Geophysical Research Abstracts
Vol. 20, EGU2018-12265, 2018
EGU General Assembly 2018

River catchments have long 'memories': evidence and implications for runoff projection under climate change

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Evidence suggests that catchment state variables such as groundwater can exhibit long 'memory'. This means their state may reflect not only recent climatic conditions, but also climatic conditions in past years or even decades. In contrast, rainfall runoff models are tuned to event and seasonal dynamics, and it is doubtful that simple 'bucket' models can replicate the long memory exhibited by some natural systems. In southern Australia, rainfall runoff models often perform poorly during droughts, casting doubt on their adequacy for climate change impact assessment. It is possible that this poor model performance may be associated with poor simulation of catchment memory.

This research aims to assess the ability of rainfall runoff models to replicate catchment memory. We compare interpolated observed groundwater levels across the state of Victoria, Australia ($2 \times 10\hat{}5$ km^2) against simulated water storage in selected locations from five commonly used rainfall runoff models. Results are confirmed and augmented by GRACE water storage estimates. Since conceptual models are not directly comparable with environmental state variables, a meaningful comparison is achieved via hydrologic signatures designed to quantify the memory in a timeseries. We investigate the spatial variability in catchment memory across the state, and the association between long memory and poor robustness of (a) hydrologic prediction by rainfall-runoff models; and (b) predictions from annual rainfall-runoff equations.

Finally, we discuss the implications of the results for the use of simple 'bucket' rainfall runoff models for hydrologic prediction in this region and other regions where similar hydrologic behaviour might be expected. We recommend further research to identify more suitable model structures for application under changing climatic conditions.