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Interactive comment on "Extreme flood events reconstruction during the last century in the El Bibane lagoon (Southeast of Tunisia): A Multi-proxy Approach" *by* A. Affouri et al.

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Responses to Reviewer Comments

Interactive comment on "Extreme flood events reconstruction during the last century in the El Bibane lagoon (Southeast of Tunisia): a Multi-proxy Approach " by A. Affouri et al. Anonymous Referee #1 Received and published: 10 May 2016 General comments: This is basically an interesting case study dealing with the tracking of palaeo-flood events in the El Bibane Lagoon (SE Tunisia) during the past century. The main objective of the study is to investigate sediment sources in the lagoon and to discriminate between fluvial, aeolian, marine end-members by using sedimentological and geochemical data. The patterns observed in modern sediments are expected to help

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Discussion paper

deciphering ancient flood events in lagoonal deposits, as preserved in a core covering the past century based on a combined chronology using 210Pb and 137Cs data. I must be honest in saying that, if the study is relatively sound and acceptable, I've not been convinced in general by the novelty of the approach, and have in addition several reservations regarding the interpretations (see the Specific Remarks). In particular, most of the results have been presented between the Results chapter and the Discussion, which renders the manuscript confusive and difficult to read. Alternatively some parts of the text have been totally overlooked and would benefit from further consideration/exploration before the manuscript can be accepted. The quality of the figures is overall acceptable, albeit some figures are of very poor graphical quality. The manuscript is not really well written, and should absolutely be revised by a native English before further consideration. I also regret that no tentative comparison with other regional datasets is provided in the Discussion, although I am pretty convinced that such a perspective would help to build a bigger picture of palaeoflood activity regionally. Finally, I do not believe that the manuscript provides the sort of conceptual and fundamental advance in our understanding of the processes and mechanisms governing lagoonal sedimentation and past central/southern Mediterranean climate that has been published elsewhere. For these reasons, I would not recommend this study to be published in Climate of the Past. However I leave this decision to the editorial board, who should appreciate the other reviewers' comments and recommendations.

Specific remarks:

1. Introduction: Page 3, Lines 1-3: Please provide more information dealing with the study of Raji et al., 2014 in Morocco, and show how the outcome of this work is related to the present study. A paragraph was added in the introduction section (page 3 line 1-3):

"Few studies have been undertaken to reconstruct past flood events from lagoon sediments (Raji, 2014). Most of the studies were interested to flooding associated with both hurricanes and tsunamis where overwash deposits preserved within backbarrier lagoons and salt ponds can provide a means for documenting previous flooding activity. Heavy rain flooding events recorded within these environments are still poorly documented".

Page 3, end of the introduction: I would have appreciated to find here, as a foremost objective of the study, a perspective of data integration with other dataset covering the same time span, at a regional/larger scale.

A paragraph has been added at the end of the introduction:

"Reconstruction of past flood events from sedimentary archives which covers the last century has not been studied in the southern Tunisia. Moreover we show in this study the importance of lagoon sediment series for reconstructing the flood activity in arid and semi-arid environment in an area where no other significant (and continuous) sediment series can be easily retrieved in fluvial valleys".

3. Climate and hydrology

Page 5, lines 10-12: Please check the phrasing of that sentence. This is a regular problem throughout the manuscript, which would highly benefit from a thorough cross reading by native English.

In the revised version we take into account the reviewer proposal:

"The annual precipitations of Medenine and Tataouine stations during the last century were obtained from the Directorate Research of Water Resource (DGRE, 2010, Figure 2). Five major precipitation events were recorded from these two stations (i.e. A.D 1932, A.D 1969, A.D 1979, A.D 1984 and A.D 1995). These events have induced large flood events on the Fessi River watershed (Poncet, 1970; Bonvallot, 1979; Ousslati, 1999; Boujarra et Ktita 2009; Fehri, 2014)".

Page 5, lines 13-16: When you refer to Figure 3, please also introduce the Medenine and Tataouine watersheds here (and not later at the beginning of chapter 4). There is a mistake with the spelling of Medenine on Figure 2.

In the revised version this figure has been corrected accordingly.

4. Materials and Methods

Page 6, lines 11-13: Please provide a general lithological description of core BL12-10, since we are not provided with any information with respect to the sedimentology at that stage.

We agree with the reviewer's comment and we take into account the reviewer suggestion:

"The lithotological description of the first 30 cm core showed coarse-grained layers of siliciclastic sand and shell fragments inter-bedded with organic rich dark grey fine grained sediment (mud) of clay and silt. Three mud layers were identified from 6 to 10 cm, 14 to 18 cm and finally from 26 to 30 cm core depth".

In general the methods are described in an extremely concise way, and would perhaps merit more devotion. The information provided in the present version of the manuscript are indeed very limited (XRF, grain size analysis and age model using 210Pb and 137Cs). Why did you opt for a 1cm-resolution (only) with the XRF data, and not a higher resolution? Is the sediment too homogeneous, thus rendering this perspective not promising? Please elaborate on that.

We agree with the reviewer suggestion. In the revised version this part has been improved accordingly.

"For elemental analyses of the bulk sediment a portable energy dispersive X-Ray fluorescence NITON XL3t was used. This technique delivers fast and accurate elemental analysis results, from a few ppm to percentage. XRF-scanning analyses are done directly on the sediments of the BL12-10 split-core section. The split-core surfaces were first flattened and covered with a thin (4 μm) Ultralene film to avoid contamination of the measurement prism of the core scanner (Richter et al. 2006). All surface samples were prepared for XRF-bead analysis by powdering and homogenizing of the dried samples using an agate mortar. The resulting powder was dried for 2 h at 105°C and kept in a desiccator at room temperature. Ca. 4 g of the powdered samples were placed in plastic cups and sealed with Mylar foil (0.4 μm). The prepared sample cups were placed on the XRF and measured for 120 sec with different filters for the detection of specific elements. Two filters were used with the following adjustments: main measuring 90 s at 10 kV tube voltage with 40 μA for Al, Si, S, Cl, K, Ca, Ti, Mn, Fe and 30 kV tube voltage for Zn, Br, Sr, Rb, Zr with 40 μA. The portable XRF scanner (NITON XL3t) has been calibrated and checked on all NITON XRF calibration standards and is certified as “Passed” by Thermo Scientific Portable Analytical inst. Lnc. In our study, the XRF-scan data will be presented as processed intensities expressed in ppm or in percentage. In this study, we choose a 2 cm resolution with the XRF data for two reasons: (1) we have used a field portable XRF scanner core that may not permit a continuous scan analysis. Furthermore the maximum outlet opening of the X-ray generator is 0.7 cm in diameter. Therefore, the maximum resolution is to make a measurement every 0.7 cm; (2) the sediment is not laminated; sediment rearrangement processes by the lagoon bottom currents and bioturbation homogenized the sediment up to few mm to cm thickness. Consequently, increasing the resolution is not necessary. Laser grain-size analyses were achieved with a Beckmann- Coulter LS13320 Particle Size Analyser (Geosciences Montpellier). Grain-size analyses were performed on the BL12-10 sequence with an average interval of 1 cm. For each sample, a small homogeneous amount of sediment was mixed in deionized water then sieved at 1.5 mm diameter before pouring in the Fluid Module of the Particle Sizer until to obtain an optimal obscuration rate between 7 and 12% in the Fraunhofer optical cell. The time of background and sample measurement was set to 90 s and sonication was applied during the measurement of the sample in order to improve the dispersion of fine particles in the fluid. Each sample was measured twice and the good repeatability of measurement was verified according to the statistics from the international standard ISO 13320-1. Dating of sedimentary layers was carried out using 210Pb and 137Cs methods on a centennial timescale. The 137Cs and 210Pbex activities analyses were performed on the fraction < 150μm by gamma spectrometry using a CANBERRA Broad Energy Ge (BEGe) detector (CANBERRA BEGe 3825). The sediment was then finely crushed after drying, and transferred into small tubes (diameter 14 mm), and stored for more than 3 weeks to ensure equilibrium between 226Ra and 222Rn. Generally, counting times of 24 to 48 h were required to reach a statistical error of less than 10% for excess 210Pb in the deepest samples and for the 1963 137Cs peak. Activities of 210Pb were determined by integrating the area of the 46.5-keV photo-peak. 226Ra activities were determined from the average of values derived from the 186.2-keV peak of 226Ra and the peaks of its progeny in secular equilibrium with 214Pb (295 and 352 keV) and 214Bi (609 keV). In each sample, the (210Pb unsupported) excess activities were calculated by subtracting the (226Ra supported) activity from the total (210Pb) activity. We then used the Constant Flux/Constant Sedimentation (CFCS) model and the decrease in excess 210Pb to calculate the sedimentation rate (Goldberg, 1963). The uncertainty of the sedimentation rate obtained by this method was derived from the standard error of the linear regression of the CFCS model. 137Cs was studied on the core BL12- 10 in order to assess sediment accumulation rates and chronology of the first 30 centimetres of the core. 137Cs (t1/2 = 30.1 yr) is an anthropogenic radionuclide. It entered the environment in response to atmospheric nuclear tests from 1954 to 1980 AD that induced global fallouts (the first year of atmospheric releases was 1953 AD, whereas the maximum atmospheric production is reached in 1963 AD. 137Cs depth profiles have been extensively used in various environments to assess sediment accumulation rates (Nittrouer et al., 1984; He and Walling, 1996; Radakovitch et al., 1999; Frignani et al., 2004)".

Page 7, lines 11-12: Please rephrase as I do not understand this sentence. Page 7, lines 11-13: I find this introduction for the PCA analyses far too simple!

As suggested by the reviewer we included in the statistical analysis a paragraph about PCA:

"Statistical methods were applied to complete and refine the analysis. Principal Component Analysis (PCA) is widely used statistical techniques in environmental geochemistry. This multivariate approaches is used to reduce the large number of variable that result from XRF analysis. Principal Component Analysis (PCA) was applied to chemical elements in order to distinguish the different sediment sources of surface sediments and link them to the geochemical processes or proprieties. In the present work, the dataset contains 18 samples, each of which includes concentration of 8 elements (Ca, Sr, Fe, K, Al, Ti, Si and Zr). Data are presented in the form of elemental concentration (8 variables). In this study, a statistical analysis was performed using the STATITCF (1987) which is based on variables and it is suitable for identifying the associations of variables with a set of observations. A representation quality of the parameters (positions in the factorial plane) was then performed".

Could you elaborate more on that? For instance, since you use percentage values (both for grain-size and XRF data), have the raw data been square-root transformed, centered and standardized before applying the PCA analysis? This is of great importance regarding the reliability of the results. Please clarify it.

The raw data (in percentage values) have not been square-root transformed, centered and standardized before applying the PCA analysis.

5. Results

Page 8, lines 2-4: On Fig. 6 the distribution of grain sizes appear different and more complex between S7 and S10 (fluvial end-member). For instance, the mode at 100μ is not present on sample S10. Similarly, the mode 20-63 μ is not really obvious in S10. Is the pattern so tricky when considering other samples from the fluvial component (e.g., S8, S9, S10-S16)? Please comment on that and eventually show more plots for the fluvial components.

In the revised version this part has been modified:

"We showed that the fluvial source has a bi to multimodal distribution with two or even three modes. In order to obtain the best resolution in the identification of the fluvial source, we choose to use the sediment samples which were collected only along the River Fessi: S9, S10, S12 and S13. These surface sediment samples show a decrease in the mean grain size from upstream to downstream of the River Fessi watershed (Fig .6). The decrease in the mean grain size could be explained by a strong change of the topographic slope around Tataouine. Here, the coarser material is deposited and the finer material is transported away by the river. These finer sediments are deposited in the low plain of the river and in the El Bibane lagoon. Therefore, we suggest that S9 and S10 (collected between Tataouine and the lagoon) characterize our fluvial component in the lagoon. The grain size distribution for S9 is unimodal with a mean grain size around 96 μm and moderately sorted muddy sand named very coarse silty very fine sand and sample S10 is fine silt with trimodal distribution in 7μm, 26μm and 73μm, and poorly sorted mud sediment type. These characteristics will serve to identify the fluvial source into the lagoon".

What about the 4th group, i.e., the lagoonal samples? It is neither presented so far in the text, nor shown on Figure 5 (although it does on Fig. 6, interestingly). The distribution looks rather complex for this fraction in Fig. 6, and obviously shows a mixture between the different modal distributions (with at least a great contribution of fluvial samples).

The samples S4 and S5 are represented in the figure 6 (see also figure 4). These samples show a grain size distribution similar to those of the fluvial samples.

Page 8, lines 15-24: Here we are provided with XRF data given as percentage values. Please explain how these values have been obtained. Have the semi-quantitative XRF core-scanning data been calibrated by discrete XRF measurements as to determine linear regressions in cross plots and calculate percentage values from scanner data? Please clarify on that, and above all, please show the raw XRF data (in cps) obtained on core BL12-10.

The elemental analyses from XRF measurement were performed in mining type ModCF prolene mode. XRF provide a semi-quantitative measurement which shows directly concentrations in ppm or in percentage values. International powder standards (NIST2702 and NIST2781) were used to assess the analytical error and accuracy of measurement, which are lower than 5% for Ti, Cr, Fe, Zn and Pb, between 5 and 15% for Ca, Mn, As, Rb, Sr, and between ca. 15 and 25% for K and Co.

Another issue: Taken into account the very low ranges of variations (0-1.5% for Fe; 0-0.2% for Ti), how can you be confident with the interpretations (i.e., the discriminations into different environmental pools)?

We distinguished and classified these surface samples into three components. We discriminated these sources by the elemental analysis of Fe and Ti. For example, even though the low ranges of variations we could clearly see that marine source have Fe<2680ppm (equivalent to Fe<0.3%), the aeolien samples have Fe in the range to 3793-4980ppm (0.3<Fe<0.5%) and finally the fluvial samples have Fe in the range to 5350-15250 ppm (0.5<Fe<1.5%). Moreover, the gradient of Fe values from the upstream of the watershed to the littoral is well pronounced. These results are significant and are higher than the error limits of the analytical measurement. We can assume from these data that the Fe and Ti can easily distinguish the three components (eolian, marine and fluvial).

Page 9, line 5: Please change Fig. 7 into Fig. 8. Done

Page 9, lines 18-19: Please rephrase here, a verb is missing. Done

Page 10, lines 5-6: Do you mean mud or clay layers? Mud is usually enriched in organic matter, whereas clayey sediments are not. What do you mean by mud layers typically composed of clay and silt sediments? By the way, there is no mud shown on Figure 9.

We mean mud. The BL12-10 core showed three dark grey layers of clay and silt (6 to

10 cm, 14 to 18 cm and 26 to 30 cm). These three dark grey layers are mud layers because they are rich in organic matter.

Page 10, lines 6-7: Where do these flood layers appear on Fig. 9? How did you identify it ? I regret that the quality of Fig. 9 is so poor! Please redraw this figure accordingly.

We agree the review and this figure was redrawn.

Page 10, lines 16-18: I do not understand this sentence! It provides a very simplistic explanation for the discrepancies observed between 210Pb and 137Cs data. Did you also measure 241Am throughout core BL12-10, which would help in solving this apparent mismatch?

The 241Am was too low to be measured. We think that the difference between the two methods could be explained by a change of the accumulation rate between the beginning and the last part of the 20 century or due to the low number of 210Pbex measures that do not allow us to use the CFCS model to its optimum. However, the accumulation rate estimated by 210Pbex and 137Cs in this dynamic environment is not too bad (0, 37 cm/y with 137Cs and 0,48 cm/y with 210Pbex).

6. Discussion

Page 11, lines 20-23 and thereafter: I do not understand why the Discussion chapter still contains results/interpretation. The outcome of the PCA analysis should definitely be treated in the Results or Results/Interpretations chapter, but not in the Discussion!! Please modify this accordingly.

In the revised version this part has been modified accordingly.

The Discussion should be the locus where the results are integrated regionally, and at a larger scale, regarding the main scientific question identified in the introduction. Here we are provided with results in the Results chapter, followed by results in the Discussion chapter. See also my comment Page 7, lines 11-13.

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Please see reply to Page 7, line 11-13.

Page 11, line 4: I do not understand why this reference is suitable and of interest here. Please check this and correct accordingly.

This reference has been removed

Page 11, lines 13-15: I do not agree that Fe and K (at least) showing negative loadings on Factor 2!!

In the revised version this sentence has been modified. Indeed, Fe and K show a positive loading on Factor2.

Overall, I am not convinced by the application of a PCA analysis here to discriminate between different sources. Please explain why the PCA analysis brings compelling useful evidence for the interpretation of environmental proxies.

PCA was performed on geochemical analysis to distinguish the different sediment components. We applied PCA to regroup these elements and to identify the main factor controlling the chemical compositions of sediments from the catchment and the El Bibane lagoon. Thereafter, elements have been regrouped as fluvial, marine and Aeolian sources with respect to the two factor loading. This method has the particularity to highlight in the same figure the different components. Such figure is easily understandable.

Page 12, lines 3-9: Are these results really unexpected? What do we learn here? Do we really need geochemical proxies, grain-size data and PCA analyses to show that lagoonal sediments are made of a mixture of continental and marine sources? Why this still is presented in the Discussion??

Yes. We think that this approach is necessary to identify extreme events of fluvial, marine or Aeolian sources which could be recorded in the lagoon sedimentary archives. At regional scale, any paleoenvironmental reconstruction would be impossible without this classical approach. The objective of this paper was not to verify that lagoon deposits were a mixture of marine and continental sediments. Our paper deals with the calibration of different environmental tracers for paleoenvironmental reconstructions.

Page 12, lines 12-15: Looking at the data, it is not really obvious that one could define genuine palaeoflood events. How do you discriminate between a background fluvial influence within the lagoon and genuine palaeoenvironmental disruptions (e.g., exceptional flood events recorded in the sediments = eventites)? Is there a threshold to be considered in the data?

The multi-proxy approach using sedimentological and geochemical analysis has permitted the identification of three flood deposits. 210Pb and 137Cs geochronology have been used to date these flood deposits. These dated three flood deposits correspond to three historical heavy precipitation events. These events are extreme events. We suggest that the El Bibane lagoon may record past extreme flood events.

Page 13, lines 17-19: May this alternative explanation account for the apparent discrepancies observed between 210Pb and 137Cs data? Apart from that, if the BL12-10 core consists of a background sedimentation disrupted by occurrences of flood events during the past century, it should definitely be taken into consideration when calculating average sedimentation rates. Did the FL1, FL2 and FL3 flood layers excluded for the estimation of sedimentation rates? If not, this has to be commented.

Numerous studies have used 210Pbex profiles to identify abrupt events. In these studies, the 210Pbex activity versus depth curve is nonlinear and thus cannot be explained by radioactive decay alone. The activity within these disturbed layers is particularly low and is linked to sediment deposits that have been reworked (Arnaud et al., 2002; Dezileau et al., 2006). Thus, the 210Pbex profile may permit us to identify the disturbed areas in a sediment core. In our study it is not the case. The FL2 flood deposit is the most obvious sedimentological and geochemical event. This event is not manifested by a decrease of 210Pbex. This result can be explained by the fact that: 1) the sediment supply from the watershed with the 210Pbex is not deeply mixed with old material.

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There is little remobilization of sediment, which is not specious given the thin lateral terraces along the River Fessi. 2) FL2 flood deposit constitutes a series of large floods between 1969 and 1979. This FL2 deposit receives 210Pbex from the watershed over a 10 years period. This study shows that we do not reconstruct a single flood event but rather a succession of events concentrated in a period of time. And 3) it is possible that the bioturbation smooth the profile of 210Pbex. In this case it is difficult to identify disturbed levels in a sediment core.

Moreover, if the FL2 layer represents more than one flood deposit (e.g., 3 floods events as suggested), why do all sedimentological proxies (i.e., Fe/Ca and Ti/Ca, clay+silt fractions) peak only once in FL2 ?

The geochronology of the FL2 flood deposit extends from AD.1965 to AD.1980. Between these dates, two historical extreme flood events are known (AD.1969 and AD.1979) and one flood event of lower magnitude (AD.1972). Only one deposit occurs in the case of the BL12-10 core. Consequently, we assume that this unique flood deposit is linked to these three high precipitation events (i.e. AD.1969, AD.1972 and AD.1979). The sedimentary supply from the different rivers in relationship to these heavy precipitation events has been trapped in the inundation plain, in the Lagoon and probably transported to the Mediterranean Sea through the passes. The sedimentation rate belonging to these events in the lagoon is not very high. Otherwise, these events are sedimentologically and geochemically recorded. Bioturbation and bottom currents in the lagoon have probably smooth the signal. Finally, the three extreme flood events are registered as only one deposit in our sedimentary archive.

What about the 1984 flood recorded in the Tataouine watershed as shown on Figure 3 ? May this correspond to the peaks observed in Fe/Ca and Ti/Ca at the lower end of FL1 (around 10 cm)?

The 1984 flood cannot correspond to the lower end of FL1 flood deposit. Taking into account our age model it is difficult to link FL1 to 1984. Moreover the 1984 flood event was a weak magnitude event. It is possible that this low magnitude event is not recorded in our sedimentary archive.

References: Many references are listed in the reference list but do not occur in the text. There are listed here below, but please check the reference list in general. Done Beker (1989) is missing in the text. Guelorget et al. (1982) is missing in the text. Plewa et al. (2012) is missing in the text. Prospero et al. (1981) is missing in the text. Raji (2014) is missing in the text. Richter et al. (2006) is missing in the text. Torres-Padron et al. (2002) is missing in the text. Done Figures: Figures 1, 2, 3, 4, 5, 7, 8 are of good visual and graphical quality in general. In contrast, Figures 6, 9, 10 and 11 are of poor quality (Fig. 12 acceptable) and should definitely be improved before the manuscript can be reconsidered. These figures have been modified accordingly.

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