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# Long-term monitoring of bedrock permafrost within the MOREXPERT project – A scale-dependent approach for the investigation of ground thermal conditions in a high alpine environment, Kitzsteinhorn, Austria

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The research project MOREXPERT ('Monitoring Expert System for Hazardous Rock Walls') has initiated a new long-term study site for bedrock permafrost monitoring in the Austrian Alps (project launched in September 2010). Based on a combination of thermal, geophysical, geotechnical and laboratory measurements surface and subsurface conditions are monitored at the Kitzsteinhorn (3.203m), Hohe Tauern, Austria. Within MOREXPERT ground thermal conditions are investigated on three different scale levels. At each scale level ground thermal conditions are studied employing different methodical approaches and therefore with different spatial and temporal resolutions. This diverse distribution of information in space and time provides a clear differentiation between vertical and horizontal thermal dynamics. Consequently it offers valuable insights on the influence of climatic changes on bedrock permafrost dynamics in a high mountain environment.

The smallest scale level is the 'borehole scale'. Five boreholes have been drilled into permafrost-affected bedrock to measure ground temperatures up to a maximum depth of 30m. At 'the borehole scale' the characterization of ground thermal conditions can be described as purely one-dimensional since temperature data is collected solely along a vertical line (thermistor chain). Horizontal variations of thermal conditions cannot be resolved, the large investigation depth however allows the examination of a broad spectrum of thermal patterns ranging from short-term variations of ground surface temperatures to shifting thermal signals in great depths that correspond to long-term climatic variations in recent decades. The 'borehole scale' represents the only scale level where direct temperature measurements are conducted within the actual permafrost body. It is therefore the only scale that provides direct permafrost evidence.

2D-geophysical investigation of subsurface conditions represents the medium scale of investigation ('slope scale'). Two permanent ERT (Electrical Resistivity Tomography) profiles have been installed on north-facing slopes for automated recording of subsurface electrical resistivity conditions. ERT surveys do not permit direct temperature measurements and therefore do not deliver direct permafrost evidence. Yet laboratory calibration of a temperature-resistivity-relationship allows the indirect inference of thermal information from electrical resistivity values obtained in the field. At the 'slope scale' depth of investigation is reduced by half (15m) compared to the borehole scale (30m), therefore eliminating the possibility to observe long-time shifts of permafrost temperatures in great depths. However, as information on thermal conditions is collected along a two-dimensional profile line, a 'horizontal dimension' is added at this scale level. At the 'slope scale' it is therefore possible to take into account the horizontal variability of active layer dynamics, freeze-thaw cycles and ground surface temperature patterns.

The entire summit pyramid of the Kitzsteinhorn (300 meters in height, 3.5ha) represents the largest investigation scale ('mountain scale'). At this scale level near-surface rock temperatures are recorded by dozens of miniature temperature loggers in various depths (up to 80cm). In comparison to the 'borehole scale' and the 'slope scale' investigation depth is further reduced implicating that information on permafrost dynamics have to be inferred from ground surface temperature patterns. At the 'mountain scale' focus shifts to the recognition of the horizontal heterogeneity of ground surface temperatures and freeze-thaw cycles over comparatively large areas. Thermal information is collected for different altitudes, aspects and slope inclinations yielding a quasi-spatial image of the Kitzsteinhorn's ground thermal regime.