AN OVERVIEW OF AVALANCHE FORECASTING IN NORTH AMERICA

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ABSTRACT: Regional avalanche forecast centers provide valuable public safety services. They are responsible for monitoring and forecasting avalanche danger in back-country areas and along highway corridors. In North America the first center was founded in 1962, followed by the creation of others in the 1970s, 1980s, and early 1990s. Currently nine regional avalanche centers operate in North America—two in Canada and seven in the United States—and forecast for areas that range in size from 10^4 to 10^5 km^2.

The author conducted a survey to determine the methods, operations, and technologies used by the avalanche centers of North America. This survey provided information on the scope and size of the centers and methods of data gathering (manned observation sites, automated data sites, stability tests, and data transmission), analyzing and decision-making (computer software, models, numerical or statistical applications), and disseminating forecasts.

The consensus that emerged from the survey is that the centers use the latest technologies to gather and receive data (such as automated weather stations) and to disseminate forecasts (such as modem, fax, e-mail, and the Internet). However, few technological aids are used in data analysis and decision-making. Rather, all the centers rely on conventional methods of avalanche forecasting based on experience, intuition, and knowledge of prevailing local terrain, weather, and snowpack conditions.

Keywords: Avalanche forecasting, forecast methodology, North America

1. INTRODUCTION

To gather information for this paper, the author conducted a survey of the avalanche forecast centers of North America. The intent was first to learn the history, operations, and organizational details of these programs, and second to learn the methods and technologies used. This paper is an update of one researched in 1996 and presented at an avalanche symposium in November, 1996, in Davos, Switzerland.

1.1 *Regional Avalanche Centers*

The first regional avalanche forecast program in North America began in 1962 at Rogers Pass, British Columbia. This was the Snow Research and Avalanche Warning Section of Parks Canada whose mission was to protect a treacherous 40-km section of the Trans-Canada highway over Rogers Pass. The first program in the United States began in 1973 with the formal opening of the US Forest Service's Colorado Avalanche Warning Program. This was the first program dedicated to forecasting for the safety of back-country recreationists.

Additional programs soon followed. In Canada the BC Highways Program was created in 1976 following an avalanche disaster on Highway 16 near Terrace that destroyed several buildings and killed seven people. In the US the Northwest Avalanche Center opened in 1976, covering Washington and Oregon. Then came the Utah Avalanche Forecast Center in 1981. In 1983 the Colorado program was abandoned by the Forest Service, and it was taken over by the State of Colorado. These three state-wide programs were then followed by regional programs in central Idaho, northwest Wyoming, southwest Montana, and central California (figure 1).

Meanwhile in the Canadian Rockies, a booming heli-ski industry created its own forecast program—as a necessity for doing business. Additionally, Parks Canada began forecast services for back-country recreationists. The heli-ski companies and Parks Canada provide their

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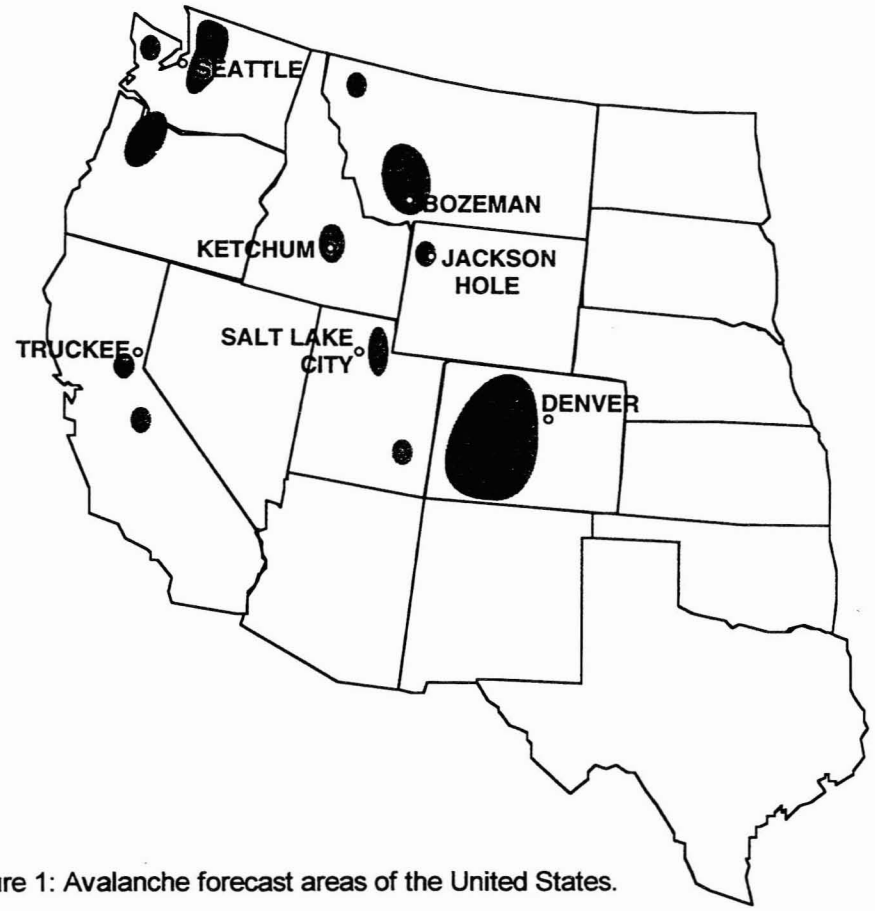
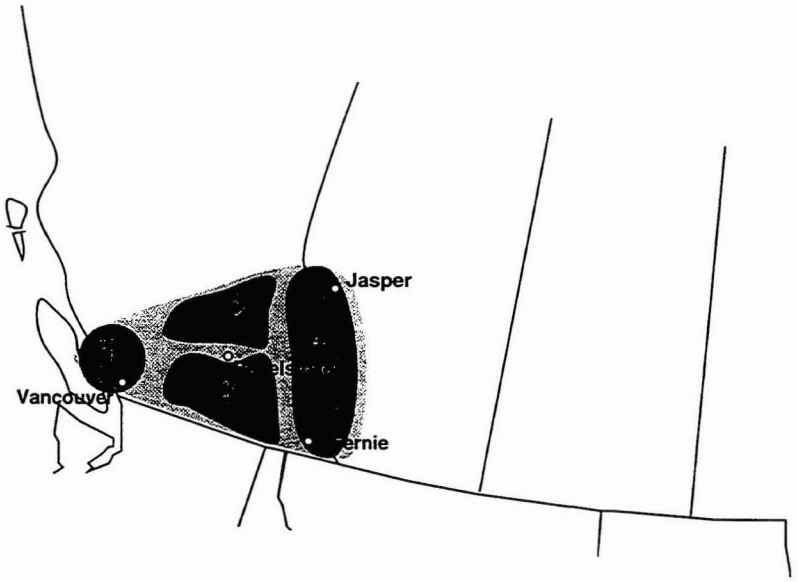


Figure 1: Avalanche forecast areas of the United States.



1. South Coast Mountains and Vancouver Island
2. North Columbia Mountains
3. South Columbia Mountains
4. Rocky Mountains

Figure 2: Avalanche forecast areas of Canada.

data to the Canadian Avalanche Centre. The CAC then reworks the individual forecasts from the providers and coordinates the broadcasting of avalanche information to the public. (For purposes of this paper, rather than list all the heli-ski companies and National Parks as separate programs, the author has listed the Canadian Avalanche Centre as the coordinating agency.)

The Canadian programs are located in Alberta and British Columbia in what is called the "Canadian Avalanche Triangle." As you might guess, this is a triangular area with the town of Jasper as the northern point, Fernie the southeast point, and Vancouver Island the southwest point. Within the triangle are contained 85% of the BC Highways Program and four areas of back-country forecasting coordinated by the Canadian Avalanche Centre. These areas are the South Coast Mountains and Vancouver Island; North Columbia Mountains; South Columbia Mountains; and Rocky Mountains (figure 2). Parks Canada, BC Highways, and numerous ski resorts and heli-ski companies contribute their data to a proprietary computer system called InfoEx, which is managed by the Canadian Avalanche Centre.

Table 1 provides organizational details of the avalanche centers of North America.

1.2 *Conventional Avalanche Forecasting*

McClung and Schaerer (1993) offer the following definition: "Conventional avalanche forecasting refers to prediction of current and future snow stability by means of information and data from diverse sources largely without the aid of analytical techniques (formal numerical procedures) or encoded symbolic logic (e.g., expert systems). [It] ... consists of assimilating the relevant information (measurements, observations, weather forecast) and using it to formulate a forecast based on experience, intuition, and local knowledge of the mountain range."

All the regional avalanche centers of North America began with conventional forecasting techniques as their guiding methodology, obviously because of its solid scientific basis and time-proven effectiveness. If the method has a fault, though, it is in its reliance in the human element. For example, it requires forecasters with many years of experience, demands accurate recall of past events, requires human analysis of potentially large amounts of data, and is prone to subjective interpretation of the data.

Since the creation of some of the avalanche centers, many technological advances have occurred that may have (or have proven to have) value as forecast tools, and can replace some of the human element. Therefore, another purpose of my survey was to determine to what extent technological advances are used by the avalanche centers of North America.

1.3 *Lack of Research Funds*

The state of the art of avalanche forecasting is dependent, to a considerable degree, on the amount and type of research being conducted. In the US, very little research is being done because of a lack of federal and state funding. Therefore, the regional avalanche forecast centers must rely on research and technology to be imported, especially from Switzerland, France, and Japan, and to a smaller degree from Canada.

In Canada, the situation is slightly better. Some years ago, the National Research Council was closed, and federal funding for avalanche studies was greatly diminished. Recently, though, there have been two positive steps: (1) Dave McClung created and sits in a Research Chair at the University of British Columbia, and (2) Bruce Jamieson at the University of Calgary is able to conduct research with funds primarily provided by the BC Heli and Snowcat Skiing Operators Association. Additionally, the Canadian Avalanche Centre has received periodic grants for research studies.

Despite the lack of funds, some valuable research for forecasters has been published recently by North American authors. This includes McClung and Schaerer (1993), Jamieson (1995), Mears (1995), Birkeland, Johnson, and Herzberg (1996), and Birkeland, Johnson, and Schmidt (1998), plus numerous studies published in the proceedings of the International Snow Science Workshops.

1.4 *Technological Advances*

The following is a partial list of products, systems, or methods available to the avalanche forecaster. Almost all have become available since the inception of regional avalanche centers in North America.

- Remote automated weather data systems

Table 1: Avalanche Centers of North America – Organizational Details

Program (Director)	**Forecast Area**	**Size of Area (km^2)**	**Central Office**	**Number of Fore-casters**	**Managing Agency**	**Other Primary Sponsors**
UNITED STATES						
Colorado Avalanche Information Center (Knox Williams)	All Colorado Mountains	65,000	Denver	10	State of Colorado	CDOT Ski industry USFS
Northwest Weather & Avalanche Center (Mark Moore)	Washington, N. Oregon, S. BC Canada	50,000	Seattle	4	US Forest Service	WDOT Wash. Parks & Rec BC Highways Nat. Park Service Ski industry
Utah Avalanche Forecast Center (Bruce Tremper)	N. Utah & LaSal Mts.	13,000	Salt Lake City	5.5	US Forest Service	State of Utah Salt Lake County
Central Idaho Avalanche Advisory (Doug Abromeit)	Central Idaho	9,000	Ketchum	3	US Forest Service	
Gallatin Nat. Forest Avalanche Center (Karl Birkeland)	Southwest Montana	10,000	Bozeman	3	US Forest Service	
Bridger-Teton Nat. For. Forecast Center (Jim Kanzler)	Northwest Wyoming	15,000	Teton Village	3	US Forest Service	
Sierra Avalanche Warning Center (Bob Moore)	Central California	6,500	Truckee	1	US Forest Service	
CANADA						
Snow Avalanche Program BC Highways (Jack Bennetto)	All BC Highways	N/A	Victoria	30	BC Ministry of Trans. & Highways	
Canadian Avalanche Centre (vacant)	Canadian Avalanche Triangle	110,000	Revelstoke	2 + many with Parks & heli-ski	Canadian Avalanche Centre	Parks Canada Heli-ski industry

- Improved National Weather Service numerical forecast models, such as the NGM, Aviation, ETA, and MesoETA
- Nearest neighbor models
- Expert systems such as NXLOG
- Avalanche Hazard Indexes for highways
- Stability tests such as shovel shear, rutschblock, compression, and stuffblock
- Geographical information systems (GIS)
- E-mail and the Internet

2. METHODOLOGY AND TECHNOLOGY USED

2.1 *Data Gathering (Input)*

Table 2 lists the methods of data input and transmission to each center. All centers use a combination of manned observation sites and remote automated weather stations. All the US centers make use of the Snotel system – a network of automated data sites throughout the western US maintained by the Natural Resources Conservation Service (formerly the Soil Conservation Service). The Wyoming center uses closed-circuit television to view its snow stake. Additionally all the US centers rely on the National Weather Service for weather forecast data, though the Montana and Sierra centers also get weather data via the Internet. The Canadian centers get weather forecast data from Atmospheric Environment Services of Environment Canada and some private suppliers.

All the standard field tests of snow stability are used, but there seems to be a consensus to use the shovel shear for locating weak layers and the rutschblock for determining stability. The Montana center likes the stuffblock test – understandable since this test was developed by that center. The shear frame is used only in Canada, mainly by the BC Highways forecasters.

All the centers use multiple means to transmit data from field sites to the center. All use voice telephone, and most use fax and e-mail as well. Four of the US centers and the Canadian centers use a computer-modem system, such as to a bulletin-board.

2.2 *Decision-making (Analysis)*

Table 3 summarizes some of the important decision-making and disseminating methods revealed by the survey. It shows that data-logging in the centers is done both by hand and by computer software. Six of the centers log incoming data (especially from manned field sites) onto hand-written forms. Some centers enter these data into a database at a later time. The Utah center uses a National Weather Service GIS for storing all its surface data. Seven of the centers use computer software for plotting snow pit data, with Snowpro being the most popular program. Two of the centers indicated they use software (Visual Log) for storing and displaying data from automated weather stations.

GIS is used operationally only by the Utah center, as described above, to store and plot surface weather data. The Colorado center has used GIS for two research studies of avalanche path behavior but does not use it in daily operations. Several other centers indicated on the survey that they have future plans to use GIS for data analysis. Two centers – Colorado and the Northwest – use orographic precipitation models as guidance for their daily quantitative precipitation forecasts (QPFs). These models have proven their value over 20 years of use. They are quick, simple, and (sometimes) very accurate.

The only nearest neighbors model in North America is used by the Wyoming center. It has been used for more than 12 years and provides the forecasters with additional guidance.

The BC Highways Program has used an expert system on Kootenay Pass for 5 years. Developed by David McClung and the British Columbia Institute of Technology, this system uses a computer to aid conventional forecasting.

What stands out in the survey is that *every center relies totally on the methodology of conventional avalanche forecasting.* While new technology is used for data gathering and transmission, it is not used in the decision-making process (with the exception of a nearest neighbors model and an expert system used by two centers, as discussed above.)

2.3 *Data Dissemination (Output)*

Table 3 also lists the methods used by the centers to disseminate their forecasts internally within the program or externally to their clients and the public. Recorded voice messages on public hotlines are used by all centers (except BC Highways which does not disseminate to the public), but modern technology in the form of fax,

Table 2: Methods of Data Gathering and Transmission

Center	Number of manned observation sites	Number of automated stations	Other sources of data	Source of weather forecast data	Field stability tests	Data transmission from field to center
UNITED STATES						
Colorado	35	7	Snotel	National Weather Service (NWS)	SS=shovel shear RB=rutschblock	phone, fax, e-mail
Utah	13	15	Snotel	NWS	SS, RB, compression	phone, computer
Northwest	12	17	Snotel	NWS	RB	phone, e-mail, fax, computer
Idaho	5	2	Snotel	NWS	RB	phone, e-mail, fax, computer
Montana	3	6	Snotel	NWS, Internet	RB, stuffblock	phone, e-mail, fax, computer
Wyoming	3	0	Snotel, Slow scan TV	NWS	SS	phone, e-mail, fax, computer
California	8	0	Snotel	NWS, Internet	–	phone, fax
CANADA						
BC Highways	37	60		Environment Canada	All tests, shear frame	phone, e-mail, fax, InfoEx
Canadian Avalanche Centre	55	0		Environment Canada, Univ. of BC	All tests	fax, e-mail, InfoEx

e-mail and the Internet are also now used widely by all centers.

One unique system of dissemination is the Canadian Avalanche Centre's InfoEx. This proprietary system provides a computer-based information exchange service for all subscribers and has tied together the avalanche practitioners employed by highway operations, parks, ski resorts, and back-country ski operations. Current weather, weather forecasts, remote weather station data, and snowpack data and stratigraphy are available on InfoEx from many sites within the Canadian avalanche triangle.

3. SUMMARY

3.1 *In the US: Fatalities, Forecasting, and Funding*

Avalanche deaths are on the rise in the United States: they have risen from 14 a year in the 1980s to 24 a year in the 1990s. Clearly there is a need for back-country avalanche forecast programs. Currently seven regional avalanche forecast centers operate in the western US. Collectively the centers employ 30 forecasters. The US Forest Service manages all the centers except the Colorado Avalanche Information Center.

A lack of funding is a chronic problem faced by all the centers. There is inadequate government funding (at both the federal and state levels) to maintain these programs, so their survival depends on alternative and creative means of finance. This includes grants and donations, fund raisers, corporate financing, grassroots (individual) support, and fee-for-service billing.

3.2 *In Canada: Fatalities, Forecasting, and Funding*

Avalanche deaths in Canada, too, have risen – from 7 a year in the 1980s to 10 a year in the 1990s. In Canada there are essentially two programs operating in a large mountainous area of southwest Canada known as the Canadian Avalanche Triangle. One of the Canadian programs is the Snow Avalanche Program run by British Columbia Highways, and the other is a cooperative effort between government (e.g., Parks Canada) and industry (numerous ski resorts and back-country ski guide businesses) and coordinated by the Canadian Avalanche Centre. About 60 forecasters are employed by these programs.

As in the US, stable funding is a chronic problem. Government funding maintains (barely) the programs run by the BC Ministry of Transportation and Highways and Parks Canada. The Canadian Avalanche Centre has been successful in funding its forecasting program with corporate sponsorship and subscription fees to InfoEx.

3.3 *Conventional Forecasting – by Choice and Necessity*

Technology advances the state of the art of all applied sciences, and in the field of avalanche forecasting, technology has greatly improved the methods by which the centers of North America gather and receive data and disseminate their forecasts. But new technology is scarcely used for analysis and decision-making. Rather, all the centers rely almost totally on conventional methods of avalanche forecasting based on experience, intuition, and local knowledge.

There are several reasons this is so.

- Conventional forecasting is a proven method. It works well when used by experienced forecasters.
- Regional forecast centers must analyze large amounts of weather, snowpack, and avalanche data gathered over large tracts of mountainous terrain. This compounds the problem of trying to use numerical techniques such as nearest neighbors, or expert systems, to aid analysis.
- The decision-making process in avalanche forecasting does not easily lend itself to modeling.
- There is no budget for research and development of new technology to produce a usable, sophisticated computer aid for conventional forecasting.

Let this be the final word: As long as avalanche forecasting remains as much art as science, conventional methods will rule. But if better science – to replace art – can be proven to produce more accurate forecasts, then a new age of forecasting will be upon us, with a technological "expert" to help the human. In other words: Build it and we will come!

Table 3: Methods of Data Analysis and Dissemination

Center	Logging field data	Models used	Forecasting technique	Public hotline calls	Internet, e-mail, and/or BBS hits	Dissemination to clients & public
UNITED STATES						
Colorado	hand, VisualLog, Snowpro	orographic snow model	conventional	85,000	80,000	phone, e-mail, fax, web site
Utah	GIS		conventional	125,000	215,000	phone, e-mail, fax, computer
Northwest	hand, VisualLog, Snowpro	orographic snow model	conventional	30,000	200,000	phone, e-mail, fax, web site, BBS
Idaho	hand, Snowpro		conventional	16,000	2,000	phone, e-mail, fax, Internet
Montana	hand, Snowpro		conventional	13,000	38,000	phone, e-mail, fax, web site
Wyoming	hand	nearest neighbors	conventional + nearest neighbors	88,000		phone, fax, Internet
California	hand		conventional	no counter		phone, fax, computer
CANADA						
BC Highways	in-house database, Snowpro	expert system at Kootenay Pass	conventional + expert system	not available to public	not available to public	phone, fax, InfoEx
Canadian Avalanche Centre	InfoEx input, Snowpro		conventional	100,000	90,000	phone, e-mail, fax, web site, InfoEx

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