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Investigating the role of geology on the spatial variability of catchment water balance and its impact on flood processes

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Geology is a main pattern of catchment organization, and we ask whether it impacts the hydrological response of catchments, especially during floods. The aim of our study is to assess which hydrological processes are linked to the geological pattern, and to which extend the latter can affect water balance and runoff coefficient at catchment scale. For that, we propose to compare the main components of the water balance to geomorphological indicators, in order to assess the potential transferability of results to ungauged catchments. Our method consists in a complete water budget assessment of catchments at their outlet, including precipitations P, evapotranspiration E, runoff Q, and intercatchment groundwater flows (IGF), combined to a geomorphological and geological characterisation. Data are based on the annual components of the water balance, calculated from pluri-annual time series at a daily time step for medium catchments (from 50 to 500 km^2). For each outlet, are differentiated global and intermediate catchments (defined as the draining area that feeds a river reach delimited by two gauging stations). The whole study site (total of 25 000 km^2) is composed by 3 zones of various geology in France (Cévennes Mountains, Jura Mountains, Normandy) including 120 gauging stations. In a first step, results show that many catchments have a "non conservative" water balance (i.e. Q > P or Qupstream > Qdownstream), and that this behaviour can be linked to the catchment geology (differentiating hard-rock, karst, and other sedimentary formations). Results also show that both quick and slow flow components (deduced from hydrograph separation) are correlated with geology, as well as the IGFs. The impact of land use is also studied, and compared with geology. In a second step, we characterize relationships between those hydrological specificities and some simple geomorphological parameters, i.e. drainage density and IDPR (Index of Development and Persistency of River networks, quantifying the terrains connectivity to hydrographic network). Results show that correlations exist, relatively strong depending on the study sites and geology. The case of karst areas – that characterize carbonate outcrops – is highlighted due to the highest variability of hydrological indicators in catchments covers by such patterns. A parallel review of the local artificial tracing tests shows that the weakness of the correlations in the karst Jura Mountains could be explained by the importance of IGFs that are highly promoted in these regions. Finally, our results highlight the geological control of catchment hydrology and the specific role of groundwater flows in karst areas on flood flows. Knowing that karst areas cover 20% of Europe outcrops, this work promises interesting perspective in mapping hydrological indicators in link with catchment organization and geology.