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Comment on cp-2022-22

Anonymous Referee #2

Referee comment on "Asymmetric changes in temperature in the Arctic during the Holocene based on a transient run with the Community Earth System Model (CESM)" by Hongyue Zhang et al., Clim. Past Discuss., https://doi.org/10.5194/cp-2022-22-RC2, 2022

Review for the manuscript

Asymmetric changes of temperature in the Arctic during the Holocene based on a transient run with the CESM

by Hongyue Zhang et al.

Submitted for publication in *Climate of the Past*

General

The manuscript investigates Arctic temperature changes in an accelerated earth system model (ESM) simulation for the Holocene with CESM. The authors present asymmetric temperature changes between the Pacific and Atlantic parts of the Arctic and attribute those changes to varying pattern of atmospheric circulation and sea ice concentrations. Moreover, authors suggest that those asymmetric changes are especially pronounced in a simulation that is only driven with changes in orbital forcings.

The manuscript is unfortunately not representing the state-of-the-art literature and more important, lacks of simulations that are currently available for the Holocene in a transient sense. Accelerated simulations for the Holocene were expedient because of a lack of computing capacities some 20 years ago. Therefore according conclusions, especially on long term changes such as ocean-related sea ice processes can be afflicted with high uncertainties, also in the context of the interpretation with proxy data.

As such I cannot suggest publication of the manuscript in the present form. Below I list a number of suggestions and more recent studies including non-accelerated simulations that can be used for a substantially revised version of the manuscript.

Specific

In the following I will just point to the main concerns and how authors might extent and update their investigations taking into account more recent studies and adapting their hypothesis to more ESM/GCM-relevant questions.

Introduction:

The introduction lacks at least one paragraph motivating recent modeling studies over the Holocene, the challenges and implications e.g. of accelerated simulations vs. non-accelerated and the uncertainties involved in reconstructing external drivers (specifically solar and volcanic) for decadal-to-multi- decadal variability (cf. also studies listed as additional references below)

Another crucial and yet missing part is on the potential drivers giving rise to an asymmetric temperature response. Some mechanisms such as changes in equator-to-pole temperature gradient and/or changes in overall sea ice concentrations are presented. But no hypothesis or guiding question in how those general changes should result in regionally different responses are discussed.

2 Method and data

2.1 The CESM model and the transient simulations

ll. 106 ff: The authors describe their acceleration technique, also using changes in solar and volcanic output. I was wondering how those changes, reconstructed on yearly time scales can be implemented in a simulation with an acceleration factor of 10. (e.g. typically more than 2 volcanic eruptions happen per decade). How is this temporal discrepancy between annual reconstructions for accelerated simulations accounted for, also considering the post-volcanic effects on the simulated climate.

ll. 116 ff: There are new, and non-accelerated comprehensive Earth System model simulations available (cf. references) that should be used as additional source of information to back-up results based on the accelerated simulations with CESM.

Another general comment relates to the questions why the authors did not at least use an ensemble approach for their simulations to estimate the amount of long-term (centennial-to-millennial scale) climate variability.

2.2 Reconstructing Paleo Proxy data

This paragraph just lists the proxy data sets used for comparison without any information on potential uncertainties involved in the reconstructions, e.g. related to the uncertainties in the proxy archives towards their meteorological/climate variables, dating uncertainties, regional sparseness of proxy data, especially in the Arctic domain.

Since the authors investigate changes in ocean-related sea ice variability, also a paragraph on proxies representing changes in sea-ice concentrations including their uncertainties would be helpful.

3. Result

3.1 Arctic temperature change

ll. 152 ff: How robust are the temperature changes ? Are they statistically significantly different to internal changes. Therefore, applying a statistical test is helpful to estimate the amount of internal variability between the two different periods, preferentially taking into account the serial correlations within the proxy-based estimations of temperature variability.

ll. 172 ff: How significant are the changes between the Arctic and the Pacific region ? (i.e. -0.67 vs. +0.09.) Especially the Pacific trend seems to be statistically indistinguishable from a zero trend).

ll. 191 ff: Also for the model-based differences of the sea ice a local statistical test on the spatial pattern including the effect of serial correlation is important to test the robustness and statistical significance of the according changes.

ll. 202 ff: Changes in atmospheric circulation are also influenced to a high degree to internal variability – as such it is very important to use additional model simulations to back-up those changes, resulting from the CESM accelerated simulation. Moreover, why are the results of the orbital simulation are "more significant" than the one for the all forcings ? On Holocene time scales changes in orbital forcing on seasonal time scales exert a larger impact than the decadal-and sub-decadal changes caused by solar and volcanic activity. Therefore it is important to describe in greater detail how changes in solar and volcanic forcings are implemented into the accelerated CESM simulation.

3.3 EOF of SLP and UV wind regression and 3.4 The connection between Arctic dipole pattern and PDO

The whole sections lack a more thorough motivation on i) how the statistical concepts are used/defined and the ii) the robustness and statistical significance of the according regression patterns between the PCs and the underlying wind/sea ice fields. For instance, the PCs presented in Fig. 6 are (obviously) filtered with a low-pass filter. This should be accounted for when discussing and presenting the results.

Further, in addition to the UV regression, a Canonical correlation analysis would be better suited for this kind of investigation in section 3.3, since the rationale is to compare the common behavior of patterns (in this case the spatially resolved SLP and wind/sea ice fields.)

A last point is again on the validity and model-dependence of the results based only on the accelerated simulation with CESM. This is in my opinion the weakest but most crucial point of the study.

4. Discussion

l. 291: Authors should formulate more nuanced that in this very version of the manuscript, results only apply to their few accelerated simulations with CESM that need to be compared with more recent, non-accelerated studies.

l. 293: How should GHG changes, only changing very moderately in the pre-industrial period of the Holocene counteract any changes in orbital forcing ? If any, volcanic (and maybe in parts) negative periods of solar activity could counteract the negative trend in orbital forcing during the JJA season over the Arctic.

l. 284: The authors state that additional simulations should be used for investigations. Since those simulations are yet available authors should use them as an integral part of their revised study and thoroughly test their hypotheses with non-accelerated simulations and those carried out with different CMIP4-types of models.

Figures:

Fig 3.1: How does the Proxy (z-score) and the Model (°C) compare on the same axis ? In my opinion it would be necessary to show both on the same scale for an appropriate comparison.

Fig. 5: Please use units of hPa when presenting changes of sea level pressure fields.

Fig 6, 9a and 10a: In this form of the presentation, the EOF pattern seem to carry normalized values (i.e. z-scores). In order to re-normalize the EOFs (i.e. eigenvectors), the patterns should be multiplied with the square root of their eigenvalue. Then the EOF patterns carry the units (in this case Pa(hPa) for SLP and K for SSTs, respectively). Eventually the according (original) PCs should be divided by the square root of the eigenvalue in order to show consistent patterns between EOFs and PCs. In addition, the temporal filtering should be indicated for the time series.

Additional references / State-of-the art Holocene ESM simulations:

Transient Holocene simulation (6ka BP - 2ka BP) with interactive vegetation and phenology:
https://vesg.ipsl.upmc.fr/thredds/catalog/work/p86mart/IPSLCM6/PROD/Holocene/TR6AV-Sr02/catalog.html

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Bader, J., Jungclaus, J., Krivova, N., Lorenz, S., Maycock, A., Raddatz, T., Schmidt, H., Toohey, M., Wu, C.-J. & Claussen, M., 2020: Global temperature modes shed light on the Holocene temperature conundrum. Nature Communications, 11: 4726. doi:10.1038/s41467-020-18478-6.

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