

# THE ROLE OF TSUNAMI RESONANCE ON THE BALANCE OF MECHANICAL ENERGY AND ITS IMPLICATIONS FOR FRAGILITY ANALYSES

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## INTRODUCTION

Tsunamis are rare events that can cause widespread damage and devastation even at remote locations far removed from the source location. Among the reasons for this damage potential are their minimal energy loss during their propagation, as well as being prone to energy trapping by mesoscale features such as continental shelves and shallow water bays, which may promote standing and edge wave activity. This may lead to an enhanced tsunami response in certain locations, which can exacerbate the hazard compared to surrounding locations.

On the other hand, tsunami hazard characterizations require determining multiple tsunami intensity metrics, such as flow depth, velocities, and momentum fluxes. These in turn can be used as input to assess vulnerability or infrastructure damage if the appropriate transfer function is available. To date, empirically derived tsunami fragility curves relating flow depth with the probability of damage are among the most used ways to estimate damage potential. This is due in part to the complexity of establishing and modeling the interaction between infrastructure and tsunami flows at a reasonable computational cost.

Among the downsides of the empirical fragility curves is that they are derived from observations and statistical analysis of the damage inflicted by past tsunamis. While this may provide real-world information, the results can be conditioned by several factors. One is the building types and building techniques used, that may prevent transferring results from one location to the next. Another is that the most readily available physical evidence from the tsunami itself is water levels (tsunami wave heights and/or flow depths). Other tsunami intensity metrics usually need to be derived using numerical modeling, as first-hand observations are rare. Past analyses and comparative analyses have shown that flow-depth-based empirical fragility curves may not be reliable enough and momentum flux-based fragility curves (Park et al, 2017; Suppasri et al., 2015).

However, little attention has been devoted to understanding the reason for this possible discrepancy, and whether it holds true for most cases. Implicitly, choosing one model over the other requires identifying whether the flow is subcritical or supercritical, or in other words, whether the flow is dominated by its potential energy or its kinetic energy. It appears that in most cases, supercritical flows have been the basis for favoring the use of momentum flux-based fragility curves.

Yet in bays dominated by resonance, the maximum inundation levels occur due to the development of a series

of standing wave modes, with slow velocities and large amplitudes, thereby potentially classifiable as subcritical flow. It is noted that the bay of Coquimbo, Chile, is a location that it is well dominated by resonance. Here, Aránguiz et al. (2018) found that the flow depth-based empirical fragility curve yielded a better correlation than the momentum flux version, in the aftermath of 2015 Mw 8.4 Illapel Earthquake and Tsunami.

## METHODOLOGY

This has prompted us to attempt to understand to which extent, resonance can drive subcritical tsunami flows. To this end, we carried out high-resolution modeling of tsunami inundation at three different locations along the coast of Chile. The aforementioned Coquimbo, the large metropolitan area of Valparaíso and Viña del Mar, and the main port of San Antonio.

A suite of 350, stochastically generated earthquakes in the Mw range 8.6-9.2 (50 scenarios for each magnitude bin, with Mw 0.1 increments) were modeled using tsunami HySEA (Macías et al., 2017) using four nested grids with a maximum resolution of 10 m. Tsunami inundation time series were obtained at several numerical tide gages along the coastlines of each city, to address the flow characteristics before bottom friction dissipation altered the energy balance.

Initial results indicate that Valparaíso and Viña del Mar are characterized by tsunami inundation driven by very fast initial waves, which are almost always the largest wave on the set. These cities, as well as San Antonio port, do not show a clear resonant structure. On the other hand, Coquimbo Bay has a clear resonant pattern with a first mode structure that has its largest amplification in the southern section of the bay. In this section of coastline, the first wave is not the largest, nor the one that carries most of the momentum, and the most damaging ones are late arriving waves when prior empirical fragility curves are used as for damage estimation. Notably, this was the area that sustained most of the damage during the 2015 event and is the area where Aránquiz et al. (2018) found better agreement with flow depth-based empirical fragility curves.

These preliminary results may suggest that fragility curves might not be as readily applicable across locations with vastly different hydrodynamic responses. We expect to dwell into more details at the conference.

## REFERENCES

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