

METEOROLOGICAL TSUNAMIS FROM ATMOSPHERIC EFFECTS AND VOLCANIC ERUPTIONS - A HAZARD FOR COASTAL REGIONS AND PORTS

Charitha Pattiaratchi, The University of Western Australia, chari.pattiaratchi@uwa.edu.au
Sarath Wijeratne The University of Western Australia, sarath.wijeratne@uwa.edu.au

INTRODUCTION

Meteorological tsunamis, or meteotsunamis, are similar to tsunami waves that are generated by seismic or volcanic activity, except they are forced through the atmospheric effects. The main forcing mechanism is an abrupt change in sea surface atmospheric pressure propagating over the ocean (Figure 1). These may be due to atmospheric effects or volcanic eruptions. Proudman resonance (Pattiaratchi and Wijeratne, 2015) is the primary generation mechanism for meteotsunamis that results when the propagation speed of the pressure jump (V) is equal to the local surface gravity wave speed (c). This is expressed as the condition where the Froude number ($F_r=V/c$) defines the energy transfer between the atmosphere and the ocean and is at a maximum when $F_r=1$ with the sea level peak in advance of the pressure jump (Figure 1). Meteotsunamis are considered as a multi-resonant phenomenon where destructive events occur only when a coincidence of several crucial factors takes place at the same time. These include (Pattiaratchi and Wijeratne, 2015): (1) the generating atmospheric system; (2) the continental shelf and slope topography; and, (3) the topography and geometry of the coastline (harbours, bays, river mouths etc.). All three of the conditions described above depend on the coastal topography and bathymetry as the speed of the shallow water waves is dependent on the water depths. Meteotsunamis are a global phenomenon with many regions have particular names that identify this phenomenon with different forcing mechanisms. For example, in south-west Australia meteotsunamis are a regular occurrence that occur throughout the year but there is seasonality in the forcing mechanisms. During the summer months, meteotsunamis are generated by thunderstorm activity and tropical cyclone forcing and during the winter months through the passage of cold fronts. Although meteotsunamis were generated by transiting atmospheric pressure jumps the resulting wave forms from the various mechanisms were also different. Meteotsunamis generated by the passage of cold fronts induced oscillations inside harbours that lasted longer than those due to thunderstorms or tropical cyclones.

In this paper, an overview of the occurrence of meteotsunamis in Australia will be provided through the analysis of sea level measurements and/or currents with an emphasis of their effects in ports and harbours. In particular, events at Fremantle Port (that resulted in breaks in ship moorings inside the port); Port Geographe marina (oscillations and strong currents inside marina); and, a recent global event that was caused by the Hunga Tonga-hunga Ha'apai volcanic eruption in south-west Pacific Ocean in January 2022 (recorded in many tide gages globally - but more of relevance to this paper in Australia and across the Indian Ocean).

Field measurements of meteotsunami events at Fremantle Port and Port Geographe had maximum wave heights $\sim 0.5\text{m}$ were associated with maximum horizontal currents a factor 2-3 above the background currents.

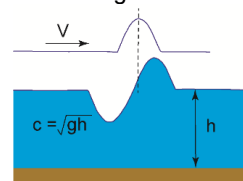


Figure 1. Schematic of the generation of a meteotsunami through Proudman resonance.

The Tonga volcanic eruptions caused volcanic and meteotsunamis that were observed across ocean basins globally. In this study, we investigated the westward propagating tsunami signals using tide gauge records and numerical simulations. The atmospheric pressure wave with fast moving pressure jump was generated by the eruption. The moving pressure jump appeared as a $\sim 6.5\text{-hPa}$ jump across Australia and was estimated to at $\sim 340\text{ ms}^{-1}$ between Norfolk Island and Perth. The westward moving tsunami signals were recorded on the tide gauges located in the east and south-west Australian coasts and across the Indian Ocean. There were two distinct signal on the tide gauge records. The first signal arrived well before the expected tsunami arrival time on the east coast of Australia. The arrival time of second signal corresponded to fault displacement generated ocean tsunami wave as a free wave. These waves were well described by numerical simulations incorporating a moving atmospheric pressure jump with a speed of $\sim 340\text{ ms}^{-1}$. The long ocean waves were amplified due to Proudman resonance in the deep ocean, where the water depths are greater than 5000 m.

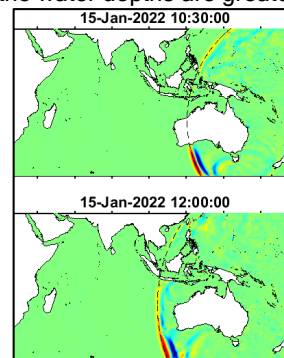


Figure 2. Simulation of the meteotsunami sea level changes associated with the pressure wave (dashed line) generated by the Tonga Volcanic eruption.

REFERENCES

Pattiaratchi and Wijeratne, (2015): Are meteotsunamis an underrated hazard? *Philosophical Transactions Royal Society of London A*. doi:10.1098/rsta.2014.0377.