

Interactive comment on “Evaluation of seasonal climates of the Mediterranean and northern Africa in the CMIP5 simulations” by A. Perez-Sanz et al.

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Received and published: 9 January 2014

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Anonymous Referee #1: Received and published: 11 November 2013

Previous climate model experiments have correctly simulated the direction but not the amplitude of precipitation change in the Sahel-Saharan region of Africa during the early-mid Holocene. This paper reviews results from the latest (CMIP5) generation of GCMs and expands the geographical coverage to include the Mediterranean basin. The authors find no improvement in the model results and they also conclude that failure to correctly simulate past climates is not due to any systematic bias in the ability

C3057

of the models to simulate modern climate. Results are clearly presented in a series of informative diagrams and the authors' interpretations and conclusions are sound and well-balanced. I would be happy to see full publication of this manuscript after only minor modifications, as set out below.

Referee Comment (RC) 1. Title. In addition to “r” being missing from “northern”, the title makes no mention of past climates which is the main focus of the paper. Perhaps it could be rephrased at “Evaluation of modern and mid-Holocene climates of the Mediterranean and northern Africa in the CMIP5 simulations”:

Author Comment (AC) 1. In agreement with suggestions of both referees, we are changing the title to: “Evaluation of modern and mid-Holocene seasonal precipitation of the Mediterranean and northern Africa in the CMIP5 simulations”

RC 2. The first four paragraphs of the introduction make almost no mention of northern Africa, although this makes up more than half the study area. This part of the paper should therefore be partly re-written to describe the whole region under investigation, not just the Mediterranean.

AC 2. There have been extensive analyses of the northern Africa monsoon through CMIP and PMIP suite models, and our goal here was not to repeat those analyses. Instead we wanted to focus on precipitation simulations over the Mediterranean region, including south Europe and north Africa. We have also looked at the northern Africa monsoon because of work suggesting this influences and is influenced by climate in the Mediterranean region. We consider that the failure to reproduce precipitation changes over the Mediterranean might be linked to the failure to reproduce the monsoon. We discuss the linkage between the Mediterranean and monsoon climates in the fourth paragraph of the introduction (page 5350) and we discuss the failure of current climate models to simulate the MH monsoon properly in the fifth paragraph (page 5351). However, we have added a sentence to this paragraph to make it clear that this underestimation is also present in the CMIP5 simulations, and refer to the paper by Harrison

C3058

et al. (2013) which shows this. We have also modified the final sentence on page 5351 to read: “Although preliminary assessments of the CMIP5 model indicate that improvements in the modern simulations do not translate into improvements in the simulation of the MH monsoon climate (Harrison et al., 2013)”

RC 3. p. 5350, line 8ff states that “Systematic comparisons with observations have shown that climate models are unable to reproduce the observed MH patterns of change in the Mediterranean”. Actually, this is only true of global climate models. The regional climate simulation of Brayshaw et al (which should be cited in this paragraph) reproduces rather well reconstructed δP for the Mediterranean (see Roberts et al. 2011, The mid-Holocene climatic transition in the Mediterranean: causes and consequences. *The Holocene* 21(1) 3-13, figs 4 and 5)

AC 3. Although our focus here is on global models, we disagree that regional climate models give a more realistic picture of mid-Holocene climate changes in the Mediterranean. The point here is that the observed vegetation shifts towards deciduous vegetation require a shift towards more rainfall in summer. The simulation by Brayshaw et al. (2011) and Figure 4 of Roberts et al. (2011) show a change in winter season precipitation (October through May). While this could explain, e.g. observed high lake levels in the Mediterranean region, it cannot explain the vegetation changes. To make this clearer, we have modified the first sentence of this paragraph (page 5350, lines 8-9) to read: “Systematic comparisons with observations have shown that global climate models are unable to reproduce the observed MH patterns of rainfall changes in the Mediterranean. In particular, they do not show a sufficiently large increase in summer rainfall to explain the shift towards deciduous vegetation.”

RC 4. p. 5352, line 19-20. I think it would be helpful to add a sentence or two explaining why pollen-based data were used as proxy-data, rather than (e.g.) lake-level fluctuations; for example, because there is good spatial coverage in the Mediterranean region. Coverage of pollen-based palaeo- δP is not, however, very good across most of northern Africa (as fig. 2, bottom right map highlights).

C3059

AC 4. We agree that there are many lines of evidence indicating that both northern Africa and the circum-Mediterranean region were wetter than today during the mid-Holocene, including extensive lake-level data from both regions (see e.g. Harrison et al., 2002 for Europe; deMenocal et al., 2000 for northern Africa). Estimates of the change in precipitation required to support higher lake levels have been made for some sites (see e.g. Coe and Harrison, 2002). However, such estimates are not available from most sites. Our goal here was to examine the qualitative differences between models and observations. Pollen data have been used to make quantitative reconstructions of mean annual precipitation (and other climate variables, such as temperature and soil moisture) both for southern Europe and northern Africa using statistical and/or model inversion techniques. The data from individual sites and multiple reconstructions have been combined to produce a gridded data set of changes in mean annual precipitation (including error estimates) by Bartlein et al. (2013) and we have used this data set in our work. To make the motivation for this clearer, and as requested by the reviewer, we have expanded the text to read: “quantitative climate reconstructions derived from pollen records. Although there are many kinds of palaeorecord that indicate that northern Africa and the circum-Mediterranean region were wetter during the mid-Holocene, including e.g. lake-level and archaeological records, these other sources of information do not provide quantitative estimates of the change in precipitation.”

RC 5. p. 5361, line 26. Although there is a significant positive correlation between modern bias and mid-Holocene anomaly in the desert region, the range of data variability is actually very small, as figure 8 highlights (i.e. they are clustered across a small range), so this result may not be very significant.

AC 5. We agree that the apparent range in data variability is small in absolute terms, but this reflects the fact that the precipitation values in desert region are low. When the change is expressed as a proportion of the actual rainfall, the range between models is much larger. The apparent clustering in Fig 8 is because we have shown the changes on the same scale for all regions. The statistical analysis is not affected by the range

C3060

of data variability: there is indeed a statistically significant correlation between modern bias and mid-Holocene anomaly in the desert region. We have therefore made no change to the text here.

RC 6. Figure 5: this might be shown linked to figure 3 (e.g. as fig 3 a and b) in order to show them together so that they can be compared. For figure 5 it might also be possible to show the latitudinal extent of different climate zones from palaeo-data as well as models for the mid-Holocene; ie monsoon zone extending further north and desert shrinking

AC 6. It would be possible to include a schematic interpretation of the palaeodata, but the reconstructions only provide estimates of mean annual precipitation not seasonal distribution. Thus, we could not define the latitudinal extent of different zones from observations in a way comparable to the definitions used for the models. Specifically, since we cannot tell whether rainfall in the desert occurred in summer or winter, we could not distinguish the monsoon/desert/Mediterranean transitions. We have therefore not modified Fig 5 to include a data-based schematic. We agree that combining the modern and MH figures in a single figure makes it easier for the reader to make comparisons, and we have therefore combined these to form a new version of Figure 3. We have renumbered the remaining figures accordingly, and updated the citations to the figures in the text.

RC 7. Discussion. Although this is well-balanced, no mention is made of why the models may be failing to simulate correctly the mid-Holocene climate of the Sahel-Saharan region. In particular, it might be appropriate to add a short paragraph discussing the role of local-regional scale hydrological recycling from 1soil moisture, 2vegetation and 3freshwater lakes and marshes, following the pioneering paper on this subject by Street-Perrott et al (1991; Milankovitch and albedo forcing of the tropical monsoons: a comparison of geological evidence and numerical simulations for 9,000 yr BP, Transactions of the Royal Society of Edinburgh, Earth Science, 81, 407-27). The 6 ka BP time horizon used for comparison was just before a major mid-Holocene climate tran-

C3061

sition in both the Sahara-Sahel and in the Mediterranean, and some features of the climate at this time may be “relict” from the early Holocene, when boundary conditions were more strongly different from the present-day than at 6 ka. In the Mediterranean, pollen evidence of deciduous forests (e.g. at Banyoles) would also have led to moisture recycling through evapo-transpiration during the mid-Holocene.

AC 7. There have been a considerable number of papers on the potential role of land-surface feedbacks since Street-Perrott’s pioneering paper. On the whole, simulations in which the surface albedo is changed through changing soil moisture, vegetation, or extended lakes and wetlands do produce a northward expansion and amplification of the monsoon. Asynchronously coupled climate-vegetation models produce more equivocal results: in general, the monsoon is strengthened but this results in only a minor expansion of the zone of monsoon rainfall. However, coupled models which included dynamic vegetation in the second phase of PMIP do not show a significant northward expansion. Coupled carbon-cycle models in CMIP5 also do not show a significant northward expansion. If we assume that the coupled models are behaving reasonably, this shows that the changes to the energy budget produced by the prescribed changes in albedo are compensated by changes in the partitioning between latent and sensible heating through increased evapotranspiration. We have implicitly made the point that dynamic vegetation and carbon-cycle models do not produce a bigger monsoon in the paragraph discussing the monsoon on page 5364 and 5365. However, given the potential that readers are not aware of the differences between prescribed and dynamic simulations in this respect, we have added a new paragraph discussing this issue (following the original paragraph on the monsoon) on page 5364.

“It was originally suggested that the underestimation of monsoon expansion reflected the failure to include feedbacks associated with climate-induced changes in land-surface characteristics, including wetter and more organic soils, the replacement of desert by grassland and shrubland, and the expansion of lakes and wetlands. Indeed, simulations in which the impacts of changes in land-surface characteristics were pre-

C3062

scribed through changing albedo produced much larger monsoons (Street-Perrott et al., 1990; Kutzbach et al., 1996; Coe and Bonan, 1997; Broström et al., 1998). However, this effect is not as pronounced in asynchronously-coupled climate-vegetation simulations (Claussen and Gaylor, 1996; Texier et al., 1997; Braconnot et al., 1999), models with dynamic vegetation from PMIP2 (Braconnot et al., 2012), or indeed coupled carbon-climate models in CMIP 5 (Harrison et al., 2013). In general, these models produce a strengthening of the monsoon in situ and only a minor northward expansion of the zone of monsoon rainfall. If we assume that the coupled models are behaving reasonably, this shows that the changes to the energy budget produced by the prescribed changes in albedo are compensated by changes in the partitioning between latent and sensible heating through increased evapotranspiration. This implies that some other mechanism, for example associated with changes in circulation, is required to produce the observed expansion of rainfall in the Sahara.”

We have added the corresponding references to support this new paragraph

RC 8. Conclusions. These are fine, but the authors could go one stage further and make explicit the implications of their study, namely that the failure of GCMs to simulate the amplitude of $_P$ in the mid-Holocene in N African and the Mediterranean implies they may also significantly under-estimate the magnitude of future changes in rainfall in these regions. At the very least, only limited confidence can be placed in the model-based predictions of greenhouse-gas warmed climate in these dryland regions.

AC 8. Although we mention the role of past simulations to assess the reliability of climate models in the introduction, but did not reiterate this point explicitly in the conclusions. Following the reviewers suggestions, we have added a new separate point in the conclusion section (page.5367, line 27).

“The failure to simulate observed mid-Holocene changes in the northern Africa monsoon and the potentially linked failure to simulate the observed shift in rainfall seasonality in the Mediterranean raises concerns about the reliability of model projections

C3063

of future climates in these regions.”

Please also note the supplement to this comment:

<http://www.clim-past-discuss.net/9/C3057/2014/cpd-9-C3057-2014-supplement.pdf>

Interactive comment on Clim. Past Discuss., 9, 5347, 2013.

C3064

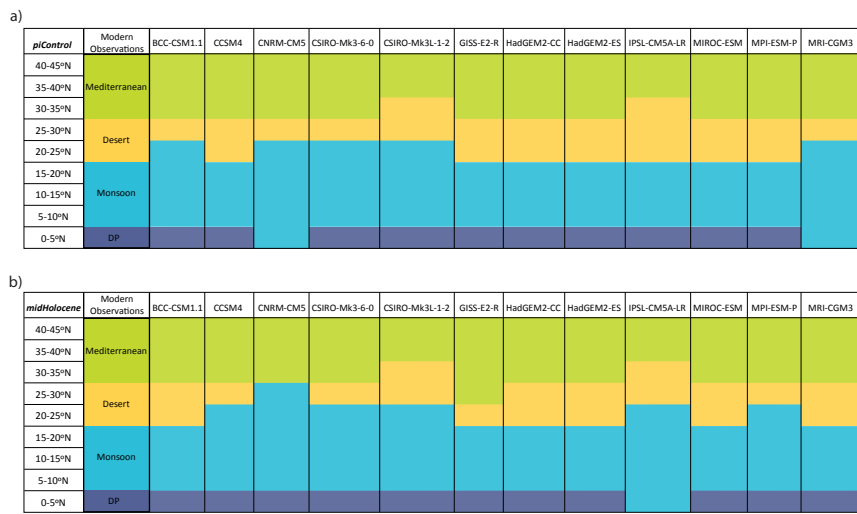


Fig. 1. new figure 3