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Geoscientific Model Development Discussions

GMDD

2, C237–C241, 2009

Interactive Comment

Interactive comment on "Simulated pre-industrial climate in Bergen Climate Model (version 2): model description and large-scale circulation features" *by* O. H. Otterå et al.

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We thank the reviewer for the useful comments. The main change made to the manuscript include a more detailed discussion on the warm-bias in the Southern Ocean. In addition several minor changes has been made and some of the figures have been modified as requested. We believe that we have responded satisfactorily to the reviewer's comments, which has contributed to an improved manuscript.

Detailed answers to the reviewers' comments follow:

Major comment: Discussion on the cause of warm bias over the Southern Ocean needs to be detailed and may be corrected

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Interactive Discussion

Discussion Paper

We agree that the discussion of the SO error had to few details and was not clearly presented. After reconsidering the model results, we now believe excessive mixing between the surface and the deep ocean in the Southern Ocean is the main cause for the warm bias and underestimation of sea ice extent in this region. The excessive mixing erodes the halocline and makes it difficult to maintain a fresh and cold surface layer required for wintertime freezing of sea-ice. The underestimation of sea-ice will in turn cause a warm bias in the model due to increased absorption of short-wave radiation.

There are several factors that might contribute to this excessive mixing, and they are now briefly mentioned in the text. Firstly, MICOMs mixed layer turbulent kinetic energy parameterization generally tends to generate too deep mixed layer depths at high latitudes. Preliminary testing with a new mixed layer depth parameterization (Oberhuber 1993) indicates much improved mixed layer depths at high latitudes compared to observations. Secondly, the ocean model uses isopycnic layers with potential densities estimated with a reference pressure at 2000 db. The profile with 2000 db reference pressure gives a poor representation of stratification, even static instability, near the surface (see Assmann et al 2009, GMDD, now in discussion). This makes it difficult for the model to represent a realistic halocline isolating the surface from the deeper ocean. Finally, in MICOM the brine rejected during freezing of sea-ice is placed in surface layer. This tends to destabilize the water column near the surface. Several studies indicate that a parameterization of salt-plumes can contribute to the maintenance of a more realistic halocline in ocean models not resolving these plumes.

Minor comments:

P511, line4: Detailed description on the turbulence scheme in the atmosphere will be useful for the readers. If there is a reference, this can be referenced.

A new paragraph has been added to the text where the vertical diffusion scheme is described in more detail with appropriate references. In particular, the limitation that has been added to the Richardson number in this version of BCM is described in detail.

P514, line 4: Version of OASIS can be specified.

Version number has been added to the text.

P514, line 9: Variables that are exchanged between ocean-coupler-atmosphere need to be described in detail.

A new table are now included, listing the variables that are being exchanged via the coupler.

P514, line 13: Benefit of the initialization technique comparing to the run without this initialization will be informative.

The following text has been added to in section 3: "One technique that has often been used to initialize pre-industrial control simulations, is to reset the radiative forcing to near 1850 conditions using near present day Levitus oceanic initial conditions. However, a model coupled in this manner will, in general, suffer from climate drifts. In this study, we therefore used a method similar to the one outlined in Stouffer et al (2004), where the radiative forcing was run backwards in time from the present to pre-industrial (1850) levels, and then held constant at this level for 3-5 centuries. One of the advantages of this method compared to other methods is that it generates internally consistent pre-industrial conditions within the framework of the model (Stouffer et al. 2004)."

P515, line5: Solar constant 1370 W/m2 is higher than is observed or accepted, and use of 1370 need to be justified.

The reviewer is right that the solar constant value is too high in the present study. In earlier runs with BCM2 a poor low-level atmospheric circulation (i.e. anomalously high pressure in the high northern regions partly contributed to an excessive NH sea-ice extent in the model. In order to remedy this, the default value of the solar constant was increased from 1365 to 1370 W/m2 . Even though this will likely not change the

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variability of the system, we agree that the use of a more physically accepted solar constant value is better and this will be the case in future development of the model system. The text has been updated accordingly.

P516, line20: TOA radiation bias 2W/m2 can be subtracted during the climate change analysis, but this value is still high and need to be reduced for further development. Maybe the use of solar constant 1365 will be helpful.

We agree that this value is too high, but as long as ARPEGE is non-conservative this will likely continue to be a problem also in the future. A reduced solar constant would improve things somewhat, but not solve the problem. An earlier control run, which was used for the IPCC simulations, had a more realistic solar constant value (1365). However, this run also showed a strong TOA bias (about 1.5 W m-2).

P520, line9: Presenting spectra of MOC strength will be informative

The Atlantic MOC and its variability is the subject of several ongoing studies. Nevertheless, we have added the power spectrum of AMOC to Figure 6.

P520, line23 As mentioned in major comments, “caused by negative sea-ice biases” should be checked and described differently if it is not. Sea-ice bias may be a result of circulation bias.

This is a good point. The discussion of the SO warm bias has been rewritten and the reference to “negative sea-ice biases” removed. We now believe that problems with the ocean mixing routine in the SO is the more likely candidate for explaining the SH sea-ice bias (see response to major comment).

P524, line4: Adding simple statistics such as skewness, kurtosis of Nino3 index will be informative for comparison to other models.

The requested statistics have been added to the Nino3-index figure.

P524, line 5: In addition to T2m regression on the Nino3, showing SLP or wind regres-

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sion will verify the good atmospheric response.

The SLP regression on the Nino3-index has been added to figure 13, and a short paragraph discussing this figure has been added to the text.

Figure 8: Showing same figures of SH will be good reference for the future development. Overlapping surface current over the ice thickness is also informative to check Gyre circulation for both hemispheres.

Two more panels have been added to the figure showing the SH response. Surface velocity has also been added to all panels and a brief discussion of the surface circulation has been added to the text.

Figure 7: Overlapping contour lines will help to read scale of SST and SSS biases.

Overlapping contour lines added in the figure.

Interactive comment on Geosci. Model Dev. Discuss., 2, 507, 2009.