Reviewer 1 comments

- The manuscript focuses on understanding the phases of aggradation and incision that occurred in the late Pleistocene and mid- to late Holocene. The authors explained the aggradation history using previously published OSL ages and added 12 new luminescence ages and 36 new cosmogenic nuclide exposure ages, of which 22 were rejected due to no or low signals, low current, or high uncertainties. But the figures show different numbers of ages used (7 OSL and 19 exposure ages). The major concerns in this study are (1) sedimentological constraint sections, (2) the incision in the valley during the mid-late Holocene is explained because of glacial/landslide-dammed lake outburst floods (GLOF/LLOF); however, no evidence of damming is preserved in the valley, and (3) the sampling strategy. The authors sampled both valleys, without regard for what they were sampling. The sedimentological characterization of litho-units is missing throughout the manuscript. None of the sections is explained sedimentologically, and it is not explained why the depositional or erosional ages are needed to characterize the particular event. The event should be characterized in the field itself (sedimentologically and geomorphologically).
    - Thank you for your comments, we are going to address each point individually:
    - Regarding the “rejected samples”: We did not reject 22 of our 36 cosmogenic nuclide results. These were the samples, where the 26Al results were questionable due to low measurement current, so we decided to use the 10Be throughout the study. As the 10Be results are independent of the 26Al measurements, we still used n=36 reliable surface exposure ages with normal errors and good sample current output. To avoid confusion, we now more clearly state the number of samples used for our analysis.
    - Regarding the different number of samples shown in the figures: We think the reviewer is referring to Figure 8 (now Figure 7), where the Ravi samples are shown. As this figure shows a profile of the Ravi River, no Suil samples are present. For the luminescence results, only the near-surface samples are shown to keep the figure intuitive. We are not showing 3 samples from one isolated dam terrace south of the Chamera Dam, which we do not relate to activity of the Ravi. We do show these results in Figure 7 (now Figure 6) - Profile 3 in the main manuscript and discuss them in detail within the supplementary, which we refer to in the text of the main manuscript. To address this, we have added an explanation in the figure caption about these 3 samples (2 luminescence and 1 cosmogenic nuclide) and where to find them.
    - To improve our sedimentological description, we rewrote most of Section 4.1 to make it more precise with the appropriate wording and extended description. We shifted the main focus to the colluvial material on the terrace surface as this is the relevant part for the new findings of this study. We think however, that an additional extensive discussion of the fluvial material below would clutter the manuscript without adding new and necessary information to the discussion, as this material was already extensively described in the previous work of Joshi et al. (2022) and is not necessary for our interpretation of the colluvial cover deposits.
    - Regarding the GLOF/LLOF discussion: This point is motivated by recent publications and observations that GLOFs (and also LLOFs) have significant impact on the valley morphology and sediment transport. There is no clear evidence of Holocene GLOF/LLOF deposits. However, we noticed some very large (> 5 m diametre) boulders within the Ravi, which were already

moderately rounded and thus likely transported within the river for some distance. This indicates that during large flood events these boulders are transported. To address this issue in the present study, we adjusted our discussion Section 5.4, discussed other potential flood origins, and pointed out that large floods do not need to be related to lake outbursts, as it has been shown in the recent catastrophic flooding within the Trishuli in Nepal in August 2026. Recent research and observation clearly indicate that large, catastrophic floods throughout the Himalaya occurred in the past decade and likely during the Holocene (Montgomery et al., 2004; Borgohain et al., 2020; Shugar et al., 2021). We therefore stand by our argument that surface overprint through flooding is a reasonable hypothesis. We note that the timing of the Mid Holocene surface ages suggests that flooding may have occurred at the end of the Mid Holocene intensified monsoon phase - a time when glaciers were generally larger. Rapid melting of glacial environments may have increased the potential for large flooding events.

- Regarding the sampling strategy: We are uncertain what the reviewer is referring to. We aimed at collecting samples along terraces to constrain their formation and surface exposure ages. Because terraces are not continuously preserved and exposed in the steep valleys, we had to take samples from the available terrace outcrops. Both rivers were sampled because they represent two different source regions with varying lithology and glacial coverage. We used standard, established methods for both cosmogenic nuclide and luminescence dating sampling, which we applied successfully in previous studies (e.g., Dey et al., 2016a; Dey et al., 2016b; Dey et al., 2022; Kordt et al., 2025).
- Concerning the sedimentological constraints: In addition to our previous comment above and the comments concerning the detailed aspects below, we emphasize that the results for surface exposure dating do not change with varying lithological composition of layers (e.g., grain sizes or mineral abundance). As long as there is sufficient quartz, cosmogenic nuclides measure the time since the surface has been exposed to cosmic radiation. If a cosmogenic surface age is drastically younger than the luminescence age sampled stratigraphically below, it can be related to either aggradation/reworking or removal of surface material. Therefore, regarding the sediment, a key point to answer is whether the material on top of the older terrace body is different from the material below. To make our point clearer, we expanded the lithology analysis to focus on the colluvium and its distinct differences from the underlying fluvial deposits. We explicitly highlight that these two units are clearly separate materials. Additionally, the consistent presence of young surface exposure ages across all terraces - irrespective of colluvial cover - indicates that the exact composition of the terrace deposit does not exert primary control on surface exposure ages. Consequently, we believe our expanded lithology section provides the necessary context for the study area.

Specific comments:

- Line 43-45; the strong monsoon in general enhances the melting of the glaciers. The monsoon's penetration into the hinterland is driven by the formation of low-pressure zones in the Himalayan/Tibetan region, which attract monsoon winds intensified by strong warming. During such warming conditions, glacier growth in the southern Himalaya is speculative. This may occur in the Greater Himalaya or Trans-Himalaya.

  - ➢ Thank you for the comment. We understand that this is an intensely debated topic throughout the literature. We point out that some glacial advances have been related to an increase in monsoon strength in the nearby northwestern Himalaya during the Late Pleistocene and Holocene (Scherler et al., 2010; Saha et al., 2018). We rephrased our statement to make it clear that there are different views on that matter and included the contrary views.

- Line 51-69; It is true that short-term events such as floods, landslides and debris flows alter the local base level of the river and modify the aggradation and incision processes locally. It is also true that to better understand such processes, we need more data, but the extreme northwestern Himalaya, where annual precipitation is limited to ~1400-800 mm/yr, is restricted by the Dhauladhar ranges from further penetration to the north. This section needs more clarification. Further, the tectonic framework and its role should be mentioned.
  - ➢ As we rewrote this part of the introduction, we moved all of the geology and climate introduction to Section 2. There, we added clarification on the precipitation.
- Line 118; The authors mentioned that in a previous study in the region, 8 cut-fill terraces were identified; however, this study has identified 10.
  - ➢ Yes, this was not clear; we added a short explanation there and expanded further on our terrace mapping in the revised manuscript Section 3.3 (see comment of reviewer 2 on that issue).
- Line 166-167; The statement is confusing. How can an older surface give a higher erosional rate? Rather, a younger surface should.
  - ➢ Thank you for pointing out that this could be unclear without explanation. For surface exposure age calculation, an erosion rate input is needed, as this cannot be derived from single surface samples. The nuclide concentration is fixed by the measurement, so changes in assumed erosion rate are influencing the calculated age. Erosion constantly removes the uppermost material with the highest nuclide concentration. If a surface is eroding faster, it needs more time to reach the same nuclide concentration as with lower erosion. So if we assume a higher erosion rate, we get an older age for cosmogenic nuclide surface exposure dating. We added an explanation to the section.
- Line 167-171; Again, the paragraph creates confusion between samples and rates, which is lower than what. Need corrections.
  - ➢ Regarding the rates, we refer to the previous comment. In addition, we added an explanation of the inheritance concept to make clear how a potential correction works.
- Line 197; How was the preheat temperature decided? How many aliquots yielded palaeodose under the aforementioned boundary conditions? There should be a figure showing the decay curve of the IRSL and OSL signals. Overdispersion should be mentioned in Table 2.

- The preheat temperature was decided based on the preheat plateau test. The plateau test was done on 3 samples. Part of this was also based on previous experiments done by co-authors S. Dey and N. Chauhan. Regarding the paleodose of aliquots, 14 - 19 aliquots out of a total of 24 satisfied the boundary conditions. We purposefully didn't give shine-down curves and paleodose histograms in the main text, because it already contains many figures and tables. We have added a supplementary figure showing the glow curve, growth curve, and kernel density estimate plot of one sample. Overdispersion of individual samples is now listed in Table 2.

- Line 262-268; In general, lithofacies analysis is the most suitable method to characterize the sedimentation processes. The explanation needs more information to characterize the terrace sediment (facies codes).
  - We rewrote our lithofacies section with a clearer, extended description that includes facies codes. We agree with the reviewer that lithofacies analyses can help in explaining sedimentary processes. However, as noted earlier, we found no sedimentological evidence of a lake outburst flood. Furthermore, young surface exposure ages persist across all surfaces regardless of whether the upper unit consists of colluvium or fluvial material. This strongly indicates that an overarching driver (and unrelated to lithology) is reshaping the terrace surfaces. Because this is a hypothesis and provides a compelling avenue for discussion, our revised lithofacies section focuses specifically on characterizing the colluvial layer and establishing its clear distinction from the underlying fluvial deposits.

Discussion:

5.1 Caveats of cosmogenic nuclide exposure ages

- All 26Al/10Be exposure ages are younger than the depositional OSL ages, hinting at possible flaws in the sampling. The authors ignored the sediment packages that need to be targeted for dating. To justify the younger ages, authors state the possibility of debris flows and landslides, but no sedimentological evidence is provided.
  - When applying cosmogenic nuclide surface exposure dating on a sediment body with a normal stratigraphic sequence (upwards younging ages), the ages can be equal or (significantly) younger than the luminescence ages below. This is because, in contrast to luminescence ages, which only provide the date of aggradation, cosmogenic nuclide ages provide the age of the last surface activity (e.g., since when the sample is receiving secondary cosmic radiation; c.f., Lal, 1991; Gosse and Phillips, 2001). This activity can be anything that brings the dated material in contact with cosmic radiation, which can be aggradation, but also incision, including removal of material above. Therefore, a young cosmogenic nuclide age is no indicator of flawed sampling or measurement processes, but instead of recent surface activity. We emphasize that the ages do not change with varying lithology and instead only with varying exposure to cosmic radiation. However, the widespread relatively young ages are still unusual, as normally the cosmogenic surface ages are only up to a few ky younger. For the surfaces covered with colluvium, this might be expected, but for surfaces with fluvial material up to the top it is unexpected. We therefore discuss other potential influences on the signal (e.g., agricultural activity) in Section 5.4. However, we agree that the split of the cosmo caveat discussion to Sections 5.1 and 5.4 might leave readers unconvinced until just

before the end of the manuscript. We therefore moved the discussion of potential influences, such as agricultural activities, to Section 5.1. We also added more explanations about the cosmogenic principle and what these ages say.

5.3 Sediment Transport and climate variability

- There is recent work available from NW Himalaya on sediment transport and the role of climate variability, which the authors should incorporate.
  - ➢ We are sorry if we missed a study; we would be grateful if the reviewer could provide us with the study name. We have now included studies from the nearby Soan Basin, to indicate the widespread presence of similar aggradation phases as in the Ravi catchment. However, we refrain from discussing these and other studies in more detail, because this was already done in the previous study of Joshi et al. (2022). Therefore, to differentiate our luminescence discussion, we focus on the comparison with the southern Dhauladhar Range because this provides the interesting opportunity to compare a glacially influenced catchment with nearby ones that did not experience extended glaciation and are not >100 km away.
- Authors argued that sediment aggradation and incision during MIS-3 and gLGM were controlled by glacial activities in both studied valleys, which seems speculative. None of the sections is constrained by sedimentological characterization or photographs to evidence the glaciogenic processes. However, the older aggradation phase mentioned in this study is synchronous with the aggradation phase present throughout the Himalaya (northwestern as well as in northeastern Himalaya).
  - ➢ We indeed have no clear sedimentological evidence on how much of the sediment is originating from the glacial areas. But we also note that the very dynamic Ravi River has a low preservation potential and is continuously being reshaped. Glacial deposits from the Holocene are unlikely to be preserved in the downstream river. However, fieldwork indicates glacial erosion features in the upstream part of the catchment (Deeken et al., 2011). Analyzing the current sediment deposits for their provenance would require extensive analysis, and this is beyond the scope of this study. Because of the large previous glacial extent in the Ravi catchment and the important role of glaciers in delivering sediment (e.g., Godard et al., 2012; Herman et al., 2013), we argue that this is a justified suggestion.

5.4 Widespread Holocene overprinting of fluvial terrace surface across the catchment

- Lines 469-475: It is true that aggradation ages reflect the timing of sedimentation; however, 10Be ages represent younger surface processes, so they are genetically different. This is probably not underestimated; rather, the selection of the horizon for dating is doubtful. It would be nice if authors select a well-constrained section (lithofacies) for exposure ages and then correlate these ages with geomorphological processes. That would have provided a logical interpretation of all younger ages.
  - ➢ Thank you for pointing out that the wording might be misleading. Indeed, we don't mean underestimation, but instead whether potential biasing factors, such as agricultural activity, could explain the young ages, which we then discussed below. The proper wording is that these surfaces have been reworked and the cosmogenic nuclide ages represent the last surface activity. Thereby, the

surface ages are "underestimated" with respect to their original formation (aggradation) time. We changed the wording and integrated this paragraph into Section 5.1, to make it more concise (see our comment above concerning this section).
    - Concerning the lithofacies interpretation of younger surface ages, we point out that we observe Holocene ages regardless of a colluvial cover. While some colluvial-covered terraces could be related to local mass wasting processes, this cannot be an explanation of all young surface ages. Therefore, the widespread Holocene ages also on fluvial surfaces suggest that there must be a different reason. We therefore argue against a single event, but suggest a combination of different factors. We argue that our extended lithology description and discussion of the young ages in Section 5.4 are able to clarify our view.
- Line 513 onward, suddenly the discussion shifted to the role of GLOF/LLOF, which enabled the modulation of the T-8, -9 and -10 surfaces situated at ~200 m above the river. In northwestern Himalaya, there is no evidence of palaeoflood records that have reached more than ~ 30 m from the present-day river. Only the Indus River attains such heights because of the availability of a large sediment flux (see Srivastava et al., 2017). So, building a flooding scenario (GLOF/LLOF) for modulating the T-9 or T-10 surfaces is more hypothetical.
    - Thank you for pointing this out. Indeed, an impact of large floods on the highest levels is speculative, but we have also phrased this as a hypothesis (and we have changed the wording to clearly indicate that this is a hypothesis in the revised manuscript). Nevertheless, we emphasize that some large (> 5 m diametre) rounded boulders within the Ravi indicate potential transport by larger floods. We also note that a similar-sized catchment in Uttarakhand experienced a significant flood in February 2021 that reached heights above 200 m (Shugar et al., 2021) and added this to the discussion.

Summary

- Line 538, None of the terraces is explained as a strath terrace. No details on the bedrock bench is provided.
    - This topic was just briefly mentioned in Section 4.1. We added details about the bedrock bench in this section.

Figures

- Figure 1; The inset Indian map has the wrong international boundaries. Authors are requested to change the map as per SOI.
    - Thank you for pointing this out. We have corrected the figure.
- Figures 3 and 4; Figure 3 shows an unpaired terrace configuration along both rivers, specifically at the higher levels T-9 and T-10; in contrast, Figure 4 shows continuous terraces along both banks.
    - We agree that this could be confusing, because Figure 4 just shows the relative elevation height above the river. Figure 4 does not provide meaningful additional information; we have decided to move it to the supplementary material. The terrace map (Figure 3) provides a better overview of the real terrace extent.

- Figure 6; (A) shows cross-beds in the colluvium; (B) In the silty-clay units of colluvium, faint ripples marks can be seen. These sedimentary features indicate channelized processes and underscore the importance of sediment characterization prior to establishing the chronologies of any horizons.
    - ➢ We fully agree with the reviewer's observation regarding the presence of cross-beds and faint ripple marks in these units. The issue stems from a difference in terminology regarding the classification of 'colluvium'. While traditional geological and sedimentological definitions often restrict colluvium to unchannelized slope processes, in our study area and in the discipline of geomorphology, we include short-distance, fluid-assisted, and channelized slope deposits (sometimes categorized as proluvium) under the broader umbrella of colluvium. To eliminate any confusion, we have explicitly clarified our definition of colluvium in Section 4.1 and added a cross-reference to this definition in the caption of Figure 6 (now Figure 5).
- Figure 11: How can the Chinese cave located near the South China Sea sense the climatic perturbation that occurred on the NW Himalaya? Himalayan data are also available for the same time.
    - ➢ We have used the well-dated cave located in the South China Sea as a monsoon proxy. While the cave is located far away from the northwestern Himalaya, the underlying driving processes of the monsoonal circulation are the same. Because the speleothems are well dated and provide a high-resolution record, they are often used to show the variations in continent-wide monsoonal strength. There is no similar high-resolution record in the Himalayan domain. If we have missed a record, we are sorry. We do not know of any d18O record that is closer to our study area and covers the complete last 40 ky (there are, however, complete records for the Holocene). Despite the large distance, the difference is small between studies, and the same long-term trends can be seen in d18O records of south China and the Himalaya (e.g., Kathayat et al., 2016; Dutt et al., 2015). We tried plotting these additional curves, but the already packed figure became more cluttered and therefore decided to just use the Cheng et al. (2016) curve.

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