

## 1. Response to general comments from Reviewer R2

*The "BARRA v1.0: Kilometre-scale downscaling of an Australian regional atmospheric reanalysis over four midlatitude domains" paper evaluates the performance of high resolution downscaled regional reanalysis datasets over four Australian cities, collectively BARRA-C, derived from the coarser resolution continent-spanning BARRA-R dataset.*

*The paper rightly points out the relative lack of very high resolution, in this case, kmscale, reanalysis datasets over Australia (and the Australasian region in general) and goes on to evaluate the four BARRA-C domains against observational datasets on annual and seasonal timescales and for case study events, acknowledging the inherent biases often present in these km-scale models.*

*Recommend acceptance for publication in GMD with consideration for the following comments and revisions (mostly around readability).*

We would like to thank the reviewer for their careful review and positive recommendation for this paper. We respond to the comments, in turn below, which we believe have improved our first submission.

## 2. Response to specific questions from Reviewer R2

1. *Throughout the text the phrase "km-scale" and "kilometre-scale" are interchanged. Advise picking one form and sticking with that.*

Agree to use "kilometre-scale" consistently.

2. *Section 1, Line 30: consider changing "over global models" to "beyond current global models" and highlight some of these new insights*

Agree to make the textual change with the revised text:

*"Similarly, CPMs have provided new insights in regional climate projections (e.g., Argüeso et al., 2014; Prein et al., 2015; Kendon et al., 2017; 2019) beyond current global models. For instance, regional CPMs have suggested that future increases in short-duration precipitation extremes are larger than what can be expected from increases in atmospheric moisture alone (Kendon et al., 2021 and references therein). Major efforts are underway toward refining the horizontal resolution of global climate models to kilometre-scale (Schär et al., 2020)."*

3. *Section 1, Line 33: change "four km" to "four kilometres"*

Agree.

4. *Section 1, Line 55: remove comma in "instruments, to form"*

Agree.

5. *Section 1, Line 63: consider changing "Higher resolution reanalyses is needed" to "Such scales are needed"*

Agree.

6. *Section 1, Line 72: consider changing "Germany with assimilation of conventional" to "Germany, assimilating conventional"*

Agree.

7. *Section 1, Line 72: consider changing "rain rates and demonstrated improved" to "rain rates, demonstrating improved"*

Agree.

8. *Section 1, Line 76: consider changing "scale finer than coarser-resolution" to "scale finer than those of coarser resolution"*

Agree.

9. *Section 1, Line 87: consider changing "10 minutes" to "10 minute"*

Agree.

10. *Section 2, Line 103: change " includes 4 " to "includes four"*

Agree.

11. *Section 2, Line 109: consider changing "to hot summer" to "to hot summers" and "differs with cooler" to "differs with a cooler"*

Agree.

12. *Section 2.1, Line 124: consider changing "model in BARRA-C" to "model used in BARRA-C" and remove comma after "time step"*

Agree.

13. *Section 2.1 details differences between the BARRA-R and BARRA-C model configurations and compares these to the RAL1 science configuration, now available in the Unified Model. Given neither BARRA-R nor BARRA-C uses RAL1 as the core science configuration, not convinced this adds much to the discussion about the performance of BARRA-C, other than to point out a newer science configuration is available for use. This discussion might make more sense if some BARRA-C runs had been done using the RAL1 configuration and comparative results presented. Otherwise would be consider re-wording to describe the OS36 science configuration used by BARRA-C.*

BARRA-C configurations are presented relative to the RAL1 configurations of Bush et al. (2020) because RAL1 is the first defined and published version of the model in a regional set up. To our best knowledge, the OS36 is not defined in a prior published work, but the closely related version OS37 is used as the baseline in Bush et al. (2020) to assess RAL1. The BARRA-C model includes many of the component configurations as RAL1 but Table 1 identifies their differences. Accordingly, the BARRA-C model can be described without needing to completely rewrite the detailed descriptions found in Bush et al. (2020).

However, we appreciate that the impact of the RAL1 configuration differences should be made clearer. In Sec. 2.1, we expand on this to highlight these impacts for differences in stochastic perturbations of moisture, land surface representation and treatment of gaseous absorption. The added text is

*“The mid-latitude version of RAL1 therefore includes stochastic perturbations of temperature and moisture and relative weak turbulent mixing, to encourage the model fields to be less uniform and help convection to initiate. It is of note that the stochastic perturbations of moisture are absent in BARRA-C, and thus may still suffer from the initiation issue. [...] BARRA-C however does not include a set of changes to the representation of the land surface and the canopy radiation model in RAL1, which have shown to improve the issue of damped diurnal cycle in near-surface temperatures. BARRA-C also does not benefit from the improved treatment of gaseous absorption in both long- and short-wave regimes in GA7 and RAL1, which improves interaction with band-by-band aerosol and cloud forcing.”*

14. Section 2.2, Line 183: consider changing "benefits of analysis in BARRA-R is inherited" to "benefits of the BARRA-R analysis is inherited"

Agree.

15. Section 2.2, Line 190: consider changing "to the UM grid" to "to the BARRA-C UM grids."

Agree.

16. Section 2.2, Line 192: consider changing "In other words, the" to "Therefore the"

Agree.

17. Section 2.2, C2 Line 193: consider changing "considered short, and is chosen to meet computational constraints and regular reinitialisation is needed" to "considered short, but is chosen to meet computational constraints with regular reinitialisation needed"

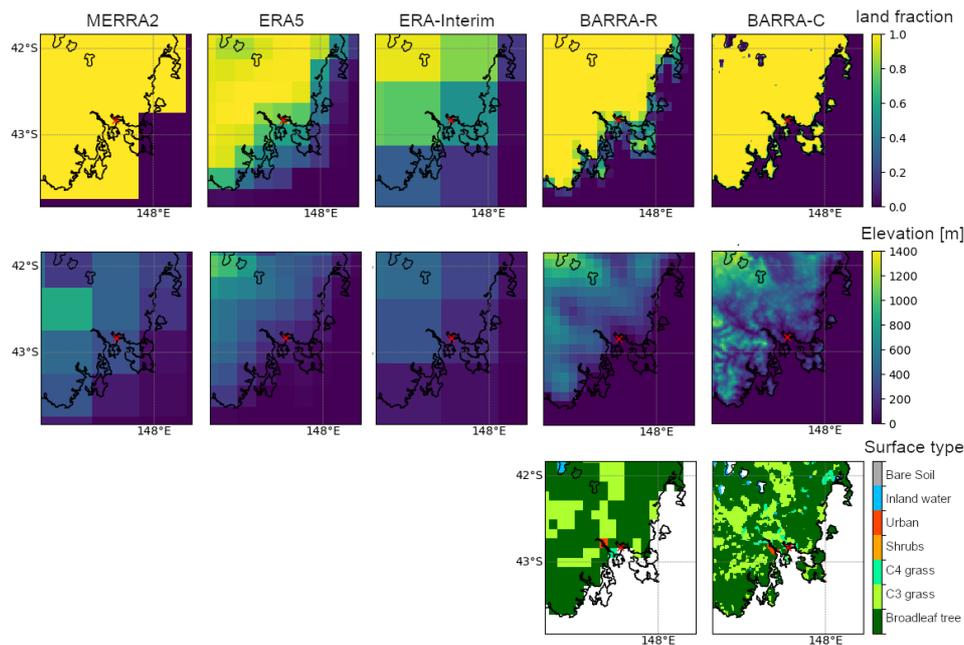
Agree.

18. Section 3.2 As part of the discussion comparing BARRA against AWAP observations, the authors begin to discuss the impact that choosing the closest model grid cell to an observation location can have on validation results, especially if the closest model grid point is of a different land use type or not even a land point at all. At this point, it would be good to see in a bit more detail about the datasets used to define these characteristics and, at least for one observation site, how different these land cover fractions or land use types are across the BARRA models. Can this assertion be backed up? Could be added to the Supplemental material.

In view of the comment R1#8 from the first reviewer on added value analysis, we have expanded this local-scale analysis of extreme temperature to become a part of this analysis in Sec. 3.6. In particular, we expand this with the added value analysis (see reply to comment R1#8) to look at warm extremes, cold extremes and wet extremes across the domains, not limiting to few selected locations. We move Figure 5 and the local-scale analysis to the Supplement, where we can add illustrations of the differences in land fractions, topography and surface cover types for Tasmania as an example to illustrate differences between the models. The Supplement notes,

*“The closest model grid cells are selected, and due to differences in spatial resolution, not all models treat these cells as land points, and even as a land point, they are treated with different land fractions. These affects how representative they are simulating temperature seen at the local scale. Figure S9 illustrates this for Tasmania, where the associated grid cell land fraction varies between*

0.55 (BARRA-C) to 0.8 (ERA5) and the elevation varies between around 2 m (BARRA-C) to about 200 m (ERA reanalyses).



**Figure S9: (top) land mask or fraction of the various models centred at the Hobart Airport (red crosses), Tasmania, (middle) their orography, and (bottom) domain surface cover types for BARRAs.**

“

19. Section 3.4, Line 299: consider changing "in all but TA domains." to "in all the TA domain."

Disagree. To improve clarity, the text is revised as "in all the BARRA-C domains but TA."

20. Section 3.5, Line 318: consider changing "blended with the gauge" to "blended with gauge"

Agree.

21. In relation to Figure 9(v), despite being orographically tied, is there anything that stands out about the storm case that might lead to BARRA-R rainfall performing markedly different from BARRA-C in this case, and from the other BARRA-R storm events shown?

The storm case in Figure 9(v) is the only summer case shown (i-v) and was attributed to one of a series of surface troughs on the NSW coast that month and positive temperature anomalies. The role of daytime convection in this case may lead to a more pronounced difference in rainfall between BARRA-R and C models compared to the other cases. The BARRA-C rainfall better matches the Rainfields rainfall accumulations in both amount and spatial pattern. BARRA-R rainfall lacks organisation which can be attributed to the lower resolution and the convective parametrisation scheme. Additionally, the lack of mass conservation in the convective parametrisation used in BARRA-R may have led to the spurious extreme rainfall amounts in the Blue Mountains area in Figure 9(v,c) (>256mm accumulation totals). We have added a brief note in Section 3.5 to this effect.

22. Section 4, Line 349: consider changing "positive (negative) bias during light (strong)" to "positive (negative) during light (strong)"

Agree.

23. Section 4, Line 354: change "reference therein" to "references therein"

Agree.

24. Section 4, Line 365: be consistent with use of "z" or "s" in parameterization/parameterisation throughout the document

Agree.

25. Section 4, Line 368: consider changing "in other studies; Lean et al. (2008) and Hanley et al. (2016) found that" to "in other studies. For example, Lean et al. (2008) and Hanley et al. (2016) found that"

Agree.

26. Section 5, Line 417: consider changing "pressure-level grids from BARRA-C" to "pressure-level gridded data from BARRA-C"

Agree.

27. Section 5, Line 427: consider changing "albeit high rainfall bias exists." to "albeit with high rainfall bias."

Agree.

28. Line 441: consider changing "UM is available" to "The UM is available"

Agree.

29. Line 445: consider changing "available as part of the version 3" to "available under Version 3"

Agree.

30. Line 455: consider changing "are subjected to" to "are subject to"

Agree.

31. For general consistency across the document should decide whether all URLs are to be hyperlinks or plain text. Currently have a mix of both formats.

Agree to remove hyperlinks.

32. Figure 1: for clarity, worth changing last sentence to "Red dots indicate the location of the state capital cities."

Agree.

33. Figures 2, 4 and 8 are quite hard to read as printed. Wonder if these would benefit from changing to a landscape orientation. In Figure 8 especially, it is hard to see the black curves indicated in the caption and these means are not mentioned in the manuscript otherwise that I noticed.

Agree. Figure 2 will be changed to a landscape orientation. Figure 4 will be split up into two figures, one on daily maximum temperature, and another on daily minimum temperature. The arrangement of Figure 8 will be improved to make the subfigures bigger so that the black curves are more visible.

*34. Figures 3 and 7: consider changing "AWAP grid with the nearest neighbour" to "AWAP grid using the nearest neighbour"*

Agree.

*35. Figure 5: consider changing "in each domain" to "in each BARRA-C domain". Also remove/add extra spaces in the coordinates of each city for consistency.*

Agree.

*36. Figure 10: change "6h" to "6-hour" for consistency with rest of the document. Wonder if the last sentence in the caption is best moved to the main text of the manuscript as part of the main discussion (Section 3.5) rather than left in the Figure caption.*

Agree. We also find the sentence needs to be expanded to explain the details of the thresholding for FSS calculation better. To this end, we move the sentence to the Supplement, and expand this.