

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

**Anonymous Referee #2**

Received and published: 4 September 2008

The authors apply concepts of dynamic systems to a 3-box model and a 3D circulation model in order to illustrate that the time to tracer equilibrium in the ocean depends strongly on the tracer boundary conditions (BCs). A Dirichlet-type BC would lead to a relatively long equilibrium time which depends on the size of the region where the BC is applied. On the other hand, a Neumann-type BC would lead to a shorter equilibrium time. The study was apparently motivated by a recent conclusion by Wunsch and Heimbach (Quat. Sci. Rev., 27, 637–651, 2008) that a transient tracer disequilibrium can account for an apparent 3900-year lag between the equilibrium times for the deep Atlantic and the deep Pacific, which has been postulated from the sediment record.

I think this is an excellent manuscript (ms.), both in its content and in its presentation. The findings should be of interest to a wide range of ocean scientists: to ocean mod-

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



elers who often incorporate passive tracers in OGCMs, to chemical oceanographers who struggle to understand the spatial distribution and temporal evolution of tracers which they measure in the ocean, and to paleoceanographers who attempt to interpret tracer measurements in the sediment. The paper could be accepted subject to minor revisions.

---

Comments about the content

---

I can offer only two comments regarding the content of the ms.

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)? This of course is a general question and should not be taken to challenge the present work. I do think that reliance on a coarse resolution model is a useful first step for understanding the effects of tracer boundary conditions on tracer equilibrium times (the present study is a very nice illustration thereof), even if the model being employed has a horizontal resolution (here, 3.75 degrees x 3.75 degrees) which is much larger than the internal Rossby radius of deformation. However, I think the authors should state explicitly (in particular for readers unfamiliar with limitations of OGCMs) that the OGCM being used has very coarse horizontal resolution and that it may not simulate very accurately even the time-mean circulation (probably no OGCM does). The tracer equilibrium times reported in the present ms. as well as in earlier model studies are only as accurate as the velocity field used to carry the tracer and the coefficients used to mix it are.

2) To which extent would the major results of this study survive in the presense of a time-dependent velocity field (obviously much closer to the real geophysical situation)? Could the powerful tools provided by the theory of dynamic systems still be used if the velocity field varies with time? 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.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



Although the ms. is in general very well-written, I do provide some comments about the presentation below.

Page 472, Abstract) Write "... Dirichlet boundary condition ..." (letter "b" should be lower case)

Page 474) Write "Their approach to equilibrium, however, is dramatically different"

Page 477) Write "... in box 1 at time  $t=0+$  (immediately after tracer injection) is" (define what is meant by " $t=0+$ " where it first appears in the text).

Page 479) Write "... satisfies the zero ..."

Page 481) "The melting of the ice prescribes a flux of d18O-depleted water into the ocean and does not depend on the circulation ...". Actually the melting may depend on ocean circulation if it is sensitive to the meridional heat flux associated with it" Phrasing the sentence in another way seems appropriate.

Page 481, last sentence) Write "The box model is sufficient ... timescales. However, in order to get more quantitative results ..."

Page 481) Write "The OGCM is a version ..."

Page 481) Write "... typical of OGCMs with similar resolution and produces ..."

Page 481) Write "It has been used to simulate transient tracers such as  $^{14}\text{C}$  and CFCs (ref) and biological tracers such as phosphate, dissolved inorganic carbon, and alkalinity (refs)".

Page 483) Define **u** and **K** where they first appear in the text.

Page 483) More appropriate symbols could be used for the vector of tracer concentrations inside the patch (e.g.,  $\mathbf{c}_i$ ) and the vector of tracer concentrations outside the patch (e.g.,  $\mathbf{c}_o$ )

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper



Page 488) Write "To compute the slowly ... we again used Arpack (ref) as ..."

Page 491) Use of the term "inertia" is a bit awkward as it is not meant to designate the mechanical concept. One could perhaps write "... is therefore not expected to have the ability to keep the d18O of surface waters ..."

Page 493) Write "... in fluid experiment - the size of the syringe used ..."

Page 493) Write "For the case of d18O, the melting ... in surface waters. The correct boundary condition ..." (split the sentence in two).

Caption of Fig. 4) Write "... to a depth of 2105 m and ..."

---

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

**OSD**

5, S139–S142, 2008

---

Interactive  
Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

