Geophysical Research Abstracts
Vol. 19, EGU2017-17083, 2017
EGU General Assembly 2017

Scale dependent controls of stream water temperatures - interaction of advective and diffusive energy fluxes

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Diurnal stream water temperature amplitudes (WTA) have a large impact on local ecohydrological conditions, e.g. aquatic habitat quality or biogeochemical cycling. Depending on discharge, streambed geomorphology, connectivity to the groundwater, hyporheic exchange flow and other local factors such as shading and climate conditions observable WTAs vary strongly from up- to downstream and can locally even exceed seasonal temperature variations. The main process which is responsible for the local expression of WTA is the energy balance which can be either dominated by advective energy fluxes (e. g. discharge and upwelling groundwater) or by diffusive energy fluxes (e. g. radiation, latent and sensible heat fluxes, heat exchange with the streambed). In recent years research has mainly focused on improving our knowledge how groundwater–surface water interaction, hyporheic exchange and shading processes influence locally observable WTA in smaller streams, while for larger streams or rivers WTA might even be non-observable throughout the year. Within this study we analyze the scaling behavior of advective and diffusive energy fluxes from small to large streams to better understand on which scales and under which conditions WTA might be dominated either by advective or diffusive energy fluxes and how groundwater – surface water interaction influences this relationship.

For this purpose, we carried out a synthetic model study. Using published hydraulic geometry relations for different types of rivers, we apply a conceptual energy balance- and mixing model, which includes GW-SW interaction, discharges from 100 l/s up to 50 m^3/s on length scales from 100 m up to 50 km. Simulated boundary conditions were constant discharges at the upstream boundary and constant and uniformly distributed exchange fluxes to the groundwater. Upstream water temperatures were 15 °C (WTA of 5 °C), while groundwater temperature was assumed to be cooler than the stream with 9°C. Net diffusive energy fluxes were estimated with a sine curve model (amplitude of 300 W/m^2, which includes all relevant fluxes by definition). For specific types of rivers we can clearly determine the scale transformation of WTA from being dominated by upstream processes (advective energy transport via surface discharges) to local processes (local energy budget and groundwater dependent processes). Moreover, we found for scales of 10 km and larger that WTAs can be locally more or less completely dampened out by the overlay of advective and local diffusive fluxes. Up to date this process has not been mentioned in the literature due to the lack of necessary temporal and/or spatial resolution of water quality monitoring stations. These findings shed new light on our understanding of the controls of locally observable water temperatures and should be considered for water quality management and stream ecology, e.g. for the planning of water quality monitoring stations or river restorations.