Biogeosciences Discuss., 4, S1598–S1603, 2007
www.biogeosciences-discuss.net/4/S1598/2007/

Biogeosciences Discussions

Interactive comment on "Spatio-temporal variability of marine primary and export production in three global coupled climate carbon cycle models" *by* B. Schneider et al.

B. Schneider et al.

Received and published: 5 October 2007

General comments

First, we would like to thank both reviewers for their valuable comments that helped to clarify and improve the manuscript. We agree with both that the conclusion that all three models represent the observed climate-productivity interactions well overstretches the results. To better distinguish between the models capability to reproduce the observed climate and PP variability a more extensive discussion of the underlying iron cycling will be given, as this explains most of the model differences and caveats.

Response to the comments made by Jorge Sarmiento (reviewer #2)

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

Specific comments

1. The assertion that all three models represent the observed climate/pp variability very well stretches the truth considerably.

   This argument definitely needs clarification in the text. However, the first result is still true, PP anomalies from the global and the stratified ocean are indeed strongly correlated in all three models, however, in MPIM the amplitude and frequency is strongly overestimated, while in NCAR slightly underestimated. This has been added to the text (p. 19, l. 22-24).

2. The conclusion that the models reproduce the observed links between climate and PP variability very well, so that they are suitable to predict future climate change, has been mitigated.

   We added a lot of information on the modeled iron cycling in the text (p. 7, l. 1-4; p. 9, l. 19, p.20, l. 3-7, p. 21, l. 16-20; p. 21, l. 21 – p. 22, l. 24; p. 23, l. 3-10).

   The conclusion from this discussion is that two models (MPIM, NCAR) are strongly iron limited. On the one hand, this allows macronutrient concentrations to climb above observed values and, on the other hand, as iron is mainly supplied by dust deposition in those models, the response of these models to climate variability must be strongly suppressed.

   For IPSL we explain that there is an 'artificial' iron source by restoring the iron concentration to a minimum value of 0.01 nM l^{-1}. For example, we added (p. 21, l. 25 – p. 22, l. 10):: 'This baseline concentration represents a non-accounted source of iron, which could arise from processes that are not explicitly taken into account in the model, like temperature or light effects on iron availability, iron released from ligands and dissolved or particulate matter, variable iron content in deposited dust, different rations of bio-available versus dissolved iron from recycling (e.g. micro- versus macrozooplankton), changes in phytoplankton size and/or physiology like half-saturation constants or iron demand. The iron restoring formulation allows to correctly represent the width of the equatorial tongue in chlorophyll and the location of the iron-to-nitrate limitation transition, thus yielding a better representation of nutrient co-limitations (Fig. 5). By doing so, the natural variability of iron is partly suppressed, dampening the signal that otherwise would be transferred into PP variability. Nevertheless, IPSL shows the best representation of interannual climate/PP variability both temporally (Fig. 10) and spatially (Fig. 12). This is due to the fact that next to the location of the iron-to-nitrate limitation transition the impact of ENSO variability on the supply of NO_3 is well reproduced.'

In the conclusions on page 25 we state: ' ... (this study) also highlights the importance of the modeled iron cycle on the impact of climate variability on marine productivity. Only one model (IPSL) is able to reproduce the observed relationship between climate (stratification, SST) and PP, and this result may to some extent be attributed to an artificial iron source.'

3. The extrapolation of the result of seasonal variability onto longer time scales (climate variability) has failed, which was not explained in more detail.

   This result was shown as a first guess under the assumption that the IPSL model captures the observed relationship between climate and PP variability very well. It is beyond the scope of this study to analyse and explain the reasons for the failure of this extrapolation. However, there is a second study in preparation that investigates the future behaviour of these model simulations, so that results and explanations about this finding will be available, soon (Steinacher et al., in prep.).

Technical corrections

BGD

4, S1598–S1603, 2007

Interactive Comment

1. The second part of the abstract has been completely rewritten, the abstract now states: 'This study compares spatial and temporal variability in net primary productivity (PP) and particulate organic carbon (POC) export production (EP) from three different coupled climate carbon cycle models (IPSL, MPIM, NCAR) with observation-based estimates derived from satellite measurements of ocean colour and inverse modelling. Satellite observations of ocean colour have shown that temporal variability of PP on the global scale is largely dominated by the permanently stratified, low-latitude ocean (Behrenfeld et al., 2006) with stronger stratification (higher sea surface temperature; SST) leading to negative PP anomalies and vice versa. Results from all three coupled models confirm the role of the low-latitude, permanently stratified ocean for global PP anomalies, but only one model (IPSL) also reproduces the inverse relationship between stratification (SST) and PP. An adequate representation of iron and macronutrient co-limitation of phytoplankton growth in the tropical ocean has proven to be the crucial mechanism determining the capability of the models to reproduce observed interactions between climate and PP.'

2. p. 4, l. 1-4 now says: 'Najjar et al. (2007) found that the global carbon export (POC and DOC) varied from 9 to 28 GtC/yr in 13 different ocean circulation models using the same biogeochemical model (OCMIP-2), yielding for POC export a range of 6-13 GtC/yr from those models who are able to realistically reproduce radiocarbon and CFC distributions (Matsumoto et al., 2004).

3. We are aware that a pic:poc ratio of 0.2 is a rough guess. A more recent version of the pisces model simulates calcite formation in dependence of the saturation state of seawater with respect to calcite (Gehlen et al., Biogeosciences, 2007).

4. All relevant tracers included in NCAR are now given in the model description.

5. R has been changed to 0.80.

BGD

4, S1598–S1603, 2007

Interactive Comment

6. This paragraph now says (p. 15, l. 11-16): 'In summary, all models show a reasonable agreement with observations of temperature and salinity fields and also with estimates of water mass transports, giving confidence in the models that the simulated circulation fields are reasonable and comparable to those of other state-of-the-art coupled climate models (Meehl et al., 2007; Randall et al., 2007). In terms of biogeochemical cycling MPIM and NCAR clearly suffer from strong iron limitation.

7. Sorry, we couldn't find a narrower range for PP in the Carr et al. (2006) paper.

8. This statement has been withdrawn, a further test showed no better spatial agreement between satellite-based and modeled PP fields, when the coastal areas were left out.

9. DOC was not included in the current study as there are no climatological reference data available. It will, however, be investigated in the future part analysis (Steinacher et al., in prep.).

10. This statement has been mitigated, it now says (p. 19, l. 19-24): 'All three models examined in the current study reproduce the behaviour described by Behrenfeld et al. (2006) where the global signal of PP anomalies is largely controlled by the permanently stratified low-latitude oceans that have annual average SSTs above 15° C (Fig. 10), however, MPIM strongly overestimates the amplitude and frequency of interannual variability while in NCAR variability is slightly too low.'

11. Here SST anomalies are also taken as stratification analogue (p. 20, l. 21-23): 'The slopes that can be derived from the anomalies of PP_{strat} versus stratification (SSLOPE) and SST (TSLOPE), here also used as an indicator for stratification, are very similar in IPSL and the observation-based estimates (Fig. 11).'

12. Changed into (p. 23, l. 22-25): 'Correlation coefficients different from 1 can be found in NCAR, even though EP is fixed to be 1/3 of PP, as local EP variability is

BGD
4, S1598–S1603, 2007

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

EGU

correlated with PP variability averaged over the entire low-latitude, permanently stratified domain. This is also the reason why negative correlations in all models may occur.'

13. This statement has been mitigated, as explained above.

14. We added to the text (p. 18, l. 27 – p. 19, l. 3): ' The discrepancies between the two fields of observation-based EP estimates, especially in the northern hemisphere and the Southern Ocean around 60° S (Fig. 9) can be explained by the fact that satellite observations may have difficulties in coastal areas due to the high abundance of suspended matter and can thus overestimate Chl and consequently EP, whereas in the Southern ocean deep Chl maxima are probably not captured by the satellite sensors (Schlitzer 2002).'

BGD

4, S1598–S1603, 2007