Storage and visualisation of relevant avalanche information at different scales

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Abstract: It is the decision-makers' perception of snow stability and how it applies to terrain that determines their decisions about closing a highway, opening additional ski runs, or choosing a descent route. Targeted education and experience have positive effects on human perception, while human biases interfere with objective reasoning. 'Good' decision-makers have developed the ability to use the available information effectively and in an unbiased way to form their perception of the current snow conditions. It is our belief that there are three crucial measures to aid in the unbiased use of information: 1) observation standards; 2) efficient data storage; and 3) meaningful information visualization. This paper presents a number of tools, which can enhance the effective use of data available to avalanche forecasters. SNOWBASE is presented as an efficient database tool to record and access information pertinent to avalanche forecasting in helicopter skiing. SNOWBASE includes tools that allow the visualization of observations of avalanches or usage of explosives on top of images of individual runs. This tool has proven to be of value for the guides' perception of snow conditions and its relation to specific terrain features. Since avalanches are relatively infrequent events, data exchange between operations is very important for avalanche forecasting. A second visualization tool is presented that creates overview maps of information relevant to avalanche forecasters over large areas. Such a tool might be very useful for large operators with numerous individual areas or even national forecasting centers.

Keywords: Avalanche forecasting, perception, database system, data visualization, software

1. Introduction

Avalanche forecasting is a crucial part of helicopter skiing operations. It is done on many different levels throughout a day. In a Canadian Mountain Holidays (CMH) operation, guides discuss general avalanche conditions for entire operations during their morning meetings. Depending on the conditions, the guides collectively decide on what type of terrain is open for skiing on this day. Once in the helicopter, the lead guide decides which runs to go to according to the conditions and her/his observations from the helicopter flight. While skiing, each individual guide constantly analyzes local terrain features for possible avalanche hazards to safely lead their groups. Each day, one guide is designated as the 'Snow Safety Guide' and does not lead groups. The snow safety guide works in the field to make observations pertinent to the assessment of snow stability. Throughout the day she/he updates the other guides about her/his findings. This stepwise procedure clearly shows the evolutionary character of avalanche forecasting (McClung, 2000). The forecast is continuously updated as new information becomes available.

The information accessible for guides at each of these steps is highly diverse. It includes weather data, snowpack factors revealing structural weaknesses, and direct observations of instability such as avalanches or stability tests. Guides process the given information on the basis of their experience, which consists of historical data about similar situations and their personal and subjective assessment. Depending on their personal experience, they interpret pieces of information differently. McClung (2002) was the first to demonstrate the importance of human aspects in avalanche forecasting. It is the guides' perception of snow stability and how it applies to specific terrain features that ultimately determines their go/no-go decisions. In many industrial accidents, the avalanches are triggered by either the guide or one of the skiers in the group (see, e.g., Jamieson and Geldsetzer, 1996). This shows that one possible cause of these accidents is a failure in human perception of either the guide or the guest. They thought the conditions were something different from what they actually were. Targeted education and experience have positive effects on human perception, while human biases interfere with objective reasoning (McClung, 2002). Skilled guides develop an effective

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and unbiased ability to use the available information to form their perception regarding snow stability, choose appropriate safety measures, and safely lead their groups.

Visual representation can have a large effect on how the significance of the available information is perceived by guides. Patterns, trends, and relationships may be made apparent by visual presentation that would have been missed if the information were only presented in a non-visual form. While individual avalanches are relatively infrequent events, avalanche cycles are normally fairly widespread (Hägeli and McClung, in preparation). As a consequence, sharing of observations between adjacent operations becomes crucial for good avalanche forecasting. Services such as the successful Information Exchange (InfoEx) program of the Canadian Avalanche Association (CAA, 2002) have clearly proven the importance of data sharing in this industry. As the data volume becomes bigger, however, the task of processing the available information can become overwhelming for avalanche forecasters. It is our belief that there are three crucial measures to make information processing as efficient and objective as possible: 1) observation standards; 2) efficient data storage; and 3) meaningful data visualization.

First of all, observation standards are necessary to ensure everybody collects and interprets the data the same way. An example is the observation guidelines and recording standards (OGRS) published by the CAA (1995). The document was first published in 1981 to facilitate sound record keeping and information exchange between different avalanche safety programs.

Secondly, it is necessary to have a database system where the relevant data can be entered, stored, and retrieved again in efficient ways. SNOWBASE is an example of such a database system. An overview of this system and its operational use is presented in the second section of this paper.

Thirdly, meaningful visualization can have a powerful effect on the perception of avalanche conditions. Modern computers and communication technology allow incredible possibilities for visual presentation of relevant information in a timely fashion. In section three, two examples are presented of how visualization can help interpret data at different scales.

Comments about the implementation of such systems and ideas for future developments are discussed in the final section.

2. SNOWBASE

Roger Atkins started the development of the SNOWBASE program in 1982 at Alta Ski Lifts, Alta, Utah. The program evolves continually, and CMH has provided the support for this development since 1994. Since the winter season of 1996/97, SNOWBASE has been in operational use in all CMH operations.

CMH is the largest helicopter ski provider worldwide (both in terrain base and number of skier days). CMH operates 11 individual operations in the Columbia Mountains of British Columbia covering a total area of approximately 20,000 km^2 (see Fig. 1 in Hägeli and McClung, 2002). Avalanche forecasting is done independently in each of the eleven operations. Important observations, however, are shared between all CMH areas on a daily radio exchange and all collected data is relayed to the main office in Banff, Alberta, once every day.

SNOWBASE is used interactively during morning and evening guide meetings to record and access information pertinent to the decision making process. This information includes local observations and assessments as well as observations and assessments available via the Internet from other operations or agencies. Time varying information is instantly accessible in visual formats such as time-series graphs of meteorological parameters (see Atkins, 1992). Spatial Information such as the location and extent of observed avalanche activity can be presented as a graphic overlay on a background photograph of the terrain.

A combination of multiple monitors and/or LCD projectors allows all guides present at the meeting to be involved in the recording and assessment of the information in SNOWBASE. Prior to the guide's meeting, the snow safety guide (and/or other guides) record their observations of the day. These observations are reviewed and completed by the entire guiding team during the meeting and a general assessment of snow stability is made by the group. During the morning meeting, the guiding team then assesses specific terrain; which terrain is available for guiding and which terrain is eliminated from consideration for the day.

It is apparent that a great deal of information pertinent to decision-making for travel in avalanche terrain is more subjective than the collection of standard measurements of atmospheric and snowpack parameters. This means that current perceptions of the team members, historical perceptions regarding the terrain and events of the past, and perceptions of other operators and areas regarding the current conditions are all of great importance. Other than a general assessment of snow stability, these perceptions are mostly anecdotal in nature and can be difficult to incorporate effectively in a computer database. SNOWBASE allows such perceptions to be recorded in text form and/or in visual form. To capture this information visually, overlays are drawn on top of background photographic images. Associated text can be accessed via links from these visual elements.

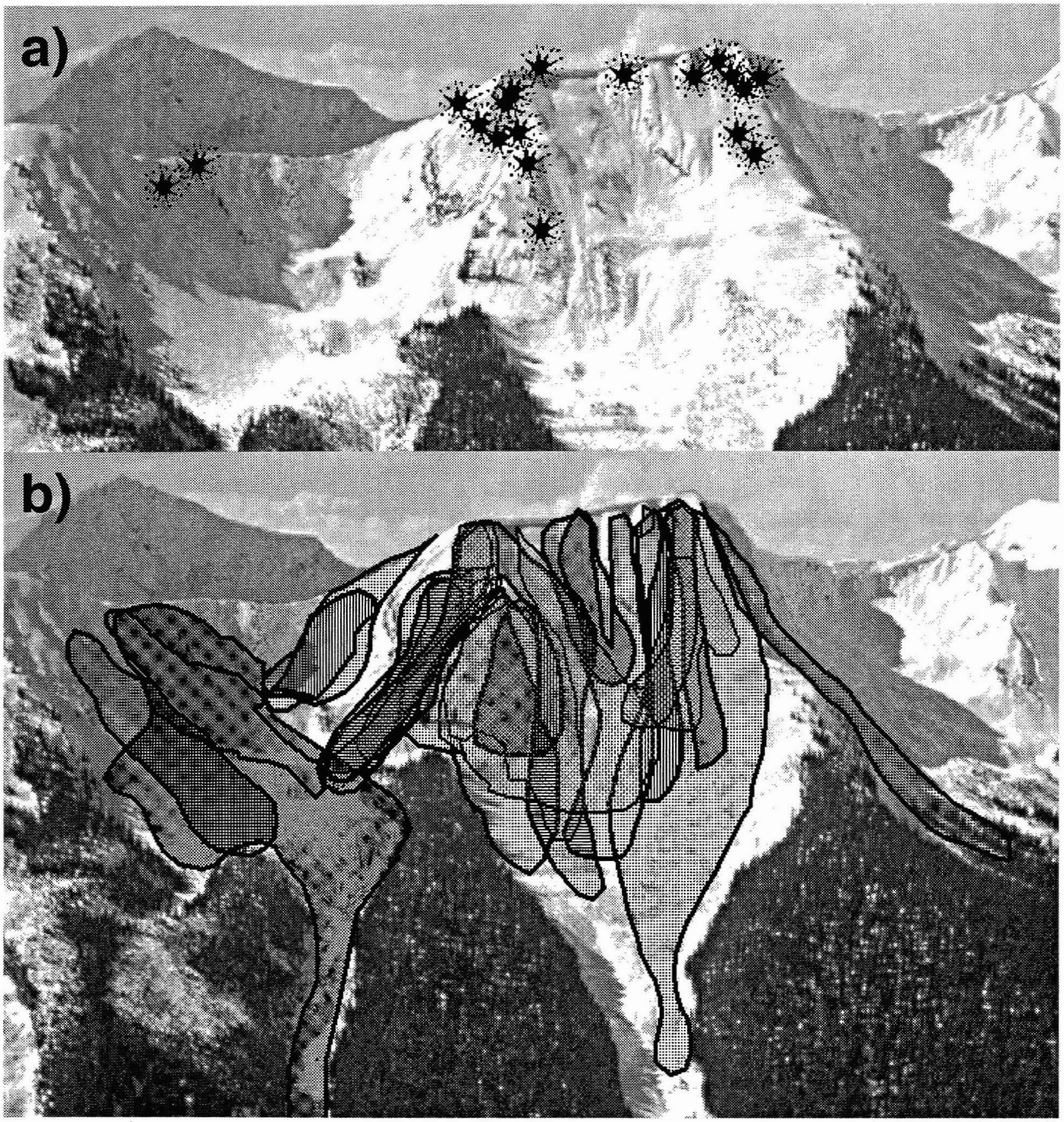

Figure 1: The top panel (a) shows the placements used for explosive control of avalanches on the run 'Graceland' at CMH Adamants from 1998/99 to 2001/2002. The bottom panel (b) shows the extent of the avalanches observed on the same run and during the same period (Most of the avalanches are the direct result of explosives placed as shown in the top panel).

3. Visualization examples

It is our belief that the density and quality of information available in even the best case will never be adequate to support a fully analytical system for determining go/no-go decisions with regard to specific terrain features encountered while traveling in avalanche terrain. This is mainly due to the multi-scale character of the avalanche phenomenon (Hägeli and McClung, 2000). Nevertheless, computer systems are very efficient in analyzing large amounts of information in an objective way. In avalanche forecasting, this works best for numerical data, such as weather observations (see, e.g., McClung and Tweedy, 1994). However, the more anecdotal information that is generally more relevant to human forecasters are very difficult to incorporate into such systems. Therefore human forecasters will always play a central role in avalanche forecasting and it is our opinion that effective visualization is key to facilitate this role.

Two visualization examples are presented in this section. The first examples deals with information regarding an individual ski run, while the second example addresses the other end of the spectrum and displays data over an entire mountain range.

3.1 Photographic Images in SNOWBASE

Included in SNOWBASE are photos of every single run of an operation. These photos are used during morning meetings to discuss possible ski lines under the given conditions and to point out risky terrain features.

Digital cameras are used to record images of significant avalanche events or other interesting features. These images can be incorporated daily into the knowledge base in relationship to the avalanche observations for that day. Such images can also be communicated to other areas via the Internet.

All photographic images in SNOWBASE are stored in a database that allows the images to be related to terrain features such as ski runs and/or related to events such as observed avalanches.

SNOWBASE includes tools that allow overlays to be drawn on top of these background images. For example, the location and extent of each avalanche observation can be drawn over the background image of the terrain. Querying tools allow the selection of the criteria for which overlays are made visible over the background image (Fig. 1). This allows the identification of patterns of both human and natural activity in the terrain. Of course, areas with a high frequency of avalanches are usually easy to identify from natural clues within the terrain itself (slope angles, wind exposure, flagged trees, etc). There is greater value in the ability to capture the location and extent of the more unexpected events that may have come as a surprise at the time. History shows that features in the terrain that may appear non-threatening are sometimes capable of producing unexpected avalanche events and these events are likely to recur, especially if the history of these events is lost. It is valuable to capture a readily accessible visual record of these events so that this information can be passed along to newcomers in an area. It is also valuable to communicate a visual record of unusual events between different operators to enhance the perception of what the current conditions are capable of producing. For example, figure 2 shows an avalanche that ran on a surprisingly low-angle slope. This photograph was taken by digital camera the day of the avalanche and distributed to all CMH areas that evening, thus globally enhancing the perception of the type of terrain capable of producing avalanches at that time!

Figure 2: A photographic record of a low-angle slab avalanche that failed on a surface hoar layer (Photo courtesy of Colani Bezzola).

3.2 Large scale visualization

While SNOWBASE focuses on individual operations, this visualization tool displays overview maps including all eleven CMH operations in order to facilitate large-scale data exchange. The tool was developed by Pascal Hägeli as an extension of ArcView 3.2 (ESRI, 1999). The user can easily display most information stored in SNOWBASE using a CMH menu. Besides the traditional weather charts, overview maps of stability ratings, avalanche occurrences, snow profile observations, as well as skiing usage are available. These overview charts give a general impression of what is happening across the entire operation area. More detailed information can be accessed in an interactive way by using three extra tool buttons (zoom, comments, and time series).

Weather maps can be created for all collected weather variables. The data is too sparse for the calculation of isolines and therefore the values are simply displayed as labels. For certain numerical variables time series can be displayed. The plotting capabilities of ArcView 3.2 are, however, only very limited and the resulting time series plots only show general trends.

Morning and evening stability ratings can be displayed for three different elevation ranges: alpine, tree line and below tree line. Clicking on an individual operation with the comment tool shows additional remarks about stability ratings and general snowpack conditions. The temporal stability development can be displayed with the time series tool.

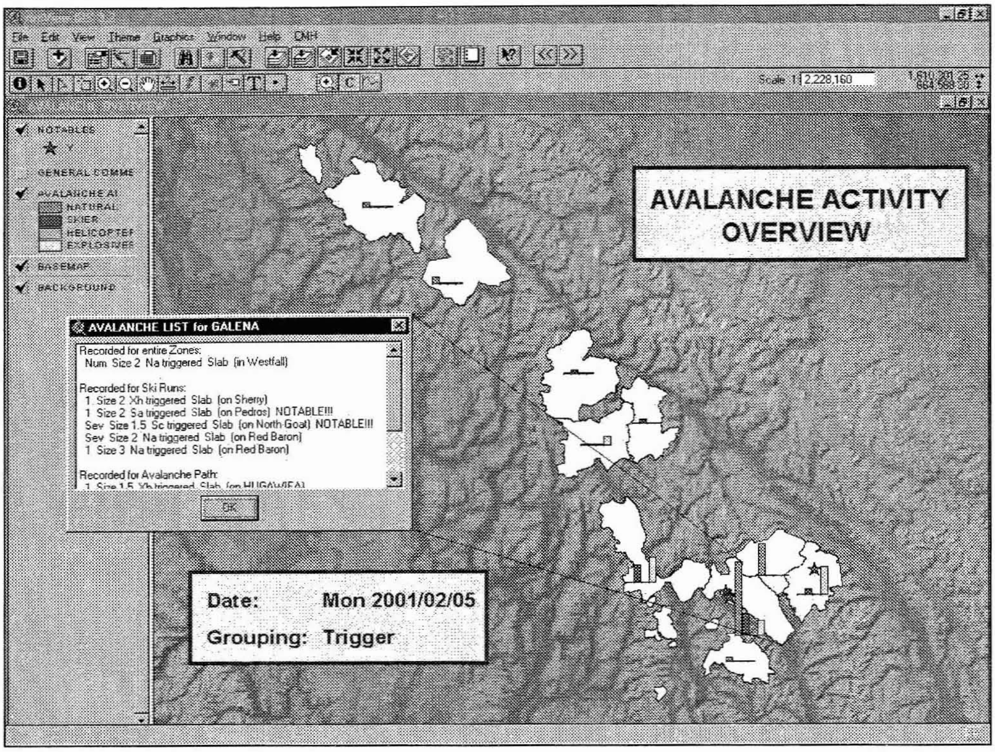

Figure 3: Overview of observed avalanche activity in all CMH operation for February 5th, 2001 with avalanche list for operation Galena. Bar graphs show avalanche activity classified according to the four main trigger groups. Stars indicate individual avalanches with human involvements.

Depending on interest, avalanche activity on avalanche overview maps can be grouped according to avalanche size, elevation range, or trigger (Fig. 3). Avalanches with human involvements are specially marked. The comment tool can be used to display short lists of recorded avalanches in particular operations (Fig. 3). The zoom tool creates new, more detailed maps of individual operations showing the exact locations of the recorded avalanche events.

The program also allows for the tracking of specific weak layers throughout a season. Labels of different avalanche parameters can help analyze activity patterns in detail. If available, information from related snow profiles analyses can also be included in these maps (Fig. 4).

Usage overview maps highlight drainages with skiing activity. Similar to the avalanche overview, the *zoom tool* can be used to have a closer look at the skiing activity of an individual operation (Fig. 5). On these more detailed maps, individual ski runs are colored-coded according to the guides' rating for that day. Runs that have been skied on the day have a pink outline. Clicking on a specific run with the *comment tool* shows how many skiers skied this run (Fig. 5).

The short description of this software shows its capabilities to give a general overview of the conditions over a large area, on one side, and also to allow fast access to detailed information of specific events. Buttons for flipping through maps of consecutive days make it easy for forecasters to visualize trends. This tool could be very useful for large operations with many individual areas, such as CMH, or umbrella organizations like the CAA, where the sheer size of the operation makes it difficult to keep a clear idea of the current conditions and their development.

4. Conclusions

The sharing of avalanche information among safety programs and the increased quantity of freely available weather information in recent years has clearly had positive effects on the general quality of avalanche forecasting. However, the increased amount of information can be overwhelming and make its analysis very challenging. It is our belief that there are three basic measures to ensure an efficient use of the available information: 1) recording standards; 2) database systems; and 3) visualization tools.

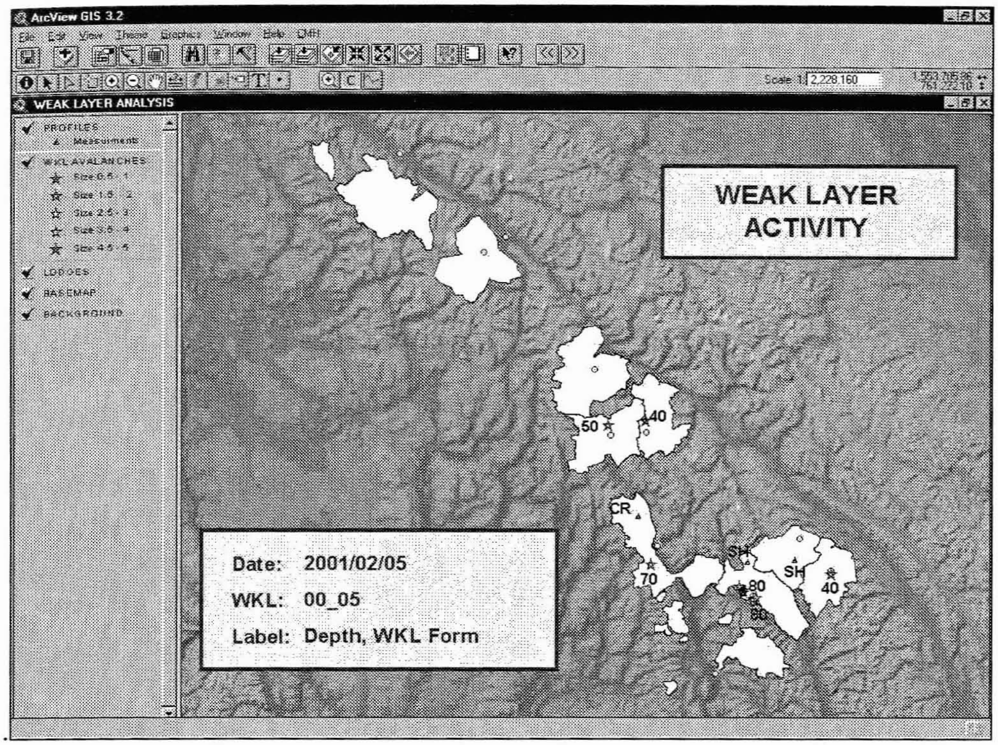

Figure 4: Observed avalanche activity on 00_05 weak layer together with observations in snow profiles on February 5th 2001. Avalanches are labeled with slab thickness while profile locations show observed weak layer form.

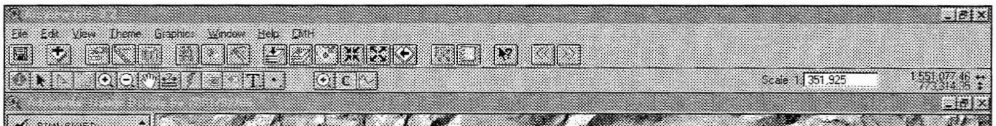

Figure 5: Detail view of Adamants operation showing rating and usage of individual ski runs. Info-box displays number of skiers that have been on this particular run on the day in question.

SNOWBASE was presented as an example of a database system of a helicopter skiing operation. Visual presentation was pointed out to be key in how the significance of information is perceived by decision-makers. Two examples were presented. The first visualization example presented relevant information on the scale of an individual ski run, while the second example displayed avalanche relevant information over large areas.

Tools like those presented have to be tailored to the specific needs of an operation. Although this paper has primarily focused on the application in a helicopter skiing operation, similar tools could be developed for avalanche safety programs of highway operations or ski resorts. For a successful implementation of such a system, two aspects seem to be important. First of all, it seems important that all these individual tools are integrated into one software package. The simplicity and user-friendliness of the entire system are crucial for its success. Secondly, a comprehensive integration of the system in the daily operational routines is key for the acceptance and future use of the system.

Additional tools, such as computer-forecasting models, could easily be integrated into such systems as an additional help for the data analysis. The same visualization tool could be used to present the model results and create all-inclusive maps. This could lead to a truly comprehensive tool that could help avalanche forecasters doing their daily job.

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