Monitoring permafrost dynamics in Antarctica with automated electrical resistivity tomography: Advances in instrumentation and data processing

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Studies of active layers and permafrost dynamics in Antarctica are typically conducted through boreholes, which are invasive, expensive, and rarely representative at the field level. Electrical Resistivity Tomography (ERT) has become one of the most widely used tools for permafrost research as it allows for non-invasive and cost-effective permafrost investigations in two or three dimensions due to the strong contrast in electrical resistivity between unfrozen and frozen materials. ERT surveys can also provide insights into the dynamics of permafrost and active layer distributions if repeated. However, few operational ERT monitoring sites exist in permafrost terrain due to the logistical requirements of repeating individual profiles annually. In contrast to manually repeated measurements, automated systems (A-ERT) enable continuous measurement of ERT, however such systems are scarce worldwide, and processing large datasets generated by A-ERT can be challenging.

We developed a low-cost and robust automated electrical resistivity tomography setup with a solar panel-driven battery and multi-electrode configuration for autonomous and non-invasive monitoring of active layer and permafrost dynamics. We implemented this system at several sites in the Western Antarctic Peninsula with existing GTN-P and CALM monitoring networks. ERT data were collected in 6-hour intervals, producing long-term quasi-continuous measurements. We also developed an automated data processing workflow to efficiently filter and invert the large obtained datasets, where the inversion process was carried out using the open-source pyGIMLi library. Extracting inverted resistivity values at a virtual borehole enabled assessment of changing site conditions over short and long-time scales and allowed for comparison to measured temperatures and frost probing. Maximum vertical resistivity gradients accurately indicated the depth of the thawed layer in the summer, showing that A-ERT can be used to autonomously monitor active layer depth.

Analyzing the obtained A-ERT datasets, we demonstrate that such low-cost A-ERT setups can operate in remote and extreme environments such as Antarctica and obtain high-resolution ERT data of high quality. Furthermore, we show how we are able to extract key information from a large amount of A-ERT data efficiently and quickly using this developed processing workflow.