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Optimization of thermal parameters of frozen ground using surface geoelectrical data from permafrost monitoring and surface temperature measurements

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Climate change is expected to significantly affect the Arctic regions. One of the effects of increase of mean annual air temperatures will be an increased soil warming. In the presence of permafrost, such a change of ground thermal regime will result in deepening of active layer, thawing of permafrost underneath and reduction of ground stability. In order to predict the extent of expected changes, it is desirable to have a modeling tool able to assess current and future thermal state of permafrost. Therefore we propose a method of calibrating ground thermal parameters based on non-invasive surface measurements, as opposite to direct borehole measurements and core sampling.

In our 1D inversion scheme, the observed apparent resistivities from a time-lapse ERT installation are used in combination with observed surface temperatures to optimize the parameters of a ground heat transport model. The surface temperature measurements are used to drive the heat transport model simulating a temperature distribution in the ground based on estimated ground thermal parameters. From the calculated temperature distribution, the effective resistivity distribution in the modeled domain is derived as geometric mean of specific resistivities of ground components (mineral grains, water and ice) weighted by their respective volumetric fractions in each model layer. An apparent resistivity response of such ground is calculated using CR1Dmod forward modeling tool. The simulated apparent resistivities are then compared to the field-measured apparent resistivities and the misfit between the measured and simulated apparent resistivity response is minimized by adjusting the parameters of the heat model. The coupling link between the thermal and electrical properties of ground is the temperature-dependent unfrozen water content. The advantage of the proposed optimization scheme is that the thermal model is coupled directly to the observed apparent resistivities, with no need for individual inversion of the resistivity profiles.

In a synthetic modeling study, the parameters used to describe the heat transport in frozen ground were recovered when synthetic apparent resistivity data with added noise were used for calibration. It was found that one full freezing season was sufficient to recover the uncertain parameters of the coupled thermo-geophysical model. One year´s worth of geoelectrical monitoring data from a field site in Ilulissat, Greenland, are used to validate the coupled inversion scheme.

It is consequently concluded that the surface geophysical measurements together with surface temperature measurements can be used to calibrate the heat model of the frozen ground without direct measurement of ground thermal parameters on soil samples. The model, when calibrated for specific site conditions, can be used for prediction of ground thermal stability changes under a chosen climate scenario when expected surface temperatures forcing is applied.