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An Optimal Transport Approach to Inversion of Receiver Functions

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Inversion of receiver functions is a widely used technique where the coda of teleseismic body waves is used to constrain the 1D structure beneath a seismic station. Most studies define a misfit function as the sum of squared differences between predicted and observed waveforms, and then minimize this misfit with linearized inversion procedures. A well-known issue is that the least-square misfit function present several local minima, leading to a strong dependence to the chosen initial model. In order to avoid getting trapped in local minima, an alternative is the use of global optimization techniques, mostly based on Monte-Carlo sampling algorithms. However, in the case of receiver functions, sampling algorithms are computationally intensive, often difficult to implement, and prone to convergence issues. The existence of local minima in the misfit function takes root in the definition of the misfit criterion. A “point-to-point” L2 distance is not suited to compare oscillatory signals such as teleseismic body waveforms, as it is poorly sensitive to time shifts and prone to cycle skipping. In the case where global optimization methods are difficult to use, this issue is particularly restricting.

Instead of the least-square criterion, we propose to use an alternative distance based on optimal transport to compare predicted and observed body waveforms. We follow the same strategy as Métivier et al. [2016] that has been successfully applied to full-waveform inversion. The optimal transport problem consists of moving mass units from one set of locations to another with minimal effort [Kantorovich, 1942. The idea is to define the distance between two distributions (here two waveforms) as the solution of the optimal transport problem. Such a distance is called the Wasserstein distance.

We construct a methodology to apply this optimal transport distance to inversion of receiver functions. Its properties are compared to the least-square misfit properties in simple synthetic tests. We show that the optimal transport distance is less sensitive to the starting model, and less prone to fall in local minima. Our methodology is then applied to real waveforms recorded at the Hyberabad station, in the Indian craton.

L Kantorovich. On the transfer of masses. In Doklady Akademii Nauk , volume 37, pages 227_229, 1942.

L. Métivier, R. Brossier, Q. Mérigot, E. Oudet, and J. Virieux. Measuring the misfit between seismograms using an optimal transport distance: application to full waveform inversion. Geophys. J. Int. , 205(1):345_377, 2016. doi: 10.1093/gji/ggw014.