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Solid Earth
Discussions

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Interactive comment on "*Instaseis*: instant global seismograms based on a broadband waveform database" *by* M. van Driel et al.

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Thanks first of all to the reviewer for these comments that helped us to substantially improve the manuscript.

General comments

This paper is based on the long-held concept of generating synthetic seismograms from Green's functions, and it demonstrates the capabilities of this approach in a modern (and future-looking) computing environment. The capabilities of the package, called Instaseis, are emphasized in the scientific applications in Section 5. The authors have done very well to demonstrate how Instaseis can be used, including finite source inversions, global tomography, ambient noise cross *correlations, and waveform model- ing. Instaseis could also have exceptional potential in helping to teach seismology; this point is explicit in Figure 17 but perhaps undersold in the paper. This is a "code paper," and the authors have gone to great lengths to provide a usable, documented code that is open-source and based on a stable framework (python). I have several minor points that may help, but overall this is an outstanding, complete treatment of a fundamental tool in seismology: the calculation of global synthetic seismograms in a 1D model.*

We agree.

Specific comments

Section 5.3. I am confused about what is meant here by finite-frequency. My under- standing is that this means volumetric sensitivity kernels are used in the place of rays. There is no mention of kernels in this section. The opening sentence (and reference) is insufficient if this is not what is meant by "finite-frequency tomography". Are we talking about databases of seismograms, of finite-frequency kernels, or of both?

We see Finite Frequency Tomography as a more general concept to 1) extract information from seismograms and 2) invert this in terms of the source and structure that goes beyond just replacing rays by volumetric kernels. The first step in finite frequency tomography is the measurement, which in contrast to ray theory is not done by picking the onset of a phase, but by matched filters (cross-correlation with synthetic reference seismograms). This step is what section 5.3 deals with. The computation of kernels is another problem in finite-frequency tomography, we are currently working on a seperate publication and code to compute these.

We expanded the introductory sentence in 5.3 to define the problem under consideration in the section more precisely.

p. 959, L27. This is an important paragraph to distinguish the current code *from existing ones. One point that is not obvious is how readily available the alternative codes (fk, WKBJ, Yspec) are. Are these other packages available? Is there a single version or are there various copies at various places? Are they documented? It would be helpful to discuss these aspects, as one of the strongest points of Instaseis is the perceived commitment by the developers to maintain it "for the next couple years" (p. 967, L20), but of course the reader and community will hope this can last longer!*

While the quoted paragraph argues from a methodological point of view, the questions raised here relate to the actual implementations. These are much more difficult to answer and can potentially change over time. We prefer to focus on the strengths of our methodological approach and strategy to share these codes with the community. To the best of our knowledge, no other methodology is published, available or capable of producing full, high-frequency seismograms as fast as Instaseis.

On a related note, there are many references to codes, libraries, and software. I wonder whether any of this will make sense 15 years from now. If 15 years from now was the goal, then I would recommend shifting these specific software names and details to an appendix; what is left behind would be more science, algorithmic, and performance details that may last 15 years. This is something for the authors to think about.

Actually almost all codes and libraries we refer to are already older than the quoted 15 years and wide spread in the community, so with some optimism they will still be around for a while. With respect to the chance of Instaseis surviving in the community even in the case that the developers discontinue their work, we follow two strategies: 1) we apply a modern test driven coding style that allows other developers to take over more easily and 2) we share and spread the code open source in the community, put a major effort into documenting all functionality and technical decisions and intent to give a number of tutorials (e.g. at the upcoming TIDES workshop) to have a wide user base.

Axisem applies to axisymmetric models. So if someone wanted a database for some hypothetical plume, wouldn't Instaseis work? If so, then doesn't this give Instaseis (or axisem) a slight advantage over the other techniques, which require a 1D model?

Using reciprocity, the structure will always need to be symmetric with respect to an axis through the receiver and the center of Earth. For a plume, this is maybe not very useful, but some applications can be thought of where inclusion of source-receiver structure may be beneficial. As we did not test any of this up to now, we only noted this down in the outlook and possibly come back to this in separate publication including more general axisymmetric local and regional domains.

The scientific applications, notable Figures 21 and 23, are excellent. In Figure 21, even within the direct P window there are significant differences between axisem and fk.

After a few more iterations between the different groups involved in computing the SIV synthetics, the results have converged a bit more and for periods longer than 20s the differences in the direct P window are now small for all methods. However, the differences for later arrivals and higher frequencies are still there and can quite certainly be attributed to the different methods. We updated the figure and interpretation accordingly.

p. 964, Eq 2. Where are sp and zp defined? In general, I'd rather see explicit notation, like s(xi, eta) and z(xi, eta) in Eq (2).

We added the definition of sp and zp in the paragraph before the equation. As these are the coordinates of the given point (in practice: the source location), they are just plain numbers in the physical domain and no functions, so the notation does not hide anything.

p. 972, L16. "With Instaseis, we can now build the whole database for all possible *sources with only two runs of AxiSEM." This is quite misleading. Just add a line like this: "(Of course, this means that the database of Green's functions has to be completely computed in advance, as described in Section XX.)"*

We don't see what is misleading here: with Yspec or similar methods, one requires one simulation per event while with AxiSEM and reciprocity it is independent of the number of events - just two simulations. However, we rephrased the sentence to articulate this more explicitly.

Figure 6. It might help to also include an example time series of time series for some chosen source depth. This might help the reader comprehend what is being shown. (Also, the "1 / N" label is odd to me.) You need to explain what the phase and envelope misfits are of. I'd recommend an (a), (b), (c), and an expanded caption here.

The paper already has quite a number of figures (23 in total), so we would prefer not to add yet another one. We added labels and expanded the caption as suggested.

Figure 14. My reading of the caption is that the dashed lines are some kind of best fit to the points. But the residuals seem to be highly systematic (and also discussed in the caption). Is the line-fitting being applied to the first few points (or first point), perhaps? Please clarify.

In the parameter optimization, we added a weighting linear in the frequency, leading to the first points beeing fitted more closely. We added a note on the weighting in the caption.

Speed is certainly a theme in this paper. But something that is conspicuously missing is the benefit from speed, in terms of an operational setting. On the data side, early warning systems are very concerned with the speed that earth-quake source parame- ters can be estimated. Would it be worth mentioning this motivation?

Essentially all examples in section 5 would be hardly doable without the speed of Instaseis compared to computing singular seismograms (up to 6 orders of magnitude) on typical computing infrastructures. To our knowledge, early-warning implementations do not typically rely on global synthetic seismograms. However, this may be an avenue of future research, and we note this down and get back to it once we implement a local or regional version of Instaseis.

Technical corrections

Title. This is a matter of personal preference, but I think that this title is stronger Instant global seismograms based on a broadband waveform database People will probably never find the code based on the title of the paper, so I don't see why it has to be in the title. Somehow it feels like the authors are trying to sell me "Instaseis" with the current title. (They do a good job!) I recommend putting "synthetic" in the title (either before seismograms or waveform), just to be clear.

We anticipate the reciprocal problem: knowing the name of the code we want to make very clear that this is the related paper where detailed technical documentation can be found. Currently, Google returns this paper among the first results for the search to 'instaseis'.

p. 958, L14. Maybe: "1-D Earth models" (since the implication is that the 1-D models are for Earth, not Mars)

In contrast to other codes, AxiSEM allows for planets very different from Earth. We rephrased to: AxiSEM is easily adaptable to arbitrary spherically symmetric models of Earth as well as other planets.

p. 960, L18. Comma: "sources, two."

Fixed.

p. 960, L5. widespread (not wide spread)

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Fixed.

italics are overused and are a distraction (e.g., Section 2.2). I don't see why they are present.

We agree and removed all italics besides for seismic phase names.

p. 962, L7. "The displacement u [move to here: within each element]"

Fixed.

p. 963, L26. The "Instead . . ." is ambiguous. Maybe "We follow a two-step, non-analytical approach to finding the reference coordinates. First, . . ."

Fixed.

p. 966, L19. Isn't open-source a big reason for choosing python?

We added this to the list of reasons.

p. 966, L22. Might want to avoid the term "use case," which may not be familiar to readers. (What about "uses for Instaseis"?) Or perhaps point the reader toward Section 5, where these use cases are listed.

Fixed as suggested.

p. 969, L10. Comma after "2 s period" or rewrite this sentence.

Fixed, added the comma.

p. 969, L11. Replace "them".

Fixed.

p. 969, L20. "which allows to do" (fix)

Fixed.

Figures. I was thrown off by the "/" used to separate the axis label from the units.

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Interactive Comment

Is that conventional? I think of / as division.

This is somewhat surprising, because it does not seem to be exotic notation but an international standard (ISO 31-0), see for example http://en.wikipedia.org/wiki/ISO_31-0. *(This is a particularly useful and widely used notation for labelling the axes of graphs[...])*. In this context, the / IS a division.

Figure 10. Would it be more appropriate to show the downsampled version as just points (unconnected)? This might also convey that it is not "bad" like the blocky one that is plotted.

Done.

Figure 13. "EM and PM [add: in the subplot title]"

Done.

Figure 17 caption. Change to "shows a three-component seismogram" (right?)

The sentence refers to the GUI, which generally shows three-component seismograms and not a single specific one (which the figure of course does).

Figure 20 caption. "southern California". Also you might want to mention that the beachball provides the orientation and predominant sense of slip. (Since a beachball usually implies a point source, which is not the case here.)

We added a note to the manuscript.

Figure 22. Is it possible to improve the perspective on this impressive figure? Perhaps adding a white equatorial great circle for each of the shells would do the job? And a white line running from the North Pole to the South Pole.

Done.

Figure 23. Just to be clear, you might want to start this caption with "Synthetics ambient seismic. . ."

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Interactive Comment

Done.

p. 968, L19. Give a parenthetical calculation for the 800 wavelengths number.

Added a note in paranthesis.

some native English editing could help in places; some examples are here:

We hope that this should happen during the production phase of the journal.

p. 960, L13. Change "AxiSEM was from the beginning designed" to "AxiSEM was designed from the beginning"

Fixed.

p. 967, L16 "from a usage perspective it thus does" to "thus from a usage perspective it does"

Fixed.

Interactive comment on Solid Earth Discuss., 7, 957, 2015.