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Fréchet kernel sensitivity

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The mapping from data to model ("sensitivity kernels") forms the basis for seismic inverse problems, and has received much attention in recent years as developments in theoretical foundations, computational resources, and high-quality broadband data converge to tackle geophysical scales of interest. Although much progress has been achieved, it is clear that the generally non-unique inversion of seismic data still poses a formidable validity challenge on all ends.

We quantify the variability and scope of subjective choices one takes upon a certain data and model selection as illuminated by the dependence of Fréchet sensitivity kernels on a multi-dimensional parameter space. We apply this to the global scale by factorizing the raw waveform sensitivity upon spherically symmetric reference models from all specifications such as source time functions and radiation patterns, receiver components, azimuth, epicentral distance and source depth, model parameterization, time and frequency windows, and a range of misfit functions. Having such spatio-temporal/spectral sensitivity kernels at hand, these choices are computationally trivial to undertake, being mere operators on the waveform kernel. Specifically, we depict the imprint of data/synthetic processing onto the sensitivity kernel as illuminated by traveltime picking, cross-correlations, complete waveforms, and phase-/envelope misfits.

It is worth assessing these dependencies for two reasons on either end of the tomographic workflow: 1) To choose appropriate a priori sub-sets of the data that significantly illuminate a given region of interest; 2) To understand the scale of influence on the mapping as induced by these choices with respect to the a posteriori tomographic image. Point 1) can be seen as a semi-automated data selection process, which, in times of the availability of vast amounts of digital data, may streamline subjective and time-intensive previous efforts. Point 2) touches upon the non-uniqueness and illposed-ness of seismic inverse problems: Subjective choices on the above-mentioned parameter space have an inevitable and quantifiable effect on the inversion and "the" final model. Thus, we argue that multiple inversions for many such choices may help in better constraining the nature and reliability as well as uncertainty of tomographic images.