

## **Revision 1**

### **Fifty-year seasonal variability of East African droughts and floods recorded in Central Afar lake sediments (Ethiopia) and their connections with ENSO**

Carlo Mologni, Marie Revel, Eric Chaumillon, Emmanuel Malet, Thibault Coulombier, Pierre Sabatier, Pierre Brigode, Gwenael Hervé, Anne-Lise Develle, Laure Schenini, Medhi Messous, Gourguen Davtian, Alain Carré, Delphine Bosch, Natacha Volto, Clément Ménard, Lamya Khalidi, Fabien Arnaud

Dear Editor and Authors of the manuscript "**Fifty-year seasonal variability of East African droughts and floods recorded in Central Afar lake sediments (Ethiopia) and their connections with ENSO**",

Thank you for considering me to read this article and to be part of the revision process. Below, I am sending the revisions of the manuscript.

Sincerely.

#### **General comments**

In this manuscript, Mologni et al. provide a multiproxy study of two lakes in the East African Rift System that is under-represented in hydroclimate models. The authors combine radionuclides, paleomagnetic, and petrophysic parameters for characterizing the sediment sequences of lakes Gemeri and Afambo. They also gather instrumental data based on satellite images of the variation of the lake areas, as well as flow models and documentary information in the last 50 years. Considering the main criteria of the Journal Climate of The Past, I include the main comments of my revision, hoping they are constructive to improve the manuscript with major modifications.

#### **Principal Criteria**

##### **Scientific significance.**

The manuscript represents a novel hydroclimate contribution to an understudied area at Central Afar region, Ethiopia. Using classical concepts, the value of this work resides in the large amount of information about these sites provided for the last 50 years. Multiple-sourced data is obtained from two different lacustrine sediment sequences, which is important to stress the local vs regional processes. Although the period corresponding to the last 50 years is sufficiently analyzed, the rest of the period (since 1300 CE) is only superficially discussed and I personally do not think they are conclusive, and perhaps they are only marginal to this work. I imagine they will be analyzed in detail in future works considering the extracted cores. Locally, the environmental significance of the hydroclimate variability in the region and locally is well developed, while the difference between the natural climate and anthropogenic changes are well represented.

**Answer:** Agreeing with the reviewer, the period ranged between ~1300 CE and 1960, represented by the lower part of the GEM18-03/-04B sequence, has been sidelined into the discussion because of: **a)** it's prodeltaic position and homopycnal deposits patterns, which don't allow a layering sedimentation patterns and favours erosional processes (hydro-sedimentary

mechanisms between the two lakes has been largely discussed into the §5.2 section); **b)** the low resolution age model (compared to AFA18-02 core and more recent periods); **c)** the lack of sedimentological or geochemical markers reflecting local extreme droughts and enchanted precipitation activity periods related to El-Nino events. Consequently, the paper is focused on high resolution record of AFA18-02 covering the last ~50 years. Nevertheless, results from GEM18-03/-04B and comparison which AFA18-02 was deemed necessary to be presented and little discussed to ensure the hydro-sedimentary functioning knowledge of the Lower Awash riverine-lacustrine dynamic for future studies. Effectively, a long core has been retrieved recently from the Lake Abhe sediments by our team (~20 km from Afambo and Gemeri lakes), which is now under study, and which will cover the late Holocene period.

### **Scientific quality.**

The scientific approaches and methodologies applied are valid and adequate, they have been used and proved in several paleolimnological researches. Some methodological details are missing and should be provided (e.g. the model used for Pb-210 age models, see the specific comments, it is not clear if the lake area variations correspond to several images averaged within a year, the wet period, the dry period, see the specific comments). Although I think they can easily be included by the authors.

**Answer:** Supplementary methodological information on radioelements application has been added in the text and more precisions has been given to the specific comments answers below.

Lakes areas variations data were generated using 4,716,475 scenes from Landsat 5, 7, and 8 acquired sub-monthly between 16 March 1984 and 31 December 2021 that has been averaged par year resulting in 37 bands images (1985 until 2021). Each pixel was individually classified into water / non-water using an expert system and the results were collated into a monthly history for the entire time period and two epochs (1984-1999, 2000-2021) for change detection. As explained in the “Global Surface Water” dataset from the Copernicus Programme, the frequency with which water was present on the surface from March 1984 to December 2021 was captured in a single product called surface water occurrence (SWO). To compute SWO, the water detections (WD) and valid observations (VO) from the same months are summed, that is, water detections and valid observations from March 1984 are added to water detections and valid observations from March 1985 and so on, such that  $SWO_{month} = \sum WD_{month} / \sum VO_{month}$ . Averaging the results of all monthly SWO<sub>month</sub> calculations gives the long-term overall surface water occurrence. The month-by-month time step normalizes occurrence against seasonal variation in the number of valid observations across the year. Typically, more cloud-free observations (and thus valid observations) are available during dry seasons than wet. Without monthly weighting, the overall water occurrence (that is, computed over the full period) would be biased by temporal distribution of the valid observations (that is, giving more weight to the dry season than to the wet season).

### **Presentation quality.**

I consider that the presentation of the results and their structure must be improved before publication and this could take major work. The organization in the presentation of the results and figures should be revised in detailed and adjusted. As general examples, the results between both lake records are unbalanced

**Answer:** The main manuscript text and figures has been improved following the suggestions of the reviewer. Please find our detailed answer to general and specific comments below.

(A), the criteria of the description are very different in both lakes. While one lake is described by facies, in the other lake facies are not mentioned, and authors use geochemical units, which are not applied for the first lake record.

**Answer:** The sedimentary description protocol for the Afambo and Gemer Lake cores has been tailored to suit the structural, textural characteristics of the respective investigated deposits. In the case of AFA18-02, there is a discernible pattern of clear alternating sedimentary layers throughout the core. Conversely, GEM-18-03-04B exhibits an homogeneous sedimentary facies throughout its length, with the exception of a pedogenized layer observed between 20 and 40 cm at the top of the sequence and few shell-beds horizons (see Sup. Mat. Fig. S19).

Given the absence of repeated sedimentary layers from Gemer Lake, the adoption of a Facies system description was deemed unnecessary, as predominantly only one main facies was represented. Consequently, we found it necessary to utilize the sedimentary facies system description for AFA18-02, while it was deemed unnecessary for GEM-18-03-04B. This decision was informed by the contrasting hydro-sedimentary functioning patterns observed in the two lake deposits, which are extensively discussed in the manuscript.

Given the absence of discernible sedimentary patterns observable to the naked eye, as well as a lack of textural (grain size) differentiation along the GEM-18-03-04B core, it was not feasible to establish a facies system for this deposit. Consequently, we opted to employ geochemical proxies to delineate the sedimentary phases within the Lake Gemer deposits. This approach proved to be successful in elucidating the linkages to changes in the lake surfaces over time.

The figures are cited without following an order (B), they are mixed in the text.

**Answer:** The order of the cited Figures has been arranged correctly.

There is data in the Figures that is not discussed or included in the results (C).

**Answer:** All data presented in figures is correctly explained into the text or/and into Supplementary Materials.

The figures in the supplementary material are not correctly explained (D),

**Answer:** Supplementary materials description has been improved following the reviewer suggestions (comments below).

there are parts of the Figures that because of their size are not visible for the reader (E).

**Answer:** New high quality figures has been replaced with the previous ones.

The excel tables in the supplement do not present units (F), etc.

**Answer:** Units in supplementary data tables has been added.

Further examples are indicated in the specific reviews. Therefore, I consider that the structure of the Results (and the supplementary data) require major modifications before publication.

**Answer:** Results and supplementary data presentation has been adjusted following the reviewer suggestions.

In the Discussion section, there are important subjects such as the chronology, and the relationship between instrumental and paleolimnological records that are not included.

**Answer:** A discussion paragraph on the relationship and discrepancy between palaeolimnological data and instrumental data has been added in detail in the Discussion paragraph (Lines 774-784) and presented into specific comments answers below.

For instance, the authors include a large set of radiocarbon data, they present them in the results where they reject most of them without major analysis of the processes that might be causing errors in these data. In this case, if they decide that the radiocarbon data do not require a discussion, I do not see the point of presenting these results.

**Answer:** We believe it is crucial for future studies to include all chronological data, even if some data points are ultimately rejected. This comprehensive approach serves to demonstrate the limitations and challenges encountered in dating techniques along the Awash River Basin System. Specifically, we observed a remobilization of ancient fine organic matter in both the Afambo and Gemeri cores, as well as prolonged residence time of dissolved inorganic carbon in the waters of Lake Gemeri. From our perspective, the absence and inconsistency of data should always be acknowledged as valuable outcomes in their own right.

However, if this explanation seems too cursory or verbose, we can consider omitting the rejected radiocarbon data altogether.

Similarly, the authors do not discuss how the hiatus in lake Gemeri affected the chronological models.

**Answer:** A sentence on the impact of the pedological hiatus on the chronological model and its resolution has been added (Lines 422-423).

In addition, the authors point in their conclusion (line 793) that the results have similarities and divergencies between instrumental data and the paleolimnological data. Nevertheless, the discussion about this subject is not provided.

**Answer:** We have included a discussion on the disparity between paleolimnological data and instrumental (hydrological) data. This discrepancy primarily stems from the absence of comprehensive instrumental data on the lower Awash River catchment area. Specifically, flow rates in Tendaho have been modelled based on discontinuous and temporally low-resolution datasets. Simulated streamflows at Tendaho are subject to uncertainties due to the rainfall-runoff model, its parameter calibration - using discontinuous observed streamflow available over a limited time period (1990-2014) - and the uncertainty of the meteorological forcing used as model inputs (the NOAA 20CR global reanalysis). These uncertainty sources have been more deeply discussed in the new paper version (Lines 774-784).

Finally, I think the authors gathered a large high-resolution dataset provided by natural proxies (Ti/Sr, laminae thickness) superposed to instrumental information (lake area, SST, streamflow rate), which is sufficient to attempt a statistical or numerical comparison of both data that support the conclusions. This could add a special quantitative value to their work and would allow them to extend the data for the pre-instrumental period if longer cores were analyzed. A comparison that is restricted to descriptive observations (as it is now) of this enormous dataset, reduces the significance of the paleolimnological proxies in this work. In this sense, if there is direct hydro-climatic data enough to characterize the exact lake variability without the use of the paleolimnological proxies, then why should the latter be incorporated?

**Answer:** These palaeolimnological data are currently being used in a specific numerical modelling calculation, combined with atmospheric teleconnection and local-to-regional hydro-climatic models. This will be the focus of an upcoming publication led by co-author and hydro-modeller Dr. Pierre Brigode. Including a simple statistical modelling now might result incomplete and superficial adding unnecessary complexity and excessive length, as it is already rich in information, datasets, and interpretations. This current manuscript aims to present the first evidence of the high-resolution sensitivity of the Awash River and Central Afar Lakes systems to short inter-continental climatic oscillations. It represents a unique data compilation and a pioneering study for ongoing and planned publications.

I explain the specific observations in the following comments.

#### MAIN MANUSCRIPT

**Title: “and their connection with ENSO”.** I think that this part of the title would be valuable once the authors have established a numerical connection with ENSO (see the comments below).

**Answer:** Even in absence of numerical support for sharpening our observations, this paper has the merit to show for the first time the high-resolution sensitivity of the Awash River and Central Afar Lakes systems to short inter-continental climatic oscillations, representing a unique data compilation and pioneer paper for future studies. Indeed, our research team is working now on a numerical modelling of those data combined with a modelled local-to-regional hydro-climatic instrumental data, and which will be the object of a new publication headed by the co-author Dr. Pierre Brigode. Consequently, we would like to maintain the original title.

#### Abstract

**Line 31-33:** The laminated facies correspond only to one lake (L. Afambo), not both lakes.

**Answer:** See the answer to general comment (A)

**Line 43:** I don't think there is a quantitative reconstruction presented in this manuscript. Although there is quantitative data, the relationships are only relative (not quantitative).

**Answer:** We have differentiated between quantitative and qualitative data in both the introduction and discussion sections to provide clarity on the nature of our reconstructions. Several results, such as layer thickness, texture, ICP-MS data, lake surface changes, and sedimentation rates, offer quantitative insights into the functioning of the Awash River hydro-

sedimentary dynamics over time. Conversely, other data, such as thin section analyses, are more qualitative, while XRF core scanner data fall within a semi-quantitative category. This distinction helps elucidate the varying degrees of precision and certainty associated with different aspects of our reconstructions.

**Line 45:** Please, indicate the meaning of the acronym.

**Answer:** the full meaning has been added.

### **Study site**

**Line 120-121:** Can you enlarge the C) pannel of the figure? It is too small and the dots are difficult to discern. The Tendaho dam is not visible in the maps.

**Answer:** Fig. 1.c has been enlarged as well as the dam sign.

### **Materials and methods**

**Line 172-173:** Please, indicate if the obtained lake area dataset is annual, monthly, seasonal, if there is missing data, etc.

**Answer:** Such information has been added.

**Line 212-214:** Were the values normalized beofre PCA? The figures in the Sup. Mat. are not clearly explained, some variables are missing. Please, provide a better description of the analysis.

**Answer:** More detailed explications has been added in the Sup. Mat. C Fig Captions.

**Line 246-247:** Please, indicate and justify the model selected for the Pb-210 chronology.

**Answer:** Model justification has been added in the main text: For the 210Pbex model, we choose the CFCS (Constant Flux Constant Sedimentation) model because CRS (Constant Rate of Supply) cannot be applied in this context in regard to 1/ the hiatus (which affect the 210Pbex inventory) and 2/ the age of the AFA core which not allow to estimate the total 210Pbex inventory need for CRS model calculation. We not applied the CIC (Constant Initial Concentration) model because it will result in age inversion in regard to 210Pbex fluctuation.

**Line 264:** Please, indicate how the counting was performed. Indicate also if varves were identified, why this term was no longer used in the text?

**Answer:** Effectively the term “varve” is not appropriate for this kind of sedimentary laminae. We change consequently the term and information has been added on the counting method.

## **Results**

### **Sedimentology and geochemistry results**

**Line 323:** Which are the components of the couplets? F1/F2 or F1/F3, or both.

**Answer:** the couplet combinations can be both.

**Line 338-339:** There is a high correlation between XRF and ICP-MS from Sr and Ca. Why do you think the correlation of the Ti is lower with both techniques?

**Answer:** such correlation feature can be the result of a XRF concentration/dilution effect: Ca and Sr are much more concentrated than Ti. Consequently, the detection of Ti counts from XRF methods can be more heterogeneous than highly concentrated elements providing this feature on geochemical XRF vs ICP-MS plots.

**Line 348.** The soft sediment deformation structures are not defined in the text.

**Answer:** A short description about soft sediment deformation has been added (Lines 352-354).

**Line 355.** The cite of this Figure is not in the correct order. Please, check this for the rest of the Figures.

**Answer:** Citation of the figure in the text has been rectified.

**Line 357.** I'm sorry, I don't understand this. Are F2 and F3 well sorted only at those pointed levels (40 cm and 60 cm?), or is it a typing error and you meant micrometers instead of cm?

**Answer:** Typing error, which has been corrected.

**Line 358.** Explain what F means in the Table.

**Answer:** Explained in the table legend.

**Line 374.** Please, justify the Log ratio use.

**Answer:** The use of Log ration has been explained in the text with the support of a citing reference.

**Line 374-380.** I noticed that you used facies for the AF1802 core, but now you are using geochemical units for classifying this core. It is difficult to compare both cores, when their description and the sediment classification is different.

**Answer:** See answer to general comment (A)

**Line 382.** I think the order of the age results should be reverted (otherwise, the table and figure order should be changed).

**Answer:** We didn't understand where and why the age results should be reverted.

**Line 383.** I consider you should indicate and explain which model you applied for the Pb-210 derived ages, as well as the basis for the application of this model.

**Answer:** See previous answer on the methodology of radioelements. For the detail in  $^{210}\text{Pb}$  model calculation please refer to Bruel and Sabatier 2020.

**Line 391.** I consider you should indicate and explain which model you applied for the Pb-210 derived ages, as well as the basis for the application of this selected model.

**Answer:** Again the model is the CFCS and all explanation on the choice is given in the answer above and has been added in the main text.

**Line 393.** Please, add the core depth to the Table.

**Answer:** Core depth has been added to the table.

**Line 397-398.** Did you find evidence in your data? Is it the only explanation? Please, try to better explain these processes since there are many rejected samples, and accepted samples and rejected samples seems to be from different levels that are not directly comparable. This is an important aspect to consider for dating older sediments in future works. So, the fact that all the samples of bulk sediments are too old is a significant finding that should be highlighted. Can you see a pattern? How much older are they? You could try to explain this in the Discussion section.

**Answer:** The aging of radiocarbon dates on bulk organic matter in large fluvial systems, such as the Awash River Basin, is often attributed to the remobilization of fine organic particles from older deposits and soils eroded along the hydrographic catchment. These particles are then deposited into terrigenous/detrital lacustrine sediments. In the case of Afambo Lake sediments, the ages of bulk organic carbon exhibit an aging effect ranging between approximately 100 and 600 years. Considering that the organic matter originates from flood deposits during the monsoonal season (F1 facies), the hypothesis of remobilized fine particles is the most probable explanation.

To address this, we have chosen to improve the radiocarbon sampling strategy by focusing on micro-vegetal remains and fish bones, which have yielded successful results and a coherent radiocarbon-based age model. This information has been incorporated into the text.

**Line 401-402.** This is not quite clear. Although I see you calculated this rate, please provide the details (depths-ages).

**Answer:** The sedimentation rate has been automatically calculated combined with radioelement results using *serac* R package as defined into the methodology section. Detailed depth of radiocarbon age samples are contained in the Tab.2. Five ages measured from fish bone and vegetal micro remains are consistent with the <sup>210</sup>Pb-derived chronology and are considered viable as part of the age model. 32 laminae were identified 401 and counted in the F1 and F2 couplets, which provides a 106 mm.yr<sup>-1</sup> sedimentation rate that 402 is highly comparable with the rate derived from the CFCS model (108 mm.yr<sup>-1</sup>; Fig. 4a.2).

I think it is also not clear in the text, if the number of laminae correspond to couplets, or to a singular F1 lamina or F2 lamina.

**Answer:** Number of laminae is referred to couplets and has been specified in the main text.

**Line 407. Figure 4.** If you include in a.4 the rejected ages in the plot as a different triangle? Maybe you could see if they are related with moments of increased influxes of the river that could bring older material to the lake, as you proposed?

**Answer:** Rejected radiocarbon ages are too much older to be contained into this graph, and no predominant logic exist about their ageing.

**Line 412. Age model of Lake Gemeri.** Even when I see that the authors included the hiatus in the image (Figure 5 a.4), it remains unclear how this hiatus was incorporated in the chronological models, and how it was defined in the lithology.

**Answer:** The origin and the characteristics of such pedological hiatus is explained into the lithological results of GEM18-03/-04B, and is double-crossed by the comparison with satellite images analysis and AFA18-02 results (prolonged drought period). Considering the drying of the lake between 1992 and 1997 (satellite images analysis) corresponding to the development of this pedogenic hiatus event, this period has been removed into the age model building.

It is also not clearly expressed the difference of the Cs-137 control ages (1963 and 1955) from the Pb-210 CFCS derived model. In addition, since rates are indeed shown as changing throughout the core, including periods of no-deposition, please justify the application of the CFCS model.

**Answer:** A hiatus period will not affect the CFCS model as well as bioturbation see Bruel and Sabatier 2020 for more details. The  $^{137}\text{Cs}$  activity profile allow the identification of one peak related to the global fallout in 1963 CE and the start of  $^{137}\text{Cs}$  activity detection which correspond to the first still detected  $^{137}\text{Cs}$  fallout deposition (Bruel and Sabatier 2020). These two independent ages are used to validate the  $^{210}\text{Pb}_{\text{ex}}$  CFCS derived model and not to constrain the model. It is previously shown in many papers that a change in sedimentation rate is well identified and quantified with CFCS model and the resulting age model is not well defined with it. Please have a look on the paper Bruel and Sabatier 2020 for more detail about all these parameters influence.

**Line 429. Figure 5.** Please, incorporate the meaning of NWT and FF, RPI to the caption. The Figure a.3 shows that the Cs-137 maximum peak is not clearly discernable. The NWT letters are actually covering the curve and the sample point, but it seems that the maximum is actually the upper point (around 40 cm). Therefore, 1963 could be located between the point you marked (around 45 cm) and the point above it (40 cm).

**Answer:** Acronyms meaning has been added in the caption, as the graphical illustration details has been fixed.

Please, include the age differences between the derived Pb-210 ages and the Cs-137 markers.

**Answer:** The difference in  $^{210}\text{Pb}_{\text{ex}}$  derived age and  $^{137}\text{Cs}$  is illustrated in figure 5a. There is not significant difference as  $^{137}\text{Cs}$  peak are within the  $^{210}\text{Pb}_{\text{ex}}$  model uncertainties (gray band)

Could you also point the levels where C-14 was applied?

**Answer:** C14 ages levels has been added into the figure.

**Line 476.** The title is incomplete.

**Answer:** The title has been completed.

**Line 484.** Figure 6 and section 4.4. Please, specify the area of which lake is considered in the plot (light-blue). If both lakes are considered in this curve, you should indicate it.

**Answer:** Both of lakes surface variations are included in the curve. Such information has been added in the caption.

I think it would be more convenient to show each lake curve separately, since the description is different for both lakes, (e.g. lake Gemberi dried up).

**Answer:** Agreeing with the reviewer and with the aim to show the details of Lake Gemberi drying and water surface changes since 1985 Figs. S26 to S28 has been added into Supplementary Materials.

I can also notice there is a difference between the fluctuations of the sedimentological records and the lake area record. Please, explain this difference in the results and later in the discussion because the sediment response to the lake variability seems to be lagged. Otherwise, the chronological model might be the cause of this lack of synchronicity.

**Answer:** Palaeolimnological and hydrological results from satellite image analyses might be not perfectly linearly correlated due to sedimentary avulsions and earth surface processes along the river course and between the two lakes (Phillips, 2003). Additionally, such offset can be attributed to the combined  $^{210}\text{Pb}/^{137}\text{Cs}$ , counting couplets and radiocarbon age model errors which can span from 1yr to 7yrs.

## **5- Discussion**

**Line 488.** The chronology should be discussed in this section (it is partially discussed in the results but actually there is interpretation and ideas that deserves to be developed in a discussion. The C-14 data meaning should also be discussed.

**Answer:** Specific details and argumentations on the age models building of both lake sequences are largely presented into the results section (4.3 Chronology Section) and in Supplementary Materials, including C-14 data meaning explanations. Following the suggestions of the reviewer, we added a short paragraph as a reminder to what is presented into the chronology section.

Otherwise, I do not understand why they are considered at all since the models are solely based on Pb-210 and Cs-137 and laminae counting.

**Answer:** Firstly, because they are the more solid and consistent, and secondly, because  $^{210}\text{Pb}$  provide a continuous estimation of the sedimentation rate and of the age. But again these  $^{14}\text{C}$  ages constrain are in good agreement with  $^{210}\text{Pb}$  derived model (within the uncertainties).

**Line 495.** I cannot see the overlapping.

**Answer:** Sentence has been changed.

**Line 507.** How do the authors distinguish between total water (dissolved?) and solid load?

**Answer:** Terminological issue, Sentence has been changed.

**Line 518.** In the text both facies, F2 and F3 are interpreted. In the subtitle, only F2 is mentioned. Please, add the F3 to the subtitle. Authors should also explain the interpretation for each of those facies, F2 and F3.

**Answer:** differences between F2 and F2 as been explained in the text and F3 has been added in the subtitle.

**Line 533-534.** “Indeed, Ca and Sr are related to intra lake precipitation of CaCO<sub>3</sub> with Sr and Ca substitution” This sentence is not clear.

**Answer:** The explanation of this sentence is contained in the following sentence.

**Line 540.** I agree that Ca and Sr indicate drought stages. How is the intensity related to the element variation? Is this relationship relative, semiquantitative, does it occur from a certain lake level? Please, explain this relationship in the manuscript.

**Answer:** The difference of chronological resolution between palaeolimnological and water surface data don't allow to point out a quantitative relationship. However, a numerical modelling of the co-variance ratio between Ca- Sr, evaporation rates and lake lowering (local hydrological modelling) will be the object of a specific paper.

**Line 562-563.** Please, include the cites of the Figures.

**Answer:** Figure cites has been added to the sentence.

**Line 571.** Sometimes the authors cite the Tables and Figures of the supplementary material with numbers S1, S2, etc. In this case, they used the letter E, that is also not in the right order (it follows the section J of the Supplementary material). Please, apply only one citation style.

**Answer:** Citation style of Supplementary materials has been homogenised.

**Line 582.** There is a contradiction between this paragraph and the following section where changes in the last 700 years are multicentennial.

**Answer:** Typing error, has been changed.

**Lines 593-595.** Please, cite the Figures.

**Answer:** Figures has been cited.

**Line 599.** Although the authors say that they explain the trends for the time-range 1300-1964 CE, they extend the temporal range in the following paragraph to 1979 CE. In addition, notice that there is a mix between AD and CE along the manuscript.

**Answer:** Chronological range has been corrected and chronological terminology has been homogenised to CE.

**Line 605.** Please, specify higher supplies of what...

**Answer:** has been precised.

**Line 605.** In this interpretation, the following periods are not explained or mentioned. Please, correct this.

**Answer:** The following period interpretation is contained in the following section, which is dedicated to the last 50 yrs.

**Line 606.** I'm sorry, I could not understand what time is "this time", and the connection of this interpretation with the data.

**Answer:** chonological range has been precised in the text.

**Line 611. Figure 8.** I consider that sedimentation should be compared using the same criteria in this Figure. If the authors consider homopycnical sedimentation, they refer to an interpretation of the depositional processes. Instead, when they say laminated sedimentation, they refer only to the structure, without any interpretation. So, please, use the same criteria for this image.

**Answer:** Terminology criteria has been changed accordingly.

At the b) panel, there is an example of the drought events (e.g. 1991-1997). Therefore, an example of the wet periods should also be mentioned for the pannel a).

**Answer:** an exemple of wet period has been added to the figure.

In addition, the Pedogenic event is not well explained in the manuscript, there is a drought event but pedogenesis is not explained.

**Answer:** The relationship between the drying of lake Gemberi and the development of a soil has been added into the discussion. Accordingly, the description of pedogenic features are contained into the result section.

**Line 631-632.** What are the bases for this assumption? Please, explain them.

**Answer:** The argumentations of this assumption has been added in the text.

**Line 639.** I do not think high temperatures were explained before.

**Answer:** high temperature term has been removed.

**Line 589. Magnitudes of the Awash River wet/drought seasons, and their connection with the impacts of ENSO events.** Considering you have a continuous and high-resolution record of the last 50 years, in one or both lakes, along with the images of lake area variability, and that you try to establish a relationship with ENSO, (El Niño 3.4), why are they not statistically compared? Regressions, a percentage of El Niño o La Niña episodes explained by the paleolimnological data, a correlation between data could be options.

**Answer:** See answer to general comment (A).

**Line 775-776.** Please, discuss the similarities and divergencies of instrumental and the obtained paleolimnological records.

**Answer:** We have included a discussion on the disparity between paleolimnological data and instrumental (hydrological) data. This discrepancy primarily stems from the absence of comprehensive instrumental data on the lower Awash River catchment area. Specifically, flow rates in Tendaho have been modeled based on discontinuous and temporally low-resolution datasets. The simulated streamflows at Tendaho are subject to uncertainties due to several sources :

- uncertainty due to the structure of the rainfall-runoff model used, partially representing the hydro-climatological processes involved.
- uncertainty linked to the monthly time step used, which may not be able to account for the seasonal variability of hydrological lake filling and drying processes.
- uncertainty linked to the calibration of model parameters, based on a short period of observed data availability, with missing data. The streamflows used are also potentially impacted by anthropogenic influences (water abstraction for agriculture, for example), and therefore only partially representative of the natural hydrology of the region.
- uncertainty of the data used as input to the rainfall-runoff model, originating from a global reanalysis at coarse spatial resolution, with only few assimilated field data from raingauges and meteorological stations.

Quantifying the impact of each uncertainty sources on the streamflow simulation was out of the scope of this paper.

## **Conclusion.**

**Line 792-293.** This should be further discussed in the manuscript because if the correlation of the indirect proxies and the direct proxies is not straightforward in some periods, then the indirect proxies are not entirely sensitive to changes in precipitation in the catchment, or other variables should be involved. Please, include this discussion considering the possible causes of the discrepancies.

**Answer:** Explanations of such discrepancy and their out-of-scope quantification are provided in the previous answer. Consequently, such sentence has been modified in the conclusion section.

SUPPLEMENTARY MATERIAL

**Figure S1.** Please, include the coordinates of the image. The names of the coring sites are superposed and not visible in the image.

**Answer:** Figure S1 has been changed following the suggestions of the reviewer.

**Figure S2.** The letters are too small.

**Answer :** The figure has been improved.

**Figure S4.** Please, explain the PCA, Dim1, Dim 2, the percentages, the variables. I cannot see Si in the PCA. Then, I see that S is also analyzed and not mentioned in the text, as well as Zr and Fe. Maybe you could mark the End-member 1 within the plot.

**Answer:** Figure and text in the caption has been improved following the reviewer suggestions.

**Figure S5.** Please, check this paragraph, it is not clear. Neither are the colors. What is black? I think the legend is hidden. Explain this Figure.

**Answer:** Figure has been explained in the caption.

**Figure S6.** Idem. Please, explain better this Figure, by indicating what is Dim 1, Dim 2, what is area, what is Sr.Ka, S.Ka, Mg.Ka. Maybe you could add a paragraph about the results of the three PCA plots.

**Answer:** Explanations has been added into the figure caption and referred to the main text interpretations.

1. **Paleomagnetic study on Lake Gemeri GEM18-03/04 core.** I think the pedogenesis events and their evidences should be described in the main manuscript.

**Answer:** Pedogenic layer in GEM18-03 core is describe in the main text.

1. **Loss on ignition.** Please, add the methodology and cite this in the manuscript. The decimals are separated by commas, you should change this. The weight, residual water, total depth (I assume it is the composite core depth) lack of units.

**Answer:** Details has been added in the main manuscript methodological section with the citation reference. Accordingly, units and adjustments has been provided into the Supp. Mat. Table.

1. **Clay X-Ray Diffraction.** The clay composition is not explained in the text, it is not used. If this methodology is applied, you should include the results of these analysis.

**Answer:** Such analysis has been performed on GEM18-03/-04B sequence with the aim to detect changes in sourcing inputs in the prodeltaic area of the Awash River. Results clearly indicated that clay composition is homogenously dominated by smectite. Consequently, clay composition is explained shortly into the text.

**Figure S14.** The image at the right of the excel sheet is not readable.

**Answer:** The image has been improved.

**Figure S20.** Please, include the units of the axes. Are they counts or  $\text{cm}^{-1}$ ? Please, include the coefficients that are mentioned in the manuscript, although they are not represented in these plots.

**Answer:** Units has been added in the caption (XRF counts)

**Figure S22.** Authors mix AD and CE in this work, please, select one unit.

**Answer:** Ages in the text and into sup. Mat. has been homogenised in years CE.

**Figure S24 S25.** I could not find this plot cited in the manuscript. Please, either explain these Figures or remove them.

**Answer:** Such figures was referred into the main text with 'Sup. Mat.J', now referred as Fig. S24 and S25

**Stokes Law calculation of Lake Afambo sediments.** This section (E) is preceded by section (J). Please, check the entire Supplementary section and the cites in the main manuscript.

**Answer:** Citation style has been adapted to Table S3