Rigorous Demonstration of Sub-Wavelength Multiple Scattering Suppression Using Advanced Seismic Data Processing Workflows

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Abstract

The size of subsurface heterogeneities is typically below the resolution limit of seismic data - reflection events are temporally separated by less than the dominant wavelength. The (also) unresolvable, so-called short-period multiples generated by these heterogeneities can give a wrong assessment of reservoir volumes and their fill. These can be generated in shallow water (surface-related) and/or inside the Earth (internal short-period multiples). Removing these events is challenging because currently-used de-multiple methods assume some kind of temporal separability between events, to either estimate the source wavelet or the multiple generation mechanism. We demonstrate that short-period multiple removal requires a paradigm shift in analyzing multiple scattering in general. The perception of the seismic signal consisting of individual primaries and multiples has to be replaced by one where the primaries and multiples collectively form a complex interference pattern with particular mathematical properties. We show how with some modification Robust Estimation of Primaries by Sparse Inversion (R-EPSI) and the Marchenko methods can handle surface-related and internal short-period multiples, respectively.

Contrary to the SRME algorithm, the R-EPSI method suppresses surface-related multiples using an additional sparsity-constraint-assisted inversion. This algorithm exploits fundamental mathematical relations between two very different reflection datasets, rather than predicting and adaptively subtracting multiples. For short-period internal multiple suppression, the inverse problem formulation, such as the Marchenko equation-based method, goes a long way to solving our problem, whereby the reflection data is used to calculate the inverse transmission response. The underlying linear inverse problem is underconstrained and an incorrect initial condition guess typically leads to incorrect suppression of internal multiples - in particular the short-period ones. We show that the problem can be constrained by (1) energy conservation of the solutions and (2) using multi-dimensional band-limited minimum-phase reconstruction. This is a significantly different approach compared to methods such as the ISS or Jakubowicz IME, which are incapable of targeting the short-period multiples. Finally, we demonstrate on complex shallow-water and finely-layered overburden synthetic models, the effectiveness of the combined R-EPSI and augmented Marchenko workflow.