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Looking at catchments in colors: combining thermal IR imagery with geochemical and isotopic tracers to document spatio-temporal dynamics of water source and flowpaths in the hillslope-riparian zone-stream system

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At present, our conceptual understanding of catchment-scale water mixing, source apportionment and hydrological connectivity is thwarted by measurement limitations. For instance, the measurement and documentation of HRS connectivity is a major impediment to better process understanding.
In recent literature, there have been repeatedly calls for interdisciplinary approaches to expand the frontier of hydrological theory and eventually overcome the well-known limitations that are inherent to conventional techniques used for tracing water source, flowpaths and residence times. The 2010 edition of the EGU Leonardo Topical Conference Series on the hydrological cycle had concluded that a major challenge for hydrology in the near future will be to apply more often multidisciplinary approaches, so to find creative solutions that will eventually allow us to move away from 'monochrome pictures of reality', and 'see the catchments in colors'.
Here, we demonstrate the potential for thermal infrared imagery to both determine adequate water sampling sites and validate the identification of water source and connectivity through conventional tracers. Until recently, the use of heat as a ground water tracer had been largely restricted to the hydrogeological literature. Thermal remote sensing of riparian and water surface temperatures has been of interest in aquatic management issues, as well as for the assessment of spatial heterogeneities.
Our proof-of-concept study in the Weierbach experimental watershed further extended the potential for infrared thermography via hand-held cameras to hydrological processes studies across various hydrological response units (HRU). Infrared thermography of surface water dynamics stemming either from infiltration excess overland flow or saturation excess overland flow was mapped throughout a complete rainfall-runoff event.
In order to grasp the spatial and temporal variability of geochemical and isotopic signatures, during and after a storm event, we have combined thermal IR imagery with grab sampling of water inside the hillslope-riparian zone-stream system. While relying on IR thermography, we also used simultaneous optical image capture to aid in classifying the incoming IR signal and differentiating between substances of different temperature. The distinction between flowing water, saturated zones, soil, wooden branches, pebbles or leaves is extremely difficult when observing the optical image alone. The IR thermography interprets the heat signal from the same source and provides a much better view for identifying both areas where water is flowing and areas where water is either seeping from the soil, flowing as surface runoff or accumulating temporarily in micro-depressions during a rainfall event. This approach has revealed how crucial the location of the grab sampling can be within extremely small geographical zones (a few square meters) due to incomplete mixing, as well as it has helped to map the dynamics of geochemical and isotopic signatures in the area of interest.
To date, our investigations have revealed: (a) the potential for infrared thermography to identify, discriminate and observe the spatio-temporal dynamics of hydrological processes, namely infiltration excess overland flow, saturation excess overland flow and subsurface return flow; and (b) the complementarity of information gained from conventional tracers (geochemicals and stable isotopes) and remote sensing (infrared thermography). Our next step will consist in assessing the individual and combined potential of these techniques for reducing uncertainties in hydrological process identification and quantification (especially with respect to hydrograph separation).