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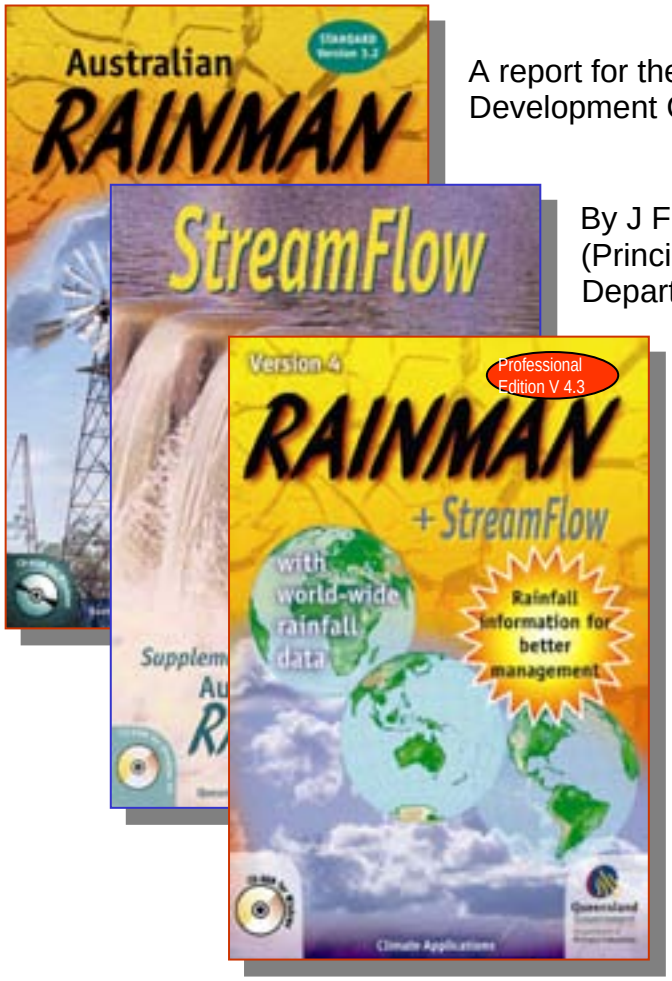
RAINMAN

Further development and application to improve management of climate variability



A report for the Rural Industries Research and Development Corporation

By J F Clewett
(Principal Investigator)
Department of Primary Industries,
Queensland

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Researcher Contact Details
Dr J F Clewett
Principal Scientist
Department of Primary Industries
PO Box 102, TOOWOOMBA QLD 4350

Phone: 07 4688 1244
Fax: 07 4688 1477
Email: jeff.clewett@dpi.qld.gov.au

Administration Contact Details
Mr E J Wright
Principal Planning Officer
Department of Primary Industries
Locked Mail Bag No 4, MOOROOKA QLD 4105

Phone: 07 3362 9406
Fax: 07 3362 9631
Email: eddie.wright@dpi.qld.gov.au

In submitting this report, the researcher has agreed to RIRDC publishing this material in its edited form.

RIRDC Contact Details
Rural Industries Research and Development Corporation
Level 1, AMA House
42 Macquarie Street
BARTON ACT 2600
PO Box 4776
KINGSTON ACT 2604

Phone: 02 6272 4819
Fax: 02 6272 5877
Email: rirdc@rirdc.gov.au.
Website: http://www.rirdc.gov.au

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Foreword

Climate variability has large and severe impacts on Australian agriculture and ecosystems. Timely knowledge of expected rainfall is an essential part of decision-making for farmers, resource managers and business people and hence the challenge is to find a practical way to lift the capacity of people to manage climatic risks so that opportunities for sustainability and profit are enhanced.

This publication describes how the Rainman series of climate analysis and education software has been developed and applied to build knowledge and skills for managing climate variability in rural and regional Australia. This includes drought and the application of seasonal climate forecast information that is based on knowledge of the El Niño / Southern Oscillation.

This project was funded by two R&D Corporations — RIRDC and LWRRDC (now Land & Water Australia). These Corporations are funded principally by the Federal Government.

This report, an addition to RIRDC's diverse range of over 1200 research publications, forms part of our Resilient Agricultural Systems R&D program, which aims to foster development of agri-industry systems that have sufficient diversity, integration, flexibility and robustness to be resilient enough to respond opportunistically to continued change.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirdc.gov.au/fullreports/index.html
- purchases at www.rirdc.gov.au/eshop

Tony Byrne
Acting Managing Director
Rural Industries Research and Development Corporation

Acknowledgments

I wish to thank the many people who have contributed to this project and have supported the research, development, application, promotion and distribution of the Rainman series. These contributions have been across many activities including: climate science research, data research and preparation; design, development and testing of climate analysis and educational material as software; design and development of reference information and artwork; climate applications and education research and development; extension, education and training; quality assurance and review processes, administration, distribution and financial accounting; and project planning and management.

The management committee was successful in planning the development pathway for Rainman and I thank and acknowledge the following for their contributions to project meetings in June 1998, August 1998 and October 2000:

Dr George Wilson (Chair), Rural Industries Research and Development Corporation
Dr Barry White, Land & Water Australia (formerly LWRRDC)
Ms Lynda Drosdowsky, Commonwealth Bureau of Meteorology
Dr Mary Voice, Commonwealth Bureau of Meteorology
Mr Greg Jones, Department Primary Industries, Queensland
Mr Nick Clarkson, Department Primary Industries, Queensland
Dr Graeme Hammer (for Dr Roger Stone) Department Primary Industries, Queensland
Mr Alan Beswick, Department Natural Resources and Mines, Queensland
Mr Cameron Archer, New South Wales Agriculture
Dr Doug Abrecht, Western Australia Department of Agriculture

The following organisations are recognised and thanked for their support of the project:

Rural Industries Research and Development Corporation
Land & Water Australia (Climate Variability in Agriculture Program)
Australian Centre for International Agricultural Research
Department of Primary Industries, Queensland
Department of Natural Resources and Mines, Queensland
Commonwealth Bureau of Meteorology
New South Wales Agriculture
Western Australia Department of Agriculture

Several organisations are acknowledged for their support of the project through their support for development of Rainman International and Rainman Streamflow as follows: National Climate Data Centre, USA (for the world-wide rainfall data set) and the following organisations for their contributions to streamflow data: University of Melbourne, NSW Department of Land and Water Conservation, Victoria Department of Natural Resources and Environment, Tasmania, Department of Primary Industry, Water and Environment, South Australia Department for Water Resources, Western Australia Water and Rivers Commission, Australian Capital Territory Department of Environment, Northern Territory Department of Lands, Planning and Environment.

Dr Jeff Clewett
Principal Investigator
Department of Primary Industries, Queensland

Contents

Executive Summary

This project builds on previous work with Australian Rainman version 2. The objectives were to enhance management of climate variability throughout Australia by further developing Australian Rainman to versions 3 and 4, applying Rainman to research on climatic variability and seasonal forecasts, and establishing an effective communication strategy that has active cross links with extension, education and agri-business.

Version 4 of Rainman was published as Rainman International V 4.1 and Rainman StreamFlow V 4.3 and released in October 2003. Version 3 was released as Australian Rainman in October 1999. Rainman is now used throughout Australia by farmers, educators, business people, consultants, extension officers and researchers. The CD is sold in three editions (Standard ($125), Educational ($125) and Professional ($450)) and includes:

- a world-wide data set of monthly rainfall (9500 locations), an Australian data set of daily historical rainfall (3800 locations), long-term monthly temperatures (625 locations) and time series data of observed and modelled monthly/daily streamflow (400 locations)
- facilities to import/export data and to update data via the Internet
- comprehensive analyses of climatic risk including droughts, flood years and seasonal forecasts of the amount, timing and frequency of rainfall and streamflow using the SOI and SST as climate indicators with results shown as tables, graphs and maps.
- educational and reference information including an electronic version of *Will It Rain?* (Partridge 2001), a map library, a suite of tutorials on using climatic information and seasonal forecasts in agriculture, a graphics library, and full text of ten scientific papers on the origin, data, analytical methods and applications of Rainman.

Over 4700 packages have been distributed with many going to groups of people. A demonstration CD of Rainman is being distributed free of charge to a further 3000 users as a promotion by Land & Water Australia. This CD times out in September 2004.

Rainman has made significant contributions to rural and regional Australia by providing a high-quality and easily accessible suite of information about climatic risk and the application of seasonal forecasts in agriculture. Application of Rainman has also contributed to research on understanding the impacts of the El Niño/ Southern Oscillation (ENSO) and the application of decision support software in climate education. On-going promotion and adoption are key challenges for the future. Other challenges are: incorporating climate change issues in climate risk analyses, long-lead forecasts and linking to data from global circulation models, development of internet capabilities for targeted forecasts, improved data updating, and greater capacity with modelled streamflow data . The projects three main publications are:

Clewett, J.F., Smith, P.G., Partridge, I.J., George, D.A. and Peacock, A. (1999). Australian Rainman Version 3: an integrated software package of Rainfall Information for Better Management. Department of Primary Industries Queensland, QI98071.

Clewett, J.F., Clarkson, N.M., George, D.A., Ooi, S., Owens, D.T., Partridge, I.J. and Simpson, G.B. (2003). Rainman StreamFlow (version 4.3): a comprehensive climate and streamflow analysis package on CD to assess seasonal forecasts and manage climatic risk. Department of Primary Industries Queensland, QI03040.

Partridge, I.J. (Ed.) (2001). Will It Rain? Effects of the Southern Oscillation and El Niño on Australia. Third Edition, Dept of Primary Industries Qld, Brisbane, QI01016, 56 pp.

Introduction

During the last decade there has been considerable progress in developing the knowledge and skills of people in rural and regional Australia concerning better management of climate variability and the use of seasonal forecasts in business decisions. This includes the progress made in the R&D, distribution and application of Rainman version 1 (Clarkson and Owens 1991), Australian Rainman version 2 (Clewett et al. 1994) and the first two editions of *Will It Rain ?* (Partridge 1991, 1994). The successful and widespread use of these resource materials by many people, together with the release of Microsoft Windows, gave impetus to further development of the Rainman software and a third edition of the book *Will It Rain?*. The two main benefits of these resources were seen as:

- providing easy access to good quality climatic information
- empowering primary producers and business people to better manage climatic risk by further building knowledge and skills to assess climate variability and the impacts of ENSO (El Niño/Southern Oscillation) on the chance of rainfall at their own location
- empowering professional agriculturalists with a powerful suite of resources for research and education.

Reviews of Rainman version 2 (Campbell 1996, Clewett 1995a,1995b, White and Stynes 1996, Walker 1996), and widespread support in the community recommended further development of Rainman to achieve:

1. **better software engineering with:**
   - conversion from MS-DOS to the Windows operating system
   - production on CD-ROM format
   - data updating via the internet
2. **improved client focus with:**
   - standard, educational and professional versions
   - reference and resource information on the CD including tutorials and on-line interactive help
3. **expanded analysis capacity with:**
   - statistical tests to improve the scientific rigour on seasonal forecast analyses
   - an improved suite of climate prediction tools stemming from recent climatic research
   - analysis of daily data so that climatic risks concerning the timing and frequency of rainfall events could be examined
   - streamflow data and analyses so that management of water resources could be examined
   - international rainfall data so that global food security and trade issues could be considered
   - data and analyses to assess impacts of ENSO on temperature and time series of run-off and pasture growth

This report describes the progress that has been made in the development, content, marketing, distribution and application that has been achieved with: (a) version 3 of Australian Rainman released in October 1999, and (b) Rainman StreamFlow Version 4.3 released in October 2003.

Objectives

The project objective as stated in the project proposal was: "to enhance management of climate variability throughout Australia by building knowledge and skills in rural communities regards climate information, climatic risks and opportunities, seasonal forecasts, and ways to improve management decisions". It was proposed that this objective be achieved by:

- climate applications research
- further developing the Australian Rainman package to version 3 as a windows, multi-media CD, internet compatible product in standard, professional and educational formats
- establishing an effective promotion / marketing strategy that seeks to improve management, has active cross links with extension, education and agri-business, and uses a sales target of 5000 packages with 50 000 users in three years as a surrogate performance indicator
- implementing a business plan so that benefits from this project are on-going, and self funding with regards to future activities such as development of Australian Rainman version 4 with improved seasonal forecast tools and streamflow / runoff data.

Methods

The project began in January 1998 and the following steps were taken to achieve objectives:

1. research and development of the RAINMAN package to achieve release of the following Windows compatible CD packages in Standard, Educational and Professional formats:
   - Australian Rainman version3.2 in March 1999 and version3.3 in October 1999
   - StreamFlow supplement to Australian Rainman version 3.3 in November 2001
   - Rainman International version 4.1 in October 2003 (Professional format only)
   - Rainman StreamFlow version 4.3 in October 2003
2. modifying *Will It Rain?* and release of the third edition in May 2001
3. establishing an effective communications plan in collaboration with other projects
4. evaluating applications of Rainman as a research, decision support and educational tool
5. establishment of project management committee as acknowledged on page (ii).

The Department of Primary Industries has been responsible for much of the RD&E through the work of Nick Clarkson, Ian Partridge, David George, David Owens, Gordon Simpson and Sea Hwang Ooi and others. However, RD&E for Rainman has been collaborative and the full listing of contributions in the acknowledgements section of Rainman version 4 software describes the contributions of 75 people and 23 agencies. A brief summary of organisational inputs is:

- Commonwealth Bureau of Meteorology: contributions to management (Dr Mary Voice and Lynda Drosdowsky), supply of climate data (rainfall, temperature, SOI, SST), new SST seasonal forecast methods (Dr Wasyl Drosdowsky), organisation of streamflow data (Ross James), development of promotion and marketing plans (Lynda Drosdowsky), evaluation and review (Dr Michael Coughlan and Dr Neville Nicholls)
- Department of Natural Resources and Mines: map library data (Alan Peacock), regular monthly internet data updates (Alan Beswick and Keith Moody) and contributions to development of tutorials (David Freebairn, Mark Wheeler)

- Ice Media: initial design and implementation of the Windows interface leading up to the release of Australian Rainman version 3 (Dr Paul Campbell, Paul Smith)
- New South Wales Agriculture: contributions to management (Cameron Archer) , to review and extension (Dr Peter Hayman and Paul Carbury) and to development of tutorials on climate risk (David Brouwer)
- Western Australia Department of Agriculture: contributions to management and analysis of daily data (Doug Abrecht)
- State Water Agencies: contributions of streamflow data
- University of Melbourne: development of extended streamflow data (Dr Francis Chiew).

Testing of the Rainman package and development of the Streamflow supplement to version 3.3 were done in association with the LWRRDC funded project QPI 39 "Seasonal Streamflow Forecasts to Improve Management of Water Resources" lead by Nick Clarkson, DPI, Toowoomba. This project was completed in July 2000 (see Clarkson 2000) and the StreamFlow supplement was released in November 2001. This supplement was later incorporated into Rainman Streamflow Version 4.3.

Development of Rainman Version 4 occurred in association with the project "Capturing the benefits of seasonal climate forecasts in agricultural management" funded by the Australian Centre for International Agricultural Research (ACIAR). A computer programmer (Sea Hwang Ooi) was employed as part of the ACIAR project and a special edition of Rainman (Rainman International version 4.1) was developed for the project with distribution of 600 copies; mainly to Indonesia, Zimbabwe and India as described in the final report (Clewett 2004).

Promotion, marketing and distribution of the Rainman suite of software has occurred and is still occurring in conjunction with several projects throughout Australia by several organisations. The most prominent is the Land & Water funded project "*Targeted Seasonal Forecasts Using Rainman V4*". This project distributed 3000 demonstration copies of Rainman StreamFlow during a 3 month promotional period (October-December 2003). Results from this project are reported separately (Clewett and Lester 2004).

Results

Some details of results are described in the project's 2001 progress report (Clewett 2001) on Australian Rainman version 3. This final report summarises what has been achieved in relation to:

1. the content and release of Rainman versions 3 and 4 (data, analyses, reference information)
2. development and release of the third edition of *Will It Rain?* (Partridge 2001) in May 2001
3. communications and distribution of Rainman
4. peer review and quality assurance
5. use of Rainman in climate science research
6. use of Rainman in climate applications research
7. use of Rainman in development and implementation of government policy
8. use of Rainman in university, professional, vocational education and training
9. use of Rainman in extension at local, national and international levels and feedback from farmers and business people using Rainman.

1. Content and Release of Rainman versions 3 and 4

An overview of the content of the Rainman series from version 1 through to version 4 is given in Figure 1. The content of Version 4 achieved all aspects of the project proposal which were: software engineering (Windows™, ease of use, internet updating), client focus (reference information, tutorials, 'on-line' help) and analytical capacity (rigour in testing seasonal forecasts, new forecast tools, analysis of daily data to assess timing and frequency of events, world-wide rainfall data, streamflow data, and streamflow, temperature and pasture growth analyses) . Further detail on versions 3 and 4 is given in a series of tables and Figures as follows:

- rainfall and streamflow data: see Table 1 and Figures 2 to 4
- drought and flood analyses: see Table 2 and Figures 2, 9 and 10
- seasonal forecast analyses: see Table 3 and Figures 5a, 5b, 5c, 7 and 8
- educational and reference information: see Tables 4 and 5 and Figures 6a and 6b.

The Queensland Minister for Primary Industries launched Australian Rainman Version 3 (Clewett *et al.* 1999) on 18th March 1999 with national media coverage and video linkages to the Outlook Conference in Canberra and a producer workshop at Alice Springs . A Streamflow Supplement to version 3 (Clarkson et al. 2001) was released in November 2001 but was later withdrawn pending release of version 4 because of concerns regarding corporate risk. This issue was thoroughly reviewed and cleared (see below in section 4)

The Federal Minister for Agriculture, Forestry and Fisheries (the Hon Warren Truss) announced the release of Rainman StreamFlow version 4.3 (Clewett *et al.* 2003) on 7th October 2003 as part of a communications plan conducted by Land and Water Australia (see press releases in the Appendices). Version 4 is an upgrade to replace version 3. Rainman StreamFlow is distributed as a comprehensive climate analysis and education CD package. Examples of the accompanying materials (brochures, order forms, news releases) are in the Appendices. Version 4 is a CD package compatible with Windows™ 95, 98, NT, 2000 and XP, has 586 Mb of information and is a big step forward from the 24 floppy disk MS-DOS product of version 2.

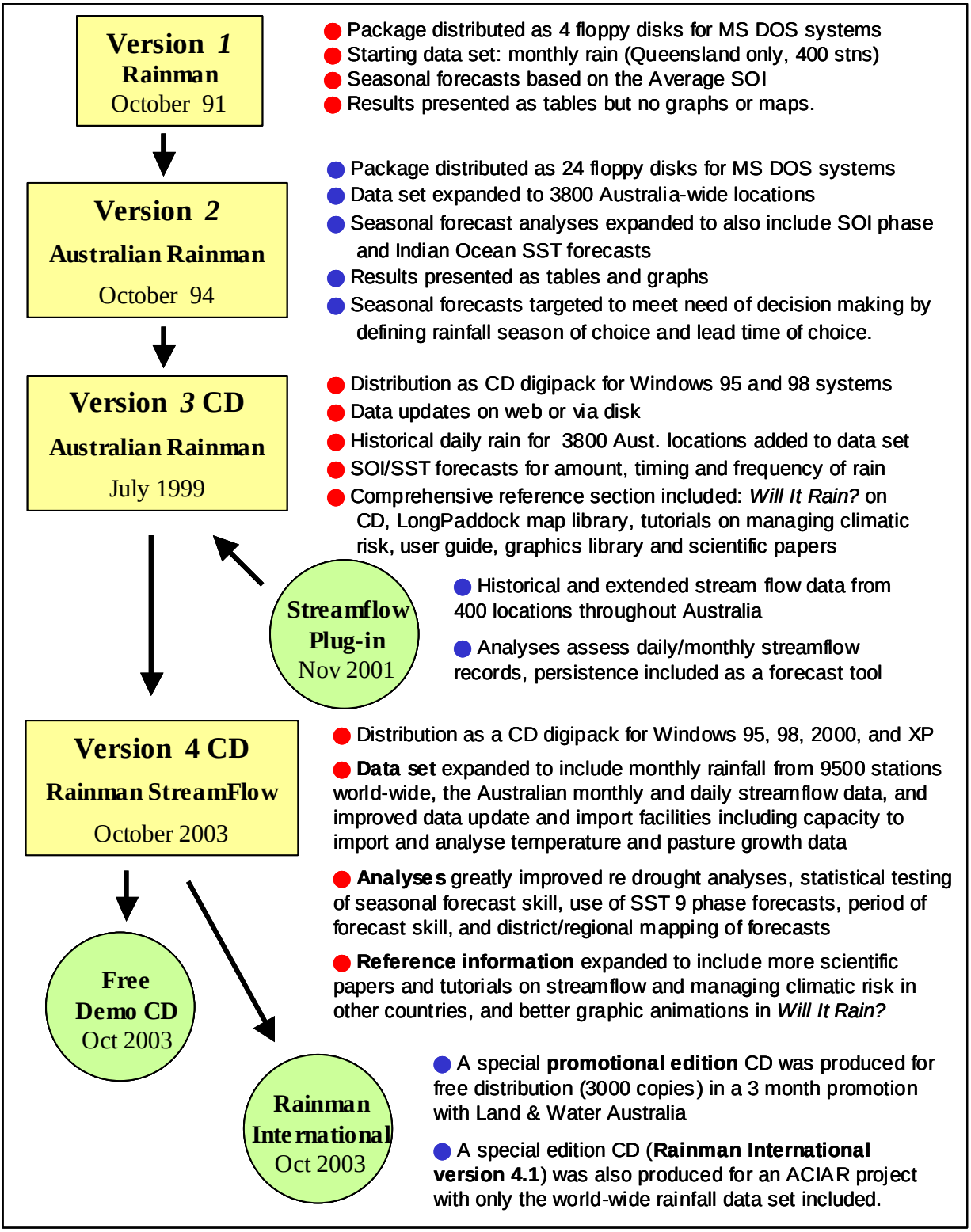


Figure 1. Development pathway and features of the Rainman software package from the release of Rainman version 1 in 1991 to the release of Rainman StreamFlow Version 4.3 in October 2003.

Table 1. Data in Australian Rainman version 3 and Rainman StreamFlow version 4.3.

Rainman	V3	V4
• Australian rainfall data (historical daily and monthly) for 3800 locations as shown in Figure 2, many with 100 years of data	yes	yes
• Australian temperature data (monthly averages of max. and min. temperature, humidity and pan evaporation) for 625 locations	yes	yes
• Facilities to "enter your own monthly rainfall data" and internet updating of monthly values of Australian rainfall, SOI and SST and monthly maps of SST patterns	yes	yes
• World-wide rainfall data (historical monthly) for 9500 locations (see Figure 3)	--	yes
• Australian streamflow data (monthly and daily) for some 400 sites with historical data for 281 sites throughout Australia but mainly along the eastern states (see geographical distribution in Figure 4), and modelled streamflow and runoff data for 286 small unimpacted catchments that have been extended using the SIMHYD rainfall / runoff model (Chiew et al. 2000 and Clarkson et al. 2000). Modelled data for NSW and Queensland were developed as shown in Figure 4 but are not included in the package as the state agencies were of the view that alternative modelled data sets would be developed in the near future and could be imported into Rainman	--	yes
• Capacity to import a large range of data file types (e.g. spreadsheet files, HYDSYS files, IQQM output files and flat ASCII files) for both daily and monthly data so that the package will continue as a relevant analytical tool as new data sets become available	--	yes
• Capacity to import and analyse daily and monthly temperature records and time series of modelled pasture growth data	--	yes

Table 2. Drought and Flood Analyses in Rainman Versions 3 and 4.

Rainman	V3	V4
• Drought analyses for both moderate (1 in10) and severe (1 in 20) droughts of 6, 12 and 24 months duration with results given as tables and graphs	yes	yes
• Analyses to assess the frequency of flood years as well as frequency of droughts	--	yes
• Sorting to compare severity of past droughts and flood years	--	yes
• Internet updating of monthly rainfall to enable up-to-date analyses of exceptional circumstances	yes	yes
• Mapping of extreme events as percentiles for droughts and excessive rainfall conditions for durations of between one and 36 months	--	yes

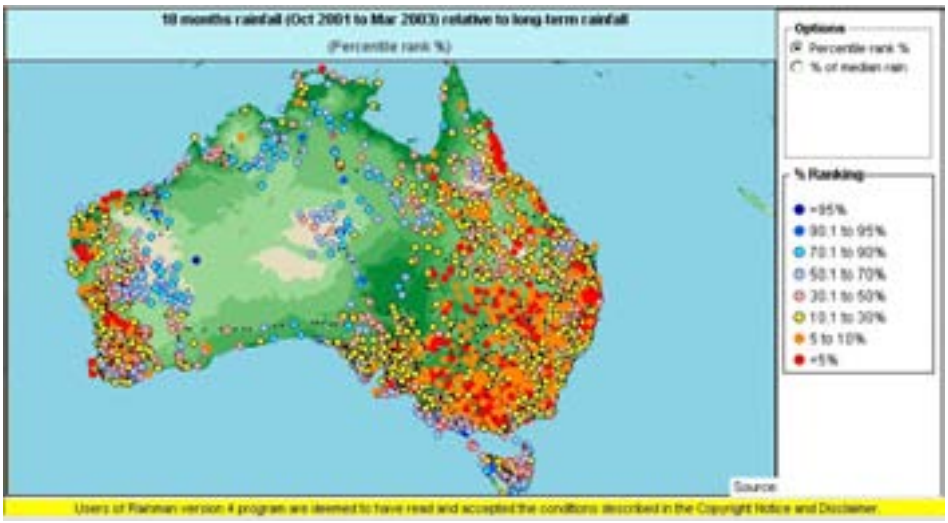


Figure 2. Locations of rainfall stations in Rainman with daily and monthly historical data. Figure also shows drought assessment in Australia for the 18-month period Oct 2001 to March 2003.

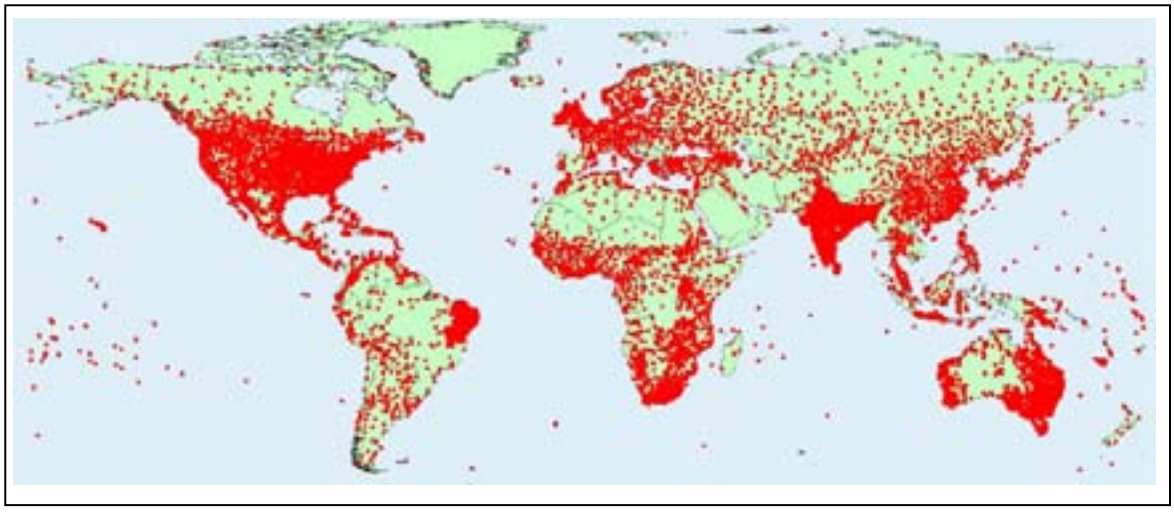


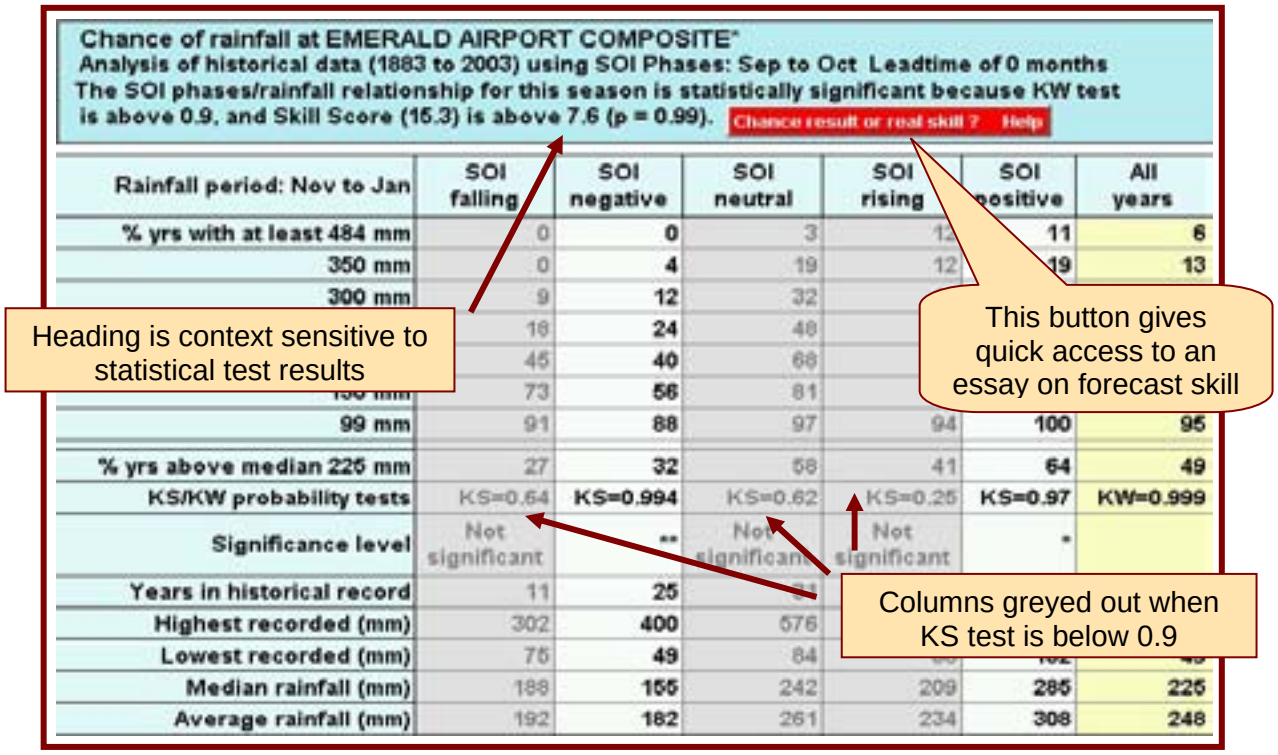
Figure 3. Geographical coverage of the world-wide monthly rainfall data set of 9500 locations from the National Climate Data Centre, USA used in Rainman International and Rainman StreamFlow.

(a) Historical (b) Extended

Figure 4. Locations of historical and extended monthly streamflow records in Rainman StreamFlow.

Table 3. Seasonal forecast analyses in Rainman versions 3 and 4.

Rainman	V3	V4
• Probability-based forecasts of seasonal rainfall from monthly and daily data so that the likely impacts of ENSO (El Niño/Southern Oscillation) on the amount of rain in a season and the timing and frequency of rainfall events can be assessed (including break of season, follow up rain and effective rainfall) using Average SOI (Clewett et al. 1991) and SOI Phase (Stone and Auluciems 1992, Stone et al. 1994) forecasts	yes	yes
• New seasonal forecast tools:		
o Pacific and Indian Ocean Sea Surface Temperatures using the SST 9-Phase system of Drosdowsky (2002) (Professional and Educational editions only)	--	yes
o persistence (Owens et al. 2003).	--	yes
• Comprehensive guidelines on how to approach ENSO-based seasonal climate forecasts through on-screen directions, help notes, tutorials and *Will It Rain?*	--	yes
• Improved rigour in testing/reporting the reliability and accuracy of seasonal forecasts concerning the amount, timing and frequency of rainfall and streamflow (colour coding of data in tables, context sensitive table headings, KW/KS tests, cross-validated LEPS skill scores, 160 pages of "Help" notes) (see Figure 5a)	--	yes
• Improved capacity to target seasonal forecast opportunities and to:		
o assess the spatial homogeneity of forecast information across regions by dynamic mapping of forecast results for multiple locations (see Figure 5b)	--	yes
o assess the consistency of seasonal forecasts as seasons and lead-times vary using the "Period-of-Skill" analyses (see Figure 5c)	--	yes
• Capacity to assess seasonal streamflow forecasts regarding:		
o amount, timing and frequency of streamflow (see Figure 8)	--	yes
o opportunities for diversion of streamflow (e.g. pumping) with a range of user defined diversion rules re minimum river flow heights and max. daily diversions	--	yes
• Capacity to assess other data such as temperature and pasture growth (see Figure 5c)	--	yes



Rainfall period: Nov to Jan	SOI falling	SOI negative	SOI neutral	SOI rising	SOI positive	All years
% yrs with at least 484 mm	0	0	3	12	11	6
350 mm	0	4	19	12	19	13
300 mm	9	12	32			
	16	24	48			
	45	40	68			
	73	56	81			
99 mm	91	88	97	94	100	95
% yrs above median 225 mm	27	32	58	41	64	49
KS/KW probability tests	KS=0.64	KS=0.994	KS=0.62	KS=0.25	KS=0.97	KW=0.999
Significance level	Not significant	**	Not significant	Not significant	*	
Years in historical record	11	25	21			
Highest recorded (mm)	302	400	576			
Lowest recorded (mm)	75	49	84			
Median rainfall (mm)	188	155	242	209	285	225
Average rainfall (mm)	192	182	261	234	308	248

Figure 5a. Example of seasonal forecast analysis from Rainman StreamFlow version 4.3. Analyses give the reliability and accuracy of seasonal forecasts including a probability-based risk profile, several statistical tests and guidelines on forecast skill, and rapid access to educational material.

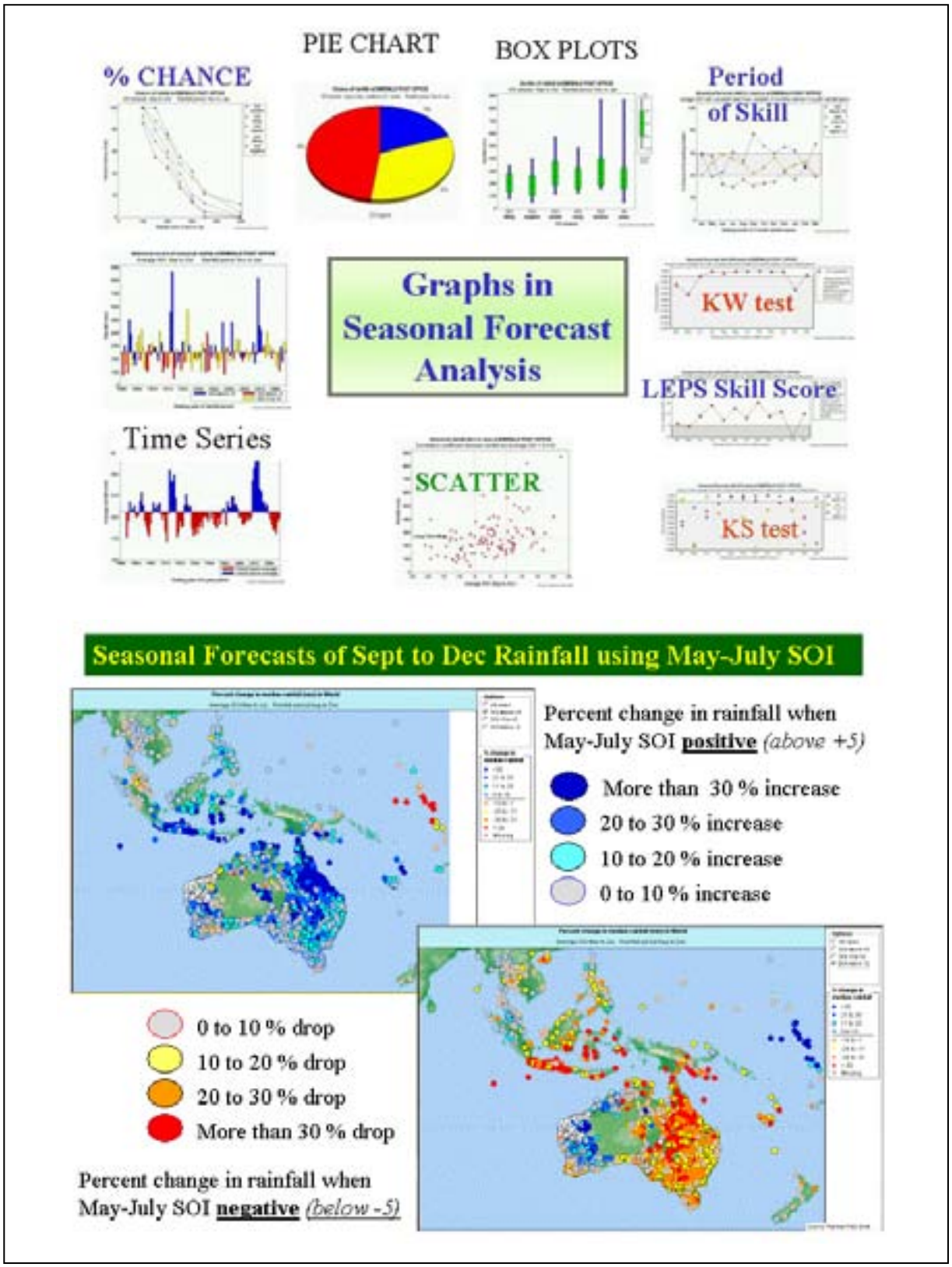
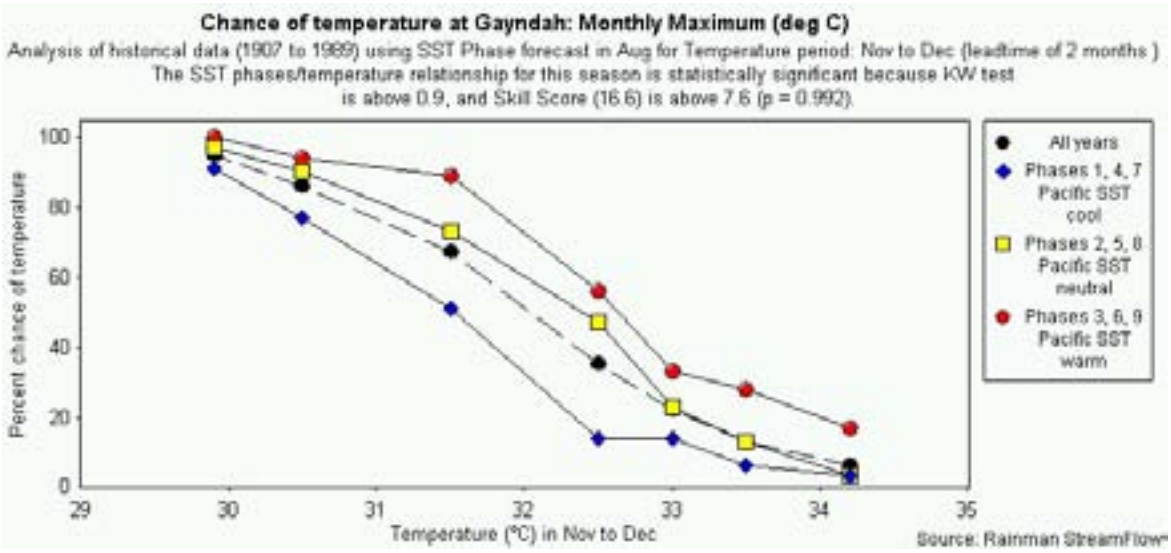


Figure 5b. Examples of graphs and maps from Rainman version 4. Other map types for all regions of the world are: median rainfall, % chance of exceeding median rainfall, statistical test results (KW, KS and LEPS Skill score) of seasonal forecast skill, and extreme events (for use in assessing exceptional circumstances).

(a)



(b)

Chance of pasture growth at Richmond NW Qld (modelled data)

Analysis of historical data (1889 to 2001) using average SOI: May to Jul Leadtime of 3 months
average SOI/growth relationship for this season is statistically significant because KW test
above 0.9, and Skill Score (13.4) is above 7.6 (p = 0.97).

Chance result or real skill ? Help

Growth period: Nov to Feb	SOI below -5	SOI -5 to +5	SOI above +5	All years
% yrs above median 832 kg/ha	33	49	65	50
KS/KW probability tests	KS=0.95	KS=0.90	KS=0.999	KW=0.991
Significance level	*	#	***	
Years in historical record	24	57	31	112
Highest recorded (kg/ha)	1,517	3,272	3,334	3,334
Lowest recorded (kg/ha)	71	45	31	31
Median pasture growth (kg/ha)	676	792	1,520	832
Average pasture growth (kg/ha)	712	927	1,709	1,098

(c)

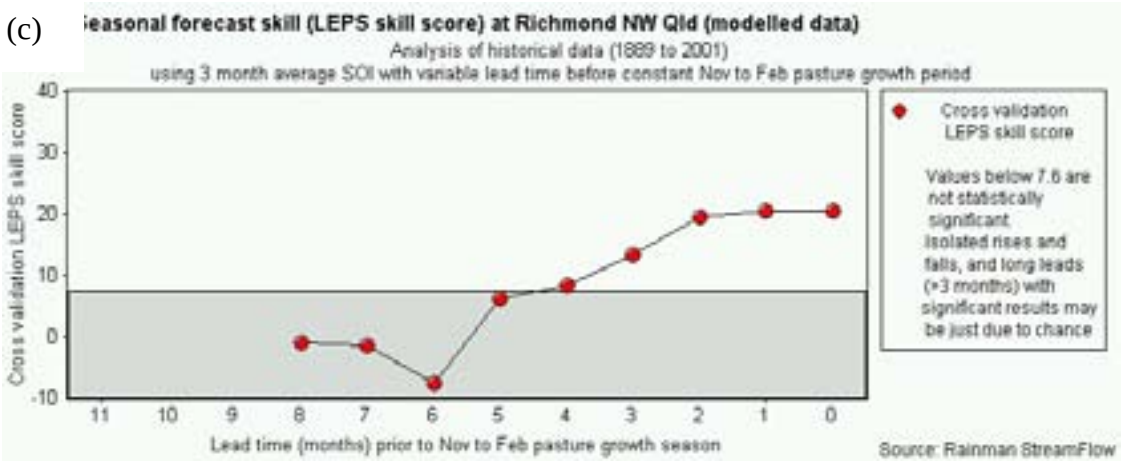


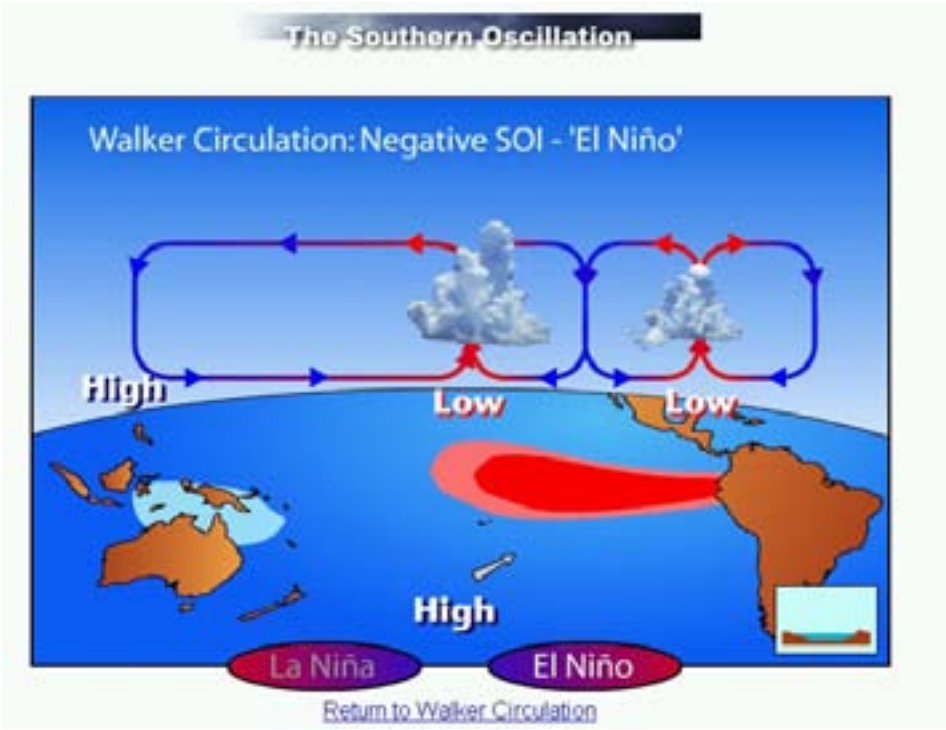
Figure 5c. Some examples of temperature and pasture growth analyses in Rainman StreamFlow. (a) Probability distributions of long-lead forecasts of early summer maximum temperatures at Gayndah, (b) relationship of winter SOI values with modelled values of summer pasture growth (Nov to Feb) at Richmond, and (c) effects of lead time on skill of forecasting summer pasture growth at Richmond.

Table 4. Reference information in Rainman versions 3 and 4.

Rainman	V 3	V 4
• an electronic copy of the 64 page book *Will It Rain?* (Figure 6) including animated diagrams such as the Walker circulation (Figure 6b) and changing SST/SOI conditions	yes	yes
• Expanded 'on-line' Help and improved animations in *Will It Rain*	--	yes
• a map library containing 1300 maps (historical rainfall and SST patterns) from The Long Paddock web site and including 120 maps of SOI phase forecasts for seasonal rainfall for both Australia and the world	yes	yes
• a set of tutorials (see contents in Figure 6b) for education concerning:		
o the use of climatic information and seasonal climate forecasts in agriculture including case studies, exercises and facilitators notes	yes	yes
o hydrological processes and the relationships of streamflow and runoff to rainfall and climate variability	--	yes
o the value of seasonal streamflow forecasts in water management with supporting case studies, exercises and facilitators notes	--	yes
The facilitators notes (in Professional and Educational editions) describe processes for conducting workshops on climate risk and provide handout sheets, workshop PowerPoint™ displays, and exercises for using Rainman in education. The full text of three scientific papers on the theoretical aspects to development, delivery and evaluation of applied climate education are included (George et al. 2003a, b and c).		
• a set of scientific papers on Rainman concerning:		yes
o the origin of Rainman (Clewett et al. 1992, 1995 and Clewett 2003)		
o rainfall and streamflow data (Owens et al. 1996, Clarkson et al. 2000a)		
o the seasonal forecast methods used in Rainman (Clewett 2003)		
o applications of Rainman (Clarkson et al. 2000b, Clewett et al. 2000a, Graham et al. 2000 and Owens et al. 2003)		
o education and communication (Clewett et al. 2000b)		
• a list of 176 scientific references for further reading on climate and seasonal forecasting of rainfall and streamflow	yes	yes
• a graphics library of 44 diagrams for educators regarding presentations on seasonal climate forecasting and including a PowerPoint™ display.	yes	yes

Figure 6. Contents of the electronic booklet *Will It Rain?* on the Rainman CD.

a.



b.

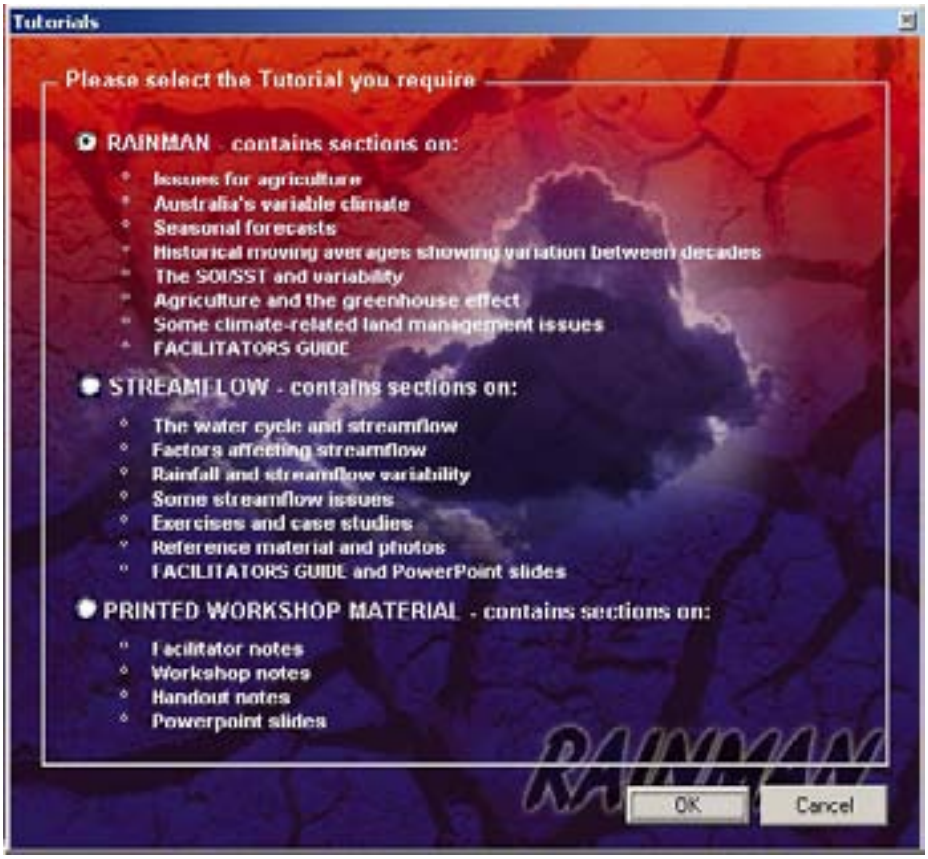


Figure 6b. Some of the educational material in Rainman: (a) an animated diagram of the Walker circulation in the on-line version of *Will It Rain?*, (b) sections of the tutorials on managing climate risk and streamflow variability.

Table 5. Scientific papers with full text included within the reference section of the Rainman StreamFlow version 4 CD (3 papers by George et al. on education are given in the tutorials).

Origin of Rainman

Clewett, J.F., Owens, D.T., Clarkson, N.M. and Partridge, I.J. (1992). Rainman: Using El Niño and Australia's rainfall history for better management today. In "Harnessing Information for a Smarter Agriculture". Proc. Australian Institute of Agricultural Science, National Conference, Launceston, Tasmania.

Clewett, J., Clarkson, N.M., Partridge, I.J., and Abrecht, D.G. (1995). Australian Rainman: Progress and Prospects. Proceedings of LWRRDC National Conference on 'Of Droughts and Flooding Rains' Managing with Climatic Variability. November 1995, Canberra. Occasional Paper CN03/96.

Clewett, J.F. (2002). Seasonal climate forecasts and decision support systems for drought prone agriculture: A case study based on the development and application of the Rainman Climate Analysis Software. In "Coping against El Niño for Stabilizing Rainfed Agriculture: Lessons from Asia and the Pacific", United Nations, CGPRT Centre Monograph No 43: pp. 37-55.

Rainfall and Streamflow data

Owens, D.T., Clarkson, N.M. and Flood, N. (1996). Development of a long-term daily and monthly rainfall collection for Australia. Proc. of the Second Australian Conference on Agricultural Meteorology. The Impact of Weather and Climate on Agriculture. University of Queensland, Brisbane, 1-4 October 1996. pp. 235-239.

Clarkson, N.M., Owens, D.T., James, R.A. and Chiew, F.H.S. (2000). Seasonal streamflow forecasts to improve management of water resources: 3. Issues in assembling an adequate set of Australian historical streamflow data for forecasting. Proc. 26th National and 3rd International Hydrology and Water Resources Symposium of The Institution of Engineers, Australia. 20-23 November 2000, Perth, Australia.

Seasonal forecast methods and Applications

Clewett, J.F. (2002). Seasonal climate forecasts and decision support systems for drought prone agriculture: A case study based on the development and application of the Rainman Climate Analysis Software. In "Coping against El Niño for Stabilizing Rainfed Agriculture: Lessons from Asia and the Pacific", United Nations, CGPRT Centre Monograph No 43: pp. 37-55.

Clarkson, N.M., Abawi, G.Y., Graham, L.B., Chiew, F.H.S., James, R.A., Clewett, J.F., George D.A., and Berry. D. (2000). Seasonal streamflow forecasts to improve management of water resources: 5. Major issues and future directions in Australia. Proc. 26th National and 3rd International Hydrology and Water Resources Symposium of The Institution of Engineers, Australia. 20-23 November 2000, Perth, Australia.

Clewett, J.F., Chiew, F.H.S. and Clarkson, N.M. (2000). Seasonal streamflow forecasts to improve management of water resources: 2. Impact of climate variability and ENSO on streamflow and runoff in Australia. Proc. 26th National and 3rd International Hydrology and Water Resources Symposium of The Institution of Engineers, Australia. 20-23 November 2000, Perth, Australia.

Graham L.B., Wheeler, M.A. and Clarkson, N.M. (2000). Seasonal streamflow forecasts to improve management of water resources: 1. Establishing needs of irrigators from pilot studies around Australia. Proc. 26th National and 3rd International Hydrology and Water Resources Symposium of The Institution of Engineers, Australia. 20-23 November 2000, Perth, Australia.

Owens, D.T., Clarkson, N.M. and Clewett, J.F (2003). Persistence of Australian streamflow and its application to seasonal forecasts. In Post, D. A. (ed.) MODSIM 2003. Proc. International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, July 2003. Vol 1, pp. 124-129.

Clewett, J.F., Thompson, P.J.M., George, D.A., Owens D.T., and Clarkson. N.M. (2000) Seasonal streamflow forecasts to improve management of water resources: 4. Communicating results to improve knowledge and skills of clients in Australia. Proc. 26th National and 3rd International Hydrology and Water Resources Symposium of The Institution of Engineers, Australia. 20-23 November 2000, Perth, Australia.

2. Development and Release of the Third Edition of Will It Rain?

The third edition of *Will It Rain? The effects of the Southern Oscillation and El Niño on Australia* (Ed. Partridge 2001) was released in May 2001. Earlier editions had proven popular as an easy reading technical book and thus all the following six chapters were retained with some revision of material:

1. The Weather
2. The Southern Oscillation
3. The weather and the SOI
4. Plant Growth and the SOI
5. Better Decisions with the SOI
6. Seasonal Rainfall Forecasting

The main changes were to include information regarding impacts of ENSO on the break of season, and the Bureau of Meteorology's seasonal forecast system using sea surface temperatures. Some information was upgraded such as the SOI/rainfall correlation map for Australia. Chapter six also includes some discussion on possible future statistical forecast tools such as the IPO (Interdecadal Pacific Oscillation) and the ACW (Antarctic Circumpolar Wave).

The full text of *Will It Rain?* is reproduced in electronic format on the Rainman CD and this includes several animations which are particularly useful in education for addressing the mechanism of the Walker Circulation and ENSO processes.

The retail price of *Will It Rain?* as the 64-page book is $22. Some 8000 copies of *Will It Rain?* have now been distributed with 3000 copies of the first edition, 4000 copies of the second edition, and so far 1045 copies of the third edition.

3. Communications and Distribution

Rainman version 4.3 is produced in three editions (similar to version 3) to achieve balance in price and relevance to customers as follows:

- **Standard Edition:** This contains a restricted set of Australian rainfall data (250 locations plus a further 20 of the user's choice), the world-wide rainfall data and the Australian streamflow data. It has all of the analytical features of the other editions except for seasonal forecasts based on SST Phases. The recommended retail price is $125.

- **Educational Edition:** This edition contains the same data set as the Standard edition and includes the SST phase analysis. It has all of the reference materials in the Standard edition plus a comprehensive set of educational resource materials for trainers and facilitators. This edition is restricted in distribution to educational institutions. The Software Licence Agreement for the Educational Edition permits users to install the Rainman software on multiple computers (up to 25) that are used for teaching purposes. Location of climate and streamflow data on a central server is permitted, but installation of the Rainman executables on a central server is not recommended or supported. The recommended retail price is $125.

- **Professional Edition**: This is the most comprehensive edition. It has the complete data set for Australia of 3800 locations, the international data set of 9500 locations and streamflow data set of 400 locations. It includes SOI, SST and persistence based seasonal forecasts and includes the educational resource materials for trainers and facilitators. Site Licences are available. Installation of the professional edition to multiple computers requires a Site Licence (see Software Licence Agreement). The recommended retail price is $450.

The demonstration CD developed for the promotion of Rainman StreamFlow (Oct - Dec 2003) was the same as the Standard Edition except that it was set to time out after 12 months (by September 2004). The ACIAR Special Edition of Rainman International (version 4.1) (Clewett et al. 2002) is the same as the professional edition of Rainman StreamFlow version 4.3, but only has the international data set of monthly rainfall. Version 4.1 does not have the daily rain, temperature and streamflow data sets from Australia.

Distribution of the package to the public is occurring from the Department of Primary Industries in Toowoomba and through standard commercial arrangements with: (a) partners in the project (including the Bureau of Meteorology, NSW Agriculture, Department of Agriculture Western Australia, and Land& Water Australia), and (b) several commercial retail outlets. The list of recommended wholesale and retail prices, and arrangements for distribution of royalties (10% of retail sales) is in the Appendices. Distribution of versions 1, 2, 3 and 4 is shown in tables 6 and 7.

Table 6 Distribution of Rainman

Version and edition	Number distributed
• Rainman versions 1 and 2	961
• Australian Rainman version 3	
Standard edition (mainly farmers, small business)	1322
Educational edition (schools, universities, TAFE)	185
Professional edition (mainly consultants, researchers)	339
Network edition (medium sized corporations)	3
• Rainman StreamFlow version 4.3 (7 Oct to 1 Dec)	
Standard Edition	302
Educational Edition	12
Professional Edition	385
• Rainman StreamFlow version 4.3 (Demonstration CD)**	3000
• Rainman International version 4.1 (ACIAR Special Edition)	600
• Seven organisations with corporate site licences: Dept Primary Industries, Dept Natural Resource, Bureau of Meteorology, NSW Agriculture, WA Dept of Agriculture, University of Sydney, University of Queensland Gatton Campus.	430
Total	

** Distributed via Land & Water Australia in the project "Targeted Seasonal Forecasts Using Rainman V4" (see final report by Clewett and Lester 2004)

Table 7. Distribution of Australian Rainman version 3: Pecentages by state and sector.

State		Sector	
ACT	6 %	Business and consultantants	10 %
New South Wales	31 %	Education	8 %
Northern Territory	1 %	Agriculture extension services	10 %
Queensland	44 %	Government business	15 %
South Australia	6 %	Primary producers	44 %
Tasmania	1 %	Researchers	13 %
Victoria	7 %		
Western Australia	5 %		

Many of the above packages are used by groups of people (land care groups, schools, small business) and thus the number of people receiving the information is much larger. DPI has re-invested revenues from the Rainman project (royalty share and margin on retail sales) back into further development of the software and to employ a marketing officer for a period of 15 months (August 1999 to October 2000) to assist in developing distribution and promotion channels. Several promotional initiatives were undertaken including:

- profiled events such as the launch of versions 3 and 4 as described above
- mail-outs to company representatives, primary producers and schools
- reviews and advertisements in newspapers, magazines and newsletters
- linkage with other extension projects e.g. extension initiatives in NSW and South Australia
- distribution of 3000 demonstation CDs in a promotion conducted from Land & Water Australia in Canberra (see separate project report by Clewett and Lester 2004).

An analysis of Rainman promotion and marketing plans by the University of Southern Queensland (Moloney et al. 2000) showed that there was substantial recognition of the *Rainman* brand name with 35% recognition throughout rural Australia and 67% in Queensland.

Rainman version 3 was awarded honours at the Asia Pacific Queensland Information Technology and Telecommunications (IT&T) Awards for Excellence in 1999. It won the Environment Award for the most innovative new IT&T project, application or solution supporting or enhancing the environment.

4. Peer Review and Quality Assurance Processes

Peer review processes have been used to both develop and assess the content of Rainman from several perspectives including scientific rigour, decision-support, corporate risk, communication, education and marketing.

The first major reviews of Rainman were the three-day national workshops convened by the Bureau of Meteorology in 1993 and attended by 40 scientists from the Bureau, Universities, CSIRO and seven state departments of agriculture (Clewett 1995). While the first of these workshops (March 1993) evaluated appropriate seasonal forecasting tools, the second (July 1993) assessed the overall approach and defined the data, analyses and user interface for Australian Rainman version 2.

Rainman has been presented for review at major national and international conferences (Clewett et al. 1992, Clewett 1995b, Clewett et al. 1996, George et al. 2000, Clewett 2003, Partridge 2002) and this has included independent review processes (White and Stynes 1996, Power et al. 2001). Rainman version 4 includes 10 scientific papers on the origin, data, scientific methods, applications and communication of Rainman as shown in Table 5. Further examples of both internal and independent review processes are as follows and comments by several reviewers are in Table 8.

- Three separate funding bodies have reviewed Rainman from scientific and decision support perspectives and found in favour of further R&D support on six separate occasions, and on two of those occasions external reviews were commissioned by the funding organisation. A beta edition of Rainman StreamFlow version 4 was reviewed by Land & Water Australia in 2003 as part of a funding application for a $50,000 promotional project "Targeted Seasonal Forecasts using Rainman V4". This review/application was successful. Land & WaterAustralia provided funding (through the Managing Climate Variability Program) and promotional support to distribute 3000 demonstration CDs of Rainman StreamFlow.
- Quality Assurance processes within DPI during development of Rainman have included:

  (a) obtaining clearance from the Legal and Legislation section in regard to wording of the Copyright Agreement, Disclaimer, Software Licence Agreement and various other screens and messages to steer users away from possible traps for the unwary and provide legal protection for the DPI as publisher of Rainman StreamFlow

  (b) exhaustive testing (and filing of test results) of the software for correct operation of: installation from CD across all versions of Windows from 95 to XP (by using actual computers and VMware software); CD keys that determine the data and analyses available in the Standard, Educational and Professional versions; all screens, menus and legends in Climate Analyses section; scientific implementation of the forecasting tools; arithmetical accuracy (checked against independent calculations); labelling of tables, graphs and maps; Help notes; copying and printing of tables and graphs; data updating, importing and exporting; saving analyses; presence of all elements in the Reference Information section

  (c) an internal review that focussed on corporate risk issues and resulted in further development of Rainman version 4 to ensure increased and appropriate scientific rigour in: (i) assessing and reporting seasonal forecast information especially in regard to the statistical analysis of forecast skill; (ii) providing guidelines for use of seasonal forecast information, and (iii) providing a more thorough set of published scientific papers concerning data and analytical methods in the reference section of Rainman.

Table 8. Quotations from reviewers of Rainman version 4 .

'Thank you for the opportunity to evaluate Version 4 of Rainman. First let me congratulate you on the three new versions which are well designed for their specific markets. The numerous revisions and enhancements you have made will ensure that Rainman maintains its image as an outstanding climate science product. The approach you have adopted to cater for users of varying levels is, I believe, highly effective.' and 'the Rainman CD is at the forefront of best practice'.

Dr Barry White
Coordinator, Climate Variability in Agriculture R&D Program
Land & Water Australia

'This new and improved version will be an excellent education and training tool for those interested in agriculture and land management. We appreciate the expanded capabilities. The data and analysis tools are easy to work with, and the new map library is an excellent resource.'

Cameron Archer
Principal, C B Alexander Agricultural College 'Tocal'

'I thought the package was a major advance on earlier versions of Rainman. I believe you have gone a long way to reducing the concerns we all had with the issue of artificial skill likely to arise from 'trawling' for an apparently useful relationship. I particularly liked the inclusion of a button to identify periods of skill. I also think the 'red button' connecting to the essay on skill and artificial skill helps in this area.'

Dr. Neville Nicholls
Bureau of Meteorology Research Centre

'You and your team are to be congratulated for the work you have done in completing the latest Australian Rainman CD-ROM (version 4.2). The CD, which includes Australian and global data, provides an excellent range of tools for the analysis and display of station based historical data and predictive information.' and 'In summary, the CD-ROM provides a robust and useful suite of interactive data exploration tools. The descriptive and supporting information is detailed and the overall design provides for a high degree of navigatability through the data and information.'

Dr Michael Coughlan
Superintendent, National Climate Centre, Bureau of Meteorology

Data entry: updating from the internet is easy ★★★★★
Practical use: worthwhile in assisting climate risk management ★★★★
Help and tutorials: comprehensive and easy to use ★★★★★
Value for money: information supplied is extensive ★★★★★

David Buckley, Kondinin Group
Review of Rainman in the rural magazine "Farming Ahead", July 2000, pp. 20-21

- Rainman has been independently reviewed by climatologists and agricultural scientists in several major RD&E organisations in Australia and has been: (a) cleared for purchase of a site licence in seven organisations (see Table 6), (b) adopted as an accredited package for training staff (e.g. Bureau of Meteorology Training Centre, South Australia Dept of Agriculture, NSW Agriculture), (c) adopted for use in research and extension by major R,D&E agencies, and (d) adopted for use in policy development and drought analyses by both federal and state governments.

- In a project coordinated through Malasia and involving the Asia Pacific Network (APN), the ASEAN group of countries have evaluated and cleared Rainman as a climate analysis and seasonal forecast tool to assess daily rainfall, temperature and other climatic variables.

- Education institutions including universities, schools, agricultural colleges and geography professionals have reviewed Rainman and recommended and/or adopted it for use in teaching programmes (e.g. for the courses *Weather and Climate in Farming* (Bayley 2000) and *Developing climate risk management strategies* (ANTA 2000), George et al. 2003d, 2004 in press).

- Farm journals have highly recommended Rainman as a decision-support package (see Table 8) and national software competitions have recognised Rainman on several occasions (e.g. First prizes at *The Australia*n Farm Software Competition in 1992 and 1995, and the Asia Pacific Information Technology and Telecommunications software competition in 2000).

- Most importantly some thousands of people have reviewed the overall value of Rainman to their situation and have demonstrated their support by purchasing a copy. Feedback from producers participating in the Masters of Climate Project (Neil Inall pers. comm.) was very positive at the CVAP funded Cli-Manage conference in October 2000 (Power et al. 2001).

5. Use of Rainman in Climate Science Research

Increasing the rigour of statistical tests on seasonal forecast skill was a key development in Rainman Version 4. This required R&D to develop the analytical capacity of Rainman as an efficient research tool for assessing seasonal forecast data.

Increased statistical rigour was achieved in Rainman in several ways (see Table 3) and included the introduction of cross-validated LEPS (Linear Error in Probability Space) Skill Scores using the continuous method of Ward and Folland (1990) and Potts et al. (1996). Like all statistical tests, the LEPS Skill Score does not provide a guaranteed assessment of forecast skill but it does help to weed out relationships in the historical data that are simply due to chance.

A challenge in introducing the LEPS Skill score was to derive a method of calculating levels of statistical significance (i.e. probabilities of significance) appropriate to different sample sizes and forecast systems. Some of the key points in the "Help" notes in Rainman used for describing the LEPS skill score and the method used for deriving statistical significance levels are as follows:

The LEPS Skill Scores calculated in Rainman use a cross-validated approach that enables each year to be used as independent data to test the accuracy of the forecast system. Skill scores are adjusted to a "Standardised LEPS Skill Score" to account for: (a) the number of groups in the forecast system and (b) the number of years of data in the analysis. The Standardised LEPS Skill Scores reported in Rainman are relative and thus can be compared across locations, seasons and forecast systems.

Standardised LEPS Skill Scores that equal or exceed a threshold of 7.6 are statistically significant and indicate that the forecast system being tested has skill (forecasts with values below 7.6 are not sufficiently skilful and forecasts with skill scores below 0.0 have no skill). The probability that the LEPS skill score is statistically significant is also reported. The level of 7.6 for the continuous LEPS skill score was identified as being statistically "significant" using randomly generated forecasts in a method similar to that of Drosdowsky and Chambers (2001). A cross-validated LEPS Skill Score of 7.6 was found to equate with the upper 10th percentile of randomly generated forecasts and to a KW test value of 0.90 for analyses with 100 years of data and three groups in the forecast system.

Rainman uses linear interpolation of a look-up table to derive a standardised skill score where the number of years in the analysis differs from 100 and there are more than three groups in the analysis (e.g. SOI Phases with five groups and SST Phases with nine groups). The look-up table contains LEPS skill scores at 15 probability levels (from 0.001, 0.01, and 0.1 through to 0.9, 0.95, 0.99 and 0.999) calculated from the frequency distributions of random seasonal forecasts for each of the seasonal forecast systems used in Rainman with N=30, 35, 50, 65, 80, 100 and 120 years. Each of these frequency distributions was derived from 50,184 random forecasts formed from six replicates of the 12 overlapping three-month rainfall seasons during the year at the 697 stations in Australia that have at least 120 years of records with at least 96% of data present. The LEPS skill scores found at a probability level of 0.90 are shown in Table 9. The influence of the magnitude and variability of the data on the threshold level of 7.6 was also investigated but was found to be very small. Further details are described in Rainman.

Table 9. Effects of forecast method and number of years of data in analysis on cross-validated LEPS Skill Scores (when p=0.90) and before the skill scores are standardised.

Number of years in analysis	3 Groups in forecast system (e.g. Average	5 Groups in forecast system (e.g. SOI	9 Groups in forecast system (e.g. SST Phase)
30	19.5	23.2	36.0
35	17.6	20.3	30.9
50	13.5	15.7	19.8
65	10.8	13.5	15.2
80	9.2	11.3	13.1
100	7.6	9.6	11.3
120	6.7	8.4	10.1

6. Use of Rainman in climate applications research

The climate analyses in Rainman are powerful and thus the package is well suited to climate research applications to improve management of climatic risk. Many researchers have used Rainman for this purpose and a few of these examples are highlighted below.

- **Spatial analyses and effect of lead-time on forecast skill.** The relationship of ENSO indicators with seasonal rainfall varies with location, time of year, lead-time and the status of ENSO. Rainman enables measurement of changes in the statistical significance of forecast skill on both temporal and geographic scales. Park et al. (2001) found large influences of ENSO on median rainfall and pasture growth with lead-times of up to five months; however, the forecast skill was not statistically significant at lead-times longer than one month at most locations. Cobon et al. (2003a) used the spatial analysis capabilities in Rainman to assess seasonal forecasts of summer rainfall in southern Africa and found that forecast skill was low at lead-times of two months or longer but there were reasonable levels of skill during La Niña years at some locations at zero and one-month lead times (see Figure 7). The spatial analysis capabilities of Rainman were also used by Clewett (2004) to assess differences in seasonal forecast skill between regions and the potential value of seasonal forecast applications in Indonesia, Zimbabwe, India and Australia.

- **Timing of rainfall.** The influence of the El Niño/Southern Oscillation (ENSO) on the amount of effective rainfall in western Queensland and the date of on-set of the wet season and follow up rainfall were evaluated by Park et al. (2001) using Rainman version 3. Their results showed that the wet season was likely occur one to two weeks earlier during a La Niña (when the SOI was greater than +5) and two to three weeks later during an El Niño (when the SOI was below –5). This knowledge could be used in a variety of ways for livestock management such as time of joining, arrangements for altering stock numbers, and pasture management. In a similar study, Cobon et al. (2003) assessed the effects of ENSO on the date of on-set of the wet season in Zimbabwe in relation to planting of maize. In this case, delays in the on-set of the wet season become critical as any delay is usually associated with a shorter growing season and a rapid fall in maize production. Analyses with Rainman showed that ENSO was related to shifts in likely planting dates of several weeks; with forecast lead-times of one or two months this could enable farmers to potentially change to more suited varieties.

- **Seasonal forecasts of temperature**. Rainman Streamflow has been set up to assess other climatic variables such as maximum and minimum temperature, particularly from the long-term historical daily data from the CVAP-funded CLIMARC project. These analyses are in progress as shown by the data in Figure 5c.

- **Effects of ENSO on Streamflow.** A series of papers by Clewett *et al.* (2000a), Clarkson *et al.* (2001) and Owens *et al.* (2003) use the analytical capabilities of Rainman to examine the impacts of ENSO on streamflow in Australia. The paper by Clarkson *et al.* assesses forecast skill and spatial coherence of climatic effects on water availability for irrigated cotton in the Condamine-Balonne Basin of southern Queensland. The capabilities to map multiple locations and to carry out rapid statistical tests for forecasting skill and shifts in probability distributions were key factors in enabling the best possible assessment of likely water availability for the coming season.

  Clewett *et al.* (2000a) examined the impacts of ENSO on regional streamflow and runoff for 212 stations in usually 11 regions around Australia. Concurrent analyses using a prototype of Rainman StreamFlow 4.3 were firstly used to show that historical impacts of ENSO on streamflow were generally twice as those large as on rainfall and statistically significant in most regions as described in the following summary of this research.

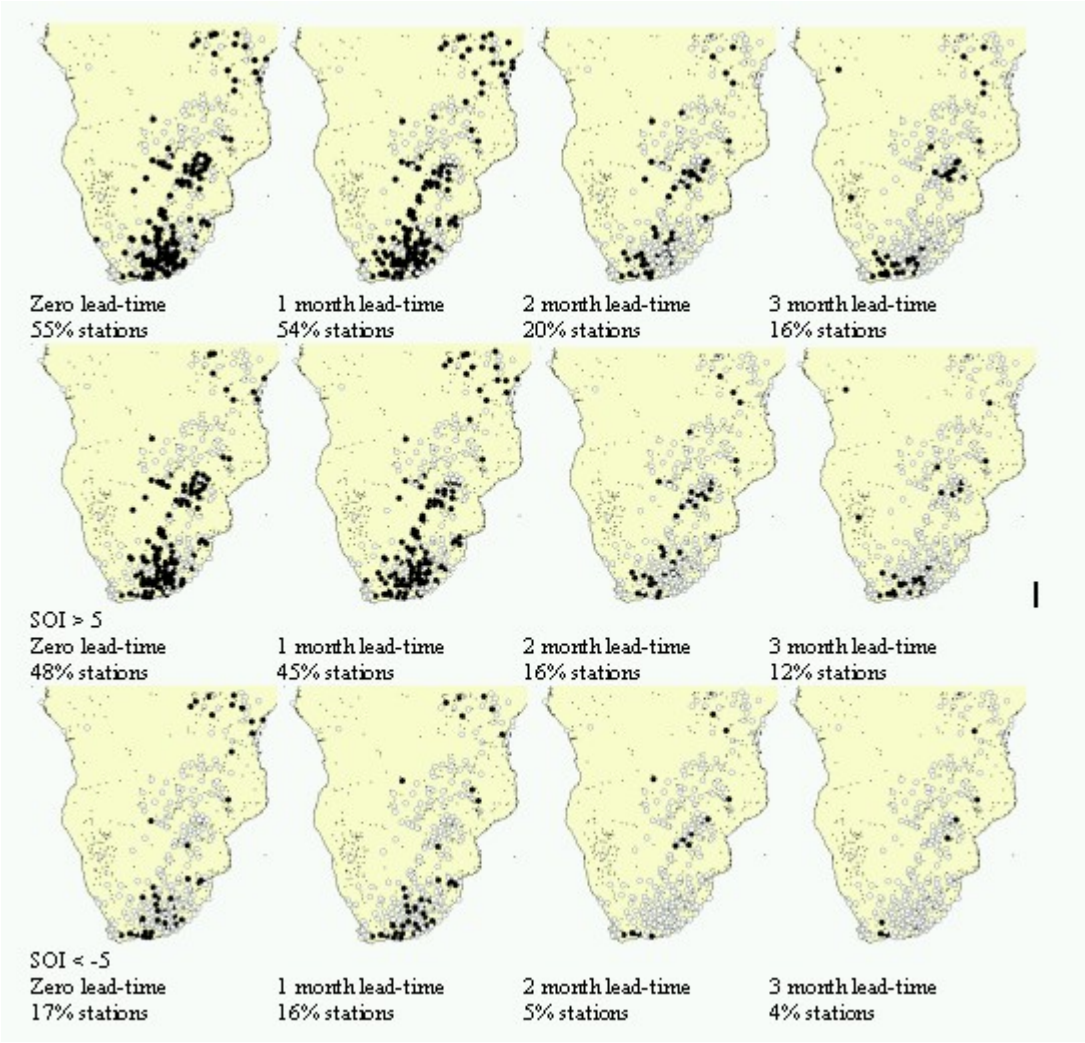


Figure 7. Locations with significant KW ($P \geq 0.90$) (top panel) indicating useful skill of a summer (Nov-Mar) rainfall forecast at lead-times of 0-3 months and significant KW and KS ($P \geq 0.90$) when the 3-month average SOI was either >5 (middle panel) or <-5 (bottom panel). ○ KW or KS < 0.90, ● KW or KS ≥ 0.90.

The impact of ENSO on observed annual streamflow was strong and significant in 9 of the 11 regions tested. The exceptions were the Northern Territory (where poor data quality reduced the number of useable years to 15 in the worst case) and the Victorian coast (Table 10). There is some difficulty in comparing regions in this analysis because of different lengths of records for the stations in each region. For the regions examined, the overall depth of average annual runoff was 172 mm but this was reduced by 33 % (to 115 mm) in those years when the average annual SOI was negative (less than minus 5). In contrast, the observed annual runoff increased by 48 % (to 256 mm) when the SOI was positive (above plus 5). The average of these two gives an overall impact of ENSO on streamflow of 41%. This is a useful general measure of describing the overall magnitude of the ENSO impact and summarises the plus and minus influences of La Niña and El Niño on streamflow in a single number. It is used in Table 11 but is distinct from the precision of the impact. The correlation values in Table 10 are generally fairly low and thus the impact of ENSO on Australian streamflow is large but variable.

Table 10. Simultaneous relationship between the median of annual historical streamflow (as catchment averaged depth of runoff) for the year April to March and the average annual SOI for the same period.

Region	Number of stations / region	Average number of years per stn	Median depth of runoff (mm)					
			SOI below minus 5	SOI From -5 to +5	SOI above plus 5	All years	Correl'n of flow v's SOI	Impact (percent change)
Northern Territory	11	24	153	195	300	205	0.46	36
North Qld Coast	15	43	158 #	292	398 #	280 #	0.38	43 #
South Qld Coast	17	49	50 #	91	177	92 #	0.41	69 #
NSW Coast	20	54	201	332	505	329 #	0.41	46 #
Qld MDB*	9	45	26 #	72	140 #	57 #	0.52	100 #
NSW MDB (north)	18	106	28 #	52	101 #	52 #	0.47	71 #
NSW MDB (south)	17	67	121	175	240 #	171 #	0.40	35 #
Victoria MDB	40	55	197	261	389 #	269 #	0.47	36 #
Victoria Coast	54	38	219	263	327	261	0.35	21
South Australia	3	68	78 #	111	146	108 #	0.30	32 #
WA (south-east)	8	37	39 #	65	91 #	65 #	0.41	40 #
Average	19	53	115	174	256	172	0.42	41

# Indicates statistically significant differences (P<0.1) with KS test in two-thirds of stations in the region.
* Murray-Darling Basin.

The impact of ENSO on the characteristics of seasonal streamflow showed large regional and seasonal differences. This analysis using the modelled extended streamflow data for the period 1901 to 1998 overcomes difficulties in assessing observations of variable length; it shows that the impact of ENSO on streamflow (% change under positive and negative SOI conditions) was large and generally more than double the effect on rain (Table 11).

Table 11. Percent change in median catchment rainfall and streamflow for three seasons (late summer/autumn, winter, and spring/early summer) with concurrent changes in the SOI over a 98-year period. Regions marked "na" were not tested because rainfall and streamflow were too low.

Region	Number of stations per region	Jan to Apr		May to Aug		Sept to Dec	
		Rain	Flow	Rain	Flow	Rain	Flow
		% change		% change		% change	
Northern Territory	4	8	15	na	na	23 #	43 #
Nth Qld Coast	9	22 #	41 #	14	13	53 #	98 #
Sth Qld Coast	9	13 #	43 #	22 #	52 #	19 #	48 #
NSW Coast	91	17	44 #	10	40	21 #	47 #
Qld MDB	31	6	25	23 #	59 #	22 #	51 #
NSW MDB (nth)	31	2	8	20 #	63 #	19 #	36 #
NSW MDB (sth)	35	3	14	22 #	65 #	22 #	47 #
Victoria MDB	45	4	7	9	26	12 #	23
Victoria Coast	15	2	1	16 #	36	14 #	25 #
South Australia	6	na	na	19 #	73 #	12 #	31
West Aust (sth east)	9	na	na	9 #	18 #	12 #	27 #
Average	26	9	22	16	44	21	43

The period of spring/early summer showed the most consistent response across Australia. The average annual coefficient of runoff (runoff/rainfall) averaged across all regions was calculated to be 0.21. However, when the SOI was negative and rainfall was less, a smaller fraction of rain went to runoff (0.18). In contrast, when the SOI was positive (above plus 5) a higher fraction of rainfall went to runoff (0.23).

The SOI has considerable skill as a forecast tool during winter for the volume of streamflow to be expected in spring in southern Australia and the frequency and timing of streamflow events in northern Australia (see examples for the Goulburn and Burdekin rivers in Figure 8). The timing of the wet season and river flow in northern Australia is an important issue for many land management decisions, and thus a tool that can indicate differences in the likely timing of an event by plus or minus 2 or 3 weeks is useful (as is the case for the Burdekin at Sellheim Figure 8). Similarly, likely changes in either the total volume or the frequency that a flow volume (or river height) will be exceeded are useful in planning and decision making. The example case studies presented in Figure 8 were typical of many rivers examined but not reported here. Similarly, the volumes of water defining "an event" (10,000 ML/day for the Burdekin and 1 ML/day for the Goulburn) are examples and are typical of results obtained for other "events" but not illustrated here. These events could be determined by environmental flow requirements or diversion conditions for irrigation.

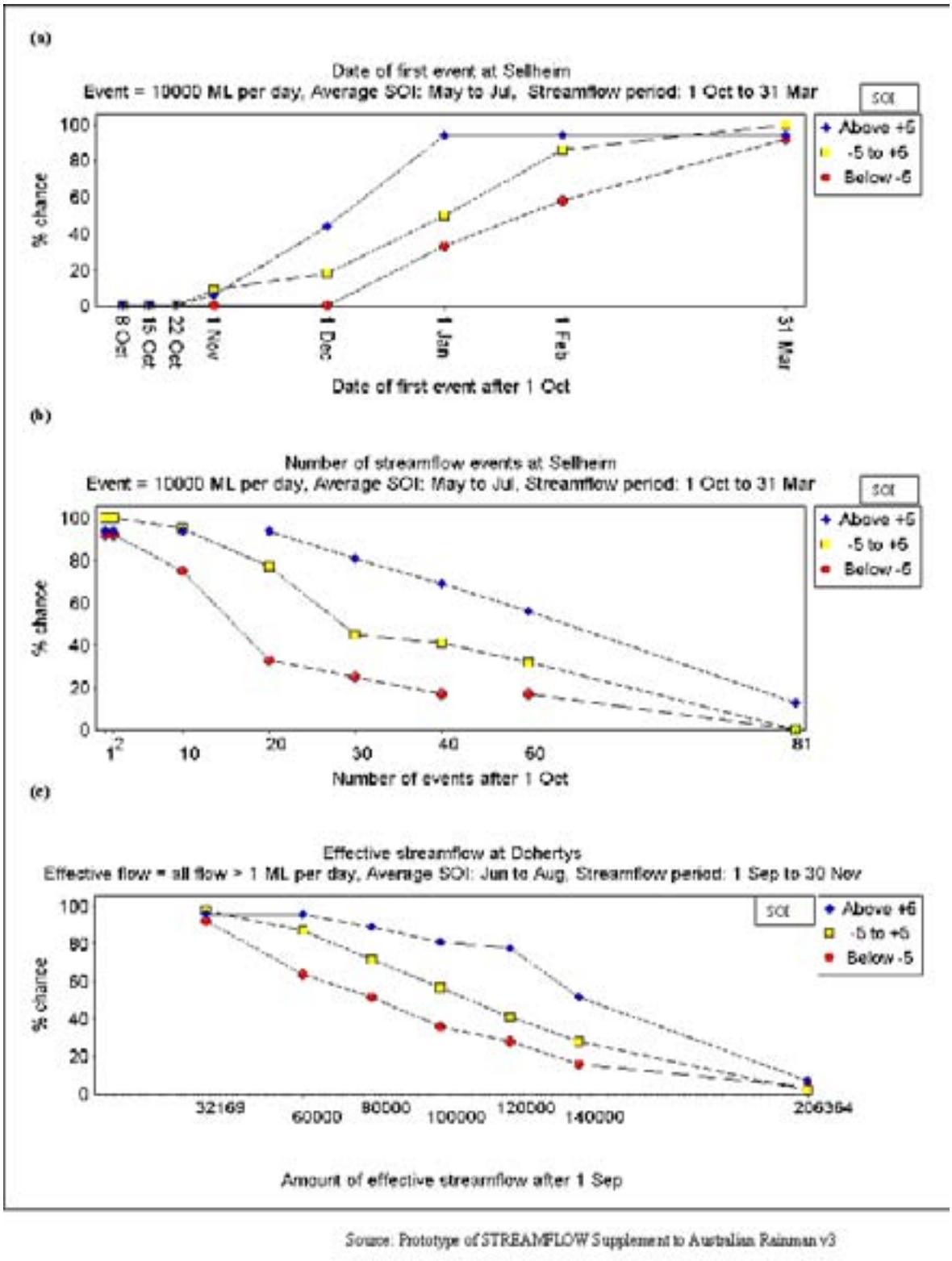


Figure 8. Relationship of the SOI in winter with: (a) the timing and (b) the frequency of streamflow events in the following summer wet season for flows greater than 10,000 ML per day in the Burdekin River (at Sellheim) in North Queensland, and (c) the total volume of flow in the Goulburn River (at Dohertys) in Victoria in spring.

- **Use of persistence in seasonal forecasts of streamflow.** A prototype of Rainman StreamFlow was used by Owens et al. (2003) to evaluate the skill of persistence as a tool for forecasting streamflow on large and small catchments in Australia; this included some comparisons with the skill of SOI-based forecasts. Monthly streamflow records for 320 unimpacted Australian gauging stations were analysed with the analytical and mapping facilities of Rainman Streamflow. The data set had 302 stations with historical time series data from state water agencies and 18 stations with extended /modelled data for small catchments. Prior flows were sub-divided into terces (high, medium and low prior flow) to give three persistence categories for forecasting, and results were evaluated spatially to compare regional responses across Australia. This study showed that persistence is a useful predictor of streamflow in all seasons over much of Australia (see table 12), and it extends the season of predictability beyond that available with ENSO-based forecasting tools. The lag relationship between prior and predicted streamflow was strongest with a lead-time of zero. The strongest relationships were in south-eastern Australia during late spring and early summer and in northern Australia during autumn and early winter. In northern Australia, SOI-based forecasts were more accurate for early summer forecasts particularly at longer lead-times.

Table 12. Regional and seasonal differences in the skill of persistence as a forecast tool for streamflow in Australia. Values are the percent stations in a region in which the forecast skill of persistence is statistically significant (as measured by % stations with LEPS skill score equal to or greater than 7.6, when duration of predictor period is one month, and lead-time is zero).

	No. stns	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Average
Qld(N)	21	33	71	76	52	**58.3**
Qld(S)	31	42	58	68	19	**46.8**
NSW	109	59	70	94	85	**77.1**
Vic	97	85	29	78	81	**68.3**
Tas	8	88	38	62	100	**71.9**
SA	12	50	8	92	83	**58.3**
WA	19	47	21	90	47	**51.3**
NT	15	40	67	67	27	**50.0**
ACT	7	86	100	100	100	**96.4**

7. Use of Rainman to Develop and Implement Government Policy

- **Developing Water Management Plans.** The StreamFlow supplement to Australian Rainman has played a useful role in assisting the Department of Natural Resources & Mines Queensland with its Water Management Plans as part of national COAG water reform. The capacity of Rainman to import data files and produce analytical tables and graphs makes it ideal for examining draft runs of the IQQM water model used to evaluate the effects of proposed water allocation rules on the availability of irrigation water to farmers. The package has been used to advantage in assessing model output for the Lower Balonne Water Management Plan. Ability to display tables/graphs of streamflow data generated under pre-development, old development and proposed development rules makes the package a useful communication tool for discussions with Community Consultation groups and ultimately for the delivery of modelled water data for individual farmers after the review is completed.

- **Defining Drought and Exceptional Circumstances.** Rainman is used regularly by the Natural Disaster Relief section of the Department of Primary Industries Queensland (DPI) to evaluate rainfall deficiencies as follows:
    - assisting rural communities to determine which areas meet the national drought criteria for Exceptional Circumstances (frequency of drought: 1 in 20-25 years)
    - assisting local Drought Committees to determine which areas meet the state criteria for Drought Assistance (frequency of drought: 1 in 10-15 years)
    - assisting DPI stock inspectors to assess whether a shire has reached the threshold criteria for a drought declaration at state level.

Rainman is also used in a similar way by other state agencies and is seen to have several advantages in assessing drought: firstly in summarising rainfall deficiencies through time (Figure 8) with capacity to sort in order of severity, and secondly a capacity for mapping rainfall deficiencies at scales and time frames to suit the investigation. The dot maps in Figures 2 and 10 are an advantage where the attention is on local variations in rainfall.

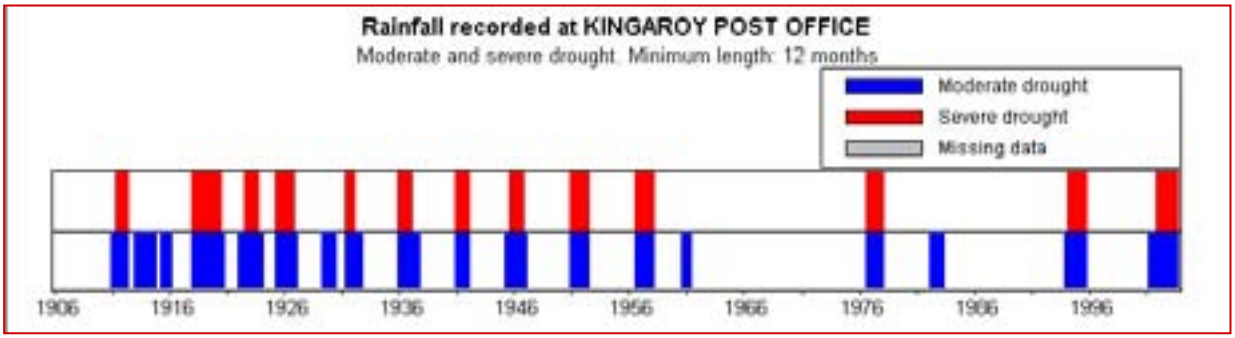


Figure 9. Analysis of drought occurrences at Kingaroy in the period 1906 to 2003. Severe drought is a rainfall deficiency in lowest 5% of years and at least 12 months duration; moderate drought is a rainfall deficiency between the lowest 10% and 5% of years.

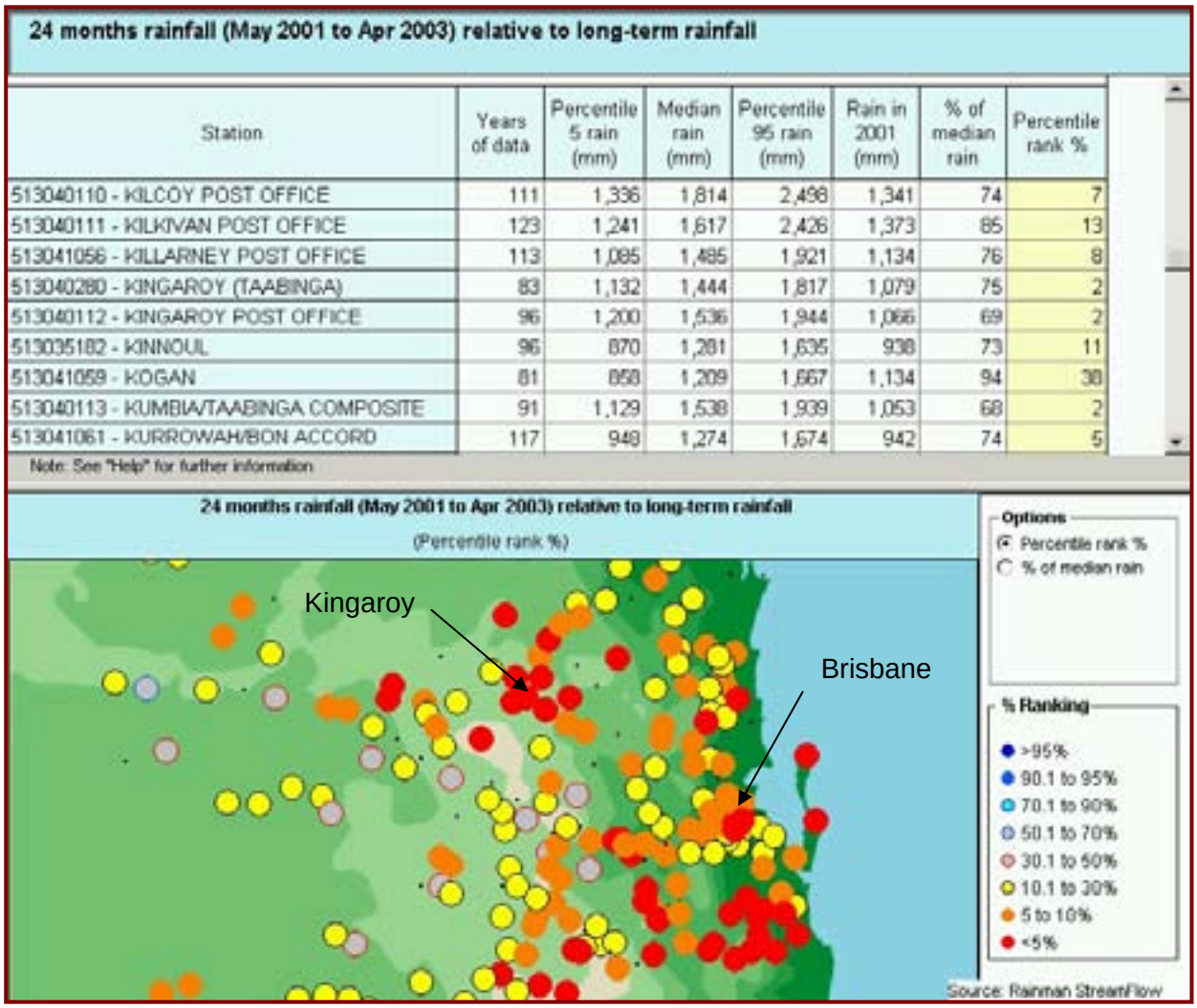


Figure 10. Rainfall deficiencies in south-east Queensland for the 24-month period May 2001 to April 2003. The dot maps of Rainman version 4 highlight local variation in drought.

8. Use of Rainman in Educational Institutions

Rainman is a valuable educational resource (George et al. 2003, Clewett 2000b). It is used and cited by several leading text books on climate and climate applications (e.g. Hammer et al. 2000, Marvi and Tupper 2003), and is used within many university, professional, vocational and school courses as shown by the following examples.

- **Bureau of Meteorology Training Centre.** Rainman is regularly used in the official training program for Bureau of Meteorology staff. A two-day training course 'Climate, weather and agriculture' for Bureau of Meteorology Observers has been conducted by David George each year from 1997 to 2003. This course contributed to an accredited course by the Bureau and WMO to Certificate level. A similar course has also been conducted for Bureau Forecasters and is accredited to Graduate Diploma level. Some 260 professional staff including some Meteorological staff from other countries have been exposed to the value of Rainman for forecasting and in education with clients and have provided supportive feedback on its value. The professional training arm of the Bureau (BMTC) assesses the value of this work and to date has continued to endorse its need each year. The Bureau uses its site licence for Rainman in this training.

- **University courses.** Rainman is used as a learning support tool for teaching about climate and climate applications at the University of Queensland in several courses such Climate Systems, Applications of Climate Analysis, Bioclimatology, and Environmental Control in Agriculture. These courses contribute to Bachelor and Masters degree courses. At La Trobe University, Rainman is used in Bachelor degree courses by Dr Mary Voice, former Head of the National Climate Centre. Rainman is available at Sydney University through the library via the University's site licence. Rainman is used by staff and students at the University of Western Sydney, James Cook University, the Australian National University and Melbourne University through the CRC for Catchment Hydrology.

- **Vocational Training.** Rainman is a key resource in the vocational training course "Developing Climate Risk Management Strategies RTE 5523 A" (Rischmueller 1999, Australian National Training Authority 2003) which is being developed through the Farmbiz-funded ClimEd project (*AAA 0290 ClimEd – An Applied climate education program for rural industry in Australia*). This project led by AgForce and DPI is seeking to enhance the capacity of Rural Training Organisations in Australia to deliver (for the first time) a Level 5 course for farmers and business people on management of climatic risk. The project held a pilot workshop for participants from across Australia in May 2003 and a "Train the Trainers" course for 20 participants in Brisbane in October 2003. People attending the "Train the Trainers" course will now take the training to the next step by conducting their own courses with farmers and businesses and will be using Rainman as one of the key resources in that process. Positive feedback on use of Rainman is documented in the project milestone reports (George *et al.* 2003).

  The C.B. Alexander Agricultural College at Tocal in NSW conducts Level 3 training courses on climate. These courses use Rainman for assessing climate variability and seasonal climate forecasts. The courses are also supported by two text books (*Climate and Your Farm* (Brouwer and George 1995), and *Weather and climate in farming* (Bayley 2000) that draw on Rainman.

9. Use of Rainman in extension at local, national and international levels and feedback from farmers and business people using Rainman

Application of Rainman has been successfully linked with many extension programs and feedback from industry has been positive as evidenced by the examples below.

- **Extension services provided by state departments of agriculture.** All state departments of agriculture in Australia use Rainman in their extension.
  - NSW Agriculture has distributed 165 copies of Rainman (Professional edition) to staff as part of the site licence agreement for use in research and extension programs; it is used regularly in extension activities.
  - The Climate service of the South Australian Research and Development Institute (SARDI) includes climate risk management workshops (for agronomists, researchers and educators), climate risk management decision support trials (a fax-back service to farmers), and a climate risk and yield information service (also for farmers). Rainman is provided as part of the Climate Risk Management Kit (Truscott 2001) and is used to assess district seasonal rainfall probabilities.
  - In Queensland, Rainman has been distributed to 140 staff in the Department of Primary Industries and the Department of Natural Resources and Mines. It is used regularly by many staff in their extension work including workshops and the media (e.g. monthly use in preparing the DPI climate web page www.dpi.qld.gov.au/climate).

- **Streamflow workshops.** A series of 18 workshops with irrigation farmers, researchers and extension staff was conducted as part of the Land & Water Australia CVAP-funded project "Seasonal Streamflow Forecasts to Improve Management of Water Resources". These workshops used a participative problem-solving format that considered an overview of climate and ENSO processes, impacts of ENSO on climate and streamflow, a set of exercises to resolve climate risk issues using Rainman and the benefits/risks of seasonal forecasting. The workshops were conducted during the period November 1999 to November 2003 at 14 locations in Queensland, New South Wales and the ACT and involved 182 participants consisting of 68 farmers and 114 consultants and agency staff. Formal evaluation of the workshops (Thompson 2000, Clewett et al. 2000b) showed that the package could provide benefits in the following ways:
    - as an analytical tool in research
    - helping to assist irrigators determine future water availability and irrigation planning
    - demonstrating the variability in stream flows
    - forecasting to minimise the effect of flood/drought
    - helping to plan the development and size of water storages
    - determining the probabilities of floods during harvest
    - planning of itineraries and setting up wet season camps
    - making better informed decisions on crop choices and whether to take allocation water
    - analysing periods of water shortages and strategic planning
    - helping to decide whether to just pump overland flows at $0/ML or water harvest at $8/ML.

  The workshop participants identified a broad range of people who would gain benefits from using the package as follows:
    - irrigators and water harvesters
    - flood plain managers (e.g. stock owners who have to shift cattle in floods)
    - hydrogeologists, hydrologists, researchers in plant ecology, modellers, system designers
    - conservation and environmental groups, tourist operators and aquaculture enterprises
    - catchment and water resource planning groups, policy makers, water boards, local authorities and emergency services
    - consultants, extension and education personnel,

  The workshop process used to achieve learning objectives was a combination of presentations to the workshop participants and active involvement of the participants in discussion and hands-on problem solving using Rainman, plus a period to reflect on learning. Thus, Rainman was used as an integral part of the workshop to develop the knowledge of participants and most people found the package software easy to use (32 out of 41 respondents). When asked What would you say to someone else about the software package?, most respondents would recommend that people buy it and try it as they believed it would be a helpful tool for anyone involved in water management (43 out of 44 respondents identified the package as useful or very useful). General comments about the package included:
    - *versatile and flexible*
    - *software was without glitches*
    - *availability of information including access to historical records*
    - *easy to quickly see the effects and relationship of SOI with rainfall and stream flows.*

  Before attending the workshop, three quarters of workshop participants did not feel competent to use the SOI as a forecasting tool for their situation. However, on completing the workshop three quarters of people felt competent to very competent in this area. In addition, 83% of people were competent to view climatic and streamflow data for their location using Rainman, with 70% of people believing they were competent in their ability to complete a streamflow decision-making exercise using Rainman. In response to the question "How did you learn most?' the answers

were evenly divided among the hands-on approach using the software (33 %), the participative workshop presentations and discussion (27 %), and a combination of learning from the software in the workshop process (31 %). Some comments about learning were:

- *ability to use package at own pace in conjunction with reading the material*
- *tutoring available whilst progressing through the exercises*
- *found playing with it in my own time provided extra learning*
- *believe using is the best teacher.*

The economic value of the learning from the package was very broad and ranged from "no idea" to "thousands of dollars". 84% of irrigators answered yes to the question Will the time you spent with the package be returned or exceeded? and responses included:

- *this package saved me one lift pumping, which is: 60 days @ 65ML/day @ $20/ML = $7,800*
- *saved me a $10,000 insurance premium this year*
- *you would only have to be right once to get your money back*
- *if 1ML = 10 kg of grain or 40-60 kg silage then each ML extra generated by the package is worth this much*
- *the more we know how to use the information included in the package the more valuable it will become*
- *saved me a $10,000 insurance premium this year*
- *will be helpful planning ahead for water sales/purchases (eg. could now sell 176 ML for $40-250/ML).*

Conclusions from the Rainman Streamflow workshops were:

1) learning was maximised where participants were involved in problem solving through the processes of discussion and practical hands-on application of the software in exercises that integrate climate science, water supplies and business decisions so that problems and benefits are clear
2) development of knowledge required quality data for an individual's own location plus exercises that were timely for current seasonal conditions and management decisions
3) the combination of theory and workshop processes involving use of the Rainman Streamflow software was useful for integrating climate information and assessing agricultural decisions and risk management options. It was also appealing to farmers, agency staff and environmentalists and thus valuable for building knowledge, skills, aspirations and positive approaches to managing climatic risk.

- **International workshops.** A series of one and two-day workshops were held in Australia, India, Indonesia and Zimbabwe between January 1999 and September 2002 to enhance understanding of climate variability, ENSO and seasonal forecasts, particularly as they impact on agricultural systems in these countries. These workshops were delivered as part of the ACIAR funded project *'Capturing the benefits of seasonal climate forecasting in agricultural management'*. They involved over 490 participants including agriculture department staff, farmers, researchers, department of meteorology staff and food security personnel. Resource materials were developed in Australia for these other countries and adapted for workshops. They included the software packages Rainman International (Clewett et al. 2002), the books *Will it Rain?* in English and Indonesian (Partridge 2001, Partridge and Ma'shum 2002). Handout notes (including exercises) were used by participants to work on local examples and to develop solutions to local problems. The nine learning outcomes for the workshops were:

  1) Investigate 'What makes it rain' in their location.
  2) Read and interpret weather maps
  3) Examine and investigate the impact of climate variability and ENSO on agriculture

4) View and discuss climatic data for their location, (including averages, median, deciles, probabilities and statistical skill)
5) Complete an enterprise decision-making exercise using Rainman
6) Identify key decision points in the agricultural system where seasonal climate forecasts may be useful
7) Review climatic information sources and references
8) Complete a 'climate related' skills audit for agricultural management
9) Observe and discuss current short and long-term forecasts.

Some key results and conclusions from the workshops as reported by George et al. (2003) were:

- The workshops clearly improved the knowledge and skills in climate technologies for key personnel in major agricultural training and education organisations in Indonesia, India, Zimbabwe and Australia.
- Some participants reached skill levels where they could continue on to train others, however, other participants would need further training before they could confidently, independently and proficiently use these technologies to train others or issue advice to decision makers and farmers. Building on the progress made with the existing participant pool to produce some climate extension 'champions' would be likely to have the greatest impacts in terms of potential capacity to train others and increase application of technologies on-farm.
- Participants have indicated a willingness to show these climate technologies to others. For example, when asked the question about what actions they could do as a result of this workshop, responses included extending research, modelling, teaching, and use in diverse areas like fisheries and forestry across broader areas of Indonesia and Australia.
- The Rainman software was identified as useful for continued application of this work. Participants and collaborators evaluated the features of Rainman International as unique, very useful and have requested copies as soon as possible.
- *Will it Rain?* (Partridge 2001) was considered to be valuable resource and teaching aid for local, regional and a national perspective. Having editions in English and Bahasa Indonesian makes it a valuable reference for lecturers and students in Indonesia.

Future Work

There is a need for on-going education and extension activities to improve management of climate risk in rural and regional Australia. Thus on-going promotion and adoption of the Rainman StreamFlow package in combination with other resources and activities is a key challenge for the future. Other challenges are:

- incorporating the effects of climate change into analyses of climate risk including seasonal forecasts of climate (rainfall, temperature) and derivative variables such as runoff, streamflow and pasture growth
- long-lead seasonal forecasts (greater than four months) and linking to data from global circulation models,
- ability to analyse a wide range of climate elements (as available from the CLIMARC data set) and to assess the value of other forecasting tools.
- development of web-sites to match the analytical and educational capabilities of Rainman for targeted seasonal forecasts
- improved data updating for a range of variables (daily rainfall, temperature, streamflow) to match the data updating capabilities now available for monthly values of Australian rainfall
- increased availability of modelled 'historical' runoff and streamflow data (daily and monthly data) for a large range of small and large catchments in Australia.

Financial Statement

Funding from RIRDC for the project was $100,000. Total royalties paid to stakeholders on sales of the Rainman package from October 1991 to 31 May 2003 is $177,965, as below. This may be subject to minor revision as some data for the 2001/2002 is estimated. Revenues from retail sales of versions 1, 2 and 3 total approximately $600,000. Royalties on Rainman version 4 have not yet been assessed but will be 10% of retail sales.

	Versions 1 and 2	*Version 3*
• Dept Primary Industries, Qld	$41,236.03	$33,270.11
• Bureau of Meteorology	$39,072.09	$22,180.06
• Dept Natural Resources & Mines	$9,036.77	$7,393.32
• WA Agriculture	$5,048.55	$3,696.67
• RIRDC	$9,638.56	$3,696.67
• Land & Water Australia	nil	$3,696.67
Total	**$104,032.00**	**$73,933.50**

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