

Interactive comment on “Mass balances of Yala and Rikha Samba Glacier, Nepal from 2000 to 2017” by Dorothea Stumm et al.

Anonymous Referee #2

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First of all, I would like to congratulate the authors for their efforts in establishing the new glaciological mass-balance programmes at two glaciers in Nepal. Direct measurements are still scarce in the entire Himalayas, and as also written by the authors in their paper, there is an urgent need for such key data for climate monitoring but also for applications such as water resources or hazard management. Moreover, such data are indispensable for model calibration and hence for projections of future developments in this regard. The presentation and discussion of direct glaciological measurements at Yala and Rikha Samba glaciers are the centerpiece of the presented paper (this focus could actually be emphasized even more explicitly in the paper). The data are complemented by other relevant glaciological information such as geodetic mass-balance data, glacier length changes, and glacier velocities. This very nicely fits to the scope

C1

of “Earth System Science Data” and I recommend the paper to be published after addressing the following comments and suggestions.

Overall, the description of data and methods is very detailed and applied methods are sound. Some clarifications and specifications might be needed at some instances, see detailed comments below. Although the presented series of glacier mass balance are still rather short, results are plausible and in line with other studies (using other methods). This is also confirmed by the mass-balance gradients observed in this study, which are consistent over the entire observation years. Regarding the mass-balance gradients, I was though wondering about the different approach to estimate the gradient at high elevations (Yala vs. Rikha Samba glaciers, Figure 3). Although the authors give some indications in the paper and refer to other studies, too, it is not fully clear why there are two different approaches chosen. I suggest that the authors address this point in the Discussion section. Or, if the effect is neglectable for the overall mass balances, it would be useful to have some quantification about the effect.

Regarding the data, I was wondering why the data are presented until 2017 only. The authors refer to the “Global Glacier Change Bulletin No. 3” by WGMS, where we can find the data up to the balance year 2016/17. On the other hand, the authors also refer to the latest version of the “Fluctuations of Glaciers” database by WGMS from August 2020, which includes data until 2018, also Figure 4 includes some data until 2018. This might cause some confusion. Regarding the available datasets, it should also be specified which data are actually available from the WGMS. If I am right, only the glaciological mass-balances are included, but the geodetic data are not (yet?) included and for instance velocity data are currently not stored by the WGMS.

The paper is very nicely structured and clearly presented. As mentioned above, the description is very detailed, which is useful for readers that are looking for comprehensive information about mass-balance programmes (almost in the sense of a review). On the other hand, I am still wondering whether the paper can be shortened and streamlined, such as the Data section and in particular the Discussion as well as the Conclusions

C2

sections. The discussion is very comprehensive and includes many interesting aspects (e.g., climatic influence such as monsoon and jet stream, local weather conditions), which however call for further answers that are not provided in the paper (and which are not in the scope of the paper). I therefore strongly recommend to limit and streamline the discussion to facts that are directly linked and most relevant to the data of the present paper, and to clearly highlight the importance and the value of the presented mass-balance series. In turn, the Conclusions should concisely focus on the key points from the Discussion.

More specific comments and suggestions are as follows:

Line 9: Should be formulated more precisely, because “essential variable” might be associated with the ECV Glacier according to GCOS/WMO terminology. Moreover, I would separate between the climate aspects (sensitive response of glaciers to climate change) and applications of the data, such as for runoff modelling.

Line 11: This sentence could be deleted as you anyway state at the end of the abstract that the data are available from the WGMS. One might also ask if the main purpose was the ingestion of the data into the WGMS database (which is of course important but probably not the main motivation).

Line 14: It is not fully clear which series refers to the glaciological method and which one to the geodetic method. General comment regarding the dates: although it becomes mostly clear from the context, it could be helpful to specify the balance years for the glaciological measurements (e.g. 2011/12 to 2016/17). Otherwise the year could refer either to the start of the measurements or to the moment when the observation period is finished.

Line 15: cumulative mass loss

Line 16: missing verb

Line 18: logically not clear, the mass balance of Yala is compared to the mass balance

C3

of another glacier. The same also applies to line 19.

Lines 18-20: Was this really investigated in the present paper? Some aspects are discussed but there are many other aspects that could be considered, and given the fact that there are only very few other glaciological mass-balance series available, I would be careful with such general or relative statements (such as “mostly because of...” or attribution to “low-lying” areas etc.).

Line 23: Specify that the glaciological mass-balance datasets are available.

Lines 28/29: This is a bit too simplified and could be further explained: the glaciological method is indeed a key in international monitoring strategies and is needed for model calibration etc., but for global sea-level rise, the largest ice masses measured by satellite remote sensing are contributing most. Moreover, you could specify what kind of local hazards you refer to.

Line 30: input variable

Line 30: water availability and the change in its availability

Line 34: or: “in support of the United Nations Framework...”

Lines 32-35: 1-2 key references should be given here

Line 37: still involve

Line 44: Some studies have focused (?)

Line 45: Not fully clear, did these studies only address the lower parts of the glaciers (where there is debris cover)?

Line 51: the longest series ... is found (?)

Line 51/52: with measurements since 2002

Line 52: why partly?

C4

Line 55: are glaciological mass-balance records available for both periods?

Line 57: What do you mean with in situ geodetic mass balance measurements?

Line 60: rather point mass-balance measurements than index measurements

Line 62: check tense: have these measurements been continued until today?

Line 63: 1970s, 1980s

Line 65: I suggest writing Pokhalde and Changri Nup Glaciers (in plural), to make clear that you refer to two different glaciers. The same spelling should be used throughout the entire paper, incl. Yala and Rikha Samba Glaciers – I leave it to the authors what they prefer.

Line 67: you could specify what they calibrated against. Geodetic mass-balance data?

Line 68: what do you mean with in situ surface surveys?

Line 69: where exactly was this applied?

Line 78: What was the glacier selected for?

Line 79: or: it offered / enabled easy access

Line 80: what do you mean with glacier processes?

Line 82: delete the comma (last character in line)

Line 87: documented

Line 87: "for Langtang valley": did they also observe other glaciers in the valley?

Line 90/91: "highlights the importance of...": you could elaborate a bit more on this very important aspect.

Line 92: Cogley et al. 2011?

Line 96: Add break and start new paragraph with the main objective.

C5

Lines 93ff: Here I am wondering about the structure: after a rather long introduction, the motivation of the present study is given here again (compare with second paragraph of the Introduction), which leads to some redundancy. Moreover, you refer to the motivation of establishing a sustainable and long-term mass balance programme. This is a very important aspect; however, the paper is about the mass-balance data themselves and not about the monitoring strategy behind. This should be clarified here. In the same paragraph, you mention the training of students and professional; another key aspect in maintaining the monitoring programme on the long-term, however, the paper does not deal with this aspect either. These aspects could be given at the end of the Conclusions in the sense of an outlook.

Line 102: Master theses

Line 104: The focus is not only on Yala glacier.

Line 104: seasonal? Bi-annual could be interpreted ambiguously (twice a year or every two years).

Line 107: For general clarification, I would just refer to the latest version of the database.

Line 109: The question is also whether the experiences are applicable to other remote areas, too. A short notice in the Discussion or as an outlook at the end could be useful.

Line 112: Altitude range of Yala glacier?

Line 114/115: What kind of data is already available for Yala glacier, and what do you mean with long gaps?

Line 116: mass-balance monitoring programmes?

Line 120, Figure 1: In the overview map, include the name Nepal. As you refer to the different rivers in the text, it could be useful to show them also in the map (I leave this up to the authors how much effort they want to put into the overview map). Regarding

C6

the glacier maps, I am though wondering whether the stake locations also include snow pits? For Yala glacier, I am also wondering why there are no stakes in the upper part of the glacier (i.e. in the northern half of the glacier). Is the area too steep or inaccessible? Are the contour lines from the DEM from 2012 for both glaciers? The hill-shaded DEM seems to apply to Yala, the background for Rikha Samba is an ortho image?

Table 1: Order of characteristics? Glacier locations could be placed first; glacier type information rather below

Line 142: not clear: if the glacier extents further to north-west, why is this area not included in the analyses? Also, not clear: how can the glacier be separated along the flowline? What do you mean exactly?

Line 144: Do the 5% of the area also include the ice cliffs or only the steep slopes? What is the influence of the ice cliffs? (it is addressed in the Discussion, maybe add make a short separate section there, because it is a special feature).

Line 146: based on radar or other measurements?

Line 148: if rockfall covered parts of the glacier, why is it outside the defined outlines?

Line 148/149: this transition zone from debris-covered ice to buried ice (dead ice?) and permafrost ground with ice should be shown on the map. And, how is a clear delineation of the glacier margin possible? Does this situation influence the mass-balance observations?

Line 149: Add a break and start new paragraph.

Line 150: Earth's

Line 150: the largest landslide so far documented (?)

Line 152: ka

Line 153: What do you mean with high glaciation? Glaciation during the ice age(s) or glacier coverage until today.

C7

Line 155: why possibly? From your own field experience, you can maybe directly assess the local meteorological conditions?

Lines 154-162: Move the aspects about the climate to the next section.

Line 162: compared to Yala glacier?

Line 169: is sparse

Line 173: "received": check tense

Line 175: the meteo stations you refer to could be added to the map

Line 177: rather mean annual precipitation (also line 181)

Line 178: start new paragraph for Rikha Samba glacier

Line 189/190: not clear: what do you mean here? How is it indicated? From the observed radiation?

Lines 189-200 and entire sub-chapter 2: Regarding the overall structure, I suggest to bring first the more general facts about the setting incl. climate, and then specifically address the two glaciers.

Line 199/200: does this apply in general or especially at Yala glacier?

Line 200: wind speeds

Line 202: was monitored

Line 202: rather write "from autumn 2011 to..."

Line 206: avoid abbreviation and "biannually"

Line 207: measurements

Line 218: stakes

Line 219/220: unclear, should be further explained. Also, in line 221/222 you refer to

C8

ablation and accumulation occurring during the same time. For a better general understanding of the seasonal mass-balance evolution at the glaciers, it would be useful to have (1) a general statement about potential accumulation/ablation seasons and (2) how this affects the mass-balance measurements (and (3) how mass-balance measurements are performed in practice).

Line 221: can be clearly identified

Line 225: why is the network stretched along one line? See also my comment regarding Figure 1.

Line 229/230: The effect of the ice cliffs and steep slopes should be placed in the Discussion.

Line 234: Snow depths and snow pits incl. snow density...

Line 238: kg m⁻³

Line 240ff: This section is very detailed (too detailed). You could just directly refer to Table S1.

Line 245: at best?

Line 255: What are the velocity measurements used for?

Line 258: Explain that "Schneider" is a particular map name (Arbeitsgemeinschaft für vergleichende Hochgebirgsforschung?)

Section 3.2 is interesting to read but very detailed. Maybe some of the information could be placed in a table instead to shorten the section.

Line 305: not clear, rewrite the last sentence

Line 332: Abbreviations should be written out when they appear for the first time.

Line 358: based on the measurements by whom? According to Figure 3, there are no data.

C9

Line 358: balance year 1998/99?

Line 360ff: Are there large changes in the area over the observation period? If not, the difference between conventional and reference-surface balance is small and a corresponding note should be added in the text.

Line 375/376: not fully clear what you mean with regression lines caused by outlying points

Line 380: not clear: what has been separated? Why based on the contour line method? It is not evident from Figure 1 (map).

Line 402: Not clear: earlier in the text you state that the ELA is derived from the mass-balance gradient; is it also observable in the field? "balanced ELA": write ELA0 as in other occasions in the paper and state at some point that ELA0 (AAR0) is the balanced ELA (AAR).

Line 410: What is/was the purpose of this additional profile line? Was it used to calibrate the geodetic data? Was there a correction applied? Or was there any benefit for the in situ glaciological measurements?

Line 434: climate stations?

Line 445: gradient for Yala Glacier from 2011/12 to 2016/17. Delete row with "1999"

Line 450: Not clear whether there was actually a measurement at Rikha Samba in 1999 or if this should be 2011. However, if the latter applies, the caption should read 2010 to 2017, or better 2010/11 to 2016/17.

Line 463: The differences between seasonal and annual balances should be further explained (in the Discussion).

Lines 474-477: Repetition of what has previously been stated.

Line 486: m a.s.l.

C10

Line 488: linear regression?

Line 493: seasonal and annual balances The consistent gradient for the glacier: an interesting finding that should be mentioned in the abstract.

Line 499: Your statements here raise the question of why there are no measurements in the higher areas of the glacier(s). Are these areas too high? Too steep? Too dangerous? This should be specified and clarified at some point.

Lines 500-509: move this paragraph to the Discussion

Line 528: The thinning rate along the profile line is not clear (-1.1 m a-1); is it the mean along the line? Would a mean even make sense? What is the purpose of this profile line?

Line 529: m a.s.l.

Line 538: Table 4 should be moved to the Discussion.

Line 540: In Table 4, you refer to WGMS (2019). The reference is missing and anyway the question is what the original source is. In the table, I would explicitly write "glaciological method".

Lines 545-552: should be moved to the Discussion

Line 550: Maybe also add Chhota Shigri glacier (cf. Discussion)

Line 551: regarding Mera and Pokalde glaciers: where are these glaciers exactly located? They could/should be added to the overview map.

Line 558/559: The comparison of the retreat rates of both glaciers is relative because the glaciers are different in size and form. For Yala glacier, it might also be more straightforward to assess area changes instead of length changes (?). Or to add area changes in addition to the length changes.

Line 579: Figure 12 should be moved to the Discussion.

C11

Line 583: The displacement of the stakes is interesting and allows the link to the velocity measurements.

Line 585: why is the profile line from Sugiyama et al. added? And is this the same profile line as mentioned before?

Line 595: All glaciers and benchmarks as used in the Discussion could be shown in the overview map. For clarification, it should also explicitly be stated

Line 614: The paragraph here as well as the subsequent ones refer always to geodetic mass balances; this should be clearly stated or structured in a clear way so that both observations types are not mixed up.

Line 637ff: What does this mean for assessing glacier mass balances over the entire Himalaya? Is it possible from the available data to draw general conclusions? The authors might elaborate a bit more on this question, which also allows to place the mass-balance data from Yala and Rikha Samba into a larger context and to streamline the Discussion (cf. my general comment above about the Discussion).

Line 640: Such a bias

Line 641: here the term mass budget is used, at other occasions the term mass balance is used. You may check for a consistent use throughout the paper. The same applies to the term net balance (e.g. in line 649 or Figure 14), which should be avoided (cf. the mass-balance glossary by Cogley et al., UNESCO, 2011).

Line 651/652: delete sentence

Line 660/661: 1980s, 1990s (see also line 680 and other occasions)

Paragraph from line 649: It should be better worked out why this context is important for the discussion of the measurements presented in this study.

Line 686: If you specifically address particular stakes with names, then these should also be labelled in the map.

C12

Line 700: There is a break and hence a new paragraph should be started here.

Line 701: why are the measurements on Yala glacier representative? Could you explain that a bit more in detail?

Line 707: The general character of Yala (and Rikha Samba) glacier(s) should be stated at the beginning of the paper (it also relates to my previous comment regarding the ablation/accumulation season, see lines 219/220). In line 708, there is now a contradiction to the what has just been stated before. This should also be clarified.

Line 715: during favorable conditions

Line 723: Is this statement really needed for the discussion?

Line 738ff: rather results, can be deleted here or just refer to Figure 11, but then also an explicit link to the mass-balance data should be made. On the other hand, the Little Ice Age extent is mentioned here for the first time, however, the location is not shown on the length change plot (either add or delete entirely).

Line 756: the mass-balance data shown only cover a few years, so it is probably more appropriate to write about an overall retreating. Or can you exclude that there were more balanced (or maybe even positive) years over the last couple of decades?

Line 760/line 770: Avoid new references or rather move to Discussion

Lines 764ff: Does this refer to Yala and/or Rikha Samba?

Line 772: m a.s.l.

Line 773: This aspect is not mentioned in the Discussion, isn't it? It is an important aspect because it also influences the glacier's mass balance (and there is also another comment above about conventional vs. reference-surface mass balance), therefore I would discuss it before and draw one conclusion that is then presented here at the end.

Line 784: Can you give a time horizon regarding the survival of the glacier? Or are

C13

there any projections for the region?

Lines 786-793: In my view, these sentences can be deleted.

Lines 794ff: In fact, the inclusion of geodetic mass-balance data is an integral part of the monitoring strategy within the Global Terrestrial Network for Glaciers (GTN-G), to compare and eventually calibrate both glaciological and geodetic time series (which is not the case for Yala glacier). This should be clearly stated here. In turn, I would rather conclude how in your case the geodetic method helped to interpret the glaciological mass-balance measurements (and will eventually help to calibrate the series at a later stage).

Line 803/804: are available and are published

Line 805: delete "World Glacier Monitoring Service, Zurich, Switzerland"

Line 810: mass balance data

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C14