Review to the manuscript 'Anthropogenic carbon dynamics in the changing ocean' by J.F. Tjiputra, K. Assmann, and C. Heinze

General Comments

The manuscript describes the changes in oceanic carbon uptake and storage over the period from 1850 to 2099 as it is computed by the Bergen Earth system model. The changes are devided into a natural and anthropogenic component. The model results are compared with recent observations of oceanic CO2 fluxes and transport estimates of anthropogenic carbon. Anthropogenic carbon cannot be measured directly but has to be inferred from observational data with different methods, and the flux observations only cover limited regions over a relatively small time scale compared with the period of the model run. Thus it is necessary to investigate these questions with numerical models, and this study provides some useful information on the expected former carbon uptake of the world's ocean, the distribution of anthropogenic carbon in the ocean interior and oceanic transports of anthropogenioc carbon. On the other hand, due to the sparse observations, it is difficult to judge how reliable the model results are or what the 'error bar' for the quoted numbers could be. In my opinion, this item could be discussed a bit more detailed in the paper.

Specific Comments

abstract line 8/9: 'changes in physical climate alone results in a release of natural carbon of about 22 Pg C'

The number of 22 Pg C is the difference between the model run with increasing atmospheric CO2 and interactive climate (EXP2) and changing climate but preindustrial CO2 levels (EXP3). My question is whether EXP2 only includes physical climate-carbon feedbacks (as it is mentioned in the abstract) or also biological-chemical-physical-carbon feedbacks such as ocean adicification and its possible impacts on marine ecosystems. The Bergen Earth system model includes a marine biogeochemical model (HAMOCC 5.1). If HACOMM5.1 includes biogeochemical feedbacks, the change of 22 Pg C is not only physical (in this case the formulation within the abstract is inadequate). If HACOMM5.1 does not include such feedbacks, the 22 Pg C are indeed physical, but the number is probably an underestimation of the real change of Cnat due to all feedbacks.

section 3 (p. 395, l. 20)

'.. recently published pCO2 climatology-based estimates (Takahashi et al., 2009) of 1.6 +/- 0.9 Pg C yr^(-1).'

The value of 1.6 Pg C yr^(-1) given in Takahashi et al. (2009) is the number for the total air-sea carbon flux. Takahashi et al. (2009) assume a preindustrial outgassing of CO2 from the oceans of 0.4 Pg C yr^(-1), resulting in an oceanic uptake of anthropogenic carbon of 2.0 Pg C yr^(-1). (see Takahashi et al., 2009, p. 575)

section 4.1 p. 397, l. 8)

'Figure 1c ... also indicates a strengthening and poleward shift (i.e. approximately 40°S to 45°S) in the Southern Ocean surface wind speed'

according to figure 1.c the wind speed is weakened between 40°S and 45°S and strengthened southward of 45°S, the discussion of fig. 1c in section 4.1 is thus misleading.

section 5 (p. 401, l. 26)

'Since deep water formation associated with the AMOC ..., the weakening leads to weaker penetration of Cant into deeper layers.'

A recent paper deals with reduced Cant storage over the last decade in the North Atlantic due to reduced formation of North Atlantic Deep Water:

Steinfeldt, R., M. Rhein, J.L. Bullister, and T. Tanhua (2009). Inventory changes in anthropoghenic carbon from 1997 – 2003 in the Atlantic Ocean between 20°S and 65°N. Global Biogeochem. Cycles, 23, GB3010 doi:10.1029/2008GB003311.

section 5 (p. 403, l. 7)
'We also note that the stabilization of atmospheric carbon uptake in most regions is partly attributed to the long-term equilibration time for atmospheric CO2 into the ocean (Archer et al., 2009).'
Archer et al., 2009, give an equilibration time scale of 200 to 2000 years, but I do not see, why this long time scale (which is probably due to the slow oceanic overturning) should lead to a stabilization of CO2 uptake under increasing emissions (which are imposed by the A2 scenario) only in some regions, but not in the Southern Ocean. How does the Delta pCO2 between ocean and atmosphere evolve with time? Maybe in the Southern Ocean, old deep water upwells, which can take up a lot of anthropogenic carbon, in contrast to central waters in the subtropics, which are younger and do not have such a large 'deficit' in Cant. If this is correct, the longer equilibration time for Cant in the Southern Ocean even leads to the increasing uptake there.
Another possible mechanism for the ongoing increase of Cant uptake in the Southern Ocean is the aforementioned decrease in sea ice. Could this effect somehow be quantified?

section 6 (p. 403, l. 25)
'Our model study thus implies that feedbacks from climate change induced circulation and other physical cahnges do not reduce the ocean's ability in taking up anthropogenic carbon substantially.'
Could 'substantially' somehow be quantified and how do the authors prove this statement? The only prove they give in the paper is the (large?) number of 538 Pg Cant that have been taken up by the oceans. The question is how large this uptake would be without climate and other physical changes. This could be computed by another simulation with preindustrial climate and increasing CO2 according to the A2 scenario. Such a simulation is not mentioned in the paper. If it does not exist, I do not expect the authors to perform it, but nevertheless the discussion should be a bit more quantitatively, e.g. by comparing the fraction and total amount of the carbon emissions that are taken up by the ocean in the present day climate state (around the year 2000) and at the end of the model run.

Figure 3, legend
'All observations value (correct: observational values) represent the modern day perioo
ds.'
Figure 3 shows Cant fluxes, which cannot be observed directly. In section 3, these 'observations' are called 'estimates', and I would prefer the formultion 'observational based estimates' instead of 'observational values' also for this figure legend, as 'observational values' is misleading.

Figure 4
The storage term for anthropogenic carbon in each region at the end of the model run could also be written within the figure, which would be a useful additional information. These numbers might show up within the graphs for Cant fluxes from the atmosphere and the lateral fluxes. The Cant storage is just the sum of these two terms, but as the graphs are quite small, an addition of the 'red' and the 'blue' lines by eye results only in a rough estimate. For some regions (Arctic, Southern Ocean), the Cant storage term is provided in the text, but not for the other regions.

Technical Corrections

abstract
Long-term response of CO2 fluxes to climate change at the ocean surface and the ocean interior ...'
In my opinion it should be 'The long-term response ...' and ' ... within the ocean interior'

'modern conditions' is used frequently throughout the paper. I would prefer 'present' or 'present day conditions'.

section 5 (p. 403, l. 10)
'537 Pg C'
at all other places the Cant uptake is given as 538 Pg C

Figure 1
legend of figure 1b
the symbol for the unit 'mole' is 'mol', not 'moles'
the symbol for the unit 'liter' is 'l', not 'L'
the correct unit is probably mikromol l^(-1) ppm^(-1) ???

caption of figure1
'... mean difference between EXP1 and EXP3'
I would prefer 'difference between EXP3 and EXP1', as EXP3 -EXP1 is meant and not EXP1-EXP3

Figure 4
Longitudes should be added along the x-axis.

Figure 5 and abstract (l. 21)
the numbers given for the Cant uptake per area and year seem to be too small by a factor of 10!
(area of ocean: 3.61 *10^14 m^2; assuming a Cant uptake of 2 Pg C yr^(-1), the Cant uptake in g C m^(-2) yr^(-1) is about 6, in the figure the mean value for the year 2000 is smaller than 1)
Also the numbers given in the abstract are too small by a factor of 10.