COMPUTER GRAPHICS APPLICATIONS IN AVALANCHE FORECASTING

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ABSTRACT

Several applications of computer-generated graphics for use in avalanche forecasting are presented. These applications include computer graphics currently in use with the SnowBase program created by the author and some possibilities not yet in practice.

Traditional graphic techniques used in avalanche forecasting or meteorology, such as snow profiling, seasonal time-lines, and wind roses are discussed. Consideration is given to the application of computer graphic techniques for creating and manipulating these images in the avalanche forecasting setting.

Computer graphics allow derived parameters to be displayed in addition to original data in the form it is collected. A derived parameter is a parameter that is not measured directly, but is computed from one or more measured parameters. For example, one may plot the vapor pressure gradient within a snow profile by computing vapor pressure from field temperature data. Another example, the snow rose, uses parameters derived from weather data. The snow rose is a polar plot combining wind and precipitation intensity data to represent slope loading patterns during a specified period.

The computer also opens the door for new graphic formats such as the snow cone. The snow cone is a plot that displays the distribution of snow surface conditions at varying elevations and aspects.

The effective use of computer graphics for avalanche forecasting requires standards for data acquisition and format and timely data display for decision making.

INTRODUCTION

The images presented in this paper are created with the SnowBase software developed by the author in a joint effort with Alta Ski Lifts. SnowBase is a comprehensive data management system for use in avalanche forecasting. The software creates these images from meteorological, snow stratigraphy, and avalanche occurrence data stored in the database. The data required to produce these

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graphics are commonly collected for avalanche forecasting purposes.

To be skilled in the art of avalanche forecasting requires the ability to track many variables and the relationships between those variables as they change with time. Through graphic presentation of data, a great deal of otherwise incomprehensible information can be displayed in a form that is readily absorbed at a glance. Graphic techniques provide visual cues to data. The term visual cue refers to the use of color and precise graphics to design images that draw attention to significant features and relationships in the data.

Traditional techniques in avalanche forecasting make use of some hand-drawn graphics, most notably snow profile plots and time-line plots. Computer graphic techniques have the potential to perform the traditional tasks and to expand on traditional methods in ways that are not practical using hand-drawn techniques. The image quality that can be obtained with computer-generated graphics can be used to provide far better visual cues than are practical when using hand-drawn graphics.

Timeliness is important for avalanche forecasting. If pertinent data is not available when it is needed, one ends up avalanche "hindcasting." The key to timely presentation of data is efficient data collection and entry to the computer. Many meteorological parameters are collected directly from data loggers but there will always be parameters that require hand entry. Even data collected from data loggers requires constant attention.

SNOW PROFILES

Any plot of a type that displays the variation of one or more parameters versus depth in the snowpack is a snow profile. Traditional snow profile parameters include temperature, hand hardness, ram number, shear plane identification, shear strength, free water content, and grain type, among others.

The generation of snow profile plots, such as the example in figure 1, is the first commonly used application of computer graphics in avalanche forecasting. I don't know exactly when the computer was first used for this purpose but it has been nearly a decade since the first snow profile appeared on my computer monitor. In recent years, the use of computer systems to produce snow profiles has become increasingly widespread.

In practice, I find that it is easier to enter snow profiles in the computer than to draw them by hand and that computer generated profiles provide far better visual cues about snow stratigraphy. I have also discovered that the snow profiles are often of value long after the data was collected. The ability to browse through many years of information collected by many people and to have instant access to graphic representation of that data is a valuable tool for today's stability assessment. A good memory is always an asset to an avalanche forecaster!

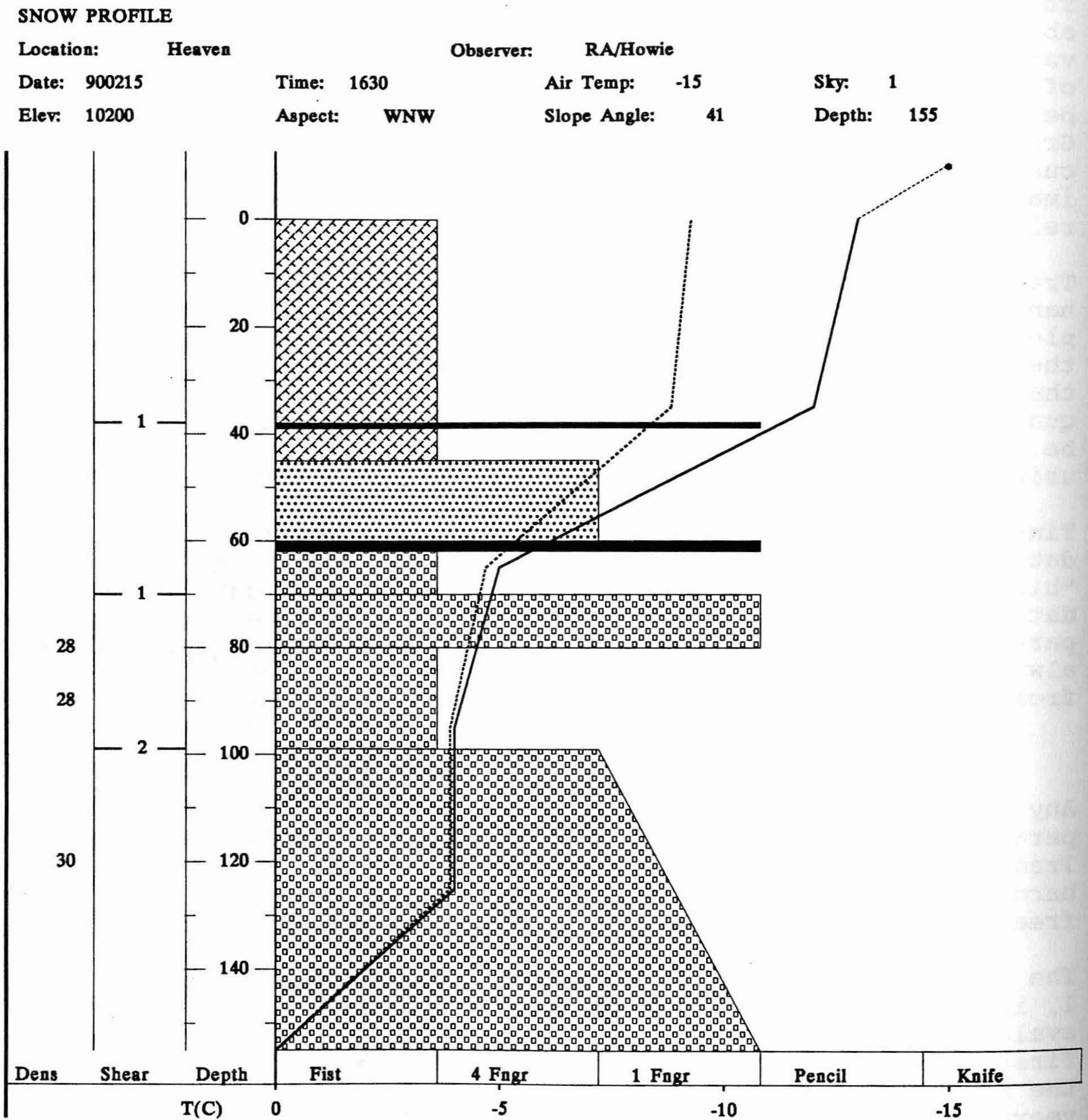

Figure 1

A computer generated rendition of the traditional snow profile. The vapor pressure parameter, derived from the temperature data, is represented as a dashed line and is scaled for comparison with the temperature profile.

An advantage of storing data in a database and using computer generated graphics is that it is possible to add "derived parameters" to the graphic output. Derived parameters are not measured directly, but are computed from one or more measured parameters.

In a snow profile, water vapor pressure is an example of a derived parameter. Vapor pressure primarily depends on temperature, although there are second order dependencies such as the radius of curvature effect of associated ice grains (Perla et Al, 1978). Although vapor pressure within the snow pack cannot be measured directly, it is possible to estimate the vapor pressure from the temperature by using psychrometric charts or tables (Hodgman, et al 1960).

The significance of vapor pressure in the snowpack is that the migration of water vapor, and therefore the formation of recrystallized forms such as depth hoar, is more closely related to the vapor pressure gradient than to the temperature gradient. Traditionally, temperature has been used to estimate the rate of recrystallization because it is easily measured and no additional computation is required. The computer makes it feasible to derive the vapor pressure from the temperature data and to add the vapor pressure profile to the snow profile without additional effort.

In figure 1, the dashed line that resembles the temperature profile is the derived vapor pressure profile. The vapor pressure profile has been normalized and plotted adjacent to temperature such that the two parameters coincide on the graph at 0°C. The non-linear relationship between temperature and vapor pressure is evident by the divergence of the two profiles at the lower temperatures measured in the upper portion of the snowpack.

TIME LINES

Time line plots, which are widely used everywhere from Wall Street to the Bugaboos, are a category of graph that shows the variation of one or more parameters over time. It is traditional for avalanche forecasters to plot time lines of meteorological parameters. Excellent visual cues about the interaction between parameters over time can be derived by plotting multiple variables in juxtaposition or superposition on the same time line. Time lines are not limited to meteorological parameters, and it is particularly useful to add avalanche occurrence data to the graph.

Traditional meteorological parameters used in avalanche forecasting time lines include temperature, wind speed and direction, interval precipitation in water equivalents, and snow depth from total depth stakes, storm stakes, and interval stakes. Another common time line shows the seasonal variation in snow stratigraphy data taken from a study plot.

Time lines need not be limited to the traditional parameters. It is possible to draw time lines for any parameter that varies with

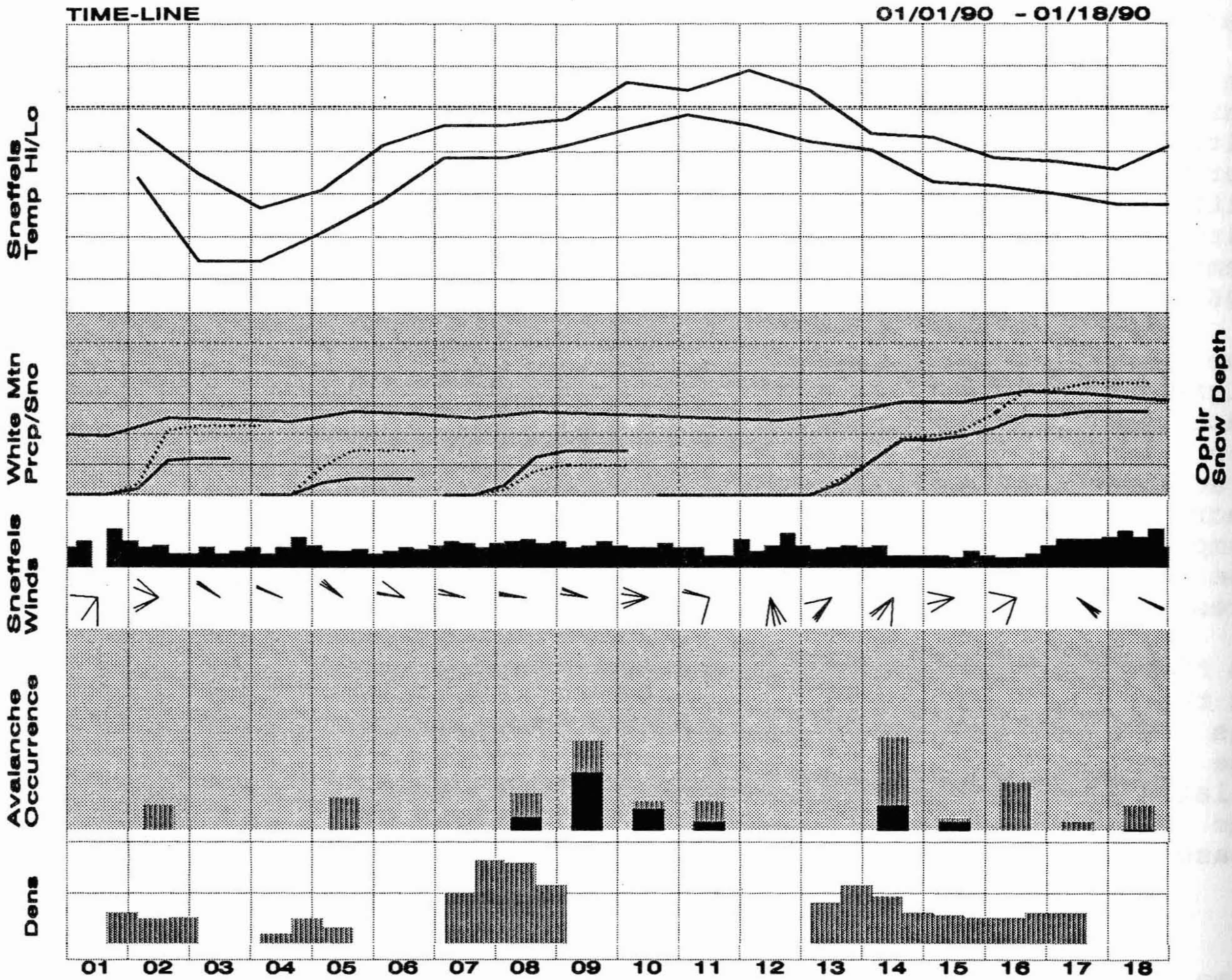

Figure 2

This eighteen day time-line plot is generated by the SnowBase program. The uppermost plot shows daily high and low temperatures from the Mount Sneffels site with a horizontal dashed line at the freezing level and 5°C grid divisions. The second plot shows snowfall (dashed), water equivalents, and total snow depth data. Grid divisions are 25 mm for water, 25 cm for snowfall, and 60 cm for snow depth. Wind speed bar graphs appear above daily wind direction roses. The avalanche occurrence graph shows the daily number of avalanche occurrences on a total scale of 50 events with the darker shaded portion representing slides involving old snow layers. The bottom graph shows new snow density, derived from snowfall and precipitation data, with 10% grid increments.

time, including derived parameters or other related parameters such as operational data. Ski area closure data, road closure data, avalanche control activities, and helicopter ski run usage are some examples of operational data that might appear on a time line. Subjective parameters, such as stability assessment, can also be useful on a time line.

Meteorological time lines with different time scales are used in avalanche forecasting. It is typical to plot storm profiles with several days of detailed information and more general time lines for the entire season. When using the computer to produce time lines from the database, it is possible to zoom in or out to the desired level of detail.

One can also select which parameters to display and vary the position and scale of the graph for each parameter. However, no matter how hard you try, there is a limit to the amount of information that can be displayed on a computer monitor without creating a chaotic plot. An excessively busy graph destroys, rather than enhances, the visual cues to the data. Careful design of the time line format can make a big difference in the practical application of computer-generated time lines.

Graphs presented on the computer monitor can only display a limited number of days without loss of detail. To compensate for this limitation, it is possible to pan forward or backward through the current season or previous seasons.

Figure 2 is an example of an eighteen-day segment of a computer generated seasonal time line. As with snow profiles, one advantage of using computer graphic time lines generated from stored data is instant access to visual presentation of large volumes of historic data.

SNOW CONES

The Snow Cone is a type of graph that displays the spatial variation of parameters with slope aspect and elevation. This year, snow cone images generated by the computer will be used for the first time. A snow cone is a polar graph presented as a topographic map of a conical mountain with data displayed in the region to which it applies.

This presentation is useful because so many parameters used in avalanche forecasting vary greatly with slope aspect and elevation. The basic snow cone shows the variation of surface snow grain type, but the spatial variation of many other data types can be added to the snow cone. In figure 3, surface grain size and foot penetration data are overlayed in locations where measurements were taken. Areas filled with symbols representing grain type provide instant visual cues about snow surface conditions.

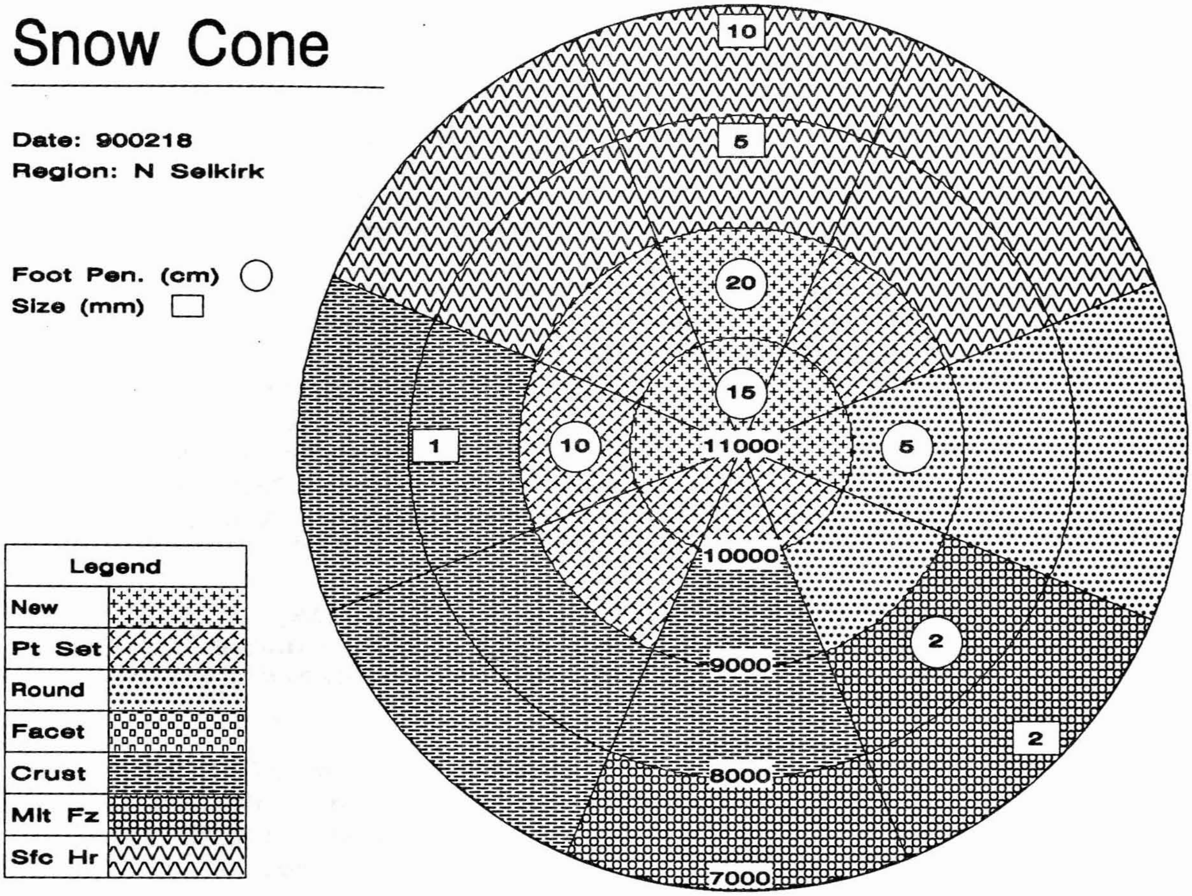

Figure 3

The Snow Cone is a polar plot showing the variation of snow surface grain type with elevation and aspect. Interpret the plot as a topographical map of a conical mountain with north toward the top of the page. Elevation contours are labeled in feet and slope aspects are divided into eight sectors. Any data that exhibit spatial variation over elevation and aspect can be superimposed on the snow cone. Foot penetration and surface grain size observations are included in this example.

A natural extension of the snow cone is to plot the number of avalanches in each size classification recorded during a time interval, displayed based on elevation and aspect. This technique combines spatial variation with cumulative effect over time.

SNOW ROSES

The snow rose is a graphic presentation of wind patterns and the estimated wind loading near ridge tops during a given period. Snow roses can be produced for any time interval from hours to years.

The snow rose is derived from the wind rose, which is a traditional technique used in meteorology to display wind patterns recorded over a period of time. In the example snow rose of figure 4, a wind rose is drawn around the periphery of the plot to categorize wind data by direction and speed. For the specified period, the wind events in each speed category are counted and then displayed in the appropriate direction sector. This plot displays the percentage of the total time that the wind was observed in each category, with the distance between concentric circles representing 25% of the total period. It may take some time to interpret this representation of wind data if it is unfamiliar. However, I have found this format to contain the most complete information and to provide the best visual cues of any wind rose presentation that I have yet encountered.

The avalanche forecaster is more concerned with the effect that the wind may have had upon the snowpack than with the wind itself. The snow rose is a variation of the wind rose that includes additional information about the snow loading near ridge tops resulting from the effect of wind and precipitation patterns. Wind speed, wind direction, precipitation intensity, and availability of surface snow for transport are used as inputs to a model that estimates combined precipitation and wind loading near ridge top as a function of slope aspect.

The polar plot at the center of the snow rose in figure 4 is the visual presentation of the output of this model. For each aspect, estimated load is represented as the distance from the center of the plot, with each concentric circle being 50 mm of water equivalents. Loading due to transport of precipitation and loading due to transport of surface snow are both presented.

Care must be used in interpreting the output of the snow rose. Snow roses, and the wind roses from which they are derived, only apply to areas represented by the data gathered from the weather sites used to produce the image. No consideration of local terrain variation has been included in this model. The snow rose is intended as a tool to provide relative visual cues and may not reliably determine the wind loading on any particular slope. However, the snow rose contains a great deal of information and can be produced readily from the existing data set. We will try it out for the first time this year.

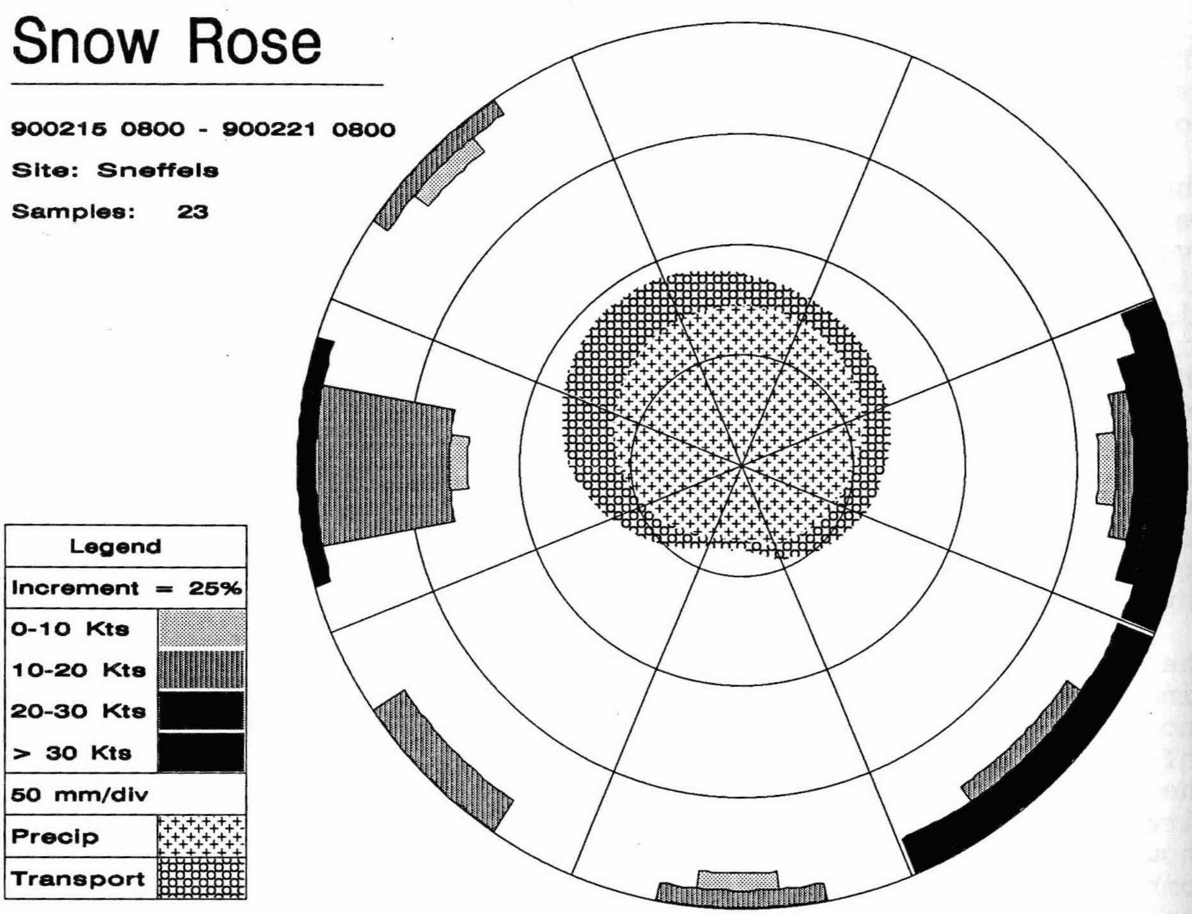

Figure 4

The Snow Rose, derived from the Wind Rose commonly used in meteorology, is a graphic presentation of wind patterns and the estimated wind loading near ridge tops during the specified period. The frequency of occurrence of wind observations is presented by speed category and direction sector around the periphery of the plot, with north at the top of the page. Each of the radial increments represents 25% of the observed period. The center of the plot shows the predicted wind loading versus aspect for both wind loaded precipitation and wind transported surface snow. The wind loading representation is output from a model that combines wind direction, wind speed, precipitation intensity, and availability of surface snow for transport.

CONCLUSION

Inevitably, a variety of computer tools will proliferate in avalanche forecasting applications due to individual efforts, and graphic display of information will be an important part of these tools. An article reviewing computer technology for avalanche forecasting states that "...the nicest thing about computer technology is its graphics" (Tremper, 1992). To obtain the maximum benefit of computer technology in avalanche forecasting will require significant commitment by organizations employing avalanche forecasters and cooperation within the snow science community to develop standards for data acquisition, storage, and exchange.

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