Slush flow thresholds for regional early warning in Norway

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Slush flows constitute a significant hazard in Norway. Therefore, the recently established national early warning system (EWS) operated by the Norwegian Water resources and Energy Directorate (NVE), also issue regional warnings for these situations. Slush flows occurs when the snow pack becomes water saturated and the initiation slope is usually between 5 and 30 degrees. The triggering mechanism of slush flows is closer to that of debris flows than snow avalanches. The Norwegian regional slush flow assessment is based on weather forecasts and information about hydro-meteorological conditions that are derived from real-time measurements, model simulations and forecasts assembled as nationwide thematic maps and time-series data available at www.xgeo.no. In addition, real-time observations on the snow cover constitute essential input. The snow pack observations are distributed through the webtool www.regobs.no and contains information on exposed snow types such as depth hoar, fresh snow on frozen ground and coarse-grained snow. As opposite to debris flows, where the soil properties are stable over time, the dynamic snowpack properties are an additional challenge. This study aims at improving the evaluation basis by establishing thresholds for the initiation of slush flows. The methodological steps will be analysis of a dataset of 70 historical slush flow events by extracting hydro-meteorological simulated and observed data for each event and initiation area. The observational data have gaps in corresponding snow types, and these will be filled by applying the Crocus snowpack model to simulate the missing data. Classification trees and multivariate analyses is used to investigate slush flow thresholds at a regional level. Warnings are issued at three awareness levels that reflects the potential danger: yellow, orange and red, while green is equal to generally safe conditions. The daily evaluation of the slush flow hazard resulting from comprehensive expert judgement of the available data and simulations are published on the web portal www.varsom.no.