PREDICTION OF SLUSHFLOW HAZARD BASED ON DATA FROM LOCAL METEOROLOGICAL STATIONS

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ABSTRACT: Seeking objective criteria for slushflow prediction and warning, meteorological data has been recorded at two slushflow sites in Rana District, North Norway, during a 10 years period. The two starting zones were equipped with standard meteorological devices. In addition, the fluctuation of water level in snowpack was monitored by pressure transmitters. The measurements were performed automatically every ten minutes. Within a distance of 20 km from the slushflow sites there are one standard climatological station and two precipitation stations.

One of the main topics of the research project is to evaluate the possibility of using neighbouring meteorological stations in the prediction of current slushflow hazard and slushflow releases. Correlation of in situ measurements with records from the local meteorological stations is the basic input to the evaluation.

The analysis has documented that observations at the meteorological stations can be used as a base for predicting slushflow hazard in the Rana District. The temperature and humidity are well correlated in slushflow situations while the wind speed and precipitation measurements had to be adjusted by simple models taking into account topographic characteristics, distance and elevation differences. Generally, the result indicates that slushflow prediction might be based on observations at local meteorological stations if the necessary models for parameter transformation are established.

1. INTRODUCTION

Slushflows – flowing mixtures of water and snow – are a major natural hazard in Norway. They interfere with dwellings, structures, communication lines, power lines etc., and are of critical concern in land-use planning (Hestnes 1985, 1998). They occur due to heavy rain on snow in winter and intense thaw in spring. Whether the snowpack will reach a critical stability during rain and snowmelt depends on the relative rate of formation and discharge of free water in snowpack, which is governed by the ground conditions, the texture and structure of the snowpack, the rate and duration of water supply and the run-off conditions Hestnes et al. (1995), Hestnes and Bakkehøi (1997).

Prediction of slushflow hazard has been the objective of a joint research project between the Norwegian Geotechnical Institute (NGI) and the Norwegian Road Authorities. Field research and monitoring of in situ parameters essential to slushflow release, have identified critical water influxes related to different snowpack conditions and weather (Hestnes and Bakkehøi 1995, 2004). The project started late in 1991 in the Rana district of Norway, see figure 1.

Figure 1: Map with the Rana district marked.

Data from the in situ measurements have been correlated with records from meteorological stations to verify if acute slushflow hazard on local and regional scale can be predicted based on standard meteorological observations. The analysis and main results are summarized.

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2. AVAILABLE DATA

The main standard, climatological station used in this investigation was Båsmoen, close to the city Mo and situated 40 m a. s. l.. Yearly standard normal precipitation for this station is 1840 mm, the standard normal yearly temperature is 3 ^{o}C. The in situ stations Illhullia and Sjånesheia were situated 14 km northeast and 8 km southwest of Båsmoen approximately 200 m a. s. l. The stations were automatic and recorded every 10 minutes. For further details see Hestnes and Bakkehøi (1995).

All observed slushflows in the district were recorded. From 1991 until spring 2002 15 situations caused slushflows, some situations caused many slushflows. In the nearby surroundings of the recording stations, 7 situations have been recorded.

The precipitation for all three stations have been recorded, and comparisons of data gives differences less than 10 % between the stations.

2.2 Meltwater calculation

Calculation of meltwater can be performed as a function of temperature, wind and humidity. As shown in Hestnes et al. (1994) the water in the snowpack is a sum of the rain precipitation and the melted water. For example, a wind speed of 5 m/s, a temperature of 4 ^{o}C and 100 % humidity gives a melting of 33 mm per day, while 4 m/s, 2 ^{o}C and 100% humidity gives 13 mm if radiation is omitted.

The winter situations in Rana with slushflows are most common in situations with overcast weather and heavy rain. The calculations of meltwater are performed with data from the in situ stations and data from the standard synoptic station at Båsmoen, using a model developed by Harstveit (1984). In addition to meteorological data, this model needs to know the roughness of the terrain, the height differences and the distances between the stations.

The slushflow hazard prediction and warning are presented in Hestnes and Bakkehøi (2004). Compared to a standard synoptic station which is observing 4 times per day, the local stations give far more precise data. In addition, the two stations also measured the water level in the surrounding areas. This will give a far more accurate probability for prediction of slushflow. But a accurate knowledge of the sum of meltwater and precipitation might give a good prediction of the probability of slushflow. As an example of available data, a plot of meteorological data from Båsmoen is presented in figure 2.

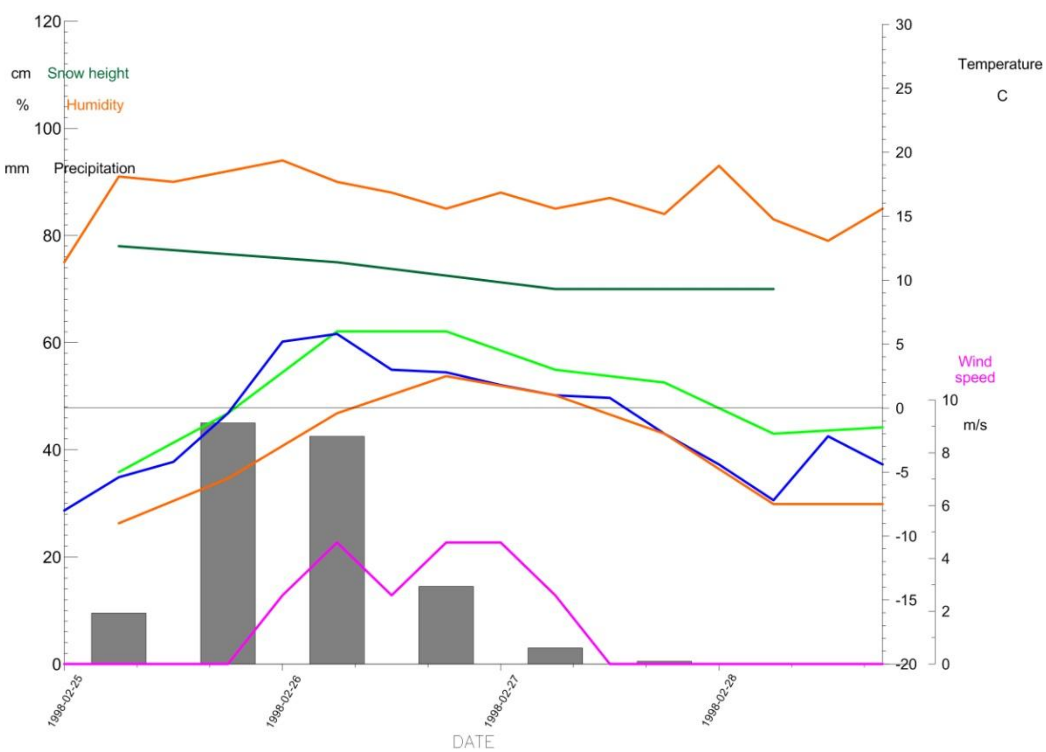

Figure 2. Example of observed data for Båsmoen February 25. – 28. 1998

3. ANALYSIS AND EVALUATION OF DATA

There have been some periods where data transferring from the in situ stations has not been working properly, but for the greater part of the project, data have been collected correctly. Some interesting periods have been used in this evaluation, and the melting in slushflow periods have been calculated with in situ data from Illhullia and Sjånesheia respectively. In addition, the meltwater has been calculated for the same periods using the formulae for data transformation for one site to another (Hestnes et al. 1994). A data program has been developed to perform the calculations faster.

Both systematic and variable differences in data are identified.
The systematic differences can be coped with by simple models taking into account topographic characteristics, distance and elevation differences. The variable differences are negligible in practical forecasting.

Figure 3 presents a time diagram of an interesting period, but without any registered slushflow. The meltwater for Illhullia in this period was calculated to 17.9 mm when using data from Illhullia, while data from Båsmoen gave 17.7 mm. The precipitation registered at Båsmoen was 56.5 mm while Illhullia recorded 59 mm in the same periode. The sum of precipitation and meltwater was approximately 85 mm. As seen on the diagram, the water table increased to 180 cm in the snow. Due to a snow height close to 230 cm, no slushflows were released.
For Sjånesheia the calculated meltwater was 28.9 mm with data from Sjånesheia while calculation with data from Båsmoen gave 18.3 mm

Another interesting period was February 21 1998. Calculation of meltwater in Illhullia in a period of 90 hours gave almost exactly same amount of meltwater 30 mm using Båsmoen and Illhullia. Both stations measured approximately 110 mm of precipitation. In this situation slushflow activity was observed close to Mo.

3.1. Results on local scale

Depending on distances and height difference from the synoptic meteorological station, data can be used as observed or they might be transformed. For a good result, registration of meteorological data should be performed more than four times per day and installation of automatic recording meteorological stations recording each 10 minutes has been more and more common. Online access to these data is important. Tuning of the parameters in the model can be performed to achieve an optimal score on the meltwater calculation

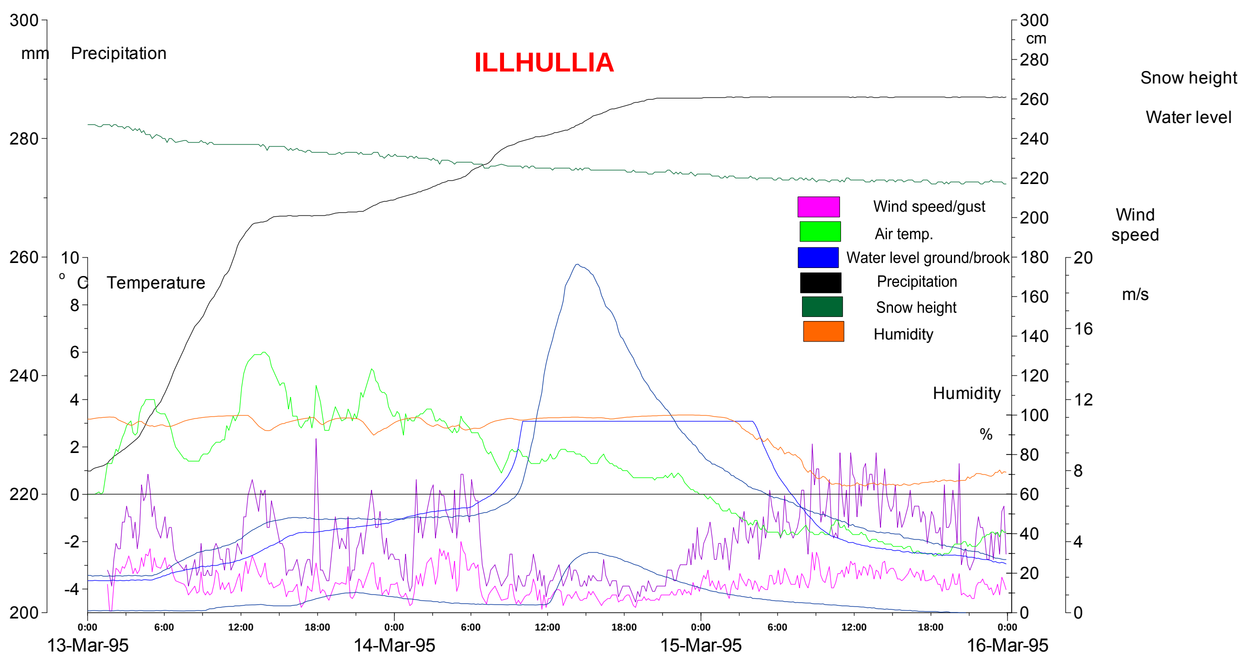

Figure 3. Meteorological data and water table data March 13 – 16 1995.

3.2. Results on regional scale

The stations in the Rana district seem to give good correlation both to precipitation and melting when appropriate models are used. In other parts of Norway with greater differences in topography it might be more difficult to use a neighbouring station to calculate real melting and precipitation. For prediction of slushflow hazard on a specific site, a preliminary automatic weather station could be placed at the site together with a water level sensor for correlating these data with data from a neighbouring permanent station when developing correlation models .

Mapping of slushflow incidents in Norway shows regional differences. Areas with sparse vegetation and bare rock with little possible infiltration of water in the ground, have more frequent situations with slushflows.

4.CONCLUSIONS

The analysis show that within certain limits meteorological data from a standard synoptic station can be used. Wind, temperature and humidity data must be transformed based on models, e.g. model of Harstveit, taking into account topographic characteristics, distance and elevation. Other can be used directly.

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