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Multiscale seismic characterization of marine sediments by using a wavelet-based approach

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We propose a wavelet-based method to characterize acoustic impedance discontinuities from a multiscale analysis of reflected seismic waves. This method is developed in the framework of the wavelet response (WR) where dilated wavelets are used to sound a complex seismic reflector defined by a multiscale impedance structure. In the context of seismic imaging, we use the WR as a multiscale seismic attributes, in particular ridge functions which contain most of the information that quantifies the complex geometry of the reflector. We extend this approach by considering its application to analyse seismic data acquired with broadband but frequency limited source signals. The band-pass filter related to such actual sources distort the WR: in order to remove these effects, we develop an original processing based on fractional derivatives of Lévy alpha-stable distributions in the formalism of the continuous wavelet transform (CWT). We demonstrate that the CWT of a seismic trace involving such a finite frequency bandwidth can be made equivalent to the CWT of the impulse response of the subsurface and is defined for a reduced range of dilations, controlled by the seismic source signal. In this dilation range, the multiscale seismic attributes are corrected from distortions and we can thus merge multiresolution seismic sources to increase the frequency range of the mutliscale analysis. As a first demonstration, we perform the source-correction with the high and very high resolution seismic sources of the SYSIF deep-towed seismic device and we show that both can now be perfectly merged into an equivalent seismic source with an improved frequency bandwidth (220–2200 Hz). Such multiresolution seismic data fusion allows reconstructing the acoustic impedance of the subseabed based on the inverse wavelet transform properties extended to the source-corrected WR. We illustrate the potential of this approach with deep-water seismic data acquired during the ERIG3D cruise and we compare the results with the multiscale analysis performed on synthetic seismic data based on ground truth measurements.