

SC1: Scott Painter

The discussion paper “A multirate mass transfer model to represent the interaction of multicomponent biogeochemical processes between surface water and hyporheic zones (SWAT-MRMT-R 1.0)” presents a coupling between the SWAT watershed model and the biogeochemical reaction modeling capabilities within the PFLOTRAN code. Coupling between flowing surface water and biogeochemically active hyporheic zones is a key consideration in the development of more mechanistic representations of nutrient transport and transformation at watershed scales. Multiscale approaches like those adopted in the discussion paper (see also Painter 2018) represent promising strategies for incorporating more detailed biogeochemical understanding in catchment and basin-scale models. In particular, the attempt to account for a range of hyporheic residence times and the effect of hyporheic zone flowpath diversity on net nutrient processing is welcome.

However, the discussion paper is unclear and appears to be internally inconsistent on how the hyporheic zone and its coupling to the flowing channel are conceptualized and represented in software. The schematic in Figure 1 shows computational cells (sub-storage zones in their terminology) that are connected in series, which would approximate a one-dimensional advection-dispersion-reaction system for each storage zone, as in Painter [2018]. That is, the sub-storage zone closest to the channel is exchanging mass with the channel, but other sub-storage zones are exchanging mass with their neighboring sub-storage zones, not directly with the channel. However, the description of mass exchange with multiple sub-storage zones in the caption of Figure 1 and in text in Sections 2.3 and 4.4 implies sub-storage zones that are each connected to the channel – i.e. sub-storage zones connected in parallel to the channel, which is the transient storage zone model generalized to multiple storage zones. The distinction is important. If connected in series, then the reaction system for a sub-storage zone will have as input the reaction products from neighboring sub-storage zones. If connected in parallel, then each would see only unreacted river water as input. Net nutrient processing for the integrated system is likely to be different for the two configurations because the parallel configuration would result in more mixing with oxygen-rich river water and thus underpredict redox zonation and the effect on redox-sensitive reactions.

Additionally, if the conceptualization is meant to be that of sub-storage zones connected in series, as in Figure 1, then there is an additional question of how reaction products are returned to the channel. Figure 1 implies that reaction products from one cell would pass back through the cells closer to the channel, which would be appropriate for hyporheic zones that are diffusion dominated. If hyporheic exchange is due to advective pumping, then reaction products from sub-storage zones should be returned directly to the stream channel (see, e.g. Figure 1 of Liao et al. [2013] or Figure 1 of Painter [2018]). Again, the distinction is likely to be important for net biogeochemical processing. In short, it would be useful to clarify the conceptualization of the spatial structure of each storage zone, its coupling to the river channel, and the representation of that process in the numerical model. If each sub-storage zone is connected directly to the channel, as implied by the text, then Figure 1 should be redrawn to represent that particular mesh topology. Additionally, a discussion of the two different ways to conceptualize the transient storage zones and their anticipated effect on simulated biogeochemical processing in stream/river corridors would be valuable to readers.

Scott Painter Environmental Science Division Oak Ridge National Laboratory Liao, Z., Lemke, D., Osenbrück, K., and Cirpka, O. A. (2013), Modeling and inverting reactive stream tracers

undergoing two-site sorption and decay in the hyporheic zone, Water Resour. Res., 49, 3406– 3422, 10.1002/wrcr.20276. Painter, S.L. (2018) Multiscale Framework for Modeling Multicomponent Reactive Transport in Stream Corridors, Water Resources Research, 54, 10, (7216-7230).

Response:

Thanks for the comment and discussion.

MRMT in this paper is an extension of the commonly used transient storage model to represent riverine solute transport assuming each storage zone is well mixed. The stream water column and the hyporheic zones can be conceptualized as separate batch reactors gaining or losing mass due to hydrologic exchange as shown in the schematics below. The sub-storage zones are in parallel and assumed to be well mixed. They don't communicate with each other, but communicate with the stream water, which reacts itself. The mass exchanges between each sub-storage zone and the stream are parameterized by NEXSS in this model. Our approach is different from the approach in Painter (2018) which simulates one-dimensional advection-dispersion-reaction system for each storage zone. We agree with Dr. Painter that the different conceptualizations will have an impact on net biogeochemical processing and a discussion of these two different approaches is necessary.

