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Elastic VTI Seismic Modeling with a Compact Formulation Based on Stiffness Matrix Coefficients.

Alberto José Ruiz Tapia (Universidade Fedeeral da Bahia), NOGUEIRA PETERSON (UfBA)

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Introduction

Accurate characterization of the geological medium is essential for realistic seismic modeling, enhancing imaging quality. Although the isotropic elastic wave equation based on *Vp*, *Vs*, and ρ is widely used, it proves limited in complex geological settings such as sedimentary basins, where vertical transverse isotropy (VTI) is prevalent.

To overcome this limitation, Thomsen parameters (ϵ, δ) are commonly employed, offering a more compact and physically interpretable description of anisotropy in VTI media. This work proposes an alternative approach in which the elastic wave equation is formulated directly in terms of the stiffness matrix elements (C_{11}, C_{13}, C_{33}, and C_{44}), replacing traditional coefficients derived from velocities and anisotropic parameters. This reformulation captures the effects of elastic anisotropy more directly, providing a robust foundation for realistic simulations and efficient application of Full-Waveform Inversion (FWI) in anisotropic media.

Method and/or Theory

The proposed formulation is based on the direct modeling of the elastic wave equation in its compact form for VTI media, using explicitly the stiffness matrix components C_{11}, C_{33}, C_{13}, and C_{44}, which are typical of transversely isotropic materials. Instead of reparameterizing these coefficients in terms of velocities or Thomsen parameters, the approach operates directly with the original C_{ij} elements, preserving their physical representation.

The compact elastic wave equation is expressed in terms of displacement fields, which are directly governed by the spatial distribution of the elastic stiffness coefficients. This direct representation allows for a more accurate capture of anisotropic effects on wave propagation and integrates naturally with high-order finite-difference numerical schemes.

To evaluate the robustness and accuracy of the proposed formulation, a modified version of the 2D Hess model was used, adapted to include VTI anisotropic properties with lateral and vertical variations in the C_{ij} coefficients. The domain was discretized using parameters compatible with numerical stability and dispersion criteria, ensuring the quality of the simulations in geologically realistic scenarios.

Results and Conclusions.

The results show that the compact formulation of the elastic wave equation in VTI media, based on the C_{ij} coefficients, generates more realistic wavefields than those obtained with isotropic models. Significant improvements are observed in the propagation of converted waves, in amplitudes, and in the resolution of complex geological structures. The modeling captures elastic anisotropy effects with greater fidelity, highlighting the importance of incorporating this phenomenon into seismic modeling and inversion workflows. The proposed approach offers a robust basis for the application of multiparameter Full-Waveform Inversion (FWI) techniques with high resolution.