

Physical Basis for Randomness of Annual Flows in Ephemeral Streams

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Abstract Physical justifications for model selection presented by Salas and Smith (1981) are not justified in most streams in Australia at an annual scale. The reason is that the assumption of catchment storage carrying over from year to year is not valid, particularly in dryer regions. Hence, in the absence of significant contribution of catchment storage to streamflow (baseflow), the structure of annual streamflow will be similar to that of rainfall which in most cases can be represented by a white noise model such as an AR(0).

Introduction

Studies of the autoregressive structure of annual rainfall and runoff from numerous global weather stations confirm that both annual rainfall and runoff are well described by white noise (Peel *et al.* 2004; McMahon *et al.* 2005). This supports the failings of time series models of rainfall, groundwater and streamflow (Table 1) to detect any structure. The implications are that traditional models (Grayson *et al.* 1996) which rely on considering an AR(1) model for predicting annual streamflow and disaggregating the predicted annual flows to monthly values are not suitable for most of Australia's rivers. Hence, future hydrological models developed for hindcasting, intercasting and particularly forecasting will need to explore different methodologies for predicting streamflow. The following sections present a brief proof of the failings of the time series models and a short discussion on the implications and suggested future directions in research.

Table 1. Relationship between Rainfall and Groundwater Storage and Streamflow models (Salas and Smith 1981)

Rainfall	Groundwater	Streamflow
White noise	AR(1)	ARMA(1,1)
AR(1)	AR(2)	ARMA(2,1)
ARMA(1,1)	ARMA(2,1)	ARMA(2,2)
MA(1)	ARMA(1,1)	ARMA(1,2)

Proof

$$z_t = cS_{t-1} + dx_t \quad (1)$$

z_t Streamflow at time t

cS_{t-1} Groundwater contribution to streamflow

$$dx_t = x_t - ax_t - bx_t$$

x_t Rainfall

ax_t Infiltration

bx_t Evapotranspiration

$$0 \leq a, b, c, d \leq 1, 0 \leq a + b \leq 1$$

If there is no contribution of groundwater to streamflow, $cS_{t-1} = 0$ then

$$z_t = dx_t \quad (2)$$

Hence, from equation 2 it is expected that annual streamflow is a function of annual rainfall x_t , infiltration ax_t and evapotranspiration bx_t in the absence of slow flow (Figure 1) and that the autocorrelation structure of both data sets is similar in that both are representative of white noise (Figure 2).

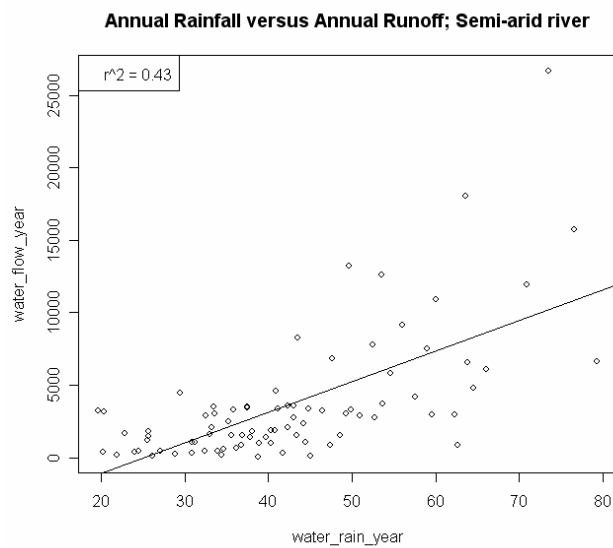


Figure 1. Annual rainfall-runoff plot for an arbitrary Australian river comparing respective water years beginning in August for Rainfall and September for Runoff.

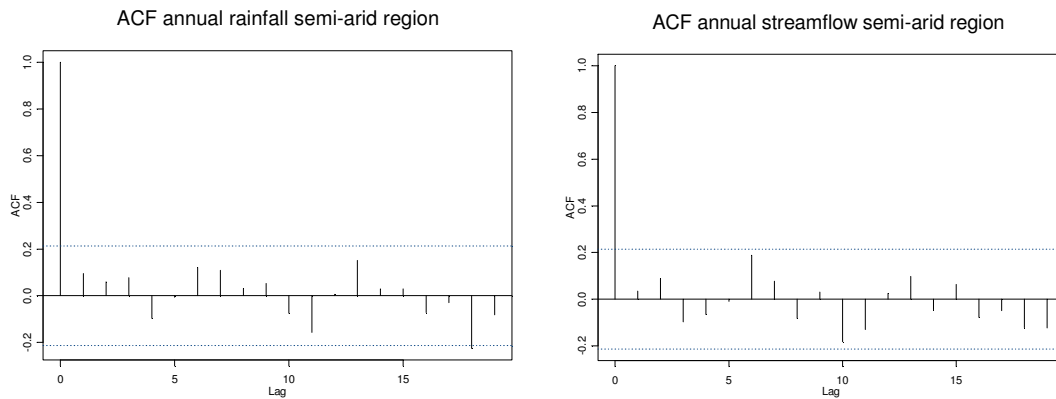


Figure 1. ACF plots for annual rainfall and runoff for a semi arid river system both showing white noise structure.

Discussion

The failure of the AR class models to adequately describe streamflow beyond a random process essentially invalidates the use of these models particularly when considering forecasts. It is our suggestion that modelling should focus more on the switching regime of flow (dry and wet) at different time scales. This approach is more suited to the extreme dynamics of Australian hydrological regime. Moreover, it can be shown that the properties of switching states exhibit structure in time. An example of such an approach is the use of a two-state Markov chain where transition probabilities are based on the probability of transiting from a dry regime to a wet regime and visa versa (Aksoy 2003). This is currently the subject of an ongoing research project.

References

- Aksoy H (2003) Markov chain-based modeling techniques for stochastic generation of daily intermittent streamflows *Advances in Water Resources* **26**, 663-671.
- Grayson RB, Argent RM, Nathan RJ, McMahon TA, Mein RG (1996) 'Hydrological Recipes: Estimation techniques in Australian Hydrology.' Cooperative Research Centre for Catchment Hydrology, Clayton. Available
- McMahon TA, Murphy R, Little P, Costelloe JF, Peel MC, Chiew FHS, Hayes S, Nathan R, Kandel DD (2005) 'Hydrology of Lake Eyre Basin.' Department of Environment and Heritage, Australian Capital Territory. Available
- Peel MC, Pegram GGS, McMahon TA (2004) Global analysis of runs of annual precipitation and runoff equal to or below the median: run length. *International Journal of Climatology* **24**, 807-822.
- Salas JD, Smith RA (1981) Physical basis of stochastic models of annual flows. *Water Resources Research* **17**, 428-430.