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Analysis of runoff generation during rainfall and snowmelt events in an Alpine catchment based on isotopic and electrical conductivity data

Daniele Penna (1), Ilja van Meerveld (2), Giulia Zuecco (3), Giancarlo Dalla Fontana (3), and Marco Borga (3)

(1) Faculty of Science and Technology, Free University of Bozen-Bolzano, Italy (daniele.penna@unibz.it), (2) Department of Geography, University of Zurich, Switzerland, (3) Department of Land, Environment, Agriculture and Forestry, University of Padova, Italy

Alpine catchments are valuable sources of fresh water. However, compared to lower altitude catchments, our knowledge of the hydrologic behavior of high-elevation catchments is still relatively poor. We, therefore, set out to identify the dominant controls on runoff generation in the 0.14-km2 Bridge Creek Catchment in the Italian Dolomites (Central-Eastern Alps). Stable isotopes of water and electrical conductivity (EC) data, coupled with hydrometric measurements (precipitation, streamflow, spatially-distributed shallow groundwater and soil moisture at different depths), were collected during nine rainfall-runoff events and six snowmelt-runoff events in spring, summer and autumn of 2010-2012. Specifically, we aimed to i) quantify the relative contributions of event water to streamflow and detect the factors affecting the event water fractions in the stream; ii) identify the dominant runoff pathways for event and pre-event water to the stream; and iii) determine if the selection of pre-event water samples significantly affects the results of the isotope-based hydrograph separation analyses.

The traditional two-component hydrograph separation technique was applied to deuterium data in two ways: i) assuming that the stream water sample taken prior to the event represented the isotopic composition of pre-event water , or ii) assuming that the average composition of stream water samples taken during baseflow conditions at different times of the year represented the pre-event water composition. For rainfall events, the hydrograph separation results for the two methods were very similar (root mean squared error=0.3 l/s) but for snowmelt events they significantly differed, especially when the event water runoff was high (root mean squared error=1.8 l/s). This was due to residual snowmelt (particularly late in the melt season) contained in stream water that influenced the isotopic composition of the stream between melt events.

The pre-event water fraction dominated streamflow during rainfall events (on average 91% of the total runoff), while its importance decreased during snowmelt events (on average, 77% or 87% of the total runoff, depending on the method used to determine the isotopic composition of pre-event water). Event water fractions were particularly high during large or intense rainfall events, and late in the snowmelt season, with maximum event water contributions up to 37% and 46%. The EC of stream water showed a distinct behavior: decreasing at the beginning of the event, reaching a minimum before peak streamflow and then increasing above pre-event stream water values. The measurements also showed that the spatial variability in the isotopic composition and the EC of groundwater was very high, which made it difficult to differentiate between hillslope and riparian groundwater contributions to streamflow. Overall, the observations indicated that that during dry periods direct channel precipitation and saturation overland flow in the riparian zone were the main processes driving the runoff response, with a smaller contributions of riparian groundwater. Conversely, during wet or very wet periods (large rainfall events or peak snowmelt), saturation overland flow contributions to streamflow were larger due to the expansion of the saturated areas. The contributions of riparian groundwater and shallow subsurface flow from the hillslopes increased with storm size and antecedent wetness as well.

Keywords: Alpine catchment; water isotopes; electrical conductivity; hydrograph separation; pre-event water.