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The Cryosphere
Discussions

Interactive comment on "Glacier melting and precipitation trends detected by surface area changes in Himalayan ponds" *by* F. Salerno et al.

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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.

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.

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.

For example in figure 3, some of the biggest ponds/lakes (eg LCN77, LCN24) show large (~5\%) 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 (~10\% 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.

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.

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.

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.

Incidentally, there seem to be some ambiguity regarding the definition of two pond classes: with and without glaciers. Table 3 uses 5\% as a threshold; text gives a threshold of 10\%; Table 4 says LCN3 has 30\% 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.

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 5\% glacier area or the ponds being in the same valley?

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.

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

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?

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.

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 nd 1992.

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?

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

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.

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

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.

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

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