We are very grateful for your detailed review. All the formal corrections and recommendations for citation, rephrasing for better readability, consistency with formatting of formulas and the grammatical errors will be considered. Your further comments will be addressed as followed:

RC2 Line 58: "maybe borehole and crosshole?" – We will formulate this more precisely.

RC2 Figure 1: "How good are the chances that you see the heat exchanger probes in the data? Dimensions? You could do some easy modeling in3D for example with gprmax once with and once without the exchanger. Can be homogeneous layers to keep the calculation times low."

Depth information will be added to the sketch to give an idea about the spatial scale. Unexpectedly, the reflection data from before and after the installation of the heat exchanger show no observable change in signal at the travel times corresponding to the distance to the heat exchangers. So we assume, that the observed reflections are reflections of the observation wells. As the heat exchangers are located in similar distance to the boreholes as the other observation wells, it is possible that any signal that does occur is superimposed.

We did not model the heat exchangers, because we expect the reflection of the ice body to arrive earlier than the heat exchangers' reflections, because we are measuring from the outside of the heat exchanger array. The ice front is closer to the observation wells, than the heat exchangers. Additionally, we do not have information on the electromagnetic properties of the heat exchangers and their casing.

RC2 Line 92: "What about temp changes during freezing and thawing in boreholes and possible effect on permittivity?"

Temperature in observation wells are indeed affected by temperature changes (4°C-8°C). Changes are small compared to the changes through freezing, but we will assess this in the discussion.

RC2 Line114: "In air or in medium?"

In the medium measured in the aquifer. Thanks for pointing out that this has to be clarified.

RC2 Line119: "Add offset between Tx and Rx"

Information on receiver offset will be added.

RC2 Line 122: "Did use a gain during the measurement and if you did you calculate this out?"

We have always used the same gain during acquisition, but have not calculated it out, as we focus mainly on the travel time for structural information. Amplitudes are only compared between profiles of the same measurement at different times.

RC2 Line 125: "not clear." – We will modify the phrase to clarify the meaning.

RC2 Line 132: "Did you do this before every ZOP or once per day? Mention"

We did zero-time measurements once before the first ZOP and after the last ZOP. Time between these is about 2 hours. This will be added to the manuscript.

RC2 Figure 2: "How large could be out of plane effects for exampel ZOPs D4-U4 or U6-D4?? I think in Haruzi et al. (2022) are some modellings to this topic. Please dicuss this also in the dicusssion a bot more."

Thank you for recommending this interesting paper. We will expand the discussion on this. There is multiple heat exchangers and observation wells within the Fresnel-zone. Since we only consider the first arrivals we expect the out of plane effects to be higher in traveltime and not affect our assessment.

RC2 Line 141: "Why no MOG and inversion? Indicate the time aspects and for first investigations not suitable."

The layers with high attenuation make MOG unfeasible, because we get no signal when the receiver and/or transmitter are in the high attenuation depths. Even in ZOP the signal is very weak in the low attenuation layers. Additionally, we aimed for a fast monitoring strategy and MOG and inversion would need more acquisition time. We will include this in the manuscript.

RC2 Line 155: "Add something about wavelength and Fresnel volume"

We will add values and have a discussion about the width of the Fresnel zone..

RC2 Line 177: "What about gradients of thawing and freezing at the boundaries? add in discussion"

Many thanks for that question, which we also discussed already. Indeed, a gradual freezing/thawing boundary would alter the signal. Laboratory tests with sediment from the test site indicate a very sharp freezing boundary with a transition zone <0.01m (not yet published). Assuming this in the test site, the effect is neglectable.

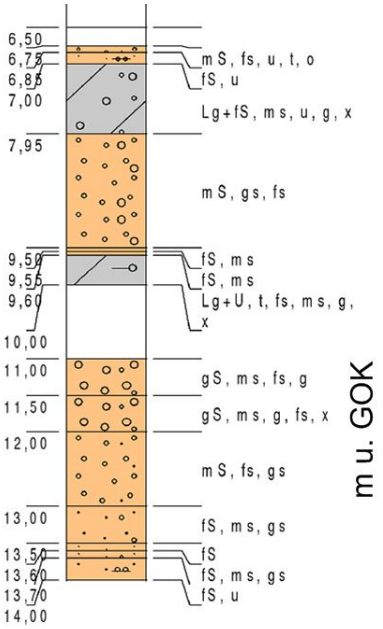
RC2 Line 184: "Do you also have porosity information from the HPT?"

No, unfortunately we do not have porosity values from the test site.

RC2 Line 184 and 194: "Where? In logging data not clear why between 7-10 m depth amplitude damped so much.... ", "I dont see this confirmend in the logging, or?"

As written, the EC-log only show thin layers with higher electric conductivity are observed, while the decreased hydraulic conductivity is observed between ~7m-10m. In a few cases we find that the EC probe is not properly coupled and the electrical conductivities are lower than expected - both methods, HPT and EC, are therefore used in a complementary manner. To ensure proper sealing of the aquiclude after installation of 2" monitoring wells, we took a sediment core at MP055 (not shown in the manuscript because used only for on-site decision) between 6,50m and 14 m. The core shows loamy material from 7m-7.95m, medium sand from 7.95m-9.60m and loamy material from 9.50m - 10m. The core confirms the HPT results and shows that the EC log has some issues resolving the loamy material between 7 m and 7,95m. In any case, it is important to note that the low conductivity zone (aquiclude) is very heterogeneous at this location, see Supplement of Löffler at al., 2022. This can also be seen in Fig 4 B & C: over the small test field we see most variations in amplitude and velocity precisely between 7m – 10m, indicating the presence of a highly heterogeneous boulder clay. We will rephrase this to make a clearer distinction. We correlate the low amplitude and low

travel time with a highly heterogeneous layer, acting as a low hydraulic conductivity layer due to the presence of clayey material.



Core at drilling point MP055;
Stable Hydrogen Isotope Fractionation of Hydrogen in a Field Injection Experiment: Simulation of a Gaseous H2 Leakage, Michaela Löffler, Merle Schrader, Klas Lüders, Ulrike Werban, Götz Hornbruch, Andreas Dahmke, Carsten Vogt, and Hans H. Richnow
ACS Earth and Space Chemistry 2022 6 (3), 631-641
DOI: 10.1021/acsearthspacechem.1c00254

RC2 Line 184: “Which one?”

Hydraulic conductivity. This will be corrected to improve readability.

RC2 Figure 4: “Or are these reduced amplitudes only visible is this ZOP? Related to heterogenous of the subsurface and/or a lense with higher electrical conductivity?”

The reduced amplitudes are visible in all ZOPs at the same depth as the increased velocity. This indicates that we are dealing with a whole layer of different material rather than a lens and/or subsurface heterogeneity.

RC2 Figure 5: “I am not sure if I totally understand the figure. So actually, its a 3D "image" of all ZOPs in the center of the planes and then you rotate them in two directions? Maybe add some explanations in the caption or the "3D" image too? “

We have formulated it improperly so far in the manuscript. We will extend the description to make clear, that the figure is a 2D view of a 3D distribution. Figure 5a is with fixed north coordinate and Figure 5b with fixed east coordinate. Due to poor visibility in the 3D view, we have not included the 3D image.

RC2 Figure 6: “Why do not all traces start at "zero" time? is this related to the casing or the time-zero correction?”

For the zero-time correction we picked the first arrival of the direct wave of every trace and used it for correction. The differences at the beginning of the traces seem to be related to the sediment surrounding the well at the corresponding depth.

RC2 Line 224: “Could this also indicate gradients in the freezing?”

Yes, it could also be due to the ice being further away from the observation well, but as the decrease is hyperbolic we interpret this as diffraction at the upper end of the ice body.

RC2 Figure 9: “Why not showing the other two ZOPs? I like seeing data.”

We decided to use only this example, because the results of the other ZOP are similar and we did not want to put to many figures in the manuscript. We will test adding an image of the other data and re-evaluate, whether showing more data emphasises the findings.

RC2 Line 291: “Maybe a combination possible. Looms et al. " Mapping sand layers in clayey till using crosshole ground-penetrating radar" combines both ZOP and MOG measurements. Like ZOP for mapping and MOGs for higher resolution information. Side note: Maybe in future, 3D forward models could include such structures.”

We agree that a combination would have increased resolution and provided additional information. Since our target was mainly the feasibility of imaging the lateral position of the freezing boundary, we decided on using only ZOP and reflection measurements. In further studies the comparison to data with MOG would be desirable. We will add information in the discussion.