South Eastern Australian
Climate initiative

Final report for Project #3.1.1

Statistical Seasonal Streamflow Forecasting Model

Principal Investigator: Francis Chiew

Contact details: (02) 62465717, francis.chiew@csiro.au

Co-Authors: QJ Wang, David Robertson

Contact details: qj.wang@csiro.au, david.robertson@csiro.au

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Abstract

This project developed a joint probability approach for seasonal forecasting of streamflows at multiple sites. The approach forecasts future streamflows from antecedent streamflows and seasonal climate indices, including SOI and ENSO. The joint probability approach quantifies uncertainty and maximises the information extracted from available data, allowing the use of records with non-concurrent and missing data. Cross validation results show that the approach produces forecasts of spring streamflows for the Murrumbidgee catchment with reasonable skill using only antecedent flows and SOI as predictors. Research into the best seasonal climate indices forecasting streamflows at different forecast lead times and at locations throughout the Murray Darling Basin will continue in Project 3.2.1

Significant research highlights, breakthroughs and snapshots

- A statistical multi-site seasonal streamflow forecasting model was developed. The model is a significant improvement over existing statistical models – it is a multi-site model, it works with non-concurrent data and it facilitates the transfer of learning acquired from regional applications.
- The model was successfully tested using multi-site streamflow data from the Murrumbidgee catchment.
- A conference paper describing the model and application to the Murrumbidgee catchment will be presented at the Hydrology and Water Resources Symposium in Adelaide in April 2008.
- A draft journal describing the model, its application to the Murrumbidgee catchment and analysis of its forecasting ability has been prepared.

Statement of results, their interpretation, and practical significance against each objective

Objective 1: *To assess and further develop statistical seasonal streamflow forecasting model for forecasting reservoir inflows across the MDB.*

The relationship between El Niño/Southern Oscillation (ENSO) and climate is the scientific basis of seasonal climate forecasts provided by research institutions and meteorological agencies throughout the world (e.g., www.bom.gov.au/climate/ahead). The correlation between Australia's hydroclimate and ENSO is amongst the strongest in the world (Chiew and McMahon, 2002). The relationship between streamflow and ENSO, and the serial correlation in streamflow, can be exploited to forecast streamflow several months/seasons ahead. The forecast can be used to help manage water resources systems, and allow decisions on irrigation water allocations and environmental flows to be more realistically based (Chiew et al., 2003).

To make risk-based decisions on activities that rely on water resources systems, a probabilistic streamflow forecast is required. Several probabilistic seasonal streamflow forecast models have been developed in Australia (e.g., Sharma, 2000; Piechota et al., 2001; and Chiew and Siriwardena, 2005). These models are generally

based on non-parametric approaches and developed for single-site, although Sharma et al. (2006) extended the model for forecasting streamflow at multiple sites.

This project developed and tested a parametric joint probability approach for seasonal forecasting of streamflows at multiple sites. A Box-Cox transformed multivariate normal distribution is used to model the joint distribution of future streamflows, ENSO signals and antecedent streamflows. A Bayesian inference of model parameters and uncertainties is implemented using Markov Chain Monte Carlo (MCMC) simulations. The approach provides probabilistic forecasts of streamflows at multiple sites, which can be used to drive river system models to provide probabilistic indications of water availability and water allocation several months ahead. The approach was implemented and successfully tested on the Murrumbidgee catchment. The cross-validation results show that the approach can forecast streamflows several months ahead with reasonable skill (relatively high LEPS skill scores and Nash-Sutcliffe model efficiencies) and maintains the cross-site correlations.

The advantages of this approach are: it models inter-site correlations for forecasting streamflows at multiple sites (important for river system applications); it quantifies the uncertainty of a forecast in terms of a well defined probability distribution; it maximises the extraction of information from available data without the need to discard non-concurrent data or infill missing data; and it provides a parametric structure for quantifying relationships between variables and therefore facilitates the transfer of learning acquired from regional applications.

This project therefore directly addresses the first research question in Theme 3, by developing an improved statistical multi-site seasonal forecasting model and demonstrating that multi-site streamflows can be forecast with reasonable skill several months/seasons ahead.

Summary of links to other projects

The improved statistical multi-site seasonal forecasting model developed in this project can be used in other projects in Theme 3 and elsewhere.

This project is very closely related to Project 3.2.1/3.2.5. Project 3.2.1/3.2.5 will further test the approach developed here using a larger data set and incorporate advantageous features of this statistical approach and outputs from climate models (dynamic modelling approach) to improve seasonal streamflow forecasting.

Publications arising from this project

Wang QJ, Chiew FHS and Roberson DE (2008) A joint probability approach for seasonal forecasting of streamflows at multiple sites. Proceedings of the 31st Hydrology and Water Resources Symposium (Water Down Under 2008), Adelaide, April 2008, Engineers Australia.

Wang QJ, Robertson DE and Chiew FHS (2008) Development and testing of a multi-site seasonal streamflow forecasting model. In Preparation.

Chiew FHS, Wang QJ and Robertson DE (2008) SEACI Project 3.1.1: Statistical seasonal streamflow forecasting model. SEACI Final Report.

Acknowledgement

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References

Chiew FHS and McMahon TA (2002) Global ENSO-streamflow teleconnection, streamflow forecasting and interannual variability. Hydrological Sciences Journal, 47, 505-522.

Chiew FHS, Zhou SL and McMahon TA (2003) Use of seasonal streamflow forecasts in water resources management. Journal of Hydrology, 270, 135-144.

Chiew FHS and Siriwardena LW (2005) Probabilistic seasonal streamflow forecasting methods. Proceedings of the 29th Hydrology and Water Resources Symposium, Canberra, Australia, February 2005, Engineers Australia, CDROM (ISBN 085-825-8439).

Piechota TC, Chiew FHS, Dracup JA and McMahon TA (2001) Development of an exceedance probability streamflow forecast. ASCE Journal of Hydrologic Engineering, 6, 20-28.

Sharma A (2000) Seasonal to interannual rainfall probabilistic forecasts for improved water supply management: Part 3 - A nonparametric probabilistic forecast model. Journal of Hydrology, 239, 249-258.

Sharma A, Ling F, Murray R, Stolp S and Allison J (2006) Multiple reservoir probabilistic inflow forecasting system: Application to the Hydro-Tasmania reservoir network. Proceedings of the 30th Hydrology and Water Resources Symposium, Launceston, Australia, December 2006, Engineers Australia, CSDOM (ISBN 0-8582579-0-4).

Project Milestone Reporting Table

To be completed prior to commencing the project				Completed at each Milestone date	
Milestone description[1] (brief) (up to 33% of project activity)	Performance indicators[2] (1- 3 dot points)	Completion date[3] xx/xx/xxxx	Budget[4] for Milestone ($)(SEACI contribution)	Progress[5] (1- 3 dot points)	Recommended changes to workplan[6] (1- 3 dot points)

1. Application of NSFM to forecast reservoir inflows across the MDB	NSFM model set-up for forecasting reservoir inflows at key locations across the MDB	31/8/2007	20k	(1) Streamflow data collated for over 200 catchments in SEACI region and a range of ENSO indices prepared. (2) NSFM applied to the above data. (3) Predictors previously not used but suggested by other researchers are being investigated. (4) A parametric joint probability approach was developed for both single and multiple site applications.	
2. Assessment and further development of statistical seasonal streamflow forecasting model for forecasting reservoir inflows across the MDB	Statistical model for forecasting reservoir inflows across the MDB and report on model development and testing	31/12/2007	30k	(1) A parametric joint probability model for seasonal forecasting of streamflows at multi-sites was developed and successfully tested. (2) A conference paper describing the method was written. (3) A draft journal paper on the application of the method and SEACI final report have been prepared.	