Geophysical Research Abstracts
Vol. 20, EGU2018-11389, 2018
EGU General Assembly 2018

Exploring Deep Earth structure and its uncertainty with transdimensional tomography

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Variations in seismic velocity determined by earthquake tomography provide the most direct constraints on the 3-D structure of the core and mantle. Global body wave traveltime observations give us the means to detect, for example, hemispheric variations in the inner core, upwelling mantle plumes in the mantle, and the remnants of ancient subduction lurking beneath North America. If we wish to rigorously relate the observed velocities variations to material properties like temperature, composition, and anisotropy, it is vital to understand the uncertainties involved. Unfortunately, popular “checkerboard” resolution tests give only a qualitative picture of where velocity structure is resolved. Furthermore, the necessity of model regularization (damping, smoothing) makes it difficult to find absolute amplitudes and sharp gradients in seismic properties.

For these reasons, we develop a novel method of probabilistic P-wave tomography and apply it to image the inner core and the mantle beneath North America. We apply a Transdimensional Hierarchical Bayesian method to efficiently search the model space without the use of regularization. This search yields ensembles of models from which we can estimate a posterior probability distribution. Using the distribution, we are able to quantify tradeoffs between model parameters, explore non-Gaussian model uncertainty, and—most basically—place error bars on velocities. Our results help determine the robustness of commonly interpreted Deep Earth structures and underscore the benefits that the EarthScope Project has had on our understanding of the mantle.