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Assessing the potential of soil wetness data for landslide early warning

Adrian Wicki and Manfred Stähli
Swiss Federal Research Institute WSL, Mountain Hydrology and Mass Movements, Switzerland (adrian.wicki@wsl.ch)

In mountainous regions, landslides triggered by heavy rainfall present a serious risk to people and infrastructure. Recent major events in Switzerland have demonstrated their numerous occurrence and abrupt nature. Hence, several research initiatives have been initiated to develop tools and fundamentals for a regional landslide early warning system (LEWS). While most studies focus on the development of rainfall-based thresholds to identify imminent landslide activity (e.g. through intensity-duration-relationships), less work has been put into explicitly addressing the antecedent soil wetness state of the subsurface. In this respect, most attempts were made using hydrological models to anticipate antecedent moisture conditions.

In this study, we assess the potential of in-situ soil moisture measurements for their use in a regional LEWS. For the first time, a comprehensive soil wetness data base is compiled for Switzerland comprising 34 measurement sites from existing monitoring networks distributed throughout the country. The database includes a total of 300 TDR, FDR and capacitance sensors installed at different soil depths. The measurements were conducted in 10-minutes to 1-hour resolution and date back 2 to 10 years in time.

To account for the heterogeneous measurement set-ups and data quality, each time series was first post-processed, homogenized and normalized by calculating the effective soil water content (saturation). Multiple time series were then compiled in ensembles, e.g. along soil depth profiles, within specific depth ranges, or at entire measurement sites. For each ensemble, individual infiltration events were identified and delimited by the onset and end of soil water infiltration. Finally, statistical properties were attributed to each infiltration event that describe antecedent wetness conditions, infiltration event dynamics and preconditioning factors. Further, a national flood and landslide damage database with 441 observed landslide events since 2008 was used to classify landslide triggering and landslide non-triggering infiltration events. To find the statistical properties that best separate landslide triggering from non-triggering infiltration events, a multi-dimensional threshold analysis was conducted. For each threshold, the confusion matrix (count of true and false positives, true and false negatives) was calculated and the forecast goodness was analysed using receiver operating characteristic curves (ROC).

First results yield the best predictive performance for ensembles along soil depth profiles with multiple depth levels. The event properties that best separate landslide triggering from non-triggering events are the ensemble mean saturation at the onset of an infiltration event (antecedent soil moisture), the peak event saturation and the two-week peak saturation preceding an infiltration event, as well as the ensemble standard deviation at the onset of the infiltration event. Our analyses demonstrate that soil moisture measurements can provide useful information for a regional LEWS. However, data quality issues and site-specific hydrologic conditions can significantly impact the results.