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Validation of a 3D geo-model for physics-based numerical prediction of the earthquake ground-motion in the Po Plain (Italy)

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The epistemic uncertainty in ground-motion prediction can be reduced with the aid of numerical modeling of seismic waves propagation. In this work we show how a good knowledge of the geological structure can be turned into quantitative site-specific features of the ground motion by means of High Performance Computing (HPC) tools for the numerical computation of the 3D seismic wavefield in heterogeneous visco-elastic media.
The study area is located in the Emilia-Romagna region (Northern Italy), covers about 5000 km2 and extends from the Po river right flank at North to the Apennine chain at South. Its northern sector encloses the epicentral area of the 2012 seismic sequence started on May, 20 with a ML 5.9 event. From a geological point of view, the investigated area is characterized by the NNE-verging fold-and-thrust system of the Northern Apennines whose outermost front is almost completely buried under late Pleistocene-Holocene deposits of the Po Plain.
We collected the available data concerning the complex geological structure in the area from surface to a depth of 20 km and built up a local 3D structural-geophysical model by means of GeoModeller®. We assigned the values of the visco-elastic properties to each structural unit according to data in literature. The resulting 3D geo-model was validated with a quantitative comparison between the empirical accelerometric records collected by the temporary and permanent stations deployed in the area during the 2012 sequence and the numerically simulated waveforms computed from the geo-model. In order to avoid the effects of the source complexity in the waveforms, we performed the validation using the data corresponding to small events of the 2012 sequence. Considering the size of details included in the model, we limited the numerical simulations to the frequency range up to 2 Hz. The simulations successfully predict some significant effects on the local seismic response caused by the presence of anticlines, the basin margin and the variable thickness of sediments.
The computations of the seismic wave propagation were performed using HPC software implemented at OGS and based on the well-established Fourier pseudospectral method (FPSM) for the solution of hyperbolic differential equations in 3D. The computations were run using the HPC resources available at the CINECA consortium in Bologna (Italy).
The validated 3D model offers not only a tool for the numerical estimation of the expected ground motion in the frequency range up to 2 Hz, but also represents a starting point for upgraded 3D models, aimed at numerical prediction in a wider frequency-range.