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Time-lapse electrical resistivity tomography (ERT) to estimate temperature changes at depth in a low elevation ventilated cold talus slope (Dreveneuse, Swiss Prealps)

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Seasonally reversible air circulation throughout a whole talus slope plays a major role on its thermal regime. The mechanism, which is dependant on the thermal contrast between the inner of the scree and the outer air, produces a strong negative thermal anomaly in the lower half of talus slope. It can also lead to the extra-zonal occurrence of permafrost at depth.

The acquisition of temperature data is generally limited to the ground surface or, in most favourable situations, to borehole(s). The dependency of ground electrical resistivity to temperature makes the use of time-lapse electrical resistivity tomography (ERT) a promising tool for documenting more precisely the spatial pattern of the seasonal temperature changes at depth.

The Dreveneuse talus slope (1550-1610 m a.s.l, Swiss Prealps, MAAT about +4°C), consists of limestone blocky and pebbly clasts. It is about 100 m long and is covered in its lowermost third by a singular forest of dwarf red spruces, a typical evidence for cold ground temperature in summertime. Larger trees cover a middle section of the slope, whereas vegetation is almost absent in the upper half part. Temperature measurements in two boreholes have permitted to observe both the particular geometry and temporal dynamics of permafrost in the talus slope, its aggradation between 2004 and 2006 (Delaloye and Lambiel, 2007) and its complete degradation in 2007.

The site has been equipped with a 141 m longitudinal fixed ERT profile (spacing 3 m, 48 electrodes) since fall 2007. The ERT survey has been carried out (Wenner-Schlumberger configuration) every 7 to 30 days depending on access possibility and meteorological evolution. Resistivity model calibration is provided by thermal monitoring in two boreholes (BH1 and BH2).

Up to now, ERT measurements have been carried out on October 18 and 26, November 9 and 29, December 22, 2007. ERT on 18 October was acquired by the end of the downstream ventilating season, that is when the lower part of the slope was the warmest. Moreover, the borehole data attested the absence of permafrost at that time. The result can be considered roughly as an image of the ground resistivity independently on its thermal state. The winter phase of ventilation, that is the aspiration of cold air refilling the internal cold reservoir, started on October 19. The following profiles have been measured after the talus slope began to freeze. Preliminary results of ERT monitoring indicate:

1. beneath a 2-3 m superficial layer, the occurrence of a resistive body (>40 kOhm.m) about 10m thick – according to borehole - and 45m long, not restricted to the dwarf spruces area but extending towards the upper part of the slope;

2. a good relationships between the mean ground temperature of the talus section at BH1 and the mean apparent resistivity values at that place agreeing with theory (Hauck 2001): linear slight increase of apparent resistivity with decreasing ground temperature above 0˚C, but strong exponential increase by ground temperature dropping below 0˚C;

3. between October 18 and December 22, the strong resistivity increase of the uppermost 3 m, and the longitudinal and vertical expansion of the deeper resistive body accompanied by an increase of specific resistivities of about 4 to 8 times, both illustrating the penetration of freezing as an effect of the cold air aspiration;

In order to assess whether features at depth – and their resistivity changes in time – are real or are artefacts of the inversion process, the DOI index (Depth Of Investigation) (Marescot et al. 2003) is applied to our data. The DOI index points out an area with values higher than 0.2, i.e. little or not reliable, just below the high resistivity body. Others tests are also applied (sensitivity graphs, use of several damping factors. . .) to prevent over- or misinterpretations.

References :

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