake Research Institute installed around Kirishima volcano, about 40 km to NNE of Sakurajima volcano. The variations are considered to be caused by changes in the atmospheric structures and possibly in the radiation patterns of infrasound generation. This study focuses on the wind effect to understand the middle-distance infrasound propagation variations.

We have been analyzing more than one thousand signals of Sakurajima explosions from July, 2011 till now. Temporal stations were installed in various distances and directions from Sakurajima. The variation of waves among the network is numerically investigated using a finite differential method, in 2-D with a correction of geometrical spreading and taking account of the topography and the profile of atmospheric temperature (Lacanna et al., 2012, AGU). Observed variations are easily explained by the effect of topography. On the other hand it is hard to explain observed variations in winter by 2-D simulation even considering large variable in atmospheric temperature. To evaluate the degree of wind effect, we tried to simulate the ray-paths by using two kinds of models. One is taking account of the wind effect as a moving medium and the other is taking account of the wind effect as the modification of temperature (medium traveling waves is static). In close-distance station both models showed similar ray-paths. On the other hand, two models sometimes showed different ray-paths in middle-distance stations. Next, although infrasound waveforms observed in the north and east directions were sometimes very similar regardless of distances, 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. 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 inverse layers were not clear or lower than Kirishima peaks, the wave amplitudes were distinctly reduced behind the peaks. In this way, wind effect is 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.