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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.

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Comments 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. Response: We are grateful to the reviewer for the appreciation, valuable comments and suggestions that improved the quality of this manuscript. We have now revised this manuscript in light of the comments and suggestions. Other comments: Comment: 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. Response: Thank you for pointing out that the study area was not clearly described. As suggested, we now introduced the study area in this section (Lines: 51-61). Comment: 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). Response: The central Himalaya was divided into the western central Himalaya (WCH) and the eastern Central Himalaya (ECH), based on the existing records of tree-ring δ18O from the region (from the Manali to Bhutan: Figure 1). Previous tree-ring isotope studies (Sano et al., 2012, 2013, 2017; Singh et al., 2019; Xu et al., 2018) as well as our analyses on the response of tree-ring δ18O records to the physical climate of the region formed the basis for the division into WCH and ECH (Please see Figure 3b and Table S6). We now presented an entirely re-designed map (Figure 1) to delineate WCH and ECH and to respond to all comments related to figure 1. A high correlation between tree-ring sites from Manali to Jageswar (WCH) may be noted, whereas correlation decline sharply towards Bhutan (Table S6). Our presentation of the map (Figure 1) showing ISM-, Westerlies-dominated area and

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transitional area is based on Huang et al. (2019). However, the reviewer has a point that these areas are likely to have tremendous overlapping. Therefore, in our modified map (Figure 1), we have removed these distinctions. Comment: 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. Response: Thank you for pointing this out. We have now avoided using the term 'Ganges basin'; instead we now used 'Uttarakhand Himalaya'. As suggested, we indicated that (Lines: 93-95, Figure 1) the six tree-ring sites distributed across the region from Manali (at the northwestern periphery of ISM incursions; Sano et al., 2017) upto Bhutan constitute the central Himalaya. The four studied glaciated valleys of the Uttarakhand Himalaya (Dokriani, Chorabari, Tipra Bamak and Dunagiri) constituted WCH, while the region around the Dasuopu ice-core site to Bhutan is ECH. The manuscript used these regions for interpretation. Comment: 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. Response: As suggested, we have now taken care of the acronyms and their use. Comment: 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. Response: We agree with the reviewer's point of view that the CRU dataset for precipitation, particularly for high-altitude regions has limitations. However, previous studies from the region comparing in-situ precipitation datasets and CRU precipitation obtained significant relations (Shekhar et al., 2018; Yadav et al., 2014, 2015). Therefore, we have complemented CRU precipitation with datasets from meteorological stations (utilized by Singh et al., 2019). This has now been indicated in the text (Lines: 110-112). Comment: 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. Response: Since our results are presented in four distinct sections (mass balance reconstruction, phases in the mass balance dynamics, regional climate heterogeneity, and local forcing factors), it was easier and more appropriate to discuss the results section-wise and separately. However, in response to the reviewers' suggestion (#1 and #2), we tried to write a respective discussion in flow and presented the results as succinctly as possible. Comment: 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. Response: In response to critical comments related to Figure 1, we have now entirely revised this figure in addition to the lower panels (now B, C, D and E). We enlarged the symbols and used a distinct color-coding. The numbers have been made clearer. The meteorological stations (stars) have been made distinct. The four glaciers have been annotated distinctly (top panel). In lower panel figures (now B, C, D and E), the name of glaciers, north arrow, scale, latitudes and longitudes have been indicated. The figure scale in top panel (A) has been modified to 250 and 500 km. Now, the new tree-ring site and the published sites have been highlighted appropriately. The source of the dashed regions (ISM, westerlies dominated area and transitional area) is Huang et al. (2019). However, the reviewer has a good point that these areas are likely to have tremendous overlapping. Therefore, in our modified map (Figure 1), we have removed these zonations. Comment: 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? Response: The reviewer appropriately noted that the length response may be affected by various geomorphological factors and the time-series data must be the same for a comparison. Therefore, we have now deleted this glacier length change data (which has been adopted after Bolch et al., 2012). Comment: 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. Response: Figure 3 as well as the rest of the figures have been modified as suggested. Comment: Figure S4: I found this figure very important, and if possible, it should be part of the main text. Response: Figure S4 describes the three distinct results, viz., (1) correlation matrix and pair plots for δ13C chronologies of different plant functional types, (2) relationship of mean δ13C conifer chronologies and observed mass balance, and (3) comparison of observed and reconstructed mass balance. Therefore, to club these distinct results, we suggest that supplementary material would be more appropriate. Comment: Please also note the supplement to this comment: https://tc.copernicus.org/preprints/tc-2020-128/tc-2020-128-RC2-supplement.pdf Response: We thank the reviewer for a patient reading and in-depth comments. We have now addressed each and every supplementary comment in the main text. Reference: Huang, et al. (2019). Temperature signals in tree-ring oxygen isotope series from the northern slope of the Himalaya. Earth and Planetary Science Letters, 506, 455–465. Shekhar, et al. (2018). Tree-ring based reconstruction of winter drought since 1767 CE from Uttarakashi, Western Himalaya. Quaternary International, 479, 58-69. Yadav, et al. (2014). Premonsoon precipitation variability in Kumaun Himalaya, India over a perspective of ~300 years. Quaternary International, 325, 213-219. Yadav, et al. (2015). Tree-ring footprints of drought variability in last ~300 years over Kumaun Himalaya, India and its relationship with crop productivity. Quaternary Science Reviews, 117, 113-123.

Please also note the supplement to this comment:
https://tc.copernicus.org/preprints/tc-2020-128/tc-2020-128-AC2-supplement.pdf

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