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On Accuracy of the Finite-difference, Finite-element and Spectral-element Schemes for Modeling Seismic Motion in Media With a Large P-wave to S-wave Speed Ratio

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The P-wave to S-wave speed ratios (Vp/Vs) as large as 5 and even larger often have to be accounted for in numerical modeling of seismic motion in structurally and rheologically realistic models of sedimentary basins and valleys. Although sediments with large Vp/Vs usually do not make a major part of the computational region, their effect can be significant because they are at or very close to the free surface. However, the accuracy of the numerical schemes with respect to varying Vp/Vs is not often addressed in studies presenting schemes.

In order to identify the very basic inherent aspects of the numerical schemes responsible for their behavior with varying Vp/Vs ratio, we included the most basic 2nd-order 2D numerical schemes on a uniform grid in a homogeneous medium. Although basic in the specified sense, the schemes comprise the decisive features for accuracy of wide class of numerical schemes. We also included 3D higher-order schemes.

We investigated the following schemes (FD – finite-difference, FE – finite-element): FD displacement conventional grid, FD optimally-accurate displacement conventional grid, FD displacement-stress partly-staggered grid, FD displacement-stress staggered-grid, FD velocity-stress staggered-grid, FE Lobatto integration, FE Gauss integration, spectral element.

We defined and calculated local errors of the schemes in amplitude and polarization normalized for a unit time. Extensive numerical calculations for wide ranges of values of the Vp/Vs ratio, spatial sampling ratio and stability ratio, and entire range of directions of propagation with respect to the spatial grid led to interesting and surprising findings.

In parallel with the numerical results and their analysis we compare the numerical schemes themselves in terms of their inherent structures, applied approximations, and truncation errors.