

The Cryosphere Discuss., referee comment RC3
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Comment on tc-2021-219

Ludovic Moreau (Referee)

Referee comment on "Seismic physics-based characterization of permafrost sites using surface waves" by Hongwei Liu et al., The Cryosphere Discuss.,
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This paper reports on the inversion of the dispersion curves from two types of seismic waves propagating in permafrost, to evaluate soil properties via a three-phase analytical model that accounts for the porosity and mechanical properties in the three layers. I think this paper is well written and is of interest for the audience of the Cryosphere. The findings are convincing, and in my opinion the paper deserves publication after the comments listed below have been considered.

General comments

For a non-specialist of permafrost-related studies, it would be beneficial that the authors provide a more systematic comparison of their approach with already existing methods. The main novelty here is the fact that the forward model includes new parameters (such as porosity, and the degree of ice saturation), and that the two waves are sensitive to different sets of parameters, which allows a separate inversion instead of a joint inversion. This should be emphasized by citing previous investigations of permafrost with seismic methods, and by checking that the parameters are consistent with other similar studies, when possible.

Specific comments

- It would be useful to have a map of Svalbard showing the location of the experiment and the seismic network, instead of figure 4a, which does not provide much information about the study.
- Section 3. There are many methods to extract dispersion curves from a shot gather. Please indicate which was used here.
- Figure 4. I am not sure that the terminology employed to describe these two waves is adequate. The spectra look similar to those encountered when dealing with a mix between surface and guided waves, which are also created by the interferences between P and S waves. Leaky guided waves are encountered in configurations where the layers have impedance discontinuities, for example sea ice on water, seismic waves in roads (a hard layer of bitumen resting on a soft substrate). Moreover, the R2 wave seems to have a cutoff frequency around 12 Hz, which indicates a higher-order mode. This needs clarifying. This could also be another explanation for the higher misfit in figure 7d. Have you checked the polarization of the two waves?
- I do not see a direct transfer of this work to the applications mentioned in introduction

and conclusion, such as

- "...the design of an early warning system for permafrost by means of an active or passive seismic test."
- "we can also predict the soil type and the sensitivity of the permafrost layer to permafrost carbon feedback and emission of greenhouse gases to the atmosphere. "

- These claims are a bit overreaching to me, because these remain to be proved. However, they could be mentioned as a follow-up to the present paper, with some guidelines on how to achieve these goals.

- In absence of ground truth for comparison, can you at least quantify the uncertainties of the inverted parameters?

- 233 " These predictions fit well within the reasonable range of volumetric unfrozen water content for clay or clayey silt". Please provide a reference.