Answer to Anonymous Referee #1

## Technical Note: Testing pore-water sampling, dissolved oxygen profiling and temperature monitoring for resolving dynamics in hyporheic zone geochemistry

First of all, we would like to thank the referee for the positive review and the helpful comments. We are pleased that the manuscript was received as well written and worth publishing. We will answer the specific comments in detail below.

You use a thermal dispersivity of 0.001 m from the literature (table 1), which probably is a very rough estimation. Usually thermal dispersion is low in comparison to thermal conductivity, but this can be different in case with high water flux, such as yours. So, the question is whether thermal dispersion is relevant and, if so, it can affect the calculation of water fluxes. Can this issue be addressed? It may also be related to the next comment.

Thank you for addressing this point. It is true that thermal dispersivity is a rough estimate from the literature. To test the influence of the parameter on estimated hyporheic exchange fluxes, we performed a Monte Carlo analysis for the sensor pair in 8 cm and 12 cm depth, and for the first period of our data. 100 runs of VFLUX were performed for each scenario on the reduced data set. The thermal dispersivity parameter  $\beta$  was chosen as a random variable with normal distribution based on the following mean and standard deviation values:

μ	σ
0.001	0.0005
0.01	0.005
0.1	0.05

The data shows that a lower dispersivity leads to larger fluctuations and higher flux estimates compared to higher dispersivity values (Fig. D2). Calculated fluxes would be smaller in absolute terms and more stable if the diffusivity was larger than initially assumed. We will add Fig. D2 and the following text to App. D:



Figure D2: Monte Carlo analysis for thermal dispersivity. Flux values are given per unit area. Three scenarios were tested for mean and standard deviation of the thermal dispersivity parameter  $\beta$ . Results were generated with n=100 runs for each scenario. Shading indicates 95% confidence intervals for each scenario. The results were calculated with the software package VFLUX and the Hatch amplitude method.

"The influence of the thermal dispersivity parameter  $\beta$  was tested with a Monte Carlo analysis on a reduced data set, including data from April and May 2022 and the sensor pair in 8 cm and 12 cm depth. A normal distribution was assumed for the parameter  $\beta$ , with different means and standard deviations. For each scenario, 100 runs of VFLUX were performed with the random variations of  $\beta$  according to the respective distribution. The results show that higher thermal dispersion would lead to lower absolute flux values and less intense fluctuations (Fig. D2). Considering that  $\beta$  was changed by two orders of magnitude, the sensitivity of the model to changes in dispersivity appear to be limited. Nevertheless, further investigations on thermal dispersivity could help to improve the use of temperature measurements for hyporheic exchange flux modeling."

Appendix D presents the water fluxes calculated from the temperatures with various methods. Differences between results of the methods are quite high (4-18 times). How accurate are the results of figure 4? Can we compare these fluxes with some other measurement?

The differences you mentioned mainly occurred between the different methods (using amplitude dampening or phase change). Results were more consistent within one method. We suggest that using the amplitude method in our case is more reliable. Amplitude dampening is pronounced in the data while phase differences between the sensor pairs were very small. In fact, trying to compare neighboring sensors did not produce any result with the phase method. Unfortunately, there is no data to validate the findings.

We added the following paragraph to App. D to better explain the differences and reasons why we chose to present the amplitude data in the paper:

"Fluxes calculated based on phase change were 4-18 times larger than fluxes based on amplitude dampening. Amplitude dampening was pronounced in the data while phase differences between the sensor pairs were only very small. In fact, it was not possible to get flux estimates from neighboring sensors with the phase method due to the minimal time lag which was smaller than the temporal resolution of the time

series. Therefore, we hypothesize that for our data set estimates based on the amplitude method are much more reliable and have chosen not to display results based on the phase method in the main paper. The data is still displayed here to allow a comparison and for transparency by showing all results."

## A porosity of 81.5% (Table 1 and appendix A) is quite high. Is there some reason for this high value?

Indeed, a porosity of 81.5% seems very high. We were surprised ourselves but found these high porosities in repeated measurements at different times. However, having porosities around and above 80% in fine, unconsolidated marine, organic-rich and lake sediments is not uncommon (Iversen & Jørgensen, 1993; Sweerts *et al.*, 1991). At our study site, the fine, organic-rich bed substrate was similar to marine or lake sediments. The site was located in a zone of reduced flow velocities due to a log lying crosswise a few meters upstream which allowed settling of very fine particles. The observed steep geochemical gradients (Fig. 2) confirm the similarity to marine or lake environments. The high porosity can also be explained by the lack of consolidation. Deposits were very loosely bedded and easy to stir as observed under light physical stress.

Why do you put profiles of Ca, Mg and Cl concentrations in appendix C and those of NO3 and SO4 in the body of the paper? I suggest, for coherence, to move the profiles of Ca, Mg and Cl to the body. The box plots can remain in the appendix.

Yes, for reasons of coherence, it makes sense to move the geochemical profiles of  $Ca^{2+}$ ,  $Mg^{2+}$  and  $Cl^-$  to the body of the paper. We will expand Fig. 2 to include these profiles.



**Figure 2**: Concentration and stable isotope profiles measured with a pore-water dialysis sampler and Rhizon samplers from the monitoring station at three different pump rates. All samples were withdrawn in May 2022. Panels show (a)  $NO_{3^-}$ , (b)  $SO_{4^{2-}}$ , (c) CH<sub>4</sub>, (d)  $Ca^{2+}$ , (e)  $Mg^{2+}$ , and (f) Cl<sup>-</sup> concentrations, (g) and (h) stable water isotopes, and (i) stable carbon isotopes in CH<sub>4</sub>. Error bars show standard deviation of repeated measurements. In addition, analytical uncertainty of the measurement devices is shown for isotope data.

## **Technical Corrections**

Line 218. I think you should not only refer to figure C3, but to figure 2c as well.

In this sentence, we only refer to CH4 concentrations which are displayed in Fig. C3. However, it makes sense to refer to Fig. C2 in line 214 where differences in  $Ca^{2+}$ ,  $Mg^{2+}$  and  $Cl^{-}$  concentrations are discussed. We would adjust the reference as follows:

" $Ca^{2+}$ ,  $Mg^{2+}$  and  $Cl^-$  concentrations were on average five to seven percent lower in the peeper data compared to Rhizon samples, but different pump rates did not have an effect on average concentrations (App. C, **Fig. C2**).

Average CH4 concentrations in Rhizon samples deviated by -30 % (lowest pump rate) to +100 % (highest pump rate) from peeper samples. While the CH4 concentration profiles recorded with the peeper showed a smooth gradient, profiles from Rhizon measurements showed large concentration differences in consecutive depths. Average measured concentrations were significantly different not only between peeper and Rhizon samples, but also for different pump rates (Fig. C3)."

## Figure A1. In the vertical axis "0" should be "60".

That's correct. Thank you for the note, we will adjust this.

Iversen, N., & Jørgensen, B. B. (1993). Diffusion coefficients of sulfate and methane in marine sediments: Influence of porosity. *Geochimica et Cosmochimica Acta, 57*(3), 571-578.

Sweerts, J. P. R., Kelly, C. A., Rudd, J. W., Hesslein, R., & Cappenberg, T. E. (1991). Similarity of wholesediment molecular diffusion coefficients in freshwater sediments of low and high porosity. *Limnology and Oceanography*, 36(2), 335-341.