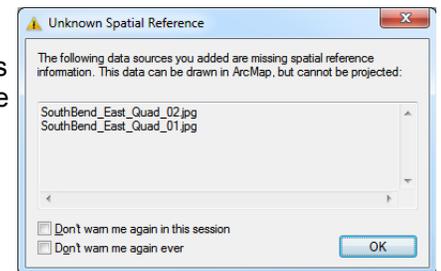


Demo 04: Projections and Georeferencing

In this lab, you will gain an understanding of the process of georeferencing and mosaicking. You will work with maps of your study area which have associated projection information (printed on the map as projection and datum, coordinate gridlines in the map) but have not had this information digitally encoded in the image itself (i.e., georeferenced). You will also learn how to mosaic together two separate georeferenced raster maps into a single continuous map. You will then apply these skills to maps and satellite images of your study area.

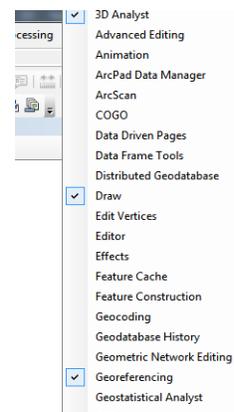
I. First, prepare the demonstration data

- Download **Demo04_Data.zip** from Sakai and extract it as we did last week.
- Load a new ArcMap document and add the images **SouthBend_East_Quad_01.jpg** and **SouthBend_East_Quad_02.jpg**.
- You will probably get a warning about the lack of coordinate system. This is normal as these are simple digital scans of a map. Our job now is to tell the computer what area of the world these images cover.
- Because there is no spatial information, one image will be on top of the other. You can make the other visible by turning off the top image or switching them in the Table of Contents.
- It should be clear that these two are the top and bottom of the same map.
- Finish with **SouthBend_East_Quad_01.jpg** on top.



II. Georeferencing scanned maps

- In this first part we will use the Georeferencing tools in ArcGIS to add coordinates to the two pieces of a scanned map.
- I have intentionally given you one quad sheet split into two pieces.
 - This is to simulate the process of scanning, georeferencing and mosaicking a paper map.
 - This is a valuable skill, so take note, but I will not expect you to find and scan a map for your park. However, this example is part of the assignment, so proceed carefully.
- To begin with we must activate the Georeferencing toolbar in ArcMap.
 - Right click on a gray area at the top of the screen. For example, under the toolbars
 - Then choose "Georeferencing"
 - This will activate the Georeferencing toolbar
- Now we should tell ArcMap what projection it should use.
 - First, find the projection and datum for the map.
 - Make sure (the bottom half) is visible.
 - Zoom to the bottom and look at the coordinates.
 - These are clearly in Latitude and Longitude, so we are dealing with a Geographic Coordinate System.
 - In fact, there are actually UTM coordinates on this map too, but they are harder to interpret, so we will reference it first in lat/long and then re-project it into UTM.
 - Now we need to find the Datum used by this map.
 - This is usually at the bottom of the map.
 - Here it is **North American Datum 1927**.
 - Access the **Data Frame Properties** by either double clicking **Layers** in the Table of Contents or right clicking and choosing Properties
 - Go to the Coordinate System tab. It should initially say **No Coordinate System** under the Current Coordinate System: section
 - In the top part of the window, navigate to **Geographic Coordinate Systems** → **North America**

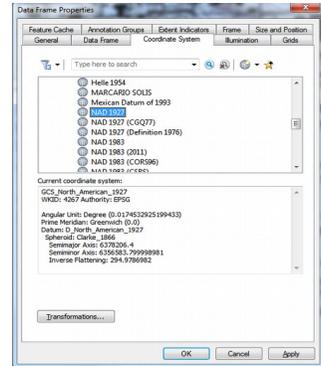


→ **NAD 1927**

iii. **Make sure to choose the one without anything after it**

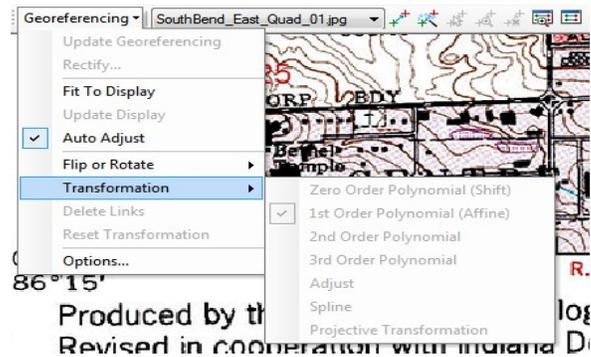
- iv. It may also be useful to choose the General Tab and change the display units to Degrees, Minutes, Seconds
- v. Select OK to exit the window.

3. You should note that now, when you run your mouse over the image the bottom right corner shows decimal degrees as the unit.
 - a. Please note that these coordinates are meaningless. The image is not georeferenced yet. These are the pixel numbers for the image if each was a decimal degree. It is only the viewer that thinks they mean something.



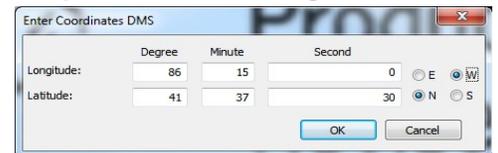
e. Now we will begin defining Ground Control Points and telling ArcMap the coordinates for them.

1. The Georeferencing toolbar has a few new buttons
 - i. First, clicking on Georeferencing gives us a new menu where we can control settings and create new, referenced, files
 - a. For now simply verify that Auto Adjust is checked and the Transformation is 1st Order



- ii. The second box is the layer that we are actively manipulating. In complex ArcMap documents it is easy to reference the wrong layer, so always be careful about which is selected.
 - a. For now, **SouthBend_East_Quad_01.jpg** should be the active layer.
- iii. The next button rotates the images independent of GCPs. If you need to do this, always do it first.
- iv. The second real button (two crosses) sets a GCP and its corresponding tie point. This is the most important one
- v. The final button pops up a table of all of the current GCPs in the image.

2. To get started, you should now zoom in on the bottom left corner of the map such that the coordinates are visible and fill most of the viewer.
3. Activate the Add Control Points tool (📍) and click once on the bottom left corner of the map
4. If you move the mouse it should now show you the line connected to that point.
5. To set the coordinate, right click on the corner of the map and choose **Input DMS of Lat/Long**
 - i. If you have a map in decimal degrees or UTM you would choose the other option



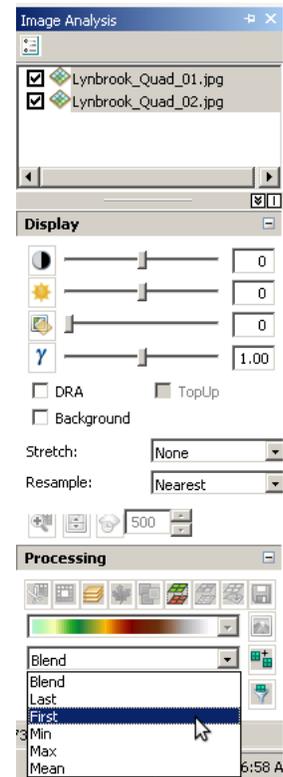
6. Enter the coordinates as shown on the map and choose OK.
 - i. Longitude is 86° 15' 0" West
 - a. The minutes (") are not listed, so we know it is blank
 - ii. Latitude is 41° 37' 30" North
7. The map should now disappear, it has moved to its accurate location.
8. To find it again right click on the layer in the Table of Contents and choose **Zoom to Layer Extent**
9. Now zoom in on the bottom right corner and enter that coordinate.
 - i. This second coordinate changes the size of the map more than its location.
 - ii. Longitude is 86° 07' 30" West
 - a. This has decreased. We are moving to the East along the bottom of the map
 - iii. Latitude is 41° 37' 30" North
 - a. This does not change. We are going along the bottom of the map which has the same Latitude
10. Finding the next coordinate is a bit more difficult. You have to locate another place with Lat/Long represented.

- i. The easiest way is to zoom in on the top left corner and scroll down until you find something that looks like DMS.
 - a. Here, you should ignore anything like "4498" because these are UTM or State Plane
 - b. The only one I see is 40'.
 - 1. Because it is along the same axis as the bottom left corner, the Longitude (x coord) should be the same as the first point: 86° 07' 30" West
 - 2. Maps usually do not repeat the degrees along the margins, so this 40' (actually 40' 0") is the only part that has changed in the Latitude, making the coordinate 41° 40' 0"
- ii. Add a control point here and enter its coordinate
- 11. These three points should be enough for our 1st Order polynomial Transformation, but we are going to add a fourth to check the error.
- 12. Zoom to the top right corner and repeat the process as above. You should notice that the default values are closer to accurate each time
- 13. Now, display the GCPs by clicking the button
- 14. The far right column shows the Root Mean Squares error value for these points.
 - i. This is basically the difference (in map units) between the expected and real coordinates.
 - ii. If any of these values is larger than 0.005 for degrees or 5 for meters you may have made a mistake.
- 15. Now, you can either save this referencing information to display the image or totally change the file.
 - i. To update the the referencing information of the file choose **Georeferencing → Update Georeferencing**
 - ii. To save everything in a new file choose **Georeferencing → Rectify**
 - iii. It is very important to do one of these before starting on the second half.
- f. **Repeat the whole process for SouthBend_East_Quad_02.jpg**
 - 1. This time you will want to start from the top of the map
 - i. Be careful, because the top coordinates are not at the exact corners of the map
 - 2. Once it is done, they should fit together. If anything looks skewed or does not match, you have made a mistake. If it during a lab session, see me before you start completely over, as sometimes you can recover from a badly placed GCP

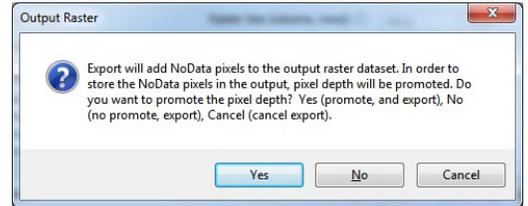
| Link | X Source | Y Source | X Map | Y Map | Residual_x | Residual_y | Residual |
|------|-------------|--------------|------------|-----------|---------------|---------------|--------------|
| 1 | 221.875835 | -2116.462943 | -86.250000 | 41.625000 | 2.88271e-005 | 4.00324e-006 | 2.91028e-005 |
| 2 | 2807.596492 | -2092.594384 | -86.125000 | 41.625000 | -2.88382e-005 | -4.00478e-006 | 2.91158e-005 |
| 3 | 212.570466 | -968.377943 | -86.250000 | 41.666667 | -2.88538e-005 | -4.00693e-006 | 2.91207e-005 |
| 4 | 2796.309082 | -944.972623 | -86.125000 | 41.666667 | 2.88498e-005 | 4.00847e-006 | 2.91418e-005 |

III. Mosaicking the map

- a. In this case, mosaicking refers to merging two contiguous images that are in the same coordinate system.
- b. Mosaicking used to be a huge pain in ArcGIS, but the new Image Analysis window makes it relatively easy now.
- c. After you open Image Analysis, select both of the of the layers with shift or ctrl-click.
- d. The mosaic tools are at the bottom of the Image Analyses window window
- e. The drop-down menu lets you choose the method of dealing with **overlap**.
 - 1. **Blend** is the default. It uses a strange algorithm to to create a new value
 - 2. **Last** simply uses the value from the lowest image in the Table of Contents
 - 3. **First** uses the top.
 - 4. **Min**, **Max**, and **Mean** all evaluate it on a pixel by pixel basis.
- f. Make sure that **SouthBend_East_Quad_01.jpg** is on top of **SouthBend_East_Quad_02.jpg**
 - 1. This should make it so you cannot see the black section
- g. Click on to run the mosaic
- h. This will create a new temporary layer with the mosaic in the Table of Contents.
 - 1. **Mosaic_SouthBend_East_Quad_01.jpg**

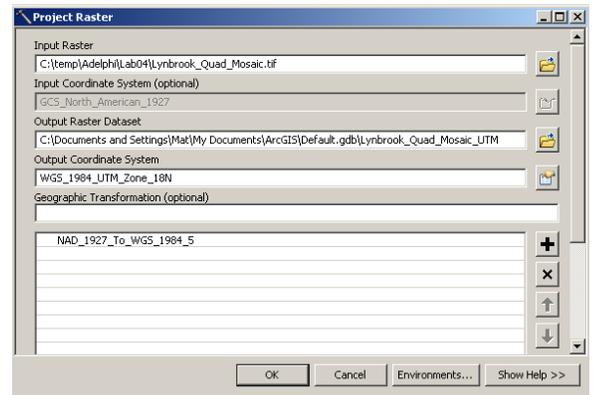


2. Despite the name, this is both of the two
- i. You should make this permanent by selecting the later in the Image Analysis window and clicking on the disc icon (📀) in the Processing section.
 1. Keep the defaults and select a folder and file name.
 2. Call the file **SouthBend_East_Quad_MosaicLatLong** and choose TIFF for output
 - i. If it asks you about NoData pixels, **Choose No**
 3. Just a note, this image is part of the assignment, so make sure you save it someplace permanent.
- j. As an additional aside, there is a mosaic tool that gives you a lot more options hidden in the ArcToolbox. You can get to it by **Geoprocessing** → **ArcToolbox** → **Data Management** → **Raster** → **Raster Dataset** → **Mosaic to a New Dataset**



IV. Re-projecting maps

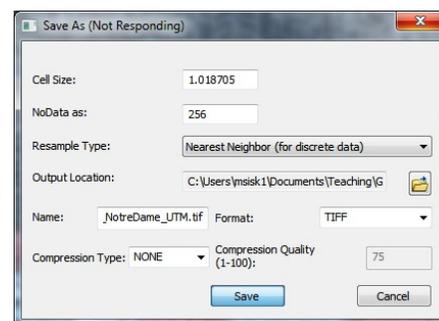
- a. So we now have a map projected in Latitude and Longitude using the NAD 1927 Datum,
- b. As presented in the lecture, it is best to have the maps in a UTM based Projected Coordinate System.
- c. There are multiple ways to do this, but the most accurate is by a tool in the ArcToolbox, a series of premade geoprocessing scripts.
- d. Access ArcToolbox by clicking on (🗄️) or going to **Geoprocessing** → **ArcToolbox**
- e. This will bring up a new window which you can dock where you see fit
- f. Within ArcToolbox you should select **Data Management** → **Projections and Transformations** → **Raster** → **Project Raster**
- g. This will bring up a new window with several options
 1. The **Input Raster** should be the SouthBend_Quad_Mosaic file.
 2. The **Input Coordinate Reference System** should be filled in automatically
 3. The **Output Raster Dataset** you should set. **SouthBend_East_Quad_Mosaic_UTM.tif** would be a good choice
 4. Click on the button to the right to set the **Output Coordinate System**.
 - i. This should pop up a new window. Choose **Select**.
 - ii. Then in the popup go to **Projected Coordinate System** → **UTM** → **WGS 1984** → **Northern Hemisphere** → **WGS_1984_UTM_Zone_16N**
 5. The **Geographic Transformation** should fill in automatically
 6. Click OK and the file should be created.



V. Georeferencing imagery

- a. Here we are going to use the now Georeferenced quad sheet to assign coordinates a small aerial photograph
- b. **VERY IMPORTANT**
 1. Close your current ArcMap Document!!
 - i. The document you have been working in is in Lat/Long, so any new images will be referenced to this coordinate system, by starting over with your new UTM image, you prevent a lot of errors.
- c. Open a new viewer and add the mosaicked, reprojected image: **SouthBend_East_Quad_Mosaic_UTM.tif**
- d. Verify that you are working in UTM by looking at the coordinates or in the **Data Frame Properties**
- e. Now add the **Aerial1998_NotreDame.jpg**
- f. You should not be able to see it because it has no spatial reference and ArcGIS defaults to thinking that each pixel is one map unit starting at zero.

- i. The puts it at the equator.
- g. Unfortunately, this means we will have to zoom back and forth until the image is referenced.
- h. Make sure that the Georeferencing Toolbar is visible and that the **Aerial1998** image is selected.
- i. Right-click on **Aerial1998_NotreDame.jpg** in the Table of Contents and choose **Zoom to Layer**.
 - i. Look at the coordinates, they should be much smaller than the other UTM coordinates.
- j. You will need to find four ground control points. I would look for ones that are at the four corners of the quad sheet or slight outside.
 - 1. The junctions of roads and the edges of buildings are good GCPs
 - 2. Shorelines, the edges of fields or forests are likely the change and do not make good GCPs.
 - 3. You should make use of the back and forward zoom arrows for the first few.
- k. When you find the first point use the Add Control Points tool () to tie it to the Quad sheet.
- l. Repeat as was presented in the proceeding section on Georeferencing by coordinates.
- m. Choose **Georeferencing** → **Rectify** when you finish
 - 1. In this new window:
 - i. Leave **Cell Size** as it is
 - ii. Change **NoData as:** to 0
 - iii. Leave **Resample Type** as is
 - iv. Next to **Output Location** click on the folder icon
 - a. Navigate to your folder on the N drive, but only click one to highlight it, so that the Name of the folder (Lab03) appears un the Name box. Then click **Add**.
 - b. Basically, in this menu you are defining the location of the folder separate from the name of the file
 - v. Change the Name to **Aerial1998_NotreDame_UTM.tif**
 - vi. Click **Save**
 - vii. You should now add this new file into to your Map Document
 - a. If it lines up correctly go ahead and remove **Aerial1998_NotreDame.jpg** by right clicking on it in the Table of Contents and choosing Remove



VI. Cropping Imagery

- a. In many cases imagery comes in large chunks. For a restricted area you may want a smaller section. This last section covers how to crop an image quickly based on a selected features.
- b. Instead of making a new shapefile (which we will cover in a few weeks) we will use a vector layer called **Parks_Outlines.shp** data which is included in the Demo Data
- c. Add this layer and make sure it is on top the Quad Sheet and **Aerial1998_NotreDame_UTM.tif** in the ToC
- d. Symbolize it as transparent with a colored boundary.
 - 1. Just click on the little color box in the ToC
- e. In the Image Analysis window make sure that the **Aerial1998_NotreDame_UTM.tif** layer is selected
- f. Then use the Select Features tool () to select the feature (rectangular polygon) representing the study area for Notre Dame
- g. Finally, in the Processing section of the Image Analysis window click on the Clip tool 
- h. This will create a new temporary layer that is clipped to the extent of the selected feature.
 - i. You may not be able to see it until you turn the original **Aerial1998_NotreDame_UTM.tif** layer invisible.
- i. Save the temporary layer (as above with the disc icon in the Image Analysis window)
- j. This clipped image is the one we will be using for all future labs, so make sure it is saved permanently
- k. You can repeat this process for other images.