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Interactive comment on "Interannual-to-decadal variability of North Atlantic air-sea CO_2 fluxes" *by* S. Raynaud et al.

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Abstract

To avoid confusion, the revised abstract no longer mentions "resolution". As pointed out by Referee #1 an ocean model resolution study is beyond the scope of the work presented here. So far, only coarse-resolution ocean models have been used to simulate interannual variability of air-sea fluxes. Our reference to the resolution problem in the submitted abstract was not intended to refer to the parametrisation of subgrid-scale processes in the ocean models, although such a sensitivity study would be interesting to tackle in the future. For this study, "resolution" in the submitted Abstract was meant to refer to the inverse atmospheric models. The regional variability in land-atmosphere carbon exchange is higher than that for air-sea fluxes. Thus small errors in attributing air-to-land fluxes in atmospheric inversion models may be responsible for large errors in the diagnosed air-sea CO2 flux (Rodenbeck et al., 2003; McKinley et al., 2004a)

in the near-coastal boxes. In our paper, the resolution refers to the size of boxes in the inverse models. Differences between ocean models are relatively small compared to differences between ocean models and atmospheric inverse models (Peylin et al., 2004). We have clarified this issue in the revised text.

The biogeochemical model (PISCES) used here has been described and evaluated by Aumont and Bopp (2006). Relative to the available data, the ORCA-PISCES model provides relatively accurate simulations for global carbon content and air-sea CO2 flux. As for sub-grid scale processes, no doubt different implementations of such parameterisations would alter results in some regions (e.g., around the Gulf Stream) and a series of computer-intensive sensitivity tests should eventually be conducted. However, as only a first study to focus on decadal variability, we have left those costly efforts to future work. Further details regarding these questions are now provided in the Methods section.

Introduction

(1) Clarify what is the exact objective of this paper.

The last paragraph of the Introduction now clarifies our two objectives: (1) to analyse spatiotemporal variability while accounting for lags in the system, and (2) to study decadal variability. No previous study has addressed either objective.

(2) Clarify what is the problem regarding Gruber's findings.

The problem has now been made clearer in the Introduction. In paragraph 1, we indicate that the Gruber et al. (2002) results (based on an extrapolation of BATS ocean data) agree with the older-style atmospheric inverse approaches.

In paragraph 2, we show that the high variability that was actually an extrapolation by Gruber et al. (2002) disagrees with the ocean model results as well as the latest state-of-the-art atmospheric inverse approach. We clarify how this problem is related to extremely coarse resolution in the older atmospheric inverse approaches as well as

OSD

2, S239–S243, 2005

the corresponding extrapolation by Gruber et al. of the BATS results from one location to the entire basin. Both the ocean models and the state-of-the-art atmospheric inverse approach have much higher horizontal resolution and do not suffer from these problems.

Climate simulation

As requested, we have now added a paragraph to the Methods Section that focuses on previous evaluations of the ORCA2 model, in particular studies most relevant to simulating interannual variability in the North Atlantic.

Other comments:

"p. 438, line 2: replace "inversions" here, with "inverse models"

This term has been replaced throughout the text.

p. 438, line 8: remove "the"

Done.

p. 439: line 3: remove "."

Done.

p. 439: line 3: replace "arealy" and replace sentence with something like: "and that the spatially integrated flux exhibits large variability".

We no longer use arealy in the text, and the sentence that is mentioned has been replaced.

p. 440, line 2 & 3: modify sentences beginning with "Such".

Done.

p. 442, line 14: What are the climatological circulation fields used in this study? Are they from ORCA2?

OSD

2, S239–S243, 2005

Yes, these climatological fields are computed from the ORCA2 ocean model. This detail has now been added parenthetically to this sentence.

p. 444, line 15: remove one "to"

Done.

p. 444, line 20: Need some discussion of the general circulation simulated. Is the Gulf Stream the only problem? Is there a reference where this problem has been discussed in detail? Why is this a problem?

The problem of the Gulf Stream mainly comes from the extreme sensitivity of the dynamics in this region to resolution and the formulation of sub-grid scale physics. Even using a high resolution model (1/10 degree), the separation of the Gulf Stream and the structure of the North Atlantic Current still suffer some deficiencies (Maltrud and McClean,2005). Section 2.1 now includes some discussion of this problem along with two new related references.

p. 445, line 8-11: Something is missing. Sentence needs to be restructured.

We have arranged this sentence, deleting an erroneous "(", which now makes this sentence much clearer.

p. 445, line 18: Is "significant correlation" used in a statistical sense here, meaning the correlation has beentested for its significance? Please clarify.

We now provide a 95% confidence interval for each correlation coefficient r. Given correlations are all significantly different from zero.

p. 446, line 2-4: Comment on the significance of the analysis given the significant difference between modeldata and observations (Fig 1 and 2)?

Fig. 1 in the revised manuscript has now been corrected for the poorly arranged subpanels in the submitted manuscript. After rearrangement, there appears generally reasonable model-data agreement for annual mean, winter, and summer climatological

OSD

2, S239–S243, 2005

air-sea CO2 fluxes. The revised manuscript also now includes a more quantitative model-data comparison (Taylor diagram) at BATS (Fig. 2). As now discussed in the revised text, this quantitative analysis reveals that all model studies to date underestimate data-based estimates of variability at BATS, although one of the models (MIT) appears more realistic than others. Conversely, in terms of phasing at BATS, our ORCA2 model is the most realistic (r = 0.52) and the MIT model is least realistic (r = 0.3). Additionally for a wider perspective,the revised manuscript also provides an analogous comparison at Station ALOHA in the subtropical North Pacific (Fig. 3), where there is much better model-data agreement.

Figure 1: Rearrange subpanels and better describe what is shown

Figure subpanels have been correctly rearranged in the revised manuscript. The text now includes a detailed description of what is shown: observations are from (Takahashi et al., 2002), and the climatological annual cycle of the model is computed over the last 55-year cycle.

Figures 8-10: Problems with titles on figure subpanels

These problems with the placement of subpanel titles have been corrected in the revised manuscript.

Interactive comment on Ocean Science Discussions, 2, 437, 2005.