Dear Editor,

We would like to thank the three reviewers for the interesting comments and also for the time they devoted to review the article. Please find attached a revised version of our manuscript. We have carefully taken into account the different points raised by the reviewers. For this purpose, we have expanded the main text by incorporating the discussion of summer NAO correlations (which was previously in the supplementary material). We have also expanded the discussion of NAO centers of action by comparing the results obtained using the station NAO index and the principal component of the atmospheric circulation. Finally, we have added in the supplementary material the figures showing the differences between the temperature bias for 6 hourly, daily and monthly precipitation weighted temperatures. We include detailed answers to the different points raised by the reviewers. We hope that this revised version will be considered for publication in Climate of the Past. Sincerely, on behalf of my co-authors, Mathieu Casado.

Reviewer #1 :

General Comment:

The authors investigate the importance of the precipitation intermittency bias in proxy records by comparing seasonal temperatures estimated with and without precipitation weighting. The authors provide evidence that this bias may reach locally up to 10°C. They further investigate the implications of this bias to reconstructions of the North Atlantic Oscillation. The importance of the precipitation intermittency bias is also analysed with respect to the precipitation isotopic composition. The authors suggest that the isotopic d18O signal may provide additional information for NAO reconstructions.

The manuscript is well written, the methodologies and statistics are well applied, and the conclusions are largely sound. Therefore, I believe the manuscript is a worthy contribution to Climates of the Past. Nevertheless, a few minor aspects should be improved before the paper is accepted. Therefore, I recommend a minor revision according to the comments given below.

Response: The authors appreciate the positive opinion of the reviewer about this manuscript and the constructive suggestions. Most of them have been implemented in the revised manuscript. The full text of the review is reproduced below, with an answer following each comment. A pdf file highlighting changes (deletions/additions) to the previous version of the manuscript is also sent to the editorial office in order to facilitate a detailed screening of changes. Please note that, following suggestions of the other reviewers, we have reorganised the article, moving four figures (with their corresponding descriptions) from the Supplement to the main manuscript. We have also enhanced the discussion on the two alternative definitions for the NAO (see comment 12).

Specific comments:

#1 Page 4961, lines 16-21: As the authors correctly state, the precipitations amounts from reanalysis datasets may be very unrealistic. Thus, the reasoning here about comparing two different reanalysis datasets does not really make much sense. Instead, I suggest mentioning already here that, due to the shortcomings of precipitation in the reanalysis, the authors also consider observational datasets (as described in page 4962).

Response: We fully agree. The comparison with observational data is essential to assess the realism of precipitation in the different reanalyses. The text has been rephrased accordingly.

Rephrased text: "This motivates a comparison among the different reanalysis datasets (see Figure 1) and with observational data from meteorological stations (see Suppl. Material, Section A)."

#2 Page 4963, line 23: I wonder about this statement, as the horizontal and spatial resolutions are very different between ERA-40 and the ECMWF operational analysis. Please add some more information here (eventually taken from Risi et al., 2010).

Response: In both cases (ERA40 and the ECMWF operational analysis), before the nudging is applied, the three dimensional wind fields are interpolated from a regular 1.125ºx1.125º grid to the resolution of LMDZiso. In either case, no jump or discontinuities associated to this change have been observed in the simulation at the beginning of year 2002.

Rephrased text: In both cases, the horizontal winds were interpolated from a regular 1.125° x 1.125° grid to the resolution of LMDZiso before the nudging is applied. No noticeable discontinuity due to the change in the nudging data was observed (Risi et al., 2010).

#3 : Page 4965, line 25 – Page 4966, line 6: This paragraph is unclear to me, particularly as all the statements are based on "not shown" data. For example, there is a very clear diurnal cycle of precipitation in some parts of the study area (e.g. over Central Europe during summer). Please enhance, and if necessary, add supplementary material to support the statements.

Response: For clarity, this paragraph has shortened, and the corresponding discussion has been extended in the supplementary material (section C), where a new figure has been added (Figure S2).

Rephrased text1 (manuscript): The temperature biases associated to each weighting resolution are compared for CRU-NCEP in the Supplementary Material (Section C). For the rest of the analysis we will exclusively focus on the precipitation intermittency bias calculated from daily values.

Rephrased text2 (supplement): In terms of their mean value (Figure S3a,b), the spatial distribution of biases is different for the three time resolutions, with the exception of the winter 6-hourly and daily outputs that show virtually identical patterns. In the summer, the largest biases are related to the 6-hour scale, and concentrate at the northern latitudes. It is also worth mentioning the negative biases in the Mediterranean area for the daily precipitation weighted temperatures, not depicted in the other two cases. Concerning the standard deviation of these temperature biases (Figure S3c,d), a better agreement is observed, in particular for both the 6-hourly and daily outputs. This good agreement between the two finer time resolutions indicates that diurnal cycle has a negligible influence on the variability of the temperature bias due to precipitation intermittency. We can therefore restrain to the analysis at the daily resolution. Also, we remark that for the monthly amounts standard deviation values remain comparatively small, which also justify the further analysis on the daily scales.

#4 Page 4968, line 13: I consider Figure S8 quite important, and suggest moving it to the main manuscript. : Moving to main manuscript as figure 4.

Response: This figure has been added to the main text (new figure 4).

#5 Page 4971, line 14 and Supplement E: The authors claim that "the NAO-Tp correlation appears remarkably stable through time". By closer inspection of Figures S6 and S7, this is actually not really the case. Please reformulate.

Response: What we intended to say is that the main centers of action for the winter NAO (i.e. negative values over the coast of Labrador and the Baffin Bay, the North of Africa and Middle East; and positive correlations across Eurasia and Eastern North America) are always present. Our initial formulation was not precise enough, as the correlation strength and the spatial extent do vary through time. The paragraph has been reformulated and moved to the main text section 3.5 with more details.

Rephrased text : "*Figures 6 and 7 investigate respectively the stability of summer and winter NAO-climate (temperature, precipitation, and precipitation-weighted temperature) relationships throughout different time periods. Three bi-decadal intervals have been compared: 1990-2010 (previously chosen for comparison with ERA-interim), and the new periods 1970-1990 and 1950 – 1970. This latter period is characterised by a weak negative NAO mean state, while the other two show strong positive mean NAO values.*

The summer is characterised by small and unstable NAO-climate relationships, as illustrated in Figure 6 and also found by Vinther et al. (2010). Both the location and sign of correlation coefficients appear to vary through our three time intervals, despite being associated to rather similar mean summer NAO values. This difficulty to identify robust features in the three periods points to shifts in the location of the summer NAO centers of action, associated to reported changes in the North Atlantic summer mean circulation (Hurrell and Folland, 2002).

In winter, the correlation patterns with the NAO are clearly more robust (Figure 7), although still subject to some spatial changes. For precipitation (Figure 7a), only the negative correlations in the Western Mediterranean region remain stable, while positive values over Scandinavia and Western Russia appear for the last two periods, both characterised by a positive mean NAO state. The correlation patterns for temperature (Figure 7b) show most robust features through time, with persistent positive values in Eastern North America, Northern Europe and negative ones around the Labrador Sea, North Africa and the Middle East. Note that again, some correlations become insignificant only during the first time interval, in this case over Eastern Greenland and Siberia. Finally, a similar picture holds for the precipitation-weighted temperatures (Figure 7c), the main difference being that the magnitude of correlations is generally smaller than for temperature, and also more affected by local conditions, which is normal given the weighting effect of precipitation.

We note that the quality of the reanalysis might be weaker for the first period (1950-1970), prior to the satellite data assimilation. It is also possible that, during this period, the negative NAO-pattern has an influence over the NAO-climate relationship that would make it differ from the most recent periods, characterised by a positive NAO-pattern.

#6 Page 4972, lines 4-11: While I generally agree with the statement, but I suggest reformulating this text segment, as it is difficult to follow the reasoning as it is.

Response: The text has been rephrased.

*Rephrased text: "So far, based on observations, it has not been possible to quantify the impact of NAO on moisture sources and therefore the possible biases introduced in local climate-δ18O relationships. Yet, through the computation of moisture back-*trajectories *for Greenland precipitation, Sodemann et al. (2008) has identified SST changes of up to 5ºC related to positive versus negative NAO winter conditions, thus suggesting that other processes than condensation temperature are probable to impact NAO - δ18O relationship."*

#7 Page 4974, lines 14-17: there has been some recent work on sources of precipitation for Europe (see some suggestions below, not exhaustive). Further, I do not think “higher resolution simulations” would actually help here, but rather the using of appropriate back tracing methodologies on reanalysis datasets. Please reformulate.

a) Drumond, A., et al. (2011), A Lagrangian analysis of the variation in moisture sources related to drier and wetter conditions in regions around the Mediterranean Basin, Nat. Hazards Earth Syst. Sci., 11, 2307–2320.

b) Gimeno, L., et al. (2010), On the origin of continental precipitation, Geophys. Res. Lett., 37, L13804, doi:10.1029/2010GL043712.

Response: We have removed the mention to higher resolution simulations. The suggested articles are clearly focused on the Mediterranean and subtropical latitudes. We have not added them as they do not support our discussion. Note that we already refer to the Lagrangian study of Sodemann et al (2008) centered on Greenland.

#8 Page 4975, lines 12-15: Please reformulate, same as comment #5.

Response: The paragraph has been rewritten.

Rephrased text: “The NCEP data shows robust features in the winter NAO-T_p *relation for three different time periods of 20 years, all highlighting four main influence regions characterised by negative correlations from Labrador to the Baffin Bay and also in the North of Africa and the Middle East, and with positive values in the North of Europe and Russia, as well as in Eastern North America. However, the extent and strength of these correlations changes with time, probably as a result of the spatial variability in the centers of action of the NAO. “*

#9 Page 4975, lines 16-18. The authors have actually not yet really demonstrated that Tp presents a real advantage for past reconstructions. I suggest weakening this statement and starting with “We suggest that the Tp variable may present some advantages as a target for calibrating (…)” .

Response: These changes have been implemented in the revised text.

Rephrased text : “We suggest that the T_p *variable (from in situ meteorological data, or from analyses) may present some advantages as a target for calibrating* $\delta^{18}O$ *proxy records, rather than the mean winter temperature, because of the magnitude and variability of the precipitation intermittency bias (Figure 3).”*

#10 Supplementary material B, second paragraph: There are actually quite big differences between the various reanalysis datasets. Compared to which reanalysis are the direct observations of precipitation intermittency bias similar to?? Please enhance.

Response: Despite some differences in magnitude, partly due to the different spatial resolution among the reanalysis and the simulation, there is an overall qualitative agreement between the three datasets and the observations. Note for example the maximum values in Scandinavia and Central Europe during winter, and the tendency to stronger negative values near the Mediterranean Sea during the summer. We have rewritten the text, now including a more detailed description of the common features.

Rephrased text: The overall structure of the precipitation intermittency bias from direct observations is in good qualitative agreement in the observations and the three datasets (Figures 3a and S1). In terms of magnitude, the best consistency with observations corresponds to ERA-interim, both in summer and in winter. This might be directly linked to its good performance in the representation of precipitation events, thanks to its fine resolution *(e.g. 0.72°x0.72°) allowing for the representation of orographic effects, and also to the realism of physical parameterizations (e.g. atmospheric convection, Jung et al., 2010).*

11: Supplementary material, Figure S2: I suggest showing first JJAS as (a), and DJFM as (b), to be coherent with Figure 2.
Response: The figure has been rearranged.

12: Supplementary material, Figure S3: The leading EOF for MLSP calculated from LMDZiso, which should represent the NAO-pattern, look particularly strange for JJAS. Please check. Additionally, I strongly suggest adding the correspondent panels for ERA and NCEP for comparison (both DJFM and JJAS).
Response: As suggested, the corresponding leading EOFs for ERA-Interim and CRU-NCEP have been added to Figure S2. All of them exhibit common features with the EOFs previously calculated only from the LMDZiso simulation, even during the summer. This first EOF for the summer, in contrast with its winter counterpart, is characterized by a tilted dipole, with maximum positive SLP anomalies over the North Sea and Scandinavia, which defines an intense SLP gradient with respect to Greenland and the northern latitudes. Our results are fully consistent with earlier works on the summer NAO (Folland et al., 2009; Hurrell and Deser, 2010; Bladé et al., 2012), both for observations and model simulations. Furthermore, Hurrell and Deser, (2010) also noted that during the summer, NAO reaches minimum values in its amplitude and spatial extent, with centers of action displaced to the northeast with respect to winter, just as displayed in Fig S2. This new description of the summer NAO has been now included in the text. For further discussion on this pattern, please see the response to the comment 13 of the second reviewer.
Rephrased text 1: The choice of an index based on pressure differences is questionable due to shifting positions of the NAO pressure centers of actions, both at the seasonal (Folland et al., 2009) and decadal scales (Raible et al., 2006;Pinto and Raible, 2012). An alternative definition of the NAO index is based on the first principal component of the sea level pressure field. Although during the summer both the variance explained and the amplitude of the NAO diminishes substantially relative to winter (Hurrell et al., 2003), this pattern is still captured as the leading mode of SLP in the North Atlantic, both in the reanalyses and most climate model simulations (Bladé et al., 2012). Note that the dipole structure is displaced towards the northeast during summer, with maximum positive anomalies in Scandinavia, and negative ones over the Arctic Ocean (Supplementary Material, Section C, Figures S2, S3 and S4). This shift might introduce differences with respect to the station-based NAO index.

Rephrased text 2: The results obtained with LMDZiso must be taken with caution, due to the fact that the simulated correlations are stronger than observed (Table S3, Figure 8a). The seasonal shift in the position of the centers of action of the NAO, which are displaced to the northeast during summer (Figure S2), can have an influence in the correlation patterns. This sensitivity to the position of the centers of action is assessed in Figures S3 and S4, showing the corresponding correlation patterns for the NAO indices defined as the leading PC of SLP in LMDZiso. In summer (Fig S3), this alternative NAO index produces significant correlations in Northern Europe not previously observed, and weaker values over Greenland, all these changes coherent with the new position of the SLP dipole.

Reviewer #2 :

General Comment:

The authors investigate the impact of precipitation intermittency on climate reconstruction such as the North Atlantic Oscillation (NAO). In particular, they analyze the stability of temporal correlations between the NAO and temperature fields showing that in some parts of the North Atlantic the intermittency plays a role by reducing the correlation.
Overall the manuscript is well written und clearly structured. The topic is certainly of interest for the paleo-climate community as it shows how model simulations and observations could be used to assess the ability of proxy archives to reconstruct climate variations (in this case the NAO). Therefore I recommend publication after a few minor revisions listed below. One major concern is that the authors are not precise with the seasonality of the phenomena NAO (comments 13, 30, 35, 37). This needs to be addressed in the revised version.

Response: The authors appreciate the thorough revision and the helpful detailed comments. All suggestions have been taken into account. A special effort has been put to strengthen the discussion on the leading mode for the SLP in summer (See responses to comments 13, 26, 30, 35). The full text of the review is reproduced below, with an answer following each comment. A pdf file highlighting changes (deletions/additions) to the previous version of the manuscript is also sent to the editorial office in order to facilitate a detailed screening of changes. Please note that following one suggestion of the third reviewer, we have reorganised the article, moving four figures (with their corresponding descriptions) from the Supplement to the main manuscript.

Specific comments:

1: P4958, L15-17: This is a rather long sentence which is hard to read. So I suggest clarifying it.
Response: The text has been rewritten.
Rephrased text: The correlations with water isotopes and their correspondence with those from true and precipitation weighted temperature are analysed using outputs of an atmospheric general circulation model enabled with stable isotopes and nudged to reanalyses (LMDZiso).

2: P4958, L23: This sentence is a bit awkward. – suggestion: “of precipitation for NAO reconstructions.”
Response: We agree that the initial sentence was misleading. It is the $\delta^{18}O$ (which is associated to precipitation in the simulations, and measured in ice cores in the reconstructions) that we propose as a good proxy for the NAO. The sentence has been rewritten.
Rephrased text: The correlations between NAO, δ18O in precipitation, temperature and precipitation weighted temperature are investigated using outputs of an atmospheric general circulation model enabled with stable isotopes and nudged to reanalyses (LMDZiso).

3: P4959, L1: Please include the publication of Wanner et al. (2001, Surv Geophys): “(e.g., Wanner et al. 2001; Hurrell et al. 2003).”

4: P4959, L17: I suggest to also include the publication Luterbacher et al. (2001, Atmospheric Science Letters), Casty et al (2007, Clim. Dyn) and Kuettel et al. (2010, Clim Dyn) to the list as the latter two show climate filed reconstructions of pressure with archives which are only pressure sensitive.

5: P4959, L22: The publications for the stalagmites are rather old, please include a new one, e.g., Fleitmann et al. (2009, GRL). Fleitmann, D., H. Cheng, S. Badertscher, R. L. Edwards, M. Mudelsee, O. M. Goektuerk, A. Fankhauser, R. Pickering, C. C. Raible, A. Matter, J. Kramers, O. Tueysuez, "Timing and climatic imprint of Dansgaard Oeschger events in stalagmites from Northern Turkey", Geophysical Research Letters, 36/L19707, 2009.

6: P4960, L5: Please include Raible et al. (2006, Clim Change) after teleconnections as they show the variability of teleconnection pattern in the North Atlantic.

7: P4960, L20: Please include Hangartner et al. (2012) for the tree ring cellulose. Hangartner, S., A. Kress, M. Saurer, D. Frank, M. Leuenberger, "Methods to merge overlapping tree–ring isotope series to generate multi–centennial chronologies", Chemical Geology, 294–295, 127-134, 2012

Response to # 3-7: All these publications have been added to the text.

8: P4961, L7: Replace “They showed” with “It was shown”.
Response: The text has been replaced.

9: P4961, L17: “assures a physical and dynamical consistency”.
Response: The change has been included in the text.

10: P4961, L18f: Recommend to reformulate the sentence in order to make it easier to understand: “however, the precipitation amounts calculated by the atmospheric models are prone to biases of the models themselves, despite the models being constrained by assimilation of several observational products.”
Response: It has been now reformulated.

11: P4961, L26: Replace ‘are’ with ‘is’.
Response: The verb was modified.

12: P4961, L27: Put ‘December-March’ in text and ‘DJFM’ in brackets. Same for JJAS.
Response: These changes have been done.

13: P4961, L27: This is maybe an important issue for the entire manuscript. In summer the dominant mode is not the NAO so the authors need to be clear about it. Later in the manuscript they use on the one hand a ‘station-based’ index to define the NAO. This is fine also for summer, but they also use an EOF analysis. The leading mode using EOFs is different in summer – sometimes it is called East Atlantic pattern. I think the authors need to discuss in the introduction that the leading mode in summer is not the NAO and they need to clarify this later also in the analysis part of the manuscript.
26: P4966, L24: As stated before the leading mode of SLP in summer is not the NAO!

30: P4969, L1-3: Again this is an issue with summer NAO definition. It is clear that the there are changes in the correlation structure as EOF 1 in summer is not the NAO whereas the station-based index resembles the NAO pattern. So the authors compare apples with oranges. This paragraph thus needs substantial changes.

35. P4974, L9-15: Again be clear about that the leading mode is not the NAO in summer.

Response: We understand that the discussion on the summer NAO was not sufficiently detailed in the initial manuscript, and maybe misleading. Because of that we have tried to improve the corresponding paragraph and have a more comprehensive discussion. However, we disagree with the objection that the leading mode for the SLP during the summer does not correspond with the NAO. Even if its structure is certainly different from that of the winter NAO, with a displacement of the centers of action to the northeast (Hurrell and Deser, 2010), this pattern is still widely referred as its summer counterpart. All the articles consulted, from the pioneering work by Barnston and Livezey (1987) on the main atmospheric circulation patterns, to subsequent analyses on the NAO (Hurrell and Van Loon 1997; Hurrell et al, 2003; Greatbatch and Rong, 2006, Hurrell and Deser, 2010), including also recent studies specifically devoted to the summer NAO (Folland et al, 2009; Bladé et al, 2012) support the leading role of the NAO throughout the whole year (see for example Fig 2 in Barnston and Livezey; 1987), despite the fact that during the summer the percentage of the total SLP variance explained by this pattern is substantially diminished. Furthermore, all our three datasets show a similar first EOF for summer SLP, characterised by two opposing centers of action, one over Scandinavia and a northern center over the Arctic, which is consistent with previous descriptions for the summer NAO (Barnston and Livezey, 1987; Hurrell and Van Loon 1997; Hurrell et al, 2003; Greatbatch and Rong, 2006; Folland et al, 2009; Bladé et al, 2012), and in contrast, differs from the two classic definitions for the East Atlantic Pattern. Indeed, for Wallace and Gutzler (1981) the EAP has three centers of action located near the Canary Islands, West of the British Isles, and over the Black Sea, while for Barnston and Livezey (1987) this pattern is defined by a strong Northewest-Southeast gradient from Western Europe to North Africa. This EAP is systematically calculated from geopotential heights, which could explain differences with respect to our SLP patterns. However, they underline that this EAP mode is mostly observed during winter. We are not aware of other alternative definitions for this index, nor of publications challenging the leading role of the NAO during the summer. Nevertheless, we acknowledge that this is mainly a terminology issue. The previous manuscript was missing some discussion on the definition of the summer NAO, and the related references. This has been added now to the new manuscript.

Rephrased text 1: The choice of an index based on pressure differences is questionable due to shifting positions of the NAO pressure centers of actions, both at the seasonal (Folland et al., 2009) and decadal scales (Raible et al., 2006;Pinto and Raible, 2012). An alternative definition of the NAO index is based on the first principal component of the sea level pressure field. Although during the summer both the variance explained and the amplitude of the NAO diminishes substantially relative to winter (Hurrell et al., 2003), this pattern is still captured as the leading mode of SLP in the North Atlantic, both in the reanalyses and most climate model simulations (Bladé et al., 2012). Note that the dipole structure is displaced towards the northeast during summer, with maximum positive anomalies in Scandinavia, and negative ones over the Arctic Ocean (Supplementary Material, Section C, Figures S2, S3 and S4). This shift might introduce differences with respect to the station-based NAO index.

Rephrased text 2: The results obtained with LMDZiso must be taken with caution, due to the fact that the simulated correlations are stronger than observed (Table S3, Figure 8a). The seasonal shift in the position of the centers of action of the NAO, which are displaced to the northeast during summer (Figure S2), can have an influence in the correlation patterns. This *sensitivity to the position of the centers of action is assessed in Figures S3 and S4, showing the corresponding correlation patterns for the NAO indices defined as the leading PC of SLP in LMDZiso. In summer (Fig S3), this alternative NAO index produces significant correlations in Northern Europe not previously observed, and weaker values over Greenland, all these changes coherent with the new position of the SLP dipole.*

14: P4962: Please be consistent in the use of 'half a degree' vs. '0.5 x 0.5'.
Response: We have revised the text to be always consistent. We now restrain to use "0.5 x 0.5"

15: P4962, L19: Please write "first, …"

16: P4963, L18: The authors could start the sentence with "To compare …"

Response to # 15-16: Both changes have been taken into account.

17: P4964, L1: I think it is not astonishing that there is a warm bias over Greenland, given that the models are coarsely resolved and the orography is lower. I suggest quantifying this effect.
Response: The effect of orography is clearly important to explain this warm bias. We have quantified the bias by comparing the climatology in LMDZ with that of the two reanalyses. Over Central Greenland, the difference in temperature corresponds to 2.6°C and 6.4°C as compared to CRU-NCEP and ERA-Interim datasets, respectively.
Rephrased text: However, its simulated winter precipitation δ18O is overestimated over central Greenland, associated to a warm temperature bias (2.6 and 6.4°C as compared respectively to CRU-NCEP and ERA-Interim; see Figure 1b), also observed in other isotopic general circulation models (Steen-Larsen et al., 2011). Note that indeed the model resolution is relatively coarse (i.e. 2.5° × 3.75° and 19 vertical levels) as compared to the two reanalysis datasets, which are thereby expected to better represent small-scale climatic features, especially those related to complex orography.

18: P4964, Ll5ff: Recommend reformulating to improve readability: "A subset of GNIP stations, for which summer and winter measurements are available for at least 10 years was extracted to evaluate the link to the NAO variability. This 10 years threshold yields a reasonable spatial coverage and allows for statistical analysis."
Response: The text has been changed accordingly.

19: P4964, L22: A figure which shows the geographical locations of the proxies might be helpful.
Response: Indeed, the particular locations of these GNIP stations are shown in Figure 8 (right column). The text now refers both to their corresponding Tables in the Supplementary Material, and the figure that illustrates their position.

20: P4965, L13: Please include 'means': "(6-hourly, daily or monthly means)".
21: P4965, L14: Please rearrange 'respectively': "[…] lon are the latitude and longitude, respectively; […]"
22: P4965, L25f: Please write "[…] identical when calculated from both 6-hourly and daily output […]"
23: P4966, L12: Please remove 'same'.
24: P4966, L13: Please replace 'for' with 'from'.

Response to #20-24 : All changes have been taken into account.

25: P4966, L24: Please include also the publication Raible et al. 2006, Clim Change.
Response: This reference was added

27: P4968, L13: I think Fig. S8 seems to be important, so that it could be included in the main text.
Response: This plot has been added to the main manuscript, and corresponds to Figure 4.

28: P4968, L21: "reanalyses"
Response: Corrected.

29: P4968, L28: I also suggest to include Fig S9 in the main text. Concerning the sensitivity to the centers of action, how is this assessed in the analysis?
Response: This plot has been added as well (New Figure 8b). The sensitivity to the centers of action was assessed by comparing the correlations for the station-based NAO indices, with those defined through EOF analysis (whose centers of action are placed at different locations than for the station-based indices). The paragraph has been improved to better illustrate this comparison.

Rephrased text: The results obtained with LMDZiso must be taken with caution, due to the fact that the simulated correlations are stronger than observed (Table S3, Figure 8a).
The seasonal shift in the position of the centers of action of the NAO, which are displaced to the northeast during summer (Figure S2), can have an influence in the correlation patterns. This sensitivity to the position of the centers of action is assessed in Figures S3 and S4, showing the corresponding correlation patterns for the NAO indices defined as the leading PC of SLP in LMDZiso. In summer (Fig S3), this alternative NAO index produces significant correlations in Northern Europe not previously observed, and weaker values over Greenland, all these changes coherent with the new position of the SLP dipole.

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31: P4971, L10f: Recommend to reformulate the sentence: "[…] datasets and during which the reanalyses systems are most strongly constrained by assimilated observations."
32: P4971, L24: Recommend to split up the sentence: "[…] conditions. However, the observational records […]"
33: P4972, L21f: Recommend to write: "[…] relationships provides an ideal test bed for searching for […]".
34. P4973, L27: Recommend to replace "and moreover" with "while at the same time".
Response to #31-34: All these changes have been taken into account.

36. P4975, L2: Recommend to write "Overall, the consistency […]" to more clearly detach this sentence from the previous one. Otherwise it sounds like you found "robust results" even though you "could not compare to direct observations".
Response: This suggestion has been implemented.

37: P4975, L23-25: Still the winter signal which is recorded in such records will be mixed with the summer signal, so how could this problem be handled? The authors need at least state that this could be a problem.
Response: The reviewer is right. This problem is now stated in the text.
Rephrased text : "Such processes could explain why, despite the probable presence of some summer climate signal, a link with the winter NAO is found in tree ring cellulose $\delta^{18}O$ *from*

Siberia, where data from Yakoutia appear in anti-phase with those from Taimyr, and in phase with the variability depicted in Greenland ice cores (Sidorova et al., 2010).

38. The following publications seem to be important for this publication:

a) "Yoshimori, M., C. C. Raible, T. F. Stocker, and M. Renold, 2006: On the interpretation of low-latitude hydrological proxy records based on Maunder Minimum AOGCM simulations, Clim. Dyn., 27,493-513": Although not directly linked to the North Atlantic, I think it is one of the first studies which show how models could be used to help in interpretation of moisture sensitive proxies. It also shows that the thermodynamic component in moisture sensitive proxies is important. This fits perfectly to this manuscript.
b) "Zorita, E., González-Rouco, F., 2002. Are temperature-sensitive proxies adequate for North Atlantic Oscillation reconstructions? Geophysical Research Letters 29": This is an important paper as it already postulates that precipitation sensitive proxies might be better suitable for NAO reconstructions. Please include this in the introduction and conclusions.

Response: Both articles are now cited at the end of the second paragraph in the introduction.
New text : The reliability of air temperature-sensitive and precipitation–sensitive proxies to reconstruct the NAO has been assessed and compared in a climate simulation for the last 490 years (Zorita and González-Rouco, 2002), suggesting that the precipitation proxies lead to more robust reconstructions. It should be noted, however, that proxy records dependent on hydrology are likely influenced both by dynamical and thermal changes (since specific humidity depends strongly on local temperature), as it was shown for Maunder Minimum simulations (Yoshimori et al., 2006). Such proxy records cannot therefore be interpreted exclusively in terms of past circulation changes.

39: Fig. 2: Please denote (a) and (b) at the panels and mention units at the colorscales. More important is that the color-scale of the lower 6 panels shows white for 0.5 to 1, but in the panels for the LMDZ model there is no white, but only green and red colors. This makes no sense.

Response: The color contours have been corrected and standardized in all the panels. Also, the labels for each panel, and the units of the colorbar have been included.

40. Fig4: The color-scale should be the same as in Fig. 3 to allow for better comparison. Also the dots in the right penal are nearly invisible, please clarify.

Response: The color-scale in Fig. 3 was white from -0.35 to 0.35 because correlation values in that range were never significant. In Fig. 4b we have represented data from the GNIP and Greenland stations, both characterised by longer timeseries, and therefore allowing the calculation of correlations with the NAO for a longer time period. These correlations, due to the increase in the degrees of freedom of the sample size, can be significant for lower correlation values. To be able to represent them in the plots, we have added two new color scales, one from -0.35 to -0.15, and another from 0.15 to 0.35. Note that in either case, the colors representing the other correlation ranges are still coherent with those in Fig. 3. Therefore, this change in the color scale does not really affect the comparison between figures and allows to convey additional information on the significant correlations observed in the longest records.

Technical comments:

- References all seem to appear in brackets, whether they are actively embedded in a sentence or not. Please distinguish.
Response: This problem came from the compilation with EndNote. We have made special attention to correct it this time.

- Recommend to put units next to color-bar in all figures; makes it easier to read.
Response: The units have been added to all color-bars.

- Please be consistent with the use of the word 'anti-correlation' vs. 'negative correlation' (e.g., p4968, 4973) and the term 'strong correlation' vs. 'large correlation' (I suggest to use 'strong correlation'); this should improve readability.
Response: We have revised the manuscript, now restraining ourselves to the use of 'negative correlation' and 'strong correlation' in each case.

- Along the same lines, please be consistent in the labeling of the datasets: 'CRUNCEP' vs. 'NCEPCRU' (text vs. figures)
Response: This inconsistency has been corrected. We have changed the labels in the figures, as CRU-NCEP is the original name for this dataset.

- Please refrain from using '…'; write 'andsoforth' or something similar.
Response: We have substituted accordingly the dots by "and so forth".

- Recommend to either consistently label figures with (a), (b), (c) andsoforth or not label them at all. I would prefer labelling and then also more often refer to the label in the text (such as 'see Fig. 2c') to make it easier for the reader to tie text and figures together.
Response: We have put special care to include the labels clearly in all figures.

Reviewer #3 :

General Comment:

This manuscript by M. Casado and colleagues examines the potential bias of precipitation intermittency on temperature reconstructions based on stable water isotope measurements. The authors use NCEP and ERA-interim reanalysis data as well as the output of the isotope-enabled LMDZiso model to determine precipitation-weighted summer and winter temperatures and delta O-18 signals for the Northern Hemisphere.
Compared to the standard non-weighting calculation, strong local temperature biases and large inter-annual variability are found. In a further step, the impact of precipitation intermittency on the correlation between NAO and surface temperatures is investigated. According to the authors' findings, precipitation-weighting reduces the correlation between temperature and NAO in many regions but does not alter the general spatial correlation patterns. With the chosen topic the authors address a very important problem of paleoclimate research, which is often overlooked in temperature reconstructions from the various archives. Thus, I rate the manuscript for highly valuable and support a publication in Climate of the Past, in general. However, in my opinion major revisions focusing on three different aspects are required before publication.
As I ask for a major text revision, I omit any list of minor corrections at this stage of the review process.

Response: The authors understand the main concerns of the reviewer and aim to address them in the revised manuscript. These three major aspects have been answered in detail in the corresponding response to each comment, which are reproduced below. We note now that, following the first suggestion, the manuscript has been restructured by moving four figures (with their corresponding descriptions) from the Supplement to the main manuscript. A pdf file highlighting main changes (deletions/addition) to the previous version of the manuscript is also sent to the editorial office in order to facilitate a detailed screening of changes.

Specific comments:

1: Restructuring of manuscript and supplement: The whole paper consists of a rather short manuscript, including 4 figures, and a rather lengthy supplement, including 9 more figures. From my understanding, any scientific paper should be fully understandable by its own, and a supplement should only add further information for part of the readership, interested to go into more detail. This is not the case with this manuscript. For example, the whole paragraph 3.2 (Impact of precipitation intermittency on JJAS NAO-temperature relationships) refers to figures (S5, S8, S9), which are just included in the supplement. Or, as a second example, a comparison of the different used climatologies is given in an inadequate extremely brief form in Supplement A, only. But such a comparison is highly critical for the paper, as all following analyses are most likely also affected by the shown differences between the chosen NCEP, ERA and LMDZiso data sets. Thus, such comparison should be moved to the main text and explain in much more detail common basic features and key differences among the three data sets.
Response: The article was first conceived to have the size of a short communication. This has undoubtedly biased the final distribution of results, and explains why the supplementary material is somewhat unbalanced with respect to the main manuscript. For the new version, we have restructured the figures, and enhanced the discussion in the sections where figures

from the previous Supplement have been included. In the current arrangement, the ratio between the number of figures in the manuscript and the Supplement has been inversed, with 8 and 5 figures in each case. As a result of these new inclusions, two new sections appear in the main text, corresponding to the description and comparison of the different climatologies in the three datasets (section 2.4), and to the analysis of temporal stability in the correlation patterns (section 3.5). Both sections have been directly moved from the supplementary material, and their corresponding discussion extended and improved to provide, respectively, a better account of the robustness and main discrepancies between the climatologies (section 2.4) and NAO-relationships through time (section 3.5).

Rephrased text: (2.4 Climatologies)

Figure 1 displays the climatologies of CRU-NCEP (1990-2010), ERA-Interim (1990-2010) and LMDZiso (1979-2008) for summer (JJAS) and winter (DJFM). Summer temperatures (Figure 1a) show a general good agreement among the 3 datasets. As compared to the reanalyses, LMDZiso exhibits a cold bias, most obvious in regions of steep orography such as the Tibetan Plateau, and also at high latitudes (e.g. Northern Russia, Alaska and Nunavut). For winter temperature (Figure 1b), the different datasets are also very coherent. An opposite bias is observed for LMDZiso with respect to the reanalyses, with comparatively higher temperatures around Greenland and Northern Yakutia. In these areas, significant discrepancies are found between ERA-interim and CRU-NCEP.
The climatologies of precipitation (Figure 1c,d) reveal larger differences among the three datasets. Despite the large differences in resolution, the largest degree of agreement, both for summer and winter, occurs between LMDZ-iso and ERA-Interim. This points to a secondary role of orography as compared to the representation of large-scale dynamics which is forced to be consistent through the nudging technique. The three datasets share common robust features, such as the distribution of summer precipitation across the Mediterranean basin, Northern Europe, Southern and Central Asia, the United States and Southern Greenland, as well as the representation of winter precipitation in the coastal areas of Europe, North America (at midlatitudes) and Southeast Greenland. The largest discrepancies again appear at high latitudes, in regions such as Western Russia and Northern Greenland.

Rephrased text: (3.5 Temporal stability of correlations)

In the previous sections, analyses were focused on the most recent period (1990-2010), where there is an overlap between our different datasets and during which the reanalyses systems are most strongly constrained by assimilated observations. We are aware that this time interval is characterised by high DJFM NAO levels in the early 1990s. Figures 6 and 7 investigate respectively the stability of summer and winter NAO-climate (temperature, precipitation, and precipitation-weighted temperature) relationships throughout different time periods. Three bi-decadal intervals have been compared: 1990-2010 (previously chosen for comparison with ERA-interim), and the new periods 1970-1990 and 1950 – 1970. This latter period is characterised by a weak negative NAO mean state, while the other two show strong positive mean NAO values.
The summer is characterised by small and unstable NAO-climate relationships, as illustrated in Figure 6 and also found by Vinther et al. (2010). Both the location and sign of correlation coefficients appear to vary through our three time intervals, despite being associated to rather similar mean summer NAO values. This difficulty to identify robust features in the

three periods points to shifts in the location of the summer NAO centers of action, associated to reported changes in the North Atlantic summer mean circulation (Hurrell and Folland, 2002).

In winter, the correlation patterns with the NAO are clearly more robust (Figure 7), although still subject to some spatial changes. For precipitation (Figure 7a), only the negative correlations in the Western Mediterranean region remain stable, while positive values over Scandinavia and Western Russia appear for the last two periods, both characterised by a positive mean NAO state. The correlation patterns for temperature (Figure 7b) show most robust features through time, with persistent positive values in Eastern North America, Northern Europe and negative ones around the Labrador Sea, North Africa and the Middle East. Note that again, some correlations become insignificant only during the first time interval, in this case over Eastern Greenland and Siberia. Finally, a similar picture holds for the precipitation-weighted temperatures (Figure 7c), the main difference being that the magnitude of correlations is generally smaller than for temperature, and also more affected by local conditions, which is normal given the weighting effect of precipitation. We note that the quality of the reanalysis might be weaker for the first period (1950-1970), prior to the satellite data assimilation. It is also possible that, during this period, the negative NAO-pattern has an influence over the NAO-climate relationship that would make it differ from the most recent periods, characterised by a positive NAO-pattern.

2: Rewording of presented results: For many statements, I rate the authors' description of the presented results as too short and sometimes also too positive. Again, I give two examples: (i) In paragraph 3.1, the authors state in the last sentence: "The inter-annual standard deviation of the summer bias (Fig. 2b) remains smaller than for winter, with the exception of LMDZiso which produces both a large and variable bias around the Mediterranean area and Central Russia." But looking at Fig. 2b, larger inter-annual standard deviation can also be detected for Western Europe and large parts of the United States. In fact, from Fig. 2b it is not clear to me, if not the total area in LMDZiso showing a high inter-annual bias is larger for summer than for winter. (ii) In paragraph 3.5, second text block, the authors write: "First, the LMDZiso model results are described (Fig. 3). The model results clearly show the same pattern of winter NAO correlation with Tp and d18O, with negative correlations over parts of Greenland and NW America (Québec area), and positive correlations in Northern Eurasia." Here, the authors omit that the negative correlations over Greenland clearly differ in region between Tp and d18O. The extent of positive correlation over Northern Eurasia between Tp and d18O is also substantially different in Fig. 3. I could give several more examples of such inaccurate and selective description of the presented figures and strongly suggest that the authors are more precise and exhaustive with their result descriptions in a revised manuscript.

Response: We understand that our initial descriptions may have not been sufficiently comprehensive, and maybe biased to highlight the agreements at the expense of the disagreements. This was probably unconsciously motivated by the number of variables (precipitation, temperature, precipitation weighted temperature, d18O isotopes), datasets (LMDZ-iso, ERA-interim, CRU-NCEP, GNIP stations) and even time intervals (1950-1970, 1970-1990, 1990-2010) included in the analysis, for which too detailed descriptions could compromise the fluidity of the text. We have now reworked the manuscript trying to provide more exhaustive and balanced accounts of the different results (see for instance the two new sections introduced following the suggestion in Comment #1). Regarding the first example stated above (i), the discussion has been fully rewritten, now not directly comparing the summer and winter values, but emphasizing in each case which are the regions showing larger inter-annual changes in the bias. Likewise for (ii), the text has been also changed in the description of previous Figure 3 (corresponding to Fig 5 in the new manuscript).

Rephrased text (i): By computing its inter-annual standard deviation (Figure 3b), we can identify the regions where the temperature bias is more variable, and therefore where precipitation weighting is more sensitive to internal climate variability. During summer, the regions with the largest standard deviations are confined to the Pacific Coast of the United States, the Mediterranean Basin and Central Asia. This is observed in the three datasets, although with higher values in LMDZiso. Less coherent results are obtained for the winter season, when the areas with largest standard deviations vary from one dataset to another. Despite these discrepancies, large standard deviations are depicted for Northern North America (including Greenland), and Northern Asia, as well as North Africa – India (for ERA-Interim and LMDZiso). LMDZiso also produces large standard deviations near Baffin Island.

Rephrased text (ii): First, the LMDZiso model results are described (Figure 5). Overall, the spatial features of the correlation patterns between the winter NAO and both Tp and δ18O are rather coherent (Figure 5c,d), with negative correlations values over parts of Greenland and NW America (Québec area), and positive values in Northern Eurasia. However, there are clear differences regarding the actual locations for the significant values (>0.35) over Greenland, as they occur near the eastern coast for Tp and more in the western side for δ18O, which is more consistent with the correlation pattern for precipitation. In Eurasia, the extent and the strength of the significant correlations are smaller in δ18O than in Tp, suggesting that other processes (e.g. changes in moisture sources, changes between condensation and surface temperature) act to reduce the imprint of NAO in δ18O. This supports the idea that the investigation of the NAO- Tp relationships provides an ideal test bed for investigating NAO- δ18O relationships.

3: More detailed explanations: At several occasions, the authors simply describe the detected differences in their results but do not propose any scientific sound explanation for their findings. This leaves the reader with uncertainness about the relevance of the presented results. Once again, two examples: (i) In paragraph 3.3 it is written "Surprisingly, LMDZiso produces a precipitation intermittency bias that is more similar to the magnitude derived from NCEP data, while its mean climate is closer to that of ERA-interim." This is a very interesting finding, but how can this be explained, given the fact that LMDZiso was nudged to ERA-fields. Is the nudging not strong enough for influencing precipitation timing in LMDZiso? And/or are the precipitation schemes in NCEP and LMDZiso more alike that the one used for ERA reanalyses? (ii) In the conclusions, the authors state "From existing isotopic datasets, LMDZiso seems to overestimate the strength of the summer NAO imprint on Greenland water stable isotopes, possibly due to the isotopic composition changes associated with different air mass origins." Why do the authors rate a mixing of different air masses as the most likely cause of the overestimated NAO signal on Greenland in LMDZiso? Isn't such mixing of air masses included in LMDZiso, and should the model not yield most realistic results if run in nudged mode? Could any other reason cause this bias, too? And could one perform further analyses (if so, which ones?) to determine the reason for this model deficit? Once again, I could give several more examples of such limited explanations and advise the authors to go one step further in their scientific analyses.

Response: We have also put special effort to provide possible explanations to give further support to our main results. In the particular case of the first example (i), we agree that this finding might imply a rather different timing and localization of precipitation for LMDZ-iso as compared to the original reanalysis data. This is not surprising as both the orography, and the key parameterisations for precipitation are different in the LMDZ-iso model. We now also put this result in the context of the different climatologies in Figure 1, which show some important differences in the regions where LMDZiso seems to underestimate the bias. Regarding the statement in the conclusions (ii), we now provide a different explanation. As the magnitude of these correlations changes considerably depending on summer NAO index definitions, we believe now that the differences are mostly related to the actual positions in the centers of action of the NAO. Also, the summer EOF pattern for LMDZ-iso (Fig S2) shows a local SLP minimum over Greenland, not seen for ERA-interim, nor for CRU-NCEP.

Rephrased text (i): Surprisingly, LMDZiso produces a precipitation intermittency bias that is more similar to the magnitude derived from NCEP data, while its mean climate is closer to that of ERA-Interim. This might indicate that the nudging in LMDZiso is not strong enough to reproduce the timing and/or location of precipitation as in the original reanalysis, or that the results are dominated by the large temperature biases of LMDZiso at high latitudes (Figure 1).

Rephrased text (ii): From existing isotopic datasets, LMDZiso seems to overestimate the strength of the summer NAO imprint on Greenland water stable isotopes, although it might be just an artefact of the particular choice for the NAO index. Indeed, the alternative definition as the leading PC for North Atlantic SLP (Figure S3), which is more faithful to the actual position of the centers of action during the summer, shows a drastic decrease in the amplitude of these Greenland correlations. We therefore remain extremely cautious about reconstructions of summer NAO using precipitation-sensitive archives.