Geophysical Research Abstracts
Vol. 15, EGU2013-7492, 2013
EGU General Assembly 2013

Impact of sediment heterogeneity on nutrient reactions in rippled streambeds

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The interactions between hydraulic and biogeochemical processes in streambeds play a relevant role for water quality of riverine ecosystems. Streambeds are commonly characterized by heterogeneous permeabilities as a result of a number of preferential sedimentation and entrainment of sediments with different size and other diagenetic processes. Sediment heterogeneity is known to influence water and nutrient exchange with the stream, but the understanding of its role on nutrient transformation is far from being complete.

In this work we studied the effect of permeability heterogeneity at bedform scale on the chemical zonation in a rippled streambed. We considered two heterogeneous permeability cases derived from field observations, and we numerically simulated patterns of DOC, dissolved oxygen, and inorganic nitrogen (NO_3^-, NH_4^+) within the streambed. We then compared the simulation results with the concentrations and reaction rates in an equivalent homogeneous streambed to identify the role of permeability heterogeneity on nutrient transformations.

Our results show that sediment heterogeneity has a relevant impact on water flow paths while it does not dramatically alter concentration patterns and nutrient reaction rates. The reason is that distributions of residence times, that control the reactions, are similar for the heterogeneous and homogeneous cases. Our findings suggest that water residence times should be a better indicator and predictor of subsurface reactions than porewater flow patterns. The variations of permeability have also shown to not alter the role of the streambed as source/sink of NO_3^-, observed for different in-stream concentrations. This result implies that the study of nitrogen fate in shallow stream sediments does not require a detailed knowledge of bedform-scale permeability variations.