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Frequency dependence of observed P-wave traveltimes and amplitudes, and their prediction by finite-frequency tomography

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Body wave observables become frequency dependent when waves interact with structural heterogeneities on the length scale of the seismic wavelength. For the purpose of multi-band finite-frequency tomography, we condense the information contained in a broadband waveform into a handful of traveltimes from cross-correlation, measured in distinct frequency passbands, and into the same number of amplitude measurements. These traveltimes dT and amplitudes dA/A thus become frequency-dependent if the wave encounters heterogeneity roughly commensurate with its own wavelength.

We observe significant and spatially systematic frequency dependence in a global data set of P-wave traveltimes and amplitudes, which spans the frequency range of 0.03 to 1 Hz. We compare to predicted traveltimes and amplitudes, for the subset of data that was used in a recent tomographic study of North America (Sigloch et al. 2008). Spatial patterns of fits and misfits are beautifully evident on the dense station grid of the USArray. We show spatial patterns of dispersiveness for dT and dA/A (highest minus lowest frequency band) and compare to dT and dA/A themselves.

At most stations, the dispersiveness of dT is a few tenths of a second – (i.e. almost an order of magnitude smaller than dT itself) – but can be much larger in tectonically active regions. Finite-frequency tomography predicts this dispersion, although not to its full magnitude. There is a tendency for data from one earthquake to either fit or not fit as a whole. This signals room for improvement of the tomographic model from specific azimuths by putting more emphasis on fitting the frequency dependence of dT.

Similar conclusions hold for amplitudes. Although dA represents a noisier observable, its relative dispersiveness is much stronger than that of dT, so that we fit or misfit the dispersive pattern of dA/A almost as clearly as dA itself.