HOW BACKCOUNTRY USERS ENGAGE WITH AVALANCHE FORECASTS: EVIDENCE FROM AN ITEM RESPONSE MODELLING APPROACH

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ABSTRACT: This study examined patterns of avalanche forecast information use among recreational-level avalanche course completers using data from the Use of Avalanche Center Forecasts (UACF) survey. Responses from 879 recreational-level avalanche course completers were analyzed with a unidimensional partial credit model (PCM) to develop a Use of Avalanche Forecast Information in Decision Making (UAFIDM) progress variable through an empirically driven, bottom-up approach. This variable represents four qualitatively distinct zones of use of avalanche forecast information among recreational users. Findings reveal four qualitatively distinct zones of forecast use, with most recreational users consistently engaging with summary-zone products while substantially fewer incorporate distributed, effort-intensive, and interpretive information sources. This pattern suggests that many recreational users may be making decisions based primarily on simplified summaries, without integrating the underlying data necessary for terrain selection and risk management. The results have direct implications for avalanche education and forecasting practice. Educational programs may need to more explicitly scaffold the transition from recognizing forecast elements to synthesizing information from multiple sources for decision-making. For forecasting operations, understanding which forecast elements are most frequently used by different user groups can help forecasters better align communication with user behavior. Identifying where engagement drops off may highlight opportunities to adjust how information is presented, emphasized, or integrated within the forecast to better support a range of users.

KEYWORDS: avalanche forecast, engagement, risk communication

1. INTRODUCTION

Avalanche forecasts are among the primary risk communication tools used by winter backcountry travelers to assess avalanche conditions and inform terrain and travel decisions (Fisher et al., 2021; Fisher et al., 2022; Haegeli et al., 2012). In North America, avalanche centers provide forecasts that synthesize weather, snowpack, and avalanche observations into a range of forecast products, including danger ratings, avalanche problems, likelihood and size assessments, weather forecasts, observations, and multimedia resources (Lazar et al., 2016; Statham et al., 2018). These products vary in complexity and purpose, providing users with information ranging from broad hazard summaries to detailed contextual information intended to support decision-making (Raftery, 2014; Statham et al., 2018).

Research has examined forecast comprehension, risk perception, information seeking and processing, user typologies, and the use of specific bulletin products (Fisher et al., 2021; Fisher et al., 2022; Haegeli et al., 2012; St. Clair et al., 2021). However, relatively little is known about how users engage with the full range of forecast components or whether distinct patterns of forecast information use emerge across users.

Previous studies have largely examined the use of avalanche forecasts as a broad behavior or focused on specific forecast products. For example, St. Clair et al. (2021) identified distinct user types for avalanche bulletins, while Fisher et al. (2022) demonstrated differences in how user groups engage with travel and terrain advice statements. However, these studies did not examine how engagement is structured across the full range of forecast components.

Consequently, little is known about whether the use of avalanche forecast information can be characterized by distinct levels of consistent engagement with forecast products. To our

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knowledge, no previous study has modeled the use of avalanche forecast information as a measurable continuum based on patterns of engagement across forecast components. The purpose of this study was to examine patterns of avalanche forecast information use among recreational-level avalanche course completers and to develop the Use of Avalanche Forecast Information Development Model (UAFIDM).

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2. METHODS

To determine how frequently winter backcountry travelers used different avalanche forecast components to inform backcountry decisions, data was collected from 870 recreational-level avalanche course completers using the Use of Avalanche Center Forecasts (UACF) survey. The most typical respondent in the sample was a male, Caucasian individual in their 20s–30s with a bachelor's degree, who primarily engaged in nonmotorized backcountry travel, spent approximately 11–20 days per year in the backcountry, preferred traveling across multiple types of terrain, reported sometimes taking risks while generally limiting exposure to avalanche hazards, and indicated that they combine multiple sources of avalanche forecast information when making decisions.

2.1 Material

The UACF survey was designed to assess respondents' use of different avalanche forecast components to inform backcountry decisions. Respondents were asked how often they looked at different sections of the avalanche forecast and how much that section influenced their decision-making. The survey was pilot-tested and reviewed by experts in the field and electronically distributed through avalanche centers, backcountry organizations, social media platforms, and industry networks targeting backcountry users throughout the United States. Survey items addressed danger ratings, avalanche problem types, weather forecasts, forecast discussions, observations, photographs, videos, and social media content. Respondents rated the frequency of their use of the various avalanche components using a six-point Likert scale (0 = Never; 1 = Seldom; 2 = Sometimes; 3 = Often; 4 = Always; 5 = N/A).

2.2 Data analysis

Data screening removed respondents with implausible response patterns and items with conceptual redundancy. Following this screening process, 16 of the 35 original items were retained. Additionally, response categories were collapsed into a three-category scale (0 = never, 1 = sometimes, 2 = always), based on a series of analyses to assess category functioning that revealed overlap among several of the original response options.

A unidimensional partial credit model (Masters, 1982) was fit to the data to examine patterns of avalanche forecast information use among recreational-level avalanche course completers. The model estimated measures of respondents' engagement with avalanche forecast information and measures of the relative difficulty of reporting more frequent use of each forecast component. The resulting item structure was used to develop an empirically derived UAFIDM progress variable that describes qualitatively different zones of avalanche forecast information use based on patterns of respondent engagement within each zone

To develop the UAFIDM progress variable, we created an item-person map in which the items were arranged in an ascending order based on the location of each item's second threshold estimate (see Figure 1, below). Second threshold estimates were used to define the progress variable because they represent the point at which respondents are more likely to report consistent (i.e., "always") use of a forecast component rather than occasional or inconsistent use (i.e., "never" and "sometimes"). Masters and Forster (1996a; 1996b) describe this as a bottom-up approach that, in the field of educational research, entails analyzing student work products to develop a progress map that describes the nature of development, progress, or growth, within an area of learning. More recently, this approach has been applied in the context of developing progress variables in the context of teacher continuing professional development (Jolin & Blum, 2026a) and identifying hierarchical structures of in-service teacher anti-racism value stance constructs (Jolin & Blum, 2026b).

To demarcate zones of qualitatively different patterns of avalanche forecast information usage, cut points were determined by examining the distribution of second threshold estimates and identifying locations where relatively large gaps occurred between adjacent items. These gaps were interpreted as transitions between

qualitatively different *zones* of avalanche forecast information use, reflecting increases in the zone of engagement required to consistently report using components of avalanche forecast information at higher frequencies.

3. RESULTS

Results from the PCM analysis suggest the UACF survey demonstrated reasonable psychometric properties. Reliability was high (EAP/PV = 0.89), all items produced acceptable weighted mean square fit statistics, and examination of the distribution of second item thresholds suggested four zones of qualitatively different information use patterns.

Table 1 presents the entire set of UACF items, in ascending order based on the estimate of the second item threshold

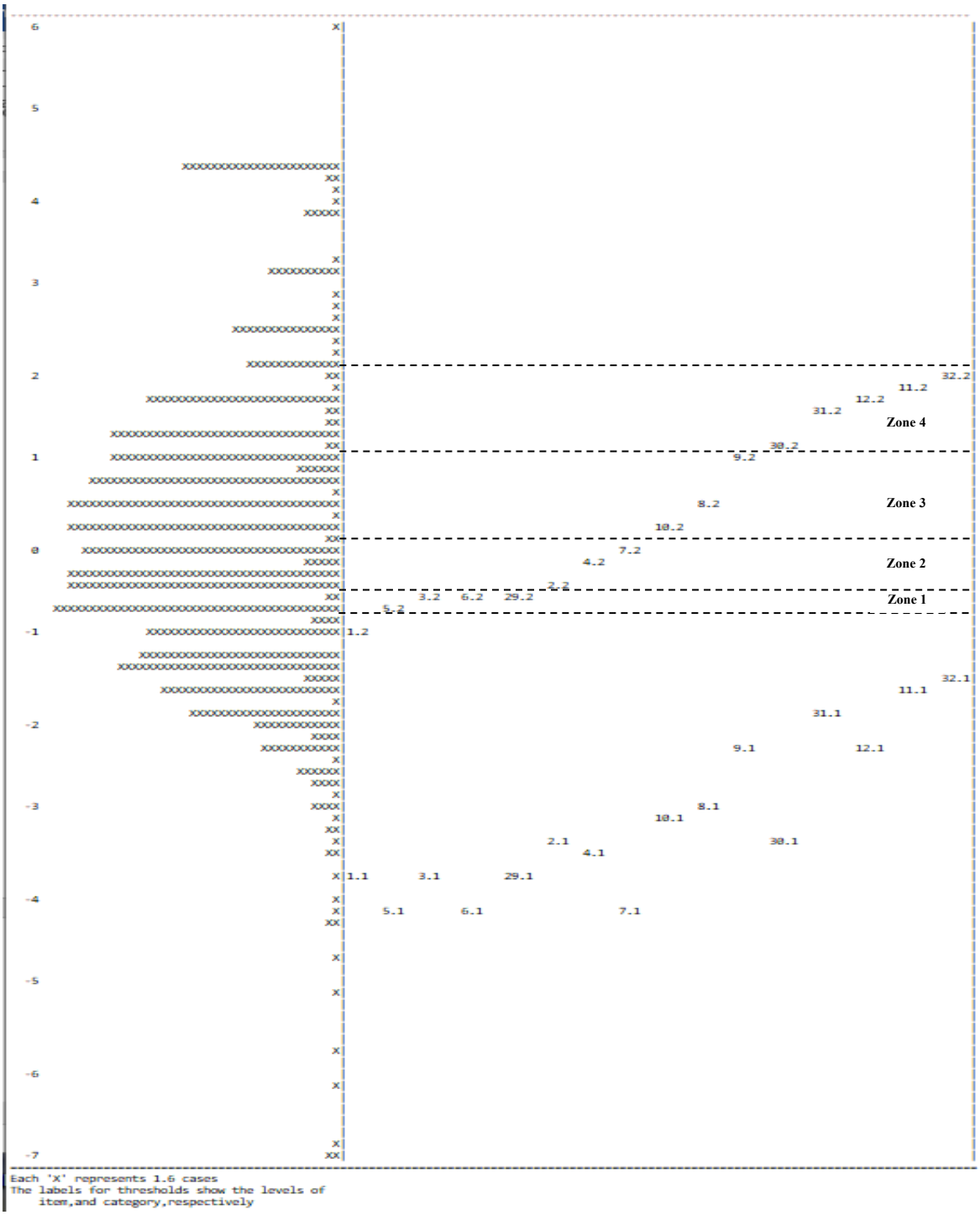
Table 1: Ordered second threshold estimates for UACF items.

Item No.	*Item Code*	*Item Stem*	*Second Threshold (Logits)*
		Zone 1 Items	
1	AF_DR_O	Danger Rating—Overall	-1.027
5	AF_WF	Weather Forecast	-0.659
6	AF_AE	Aspect/Elevation	-0.628
3	AF_APT	Avalanche Problem Type	-0.584
29	AF_DR_C_E	Danger Rating—Changes w/ Elevation	-0.515
		Zone 2 Items	
2	AF_BL	Bottom Line	-0.376
4	AF_FD	Forecast Discussion	-0.104
7	AF_L	Likelihood	-0.012
		Zone 3 Items	
10	AF_RF	Read Forecast Top to Bottom	0.164
8	AF_S	Size	0.558
9	AF_PEF	Photos Embedded in Forecast	0.993
		Zone 4 Items	
30	AF_O	Observations	1.119
31	AF_VEF	Videos Embedded in Forecast	1.536
12	AF_VST	Videos of Snowpack and Test	1.697
11	AF_SMP	Social Media Posts—Photo	1.857
32	AF_SMP_V	Social Media Posts—Video	1.922

Figure 1 presents the item–person map. The map displays the distribution of respondent avalanche forecast components use estimates (i.e., the Xs on the left part of the map) and item thresholds (i.e., the .1s and .2s on the right part of the map) on a common measurement scale. Items located lower on the scale were more easily endorsed by the sample (i.e., respondents were *more* likely to report using these avalanche information components more frequently in their decision-making). For items higher on the scale, respondents were *less* likely to report using these avalanche information components more frequently in their decision-making. Respondents with estimates located higher on the scale were *more* likely to report using a broader range of avalanche forecast components in their decision making, whereas respondents lower on the scale were *less* likely to report doing so.

To develop the profiles of respondents within each of the four zones, cut points were determined by examining the distribution of second threshold estimates and identifying locations where relatively large gaps occurred between adjacent items. These gaps were interpreted as possible transition points between qualitatively different zones of avalanche forecast information use.

Figure 1: Item-person map



4. DISCUSSION

The primary objective of this study was to examine patterns of avalanche forecast information use among recreational avalanche course completers and determine whether distinct levels of use could be identified based on patterns of consistent engagement with forecast components. Results indicate that avalanche forecast information use is not uniform across forecast products. Rather, some forecast components were consistently used by a large proportion of respondents, while others were consistently used only by respondents exhibiting broader patterns of forecast engagement.

The UAFIDM progress variable identified four empirically derived levels of avalanche forecast information use (Table 2). These levels reflect distinct patterns of engagement with forecast products that differ in visibility, accessibility, informational purpose, and the effort required to locate and interpret them.

4.1 Zone 1: Core summary forecast products

Zone 1 included the overall danger rating, weather forecast, aspect/elevation information, avalanche problem type, and elevation-specific danger ratings. These products represent the most visible and frequently used elements of avalanche forecasts and appear to form the foundation of forecast use among recreational avalanche course completers.

4.2 Zone 2: Explanatory forecast products

Zone 2 included the Bottom Line, forecast discussion, and avalanche likelihood information. These products provide context for forecast conclusions and help users understand the significance and implications of current avalanche conditions.

4.3 Zone 3: Integrative forecast products

Zone 3 included reading the forecast from top to bottom, avalanche size information, and embedded photographs. Together, these items suggest a pattern of broad engagement with forecast information that supports development of a more complete understanding of avalanche conditions.

4.4 Zone 4: Supplementary forecast information sources

Zone 4 included observations, forecast videos, snowpack and stability test videos, and forecaster-generated social media content. These products go beyond the primary forecast structure, providing additional evidence and context on current conditions.

Viewed collectively, the four levels indicate that avalanche forecast information use can be characterized by distinct patterns of engagement with forecast products. The levels range from consistent use of highly visible summary products to consistent use of supplementary and externally distributed information sources.

The ordering of forecast components suggests that users who consistently engage with supplementary information sources also tend to consistently engage with core forecast products, whereas the reverse is not necessarily true. Thus, users appear to differ not only in the amount of forecast information they use but also in the types of forecast products they consistently use.

Importantly, the present study does not establish that individuals move between levels over time. Rather, the levels represent empirically derived patterns of engagement with avalanche forecast information. While the ordering of forecast components suggests a continuum from engagement with core summary products to supplementary information sources, future research is needed to determine whether these patterns reflect changes associated with increasing experience, education, or exposure to avalanche forecasting system

Table 2: Characteristics of the Four Zones of Avalanche Forecast Information Use

Zone	Description	Representative Forecast Components	Primary Information Function	Guiding Question
Zone 1: Core Summary Forecast Products	Consistent use of highly visible forecast products that communicate overall hazard conditions and terrain distribution.	Overall Danger Rating, Weather Forecast, Aspect/Elevation, Avalanche Problem Type, Danger Rating by Elevation	Hazard identification and situational awareness	What are the main avalanche hazards today?
Zone 2: Explanatory Forecast Products	Consistent use of forecast products that provide context and rationale for forecast conclusions.	Bottom Line, Forecast Discussion, Likelihood	Understanding forecast reasoning and avalanche conditions	Why do these conditions exist?
Zone 3: Integrative Forecast Products	Consistent use of forecast products that support synthesis across multiple forecast components.	Read Forecast Top to Bottom, Avalanche Size, Embedded Photos	Integrating information across forecast products	How do the different pieces of forecast information fit together?
Zone 4: Supplementary Forecast Information Sources	Consistent use of supplementary information sources that extend beyond the primary forecast structure.	Observations, Forecast Videos, Snowpack/Test Videos, Social Media Photos and Videos	Refining understanding through additional evidence and context	What additional evidence can help me better understand current conditions?

5. CONCLUSION

5.1 Implications for avalanche education

The findings suggest that avalanche education programs may benefit from placing greater emphasis on how learners engage with different forecast products rather than treating forecast consultation as a single behavior. The UAFIDM progress variable provides a framework for understanding these patterns of engagement and may help instructors identify which forecast products students use consistently and which receive less attention during trip planning and decision-making.

Rather than viewing forecast use as a binary behavior, educators may find it useful to encourage engagement with a broader range of forecast products and to explicitly address how summary products, contextual information, and supplementary resources contribute to a comprehensive assessment of avalanche conditions. The UAFIDM progress variable may also provide a useful framework for future work examining relationships between forecast use, avalanche education outcomes, and decision-making practices.

5.2 Implications for forecast communication

The findings also have implications for avalanche forecasting operations and forecast design. Core summary products were consistently used by a large proportion of respondents, whereas observations, videos, and social media products were consistently used by a considerably smaller subset of users.

These patterns suggest that visibility, accessibility, and presentation influence user engagement with forecast information. Forecast centers invest substantial effort in producing observations, videos, and social media content, yet many recreational users may not consistently engage with these resources. Understanding where engagement declines across forecast products may help forecasters assess whether important supporting information is sufficiently visible and integrated into the forecast experience.

5.3 Limitations

Several limitations should be considered when interpreting these findings. First, the study relied on self-reported measures of forecast use rather than direct observation of user behavior. Second, the sample consisted of avalanche course completers and therefore may not represent all avalanche forecast users. Third, the cross-sectional design does not permit conclusions regarding how individuals move between levels of forecast information use over time.

5.4 Future Research

Future research should examine whether the UAFIDM progress variable can be replicated in other user populations and forecasting regions. Longitudinal studies may help determine whether the identified levels reflect stable patters of forecast use or changes associated with additional training and experience. Future work could also investigate how different levels of forecast information use relate to terrain choices, risk management practices, decision quality and other avalanche safety outcomes

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