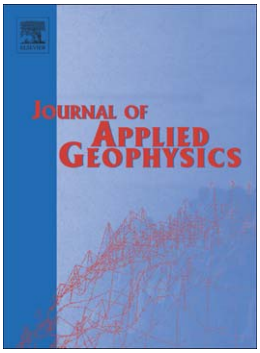

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Resolution Limits for Wave Equation Imaging

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Abstract

Formulas are derived for the resolution limits of migration-data kernels associated with diving waves, primary reflections, diffractions, and multiple reflections. They are applicable to images formed by reverse time migration (RTM), least squares migration (LSM), and full waveform inversion (FWI), and suggest a multiscale approach to iterative FWI based on multiscale physics. That is, at the early stages of the inversion, events that only generate low-wavenumber resolution should be emphasized relative to the high-wavenumber resolution events. As the iterations proceed, the higher-resolution events should be emphasized. The formulas also suggest that inverting multiples can provide some low- and intermediate-wavenumber components of the velocity model not available in the primaries. Finally, diffractions can provide twice or better the resolution than specular reflections for comparable depths of the reflector and diffractor. The width of the diffraction-transmission wavepath is approximately λ at the diffractor location for the diffraction-transmission wavepath. This unexpectedly high resolution is observed in tomograms obtained by migration velocity analysis (MVA).[3]
Keywords: Wave scattering, Wave diffraction, Computational seismology, Tomography, Migration

1 Introduction

FWI (Lailly, 1984; Tarantola, 1984, 2005), RTM (McMechan, 1983; Baysal et al., 1983; Whitmore, 1983), LSM (Nemeth et al., 1999; Duquet et al., 2000; Tang, 2009; Dai et al., 2012) and wave–equation traveltime inversion (Woodward, 1989, 1992; Luo, 1991; Luo and Schuster, 1991; De Hoop and van Der Hilst, 2005) are important tools for imaging seismic data at the engineering (Buddensiek et al., 2008), exploration (Mora, 1988, 1989; Pica et al., 1990; Pratt and Goulty, 1991; Zhou et al., 1995; Shin and Cha, 2008; Krebs et al., 2009; Virieux and Operto, 2009) and earthquake (Marquering et al., 1999; Tong et al., 1998; De Hoop and van Der Hilst, 2005; Van Der Hilst and Maarten, 2005; Tape et al., 2009; Fichtner et al., 2009; Fichtner, 2011; Fichtner and Trampert, 2011a,b) scales. In all of the above methods, the wave equation is inverted to estimate the model that minimizes, in some sense, the difference between the predicted and observed data. The main value of these wave equation–based imaging methods is that they overcome the high–frequency assumption of ray–based methods and use many, if not all, of the arrivals to reconstruct a finely detailed earth model. The hope is to find models with spatial resolution of one–half

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[3] Abbreviations: LSM—least-squares migration, FWI—full waveform inversion, FZ—Fresnel zone, MVA—migration velocity analysis, RTM—reverse time migration.