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On-site visualization and analysis of hydrological processes using handheld thermal imaging.

Our abilities to understand and to predict the dynamics of hydrological processes in natural systems will be fundamentally improved by applying novel distributed sensors in field research. Due to the technical development of commercial handheld thermal imaging systems regarding the relative accuracies of infrared radiation temperatures and absolute pixel numbers, we tested these systems for several on-site applications in hydrological process studies.

During low flow conditions in headwaters, surface water (SW) temperature is directly affected by air temperature. Since stream discharge may be composed of springs, diffuse groundwater (GW) discharge and localized GW contributions, the SW temperatures can vary at scales of meters or smaller. Handheld thermal imaging, as a remotely applicable tool to map heterogeneities of SW temperatures, was used for the detection and quantification of localized GW inflow in small streams. Complete mixing lengths for different water origins and temperatures could be determined for SW confluences and GW inflows using thermal images. End-member mixing calculations for the quantification of discharge contributions as fractions of downstream discharge were done using observed water surface radiation temperatures and point measurements of electrical conductivity and kinetic SW temperatures. Results were consistent for all measures.

Inside streams and wetlands the spatial distribution of areas dominated by fast flow velocities versus low or no flow areas can have a significant impact on solute transport and therefore on water quality. However, the description of solute transport processes including advection and dispersion can be difficult due to the high spatial variability in these systems. Typically we use analytical models to estimate advection and dispersion. In this study advection and dispersion were determined with a novel tracer approach, where slug injections of heated, NaCl-enriched water are monitored with a hand-held thermal imaging system. Using two-dimensional moment-analysis mean flow velocity and longitudinal and transversal dispersion were estimated (depth averaged) by comparing thermal images taken at different time steps. Point measurements of water temperature and electrical conductivity were used to quantify the impact of NaCl concentrations on water density and to directly compare the transport of heat and NaCl-solutions.

In summary, the on-site observation of SW infrared temperatures allowed us to remotely assess base flow composition and basic flow characteristics of smaller streams and wetlands.