# Pursuing high resolution downscaling for hydrological applications in the Victorian Climate Initiative (VicCI)

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The main objective of the Victorian Climate Initiative (VicCI) is to provide an improved understanding of the risks that climate change poses to water supplies and enrich the information that underpins current water resource planning decisions. Fine scale resolution dynamical downscaling has the capability to enhance such understandings, but what resolution is fine enough?

## Context

Following years of sustained drought conditions in southeast Australia, there is an expressed desire by the State government to improve the understanding of the nature and causes of climate variability in this region and the risks it poses for water supplies.

A general weakness in the methods applied in this region is the underestimation of 3-5 day rainfall totals and the magnitude of extremes (e.g. the persistence of rainfall events and their intensity), which leads to underestimation of high runoff events and the mean annual runoff.

Recent examples in the literature[1], have shown that improved spatial and temporal characteristics of rainfall can be obtained when using convective permitting fine resolution regional climate models (RCMs). Further, commonly known RCM problems, such as too much persistent light rain and errors in the diurnal cycle, are much reduced in fine resolution models[2]. There are however a number of drawbacks with the method, such as their heavy usage of computation and data storage resources. This typically implies that dynamical downscaling is run only for a selection of host GCMs and emission scenarios, which limits their ability to represent uncertainty in these components

To improve realism and credibility in rainfall and subsequent runoff projections in this region there is a wish to pursue fine spatial scale dynamical downscaling. But, what resolution is sufficiently fine to capture important spatial and temporal characteristics in rainfall in the context of producing runoff projections?

## Physics ensemble case study

To test the importance of spatial resolution in downscaling data for runoff projections, the Weather and Research Forecasting (WRF)[3] community model (version 3.5.1) was set up to conduct a series of experiments for selected case studies. The scales of interest are 3 and 10 km. These resolutions relate to the spatial scales where WRF is able to resolve convective motions in the atmosphere (<3km) and the finest resolution whereby it is advisable to use parameterised convection in WRF (>10km). WRF was set up to use three nested spatial domains, with a resolution of 50 km (d01), 10km (d02) and 2km (D03) respectively (Figure 1a). Ten configurations of WRF (in terms of physics options) were tested, focusing foremost on the sensitivity of the more complex microphysics options (see Table 1 and Box 1).

### Case study

This poster presents skill in simulating daily rainfall totals for model domains d02 and d03 for the first completed case study. This study representing a 2 week period in the cold season (April to October) case (8th to 21st of August 2010). During this period, rainfall is triggered by an upper level trough and low level cold front associated with a low pressure system developing on the 10th of August over Victoria, which moves westward over the next few days. Further passages of cold fronts occur during the period 15-17th of August (Figure 1b), and again on the 19th-20th of August.

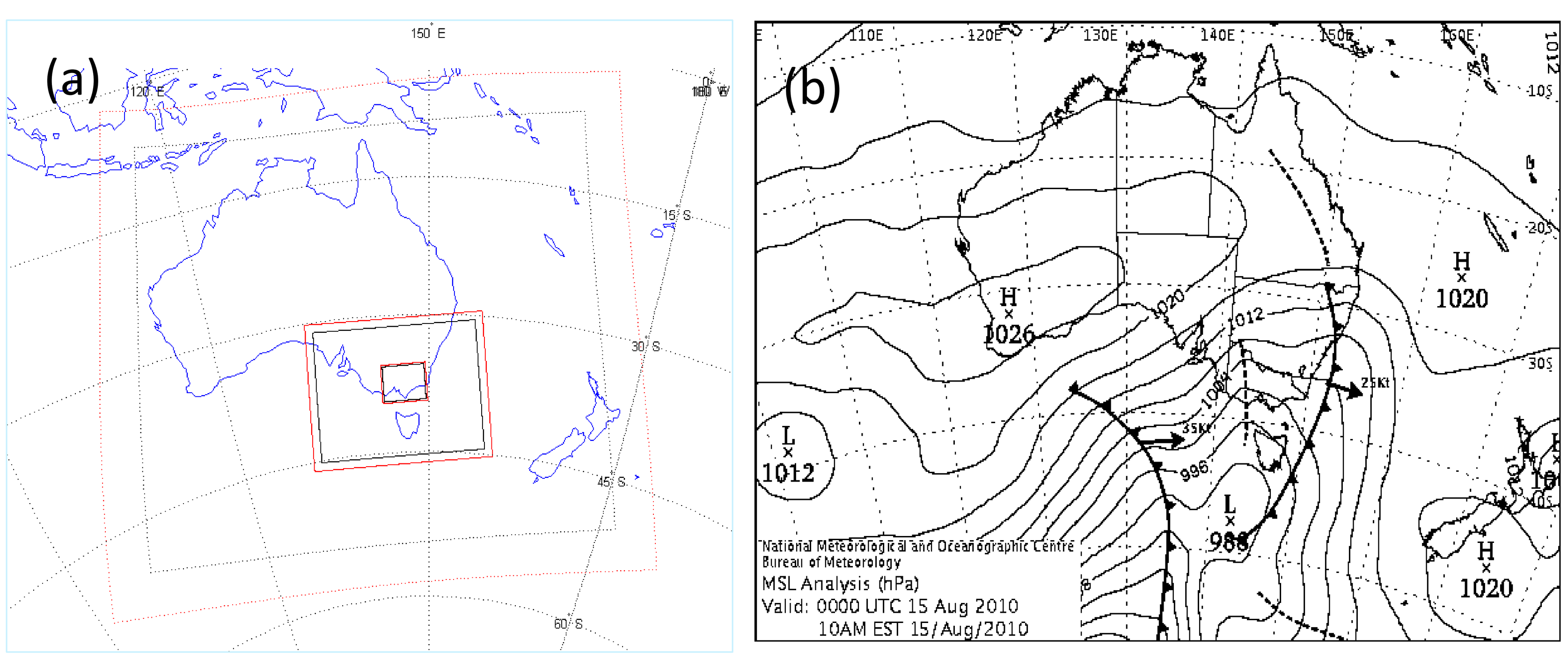


Figure 1: a) Spatial extent of the three model domains d01, d02 and d03 (in decreasing size). The red lines denote the outer boundary and the black lines outline the domain excluding the relaxation zone where information from bordering nests are blended. (b) Mean sea level pressure analysis (00UTC) from the 15th of August 2010. Source for b): The Australian Bureau of Meteorology online analysis chart archive.

Table 1: List of micro physics and planetary boundary layer (PBL) options for ensemble members N1-N10. Acronyms are spelled out in Box 1.

| ID | N1 | N2 | N3 | N4 | N5 | N6 | N7 | N8 | N9 | N10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Micro-physics | WDM6 | Thompson | Milbrandt | Morrison | NSSL | WDM6 | Thompson | Milbrandt | Morrison | NSSL |
| PBL | MYNN | MYNN | MYNN | MYNN | MYNN | YSU | YSU | YSU | YSU | YSU |

### Skill metrics

An initial evaluation of WRF performance focused on the simulation of daily rainfall totals, where WRF rainfall output was assessed against daily gridded observed rainfall from the Australian Water Availability (AWAP) project[4] available on a 5 by 5 km resolution grid. The evaluation was conducted on the native grid of the model; hence the AWAP data was re-gridded to the model domains d02 and d03. Further, model output was aggregated to daily totals matching the local time.

Model skill in simulating rainfall was assessed using skill measures adapted for deterministic categorical forecasts, i.e. for variables that are event based. Five measures were considered: bias, simple accuracy, false alarm ratio and threat score[5](Box 2). In addition to the simple scores, a more complex score is also considered, the Fractions Skill Score (FSS)[6]. The FSS metric is a spatial skill metric that attempts to compensate for the 'double penalty' problem, commonly experienced by simple scores when assessing skill on grid cell basis. Unlike the simple scores, the FSS metric conducts the skill calculation on fraction of rainfall occurring within a neighbourhood area.

### First results

For the first case study, ensemble members using mp-scheme NSSL became unstable and terminated (i.e., N5 and N10). Other ensemble members gave a good representation of the timing of events and overall rainfall totals falling within the model domain (Figure 2). In both domains, ensemble member N1 (mp scheme WDM6 in combination with pbl scheme MYNN) showed the closest resemblance to the observed totals (Figure 2).

The same ensemble member was also the (somewhat) better performer when considering the used skill scores. Overall, simulation of rainfall in the 10km domain appeared to have good skill as judged by a number of skill scores (Figure 3). However, model performance in the innermost domain (2km) proved worse (Figure 4), and a visual assessment of rainfall patterns indicate spurious striation in the rainfall pattern (not shown), which may be corrected by different choices of dampening or movement of the lateral boundaries away from complex topography. Further work will address the spurious patterns, complete all case studies and subsequently make recommendations for a multi-decadal GCM forced hind-case ensemble.

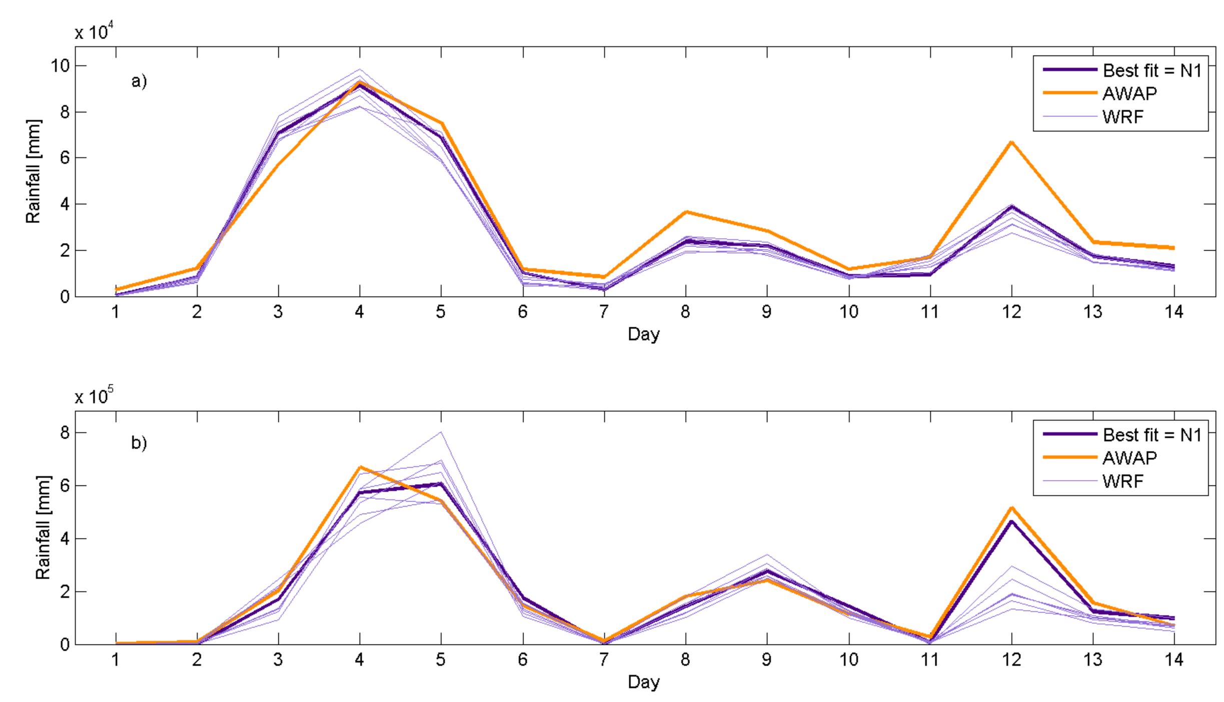


Figure 2: Temporal evolution of rainfall in domain (a) d02 and (b) d03. Blue lines indicate WRF simulations (thick line indicates best fit), orange line is observed (AWAP).

**Box 2: Simple skill scores depicted in Figure 3 and 4**

- Bias score (a measure of over/under simulation of rainfall); *A value of 1= unbiased forecast, whilst values smaller than one indicate under-forecast and values above one indicate over-forecast.*
- Simple accuracy score (fraction correct); *This score takes values between 0 and 1, where the best score is 1*
- False alarm ratio (fraction of simulated events that were false); *This score takes values between 0 and 1, where the best score is 0*
- Threat score (fraction of hits relative to all forecasted or observed events); *This score takes values between 0 and 1, where the best score is 1*

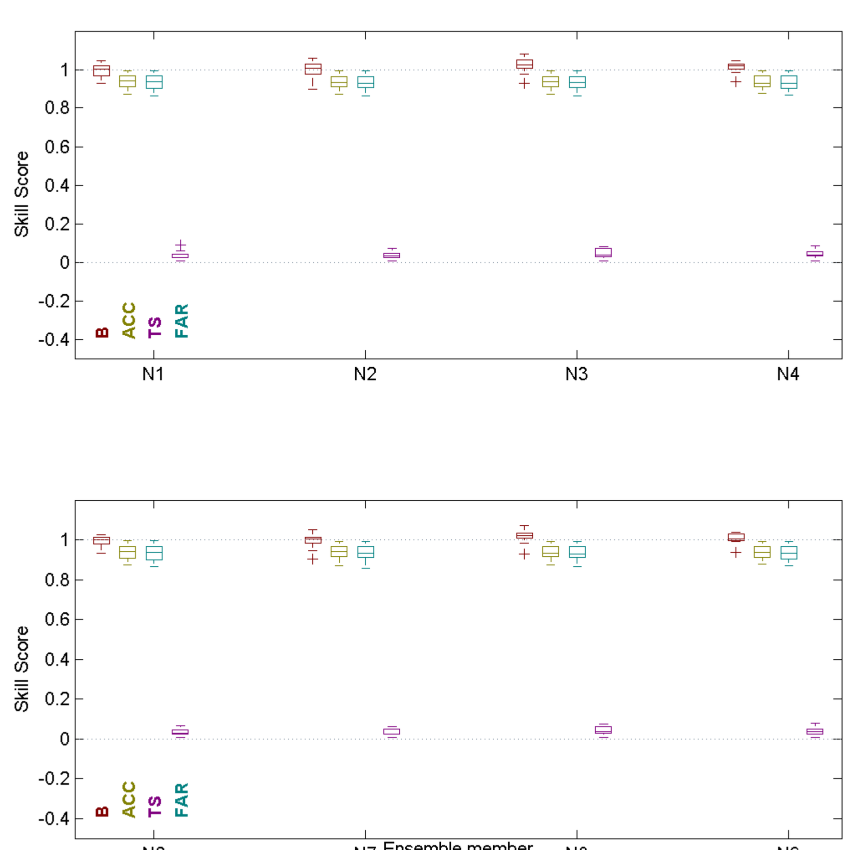


Figure 3: Simple skill scores for domain d02. Upper panel shows ensemble members N1-N4 (using pbl scheme MYNN) and lower panel shows ensemble members N6-N9 (using pbl scheme YSU). B=bias, ACC= simple accuracy score, FAR= false alarm ratio and TS= threat score.

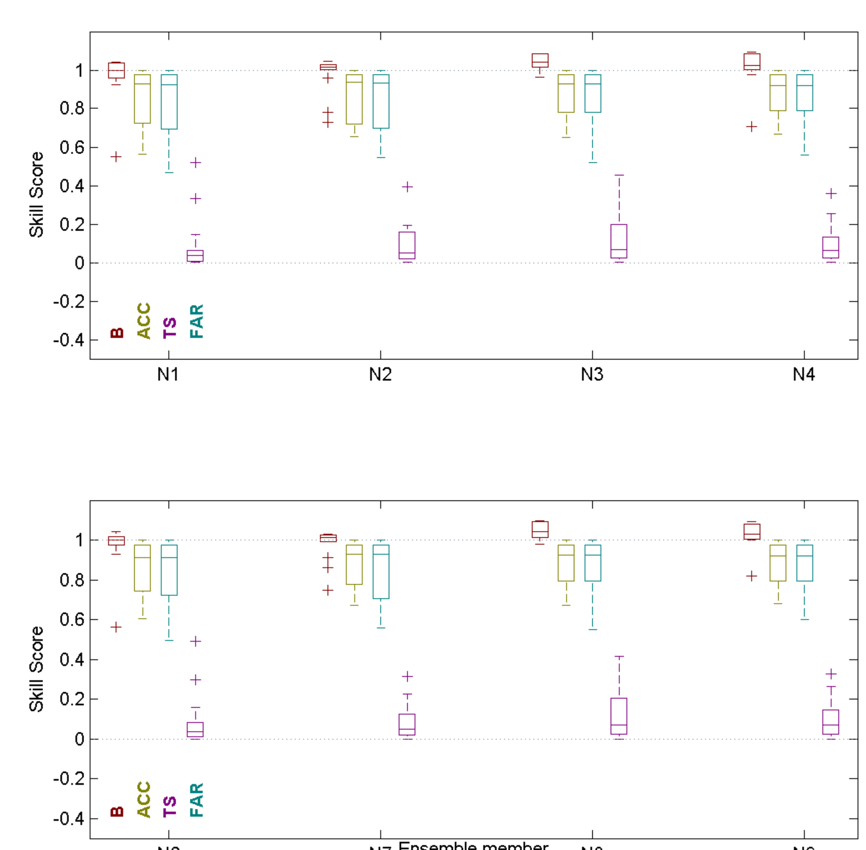


Figure 4: Simple skill scores for domain d03. Upper panel shows ensemble members N1-N4 (using pbl scheme MYNN) and lower panel shows ensemble members N6-N9 (using pbl scheme YSU). B=bias, ACC= simple accuracy score, FAR= false alarm ratio and TS= threat score.

**Box 1: Physics ensemble details**

Selecting physics schemes for WRF was made with the requirements for the fine-resolution innermost domain at focus. Guidance was sought from WRF support material and peer-review literature relevant for the VicCI case study in terms of it s geographical location and application[7]. The following schemes are common to all ensemble members: ***short and long wave radiation schemes***: the rapid radiative transfer model for GCMs for long and short wave radiation (RRTMG); ***land surface model scheme***: Noah Land surface model; ***cumulus scheme*** (d01 and d02): Betts-Miller-Janjic (BMJ); ***surface physics scheme***: fifth generation Penn State/NCAR Mesoscale Model (MM5); ***microphysics scheme*** (allowing 5 hydrometeors, some estimated using double moment schemes): the WRF double moment 6-class (WDM6) scheme, the Thompson scheme, the Milbrandt scheme, the Morrison scheme and the National Oceanic and Atmospheric Administration (NOAA) National Severe Storms Laboratory (NSSL) scheme; ***planetary boundary layer (PBL) scheme***: local closure scheme Mellor-Yamada Nakanishi and Niino Level 2.5 scheme (MYNN) and the non-local closure scheme Yonsei University scheme (YSU). References for each parameter scheme are given at: http://www2.mmm.ucar.edu/wrf/users/wrfv3.5/phys_references.html

**FOR FURTHER INFORMATION**

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**ACKNOWLEDGEMENTS**

The Victorian Climate Initiative (VicCI) is a three year State funded initiative involving the Australian Bureau of Meteorology and the CSIRO. The production of this poster is supported by a CSIRO Payne Scott Award, awarded to Marie Ekström in 2012.

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