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Probabilistic Hazard for Seismically-Induced Tsunamis in Complex Tectonic Contexts: Event Tree Approach to Seismic Source Variability and Practical Feasibility of Inundation Maps

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Probabilistic Tsunami Hazard Analysis (PTHA) rests on computationally demanding numerical simulations of the tsunami generation and propagation up to the inundated coastline. We here focus on tsunamis generated by the co-seismic sea floor displacement, which constitute the vast majority of the observed tsunami events, i.e. on Seismic PTHA (SPTHA). For incorporating the full expected seismic source variability, aiming at a complete SPTHA, a very large number of numerical tsunami scenarios is typically needed, especially for complex tectonic contexts, where SPTHA is not dominated by large subduction earthquakes only. Here, we propose a viable approach for reducing the number of simulations for a given set of input earthquakes representing the modelled aleatory uncertainties of the seismic rupture parameters. Our approach is based on a preliminary analysis of the SPTHA of maximum offshore wave height (HMax) at a given target location, and assuming computationally cheap linear propagation. We start with defining an operational SPTHA framework in which we then introduce a simplified Event Tree approach, combined with a Green's functions approach, for obtaining a first controlled sampling and reduction of the effective source parameter space size. We then apply a two-stage filtering procedure to the 'linear' SPTHA results. The first filter identifies and discards all the sources producing a negligible contribution at the target location, for example the smallest earthquakes or those directing most of tsunami energy elsewhere. The second filter performs a cluster analysis aimed at selecting groups of source parameters producing comparable HMax profiles for each earthquake magnitude at the given test site. We thus select a limited set of sources that is subsequently used for calculating 'nonlinear' probabilistic inundation maps at the target location. We find that the optimal subset of simulations needed for inundation calculations can be obtained basing on just the offshore HMax values, provided that the set of the offshore control points is representative of the inundation zone. The two-stage scenario filtering procedure is semi-automatic and it can be easily repeated for different target locations. We describe and test the performances of our approach on a case study in the Mediterranean, considering potential subduction earthquakes on a section of the Hellenic Arc, and for three target sites on the coast of eastern Sicily and one site on the coast of southern Crete. Comparing the filtered SPTHA results with the full set of inundation maps indicates that our approach allows a reduction factor of 75-80% of the numerical simulations needed for practical applications while preserving the consistency of results. The differences are indeed likely within potential epistemic uncertainties, not considered here, such as those related to tsunami generation and propagation models, bathymetric and topographic models, or other basic and less constrained unknowns related to earthquake activity rates or slip distribution probability.