Hunga-Tonga Hunga-Ha'apai Eruption lightning as seen by remote MT measurements in New Zealand and Japan

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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 volcanic lightning produced. Worldwide lightning detection networks recorded approximately $4x10^5$ lightning strokes centred on HHTH in 2 hours starting around 04:10 Jan-15th UTC. During the eruption, two continuously recording MT stations were operating on the east coast of New Zealand's North Island, approximately 2000 km from HTHH. These stations continuously record the magnetic field variations at a sample rate of 150 Hz using induction coils manufactured by Phoenix Geophysics. A similar recording site in Japan, about 8000 km from HHTH, was also operating during the eruption. The magnetic field signals in the 10^{-2} s to 1 s period range in both New Zealand (NZ) and Japan are tangentially polarized with respect to the direction of propagation from HHTH; consistent with the expected surface-guided electromagnetic-wave propagation in the resonant cavity formed by the earth and the ionosphere. The agreement between spectral-time plots of the MT data and lightning count-rate data recorded by the Vaisala Global Lightning Detection Network (GLD360) at HTHH is remarkably good.

The NZ and Japanese MT data indicate volcanic lightning associated with the main eruption commenced between 04:08 and 04:14 Jan 15th (UTC). This agrees 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 50 minutes after onset. The NZ MT data also show that a less-intense burst of electrical activity first developed the day before the main eruption (Jan 13th), at about 17:00 UTC lasting about 0.5 hours. Later that morning, the Tongan Geological Service 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.

A remarkable feature of the eruption was the atmospheric pressure wave that propagated worldwide. Barometric pressure data recorded throughout NZ and on islands in the Pacific to the north and south of New Zealand shows that the origin time for the ‘detonation’ event that caused the pressure pulse occurred about the same time as the onset of lightning seen in the MT data. Such an energetic explosion suggests that large quantities of magma and seawater came into contact producing an eruption column that was water rich; conditions needed for ice formation and thus lightning production in the eruption column and in the high-altitude umbrella-cloud that spread outwards from the eruption centre.

Keywords: Hunga-Tonga Hunga-Ha'apai (HTHH), eruption, lightning, magnetotellurics