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Source wavelet inversion for laterally-varying scaling errors using Marchenko focusing functions

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We present a novel approach to invert for laterally-varying scaling errors of seismic sources using Marchenko focusing functions and demonstrate the improvement of images created with Marchenko redatumed data using the proposed inversion algorithm in case of laterally-varying sources. Marchenko focusing in combination with multi-dimensional deconvolution (MDD) allows one to create a redatumed reflection response for virtual sources and receivers at an arbitrary level in the subsurface using one-sided illumination (i.e. sources and receivers located on the Earth's surface) of the medium only. The redatumed reflection response can then be used to create an image of the target zone below the redatuming level using standard imaging methods such as reverse-time migration. Such images are free of internal multiples that originate in the overburden part of the model above the redatuming level.

However, an accurate Marchenko focusing requires the correct deconvolution of the source wavelet from the surface reflection response, being one of the required inputs for the Marchenko method. Using an incorrectly scaled source wavelet for deconvolution creates artifacts in the redatumed data and in images created with these data. In focusing functions calculated by the iterative solution of the coupled Marchenko equations, these artifacts appear as additional unwanted coda events. By minimizing such events, we invert for the correct scaling of the source signature of the reflection data acquired at the surface. Multiple, laterally spread virtual sources (VS) in the subsurface allow to calculate the sensitivity of individual sources at the surface with respect to the focusing functions at different VS. Thus, we can formulate a Gauss-Newton based inversion to retrieve the correct scaling of the source wavelet of sources at the surface. Minimizing the energy of unwanted coda events in the focusing functions of multiple VS yields the correct laterally-varying scaling of sources at the surface and, thus, enables accurate Marchenko redatuming and imaging. This is demonstrated with two numerical examples.

For a laterally-varying source scaling, we show that the scaling of the individual sources at the surface is retrieved correctly by the proposed inversion algorithm. Furthermore, we demonstrate the improvement of Marchenko images using the final inverted source scaling for deconvolution compared to images created with the incorrect initial scaling of sources. In a second synthetic example, we show that, using the proposed algorithm, we can successfully correct for the (laterally-varying) failure of individual airguns in an airgun array, increasing the accuracy of the subsequent redatuming and imaging steps.