For further information please contact:

Assoc Prof Francis Chiew
CRC for Catchment Hydrology
Department of Civil &
Environmental Engineering
The University of Melbourne
Vic 3010 Australia
fhsc@unimelb.edu.au

Climate Variability

Project 5.1: Modelling and Forecasting Hydroclimate Variables in Space and Time

Project Leader: Assoc Prof Francis Chiew (The University of Melbourne)

Background

The considerable variation of rainfall and runoff from year to year is part of the natural variability in the climate system. The management of land and water resources involves designing and operating to cope with this variability. The management challenges in Australia are compounded by Australian streamflow (and to a lesser extent climate) that is much more variable than elsewhere in the world.

The mission of the CRC for Catchment Hydrology is to deliver to resource managers the capability to assess the hydrologic impact of land-use and water management decisions at whole-of-catchment scale. Climate is a key driver in models developed by the CRC and other groups. The goal of the Climate Variability Program is to improve our ability to quantify climate variability by developing tools that can be used with hydrological and ecological models to quantify uncertainty in environmental systems associated with climate variability.

There are two research areas in the Climate Variability Program. The aim of the first research area is to improve models for forecasting rainfall and streamflow for various lead times. The aim of the second research area is to develop and test stochastic climate data generation models.

Project objective

The objective of this project was to carry out research studies to improve models for forecasting rainfall and streamflow for various lead times. The research studies completed as part of this project are described here under three headings:

- Rainfall Nowcasting (forecasting rainfall out to a lead time of six hours);
- Land Surface Modelling in Numerical Weather Prediction Models (land surface modelling and field monitoring studies to improve numerical weather prediction model forecasts out to a lead time of several days);
- Seasonal Streamflow Forecasting (forecasting streamflow and climate variables out to a lead time of several months).

COOPERATIVE RESEARCH CENTRE FOR CATCHMENT HYDROLOGY

Published June 2004

Completed Projects
1999-2002

Project 5.1:
Modelling and Forecasting Hydroclimate Variables in Space and Time

Rainfall Nowcasting

Rainfall forecasts out to a lead time of six hours and more are required for a range of applications, particularly hydrological forecasting for flood warning. These applications require quantitative rainfall forecasts as well as an estimation of the error bounds surrounding the forecast so that they can be used to estimate the risk within the particular application. For example, flood warning managers require the probability that a critical threshold in a river level will be exceeded in the forecast period.

The project developed S_PROG, a stochastic nowcasting model, which can successfully forecast rainfall one or two hours ahead (see Figure 1). S_PROG is essentially an advection type nowcasting model where the motion of the rain field (a two-dimensional grid of rainfall intensities measured by a radar) is estimated and used to predict the location of the raining areas into the future. The lifetime of a storm is a function of the size of the storm; large systems live longer than small systems. S_PROG exploits this by estimating the lifetime of systems observed in the rain field in real-time and then systematically smoothing the forecast field as the lead time increases so as to represent the loss of information as the rain field evolves in time.

S_PROG has been tested in Australia, New Zealand, the United Kingdom and Spain, and was the simplest and one of the best performers amongst rainfall nowcasting models tested during the Sydney Olympics in 2000. The Australian Bureau of Meteorology is developing an operational radar data processing and nowcasting system based on S_PROG to generate rainfall nowcasts at each of the 50 radars in the Australian radar network.

Research effort currently underway in the CRC (2003-2006) in collaboration with the U.K. Met Office is concentrating on developing a joint stochastic forecasting engine that combines the stochastic nowcasting of S_PROG with deterministic rainfall forecasts from numerical weather prediction models to give stochastic rainfall forecasts with longer lead times (out to six hours or more).

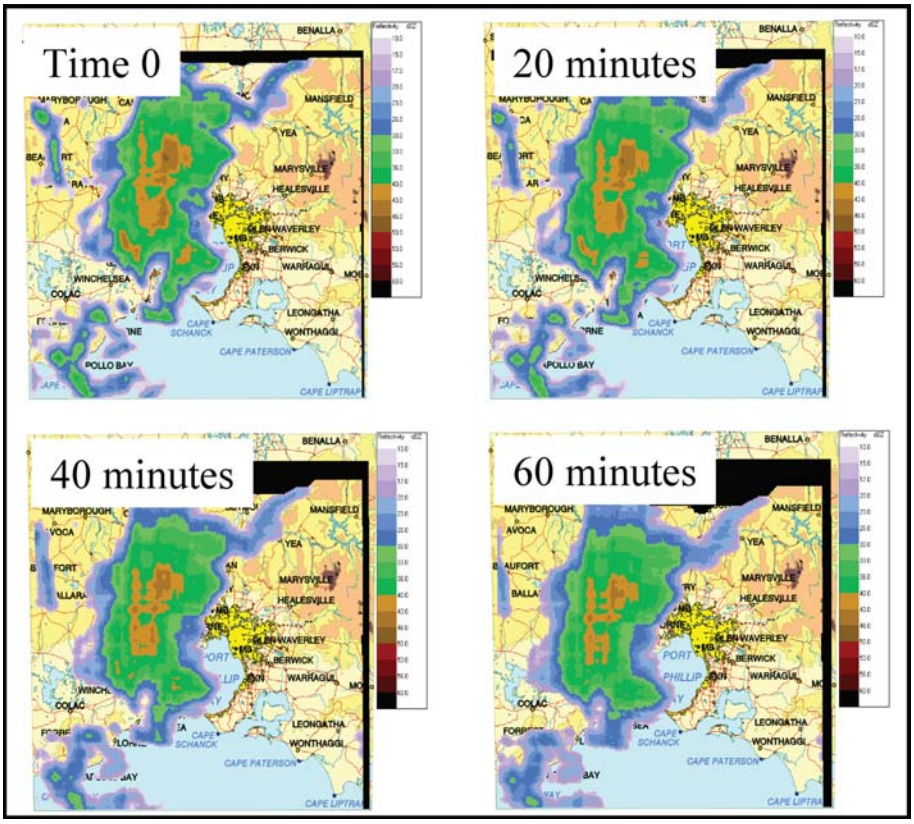

Figure 1: Example deterministic nowcast of Melbourne rainfall (16:00 21 Apr 2001) out to 60 minutes.

COOPERATIVE RESEARCH CENTRE FOR CATCHMENT HYDROLOGY

Project 5.1:
Modelling and Forecasting Hydroclimate Variables in Space and Time

For further information:

Seed, A.W. (2003) A dynamic and spatial scale approach to advection forecasting. Journal of Applied Meteorology, 42: 381-388.

Land Surface Modelling in Numerical Weather Prediction Models

The aims of this research were to improve the land surface modelling and the initialisation of soil moisture in numerical weather prediction (NWP) models. These improvements should lead to better weather forecasts by the Bureau of Meteorology's NWP models out to several days.

As part of this research, an extensive soil moisture monitoring network was established across the Murrumbidgee River Basin (see Figure 2). This research is part of the Murray-Darling Basin Continental Scale Experiment (MBD CSE) in GEWEX (Global Energy and Water Cycle Experiment; see www.gewex.org), and the data sets compiled have also been used in other international studies. The data sets include: forcing data for ten locations at 30-minute time steps from January 2000 (rainfall, temperature, specific humidity, shortwave radiation, longwave radiation, wind speed), 30-minute soil moisture data and 6-minute soil temperature data over four depths at 18 locations from October 2001, and daily streamflow data for over 20 unimpaired catchments (these data will available as a data product from the Catchment Modelling Toolkit at www.toolkit.net.au before December 2004); and national spatial data set of soil properties, land cover and vegetation (available now as a data product from the Catchment Modelling Toolkit at www.toolkit.net.au).

Results from the modelling studies indicate that the land surface scheme (VB95) used in the Bureau of Meteorology's NWP models can simulate realistically the temporal fluctuations in soil moisture, and therefore the surface moisture fluxes. However, the model exhibits a significant (generally wet) bias in the absolute soil moisture, and the use of the best Australia-wide soils and vegetation information did not improve VB95 simulations consistently. The soil moisture bias could be largely eliminated by using soil parameters derived directly from soil moisture observations, but such parameters are only available at very few point locations. The results also indicate that the modelling of runoff processes is important in determining long-term evapotranspiration and evapotranspiration following infiltration events, but modelling of runoff is probably the weakest component of land surface models.

Current research efforts (2003-2006) are concentrating on improving the runoff modelling in VB95, improving the initialisation of soil moisture, assessing NWP simulations over irrigation areas, forecasting potential evapotranspiration from NWP climate forecasts for irrigation water management, and generalisation of parameters in a simple rainfall-runoff model for runoff estimation in ungauged catchments.

For further information:

Richter, H., Western, A.W. and Chiew, F.H.S. (2004) The effect of soil and vegetation parameters in the ECMWF land surface scheme. Journal of Hydrometeorology, In Press.

Richter, H., Western, A.W. and Chiew, F.H.S. (2003) Comparisons of soil moisture simulations from the VB95 land surface model against observations. Proceedings of the International Congress on Modelling and Simulation (MODSIM 2003), Townsville, July 2003, Volume 1, pp. 160-165.

Siriwardena, L., Chiew, F.H.S., Richter, H. and Western, A.W. (2003) Preparation of a Climate Data Set for the Murrumbidgee River Catchment for Land Surface Modelling Experiments. Cooperative Research Centre for Catchment Hydrology, Working Document 03/1, 50 pp.

Project 5.1:
Modelling and Forecasting Hydroclimate Variables in Space and Time

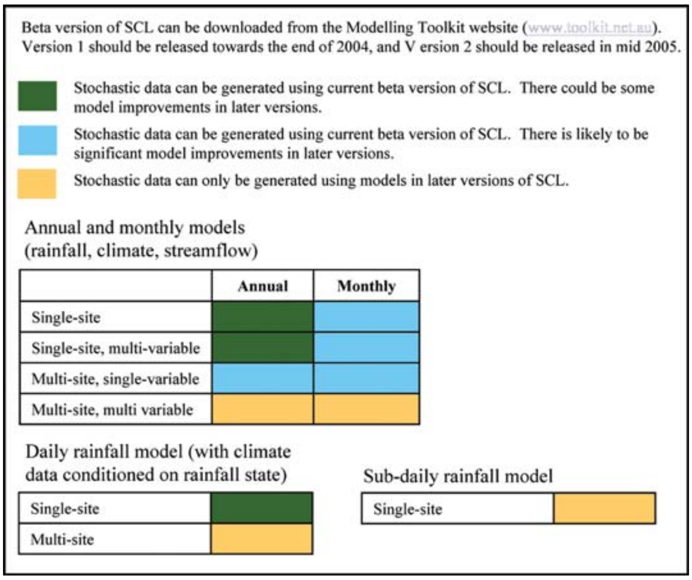

Figure 2: Soil moisture monitoring in Murrumbidgee River focus catchment Monitoring at 18 sites (b) Setup for monitoring rainfall, and soil moisture, temperature and suction over four depths (c) Transect measurements to describe the spatial representativeness of the point soil measurements.

Seasonal Streamflow Forecasting

The teleconnection between Australia's hydroclimate and El Niño/Southern Oscillation (ENSO) is amongst the strongest in the world. The lag streamflow-ENSO relationship and the serial correlation in streamflow can be exploited to forecast streamflow several months ahead. The use of seasonal streamflow forecast can benefit the management of land and water resources. For example, seasonal streamflow forecast could allow water managers to make more realistic decisions on water allocation for competing users, and forecast of variables like water allocation, streamflow volume and number of pumping days would help farmers make better informed risk-based decisions for farm and crop management.

This project has developed and tested a non-parametric seasonal forecast model (NSFM) that forecasts continuous exceedance probabilities of streamflow (or any other variable) (see Figure 3). NSFM uses linear discriminant analysis to empirically fit the data, without making any prior assumption of the model structure. The basic data required to develop each model is a historical time series of the streamflow to be forecast and the explanatory variables.

Several water agencies are starting to use seasonal inflow forecast as input into water system model to provide probabilistic indication of irrigation allocation further into the irrigation season.

Completed Projects
1999-2002

Project 5.1:
Modelling and Forecasting Hydroclimate Variables in Space and Time

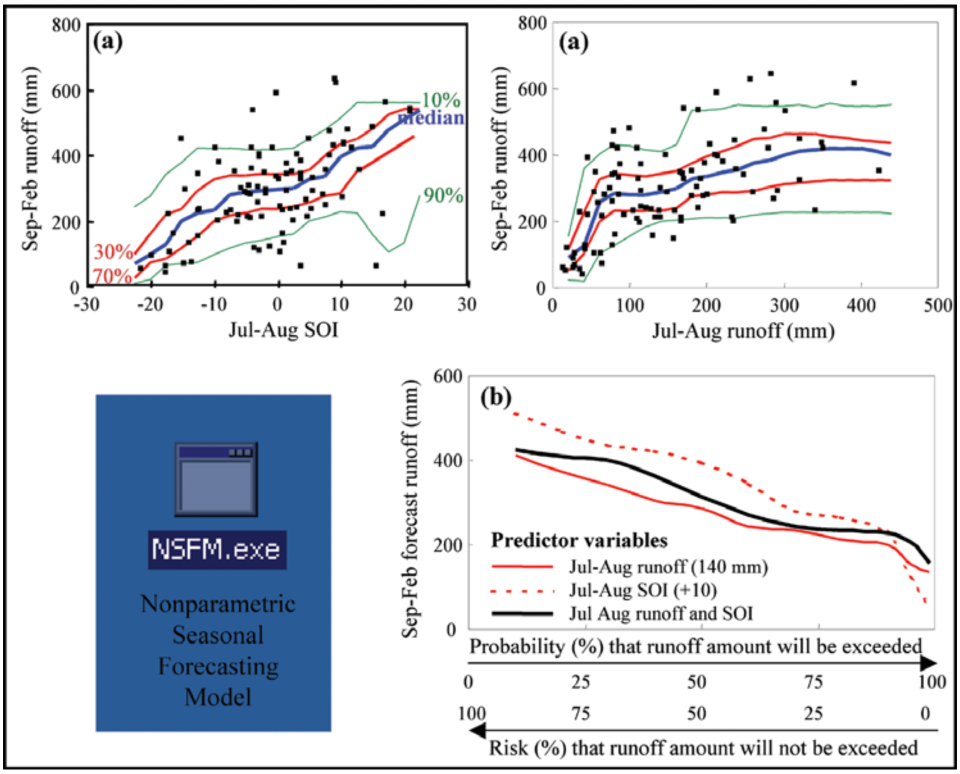

Figure 3: Forecasting continuous exceedance probabilities of streamflow for use in land and water resources management (a) Sep-Feb runoff versus Jul-Aug SOI and versus Jul-Aug runoff at Nariel River catchment (south-east Australia) and NSFM 10%, 30%, 50%, 70% and 90% fits to the data (b) Example forecast for Sep-Feb runoff for forecasts based on antecedent runoff alone, SOI alone and both antecedent runoff and SOI (for Jul-Aug runoff = 140 mm and Jul-Aug SOI = +10).

For further information:

Chiew, F.H.S. (2003) Climate variability, seasonal streamflow forecast and water resources management. Climate Impacts on Australia's Natural Resources: Current and Future Challenges, Surfers Paradise, November 2003, pp. 21-23.

Chiew, F.H.S. and McMahon, T.A. (2002) Global ENSO-streamflow teleconnection, streamflow forecasting and interannual variability. Hydrological Sciences Journal, 47: 505-522.

Chiew, F.H.S., Zhou, S.L. and McMahon, T.A. (2003) Use of seasonal streamflow forecasts in water resources management. Journal of Hydrology, 270: 135-144.

Acknowledgements

Project 5.1 Researchers:

Francis Chiew, Tom McMahon, Graham Mills, Harald Richter, Alan Seed, Lionel Siriwardena, Andrew Western, Rodger Young

Project 5.1 Reviewers:

Trevor Daniels, Jetse Kalma, Rory Nathan

COOPERATIVE RESEARCH CENTRE FOR
CATCHMENT HYDROLOGY