Revealing Ground Ice by Spectral-Induced Polarization

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What is SIP? And what can it tell us about permafrost?

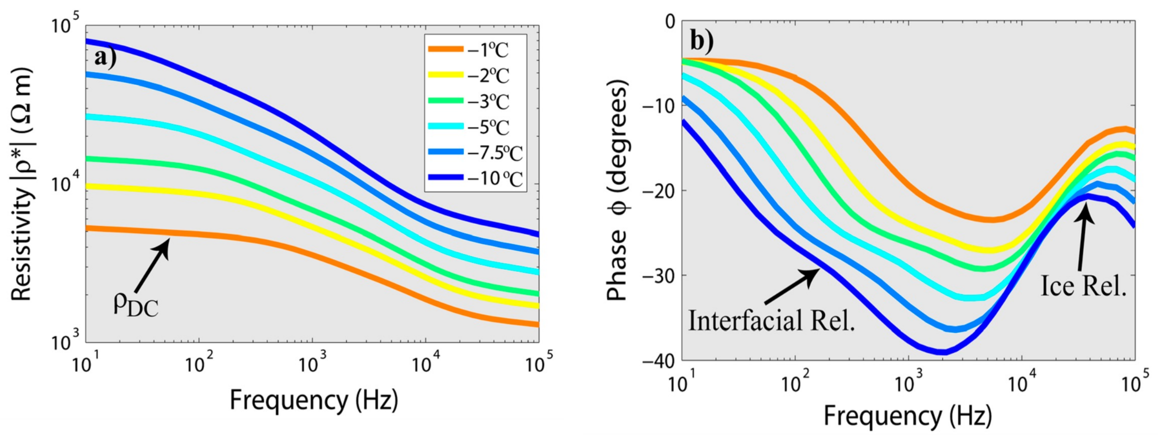
Spectral Induced Polarization (SIP) uses sensors on the ground surface to produce the earth's complex resistivity (resistivity and phase) profile. SIP is a very effective way to understand subsurface conditions without drilling. SIP has two main parts: resistivity (magnitude) and phase shift profiles for different frequencies. Ice has a much higher electrical resistivity than water which can be identified in the resistivity (magnitude) part, and ice shows relaxation in lower frequencies than bedrock which can be detected in the phase shift part. Also, SIP spectra have temperature and ice volume dependency that can reveal more details of permafrost conditions.

SIP VS **ERT**

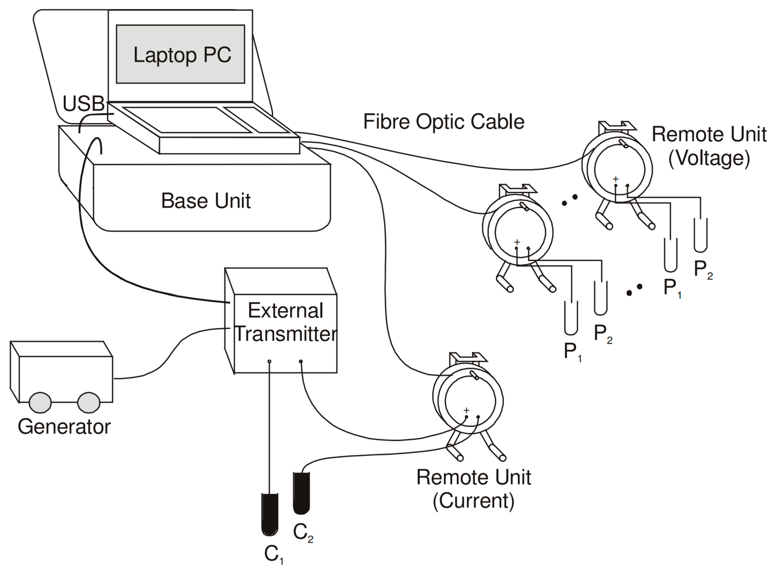
SIP:
- **High Resistivity**
  - **Bedrock**
  - **Frozen Area**
    - **Temperature**
    - **Water content**
    - **Ice content**
- **Low Resistivity**

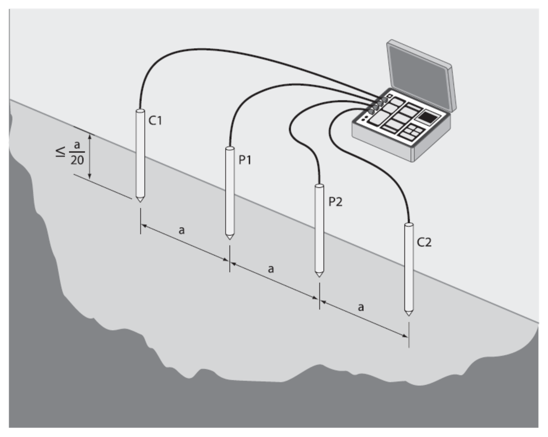
ERT:
- **High Resistivity**
- **Low Resistivity**

The temperature dependencies of the SIP measurements



Measuring instrument and configuration

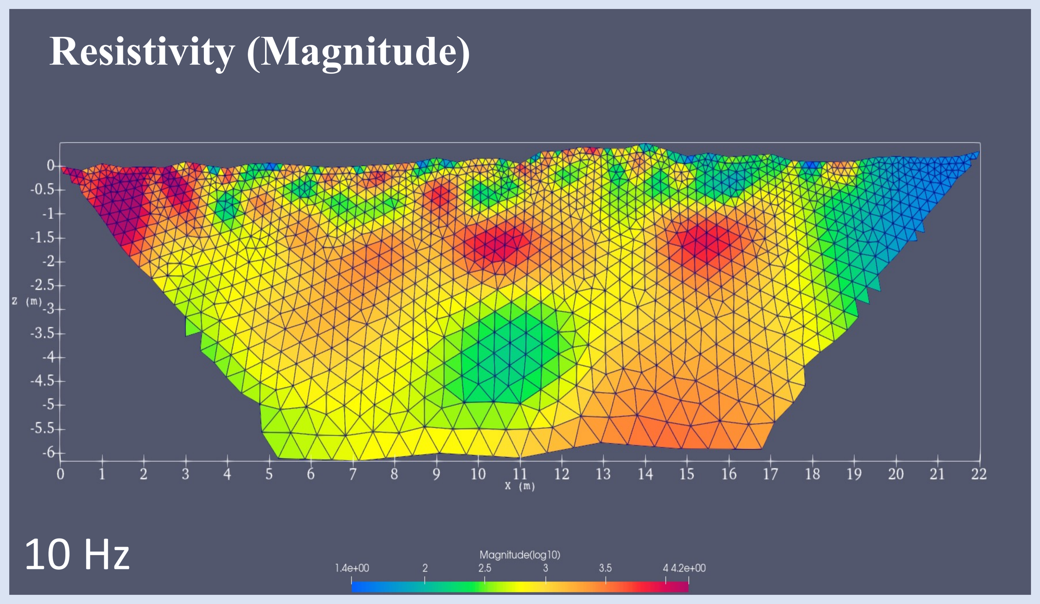


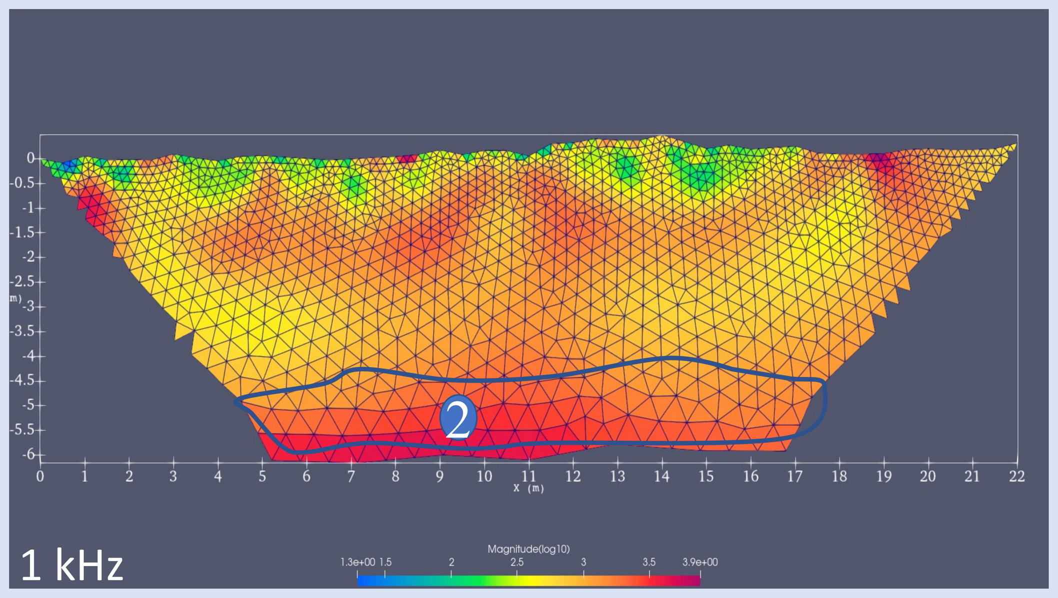


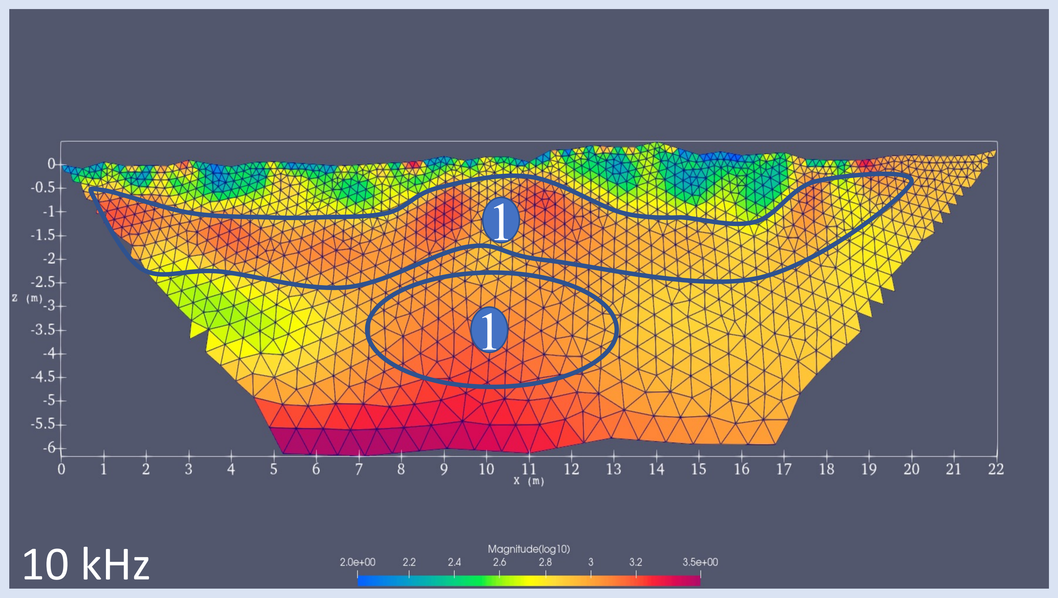
Study Area

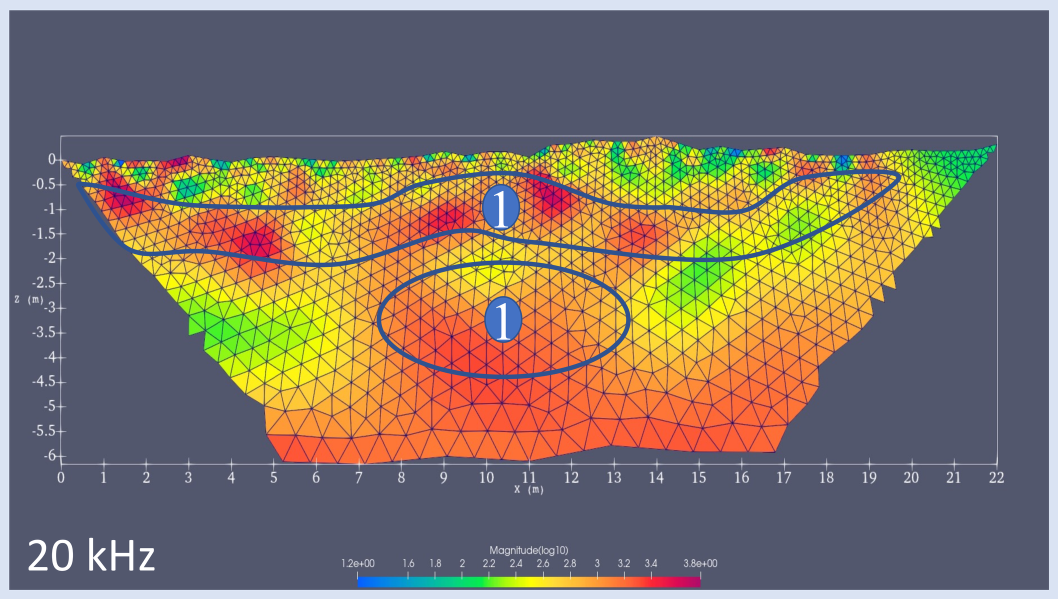
Study area is located at Yellowknife, for a 22 m profile. The measurements were performed on Nov. 9, 2017. Nearby cores suggest ~1.5 of peat underlain by a layer of fluvial sand and a layer of silt and clay.

Inversion Results (using Pybert package)

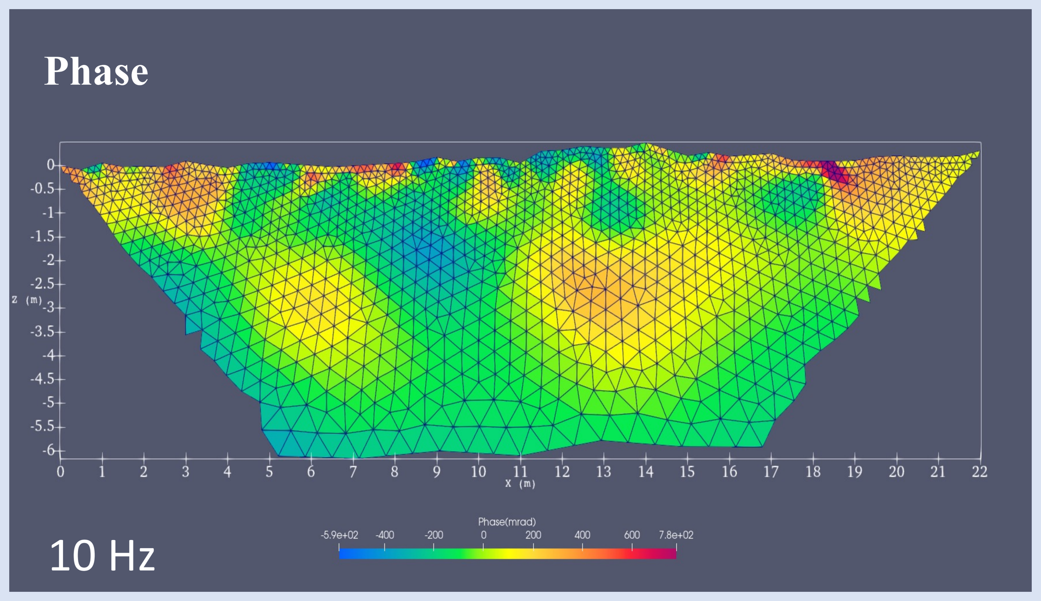


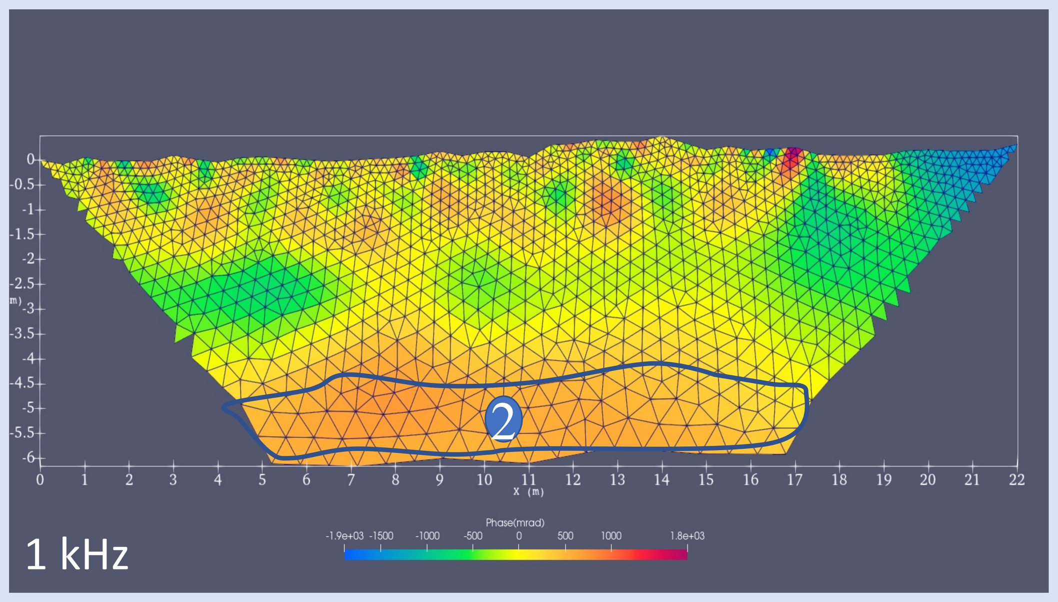


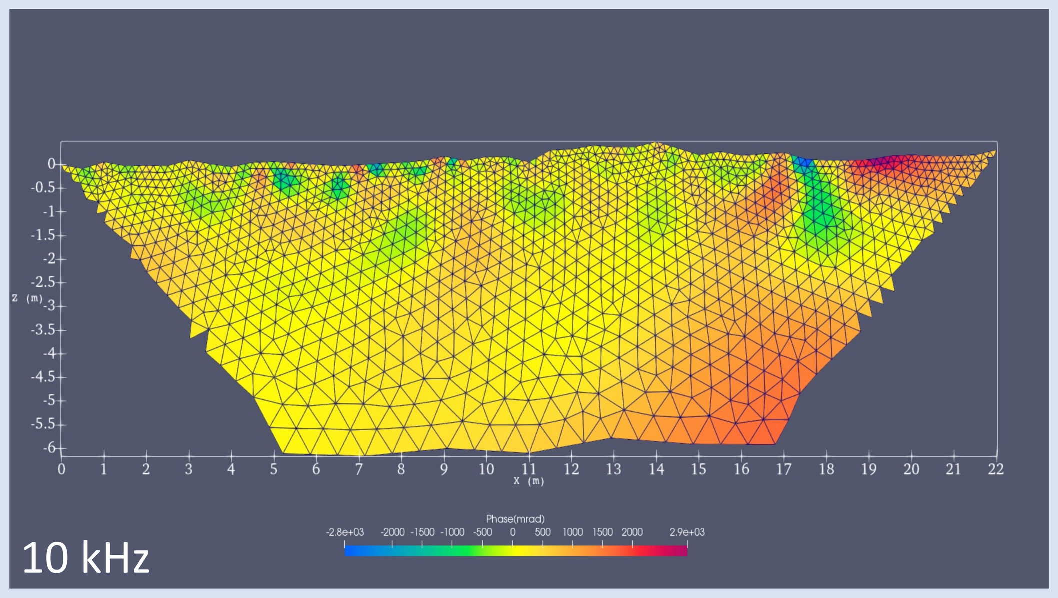


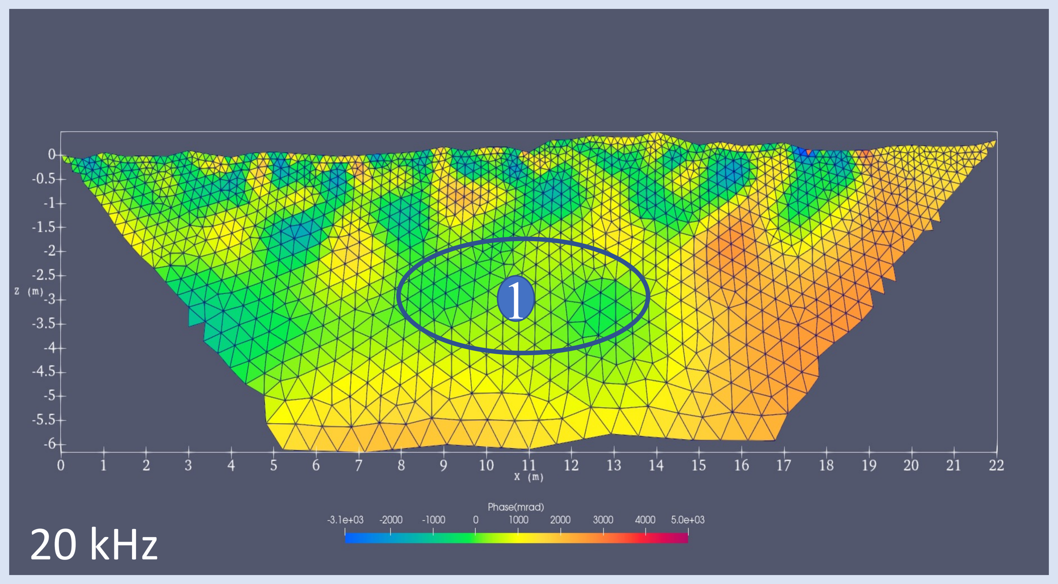


1. High Resistivity with high phase shift changes at different frequencies
2. High resistivity with smooth phase shift changes at different frequencies



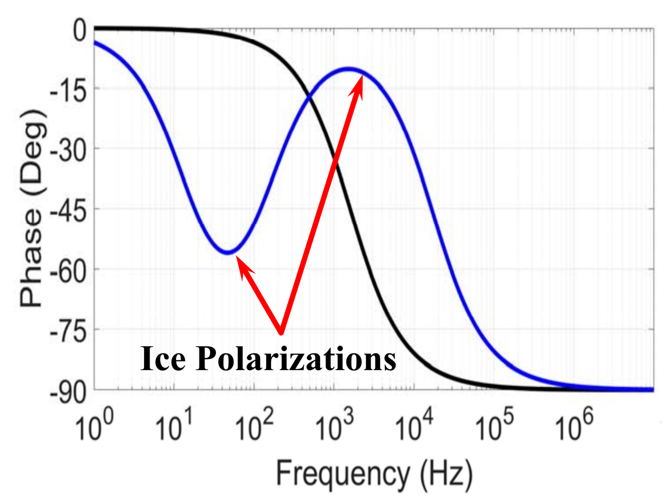






Phase shift changes

This study presents a new way to process of SIP data which allows the recovery of phase. 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.



Discussion & Conclusions

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 unfrozen ground at the top (low resistivity) and frozen ground (high resistivity, high phase shift changes) at a depth of 0.5 to ~1.7 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)

- SIP can discriminate between frozen and bedrock area
- Good electrode contact is necessary to obtain clean data and is hard to accomplish in peatlands.
- Extraction of dielectric spectra can reveal more properties (like temperature, and water content) of ice.

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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.