Geography 360: GIS & Mapping

Georeferencing I

Vaishnavi Thakar

UNIVERSITY of WASHINGTON

Summary from Last Week

- **From paper maps to digital representation**
- **The fundamental problem** (infinitely complex world; finite computer systems; limit the amount of detail captured.)
- **Discrete objects and continuous fields**
  - **Two fundamental ways of representing geography**
- **Raster and vector**
  - **two methods of representing geographic data in digital computers**
- **Representation, is a fundamental issue in GI**

Learning Objectives

- Know the requirements for an effective system of georeferencing.
- Be familiar with the problems associated with place-names, street addresses, and other systems used every day by humans to define locations that are important in their daily lives.
- Know how the Earth is measured and modeled for the purposes of positioning.
- Know the basic principles of map projections, and the details of some commonly used projections.
- Know about conversion between different systems of georeferencing.

Outline

- Introduction
- Place-names and points of interest
- Postal addresses and postal codes
- Linear referencing systems
- Cadasters and the US Public Land Survey System
- Measuring the Earth: latitude and longitude
- Projections and coordinates

Georeferencing

Georeferencing :

- refers to the ability to locate features accurately in geographic space.

- is essential in GIS, since all information must be linked to the Earth's surface

The primary requirements for a georeference are:

- ***Unique***

  linking information to exactly one location

  - **Smith Hall, 408 Skagit Ln, Seattle, WA 98195, USA**

- ***Shared***

  so different users understand the meaning of a georeference

  - **E.g., track shipping status**

- ***Persistent through time***

  so today's georeferences are still meaningful tomorrow

Earth as Seen from Space

a. Photograph of the Earth taken by the crew of NASA Apollo 17.

Georeferencing Systems

1. Place-names
2. Postal Addresses and Postal Codes
3. IP Addresses
4. Linear Referencing Systems
5. Cadasters
6. The Public Land Survey System (PLSS)
7. Latitude and Longitude
8. Projections and Coordinate Systems

Georeferencing Systems

1. **Place-names**
2. Postal Addresses and Postal Codes
3. IP Addresses
4. Linear Referencing Systems
5. Cadasters
6. The Public Land Survey System (PLSS)
7. Latitude and Longitude
8. Projections and Coordinate Systems

Place-names

- Any **distinctive feature** on the landscape can serve as a point of reference, and these are often **named.**
  - Oceans, continents, cities, towns, villages, mountains, rivers, and other prominent features.
- The **earliest form of georeferencing**

Detail of the Waldseemüller map of 1507, which for the first time showed the name the cartographer selected for the new continent

(Courtesy: Library of Congress Map Collection)

- The most **commonly used in everyday activities**
  - Conversation, newspaper, music (lyrics), and many other types of communication via Internet
    - E.g., UW instead of Smith Hall, 408 Skagit Ln, Seattle, WA 98195, USA
- Language **extends the power of place-names through words** like
  - “between”, “near”, or by the addition of directions and distances

Place-names

- **Limitations of Place-names**
  - **They often have very coarse spatial resolution e.g. "Asia " covers 43 million sq km.**
  - **Many names of geographic features are universally recognized. Others may be understood only by locals.** (e.g. UW)
  - **The meaning of certain place-names can become lost through time.** (e.g. name changes).
  - **One name corresponds to multiple features.**

There are many Londons, for example, besides the largest and most prominent one in the UK. People living in other Londons must often add more information (e.g., London, Ontario, Canada) to resolve ambiguity.

Unique ?

Shared ?

Persistent through time?

Place-names are not necessarily unique at the global level

Basemap courtesy: Google. Imagery copyright 2013 by NASA and TerraMetrics, map data copyright 2013 by MapLink and Tele Atlas

This map shows the locations of 40 places named Santa Barbara in the Geonames database (geonames.org). Additional information would be needed (e.g., limiting the search to California) to locate a specific Santa Barbara.

Georeferencing Systems

1. Place-names
2. **Postal Addresses** and Postal Codes
3. IP Addresses
4. Linear Referencing Systems
5. Cadasters
6. The Public Land Survey System (PLSS)
7. Latitude and Longitude
8. Projections and Coordinate Systems

Postal Addresses

- Postal addresses were introduced after the development of mail delivery in the 19th Century.
  - Delivery of mail, place of residence, or place of business.
    - e.g., Smith Hall, 408 Skagit Ln, Seattle, WA 98195, USA
- Postal addresses rely on several assumptions:
  - Every dwelling and office is a potential destination for mail.
  - Dwellings and offices are arrayed along streets, and numbered sequentially.
  - Streets have names that are unique within local areas.
  - Local areas have names that are unique within larger regions.
  - Regions have names that are unique within countries.
- If these assumptions are true, then a postal address is a useful georeference.

Where do Postal Addresses Fail as Georeferences?

- **Postal addresses fail in locating anything that is not a potential destination for mail.**
  - **For natural features**
    - **Lakes, mountains, and rivers cannot be located using postal addresses.**





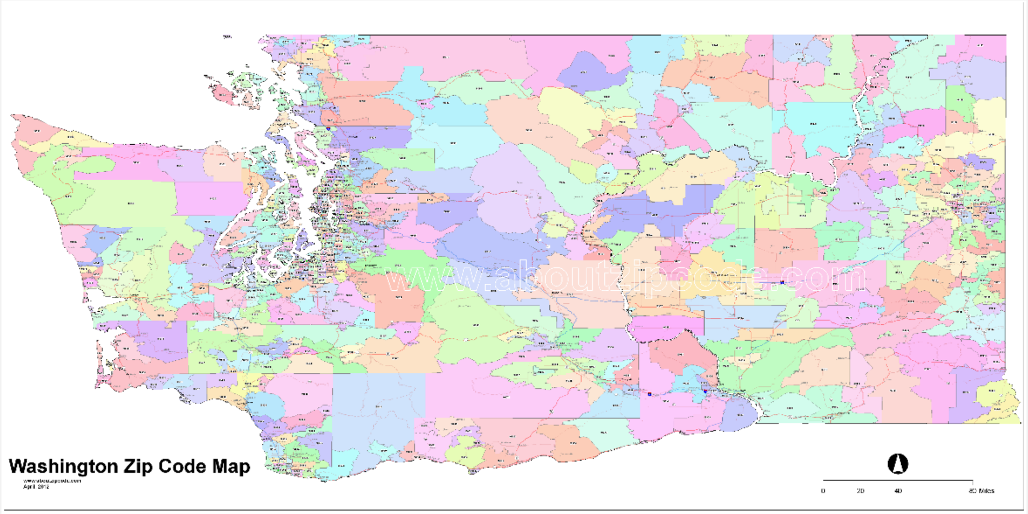
- **When numbering on streets is not sequential**
  - **E.g., Japan** *(Street numbers reflect date of construction ; Temporal rather than Spatial)*

Georeferencing Systems

1. Place-names
2. Postal Addresses **and Postal Codes**
3. IP Addresses
4. Linear Referencing Systems
5. Cadasters
6. The Public Land Survey System (PLSS)
7. Latitude and Longitude
8. Projections and Coordinate Systems

Postal Codes as Georeferences

- Postal codes were introduced in the late 20th century, which is useful for **sorting mails and mapping.**
  - **Coarser spatial resolution than postal address**
- **Defined in many countries**
  - **E.g. ZIP codes in the US**
  - **http://www.aboutzipcode.com/zip-code-map-Washington.html**



Georeferencing Systems

1. Place-names
2. Postal Addresses and Postal Codes
3. **IP Addresses**
4. Linear Referencing Systems
5. Cadasters
6. The Public Land Survey System (PLSS)
7. Latitude and Longitude
8. Projections and Coordinate Systems

IP Addresses

- **Every device (computer, printer, etc.) connected to the Internet has a unique IP (Internet Protocol).**
  - **E.g., 128.111.106.183**
- **The IP address allows the operators of major sites to determine the user's location.**

Geolocation is just one of the risk monitoring tools used

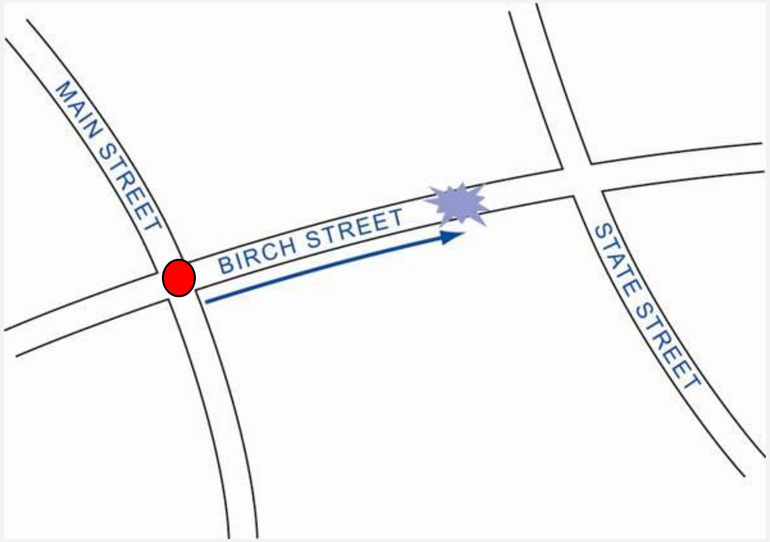
- The 2008 Edition of the CyberSource Online Fraud Report highlights that out of 318 online sellers surveyed an average 1.4 % of their orders are lost to **online fraud**, often resulting from buyers who **used credit card numbers** later identified as **stolen**.
- Each **IP address that can help** to further determine if users really are where they say they are.
- Equipped with this information, **e-merchants can use geolocation to flag suspect transactions and address them individually.**

Georeferencing Systems

1. Place-names
2. Postal Addresses and Postal Codes
3. IP Addresses
4. **Linear Referencing Systems**
5. Cadasters
6. The Public Land Survey System (PLSS)
7. Latitude and Longitude
8. Projections and Coordinate Systems

Linear Referencing

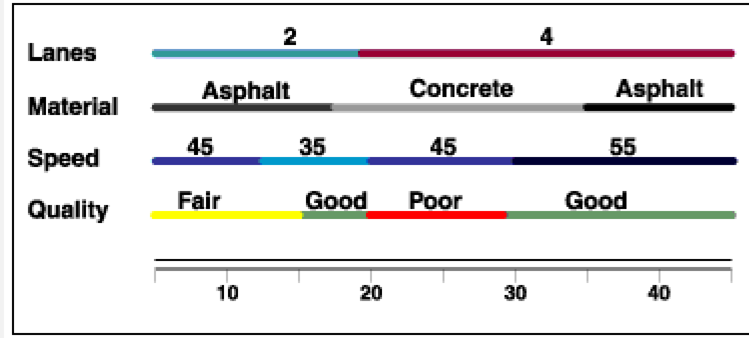
- **A system for georeferencing positions on a network (road, street, rail, or river network) by measuring distance from a defined point along a defined path.**
  - Is closely related to street address but uses an explicit measurement of distance.
  - Combines the name of the link with an offset distance along the link from a fixed point, most often an intersection.



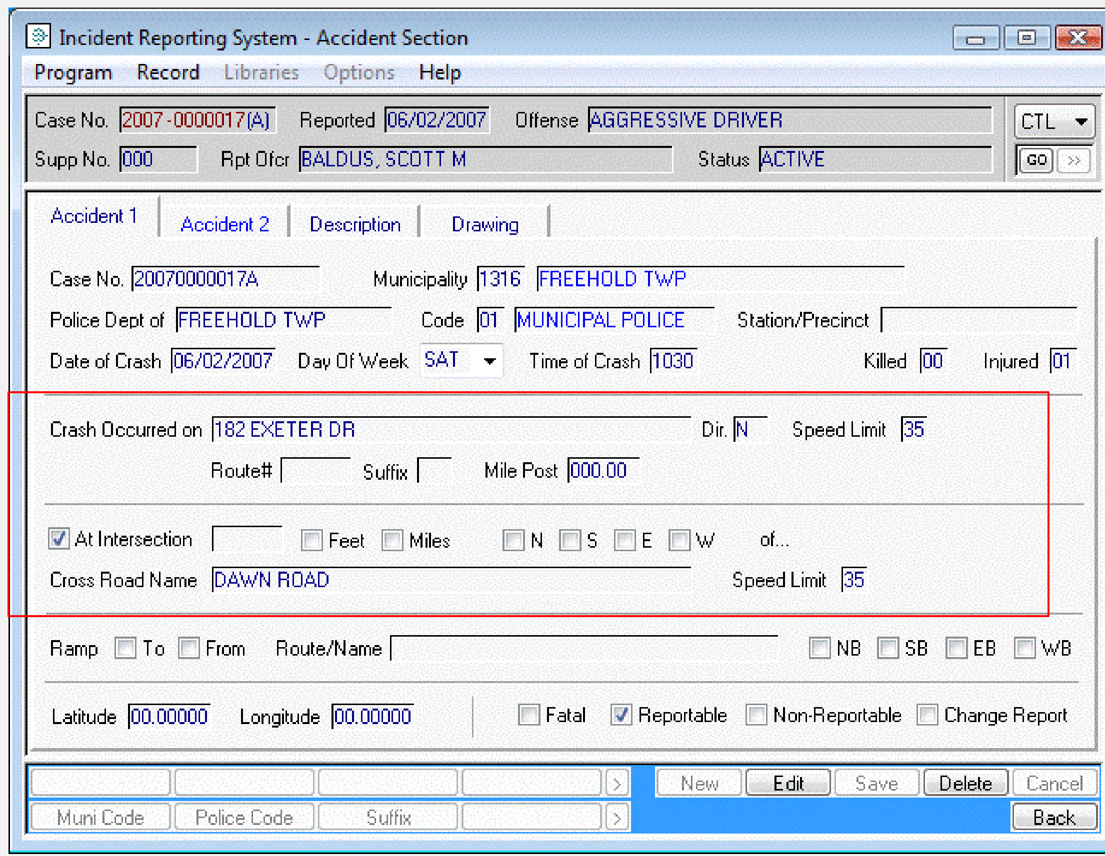
Linear referencing—an incident's position is determined by measuring its distance (87 m) along one road (Birch Street) from a well-defined point (its intersection with Main Street)

Users of Linear Referencing

- **Transportation authorities → To keep track of pavement quality, signs, traffic conditions on roads**



- **Police → To record the locations of accidents.**



- Used in applications that depend on a **linear network** . E.g. Transportation management, electricity transmission, pipelines, canals, dealing with emergencies.

Limitations of Linear Referencing

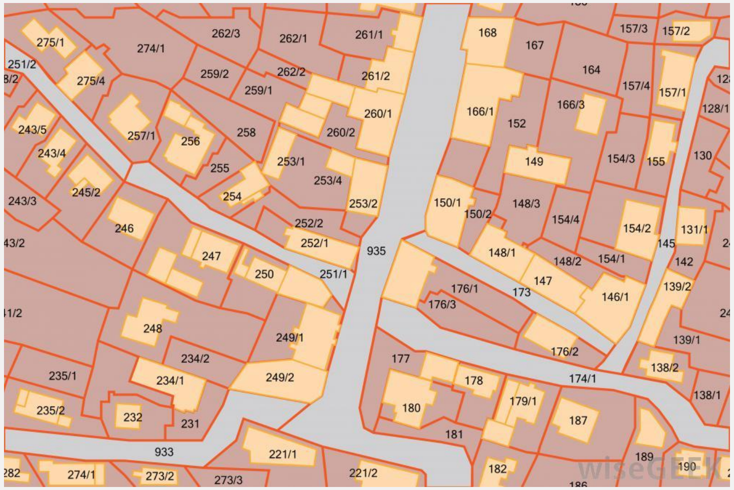
- **Problem Cases**
  - **Locations in rural areas may be a long way from an intersection .**
  - **Pairs of streets may intersect more than once.**
  - **Street intersecting with itself.**

Georeferencing Systems

1. Place-names
2. Postal Addresses and Postal Codes
3. IP Addresses
4. Linear Referencing Systems
5. **Cadasters**
6. The Public Land Survey System (PLSS)
7. Latitude and Longitude
8. Projections and Coordinate Systems

Cadasters

- The map of **land ownership** in an area, maintained for the purposes of taxing land, or of creating a public record of ownership.



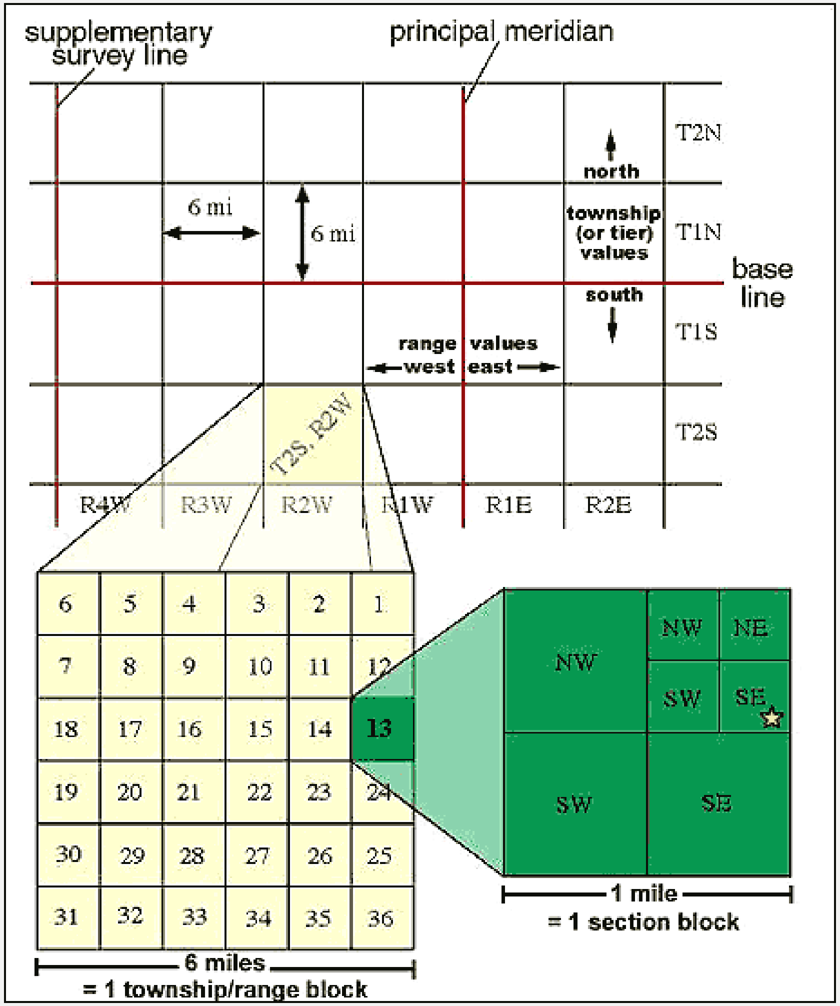
- Parcels of land
  - Are **uniquely identified** by number or code (PIN).
  - Are reasonably **persistent through time**.
  - But, very few people know the identification code of their home parcel. Thus, the use of the cadaster **is limited to local officials**.

Georeferencing Systems

1. Place-names
2. Postal Addresses and Postal Codes
3. IP Addresses
4. Linear Referencing Systems
5. Cadasters
6. **The Public Land Survey System (PLSS)**
7. Latitude and Longitude
8. Projections and Coordinate Systems

The Public Land Survey System (PLSS)

- **The Public Land Survey System (PLSS) defines land ownership over much of western North America**
  - Particularly for rural, wild, or undeveloped land.



Georeferencing Systems

1. Place-names
2. Postal Addresses and Postal Codes
3. IP Addresses
4. Linear Referencing Systems
5. Cadasters
6. The Public Land Survey System (PLSS)
7. **Measuring Location; Representing the Earth**
8. Latitude and Longitude
9. Projections and Coordinate Systems

Measuring Location

- **Before we can start to load data into GIS, we first need some sort of spatial framework that we can use to determine where in the world things are**
  - We need a system for measuring locations across the world
  - We need a method for translating that system onto a two-dimensional space
  - We need to understand what types of distortions that method introduces into our maps
    - Can have a huge effect not only on how things are visualized, but also on our spatial analysis!!!

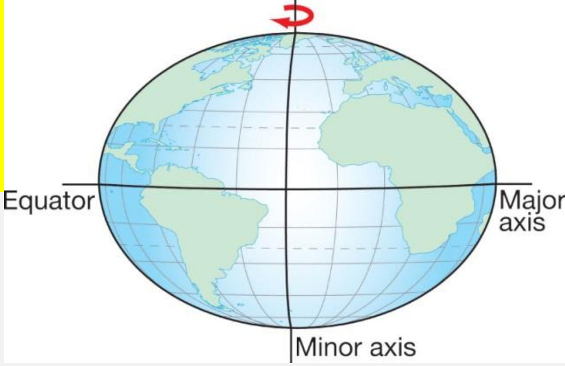
Representing the Earth: Topics

- **Geoid and Spheroids:** ***modeling the earth***
- **Latitude and Longitude:** ***position on the model***
- **Datums and Surveying:** ***measuring the model***
- **Map Projections:** ***converting the model to 2 dimensions***
- **Scale:** ***sizing the model***
  - ***cover under Data Quality***

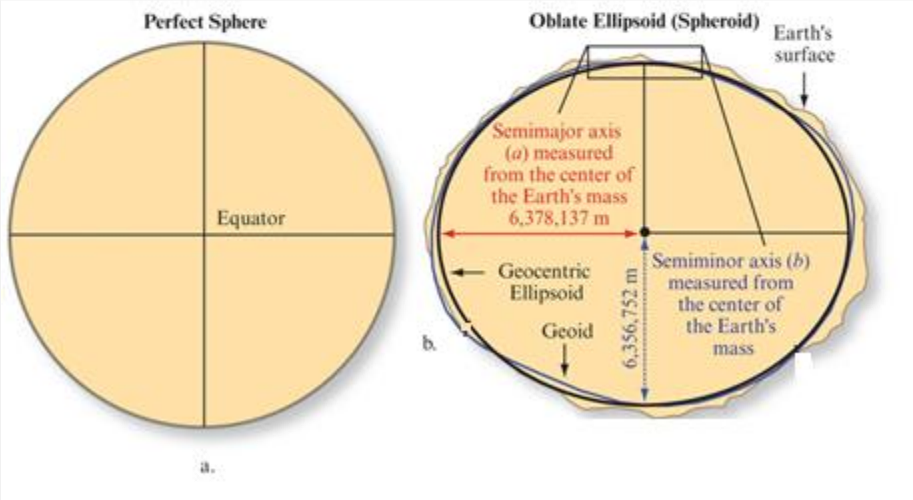
Measuring the Earth: Latitude and Longitude

- **Is the most powerful systems of georeferencing**
  - **Provide the potential for very fine spatial resolution**
  - **Allow distance to be computed between pairs of location**
  - **Support other forms of spatial analysis**
- **Is the most comprehensive**
- Often called ***geographic system of co-ordinates***

The Earth's Shape



- The Earth is not a perfect sphere, but slightly flattened
  - The N-S diameter is roughly 1/300 less than the E-W diameter



- $f = \frac{(a-b)}{a}$

- $f = \frac{(6378137-6356752)}{6378137} = 0.00335 \sim \frac{1}{300}$

- More accurately modeled as an ellipsoid than a sphere.

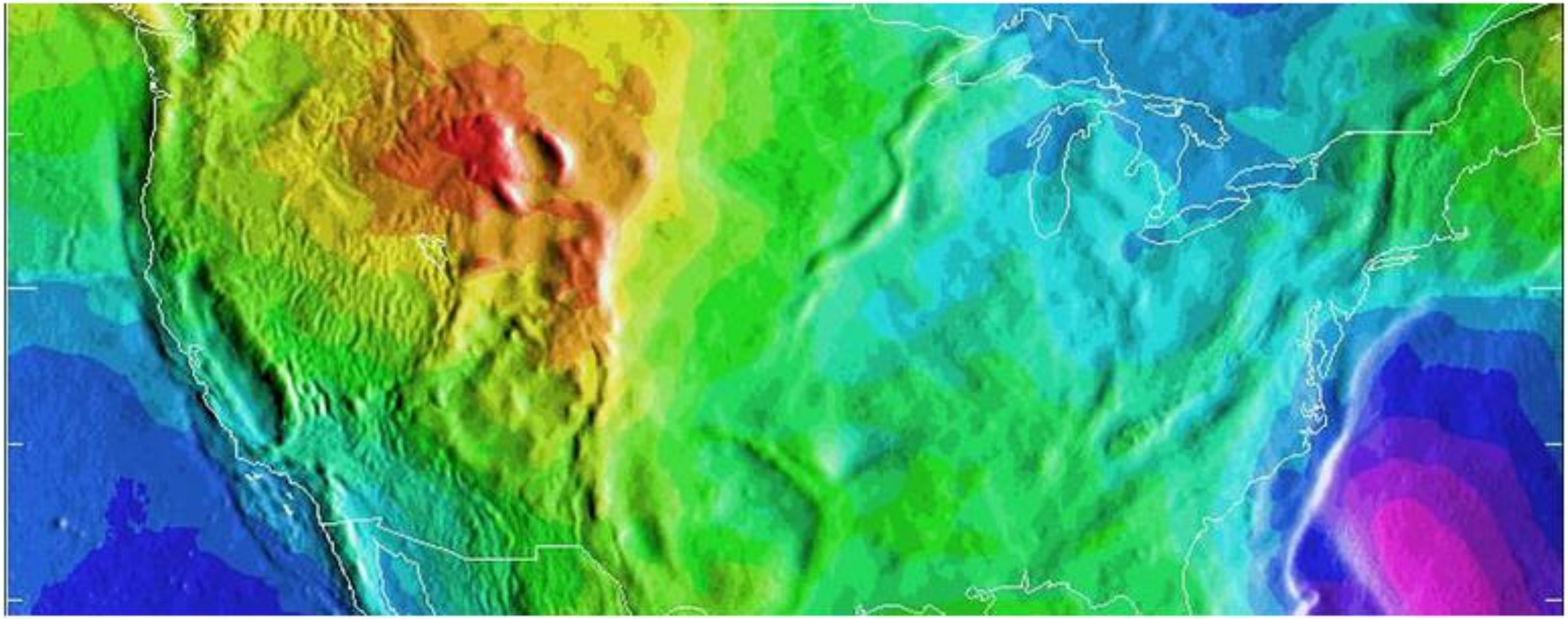
- An **ellipsoid** is formed by rotating an ellipse about its minor axis (corresponding to the axis of the Earth's rotation).

- the ellipsoid **assumes** that Earth's surface is **smooth.**

Geoid

- While we often think of the earth as a sphere, our planet is actually very bumpy and irregular.
- The radius at the equator is larger than at the poles due to the long-term effects of the earth's rotation. And, at a smaller scale, there is topography—mountains have more mass than a valley and thus the pull of gravity is regionally stronger near mountains.
- All of these large and small variations to the size, shape, and mass distribution of the earth cause slight variations in the acceleration of gravity (or the "strength" of gravity's pull). These variations determine the shape of the planet's liquid environment.
- This irregular shape is called "the geoid," a surface which defines zero elevation.
- To simplify the model, various spheroids or ellipsoids have been devised.

Geoid



A depiction of the United States geoid. Areas in yellow and orange have a slightly stronger gravity field as a result of the Rocky Mountains.

Source: National Oceanic And Atmospheric Administration (NOAA)

Ellipsoids

- Because the Earth is not shaped precisely as an ellipsoid, each country adopts its own as the most accurate approximation to its own part of the Earth.
- Without a single standard the maps produced by different countries using different ellipsoids could never be made to fit together.
- Today, an international standard has been adopted known as WGS84 (the World Geodetic System of 1984)
- ArcGIS supports over 50 different ellipsoids!

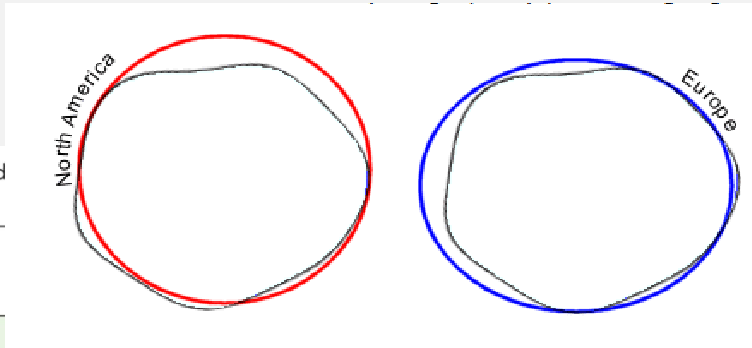


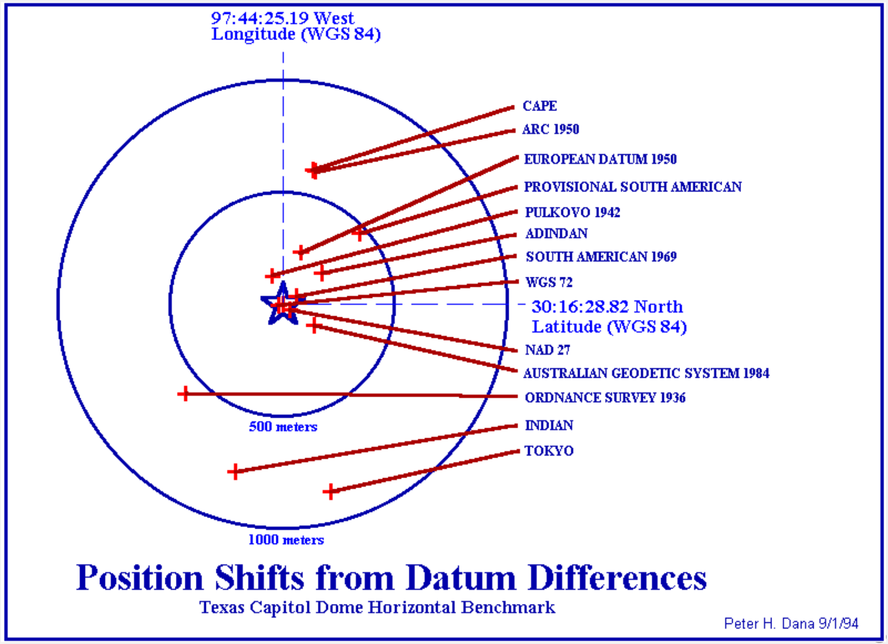
TABLE 2–1 Selected common ellipsoids used for regional, national, and international mapping and GIS applications (ad from Lo and Yeung, 2007; Leica Geosystems, 2008).

Ellipsoid	Semimajor axis, *a* (m)	Semiminor axis, *b* (m)	Use
Australian National 1966	6,378,160	6,356,774.719	Australia
Clarke 1866	6,378,206.4	6,356,584.467	North America
International 1924	6,378,388	6,356,911.946	Remaining parts of the world
GRS80: Geodetic Reference System 1980	6,378,137	6,356,752.3141	Adopted in North America for1983 Earth-centered coordinate system (satellite)
WGS84: World Geodetic System 1984	6,378,137	6,356,752.3142	Used with the Global Positioning System (GPS) and by NASA (satellite)
Nominal Radius of the Earth	6,370,997	6,370,997	A perfect sphere

A particular ellipsoid can be selected for use in a specific geographic area, because that particular ellipsoid does an exceptionally good job of mimicking the geoid for that part of the world.

Datum

- A datum is built on top of the selected ellipsoid (spheroid), and can incorporate local variations in elevation. With the spheroid, the rotation of the ellipse creates a totally smooth surface across the world. Because this doesn't reflect reality very well, a local datum can incorporate local variations in elevation.
- The datum provides a frame of reference for measuring locations on the surface of the Earth.
- Just as there are different ellipsoids for different parts of the world, there are different datums to help align the ellipsoid to the surface of the earth in different regions.
- A datum is chosen to align a ellipsoid (spheroid), to closely fit the Earth's surface in a particular area.

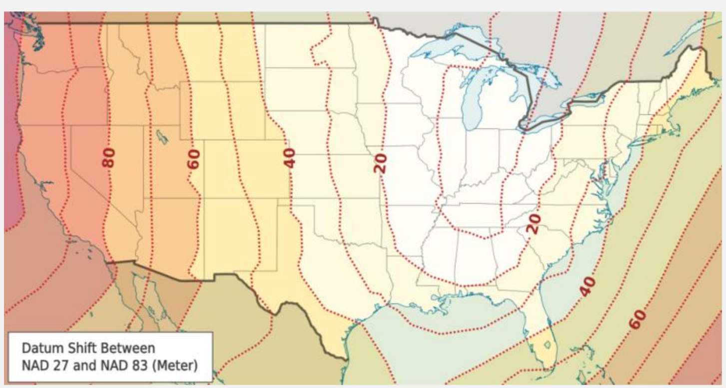


North American Datum (NAD)

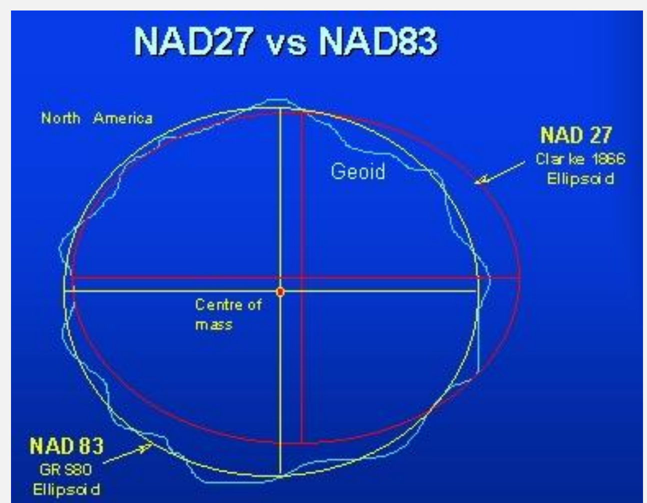
- In both the NAD 1927 and the NAD 1983 datums, the ellipsoids match the earth closely in one part of the world (North America) and is quite a bit off in others.
- Datums use different spheroids
  - Clarke 1866 for NAD27
  - GRS80 for NAD83

Ellipsoid	Semimajor axis, *a* (m)	Semiminor axis, *b* (m)	Use
Clarke 1866	6,378,206.4	6,356,584.467	North America
GRS80: Geodetic Reference System 1980	6,378,137	6,356,752.3141	Adopted in North America for1983 Earth-centered coordinate system (satellite)

- Datums use different origins.
  - For NAD 1927, the origin (Meades Ranch in Kansas) aligns the Clark 1866 spheroid with a point in North America.
  - For NAD 1983, the origin (the center of the earth) aligns the center of the spheroid with the center of the earth.



Points can differ up to 100m from NAD27



Datum

Datum	Longitude	Latitude
NAD 1927	-122.46690368652	48.7440490722656
NAD 1983	-122.46818353793	48.7438798543649
WGS 1984	-122.46818353793	48.7438798534299

The underlying datum and spheroid to which coordinates for a dataset are referenced can change the coordinate values. An illustrative example using the city of Bellingham, Washington follows. Compare the coordinates in decimal degrees for Bellingham using NAD27, NAD83 and WGS84. It is apparent that while NAD83 and WGS84 express coordinates that are nearly identical, NAD27 is quite different, because the underlying shape of the earth is expressed differently by the datums and spheroids used.

Source: ESRI

Datum

Danger in Using the Wrong Datum

Did you know that using the wrong datum can create an error of up to 200 or 300 meters on your map? In this fact sheet we explain what a datum is and make some recommendations about managing datums.

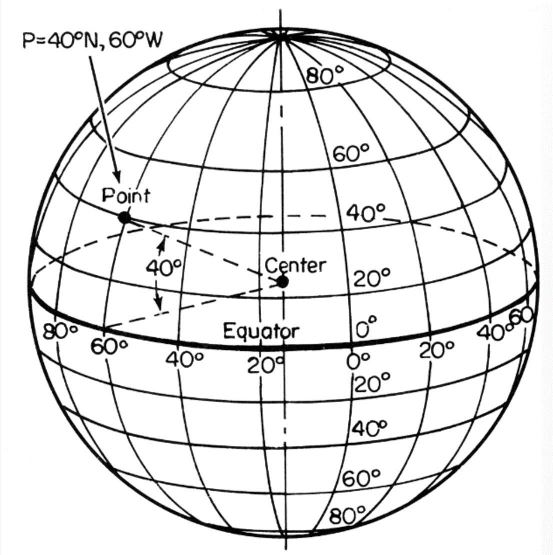
An example of datum error:

- In the map at the right, two teams have mapped minefield perimeters using GPS. They are for the same minefield, but when they are displayed on an air photo in a GIS, it is obvious that one of them is wrong.
- In this case, the lower one is in the wrong location. Why? Because the team that mapped it used the wrong datum. Their perimeter is 200 meters south of the correct location.
- Using the wrong datum usually results in errors of a few meters to several hundred meters. These kinds of errors are not as obvious as errors of 10,000 meters, so they may not be noticed, but they are important!

WGS84 – The International Standard

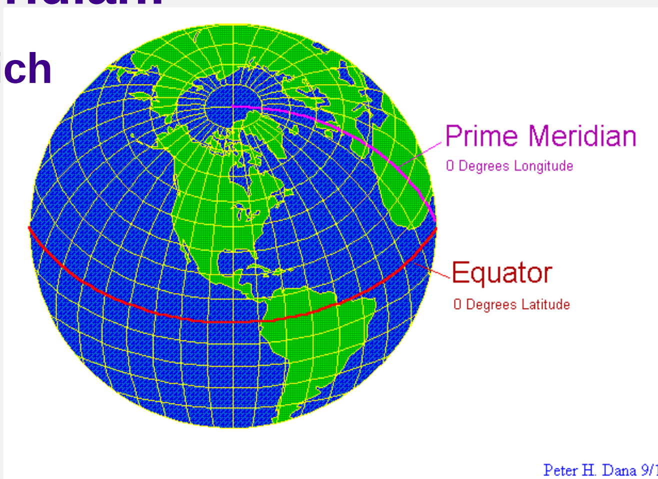
- **World Geodetic System of 1984**
  - Created in 1984, but updated in 1994 from GPS measurements.
  - Only major worldwide reference datum in place today.
  - Default standard datum for most commercial GPS.
  - A generalized earth-centered coordinate system (WGS84) provides a good overall mean solution for all places on the earth. However, for specific local measurements, WGS84 cannot account for local variations.
- **WGS84 VS NAD83**
  - Ellipsoid
    - NAD83: GRS80
    - WGS84: WGS84
  - One fundamental difference is that NAD83 is defined using the points on the North American, whereas WGS84 is defined with respect to the average of stations all over the world.

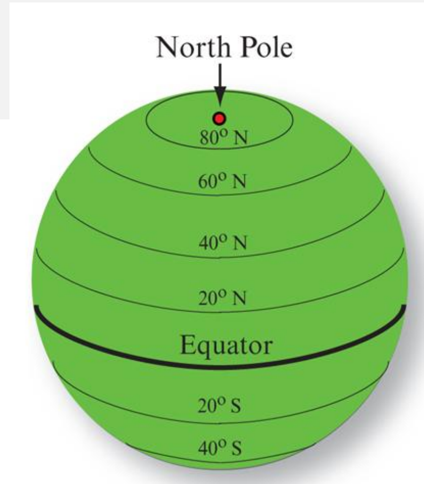
- Of course, that model doesn't do us any good if we cannot locate things on it
- Therefore, we dice these models up with gridlines called graticules
- Most often, these graticules are used to indicate latitude and longitude



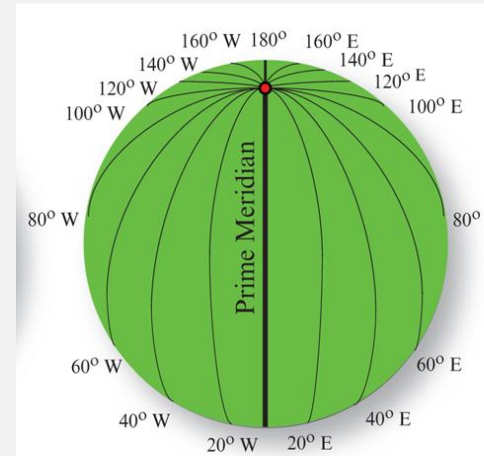
Latitude and Longitude

- **Equator:** **the plane through the center of mass perpendicular to the axis of the Earth's rotation**
- **Prime meridian:**
  - **Greenwich**

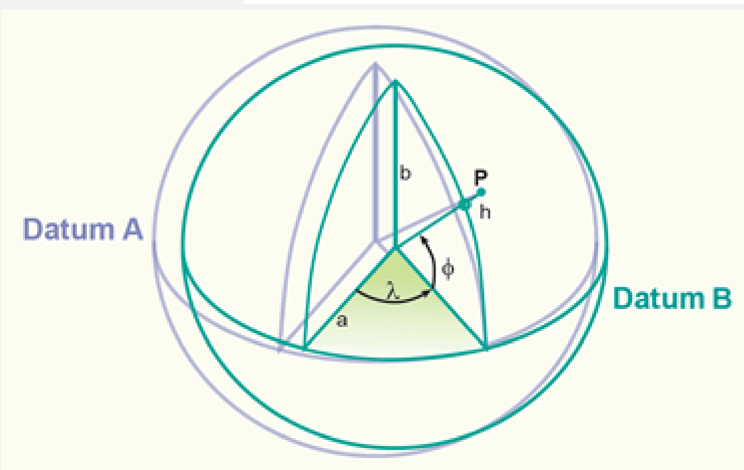




a. Lines of Latitude (degrees North and South of the Equator).



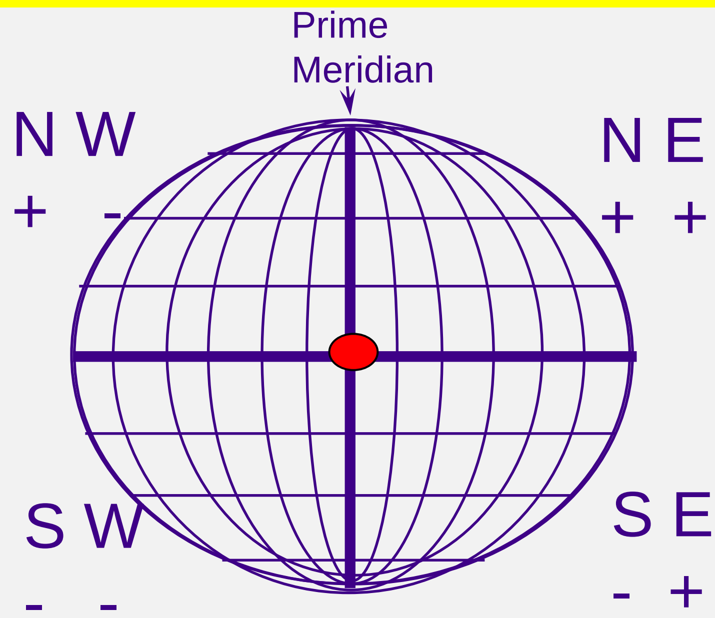
b. Lines of Longitude (degrees East and West of the Prime Meridian).



lat./long coords. for a location will change depending on spheroid chosen!

Latitude and Longitude: Graticule

- **Graticule: network of lines on globe or map representing latitude and longitude.**
  - **Origin is at Equator/Prime Meridian intersection (0,0)**
- **Lat and long measured in:**
  - **degrees° minutes' seconds"**
    - $1^{\circ} = 60'$
    - $1' = 60''$
  - **Decimal degrees**
    - **dd= d° + m'/60 + s"/3600**



When entering data, be sure to include negative signs.

- **DD to DMS**
  - E.g., **111.2358**

$d = \text{int}(111.2358°) = 111°$

$m = \text{int}((111.2358° - 111°) \times 60) = 14'$

$s = (111.2358° - 111° - 14'/60) \times 3600 = 8.88''$

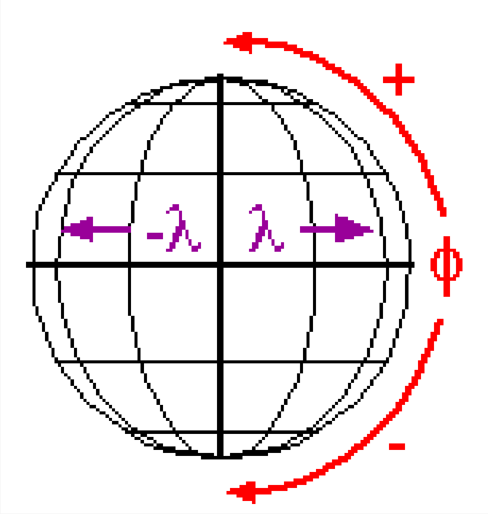
$111.2358°$

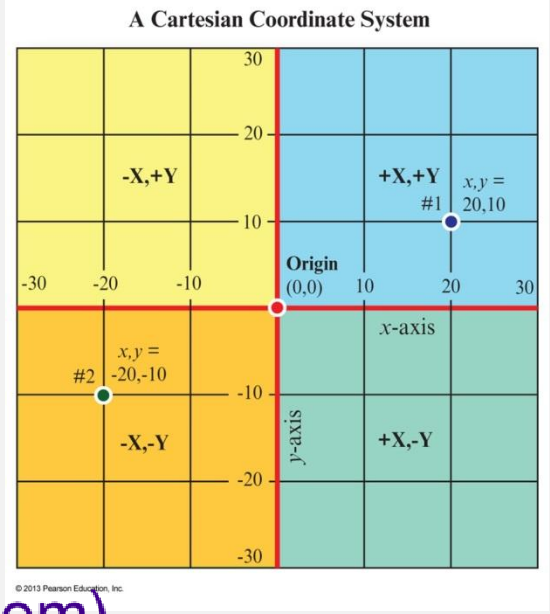
  - **111° 14' 8.88"**

- **DMS to DD**
  - **E.g.,** $111^{\circ}14'8.88''$
    - $8.88/60 = 0.148$
    - $\frac{0.148+14}{60} = 0.2358$
    - $111 + 0.2358 = 111.2358$

- **Carry enough decimal points for accuracy!**
  - **6 decimals give 4 inch (10cm) accuracy**
  - **but must use double precision storage--single precision accurate to only 2m**

Coordinate Systems





- **Angular** (Geographic Cordiante System)
  - **Latitude, longitude (λ, Φ)**
- **Cartesian**
  - **Distances from an origin in the x- and y- direction**
  - **Both have positive and negative values**

Conclusions

- There are several different systems which we may use to georeference data
- Common referencing systems vary around the world
  - Place-names and points of interest
  - Postal addresses and postal codes
  - Linear referencing systems
  - Cadasters and the US Public Land Survey System
  - Measuring the Earth: latitude and longitude
  - Projections and coordinates

Questions ?

https://www.google.com/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwihuqvgkpjcAhU3IDQIHZbqB8QQjRx6BAgBEAU&url=http%3A%2F%2Fwww.cityofrockhill.com%2Fdepartments%2Finformation-technology-services%2Fmore%2Finformation-technology-services%2Fgeographic-information-systems-gis-%2Fgis-frequently-asked-questions&psig=AOvVaw2fEUXAIjbJY26W-bnjS0wY&ust=1531436220322311

Upcoming

- Monday: No Lecture (Holiday)
- Submit today’s class participation to TA.
- Wednesday (Lecture) : Georeferencing II
- GIS Lab 01 due in Week 3.
- Readings updated on canvas.