

## INTRODUCING SUBLEVELS IN THE SWISS AVALANCHE FORECAST

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**ABSTRACT:** In public avalanche forecasts, avalanche danger is commonly summarized using one of five ordinal danger levels. This strong simplification of a complex phenomenon inevitably leads to a loss of information. To compensate for this information loss and to ease interpretation of the forecast, the Swiss avalanche warning service introduced sublevels, that indicate whether the forecast danger is in the lower (-), middle (=) or higher (+) range of the danger level. After a 6-year test period, during which it showed that forecasters can reliably assign sublevels to a danger level, the sublevels were published for the first time in the public avalanche forecast in the winter season of 2022/2023. To evaluate the general understanding and the usefulness of the sublevels, and to understand how they influence people's backcountry behavior, we performed a user survey towards the end of the season. The survey with 3403 participants showed that participants perceived the sublevels as generally useful (85%) and that they understood them in the intended manner (94%). Sublevels also had a positive influence on the planning of backcountry tours. Faced with a forecast sublevel (+), almost half of the participants claimed they would change their plans to a less exposed tour than they had before when the same danger level was given but without sublevel information. This self-stated influence of the sublevels on the choice of a backcountry tour was especially important for participants with little or no avalanche training, showing that sublevels seem most useful for less experienced forecast users, who may find it difficult to extract similar information from the forecast text description.

**KEYWORDS:** avalanche forecast, sublevels, warning, communication, user survey

### 1. INTRODUCTION

In Switzerland, as in most countries where avalanche forecasts (hereafter also referred to as bulletins) are provided to the public, avalanche danger is summarized and communicated using an ordinal scale of five danger levels (in Europe according to the European Avalanche Danger Scale (EAWS, 2023a)). This simplification of a complex, multi-dimensional natural phenomenon into a small number of discrete classes inevitably leads to a loss of information (Murphy, 1993). Moreover, in many countries in Europe, the forecast danger level (DL) is either 2 (moderate) or 3 (considerable) on about 75% of the forecasting days (Techel et al., 2018). This poor discrimination of the most relevant piece of information summarizing the severity of avalanche conditions may be one reason why users of the Swiss avalanche forecast expressed the wish that DL 3 (considerable) be further subdivided into two danger levels to better differentiate between situations at opposite ends (situations A and B in Figure 1) of the broad DL 3 (considerable) (Swiss bulletin user survey conducted in 2014, (Techel et al., 2015)). The Swiss forecast provides additional information describing the severity of avalanche conditions in more detail in the danger description of the forecast. However, as the information

in the forecast is organized according to the information pyramid (EAWS, 2023b), users access the danger description much later than the danger level itself. As a result, this information may not be read and or not be understood, particularly by novice users.

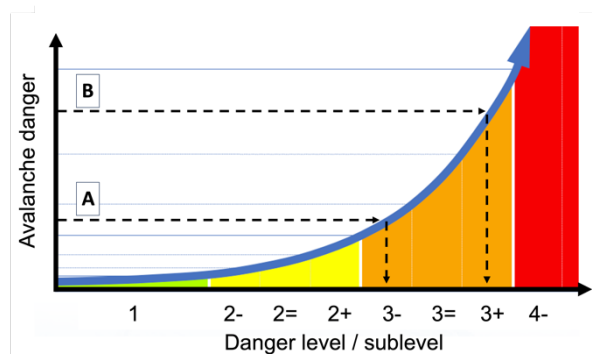


Figure 1: Correspondence between avalanche danger (continuous) and the danger levels (colors, ordinal) and sublevels (i.e., 2+). Within a danger level, the difference in avalanche danger can be large, as, for instance, between situation A (sublevel 3-) and B (sublevel 3+).

At first sight, the information loss at the uppermost level of communicating avalanche danger could indeed be tackled by increasing the number of danger levels. However, upon closer examination, there are compelling reasons to refrain from introducing more danger levels. First, this would be in contradiction to the European Avalanche Danger Scale (EAWS, 2023a). Second, additional danger levels require

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clear definitions, which are presumably hard or even impossible to describe, given the general lack of objective data and the qualitative nature of the danger levels. Finally, it is well established that absolute judgements on scales with many classes become more unreliable (Miller, 1956). Hence, the Swiss avalanche warning service deemed that increasing the number of danger levels by following the user's wish and dividing DL 3 (considerable) into two levels was a non-viable option. However, as an alternative way to increase the information provided with the danger levels, a two-step approach combining absolute and comparative judgements (Kahneman et al., 2021) was explored, resulting in the assignment of a sublevel (SL) to each danger level (DL) (described in Section 2). Following a six-year test phase, the sublevels were published in the Swiss avalanche bulletin since the forecasting season 2022/2023.

The introduction of the sublevels, of course, raises the questions whether forecasters can assess these sublevels consistently and accurately, and whether the sublevels are understood by users in the intended way and if they are useful in practice. In the following, we first summarize the research regarding the assessment of the sublevels by the forecasters (Section 2). We then present the results of a user survey we conducted, in which we addressed the understanding and usefulness of the published sublevels, and their impact on user behavior (Section 3ff).

## 2. SUBLEVELS IN THE SWISS AVALANCHE FORECAST: CONCEPT AND VALIDATION

As an alternative to an expansion of the danger scale, the Swiss avalanche forecasting service decided to introduce a method allowing a finer-grained danger assessment by combining absolute and relative judgements. Such an approach is shown to allow finer assessments within a coarser scale (e.g., (Kahneman et al., 2021; Goffin and Olson, 2011)). To this end, forecasters first determine the danger level (absolute judgement), then they make a relative rating of the danger by specifying whether the danger is at the lower (-), middle (=) or upper (+) end of the previously assigned danger level (DL). To test this approach, a sublevel (SL) was assigned to the DL in the forecast since the forecasting season 2016/2017, but this information was not published in the bulletin. In the following, we refer to the danger levels using the integer-signal word combination (i.e., 2 (moderate)) and to the sublevels using the integer value and sublevel classifier (i.e., 2+).

The introduction of the sublevels raised the important question whether forecasters were able to consistently assign sublevels and whether these had a correlation with observations related to the factors determining avalanche danger. Thus, prior to considering whether such information could eventually be communicated to the public, and following Murphy (1993), we analyzed consistency and accuracy of the

assigned sublevels in a first step, and in a second step we explored whether the supplementary information provides added value to the user as part of the user survey.

*Consistency*, in our case, means that forecasters come up with the same SL given the same data. Therefore, we analyzed the forecast drafts of the two or three forecasters on forecast duty. In Switzerland, each forecaster has the task to prepare a complete draft of the forecast for the following day, prior to the afternoon forecaster briefing. These drafts are prepared independently. Based on more than 45'000 comparisons and using the pairwise agreement rate between any two forecasters as a measure of consistency, forecasters agreed 59% of the time on the same SL, with a further 33% having one SL difference, highlighting the comparably high agreement when assessing sublevels (unpublished data).

*Accuracy* of a SL (or DL) is obviously impossible to measure and can be estimated at best. Nonetheless, it is necessary to obtain some idea regarding the correlation with actual conditions. Therefore, we used two different approaches to explore "accuracy". In the first study, Techel et al. (2020) compared the forecast danger level ( $DL_{fx}$ ) and the unpublished SL with the danger level assessments made after a day in the field by observers ( $DL_{obs}$ ). The results showed that, in case of differences between  $DL_{fx}$  and  $DL_{obs}$ , most of the time the SL closest to  $DL_{obs}$  was forecast, indicating that the "error" in the forecast was often less than a "full" DL. In the second study, Techel et al. (2022) explored the correlation between the sublevels on one hand and observations and models relating to the factors determining avalanche danger (snowpack stability, the frequency of snowpack stability, and avalanche size) on the other hand. The authors observed that, on average, the forecast sublevels correlated with the expected increase in the number of locations with poor snowpack stability and reflected the increase in avalanche size with increasing forecast danger level and sublevel.

However, during the trial period, forecasters quickly realized that they were not able to reliably attribute sublevels when forecasting wet-snow avalanche conditions and for danger level 1 (low). Therefore, they limited the use of sublevels to the danger levels 2 (moderate) through 5 (very high) for dry-snow avalanche conditions.

These studies showed that a reliable assessment of sublevels is possible in the Swiss forecasting context. With these encouraging findings and 6 years of practical experience of assessing sublevels, the Swiss avalanche warning service decided to communicate the sublevels in the avalanche bulletin with the beginning of the forecasting season 2022/2023. To integrate the sublevels in the bulletin, while maintaining the concept of the information pyramid, the information was presented as follows: when opening

the bulletin, the user is first presented with an overview of the different regions and their respective danger level (Figure 2a). Once they select a region, more details including the SL are shown (Figure 2b).

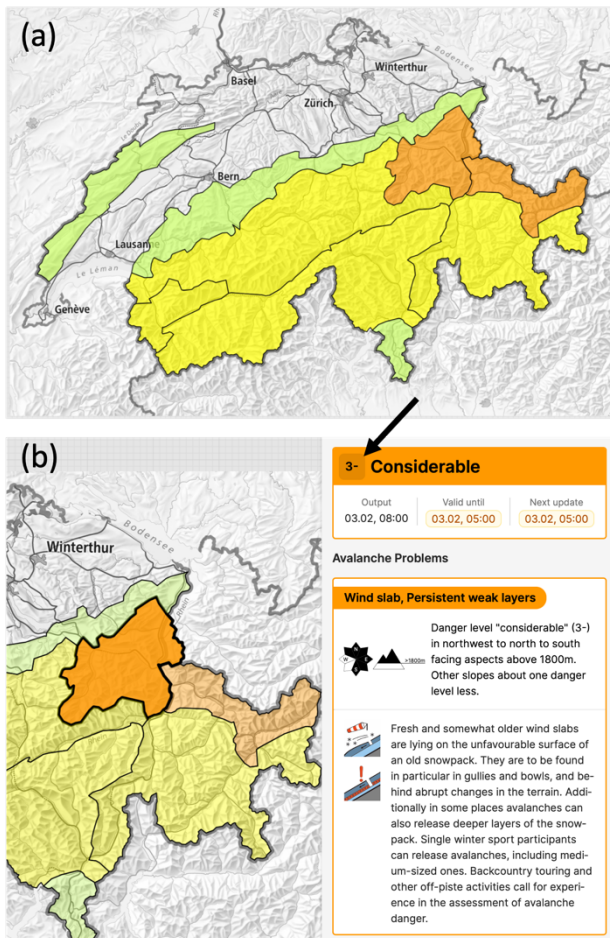


Figure 2: Swiss avalanche forecast on the SLF-App WhiteRisk (a) Overview of the different regions (b) Detailed information for a selected region, including the SL, indicated with black arrow.

While we could show that forecasters were able to reliably assess sublevels, we still had to analyze whether users understand this additional information, whether the sublevels are useful, and if or how they impact the users' decision-making. To this end, we conducted a user survey, which we address in detail in the following sections.

### 3. USER SURVEY – SETUP

We performed a user survey in March 2023. We aimed at obtaining feedback regarding whether users understand the meaning of the sublevels (Section 4.2), whether they find them useful (Section 4.2), and whether the sublevels impact the behavior in the backcountry (Section 4.3). In addition, we asked participants to indicate their avalanche training level, age, gender, and main winter outdoor activity.

The survey was conducted online and was accessible for a time span of about 2 weeks. Beside advertising the survey in the avalanche bulletin, we tried to reach different user groups, from novice to professional users through extensive distribution via our social media channels, and by distributing it through websites relevant to backcountry skiers and snowshoe hikers. The survey was available in the Swiss national languages German, French and Italian and also in English.

## 4. RESULTS

### 4.1 Participants

3403 people participated in the online survey. Most participants were between 25 and 64 years old (Figure 3). 83% of participants identified as male, 15% as female. 2% did not identify with either gender or preferred not to say.

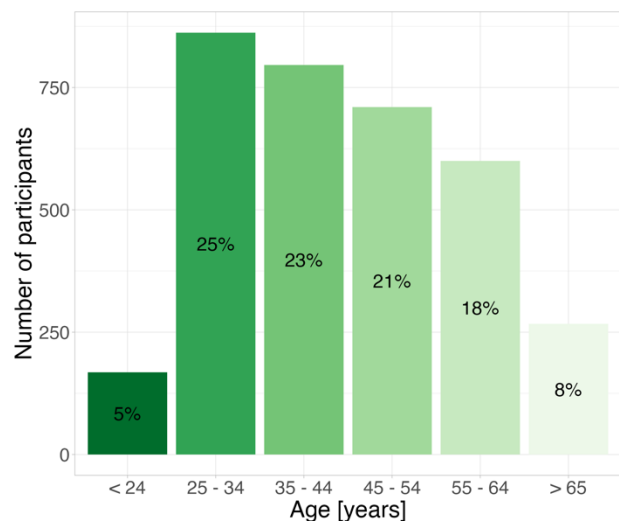


Figure 3: Distribution of age of the survey participants

Figure 4 shows the avalanche training of the participants. About 18% of participants were experts in the avalanche domain (groups mountain guides and ski patrollers), 25% had good avalanche training (groups tour guides and ski instructors). A bit more than half (54%) had no or little formal avalanche training (groups avalanche course and no education). A detailed breakdown of the groups is given in the Caption of Figure 4.

Participants were mostly backcountry skiers and freeriders while snowshoe hikers only constituted a small share (2.5%).

84% of the participants disclosed that most of their backcountry activities occurred in Switzerland or Liechtenstein, both of which fall within the area covered by the Swiss bulletin. Consequently, it can be assumed that most of the survey participants were familiar with the Swiss avalanche forecast.

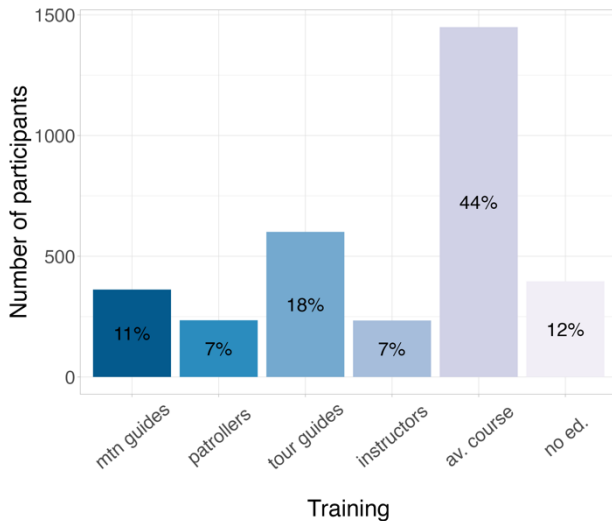


Figure 4: Highest level of avalanche training. mtn guides: mountain guides and aspiring mountain guides; patrollers: ski patrollers, people working in avalanche services, mountain rescuers; tour guides: alpine club winter tour guides; instructors: professional ski/snowboard instructors; av. course: people who have taken at least a 1-day avalanche course; no ed.: people with no formal avalanche training.

#### 4.2 Understanding and usefulness of the sublevels

The first goal of the survey was to assess the comprehensibility of the sublevels. To this end, two survey questions (Q) were specifically designed to evaluate whether the sublevels are being understood in the manner intended by the forecasters.

Q: Which of the three sublevels (2-, 2=, 2+) describes the highest danger? (Correct answer: 2+)

Q: What is the meaning of 3- ?

- The danger is practically 4 (high).
- The danger is towards the top end of 3 (considerable).
- The danger is somewhere within 3 (considerable) and will decrease to 2 (moderate) tomorrow.
- The danger is towards the bottom end of 3 (considerable). (correct answer)
- The danger is practically 2 (moderate).

94% of the participants provided accurate answers to both questions.

A third, more subtle, comprehension question was designed to identify the participants who had an in-depth understanding of the sublevels.

Q: Is there a difference between 2 (moderate) and 2= ?

- No, both notations mean the same.

- The question cannot be answered because the sublevel is not indicated.
- Yes, 2 (moderate) is more dangerous than 2= .
- Yes, 2 (moderate) is less dangerous than 2= .
- Yes, 2 (moderate) describes a danger somewhere within the danger level 2 (moderate) and 2= a danger more or less in the middle of danger level 2 (moderate). (correct answer)

People who replied correctly to all 3 questions were categorized as having a very good understanding (57%), those who replied correctly to the first two, basic comprehension question as having a good understanding (37%). We considered those who only replied correctly to one or none of the three questions as having a poor or very poor understanding (6% and 1%, respectively, Figure 5a). The level of understanding did not differ significantly between participants with higher or lower levels of avalanche training. In the two groups with the highest avalanche training (mountain guides and ski patrollers), the proportion of participants with good or very good understanding was 92%, as opposed to 94% for the groups with the least training (av. course and no ed.,  $p > 0.05$ , proportion test).

A second aim of the survey was to obtain an idea about the perceived utility of sublevels. A significant majority of the participants (85%) regarded sublevels as useful or partly useful, while only about 15% expressed a negative opinion about the sublevels, Figure 5b). The proportion of participants regarding sublevels as either *dangerous* or as *confusing* was significantly higher for groups with higher avalanche education (14%, mountain guides and ski patrollers) compared to those with little avalanche training (8%, groups av. course and no ed.,  $p < 0.001$ , proportion test).

Further analysis showed a noteworthy correlation: as the level of understanding regarding the sublevels decreases (from left to right in Figure 5c), the share of people who perceive them as either *dangerous*, *useless*, or *confusing* (yellow to red colors) increases. In other words, participants who have difficulty comprehending the sublevels are more likely to perceive them as potentially dangerous or confusing.

#### 4.3 Influence of sublevels on self-stated backcountry behavior

In the previous section we established that users generally have a good understanding of the sublevel concept and that they mostly find sublevels useful. However, a relevant question remains: How do the sublevels impact people's behavior in the backcountry? To shed light on this, we presented participants with two additional questions:



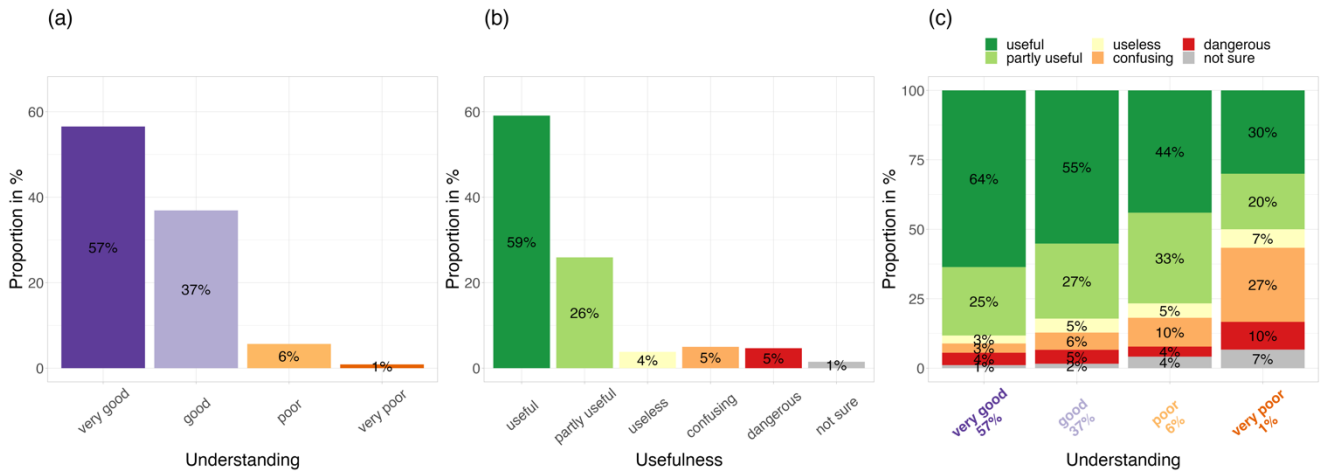


Figure 5: Understanding and perceived usefulness of the sublevels. (a) Understanding of the sublevels: very good to very poor understanding for 3 to 0 correct answers to the comprehension questions. (b) perceived usefulness of the sublevels, and (c) perceived usefulness of the sublevels as a function of the understanding of sublevels from (a). In (c), each category describing the understanding (very good, good, poor, and very poor) is normalized to 100%. The proportion of the respective groups is shown in the label of the x-axis.

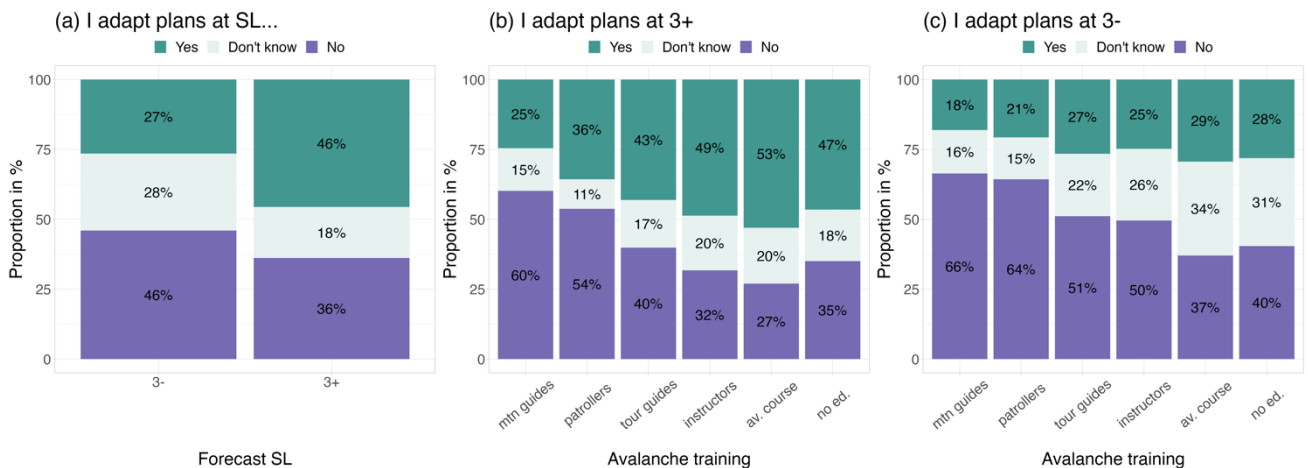


Figure 6: How do the sublevels influence the users (self-stated) backcountry behavior? (a) Percentage of users adapting their plans at forecast sublevels 3- (left) or 3+ (right) compared to a forecast danger level 3 (considerable) without sublevel information. (b) Percentage of users adapting their plans at 3+ in function of avalanche training. (c) Percentage of users adapting their plans at 3- in function of avalanche training.

Q: Are there backcountry tours that you would formerly not have undertaken if danger level 3 (considerable) was forecast, but now, in light of a forecast of 3-, you would undertake?

Q: Are there backcountry tours that you would formerly have undertaken if danger level 3 (considerable) was forecast, but now, in light of a forecast of 3+, you would not undertake?

Figure 6a shows that about a quarter to half of the participants claimed they would adjust their route planning when knowing the SL rather than just the DL. Furthermore, more people (46%) indicated to adapt their plans towards a more defensive route when faced with a 3+ as opposed to 27% that tended to a more offensive route when 3- is forecast in comparison to a forecast 3 (considerable) without additional sublevel information.

These findings suggest that, first, the tendency to adopt a more cautious route in response to a higher SL and the comparatively lower inclination to adopt a more offensive route in response to a lower SL may lead to an overall reduction of the risk in the backcountry. Second, a substantial proportion of participants affirmed that they would adjust their plans based on the SL information. This suggests that they can derive valuable supplementary information from the sublevels which reinforces the findings from section 4.2.

Figure 6b, c show the percentage of participants that would adapt their plans when knowing the SL in function of their avalanche training. Individuals with lower levels of avalanche training are more likely to adjust their plans based on the sublevel information. We suspect that expert users were able to extract this in-

formation from the danger description before the introduction of the sublevels and are therefore less likely to obtain crucial new information from the sublevels. For less-experienced users, however, sublevels seem to provide important new information. This trend is more pronounced for 3+ than 3- and slightly reverts for people with no formal avalanche training.

## 5. DISCUSSION

### 5.1 *Benefits of the sublevels*

From the perspective of the information provided to forecast users in the avalanche bulletin, the publication of the sublevels was certainly the most significant change in the Swiss avalanche forecast since introducing the avalanche problems in 2013 (Winkler and Techel, 2014). Therefore, it was important to ensure that this additional information is reliable, as well as comprehensible, useful and has a positive impact on people's behavior in the backcountry. With our survey we showed that people generally understand the sublevels in the intended way and that they perceive them as useful for decision-making at the planning stage of a tour. Furthermore, it seems, that especially for less-experienced users sublevels can help to adapt backcountry plans to the forecast avalanche situation. For users who carefully read the danger description, the sublevels can support the interpretation of the danger description. In general, we believe that particularly less-experienced users benefit from the sublevels.

Sublevels can easily be applied to tour planning tools, such as the graphical reduction method (GRM) (Harvey et al., 2018) or as provided on the Skitouren-guru website (Skitouren-guru GmbH, 2023). The GRM, for instance, provides a simple risk check that can be used as a tool to support trip planning. By making use of the sublevels, the risk assessment can be refined in the GRM: depending on the forecast SL, the user can enter the diagram on the left (when SL (-)) or right side (when SL (+)) of the column representing the forecast DL to obtain an indication of the risk (color-code) given a slope angle. For example, for a given slope angle of 35°, the risk increases from *slight risk* (at SL 2-, green color) to *elevated risk* (at SL 2+, orange color) in the GRM (Figure 7). This is in line with the findings presented by Techel et al. (2022) who showed that different observations related to the frequency of triggering locations and risk, calculated as the ratio of accident points to movement points, increased with increasing forecast sublevel. Risk, as defined there, was generally low at 2 (moderate), but increased by a factor 5 from 2- to 2+.

Skitouren-guru has already been calculating the risk of backcountry tours using the additional information

of the sublevel for several years (pers. comm., Günther Schmulach, Skitouren-guru GmbH), therewith refining their risk computations.

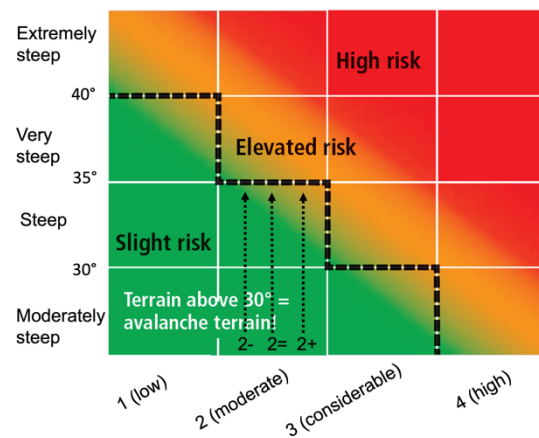


Figure 7: Application of the new sublevels in the graphical reduction method (GRM). Figure modified from (Harvey et al., 2018)

### 5.2 *Risks*

Benefits rarely come without risks and the same is true for sublevels.

The sublevels help users to locate the avalanche situation within a DL without having to read the danger level description. This could have the effect that less people read the danger description. However, we want to emphasize that the SL cannot replace the danger level description, where forecasters not only provide information on the severity of the situation but for example also describe the temporal evolution of danger or indicate the most dangerous locations and give travel advice. We assume that people who regularly read the description before the introduction of the sublevels, will keep on doing so to profit from the additional information provided there. On the other hand, people who did not and will not read the description, or had trouble understanding it, in the future at least get some additional information to help with their planning.

Our survey had a free-text field for participants to comment on the sublevels. Beside numerous positive comments, one of the most frequent comments was that people might take the sublevel (-) lightly and treat the situation as though the danger was one level lower, i.e. that 3- would be treated like a 2 (moderate). However, in our survey we found no indication for such an interpretation. In fact, the opposite was the case: only about a quarter of the participants stated they would undertake a backcountry tour at a 3- that they would previously not have done at a danger level 3 (considerable) without sublevel information. It is further noteworthy that participants mostly assumed others may react in this way, but

only rarely stated that they themselves were prone to fall into this trap.

Another recurring comment was that because the sublevels are more detailed than the danger level alone, people might be less inclined to question the accuracy of the forecast. Whether this assumption is warranted or not, we do not know.

### 5.3 *Limitations*

The user survey was conducted in March 2023, only about three months after the introduction of the sublevels in December 2022. During this period avalanche conditions were often rather favorable with comparably mediocre skiing conditions due to historically low snow depths. Therefore, respondents may have had only little experience with the new sublevels at the time of the survey. We do not know how much influence this has on the replies users gave in the survey. However, the survey results show that even after only three months, participants had a solid understanding of the sublevels. Additionally, the majority of the participants found the sublevels at least partly useful and indicated that the sublevels had an impact on their (self-stated) backcountry behavior. Hence, even if people had only limited experience with the new sublevel concept at the time of the survey, the results indicate a positive effect.

Despite reaching many forecast users, certain user groups are presumably underrepresented. In this case, especially women and people under age 24, as well as snowshoe hikers are underrepresented, which is similar to other studies (e.g. Morgan et al., 2023, Terum et al., 2023). We are confident that the results of this study are still robust for different user groups.

In the survey, we tried to elicit the influence of the sublevels on people's behavior in the backcountry. However, we could only investigate the self-stated influence. Determining the true effect on people's decisions in the backcountry is a difficult task that goes beyond the scope of this study and requires further research.

The choice of the symbols -, =, and + for the sublevels has been subject to some controversy. They were chosen because they are mostly intuitive and analogous to the difficulty ratings in many outdoor sports. So far, we have not had any indications, that the sublevel symbols lead to confusion, neither in Switzerland, nor for users from abroad.

## 6. CONCLUSION

The positive feedback and the results from the survey show that sublevels seem to be generally well understood, that they are considered useful for tour planning, and that they potentially also have a positive impact on people's backcountry behavior. Thus,

we are convinced that the sublevels add value to our product and can support forecast users to correctly understand the avalanche forecast.

Assigning sublevels using a two-step approach has been intuitive for the forecasters in the Swiss avalanche warning service from day one of the test phase and did not require a training period, as they simply passed on information that they already possessed in a new manner. On a general note, we still recommend that other avalanche forecasting services who consider introducing sublevels in their forecast should test this new information, like any new parameter added to the forecast, regarding consistency and accuracy, as information provided to users must be reliable to be credible.

Even after the long test phase in the Swiss avalanche warning service and several studies on the topic, officially introducing the sublevels for the public was a big live experiment. After one winter, we believe that the experiment was a success, and we are planning to continue publishing the sublevels next winter. We hope that other warning services will consider introducing the sublevels in their forecast as well.

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