Earth Syst. Sci. Data Discuss.,
https://doi.org/10.5194/essd-2020-79-AC1, 2020

Open Access Earth System Science Data Discussions

Interactive comment on "More dynamic than expected: An updated survey of surging glaciers in the Pamir" *by* Franz Goerlich et al.

Franz Goerlich et al.

franz.goerlich@geo.uzh.ch

Received and published: 30 July 2020

General comments

This paper provides a useful update of the number of known surging glaciers in the Pamir, in-cluding the identification of several new ones. The dataset is certainly useful, and will help to build on our global knowledge of why some glaciers surge, while others in the same region do not. However, I currently find the text a bit difficult to follow as the paper lacks a clear de-scription of how surging glaciers were identified, and there is a lack of clarity and preciseness in the wording. The authors implicitly assume that the reader will understand what they're re-ferring to in relation to glacier surging, but terms need to be better defined. For example, there needs to be a clearer definition

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of what a ‘typical surge pattern’ is (L243), and what is meant by ‘opposing patterns of surface elevation change’ (L240)

>We fully agree that a clear terminology is important and have revised the related sections.

Detailed comments are provided by line number below, and minor language and typograpicali sues are addressed in the attached PDF (make sure to view comments in the PDF to see all of them). Thank you for the comprehensive review of our study!

Detailed comments

L1: you haven’t really demonstrated that the surging glaciers are ‘More dynamic than ex-pected’, so I would suggest dropping this part of the title. Indeed, you don’t determine glacier velocities and so it’s hard to say that you’ve quantified dynamics, and your 186 surging glaci-ers are less than the 561 presented as possibly surge-type by Sevestre and Benn (2015)

>We agree that we should make clearer where the title comes from and have done so. It is in-deed not related to flow velocities, but to a) the much higher number of confirmed glacier surges (186 instead of the 90 by Sevestre and Benn (2015), to b) small glaciers (<1 km2) that also show massive surges, sometimes more than doubling their minimum length and c) the high number of active surges in any year (min 54, mx 120). This means they are much more dynamic than we expected. A related description of point c) has been added to the text.

L14: in the paper it’s clear that you use more than just Landsat images to identify surges (e.g., Corona, Bing), so it would useful to mention those other sources here

>You are right. This information comes only later in the abstract. We have thus now written here ‘are largely based on’.

L15: instead of listing the methods used to analyse satellite imagery (e.g., animations, flicker images), it would be more useful to list the physical characteristics that you used

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in the satel-lite imagery to uniquely identify a glacier as surging (e.g., rapid terminus advance, large eleva-tion change)

>We have actually not calculated terminus advance rates or elevation changes to apply the suggested criteria ('rapid' or 'large'), but build our basic analysis on the visual interpretation of the three criteria mentioned in L15/16.

L50: for readers unfamiliar with previous literature it would be useful to provide a more com-plete description of the evidence used to identify surge-type glaciers (e.g., Why are looped moraines associated with surging? What exactly are 'post-surge down-wasting features'?), and references to back up your statements

>We agree that some explanations of these terms are useful and have added further refer-ences explaining such features (and their changes over time) in more detail. As we have a long Section 4 explaining the characteristic morphologic changes in detail, we would prefer to not further expand the introduction with such details.

L61: I assume that this sentence refers to Pamir surge-type glaciers only? If so, then make this clear.

>Yes, indeed. Pamir has been added.

L63: Unclear as to what the 'three instead of six classes' here refers to; needs better descrip-tion.

>We deleted this information – it is only a technical detail and would need a relatively long ex-planation.

L70-76: this para would seem to fit better in the Discussion than here, as you haven't yet fully described your approach or that of Osipova et al. (1988). Or if you want to leave this text in the intro, then the Osipova et al. (1988) study needs to be much better described at the start of the previous para.

>We have now extended the text in L61 to better describe what the study by Osipova

et al. (1998) has done. We think it is important to have the differences of our approach stated in the introduction, as we want to show why our study is meaningful.

L78-85: unclear as to what 'this inventory (here named GI-1)' refers to. It's also unclear as to whether GI-1 or GI-2 refer to an inventory of all glaciers in the Pamir, or just surging ones? I see later that you provide a better description of these datasets in Section 3.3 (L201-L214), which basically duplicates everything written here, so I think that you should delete or dra-matically shorten this earlier text.

>We have removed the short descriptions of the various inventories here and just noted that we had to rework them for our purposes.

L92: please provide more detail about the Russian topographic maps so that a reader could find them if they wanted to – e.g., name of publisher, date of publication, name of series

>We have added a section 3.4 describing these maps in a traceable manner. Unfortunately, there is no clear citation option for the maps. But we listed all used maps by their ID and publication date in the supplement.

L100: it would be useful to include labels in Fig. 1 or elsewhere for major features mentioned in the text, such as Mt Kongur and Fedchenko Glacier, as well as country boundaries

>We have added new symbols to mark the location of some further features mentioned in the text. We would prefer to avoid showing country boundaries as they are politically sensitive.

L107: provide the elevation of Fedchenko weather station

>Added.

L123: clarify what's meant by 'possibly cycle'. E.g., do you mean length of the active surge phase?

>Done, it refers to the duration of a full surge cycle i.e. from one surge to the next.

L156: it would be useful to provide an estimate of the resolution of the 'very high-resolution satellite images' that you refer to in this section

>The resolution is in general not known as the sensor is not known. For the purpose of this study we use 'higher than a few m'.

L182: note that the GDEMv2 has now been superseded by GDEMv3: https://asterweb.jpl.nasa.gov/gdem.asp. This is for informational purposes; there isn't a need to complete new analyses using it, unless it can improve your results.

>Thank you very much for this hint. We checked the results of the topo parameter calculations with the GDEMv3 and noticed that e.g. the maximum heights improved a lot. The GDEMv2 as well as the AW3D30 had some issues in high altitudes. For the analysis, the change of the DEM has only a small impact but we decided to recalculate everything nevertheless.

L188/189: I assume that you mean 15 km x 180 km here? This is a very different meaning to 15 x 180 km2 (=2700 km2!). Also for 130 x 130 km2 (= 16,900 km2!)

>Yes, fully agreed. We have now corrected it.

L195: there are three clauses here (gain/loss, lower/upper, active/quiescent), so it's ambiguous as to what exactly you're referring to for each one

>It is just linear: the names before the dash belong together and those after the dash. However, we have rewritten it for clarity.

L216-L268: what I'm missing in this section (and the paper in general) is a clear definition of how you distinguished surging glaciers from non-surging glaciers? You mention things such as changes in surface elevation, but by exactly how much does a glacier have to change to be classified as surging? Similarly, how quickly does a glacier terminus have to advance? Exactly what changes in surface characteristics indicate a

surge? The current explanation is quite gen-eral, and doesn't provide enough detail for a reader to go back and unambiguously identify the same glaciers that you did as surging. Several of the comments below provide specific questions in relation to this.

>We fully agree that our description is vague in this regard, as we have not worked with abso-lute values but visual interpretation. And this is often based on a combination of different crite-ria rather than a single one (as described in Section 4.1). In consequence, other analysts might come to different conclusions for individual glaciers. Using absolute values has two ma-jor challenges: a) they cannot be determined for all glaciers and b) other analysts might prefer using different thresholds (as there is no clear definition) for deciding if they see a surge or just an advancing terminus. Due to this, their sample would also be a different one. Point (a) has to consider that not all glaciers that surge do also advance and that flow velocities can only be calculated for larger glaciers and when suitable images are available. Even if we would have velocities and maybe even if a dense time series would be available for each glacier, the problem and the consequences would remain, we have to subjectively interpret and decide on what we see. Hence, the problem of distinguishing surges from usual advanc-es is just transferred to a different level rather than solved. We would thus prefer sticking to the criteria we have presented. All datasets used are freely available and can be analysed in the same way by others. We acknowledge that our selection might be different then but think that only a few glaciers (5-10%) are critical in this regard.

L227: it would be useful to list the period over which the Osipova et al. (1998) and Sevestre and Benn (2015) 'confirmed' glaciers relate to, so that it's clear how they relate to the period covered by your inventory

>We here only refer to the assignment of classes. The datasets considered in Sevestre and Benn (2015) are the same as in Osipova et al. (1998). They used a variety of sources (aerial and satellite imagery) covering the period 1945-1991.

L240: clarify what you mean by 'opposing patterns of surface elevation change' – e.g.,

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Along the glacier length? Within just the ablation zone? Over a multi-year period?

>This mass transfer pattern is likely one of the best criteria to differentiate surges from ad-vances, as it is usually not observed for the latter. We have now clarified what we mean. It is meant along the glacier but not related to a specific period or location of the glacier.

L243: explain what the 'typical surge pattern' is

>We have now added a description of the term "typical surge pattern" in the sentence before.

L244: clarify what you mean by 'limited changes of the terminus'. E.g., Changes in terminus extent? Figure 3 shows that there were marked changes in the elevation of some termini, but I don't think that you're referring to that here

>We clarified the sentence. It refers to the limited/missing change in the terminus position.

L257: explain how you differentiated between 'surges' and regular 'advances'

>We added a sentence explaining the criteria to deselect a surging glacier.

L258: provide details about the 'indirect evidence' you refer to here

>We added the term of "indirect evidence" to the explanation sentence mentioned above.

L275: please indicate how the reader can access the attribute table. I assume that this relates to a shapefile? However, I can't find a shapefile to download from the URL provided in section 8 (unless this will be added once this paper has been accepted for publication?)

>The attribute table is part of the shapefile that has been submitted to Pangaea from where it will be available once the paper is accepted. For easy access, the three

datasets are also provided as supplemental material (csv).

L285-L290 & L718: there seems to be an offset in timing between what's described in the text compared to the Figure 5 caption. In the text it says that the surge of glacier (2) is in Fig. 5a, but the figure caption says it starts in Fig. 5b. The text says that glacier (3) starts surging in Fig. 5b, but the figure caption says that it starts in Fig. 5c. Please make these consistent!

>Yes, thank you for spotting this. We changed the caption and added a link to the text for fur-ther description.

L302: somewhere in this section please provide a description of the difference between 'ad-vancing', 'internal' and 'combined' surges

>To be less confusing, we have added two sentences describing the difference be-tween the three types.

L312: please state the date used for the area in km2, and whether the area is varied for GI-3min and GI-3max.

>We have now better explained the dates of the attributes. We also mentioned that values vary due to the minimum and maximum extent of the glacier. The respective dates vary for each glacier and can be checked via the minimum/maximum extent in the attribute table. However, the date of the DEM is always the same, resulting in related inaccuracies.

L319-L320: please include these place names in Fig. 6 so that the reader can under-stand what's being referred to

>We have added now region numbers to Fig. 6 (and names in the caption of Fig. 6) and refer to this figure for locations.

L347: please provide some information as to how the aspect was calculated. E.g., how was the aspect defined for glaciers which dramatically change their orientation along

their length, such as when as they join a main valley from a tributary valley.

>We have added in section 4.3 a reference describing how topographic information (incl. mean aspect) has been calculated for all glaciers (it is the arithmetic average of all DEM cells cov-ered by the respective glacier).

L355: the axis labels on Fig. 9 indicate median elevation, rather than mean elevation. Please make sure that wording is consistent, and check elsewhere.

>Thank you for spotting; the mean elevation in the text has been changed.

L366-367: as with earlier comment, make sure that place names you refer to here are shown on a map (e.g., Mustagh, Petr Alervogo west)

>Added to Fig. 6.

L394: please provide information as to how you determined surge duration. You didn't de-termine glacier velocities in your study, so how can you know how long a surge lasted for?

>We have added to former L282 that surge duration has been calculated by subtracting the 'surge start' year from the 'surge end' year. These are calculated as described in former L277-282. Velocity data cannot be used for this as they (a) can not be calculated for all glaciers (too small, clouds, missing scenes) and (b) are less clear in interpretation (e.g. residual movement after the surge, seasonal fluctuations), i.e. threshold values for the start and end of a surge are not defined (see also reply to L216).

L406-L416 & L690: I can't follow the text here and don't understand what Table 4 is trying to show or how the numbers were calculated. What does DEM 1, 2 and 3 refer to? What does Tongue, Type, Duration and Distance refer to? My guess is something related to the descrip-tion in Section 4.1, but I can't tell what. I also don't understand why glaciers without termi-nus advance aren't included here, when they're included everywhere else. Please completely rewrite this section.

>Thank you for spotting, the ‘DEM’ in Table 4 makes no sense indeed and has been deleted. The numbers in the table are just the counting of classes presented in former L301-304. The purpose is to just give a generalized overview of major surge characteristics to illustrate their variability. The 30 glaciers (198-168) with internal surges do not show a terminus change and are thus not included in the ‘Distance’ row.

L419-L430: it would be useful to add a figure or table to help illustrate what is being dis-cussed in this para

>We have decided to only provide here some short notes about interesting findings rather than figures showing the related data, as these would require additional scientific discussions be-yond the nature of a data description paper in ESSD.

L427: provide specific example(s)

>This statement has now been removed as it was related to a calculation error (that did not happen with GDEMv3).

L430: provide the reference numbers of the glaciers being referred to here

>Values have been recalculated (see reply before) and the respective glaciers are now identi-fied by their number.

L453: I don’t understand what ‘handed flexible’ means. This section is also difficult to follow as you haven’t clearly described how you identified surges earlier in the paper (comments for L216-L268)

>Agreed, see reply to L216 comment. This ‘flexible handling’ was required due to the different evidences available for each glacier. It certainly resulted in a subjective interpretation that can be questioned by other analysts. However, as surges are not yet defined by objective criteria (and maybe never will be as they might depend on glacier-specific characteristics), we think this is the best approach we can currently apply. So we here just confirm that it is really diffi-cult to differentiate between surges and advances and this is just our best estimate.

L461: I'm unclear whether the 'additional minimum and maximum extents' were included in your database? You say that your study period covers 1988-2018, but this statement suggests that you also included data from earlier times.

>We described that we used Corona and Hexagon data to check back surface features. We also used this high-resolution dataset to derive outlines for minimum or maximum extents. However, we agree that it is inconsistent to mix 1968 outlines with later surge outlines. Thus, we changed the affected outlines to the maximum/minimum extent of the 1988-2018 period and recalculated the length changes.

L503: how many of the glaciers you identify as surge-type overlap with the 561 identified as possibly surge-type by Sevestre and Benn (2015)?

>The overlap with this sample is 79.5% (147 glaciers). Further there was a small confusion with numbers. We corrected the number from SB15 to 820. We mention the numbers of the respective classes and percentages in the next sentences. The 561 refer to the catalogue of Osipova et al. (1998). Furthermore, Osipova et al (1998) mentioned a second sample con-taining 845 glaciers of all possible classes they applied. Thus, the sample/numbers of Se-vestre and Benn (2015) seems to be a mix of both.

L504-L506: please define what categories 3, 2 and 1 refer to here. On L226 you indicate that confirmed = 1, probable = 2 and possible = 3, but here it seems that the sequence is reversed. For example, your statement that 'the 51 most reliably classified (3) surge-type glaciers' sug-gests that category 3 refers to confirmed surges.

>Thank you for spotting. There is indeed some confusion with the numbers as the categoriza-tion presented in the RGI differ from those presented in the paper by Sevestre and Benn (2015). We have now looked at this again and revised all numbers.

L510-L511: as with earlier comments, I don't know where these regions are as they aren't la-belled on any of your maps

>Indeed, this is difficult to follow without a map. We have now marked these regions in a re-vised version of Fig. 6.

L534: in addition to the electronic dataset I would like to see a printed Table included in the paper (either in the main text or as supplementary material) that lists the basic characteristics for each glacier. E.g., ID number, latitude, longitude, elevation, aspect, surge timing. This would enable the paper to stand alone if access to the electronic re-source is ever lost, and make it easier for the reader to follow the descriptions provided in the text.

>We have now also provided a csv file in the supplement.

L709: Provide dates for the DEMs mentioned here. Would also be useful to add a comment in the caption as to why the elevation changes don't line up with some glacier outlines (e.g., 80)

>Yes, agreed. We have added the dates of the outlines and DEMs.

L713: the white outlines are difficult to see in the figure; please use a different colour!

>Agreed, they are now marked in green.

L714: please provide a date for the base image used in this figure, as well as the ID numbers/names of the glaciers shown

>We added the date of the base image.

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