

HOW BACKCOUNTRY SKIERS TRANSLATE AVALANCHE BULLETINS INTO DECISIONS: A SEASON – LONG STUDY IN THE SONDRIO PROVINCE (ITALY), WINTER 2024/25

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ABSTRACT: Public avalanche forecasts are published daily by avalanche warning services to communicate avalanche hazard to the public for a particular area. They typically include the danger level, the prominent avalanche problems, and an overview of current snowpack conditions. Despite the extensive research on avalanche forecasting, one area that has not received attention so far is how individuals' behavior and perception of avalanche hazard evolve over the course of an entire winter season. In this pilot study, we present the results of daily surveys conducted in the Sondrio province (Italy) throughout the 2024/25 winter season with approximately 40 backcountry skiers of different experience levels: mountain guides and/or members of the mountain rescue, expert skiers, and occasional recreationists. Each evening, after reading the public avalanche forecast for the following day, participants completed a questionnaire on their intended skiing plans and their opinion on the overall ski conditions. This repeated design allowed us to capture how public avalanche forecast information was processed and translated into planned travel behavior under real-world conditions. In particular, it allowed us to identify differences across experience levels and to examine how intended behavior changed as environmental conditions varied. In addition, we conducted a complementary one-time survey across Italy to collect broader information on backcountry skiers, which we used to place the seasonal analysis in a wider context and to examine how these stated preferences translate into actual day-to-day decision-making. By spanning an entire winter season rather than focusing only on isolated events or individuals' knowledge, this work complements existing literature and offers a wider perspective on how public avalanche forecasts are used in practice. The results contribute to a better understanding of the link between traditional avalanche communication and backcountry decision-making, with potential implications for the design of more effective and user-oriented public avalanche forecasts.

KEYWORDS: avalanche safety; hazard communication; winter backcountry recreation; avalanche danger; avalanche bulletin

1. INTRODUCTION

Backcountry skiing has always been extensively practiced in the Alps, even if avalanches pose a serious threat, causing approximately 100 fatalities per year in Europe (EAWS 2026). To inform the public, avalanche warning services publish daily public avalanche forecasts (also called bulletins), which typically include the danger level, the prominent avalanche problems, and an overview of current snowpack conditions (EAWS 2026). In the last years, growing research focused on the human factors related to avalanche accidents and, more in general, backcountry decision-making (Hetland et al. 2025). For example, relevant studies were dedicated to danger scale perception (Morgan

et al. 2023), group decision-making (Zweifel and Haegeli 2014), users' awareness and response to uncertainty in bulletins (Latosuo et al. 2024), and trend effects in perceived avalanche hazard (Terum et al. 2017).

Despite this extensive research, little attention has so far been devoted to understanding how individuals' perception of avalanche hazard and intended ski plans evolve throughout an entire winter season. For example, how the maximum skiable slope angle and the choice of skiable terrain change in response to variations in overall snow conditions. The goal of this pilot study is to provide first insights into these aspects. By covering a full winter season rather than focusing only on isolated events or on individuals' knowledge, this work complements the existing literature and offers a broader perspective on how public avalanche forecasts are used in practice. Moreover, this study investigates the agreement between public avalanche

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forecasts and skiers' personal perception of snow conditions, since discrepancies between the two may lead users to rely primarily on their own experience and judgment (Hallandvik et al. 2017).

Specifically, we designed a two-stage study combining complementary data sources. We first conducted a nationwide one-time survey to characterize how Italian backcountry skiers use public avalanche and weather forecasts, and which forecast components they consider most relevant. These results were then used both to provide a broader context for interpreting the findings and to design daily surveys conducted in the Sondrio province during the 2024/25 winter season. These repeated daily surveys capture how intended terrain choices, avalanche problem perception, and overall assessments of skiing conditions evolve in response to changing avalanche and weather conditions throughout an entire season.

2. ONE-TIME SURVEY

The one-time survey was conducted to determine the proportion of Italian backcountry skiers who consult public avalanche forecasts and the influence of each weather factor: cloud cover, wind, and temperature (see Fig. 1 for more details). Moreover, we investigated how these preferences vary across three categories of backcountry skiers: occasional recreationists; expert skiers; mountain guides and/or members of the mountain rescue. This survey was distributed throughout Italy between December 2024 and January 2025, and its results, presented in Sect. 4.1, were used to design the daily surveys. In total, we collected 541 responses: 250 from occasional recreationists; 206 from expert skiers; 85 from mountain guides and/or members of the mountain rescue.

3. DAILY SURVEYS

3.1. *Study area, avalanche bulletins, and cloud cover*

The study area includes the Alps of the Italian region of Lombardy (province of Sondrio), whose highest glacier is Piz Bernina (4048 m a.s.l.). The numerous ski areas and backcountry ski itineraries make it a primary destination for backcountry ski enthusiasts. The winter season 2024/25 was characterized by late relevant snowfalls, therefore this study was conducted between January 26th and May 1st.

Public avalanche forecasts for the study area are published by ARPA Lombardia (2026) and were more or less homogeneous over the area

during the period of our study. They consisted of the avalanche danger level, the main typical avalanche problem (TAP), and a general description of the snowpack conditions (EAWS 2026).

According to the results of the one-time survey, cloud cover is the most influential weather factor for backcountry skiers. We chose 75 % as threshold to distinguish between good and bad cloud conditions, which were more or less homogeneous over the study area, allowing us to consider a unique description for each day (we downloaded ECMWF data from Open-Meteo (2026)). Wind and temperature are also important environmental factors, however we will see that they are considered less influential by backcountry skiers. Moreover, they are partially and implicitly taken into account in our analysis through the avalanche problems.

3.2. *Surveys structure and analysis strategy*

Building on the findings of the one-time survey, we conducted daily surveys, asking participants the questions reported in Table 1. The surveys were distributed each evening, after the public avalanche forecast for the following day had been published, and participants were instructed to respond with reference to the following day. In their answers, they were asked to consider only environmental conditions, including the (forecasted) weather.

The participant group consisted of approximately 40 backcountry skiers. In total, we collected 719 responses, corresponding to an average of 7.5 per day: 195 from occasional recreationists; 259 from expert skiers; 265 from mountain guides and/or members of the mountain rescue. In cases where environmental conditions remained unchanged over consecutive days, many participants completed the survey only once. To address this issue and improve the robustness of the analysis, we grouped the responses of consecutive days sharing the same danger level, TAP, and cloud cover classification (recall Sect. 3.1).

4. RESULTS

4.1. *One-time survey*

Figure 1 reports the results of the one-time survey. The vast majority of backcountry skiers (> 90 %), regardless of their experience level, consult public avalanche forecasts. This percentage is slightly larger for occasional recreationists, however approximately 10 % of them only read the danger level. The influence of the danger level on backcountry skiers turns out to be very relevant, even

Table 1: Structure of the daily surveys.

Question	Response options
1. What is your experience level?	a. Occasional recreationist b. Expert skier c. Mountain guide and/or member of the mountain rescue
2. On which terrains would you ski tomorrow? (more than one answer possible)	a. Couloir b. Large open slopes above treeline c. Ridges/small open slopes above treeline d. Forest e. Glacier f. None of the above (tomorrow skiing will be too dangerous)
3. Up to what slope angle would you ski tomorrow?	a. More than 40° b. Up to 40° c. Up to 35° d. Up to 30° e. None of the above (tomorrow skiing will be too dangerous)
4. How strongly do you perceive the forecasted avalanche problem?	a. Strongly perceived b. Well perceived c. Slightly perceived d. Not perceived at all e. I do not know
5. What other avalanche problems do you perceive for tomorrow? (more than one answer possible)	a. New snow b. Wind slab c. Persistent weak layers d. Wet snow e. Gliding snow f. None of the above
6. How do you rate tomorrow's overall conditions?	a. Excellent b. Good c. Bad d. Terrible

if it decreases as the experience level increases.

Concerning weather variables, cloud cover is the most influential factor across all experience levels. Wind and temperature are considered less important by all backcountry skiers, in that order. Importantly, all weather-related variables are generally perceived as less influential than the avalanche danger level, with the exception of cloud cover, which is rated as approximately equally important among mountain guides and/or members of mountain rescue. Notably, the distributions of perceived influence for weather variables are similar across the different skier groups. In contrast, a clear difference emerges for the avalanche danger level, which is assigned substantially greater importance by occasional recreationists than by the other groups.

4.2. Daily surveys

Figure 2 shows the results of the daily surveys during the entire winter season, where subsequent days are grouped together according to Sect. 3.2. The curves associated with the different groups of backcountry skiers generally exhibit similar patterns. In particular, pairwise comparisons of them yield Spearman correlation coefficients ranging between 0.7 and 0.8 for the overall daily judgments, and approximately 0.55 for the perception of TAPs, with p -values consistently below 0.001. At the end of January, a heavy snowfall led to danger level 4 and bad daily judgments. During this period, no data on TAP perception are available; however, the new snow problem was clearly dominant. As soon as the danger level and cloud cover decreased to 3, overall judgments improved across all skier groups, even though the wind slab problem was not particularly well perceived. Indeed, 66 % of occasional recreationists, 50 % of

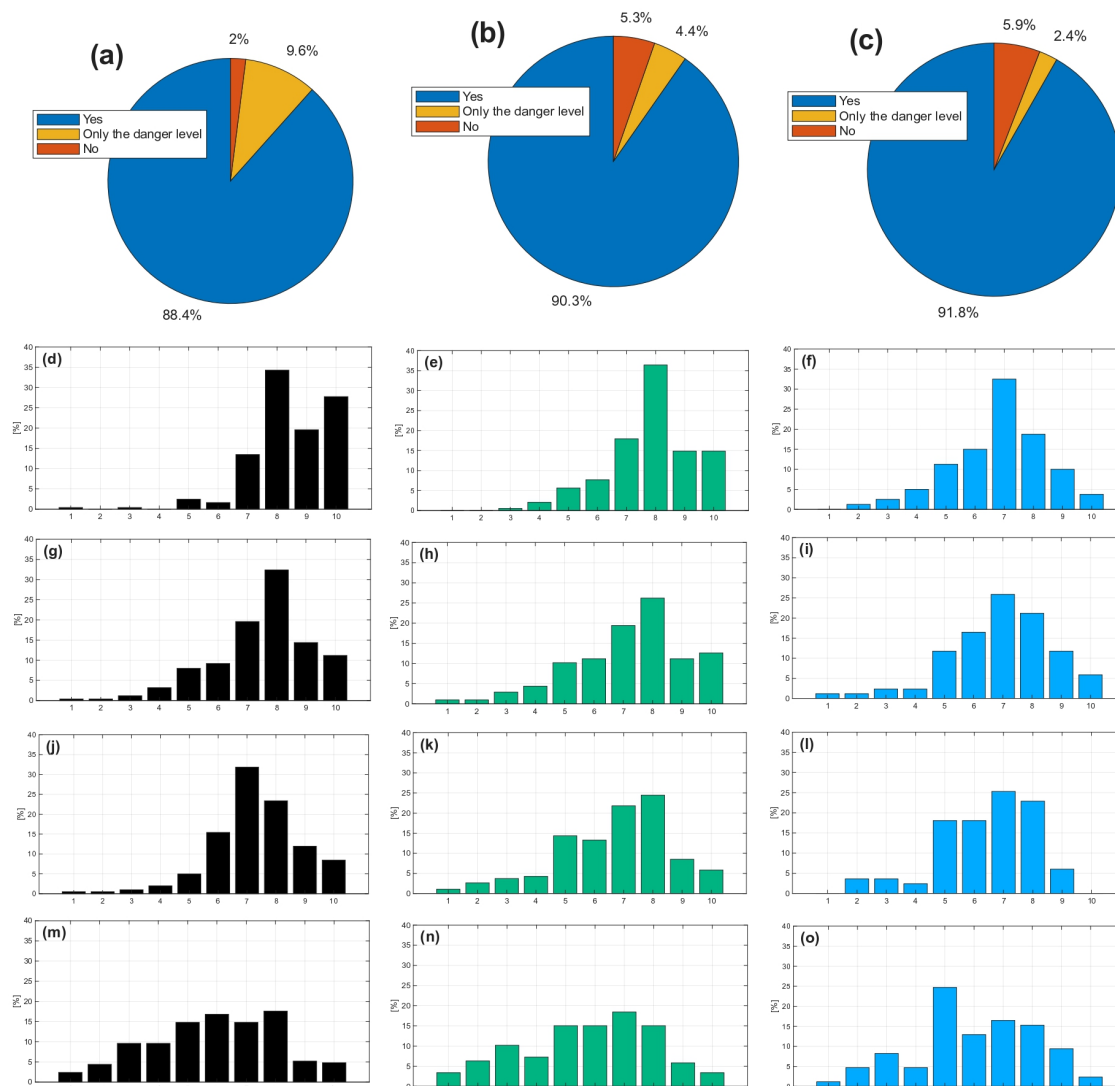


Figure 1: Results of the one-time survey. Graphs on the first column refer to occasional recreationists, on the second to expert skiers, and on the third to mountain guides and/or members of the mountain rescue. (a) – (c) *Do you usually read public avalanche forecasts?* (d)–(f) *How much are you influenced by the avalanche danger level?* (g)–(i) *How much are you influenced by cloud cover?* (j)–(l) *How much are you influenced by the wind?* (m)–(o) *How much are you influenced by the temperature?* The second question was not shown to participants who answered “No” to the first one. Answering 1 means *not influenced at all*, while 10 means *extremely influenced*.

expert skiers, and 83 % of guides and/or member of the mountain rescue perceived persistent weak layers as the dominant problem. Until the end of February, conditions were generally considered good, with some fluctuations related to cloud variability. Interestingly, TAP perception increased in association with persistent weak layers. March began with a relatively long period of stable conditions: danger level 2, low cloud cover, and wind slabs. Although the TAP was well perceived only among occasional recreationists, overall judgments ranged from good to excellent across all skier groups. In this period, expert skiers

did not perceive a dominant avalanche problem, while 73 % of guides and/or member of the mountain rescue perceived persistent weak layers. In mid-March, a snowfall led to an increase in danger level, cloud cover, and the new snow problem. During this period, the TAP was well perceived and the days were generally rated as bad for skiing. Until the end of March, several fluctuations occurred, driven by varying snow and weather conditions. As before, TAP perception increased with persistent weak layers. Interestingly, mountain guides and/or members of the mountain rescue were the only one who did not perceive well new

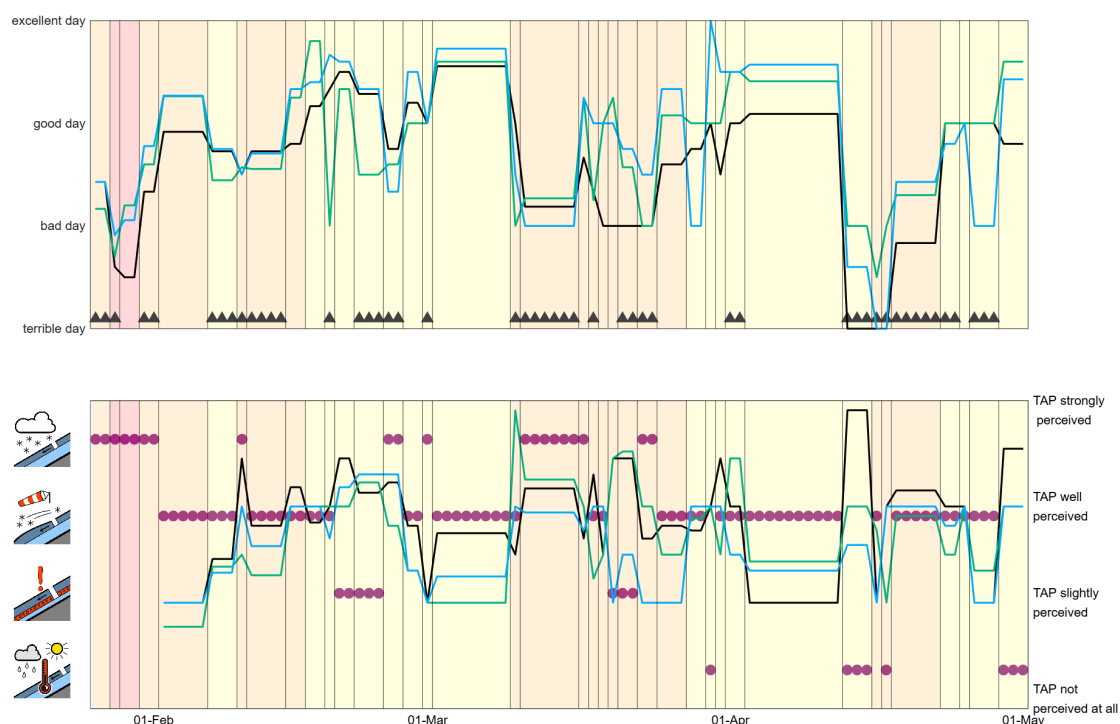


Figure 2: Results of the daily surveys. The black curves refer to occasional recreationists, the green curves to expert skiers, and the blue curves to mountain guides and/or members of the mountain rescue. The vertical black lines separate clusters of similar consecutive days (see Sect. 3.2), which are colored according to the forecasted danger level (red $\rightarrow$ 4, orange $\rightarrow$ 3, yellow $\rightarrow$ 2). (top) Average judgment of overall conditions, the gray markers indicate the days with more than 75 % cloud cover. (bottom) Average perception of the TAP (no data available at the beginning of the study), the purple markers indicate the TAP in the public avalanche forecast.

snow and wind slab problems toward the end of the month, indeed 50 % of them perceived persistent weak layers as the dominant problem. The first part of April was similar to early March. In particular, wind slab problems were slightly perceived by all skiers: 82 % of occasional recreationists and 59 % of expert skiers perceived wet snow as the dominant problem, while guides and/or member of the mountain rescue did not perceived a dominant TAP. Later, the combination of cloud cover and high temperatures, leading to wet snow problems, resulted in the worst daily judgments of the season, together with a strong perception of the TAP, particularly among occasional recreationists. The last days of April showed improving, although still predominantly negative, judgments associated with lower temperatures, but higher avalanche danger and increased cloud cover. Once again, wet snow problems were well perceived by all skiers.

Figure 3 illustrates how overall daily judgments vary across different skier groups as the danger level increases. As expected, higher danger levels are associated with worse judgments. This trend

is particularly evident between danger levels 3 and 4, where no one rated conditions as excellent. In particular, occasional recreationists consistently rated conditions as bad or terrible with danger level 4, while, in contrast, some of the more experienced skiers still considered such days to be good for backcountry skiing.

We now focus on the days when the forecasted TAP was new snow (Fig. 4) or persistent weak layers (Fig. 5). Indeed, the former is the only TAP with danger levels ranging from 2 to 4, while the latter is directly related to skier-triggered avalanches and was always well perceived during the season. As the danger level increased, skiers showed a significant shift toward less steep terrain (Marengo et al. 2017). Moreover, almost 40 % of occasional recreationists and 10–20 % of the other skiers considered skiing too dangerous at danger 4. Concerning new snow, all groups of skiers generally shifted toward forests and small slopes at danger 3, and toward forests only at danger 4. Similarly, in presence of persistent weak layers, both forests and small slopes were the most frequently selected

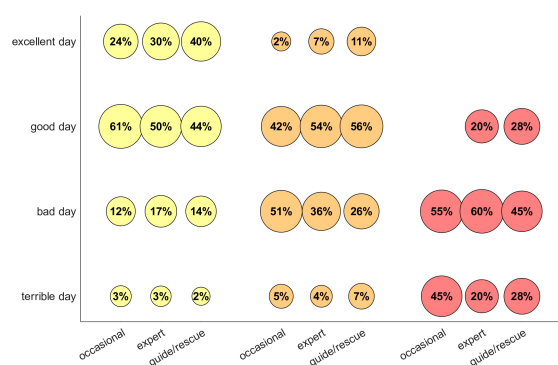


Figure 3: Percentages of opinion regarding the overall conditions as a function of danger level and experience level. Colors indicate forecasted danger levels (red → 4, orange → 3, yellow → 2).

terrain types at danger level 3. Anyway, under these conditions, 80 % of guides and/or members of the mountain rescue still considered skiing large slopes, while 40 % of them also considered couloirs or glaciers. Importantly, we remark that glacier terrain was almost only chosen toward the end of the season, when low elevations were partially characterized by snow melting. Therefore, when considering only this period, glacier terrain accounted for a substantially larger proportion of the selected terrains.

5. DISCUSSION

5.1. Consultation of public avalanche forecasts

Public avalanche forecasts proved to be a fundamental tool for backcountry ski planning. Almost all occasional recreationists reported consulting them, although the relatively large proportion of users reading only the danger level suggests that public avalanche forecasts may still be challenging to interpret for less experienced skiers (Fisher et al. 2022a). In contrast, only a small proportion of expert skiers and guides and/or members of the mountain rescue reported relying exclusively on the danger level. However, a larger fraction of them does not consult the public avalanche forecasts at all. This may indicate that, as field experience increases, skiers tend to rely more on their personal knowledge and observations.

5.2. Perception of avalanche problems

The perception of avalanche problems was broadly similar across the three skier groups. Persistent weak layers, which is the avalanche problem most closely associated with avalanche accidents, were generally well perceived by all participants when

they were forecasted in the bulletins. In particular, many mountain guides and/or members of mountain rescue tended to perceive this problem more frequently than the other skiers, especially when it was not explicitly indicated in the public avalanche forecast. This suggests that their extensive experience is associated with a better ability to recognize hidden snowpack instabilities (Hallandvik et al. 2017), whereas less experienced skiers may be more influenced by the visible appearance of the snow surface. Indeed, new snow and wet snow problems, which are generally easier to recognize in the field, were more strongly perceived by occasional recreationists and expert skiers. Wind slab problems were the least perceived, on average, although this result should be interpreted in light of their high frequency in the public avalanche forecasts. Since wind slabs appeared in the bulletins during a large portion of the study period, their repeated exposure may have increased familiarity with them, potentially influencing recognition judgments (Lloyd et al. 2003). Importantly, even when the forecasted TAP did not coincide with the most perceived one, the bulletin texts often contained implicit information regarding secondary TAPs (EAWS 2026). This further highlights the importance of consulting public avalanche forecasts in their entirety.

5.3. Influence of the danger level

The results of our study clearly show that the avalanche danger level is a highly influential factor in backcountry ski planning. In particular, as the danger level increased, skiers tended to choose less steep slopes and safer terrain (Marengo et al. 2017). This trend was especially evident among occasional recreationists: many of them would have avoided skiing under danger level 4 (Mannberg et al. 2026), and none considered such days to be good for backcountry skiing. Expert skiers and mountain guides and/or members of mountain rescue, however, showed a different approach. Although they also adopted more conservative terrain choices with high danger level (danger 4), many of them still reported being willing to ski in forested terrain below 30°. This highlights the role of experience in shaping backcountry ski planning under challenging conditions. Moreover, concerning occasional recreationists, the transition from danger level 3 to 4 appears to represent a qualitative shift in how they assess the suitability of the day, rather than simply a gradual increase in perceived hazard.

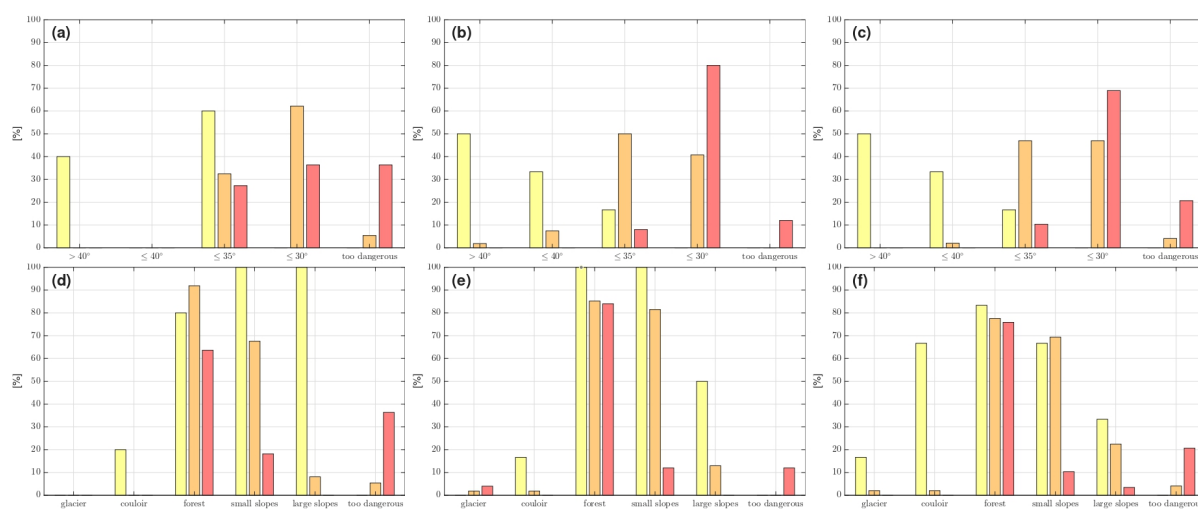


Figure 4: New snow TAP. Maximum slope angle (a)–(c) and chosen terrains (d)–(f) as a function of the danger and experience level. Colors indicate the forecasted danger level (red → 4, orange → 3, yellow → 2). Graphs on the first column refer to occasional recreationists, on the second to expert skiers, and on the third to mountain guides and/or members of the mountain rescue.

5.4. Final remarks

Snowpacks are characterized by strong local variability that cannot be fully represented in public avalanche forecasts. Therefore, the results presented in this study should be interpreted as describing skiers' opinions and intended behaviors in response to the published forecast, rather than their actual decisions in the field. In practice, some skiers, especially more experienced ones, may rely on direct observations and personal experience in areas where local conditions differ from those described in the forecast (Fisher et al. 2022b). Moreover, directly observing the slope to be skied may itself influence perception and decision-making, leading to behaviors that deviate from the general trends identified in this study (Greene et al. 2022; Haegeli and Strong-Cvetich 2020). We also did not account for slope aspect, both to avoid an excessive increase in the complexity of the analysis and because the dangerous aspects reported in the public avalanche forecasts generally involved all slope orientations. Finally, note that our results are not related to whether or not a skier intends to ski (Schäfer et al. 2026), but exclusively on what they would think during the planning phase, in case they decide to ski.

6. CONCLUSIONS

This season-long study provides new insights into how backcountry skiers translate public avalanche forecasts into risk-related decisions under real-world conditions. By combining a nationwide one-

time survey with repeated daily surveys conducted throughout the 2024/25 winter season in the Sondrio province (Italy), we were able to examine how perceptions and planned behaviors evolve as environmental conditions change over time. From an operational perspective, our results suggest two main implications for the design of public avalanche forecasts. First, explicitly reporting persistent weak layers as typical avalanche problem whenever they are present is particularly important. Indeed, less experienced recreationists often rely on simplified avalanche bulletins and are generally unable to recognize these hidden instabilities in the field. When appropriate, reporting persistent weak layers as a second typical avalanche problem could help ensure that this information reaches less experienced users. In addition, the observed changes in terrain preferences across danger levels indicate that forecasts could potentially provide more terrain-specific guidance. For example, during periods of high avalanche danger (danger 4), experienced users frequently reported shifting toward forested terrain. Providing more detailed information about snow and avalanche conditions in this terrain could therefore support more informed decision-making.

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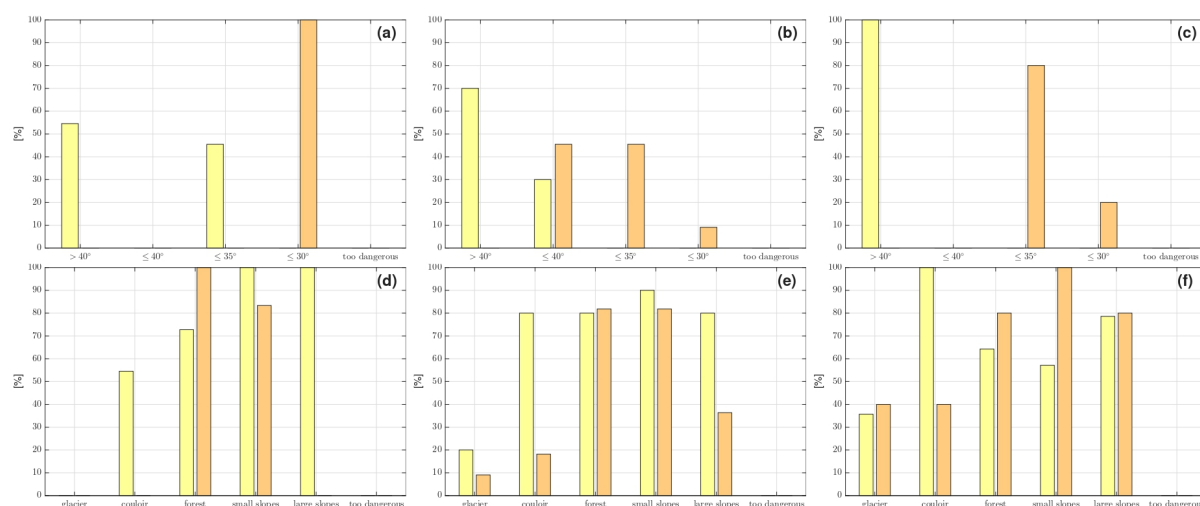


Figure 5: Persistent weak layers TAP. Maximum slope angle (a)–(c) and chosen terrains (d)–(f) as a function of the danger and experience level. Colors indicate the forecasted danger level (orange → 3, yellow → 2). Graphs on the first column refer to occasional recreationists, on the second to expert skiers, and on the third to mountain guides and/or members of the mountain rescue.

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