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Assessing the predicative capability of hydrological models and ensemble averaging techniques under contrasting climate conditions

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Robust climate change planning and adaption necessitates application of hydrological models which have good predicative capability when applied to simulate future climate and regime types of which they may have no prior experience. Hence understanding the limitations of hydrological models when extrapolated beyond training conditions is essential when implementing a robust framework for assessing climate impacts. Using a modified version of the Differential Split Sample Testing (DSST) framework we examine the performance of six hydrological models (HBV, GR4J, AWBM, Tank, NAM, and HyMod) for 37 Irish catchments under climate conditions dissimilar to those used for model development. Additionally, we analyse four ensemble averaging techniques to similarly establish their performance when transferred between contrasting climate periods.

Differential testing was conducted using two/three-year non-continuous blocks of (i) the wettest/driest years based on total annual precipitation, and (ii) years with a more/less pronounced seasonal precipitation regime. Generally, HBV, GR4J and to a lesser degree NAM were consistently the best performing models, with GR4J (HBV) typically producing best results for catchments with a higher (lower) groundwater component. Transferability was observed to vary depending on the testing scenario, catchment and performance metric considered. As would be expected, the ensemble average performed better than most individual model-members. However, averaging techniques contrasted noticeably in the frequency with which they outperformed the best individual member. Bayesian Model Averaging (BMA) and the Granger-Ramanathan (GRA) method were found to perform better when compared to the Akaike Information Criteria Averaging (AICA) or simple arithmetic mean (SAM). In this case, GRA outperformed the best individual model in 51% to 86% of cases (based on the Nash-Sutcliffe criterion). When using hydrological models to inform climate impact and adaptation analyses we recommend (i) using DSST to identify the best available analogues of expected annual mean and seasonal climate conditions; (ii) avoiding reliance on a single criterion for model performance; (iii) establishing transferability based on a diverse set of catchments and; (iv) employing a multi-model ensemble alongside a well performing averaging technique. In this case, based on the lesser computational costs and comparable performance of GRA relative to BMA, the former is suggested as a suitable averaging technique for climate studies.