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Performance analysis of regional landslide early warning based on soil moisture simulations

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In mountainous regions, rainfall-triggered landslides pose a serious risk to people and infrastructure, particularly due to the short time interval between activation and failure and their widespread occurrence. Landslide early warning systems (LEWS) have demonstrated to be a valuable tool to inform decision makers about the imminent landslide danger and to move people or goods at risk to safety. While most operational LEWS are based on empirically derived rainfall exceedance thresholds, recent studies have demonstrated an improvement of the forecast quality after the inclusion of in-situ soil moisture measurements.

The use of in-situ soil moisture sensors bears specific limitations, such as the sensitivity to local conditions, the disturbance of the soil profile during installation, and potential data quality issues and inhomogeneity of long-term measurements. Further, the installation and operation of monitoring networks is laborious and costly. In this respect, making use of modelled soil moisture could efficiently increase information density, and it would further allow to forecast soil moisture dynamics. On the other hand, numerical simulations are restricted by assumptions and simplifications related to the soil hydraulic properties and the water transfer in the soil profile. Ultimately, the question arises how reliable and representative landslide early warnings based on soil moisture simulations are compared to warnings based on measurements.

To answer this, we applied a state-of-the-art one-dimensional heat and mass transfer model (CoupModel, Jansson 2012) to generate time series of soil water content at 35 sites in Switzerland. The same sites and time period (2008-2018) were used in a previous study to compare the temporal variability of in-situ measured soil moisture to the regional landslide activity (currently under review in *Landslides*). The same statistical framework for soil moisture dynamics analysis, landslide probability modelling and landslide early warning performance analysis was applied to the modelled and the measured soil moisture time series. This allowed to directly compare the forecast skill of modelling-based with measurements-based landslide early warning.

In this contribution, we will highlight three steps of model applications: First, a straight-forward simulation to all 35 sites without site-specific calibration and using reference soil layering only, to assess the forecast skill as if no prior measurements were available. Second, a model simulation after calibration at each site using the existing soil moisture time series and information on the soil texture to assess the benefit of a thorough calibration process on the forecast skill. Finally, an

application of the model to additional sites in Switzerland where no soil moisture measurements are available to assess the effect of increasing the soil moisture information density on the overall forecast skill.