*The Cryosphere*

# Brief communication: Tropical glaciers on Puncak Jaya (Irian Jaya/West Papua, Indonesia) close to extinction. EGUsphere [preprint]. https://doi.org/10.5194/egusphere-2025-415

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RESPONSE TO REVIEWERS:

We would like to thank the two referees and the editor for providing such constructive and positive feedback. We appreciate it. Below we indicate point by point how we plan to revise our manuscript in accordance with the reviewer comments. We would be delighted if these revision plans would qualify our paper for further consideration.

Sincerely yours,

David Ibel, Thomas Mölg, Christian Sommer

## Mauri Pelto (30 Mar 2025)

**Specific comments**

7: Reword to be more accurate, recognizing that in many regions including New Zealand, Norway, Western North America and the European Alps glaciers did advance during portions 1950-1990s period. Hence it has not been many decades at a global scale. “Glaciers have been retreating for the last several decades on a global scale due to anthropogenic climate change, including the mostly small glaciers in the Tropics.

**Response:** We understand that a more specific sentence is needed while keeping it brief. Change can be made like “The majority of glaciers have been retreating for the last several decades on a global scale due to anthropogenic climate change, including the mostly small glaciers in the Tropics.”

9-12: Reword this is the abstract where sources/methods need not be reviewed. “The survey was based on recent 2023 and 2024 high resolution multispectral satellite imagery of PlanetScope and Pléiades missions, that were compared with digitized and georeferenced

historical glacier extent, resulting in a new overview map of glacier change on Puncak Jaya since 1850."

**Response:** Sentence will be revised, shortened and specified: "The survey was based on recent 2023 and 2024 high resolution multispectral satellite imagery of PlanetScope and Pléiades missions, which were compared with historical glacier extents, resulting in a new overview map of glacier change on Puncak Jaya since 1850."

17: The first paragraph discusses global temperature and regional temperatures. The focus of the paper is glacier change start your introduction with paragraph 2 and move the temperature portion down.

**Response:** We agree that this would be an option, but our preference would be to maintain the current structure. In our opinion, the current one has a higher logic flow (in cause/effect thinking).

Figure 2: Include a PlanetScope or Pléiades image, without the annotated coloring for the reader to be able to see the actual relict ice/glacier character. Given how cloudy the region is, such imagery would be a rare view for the community.

**Response:** We agree that providing such an image would be a valuable support for our paper and an interesting view for the reader. However, due to the limitations of figures for the "Brief Communication" format, we will provide this image in the Supplement.

170: Please move at least a condensed version of Table S1 into the main paper, leaving out years with limited observations. All the information in Table S5 can be put into this table as well. It is important to reference in the text here the area change of individual glaciers vs just the overall glacier area loss.

**Response:** Some important results of Table S1 are mentioned in the text. Due to figure and space limitation of our article type, it is not easy to move even a condensed version of Table S1 to the main text. Also, we believe that only providing the complete Table S1 gives the reader the option to fully resolvethe glacial extent changes from 1850 to 2024. If there are no strong hesitations from the editor, we would prefer to keep Table S1 in full in the supplement, also because it is rather technical. However, we can consider to move Table S5 to the main text, which would be in the vein of the reviewer comment.

199: Given the limited area and volume are any of the remaining four ice masses in Figure 2 still glaciers? Any evidence of movement from repeat imagery or crevassing? Either way please indicate that this may just be relict ice and not glaciers anymore. All ice will vanish by 2030, though the glaciers may well be gone now. The ice thickness is referenced in line 127, with your high resolution imagery, are there any indications or estimates of ice thickness?

**Response:** To the best of our knowledge, no movement was detected within the last decades but changes of crevasses haven't been checked in this study. We agree that it would be beneficial to add information about ice thickness changes. Due to the remote and rugged mountain area, however, expeditions for reading the ablation stakes have been rare and the results of such expeditions are presented in our preprint (127-129) to give the reader in insight into the ice thickness loss. Additionally, the coverage of this rugged terrain by satellites carrying radar or laser altimeters isn't good enough to conduct volume change measurements

without a big effort (that would exceed the scope of our paper). We will, nonetheless, try to add a short sentence indicating the current absence of ice dynamics and consult relevant databases (e.g. Millan et al. 2022).

218: For the remaining ice the orientation is indicated as being an important component is preservation. Is there any evidence of accumulation enhancement via wind drifting or avalanching.

**Response:** During our literature review we didn't find any hints on accumulation changes due to wind drifting or avalanches. However, due to the fast metamorphosis and densification of fallen snow within hours or days due the tropical climate setting (with strong diurnal cycles), wind drift isn't expected to play an important role (which was found in a long, detailed project on the Kilimanjaro glaciers by one of the co-authors).

249: The paper begins appropriately discussing tropical glacier change. It is worth adding here other glaciers lost or nearly gone in this latitude belt. The World Glacier Monitoring Service reported that Conejeras Glacier, Colombia 4.8 N ceased to exist in 2024.

**Response:** We agree and will add examples of tropical glacier loss in the introduction.

# Anonymous Referee #2 (28 May 2025)

**Major comments:**

Uncertainty analysis – While I can appreciate that this contribution is submitted as a 'brief communication', this should not prevent the authors from reporting on the uncertainties in their data and overall reports. Glacier mapping is not perfect, even when the quality of imagery is good, and the mapper is experienced. Glacier areas (and rates of change) are reported with no uncertainties. The uncertainty in the map from 1850 CE must also be high, but it sounded like only three 'landmarks' were used geocoding (authors mention distortion and shifts). What translation was used? Three ground control points for the map would yield an extremely high RMSE unless a thin plate spline was used (which assumes no errors, but this really would be unrealistic anyway). I would recommend that the authors consult papers that describe how to complete an uncertainty analysis for glacier mapping (e.g. Granshaw and Fountain, 2006; Fountain et al., 2023).

**Response:** We agree that it is important to assess the uncertainty of manually delineated surface areas. We suggest calculating the uncertainty based on the findings of Paul et al. (2013), who estimated the uncertainty in the outlines of glaciers in Alaska and the European Alps mapped from images with different spatial resolutions and by different analysts. For glaciers with a high contrast between the glacier surface and the surrounding ice, i.e. clean ice glaciers, as in the case of this study (see supplementary Figure S2), the authors reported an uncertainty in the digitised glacier area of ~5%. In line with this, we will calculate the uncertainty of each glacier and timestamp and include the respective values in the main text and the supplementary table S1.

We will conduct another uncertainty analysis for the 1850 CE map, but due to limited information regarding landmark positions a better result might not be possible.

Attribution of loss – Why did the authors not attempt to attribute the observed area changes to climate drivers. The end of the discussion section points out a few possible factors which could explain these changes, but the reader is left wondering what the primary driver really is. They describe, for example, temperature changes between 1972-2000 but their data is mostly after 2000. It would be relatively easy to analyze temperature at the appropriate pressure level (they cite 550 hPa) from ERA5 over the period 1950-present for the closest grid point. Even a simple descriptive analysis may allow the authors to at least partition some of their results into climatic vs. non-climatic factors.

**Response:** While we fully agree that this would be an exciting question, in our opinion it exceeds the scope of a "brief communication" paper. It is true that there is experience in our author team as one of us is specialized in the attribution of cold-region climate change to atmospheric processes (T. Mölg). However, based on that previous work we argue that including a simple analysis would not cover the question sufficiently. We could include records from ERA5 for the location, but this would raise the issue and critique of reanalysis data not being representative (or only to a limited degree) for mountain regions. We feel that

this would introduce further uncertainties, which are impossible to address within a "brief communication" (especially since we will have to include more on the uncertainty in glacier mapping, suggested by the same referee). Hence, the proposed separation of climatic versus non-climatic factors can, unfortunately, not be done within a simple analysis. See, for example, Mölg & Kaser (2011, https://doi.org/10.1029/2011JD015669) for more background on our argument.

Short history section is too long – While the length of this section might be fine for a full-size manuscript, I found this section to be perhaps too rich in details (e.g. do we really need to know names of past explorers for the data presented in the paper?). I would prefer to see more details that pertain to supporting the objectives of the paper and/or the reliability of the results (uncertainties).

**Response:** We will try to shorten this section a bit. While working on this study, we noticed that bits and pieces of information about the glacier's history were scattered over different kinds of literature types and there was no good coverage of the history in one place. Hence we think that readers would appreciate this section.

**Minor points:**

Line 11: not certain what authors imply by 'accounts'

**Response:** We will replace accounts with extents.

Line 13: change to 'In 2024, glacier area was …'

**Response:** We will make this change

Line 14: Strike 'very' – a vague qualifier unless you are talking about a definition (e.g. 'very fine sand' is defined by a size range).

**Response:** We agree that qualifiers like "very" should be used with caution, but the term "very likely" is, in our opinion, accepted usage for the highest likelihood level following IPCC report terminology.

Line 27: Use 'First', 'Second,' … rather than 'Firstly' – less wordy.

**Response:** We will make this change.

Line 73: Either refer to their position in terms of pressure level (e.g. 500-600 hPa) ,or actual elevation above sea level. Using both is confusing since they often don't coincide.

**Response:** We will add the actual elevation above sea level in this sentence.

Line 80: As described in the major comments, I would recommend that the authors at least consult reanalysis data for attribution (at least annual or warm-season temperature anomalies).

**Response:** Please see our argument above.

Line 88: Do we know these glaciers actual surge? Or do the authors mean ‘advance’ or ‘underwent expansion’?

**Response:** We will replace “surge” with “advances” as in the cited literature it is only explained that advances have happened but not whether these advances were surges.

Line 111: Uppercase ‘glacier’ after Maren. Formal names use ‘Glacier’. Same logic is Green Lake but Green and Blue lakes (lowercase when referring to plural).

**Response:** We will make this change.

Line 119: Strike ‘very’

**Response:** We will replace “very” by “only”.

Line 120: I think the convention for units is to use superscripts ‘no slash’) so m^{3} w.e. yr^{-1} throughout

**Response:** We will make this change.

Line 120 onward: The use of the term ‘mass balance’ when referring to mass (volume) change is confusing. If you don’t have surface area I suggest you use ‘mass change’.

**Response:** We will make this change.

Line 140-145: There are few details provided so it become difficult for a reader to agree with your interpretation as to the quality of the co-registration. Can you provide some more information to support this claim (RMSE, number of control points used, etc)?

**Response:** We will provide the requested information.

Line 151: Strike ‘very’ and throughout paper.

**Response:** We will strike “very” throughout, except for “very likely” (see response above).

Lines 145-160: As described in the major comments section, more information is required and some uncertainty estimates for the glacier mapping.

**Response:** Uncertainty estimates will be given according to the reply provided in the major comment section.

Lines 165: So if Permana et al., (2019) report on these glaciers, how do your extents compare to that work? This comparison would provide you with at least some assessment of the reliability of the mapping between these projects.

**Response:** Unfortunately, upon request this data could not be provided by Permana et al. (2019).

Line 190: Not a big deal, but deep blue typically used to demarcate water on maps. Can you simply use a given color with varied saturation levels ? Also, showing polylines is preferred rather than polygons as one can’t see examine imagery or present-day ice.

**Response:** Due to the size of some glacier parts the use of polylines would make these parts almost invisible for the reader. Hence, we decided to use colour-filled polygons. We will consider changing the colour range.

Line 208: You can't assert that there was no period of growth especially between 1850 CE and late 1940s since you have no data. Statement needs revision.

**Response:** Agree. Will be revised.

Line 225: If you log right panel x axis, what year does area =0.0 km2? As described in major comments section, how has temperature (500 hPa pressure level) varied over this time? ERA5 goes back to the 1950s. You can download monthly data for seasonal, annual anomaly calculation.

**Response:** See reply to major comment above. We argue that using ERA5 without deeper analysis is not robust enough.

Line 235: There is a logic gap here. The authors suggest that attribution is not possible given the lack of meteorological data yet in the introduction there is mention of glaciers like this being good indicators of global climate. The two last authors have used reanalysis in the past. Why not do a simple analysis to help attribute changes of these glaciers?

**Response:** Again, as argued in the major comment reply, a simple analysis would not cover the question sufficiently and introduce further uncertainties. In the introduction, we refer to glaciers on a large-scale, for many of which this attribution was made. That is why in Line 235 we phrased the statement carefully for the Indonesian glaciers ("harder to identify").

Tables and Figures:

Fig 1 (a and b) are quite pixelated for me. Can they be reproduced at a higher resolution?

**Response:** Yes, will be done.

Thank you very much for these detailed comments.

**References:**

Millan, R., Mouginot, J., Rabatel, A., and Morlighem, M.: Ice velocity and thickness of the world's glaciers, Nat. Geosci., 15, 124–129, https://doi.org/10.1038/s41561-021-00885-z, 2022.

Paul, F., Barrand, N. E., Baumann, S., Berthier, E., Bolch, T., Casey, K., Frey, H., Joshi, S. P., Konovalov, V., Le Bris, R., Mölg, N., Nosenko, G., Nuth, C., Pope, A., Racoviteanu, A., Rastner, P., Raup, B., Scharrer, K., Steffen, S., and Winsvold, S.: On the accuracy of glacier outlines derived from remote-sensing data, Ann. Glaciol., 54, 171–182, https://doi.org/10.3189/2013AoG63A296, 2013.