Lab 5: EM Surveying at the Penrose Farm

General Comments

- Lab report is **due by 5 p.m. on March 16, 2026**
- Late reports require a valid reason to be accepted. Late reports should be handed to the TA directly.
- Include all codes, answers and required figures.
- Use MATLAB for plotting. Remember to include titles, axis labels, and units in your graphs.
- All work should be your own and original.
- All lab material can be downloaded from the class webpage at:
  https://sites.ualberta.ca/~unsworth/UA-classes/424/labs424-2026.html

Introduction

Extensive surveys of the underground conductivity were performed with the EM31 in August 2009. The instrument was carried at hip-height and mostly used in the vertical dipole mode (VDM), i.e. with horizontal coplanar coils, which is the standard mode of operation.

Three surveys were performed in 2009:

1. A grid-type survey between the cliff in the North and the Milk River in the southeast, composed of ten lines spaced approximately 10 m apart, and with a spacing of 5 m between each measurement point along each line. The grid covers a zone of old gravel (?) terraces and alluvial sediments in a region which must have been repeatedly flooded during past storm events. On lines 9 and 10, additional measurements were performed in the horizontal dipole mode (HDM) by turning the instrument 90° around its long axis. See Figure 1 for a map of the grid survey.

2. A survey along the base of the cliff (see Figure 1).

3. A short experimental survey with the EM31 perpendicular to the instrument's long, thin metal lid.

The data have been split into separate files (Part2, Part3, etc.) to simplify loading into MATLAB. Use *'load'* or *'xlsread'* as necessary. With all measurements, both the Quadrature and In-phase components were recorded. These describe the strength and phase of the secondary EM field H_s relative to the primary EM field H_p. Note that the Quadrature component has been calibrated and is therefore displayed as "Apparent conductivity" (in mS/m); the In-phase component is not calibrated and is in parts-per-thousands (ppt).

For low induction numbers (low conductivity of the underground) the apparent conductivity represents the true conductivity of the underground, neglecting any effects of layering. However, the In-phase signal is very sensitive to local anomalies of high conductivity. This will be demonstrated in this lab.

Photo 1: View from the terrace at the base of the cliff towards southeast, across the alluvial plain and towards the Milk River, which can be seen in the background. The EM31 is operated at hip height in VDM.
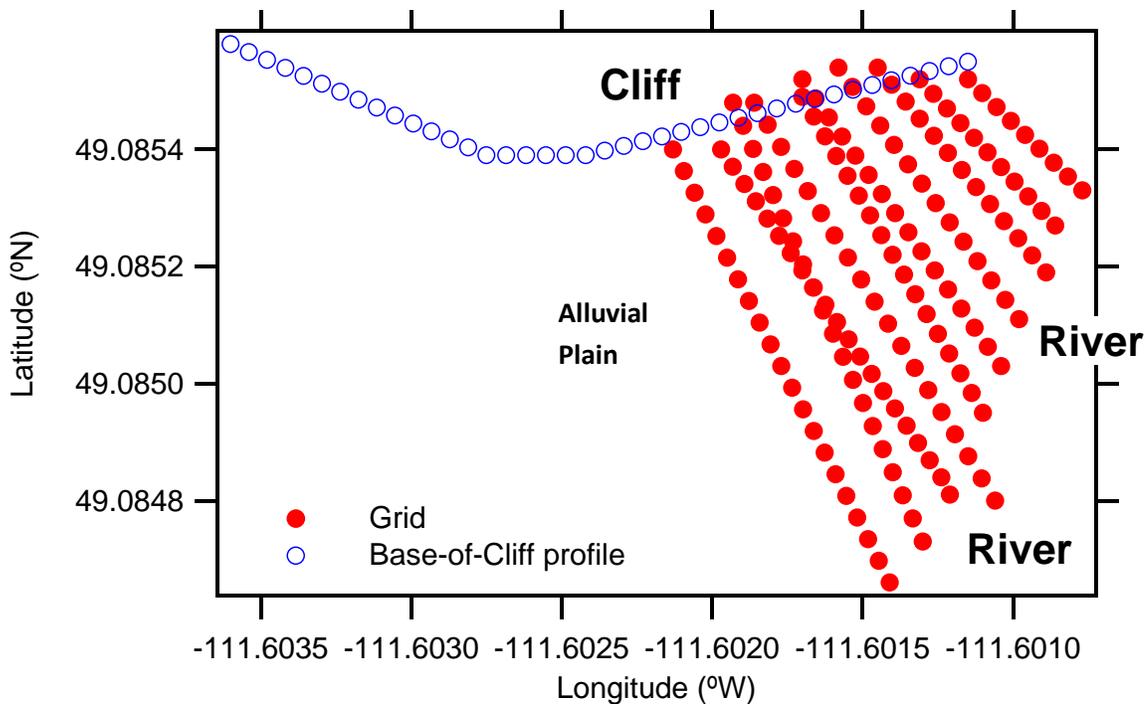

Figure 1: Map of the survey area showing the grid profile lines and the profile along the base of the cliff (the alluvial plain is located between the river and the cliff).

PART 1: Introduction

1. Briefly describe the EM-31 survey method, focusing on primary and secondary fields. Provide a detailed hand-drawn or original sketch of how these interact at the transmitter and receiver.

2. Explain the VDM and HDM (vertical and horizontal dipole) configurations and the differences between them. Which one is more sensitive to deeper structures?

3. Explain and compare both the quadrature and in-phase components. How do you distinguish between 'good' and 'bad' conductors in the earth?

PART 2. Grid Survey Apparent Conductivity

4. Using MATLAB, create a 2-D, interpolated map view of the apparent conductivity measured in VDM along all ten lines of the grid survey. It is recommended that you follow the guidelines listed below.

    - The measurements were not collected in a perfect grid. Use '*meshgrid'* to generate a regularly-sampled 2-D grid of latitude and longitude. Ensure that this grid includes the entire latitude/longitude range covered in the survey, and that the mesh is not too coarse. (There will be some distortion without using a projection such as UTM, but for our small survey area this effect is relatively small).

    - Use '*scatteredInterpolant'* to generate an interpolant function, which you can then evaluate at any given point. Use the 'linear' interpolation method and extrapolation 'none'. In this case, create an interpolant called F that interpolates apparent conductivity values onto a x,y grid. Then evaluate the interpolant for each point in the grid created by '*meshgrid'*. (Alternatively, you may use '*griddata*' which does the interpolation and evaluation in one step.)

    - Use '*pcolor'* to create the 2-D plot, and '*shading flat'* to remove the gridlines. Show the colorbar and provide all figure labels and units.

    - Use *'hold on'*, and *'plot'* to show the location of each measurement.

5. Describe the general differences between measurements at the base of the cliff, over the interior of the alluvial plain, and at the shoulder of the river. Relate the apparent conductivity at each region to the underlying geology.

PART 3. Comparing VDM and HDM

6. Plot the In-phase signals measured along lines 9 and 10 versus distance, for both measurements in VDM and HDM. Use '*hold on´* to show the responses on the same plot.

7. Describe the behaviour and variations in the VDM and HDM measurements. What is the reason for the different responses when switching the instrument orientation?

PART 4. Comparing Quadrature and In-phase Components

8. Demonstrate the correlation between the In-phase and Quadrature components by plotting them against each other for lines 7, 8, and 9. Plot VDM In-phase along the y-axis and VDM Quadrature along the x-axis. Use '*hold on'* to show all three lines on the same plot and use individual points (not a connected line) to plot the data. Perform a linear fit to the data (using the provided *'linfit'* function, or similar), and plot the best-fit lines with the data. Report the coefficient of determination (R^2) for each line.

9. Explain the observed correlation. Is the In-Phase component sensitive to apparent conductivity?

PART 5. Cliff Survey

A long line was collected along the base of the cliff, with a spacing of 5 m between each measurement point. The line crosses a sediment fan at the base of a gap in the cliff, and some anthropogenic artefacts.

10. Plot the Quadrature and In-phase signals from the cliff survey on the same plot. Use different left and right axes (with *'plotyy'*) to show both variables at appropriate scales, allowing for an easy comparison.

11. Consult the data file for notes on what caused the strong anomalies and describe them. Does every anomaly in the notes appear in both the in-phase and quadrature responses, why or why not?

12. Based on these results, which EM component would you use with the EM31 for this survey to locate buried metal objects? Why?

13. Compare the In-phase and Quadrature components in the cliff survey data by performing a linear least-square fit (using linfit, or similar). Plot In-phase along the y-axis and Quadrature along the x-axis, and show the best-fit line on the same plot. Report the R^2 value, and explain why the correlation is different than in Part 4 (think about theoretical assumptions for EM31).

PART 6. Metal Lid Survey

A short (10 m) EM31 survey was performed perpendicular to the long axis of the instrument's metal lid (see Photo). The spacing between individual measurement points was 0.5 m, and measurements of the Quadrature and In-phase signal were performed in vertical (VDM) and horizontal (HDM) Dipole Mode.

14. Use '*subplot'* to create a plot with the first panel showing the Quadrature and In-phase signals for VDM vs. distance, and the second panel showing HDM vs. distance. As in part 5, use different left and right axes to show the Quadrature and In-phase responses at appropriate scales.

15. First, look at the VDM measurements. What sharp anomalies do you observe? What is causing the two anomalies? Note that distance corresponds with the position of the instrument operator (halfway between the transmitter and receiver), and the length of the EM-31 instrument is 3.66m. Show calculations for the location of the lid, and mark this location on your plot.

16. Consider the HDM measurements across the lid. Describe the difference between the measurements in VDM and HDM, and what might be causing this difference.
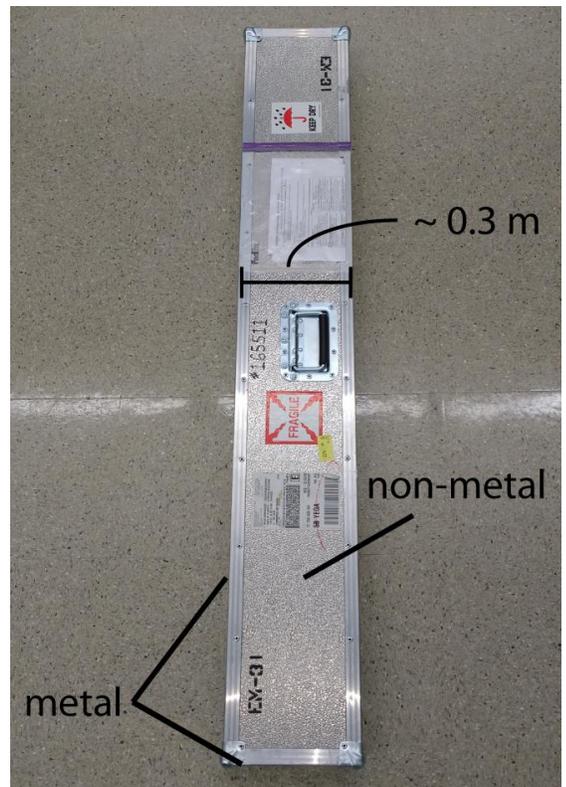

Photo 2: EM-31 instrument lid.