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Downscaling homogeneized tomographic models

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The level of resolution in tomographic models has rapidly improved in the last decade with the advent of full waveform inversion and exact numerical methods for wave-field calculation. However, a remaining problem is computational cost, which leads seismologists to only interpret the long periods in seismic waveforms, and hence only constrain long-wavelength structure. In this way, tomographic images do not represent the true Earth, but rather a smooth effective, apparent, or equivalent model that provides a similar long-wavelength data fit. It can be shown that heterogeneities of smaller scales than the minimum wavelength are directly mapped into 'extrinsic' anisotropy. This poses a major challenge to interpret tomographic images in terms of geological structures.

Finding the fine scale, discontinuous Earth models that are compatible with a smooth and anisotropic tomographic image can be formulated as an inverse problem, which we designate as 'downscaling'. For this, we propose a Markov chain Monte-Carlo algorithm to explore a reduced space of fine scale models describing plausible and realistic geological features. For each sampled model, we compute its effective long-wave equivalent, and compare it to the long period tomographic image.

The method is illustrated with a synthetic toy example where the unknown model is a homogeneous medium that contains cavities with different shapes, and which sizes are smaller than the minimum wavelength of the observed wavefield. A full waveform inversion only provides a smooth and anisotropic medium that is not directly interpretable in terms of cavities. But when this image is downscaled with the proposed approach, we recover the position, aspect ratio, and orientation of the cavities.