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Accommodating undulating tidal planes in tsunami models

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Abstract: Tsunamis interact with the tides as they propagate through the ocean. However, emergency risk management often prefers to assume a conservatively high static sea level – typically the highest astronomical tide (HAT) – which is unlikely to be exceeded at the time of a real tsunami. Modellers then simulate tsunami scenarios using this high background sea level, either on a case-by-case basis or as part of a probabilistic model of tsunami hazards, which may involve thousands of simulations.

However, HAT is not a uniform height above mean sea level (MSL); it varies from location to location due to the interplay of the ocean and topography under astronomical forces. This spatial variation is salient near Broome (WA) and Mackay (QLD). For example, in the region surrounding Mackay, HAT varies from 1.4 m above MSL at Lady Elliot Island to over 5.4 m near St Lawrence: a 4 m variation. Selecting any single tidal plane in such regions leads to over- or under-estimation of the tsunami hazard. Alternatively, imposing an uneven background sea level will not work because it will induce spurious flows, unrelated to the tsunami. This poses a challenge for tsunami inundation modelling in these regions.

Existing solutions, such as running scenarios at multiple background sea levels or tidal phases, suffer significant computational overhead. Dynamical tide models need a burn-in period and multiple runs to account for the random timing of the tsunami. Both solutions have impracticalities for high resolution inundation modelling, which is already computationally expensive.

We propose a simple yet effective technique to model tsunamis with a spatially varying HAT. Unlike existing methods, it does not require separate simulations at multiple tidal levels and does not induce spurious flows due to an uneven sea surface. We demonstrate the accuracy of this method in a case study of the Gladstone region, south of Mackay. To do this, we developed, tested and validated an open-source hydrodynamic model of tsunami propagation across the Pacific Ocean, using nested grids to resolve sites of interest in Gladstone with resolution down to 10 m. Earthquake-tsunami scenarios are sampled from the 2018 Australian Probabilistic Tsunami Hazard Assessment database (Davies & Griffin, 2018). Scenarios are randomly sampled from four major earthquake sources aided by importance sampling to emphasise significant tsunamis.

We ran scenarios with the proposed tidal adjustment technique and compared them to models using a single static tide. These tests were done at three tidal levels appropriate for three distinct sites: Lady Elliot Island, Boyne Island, and Rosslyn Bay, which have markedly different HAT levels. The results reiterate that a single tidal plane would be insufficient to model hazards at all sites. However, the new approach showed good agreement with the models using static tides tuned to each area of interest. Tsunami depths at key spots matched expectations. Probabilistic hazard maps of inundation and hazardous speeds produced using the proposed method showed similar patterns to the static version, confirming the accuracy of the new method.

The proposed tidal adjustment technique allows tsunami hazard assessments to be conducted efficiently in regions with spatially heterogeneous tidal planes. While the technique should be validated on a site by site basis, this is a comparatively small numerical effort. Otherwise, it bypasses the need for scenario re-runs at multiple tidal levels, which is important for computationally intensive tsunami inundation modelling. The technique may also be adapted and tested for other coastal hazards such as storm surges or meteo-tsunamis.

REFERENCES

Davies G and Griffin J (2018) The 2018 Australian Probabilistic Tsunami Hazard Assessment: Hazards from earthquake generated tsunamis. Geoscience Australia Record 2018/41

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