Interactive comment on "Late Pleistocene to Holocene climate and limnological changes at Lake Karakul (Pamir Mountains, Tajikistan)" by Liv Heinecke et al.

BW Wuennemann (Referee)

Received and published: 4 May 2016

Dear Prof. Wünnemann,

Thank you for your general statement and constructive comments. We think we will be able to incorporate the majority of your comments and are certain that they will improve the manuscript.

General statements

The authors Heineke et al. used a variety of different proxy records from the eastern basin of Lake Karakul and reconstructed climate-driven sedimentary processes throughout the last 28 kyr BP. They combined endmember modelling approaches on grain size data with geochemical parameters (TOC, TIC, TN/CN, TiO2), stable 13C and 18O isotopes from authigenic carbonate and selected xrf-derived ratios of Sr/Rb, Zr/Rb and Fe/Mn to infer variations in depositional conditions in the lake, governed by the Westerlies and the Summer Monsoon system. According to their grain size results the authors assign all grain size parameters primarily to eolian and fluvial input, of which the endmembers EM1,2 and 4 are characteristic of westerly-derived sources whereas the fluvial sediments(EM3) are interpreted as indicators for monsoon precipitation in that region. In general the manuscript is well organized and partly well written. Meanwhile, the figures need substantial improvement for better visualization and clearness. The interpretation of the processes related to climate control remains a matter of debate. The manuscript needs substantial improvement before acceptance can be recommended.

Detailed scientific comments are below

Referee 1 Comment 1

Study site: The description of the study site remains more general. Information about the relationship between the eastern part of the lake and related catchment conditions (glacier contact, inflow regions, former shorelines, potential terraces, and other morphological features such as dunes etc.) close to the drill site are not considered well enough. It should be noted that a larger drainage system enters the lake in close vicinity to the drill site, which could influence the lake record to a certain extent.

Authors Response 1

We thank the Prof. Wünnemann for this comment and will extend the study site description accordingly.

Referee 1 Comment 2

Materials and methods. It is a pity that overlapping drilling could not take place which is

meanwhile a common practice in drilling activities. The expected “small gaps” between the core sequences are hard to calculate. Even doubling of sediment retrieval could be possible. It would be interesting to know whether a UWITEC ground plate was used to fix the exact opening of the piston within the same hole or whether this was done by more or less free calculation from the rope length. Both, gaps or doubling, can influence the exact stratigraphy and thus also the chronology.

Authors Response 2

A UWITEC ground plate was not available for the drilling of the cores from Lake Karakul. However, two parallel cores were drilled 10 m aside. The parallel cores can be correlated and the small gaps “filled” when a master core is produced. Unfortunately, this work was not possible and not included in the ongoing PhD study project of the first author due to time constraints. Preliminary correlations of both parallel cores and first dating results for the second core show that the first core (discussed in our manuscript) has a robust chronology and does not include large gaps in the sediment stratigraphy). However, the description of the correlation of both cores and additional dating results for the second core are not included in the current manuscript which is already very long due to the many proxies presented. Information about both correlated and dated cores will be presented in a planned manuscript in the future.

Referee 1 Comment 3

Laboratory analyses: The sentence (lines 23-25) is incomplete. Re-phase.

Authors Response 3

The sentence will be rephrased and thus will be clearer.

Referee 1 Comment 4

Calculatinga mean reservoir error from two modern plants seems reasonable, although there are plenty of examples that the reservoir error at a certain site of the lake can vary considerably. The assumption of unchanged reservoir errors through time is unlikely and limits the validity of the chronology. This should be mentioned. To my knowledge the parameter setting for the Bacon model (mean accumulation rate and memory strength) is the default in this model. Hence, it is unclear what has been changed and why it was changed. On the other hand I wonder why the authors did not use 210Pb/137Cs dating to prove the upper several centimeters of sedimentation and to check the reservoir error of the second dated sample at 0-1 cm depth. Just discarding because of post bomb effects on the age is a somewhat simple explanation. Furthermore, the age of sample no KK12-1 538 shows an unusual low age (2430 +/- 30 14C yr BP). Why does this age correspond to 10313-12057 cal yr BP (Tabple 1)? Is there a mistake in type writing? If not, this has to be commented.

Authors Comment 4

Thank you for this comment.

Of course we cannot be sure that the lake reservoir effect did not change through time. However, we sampled two living macroalgae from the lake floor during different years and at different sites within the eastern basin which provided similar ages within dating uncertainties (1420 and 1315 yrs). Because we were not able to find terrestrial plant matter for dating core materials we had to assume a constant reservoir effect to be able to calculate an age-depth model. We will describe this in more detail the revised manuscript.

Concerning the Bacon model, we will show the model figure with the default settings if this is preferred. The model parameters have been adapted to the specific features of the core, which is very rich in macrophyte remains. Therefore, an increasing memory effect can be assumed, especially in the upper part of the core. The mean accumulation was set to 20 years per cm, as the average calculated accumulation is 0.49 mm/yr.

We did not use $^{210}Pb/^{137}Cs$ dating as we are not focusing on the last 1000 yrs or the late Holocene and rather focused on radiocarbon dating to cover longer timescales. It is moreover likely that the dense modern cover of macrophytes at the core site cause bioturbation of the sediment, especially in the upper part of the core. *Radix* and especially ostracods and insect larvae living in the sediment were also found and are likely to disturb the sediment at least in the upper centimetres. So, we expect that the use of $^{210}Pb/^{137}Cs$ dating is not providing robust results.

We did not use a surface sediment sample (0-1 cm) for the determination of the reservoir effect since the calculation of the radiocarbon age requires knowledge of the atmospheric ^{14}C concentration during the time of the sediment accumulation. A sediment slice of 1 cm thickness certainly includes several years of sediment accumulation during which postbomb-testing atmospheric ^{14}C concentrations were not stable but decreasing. Instead of using a surface sediment sample, two living macro-algae provide a significantly better way to access the modern lake reservoir effect.

Sample KK12-1 538 shows a very young age confirming our suspicion that young overlying material got into the coring tube during core recovering. This is furthermore confirmed by the lithology of this part of the core. For this reason we excluded this part and marked it as contaminated/core loss.

Referee 1 Comment 5

Results and Discussion: To my understanding, a detailed description of the lithology is missing.

Authors Response 5

Thank you for this suggestion. A paragraph to describe the core as well as a Figure showing the lithology will be added to the manuscript.

Referee 1 Comment 6

A combination with original grain size classes against sediment depth could perhaps show, why the calculated sedimentation rates along the core are so different between 0.15 and 0.84 mm/yr. For example, what is the reason that the upper sediments display much higher rates than the lower parts? Is there a clear change in sediment grain size composition? If not, a clear reason has to be stated. Perhaps the older ages are strongly overestimated.

Authors Response 6

We thank you for this comment and suggestion. We will describe more clearly that the upper part of the core contains very abundant macrophyte remains which explains the higher accumulation rates in this section. The lowest accumulation rates are found in the core sections where no macrophyte remains were found. Therefore, although the grain-size composition is probably affecting the sediment accumulation rate, we assume that the occurrence and concentration of macrophyte remains influences the accumulation rate more significantly. The grain-size data alone do not represent very significant variations to explain the large changes in sediment accumulation rate.

Referee 1 Comment 7

The explanation with respect to the endmembers seem to be not really consistent. The authors argue that EM 1 is related to very fine far-distance eolian transport, deposited with precipitation events derived from the Westerlies. The same applies to EM2 which is somewhat coarser in grain size. However, the authors mention the potential contribution of these grain size classes also by meltwater from the nearby glaciers. This is a contradicting process which was not thoroughly considered at all. Why is it not possible that meltwater discharge with generally high proportions of clay and silt (glacier milk), producing at least the offshore fine components (EM1 and EM2) at the drill site? If this process would be an important contributor to the overall lacustrine deposition, the inference of westerly-derived remote sources becomes less important.

"A dominance of EM2 sediments in the LGM indicates high influx of dust and generally arid and cold conditions" (page 12, lines 6 ff). Why must the climate be arid and cold? There are several papers demonstrating eolian transport also during so-called warm-wet climate conditions (e.g. Stauch et al., 2012, QSR, Stauch 2015, ESR).

Authors Response 7

Thank you for this comment. We mention in the interpretation, that it is not certain where the sediments with very fine grain sizes come from. We assume that they mainly originate as dust transported by the westerlies, however we also mention the possibility of sediments derived from "glacier milk" which would reflect a meltwater discharge signal. While end-member modelling can be used as a tool to decipher grain size signals, the related transportation and deposition processes of the identified endmembers are a matter of interpretation. The EM1 and EM2 signals were not reproduced by the reference samples, which leaves room for assumptions. Nevertheless we will pay more attention and expand the discussion of the possibility of EM1 and EM2 as a meltwater-induced signal.

Referee 1 Comment 8

The assignment of fluvial sediments to summer-related runoff (at least from the glaciers as mentioned by the authors because annual precipitation is very low) is reasonable. But why is this water supply related to summer monsoon influence. Where is the real evidence for this?
Most of the cited references refer to locations much farther east (Monsoon realm). It is rather doubtful to transfer those results to Lake Karakul region. Furthermore, a recently published paper by Ramisch et al. (2016, SR) shows evidence for the limited

northward extension of the summer monsoon during the Lateglacial-Holocene period.

Authors Response 8

Thank you for this comment. We agree that the EM3 is a summer-related runoff signal and agree that we will phrase our assumptions more carefully. We agree, it is not possible to relate the sedimentological signal to precipitation as a result of the summer monsoon. Studies that have been performed in the area declare that the region is at present dominated by the Westerlies, yet mainly agree that it is located in a transition zone. However, clear statements are hard to find, with regard to the north-western boundary of the Indian Monsoon during its maximum extension in the Holocene. Arguing with studies that show a clear increase of moisture in the area (e.g. on Be-dates of glacial extensions, Dortch et al. 2013, Zech et al. 2005), one may speculate that a northward stream of the monsoon reached the north-western margin of the Himalaya and the Pamir. Nevertheless we agree that more and probably other data would be needed to underpin this hypothesis and we will remove the proposition that EM3 is reflecting a summer monsoon signal.

Referee 1 Comment 9

Finally, it should be paid more attention on the real catchment-related processes when interpreting grain size data towards almost solely eolian activity in this region, as stated in the abstract and discussion part.

Authors Response 9

We agree. We will not only discuss aeolian contributions to the sediment accumulation in Lake Karakul in the abstract and discussion part but will include fluvial influx too.

Referee 1 Comment 10

The authors argue that changes in redox conditions are due to variations in lake level that induced changes in ventilation (aerobic vs anaerobic conditions). If the core was taken from 12 m water depth, how much deeper water would be necessary to enable anoxic conditions in bottom waters? Furthermore, the data resolution is quite low (10 cm sample distances indicate a resolution of 150-250 years, according to the tentative chronology) which is currently not a step forward in this field of research.

Authors Response 10

Thank you for your remark. We are not certain how much deeper the lake would have to be at the coring site to induce changes in redox conditions since data concerning the dissolved oxygen concentration for different depths are not existing for Lake Karakul. However, many lakes on the Tibetan Plateau have a thermocline at 20 m water depth or slightly below during summer, and at least seasonal anoxia may form already with a lake level increase of ca. 8 m at Lake Karakul. However, the sediment core data show a clear change in redox conditions in zone two. Taking the changes in sediment composition of the core into account, an abrupt shift in the lake setting has to be assumed. Numerous studies implied changes in redox conditions based on Fe/Mn ratio changes, which can have several reasons, such as lake level changes or prolonged ice cover, both influencing the ventilation of bottom waters. Komatsu and

Tsukamoto (2015) investigated higher palaeo-shorelines above the lake which were probably formed during zone two. Thus, it is likely that Lake Karakul experienced a phase of increased lake level.
Concerning the data resolution, we are aware that a higher resolved record would be better. However, since only one short record exists from the area (104cm; Mischke et al., 2010), and since there are many different analysis and data presented in the current manuscript, we feel that the current data set provides a good base to improve the knowledge and understanding of the climate history of an intensively discussed region.

Referee 1 Comment 11

With respect to the figures, some improvements are really necessary: 1. Fig.1 is a copy from Google maps. This is generally ok but it should be mentioned in the figure caption. Also Google maps provide the date of the imagery which might be importan

Authors Response 11

Thank you for your comments concerning the figures. We will revise these.
Figure 1 is actually a satellite image (Landsat-8 (OLI) - also used by google maps) acquired on July 22 2014. We will make this clear in the Figure caption.

Referee Comment 12

Fig.2 is incomplete. Using Bacon package in R, additional graphs about the data performance, sediment accumulation rate and memory strength should be added. The axis description need to be adjusted (starting with capitals) according to the other figures. Yr cal BP should be replaced by Age (cal yr BP).

Authors Response 12

We will add the additional graphs and revise the axis description.

Referee 1 Comment 13

3. Fig.3 is the most unpleasant figure because it is too small in size and numbering and provided too thin lines. Lines between the units are not really visible. Each individual graph in both parts should have a numbering too. It is not suitable to refer to fig 3 without mentioning which of the graphs shall be considered. I suggest to split the graphs and show them in horizontal order. You may also decide to present the graphs in color. Furthermore, the EM 1-4 should also contain the related process to avoid backward search for the meaning of each EM. The same applies to the PCA axes. You may also think to skip TOCBr from the graphs, as the data are directly comparable with TOC values. This graph may be placed in the supplementary data set.

Authors Response 13

We will revise Fig. 3. and split 3A into two parts. The line thicknesses and label sizes will be improved. We refrain from labelling all EM 1-4 graphs with related processes because a direct assignment of processes is considered as over-simplifying. However, we will strive to name processes in cases of relatively robust EM-process relationships.

Referee 1 Comment 14

4. Fig. 4B shows the data from on-shore regions. The figure caption does not fit to the two graphs. It remains unclear what is the meaning of modern pond? Frequence should be replaced by Frequency.

Authors Response 14

We will revise the figure and follow the referee's suggestions.

Referee 1 Comment 15

5. Fig 5. Also too thin lines exist, similar to Fig 3

Authors Response 15

We will revise the figure and follow the referee recommendation.

Referee 1 Comment 16

6. Finally, an overall summary figure could be helpful to demonstrate the processes through time and the climatic inferences.

Technical corrections The graphs have to be improved as mentioned above.

Authors Response 16

Thank you for this suggestion. We will prepare a summarizing figure which compares the key proxies (such as the PCA scores currently shown in Fig. 3).

Referee 1 Comment 17

There are several incomplete sentences which should be corrected during re-writing. English proofread could be helpful too.

Authors Response 17

Thank you for this comment. We will check for incomplete sentences. The manuscript went through prove reading by a native speaker before submission and the revised version of the manuscript will undergo the same process.

Interactive comment on Clim. Past Discuss., doi:10.5194/cp-2016-34, 2016.