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Downscaling Smooth Tomographic Models: Separating Intrinsic and Apparent Anisotropy

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In recent years, a number of tomographic models based on full waveform inversion have been published. Due to computational constraints, the fitted waveforms are low pass filtered, which results in an inability to map features smaller than half the shortest wavelength. However, these tomographic images are not a simple spatial average of the true model, but rather an effective, apparent, or equivalent model that provides a similar 'long-wave' data fit. For example, it can be shown that a series of horizontal isotropic layers will be seen by a 'long wave' as a smooth anisotropic medium. In this way, the observed anisotropy in tomographic models is a combination of intrinsic anisotropy produced by lattice-preferred orientation (LPO) of minerals, and apparent anisotropy resulting from the incapacity of mapping discontinuities. Interpretations of observed anisotropy (e.g. in terms of mantle flow) requires therefore the separation of its intrinsic and apparent components. The "up-scaling" relations that link elastic properties of a rapidly varying medium to elastic properties of the effective medium as seen by long waves are strongly non-linear and their inverse highly non-unique. That is, a smooth homogenized effective model is equivalent to a large number of models with discontinuities. In the 1D case, Capdeville et al (GJI, 2013) recently showed that a tomographic model which results from the inversion of low pass filtered waveforms is an homogenized model, i.e. the same as the model computed by upscaling the true model. Here we propose a stochastic method to sample the ensemble of layered models equivalent to a given tomographic profile. We use a transdimensional formulation where the number of layers is variable. Furthermore, each layer may be either isotropic (1 parameter) or intrinsically anisotropic (2 parameters). The parsimonious character of the Bayesian inversion gives preference to models with the least number of parameters (i.e. least number of layers, and maximum number of isotropic layers). The non-uniqueness of the problem can be addressed by adding high frequency data such as receiver functions, able to map first order discontinuities. We show with synthetic tests that this method enables us to distinguish between intrinsic and apparent anisotropy in tomographic models, as layers with intrinsic anisotropy are only present when required by the data. A real data example is presented based on the latest global model produced at Berkeley.