CE-317 GIS/RS Application to Civil Engineering
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•Lecture 04b: Latitude, Longitude and Projections

Authalic Latitude

- It is based on a spherical earth.
- It measures the position of a point on the earth's surface in terms of the angular distance between the equator and the poles.
- It indicates how far north or south of the equator a particular point is situated.
- It is known as an arc of the meridian.

North Latitude

- all points north of the equator in the northern hemisphere.

Geodetic Latitude

- Geodetic Latitude is based on an ellipsoidal earth.
- The ellipsoid is a more accurate representation of the earth than a sphere since it accounts for polar flattening.
- Modern large-scale mapping, GIS, and GPS technology all require the higher accuracy of an ellipsoidal reference surface.

Geodetic Latitude

- When the earth's shape is based on the WGS 84 Ellipsoid, the length of 1° of latitude is not the same everywhere as it is on the sphere.
  - At the equator, 1° of latitude is 110.57 kilometers (68.7 miles).
  - At the poles, 1° of latitude is 111.69 kilometers (69.4 miles).

Latitude and Distance

- Parallels of latitude decrease in length with increasing latitude.
- Length of parallel at latitude x = (cosine of x) * (length of equator).
- The length of each GIS Basics 64 degree is obtained by dividing the length of that parallel by 360°.

Latitude and Distance

- For example, the cosine of 60° is 0.5, so the length of the parallel at that latitude is one half the length of the equator.

- Since the variation in lengths of degrees of latitude varies by only 1.13 kilometers (0.7 mile)

- the standard figure of 111.325 kilometers (69.172 miles) can be used.

Latitude and Distance

- For example, anywhere on the earth, the length represented by 3° of latitude is

  $(3 \times 111.325) = 333.975$ kilometers.

Longitude

- Longitude measures the position of a point on the earth's surface east or west from a specific meridian, the prime meridian.

- The longitude of a place is the arc, measured in degrees along a parallel of latitude from the prime meridian.

Longitude

- The most widely accepted prime meridian is based on the Bureau International de l'Heure (BIH) Zero Meridian.

- It passes through the old Royal Observatory in Greenwich, England.

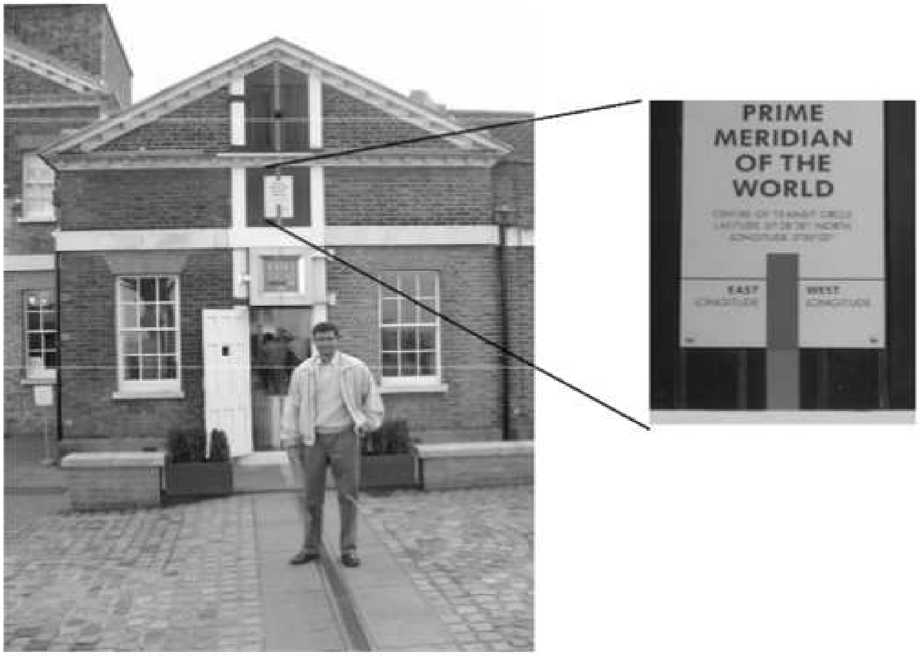

Figure 3.13: The author at Royal Observatory in Greenwich, England.

Table 3.5: Length of a degree of geodetic latitude and geodetic longitude.

Latitude (°)	Length of a Degree of Geodetic Latitude		Length of a Degree of Geodetic Longitude	
	Miles	Kilometers	Miles	Kilometers
0°	68.71	110.57	69.17	111.32
10°	68.73	110.61	68.13	109.64
20°	68.79	110.70	65.03	104.65
30°	68.88	110.85	59.95	96.49
40°	68.99	111.04	53.06	85.39
50°	69.12	111.23	44.55	71.70
60°	69.23	111.41	34.67	55.80
70°	69.32	111.56	23.73	38.19
80°	69.38	111.66	12.05	19.39
90°	69.40	111.69	0.00	0.00

Map Projection

- A map projection is a system in which locations on the curved surface of the earth are displayed on a flat sheet or surface according to some set of rules.

- Mathematically, projection is a process of transforming global location to a planar position.

Tissot's Indicatrix

- This is a convenient way of showing distortion.
- If a tiny circle drawn on the surface of the globe, on the distorted map the circle will become an ellipse, squashed or stretched by the projection.

Figure of the Earth

- The figure of the earth is a geometrical model used to generate projections
- A compromise between the desire for mathematical simplicity and the need for accurate approximation of the earth's shape.

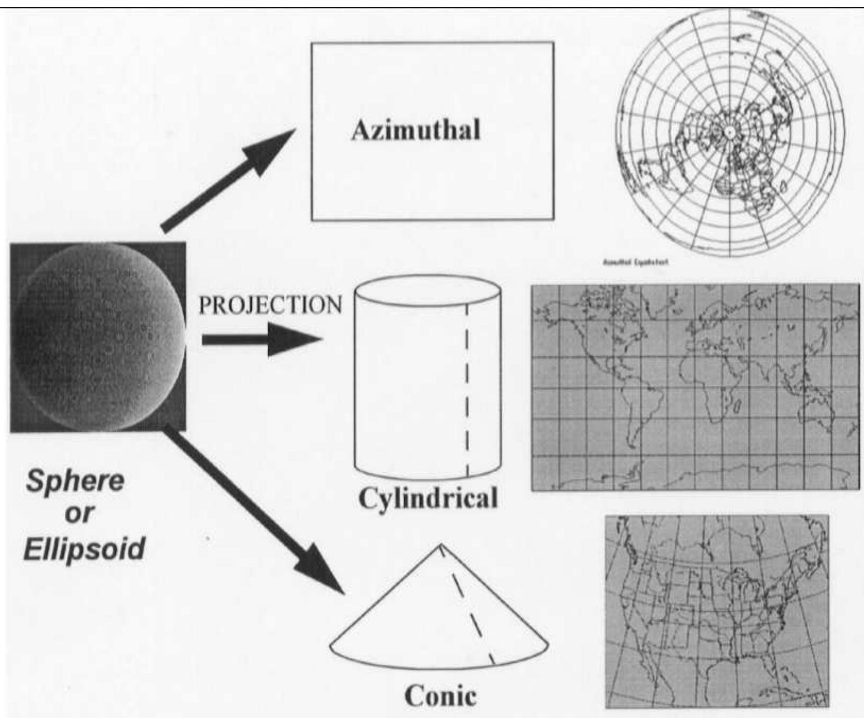

Figure 3.15: The earth can be projected in many ways, but basically into three shapes that can be unrolled into a flat map. A flat plane, a cylinder and a cone.

Figure of the Earth

- The common types are:
  - Plane: It assume the earth is flat (use no projection)
    - used for maps only intended to depict general relationships or for maps of small areas.
    - At scales larger than 1:10,000 planar representations has little effect on accuracy.
    - Planar projections are usually assumed when working with air photos.
  - Sphere: It assumes the earth is perfectly spherical thus does not truly represent the earth's shape.

Figure of the Earth

- Ellipsoid: This is the figure created by rotating an ellipse about its minor axis.
  - The ellipsoid models the fact that the earth's diameter at the equator is greater than the distance between poles, by about 0.3%.

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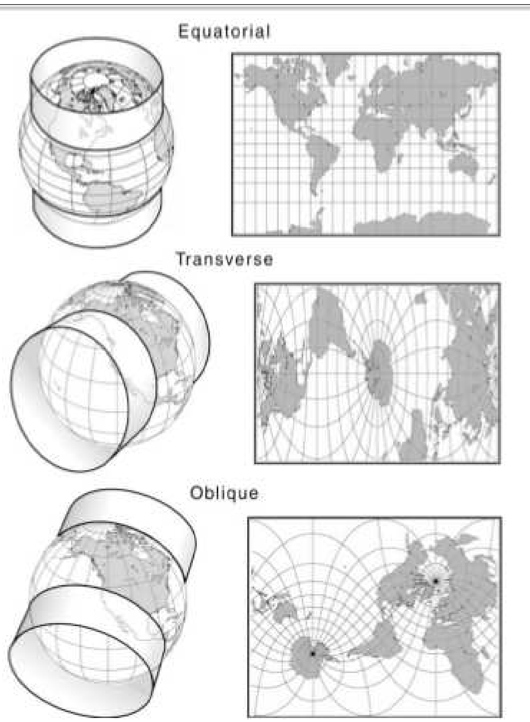

Figure 3.16: Variations on the Mercator projection shown as **Secant**.

Planar or Azimuthal Projections

- A flat sheet is placed in contact with a globe, and points are projected from the globe to the sheet.
- Mathematically, the projection is easily expressed as mappings from latitude and longitude to polar coordinates with the origin located at the point of contact with the paper.

Planar or Azimuthal Projections

- The examples are:
  - Stereographic projection
  - Gnomic projection
  - Lambert's azimuthal equal-area projection
  - Orthographic projection

Conic Projections

- The transformation is made to the surface of a cone tangent at a small circle (tangent case) or intersecting at two small circles (secant case) on a globe.

- Mathematically, this projection is also expressed as mappings from latitude and longitude to polar coordinates, but with the origin located at the apex of the cone.

Conic Projections

- The examples are:
  - Alber's conical equal area projection with two standard parallels
  - Lambert conformal conic projection with two standard parallels
  - Equidistant conic projection with one standard parallel

Cylindrical Projections

- These projections are developed by transforming the spherical surface to a tangent or secant cylinder.
- Mathematically, a cylinder wrapped around the equator is expressed with x equal to longitude, and the y coordinates some function of latitude.
- The Example is Mercator projection.

Non-Geometric Projections

- Some projections cannot be expressed geometrically, they have only mathematical descriptions.

- The examples are Molleweide and Eckert etc.

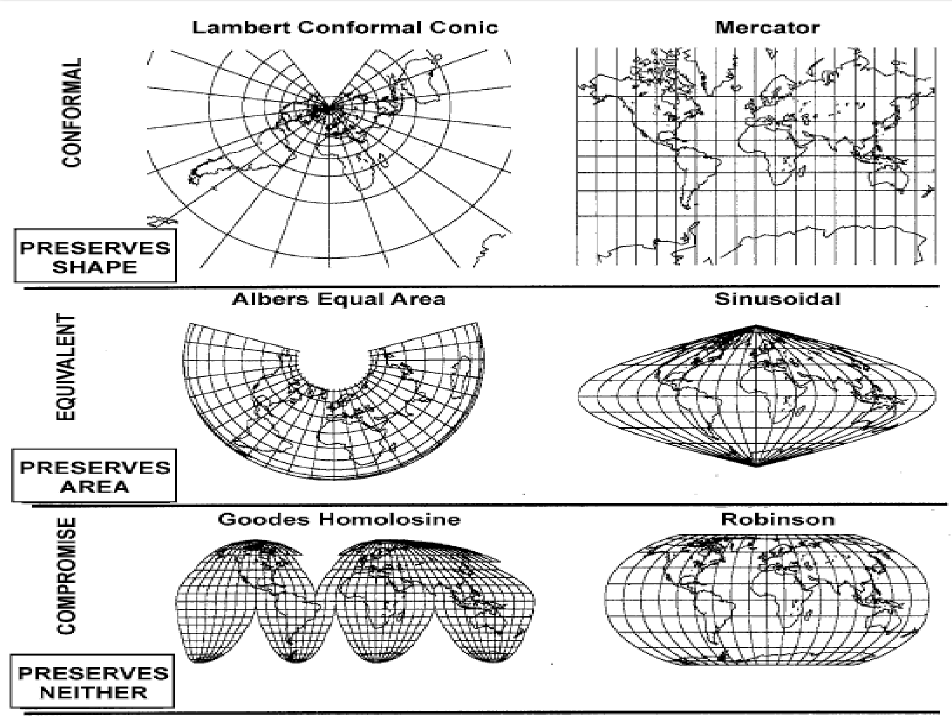

Figure 3.17: Examples of projections classified by their distortions.

Table 3.6: Common map projections: Their properties and their application areas.

Projection	Properties	Application
Albers equal area	Equal area: conformal along standard parallel	Small regional and national maps
Azimuth equidistant	Equidistant: true direction from centre	Air and sea navigation, large scale maps in the equatorial areas.
Lambert conformal conical	Conformal: locally true direction	Navigation, US – state plane system
Mercator	Conformal: true dirction	Navigation, world maps
Equidistant conical	Equidistant along standard parallel and central meridian	Mid latitude areas with east – west extent, atlas mapping for smaller countries
Polyconic-conical	Equidistant along each parallel and central meridian	Topographic maps, Survey of India maps, USGS
Sinusoidal-cylindrical	Equal area, true direction along central meridian and equator	World maps
Stereographic-planar	Conformal: true direction	Navigational maps
Transverse Mercator–cylindrical	Conformal: locally true direction	Topographic mapping for areas with north south extents

Geometric Analogy

- The most common methods of projection can be conceptually described by imagining the developable surface

- Which is a surface that can be made flat by cutting it along certain lines and unfolding or unrolling it.

Geometric Analogy

- If the developable surface touches the globe, the projection is called **tangent**
- and if the surface cuts into the globe, it is called **secant**.
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Geometric Analogy

- **Conformal (Orthomorphic) Projections:** A projection is conformal if the angles in the original features are preserved
- over small areas the shapes of objects will be preserved.
- Preservation of shape does not hold with large regions (i.e., Greenland in Mercator projection).

Geometric Analogy

- **Equal Area (Equivalent) Projections:** The representation of areas is preserved so that all regions on the projection will be represented in correct relative size.

- Equal area maps cannot be conformal, so most earth angles are deformed and shapes are strongly distorted.

Geometric Analogy

- **Equidistant Projections:** We cannot make a single projection over which all distances are maintained.

- Thus, equidistant projections maintain relative distances from one or two points only

- i.e., in a conic projection all distances from the center are represented at the same scale.

Universal Transverse Mercator (UTM)

- UTM provides georeferencing at high levels of precision for the entire globe.
- Established in 1936 by the International Union of Geodesy and Geophysics
- It is adopted by many national and international mapping agencies.
- It is commonly used in topographic and thematic mapping, for referencing satellite imagery and as a basis for widely distributed spatial databases.

Universal Polar Stereographic (UPS)

- The Universal Polar Stereographic (UPS) coordinate system is used in conjunction with the Universal Transverse Mercator (UTM) coordinate system to locate positions on the surface of the earth.
- Like the UTM coordinate system, the UPS coordinate system uses a metric-based cartesian grid laid out on a conformally projected surface.

Universal Polar Stereographic (UPS)

- UPS covers the Earth's polar regions, specifically the areas north of 84° N and south of 80° South, which are not covered by the UTM grids
- plus an additional 30 minutes of latitude extending into UTM grid to provide an amount of overlap between the two systems.

Universal Polar Stereographic (UPS)

- The UPS system uses a stereographic projection.
- It is conformal, meaning that it preserves angles.
- Specifically, the projection used in the system is a secant version based on an elliptical model of the Earth

Q & A

- Thanks