Lab 8: Electromagnetics Part II

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DUE: November 16 & November 18, 2016

Overview

In this lab, we examine data sets obtained at the old expo site in the false creek area of Vancouver. The site has a fairly complex industrial history, and was set to be remediated and turned into a public space. Before any remediation could take place, the site needed to be characterized.

You will be examining geophysical data collected over this site. To detect anomalous conductive or resistive targets, we first treat frequency domain EM data collected with the EM-31 instrument. We will interpret the measured EM data sets and characterize the subsurface of the site. To increase reliability we also study gradient magnetics data to obtain information about the magnetic susceptibility subsurface. By integrating these two geophysical data sets we better characterize isolated targets embedded in this region.

Instructions

- Read the introduction and chapters 1-4 of the Industrial site characterization report and use it to answer questions regarding the EM-31 and magnetic gradient surveys
- Load the FEM Jupyter notebook (same notebook as last week)
- Use the notebook to help you answer the questions in this lab
- Copy images from the notebook if they will help your explanation

Resources

- Industrial site characterization webpage
- Jupyter notebook. Thanks to Dikun Yang for the original FEM3pipe code!

Survey 1: EM-31

Q1. The EM-31 is used to map variations in the Earth's conductivity. Below are maps of the apparent conductivity measured using both EW and NS boom orientations (error readings and negative readings are plotted as white). Use the data spreadsheet to answer the following questions.

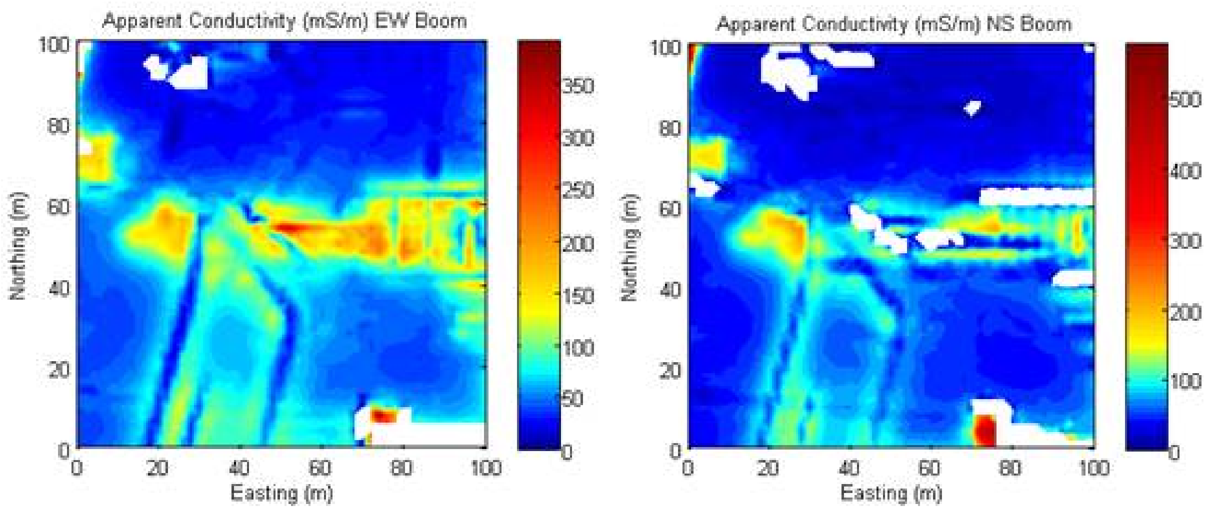

Figure 1: Interpolated maps of apparent conductivity. Left and right panels indicate East-West (EW) and North-South (NS) boom, respectively.

a. What are the maximum and average apparent conductivities for each map? Calculate the skin depths for the maximum and average conductivities for each map.

b. Based upon this criterion, do you think the measurements at the location with maximum apparent conductivity are reliable? Why or why not?

Q2. The apparent conductivity values computed using the EM-31 data are based on the assumption that the earth is a uniform half-space. That is to say the surface of the earth is perfectly flat and subsurface conductivity is uniform

a. Based on the apparent conductivity maps, how do you find the regions that might satisfy this half-space assumption?

b. There are some areas with negative apparent conductivities, which are not realistic. Why could this happen? Hint: EM-31 estimates the apparent conductivity by measuring the quadrature component of $\mathbf{H}_s/\mathbf{H}_p$ and multiplying it by a system-specific constant to get the apparent conductivity reading. Think about why you sometimes get negative quadrature measurements, for instance in the three-loop model we used in EM lab 1.

Q3. Oil/hydrocarbon-bearing strata are usually more electrically resistive than their hosts. Oil was found to have contaminated the water table in the North-West section of the map at (20E, 80N). Knowing that oil is present in the region near (20E, 80N), draw a contour line on the apparent conductivity map below (either EW or NS boom) that might indicate an approximate extent of the hydrocarbon contamination.

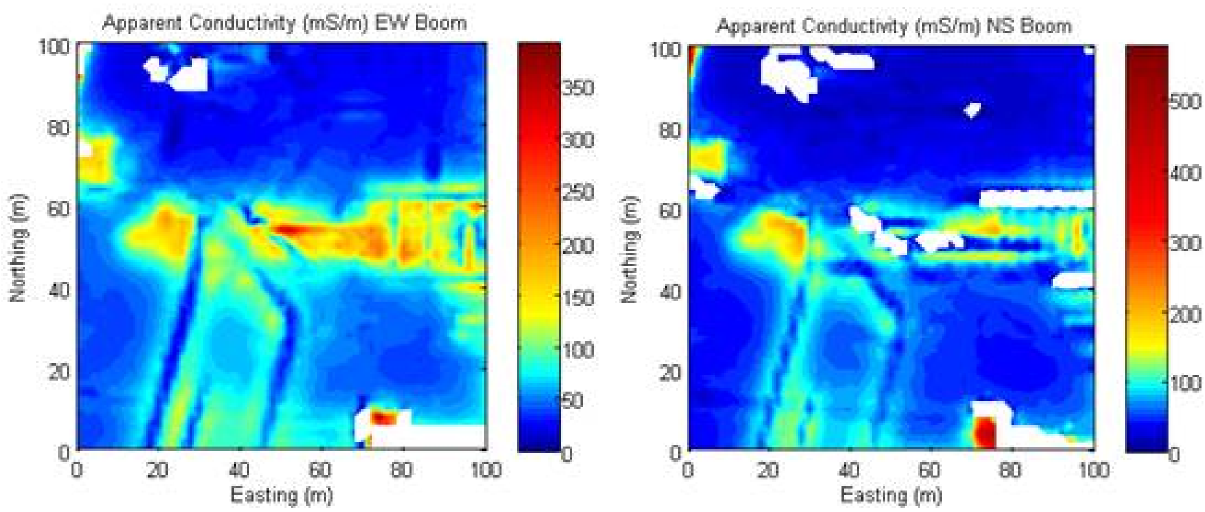

Figure 2: Interpolated maps of apparent conductivity. Left and right panels indicate East-West (EW) and North-South (NS) boom, respectively.

Q4. There is a concentration of very low or negative apparent conductivity near (25E, 95N). Look at the in-phase measurements in this location. Do you believe the apparent conductivity values? Why or why not?

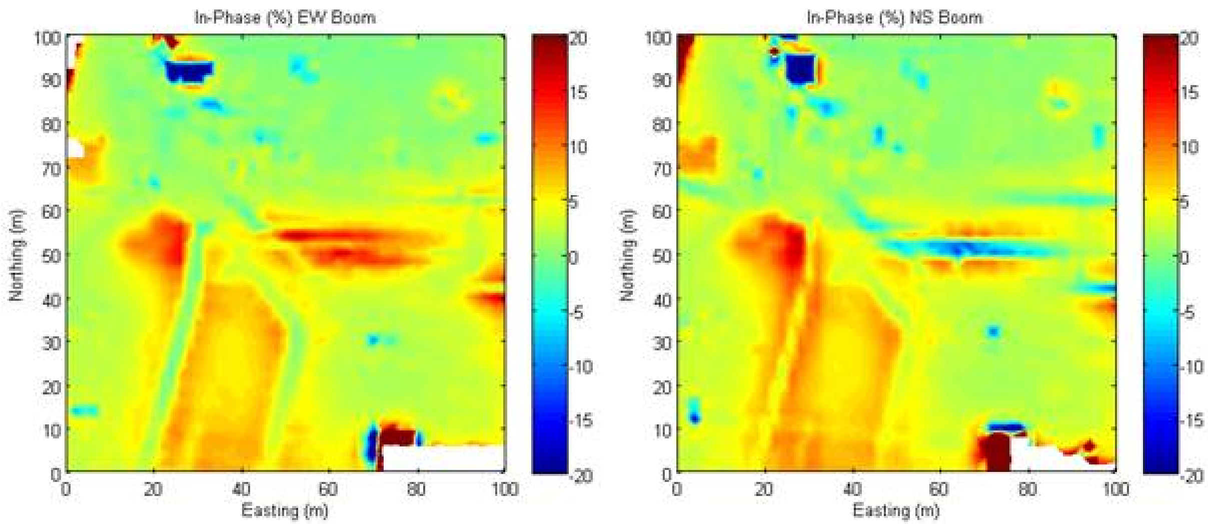

Figure 3: Interpolated maps of In-phase component. Left and right panels indicate East-West (EW) and North-South (NS) boom, respectively.

Q5. Note that there is considerable structure in the images. From the data spreadsheet , extract the in-phase and quadrature data along a N-S profile recorded at Easting = 70 for both of the boom orientations. For the NS boom orientation data, make a line plot of the data for the in-phase and quadrature. Now perform the same excercise for the EW boom orientation. Use different colors and line styles to distinguish them from each other. Adjust the scale of the y-axis so that the features at Northing = 50 can be properly visualized.

a. Compare the amplitudes of in-phase and quadrature data at each location. What information about the conductivity of the target near Northing = 50 can be inferred?

b. What is the major difference between the anomalies observed with EW and NS boom orientations near Northing = 50? Why does the orientation of the boom make such a large difference (use sketches to explain)?

c. Now look at the plot of the in-phase NS boom data from 40N to 60N. What is the distance between the two zero crossings? What should this value equal?

d. From the information obtained in the previous parts of this question, and by looking at the in-phase maps, what type of object do you think could explain the observed data? Support your answer with evidence based on conductivity and shape of the anomaly.

Q6. Comparing in-phase and quadrature data is diagnostic for finding metallic objects. Use the below plots of the in-phase and quadrature data to answer the following questions.

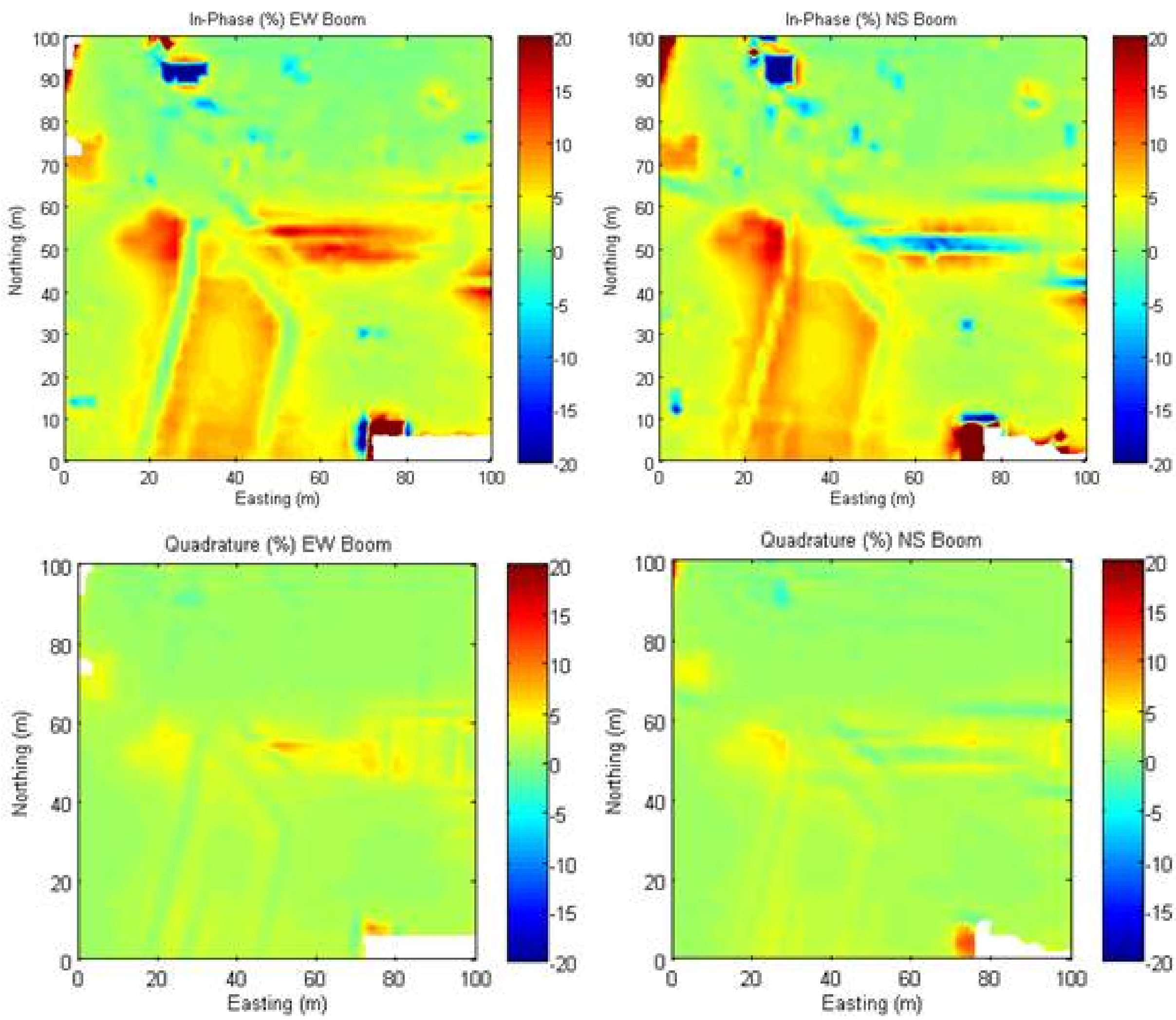

Figure 4: Interpolated maps of In-phase (top panel) and Out-of-phase (bottom panel) components. Left and right panels indicate East-West (EW) and North-South (NS) boom, respectively.

a. Using the EM response curves you have seen from EM Lab Part 1 (plot 1), explain how you would use both the in-phase and quadrature data to estimate the conductivity of the object.

b. On the in-phase data map, circle those places (at least four) that you suspect could have buried metal conductors.

c. Bonus question: There are two outstanding conductors at (25E, 93N) and (70E, 5N). They all have square shapes indicating signature of metallic box/case/tank, however, they show opposite patterns of polarity: the one at (25E, 93N) is positive-negative-positive while the one at (70E, 5N) is negative-positive-negative. Can you explain why?

Q7. The linear anomaly we have investigated in Q6b can be modeled by the method similar to the 3-loop modeling in the EM lab Part 1.

a. Estimate the ratio of in-phase to quadrature data from the target near 50N on the profile in Q5. Use this ratio to get the inductive response number (α) of the conductor.

b. For this question, use the FEMpipe widget. In this program the boom height is pre-set to 1 m above the surface and the Tx-Rx separation is 3.6 m. The EW and NS boom surveys are simulated on a 10 $\times$ 10m grid with 0.5 m interval. Adjust the value of α to the value you obtained in the previous question. The program will create three plots: in-phase map for the EW boom, in-phase map for the NS boom and a NS profile of all the data that goes through the center of the maps. The profile will be similar to the profiles you generated in Q5, but they will not be identical. You will vary parameters in the widget to make a best match. The objective is to determine an estimate of the depth of the assumed cylindrical pipe. While keeping α fixed, change the depth to make the pattern of your simulated data match the field data in Q5. Which orientation of the EM31 is most sensitive to depth? Report the depth and attach the plots from your modeling.

Q8. There are other linear features striking NNE in the bottom left hand portion of the in-phase maps.

a. Describe the difference of these anomalies in the EW boom map and in the NS boom maps and provide an explanation. Can you speculate on what type of objects could cause these features?

Survey 2: Magnetic Gradient

High magnetic gradients will be observed when there are magnetic objects close to the surface. From your background reading about the site, there could be many of these. Iron, rebar, pipes, drums and buried locomotives are conductive and magnetically permeable. Thus, the EM-31 and the magnetic gradient results can provide complementary information. Use the gridded magnetic maps to answer the following questions.

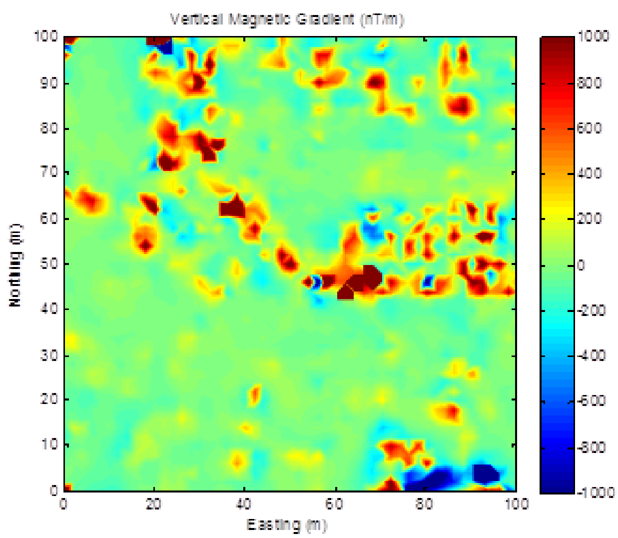

Figure 5: Interpolated map of vertical magnetic gradient.

Q9. Briefly describe what the vertical magnetic gradient is. How is it acquired?, What is it sensitive to? and what benefits does it provide over a total field survey?

Q10. How does the use of both magnetic gradient and EM-31 data help in the identification of iron targets? How would the two responses from an iron target differ from that produced by a copper target?

Q11. Which map(s) from the EM-31 are most useful when trying to find iron targets in conjunction with the magnetic gradient data? Why?

Q12. What inferences could you make about the NNE linear features (in the south-west quadrant of the plots) when you compare the EM and the magnetic plots?