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Detection and quantification of localized groundwater inflow in small streams using ground-based infrared thermography

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Localized groundwater (GW) inflow into small streams can be a major source of runoff during low flow periods in headwater catchments. The localization and determination of the fraction of runoff corresponding to a certain area may give insights into aquifer type, flow processes, the composition of base-flow concerning the spatial distribution of catchment storage and water quality issues. Though GW temperature has a small amplitude during the year compared to surface water, a significant temperature difference between stream water and groundwater can be expected in summer and winter. As the technical development of infrared thermography is progressing (the spatial resolution of infrared camera systems is increasing and the measuring error is decreasing) we tested ground based infrared thermography as a non-invasive and remote applicable method to detect and quantify GW entries in small streams during baseflow periods (<10 l/s). This method offers the possibility to determine the exact location of inflow and the reach length that is needed for complete mixing of stream and ground waters.
Several experiments were conducted in two headwater catchments in southern Germany with flow varying between 0.5 l/s in summer and 3 l/s in winter. The locations of GW entering the stream and the flow lengths of complete mixing were detected using a handheld thermographic system (INFRATEC). In addition, water temperature and electric conductivity of the groundwater entering the stream and of the stream water up- and downstream of localized GW inflow were measured with temperature and EC sensors. Though the zones of complete mixing were identified, point measurements and surface radiation temperatures were taken from the same areas. Discharge measurements were conducted using the salt dilution method with continuous injection. End-member mixing calculations were done using the measured EC and water temperature data and compared to the results of mixing calculations of observed water surface radiation temperatures. The discharge observations were used to validate the fraction calculations. Calculated GW entries using thermogramms had comparable deviations from the measured runoff fractions to those from direct temperature and EC measurements. This leads to the conclusion that the use of ground-based infrared thermography for the detection and quantification of localized groundwater inflows into small streams is a valuable and easy applicable tool for field hydrology.