Weather Clim. Dynam. Discuss.,
https://doi.org/10.5194/wcd-2019-15-AC2, 2020

Interactive comment on "An attempt to explain recent trends in European snowfall extremes" *by* Davide Faranda

Davide Faranda

davide.faranda@lsce.ipsl.fr

Received and published: 13 March 2020

General comments: The article investigates extreme snow depth trends in Europe in the last 40 years and attempts to explain these trends in light of global warming and changes in atmospheric circulation. I find the topic interesting and definitively of scientific interest for WCD.

I thank the reviewer for the positive comment. In the new version of the manuscript, I will take into full account the comments raised by the reviewer to improve the presentation of the paper.

1) I'm puzzled by the data. I'm not familiar with ERA5 and E-OBS but reading the data section, it seemed to me that the author actually analyze SWE, not snow depth. It may only be a vocabulary issue.

Indeed I am using snowfall (sf) data and not snow depth. I have corrected this issue through the paper.

2) Figure 5 shows that applying a linear regression to annual maxima is not robust since it may be much influenced by 1-2 largest points. Therefore 2 subperiods are considered in Figures 6 to 9, which I support. But then wouldn't it be more consistent to consider in Figures 2-3-4 differences between the two subperiods rather than linear trends? This is not anecdotal since the regions with largest increase/decrease might partly change (e.g. ITF1). A t-test, e.g., could be applied to test differences in means.

As suggested by the reviewer, the new version of the paper will contain differences between the two sub periods (with a T-test) instead of the linear trends computation. Another important addition will be the use of the two components of snowfall: the large scale snowfall (lsf) and the convective snowfall (cf). They allow to separate the local themodyanmic component of the trends (cf) from the large scale, synoptic component (lsf). Figures 1,2,3 of this review show the results for the three components.

Note that another way to get more robust trends in annual maxima is to fit a nonstationary GEV distribution but it may be unnecessarily complicated here.

I have tried the GEV fitting but the results show a very large sensitivity to data. This means that by considering 21 or 19 years, the estimation of the parameters

largely fluctuates, whereas it is more stable when considering differences between sub-periods

3) I find the idea of comparing atmospheric fields during extreme events excellent . However I'm puzzled by several interpretations (see below) and I'm not sure that the conclusions are supported by the analysis. First I'd like to see the average Z500 fields for period 2 because I don't think one can interpret anomalies without the mean field (or at least I'm not able to). In Figure 6 the author shows that decreasing trends are mainly associated with negative anomalies over eastern Europe. I see the correlation but is this causality? In particular if one considers a neighboring region with positive trends, don't we have the same pattern (i.e. negative anomalies over EE)? Idem for the positive trends.

Thank you for the encouraging comment. In order to progress in the interpretation of the results, in the new version of the manuscript I have used both the large scale and convective snowfall components of the ERA5 dataset. The use of the two components enable to attribute the changes in the snowfalls in the two periods either to large scale flow dynamical changes (and therefore to the anomalies of Z500 fields) or to the thermodynamic changes. Figures 1-3 at the end of this review answer will be added to the new version of the paper. They show that the contribution to the negative or positive trends come mostly from large scale snowfall components. I will therefore simplify the discussion on the circulation patterns in the new version of the paper.

4) More generally, looking at the quite noisy map of Figure 4d), is there good hope to be able to explain trends from atmospheric circulation? For example in Italy I can see quite positive, null and negative trends within a few km of a quite flat region. I expect all these regions to be influenced by the same atmospheric circulation, therefore

differences in trends are either due to regional characteristics or this is merely rainfall variability (or data issues). Please consider analyzing larger regions to be able interpret smoother maps.

In the new version of the manuscript, trends will be separated by convective snowfall (local and thermodynamic) and large scale snowfall (regional and dynamical). This analysis provides a more precise assessment of the origin of the trends. The suggestion of looking at larger regions has also been attempted but discarded (NUTS0) because the regions are too large to provide a coherent picture of the large scale atmospheric circulation. Let us consider the emblematic case of Italt: the Italian peninsula is crossed by two mountains ranges (Alps and Apennines), plains. Large countries include geographical features that can indeed trigger a large variability in the snowfall in neighboring regions . Indeed, the suggestion of considering differences in the quantity for the two sub periods instead of linear trends, improve the understanding of the modifications.

Specific comments

L5: "coherent with the mean global warming and previous findings": I'm not sure to understand to which of your results you refer to here.

I will rephrase this sentence as: "coherent with previous studies: they allow to link the decrease in snowfall to mean global warming"

L6: "discrepancy between trends in average and maximum SD": to investigate this, wouldn't be interesting to look at the regions with the largest discrepancies between means and extremes? Introduction: please consider referring to Beniston et al.

2018, The European mountain cryosphere: a review of its current state, trends, and future challenges, which gives a good overview of changes in the European mountain crysophere.

Thank you for the additional reference that will be added to the new version of the paper.

L95: “large SD amounts correspond to snow to be removed“: I’m not sure about that. The weight of the snow (SWE) is much more important than the depth.

As answered in comment 1, there was a problem in naming the variable used in the first version of the manuscript. SD will be changed to “snowfall” and references to SD will be dropped.

L 100: “total amount of water”: does ER5 really give you a total amount of water? Then this would be a SWE (mm of water), not a depth. Or do you mean “total snow depth”?

Again, thanks for pointing out the problems with this variable. In the new version of the manuscript it will be changed to snowfall.

L 108: “from daily total precipitation”: Idem I don’t understand how you get snow depth from water amount.

Also here I will change the description to point out that from total daily precipitation we can get a proxy of snowfall (and not snow depth) variables.

L113: where does this 2/3” coefficient come from? Figures 2-3-4; please consider exchanging colors since later on red=decrease, blue=increase. Please consider merging Figures 2 and 3 (e.g. by crossing out the significant regions)

The coefficient $\frac{2}{3}$ is the best match between the EOBS and the ERA5 data, this will be added to the text. I will merge figure 2 and 3 as suggested. I prefer to keep red and blue in Figure 2 and 3 and exchange them in the boxplot figures for coherence.

Figure 4: are you sure these are NUTS-2 regions? It seems to me they are much larger. L 146-147 “Indeed . . . trends” : actually this was also the case in Fig 3a)

According to wikipedia, the NUTS-2 regions used in the paper are correct: https://en.wikipedia.org/wiki/Nomenclature_of_Territorial_Units_for_Statistics
The level of “department” or “province” is NUTS-3 while the level of states is NUTS-1

L 164 “due to the two outliers” : I guess these two outliers occurred at the end of the period

That is right, I will specify this in the text of the next version of the manuscript.

Figure 6: please consider showing the average field of period 2. Also the windows are much too large. Please consider showing smaller windows centered on the considered locations.

I will follow the suggestions by the reviewer in the next version of the manuscript.

L 178 “weaker cyclonic structure” : I understand that geopotential heights are higher (positive anomalies) but don’t you need the mean field to interpret it as a “weaker cyclonic structure”? L 179 “an anti-zonal of a blocked pattern”: I’m not an expert in atmospheric circulation but I don’t understand where you see that Figure 8: is the scale the same for all panels? L 182 “the surrounding . . . events”: is tis particular to CZ03? Actually I see that in all panels. L 187 “negative SD anomalies . . . viceversa”: I don’t see that (or I don’t understand) L 195 “tend to suggest a stronger meridional flux” : I don’t understand this interpretation L 196 “deeper cyclones” : I don’t understand why negative anomalies imply deeper cyclones. L 220: “we observe more anticyclonic conditions” : where do you show that? I’m not sure that this kind of conclusion can be drawn from a few events.

I will address all the comments relative to the discussion of synoptic trends in the manuscript focusing more on the differences between csf and lsf and their contribution to the total sf trends.

Technical corrections: L 63: Luthi et al: commas L 101: “higher” → larger L 120: “tend coincide” L 143: “NUTS2” is “NUTS-2” above L 153: “could hep” L 155 Altman: commas Figure 5: NUTs2. Also I guess a) is positive and b) is negative L167: “atmospheric” → meteo? L 182 “positive anomalies” → negative? L 183 “positive SD anomalies” → negative? L 193: CH5 → CH05

All the minor points will be fully addressed in the new version of the manuscript

Detailed caption of additional Figures of this review

- **Figure 1: Climatology of the components of snowfall for the NUTS2 regions. a-b) total snowfall, c-d) snowfall from large scale precipitations**

(lsf), e-f) snowfall from convective precipitation. a,c,e) average of yearly accumulated snowfall, b,d,f) average of yearly maxima .The data are expressed in units of cm.

- **Figure 2: Differences of the averages for the (1999-2018) and those for the (1979-1998) periods for the NUTS2 regions: a-b) total snowfall, c-d) snowfall from large scale precipitations (lsf), e-f) snowfall from. a,c,e) average of yearly accumulated snowfall, b,d,f) average of yearly maxima .The data are expressed in units of cm.**
- **Figure 3: Convective and large scale snowfall contributions to the differences observed in total snowfall divided by sign of the total snowfall differences: a) positive differences in the mean sf, b) negative differences in the mean sf, c) positive differences in the max sf, d) negative differences in the max sf.**

Interactive comment on Weather Clim. Dynam. Discuss., https://doi.org/10.5194/wcd-2019-15, 2019.

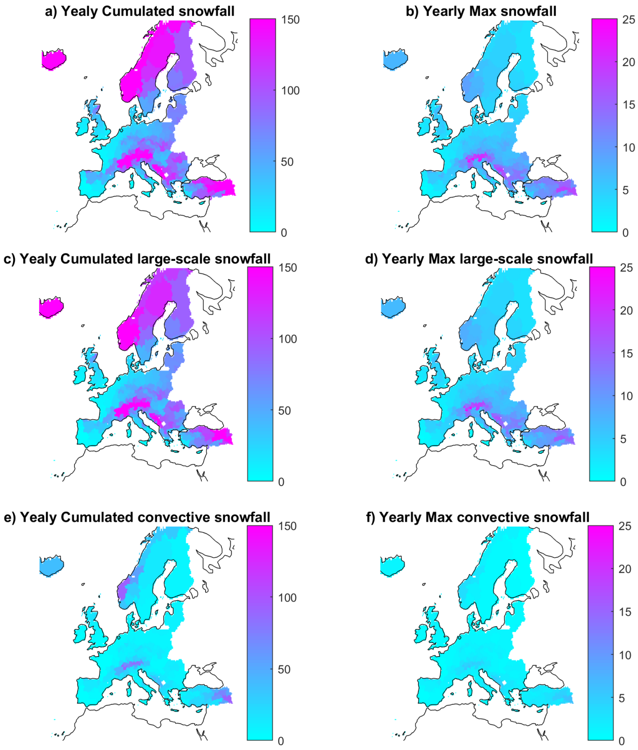

Fig. 1. Climatology of the components of snowfall for the NUTS2 regions.

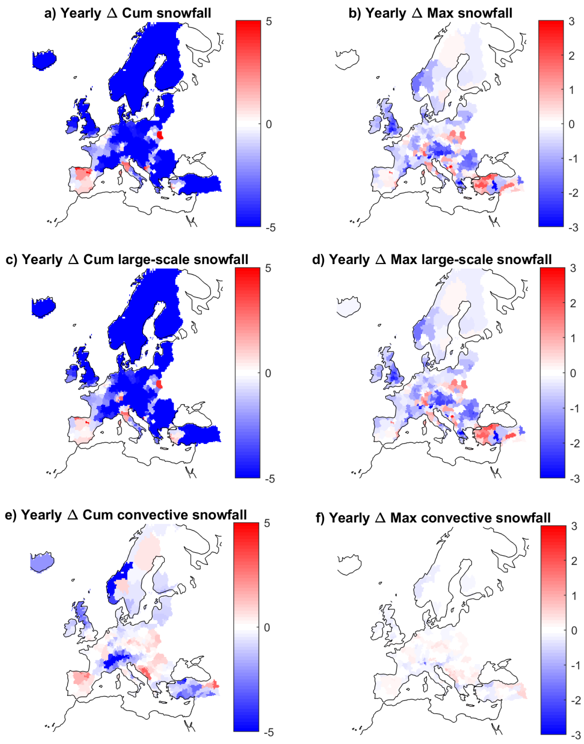

Fig. 2. Differences of the averages for the (1999-2018) and those for the (1979-1998) periods for the NUTS2 regions

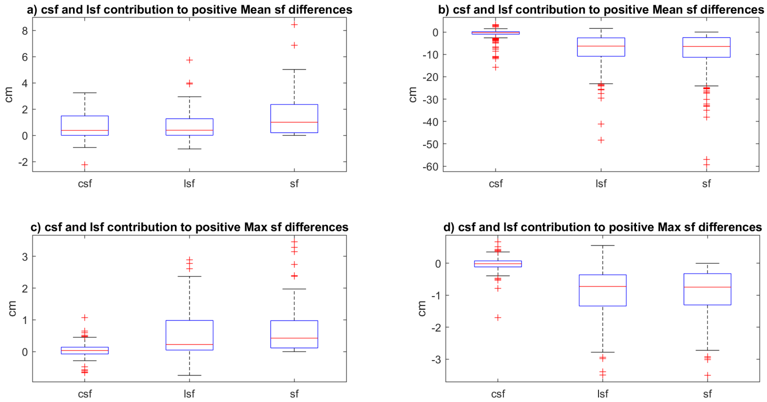

Fig. 3. Convective and large scale snowfall contributions to the differences observed in total snowfall divided by sign of the total snowfall differences