Development of a transdimensional Bayesian joint inversion and its application of USArray ambient noise tomography

Chao Gao[1], Tolulope Olugboji[1], Vedran Lekic[1]

Due to their different and complementary sensitivities to subsurface structure, multiple seismic observables are increasingly often combined to image the Earth's deep interior. We use a reversible jump Markov chain Monte Carlo (rjMcMC) algorithm to incorporate complementary seismic observables including surface wave dispersion, particle motion Ellipticity (ZH ratio), and receiver functions into a transdimensional, Bayesian inversion for the profiles of shear velocity (Vs), compressional velocity (Vp), and density beneath a seismic station. In addition, we apply a Parallel Tempering sampling method to improve the sampling efficiency of rjMcMC for the joint inversion. While traditional inversion approaches seek a single best-fit model, Bayesian approaches yield an ensemble of models, enabling us to fully quantify uncertainty and trade-offs between model parameters.

We perform tests on idealized (synthetic) data in which all three data types are analyzed individually and together. We demonstrate that by treating the number of model parameters as an unknown to be estimated from the data, we can both eliminate the need for a fixed parameterization based on prior information, and obtain better model estimates with reduced trade-offs. By analyzing the inversion results obtained using different combinations of data types, we show that while an individual data type is able to retrieve certain features of the profiles of Vp, Vs, and density, a joint inversion can leverage their complementary sensitivities to recover more accurate profiles.

We apply transdimensional hierarchical Bayesian inversion (THBI) using ambient noise Love and Rayleigh wave dispersion measurements in the 5s—40s period range (Ekstrom et al., 2013) to obtain phase velocity maps across the USArray footprint. We parameterize the phase velocity maps at each period and for each wave type by an unknown number of Voronoi cells of unknown wavespeed and location. Given the ensemble inversion result, we demonstrate that we are able to constrain the wavespeeds while quantifying uncertainties (and trade-offs), without making subjective prior assumptions on parameterization nor on the smoothness or amplitude of velocity variations. We then use phase-dispersion curves extracted from the ensembles of phase velocity maps to invert, again using a THB approach, for 1D velocity profiles across distinct geological provinces in the US continent. We analyze the distributions of the retrieved velocity profiles with depth, and compare our inferred results with those from other studies.

[1] Department of Geology, University of Maryland, College Park, MD