Characterizing Tsunami Signals from the Hunga Tonga Hunga Ha'apai Eruption and its Effects on the Caribbean

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1. INTRODUCTION

Purpose & Objectives:

- To characterize the tsunami wave associated with the Hunga Tonga eruption of January 15, 2022
- To examine the fluxes and disturbances in tide gauge data observed around the Caribbean
- To determine if there is a relationship between the tsunami wave arrivals and the barometric pressure spikes (possibility of air-coupled surface waves)
- To provide valuable information for the advancement of knowledge into the factors that drive volcanic tsunamis

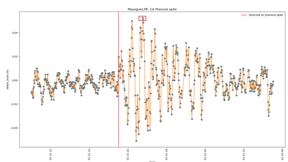
Background:

The eruption was distinguished by a massive explosion that obliterated the volcanic island of Hunga Tonga-Hunga Ha'apai and caused tsunami waves to propagate through the Pacific Ocean, reaching great distances and being recorded around the world. About 12 hours after the eruption, multiple stations in the Caribbean detected small-amplitude waves, which is considered far too early for the eruption to have arrived (UNESCO-IOC-NOAA). For instance, the PRSN Tide Tool estimates predicted an arrival from a water column displacement at 07:22 UTC on January 16, 2022, whereas the Mayagüez station recorded a tsunami signal at 15:30 UTC on January 15, 2022 (Personal communication, E. Vanacore and B. Colón). These fluctuations have therefore been attributed to air pressure waves from the eruption, which were detected at numerous barometric stations.

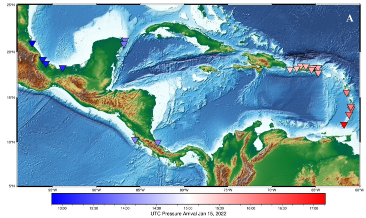
2. METHODS AND DATA

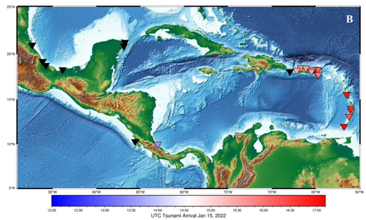
Data was collected from Jan 14-Jan 21, 2022. The collection of data from the barometer stations was done through the NOAA tides and currents database. The data recovered from these barometric stations were used to identify the specific arrival time of each barometric pressure spike associated with the eruption of Hunga Tonga. The millibar and polarity of the barometric pressure spikes were also noted. The sea-level data was collected from the PRSN and IOC repository.

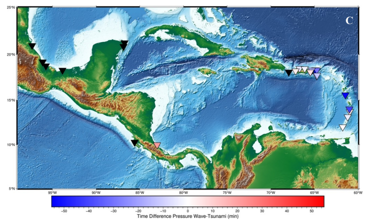
For the sea level stations, 1-minute sample data was used. A high pass filter was used to remove the tides, retaining periods shorter than approximately 2 hours while retaining the tsunami signal. The mean was also removed to center the water level readings at 0, given that some stations could have a constant offset. Frequency and sea-level plots were used to record the dominant frequency as well as the maximum amplitude, measured as half amplitudes. The difference between the barometric pressure spike and the tsunami signal arrival times was calculated. Frequency analysis of each pressure spike relative to sea level was done using the resulting plots.



3. RESULTS







Overall, there were around 3-5 observed barometric pressure spikes in Puerto Rico and varied widely across the Caribbean. In the case of Mexico, there were no observed tsunami wave arrivals. The first pressure wave was the most noticeable and then the rest showed to dissipate over time. In addition, the polarity of the first pressure wave on January 15 was observed to be positive throughout the region as well, with the following spikes showing different polarities throughout the region. Therefore, the focus of the plots on the left are of the first observed pressure wave on the day of the eruption: January 15, 2022.

A) This map shows the arrival times in UTC of the spikes in barometric pressure throughout the region. Here it is evident that the pressure wave of Jan 15 traversed the Caribbean from East to West. The latest arrival was recorded in the Mexican stations at about 13:00 and the earliest in the West Indies at around 17:00.

B) The map shows the arrival times in UTC of the tsunami wave. This displays that the tsunami wave was first recorded in the stations of the West Indies, at about 17:00, followed by Puerto Rico with arrival times near 15:30 and finally Costa Rica at about 14:00. Here the black triangles are stations that had no observable data.

C) This map shows the differences in arrival times between the tsunami and the air pressure wave. Here it is evident that the air pressure spike was generally near coincident with the arrival of the tsunami wave for the stations in Puerto Rico and the southernmost West Indies, showing time differences between 0-5 minutes. Results also show some disparities within the region.

It is important to note that due to the lack of standardization in the picking of arrival times, some stations resulted in no observations, which in turn poses a difficulty for comprehensive analysis.

4. CONCLUSIONS

- Around 3-5 observed barometric pressure spikes in Puerto Rico and varied widely across the Caribbean.
- Air pressure and Lamb wave generated tsunami was coincident with a difference of 3-5 min (except 2nd air pressure wave).
- There is a clear character change in water level once the pressure wave arrives, resulting in amplitudes a lot larger than those produced by the tsunami arrival.
- 2nd air pressure wave with a delay of 80-90 min, differences in frequency, and longer duration suggest a different mechanism is at play.
- There were only 2 pressure waves to have coherent observations throughout the region, the first being on Jan 15 and the second on Jan 16 ~04:00 UTC.
- Differences in coincident arrival times may be due to the directionality of the wave, bathymetric impacts, different geology or instrumentation.

Future work:

- Examining and analyzing the causes of the variation between the 2nd barometric spike and the others.
- Collaborations are underway with studies of this event on Brazil, Mexico and Costa Rica.

5. ACKNOWLEDGEMENTS

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