Probabilistic Submarine Landslide Tsunami Hazard Assessment along the United States Northeast Coast

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Abstract

Tsunami hazard assessment is critical for coastal communities, emergency services, and industry, to develop regional risk and response management plans, for catastrophic tsunami events (such as the recent 1998 Papua New Guinea (PNG) and 2004 Indian Ocean tsunamis). Along the northeastern United States coastline, tsunami hazard assessment is in its infancy, mostly due to the lack of historical tsunami record and the uncertainty regarding the return periods of potential large-scale events. The latter includes large transoceanic tsunamis, such as could be caused by a collapse of the Cumbre Vieja volcano in the Canary Islands or a large co-seismic tsunami initiated in the Puerto Rican trench, as well as large local tsunamis, such as could be caused by a Submarine Mass Failure (SMF) occurring on the nearby continental slope. In this region, considerable geologic and some historical (e.g., the 1929 Grand Bank landslide tsunami) evidence suggests that the largest tsunami hazard may arise from tsunamigenic SMFs, triggered by moderate seismic activity. The coastal impact of SMF (or landslide) tsunamis, indeed, can potentially be narrowly focused and affect specific communities.

This research presents the development, validation, and results of a probabilistic geotechnical and coastal tsunami impact analysis model, to estimate the tsunami hazard on the upper northeast coast of the United States. Results are presented in terms of nearshore breaking wave height and runup, caused by seismically induced tsunamigenic SMFs, with a given return period. A Monte Carlo approach is employed, in which distributions of relevant parameters (seismicity, sediment properties, type and location, volume, and dimensions of slide, water depth, etc.) are used to perform large numbers of stochastic stability analyses of submerged slopes (along actual shelf transects), based on standard pseudo-static limit equilibrium methods. The distribution of predicted slope failures along the upper U.S. East Coast is found to match published data quite well.

For slopes that are deemed unstable for a specified ground acceleration (with given return period), the tsunami source characteristic height is found using empirical equations (based on earlier numerical simulation work), and corresponding breaking height and runup are estimated on the nearest coastline. For a 0.2% annual-probability ground acceleration, for instance, simulations yield a return period of tsunamigenic SMFs of 3,350-yr (i.e., a 0.03% annual-probability of occurrence). To quantify the hazard, in comparable terms of typical engineering design hazards (i.e. 100-yr and 500-yr events), a statistical methodology was devised to determine “design” tsunami magnitudes associated to given return periods (i.e 100 and 500-yr return periods). The resulting estimate of the overall coastal hazard, from 100 and 500-year SMF “design” tsunami events, is found to be quite low at most locations, as compared to the typical 100 year hurricane storm surge in the region (~4-5 m). Specifically, for the 100 year event, SMF tsunami hazard is quite low with no coastal region exceeding a 1 m runup. For the 500 year event, however, two regions of relatively elevated hazard are found: (1) near Long Island, NY, with a peak runup of 3 m; and (2) near the New Jersey coast, with a peak runup of 4 m. It should be stressed that these are only first-order estimates and detailed tsunami inundation modeling is required to fully quantify tsunami runup (and inundation) at these sites. This will be the object of more detailed studies in future work.