The Application of Time Series Techniques to Groundwater Level and Climate Relationships

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Introduction:

The response of the groundwater table (GWT) to climate variability depends on a complex combination of geology, topography, vegetation, soil type and moisture status. To predict future behaviour of the GWT with respect to climate, it is important to analyse historical GWT and climate data. The primary driver for groundwater recharge or changes in the GWT is the net flux – or the difference between rainfall and actual evapotranspiration (ET).

For this project, a number of methods have been utilised for estimating the correlation between the net flux and groundwater recharge. Traditional statistical techniques produced poor correlations, and hence time series techniques were adopted for more realistic representation of the ongoing hydrologic processes (Berendrecht 2004) . A class of time series models called transfer function-noise (TFN) models have become popular for describing dynamic causal relationships between time series. The TFN model is a combination of stochastic and deterministic components.

This paper will summarise the results to date in the application of time series techniques to understanding groundwater and climate variability towards formulating the stochastic part of the intended TFN model. The study site is the Ranger uranium project, surrounded by Kakadu National Park, Northern Territory.

Methodology:

We have existing data on rainfall and ET from nearby weather station Jabiru, and GWT elevations in the surrounding bores for 1980 to 2005. The times series techniques applied in this research consists of estimation of auto correlation function (ACF), partial auto correlation function (PACF), cross correlation function (CCF), seasonality and trend components, auto regressive moving average (ARMA) models and prediction by ARMA model (Brockwell and Davis 2002).

To undertake a robust statistical technique for analysing the hydrologic data, which relates to time series process, such as rainfall, ET, stream flow runoff, groundwater recharge, time series analyses have been employed in the study. The estimation of ACF is used to identify seasonality in climate and GWT data. The CCF assesses the statistically significant time lag between the responses (GWT) and cause (climate) which has been utilised in a companion conference paper to (Kabir et al. 2006). Classical decomposition technique is used to identify the seasonal component of the GWT elevation. The trend component has been calculated and was found to be approximately quadratic (concave) with a minimum caused by dry period between 1987-1991.

The wide range of variation of the annual maximus and minimus is handled with the incorporation of suitable ARMA models. Separation of seasonality from the non-stationary data has been done by using monthly data of climate and GWT for 20 to 25 years duration. The residuals have been checked for randomness and after that the values of ACF and PACF have been used in the preliminary estimation of the orders (*p*, *q*) of suitable ARMA model. The respective estimated ARMA models have been used for the prediction of future values of climate flux and GWT of the bores with specified prediction bounds (Figure 2).

Result:

The ACF of climate fluxes and GWT of the selected bores showed the seasonality with a cycle of 12 months. The cross correlation between monthly flux and corresponding change in GWT for the bores showed that up to a maximum lag of two month was statistically significant to influence current months GWT (Figure 1). By comparing the unsaturated thickness of the selected bores, it was found that the lag was more with the bores that had greater thickness of unsaturated soil. The bores analysed result a maximum of two month and minimum of one-month lag to be significant.

An ARMA model forecast of the GWT for bore OB27 is given in Figure 2. This predicted range is within previous GWT fluctuations, and future research is planned to utilise unsaturated flow models for more rigorous modelling of moisture movement.

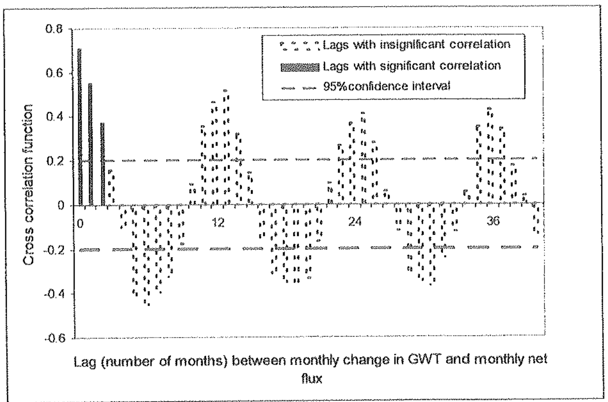

Figure 1 CCF for monthly change in GWT as response to monthly net flux for bore OB27 for 1981 to 1988

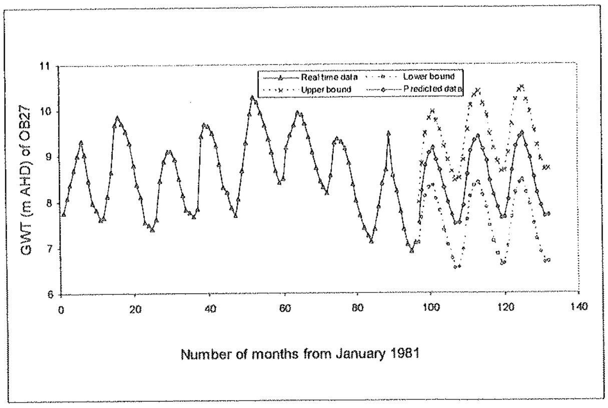

Figure 2 ARMA forecast for GWT of OB27 with 95% prediction bounds, real time data for 1981 to1988

Conclusion:

The ability to predict the future behaviour of the GWT with respect to climate is important. To date, applying univariate time series statistical techniques has shown good results in auto-correlating key variables. In future, multi-variate time series techniques are planned to be investigated. The outputs from these statistical analyses are useful in quantifying past relationships as a basis to undertake more deterministic modelling of the hydrologic cycle of climate, soils and groundwater recharge.

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