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Receiver functions: An exploration seismic perspective

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The receiver function technique is arguably the most successful technique in seismology for crustal and upper mantle characterisation. Prompted by the successful application of the receiver function method to multi-component seabed seismic data to derive shear-wave statics, we explore to what extent the receiver function method can be used for general multi-component reflection seismic data processing and vice-versa. We show that the work in the seismological community on moveout correction and stacking of receiver functions can be extended significantly, building on results from the exploration seismic community. We introduce a novel type of space-time domain receiver function, computed by 2D deconvolution, which treats the spatial aspects of mode-conversion completely analogously to the temporal aspects. Thus, the receiver function becomes a two-dimensional transfer function, which shows how far the P-waves have to be shifted in space and delayed in time to match the corresponding PS-converted waves. In addition, series expansions of the traveltime differences lead naturally to two-term moveout approximations and Dix-Krey-type velocity inversion formulae for both the conventional (i.e. time difference as a function of slowness) as well as novel (i.e. time difference as a function of offset) receiver functions. The two approaches, and the required data pre-processing, are illustrated using synthetic multi-component seismic data. We also introduce a model-independent method for reflection receiver function computation, based on stationary phase analysis, which can be used for deconvolution of anelastic and all other propagation effects. This method is inspired by, and closely related to, interferometry and relies on matching the slowness of a particular PP-reflected wave to the slowness of the corresponding PS-converted wave on the source side, and exploiting the fact that the traveltime difference is stationary for the PP- and PS-wave that is reflected and mode-converted at the same subsurface point. A simple method for pre-stack migration of the resulting model-independent receiver function in homogeneous elastic media is also presented. Finally, we show that in general, dynamic aspects of reflection data require the introduction of a more involved cascaded non-stationary filter model consisting of inverse Q-filtering, stretching/squeezing, and forward Q-filtering. This approach, motivated by a simple two-layer example, highlights some of the challenges of the application of the receiver function technique to reflection data which ultimately can be attributed to the fundamental differences between reflection and transmission data.