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Source Parameter Sensitivity of Earthquake Simulations assisted by Machine Learning

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After large magnitude earthquakes have been recorded, a crucial task for hazard assessment is to quickly estimate Ground Shaking (GS) intensities at the affected region. Urgent physics-based earthquake simulations using High-Performance Computing (HPC) facilities may allow fast GS intensity analyses but are very sensitive to source parameter values. When using fast estimates of source parameters such as magnitude, location, fault dimensions, and/or Centroid Moment Tensor (CMT), simulations are prone to errors in their computed GS. Although the approaches to estimate earthquake location and magnitude are consolidated, depth location estimates are largely uncertain. Moreover, automatic CMT solutions are not always provided by seismological agencies, or such solutions are available at later times after waveform inversions allow the determination of moment tensor components. The uncertainty on these parameters, especially a few minutes after the earthquake has been registered, strongly affects GS maps resulting from simulations.

In this work, we present a workflow prototype to produce an uncertainty quantification method as a function of the source parameters. The core of this workflow is based on Machine Learning (ML) techniques. As a study case, we consider a domain of 110x80 km centered in 63.9°N-20.6°W in Southern Iceland, where the 17 best-mapped faults have hosted the historical events of the largest magnitude. We generate synthetic GS intensity maps using the AWP-ODC finite-difference code for earthquake simulation and a one-dimensional velocity model, with 40 recording surface stations. By varying a few source parameters (e.g. event magnitude, CMT, and hypocenter location), we finally model tens of thousands of hypothetical earthquakes. Our ML analog will then be able to relate GS intensity maps to source parameters, thus simplifying sensitivity studies.

Additionally, the results of this workflow prototype will allow us to obtain ML-based intensity maps a few seconds after an earthquake occurs exploiting the predictive power of ML techniques. We will evaluate the accuracy of these maps as standalone complements to GMPEs and simulations.