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Low frequency induced polarization of porous media undergoing freezing: from pore to the field scale

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Induced Polarization and Electrical Resistivity are non-intrusive geophysical methods that can characterize thermal anomalies (e.g. geothermal system) or monitor thermal changes in different environments (e.g. permafrost). To improve our interpretation of geophysical observables in such environments, we need to understand the thermal dependency of the complex conductivity associated with (or without) a phase change. Thus, nine samples were selected to perform spectral conductivity measurements with respect to temperatures ranging from +20 to -15°C. We selected three clayey soils, two granites, one graphitic tight sandstone and three clay-sand mixes. A total of 12 experiments were conducted, including one soil sample measured at different salinities to provide the impact assessment of salinity on the freezing point and on the complex conductivity response. Complex conductivity spectra were analysed with the dynamic Stern layer polarization model associated to a freezing curve. At low frequencies (< 10Hz) and without phase change, the in-phase and quadrature conductivity increased by 2% per degree, due to the thermal dependence of the charge carrier mobility. The phase change can be reflected by reducing the liquid water content and increasing the pore water salinity (salt segregation) which led to a brutal decay with temperature of the in-phase and quadrature conductivity. The dependencies of in-phase parameters (i.e. bulk, surface conductivity) and quadrature conductivity can be linked by an exponential freezing curve which in turn described the thermal dependence of liquid water content. In addition, one of the soil sample came from an alpine rock glacier from Val-Thorens (Vanoise massif, France), where a 3D induced polarization study was performed. Field and laboratory measurements are consistent, and the ratio between normalized chargeability and surface conductivity is close to dimensionless number R = 0.08. The theory implies that this dimensionless number R is independent of water content and temperature in agreement with laboratory experiments.