Clim. Past Discuss., 5, C1294–C1297, 2010
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Climate of the Past Discussions

Interactive comment on "A simple mixing explanation for late Pleistocene changes in the Pacific-South Atlantic benthic δ^{13}C gradient" *by* L. E. Lisiecki

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Received and published: 1 April 2010

Referee 2 presents several interesting points of discussion, which my revised manuscript now addresses in more detail. However, some of these important questions about the NCW and SCW formation are largely beyond the scope of the current study.

The purpose of this study is specifically to answer whether a change in PDW circulation can be inferred on the basis of changes in benthic d13C gradients. Regardless of whether glacial AABW ventilation is similar to modern or greatly reduced, the glacial PDW-AABW d13C gradient seem to require ventilation of glacial PDW from some

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source in addition to AABW. There seem to be 4 other possible ventilation sources: NCW, NPIW, AAIW and Ross Sea Water. The NCW ventilation source is essentially the null hypothesis on which I focus. (The introduction in the revised manuscript now gives this equal billing with the NPIW hypothesis). I also place focus on the NPIW hypothesis because I am able to compare glacial Pacific d13C gradients with those that would be expected for NPIW ventilation. I wait until Section 5 to discuss AAIW and Ross Sea Water as possible ventilation sources because the available d13C data are inadequate to say anything definitive about these hypothesis.

The results of my simple mixing model suggest that no change is necessary in the relative contributions of NCW and SCW to PDW. In the discussion section I present several lines of evidence that might support a constant mixing ratio as well as several other possible scenarios for changes in glacial PDW circulation. It is not my intention to disprove these circulation changes during glacial cycles, only to demonstrate that constant PDW ventilation would be consistent with glacial benthic d13C gradients.

A. Can GNAIW be the NCW end member?

My meaning on page 2612, lines 11-15 of my original submission seems to have been unclear. I am assuming that intermediate waters contribute to ventilation of the Pacific above 2500 m, so I am focusing this study on the question of whether or not d13C gradients provide evidence that intermediate waters ventilated the Pacific below 2500. I have changed the wording of this paragraph to make my meaning more clear.

The referee points out that I have taken it to be more likely that GNAIW contributed significantly to ventilation of the deep ocean than that NPIW or AAIW did. One reason for this is evidence of strong overturning of GNAIW at 2000 m whereas modern NPIW and AAIW are centered at or above 1000 m (Johnson, 2008). The primary reason why I consider PDW ventilation from NPIW unlikely is the fact that PDW d13C values are lighter in the North Pacific than the South Pacific (Matsumoto, 2002). I have added to Section 5.2 a paragraph which specifically discusses the possible con-

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tributions of AAIW to PDW ventilation. AAIW may have contributed to glacial PDW ventilation (perhaps the same 20% as modern), but I do not think that it is the primary source of ventilation because PDW d13C does not become progressively lighter with depth (Matsumoto, 2002), unlike the pattern observed in the Atlantic for mixing between GNAIW and AABW (Curry and Oppo, 2005). The model results of Toggweiler et al (2006) suggest that it is possible that GNAIW ventilated the glacial deep Pacific without an increased contribution from AAIW. However, larger glacial contributions from AAIW remain a possibility (see final paragraph of revised manuscript).

The referee also presents the question of whether NCW ventilation is provided by GNAIW or by GNADW (deeper convection in the North Atlantic). I use the term NCW because I do not wish to focus on the exact details of overturning in the North Atlantic. If the d13C values are similar for GNAIW and GNADW, the same model results would apply. Raymo et al (2004) find only transient d13C gradients between different NCW components from 600-0 kyr ago. Their results suggest that perhaps two NCW water masses could be distinguished by d13C values in the data before 600 kyr ago; however, they conclude that low-d13C NGS overflows were unlikely to be "a volumetrically significant source of deep water over much of the Pleistocene." I have added citations to Matsumoto and Lynch-Stieglitz (1999) and Millo et al (2006) regarding GNADW, but there are not enough d13C measurements of GNADW for me to analyze its possible contributions to PDW ventilation.

B. What is the nature of the SCW end member?

I agree with referee 2 that the current paradigm for explaining low-d13C values in the deep South Atlantic is a decrease in AABW ventilation. This was mentioned in the background section of the original manuscript. The revised manuscript now also mentions it in the abstract. The reason that I do not devote more emphasis to the question of AABW age in this manuscript is that the analysis technique I am using cannot directly address the question of AABW ventilation rates. Different modeling studies have found glacial d13C gradients to be consistent with either modern overturning rates

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(Huybers, 2007; Marchal & Curry, 2008) or reduced AABW overturning (Toggweiler, 2006). In section 5.5, I briefly discuss the implications that each of these scenarios has for changes in air-sea gas exchange and remineralization rates.

The revision to section 5.4 now mentions that the results of Adkins et al (2002) suggest that PDW may be more similar to NCW than SCW. However, I do not feel it would be appropriate to compare the results of my d13C mixing model with a mixing ratio estimated from their temperature and salinity measurements because ODP Site 1123 at 3300 m in the Southwest Pacific may not be representative of PDW (McCave et al., 2008).

C. “Old” vs. “young” definition

I have added a definition for water mass age at the beginning of Section 2. I have also changed “age offset” to “remineralization offset” throughout the manuscript.

Interactive comment on Clim. Past Discuss., 5, 2607, 2009.