Hydrol. Earth Syst. Sci. Discuss., 11, C5428–C5435, 2014
www.hydrol-earth-syst-sci-discuss.net/11/C5428/2014/

Hydrology and Earth System Sciences
Discussions

Interactive comment on "How does bias correction of RCM precipitation affect modelled runoff?" *by* J. Teng et al.

J. Teng et al.

jin.teng@csiro.au

Received and published: 3 December 2014

We thank the two reviewers for their constructive comments and suggestions. Please find below our responses (in blue) to the reviewers' comments (in black).

Anonymous Referee #1

Received and published: 22 October 2014

Overview

The paper explores various bias correction techniques applied to 'correct' climate model precipitation to facilitate their propagation through hydrological models. More

specifically, a number of distribution mapping techniques are applied using a split sample approach to explore the performance of each approach and the influence it has on the resulting change signal.

General Comments

The paper is focussed upon an important topic related to the application of climate models in impact studies, more specifically their use in exploring the potential impacts of climate change on precipitation and discharge. I found the paper to be relatively well-written, although a further read through to check grammar is needed. I agree with the authors that as RCMs continue to improve they will become more readily applied in hydrological impact studies. Significant biases currently exist however and are unlikely to be completely overcome in the near future. Clearly improving the applicability of climate models in hydrological impact studies is a challenging problem with obvious significance. The paper is therefore relevant, exploring how the choice of bias correction approach may impact the resulting projections.

The manuscript primarily focusses on these differences. It also reaches some important conclusions regarding the overall effectiveness of bias correction techniques and how they should be applied in impact studies.

Noted with thanks.

However, many of the results are largely unsurprising given the relative similarities in the methods applied. Nevertheless there are some important discussions that emerge from the results that have largely been over looked. Some further clarity to the methods and data applied are also required. I therefore recommend publication after minor revision to address the following points:

1) The paper is missing an important discussion around the role of bas correction in impact studies and should be more specific in its recommendations. The paper itself identifies that even when there is a 'perfect' distribution bias correction as is the

case with QM method, the limitations of the RCMs cannot be overcome. This raises important questions as to the application of RCMs in climate impact studies. Should we even be using RCMs in impact studies? Particularly for extremes. Some comments around this would be welcome.

We agree with the reviewer and have discussed this at the end of Section 5.1.

2) A broader view of the application of RCMs in impact studies is needed. Bias correction isn't the only way in which climate models are applied in impact studies. For example Smith et al.(2014) used multiple application techniques. There is a rich literature around these alternative methods that should be included.

We have now added the statement saying 'Projections derived from bias corrected input data should therefore be interperated cautiously and/or combined with other approaches'. It is clear that bias correction is just one way of providing climate scenarios. To explore the whole range of uncertainties, one should consider many other techniques. This has also been broadly discussed in the introduction.

3) The authors should review and include a paper by Cloke et al. (2013), which explored the significance of MOS on flood projection in the UK. The paper strongly recommended that bias correction techniques should not be used alone, owing to their unknown effects. How do the conclusions drawn here compare?

We have now cited Cloke et al. (2013) paper and included the comparision in Sections 4.3.

4) More generally, the paper focusses upon the correction of various precipitation metrics but fails to make the connection between what these metrics mean in terms of potential impacts. For example, the paper states that at 'high' precipitation quantiles, the uncertainties introduced as a result of different bias correction techniques are amplified. Some comments as to what the implications are for flood impact studies, for example, would be welcome. i.e. Should flood impact studies use multiple bias correc-

tion techniques?

The precipitation metrics presented in this paper are those important to runoff generation in general. We have cautiously used the term 'high precipitation' instead of 'extreme precipitation' as floods are influenced by even more extreme precipitation. It is difficult to draw conclusions on flood risk from this study. Nevertheless, we have mentioned this in the discussion added in Section 5.1.

5) Further description of the hydrological modelling procedure is needed. The paper states that the hydrological model uncertainty is relatively small. Yet there is no description as to how hydrological modelling uncertainty was handled. Was the model calibrated under an uncertainty framework? Figures 4 and 5 appear to suggest that for some seasons, the hydrological model (HM calib) bias is actually comparatively large. Some clarity here would be welcome.

The general consideration on the impact of bias correction would be similar between hydrological models, but the magnitude of the impact may differ between models. We now mention this in Section 4.3.

Specific Comments/Technical corrections (P:Page L:Line)

P10684 L14, 'limitation of RCM'. Doesn't make sense.

Changed to 'limitations of the RCM'.

P10685 L5, Specifically hydrological impact studies.

Text modified.

P10686 L11, 'Precipitation'? should be modelled?

Text modified.

P10688 L17, A little more as to how the observed precipitation data was aggregated up to the RCM resolution is needed.

The observations and RCM simulations are aggregated to each catchment and compared at catchment level. Description added in Section 2.1.

P10690 L15, Smith et al.,(2014) used a combination of gamma and GEV distributions. This may lead to some improvements in correcting extremes.

Noted with thanks. We have now included this paper in Section 3.1.3.

P10694 L25, The RCMs appear to be particularly poor during winter (JJA). Are there any specific mechanisms causing this?

The RCM simulations used in this study were opportunistic datasets from a previous unrelated study. The reason why this RCM performed poorly during winter is something we can only speculate. Since this study is mainly about the impact of bias correction, we would prefer to leave this out of our discussion.

P10693 L18, Revise sentence.

Sentence changed to 'In this study, four and 14 parameters were calibrated for GR4J and Sacramento respectively'.

P10695 L18, QM? abbreviation. First time this appears, should be QM next to 'empirical quartile mapping'?

Abbreviation added.

P10700 L19, However figure 11 appears to show that the raw RCM output performs better than both QM and DM2G at high precipitation quantiles. What are the implications of this?

Figure 11 is only one selected example for the constructed CDFs. There is not enough evidence to support any suggestions on the performance of QM and DM2G at high precipitation quantiles.

Figures: Some of the figures are a little hard to read. May need to adjust some the

scales to make box plots clearer.

Figures 3, 4, 5, 6, 7, 8, 9, 10, and 13 were updated with larger plots and fonts.

Figure 11. State that observed precipitation is hidden by QM.

Statement added.

Refs

Cloke, H. L., Wetterhall, F., He, Y., Freer, J. E. Pappenberger, F. 2013. Modelling climate impact on floods with ensemble climate projections. Quarterly Journal of the Royal Meteorological Society, 139, 282-297.

Smith, A., Freer, J., Bates, P. Sampson, C. 2014. Comparing ensemble projections of flooding against flood estimation by continuous simulation. Journal of Hydrology.

Anonymous Referee #2

Received and published: 26 October 2014

The focus of this paper is on the correction to precipitation estimates from RCMs. While this is important, there is the underlying question about the need to correct potential evaporation estimates used to predict future water resources. In this study, the authors have used the same PET dataset derived from the observed climate variables, so there is still an underlying question about the need to consider bias correction of PET. Are RCM precipitation estimates independent of PET? If not, then what impact might this have on the predictions of future water resources?

We agree with the reviewer that PET is also important for runoff estimation. There is abundant literature on the impact of PET on future water resources, and bias correction of RCM temperature which influences PET. However, as discussed in the introduction (also highlighted in the title), and as correctly pointed out by the reviewer, the focus of this paper is on the precipitation, as it is the most critical and difficult-to-model variable

in hydrological studies. We kept PET the same to focus the study on the impact of precipitation. We have added a statement in Section 3.2 to acknowledge the possible impact from PET and the correlation between RCM precipitation and PET.

That said, the work is thorough. While it is not surprising that the conclusion is that a correction based on quantile matching or double gamma distribution would work well, it is good to see this confirmed by a thorough analysis. There is the question about the use of daily data. The use of a daily timestep is common in applications to the study of water resources in many areas (including Australia) because of the limited availability of high temporal resolution data. In calibrating a model on a daily time step, the parameter values are optimised to capture the catchment behaviour, including the unseen behaviour at a sub-daily timestep that can influence the daily observed discharge. This means that any estimation of future water resources requires the same effect from sampling to a daily timescale.

Noted with thanks.

While these points go beyond the scope of the existing paper, it would be worth pointing out to the reader that this paper does not give the definitive answer on how RCMs can be used, and only looks at the question of bias correction (in the broader cease of bias given the correction to the PDF). The remaining issues that need to be addressed should be pointed out to reinforce the a reader that they should use even a good bias correction method with care.

Statements added in the discussion and conclusions to reinforce this.

In general, the paper is well written, with a few grammatical errors (see comments by reviewer #1). The font is a little small on most of the figures. While the display can be zoomed to look at each figure, this does make it more difficult to read the paper. I suggest the authors think about reformatting the figures to make it easier for the reader.

We have now corrected the errors and reformated most of the figures with larger plots

and fonts.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 10683, 2014.