We thank Referee #2 for the constructive review of our manuscript. To facilitate the discussion, we have copied his/her comments below in black and inserted our responses in green.

Review of "Glacial d13C decreases in the western South Atlantic forced by millennial changes in Southern Ocean ventilation" by Campos et al.

The authors use the d13C of planktonic foraminifera to infer variability in the d13C of DIC in surface/thermocline waters in the SW Atlantic. One strength of the paper is the comprehensive review of the modern oceanographic setting. Another is that the planktonic time series are based on a sediment core with very high sedimentation rates, allowing for high resolution reconstruction of surface ocean d13C during Heinrich Stadial 2 and 3. It is also important that the authors used two different species to reconstruct d13C (one surface dwelling and another thermocline dwelling) to account for potential biases in habitat and vital effects that could overprint changes in the d13C of DIC. Given the high resolution and replicated nature of the record, the authors clearly show that this part of the Southwest Atlantic underwent significant changes in d13C during Heinrich Stadial 2 and 3.

The primary weakness of the paper is the interpretation of the d13C and sedimentation rate results. The authors are quick to assume that their d13C records reflect the input of light carbon from the Southern Ocean and neglect other possible explanations that are well documented in the published literature.

Comment #1 - We agree that other mechanisms could have also contributed to our records. Considering this comment and similar suggestions from Referee #1 and Dr. Schmittner, we have incorporated two additional hypotheses (see below) in the revised version of our manuscript, in order to have a more thorough and balanced discussion:

  i.   AMOC–induced weakening of the biological pump

As shown by model experiments (e.g., Schmittner and Galbraith, 2008; Schmittner and Lund, 2015), AMOC slowdown events may cause a decrease in the global efficiency of the oceanic biological pump, being an important driver for the oceanic CO_2 outgassing during the last deglaciation, i.e., HS1 (but most likely also during other HS, e.g., HS3 and HS2). Two factors acting in conjunction are claimed to be responsible for the simulated weakening of the efficiency of the biological pump (Schmittner and Galbraith, 2008). First, the reduction in North Atlantic Deep Water (NADW) formation decreases the input of low preformed nutrient (high $\delta^{13}C_{DIC}$ values) waters to the interior ocean which becomes more dominated by the high preformed nutrient southern component (low $\delta^{13}C_{DIC}$ values) waters (e.g., Antarctic Bottom Water and Antarctic Intermediate Water). Second, the reduction of the Southern Ocean stratification induced by the decrease of salt input via NADW formation promotes the strengthening of the upwelling and subsequent sinking of high preformed nutrient (low $\delta^{13}C_{DIC}$ values) waters to the interior ocean, thus reducing the capacity of those unutilized nutrients to sequester carbon via the biological pump.

The weakening of the biological pump would promote the accumulation of isotopically light organic carbon in the upper water column of the South Atlantic and the negative anomaly of the $\delta^{13}C_{DIC}$ as well as of the $\delta^{13}CO_{2atm}$ (Schmittner and Lund, 2015). This $\delta^{13}C_{DIC}$ anomaly should be captured by the tests of planktonic foraminifera $\delta^{13}C$ because they incorporate $\delta^{13}C_{DIC}$ during calcification (Spero and Lea, 1996; Bemis et al., 2000). Our planktonic foraminifera $\delta^{13}C$ records agree with this hypothesis by showing negative anomalies during HS3 and HS2. Additionally, this mechanism also provides a possible explanation for the larger negative $\delta^{13}C$ anomaly in *G. ruber* w (mixed layer–dwelling) relative to the anomaly in *G. inflata* (permanent thermocline–dwelling).

ii.   the role of air–sea gas exchange

In the original version of our manuscript (page 7, line 13) we briefly mentioned the role of air–sea gas exchange. However, we see the need to further expand this topic in order to have a more thorough and balanced discussion.

We are aware that the $\delta^{13}C_{DIC}$ of the surface ocean can be affected by air–sea gas exchange (Oppo and Fairbanks, 1989; Charles and Fairbanks, 1990; Lynch-Stieglitz et al., 1995). Therefore, we cannot exclude the possibility that the likely decrease in $\delta^{13}CO_{2atm}$ during AMOC slowdown events (Eggleston et al., 2016) (e.g., HS3 and HS2) could have affected the $\delta^{13}CO_{2DIC}$ via air–sea gas exchange, especially in regions of water mass formation. The formation regions of South Atlantic Central Water and Tropical Water are areas of major ocean CO_2 uptake and may contribute to the $\delta^{13}C$ anomalies observed in our records. Additionally, since the isotopic fractionation during air–sea exchange is temperature–dependent, the weakening of the AMOC and subsequent warming of the upper subtropical South Atlantic (Barker et al. 2009; Chiessi et al. 2015) could also have contributed to the observed $\delta^{13}C$ anomalies in our records (as suggested by Referee #2).

However, for the reasons stated below we still consider the possible role played by changes in Southern Ocean ventilation in producing our $\delta^{13}C$ anomalies:

i.   the mechanisms that invoke the Southern Ocean as one of the CO_{2atm}–sources during the last deglaciation are based on reconstructions as well as conceptual and numerical models that, to our understanding, have not yet been negated (Toggweiler et al., 2006; Anderson et al., 2009; Sigman et al., 2010; Tschumi et al., 2011; Lee et al., 2011; Burke and Robinson, 2012);

ii.   model experiments that question the role of the Southern Ocean (e.g., Schmittner and Lund, 2015) were performed under preindustrial boundary conditions, which can significantly influence the results (e.g., Menviel et al., 2008), and do not constitute a firm negation of the Southern Ocean hypothesis.

The authors also invoke speculative connections between rainfall and sedimentation rate in the core as support for their climate interpretation, despite disagreement between the sedimentation rate and planktonic d13C patterns.

Comment #2 - We agree that the second HS2 peak in sedimentation rate and the respective planktonic $\delta^{13}C$ anomaly are not perfectly aligned in time. However, this apparent offset can be exclusively due to (i) the occurrence of ^{14}C plateaus during HS (e.g., Sarnthein et al., 2007; Franke et al., 2008), and/or (ii) the discretized way our age model was produced in relation to the "continuous" $\delta^{13}C$ measurements.

Finally, the authors neglect to mention much of the work at the Brazil Margin spanning the last deglaciation (including Heinrich Stadial 1) that is both relevant to their work and inconsistent with a Southern Ocean driver.

Comment #3 - We have included relevant publications from the Brazil Margin (e.g., Tessin and Lund, 2013; Lund et al. 2015) in the revised version of our manuscript together with a thorough and more balanced discussion (please see our Comment #1 above). However, the hypothesis that the Southern Ocean acts as a possible CO_{2atm}–source during HS has, to the best of our knowledge, not yet been proven incorrect and we still see the need to discuss it together with other possible explanations (please see our Comment #1 above).

Major issues:

While the prevailing view is that Southern Ocean outgassing drove surface ocean d13C anomalies during the last deglaciation, the authors also need to reference to Andreas Schmittner's work that shows that weakening of the AMOC can alter the preformed nutrient budget of the global ocean and therefore the efficiency of the biological pump. Weakening of the biopump would preferentially leave light carbon in the surface and create negative d13C anomalies in multiple ocean basins (e.g. Schmittner, 2005; Schmittner and Galbraith, 2008).

Also, detailed reconstructions from the Brazil Margin show that benthic d13C and d18O changed late in the deglaciation, suggesting that the abyssal ocean was an unlikely source for the surface ocean anomalies during HS1 (Lund et al., 2015). Additional published records from the SE Atlantic shows a similar pattern, with a late deglacial response in the abyssal records (Waelbroeck et al., 2011; Roberts et al., 2016).

Comment #4 – Considering that the role of the weakening of the biological pump was also raised by Referee #1 and Dr. Schmittner, we have incorporated this hypothesis in the revised version of our manuscript (please see our Comment #1 above).

Our records complement the Brazil Margin depth transect (e.g., Tessin and Lund, 2013; Lund et al., 2015) with upper water column high temporal resolution data that also agree with the model output of Schmittner and Lund (2015) by suggesting a decrease in $\delta^{13}C_{DIC}$ at the upper water column of the western South Atlantic.

However, it is worth noting that while Tessin and Lund (2013) and Lund et al. (2015), for example, focus on bottom waters, we concentrate on the upper water column. In the revised version of our manuscript, we suggest that three processes may have contributed to the negative $\delta^{13}C$ anomalies in our records during HS3 and HS2: (i) changes in Southern Ocean ventilation; (ii) AMOC–induced weakening of the biological pump; and (iii) changes in air–sea gas exchange.

Furthermore, intermediate depth d13C reconstructions from the Brazil Margin (Oppo and Horowitz, 2000; Curry and Oppo, 2005; Lund et al., 2015) imply that AAIW and SAMW were not carriers of a light carbon signal during HS1, which is inconsistent with the mechanism invoked by Campos et al. While the authors did a commendable job summarizing the literature pertaining the modern oceanographic setting, the introductory material includes surprisingly little information from previously published work along the Brazil Margin. As a result, the introductory material is incomplete and the lack of context limits the interpretation in the discussion section.

Comment #5 - To account to this additional mechanism in the revised manuscript we have inserted a new section describing the AMOC–induced weakening of the biological pump (please see our Comment #1 above).

The other main issue with the data interpretation is that the continental hydroclimate response isn't well supported by the sedimentation rate data. While sedimentation rates peak early in HS2, at about the same time as a planktonic d13C minimum, there is a second peak in sedimentation rate after HS2 that corresponds to a broad maximum in d13C. Furthermore, there is no peak in sedimentation rate during either HS3 or HS1. Taken as a whole, the sedimentation rate data therefore do not support a continental hydroclimate connection, which perhaps isn't surprising given the many factors that can influence sedimentation rates at a single core site.

Comment #6 - Please see our Comment #2 above. Additionally, although HS3 seems not to be related to a positive anomaly in sedimentation rate at our core site, HS1 and the Younger Dryas are both related to positive anomalies (of smaller amplitude during the Younger Dryas if compared to the anomalies during HS2 and HS1). The relatively high sea–level during HS3 and the Younger Dryas if compared to the intervening period (Waelbroeck et al., 2002) may have dampened a more significant anomaly in sedimentation rates during HS3 and the Younger Dryas (e.g., Lantzsch et al., 2014). This discussion has not been inserted in the revised manuscript because we have focused in HS3 and HS2.

Finally, the manuscript would benefit from inclusion of the planktonic d18O data. If there is a clear hydroclimate signal at this site, it could appear in the d18O data as intervals of unusually low d18O. The d18O data would also be informative for assessing the influence of air-sea gas exchange effects on the d13C signal. The d13C of surface ocean DIC is influenced by temperature dependent gas exchange, with a relationship of -0.1 per mil per deg C of warming (Broecker and Maier-Reimer, 1992; Lynch-Stieglitz et al., 1995). While such an effect is unlikely to explain the full

magnitude of the d13C signals, it should be included in the discussion. Model results suggest that weakening of the AMOC warms the upper subtropical South Atlantic by 2-3 deg C (Marcotte et al., 2011) which would account for up to 0.3 per mil of the planktonic d13C anomalies.

Comment #7 - A similar topic was also raised by Referee #1. Please refer to our Comment #5 to Referee #1. Additionally, a section expanding the discussion on the possible role of air–sea gas exchange is included in the revised version of our manuscript. This mechanism is described in our Comment #1 above.

It is worthy of note that our foraminiferal δ^{18}O data do not present clear trends during HS3 and HS2. The δ^{18}O of planktonic foraminifera is markedly influenced by the temperature and salinity of the sea water where the tests calcified (e.g., Rohling and Cooke, 1999). The relationship between temperature and δ^{18}O of planktonic foraminifera is inversely proportional, and the relationship between salinity and δ^{18}O of planktonic foraminifera is directly proportional. Therefore, higher temperatures decrease foraminiferal δ^{18}O, whereas higher salinities increase foraminiferal δ^{18}O (e.g., Rohling and Cooke, 1999).

For periods and regions of the global ocean where an increase (decrease) in temperature is associated to a decrease (increase) in salinity, the δ^{18}O of planktonic foraminifera will clearly record such environmental changes (e.g., Guilderson and Pak, 2007). However, for those cases where temperature and salinity increase (decrease) simultaneously, these environmental changes may not be clearly recorded in foraminiferal δ^{18}O. The last scenario seems to be the case for the upper water column under the influence of the Brazil Current for centennial-scale events of the Holocene (Chiessi et al., 2014), as well as for HS1 (Chiessi et al., 2015), and possibly also for HS3 and HS2 (given the lack of regional SST reconstructions for HS3 and HS2).

Minor issues:

Page 6, Line 12: Here the authors should consider the possibility that weakening of the biological pump could have produced d13C anomalies not only locally, but on a larger spatial scales.

Comment #8 - Agreed. We have changed the revised version of our manuscript accordingly.

Page 6, Line 20: It is important to mention that published mode and intermediate water records from the Brazil Margin either show a positive d13C anomaly during HS1 or a delayed negative d13C response that is inconsistent the light carbon being transported northward via mode and intermediate water.

Comment #9 - Agreed (please see our Comment #1 above). We have revised the manuscript accordingly. Additionally, we also incorporate two more hypotheses (i.e., (i) AMOC–induced weakening of the biological pump, and (ii) the role of air–sea gas

exchange) to the revised version of our manuscript, in order to have a more thorough and balanced discussion.

Page 7, Line 5: The authors seem to take it as a given that Southern Hemisphere westerlies drives greater upwelling of deep waters when it actuality there is limited data to support such a link. Please qualify these types of statements to reflect the limited constraints that exist.

Comment #10 – Agreed (please see our Comment #8 to Referee #1). We have revised our manuscript accordingly.

Page 7, Line 9: See comments above that published intermediate depth records from the Brazil Margin don't show clear negative carbon isotope anomalies during HS1, which is relevant to whether a similar process occurred during HS2 and HS3.

Comment #11 - Agreed (please see our Comment #1 above). We have revised our manuscript accordingly. Additionally we also incorporate two more hypotheses (i.e., (i) AMOC–induced weakening of the biological pump, and (ii) the role of air–sea gas exchange) to the revised version of our manuscript, in order to have a more thorough and balanced discussion.

Figure 4: If the authors are going to pursue the sedimentation rate-hydoclimate link, then the sedimentation rates should also be included in this figure for comparison to the d13C. The d18O records should also be included to assess the potential impact of sea surface temperature on d13C.

Comment #12 - Agreed. We have inserted the sedimentation rate record in Figure 5 of the revised version of our manuscript. Regarding the $\delta^{18}O$ data, please refer to our Comment #5 to Referee #1 and our Comment #7 above.

Figure 5: There are several time series in this plot that aren't essential for the discussion, such as the Iberian Margin SST record, the EDML d18O time series, and the Siple Dome CO2.

Comment #13 - We agree that removing the $\delta^{18}O$ EDML curve (EPICA Community Members, 2006) would not harm the main focus of our manuscript. In addition, we have also removed the Taylor Dome $\delta^{13}CO_{2atm}$ curve (Smith et al., 1999) for the reason mentioned in our Comment #7 to Referee #1.

However, we would prefer not to delete the following curves: (i) the Iberian Margin SST curve (Bard, 2002) because it shows a "w–structure" during HS2 that gives support to the proposed "w–structure" of HS2; and (ii) the Siple Dome CO_{2atm} (Ahn and Brook, 2014) due to its fundamental importance to our manuscript (please see our Comment #6 to Referee #1).

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