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Wave Propagation Direction from Poynting Vector and its Application to RTM Angle Gathers

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ABSTRACT

Wave propagation direction is essential to compute reverse time migration (RTM) angle gathers. Full waveform inversion (FWI) integrates the wave propagation direction into the RTM-based gradient to constrain the correlation of forward and backward propagating wavefields within some specific range of opening angle and azimuth. Several techniques like Poynting vector, optical flow, wavefield decomposition and shifted cross-correlation are being used to compute wave propagation direction. Computation of Poynting vector is straightforward and it does not require the transforms to the wavenumber or frequency domain, which cause smearing effects in the angle gathers. We apply the Poynting vector approach to compute forward and backward wave propagation directions. RTM angle gathers were generated using the opening angle and the azimuth of the plane common to the two wave propagation vectors. The Poynting vector is the density of energy flux. In seismic waves, instantaneous Poynting vector can be estimated by multiplying time and spatial first derivatives of the wavefield. First derivatives of seismic waves can have tiny values around the peaks and troughs. These tiny values cause numerical errors in computing the Poynting vector. A coarse computational grid, which RTM commonly requires to reduce turnaround time, causes unstable wave propagation direction estimates. To get accurate first derivative terms, we used the pseudo-spectral method for seismic wave extrapolation and computation of the instantaneous Poynting vectors because the pseudo-spectral method can better handle larger computation grids than high-order finite difference methods. To avoid unstable values of instantaneous Poynting vectors around peaks and troughs of seismic waves, 1-D spatial smoothing and time integration techniques were utilized. Both techniques efficiently make sinusoidal waves within a wavelength have the same propagation direction. This approach was applied to both source- and receiver-side Poynting vectors and stable and accurate RTM angle gathers were estimated without dip/azimuth information.