TESTING AND DEVELOPING METHODS FOR AVALANCHE FORECASTING IN NORWAY

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ABSTRACT: NVE[1] was in 2009 appointed the national authority responsible for avalanches and landslides. A project was initiated, aiming to test and develop methods for avalanche forecasting on a national/regional scale in Norway. The project focuses on developing methods and assembling data for the avalanche forecasting service. It also has a component on data processing and visualisation (weather data, snow and hydrological modelling and data dissemination) which supports a complementary project aimed at developing tools for the national/regional landslide forecasting service (a service which is not yet established). The project is split into five components: (1) a review of existing tools on setting the danger level, (2) local snow observations and collaboration with local partners, (3) weather data, (4) snow simulations and (5) web portal development based on an existing web application seNorge.no[5]. The project and preliminary results are presented in this paper.

1. INTRODUCTION

In January 2009, NVE was appointed the national authority responsible for avalanches and landslides. A project was initiated, aiming to test and develop methods for avalanche forecasting on a national/regional scale in Norway. The project is planned for three years (2010-2012) and is implemented by NVE, met.no[2], NGI[6], NPRA[4] and NNRA[5]. NVE will be managing the project.

The project is divided into five parts which are: (1) reviewing existing methods and tools, nationally and internationally; (2) establishing local collaboration for snow cover observations, feedback and validation; (3) improving availability and quality of weather forecasts and observations; (4) developing snow models and index layers; (5) developing a test platform for a risk evaluation tool for a future avalanche warning expert team.

Two reviews are completed and published in Norwegian (Jaedicke et al. 2009 and Kronholm et al. 2010). The project is making plans for collecting field observations during the upcoming winter by cooperating with organisations, which in earlier years have dealt with avalanche danger in their region, thus giving our project a connection to future users of a warning system. A recent workshop on weather indexes important to avalanche forecasting resulted in a prioritized work list on methods to be developed based on already existing input data. Also, new input data such as wind fields and snow observations were discussed. The web portal, Føre Var[7] built on the seNorge.no technology, has been found suitable as test platform for further development. Føre Var was initiated by NPRA, NNRA and NVE through the Climate and Transport project (Humstad 2010).

In the next sections we present a brief summary of plans, status and results in each of the parts of the project.

2. METHOD

2.1. Review of existing methods and tools

NGI coordinated the work on reviewing methods and tools for making a national avalanche

[1] Norwegian Water Resources and Energy Directorate (NVE)
[2] Norwegian Metrological Institute (met.no)
[3] Norwegian Public Roads Administration (NPRA)
[4] Norwegian National Rail Administration (NNRA)
[5] http://www.senorge.no/
[6] Norwegian Geotechnical Institute (NGI)
[7] http://forevar.senorge.no/

forecasting system and the final report (Kronholm, 2010) functioned as a basis for planning the other parts of the project. In short, the report emphasises the importance of unifying sources of data and presenting them in one expert evaluation tool.

Furthermore, the report underlines the need for an expert team, which evaluates observations and modelled results in order to determine the avalanche risk level. NGI's suggestion for regional avalanche forecasting in Norway is presented in Jaedicke et al. (2009).

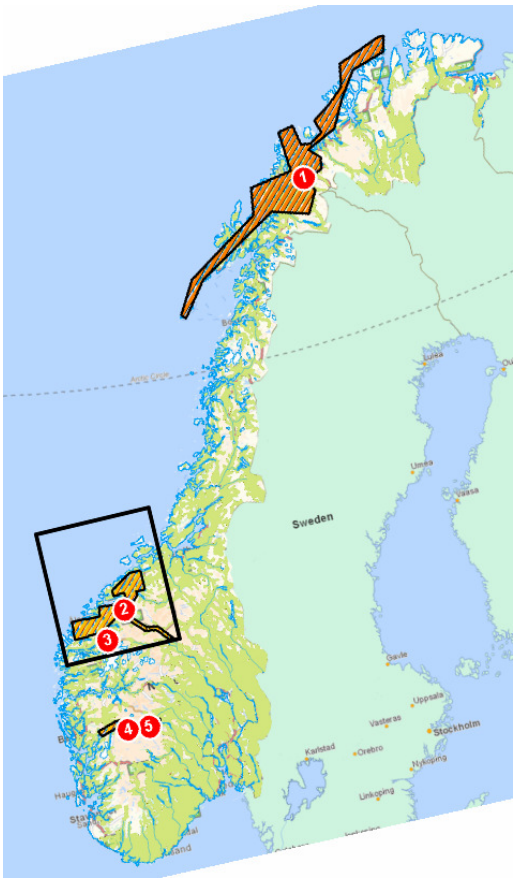

Figure 1: The map shows the five planed test regions (red circles), areas where NGI issued local forecasts during the winter 2009/2010 (hashed areas) and the section of the west coast displayed in figure 2 (black outlined rectangle). The test regions are numbered: (1) Troms, (2) Romsdalen-Trollheimen, (3) Strynefjellet- Sunnmøre, (4) Langfjella Bergensbanen and (5) Langfjella Øst.

2.2. *Local dissemination*

Contact with local organisations which have an interest in a well-functioning forecasting service, is an important part of the development of a national forecasting system. Such groups are local municipalities, local road and railway departments, land-use enterprises and mountain rescue teams, to mention only a few. Common for these organisations is that they have their crew in the field on a regular basis and that they have recourses to assist in establishing test regions for the project.

This winter (2010/2011) we plan on establishing five test regions: Nord-Troms, Romsdalen-Trollheimen, Strynefjellet- Sunnmøre, Langfjella Bergensbanen and Langfjella Øst (see figure 1). These areas are chosen for their demographic and geographic exposure to avalanche hazards. E.g. in Nord-Troms there are roads and buildings which are located in avalanche exposed areas. Some of theses regions has had local forecasts issued by NGI, partly since the 1980's. Areas where such local forecasts where issued during the winter 2009/2010 are shown in figure 1.

A standardised procedure and set of observations will be carried out in each test region in order to observe snow stability, avalanche occurrences and snow profiles. The project provides access to the tools which are prepared for assessing snow conditions and submitting observations. The goal is to use feedback in shaping the products of the project. We also wish to create awareness and demands on the subject of avalanche forecasting and to get access to data series on avalanche and snow observations.

2.3. *Improvement of weather data*

Met.no has 455 precipitation stations and of them are 155 weather stations in Norway. Given an area of 320.000 km^2 for the Norwegian mainland, an average distance between each station is calculated to 23 km (Humstad 2010). Additionally, the stations are located in areas with denser population and around important infrastructure (e.g. airports, in the valleys, along the coast, etc), so the density in remote and mountainous areas is in reality much lower. For comparison, Switzerland has 590 stations, giving and average density of 8 km. If Norway was to have the same density of observations, we would need to upgrade the network to approx 6000 stations, which is an unlikely large number. Thus, efforts are made to

improve routines for interpolating observations and to use numerical weather prediction models and snow models to provide the forecasting service with relevant daily data. Short term forecasts from both the Unified Model (Lean et al. 2008) and HIRLAM model will be used for this purpose. The temperature forecasts will be corrected with observations using a kalman filter routine (Homleid et al. 1995).

2.4. Numerical method development

The web portal Føre Var focuses on index layers indicating potential avalanche danger based on temperature and precipitation observations interpolated to a 1x1km^2 grid and prognosis. Index layers currently implemented are e.g. "snowfall snow last 24 hrs" and "rain into snow unstable cover". Index layers using modelled data based on parameters such as wind, humidity and radiation are currently under development.

The project aims also to make index layers for evaluating weak layers in the snowpack. E.g. index layers based on temperature change or development of surface hoar based on calculations from humidity and temperatures.

We will model the snow-cover stratigraphy and its evolution with numerical snow-cover models. Different models will be evaluated. SNOWPACK (Bartelt et al. 2002) is made available for experiments through collaboration with WSL Institute for Snow and Avalanche Research (SLF), Switzerland. Similar collaboration with MeteoFrance allows us to carry out experiments with Crocus (Brun et al. 1989), which is recently implemented in the externalized surface model SURFEX (Le Moigne et al. 2009).

2.5. Development and testing of an expert tool

Availability of weather and snow condition data is crucial for evaluating avalanche risk. Compiling and presenting data from different databases, field observations and various numerical models, is probably the most important tool in a functioning avalanche warning system in Norway (Kronholm, 2010). The GIS portal seNorge.no was found suitable for developing and testing newly developed products. The upgrade of seNorge.no is in addition a test portal for research on land slides.

Ongoing activities include accessing the joint National Avalanche and Landslide Database (Jaedicke et al. 2008) as an interactive database made available for the project partners and accessing NPRA's, met.no's and NVE's databases for more weather observations. There is also work on getting data from metrological models, integrating snow cover simulations from hydrological models and retrieving forecasts from yr.no[8] which can be used as input for index layers or models.

3. PRELIMINARY RESULTS

3.1. Methods

The NGI report (Kronholm, 2010) documents the current state of local and regional avalanche forecasting and points out the importance of gathering information for the operational avalanche forecasting. The report states the most important challenges for improving the regional avalanche forecast in Norway to be (in order of priority):

1. Compile and facilitate in one system, all relevant metrological data.
2. Organize and train personnel for field observations.
3. Develop methods to combine observations with the system described in 1.
4. Develop weather and hydrology based indexes as tools for an avalanche expert group.
5. Test existing snow cover models as a source for more information about the snowpack.

The current project aims to address these challenges, to an extent suitable for an R&D project. E.g. organizing and training of personnel are taken within the project only in test regions and then in cooperation with organisations who have some experience with handling the avalanche risk and who know the local area. Organizing a national observation corps is not within the scope of this project.

3.2. Modelling

Some index layers developed in Føre Var were evaluated against avalanche activity in the Møre and Romsdal county in the period 14th to 19th March 2010 (see figure 2). We suggest the following adjustments of the preset threshold values:

[8] http://www.yr.no

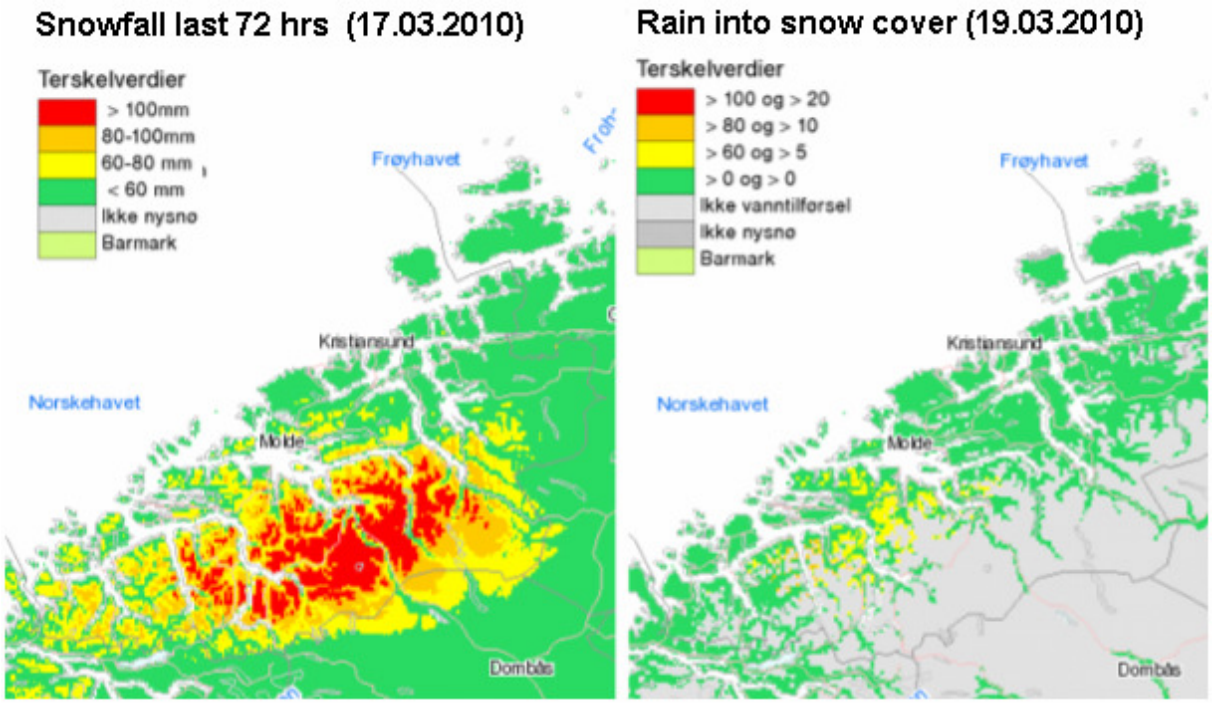

Figure 2: Examples of index layers "Snowfall last 72 hrs" (left) and "Rain into snow cover" (right). The last layer combines snowfall snow data from the previous three days (in mm snow water equivalent) with liquid water input to the snow cover from rain and snowmelt the last day (Humstad 2010).

- snowfall last 24hrs is adjusted up from 30, 40 and 50mm to 30 (yellow), 45 (orange) and 60mm (red)
- snowfall last 72 hrs is adjusted up from 60, 80, 100mm to 60 (yellow), 90 (orange), 120 mm (red)
- rain into snow cover is adjusted according to the necessary amounts of snowfall, rain and melt water. More calibration is necessary.

The index layers "snowfall last 24 and 72 hours" proved to be most useful this season, and we plan to improve these index layers coupling them to wind and the temperature gradient for the precipitation period.

4. FUTURE WORK

The project is planned to run for three years until 2012. The main challenges are finding tools which will assist in determining the lower avalanche hazard levels 2 and 3, and improving information about weak layers in the snow pack. Also, getting observations on avalanche activity and snow stability will be important for evaluating the danger level as well as evaluating the methods and tools developed in the project. These observations should be made available and visualized with weather data and hydrological data.

The project aims to disseminate test data and applications through http://forevar.senorge.no/ throughout the project. Some data layers will be public and some data will be accessible for the project group only, in order to avoid information being misinterpreted by the public.

5. REFERENCES

Jaedicke, C, Brattlien, K., Sandersen, F., Solheim, A., Domaas, U., 2009. Oversikt over skredvarsling i tre land og anbefalinger for Norge (Overview of avalanche forecasting in three countries and recommendations for Norway). NGI. Document no. 20091219-00-1-R.

Kronholm, K., Jaedicke, C., Sandersen, F., 2010. Metoder og data til vurdering av faregrad (Methods and data for assessing danger level), NGI. Document no. 20100461-00-1-R.

Bartelt, P. & Lehning, M., 2002. A physical SNOWPACK model for the Swiss avalanche warning: Part I: numerical

model. Cold Regions Science and Technology, 35, 123 – 145.

Humstad, T., 2010. Databehov ved trinnvis varsling av snøskredfare (Data demands for stepwise forecasting of snow avalanches), Norwegian Public Road Administration, Project report no. SVEIS-2010002585-25.

Homleid, Mariken, 1995. Diurnal Corrections of Short-Term Surface Temperature Forecasts Using the Kalman Filter. Wea. Forecasting, 10, 689-707.

Lean, Humphrey W., Peter A. Clark, Mark Dixon, Nigel M. Roberts, Anna Fitch, Richard Forbes, Carol Halliwell, 2008. Characteristics of High-Resolution Versions of the Met Office Unified Model for Forecasting Convection over the United Kingdom. Mon. Wea. Rev., 136, 3408-3424.

Brun, E.; Martin, E.; Simon, V., 1989. Gendre, C. & Coleou, C. An energy and mass balance model of snow cover suitable for operational avalanche forecasting J. Glaciol, 35, 333-342.

Ed. Le Moigne, P., 2009. SURFEX Scientific Documentation. CNRM7GAME, Météo-France/CNRS, Toulouse, France.

Jaedicke, C, Lied, K, Kronholm, K. 2009. Integrated Database for Rapid Mass Movements in Norway, Nat. Hazards Earth Syst. Sci., 9, 469-479.

Jaedicke, C., Bakkehøi, S., Sandersen, F., Brattlien, K., Solheim, A. 2009. Regional avalanche warning in Norway, a new concept for a large country. Proceedings of the International Snow Science Workshop Davos 2009, 371-374