Answer to Referee 1

We are very grateful to Reviewer 1 for the in-depth reading and for the relevant review we received. We present below our detailed answer to the discussed points. The reviewers' comments appear in orange and our responses appear in black.

0.

This paper presents in situ observed precipitation at three locations in the central Himalaya and compares these in situ precipitation measurements to two simulated estimates. One of the in situ measurement uses a novel technique where precipitation is derived from pressure measurements taken from a frozen lake. The results demonstrate a large gradient in the observed precipitation across a very small distance, and briefly discuss the ability of the simulated datasets to represent those gradients.

Generally it's well known that large windward/leeside gradients can exist in regions where the precipitation is strongly modified by terrain, and I think this could be better referenced in this paper. However, the novelty here is in the use of the frozen-lake-measured precipitation and in particular its utility in such a data-sparse environment, and the test and figures are generally well presented. I have several specific comments below that would improve the paper that I recommend addressing before acceptance.

We thank the reviewer for their positive appreciation of our work. We are grateful for these scientifically relevant comments and we will attempt here to respond to them as best we can.

1.

Figure 1 comment 1: It would be very helpful for the reader less familiar with the region to include a thumbnail/inset panel showing the broader location of this (fairly small) geographical location

We added a subfigure on figure 1, allowing the reader to locate the study sites:
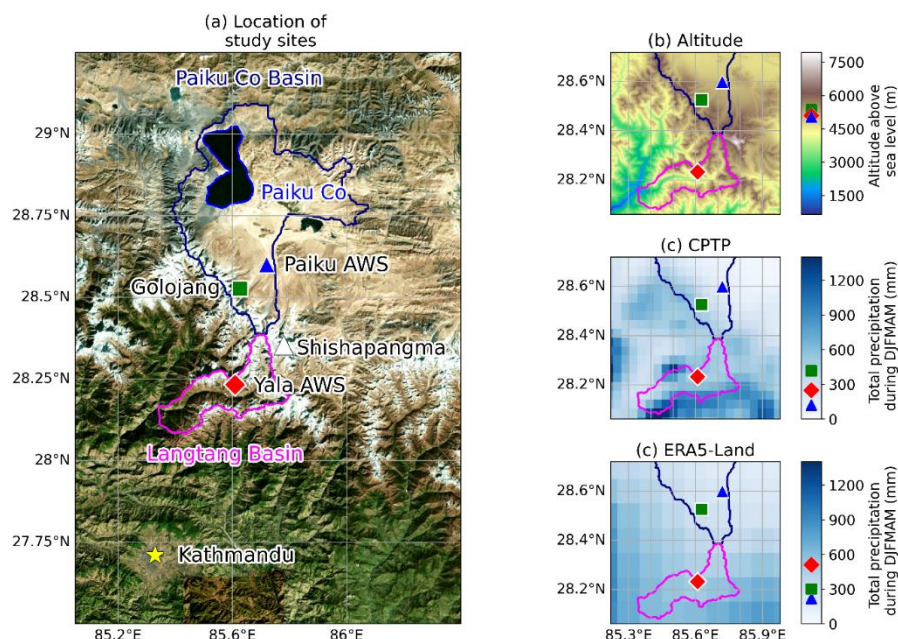
2.

We understand that the caption lacks clarity. We modified the caption to:

" Figure 1. (a) Location of study sites. (b) Elevation and (c & d) spatial distribution of total precipitation over the study area from CPTP and ERA5-Land models from 5 december 2019 to 15 July 2020. On the maps, the symbols show the locations of the in-situ recordings. On the color bars on the right side of the maps, symbols indicate interpolated values of precipitation at the study sites. The solid lines mark the boundary of the Langtang National Park and Paiku Co basin."

We tried to plot outline markers instead of filled markers, but it was not successful in improving the readability of the figure as the markers were not visible above the raster layer. We choose to keep the color theme of the study sites that is used in all three figures. We clarified the caption to make it more explicit.

3.

We added the lake on the figure (see answer to Figure 1 comment 1).

4.

We agree that the text lacks clarity. We added Paiku Co level change values from the series of Lei et al. (2021). We chose not to include precipitation data collected in villages close to Paiku Co shores because they are measured with unshielded gauges which we find less reliable than the shielded OTT2.

- 118-122: We added the amplitude and the rate from Lei's 2021. modify to: "Golojang Co seasonal level cycle is more pronounced than the cycle of Paiku Co (Lei et al., 2021). During 2013 to 2017, Paiku Co water level had an average amplitude of 51 cm, and had a near constant decrease rate of 7 cm month^{-1} during the post monsoon and the winter on average. Paiku Co level rises sharply at the end of pre-monsoon (Lei et al., 2018), but its level decreases slower than Golojang Co during post-monsoon with a decrease rate greater than 23 cm month^{-1} during 2021 and 2022, and a much lower rate of 4 cm month^{-1} during the winter."

- 158-159 modified to: "While the Yala and Golojang Co snowfall observations are similar, the much lower precipitation totals recorded at Paiku AWS have the same order of magnitude as the 150 mm – 200 mm precipitation previously measured close to Paiku Co (Lei et al., 2018)"

5.

Comment 2: 190-199: The text in this paragraph meanders and is a bit challenging to follow. I suggest dividing it into two paragraphs, one which describes the comparison of in situ to models and one which describes the potential differences between the AWS and PT methods (and the latter's potential to miss smaller snowfall events)

190-199 This paragraph is indeed too complex to be clear. We divided it into three smaller ones. The first two about the comparison of the in-situ and the models, and the third one about the potential source of error of the PT. This part now reads:

180 : *"ERA5-Land has a very good estimation of the cumulative DJFMAM precipitation in Yala since the in situ is, on average, only 8% greater than the AWS during 2020-2021 and 2021-2022 (Fig. 3 - e and f). Unfortunately, Yala AWS was not working during most of the year of the CPTP simulation, and completely missed winter precipitation as it started recording from 27 March 2020. For the period with recording (from 27 March 2020 to 31 May 2020), Yala AWS recorded 241 mm of precipitation (Fig. 3a), against 76 mm estimated by CPTP, which is a large underestimation (Fig. 3g).*

At Golojang Co, CPTP provides a DJFMAM cumulative snowfall estimate that differs from the PT estimation by only 1.2% during 2019 - 2020, although CPTP slightly overestimates precipitation at the beginning of the study period and underestimates precipitation at the end compared to in situ (Fig.3 - g). ERA5-Land shows much lower precipitation at Golojang Co, with PT estimates being on average 1230% greater for the three years (Fig. 3d, e, and f).

Although we use Golojang PT estimates as references here, they are likely underestimated, as the pressure time series primarily captured wet spells averaging 73 hours, while shorter snowfalls may have been masked by noise. For comparison, during the period from 01 December 2020 to 31 May 2021 (the only complete meteorological year during which all sensors were working), there was 26 events recorded at Yala site by the AWS, of which 18

lasted less than 2 days and had an accumulation less than 10 mm of snow. At Golojang, the pressure time series allowed us to identify 23 events in the same period, of which only 7 could be matched with Yala small events."

6.

209-210: While the larger gradients in CPTP may be promising, it's difficult to know whether the even larger values in CPTP to the west and south of Yala AWS are realistic or overdone (while numerical models can accurately depict orographic precipitation, some studies have shown wet biases in high terrain, e.g., He et al. 2019) – perhaps some comment along these lines could be added.

209-210: modified to:

" [...] because our results suggest that such gradients can exist. Previous studies demonstrated that high resolution modeling can present large positive biases (He et al. 2019). In situ recordings are still needed to determine whether the large gradients around the study area are realistic or exaggerated, even though observational networks are never perfectly fitted to evaluate model precipitation (Lundquist et al., 2019).

7.

218: These results are not shown and thus should, at a minimum, be stated as such. However, I would encourage adding these results, either as an additional figure, panel in an existing figure, or to Figure A1

This section indeed lacks data. As the brief communication are limited to only 3 figure, it will be added as supplementary figure A2:
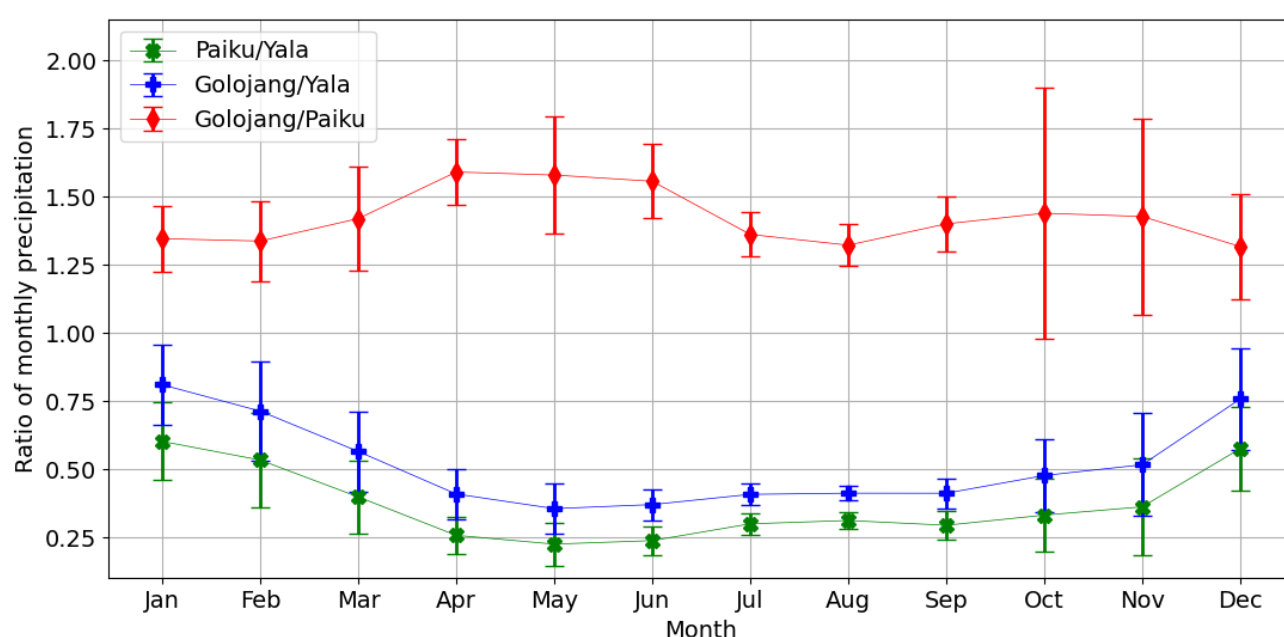
Supplementary figure A2: Comparing precipitation records using 1 to 1 ratios of mean total monthly precipitation at different locations. Mean ratio of total precipitation are calculated for each month during 1992 – 2021 in ERA5-Land dataset. The error bars represent ± 1 std of the monthly precipitation during the 30 years period.

8.

222: I suggest citing figure A1 somewhere in this sentence

222 Modify to:

  "[...] the monsoon, then increasing back progressively (fig A1)."

9.

231-232: 'However... magnitudes.': I suggest rewriting this sentence somewhat for clarity, e.g., 'It's possible smaller events were not detected because of their small signal compared to large noise in the measurements.'

231-232: modify to:
  'Smaller events may not have been detected because their signal was too weak compared to the measurement noise.'

10.

237: 'despite it is located much closer to the lake.' – please rewrite for clarity, e.g., 'Golojang is closer to Paiku AWS than to Yala AWS'

We have modified it to:
  "Golojang Co cumulative snowfall during DJFMAM (200–400 mm) is closer to Yala AWS than to Paiku Co (5–35 mm), despite its proximity to Paiku Co."

11.

1. 7: 'gradients marks' -> 'gradient marks'. As written this phrase contains a subject-verb agreement error (gradients is plural, marks is singular) – several errors of this type appear in the paper, and hereafter I simply note them without description

2. 217: 'thirty year' -> 'thirty years'

3. 218: 'precipitation... reveal' -> 'precipitation ... reveals'

4. 232: 'signals'->'signal'

We have corrected all these points. Thank you for pointing them out.

References:

Lundquist, J., Abel, M. R., Gutmann, E., & Kapnick, S. (2019). Our Skill in Modeling Mountain Rain and Snow is Bypassing the Skill of Our Observational Networks. Bulletin of the American Meteorological Society, 100(12), 2473-2490. https://doi.org/10.1175/BAMS-D-19-0001.1