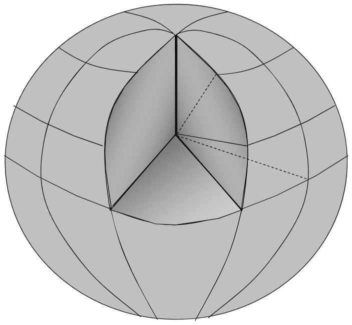
Geographic Coordinate System



Great Circle Distance
(For the geographic grid coordinate system)

cos *D* = (sin *a* * sin *b*) + (cos *a* * cos *b cos |δλ|)**

where

- ***a* and *b* are geographic latitudes of *A* and *B*.**
- **|δλ| is the absolute value of the difference in longitude between *A* and *B*.**

The *D* value will be in decimal degrees. Each degree represents 69 miles of great circle distance

Projections

Learning Objectives

- Describe the need for map projections
- Outline the two step process in making projections
- List projection methods and projection families
- Identify individual projections with that are appropriate for a given purpose
- Recognize some important grid systems used for mapping

Map Projections

- Why project?
  - Goal: Spherical earth to flat display (computer screen or paper map)
  - Principle: Project to a surface and then flatten that surface
  - The generalized functional relationships (GC to rectangular)
    - $x = f_1(\phi, \lambda)$
    - $y = f_2(\phi, \lambda)$

Steps in Projection

1. Imaginary (mathematical, if you will) representation
   - Actual globe to *reference* globe (based on desired scale)
   - Principal scale – Representative faction (RF) for *reference* globe
     - *1:x* where *x* = (Radius of Earth / Radius of Ref Globe)
2. Project reference globe to flat map
   - Flat map has its own scale (actual scale)
   - Scale factor = actual scale (of flat map) / principal scale (of ref globe)
     - SF will vary with place on the globe

Projection Methods

- Cylindrical
  - Cylinder is assumed to surround the transparent reference globe
  - Cylinder touches the ref globe around equator
- Conic
  - A conic is placed over the ref globe in such a way that the apex of the cone is exactly over the polar axis
  - The cone touches the ref globe at *standard parallel.*
  - Along this standard parallel, the scale is correct and the distortion is the least
- Planar or Azimuthal Projection
  - A plane is placed on the ref globe so that it touches the North or South Pole

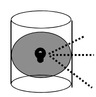
Aspects of Map Projections

- The Normal Aspect
  - Axis of cylinder (or cone) is parallel to the polar axis
- Transverse Aspect
  - Axis of the cylinder (or cone) is at different direction from polar axis
  - Normally, the axis of cylinder is normal to polar access
- Oblique Aspect
  - The axis of the cylinder (or cone) is located somewhere between poles and equator

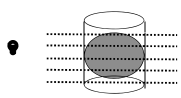
 Projections

Viewpoints of Map Projections

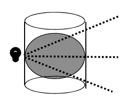
- Gnomonic projection
  - Light source at the center of the earth



- Orthographic projection
  - Light source from infinity



- Stereographic
  - Light source at far side of the globe



 Projections

Properties of Projections

- With any projection, one or more of these properties will have to be compromised (or lost)
  - Area
  - Shape
  - Distance
  - Direction

 Projections

Projection Families

- Equal Area (*a.k.a* equivalent) projections
  - Achieved by distorting the shape
  - Employed to show spatial distributions and relative spaces of special features
  - Examples:
    - Albers Equal-Area Conic
    - Lambert Azimuthal Equal-Area
    - Sinusoidal Equal-Area

Projection Families (2)

- Shape (*a.k.a.* conformal or orthomorphic)
  - Shape is preserved by making the scale along the meridian and the parallel the same in both directions. (meridians intersect parallels at 90^0)
  - Distorts both area and distance
    - Compare Greenland and South America in a conformal projection)
  - Examples
    - Mercator
      - Belongs to cylindrical class
      - very popular and has variants
    - Lambert Conformal Conic (conic type)

Projection Families (3)

- Distance (Equidistant)
  - The distance between two points measured on the map is equal to that between the same two points measured on the Earth's surface and scaled
  - Maintaining equidistance in all directions – impossible
    - Distances can be measured accurately in only one direction (a.k.a. line of true scale)
    - Lines of true-scale
      - Central meridian for cylindrical class
      - Standard parallel for conic class
  - The equidistance property is sensitive to scale change
    - Increase the scale, measurement offline of true-scale – erroneous
  - Examples
    - Azimuthal Equidistant
    - Equidistant Conic

Projection Families (4)

- Direction (Azimuthal class)
  - Azimuthal = all meridians pass through the pole
  - Direction measurements made on the map are the same as the ones made on the ground
  - Direction can be preserved along with one or two of (area, distance, and shape)
    - One exception – true direction in conformal *cum* azimuthal is not true direction. Here accurate directions are obtainable in one or two directions only
  - Examples
    - Lambert Azimuthal Equal-Area

Property Preservation

PROJECTED GRID OF GRATICULE	SCALE		PROPERTIES			
	Parallel	Meridian	Area	Shape	Distance	Direction
	Correct	Correct	Preserved	Preserved	Preserved	Preserved

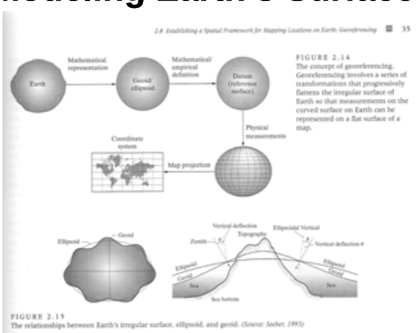
Property Preservation - 2

PROJECTED GRID OF GRATICULE	SCALE		PROPERTIES			
	Parallel	Meridian	Area	Shape	Distance	Direction
	Doubled	Halved	Preserved	Distorted	Distorted	Preserved only along parallels & Meridians
v	Correct vertical interval (*v*)	Distorted	Preserved	Distorted	Preserved E-W; slightly distorted N-S	Preserved only along parallels

Map Projections

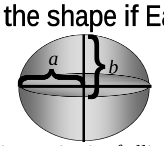
- Several internet resources provide extensive details on Projections. Examples:
  - http://geography.about.com/library/weekly/aa031599.htm
  - http://www.btinternet.com/~se16/js/mapproj.htm
  - http://members.shaw.ca/quadibloc/maps/mpse04.htm
  - http://lazarus.elte.hu/~guszlev/vet/

Modeling Earth's Surface



Components of Spatial Framework

- Projection mechanism
- Models to represent the shape if Earth
  - Ellipsoid
  - Geoid
- Datums
  - Geodetic
  - Vertical



a = major semi axis of ellipsoid (equatorial radius)

b = minor semi axis of ellipsoid (polar radius)

$f = (a - b) / a$ = polar flattening

$1/f$ = inverse flattening

Datum

- Accurate measurements depend on a reliable starting point
  - Datum is that starting point
- Geodetic datum
  - Established to provide positional control for surveying and mapping projects
  - Defined by five elements:
    - Longitude and latitude (or other systems)
    - Orientation of geodetic network
    - Ellipsoid/geoid parameters (major semi axis and flattening)

Datum – 2

- Geodetic datums
  - Global geodetic datums
    - Developed for georeferencing based on a single point – center of Earth.
  - Local geodetic datum
    - Based on ellipsoids that best fit Earth's surface
    - Established to reference a country or a group of neighboring countries
    - Most popular datum – North American Datum (NAD)
    - Origin of NAD27: Meades Ranch, Kansas
    - Origin of NAD83: Center of mass of earth

Datum – 3

- Vertical Datum
  - It is the *zero surface* from which all elevations or heights are measured.
    - Example:
- HW assignment:
  - What are the differences between NAD27 and NAD83 in terms of:
  - Reference ellipsoid parameters (i.e. *a, b, and f*)
  - Datum origin
  - Longitude origin
  - Azimuth orientation
  - Best fitting (where it suits the best)

Grid Systems

- Tradition
  - We usually give *x* (longitudes) values first and then *y* (latitudes) values
  - Be careful with the use of "Lat-longs" – which is a colloquial reference
- When map is oriented with North at top
  - To your right – from (0,0) – are x values, called *eastings*
  - *y* values are called *northing*s
- Allows the user to read first right and then upward – a.k.a. Right-up

Grid Systems – 2

- When the area is very large
  - Measuring from origin, which may be situated far away, may instill errors
  - To counted this: establish *false origins*
  - Measurements from false origins are
    - *False eastings*
    - *False northings*

Grid Systems – 3

- Popular grid systems
  - Universal Transverse Mercator (UTM)
    - Seven digit northings and six digit eastings (all in meters)
    - Most of the world except poles
  - Universal Polar Stereographic (UPS)
    - North and South poles only
  - The United States Plane Coordinate (SPC) system
    - Most states in two or more grids
    - Measured in feet

UTM – 1

- E-W: all Earth
- N-S: 80^0 S latitude to $84^{0\ N}$ Latitude
- 60 zones, each 6^0 longitude
- Numbering begins at IDT and counts eastward
- Each 6^0 zone is bisected by ***central meridian***

UTM – 2

- Each UTM zone is divided into horizontal bands spanning 8^0 latitude
  - Identified by letters A through X (except I and O)
  - Band X, the northern most, is 12^0
- Grid
  - Central meridian has a value of 500,000 m
    - Implies – false origin is 500,000 m to the west of central meridian
  - Eastings are referenced to the central meridian
  - Equator – northing value of zero (0) for Northern HS
  - Equator – northing value of 10^7 m for Southern HS

UTM Zone 18

State Plane Coordinate Systems

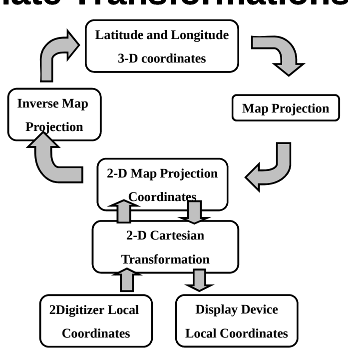
- Developed in the 1930s for conformal mapping system that would accommodate
  - Surveying
  - Mapping and
  - Engineering needs

  at state level
- Derived from three conformal projections
  - Transverse Mercator
  - Oblique Transverse Mercator
  - Lambert Conformal Conic

SPC Systems – 2

- Most of the states are divided into two or more zones
- Each zone is projected individually
  - Result: scale distortion of SPCS is kept within the accuracy of 1:10,000.
- Origin – extreme southwestern corner of the map (arbitrary)
- In general, the zone boundaries within a state follow county lines
- Most common SPCS these days uses NAD 83 [SPCS 83]

Coordinate Transformations



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  - http://members.shaw.ca/quadibloc/maps/mpse04.htm
  - http://lazarus.elte.hu/~guszlev/vet/

Next Week

- Elementary computer graphics
- Data models for GIS
- Databases – basics
- Data input
- Storage, and
- Editing