

Review of “A user perspective on the avalanche danger scale – Insights from North America” by Morgan et al.

The authors present a study based on more than 3000 survey responses on the perception and application of the avalanche danger scale in North America. Analyzing the data using a latent-class mixed effect mixed model (LCME) and conditional inference trees, two key findings emerge:

- Survey respondents perceive the increase in the severity of avalanche hazard with increasing danger level differently (linear increase) compared to scientific findings (exponential increase).
- However, despite this perception, there are strong (non-linear?) differences when asked how a specific forecast danger level impacts the users’ decision-making during trip planning. The use of the danger levels varies as a function of the users’ avalanche skills and back-country touring experience.

These findings, from my perspective, are robust and provide a relevant and novel insight into the users’ perception and self-stated use of the avalanche danger scale and the five levels. This user-centered perspective may provide valuable input for avalanche warning services aiming to optimize the communication of avalanche hazard to the public. The survey design is well introduced. The methods used for data analysis are, as far as I can judge, applicable and are clearly described, providing sufficient detail. The manuscript is well written.

I only have two points, which the authors may want to consider.

The manuscript is rather long. Shortening some sections might help the reader to focus on the key findings. Moreover, I personally would have liked to see a summary of the results with the responses stratified by the bulletin user typology classification scheme as shown in Table 1. I would expect that this would make the key findings more tangible for practitioners interested in the relevant outcomes of this study. I will provide more details on these two points below.

I consider the topic of the study as suitable for publication in NHESS.

General comments:

Section 3 Results

Each of the **Result sections 3.1, 3.2 and 3.4** starts with the number of responses available for the respective analysis, and introduces the number of significant classes obtained from the LCME model (e.g. 304-308, 350-359, 416-420). While this makes it very transparent, which data was excluded, I wonder whether there would be a way to present this information in a more concise way to make these sections more focused. For instance, could this information be moved to either a small table and/or a short section at the end of the Methods-Section? By doing so, the reader would still be able to find this information, if interested, but could focus more easily on the findings.

Section 3.1 Recall of danger scale levels

Consider moving some of the results to a table. This would provide an easy-to-read overview of some of the results and may also allow to shorten the text. For instance, moving the findings on I304-312 to a Table like this:

Question	Answers (proportions)
Number of levels?	5 levels (78%)
	4 levels (16%)
	3 levels (4%)
	...
Recall of signal words?	Moderate (97%)
	Considerable (93%)
	Low (92%)
	...

Section 3.3 Perception of danger scale

A large part of this section describes in detail what is shown in Figure 5. While this is certainly a very interesting way of analyzing the survey respondents' perception of the danger levels, I feel that this entire section could be shortened. Firstly, the slopes shown in the plots of the three largest classes (classes 2, 4 and 1 combined 85%) look rather similar even though statistically different. I understand that the authors also consider these variations as rather subtle (e.g., I508, I597). Secondly, these three classes combined seem equally frequent in the three nodes in the CTree analysis shown in Figure 6 (80 to 85%?), suggesting that the variables used to explain differences in how participants perceive the danger scale fail to really differentiate between class membership. My interpretation of these findings is that most respondents understand the scale as a linear one (about 60%), with some respondents having a (slight?) tendency towards a concave or a convex interpretation, and that the variables describing the respondents' skills and experience can't really explain the LCME class membership. The take-home message is that respondents perceive the danger scale primarily as a linear scale, and thus different compared to the scientific interpretation. This is a robust and relevant finding. – I propose to emphasize the key findings, maybe at the end of this section, and to consider shortening this section.

Summary of results using bulletin user typology

I feel that it could be beneficial to the reader, and particularly to those who are interested in gaining insights on the different bulletin user groups, to summarize the key results in a short section and a graph/table, potentially like the following figure:

Bulletin user typology	Recall and order of DL	Perception of DL	Use of DL in trip planning	Background variable (median, mode)	N (%)
A	x% five levels x% levels in correct order	---	---	years of experience, number of days, ...	45 (1.3%)
B	x% five levels x% levels in correct order	xx% linear x% concave	Barplot similar to subplots in Fig 5	years of experience, number of days, ...	...
C	...	...	Barplot similar to subplots in Fig 5	...	...
D	...	...	...	...	...
E	...	...	...	...	45.4%
F	...	...	...	...	...

Personally, I would have liked to see such an analysis/summary, as it would have allowed me to link the key findings more easily to different bulletin user groups. Sections 3.1, 3.3 and 3.4, and the corresponding explanations in the manuscript provide similar information, though always from the perspective of the CLME class assignment. However, I had trouble linking the class assignment to the user typology shown in Table 1, which I find a helpful and intuitive classification. Therefore, I propose to look at the data from this perspective too. Such a section may also support the statement on l673-675. Furthermore, linking bulletin user class and the most relevant background variables could provide a helpful overview describing the survey respondents (described also on l 185-199).

4.3 Practical implications for avalanche risk communication

A reduction of five to four levels is discussed thoroughly in this section. Beside the numerous arguments for and against such a change (l679-803), it might be worth taking up the point that avalanche forecasts in Europe, and thus the avalanche danger scale, not only target recreational users but are also an important source of information for decision-makers responsible for the safety of the public in residential areas or on transportation networks. For these decision-makers, but also the public at large, the two highest danger levels are particularly relevant to communicate these rare, but very dangerous situations clearly.

Furthermore, a different approach is used by the Swiss avalanche warning service. As of this winter, in the published forecasts the danger level will be shown together with a qualifier (-, =, +) indicating where within the level the avalanche hazard is expected (e.g., SLF, 2022a, SLF, 2022b; described for instance in Techel et al, 2022). This development would also go against the discussed reduction to four levels and could maybe be mentioned/discussed?

Further remarks

- L16-17: This statement is correct though one could add that this linear perception is also in line with the danger scale being an ordinal scale.
- L38, 102 (and maybe other places): I am not sure if calling the Canadian avalanche warning services *local* is the most appropriate term. I would find *regional* forecasting more suitable. For instance, the European Avalanche Warning Services provide a forecast for a *region*.
- A terminology question: do you call the *danger levels* (Figure 1) in North America also *danger rating levels* (as for instance in title of Section 3.4)? - Consider using *danger level* throughout, if appropriate.
- Section 2.1 Survey Design: The survey design is described clearly and with sufficient detail. As I am not an expert in designing surveys, I can't judge, for instance, what effect the provision of numerical sliders may have on the responses.
- L170: spend → spent
- L185 vs. 207: Maybe check whether there is a typo in one of the numbers: 3195 responses (L185) minus the 42 A-responses (l343) would result in 3153 rather than 3130 (l207).
- L285: estimate → estimated
- L322-324: is there a word missing in this sentence? After "training"?
- L325-330: In case you intend to shorten some sections, maybe the text describing the two final splits in Figure 4 could be omitted.
- Sect. 3.3 and Sect. 3.3: the classes obtained with LCME model are referred to by numbers (1-7, 1-6) using the same color scheme in Fig. 6 and 8. While the legend titles in these figures indicate that classes are different, this fact could maybe be supported by using different color schemes, and maybe by using once numbers and once letters for labeling.
- L425-437: Consider including the proportion of self-identified bulletin user types – maybe the proportion of B and C combined vs. the proportion of E and F combined – to the description of the six classes.
- L444-448: This is, of course, just a personal preference, but maybe consider moving the overall results to the beginning of this section, followed by the detailed analysis.
- L499: It might be worth repeating that the avalanche danger scale is primarily an ordinal scale (l47), with categorical descriptions of the danger levels. A large share of the respondents got the order of the levels right.
- L510-513: Maybe of interest: a recent study exploring numerous observations related to the contributing factors of avalanche hazard and the corresponding increase in the severity of the hazard with increasing danger level is Techel et al. (2022). This study also shows changes within the forecast danger levels.
- 521-523: Just an observation: At least some warning services in the European Alps present the danger scale as a scale which shows an exponential increase. Examples include the websites from the Swiss avalanche warning service (SLF, 2022a), as well as the avalanche warning service in Tyrol-South Tyrol-Trentino (avalanche.report, 2022). However, there are also European warning services where no such presentations can be found. The question you raise, would therefore indeed be an interesting one to answer: do avalanche forecasters and educators themselves perceive this non-linear increase in the severity of avalanche hazard with increasing danger level, and if they do, do they consider it important to communicate? Given the findings on the use of the danger scale, with danger levels having a considerable impact on stated

decision-making during trip planning, how important is it that users have a different perception of the danger scale?

- L525: Another reason for this linear perception is maybe also the fact that the scale is primarily an ordinal scale with categorical descriptions.
- L591-593: As suggested before, it would be nice if you could link this statement to a figure or short section emphasizing the relationship between the bulletin user typology and the results.
- L714-717: maybe worth mentioning that such terrain-based tools are already operational, as for instance the website skitouren.guru.ch, where back-country ski touring routes in the European Alps are risk-rated according to the forecast avalanche conditions and the terrain
- L764-765: Maybe add “in North America” after “bulletin products”, as this statement would not be true in Europe.
- L773-775: maybe of interest as you are mentioning how trends in forecast danger level are perceived, Terum et al. (2022) address this topic in their study

References

avalanche.report (2022): https://avalanche.report/content_files/ava_danger_en.png (last access, 26 Nov 2022)

SLF, 2022a:

https://www.slf.ch/style/respimg/f_a8_0177673001669383856_csm_Lawinengefahr_Bandbreite_EN_a55cd0022d.jpg (last access: 26 Nov 2022)

SLF, 2022b: https://www.slf.ch/en/news/2022/11/subdivision-of-danger-levels-in-the-avalanche-bulletin.html?fbclid=PAAAa1bhxJ-S2RhbPMaaBkiTXaOWKB7AFcrmDxOsc-wtq6wt_0HD9C_-fF3jc (last access: 29 Nov 2022)

Techel, F., Mayer, S., Pérez-Guillén, C., Schmudlach, G., and Winkler, K. (2022): On the correlation between a sub-level qualifier refining the danger level with observations and models relating to the contributing factors of avalanche danger, *Nat. Hazards Earth Syst. Sci.*, 22, 1911–1930, <https://doi.org/10.5194/nhess-22-1911-2022>.

Terum, J. A., Mannberg, A., & Hovem, F. K. (2022). Trend effects on perceived avalanche hazard. *Risk Analysis*, 00, 1–25. <https://doi.org/10.1111/risa.14003>

Walcher, M. (2022): personal communication