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A Stable Algorithm for a Discontinuous Staggered Grid in the 4th-order Velocity-stress Finite-difference Modeling of Seismic Ground Motion

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If the minimum wave speed in an upper part of a computational model is smaller than that in a lower part of the model it may be reasonable to use a discontinuous spatial grid with a finer part, with a grid spacing h, covering the upper part of the model and a coarser part, with a grid spacing H>h, covering the lower part of the model. A total number of grid points in such a grid can be significantly smaller than that in a uniform grid. This simple idea led modelers using grid methods, mainly the finite-difference (FD) method, to implement discontinuous grids.

A number of algorithms to include discontinuous spatial grid have been developed. They mainly differ in the allowed grid ratio H/h and the way they interpolate values in the missing grid positions in the coarser grid. In general, the larger H/h, the larger possibility of inaccuracy and, mainly, instability with increasing number of time steps. The interpolation itself does not play a key role. These aspects, however, are not often explicitly addressed in the publications, and the inevitable instabilities (in most cases) are only rarely admitted.

Two basic problems are to be solved. The obvious one is that of the missing grid points: how to update particle velocity and stress at grid points of the finer grid close and at the boundary of the finer grid. The other, and apparently not so obvious, problem is how to update particle velocity and stress at grid points of the coarser grid close and at the boundary of the coarser grid, that is, at those grid points of the coarser grid which coincide with grid points of the finer grid.

We present an algorithm of a stable discontinuous velocity-stress staggered-grid for a 4th-order finite-difference modeling. The grid ratio H/h can be an arbitrary odd number. We demonstrate the stability and accuracy of the algorithm for large number of time steps, and for grid ratio as large as 19.