Comparing regional forecasts of avalanche danger with local "nowcasts" – First results

Bruce Jamieson[1], Alan Jones[2] and John Kelly[2]
[1]Dept. of Civil Engineering, University of Calgary
[2]Canadian Avalanche Centre, Revelstoke, BC

1. Introduction

One way of assessing a regional bulletin is to compare the forecast danger level with local observations, stability ratings or danger ratings (Schweizer et al., 2003). In this article we use this approach to explore the effect of spatial and time scales on the accuracy of regional forecasts. University of Calgary researchers provided the local danger ratings that are compared to regional danger ratings. This study is a spin-off from the Canadian Avalanche Association's Avalanche Decision-making Framework for Amateur Recreationists (ADFAR) project.

2. Regional bulletins

Two scales of regional bulletins were used as shown in Figure 1: The Canadian Avalanche Centre's (CAC) bulletin for the South and North Columbia Mountains (approx. 45,000 km^2 and 60,000 km^2, respectively) and Parks Canada's bulletin for the highway corridor through Glacier National Park (GNP, approx 450 km^2). The forecast regions for the South and North Columbia Mountains are approximately a hundred times larger than the GNP forecast area. (See Haegeli and McClung (2003) for a discussion of the scale of avalanche activity patterns in the Columbia Mountains.)

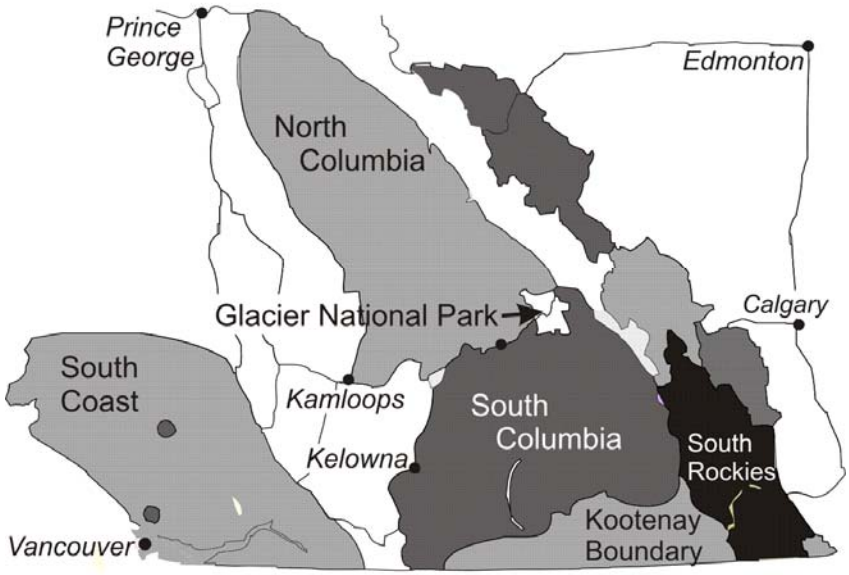

Figure 1. Map of forecast areas for Canadian Avalanche Centre and for Glacier National Park.

The GNP bulletin is produced each morning in the winter for the current day and for each of the following two days. The CAC bulletin is produced at least three times per week, occasionally more frequently. In the afternoon, the danger level is forecast for each of the following two or three days. Both the CAC and the GNP bulletins rate the avalanche danger separately for the alpine, tree-line (TL) and below treeline (BTL) areas. The danger is rated as either Low (1), Moderate (2), Considerable (3), High (4) or Extreme (5). The numbers for the danger ratings are currently not used in Canadian bulletins, but are used in some European countries and in this study. In addition to the danger ratings in each bulletin, avalanche forecasters consistently provide a paragraph or two of text, often to explain how the weather and snow conditions are contributing to the avalanche danger, and to discuss the avalanche danger in terms of the terrain.

3. Local "nowcast"

The observations for this study were made between 12 January 2005 and 14 April 2005. On each of 34 observation-days, University of Calgary researchers selected a sheltered site at or below tree-line. Usually on touring skis in teams of two or three, they traveled to the site and observed a detailed snow profile, at least two compression tests noting the fracture character, and usually a rutschblock test noting the Release Type (Schweizer and Wiesinger, 2001). They made other observations of snow stability and avalanches while traveling to and from the site. Also, they had access to weather, snowpack and avalanche observations from the hosting operation and from neighbouring avalanche safety programs. Using *all* available information, a *danger rating for the drainage and the current day*, called the local "*nowcast*", was selected by consensus for tree-line and or below tree-line—provided this could be done with confidence. Although on some days field staff were aware of the regional danger ratings, local field observations strongly influenced the local nowcast, as explained in the next section. On most days, ratings were recorded for both treeline and below tree-line, yielding two cases per day. The snowpack and avalanche experience of the researchers was typically less than that of CAC or GNP forecasters; however, this likely did not affect the ratings which required little extrapolation over time or space, and were reached by consensus between at least two people. During the discussions leading to the local nowcast, a systematic difference in ratings between those with more and less experience was not apparent.

In this study, the local nowcast is the reference danger rating to which the regional rating is compared. The local nowcast and the regional forecast danger rating are expected to differ in many cases because the CAC and GNP forecasters are extrapolating over time and over areas much larger than the drainage scale of the local nowcast.

4. Results

Occasionally, the regional forecast or the local nowcast for treeline or below treeline involved more than one rating, e.g. "moderate increasing in the afternoon", or "moderate with areas of considerable". To simplify the analysis—and not because we question the relevance of such ratings—these two-level or transitional ratings were excluded, leaving 25 local nowcasts in Glacier National Park, six in the Dogtooth Range of the North Purcells, and 25 in the Cariboos near Blue River BC. These were paired with regional danger ratings as shown in Table 1. Because of differences in spatial scale, the 25 data from Glacier National Park were assessed separately from the 31 data from the North Purcells and Cariboos. The distributions of the regional ratings that were paired with nowcasts are shown in Figure 2. We used the GNP ratings prepared on the morning of each

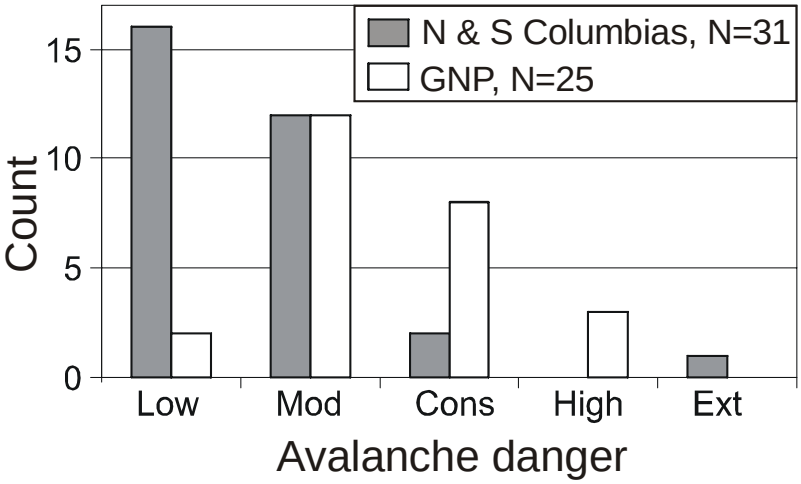

Figure 2. Distribution of danger ratings when corresponding local nowcasts for tree-line or below tree-line were available.

nowcast. Ratings for the day of the nowcast that were produced one or two days prior to the nowcast are analyzed in the next section.

Table 1: Summary of data for comparing local nowcast with regional forecasts

Number of days	**Number of cases**	**Sites for local nowcasts**	**Forecast region** (Fig. 1)	**Source of regional forecast**
5	6	North Purcell Mountains	South Columbia Mountains	Canadian Avalanche Centre (CAC)
16	25	Cariboos near Blue River, BC	North Columbia Mountains	Canadian Avalanche Centre (CAC)
13	25	Highway corridor in Glacier National Park	Highway corridor in Glacier National Park	Parks Canada

For each nowcast paired with a regional danger rating, the difference was calculated by subtracting the number of the danger rating for the local nowcast from the number of the danger rating from the regional forecast. A positive difference indicates that the regional danger rating was higher than the local nowcast, and negative difference indicates that the regional danger rating was lower than the local nowcast. The distributions of the differences are plotted in Figure 3. The number of non-zero differences and the experience of making local nowcasts suggests the field teams were strongly influenced by local observations.

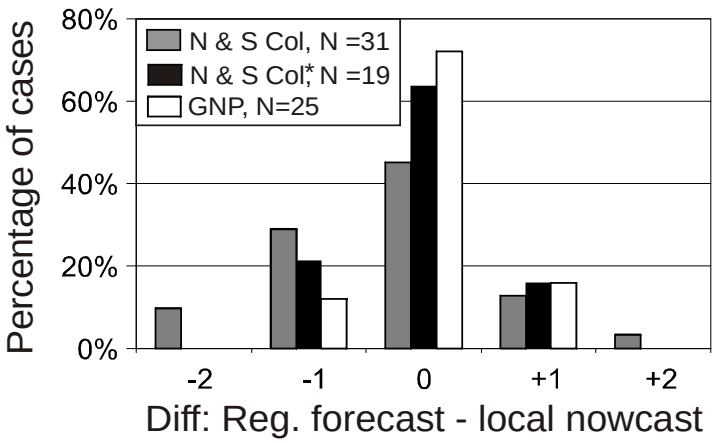

Figure 3. Relative frequency of differences between danger rating from the regional forecast and from the local nowcast for Glacier National Park (GNP) and for North and South Columbias. For the Columbias, the gray bars include twelve cases in which the regional forecasts identified factors contributing to higher danger in the sub-region of the local nowcast and the black bars exclude these cases.

Notably, Figure 3 shows that in 72% of cases the GNP forecast agreed with the local nowcast (difference of 0) whereas the CAC forecast agreed with the local nowcast in 45% of cases. The CAC forecasts involve some differences of ±2 whereas there were no cases in which the GNP forecast differed by ±2 from the local nowcast. The greater agreement of the local nowcasts with the regional forecast in GNP could be due to various factors including the smaller scale of the GNP forecasts compared to the CAC forecasts and/or to the shorter time scale (i.e. higher frequency) of the GNP forecasts. All of the GNP forecasts used in Figure 3 were prepared the morning of the nowcast whereas 58% and 42% of the CAC forecasts were prepared one day and two days ahead of the local nowcasts, respectively. This is discussed further in the section on comparing the effect of spatial and time scales

Also, notable in Figure 3 is that 16% of GNP forecasts rated the danger higher than the local nowcasts whereas 12% rated the danger lower than the local nowcast. This difference of 4% is due to only one case. Surprisingly, CAC forecasts in which the regional danger rating was less than the local nowcast (gray bars in Figure 3) occurred in 39% of cases—more than twice as often as the cases in which regional rating exceeded the local nowcast (16%). This is inconsistent with forecasters "erring on the side of caution" as they extrapolate avalanche danger over space and time because of the high consequences of avalanche involvements.

There are at least two reasons for this *apparent* under-estimation of avalanche danger by the CAC regional ratings. First, the three differences of -2 occurred on 22 March (TL and BTL) and 23 March (TL) in the Cariboos. On all of these three cases, the text part of the bulletin for the North Columbias stated "Up to 80 cm of snow fell in the last storm, with highest amounts in the Cariboos". In five of the nine cases in which the difference was -1, the sub-region of the local nowcast (Cariboos or North Purcells) was identified in text as having received more snow, more wind or had a poorer bond to a crust compared to most areas within the forecast region. This highlights the importance of the text part of the bulletin and the potential of smaller forecast areas to improve accuracy. There were a total of twelve cases in which the text part of the bulletin identified the sub-region of the local nowcast as having conditions favourable to higher danger: the eight cases identified above, plus two cases in which the local nowcast was the same as, and two cases in which the local nowcast was lower than, the regional danger rating. Excluding these twelve cases leaves three cases in which the regional danger rating was higher, and four cases in which the regional danger rating was lower than the local nowcast. Also, the frequency of cases in which there is no difference increases to 63% for the North and South Columbias (black bars in Figure 3), which is closer to the 72% calculated for GNP.

The second reason for the apparent under-estimation of avalanche danger by the CAC regional ratings involves the days chosen for the observations. For four of six cases in the North Purcells, the danger rating was low for the South Columbia Mountains, and for 12 of 25 cases in the Cariboos, the danger rating was low for the North Columbia Mountains (Figure 2). When the danger rating is low, the local nowcast cannot be lower and hence the distribution of the difference is truncated, i.e. each difference has to be 0 or negative. (There was only one case in which the observations were made when the regional danger rating was extreme and in this case the local nowcast was also extreme.) Considering these two factors, there is no evidence of systematic under-estimation of avalanche danger in the CAC forecasts.

5. Effect of forecast time

Fortuitously, the GNP regional forecast for each observation day was available in the morning of the observation day, the previous day and two days previously. This allows the local nowcast to be compared with regional forecasts that were prepared zero, one

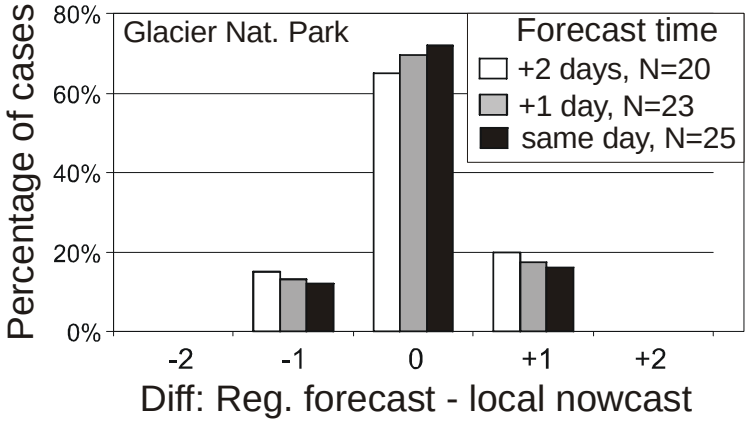

Figure 4. Relative frequency of differences between the Glacier National Park danger rating and the local nowcast. The number of days with no difference increases by 7% when the forecast time is reduced from two days to the same day.

and two days ahead, as shown in Figure 4. The percentage of cases in which there is no difference between the regional forecast and local nowcast increases from 65% to 70% to 72% as the forecast time decreases from two days to one day to less than a full day. At each of the three different forecast times, there are four cases with a positive difference and three cases with a negative difference.

6. Comparing the effect of spatial and time scales

Ignoring the comments about the spatial distribution of avalanche danger in the text part of regional bulletins, the differences in danger ratings between the regional forecast and local nowcast can be assessed to cautiously compare the effect of spatial and time scales. One and two days ahead, the GNP rating agrees with the local nowcast in 65% and 70% of 25 cases, respectively. Also one or two days ahead, the CAC forecast danger rating agrees with the local nowcast in 45% of 31 cases. Consequently, the GNP regional forecast agrees with the local nowcast 20% to 25% more often than the CAC forecasts with similar forecast time, and the improved accuracy by decreasing the GNP forecast time from two to one days or one to zero days is 2% to 5%. Hence the difference in spatial scale between the large forecast regions of the Columbia Mountains and the smaller forecast region within Glacier National Park appears to have greater effect on the accuracy of the bulletin than would be achieved by reducing the average forecast time by a day. This result must be interpreted cautiously since

1. the datasets are small.
2. there are differences in the distributions of danger ratings for the forecast regions. Specifically, the CAC dataset involves an unusual number of low ratings (Figure 2) which skews the distribution of differences.
3. the density of weather stations in Glacier National Park is greater than most areas of the CAC forecast regions for the North or South Columbia Mountains.

As part of the spatial scale effect, it is difficult for CAC forecasters to be as familiar with many sub-regions of the North or South Columbias as the GNP forecasters are familiar with the highway corridor in Glacier National Park. However, CAC forecasters have shown they can often identify sub-regions such as the North Purcells or Cariboos when the weather or snowpack contributes to greater avalanche danger. Consequently, there is more potential for improved accuracy of the danger rating of the bulletin by decreasing the size of some forecast regions—provided there are sufficient weather and snowpack observation sites—than by increasing the frequency of the bulletin from three to, say, five times per week.

7. Summary

Based on data from the winter of 2004-2005 in the Columbia Mountains, 56 drainage-scale ratings of current avalanche danger (local nowcasts) were compared with regional ratings of avalanche danger prepared zero, one or two days in advance. For the smaller forecast region (approx. 450 km^2), the agreement of the regional danger with the local nowcast increased from 65% to 72% as the time of the forecast decreased from two days ahead to the morning of the nowcast, showing improved forecast accuracy with decreasing forecast time. For two much larger forecast regions (approx. 45,000 and 60,000 km^2), the regional danger rating and the local nowcast only agreed on 45% of cases although the text portion of the bulletin often identified sub-regions where the weather or snowpack was contributing to locally higher avalanche danger.

This indicates the importance of using the text portion of the bulletin in addition to the danger rating. It appears that danger rating part of the forecast for the larger regions has the potential to be improved more by reducing the size of the forecast regions (and hence increasing the number of forecast regions) than by increasing the frequency of forecasts from three times per week to, say, five times per week.

These effects of the time and spatial scale will be reassessed after the winter of 2005-06 when more local nowcasts are available from the Coast Range and the Rocky Mountains.

Acknowledgements

For meticulous snowpack observations, we thank Paul Langevin, Antonia Zeidler, Ken Matheson, Cam Campbell, Laura Bakermans, James Floyer and Dave Gauthier. The study relied on the logistical support and advice from the Avalanche Control Section of Glacier National Park and from Mike Wiegele Helicopter Skiing. Thanks to Pascal Haegeli, Susan Hairsine and Clair Israelson for encouragement and funding for the field work part of this study under the CAA's ADFAR project. For funding to analyze these data, Bruce Jamieson is grateful to the Natural Science and Engineering Research Council of Canada, the BC Helicopter and Snowcat Skiing Operators Association, the Canadian Avalanche Association (CAA), Mike Wiegele Helicopter Skiing, Canada West Ski Areas Association, the Canadian Avalanche Foundation and the Canadian Avalanche Centre.

References

Haegeli, P. and D. McClung. 2003. Avalanche characteristics of a transitional snow climate—Columbia Mountain, British Columbia, Canada. Cold Regions Science and Technology 37(3), 255-276.

Schweizer, J., K. Kronholm and T. Wiesinger. 2003. Verification of regional snowpack stability and avalanche danger. Cold Regions Science and Technology 37(3), 277-288.

Schweizer, J., and T. Wiesinger. 2001. Snow profile interpretation for stability evaluation. Cold Regions Science and Technology 33(2-3), 179-188.