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## ***Interactive comment on “Spatial patterns in glacier area and elevation changes from 1962 to 2006 in the monsoon-influenced eastern Himalaya” by A. Racoviteanu et al.***

### **Anonymous Referee #1**

Received and published: 4 September 2014

Review of paper on “Spatial patterns in glacier area and elevation changes from 1962 to 2006 in the monsoon-influenced eastern Himalaya” by Racoviteanu et al.

#### General remarks

Racoviteanu et al. (2014) analyse spatial patterns in glacier area and elevation changes in the eastern Himalaya using remotely sensed products and the topographic map. The manuscript is interesting and deals with a topic of much interest. In general, I have an impression that the paper addresses the state of glaciers in detail, but weakly on the drivers of change. The work is of good scientific potential for publication with such a suitable topic in a data scarce region of the Himalaya, however there

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are plenty of space for further improving and making the paper more informative and well-organized contents. In fact, this should not be so difficult to fix.

The glacier analysis in the manuscript is limited to 2006. Though the time frame of the analysis is significant, it is not clear to me why do the authors decided to restrict their analysis until 2006. There are enough potential for extending the analysis until recent year (2013 or 2014) using freely available additional Landsat data. Adding an image of recent year make the paper much worthy with the latest information on the state of the glaciers.

The paper needs editing and thorough check for english language to ensure the clarity, correctness, and consistency in language, and for improving communication of work. Authors should be careful in while presenting data using “retreat” or “loss” or simply, “change” for glaciers. No need of negative (–) sign when using retreat or loss. I suggest for checking the appropriate use of the terminologies like, “spatial pattern”, “trend”, “inventory” in the manuscript.

Looking into the title and objective of the study, I expect some results on the elevation changes in the result section, but nothing is presented there in result section about elevation change. I read interesting results in the discussion section. The author can simply separate the results from discussion and make a new section in the results for the glacier elevation change. Furthermore, I expect brief statement on the rationale of this study in the introduction and also in abstract. The study output would be much usable and supportive for future studies by providing glacier datasets for this part of Himalaya, if the glaciers datasets for each glacier (inventory) are tabulated in the Supplement.

Specific remarks

P3950

L2: not only deal with eastern Nepal and Sikkim, but include also China and Bhutan

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(as in Table 4), right?

L7-L13: here objectives are explained in detail, but the presented results afterward do not address systematically to the objectives.

L8: why is there, new “reference” geospatial?

L9: why “~” before 2000 when both the Landsat and ASTER imagery are of 2000? It is not necessary. - “glacier surface area” would be more appropriate.

L12: include the time period; Can “debris-covered tongue” be written as “ablation area”?

L14, L16 and else where in the manuscript: Avoid repeating of unit while reporting uncertainty. Eg, remove km<sup>2</sup> after 1463. Check in the whole manuscript.

L19: as pointed out in the general remark, here not necessary to include “-“ sign when writing “loss of . . .” “retreat”, Check the use of sign over whole manuscript.

- 1960s, not 1960’s, please check in the whole manuscript

- Instead of 2010’s in the sentence, use 2010s. It is really 2010s or 2000s?

- Instead of “retreat” for surface area change, “surface loss” is appropriate. Ensure consistent word in the whole manuscript.

L20: Use the same number of significant digits after decimal point for the values and its uncertainty reporting. Check in the whole manuscript.

L25: I suggest including a brief concluding remark in the abstract.

P3951

L2: “raised” or some other word may sound good for “aroused”.

L5-L7: these citations are not complete list. use “eg.,” instead.

L21: hampers quality satellite image acquisition.

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P3952

L10-L21: These descriptions are more methods than introduction.

L18: Why the elevation change analysis only focused in the debris-covered tongues?  
Authors should briefly mention this consideration.

P3953

L5: topographic relief

L18: not “May”, it’s “June”, right?

L16: it is commonly known that the Himalayan high mountains act as a barrier for monsoon, but also Tibetan plateau? Any reference?

L21: from 500 to 5000 m yr<sup>-1</sup>. Would be valuable information to indicate also the locations of these precipitation measures?

P3954

L5: change 1960’s to 1960s; remove “decade”.

L6: why “reference”?

L6: remove “year”, not necessary before “1962”.

L15: I am not clear, why did the authors calculate an actual pixel size of approximately 2 m using the scale of the photos and the scan resolution?

L17: Are there also processed Corona images available? Otherwise, “Raw, unprocessed” can be removed.

P3956

L2: trend

L10: why did the authors use cubic convolution method for resampling?

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L16: why SRTM DEM was hydrologically-sound? Is it void filled SRTM?

Authors should be aware of the use limitation of SRTM DEM in the high elevation mountain region. Uncertainty related to the elevation change, especially the c-band penetration (Gardelle et al 2012) and the huge data gaps in the higher elevation in the original SRTM DEM (Bolch et al., 2011) need to be acknowledged.

L18: remove “decade”.

L25 and else where: 1960s or 1960’s? They have different meaning, use consistently.

P3958

L2: here “1960s” appropriate for “1960’s decade”.

L25: QB (2000) and WV2 (2009)

- clean-ice surfaces were delineated using. . .

L27: Did the authors use information on the lateral and frontal moraines for delineating the debris-covered tongues?

P3959

L28: The authors have discussed well in sufficient details about the uncertainties, however can the authors present little statement on the formulas and equations that they used for associating uncertainties in the observed values, so that the approach can be easily replicable in the future studies to evaluate the errors?

P3960

L7: a total area of

L9: is the % of supraglacial debris comparable with the previous studies? The % debris coverage were published in Scherler et al., 2011; Nuimura et al., 2012, Thakuri et al., 2014.

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P3961

L2: “frequency histogram” or simply “histogram”?

P3962

L25: again here when you write area loss “-“ not necessary, check in the whole manuscript.

L27: - 0.16% yr-1

P3963

L1-L3: I suggest for checking the sentence structure.

L6-L8: Have they been preserved more than other areas? Compare the surface area change and elevation change with the other studies in the Himalaya region. The result is in line with the conclusion in the recently published paper of Thakuri et al (2014). Thakuri et al extensively evaluated the glacier surface change in the entire Himalaya and have summarized the glacier status in the Himalaya and Tibetan Plateau. Further, the discussion in the 5.1 section has been addressed in the Thakuri et al for the Mt Everest region. Here authors can compare the finding with that of glaciers in the Everest region as the glaciers characteristics they considered are similar.

L19: The larger glaciers have a higher accumulation zones and lower elevation termini. It would be useful to evaluate the glacier dividing into two parts for surface area change.

L26: It would be interesting to see the relationship glacier area change separately for accumulation and ablation areas' elevation and their slope.

P3964

L10: Does the higher area losses of small glaciers suggest that they have the lowest elevation accumulation zones and they are most impacted by climate change?

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L18: Can be reorganized contextual part. eg Section 5.4 may be suitable to present in the method section.

P3968

L10: root mean square error?

P3971

L11: what is the significance of repeating the summary again in the conclusion section? Abstract itself provides the summary of the paper.

P3972

L25: you mean, “can be further applicable to understand”?

The tables and figures are quite good. Herewith, presented some suggestions for some improvements.

Table 1: Add a column “Image type” after “Spatial resolution” field to present image types: PAN, VIS, SWIR,. . . .

- include all ASTER data used in the study in the Table.

- Use a same format for the date ( see Date column of QuickBird and WorldView-2).

Table 2: Is it possible to make spatial domain 3 for elevation change study?

Table 3: caption: only “topographic zones” enough. Are the four zones presented here exactly corresponds the region presented in table 4?

Table 4: L2: why ~ ?

Table 6: reporting p-value as  $< 0.001$  or  $< 0.01$  for significant values would be enough.

Table 8: why “# glcfs” in column heading? Use full description.

Why are there different in column headings ? “% area change” and “Rate of loss yr<sup>-1</sup>”?

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“Rate of change % yr<sup>-1</sup>” is correct, right? Also, not necessary to put unit in each value and also in column heading.

Figure 1: Not much visually promising and informative with all the data overlaid. I would suggest to use only one image as a base layer and draw spatial domain, glacier outline, country boundary, and label them.

Caption L1: which six 2000-2006 ASTER scenes? They are not listed in Table 1.

Figure 4: x-axis, why sq.km? else where written km<sup>2</sup>; slope (degree).

Figure 5 Caption L2: remove “two direction”. L3: Is it necessary to put “corresponding to topographic/climatic barriers”?

Figure 6 Caption L1: why is there WV2? Typo?; L2: remove “shown on a glacier-by-glacier basis”.

Figure 8 Caption L2: why is there WV2? Typo?; L3: Did you also analyzed terminus retreat?

Figure 9: Label the glacier names mentioned in the caption.

Caption L: can use “1962 to 2006” in place of “1962 to 2000 and 2006”,

L4: Did you test also acceleration of pro-glacial lakes?

Figure 11: The primary Y-axis show positive elevation change, is it true?

Caption L1: 1960s. “surface temperature distribution” instead of “day temperature trends”.

Bolch, T., Pieczonka, T., and Benn, D. I.: Multi-decadal mass loss of glaciers in the Everest area (Nepal Himalaya) derived from stereo imagery, *The Cryosphere*, 5, 349–358, doi:10.5194/tc- 5-349-2011, 2011.

Gardelle, J. E., Berthier, E., and Arnaud, Y.: Impact of resolution and radar penetration on glacier elevation changed computed from DEM differencing, *J. Glaciol.*, 58, 419–



422, 2012.

Nuimura, T., K. Fujita, S. Yamaguchi, and R. R. Sharma (2012), Elevation changes of glaciers revealed by multitemporal digital elevation models calibrated by GPS survey in the Khumbu region, Nepal Himalaya, 1992–2008, *J. Glaciol.*, 58(210), 648–656, doi:10.3189/2012JoG11J061.

Scherler, D., Bookhagen, B., and Strecker, M. R.: Spatially variable response of Himalayan glaciers to climate change affected by debris cover, *Nat. Geosci.*, 4, 156–159, 2011.

Thakuri, S., Salerno, F., Smiraglia, C., Bolch, T., D'Agata, C., Viviano, G., and Tartari, G.: Tracing glacier changes since the 1960s on the south slope of Mt. Everest (central Southern Himalaya) using optical satellite imagery, *The Cryosphere*, 8, 1297–1315, doi:10.5194/tc-8-1297-2014, 2014.

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