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Investigating runoff generation at low flow conditions - how valuable are tracer methods?

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The role of antecedent conditions for the catchment response is widely acknowledged. However, most studies concentrate on flood generation at relatively high moisture states excluding process investigations at low flow conditions. To cover a larger range of hydrological preconditions - especially at low flow - we conducted extensive field measurements in a steep 1.3 km2 forest catchment in southern Germany during a 4 month summer period. These included (a) continuous soil moisture measurements; (b) continuous stream flow measurements of runoff, temperature, conductivity and turbidity; (c) continuous riparian zone measurements of groundwater levels, temperature and conductivity; and (d) weekly sampling for tracers (major ions and O-18) in the stream and neighboring hillslope springs. Measurements started during a five week drought in May/June (period of intense forest growth) to continue with more rainfall up to the end. Runoff recession analysis pointed to a gradual filling of hydrological reservoirs. These hydrological reservoirs were assumed to be located in periglacial drift covers on hillslopes, since riparian zones were limited and measurements did not suggest significant runoff contributions. Hillslope soil moisture measurements supported this theory since they showed a gradual wetting of deeper soil layers. Still hydrometry was not enough to provide a final proof for runoff generation processes relevant at the catchment scale. Tracers provided the missing information in a two-fold way. First, classic two-component hydrograph separations (using both continuous temperature and conductivity readings) showed a gradually rising pre-event component in measured runoff events. Second, natural tracers provided the link between springs and stream to identify source areas of runoff. Due to metamorphic, crystalline lithology chloride enrichment by the influence of transpiration served as tracer to assign different springs to contributing reservoirs and to document their relative importance for stream flow generation. While chloride concentrations of most springs corresponded to long term values of transpiration and groundwater recharge, two springs at upper hillslope positions were significantly elevated in chloride. Hence a three-component end member mixing analysis using chloride and O-18 could be used to show the limited importance of the root zone in summer streamflow. Our data rather suggested that retarded flow recession and enhanced pre-event contributions towards the end of summer were not directly linked to a filling of the root zone but originated from deeper reservoirs. For this distinction silica was less applicable, because silica concentrations seemed to be dominated by differences in longer term residence times rather than by a functional distinction between contributing hillslope reservoirs.