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Ocean Science Discussions

Interactive comment on "Effects of mesoscale eddies on global ocean distributions of CFC-11, CO_2 and $\triangle^{14}C$" *by* Z. Lachkar et al.

Z. Lachkar et al.

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1 General Comments:

Ref. #1 points out that most of our analyses are focused on the thermocline and little is said about the deep ocean, which plays an important role on the century time scale or longer. In a related comment at the end of his review, this Ref. #1 states that we should either (1) focus on the AAIW and ventilation of the thermocline in the Southern Hemisphere, without drawing too general conclusions about other water masses in terms of climate (minor revisions), or (2) widen the paper to discuss NADW, AABW, etc. to be consistent with some of general conclusions (major revisions).

The goal of this manuscript is certainly the first option. To investigate how horizontal resolution would affect long-term ocean uptake (and climate evolution) we would need to run much longer eddy-permitting simulations, which would go well beyond our available computational resources. We also agree with Ref. #1 that to study longer-term uptake (centennial scale and beyond), our model's vertical resolution and z-coordinate system may not be adequate. In the revised manuscript, our focus on the thermocline and the intermediate waters, and thus more on decadal timescales, has been made clearer. In this regard, we are also now more restrained in our Conclusions section, the last paragraph of which has been rewritten with that in mind.

2 Specific Comments:

1) Ref. #1 would like to see more information about the vertical structure of the tracer distributions, particularly in the Atlantic

In response, we have added 2 new meridional sections, which offer insight concerning the focus of the paper (intermediate water ventilation in the southern extratropics). These sections cover the South Atlantic (AJAX) as well as the North Atlantic (Na20w) (Figures 11 and 12, with associated discussion in lines 366-378). We have not added zonal sections it is known already that western boundary currents are poorly represented even in eddy permitting models and because with so many figures already, a choice had to be made..

2) Ref. #1 requests that we clarify the use of the offline approach in a relatively high resolution model.

We follow the lead of Hill et al (2005) who made $1/6^\circ \times 1/6^\circ$ regional simulations using both offline and online approaches. They found that the offline model faithfully reproduced the online results when using a forcing frequency that is close to the inertial

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period (about 1 day). Here we resolve only the upper range of mesoscale spectrum (energetic eddies of diameter about 100 km or more, which persist for about several weeks); small eddies associated with high frequency variability (nearer to the inertial period) are not resolved. Therefore, our use of 5-day forcing appears justified. To make this aspect clearer in the revised manuscript, we have added the following statement in P. 5, lines 146-148: 'Here, small eddies associated with high frequency time variability (close to the inertial period) are not present in the flow given that we resolve only the upper range of mesoscale spectrum' (lines 146-148). In addition, to reduce the large number of figures in the revised manuscript, we have removed the figure (Fig. 2 in the original OSD manuscript) that compares online vs. offline CFC-11 inventories in the non-eddying model because differences are minute.

3) Ref. #1 points out that not only does resolution differ between the two models, but so do the friction operators (Laplacian vs. biharmonic).

Ref. #1 rightly points out this difference. We argue that the change in the formulation of the friction operator must go hand in hand with the change in resolution. In the revised version of the manuscript, we now better explain our choice of using different friction operators in the eddying and the non-eddying models (lines 170-176). In brief, the Laplacian operator is typically used in coarse-resolution models, whereas it is not used at eddying resolution because it dissipates eddies and dramatically reduces the advantage of higher resolution. Conversely, the biharmonic operator offers no advantages in non-eddying models, but it is the typical choice for eddying simulations because with it advection is able to dominate flow and hydrodynamic instabilities are allowed to develop (Griffies and Hallberg, 2000; Griffies et al, 2000).

4) Ref. #1 is surprised that although the model is not really eddy-resolving, the modification in the tracer uptake is so important. This referee wonders why there is such a large change and if such improvement holds for other regions

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Although at least a 1/10 degree model is needed to come close to fully resolving mesoscale eddies, we still do not know the minimum resolution necessary in order to properly resolve large-scale uptake and transport of transient tracers. Our improved resolution, although still modest, shows a major change in the ventilation rate of surface to intermediate waters in the southern extratropics. In that region, where the fluxes are also largest, there are dramatic changes in the near-surface ocean circulation (Fig. 18) and in surface ocean residence time (Fig. 20). Our analysis of the effects of resolution through 'the eyes of' its effect on transient tracer distributions also provides insight into ventilation of surface-to-intermediate waters that previous studies were unable to assess. Certainly our eddying simulation does not resolve the entire spectrum of mesoscale eddies, but its resolution might be sufficient to have reached a threshold, beyond which further increases in horizontal resolution will not substantially alter large-scale patterns of uptake and storage of tracers such as CFC-11 and anthropogenic CO2. The revised manuscript more clearly states of this objective (lines 111-115). Future, higher-resolution simulations should help to locate this threshold more precisely. The revised manuscript also offers more detail on regional improvements and the causes of the changes due to resolution enhancement.

5) Ref. #1 requests that we clarify the discussion about the ventilation of AAIW

To make this discussion clearer, we have rewritten the paragraph detailing the link between AAIW ventilation and the residual circulation in the Southern Ocean (section 4.2, lines 469-492). Please also refer to our response to Ref. #2's remark #8.

6) Ref. #1 recommends that we limit the general conclusions, in terms of climate change, to the decadal time scale.

Done. See last paragraph of the Summary and Conclusions.

Interactive comment on Ocean Sci. Discuss., 3, 1011, 2006.