Map Projections

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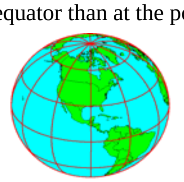
Outline

- *Geodesy and map projections*

Shape of the Earth

We think of the earth as a sphere

It is actually a spheroid, slightly larger in radius at the equator than at the poles



Geographic Coordinates (ϕ, λ, z)

- Latitude (ϕ) and Longitude (λ) defined using an ellipsoid, an ellipse rotated about an axis
- Elevation (z) defined using geoid, a surface of constant gravitational potential
- Earth datums define standard values of the ellipsoid and geoid

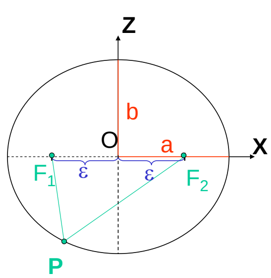
Ellipse

An ellipse is defined by:

Focal length = ε
Distance (F1, P, F2) is constant for all points on ellipse
When ε = 0, ellipse = circle

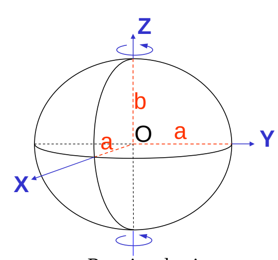
For the earth:

Major axis, a = 6378 km
Minor axis, b = 6357 km
Flattening ratio, f = (a-b)/a
~ 1/300



Ellipsoid or Spheroid

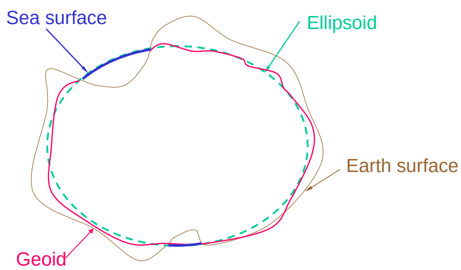
Rotate an ellipse around an axis



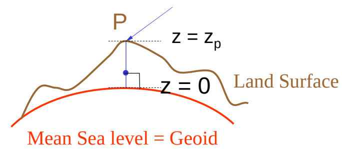
Rotational axis

Representations of the Earth

Mean Sea Level is a surface of constant gravitational potential called the Geoid



Definition of Elevation



Elevation is measured from the Geoid

Earth Models and Datums

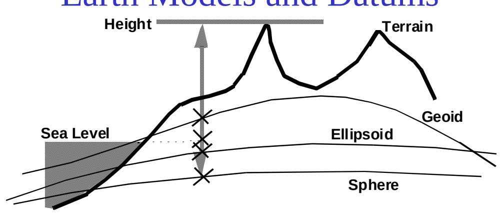
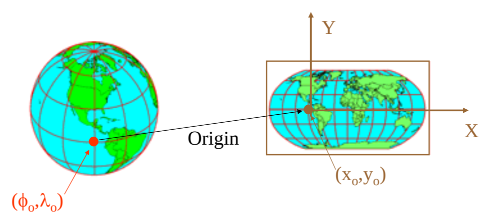


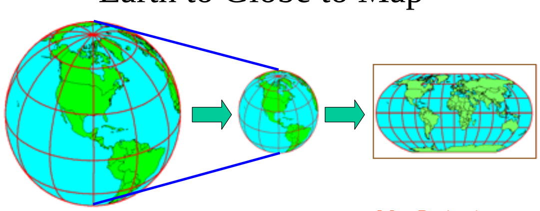
Figure 2.4 Elevations defined with reference to a sphere, ellipsoid, geoid, or local sea level will all be different. Even location as latitude and longitude will vary somewhat. When linking field data such as GPS with a GIS, the user must know what base to use.

Coordinate System

A planar coordinate system is defined by a pair of orthogonal (x,y) axes drawn through an origin



Earth to Globe to Map



Map Scale:

Representative Fraction

$$= \frac{\text{Globe distance}}{\text{Earth distance}}$$

(e.g. 1:24,000)

Map Projection:

Scale Factor

$$= \frac{\text{Map distance}}{\text{Globe distance}}$$

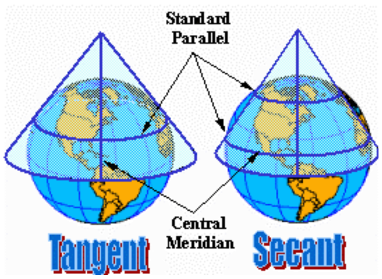
(e.g. 0.9996)

Map Projections

- A transformation of the spherical or ellipsoidal earth onto a flat map is called a map projection.
- The map projection can be onto a flat surface or a surface that can be made flat by cutting, such as a cylinder or a cone.
- If the globe, after scaling, cuts the surface, the projection is called secant. Lines where the cuts take place or where the surface touches the globe have no projection distortion.

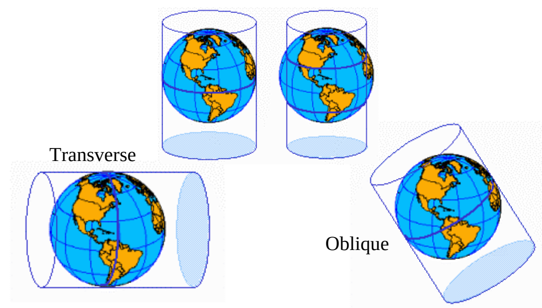
Conic Projections

(Albers Equal Area, Lambert Conformal Conic)



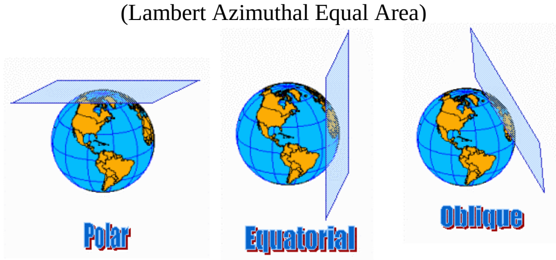
Cylindrical Projections

(Universal Transverse Mercator)



Azimuthal

(Lambert Azimuthal Equal Area)



Map projections

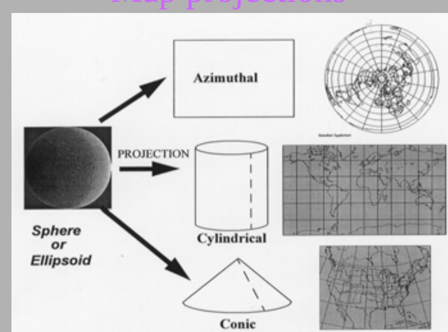


Figure 2.6 The earth can be projected in many ways, but basically onto three shapes that can be unrolled into a flat map: a flat plane, a cylinder, and a cone.

"no flat map can be both equivalent and conformal."

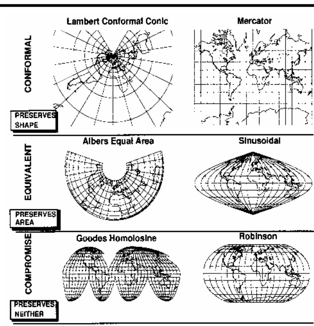


Figure 2.9 Examples of projections classified by their distortions. Conformal projections preserve local shape, equivalent projections preserve area, while compromise projections lie between the two. No projection can be equivalent and conformal.

Map Projections (ctd)

- Projections can be based on axes parallel to the earth's rotation axis (equatorial), at 90 degrees to it (transverse), or at any other angle (oblique).
- A projection that preserves the shape of features across the map is called conformal.
- A projection that preserves the area of a feature across the map is called equal area or equivalent.
- No flat map can be both equivalent and conformal. Most fall between the two as compromises.
- To compare or edge-match maps in a GIS, both maps MUST be in the same projection.

Standard parallels

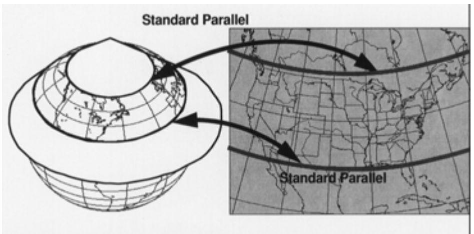


Figure 2.7 Standard Parallels. The conic projection cuts through the globe, and the earth is projected both in and out onto it. This is a secant conic projection. Lines of true scale, where the cylinder and sphere touch become standard parallels.

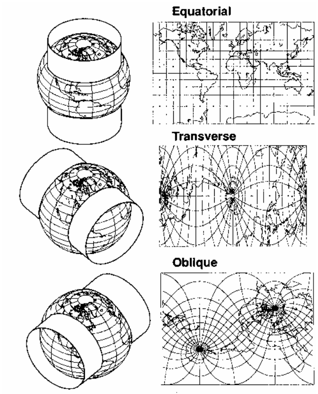


Figure 2.8 Variations on the Mercator (Pseudocylindrical) Projection shown as secant. Top: Equatorial. Middle: Transverse. Bottom: Oblique.

Secant map projections

Coordinate Systems

- A coordinate system is a standardized method for assigning codes to locations so that locations can be found using the codes alone.
- Standardized coordinate systems use absolute locations.
- A map captured in the units of the paper sheet on which it is printed is based on relative locations or map millimeters.
- In a coordinate system, the x-direction value is the easting and the y-direction value is the northing. Most systems make both values positive.

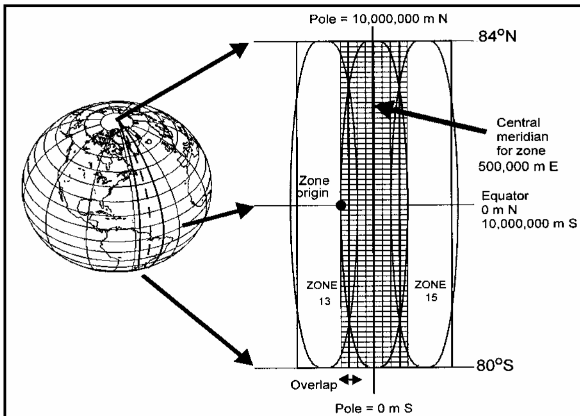


Figure 2.12 The Universal transverse Mercator coordinate system.

Coordinate Systems for the US

- Some standard coordinate systems used in the United States are
  - geographic coordinates
  - universal transverse Mercator system
  - military grid
  - state plane
- To compare or edge-match maps in a GIS, both maps MUST be in the same coordinate system.

UTM zones in the lower 48

UTM zones in the lower 48

The UTM system divides the surface of the Earth between 80° S latitude and 84° N latitude into 60 zones, each 6° of longitude in width and centered over a meridian of longitude. Zones are numbered from 1 to 60. Zone 1 is bounded by longitude 180° to 174° W and is centered on the 177th West meridian. Zone numbering increases in an easterly direction.

Each of the 60 longitude zones in the UTM system is based on a transverse Mercator projection, which is capable of mapping a region of large north-south extent with a low amount of distortion. By using narrow zones of 6° (up to 800 km) in width, and reducing the scale factor along the central meridian by only 0.0004 (to 0.9996, a reduction of 1:2500) the amount of distortion is held below 1 part in 1,000 inside each zone. Distortion of scale increases to 1.0010 at the outer zone boundaries along the equator.

The secant projection in each zone creates two standard lines, or lines of true scale, located approximately 180 km on either side of, and approximately parallel to, the central meridian. The scale factor is less than 1 inside these lines and greater than 1 outside of these lines, but the overall distortion of scale inside the entire zone is minimized.

Military Grid Coordinates

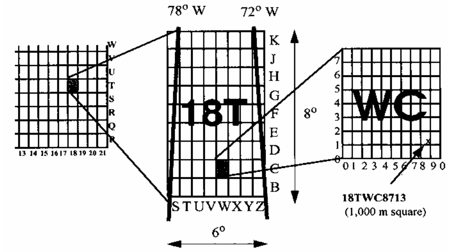


Figure 2.14 Military grid cell letters.

GIS Capability

- A GIS package should be able to move between
  - map projections,
  - coordinate systems,
  - datums, and
  - ellipsoids.

Geographic information

- Characteristics
  - volume
  - dimensionality
  - continuity

Building complex features

- Simple geographic features can be used to build more complex ones.
- Areas are made up of lines which are made up of points represented by their coordinates.
- Areas = {Lines} = {Points}

Areas are lines are points are coordinates

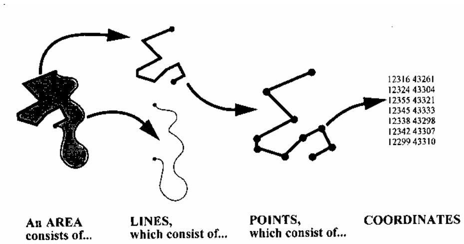


Figure 2.16 Geographic information has *dimension.* Areas are two-dimensional and consist of lines, which are one-dimensional and consist of points, which are zero- dimensional and consist of a coordinate pair.

Properties of Features

- size
- distribution
- pattern
- contiguity
- neighborhood
- shape
- scale
- orientation.

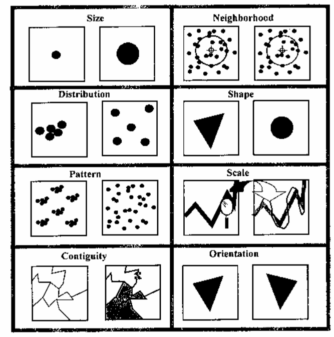


Figure 2.17 Basic properties of geographic features.

Basic properties of geographic features