

Review: An assessment of the North Atlantic Oscillation in the Late Pliocene and its impact on European climate

August 21, 2026

General comments

This paper uses the results from PlioMIP2 to examine the NAO and North Atlantic circulation during the late Pliocene. The topic is of interest and importance, with both significance to paleo and future climate. Therefore, there is definitely a need for this research. It can help to fill in the research gaps on North Atlantic variability during the LP, plus providing a better understanding of the behavior of the NAO is vital to improving modelling work focusing on future projections.

Considering this importance, I think the paper could do a better job of communicating its findings. The work conducted is extremely thorough and methodically robust, yet the results are hard to extract, and the conclusions perhaps unclear. I think with some restructuring and a better focus on answering the hypothesis the paper sets out to do, it would greatly improved.

Introduction

I feel this section could be improved by condensing 1.1 and 1.2, and with a slight restructuring. There is a fair amount of repetition on the importance of studying the NAO, which I agree with, but it is currently scattered throughout the text. It may have more impact if there was a dedicated paragraph detailing this. On that note, section 1.3 is interesting and well written. I would condense the text prior to this, so you arrive at this section faster. This is what makes the study unique and interesting so let this be the focus.

I am confused by lines 27 to 40. It states "studies of the LP", which studies? Are these the studies then referenced in lines 29-30, or are these studies that have only focused on the long term state? But then Pontes et al is referenced again when discussing high frequency. If the aim of these paragraphs is to identify the research gap or where current literature has not yet gone, perhaps be clearer on this. Lines 40-44 are really clear with the delivery of the aims, so tidying up the paragraphs before so they lead into this could really help.

Results and Interpretation

I understand that this section is both a combined results and discussion, but I found it hard to draw out the results due to the constant discussion elements. I think this section could benefit from some restructuring.

Firstly, the results that are presented are quite vague. The wording is often "general agreement," "larger changes", "diverse changes", "more positive on average," but these are more descriptive than concrete results. Quantifying these changes would make it much clearer what the study has found and why it is important. Statistics to actually demonstrate the range of what diverse means, or how agreed results are are needed. The maps and figures 4-5 show the changes, but quantities are hard to interpret from the figures alone.

Secondly, I think the flow would be improved by establishing the results first, and interpreting them after. The continued sentences with very speculative wording like "which suggests," "indicates", "may also be influenced," "likely due", not only makes it harder to find, absorb and remember the results, but it makes the reader continually question the results presented. Whilst interpretation and discussion is vitally important, and I don't want it be removed, I wish that the findings had been presented in a clearer way, before the issues associated with them were dissected.

In this vein, I think a dedicated limitations paragraph is needed, as opposed to having single sentences spread out. This could delve properly into the issues working with higher frequency variability modes and wind characteristics, with just monthly data from PlioMIP simulations. This is touched on briefly in line 234, but is important to address as it must have a big impact on the result, or what we can learn from it. A limitations section could also cover the other factors that must have an impact on the findings but are only sporadically mentioned (e.g line 193 vegetation, line 199 orography, line 248 East Atlantic pattern). By having a dedicated limitations, it would reduce the amount of doubt that's continually cast on the findings, and instead present it more in a light of what we can be done better in future. This would also help improve the conclusion - see below.

Section 3.4 Impact of NAO, is interesting. Evaluating the impact on the climate is, I feel, at the core of the significance of the study and should be thoroughly explored. Quantifying values would aide the section, "Northern Europe has increased precipitation whereas Southern Europe ..." how much? Same can be done for temperature. From figures 6/7/8 it is hard to define what amount the colours respond to.

Section 3.5 I am slightly confused by. No data comparison has been done, although possible datasets are mentioned, but the problems associated with data comparison are discussed and future possibilities. Also data comparisons are mentioned in the previous sections to, so there is somewhat repetition. Therefore, i struggle to find the outcome of this section. If it is not possible to do a data comparison, then this is something to be discussed in limitations, along with what is needed to in the future. Or if the authors want to do a data comparison, however how small, I think it would benefit the study. This perhaps goes back to my earlier comment on providing quantities, definite numbers may be easier to evaluate against proxy reconstructions then just descriptions.

Conclusion

This section is concise and well written, but considering the sporadic nature of the results, I was hoping that the conclusion would be more affirmative in what was achieved. Perhaps with a less descriptive and more quantative results section, the conclusion can naturally improve, with a clearer message in what was achieved. Parts of this section, e.g. line 325 would work better in a separate limitations section.

Minor Comments

- Line 18: "and palaeoenvironmental reconstructions using proxy data" Unclear phrasing, do you mean climate is focus of both the modelling and the proxies?
- Line 19: change to "comprises of outputs from 17"

- Line 20: "consistent manner" wording is too vague, do you mean with same experiment setup?
- Line 21: "Late Pliocene experiment, CO₂ concentrations were set to 400 ppmv and the Antarctic and Greenland ice sheets were reduced in size compared to modern." You state this later in the methods, i think keep it there and remove it from the introduction as it doesn't quite fit.
- Line 24: "The PlioMIP2 multi-model mean (MMM) simulates global annual mean surface" Is this referring to MMM of LP core experiments? Specify.
- Line 35: "report a reduction" Unclear statement. A reduction in LP? A reduction compared across the models? Compared to what?
- Line 36: "Changes in circulation patterns", this is unclear, does this refer to changes in ENSO? Or Atlantic?
- Line 47: " over the North Atlantic associated with", change to "which is associated"
- Line 52: "closer to Ireland" and "in summer the westerly winds sit equatorward". These sentences feel incomplete or arbitrary - either explain or remove.
- Line 54: "a strong influence on European climate and hence on agriculture" change to "on European climate, which affects agriculture and ..."
- Line 59: "present day climate" maybe would be better referred to as "modern climate"
- Line 61: "with reanalysis data showing a stronger relation to jet stream" this is unclear, a stronger relation of what exactly?
- Line 113: "PlioMIP2 data" very small thing, but data is maybe more associated with proxies, so maybe use model output instead?
- Line 140: "fully separate out the orography and ice sheets". I can't find if the ice sheets are interactive or static, perhaps add this in.
- Line 163: "pressure that is too high" and "too low". This wording is misleading, too high/low implies it's wrong, and if this is a comparison with reanalysis - which you have previously stated cannot be fully trusted, then there isn't necessarily a right or wrong.
- Line 167: Why do we already jump to figure 6 and 7? what happened to 2,3,4.
- Line 173: "opposite to that projected by higher (abrupt 2×,4× and 8× CO₂)" I don't quite understand the importance of this, I can't find if this simulation is discussed again or why it matters in the LP context.
- Line 183: "change in SLP is diverse" vague wording, what does this mean? Can we have some quantification of what diverse is?
- Line 197: "Changing the Greenland ice sheet impacts North Atlantic circulation. By implementing Late Pliocene ice sheets, the orography of Greenland is changed" Consider rewording this. "By implementing Late Pliocene ice sheets, the orography of Greenland is changed, which in turn affects North Atlantic circulation"
- Line 206: "more positive on average (Fig 4). However, there is large model spread" This would really be improved with quantitative support. How much? What range?

- Line 231: (Fig. 5 Missing bracket.
- Line 314: missing comma after ensemble
- Line 322: "data set are likely within the range of internal variability of the models" Does this mean none of the NAO results can be trusted? Perhaps consider rewording - or address properly in limitations to avoid confusion.
- Figure 5: "Change to the North Atlantic" Please specify change from what to what.
- Figure 8: Panel showing Residual, it is very hard to distinguish the different red shades and therefore differences.
- Figure 9: "The change in the mean" Please specify if this is LP-PI difference. I think the values that have been added to this figure would be far easier to read as a table.
- Figures 1-3 and 6-8: The boundary lines on the continent are way too thick and make it the maps very busy, especially around Canadian and Norwegian coasts.