

## Author responses

### Referee 1

We thank referee 1 for the valuable comments. Please find our detailed answers (in blue) below.

#### Specific comments

*(1) I would suggest to change the title to “Local bias of...” and to avoid the term “uncertainty” here and in the discussion. “Local bias” is used most in the manuscript, and is in terms of locally specific characteristics in snow accumulation at the station just a part of the overall uncertainty in local snow measurements in addition to e.g. measurement errors. A complete analysis of the uncertainty in terms of variability of the local bias might include not only the mean values, but also max/min/range/sigma of the seasonal values (see detailed comments/ L98). “Local variance” or “Local variation” might by another options more presenting the local effects of station setting as mentioned in the manuscript (e.g. soil, buildings, ...).*

[Answer]: We agree and avoided the term “uncertainty”. We changed the title to:  
Local-scale variability of seasonal mean and extreme values of in-situ snow depth and snowfall measurements

And used “local bias” or variability instead of “uncertainty in the manuscript.

*(2) The presented analysis is an update of the work published by Buchmann et al. (2021) with an increased number of station pairs for a longer time period. Nevertheless, basic methods are the same, and results do not differ fundamentally. I recommend the authors to accordingly present the new findings and differences between both studies.*

[Answer]: Buchmann et al. (2021) (<https://doi.org/10.16904/envdat.218>, 2021) is the data set for this paper. We cited the data set using the doi instead of the author (year) in order to make it less confusing. Further, we rectified the erroneous years in the references

Buchmann et al. (2021) focused on the robustness of snow climate indicators, regardless of any local influences, using station pairs with data during the same 25-year period. Our focus in this study is on local bias, introduced by different local factors. We use an extended version of the parallel data set, both in number of available stations and available years. Further, we introduce snow onset and disappearance dates, extreme value analyses, and potential sunshine durations to conduct our analyses. We kept the RPD as an error metric, to be able to compare our findings with previous results.

We slightly rephrased the introduction to clarify the differences.

Using and extending the data set of parallel time series introduced by Buchmann et al. (2021) in available number of stations, months and years, enables the investigation of the impact of the above-mentioned bias introduced by sometimes not ideal measuring locations, hereafter referred to as “local bias” or variability. Introducing snow onset and disappearance dates, as well as extreme value analyses, we strive to answer the following questions:

*(3) In the current version of the manuscript, results and discussion are presented right together. I suggest to separate both and to align the discussion linking the different results (some biases are related to the same source of error). Further, the conclusion are rather to long and can be shortened by several sentences (see specific comments) to be more condensed. The conclusion might present*

*aspects on the order of local biases, that might be negligible and what the local station bias means for the interpretation of climatologies (trends) based on single (mountain) stations.*

[Answer]: We rephrased and shortened the conclusion and added another chapter 4.6 covering metadata. We tried the suggested structure in an earlier draft but changed it to the current structure after in-house revisions as we think it is more reader friendly that way.

#### **Detailed Comments (L = line)**

*L10: Remove daily scale and change to: "Daily measurements of snow depth..."*

[Answer]: done

*L22: Here and throughout the manuscript: for me it was difficult to follow with the shortening with the brackets. At least it stopped the flow in reading. Please consider to present in two separate sentences.*

[Answer] : done

The highest percentage (90%) of station pairs with uncertainty less than 15% is observed for days with snow on the ground with 90%. The lowest percentage (30%) of station pairs with uncertainty less than 15% is observed for average snow depth.

*L47: Here and throughout the manuscript: there appears on redundant pair of brackets in the citation using e.g.*

[Answer]: We agree and removed the one pair of brackets.

*L48: Please add "half year" in front of period*

[Answer] :We changed period to six months.

*L56ff: the research questions are announced but not formulated as such. In addition methods are presented here (point 2). Please rephrase this part to list the analysed parameters or formulate the RQs*

[Answer]: We agree and rephrased said part.

*L72: remove the brackets and write: "...within a distance of 3 km horizontally and 150 m vertically..."*

[Answer] : done

*L72/73: 1 km: Please fix the space between number and unit such that it is not seperated at the line break (here and in the entire manuscript)*

[Answer]: done

*L74: 1770m: This might be a high elevation for station pairs, but it is not in context of mountain stations and snow measurements. Would be nice to see a discussion if and how the results are expected to be scaleable to higher located mountain stations.*

[Answer] : We agree, 1770 m a.s.l. is not a high elevation in absolute terms, however, it is for parallel measurements in Switzerland. Our focus here is solely on parallel measurements. The scaleability is limited by the fact that there are practically no stations between 1800 and 2500 m a.s.l. The few existing long-term measurements at high altitude in Switzerland are located around 2500 m a.s.l. So any scaleability attempts involve a lot of speculation and that is way we don't want to delve into that.

*L75/76: Shift the dates of the 77 year time period (1943 to 2020 ;*

[Answer]: We rephrased the sentence to:  
It includes one station pair with 77 years of parallel data (1943-2020) and 10 station pairs with more than 50 years of parallel data, and incorporates a total of 1338 station-years covering the time period from 1943 to 2020.

*L76) directly to this number (L75). End the sentence after "station-pairs" in L76.*

[Answer]: see previous comment

*L86: since all measurements are made in the past, please present more detail here.*

[Answer] : We rephrased the sentence.  
[..] until about two decades ago, only approximate coordinates were recorded.

*L98: since time periods are presented, the analysis of the distribution of seasonal/monthly values within the time span would be of interest, too. Please consider to give those numbers.*

[Answer] : In Table A1 and Figure A1 we show mean values of average snow depth and days with snow on the ground for each station pair as a selection of statistical properties. As there are a lot of different time series, such detailed information would in our opinion just distract from the main findings and go beyond the scope of this study. However, as we are currently working on a separate data paper focusing on the parallel data set, we think that would be a more appropriate place to go much more into detail concerning the individual time series.

*L104: To my knowledge the standard hydrological year of mid Europe is defined by 1.10. to 31.09.. Why did you use the period from 1.9. Please give at least a citation.*

[Answer] We used 1.9.-31.8. to make sure to capture entire seasons (especially important for analyses of onset and disappearance dates, as some of our stations can have snow before 1.10. We added a sentence to clarify our intentions.  
To be able to capture all onset and disappearance dates, we defined the current hydrological year as the period from 1 Sep of the previous year to 31 Aug of the current year.

*L121: Consider to use an abbreviation of “local bias” for further use in the manuscript*

[Answer] : Since our manuscript has already quite a lot of abbreviations (as pointed out by referee 3), we don't consider it wise to add any more. However, as added in the introduction, we use “local bias” and variability synonymously, hence improving the reading process by not overly repeating “local bias”..

*L138: The finding that all outliers are produced by the same station pairs should be discussed in terms, if such station-pairs are representative at all.*

[Answer]: Our aim is to analyse the local-scale variability as close to reality as possible. The station-pairs and their environment are given and we don't want to focus on ‘perfect’ pairs only. However, the parallel analysis allows to identify ‘problematic’ stations that can then be avoided in further applications. We touched upon that issue in our conclusions.

*Figure 1: The RPD for all HN parameters is between 10 and 20%. Please present this in the results. It would be interesting to see the statistics on the variability of the parameters when moving a 30-year period over the entire time series of the three station pairs with most parallel years.*

[Answer]: a) We added the information about HN in the results.

For a majority of station pairs, all HN variables are below 20%.

b) Thank you for bringing up that idea. Our RPD are mean values over the whole time series and thus do not reflect any fluctuation of the RPD with time. This is by design, as in this study we want to compare various station pairs and investigate the overall variability; and not the variability within each individual station pair. We calculated the standard deviation of RPD for the three longest station pairs for a moving 30-year window. This approach provides insight information about the variability of temporal evolution of RPD. But in order to be comparable with all the other stations in the data set (some of them way too short for this approach) we decided against using it. Moreover, as the temporal evolution of RPD is not our main focus in this study. However, this approach might be very helpful in investigating breaks in these series which is another project we are currently working on.

*L152: Replace “entire” ba “half-year”*

[Answer] : Changed to: six months

*L207: Replace “uncertainty” by “local bias”*

[Answer]: Changed to: variability

*L208: Figure A2: Please consider to put the Figure in the manuscript.*

[Answer]: Wee agree and put the figure in the manuscript. Now Figure 5 in the manuscript.

*L219: I did not get the sentence starting with “Among...”. Please rephrase.*

[Answer]: We removed that paragraph as we agree with referee 2 (Craig Smith)

*Figure 4: Here and in the text: Consider to use Dend instead of Dstop.*

[Answer]: We changed Dstop to Dend

*L238-244: This is an good example to open a separate discussion*

[Answer]: We added a separate section 4.6 to discuss the metadata and an example

*Figure 5: What does the error-bars show? Please present in the caption.*

[Answer] We improved the caption.

*L259: “Analysis....” This is a result and has not to be mentioned in the conclusions again. Please revise the conclusion section and avoid to present redundant results and discussions.*

[Answer]: We tidied the conclusion.

*L264: Which estimation uncertainty is meant here?*

[Answer]: We refer to the uncertainty of the return level value, which is based on the method of estimating the parameters of a probability distribution by maximizing a likelihood function (maximum likelihood estimation).

*L291: What is the threshold to neglect local biases? This might be an interesting discussion for the discussion sector, too.*

[Answer]: We added a discussion of that point in section 4.6. And to soften the statement, we changed neglect to small, as there is no feasible threshold.

Generally, “local-bias” is often small and negligible for many applications, at least for the large majority of the stations.