Review: Understanding the Interannual Variability of Hail in Switzerland

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1 Summary

This manuscript investigates large- and local-scale atmospheric patterns associated with hail-active years in Switzerland. The analysis is conducted separately for northern and southern Switzerland, and highlights the similarities and differences of the discussed mechanisms. The manuscript is well written and clearly structured. The methodology is robust and explained with an appropriate level of detail. The figures are informative and comprehensive, and the results are both original and noteworthy, making the study suitable for publication. I have only minor comments that should be addressed prior to publication.

2 Minor comments

1. Line 5-10: In the previous sentence the two geographic regions (north and south of the Swiss Alps) are mentioned. In line 5 it is a little unclear to which region the description refers to. I understood it as a general statement referring to both. A clarification could help the reader.
2. Line 25: The parenthesis should appear before the line break.
3. Line 36: I recommend using the phrase "...modulated by complex terrain..." here, instead of "...interactions are further complicated by complex terrain..."
4. Line 48: I think "lapse rate" should be without a hyphen here.
5. Line 56: I would recommend removing the hyphen in "British-Isles" (although it is usable here) but British Isles is a familiar proper noun.
6. Line 56: Θ_e has not yet been introduced.
7. Line 59 and 60: The citations are not in the correct order.

8. Line 62: One need a comma after "instead", additionally remove the "the" duplication.

9. Line 75: The citations are not in chronological order.

10. Line 70-75: The literature regarding the NAO and thunderstorm activity in Europe is not quite accurately portrayed here. See the 40th comment for a more detailed explanation.

11. Line 77: Additionally, Augenstein (2025) found a further intensification of thunderstorm activity during positive SST anomalies of the Mediterranean during Scandinavian Blocking patterns. Scandinavian Blocking is already associated with more frequent thunderstorm occurrence in central Europe (Mohr et al., 2019).

12. Line 83: this sentence seems a bit out of context. I would consider removing it, providing a better logical reading flow. Additionally, consider merging this paragraph with the previous. Furthermore, the sentence ,"Improving our understanding of how..." could be used as the start for a new paragraph leading to the main purpose and goal for this paper.

13. Line 85: I would recommend using a comma after "...and climate models".

14. Line 88: I guess its more about sub-seasonal forecasting, not forecasting in general?

15. Line 93-94: Although it is understandable from the context that “northern” and “southern Switzerland” refer to the northern and southern parts of the Swiss radar domain, this appears to be the first time where this terminology is explicitly introduced. On first reading, the use of different terms between the first and second research question is somewhat confusing. I would therefore recommend using a consistent naming convention for the scientific questions and explicitly stating in the data section that “northern/southern Switzerland” is used synonymously with the respective radar domains.

16. Line 96: I would recommend slightly rephrasing this research question. In its current form, it mainly invites a simple yes/no answer (“Can we identify...”), whereas the analysis actually investigates which precursor signals are associated with active hail seasons and to what extent they may be useful for seasonal forecasting. A formulation reflecting this more explicitly may therefore better represent the objectives of the study.

17. Line 109-114: This part could possibly be improved by linking the methodological choices more directly to their purpose. For example, formulations such as “...to reduce the influence of long-term thermodynamic trends, an 8-year moving window was applied...” and “...additionally, a 30-day moving window was used to reduce...” may help clarify the reasoning behind these choices.

18. Line 129: "...(Richman, 1986) and (Barnston and Livezey, 1987)." Style of citation should be "...Richman (1986) and Barnston and Livezey (1987)."

19. Line 130-134: It could be worthwhile to test similar calculations while excluding months with only weak teleconnection index values (e.g. considering only values $> |0.5|$). This would help to filter out the less pronounced large-scale configurations that are likely to have only a limited influence on hail occurrence in Switzerland and which would then be overshadowed by other factors.

20. Table 1: I would suggest slightly increasing the spacing between the rows corresponding to the northern and southern regions to improve visual separation.

21. Line 159-169: These points are very important and well developed, and they provide a strong foundation for the subsequent discussion and conclusions. Depending on the intended structure, parts of these points might also fit well within the discussion section.

22. Line 177: The abbreviation SST has already been introduced, additionally, I suggest moving "(Fig. 2)" at the end of the sentence.

23. Line 180: It is not exactly clear what is meant by "...**this** Central European ridge...". Clarify this to avoid ambiguity.

24. Line 178-180: The wording here should be more precise: We are examining pressure anomalies here and therefore cannot interpret them directly as specific synoptic (dynamic) configurations, even though, in practice, the findings discussed here indicate exactly the synoptic patterns described here (in Line 187 - 188 the authors explain this). It may be helpful to move this explanation earlier?

25. Line 196: Use dashes rather than hyphens here: "ridge-trough-ridge".

26. Figure 4 and Figure 7: In the caption, the 500-hPa geopotential height anomaly contours are described as being plotted "in steps of 30 DAM". Interpreted as 30 decameters (300 m), this would be unusually large and I am not sure whether this is consistent with the figure.

27. Line: 213: The formulation "besides ... also requires..." may underemphasize the role of large-scale forcing in shaping local instability. A more coupled wording could improve accuracy here.

28. Section 4.1.1 and Section 4.1.2: Figure references are here inconsistently placed, sometimes following the variable name (e. g. "blocking frequency anomalies (Fig. 2c)") and sometimes appearing at the end of the sentence. For consistency and readability, I recommend using a uniform style throughout the manuscript (either consistently after the variable or at the end of the sentence). This is also the case in other parts of the manuscript, but I found it particularly noticeable here.

29. Line 219-222: The contrasting signals between specific humidity and relative humidity anomalies at both levels are physically consistent with the strong positive temperature anomalies, which increase saturation vapor pressure. In this context, the decrease in relative humidity is likely a thermodynamic response to warming, even under increased atmospheric moisture content. It may be helpful to state this more explicitly to avoid possible ambiguity in interpretation. The term "saturation vapor deficit" is not commonly used; if vapor pressure deficit is intended, it would be preferable to use the standard terminology. Additionally, the term "demonstrates" is somewhat strong in this context (if not explicitly calculated), and I would suggest replacing it with a more cautious formulation such as "strongly suggests."

30. Line 250: In reference to the 27th comment, a possible alternative formulation could be "...the large-scale forcing provides the dynamical framework for favorable local conditions..."

31. Line 312: The use of repeatedly closed and reopened parentheses should be avoided. In addition, the sentence would benefit from rephrasing to improve readability.

32. Line 326: The sentence is slightly repetitive due to the repeated use of "support." I would suggest rephrasing for improved readability and flow, for example by replacing one occurrence with "favor" or "promote".

33. Line 360: The use of repeatedly closed and reopened parentheses should be avoided.

34. Line 360-361: This interpretation is reasonable, but the wording appears somewhat overly mechanistic. A slightly different formulation may therefore be preferable, for example something like: "This suggests that the processes associated with hail formation are qualitatively similar across seasons, but occur with greater magnitude during particularly hail-active years."

35. Line 415: This could benefit from citations:

    (Mantua et al., 1997) (Newman et al., 2016)

36. Line 426: I would suggest removing the first part of the sentence, as it could be somewhat misleading. I assume that by "key processes" the authors refer to the typical thermodynamic and dynamical processes associated with hail formation, which may be expressed more explicitly.

37. Line 432: The use of repeatedly closed and reopened parentheses should be avoided, maybe just use a comma to merge them.

38. Line 446: There appears to be a typo "or and" in the sentence (likely intended as "and").

39. Line 445-458: I find the discussion here, the methodological approach and conclusions solid and compelling. The section could be further strengthened by moving Figure A5 into the main text here, as it appears highly relevant to the presented arguments.

40. Line 459-470: The statement "Previous studies have linked enhanced convective storm activity in Central Europe to the negative phase of the NAO" is actually not supported by the first three cited studies. Giaiotti et al. (2003) does not report enhanced convective storm activity in Central Europe during negative NAO phases. In contrast, Piper and Kunz (2017) and Piper et al. (2019) present results that are not consistent with such a general linkage, showing reduced convective storm activity during positive NAO phases in western and central Europe despite thunderstorm-favourable atmospheric conditions, which would in fact suggest the opposite relationship. Augenstein et al. (2025) reports reduced thunderstorm activity during negative NAO phases, and this discrepancy is further discussed in Augenstein (2025, see p. 130). In fact, the authors' results appear generally consistent with Augenstein (2025) and, when interpreted correctly, also with Piper and Kunz (2017) and Piper et al. (2019). The paragraph should therefore be revised accordingly to accurately reflect the cited literature.

41. Line 481-490: This is a very interesting and well-written discussion. The link to Pacific SST anomalies and the resulting implications for seasonal predictability are plausible. The authors appropriately acknowledge the limitations regarding causality, which strengthens the argument in my opinion.

42. Line 529: Change the order of the cited literature.

43. Figure A6: To avoid confusion, the label of the colorbar could be simply written out?

44. I am somewhat unsure about the current title. As it stands, it may give the impression that the study provides a comprehensive explanation of the causes of interannual variability. While the work clearly identifies key drivers and makes a valuable contribution to understanding this variability, the title may come across as somewhat strong in its claim. In my view, more cautious formulations such as "Towards understanding…" or "Identifying the major drivers…" might be more precise and appropriate.

References

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