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Novel numerical modelling of tsunamis from volcanic explosions

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The highly explosive eruption at Hunga Tonga-Hunga Ha'apai and subsequent tsunami in January 2022 has reinforced the necessity to explore and quantify volcanic tsunami sources. However, a lack of previous field data and modelling effort means that volcanogenic tsunami and wave hazard remains less understood than that of other tsunami sources. Numerous localities across the Pacific, including the northern shores of New Zealand, may yet be found to be exposed to such events in the future. Caldera lakes, such as Lake Taupō, may also experience tsunami-like hazards from volcanic eruptions.

The study simulates 20 volcanic explosion scenarios across Lake Taupō of varying magnitudes to explore the scope and scale of potential wave hazard on the foreshore of the lake from such eruptions. To do this, a non-hydrostatic multilayer numerical method is used to reliably capture the higher dispersivity of waves generated from an explosion and simulate their propagation through to their interaction with the shores, including that of the built environment. The outputs from simulations include mapping of significant wave amplitudes, any inundation near built areas and roads, and a more targeted hydrographic analysis of incident waves flowing towards the Waikato River control gate.

Results from the scenario suite indicate that locally significant waves start being generated in the lake at an eruption size approximately equivalent to one at 5 on the Volcanic Explosivity Index – a large eruption. In addition, the most hazardous inundating waves were often found on shores most directly exposed to the eruptions, including the eastern shore where State Highway 1 often runs nearby or alongside. Given the location, little resilience to this hazard is likely present and may be a compounding factor to the many hazards present during a volcanic eruption.

While the event at Tonga showed the effectiveness of a community-driven response, many other coastal areas within proximity of volcanoes may currently be less prepared for tsunamis of this type, even when considering current tsunami warning systems. The current opportunity of incorporating field data from Tonga into further experimentation and hazard investigations should not be missed; exposed coastlines around the Pacific should be aware to incorporate this mechanism into hazard studies.

To read the full paper on modelling volcanogenic tsunamis, go to https://doi.org/10.5194/nhess-23-955-2023

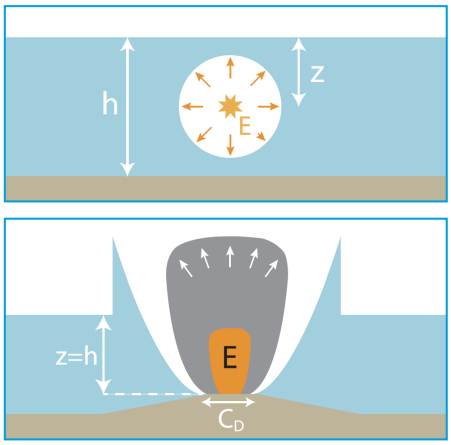

Figure 1 (right): Illustration of the submarine explosion problem (above); and an explosion of yield E and depth z in water of depth h (below). Schematic of a volcanic scenario in which such an explosion would occur where z=h, and crater diameter C_D can be measured or calculated using estimated ejecta volume V.

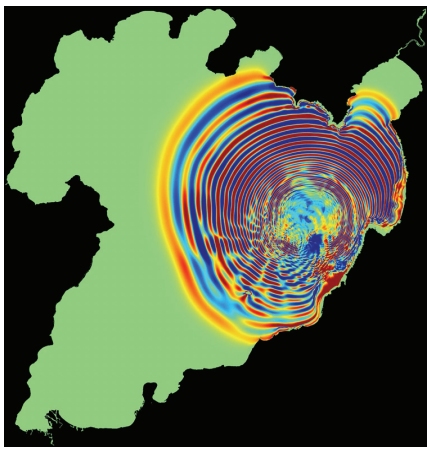

Figure 2 (above): Snapshot of wave amplitudes from a simulation of waves generated by a possible volcanic eruption within Lake Taupō, where the maximum amplitudes were approximately 2 m.

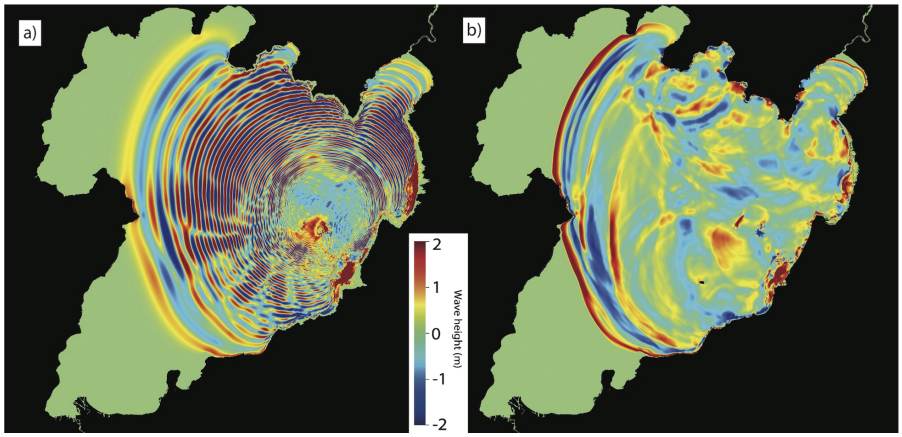

Figure 3 (left): Simulation snapshots of waves generated by a volcanic explosion in Lake Taupō using (a) the multilayer non-hydrostatic model, and (b) the usual shallow water equations model.