THE DANGERATOR: A METHOD FOR ESTIMATING AVALANCHE DANGER IN AREAS WITH NO PUBLIC AVALANCHE FORECAST

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ABSTRACT: Avalanche Canada has developed a simple methodology for estimating avalanche danger to support Avalanche Skills Training (AST) students and instructors in areas where no public avalanche forecasts are available or in the early/late season when ratings are not available within official forecast regions. The methodology provides very simple guidance in the form of a decision tree. The Dangerator decision tree assumes that if you know nothing about the current state of the snowpack, your starting point should be to assume a considerable (Level 3) rating. There are then two steps which may adjust this danger rating, based on a simple analysis of current conditions using existing AST concepts and terminology: 1. If critical loading applies or critical warming conditions exist, the danger increases to high (Level 4); 2. If, there is no recent loading and no recent slab avalanches and no recent signs or reports of a persistent slab problem, the danger reduces to moderate (Level 2). In one validation study, the Dangerator predicted the same danger or higher compared with Avalanche Canada's regionl danger ratings on over 90% of the days. A general bias towards a more conservative assessment was observed, particularly under early season and late season (spring) conditions.

KEYWORDS: Dangerator, avalanche, danger ratings, avalanche skills training, forecast, data sparse

1. INTRODUCTION

Avalanche Canada's recommended decision framework for winter backcountry recreationists is built around using the Avaluator v2.0—a two-part decision aid comprising of the Trip Planner and the Slope Evaluation card. Avalanche Skills Training (AST) courses in Canada are universally built around this framework.

Both the Trip Planner and Slope Evaluation card use the avalanche danger rating from the regional avalanche forecast as input (Haegeli, 2010). In the case of the Trip Planner, it is the primary input that allows users to select appropriate ATES-rated terrain. (ATES is Avalanche Terrain Exposure Scale (Statham, et al., 2006)—a three-level scale categorizing terrain into *Simple*, *Challenging* or *Complex* based on its avalanche severity.) In the case of the Slope Evaluation card, it is one of six factors that make up an assessment of local avalanche conditions.

Since the Avaluator decision making method relies on avalanche danger ratings, it can only be applied in areas for which regional avalanche forecasts are available. In areas or at times where no avalanche forecast is available, the tool cannot be correctly employed to help users make decisions.

This presents a problem for winter recreationists wishing to employ the framework they learned during their AST course in areas not served by a public avalanche forecast. In the North Rockies area of western Canada, Storm & Helgeson (2014) have argued the lack of danger ratings in this area has restricted the use of the Avaluator, which in turn has resulted in a diminished level of engagement by users in other parts of the avalanche safety process. They suggested developing a technique to allow users with minimal training to approximate the regional avalanche danger. Similar recommendations have been made by AST instructors teaching courses outside of avalanche forecast regions, who are acutely aware they are teaching students a method that has limited applicability for their area.

This paper introduces a practical tool for estimating avalanche danger in areas where limited information is available. We have called it the *Dangerator.* It is designed for use by recreationists with AST 1 level avalanche training. It is intended to compliment the use of the Avaluator in areas where avalanche forecasts are not available.

2. THE DANGERATOR

The Dangerator was formulated with input from experienced forecasters at Avalanche Canada. It is designed to mimic the important aspects of the avalanche forecasting process, pared down to a minimum to allow use by recreationists with basic training and in situations where data may or may not be available. It has been reviewed by several experienced avalanche practitioners and avalanche educators.

2.1 General Considerations

The Dangerator is intended to be used prior to travel during trip planning. It is best applied in the morning of the day of travel, although it may be applied at an earlier time, such as the evening before travel.

The Dangerator will estimate avalanche danger as either moderate, considerable or high. It does not allow for a low or an extreme danger rating.

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The Dangerator will give one estimation of avalanche danger for a given area; it will not determine different ratings for different elevation bands.

2.2 The Method

The process of estimating danger is illustrated in Figure 1.

The starting point is to assume a considerable rating. Users then have two opportunities to adjust the danger away from considerable, if specified conditions exist.

Step 1 involves determining whether the danger should be elevated to high. High danger is determined if either of the following conditions are present:

- critical loading, or
- critical warming.

Step 2 involves determining whether the danger should be lowered to moderate. Moderate danger is determined if all of the following conditions are met:

- no recent loading, and
- no slab avalanches, and
- no persistent avalanche problem.

If the danger cannot be raised to high or lowered to moderate, it should not be adjusted and a considerable rating for the area should be given.

If a factor cannot be determined because of a lack of information, or if the user is unsure whether to answer yes or no to a question, the default decision should be to use a considerable danger rating.

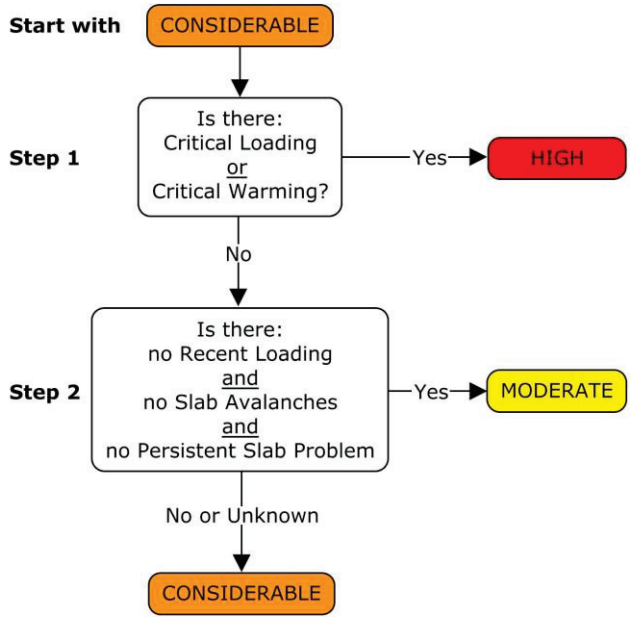

Figure 1: The logic used by the Dangerator to estimate avalanche danger.

2.3 Determining the Factors

Table 1 lists the definitions for each factor and gives advice on where to find appropriate information to help determine whether they apply or not. With the exception of critical loading, all the factors also appear in the Avaluator Slope Evaluation card.

As the method is designed to be used in areas that may only have sporadic information, it is important to give some guidance on utilizing less current information in the analysis. For critical loading and critical warming factors, it is important that recent weather observations are used in conjunction with forecasted weather values during the day of travel. Observations pertaining to recent loading and slab avalanches would typically have a currency of 48 hours, and perhaps a little longer in the case of powerful storms, large avalanche cycles or significant avalanche events. Observations about whether a persistent slab problem exists typically remain relevant for a few days, depending on how rapidly the environment (and therefore the snowpack) is changing.

If information is deemed not to be current, users should assume the factor in question is unknown.

3. VALIDATION

We performed a validation study to test how well the Dangerator performed in an area where regional avalanche danger ratings were also available.

The location chosen for the validation was Kootenay Pass, which is within the Kootenay Boundary region. The location was chosen because avalanche danger at Kootenay Pass is generally considered representative of the avalanche danger in the region as a whole. Additionally, this area has a good supply of professional and public information, allowing us to test the method under ideal and (using techniques to degrade the data) data sparse conditions.

3.1 Validation Method

Information was gathered from a variety of sources to determine the applicable factors for each winter day between December 1, 2017 and March 31, 2018. The following sources were considered:

- Remote weather station data from Kootenay Pass
- Environment Canada's GEM Global weather forecast in meteogram format for Kootenay Pass.
- InfoEx (Slab Avalanches and Persistent Slab Problem factors)
- Mountain Information Network (MIN) posts
- MCR (Mountain Conditions Report) posts
- Relevant Facebook posts

- Avalanche Canada's Special Public Avalanche Warnings

Critical loading was determined by summing the prior 24 hours of snow amounts from Kootenay Pass and adding the amount from the 12-hour forecast from the GEM global model.

Critical warming was determined by assessing the freezing level from the GEM global model during the warmest part of the day. If the freezing level exceeded 1800 m, rapid warming was determined.

Recent loading was determined by summing the prior 48 hours of snow amounts from Kootenay Pass.

Slab avalanches were determined from InfoEx posts, and/or MIN, MCR and Facebook posts from the area. Posts older than 48 hours prior to the start of the trip were only used if they met the following criteria: a) they had previously indicated that avalanches were not observed; and b) subsequent daily snowfall amounts were less than 5 cm, winds were light and there was no evidence of warming. In other cases where observations were more than 48 hours old, an unknown determination was given.

Presence of a persistent slab problem was also determined from InfoEx posts, and/or MIN, MCR and Facebook posts from the area. Posts older than 96 hours prior to the start of the trip were not included and if more recent information was not available, an unknown determination was given.

Analyses were performed for three cases of varying data quality: a) all data available, both professional and recreational; b) recreational data only (InfoEx data was excluded); c) degraded recreational data, where 25% of observations from sources other than weather stations were excluded from the analysis by random selection.

3.2 Validation Results

Figure 2 shows that under ideal conditions the Dangerator correctly predicted avalanche data on 69% of days (orange bar). However, the prediction rate fell when early and late season data was included in the analysis.

Table 1: Factor definitions and advice on sourcing the required information.

Definition	*Sources of Information*
Critical Loading Do you expect loading of roughly 30 cm of new snow or more, significant wind transport or rain to occur during the period from 24 hours prior to travel up to the end of the travel day?	• Combine recent observations of new snow, wind and rain with the forecast amounts from a local weather forecast product (e.g. SpotWX) for the day of travel.
Critical Warming Do you expect a rapid rise in temperature to near 0°C, or the upper snowpack to become wet due to strong sun, above-freezing air temperatures or rain?	• A local weather forecast product that indicates expected freezing levels on the day of travel (e.g. SpotWX).
Recent Loading Has there been loading within the past 48 hours including roughly 30 cm of new snow or more, significant wind transport or rain?	• Remote weather stations • Your own previous or trailhead observations • Recent MIN[1] or MCR[2] posts • Recent social media posts
Slab Avalanches Are there signs of slab avalanches in the area from today or yesterday?	• Reports of avalanche activity from nearby forecast regions • Your own previous or trailhead observations • Recent MIN or MCR posts • Recent social media posts
Persistent Slab Problem Is there a persistent or deep persistent slab problem in the snowpack?	• Special Public Avalanche Warnings • Avalanche Canada blog posts or Special Information pieces • Persistent slab problems listed in nearby forecast regions • Your own previous observations of persistent slab avalanches, remote-triggered avalanches or signs of whumpfing • Reports of "easy" or "sudden" snowpack test results • Recent MIN or MCR posts • Recent social media posts

[1] MIN refers to the Mountain Information Network, a platform maintained by Avalanche Canada for users to post information about local conditions (www.avalanche.ca).

[2] MCR refers to Mountain Conditions Reports, which are reports made by ACMG (Association of Canadian Mountain Guides) accredited guides (www.mountainconditions.com).

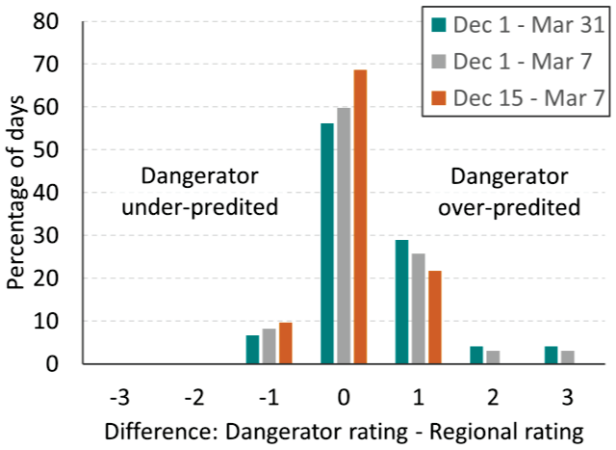

Figure 2: Difference between Dangerator and regional danger ratings for three season lengths: green = complete season (Dec 1 - Mar 31); grey = late season excluded (Dec 1 - Mar 7); and orange = mid-winter only (Dec 15 - Mar 7)

The results show a skew towards over-predicting danger. Depending on the season length, the Dangerator predicted the same danger or higher compared with the regional danger ratings on 90-93% of the days.

Figure 3 shows that degrading the data quality had only a marginal effect in our data set for the mid-winter data set. Correct prediction was approximately 2% higher when both recreational and professional data were used. Under-prediction rates were actually lower for the degraded recreational data compared to when all recreational data (but no InfoEx data) was used.

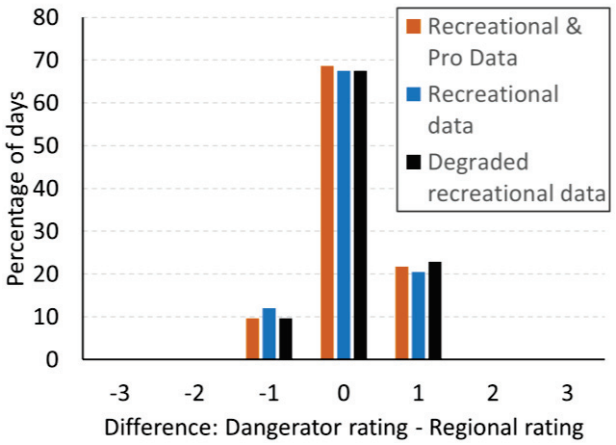

Figure 3: Difference between Dangerator and regional danger ratings for three data qualities: orange = all available data, both recreational and professional; blue = recreational data only; and black = degraded recreational data only.

4. DISCUSSION

By paring down the forecast process to its most basic elements, we have created a technique that even inexperienced users can make use of in areas with scarce data. On account of the simplifications made, we must accept there will be limitations to its predictive power. We argue these limitations are appropriately balanced out by building in a bias towards a considerable rating—leaning it, on average, towards a more conservative estimation of danger.

4.1 Conditions Resulting in Over-Prediction

From our dataset, the Dangerator consistently over-predicted avalanche danger on days when critical warming did not result in elevated avalanche conditions. There were two cases where this occurred: early season, where early-season high pressure conditions resulted in temperature inversions, and late season under spring conditions where significant diurnal fluctuations in temperature were observed.

The warming variable is complex and even experienced avalanche forecasters sometimes have difficulty predicting if or when a warming trend will influence the likelihood of avalanches. Bakermans & Jamieson (2009) noted that daytime warming is not important in every instance when evaluating snow instabilities.

More experienced users could be coached to recognize instances where the presence of warming is unlikely to lead to an increase in avalanche hazard. Less experienced users, such as those graduating with AST 1 training, are probably best served (initially at least) by a more simple tool without the complexity of caveats and exceptions.

4.2 Conditions Resulting in Under-Prediction

Three themes resulting in under-prediction could be identified. The first could be linked with the incremental development of a persistent slab problem. During the period 7 to 17 January, 2018, the snowpack was unusually sensitive to large human triggered avalanches, and on several days during this period the regional danger was rated high, even in the absence of significant storms and natural avalanche activity.

The second appeared to be related to instances where amateur observations indicated no slab avalanches or persistent avalanche problems existed, in contrast to data provided by professional observers.

The third was observed when snow amounts for the critical loading factor were almost, but not quite at the 30 cm threshold.

4.3 Wicked Learning Environment

Travel in avalanche terrain presents a wicked learning environment (Hogarth, et al., 2015) where predictions of slope behaviour do not always match those experienced in the past. McCammon & Haegeli, (2006) argued that inexperienced recreational travelers are better served by more simple rules-based decision aids compared with more complex analytical

or experience-based techniques. Since the 1990's there have been a number of rules-based decision aids developed, including the Reduction Method (Munter, 1997) and the original version of the Avaluator (Haegeli, et al., 2006). However, without the required inputs, these rules-based aids are ineffective.

4.4 The Missing Link

We argue the value of the Dangerator extends beyond just its predictive power. It fulfills an important role by providing the missing input for the Avaluator v2.0 Trip Planner and Slope Evaluation card. As such, it permits users to engage more completely with these decision aids meaning they are less likely to abandon the tool due to a lack of critical information.

Moreover, it is likely that users who retain their engagement also recognize value in other aspects of the avalanche safety process, such as carrying the correct avalanche safety equipment and engaging in good travel habits such as moving one at a time across a slope. This enhanced engagement is likely more important to avalanche safety as a whole than a deliberation over the precise predictive power of the tool.

4.5 Mimicking Professionals

Part of the elegance of the Dangerator is that it mimics, albeit at a simplistic level, the process by which professional avalanche forecasters make determinations of avalanche danger. As a result, if a factor is unknown, it serves as a prompt to the user for what information would be particularly valuable to gather while traveling. More experienced users may be able to add caveats to improve predictive power, such as disregarding critical warming for morning travel after several days of spring weather conditions.

The method is also consistent with how professionals approach travel in areas for which they do not have information about. Professionals are trained to assume there is something inherently unstable about the snowpack that would allow for human triggered avalanches to occur until it is proved otherwise. This would typically be consistent with a considerable danger rating. Professionals do not need to always assume high danger is present, as the determination of high danger can reliably be made from an assessment of recent and forecast weather; factors that can usually be determined with reasonable confidence.

4.6 No Low or Extreme Ratings

The decision not to permit a low or extreme avalanche danger rating was made due to the extra complexity it would add to the method. We argue that a more complicated tool would likely see less use, diminishing its primary role, which is to enhance user engagement with a sound decision making framework. In reality the loss of extreme is not severe, since extreme is used rarely in forecasts and users most likely respond in a similar way to high. The loss of low is a bigger blow, as it is sound advice to wait for low avalanche danger before attempting travel on a big slope or an exposed route. Our advice for those wishing to push into more extreme terrain would be to get more avalanche training and mentored experience.

5. CONCLUSION

The Dangerator holds significant promise to assist recreational backcountry users in areas where no avalanche forecast is available. Key features are its simplicity and choice of terms to be consistent with those used in the Avaluator v2.0.

By providing a tool that permits an estimation of avalanche danger, we hope to encourage users to more fully engage in all aspects of the avalanche safety process.

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