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Nonlinear slope tomography: a versatile data- and challenge-driven velocity model building technique

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Summary

Most recent depth seismic imaging studies involve both full-wave and ray-based methods as the resolution of complex ill-posed problems often require a wide range of tools. Also ray based methods suffer from well-known drawbacks, they will provide accurate results in most of the cases. Moreover, relying on nonlinear slope tomography, a challenge-driven approach can be designed for each problem by incorporating prior or external information as needed. Here we propose to show such examples of the challenge-driven approach.

Abstract

Most current depth seismic imaging studies involve both full-wave and ray-based methods, since the resolution of complex ill-posed problems often requires a wide range of tools. This is not surprising given the fact that most areal high density seismic surveys are acquired using devices positioned on free-surface or seabed only: how well would a medical imaging of the full human body succeed if it only acquired from devices positioned on a cap covering the head? Additional complication is due to the constant evolution of the physical model descriptions of the subsurface, sometimes using as many as eleven parameters in attenuated elastic media with tilted orthorhombic symmetry, and the complexity brought by strong or rugose contrasts.

Ray-based tomography provides accurate results and resolves model parameters in most cases. The main limitation of ray-based methods relates to the high frequency asymptotic approximation of seismic wave propagation, while their main advantage is to provide a highly discriminating tomographic operator made up of Fréchet derivatives. Among raybased methods nonlinear slope tomography brings two interesting features: (1) observed times and slopes of locally coherent reflection events allow us to minimize assumptions regarding data collection and (2) a nonlinear approach allows the initial inversion model to be far off. Most importantly, for each geophysical / structural complexity making the tomographic problem even more difficult to solve, a specific challenge-solving approach can usually be designed, using prior or external information as needed. Here, we show such examples where salt and multi-layer tomography can deal with strong velocity contrasts, where joint reflection / refraction tomography can help FWI flatten common image point gathers, or where dip constrained tomography can detect features characterized by short wavelength variations in lateral velocity.