Nonstandard Finite-Difference Method for Seismic Wave Computations

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Finite-difference method in the time-domain (FDTD) is one of the most popular methods used for numerical modeling of elastic wave propagation in heterogeneous media. The main drawback of the standard FDTD, especially for models that are much larger than the wavelength, is phase error due to grid dispersion. In large scale modeling, hence long propagation distances, the phase error due to the grid dispersion becomes very severe. There have been several attempts to reduce grid dispersion and anisotropy of the FDTD. Among them the nonstandard scheme which was originally proposed in computational electromagnetics, is one of the most successful schemes to reduce grid dispersion and anisotropy. Recently, we developed a nonstandard finite-difference time-domain (NS-FDTD) scheme (fourth-order accurate in space and second-order accurate in time) for elastic wave computations (JafarGandomi and Takenaka, 2009, Geophys. J. Int.). The nonstandard scheme improves the accuracy and efficiently reduces numerical dispersion and grid anisotropy. However, our original scheme could not significantly reduce numerical dispersion errors of both of P and S waves at the same time. In this study we propose an extended nonstandard scheme which gives highly accurate solutions both for P and S waves. This scheme is applicable to both modeling of seismic waves exited by kinematics and dynamic sources. The NS-FDTD scheme is very efficient especially for large scale seismic wave modeling where the cumulative effect of phase velocity error becomes significant.