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A machine learning approach for alpine permafrost distribution modeling

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Several models of the alpine permafrost distribution show a direct correlation between the permafrost occurrence and the increase of altitude. If this may be correct at a regional scale, it is often not valid at a more local scale, because of the high spatial discontinuity of alpine permafrost. For instance, recent studies illustrated that alpine permafrost is usually present only in the lower part of talus slopes. However, this phenomenon has never been integrated in numerical models.

The purpose of this study was the development of a new empirical-statistical model of the alpine permafrost distribution in unconsolidated landforms, such as talus slopes, rock glaciers or glacial deposits, which includes the recent knowledge obtained from field investigations. The main goal of the present work was to develop a model reliable at the local scale. Predictor variables cover the Mont Fort-Mont Gelé region (Valais, Switzerland) and the model was tested on the Swisstopo 1:25'000 "Rosablanche" topographic map. Inputs such altitude, mean annual air temperature, direct solar radiation, aspect, glaciers, glacier forefields, rock glaciers, talus slopes or vegetation were extrapolated from a 25x25 m digital elevation model, the Swisstopo primary surfaces map and a rock glacier inventory. The dataset was completed by empirical data obtained during field campaigns.

In a first step, a machine learning approach for permafrost occurrence calculation in sedimentary deposits was chosen by using Support Vector Machines (SVM). This technique permits to solve nonlinear discrimination problems leading to high classification performances. SVM effectively represents a data-driven (non-parametric) approach that is suitable for high-dimensional datasets, avoiding overfitting and allowing a probabilistic interpretation of the outputs through a continuous decision function. However, less importance is given to the contribution of these features for the phenomena. In a second step, the lower limits of rock walls permafrost obtained by field measurements were added to the model.

The resulting map shows that the strong discontinuity of mountain permafrost could be satisfactorily simulated. For example, the permafrost lower limits for unconsolidated landforms were correctly recognized. In talus slopes, the decreasing probability of permafrost occurrence with altitude could be simulated in some cases, but improvements are needed.