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Finite-difference modelling of seismic wavefields around cavity based on the immersed interface method

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A uniform-grid finite-difference modelling of seismic wavefields around vacuum-filled cavity still poses a non-trivial problem because the traction-free condition has to be satisfied at a curved interface between the vacuum and elastic/viscoelastic solid. We present an algorithm that we have developed using the immersed-interface approach.

We use staggered-grid finite-difference scheme 4th-order accurate in space and 2nd-order accurate in time, SGFD (4,2), at all grid points except those at or near the boundary of the cavity. At these points we apply SGFD (2,2). A near grid point means that for updating wavefield in this point, the FD stencil needs at least one grid point inside cavity. We calculate the wavefield at the grid point inside cavity using an immersed interface method in order to account for the vacuum-solid boundary conditions. That is, we apply special extrapolation inside a 9x9x9 grid-point cube centered at the near point. Calculation of the 9x9x9 coefficients can be performed just once – when preparing a grid model. Effectively, the FD simulation itself is then only about 10% slower compared to the case of the same model without cavity. For calculating the coefficients we use subroutines generated by the Mathematica software. The use of Mathematica is based on the suitable parameterization of the interface.

We verified our FD algorithm by comparing the FD simulations with the finite-element simulations. We have not encountered any problem with accuracy or instability even for long time windows (we testes 225 000 time levels). The level of agreement is excellent.

We have applied the developed FD algorithm for simulating seismic wavefields in the medium modified by an underground nuclear explosion.