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Evidence and implications of the highly-variable tracer signature of water sources in a glacierized catchment

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Glacierized catchments are essential sources of fresh water in Alpine areas especially during warm and dry periods. Therefore, the quantification of glacier melt contribution to stream runoff represents a crucial issue in Alpine catchments affected by rapid glacier shrinking. The glacier melt water contribution to stream runoff can be estimated by different approaches, one of which is represented by the application of geochemical tracers. However, the spatial and temporal characterization of geochemical tracers in water sources in glacierized catchments is particularly difficult.

In this work, we aim to characterize the tracer signature (δ^2H and electrical conductivity (EC)) of the main water sources and study the hydrological response of a glacierized catchment during three consecutive summer seasons. The specific objectives are to: i) analyze the spatial and temporal variability of the tracer signature of snow, glacier ice and glacier melt water, in relation to the fractional snow cover of the catchment, ii) analyze the inter-annual and seasonal dynamics of streamflow, stream water EC and isotopic composition in relation to the hydro-meteorological conditions, and iii) identify the main end-members to stream runoff.

The study area is an 8.4-km^2 catchment (42% glacierized) in the Eastern Italian Alps. Meteorological and streamflow data were collected continuously during the 2013-2015 ablation seasons. Samples for EC and isotopic analyses were taken from rainfall at the outlet of the catchment and from fresh and residual winter snow, firn, glacier ice and melt water at different elevations on the glacier. Stream water samples were taken manually and by an automatic sampler at the outlet, and from three sections close to the glacier fronts.

Results showed that variations in the daily streamflow range due to melt-induced runoff events were controlled by maximum daily air temperature and snow covered area in the catchment. Maximum daily streamflow decreased with increasing snow cover and a threshold relation was found between maximum daily temperature and daily streamflow range. There was a high spatial and temporal variability in the isotopic composition of snow, glacier ice and glacier melt water. The isotopic composition of snow, glacier ice and melt water was not significantly correlated with the sampling point elevation and the spatial variability was more likely affected by post-depositional processes. During melt-induced runoff events, stream water EC decreased due to the contribution of glacier melt water to stream runoff. In this catchment, EC or more conservative tracers could be used to distinguish the contribution of subglacial flow (enriched in EC) from glacier melt water to stream runoff at the seasonal and daily timescale. The high spatial and temporal variability in the tracer signature of the identified end members (subglacial flow, rain water, glacier melt water and residual winter snow), together with small daily variability in stream water δ^2H dynamics, are problematic for the quantification of the contribution of the end members to stream runoff, and call for further research, possibly integrated with other natural or artificial tracers.

Keywords: runoff generation; stable water isotopes; electrical conductivity; end members; glacier; snow; Alpine catchment.