Clim. Past Discuss.,
doi:10.5194/cp-2015-194-AC3, 2016

Climate of the Past Discussions

Interactive comment on "Comparison of simulated and reconstructed variations in East African hydroclimate over the last millennium" *by* F. Klein et al.

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Received and published: 10 May 2016

- In blue: referees' comments
- In black: our answers
- *In black italic: what we propose to add in the text*

This paper deals with a very important subject: Comparison of the simulated and reconstructed climate. Working out similarities and differences is key for a better understanding of the climate drivers and their quantification.

The authors have chosen four fairly high-resolution climate curves from East Africa

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Discussion paper

which they compare with model results. Interestingly, some of the reconstructed climate curves differ markedly. In Figure 5 the Naivasha and Masoko lakes show a dry Medieval Warm Period (MWP) / Medieval Climate Anomaly. In contrast, Challa appears to be more humid, even though the record starts slightly later and the beginning is unclear. In the Lake Malawi climate curve the time 1000-1300 AD is absent, therefore it is unclear if the MWP was dry or wet here. I suggest you add information from Johnson et al. 2004.

According to those authors: “Diatom productivity was high during the Little Ice Age (LIA) and relatively low around 1 kyr, the time of the Medieval Warm Period (MWP)”. The low diatom productivity during the MWP may be linked to low river discharge, i.e. drought conditions. During this time the rivers may have supplied lower amounts of dissolved silica to the lake. During the wetter Dark Ages Cold Period and Little Ice Age, chemical weathering of bedrock intensified and increased the BSi concentrations and diatom productivity in the lake. http://link.springer.com/chapter/10.1007

Thank you for your comment. The reconstruction of Johnson et al. (2004) is certainly interesting, but we prefer not to discuss it in the revised version, since it would add complexity to our manuscript (which is already long as underlined by the reviewers) without adding much extra value for the model-data comparison. Indeed, our goal here is not to extensively review the available proxy-based reconstructions of hydroclimate, but to compare model simulations with available reconstructions that have a sufficient temporal resolution to make the comparison meaningful. Nevertheless, we have now mentioned in the Section 2.2 of the manuscript (Proxy-based hydroclimate reconstructions) that comparing to additional records would be an interesting follow up to the present work (see sentence below).

I would like to draw your attention to an ongoing project in which I am mapping the climate characteristics of the MWP on a global scale, based on the large number of published case studies. The interactive online map is freely accessible here: http://t1p.de/mwp

In East Africa you see a large number of yellow points that represent studies which reported drought/arid conditions for the MWP time. When you click on the respective dot, key information from the paper appears, including a link to the key climate curve. Arid conditions seem to be the general pattern that existed 1000-1300 AD in East Africa. The arid MWP belt appears to continue northwards along the coast of the Arabian Sea, including Ethiopia, Yemen, Oman, Pakistan and coastal northwestern India. There, the MWP climate regime seems to change. Southern and eastern India and the Bay of Bengal appear to be humid during the MWP. Mapping is still ongoing and many more studies will have to be integrated. It is also clear that in detail things are more complex. Nevertheless, I think it would be important to initially compare the models to these general, high-level patterns.

Thank you very much for the information. The map is really interesting, showing large-scale features whilst taking into account local patterns. In our manuscript, we have chosen to use the compilation of hydroclimate proxy-based reconstructions for our study region, as done in Tierney et al. (2013). Although your map contains some East African hydroclimate reconstructions that may be interesting to compare with model results, it appears that the number and type of the reconstructions used in our study is not critical to reach our conclusions, given that we suggest that simulated hydroclimate is mainly driven by internal variability in this region. Hence, we do not expect to find much agreement between model results and hydroclimate reconstructions over the last millennium, and, if any was found, it would be coincidental only. However, a comparison with additional records would certainly be interesting to assess the robustness of the changes inferred from the records selected here and to refine the spatial structure of those changes. This is now specified as a possible future perspective of our work, in Section 2.2 of the manuscript (Proxy-based hydroclimate reconstructions):

Several other proxy records exist describing East African hydroclimate variability during the last millennium (Verschuren, 2004; see also http://t1p.de/mwp). The majority of these mostly lake-based records do not possess sufficient age control to assess the *regional coherence of inferred (multi-) decadal and century-scale hydroclimate variation. Since our goal here is not to extensively review the strengths and weaknesses of those individual reconstructions, we follow Tierney et al. (2013) to consider only the handful of records which combine high temporal resolution with adequate age control. However, a critical review of all available records could potentially refine the spatial structure of documented hydroclimate changes and allow further assessment of the robustness of broad-ranging climate-dynamic inferences.*

From your study and reference list I have gathered quite a few new publications that I will add to the MWP map in due course. Thanks for that.

Thanks for the comment.

Concerning the forcing of pre-industrial climate change, I am not comfortable with models that gain their simulated climate variability mostly from internal variability. There are clear MWP patterns and additional millennium cycles (e.g. Bond et al. 2001) which point towards powerful external climate drivers. Numerous papers have highlighted the important role that solar activity changes play in the climate equation. I want to encourage you to also run models and scenarios with a solar radiative forcing higher than that assumed by the IPCC. If not for this paper, maybe in a future one. The current RF proposed by the IPCC does not honour the great number of studies which highlight the intense coupling of climate with solar activity changes: http://chrono.qub.ac.uk/blaauw/cds.html

Indeed, many studies have emphasized solar forcing of climate change, based on comparison between proxy reconstructions of different climate variables (temperature, rainfall, etc.) and reconstructed solar activity variations. However, the changes in total solar irradiance are small. To induce a significant impact on the climate system, feedback mechanisms are required to amplify these initial changes, but these mechanisms are not well known. Furthermore, previous studies have had trouble to formally detect the influence of solar irradiance on climate of the past millennium and to determine whether simulations with low or moderate solar forcing are more realistic (e.g., Schurer et al., 2014; Jungclaus et al. 2010, PAGES2k-PMIP 2015). By contrast, simulations driven by very large solar forcing are not compatible with many available reconstructions. Running new model experiments with enhanced solar forcing could provide insights into this controversial topic, but unfortunately, it will not be possible to include this in the present study.

Here, we have not run any simulations ourselves. Making new simulations covering the last millennium with these GCMs requires a tremendous amount of computer time, in addition to technical expertise adapted to each model. We have thus used the publicly available experiments that were performed by different modeling groups. All those simulations have been performed following the well-defined frameworks (changes in forcing, periods covered by the simulations, etc) of the projects PMIP3 (for the past1000 simulations, from 850 AD to 1850 AD, Otto-Bliesner et al., 2009) and CMIP5 (for the historical simulations, from 1850 AD to present, Taylor et al., 2012). Making new coordinated model experiments with enhanced solar forcing would thus require a joined and long-term effort, and although potentially very interesting, is out of scope of this study.

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