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Modeling of generation, propagation and runup of tsunami waves caused by oceanic impacts: Deep–water impacts

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The impact of an asteroid or comet onto water is the most likely case since oceans cover two thirds of the Earth surface. Even if the distribution of shallow and deep-water environments of ocean basins is taken into account, the probability of an impact into deep-water (>3 km) is twice as large as a continental impact. To address the consequences of an oceanic impact with respect to the generation and propagation of tsunami waves we applied the following strategy: First we conducted simulations of the impact process mainly to account for the generation of potential waves and subsequently we used these results in a separate model to compute the propagation of these waves over a given bathymetry and the run-up on the coast. The SALE-3MAT hydrodcode is used for the impact cratering. The most striking difference compared to more common hydrodynamic models is that SALE considers compressible behavior of matter as well as brittle and ductile stresses. Accounting for compressibility is compulsory because shock waves travel faster than sound speed. The extent of the excavated cavity (either in the water column and the ocean floor underneath) depends on the kinetic energy of the impacting meteorite. Therefore the characteristics of resulting tsunami waves caused by an oceanic impact are determined by the kinetic energy of the impactor.

The thickness of the water column also has a large effect on the characteristics of subsequent tsunami waves. In case of deep-water impacts, most of the kinetic energy of the impacting meteorite is absorbed within the water column. Owing to this fact, characteristics of tsunami waves in case of impacts in shelf areas are profoundly different from the ones of deep-water impacts. In the latter case, much more energy is consumed by the excavation of the crater in the earth crust than is provided for the generation of tsunami waves.

Finally the propagation of the respective tsunami waves is computed by a 2D wave code based on the non-dispersive Shallow Water Equations (SWE) and simplified Boussinesq equations (BE), taking dispersion into account. To compute the run-up of the respective tsunami waves, we apply the well-established MOST code which is able to handle the runup of breaking and non-breaking waves. For the propagation of tsunami waves the generation mechanism rather than bathymetric changes play a more important role. But topographic changes of the sea floor become the dominating parameter for the run-up process of the wave. Comparing dispersive with non-dispersive computations, it is possible to affect the artificial dispersion of the numerical scheme of the non-dispersive SWE. This influence leads to similar run-up curves even if the shape of the wave right before the run-up is different.

We present simulations of the impact of a 500 m diameter impactor into a 5000 m deep sea and the subsequent propagation and run-up of resulting tsunami waves. Propagation and runup computations are based on a linear bathymetry. For such a linear bathymetry the damping of the wave amplitude obeys a 1/r law. The runup height and the runup distance are given along the parallel-shore coordinate. These parameters are investigated as a function of angle of the dry (land) component of the linear bathymetry. The same kind of investigation is carried out for the near-beach and overland flow velocity.