

NON-STATIONARY PROBABILISTIC TSUNAMI HAZARD ASSESSMENTS INCORPORATING TIDES AND SEA LEVEL RISE

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INTRODUCTION

Tides and climate driven sea level rise (SLR) contribute significantly to water level changes in the short and long term, respectively. In terms of magnitude, they could be comparable to tsunamis of interest at certain coasts. New non-stationary probabilistic tsunami hazard assessment (nPTHA) methods that were developed to include the mean sea level changes due to a warming climate are now extended to incorporate the uncertainty of the tidal phase at the moment of tsunami occurrence. Here, a collocation-based model is used in the nPTHA method to render the calculation feasible and efficient.

FORMULATION

Tsunami responses are affected by a temporally evolving SLR, s , and tides, η , as shown in Fig. 1(a). Let T be the exposure time of a given coastal structure, and $H_1, H_2, \dots, H_{N_{Ei}(T)}$ be the tsunami hazard responses (intensities) of a variable of interest (e.g. a tsunami elevation), corresponding to a number of samples $N_{Ei}(T)$ of random earthquakes, being triggered when the mean sea level is $s_1, s_2, \dots, s_{N_{Ei}(T)}$ and the tides are $\eta_1, \eta_2, \dots, \eta_{N_{Ei}(T)}$. The probability that none of the $N_{Ei}(T)$ tsunami responses exceed a critical value h_c , denoted as $N_{hc}(T)=0$, can be provided by an nPTHA formulation using a collocation-based model. The formulation of Sepulveda et al. (2021) is extended to include the influence of tides. The new formulation is given by,

$$P(N_{hc}(T) = 0) = e^{-\sum_i \sum_{j=1}^{N_{bin}} P_{\eta_j} \int_0^T \lambda_{E_i} P(H > h_c | E_i, \eta_j, s(t)) dt} \quad (1)$$

where E_i corresponds to an ensemble of earthquakes having the same target magnitude, occurring within the same seismogenic region and having an average recurrence rate λ_{E_i} . η_j corresponds to a partition of the tidal range, at the evaluated site, into N_{bin} non-overlapping intervals with probability of occurrence P_{η_j} (which can be determined from histograms of long-term tide records). A quadrature method is employed to solve for the integral in Eq. (1) and a collocation-based model is then used to solve for $P(H > h_c | E_i, \eta_j, s(t))$. The collocation method consists of a small set of $P(H > h_c | E_i, \eta_k, s_k)$ curves which are solved for specific pair of values (η_k, s_k) . The distribution curves for any other η and s can be then obtained by interpolation.

EXAMPLE CASE FROM THE SOUTH CHINA SEA

The tsunami hazard due to earthquakes generated in the Manila Subduction Zone is evaluated. Eleven earthquake ensembles ranging in magnitude from Mw 7.5 to Mw 9.0 and located in 3 seismogenic regions are considered. Earthquakes are modeled with a random

slip and location. The tidal stage is represented by a constant tide level for a given simulation. Thus, the sea level at the time of tsunami occurrence is simply the sum of η and s . Four collocation points with $\eta+s$ being -1.5, 0, 0.56, and 1.125 m are used to build 4 distribution curves $P(H > h_c | E_i, \eta_j, s(t))$. The curves are built by adopting a stochastic reduced order model to include the uncertainty of tsunamis due to the uncertain earthquake slip and location. The COMCOT tsunami model is adopted to map earthquake samples to tsunami responses and where the collocation sea levels are also specified. Tide records and SLR models for the South China Sea are used to determine P_{η_j} and $s(t)$.

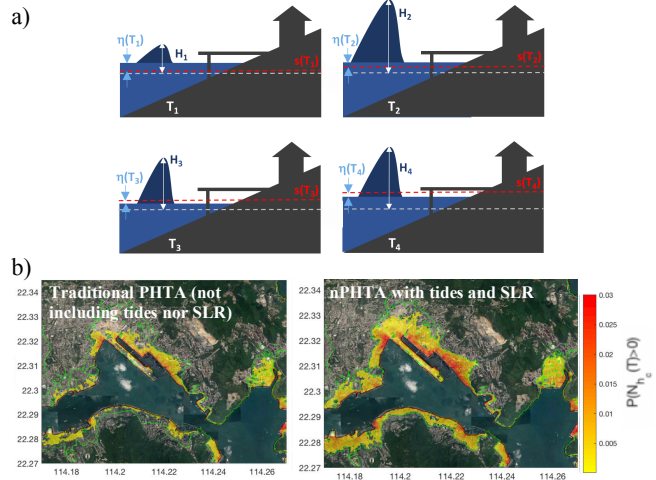


Figure 1: (a) Schematic of the tsunami, tide and SLR in a nPTHA. Earthquakes generate different tsunami wave heights, which are then influenced by tides and SLR to give the intensity H . (b) Probability of inundation of Hong Kong for $T=100$ years ($P(N_{hc}(T) > 0)$) when considering tsunamis only (left panel), and tsunami, tides and SLR (right panel).

RESULTS

nPTHA results show that tides and SLR are relevant factors when they are comparable to the size of tsunamis of interest within the exposure time. Fig. 1b shows a significant impact of tides and SLR when performing a probabilistic tsunami assessment of inundation in Hong Kong for an exposure time of $T=100$ years. Further studies are planned to understand the role of time-varying tidal levels and currents.

REFERENCES

Sepulveda, Haase, Liu, Grigoriu & Winckler (2021). Non-stationary probabilistic tsunami hazard assessments incorporating climate-change-driven sea level rise. *Earth's Future*.