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Modelling hyporheic exchange: From the boundary layer to the basin

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Hyporheic exchange is fundamental to vertical connectivity, transporting mass, energy, and momentum between the sediment and the water column. Recent work has led to the development of new resistance model of sediment-water interfacial flux at the patch-scale (ca., 1 to 10 m) including processes of hyporheic exchange. The model parameterizes patch-scale hyporheic exchange in terms of a mass transfer resistance coefficient R, and a scaling law for R has been developed based on a meta-analysis of previously published hyporheic exchange experiments in recirculating laboratory flumes. For this study, we adapt this scaling law to natural stream channels in the Murray-Darling Basin using reach-averaged values of key hydraulic variables that are assumed to be fixed throughout the stream network or modeled using hydraulic geometry relations. This model predicts much more frequent exchange between the water column and the streambed in steeper upland streams. A molecule of water transported along a 100 km length of upland stream may journey into the streambed more than 1000 times. In contrast, the same molecule might only pass into the streambed once while being transported a similar distance in a lowland river. This suggests that any hyporheic processes influencing the character of the water column (through biogeochemical transformations or source-sink dynamics) will have a much stronger effect in steeper gradient rivers. The stronger hydrological connectivity between water column and hyporheic zone in steeper rivers is likely to promote buffering of solute and suspended contaminants delivered as a pulse from headwater catchments. This suggests an interesting interaction between vertical and longitudinal hydrological and biogeochemical connectivity at the basin-scale. Upland rivers may be characterized by strong vertical and weak longitudinal connectivity whereas the reverse may be true in lowland rivers.