South Eastern Australian
Climate initiative

Final report for Project #2.2.2

Projections of Water Availability

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Abstract

The first part of this project assessed simple methods for transforming climate outputs from global climate models (GCMs) to drive hydrological models. Climate change projections generally come from GCMs, but the information provided by GCMs is at a resolution that is too coarse for direct use in hydrological modelling. Statistical and dynamic downscaling methods can be used to downscale GCM simulation to catchment scale rainfall, but they involve significant development, data needs and modelling run times. The simpler empirical methods, based on scaling or transforming a historical climate series to obtain a future climate series, offer a more immediate solution. The results from this study indicate that the constant scaling method can be used in most applications to transform climate outputs from GCMs to drive hydrological models. Because the constant scaling method is very simple, it can be applied to outputs from a number of runs of different GCMs, therefore taking into account the large uncertainties associated with global warming projections and GCM modelling of local climate. However, where more detailed analyses of runoff distribution is required, the daily scaling and daily translation methods are potentially better, particularly if used to transform outputs from a GCM that has skill in modelling extreme rainfall and daily rainfall series.

The second part of this project developed future projections of catchment water yield for 0.05^o (~ 5 km x 5 km) grid cells across the SEACI region. The hydrological modelling is carried out using two lumped conceptual daily rainfall-runoff models (SIMHYD and Sacramento), calibrated against streamflow data from about 219 catchments. The 1895–2006 daily climate data from 'SILO Data Drill' are used to model the historical runoff. The future climate series for ~2030 is obtained by scaling the historical daily rainfall and PET data using the daily scaling method, informed by the IPCC SRES A1B global warming projection (0.9 ^{o}C warmer in ~2030 relative to ~1990) and 15 GCMs. There are considerable differences in the rainfall projections between GCMs, although the majority of GCMs shows a decrease in future mean annual rainfall, particularly in southern SEACI region. The modelling results indicate that the mean annual runoff in ~2030 relative to ~1990 for the SRES A1B global warming scenario in northern SEACI region (central and northern MDB) will change by -25 percent to +20 percent (median of -5 percent), and the mean annual runoff in southern SEACI region (southern MDB and Victoria) will change by -30 percent to 0 (median of -15 percent)

Significant research highlights, breakthroughs and snapshots

- The project assessed runoff results from a rainfall-runoff model driven with future climate inputs obtained from different simple scaling/translation methods for transforming climate outputs from GCMs to drive hydrological models. The results provide guidance on the choice of appropriate methods to obtain future climate series for climate change impact on water resources studies. Because these methods are simple to use, they can easily consider different future scenarios, therefore taking into account the large uncertainties associated with global warming projections and GCM modelling of local climate. The results from this study have been written as an international conference paper and a journal paper (see Publications). A summary of the results is given in Objective 1 below.

- The project calibrated and parameterised two rainfall-runoff models (SIMHYD and Sacramento) to estimate daily runoff from daily rainfall and PET data for 0.05^o x 0.05^o (~ 5 km x 5 km) grid cells across the SEACI region. The parameterised models can be used for various rainfall-runoff modelling applications, including future climate change impact assessment with new and improved projections.
- The project estimated the likely range of changes to catchment water yield and runoff characteristics by ~2030 relative to ~1990, for 0.05^o grid cells across the SEACI region. The methods and results will be published as a SEACI report and a journal paper. A summary of the method and key results is given in Objective 2 below.

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

Objective 1:
To assess simple methods for transforming climate outputs from GCMs to drive hydrological models

Most climate change impact on water resources studies involve the use of a hydrological model where: (a) the model is calibrated against historical streamflow data; (b) the model is driven with rainfall and PET series for a future climate using the same optimised parameter values; and (c) the modelled streamflows for the future and historical climates are compared to provide an estimate of the climate change impact on streamflow.

The climate change projections generally come from global climate models (GCMs). However, GCMs provide information at a resolution that is too coarse for direct use in hydrological modelling. Statistical and dynamic downscaling methods can be used to downscale GCM simulations to catchment scale rainfall, but they involve significant development, data needs and modelling run times. The simpler empirical methods, based on scaling or transforming a historical climate series to obtain a future climate series, offer a more immediate solution. Because they are simple to use, they can be applied to outputs from a number of runs of different GCMs, therefore taking into account the large uncertainties associated with global warming projections and GCM modelling of local climate.

This study assessed runoff results from a rainfall-runoff model driven with future climate inputs obtained from three simple scaling/translation methods for transforming climate outputs from several GCMs transient experiments: ‘constant scaling’; ‘daily scaling’; and ‘daily translation’. In the constant scaling and daily scaling methods, the historical rainfall and PET series are scaled by the changes indicated by the GCM to provide the future climate inputs. In the constant scaling method, the entire climate series (in each of the four seasons) is scaled by the same factor. In the daily scaling method, the different rainfall amounts are scaled differently, as indicated by the different changes to the different rainfall ranks/percentiles simulated by the GCM. In the daily translation method, a relationship between GCM simulation of the present climate and the observed catchment-scale climate is established (at the different rainfall ranks/percentiles) and this relationship is used to convert the future GCM time series simulation to catchment-scale rainfall time series.

The constant scaling method is used in most hydrological impact modelling studies due to its simplicity. The daily scaling method is likely to be a better method because it considers different changes to different rainfall amounts. This is potentially important because many GCMs indicate that the extreme rainfall in a future climate is likely to increase, even in some regions where the mean annual rainfall is expected to decrease. As high rainfall events generate significant runoff, the runoff estimated from the daily scaling method will be higher than that estimated by the constant scaling method. However, the results from this study indicate that the difference between the constant scaling and daily scaling methods is small compared to the mean annual runoff estimated using rainfall projections from different GCMs. In addition, GCM simulation of extreme climate and daily series is relatively poor compared to its ability to simulate the mean climate. The daily translation method considers changes in the sequencing of future rainfall time series, and runoff results from the daily translation method can be significantly different to the constant scaling and daily scaling methods.

In summary, the constant scaling method can be used in most applications to transform climate outputs from GCMs to drive hydrological models. However, where more detailed analyses of runoff distribution is required, the daily scaling and daily translation methods are potentially better, particularly if the GCM used have skill in modelling extreme rainfall and daily rainfall series.

Objective 2:
To develop future projections of catchment water yield and runoff characteristics across the SEACI region

This study developed future projections of catchment water yield and runoff characteristics for 0.05^o x 0.05^o (~ 5 km x 5 km) grid cells across the SEACI region. The hydrological modelling is carried out using two lumped conceptual daily rainfall-runoff models (SIMHYD and Sacramento), calibrated against streamflow data from about 219 catchments. The runoff for each grid cell is modelled using the optimised parameter values from the closest calibration catchment. The 1895–2006 daily climate data from the ‘SILO Data Drill’ (www.nrw.qld.gov.au/silo) are used to model the historical runoff.

The future climate series for ~2030 is obtained by scaling the historical 1895–2006 daily rainfall and areal PET data using the daily scaling method, informed by the IPCC SRES A1B global warming projection and 15 GCMs. The future climate series is then used to drive the SIMHYD model (using the same parameter values for modelling the historical climate) to estimate the future runoff (~2030 relative to ~1990).

The key results from the modelling are summarised below.

- The global warming by ~2030 relative to ~1990 in the IPCC SRES A1B greenhouse gas emission scenario is 0.9 ^{o}C.
- The mean annual APET in ~2030 relative to ~1990 will increase by 2 to 4 percent.

- There are considerable differences in the rainfall projections between GCMs, although the majority of GCMs shows a decrease in future mean annual rainfall. In the southern SEACI region, more than three-quarters of the GCMs show a decrease in future mean annual rainfall. Almost all the GCMs indicate that future winter rainfall will decrease.
- The projections from the 15 GCMs for future mean annual rainfall for ~2030 relative to ~1990 for the SRES A1B scenario range from a 10 percent decrease to a 5 percent increase (median of 2 percent decrease) in northern SEACI region (central and northern MDB) and a 10–15 percent decrease to no change (median of 5 percent decrease) in southern SEACI region (Victoria and southern MDB).
- The rainfall-runoff modelling using the rainfall projections indicate that future mean annual runoff for ~2030 relative to ~1990 for the SRES A1B scenario will change by -25 percent to +20 percent (median of -5 percent) in northern SEACI region and by -30 percent to 0 in southern SEACI region (median of -15 percent).
- The projected decrease in mean annual runoff in southern SEACI region is higher than in northern SEACI region because: the projected decrease in rainfall is slightly higher in the south; and most of the projected rainfall decrease is in winter when most of the runoff in the south occurs.

The method used here is very similar to the method used for the Murray-Darling Basin Sustainable Yields Project, but the results presented here are specifically for the SRES A1B scenario. The climate change projections are also similar to the CSIRO and Bureau of Meteorology projections (www.climatechangeinaustralia.gov.au) which use 23 GCMs compared to the 15 GCMs used here. It is likely that the use of fewer GCMs chosen based on their abilities to simulate present-day Australian climatology will give more consistent climate change projections, and this is being addressed in SEACI Project 2.2.3.

The method and the calibrated rainfall-runoff models can be used to estimate climate change impact on runoff for different future periods and different global warming scenarios, and to update results as climate change projections improve.

Summary of links to other projects

This project is very closely related to Project 2.2.1.

Climate change projections and climate inputs from other projects in SEACI Theme 2 can also be used to drive the hydrological models that have been developed for the SEACI region in this project.

Publications arising from this project

Chiew FHS (2006) An overview of methods for estimating climate change impact on runoff. Proceedings of the 30th Hydrology and Water Resources Symposium, Launceston, December 2006, Engineers Australia, CDROM (ISBN 0-8582579-0-4).

Chiew FHS, Post DA, Teng J, Vaze J and Perraud J-M (2008) Modelling climate change impact on runoff in southeast Australia. Journal Paper, In Preparation.

Mpelasoka F and Chiew FHS (2008) Runoff projection sensitivity to rainfall scenario methodology. Proceedings of International Congress on Environmental Modelling and Software (iEMSs 2008), Barcelona, July 2008, In Press.

Mpelasoka F and Chiew FHS (2008) Influence of rainfall scenario methodology on runoff projections. Submitted to Journal of Hydrometeorology.

Post DA, Chiew FHS, Vaze J, Teng J, Perraud J-M and Viney NR (2008) Future Runoff Projections (~2030) for Southeast Australia. SEACI Report, Completed and being assessed for publication.

Acknowledgement

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Project Milestone Reporting Table

To be completed prior to commencing the project				Completed at each Milestone date	
Milestone description[1] (brief) (up to 33% of project activity)	Performance indicators[2] (1- 3 dot points)	Completion date[3] xx/xx/xxxx	Budget[4] for Milestone ($)	Progress[5] (1- 3 dot points)	Recommended changes to workplan[6] (1- 3 dot points)
1. Rainfall-runoff modelling across study area for climate change impact assessment	Complete set-up of rainfall-runoff model for climate change impact assessment across study area	30/06/2007	35k	The SIMHYD rainfall-runoff modelling for climate change impact assessment has been set up to simulate daily runoff for ~ 5 km x 5 km grid cells across Australia.	

2. Projections of catchment water yield and runoff characteristics across study area for ~2030 and ~2070	Report/Paper on methods and data files of runoff projections for MDBC and DSE	31/12/2007	40k	Assessed runoff results from a rainfall-runoff model driven with future climate inputs obtained from different simple scaling and translation methods for transforming climate outputs from GCMs. Results have been written up as two research papers. Estimated the potential range of changes to catchment water yield and runoff characteristics by ~2030 relative to ~1990, for ~ 5 km grid cells across SEACI region. A SEACI report has been completed and a journal paper on the research is being written. The method and the calibrated rainfall-runoff models can be used to estimate climate change impact on runoff for different future periods and different global warming scenarios, and to update results as climate change projections improve. The 2030 runoff projections are shown as an indication of the potential impact of climate change on future runoff. In the method used here, the potential impact in 2070 is likely to be 2.5 times bigger than the impact in 2030 (A1B warming of 2.1^{o}C by 2070 compared to 0.9^{o}C by 2030). The actual numbers are only meaningful in the context of the application, and we have provided guidance to DSE and MDBC on this.	