Comment on egusphere-2023-45 by Anonymous Referee #2

We sincerely thank the referee for the valuable comments which will help to improve the paper. Please find a point-by-point response to the comments. Our responses are in red. Actual changes to the manuscript are written in *italic.*

On behalf of all authors, Yours sincerely,

Fabian Limberger

Comments by Anonymous Referee #2:

Limberger et al. use numerical models to simulate the effect of wind-turbine generated noise on seismic stations installed in boreholes. In particular, they model the Landau region geology and nearby wind farms to validate their results against existing measurements from Zieger and Ritter (2018). The study is well structured and the effect of wind turbine noise is systematically analysed for different sensor depths, geological layering and associated seismic velocities, and damping parameters of the subsurface, requiring minor revision. However, I am missing some explanation on the authors' choices of the input and presented results in several parts of the manuscript. Also, by giving recommendations on how to apply the model for designing new borehole stations in existing settings, where seismic monitoring is necessary and wind farms are present. These suggested changes would make the study more practical and give the work more impact. For example, this could be addressed i) by stating the performance of the modelling in the more complex Landau setting and ii) by showing which settings (number of layers, dimensions, etc) can be simulated and which not. Also, it would be nice to show for which borehole depth the gain of placing borehole sensors is highest.

l. 57: The authors should describe in more detail why this source signal was chosen. In particular, is this an average signal of WT noise due to strong winds or a specific tower height? What controls the frequency content? This could be explained with respect to the presented results of Zieger and Ritter (2018), that classify strong versus weak noise conditions.

> The chosen frequency range of the source signal (0.2 Hz-6 Hz) is typical for wind-turbine induced signals, as explained in line 66. Especially, waves with a relatively low frequency (about 1 Hz) are widely observed at seismometers in the neighborhood of wind turbines. The frequencies of about 1 Hz and 3.7 Hz are typically related to bending modes of the tower. We agree that, depending on the wind turbine type, these frequencies might be slightly shifted from turbine to turbine. To keep the estimations and methods universal, we have chosen to use all frequencies between 0.2 Hz and 6 Hz as source signals, instead of specific ones.
>
> We add the following text to line 67 for clarification:
>
>> *Signals at about 1 Hz and between 3 Hz and 4 Hz are widely observed by seismometers close to WTs. These frequencies are related to the tower eigenmodes of a WT (Zieger & Ritter, 2018; Zieger et al., 2020) and depend on the type and specifications of the WT. Hence, instead of choosing just a few specific frequencies corresponding to one specific wind turbine type, we keep the approach universal and study various frequencies between 0.2 Hz and 6 Hz.*

l. 158ff: This section is a theoretical approach but not very useful. It would be much more applicable if a more realistic attenuation could be modelled, as shown e.g. by Bethmann et al.

(2012) https://doi.org/10.1111/j.1365-246X.2012.05555.x or a gradient rather than just 2 layers with constant values. Attenuation is important to consider in the analysis but should not be too simplified. This is similar to my suggestion of stating the complexity of settings that could still be simulated with the model and should be included in the discussion.

That is an interesting point. We agree that in some cases, the chosen attenuation model should be more complex including more layers with attenuation or even a gradient. However, with our simulations we find that the attenuation is not the key parameter that controls the amplitudes as function of depth. Therefore, we did not go into further detail concerning attenuation. We wanted to look systematically at various effects, starting with simple models. In general, using the Mondiac-software package Salvus (as we did), models can be designed with high complexity including a large number of layers, parameter gradients etc. This means that the limit of complexity is rather defined by the available amount of subsurface data, than by the software that is used.

l. 258: Maybe a similar figure as Fig 2 of Prevedel et al. (2015) https://doi.org/10.1007/s00531-015- 1147-5 could be attempted based on the modelling results of wind turbine noise.

We see the advantage of such a figure. However, the analysis of signal to noise ratio would require the simulation of a target signal (such as earthquake signals) as well, which is beyond the scope of our study, but could be an important step in the future.

4 Discussion and conclusions: How difficult would it be to include other measures in the m odelling (e.g. trenches as given by FAWind (2021), Minderung seismischer Wellen von Windenergieanlagen. Strukturelle Maßnahmen auf dem Wellenweg.)? As the authors state themselves the study would benefit from more data for validation.

That’s a very good point. As mentioned above, using the software package Salvus, models can be designed to be very complex. This means that trenches, filled caverns, or other structural aspects (e.g., topography) could be included in the simulation. We agree that this is an important point to be considered in the future to effectively reduce noise from wind turbines. However, within our study we wanted to focus on general (“natural”) effects of the subsurface, such as layering and velocity parameters. The incorporation of structural measures (see Abreu et al., 2022) and borehole installations could be a promising solution and should be studied in further research.

We added a sentence to the discussion (line 246) to specifically point to that aspect:

Moreover, additional structural measures (e.g., filled trenches) as studied by Abreu et al. (2022) could be included in the simulation to incorporate the noise-reducing effects due to boreholes as well as structural measures. .

Minor comments:

l. 54 <u>of </u>the complete wavefield

This mistake is corrected.

Fig. 2: The red line in Fig. 2 requires a more detailed description and explanation in the text. Should the red labelling be displayed on the vertical axis? What controls the amplitudes of the synthetic traces? Are the relative amplitudes normalised to the input signal? Please explain better the meaning of this figure.

We extended the caption of the figure to clarify the normalization and "how-to-read" the figure.

Fig 5: Show the reference values from Model 4 (e.g. black line in Fig 4 d) by dashed lines in this figure.

Thank you for this suggestion. We added the 50% reduction line from Fig. 4d (which is actually identical to Fig. 5d) as a dashed line in all other subfigures in Fig. 5.