Interactive comment on “Quantifying ice loss in the eastern Himalayas since 1974 using declassified spy satellite imagery” by Joshua M. Maurer et al.

T. Nuimura (Referee)

tnuimura@cis.ac.jp
Received and published: 9 May 2016

General comments

This manuscript addresses glacier variation over long period (1974–2006). The consistent procedure for generating DEMs use with HEXIMAP enables DEM differentiation with high accuracy, and overcomes procedure-dependent error. The estimated regional mass budget shows little discrepancy with previous studies. However, authors explanation about the discrepancy come from difference of analysed time span (previous studies only cover last decade) is reasonable.

Thank you for your thoughtful consideration of our manuscript. We have carefully considered your comments, and address all of them directly below.

Specific comments

P5 L9-10: Could you show the rate of estimated thickness change in each elevation band in Figure? For example, stack histogram in Fig. 4 might be better (extrapolated data with another color on blue histogram bar).

The rate of change is a simple scalar of the thickness change (i.e. thickness change divided by 32 years). We would like to keep this figure as simple as possible, and thus avoid adding extra information in the elevation bands. Accordingly, we have left the figure as is, and instead notify the reader that in order to get the rate of change, values on the vertical axis can be divided by the timespan of 32 years. To provide additional visualization of individual glacier changes and processing steps, we now include additional supplemental figures – 1) Fig S2 showing individual glacier profiles, and 2) Fig S3-S5 which show the processing steps for each glacier, including areas with interpolated data.

P6 L28: Does "standard error (SEM)" mean "standard error of the mean (SEM)" or "standard error (SE)"?

This was a typographical error, we have corrected it, and now state "standard error of the mean" on P7 L30.

P8 L12-13: The geodetic mass balance by Kääb et al. (2012) also includes East Nepal. Strictly speaking, elevation difference around Bhutan is more negative. In Gardelle et al. (2013), they re-calculated it as -0.52_0.16 in Table 5. The value should be used here.

We fixed this to show updated values from Table 5 in Gardell et al (2013) as suggested on P8 L30

P10 L13: Fig.4 is appropreate figure for checking summary of glacier variation tendency for each glacier type. However, such aggregation of each data make unclear each glacier characteristics. Is it possible to add ice thickness change profile of each glacier as colored lines into Fig.4? If it makes Fig. 4 ambiguous, please add it as another new figure.

A new figure (Figure S2) is now included in the supplement showing thickness changes for individual glaciers.

P10 L13–20: You have mentioned the three possibilities of the small lowering elevation bands (about 4600-4800 m) here. I recommend to investigate the reason by checking individual glaciers. Number of glaciers in these elevation bands (about 4600–4800 m) are 2 and 6 (from Fig. 4), so it is not laborious work. I guess your second possibility is correct.

As recommended, we carefully inspected the individual glaciers contributing to the lower elevation bins, using both Figure S2, the Hexagon and ASTER satellite imagery, as well as high resolution Google Earth imagery.

For clean-ice glaciers:

As noted in the text (and which can be seen in figure S2), glacier k is the dominant factor affecting the clean-ice profile in Figure 4. Since glacier k does not contribute to the lowest elevation bin, the bin exhibits an apparent smaller thickness change.

On closer inspection of glacier toes, we observe that several glacier toes appear darker toward their termini, which we interpret as increased amount of debris cover (glacier s and glacier o for example). The insulating effects of debris-cover likely contribute somewhat to the observed pattern, but based on our analysis, we conclude that the primary factor explaining this phenomenon is that glacier toes are thin to begin with, and thus have less ice to lose. Our 1974 glacier outlines include glacier toes which were already thin at that time, and we expect thinning from that point in time onwards to be smaller near the termini. This (in combination with emergent flow velocities associated with glacier dynamics) likely leads to smaller thickness changes near glacier toes. For example, see the toe of glacier “a” in Fig S6.

For debris-covered glaciers:

Polygon glacier outlines have accuracy problems near debris-covered glacier toes. This is a well-known problem, as heavy debris-cover is indistinguishable from surrounding terrain. Unfortunately, without field measures of debris-thickness we find it impossible to back out the relative contributions of insulation effects vs. inaccurate glacier polygons at debris-covered glacier toes. However, we suggest that future work using SAR velocities may be able to address this problem.

For calving glaciers:

As mentioned in the text, meltwater is effectively stored adjacent to glacier termini in proglacial lakes, making the thickness change appear smaller due to the filling effect of the lake.

We have updated the text to better reflect these findings in section 4.3 on P11.

P11 L1–20: As I commented before, figure about ice thickness change profile for each glacier should be add. It make easy to understand discussion here.

We agree, and now include such a figure (Figure S2).

Figure 3: Description about elevation change for each glaciers (Glaciers a and b ...) should be moved to main text.

The discussion has been moved to main text as suggested.

typing errors

P9 L17, P15 L29: Correctly, his family name is notWatanbe butWatanabe. It is erratum by the journal 'Mountain Research and Development'.

Thank you, we have updated his family name.