Banerjee (Referee)

This paper reports on the surface area changes of unconnected glacial ponds in the south of Mt Everest during the period 1962 to 2013 using maps and satellite images. This time-series data is analysed to identify the drivers of the change using statistical analysis of the correlations with available meteorological data. However, the present draft may greatly benefit from a more careful analysis of this very interesting data set, and also a slightly more systematic description of the methodological details.

Comment: we thanks the reviewer for the revision. Generally, we hope to have suitably followed the suggestion received in particular in relation to the new analysis and the more detailed methodology.

My major concerns are as follows:

1) While it has been argued at the outset rather briefly that lakes and ponds are sensitive indicators of climate change, this point demands more serious consideration. The cited references of Beniston et al, 2006 do not seem to discuss lake/pond, while the other referred article by Burasachi et al, 2005 does not include a relevant discussion of climate sensitivity of the lake/pond area and particularly of the response time scales.

Answer: Thanks for the suggestion. The references are wrong as suggested by the reviewer.

Correction: the right reference is Smol and Douglas, 2007. PNAS

The temporal variation of the surface area of a given pond must be controlled by 1) the balance between water in and out - therefore by the climate, and 2) the bathymetry. But, any attempt to infer climate signal from sparse point measurements of such a time series has to take into account the relevant time-scales associated with response to the fluctuating climate variables.

Answer: we hope having followed all revision provided by reviewers, the suggestion provided by the reviewed could be suitably addressed.

For example in figure 3, some of the biggest ponds/lakes (eg LCN77, LCN24) show large (_5n%) increase/decrease in their area in a month's time, indicating a strong control of high frequency changes of the climate variables. For the rest of the ponds which are even smaller in size, these high frequency noise would presumably be even larger. How can this sparse time series with high frequency 'noise' that is of similar magnitude as the low frequency signal (_10n% change over 50 years), possibly be used to infer low frequency changes of the climate? In this context it may be noted that glacier length fluctuations can be inverted for temperature change as their slow response makes them immune to high frequency noise.

Answer: Figure 3 shows that some single pond presents singularly an Oct-Dec dispersion of around 5%. However, the same figure points out that just averaging this information on a population only a little bit larger, the dispersion between October and December becomes almost zero (1%). Climatic inferences from the behavior of ponds population surely needs to consider the widest number of ponds as possible in order to reduce the dispersion due to the local conditions of each lake. The same approach is used also in dendrochronology where a lot of cores are sampled and analysed.

Correction: the suggestion of the reviewer has been considered carefully inserting these concepts in the new text.

Similar large fluctuations are also seen in the annual rates reported in Table 3: During 1992 to 2011, rates are very small or insignificant and then there is a very large (1 to 2 order of magnitude larger than the background) spike during 2011-2013. In fact this spike dominates the mean. Is this a signal from a particular short-lived event picked up due to sparse sampling or a real climate change signal? Surprisingly, no such sharp changes are seen in the precipitation or glacier melt data during 2011-2013 as presented here. This needs to be considered very very carefully before accepting the interpretation offered by the authors here.
Further, this issue of high frequency noise can not be overcome simply by averaging over a large set of ponds from the same region, as they are all seeing a strongly correlated noise due to their spatial proximity. And of course, practical limitations like unavailability of suitable images etc would prevent a higher temporal resolution.

Answer: In relation to the abrupt change observed by the reviewer (-7% vs -25%,i.e., -18%), we can start observing Table SI2. The resolution of the two images is the same. Moreover giving a look at fig. 8 Fig. 8. Probably here it looks much less strange. From 1992 to 2011 the decreasing is 20% (the computation can be done also from the table 3 from +13% to -7%). Surely -18% in two years is a lot, but in in line with the decreasing of precipitation observed since the early '90s (Fig. 8). Furthermore the behavior of surface are change has been observed significantly correlated with precipitation.

Correction: this concept has been discussed in the text.

2) While the authors have employed a careful statistical methods to derive their conclusion regarding the climate signal, some simple physical considerations might strengthen their analysis. For example, the climate data (reanalysis/gridded) used is from the grid point that is closest to the Pyramid station. Would not be better to use the grid point closest to a given pond for analysing the area change data for that particular pond? This choice might have led to serious biases in the results as pointed out below.

Answer: Unfortunately, the grid resolution for Era Interim and GPCC does not allow to use the grid point closest to a given pond, because this point is common to all points and at same time it is the same grid node used in the comparison with the land wheatear station. We agree with the reviewer. In fact in the introduction we wrote: "their use for climate change impact studies at the synoptic scale must be performed with caution due to the absence of weather stations across the overall region, which limits the ability to perform land-based evaluations of these products". The added value of this work to have carried out a land-based evaluation of these products. Probably, the comparison presented in this work in the unique case where this comparison has been done for a so long period of time in the overall Himalayan range due to other long time climatic series do not exist in the region at so high elevation.

Moreover the comparison between ponds surface area and climatic variables is done with Pyramid data. To avoid further misunderstanding we tried to clarified these concept as specified below.

Correction: the method section has been rewritten to clarify the methodological approach followed in the paper: Moreover a map of Nepal showing the location of all 64 considered ponds and the grid/reanalysis nodes has been inserted in the Supplementary Material. In this way it is clear the comparison between the resolution of grid/reanalysis products and the distribution of the 64 considered lakes.

All the 'ponds with glaciers' (LCN 24,9,3,68) that show significant correlation with glacier-melt, are located in the Khumbu valley, within may be five km of the Pyramid station. So, how can one be sure about the controlling factor behind this pattern - Is it the glacier cover as claimed, or it is just the proximity of the grid point? In fact, data from LCN11 in the same valley has a relatively large correlation coefficient (_0.5, though probably not significant) with calculated glacier melt, while far-away ‘ponds with glaciers’ (LCN 76 and 77) has small (0.2-0.3) correlation with the glacier melt. This requires explanation.

Answer: please see the answer above.

Incidentally, there seem to be some ambiguity regarding the definition of two pond classes: with and without glaciers. Table 3 uses 5n% as a threshold; text gives a threshold of 10n%; Table 4 says LCN3 has 30n% glacier cover, while Figure 3 claims LCN3 is a pond without glacier. These differences need to be clarified and the sensitivity of the conclusions to this choice of threshold value may be discussed.

Answer: the threshold of 5% reported in the heading of Table is a mistake. The second suggestion is not clear when the reviewer says: “while Figure 3 claims LCN3 is a pond without glacier”… we do not know where this is discussed.

Correction: Table 3 has been corrected.

Also, the authors may discuss the spatial pattern of changes as seen in figure 7. For example, looking at this figure it seems statistically significant differences may emerge in trends from the set of ponds near Ngzumpa glacier (Gokyo valley) and Khumbu glacier (Khumbu valley), irrespective of glacier cover extent. If so, then what is the relevant control, having more than 5n% glacier area or the ponds being in the same valley?

Answer: According to the suggestion we tested the significance of possible differences of surface area changes (1992-2013 period) among ponds located in different river basins. Moreover we tested the significance of possible differences of surface area changes among ponds with different glacier cover.

Correction: a new figure in the Supplementary Material has been added showing box-plots representing surface area changes of ponds located in different river basins. A parametric test (ANOVA) shows no significant difference among the different river basins. The same Figure reports box-plots representing surface area changes among ponds with different glacier cover. A parametric test (ANOVA) shows in this case significant differences between ponds with different glacier cover within basins.

In addition, the ponds with glacier cover seem to be larger (table 2). Could it be that the difference in shrinkage are correlated with pond size? A possibly larger intrinsic climate sensitivity of the smaller ponds could be an alternate explanation for the differences seen between the signal from the two class. This possibility needs to be ruled out as well to justify the conclusions reached.

Answer: According to the suggestion we tested the significance of possible differences of surface area changes (1992-2013 period) among ponds with different size.

Correction: a new figure in the Supplementary Material has been added showing box-plots representing surface area changes among ponds with different size. A parametric test (ANOVA) shows no significant difference.

Other comments:

1) Many of figures presented needs to be carefully redone, checking the axes labels for missing units, choosing proper x and y range so that all data-points are seen, putting legends that are missing, giving complete and accurate plot captions etc. Some examples: i) what are the units of vertical scales in figure 3, 4a, 4b, 6a, ... ii) Figure 3 horizontal axis: tics read 06,07,07,08,... . Also horizontal separation of the points

are inconsistent with time stamps given in table SI4. iii) what are the criteria for the selecting the ponds whose records are presented in figure 6? why LCN 24 is not shown? iv) What are the filled and unfilled boxes in figure 8a? v) similarly colored solid lines used for LCN 139, 11, 77, 76 vi) indistinguishable colors for various p values used in Fig 7a vii) error bars need be added in 4c, 4d

Answer: Following the comments received by all the reviewers all figures and tables have been checked and redone.

Correction: i) the units have been written in the caption; ii) checked and redone; iii) there was an error, LCN24 has been inserted; iv) the legend has been added; v) corrected; vi) corrected; vii) error bars have been added

2) In all these unconnected glacial ponds, particularly those with significant glacier coverage in their basin, could it be checked if the corresponding glacier drains into the pond?

Answer: The hydrological basins have been digitalized using ArcGIS® hydrology tools as carried out by other authors (e.g., Pathak et al., 2013), each basin has been then visually checked.

Correction: this methodological aspect has been inserted.

3) As acknowledged by the authors the study area is full of debris covered glaciers. The applicability of the glacier melt model used for debris covered glacier must be discussed.

Answer: The glaciers within the pond basins are not debris covered. In this region debris covered glaciers are usually glaciers of a certain size with a developed flat ablation area. In all considered pond basins, the glacier are very small, steep (31°), clings to the mountain peaks, without having developed debris covered ablation area.

Correction: following the suggestion of the reviewer we specified in the text these features of glaciers within the pond basins.

4) It is known that SOI toposheets derived from winter time areal imagaries may contain significant errors. Some of the authors have published results using high resolution Corona KH4 images from 1962 in this area. Could the same images be used to verify the baseline 1962 extents of the ponds studied? Corona data should help in filliing the large time gap between 1962 and 1992.

Answer: We did not used only Corona image for digitalizing all 64 considered ponds because many of them in this image are snow-covered, but, we checked the quality of the map comparing the size of some ponds in both data sources.

Correction: "The topographic map of the Indian survey of 1963 (hereafter TISmap-63, scale 1:50,000) was used to complement the results achieved using the declassified Corona KH-4 (15 Dec 1962, spatial resolution 8 m). Thakuri et al., 2014 describe the co-registration and rectification procedures applied to the Corona KH-4 imagery. Unfortunately, on these satellite images many ponds are snow-covered. Therefore here the ponds surface area digitalized on TISmap-63. The accuracy of this map has been tested comparing the surface areas of 13 ponds digitalized on both data sources (favoring the cloud and shadow free ponds). Figure SI1 shows the proper correspondence of these comparisons. Furthermore, in order to estimate the mean bias associated with TISmap-63, we calculated the mean absolute error (MAE) (Willmott and Matsuura, 2005) between data, which resulted sufficiently low (3.6%), assuring in this way the accuracy of ponds surface area digitalized on TISmap-63."

5) Which climate data is used for the correlation studies? Pyramid data or reanalysis/ gridded products? If pyramid data is used then what is need of describing the others? If the gridded/reanalysis data are used then why not study the correlations for a period longer than the time-window of 2000-2013? What happens if the analysis is extended to all the ponds and for the duration of 1962-2013 using the GPCC precipitation data?

Answer: As described above the correlation studies have been done using the Pyramid data due to the continuous series of annual ponds surface area are available only for the 2000-2013 period and land meteorological data are available for 1994-2013 period. This explains, answering to the reviewer, why a time-window longer than 2000-2013 does not exist. Extending the analysis to the 1962-2013 is not possible because before 2000 we have just two years in which it was possible to digitalize the ponds (1963 and 1992).

Gridded/reanalysis data are not used here for correlation studies, but to obtain information, as written in the paper, on climatic trends in the antecedent period (before 1994). For this reason they have been compared with land data and the best products have been chosen.

Correction: following this suggestion and all other comments received in particular from reviewer 1 a need of clarification clearly emerges. Therefore the method section of the paper has been restructured and these concepts clarified.

6) The details of the computation of the mean pond area change and its uncertainty may be explicitly pointed out.

Answer: as even suggested by another reviewer the section related the uncertainty computation is too hermetic.

Correction: Therefore it has been rewritten.

7) While the authors do a good job of pointing the reader to the appropriate references, at times they may become distractions. For example while both the following cited references are great read in their own ritght, the citations here may be a bit far-fetched - "The current study is focused on the southern Koshi (KO) Basin, which is located in the eastern part of central Himalaya (CH) (Yao et al., 2012; Thakuri et al., 2014) (Fig. 2)". Also refer to Major comment (2) in this context.

Correction: we deleted Yao et al., 2012

8) How are the periods of 1992-2000, 2000-2008, 2008-2011 and 2011-2013 used in table 3 selected?

Answer: the periods have been selected in relation to the availability of satellite imagery

9) The conclusion has lengthy discussions about glacier changes and only a few words on the multi-temporal pond extent data described in the rest of the paper. The connection between the claimed signal from pond area change and glacier changes in the region is not explicitly mentioned as well.

Answer: the conclusions have been rewritten and the “connection” has been more explicitly mentioned

10) Some typographical errors: l 67 "opeping" l 122 : "montly comulated" l 194: morphologicalal

Answer: The suggestion has been followed