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Climate of the Past Discussions

Interactive comment on "Mid-depth South Atlantic ocean circulation and chemical stratification during MIS-10 to 12: implications for atmospheric CO_2" *by* A. J. Dickson et al.

A. J. Dickson et al.

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(Referee comments in bold, responses in italics)

Reviewer 1

1. Much of the discussion on millennial scale variability in deepwater advection is based on very small scale changes in d13C (0.1 to 0.3 per mil), which is close to the 0.2 per mil noise usually cited in late Pleistocene benthic carbon isotope studies. It is important to know, therefore, what the magnitude of the single specimen variance in at least some of the samples would be. *Some tests for intra-sample variance were performed on single samples but the results were overlooked when writing the initial manuscript. To better understand this variance, we are currently*

running a number of repeats (3-4 each) on seven samples with a high abundance of C. wuellerstorfi taken from the interval between 397-362 ka, the results of which will be included in our revised manuscript.

2. **Abrupt increases in d13C superimposed on the glacial-interglacial long-term trend are only seen for two events (starting at 376 and 361 ka, respectively), all others are more gradual. A significant decrease in foraminifer fragmentation is only seen in the same two events, belonging to the MIS 11 - 10 transition.** *We agree that the events at 376 and 361 ka are the most pronounced and abrupt but other events also seem to occur, albeit with slower rates of d13C change. The word abrupt has therefore been removed from their description in the results sections.*

3. **The question is, why millennial scale drop downs in NADW supply are expected during interglacials? As already discussed at the end of subchapter 5.4.1, some climate parameters like IRD records would tend to argue against changes in NADW production during warm climates. And the cited evidence for regional cooling in the Southern Ocean (page 677 line 27) occurs at a time of only small scale changes in d13C gradients. What mechanism would the authors suggest for an interglacial variability in NADW supply?** *Assuming air-sea changes are not responsible for d13C changes (see below), this is getting into the realms of speculation. One possibility could be a reduction in the rate of CDW upwelling in response to a northwards shift in the zone of Southern Hemisphere westerlies, influencing a change in circulation vigour- this possibility is noted in the revised manuscript.*

4. **Furthermore, is it possible to give an estimate for the amount of NADW reduction necessary to produce the observed changes in d13C?** *This may be possible but since changes in d13C are due to both changes in NADW production/flux and in water mass configuration, (e.g. NADW mass transport may be high but confined to different depths) it would be imprecise to produce such estimates without a greater understanding of changing vertical d13C throughout the Atlantic water column at a greater temporal resolution than is currently possible for this period.*

CPD

4, S383–S387, 2008

5. **What about small scale changes in air-sea fractionation in the source regions of the northern component water masses?** *We agree that this could be important but we do not have the data (benthic Cd/Ca) to test it. Source regions of Northern Component Water have a low d13Cair-sea signature due to high rates of atmospheric CO2 invasion. Therefore a reduction in CO2 invasion could be responsible for the small d13C increases seen in ODP-1085. How this could have come about (warmer surface waters leading to less CO2 solubility, or an increase in sea-ice which physically reduced the amount of CO2 flux) requires more discussion of the surface water records from this region (e.g. Bauch et al, 2000), which we will address in our revised manuscript. Generating benthic Cd/Ca data for some of the d13C excursions between 380-360 ka could be a target for future work.*

6. **In subchapter 5.4.1 a strong 41 000 periodicity in the deepwater proxy is related to the modulation of intermediate-depth ventilation by changes in high latitude sea-surface temperatures and sea-ice in response to obliquity. This should be explained in more detail, and the coherence of the proxy record with the orbital parameter should be checked.** *An obliquity curve will be added to Figure 4c to show its approximate phasing relative to intermediate water ventilation.*

TITLE

Could be more concise to better reflect the millennial scale variability of deepwater circulation. *We would prefer to keep it the same to encompass the discussion on South Atlantic vertical d13C gradients as well as larger-scale circulation patterns.*

METHODS

671 line 1 please give number of picked specimens for isotope measurements. *We used between 2 and 6 individuals per measurement. This has been added to the methods section.*

671 line 11 as has been stated in many previous publications, the correction

CPD
4, S383–S387, 2008

of Uvigerina d13C values to equlibrium is problematic with respect to changing organic matter supply. The authors should provide a supplementary figure with the 43 paired measurements of Cibs/Uvi. *These data have been plotted and will be included as an additional figure with the revised manuscript.*

DISCUSSION

672 line 22 phytodetritus effect (not photodetritus). *This has been corrected.*

675 line 27 ODP 1063 d18O record should be better aligned to that of LRS04, especially at the termination of MIS 12. Table 2 Why are the age control points for the given sites are not chosen at same ages? *As requested, each site has been adjusted to a series of common age control points. This has not produced any large changes in the age-models and does not affect the original conclusions. Some control points are retained for individual sites because of the presence of isotope events that are not common to all d18O records.*

FIGURES

Figure 1 The schematic arrows for the deep water masses are misleading, better introduce a more realistic pattern. *NADW, CDW and SCW pathways have been slightly changed to a more realistic pattern.*

Figure 3 C. wuellerstorfi and Uvigerina data points are not distinguishable. Please use larger symbols. *Symbols will be plotted larger as requested.*

The isotope records contain several outliers - have those been checked by repeated measurements? *Some repeat measurements have been made which fall close to the original data. However, the new repeat measurements being made (see above) should provide a further test. These data will be included in our revised submission.*

Figure 4a The oxygen isotope records should be offset by 1 per mil each for clarity. *This will be included in the revised manuscript.*

CPD

4, S383–S387, 2008

Interactive Comment

Figure 4c Please add a obliquity curve to the Delta d13C (980-1085) record. *An obliquity curve has been added to this figure.*

Reviewer 2

The citation errors noted by Reviewer 2 have been corrected.

AD

Interactive comment on Clim. Past Discuss., 4, 667, 2008.