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Geoscientific Model Development Discussions

Interactive comment on "A multirate mass transfer model to represent the interaction of multicomponent biogeochemical processes between surface water and hyporheic zones (SWAT-MRMT-R 1.0)" *by* Yilin Fang et al.

Anonymous Referee #2

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The manuscript addresses the transport of nitrogen in river networks, and proposes an extension of the SWAT model that includes water exchange and biogeochemical reaction in the hyporheic zone. The model is applied to the watershed of the Columbia River. Proposing an extention of SWAT that includes the effect of hyporheic process is a valuable contribution to research in solute fate in catchments, as catchment-scale models usually do not encompass these processes. However, additional efforts are needed to clarify some methodological parts. The main issues are described below.

Main comments:

- ROLE OF GROUNDWATER: Vertical upwelling of groundwater through the hyporheic zone and to the stream seems not to be included (see detailed comments, line 205). The contribution of groundwater as lateral flow should be better explained (206). - USE OF RESIDENCE TIME DISTRIBUTION: the authors explore the impact of using a distribution of residence time instead of an average value. This is a valuable attempt, but the way these distributions are chosen is unclear (251, 305).

Detailed comments:

line 205 "the bottom boundary has a prescribed flux" -> how is it chosen? Is it equal to zero?

206 "flow is solved by the vertically integrated groundwater flow equation with the Dupuit–Forchheimer assumption" -> for consistence, I suggest to briefly state boundary conditions also for determining lateral flow.

230 "Compared to other reaches in the watershed, the Columbia River is characterized by relatively larger exchange flow" -> Fig. 3 shows exchange flow values up to the order of 100 m3/s (vertical flow) and 1 m3/s (lateral flow). These values are extremely high and deserve some explanation on why they are considered realistic. It is possibly that they occur only on very long reaches, but I would check this and verify the values of flux per unit area that provide values whose magnitude can be more easily assessed.

247 "only one exchange rate [...] for each zone" -> I would state more clearly that two zones are used to represent vertical and lateral exchange, as it comes out later.

251 "1) replacing the residence time and exchange flux with those predicted by NEXSS using seasonal flow conditions; 2) replacing the single storage zone in vertical and lateral with sub-storage zones within a storage zone, assuming a distribution of residence time [...]" -> a few additional words would make easier to understand how these scenario have been built. Specifically, I recommend to specify 1) which "seasonal flow conditions" have been considered and 2) how the characteristics of the "distribution of

residence time" have been determined. There is a mathematical explanation for it, but it is unclear how the specific values of tau_s,j have been chosen. At present, some of (but not all) these information are provide in sections 4.3 and 4.4 of the Results' section, but they would be better located here rather than among the Results. Alternatively, is should be at least anticipated that they are reported later.

288 "It's not true [the fact that lateral HZ are in dynamic steady state] for RCH77 and RCH88 as their exchange flows are much smaller" -> why only these reaches? RCH67, 53, 93, 100 and 101 all exhibit the same behavior.

Fig. 5, caption: it should specified that this is the MRMT scenario. Same for other figures.

305 "Using exponential residence time distribution and 20 sub-storage zones, we had multiple rates based on the mean residence time from NEXSS. Assuming the exchange flux from the NEXSS estimation is equally distributed in each sub-storage zone, the residence time for each sub-sotrage zone is calculated using Eq. 12." -> this explanation is unclear. How has each residence time estimated with NEXSS (denoted here as T) transformed into multiple (20) residence times? From this description I imagine that for each zone an expontial distribution with mean equal to T was defined, and then 20 values with their corresponding probability were extracted from this distribution. Anyway, this is not fully clear from the text, and in any case many details are missing (e.g., how was the maximum residence time chosen?). I strongly recommend to provide more details about this part as it is fundamental to obtain a representative distribution of residence times. As a further notice, the choice of equally distributed fluxes is simple but debatable, as it is known from the classic theory of Elliott and Brooks (1997) that exchange flowpaths with higher fluxes penetrate deeper in the streambed and are hence characterized by longer times. I am unsure if this would entail a significant difference, but if it is feasible I recommend verifying the impact of this assumption.

307 "sotrage" -> "storage"

307 "Simulation with multiple exchange rates within each storage zone showed less removal of nitrate in the stream through microbial respiration in the HZs compared to the single-rate simulation (Fig. 7)." -> as far as I can see by eye, the difference is rather small. If so, I would mention it.

Fig. 6: because all these scenarios include biogeochemical reactions, I recommend labeling them coherently, i.e., MRMT+BGC, SEASONAL MRMT+BGC.

318 "high stream nitrate concentration than those shown in the bASE case can occur" -> is this a regular feature or has it only been observed occasionally?

319 "bASE" -> "BASE"

325 "nitrate coming from these wasteways will exchange in the HZs in a short time and will not be expected to have a big impact on surface water quality" -> the link between residence time and impact on water quality is not so evident. What is clear from fig.10 is that in this reach HZ and river concentrations exhibit syncronous variations, as already expected from the previously shown results. I understand that if the residence time in the HZ is large enough then the increase in NO3 concentration due to the point source can be buffered and possibly attenuated, but the comments here do not clarify this well enough.

341 "our simulations show that HZs can attenuate the peak nitrate concentrations in the stream" -> it would be useful to report a quantative assessment (e.g., concentration reduction between xxx and yyy %) instead of just sending back the reader to fig.4.

375 "limations" -> "limitations"

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