Response to Reviewers Comments (essd-2019-249)

REVIEWER #3 (JEREMY HOFFMAN)

Turney et al. have compiled the most comprehensive data base of sea-surface temperatures spanning the last interglaciation (LIG) to date. Their results support the conclusions of several recent studies in important ways, even given their (novel) attention to potentially confounding effects present within SST reconstructions from planktonic sources (their "ocean drift") that were largely unaddressed in previous LIG work.

Understandably there has been considerable attention to the LIG as it can serve to assess the sensitivity of important Earth systems (such as the cryosphere, which was considerably smaller than at present due to higher insolation and warmer global tem- peratures) to natural climate fluctuation in recent Earth history, potentially illuminating mechanisms currently unaccounted for or underestimated in present-day climate models.

Having a "living repository" of LIG datasets from the marine realm will do well to improve future (and ongoing) LIG model-data comparisons, as is highlighted by the authors. The accompanying article is appropriate to support the publication of this dataset. The dataset is highly useful, unique in its comprehensive nature, and functionally complete. This dataset is of extremely high quality.

We were very surprised to receive this review after the completion and closure of the review process but thank the reviewer for their opening comments.

However, Turney et al. add only marginally to the existing story about total LIG warming amplitude relative to recent climatology (their uncertainties on a global anomaly overlap with basically all previous work!) and, by their chosen study design, can't add anything to the discussions ongoing about rates, extents, and locations of warming or sea-level change at particular times within the LIG. These stories have recently been borne a bit more out of work in modeling (Clark et al., 2020, Nature - referenced below) and a new ice-core based SST reconstruction (Shackleton et al., 2020, Nature Geoscience).

We are sorry to read the reviewer's comments. There is considerable work still to be completed for understanding the impact of Last Interglacial warming on the Earth system. Here we report new innovations that complement previous work. This work includes several contributions including a study into the potential role of ocean drift in reconstructing Last Interglacial temperatures, the development of a robust reconstruction of mean temperatures, the largest yet published network of quantified sea surface temperatures, and an analysis of published seasonal SSTs. The papers cited by the reviewer are important but were both published after our manuscript was submitted. In the revised manuscript we now discuss both of these studies. The paper by Clark et al provides an important analysis on the possible drivers of ice sheet melt but unfortunately restricts their model simulations of ocean temperatures to Termination 2. Here the model output suggests smaller temperatures than proxy data, highlighting the importance of extending the reconstruction further back in time. To help meet the need for future proxy-model comparisons, we have expanded on the submitted manuscript by generating late Marine Isotope Stage 6 SST estimates for records polewards of 40˚. These provide the first quantified estimates of the magnitude of the warming from the penultimate glaciation in key ocean sectors. We are now able to recognise warming patterns in different ocean sectors. The resulting figure is provided below.

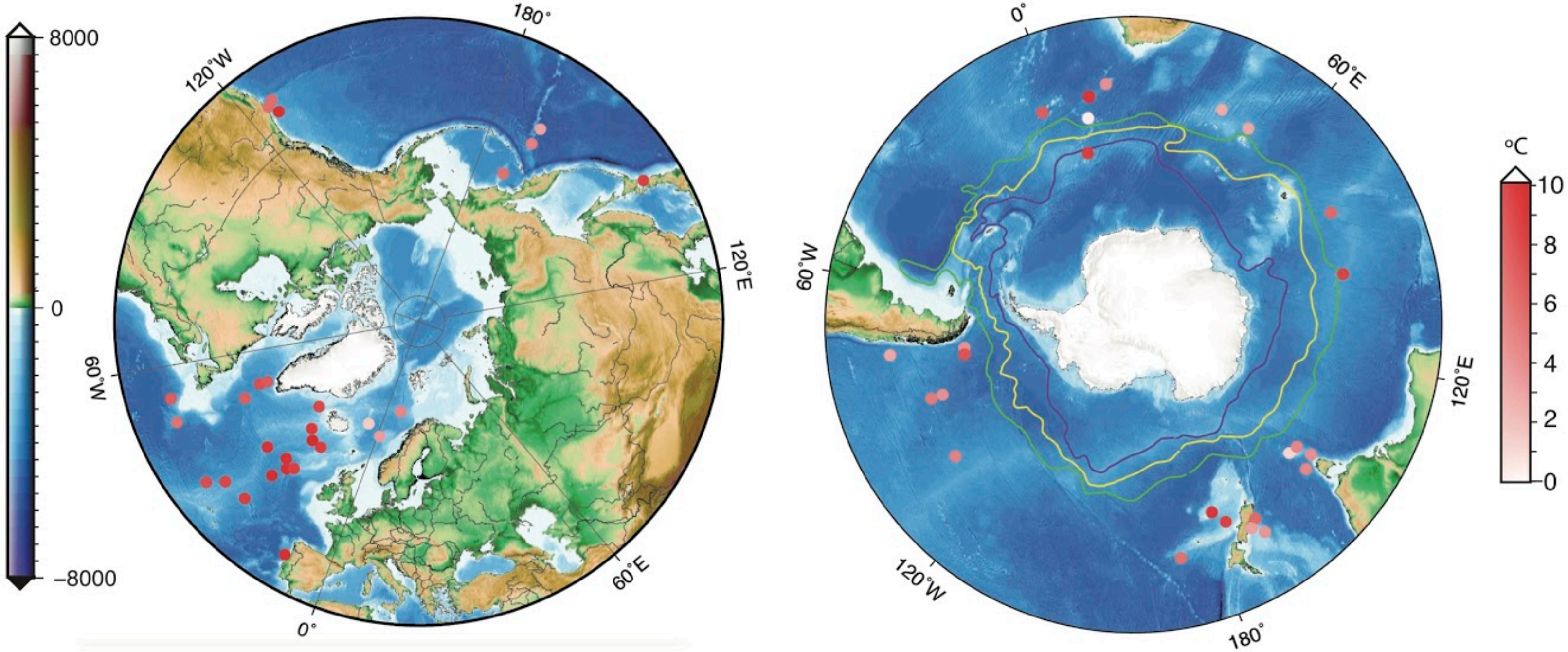
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Figure showing the sea surface temperature increase from late Marine Isotope Stage 6 through to the maximum values reported in the early Last Interglacial. Most notably, where records are available, the greatest warming can be seen in the northeast Atlantic and south Atlantic, suggesting Greenland and the West Antarctic ice sheets would have been particularly vulnerable to warming in the early interglacial. We hope these new data may help with future coupled ocean-ice sheet modelling projects. The study by Shackleton et al. (2020) is described at length in the other rejoinders but will also be discussed (see other responses for more fuller consideration of our new analyses in respect to Shackleton et al.).

I am curious how the authors can work on an update to the manuscript that incorporates more discussion of the understanding of intra-LIG variability in sea level, temperature, and other variables, and as such, work to clearly justify just why the multi- millennial, LIG-long averages that they have generated help us to better understand those variables or model outputs. Are there modeling studies planned (lig127k PMIP?) that they can point to that would be targets for comparison with their new reconstruction? If the main SST magnitude conclusions aren't different from previous work, and the work can't resolve anything particularly new within the LIG time period, maybe the effort of the paper should simply focus on updating the maximum possible thermosteric component of LIG sea level and make that the centerpiece of the analysis?

The reviewer has correctly identified this is indeed the main objective of the study(!): to determine the contribution of ocean warming to thermosteric sea level rise. This was (and remains) the title of the manuscript: A global mean sea-surface temperature dataset for the Last Interglacial (129-116 kyr) and contribution of thermal expansion to sea-level change. We have now made explicit statements through the manuscript that we are not aiming to resolve millennial and centennial-scale variability given the considerable challenges of meaningfully resolving the timescale of many published records (as this reviewer has demonstrated).

Specific comments

Lines 188-197 – Are the ocean drift correction calculations estimated using the HadISST data used to calculate the anomalies from climatology as well? How are these "life trajectory" SST averages (which presumably have some sort of standard deviation or variance across space/time) then incorporated into the SST reconstruction uncertainty? Addressing this additional source of uncertainty in the SST estimates may further complicate the story that arises from the drift-corrected SSTs, but perhaps maybe only subtly. This might be worthwhile discussing or exploring in a couple of particular locations, especially those where the signals due to drift correction are large. I would suspect that as these areas have large SST gradients themselves that estimating an "average" SST across their lifetime/drift might generate some additional uncertainty in the estimated anomaly.

The temperature drift for the contemporary ocean is derived from the eddy-resolving ocean model, the Japanese Ocean model For the Earth Simulator or OFES. This temperature offset was then taken off the reconstructed SST values for each site. As the reviewer correctly identifies, there is more work to be undertaken investigating the impact of drift on the calibration of individual organisms into temperature, the role of differential lifespans and settling rates etc. but that is beyond the scope of this study. We hope our work will provide a future focus for reconstructing ocean temperatures incorporating the effects of drift.

Lines 63-68 – please add Clark, P.U., He, F., Golledge, N.R. et al. Oceanic forcing of penultimate deglacial and last interglacial sea-level rise. Nature 577, 660–664 (2020). https://doi.org/10.1038/s41586-020-1931-7 to references about ice sheet modeling during this time period, as well as amounts from particular reservoirs/sources of sea-level rise. Given these recent estimates of intra-LIG sea-level change (citations within), what does this "maximum" LIG thermosteric component tell us?

We have now expanded our discussion to include Clark et al. This was published after our study was submitted to the journal and is an important contribution to the field, exploring the impact of transient changes. We have made explicit that the maximum early LIG temperature provides an upper limit on the contribution of thermosteric sea level and that later in the interglacial, the contribution was negligible. This database implies a more substantial contribution from polar ice sheets than previously supposed, particularly later in the interglacial, something we hope will be of value to the community who wish to explore ice sheet contributions to high sea-level in the interglacial.

Discussion of the LIG-long averages and addressing the small specific considerations would, in my mind, improve the clarity of this largely incremental - however important! - addition to the body of LIG SST knowledge. I thank the authors for the opportunity to comment and look forward to reading an updated draft of the manuscript.