The role of subsurface topography and its implications on the water regime in the Urseren Valley, Switzerland

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Introduction

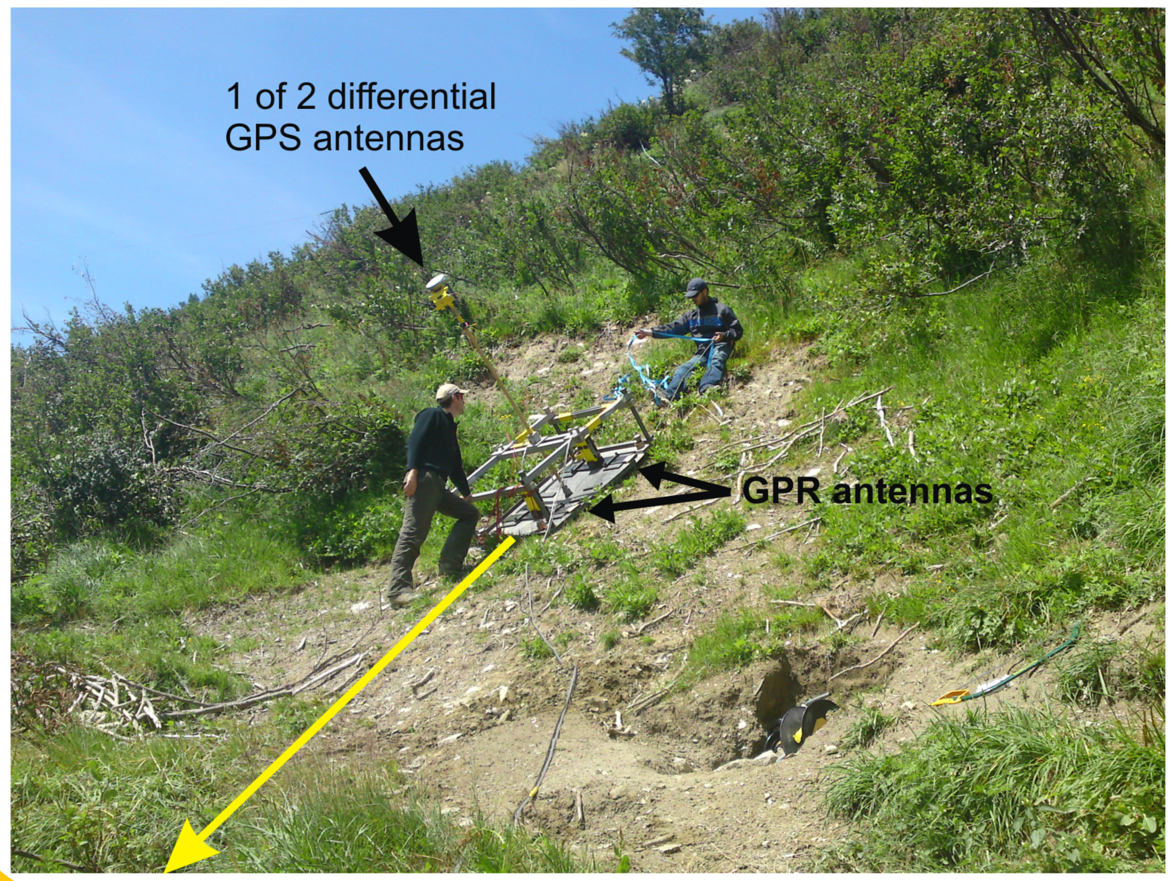
To improve the understanding and the modelling of soil water regimes in alpine areas it is essential to know not only the number and the properties of the soil layers, but also their spatial distribution. One common assumption used in many simulations in the literature is that that the soil layers and the bedrock are parallel to the surface, which sometimes deviates significantly from the reality.

Field Campaign

A field campaign was conducted in the Urseren Valley, which lies in the heart of the Swiss Central Alps. This region is very susceptible to infiltration-triggered shallow landslides and for this reason a realistic simulation of soil water regime is crucial to predict soil slip occurrences. The primary method used for the determination of subsurface topography is the Ground Penetrating Radar. Additional trenches were dug up at strategically important points to verify the soil stratigraphy obtained from the GPR analysis.

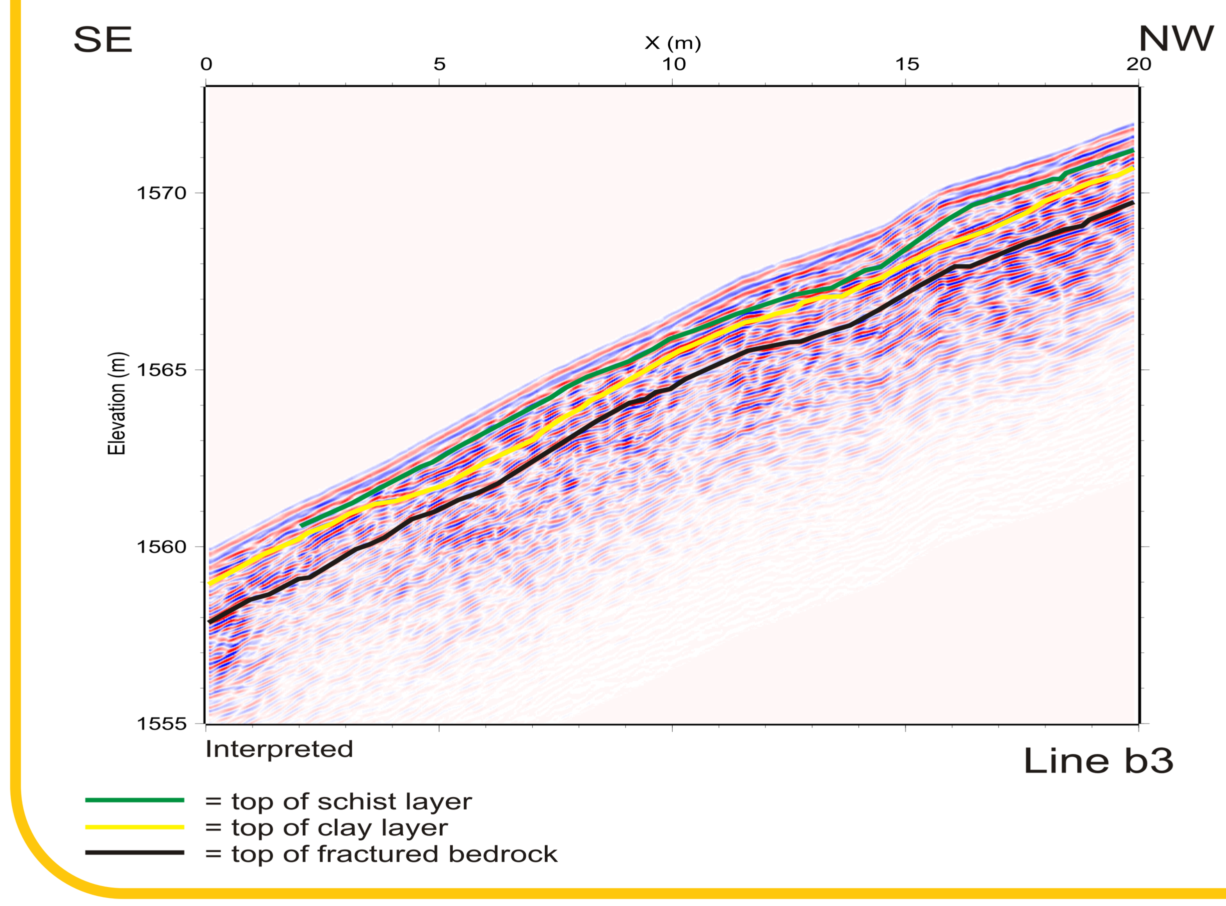
GPR data acquisition

In order to obtain information about the possible sliding planes of the soil slips, a total of 36 GPR profiles were acquired (20 x 100 MHz data, 16 x 250 MHz data). Trace spacing of the 100 MHz data was 20 cm, and 5 cm for the 250 MHz data. Differential GPS enabled +- 3 cm precise absolute coordinates for each trace.



GPR data intepretation

The 100 MHz data achieved deeper signal penetration than the 250 MHz, at the cost of lower resolution. Both data have however imaged similar structures, confirming the reliability of the latter. In general, strong subsurface topography is observed in some major interfaces. Due to sudden lateral changes in GPR depth penetration and a consistent observation in several trenches, it is assumed that one of the major interfaces is a clay layer. This clay layer is undoubtedly an erosional product of the Permian schist bedrock, and very probably acts as a sliding plane for the soil slips, under the influence of water flow patterns.

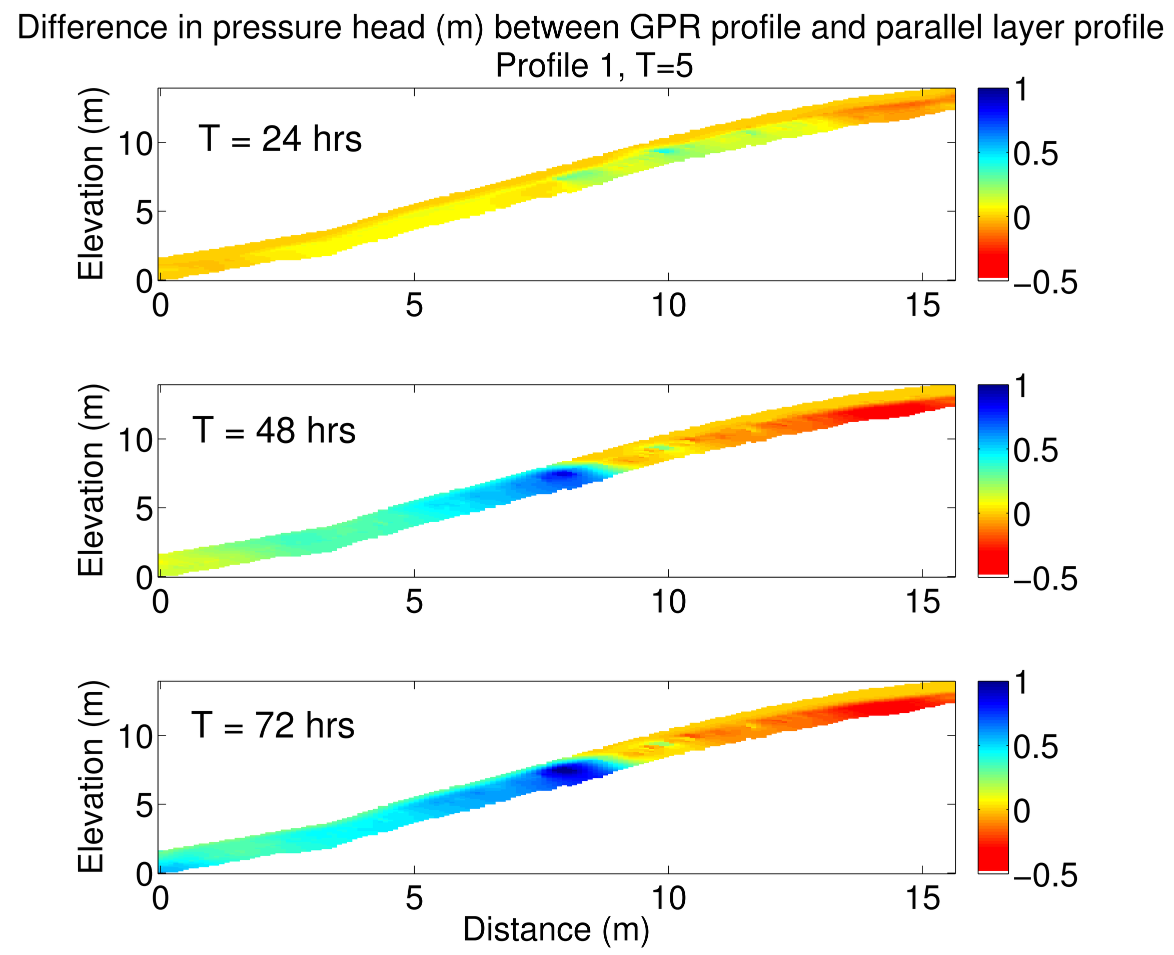


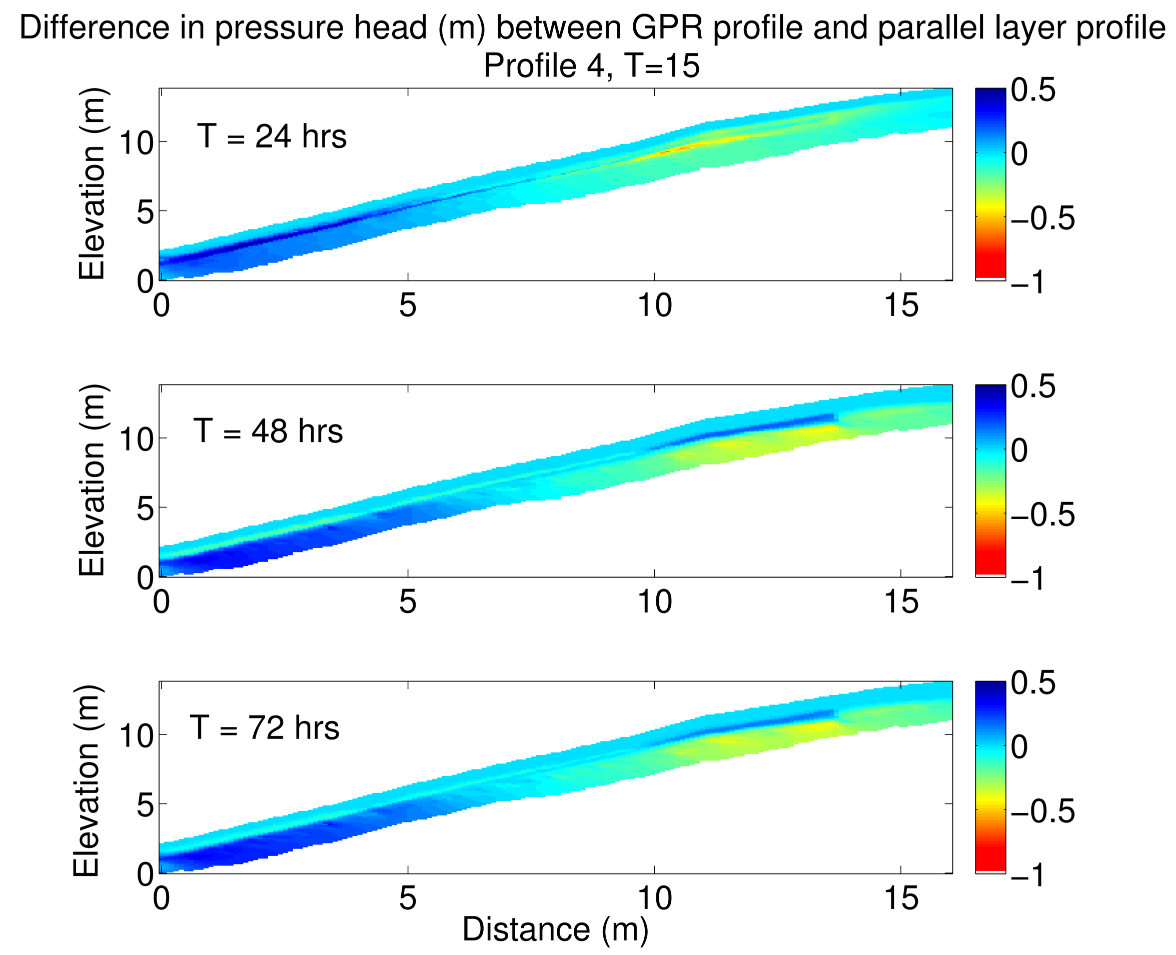
Hydrological simulations

The soil profiles obtained from the GPR analysis were used in a model based on Cellular Automata for the simulation of unsaturated and saturated flow. Soil samples were collected and tested in order to obtain some soil properties of the soil layers composing the profiles. Simulations were run using representative rainfall events as recorded at the neighboring station of Andermatt. The IDF (Intensity-Duration-Frequency) curves were extracted using the historical record of the Andermatt station. 3-day events are selected from this record, which have the same total amount of precipitation as a constant intensity event with the intensity given by the IDF for different return periods. Three events were used with return periods $T = 2$, $T = 5$, and $T = 15$ years.

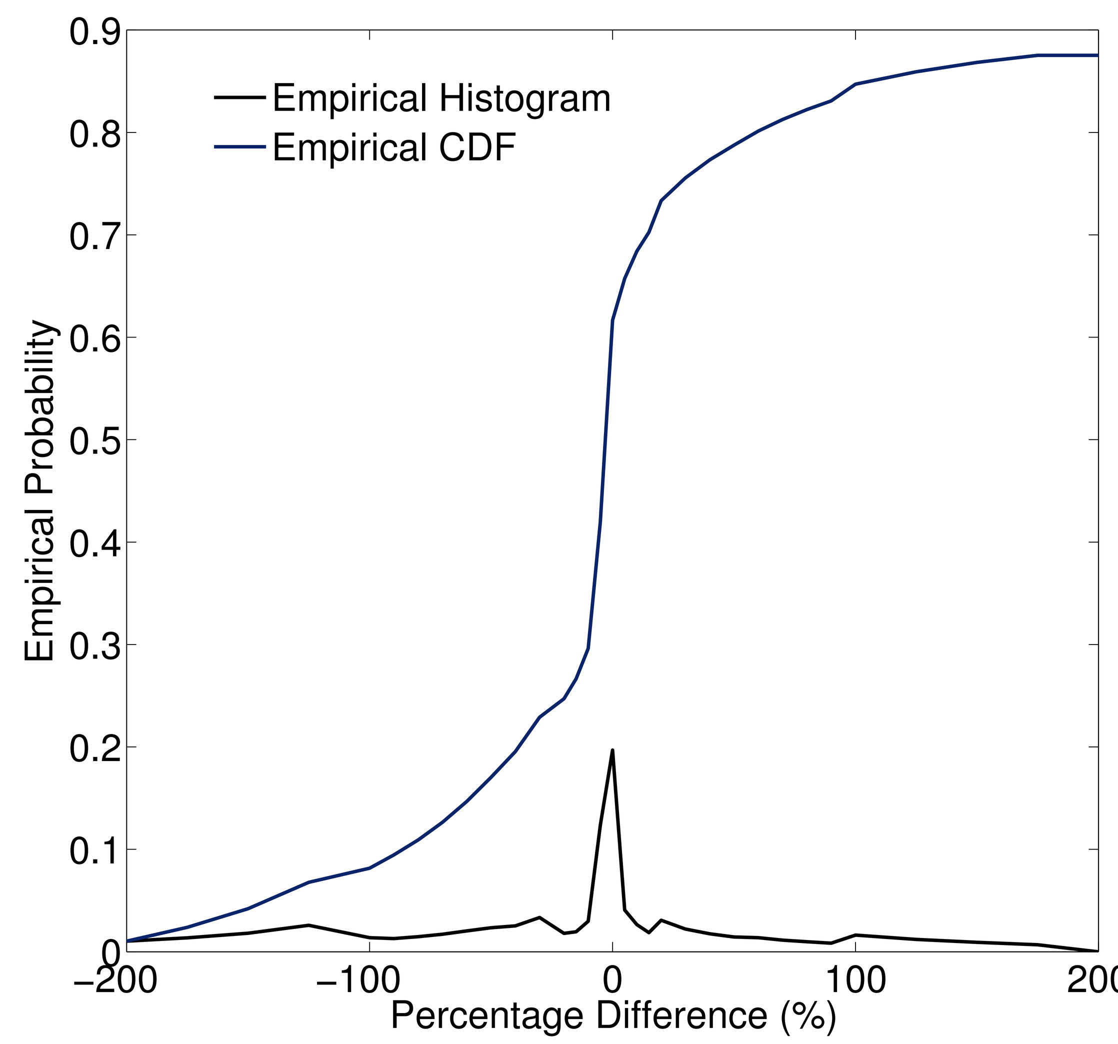
Results

We run the numerical model for seven profiles, using two different stratigraphy configurations. First, we used the the interfaces from the GPR interpretation and afterwards we used the assumption that the soil layers are parallel to the surface. The results clearly reveal the importance of the detailed knowledge of the subsurface topography in such types of simulations. In the next two figures the differences in pressure head between the GPR profile and the parallel layer profile are presented.





At the figure on the right the empirical histogram and empirical cumulative distribution function of the percentage difference between the GPR and parallel layer profiles are presented. It is obvious that around 40% of the cells across all the simulated profiles for the three different rainfall events have pressure differences that vary between 25% and 200%. These cells can create "bottle-neck" effects, where zones of high pressure head are observed. A local increase in the pore water pressure can significantly decrease the shear strength of the region and could initiate a slope failure. These results show that the role of subsurface topography is not at all negligible especially in phenomenon where the fluctuations of the water regime are very important (e.g. rainfall-induced landslides).



References

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[2] N.J. Cassidy, (2009). Ground Penetrating Radar data processing, modelling and analysis, *Ground Penetrating Radar Theory and Applications, p. 141-176, Elsevier, Amsterdam*