General response to reviewers and Editor Stumpp,

Thank you for the thoughtful comments and review of the manuscript. We revised the manuscript in response to the reviewers' comments and suggestions. The major changes to the manuscript include:

(1) Both reviewers were concerned with the combining all water samples in the isotope-altitude analysis. We provide an updated analysis of the altitude-isotope relationship partitioned by sample type: river samples, snowmelt-sourced samples, glacial melt-sourced samples, and groundwater-derived samples separated by either groundwater wells/springs or groundwater-sourced surface water tributaries. Our major findings (a non-linear relationship between oxygen/hydrogen stable isotopes with increasing elevation, especially above 3000 m in altitude) are consistent with our original results and the pattern is, in fact, stronger.

(2) We include additional discussion about the "catchment effect" on oxygen and hydrogen isotope values in river water that has been collected along an elevation transect. Specifically, we address how river samples represent an integrated value from mixing of sources (snowmelt, glacial melt, and groundwater). To further assess the "catchment effect", we provide additional interpretation of the isotopic values of our river, snow, glacier, and groundwater-sourced samples both separately and collectively.

(3) We edited the manuscript to focus the narrative on the application of deuterium excess as well as oxygen and hydrogen isotope lapse rates to elucidate the water budget in the low-flow periods before and after the monsoon. We recognize that full hydrograph partitioning is not possible without gauge data; however, we argue that the isotopic tracers and methodological approach used in the manuscript provide relative assessments and useful tools to investigate base flow conditions (incorporating groundwater as well as meltwaters from snow and glaciers) in Himalayan catchments. See further discussion in our response to Reviewer #1's fourth comment.

(4) Language throughout the manuscript is revised to use appropriate terminology when describing oxygen and hydrogen isotopes as they relate to altitude.

We provide this introduction to describe the broad changes made to the manuscript. Specific responses to the individual reviews are provided below. Figure and text updates are available in the Supplement .zip file.

Anonymous Review #1
The authors present the results of oxygen and hydrogen stable isotope measurements in river, ground, snow, glacier and lake waters in two river basins in the Himalaya Mountains and based on the discussion of the data, they conclude "Himalayan surface water stable isotope lapse rates strengthen in high-elevation regions". Further, several inferences are made on the importance on the contribution of different water types (snow, lake, glacier) and weather types to river

discharge. The topic of water sources in Central Asia is an important one and such studies are most needed and welcomed; however the present manuscript does not fall in these categories – there are several methodological shortcomings that render the results and their interpretation, to say the least, problematic. These are detailed below. Some can be addressed, but some not - the data set is all the authors had and the study must do with it. Main issues:

1) Sampling – while I understand the difficulty of sampling in the mid- and high-altitude Himalayas, a well-planned field campaign could have resulted in better data. For instances, if groundwater samples were collected in SK watershed, I don't understand why river samples were not. Two maps of stable isotope distribution in groundwater and surface water would have yielded a better picture of the processes in the region. Anyway, what we have is what we have; this is merely a suggestion for future studies.
We thank the reviewer for their comment and the broader discussion of field campaigns in the Himalaya. Regarding the sampling approach, river samples were, in fact, collected in the Sabha Khola (SK) as well as the Barun Khola. In the data table (Table 1) these samples are described as "Stream" in the column "Dominant Source Water for Drainage Area" and are marked with a triangle in the study description map (Figure 1). Where possible, we revised the manuscript to clarify our sampling approach and to highlight that river samples were collected (lines P2L28-30, P4L16-22). The additional analysis of the isotope-altitude relationship for the river samples further highlights these samples.

2) Amalgamation of different water types. This is my main concern – why (fig. 2) were all water types mixed in the analyses of lapse rates (at least, this is my understanding of the plots in fig. 2). Groundwater is very conservative in terms of O and H stable isotopes, while river water reflects minute changes (e.g., fig. 4 in the manuscript by Voss et al.) – as such, calculating lapse rates based on mixing all water types is wrong (were indeed glacier data included in the charts in fig. 2? The ice could be thousands of years old…). I suggest calculating the lapse rates separately for river and snow data. Further, I it seems that the lack of correlation in the pre-monsoon values (fig. 2) in the SK basin is an indicator of the bias towards groundwater samples, which are more conservative. In the BK basin, where mostly river samples are used, the lapse rates seem more consistent (both between them and with previously published data).
The reviewer raises an important point (which is echoed in Reviewer #2's comments) regarding the combination of all water samples in the δ^{18}O and δD lapse rate analysis. We reanalyzed the data for each specific water type (river, snowmelt-sourced, glacial melt-sourced, groundwater springs/wells, and groundwater-sourced surface water tributaries). These results are illustrated in updated figures 2 and 3, and the new oxygen and hydrogen stable isotope lapse rates of the river samples are reported in Tables 1 and 2. We updated our results (P6L26-38) and discussion (P15L14-L41) to incorporate this new analysis.

Overall, the major finding of a strengthening δ^{18}O and δD lapse rate in high-elevation surface water samples is still valid. By partitioning out the samples by water source, we find that our new δ^{18}O and δD lapse rates in river samples are, in fact, steeper across the Sabha Khola and Barun Khola samples. The δ^{18}O and δD lapse rates in the Sabha Khola match well with previously reported studies (see Table 1); however, our updated δ^{18}O and δD lapse rates from the Barun Khola river samples remain much steeper than previously reported rates, but these were from different geographic regions and across different

elevations. Since all river samples represent an integrated isotopic signature derived from mixing sources (snowmelt, glacial melt, and groundwater), we argue that our initial hypothesis – that $\delta^{18}O$ and δD lapse rates are largely strongly controlled by elevation and moisture source, particularly at high elevation sites – remains a significant finding. Furthermore, the partitioning of the samples by dominant source alludes to the "mixing" of water sources in the river samples and seasonal changes in contributions to discharge. We provide new discussion of these findings in P15L24-41.

3) I am not sure I understand how the presentation of data in fig. 3 is used to understand the "elucidate the relationship between precipitation moisture source and d-excess". In the absence of moisture source determination using precipitation data (e.g., by using the HYSPLIT model) the above inference seems difficult to make. Fig. 3 seem to indicate that the stable isotope values in snowmelt change more between the pre and post monsoon period, than in glaciers (which is normal, melting of snow – X axis does not influence much the stable isotope composition of glacier-dominated rivers – as expected).
We agree that application of the HYSPLIT model would provide additional data and insights to precipitation oxygen and hydrogen stable isotope values during the study period; however, we feel that our broad characterization of deuterium excess values related to ISM- versus WWD-derived precipitation (as discussed in P16L22-P1715) is reasonable based on previous studies in the Himalaya and on the strong seasonal differences between these atmospheric systems. Our presentation of data in Figure 3 (now Figure 5) is meant to illustrate that a loss in seasonal snowpack (change in the x-axis) is directly correlated to a change in deuterium excess values (change in the y-axis). The trend indicates that a loss of snowpack correlates to a decline in deuterium excess, i.e. a transition for a high d-excess value (aligning with known WWD d-excess values) to a low d-excess value (within normal ISM d-excess values). Our new Figure 4, which illustrates d-excess versus mean catchment drainage elevation portioned by water source, further demonstrates that snowmelt-sourced samples decline from the pre- to post-monsoon season with values transitioning from known WWD d-excess values to ISM d-excess values.

4) No information is given on discharge – this is mandatory if water resources are to be discussed. The discussion in chapter 5.2 is the most important section of the text, although it is difficult to assess its accuracy, given the mixing of data described above. Further, the conclusions seem to be a collection of generalist information, rather than the outcomes of the study.
While discharge data would be a fantastic addition to this study, no discharge data are available for either the Barun Khola or Sabha Khola as these are remote and ungauged watersheds in highly dynamic geomorphologic and hydrologic environments. Maintaining gauge stations in these environment has proven to be very difficult in the past. We politely disagree with the reviewer that discharge data are mandatory if water resources are to be discussed; however, we agree that the discussion of water management detracts from the main finding of the paper, which is that deuterium excess as well as oxygen and hydrogen isotope lapse rates can be used to elucidate the relative influence of snow and glacial meltwaters as well as groundwater on streamflow before and after the peak-flow monsoon season.

The data described in the manuscript provide a snapshot of the oxygen and hydrogen isotopic lapse rates as measured from river samples taken at the shoulder periods of the annual water cycle. The majority of discharge occurs during the monsoon rain period, but we do not capture that period in our data. This omission does not detract from our conclusions as the goal of the study was not to assess streamflow conditions during the monsoon, when rivers are flushed with ISM rainfall, but instead focus on the shoulder periods with low-flow conditions when the monsoon influence is weakest.

Our aim in sampling during the pre- and post-monsoon seasons was to capture the base flow and recessional curve conditions when ISM rainfall is not dominating streamflow. Indeed, the monsoon period will likely have different δ^{18}O and δD lapse rates because the river samples would be controlled by, if not fully reflect, ISM rainfall. By targeting the periods before and after the monsoon, we are able to more accurately assess the impact of snow and glacial meltwaters as well as groundwater on river samples' isotopic values. Specifically, our manuscript describes how these sources influence the δ^{18}O and δD lapse rates of river samples. Furthermore, this sampling approach allows us to explore the utility of deuterium excess as a tracer of baseflow conditions before the monsoon, when streamflow is dominated by WWD-sourced precipitation (snowpack), glacial melt, and groundwater. We made this point clear in the manuscript (P2L28-42; P5L27-32) and honed the narrative throughout the article to reflect this discussion of river conditions outside of the monsoon period.

I suggest the authors 1) to separate the analysis of data based on water types, and 2) re-focus the discussion on the variability of the stable isotope values in rivers and next how are these changed by snowmelt.
As previously discussed, we reanalyzed the oxygen and hydrogen stable isotope data to individually assess the δ^{18}O and δD lapse rates in the Barun and Sabha Khola river samples as well as drainages sourced from snowmelt, glacial melt, and groundwater. Our discussion section has been updated to describe how the δ^{18}O and δD lapse rates in river samples are augmented by contributions from snowmelt, glacial melt, and groundwater sources (P15L24-41).

The discussion of seasonality seems difficult, due to the lack of data (stable isotope values in snow measured several months after snowfall (indeed, how were these samples collected – surface snow, vertical profile through the entire snowpack?) are a poor proxy for the initial value of precipitation.
We provide additional clarification of how snowmelt samples were collected (P5L27-29). While we agree that these samples do not represent the initial δ^{18}O, δD, or deuterium excess value of precipitation, the sample does represent an integrated value of melt processes upstream of the sample collection point and the most accurate value of snowmelt-sourced runoff contributing to the river system. Since snow δ^{18}O and δD values vary significantly across surface snow and vertically with depth, we argue that this integrated value best represents the overall δ^{18}O and δD value for snowmelt within the drainage area captured by the sample.

There are several short comments, but these could be left out now. A word on terminology:

while common in oral communication, several phrases are not accepted in written text: water isotopes do not exists, only O and H isotopes in water, “isotopically depleted snow” should be “isotopically heavy snow”, “Isotopic lapse rates” do not exists and so on. Please read carefully throughout the text an correct all these errors. A good starting point for nomenclature and terminology could be Z. Sharp’s “Principles:…”

Thank you for your reference for the nomenclature for the isotopes. We revised the terminology throughout the manuscript.

References cited in the response:

Dutton, Andrea, Bruce H. Wilkinson, Jeffrey M. Welker, Gabriel J. Bowen, and Kyger C. Lohmann. 2005. “Spatial Distribution and Seasonal Variation in 18O/16O of Modern Precipitation and River Water across the Conterminous USA.” *Hydrological Processes* 19 (20): 4121–46. https://doi.org/10.1002/hyp.5876.

Gat, Joel R. 2010. *Isotope Hydrology: A Study of the Water Cycle*. Vol. 6. Series on Environmental Science and Management. PUBLISHED BY IMPERIAL COLLEGE PRESS AND DISTRIBUTED BY WORLD SCIENTIFIC PUBLISHING CO. http://www.worldscientific.com/worldscibooks/10.1142/p027.

Poage, Michael A., and C. Page Chamberlain. 2001. “Empirical Relationships Between Elevation and the Stable Isotope Composition of Precipitation and Surface Waters: Considerations for Studies of Paleoelevation Change.” *American Journal of Science* 301 (1): 1–15. https://doi.org/10.2475/ajs.301.1.1.