

REGIONAL CLIMATE CHANGE PROJECTIONS FOR USE IN IMPACTS AND ADAPTATION RESEARCH IN SOUTH-EAST AUSTRALIA

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Abstract: *Aim* - NARClIM (NSW/ACT Regional Climate Modelling project) is a regional climate modelling project designed to provide regional climate change data for use in impacts and adaptation research across sectors.

Method - The climate models used were carefully chosen to satisfy the following criteria:

- The chosen models perform adequately for the recent past compared to observations.
- The chosen models do not exhibit the same strengths and weaknesses in their representation of the climate (i.e. they are independent).
- The chosen models span the plausible future climate change space.

Using these criteria, an ensemble of 12 high-resolution simulations was performed using three Regional Climate Models (RCMs) driven by four different Global Climate Models (GCMs). First a series of long hindcast simulations (60 years) driven by reanalysis boundary conditions were performed to evaluate the regional climate model performance. Subsequently, a set of three 20-year simulations driven by GCM boundary conditions were performed. The three simulations cover the periods 1990-2009, 2020-2039, 2060-2079.

Results - The ensemble is shown to span the range of uncertainty in the future climate change and can be used to inform risk assessments. The regional climate changes projected within NARClIM are compared to those obtained from the driving GCMs. Results show that regional scale climate influences can alter the projected future changes in various locations across Australia.

Conclusion - Climate change impacts or adaptation research that relies directly on Global Climate Model simulations may be using future climate changes that are not a good estimate for their area of interest.

Keywords: Regional climate model, climate change projection, south-east Australia, NARClIM

1 Introduction

Projections of future climate change are produced using global climate models as the climate system is inherently global in nature. Due to computational limitations these global models are run at horizontal resolutions of 150km² or more. At such resolutions the GCMs are not able to simulate local and regional features of the climate that may be important for understanding the impact on, and potential adaptation strategies for, various human and natural systems. In order to overcome this spatial limitation of GCMs, RCMs can be used to dynamically downscale the global climate projections to higher resolution with the intent of capturing these local and regional climate phenomena.

NARClIM (NSW/ACT Regional Climate Modelling project) is a regional climate modelling project for south-east Australia. It is providing a comprehensive dynamically downscaled climate dataset for at a resolution of 10km. The NARClIM ensemble was designed to provide climate projections at a scale that captures the local climate features and is relevant for climate change impacts and adaptation studies. It was also intended to span the range of uncertainty in future climate changes found in the full GCM ensemble, thus enabling risk based assessments. The data will be used by the NSW and ACT governments to design their climate change adaptation plans.

2 Methods

2.1 NARClIM ensemble design

Details on the NARClIM ensemble design can be found in Evans et al. (2014) and are summarized here. Given computational limitations a small set of GCMs and RCMs must be chosen to perform the downscaling. With this selection we aim to satisfy the following criteria

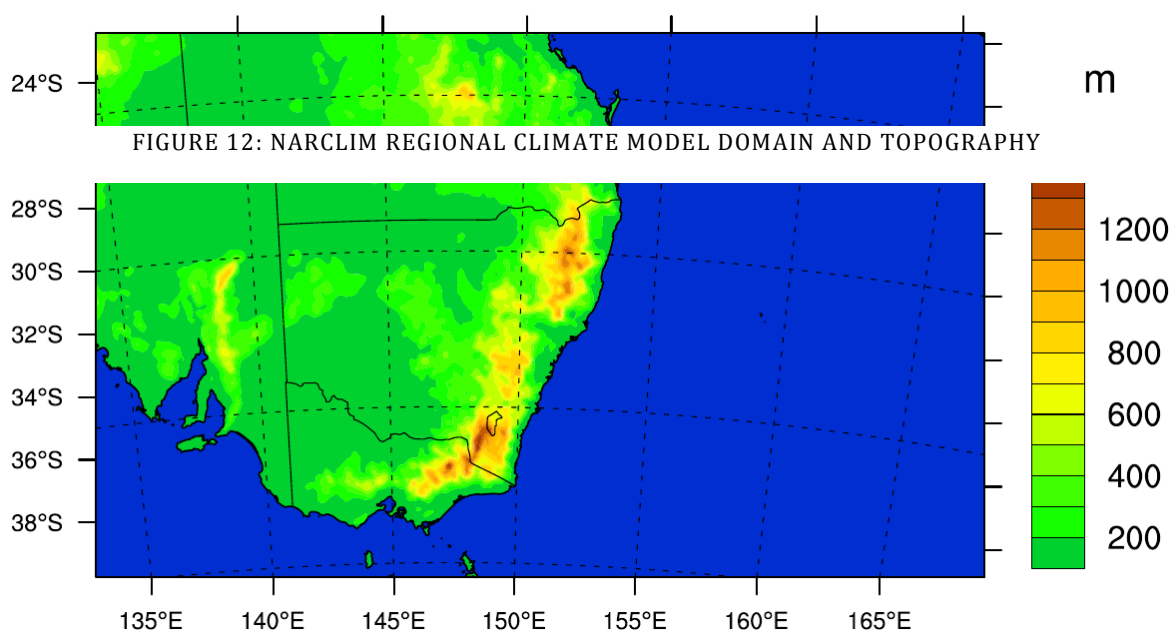
1. Models perform adequately for the recent past compared to observations.
 2. Models do not exhibit the same strengths and weaknesses in their representation of the climate (i.e. they are independent).
- And for the GCMs
3. Models span the plausible future change space.

In order to address these criteria in the selection of RCMs we investigated 36 different configurations of WRFv3.3. They were all run for eight 2-week periods that contained representative events for the region. Model performance was assessed using observations and analysis of five climate variables (precipitation, maximum daily temperature, minimum daily temperature, wind and mean sea level pressure) and multiple performance metrics. A subset of six models was found to perform consistently worse than the others and was excluded from possible selection. Model independence was quantified using a method based on the covariance of model errors (Bishop and Abramowitz 2013). Models whose errors varied most differently (independently) from the rest of the ensemble were chosen.

For GCM selection the model performance was assessed based on previously published evaluations relevant for the region. These were combined through a fractional demerit score where a score of 0.5 or above indicates poor performance. Models with such scores were removed from the selection process. The same independence measure that had been previously applied to the RCMs was then applied to the GCMs in order to identify GCMs whose errors are most different from others in the ensemble. This method has been found to produce desired ensemble characteristics such as minimizing error and maintaining ensemble variance (Evans et al. 2013). This independence ranking can then be placed within the GCMs future climate change space, here defined in terms of the change in temperature and precipitation, and the highest rankings that span the space were chosen in a subjective manner.

The RCM model domain and topography is shown in Figure 1. The domain includes most of the Tasman Sea as this is where many of the storm systems that are important on the east coast develop and evolve. The mountains of the Great Dividing Range are clearly visible with much of the detailed mountain peaks and valleys included. Smaller features such as the Flinders Range in South Australia are also present, such features are absent in the GCM simulations due to their low resolution.

2.2 Observational data and Climate regions



Model results are compared to gridded observations of temperature and precipitation from the Bureau of Meteorology's Australian Water Availability Project (BAWAP – Jones et al. 2009). This gridded dataset is used to identify climatologically similar regions within south-east Australia. The NARClIM domain was divided into 11 climatological regions using a multi-step methodology (Figure 2). The BAWAP data over the period 1950-2009 was selected as a reference. The methodology makes use of daily maximum and minimum temperature and precipitation and is aimed at identifying similarities in the probability distribution functions (PDFs) of these variables. Two clustering methods were applied to PDFs to define the regions: an agglomerative hierarchical clustering and a non-hierarchical k-means clustering.

Two advantages of using this multi-step method are that the number of subjective choices is reduced to the minimum possible, and that it is based on the most commonly used variables. Furthermore it makes the most of the strengths of each the steps and reduces the weaknesses traditionally associated with each of the methods. For instance, PDFs reduce information redundancy existing in the original data while merging information from different variables, hierarchical methods determine appropriate numbers of clusters and initial configurations to be passed on to the non-hierarchical method, and finally, k-means allows for recombination of clusters and uses information from previous steps for initialization.

3 Results

The NARClIM ensemble mean 2m temperature bias for the present day, calculated against the BAWAP observations, as well as the driving GCM bias, is shown in Figure 14. In both cases most of the land area has biases of $\sim -1^{\circ}\text{C}$. The GCM ensemble has biases of more than 2°C in areas with significant topography, while the RCM ensemble has biases reaching -2°C . The biases in mean

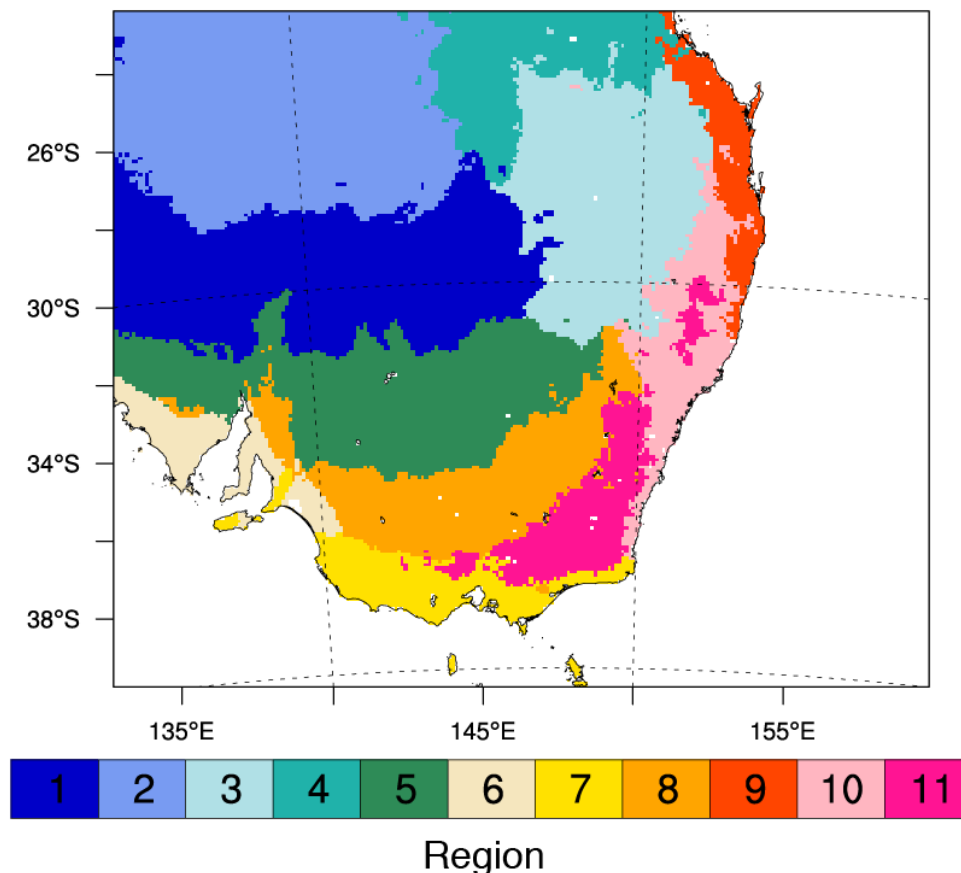


FIGURE 13: CLIMATE REGIONS OF SOUTH-EAST AUSTRALIA BASED ON THE SIMILARITY OF BAWAP TEMPERATURE AND PRECIPITATION FIELDS

precipitation are shown in Figure 15. Here we can see opposite biases in the GCM and RCM ensembles. The GCM ensemble underestimates the precipitation by more than -10mm/month almost everywhere, with large areas around the coast and Great Dividing Range under-predicting precipitation by more than -50mm/month. The RCM ensemble has a tendency to overestimate the precipitation everywhere. Most of southeast Australia does, however, display biases of less than 10mm/month, though in the north-east of the domain and on the highest mountain peaks these biases can reach 50mm/month.

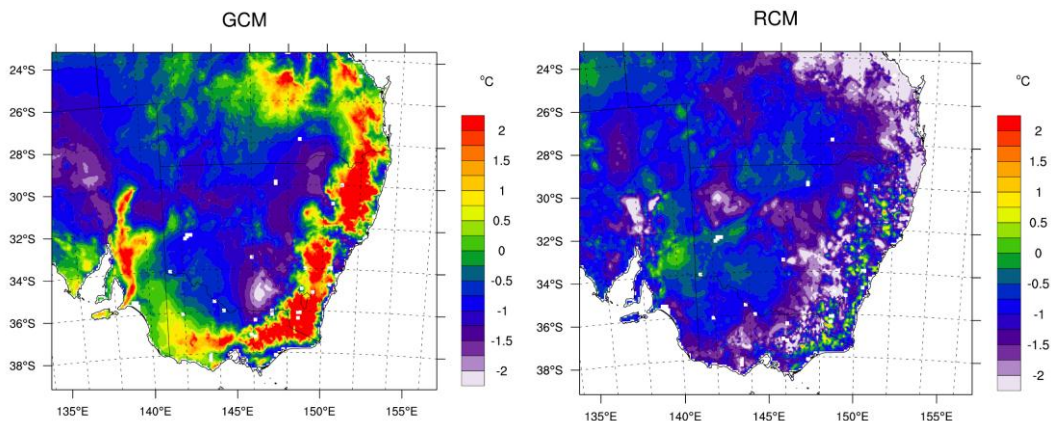


FIGURE 14: MEAN 2M TEMPERATURE BIAS: MODEL ENSEMBLE MINUS AWAP OBSERVATIONS (1990-2009)

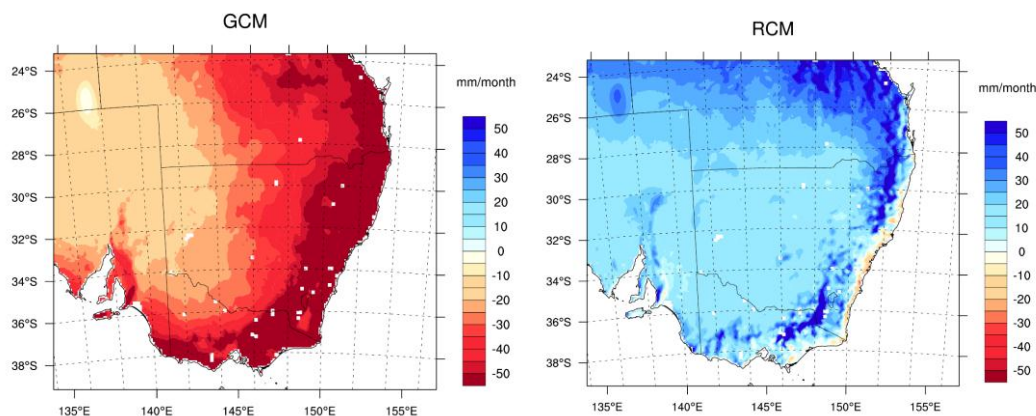


FIGURE 15: MEAN PRECIPITATION BIAS: MODEL ENSEMBLE MINUS AWAP OBSERVATIONS (1990-2009)

The GCM and RCM ensemble mean changes for 2m temperature and precipitation between the present day (1990-2009) and the future (2060-2079) are presented in Figure 16 and Figure 17. The general pattern of temperature increase is similar in the two ensembles with the GCM increase being 0.1-0.2K larger. The RCM ensemble also displays more fine-scale structure near the coast and mountain regions, particularly the Snowy Mountains. In some regions precipitation changes are similar, e.g. the drying in southern South Australia and Victoria, and the wetting in the north-west of the domain and through south-west Queensland and across much of NSW. In many locations this wetting is larger in the RCM ensemble. The two ensembles differ substantially in southeast Queensland where the GCM ensemble projects drying while the RCM ensemble projects a wetting with the area that is drying being pushed offshore to the east.

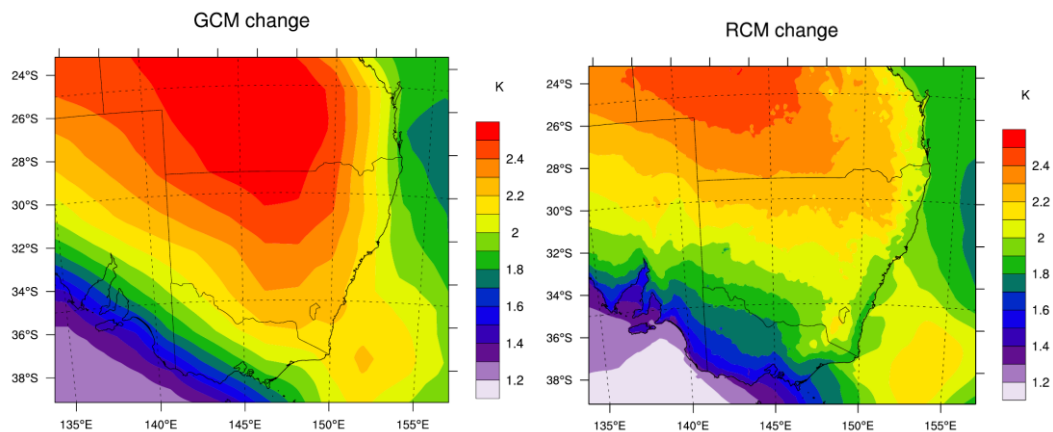


FIGURE 16: MEAN 2M TEMPERATURE CHANGE: 2060-2079 MINUS 1990-2009

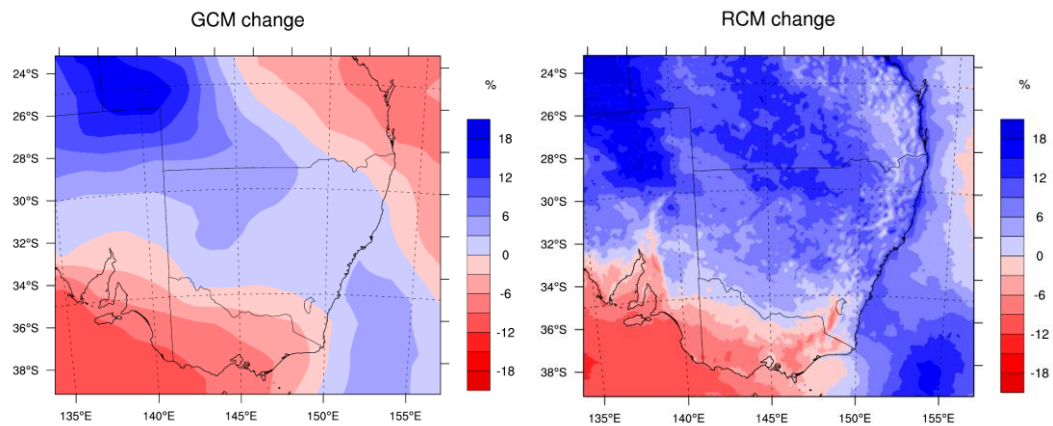


FIGURE 17: MEAN PRECIPITATION CHANGE: 2060-2079 MINUS 1990-2009

Comparing the changes from individual RCM and GCM simulations is done in Figure 18. Here you can see the mean change in temperature and precipitation averaged over regions 5, 7 and 10 (see Figure 2). Colours indicate the GCM (circles) and the RCMs driven by that GCM. Both region 7 and region 10 are coastal regions where we would expect the RCMs to better resolve the local climate processes. In region 7 the main difference between the GCM simulated changes and the RCM simulated changes is the $\sim 0.2\text{K}$ larger increase in temperature projected by the GCMs. Both ensembles project a decrease in precipitation with the RCMs showing a slightly smaller decrease. In region 10 the RCMs similarly project slightly less warming but in this case they more often project an increase in precipitation while most GCMs project a decrease. Similarly, for region 5, most RCMs project an increase in precipitation while most GCMs project a decrease. In this case the changes are not related to coastal or topographic influences but reflect a change in modelled processes such as atmospheric convection between coarse (GCM) and fine (RCM) spatial scales.

Figure 18 also serves to demonstrate some differences between the GCM and RCM ensembles in terms of risk analysis. Consider the case of a system with temperature related damages. We can see that the maximum temperature change that is projected by the RCM simulations is $\sim 0.4\text{K}$ smaller than the maximum in the GCM ensemble. Thus the RCM ensemble is projecting a lower risk for these systems. Next, consider the case of a system with drying related damages. The maximum drying projected in the RCM ensemble is $\sim 5\%$ smaller than that projected in the GCM ensemble, so again the RCM is projecting a lower risk for these systems. If however, your system is sensitive to precipitation increases then the maximum increase within the RCM ensemble is $\sim 10\%$ more than the maximum in the GCM ensemble, thus projecting a higher risk for these systems.

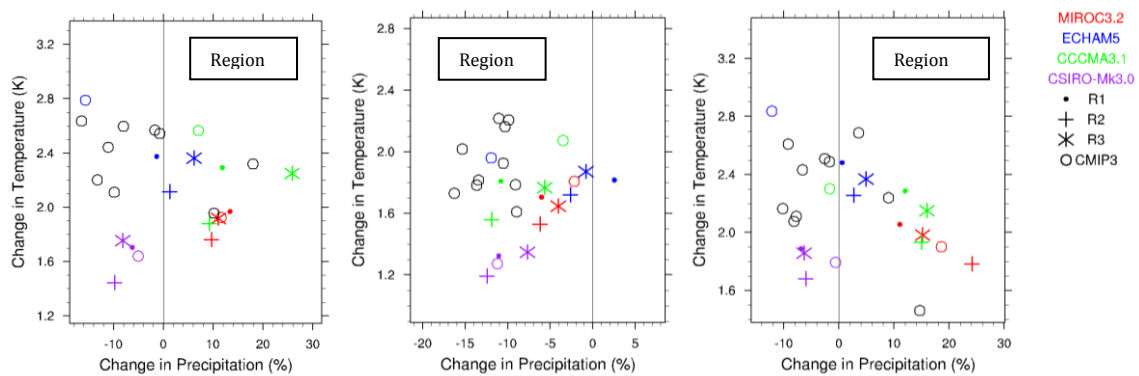


FIGURE 18: FUTURE CHANGE IN MEAN TEMPERATURE AND PRECIPITATION FOR THREE DIFFERENT REGIONS: REGION 5 (CENTRAL-WEST NSW); REGION 7 (SOUTH COAST); REGION 10 (SOUTH-EAST COAST)

4 Conclusions

NARClIM has created a high resolution regional climate projection ensemble for south-east Australia. Overall these regional projections have slightly less warming than the global projections between the recent past and ~2070. Projected changes in precipitation are location specific but in many places the regional projections are wetter than the global projections. These two overall differences are likely to be linked to each other.

Due to their higher resolution, NARClIM simulations produce more realistic climates, and more justifiable future changes, in locations significantly affected by regional scale climate processes such as near coastlines and in mountainous regions. It should be noted however that, even in locations distant from fine-scale surface forcings, the higher resolution means that processes such as atmospheric convection are modelled differently and can produce results that differ from the global models.

When performing risk analysis the systems of interest are often local in nature so the higher resolution of the NARClIM projections allows a more detailed examination of changes projected at that location. For the three regions examined here, compared to the global model ensemble, the NARClIM projections suggest a decrease in risk for systems sensitive to high temperatures or low precipitation, but an increase in risk for those sensitive to high precipitation.

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