Cross-correlation analysis of infrasound and seismic signal during the phreatic eruption at Hakone in 2015

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The activity of volcanic tectonic earthquakes in Hakone volcano gradually increased from the end of April, 2015, and small phreatic eruption was observed at Owakidani geothermal region from 29 June to 1 July in this year (Mannen et al., 2015). At the morning of 29 June (at 7:33), abrupt tilt changes of approximately 10 micro radian were detected during two minutes by using tilt meters and broadband seismometers installed around Owakidani geothermal region (Honda et al., 2015). Honda et al. (2015) concluded that these tilt changes could be explained by assuming a shallow open crack source oriented in the NW-SE direction, and they interpreted that hydrothermal fluid of 100,000 m^3 intruded into the region above sea level during the tilt changes. Mannen et al. (2015) reported that volcanic mud flow and ash fall were observed at about 11 and 12 o'clock on 29 June, respectively. However, due to poor visibility around Owakidani region during the eruption, we could not obtain detailed temporal sequence of eruptive activity. In the present study, we conducted a cross-correlation analysis of infrasound and seismic signal to clarify the eruptive activity. Ichihara et al. (2012) demonstrated that infrasonic signals could be identified from a wind noise by using a cross-correlation function of signals from a microphone and a collocated seismometer. We used the waveform record obtained by the microphone and the short-period velocity seismometer at Owakidani station that is located 500m away from the craters. We applied a 3-12 Hz band-pass filter to the infrasonic and UD component seismic signals, and calculated a normalized cross-correlation function of the filtered records, using a 5-s sliding time window. According to Ichihara et al. (2012), significant infrasonic signal can be identified as a pattern of correlation function: the highest peak of correlation function, the negative peak and its node is located around $tau=1/(4f_0)$, $tau=-1/(4f_0)$ and at $tau=0$, respectively, where *tau* is defined as the delay time of seismic and infrasonic signals, and f_0 is the characteristic frequency of infrasonic signal. As a result, we identified the pattern of correlation function in the period from 7:32 to around 10:30 on 29 June, 2015. The appearance time of this correlation pattern is almost coincident with the onset time of the abrupt tilt changes. This result suggests that the emission of volcanic material, such as volcanic gas, started almost simultaneously with the tilt changes, and the infrasonic waves accompanied by the emission generated the ground motion in the immediate area of Owakidani station.

Figure 1 Ground velocity and acoustic signals during the abrupt tilt change on June 29, 2015. (a and b) The raw and the band-passed signals of the vertical component of a seismometer (SU) and a microphone (MC) at OWD station are shown, respectively. (c) RMS amplitudes of the band-passed signals. (d) Examples of tilt records. (e) Normalized cross correlation function of the band-passed seismic and infrasonic signals.

Keywords: phreatic eruption, infrasonic wave