## Replies to Reviewer 2

The author carried out a study about the survival of the Qaidam mega-lake system in Pliocene by analyzing the modern water balance of the basin. The author finds that the water balance of Qaidam basin is nearly zero under present climate condition and believes that Qaidam basin may switch from negative to positive in the near future.

Reply: The study addresses both the state of the Qaidam basin's water balance during present-day conditions, and its sensitivity to variations in mean annual near-surface air temperature and humidity spatially averaged over the basin. I as the author do not believe anything; I am just reporting and interpreting the results of the study, which is based on data that has been rigorously validated against independent observations. In particular, I do not speculate on the evolution of the Qaidam basin under future climates, moreover I showed that the basin's water balance is highly sensitive to changes in mean annual air temperature and specific humidity such that it is physically possible that the mega-lake system could be restored on geological time scales, as it has happened several times in the past as independent proxy-based studies have revealed.

Although the story is quite interesting, there is a lack of robust evidence. In particular, the time scale of data used in the analysis is so different from a geological epoch, and therefore their connection is reluctant.

Reply: The study does not intend to reconstruct the water balance of the Qaidam basin during the mid-Pliocene epoch. This is indeed impossible since no suitable paleogeographic or paleoclimate data required for detailed hydrological analyses or modelling studies are available, today. Moreover, I analysed the sensitivity of the present-day water balance of the entire Qaidam basin to variations in spatially averaged mean annual near-surface air temperature and specific humidity. Then, I used results from independent paleoclimate studies on the Qaidam basin for the mid-Pliocene epoch (both from proxy-based and numerical modelling studies) to illustrate that the long-term mean water balance would have been positive during this period. The rationale behind this approach is given by the fact that physical laws do not change over time, and the results are in accordance to independent findings by the proxy-based studies that show the existence of a mega-lake system during a period of intensifying aridification of the region. I will add further details and additional references on this topic. I also discussed the assumptions and limitations of this approach (P7 L210-221).

I do not know how robust this linear speculation between the current and past lake conditions could be. As far as my knowledge, there are several fundamental flaws.

Reply: I don't speculate but carried out a study that strictly follows the principles of transparency and reproducibility. If the reviewer questions the correctness of my analyses he/she might download the freely available data and check my statistical analyses. The reviewer might also give reference to studies that contradict my findings. Again, it is important to recognise that the study does not try to reconstruct the water balance of the mid-Pliocene epoch. In this case, I would, indeed, have to prove that the current sensitivity would have been the same in the past. I only showed with my study, that the current sensitivity, which is statistically significant and in accordance with findings from independent studies, would be able to explain how the mega-lake system has survived under the still very dry climates of the mid-Pliocene epoch. I also discussed the limitations of

this approach, but I realise from the comments of the reviewers that the whole concept behind the study needs to be better explained, and that the results need to be further substantiated by adding more references.

1. Line 32, lake evaporation is missing in the equation. Lake evaporation is very different from land evaporation. Although it is very small in modern time because the lake area is small (only ~1000 km2), it can be much large when the lake area is hundred times (~120, 000 km2) in Pliocene. Moreover, it is hard to derive the water balance in such a case from current HAR data, considering very different effects of a large lake area that is not included in HAR data. Lake evaporation is neither considered in the remaining discussion. For example, in line 227-231, the author did not consider the impact of lake evaporation.

Reply: Evaporation of lake water is included in the study. Spatial averages of all physical quantities also comprise grid points indicated as lakes in the HAR data set. I also discussed the specific role of lakes in P4 L116-125. In addition, I stated in P8 L242-243 "…*Since lakes tend to reduce precipitation while concurrently showing high actual evaporation, there should be an upper limit for lake growth, which is, however, not yet known*…" If the reviewer is aware of any study that quantifies lake evaporation of the mega-lake system of the Qaidam basin (or a mega-lake in any other basin) during the Pliocene, I would be very happy to get knowledge about the results. There must definitely be such a negative feedback mechanism limiting lake growth, and it would be of utmost importance for reconstructing the evolution the mega-lake system to know more about the details. I have also mentioned in P8 L243-246 that regional water recycling could counteract this feedback, but the quantitative role of this process is also still unknown. Thus, I concluded that further studies are required on these topics.

As shown in Eq. (1), the water balance of a large endorheic basin can be approximated by net precipitation, i.e., the difference between precipitation and actual evapotranspiration, which also comprises lake evaporation. Thanks to the comments of reviewer 1, I detected an error in Eq. (1) that needs to be corrected in a revised version of the manuscript: the term $\Delta Q_{sub}$ (indicating subsurface) in the equation must be replaced by $\Delta Q_{gw}$, which is the term used in the text for changes in groundwater storage. I will also change the terminology in the revised manuscript, such that the term water balance is only used when referring to the spatial average of net precipitation over the entire basin. Net precipitation shall be used when referring to individual grid points or areas within the basin, because then, lateral fluxes inside the basin are correctly treated.

In fact, when the lake continues to increase, lake evaporation increases and an equilibrium between input and output will be reached. Therefore, lake water level would not rise by 400 m over the basin within only 10 ka, even there is a positive long-term mean annual water balance.

Reply: See my comments above. Since lake evaporation is included in the water balance, a positive water balance would in fact result in an increase in terrestrial water storage (TWS) and subsequent recharge of the reservoirs including the lakes as stated in P8 L227-231. As proxy-based studies have shown, lake levels in the Qaidam basin have indeed shown drastic changes in the past during the Pleistocene glacial cycles. The interglacial periods have usually been shorter than the glacial periods, lasting for about 10 to 15 ka. So, the question arises how the mega-lake system could have been restored, at least partially,

during such comparably short time periods. The findings of my study imply that lake restoration could take place within such short time periods without requiring drastic climatic changes, for which there is no evidence. I do not say that the sensitivity of the water balance of the Qaidam basin has been the same as today. But as Dowsett et al. (2010); cited in the manuscript, have stated that the paleogeographic situation of the mid-Pliocene epoch has been similar to the presence, this holds even more true for the Pleistocene, and definitely true for the near future. I am not aware of any study that has shown that the sensitivity of the water balance to changes in air temperature and humidity has been different than today. So far, this remains to be an unproven hypothesis. Therefore, I do not understand, why my approach, i.e., applying the physically based sensitivities as shown in Table 2 to estimates of the plausible range of changes in air temperature and precipitation during the mid-Pliocene as inferred from independent studies, both proxy-based and model results, should be scientifically wrong.

2. Line 166-174, as the author said, both lake area and lake number in the Qaidam basin have increased from the last two decades. The groundwater in the Qaidam basin was recharged between 2003 and 2012 due to changes in terrestrial water storage of 20.6 km3 at rate of 8 mm/a. These studies indicate that there should be considerable positive water balance during the last two decades in Qaidam basin, which contrasts with the main conclusion of the study, which shows the water balance of the basin is almost zero (Line 174).

Reply: I discussed that the results from GRACE satellite-based analyses are also showing that the hyperaridity of the low-lying regions of the Qaidam basin is misleading, when water balance of the entire basin including the high-altitude regions is to be assessed. For the same time period, the GRACE data show +8 mm/a while the HAR data set indicates 0 mm/a. Unfortunately, I could not find a specification of the error of the GRACE-based results in the publication of Jiao et al. (2015), but it is obvious that the error is in the order of at least ±10 mm/a. The uncertainty of the water balance as derived from the HAR data set is ±34 mm/a for the entire study period as specified in P4 L94. So, both results are not in contradiction. I also discussed further results from independent studies that clearly indicate that the water balance of the Qaidam basin has been positive during this period which showed warmer and less dry climate conditions. There is no study that is in contradiction to the results derived from the HAR data set for the recent time period.

3. L194-197: “the estimated changes in precipitation due to changes in air temperature would be 52 to 105 mm/a. The mean change in water balance as inferred from the changes in air temperature would lead to a positive mean annual water balance of 49 mm/a.” I cannot believe this derivation. The positive water balance is too big, because most of precipitation would be lost through evaporation in such a dry environment.

Reply: It is not a matter of belief but just the result of a computation using a) the present-day sensitivity of mean annual precipitation to changes in mean annual air temperature, and b) the present-day sensitivity of mean annual water balance to changes in mean annual precipitation, all quantities spatially averaged over the entire Qaidam basin, i.e., including the less dry and colder high-mountain regions. The starting point of this computation is the range of plausible changes in mean annual air temperature relative to the present-day situation, which has been taken from the literature, and is conservatively set to 1 to 2 K

in my study. Applying a) gives 52 to 102 mm/a more presentation than today. This range of precipitation change is in accordance with the paleoclimate studies I have cited in the manuscript. Taking these values as input in b) leads to 42 to 84 mm/a higher values for the water balance than today. In absolute terms, i.e., taking the value of -14 mm/a as the current estimate, the water balance would be between +28 and + 70 mm/a, i.e., +49 mm/a on average. Please regard that any kind of evaporative water losses are in fact included in the sensitivity of b).

4. The main conclusion of the study is 'near-future climates not much different from present conditions could cause rising lake levels and expanding lake areas, and may result in restoration of the Qaidam mega-lake system over geological time scales' (line12-14). Although I am not a paleo-climatologist, I guess the formation of megalake system over geological time scales might have underwent special climate conditions (e.g. different scales of lake-air interaction, different land cover condition), and this speculation is quite uncertain. Even current climate yields positive mass balance, this positive balance would be lost soon due to the increase of lake evaporation when lake expands.

Reply: As discussed above, my study results are neither a reconstruction of the water balance of the mid-Pliocene nor a projection of the future water balance. I only conclude that there is no need for drastic climatic or environmental changes to explain the existence of a mega-lake system in the Qaidam basin. Using the results from the scientific literature that I have referenced in the manuscript, there is proven evidence that the mega-lake system has actually existed in the Pliocene. So, there must have been a physical mechanism that has allowed the mega-lake system to sustain such a large lake surface (about 120.000 km²) for long time without losing more water by lake evaporation and evapotranspiration over land than gaining by precipitation. The feedback mechanism that limits lake growth has been prominently mentioned in the conclusions part of my manuscript to make clear that the positive water balance will not be able to persist over unlimited time, and finally must reach an equilibrium. However, I stated that we do not yet have enough knowledge on this mechanism to use it for quantifying the effect, which would be prerequisite for any attempt to reconstruct the paleo-lake evolution in the Qaidam basin.