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Numerical forward modeling of seismic wave propagation in complex media

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Modeling of seismic wave propagation resulting from large earthquakes in the three-dimensional Earth is of considerable interest in seismology because analyzing seismic wave propagation in the Earth is one of the few ways of studying the structure of the Earth's interior, based upon seismic tomography. In particular, pressure waves called PKP can be used to study the solid inner core of the Earth and its anisotropy (i.e. varying seismic wave speed in different spatial directions).

The field of numerical modeling of seismic wave propagation in 3D geological media has significantly evolved in the last decade due to the introduction of the spectral-element method (SEM), which is a high-degree version of the finite-element method that is very accurate for linear hyperbolic problems such as wave propagation, having very little intrinsic numerical dispersion. In addition, the mass matrix is exactly diagonal by construction, which makes it much easier to implement on parallel machines because no linear system needs to be inverted.

In this study, we use this numerical technique on 2166 processors of the MareNostrum (IBM PowerPC 970) supercomputer to model seismic wave propagation in the inner core of the Earth following an earthquake. This enables us to study the effect of different models of the anisotropic structure of the inner core. We use a mesh with 21 billion grid points (and therefore approximately 21 billion degrees of freedom because a scalar unknown is used in most of the mesh). A total of 2.5 terabytes of memory is needed. The very high resolution of the mesh allows us to perform fully three-dimensional geophysical calculations at seismic frequencies as high as half a

Hertz in the full Earth.