GLOBAL TRAVELTIME TOMOGRAPHY WITH USARRAY TRANSPORTABLE ARRAY

SCOTT BURDICK & VEDRAN LEKIC, UNIVERSITY OF MARYLAND, COLLEGE PARK

With its images of descending slabs and rising plumes, global tomography provides us with a snapshot of the dynamic mantle. In particular, traveltimes from the USArray Transportable Array have allowed us to create tomographic images of large-scale structures beneath North America in ever finer detail and with less risk of artifacts due to sparse and irregular data coverage. Tomography works by finding a model of seismic velocities that best explain the traveltime data, and structure in the velocity model can be inferred to be variation in temperature, composition, or volatile content.

If we wish to accurately relate these velocity variations to the physical properties of the Earth, and to estimate the their strength and spatial extent, it is of vital importance that we have a good grasp of the uncertainty in the model. Rigorous examination of model uncertainty has long been a thorn in the side of seismic tomography due to the typically vast number of model parameters and the computational cost of the forward modeling problem. Standard resolution tests (i.e. checkerboard tests) can give a qualitative picture of where the data are able to constrain velocity structure, but they rest on questionable assumptions about uncertainty in the data, neglect forward modeling uncertainty, and do not provide estimates of covariance between model parameters.

For these reasons, we turn to Bayesian inference. We perform a transdimensional hierarchical Bayesian inversion on traveltimes from the USArray Transportable Array and global catalogues. In our approach, we parameterize the structure beneath North America as a set of three dimensional Voronoi volumes. Using the reversible-jump Markov chain Monte Carlo method, we create chains of models by allowing the location of the volumes and the velocity within them to vary at random. New volumes can be added and old volumes removed. Each new model is accepted or rejected according to its effect on the error function with a probability based on Bayes' Theory. The end result is chains of models, all of which satisfy the error function to some degree.

The point of this process is not only to converge to the velocity model that best fits the data, but to generate an ensemble of models from which statistical inferences can be drawn. From the ensemble, we create a probability distribution for the velocity at each point. By analyzing the distribution, we can determine the mean model and the model variance, effectively allowing us to put error bars on our estimates of the velocity structure. The most likely velocity can be determined from the peak value of the distribution, and sharp boundaries in structure can be inferred from regions where two or more peaks are present. We can furthermore quantify the trade-offs between velocity variations inferred at different locations This approach gives us new insight on the major questions about the mantle beneath North America, including the extent to which certain prominent features, like the mantle plume related to the Yellowstone hotspot, are required by the data, the difference in complexity of structure between the stable east and tectonically active west, and thickness variations of the continental mantle lithosphere.

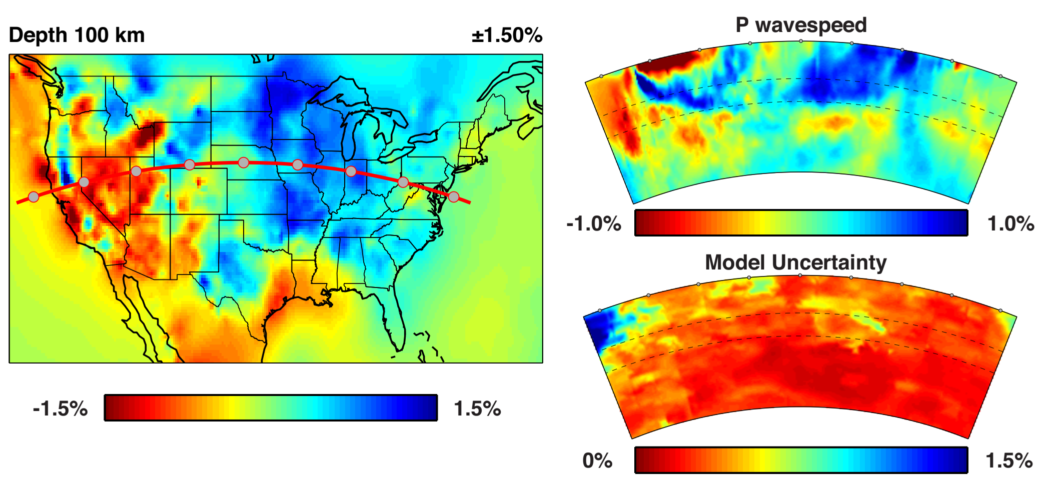

FIGURE 1. Left: P-wave velocity model at 100 km depth given in %dV/V. Red line shows location of cross-sections. Right: Section through model down to 1400 km. Model uncertainty calculated by transdimensional Bayesian inversion.