Geophysical Research Abstracts
Vol. 16, EGU2014-8564, 2014
EGU General Assembly 2014
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Scale effects of nitrate sinks and sources in stream networks

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Increasing N-fertilizer applications in agricultural catchments are considered as one of the major sources for dissolved nitrate-nitrogen (NO_3-N) in surface water. While NO_3-N mobilization pathways depend on catchment's pedological and hydrogeological characteristics and its runoff generation processes, in-stream retention and removal processes depend on local/reach-scale conditions such as weather, discharge, channel morphology, vegetation, shading or hyporheic exchange and others. However, knowledge is still limited to scale up locally observable retention and removal processes to larger stream networks to understand the spatial and temporal dynamics of in-stream NO_3-N concentrations. Relevant processes to consider explicitly are the effects of "hot spots", dominant NO_3-N sources (e.g. sub-catchments, "critical source areas") or specific NO_3-N sinks (e.g. riparian wetlands and stream reaches with high biogeochemical activity). We studied these processes in a 1.7 km^2 agricultural headwater catchment, where distinct locations of groundwater inflow (a dense artificial drainage network) and a predominantly impervious streambed allowed separating mixing and dilution processes as well as in-stream retention and removal processes. During two summer seasons we conducted a set (25) of stream network wide (stream water and drainage water) synoptic sampling campaigns including climate parameters, discharge, channel geomorphology, vegetation, stream water chemistry and physical water parameters (dissolved oxygen concentration, water temperatures, electrical conductivity, pH). Analyzing these data sets we were able to determine a) time variant NO_3-N concentrations and loads for all sub-catchments (sources), b) time variant in-stream removal rates for all stream reaches (sinks) and c) the hierarchical order of all contributing NO_3-N sinks and sources and their time variant influence on total NO_3-N export. Climate parameters, discharge, channel geomorphology, vegetation, stream water chemistry and physical water parameters were then used to identify controls of in-stream removal processes. The strongest correlations with NO_3-N in-stream removal rates were found for stream water temperatures, vegetation density and shading. We developed a data-driven mixing-and-removal model to directly quantify the spatial scaling effects on the reproducibility of observed in-stream NO_3-N concentration patterns. The position of the largest sinks and sources in the stream network is the major control, due the local impacts on the relationship between discharge, concentration and load. The upstream positions of sources control the efficiency of downstream sinks by regulating in-stream NO_3-N availability, while the upstream positions of sinks have an impact on downstream mixing and dilution processes. Understanding the interplay of NO_3-N sinks and sources in stream networks will contribute to a better description of NO_3-N export and retention processes even for catchments with a more diffuse occurrence of NO_3-N sinks and sources.