GIS Tutorial for

Atmospheric Sciences

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Section 2: Intermediate GIS Functionality

Exercise 1

Working with Weather Data in Raster Format

Use Case: Mapping and analyzing extreme rainfall data

In October 2015, much of South Carolina experienced one of the wettest months ever on record due to a pro-longed heavy rainfall event that occurred during the first five days of October. The cause of the event was an unusual combination of meteorological factors. Hurricane Joaquin's warm moist air interacted with a cold front that stalled just offshore of the Carolinas. This interaction resulted in almost a week of continuous rainfall. Many locations experienced over two feet of rain and recorded their wettest month ever on record. For part of the state this was a 500 year or 1000 year event. Flooding was widespread and catastrophic, and caused over 20 deaths, destroyed hundreds of homes, businesses, and bridges, all of which totaled $12 billion in damages.

Precipitation data is collected and stored by the National Atmospheric and Oceanic Administration (NOAA) in a variety of formats and for multiple applications. Data for specific sites can be accessed, as well as gridded data can be derived from satellite and radar precipitation estimates. These data can be used in GIS to map precipitation, create event maps or climatologies, and for storm impact analysis.

Sub-Sections in Exercise 1:

1. *Interpolating point data into raster data*
2. *Computing the difference in values between two raster layers*
3. *Using geoprocessing tools to assess weather impacts*

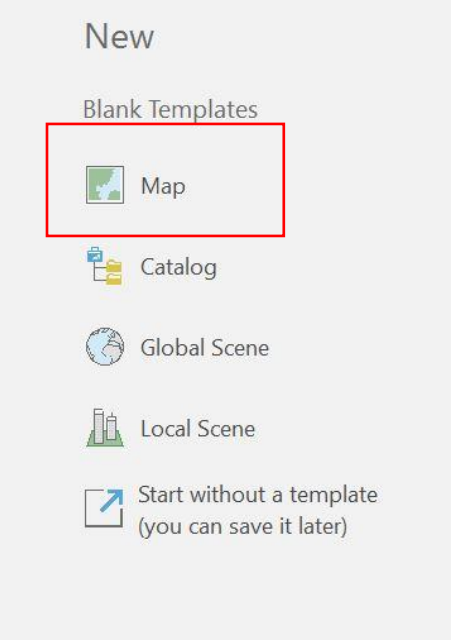
Interpolating point data into raster data

Interpolation of point data predicts values for cells in a raster from a limited number of sample data points. It can be used to predict unknown values for such phenomena as elevation, rainfall, chemical concentrations, noise levels, and so on. The assumption that makes interpolation a viable option is that spatially distributed objects are spatially correlated; in other words, things that are close together tend to have similar characteristics. For instance, if it is raining on one side of the street, you can predict with a high level of confidence that it is raining on the other side of the street.

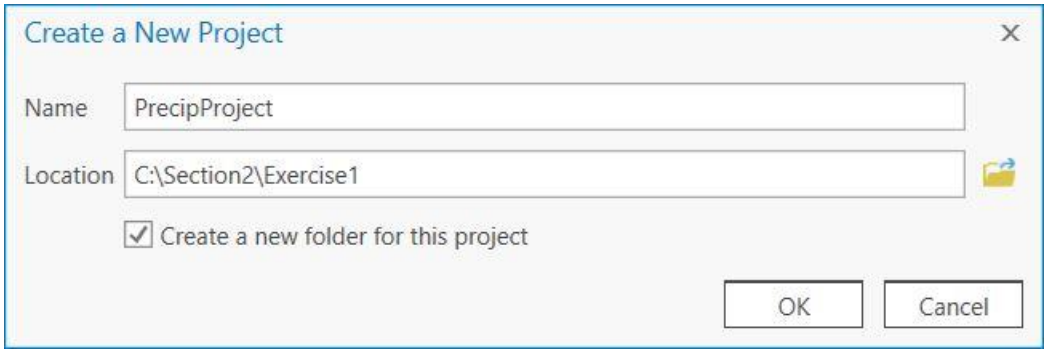
Step 1 Clipping data to your area of interest

In this first step you will use ArcGIS Pro geoprocessing tools to interpolate rainfall accumulations.

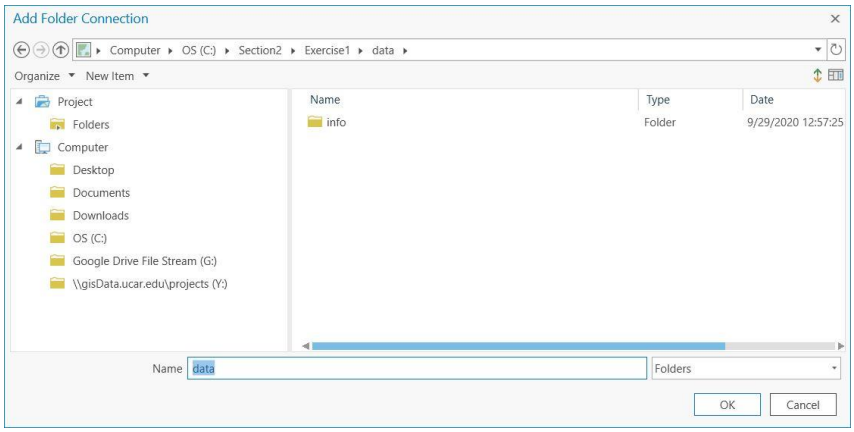
- Open a blank ArcGIS Pro Project.



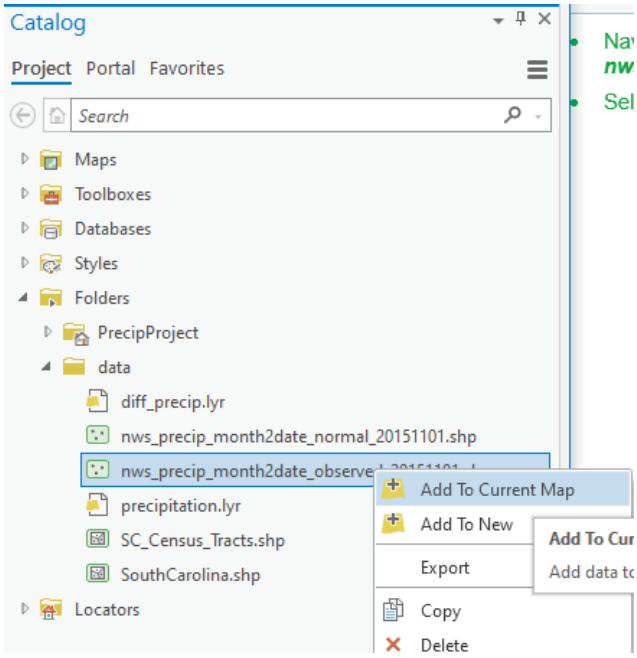
- Set the Name of your project to "**PrecipProject**".
- Set the Location of your project into ***C:\Section2\Exercise1***.
- Make sure the "*Create a new folder for this project"* is checked.



- In the Catalog pane, right click on **Folder** and select **Add Folder Connection**.
- Navigate to ***C:\Section2\Exercise1\data***.
- Click **OK**.



- Navigate to Folders > data and right click ***nws_precip_month2date_observed_20151101.shp.***
- Select **Add to Current Map.**



It may take a few seconds for this layer to draw because it is so large. If you were to zoom into a smaller area, you would see individual points. Also notice that this file contains data for the entire U.S, including Alaska and Puerto Rico, though Hawaii is not included. For the purposes of this exercise and our analysis, we will clip this shapefile to the border of South Carolina.

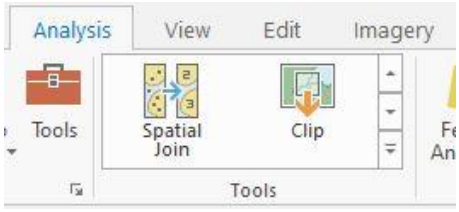
- On the Map tab, in the Inquiry section, click **Locate**.
- Type in **Columbia, SC** into the Search box and click Enter.

You will now be zoomed into the city of Columbia, SC and you will be able to see the individual points in this layer.

- Click the **Explore** Tool and then click on any point on your map.

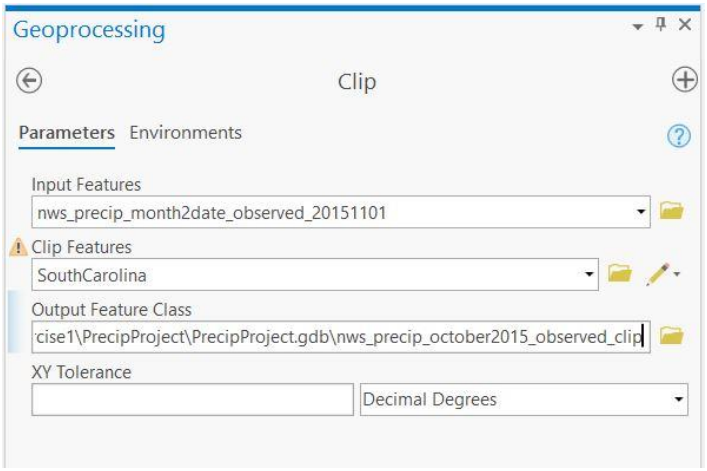
In the Pop-up that appears you can now see all the attributes for these points. The attribute GLOBVALUE is the precipitation accumulation for the month of October, 2015.

- Turn off ***nws_precip_month2date_observed_20151101*** in the Contents pane.
- Add the layer ***SouthCarolina*** from your ***data*** directory.
- Right click on ***SouthCarolina*** in the Contents pane and select **Zoom to Layer**.
- Click on the **Analysis** ribbon.
- In the Tools section click **Clip**.



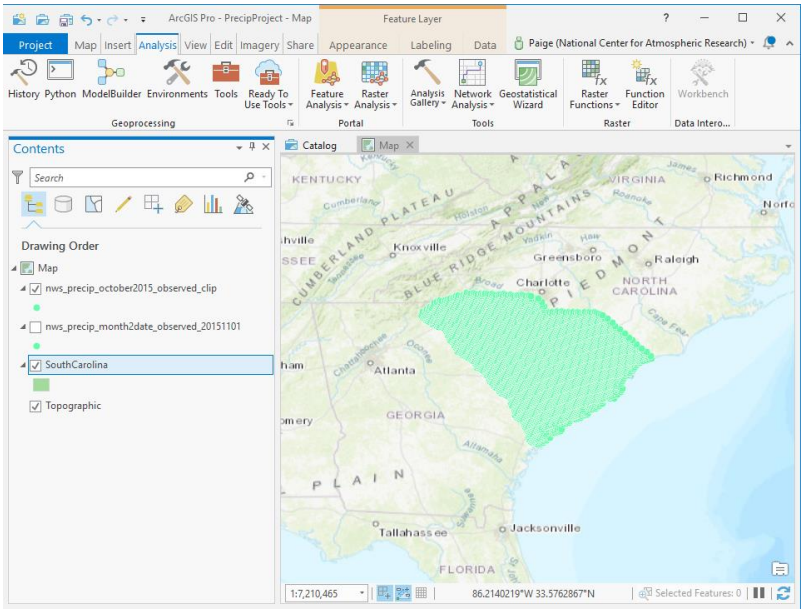
TIP: You can also clip Tools and use the Search Window to find a geoprocessing tool in ArcToolbox.

- Use the Clip geoprocessing tool set the following parameters :
  - Input Features = ***nws_precip_month2date_observed_20151101***,
  - Clip Features = ***SouthCarolina***,
  - Output Feature Class = ***nws_precip_october2015_observed_clip***



- Click **Run** (ignore the caution sign)

The ***nws_precip_october2015_observed_clip*** layer is added to Map.



- Open the attribute table for ***nws_precip_october2015_observed_clip,*** by right clicking on the layer in the Contents pane and selecting **Attribute Table**.

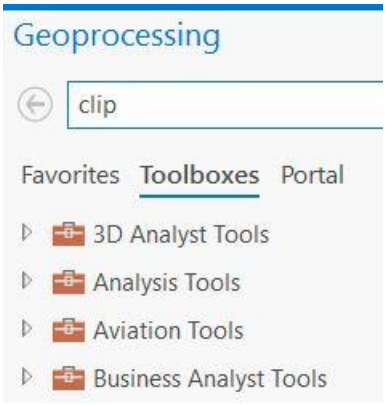
Remember that the field you will be working with is called “GLOBVALUE”. The values in this field represent the total amount of rainfall for a given point for the entire month. The units are in inches.

- Close the attribute table.
- **Save** your project.

Next we will interpolate the points into a raster grid.

Step 2 Interpolate point layer to raster surface

- In the **Analysis** tab, click on the **Tools** button.
- In the Geoprocessing pane, click on **Toolboxes**.



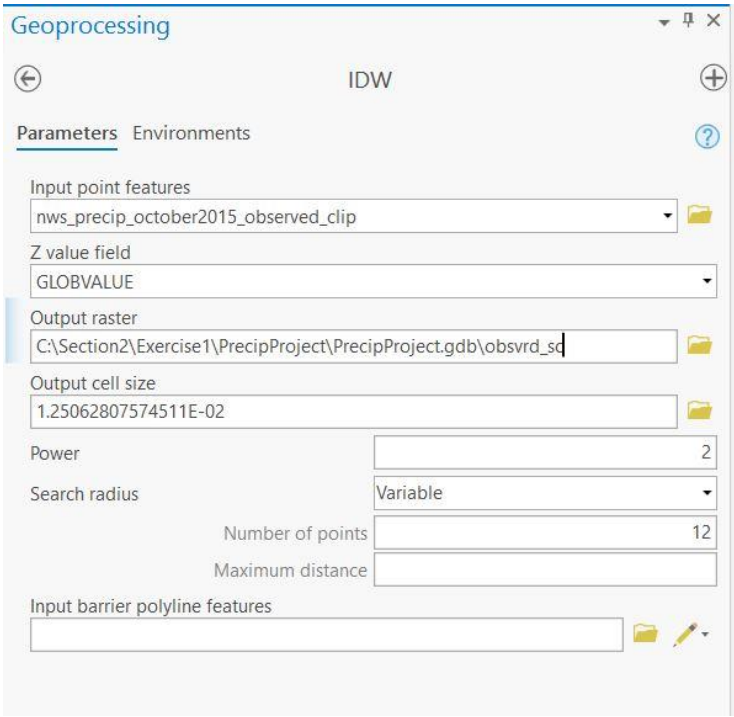
- Browse to the **Spatial Analyst Tools** and expand the **Interpolation** toolset.

TIP: You may need to turn on the Spatial Analyst Extension. Go to Customize > Extension and make sure the box for Spatial Analyst is checked.

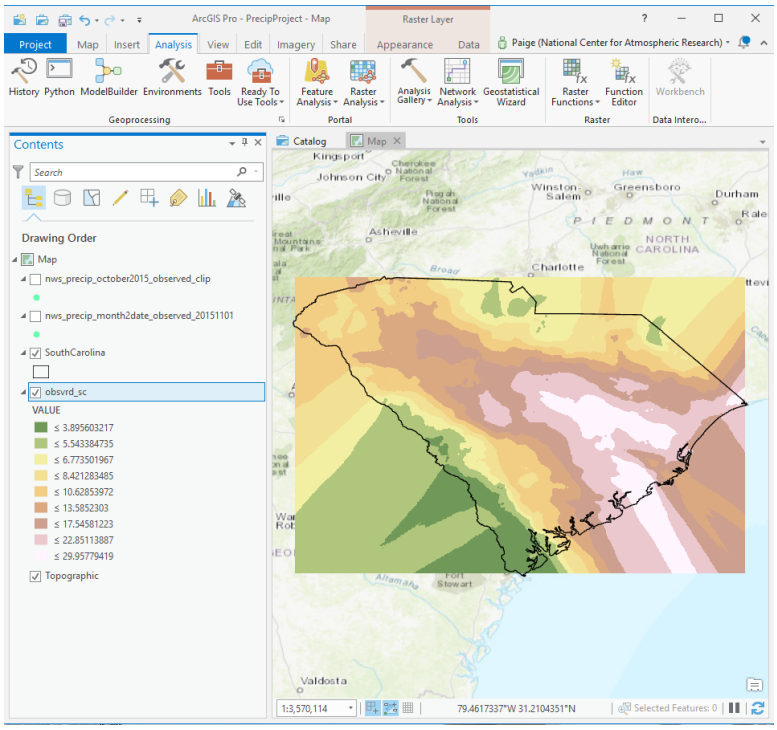
- Double-click the **IDW** tool to open the tool.

In ArcGIS Pro, there are multiple options for interpolating data including IDW (Inverse Distance Weighted), Kriging, Natural Neighbor, Spline, Topo to Raster, Topo to Raster by File, and Trend. IDW determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance.

- Set the Input point features to the ***nws_precip_october2015_observed_clip*** layer.
- Set the Z value field to **GLOBVALUE** (the precipitation values).
- Save the output raster to ***obsvrd_sc***
- Accept the default for the output cell size.
- Accept the remaining defaults as well. No "Maximum distance" or "Input barrier polyline features (optional)" are needed.
- Click **Run**.

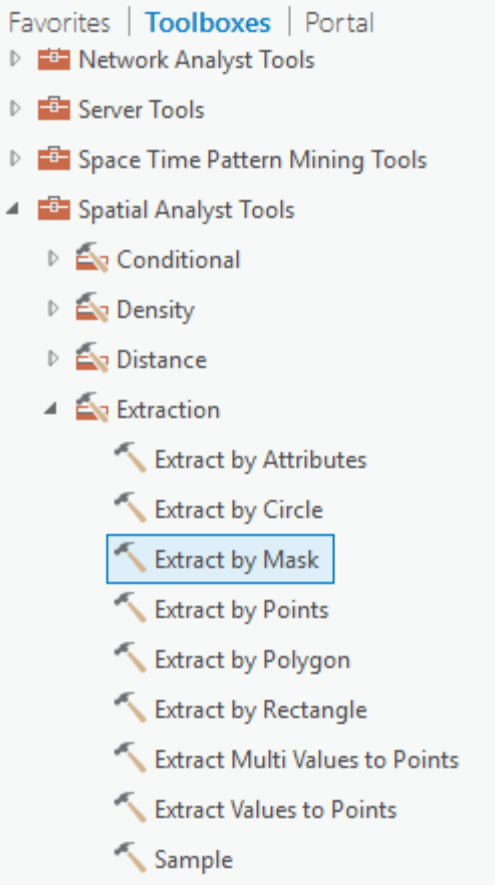


- Turn off the ***nws_precip_october2015_observed_clip*** layer.
- Change the symbol of the ***SouthCarolina*** layer to be hollow with an outline width of 1 and an outline color of black.

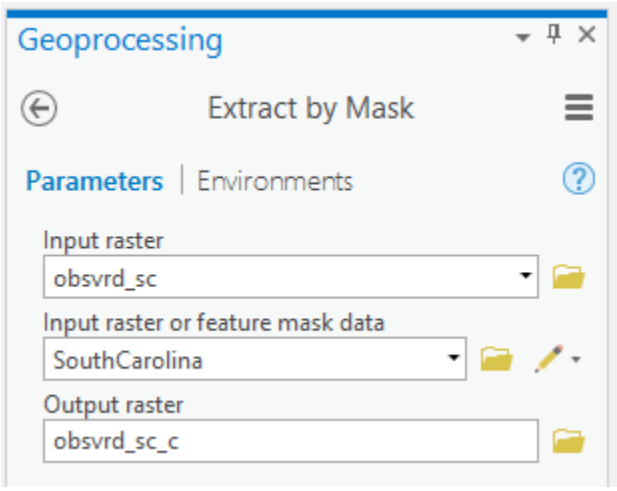


Once the process is completed, the new raster layer is added to the data frame. Raster processing is done based on the total rectangular extent of the input values, thus you will see data extending beyond the boundary of the South Carolina. Next we will clip the raster to the border of South Carolina for better display.

- Open the **Toolbox**.
- Browse to the **Spatial Analyst tools** and expand the **Extraction** toolset.
- Double-click the **Extract by Mask** tool to open the tool.



- Set the input raster as the ***obsvrd_sc*** layer.
- Set the input raster or feature mask data as the ***SouthCarolina*** shapefile.
- Save the output raster to your data folder with the name as ***obsvrd_sc_c***



- Click **Run**
- Turn off the ***obsvrd_sc*** layer.

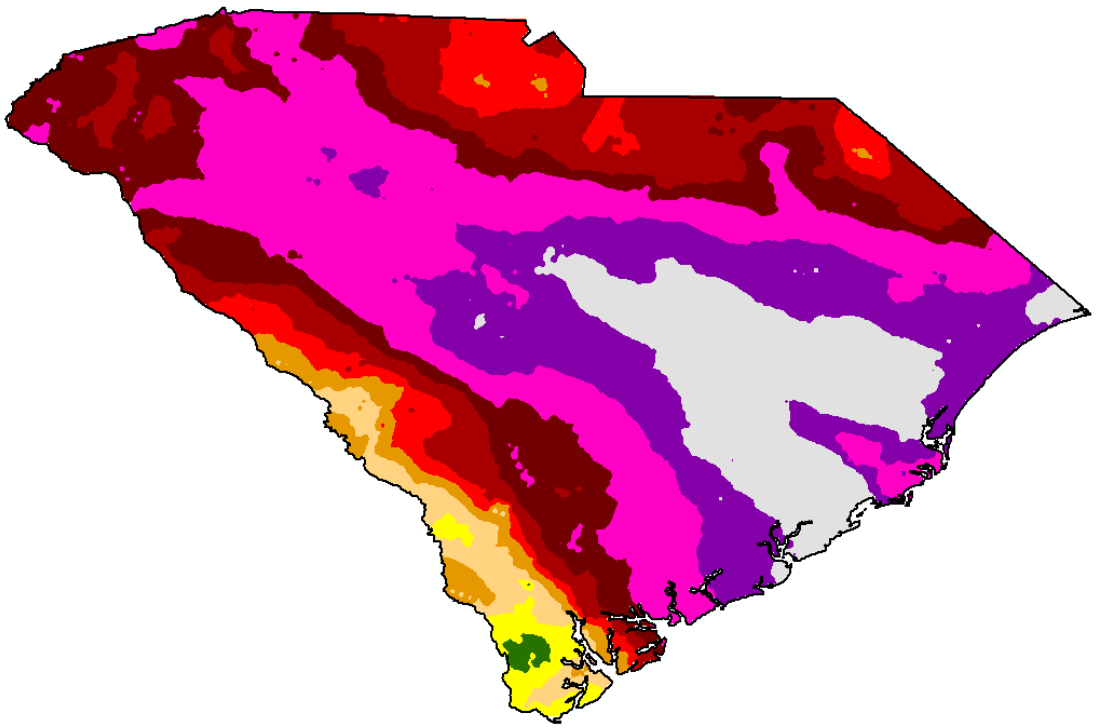
TIP: Go to Analysis > History. This will open the History window. You can double click on the processes you have performed, change the input values and output values and rerun the tools.

Once the process is completed, the new raster layer is added to the data frame. Next we will want to change the symbology to be more meaningful by importing a layer file which contains the appropriate symbology.

- Right click on the layer ***obsvrd_sc_c*** in the Contents pane and select **Symbology**.
- In the **Symbology** pane, change the display type to **Classified**.
- In the upper right, click the browse icon and click **Import from layer file**. Browse to your ***data*** directory.
- Select the ***precipitation.lyr*** layer file and click **Ok**.

This layer file was created for displaying a range of precipitation values between 0.01 inches to over 20 inches for the entire U.S. Not every value listed in the layer file may be seen in our area of interest, South Carolina.

- Close the Symbology window.
- Uncheck the ***Topographic*** basemap that was added to your map by default when you opened the project



This raster layer now represents the total observed rainfall in South Carolina for the month of October, 2015. According to the symbology, the values range from 2 inches in the southwestern part of the state to over 20 inches in a large part of the eastern central part of the state. Next you will see how this compares to average rainfall for the month of October in South Carolina.

Next you will add the normal rainfall layer for South Carolina for the month of October.

- From the **Map** ribbon > **Add data** > **Data**
- From your data directory select ***normal_sc_c.tif*** raster.
- Symbolize this layer like you did the ***obsvrd_sc_c*** raster using the ***precipitation.lyr***.
- **Save** your Project

This raster layer now represents the total normal rainfall (or average rainfall) in South Carolina for the month of October. According to the symbology, the values range from just 3 inches to 6 inches, with a large part of the state only receiving 4 inches of rainfall on average for the month of October. In comparing the two rainfall maps, October 2015 received much more rainfall than average.

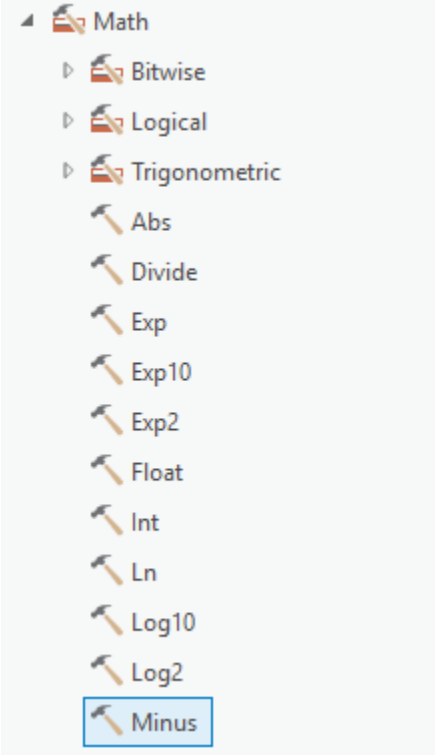
In the next step you will use additional raster processing tools to determine the exact difference between the observed and normal rainfall layers.

Computing the difference in values between two raster layers

Step 3 Creating a departure from normal grid

In weather or climate terms, the difference between an observed value and a normal value is referred to as departure from normal. In this step you will create a departure from normal grid by calculating the difference between the observed and normal layers that you just created.

- Open the Toolbox.
- Browse to the **Spatial Analyst tools** and expand the **Math** toolset.
- Double-click the **Minus** tool to open it.

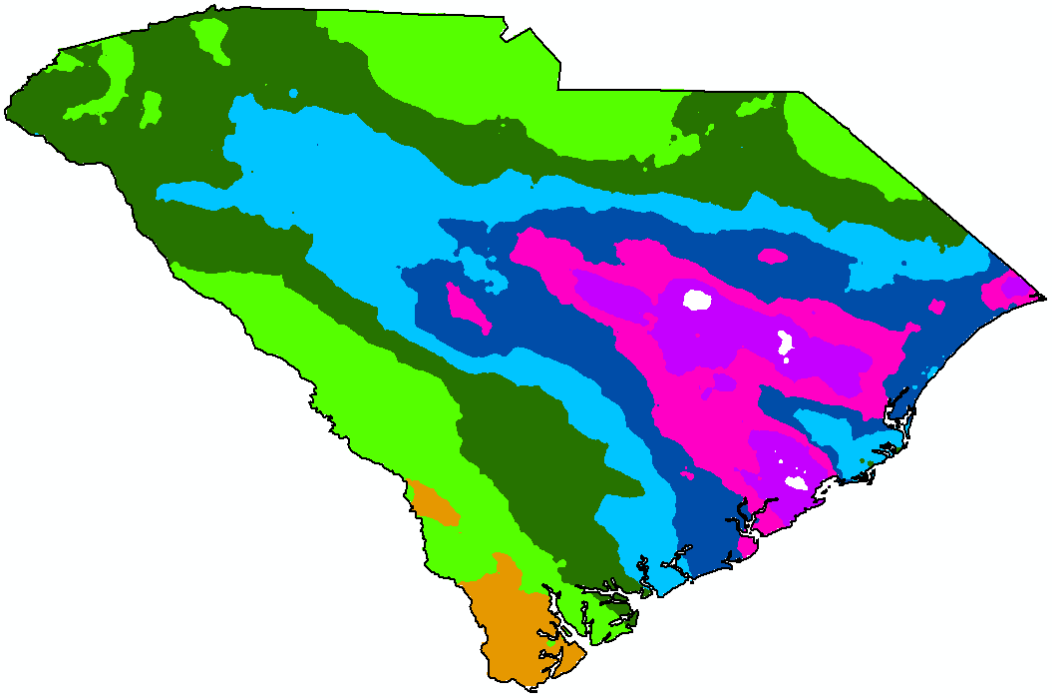


- Set the input raster value 1 as the ***obsvrd_sc_c*** layer.
- Set the input raster value 2 as the ***normal_sc_c*** layer.
- Save the output raster layer as ***difference***
- Click **Run.**

The new layer is added to the data frame. Next, you will change the symbology to be more meaningful by importing a layer file which contains the appropriate symbology.

- Open the Symbology pane for ***difference*** layer.
- Change the Primary Symbology type to **Classify**.

- In the upper right, click the browse icon and click Import. Browse to your ***data*** directory.
- Select the ***diff_precip.lyr*** layer file and click **Ok**.
- Close the Symbology window



This final raster layer now represents the departure from normal rainfall in South Carolina for the month of October, 2015. According to the symbology, you can see that the values range from -2.1 inches to over 26 inches. This means that some areas of South Carolina received over 26 inches more rainfall during October 2015 than what would normally be experienced.

- **Save** your Project

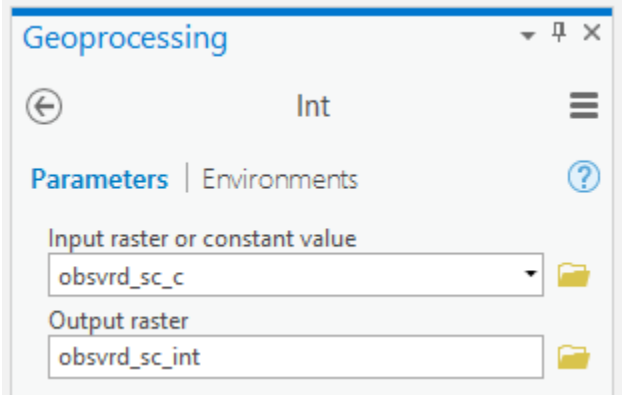
Using geoprocessing tools to assess the impact from weather

GIS is a great tool for assessing the impacts of weather events. In this section, you will use the observed rainfall raster layer that you previously created to determine how many people in South Carolina were impacted by heavy rainfall.

Step 4 Converting a floating point raster to an integer raster

To facilitate the assessment of how many people were affected by extreme precipitation we will use ArcToolbox and the geoprocessing tools. Some of these tools require the input data to be in vector format. To convert the current observed rainfall raster layer to a vector layer, you will first need to convert the dataset which is a floating point raster layer, to an integer raster layer.

- Open the **Toolbox**.
- Browse to the **Spatial Analyst Tools**.
- Expand the **Math** toolset.
- Open the **Int** tool.
- Set the input raster as your ***obsvrd_sc_c*** layer.
- Set the output raster as ***obsvrd_sc_int***.



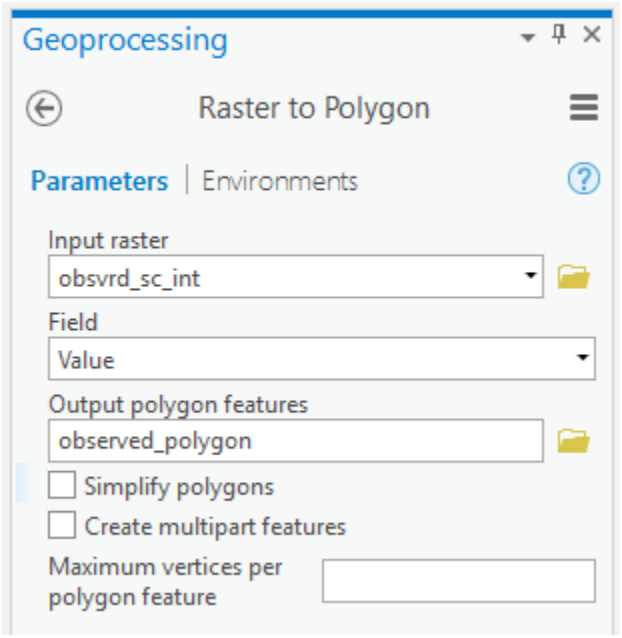
- Click **Run**.

The new raster layer is added to the data frame.

An integer raster layer rounds the numeric cell values to whole numbers. Now that you have an integer raster layer, you can convert this to a vector polygon layer. Only raster integer layers can be converted to vector polygons.

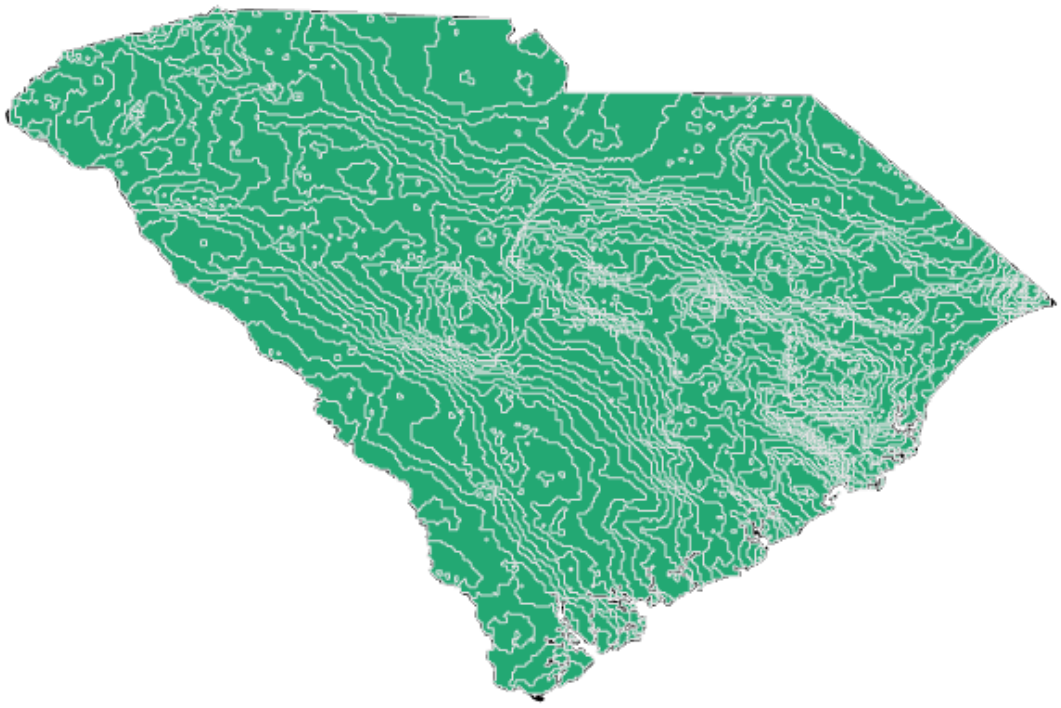
- In the Toolbox, browse to the **Conversion Tools**.
- Expand the **From Raster** toolset.
- Open the **Raster to Polygon** tool.
- Set the Input raster as ***obsvrd_sc_int***, the raster layer you just created.
- The Field should be set to **Value**.
- Set the Output polygon features as ***observed_polygon***, saving it to your Exercise 1 data folder.

- Uncheck the box to **Simplify polygons**.



- Click **Run**.

The new polygon layer is added to the data frame.



When raster layers are converted to vector polygon layers, their values are carried over and stored in the new attribute table.

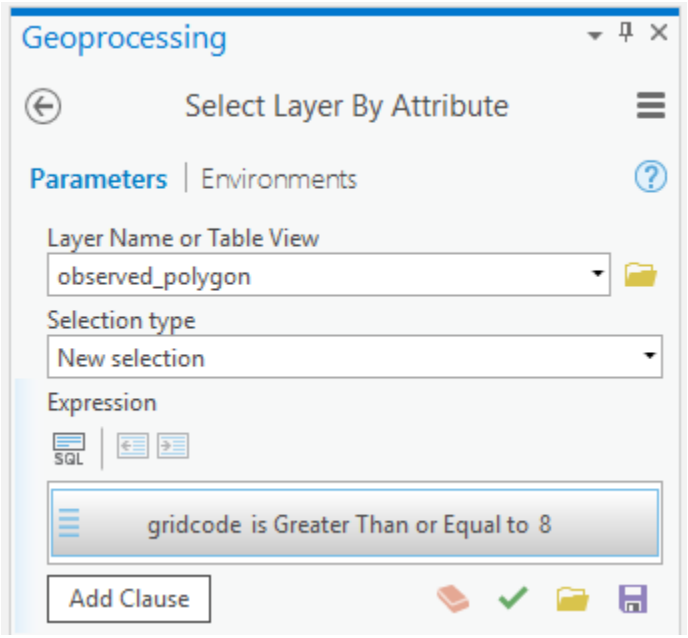
- Open the Attribute Table for the ***observed_polygon*** layer.
- Examine the "gridcode" field.

The gridcode field is the field that contains the precipitation values from the raster layer. We can use the gridcode values to extract out values of interest. In this case, you will select all gridcode values of 8 (inches) or more and export the selection to a new shapefile.

- Navigate to the **Map** Ribbon
- Click **Select By Attributes…**

The Select By Attributes window opens.

- In the Layer dropdown box, choose your ***observed_polygon*** layer.
- Selection type: New selection
- Add New expression. Make the expression display **gridcode is greater than or equal to 8**



- Click **Run**.

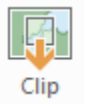
The polygons containing values of 8 inches or more are selected. Now you will export these to a new layer.

- In the Table of Contents, right-click on the ***observed_polygon*** layer and choose **Data** > **Export Features**.
- Save the new date in the PrecipProject.gdb as ***heavy_rainfall***.
- Click **Run**

The new layer is added to the data frame.

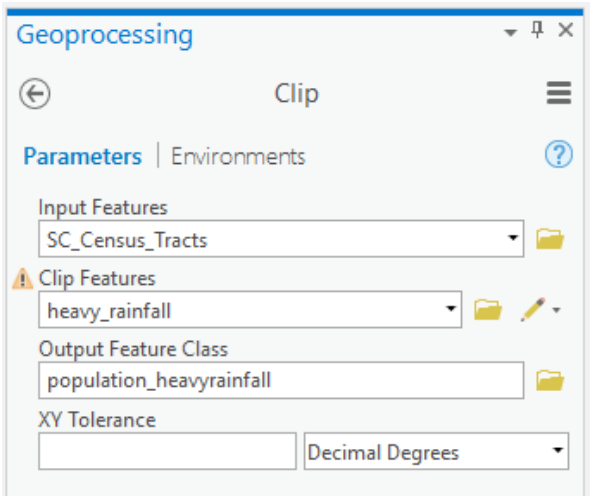
You will now use this layer to assess the amount of people in South Carolina that was impacted by 8 or more inches of rainfall from the historic rainfall event.

- Uncheck the **observed_polygon** layer.
- Click the **Add Data** button and browse to your ***data*** folder.
- Add the ***SC_Census_Tracts*** layer.
- From the Analysis ribbon, click on the **Clip** icon.



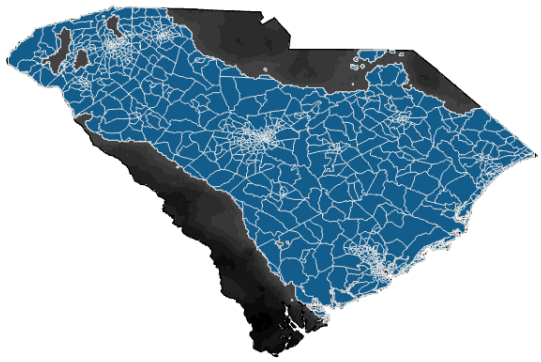
TIP: Note that there are shortcuts to some of the most common tools in the Analysis ribbon. If you cannot find your tool here, you can find all of them in the toolbox.

- Set the Input Features as the ***SC_Census_Tracts*** layer.
- Set the Clip Features as the ***heavy_rainfall*** layer.



- Click **Run**.
- Uncheck the ***SC_Census_Tracts*** layer in the Contents pane.

The new layer is added to the data frame.



- Open the attribute table of the ***population_heavyrainfall*** layer.
- Locate the *"POP2010*" field.
- Right-click on the field and click **Statistics…**

Notice that the sum of the population is 3,966,293

According to this assessment, over 3.9 million people were impacted by 8 inches or more of rainfall during the historic rain and flood event in South Carolina in October 2015.

- **Save** your Project.
- **Close** ArcGIS Pro.