

Clim. Past Discuss., referee comment RC2  
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## Comment on cp-2021-70

Anonymous Referee #2

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Referee comment on "An energy budget approach to understand the Arctic warming during the Last Interglacial" by Marie Sicard et al., Clim. Past Discuss., <https://doi.org/10.5194/cp-2021-70-RC2>, 2021

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### General Comments:

This paper adds to the literature on the Last Interglacial, which has assumed newfound relevance as the modern climate continues to warm, while the Arctic heats up even faster. In this light, the paper is timely and based on a solid approach of diagnosing the Arctic warmth of the Last Interglacial in a climate model through the lens of energy changes and physical processes. That said, I come away underwhelmed by the purpose and significance of this study in its current form, because there is not a clear explanation of what new insights were gained. In other words, what did we learn about the Last Interglacial from this research that we didn't already know?

The major takeaways about insolation forcing leading to large changes in sea ice, surface fluxes and time-lagged warming (e. g., peak warming during autumn, despite peak insolation forcing during summer) are consistent with findings from previous studies of the Last Interglacial and other orbitally warmed Arctic time periods such as the middle Holocene. However, that alone isn't grounds for an interesting new contribution. There may well be some new discoveries here that fill knowledge gaps, but those need to be articulated in the manuscript, especially since another recent paper on the Last Interglacial also reported changes in the Arctic energy balance and cloud responses using a different GCM (Guarino et al. 2020, Nature Climate Change). For example, it would help if the manuscript described which components of the diagrams of climate processes and feedbacks in Figures 13 and 16 are new and important discoveries from this study.

### Specific Comments:

The Introduction needs a better motivation for the present study. This section contains a lot of general information about Arctic amplification and some background about the Last Interglacial climate, but there is no information given about what the numerous past

studies of this time period have revealed about the causes of the pronounced Arctic warming and what knowledge gaps the present study will fill. To first order, the enhanced Arctic warming is simply a consequence of much greater warm-season insolation, so there is no mystery. I suggest a structure along the lines of, "These previous studies of the Last Interglacial suggest <X, Y, and Z> as the major factors for the enhanced Arctic warming, but they were limited by <omissions or weaknesses in these past studies>. To better understand the physical mechanisms responsible for the dramatic Arctic warmth of the Last Interglacial, we are using a <better?> climate model to diagnose the regional energy budget during this time period." A helpful framework is the "And, but, therefore" statement popularized by Randy Olson (<https://www.sesync.org/for-you/communications/toolkit/and-but-therefore-statement>).

Line 87: Please include the latitude/longitude resolution of the model in degrees

Section 2.1/2.2: There should be more justification for using this particular climate model in the study, especially because this is considered a low-resolution model. The improvements to this model version described in Section 2.2 are helpful, but how well does it simulate global and/or Arctic climate compared with other models (say those in CMIP5)? Also, what are the implications and limitations of using a low-resolution model for this study, which investigates dynamical changes in the atmosphere and ocean that might depend on relatively small-scale features such as transient eddies?

The 500-year spin-up is apparently not long enough for AMOC to reach equilibrium in the Last Interglacial run. It also isn't long enough to accurately compute stable deep-ocean temperatures as part of the energy budget analysis (Figure 5), so how confident can we be in the energy budget calculations of the ocean? The deep ocean heat content drift is quite large.

Figure 2: This figure needs a better explanation. For one thing, the caption should say that green symbols—not the green contour---show good model-proxy agreement (and state what is considered to be good agreement). Second, the overlain symbols show the paleodata as a point comparison with the model, but the caption implies that the entire maps are a proxy comparison with the model. I think the shadings on the maps are showing just the model-simulated difference between Last Interglacial and Pre-industrial climate, correct?

Line 165: Why was the energy budget calculated over the final 200 simulation years, rather than just the final 50 (as implied in line 112)?

Lines 239-241: Please discuss the large discrepancies in simulated global temperature anomalies at the Last Interglacial (near zero) versus the 2 K warming reported earlier (from proxy data?) in lines 55-56.

Line 249: Should "anomaly" be changed for clarity to "anomalies" in reference to the separate magnitudes of the ocean and land temperature anomalies, both of which are larger during winter than spring in Figure 7a,b?

Line 258-259: Is it correct to say that snow cover in Figure 7k doesn't respond to the summertime warming? Most places appear to show a decline compared with PI.

Lines 303-304: Why does only the upper ocean warm during summer (top 100 m)?

Line 329: The latent heat flux has to be directly correlated with evaporation, because that flux is the evaporation rate times the latent heat of vaporization.

Line 342: Could you briefly explain what Bjerknes theorized regarding heat transports, rather than just pointing readers to an indirect reference?

Lines 377-378: What is the physical explanation for the contribution of potential energy storage and its seasonal dependence? The text states that the change in potential energy storage follows the same seasonal variation as the internal energy storage, which is clearly temperature-dependent. But Table 2 shows differences between these two components, such that internal energy storage increases equally during spring and summer in LIG, whereas potential energy storage has a distinct spring peak.

Line 384: How does Figure 8 show that feedbacks operate in the lower atmosphere but not above, given that the maximum atmospheric warming in that figure occurs aloft in the 300-600 hPa layer?

Technical Corrections:

A thorough proofreading is needed. I identified a few typos or misspellings below but stopped keeping track.

"radiation", rather than "radiations"

Line 30: should be "have" been

Line 43: clarify what's meant by "blocks longwave radiation" (trapping longwave emission from the surface?)

Line 46: Should be "another" process

Lines 93-94: I don't understand what this sentence means ("which implies that event through vegetation type. . .").

Line 101: typo

Line 108: "Interglacial"

Line 110: typo

Line 141: typo

Line 209: Should the arrow for  $F_{bot}$  in Figure 3 be reversed, since the text says that  $F_{bot}$  cools sea ice when positive?

Figure 4: State in the caption that this result applies to the pre-industrial simulation. Likewise, state that Figure 5 refers to the Last Interglacial simulation.

Line 320: Shouldn't the text refer to Figure 9 (summer), rather than Figure 14 (autumn)?

Line 351: Figure 7d is the autumn map, not 7a.

Line 369: Likewise, the references to Figure 15c,f should be Figure 15b,e