Referee comments – RC1 – on 'Comment on egusphere-2026-414'

Anonymous Referee - https://doi.org/10.5194/egusphere-2026-414-RC1

Referee comments by RC1 in black

Author comments (AC) in purple

Summary: The manuscript presents the analysis of several types of geobiochemically derived proxy data extracted from a lacustrine record in Morocco spanning the Holocene. The proxies are mostly believed to represent broad hydroclimatological conditions in the region. The proxies are grouped into three categories based on their cross-correlation. The time series is subject to a spectral analysis to identify the main periodicities. These periodicities are interpreted, mostly heuristically, as driven by large-scale hydroclimatic conditions or by more local lacustrine processes.

Recommendation: This careful and comprehensive analysis is well reflected in the manuscript, and it is also compared to other records from this region. I have a few suggestions, mostly concerning the statistical analysis, that the authors may want to consider

Thank you very much for reviewing our study and for the overall positive evaluation.

1) The grouping of the proxies seems a bit simplistic: just subjectively grouped by their cross-correlations. A more objective grouping could be achieved simply by principal component analysis. This would have the additional advantage of providing a single time series for each component that could then be compared to a series of reconstructed solar activity, for instance. (see point 2)

Thank you very much for your comment. The grouping of proxies was based on cross-correlations of their spectral properties within the frequency domain.

A principal component analysis (PCA) combines the input variables linearly within the component scores. This can modify the original spectral signal and may strengthen, weaken, or artificially introduce periodicities (Gallant et al., 2018). Therefore, we aimed to conduct the time-series statistics, as far as possible, using the original ("raw") proxy data rather than transformed component scores. For this reason, the proxy grouping was primarily carried out on the basis of their spectral characteristics.

Nevertheless, we additionally performed a PCA in the frequency domain (PCA_{freq}) to evaluate the robustness of the grouping approach. The PCA results independently confirm the proxy groups identified by the correlation matrix shown in Fig. 2D. The corresponding PCA results (biplot with loadings) are now provided in the Supplementary Materials (Supplementary Figure 8). We further added a new subchapter in the material and methods section, that explains and describes our PCA analyses (3.3.2).

For the comment regarding the use of principal components for spectral analyses, please also see our response to point 2.

2) The physical interpretation is essentially heuristic. The authors visually identify the more important spectral ranges, thereby attributing those variations to known forcings that exhibit similar spectral ranges. Whereas this is common in this type of study, this approach seems a bit superficial, as a common spectral band is a necessary but not sufficient condition: also, the phase of the variations is important for attributing them to, say, solar forcing.

Calculating the PCA components would simplify that comparison. Figure 4 attempts this type of attribution by visually identifying the maxima and minima of the individual time series, but this Figure also illustrates that a confirmation bias is dangerously possible. One can always find maxima or minima that, to some extent, agree.

In this case, to claim the identification of solar forcing, the series of one of the PCs should closely agree with the reconstruction of solar activity of Usoskin et al. 2016 (their figure 3c). Such an agreement would be a much more robust confirmation.

It was important for us to retain the analyses as long as possible within the original/raw-data domain and to calculate the spectral properties directly from these proxy records. A PCA can be a useful approach for reducing the dimensionality of XRF elemental datasets (Evans et al. 2019, Bertrand et al. 2024). The use of PCA scores from the dominant principal components for spectral analyses has occasionally been applied in previous studies (Gebregiorgis et al. 2020, Ferreira et al. 2025), however, this procedure mixes the original proxy signals and may alter their spectral characteristics. For example, phase shifts in the original proxy data may lead to distortions in the resulting principal components.

Nevertheless, we performed a PCA on the proxy dataset (PCA_{time}) and additionally used the scores of the first three principal components for the Redfit and wavelet analyses. For this purpose, we applied the same methodological workflow as used for the XRF data in the main manuscript. Both the PCA results and the corresponding Redfit and wavelet analyses have been included in the Supplementary Material (Supplementary Figures 7-9).

However, the grouping of the elemental proxies differs between the PCA-based approaches and the original Redfit Proxy Groups (RPGs). We interpret this discrepancy as a consequence of the linear mixing inherent to PCA ordination. PCA combines the original proxy signals within orthogonal component scores, which may alter their original spectral characteristics and potentially strengthen, weaken or distort periodicities (Gallant et al., 2018). In particular, phase shifts between cyclic proxy signals are not preserved explicitly within the resulting principal components. We therefore decided to retain the RPG concept based directly on the spectral properties of the original (“raw”) proxy records, as this approach preserves the individual frequency behaviour of the proxies more directly. We added a short discussion chapter in the supplementary materials (Chapter S5).

A more detailed methodological evaluation of the interaction between ordination techniques and spectral analyses in palaeoclimate time series would certainly be highly valuable. However, we consider such a dedicated methodological investigation to be beyond the scope of the present manuscript. Nevertheless, we hope that the additional PCA analyses included in the Supplementary Material may stimulate further discussion about the combined use of ordination methods and spectral analyses in palaeoenvironmental research.

Particular points

3) ' Further, Sha et al. (2019) presented a speleothem record from the SW High Atlas Mountains, that seems not to be influenced by Atlantic air masses but rather tropical-monsoonal air masses'

The use of commas to introduce subordinate clauses is sometimes incorrect throughout the manuscript, but this is an example that impacts the meaning. With the comma, the sentence indicates that the Atlas Mountains are not influenced by the Atlantic air masses. Without the comma, it is the record that is not influenced by the Atlantic air masses. I guess the authors meant the latter case, so the comma should be deleted.

Thank you very much. We have checked the entire manuscript for correct punctuation and revised the manuscript accordingly.

4) 'Currently, the lake is seprated '

Separated

Thanks. Corrected.

5) 'The red noise background is sensitive to the specific persistence of the data and therefore higher frequencies are often covered by the red noise'

I cannot understand what this sentence would mean. Perhaps they mean that the existence of red noise in a time series blurs the high-frequency variations?

But red noise is not a 'background', it is a property of the time series. Whether or not high frequency variations are blurred or not depends on the relative spectral energy in their respective bands

Thanks. We have deleted the sentence.

6) We used the most conservative critical false alarm level (Schulz and Mudelsee, 2002)'

I guess the authors mean that they used the most conservative choice offered by the software. The most conservative option possible is always that no peaks is considered significant.

We used the critical false alarm level, that is determined by the properties of the data and therefore may be more conservative than commonly selected thresholds of 90, 95 or even 99 % confidence. We revised the sentence accordingly.

7) ' Zielhofer et al. (2017a) argued for the Sidi Ali record, that..'

Delete comma

Corrected.

8) 'The latter is in accordance to the 1 ky periodicity of the hydroclimatic δ18O signal '

in accordance with

Thanks. Corrected.

9) 'Stewart et al. (2017) presented a Bromine record from a peat bog in Scotland, which shows a distinct 2 ky cycle pattern'

... Scotland that shows a .....

Again, delete the comma. I guess that Scotland does not present a 2 k cycle pattern.

😉 Correct. Thanks. We have checked and corrected the punctation of the entire manuscript.

Referee comments – RC2 – on 'Comment on egusphere-2026-414'

Anonymous Referee - https://doi.org/10.5194/egusphere-2026-414-RC2

Referee comments by RC2 in black

Author comments (AC) in purple

This is an interesting and potentially valuable study from Schmidt et al and I am confident that it would make a great addition to Climate of the Past. The manuscript applies an innovative frequency-domain approach to high-resolution lacustrine geochemical data from an underrepresented palaeoclimatic region, and the attempt to group XRF proxies based on shared spectral behaviour is original and promising. The Lake Sidi Ali record has clear potential to contribute meaningfully to discussions of Holocene hydroclimatic variability in northwest Africa. I really enjoyed reading this manuscript and learnt a lot about the methodology.

Thank you very much for reviewing our study and for the overall positive evaluation.

Comments:

The abstract is detailed and methodologically informative, which I appreciate. However, the main scientific findings and their broader significance could be communicated more clearly. The key conclusions are present, but they appear rather late and are somewhat overshadowed by methodological detail. I suggest ending with one or two more direct sentences that state the principal findings and why they matter for clarity.

Thanks. We adjusted the abstract based on your comment and added information about further analyses we did during the review process.

The statement of aims is slightly inconsistent in structure. The manuscript first presents aims (i)-(iii), then follows with an additional summarising aim introduced differently. It would read more clearly either to frame (i)-(iii) explicitly as objectives and have the final sentence as the overarching aim, or to keep all aims in the same format.

Thanks. Very good point. We have framed the specific “aims” as objectives complemented by the overarching aim.

Line 97 - “with individual trees exceeding 800 years in age” may read more smoothly than “trees reaching up to more than 800 years”.

Thanks. Corrected.

Table 1- Because the temporal resolutions are given as approximate values throughout, it may be clearer to title the relevant column “Approximate temporal resolution” rather than repeating an approximation symbol in each cell.

Thanks. Corrected. It reads better this way.

Figure 2 is a helpful conceptual illustration. However, the label “significant spectrum” in panel C is difficult to read at page size. Please consider improving legibility, for example through font size, or revised labelling.

We have revised the figure and the label. Thanks.

Please justify more clearly why a third-order polynomial regression was selected for detrending. Polynomial detrending can remove genuine low-frequency climate variability as well as edge effects, so it would be useful to explain why this choice is appropriate here, or ideally to show that the principal spectral results are not overly sensitive to the detrending method.

Cubic polynomial regression detrending is common in palaeoclimatic time series detrending. For example, Zielhofer et al. (2017a), who also worked at the Holocene sediment sequence of Lake Sidi Ali, chose a cubic polynomial fit (and many studies more). A linear or quadratic fit may be too restrictive, whereas a cubic term allows inflection points and better represents smooth, low-frequency structure without overfitting. Higher-order polynomials can begin to fit higher-frequency variability, which are our signals of interest in the periodicity analysis. A cubic polynomial is, therefore, a pragmatic upper limit that removes only the broadest trend component.

Concerning edge effects: A (windowed) LOESS-based detrending (span = 0.75) was also tested exemplarily to evaluate edge effect sensitivity to the detrending method. Of course, it introduces its own bias in edge asymmetry. Nevertheless, the resulting spectra are consistent with those obtained using a third-order polynomial, indicating that the identified spectral features are not an artifact of the detrending approach. We therefore revised and expanded the methodological description in order to present the workflow more transparently and clearly, allowing the robustness and limitations of the approach to be more easily assessed by the reader.

We added the following sentence: “The order of the model was chosen to ensure that variability with periods longer than approximately half the length of the record is removed prior to spectral analysis.”

Grouping proxies based on correlations among significant Redfit spectra is innovative, but the robustness and limitations of this procedure deserve further discussion. For example, how sensitive are the groups to the chosen significance threshold, detrending approach, interpolation method, or age uncertainty? A short sensitivity analysis, or at least a fuller discussion, would strengthen confidence in the grouped interpretations.

Thanks for the important comment. Of course, limitation and robustness are important to strengthen the main interpretations. We therefore expanded Section 5.1 and clarified that the RPGs should be interpreted as groups of proxies with coherent spectral behaviour rather than as direct process classifications. We further discuss the influence of the conservative AR(1) significance threshold, detrending and interpolation procedures, as well as chronological uncertainties. In particular, we emphasize that the Redfit-based grouping itself is independent of interpolation, because the Redfit analyses were conducted on the unevenly spaced original datasets.

Additionally, to further evaluate the robustness of the identified periodicity structures, we conducted supplementary PCA analyses on both the original proxy dataset (PCA_{time}) and the extracted spectral information (PCA_{freq}). The first principal components (PCA_{time}) show periodicity patterns comparable to those obtained from the original proxy records. These additional analyses, now included in the Supplementary Materials (Supplementary Figures 7-9), support the robustness of the identified millennial-scale spectral structures.

The manuscript would benefit from a clearer explanation, earlier in the paper, of why these particular elements and element ratios were selected and what process hypotheses they are expected to represent at Lake Sidi Ali. While the later discussion develops these interpretations, readers would benefit from more guidance before reaching that section. I would agree with Reviewer 1 and suggest that a PCA could be used here as I have no doubt that the chosen elements are grouped together, but visually it would be good to see. Perhaps this could go into the supplementary information if not needed in the main manuscript.

There is no straightforward or universal interpretation of XRF elemental data in lacustrine systems (Davies et al., 2015). Individual elements may reflect different lake-internal or catchment-related processes depending on the specific limnological, geological and hydroclimatic setting of the study site. Therefore, a central aim of this manuscript is not to rely solely on “standard” interpretations of individual elements or elemental ratios, but rather to evaluate their behaviour within the spectral domain.

We used a wide set (based on Davies et al. (2015) and Cohen (2003)) of XRF-derived elements and elemental ratios (without directly referring to their interpretation). By analysing the spectral signatures of the XRF proxies and their cross-correlations, we identified two major groups of proxies showing coherent periodicity patterns. Subsequently, we integrated independent and more established environmental proxies from the same sediment core, including *Cedrus* pollen abundance and ostracod-shell $\delta^{18}O$ values, in order to constrain the environmental interpretation of these frequency-based proxy groups. Combining the spectral characteristics with these independent palaeoenvironmental indicators allowed us to distinguish between two dominant process domains: (i) hydroclimatic and lake-level variability, and (ii) catchment-erosion processes.

It was important for us to retain the analyses as long as possible within the original/raw-data domain and to calculate the spectral properties directly from these proxy records. A PCA can be a useful approach for reducing the dimensionality of XRF elemental datasets (Evans et al. 2019; Bertrand et al. 2024). The use of PCA scores from the dominant principal components for spectral analyses has occasionally been applied in previous studies (Gebregiorgis et al. 2020; Ferreira et al. 2025), however, this procedure mixes the original proxy signals and may alter their spectral characteristics. For example, phase shifts in the original proxy data may lead to distortions in the resulting principal components.

Nevertheless, we performed a PCA on the proxy dataset (PCA_{time}) and additionally used the scores of the first three principal components for the Redfit and wavelet analyses. For this purpose, we applied the same methodological workflow as used for the XRF data in the main manuscript. Both the PCA results and the corresponding Redfit and wavelet analyses have been included in the Supplementary Materials (Supplementary Figures 7-9).

However, the grouping of the elemental proxies differs between the PCA-based approaches and the original Redfit Proxy Groups (RPGs). We interpret this discrepancy as a consequence of the linear mixing inherent to PCA ordination. PCA combines the original proxy signals within orthogonal component scores, which may alter their original spectral characteristics and potentially strengthen, weaken or distort periodicities (Gallant et al., 2018). In particular, phase shifts between cyclic proxy signals are not preserved explicitly within the resulting principal components. We therefore decided to retain the RPG concept based directly on the spectral properties of the original (“raw”) proxy records, as this approach preserves the individual frequency behaviour of the proxies more directly. We added a short discussion chapter in the Supplementary Materials (Chapter S5).

A more detailed methodological evaluation of the interaction between ordination techniques and spectral analyses in palaeoclimate time series would certainly be highly valuable. However, we consider such a dedicated methodological investigation to be beyond the scope of the present manuscript. Nevertheless, we hope that the additional PCA analyses included in the Supplementary Material may stimulate further discussion about the combined use of ordination methods and spectral analyses in palaeoenvironmental research.

Additionally, we performed a PCA in the frequency domain (PCA_{freq}) to evaluate the robustness of the grouping approach. The PCA results independently confirm the proxy groups identified by the correlation matrix shown in Fig. 2D. The corresponding PCA results (biplot with loadings) are now provided in the Supplementary Materials (Supplementary Figure 8).

We further added a new subchapter in the material and methods section, that explains and describes our PCA analyses (3.3.2).

Figure 5 presents an interesting summary of proxy evolution through time, but I found it difficult to extract the main message. If the figure is retained in its current form, I suggest adding annotations or a clearer explanation in the caption and main text to direct readers toward the major patterns and take-home points.

Thank you for this comment. We agree that the previous version of Fig. 5 was not sufficiently clear. We hope that the revised figure and caption now provides a clearer overview of the major hydroclimatic and catchment-related trend changes throughout the Holocene.

More generally, I encourage the authors to distinguish carefully between proxies that show similar frequency behaviour and proxies that can be confidently interpreted as reflecting the same environmental process. The grouping is compelling, but the mechanistic interpretation remains an inference and should be framed as such.

Thank you for this important comment. We agree that a clearer distinction between coherent spectral behaviour and environmental process interpretation is necessary. We therefore added a short paragraph at the beginning of the Discussion section (Section 5.3) to explicitly clarify that the environmental interpretation of the RPGs is based on the integration of the XRF-derived frequency analyses with independent palaeoenvironmental proxies and established process understanding.

In addition, we carefully revised the manuscript throughout and reformulated several interpretations more cautiously in order to better distinguish between statistical proxy coherence and inferred environmental mechanisms.

The manuscript usefully notes that age uncertainty constrains the robustness of shorter periodicities and that comparisons with lower-resolution non-XRF proxies are partly visual. These caveats are important and could be made more visible where the shorter-period features and cross-proxy comparisons are discussed in the Results and Discussion.

We expanded Section 5.1 regarding the robustness and sensitivity of the frequency analyses, and the associated caveats should now be more clearly visible throughout the manuscript. In addition, we included several short notes within the interpretation sections of the individual proxy groups to explicitly highlight the need for caution when interpreting shorter periodicities and cross-proxy similarities.

Furthermore, the robustness assessment following Hatvani et al. (2022) indicates that periodicities with cycle lengths of approximately ≥300 years can be interpreted robustly within the constraints of the chronology and temporal resolution of the record. Consequently, shorter periodicities were not used as a basis for the main palaeoenvironmental interpretations presented in the manuscript.

You change between hydro-climatic and hydroclimatic. I believe either is fine, but best be consistent throughout.

Thanks. We changed all instances of the term to "hydroclimatic".

Referee comments – RC3 – on 'Comment on egusphere-2026-414'

Anonymous Referee - https://doi.org/10.5194/egusphere-2026-414-RC3

Referee comments by RC3 in black

Author comments (AC) in purple

Paper summary

This paper presents an interesting interpretation and summary of a multiproxy dataset from Lake Sidi Ali in Morocco. It identifies recurring periodicities across multiple proxies that may reflect hydrological and climatic variability throughout the Holocene. The results suggest that lake and catchment processes may respond to a combination of external climate forcing dynamics (primarily solar cyclicity) operating at multi-centennial to multi-millennial timescales.

Whilst this paper represents a potentially valuable addition to the journal, there are a number of key weaknesses, particularly in the proxy analysis that require strengthening. These are outlined below.

Thank you very much for reviewing our study and for the overall positive evaluation.

Major Comments

1. Interpretation and presentation of XRF data

A more detailed and earlier description of the XRF dataset in the results is essential. At present, the manuscript lacks:

A substantive section describing what the measured elements represent in terms of lake and catchment processes.

Identification and discussion of key trends within the XRF data and a critical assessment of how the associated lake processes reflect hydroclimatic signals.

A strong rationale for selecting elements and log ratios into the RPGs.

Currently, the only summary provided is a covariance matrix in Figure 2d, which is insufficient for understanding the controls on these geochemical signals. Strengthening the interpretation of the XRF data in the context of lake processes is fundamental for supporting the broader process discussion presented in Section 5.4.

There is no straightforward or universal interpretation of XRF elemental data in lacustrine systems (Davies et al., 2015). Individual elements may reflect different lake-internal or catchment-related processes depending on the specific limnological, geological and hydroclimatic setting of the study site. Therefore, a central aim of this manuscript is not to rely solely on "standard" interpretations of individual elements or elemental ratios, but rather to evaluate their behaviour within the spectral domain.

We used a wide set (based on Davies et al. 2015 and Cohen 2003) of XRF-derived elements and elemental ratios (without directly referring to their interpretation). By analysing the spectral signatures of the XRF proxies and their cross-correlations, we identified two major groups of proxies showing coherent periodicity patterns. Subsequently, we integrated independent and more established environmental proxies from the same sediment core, including *Cedrus* pollen abundance and ostracod-shell δ18O values, in order to constrain the environmental interpretation of these frequency-based proxy groups. Combining the spectral characteristics with these independent palaeoenvironmental indicators allowed us to distinguish between two dominant process domains: (i) hydroclimatic and lake-level variability, and (ii) catchment erosion processes.

To further evaluate the robustness of the identified proxy groupings, we additionally conducted PCA analyses of the XRF proxy dataset (Supplementary Figures 7+8).

2. Need for multivariate analyses (e.g., PCA)

I agree entirely with the comments from Reviewers 1 and 2 that it is unclear why multivariate statistical approaches particularly PCA were not employed to reduce the dimensionality of the XRF dataset and to objectively identify the major sources of variance. Given the complexity of the dataset, a PCA would simplify and clarify the geochemical dataset upon which the paper heavily relies.

It was important for us to retain the analyses as long as possible within the original/raw-data domain and to calculate the spectral properties directly from these proxy records. A PCA can be a useful approach for reducing the dimensionality of XRF elemental datasets (Evans et al. 2019, Bertrand et al. 2024). The use of PCA scores from the dominant principal components for spectral analyses has occasionally been applied in previous studies (Gebregiorgis et al. 2020, Ferreira et al. 2025), however, this procedure mixes the original proxy signals and may alter their spectral characteristics. For example, phase shifts in the original proxy data may lead to distortions in the resulting principal components.

Nevertheless, we performed a PCA on the proxy dataset (PCA_{time}) and additionally used the scores of the first three principal components for the Redfit and wavelet analyses. For this purpose, we applied the same methodological workflow as used for the XRF data in the main manuscript. Both the PCA results and the corresponding Redfit and wavelet analyses have been included in the Supplementary Material (Supplementary Figures 7-9).

However, the grouping of the elemental proxies differs between the PCA-based approaches and the original Redfit Proxy Groups (RPGs). We interpret this discrepancy as a consequence of the linear mixing inherent to PCA ordination. PCA combines the original proxy signals within orthogonal component scores, which may alter their original spectral characteristics and potentially strengthen, weaken or distort periodicities (Gallant et al., 2018). In particular, phase shifts between cyclic proxy signals are not preserved explicitly within the resulting principal components. We therefore decided to retain the RPG concept based directly on the spectral properties of the original ("raw") proxy records, as this approach preserves the individual frequency behaviour of the proxies more directly. We added small discussion chapter in the supplementary materials (Chapter S5).

A more detailed methodological evaluation of the interaction between ordination techniques and spectral analyses in palaeoclimate time series would certainly be highly valuable. However, we consider such a dedicated methodological investigation to be beyond the scope of the present manuscript. Nevertheless, we hope that the additional PCA analyses included in the Supplementary Material may stimulate further discussion about the combined use of ordination methods and spectral analyses in palaeoenvironmental research.

3. Interpretation of redox-related signals (section 5.4.3)

Redox-sensitive elements can be influenced by multiple processes, such as lake circulation and eutrophication, in addition to hydroclimatic forcing. The manuscript does not sufficiently demonstrate that the observed redox trends are primarily climate-driven. A multivariate analysis would again be valuable to determine the relative importance of different redox-sensitive elements to the dataset variability.

Redox-sensitivity (Mn and Fe) is discussed carefully in Section 5.4.3. Our results indicate that Fe is not exclusively controlled by redox-related processes, but is also influenced by the same mechanisms that govern erosional dynamics and the input of detrital mineral material into the lake. In contrast, Mn and the Fe/Mn ratio show a distinctly different behaviour and frequency pattern, suggesting the influence of an additional process domain, which we cautiously interpret as being related to redox-sensitive lake-internal processes. The same pattern can also be observed in the PCA analyses (PCA_{time}) in the Supplementary material, where Mn as sensitive element is related to PC 3.

We therefore revised the respective sections and formulated the interpretations more carefully in order to better acknowledge the potential influence of multiple interacting processes.

4. Ostracod isotopes

The interpretation of the ostracod $\delta^{18}O$ and $\delta^{13}C$ signals requires strengthening. At present, the treatment of these data is incomplete, and the manuscript does not justify the species selected for analysis. Moreover, the potential covariance or anti-correlation between $\delta^{18}O$ and $\delta^{13}C$ – patterns that may have important implications for reconstructing hydroclimatic variability – is not explored. These relationships should be examined and discussed in greater detail to support the claim that the isotopic signals reflect regional climatic forcing rather than just local lake-specific processes.

Thank you for this important comment. In Line 140 we refer to the picked and analysed ostracod species (*Fabaeformiscandona* sp. and *Candona* sp.). We agree that the interpretation of ostracod $\delta^{18}O$ and $\delta^{13}C$ signals requires careful consideration. However, we note that these proxy records have already been extensively presented and interpreted in previous studies (Zielhofer et al., 2017a; Zielhofer et al., 2019), including a detailed justification of species selection and a comprehensive discussion of the hydroclimatic significance of the isotopic signals.

In the present manuscript, our objective is not to re-evaluate these isotope records in isolation, but to build upon the established hydroclimatic interpretations and integrate them with the XRF-based proxy data. We therefore rely on the published interpretations of the $\delta^{18}O$ and $\delta^{13}C$ records and use them as a reference framework for comparison with our geochemical analyses.

We have checked the manuscript to more explicitly state that the isotope data and their interpretation follow Zielhofer et al. (2017a, 2019), and that we focus in this study on the integration of these established hydroclimatic signals in the spectral analyses framework. We hope that the revised manuscript now presents these aspects more clearly to the reader.

5. Additional figure recommendation

The manuscript would also benefit from an additional figure plotting the main proxy datasets against core depth. This would assist in visualising stratigraphic changes and contextualising the proxy interpretations.

Thank you for this suggestion. However, we decided not to include a full stratigraphic plot of all elemental proxy records against core depth in the manuscript, as the focus of this study is not primarily stratigraphic but rather on the frequency-domain behaviour and coupling of the proxy signals. Detailed stratigraphic descriptions and presentations of the Sidi Ali sediment record have already been provided in previous publications on the same core (e.g. Zielhofer et al. 2017a, b).

To improve the readability and contextualisation of the proxy variability, we instead focus on the major trend changes and peak structures of the proxies in Fig. 5, which provides a condensed overview of the temporal behaviour of the different proxy groups while avoiding excessive figure complexity in the main text. Nevertheless, we also improved the description of the figure to provide a clearer understanding and facilitate easier interpretation by the reader (as Reviewer also suggested).

Specific comments

Figure 5: I agree with the comments of Reviewer 2 that I find this figure unclear. Annotations and a clearer explanation of the key trends are required.

Thank you for this comment. We agree that the previous version of Fig. 5 was not sufficiently clear. We hope that the revised figure and caption now provides a clearer overview of the major hydroclimatic and catchment-related trend changes throughout the Holocene.

L319: it is stated that $\delta^{18}O$ and $\delta^{13}C$ values are anti-correlated. This could have important implications for the interpretation of the isotopic signal, but no further information is provided. Either remove this sentence and discuss elsewhere or provide more information on the relevance of this signal.

We have deleted the sentence. $\delta^{18}O$ and $\delta^{13}C$ data of our record were published, interpreted and discussed by Zielhofer et al. 2017 and Zielhofer et al. 2019. See comment above (Point 4: Ostracod isotopes)

L363: Delete accelerated.

Corrected.

L366: Remove 'described to be'

Corrected.

L383-385: Unclear how a 2ka signal in Scotland is relevant to N. African hydroclimate. Either remove or discuss the relevance of this point to the Sidi Ali hydroclimate record.

The sediment sequence and bromine (Br) record from Stewart et al. (2017), derived from a coastal peat bog in northern Scotland, has been interpreted as a proxy for Holocene storminess. This record reflects variability in North Atlantic atmospheric circulation, which is closely linked to the NAO-like (North Atlantic Oscillation) pattern. We include this record in our analyses to compare periodicity patterns with NAO-related variability. A widely used reference in this context is the record by Olsen et al. (2012); however, it extends only back to ~5 ka BP. In contrast, the Stewart et al. (2017) storminess record captures North Atlantic variability back to ~8 ka BP, thereby covering a substantially longer time interval relevant to our study. We, therefore, prefer to retain this record in our comparative framework. Although geographically distant from the study site, it reflects large-scale North Atlantic climate dynamics and, thus, provides valuable context for interpreting supra-regional hydroclimatic variability.

We added the following sentences along the first mention of the record in the discussion chapter. “Stewart et al. (2017) reconstruct past variations in North Atlantic storminess and atmospheric circulation, reflecting changes in the NAO-like. As such, it represents an important archive of North Atlantic climate variability, which is directly relevant for interpreting hydroclimatic changes at Sidi Ali due to the strong influence of NAO-driven westerlies on moisture transport into the Mediterranean region.”