Geological modeling
Week 1 – 09/12/2022
ArcGIS and spatial analysis

Activity 1.1 – Importing data, setting symbology, creating and editing a shapefile, making a map

1. In Windows open ArcMap
2. Within ArcMap open the ArcCatalog toolbar
3. Within ArcCatalog navigate to your personal folder assigned for this class
4. There should be a geodatabase titled "FIIS_2011.gdb" within your class folder, expand the contents of it by clicking on the plus sign next to it.
5. Right click on the raster file "FIIS_2011_Orthos" and select properties
6. Note the cell size, number of raster bands, the spatial reference of the data set, and the statistics associated with the raster bands (its an RGB image, so these numbers wont be intuitively meaningful).
7. Drag the data set into ArcMap. An image of a portion of the national wilderness area on Fire Island taken during the summer of 2011 should display. You can zoom, pan, and return to a view of the full dataset using these toolbar buttons  .
8. Zoom into the map using the magnifying glass on the ArcMap toolbar to a degree where the image appears pixelated.
9. Using the measuring tool, which looks like a small ruler on that same toolbar, measure the size of a single pixel.
10. In the "Table Of Contents", to the left of the screen, right click on "Layers" and select properties.
11. In the data frame properties, select the "Coordinate System" tab and type "NAD_1983_UTM_Zone_18N" into the search window. Click on that coordinate system and click "Apply" and "OK".
12. Reduce the display scale (i.e., view more area). Quickly scan the area to try to identify the smallest readily discernible well-defined object. Note what that object is (e.g., car, boat, tree, etc.) and measure its dimensions (i.e., length/width or diameter). How many multiples of the data resolution is the diameter of the small discernible object?
13. Clicking the globe button will return you to a view of the entire data set.
14. Return to ArcCatalog and right-click on "FIIS_2011_be_lidar" dataset and select properties. This is "bare earth" lidar collected in 2011, around the same time as the orthophotos.
15. Again, note the dataset cell size, number of raster bands, the spatial reference of the data set, and the statistics associated with the raster bands.
16. Drag this data set into ArcMap. The lidar dataset will display within the map. The default display for a single band raster data set and black to white from the lowest value to the highest value,

17. Right-click on the data set arc map toolbar and select properties. Under the “Symbology” tab, switch the highlighted value in the “Show:” window from “Stretched” to “Classified”.

18. Click on “Classify…”, and select “Defined Interval” as the classification method. Assign an interval value of 0.1. Click “OK”.

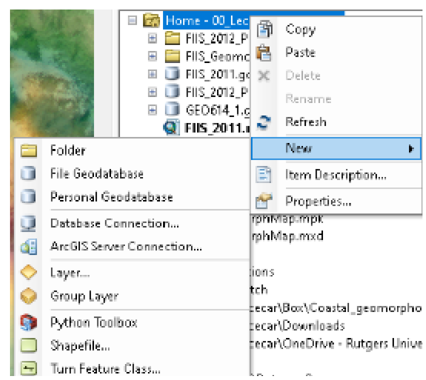
19. Highlight all of the bins including and higher than 8.1-8.2 m and remove them. Do so by right-clicking on the selected rows, choose “Remove Classes” from the menu. Do the same for all bins including and below -0.1 - -0.2 m. Choose a new color scheme, or reselect black-and-white.

20. You can change the representative color for individual bins of values. Change the bin with values below zero to blue. This should display all topographical data below mean sea level is distinctly different from that above.

21. In the table of contents arrange the two data layers so that the ortho photos are listed higher than the lidar DEM (digital elevation model). This will result in the ortho photos being rendered on top of the DEM.

22. To see how the elevation relates to the imagery, we can make the imagery semi-transparent. Right-click on the ortho photo layer, and select properties. Select the display tab change transparency to 50%. The ability to overlay and visualize precisely geo-referenced data is one of the powerful aspects of GIS software with a GUI.

23. These two raster data sets were the primary data sources used to map the geomorphology of Fire Island. For use in the next activity, we will create a dataset here and interpret the boundary between the beach and the dune for a small portion of the shoreline. In your Box folder, create a line shapefile. Right-click on the folder itself, toggle over the “New” menu option and select shapefile. Name the shapefile [last name]_dune_2011. Make the “Feature Type” a “Polyline”. Make “NAD_1983_UTM_Zone_18N” as the spatial reference by selecting the “Edit” button and searching for that coordinate system.



24. Right-click on the new shapefile in the “Table Of Contents” window, toggle over the “Edit Features” menu option and select “Start Editing”.

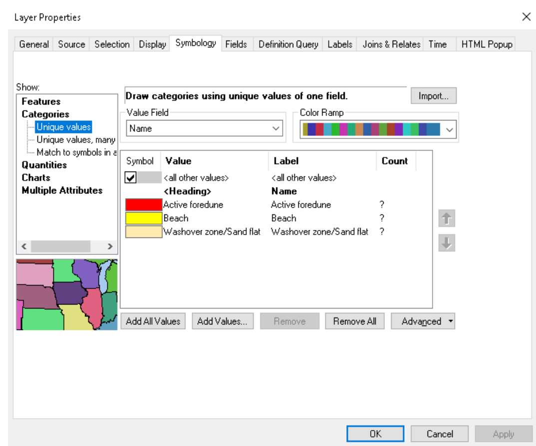
25. You can draw a line in the map by selecting the pencil and notepad button in the “Editor” toolbar. This will create a “Create Features” window at the right side of the screen. In the “Construction Tools” select a “Line”. Draw the boundary between the beach and the dune for about 300-500 m of shoreline, or across the screen with a display scale of 1:1000. When finished, click the “Editor” drop-down menu and click “Save Edits” then “Stop Editing”.

26. A geomorphological map created using these data is provided in the “FIIS_2011.gdb”. It is named “FIIS_Geomorphology_Units_2011”, import it into the map document.

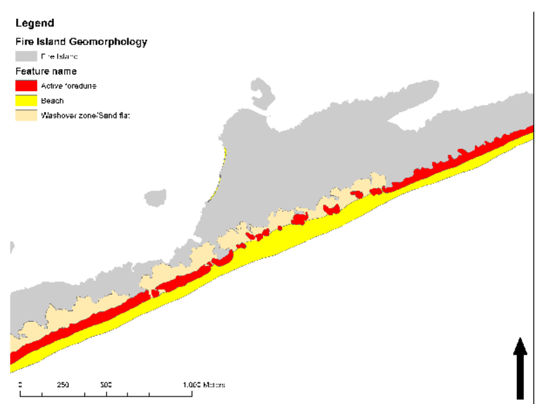
27. Right-click on the “FIIS_Geomorphology_Units_2011” layer in the “Table Of Contents” window, choose “Open Attribute Table”. Note the variety of features mapped.
28. This table can be searched/queried to identify the location of certain features. Select the notepad drop down menu at top left of the “Table” window. Select “Select by Attributes”. Within the text box, type:

    Name = 'Active foredune'

    and click apply. This will highlight where the foredune was interpreted to be in the map. Clear the selection using the clear selection toolbar button. 
29. We will change the “symbology” and make a map from these data. Again, right-click the “FIIS_Geomorphology_Units_2011” layer, select “Properties”. Choose the symbology tab, click “Categories” and “Unique Values” in the “Show” window. Under “Value Field”, select “Name”. Click the “Add Values” button. Add the “Active foredune”, the “Beach”, and the “Washover zone/Sand flat”. Double-click the symbol box of the “<all other values>” entry, change the outline width to zero and choose a neutral color for its fill. Change the foredune, beach, and washover symbols to a representative color. Change the label for “<all other values >” to “Fire Island”. Change the label for the “<heading>” to “Feature name”.



30. Toggle off the imagery, lidar, and beach/dune boundary shapefile data layers using the “Table Of Contents”.
31. Click on the “View” dropdown menu and choose the Layout View. Click on “File”, “Page and Print Setup”, and change the “Map Paper Size” to “Landscape”
32. Use the rulers to set a 0.5 inch margin between the “Data Frame” and the edge of the paper.
33. Set the map scale to “1:12000”. Using the “Insert” dropdown menu and add a map legend, a scale bar, and a north arrow.
34. Bookmark the location of the map by going to the “Bookmarks” menu and selecting “Create Bookmark”. Name it “Map 1”.
35. Save this map document as an “.mxd” file. Name it [last name]_FIIS_2011. Export the map as a “.png” image using the same filename. Save these files in your Box folder.

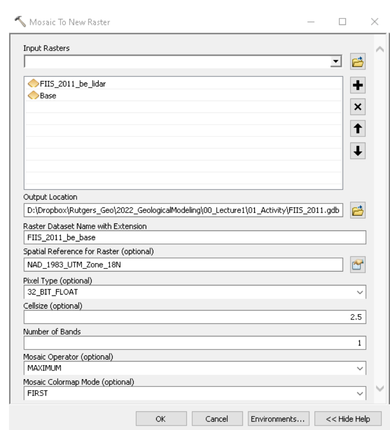


Activity 1.2 – Spatial analysis

1. Open the ArcMap document we saved in the previous activity, return to "Data View" from "Layout View". There should be a geodatabase titled "FIIS_2012_PostStorm.gdb" within your class folder, expand the contents of it by clicking on the plus sign next to it.
2. In this database, there are orthophoto and lidar data that were collected in the first week of November in 2012, the "FIIS_2012_PostStorm_Orthos" and "FIIS_2012_PostStorm_be_lidar" datasets, respectively. They show the effect on the beach and dunes of Fire Island from forces created by Hurricane Sandy as it approached the New York Bight and ultimately made landfall as a tropical storm in Brigantine, New Jersey. Like we did for the datasets collected in 2011, check the properties of the data. Despite that 3 of the 4 datasets are assigned different coordinate systems, the GIS software will seamlessly project them within the coordinate system assigned to the data frame. Drag the datasets into the map document.
3. Change the transparency of layer "FIIS_2011_Orthos" back to 0%. Click the globe button to zoom to the extent of all datasets, and toggle between the "FIIS_2012_PostStorm_Orthos"and "FIIS_2011_Orthos" datasets. Note the readily apparent geomorphological changes.
4. With the measure tool, try to identify the scale of some of the changes. E.g., measure the width of the inlet or the width and length of the washover deposits.
5. The DEMs can provide additional qualitative and quantitative information. Right-click on the "FIIS_2012_PostStorm_be_lidar" layer. Under symbology, select "Classified" in the "Show:" window, then click on the folder button with a blue arrow . Then import the symbology from the "FIIS_2011_be_lidar" layer. This makes the representation of elevation consistent between the two datasets
6. Toggle between the lidar collected in 2011 and in Nov. 2012. Try to note a geomorphological change that can be identified in the elevation data, but not the imagery.
7. Turn off all layers aside from the post-storm orthophotos and the post-storm DEM. Like the previous exercise, change the transparency of the orthophoto to 50%. In your Box folder, create a line shapefile. Name the shapefile [last name]_dune_2012_PostStorm. Again, draw the boundary between the dune and the beach for about 300-500 m of shoreline.
8. These geomorphological changes were mapped using these post-storm datasets. Drag the "FIIS_Geomorphology_Units_2012_PostStorm" dataset into ArcMap from the "FIIS_2012_PostStorm.gdb" geodatabase. Right-click the data layer and navigate to change the symbology. Within the symbology tab of the layer properties, select "Import…" and import the symbology from the "FIIS_Geomorphology_Units_2011" layer. Quickly toggle between the two layers to note the changes.
9. The next few steps will facilitate the calculation of differences in the elevation datasets. First, open the ArcToolbox window in ArcMap, by clicking the toolbox button .
10. First, we will clip the 2011 and 2012 post-Sandy lidar datasets to the mapped extent of Fire Island. The 2011 dataset first. In ArcToolbox, expand the expand "Spatial Analyst Tools", expand the "Extraction" sub-selection, and choose the "Extract By Mask" tool.

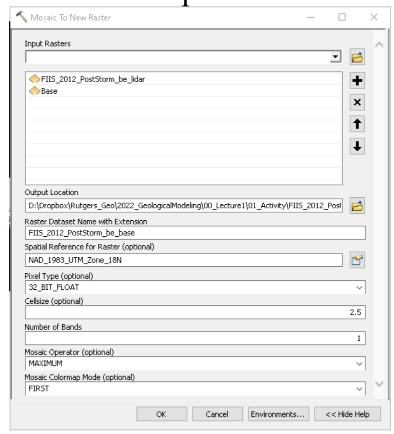
   a. The “Input raster” is the “FIIS_2011_be_lidar” layer.
   b. The “Input raster of feature mask data” is the “FIIS_Geomorphology_Units_2011” layer.
   c. Name the new dataset “FIIS_2011_be_lidar_clip” and save it in the “FIIS_2011.gdb” using the “Output raster” entry form.
   d. Select the “Environments…” button and select “Processing Extent”. Make the extent “Same as layer FIIS_2011_be_lidar”

11. We will repeat step 10 with the 2012 post-Sandy dataset. In ArcToolbox, expand the expand “Spatial Analyst Tools”, expand the “Extraction” sub-selection, and choose the “Extract By Mask” tool.
   a. The “Input raster” is the “FIIS_2012_PostStorm_be_lidar” layer.
   b. The “Input raster of feature mask data” is the “FIIS_Geomorphology_Units_2012_PostStorm” layer.
   c. Name the new dataset “FIIS_2012_PostStorm_be_lidar_clip” and save it in the “FIIS_2012_PostStorm.gdb” using the “Output raster” entry form.
   d. Select the “Environments…” button and select “Processing Extent”. Make the extent “Same as layer FIIS_2012_PostStorm_be_lidar”
12. From either the “FIIS_2011.gdb” or the “FIIS_2012_PostStorm.gdb” geodatabase, drag the “Base” raster dataset into the map document. We will use it to make the three-dimensional space we evaluate consistent between the two datasets.
13. Within the ArcToolbox, expand “Data Management Tools”, expand the “Raster” sub-selection, and choose the “Mosaic To New Raster” tool.
   a. As the input rasters, select the “FIIS_2011_be_lidar_clip” and “Base” data layers.
   b. Choose the “FIIS_2011.gdb” geodatabase as the “Output Location”.
   c. Make the “Rater Dataset Name with Extension”: “FIIS_2011_be_lidar_base”.
   d. Spatial reference should be set to “NAD_1983_UTM_Zone_18N”.
   e. The pixel type must be “32_BIT_FLOAT”.
   f. The cellsize must be 2.5.
   g. There should be a single, “1”, band.
   h. The mosaic operator must be “Maximum”.
   i. Make colormap “FIRST”.
14. Repeat step 13 using the “FIIS_2012_PostStorm_be_lidar” and “Base” data layers. I.e.,:



a. As the input rasters, select the “FIIS_2012_PostStorm _be_lidar_clip” and “Base” data layers.

b. Choose the “FIIS_2012_PostStorm.gdb” geodatabase as the “Output Location”.



c. Make the “Rater Dataset Name with Extension”: “FIIS_2012_PostStorm_be_lidar_base”.

d. Spatial reference should be set to “NAD_1983_UTM_Zone_18N”.

e. The pixel type must be “32_BIT_FLOAT”.

f. The cellsize must be 2.5.

g. There should be a single, “1”, band.

h. The mosaic operator must be “Maximum”.

i. Make colormap “FIRST”.

15. Toggle the new datasets on and off. Note any aspects of the two datasets that might result in inconsistency (difference unrelated to physical processes) when calculating differences between them.

16. In the Spatial Analyst Tools, expand the “Map Algebra” subselection and selct the “Raster Calculator” tool.

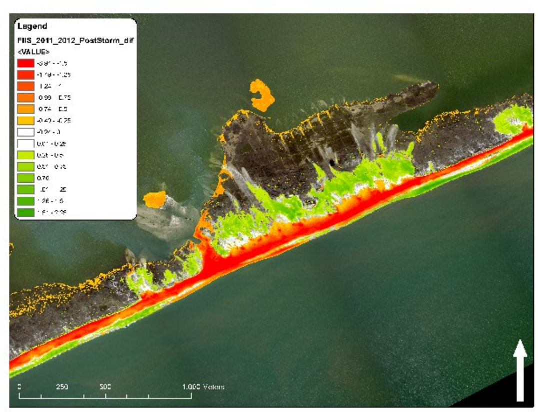
    a. Subtract the "FIIS_2011_be_lidar_base" layer from the "FIIS_2012_PostStorm_be_lidar_base" layer

    b. Name this output raster “FIIS_2011_2012_PostStorm_dif” and save it in a new “File Geodatabase” that is named “[last name]_FIIS_SpatialAnalysis.gdb”.

    c. "FIIS_2012_PostStorm_be_lidar_base" - "FIIS_2011_be_lidar_base"

17. Change the symbology from stretched to classified, choose a defined interval of 0.1, and remove all bins that show change of greater or less than 2 m. Choose a color ramp that appropriately displays the elevation change. Change the bins with no change, i.e., -0.2 to 0.2 m, to transparent.

18. Plot this dataset over the post-Sandy orthophotos and make a map of these data. Use the bookmark, “Map1” to go back to the same spatial extent used for the previously created map. Save the map as “[last name]_FIIS_SpatialAnalysis.mxd”.



19. We can quantify the amount of volumetric change that has occurred within this map frame. Open the Extraction tool and reselect the “Extract by Mask” tool.

    a. Set the Input raster as the difference raster, and the mask as the “Base” layer.

b. Name the new raster as [last name]_FIIS_2011_2012_PostStorm_dif_clip and save it within the "[last name]_FIIS_SpatialAnalysis.gdb" geodatabase.

c. In environments, set the "Processing Extent" to "Same as Display", ensure that you are still in "Layout View" using the same spatial extent as the "Map 1" bookmark.

d. Click "OK"

e. Assess the spatial extent of the new dataset in the Data View.

20. Go to the new dataset in ArcCatalog, and look at the raster dataset properties

    a. Calculate the area of coverage by

        i. Multiplying the number of columns (should be 1220) by the cellsize of the raster (should be 2.5). Result should be 3050 m of length in the x direction.

        ii. Multiplying the number of columns (should be 916) by the cellsize of the raster (should be 2.5). Result should be 2290 m of length in the y direction.

        iii. Multiplying the length of the map in the x and y dimensions together, should give 6984500 m^2 of area. This could vary for your map if the page size is not 8.5 x 11 in., the margins are not 0.5 in., or the map scale is not 1:12000. Use the value you come up with even if it is different.

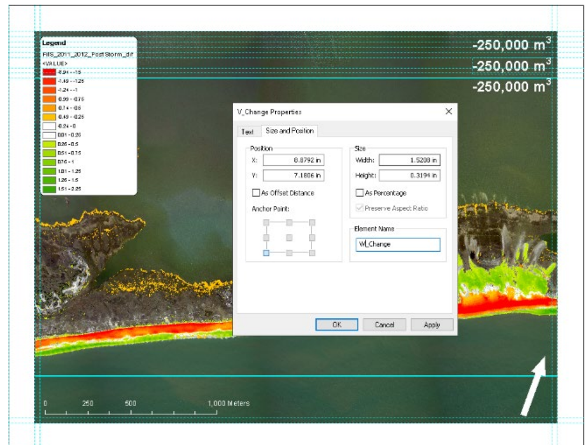
    b. Multiply that by the average variation in elevation across the map area (look in the statistics section of the properties for the mean value). This will give a volume. The areas will be negative on the order of 10^5 m^3.

21. Go back to "Layout View", choose the "Insert" menu, and inset text. Write the volumetric change that occurred in the area of your map. Make the text visible on the dark background. Before clicking OK, go to the "Size and Position" tab and type exactly "V_Change" as the "Element Name". It is important that this is exactly the text in the box, it will be used in code in the next activity.

22. Save the map document and export a ".png" image of this map with the volumetric change in your Box folder.

Activity 1.3 – Programmatic application in ArcPy

1. Open the ArcMap document we saved in the previous activity, [last name]_FIIS_SpatialAnalysis.mxd.
2. Stay in "Layout View". Rotate the data frame by right-clicking "Layers" and going to properties, under the "General" tab change the "Rotation" value to -20.
3. Import the "Frames" feature class from either the 2011 or the 2012_PostStorm geodatabase.
4. We will make three new maps. First, remove the Frames from the legend items.
5. Select the westernmost polygon in the "Frames" feature class. In the "Selection" menu, choose "Zoom to Selected Features". Reset the map scale to 1:12000. Copy and paste the text with the volumetric change 2x. Name these two new text elements as "W_Change" and "D_Change" Save this map as "[last name]_FIIS_SpatialAnalysis_01.mxd". Toggle off the "Frames" layer.



6. Repeat this with the other two polygons in the Frames, naming them "[last name]_FIIS_SpatialAnalysis_02.mxd" and "[last name]_FIIS_SpatialAnalysis_03.mxd".
7. I have provided a python script that with a few changes will use the raster math we applied in Activity 1.2 to calculate total volumetric change, volumetric loss of the active foredune, and volume deposited in the backshore from overwash processes within each of the three areas defined in the "Frames" feature class. The changes to be made are marked in the script, we will go over how the script works and what to change within it together.