Lecture 04: Map Coordinates and Projections

(Chapter 2)

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Map scale and accuracy

Maps with larger map scale often has **lower accuracy!!!**

original slides: higher accuracy

More details → higher chance to be wrong!
Review

- Symbols - representation of geospatial information
- Map scales - granularity of geospatial information
- Model of the Earth - locating geospatial information
  - On the Earth
    - Geodesy
    - Geodetic datum
    - Geoid
      - Geographic coordinate system
  - On maps
    - Projected coordinate system
Review

Symbols

Map scales

Ellipsoid / Datum

Geoid
Overview

- Symbols - representation of geospatial information
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How to determine locations?

Geographic coordinates - latitude and longitude
Geographic coordinates

- Geographic coordinates are the Earth’s latitude and longitude system
- **Latitudes** range from 90 degrees south to 90 degrees north \([-90, 90]\]
- **Longitude** range from 180 degrees west to 180 degrees east in longitude \([-180, 180]\]
- 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 south pole is called a **meridian**
- The zero-longitude meridian is called the **prime meridian**.
- A grid of parallels and meridian shown as lines on a map is called a **graticule**
Prime Meridian

- The American Meridian

The American Meridian

To your left is the hemisphere of the Atlantic, the hemisphere of Europe and Africa, of Roman numerals and Indian script, of the Silk Road and the rising sun.

To your right is the hemisphere of the Pacific and the American West, the hemisphere of Japan and China, of calligraphy and rocketry, of towering volcanoes and the starry night.

Beneath your feet is the line that divides the two.

From 1848 to 1884, the United States of America marked the center of its world at this line. Before it accepted the Meridian at Greenwich, England, as the "Prime Meridian," the United States separated the world into eastern and western hemispheres along the American Meridian, a line that originated at the old U.S. Naval Observatory and passed through this point.

This Meridian was used to survey the western states, and the straight borders of those states are measured in integral degrees from this point.

- Wyoming Eastern Border: 29 Degrees (Am.) West
  - Western Border: 36 Degrees (Am.) West
  - Colorado Eastern Border: 27 Degrees (Am.) West
  - Western Border: 34 Degrees (Am.) West
  - Oregon Eastern Border: 42 Degrees (Am.) West

Also borders of Arizona, California, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North and South Dakota, Utah, and Washington.

Stephen Joel Trachtenberg
President
June 2000

American Eastern Hemisphere American Western Hemisphere
Prime Meridian

- Greenwich Observatory
Prime Meridian

- (0, 0) based on the **American Meridian** is not the same as the (0,0) based on the **Prime Meridian at Greenwich**

- In 1884 at Washington DC, the International Meridian Conference suggest the one at **Greenwich Observatory** to be the standard Prime Meridian.

“*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)
Zero meridian of WGS84

WGS84 meridian of zero longitude is about 102 m east of the Observatory

Why?
Why?

Tools to measure the Earth changed!

Astronomical way → Space way
Coordinate systems

- How to represent geospatial data on map?
  - A coordinate system is a standardized method for assigning codes to locations so that locations can be found using the codes alone

Step 1: Mapping data onto the Earth surface
Geographic Coordinate System (GCS)

Step 2: Projecting data onto a flat map
Projected Coordinate System (PCS)
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.
Geographic coordinate systems

- Have:
  - Datum (shape & origin of spheroid)
  - Prime meridian
  - Units

- Most common GCS:
  - WGS84
  - NAD83
  - NAD27
  - Your GPS → WGS84
Geographic coordinate systems

- It is critical to know the GCS of your data layers in GIS!

- Information about coordinate systems are stored in the .prj file in your project.
Overview

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GCS → PCS
Projected coordinate systems

- Geographic coordinates systems are based on ellipsoids
- To transform coordinates from GCS to a flat map, we need map projection
- **Map projection**: a transformation of the spherical or ellipsoidal Earth onto a flat map
Three main ways to project

- 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.
Secant projections

- Lines where the cuts take place (secant) have **no projection distortion**
Tangency projections

- Lines where the surface touches the globe (tangent) have no projection distortion
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.
Projection distortions

- 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

![Projections Diagram]

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.
Summary

What is GCS?

What is PCG?

What is coordinate systems?
Summary

What is GCS?

→ A GCS is defined by the parameters of the *datum* and *prime meridian*

What is PCS?

→ A PCS is defined by all the parameters of a GCS as well as a *map projection*

What is coordinate systems?

→ It is a general concept which include both GCS and PCS
Examples of coordinate systems ...
Coordinate systems

- **Global coordinate systems**: often use absolute locations based on the same reference point of the Earth
- **Local coordinate systems**: focuses on a sub-region of the Earth surface, and often use relative locations based on its own reference point
- In a coordinate system, the x-direction value is the *easting* and the y-value is the *northing*
- Most local coordinate systems make both easting and northing positive
Common coordinate systems in US

- Universal Transverse Mercator (UTM)
- Military grid reference system (MGRS)
- National grid
- State plane coordinate system

Again, to compare or edge-match maps in a GIS, both maps MUST be in the same coordinate system!
UTM coordinate system

- A PCS based on transverse Mercator projection
- Can be based on different GCS (e.g., NAD27 and NAD83)
- Widely used in the USGS topological maps
UTM coordinate systems

- Divides world into 6-degree-wide N-S strips
- Minimize distortion along strips
UTM coordinate systems

- Each zone cuts into the Earth surface (secant)
- Two cutting line with no distortion
- Origins of Northern and Southern zones are defined separately
  - Y value:
    - Southern zone: south pole
    - Northern zone: equator
  - X value:
    - Southern and Northern zones have the same value
    - A value outside the west limit of the zone, which makes the x of central meridian as 500,000 meters
- Unit is meters
Origins of UTM zones
Practice question:

- Ellison Hall is located at around \( (23846, 3811950) \) at Zone 11, Northern hemisphere in a UTM coordinate system:
  - What is the longitude range of the zone?
  - What is the longitude of the central meridian?
  - Is Ellison Hall to the west or to the east of the central meridian?
  - What is the approx. distance between Ellison Hall and the North Pole?
Central meridian for zone 500,000 m E
Equator 0 m N (North) 10,000,000 m N (South)
Zone origin
Overlap
Pole would be 0 m N (South)
Pole would be 10,000,000 m N (North)
Practice question:

- Ellison Hall is located at around (23846, 3811950) at Zone 11, Northern hemisphere in a UTM coordinate system:
  - What is the longitude range of the zone?
    - [114° west, 120° west] (6°×20-6° and 6°×20)
  - What is the longitude of the central meridian?
    - 117° west (114°+3°)
  - Is Ellison Hall to the west or to the east of the central meridian?
    - West (23846 meters is smaller than 500,000 meters)
  - What is the approx. distance between Ellison Hall and the North Pole?
    - About 10,000,000 meters - 3,811,950 meters = 6,188,050 meters
    - To south pole? About 10,000,000 meters + 3,811,950 meters = 13,811,950 meters
Military Grid Reference System (MGRS)

- Based on the UTM coordinate systems
- Adopted by the U.S. Army in 1947
- Used by many other countries and organizations
- Each south-north strip is divided into 20 cells (every cell covers 8 latitudes and 6 longitudes)
- These cells are named from letter C to letter X (letters A, B, I, O, Y, Z are not used)
Military Grid Reference System (MGRS)
MGRS grid cells

- Each cell is further divided into **squares** (100,000 by 1000,000 meters)
- A-Z has been used to label **west-east** direction
- A-V has been used for the **south-north** direction
- Letter I and O are not used
- One square can be labeled as “11SKU”
- Advantage: given a code, a computer can quickly locate it
National grid

- Very similar to MGRS
- Based on NDA83 datum (MGRS is based on WGS84)
- Focuses on the US
- Fine grids (each grid covers a small area)
- Representing codes can be very long
- E.g., “14R PU 21164 49875”
The representing codes are very long; only the last numbers are kept in the figure.
State plane coordinate systems (SPCS)

- For **individual states** in the US
- Locally defined with **local origins**
- Each state is arbitrarily divided into multiple zones
- Can be based on either **transverse Mercator** (if the zones are elongated in south-north) or **lambert conformal conic projection** (if the zones are elongated in west-east)
State plane coordinate systems (SPCS)

- Lambert conformal conic projection
Metadata about the coordinate system

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]]
Coordinate systems and GIS

- A GIS should be able to convert between coordinate systems
  - Add projection to convert GCS to PCS
  - Transform PCSs in different map projections
  - Transform PCSs or GCSs in different datums
Coordinate systems Summary

- Map projections and GIS
You tasks

- Finish Chapter 2
- Review slides
- Lab 1 due on Sunday, August 12th at 23:55 pm
Next week

- GIS data models (Chapter 3 and 4)