Clim. Past Discuss., 6, C44–C54, 2010
www.clim-past-discuss.net/6/C44/2010/

Climate of the Past Discussions

CPD

6, C44–C54, 2010

Interactive Comment

Interactive comment on "The Southern Hemisphere semiannual oscillation and circulation variability during the Mid-Holocene" *by* D. Ackerley and J. A. Renwick

D. Ackerley and J. A. Renwick

d.ackerley@niwa.co.nz

Received and published: 25 March 2010

Reviewer 2 suggested that further analysis of the available PMIP2 fields may yield a reason why the SAO responds to the Mid-Holocene insolation forcing and may also shed light on why there is an apparent lack of baroclinicity in the spring. We agree with the reviewer and have undertaken further analysis and produced the following results. The document will also be changed to incorporate the relevant figures produced from this response. However, it does not include them all as the references and the inclusion of the extra figures in this response should be sufficient to provide extra background material for readers.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

Response:

The work by Raphael and Holland (2006) and Bracegirdle et al. (2008) have both already shown that the models used in the AR4 analysis struggle to capture the peak in 500 hPa DT during spring in the SH. Raphael and Holland (2006) state that their

"Fig. 3 suggests that the weak SAO produced by the models is linked to their inability to simulate the temperature gradient between 50 and 60S. Given also the lack of a second peak in the zonally averaged SLP at 50S, we suggest that the reason for this inability in the models may lie in their simulation of the temperature cycle at 50S."

Further to this, Drost et al. (2007) used HadAM3H to look at the SAO and state that

"The fact that CONTROL (pre-industrial run) does not reconstruct the SAO signal during the austral spring is because HadCM3 fails to produce accurately the annual cycle of SSTs at 40S - 60S [Gordon el al., 2000]."

Also, a review of the models in Randall et al. (2007) indicated that GCMs really struggle to capture the true SSTs around the Antarctic Circumpolar Current, which adds further weight to the argument that SSTs are responsible for the issue (with the SAO) in austral spring.

We have therefore acquired HadSST2 data from the Met. Office (see Rayner et al., 2005, for a review) and compared the climatology of the seasonal, zonal mean cycle of SST in HadSST2 with the control run of each available PMIP2 model. IPSL was discounted and ECHAM had no SST data available so the analysis was done on CCSM, FGOALS, HadCM3_UB and MIROC. Each of the models were re-gridded to the 5 x 5 deg resolution of the HadSST2 data set for comparison and the differences between each model and HadSST2 are given in Figure 1 for 10S - 70S. As can be seen in the figure, there are obvious errors in the SST throughout the SH in each of the models, with cooler temperatures between 10S - 50S in CCSM, HadCM3_UB and MIROC. FGOALS however had generally positive SST anomalies compared to HadSST2. The full discussion of these anomalies lies beyond the scope of this analysis and our funding and the authors refer the reviewer to Randall et al. (2007) for a more in-depth discussion of the limitations of representing SSTs in these GCMs.

We next derived the zonal mean seasonal cycle of SST at 47.5S in each model and HadSST2, which can be seen in Figure 2. There are again many differences between the models and HadSST2 in Figure 2, but understanding these are again beyond the scope and resources of this work. The SST in HadSST2 is at a minimum in September along 47.5S but all of the PMIP2 models have their minima in October. Subsequently, the gradient of the increase in SST along 47.5S is weaker in HadCM3_UB and MIROC than HadSST2, which agrees with Figure 1 in the discussion paper as HadCM3_UB and MIROC have the weakest 500 hPa DT values in spring compared to CCSM and FGOALS. The increase in SST (gradient) at 47.5S in CCSM and FGOALS after the October minimum is similar to HadSST2 and subsequently the 500 hPa DT values for CCSM and FGOALS are closer to the NCEP values given in Figure 1 of the discussion paper. This agrees with the notion from Raphael and Holland (2006) and Drost et al. (2007) that the issue with the spring peak in the SAO is associated with the mid-latitude SST.

Now moving into the Mid-Holocene, the changes in zonal mean insolation at the top-of-the atmosphere for the Mid-Holocene relative to the pre-industrial simulations (averaged over all models and seasons) can be seen in Figure 3. The suggestion from this plot is that there was more insolation in the SH in late winter into spring with a reduction in early summer to early winter. The response of the zonal, seasonal mean SST to the Mid-Holocene solar forcing, relative to the pre-industrial control, can be seen in Figure 4. General cooling of the low to low-mid-latitudes can be seen in all models from January to August with a slight warming in high-latitude regions. This contributes to the reduced MAM baroclinicity in all models. In the late winter / spring, there is a strong reversal in the low to mid-latitude SSTs and little change at high-latitudes for CCSM, FGOALS and HadCM3_UB, which is likely to increase the baroclinicity during

CPD

6, C44–C54, 2010

this season relative to the PI control run and can be seen in Figure 5 of the discussion paper. The exception to this is MIROC (Figure 4(d)) which has the SSTs cooling at low to mid-latitudes extending well into the spring with only a short period of weak warming in late spring / early summer. The weak spring response of the SST explains why MIROC is the only model to have a different spring SAO response to the Mid-Holocene orbital forcing. However, the cause of the weak SST response is beyond the scope of this work, which is identifying changes to atmospheric variability.

From this analysis, the authors will include Figures 3 and 4 in the updated version of the paper (also based on Reviewer 1's comments) and the references used in this response have also been included in section 2.2 to show why the models struggle to capture the spring peak in the SAO. We will also refer readers to this discussion for a further look at the causes of the poor spring representation (if possible) and also the extra figures. As the references do provide a good background to the limitations of the models (as well as this discussion) and as the problems with the models are not the main focus of the paper (mainly to add context to the results) we will not include Figure 1 and 2. However, the discussion forum of this journal provides an excellent opportunity for the analysis done here to be considered as supplementary material and may spark a more in depth analysis of the ocean - atmosphere coupling of the SAO in the AR4 models.

Proposed changes to the manuscript:

Insert after "spring." in line 15, page 192, section 2.2:

According to Raphael and Holland (2006) the poor representation of the spring peak in 500 hPa DT in the GCMs can be attributed to a poor representation of the SST around 50S, which agrees with Drost et al. (2007) (and references therein). Extensive work by Randall et al. (2007) (and references therein) has shown that the AR4 ensemble of GCMs has large errors in and around the Antarctic Circumpolar Current and agrees with the assessment of Raphael and Holland (2006) and Drost et al. (2007). The seasonality of the PMIP2 SSTs around 50S is out of phase with the HadSST2 dataset (produced by Rayner et al., 2006) by one month in spring (not shown) and is likely to be the cause of the poor representation of the spring 500 hPa DT (further discussion can be found in the interactive discussion pages).

Insert as a new paragraph at line 10, page 194, Section 3.1:

The zonal mean response of the model SSTs to the Mid-Holocene insolation changes in Figure 1 can be seen in Figure 7. SST data were available for four of the PMIP2 models - CCSM, FGOALS, HadCM3_UB and MIROC (IPSL was not included). There is a general reduction in SST throughout the SH low- to mid-latitudes in all models from January to June with either a slight warming or no change to high-latitude SST. This contributes to the reduced MAM 500 hPa DT in all models by reducing the equator to pole temperature gradient. In late winter / spring however, there is a strong reversal in the mid-latitude SST anomalies and little change at high-latitudes in CCSM, FGOALS and HadCM3_UB, which suggests an increase in the equator to pole temperature gradient and thereby increasing 500 hPa DT during the Mid-Holocene. The exception to this is MIROC (Figure 7(d)), which has cooler SSTs persisting well into the spring and only a short period of weak warming in late spring / early summer. The warming (cooling) of low- to mid- latitude SSTs in response to the insolation changes are likely to be driving the strengthening (weakening) of 500 hPa DT during the Mid-Holocene.

Insert into line 10, page 203, section 6 - after "during SON.":

The changes in 500 hPa temperatures agree with the changes in the SH SSTs for the Mid-Holocene, which are responding to the changes in insolation. The discrepancy in the MIROC model can also be attributed to its own seasonal SST response in the SH. As the SAO is a coupled ocean - atmosphere process, it is unsurprising that the insolation driven changes in SST influence the CPT. The results in this study therefore suggest that

References:

CPD

6, C44–C54, 2010

Drost, F., Renwick, J., Bhaskaran, B., Oliver, H., and McGregor, J.: Variability of the atmospheric circulation in the Southern Hemisphere during the last glacial maximum, J. Geophys. Res., 112, D10101, doi:10.1029/2005JD006970, 2007.

Gordon, C., Cooper, C., Senior, C.A., Banks, H., Gregory, J.M., Johns, T.C., Mitchell, J.F.B. and Wood, R.A.: The Simulation of SST, sea ice extents and ocean heat transports in a version of the Hadley Centre coupled model without flux adjustments. Climate Dynamics, 16, 147-168, 2000.

Randall, D.A., R.A. Wood, S. Bony, R. Colman, T. Fichefet, J. Fyfe, V. Kattsov, A. Pitman, J. Shukla, J. Srinivasan, R.J. Stouffer, A. Sumi and K.E. Taylor, 2007: Cilmate Models and Their Evaluation. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Raphael, M.N. and Holland, M.M.: Twentieth century simulation of the southern hemisphere climate in coupled models. Part 1: large scale circulation variability. Climate Dynamics, 26, 217-228, 2006.

Rayner, N.A., Brohan, P. Parker, D.E., Folland, C.K., Kennedy, J.J., Vanicek, M., Ansell, T.J. and Tett, S.F.B.: Improved analyes of changes and uncertainties in sea surface temperature measured in situ since the Mid-Nineteenth Century: The HadSST2 dataset, Journal of Climate, 19, 446-469, 2006

FIGURES (full captions):

Figure 1: The difference in SST (K) between the HadSST2 dataset and each of the available PMIP2 models control (PI) runs - (a) CCSM, (b) FGOALS, (c) HadCM3_UB and (d) MIROC. Positive (negative) values are indicated by the solid (dashed) lines.

Figure 2: Zonal mean SST (K) at 47.5S from the HadSST2 data set and each of

the available PMIP2 models' control (PI) runs (CCSM, FGOALS, HadCM3_UB and MIROC). The data are monthly means, averaged over all available years.

Figure 3: The difference in zonal mean seasonal insolation for the Mid-Holocene relative to the control, averaged over all seasons in the run (Wm-2). Positive (negative) values are indicated by the solid (dashed) lines. The zero line is given as the thick black line.

Figure 4: The difference in SST (K) between the available PMIP2 Mid-Holocene and control (PI) runs - (a) CCSM, (b) FGOALS, (c) HadCM3_UB and (d) MIROC. Positive (negative) values are indicated by the solid (dashed) lines.

Interactive comment on Clim. Past Discuss., 6, 185, 2010.

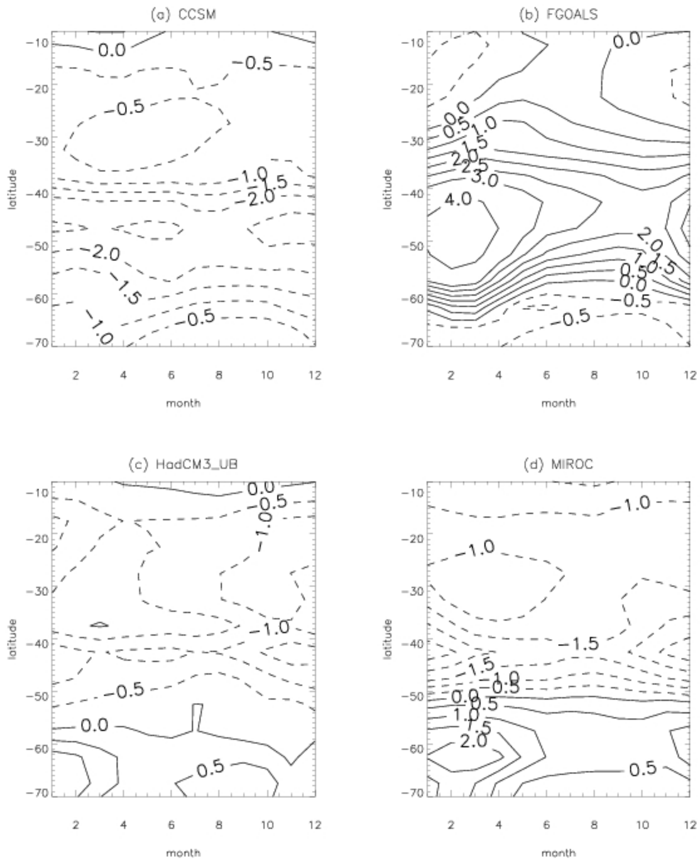

Fig. 1. The difference in SST (K) between the HadSST2 dataset and each of the available PMIP2 models control (PI) runs - (a) CCSM, (b) FGOALS, (c) HadCM3_UB and (d) MIROC.

CPD

6, C44–C54, 2010

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

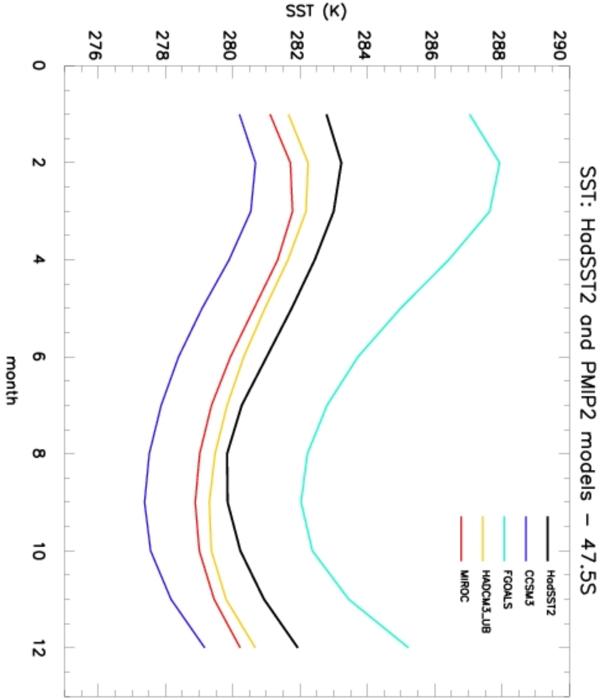

Fig. 2. Zonal mean SST (K) at 47.5oS from the HadSST2 data set and each of the available PMIP2 models' control (PI) runs (CCSM, FGOALS, HadCM3_UB and MIROC).

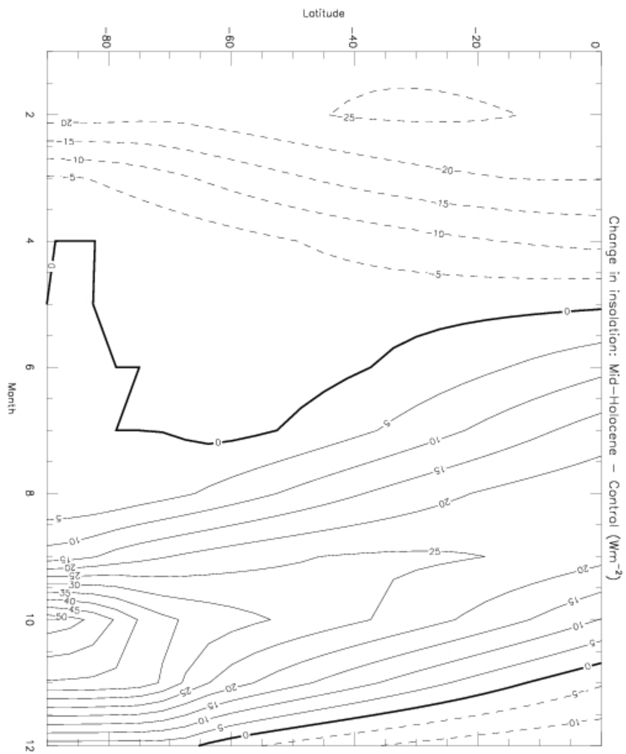

Fig. 3. The difference in zonal mean seasonal insolation for the Mid-Holocene relative to the control, averaged over all seasons in the run (Wm-2).

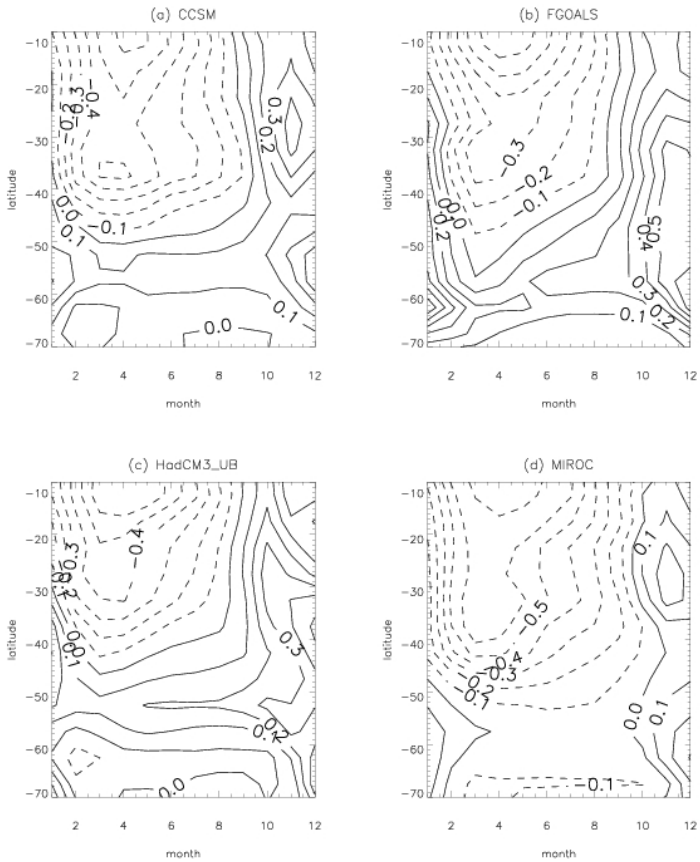

Fig. 4. The difference in SST (K) between the available PMIP2 Mid-Holocene and control (PI) runs - (a) CCSM, (b) FGOALS, (c) HadCM3_UB and (d) MIROC