Solid Earth
Discussions

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Interactive comment on "Imaging Seismic Wave-Fields with AlpArray and Neighboring European Networks" *by* Marcel Tesch et al.

Marcel Tesch et al.

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We thank the reviewer for their thorough and constructive feedback!

The authors proceed to an interesting and rather recent exercise in the field of passive seismology, which consists in processing the seismological records of natural earthquakes at dense large-aperture arrays and visualize ground motion vibrations as a function of space and time in a map (see e.g. IRIS Data Products http://ds.iris.edu/ds/products/gmv/).

As pointed out in the conclusion section of the article, this exercise is interesting for reaching a broad audience public, and there is probably also a potential for using such animations in joint science and graphic art experiments.

However, my first major comment is to question the general relevance of the exercise in the broad context of Geophysics: * What do we learn about the Earth? * What do we learn about the physics of wave-propagation? * Apart the images and videos, what are the results/products of this analysis, and how and why other scientists should use these? This information is not missing but spread over small portions of the manuscript, in result sections associated to each earthquake. Consequently the reader does not immediately grasp the full utility of such an approach. I would recommend better introducing the approach in introduction, with its impacts and benefits.

We revised the abstract and introduction to more succinctly state the utility provided by spatial observations of this nature. Examples include the better understanding of properties of the wave-field and its individual phases, or the necessity for correction of deformations for structural analysis. The use as a tool for data quality assessments and identification of faulty stations is also relevant.

My second major comment is about the displayed goal of revealing the resolution capabilities of the network and the spatial complexity of the wavefield through seismogram sections, times slices and wavefield animations. Are these standard ways of judging the resolution capabilities of an array?

The point is, that this is the first time in history where a seismological array provides the ability to spatially resolve wavefields from *single-event datasets* at such scale. Similar seismogram sections have been obtained previously by stacking waveforms of many events. In that sense it is not a standard way of judging resolution capability, as it wasn't possible before. We revised the manuscript to better reflect this.

What about other tools classically used in array seismology (array response functions, beamforming, importance for eikonal tomography or time reversal imaging, in tomography)? Such a goal does not seem to be completely fulfilled because the analysis is mostly qualitative, and would require being more quantitative.

Absolutely. The assessment of these datasets ultimately serves the purpose of un-

The authors suggest that the wavefield spatio-temporal complexity should be accounted for in tomography, but a question is what is the amount of the deviation with respect to an unperturbed case, and is this amount so large that tomography, with its parameterization, damping, or smoothing, makes a large mistake by taking wave propagation in 1D Earth's reference models? Could a quantitative estimate of the spatio-temporal complexity come from the extraction of first-order perturbations (scattered wavefield) with respect to a reference state (direct wavefield)? The records could for instance be processed with a principal component analysis to separate both components.

Another mean of judging the capability of the Array could be comparing the wavefield reconstruction with and without AlpArray.

Finally, my third major comment is about the organization of the paper. The Discussion

section is a mixture between a result section for each individual earthquake, and in each of these result sections, a discussion of the significance of the results. The article would benefit in presenting instead the results by type of observations of interest, e.g. 1. Spotting polarity and timing errors; 2. Wavelength of the wavefield; 3. Examples of scattering and resolution. 4. Spotting exotic phases. 5. Dispersion anomalies. 6. Amplitude anomalies; and then discuss the significance for the physics of wave propagation.

Minor comments: Page 1 line 31, left: Deviation from a plane wave. Any quantitative estimate?

Page 1 line 25, right: Seismic arrays: why not using classical tools from array seismology?

Page 1 line 35, left: I would say that the goal of tomography is to use (not really correct) this spatio temporal variability to image the structure at the origin of the variability.

Page 3 line 26, right: Why these 6 events and not others? Why are they representative?

The events cover a range of azimuths and distances (both local and teleseismic) and feature similar magnitudes, so that they can be compared within reason. After assessing a number of events we decided that this set best represented the properties we wanted to highlight. The text has been amended to make that clearer.

Page 3 line 40, left: Maybe compare with Hi-Net / F-Net?

These networks are now mentioned in the text.

Page 3 line 55, left: Is Faccenna et al. (2001) the first reference to introduce the concept of nappe stacking? This is ambiguous.

Further references have been added and the text is now formulated more clearly.

Page 3 line 37, right: how to go beyond the "illustration" of spatial resolution capabilities?

(see above)

Page 4, line 13, right: I am quite surprised that the large amplitude surface-wave past 45 s appears as small oscillations in your gray-scale background plot when the earlier long period wavetrain appears a lot stronger in the image. Is the result of amplitude normalization by the envelope, or an effect of time sampling (binning)?

This is caused by the envelope weighting. The individual seismograms plotted on top have the same time sampling as the background for comparison. Binning has almost no influence, as the bins are so small that usually only a few traces are averaged per bin.

Page 4, line 8, left, and Page 5, line 17, left: Concerning the processing, it is said that "all traces are detrended, instrument response-corrected, band-pass filtered between 100-500 s, and resampled to 1Hz" (page 4 line 8, left). This is long-period. Ok for looking at surface waves but what about body (P, S) waves? Figures 16 17 show âĹij3 cycles of a P-wave in a 1 min window, so I suppose that this particular figure does not

use the same bandpass as in the basic processing.

Yes, the processing as described is applicable to the seismogram sections, animations, and time slices.

Page 5, line 48, left: 8S, 9S, [. . .] →1. These are faint. 2. How can you be sure that these are corresponding phases? I think a close-up is needed for better demonstration...

We computed synthetic arrival times for many higher order body wave phases to be able to properly identify them in the section, so though they are faint, they are discerable and they are exactly where we would expect them. In the text we also clarifiy why some of them are labelled twice, due to arrivals from opposite directions.

Page 5, line 47, right: Discussion → Is this a discussion or a result section? In a discussion, instead of fo- cusing on events themselves, maybe you could focus on the particular features that you recognized in this data (see my major comment 3).

As addressed for the previous comment, the discussion has been revised accordingly.

Page 6, line 7, left: "artifact of projection" but what is the projection used here?

It's an equirectangular projection. Text amended.

Page 7, line 7, left: Aren't body-waves little dispersive? What difference in frequency content is there between the early and late part of the P-wave coda? Why do long-periods arrive late? Maybe a spectrogram could help? Which mechanism do you think is at the origin of this dispersion?

Body waves are little dispersive but they ultimately *are* dispersive. Analysis of body wave dispersion would require again an entire publication on its own.

Page 8, line 8, right: Fig. 7 -> Fig. 6 Page 8, line 11, right: spot instrumental problems → This is an interesting application, that could be introduced / listed in introduction and possibly abstract.

Has been added.

Page 9 line 28, left: Fig. 8-12 → why this reference to 4 figures when considering only the P/Pdiff case?

That was a mistake, has been corrected.

Page 9 line 45, right: Is this dispersion opposite to the one observed on R1? If so why?

It is. This is a result of the dramatically increased damping introduced by an entire additional orbit as well as the increased separation of the frequencies at such distances. Text has been amended.

Page 15 line 14-16, left: "Furthermore, amplifications in narrow bands often oriented almost parallel to the propagation direction are frequently observed". Could you show examples of these?

An example is given in Fig. 21. This is now clarified in the text. References to publications with similar observations have been added.

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