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Using a multi objective framework for improved calibration and spatial interpolation in hydrological models of the Berg river catchment, South Africa

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As understanding river flow regime dynamics is important for future management and conservation of global water resources, the use of hydrological models in ungauged rivers systems has become increasingly common. As the effectiveness of hydrological models to replicate streamflow is limited by the spatial and temporal density of climate stations, it becomes necessary to understand the climate representation of the model at various timesteps. As climate stations are often most dense near cities at low altitude, the importance of having enough stations at different elevation bands impacts the effectiveness of the hydrological model to replicate the sub-basin flow contribution. The use of multi-objective criteria to understand model performance at gauged sub-basins is important during model parameter transfer to ungauged sections. During this study the distributed J2000 rainfall/runoff model was used to understand the impact that climate station density has on model regionalisation and the simulation of hydrological flow components. Furthermore, a station importance factor was used to identify the models station reliance, the maximum station distance for effective hydrological simulation and the relative importance of flow from different sub-basins at the catchment outlet. The rainfall/runoff model was calibrated and validated using multi-objective criteria namely; Nash-Sutcliffe-Efficiency (E1 and E2), Percent Bias (PBIAS) and Kling-Gupta-Efficiency (KGE) coefficients for two gauges, located on the main stem of the river system, to determine a global model parameter dataset which can be used for the model sub-basins. The approach was applied to the Berg River, an inland catchment (7700 km^2) located in the Western Cape province of South Africa. While the Berg River is an important agricultural area which is dominated by irrigation, it is also the source of large-scale inter-basin transfers to the metropolitan city of Cape Town. The Western Cape has recently (2012-2017) been subject to a crippling drought which had devastating impacts on agricultural production, as well as inter-basin transfers to the city of Cape Town. The results from the hydrological model showed that for precipitation spatial representation, a station density of 1/20 km^2 as well as good mid-altitude (200-300 masl) coverage resulted in good hydrological modelling performance. For the simulation of evaporation, the spatial density of measurements impacted the estimation of potential evaporation, but simulated soil-moisture was the main control and station density did not affect the model results. This study highlights the importance of ensuring

that precipitation station coverage is sufficient for effective hydrological simulations from sub-basins, with recommendations of both spatial coverage and elevational representation being provided for semi-arid Southern African conditions. The spatial accounting of micro-climatic variability goes some distance to ensure representative sub-basin flow contributions, improving the ability of hydrological models to replicate river flow regimes in semi-arid heterogenous catchments.