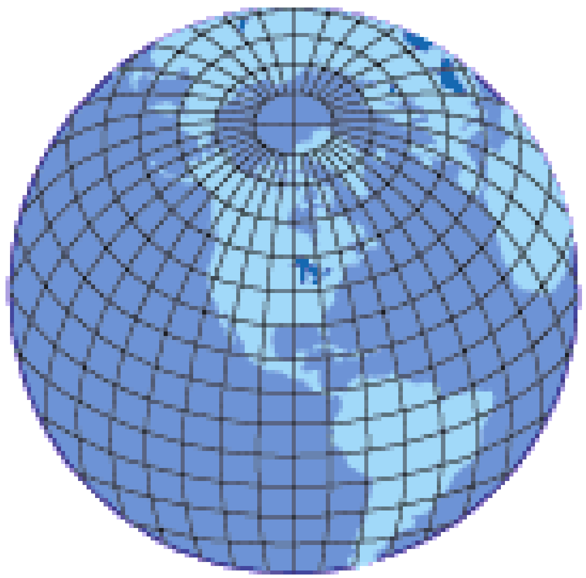
Map Projections and Coordinate Systems

Georeferencing

- When working with remote sensing data and GIS, you often want to analyze the relationships between real-world objects.
- This requires that the different objects and their locations are portrayed as accurately as possible.
- It is critical to reference the data to the correct location on the earth’s surface – to georeference the data.
- Georeferencing is the process of establishing a relationship between the data displayed by your software and its actual location.
- Defining the appropriate coordinate systems are an important part of the process.

Geographic Coordinate System

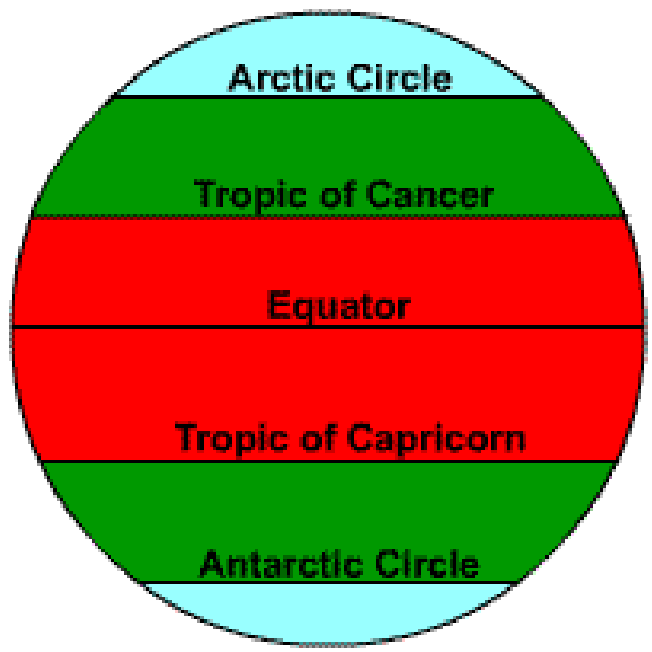
- The most commonly used reference system is the spherical coordinate system based upon latitude and longitude. This is often called the Global Reference System.
- These are the angles measured from the earth's center to a point on the surface.
- Latitude and longitude are measured in degrees, minutes, and seconds, where there are 60 minutes per degree and 60 seconds per minute.
- However, latitude and longitude are not uniform across the earth's surface.



http://www.mcwdn.org/MAPS&GLOBES/

Geographic Coordinate System

- Latitude is the distance north or south of the equator, measured in lines that are parallel, from north to south.
- There are a total of 180º between the south pole and the north pole, in 20º increments.
- The equator is at 0º latitude, while the north pole is 90º latitude and the south pole is -90º.
- Lines of latitude are circles of different size. The longest is the equator, at the earth's maximum diameter, while at the poles the circles shrink to a point.



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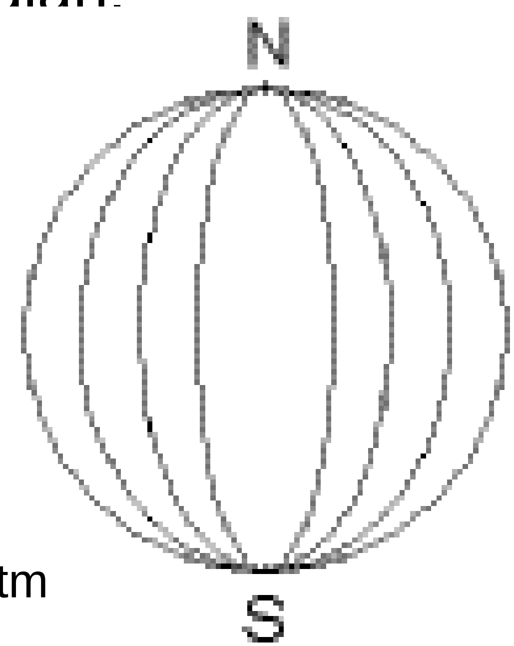
Geographic Coordinate System

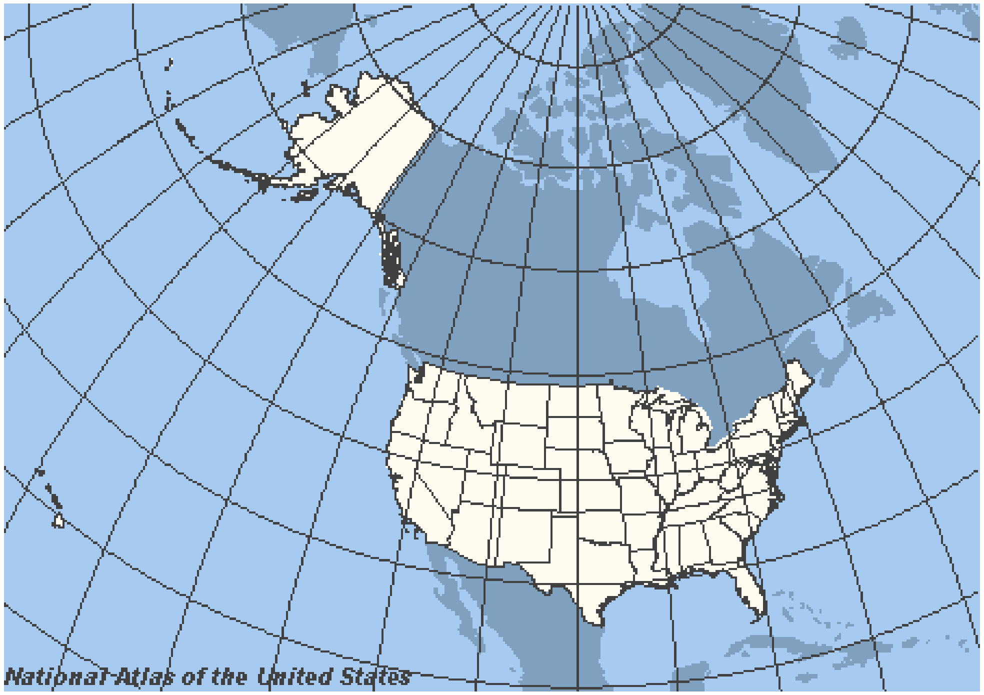
- Lines of longitude run north-south and are called meridians. Every meridian must cross the equator. The equator is a circle, and can be divided into an even number of degrees, 360º.
- Longitude meridians range from 0 to 360º, starting at the Prime Meridian, located in Greenwich, England.
- Note that noon, at any given location, is that time when the sun passes directly over the local meridian.
- Again, the distance between meridians narrows as they approach the pole. As a result, one degree of longitude is a shorter distance at the poles than at the equator.



http://www-istp.gsfc.nasa.gov/stargaze/Slatlong.htm

Planar Coordinate Systems

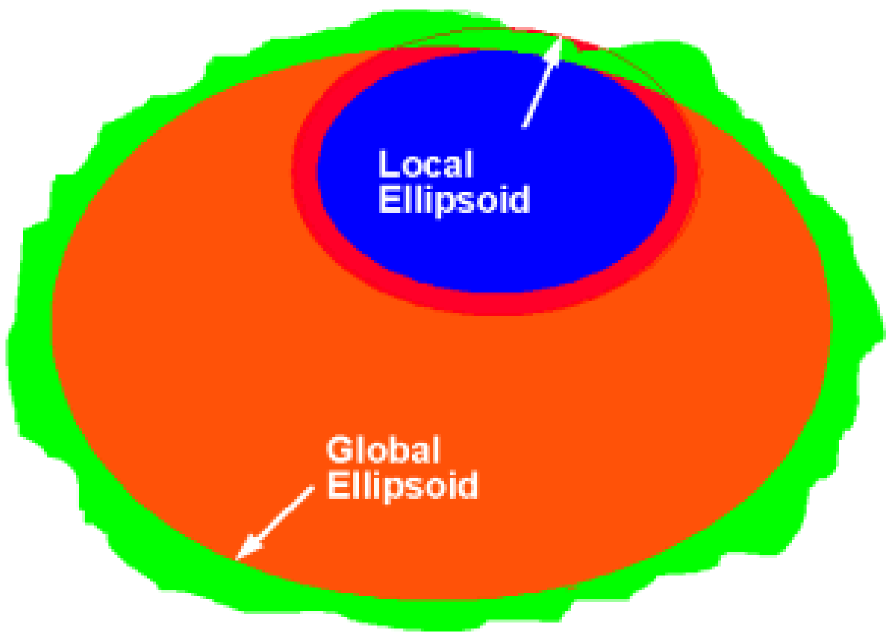
- Because it is difficult to make measurements in spherical coordinate systems, geographic data is often projected into cartesian, or planar, coordinate systems.
- In cartesian systems, you specify x-y coordinates on a grid, referenced to some central location.
- The particular reference frame measured against is called the *horizontal datum*.
- These can be either local, aligned with the earth's surface, or earth-centered.
- There are different versions of even these, depending on their origins and uses.



http://www.mcwdn.org/MAPS&GLOBES/

Datums

- Because the earth is not actually a sphere, but an ellipsoid, all datums, whether local or earth-centered, are based upon a symmetric ellipsoid centred (approximately) at the equator.
- WGS84 is the current global reference frame. It is consistent with the GPS reference frame, International Terrestrial Reference Frame (ITRF), to within centimetres.
- NAD83, an older, geocentric reference frame that you will see used for some data sets, was based on a different ellipsoid model.
- On the other hand, NAD27 and the European datum are local (regional) datums.



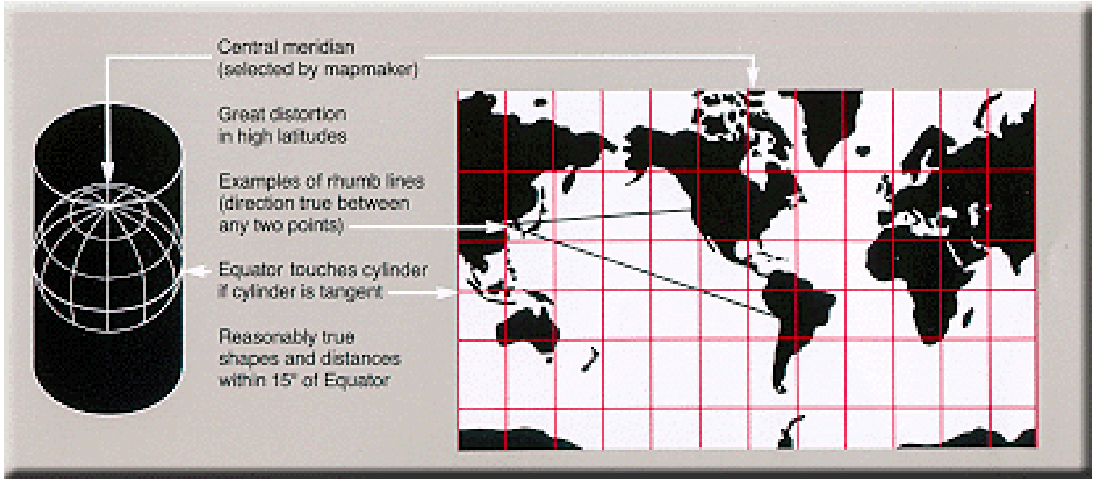
http://www.wgs84.com/wgs84/wgs84.htm

Map Projections

- A map projection is a method for converting the earth's 3-D surface to a two-dimensional plane surface, in part or in its entirety.
- These are called projections, historically, because the early concept was based on the idea of a light shining on the earth onto a 2-D surface.
- Today, mathematical formulas are used to convert data from latitude and longitude into a map projection.
- The important point is that all map projections distort the spherical surface as they convert it to a flat surface. Each projection, then, has its drawbacks and its advantages.
- Note that both the datums and the map projections of your remote sensing and GIS data should map in order to minimize location errors.

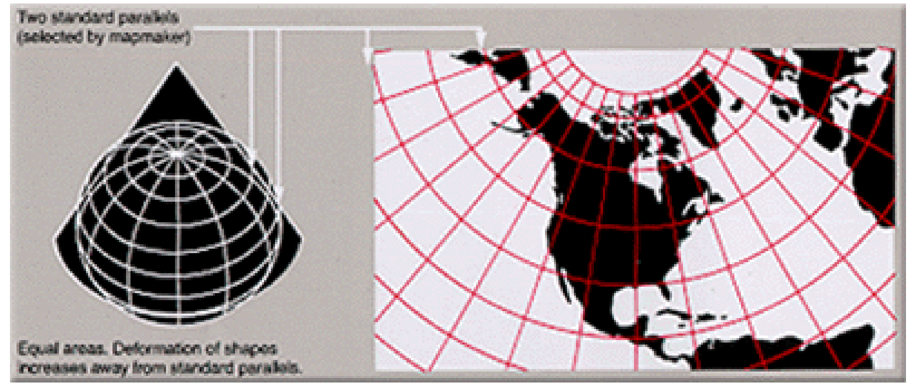
Map Projections

- Map projections are broken down into three broad categories, based upon the type of surface the projection is based upon – cylinder, cone, or plane.
- A surface that can be unfolded or unrolled into a flat plane or sheet without stretching, tearing or shrinking is called a developable surface.
- While a sphere and ellipsoid are not developable surfaces, a cylinder is. If we project the earth's surface onto a cylinder or cone and unroll it, we have the projection.
- The first step inevitably distorts some properties of the globe, the developable surface may then be unfolding does not.

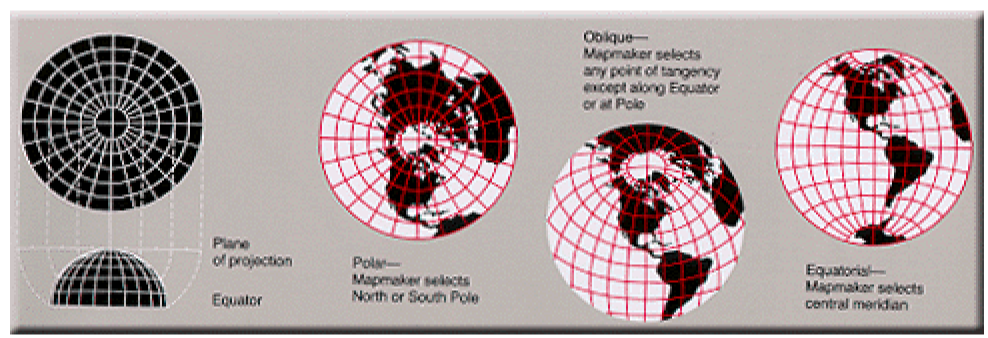


http://en.wikipedia.org/wiki/Map_projection

Map Projections



- Conic projections are similar to cylindrical projections, they also unroll a projection that has a different perspective.
- A planar projection is also called an azimuthal projection. In azimuthal projections, directions from a central point are preserved, and the great circles through the central point are represented by straight lines on the map.
- Usually these projections also have radial symmetry in the scales and hence in the distortions. Some are true perspective projections; others are not.



http://en.wikipedia.org/wiki/Map_projection

Map Projections

- There are many different versions of these map projections, depending on orientation, perspective, and scale. Which one that's appropriate depends on what you want to use it for.
- The first important thing to remember is that each projection produces different features. Cylindrical projections have straight parallels. Conical projections form concentric circles. Azimuthal projections result in eccentric circles.
- The second point is that each type of projection distorts shape, area, distance, or direction to one extent or another. That distortion, or lack thereof, makes certain projections more appropriate for certain uses.

Map Projections

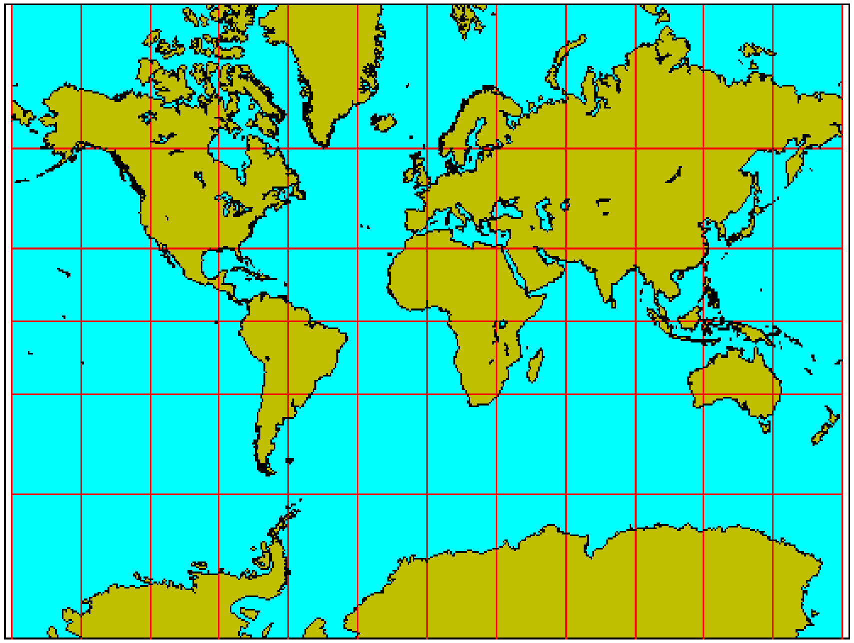
- All map projection conversions cause distortion – in shape, area, distance, or direction.
- The projection you choose affects the analysis of the relationship between various points in your data.
- Generally, the following holds true:
  - Conformal projections maintain shape, i.e. circles remain circles, are not transformed to ellipses.
  - Equal area projections preserve the areas of those shapes.
  - Equidistant projections preserve the distances between certain points.
  - Azimuthal projections preserve the direction from one point to all other points.
- These projection types can be combined, in some cases.

Map Projections

- http://www.btinternet.com/~se16/js/mapproj.htm
- The above website illustrates how different maps distort areas differently. The image shows a division of the earth into roughly equal area rectangles. The grid is 8 by 24, so that each rectangle covers about 1/192 of the earth or just over 0.5%.
- Each projection shown in the applet has its own particular properties. As an example, the Mercator projection is conformal and can be used for navigational purposes since angles on the map represent bearings on a compass. Any scaling needs to preserve this property - but since a complete Mercator projection is of infinite height, different rectangles can include different amounts of northern and southern extremities.
- Similarly the polar azimuthal projections keep lines of latitude as concentric circles, and this needs to be preserved in scaling.
- For the infinite gnomonic and stereographic maps, different amounts of the sphere can be included at different scales. The conformal gnomonic projection cannot cover an entire hemisphere, while the stereographic projection covers the whole sphere but only at the cost of losing much of the detail.

Map Projections

- Finally, we should discuss the Universal Transverse Mercator (UTM) projection. Mercator projections are cylindrical projections – they have straight parallels.
- Mercator projections are conformal projections, so that angles and small shapes project as the same angles or shapes on the map. Conformal projections, however, produce great variation away from the central portions of the map.
- Greenland on a Mercator map appears as large as S. America, although it has only 1/8 the area. However, a small portion of the coast has the same shape on the map as it does on the ground.



http://www.uwgb.edu/dutchs/FieldMethods/UTMSystem.htm

Map Projections

- But, within ten degrees or so of the equator, the scale error on a Mercator map is only a percent or so, so in that region a Mercator map is more accurate than most projections.
- Remember, there's no reason the cylinder has to touch at the equator. To map Argentina, which is long and oriented north-south, a good choice would be a Mercator projection whose cylinder touches the earth along a local meridian of longitude. Such a projection is called a Transverse Mercator projection.
- A Transverse Mercator projection is very accurate in narrow zones, and so it has become the basis for a global coordinate system called the *Universal Transverse Mercator (UTM) System.*
- The globe is subdivided into narrow longitude zones, projected onto a Transverse Mercator projection. A grid is constructed on the projection, and used to locate points. Because the grid is rectangular and decimal, it is easier to use than latitude and longitude. However, unlike latitude and longitude, there is no way to determine grid locations independently, it must all be referenced back to individual grids.

http://www.uwgb.edu/dutchs/FieldMethods/UTMSystem.htm