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# Debris flow early warning systems in Norway: organization and tools

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In Norway, shallow slides and debris flows occur as a combination of high-intensity precipitation, snowmelt, high groundwater level and saturated soil. Many events have occurred in the last decades and are often associated with (or related to) floods events, especially in the Southern of Norway, causing significant damages to roads, railway lines, buildings, and other infrastructures (i.e November 2000; August 2003; September 2005; November 2005; Mai 2008; June and Desember 2011).

Since 1989 the Norwegian Water Resources and Energy Directorate (NVE) has had an operational 24 hour flood forecasting system for the entire country. From 2009 NVE is also responsible to assist regions and municipalities in the prevention of disasters posed by landslides and snow avalanches. Besides assisting the municipalities through implementation of digital landslides inventories, susceptibility and hazard mapping, areal planning, preparation of guidelines, realization of mitigation measures and helping during emergencies, NVE is developing a regional scale debris flow warning system that use hydrological models that are already available in the flood warning systems.

It is well known that the application of rainfall thresholds is not sufficient to evaluate the hazard for debris flows and shallow slides, and soil moisture conditions play a crucial role in the triggering conditions. The information on simulated soil and groundwater conditions and water supply (rain and snowmelt) based on weather forecast, have proved to be useful variables that indicate the potential occurrence of debris flows and shallow slides. Forecasts of runoff and freezing-thawing are also valuable information. The early warning system is using real-time measurements (Discharge; Groundwater level; Soil water content and soil temperature; Snow water equivalent; Meteorological data) and model simulations (a spatially distributed version of the HBV-model and an adapted version of 1-D soil water and energy balance model COUP). The data are presented in a web- and GIS-based system with daily nationwide maps showing the meteorological and hydrological conditions for the present and the near future from quantitative weather prognosis. In addition a division of the country in homogenous debris flow-prone regions is also under progress based on geomorfological, topographic parameters and loose quaternary deposits distribution. Threshold-levels are being investigated by using statistical analyses of historical debris flows events and measured hydro-meteorological parameters.

The debris flow early warning system is currently being tested and is expected to be operational in 2013. Final products will be warning messages and a map showing the different hazard levels, from low to high, indicating the landslide probability and the type of expected damages in a certain area. Many activities are realized in strong collaboration with the road and railway authorities, the geological survey and private consultant companies.