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Parsimonious finite-volume frequency-domain method for 2D P-SV-wave modeling

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A new numerical technique for solving the 2D elastodynamic equations based on a finite-volume approach is proposed. The associated discretization of the medium is through cells as triangles. Only fluxes of required quantities are shared between cells, relaxing meshing conditions compared to finite element methods. The free surface is described along the edges of the triangles which may have different slopes. Free surface and fluid-solid boundary conditions are explicitely expressed in the scheme by a local modification of numerical fluxes. By applying a parsimonious strategy, stress components are eliminated from the discrete equations and only velocities are left as unknowns in triangles, minimizing the core memory requirement of the simulation. Efficient PML absorbing conditions have been designed for damping waves around the grid. Since the technique is devoted to full waveform inversion, we implemented the method in the frequency domain using a direct solver, an efficient strategy for multiple-source simulations. Standard dispersion analysis in infinite homogeneous media shows that numerical dispersion is similar to those of $O(\Delta x^2)$ staggered-grid finite-difference formulations when considering structured triangular meshes. The method is validated against analytical solutions of several canonical problems and with numerical solutions computed with a well-established finite-difference time-domain method in heterogeneous media. Assuming a characteristic length L_t for triangles more or less constructed as equilateral ones, the finite-volume method requires ten lengths L_t per wavelength for a flat topography and fifteen L_t per wavelength for

more complex shapes, well below criteria required by the staircase approximation of finite-difference methods. Comparison between the frequency-domain finite-volume and the $O(\Delta x^2)$ rotated finite-difference methods also shows that the former is faster and less-memory demanding for a given accuracy level. We have developed an efficient method for 2-D P-SV-wave modeling on structured triangular meshes as a tool for frequency-domain full-waveform inversion. Further work is required to assess the method on unstructured meshes.