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Predicting Catchment Behaviour

Project 1.2: Scaling Procedures to Support Process-Based Modelling at Large Scales

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Introduction

While the definitions of scale and scaling are wide and varied, this project was concerned with how best to represent processes (and their variability) known to occur at the point scale, in large-scale catchment models. The difficulty in transferring small-scale process algorithms to large-scale elements is a fundamental restriction to the 'whole-of-catchment' modelling that lies at the heart of the CRC for Catchment Hydrology mission. This difficulty comes from two inter-related sources: small-scale spatial and temporal variability, and the limited length and time scales associated with what are generally non-linear runoff and contaminant processes.

Research focus

A common approach to up-scaling in catchment-scale models is to assume uniform conditions within an element or timestep – i.e. that the processes and their variability can somehow be represented by single 'effective' values. This project set out to address problems with this approach by developing parameterisations for sub-element and sub-timestep variability that reproduce the impacts of that variability in a tractable manner for large scale, long term modelling. This was achieved through the development of functions that represent the distribution of the variable (in either space or time) and process algorithms that can utilise these functions (i.e. that can account for the non-linearities of the responses being modelled). Applications of these approaches within CRC for Catchment Hydrology projects include land surface representation methods in the Climate Variability Program and large-scale yield modelling in the Land-use Impacts on Rivers Program. The methodologies developed in this project are applicable to other modelling exercises and are being incorporated where appropriate within the Catchment Modelling Toolkit.

Key outcomes

The key outcomes from this research fall into a number of categories:

Outcomes Related to Soil Moisture

- Collation and analysis of spatial soil moisture data sets for 'probability density function' (pdf) properties – seven Australian catchments and six international catchments were analysed. This included relating variance and skewness to wetness and recommending a best fit pdf model for spatial soil moisture distributions, and resulted in a data set that has no international precedent.

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- Two international reviews of soil moisture and soil moisture scaling.
- Work on the use of pedo-transfer approaches for soil water storage estimation at large scales

Modelling Developments

- Development of a method for generating spatio-temporal patterns of soil moisture based on combining features of deterministic patterns (from terrain analysis or soils or vegetation maps) using weightings that are dependent on catchment average moisture state. The concepts that underlie the work have general application outside the realm of the CRC.
- Testing of methods for comparing simulated and observed spatial patterns in models. Software was produced to undertake pattern comparisons using a number of environments. These routines are being rewritten and enhanced in the software development framework TIME (The Invisible Modelling Environment – see www.toolkit.net.au/time) to become part of the Toolkit, and will form the basis of a terrain analysis library with features and functions previously unavailable to the research community.
- Development of a method to provide sub-grid patterns of depth to water table and surface discharge of groundwater for use in models using coarse computational elements. The work was specifically used with the FLOWTUBE model, and offers a method for improving the application of this model across salt affected areas of Australia.
- Advances in distributed modelling and terrain analysis including assessing the need for spatial details of rainfall patterns in modelling, development of sub-grid algorithms for runoff generation, computation of the Quasi-dynamic wetness index that overcomes computational problems with multiple flow direction algorithms often applied to gridded Digital Elevation Models (DEMs), and development of the Multi-Resolution Valley Bottom Flatness index (MRVBF).
- Methods for sub-time step representation of precipitation characteristics for application in runoff and erosion modelling.
- An extensive numerical simulation experiment was also undertaken, based on the Kyeamba Creek catchment and the Murrumbidgee basin in New South Wales. The intention was to document the effects of different methods and scales for representing variability in soils, vegetation and precipitation. The outcomes are used to provide advice on these methods: when to use what method depending on the question being asked and model type being used and also to indicate the relative sensitivities of these methods to variability in soils, vegetation and precipitation. This has direct application in the improved model selection for whole-of-catchment prediction, and is being completed in the CRC's Climate Variability research Program's activities (2003-2006).

Contributions to the Catchment Modelling Toolkit

- Pattern comparison software
- Generation routines for patterns
- Enhanced terrain analysis including terrain and moisture metrics such as the QDWI, MRVBF, and LOWNESS
- Several sub-grid variability approaches that will be incorporated into other modelling.

Outputs

The international profile and credibility of this work has been highlighted through a wide range of research communication and adoption pathways. In addition to production of a text book, the significant contribution of the CRC for Catchment Hydrology in this area has been reflected in seven book chapters, at least twelve papers in journals that include Water Resources Research, the Journal of Hydrology and Hydrological Processes, and over ten conference publications.

Primary authors of this work to contact for further details are Grayson, R.B., Western, A.W, Kandel, D.D., Chirico, G.B., and Wilson, D.J. (keyword search: Scaling, Soil Moisture, Pattern Comparison).

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References for further information

Blöschl, G. and Grayson, R.B., 2000. Spatial observations and interpolation. Chapter 2 in Spatial Patterns in Catchment Hydrology: Observations and Modelling. Cambridge University Press. Pp17-50.

Chirico, G.B., Grayson R.B. and A.W. Western, 2003. A downward approach to identifying the structure and parameters of a process based model for a small experimental catchment, Hydrological Processes,. Volume 17, Issue 11: 2239-2258

Chirico, G.B., Grayson R.B. and A.W. Western, 2003. On the computation of the quasi-dynamic wetness index with multiple-flow-direction algorithms. Water Resources Research VOL. 39, NO. 5, 1115, doi:10.1029/2002WR001754, 2003

Chirico, G.B., Grayson, R.B., Longobardi, A., Villani, P. and Western, A.W., 2001. Shallow landslide hazard mapping based on a quasi-dynamic wetness index, Modsim 2001, Canberra, Australia, 10-13 December 2001.

Chirico,G., B., Grayson, R.B.,Western, A.W., Woods, R., Seed, A. 2001. Sensitivity of Simulated Catchment Response to the Spatial Resolution of Rainfall. International Conference on Modelling and Simulation, Modsim 2001, Canberra, Australia, 10-13 December 2001.

Gallant J. C., T. I. Dowling, A multiresolution index of valley bottom flatness for mapping depositional areas, Water Resour. Res., 39 (12), 1347, doi:10.1029/2002WR001426, 2003.

Grayson, R.B. and Blöschl, G. 2000. Summary of pattern comparison and concluding remarks. Chapter 14 in Spatial Patterns in Catchment Hydrology: Observations and Modelling. Cambridge University Press.pp 355-367.

Grayson, R.B. and Blöschl, G., 2000. Spatial modelling of catchment dynamics. Chapter 3 in Spatial Patterns in Catchment Hydrology: Observations and Modelling. Cambridge University Press. pp. 51-81.

Grayson, R.B. and Blöschl, G., 2000. Spatial processes, organisation and patterns. Chapter 1 in Spatial Patterns in Catchment Hydrology: Observations and Modelling. Cambridge University Press. pp 3-16.

Grayson, R.B. and G. Blöschl, 2000. Spatial Patterns in Catchment Hydrology: Observations and Modelling. Cambridge University Press. 404p

Grayson, R.B., G. Blöschl, A.W. Western, and T.A. McMahon, 2002. Advances in the use of observed spatial patterns of catchment hydrological response. Advances in Water Resources 25th Anniversary Issue (invited paper) 1313-1334

Kandel, D.D., Grayson, R.B., Western, A.W.and H.N. Turral, 2002. Surface runoff modelling: Part 1. Testing at fine timescale for Scaling up to Daily scale. Hydrology and Water Resources Symposium, July, 2002.

Kandel, D.D., Grayson, R.B., Western, A.W.and H.N. Turral, 2002. Process time scale Using Plot Scale Data from a Mid-hill Catchment of Nepal., Hydrology and Water Resources Symposium, July, 2002.

Kandel, D.D., Western, A.W., Grayson, R.B., Turral, H.N., 2001. Testing physically based soil erosion models at two-minute and daily time-steps against plot scale data from a mid-hill catchment of Nepal. International Conference on Modelling and Simulation, Modsim 2001, Canberra, Australia, 10-13 December 2001.

Kandel, D.D., Western, A.W.and R.B. Grayson, 2003., A scaling approach to capture sub-time-step rainfall variability in rainfall-runoff and erosion modelling. Submitted to MODSIM 2003

Kandel, DD., Western, A.W., Grayson, R.B., and H.N. Turral, in press. Process parameterisation and temporal scaling in surface runoff and erosion modelling, Hydrological Processes.

Ladson, A., Lander, J., Western A.W., Grayson, R. B. and L. Zhang, 2002. Estimating Extractable Soil Moisture Content for Australian Soils. 27th Hydrology and Water Resources Symposium. IE Aust, Melbourne, Australia, July, 2002.

Petheram C, Dawes W, Grayson R.B., Bradford A, Walker G., 2003. A sub-grid representation of groundwater discharge using a 1-D groundwater model. Hydrological Processes in press. Volume 17, Issue 11: 2279-2295

Thierfelder, T.K., Grayson, R.B., von Rosen, D. and Western, A.W, 2003. Statistical inference for the location of Catchment Characteristic Soil Moisture Monitoring sites I. covariance structures in the Temporal Domain. J. of Hydrology. Vol 280, Nos 1-4, pp 13-32

Western A.W. and Grayson, R.B., 2000. Soil moisture and runoff processes at Tarrawarra. Chapter 9 in Spatial Patterns in Catchment Hydrology: Observations and Modelling. Cambridge University Press. pp. 209-246.

Western, A.W., Blöschl, G., R.B. Grayson. 2001. Towards capturing hydrologically significant connectivity in spatial patterns. Water Resources Research. 37(1) 83-97.

Western, A.W., Grayson, R.B. and G. Blöschl, 2002. Scaling of soil moisture – a hydrological perspective. Ann. Rev. Earth and Planetary Sci. 30:149-180.

Western, A.W., Grayson, R.B., Blöschl, G, D.J. Wilson, 2003. Spatial variability of soil moisture and its implications for scaling. Chapter 8 in "Scaling methods in soil physics" Ed. Pachepsky, Y., Radcliffe, D.E. and H.M Selim.CRC Press. 119-142.

Western, A.W., Zhou, S.L., Grayson, R.B., McMahon, T.A., Blöschl, G. and Wilson, D.J, 2004. Spatial correlation of soil moisture in small catchments and its relationship to dominant spatial hydrological processes. J.of Hydrology, 286 (1-4):113-134.

Wilson, D. J., Western, A.W., Grayson, R.B. , Woods, R.A. and T. A. McMahon, 2002. Predicting the spatial distribution of soil moisture from measurements made at a limited number of point locations, Proc. 3rd International Conference on Water Resources and Environment Research., Eigenverlag des Forums für Abfallwirtschaft und Altlasten e. V., 1, Dresden, Germany, 22-25 July 2002, pp 214-218.

Wilson, D.J. Western, A.W. and R.B. Grayson, in press..Identifying and quantifying sources of variability in temporal and spatial soil moisture observations. Water Resources Research

Wilson, D.J. Western, A.W., Grayson, R.B., Berg, A.A., Lear, M.S., Rodell, M., Famiglietti, J.S., Woods, R.A. and T. A. McMahon. In press. Spatial Distribution of Soil Moisture at 6cm and 30cm Depth, Mahurangi River Catchment, New Zealand, J. of Hydrology