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Interactive comment on "Structure of Suasselkä Postglacial Fault in northern Finland obtained by analysis of local events and ambient seismic noise" *by* Nikita Afonin et al.

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Comments by Anonymous Reviewer

This paper presents a seismological study of a postglacial fault in Finland instrumented by a local seismic network of 12 seismometers. The array recorded during 20 months. After rejecting the mine blast events, the authors found 40 natural seismic events, with tens of them originating from the postglacial fault. The authors studied the ambient noise recorded by the array. The deduced a 5 m thick quaternary sedimentary layer from H/V ratio analysis. By inverting group velocity dispersion curves extracted from ambient noise cross-correlations, they showed that the seismic velocities in the vicinity of the fault are significantly lower than further away. They concluded that even if the

postglacial fault seems non-active from a regional seismic network point of view, a more careful a closer analysis shows that these faults are still active and that they did not heal since their creation 9000-15000 years ago. The topic of this study is of great importance to characterize the seismic hazard in a certain areas where hidden or supposedly non-active faults can present a serious threat for the populations. It clearly shows that often, regional seismic networks don't have the sensitivity to detect micro-seismicity evidencing the potential activity of such faults. Some areas that were thought safe may actually be not. I am a little bit less enthusiastic about the ambient noise analysis, both the H/V analysis and the dispersion curves measurements from the noise cross-correlations needs some clarifications. I am quite surprised by the high frequency resonance frequency at 30 Hz, which seems very high compared to what is usually found in the literature. Parolai et al. (2002, BSSA) derived an empirical law for the relationship between the depth of the layer and the resonance peak and found that a 5 m layer would resonate between 5 and 10 Hz. However, their shear-wave velocity is different. Can you explain how you found this value of 5 m: is it an inversion, a fit from empirical relationship?

Reply: In our study we used the Geopsy software (www.geopsy.org) and correspondent recommendation for H/V spectral ratio analysis and interpretation in terms of thickness. It is approximate value. According to petrophysical data, the S-wave velocity estimation for the uppermost sedimentary layer in this region is about 300-500 m/s. Therefore, thickness of this layer is about 3-6 m and the averaged thickness is about 5m.

Comment: For the dispersion analysis, I suggest to show some Frequency-Time analysis diagrams, so that the reader can see by himself the fundamental mode and the first overtone because they are not obvious from the correlation waveforms shown in the paper.

Reply: For dispersion curves estimation we did not use frequency-time analysis, as we noticed that in the same EGF only fundamental or the 1-st higher mode prevails (but not two of them appear together). Moreover, for some station pairs we observed only fundamental or the 1-st higher mode. Therefore, it was not possible to show them together in one spectrogram. Figure 11 with 2 modes is shown just as an example that two modes were seen in the data.

Comment: Also, I understand that the dispersion curves can be noisy and hard to pick, but I would suggest to do a full 2D inversion of the individual dispersion curves to compute group velocity maps of the area covered by the array. These maps can then be inverted at depth to produce a 3D velocity model of the fault zone. The results would be more convincing than the inversion of two ad hoc averaged dispersion curves to show the low velocity around the fault.

These are the main reasons why I would ask for a major revision before publishing this paper.

Reply: This is the question that was asked also by Reviewer 1. At the early stage of our research we tried to calculate 2D velocity sections. Our major conclusion from this exercise was that it would be better to provide reliable and stable solution for the first-order approximation of the fault zone area than not very reliable 2D model of the area. For station pairs installed on the same sides of the fault there were too few dispersion curves for reliable 2D results, but scatter and bimodal distribution of dispersion curves is a very well documented feature (see Fig. 12 of the revised manuscript). Therefore, we calculated 2 averaged dispersion curves and solved inversion problem for each of them. These models can be considered as the first-order approximation of the general structure of the fault zone. We hope that our paper would motivate further studies of this particular fault zone with denser network and better spatial resolution.

Specific comments: - Page 2, Lines 25-28-30: the acronym of 'postglacial fault' should be define at the first occurrence and be consistent all along the text (use always PGF for instance).

Reply: The first occurrence of the acronym of 'postglacial fault' is defined in the Abstract (Page 1, line 16).

- Page 5, lines 3-4: Provide a figure showing examples of the two waveform groups along with their spectra.

Reply: The figures 4 and 5 with examples of events of two groups (waveforms and spectrograms) are added.

- Page 5, line 28: typo ! 'f'rom Corrected.

- Page 6: The description of the beamforming procedure is not clear. Do you perform the beamforming of the cross-correlations or on the raw seismic noise? What do you call 'surface wave parts' (line 15). You should consider to write the beamforming equation you used to make everything clearer.

Reply: We applied beamforming procedure in the time domain to cross-correlation functions (see P 6, L 18). Surface wave part of EGF has elliptical polarization, so visual analysis of seismograms of ambient noise on screen is possible to apply and to see whether the waveforms corresponding to noise are correlated or not. We used a standard time-domain beamforming procedure (Rost and Thomas, 2002, and Schweizer et al., 2012). This procedure is implemented into the Seismic Handler Motif software: the selected waveforms are marked on seismograms of all stations of the array on screen, then the beam forming in time domain is applied and provides the value of the azimuth.

- Page 7, line 13: why don't you use the whitening, it is often necessary to use it in order to obtain reliable correlation functions and dispersion curves. You should at least try both, with and without to see the difference.

Reply: we tried both in the beginning of our study, but the difference was not significant, in our opinion, that is why we finally decided not to apply whitening.

- Page 7: The explanation of the asymmetry of the correlation functions is dubious. It is not the distance between the stations that creates this asymmetry, but the noise sources strength azimuthal distribution.

Reply: Overlapping of pulses for waves with length of more than interstation's distances, of course, is not related with asymmetry, we just observe two part of EGF overlapping, because time shift for casual and acasual parts of EGF's is less or equal to about one period. Such EGF with overlapping pulses appear as asymmetric ones, therefore in the text we used the term "asymmetry". We corrected it to "apparent asymmetry" in the revised manuscriprt.

- Page 7, line 24: Specify what type of velocity you are measuring (group or phase).

Reply: We measured group velocities for frequency bands with width of 0.125 Hz. But for dispersion curve extractions these velocities approximately may be taken as phase velocities. The explanation is added to the text.

- Page 8, lines 3-6: The inter-station distances for group 1 pairs may be significantly smaller than for group 2 pairs (and with a main NW-SW orientation). Can the difference of velocity be explained by the difficulty to pick the dispersion curves for short distance station pairs or from a bias due to a predominant direction of noise sources. Using the whitening could also help to 'homogenize' the nose source distribution.

Reply: For station pairs from different groups, the distances are approximately equal.

- Page 8, line 15: remove the first 'seismic' Corrected.

- Page 8: You use the Neighbourhood Algorithm to invert the dispersion curves at depth: what parameters do you invert (how many are they?) and what parameters boundary do you used?

Reply: We added a new Table 3 with parameters of the starting velocity model for inversion of dispersion curves. It shows also the boundaries for model parameters.

- Page 9, line 23: typo, 1200 m Corrected

- Page 9, line 23: Can this high velocity layer seen at 1200 m for both models be an artifact due to the fact that you set the depth parameter boundary for the last layer around 1200 m, so the inversion cannot find a deeper layer?

Reply: We added to Table 3 more detailed information about parameters of starting model. As one can see, we used 4-layered model and the range of parameters variations is large both for boundaries depths and velocities. But solutions with minimum misfit were found for 2 and 3-layered model. Inversion cannot find deeper layers, because of frequencies of the signal.

- Figure 1: Show an inset of a larger view of the geographical area show in the main figure. You should also consider to use the same coordinate system and coordinate boundary for all the map that you show in the different figures.

Reply: We made a new Figure 1.

- Figure 2: Merge figure 2 and 3 and show the fault on the map.

Reply: Figures 3 and 4 are merged into one, and position of fault is shown on the map. We decided to keep Figure 2, as it gives more information about seismicity detected previously by regional networks.

- Figure 4 and 5: use a logarithmic color scale to better show the details of the spectrograms. And use always the same amplitude limits to help for the comparison between the different panels.

Reply: Colour scale in Figures 4 and 5 corrected taking into account also comments of Reviewer #1 (new Fig. 6 and 7)

Figure 6: Plot the dates in abscissa instead of the number of days. We see the figure we believe that the data point are continuous whereas there is a big gap between the dates. It's misleading.

Reply: We used numbers of days because of the data gaps, in order to make the figure more compact. But we provided a detailed explanation in the text about correspondence of dates to numbers of days.

Figure 9: Show the Frequency-Time diagram with the picked dispersion curves on top

of it

Reply: For dispersion curve estimation, we did not use frequency-time analysis, as we noticed that in the same EGF either fundamental mode or the 1-st higher mode prevails. Moreover, for some station pairs we observed only fundamental or 1-st higher mode. Therefore, it was not possible to show them together in one spectrograms. The figure shows just examples of fundamental and 1-st higher mode, because we wanted to demonstrate that two of them were present in the data.

Figure 10: Show every dispersion curves from both groups along with their respective average.

Reply: The figure is corrected (new Figure 12).

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