Reviewer 2:

General comment

The authors have conducted a sensitivity experiment considering local-scale snow and ice distribution in the valleys of the Karakoram region, comparing it with a control experiment that does not account for such distribution. Their key finding suggests that incorporating local-scale snow and ice distribution modifies local-scale circulation associated with mountain-valley topography and further influences synoptic-scale monsoonal circulation and precipitation. Understanding the upscaling effects of local glacier distribution on large-scale atmospheric circulation is an important research topic. However, the current version of the manuscript does not yet fully achieve its objective. The presented figures are insufficient to support the authors' conclusions, and additional, more detailed analysis is necessary before publication.

We thank the reviewer for the comments and reply to each in turn below.

Major comments

1. Before discussing the sensitivity experiment results, the simulation output should be validated using in-situ and/or satellite-based observational datasets. While we acknowledge the limitations of observational data over high mountain regions, validation is an essential step to ensure the reliability of the simulated differences between the control and sensitivity experiments.

   Thanks for pointing this out and we agree that it is a critical step. While we acknowledge the challenges of direct validation in high mountain regions due to limited observational coverage, extensive previous research has already evaluated the performance of the model in this region. In particular, our study cited in the paper (Dars et al., 2020) provides a thorough assessment of the model's ability to simulate key atmospheric and hydroclimatic processes, and this configuration has been used in several other projects also cited in the paper, including Wolvin et al. (2024). Our study builds upon this prior work by focusing on the sensitivity of large-scale atmospheric circulation and precipitation to glacier modifications, rather than re-evaluating the model's baseline performance.

   To ensure transparency, we explicitly referred these validation studies and clarified that our approach relies on their findings as a foundation for interpreting the sensitivity experiments by adding text:

   > "*...Working with our previously validated configuration of a regional climate model (Dars et al. 2020; Wolvin et al. 2024), which has been extensively tested against observational datasets to ensure reliability in simulating hydroclimate processes over high mountain regions, …*"

2. The differences in precipitation and other variables between the two experiments, particularly in domain D02, seems to show chaotic noise. Please provide statistical significance testing to confirm whether these differences are meaningful.

Failure to include statistical significance was an oversight, and we appreciate the suggestion.

To ensure that the precipitation differences between the control and sensitivity experiments in domain D02 are meaningful rather than chaotic noise, we conducted a statistical significance test. Specifically, we applied a two-tailed *t*-test on the difference between the mean precipitation in the experiment and control. This method allows us to determine whether the observed differences are statistically significant, rather than arising from random variability in the model. The results confirm that the precipitation anomalies in key regions of the innermost two domains are statistically significant, particularly where the large-scale monsoonal flow interacts with the modified glacier extent, and this is indicated using stippling on revised Figures 3a,d.

In addition, we now report the domain-average precipitation responses (first paragraph of Results), which are effectively zero for d02 and d03. This is useful to report, but also completely expected because we make only small changes to the surface latent heat flux and domain integrated moisture flux is constrained by the prescribed lateral boundary conditions. We emphasize that the response involves shifting the location of the precipitation laterally on the domains without introducing or removing any of the total water.

We also contextualize the magnitude of the precipitation response relative to the monthly mean taken from the control, reporting results now as mm per month (in text) and % anomalies in Figures 3a,d. Anomalies locally exceed 50 mm per month in magnitude, amounting to +/- 30% percent anomalies.

As described in Section 2, precipitation in the target region is influenced by both winter westerly disturbances and the summer monsoon. Why was the analysis limited to July? Does the upscaling impact of glaciers on atmospheric circulation occur in other seasons as well?

The analysis was limited to July because this is the period when the interaction between glaciers and atmospheric circulation is most pronounced. During the summer monsoon, moisture transport into the region is at its peak, and changes in glacier extent have the strongest influence on large-scale precipitation patterns. Our results show that modifications to the glacier termini alter the monsoonal moisture flux and precipitation in a way that overwhelms localized orographic effects, making July the most relevant month for evaluating the large-scale atmospheric response.

While winter westerly disturbances also contribute to precipitation in the region, their interaction with glacier-driven processes occurs under different atmospheric conditions, where large-scale synoptic dynamics dominate. The upscaling effect of glaciers on atmospheric circulation is therefore expected to be less pronounced in winter compared to the summer monsoon season. Additionally, summer is when surface energy balance interactions between ice and the atmosphere are strongest, further justifying our focus on this season.

The contrast between the surrounding lands and glaciers is the biggest. We have text in Section 1 third paragraph "*We focused on summertime because the temperature contrast between the glaciers and surrounding land surface is strongest*."

Although our study primarily examines July, the methodology used here could be extended to other seasons in future work. However, given our focus on the monsoonal hydroclimate response to glacier modifications, limiting the analysis to the peak monsoon period allows us to isolate the most significant and physically meaningful impacts.

3. Several conclusions described in the manuscript are not sufficiently supported by the presented figures. More comprehensive analysis, additional evidence, and substantial revisions are necessary to justify the authors' claims.

   Reviewer 1 also pointed to some places where results may have been overstated relative to the presented evidence. We have addressed these specific comments by expanding or improving the presentation of results and/or modifying the language reporting the results. Specifically see our replies above to:

   - Major comment 3 on magnitude and seasonal context for precipitation anomalies
   - Minor comment 10 on terminology and interpretation of "synoptic scale shifts"
   - Minor comment 11 on appearance of synoptic-scale and valley-scale results
   - Minor comment 12 on presence of mountain waves as a component of the response
   - Minor comment 13 on influence of glacier ice on monsoon processes
   - Minor comment 15 on the depiction and discussion of the surface wind response
   - Minor comment 16 on the discussion of glacier wind response
   - Minor comment 17 on the synoptic versus valley-scale of the response features

Minor comment

L43 while (Collier et al., 2015) -> while Collier et al. (2015) Fixed