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Geodynamic Tomography: Constraining Upper-Mantle Deformation Patterns from Bayesian Inversion of Surface Waves

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In the Earth's upper mantle, seismic anisotropy mainly originates from the crystallographic preferred orientation (CPO) of olivine due to mantle deformation. Large-scale observation of anisotropy in surface wave tomography models provides unique constraints on present-day mantle flow. However, surface waves are not sensitive to the 21 coefficients of the elastic tensor, and therefore the complete anisotropic tensor cannot be resolved independently at every location. This large number of parameters may be reduced by imposing spatial smoothness and symmetry constraints to the elastic tensor. In this work, we propose to regularize the tomographic problem by using constraints from geodynamic modeling to reduce the number of model parameters. Instead of inverting for seismic velocities, we parametrize our inverse problem directly in terms of physical quantities governing mantle flow: a temperature field, and a temperature-dependent viscosity. The forward problem consists of three steps: (1) calculation of mantle flow induced by thermal anomalies, (2) calculation of the induced CPO and elastic properties using a micromechanical model, and (3) computation of azimuthally varying surface wave dispersion curves. We demonstrate how a fully nonlinear Bayesian inversion of surface wave dispersion curves can retrieve the temperature and viscosity fields, without having to explicitly parametrize the elastic tensor. Here, we consider simple flow models generated by spherical temperature anomalies. The results show that incorporating geodynamic constraints in surface wave inversion help to retrieve patterns of mantle deformation. The solution to our inversion problem is an ensemble of models (i.e. thermal structures) representing a posterior probability, therefore providing uncertainties for each model parameter.