Author's response to the Reviews on the Manuscript "Hysteresis between groundwater and surface water levels indicates the states of hydrological turnover affecting solute transport and redox processes" (egusphere-2025-1674)

Dear Dr. Hongkai Gao,

we sincerely thank you for taking the time to review our manuscript yourself after the difficulty in securing additional reviewers

We are particularly grateful for your positive assessment of the study and your emphasis on the importance of experimental, process-based research at the catchment scale. Your perspective on the current trends in hydrology and the value of mechanistic understanding is highly encouraging and aligns strongly with the motivation of our work.

We also thank you for your thoughtful and helpful comments aimed at improving the clarity and accessibility of the manuscript for a broader audience. We have carefully considered all points and revised the manuscript accordingly. In the following, we provide a detailed, point-by-point response to your comments.

With kind regards,

Lars Bäthke and Tobias Schuetz

<u>Responses:</u>

Comment 1:

The term "hydrological turnover (HT)" is new to me. I would like to know: does HT have a characteristic time scale? And how is it related to residence time?

Response:

We thank the editor for this important comment. We agree that the concept of hydrological turnover (HT) required clearer definition. We have therefore revised the manuscript to clarify that HT is conceptually rooted in the nutrient spiraling framework, but focuses on hydrological exchange rather than biogeochemical reactions. HT describes the intensity of exchange-driven renewal of water between the stream and adjacent storage compartments and does not represent a single characteristic time scale. We now explicitly distinguish HT from residence time, which refers to the duration of water storage, whereas HT captures the rate of exchange and mixing between hydrological compartments.

Line 79-88

> "Several studies advocate that the exchange between GW and SW along streams needs to be addressed as bidirectional, consisting of gross gains and losses, with the cumulative bidirectional flux understood as a hydrological turnover (HT) (Payn et al., 2009, 2012; Covino et al., 2011; Mallard et al., 2014; Jimenez-Fernandez et al., 2022; Jähkel et al., 2022; Bäthke & Schuetz, 2024). *Conceptually rooted in the nutrient spiraling framework (Stream Solute Workshop, 1990), HT in this study refers to the intensity of exchange-driven renewal of water between the stream and adjacent storage compartments such as the hyporheic zone and near-stream groundwater. Unlike residence time, HT does not describe how long water remains within the system, but rather how rapidly water is exchanged and mixed across hydrological compartments (Covino et al., 2011). Consequently, HT is a process-based and state-dependent*

metric that does not have a single characteristic time scale at the reach scale. Instead, it emerges from the temporal dynamics of exchange processes, particularly during hydrological events (Payn et al., 2009; Ward et al., 2013). Thus, HT shapes stream chemical signatures, making it a critical framework for understanding the bidirectional GW-SW interactions explored in this study."

Line: 399-401

"Thus, emphasizing that HT reflects exchange-driven renewal processes rather than storage duration, distinguishing it conceptually from residence time metrics."

Comment 2:

I am not sure whether there is vegetation cover in the riparian zone. If so, how would this impact root water uptake, GW–SW interaction, water loss and gain, solute transport, and redox processes?

Response:

We thank the editor for this helpful comment. The study reach is characterized by a vegetated riparian zone, which we now clarify in the manuscript. We agree that riparian vegetation can influence GW–SW interactions through root water uptake, evapotranspiration, and associated modifications of hydraulic gradients, particularly during low-flow and drought conditions. In addition, vegetation may affect solute transport and redox dynamics by supplying organic matter and influencing oxygen availability in near-stream sediments. While these processes were not directly quantified in this study, we have expanded the discussion to acknowledge their potential role in modulating the observed hysteresis patterns and hydrological turnover.

Line: 403-408

"In addition, the riparian zone at the study site is covert by vegetation, which further influence GW–SW interactions. Root water uptake and evapotranspiration can modify near-stream hydraulic gradients, particularly during low-flow and drought conditions (Tabacchi et al., 2000), thereby potentially reinforcing strong gradients and affecting exchange fluxes between stream and the riparian zone (Wondzell et al., 2010; Boano et al., 2014). While these processes were not explicitly quantified in this study, they likely interact with the observed hysteresis patterns and hydrological turnover and should be considered when interpreting GW–SW exchange dynamics."

Comment 3:

Line 18. The h-index should be defined when it is first used.

Response:

We thank the editor for this comment. The abstract has been revised to define the h-index at its first occurrence by briefly explaining its physical meaning in terms of hysteresis direction and magnitude.

Line: 19-21

"The h-index quantifies the direction and magnitude of hysteresis based on the integrated difference between rising and falling limbs, thereby capturing time lags and asymmetries in GW–SW interactions."

Comment 4:

Table 1: please use a decimal point (dot) rather than a comma.

Response:

We thank the editor for this comment. The formatting of Table 1 has been revised, and decimal commas have been replaced with decimal points throughout.

Citations:

Boano, F., Harvey, J. W., Marion, A., Packman, A. I., Revelli, R., Ridolfi, L., and Wörman, A.: Hyporheic flow and transport processes: Mechanisms, models, and biogeochemical implications, Rev. Geophys., 52, 603–679, https://doi.org/10.1002/2012RG000417 , 2014.

Stream Solute Workshop: Concepts and methods for assessing solute dynamics in stream ecosystems, *J. N. Am. Benthol. Soc.*, **9**, 95–119, https://doi.org/10.2307/1467445, 1990.

Tabacchi, E., Lambs, L., Guilloy, H., Planty-Tabacchi, A.-M., Muller, E., and Décamps, H.: Impacts of riparian vegetation on hydrological processes, *Hydrol. Process.*, **14**, 2959–2976, https://doi.org/10.1002/1099-1085(200011/12)14:16/17<2959, 2000.

Wondzell, S. M., Gooseff, M. N., and McGlynn, B. L.: An analysis of alternative conceptual models relating hyporheic exchange flow to diel fluctuations in discharge during baseflow recession, Hydrol. Process., **24**, 686–694,https://doi.org/10.1002/hyp.7507 , 2010.