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A new Paradigm for Seismic Imaging of the Earth's Crust and Upper Mantle: Transdimensional Inversion of Receiver Functions and Surface Wave Dispersion With Hierarchical Bayes Algorithm

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Here we present a novel powerful method for a joint inversion of receiver functions and surface wave dispersion data, in which a trans-dimensional Bayesian formulation is used to produce a multidimensional posterior probability distribution.

Receiver functions are sensitive to strong gradients in elastic properties (e.g. velocity discontinuities in the crust and upper mantle), but are not sensitive to absolute velocity structure. Therefore, receiver functions data are often combined with surface wave dispersion data, which provide necessary complementary constraints on absolute velocities beneath the seismic station. With a recent expansion of seismic instruments, this receiver-based approach has become a routine choice in Earth imaging in many parts of the world.

We use a trans-dimensional Bayesian inverse method, as it has an excellent property that it treats the number of model parameters (e.g. number of layers) as an unknown in the problem. The dimension of the model space is variable and Markov Chain Monte Carlo schemes are used to provide a parsimonious solution that fully quantifies the degree of knowledge one has about seismic structure (i.e. constraints, resolution, and trade-offs).

Some issues of traditional techniques for joint inversion of receiver functions and surface wave dispersion that are addressed here include treating an inaccurate approximation of data noise (i.e. the data covariance matrix) and the inadequate definition of the misfit function, which becomes even more important in the context of a joint inversion. The level of data noise is crucial because it effectively quantifies the usable information present in the data (a very noisy dataset does not contain much retrievable information) and here it naturally controls the quantity of information that consequently should be present in the model (i.e. the number of model parameters).

In this work, we show how the Hierarchical Bayes method can be used to solve the above problems. First, we extend the Bayesian formulation to hierarchical models, which are able to consider the lack of information that the user has on the data errors. In other words, we let the data infer their own degree of uncertainty treating the magnitude and correlation of noise as unknowns in the inversion. Second, we design a scheme that naturally weights the contribution of different data types in the likelihood function thus removing the arbitrary choice of a weighting factor.

To demonstrate the applicability of the method, we show examples of joint inversion of teleseismic receiver functions and surface wave dispersion curves.