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Investigating inter-catchment groundwater flows in the Meuse basin

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Most conceptual hydrological models are mass conservative, meaning that catchment boundaries derived from surface elevation models also apply in the subsurface. This further implies the absence of inter-catchment groundwater flows. Adding a loss/gain term representing such inter-catchment groundwater flows is often not warranted in models due to limited data availability for calibration (often only streamflow) and the difficulties involved in determining potential and actual evaporation. Yet, assuming this process to be negligible may introduce considerable misrepresentation of the natural system in hydrological models, for example in regions where karstification processes in limestone and chalk deposits characterize the subsurface. The presence of Devonian limestone formations in the Condroz and Famenne regions of Belgium, and Jurassic limestones in the French and Belgian Lorraine thus motivate to question the validity of assuming mass conservative catchments in the Meuse basin. To isolate and quantify the potential relevance of inter-catchment groundwater flows in this study, the long term water balances of approximately fifty catchments in the Meuse basin are analysed in the Budyko framework. The data suggest that a number of relatively small headwater catchments plot very close to the energy limit in the Budyko framework. Implying long-term mean actual evaporation rates close to potential evaporation, the hypothesis is tested that for these catchments actual evaporation is over-estimated at the cost of losses due to inter-catchment groundwater flow. The relative position of each catchment from the energy limit line in an adapted Budyko framework (Q/P as a function of E_p/P) is used to assess possible gains/losses to/from the catchment. Overall, this distance increases with catchment size. The data thus suggest that part of the groundwater flow bypasses headwater stream to reach the channel only further downstream. Several discharge stations along the Semois River provide strong supporting evidence that the distance towards the energy limit increases as we move further downstream along the same river. Additionally, a slight increase in baseflow index is observed as catchment size increases along the Semois River. A simple hydrological model is then used to estimate that the groundwater flow which bypasses the most upstream station is about 10% of the precipitation of that catchment.