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Seismic reflection imaging, accounting for primary and multiple reflections

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Imaging of seismic reflection data is usually based on the assumption that the seismic response consists of primary reflections only. Multiple reflections, i.e. waves that have reflected more than once, are treated as primaries and are imaged at wrong positions. There are two classes of multiple reflections, which we will call surface-related multiples and internal multiples. Surface-related multiples are those multiples that contain at least one reflection at the earth's surface, whereas internal multiples consist of waves that have reflected only at subsurface interfaces. Surface-related multiples are the strongest, but also relatively easy to deal with because the reflecting boundary (the earth's surface) is known. Internal multiples constitute a much more difficult problem for seismic imaging, because the positions and properties of the reflecting interfaces are not known.

We are developing reflection imaging methodology which deals with internal multiples. Starting with the Marchenko equation for 1D inverse scattering problems, we derived 3D Marchenko-type equations, which relate reflection data at the surface to Green's functions between virtual sources anywhere in the subsurface and receivers at the surface. Based on these equations, we derived an iterative scheme by which these Green's functions can be retrieved from the reflection data at the surface. This iterative scheme requires an estimate of the direct wave of the Green's functions in a background medium. Note that this is precisely the same information that is also required by standard reflection imaging schemes. However, unlike in standard imaging, our iterative Marchenko scheme retrieves the multiple reflections of the Green's functions from the reflection data at the surface. For this, no knowledge of the positions and properties of the reflecting interfaces is required. Once the full Green's functions are retrieved, reflection imaging can be carried out by which the primaries and multiples are mapped to their correct positions, with correct reflection amplitudes. In the presentation we will illustrate this new methodology with numerical examples and discuss its potential and limitations.