Using energy balance functions to constrain future climate runoff trajectories

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Abstract: Water balance formulas such as those proposed by Budyko (1963) and Zhang et al. (2001), describe the relationship between long-term average streamflow Q (mm yr^{-1}), potential evaporation E_0 (mm yr^{-1}), precipitation P (mm yr^{-1}) and evaporation E (mm yr^{-1}), where E is estimated as the residual of precipitation and specific streamflow:

$$E = P - Q$$

Change in catchment storage S is assumed to be zero or negligible as is inter-catchment groundwater exchange. The various water balance formulations typically have one or two parameters that allow the relationship to be fitted to long-term observations. These formulations have had widespread application, and are of interest for the prediction of streamflow in ungauged areas or to estimate streamflow in future climates. Similar approaches have proved successful for limited geographical extents (e.g. Croke and Norton, 2004).

Questions remain about the robustness of using water balance formulations derived from a database of studies encompassing a large geographical extent for projecting the streamflow trajectories of individual catchments as they experience a change in climate. To that end, this study utilises over 400, high quality, long-running stream gauges from a broad geographical and climatic range across the Australian continent. Catchment streamflow and climate data were aggregated into 5-year blocks and the 'Zhang curves' (Zhang et al. 2001) were fitted to the data where :

$$C = 1 - {(1 + w * A)}\Big/{(1 + w * A + A^{-1})}$$

Where C is the runoff coefficient $\left({Q}/{P}\right)$ and A is the catchment aridity $\left({E_0}/{P}\right)$ for each period. As an alternative to the Zhang function, linear regressions are fitted to the C and A data for each catchment and likelihoods are calculated for both models for each catchment.

Using a Bayesian model averaging approach, for most catchments, the linear model has a higher likelihood and weighting than the Zhang curve estimates. In most of those cases, the linear model predicts that the rate of decline in C with increasing A is higher than the Zhang curve prediction. Some interesting, regional and climatological patterns in the data and results are noted and discussed, as well as the prospect for using this method for constraining future climate streamflow projections.

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