GIS IN ECOLOGY:
SPATIAL REFERENCING

Department of
Biological Sciences

A
C
C
R
U

UNIVERSITY OF
ALBERTA

Contents

This is an applied course on how to use ESRI's GIS software to work with layers from different sources more effectively. It focuses on georeferencing, coordinate systems, and projections.

Excellent learning options are available through **ESRI's Online Training** courses, workshops and training seminars:
- Basics of Map Projections
- Understanding Map Projections and Coordinate Systems
- Georeferencing Rasters in ArcGIS
www.biology.ualberta.ca/facilities/gis/index.php?Page=484#virtualcampus

References:

ESRI. 2004. **Understanding Map Projections**. Environmental Systems Research Institute, Inc. Redlands, CA.
ESRI. 2013. **Map Projections Guide Book**. Online: http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/What_are_map_projections/003r00000001000000/

GIS IN ECOLOGY: SPATIAL REFERENCING

Introduction

In this short course you will use ArcGIS software to learn how to define coordinate systems, project and transform from one projection to another, and georeference spatial data. There is actually a lot more involved in spatial referencing than the following basic definitions and explanations provided. You are encouraged to check out the **For Further Reading** appendix to gain more theoretical knowledge.

Coordinate Systems

A **COORDINATE SYSTEM** is the specified units and origin point used to locate features on the two-dimensional map. There are two types of coordinate systems: geographic and projected. Geographic coordinate systems use latitude and longitude coordinates on a spherical model of the earth's surface. Projected coordinate systems use a mathematical conversion to transform latitude and longitude coordinates that fall on the earth's three-dimensional surface to a two-dimensional surface.

The projection (see below) is the mathematical translation of the geographic coordinate system to the projected coordinate system.
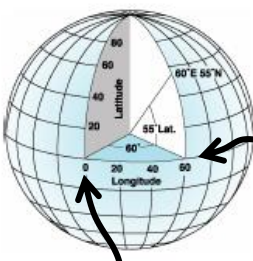
**Parallels** *(east-west lines of latitude); e.g. equator*

Meridians *(north-south lines of longitude); e.g. prime meridian*

In a **geographic** coordinate system, a three-dimensional spherical surface defines locations

on the earth along lines of *latitude* (east-west horizontal lines – a.k.a parallels) and *longitude* (north-south vertical lines – a.k.a meridians) and includes:

- an angular unit of measure; e.g. degree/minute/second, decimal degree
- a central meridian
- a datum (based on a spheroid)

A *datum* is the set of parameters and control points used to accurately define the three-dimensional shape of the earth (a.k.a. spheroid). For example, the North American Datum for 1983 (NAD83) is the datum for map projections and coordinates throughout North America.
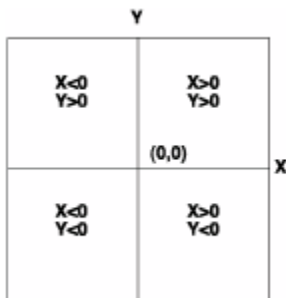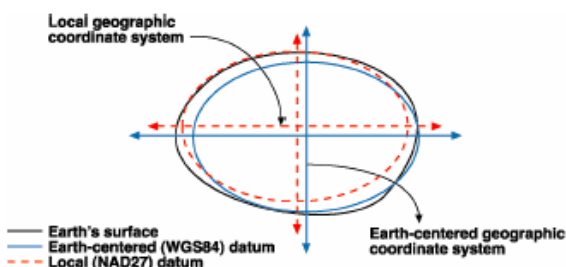

In a **projected** coordinate system, a two-dimensional flat surface defines locations based on a geographic coordinate system as x,y coordinates identified on a grid. Unlike a geographic coordinate system, a projected coordinate system has constant lengths, angles, and areas across the two dimensions. In a projected coordinate system, locations are identified as follows:

- by *x,y coordinates* on a grid on a gridded network of equally spaced horizontal and vertical lines
- with the origin at the center of the grid (x=0, y=0)
- each position has two values that reference it to that central location – one specifies its horizontal position (x-coordinate) and the other its vertical position (y-coordinate)

There are several projected coordinate systems because there are particular map projections (see below) that may be more suitable to your mapped region on the earth. Projecting your data from one coordinate system to another often involves a *geographic transformation* to move between the geographic coordinate systems that the projected coordinate systems are based on. There are several methods,

which have different levels of accuracy and ranges, for transforming between datums. For example, the NADCON or NTv2_Canada methods convert between NAD 1927 and NAD 83 in the UTM projected coordinate system – a common transformation.


Local geographic coordinate system

Earth's surface
Earth-centered (WGS84) datum
Local (NAD27) datum

Earth-centered geographic coordinate system

Map Projections

A **MAP PROJECTION** is the mathematical translation of locations from the spherical earth onto the flat surface of your map. Various methods have been devised to "flatten" 3-dimensional locations onto a 2-dimensional plane and minimize distortion in one or more (but NOT all) of the following *spatial properties*:

- **Distance** – equidistant projections have one or more lines for which the length of the line on a map is the same length (at map scale) as the same line on the globe
- **Area** – equal area projections preserve the area of displayed features, usually at the expense of the other spatial properties
- **Shape** – conformal projections preserve local shape (but not larger regions)
- **Direction** – true-direction or azimuthal projections maintain some of the great circle arcs (spherical equivalent of a straight line on a flat surface)

Because maps are flat, some of the simplest projections are made onto geometric shapes that can be flattened without stretching their surfaces. These are called *developable surfaces*, and may touch the globe at one location (tangent) or two locations (secant). Common examples are cones, cylinders, and planes. Each map projection is distinguished by its suitability for representing a particular portion and amount of the earth's surface and by its ability to preserve distance, area, shape, or direction. Some minimize distortion in one property at the expense of another, while others attempt to balance overall distortion.
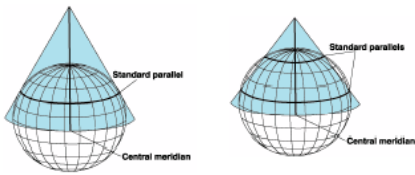
| **Conic Projections** |
|---|
| |
| • meridians are projected onto a conical surface meeting at the apex, and parallel lines of latitude are projected onto the cone as rings; e.g. Albers Equal Area Conic
• tangent along a line of latitude. (a.k.a one standard parallel)
• secant at two locations (a.k.a two standard parallels) |
| **Cylindrical Projections** |
| |
| • meridians are geometrically projected onto the cylindrical surface, and parallels are mathematically projected; e.g. Transverse Mercator
• tangent or secant may be normal (touching the equator), transverse, or oblique |
| **Planar Projections** |
| |
| • (a.k.a azimuthal or a zenithal projection) meridians and parallels are projected onto planar surface; e.g. Gnomonic, Orthographic, Stereographic
• possible perspectives are polar, equatorial, and oblique |
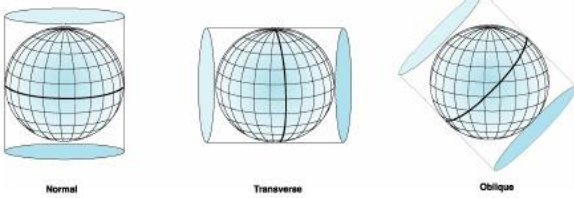
You should decide which properties are most important and choose a projection that suits your needs.

See "**Understanding Map Projections**" or the Further Reading section below to determine which projected coordinate system will give you the most minimal distortion.

Georeferencing

GEOREFERENCING is the process of defining how raster data is situated in map coordinates.

Target Layer   *Raster*

Links

Rectified Image
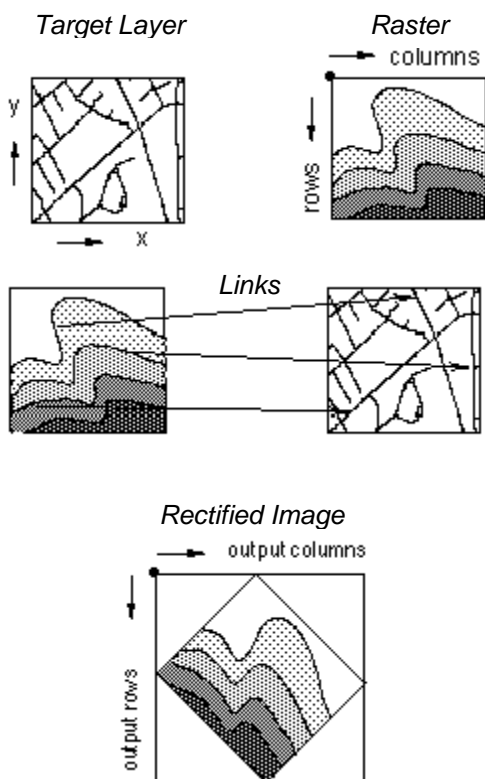
Scanning maps or collecting aerial photographs and satellite images is a common method of obtaining raster data. However once scanned, they don't usually contain information indicating the specific location where they fit on the earth's surface. Georeferencing – or aligning to a map coordinate system – of the raster data allows for viewing, querying, and analysis with other geographic data layers.

Generally, you align the raster to an existing *target layer* in a desired coordinate system that contains features easily recognizable in the raster (e.g. road intersections, building footprints, distinctive landmarks that don't change with time). You may also read the coordinates of these features from a paper map for input into the georeferencing transformation.

To align the raster layer with the target layer, you must identify several pairs of *ground control points* from the identifiable features in the raster and the corresponding known x,y coordinates of the target layer to link the two layers. These *links* should be spread evenly throughout, so that the alignment results are not concentrated in one area. The best method is to have at least one link in each corner and a few throughout the interior.

When you've created enough links, you may transform the raster by applying a mathematical transformation that warps it to the target coordinate system. The number of links that you need depends on the *transformation order* you want to use. Note: More is not necessarily better; you can often get good results with the first order transformation using three or more links. A higher transformation order can rectify more complex distortions of the scanned raster.

Refer to the **ArcGIS Desktop Help** for details on *georeferencing*, *transformation*, *root mean square error*, and *rectifying*.

The general steps of georeferencing include:
- Add the raster image (and any target layers you want to align it to)
- Add control points that link known raster positions to known target data positions in map coordinates
- Save the georeferencing information or permanently *rectify* the raster

Acquiring the raster data and required info for efficient georeferencing:

Scanning tips and tricks:

- Each project will differ in the amount of spatial detail required. Generally…

    the more detail required >>>

        the higher the resolution required (e.g. 1200 dpi) >>>

            resulting in larger file sizes and slower processing time in the GIS.

- You may need to compromise between detail and computer processing abilities, especially if the image you scan is also large in extent. Although 1200 dpi would be optimal, 300 dpi may be sufficient in most cases.

- If scanning multiple airphotos, it is a good idea to make sure they were all acquired on the same date and same time to avoid seasonal and shadowing differences.

- Note: Bio-DiTRL has a larger flatbed scanner than the GIS Research Lab and will accommodate regular-sized airphotos.

File format conversion (.tif, .bmp, .jpg):

- File format affects the size of the scanned image that the computer must deal with.

- From larger to smaller file size, TIFFs, Window's bitmaps, and JPEGs are the generic image types that ArcMap can readily work with. If your nicely scanned TIFF turns out to be too large to work with, or your raster image is a .gif that you downloaded from the internet, then you will need to convert it. Use a graphical software package such as IrfanView (free!) or Adobe Photoshop to make the conversion.

Co-locating ground control points (links) on the target map and image:

- Simultaneously examine the scanned image on-screen and the target map

- Record a list of links (ground control points) that

Link	X Source	Y Source	X Map	Y Map
1	0.000000	0.000000	-113.500000	54.500000
2	0.000000	1600.000000	-113.500000	54.750000
3	3200.000000	1600.000000	-113.000000	54.750000
4	3200.000000	0.000000	-113.000000	54.500000

    you can accurately identify in both maps; e.g. (*Source* refers to the raster, *Map* refers to the known target locations)

- Be as methodical and as accurate as possible, especially if using paper maps that you must measure coordinates from. Use a ruler or coordinate measuring tool to help you.

- When selecting links make sure they are scattered throughout the image; when they are clustered then only the area surrounding the links will be georeferenced properly.

- Choose many more links than you think you'll need, because you can delete erroneous ones to increase accuracy.

- Road intersections and human features that don't change over time are the best ground control points to identify as your links. Bends in rivers and mountain peaks are subject to natural dynamic processes and are often difficult to co-locate accurately enough to be useful.

Data Sources

The following summarizes the metadata for each geographic layer in the course dataset that has been made available to you on the local server \COURSES\GIS-100\5_GCP:

Name	Description	Area	Scale	Spatial Reference
Airphoto 300.jpg	Aerial photograph scanned at 300 dpi	Clifford E. Lee Nature Sanctuary, south west of Edmonton	1:15,000	Unknown
083h05 .gdb	Various NTDB layers for NTS map sheet 083h05	Southwest Edmonton	1:50,000	GCS NAD 1983
World .gdb	ESRI data of various World features	World	Global	WGS 1984
Alberta .gdb	GeoGratis data of provincial boundaries, lakes, and rivers	Alberta and Canada	1:1 million	Various

Tasks

Defining and reprojecting coordinate systems: working with map projections and coordinate systems in ArcGIS, and how to georeference an image.

Undefined versus Unprojected Data

Copying the course dataset:

1. Double click on the COURSES shared directory icon on the Desktop
2. Open the "**GIS-100**" folder by double clicking on it
3. Click on the FOLDERS icon along the top menu bar
4. On the left side of the exploring window, click and drag the scroll bar until you can see "My Computer"
5. Expand "**My Computer**" by clicking the "**+**"
6. Expand "**Local Disk (C:)**" by clicking the "**+**"
7. Click and drag the "**5_GCP**" folder to the **C:\WorkSpace** directory
8. Once all the files have copied over, close the exploring window

Opening an existing map document:

9. View Windows Exploring (TIP: Right-click the START menu and choose the program)
10. Navigate to your working directory and double click to open:
    C:\WorkSpace\5_GCP\ **Projections.mxd**

Exploring various map projections:

The world data displayed in the five data frames of the **Projections.mxd** *map document are defined using a geographic coordinate system based on the WGS84 spheroid. They are presently **unprojected**. Having your GIS data in a geographic coordinate system allows for more flexibility in setting the data frame properties' coordinate system to match projected coordinate systems of other data. Take a look at a few different systems at the global scale.*

11. Right click on **Data Frame 1** and select ACTIVATE
12. Double click on **Data Frame 1** to view the PROPERTIES
13. Select the COORDINATE SYSTEM tab
14. In the "Select a coordinate system:" box, click PREDEFINED >>> PROJECTED COORDINATE SYSTEMS >>> CONTINENTAL >>> NORTH AMERICA >>> **Canada Lambert Conformal Conic**
15. Click OK
16. Click on the ZOOM TO FULL EXTENT button

What kind of developable surface was used for this projection?

17. Hold the ALT key and click on **Data Frame 2** to activate it
18. Double click on **Data Frame 2**
19. Select PREDEFINED >>> PROJECTED COORDINATE SYSTEMS >>> WORLD >>> **Mercator**
20. Click OK
21. Click on the ZOOM TO FULL EXTENT button

What kind of developable surface was used for this projection?

22. ACTIVATE **Data Frame 3** and open its data frame PROPERTIES
23. Click PREDEFINED >>> PROJECTED COORDINATE SYSTEMS >>> POLAR >>> **North Pole Gnomonic**
24. Click OK
25. Click on the ZOOM TO FULL EXTENT button

What kind of developable surface was used for this projection?

26. ACTIVATE **Data Frame 4** and open its data frame PROPERTIES
27. Select PREDEFINED >>> PROJECTED COORDINATE SYSTEMS >>> POLAR >>> **North Pole Orthographic**
28. Click APPLY – temporarily move the properties window so you can see the data
29. Click on the MODIFY button
30. Change the Longitude of Center = **-110**
31. Change the Latitude of Center = **50**
32. Click OK (in both windows)
33. Click on the ZOOM TO FULL EXTENT button

What was the developable surface? What is the effect of modifying the projection parameters? Zoom in on North America in each data frame and note how each appears.

Exploring various spatial references:

34. Choose FILE >>> NEW
35. Select a new **Blank Map**
36. Click YES to save **Projections.mxd** – *you may want to go back to this map document and experiment with other projections and parameters later*
37. In the new blank map document, switch to DATA VIEW
38. Click the ADD DATA button
39. CONNECT TO FOLDER and navigate to **C:\WorkSpace\5**_GCP

40. In **Alberta.gdb** select **Alberta_utm_nad27**
    and click ADD
41. Double click on the layer name to view the
    SOURCE tab in its layer properties
42. Next ADD DATA and select **PROVINCES**
43. Modify the drawing order so that
    PROVINCES is on the bottom
44. Double click each layer to view the
    SOURCE tab in its layer properties
45. Examine the *data frame* properties
46. Click on the TRANSFORMATION button
    and set the appropriate method

*Notice the Coordinate Systems for the data
frame and each of the layers. Because the
projected data, **Alberta_utm_nad27** was
added first, the data frame assumed that
coordinate system. Then when the unprojected
data, **provinces**, was added, ArcMap
reprojected it to match the data frame. This **on-
the-fly reprojecting** is very handy for viewing
defined data from different sources.*

47. ADD **all other layers** from the \Alberta.gdb
48. Click ZOOM TO FULL EXTENT
49. Examine the layers in the data view and
    peruse their layer properties (SOURCE tab)

*TIP: Access the Data Frame PROPERTIES and
in the Coordinate System tab, expand each of
the Layers to quickly access each coordinate
system (just be sure to click CANCEL so you
don't accidentally apply their spatial reference
to the entire data frame).*

*Which data are undefined? What is the effect of
displaying the various undefined layers with
projected and unprojected data? Often spatial
data may come to you projected, but
undefined. Make sure you have access to the
metadata for your data layers if they are
undefined (typically, more of an occurrence with
shapefiles when the **.prj** file is not included with
the required files).*

50. ZOOM in to examine the edges of the
    Alberta_utm_nad27 (defined) and
    Alberta_utm_nad83 (undefined) layers
51. Use the MEASURE tool to quantify the
    difference

*The table below provides the coordinate system
metadata for the Alberta layers – needed
information for the exercises below.*

Layer Name	Defined ?	Coordinate System	Units	Parameters

Alberta_10tm	No	Alberta 10TM (modified UTM)	Meters	Central Meridian = -115 Scale Factor = 0.9992
ABrivers	No	Canada Albers Equal Area Conic	Meters	Default
ABlakes	No	GCS North America NAD83	Decimal degrees	Default
Alberta_utm_nad27	Yes	NAD27 UTM Zone 11	Meters	Default
Alberta_utm_nad83	No	NAD83 UTM Zone 11	Meters	Default
Provinces	Yes	GCS North America NAD83	Decimal degrees	Default

Setting the Coordinate System in the Data Frame

If your data is in decimal degrees and you don't require a high level of locational accuracy – i.e. you won't be performing queries based on location and distance, or you just want to make a quick map – you may decide to not transform your data to a projected coordinate system. If, however, you need to make precise *measurements* on your map, you should choose a projected coordinate system. Often, parameters are modified to provide a better fit or view of a geographic region, such as in Alberta, which spans two UTM zones.
*This example shows you how to **set the data frame coordinate system to the Alberta Government's 10TM system***:
1. Choose VIEW >>> DATA FRAME PROPERTIES
2. Click on the COORDINATE SYSTEM tab
3. Choose PREDEFINED >>> PROJECTED COORDINATE SYSTEMS >>> NATIONAL GRIDS >>> CANADA >>> **NAD 1983 10TM AEP Forest.prj**
4. Click OK twice
5. Turn ON/OF layers and adjust drawing order to help you see better
*Notice that the undefined **Alberta_10tm.shp** layer now aligns properly with the projected-on-the-fly, but defined provinces layer. The advantage of this system is to orient Alberta vertically at its center, rather than viewing it slightly tilted to the west (Zone 11) or east*

(Zone 12). Obviously, these projections are not suitable for eastern Canada.

6. Set the data frame's COORDINATE SYSTEM to **Canada Lambert Conformal Conic** – *do any of the layers align? By experimenting with different coordinate systems, you may be able to troubleshoot what an undefined layer should be*

7. Set the FILE >>> MAP PROPERTIES and SAVE; e.g. **AlbertaProjections.mxd**

Defining the Coordinate System for an Undefined Layer

Often, features may not have any information defining which coordinate system was used (i.e. there is NO **.prj** file with the same name as the shapefile). In this case, the Shape attribute's Spatial Reference property will be "unknown" or may be "assumed geographic". You can work with features even if their coordinate systems haven't been defined, but you may not be able to take advantage of all the available functionality (e.g. you may be *unable* to add the features to some maps or work with them using the geoprocessing tools). You define coordinate systems by:

- selecting one of the predefined coordinate systems provided with ArcGIS
- importing the coordinate system parameters used by another data source, or
- defining a new, custom coordinate system

You can define coordinate systems using ArcToolbox; however, ArcCatalog also has the capability of allowing you to set the Spatial Reference in the File Properties (see below).

1. Click on the ARCTOOLBOX WINDOW button and dock ArcToolbox to the side

*This example shows you how to **define a feature coordinate system by selecting a predefined system (the Alberta 10TM)**:*

2. Navigate to DATA MANAGEMENT TOOLS >>> PROJECTIONS AND TRANSFORMATIONS
3. In ArcToolbox, double click on the DEFINE PROJECTION tool
4. Drag **Alberta10tm** from the table of contents to the Input box

Alternatively, select the layer from the drop-down list.

5. Click on the PROPERTIES button
6. Click on the SELECT button

7. Navigate to select the PROJECTED COORDINATE SYSTEMS >>> NATIONAL GRIDS >>> CANADA >>> **NAD 1983 10TM AEP Forest.prj**
8. Click ADD
9. Click OK to apply and dismiss the Spatial Reference Properties dialog
10. Click OK to run the tool
11. Examine the Data View window to see how the various layers spatially coincide

*Repeat the same steps to define the spatial reference for the **ABRivers** and **Alberta_utm_nad83** layers:*

12. In ArcToolbox, double click to open the DEFINE PROJECTION tool
13. Set the input dataset as **ABrivers.shp**
14. Click on the PROPERTIES button
15. Work through the dialog boxes as in the above example to select **PROJECTED** >>> **CONTINENTAL**>>> **NORTH AMERICA** >>> **Canada Albers Equal Area Conic**
16. Consult the metadata (table on page 13) to define **Alberta_utm_nad83** – *pay attention to the ZONE!*

*A shortcut when defining **Ablakes** is to import the spatial reference from the PROVINCES layer since they are the same.*

17. Double click to open the DEFINE PROJECTION tool
18. Set the input dataset as **ABlakes**
19. Click on the PROPERTIES button
20. Click IMPORT to define your coordinate system based on an existing data source
21. Select **PROVINCES.shp** as the defined geographic dataset
22. Click ADD
23. Click OK twice

*The definition process works the same in both ArcCatalog and ArcMap by using similar ArcToolbox tool dialogs to prompt you for your input. Therefore, these examples can be used as a guide in defining and projecting your GIS data files. **Works for raster layers, too!***

Projecting a Layer to a Different Coordinate System

*This example shows you how to **project a shapefile** from NAD 1927 UTM Zone 11 to NAD 1983 UTM Zone 12 (a very common datum transformation for Canadian data):*

1. In ArcToolbox, navigate to DATA MANAGEMENT TOOLS >>>

PROJECTIONS AND
TRANSFORMATIONS >>> FEATURES
2. Double click on PROJECT
3. Set the input dataset; e.g.
   Alberta_utm_nad27
4. Specify a new output filename (click the
   BROWSE button to navigate to the directory
   path); e.g.
   **C:\WorkSpace\5_GCP\Alberta.gdb\albert
   a_utm_nad83z12**
5. Click on the PROPERTIES button
6. In the Spatial Reference Properties dialog
   window, click SELECT and navigate to
   select the **NAD 1983 UTM Zone 12N.prj** file
   (*pay attention to the <u>DATUM</u> and <u>ZONE</u>*)
7. Click OK
8. Select a GEOGRAPHIC
   TRANSFORMATION appropriate to your
   particular datum conversion; e.g. **NADCON**
   or **NTv2_Canada** for going between NAD27
   <<<>>> NAD83
9. Review the summary of your input and if all
   is well click OK
10. Click ZOOM TO FULL EXTENT and
    examine the various layers
11. SAVE when finished

Please consult the **metadata** associated with
your data for the *exact projection and
coordinate system parameters* of your data. If
you do not have this information, contact the
original data provider or you may be out of luck!

Georeferencing a Raster Image

In this example, you will use the
GEOREFERENCING toolbar in ArcMap to
georeference a scanned aerial photograph of
the Clifford E. Lee Sanctuary (located outside
the Edmonton city limits) by linking ground
control points on the raster image to known
locations of map reference data. A map
document has already been set up with the
target layers in place, and the data frame has
been set to use the *projected coordinate
system* **NAD 1983 UTM Zone 12**. By doing this,
the airphoto will be directly georeferenced to
the same projected coordinate system, but you
may opt to use a *geographic coordinate system
(GCS)*, by setting this in the data frame
properties.

The Georeferencing toolbar:

1. Open the *5_GCP.mxd* map document and switch to DATA VIEW
2. Add the **airphoto300.jpg** raster layer to the map document
3. Show and take a moment to look at the GEOREFERENCING toolbar

*See ARCGIS DESKTOP HELP for details on the '**Georeferencing toolbar**.'*

4. Make sure that the raster you want to georeference is the layer displayed in the Georeferencing layer list; e.g. **airphoto300.jpg**
5. In the table of contents, right click on the **airphoto300.jpg** layer name
6. Choose ZOOM TO LAYER
7. Display the SYMBOLOGY as Stretched using the Histogram Equalize type (or other type that suits your viewing preferences)

Aligning locations to a target layer:

You will use the NTDB map sheet 083H05 data layers as the target to georeference the air photo to. Concentrate on finding control points such as human features that don't change (e.g. road intersections), rather than natural features that may be dynamic over time (e.g. lake boundaries). Look throughout the target layer for identifiable shapes that you can accurately identify in the airphoto as well.

8. Choose VIEW >>> BOOKMARKS >>> CLIFFORD E LEE SANCTUARY to zoom to the sanctuary location
9. Choose GEOREFERENCING >>> FIT TO DISPLAY
10. Repeat the above two steps using the AIRPHOTO EXTENT bookmark

This will display the raster in the same area as the target layers. You can also use the Shift and Rotate tools to move the raster as needed

11. Turn off all layers *except* for **target layer** (i.e. the access features symbolized in red for better visibility over the black and white airphoto) and **airphoto300.jpg**
12. Click on the CONTROL POINTS button
13. Add a link:
    - Click the mouse pointer over a known location on the raster
    - Then click over the matching known location on the target data

You may find it useful to use a Magnification window to add your links in.

14. Continue adding enough links for the transformation order you wish to use

You need a minimum of 3 links for a first order **transformation***, 6 links for a* second order*, and 10 links for a* third order*. Refer to the Help system for info.*

15. Click the VIEW LINK TABLE button
16. Examine the residual error for each link and the RMS error
17. Add some more links and delete those with large residuals – *try to reduce the RMS to one output cell or less AND check the raster image to see if it is acceptable*
18. When satisfied, choose GEOREFERENCING >>> UPDATE GEOREFERENCING to save the transformation information with the raster

This creates a new .aux file with the same name as the raster. This file tells ArcMap how to define the coordinate system for the georeferenced raster whenever you add it to a new map document.

19. SAVE the link table and SAVE the map document

Georeferencing tips:

- Delete an unwanted link from the Link Table dialog box by highlighting it and pressing the DELETE button on the keyboard.
- Press the ESC key to remove a link while you are in the process of creating it.

Why rectify the raster?

- ArcMap doesn't require a rectified raster to display it with other referenced spatial data.
- You can permanently transform your raster after georeferencing by using the rectify command. Choose GEOREFERENCING >>> RECTIFY. Work through the dialog boxes to create a new raster dataset in GRID, TIFF, or IMAGINE format.
- You need to rectify your raster if you plan to perform analysis with it or want to use it with another software package.

Understanding RMS:

To mathematically describe the degree to which the transformation can accurately map all control points, compare the target coordinate (destination map location) to the transformed position in the raster (source location). The distance between these points is known as the residual error (**e**) and is measured for each link.

+ Destination Control Points

+ Transformed Source
   Control Points
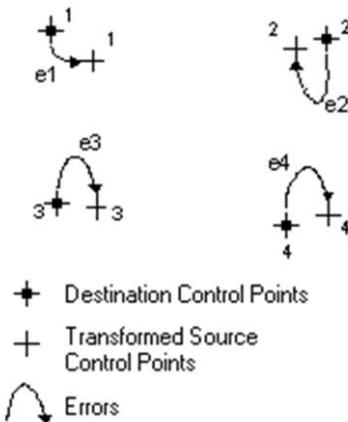
⌒ Errors

Take the root mean square (**RMS**) sum of all the residuals to compute the total RMS error; this value describes how consistent the transformation is between different control points.

$$\text{RMS error} = \sqrt{\frac{e_1^2 + e_2^2 + e_3^2 + \cdots + e_n^2}{n}}$$

*** While RMS error is a good assessment of the accuracy of the transformation, don't confuse a low RMS error with an accurate registration (you may have poorly entered control points).

For Further Reading

Note: Source of figures contained in this manual is ESRI's "Understanding Map Projections" book.

Foote, K. Department of Geography, University of Colorado. 1999. **Map Projections**. http://www.colorado.Edu/geography/gcraft/notes/mapproj/mapproj_f.html

ESRI. 2004. **Understanding Map Projections**. Environmental Systems Research Institute, Inc. Redlands, CA.

Natural Resources Canada. 2004. **The Atlas of Canada – Map Projections**. http://atlas.gc.ca/site/english/learningresources/carto_corner/map_projections.html

Natural Resources Canada. 2003. **Canadian Topographic Maps - Maps 101 - Topographic Maps, The Basics**. http://maps.nrcan.gc.ca/maps101/

Natural Resources Canada. 2003. **Geodetic Survey Division – Geodesy**. http://www.geod.nrcan.gc.ca/edu/geod/index_e.php

Robinson, A.H., Morrison, J.L., Muerhcke, P.C., Kimerling, A.J., and Guptill, S.C.1995. **Elements of Cartography**. 6th edition. John Wiley & Sons, Ltd. Toronto.

…visit the Libraries for many more references available to help you understand and work with the complex issues of georeferencing, coordinate systems, and map projections in a GIS…

Troubleshooting Coordinate System Issues

If all the data you want to display on your map is stored in the same coordinate system, you can just add it to a map document and not worry about if the layers will overlay properly because they will. But if you've collected data from different sources, you'll need to know what coordinate system each dataset uses to ensure ArcMap™ can display them together. You may need to define, project, and/or transform.

When you add data to a map document in ArcMap and…	**You will need to…**
If your data layers are in a Geographic Coordinate System (**decimal degrees**) and: • You do not like the stretched out appearance of the layers • You need to perform area and/or distance calculations • You want to display features in their true shapes, or another reason…	**Set the coordinate system** in the Data Frame Properties of ArcMap OR **Project** the layer
You get a warning that there is an 'Unknown Spatial Reference'; i.e. the data can be drawn in ArcMap, but not projected	**Define** the coordinate system using ArcToolbox or ArcCatalog
You get a warning that one or more data sources in the map differ from the data frame coordinate system; there may be alignment and accuracy problems unless you specify or modify the appropriate transformation method.	**Set the geographic transformation** method that is appropriate OR **Project** the layer to match the coordinate systems of the other layers using ArcToolbox (which will also require the proper transformation method Look up the appropriate method… C:\Program Files\ArcGIS\Desktop10.0\Documentation **geographic_transformations.pdf** and search by area of interest

When you add data to a map document in ArcMap and…	You will need to…
Layers do not spatially coincide within the data frame and you are certain that they are of the same location. For example, upon inspecting the metadata for each layer, you notice that both are in the UTM coordinate system but one layer is in NAD 83 and the other is in NAD 27.	**Project** the layers to matching coordinate systems using ArcToolbox OR **Set the geographic transformation** method that is appropriate

C:\Program Files\ArcGIS\Desktop10.0\Documentation has the following useful references:
- *geographic_coordinate_systems.pdf*
- *geographic_transformations.pdf*
- *projected_coordinate_systems.pdf*