

Title: Review of "Performance and process-based evaluation of the BARPA-R Australasian regional climate model version 1"

Howard et al. (2023)

Overall Recommendation: Minor Revisions

General Comments:

The paper provides a comprehensive assessment of BARPA-R's performance by downscaling ERA5 reanalysis data for Australia. It examines its representation of various climate variables (surface air temperature, rainfall, and 10-m windspeed), large-scale atmospheric circulation features, and weather systems. Overall, this paper provides a thorough and informative assessment of BARPA-R's performance in downscaling ERA5 for the Australasian region. The findings presented here contribute valuable insights into the model's capabilities and limitations, which will be essential for future climate change research applications.

Specific Comments:

Abstract

In the abstract, the authors indicate that the temperature assessment is performed in the Kelvin unit (e.g., line 10), but the analysis in the paper seems to be in degree C.

1. Introduction:

The paper outlines the need for high-resolution climate projections for hazard risk assessment in Australia. It discusses the need for coordination in high-resolution and accurate climate modelling efforts like CORDEX. They introduce BoM's BARPA-R, a regional climate model for Australasia, in the context of producing high-resolution regional climate projections for Australasia. The paper aims to present an assessment of the BARPA-R simulation using ERA5.

The research question is well-defined and relevant.

- Minor typos:
 - Line 28 – space after "risk".
 - Line 32 – change RCMS to RCMs.
- Line 34 – add McGregor 2005: CCAM: Geometric aspects and dynamical formulation. Technical Paper 70. CSIRO Atmospheric Research, Melbourne.
- The authors should mention and describe "the ESCI prototype" as they utilise it later in the discussion section to show BARPA-R's improvements.

2. Data and Methods:

The authors describe in detail the model domain, the experimental design and model configuration, initialisation and boundary conditions, as well as model formulation and coupling. They then introduce the reference dataset (AGCD, ERA5 and BoM's station data) and the evaluation methodology, which focuses on ICCLIM climate indices, seasonal additive

bias, annual multiplicative bias, climatological seasonal correlations and climatological spatial correlations based on NRM regions.

Overall, the "Data and Methods" section and the evaluation approach appear well-structured and comprehensive in their coverage of the research methodology, the reference dataset, and evaluation techniques.

- The authors could provide equations for the indices and metrics calculation.
- Minor typos:
 - Line 91 – “above ground level (AGL)” with capital first letters.
 - Line 131 – Remove the comma before "to a regular grid".

3. Performance Evaluation:

3.1. Mean State

The authors examine the mean-state bias maps of seasonal-mean diurnal maximum and minimum temperatures and precipitation and spatial and temporal characteristics of six temperature and four precipitation indices aggregated over the 8 NRM clusters. Overall, the "Mean State" section offers a thorough and well-structured evaluation of BARPA-R's performance in simulating the climate mean state and key climate metrics.

- Figure 2: The authors should improve labelling and caption – "TX, TN, and PRCPTOT" labels are misleading. One could assume these are indices, but they are referring to mean Tasmax as TX, mean Tasmin as TN and total precip as PRCPTOT; these need to be explained in the figure caption and in the running text (line 170). Also, indicate in the caption that the digits in the plots represent the averaged bias.
- Line 174 – The authors refer to a reduced diurnal range, which, I assume, is the difference between maximum and minimum temperature; they could elaborate on how they read this from the plots? Is that the case when Tasmin shows warm bias and Tasmax cold bias over a specific region? This could be explained in the running text; it's a bit confusing to me, and it might not be clear to everyone. Describing the Tasmin and Tasmax patterns separately (and referring to them as daily Tasmax/Tasmin) may be clearer than referring to "diurnal" patterns.
- Line 183: Is a reference missing "NWP (cite)"?
- Line 190: I assume with "daily maximums", the authors mean "diurnal maximum"?
- Line 190: It would be good to have some equations.
- Line 204-205: It would be good to have some equations.
- Line 205: Please indicate what SDII stands for and how it is calculated.
- Figures 3 and 4 – Please improve the caption: indicate what the indices abbreviations stand for, e.g., "number of summer days, SU, (with daily maximum temperatures exceeding 25 degrees C)", and so on.
- Figures 5 and 6 – Add units for "Delta".

3.2. Trend

In this chapter, the authors investigate the BARPA-R's ability to simulate climate changes, specifically focusing on its performance in reproducing observed trends in contemporary climate. The analysis presented in this section provides valuable insights into BARPA-R's performance in simulating climate trends. The agreement between BARPA-R and AGCD for temperature-related indices is encouraging, though the discrepancies for minimum temperature-based indices need further investigation. The challenges in simulating extreme rainfall events noted in the warm season are essential findings, and the potential reasons behind this should be explored further, which is probably done in the paper's discussion section?

3.3. Interannual Variability

The section focuses on three major modes of interannual climate variability, especially during the Austral Spring, which is highly relevant to understanding the performance of BARPA-R in capturing significant climate drivers in the Australian region. The results suggest that, overall, BARPA-R performs well in simulating the teleconnections associated with ENSO, IOD, and SAM.

The authors could consider exploring the sensitivity of BARPA-R to different model configurations or parameters, which may help improve its performance in capturing interannual temperature variability associated with ENSO.

- Line 251 – what is meant by "diurnal maximum temperatures"? Is it daily Tasm_{max}, or the range between Tasm_{max} and Tasm_{min}? Maybe the authors could avoid using the term "diurnal", as it might confuse some.

3.4. 10-meter Winds

The section comprehensively evaluates BARPA-R's performance in simulating 10-metre wind speeds. The improvement in high percentile wind speeds compared to ERA5 (reference) is a positive finding, indicating that BARPA-R better captures extreme wind events in many regions. However, the persistent underestimation of calm weather conditions suggests that there is still room for refinement. The authors could explore whether model parameterisation or resolution adjustments can address this issue?

- Line 262 – remove space between 1 and 0 "of 1 0m AGL".
- Figure 8. – Is it possible to make this plot larger? The labels are hard to read.

4. Process Evaluation:

4.1. Circulation

This section shows that the four identified large-scale circulation features are present in both BARPA-R and ERA5 (reference), and their seasonal cycles match. Identifying biases and discussing their potential causes contribute to a better understanding of model limitations

and areas for improvement. How can the biases related to the monsoon westerlies and the SPCZ be addressed?

- Line 301 – Remove TODO "(not shown, TODO)"?
- Figure 9 – Change the labels "barpa" and "era5" to upper case. And add colour bar labels.
- Tabel 1 – Captions for tables are placed above the table.

4.2. Weather Systems

The authors investigate BARPA-R's performance in simulating key large-scale weather systems that influence Australia, including tropical and extra-tropical cyclones and Australian Northwest Cloud-Bands (NWCBS). While extra-tropical cyclones are generally well represented, biases and decoupling of interannual variability are observed for tropical cyclones and NWCBS. Addressing these issues and further investigating the causes would enhance the overall understanding of BARPA-R's capabilities in simulating important weather systems in the Australasian context.

- Line 325 – What are these direct observational products? I think they are listed in the caption of Figure 10, but they need to be mentioned here as well.
- Line 325 – The authors say that Obs are replacing ERA5, but as they mention in the caption of Figure 10, ERA5 is a part of "Obs". Please clarify.
- Line 339 – The first letters in upper case "outgoing longwave radiation (OLR)"
- Line 344 – Please mention that ERA5 is part of "Obs"? Because you say in line 325 that Obs are replacing ERA5.
- Tabel 2 – Captions for tables are placed above the table.
- Figure 10 – Please add labels to the colour bars.
- Figure 10 – This part of the captions is not clear: "NWCBS (red lines; contour interval: 1 event/season, first contour: 2 events/season)"

5. Lagged Temperature-Precipitation Relationship:

In this section, the authors calculate Spearman's ranked correlations with a lag time of ± 10 days between diurnal temperature and precipitation outputs, focusing on DJF and JJA over different NRM clusters, and demonstrate that BARPA-R's capability to capture multivariate relationships, particularly between temperature and precipitation, as compared to observational and reanalysis datasets. However, there are regional variations that may have implications for climate impact assessments. How could these discrepancies be addressed? And what are the practical implications of these findings for climate impact assessments?

- Line 370 – Maybe use the term daily temperature-precipitation relationship instead of "diurnal"; it can be confusing.
- Figure 11 – Please add a legend.
- Figure 12 – Caption typo: minimum temperature instead of maximum temperature
- Line 376 – Add the abbreviation "precip" after rainfall, as you start using it in the paragraph below.

- Line 392 – Remove the dot after "(Figure 12 f-h)."
- Line 398 – Remove "between the two variables", it's a repeat.

6. Discussion and Conclusion:

Overall, the discussion provides a comprehensive summary of the key findings and implications of the study. It effectively communicates the strengths and weaknesses of BARPA-R, highlights improvements over previous RCMs, and underscores the importance of hazard analysis and ongoing work in downscaling CMIP6 GCMs. The conclusions drawn are well-supported by the study's results and contribute valuable insights to the field of regional climate modelling in Australia. The conclusion highlights the significance of the study and suggests avenues for future research.

The authors could consider providing a more detailed discussion of the potential reasons behind BARPA-R's limitations, and the specific discrepancies observed between BARPA-R and the reference data and recommend potential strategies to address these limitations, e.g., exploring the sensitivity of BARPA-R to different model configurations or parameters.

- Line 423 – Why is the cold bias referred to as "1K" when the analysis was in degrees Celsius?
- Line 429 – The authors mention the ESCI prototype for the first time here. This needs to be referenced and briefly described in the introduction, too.
- Line 431 – Add "C" after -1.1 degrees.

7. Citations and References:

The references are appropriate.

Recommendation:

I recommend that this journal paper be accepted for publication after addressing the minor revisions suggested above.