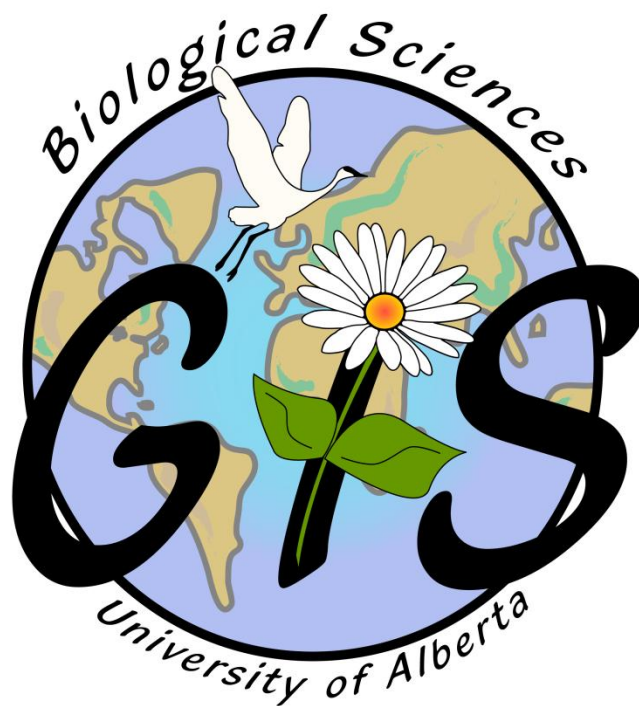


# GIS IN ECOLOGY: SPATIAL REFERENCING



## Contents

Introduction .....	2
Coordinate Systems.....	2
Map Projections .....	3
Georeferencing .....	5
Data Sources .....	7
Tasks .....	7
Undefined versus Unprojected Data.....	7
Setting the Coordinate System in the Data Frame.....	10
Defining the Coordinate System for an Undefined Layer .....	10
Projecting a Layer to a Different Coordinate System .....	12
Georeferencing a Raster Image .....	13
For Further Reading.....	15
Troubleshooting Coordinate System Issues .....	16

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** (<http://training.esri.com>) online courses, workshops and training seminars:

- Understanding Map Projections and Coordinate Systems
- Georeferencing Rasters in ArcGIS

<http://www.biology.ualberta.ca/facilities/gis/index.php?Page=484#virtualcampus>

## References:

- ESRI. 2004. **Understanding Map Projections**. Environmental Systems Research Institute, Inc. Redlands, CA.
- Harlow, Melanie, Rhonda Pfaff, Michael Minami, Alan Hatakeyama, Andy Mitchell, Bob Booth, Bruce Payne, Cory Eicher, Eleanor Blades, Ian Sims, Jonathan Bailey, Pat Brennan, Sandy Stevens, and Simon Woo. 2004. **Using ArcMap**. Environmental Systems Research Institute, Inc. Redlands, CA.
- Vienneau, Aleta, Jonathan Bailey, Melanie Harlow, John Banning, and Simon Woo. 2004. **Using ArcCatalog**. Environmental Systems Research Institute, Inc. Redlands, CA.

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

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*GIS in Ecology is sponsored by the Alberta Cooperative Conservation Research Unit*  
<http://www.biology.ualberta.ca/accru>

# 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

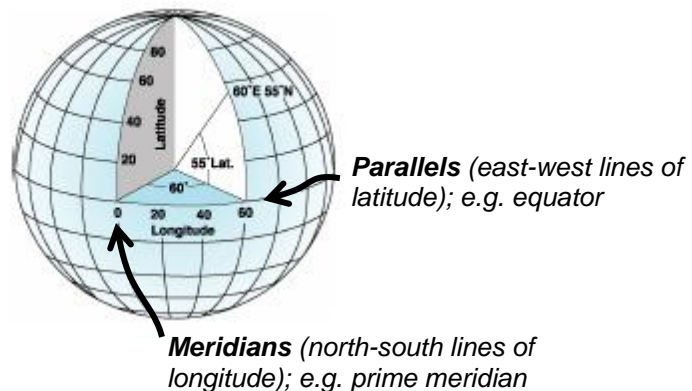
A **COORDINATE SYSTEM** is the specified units and origin point used to locate features on the two-dimensional map. There are two types of coordinate systems: geographic and projected. Geographic coordinate systems use latitude and longitude coordinates on a spherical model of the earth's surface. Projected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

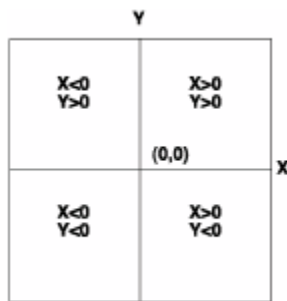
The projection (see below) is the mathematical translation of the geographic coordinate system to the projected coordinate system.

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.

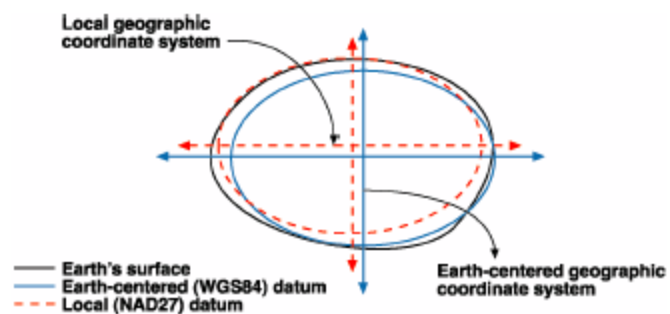




In a **projected** coordinate system, a two-dimensional flat surface defines locations based on a geographic coordinate system as  $x, y$  coordinates identified on a grid. Unlike a geographic coordinate system, a projected coordinate system has constant lengths, angles, and areas across the two dimensions.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

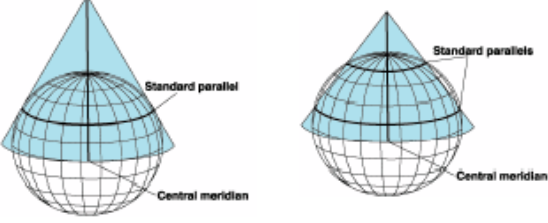
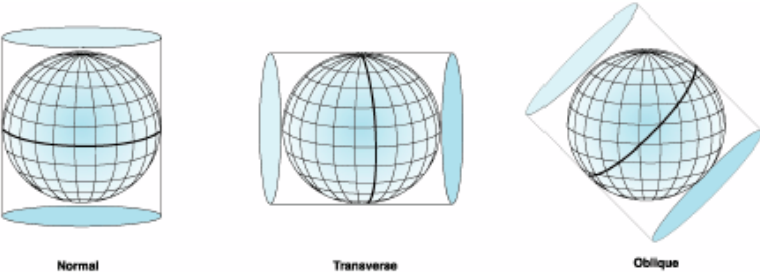



## Map Projections

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.

<p style="text-align: center;"><b>Conic Projections</b></p> 	<ul style="list-style-type: none"> <li>• 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</li> <li>• tangent along a line of latitude. (a.k.a one standard parallel)</li> <li>• secant at two locations (a.k.a two standard parallels)</li> </ul>
<p style="text-align: center;"><b>Cylindrical Projections</b></p>  <p style="text-align: center;">Normal                      Transverse                      Oblique</p>	<ul style="list-style-type: none"> <li>• meridians are geometrically projected onto the cylindrical surface, and parallels are mathematically projected; e.g. Transverse Mercator</li> <li>• tangent or secant may be normal (touching the equator), transverse, or oblique</li> </ul>
<p style="text-align: center;"><b>Planar Projections</b></p>  <p style="text-align: center;">Polar                      Equatorial                      Oblique</p>	<ul style="list-style-type: none"> <li>• (a.k.a azimuthal or a zenithal projection) meridians and parallels are projected onto planar surface; e.g. Gnomonic, Orthographic, Stereographic</li> <li>• possible perspectives are polar, equatorial, and oblique</li> </ul>

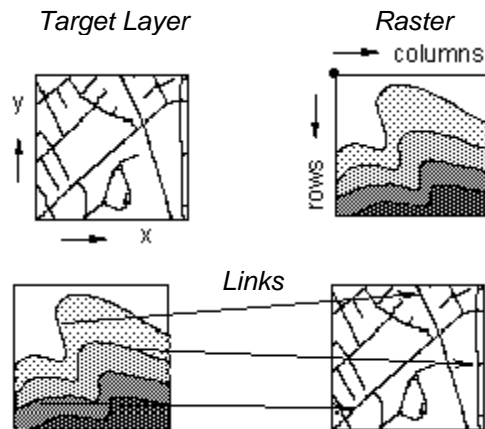
Each map projection is distinguished by its suitability for representing a particular portion and amount of the earth's surface and by its ability to preserve distance, area, shape, or direction. Some minimize distortion in one property at the expense of another, while others attempt to balance overall distortion. 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.

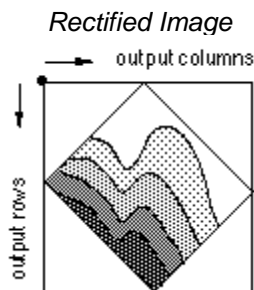
## Georeferencing

**GEOREFERENCING** is the process of defining how raster data is situated in map coordinates. 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** and **Using ArcMap** for details on *georeferencing, transformation, root mean square error, and rectifying*.

The general steps of georeferencing include:

1. Add the raster image (and any target layers you want to align it to)
2. Add control points that link known raster positions to known target data positions in map coordinates
3. 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 you can accurately identify in both maps; e.g. (*Source* refers to the raster, *Map* refers to the known target locations)

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

- 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 table provides metadata for each geographic layer in the course dataset found in the [\\bio\\_print\Courses\GIS-100\5\\_GCP](#) folder:

Name	Description	Area	Feature	Data Model	Scale	Projection / Datum	Coordinate System Units
<b>Airphoto300.jpg</b>	Aerial photograph scanned at 300 dpi	Clifford E. Lee Nature Sanctuary, south west of Edmonton	Image	Raster	1:50,000	Unknown	Unknown
<b>083h05.gdb</b>	Various NTDB layers for NTS map sheet 083h05	Southwest Edmonton	Points, Lines, Polygons	Vector	1:50,000	GCS NAD 1983	Decimal Degrees
<b>World.gdb</b>	ESRI data of various World features	World	Polygons	Vector	Global	WGS 1984	Decimal Degrees
<b>Alberta.gdb</b>	GeoGratis data of provincial boundaries, lakes, and rivers	Alberta and Canada	Polygons	Vector	1:1,000,000	Various	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 on the “+”
6. Expand “Local Disk (C:)” by clicking on 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:

1. Click the START MENU
2. Point to PROGRAMS >>> ARCGIS >>> ARCMAP
3. Start using ArcMap with an existing map and browse to C:\WorkSpace\5\_GCP
4. Select **Projections.mxd** and click OK



## 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.

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

*What kind of developable surface was used for this projection?*

7. Hold the **ALT** key and click on **Data Frame 2** to activate it
8. Double click on **Data Frame 2**
9. Select **PREDEFINED >>> PROJECTED COORDINATE SYSTEMS >>> WORLD >>> Mercator**

10. Click **OK**
11. Click on the **ZOOM TO FULL EXTENT** button

*What kind of developable surface was used for this projection?*

12. **ACTIVATE Data Frame 3** and open its data frame **PROPERTIES**
13. Click **PREDEFINED >>> PROJECTED COORDINATE SYSTEMS >>> POLAR >>> North Pole Gnomonic**

14. Click **OK**
15. Click on the **ZOOM TO FULL EXTENT** button

*What kind of developable surface was used for this projection?*

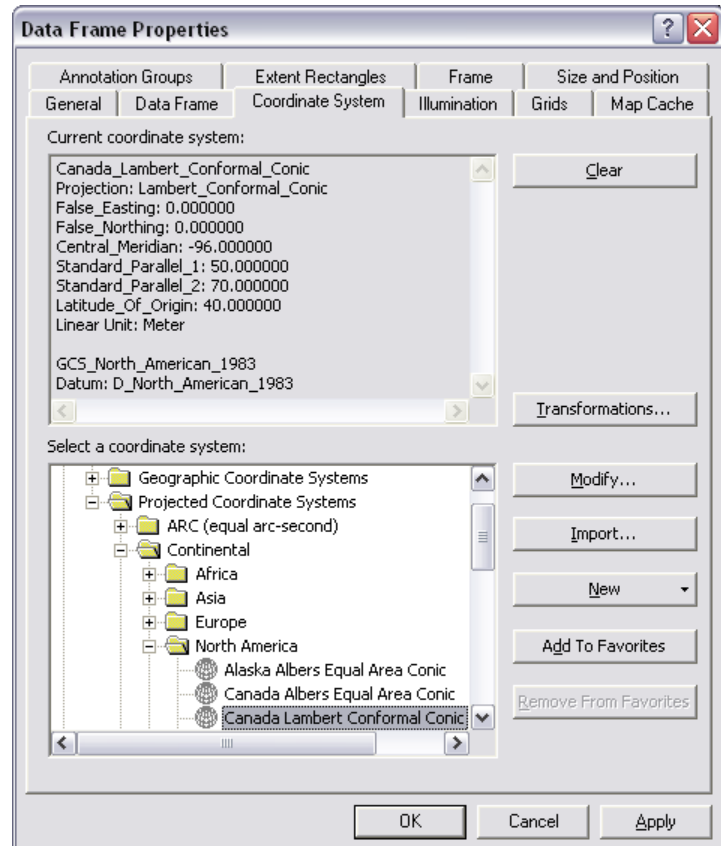
16. **ACTIVATE Data Frame 4** and open its data frame **PROPERTIES**
17. Select **PREDEFINED >>> PROJECTED COORDINATE SYSTEMS >>> POLAR >>> North Pole Orthographic**

18. Click **APPLY** – temporarily move the properties window so you can see the data
19. Click on the **MODIFY** button

20. Change the Longitude of Center = **-110**

21. Change the Latitude of Center = **50**

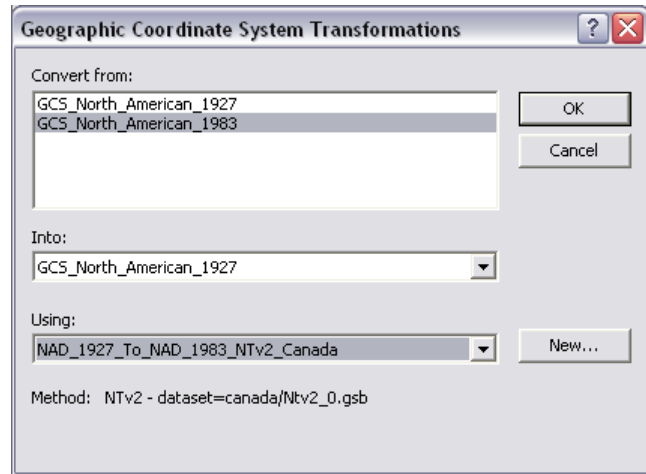
22. Click **OK** (in both windows)



- 23. 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:**

- 24. Choose FILE >>> NEW
- 25. Select a new **Blank Document**
- 26. Click YES to save **Projections.mxd** – *you may want to go back to this map document and experiment with other projections and parameters later*
- 27. In the new blank map document, switch to DATA VIEW
- 28. Click the ADD DATA button
- 29. Navigate to the **C:\WorkSpace\5\_GCP\Alberta.gdb**
- 30. Select **Alberta\_utm\_nad27** and click ADD
- 31. Double click on the layer name to view the SOURCE tab in its layer properties
- 32. Next add **PROVINCES**
- 33. Modify the drawing order so that **PROVINCES** is on the bottom
- 34. Double click each layer to view the SOURCE tab in its layer properties
- 35. Examine the *data frame* properties
- 36. 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.*

- 37. ADD **all other layers** from the \Alberta.gdb
- 38. Click ZOOM TO FULL EXTENT

39. Examine the layers in the data view and peruse their layer properties (SOURCE tab)  
*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 the **.prj** file is not included with the required files of a **shapefile**. 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

40. ZOOM in to examine the edges of the **Alberta\_utm\_nad27** (defined) and **Alberta\_utm\_nad83** (undefined) layers
41. Use the MEASURE tool to quantify the difference

**DEMO** on defining projections for shapefiles

## 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

*Notice that the undefined **Alberta\_10tm.shp** layer now aligns properly with the projected 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.*

5. 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
6. Set the FILE >>> MAP PROPERTIES and SAVE; e.g. **AlbertaProjections.mxd**

## Defining the Coordinate System for an Undefined Layer

Often, shapefiles 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 shapefiles 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 shapefiles to some maps or work with them using the geoprocessing tools). You can create **.prj** files that parameterize the shapefile's coordinate systems by:

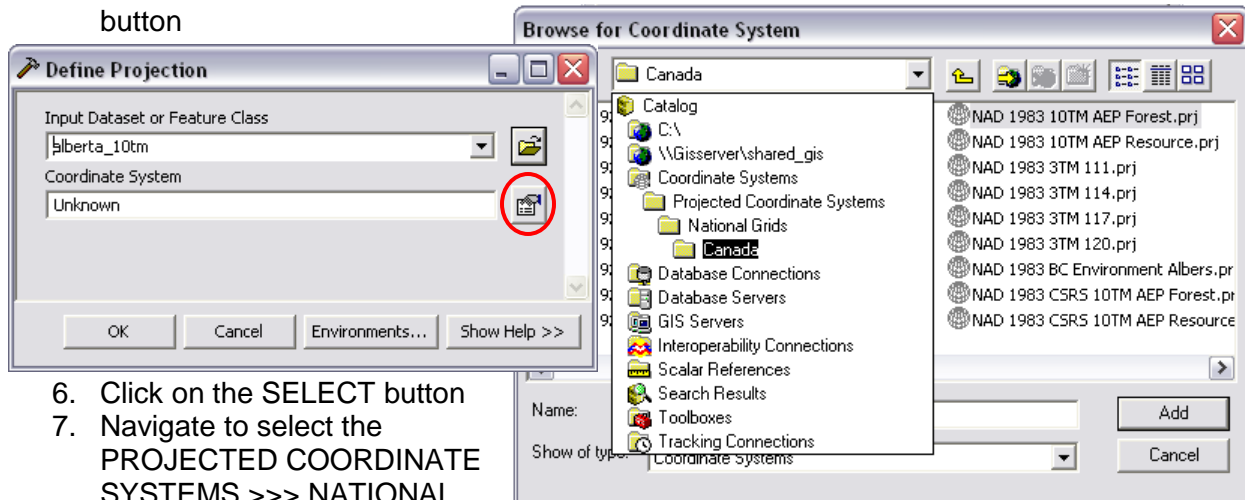
- selecting one of the predefined coordinate systems provided with ArcGIS
- importing the coordinate system parameters used by another data source, or
- defining a new, custom coordinate system

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 SHOW ARCTOOLBOX WINDOW button

*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



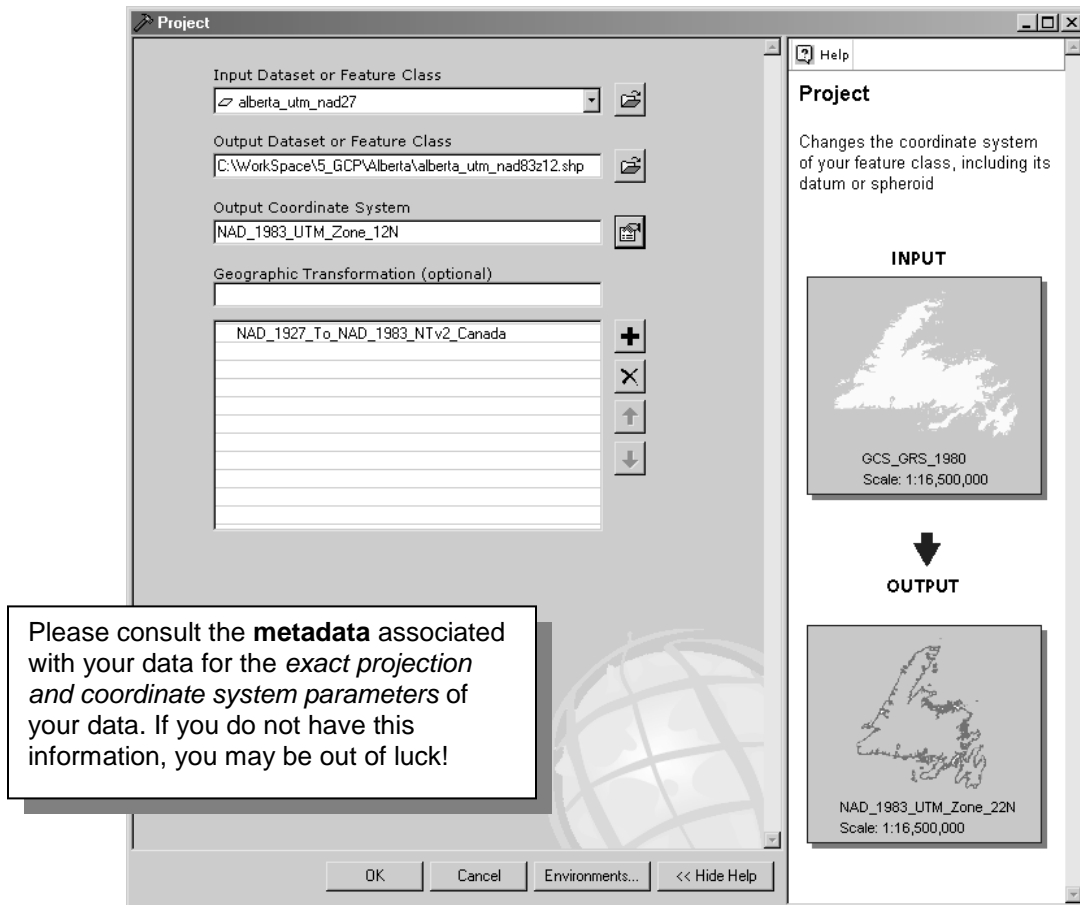
6. Click on the SELECT button
  7. Navigate to select the PROJECTED COORDINATE SYSTEMS >>> NATIONAL GRIDS >>> CANADA >>> **NAD 1983 10TM AEP Forest.prj**
  8. Click ADD
  9. Click OK to apply and dismiss the Spatial Reference Properties dialog
  10. Click OK to run the tool
  11. Examine the Data View 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 9) to define **Alberta\_utm\_nad83** – *pay attention to the ZONE!*
- When defining **Ablakes** 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\alberta\_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 DATUM and ZONE)
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



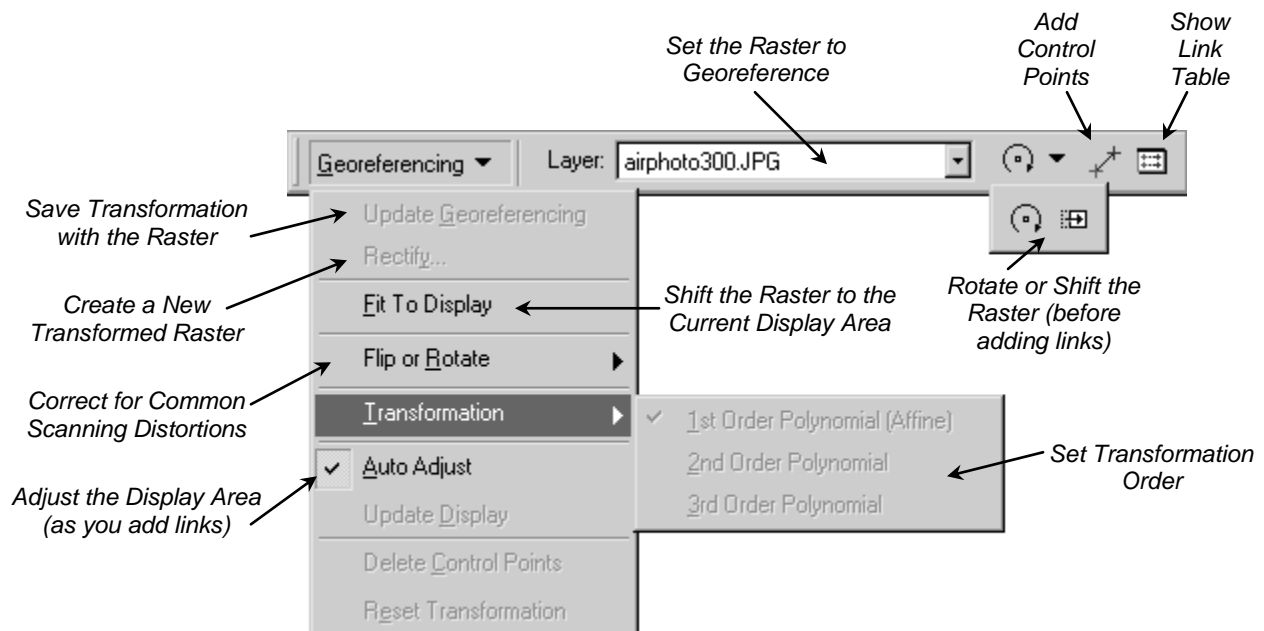
9. Review the summary of your input and if all is well click OK
10. Click ZOOM TO FULL EXTENT and examine the various layers
11. SAVE when finished

## 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. 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  
*You should get a “missing spatial reference information “ warning.*
3. Show and take a moment to look at 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.*

1. Choose VIEW >>> BOOKMARKS >>> CLIFFORD E LEE SANCTUARY to zoom to the sanctuary location
2. Choose GEOREFERENCING >>> FIT TO DISPLAY
3. 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*
4. 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**
5. Click on the CONTROL POINTS button
6. 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.*

7. 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.*

8. Click the VIEW LINK TABLE button 

9. Examine the residual error for each link and the RMS error

10. 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*

Link	X Source	Y Source	X Map	Y Map	Residual
1	665.793692	-348.975652	313174.358371	5923265.689483	0.67104
2	2742.427267	-403.030989	315855.738769	5923152.773898	1.05159
3	628.357296	-2038.073325	313082.684155	5921119.986567	0.72724
4	2517.392913	-2294.383186	315488.535794	5920726.552321	1.50673
5	1925.523294	-1011.732164	314768.041682	5922389.106326	2.04144
6	1935.371038	-387.486282	314803.269255	5923194.848760	2.92245
7	1901.636941	-2282.423737	314695.734731	5920762.251843	1.58245

Auto Adjust    Transformation: 2nd Order Polynomial    Total RMS Error: 1.67194  
       

SAVE the map document

11. 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.*

12. SAVE the link table and

### 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.

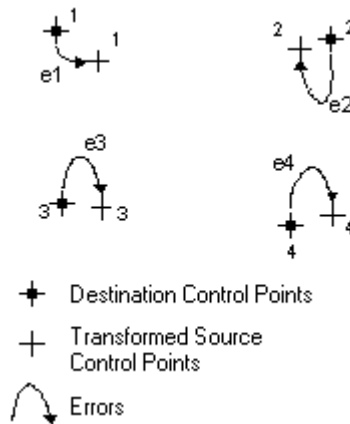
### Why rectify the raster?

- 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.



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.

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

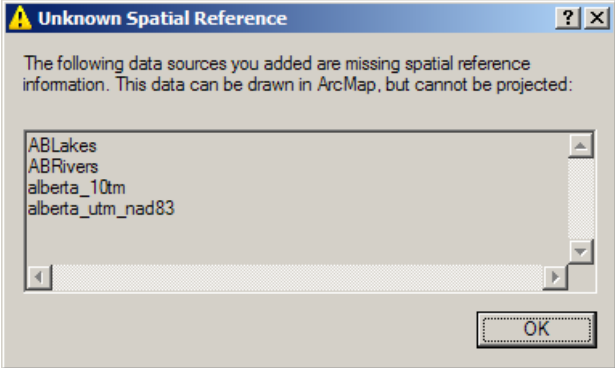
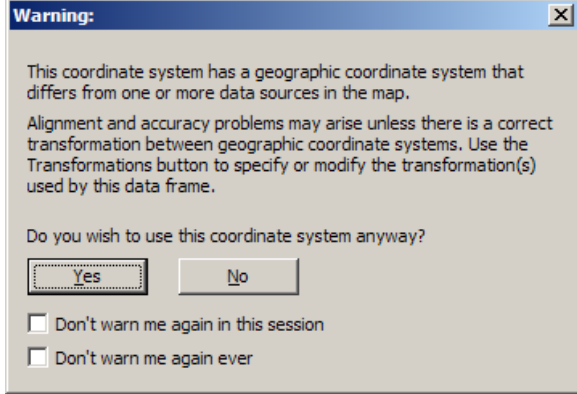
\*\*\* While RMS error is a good assessment of the accuracy of the transformation, don't confuse a low RMS error with an accurate registration (you may have poorly entered control points).

**For Further Reading**

- Foote, K. Department of Geography, University of Colorado. 1999. **Map Projections**.  
[http://www.colorado.edu/geography/gcraft/notes/mapproj/mapproj\\_f.html](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/cartocorner/map\\_projections.html](http://atlas.gc.ca/site/english/learningresources/cartocorner/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](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**. 6<sup>th</sup> 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...
<p>If your data layers are in a Geographic Coordinate System (<b>decimal degrees</b>) and:</p> <ul style="list-style-type: none"> <li>You do not like the stretched out appearance of the layers</li> <li>You need to perform area and/or distance calculations</li> <li>You want to display features in their true shapes, or another reason...</li> </ul>	<p><b>Set the coordinate system</b> in the Data Frame Properties of ArcMap OR <b>Project</b> the layer</p>
	<p><b>Define</b> the coordinate system using ArcToolbox or ArcCatalog</p>
	<p><b>Set the geographic transformation</b> method that is appropriate OR <b>Project</b> the layer to match the coordinate systems of the other layers using ArcToolbox</p> <p>Look up the appropriate method... C:\Program Files\ArcGIS\Documentation <b>geographic_transformations.pdf</b> and search by area of interest</p>
<p>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.</p>	<p><b>Project</b> the layers to matching coordinate systems using ArcToolbox OR <b>Set the geographic transformation</b> method that is appropriate</p> <p>The _documentation folder has <b>PEgt_namewhere93_81408.doc</b></p>