

Constraints on the Hunga Tonga-Hunga Ha'apai eruption timing from remote magnetic field measurements.

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One of the astonishing aspects of the Jan-15 2022 Hunga Tonga-Hunga Ha'apai (HTHH) eruption was the intensity of the produced volcanic lightning. World-wide lightning detection networks recorded approximately 4×10^5 lightning strokes centred on HHTH in a 2-hour period starting around 04:10 Jan-15th UTC. Worldwide thunderstorm activity is one of the main sources of short-period electromagnetic wave energy used in magnetotelluric (MT) surveys. During the eruption, two continuously recording MT stations were operating on the east coast of New Zealand's North Island (~2000 km from HHTH), recording magnetic field variations continuously at 150 Hz using induction coils. The disturbances recorded in the magnetic field in the 10 ms to 1 s period range are tangentially polarized with respect to the direction of propagation from HHTH, consistent with a source at HHTH and electromagnetic wave propagation in the resonant cavity formed by the earth and the ionosphere. A weaker MT response was also recorded at an MT recording site in Japan; ~8000 km from HHTH.

Data from both the New Zealand (NZ) and Japan MT stations indicate volcanic lightning associated with the main eruption commenced between 04:08 and 04:14 Jan. 15th (UTC). This is in agreement with time estimates of the eruption initiation from visible satellite imagery and global seismic datasets. The intense electrical activity associated with the eruption lasted 2 hours, peaking about an hour after onset. The NZ MT data also show that a less-intense burst of electrical activity first developed the day (Jan 13th) before the main eruption, at about 17:00 UTC lasting about 0.5 hour. Later that morning, the Tongan Geological Service visually observed a towering eruption cloud with volcanic lightning at its margins. Additionally, a 0.7-hour long episode of intense lightning occurred about 4.5 hours after the onset of the main eruption, indicative of a second significant eruption, also seen in satellite imagery and seismic data, occurred at this time.

A further remarkable feature of the eruption was the atmospheric pressure wave that propagated across the world. Such an extremely energetic explosion suggests large quantities of magma and sea water came into contact. Based on barometric pressure data recorded throughout NZ and on islands to the north and south, the origin time for the 'detonation' event occurred about 0.25 hours after the onset of lightning. This delay suggests that the detonation was triggered post eruption onset, e.g., caused by roof collapse of a shallow magma chamber, allowing efficient magma-water mixing.

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