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Emulators for Predicting Tsunami Inundation Maps at High Resolution

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Predicting coastal tsunami impact requires the computation of inundation metrics such as maximum inundation height or momentum flux at all locations of interest. The high computational cost of inundation modelling, in both long term tsunami hazard assessment and urgent tsunami computing, comes from two major factors: (1) the high number of simulations needed to capture the source uncertainty and (2) the need to solve the nonlinear shallow water equations on high-resolution grids. We seek to mitigate the second of these factors using machine learning. The offshore tsunami wave is far cheaper to calculate than the full inundation map, and an emulator able to predict an inundation map with acceptable accuracy from simulated offshore wave height time-series would allow both more rapid hazard estimates and the processing of greater numbers of scenarios. The procedure would necessarily be specific to one stretch of coastline and a complete numerical simulation is needed for each member of the training set. Success of an inundation emulator would demand an acceptable reduction in time-to-solution, a modest number of training scenarios, an acceptable accuracy in inundation predictions, and good performance for high impact, low probability, scenarios. We have developed a convolutional encoder-decoder based neural network and applied it to a dataset of high-resolution inundation simulations for the Bay of Catania in Sicily, calculated for almost 28000 subduction earthquake scenarios in the Mediterranean Sea. We demonstrate encouraging performance in this case study for relatively small training sets (of the order of several hundred scenarios) provided that appropriate choices are made in the setting of model parameters, the loss function, and training sets. Scenarios with severe inundation need to be very well represented in the training sets for the ML-models to perform sufficiently well for the most tsunamigenic earthquakes. The importance of regularization and model parameter choices increases as the size of the training sets decrease.