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The Cryosphere Discussions

Interactive comment on "Spatial variability in mass change of glaciers in the Everest region, central Himalaya, between 2000 and 2015" *by* O. King et al.

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Review - King et al., TC-2016-99

King et al. present an analysis of glacier surface lowering data for 31 large glaciers in three catchments in the Everest region of the Himalaya. They examine the role of lakes in the observed spatial variabilty, compare surface elevation change profiles with the conceptual model given by Benn et al. (2012), suggest potential future changes based on equilibrium line altitude and climate change assumptions, and conduct an analysis of glacier hypsometry.

The topic is relevant and interesting, and the paper is generally well-written, but there

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are a number of substantial issues that must be addressed. I provide general and specific comments below.

GENERAL COMMENTS

1) The title of the paper and section 3.6 suggest that glacier "mass change" is examined. However mass change estimates cannot be calculated for only part of a glacier (e.g. the ablation zone) using the geodetic approach! Emergence velocity somehow needs to be taken into account. Fortunately, the authors have also neglected to show or discuss mass changes, so I would suggest that section 3.6 be removed and the title changed.

2) As a short follow-up to point 1, the authors should provide the caveat that emergence velocities will affect the observed surface lowering rates, though this cannot be quantified (or can it?).

3) The authors focus on the largest glaciers within the respective catchments, and justify this decision by saying that these glaciers 'provide the greatest volume of meltwater to downstream areas'. I see two problems with this: first, this justification is unreferenced, and possibly incorrect as the largest glaciers will likely also be debris-covered and have the lowest melt rates. Second, the melt rates of smaller glaciers are also of significant interest, and excluding them may result in biased average lowering rates.

4) Equilibrium line altitudes are not discussed until the Results section (4.2.3) but this is a very important part of the overall approach used (i.e. surface lowering is only considered for areas below the ELA). A section needs to be added to the methods describing how the ELA is determined, and how are future ELAs calculated. Section 5.4.1 is rather slim on details.

5) The range of temperature projections (+0.9 to +2.3C) appears to be a global mean, though this is not defined or justified, and higher emission scenarios show higher increases (+3.7C by 2100 for RCP8.5; Collins et al., 2013). Also, temperatures in the

Tibetan Plateau and Himalayas are expected to increase at a higher rate (e.g. Rangwala et al., 2013). Potential increases in freezing level have been examined by other authors (Shea et al., 2015; Viste and Sorteberg, 2015)

5) I am confused by the 'highlighted glaciers' and the presentation of the results, because the classes can be mixed. For example: Figure 5 shows all land terminating glaciers. Figure 6 shows clean Tibetan Plateau glaciers (top) and lacustrine terminating glaciers (bottom). Are some clean TP glaciers land-terminating? Are they counted in both graphs? Perhaps a more rigourous classification by basin would be useful to highlight the differences by glacier type and by region (e.g. Dudh Koshi -> land-terminating -> clean ice).

6) Formulas in the error analysis need to be presented correctly, and suitable symbols applied, see specific comments below.

SPECIFIC COMMENTS

Abstract: somewhere in here the time period for the analysis should be defined.

P1L13: what kind of glacial lakes? Be specific.

P1L18: 'Average surface lowering rates...'

P1L21: what is deep water calving?

P1L23: 'area', not volume...

P1L26: 'respectively' is missing somewhere

P2L2: The area and number of glaciers refers to the Himalayas, the Hindu Kush, and the Karakoram (not just the Himalayas).

P2L17: 'more stable' in the eastern Himalayas is incorrect. The greatest rates of surface lowering are observed in eastern Himalayas (Kaab et al., 2015).

P3L2-3: 'and it thus remains untested' is superfluous.

P3L20: clarify are these 40 largest glaciers *partially* debris-covered?

P4L4-7: There are observed and modelled ELA data from Wagnon et al., (2013) and Shea et al., (2015), respectively.

P4L19:what is 'non-void filled'?

P5L10-15: do you do any comparison between the ASTER and SETSM DEMs on stable ground?

P5L20-25 : Just to clarify, you take the GLIMS glacier extents, and modify them for 2000 and and 2014 extents based on Landsat imagery. And it should be mentioned here that you use the 2000 and 2014 extents to calculate area changes.

P7L9: Gardelle et al (2013) add a 50

P7L14: The graph shown in the Supplementary Information could be placed in the main text, but the caption needs to be improved as it is not clear what is being presented.

Eq.1 and below: I'd suggest using σ_{stable} for standard deviation. And the root symbol should be over the whole term: $\sqrt{n_{diff}}$.

P8L1-10: Fix terms in the text: subscripts and italics are missing or inconsistent Eq. 2: italize n_{diff}, n_{tot}, PS

P8L7-8: this sentence is unclear. What value of d was used in this study?

Eq.3: root symbol needs to be over the whole expression: $\sqrt{SE^2 + MED^2}$, and I would suggest using $\overline{dZ_{stable}}$ for mean elevation differences (MED). MED looks a lot like median...

P9L3: "...the MEDIAN elevation...'

Section 3.6: suggest removing completely.

P9L25: report lowering rates with negative sign (e.g. -0.80 +/- 0.35) to be consistent with Table 4.

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P10L1-3: ’Mass loss’ should be ’surface lowering’ here, and don’t rates increase downglacier in all cases (not only lake-terminating glaciers)?

P10L2: surface lowering rates right at glacier termini are always negligible because there is limited ice available for melt.

P10L24: Refer to Figure 5 here.

P11L13: ’patterns’, not ’scenarios’

P11L13-25: provide rates of area change per year for comparison with other studies?

P11L19: This is where the more rigorous classification would be useful. E.g.: Land-terminating clean vs. land-terminating debris-covered?

P12L13-20: Suggest moving this section to methods and adding more details on how current and future ELAs are determined.

P12L16-17: This phrasing is a bit awkward. It seems like you are trying to say that the approximated ELAs give an AAR of 0.37 in the Dudh Kosi catchment. (AAR = Accumulation Area/Total Area)

P13L3: Though around 80

P13L18-25: Some skepticism might be warranted when referencing the snow line altitude shifts given by Thakuri et al., (2014): these are based on single-image delineations of transient snowlines, and in the Himalayas these do not remain constant at the end of the summer season.

P14 Sec5.2: "surface lowering", not "mass loss"

P14L26-27: For lake terminating glaciers its complicated, but for land-terminating glaciers thinning should reduce the driving stresses and lead to decreased glacier velocities (e.g. Berthier and Vincent, 2012; Haritashya et al., 2015)

P15L25: the sensitivity of Dudh Kosi glaciers to future ELA changes based on its

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hyspometry was noted previously by Shea et al. (2015)

Table 3: separate columns for means and standard deviations

Figure 1: Add the imagery extents here?

Figure 2: text labels with glacier names are impossible to read. Also, is it possible to show the data voids in the DEM differencing?

Figures 3 and 4: Why are glacier extents shown in 2014 (left panel) not also present in 2000 extents?

Figure 5 and 6: Larger fonts required! Caption should point out that surface lowering curves are on the right and hypsometry on the left. Maybe show hypsometry as relative (% of total area) as opposed to absolute? and show surface lowering rates as boxplots by elevation band?

Figure 6: Why is approximate ELA only shown on top panel? What about project future ELAs?

REFERENCES

Berthier, E. and Vincent, C., 2012. Relative contribution of surface mass-balance and ice-flux changes to the accelerated thinning of Mer de Glace, French Alps, over 1979–2008. Journal of Glaciology, 58(209), pp.501-512.

Haritashya, U.K., Pleasants, M.S. and Copland, L., 2015. Assessment of the Evolution in Velocity of Two DebrisâĂŘCovered Valley Glaciers in Nepal and New Zealand. Geografiska Annaler: Series A, Physical Geography, 97(4), pp.737-751.

Kääb, A., Treichler, D., Nuth, C. and Berthier, E., 2015. Brief Communication: Contending estimates of 2003–2008 glacier mass balance over the Pamir–Karakoram–Himalaya. The Cryosphere, 9(2), pp.557-564.

Rangwala, I., Sinsky, E. and Miller, J.R., 2013. Amplified warming projections for high altitude regions of the northern hemisphere mid-latitudes from CMIP5 models. Environmental Research Letters, 8(2), p.024040.

Shea, J.M., Immerzeel, W.W., Wagnon, P., Vincent, C. and Bajracharya, S., 2015. Modelling glacier change in the Everest region, Nepal Himalaya. The Cryosphere, 9(3), pp.1105-1128.

Viste, E. and Sorteberg, A., 2015. Snowfall in the Himalayas: an uncertain future from a little-known past. The Cryosphere, 9(3), pp.1147-1167.

Wagnon, P., Vincent, C., Arnaud, Y., Berthier, E., Vuillermoz, E., Gruber, S., Ménégoz, M., Gilbert, A., Dumont, M., Shea, J.M. and Stumm, D., 2013. Seasonal and annual mass balances of Mera and Pokalde glaciers (Nepal Himalaya) since 2007. Cryosphere, 7(6), pp.1769-1786.

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