CLIMATE DATABASE FOR AVALANCHE WARNING IN NORWAY

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ABSTRACT: Climate data is an essential tool for the study of weather induced geotechnical processes like avalanches. Climate data provides on overview of normal and extreme weather conditions at a given location. This information can be used in risk analysis, for the evaluation of past avalanche events, and for every day forecasting services. The data can be analyzed for the return period of extreme events with focus on hazard zoning and design standards. A database was designed to serve as a practical tool for everyday avalanche work at NGI. The database includes weather observations from over 100 Norwegian synoptic stations with three to four observations a day. The focus is on stations in avalanche prone areas, such as fjords on the west coast and the coastal areas in northern Norway. Since synoptic stations in the Norwegian mountains are sparse, the analyzer still has to use experience in judging the avalanche situation in the mountains from observations near the coast. The analysis tools connected to the database are collected in a graphical user interface that allows easy access to the data, plotting of the results as wind roses and time series performing a number of statistical analyses such as return periods for extreme events. The climate database builds a basis for further development of a cross-connected avalanche-climate database currently developed at NGI.

Keywords: avalanche warning, climate, mountain weather

1. INTRODUCTION

Weather observations at a given location provide a record of weather conditions. Long term weather observations allow calculating averages and extreme values of the measured parameters. Covering several years, these time series give the history of the weather and allow a general analysis of the climate. Climate is usually referenced to normal values, e.g. averages over 30 year periods. This data is often available from the national meteorological services.

For avalanche work further analysis of the climate data is needed. For evaluating the avalanche danger at a given location the wind direction during winter precipitation events is important. This can be found by database queries including threshold values for precipitation, air temperature and wind speed. The results can be used to predict the probability of such conditions to happen in a given time period (Bakkehøi, 1987). The maximum effect of avalanches depends largely on extreme precipitation events. An extreme value analysis allows calculating the return period of extreme events by extrapolating the existing data (Aune & Iden, 1981).

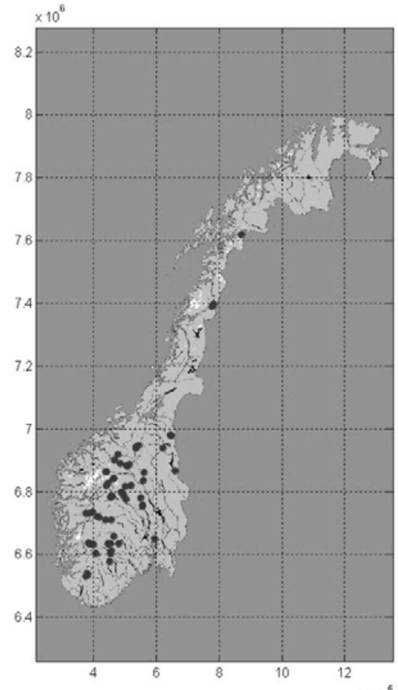

Figure 1: Map of Norway showing meteorological stations higher than 500 m altitude.

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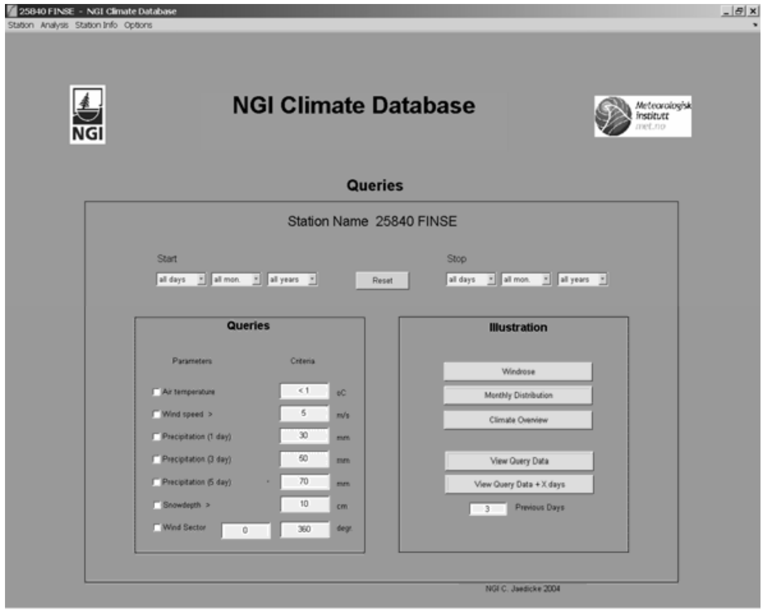

Figure 2: Graphical user interface of the query option in the database application

Monthly normal values of wind direction, precipitation and air temperature as well as extreme values give an overview of the general climate at a selected station. To analyze weather conditions during past avalanche events the data must be presented as a time series for the selected period, including the average, minimum and maximum values (Fitzharris, Bakkehøi, 1986). Most of these analyses can be performed in standard spreadsheet applications. However, when different users perform analysis individually for each station, the results are prone for errors. The presented application incorporates all important routines and the graphical output in a standardized form. This simplifies the daily work and secures the quality of the results. The database was developed with focus on snow avalanche applications but can also be used for other applications where climate data plays an important role; such as landslide occurrence and flooding.

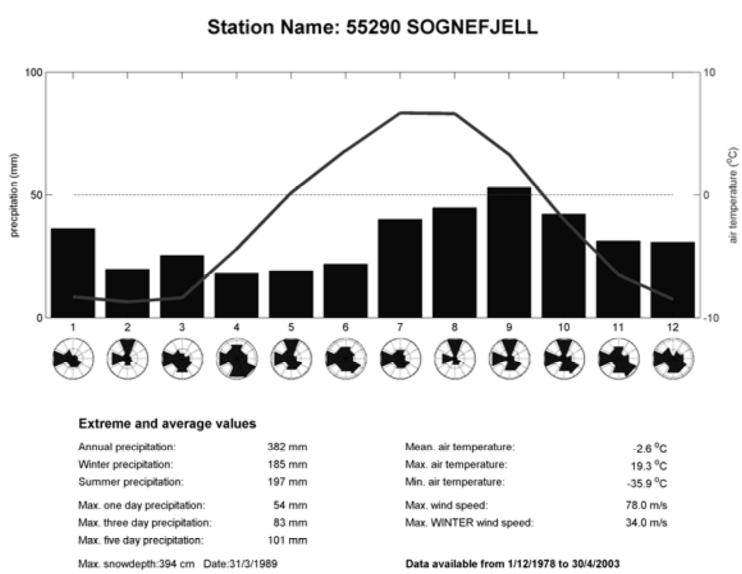

Figure 3: Results from the climate overview for the mountain station Sognefjell at 1431 m altitude.

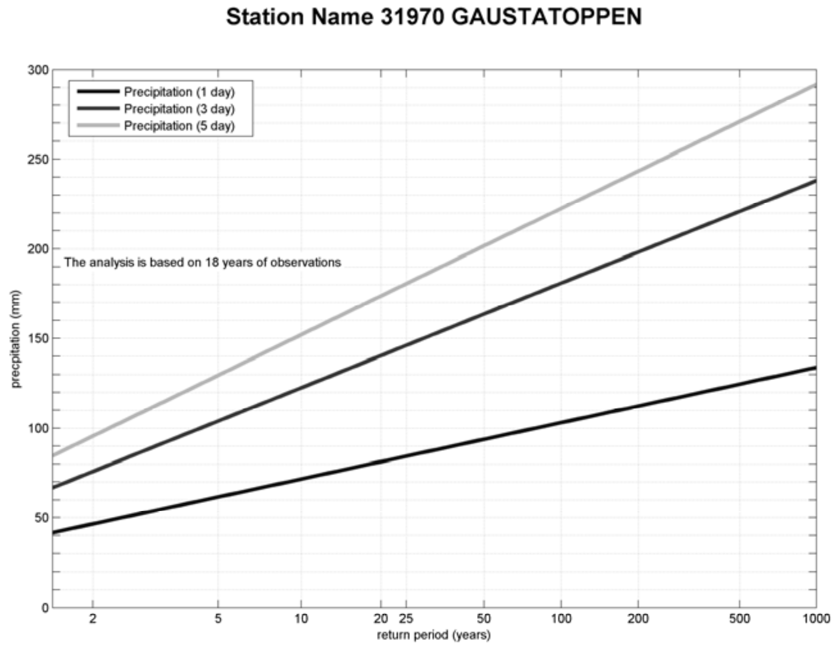

Figure 4: Results from the extreme value analysis for cold precipitation at Gaustatoppen

2. DATA

The database consists of standard observation files provided by the Norwegian Meteorological Institute (MI). In Norway meteorological observations were started around 1900. Approximately 200 synoptic stations have been in service during the past 100 years (MI, 2004). Digital recording of observation data started in Norway in 1957. During the past ten years, large efforts were made to digitize earlier observations and data for the most important stations are now available back to the 1940's.

Many stations have been moved and observation techniques have changed since the observations started. The MI tries to correct for these effects so that the data series are consistent through time. The Norwegian network of stations consists of precipitation stations (recording only precipitation and snow depth), climate stations (reporting observations only once a month) and synoptic stations (follow an international standard observation program). Unfortunately, only a minority of the Norwegian stations are located in the mountains at altitudes over 500 m (Figure 1). The synoptic and partly some climate stations follow a full standard observation program that includes recording up to 40 different parameters three or four times a day. The observation program varies from station to station but the necessary parameters for avalanche warning are observed at all stations. All data is stored in a common folder with a separate ASCII file for each station. The time period covered at each station varies from ten to forty years. A separate file contains all station information including the location, type of station, observation hours, etc. So far, about 100 stations are included in the database.

3. TOOLS AND METHODS

The analysis tool for the data was programmed in MATLAB and was compiled to a stand alone C++ application. The application allows quick and easy access to the data in the climate database. All tools are independent of the data itself and additional stations can be added to the database without modifying the application. Data analyses are mainly based on standard MATLAB routines, e.g. mean, standard deviation and minimum / maximum values. A new routine allows the analysis of extreme precipitation and wind speed events. The results are presented in graphics suitable for direct cut and paste into documents or internet presentations. The application is available in three languages and can be extended to additional languages.

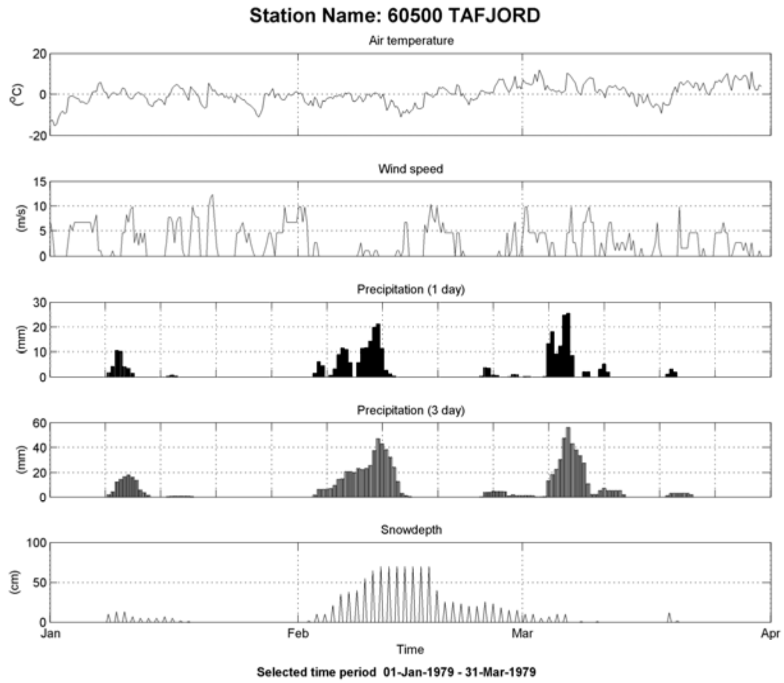

Figure 5: Time series plot for a major avalanche event in 1979

4. APPLICATION FEATURES

The database application is started by opening the basic graphical user interface. The user can then select the language and access information about the application (Figure 2).

To start a climate data analysis the station of interest is selected from a list of available stations. The climate data and information about station location and operation time is loaded automatically and an overview of the basic station statistics and the location on a map are now available. The different analysis tools currently available are discussed below.

4.1 Climate

The Climate analysis presents a general overview of the climate conditions at the selected station (Figure 3). Normal values for air temperature and precipitation are calculated and presented graphically for each month followed by listed extreme values of precipitation, air temperature, and wind speed.

4.2 Extreme values

A Gumbel distribution (Gumbel, 1954) is fitted to the precipitation and wind observations to calculate the return period of extreme precipitation and wind events. The application allows concentrating the analysis on special months or snow / rain events by selecting different scenarios in the figure menus. The analysis results are shown graphically as well as the data range that was used for the analysis. An example is presented in Figure 4.

4.3 Time series

This routine allows displaying a selected time period for data at the given station. This is especially useful for analyzing past avalanche events or weather conditions on a certain day, e.g. your birthday. Values for calculated 24h, three day and five day precipitation can be displayed together with the observed values of wind, snow cover and temperature (Figure 5). The selected period can be exported to a text file for use in other applications. The statistical overview shows the min / max and mean values for the period and a wind rose presents the wind direction and speed distribution for the period.

4.4 Queries

For the specific analysis of certain weather situations, queries can be designed to include for example threshold values for one day, three and five day accumulated precipitation, wind speed, snow on the ground, temperature, and wind direction. The results of the queries can be viewed graphically for example as a wind rose displaying the wind direction at which such conditions can be

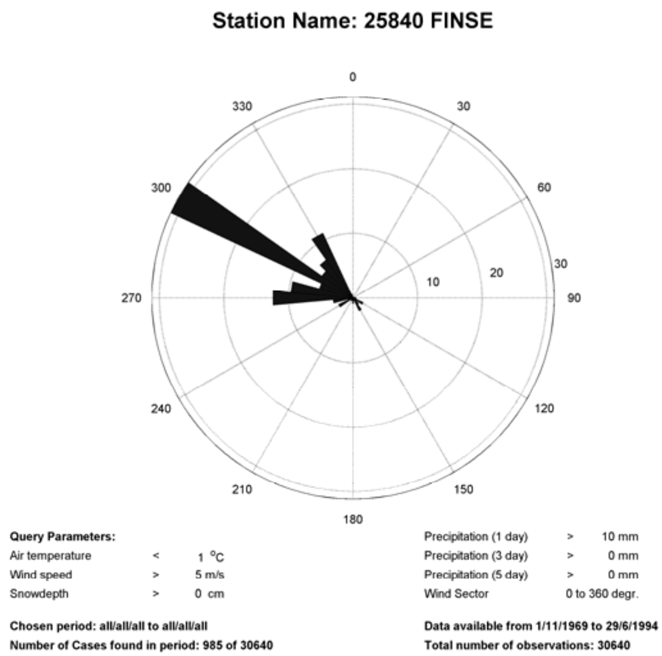

Figure 6: Wind directions at the station Finse with air temperature < 1 °C and wind speed > 5 m/s

expected. A monthly distribution of the events is also graphically available. This tool is often used when the most avalanche prone wind directions have to be found for a given location. An example for the station Finse in Norway is shown is Figure 6.

5. RESULTS

Results from the analysis tool are shown in Figures 3 to 6. The calculations are done by the application based on raw data provided by the MI. The data remains unchanged from its original format. The results of the calculations are presented graphically in standard figures that can easily be copied into reports and internet presentations. The quality of the calculations is high since they are based on standard routines that are the same regardless of the input data, location of the station, or user application.

6. DISCUSSION

The present version of the database application allows fast and easy access to the data. The results are displayed graphically and can easily be transferred to documents or internet presentations. The results of the routines were cross checked with the normal values issued by the MI. The comparison showed that the results are the same or comparable to the MI standard values. Any differences are minor and can be explained by using different time periods for the analysis as well as different filters for outliers in the data set. A major drawback is the small number of observations in the mountains. This has to be compensated for by combining inland precipitation station data with wind data from coastal stations. This feature is now included in the latest version of the application. Bugs in the software are reported from the users and are fixed constantly to improve the application.

7. CONCLUSION

The database provides easy access to important data needed in avalanche applications. The included features are based on the needs of the avalanche work in Norway and will be developed according to the suggestions and ideas of application users. Further work will integrate the data in an oracle database which will allow a coupling of the climate data to registered avalanches in Norway opening the possibility of a countrywide nearest neighbor system for the avalanche warning.

8. ACKNOWLEDGEMENTS

The project was funded by the Norwegian Research Council. The Norwegian Meteorological Institute (MI) kindly provides the climate data within the inter-institutional research cooperation. Thanks to Ketil Isaaksen at MI for the support.

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