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Mountain Permafrost - a useful indicator for climate change?

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Permafrost is often used as an indicator for climate change. It is assumed that its changes in temperatures are related to changes in atmospheric conditions. But compared to polar regions, permafrost in high mountain areas occurs in highly variable surface and subsurface material and texture over short distances. Therefore, the thermal regime of the active layer strongly depends on site-specific factors like the grain size, the pore volume and the type of material. By using mountain permafrost as an indicator of climate change it is essential to understand the processes depending on the different materials and textures as well as all mass and energy fluxes within the subsurface.

This work is based on a field experiment in the Murtèl- Corvatsch area, Upper Engadin, Switzerland, where 10 boreholes were drilled in different subsurface materials and landforms including rock glaciers, talus slopes and bedrock. A meteorological station within the investigated area is measuring air temperature, wind speed and direction, humidity, in- and outgoing longwave radiation, in- and outgoing shortwave radiation and the height of the snow cover. For all boreholes the mentioned microclimatic factors as well as the topographic situation (exposition, slope angle) are similar whereas the subsurface material changes. The material in which the boreholes were drilled varies from bedrock to coarse blocky and fine-grained substrate in which the texture and the ice content varies as well. Therefore, observed changes in subsurface temperatures are rather due to the subsurface material and texture than to varying atmospheric changes. Eight years of borehole temperature data allowed an estimation of the sensitivity of the different materials by analyzing the apparent thermal diffusivity as well as the soil heat flux for all sites.

The results show that the evolution of the subsurface temperatures within the last eight years and the calculated apparent thermal diffusivities reveal strong differences depending on the material. The thermal regime of bedrock is mainly driven by heat conduction within the rock and shows a strong responds to air temperature change due to comparatively high heat capacity. The subsurface temperature of the rock glacier is strongly influenced by its ice content. If the temperature of the ice is considerably below the freezing point the rock glacier sites respond only weakly to changes in surface temperatures. The talus slope is mainly governed by a process called the balch- effect, i.e. warm air of the subsurface will be replaced by subsiding cold air. At this site the thermal response to air temperature changes depends strongly on the temperature gradient of the exterior and interior, respectively the intensity of the balch- effect between the blocks.

If mountain permafrost is used as an indicator for climate change, it is essential to be aware of the different sensitivities depending on the material and texture. The calculated thermal diffusivities and the soil heat flux for different materials can also be used as important input parameters for modelling the development of mountain permafrost.