Quantification of liquid phase connectivity in permafrost soils

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In recent years, ERT imaging is more frequently used in the context of monitoring of climate induced thawing of permafrost soils. However, to detect the unfrozen water in the active layer using geoelectric methods, resistivity values must be linked to the liquid water content in the subsurface. By comparing ERT and borehole data from the Swiss permafrost monitoring network (PERMOS) at the Schilthorn site (Switzerland), conditions with frozen and liquid water could be distinguished. To classify electrical conductivity values with respect to the presence of a continuous liquid phase, we calculated various connectivity measures like the Euler-Poincaré-characteristic and (local) percolation thresholds of resistivity patterns in frozen and unfrozen soils. By increasing systematically the electrical resistivity values separating an ERT image into regions of high and low conductivity, a resistivity threshold could be defined that must be exceeded to form a continuous pattern of the conductive regions. We show that this critical resistivity value is systematically lower for unfrozen soils, and we apply it to classify ERT-transects with respect to the existence of continuous liquid structures without complementary borehole measurements. The definition of such critical resistivity value separating between frozen and unfrozen regions depends on the relationship between temperature, volumetric water content, and electrical conductivity. This relationship is ambiguous and depends on the amount of liquid water at onset of freezing and the spatial arrangement of the four phases (grains, air, water, and ice). By comparing point measurements of water content and electrical conductivity in a soil profile with ERT transect data, the magnitude of the hysteretic relationship could be quantified to assess its effect on classifying ERT patterns with respect to liquid phase continuity.