Authors response to anonymous referee 2

Suggestions for revision or reasons for rejection

Referee:

Thanks for the last corrections and additions. The manuscript and the English usage has improved a bit; however, there is still much room for improvements and main issues have not been solved. In particular, the introduction has to improve a lot to allow the reader to put your method in context and to clearly know the similarities and the differences with existing alternative methods. In addition to field data examples, synthetic examples and comparisons with conventionally used methods are often essential to illustrate the key contributions.

Authors:

Thanks a lot for the pointing to some typos and misleading in the text.

The main advantage of our method is using of global optimization algorithm for obtaining the solution with the best "signal-to-noise ratio". The global optimization approach is widely used for solution of inversion problems in geophysics. Moreover, it is also used in the recent applications of various artificial intelligence techniques (machine learning, deep learning) for processing of geophysical data. In our case, a SNR, calculated on each iteration, is an objective function in some parameter space (see Section 2 for description of model parameters) that is optimized. Global optimization approach ensures that the algorithm finds not some local, but global optimum for SNR. It is the main difference of our and existing approaches, described in numerous papers.

The corresponding text have been added to the Abstract and Introduction.

Referee:

MAIN COMMENTS

The third paragraph of the introduction (Pg. 2, lines 9-27) has several errors and some parts are misleading.

• Line 16: The time-frequency phase weighted stack (tf-PWS) was introduced by Baig et al. (2009) and Schimmel et al. (2011). Li et al. (2017) study the errors that some inverse S-transforms may introduce on subsequent phase-velocity measurements.

Authors:

This part of the introduction has been corrected. In our text we refer to all these authors.

Referee:

• I have to insist Li et al. (2017) should be Li et al. (2018), doi: 10.1093/gji/ggx448 . Although Advance Access publication dates from October 2017, the official publication date is from February 2018. I will use Li et al. (2017) below to avoid confusion.

Authors:

Reference to this paper has been changed as proposed.

Referee:

• As its name indicates, the time-frequency phase weighted stack studied by Li et al. (2017) is using stacking in the time-frequency domain not the frequency domain.

Authors:

These typos have been corrected.

Referee:

• Line 17: The time-scale phase weighted stacking from Ventosa et al. (2017) is not using stacking in the domain. It works on the time-frequency domain, as the tf-PWS, using the wavelet transform instead of the S-transform.

Authors:

This part of text has been corrected.

Referee:

• Line 17-19: This sentence has not much sense. Coherence can be written as a function signal-to-noise ratio (SNR). In order to improve SNR, the tf-PWS methods focus on weighting the components of the cross-correlation function (in seismic ambient noise applications) represented on the time-frequency domain in function of their coherence. I agree on that all cross-correlation are weighted equally. However, in conventional processing flows, anomalous cross-correlation are discarded in advance or in a second iteration. For example, Boué et al. (2015) classify day-long cross-correlation in high- and low-coherence days according to its coherence with the stack of one year of day-long cross-correlations and then stack them linearly. In addition, 1-bit amplitude normalization followed by cross-correlation, normalized cross-correlation or phase cross-correlation (PCC) methods contributed to severely improve the quality of the resulting EGFs by weighting signals instantaneously (1-bit & PCC) or per pair (normalized cross-correlation). Consequently, (1) it is not correct saying that these methods do not analyze SNR, and (2) it is not important that "ALL non-suitable cross-correlation functions are excluded from the final stack" as long as there are a subset of cross-correlation functions that contributes to the "final stack" with enough energy to be able to detect the signals under study.

Authors:

We corrected several typos in the text and tried to make it more clear.

We did not mean that these methods do not analyze SNR. We mean that these methods do not use SNR itself as an objective function for excluding of cross-correlation functions from the stack. We compared our results with weight stacking and this comparison shows that excluding as much as possible non-suitable cross-correlation functions is very important in the case when 1) one cannot continue experiment for a long time; 2) spatial distribution of noise sources is not stable during the

data acquisition period. Such factors may be not important for studies using, for example, coda waves, or experiments using ambient noise for lithosphere studies, but they are important in applied geophysics tasks. In our example, exclusion of non-suitable functions from stack allowed to increase SNR four times.

Referee:

• Line 19-21: In teleseismic coda-wave interferometry the source is known indeed. Conventionally, only a few hours of data are cross-correlated at once. As the source is an earthquake using the term "distribution of noise sources" is at least misleading. You may check Pham et al. (2018) for recent work on this topic.

Authors:

We changed “distribution of noise sources” to “source location” in this place.

Referee:

• Line 23: We cannot control or change the distribution of sources; at most, what we can pursue is improving the balance of sources.

Authors:

Under the word “control”, we mean “take into account”. This sentence in the text has been changed.

Referee:

• Line 25: It is not correct citing Li et al. (2017) here, see comment from line 16 and lines 17-19 above.

Authors:

The reference has been changed.

Referee:

• Line 24-26: Methods weighting or selecting correlations according to its coherence (e.g., Boué et al 2015 or yours), SNR (e.g., Cheng et al., 2015 and Nakata et al., 2015), or even rms (e.g., Shirzad et al., 2014) are close related. They all seek an improvement on the quality of the signals observed in stacked interstation correlations. They only differ on the strategies used to evaluate the contribution of each correlation to build up signals in the final stack and how they are weighted. In my opinion, it is key that you explain these ideas very clearly to allow the reader judge the contribution of your method in comparison to existing alternatives and to evaluate its potential contribution in their applications.

Authors:

We compared SNR of EGFs after using some of these methods and our method. The result of this comparison is presented in Figure 6. Moreover, in our method the global optimization is used for obtaining the best solution for SNR. This is the key difference of our method from other methods. We described this in Introduction and in the section with the description of the method.

Referee:

Pg. 3, eq. (1): Your SNR estimator evaluates the signal level assuming that the signal arrives from -t_{ds} to t_{ds} and considers everything as noise outside this range in order to evaluate the noise level. Two things have to be discussed to justify that this estimator is sufficient for your application: what happens when strong signals (not noise) are present from t_{ds} to t_{m} or from -t_{m} to -t_{ds}, and when signals are too weak to be observed in a cross-correlation function but arise after stacking.

Authors:

For calculation of noise level and SNR estimation, we use intervals from -t_{ds} to -t_{m} or from t_{m} to t_{ds}. Of course, inside these intervals some signal also may exists. In this case, this signal is considered as an artefact and this function is excluded from stack because of low SNR. To the moment, we did not notice that rejection of such cross-correlation functions (in other words, removing of outliers) makes impact on the final solution of optimization problem. If such problem arises in the future, further improvement of noise level estimation method (for example, by using mode instead of the average) can solve the problem. To the moment, this option is not implemented because it increases significantly the calculation time. This problem is partially addressed in Discussion part of the manuscript.

We also would like to pay attention that our task was to develop a practical technique for investigating mainly relatively shallow targets (e.g. the depth range that is relevant for environmental and explorational geophysics). For such areas the range of apparent velocities in this depth range (which is one of the parameters in our algorithm) is known from a-priori information (DSS, drilling etc.). In particular, both test areas in our paper are located in the Fennoscandian Shield (e.g. not completely unknown region) so we actually can predict quite well what phases we need to look for and in what time intervals they can appear.

Referee:

Pg. 9 lines 18-20: Standard array methods such as beamforming allow us to measure backazimuth and apparent slowness of signals generated by punctual noise sources and then estimate the direction of arrival of surface waves or the location of body waves (e.g., through backprojection). To first order, the aperture of the array determines the resolution of these measurements. Can you be more specific on how you can relate directly the aperture of the arrays with the location of noise sources.

Authors:

This comment is confusing, because we were not relating the aperture of the arrays with the location of noise sources in the text. In our paper we used the classical array techniques (Rost et al., 2002; Schweizer et al., 2012) that are based on the plane-wave approximation, and array aperture is a constraint that is used for testing whether the plane-wave approximation is valid for selected wave frequency.

Referee:

Pg. 10 lines 3-8: The figure of using from about 8 to 35% of the number of correlations available in the final stack is important for the reader, could you add this information to the manuscript.

Authors:

The is added.

Referee:

Finally, the English usage has to further improved. For example, in pg. 3 lines 23 and 24 and in pg. 4 lines 3 and 6, using "Let it is" or "Let they are" is not correct. You may use "It is / They are" or "Let it be".

Authors

The language was checked**.**

REFERENCES

Phạm, T.-S., Tkalčić, H., Sambridge, M., & Kennett, B.L.N. (2018). Earth's correlation wavefield: Late coda correlation. Geophysical Research Letters, 45, 3035–3042. doi:10.1002/2018GL077244