Solid Earth Discuss.,
https://doi.org/10.5194/se-2019-29-AC3, 2019

Solid Earth
Discussions

Interactive comment on "Improving quality of empirical Greens functions, obtained by cross-correlation of high-frequency ambient seismic noise" *by* Nikita Afonin et al.

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Received and published: 1 May 2019

Anonymous Referee #2 Received and published: 2 April 2019

Improving quality of empirical Greens functions, obtained by cross-correlation of high-frequency ambient seismic noise

General overview A main problem in exploration geophysics applications using anthropogenic sources of seismic ambient noise often is its far from ideal distribution that hinders the extraction of empirical Green's function using methods conventionally used at much larger scales using natural sources, for example, in seismology. The authors

introduce a method that seek for a subset of interstation correlations that maximize the signal to-noise ratio (SNR) after stacking to promote converge to the empirical Green's function. Overall the manuscript is interesting but the English usage has to improve and many places need for greater clarity. I just have a few comments.

Main comments

Referee: âĂć Pg. 2: The introduction on the stacking methods is confusing. I would distinguish methods that weight correlations according to the SNR of each correlation (Cheng et al., 2015) or that stack only correlations with high or low coherence (Boué et al., 2014) from methods that weights signal coefficients in a transformed domain after a linear stack, such as the time-frequency phase weighted stack (Baig et al., 2009; Schimmel et al., 2011; Li et al., 2018) or the time-scale phase weighted stack (Ventosa et al., 2017). A clear separation between these methods can help the reader to place your method in its proper context.

Authors: Thanks a lot for more clear formulation of the sentence. Correspondent text in the manuscript has been changed.

Referee: Pg. 2, line 10 and 14: Li et al. (2017) should be Li et al. (2018).

Authors: This work published in 2017: Li, G., Niu, F., Yang, Y., & Xie, J. (2017). An investigation of time–frequency domain phase-weighted stacking and its application to phase-velocity extraction from ambient noise's empirical Green's functions. Geophysical Journal International, 212(2), 1143-1156.

Referee: âĂćPg. 2, line 25-26: Can you give detailed information on the pre-processing and the cross-correlation function you apply?

Authors: There is a number of studies devoted to calculating of EGF from ambient seismic noise. In our study, we used the preprocessing routine described in details in Benson et al. (2007), Poli et al. (2012, 2013). These procedures now are the "standard" pre-processing procedures in passive seismic interferometry. That is why we did

not concentrate in our paper on these details, but only refer to the papers mentioned above.

Referee: âĂć Pg. 2, line 28-30 and Pg. 3, line 11: These sentences are misleading. Interstation correlation functions do not always give an empirical Green's function. They converge to an empirical Green's function when the distribution of source is fairly well distributed. Hence, the importance of the pre-processing, correlation, stacking methods, and potentially the method you introduce, to seek a good balance of sources.

Authors: We put a corrected, more clear explanation into the text.

Referee: âĂć Pg. 3, eq. (1): This estimation of SNR is fine when the strongest signals arrive on the expected time lags (from ôĂĂĂtds to tds) and you have no signal outside. Have you considered using more robust estimators of the noise level such as median absolute deviation (MAD). What happens when signals are too weak to be observed in a cross-correlation function but arise after stacking?

Authors: This estimation is out of the scope of our paper. Signal-to-noise ratio could be estimated by several methods. Of course, the results depend on the choice of method for this calculation. The main thing that we were going to demonstrate in our paper is our technique that is using the stacking method together with the global optimization of the signal-to-noise ratio. Analysis of different methods of SNR calculation is a task for our further studies, and we agree that there is a potential for further improvement of the method.

Referee: âĂć Pg. 4, lines 14-21: This paragraph is not clear. If I understood what you mean, you need to know seismic velocity in order to measure the azimuth of the strongest source; however, seismic velocity structure is often what we seek in most applications. In addition, you mention that a 2-D array is necessary. Can you further explain how you use it to estimate the azimuth distribution of sources.

Authors: Estimation of time lags intervals with expected signals is calculated according

to the plane wave condition as in beamforming. Limits of velocities are selected according to a priory information about the studied medium. After this, such parameters as the SNR, apparent velocity and azimuths are optimized. Therefore, we can estimate probable values of azimuth and velocity. The explanation has been added to the text.

Referee: âĂć Pg. 5, around Fig. 1 & 2: I would personally emphasize in these figures which stations use MEMS and which Trillium Compact.

Authors: Figure caption has been corrected.

Referee: âĂć Pg. 8, line 1: An extra sentence is needed here to explain how you locate highfrequency noise sources at distances from about 0.7 to 3 km from the center of the arrays.

Authors: As we apply standard array methods for location of noise sources, we assumed these values from apertures of these arrays. The additional sentence has been added to the text.

Referee: âĂć Pg. 8, line 17-22: Which is the portion of correlations that conventionally build up the final stack?

Authors: It is difficult to estimate because it is strongly dependent on features of the noise wavefield. In two cases considered in our study, the number of cross-correlation functions used in the final stack varies from about 8 to 35% of the total number of calculated functions.

References Boué, P., Poli, P., Campillo, M. and P. Roux (2014). Reverberations, coda waves and ambient noise: Correlations at the global scale and retrieval of the deep phases, Earth Planet. Sci. Lett., 391, 137–145, doi:10.1016/j.epsl.2014.01.047 Baig, A., Campillo, M. and F. Brenguier, F. (2009). Denoising seismic noise cross correlations, J. Geophys. Res., 114(B8), 2156–2202, doi:10.1029/2008JB006085 Ventosa, S., Schimmel, M. and E. Stutzmann (2017). Extracting surface waves, hum and normal modes: time-scale phase-weighted stack and beyond, Geophys. J. Int., 211(1),

30–44, doi:10.1093/gji/ggx284

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