# Georeferencing Imagery in ArcGIS 10.3.x

Georeferencing is the process of aligning imagery (maps, air photos, etc.) with spatial data such as point, lines or polygons (for example, roads and water bodies). The process of georeferencing essentially defines the location of a raster file and assigns real-world coordinates to the image so that it may be analyzed with geographic data. In a GIS environment, raster data is georeferenced using a control layer such as a highly accurate road network, but any layer that contains known coordinates can be used as a point of reference.

This document provides guidance through the basic steps involved with georeferencing an aerial photograph in the ArcGIS 10.3.1 environment.

Step 1 Set up your work environment

Note: The following instructions assume that the raster images to be georeferenced have been scanned and loaded to your working directory.

1. Open ArcMap and create a new, blank map document.

2. Browse to *Geoprocessing > Environments*. Under *Workspace*, set the variables for *Current Workspace* and *Scratch Workspace* to the directory where you wish to save your results. It is a good idea to create an empty file geodatabase for this purpose. Further information about the file geodatabase format can be found **here**.
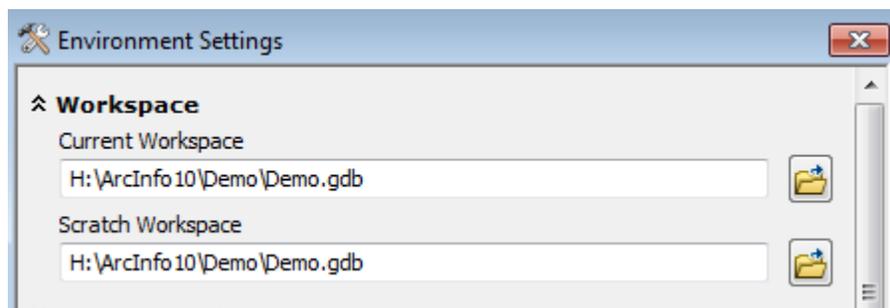

3. Open the data frame properties dialog (right-click on **Layers** in the table of contents and select *Properties*) and access the *Coordinate System* tab. Set the coordinate system for the map document by selecting an option from the *Select a coordinate system* section of the dialog.

   Note: It is very important that the map's coordinate system is set prior to adding imagery to the map; if the coordinate system is not set, then the software will not apply coordinate system information to the georeferenced image.
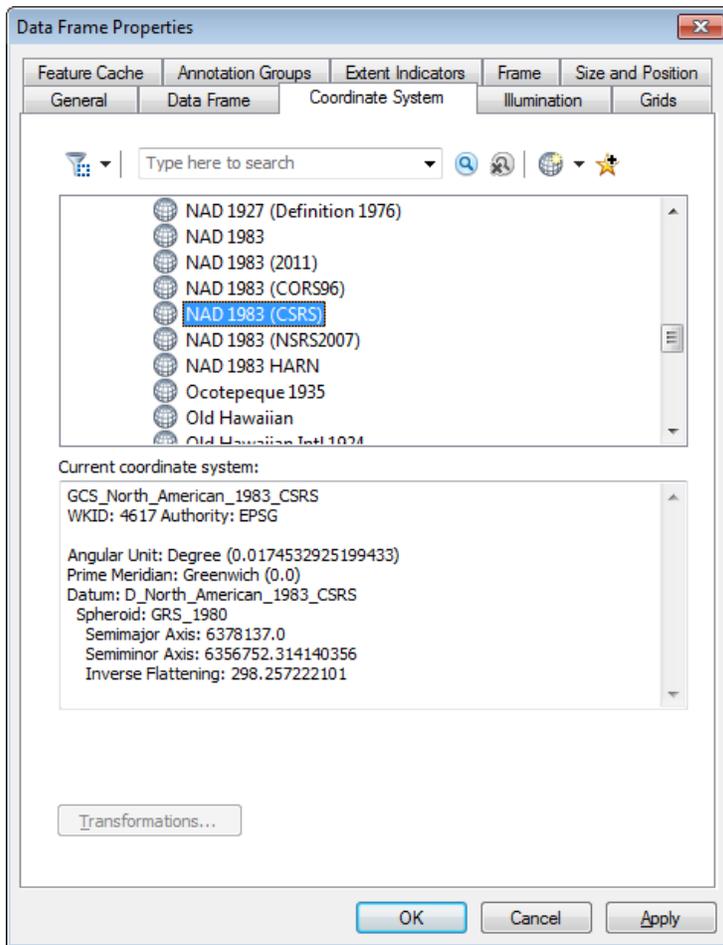
4. Add the raster image/s and reference data to the map document using the *Add Data* button. If you are asked to build pyramids, select *Yes* – pyramids are built once and stored for faster display of raster images. You may also receive a warning indicating that the image/s lack spatial reference information – this is fine, as we will be applying the spatial reference using the steps below.
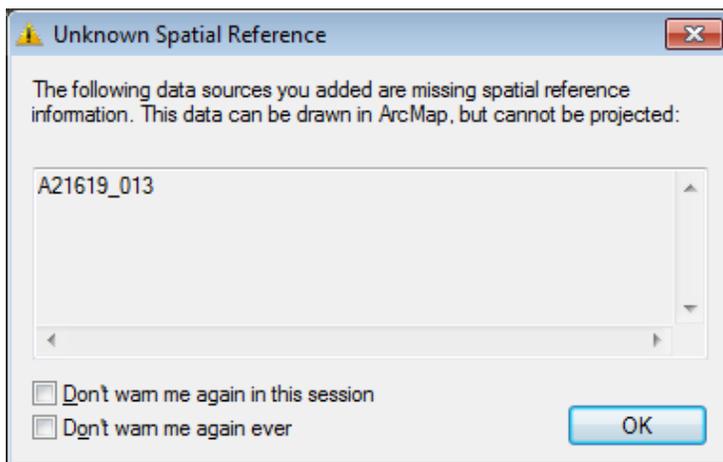
5. If necessary, open the *Georeferencing* toolbar (*Customize > Toolbars > Georeferencing*) and dock it on the ArcMap interface. The target layer will default to the first raster in the table of contents. If you wish to change this then use the drop down arrow to re-set the target layer.



6. Save the map document (*File > Save*).

Step 2   Position the image

It is important to note that you should have information related to the relative location of the image you are georeferencing prior to beginning the process. This information can be in the form of visual aids (such as a paper index), an intersection, or actual coordinate values.

1. Zoom in to the approximate area where the image should be located. This can be done manually using the *Zoom* tools in ArcMap or an attribute query.

   If you have coordinate values for the image then you can use the *Go To XY* tool to position the map on your area of interest.

   In this example, we know that the image exists near the intersection of Hamilton Road and Veteran's Memorial Parkway. A simple attribute query selects these two streets, and we have zoomed in to the area on the map document.
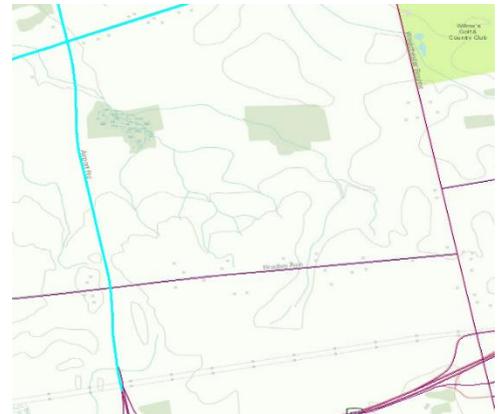
2. Click the *Georeferencing* drop down arrow and select *Fit to Display*. The image will be transposed over top of the reference layer within the display extent of your screen.
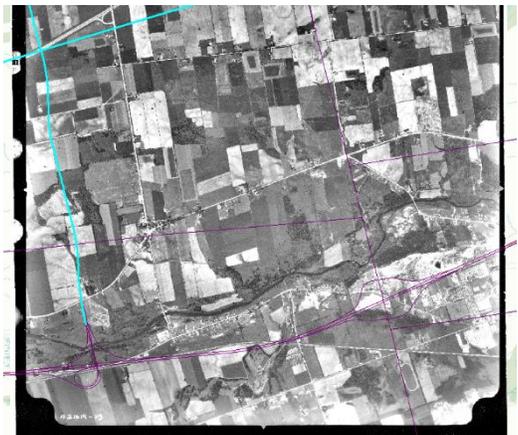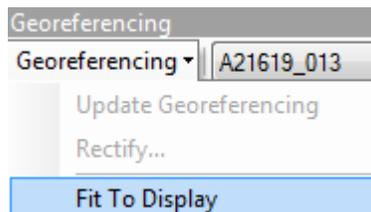
3. There are a number of tools available via the *Georeferencing* toolbar that allow you to rotate, shift, and scale the image to line up with the reference data.

 Rotate   Shift   Scale
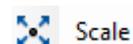
These tools should be used to manipulate the positioning of the image until it is basically in line with the reference data. Keep in mind that you may have to rotate the image entirely if it is upside down or sideways on the screen. Don't worry if the image does not line up perfectly with the reference data; as long as you are able to visually identify common features between the image and the reference data, then you will be able to continue with the process.

*Note: The **Image Analysis** window (Windows > Image Analysis) allows you to manipulate image properties to facilitate the georeferencing process. For example, under Display you will see options to reset the contrast, brightness, transparency, and gamma. The transparency option is especially useful, as you can view overlap and match points between images without having to turn the layers on and off. Another useful tool is the Background option, which temporarily eliminates the image's black frame.*

Step 3   Add Control Points

After transposing and positioning the image in its general location, it is time to begin selecting and adding control points. Control points should be selected to coincide with distinct features that are easily identifiable in both the image and the corresponding reference layer; for example, clear intersections or the corners of buildings, fences, or fields often provide good choices for control points.

*Notes: 1. The **Magnifier** window (Windows > Magnifier) offers the opportunity to view the image through a window that operates like a magnifying glass. As you pass the window over the image, you will see a magnified view of the location based on the scale set in the window. This is useful because it allows you to visually zoom in and view areas of the image without having to change the scale of your display. 2. The Snapping tool will help in placing control points on the reference layer but can be irritating when adding control points to the image. The Snapping Toolbar can be accessed through Customize menu (Customize > Toolbars > Snapping). Snapping can be disabled or enabled at any time by clicking the* Use Snapping *option in the Snapping drop down.*

1. Select the *Add Control Points* tool from the *Georeferencing* toolbar. Note that there are two options for this step; control point placement using visual identification, and/or control point placement with known coordinates. Instructions for both are provided below.

   a. Visual Placement

   Zoom in, or use the Magnifier locate the first control point you have selected. Carefully place your control point on the image, and then place a corresponding point at the same location on the reference layer. It is essential that you always place the point on the image first. A cross mark will appear to indicate the location of the control point.

   b. Known Coordinates

   In the event that you have known coordinates for the image, zoom to the point and select the *Add Control Points* tool. Click once on the control point location on the image, move your cursor very slightly, then right-click to view the hidden menu and select *Input X, Y*. A small dialog will open and prompt you to enter the coordinates corresponding to your chosen location. *X* denotes longitude, and *Y* denotes latitude. Click *OK*. A cross mark will appear to indicate the location of the control point.
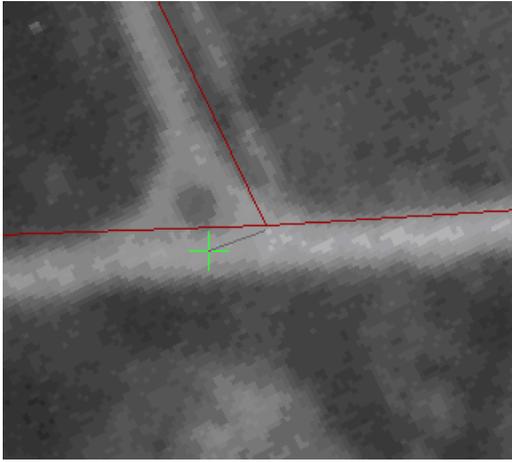
Repeat the process of adding control points until you have placed a minimum of 5-6 points. A general rule to follow is to try to locate a control point near the centre and four corners of the image, as points that are clustered together may cause distortion and warping. If the *Auto Adjust* option is enabled (*Georeferencing > Auto Adjust*), then the image will automatically adjust each time you add a new control point. The image shown below has been automatically adjusted following the addition of four control points.


Step 4   Examine RMS Error

Root Mean Square (RMS) error measures the accuracy of control points, and can be used to find and delete inaccurate entries. It is the measure of fit between the true and transformed locations of the control points. RMS error values will appear in the *Links* table after at least four control points have been placed.

1. View the RMS error values by opening the *Link Table* ▦ from the *Georeferencing* toolbar. For each set of control points, an entry is created in the *Link* table that records the original coordinates, the control point coordinates, and the residual error.

Entries can be modified or deleted by highlighting an individual point in the list and either manually changing the coordinates, or clicking the delete icon.
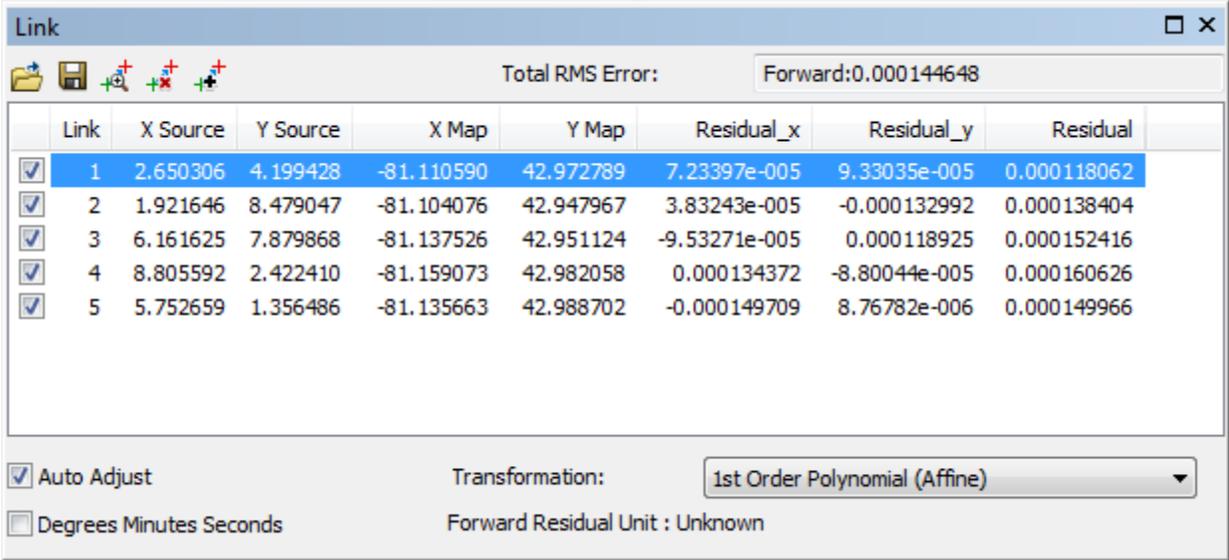
Link	X Source	Y Source	X Map	Y Map	Residual_x	Residual_y	Residual
1	2.650306	4.199428	-81.110590	42.972789	7.23397e-005	9.33035e-005	0.000118062
2	1.921646	8.479047	-81.104076	42.947967	3.83243e-005	-0.000132992	0.000138404
3	6.161625	7.879868	-81.137526	42.951124	-9.53271e-005	0.000118925	0.000152416
4	8.805592	2.422410	-81.159073	42.982058	0.000134372	-8.80044e-005	0.000160626
5	5.752659	1.356486	-81.135663	42.988702	-0.000149709	8.76782e-006	0.000149966

Link — Total RMS Error: Forward:0.000144648

Auto Adjust — Transformation: 1st Order Polynomial (Affine)
Degrees Minutes Seconds — Forward Residual Unit : Unknown

Depending on the number of control points you are using, you can choose to perform a 1st, 2nd, or 3rd order transformation. These transformations compare the coordinates of the source image with the control points, creating two least-square fit equations to translate the image coordinates into map coordinates. A 1st order transformation will shift the image up, down, right, or left, stretches the image larger or smaller, or rotates the entire image. A 2nd or 3rd order transformation will fit higher-order polynomial equations to the data, allowing points to be shifted in a non-uniform manner. Most of the time either a 1st or 2nd order transformation will suffice, but feel free to experiment with all three to determine which transformation fits best.

Note: There is no hard and fast rule when it comes to RMS error, as the values will depend greatly on the type of file you are georeferencing. For example, RMS error for a recent topographic map will be much lower than RMS error for a historical air photo from the 1920's. A general suggestion to follow is to ensure that your RMS error never exceeds the size of one cell in your raster image. If you are uncertain of the cell size, right-click the raster layer in the table of contents and select Properties, then view the Source tab.

Step 5   Rectify the image

When you are satisfied that you have placed enough control points and the RMS level has reached an acceptable value, it is time to save the georeferenced image. There are two options here; you can opt to simply update the georeferencing information, which saves the spatial reference information to the existing image, or you can create a new georeferenced image while keeping the original as-is.

To save the georeferencing information with the existing image, select *Georeferencing > Update Georeferencing*. To rectify the georeferenced image to a new file, select *Georeferencing > Rectify* and specify the output path, file name and format in the resulting dialog.

Note: ArcGIS 10.1 and later versions will increase the bit depth of a georeferenced file if the NoData parameter is left as the default value during rectification. This results in an 8-bit file becoming a 16-bit file, and a 16-bit file becoming a 32-bit file, etc. This is problematic, as the values associated with bit depth change drastically with

each increase. In order to avoid this, it is crucial that you delete the default value from the NoData as: box before rectifying the file (shown below).
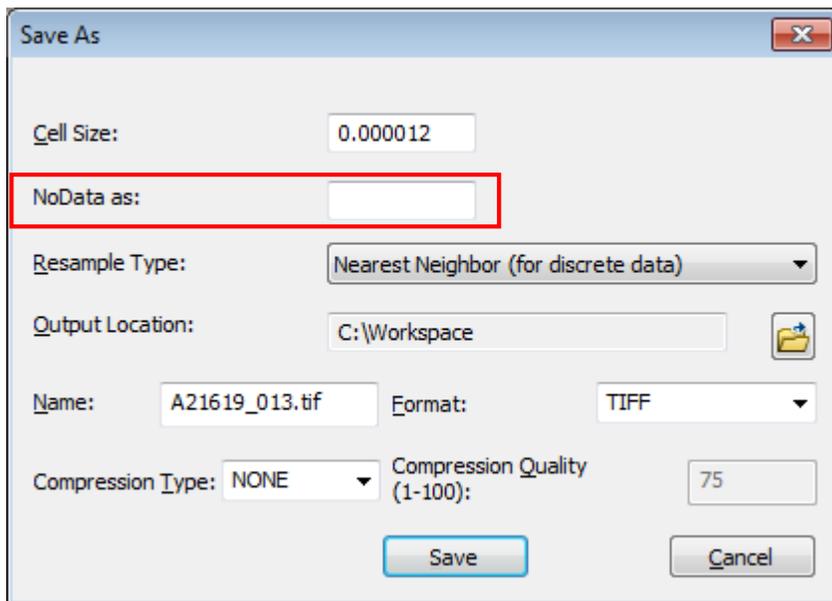
A new raster image will be saved to the directory you've specified with the associated spatial reference information. Your original image will remain intact.

For further assistance with this guide or other topics related to geospatial and/or statistical data and software, please contact us at madgichelp@trentu.ca.