Anisotropic waveform inversion of VSP data

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P-wave kinematics in VTI media

\[ V_{P0}, \varepsilon, \delta \text{ or } V_{nmo}, \eta, \delta \]

\[ V_{nmo} = V_{P0} \sqrt{1 + 2\delta} \]

\[ \eta = \frac{\varepsilon - \delta}{1 + 2\delta} \]
Methodology

- wavefield extrapolation operator
- objective functions
- gradients from adjoint state method
VTI wavefield extrapolation

Differential

Integral
Data-difference objective function

\[ J(m) = \frac{1}{2} \sum_{n=1}^{N} ||d_{cal} - d_{obs}||^2 \]

\[ d_{cal} : \text{calculated data} \]
\[ d_{obs} : \text{observed data} \]
Correlation-based objective function

\[ J_c(m) = - \sum_{\tau} \mathcal{W}(\tau) \mathcal{C}(e_{\text{obs}}, e_{\text{cal}}, \tau) \]

\( \mathcal{W}(\tau) \) : penalty operator
\( \mathcal{C}(e_{\text{obs}}, e_{\text{cal}}, \tau) \) : normalized cross correlation
\( e_{\text{cal}} \) : envelope of calculated data
\( e_{\text{obs}} \) : envelope of observed data
\( \tau \) : lag

\( \text{(Wu and Alkhalifah, 2017)} \)
Marmousi-II model
Anisotropy parameters
Shot gathers
Initial $V_{nmo}$-model ($\eta = \delta = 0$)
Inversion gradient for $V_{nmo}$

Correlation

Data-difference
Smoothed $V_{nmo}$-gradient

Correlation

Data-difference
Smoothed $\eta$-gradient

Correlation

Data-difference
Smoothed $\delta$-gradient

Correlation

Data-difference
Research plan

- extend to elastic VTI and orthorhombic media
- implement for Distributed Acoustic Sensing (DAS) data
- explore machine-learning-based model constraints
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