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Characterizing streamflow generation in Alpine catchments

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Developing effective hydrological models for streamflow generation in Alpine catchments is challenging due to the inherent complexity of the intertwined processes controlling water transfer from hillslopes to streams and along the river network. With water discharge as the sole observational variable it is impossible to differentiate between different streamflow sources, and modelling activity is often limited to simplified phenomenological rainfall-runoff models. This study focuses on quantifying streamflow sources at different temporal scales and the associated uncertainty by using natural tracer data (electrical conductivity, oxygen and hydrogen stable isotopes ratios) as observational variables supplementing streamflow measurements. We determine the spatial and temporal hydrological behavior and the mean residence time of water in the Vermigliana catchment, North-Eastern Italy and we separate contributions to streamflow originating from Presena and Presanella glaciers, both exerting a strong control on the hydrologic budget of the study site. Furthermore, we identify a seasonal control on the effect of storm events. The catchment responded rapidly to precipitation events in early autumn, it was unaffected by precipitation events in early spring, while runoff generation was enhanced by snow melting in late autumn. Air temperature is identified as the main controlling parameter, in addition to precipitation. Two-component mixing analysis showed that the relative contribution of new water, which can contribute up to 75% of total streamflow, is very rapid. Only two hours time-lag was observed between the beginning of the precipitation event and the emergence of a significant contribution of new water. These results evidence the relevance of mixing between pre-event and event water in the Vermigliana catchment, and in similar high elevation Alpine catchments. This study provides new insights on the dynamics of streamflow generation in Alpine catchments and a framework to develop and validate hydrological models in this rather complex context, where several sources of streamflow combines in a complex way depending on precipitation and air temperature as meteorological forcing.