Monitoring Snow Avalanches by Infrasonic and Seismic Sensors on Mt.Fuji in 2018-2019 Winter Season

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While infrasonic studies of snow avalanches were already reported (e.g., Arai et al.,2017), few observations have been carried out to analyze seismic and infrasonic waves at the same time. Kogelning et al. (2011) reported that big avalanches generated infrasonic waves before the seismic waves. They interpreted it as that a snow avalanche started as low-density snow debris and increased its density when it got big in the last stage. They suggested that infrasonic signals are useful to detect the beginning of the avalanche, and seismic signals are to estimate its end. Therefore, separation of seismic and infrasonic signal is essential to determine the beginning and ending time, location and type of the avalanche.

In this study, we set infrasonic and seismic sensors around Mt. Fuji for a whole winter season. We used signals detected by the multiple sensors to identify events and estimate the direction of sources by calculating the delay of signals. We also compared the power spectra between the data recorded by an infrasonic sensor and a collocated seismometer for each event to distinguish seismic signals and infrasonic signals and to determine the location and type of the avalanche.

We set two infrasonic stations with a relative distance of 1km, each of which consists of a pair of microphones separated about 10m. Two 3-component seismometers and three 1-component seismometers were also installed, as shown in fig1. At AKD station, both infrasonic and seismic sensors were installed. Observations were carried out from December 2018 to May 2019, with a sampling rate of 100Hz. We also installed a probe-like thermometer that had three elements in vertical 40-cm grids next to the infrasonic sensors in AKD to record the temperature and snow depth.

We calculated cross correlation in the frequency band of 1-10 Hz for the data recorded by the microphone pair at each of AKD and KMT to mitigate the signals generated by wind noise. Then, we extracted events whose correlations of the microphone pairs were higher than 0.8 at the both stations. Around 50 samples were selected as likely signals of avalanches after excluding earthquake and artificial signals.

Seismic sensors record both seismic waves and infrasonic waves, and so do infrasonic sensors. In order to distinguish the ground motion triggered by infrasound from seismic waves, we analyzed the data of AKD where seismic and infrasonic sensors were both installed. The response function of the seismometer to infrasound waves was calculated by averaging the power spectral ratios between the seismic and infrasonic records of clear infrasonic signals from the nearby military exercises. Ten events of military exercises were used in the analysis. Then, we used the response function to normalize the seismic-to-infrasonic ratio of the power spectra in the 50 events of likely avalanches. If the seismic sensors detect only infrasonic waves, the normalized ratio ideally goes to 1. In the case of seismic waves, however, it becomes much larger. We focused on this point and found that most of the events only had infrasonic signals. Still, infrasonic and seismic signals were both recorded in 4 events.

The infrasonic part of the signals was recorded by the multiple infrasonic and seismic stations. The relative arrival times were estimated by the cross-correlation analyses for the microphone pairs and by the amplitude delay among the different stations. They indicate similar source directions for most of the cases, though the resolution was poor. In some cases, we found evidence that the sources were moving. Based on these results, we believe that the signals were generated by snow avalanches. In the 4 events which had both infrasonic and seismic signals individually, we recognized the seismic signals only at a few stations, and could not observe their propagation over the stations. The 4 events occurred from 16th to 27th of April. The thermometer data showed that there was more than 30-cm snowfall from 10th to 11th of April, and the temperature rapidly rose after that. It is possible that the weather conditions made the avalanches denser in the four events.

Currently, the observation of snow avalanches in the 2019-2020 winter season is going on. This winter, we set 4 microphones in a 100-m scale array, the seismic stations, and two probe thermometers. Further detailed observation and analyses will help understanding snow avalanches.

Keywords: Avalanche, Infrasound, Seismology

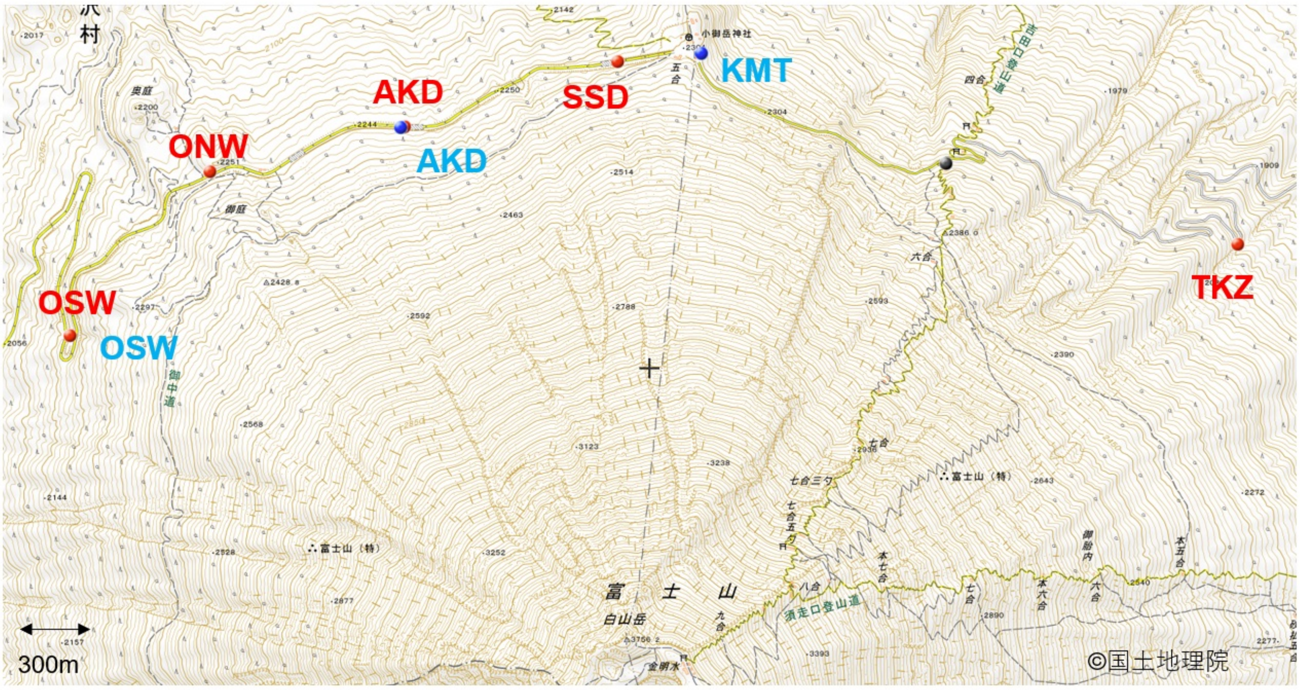

Fig1: Placement of seismic and infrasonic sensors

Infrasound Sensors
Seismic Sensors

