Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.20721

A multiscale model for reactive transport in river networks

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Process-based models for reactive transport in streams and rivers are challenged to resolve processes in small biogeochemically important regions adjacent to the channel—the hyporheic zone—while remaining tractable at the societally relevant scales of watersheds and river basins. We summarize work to bridge those scales using a multiscale modeling approach (Painter et al. 2018; Jan et al. 2020) that associates a subgrid model for transport and reactions in the hyporheic zone with each channel grid cell in a network-based flow and transport model. The subgrid models account for transport and reactions along water flowpaths that leave the channel and travel through the hyporheic zone before returning to the channel. By expressing the subgrid models in hyporheic age-based Lagrangian form, flowpath variability in the hyporheic zone is efficiently accounted for through hyporheic lifetime distributions. This model has been implemented in the highly parallel integrated flow and transport model ATS. The ATS implementation provides significant flexibility allowing, for example, full 3D watershed models with subgrid models on the river network. We show examples of how parameters in our multiscale model can be estimated without conflating physical exchange and chemical reaction parameters by combining stream tracer tests, laboratory measurements, and temporally resolved measurements of water chemistry. We also explore how different representations of hyporheic exchange can affect those estimated parameters. A network-scale reactive transport model of denitrification in an agricultural watershed provides an example of how this modeling framework can link hydro-biogeochemical processes occurring at small scales into a network context.

1. Scott L. Painter, Water Resources Research 54, 7216 (2018).
2. A. Jan, E. T. Coon, and S. L. Painter, Environmental Modelling & Software 145, 105166 (2021).