Trends in hydrological forecast skill in a changing climate

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Abstract: Changes to rainfall and potential evaporation have induced trends in soil moisture in many Australian catchments over the past several decades, for example reductions in soil moisture stores in much of southeast Australia (Wasko and Nathan 2019). This occurs despite observed increases in short-duration rainfall extremes, increases that are projected to continue. Streamflow forecasting systems may offer crucial assistance in managing streamflows in a changing climate. Increases in rainfall extremes and decreases in soil moisture are likely to have countervailing and complex impacts on streamflow predictability. Reduction in soil moisture gives the soil greater capacity to buffer rainfall events, in theory sending a greater proportion of precipitation through slow-flow pathways into streams. We hypothesise that decreases in soil moisture should lead to improvements in accuracy in streamflow forecasts over the long term.

We test this hypothesis by calibrating conceptual hydrological models at the daily timestep for the period 1982-2021 (the *study period*) on >400 catchments from the CAMELS-AUS v2 dataset (Fowler et al. 2025). We then generate synthetic observations for the study period by running these models with perfect forcings, warming up the model by running it from 1975 first. To test predictability, we generate streamflow forecasts for each day of the study period by warming up the models from 1975 using *ESP* (ensemble streamflow prediction) forcings. The ESP forcings are generated by sampling 10-day rainfall and potential evaporation sequences starting from each ordinal date (1-365) from each year in the period 1971-2021, under leave-one-year out cross-validation. This allows us to assemble a 50-member forcing ensemble, from which we generate an ensemble streamflow forecast with a 50-member ensemble to a lead time of 10 days. We then compute forecast errors with the average continuous ranked probability score (CRPS) for each year in the study period, compared to the synthesised observations. We convert this to a skill score (CRPSS) by comparing our forecasts to the performance of a 50-member climatological ensemble, sampled from streamflow under cross-validation. For each catchment, this gives us 40 data points of forecast skill, one for each calendar year of the study period. We then compute the trend in forecast skill using Sen's slope.

Trends in forecast skill vary substantially between catchments. We show that the median trend is positive for lead-times of 1-3 days. For the median catchment at lead 2 streamflow forecast skill is increasing at a rate of ~0.02% per year. We show also that positive trend in forecast skill is positively correlated with a negative trend in soil moisture. In summary, we cannot reject our hypothesis, at least in theory. Operational forecasting systems generally do not use calibration procedures like the one we have presented above. We therefore test a more operationally realistic calibration procedure: for each forecast issued, we calibrate the hydrological model for the 10 calendar years preceding the forecast (with a warmup of 5 years). This reverses trends in forecast skill.

When forecast errors are computed with respect to gauged (rather than synthesised) streamflow observations, a more complex picture arises, as the performance of the hydrological models with respect to observations changes through time. We discuss these complexities in our presentation.

REFERENCES

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