Explosion energy derived from the 2015 Kuchinoerabujima eruption: Estimation from infrasound less than 0.01 Hz detected by barometers, seismometers, and TEC

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This study discusses the amount of energy emitted to the atmosphere as acoustic waves of less than 0.01 Hz by the 2015 Kuchinoerabujima volcano, southwest Japan, eruption derived from barometers, broadband seismometers, and GNSS-TEC observations.
Kuchinoerabujima is one of the volcanic islands of active recently. The volcano erupted at 0:59 UT on 25th May 2015. Many previous studies pointed out that this is a phreatomagmatic eruption and involves a lateral signal (e.g., Kobayashi, 2017; Matsuzawa et al., 2016; Yamada et al., 2017). Yamada et al. (2017) found that barometric data include two phases in about 20 sec. In the first stage, the volcanic plume went up with a pressure pulse, and the second another pulse corresponds to the plume growing laterally. The seismic source time function of that has a component of north-south direction obviously (Matsuzawa et al. 2016).
We found atmospheric disturbances with a characteristic frequency of ~0.01 Hz in all the observations. The frequency range is equivalent to the highest part of the detectable band in the ionosphere. We detected the signal of lower atmospheric perturbation from F-net, an array of broadband seismometers installed by NIED, and a barometer array along the Japanese coastline in front of the Pacific ocean by AIST. As the ionospheric observation, we used GNSS-TEC time series extracted from GEONET 1 Hz sampling data. The waveform feature is very similar to ionospheric disturbances excited by Asama volcano on 1st September 2004 (Heki, 2006; Chonan et al., 2017).
We tried to reproduce the observed signal and estimate the magnitude of the energy source using the ray-tracing method. Atmospheric parameters are inputted from NRLMSISE-00 (Picone et al., 2002), HWM-14 (Drob et al., 2015), IRI2016 (Billitza et al., 2016), and IGRF-12 (Thébault et al., 2015). We put an isotropic energy source on the ground in the windy atmosphere.
The estimated travel time by ray-tracing is consistent with the observation, indicating that the excited atmospheric perturbation simply propagates isotropically without wave broadening due to dispersion discussed in Dautermann et al. (2009a).
If we choose the source energy as 10^8 J, our model expects about one-third of the observed signal in both the lower atmosphere in the far field and the ionosphere. This amount of energy is 10^{1-2} times larger than that of the 2004 Asama eruption estimated from TEC observation (Heki, 2006). It seems to depend on not only the difference of volcanic eruption magnitude but also the crude assumption like ignoring the geomagnetic effect and geometrical spreading same as Dautermann et al. (2009) suggested.
We were not able to find any evidence for anisotropic radiation of energy as stated in some previous studies, suggesting that infrasound of such very low frequencies infrasound (< ~0.01 Hz) responds to with a longer time constant such as the growth of the thermal plume.
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Keywords: GPS-TEC, GNSS-TEC, Volcanic eruption, Infrasound, Broadband seismometer

