Lab 3: Magnetics Part II

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Overview

Magnetic surveys are useful when trying to identify a target which has a significant contrast in magnetic susceptibility with the background material. Some examples include unexploded ordinance (UXO) detection, locating steel infrastructure, and mineral exploration. Last week, you collected data over re-bar buried on the beach. This week, we will process and interpret those data.

Given all of the datasets collected by your lab session your task is to now formulate an interpretation which is consistent with the data. Some of the difficulties that you may encounter during this process include: inconsistencies between data collected by different groups, noise-contaminated data, outliers, and data ambiguities resulting from incomplete field notes.

Instructions

- To analyze the data, you are free to work together in groups, but lab reports need to be completed individually.

Resources

- Jupyter Notebook App: FitMagProfile.ipynb
- Instructions for downloading and using the Jupyter Notebook: here
- GPG: Magnetics

Magnetic Profile across buried re-bar

Data

Q1. Sketch a cross section, along the length of the data collection line, of what you expect the **total field anomaly** to look like over the horizontal rebar. In your sketch, include

- the direction of the inducing field in Vancouver,
- the direction of induced magnetization,
- and the secondary field lines.

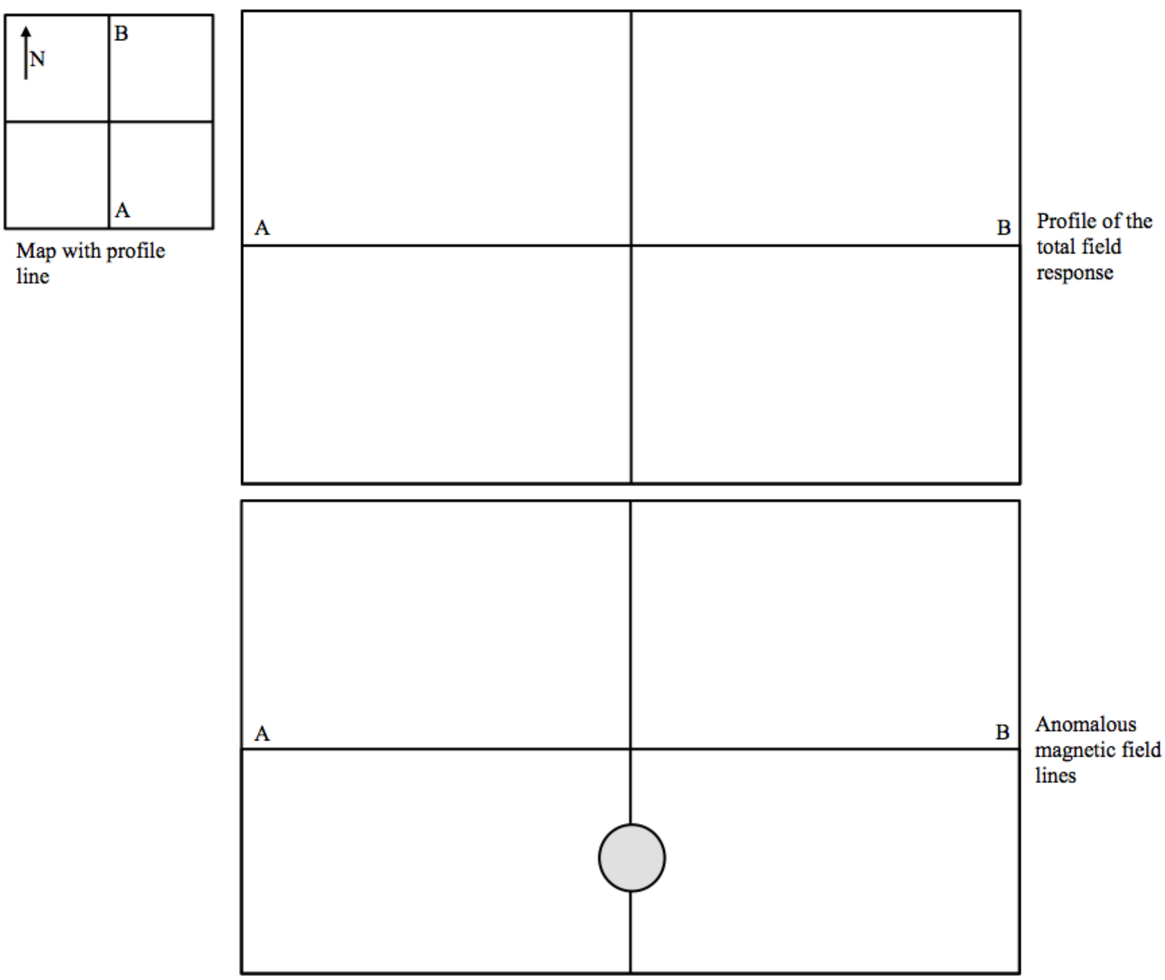

Figure 1: Sketch of field lines and expected total field anomaly over buried re-bar.

Q2. Three datasets are provided for your analysis: student field data from the Monday lab (Figure 2), student field data from the Wednesday lab (Figure 3, Blue), and a dataset collected by the TA team on Wednesday after the student lab was completed (Figure 3, Red). For each data set, the data were processed as follows:

- Multiple measurements at each station from an individual team were averaged and standard deviations are calculated.
- Large outliers were removed.
- Diurnal corrections were applied which crudely accounted for diurnal variations over each team's measurement period using their reading at the base station.
- Each team's dataset was leveled (statically shifted) to account to diurnal variations between measurement periods and changes that occur as a result of switching data collectors. This brought all base station readings to a constant level.
- There are a couple of specific items pertaining to each data set:
  - For the Monday data, the quality of the data looks really good and consistent throughout the afternoon. Both line data acquired by the TAs and students were combined in a single survey. Notice that the error bars are fairly small compared to the amplitude of the anomaly, hence a low Signal to Noise Ratio (SNR). We will focus on this dataset for the remaining of the lab.

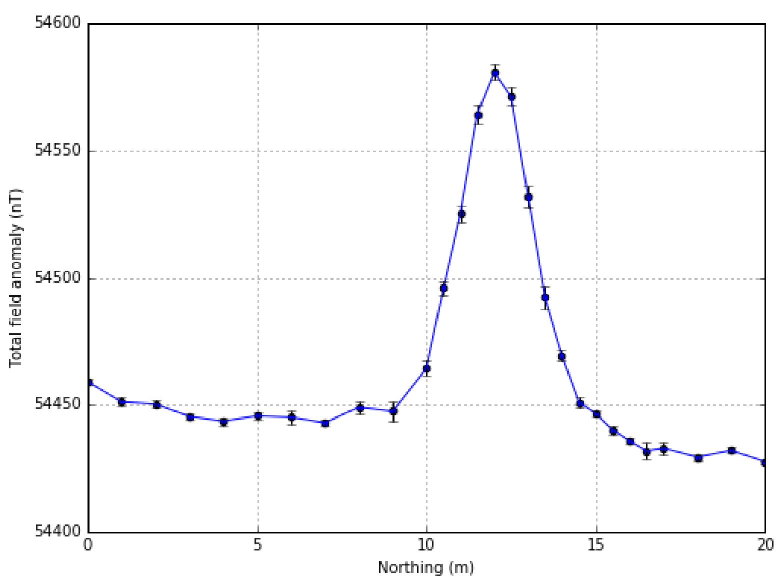

Figure 2: Monday's collective data.

- Things look a lot more complicated for the Wednesday's lab. Notice the large gradient around location 13 m, followed by a large and broad negative anomaly. The observed anomaly is consistent between the TAs and students' survey, but the large standard deviations and atypical shape of the anomaly makes it dubious. This data set will be used as a bonus exercise.

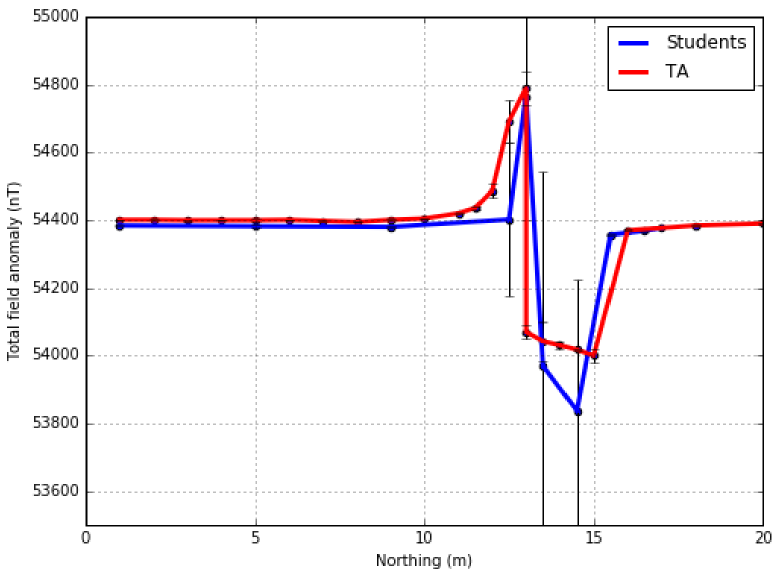

Figure 3: Wednesday students and TAs data.

a. Which of these data sets is most consistent with your expectation of the induced total field response over horizontally buried re-bar, explain why?

b. Different pieces of rebar were used for the labs on Monday and Wednesday. The length and diameter of the pieces of re-bar are the same, and both pieces were buried so that the measuring tape laid in the sand crossed the center of the horizontal extent of the rebar. What might account for the difference in the observed total field data shown in Figures 2 and 3?

Interpretation

Q3. We will start by analyzing the data from Monday's lab using the Jupyter Notebook: FitMagProfile.ipynb

a. First, we need to remove the background field to get the total field anomaly. The average base station reading during the collection time was 54,448nT. The IGRF value for September 19, 2016 is found using the Magnetic Field Calculator to be:

$$|B| : 54,292 \; nT, \;\; D : 16.5^\circ, \;\; I : 70.0^\circ. \tag{1}$$

Using these values, and the observations of the field far from the anomalous response, record which value you use for the background field. Also enter it as **Bigrf** in the notebook.

b. Next, try to fit the data assuming no remanent magnetization (ie. $Q = 0$). The diameter of the rebar is 1.4cm and the length of the rebar is 10ft ($\sim$ 3m). Note that the magnetometer height was 1.9m above the surface. Record the value of the depth, susceptibility, and along-line location of the re-bar that best fits the observed total field anomaly. Remember to orient the bar EW and the orientation of the survey line along NS.

c. The manufacturing of re-bar requires steel to be melted down and poured into bars and cooled. The magnetic domains within the steel acquire a remanent magnetization, in the orientation of the inducing field, as the bar cools to below the Currie point. The magnetic response of the re-bar, and many other susceptible bodies, is the sum of their remanent and induced magnetization vectors. Assume the susceptibility of the rebar is known to be 500 SI. Does incorporating a remanent magnetization help you better fit your observed data? Record the model parameters used to fit the data.

Q4. BONUS: Using Wednesday's surveys, can you find a combination of susceptibility and remanence that can account for the measured data?

Shovel Search Area Grid

The data shown in Figure 4 were collected by your TA team over a buried rebar couple years back on Monday, Sept. 15th, 2014. The depth of burial for the rebar was similar to both

Monday and Wednesday's labs this year. We collected 6 N-S lines with a station spacing of 0.5m and a line spacing of 1m. Since some of the data were collected before the lab and some after, diurnal corrections had to be applied to account for variations in the Earth's magnetic field which occurred over this 2 hour window. An average base station value was then subtracted from the data to remove the inducing field and leave us with the anomalous total field.

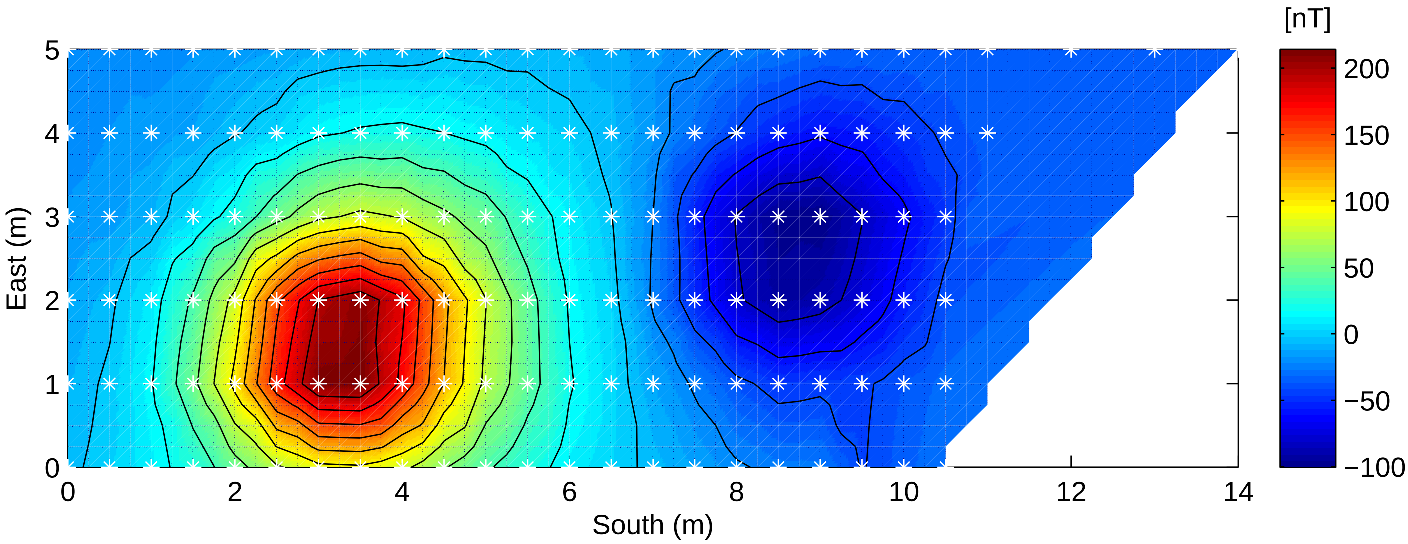

Figure 4: Gridded anomalous total field magnetic data which was collected over the shovel search area from Lab #2. The data locations are marked by the white asterisks.

Q5. Based on your understanding of the magnetic response of simple susceptible bodies, provide a qualitative interpretation of the data. In your interpretation be sure to include the number of buried targets, the orientation of the target/targets, and any effects of remanent magnetization.

Q6. After seeing these data, where would you dig?

Q7. For a long vertical cylinder, the depth to its top can be estimated using the half width of the observed anomaly using

$$z \sim 1/2x_{1/2}$$

where $x_{1/2}$ is the width of the anomaly at the half-maximum.

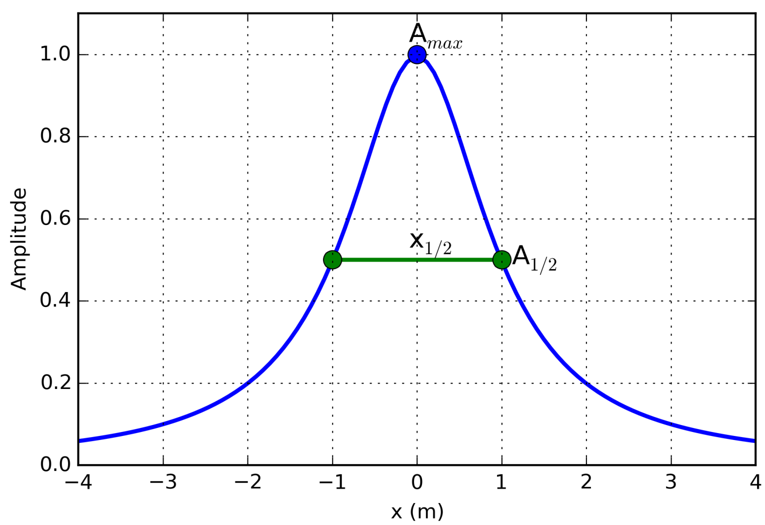

Figure 5: Basic diagram defining Half-width of an anomaly.

a. Estimate the depth of burial using $z \sim 1/2x_{1/2}$. Note that the magnetometer height is 1.9m above the surface. Be sure to take your measurements from the data plot in Figure 4.

b. The rebar is not actually infinite in length, so the value you just calculated may be an underestimate of the depth. If the rebar is short enough in length, we will see a more dipolar response, where $z \sim x_{1/2}$. Estimate the depth using $z \sim x_{1/2}$.

c. Based on these two calculations, we have upper and lower estimates of the depth. Name one way in which we could better constrain the depth of the rebar.