GIS in Ecology

SPATIAL REFERENCING

COORDINATE SYSTEMS
MAP PROJECTIONS
GEOREFERENCING

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Where on earth… ?

- Early mapmakers recognized the need for a system that could locate features on the earth's surface.
- The earth's **shape** and **size** first had to be learned to apply a **coordinate system** for the **projection** of earth's 3D features onto a 2D planar map.

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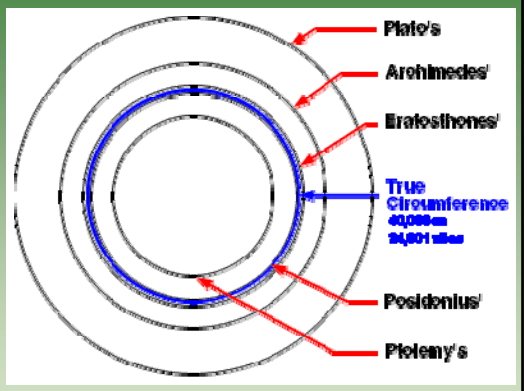
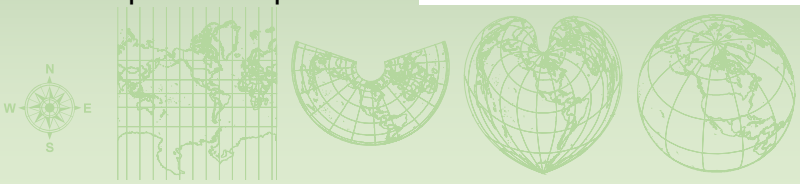
Shape and Size of the Earth

- After millennia, the "true shape" and "true size" of the earth became known.
- As explorers and scientists investigated the earth more closely, they realized that it is not a perfect sphere… but an imperfect ellipsoid.





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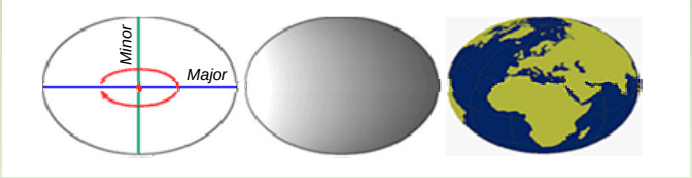
Ellipsoid – Spheroid – Geoid

- An **ellipsoid** is created by rotating an ellipse about either its major axis (called a prolate spheroid) or its minor axis (called an oblate spheroid).
- A **spheroid** is an ellipsoid that approximates the shape of a sphere.
- A **geoid** is the earth's actual shape (bumps and all).



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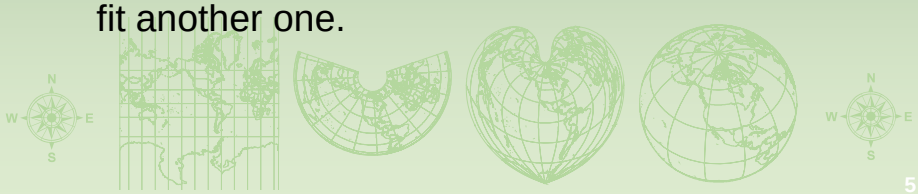
Refining the Earth's Shape

- Earth's general shape can be approximated as an oblate ***spheroid*** where the circumference of Earth from pole to pole is 39,939,593.9 meters and the distance around the equator is 40,075,452.7 meters.
- But… the earth is not perfectly symmetrical, so the semi-major and semi-minor axes that fit one geographical region do not necessarily fit another one.



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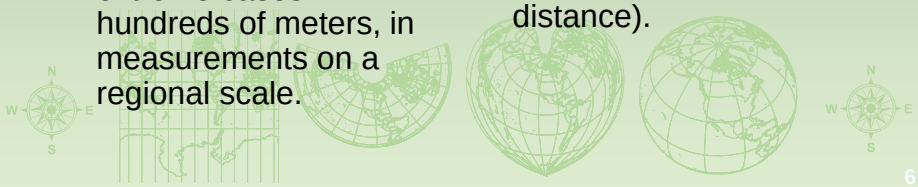
Datums

- …the spheroid used to define the position relative to the center of the earth.
- Accounting for deviations and using an appropriate datum for each location on the earth may avoid errors of several meters, or in extreme cases hundreds of meters, in measurements on a regional scale.
- For example, when mapping at a scale of 1:100,000 or greater it is important that the datum is known. This is especially true if comparing one map to another (i.e. NAD27 differs from NAD83 by as much as 200-300 meters in spatial distance).



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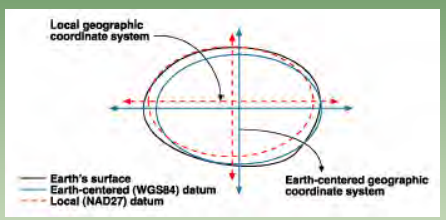
Common Datums

- North American Datum of 1927 (NAD27) - ground based spheroid originating at Meades Ranch, Kansas.
- World Geodetic System 1984 (WGS84) - satellite based spheroid.
- North American Datum of 1983 (NAD83) – modified WGS84 based on the Earth's center of mass.



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On-line Conversion Tools

- In 1990, Natural Resources Canada officially adopted the North American Datum of 1983 (NAD83) as its new geodetic reference system.
- Map users need to know the datum, especially when using GPS receivers.
- To convert between datums or lat/long: http://www.geod.nrcan.gc.ca/tools-outils/index_e.php
- US tools: http://www.ngs.noaa.gov/TOOLS/

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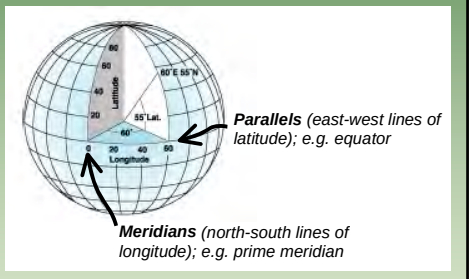
Establishing Location

- A system of imaginary intersecting lines was created based on the 360-***degree*** Babylonian system for dividing a circle or sphere.
- ***Parallels*** **= Latitude** lines that run east-west measuring distances north and south of the equator.
- ***Meridians*** **= Longitude** lines that run north-south measuring distance east and west of the Prime Meridian, intersecting at the poles.



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Coordinate Systems

- …the specified units and origin point used to locate features on the 2D map. Two types:
- ***Geographic*** coordinate system – defines locations using latitude and longitude on a spherical model of the earth (includes angular unit of measure, central meridian, datum)
- ***Projected*** coordinate system – defines locations as x,y coordinates identified on a grid using a mathematical conversion from lat/long (includes unit of measure, an equally spaced grid, origin at the center x=0, y=0)

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Map Projections

- The mathematical transformations from earth's 3D surface to create a flat map sheet are the building blocks to any geographic coordinate system – the mathematical formulas relate spherical coordinates on the globe to flat, planar coordinates.
- They are based on ***standard parallels*** and ***central meridians***.
- One of the first map projections was the plane chart, or ***plate carrée***, which treats the graticule as a grid of equal squares, forcing meridians and parallels to meet at right angles.
- Each map projection is designed for specific purposes: one type may be used for large-scale data in a limited area, while another is used for a small-scale map of the world.

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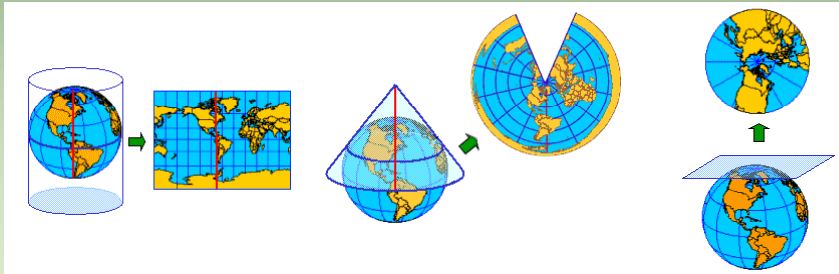
Developable Surfaces

- …a systematic method to represent the earth's surface by theoretically projecting coordinates from a spherical coordinate system onto a surface that can be laid flat without distortion.



Cylindrical **Conical** **Planar**

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Spatial Properties

- The conversion of geographic locations from a spherical coordinate system to a flat surface causes distortion in spatial properties:
  - ***Distance*** – preserved by Equidistant projections
  - ***Shape*** – preserved by Conformal projections
  - ***Area*** – preserved by Equal Area projections
  - ***Direction*** – preserved by Azimuthal projections
- There are many map projections and each one is good at representing one or more spatial properties, but no single projection preserves all four properties.

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Tissot's Indicatrix

- …an infinitely small circle on the earth's surface that will be projected as an infinitely small ellipse on any given map projection (a two-dimensional surface).
- Tissot's Indicatrix helps visualize and quantify the inherent distortion of many different map projections.
- The amount and type of distortion exhibited by the ellipses indicates the amount and type of distortion of the map features at that location.

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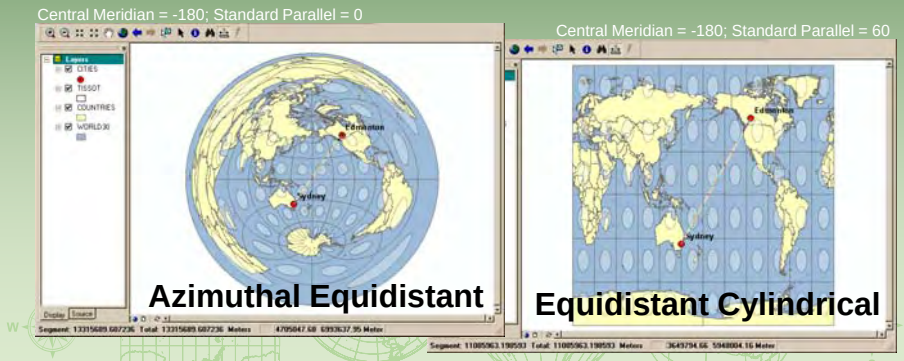
Example Distortions

- Modifying projection ***parameters***, such as central meridians and standard parallels, can minimize (or in this case, maximize) distortion for local areas.



~13,316 km ~11,086 km

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Unprojected versus Undefined

- ***Unprojected*** data
  - Having your data in an unprojected geographic coordinate system allows for more flexibility in setting ArcMap's data frame coordinate system to suit your analysis needs.
  - Use when you don't need a high level of locational accuracy, or won' t be performing queries based on location, area, and distance.
- ***Undefined*** data
  - When data does not have the auxiliary files (e.g. *.prj) to enable ArcMap to "read" and reference them with other data layers, you must provide the definition to be able to work with ArcMap's full functionality.

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Georeferencing

- Raster data (scanned maps, aerial photographs and satellite images) do not usually contain information as to where the area represented fits on the earth's surface.
- You must ***align the raster to the desired map coordinate system of existing spatial data*** (e.g. target layer or paper map)
  - by identifying a series of ***ground control points*** – of known x,y coordinates – that ***link*** locations on the source raster with locations in the target data,
  - thus allowing to be viewed, queried, and analyzed with other geographic data.

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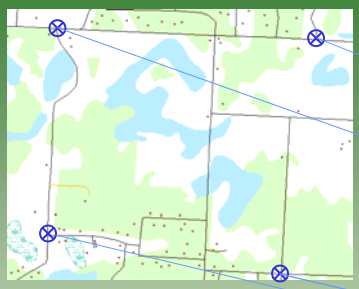
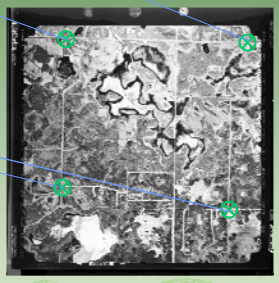
Control Points and Links



- The number of links needed depends on the desired ***transformation*** method.



- The combination of one control point on the raster and the corresponding control point on the target data is called a ***link***.

3 links for a first order transformation
6 links for a second order
10 links for a third order (*see page 15*)

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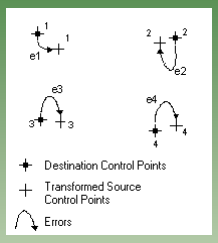
RMS Error

- Measure each pair-wise distance between the actual location of the target map coordinate to the transformed position in the source raster to get the ***residual error***.
- Take the root mean square sum of all the residuals to compute the ***RMS error***.



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

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Using the RMS Error

- The RMS error for raster images should be approximately less than half the resolution of the source image.
- To reduce high RMS error, it is recommended that the control point(s) with the highest residual be deleted.
- It is important, however, that the link file retain control points in all areas within the image.

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Take Home Messages

- You need the ***metadata*** to tell you what coordinate system/projection your GIS files are in.
- ***Undefined*** data may have a projected coordinate system; ***Unprojected*** data have a defined geographic coordinate system.
- ***Projecting*** data converts from one coordinate system to another, yielding a new output file.
- ***Georeferencing*** data transforms unknown locations to a real world coordinate system.

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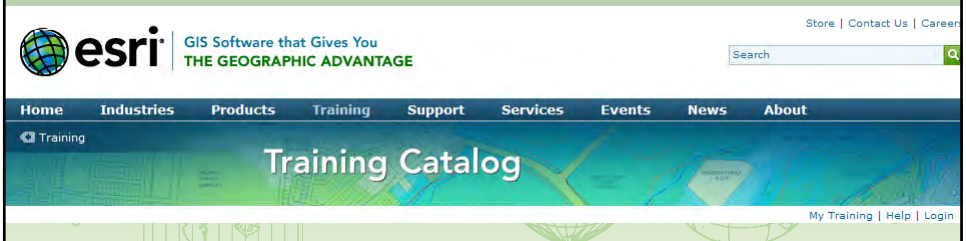
Free Online Training

- Take ESRI's online course "***Understanding Map Projections and Coordinate Systems***" and training seminar "***Working with Map Projections and Coordinate Systems in ArcGIS***"

http://training.esri.com



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