Exercise: Electromagnetic induction, Gamma radiometric and peat thickness

1 Introduction

In this exercise we will use data from an electromagnetic induction (EMI) and Gamma radiometric (GR) sensor to map peat thickness for a field in the Nørreå Valley (Beucher et al., 2020). The data for the exercise include:

1. Peat thickness measurements (Noerreaa_peat_thickness.xlsx)

2. Measurements from an EMI sensor (DUALEM421.shp)

3. Measurements from a GR sensor (Gamma.shp)

4. A digital elevation model (DEM.tif)

5. The field extent (Field.shp)

6. An RGB orthophoto (Orthophoto.tif)

To get started, we will need to load the data into a project in ArcGIS.

1. Create a new project in ArcGIS for the exercise.

2. Load the files into the project. Click the *Add Data* icon and browse to the folder where the data are located and add them to the map.
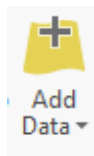

3. If the layers do not show up on the screen, right click on the layer in the contents pane and click *Zoom To Layer*.

2 Explore the data

Before we start any analyses, we will need to visualize and explore the data. In this way, we will be able to compare the DUALEM, Gamma and peat thickness measurements, to see if there is any apparent relationship in the data.

2.1 DUALEM and Gamma measurements

1. Make an exploratory analysis:

2. Measure the spacing of the points, use the *Measure* button from the toolbar:
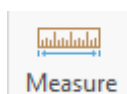
3. Open the attribute table of the shapefile and see the number of points. Right click the layer in the contents pane and click *Attribute Table*.

4. Calculate basic statistics for the attributes HCP4m and countrate. There are different possibilities to get the basic statistics. Right click on one of the attribute fields in the attribute table and choose *Statistics*.

5. You can visualize the measurements from each of the channels over the field using different legends for the shapefile. Right click on the layer in the contents pane and click *Symbology*. In the *Symbology* pane, click the *Primary Symbology* field, and change it from *Single Symbol* to *Graduated Colors*. In this exercise we will use the channels HCP4m and countrate.

6. The default symbol has a black outline, which makes it difficult to see the colors, when we have a large number of points. Click the box *More* above the table showing the classes. Click *Format all symbols*.
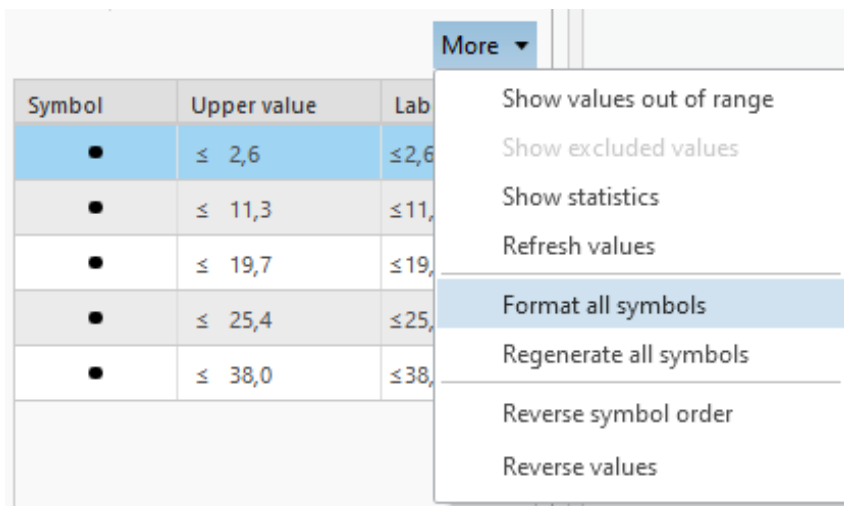
7. Select *Circle 1*, which does not have an outline.

Circle 1

8. This symbol is large by default, but we can reduce its size in the *Properties* menu:

9. Return to the *Symbology* pane (↩). Select a color scheme for the measurements.

10. Now, try to classify the measurements in 5, 10 and 15 classes. Try to use different classification methods to create the intervals in the legend. If some of the points do not show, they are most likely outside the specified range. You can solve this by increasing the highest *Upper value*.

2.2 Peat thickness

The table with the peat thickness measurements is not a spatial dataset. We will therefore need to project the measurements in geographic space in order to visualize them.

1. Right click on the table with the peat thickness measurements in the contents pane.

2. Click Display XY Data.

3. In the dialog box, change the coordinate system to *ETRS_1989_UTM_Zone_32N* (Should be the same as the current map).

4. Click OK. We should now see the locations of the measurements.

5. Now define a Symbology for the measurements and conduct an exploratory analysis as in the previous section.

6. Compare the peat thickness measurements to the EMI and Gamma data. Do you see any relationships?

3 Data cleaning

In order to use the EMI and Gamma data for mapping, we will need to interpolate the measurements to produce a continuous prediction surface. However, before we do this, we will need to remove outliers from the dataset. Most importantly, we will need to remove the measurements with negative EC values from the channels that we wish to interpolate. We will use the channel HCP4m for this exercise, but you would have to repeat these steps for each channel in other applications including the Gamma radiometric data.

1. Save the channel that you wish to interpolate with a different name, for example *DUALEM421_HCP4m and Gamma_CR*. To do this, right click the layer in the contents pane and select *Data → Export features*. Save the data to a new shapefile.

2. Find and remove outliers in "feature space" by looking at the result from the basic statistical analysis. You can use *Select By Attributes* to select points with measurements above or below a certain threshold.
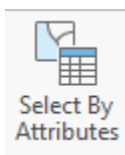

3. Once you have selected the points that you want to delete, simply hit *Delete* on your keyboard.

4. Find and remove outliers in "geographical space" by looking at the data points with graduated colors or symbols. Find points that are out of place, select them with the cursor and delete them the same way as before.
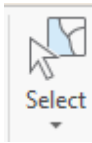

4 Modelling the variogram and interpolating measurents

1. Try to interpolate the attributeS HCP4m and countrate from the file DUALEM421_HCP4m and Gamma_CR, using the kriging tool from the *Geostatistical Wizard*. Go to the *Analysis* menu and find the *Geostatistical Wizard*.
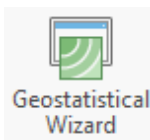
2. Select *Kriging / CoKriging*. Select the dataset that you want to use and the field that you want to interpolate (use HCP4m). Click *Next*.
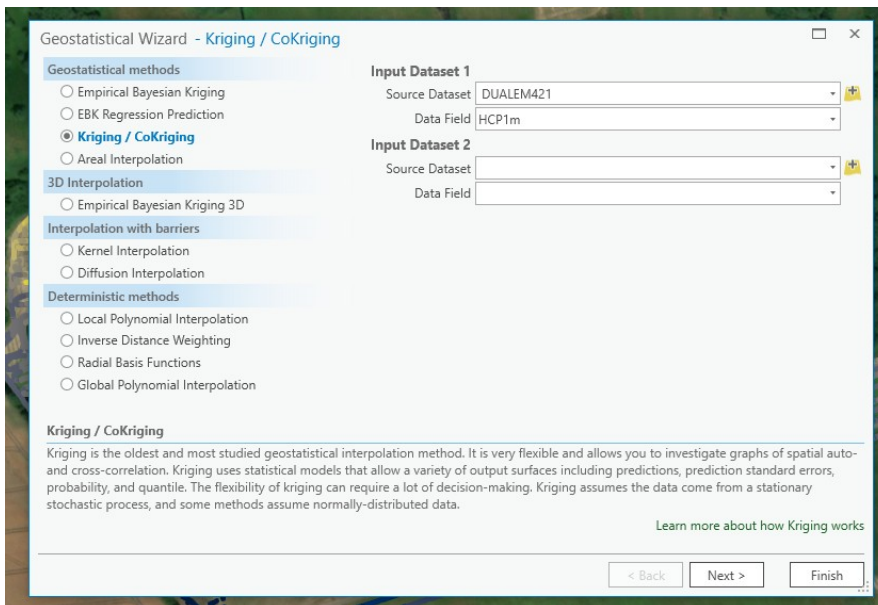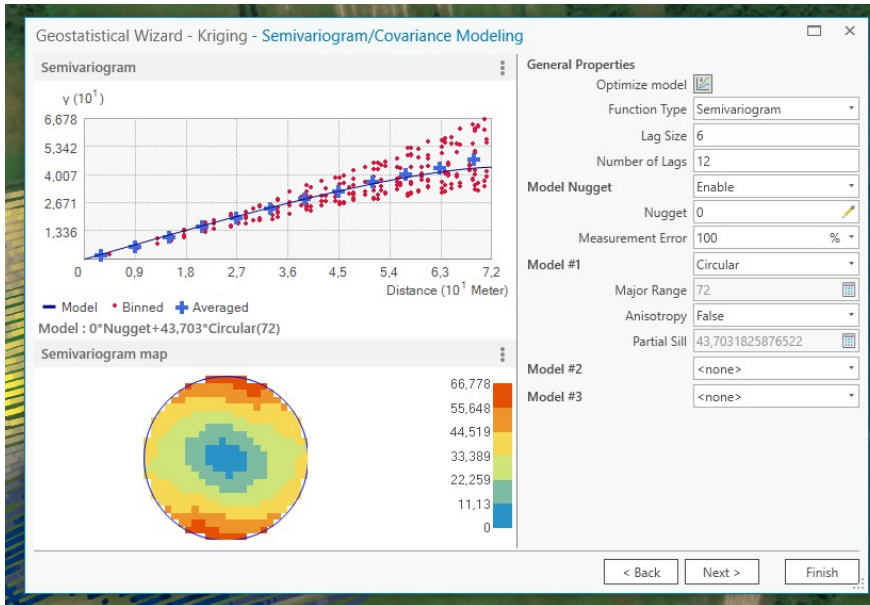

3. Select Ordinary Kriging ➔ Prediction.

4. Try different model types, lag sizes and numbers of lags.

➔ **Lag size should be larger than the largest distance between points**

➔ **(Lag size * number of lags) should be smaller than the 2/3 of the shortest area length**

5. You can also click *Optimize model* and see how this changes the variogram.

6. Click *Finish*. You now have an interpolated map of the apparent electrical conductivity.
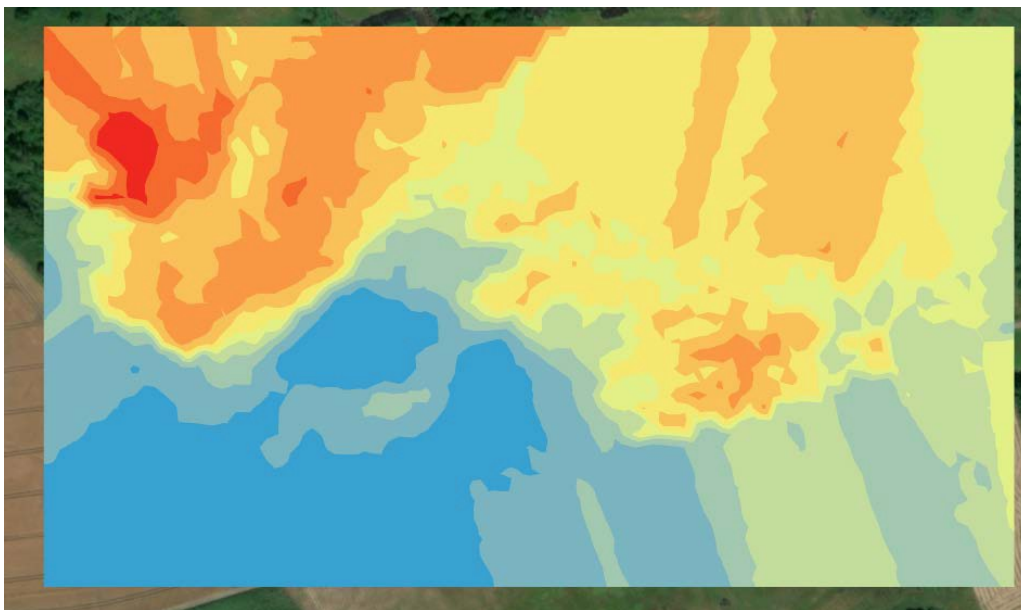
7. You can export this layer by right clicking on it in the *Contents* pane and selecting *Export Layer* → *To Rasters*.

8. Set the output cell size to 1 meter. In Environments set the processing extent to *Same As Layer* → *Field*. Round the resulting values to whole numbers. This ensures that the raster aligns to the geographic coordinate system. Click *Run*.

9. Next, we will want to crop the raster to the field extent. Click *Tools*.
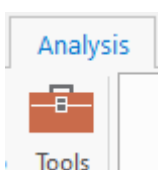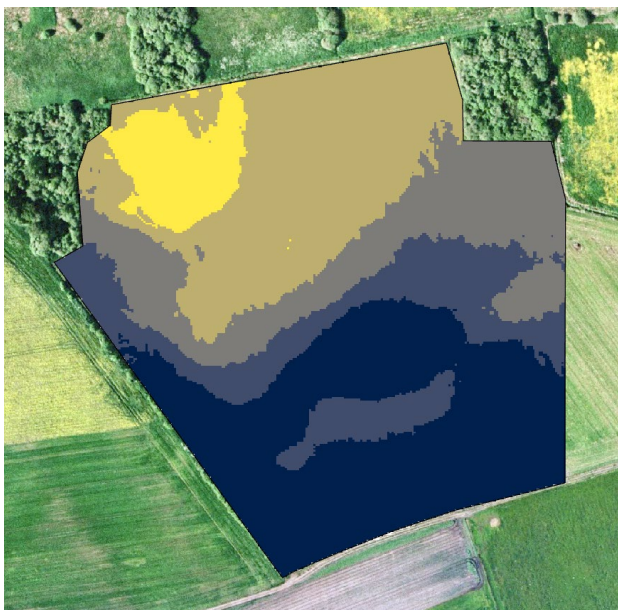
10. Find the tool *Clip Raster*. Set the *Input Raster* to the map layer with interpolated values. Use the *Field* polygon layer for *Output Extent*. Tick the box *Use Input Features for Clipping Geometry*. Click *Run*. We now have interpolated EC_a values for the field.

11. Repeat the steps 2 – 10 for the countrate data.
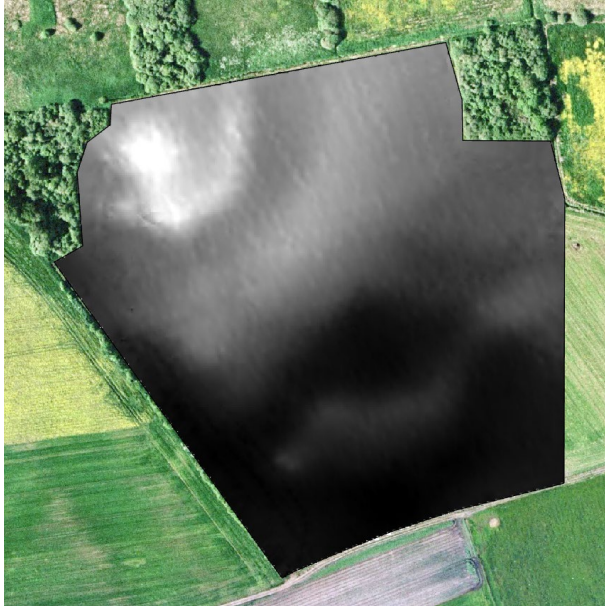
5 Analysis

We will now compare the interpolated EC_a and countrate data to the peat thickness measurements. In this case, we will cluster the EC_a and countrate values into a set of zones.

1. Click *Tools*. Find the tool *Iso Cluster Unsupervised Classification*.

2. Specify the *Number of classes* that you want to produce and click *Run*.

3. Choose an appropriate color scheme for the cluster layer.

4. To get the peat thickness measurements for each zone, you can use the tool *Extract Values to Points*. Use the peat thickness measurements as the *Input point features* and the EC$_a$ or countrate clusters as the *Input raster*. Click *Run*. This produces as new point dataset containing the peat thickness measurements alongside the EC$_a$ or countrate clusters.

5. Open the attribute table for the points with the extracted values. Select all the points (*Clear* → *Switch*), and *Copy* them to the clipboard.

ObjectID *	Shape *	X	Y	Depth	RASTERVALU
1 1	Point	541616,33	6257333,57	730	5
2 2	Point	541629,2858	6257318,669	664	5
3 3	Point	541634,3511	6257207,135	173	2
4 4	Point	541642,5333	6257303,338	667	5
5 5	Point	541647,7179	6257285,332	599	5
6 6	Point	541652,1664	6257264,734	489	4
7 7	Point	541654,6654	6257183,23	134	2
8 8	Point	541657,4286	6257214,16	300	3
9 9	Point	541662,2491	6257242,841	466	3

6. Paste the values into an Excel spreadsheet for a direct comparison. What is the mean, minimum and maximum peat thickness within each of the zones? Are there any overlaps between them?

7. Try this for different numbers of clusters, for example 3, 5 and 10. How does the number of clusters affect the results? Is there an optimal number of clusters?

8. Decide on a final number of clusters. Make an appropriate legend for this layer, as well as a layout including a scale bar and north arrow.
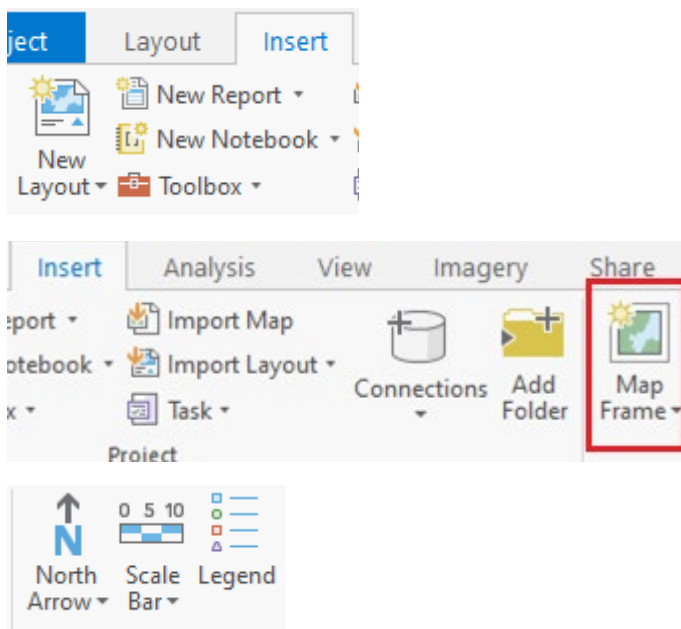
9. Export this layout and use it in the report the report.
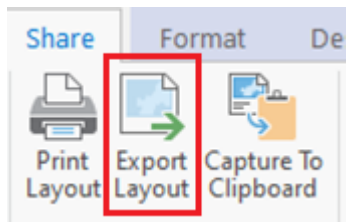
References

Beucher, A., Koganti, T., Iversen, B.V., Greve, M.H., 2020. Mapping of Peat Thickness Using a Multi-Receiver Electromagnetic Induction Instrument. Remote Sensing 12(15), 2458. https://dx.doi.org/10.3390/rs12152458