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Can simple magnitude-dependent 2D Gaussian representations of co-seismic slip distributions improve real time tsunami simulations?

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Retrieving reliable finite-fault models (FFMs) for large earthquakes worldwide is a problem which is of interest to several fields in geosciences, ranging from the pure seismological to the tsunami research. The time needed to obtain a reliable FFM for a given earthquake after the earthquake onset can have important implications in real-time warning and hazard assessment perspectives. In this contribution, we are especially interested in large earthquakes capable of generating tsunamis and in the possible advantages of representing the real, and often complex coseismic on-fault slip distribution by means of simple, yet realistic 2D Gaussian functions (2D-GF) depending exclusively on the parent earthquake's magnitude.

To this purpose, we adopt the following strategy: starting from a suitable database of FFMs (in particular, a subset of SRCMOD), we explore characteristic patterns of slip distribution for large earthquakes and focus on those FFMs that exhibit a single and clear region of high slip (i.e. a single asperity), which are found to represent the majority of the events. For these FFMs, we best-fit the slip model by means of a 2D-GF defined by three parameters (semi-major and semi-minor axes, rotation angle), whose values are retrieved based on suitable regressions against the earthquake magnitude. The discrepancy with respect to the original FFM is measured through a misfit computed by taking the co-seismic vertical surface displacement as the metric for comparison. In the large majority of the studied events, the misfit obtained for the 2D-GF is found to be much less than that obtained for the uniform slip distribution and for other simple heterogeneous patterns, such as that based on the "smooth-closure condition" (SCC).

Restricting our attention to large tsunamigenic earthquakes, we tested our procedure on a couple of historical earthquake-generated tsunamis sharing the following characteristics: 1) the FFMs proposed in the literature for the parent earthquakes are characterized by a single main slip patch, 2) the earthquakes generated tsunamis that are well-documented in terms of "experimental" data (water level time series and/or run-up/flow-depth measurements), especially in the near-field. The choice involved the November 15th, 2006 Kuril Islands and the September 9th, 2015 Coquimbo (Chile) earthquakes. For each of the chosen events, we compute the tsunami initial condition, coinciding with the seafloor co-seismic vertical displacement field, starting from four different on-fault slip distributions (the original FFM, the 2D-GF, the uniform and the SCC distributions). In each case, the propagation of the ensuing tsunamis and their impact on the coasts are simulated numerically by means of the shallow-water code UBO-TSUFD. We compare the numerical results for different initial conditions against the experimental data, focussing on the near field. The results are discussed both from the seismological and from the tsunami early warning perspectives, posing special attention to the performance of the 2D-GF.