NEW SNOW MAPS FOR NORWAY

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ABSTRACT

met.no has provided snowaccumulation maps for Norway for more than 50 years. These maps are now produced twice a month in the winter season. They show the accumulated precipitation in the winter season from the day the permanent snow cover is established. They do however not take melting into account, and do therefore not give a good description of the actual snow amounts during and after periods with snowmelt. Due to an increased need for a direct measure of water stored in the snow cover, *met.no* and NVE have started a joint project in order to establish maps of the actual snow cover expressed in water equivalents. The project utilizes recent developments in the use of GIS in spatial modeling. Precipitation and temperature are distributed in space by using objective spatial interpolation methods. The interpolation includes topographical and other geographical parameters. A degree-day model is used at each modeling point to calculate snow-accumulation and snowmelt.

INTRODUCTION

The Norwegian Meteorological Institute has provided snow accumulation maps for more than 50 years. For the last six years the maps are produced by utilizing geographical information systems (GIS), with advanced routines for filling in missing data etc. The maps are produced on the fifteenth and on the last day in the months from January to April, and they are usually available a few hours after the 06UTC observation the same day.

The maps show the accumulated precipitation in the winter season from the day the snow cover is established. They are derived for three altitude levels, for which regional measures of this day can be defined. The maps do not account for snow melting, and do therefore not describe the actual snow reservoir when melting has occurred.

During the recent years, improvements have been made both with respect to modelling methods and tools as well as presentation and distribution to users. These improvements, and the always increasing need of accurate, representative and updated information from users as hydropower producers, energy traders, authorities etc, initiated a project in order to establish a new approach to give updated information on the snow reservoir in Norway in terms of water equivalents. The project is a collaboration between the Norwegian Water Resources and Energy Directorate (NVE) and the Norwegian Meteorological Institute (*met.no*).

The objectives are to improve the methodology for estimation of snow accumulation and snow melting based on the observations collected by NVE and *met.no*. Furthermore, the project aims to use this methodology in combination with novel methods for spatial estimation of climatological elements, in order to establish spatially distributed estimates of the current snow cover. The project will lead to an operational tool for presentation of the current snow cover as continuous maps for Norway, which will be issued 1-4 times monthly during the winter season.

The project period is three years, and it was started in the autumn 2001. This paper presents the methodology that will be used, and some provisional results. Our intention is to run a first version model for point estimation during the spring 2002. A gridded model is planned to be operational within spring 2003.

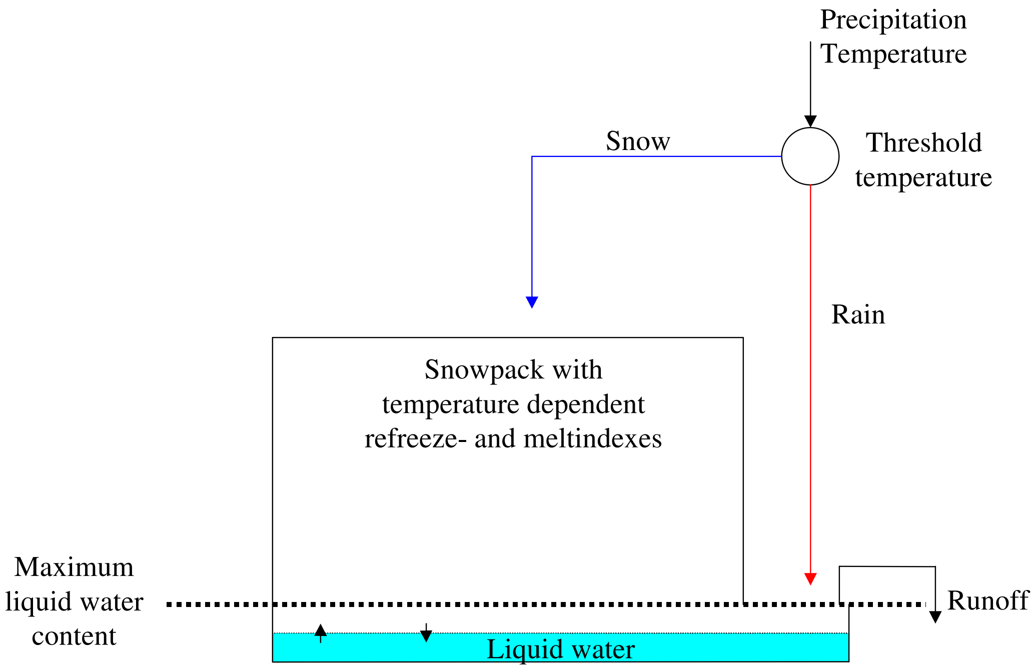


Figure 1. The snow model.

SNOW MODEL

The snow model (figure 1) simulates snow accumulation. Snowmelt is modeled using a degree-day approach (Bergstrøm 1992). Liquid water and refreezing is also simulated. Daily precipitation, corrected for wind-loss, and air temperature are used as input variables. Internal variables are used for separating rain from snow using a fixed temperature-dependent threshold, and fixed temperature-dependent thresholds are also used to identify snowmelt and refreezing. Snowmelt intensity is specified by a time-varying variable, and refreezing intensity is fixed. The state variables describe snow water equivalent and snow liquid water content, and they are updated on a daily basis. The model also simulates water yield from snowmelt and rain.

At NVE a network of 23 snow pillows has been established to get more accurate information about the snow water equivalent. Engeset at al. (2000) investigated how well the described snow model could simulate the temporal variation in snow water equivalent at each pillow. Beldring et al. (2002) evaluated snow simulations for points using a degree-day model in a distributed hydrological model.

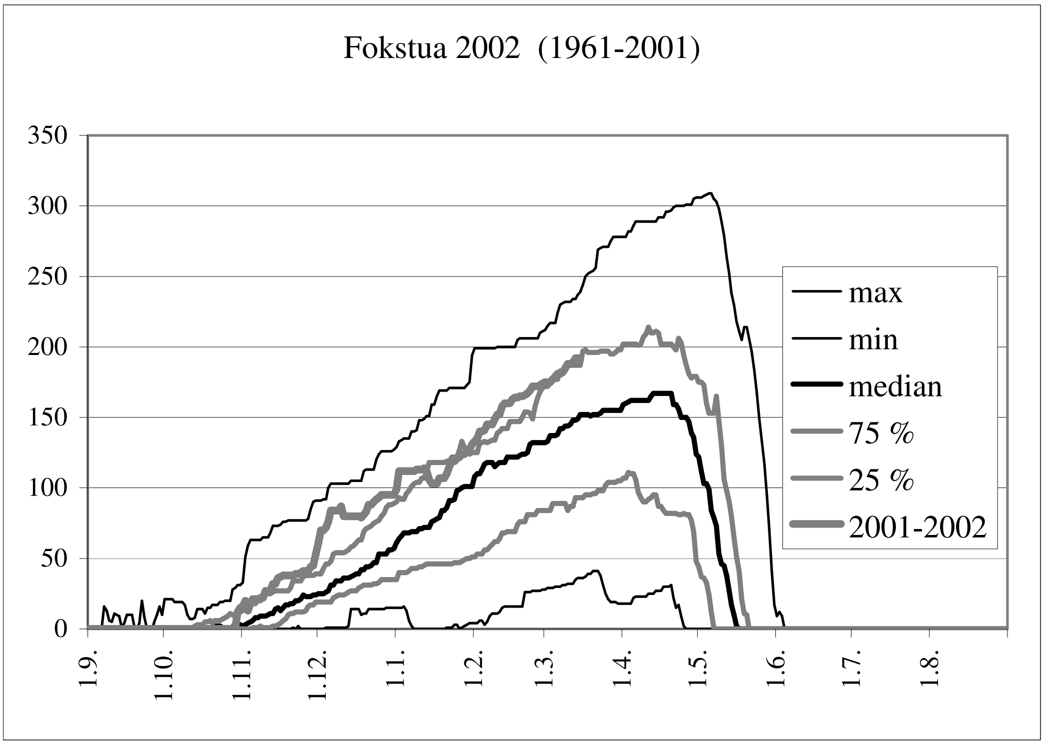
CLIMATOLOGICAL INPUT

The snow model requires daily inputs of temperature and precipitation data. Since the precipitation station network (approx. 530 stations in Norway) is denser than the weather station network where temperature is observed (approx. 200 stations), spatial estimation of temperatures at the precipitation stations is necessary to run the snow model for all precipitation stations. The temperatures are estimated by a residual kriging approach. Residual kriging is used to overcome the problems of non-stationarity, which prevents the use of ordinary kriging directly on observed meteorological elements.

Residual kriging is based on the principle that non-stationarity and anisotropy can be explained by one or more external factors, e.g. topography and distance to sea, in order to describe a regional field. The theory of regionalized variables can then be used on local residuals from this field. Tveito et al. (2000) describe in detail a residual kriging approach for estimation of temperatures in Fennoscandia using five independent predictors to describe the regional field (Altitude, average altitude and lowest altitude within a radius of 20 km, longitude and latitude). Expressions were established for each month, based on the 1961-90 normal temperatures. The method is used to estimate daily mean temperatures at the precipitation stations.

RESULTS

In the first phase of the project a prototype based on observed daily precipitation and temperature is used. The snow model is adapted to this input. The model is run on observed precipitation and temperature at selected weather stations for the period 1961-2001. Simulations are also run for the season 2001/2002 to compare the actual snow conditions to the statistics for the period 1961-2001. Figure 2 shows the results from two stations, one in southern Norway (Fokstua) and one in northern Norway (Karasjok).



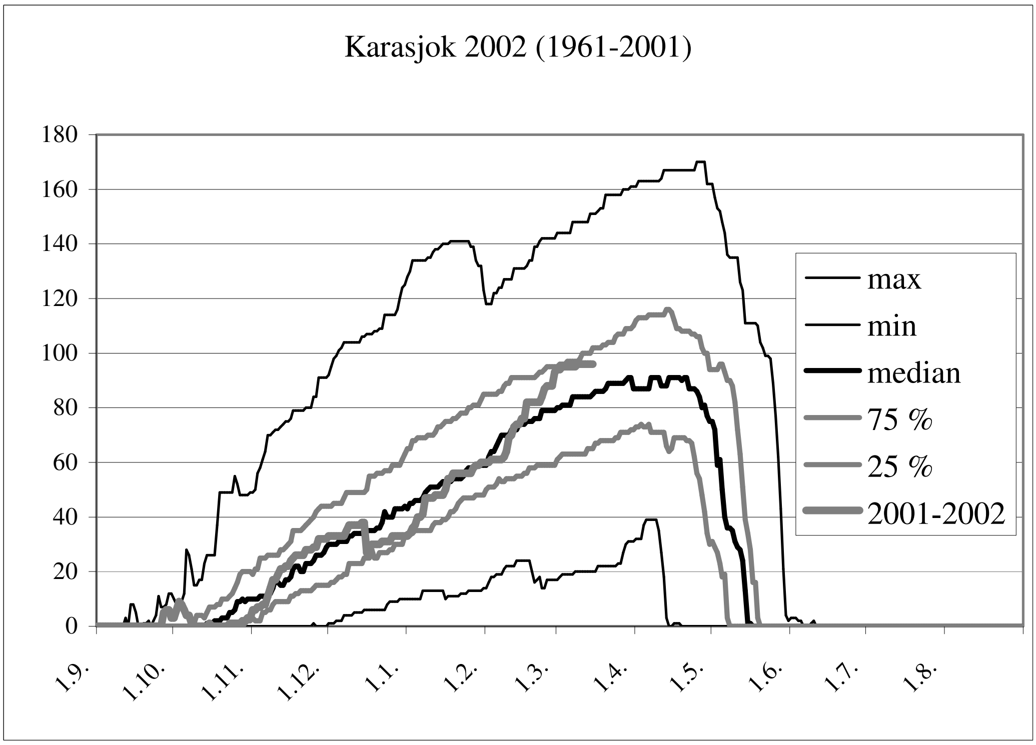
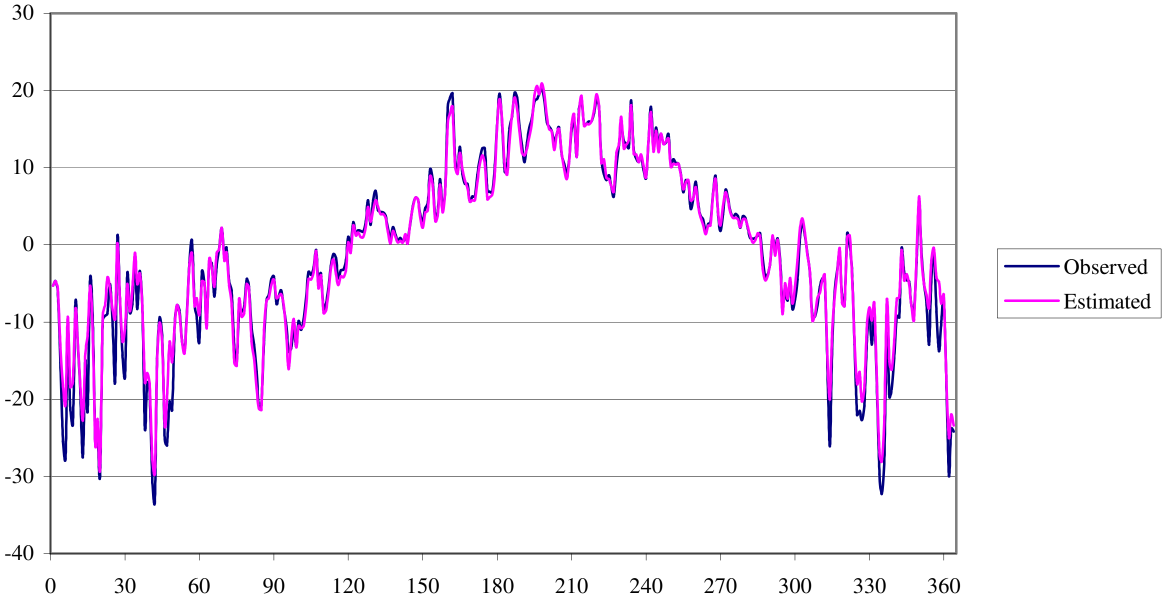


Figure 2. Median, maximum, minimum, 25 and 75% percentiles and the winter 2001-2002 conditions of the snow reservoir (in mm) at the weather stations Fokstua (top) and Karasjok (bottom) for the period 1961-2001.

97250 Karasjok



16610 Fokstua II

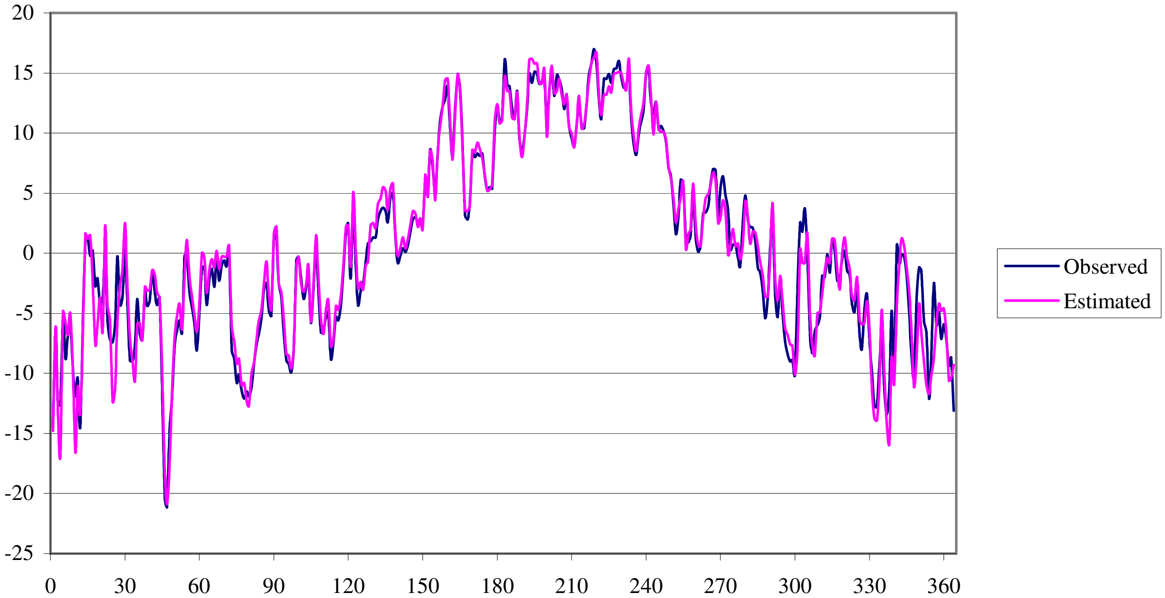


Figure 3. Observed and estimated daily mean temperature in 1997 at 16610 Fokstua II and 97250 Karasjok.

To be able to use the precipitation station network in the snow modeling, a spatial interpolation of the temperature at these stations is required. The method described in the previous chapter was used. Even if the method is developed for monthly mean temperatures, the residual kriging approach shows very good performance for daily temperatures. Figure 3 shows the observed and the independently estimated temperatures for the same stations that were used in the snow simulations, for the year 1997.

DISCUSSION AND CONCLUSIONS

Preliminary results show that the new approach to snow modelling gives a reasonable reproduction of the snow water equivalent. It is also shown that the residual kriging approach developed for mean monthly temperatures can be used for mean daily temperatures.

Temperature series for the period 1960-2001 will be estimated for all precipitation stations in Norway, and will be used as input to the snow model together with observed precipitation. Statistical properties about the snow reservoir will then be established for all precipitation stations. Based on these properties and the current situation, maps of the snow reservoir as percentage of the mean conditions will be produced. This map can be frequently updated in order to present actual conditions.

In the next phase of the project, also precipitation will be interpolated in space. Snow reservoir characteristics may then be estimated in arbitrary points. Thereby a gridded approach can be used, allowing more advanced spatial analysis to be performed (e.g. catchment statistics). This approach can also easily use weather prediction fields in order to forecast the development of the snow reservoir.

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