Georeferencing Raster Datasets

Georeferencing allows you to take a scanned map, air photo, or satellite image and give it a spatial reference on the Earth, so you can use it in a GIS for spatial and historical analysis.

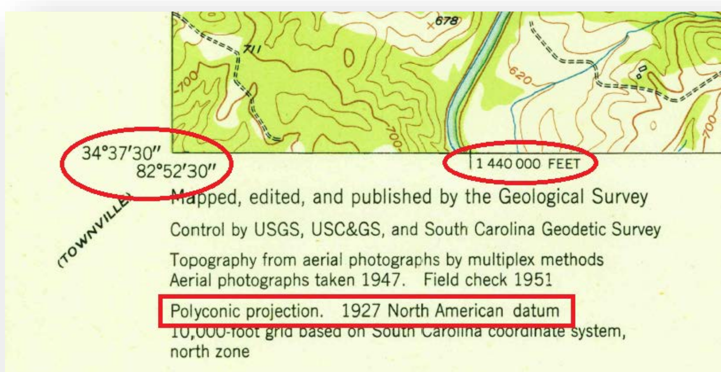
Get Familiar with your image

Take a look at ***SC_Clemson_260869_1951_24000_geo.tiff.*** It is a historical topographic map of the Clemson area in 1951 downloaded from the USGS website.

This is image was originally a pdf that we transformed into a tiff file so we can use it in ArcGIS. However, in order to use this image in a GIS application, it needs a coordinate system.

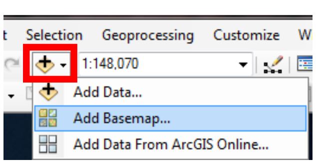
Let's explore the image to look for geolocation information. If you look at the border of the map, you will see a series of numbers in minutes, degrees and seconds. Those are geolocated points that help us reference this map to a geographic coordinate system (lat/long).

Scroll to the bottom left corner of this map. You will see that there is another coordinate system of reference in feet and some information regarding the datum and type of projection of the map.



Set up your Data Frame

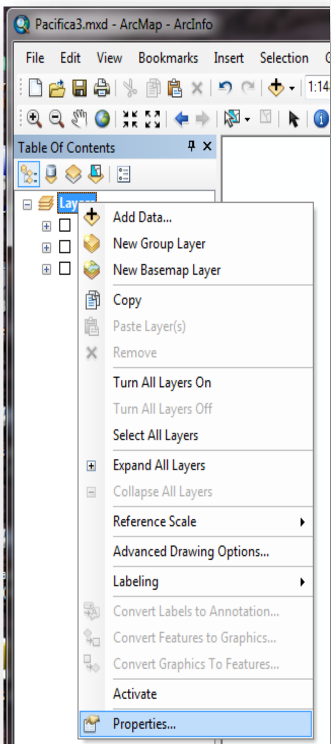
Begin by opening ArcMap. Select the small downward arrow next to the ***Add Data*** button and choose ***Add Basemap…*** then select ***Imagery with Labels***. If prompted to set hardware acceleration choose NO. Now zoom into the Clemson area.

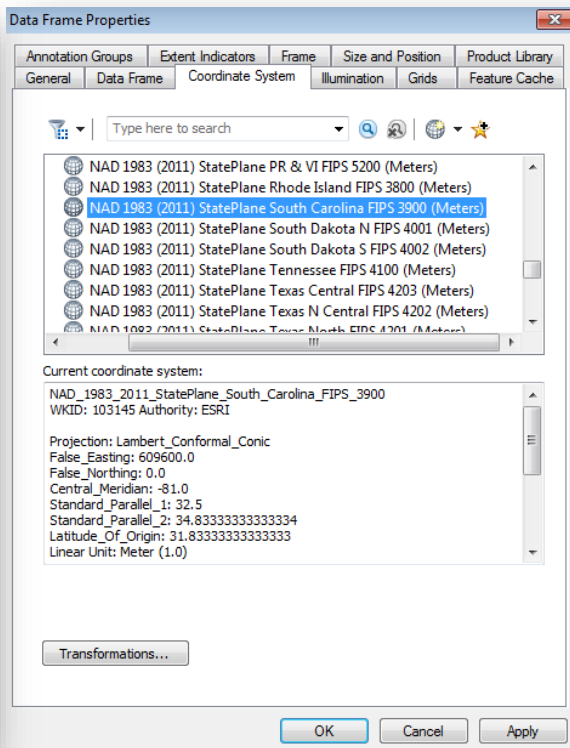


Set the Coordinate System for your Data Frame

You will choose the coordinate system matches the coordinates of the points that you will use to geolocated your topo map. In this case, the easiest way is to use the corners of the map that are currently in geographic coordinate system.

Change the coordinate system of your data frame by right clicking on ***Layers*** in your table of contents and select ***Properties***. Choose the Coordinate System tab. Scroll up until you see ***Projected Coordinate Systems.*** Select this option and navigate to ***State Plane* > *NAD 1983 (2011) (Meters) > NAD 1983 (2011) StatePlane South Carolina FIPS 3900 (Meters).*** Click OK.



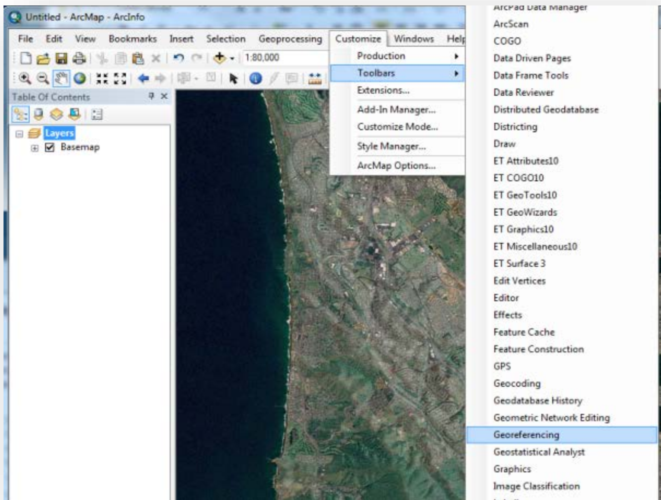


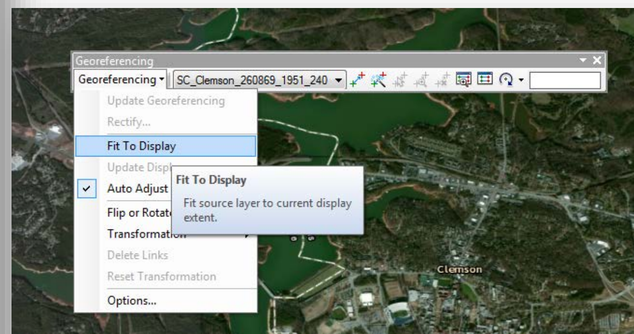
A warning message will appear that asks you to change the coordinate system of your data layers. Click Yes. Go to the General tab and change the display units to Decimal Degrees. Click OK and Yes.

Next add the image to be georeferenced, ***SC_Clemson_260869_1951_24000_geo.tiff***. ArcMap immediately warns you that your data as no spatial reference. Click OK. You may see a message asking to build pyramids, it is always recommended to choose yes, so rendering and zooming will be much faster.

The Georeferencing Toolbar

To display the Georeferencing toolbar, click the ***Customize*** menu, point to ***Toolbars***, and then click ***Georeferencing***.





Make sure the ***Layer*** selection drop down is set to your image (*SC_Clemson_260869_1951_24000_geo.tiff*), then click ***Georeferencing*** and hit ***Fit To Display***.

This fits the raster dataset you want to georeference (*SC_Clemson_260869_1951_24000_geo.tiff*) in the same area as your source layers (World imagery).

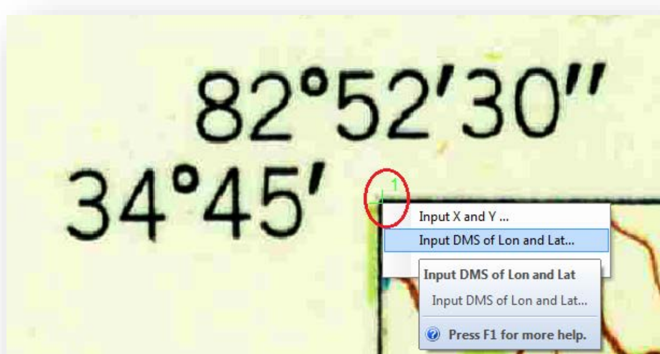
To see all the datasets, adjust their order in the table of contents. Move the georeferencing toolbar to the upper part of ArcMap so you can better see the image.

Click the ***Add Control Points*** button to add control points.

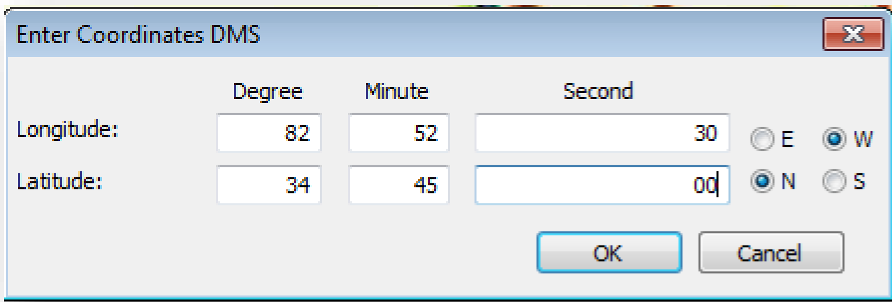
To add a link, click a **known location on the raster dataset** (*SC_Clemson_260869_1951_24000_geo.tiff*), for example, the top left bottom corner, and then add the real coordinates for that location (the referenced data).

To do this, click on the add control points button, zoom into the top left corner and add a point. Right-click and select Input DMS of Lon and Lat.

Enter the latitude and longitude coordinates corresponding to that location, as seen in the graphic below.



Make sure your longitude input is West, not East.



You can also add your links in the Magnification window or the Viewer window.

When working with two raster datasets, you can open the ***Image Analysis*** window and adjust the transparency or turn layers on and off in the table of contents to view each image as you add your links.

Tip: *Press ESC to remove a link while you're in the middle of creating it.*

Repeat this process for each corner of your topographic map. These are enough links for the type of transformation that we will be using in this example.

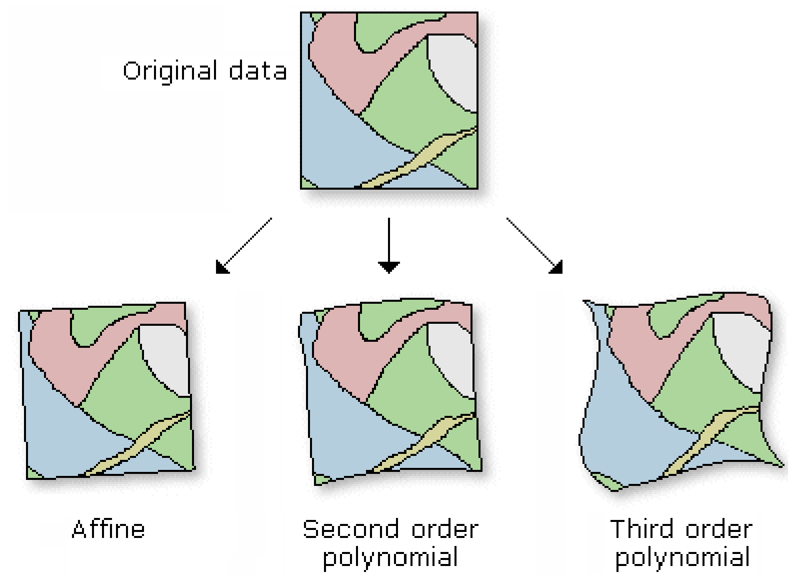
As a general rule, you need a minimum of **4** links for a spline **or first-order polynomial** (maps), **9** links for a **second-order polynomial** (aerial photos), and 10 links for a third-order polynomial.

Adding more links will not necessarily yield a better registration. If possible, you should **spread out the links** over the entire raster dataset rather than concentrating them in one area. Typically, having at least one link near each corner of the raster dataset and a few throughout the interior produces the best results.

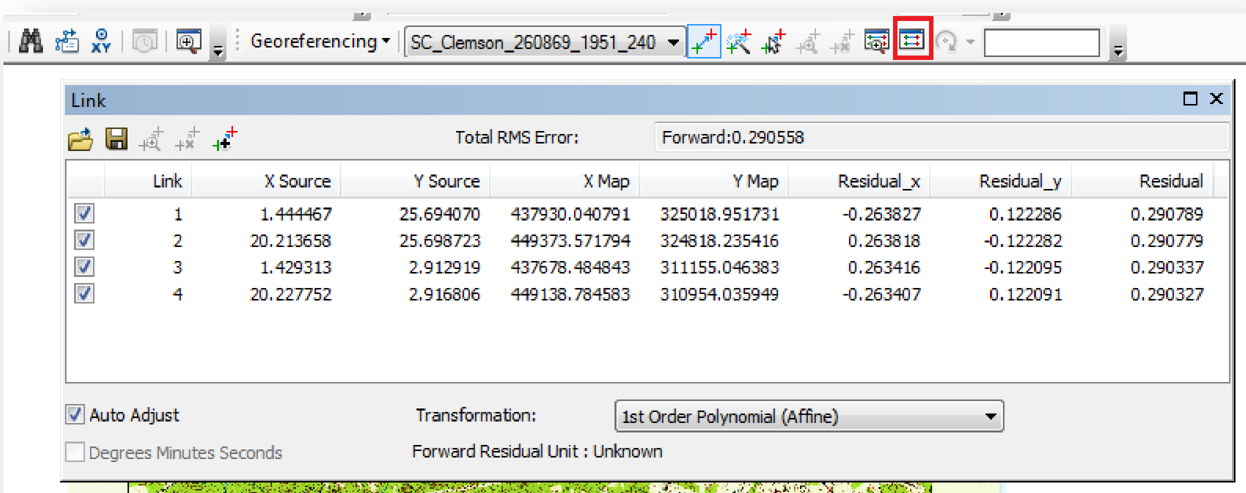
Transformations:

Use a **first order**, or affine transformation, to shift, scale, and rotate a raster dataset. This is most common used when georeferencing maps.

If, however, the raster dataset must be bent or curved, use a **second- or third-order transformation**.



Click the ***View Link Table*** button to evaluate the transformation.



You can examine the residual error for each link and the RMS error. If you're satisfied with the registration, you can stop entering links.

You can delete an unwanted link from the Link Table dialog box by clicking on the link and hitting the Delete button.

Interpreting the root mean square error (RMS)

When the general formula is derived and applied to the control point, a measure of the error—the residual error—is returned. The error is the difference between where *the from point* ended up as opposed to the actual location that was specified—*the to point* position.

The total error is computed by taking the root mean square (RMS) sum of all the residuals to compute the RMS error. This value describes how consistent the transformation is between the different control points (links). When the error is particularly large, you may want to remove and add control points to adjust the error.

Although the RMS error is a good assessment of the accuracy of the transformation, don't confuse a low RMS error with an accurate registration. For example, the transformation may still contain significant errors due to a poorly entered control point. The more control points of equal quality used, the more accurately the polynomial can convert the input data to output coordinates. Typically, the adjust and spline transformations give an RMS of near zero or zero; however, this does not mean that the image will be perfectly georeferenced.

Acceptable RMS error

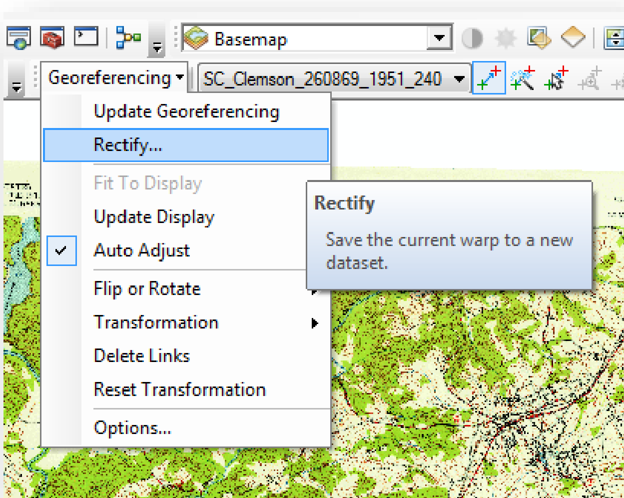
Some literature suggests that it should be "less than or equal to 1/2 of the side of a cell which make up the total resolution of the image." However, **there is no absolute value for RMS**, because it depends on the quality of the map being georeferenced, the quality of the target (base) map, and the purpose of the georeferencing.

Saving your results

Click ***Georeferencing*** and click ***Update Georeferencing*** to save the transformation information with the raster dataset.

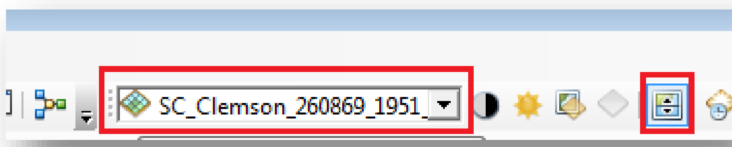
This creates a new file with the same name as the raster dataset but with an .aux.xml file extension. It also creates a world file for some of the file formats, including .tif and .img files.

It is highly recommended that you can **permanently transform your raster** dataset after georeferencing by using the Rectify command; click ***Georeferencing*** and click ***Rectify***. Choose bilinear interpolation as the preferred method for exporting aerial photography. This interpolation method results in a smoother-looking surface than can be obtained using nearest neighbor (the default).



Checking your results

Add the **Effects** custom toolbar to your ArcMap document (hint: same process as adding your Georeferencing toolbar).Make sure the layer for this toolbar is your topo map. Click the Swipe button and swipe the tool across your topographic map to see the results of your Georeferencing.



Play with the transparency settings as well. This will allow you to see both layers and the accuracy of your overlay.

Exercise: Georeferencing a map in jpg format

Let's practice georeferencing the following jpg: SC_Landform_regions.jpg. This map represents the landforms in South Carolina.

Congratulations, you are a georeferencing tiger expert!

Data Sources

Historic Topographic Maps

The USGS maintains several sites to access and download historic topographic maps. This page gives an overview of the possible options. Below are the most functional for your project.

- **USGS National Map Viewer**

http://viewer.nationalmap.gov/viewer/

Platform to download historical topo maps, elevation data, hydrography, watersheds, transportation and structure features, among others.

It requires an email account to download the data. Try the Bulk Download Application if you want to download more than a couple of files.

- **USGS US Topo and Historical Topographic Map Collection**

http://geonames.usgs.gov/apex/f?p=262:1:1689123974535

Text query to find historical topographic maps. Immediate download.

- **University of South Carolina Libraries**

http://digital.tcl.sc.edu/cdm/search/collection/topo/order/title/ad/asc/cosuppress/0

Historic Aerial Photography

- **USGS Earth Explorer**

http://earthexplorer.usgs.gov/

Map query to find historic aerial photography, digital line graphs, and current remote sensed data such as satellite imagery and elevation.

- **Clemson University Special Collections** (not available for download)

- **South Carolinian Map Collection** (not available for download)

http://library.sc.edu/digital/collections/schmscl.html