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On the generation of tsunami under time-dependent disturbances of the seafloor

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Tsunamis are water waves often generated by large-scale seafloor disturbances due to source mechanisms such as earthquakes, landslides or volcanic activities. Some of them may only act for seconds and thus instantaneous initial conditions may be assumed; yet others may last much longer, enough to influence the generation and subsequent evolution of tsunamis. Typical examples are tsunami earthquakes and submarine landslides. To account for temporal and spatial effects of such disturbances on tsunami generation, a two-layer numerical model was developed to study tsunami hazard triggered by tsunami earthquakes and submarine landslides. In this two-layer system, the lower layer unifies earthquake and landslide tsunami generation mechanisms as a time-dependent topographical disturbance on the seafloor, and calculates the topographical variation as a function of time and space. This variation then serves as a forcing bottom boundary condition of the upper water layer for the simulation of tsunami generation and evolution through time integration.

Using this numerical model, we investigated a typical tsunami earthquake offshore Gisborne New Zealand in March 1947 and were able to explain the exceptionally high tsunami waves observed in this event. We also found that in tsunami simulations using a dynamic fault rupture model tsunami waves are generated that are over 10% higher than using traditional static fault displacement models, e.g., Okada's method which estimates steady-state displacements in an earthquake event. A submarine debris avalanche in the Southern Hikurangi trough offshore New Zealand was also studied using this dynamic rupture model, using high-resolution multi-beam imaging data for the estimate of its failure volume and the reconstruction of the pre- and post-failure bathymetry. The modeled deposition agrees fairly well with the observation. This model has demonstrated a high computational efficiency and good accuracy. This is crucial for large-scale computations, e.g., probabilistic hazard analysis that usually requires hundreds to thousands of simulations.