EGU2020-3018
https://doi.org/10.5194/egusphere-egu2020-3018
EGU General Assembly 2020

Evidence-based conceptual requirements of regional groundwater processes for hydrological simulations

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River flows are the result of dynamically changing, interacting and non-linear processes of surface, near subsurface and often deeper groundwater flow from climatic drivers. Conceptual rainfall-runoff models, whilst providing advantages in computational efficiency and more minimal data requirements, often struggle to simulate contributions from groundwaters, resulting in poor model calibration. Improving predictions of river flows in these catchments is, however, critical to water resources planning and management, particularly in the UK where groundwater contributes 30% of public water supply in England. In order to improve model predictions in groundwater-dominated catchments, we conduct a detailed analysis of available observational data to better understand groundwater-surface water interactions and processes on a regional (aquifer) and local (river reach) scale, over geologically variable areas.

National meteorological, hydrological, hydrogeological, geological and artificial influence (characterising abstractions and return flows) datasets are used to develop a conceptualisation of the groundwater processes occurring in 99 subcatchments of the River Thames in the UK. We use these data to characterise the water balance, intercatchment groundwater flows, gaining/losing river reaches and hydrograph dynamics of these subcatchments, and investigate how dominant groundwater processes vary spatially and temporally. The River Thames has been selected as our case study owing to its wealth of data, densely gauged river network and geological variability.

We show that intercatchment groundwater flow is needed to ‘close’ the water balance in many catchments located on aquifer outcrops and find evidence of river-groundwater level flow thresholds. Importantly, we find that seasonality is a key control on the accurate representation of groundwater-surface water interaction processes and that the spatial and temporal variability of those processes varies greatly for different geologies across the Thames basin. We also demonstrate the importance of human influences to understand some of these spatial processes. We then identify the physical processes that existing conceptual rainfall-runoff models are likely missing, and what may be required to enable model calibration improvements in groundwater-

dominated catchments.