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DC resistivity tomography applied to monitoring active layer environments below patterned ground in Svalbard

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Patterned ground is one of the most characteristic features in arctic periglacial landscapes that originated from various periglacial processes. On flat tundra surfaces composed of fine-grained soils, ice-wedge polygons are dominant, but mud boils and hummocks are also developed. Their distribution is constrained by local ground material, hydrology, snow cover, vegetation and freeze/thaw regimes. Whereas there have been a large number of studies on patterned ground phenomena, environmental factors distinguishing the types of patterned ground are not well understood. We applied DC resistivity tomography to understanding hydrological characteristics and freeze/thaw dynamics at adjoining ice-wedge and mud-boil sites in Adventdalen, Svalbard, where comprehensive periglacial process monitoring has been undertaken. Electrode arrays consisting of 81 nails spaced at 20 cm intervals were fixed at each site early in June 2009 immediately after the snow cover disappeared. The nails were stuck within the top 5 cm to resolve the top layer of the ground. Measurements were carried out repeatedly at approximately two week intervals.

Spring results from both sites are characterized by an increase in resistivity near surface due to drying up. This tendency is prominent in the ice-wedge polygon centre where standing water remains until late spring. Time-lapse analyses indicate a distinct decrease in resistivity in seasonal frozen layer at both sites probably due to an increase in unfrozen water content by downward heat transfer. Summer profiles from both sites display a distinct resistivity boundary propagating downward with time, corresponding well with the thaw depth measured by mechanical probing. These data also show near-surface high resistivity spots indicating the location of desiccation cracks. Profiles from the mud-boil site show higher resistivity in the thaw layer than those of ice-wedge site, implying different drainage condition between them. After seasonal freezing starts, the difference in resistivity variations is intensified between the two sites. Resistivity profiles at the mud-boil site show a high resistivity zone slowly descending from the ground surface, which is likely to reflect a decrease in unfrozen water content rather than the freezing front invasion. Time-lapse analyses reveal that the resistivity increased conspicuously just below the mud boils in autumn during freeze up, which indicates the growth of ice lenses as observed in frozen soil cores obtained in the spring of 2009. Another characteristic feature is low resistivity spots located just below the near-surface high resistivity zone, implying the migration of unfrozen water toward the ice segregation formation area. In contract to the seasonal analyses of the mud-boil site, the ice-wedge site shows resistivity profiles lacking changes in resistivity until the ground surface temperature decreases to a few degrees below zero during freeze up. This is probably due to weak ice segregation activity as shown in frozen soil cores lacking visible ice lenses. Time-lapse analyses show increasing resistivity beneath snow-free ramparts, which reflects both preferential cooling from the exposed ramparts and a decrease in unfrozen water content during freeze up. A time series of resistivity profiles show seasonal variations and site-specific characteristics, especially after the onset of seasonal freezing. However, resistivity profile acquisitions were limited to early October due to poor grounding even though monitoring sensors had been indicating further frost heaving by ice segregation and a decrease in unfrozen water content in the grounds.