Responses to the comments from Reviewer #1 for Fujita and Kayastha, submitted to TC

Dear Reviewer #1,

I'd like to thank you for your comments on our manuscript. My answers to each comment are indicated in blue below. Added descriptions are indicated with bold & underline.

Best regards,
Koji Fujita, on behalf of all authors of the manuscript

**Reviewer #1**

In this study, Koji Fujita and Rijan B. Kayastha reconstruct the evolution of AX000 and AX010, two small glaciers of the Nepal Himalaya. This contribution is of great importance given that AX010 is among the first Himalayan glaciers that were observed with modern methods in the late 1970s. This brief communication is a concise article that efficiently convey the main message about the importance of temperature in driving the mass loss of AX000 and AX010. The figures are of very high quality and the text is very clear. I recommend to publish the paper after some minor revisions.

Thank you for your positive evaluation.

General comments:

In some places, I think that the authors could better acknowledge the glaciology research conducted in the region. This is detailed below.

It is difficult to keep track of all the geodetic mass balances. Especially, some results originate from previous studies and are not easily available (Fujita and Nuimura, 2011; Nuimura et al., 2012). I suggest to add a dedicated section in the data and method about these previous estimates, and to distribute these data together with the 2008 and 2023 elevation data.

Does this comment mean that I should repeat the explanation of the method of Fujita and Nuimura (2011)? If I omitted the method used in this study by citing the previous study, this comment is understandable (such as "Even if you use the same method of a previous study, it should be clarified in the current study."). But I cited the mass-balance values reported in the previous study even though it was published by the same first author. As I don't need to describe the detailed methods of Maurer et al. (2019) or Shean et al. (2020) or Hugonnet et al. (2021), I don't think that I should provide the details of Fujita and Nuimura (2011). Nuimura et al. (2012) cited to describe the analysis method but dealt with the Khumbu Glacier rather than AX glaciers, using satellite-based remote sensing data, so I would not touch it.

The approach to take ERA5 temperature from pressure level instead of surface data of the grid point is relevant (L99-101). The drawback of this method is that the surface variables are then

likely not physically consistent. This is probably the case for the relative humidity at least. Then the debiasing of ERA5 variables based on Trakarding AWS injects another level of inconsistency, because variables are debiased one by one (L146-148). I don't see any way around, but the authors should at least acknowledge this issue.

Thank you for the critical comment. I added the following description for the inconsistency in the calibrated variables at the end of Section 3.2 as "**While the estimated temperature from pressure levels showed good reproducibility with observational data from both Trakarding and AX010 (Figures S6 and S7), observational data for other variables from Glacier AX010 were unavailable, so the relational formulas from the Trakarding AWS were applied (Figure S6 and Table S3). Therefore, site-to-site bias may remain in these variables. Although previous studies have shown that the mass balance is insensitive to changes in variables other than temperature (Fujita & Ageta, 2000; Khadka et al., 2024), the possibility that the bias correction is affecting the reconstructed precipitation parameters and mass balance cannot be ruled out.**"

Most numbers come with too many digits in the text and tables (e.g. L128 the error should be 0.04 m w.e. a-1); please check carefully everywhere

Although 0.604 m / 15 yr yields 0.0403 m $a^{-1}$, this is the correct value if the ice density is taken into account (0.604 m / 15 yr * 0.89 = 0.0358). I confirmed that all of the values were correct.

Some references to small glaciers could be added (Huss and Fischer, 2016; Parkes and Marzeion, 2018). I understand that this contribution is a "Brief communication" with associated space constraints, so my request is only optional.

Although I already cited Parkes and Marzeion (2018), I added the following sentence "**A modeling study showed that most small glaciers in Switzerland were expected to disappear within the coming decades, with significant impacts on regional hydrology (Huss and Fischer, 2016), while it has also been estimated that "uncharted" small glaciers contributed non-negligibly to the 20th-century sea-level rise (Parkes and Marzeion, 2018). These studies demonstrate that although individually inconspicuous, the small glaciers are, owing to their sheer numbers, an essential subject for assessing the impacts of climate change.**"

Specific comments:

L1-2: "longest" should be change to "oldest" as observations are not continuous for AX010

Corrected.

L2: "accelerating" is not matching the number provided in the sentence, which is the mass loss rate for the latest period. I suggest removing "accelerating" or otherwise calculate the acceleration in m w.e. a-1/decade.

"accelerating" deleted.

L12: I can't find the mention of a "tipping point" in Beniston et al. (2018). Consider rephrasing or citing another reference.

Sorry. By adding the sentence citing Huss and Fischer (2016) and Parkes and Marzeion (2018), I omitted this sentence. (see response to the general comment above)

L18-20: this sentence is ambiguous, as it is not clear if it refers to the number of series or to the mass balance trends. Consider rephrasing.

I rephrased the sentence as "Although **the number of** in-situ observations of glacier mass balance in the Himalayas **has** shown an increasing trend since the beginning of the 21st century,,,"

L52: provide the duration of the GNSS record

I rephrased the sentence as "The coordinates of the base station placed on the benchmarks **for 31 hours during three days (14-16 Nov.)** were determined by an online precise point positioning processing service,,,"

L67: why is the density assumption different from the most commonly used (Huss, 2013)?

During the 2008 observation, I confirmed that there was almost no snow at the upper part of the glacier. It can be assumed that the entire glacier was in the ablation zone between 2008 and 2023. Therefore, I assumed the ice density for converting the dh/dt to water equivalent. I rephrased the sentence as "Ice density was assumed to be 890 kg $m^{-3}$ **because we confirmed that there was almost no snow at the upper part of the glacier, suggesting that the entire glacier was in the ice-composed ablation zone between 2008 and 2023**."

L75-77: I did not find a direct comparison of the ice radar measurements with the bed reconstructions. It would be good the add the three ice radar points on the closest cross section on figure S11

Thank you for the good suggestion. I added the surface and bottom by ice radar in 1995 in the nearest cross section (b) 100 for IR3 and (j) 500 for IR2. The figure caption was rephrased too.

L82: how is the albedo evolving in the model?

I added the following sentence as "**The surface albedo is calculated using a scheme that applies an exponential, temperature-dependent attenuation with time after a fresh snowfall (Fujita and Sakai, 2014).**"

L96: missing details about the 1978 hypsometry (and associated DEM of the glacier surface)

I rephrased the sentences as "The glacier hypsometry was obtained from in-situ surveys **(Fujita et al., 2001; Fujita and Nuimura, 2011)** and the UAV photogrammetry **of this study** (Figure S3). **Elevations of the past hypsometry are calibrated using GNSS-collected benchmarks. The** annual hypsometry was prepared by interpolating each elevation band."

L114-115: I did not understand whether there would be one or multiple values for r_P at the first reading, because I was not expecting r_P to change through time. I suggest to formulate the method more explicitly, and write that you calculate five different r_P (Table S4)

I rephrased the sentence as "We determined $r_P$ to yield the same value as the observed geodetic mass balance **($B_{geod}$) by an iterative calculation** (Figure S5). **A period-weighted $r_P$ was then obtained from five $r_P$ corresponding to the geodetic observations.**"

L120-125: I find the uncertainties on the GNSS-UAV DEM difference a bit optimistic, especially given that there is a systematic offset between the GNSS and UAV for both study sites (fig. 1b).

I corrected the biases, which changed the mass balances by +0.042 m w.e. $a^{-1}$ for AX010 and +0.007 m w.e. $a^{-1}$ for A000. I also revised the mass balance values throughout the manuscript (text, figures, and tables). Because the difference is so small, I did not recalculate the simulations for precipitation parameters and others. I added the following description. "**The elevations from the 2023DEM and 2008GNSS outside the glacier had biases of –0.703 m (AX010) and –0.118 m (AX000), respectively. Considering a 15-year duration and ice density, these biases (+0.042 m w.e. $a^{-1}$ for AX010 and +0.007 m w.e. $a^{-1}$ for A000, respectively) were taken into account when calculating the volume changes of the glacier.**"

L120-135: I am missing the actual values of the geodetic mass balance in the text and/or in a table in the main article. I would suggest swapping table 1 and table S4/S6.

No. I don't think that $B_{sim}$ and $B_{nc}$ (in Tables S4 and S6) should be shown in the main table. I added the values and cited Table 1 in the main text. I rephrased the sentence as "As results, we update the geodetic mass balance (*Bgeod*, **–1.214 ± 0.036 for AX010 and –1.060 ± 0.023 for AX000, respectively**) of the glaciers for the 15-year period from 2008 to 2023 (Figure 1d **and Table 1**)."

L129: what are the "sparse survey points"?

Survey points before 2008 are substantially fewer than those from the 2008 GPS survey because they were measured by a theodolite with a laser distance finder. I did not change here.

L136: references about local meteorological measurements and comparison with ERA5 could be relevant here (Khadka et al., 2022; Matthews et al., 2020)

Thank you for the suggestion. While I did not cite Matthews et al. (2020) because they only compared the maximum wind speed in ERA-Interim, Khadka et al. (2022) is a good previous study for comparison. I added the following description as "**Similar biases and RMSEs of ERA5-Land have been confirmed through the comparison with the local meteorological variables observed in the Khumbu region, immediately east of the studied site (Khadka et al., 2022).**"

183-184: a reference to Florentine et al. (2023) could be relevant here

Thank you for the suggestion. I added the following description as "**The bias in the satellite-based $B_{geod}$ due to glacier shrinkage has been pointed out for glaciers in Alaska and the U.S. Rocky Mountains (Florentine et al., 2023).**"

L205-209: the authors could update the references cited here because a lot of work has been produced on the this topic in the recent years (Jouberton et al., 2022)

I cited this (and another one, which has been cited already) after "but also indirectly by changing precipitation phase from snow to rain **(Fujita, 2008; Jouberton et al., 2022)**."

L217-219: compare with the results of (Khadka et al., 2024)

Thank you for the suggestion. I added the following description as "**In addition, for Mera Glacier, which lies 33 km east of Glacier AX010, the mass-balance anomaly correlates significantly with the anomalies of annual mean temperature ($r$ = –0.79, $p$ < 0.001) and annual precipitation ($r$ = 0.87, $p$ < 0.001) (Khadka et al., 2024).**"

L243: "longest" -> "oldest"

Corrected.

L253-254: it would be clearer to write the name of Trambau Glacier explicitely

I changed here to "**neighboring Trambau Glacier**"

Fig. S6b -> relative humidity should be corrected for the pressure difference, no?

I don't think so. ERA5 relative humidity is obtained from the 2-m height air temperature (t2m) and 2-m height dewpoint temperature (d2m). I assume that the "relative" vapor condition is the same at the surface in the same ERA5 grid cell. I did not change this part.