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Effect of surface cracking propagation on induced polarization of clay under freeze-thaw cycling and desiccation processes

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Freeze-thaw cycles and desiccation significantly influence soil surface cracking and shrinkage, reshaping pore structures and altering hydraulic properties. Despite their importance, studies using geophysical methods to evaluate how soil crack patterns and shrinkage respond to climate change remain limited. In this study, we utilized induced polarization (IP), a sensitive and non-intrusive geophysical technique, to investigate the relationship between soil surface crack patterns and complex conductivity during freeze-thaw-desiccation and desiccation-only processes. Laboratory experiments revealed that the desiccation-only sample exhibited a distinct surface texture and different types of crack intersections compared to the freeze-thaw-desiccation sample. While Y-junction-dominated crack patterns form on the sample surface during the freeze-thaw-desiccation process, the desiccation-only sample predominantly displayed more T-junctions at the crack intersections. SIP measurements revealed a sharp decline in both in-phase and quadrature conductivities below the freezing/thawing point, with high-frequency ice polarization signals emerging. During desiccation, these components exhibited an exponential decline with a consistent decay time (τ = 358 mins). Furthermore, a clear linear relationship was observed between both conductivities and surface crack ratio, as well as gravimetric water content. These findings highlight the potential of IP for monitoring crack propagation and subsurface water dynamics in clayey soils, offering a promising tool for field applications like time-lapse tomography on clayey slopes to assess water transport and structural stability.