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Interactive comment on "Lower oceanic δ^{13}C during the Last Interglacial compared to the Holocene" *by* Shannon A. Bengtson et al.

Anonymous Referee #2

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The manuscript by Bengston et al. seeks to document the d13C of the LIG ocean for comparison to the mid-Holocene. Using published datasets, the authors calculate the average d13C for the LIG and Holocene and find that the LIG in certain areas was more 13C-depleted, by ∼0.2 per mil. Given that atmospheric d13C was lower during the LIG, differences in air-sea gas exchange cannot be invoked to account for the oceanic discrepancy. Instead, the authors suggest the light LIG reflects a long-term imbalance between weathering and burial of carbon.

Strengths

The background section is a comprehensive review of the LIG literature that nicely summaries the keys aspects of LIG climate.

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Discussion paper

The authors assembled an impressive array of time series and evaluated potential biases associated with the averaging techniques. While it would always be useful to have more d13C data, especially in the volumetrically dominant Pacific, they make a compelling initial case that oceanic d13C in certain oceanic regions during the LIG was lighter than during the Holocene.

The authors explicitly acknowledge the paucity of data in the Indian and Pacific Oceans, and work to address the issue by focusing on a few areas with relatively high density of d13C records. In doing so, they are able to demonstrate, at least in certain regions, that there is a statistically different mean d13C during the LIG.

Weaknesses

The treatment of AMOC differences between the Holocene and LIG is underdeveloped. While there is evidence of short-term AMOC changes during the LIG that do not occur during the Holocene (e.g. Galassen et al., 2014), there are several other records from the North Atlantic that suggest the first half of the LIG had lower d13C values, which may reflect a weaker AMOC (see records summarized in Hodell et al., 2009, EPSL, 288, 10-19).

The age models used in the compilation are taken from published records. Given that most of the cores are from Lisiecki and Stern (2016), this shouldn't be a major issue because LS16 uses a consistent tuning method. However, the records in Oliver et al. (2010) and the other papers may use slightly different approaches. It would therefore be very useful to apply the methodology from LS16 to all of the cores in the presented compilation to eliminate potential age model biases. In lieu of such an effort, the authors could show how well the various d18O records during MIS 5d, 5e, and 6 align with the LS16 stack as evidence that age model offsets are not a major concern.

The other primary weakness is the limited number of records for the Pacific (18 LIG, 19 Holocene) and Indian Oceans (4 LIG, 7 Holocene). Given that the Pacific and Indian Oceans combined have ~3x the volume of the Atlantic, and therefore >3x the DIC, the paucity of data coverage in the Pacific and Indian Oceans is the greatest source of uncertainty for the mean oceanic d13C estimate. The addition of only a handful of Pacific records with slightly more positive d13C values could alter the conclusion that the mean oceanic d13C during the LIG was less than the Holocene.

Additionally, a non-trivial proportion of the Pacific records appear to come from relatively shallow locations, creating another source of potential bias. Here it would be useful to show not only the spatial coverage, as in Figure 1, but also a figure showing the depth coverage in zonal sections through the three major ocean basins. The authors address the depth dependency in Figure 3, where they calculate mean values based only those cores deeper than 2500 m. They also note that the volume weighted regional values are based on cores deeper than 1000 m. For the reader to get a better sense of the data coverage vs. depth, however, it would be very helpful a figure with the zonal sections or a figure showing the eight regions used to estimate the regional values, with core locations superimposed.

The other main weakness of the paper is the focus on the late LIG, which is motivated by the desire to avoid the lighter d13C observed in the early portion of many early LIG records. The authors note that their focus on the late LIG is to avoid low d13C values associated with the penultimate deglaciation, which is a reasonable consideration. However, many of these light d13C values occur well within MIS 5e as defined by the oxygen isotope stratigraphy in the associated cores (see for example the records in Hodell et al., 2009). Focusing on the late LIG for comparison to the Holocene makes sense for the mean d13C comparison, but it biases the Atlantic LIG records towards heavier d13C values, which therefore minimizes any differences in d13C that are related to AMOC variability. In other words, it is very likely that the authors are missing differences in the AMOC between the LIG and Holocene by focusing on the late LIG in the Atlantic d13C records.

Additional points:

Title: As ‘interglacial’ is an adjective, please consider using instead ‘interglacial period’ or ‘interglacial interval’.

Figure 1: Given the issues associated with scaling dD to temperature, it would be helpful to use only dD for the y-axis here, with some explanation of how dD scales to temperature with modern spatial relationships. Alternatively, consider including dD on one of the y-axes so the reader understands the source of the temperature estimate. Please also include error estimates for the SST record so it is clear what part of the temperature signal is statistically meaningful. (On the positive side, the comparison of the LIG and Holocene on the same x and y axes is very useful for showing the clear difference in CO2 history between the two intervals.)

Figure 2: Please specify the confidence limit associated with the whiskers. Also note the statistical range noted by the colored boxes (box and whisker diagrams aren’t particularly common in the paleo literature).

Figure 3: Note that the choice of averaging interval for the LIG has a non-trivial influence on the mean d13C for the equatorial and SE Atlantic. Given that the chosen interval of 125-120 ka is somewhat arbitrary, it is necessary to more fully explore the sensitivity of the findings to the choice of time interval. For example, if the defined LIG interval were 124-120 ka, several light d13C points would be excluded, resulting in a higher mean LIG d13C. If the lighter points are excluded, like those earlier in the LIG, what is the resulting mean LIG d13C for the equatorial and SE Atlantic? Is it statistically different than the Holocene d13C?

Line 85: While remineralization contributes to the lowering of NADW d13C as waters flow toward the Southern Ocean, the residence time of NADW is quite short in the Atlantic, minimizing the influence of remineralization. Mixing with 13C-depleted UCDW and AABW also contributes to the deep South Atlantic being 13C-depleted relative to the North Atlantic.

Line 87: This sentence is written in such a way to give the impression that the use of

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d13C as a circulation proxy is a recent phenomenon. But in the following sentence, there are citations of classic papers where d13C was used for exactly this purpose. Please clarify.

Lines 285-305: The authors suggest that the -0.2 per mil difference in mean oceanic d13C during the LIG may have been due to less organic carbon in the land biosphere. Unfortunately, there is no effort to estimate how much land carbon would be required to create the d13C anomaly. While this would assume a closed atmosphere-biosphere-ocean system, making this assumption explicit would then allow for informed speculation on the likely sources of terrestrial carbon. The estimate of terrestrial carbon loss could then be compared to various reservoirs (e.g. peats) to assess whether they are likely sources.

Lines 309-311: The idea about long-term imbalance between weathering and burial of carbon needs to be explained more thoroughly. How would these processes create the difference in LIG and Holocene d13C of DIC? The cited paper by Jeltsch-Thommes and Joos (2020) is a modeling study that evaluates the influence a large pulse of carbon introduced to the atmosphere, assuming that the carbon comes from the terrestrial biosphere. The simulations suggest that that oceanic d13C responds quickly to the addition of 500 Gt of terrestrial organic carbon, creating an oceanic anomaly of $\sim$ -0.2 per mil within about 500 years. The d13C anomaly persists for 10 kyr, before slowly returning to its initial value after approximately 100 kyr (due to removal of light carbon through biogenic sedimentation). Are the authors suggesting that such a process could explain the apparent difference between LIG and Holocene d13C?

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