

Dear Editor,

Thank you for handling our manuscript and for the suggestion. We reply to reviewer's comments point by point, and to your major comments. Comments and replies are shown in Centruy style and **Arial bold with line number**, respectively.

One issue is still the representativeness and that the authors focus on one glacier only. We have discussed that you cannot extend due to the high workload. But you should make more efforts to show the representativeness or clearly state that this is the mass balance of one glacier. I also want to again emphasize that there are now more and more studies using Hexagon which cover a much larger area and it is not too much effort to generate a DEM using standard photogrammetric software. It may not be so precise but this could then be nicely shown.

[L352-] According to the reviewer's suggestion, we address limitation of this method and the representativeness at the last paragraph in Conclusion.

Another important issue is that the role of supra glacier lakes/ice cliffs is not clear, as you show that the studies glacier has not experienced large rates of elevation change, but then refer to “high” rates of surface lowering around lakes towards the end of the paper.

[L344-] Pond plays a key hot spot enhancing the ice melting under the debris-cover while the entire mass loss of Kanchenjunga Glacier is moderate than others. We think that the different issues are adequately addressed at the latter part of the first paragraph in Conclusion acknowledging to the reviewer's suggestion.

The discussion of debris-covered vs clean glaciers should also be improved.

[L203] We added more descriptions and one reference (Juen et al., 2014) at the latter part of the second paragraph in Sect. 3.1.

Dear Reviewer,

Thank you for the detailed comments, which are greatly helpful. We reply to your comments point by point. Comments and replies are shown in Centruy style and **Arial bold with Line number**, respectively.

1 Introdcution

This phrase still reads awkwardly in the current form. I understand what the authors want to convey but this phrase is not so clear. May I suggest: “In recent decades, glaciers in the Himalayas, a heavily glacierized mountainous area, have been widely losing mass, although this mass loss has exhibited a high degree of spatial heterogeneity”

[L21] We corrected here according to the suggestion.

Studies on the change of Himalayan glaciers -> Studies on Himalayan glacier changes

[L23] We corrected here according to the suggestion.

suggestion: replace “and the existence of Mt. Everest” with “due to the presence of Mt Everest”

[L27] We corrected here according to the suggestion.

This new line: “modern satellite observations are mostly limited to the year after 2000, despite their large spatial coverage.” doesn't read accurately. Modern satellite observations began in the 70's. I think the authors mean” “geodetic mass balance estimates started after 2000” (after SRTM coverage, I assume the authors mean?) Please clarify/revise this.

[L32] Yes, we mean "geodetic mass balance estimate". We corrected here according to the suggestion.

I appreciate the authors added the references suggested. However: the debris-covered mantle can have either an insulation or acceleration of melt effect. Surely the authors are well aware of this. Written as it is, this

statement implies the debris mantle *always* has an insulating effect. I suggest considering: “their responses to climate change are more complex than those of debris-free glaciers because the debris mantle can either insulate the ice or accelerate ice melt rates, depending on its thickness”

[L38] We corrected here according to the suggestion.

2.1 Data

replace this with the date; "final" is not clear (referring to “last image” is confusing since chronologically this is not the last).

Also note the word repetition (glacier outline of Kangchenjunga glacier-suggestion made).

Long phrase and still hard to understand. Consider breaking and re-phrasing to: "The October 2008 images were used for mapping supraglacial ponds of Khumbu Glacier; the March 2010 was used for initial velocity measurement of Kanchenjunga Glacier; the December 2010 images was used for the DEM generation; the October 2008 image was used for velocity measurements, and for mapping the area and the supraglacial ponds of Kanchenjunga Glacier”

[L64] We corrected here according to the suggestion but we did not use October 2008 image for the velocity measurement. Therefore, we wrote here as "The October 2008 image was used for mapping supraglacial ponds of Khumbu Glacier; the March 2010 was used for initial velocity measurement of Kanchenjunga Glacier; the December 2010 images was used for the DEM generation, for velocity measurements, and for mapping the area and the supraglacial ponds of Kanchenjunga Glacier."

2.2 Glacier delineation and hypsometry

specify what kind of experience- field ? remote sensing? both?

[L74] We added "in remote sensing analysis" after "experiences".

add here: "cf section x,x"

I feel the DEM section should come before the authors mention the hypsometry-otherwise in the text refer to the section number (ie "see section

2.3 and 2.4 " so that the reader can follow.

[L78] We added "(Sect. 2.3 and 2.4)" after "the entire glacier".

2.3 DEM generation from ALOS PRISM imagery

need to spell out

[L81] Although RPCs is spelled out in L63, we spelled out again here.

Do the authors really mean precision (ie number of decimals) or accuracy? I think it is accuracy.

[L90] We corrected here to "an accurate".

what are "mass points"?

[L94] This is vertices of triangle, which form triangulated irregular network. This is generally used in this method so that we did not add the explanation.

2.5 Mass balance and uncertainty estimates

These are results and should be moved there unless they come from a different study

[L194] Although we feel that this introductory sentence is necessary for the following description, anyhow we move this to the latter results section 3.1, before the distribution map of elevation change.

This phrase reads awkwardly. Suggested phrasing: "DEM generation was possible at xx location [], resulting in a patchy DEM"

[L115] We corrected here according to the suggestion as "DEM generation was possible at nine location in the upper area due to a better local image contrast, resulting in a patchy DEM (hereafter point sites, Fig. 2a)."

This is confusing- how do the authors know the elevation change is positive? Is this a result of the study, or is this an assumption? If the latter, please state so, ie, "elevation change is assumed to be positive" and reference this.

[L119] This is a result of this study so that we refer Fig. 3a.

This is contradictory with line 18 where the authors say that above 5800m, elevation change is positive. Please revise.

[L119] We rephrased the Line 18 as "the positive elevation change is available between 5800 and 6100 m a.s.l. (Fig. 3a)".

2.6 Glacier velocity

the definite article should not be used in a lot of cases because it refers to general nouns, not a specific "terrain" or "glacier velocity". Please correct throughout.

Again, here, no need for "the", it is not correct in English language.

[L168] We corrected here according to the suggestion. Thank you for the detailed check.

insert "associated with", or replace with "uncertainty in flow velocity measurements"

[L172] We corrected here according to the latter suggestion.

2.7 Supraglacial ponds

perhaps add something to the subtitle, for ex. "mapping"?

[L174] We changed here as "Mapping of supraglacial ponds".

add "spatial" before "distribution"

[L176] We corrected this according to the suggestion.

Can this be simplified to just "Concomitantly with DEM creation [section xx], we delineated xxxx. It would read more easily.

[L177] We corrected here according to the suggestion.

what is meant here? you mean to avoid misinterpretation due to topographic features? clarify

[L180] We corrected here according to the suggestion.

insert "only" before "delineated"

[L180] We corrected here according to the suggestion.

Elevation change was already mentioned in the section above. Rephrase here to something like "we computed the rate of elevation change at the mapped ponds on a pixel by pixel basis...etc...etc.."

[L182] We corrected here according to the suggestion.

3.1 Changes in area, elevation, and mass of the glacier

Also- not clear if this was treated differently than the overall elevation change over the entire glacier.

[reply] The ponds are part of the glacier so that they are included in the calculation for the entire glacier.

period of study (35 years)

[L187] We corrected here according to the suggestion.

cannot use definite article if this is something which has not been noticed. Could replace with "No frontal retreat was noticeable"

[L188] We corrected here according to the suggestion.

how small? can a number be given?

[L190] We added areas lost at two tributaries.

replace with "in"

[L191] We corrected here according to the suggestion.

insert the +/- sign before the numbers for uncertainty

[L191] We corrected here according to the suggestion.

insert "spatial" before "distribution".

Also remove "map of..." since it is the elevation which is distributed, not the map.

insert "is shown in Fig..".

These are results not methods, so should be written as such.

[L193-] We corrected here according to the suggestion. We moved the sentence addressing how the extent of generated DEMs is here.

the word "lower", "lowered" is repeated too many times in this phrase.

[L196] We replaced "lowermost ablation" by "terminal".

please avoid using words such as "remarkable". Could use "significantly" and give a number, or simply mention "high rates of elevation loss [number] or "low rates"

[L196] We replaced "remarkably" with "significantly", and added numbers.

is notable (=significant") or "noticeable (= observed") meant here?

[L198] We corrected this according to the latter suggestion.

Again, please fix this!! the authors keep referring to debris cover with an insulation effect, this is not correct. Do they authors know is debris cover in the ablation zone is thick? if so, mention it, and say it clearly: "despite the thick debris cover in the ablation area [reference here]. etc etc,...". But again, this should be based on observation or previous studies. One cannot assume that debris cover is insulating.

[L198] We corrected here with "is expected to cause" citing Vincent et al. (2016).

again" "remarkable", please replace.

[L199] We replaced it with "significant".

This result here might indicate that debris cover is NOT thick in the lowermost ablation area. Please clarify.

[L199-] We added a sentence as "It suggests that the insulation effect does not work effectively as expected though thickness distribution is totally unknown."

insert "similar" before "thinning"

[L207] We corrected here according to the suggestion.

insert "other" before "regions"

[L208] We corrected here according to the suggestion.

Two new refs to add here: a new study by Vincent et al (2016), and also a short communication by Banerjee (2017) in TC showing that debris covered glaciers can experience similar rates of thinning to clean glaciers.

Vincent, C., Wagnon, P., Shea, J. M., Immerzeel, W. W., Kraaijenbrink, P., Shrestha, D., Soruco, A., Arnaud, Y., Brun, F., Berthier, E., and Sherpa, S. F.: Reduced melt on debris-covered glaciers: investigations from Changri Nup Glacier, Nepal, *The Cryosphere*, 10, 1845–1858, doi:10.5194/tc-10-1845-2016, 2016.

Banerjee, A.: Brief communication: Thinning of debris-covered and debris-free glaciers in a warming climate, *The Cryosphere*, 11, 133-138, doi:10.5194/tc-11-133-2017, 2017.

[reply] Vincent et al. (2016) concluded that the debris cover surely prevented the ice melting underneath so that it is not consistent with the results cited here. Banerjee (2017) supported the comparable ice melting under the debris to those exposed. But it is based on conceptual model while here we cited "observational facts" here. We cited Vincent et al. (2016) at L198 but not Banerjee (2017).

Again, this was written as methods whereas it is results. Consider rephrasing to "The Area-weighted geodetic mass balance...etc etc.." is shown in Fig 3a.

[L210] Because two scenarios are assumed, we cannot directly address the geodetic mass balance here. We think it is necessary to remind here how we estimate the geodetic mass balance of the entire glacier. We did not rephrase here.

why present tense here while rest of phrase is in past tense?

I recommend giving range first and the average in parenthesis.

[L214] We corrected here according to the suggestion.

"resulted" should be "resulting"

[L217] We corrected here according to the suggestion.

awkward phrasing. Suggested change: "Although the mass balance estimates are most largely influenced by from the scenario used (case 1 or 2).", etc..

[L219] We corrected here according to the suggestion.

3.2 Effect of the flow velocity and topographic variables on the elevation change

This entire section is hard to follow as it goes back and forth from general statements to the studies glacier and it is not clear when authors refer to one or the other. I suggest revising this section and presenting first the results of this study, and after that refer to general cases commenting on how the observed trends fits or not the general trends.

[reply] In the second paragraph, we moved "Elevation change of ... (Cuffey and Paterson, 2010)." to one sentence later as "velocity, are shown in Figs. 4c-e because elevation change of ... ". L235-

In the third paragraph, we think that the introductive three sentences "In general, mass balance of ... cooler air temperatures." are necessary at the present position for the readers to keep these points in their mind and then to read/see the following results. L248-

In the fourth paragraph, the first two sentences describe a general relationship. We also think that here is good position for the following sentences which address our results. L261-

Although the reviewer seems not to prefer the present order of the manuscript, we do not think that the descriptions are fragmented as going back and forth.

insert "spatial"

[L223] We corrected here according to the suggestion.

insert "on this figure"

[L224] We corrected here according to the suggestion.

how can a spatial distribution of displacement show uncertainty? Not sure what is meant here. A figure shows the amount of displacement. The uncertainty estimates should be based on some other evaluation. Please clarify.

[L224] We do not understand what the reviewer means. We think that amount of displacement over off-glacier surface has been as uncertainty in previous studies. We added here ", which we assume uncertainty of the flow velocity,".

velocity cannot be stagnant, as it is a quantity. Rather, we can say that velocity is minimal or negligible.

[L225] We corrected it to "negligible".

Again this is written as methods- please write as for results: "Elevation change versus flow velocity ...is shown in Fig xxx"

[L228] We corrected this sentence according to the suggestion.

Elsewhere in the paper, the elevation change is referred to as "loss" and given as positive. Please standardize, ie. either use the term "loss" with positive sign or "change" with negative sign.

[L196] This comment is solely applicable to the earlier part of the second paragraph in Sect. 3.1. We corrected the words "lowering/thickening" by "negative/positive" to keep consistency in sign.

this is general, so state as "Glacier surface elevation changes are generally controlled by ..."

[L235-] We removed "the" and added "generally".

again reads as methods, replace "were calculated" with "are shown in Fig xx"
[L235] We corrected here according to the suggestion.

add "optical" here, otherwise statement is not correct.

[L239] We corrected here according to the suggestion.

This statement seems to refer to ice thickness in general, ie clean ice thickness. This was done by Huss et al, who derived glacier ice thickness at large spatial scales based on RS derived glacier outlines. Please revise, and/or mention Huss et al. 2012 If authors refer to debris covered thickness, then this should be re-written.

Huss, M., and D. Farinotti (2012), Distributed ice thickness and volume of all glaciers around the globe, J. Geophys. Res., 117, F04010, doi:10.1029/2012JF002523.

[reply] Here we are addressing the ice thickness distribution which is able to calculate the emergence velocity. Although thickness by a method of Huss and Farinotti (2012) may be useful to estimate entire volume of glacier (actually we are using their parameters in our another study), their thickness cannot be used to calculate emergence velocity. In addition, we are dealing with debris-covered glacier, for which the method by Huss and Farinotti (2012) was not tested because their method needs surface mass balance, which is not simply calculable on debris-covered glacier. We do not think that we should use many words to explain that we recognize their method but why we do not use it.

This seems duplicate to line 18, please merge these two.

[reply] Because we rephrased the sentence what the reviewer pointed out, we do not change this.

which debris-free glacier? Using the definite article "the" makes it read as if you are referring to ONE particular glacier. Or, do you mean here debris-free glaciers in general? please be more precise.

[L249] We remove "the". We are sorry to make you confusing.

change to "rates".

Use of definite article not appropriate, these are general statements.

[L252] We corrected here according to the suggestion.

Now this statement refers to the glacier in this study? please be precise, it is hard to understand when the studied glacier is referred to

[L255] Yes, this sentence refers to Kanchenjunga Glacier we analyzed. We did not change here.

this is not a definition.

Could replace with "strictly speaking" or "generally"

[L261] We replaced with "In general", and removed "the" in this sentence.

again: in this study ?

[L263] Yes, this sentence refers to Kanchenjunga Glacier we analyzed. We did not change here.

3.3 Role of supraglacial ponds on the surface lowering

There is a contraction here: if I understand the way it is written, if the correlation is negative, then larger ponds would mean less elevation change, ie less thinning. But the statement on line 35 says the contrary.

[L281] To avoid confusion, we change the terms "down-wasted" to "elevation change of / negative".

insert "a higher rate of.."

the word "lower", "lowering" is repeated many times, This can be said simply "higher rates of elevation change", no need for "is characterized by.."

[L283] We corrected here according to the suggestion.

insert "entire"

[L284] We corrected here according to the suggestion.

remove the comma, replace with "in areas where"

the phrase is hard to understand as written. Suggested change:

Supraglacial ponds and ice cliffs, which often coexist, are the principal spots of extensive heat absorption (Sakai et al., 2000,2002; Röhl, 2008; Steiner et al., 2015). These features do not persist at the same location at decadal scales, but rather their location changes every few years (Miles et al 2017). We report a significant lowering of the glacier surface around the supraglacial lakes and ponds in this study, suggesting that these ponds enhance glacier melt.

I suggest removing "leave their trances.." as it is redundant;

also not sure what is meant by

"hot spots may repeat a development and decay cycle" in relation to the lowering observed? might need to continue this idea with the explanation on line 10 so that this makes sense.

[L287-] We corrected here according to the suggestion but replaced "but rather their(maybe their?) location changes every few years" by "but for a few to several years" because Miles et al. (2017) did not conclude that ponds changed their location every few years but concluded that ponds persisted for several years. And we removed "lakes" because we do not think that those in this study are ponds.

However recent studies (see also Vincent et al, 2016) do not support this idea. See also Banerjee in 2017:

"Given that these features typically contribute ~ 10–20 % of the total melt (Sakai et al., 2000; Reid and Brock, 2014), it is unlikely that they can lower the glacierwide mean melt rate on debris-covered glaciers sufficiently so that it matches that on the debris-free glaciers.

Please refer to this study/ reference it.

I think the phrase can be removed or added at the end of the section, with reference to the papers.

[L289] That's why we addressed "one of the causes". Although Banerjee (2017) is an interesting study, it was a conceptual model analysis which

did not quantify contributions of dynamics and enhanced melting through ponds and ice cliffs to surface lowering.

what is the idea in this paragraph? One study shows stagnant lakes- the other shows a net increase- so what is the conclusion here, that the authors would like to point out?

[L293-/L296-] We separated these two sentences to relate to our results. Supraglacial ponds in Kanchenjunga Glacier are found over the slow velocity area, and it is found on Langtang Glacier too. It suggests that these ponds are expected to stay at the same locations, which were observed in Langtang Glacier too. Increase of number, area and size is another finding of this study, and it is also found in the Khumbu region. We think that these two issues (persistent and increase) are now adequately addressed.

I do not agree that the rates of elevation change in this study are high- this seems a contradiction. Perhaps what is meant a "higher" rate than the overall glacier?

[L298] Yes, we intended to mean higher rate than the overall glacier. We revised this part as "Considering the higher rate of surface lowering than the overall glacier,".

3.4 Comparison with other studies

again it read like methods, consider rephrasing to "Comparison with other glaciers in nearby areas: [list here]..(Fig 7) shows thatetc etc..."

[L325-] We rephrased this though we feel it looks difficult to read.

larger (give area threshold as for small glaciers)

[L328] We added > 20 km² after larger glaciers.

add "if the entire glacier area were available".

[L331] We corrected here according to the suggestion.

This is a separate statement, make a new phrase and state this as a limitation of the current study, that could perhaps be addressed in a future study. Also comment on the limitation of the method chosen, ie TIN provides an increased accuracy for the mass balance, but the area coverage is sacrificed. I'd suggest even adding here a short section on limitation and further studies.

[L352-] We think this suggested description is already in the last part of conclusion section. But we added here (the last part of Conclusions) more descriptions as "Because of the time-consuming TIN editing method, the area coverage is limited within a single glacier. Therefore, regional mass loss is yet to be fully understood with the geodetic mass balance of the single Kanchenjunga Glacier though the larger size glacier tends to represent its area-weighted regional mass balance."

4 Conclusions

numbers?

give numbers again in the conclusion, for each of the glacier part, including the uncertainty.

[L336-] We provided values.

this statement is redundant with the previous one, this is the same idea. Merge these two.

[L337] We replaced "Considering ... area," by "suggesting that".

not sure this is a conclusion here, previous studies show that this does not play a major role. The authors need to comment on the emergence velocity, or at least mention it.

[L344-] I do not know any study proposing other process resulting in "intense ice wastage" on debris-covered glacier. Although previous studies in this comment seem Vincent et al. (2016) and Banerjee (2017), these dealt with NOT ice melting BUT surface lowering. We added a sentence to address the effect of emergence velocity as "It also should be noted that supraglacial ponds in debris-covered glacier tend to form at

dynamically stagnant area, at which emergence velocity is too little to sustain glacier surface lowering by ice melting."

this statement is contradictory to the previous one: the authors state that supra-glacial ponds play a key role but then they state that geodetic mass balance is less negative. Please clarify what the conclusion is there.

[L346-] We added a sentence as "Although the supraglacial ponds accelerate the surface lowering, the entire mass loss of Kanchenjunga Glacier is moderate compared to the other debris-covered glaciers in neighboring regions."

what kind of automated method do authors refer to? glacier-wide or region-wide geodetic mass balance? this is not necessarily automated. Please revise.

[L352] We replaced "other" by "region-wide" before DEMs then an automated method is necessary.

Figure 7

if this is mentioned here then no need to mention again in text.

[reply] We deleted this sentence.