

Interactive comment on “Precipitation bias correction of very high resolution regional climate models” by D. Argüeso et al.

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We thank all the reviewers for their suggestions, remarks and discussion, which has definitely strengthened and improved this paper. We consider that the manuscript is now easier to follow as well as more rigorous. All three reviewers are generally positive and highlighted that the manuscript is well written and concise. They also believed that the manuscript has potential influence in the field. Two major concerns are shared by most of the reviewers: a) The fact that the model could still produce fewer days than the station observations and thus the problem is not completely solved but reduced and b) the selection of the parameters. We paid especial attention these two issues both in our replies and the revised version of the manuscript. We also tried to address

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all remarks by the reviewers.

Reviewer comments are here repeated in **boldface**. Our replies to the reviewer follow in normal typeface.

The manuscript tries to call attention to the existing assumption used to bias-correct regional climate models' precipitation, which is that the RCM produces the same or a higher number of rain days than the observational datasets (e.g. gridded datasets). However, with higher resolution RCM, this assumption will be invalid. The higher resolution RCM will produce fewer rain days than the gridded observation. To offer a solution for this emerging problem in future simulation, the manuscript proposes a method to use station data directly to correct the very high resolution RCM outputs. In general, this manuscript is well written and has potential influences on the community. Therefore, the suggestion is to accept this manuscript, with minor revision. There are some details required to be described explicitly. General Comments:

1. It is understandable to use gridded dataset to do the regionalization by using the multi-step method, due to its continuity in space and time. However, the reference data used to regionalize climatological affinity of precipitation is crucial in interpreting the final results. Therefore it is important to explain why use the AWAP data set to do the regionalization, instead of using station data. Is it simply due to data continuity issue or is there any other issue? If only AWAP data set can be used, at least, the check on comparison in monthly climatology of precipitation in different region, between the AWAP and the station data should be implemented.

We acknowledge that gridded datasets do not always represent the in-situ observations accurately, especially when the spatiotemporal coverage of the observations is relatively poor. Despite the fact that the observational network in the region and in the period of interest are of good quality, there are some differences between the in-situ

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and the gridded observations. Indeed, this could be regarded as an additional reason why stations should be used instead of gridded datasets to bias correct high-resolution model outputs, because the spatial representativeness of the stations is closer to the spatial scale of the model output.

In our study, AWAP dataset is only used to identify areas with similar precipitation regimes. The main reason to use AWAP for this purpose was, as pointed out by the reviewer, its temporal and spatial completeness. Figure 1 (in this comment) shows the annual cycle for all 5 regions from GHCN and AWAP. Two versions are provided for AWAP: Using only the grid points nearest to each of the stations (AWAP) and using all grid points within a region (AWAP_all). The similarities in the climatologies from the two datasets suggest that the choice between stations and AWAP has only a minor impact on the definition of regions, but AWAP provides a better coverage.

A sentence mentioning this comparison has been added to the text, which now reads:"...The monthly climatologies of AWAP precipitation averaged over the grid points from each of the regions are illustrated in Figure 4 to show how different their rainfall regimes are, particularly during the first half of the year. A comparison between AWAP and GHCN monthly was also conducted to verify their consistency (supplementary material). Using the regionalisation. . ." The figure has also been added to the manuscript as supplementary material.

2. Before doing the comparison mentioned above, the general comparison (e.g. pattern in time and space) between the two datasets will help readers understanding more about the data set.

We agree with the reviewer that the quality of the gridded dataset must be assessed by comparing with stations. Such an assessment was provided in the original paper that introduced the dataset (Jones et al. 2009), as well as in a subsequent publication (King et al. 2013). We consider that sufficient validation of the gridded dataset has already been performed and including further assessments provides little added value

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to the paper while affecting the conciseness. The papers addressing the comparison between datasets are now cited in the manuscript.

3. The approach has been described very clearly. However, the mathematic forms related to the algorithms should be present in details. It is important for readers who are interested in the methodology, and tries to repeat the same approach with their own datasets. Please list all equations related to the methodology used for the new paradigm.

The equations used in the algorithm have been included in the manuscript and its terms explained in the text.

4. Why the 5 nearest stations? Why not 3 or 6? Please discuss more on this point.

Please see comment #6

5. Why the penalty factor is 0.5? Why not 0.7 or 0.1? Please discuss more on this point. The determination of the threshold value is important.

Please see comment #6

6. Instead of saying 5 nearest stations or a penalty factor of 0.5, the sensitivity analysis on the choice of the number of the nearest stations, or the penalty factor should be implemented to enrich the content of the manuscript.

We carried out a sensitivity analysis to determine the impact of the choice of both the penalization parameter and the number of nearest stations. Ten possible combinations of these two parameters were selected and their performance was investigated. In particular, three values of the penalisation parameter (0.1, 0.5 and 0.9) and three values of the number of stations (3, 5 and 7) were examined, which yield 9 possible combinations. An additional configuration using a single nearest station is also included (penalisation does not apply in this case).

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The bias correction was applied 50 times for each of the parameter configurations removing a random 10% of the stations each time as a means of perturbing the corrected solutions and thus studying the method sensitivity to these choices. Figure 2 (in this comment) illustrates the results of this sensitivity analysis through two different statistical measurements. Corrected WRF outputs were compared with GHCN (each station with the nearest grid point) on seasonal timescales and the mean absolute error (MAE) is calculated averaging over all stations and all seasons to generate a boxplot including the 50 realisations of the bias correction for each of the parameter configurations. The pattern correlation is also calculated to measure the spatial pattern similarity between corrected WRF outputs and AWAP, and also represented using a boxplot.

The seasonal MAE shows that the choice of the parameter has a minor impact on the results and all possible configurations give a similar value (~ 8 mm/month), including the use of a single station, for which penalisation does not apply. However, the analysis of the pattern correlation reveals that in this particular case, the spatial structure is better represented using more than a single station, showing a very slight decay with larger penalisation values. The stability of the method with respect to the parameters is probably enhanced by the network density and the inverse distance weighting, which tends to give much larger importance to closer stations. In this particular case, we have chosen a moderate number of stations and penalisation in order to provide a test of the method. The sensitivity test suggest that different choices should not significantly affect the results, although this is likely dependant on the characteristics of the region and the network and thus different values might be more suitable under different conditions.

We have included a sentence on the manuscript to mention that the method was found to be slightly sensitive to the choice of the parameters, except that the use of several stations is generally preferred to improve the spatial structure of precipitation climatology. Figure 2 in this comment was also added as supplementary material.

Minor Comments:

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1. On page 8152, in line 21, the author mentioned the topography effect. However, what is the detail related to this topography effect is not presented. Please detail the statement on this point.

In this sentence we actually refer to a possible explanation of the spatial distribution of the biases. It seems that the model is overestimating the precipitation induced by orography generating too much precipitation in the mountains and amplifying their blocking of fronts coming from the ocean, thus leading to underestimation of rainfall towards the interior. We have rephrased the sentence in order to clarify this point. It now reads:

"The biases of the original model outputs show that it overestimates the precipitation induced by orography, generating too much precipitation in the mountains and amplifying the orographic blocking of fronts coming from the ocean, thus leading to underestimation of rainfall towards the interior. This spatial distribution of the biases suggest that the model is overestimating the topographic effect on precipitation at this resolution"

2. On page 8153, paragraph starting from line 20, why the traditional probability distribution function is abandoned? You should present both results to demonstrate the statement in this paragraph.

It is not our intention to suggest that the traditional probability distribution (PDF) should be abandoned in all cases. The choice of representing the rainfall distribution according to each intensity contribution to total precipitation (pseudo-PDF) was carefully made according to this particular study. The PDF is not always adequate to illustrate the differences between two precipitation distributions because errors in one of the tails could be imperceptible, although having an important contribution to total precipitation, depending on whether the logarithmic or the linear scale is used. A second issue is that the PDF is not useful in a context where the analysis of the number of rain days is important, because it just provides probability information with regard to its own number of wet days. Contrary to the traditional PDF, the pseudo-PDF gives information in terms of both the distribution and the over/underestimation of wet days, which is a

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major aspect of this study.

We generated two figures using logarithmic and linear scales to illustrate the traditional PDF (Figures 2 and 3 in this comment). Compared to the use of the pseudo-PDF (now Figure 7 in the manuscript), the systematic deviation of events below 10mm in AWAP with respect to GHCN is not properly displayed in either PDF plots, which is one of the motivations of this paper. Also, in situations like that of region 3, the PDF in all four datasets seem to be very similar, but AWAP is consistently overestimating the number of rain days.

In order to overcome these issues, we believe that the best approach is to use the pseudo-PDF, so they are equally weighted in the plot and the error with respect to their relative contribution is easier to see. In addition, both the rainfall probability and the over/underestimation of wet days are represented in this kind of plot. We have included a sentence in the manuscript to explain this decision.

3. On page 8153, in the paragraph starting from line 14, it is indeed the argument that the correct distribution of events according to their intensity as well as their occurrence is crucial to evaluate the risks and characterize their possible impact. However, there are no results or discussion related to occurrence being presented in the manuscript. This should be examined to enrich the content of the manuscript. The importance of occurrence time of precipitation should be addressed, associated with the precipitation density. It will help assessing climate impacts on the local region.

"Occurrence of precipitation" could be understood either as the timing or the frequency of rain events. In this paragraph, we referred to frequency when we used the term occurrence. Although there is no doubt about the importance of capturing the precipitation timing for some impact assessments, we focused here on the climatological point of view, thus the correction is aimed at correcting the long-term statistics. Also, this study was designed with the use of regional climate models driven by both reanal-

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yses and global models in mind, in which case the frequency of precipitation events is expected to be represented adequately, but not the exact observed timing. However, we agree that the term might lead to misunderstanding and hence we have rephrased the sentence to clarify this point.

REFERENCES Jones DA, Wang W and Fawcett R (2009) High-quality spatial climate data-sets for Australia. *Australian Meteorological and Oceanographic Journal* 58(4): 233–248. King AD, Alexander LV and Donat MG (2013) The efficacy of using gridded data to examine extreme rainfall characteristics: a case study for Australia. *International Journal of Climatology* 33(10): 2376–2387: doi:10.1002/joc.3588.

Please also note the supplement to this comment:

<http://www.hydrol-earth-syst-sci-discuss.net/10/C4860/2013/hessd-10-C4860-2013-supplement.pdf>

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 8145, 2013.

HESSD

10, C4860–C4871, 2013

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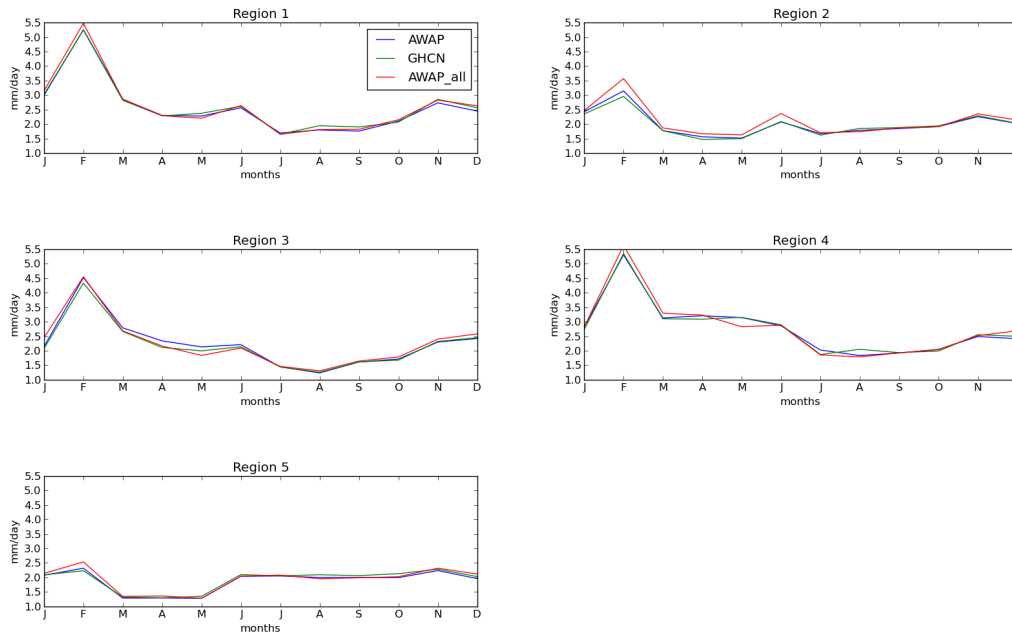


Fig. 1. Monthly climatologies using all AWAP grid points within each region (red), all GHCN stations within each region (green), and the nearest AWAP grid point to each station within each region (blue)

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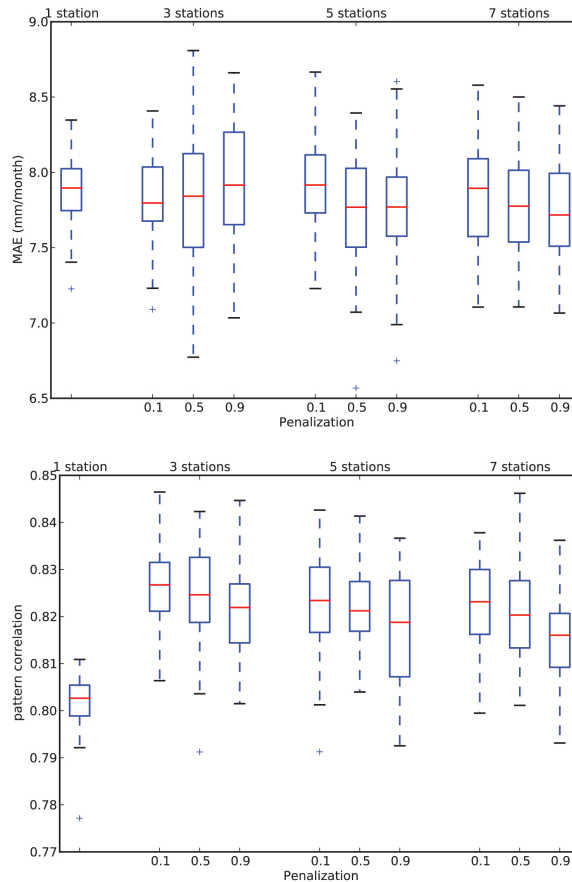


Fig. 2. Top: Seasonal MAE between the 50 perturbed realisations of each bias correction configuration and GHCN. Bottom: as top but for pattern correlation and using AWAP as reference

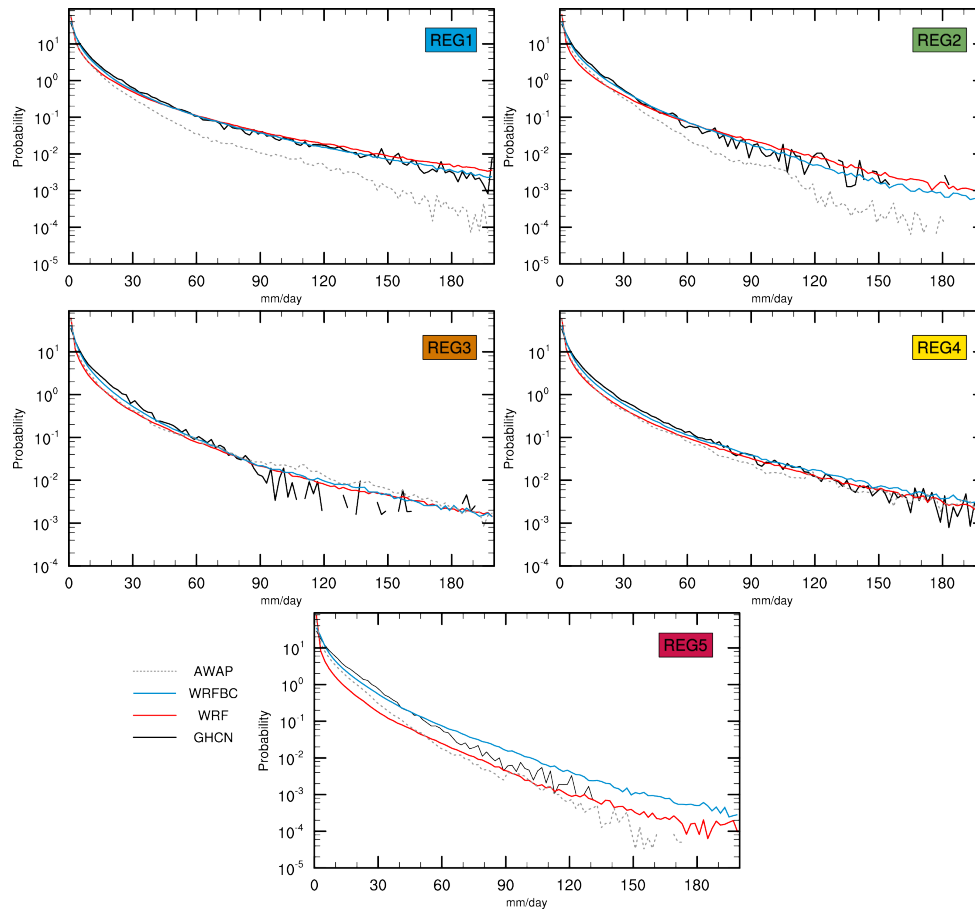


Fig. 3. Probability distribution function in each of the regions for AWAP (dashed), GHCN (black), original (red) and corrected (blue) model outputs using 1 mm bins. Logarithmical y-axis

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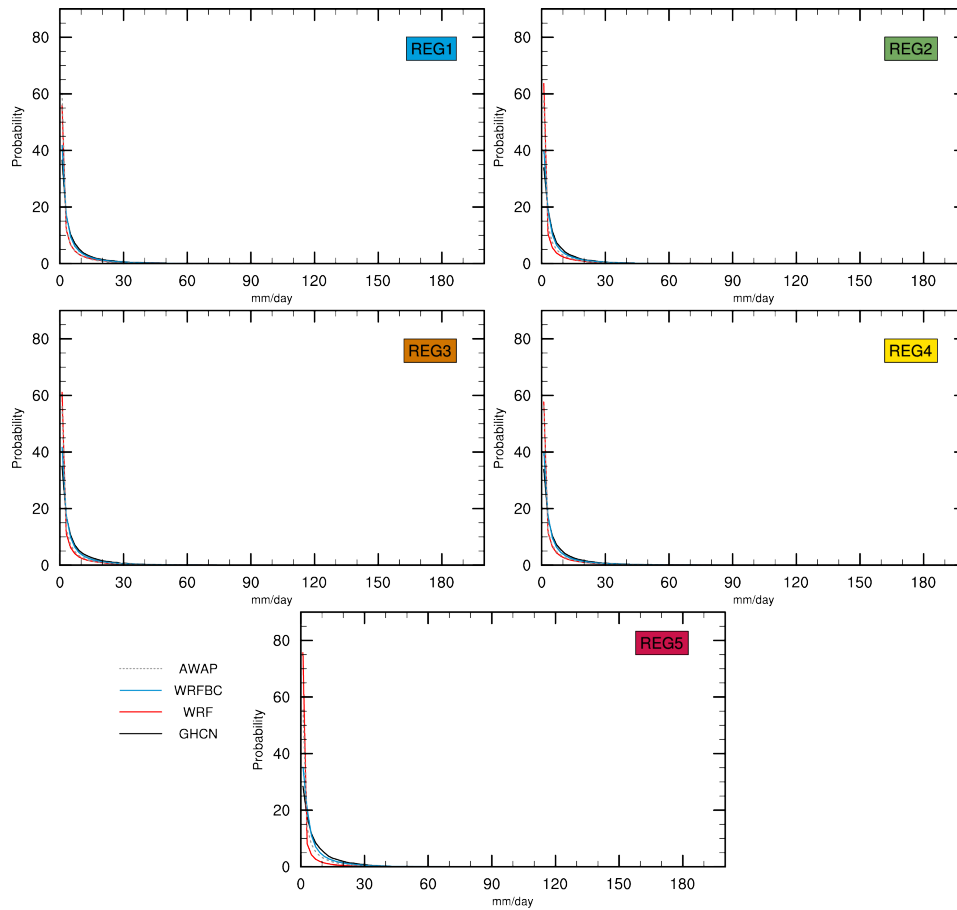


Fig. 4. As figure 3, but using linear y-axis

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