Volcanogenic tsunamis during the 2022 Hunga eruption, Tonga –constraints from numerical analysis and comparison with the 1883 Krakatau event –

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Large tsunamis were generated during the 15 Jan 2022 Hunga eruption and caused severe damage to coastal infrastructures and human activities in Tonga Islands. In the far-field including Japan, a major cause of tsunamis is thought to be the interaction between atmospheric pressure waves and the ocean (meteotsunamis); it is however still unclear for the near-field. In this study, the mechanism of the near-field tsunamis is discussed based on some evidence on tsunami arrival in the surrounding islands and numerical simulation. The tsunamis from the Hunga eruption were recorded at a tide gauge station at Nukualofa, Tongatapu Island, where the arrival time of the first wave with a height of ˜30 cm was 4:27 on 15 Jan (time is UTC hereafter), the amplitude gradually increased with the period of ˜5 min, and the wave amplitude reached the maximum of 1.2 m at 4:46. After that, the oscillation gradually declined. On the western coast of Tongatapu Island, the inundation height reached a maximum of ˜15 m (Tonga Geological Service). The large tsunamis also hit Haapai Islands, >70 km NE from the source, and some coastal areas were heavily damaged. The eruption destroyed the submarine cables around Tongatapu Island. The domestic line with the cable aligned in the eastern foot of the Hunga volcano was disconnected at ˜4:30 (Kentik), indicating that submarine mass flows, potentially caused by the summit (flank) collapse, hit this area. In the numerical simulation, non-linear shallow water wave equations are used. The methods and source models are almost the same as the ones used in the study of the 1883 Krakatau tsunamis (Maeno and Imamura, 2011 JGR). The study for the Hunga eruption examined phreatomagmatic explosion models (PME) with the explosion energy of 10^{17}-10^{18} J and two-layer models (SLIDE) representing the summit collapse with a volume of 0.3-4.8 km^3. In the SLIDE model, the propagation of submarine mass flows is considered. In all cases, the tsunami travel time to Nukualofa was ˜20 min. Therefore, if we assume the first positive wave was directly caused by the source volcanic process, the origin time of the tsunamis should be 4:07, which is the same timing as the onset of the eruption plume. Both models can explain the first positive peak at Nukualofa; however, fail to reproduce the waveforms such as the following successive higher amplitude characteristics. PME models may be difficult to explain the tsunamis on the western side of the Tongatapu and the Haapai Islands because the wave amplitude is rapidly decreased with distance, resulting in small-scale tsunamis in many cases. However, the SLIDE model with larger collapse volumes can explain the far-reaching higher-amplitude tsunami characteristics. Also, some results from this model suggest that the submarine mass flows can reach the eastern foot of the volcano within 6-10 min after the summit collapse was initiated. Assuming the summit collapse initiated around 4:20, submarine mass flows may reach the eastern foot at ˜4:30. In this case, the tsunamis caused by the collapse should arrive at Nukualofa after 4:40, which may explain the later higher peak arrivals. Another source is however required to explain the earlier smaller peak arrivals. At this stage, not all observations are reasonably explained by a single and simple mechanism like the 1883 Krakatau event. Coupled source models, more valid initial and boundary conditions based on bathymetry change, and other factors such as strong atmospheric pressure disturbance during the initial explosive phase may provide better constraints to the mechanism of the near-field volcanogenic tsunamis during the Hunga eruption.

Keywords: volcanogenic tsunamis, phreatomagmatic explosion, flank collapse, Hunga volcano