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Projection of permafrost and snow cover evolution under climate change scenarios

Martin Scherler, Christian Hauck, and Martin Hoelzle
University of Fribourg, Geography, Department of Geosciences, Fribourg, Switzerland (martin.scherler@unifr.ch)

In this study a one dimensional coupled heat and mass transfer model of the soil snow atmosphere boundary layer (COUP Model) is used to simulate the evolution of two high alpine permafrost sites in Switzerland under the influence of climate change as projected by regional climate models (RCM's).

The soil model is driven by meteorological parameters (air temperature, relative humidity, wind speed, incoming short-wave radiation, incoming long-wave radiation, and precipitation). A complete energy balance is calculated for the snow or soil surface, yielding a surface temperature representing the upper thermal boundary condition of the soil profile. A constant geothermal heat flux determines the lower thermal boundary. The model includes the accumulation and melt of a seasonal snow cover, as well as freezing and thawing of the soil.

The sites of this study are Schilthorn in the Bernese Oberland and Murtèl in the Engadin. The sites were chosen because of their different morphologies and substrates, i.e. a rock slope with a substantial fine-grained surficial cover at Schilthorn and a bouldery surface with large blocks at rock glacier Murtèl.

The model has been driven by daily mean values of meteorological parameters taken from the output data of 6 different RCM runs (ENSEMBLES Project) for the time period of 1991 to 2050/2098. The seasonal bias in relation to the measured climate data has been determined on the basis of an observation period from 1999 to 2008 for Schilthorn and from 1997 to 2008 for Murtèl. The relative deviations have been corrected in the model input for air temperature, incoming short-wave radiation, incoming long-wave radiation, wind speed and precipitation.

The projected snow cover (> 10cm) at the two sites shows a general decrease in duration of about 50 to 80 days per year during the 21st century. The onset of the snow cover is delayed and the time that the sites become snow-free is earlier than observed in the recent years. For the Schilthorn site three scenarios show that the active layer varies between 5m and 12m until around 2020. After that period, the thaw layer does not freeze up anymore and a talik develops. Two scenarios show no stable permafrost conditions after 1998. One scenario predicts stable permafrost until 2050. For the Murtèl site three scenarios show an increase of active layer depth from 2.5m to around 7m in 2090. One scenario shows no change until 2050. Two scenarios predict the development of a talik at the Murtèl site in the late 21st century.

Although the predicted increase in air temperature and the decrease in snow cover duration are of the same magnitude for both sites, permafrost conditions at Murtèl are more stable. This is most probably due to the massive ice core in the rock glacier which absorbs a large amount of energy during melting.