Clim. Past Discuss., 4, S207–S215, 2008
www.clim-past-discuss.net/4/S207/2008/

Climate of the Past Discussions

CPD

4, S207–S215, 2008

Interactive Comment

Interactive comment on "Influence of the Atlantic thermohaline circulation on neodymium isotopic composition at the Last Glacial Maximum – a modelling sensitivity study" *by* T. Arsouze et al.

T. Arsouze et al.

Received and published: 29 May 2008

We would first like to thank anonymous referee for his remarks that have greatly helped to improve our manuscript Influence of the Atlantic meridional overturning circulation on neodymium isotopic composition at the Last Glacial Maximum a modelling sensitivity study submitted by T. Arsouze, J.-C. Dutay, M. Kageyama, F. Lacan, R. Alkama, O. Marti, and C. Jeandel submitted to Climate of The Past.

The authors replies to the reviewers are added following each comment.

Please find joined to this Reply to the reviewers a corrected version of the manuscript.
Sincerely.

The authors used an OGCM to test how changes in ocean circulation, sea ice cover and bathymetry affect the simulated values of _Nd, with the assumption that their parameterization of boundary exchange drives the Nd isotope composition of the ocean. Specifically, they sought to recreate the possible conditions during the Last Glacial Maximum. The authors first ran their simulation using modern ocean conditions, an then ran three other simulations that each test conditions that might have existed during the LGM. The authors ran an additional modern simulation where the land-sea distribution was set to that of the LGM, which they used to determine how changes in bathymetry might affect the modeled _Nd values of end-members by restricting the interaction of seawater with certain very unradiogenic margins in the North Atlantic. The authors are attacking a difficult, but very important question, and because this is the first attempt at solving the problem of how Nd isotopes in the ocean might have changed through time, their paper should be published. However, it is in need of major revisions before it should be considered ready for publication. Below is a list of comments that I hope will help the authors improve their interesting work.

General Comments:

1. My main concern is that the authors do not give the reader the tools to evaluate the ability of their parameterization of boundary exchange to recreate the modern distribution of Nd isotopes in the oceans. Neither in this study nor in Arsouze et al. (2007) is there a figure with a point-by-point comparison of modeled and observed values from the same grid point. The authors should also consider including figures that compare profiles from the model and the data so that they demonstrate the ability of the model to recreate the vertical structures that are present in the ocean, particularly in the Western Atlantic. The presentation of results for the modern simulation in this paper needs significant improvement, as this is the readers’ only chance to evaluate the ability of this parameterization to recreate Nd isotopes in the past, which is the stated goal of this paper.

A point to point comparison between modelled and observed values has been added in Fig. 3. It provides to the reader the opportunity to better evaluate the modern simulation. The model globally produces realistic first order Nd gradient and water masses characteristics in the Atlantic Ocean so that it appears reasonable to consider using it for investigating changes of ocean circulation in the past.

2. Also, the presentation of the LGM results could be improved. The paper focuses on reporting entire basin averages for the different simulations, despite the fact that the cross-sections (figure 3) show significant differences between each LGM simulation and the modern, in addition to significant differences from one individual LGM simulation to the next. The authors might consider reporting averages over certain depth ranges in the northern and southern Atlantic basins, as they would be more instructive than reporting entire basin averages. Some comparison of these depth range averages for the modern control simulation with modern observational data might also be helpful. In addition, the presentation of the cross-sections for the LGM simulations makes it difficult for the reader to determine the _Nd values for each simulation. The authors might consider adding another figure that shows the _Nd values for each cross-section, rather than just the differences between each simulation and the modern.

An Eps_Nd cross-section for all simulations for the LGM has been added (Fig. 3) and more information is provided in table 1.

3. I think that improvements in the presentation of the authors’ results will lead to more coherent “Results” and “Discussion” sections.

Sections Results and Discussion have been re-organized so as to be clearer and more coherent (sections 4 and 5).

4. Another area of concern is how uncertainty in the model circulation might affect the results of the modern simulation. The strength of the MOC for the modern control run was admitted to be too weak. An interesting feature of the control run cross-section (figure 3) is that this simulation fails to create a homogenous water mass in the North Atlantic. Instead, there is a strong gradient from the deep to bottom waters of the

CPD

4, S207–S215, 2008

North Atlantic, with the bottom waters of this simulation yielding _Nd values as low as -7.5– a result that is not at all supported by the available data (Piepgras and Wasserburg (1983)). Even more interesting is the fact that simulations LGMA and LGMB, both with more vigorous MOC, seem to lack this gradient and yield a more homogeneous _Nd value for NADW (I think this is true, but would be sure after the authors make improvements in the presentation of their results). This observation might imply that the circulation in the modern control run is not representative of the modern ocean. Instead, some stronger representation of MOC, as in LGMA and LGMB, may yield a more realistic distribution of Nd isotopes for the deep North Atlantic.

Description of control simulation has been reformulated (section 4.1). However, LGMa and LGMb do not give better agreement when compared with the modern data (cf. Fig. 3, other figures and analyses not shown here). Also, this study aims to learn about the processes that control Eps_Nd distribution. Although we are aware that the model lacks in reproducing all the data at Holocene, we are more interesting to study the changes induced by bathymetry and ocean circulation than to reproduce the absolute value.

5. In relation to comment 4, another possibility is that the circulation is sufficiently realistic, but that the forcing term is missing some input of unradiogenic Nd in the deepest parts of the North Atlantic basin (i.e. the boundary exchange term is deficient and needs revamping).

Last paragraph of section 3, we acknowledge that the parameterization only resolves first order Eps_Nd distribution probably lacks in reproducing some features.

6. Another area of concern is the lack of information on _Nd values of waters entering the Southern Ocean from the Pacific and Indian Oceans, as both of these should have some affect on the _Nd value of waters exported from the Southern Ocean. It may be the case that changes in the _Nd values of waters entering the Southern Ocean from these other ocean basins are insignificant, but if that is the case, then the authors

CPD

4, S207–S215, 2008

Interactive Comment

should mention it.

We now mention the influence of water masses from the pacific in the description of the three LGM simulations in the Southern Ocean (section 4.2).

7. Without specific evidence to the contrary, I am also concerned with the ability of this model, or any model with this parameterization of boundary exchange, to create changes in the southern end-member due to the rapid exchange of Nd in the upper 3000m of the water column, regardless of MOC strength. If we assume that the Southern Ocean primarily reflects mixing of North Atlantic and North Pacific waters entering this basin at depth, then the addition of Nd from boundary exchange at the surface and at depth may erase the _Nd signatures of water masses entering the Southern Ocean.

From Fig. 5, it is clear that the Nd signature of the southern ocean at depth (3000-5000) changes with circulation. Same figure in the upper 3000 of the water column (not shown here, but available on demand) shows variations up to +1.5 Nd. Hence, our parameterization of BE does not prevent variation of Nd in surface and intermediate waters.

8. I think some additional sensitivity tests would be most helpful in addressing my concerns in comments 4-7. More model runs that use modern forcing, but have stronger MOC, in addition to a shortened exchange timescale of certain unradiogenic boundaries in the North Atlantic will both increase the amount of NADW reaching the Southern Ocean and lower the _Nd value observed for this end-member. This will help determine the sensitivity of the southern end-member to changes in the North Atlantic. Without sensitivity tests that examine extreme situations we cannot be sure that it is possible to create a 3 _-unit change in the southern end-member by varying the strength of the MOC, given their forcing term.

Unfortunately, we cannot provide sensitivity tests of the dynamics of the model and of the parameterization. Simulations are atmospheric-oceanic-land coupled simulations, which are really computationally expensive. Also, changing the parameterization of

CPD

4, S207–S215, 2008

the BE as a function of different factors (margin, dynamics, etc…) constitutes a long and difficult task. We chose to apply the same parameterization as used in Arsouze et al. because it gave satisfactory results. We are aware that the dynamics of the coupled model used here, and the Nd distribution, are less realistic than in Arsouze et al., but that was the only way to compare modern run with three LGM runs. Still, the modern simulation gives satisfactory results and our experiments were designed to understand the impact of LGM vs modern changes in ocean circulation. We hope to be able to compute more realistic values in the future, but we think we can still learn a lot on the mechanisms controlling Nd changes for the LGM from our experiments.

Specific Comments:

1. No information is given in the abstract on how the authors force the model with respect to the Nd isotope ratio. The forcing is an important piece of information and it probably should be mentioned in the abstract.

Abstract now mentions that this modelling is done using a relaxing term.

2. Page 314; lines 1-4: The author is incorrect in stating that Piotrowski et al. (2005) assume no changes in the _Nd value of the Southern end-member. The point of their paper is that there are changes in the _Nd value of the Southern end-member and that their core location is sensitive to these changes. The author needs to differentiate between what are considered to be global end-members and the end-members that are specific to the Atlantic Ocean. Piotrowski et al. (2005) interpret their data to imply a change in the proportion of North Atlantic and North Pacific waters that are mixed in the Southern Ocean. A change in the proportion of these two end-members would drive a change in the observed _Nd values in the Southern Ocean and in the waters exported from this basin. It would be correct to say that Piotrowski et al. (2005) assume no change in North Atlantic and North Pacific end-members. I think more time should be spent clarifying this paragraph because in it are the reasons for undertaking this

study.

We now say that Piotrowski et al. (2005) assume no change in North Atlantic and North Pacific end-members.

3. Page 314; lines 19-21: The authors should qualify that their ability to determine the extent to which changes in circulation drive changes in the northern end-member is limited by the degree to which their parameterization of boundary exchanges reflects reality and the degree to which boundary exchange is the driving force in the distribution of Nd isotopes in the ocean.

This limitation has been emphasized. In paragraph 3, more details are given in the description of the model, of the parameterization and of the limitation of both.

4. Page 317; lines 12-24: The authors do address some uncertainties in the boundary exchange parameterization through time, but they do not address the possibility of spatially variable restoring timescales.

Some precision has been addressed concerning the possible spatial changes earlier in the paragraph.

5. Page 318; lines 1-4: The authors cite figures in Arsouze et al. (2007) and state that the model successfully simulates the _Nd values of major water masses. The figures referenced in this sentence do not strongly support the statement made by the authors because there are obvious differences between the model and the observed data in these figures. Also, it is difficult to determine the exact offset between the model and the data because the authors do not present a point-by-point comparison, or a comparison of profiles for the modeled and observed data.

Precisions concerning the use of the model and the aim of this study have been added. The ability of the model to reproduce the Eps_Nd distribution is now commented more critically. A point-by-point comparison has been added Fig. 3

6. Page 321; lines 2-6: The authors ascribe the lack of agreement between their simu-

CPD
4, S207–S215, 2008

Interactive Comment

lations and the available paleo data simply to the coarse resolution of the model. The lack of agreement could also be created by a deficient forcing term, deficient circulation, or both.

This forcing factor has been added to explain the lack of agreement.

7. Page 321; lines 5-11: The authors mention some complicating factors associated with the observations of _Nd values at the core location of Piotrowski et al. (2005), but do not address how these factors will influence the simulated _Nd values of this model. If they mention these factors they should address their consequences in greater detail.

Consequences of these factors are now mentioned section 5.2.

8. Page 321; lines 23-29: The authors understate the importance of the constraints provided by the data from van de Flierdt et al. (2006). These data show strong evidence that the _Nd value of the northern end-member is stable through time. As a result, the authors should give the constraints provided by this work greater importance in the manuscript, rather than focusing solely on the LGM constraint of Piotrowski et al. (2005).

As added in the article, van de Flierdt et al. (2006) as well as article by Foster et al. (2007) are strong constraints, but recent paper Gutjahr et al. (2008, EPSL 266, 61-77) provides a contrary conclusion to the problem. We think that this still remains an open question.

Technical Comments:

1. Page 310; lines 10: “values are remain”, delete “are” or “remain”

“remain” has been deleted.

2. Page 321; line 23: make the “V” in van de Flierdt a lowercase

“V” in van de Flierdt is now a lowercase.

CPD

4, S207–S215, 2008

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

3. Page 332; figure 3: both colorbars are non-linear

The legend now mentions the non-linearity of all colorbars.

Interactive comment on Clim. Past Discuss., 4, 309, 2008.

CPD

4, S207–S215, 2008

Interactive Comment