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Ocean Science Discussions

Interactive comment on "Impact of hydrographic data assimilation on the Atlantic meridional overturning circulation" *by* G. C. Smith et al.

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General response to all reviews

We would like to thank all the referees for their insightful comments. All referees suggested the paper be shortened and made more succinct and this will be done in addition to the main points made by the referees that are addressed below, with the various minor comments easily addressed in a new manuscript.

Anonymous Referee #1

1. We already posted a short comment concerning the referee's desire to see recycled hindcasts over many decades. It is not the purpose of this paper to examine how well this model can simulate the MOC in a steady free running simulation; the answer is

that it is fairly poor, as in many ocean models. The main focus is to see if the MOC can be improved by the assimilation of upper ocean profiles data, particularly in the period in 2004-05 when good Argo data are available for assimilation and the Rapid mooring array is available for validation of the results. Thus long free model runs would not help to answer this question.

2. While additional figures showing a meridional section of the MOC, heat transport and bottom topography could be easily added, reviewers 2 and 3 suggest the paper be shortened. In addition, the focus of this paper is to understand the impact of data assimilation on the MOC using the RAPID array estimates at 26N and thus speculating about changes at other latitudes would not substantially add to the results, nor would expanding the discussion to include heat transports. Also, considerable detail of the bottom boundary and mooring array are given in Figure 1.

3. We agree with the referee that more discussion of differences with Baehr et al. (2009) should be included. This will be added to a revised version of the manuscript.

4. An additional figure showing the differences after 3 years will be added to a supplementary material section.

Responses to specific comments: - P.2671, l.14: text to be modified as suggested - P.2671, l.16: typo. Text to be modified to change AMOC array to RAPID/MOCHA array - P.2672, l.12-13: text to be modified as suggested. - P.2672, l.19: The GM90 scheme is not being used in the $\frac{1}{4}$ degree run although it is used at 1 degree. We agree with the referee that it may be better to use GM90 even at $\frac{1}{4}$ degree but this work tries to be consistent with model runs in Grenoble and the GM differences would not affect the MOC results of this paper which in any case focus at 1 degree. - P.2672, l.20: text to be modified as suggested: Blanke and delecluse 1993. - P.2672, l.25: text to be clarified - P.2672, l.27: text to be modified as suggested. - P.2673, l.14: “Innovation” is a common term in data assimilation. The text will be modified to better define this term. - P2677, l.22: text to be reworded - P2680, l.10: sentence to be added to

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clarify. - P.2680, l.28: text to be modified - P.2681, l.9: text to be modified as suggested - P.2681 : Rapid array profiles do not extend to the surface due to data loss from some of the moorings. - P.2682, l.9: We agree that there is not really an improvement between 1500-3000m in the transport in Fig 5d but we are not assimilating data in that range and thus do not expect much improvement. The density errors make it clear that improvements can only be expected above 2000m - P.2685-l.15: There is a clear intensification of the southward flow below 3000m from the Rapid data (thick black) in Fig 7d in May and Aug-Oct. - P.2685, l.24: text to be modified as suggested. - P.2687, section 5: P2687 It is of course true that the full development of the AMOC is a multidecadal coupled development. However the AMOC at 26.5N will also adjust on shorter timescales depending on the local density distributions in the vicinity and the wind forcing. These are the adjustments referred to in this section 5 and will be clarified in new text. - P.2703: sizing done to align longitude in two panels. - P.2715: caption modified as requested.

Anonymous Referee #2

The referee is concerned that the experiments were only run for a few years and that this may be insufficient for assimilation to impact the MOC at 26.5N. The presentation of several experiments with assimilation starting only in 2002 allows most issues to be best addressed however we do have assimilation experiments run for 40 years of the 1 degree model although there is much less data (the WOD05 data) available in earlier years. There are no substantial differences between these runs and those of a shorter duration provided assimilation has been in operation for a year or so. This will be clarified in the new manuscript.

We also agree that the manuscript is overly long and will be shortened considerably following specific advice from Referees #2 and #3.

Detailed comments: - Text to be modified to be more consistent about how AMOC is referred to. - P.2672, l.12-13: text modified as suggested - P.2681, l.9: text modi-

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fied as suggested - P.2684, l.1: A description of Baehr et al. (2009) to be added as noted above. - P.2685: Discussion of results in Sections 4.2-4.4 to be shortened as requested. P.2685, l.11-18: We agree that there is a seasonal cycle in the model and comments will be changed. - P.2689: The ORCA025 experiment from 1987 was used as it was available for comparison and as stated above the longer period of assimilation in either ORCA1 or ORCA025 does not substantially affect the results for the MOC at 26.5N. To shorten the manuscript we will move the section on ORCA025 to a supplementary materials section. - P.2704: Figs. 1 and 2 will be moved to a supplementary material section. - P.2707, Fig5: Differences between the Rapid data and the WOA will be due mainly to the strong smoothing of the WOA data which will not therefore capture boundary values well. - P.2712, Fig10: Initial conditions do affect the MOC results in particular because the deep initial conditions, although not the same as Rapid, are better for WOA than they are for the ORCA1 model when it has been spun up for some decades. Since the assimilation cannot improve these deep densities we do see a stronger MOC, e.g. in Fig 10e,f. - P.2713, Fig11: This figure and supporting text will be removed. - P.2714, Fig12: This figure and supporting text will be moved to supplementary material section. - P.2690: text to be modified as suggested. - P.2691, l.12-13: statement to be modified to better reflect limitations of current study.

Referee 3:

1. We agree that diapycnal diffusion is often too large in z level models, although the actual diffusion is a function of the gradients induced by the circulation as well as the actual parameter of course. For the deep ocean, the vertical diffusion usually falls to the background value, which for these simulations was the fairly standard value of 1 x 10-4.

2. While we agree that it would be interesting to examine the changes to the global density structure by assimilation, the manuscript focuses on comparing to the RAPID observations at 26N, and is already too long as noted above.

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3. The differences between RAPID and WOA are discussed briefly above (Referee #2). In addition to the smoothing noted above, RAPID provides a near-instantaneous snapshot of the state of the MOC while the WOA is a climatology, so significant differences due to interannual and high-frequency variations should be expected. Initializing ocean models from WOA is standard practise and thus CTL-IC and SYN-IC provide an assessment of the impact of model drift in deep water masses on the modelled MOC.

4. The difference between the thermal wind obtained from RAPID and WOA is a combination of horizontal smoothing across the deep western boundary current (as seen in Fig. 5a) and variability (as noted above).

5. We agree that the paper should be shortened. This will be accomplished by shortening some of the discussion, removing Fig. 9 and moving Figs. 1,2,12,13 and the associated discussions to the supplementary material section.

Specific comments: - p.2670, l.14-15: statement in text to be modified to reflect uncertainty of importance of MOC on heat transport. - P.2672, .l13: typo in text. To be modified to show model is 1/4deg resolution. - P.2684, bottom: In the interests of simplifying the paper we feel it would be better not to introduce a discussion on the variance of transports. - P.2692, l.10-14: It is true we have not focussed on assimilation of high latitude data but the errors at 26.5 N are clearly present in the deeper waters coming from the north and therefore we believe these must be monitored upstream in order to fully capture the MOC variability further south.

Interactive comment on Ocean Sci. Discuss., 6, 2667, 2009.