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Interactive comment on "Observation and explanation of spurious seismic signals emerging in teleseismic noise correlations" *by* Lei Li et al.

Lei Li et al.

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Pilar Sánchez Sánchez-Pastor (Referee #2)

This is an interesting manuscript that studies a spurious signal observed in the correlograms of seismic noise between two distant seismic networks. The authors employ the double-beam method to estimate the slowness of several seismic phases as a function of distance and thus, track the observed interfering waves and determine the origin of that spurious signal. Furthermore, the authors provide a physical explanation for such signal through numerical simulations and observe it as well in synthetic correlograms. In my opinion, the study is well addressed and scientifically valuable. However, the presentation of the manuscript should be improved before possible publication. Basi-

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Discussion paper

cally, the manuscript needs to be written with more care and some minor corrections are required. My suggestions and comments are described below.

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Reply: The authors would like to thank the reviewer for her careful reading and constructive comments. Point-to-point replies are provided below.

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- In the Introduction, I would have liked a better introduction of spurious signals, why is useful to study them, mention the previous similar studies and, in general, explain better the problematic. Also, I would update some references with new studies and add some in pag. 2, lines 4-9.

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Reply: The authors recognize that the initial version of Introduction needs to be extended. We thank the reviewer for this comment. The other reviewer made a similar comment on the Introduction. We have added new citations and extended the Introduction to better describe the background, especially, some existing applications of noise-derived deep body waves (including spurious phase).

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- Line 29, pag. 2: Vague sentence. Some readers very likely would not understand what you mean.

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Reply: We agree with the reviewer and have removed this dispensable sentence.

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- Line 30, pag. 2: It is worth it to specify the amplitude threshold (how many times of the standard deviation) that you consider to clip the waveforms and avoid large transients.

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Reply: We mention in the revision that we clipped at 3.8*std, which is just an empirical choice following previous studies (Poli et al., 2012; Boué et al., 2013). We did not specify the value because the choice is more or less arbitrary. No problem to choose other values. Of course, a very large value (e.g., 100 times) would make the clipping ineffective in removing impulses. A very small value (e.g., 0.1 times) would have a similar effect as the one-bit resampling. A modest choice of 3.8 leads to an effective clipping of large transients and retains the waveform of stationary noise (Fig. 3 for examples).

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- Line 5, pag. 3: If it is the first time that the kurtosis is employed in seismic noise processing, the authors should explain it better. For example, the equation described is a comparison between the kurtosis of the distribution under study and the kurtosis of a normal distribution, which is 3.

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Reply: Following comments by both reviewers, we have described more on kurtosis, and also explained, as suggested here, that including the term 3 makes the kurtosis of Gaussian distribution zero.

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- Line 8, pag. 3: "the segments beyond 1.5 are discarded" why this value? It would be proper a short comment to explain it.

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Reply: We have clarified in the revision the threshold of 1.5 is empirical. The threshold, if too small (below $\sim$1), will reject good noise segments, and if too large (above 3-5), will let pass impulsive segments. A value between 1 and 2 is suggested. From our

experience, 1.5 works fine for various datasets.

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- Line 20, pag. 4: Vague sentence. Which numerical experiments?

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Reply: This problem was also raised by the other reviewer. We have described more on the numerical experiments in the revision: “To investigate the resolution capability of the double-array slowness analysis for the FNET-LAPNET geometry, we make numerical experiments by presuming (a) the same slowness at FNET and LAPNET (4.6 s/deg), and (b) different slownesses at FNET (4.7 s/deg) and LAPNET (4.2 s/deg). Assuming plane waves passing through FNET and LAPNET, the time delays between FNET and LAPNET station pairs can be calculated from Eq. (1). The wavelet of the observed spurious phase (5 to 10 s bandpass filtered) is convolved with the time delays to synthesize the correlation functions. The synthesized correlations are beamed by Eq. (2) for various slownesses.”

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- Lines 4-9, pag. 5: I think the proposed slowness-track method to identify the ray paths of the interfering waves is not enough clear. In my opinion, this paragraph can be improved and make easier to follow the idea. - Line 7, pag. 5: “The pairs of seismic phases are rejected if the difference between the distances from the source to the receivers differs from 63 âÛę or if their time delay deviates from 430 s” why? It could be obvious but indicating a reason works out well for a better understanding.

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Reply: We agree with these comments and have rephrased this part.

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- Line 20, pag. 7: I imagine those results imply a lot of work and they are interesting.

So perhaps it is worth adding a supplementary figure.

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Reply: See the new Fig. S6 and relevant supplemental text. Thanks for this suggestion.

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FIGURES: - Figure 3: you should use same colours as in Fig 2 to be consistent. Also, the title “after clipping” I would say amplitude clipping or something similar in order to avoid misunderstandings.

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Reply: Modified accordingly. Thank you for pointing this out. We ignored this detail.

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- Figure 4: The labels a) b) etc are missing. Moreover, you should explain the overlapped signal in the figure caption.

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Reply: Labels and text annotation for the beamed signal have been added.

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- Figure 5: From my point of view, it can be added to the supplementary material. If you consider the supplement is already too long, the Figure S1 is dispensable.

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Reply: Thanks for your suggestion. Considering that double-array slowness analysis is first proposed in this paper and the resolution is critical to our argument that the interfering waves have distinct slownesses, and also that SE is an electronic journal that has no constrains on the paper length, we prefer to keep the figure in the main text.

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- Figure S1: I would change “removed-mean series” for pre-processed series because you correlate after removing the mean, trend, filtering, whitening... Moreover, I would add in the colored bars at the top a label “i” and in the bars at the bottom “i” and “i-τ” (following the notation of the eq) to illustrate the dislocation applied by the correlation. Although, I believe it is better only correlate the “effective samples” instead of adding zeros. In this way, for large lag times you underestimate the correlation.

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Reply: Figure S1 is intended to explain the computation of correlation function in a general sense. The formulae displayed in the figure only require the series being de-meaned. So, it is not a problem. Of course, the referee is right in the context of seismograms. The correlation function is routinely calculated by FFT for efficiency. The zero padding at the bottom of Fig. S1 is just for explanatory purpose. Concerning the underestimation of correlation function at large lags, a modified scheme for calculating the correlation function described in figure 2.21 in section 2.4.2 of my thesis can deal with this problem (https://www.theses.fr/2018GREAU023.pdf). This is irrelevant to the topic of this paper. So, we do not talk much on it.

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- Figure 8: is it computed or taken from other study?

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Reply: All data sources are indicated in the Acknowledgement. We have clarified in the caption that the data in Fig. 8 come from Rascle and Ardhuin (2013).

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- Figure 10: you should describe what the red point represents in the figure caption even if this seems obvious. In my view, figure captions should be auto-explicative and

if they are not, one should indicate where the reader could find the information.

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Reply: We agree that it is common to describe lines and symbols in the caption. But this appears discouraged by Solid Earth. “A legend should clarify all symbols used and should appear in the figure itself, rather than verbal explanations in the captions (e.g. "dashed line" or "open green circles").” (https://www.solid-earth.net/for_authors/manuscript_preparation.html) We used text annotations on the figure to indicate that the red dot corresponds to the observed spurious phase beamed at 63° distance.

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OTHER MINOR COMMENTS: - Line 2, pag. 2: “We refer to (Campillo and Roux, 2015)” without parenthesis.

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Reply: Corrected. Thanks.

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- Lines 26-29, pag. 5: reference?

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Reply: Added.

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- Line 17-20, pag. 6: Those sentences can be improved.

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Reply: We have rephrased this part.

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- Line 29, pag. 6: “The ray-based simulation above” would be better like: The above-described ray-based simulation... - Line 23, pag. 7: In my opinion, this section should be called ’Conclusions’.

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Reply: Modified accordingly. Thanks.

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