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Quantitative resolution analysis in full seismic waveform inversion

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Full waveform inversion (FWI) is a promising tool that is expected to yield tomographic images of unprecedented quality. While the tomographic technique itself has advanced substantially, another crucial part of this inverse problem has hardly received any attention: the rigorous quantification of resolution.

Here we present a new methodology for the quantification of resolution and trade-offs in FWI. This is based on an extension of the adjoint method that allows us to compute the exact second derivatives of seismic observables, which are the carriers of covariance information.

Each row of the Hessian is a correlation of two forward and two adjoint fields, all of which are governed by the wave equation. Formulas for Fréchet kernels can be reused for the Hessian, so that pre-existing codes do not need to be modified.

To increase the computational efficiency, we expand the rows of the Hessian into a generalised Gram-Charlier series. We then estimate the leading coefficients of the series from a small number of spatial Fourier transforms. This procedure allows us to compute 3D distributions of the resolution length and to estimate the trade-offs between model parameters.

We illustrate our developments with several examples that are based on a FWI for upper mantle structure beneath Eurasia.