Defining the Green's function derivative for imaging & inversion without the Born approximation

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The goal of most seismic experiments is to use data readily available at the surface of the Earth to characterise the inaccessible interior. In order to solve this inverse problem, we generally make a number of assumptions about either the data or the Earth to simplify the physics. For example, we often assume that the Earth is an acoustic medium rather than an elastic medium, which for data without S-waves makes the problem far more tractable computationally than the full elastic problem.

One of the most common assumptions made about the data is the single-scattering assumption, widely known as the Born approximation. Clearly this is invalid in the presence of multiple scattering, which occurs in all seismic experiments. Despite this, the majority of imaging and inversion methods applied to seismic data are dependent on this assumption, including most full waveform inversion algorithms. As a consequence, seismic data processing requires a great deal of effort to remove multiply scattered waves from data.

A key justification for making this assumption is that a priori we can only estimate a relatively smooth Earth model that does not predict multiply scattered waves. However, with the recent emergence of so-called Marchenko methods, we now have access to full Green's functions between sources and receivers at the Earth's surface and virtual source or receiver locations inside the Earth's interior. Green's functions which can be estimated using only recorded reflection data and an estimate of the direct (non-scattered) wavefield travelling into the subsurface. As Marchenko methods become more commonplace, our justification for the single-scattering assumption diminishes, and hence we require new methods to use this information.

By iterating the Lippmann-Schwinger equation, we define a new compact form of the Frechét derivative of the Green's function that involves all orders of scattering. In combination with Green's functions obtained by a Marchenko method, these may be used for imaging and inversion of seismic data. We will describe an example of such a scheme, which we call "Marchenko Lippmann-Schwinger Full-Waveform Inversion", to demonstrate how our redefined Green's function derivative may be applied to solve seismic inverse problems for the Earth's subsurface structure.

How to cite: Cummings, D. and Curtis, A.: Defining the Green's function derivative for imaging & inversion without the Born approximation, EGU General Assembly 2020, Online, 4–8 May 2020,