Solid Earth
Discussions

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Interactive comment on "Green's theorem in seismic imaging across the scales" *by* K. Wapenaar et al.

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Dear Kees, Joeri and Jan, Dear editor,

This manuscript presents a summary of various imaging methods in seismology and exploration geophysics that are all connected by the classical representation theorem for the homogeneous Green's function. These methods include time-reversal acoustics, seismic noise interferometry, back propagation, and double focusing.

The manuscript is very well written and a true pleasure to read. It highlights the broad knowledge of the authors and their ability to draw connections that will help many readers to gain deeper understanding of wave-based imaging.

Most of my comments are of rather cosmetic nature. Assuming that the main purpose

of such a review-style paper is educational, I only have two major comments related to the presentation and justification of the many approximations, and to the concept of focusing functions, which is essential for the understanding of section 3. Taking these comments into account would make the paper more accessible and more valuable for young readers who may not have read many of the author's earlier publications.

Since this does not require more than some modifications of the text, I would like to suggest that this manuscript be published following a minor revision.

Please find my detailed comments and suggestions below, as well as in the annotated manuscript.

With kind regards

Andreas Fichtner

MAJOR COMMENTS

[A] Approximations: My first, and most important, concern is the treatment and presentation of approximations. I think we agree that any approximation is useful only when its quality is known. For instance, we have confidence in using a truncated Taylor expansion of f(x) because we can compute the truncation error as a function of x.

In this manuscript, many approximations are made. Elasticity and attenuation of the Earth are ignored, integral boundaries are smoothed and coarsely discretised by a few points, integrands are simplified, waves are assumed to only propagate either up or down, and so on and so forth. However, it often remains unclear how exactly the approximations are justified, and under which conditions they are actually meaningful.

A good example is relation (12) on page 7, which is supposed to be a far-field approximation. In fact, however, it is clear that the approximation breaks down when a (nearly) plane wave in the far field propagates nearly parallel to the boundary. This can easily happen in even a mildly heterogeneous medium that contains some smooth velocity gradients. Despite this obvious failure of the approximation, it is not at all explained.

While I do understand that space in a manuscript is limited, I think this style can have various negative effects:

[1] Given the large number of approximations, it remains somewhat unclear why this actually works in the real Earth. The fact that it works in the numerical examples may appear as coincidental magic and not as a consequence of logic.

[2] More importantly, this style may frustrate those readers who really want to understand why this all works in practice. But these are precisely the readers who you would like to have! So, please, make a step towards them.

[3] Since the quality of the approximations is not obvious, it also remains somewhat unclear what kind of quantitative information can actually be extracted, e.g., from an ambient noise correlation. Of course, all the illustrations are visually nice, but to which extent are they quantitative inferences? In the end, we need a hard number with an uncertainty attached.

[B] Focusing functions: I admittedly have difficulties understanding section 3. This is mostly because the developments have too large jumps (given my prior knowledge of this topic), and because the concept of a focusing function is not cleanly defined. For instance, at the very beginning of section 3.1, the authors write "we define a focusing function $f_1(x;x_A; t)$, where x_A denotes the focal point." However, this is not actually a definition of what a focusing function is supposed to be. In fact, it only assigns a symbol (f_1) to some technical term (focusing function). Similarly, one could say that we define a gdkjfghdskfsgj z. Obviously, this does not tell you much. ;-)

Of course, I could fix my problem by reading all your earlier papers; but I do not think this is the point of such a review paper. I would very much like to give your paper to my students; and I want them (and myself) to understand it entirely.

Please also note the supplement to this comment:
https://www.solid-earth-discuss.net/se-2018-141/se-2018-141-RC1-supplement.pdf