Upwind Summation By Parts Methods for Large Scale Elastic Wave Equation
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High-order accurate finite difference operators based on the summation-by-parts (SBP) framework constitute efficient numerical methods for simulating large-scale hyperbolic wave propagation problems. Traditional SBP finite difference operators that use standard central difference stencils for approximating spatial derivatives often have spurious unresolved wave-modes in their numerical solutions. For marginally resolved solutions, these spurious wave-modes have the potential to destroy the accuracy of numerical solutions for first order hyperbolic partial differential equation, such as the elastic wave equation. To improve the accuracy of numerical solutions of elastic wave equations in complex geometries, we discretize the 3D elastic wave equation with a pair of non-central (upwind) finite difference stencils [Ken Mattsson 2017], on boundary-conforming curvilinear meshes. Using the energy method, we prove that our scheme is numerically stable and computationally demonstrate robustness. The simulation of nonlinear dynamic earthquake ruptures and propagation of elastic waves in heterogeneous media with free surface topography are presented, including simulation of community developed seismological benchmark problems. Our results show that the upwind SBP operators are more robust and less dispersive on marginally resolved meshes, when compared to traditional operators.