Replies to Reviewer 3

The paper provides a nice straightforward estimation of the regional water balance of the Qaidam basin. It is interesting to observe that the water balance calculations confirm that the balance is near zero. It implies that although parts of the basin has hyper arid conditions, there is apparently a zero balance. This as such answers the question: can a lake exist for prolonged periods in this basin under arid conditions.

Reply: This is exactly the main focus of the study. I will need to make this much better visible than in the current version of the manuscript.

I am struggling with the way this is framed. We have no future time series so we can only speculate what will happen in the future. It is interesting that the current trends of climate change seems to lead to a positive water balance. The problem I have is that this does not automatically imply that the lake level will rise.

Reply: Any kind of projection, e.g. the climate projections used by the IPCC or studies of future changes of the Asian monsoon system, would then be purely speculative. As the formulations in the first paragraph of the Conclusions section (lines 223-231) clearly indicates, I don't make any predictions but only refer to the consequences of a slightly positive water balance. All sentences are written as conditional statements, which means that I am fully aware that we don't know how the situation of the basin's water balance will develop in the future. If the long-term mean water balance of the Qaidam basin would be positive, then (and only then) the consequence would be that reservoirs would start to restore. I described this in the first paragraph, and I also stated that the first response would be that the groundwater reservoirs would be recharged, and then the lakes would also start to restore, which seems to be happening already now (see literature review in lines 162-174).

I think the claim of a tipping point (line 15) is not substantiated, it could be a threshold but a tipping point suggest a complete new system equilibrium. This can not be predicted with linear regressions based on the current system dynamics.

Reply: That is correct; I will use the term "threshold" in a revised version of the manuscript.

The link with the Mega Lake is also unclear. No information of its extent, depth etc is given. The existence of such a lake would invalidate many of the assumptions now made to calculate the water balance.

Reply: There is no spatially explicit information on the mega-lake system existing from the literature. But the geological evidence of its existence is referenced in the manuscript. The intention of the manuscript is not to reconstruct the mid-Pleistocene conditions of the mega-lake system but only to find a physical explanation for the existence of such a mega-lake system. The main answer is that the high-mountain parts of the Qaidam basin could have acted as regional water towers under slightly wetter and warmer climates that prevailed during the mid-Pliocene epoch (as indicated by the literature referenced in my study) such that the long-term water balance would not have been negative. In an (unknown) equilibrium state, water balance would have been zero, and positive during time periods when the mega-lake system would have been restored after periods of lake shrinkage, which have occurred several times in geological history.

Please discuss possible feedbacks in the studied system. You now seem to assume they dot not exist, which I consider unlikely.

Reply: In the last paragraph of the Conclusions section (lines 241-246) I discussed feedbacks that need to be addressed in future studies. I mentioned the most important negative feedback, i.e., increasing lake evaporation, that would finally lead to zero water balance even when precipitation would be higher than today due to changes in atmospheric circulation. There must be an upper, yet unknown limit for lake growth, which is, however, not subject of this study. I will make this point even more explicit in a revised version of the manuscript. I also mentioned the feedback that local recycling of water could be intensified when lake surface increases. Higher lake evaporation could potentially result in more precipitation within the boundaries of the Qaidam basin, which is large enough to support local recycling. This is, however, not yet quantifiable. I also discussed feedbacks due to orographic changes (see replies below), which would be relevant for the mid-Pliocene epoch but not for the next hundred thousand years.

Minor comments:

Line 7: the phrase increasingly arid climates is confusing given the fact that the analysis is not suitable to deal with large long term climate changes.

Reply: This sentence in the abstract is referring to the scientific literature that forms the motivation and background of my study. As it is part of the abstract, no references to scientific studies are given there. This is done in the Introduction section.

Line 14: the restoration of the mage-lake is very speculative given the fact that the calculations are based on 14 years of data. Such a restoration would need ten thousands of years.

Reply: See my replies above. I don't speculate on the future development of the basin but only describe what would happen if long-term mean water balance would become positive, which is a realistic scenario as my study reveals. My study shows that this could happen (or may even have already started to happen) under subtle changes in the regional atmospheric circulation. Using the results from my study, I made an example calculation (lines 223-231) to illustrate that even a slightly positive, physically realistic water balance would have a huge cumulative effect over ten thousand years. This is, of course, not a prediction since no feedbacks are considered in the example calculation, and future changes in atmospheric circulation are not known!

Line 24: the disappearance of the lake during the last 100 ka is intriguing. What was different?

Reply: This is a very interesting question but not part of my study. The disappearance of the mega-lake system is described in the scientific literature. However, the details of the lake and climate conditions are not well constrained by observational data. I would regard to find an answer to this question as a highly ambitious but valuable goal for future research. My study reveals that climates colder and drier than today would probably drop the water balance due to reduction in precipitation. Although the mega-lake system disappeared there are nevertheless substantial variations in lake levels during this period. Such lake-

level variations have been reported even for the Holocene, showing that the remaining lakes are highly sensitive to small changes in climate conditions, as revealed in my study for present-day geographic conditions.

Line 30-40: please provide units and support (10*10 km for example)

Reply: I will need to reformulate the manuscript regarding the terms "net precipitation" and "water balance", as already mentioned in my replies to the other reviewers. The term "water balance shall only be used when net precipitation is integrated over the entire basin. I will add suitable references as support. However, I don't understand, in which context units are missing.

Line 45-50: please formulate a concrete testable hypothesis. I propose that within the Qiadam basin the water balance is near zero.

Reply: In fact, this was not the starting point of my study. I didn't expect a near-zero water balance. Moreover, the original hypothesis was that increasing air temperatures would make the water balance less negative under present-day conditions. The results of my study showed that this is indeed happening, but the statistical analysis showed that not air temperate but specific humidity and the combined effect of air temperature and specific humidity are driving annual water balance variations. I will explicitly formulate this in a revised version of the manuscript.

Line 74: what are valid data? How is this supported by evidence?

Reply: The expression "valid data" refers to the fact that meteorological data are existing for the time period and are not flagged as invalid by the data provider.

Line 82-84: is there possibly spatial autocorrelation in your analysis?

Reply: The results presented in Figure 4 are spatially averaged pairs of annual values for the entire Qaidam basin, thus there are no problems with spatial autocorrelation.

Line 103: are you implying that there are feedbacks in the system? If this is the case, it implies that you should be very carful to use your regression relationship outside current conditions.

Reply: There are definitely feedbacks in the system when paleographic or future geographic conditions (especially total lake surface) would change. For this reason, I always use the term "sensitivity" and refer to the present-day geographic conditions. All statements referring to the mid-Pleistocene epoch or to the future are thus conditional, indicating that they are only simplified projections, and shall in no way be regarded as predictions.

Line 120: an important conclusion. Please emphasize this more in abstract and conclusions

Reply: I will consider this in a revised version of the manuscript.

Line 134: same as above important insight in current system

Reply: I will consider this in a revised version of the manuscript.

Line 174: how sensitive is your study for spatial resolution?

Reply: Interestingly and surprisingly, the results did not substantially differ between the 30 km and 10 km gridded HAR data (see lines 218-221 and the results presented in the supplement). As long as major features of the orography of the Qaidam basin are present in the dynamical downscaling runs, and thus, the mesoscale atmospheric processes induced by orography are resolved by the model, then the results are similar. I will add more details on this topic in a revised version of the manuscript (see also my reply below).

Line 197: how long would it take to fill up the whole mage-lake (with this rate of 49 mm/a).

Reply: I have made an example calculation using 40 mm/a as long-term mean value for the water balance (see lines 227-231). Since no feedbacks are included and no differentiation between the reservoirs (groundwater, lakes, …) has been made, the result (400 m rise of the water table in any of the reservoirs averaged over the entire basin within ten thousand years) is only illustrating that huge lakes could form within a geologically short time period. This calculation serves to show that 'rapid' (time scales of thousands to hundred thousand years) lake-level changes as reported in the scientific literature are not physically unfeasible. Since there is no spatially explicit information on area, depth or volume of the mega-lake system available from the literature, a spatially explicit computation would be impossible, even when feedbacks would be included (making the water balance time dependent).

Line 238: how important can the orographic precipitation be? You now assume this not to happen. Ad how does the presence of a big lake affect this effect?

Reply: My study shows that orographic precipitation is one of the most important processes with respect to basin-wide water balance. As Figure 3 shows and is discussed in the manuscript (see e.g. lines 111-115), precipitation increases with altitude, which is a direct consequence of orographic precipitation. It is not altitude itself but relief that induces precipitation in the mountain ranges. The results of my study only show the sensitivity of water-balance components to variations of climate conditions under present-day geographic conditions. A changed orography and the existence of a mega-lake system would induce additional feedbacks (as discussed in my manuscript; see my replies above). This could also affect orographic precipitation. The effect of lower altitudes is partly captured by the HAR 30 km data set, since highest altitudes in the 30 km gridded topography are lower by a few hundred meters than in the HAR 10 km data set (see lines 220-221). This has two counteracting effects as discussed in the manuscript (see lines 210-221): precipitation would tend to decrease since orographic precipitation would possibly be weakened, but blocking of atmospheric water transport to the Qaidam basin by high mountain ranges would also be reduced. The latter effect seems to be stronger than the first one, since mean water balance of the Qaidam basin is +3 mm/a in the HAR 30 km data set while it amounts to -14 mm/a in the HAR 10 km data set.