THE CANADIAN AVALANCHE CENTRE'S LONG-RANGE FORECASTING PROGRAMME

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ABSTRACT: The Canadian Avalanche Centre (CAC) provides non-commercial backcountry users with regional avalanche forecasts and Special Public Avalanche Warnings in western Canada to support pre-trip planning and on-slope decision-making. To encourage pre-trip planning, danger ratings are issued daily with lead times out to day four. Special Public Avalanche Warnings are issued when periods of elevated risk are identified. These periods are often forecast with the six to ten day lead time. Publicizing information well in advance is imperative to encouraging people to plan appropriate trips or re-consider their objectives.
This paper discusses the methodology used for producing long-range (6 to 10 day) avalanche outlooks. Ensemble weather products, their interpretations, and some of their inherent limitations are discussed. I show how the CAC integrates existing snowpack structure with long-range weather forecasts to facilitate strategic planning. The resultant "Period Strategies" allow CAC forecasters to work out approaches that improve forecasts and maximize the effectiveness of additional warnings. Finally, the paper assesses the CAC's experience with the effectiveness of long-range avalanche outlooks and discusses ideas for future development.

1. BACKGROUND

The Canadian Avalanche Centre (CAC) provides public avalanche warnings and safety programmes, including public avalanche forecasts for mountainous areas of British Columbia and Alberta. Like most public avalanche bulletins, CAC forecasts serve diverse user groups (including backcountry skier & boarders, mountain snowmobilers, and out-of-bounds riders) composed of people with a wide variety of avalanche training, skills, and risk tolerance. CAC forecasters face challenging spatial scale issues: like many public forecasting programmes, CAC regions are large (some of the largest in the world) and, unsurprisingly, full of heterogeneity.

Bulletin verification work (Jamieson et al. 2008) investigates the effect of bulletin region size and frequency in terms of forecast accuracy and the potential benefits accrued from shrinking forecast regions or increasing bulletin frequency (from 3 times per week to daily forecasts). In short, Jamieson explores the benefits of increased resolution. This paper considers the value of an opposite approach: long-term (6 – 10 day), low-resolution outlooks subject to high levels of uncertainty.

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2. GOALS

The effectiveness of public avalanche forecasts is contingent on a host of factors including (but not limited to) the accuracy of current & forecast conditions, wisdom of the advice provided, matching communication techniques with distribution channels, and user retention. Ultimately, the effectiveness of a public avalanche product is tightly coupled to how it affects – dare I say changes – user decision-making and behaviour.

CAC forecasts support both pre-trip planning and on-slope decision-making. Long-range outlooks allow the CAC to publicize information and warnings well in advance. Providing users adequate lead-time is imperative to encouraging people to plan appropriate trips or reconsider their planned objectives. This is especially true in the Canadian context where "locals" routinely drive hundreds of kilometers for a day of mountain recreation and visitors come from even further afield. Given the scope of choices people have about where to recreate, and the options available for appropriately matching activities to conditions, some of the most important decisions may occur before the trailhead and even before leaving home.

The CAC runs purely office-based warning and forecasting programmes; there is no field component. Hence communication with field-

based colleagues is critical. Creating six to ten day long-range outlooks provides CAC forecasters the opportunity to generate big-picture hypotheses about how conditions could evolve, discuss scenarios with select practitioners working within forecast regions, monitor developments over time, and incorporate the best insights and ideas into public bulletins and warnings. It seems that office-based programmes such as ours, where much of our field data takes time to reach us and is possibly outdated[1], are susceptible to being late in recognizing significant changes. Collaboration with select field practitioners to vet ideas found in Long-Range Forecasts reduces the chance of being "flat-footed" in our regular public avalanche forecasts and warnings.

Additionally, long-range thinking by front-line forecasters translates into better-informed managers (who can approve increased staffing levels for critical periods) and improved communication within the CAC forecaster team (all forecasters are part-time at the CAC; most also work in a field-based avalanche programme).

3. PROCESS & CONTENT

The foundation of long-term avalanche forecasts is extended-range weather forecasts. The CAC contracts meteorologist Uwe Grahmann (Mountain Weather Services) to produce a weekly custom weather forecast and briefing. Tuesday's Day 3 – 5 forecast provides information for the Thursday to Saturday period. The Day 6 – 10 outlook provides information for the remainder of the weekend through most of the next week. If better information is required for the weekend (when backcountry use is greater), this process is repeated on Thursday.

Three to five day forecasts typically include:

- Series of 12z 500 hPa charts from the GFS or GEM global models.
- Tables summarizing daily freezing level, solar radiation, temperature, wind, and precipitation at alpine and treeline elevations for four general regions (North Coast, South Coast, North Rockies, Columbia – South Rockies).
- Discussion of daily synoptic pattern and regional features.
- Four XT-Diagrams covering Days 1 – 3 for point locations representing each region.

The six to ten day overview is based entirely on ensemble forecast products. Typically it includes a combination of:

- Series of daily 546 dam Spaghetti plot with 500hPa Standard Deviation charts.
- Series of ensemble mean and standard deviation charts for relevant parameters (precipitation, wind, temperature) from the Canadian North American Ensemble Forecast (NAEFS) website (http://www.weatheroffice.gc.ca/ensemble/naefs/index_e.html).
- Probabilistic exceedance charts for precipitation, wind or temperature (available from the NAEFS website).
- EPSgrams (box & whisker plot) for up to four regionally representative point locations (available from the NAEFS website).

Additionally we consult the National Weather Service Climate Prediction Center 6 – 10 Day & 10 – 14 Day Extended Range Outlook charts and Prognostic Discussion (http://www.cpc.noaa.gov/products/forecasts/).

Armed with the best available meteorology, the avalanche forecaster has two initial tasks:

1. Assess weather forecast confidence, localizing where uncertainty is found in the forecasts. The goal is to generate a range of possible weather scenarios.
2. Based on possible weather scenarios, hypothesize likely snowpack implications – for example development of persistent weak layers, passing critical load thresholds for existing weak layers, or implications of warming trend.

This sets the forecaster up to prepare a Discussion and provide Recommendations for both the Day 3 – 5 and Day 6 – 10 periods. Discussion sections typically focus on a technical snowpack commentary that includes both likely scenarios (usually based on ensemble means) and alternate outcomes (derived from outlier ensemble member solutions). Discussions also include an assessment of issues relating to user-group activity and psychology: riding conditions,

[1] InfoEx™ is a major source of data and information for the CAC's public avalanche forecasts. Typically however, most InfoEx™ data is from the previous day or earlier. In other words, a forecast issued Friday afternoon for Saturday through Monday is informed by Thursday's InfoEx™ summaries.

who's out there and what they're doing (or will be tempted to do), pent-up demand, and other identifiable human factors likely to influence decision-making. The Recommendation section provides the foundation for creating Period Summaries & Strategies discussed below.

Ideally, long-range avalanche outlooks support forecasters working on regular forecasts and services with:

1. "Straw-man hypotheses" – ideas & scenarios to jump-start day-to-day technical discussions. Additionally, prompts that highlight critical data to monitor have proven valuable for updating and refining theories. For example watching for anomalous avalanche activity can provide key early data points strengthening (or weakening) confidence in a certain line of thinking.
2. Suggestions for public messaging and additional communication strategies.
3. A decision for whether another long-range forecast is required on Thursday to support upcoming decisions and weekend services.

Generally long-range outlooks are undertaken by senior forecasters who are able to move between big-picture high-level patterns and small-scale details, create valuable synoptic overviews and envisage scenarios that incorporate the psychology of user decision-making, and identify key ideas and parameters that assist daily (short-range) forecasting processes and products.

4. STRATEGIC PLANNING

Long-range forecasts are used internally to support standard operating procedures for issuing Period Summaries & Strategies (Figure 1). In terms of CAC strategic planning, Period Summaries indicate normal procedures. Period Strategies mark times of elevated risk requiring increased caution. A Period Strategy is developed collaboratively with input from Forecasters, CAC Operations Manager, and Communications Director. Briefing summaries keep the CAC Executive Director, CAA Operations Manager, and other CAC partners apprised of operational thinking. Action plans typically follow these options:

1. Specific & consistent messaging in regular public forecasts.
2. Targeted actions with other bulletin producers and the professional community.
3. Special reports and non-forecast communications (e.g. web forum postings).
4. Targeted actions with media (seeding stories).
5. Special Public Avalanche Warnings (SPAW).

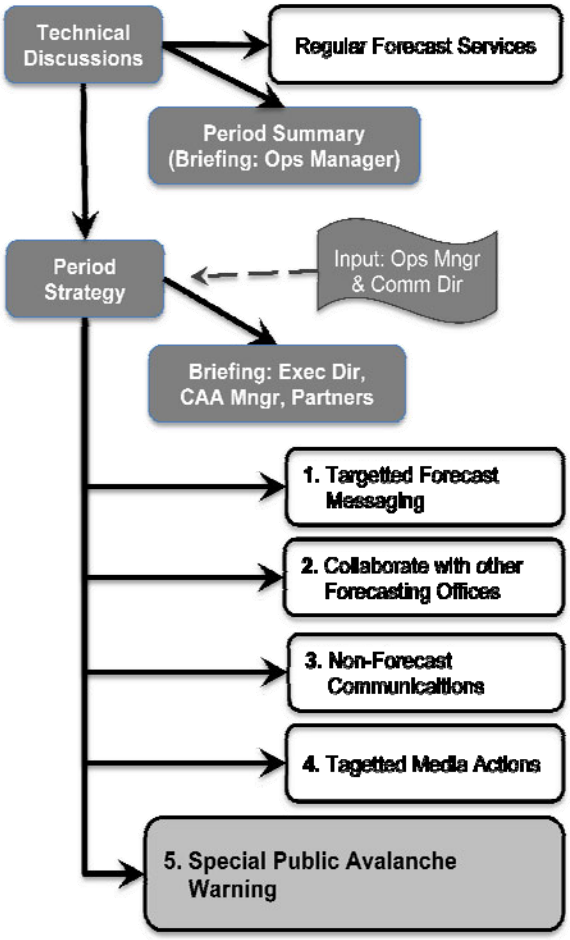

Figure 1: CAC operational procedures for non-forecast communications and warnings supported by long-range outlooks.

This approach represents increasing levels of warning up to our highest alert – Special Public Avalanche Warnings (Kelly et al. 2006). It also presents a progression in which we increasingly "*push*" messages to non-regular users, and even the general public at large. As forecasters judge the risk of avalanche accidents increasing, we tend to transition efforts away from "preaching to

the converted" – those who likely already understand the developing situation – to casting a broader net in order to catch people who don't normally "*pull*" information from regular distribution channels like our website.

Our experience over the past several years is that we've adopted an effective suite of communication products; however, it takes time to develop messages, to collaborate with partners, and to execute plans far enough in advance for public recreationists to assimilate the CAC's advice. Three to five day lead-time improves the quality of our products and ultimately the initiatives' success.

5. ASSESSMENT

Long-range avalanche forecasts support many facets of the CAC's work. Extending forecaster thinking to 10 days in a structured manner strengthens collaboration with avalanche professionals working in the field, it improves regular avalanche safety services including Public Avalanche Forecasts, it bolsters our ability to provide these services with adequate lead-time, and it's an avenue to keep managers informed and involved of the forecast office's high level thinking.

Recognizing the limitations of these long-range outlooks is critical; don't ask for too much! Reliable, sharp weather forecasts with long lead times are simply not possible, if for no other reason than errors grow over time. Then of course, uncertainty compounds when a (avalanche) forecast is derived from a (weather) forecast.

The CAC's Long-Range Forecasts rely heavily on probability weather forecasts – namely ensemble forecast products. Ensemble outputs generally provide a range of scenarios that may occur as well as the most likely outcome. One needs to interpret the uncertainty presented in these weather forecast products, which is akin to understanding probability distribution functions. Uncertainty doesn't render long-range outlooks (weather or avalanche) worthless, but it does preclude using simple notions like "right vs. wrong" to assess performance (Doswell & Brooks, online). According to Doswell & Brooks "This is the price one pays for the added flexibility and information content of probability forecasts."

By working within their limitations, Long Range Outlook's are proving a useful tool to address some of the CAC's particular challenges.

6. FUTURE DEVELOPMENT

Ideas for further development of our long-range forecasting programme include:

- Verification: to better understand the accuracy, strengths, and shortcomings. Of particular interest is assessing how many days out can we look before uncertainty increases to where it's rendered ineffective.
- Forecaster Training: to improve our understanding and interpretation of ensemble weather products specifically, and our grounding in the theories and practices underlying probabilistic forecasting in general.
- Improving the content distributed to public users of our avalanche forecasts and InfoEx™ submissions for professional colleagues.

7. REFERENCES

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