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Interactive comment on "Central Himalayan tree-ring isotopes reveal increasing regional heterogeneity and enhancement in ice-mass loss since the 1960s" *by* Nilendu Singh et al.

Anonymous Referee #2

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Dear Editor,

Thank you for the opportunity to review the manuscript, titled "Central Himalayan tree-ring isotopes reveal increasing regional heterogeneity and enhancement in ice-mass loss since the 1960s." I enjoyed reading the manuscript. The manuscript presents some exciting results. There are several statistical results presented that show the depth of the analysis carried out by the authors. However, I have several minor comments which the authors must address. Specifically, the figures in the main text need substantial modifications. Please kindly see my comments that are provided below and also throughout the main text pdf. Once these comments are addressed, the manuscript should be good for publications. Please kindly let me know if you any further questions.

To the authors: The manuscript, titled "Central Himalayan tree-ring isotopes reveal increasing regional heterogeneity and enhancement in ice-mass loss since the 1960s", tries to address the correlation between δ13C and glacier mass balance and their temporal evolution in the past. The authors provided a detailed description of their tree ring isotope measurements and showed a decent correlation with the reconstructed glacial mass balance for the past 273 years in the central Himalaya. The authors attempted several different statistical tests and presented their results. The results clearly show a shift in climate proxies since 1960's. The supplementary figures were very helpful to assess the results and to understand the in-depth discussion presented in the paper. However, several areas could be improved. Please kindly see my minor comments throughout the main text pdf and the comments attached here as follows.

Other comments: In the introduction, it is not apparent immediately what is the exact study area. What I understood after much reading is that the four major glaciated valleys that are located in the central Himalaya are chosen because of the availability of the mass balance data for the past few decades. The central Himalaya was arbitrarily divided into the western central Himalaya (WCH) and the eastern Central Himalaya (ECH). No such map is presented to delineate what areas the authors mean by WCH and ECH. The authors started their introduction with the "transitional western Himalaya." They presented an arbitrary map of what is shown here as the ISM dominated area, westerlies dominated area, and in between is the transitional area. These areas are not well defined and likely have tremendous overlapping (see my comments below in figure 1). The authors frequently also invoked the Ganges basin. The Ganges basin is enormous and incorporated areas beyond the central Himalaya. I highly recommend that the authors must clarify, first, what area is the central Himalaya in this study and what glaciated valleys constitute ECH and WCH. It must also be clear if any portion of ECH and WCH is part of westerlies/ISM/transitional. The manuscript then must use consistent regions for interpretation. Avoid using the Ganges basin unless results from the entire basin are presented.

So many acronyms were used to the point that it distracts the reader from the smooth reading of the paper. Sometimes the acronyms were used only a handful of times. I recommend only use acronyms that are repeated on several occasions, are commonly used (e.g., SST), and are mentioned in the figures, tables, or equations. In every other case, spell the full acronyms.

Lines 103: The CRU dataset for precipitation for the high-altitude sites has several limitations. This needs to be explained somewhere in the text or supplementary.

Results and discussions must be presented distinctly. It is hard to follow, which is a result and which is a discussion material. This would also make the discussion flow well.

Figure 1: The symbols are hard to read. I would suggest making them slightly bigger and use distinct color-coding to make them visible. Similarly, the numbers are hard to read. Consider making them bold black, or red. I could not see the stars (meteorological stations). The four major glaciers must also need to annotate in the main figure (top panel). The north arrow is missing in Figures B, C, D. The scale is also very small in figure A. All other panels need scale. Why are latitudes absent? Similarly, longitudes are required for A and B. Ideally, the top panel figure must be A, then from left to right (bottom panel), it should B, C, D, E. The figure scale at the top panel is 265 and 530 km. That's very odd. Consider making them round by zoom in or out (e.g., 250, 500 km). Please annotate the name of each glacier in each bottom panel. What are the main tree ring sites studied in this paper (i.e., the new sites)? This needs to be appropriately highlighted, and their symbols must be distinct from the published sites. Finally, what is the source/basis of the dashed regions? It is not clear to me how you defined those regions. Presently there is a strong latitudinal, altitudinal, and longitudinal climate gradient in the orogen. If the paper is based on comparing the tree ring/glacier signals

across distinct climatic regions, they must be well defined. I'm afraid I have to disagree that ISM does extend in the NW Himalaya and even in parts of the NW and interior of Tibet. ISM extended further north in the past when it was stronger than the present. Similarly, westerlies also largely influence parts of the central Himalaya in the winter currently shown under ISM dominated. Therefore, the current zonation is vague and needs proper justification.

Figure 2: The x-axis of all the time-series data must be the same for qualitative comparison. It is hard to find the usefulness of the ice core proxies and glacier length change data at its current configuration. Also, note that length response may be affected by glacier size, slope, and hypsometry. A better explanation is required as to why they should be used as a proxy for glacier health. How about changes in the ELAs?

Figure 3: This figure is not well organized at the moment. I recommend organizing them into a single page robust figure or separate figures. Each panel must be designated as A), B) . . . for easier understanding and reading the figure caption (this applies to other figures as well). There is no need to show MB twice in the same plot. Keep the x-axis range and length for all the graphs the same.

Figure S4: I found this figure very important, and if possible, it should be part of the main text.

Please also note the supplement to this comment:
https://tc.copernicus.org/preprints/tc-2020-128/tc-2020-128-RC2-supplement.pdf

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Central Himalayan tree-ring isotopes reveal increasing regional heterogeneity and enhancement in ice-mass loss since the 1960s

Nilendu Singh[1], Mayank Shekhar[2], Jayendra Singh[3], Anil K Gupta[4], Achim Bräuning[5*], Christoph Mayr[5], and Mohit Singhal[1]

[1]Centre for Glaciology, Wadia Institute of Himalayan Geology, Dehradun 248001, India
[2]Birbal Sahni Institute of Palaeosciences, Lucknow 226007, India
[3]Wadia Institute of Himalayan Geology, Dehradun 248001, India
[4]Center for Oceans, Rivers, Atmosphere and Land Sciences, IIT Kharagpur 721302, India
[5]Institute of Geography, University of Erlangen-Nuremberg, Erlangen 91058, Germany

Correspondence to: Achim Bräuning (achim.braeuning@fau.de)

Abstract. Tree-ring $\delta^{18}O$ values are a sensitive proxy of regional physical climate, while their $\delta^{13}C$ values are a strong predictor of local ecohydrology. Utilizing available ice-core and tree-ring $\delta^{18}O$ records from central Himalaya (CH), we show an increase in east-west heterogeneity since the 1960s. Further, $\delta^{13}C$ records from transitional western glacier valleys provide a robust basis of reconstruction of about three centuries of glacier mass balance (GMB) dynamics. Annually resolved GMB is based on regionally-dominant and diverse plant-functional species since the 1743 CE. Results indicate three major phases: positive GMB up to the mid-nineteenth century, the middle phase of slightly negative but stable GMB, and an exponential ice-mass loss since the 1960s. Reasons of accelerated mass loss are largely attributed to anthropogenic climate change, including concurrent alterations in atmospheric circulations (weakening of the westerlies and Arabian Branch of the Indian summer monsoon). CH-scale, multi-decadal isotopic and climate coherency analyses specify an eastward declining influence of westerlies in this monsoon-dominated region. Besides, our study provides a long-term context for recent GMB variability, which is essential for reliable projection and attribution.

1 Introduction

Glaciers in the Himalaya-Tibet orogen are an important component of the regional hydrological cycle, and a major fraction of regional potable water is stored and provided by them. However, recent shifts in climate dynamics have imposed a serious alteration in the equilibrium of these glaciers (Bandyopadhyay et al., 2019; Bolch et al., 2012; Maurer et al., 2019; Mölg et al., 2014; Yao et al., 2012; Zemp et al., 2019). High uncertainty prevails in future projections, as a sound understanding of glacier fluctuations and its response to climate change on a longer timescale is completely lacking (e.g., erroneous statement in the Fourth Assessment Report of the IPCC, Kargel et al., 2011). Reliable projections of future Himalayan ice mass loss require robust observations of glacier response to past and ongoing climate change. Long-term estimation of glacier mass balance (GMB) is also imperative for regional water security. Currently, coupled glacier-climate models even do not agree on the sign of change and hence projections on GMB is ambiguous (Watanabe et al., 2019, Jury et al., 2019; DCCC, 2018).

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Fig. 1.

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Discussion paper