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Interactive comment on "Four decades of glacier variations at Muztag Ata (Eastern Pamir): a multi-sensor study including Hexagon KH-9 and Pléiades data" *by* N. Holzer et al.

Anonymous Referee #2

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The research paper "Four Decades of glacier variations at Muztag Ata (Eastern Pamir): a multi-sensor study including Hexagon KH-9 and Pleiades data" presents new and relevant information on glaciers in a region where so far only sparse data is available. The data base is sound, the article is clearly written and understandable. Nevertheless, here and there the structure of the article and the phrasing could be improved. The description of the climate data remains unclear, here some additional information is needed. Generally, following changes could help to improve the presentation of data, methods and results as well as the discussion: The climate data is now part of chapter 2, Study area. This should be part of the data section, and the location of the climate measurements should be evident from Figure 1. At least seasonal mean(s) winter pre-

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cipitation, summer temperatures) should be shown in a graph, as these are discussed later. Where in the introduction only one station is located above 3000m, later on high elevation climate changes are discussed. It would help to have more clarity on the data base. The methods, results and discussion parts are mixed up somehow. The term mass balance is used for geodetic mass balances as well as direct mass balances in the same paragraphs, which is confusing. If mean annual change rates are derived from geodetic balances, it should be clearly distinguished in the phrasing from measured annual balances, as the difference could be high. The presentation of the periods is also confusing, I would recommend to present the total period 1973-2013 and the subperiods (1973-1999, 1999-2009, 2009-2013). I miss a general discussion if the accuracy of the DEMs does allow this high temporal resolution, when large parts of the glaciers show low altitude changes. The amount of snow covered or oversaturated area should be indicated in the remote sensing images, which would be nice to see in the article. The impact of the method for calculating dh on the volume change and mass balance should be more explicitly discussed. Some of the following detailed comments might just be a hint on a lack of clarity in the description, but should help to find out where changes in the text could help to avoid such misunderstandings.

Specific comments: Abstract: 1: Does this first sentence refer to results of this study, or to direct measurements? Is there a research question to ask here to explain the aim of the study, e.g. to find if these measurements represent singularities or large scale mass balance trends? 12: What is meant by fluctuated or advanced? Aren't fluctuations advances and retreats? 13: Did you really observe continuous shrinkage, or just in the resolution of your data (maybe missing some short annual or seasonal advance?) 14: What is a visual advance, do you mean that as synonym of meaasureable, or as contrast to any other (radar?) method? 21: The choice of presenting overlapping periods is somehow obscure. If the accuracy of the DEMs and the amount of seasonal snow does allow a presentation of the single periods, I would prefer that. If not maybe just present 1999-2013? 1814 16-20: For which periods have these mass balances been measured? 23: Is this really gridded data, and what is the variability?

TCD
9, C707–C712, 2015

Or do these numbers refer to a specific station (in this case we would like to know which station, coordinate, altitude . . .). What is the reference period of the presented anomaly? Are the 7.4 mm /decade significant? Please also give the annual mean and precipitation of the reference period. 24 ff: What do you mean by warming? A seasonal mean would be better than a annual mean. How many stations and where, in which elevations, show changes in which climate parameter? Does that mean that close to these glacier tongues stations are located? Maybe shift this paragraph to the data section and describe the measurements more extensively. 1815 20: Here comes another piece of climate, please shift that to the data section. Why do you present annual values and not seasonal ones? 27: Is summer June July August or May to September? I do not get the message: Did you compare periods (which) or calculate a trend (how) to end up with a warming of 0.7°C. Is 1957 the start of your period and 2000 the end? But what did you compare that to? Please explain that more explicitly preferable in the data section.

1816 3: is there a reference to cite, at least any indication where this information comes from? 5: Where was a warming observed – in the core? Or was it an isotope variation, which is for sure not related to a shift in the precipitation regime? What means the 'from2,0 °C to 2.4°C – a range for different stations, an error bar, different periods, an altitudinal effect? Does it make sense to compare a station at 3000 m with a station (or whatever) at 7000 m? And why? 1818 12: Are the images free of seasonal snow? 15 ff: What about the steep parts – was the geometry of SRTM sufficient to map all the areas? Which parts were hole filled? 1819:1: What about the snow conditions then?

6: I did not really get if you excluded the moving ice and snow areas for coregistration. Did you? 1820: 10 What about the ICE SAT footprint – which accuracy has the elevation of this data in the view of the rough terrain? 1821 25: Would be nice to indicate erroneous parts in the map and find them in the discussion of the uncertainty of the geodetic mass balance. 1822: 3: Did you exlude moving parts (glaciers) from coregistration? 1823: any decorrelation ? 11: I would see here rather a section on results

TCD
9, C707–C712, 2015

with subchapters. . . 1824: 1: So this is rather a chapter on geodetic balances, which I would like to read in the title. What about seasonal snow, the accuracy of the DEMs and the resulting maximum temporal resolution? This could be stated in a section on methods, together with the density assumption. As the geodetic balance can only be calculated for the full glacier area, especially in case of surging glacier, how did you proceed with data gaps? What was the threshold for example to skip a glacier in case a part of the area was not mapped? Why did you choose these glaciers?

26: It is not clear how these ELAs have been derived, and how you can cross check it with satellite images, especially if there is a potential offset between ELA determination time and acquisition of the satellite data? Later is seems that you presume that this ELA has something to do with accumulation and ablations zones on the glaciers in your data, if I understand correctly. Why? 17ff: If I do understand correctly you set the elevation change in the accumulation area to zero? Why? Especially in case of surging glacier one would expect to miss an important part of mass balance when doing so, even on every other glacier one could not calculate mass balances without including the accumulation area.

20: In case this is a section on results, I clearly see the penetration depth in a methods or data section. 1826: 6: If this is a section on result, basic explanations of how to measure velocities should be part of a methods section. 16 ff either present first the eq. 1 and explain the symbols or eq 2 and the symbols, but do not mix it.

21: Section 6 is important, but parts of it are spread all over the text. The discussion of the uncertainties should be point by point, and the results of every step on the geodetic mass balance should be summarized at the end. In the current version, important sources of uncertainty are not discussed, and partly the quantification is missing.

1827: 21: The term mass balance rate is not very clear. The discussion of the effect of hole filling and skipping accumulation areas is missing.

1828: I do not completely understand the difference between the glacier variation chap-

TCD
9, C707–C712, 2015

ter and the results chapter. 5 ff: This collection of numbers is nearly unreadable; the table does its job. I would rather see here some text. 25: What do you mean by steep tongue? Possible not an average slope or something like that? 1829: 1: This should be GEODETIC mass balance 26: Seem to fit is not very precise, especially as it is not clear to what. 1830: 3: We all know that this assumption is not valid, so what is the sense of the extrapolation? Would be nice to have the velocity map.

1831: 5: Geodetic mass balances 10 ff: I find the wording a bit confusing, and think it could help to add either direct or geodetic to the mass balance results. Is there any possibility to present the various results, periods, methods, authors and regions in a table? 1832 7: Fedchenko 20: could also be the case that a surge type glaciers stores mass in the accumulation are, despite mass loss at a tongue. So basically what happens at one single part of the glacier never can give an indication on total mass balance.

23: terminus position I suppose 1833 9: What is the toe? IS this tongue? 27: Why opening here the field of Holocene oscillations? Maybe better in the introduction? 1834 5ff: I do not understand the sentence with ablation in summer and why we find it here. The next sentences on the climate at 5910 m is a clear contradiction to the introduction, with only one station above 3000 m located close to the study site. This climate data would rather fit into the climate section before – why is it placed here? Lines 5 to 19 are either rather speculative or fit into the climate section. 19-21: I presume the colder years are too few to cluster in a period. It is unclear which normal period you refer to when classifying these years as 'cooler'. Cooler than what? And how much? And how large have the precipitation changes been? 21 ff: We have just gone through a chapter on uncertainties, so that we do not want to go back to this once more. In any case, the impact on mass balance is not discussed! 1835: 13: This would fit in a metheod section, or in the chapter on penetration depth. 1836: 24: Please give also the second period. Table 3: please organize the last column similar to the previous one, the -+ in one line. How is the ELA calculated? Table 4: See main remark on periods. Annual

TCD
9, C707–C712, 2015

mass balance: Should be mean annual geodetic mass balance. Figure 1 : Stations lacking Figure 3: Below T3 some stripes are visible – is that an artefact? Figure 4: The ELA is a calculated value, and could not be indicated in an image as line as done here. Is this a snow line, or a contour line of elevation? What is the black area? Figure 5: Where does the volume loss outside the glaciers come from?

Interactive comment on The Cryosphere Discuss., 9, 1811, 2015.