Interactive comment on:

"2001–2010 glacier changes in the Central Karakoram National Park: a contribution to evaluate the magnitude and rate of the "Karakoram anomaly"

by U. Minora et al.

Response to comments by anonymous referee #1

Comments

Response

The highlight of the manuscript is a set of two new glacier inventories covering the Central Karakoram National Park, based on Landsat scenes from 2001 and 2010. Glacier change from comparison of glacier margins mapped in these two inventories is then discussed in connection with regional climate trends inferred from neighboring weather stations (temperature and precipitation) and MODIS-derived snow cover extent, used as a proxy of accumulation. The region is already covered by the Randolph Glacier Inventory, but the quality of the existing polygons is likely inadequate to detect the very small glacier change being investigated. It was therefore a sensible choice to produce two new glacier masks and inventories, and they are an important contribution adding to the discussion of this anomalous region. However the ms. should briefly mention the existence and limitations of previous datasets.

I'm not an expert on the existing weather observations and regional climate analyses for this region, so I will not comment on the novelty and exhaustiveness of the climate analysis presented in this work.

The major problem with the ms. in its present form is a lack of details in the Methods and Results sections, and the language is at times unclear or imprecise. This makes it difficult to completely understand it. In particular:

1) Were the glacier outlines produced mostly by automatic classification followed by manual corrections, as I would understand from lines 2899/19-24, or were they mostly digitized manually, with automatic classification only for shadowed areas (line 2900/3- 4)? If they were mostly done automatically, what method was used for non-shadow areas?

-> add something on previous dataset of the same zone (ICIMOD, RGI);

1) Here, we mostly used manual classification (2899/22-24: "Such items make the accuracy of the final classification LARGELY driven by operator's sensitivity (ESA, 2013)"). We used the term "semi-automatic" to indicate the digitization was tried both automatically and manually, and the final result is the combination of the two methods. Specifically, we tried the automatic approach presented in Paul et al. (2004), but we came up with a bad result due to the high debris coverage of the glaciers of the CKNP. Then we tried a supervised classification (Maximum Likelihood type) with different classes and different ROIs. Then we chose the best result of it, and we found it was useful to detect shadows areas, while glacier outlines where still bad. Having tried these two methods (also also a non-supervised classification, which we didn't discuss in the paper because its result were the poorest), we proceeded to manually digitize the outlines, dropping the shadow areas as found by the max likelihood classification at the glacier margins. Eventually, glacier outlines were most digitized manually, with automatic classification only for shadow areas. Now made clearer in the text

2) Were ice polygons split into individual glaciers, and if so, how were the ice divides identified? If they were not, discussing them in terms of 'glaciers' is misleading. If they were, what exactly was entered as perimeter in Eq. 1? The parts of the perimeter belonging to ice divides between adjacent glaciers has no relevance to LRE, and they would even get double-counted if the complete perimeters of each glacier were used. The perimeter of the 'unsplit' ice polygons should be used, and it should be clarified in the description of Eq. 1 parameters.

2) Due to the choice of the images we've been using, to shadow areas identification (see point 1), and (more importantly) to CKNP limits, our polygons were always single ones, with no overlapping between adjacent glaciers. Thus, ice polygons are treated singularly as individual glaciers. Therefore, the issue of adjacent glaciers in Eq.1 doesn't affect accuracy calculation.

3) Some of the 'semi-automatic' classification seems to use pan-sharpened combinations of various bands. Why is the uncertainty of the resulting ice masks calculated on the basis of the 15 m panchromatic band? The spectral information is still at 30 m.

3) Since the "semi-automatic" classification was carried out, as pointed out in point 1, this problem doesn't arise. We carried out manual digitization upon the 15m resolution image (which entails some interpretation by an expert operator);

4) What is the actual expression of the error in area change? Eq. 1 does not seem to match the text immediately above it: the two terms squared and summed are not 'the root of the squared sum of all the buffer areas' (line 2901/14-15).

4) Indeed, the sentence will need be changed to " the root of the squared sum of buffer areas for 2001 and 2010 ". Thank you for pointing out this.

5) Were the detected surge events removed from the analysis? They do not contain a usable climatic signal, so they should not contribute to glacier change figures discussed in the context of regional climate.

5) (DA DISCUTERE INSIEME!!! sui surge); Albeit Surge events are likely uncorrelated with climate, they still contribute to area variation between the two dates in study, and in our opinion they have to be counted. Within the text we then made clear whenever a surge event could be detected, and the corresponding (estimated) areal extent of surges, so that global (in the CKNP) area change, and potential linkage to climate change therein, can be interpreted, at least qualitatively, more neatly either with or without surges.

6) The statement about 2001-2010 area change being detected at only 40 out of 700+ glaciers (line 2910/23, reiterated at 2914/11) is unclear. Is this to be understood as 'no change at all', or 'no significant change'? If the former: minor misclassifications of one pixel around the ice margin are to be expected in the assumed error model, so how did you discriminate between mapping uncertainty and genuine margin fluctuations? If the latter: how was significance defined and determined for each individual glacier?

6) Glacier polygons (that we were able to classify as) changed between 2001 and 2010 were 40 in total, the rest remained unchanged. Therefore, visible glacier changes occurred during the two chosen years, but the number of involved glaciers is small against the whole glacier cover, and the overall situation could be considered stable (therefore, no significant change occurred). We did not consider absolute significance for each individual glacier, as we focused upon the general situation of the park.

7) Area change of +27 +-42 kmˆ2 only indicates stability, it cannot be claimed to indicate any increase, either 'remarkable' or not, so please improve lines 2910/20-22 and 2914/7-10. The abstract got this right.

7) Yes, we will correct this point. Thank you for pointing this out;

LINES 2910/20-22

BEFORE

"*Based on this analysis, the total glacier surface increased slightly, by ca. 27 km2 during 2001–2010. The relative area change is not remarkable (+0.6 % of the 2001 area), and it is smaller than the error we calculated from Eq. (1) (±42 km2), thus suggesting rather stable conditions.*"

AFTER

"*Based on this analysis, the total glacier surface seems rather stable during 2001-2010. The relative area change found in this study (+0.6 % of the 2001 area), is indeed smaller than the error we calculated from Eq. (1) (±42 km^2).*"

LINES 2914/7-10

BEFORE

"*In 2010 we found an ice coverage of 4613 km2 (±38 km2), thus giving a not remarkable area change (+0.6 % of the 2001 area), which is also smaller than the error affecting our computation (±42 km2), thus suggesting rather stable glacier conditions.*"

AFTER

"*In 2010 we found an ice coverage of 4613 km^2 (±38 km^2), giving an area change smaller than the error affecting our computation (±42 km^2), thus suggesting rather stable glacier conditions.*"

8) Error assessments seem either incompletely developed, or incompletely described: the 'errors from specific scene conditions' are discussed at page 2901, and they are not argued to be negligible, so were they quantified and included? If not, the +- 42 kmˆ2 accuracy stated later on would be too optimistic.

8) As specified at page 2901, these "errors from specific scene conditions" were limited as much as possible by accurately selecting the scene. Also, shadowed area are excluded from the inventory, thanks to the SML classification (see 2902/8-9). Clouds are less than 6% and they were mostly out of the glaciers perimeters in the scene. Possibly, snow coverage within the high accumulation zones (ca. above 6000 m asl) could increase the error. However, we could not quantify this latter point given that some snow cover is basically always present upon ice at high altitudes, and it is impossible, given the present information, to highlight presence (or lack) of ice under the snow cover.

9) Except for well-developed medial moraines, the transition between clean ice and debris-covered ice is typically gradual. This is especially the case for most parts of glaciers newly becoming debris covered. Here,

two classes “clean-ice” and “supraglacial debris” were used for training, so I would expect “supraglacial debris” to mean “complete supraglacial debris cover”. Fig. 7 (top) is quite small, but it looks like mixed pixels between the two end-members were also recognized as “supraglacial debris” (see the ‘swarm’ of yellow pixels where the southernmost medial moraine fades eastwards into clean ice). Was this the case, or is Fig. 7 just too small? Inclusion of mixed pixels would raise the issue of how consistently the supervised classification performed between scenes with different illumination and ground conditions. The ms. only mentions ‘visual validation’, but gives no information about what fraction of debris cover was taken to separate “clean ice” and “supraglacial debris”, and how this could be consistently enforced without concurrent ground observations.

9) Our attempt was first trying and verify whether there was any (significant) debris cover increase between 2001 and 2010, which we did not find out. Likely, the presence of areas covered with snow, and difference of scene conditions would lead to a different debris mapping in the two periods. We selected our scenes in periods similar as possible, to avoid different seasonality issues. We used a Median [3x3] filter to eliminate "spotted", or “dark” areas within the debris class, folding them in the "clean-ice" class. We relied upon the assumption that use of a consistent rule between the two different images, would specifically allow accurate assessment of the differential debris covered area (if any).

10) The half-pixel buffer concept underlying Eq. 1 estimates a very high uncertainty when the size of many objects mapped as distinct entities approaches the pixel size of the satellite image. From Fig. 7, this seems to be the case of the ‘debris’ class, and it is the reason for the very poor accuracies reported (+-14% in 2001 and +-18% in 2010). This is not to suggest that the debris cover estimates are more accurate than reported, but rather that this purely geometrical accuracy estimate entirely neglects what may be the largest error source (see my previous point on the performance of the supervised classification).

10) The main aim of the article is estimating areal changes, therefore, being the area covered by small size glaciers very little against the full extent (glaciers smaller than 2 km^2 contribute about only 6% of the total area, see Table 5, at page 2928), the error of distinct entities approaching the pixel size of the satellite image could be neglected;

11) What is the accuracy of snow cover extent figures given in section 4.3 and Tab. 2? Section 3.2.2 discusses this issue but does not attempt any actual estimate. Section 3.2.1 further states that the time series is too short for any statistical analysis of the observed trends, but then there is no basis at all for fitting any trend, and the MODIS work should be left out entirely.

11) Use of MODIS snow cover products, and accuracy therein is a widely discussed issue, with several contributions presented in literature. Here, we used as a reference, among others, the work of Parajka and Bloschl (2012). Also, we report that Tahir et al. (2011) used MODIS images for snow covered area estimation in Karakoram, nearby our study area, reporting about their good accuracy. Although such a short series cannot be used to assess any significant trends, notice that i) SCA is hardly available from any source for longer periods, and ii) MODIS images area used routinely for assessment of SCA, and qualitative illustration of snow cover area modification is surely of interest. Also, comparisons with Tahir et al. (2011) as reported provides a relevant benchmark in this area.

Clarifying and adding the details listed above should be possible without making the ms. longer than it is, because the present version is not concise, with several repetitions both among and within sections, and with long paragraphs only marginally relevant or misplaced. For instance, most or all of page 2897 can be deleted or briefly summarized and moved to the Introduction.

When resubmitting the modified manuscript, including modification after reviewers' comments, we'll try and shorten the manuscript, while including all the relevant points raised by the reviewers. Text in page 2897 will be shortened, and possibly moved to introduction.

Sentences like 2911/1-2 are entirely self-apparent.

The sentences

"*These advances consisted in a downshift of the glacier minimum elevation in 2010. In some cases they even advanced on top of their bigger neighboring glaciers.*"

Were dropped, as they are indeed unnecessary.

A page worth of text should be deleted from line 2907/14 to 2908/10 and replaced by an appropriate reference.

The text from 2907/14 to 2908/10 was now shortened to

"Here the MK test was applied to raw data, without pre-whitening, according to Yue and Wang (2002)."

The style and occasionally grammar need to be improved.

When resubmitting the modified manuscript we'll try to improve style and grammar.

Other remarks: Line 2894/22: : :29 'recent' terminus fluctuations in general do not simply reflect 'recent' climate, especially for large glaciers, and the response time of each glacier must be taken into account to properly relate the two mentioned in the same ms. Perhaps 'to link surface mass balance and local climate' may be better?

LINE 2894/26-27

BEFORE

"*These observations were explained with the recent climate peculiarities...*"

AFTER

"*These observations keep pace with the local climate peculiarities, such as…*"

2896/24 'rainfall' or 'precipitations'?
"*precipitation*" , as its form depends upon temperature.

2900/12-15 what do you mean by 'analyze'?

LINE 2900/12-15

BEFORE

"We also referred to Google Earth© to analyze high resolution SPOT images from the study area."

AFTER

"*We also used Google Earth© images to have a further control on the inventory with high resolution SPOT images from the study area.*"

2900/19-20 ': : :due to co-registration and classification errors.'?

Rewritten as "…due to co-registration and classification errors."

Yes, that's what I meant.

2900/24-25 clarify/rephrase

LINE 2900/24-25

BEFORE

"*This type of error depends upon the referencing quality with respect to the specific projection system*"

AFTER

"*Georeferencing error arises when one tries and pursue the accurate location of an object within the physical space (georeferencing), and mostly depends upon the availability and accuracy of the spatial data related to that specific object (i.e. here the accuracy of the estimated coordinates of objects within the Landsat image in a specific projection system).*"

2900/27 'correction process' -> georeferencing and orthorectification?

Exactly, it's all explained in the Landsat7_Hanbook, which is included in the reference list.

2901/4 'contrast' do you mean 'roughness'?
Roughness is better in this case.

2901/22 image -> pixel
We think *image* is more appropriate, because the pixel used are those in the visible, but the *visual comparison* we make afterwards is done over the resulting FCC image.

2902/25 'highest line of ablation' do you mean ELA?

LINE 2902/25

BEFORE

"Eventually, to investigate the role of debris cover within glacier ablation area, we set the highest line of ablation to 5200 ma.s.l."

AFTER

"*Eventually, to investigate the role of debris cover within glacier ablation area, we set the equilibrium line altitude ELA to 5200 m a.s.l. for the entire zone*"

2903/20 I never saw a general purpose programming language referenced in this way

BEFORE

"..using Python language (Python, 2013) combined with a GIS."

AFTER

"*…using Python language (http://www.python.org/) combined with a GIS.*"

2904/16 if there is no significance, there is no trend either

We do not agree. Trends are seen and commented (increase or decrease), as discussed in Results section, but we do not test their significance.

2907/5 LR?

Linear regression, as introduced in 2905, Line 23.

2908/12 N in NAO is 'North'

BEFORE

"Northern Atlantic Oscillation (NAO)"

AFTER

"*North Atlantic Oscillation (NAO)*"

2910/1 what is rho? The Spearman correlation? Significance of this 'significant correlation'?

It's linear correlation coefficient, now explained.

2910/20 change within uncertainty, can't say it increased.

Our analysis displays increase. We underline however this is not significant.
Changed to:

“Based on this analysis, the total glacier surface increased (not significantly) by ca. 27 km^2 during 2001–2010.”

2911/1-2 sentence doesn’t add anything
We deleted this sentence.

/13 ‘movements’ ->fluctuations
We prefer “*movements*” as we are talking about two different types of “advance” rather than “advances and retreats”

/13-28 were these surging glacier excluded from the climate-related analysis and discussion?
No, they were included (see answer 5 above)

/28 what is a ‘complex perimeter’?
We call “complex perimeter” a perimeter which has a high ratio between its value and the circumference of the circle having the same area (namely, the more the polygon shape is far from a circle shape, the more complex its perimeter is). To be explained shortly in text.

2912/17-21 AND tab 2: why these particular ‘elevation belts’? Give elevation ranges,
not A,B,: : :
We tried to match those of Tahir et al. 2011 as much as possible, for comparison. Table2 reports the ranges.

2913 DT_G ?

Global thermal anomalies, introduced in 2908, line 19.

2914 Conclusions: several remarks above apply again here

Conclusions will be rewritten.

2915 last paragraph is awkward

It will be reformulated.

2916 add acknowledgment for MODIS data

This will be introduced.

Fig 8 Julian day – Day of year. Trend lines are not trends unless shown significant

See answers 11 and to 2904/16 above. We want to qualitatively display increase or decrease, while we state clearly this is not significant statistically.

Fig 7 too small
We’ll make it bigger.

Fig. 5 may be left out
This figure seems of interest, we’d rather keep it.

All tables: on my pdf I don't see any bold typeface. Also, verify that all symbols are consistent with, and defined in the text. Interactive comment on The Cryosphere Discuss., 7, 2891, 2013.
Those went lost in editing, need be re-edited. We'll check for consistency.

-> add something on previous dataset of the same zone (ICIMOD, RGI);

INTRODUCTION

BEFORE

"From the intercomparison of the different data sources exploited here we try to draw an updated picture of the CKNP glaciation, and discuss its peculiar behavior and features against the recent literature upon HKKH glacier changes."

AFTER

"*From the intercomparison of the different data sources exploited here we try and draw an updated picture of the CKNP glaciation, possibly contributing to implement other existing inventories in the same area, such as ICIMOD (2012), and the Randolph Glacier Inventory (Arendt et al., 2012), and discuss the peculiar behavior and features of Karakoram against the recent literature upon HKKH glacier changes.*"

Reference for Randolph glacier inventory:

Arendt, A., Bolch, T., Cogley, J. G., Gardner, A., Hagen, J.-O., Hock ,R., Kaser, G., Pfeffer, W. T., Moholdt, G., Paul, F., Radic, V., Andreassen, L., Bajracharya, S., Beedle, M., Berthier, E., Bhambri, R., Bliss, A., Brown, I., Burgess, E., Burgess, D., Cawkwell, F., Chinn, T., Copland, L., Davies, B., de Angelis, H. , Dolgova, E., Filbert, K., Forester, R., Fountain, A., Frey, H., Giffen, B., Glasser, N., Gurney, S., Hagg, W., Hall, D., Haritashya, U. K.,

Hartmann, G., Helm, C., Herreid, S., Howat, I., Kapustin, G., Khromova, T., Kienholz, C., Koenig, M., Kohler, J., Kriegel, D., Kutuzov, S., Lavrentiev, I., LeBris, R., Lund, J., Manley, W., Mayer, C., Miles, E., Li, X., Menounos, B., Mercer, A., Moelg, N., Mool, P., Nosenko, G., Negrete, A., Nuth, C., Pettersson, R.,

Racoviteanu, A., Ranzi, R., Rastner, P., Rau, F., Rich, J., Rott, H., Schneider, C., Seliverstov, Y., Sharp, M., Sigur˘sson, O., Stokes, C., Wheate, R., Winsvold, S., Wolken, G., Wyatt, F., and Zheltyhina, N.: Randolph Glacier Inventory [v2.0]: A Dataset of Global Glacier Outlines. Global Land Ice Measurements from Space,

Boulder Colorado, USA, Digital Media, 2012.