Reducing ambiguity in ground ice detection through Spectral Induced Polarization

INTRODUCTION

The ability to differentiate between frozen and unfrozen water content can be improved through SIP. In the case of unfrozen materials, the low resistivity is caused by electrolytic conduction that occurs via the interconnected pores. Considering the fact that air, rock matrix, and ice can produce similar values of electrical resistivity, it is difficult to interpret the subsurface electrical resistivity in many practical applications.

Resistivity methods determine whether or not a medium has the ability to conduct electric current in terms of transfer resistances; SIP methods find out whether the medium is additionally. Using SIP measurement, it is possible to estimate the electrical properties of the ground at different frequencies in the hertz to kilohertz range and relate subsurface electrical properties to the ground's lithological, textural, hydraulic, and geochemical properties. Several studies have demonstrated that SIP measurements taken in soils and rocks are sensitive to changes in temperatures above the freezing point and under freezing conditions, so SIP can be employed to detect ground ice.

STUDY AREA

The study area is located at the Birch Syrup Lithalsa (114.2768˚W, 62.5071˚N) for a 36-m profile. Silt/clay soils cover the study area; the dry top of the lithalsa (profile start) has a tall birch forest and temperatures at 10 cm deep (on Nov. 8, 2017) are between -8.2˚C and -5.7˚C; while the foot (profile end) is in a moist spruce forest with temperatures between -0.0˚C and -0.3˚C.

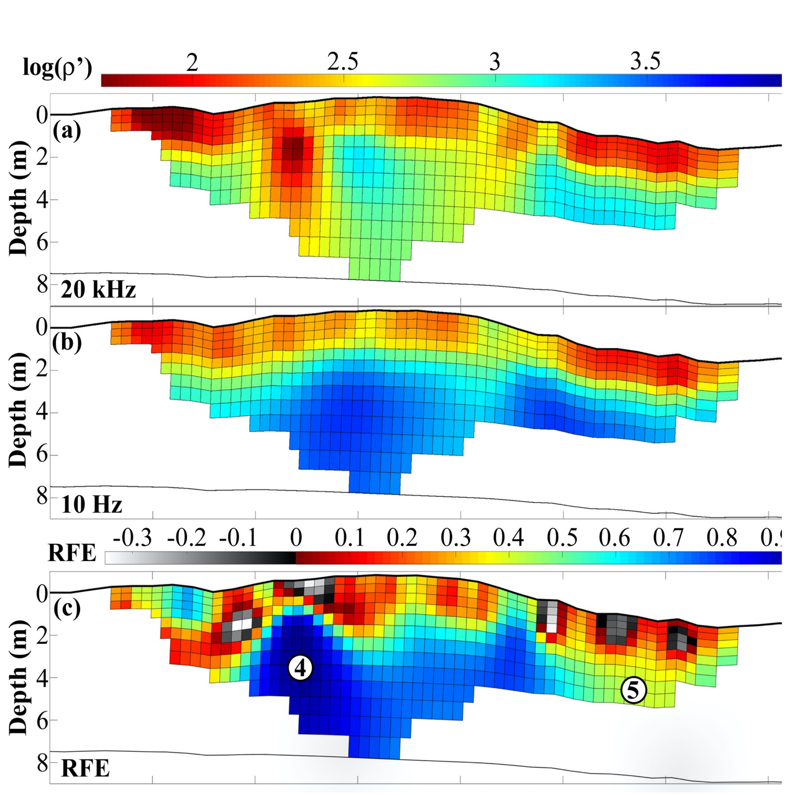
DATA ACQUISITIONS

SIP field measurements were done with the Fuchs SIP III. System characteristics include a 20-kHz bandwidth, high input impedance, fiber-optic communications from the receiver electrodes, a remote reference electrode for noise reduction.

Initially, the current) and potential electrodes are spaced equally with a dipole separation of 1 or 2 meters to maximize efficiency. The measurements of SIP were conducted using four sets of potential electrodes that dipole spacing was 0.5, 2, 3.5, and 5 meters at 10 Hz, 1 kHz, 10 kHz, and 20 kHz.

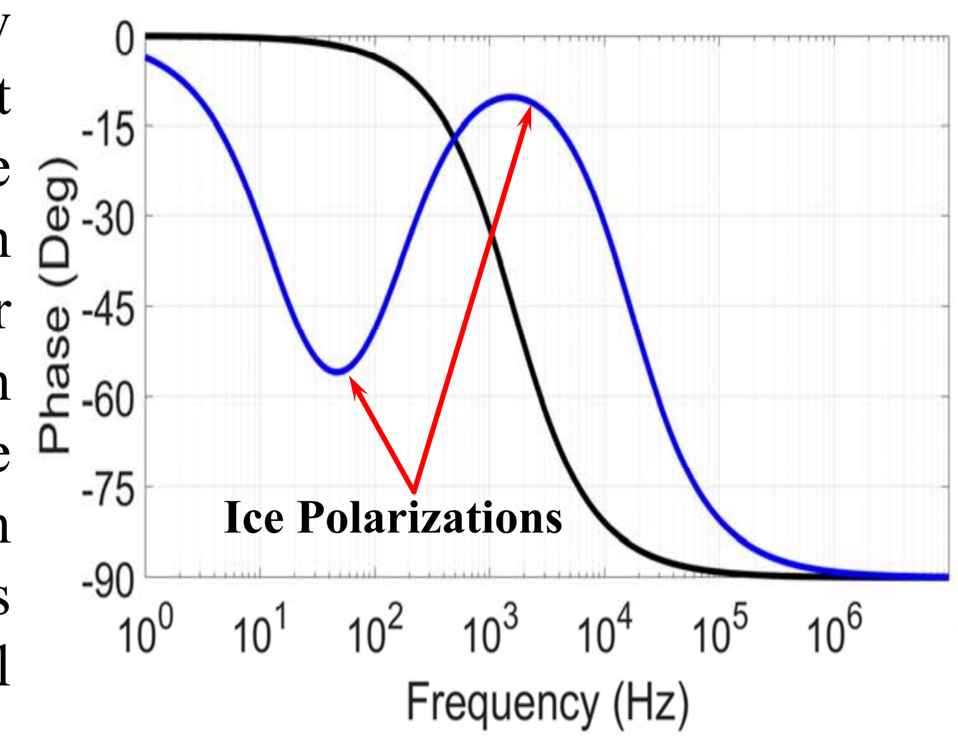
RESISTIVITY

David Stillman et al. (2018); by considering the Resistivity Frequency Effect (RFE), which is the difference between the low- and high-frequency resistivities normalized by the low-frequency value; concluded that on the left-hand of the study area (marked 4) because of the high value of RFE, there is high ice content (drilling results confirmed it), and on the right hand, there is waning ice (because of the low value of RFE).

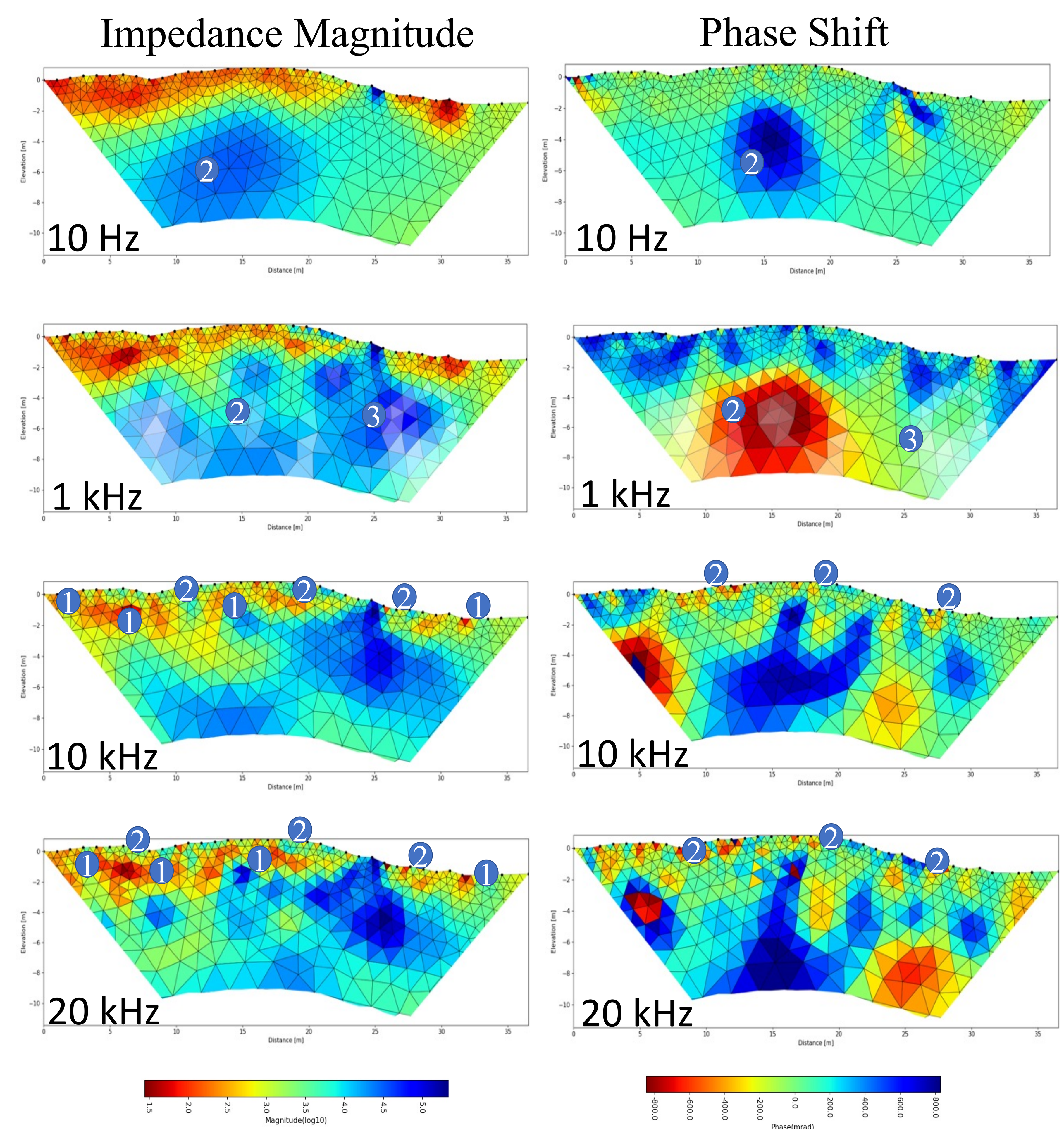


PHASE SHIFT CHANGES

This contribution presents new processing of this data, so that phase (polarization) can be recovered. Phase shift changes can help to discriminate ice from other materials. For example, as shown in the front figure, the blue line indicates a phase angle spectrum for ice and the black line indicates the response for a solid material like bedrock.



RESULTS



1. Low resistivity
2. High Resistivity with high phase shift changes at different frequencies
3. High resistivity with smooth phase shift changes at different frequencies

INTERPRETATION

Higher frequencies translate to better resolution at shallower depths, while lower frequencies have deeper penetration depths. In the shallower depth, we used 10 kHz and 20 kHz profiles to identify frozen ground in the top 10 to 15 centimeters (high resistivity, high phase shift changes) and unfrozen ground (low resistivity) at a depth of 2 meters. Deeper in the ground, we used 10 Hz and 1 kHz profiles to determine frozen ground (high resistivity and high phase shift changes) and bedrock (high resistivity and smooth phase shift changes).

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Reference

Stillman, D., Robert, G., Stephan, G. (2018). Spectral Induced Polarization Surveys to Infer Ground Ice in a Peatland and a Lithalsa in Warm Permafrost Near Yellowknife, Canada., 5TH EUROPEAN CONFERENCE ON PERMAFROST.