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The Cryosphere Discussions

Interactive comment on "Observed snow depth trends in the European Alps 1971 to 2019" *by* Michael Matiu et al.

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General comments: This paper provides an analysis of snow cover regional variability and trends over the European Alps based on a new in situ daily snow depth dataset developed through the collaboration of more than 20 institutions from six countries. The dataset covers the entire European Alps with more than 2000 surface snow depth observations, and represents an important contribution for research and development. The authors are to be congratulated for their efforts to develop this dataset and in particular, to make it available to the research community. The creation of a pan-Italian snow depth dataset from various agencies is a noteworthy achievement.

The paper presents the results of a PC and cluster analysis to characterize the re-

gional snow climate, along with trend analysis to document trends by climate region and elevation over almost 50 years (1971-2019). The paper is in general well-written and clearly explained, and is close to publishable quality once some issues with overly-long sentence construction are rectified. I have three main comments concerning the methodology. First (comment #6 below), I question the need for the moving window analysis for trend variability, and recommend it be removed from the paper. Second (comment #10), the PC results reflect an uneven spatial distribution of stations with oversampling of elevations below 1000 m and undersampling of elevations above 2000 m. It is unclear to what extent this distorts the analysis results compared to those obtained based on a gridded representation of the station data that evenly samples the full spatial and elevation domain. Third, the paper provides no insights into interannual variability of snow cover and its relative magnitude compared to the long-term trend. The authors may feel this is beyond the scope of the current paper, but presenting trends without discussing the interannual and multi-decadal variability is a major oversight in my opinion.

I look forward to seeing the revised paper and congratulate the authors again for their significant contribution.

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Detailed comments: 1. Lines 74-75: Suggest rewording as "The main limitation .... that their number decreases sharply with elevation, with few stations available above 3000 m in the European Alps."

2. Lines 90-126: There is a lot of useful material presented here on published snow cover trends in the various countries, but it is difficult to read with very long sentences joined with rather unwieldy constructions like "which, however". I recommend you organize this material in a summary table, and provide a few lines that capture the common elements. This would lead very nicely into the paragraph starting on line 128.

3. Lines 155-160: It would be instructive to show the main climatic divides on Figure 1.

4. Lines 204-206: consider rewording as “Many stations contain an important data gap for the 1981–1997 period that rendered a large fraction of the stations unusable for this study.”

5. Line 279: Suggest deleting the following “The predicted variable was the mean monthly HS and the only predictor the year (shifted to 0)” and replacing the previous sentence with “Linear trends in monthly mean HS were computed separately for each month from November to May for stations with complete data in the period.”

6. Line 280: “The second approach was a moving window approach that aims at identifying the short-term changes in trends.” I think it would be clearer to say “A second moving window approach was used to examine the variability in 30-year trends over the period from 1961”. I would consider removing this analysis for the following reasons: (1) the lack of a clear rationale for the analysis, (2) the inconsistency introduced by the different start period (1961 vs 1971), (3) the fact that overlapping windows are not independent, (4) the use of what is essentially an arbitrary 30-year period for the trend, and (5) the fact that the network density changes over time. I think it would be more instructive to look at the signal-to-noise properties of the 1971-2019 trend, by breaking it up into the amount of variance explained by the trend vs the amount of variance explained by interannual variability. Mapping the two quantities would highlight areas where trend was stronger relative to natural variability and vice versa.

7. Line 297: Not clear what you mean here... the homogeneity of the data used in a gridded dataset is the key issue. Several reanalyses have well documented discontinuities related to changes in data input streams.

8. Line 317: There is no season dedicated to the snow-cover onset period (Nov-Dec?), but there is one (March-May) for the spring season. Any reason for this? In my work documenting snow cover variability over Bulgaria (Brown and Petkova, 2007, Int. J. Climatol. 27, 1215–1229) and Quebec (Brown, 2010, Hydrol. Process., 24, 1929–1954) we found different trends in the fall and spring periods as well as different modes

of atmospheric variability influencing snow cover variability in each season.

9. Line 400: Can you please include the variable(s) the trend is computed for to remind the reader what the results refer to.

10. Lines 473-474: “In relative terms, the elevations of the stations used in this study oversample the elevations up to 1000 m, are similar from 1000 to 2000 m, significantly underrepresent 2000 to 3000 m, and do not cover elevations above 3000 m”. This begs the question of why you did not attempt to transform the observations to an equal area grid (e.g. by kriging, or pseudo obs from modelling) to force the spatial coverage to be representative prior to the PC analysis?

11. Conclusions: This study provided useful new insights into snow-climate regions and trends for the European Alps, but did not look at interannual variability in snow cover e.g. PC analysis of annual time series of snow cover duration and maximum accumulation. Is there a particular reason why you chose to ignore this? Documenting and understanding interannual variability is a key component of interpreting long-term changes (e.g. the signal-to-noise ratio of climate heating induced changes).

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