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Optimization of earthquake source description for tsunami early warning purposes

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It is well known that ruptures on the generating faults of large earthquakes are strongly heterogeneous and, in the case of tsunamigenic earthquakes, the slip heterogeneity strongly influences the spatial distribution of the largest tsunami effects along the nearest coastlines. The main problem in both tsunami hazard assessment and early warning applications is that the pattern of the slip heterogeneity cannot be forecasted in advance. Moreover, the relative position of the earthquake hypocenter and of the main asperities is not predictable. As a consequence, typical approaches used for tsunami hazard assessment and early-warning involve the building of databases of a large number of pre-computed tsunami “scenarios”, obtained either starting from elementary (uniform slip) earthquake sources or for arbitrary heterogeneous slip patterns, which are then combined together or weighted suitably to reproduce the tsunami real-time/post-event observations.

In this study, focused on earthquakes large enough to be capable of generating tsunamis, we describe the first stages of an alternative approach aimed at involving the least possible number of tsunami numerical simulations and having the double scope of 1) representing the real, complex coseismic on-fault slip distribution in a suitable way, and 2) providing the distribution of the expected tsunami heights along a given coastal stretch. The methodology is valid when the on-fault heterogeneous slip pattern reduces to one single main asperity. The starting point consists in the modelling of the asperity with 2D Gaussian function (2D-GF), whose geometrical properties depend exclusively on the parent earthquake’s magnitude through suitable regression laws. Since the position of the 2D-GF with respect to the hypocenter over the fault plane is unknown, we build a fault plane having a much larger area than what would result from classical scaling laws against magnitude/seismic moment. The on-fault slip distribution over this larger source, which we will call “megasource”, is obtained by considering the contribution of an infinite number of 2D-GFs located around the hypocenter, placed at the center of the “megasource” itself. A first set of theoretical tests consists in comparing the time histories of the tsunami amplitudes and the tsunami elevation maxima along the coastline of computational domains involving simplified bathymetries and rectilinear coastlines: the aim of the comparison is to check the compatibility of the results obtained for the “megasource” with those obtained by summing up the contributions from a drastically-reduced number of simulations relative to individual 2D-GFs displaced around the hypocenter. Secondly, we introduce more complicated coastlines, either deduced from simple analytical functions or mimicking real coastline morphologies, and repeat the comparison described above. The goal of these comparisons is to deduce a criterion allowing to reduce the number of single 2D-GFs, and hence of tsunami simulations, and to deduce proper weighting functions/probability distributions to be directly applied to the coastal tsunami elevation maxima.