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Some Like it Hot: Combining infrared imagery and classic isotopic and geochemical tracers to differentiate sources of streamflow in a small headwater stream (Luxembourg, Europe).

Jay Frentress (1,2), Núria Martínez-Carreras (1), Laurent Pfister (1), and Jeff McDonnell (2)

(1) Department Environment and Agro-Biotechnologies CRP - Gabriel Lippmann, 41 rue du Brill, L-4422 Belvaux, Luxembourg, (2) Department of Forest Engineering, Resources & Management, Oregon State University, Corvallis, USA.

Hydrologic sources during precipitation events have often been partitioned using simple mixing models that differentiate stored and event water in stream discharge. However, such models suffer from invalid assumptions and it is difficult to distinguish among multiple hydrologic processes. In an effort to better constrain end-members for mixing models, we investigate the potential to differentiate streamflow sources according to temperature and geochemical and isotopic composition. Near-stream zones with persistent surface saturation offer the opportunity to test the feasibility of such a classification of surface and subsurface sources of streamflow in situ. A hand-held thermal infrared camera was used to generate infrared images of multiple near-stream areas in the 50 ha Weierbach catchment (Luxembourg). Infrared (7 – 13 mm) images of saturated areas (4 - 200 m2) were taken before, during, and after a significant rain-on-snow event. In order to validate thermal imagery results and to better identify source end-members, water samples throughout the photographed areas were collected for major cation/anion concentrations and d 18O and d 2H analyses. Results indicate that infrared imagery greatly enhances our ability to ‘see’ saturated areas in the riparian zone and to infer the direct sources of water to these areas. Under low-flow conditions, groundwater sources in near-stream saturated zones were readily identifiable in infrared imagery. Persistent groundwater sources typically reflected a temperature of $\sim$ 6 °C while other subsurface sources, probably reflecting shorter flowpaths, were more temporally and thermally variable with temperatures ranging from 3 to 5 °C. Many subsurface runoff sources only appeared during the peak of snowmelt. As snowmelt increased during a precipitation event, the channel network extended considerably upslope and patches of overland flow were visible beneath the snowpack. Surface saturation outside the perennial channel areas (snowmelt resulting in overland flow) ranged in temperature from 1 to 3 °C. Direct comparison of isotopic and geochemical analyses with temperatures derived from infrared images allowed us to infer connectivity in the study area at different moments along the hydrograph. Near-stream saturated areas differed by as much as 4 °C from stream channel temperatures. Geochemical and isotopic results and sample temperatures were poorly correlated across time but showed distinct trends at specific points on the hydrograph. Groundwater sources were dominant runoff producers under low-flow conditions while overland flow produced from snowmelt dominated during the hydrograph peak. Additionally, a new tracer approach based on living diatoms as indicators of surface water sources was used to corroborate evidence of overland transport in riparian and hillslope areas where surface saturation occurred.