The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2019-52-RC1, 2019

The Cryosphere
Discussions
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Interactive comment on "Improved characterization of alpine permafrost through structurally constrained inversion of refraction seismic data" *by* Matthias Steiner et al.

Anonymous Referee #1

Received and published: 15 April 2019

The manuscript "Improved characterization of alpine permafrost through structurally constrained inversion of refraction seismic data" by Steiner et al. provides a novel inversion approach of seismic data to identify alpine permafrost. For this purpose, the authors conduct a review of geophysical applications in permafrost studies. They collect Ground Penetrating Radar (GPR) data to get subsurface information, which they use to constrain the inversion of refraction seismic data (RST). The authors apply synthetic data to test the sensitivity of their approach to seasonal variation of the active layer. Furthermore, they apply their new inversion scheme to their collected seismic data and can validate one time step of their synthetic model. Unfortunately, this paper is very technical and addresses a geophysical audience, therefore, the manuscript

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Discussion paper

should be more focused on permafrost data to address the cryospheric community reading "The Cryosphere". The geophysical approach is interesting, however, (1) numerical examples incorporating topography should be improved and anisotropic effects addressed. Furthermore, there are also substantial problems of manuscript. The paper aims to (2) address alpine permafrost, however, provides no new information on permafrost compared to the previous study by Schoener et al. (2012), which is due to the chosen time of data collection and research set up. The paper could be suited for publication in Cryosphere if the authors can provide more data to validate their time-step model (Fig. 5 and 6) and discus the observed and modelled permafrost dynamics. (1) The geophysical approach is very interesting but solely focused on a geophysical community. To generate starting models by incorporating structural data is a good but also an existing idea. The authors want to show the applicability in rough terrain (Figures 1 and 2), however, they choose a topography that challenges maybe geophysical model approaches but does not exist in nature. The author should demonstrate their approach on realistic slopes such as inclined slopes with ledges and rock steps or ridgelines. In addition, the authors assume an isotropic underground as most seismic models, however, a dominant vertical fracture set cause anisotropy that can impede recognition of permafrost layers (e.g. Phillips et al., 2016). The authors should discuss these effects. The time-step scenarios (Fig. 5) are interesting, however, water cannot saturate the voids of debris layers on slopes (Fig.5 T1), and the water would simply run off on steep alpine slopes. Furthermore, the frozen scenarios (Fig. 5 F1 and F2) will not exist in this way. The voids of the debris layer will not be frozen to the surface, thus, saturated conditions are unrealistic. However, the pores of the individual rocks forming debris layer can be saturated and frozen and, therefore, increase p-wave velocities and enable the application of seismic methods. In general, the approach of geophysics should be a tool to provide realistic models of nature in this case alpine permafrost terrain and should be used to provide new information on permafrost dynamics interesting to the readership of The Cryosphere rather than test synthetic data of unrealistic scenarios that demonstrate the applicability of the used algorithms. The latter use is a valid approach, however, more interesting to a geophysical community and a journal focusing on geophysics, algorithm and inversion approaches.

Phillips, M., et al. (2016). "Seasonally intermittent water flow through deep fractures in an Alpine rock ridge: Gemsstock, central Swiss Alps." Cold Regions Science and Technology 125: 117-127.

(2) The authors collected GPR and seismic data in May at a point in year when the active-layer is frozen. Therefore, the authors can identify structural differences in their GPR and seismic data that show a snow layer underlying by a frozen debris and a subsequent frozen bedrock layer. They cannot provide any information on permafrost, thus, the timing of data collection inhibit the differentiation of an unfrozen active layer above a frozen permafrost layer. Therefore, the novel seismic model maybe improves the data inversion but the applicability to permafrost is purely based on synthetic models. These models should be validated by data. Therefore, I recommend including minimum one more time step that shows the maximum or near maximum active layer depth in late summer and beginning of autumn. This is the usual timing permafrost scientists apply geophysical techniques to get information on active layer depth and annual changes of permafrost distribution to estimate effects of climate change such as the authors introduced. Furthermore, the authors should provide some independent data to validate their models in terms of unfrozen and frozen status. By incorporating GPR data in the seismic inversion routine, there is a lack of independent data to validate the model results such as temperature boreholes or 1D to 3D temperature models could provide. Schoener et al. (2012) used an interesting approach combining GPR, seismic data, borehole data and temperature models to show active layer dynamics and permafrost distribution in the Hoher Sonnblick. Compared to Schoener et al.'s study, this study currently provides no new insights on permafrost dynamics at Hoher Sonnblick.

See detailed comments in attached pdf

Please also note the supplement to this comment:
https://www.the-cryosphere-discuss.net/tc-2019-52/tc-2019-52-RC1-supplement.pdf

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