GIS's Roots in Cartography

Getting Started With GIS
Chapter 2

Following up on the last lecture…

2. New Geospatial Occupations

Occupation	Employment (2008)	Projected Growth (2008-18)	Growth Rate (2008-18)
Geospatial Information Scientists and Technologists*	209,000	72,600	7-13% (Average)
Geographic Information Systems Technicians*	209,000	72,600	7-13%
Remote Sensing Scientists and Technologists*	27,000	10,100	7-13%
Remote Sensing Technicians*	65,000	36,400	7-13%
Precision Agriculture Technicians*	65,000	36,400	7-13%
Geodetic Surveyors*	58,000	23,300	14-19%
Surveyors	58,000	23,300	14-19%
Surveying Technicians	77,000	29,400	≥ 20%
Mapping Technicians	77,000	29,400	≥ 20%
Cartographers and Photogrammetrists	12,000	6,400	≥ 20%
Totals	**857,000**	**339,900**	

Department of Labor Employment and Training Administration (2010). O*Net Online.
http://online.onetcenter.org/

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Information ordering: Lists and indexes

Organizing data and information

- Information can be organized as lists, numbers, tables, text, pictures, maps, or indexes
- Clusters of information called data can be stored together as a database
- A database is stored in a computer as files
- File systems are often hierarchical

The elements of GIS

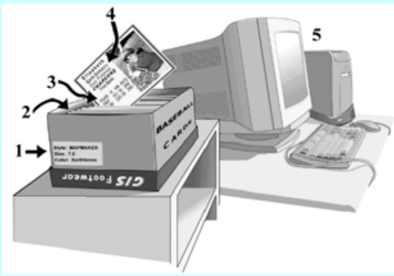


Figure 2.1 The elements of a GIS. (1) The database (shoebox); (2) the records (baseball cards); (3) the attributes (the categories on the cards, such as batting average, (4) the geographic information (locations of the team's stadium in latitude and longitude); (5) a means to use the information (the computer).

The GIS database

- A database handles information storage, retrieval and query
- In a database, we store attributes logically as column headers and records as rows
- The contents of an attribute for one record is a value
- A value can be numerical or text

Flat file database

	Attribute	Attribute	Attribute
Record	Value	Value	Value
Record	Value	Value	Value
Record	Value	Value	Value

Attributes have units

The GIS database (ctd)

- Data in a GIS must contain a geographic reference to a map, such as latitude and longitude
- The GIS cross-references the attribute data with the map data, allowing searches based on either or both
- The cross-reference is a link or index

Cartography and GIS

- Understanding the way maps are encoded to be used in GIS requires knowledge of cartography
- Cartography is the science that deals with the construction, use, and principles behind maps and mapping
- A map is a depiction of all or part of the earth or other geographic phenomenon as a set of symbols and at a scale whose representative fraction is less than one to one

Geodesy: Models of the earth

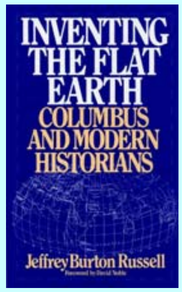
The earth can be modeled as a

- –sphere
- –oblate ellipsoid (“spheroid”)
- –geoid
- –flat surface

The Flat Earth Society

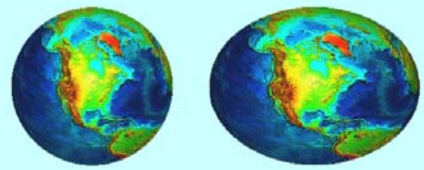
Homer, pre 900BC

http://www.ethicalatheist.com/docs/flat_earth_myth_ch8.html



Disclaimer: These maps are for entertainment use only!
Do not use for navigation purposes!

Earth Shape: Sphere and Ellipsoid (Spheroid)



Measuring the Ellipsoid

- Oblate ellipsoid predicted by Newton
- Existing triangulation along Paris meridian in France (Cassini-Prolate spheroid)
- French Academy of sciences sent expeditions to Lapland and Peru (now in Ecuador) to measure the length of a degree along a meridian
- La Condamine sent to Mitad del Mundo, Peru (Equador) (Bouguer, 3 deg.)
- Moreau de Maupertuis sent to Tornio River Valley, Finland

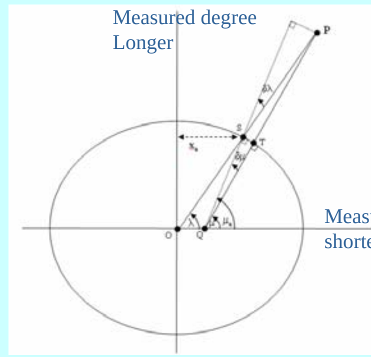
Measuring the Ellipsoid (ctd)

- Maupertuis reported a meridian degree as 57,437.9 toises (1 toise = 1.949 m)
- Meridian degree at Paris was 57,060 toises
- Concluded Earth was flatter at poles
- Measures were erroneous but conclusions were correct
- Published as “La Figure de la Terre” (1738)

La Figure de la Terre (1738)

MAUPERTUIS, M. de : La figure de la terre, déterminée par les observations. Amsterdam 1738.

Earth as Oblate Ellipsoid



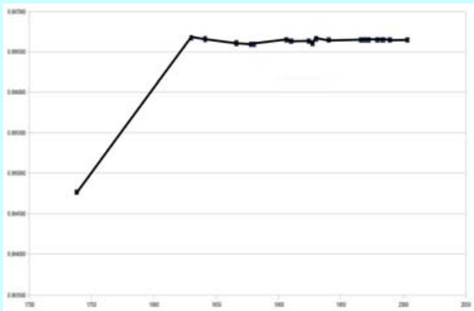
Maupertuis's Map

- River Tornio in modern Finland
- 14.3 km base line laid out on the ice
- Surveyed line by triangulation
- Anders Celsius, Swedish physicist, was a member, and had suggested solution by direct measurement

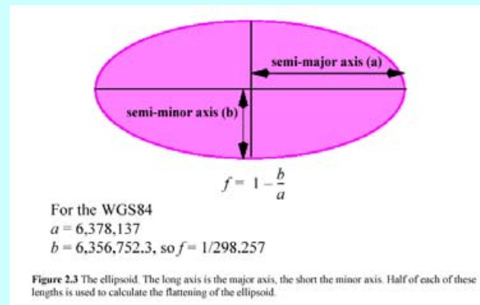
The spheroid and ellipsoid

- The sphere is about 40 million meters in circumference.
- An ellipsoid is an ellipse rotated in three dimensions about its shorter axis.
- The earth's ellipsoid is only about 1/298 off from a sphere (difference in circumferences is about 42km)
- Many ellipsoids have been measured, and maps based on each.
- Examples are NAD27, WGS84 and GRS80
- Major difference when earth-centered
- IERS: International Terrestrial Reference Frame

Closing in on a value (e) = 1-(1/f)



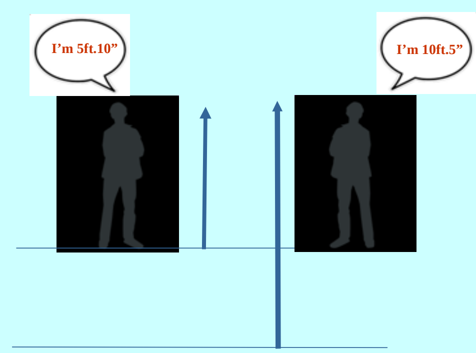
Earth as the WGS84 ellipsoid



What is a datum?

- Geodetic datums define the size and shape of the earth and the origin and orientation of coordinate systems used in mapping
- Hundreds of different datums have been used
- Datums have evolved from a spherical earth to ellipsoidal models derived from satellite measurements

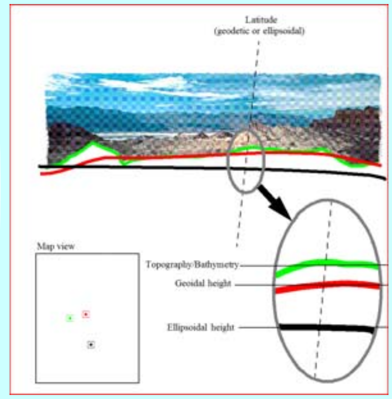
Datums matter



Datum

- While cartography, surveying, navigation, and astronomy all make use of geodetic datums, the science of geodesy is central
- Different nations and agencies use different datums as the basis for coordinate systems used in geographic information systems, precise positioning systems, and navigation systems
- Referencing geodetic coordinates to the wrong datum can result in position errors of hundreds of meters

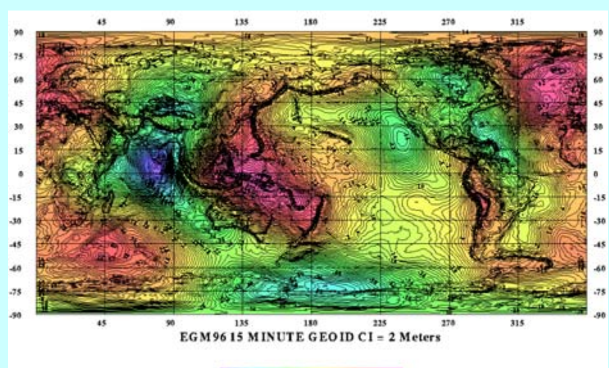
Earth models and datums



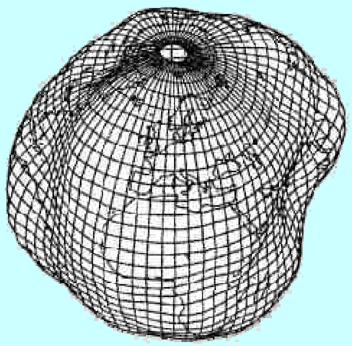
The datum and the geoid

- An *ellipsoid* gives the base elevation for mapping, called a datum
- Examples are NAD27 and NAD83
- The *geoid* is a figure that adjusts the best ellipsoid and the variation of gravity locally
- It is the most accurate, and is used more in geodesy than GIS and cartography
- Geoids are dynamic!

EGM96 geoid



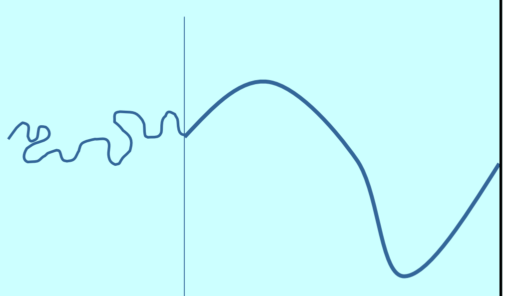
Geoid (exaggerated!)



Map scale

- Map scale is based on the representative fraction, the ratio of a distance on the map to the same distance on the ground
- Most maps in GIS fall between 1:1 million and 1:1000
- A GIS is scale-less because maps can be enlarged and reduced and plotted at many scales other than that of the original data
- To compare or edge-match maps in a GIS, both maps MUST be at the same scale and have a common extent
- The metric system is far easier to use for GIS work

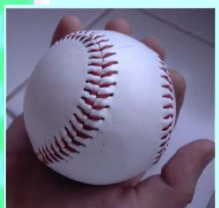
Why scale is an issue



Scale and accuracy

Degrees to 6 decimal places
1 degree approx 111,111m --- 0.000001 degree=11cm

Scale of a baseball earth



- Baseball circumference = 226 mm
- Earth circumference approx 40 million meters
- RF is : 1:177 million

Geographic coordinates—latitude and longitude

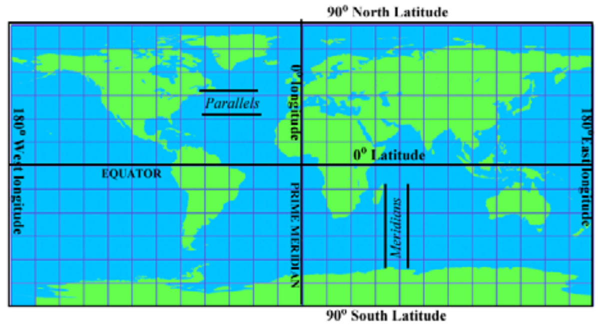


Figure 2.6 Geographic coordinates. The familiar latitude and longitude system, simply converting the angles at the earth's center to coordinates, gives the basic equirectangular projection. The map is twice as wide as high (360° east-west, 180° north-south).

The American Meridian

The International Meridian Conference (1884: Washington DC)

"That it is the opinion of this Congress that it is desirable to adopt a single prime meridian for all nations, in place of the multiplicity of initial meridians which now exist."

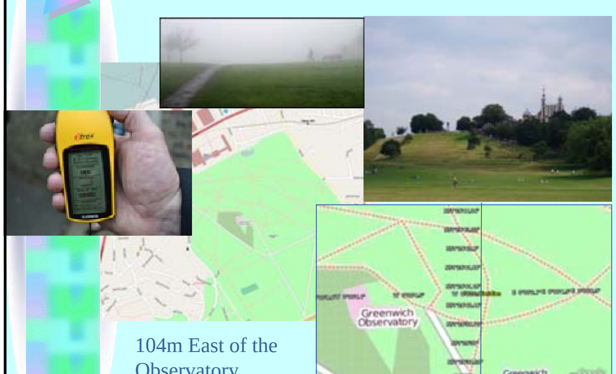
"That the Conference proposes to the Governments here represented the adoption of the meridian passing through the center of the transit instrument at the Observatory of Greenwich as the initial meridian for longitude."

"That from this meridian longitude shall be counted in two directions up to 180 degrees, east longitude being plus and west longitude minus."

The Prime Meridian (1884)

Greenwich observatory

Remember: datum changes location



104m East of the Observatory

Geographic coordinates

- Geographic coordinates are the earth's latitude and longitude system, ranging from 90 degrees south to 90 degrees north in latitude and 180 degrees west to 180 degrees east in longitude
- A line with a constant latitude running east to west is called a parallel
- A line with constant longitude running from the north pole to the south pole is called a meridian
- The zero-longitude meridian is called the prime meridian and passes through Greenwich, England
- A grid of parallels and meridians shown as lines on a map is called a graticule

Geographic coordinates as data

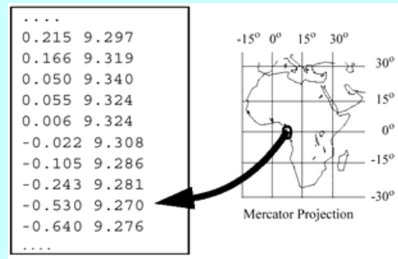


Figure 2.12 Part of the World Data Bank I listing of the coordinates of the coastline of Africa. Format is geographic coordinates in decimal degrees.

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

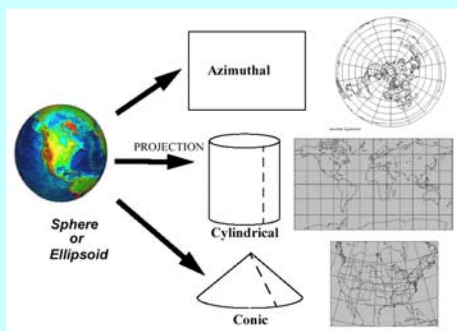


Figure 2.7 The earth can be projected in many ways, but basically onto three shapes that can be unrolled into a flat map: a flat plane, a cylinder, and a cone.

No flat map can be both equivalent and conformal

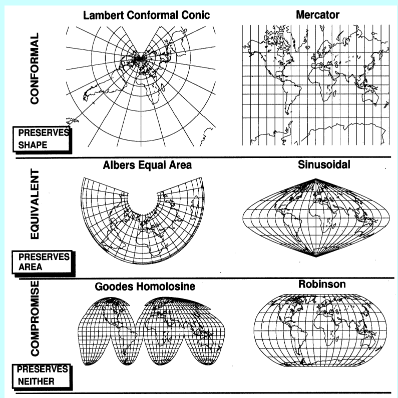


Figure 2.9 Examples of projections classified by their distortions. Conformal projections preserve local shape, equivalent projections preserve area, while compromise projections lie between the two. No projection can be equivalent and conformal.

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

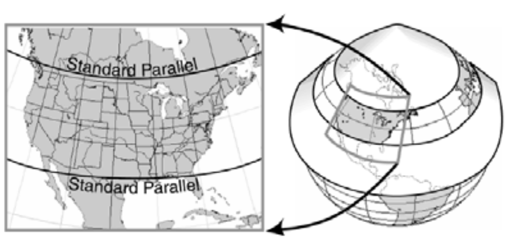


Figure 2.8 Standard parallels. The conic projection cuts through the globe, and the earth is projected both in and out onto it. This is a secant conic projection. Lines of true scale, where the cylinder and sphere touch, become standard parallels. If the touching is along one line, the projection is tangent and has one standard parallel.

Secant map projections

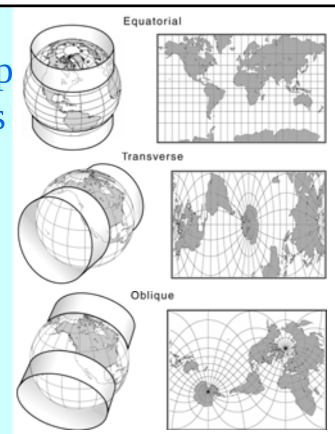
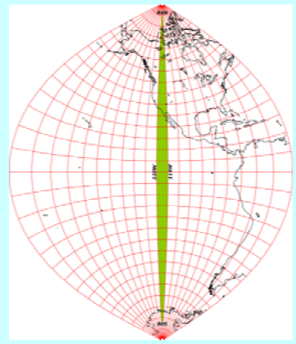


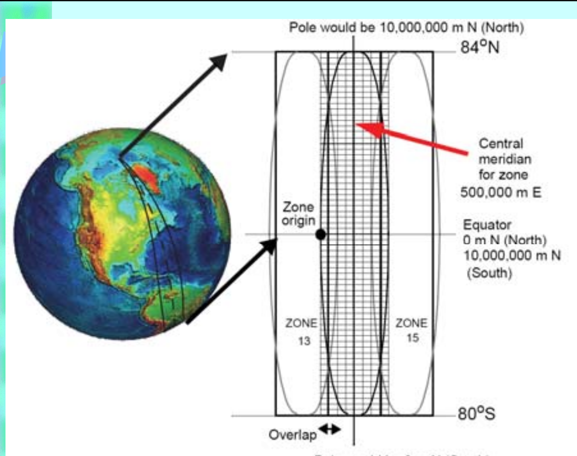
Figure 2.9 Variations on the Mercator (pseudocylindrical) projection shown as secant

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, we want earth coordinates
- 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

The advantage of the transverse Mercator projection

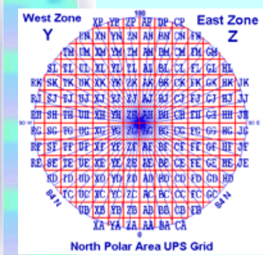


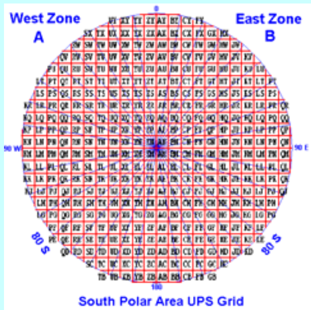


Example, CN Tower in Toronto

- **630084E; 4833438N 17N**

Universal Polar Stereographic (UPS)

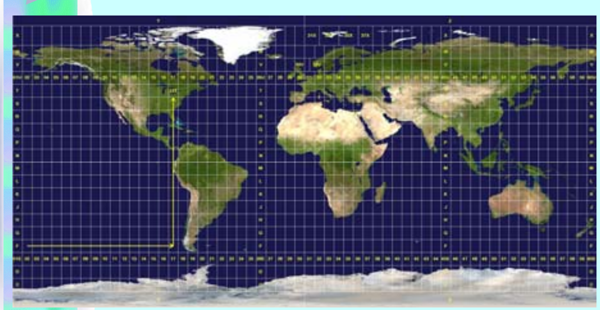




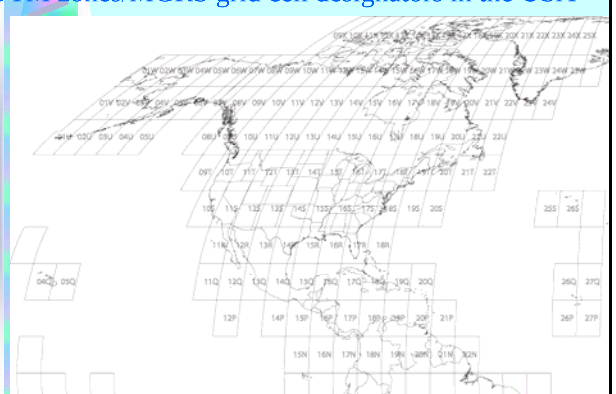
Coordinate Systems for the US

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

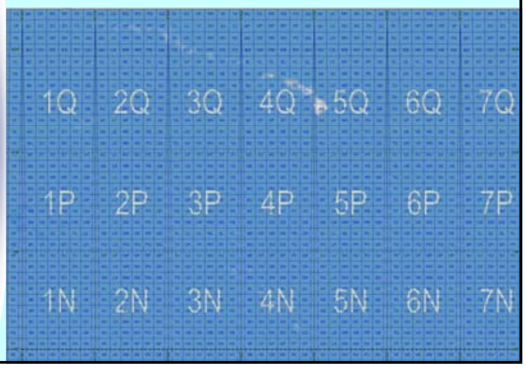
Military Grid Coordinates



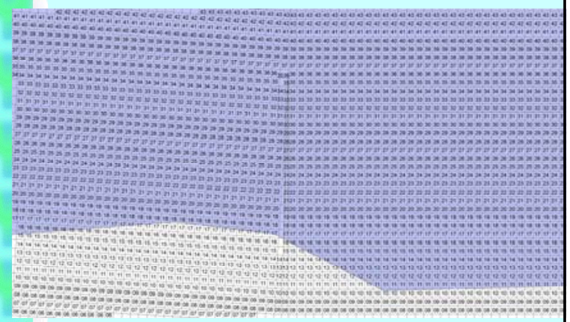
UTM zones/MGRS grid cell designators in the USA



USMG: Grid cell designators and 100,000m cells



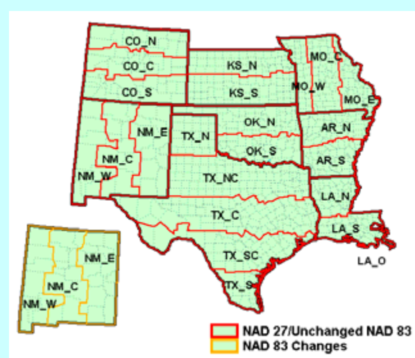
USMG WGS84 / National Grid (NAD83)



State Plane Coordinates

Zones:

Lambert conformal conic vs. transverse Mercator

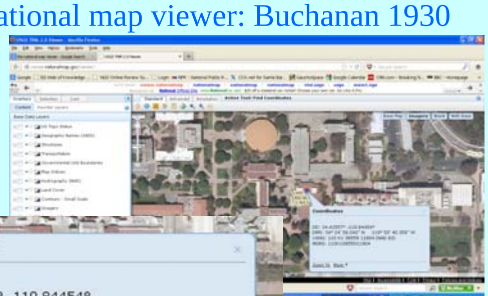


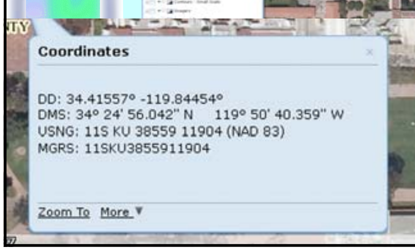
State plane for California

Coordinate examples

- **238,479 mE; 3,811,950 mN; 11, N**
- **11SKU3847911950**
- **N 34º24’57.24” W 119º50’42.9”**
- **603153 1830382 CA 5**

National map viewer: Buchanan 1930





State Plane NAD83 m
603114 1830446 CA 5

GIS minimum capability

- **A GIS package should be able to move and convert between:**
  - **map projections**
  - **coordinate systems**
  - **datums**
  - **ellipsoids**

Projection metadata

```
PROJCS["Teale_Albers",GEOGCS["GCS_North_American_1927",DATUM
["D_North_American_1927",SPHEROID["Clarke_1866",6378206.4,
294.9786982]],PRIMEM["Greenwich",0],UNIT["Degree",
0.017453292519943295]],PROJECTION["Albers"],PARAMETER
["False_Easting",0],PARAMETER["False_Northing",-4000000],
PARAMETER["Central_Meridian",-120],PARAMETER
["Standard_Parallel_1",34.0],PARAMETER["Standard_Parallel_2",40.5],
PARAMETER["Latitude_Of_Origin",0],UNIT["Meter",1]]
```

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

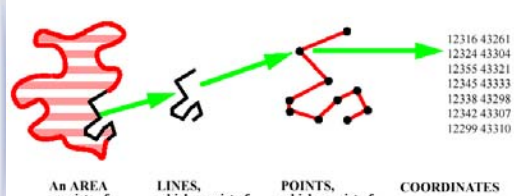
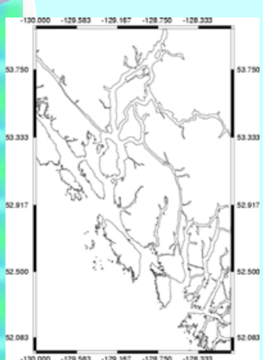
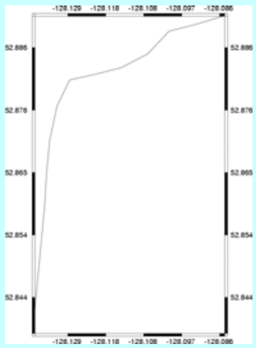


Figure 2.19 Geographic information has *dimension*. Areas are two-dimensional and consist of lines, which are one-dimensional and consist of points, which are zero-dimensional and consist of a coordinate pair.

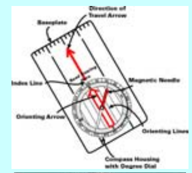
Example

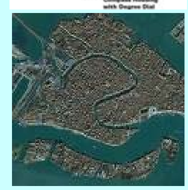




Properties of Features

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





Basic properties of geographic features

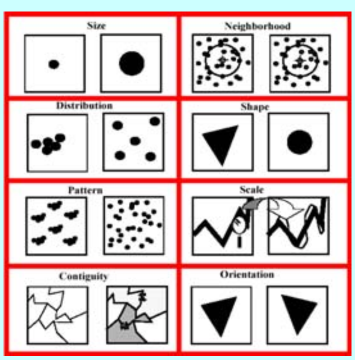
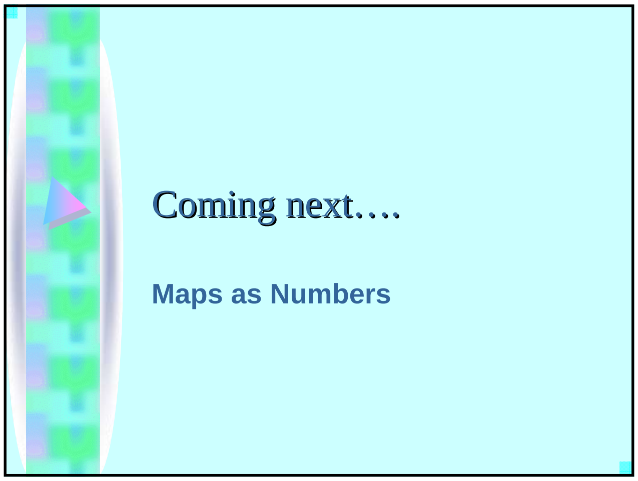


Figure 2.20 Basic properties of geographic features

GIS Analysis

- Much of GIS analysis and description consists of investigating the
  - properties of geographic features and
  - determining the relationships among them
- Shape, distribution, size, etc.
- Adjacency, proximity, intersection


Coming next….
Maps as Numbers