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A numerical comparison of the 1D FD schemes based on application of the conventional, staggered-grid and optimally accurate operators to the heterogeneous formulation of the equation of motion

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We present a heterogeneous FD scheme, Doptm2, based on the application of the optimally accurate operators developed by Geller and Takeuchi (1998) to the heterogeneous strong formulation of the equation of motion developed by Moczo et al. (2002) for the 1D problem. We numerically compared Doptm2 with two other schemes - Dconv2 based on the application of standard conventional 2nd-order FD operators to the heterogeneous strong displacement formulation of the equation of motion for the 1D problem, and DSstag4 based on the application of the staggered-grid 4th-order operators to the heterogeneous strong displacement-stress formulation of the equation of motion for the 1D problem. The numerical comparisons were performed for three types of models - homogeneous space, two halfspaces in contact, and an interior layer with the strong velocity gradient. The accuracy of the numerical solutions was quantified by evaluating the envelope and phase misfits with respect to the exact analytical solutions. We investigated the envelope and phase misfits due to the cumulative effect of the grid dispersion and also due to the approximation of the boundary condition at the interface. We demonstrate errors due to improper treatment of material parameters as well as superiority of the Doptm2 scheme.

The main conclusion is that Doptm2, the scheme applying Geller and Takeuchi's (1998) optimally accurate operators to the strong heterogeneous formulation of 1D equation of motion of Moczo et al. (2002) can be an efficient FD scheme for 1D numerical simulations in heterogeneous medium. The formally 4th-order accurate DSstag4 cannot compete in accuracy with the formally 2nd-order Doptm2.