

# Plume height estimated from the Earth's acoustic resonant oscillations excited during large volcanic eruptions

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Shortly after the explosive 2022 Tonga volcanic eruption, harmonic Rayleigh waves with periods of ~230 s and ~270 s were radiated from Tonga and propagated around the globe. Harmonic Rayleigh waves, or the normal modes of the Earth, with the same two periods had been also observed during the 1991 Mt. Pinatubo volcanic eruption. Watada and Kanamori (2010) explained the harmonic ground motion as resonant oscillations between the solid Earth and the atmosphere excited by the eruption. The same acoustic resonance occurred after the explosive Tonga volcanic eruption.

The two periods were the same, but the amplitude ratios were different. For the Pinatubo eruption, the amplitude of the 230 s mode globally dominated, whereas for the Tonga eruption, the 270 s mode globally dominated.

We simulated the harmonic ground motion by calculating the synthetic ground motion of the atmosphere-solid Earth coupled system for explosive point sources at various altitudes in the atmosphere, and found that the amplitude ratio changes drastically with the source altitude. The 230 s overtone atmospheric acoustic mode is more efficiently excited than the 270 s fundamental atmospheric acoustic mode by a low-altitude (~10 km) source, whereas the 230 s mode is less efficiently excited than the 270 s mode by a high-altitude (>30 km) source. To explain the observed amplitude ratio of the two modes, 2~6, we found that the excitation source altitude should be at 40–50 km. This unusually high altitude, close to the stratopause, is consistent with the maximum height of the Tonga plume determined from the analysis of geostationary satellite images (Carr et al. 2022). The energy input to the atmosphere estimated from the isotropic seismic moment, which explains the observed resonant mode amplitudes, is  $9 \times 10^{16}$  J.

Keywords: acoustic resonant oscillation between the atmosphere and the solid Earth, 2022 Tonga submarine volcanic eruption, 1991 Mt. Pinatubo volcanic eruption, amplitude ratio of excited modes, plume altitude, eruption energy