Reply to Reviewer #1

The study introduces a way of implementing snow course data to get a better estimate of precipitation gradients in high elevations. Therefore the authors hypothesize the snow course data to serve as additional precipitation gauges (totalisators) and test this with runoff ratios as well as in the performance of predictions of a snow-hydrologic modelling chain. The paper is written clear and is well structured. I have only some minor comments to be clarified before I recommend publication.

We thanks Reviewer #1 for their constructive comments. We confirm that all requested revisions are feasible and we will work in this direction as soon as the interactive discussion will be finalized.

Snow course representatively: 1. Are there concave features in the snow courses that influence snow depth and as consequence the calculated lapse rates and if are these representative for the hypsography of the catchment(s) or could they introduce a bias in the estimation? If that is the case how could that be accounted for? Please add some words on this issue in the discussion.

We confirm that topographic patterns in our study region are particularly complex, including an alternation of convex-concave features. However, the spatial scale of the process we investigate here (orographic enhancement) is certainly much larger than that involved in snow deposition in concave features and snow erosion in convex features. This together with our choice of spatially averaging snow-course data above 3000 m ASL, rather than considering each data point, aimed at minimizing the impact of such local effects on our estimates of precipitation gradients. We agree that it is worth commenting on this matter in the Discussion and will do so.

2. How about wind drift effects in the snow courses? Do the courses under- or overcatch or do the authors think that wind drift is covered well with the courses used (considering also that wind drift might vary depending on the weather pattern)

We agree with the reviewer that wind drift is certainly a driver of snow distribution at high elevations in our study region. It is also well known that wind reduces SWE at high elevations through sublimation of blowing snow. Our choice of spatially averaging snow-course data above 3000 m ASL, rather than considering each data point, aimed at minimizing the impact of such local effects on our estimates of precipitation gradients (see also the previous comment regarding concave features). Also, the sampling protocol avoided known deposition or erosion areas, as far as this was possible. Both aspects increase our confidence that the large-scale precipitation gradients presented in this paper are only marginally impacted by wind-drift effects. Still, we aknowledge that this is certainly a factor to consider and we will expand the discussion to touch on this.

- ephemeral snowpack: how are these accounted for in the calculation of the elevation gradients? If the precipitation reaches the ground and infiltrates the assumption of the snowpack as totalizator does not hold anymore

Ephemeral snowpacks would indeed challenge the overarching assumption of our orographic-gradient estimation method, as this is based on peak SWE being a direct measure of total precipitation during the snow season. We were already mentioning this at lines 178ff page 6, where we discussed that such instances are relatively rare at the investigated elevations above 3000 m ASL. In this regard, we also pointed out that we defined the onset of the snow season from the first hour with at least 20 cm of snow on the ground for a reference snow-depth sensor (see the original manuscript). This aimed at capturing precipitation totals for the bulk of the accumulation season, while excluding early-season snowfall events that might result in complete or partial depletion of the snowpack. We appreciate this comment and we will be more explicit on this matter in the revised manuscript.

- glacier melt: the authors mention that the catchments are influenced by glaciers. Please add some information on how much the melt water might influence the observed streamflow

We confirm that both catchments are partially covered by glaciers, the contribution of which to total streamflow is challenging to assess due to a lack of measurements. Our models may provide a quantification of this contribution, but we preferred not to include this in the paper given that our glacier implementation in these specific valleys has never been fully validated (again, due to the lack of measurements). Based on qualitative inspection of the observed hydrographs, we expect glaciers to particularly contribute to late-summer streamflow, when input from snowmelt declines. This is in line with glacier role in other catchments across the Alps.

- application of lapse rate for summer period: The authors discuss that their use of the estimated lapse rate also in summer (full year simulation) is not optimal. I see that this is problematic particularly because of the different dominant precipitation type during summer. Can this not be disentangled in the interpretation or can this in the simulation not be changed in the first place?

We agree that this is an open issue for future work. On the one hand, one may hypothesize that orographic enhancement exists both for stratiform and convective precipitation, and especially during early fall or spring the latter may contribute to some extent to peak-SWE values as the former. However, synopctic-scale circulation and its interactions with mountains are significantly different between the winter and the summer season. While one may compare simulations with or without summer orographic enhancement to draw some preliminary conclusions on this matter, it is also true that doing so would leave several questions unanswered and potentially raise further issues. For example, is this difference really due to orographic precipitation, or is it related to how Flood-PROOFS parametrizes evapotranspiration? May snowmelt infiltration and so groundwater recharge also play a role?

In practice, we are currently developing an operational version of this algorithm, where we are considering whether this orographic-enhancement spatialization approach should be limited to winter only. In this paper, we preferred to apply it to the entire water year both for consistency and because we deemed that an exhaustive discussion of winter vs. summer precipitation patterns and their relation with orography would go well beyond the scope and brevity of one paper. Doing so may also add confusion and dilute the core message. We will improve our discussion based on the points above, including some operational outlooks.

All minor comments will be addressed in the revised manuscript. Here, we comment on those requiring further details from our side.

L27 the impact on societies is not obvious, please add a short example or a better explanation here

A very simple example in this regard is that the wet side of continental orographic barriers has historically been much more populated than the dry side, which often corresponds to deserts (e.g., the Atacama desert or to some extent the California eastern Sierra region). In Europe, this has corresponded to different timing and amount of ecosystem services such as the seasonal freshet. We will improve this passage.

L120 filtering regarding which aspects? please add

Filters include out-of-range or negative values (where applicable, for example for snow depth). That said, the main strength of this dataset is the supervised-filtering part, with one expert visually screening weather data on a periodical basis (roughly every week, although this varies) and assigning quality flags to each data point.

L125-127 please add based on what (which evaluation) that was found to be best

The evaluation involved comparing precipitation totals at snow-depth sensor locations with concurrent snow-depth increases. Precipitation totals were estimated using various parametrizations and that by Allerup et al. (1997) was found to yield the lowest error (unpublished work).

L13 "and importantly precipitation vs. observed streamflow" not clear does that belong to remedy still?

Yes, we will fix this.

L509 here you could refer to innovative measurement developments that make the snow course measurement much more easier and effective such as the study by Griessinger et al. 2018

Agreed, we will include this.

References

Allerup, P., Madsen, H., Vejen, F., 1997. A Comprehensive Model for Correcting Point Precipitation. Hydrology Research 28, 1–20. URL: `https://doi.org/10.2166/nh.1997.0001`, doi:`10.2166/nh.1997.0001`, `arXiv:https://iwaponline.com/hr/article-pdf/28/1/1/3737/1.pdf`.