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Ocean Science Discussions

Interactive comment on "On the time to tracer equilibrium in the global ocean" *by* F. Primeau and E. Deleersnijder

F. Primeau and E. Deleersnijder

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Response to Referee #2

We would like to thank Referee #2 for providing helpful comments on our manuscript.

In regards to comment 1 "To which extent should we trust results from an OGCM that does not simulate explicitly the most energetic elements of the general circulation (i.e., eddies)?..."

We have modified the Conclusions section of the paper to add the following:

''Our three-dimensional model results suggest that the relative disequilibrium between the modern day deep Atlantic and Pacific oceans is on the order of 1200 years or less. This tracer equilibrium timescale depends of course on the accuracy of our model's velocity field and eddy diffusivity coefficients. Given that the model resolu-

tion is very coarse one might wonder how accurately it can simulate the time-mean circulation. Early studies such as Cox, (1989) and England (1993) have shown that coarse-resolution models are capable of representing the global-scale water masses suggesting that at least on the largest scales the model circulation is reasonably accurate. Given that the most slowly decaying eigenmodes are associated with the largest spacial scales we do not expect that our result should be very sensitive to the model resolution."

In regards to comment 2 "...It would be interest to this reader to see a discussion about whether the different tracer equilibrium times obtained for Dirichlet- and Neumann-type BCs would also occur for a time-dependent flow. The authors might just speculate on this."

Because the most slowly decaying eigenmode is associated with the largest spacial scales we expect that time-dependent variability of the flow associated with the largest scales will be most important. If the large-scale flow has low-frequency variability then it is possible that the equilibration timescale will itself be a function of time. In other words if the circulation varies significantly on timescales of thousands of years, then the tracer equilibration time will depend on the specific time at which the tracer was introduced in the ocean.

To compute the eigenmodes of the system we have to use either the time-averaged flow or perhaps an instantaneous snapshot. We have used the time-average flow. We believe that this is adequate for our model because the time-dependence of the large-scale flow in our simulation was weak. However if the large-scale flow is significantly time-dependent on the largest scales then using the time-average flow to disperse the tracer will tend to overestimate the equilibration time. As an extreme example imagine a situation in which the flow is dominated by a large amplitude periodic circulation whose time average vanishes. Using the time-averaged flow to estimate the tracer would result in an equilibration time that is dominated by diffusion alone and therefoere be much longer than if the full time-dependent flow had been used to compute the

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equilibration time. The mixing of tracers in time-dependent flows is an interesting and non-trivial problem that goes beyond the scope of our current study.

Finally we have followed all the reviewers suggestions and comments about the presentation in our revised manuscript.

Interactive comment on Ocean Sci. Discuss., 5, 471, 2008.