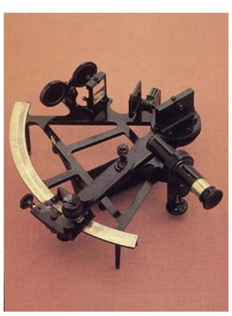
Analytical and Computer Cartography

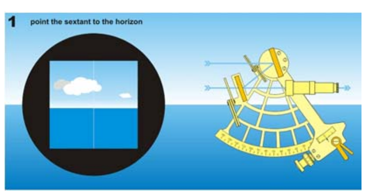
Lecture 2:
Review: Map Projections

The Story so far

- Earth model for mapping: Ellipsoid
- Datums standardized, earth centered
- Memorable dimensions (40Mm and 111 111 m)
- Scale transformation impacts detail and level of abstraction (generalization)
- Next transformation: Round earth to flat map is T3

Measuring latitude





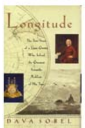
The longitude problem

- Latitude has as a point of origin (the equator) and ends at the poles: distinct locations
- It can be measured directly by observing the sun or the stars
- Can also measure the tropics

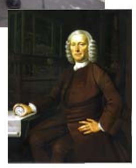
of Cancer and Capricorn

- Not so for longitude
- Hard to measure

The longitude solution



John Harrison's
Chronometer
Won longitude
Prize 1773



At first, each country had its own prime 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."

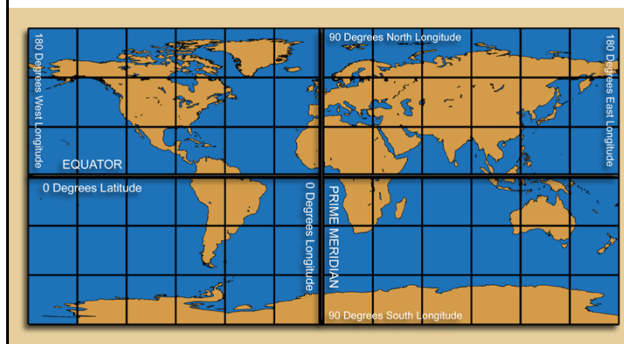
"That from this meridian longitude shall be counted in two directions up to 180 degrees, east longitude being plus and west longitude minus."

The Prime Meridian (1884)

Remember: datum changes location

104m East of the Observatory

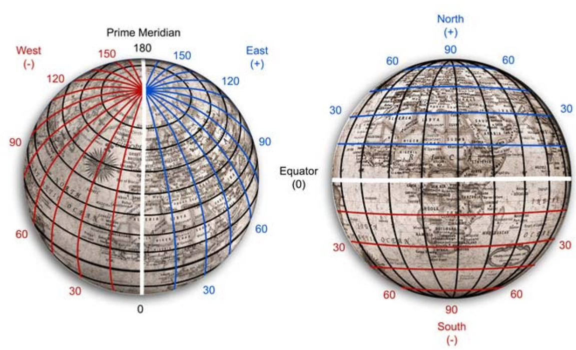
Geographic Coordinates



The graticule

- **graticule:** The latitude and longitude grid drawn on a map or globe. The angle at which the graticule meets is the best first indicator of what projection has been used for the map.

The graticule shows increments of latitude and longitude



Length of a degree of latitude

Latitude	Length of a degree (m)
0-1	110 567
39-40	111 023
89-90	111 699
Approximate average	111 111

Now, on to projections

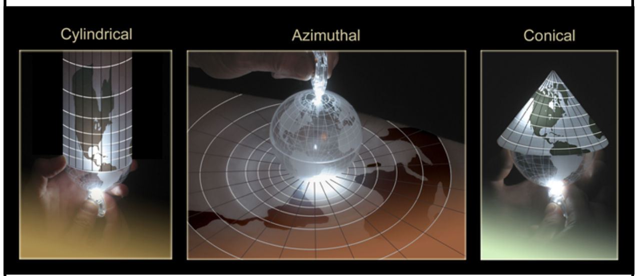
Round

Flat

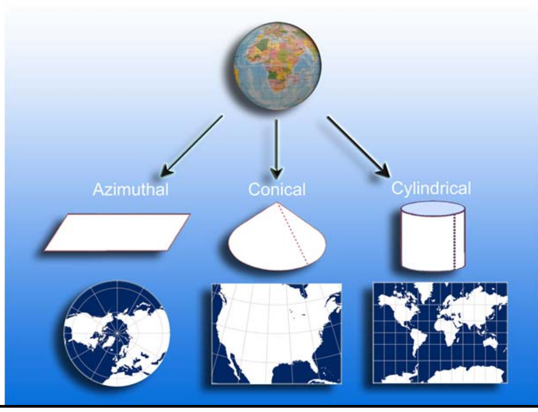
Projection properties

- Form: cylindrical, planar, cylindrical
- Aspect: Equatorial, polar, oblique
- Tangency: Tangent vs. Secant
- Distortion: Conformal vs. Equivalent
- Interrupted vs. Continuous
- Analog vs. mathematical
- Shape: Ellipse with flat poles preferred
- Purpose
- Extent: World vs. Country

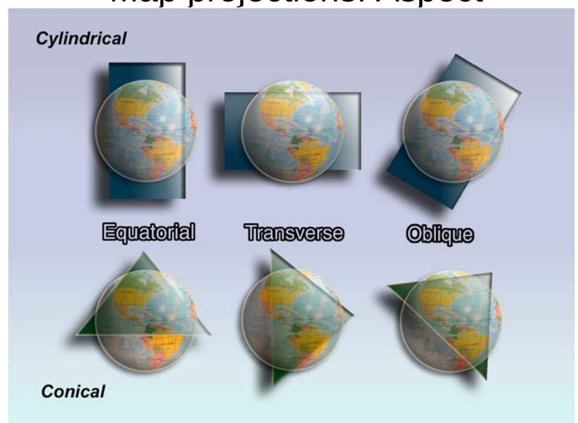
Thinking about projections



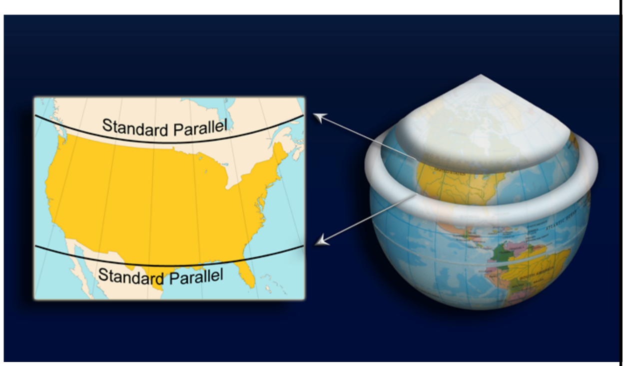
Map projections: Form

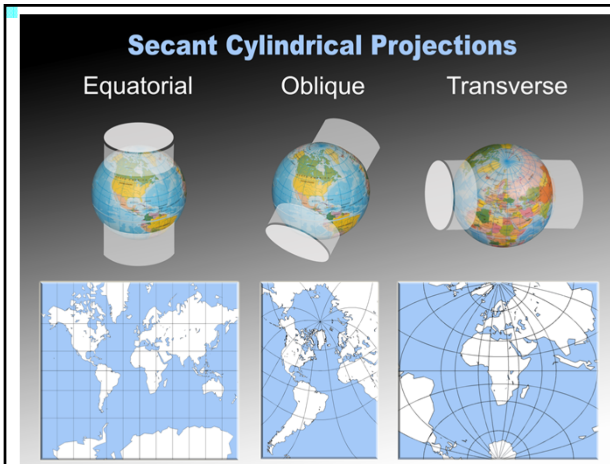


Map projections: Aspect



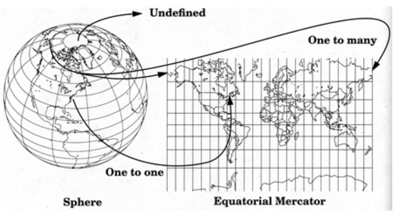
Secant vs. Tangent





Thinking about projections

- Mathematical (and digital)
- Input is long/lat pair (λ, ϕ)
- Output is (x, y) coordinates on paper



Again, mathematically

$$x' = Rs(\lambda - \lambda_0)$$

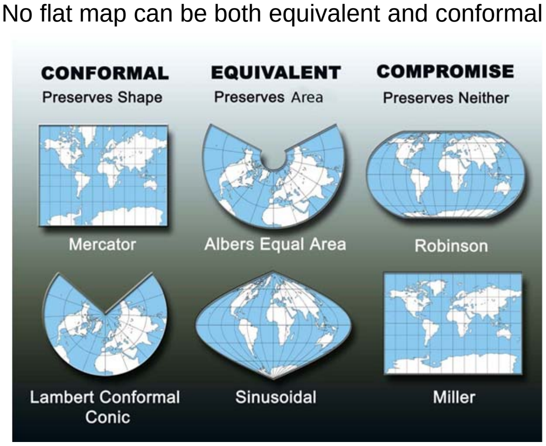
$$y' = Rs\log\left(\tan\left[\frac{\pi}{4} + \frac{\phi}{2}\right]\right)$$

We already know R and s

During the projection transformation

- We have to distort the 3D earth
- We reduce scale (generalize)
- We make break lines (interruptions)
- We distort scale
- We distort area
- We distort directions

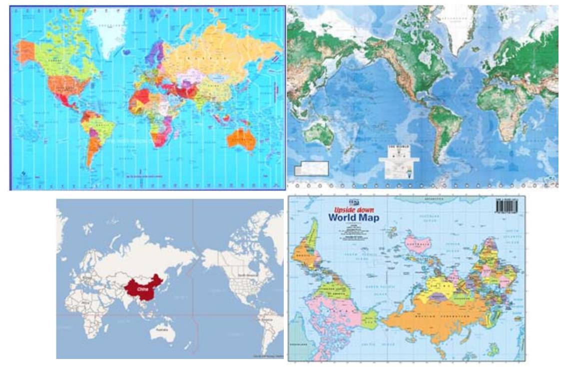
No flat map can be both equivalent and conformal



The central meridian

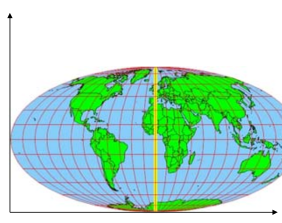
- In the mathematical derivation, x can map onto any meridian, by default we get 0º
- $x' = f(\bullet - \bullet_0)$
- We can change the center of the map
- Can even change the direction of the axis

Changing the central meridian



Mollweide: An equal area pseudocylindrical projection

x and *y* are not independent



y

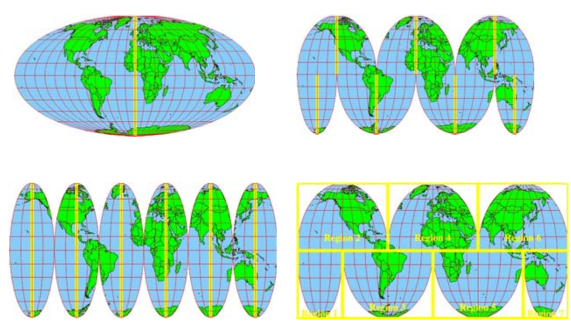
x

$$x = \frac{2\sqrt{2}}{\pi}\lambda\cos\left(\frac{\theta}{2}\right)$$

$$y = \sqrt{2}\sin\left(\frac{\theta}{2}\right)$$

$$2\theta + \sin(2\theta) = \pi\sin(\phi) \qquad (1)$$

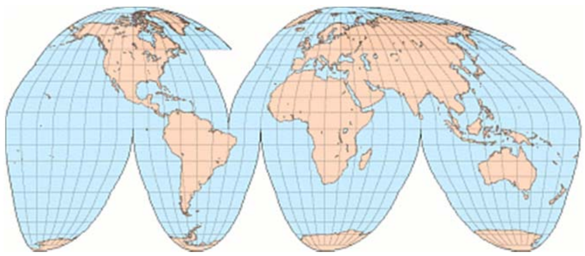
We can also choose the interruptions



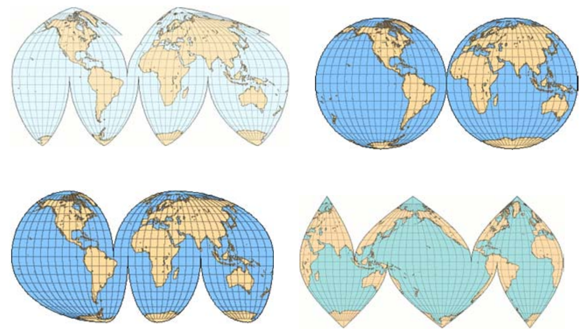
Interrupted Mollweide

And mix projections together

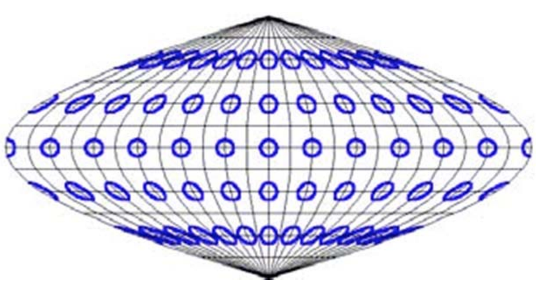
Goode's Homolosine=Mollweide (lobes) plus sinusoidal near the equator (J.P. Goode, 1923)



Many possible interruptions

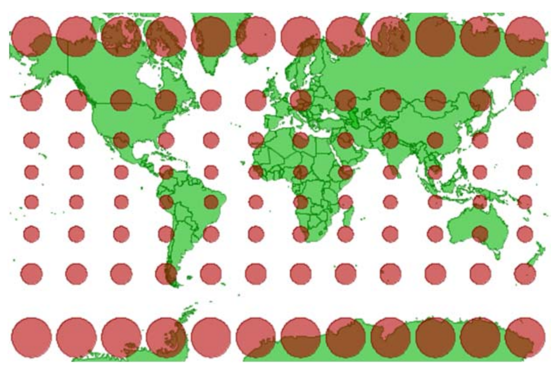


Projection distortion: Tissot's Indicatrix

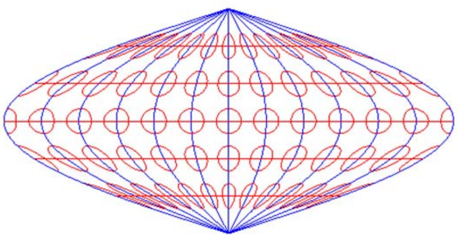


Werner projection

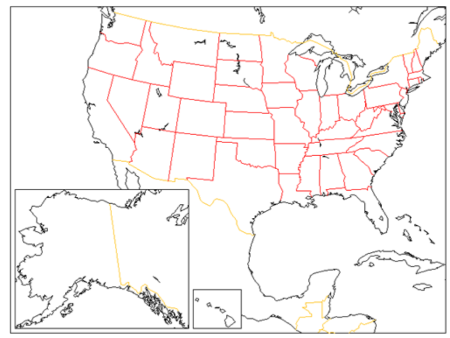
Mercator plus Tissot



Sinusoidal plus Tissot

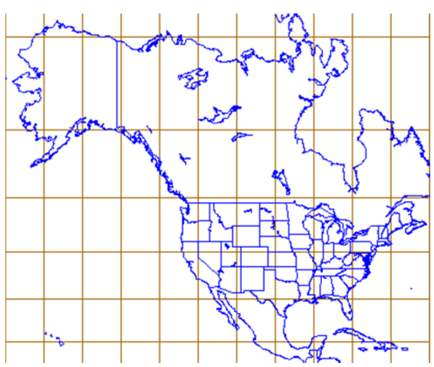


Projections for the USA



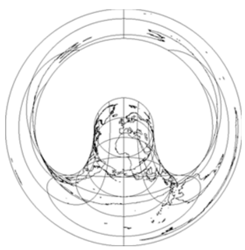
Lambert conformal conic

USA on Mercator

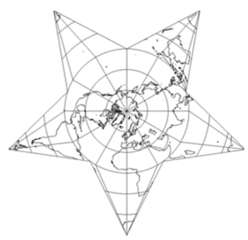


GS-50 Snyder

Fun projections

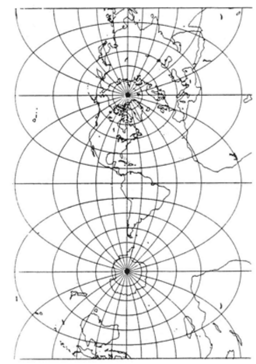


Hammer retroazimuthal

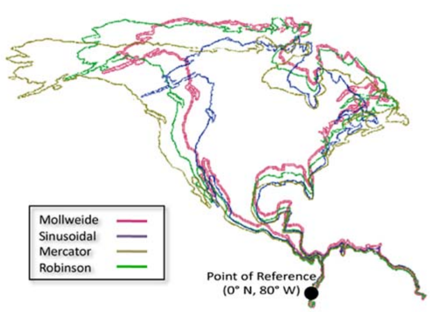


Berghaus star

Customizing error



Projection does matter!



Projection websites

- Geographers Craft:
  http://www.colorado.edu/geography/gcraft/notes/mapproj/mapproj_f.html
- Wikipedia:
- http://en.wikipedia.org/wiki/Map_projection
- Gallery of Map Projections:
- http://www.csiss.org/map-projections/index.html
- Carlos Furuti:
  http://www.progonos.com/furuti/MapProj/Normal/TOC/cartTOC.html
- Hunter College: http://www.geography.hunter.cuny.edu/mp/

Map Projections : Summary so far (1)

- The second important cartographic transformation is the projection
- Globes are round, maps are flat
- There are 180 degrees of latitude and 360 of longitude
- It is easy to measure latitude, harder for longitude
- The prime meridian was standardized in 1884 at Greenwich
- Map projections can be created mechanically or mathematically

Map Projections : Summary so far (2)

- We can project onto a plane, a cylinder or a cone
- We can orient the projection as equatorial, oblique or transverse
- We can make the projection tangent or secant
- No flat map can be both equivalent and conformal
- Projection matters