

Review of “Contribution of sea-ice albedo and insulation effects to Arctic amplification in the EC-Earth Pliocene simulation” for *Climate of the Past*.

Summary:

This manuscript examines the impact of sea ice changes on the surface air and sea temperatures in the Arctic during the Pliocene, as simulated by EC-Earth. Specifically, they examine the energy flux impact of differences in surface albedo and surface ocean insulation spatially correlated with the changes in sea ice between the Pliocene and pre-industrial eras. They found that a reduction in albedo allows for much stronger short-wave heating during May, causing the biggest SST difference between the two eras to be during August. They also found that this extra stored heat was released back to the atmosphere via enhanced surface heat fluxes due to the decrease in sea ice insulation. This resulted in SAT differences between the two eras being largest during winter, and with an inverse seasonal timing relative to SST.

Paper recommendation:

Understanding how sea ice influences Arctic climate, particularly for higher-CO₂ forcing scenarios, is of great importance in terms of understanding what our future climate state will be. The Pliocene also provides a unique test bed to examine sea ice in a warm climate, given that it was in near-equilibrium with a similar forcing compared to now, along with enough proxy data to validate model results. Thus I do believe this paper is a beneficial contribution to the literature. However, I do have some concerns in regards to the interpretation of their results, particularly sea ice’s influence on clouds and water vapor. I also believe there needs to be some grammatical improvements to the text itself, to help make the manuscript easier to read. Given this, I am recommending **Major Revisions**. Although I hope these revisions are not too difficult to implement, I do believe they will significantly improve the final manuscript.

Major issues:

1. I am worried that some of the changes, especially related to water vapor and cloud cover, may not be directly related to changes in sea ice, but instead are related to a third variable that is also correlated with the sea ice (which would produce the correlation you found). The reason for this concern is that (I believe) you are using multi-year temporal averages to calculate the spatial correlation. However, over those time-scales potentially significant changes in the large-scale circulation could be present, which would impact clouds, water vapor, and sea ice through, for example, changes in atmospheric and oceanic heat transport. I sadly don’t know of a great way to untangle all of these effects, but I could imagine calculating the correlation between sea ice and, say, vertically-integrated atmospheric moisture and heat flux, to see if it changed substantially in regions with substantial sea ice loss, or regions with noticeable changes in water vapor/cloud cover.

If that correlation analysis produces a relationship that is difficult to interpret, then I would at least add a plot showing the annual average differences between atmospheric heat and moisture fluxes, or at least wind fields, to help the reader understand how the atmospheric circulation over the Arctic is different in the Pliocene relative to the pre-industrial.

Related to this, are your correlations and analyses including the entire Arctic, or just the regions that have or had sea ice? If you are examining the entire Arctic, then I might recommend examining only the sea ice regions, as there appears to be large surface heat flux changes in regions that contain little-to-no sea ice in both eras, which could be contaminating the statistical relationships between sea ice and the associated surface flux changes.

2. I would strongly recommend having a native or very-proficient English speaker edit this document, as there are a large number of minor but noticeable grammatical errors, such as missing articles (a, an, the), and misuses of pluralization, combined with some strange phrasing that made the document difficult to understand sometimes. By improving the grammar/wording, I believe this manuscript would be made much stronger and more accessible to a wider audience.

Minor issues:

1. Are all the maps shown in this manuscript annual averages? If so this should be stated in the text (you mention it in a few locations in the text, just not everywhere).
2. It is interesting in your supplemental figure that the net TOA is negative (implying energy loss), yet all the surface variables show increasing warming. Does this imply a cooling higher up in the atmosphere, and thus a change in the atmospheric lapse rate (which could impact clouds and water vapor)?
3. The modeled SSTs do well in the Atlantic, but quite poor in the (North) Pacific. Could this imply a bias in the Pacific basin, which could impact heat fluxes coming from the Pacific into the Arctic? Just a short sentence or two on it would be all that I would recommend.
4. It would help to include the striping and cross-hatching in Figure 2f as well, so the reader can see how the surface heat flux changes with respect to the sea ice transitions.
5. How does sea ice thickness change in the regions where sea ice is still present in the Pliocene?
6. I assume the correlation shown in Figure 5 is significant, but it would still be good to state that somewhere in the text (as a high r-squared value doesn't always imply significance).
7. Line 252: If sea ice insulation reduces local water vapor and cloud cover, then it could certainly impact the local surface radiation budget, at least in the long-wave. Not sure if this sentence was just not worded correctly?

8. It would help to show how the actual cloud cover is changing over the Arctic in the Pliocene (just showing cloud fraction by low and high clouds would help). That would put the changes shown in Figure 7 into better context.

9. It would be beneficial to see a spatial map of the latent and sensible heat flux changes, similar to Figures 2 and 3.

10. Figure 8: Any idea as to why the longwave cloud forcing in September is so large relative to all the other months? Again, just a sentence or two would probably be all that is needed.