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Quantification of heat retardation of in-stream discharge by heat exchange with rock clasts

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Temperature is a powerful tracer for many hydrological processes. With the introduction of Distributed Temperature Sensing (DTS), observations at the meter scale and minute interval have become available. In order to quantify lateral contributions to the stream discharge, we applied high resolution temperature observations in a 1st order stream, However, the observed temperature signal is often difficult to interpret because of its non-conservative behavior. In this paper, we developed an energy balance model and coupled it with a hydraulic model of the stream.

The hydraulic model considers all inflows and outflows of the stream, and is constrained by upstream and downstream discharge observations. The energy balance model takes the advection of heat into account as well as all major energy fluxes influencing the water temperature. The simulated temperature is then tested against the temperature observations obtained with the DTS system.

Interestingly, on warm days, we observed a temperature decrease of a few degrees over ca 100 m during the warmest moment of that day. However, the net incoming energy is positive during these moments, meaning that the water should warm up.

We conclude that the hypothesis of retardation of heat in the stream caused by heat exchange with rock clasts is the most plausible explanation for the phenomenon observed. Due to the storage of heat in the rock clasts, the heat travels with less than a meter per minute, making it hard to see in the observations.

Subsequently, we incorporated thermal heat exchange between stream water and rock clasts in the energy balance model to be able to retard the advection of heat in the simulation. Besides simulation of the exchange of heat with the rock clasts, we also introduced a more efficient mathematical method, which assumes rock clasts to have the same temperature as the stream water. In this way we introduce only 1 additional parameter, which is the ratio between the cross sectional area of the stream water and the rock clasts. The differences between the two methods will be discussed in detail.