

12 December, 2023

Dear Editor and Reviewers,

Thank you for your recent communications and comments regarding our paper, *Brief Communication: An Ice-Debris Avalanche in the Nupchu Valley, Kanchenjunga Conservation Area, Eastern Nepal*.

Your comments, and our responses, are shown below:

- **1. (Reviewer)** The paper improved as it now focusses on the event which is the main topic of the contribution. However, the paper still lacks reference on how typical such events could be. The abstract states widespread distribution of such events, but no further discussion or assessment is given later in the paper. Rather the paper refers to other types of high mountain hazards that the paper doesn't study. The authors would need to improve the general significance of the study based on discussing or assessing the same type of events as described in the paper.
- **(Authors)** To address Reviewer #2's request to include information regarding the (a) frequency/magnitude of events such as the Nupchu ice/debris flow, and (b) their relation to climate change, we have revised the following paragraph under Discussion, starting at line 144, as follows:

*Still, the acceleration of torrent-like pulses of debris upon the historic debris cone since 2020 suggests that these events may be linked to contemporary warming trends, similar to those that may have triggered larger-scale mass wasting events elsewhere in the Himalaya (e.g., Shugar et al. 2021; Käb et al. 2021; Taylor et al. 2023). The frequency of such ice-debris flow events within the KCA region, and more broadly across the Himalaya, is unknown. However, with projections of continued warming in these regions (e.g., Lalande et al. 2021), a more systematic approach to determining their historic frequency, as well as a better understanding of their triggers, is warranted. After further evaluation, vulnerable villages, such as Kampuchen, may wish to consider the installation of preventative floodwater diversion mechanisms, such as the rock-filled gabion walls currently protecting tourist lodges in the Mt. Everest region (e.g., Rounce et al. 2017; Byers et al. 2022) using participatory processes as outlined in Watanabe et al. (2016).*

[Note that the paragraph above also includes a new reference (i.e., Lalande et al. 2021) to climate change trends in the High Mountain Asia region as well].

- **2. (Reviewer)** I see that the HMA DEM has some voids over the study area, but these seem not massive and could be interpolated (from what is visible in the figure). The ALOS DEM has also been processed and might have been void-filled that way. A brief comparison of results using the ALOS and HMA DEMs could be useful to investigate the sensitivity of the modelling to the DEM used. I would be happy to learn that the difference is minor, but many readers could wonder the same (as the co-author discussion confirms).
- **(Authors)** We ran a R.Avaflow model using the HMA-DEM that was void filled in ArcGIS, and the same parameters used in the original model for an avalanche of 1 MM. We then visually

compared the debris cone deposit observed from optic images with this new result, and they look, generally, in good agreement.

However, as is shown in Figure 1 below, we can see that the results from the Alos Palsar RTC DEM are in better agreement with the delineation of the debris cone. It seems that the flow modeled using the HMA-DEM develops faster which ends up extending the debris cone deposit in the main direction of the flow having some uphill runout in an area where the optic images do not show debris cone.

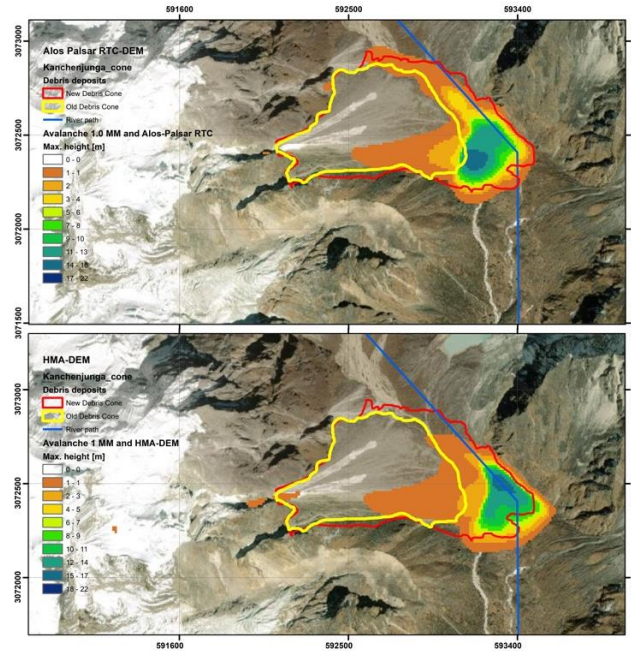


Figure 1: Comparison of the deposit using the ALOS PALSAR Radiometric Terrain Corrected high-res (Above) and the HMA-DEM (below). The delineation of the actual cone is superimposed to visualize the differences.

- 3. (Reviewer) I am still puzzled about the "ALOS PALSAR DEM" used. According to the cited ASF there is no such DEM. The ASF PALSAR data contain other DEM data for reference. Are you referring to this?

<https://asf.alaska.edu/data-sets/derived-data-sets/alos-palsar-rtc/alos-palsar-radiometric-terrain-correction/>

Or the ALOS PRISM DEM by JAXA? Or else?

(Authors) We appreciate the reviewer's comment which allows us to clarify in more detail the DEM used in the text. As is mentioned by the reviewer and in the first reference in the list of references, we are referring to an ALOS PALSAR Radiometric Terrain Corrected high-res product as shown in the figure below. When we did the search in the <https://search.asf.alaska.edu/> website we only indicated ALOS PALSAR as the dataset of interest (see figure below). As a result, in the paper we thought it only necessary to include that information to allow the readers to find the DEM used. However, we accept the reviewer's comment which clarifies further the datasets

used. In the paper at line 93 to 94, we now indicate that we are referring to an ALOS PALSAR Radiometric Terrain Corrected high-res file. We have also included this information in the Data Availability section as “The ALOS PALSAR Radiometric Terrain Corrected high-res DEM “AP\_13152\_FBD\_F0540\_RT1” used for the R.Avalflow is available at <https://search.asf.alaska.edu/>.”

- The instruction for the citation can be found at: <https://asf.alaska.edu/data-sets/sar-data-sets/alos-palsar/alos-palsar-how-to-cite/>

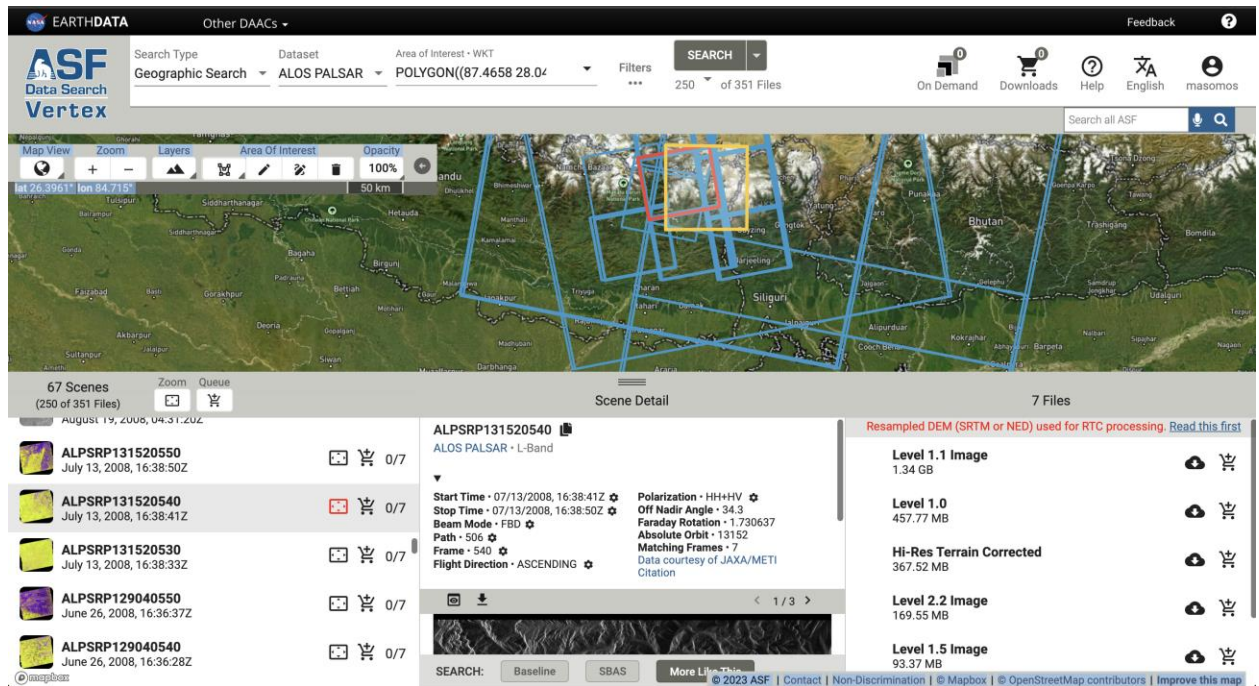


Figure 2: Screen shot of the <https://search.asf.alaska.edu/> where the DEM was downloaded on February 11, 2023.

- **4. (Reviewer)** You write that you compare modelled deposition depths to field data but don't describe field investigations of deposit depths. Line 144 in the ATC.
- **(Authors)** On line 82/93, in the Methods section, the following clarification has been added: regarding the use of a Nikon Forestry Pro Rangefinder to determine depths of the ice-debris avalanche:

*Field-based observations and assessments of Nupchu Pokhari (glacial lake), other nearby lakes, and the ice-debris avalanche were conducted between 1–20 September 2022. Methods included GPS-based route mapping, photography of avalanche features, oral testimony, and literature reviews. A Nikon Forestry Pro Rangefinder was used to determine the depth of ice/debris deposits where the Nupchu river had incised deposits down to the original streambed. Historic*

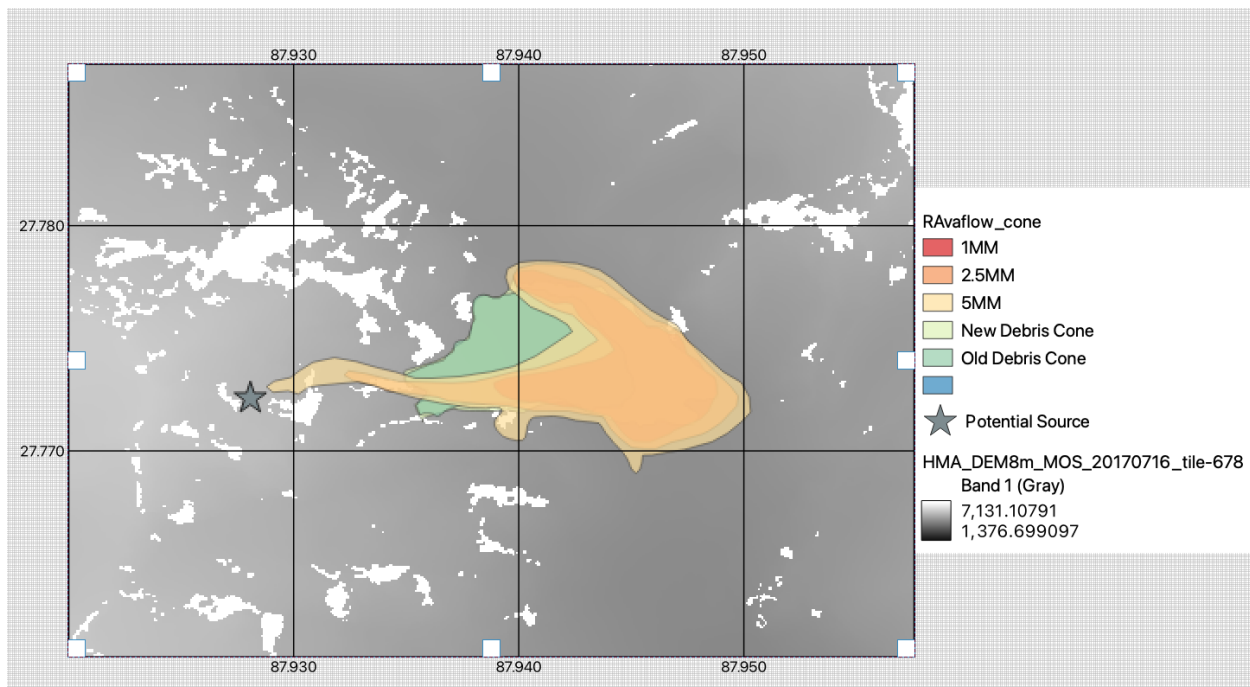
.....

- **5. (Reviewer)** Fig XXXX in the Author response is not explained and rather contains an open to-do item
- **(Authors)** Our initial simulation was conducted on the ALOS-PALSAR DEM since prior research (e.g., Bhardwaj, 2019; Shawky et al. 2019) suggested it had the best resolution and elevation accuracy in mountainous and rugged terrain. Given this suggestion, we investigated the use of the HMA DEM (Shean 2017) but found that there are several data gaps (Figure 1) within our simulation area that would require data interpolation to make it suitable for study. As we do not expect significant sensitivity in the model results to modest changes in the input DEM, we feel that the use of the original DEM is sufficient.

Bhardwaj, A. (2019). Assessment of Vertical Accuracy for TanDEM-X 90 m DEMs in Plain, Moderate, and Rugged Terrain. The 2nd International Electronic Conference on Geosciences, 8. <https://doi.org/10.3390/IECG2019-06208>

Shean, D. (2017). High Mountain Asia 8-meter DEM Mosaics Derived from Optical Imagery, Version 1 [Data Set]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. <https://doi.org/10.5067/KXOVQ9L172S2>. Date Accessed 09-25-2023.

Shawky, M., Moussa, A., Hassan, Q. K., & El-Sheimy, N. (2019). Pixel-based geometric assessment of channel networks/orders derived from global spaceborne digital elevation models. Remote Sensing, 11(3). <https://doi.org/10.3390/rs11030235>



**Figure 3: HMA DEM elevations [m] in the vicinity of the debris flow. Data gaps in the model domain would require interpolation in order to be suitable for simulations.**

- **6. (Reviewer)** The discussion comments between co-authors in the ATC are unusual to submit but could be viewed helpful. Though, these comments and some open do-todo's in the response letter (and ATC?) give the impression that the items have been re-submitted before carefully finalizing them.
- **(Authors)** We apologize if the discussion comments created the impression of lacking careful consideration before finalization. In fact, all authors found the candid conversations to be most helpful in refining the manuscript before its re-submission.
- **7. (Reviewer)** The fact that I can still not find all text references in the reference list confirms this impression (ICIMOD, WWF, Rounce ...).
- **(Authors)** All missing references have now been added to the Reference list.

Thank you again for kind attention to and interest in our Brief Communications submission. Please feel free to contact me at any time if there are any remaining concerns or questions.

Sincerely,

A handwritten signature in black ink that reads "Alton C. Byers". The signature is written in a cursive, flowing style with a long horizontal stroke extending to the right.

Alton C. Byers, Ph.D.