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 (\(\phi, \lambda, z\))

• Latitude (\(\phi\)) and Longitude (\(\lambda\)) 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 = \(\varepsilon\)
Distance (\(F_1, P, F_2\)) is constant for all points on ellipse
When \(\varepsilon = 0\), ellipse = circle

For the earth:
Major axis, \(a = 6378\) km
Minor axis, \(b = 6357\) km
Flattening ratio, \(f = (a-b)/a \approx 1/300\)

Ellipsoid or Spheroid

Rotate an ellipse around an axis

b

F_2

F_1

a

P

Z

X

Y

Rotational axis
Representations of the Earth

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

Earth Models and Datums

Elevation is measured from the Geoid.

Coordinate System

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

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.
Map projections

Conic Projections
(Albers Equal Area, Lambert Conformal Conic)

Cylindrical Projections
(Universal Transverse Mercator)

Azimuthal
(Lambert Azimuthal Equal Area)

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.
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.

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

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 1.2589) 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.

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

- An AREA consists of...
- LINES, which consist of...
- POINTS, which consist of...
- COORDINATES
Properties of Features

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

Basic properties of geographic features