

## ***Interactive comment on “Applicability of time-lapse refraction seismic tomography for the detection of ground ice degradation” by C. Hilbich***

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REPLY TO REFEREE #1 (O. SASS)

Many thanks for your review. I agree with almost all of your comments and revised (and shortened) the paper accordingly. However, due to a number of further details, which had to be added as requested by Referee #2, the overall length of the paper did not reduce significantly. Below, I shortly indicated my changes and commented in a few cases, why I decided to keep things as they were or why I changed it differently.

p. 79, line 15: Due to its complementary nature → unclear, seismic refraction is not per se complementary

- REPLY: as seismic refraction is investigating the elastic properties of a material, it is  
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complementary to ERT which measures the electrical properties. However, the sentence was deleted.

80,11 seismic refraction is also less affected by temperature changes compared to ERT

- REPLY: I do not agree: the temperature dependence is almost entirely a consequence of freezing and thawing processes, which affect both methods.

80,21 ff "In exploration geophysics..." - I'm not sure if exploration geophysics is particularly relevant for shallow permafrost investigation - the next two paragraphs might be shortened

- REPLY: DONE

82-8 "Relating the temperature dependence to time" - leave out, better: Thus, thawing  
...

- REPLY: DONE

83-12 "intervals of roughly 1.5 months in the summer season of 2008" is a bit misleading, as it comes out later that it is only two measurements at each site!

- REPLY: REMOVED

85,15 you should mention the different geophone spacing of 2m and 8m, respectively, even if it is shown in table 1

- REPLY: DONE

86,1 maybe you should briefly outline the settings?

- REPLY: see reply to similar comments by the other reviewer

86,10 "pointing to a high reproducibility of the seismic signal" - this is not quite correct. The waveform is relatively different between the dates and there is the pronounced shift (which you clearly address). In order to test reproducibility, it would have been

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better to measure a second time after two or three days when permafrost melt as a reason for deviations can be ruled out.

- REPLY: Maybe this was a misunderstanding: the order of the two sub-plots in Figure 3 was swapped by mistake. For the Lapires site, the waveform is very similar for both dates, thus I assume a high reproducibility in case of small changes in the subsurface (Lapires), whereas for the Schilthorn site there is no correlation between the two dates due to the large changes which occurred between the two measurements. Former data from the Schilthorn site (acquired during the diploma thesis of Lars Schudel, University of Zürich) proved a high reproducibility of the seismic signal on very short time scales (days). The order of the plots in Figure 3 was changed (and labelled), and a reference was included for these tests at Schilthorn.

88,21 "The mean velocity of the only significant refractor" - is this zone C? - Yes, this was clarified in the text.

90,7-20 As bedrock depth is not the primary target of the investigations, the entire paragraph might be better left out. "The maximum depth of penetration is marked by a dashed line" (line 20) is the only important sentence.

- REPLY: In my opinion, this problem has important implications for all readers who want to conduct seismic monitoring in similar environments. In the conclusion I refer to this part, that's why this paragraph was not removed.

91,1-12 "For the interpretation of velocity changes [...] or vice versa (blue colours)." Unnecessary repetition, self-evident - leave out.

- REPLY: Was shortened

91,12-15 "Consequently, a thorough interpretation of [...] is only possible with respect to the absolute velocities in the refraction seismic tomograms." - I don't understand this sentence, is it necessary?

- REPLY: Yes, it is important to note, that a velocity decrease does not necessarily

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mean a decrease in layer velocity but can also be caused by a shift of the refractor (with constant layer velocities of the unfrozen and frozen layers. The paragraph was condensed and this phenomenon and its significance was described more precisely.

91,24-25: "In addition to the data discussed in detail in the previous sections ..." - leave out

- REPLY: DONE

91,26-27: "... to show the potential application of a time-lapse refraction seismic approach in the context of operational annual permafrost monitoring" - leave out

- REPLY: DONE

94,5-7: "As both [...] interpreted for both sites." - leave out, redundant

- REPLY: DONE

95,16-20: "Also, the absence of pronounced changes [...] between frozen and unfrozen conditions occur." - leave out, self-explaining

- REPLY: DONE

96,7-8 "The latter hypothesis was already proposed from the analysis of ERT monitoring data (Hilbich, 2009)" - leave out, Hilbich 2009 is adequately cited in the previous sentence.

- REPLY: DONE

96,14-15 "velocity changes correspond remarkably well to resistivity changes" - only if you look at it very generally; the overall pattern seems to be rather different.

- REPLY: Changed to "... the general pattern of velocity changes corresponds remarkably well..."

99,8: As said before, in my opinion "the analysis of reproducibility of the seismic signal" has not been carried out!

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- REPLY: deleted

99,6-12: These are not conclusions, this is repetition of the introduction – delete

- REPLY: DONE

99,13-14: Time-lapse data sets cannot "evaluate the performance" of the RSTM approach – reword

- REPLY: DONE

Fig. 3: Caption: Change the order of Lapires and Schilthorn

- REPLY: The order of the plots was changed in the Figure.

Fig. 8: The parts below the maximum depth of penetration should better be blanked out

- REPLY: DONE

Technical comments

- REPLY: all DONE, except for:

98,16 better mean than common

- REPLY: here, really the common investigation depth of both dates is meant - "mean" would be misleading.

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Interactive comment on The Cryosphere Discuss., 4, 77, 2010.