Response to Comments from Referee #1

Initial Comments

The authors of this paper use USGS gauge data with diel fluctuations in discharge and river temperature to model hyporheic exchange rates in order to better understand how daily groundwater table fluctuations change hyporheic exchange rates in gaining, losing, or neutral streams. The authors use complex modeling to show how in-phase or out-of-phase daily groundwater table drawdown can influence hyporheic exchange rates. The model created for this paper makes hard assumptions about river morphology, network position, and sediment characteristics to step back and look at daily groundwater table dynamics conceptually. While much of the paper is modeling hyporheic exchange the authors also ask how diel groundwater table fluctuations and river temperature impact residence time for denitrification potential and thermal refugia for aquatic species. The authors conclude that groundwater table dynamics modulate hyporheic exchange process differently than diel river temperature. When diel groundwater table drawdown is out-of-phase with river temperature hyporheic exchange is greater than when in-phase. Under gaining conditions upwelling groundwater buffers diel river temperature and increases hyporheic exchange rates. Under losing conditions surface water temperature penetrates deeper into the hyporheic zone and decreases hyporheic exchange rates. The authors do a good job in the modeling and data analysis sections of this research yet need to make the objectives of this paper clearer to support the data presented in this paper.

> **Response:** Thank you for the positive comment on the modeling and data analysis, and also for the insightful suggestions on improving the manuscript. The point-by-point reply to the comments is given below. Changes that will be made in the manuscript after the online discussion are indicated by *underlined text in italic*. Line numbers in this response refer to the numbers in the original manuscript. By responding to the following comments, we incorporated the changes to clarify the objectives, model assumptions, and to improve the structure for a better readability.

Specific Comments

1. The objective statement of this paper is not well defined. After a good introduction, the last paragraph is lacking in clarity as to what this paper is about. Suggestion for the authors to use language like: "In the present study, we aim to quantify the impact of groundwater withdrawal on hyporheic exchange processes at the daily scale as well as better understand impacts on potential denitrification and thermal buffering". Then move on to how this paper accomplished the objectives. "To investigate these objectives we built a complex model that…." This will also help guide the reader towards the start of the methods section.

   Response: Thank you for the good suggestion. To better present the objectives, we modified the last paragraph of the introduction (from Line 71-75) in the following way:

   "*In the present study, we aim to quantify the impact of river temperature fluctuations and groundwater withdrawal on hyporheic exchange processes at the daily scale, as well as to better understand implications on hyporheic zone's potential for denitrification and thermal buffering. With these objectives in mind, different groundwater scenarios corresponding to different timings of groundwater withdrawal under gaining and losing conditions are applied in a physically based hyporheic flow and heat transport model.* ***"***

2. The connection from the modeling to RSF and thermal refugia for aquatic species is weak. It feels like the nutrient processing and ecosystem services provided by hyporheic exchange are tossed into this paper to try to broaden the scope of the paper. I suggest that the authors leave nutrient processing to the discussion section rather than a main objective of this paper. Much of the paper does good modeling of hyporheic exchange rates and that should be the focus. There is also some confusion in if this paper wants to just focus on denitrification or RSF and this distinction needs to be clear to the audience. The authors also provide no hard numbers as to how RSF was applied to their model. The Gomes-Velez (2016) paper provides a range of RSF for stream orders 1-12 and how RSF varies throughout stream orders. The authors fail to mention what RSF values were chosen

amongst that range. While the result of the RSF analysis is interesting, the explanation as to what this mean ecologically is missing.

Response: To better address this comment, we will answer the three sub-comments in the following order:

1) How does RSF calculated? Were RSF values chosen from Gomez-Velez (2016)?

The RSF values were not chosen from Gomez-Velez (2016). They were calculated under the specific flow and sediment characteristics in the present study by Eq 8 which was first introduced by Harvey et al. (2013):

$$\mathrm{RSF_a} = \frac{q_{HZ}}{Q} \cdot \frac{\tau_{HZ}}{\tau_{dn}} \quad \text{(Eq. 8)}$$

where Q is the river discharge, q_{HZ} is the exfiltrating hyporheic fluxes calculated with Eq 1-3, τ_{HZ} is the mean residence time of hyporheic flow calculated with Eq 6, τ_{dn} is the characteristic time scale for denitrification determined based on Gomez-Velez and Harvey (2014) and Gomez-Velez et al. (2015).

To better present the values of τ_{dn}, we will add the following figure in the supplementary information to show the quantiles of the characteristic time scales for denitrification.

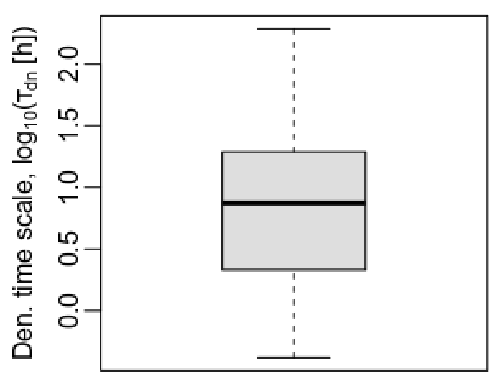

Figure S1: Box plot of the characteristic time scale for denitrification ($\log_{10}$[h]). The 25th quantile is 0.38, the 50th quantile is 0.87, and the 75th *quantile is 1.28. (Taken from Gomez-Velez and Harvey (2014) and Gomez-Velez et al. (2015))*

2) Does the paper focus on denitrification or RSF? What are the differences?

   We calculated the reaction significance factors for denitrification with equation 8. However, the interpretations of results shown in Figure 8 are not limited to denitrification processes. For a different biogeochemical reaction, another characteristic time scale is applied instead of τ_{dn}. Results presented in Figure 8 will only be scaled by a different biogeochemical time scale for the reaction of interest. The relative variations of RSF remain the same for other biogeochemical reactions (line 367-370).

3) Are nutrient processing and ecosystem services main focuses on this paper?

   We partly agree with the reviewer. The ecosystem service is not the main focus of this paper. The impact on ecosystem was not quantified but only discussed in Discussion to show the impact of timing of groundwater table drawdown on the hyporheic zone's function as thermal buffers for aquatic communities qualitatively. However, the nutrient processing as we presented for denitrification was quantified with equation 8 and the results are presented in Figure 8. We think the results have clearly demonstrated the different impacts of groundwater table fluctuation on reaction potentials under gaining and losing conditions, which is a worthwhile message for readers who are interested in exploring biogeochemical reactions under different groundwater conditions. Therefore, we would like to keep the quantifications of reaction potential in the main objective.

3. Hyporheic connectivity is not discussed or mentioned in this paper. How does connectivity change during these diel fluctuations or during storms? How connected the hyporheic zone is could impact the thermal buffering capacity. A short paragraph on this topic should be added.

Response: This is a good point. We added a short paragraph about hyporheic connectivity by the end of discussion in line 371:

The first term in RSF_a ($\frac{q_{HZ}}{Q}$) describing the proportion of the river discharge passing through the hyporheic zone per unit bedform area can be used to quantify the connectivity between river and hyporheic zone (Harvey et al., 2019). This connectivity underpins many ecosystem processes and important reactions that take place in close contact with biogeochemical reactive sediments (Boulton, 2007; Ward et al., 2000; Malard et al., 2002; Roley et al., 2012). Maintaining a good hydrological connectivity is therefore crucial. Under the same river discharge rates (Q), hyporheic exchange rates (q_{HZ}) are higher when groundwater drawdown is in an out-of-phase pace to diel river temperature fluctuations than in an in-phase pace. Consequently, the hydrological connectivity is higher in a groundwater out-of-phase scenario. The temperature differences between river and exfiltrating hyporheic fluxes with in-phase and out-of-phase groundwater table drawdown also proves this finding (Fig. 7). Hydrological connectivity is higher in out-of-phase groundwater table drawdown scenarios than in in-phase scenarios, making hyporheic zone a better thermal buffer.

References added:

- *Boulton, A. J. (2007). Hyporheic rehabilitation in rivers: restoring vertical connectivity. Freshwater Biology, 52(4), 632-650.*
- *Harvey, J., Gomez‐Velez, J., Schmadel, N., Scott, D., Boyer, E., Alexander, R., ... & Moore, R. (2019). How hydrologic connectivity regulates water quality in river corridors. JAWRA Journal of the American Water Resources Association, 55(2), 369-381.*
- *Malard, F., Tockner, K., DOLE‐OLIVIER, M. J., & Ward, J. V. (2002). A landscape perspective of surface–subsurface hydrological exchanges in river corridors. Freshwater Biology, 47(4), 621-640.*
- *Roley, S. S., Tank, J. L., & Williams, M. A. (2012). Hydrologic connectivity increases denitrification in the hyporheic zone and restored floodplains of*

an agricultural stream. Journal of Geophysical Research: Biogeosciences, 117(G3).

- *Stanford, J. A., & Ward, J. V. (1993). An ecosystem perspective of alluvial rivers: connectivity and the hyporheic corridor. Journal of the North American Benthological Society, 12(1), 48-60.*
- *Ward, J. V., Malard, F., Stanford, J. A., & Gonser, T. (2000). Interstitial aquatic fauna of shallow unconsolidated sediments, particularly hyporheic biotopes. In 'Subterranean Ecosystems'.(Eds H. Wilkens, DC Culver and WF Humphreys.) pp. 41–58.*

4. The is also confusion as to what a groundwater table drawdown means. The diel groundwater fluctuations presented here are due to plant uptake, yet the authors also mention groundwater pumping. The introduction paragraph (Lines 64-70) sets up the pumping problem well but does not mention plants. The discussion section does not discuss the pumping problem well enough to support the management implications in the conclusion. The implications for poorly designed pumping schedules are huge given your data during the flood event!

Response: Thank you for the comments. As introduced in line 46-48, both the phreatophytes water-use and anthropogenic pumping can cause groundwater table drawdown at a daily scale. Therefore, the daily groundwater table drawdowns in the present study were conceptualized as sinusoidal curves with varying amplitudes and phases.

We also understand the reviewer's confusion on line 64-70. To clarify the research set up, the description of pumping problem will be removed from introduction. This issue instead will only be discussed in Discussion to present the implications of our results on pumping management. A short paragraph will be added in line 288:

Modern regulating reservoirs are usually designed with enough storage capacities allowing planning of pumping schedules independent of user demand (Reca et al., 2014). A poorly designed pumping regime is detrimental to the biological and ecological functioning of the fluvial systems (Moore, 1999; Libera et al., 2017; Bredehoeft and Kendy, 2008). Consequently, careful selection of aquifer pumping schedules with considerations of both timing of flood and groundwater table dynamics are critical for water management agencies to minimize the environmental footprint of the withdrawal process.

5. The conclusion is also weak and doesn't drive home the answers found from the objective statement. The closing sentence is subjective and needs to be reworded: "Our data show that hyporheic exchange rates in a gaining river increase significantly during storm events. When combined with an in-phase diel groundwater table fluctuation, hyporheic exchange rates are higher than an out-of-phase fluctuation (Fig 3f storm vs. Fig 5f storm). Anthropogenic aquifer pumping schedules should be out of phase with diel river temperature to ensure minimal contaminant uptake". RSF or denitrification also needs to me worded stronger here.

   Response: Thank you for the comment. The conclusion has been rephrased. Please find it in the response to the last comment on Conclusion.

6. Transitional sentences between paragraphs and sections need to be stronger making it hard for the reader to follow

   Response: Thank you for the comment. We rephrased last paragraph of Introduction and entire Conclusions to improve the connections between sections. Please refer to responses to comments on line 71 and conclusions below.

Technical Comments

- Abstract ok
  - The phrasing of groundwater withdrawal makes it sound like there is anthropogenic influence. You do not specifically look at this so I would keep it to the discussion section

Response: Done as suggested. Groundwater withdrawal is replaced by groundwater level drawdown to reflect the groundwater level fluctuation in a more general way. The text now reads:

The timing of groundwater table drawdown has a direct influence on hyporheic exchange rates and hyporheic buffering capacity on thermal disturbances.

- Line 14, I would turn this first sentence in a strict definition of the hyporheic zones
  - Something like hyporheic zones are transitional areas between surface water and groundwater environments that often exhibit marked physical, chemical, and biological gradients that drive the exchanges of water flow, energy, solute and microorganisms between surface and subsurface regions.
  - This will help focus the readers the research in this paper

  Response: Thank you for the suggestion. We modified the sentence as suggested in line 14:

  Hyporheic zones are transitional areas between surface water and groundwater environments, which often exhibit marked physical, chemical, and biological gradients that drive the exchanges of water flow, energy, solute and microorganisms between surface and subsurface regions.

- Line 18, what makes researching spatiotemporal variability of hyporheic exchange key to water resources management? Provide a reference

  Response: Thank you for the question. The important role hyporheic zone playing in connecting surface and subsurface water environments as outlined in line 14-17 justified the necessity of understanding spatiotemporal variability of hyporheic exchange for water resources management. Here we added the following reference:

Lewandowski, J., Arnon, S., Banks, E., Batelaan, O., Betterle, A., Broecker, T., ... & Gomez-Velez, J.: Is the hyporheic zone relevant beyond the scientific community? Water, 11(11), 2230, 2019.

- Line 19, what and how is it key to ecosystem restoration

  Response: Hyporheic zone's effects on ecosystem restoration were not introduced with details, because as the reviewer suggested in the second specific comment it is not the main focus. Here we added a new reference of *Lewandowski et al., 2019* (listed in the comment on line 18 above) to help readers to find the relevant information.

- Line 23, change to factors influencing the hydraulic….

  Response: Done as suggested.

- Line 26, change language. Make this more clear

  Response: Please refer to the next comment below.

- Entire second paragraph needs to be worded better

  Response: Entire second paragraph is re-worded as below:

  Hydrological drivers and modulators of time-varying hyporheic exchange processes have been extensively studied in the last decade. The hydraulic gradient as the main driver of hyporheic exchange processes is changing along the sediment-water interface, determining (1) the spatiotemporal variability of hyporheic zone extents and (2) characteristic time scales of hyporheic exchange (Boano et al., 2013; Ward et al., 2017; Gomez-Velez et al., 2017). Factors influencing the hydraulic gradient at the sediment-water interface include channel flow (Trauth and Fleckenstein, 2017; Grant et al., 2018; Broecker et al., 2018), geomorphological settings (Tonina and Buffington, 2011; Schmadel et al., 2016; Singh et al., 2019), and regional groundwater flow (Nützmann et al., 2014; Malzone et al., 2016; Wu et al., 2018). Sediment and fluid properties do not drive hyporheic exchange, but they modulate hyporheic exchange substantially:

sediment heterogeneity can alter hyporheic flow paths and residence time distributions, creating hot spots for biogeochemical transformations (Sawyer and Cardenas, 2009; Gomez-Velez et al., 2014; Pescimoro et al., 2019); fluid properties, i.e., density and viscosity, are functions of temperature and directly influence the hydraulic conductivity, thus hyporheic flow. Consequently, river temperature variability (i.e., diel and seasonal river temperature fluctuations) induces significant changes of hyporheic exchange processes (Cardenas and Wilson, 2007a). The spatiotemporal variability of the drivers and modulators eventually results in dynamic hyporheic exchange processes. Among these drivers and modulators, the combined effects of regional groundwater flow and river temperature on dynamic hyporheic exchanges are comparably understudied.

- Line 43 – Good sentence here

  Response: Thank you!

- Figure 1
  - Groundwater table A and B separation is confusing to the eye

    Response: To better separate groundwater table A and B, we will color differently for groundwater table A and B.

  - Do these relate to either the gaining or losing condition

    Response: Yes, groundwater table A refers to gaining condition where the groundwater table is higher than river stage; groundwater table B refers to losing condition where groundwater table is lower than river stage,

  - Suggestion to color the lines differently

    Response: Thank you for the suggestion. We will do as suggested.

  - Remove the tree image or add more. Suggestion to use a tree silhouette.

    Response: We will use a tree silhouette as suggested.

- Line 45, reference needed for 1st sentence

Response: Done as suggested. The following reference will be added:

Todd, D. K. and Mays, L. W.: Groundwater hydrology edition, Welly Inte, 2005.

- Line 58, Wu et al. observed….

  Response: Done as suggested.

- Line 71, This entire paragraph needs to be stronger

  Response: This paragraph is rephrased. Please refer to the first specific comment and the next comment below.

- Transition from objective statements to modeling section is poor
  - Ideas for objective statements
    - Stronger, need to be more focused. This paragraph is short and weak when it should be the strongest hit of the paper
      - In the present study, we aim to quantify the impact of groundwater withdrawal on hyporheic exchange processes at the daily scale as well as better understanding river temperature impacts on potential denitrification and thermal buffering.

  Response: Thank you for the suggestion. We have modified as below:

  In the present study, we aim to quantify the impact of river temperature fluctuations and groundwater table drawdown on hyporheic exchange processes at the daily scale, as well as to better understand implications on hyporheic zone's potential for denitrification and thermal buffering.

  - Modeling transition
    - Use the last paragraph to transition to the modeling
      - This is poor

  Response: Thank you for the suggestion. The following sentences are added to act as a transition to the modeling section from line 73:

With these objectives in mind, different groundwater scenarios corresponding to different timings of groundwater table drawdown under gaining and losing conditions are applied in a physically based hyporheic flow and heat transport model. Hyporheic exchange rates, temperature distribution and denitrification efficiency are quantified to assess the impacts of river temperature and groundwater level fluctuations on hyporheic exchange processes.

- Line 80, need a transition sentence to connect to the aims

  Response: The following sentence is modified in line 80 to connect to the aims:

  To understand the hyporheic exchange in response to changing river discharge, temperature and groundwater table fluctuations, a two-dimensional conceptualization is proposed based on Wu et al. (2018) and Wu et al. (2020) (Fig. 2a).

- Line 84, need reference for COMSOL method and mesh-independent.

  Response: The COMSOL model was developed based on Wu et al. (2018) and Wu et al. (2020) (Fig. 2a) as mention in line 81.

- Figure 2
  - Good conceptual figure

    Response: Thank you!

- Figure 3
  - Say that discharge is not to scale, rather than not labeled. Or that you are using it for visual aid and not to scale

    Response: Thank you for the suggestion. The figure caption is modified as below:

    For figure clarity, discharge is not scaled in e and f, and used only for visual aid.

- Line 214, you say only in-phase results are shown but Figures 3 and 5 show out of phase results

  Response: Thank you for the comment! Effects of groundwater table fluctuation amplitudes on dynamic hyporheic responses are only explored under in-phase scenarios, because under out-of-phase scenarios, fluctuations of exfiltrating hyporheic fluxes are almost always in the same phase with the diel river temperature fluctuations. Therefore, unlike in-phase scenarios, the phase shifts due to reduced amplitudes in groundwater table fluctuation are not observed. Reduced amplitudes in groundwater table fluctuation under out-of-phase scenarios only contribute to reduced amplitudes in exfiltrating hyporheic flux fluctuations. Based on these reasons which are also stated in line 210-214, only results in in-phase scenarios are presented in figure 4.

  To clarify in the text, the following sentence is modified in line 214 as below:

  For simplicity, only results in in-phase scenarios are presented in Fig. 4.

- Figure 4
  - I don't like the positioning of Figure 4 but don't know if you have control over this or the journal does. It looks odd to have a figure showing gaining conditions in the 3.1.2 under Losing Conditions section of the paper

  Response: Thank you for the suggestion. We will fix the position of the figures.

- Figure 5
  - Caption says discharge is not labeled when it is in Fig 5c and Fig 5d
  - I think you may mean that discharge is not to scale in 5e and 5f

  Response: The caption is correct in referring to Fig 5c and Fig 5d. There are no fig 5e and 5f.

- Line 260, please state the values you used for you models or at least a range of values

Response: These values are stated in response to the second specific comment and presented in figure S1.

- Figure 6
    - I'm not sure how necessary figure 6 is in this paper. While I like the figure, I believe you could and do explain this information in the text.
    - This could help you shorten the paper
    - You could slow spice this up by clipping a few of these snapshots together and then playing them in a .gif over the course of a storm so you could see the variations in the losing condition sections of the figure

    Response: Thank you for this comment. Figure 6 conveyed an important message that the heat distribution is significantly different in gaining and losing groundwater systems under the same hydrological and climate condition. Although we could explain this information in the text, this figure has the direct visual explanation of this key point, which could help those readers who skip the text and only scan the figures to capture this important point. As the reviewer suggested, we will also include a gif figure showing the animation of the heat distribution along the course of changing discharge conditions.

- Figure 7
    - Same weird out of place figure placement
    - I like this figure. It tells me clearly that gaining in-phase hyporheic zones have less variable temperature from the constant upwelling of groundwater
    - Get rid of the underscore in gaining in-phase, keep it consistent with the figures above. Same goes for the color scheme if possible

    Response: Thank you for the suggestion. We will fix the position of the figure and remove the underscore in the figure legends.

- Line 260

- Gomez-velez et al 2015 reports RSF over entire river networks. How you are you implementing these findings into this new model? The also include river bedform information and this paper assumes uniform sediment. So please list what metrics you are using from this Gomez-velez paper. What are the quantiles???

  Response: We have addressed this comment in the second specific comment.

- Figure 8
  - Under loosing conditions reaction significance time is 3 orders of magnitude less than gaining conditions
  - This figure indicate that the RSF can vary by ~1 order of magnitude over the course of the day. While the difference between gaining and loosing conditions is and interesting result. How do you justify this with the range of stream orders, sediment size, and hydraulic conductivity show in the Gomez-Veles papers?
  - Are you using the stream order of the USGS gauge you gather the data from? If so report these information and explain this process in the text

  Response: Thank you for the questions. As we responded to the second specific question, the RSF values were calculated with equation 8, where stream orders, sediment size and hydraulic conductivity were not variables determining the values. However, variables in equation 8, such as the discharge Q, are directly influenced by the geomorphological settings. Studying these influences is beyond the research scope of the present paper.

- Discussion
- Line 267, Water table drawdowns coupled with hydraulic gradient changes through temperature contribute to enhanced diel fluctuations of exfiltrating hyporheic fluxes

  Response: Thank you for the suggestion. We modified the sentence as suggested.

- Line 269, Under the neutral condition

  Response: Modified as suggested.

- Line 272, 269 –
    - You only reference figure 3 here which is the gaining condition, should you also mention figure 5 the loosing condition?
    - Or be more specific in the text

  Response: In line 269, neutral conditions were only plotted in figure 3 and not in figure 5. In line 272, both gaining and losing conditions were referenced.

- Paragraph on Line 285
    - I agree with what you are saying
    - Don't pump an aquifer during a storm because the drawdown could pull pollutants into the hyporheic zone
    - Could you provide an example of a usgs site that has daily drawdowns from groundwater pumping like the ones shown in this paper from the plants?
    - This may be a hard reach but could have important management implications

  Response: Thank you for the question. Daily groundwater table fluctuations were conceptualized as sinusoidal curves with varying amplitudes and phases, which were not observations in USGS sites. Limitations of this simplification were discussed in section 4.5 from line 378 to 393. In the present study, only river discharge and temperature time series are observations in USGS gauging stations.

- Line 307, could you use your data (from figure 6 maybe) to show this?
    - Upwelling keeps warm surface water from connecting to HZ

  Response: Thank you for this question. As we responded to the reviewer's comment on Figure 6, a gif figure will be added to illustrate the dynamics of temperature fields in the sediment. In this figure, hyporheic zones can be completely compressed by upwelling fluxes when the river stage is low, which prevents the warm surface water from penetrating into the sediment especially during summer.

- Therefore, in summer when river temperature is relatively high, the hydraulic conductivity is enhanced and becomes the main modulator for hyporheic exchange rate under losing condition.
    - Change the therefore language. The authors use this word a lot

      Response: Thank you for the suggestion. “Therefore” is replaced by “consequently”.

- Combine the paragraphs between Lines 310 and 320

  Response: Changed as suggested.

- Line 343, Therefore, hyporheic zones have a larger cooling effect during high river temperature under out-of-phase gaining conditions than under in-phase conditions (under gaining conditions)

  Response: Added as suggested.

- Too many conditions maybe think of different wording for in-phase and out-of-phase (conditions)

  Response: We replaced a couple of “conditions” with “scenarios”.

- Loosing conditions speeds up residence time (RSF = reaction scale factor)

  Response: Reaction significance factor is proportional to the residence time (equation 8). RSF_a under gaining conditions is around three orders of magnitude higher than under losing conditions due to the significantly longer residence time resulting from mixing between surface water and groundwater under gaining conditions.

- Gaining conditions slows down residence time and allows mixing of GW and SW

  Response: Groundwater has significantly longer residence time. The mixing between groundwater and surface water under gaining conditions thus increases the mean residence time of the exfiltrating hyporheic fluxes. Therefore, RSF_a under gaining conditions is higher than under losing conditions.

- In conclusion, the timing 365 of groundwater table drawdown is more important under gaining conditions than under losing conditions for denitrification reactions.

  Response: Yes. With groundwater losing conditions, even though RSF_a display peaks on a logarithmic scale, the actual differences of RSF_a (in the scale of 10 to the power of −5) between in-phase and out-of-phase conditions are insignificant compared to gaining conditions.

- Line 668 – could you mention this fact earlier in the paper, so the reader is not thinking about denitrification the entire time?

  Response: Thank you for the suggestion. The scaling of RSF for different reactions will be explained as soon as the RSF is first introduced in line 260:

  <u>*It's worth noticing that instead of the denitrification, reaction potential of a different geochemical process can be assessed if a different characteristic time scale is applied in equation 8.*</u>

- Study limitations?
  - What about connectivity? A reference to some of this great work would be nice to see in this paper

    Response: Thank you for the suggestion. We added a short paragraph discussing hydrological connectivity at the end of discussion. Please refer to the specific comment #3.

- Conclusion
  - Not strong enough or long enough
  - Need more space and references to specific aquatic community impacts and groundwater table diel drawdown.

Response: Thank you for the comment. The conclusion is rephrased as below:

Groundwater table dynamics substantially modulate hyporheic exchange processes. Daily groundwater table drawdown causes additional variability of hyporheic exchange besides the variability induced by the diel river temperature fluctuations. However, the variability induced by daily groundwater table drawdown is not necessarily an addition to the fluctuations induced by the diel river temperature changes. More specifically, groundwater flow fluctuations that are out-of-phase to diel river temperature fluctuations are likely to promote hyporheic exchange to a larger extent than groundwater flow fluctuations that are in-phase to diel river temperature fluctuations. Even though both groundwater table fluctuations and diel river temperature fluctuations affect hyporheic exchange dynamics, under the same discharge condition river temperature has a more dominant role in determining hyporheic exchange variability under losing conditions than under gaining conditions. This is because under gaining conditions, heat advection of upwelling groundwater is more dominant; under losing conditions heat advection and conduction of surface water is more dominant in hyporheic zone's heat exchange.

The timing of groundwater table drawdown modifies the rates of hyporheic exchange, and as a result the mixing and spreading of pollutants in the aquifer. The timing of aquifer pumping should be adjusted to avoid flood events in order to ensure minimal contaminant uptake. Additionally, the timing of groundwater table drawdown also affects the hyporheic zone's ability to act as a temperature buffer that protects aquatic communities from thermal extremes. Although not as significant as the effect of flood events, hyporheic denitrification potential (and potentially for other biogeochemical reactions) is also changing following the groundwater table drawdown. Therefore, careful considerations must be taken when planning aquifer pumping schedules in order to minimize negative environmental impacts.