

Interactive comment on “Extratropical cyclones over the North Atlantic and Western Europe during the Last Glacial Maximum and implications for proxy interpretation” by Joaquim G. Pinto and Patrick Ludwig

Anonymous Referee #1

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GENERAL COMMENTS

This paper outlines the use of cyclone tracking to identify some key points of the climate and weather over the North Atlantic and Western Europe during that Last Glacial Maximum (LGM). The paper identifies changes in the mean state that may be both conducive to dust emission (e.g. increase in wind speeds) and also those which may hinder it (e.g. more storm activity and associated precipitation). The key point in the authors' analysis is the cyclone tracking and compositing, which provides important information on how the mean climate state is felt at the surface through the extratropical

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cyclones (in this case, the 30 most extreme). It is very clear from their results that the strengthening of the thermal gradients in the LGM (relative to the base period) simulations do not cause an increase in precipitation (at the fronts) and that overall there is less precipitation in the extratropical cyclones (for clear physical reasons, which are stated). The high-resolution model data is also useful for reaching their conclusions as they do not have to make inferences from other (statistical) downscaling methods. The cyclone composites also clearly show the increase in wind speed and lower precipitation associated with these systems and therefore the authors reach the logical conclusion that the increased cyclone activity, combined with stronger low-level winds and lower precipitation, are likely to be responsible for the frequent dust storms the proxy data suggest. The manuscript is well written, provides a logical sequence of evidence and draws sound conclusions from them. The paper would be a good addition to the literature and should encourage other similar analyses for other models/epochs. I do have a fairly large number of minor points that should be considered, but they should be very straightforward to address.

SPECIFIC POINTS

Line 19/20: “. . .which is typically. . .” change to “. . .which are typically. . .”

End of line 37: change stronger to larger (“larger differences” reads better).

Lines 41-42: Re-word to something more concise like, “One important issue preventing non-recent or non-21st century cyclone analysis is the availability of climate model output with sufficient spatial and temporal resolution to enable identification, tracking and characterisation of such cyclones.”

Line 56: Change “enhanced” to “stronger”.

Lines 57-58: change to: “. . .leading to a southward displaced, more intense and less variable North Atlantic jet than under. . .”

Line 59: change “related with” to “related to”.

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Lines 68-71: the sentence starting “For example,” in line 68 is too long and I struggled to make sense of it. Please would you break it up into two sentences and re-word it.

Line 66: insert “the” before “LGM in PMIP3”. Whole paragraph, lines 56-74: There is this paper (below) that suggests reduced storminess over the North Atlantic at the LGM, which the authors should consider as a counter-view to their paper. It does not invalidate the results here whatsoever, but does provide an important (and perhaps opposing) view of the North Atlantic at the LGM. Just a sentence acknowledging this and citing the paper would be sufficient: Rivière, G., S. Berthou, G. Lapeyre, and M. Kageyama, 2018: On the Reduced North Atlantic Storminess during the Last Glacial Period: The Role of Topography in Shaping Synoptic Eddies. *J. Climate*, 31, 1637–1652, <https://doi.org/10.1175/JCLI-D-17-0247.1>

Line 78: change to “. . .compared to their modern counterparts at high spatial. . .”.

Line 84: change to “. . .our analysis is data from the third phase. . .”

Lines 87-88: change “adapted” to “lower” as the greenhouse gas concentrations are lower.

Line 90: Remove the “have” after the Ludwig et al. (2016) reference.

Line 91: Include “the” before “LGM”.

Line 92: Change to “. . .slightly different jet structure to some of the other. . .”

Lines 92-93: remove the words, “in terms of the difference between PI and LGM conditions” as they unnecessarily make the sentence too long.

Lines 108-109: change to “. . .to simulate the TOP 30 cyclones (from PI and LGM) with a grid spacing of. . .”

Lines 112-114: Different spellings of parametrisation/parametrization – make sure you are consistent (either way seems OK with Copernicus Publications but you need to be consistent – see manuscript preparation guidelines).

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Line 112: Change to “An overview of the parametrisation choices is given in Table 2.” As it is more concise. Paragraph for lines 119-126: Start the paragraph with something like, “The TOP 30 cyclone tracks simulated by WRF were identified manually. . .”. Just to be clear that you have not manually tracked all cyclones in these simulations.

Line 121: Change “equally” to “each”.

Line 123: Change “For the sake of succinctness,” to “For brevity,”.

Line 124: Change “The here analysed target variables based on the 12.5. . .” to “The variables analysed from the 12.5. . .”.

Lines 130-131: I think you should actually include the plot of MPI-ESM-P vs reanalyses in the paper to help this section. It makes it quicker and easier for the reader to verify your statement. Including the figure in the supplement would be absolutely fine.

Lines 136-137: Change “The North Atlantic storm track looks quite different under LGM conditions: the cyclone track density is strongly enhanced over the North Atlantic and more constraint along a corridor close to the ice edge (Fig. 2b).” to “The North Atlantic storm track looks quite different under LGM conditions relative to PI: the cyclone track density is higher over the North Atlantic and more constrained to the ice edge (Fig. 2b).”

Line 142: I read the numbers 12.071 vs. 9.541 as “twelve versus nine-and-a-half” cyclones over a 30 year period. Is this supposed to be 1000 times that i.e. twelve and nine thousand, respectively over a 30 year period? That would be about 2.2/day vs. 1.8/day, which seems right. If it is ‘thousands’ of cyclones then just put 12071 and 9541 as the inclusion of the decimal point could mean different things to different readers and removing it would remove any confusion.

Line 144: add ‘the’ here, “for the LGM”

Line 146: change “cyclogenesis is enhanced” to “the rate of cyclogenesis has increased”. I find the use of “enhanced” can be ambiguous. Do you mean the cyclones

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deepen faster? More cyclones generated? Other features associated with cyclogenesis strengthen? Stating that the number of storms being formed has increased (instead of enhanced) makes the sentence much clearer. Please consider the use of “enhanced” elsewhere and whether a more direct statement can be made (as above).

Line 146: regarding enhanced... you could say, “On the other hand, there is more cyclolysis along the borders...”. Again, what aspect of cyclolysis is “enhanced”? If you mean more storms are decaying there then you can just use the suggested wording above.

Line 147: Change “in strong deviation” to “relative”.

Line 149: remove the word “reveal” and replace with “have”.

Line 152: remove “particularly”.

Line 153: do you mean ice sheets not shields?

Lines 153-154: Sentence starting “This is in strong...” does not seem to quite make sense to me and I am not sure how to re-word it. Could you check to make sure it is clearly stating what you want it to say.

Line 158: “LGM cyclones are on average more intense than their PI counterparts”. While I accept this is true, your analysis/summary of the figure does not clearly show this. All I can see is a skewed distribution. You just need to quantify this and then quote the mean (and median, given the distribution shape) in the text to back this statement up.

Line 169: Again, quote the actual mean/median value from the cyclones in Table 3 to clearly show that the vorticity is higher for the LGM relative to PI.

Line 188: Change “Take” to “Taking”.

Line 193: Change to “. . . temperature at 850 hPa for LGM relative to PI”.

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Line 194: Change “apparently faster” to “displaced forward in the cyclone”.

Line 200: Change “for LGM extremely cyclones” to “for the LGM extreme cyclones”

Line 202: Change “strongly increased” to “much higher”.

Line 203: Change m/s to m s⁻¹.

Line 213: Change “occurring climate” to “climatic conditions”.

Line 214: Change “under LGM conditions” to “at the LGM”.

Line 229: Just say “shortcomings” not “some shortcomings”, also give an example the sort of shortcoming you are referring to.

Line 230: Change “this caveat” to “those shortcomings”.

Line 231: Change “Pfahl et al. (2015) had” to “Pfahl et al. (2015) has”.

Lines 234-239: Sentence starting “Even though...” is far too long and needs to be broken into at least two sentences.

Line 240: change to “close to the Iberian Peninsula for cyclone selection leads...”.

Line 243: add ‘the’ – “typically initiated by the wind...”.

Line 246: change to “have been stronger than at present... (Maher...)”.

Line 247: Change “document of a past when” to “indicate that”

Line 250: What’s an “adequate large-scale circulation”? Do you mean, “stronger large-scale flow”?

Line 255: remove “European” as you state Europe at the start of the sentence.

Line 257-258: change to “. . . individual LGM cyclones could trigger such dust...”.

Line 258: Change “strong wind speeds” to just “strong winds”.

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Line 259: change to “. . .trigger dust emission and transport over short. . .”.

Line 260-261: sentence starting “As the precipitation. . .” was confusing. You need to say something like, “As moisture acts to make surface dust particles more cohesive (REFERENCE*), the reduced cyclone precipitation and higher wind speeds in LGM cyclones would have actually been more conducive to generating dust storms” – or something close to those words. *please find and insert an appropriate reference here.

Line 273: change “featuring an enhanced number and” to “featuring more frequent and intense” which is much clearer.

Lines 276-277: Change “LGM cyclones were more intense due to stronger baroclinicity and apparently less influenced by diabatic processes (lower rainfall, lower temperatures, lower water vapour content).” to “LGM cyclones were more intense due to stronger baroclinicity with less influence from diabatic processes (lower rainfall and lower water vapour content).” Note: I removed ‘lower temperature’ as temperature can change adiabatically, which matters given e.g. lower sea levels and therefore higher mean sea level pressure, which would affect temperature.

Line 293: change “in favour of an extended used” to “for the extended use”.

Figure 1 caption: change “extends” to “extents”.

Figure 3 caption: change “. . .ice sheet extends marked by blue line. . .” to “ice sheet extents marked by the blue line. . .”.

Figure 4 caption: change “. . . the y-axis is zoomed in.” to “. . .the y-axis is adjusted (right figure).”

Figure 6: the MSLP in WRF 12.5 Fig. 6(d) is lower at the cyclone centre than WRF 50’s cyclone centre in Fig. 6(c) but the MSLP is higher (and not even below 990 hPa, whereas I can see a 985 hPa closed contour in Fig. 6d) in the WRF 12.5 km than either of the other two models. This does not look correct. Please check this as the MSLP changes in Fig 6(b) would not be consistent with the vorticity changes given the

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method of calculating vorticity.

Figure 7: The caption is incorrect. Where you refer to (d, e) and (f – g) I think you mean (d – f) and (g – i). Please re-read the caption carefully and make sure it corresponds to the correct figure panels. Also, you refer to the ‘field mean’ in the caption – averaged over what area? The cyclone area? Hemisphere? Globe? Please be clear on that.

Figure S1: The same issue as described for the Figure 7 caption applies to this figure too. Please check through it.

Interactive comment on Clim. Past Discuss., <https://doi.org/10.5194/cp-2019-139>, 2019.