Electromagnetic induction sounding – ice thickness measurements at the University Bremen Campus?

Course: Introduction to Environmental Measurement Techniques

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Instruments: Geonics EM31-MK2 induction sounder and hand-held GPS receiver

Background

For many environmental, geophysical, and natural resources applications, knowledge of the electrical conductivity of the underground is of high importance. Examples are mapping of minerals and metallic ores, ground water, and detection of landfills or groundwater and soil contamination. There are several geophysical methods that are sensitive to the electrical conductivity of the underground and can therefore be used in those applications. With electromagnetic induction (EM) sounding the conductivity of different layers can be measured by actively inducing eddy currents in the layers by means of electromagnetic fields (primary EM field; Figure 1). These eddy currents will induce their own electromagnetic fields (secondary EM field) whose amplitude and phase depend on the electrical conductivity of the respective layers. By measuring the amplitude and phase of the secondary field the conductivity structure of the underground can therefore be observed. The advantage of the EM method over other conductivity-sensitive methods is that it does not require contact with the ground. It can therefore be carried out while walking, driving, or flying over the ground.

EM sounding is widely used for sea ice thickness measurements. These take advantage of the fact that sea ice is highly resistive while sea water is very conductive. Therefore the distance to the ice-water interface can be accurately sensed. Figure 2 shows the typical, negative-exponential relationships between the measured (apparent) conductivity and ice thickness determined at drill holes. Measurements can be performed by walking, driving by snowmobile, or flying over the ice (Figure 3).

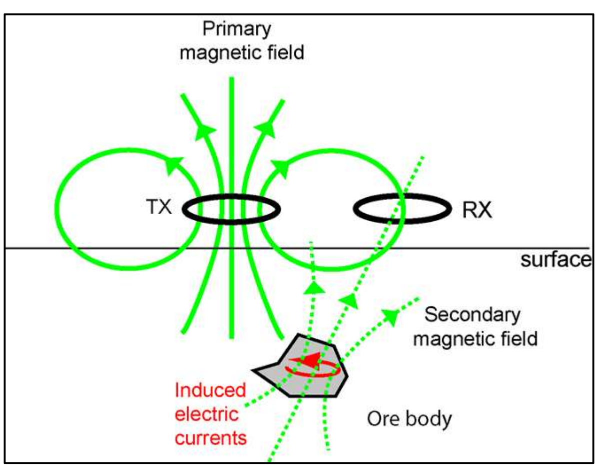

Figure 1: Principle of electromagnetic induction (EM) sounding measurements of the underground conductivity (left, Tx and Rx are the transmitter and receiver coils, respectively); Typical EM measurements with a Geonics EM31MK2 instrument (right; photo by C. Haas @ southern Alberta).

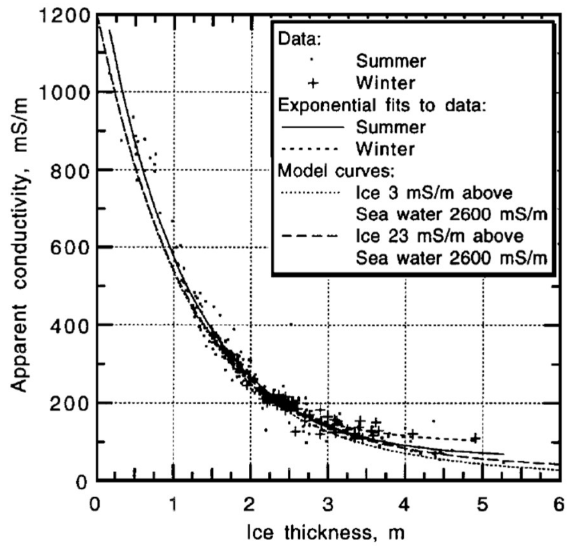

Figure 2: Measured apparent conductivity versus ice thickness for winter and summer data sets with different ice temperatures, porosities, and conductivities. Curves show exponential fits that can be inverted to convert measurements of apparent conductivity to ice thickness. Also plotted are two theoretical, two-layer 1-D model curves for ice floating on water with a conductivity of 2600 milli-Siemens per meter (mS/m). Ice conductivities of 3 for winter and 23 mS/m for summer have been assumed. From Haas et al. (1997).

Figure 3: Examples for ice thickness measurements by snowmobile (left; compare instrument with Figure 1) or aircraft (right, using a towed EM Bird).

Ice thicknesses are generally displayed on maps, as profiles, or summarized as histograms, so-called ice thickness distributions. Examples are shown in Figure 4. With most mapping sensors geographical information is usually recorded by Global Positioning System (GPS) satellite navigation systems. The obtained geographical positions of latitude, longitude, and time have to be converted to Cartesian coordinates and distance and time to be useful for further analysis.

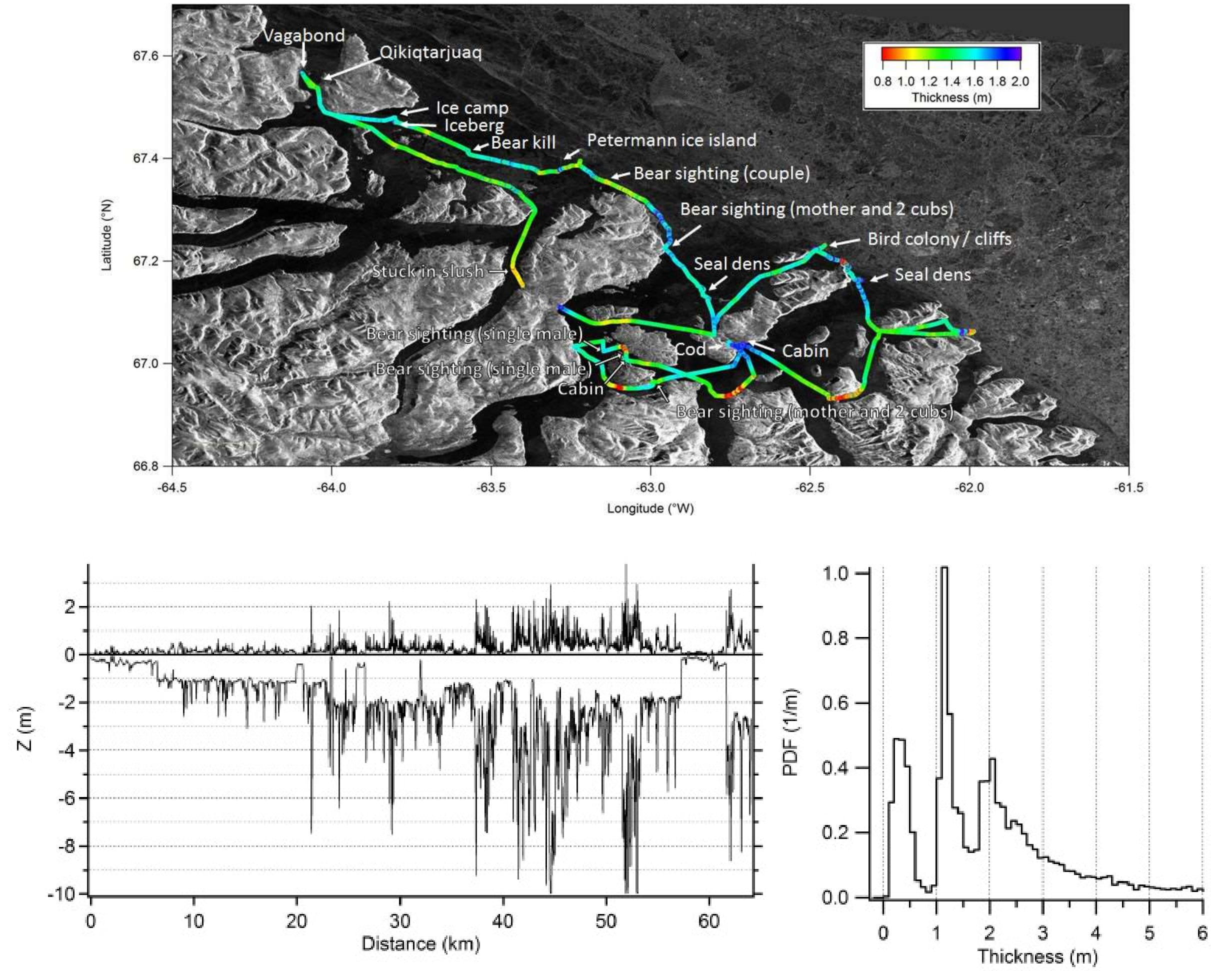

Figure 4: Examples for results of ice thickness measurements displayed on a map (top; from a 400 km snowmobile trip)) or as profiles (bottom left; from airborne EM), or as histograms (thickness probability density function; bottom right).

Experiment description

You will carry out an electromagnetic induction survey with an EM31-MK2 instrument on the University Bremen campus, and will map variations in underground conductivity that are due to different geological materials present in the survey area, for example sand and dry and wet clay. You will also be able to detect metal anomalies, for example from bridges or sewers. An example is shown in Figure 5. You will carry out the survey with two different dipole modes (vertical and horizontal dipole mode) which results in four observables, because each measurement consists of readings of Quadrature and Inphase (corresponding to the Amplitude and Phase of the secondary EM field). In addition, all recordings are georeferenced with coincident GPS measurements. You will plot the results on a map and will create profile graphs showing the readings along your walking route. Finally, you can imagine that the measurements were carried out over sea ice. Therefore you can convert them into values of apparent ice thickness. Is the campus covered by thick or thin ice, and where will the thin ice be located?

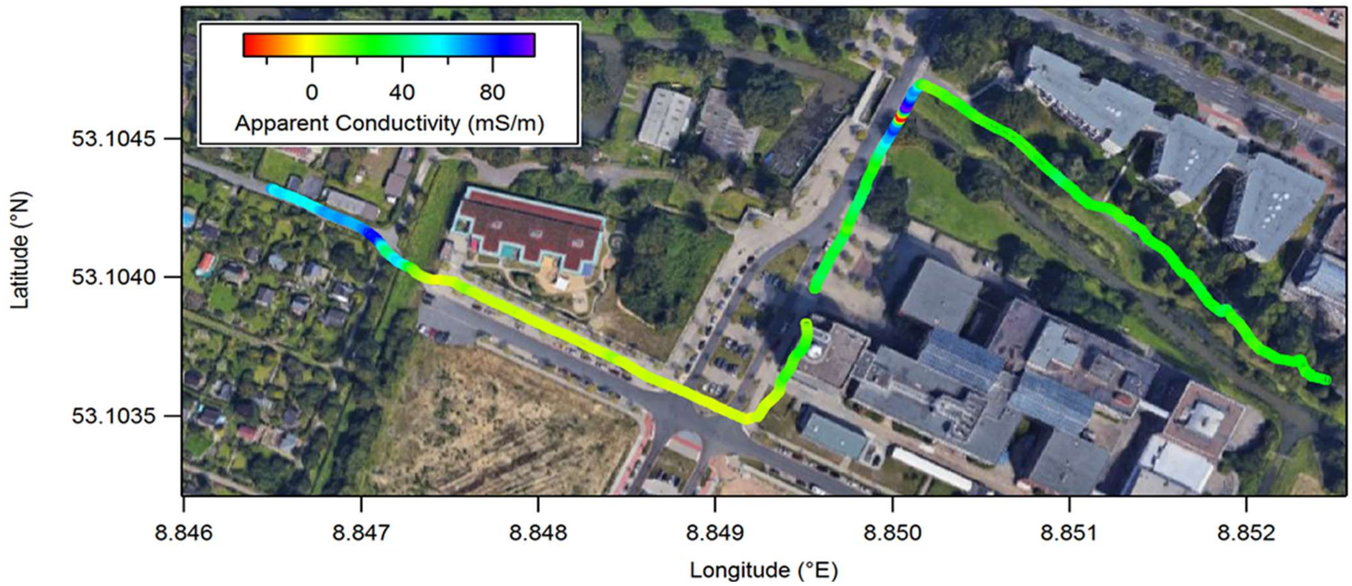

Figure 5: EM survey in the vicinity of NW1. The map shows the variation of apparent conductivity along the walking route. Note regions of low, medium, and high apparent conductivity.

Learning objectives

- Learn about electromagnetic induction (EM) sounding
- Learn about EM sea ice thickness surveying
- Learn about Global Positioning System (GPS) georeferencing of geophysical data
- Learn about different data formats originating from measurement systems
- Learn about conversion of geographical coordinates into Cartesian coordinates, distances, and speed
- Learn about resampling of heterogeneous data to create equidistant, coincident data sets.

Reading material:

Geonics EM31-MK2: http://geonics.com/html/em31-mk2.html

Geonics Technical Note TN5: Electrical Conductivity of Soils and Rocks:
http://geonics.com/pdfs/technicalnotes/tn5.pdf

Geonics Technical Note TN6: Electrical Terrain Conductivity Measurement at Low Induction Numbers
http://geonics.com/pdfs/technicalnotes/tn6.pdf

Paper about ice thickness measurements:

Haas, C., S. Gerland, H. Eicken, and H. Miller (1997). "Comparison of sea-ice thickness measurements under summer and winter conditions in the Arctic using a small electromagnetic induction device." GEOPHYSICS, 62(3), 749-757. https://doi.org/10.1190/1.1444184