No more multiple removal: Construct Primaries then Migrate

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Advanced methods of seismic data processing such as full-waveform inversion account for data that include multiply scattered waves, but such methods are prohibitively expensive across the seismic frequency range. Consequently, many standard processing steps including reverse-time migration (RTM) use the Born approximation: this approximation is to assume that waves have only scattered from heterogeneities in the medium once, thus requiring that data consist only of primaries (singly scattered energy).

A variety of methods are therefore usually deployed as pre-processing, to predict multiples (waves reflected several times) in recorded data; however, accurate removal of those predicted multiples from recorded data using adaptive subtraction techniques proves challenging, even in cases where they can be predicted with reasonable accuracy.

To overcome this problem, we propose an entirely new strategy: instead of synthesizing and removing multiples, we construct a parallel data set consisting of only primaries, which is calculated directly from recorded data. This approach thus obviates the need for both multiple prediction and removal, since no multiples exist.

We show how primaries can be constructed using convolutional interferometry to combine first arriving events of up-going and direct-wave down-going Green's functions to virtual receivers in the subsurface.

The required up-going wavefields at subsurface virtual receivers are constructed by Marchenko redatuming, a novel technique that estimates up- and down-going components of Green's functions between an arbitrary location inside a medium such as the Earth's subsurface, and the locations of real receivers (or sources) located at the Earth's surface. Crucially, this is possible without detailed models of the Earth's subsurface velocity structure: similarly to most migration techniques, the method only requires surface reflection data and estimates of direct (non-reflected) arrivals between virtual subsurface sources and the acquisition surface.

The method is demonstrated on a stratified synclinal model. It is shown both to be particularly robust against errors in the reference velocity model used, and to improve migrated images substantially.