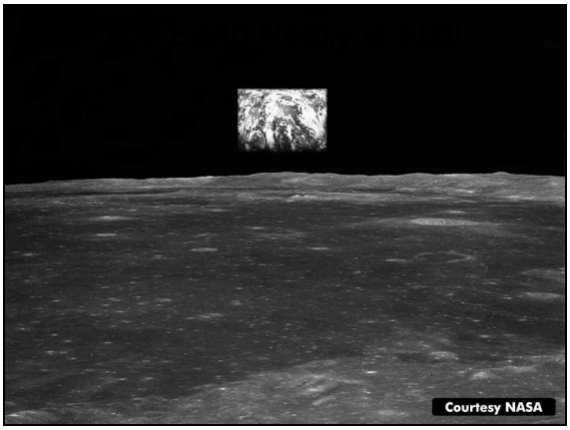
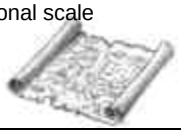
The Globe and Coordinate Systems

Intro to Mapping & GIS



The Earth is Flat

- Day to day, we live life in a flat world
  - sun rises in east, sets in west
  - sky is above, ground is below
  - we orient travel by north-south, east-west thinking
    - Ex. Philly is "north west" of Glassboro
- Map = Representation or **Model** of landscape
- A Flat map (ie model of space) is a perfectly rational model for a local or regional scale



Long History of Mapping

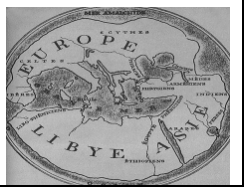
- Prehistoric Renderings, Rock Paintings from the KhoiSan People in South Africa

- Traditional Australian Aboriginal Art Symbols Communicated Place

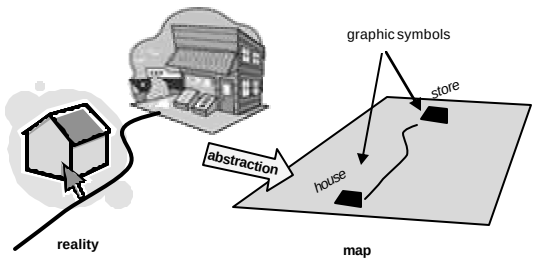
Long History of Mapping

- Ancient tablet from the 7th Century BC depicting the world at the time of Sargon (2300 BC) as a circle surrounded by water, with Babylon at its center. (British Museum)

- Map of known world by Hecataeus
  - about 500 BC
  - Greeks believed world a sphere



Mapping on a flat surface is relatively easy

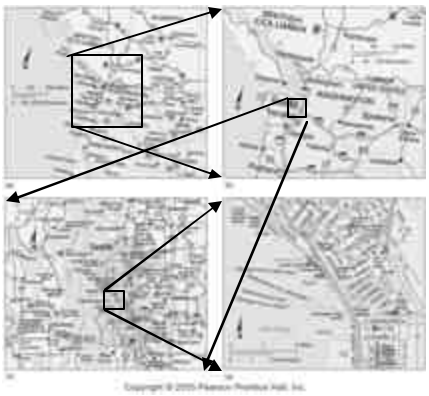


Map Making

- Cartographic Symbology
  - Abstracting spatial reality with graphic representation
- Extent
  - The area being mapped
- Scale – relationship of size of realworld to map
  - Fraction 1/24,000
  - Ratio 1:24,000
  - Written statement "1 inch equals 1 mile"
  - Bar style

0 1 2 3 4

- Generalization
  - The amount of detail included in the map
  - Depends on the scale



Coordinate Systems

(knowing where it's at)

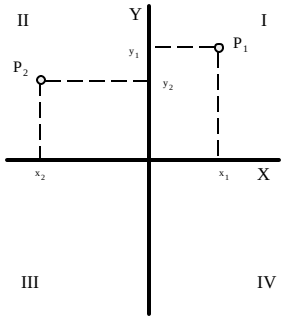
- Numerical systems that specify location in space.
- Types of coordinate systems:
  - Plane coordinates (i.e. FLAT Surface)
    - Cartesian
    - Angular / polar
  - Global or spherical coordinates

Cartesian Coordinates

- Origin
- Abscissa or X Axis
- Ordinate or Y Axis
- Position X,Y
- Quadrants I through IV
- Point Locations:

Point	X	Y
1	x_1	y_1
2	x_2	y_2

- Used for most projections.



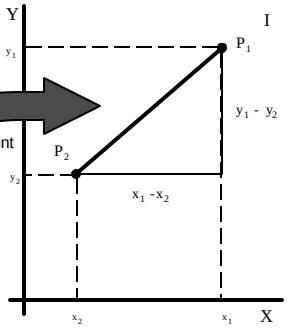
Distance Calculation for Points Measured in Cartesian Coordinates

- Point Locations:

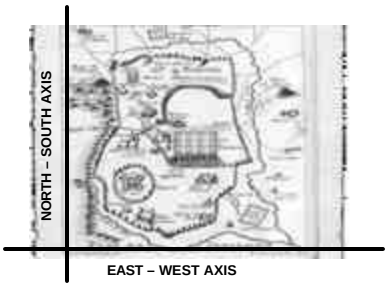
Point	X	Y
1	x_1	y_1
2	x_2	y_2

- Distance Formu
  - Distance from Point 2:

$$\sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2}$$



Most Flat Maps Utilize a Cartesian Coordinate System

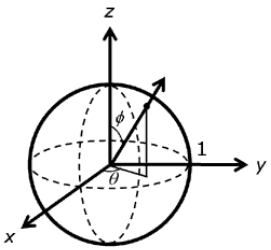


Ancient Plan of Jerusalem

The Flat Earth Model Doesn't Work at a Large Scale.

Long distance travel required a better model.

Defining Location on a Spear, the Global Coordinate System

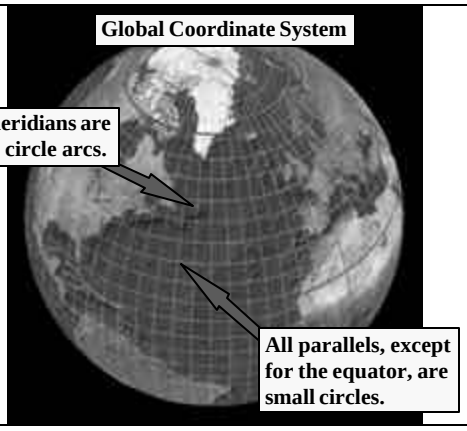


Basis of Global Coordinate System

- Earth's rotation gives **poles** and **axis** as two natural points of reference on the sphere.
  - **Equator**: locus of points on sphere's surface that are equidistant from the poles.
  - **Great Circle:**
    - Pass a plane through a sphere's center.
    - Connect the points along which plane intersects sphere's surface.
    - Line defined by the points is a **great circle.**
  - **Equator** is only great circle **perpendicular** to axis of rotation.

Terms to Specify Position on Globe

- **Latitude:** degrees north and south of equator.
- **Longitude:** degrees east and west of Greenwich, England.
- **Meridian** = line of constant longitude.
- **Parallel** = line of constant latitude
- **Great circle** = circle inscribed on surface by a plane passing through earth's center.
- **Small circle** = circle inscribed on surface by a plane that passes through earth, but misses the center.



Units of Measure

- Angular Measure:
  - Degrees: 360 per circle.
  - Minutes: 60 per degree.
  - Seconds: 60 per minute.
- Great Circle Degree Distances:
  - Degree = 69 miles.
  - Minute = 1.15 miles.
  - Second= .02 miles
  - One tenth second = 10.12 feet
  - One hundredth second = 1.012 feet.

Units of Measure

- Traditional Angular Measure:
  - Degrees: 360 per circle.
  - Minutes: 60 per degree.
  - Seconds: 60 per minute.

Decimal Degrees

- Based on decimal fraction of a degree
- Easier to work with
- can express angles to any precision - to hundredths of a degree, to thousandths of a degree, and so on
- Better for digital mapping

- Decimal Degree Conversion:
  - Multiply minutes by 60
  - Add seconds to results of minutes multiplied by 60.
  - Divide total by 3,600
  - Add result to degrees

Example of Decimal Conversion

Traditional Measure:	**45°20'30"**
Convert minutes to seconds:	*** 60 = 1200"**
Add seconds to converted minutes:	**+ = 1230"**
Convert seconds to degree fraction:	**/ 3600 = .3416667**
Add whole degree to fraction:	**45.3416667 °**

Global Grid Properties

1. All meridians equal length
2. All meridians converge at poles (true north orientation)
3. All lines of latitude are parallel to the equator
4. All parallels maintain the same spacing
5. Meridians and parallels intersect at right angles
6. The scale on a globe is the same everywhere (unlike a map)

Arc and Great Circle Distance

- Proper measure for long distances
- Data required:
  - Latitude in decimal degrees of each place.
  - Longitude in decimal degrees of each place.
- Procedure:
  - Calculate angular distance over the great circle route.
  - Convert angular distance into miles or kilometers.

Great Circle Arc Distance

Given the latitude and the longitude of two locations on the globe. How do you measure the distance in **degrees** of great circle arc?

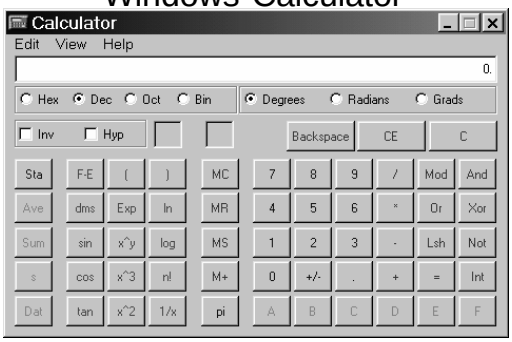
$$\theta^\circ = \text{Arccos}\,(\text{Sine}(\text{Lat}_1)*\text{Sine}(\text{Lat}_2)) + (\text{Cosine}(\text{Lat}_1)*\text{Cosine}(\text{Lat}_2)*\text{Cosine}(|\text{Long}_1 - \text{Long}_2|))$$

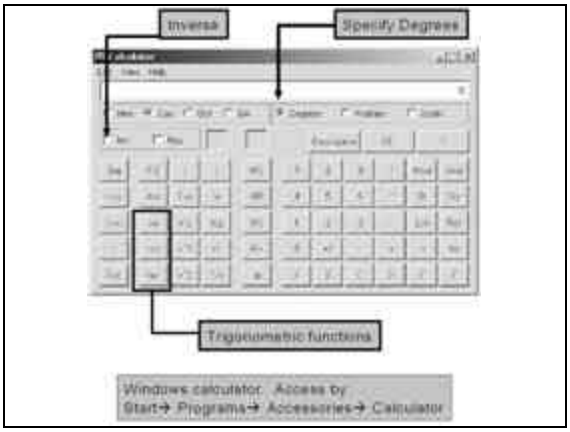
Great Circle Arc Distance

Given the great circle **arc** distance between two locations on the on the globe. How do you measure the **distance in miles**?

Distance in miles = $69 * \theta°$

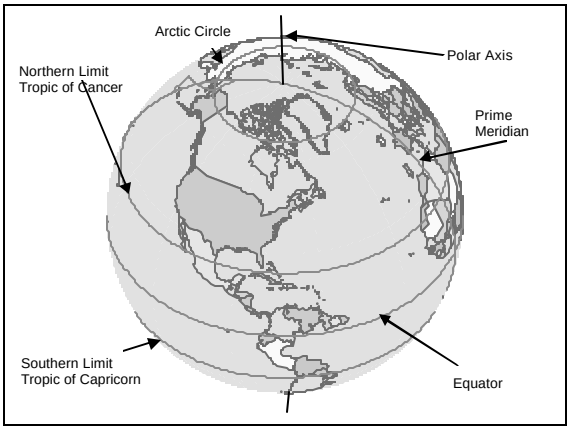
Windows Calculator



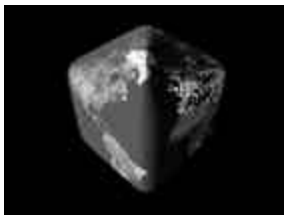


Seasonal Variation of Solar Angle

Tropics and Polar Circles



What Shape is the Earth?



Earth's Shape

- E… in history:
  - …nimals.
  - …fect as they are.
  - Most …
  - **Therefore th…**

– He was almost perfectly c…

Question: What kind of argument is this?
Inductive
Deductive
Empirical

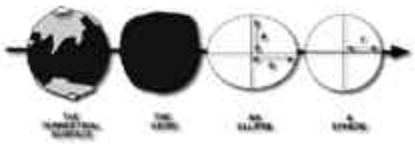
Earth's Shape

- E… in history:
  - …e is exerted on mate… …is faster than near p…
  - This force pulls o… deviate from a perfect s…
  - **Therefore the Earth must be … spheroid.**

– He also was almost perfectly correct!!!

Question: What kind of argument is this?
Inductive
Deductive
Empirical

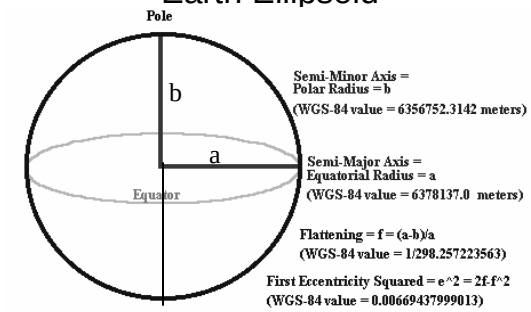
Shape of the Earth



Shape of the Earth

- Ellipsoid: Earth as slightly flattened ball
- Ellipse of Earth's shape:
  - Semi-major axis = 6,378,137 meters
  - Semi-minor axis = 6,356,733 meters
  - 1/298th difference pole to pole versus equatorial
  - Resulting ellipsoid provides mathematical model of planet's shape.
  - Used for creating accurate large scale maps

Earth Ellipsoid



Ellipsoidal Parameters

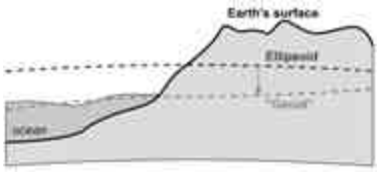
Does It Matter?

- Small scale maps. No, go ahead and use the sphere as model.
- Large scale maps. Yes, use ellipsoid as model.
- Difference in length of a degree of latitude due to flattening:
  - 0° = 68.708 miles
  - 45° = 69.054 miles
  - 90° = 69.403 miles

Which Ellipsoids Are Used?

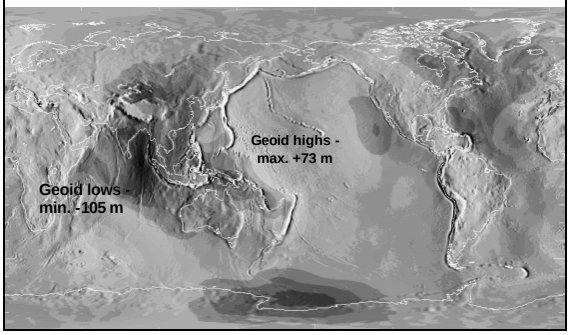
- NAD 1927: Based on calculations by British geodesist Alexander Clark.
- NAD 1983: Based on Geodetic Referencing System of 1980.
- Conversion from NAD27 to NAD83 can be troublesome

The Geoid Represents mean sea level which varies due to gravity anomalies



Earth is actually lumpy – proper term
Oblate Geoid

The Geoid Diverges from the Ellipsoid by as much as 100 meters



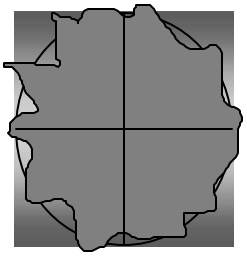
Who cares about the Geoid?

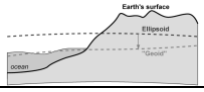
- We all do
  - It is the reference level against which elevations are measured
  - It skews the orbit of satellites
- Earth scientists do
  - It tells us about the deep interior of Earth
- Surveyors do
  - It purturbs leveling measurements
  - That is, it changes the direction of "straight down"

Earth's Surface varies from the Geoid

Size of the Earth:

- Maximum Vertical Surface Difference:
  - Greatest ocean depth = 36, 161 feet [Mariana Trench].
  - Greatest mountain height = 29, 028 feet [Mount Everest].
  - Difference = 65, 189 feet.
- Maximum Elevation Difference as Proportion of Diameter
  - .001558 which on a 12" globe is equal to .0186 inches.





Size of the Earth

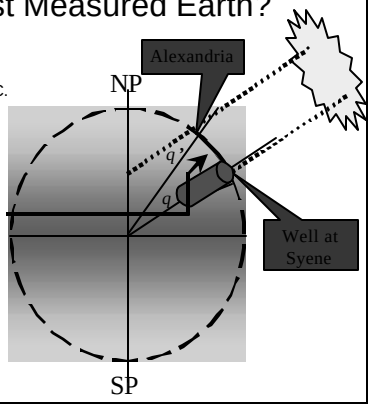
Class survey

Which of the following closest to the circumference of the earth?

A) 9,000 miles
B) 12,500 miles
C) 25,000 miles
D) 50,000 miles
E) 120,000 miles

Who First Measured Earth?

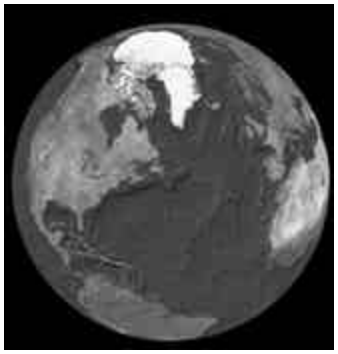
- Eratosthenes in 250 B.C.
- $\theta = \theta' = 7.2°$
- 7.2 = 1/50 0f 360°
- Arc length = 5,000 stadia
- 5,000 x 50 = 250,000 stadia
  - He was very close!!



Earth's Size

Size of the Earth:

- Diameter:
  - 12, 756,370 meters.
  - 41, 851, 607 feet.
  - 7, 926 miles.
- Circumference:
  - 40, 075, 318 meters.
  - 131,480, 703 feet.
  - 24, 901 miles.



Earth's Rotational Speed

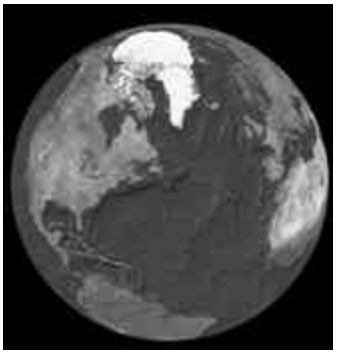
Rotation Earth:

- Circumference:
  - 24, 901 miles.

  Divide by 24 hours = 1,038 mph

  Faster than commercial jet (580 mph)

  Faster than sound (769 mph)



Time and Time Zones

Mean Solar Time

- A sundial keeps apparent solar time and it will differ from the time on your watch during the course of a year.
- This means that the true Sun is not always on the meridian at exactly noon.
  - Sometimes the Sun is on the meridian before noon and sometimes after noon.
  - The difference, called the equation of time, can be as much as 17 minutes.

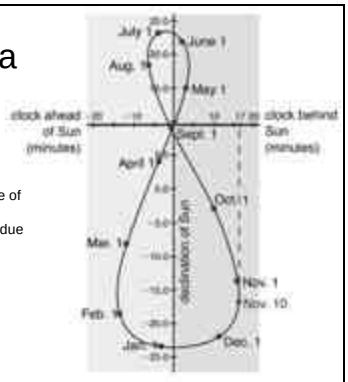
Sundial

Apparent Solar Time

- The path of the Sun at noon during the year makes a figure 8 shape called the analemma.
  - The north-south motion is due to the 23.5 degree tilt of the celestial sphere with respect to the ecliptic.
  - The east-west motion is primarily caused by the varying speed of Earth in its orbit around the Sun.

Analemma

Represents the amount of time of that apparent solar noon divergences from mean noon due to the changing speed of the earth around the sun.



Time Zones

- Both the mean solar time and the apparent solar time differ with longitude.
  - Imagine starting in Charlottesville at exactly noon.
  - As you travel to the west, the Sun will appear further east in the sky (i.e. lower and further from the meridian).
  - Even if you travel only a few miles west, the Sun moves off the meridian.
  - Each city would have its own time.

Time Zones

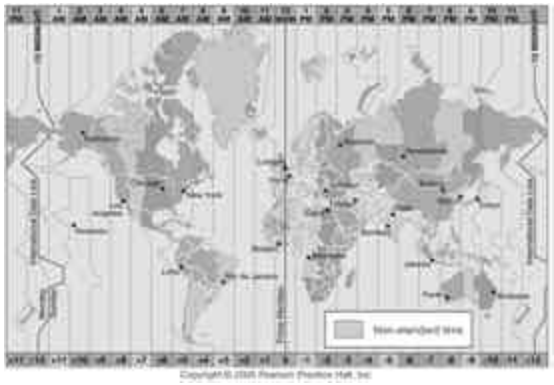
- With the advent of rapid travel by trains in the 19th century, it became necessary to standardize the time for all cities within a certain region.
- In November 1883, the railroad companies divided the United States into four time zones.
  - Everyone in a time zone set their clocks to the same standard time.

Time Zones

- In 1884, an international conference was held in Washington D.C. by 26 countries.
  - The world was divided into 24 times zones, with each zone being roughly 15 degrees wide in longitude.
  - Time zones have been modified for political, social and economic reasons.
  - Since there are 24 hours in a day, and 360/15=24, the time in each zone differs from the time in adjacent zones by one hour.
  - Some time zones are not standard (example India)
  - China has only 1 time zone

International Date Line

- Standard time gets earlier as you travel to the west.
- The International Date Line line was established in the middle of the Pacific Ocean.
- As you go from east to west, you gain a day as you cross the line.
- As you go from west to east, you lose a day as you cross the line.



Calculating Differences in Time

- 8am England to Beijing
  - Beijing is to the east so it is Later
  - Beijing is 8 time zones east so it is 8 hours later
  - ANSWER = 4pm
- 1pm Auckland New Zealand to Los Angeles
  - Auckland is 12 hours east (later in the day) than London
  - London = 1am
  - LA is 8 hours west (earlier) of London
  - 1am – 8 hours
  - ANSWER = 5pm the evening before