Map Projections I

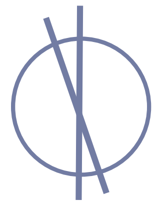
GEOG380 FA 2018

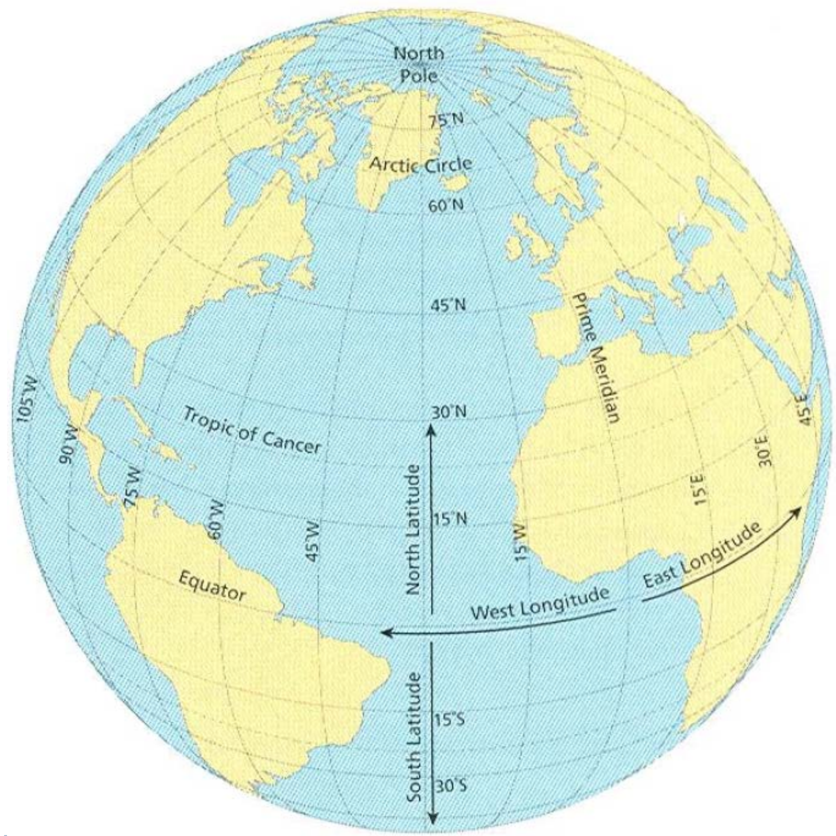
The round earth vs. a flat map/screen

- Map Projections I (Session 1)
  - The process of map projections
  - Geographic coordinates
  - Projected coordinates
  - Map projection characteristics
  - Distortion
  - Scale
- Map Projections II (Session II)
  - Projections in depth
  - Selecting an appropriate map projection

The spherical Earth

- Points of reference based on Earth's position relative to the sun…
  - Equator
  - North and south poles
    - Cf. Magnetic poles
- …and arbitrary agreements
  - Prime meridian
- Reference system
  - A geographic grid (graticule) measured in a *sexagesimal (base-sixty) scale; degrees, minutes,* and seconds





View of earth centered on 30° N, 30° W

Source: Goode's World Atlas

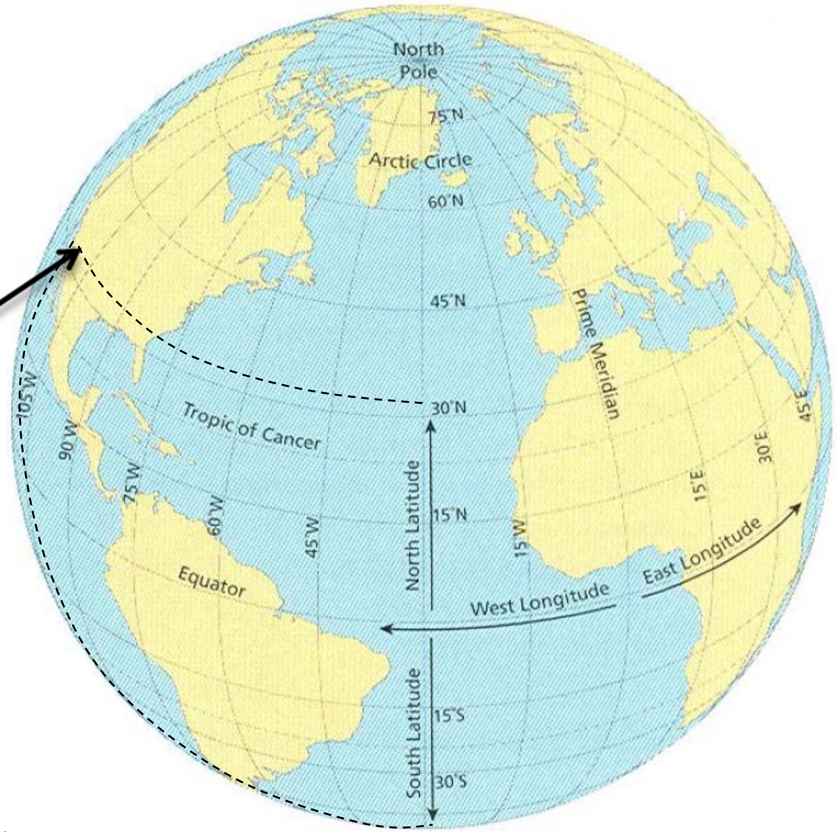
The spherical Earth – the geographic grid

- Lines of longitude – Meridians (|)
  - From pole to pole
  - E and W of the Prime meridian

- Lines of latitude – Parallels (—)
  - East ←→ West
  - N and S of the Equator

- Ex. 1250 N Bellflower Blvd
  Long Beach, CA 90840

	Decimal Degrees	Deg:Min:Sec
Lat:	33.781466	33° 46' 53.28" N
Lon:	-118.119035	118°7' 8.53" W



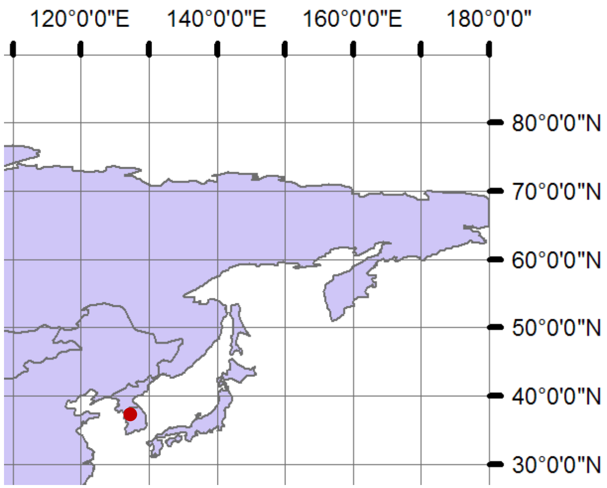
View of earth centered on 30° N, 30° W

Source: Goode's World Atlas

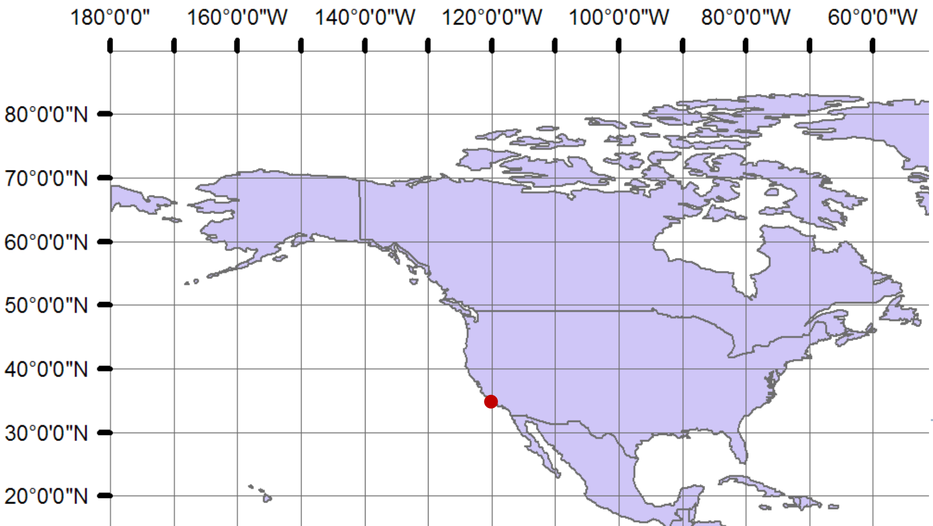
Some examples

- Where is Seoul, Korea?

37° 34' N
126° 58' E



- What's at
  - 33° 49' N
  - 118° 9' W ?



Long Beach, CA

Converting from DMS to DD

- To convert degrees, minutes, and seconds (DMS) to degrees and decimals of a degree (DD): ex) **59°19′ 48 ″ N**

  1. Convert the seconds

  Since there are 60 seconds in each minute,
  59°19′ $\boxed{48'' / 60}$ converts to 59°19.$\boxed{8}$ ′

  2. Convert the minutes

  Since there are 60 minutes in each degree
  59°$\boxed{19.8' / 60}$ converts to **Lat. 59.$\boxed{33}$ °**

  Calculator example: **18° 04′12″ E**

  Enter 12.00 / 60 = then displays 0.2

  Enter + 4 = then displays 4.2

  Enter / 60 = then displays 0.07

  Enter + 18 = then displays 18.07

  Long. 18.07 is your final decimal degrees for longitude

  3. For South or West Coordinates, add a negative sign to the DD

Converting from DD to DMS

- To convert degrees, minutes, and seconds (DMS) from degrees and decimals of a degree (DD): ex) **Lat. 59.33**

1. The whole number part is the whole degrees, 59 °.
2. Subtract the whole degrees (59.33 – 59 = 0.33) and multiply the decimal degree to minutes. 0.33 * 60 = 19.8 (the number of minutes in a degree).
   The whole number of the answer is the whole minutes, 19 ′.
3. Subtract the whole minutes from the answer (19.8 – 19 = 0.8) and multiply the decimal minutes to seconds. 0.8 * 60 = 48 (the number of seconds in a minute).
   The answer is the seconds, 48 ″.
4. If there is a decimal remaining, keep as the decimal of a second.

Answer: 59° 19′ 48″ N

Calculator example: Long. -18.07

Enter 18.07 - 18 = then displays 0.07

Enter *60 = then displays 4.2

Enter -4 = then displays 0.2

Enter *60 = then displays 12

Remember the - (for West)
Write down 18°
Write down 4′

Write down 12″
Answer: 18° 4′ 12″ W

Some things to note

- On a spherical grid:
  - Scale is the same everywhere on the globe
  - Meridians (|) are spaced evenly on parallels and converge towards the poles
  - Parallels (—) are parallel… and spaced equally on the meridians
  - Meridians and parallels intersect at right (90°) angles
  - Quadrilaterals of a certain longitudinal extent have equal areas
  - Areas of quadrilaterals decrease towards the poles

Terms related to distance and direction

- Great Circle
  - Formed by plane cutting through the center of the Earth and its intersection with the surface
  - Ex) Equator, meridians – measure shortest distance from a Great Circle (themselves)
    - All great circles have equal lengths
- Small circle
  - Ex) Parallels

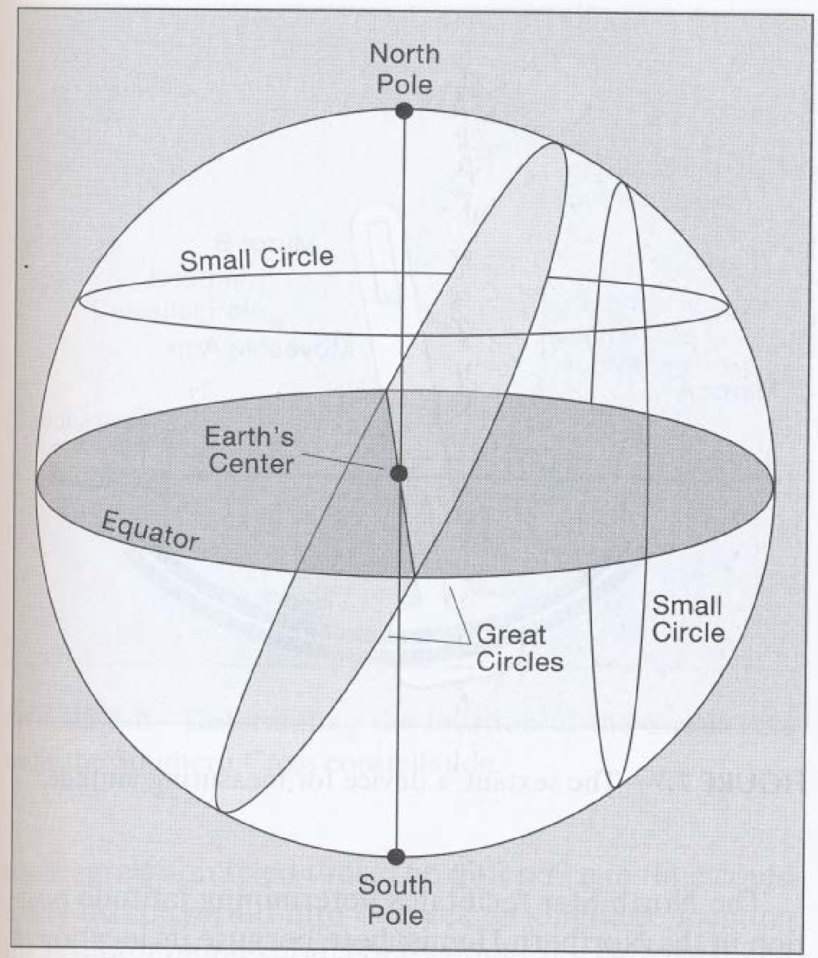


FIGURE 7.4 Examples of great and small circles on the Earth's surface.

(Source: Slocum et al. 2009)

Terms related to distance and direction (cont.)

- Azimuth
  - Measures angles between meridian from points A to B
    - Ex) a, b, and c in the figure 7.5
  - Useful for describing direction of the shortest path (on a great circle) between two points
    - Ex) points A and B

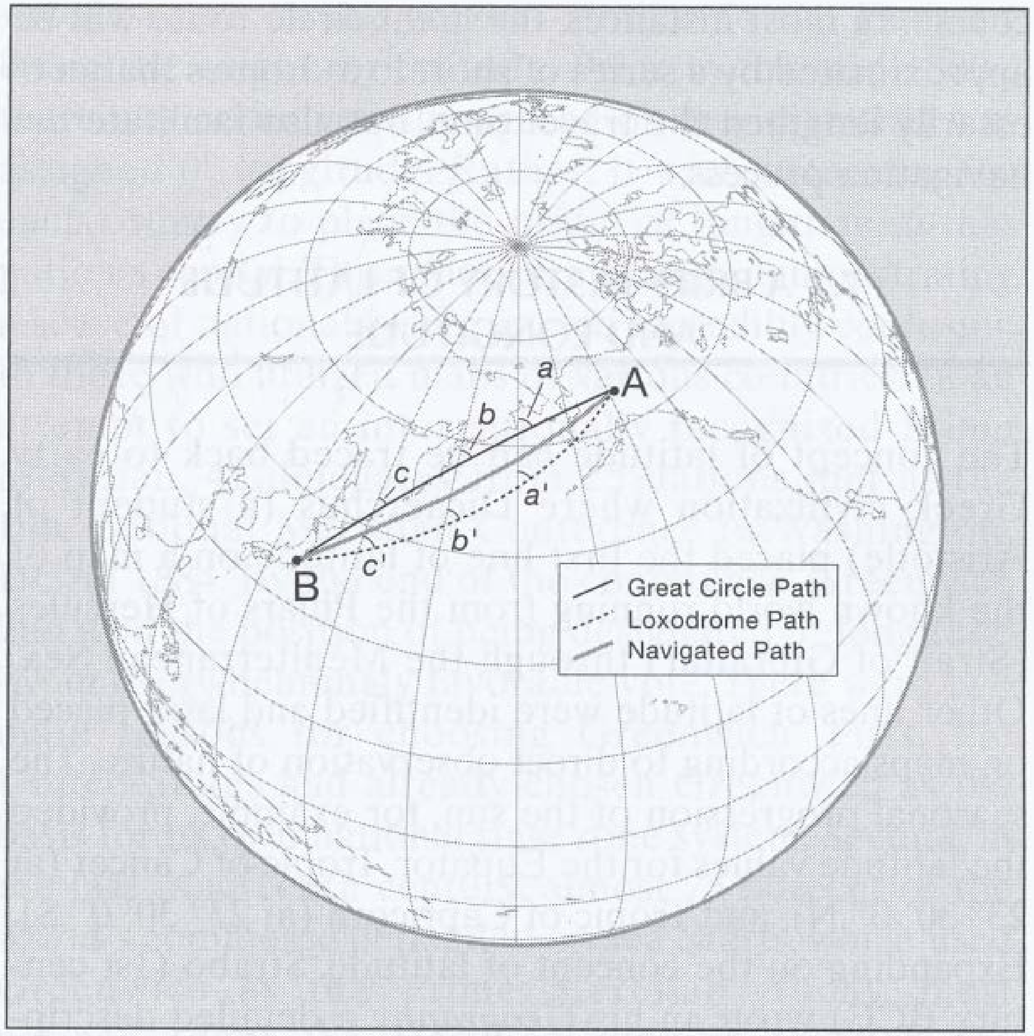


FIGURE 7.5 A great circle arc from point A to point B

(Source: Slocum et al. 2009)

Terms related to distance and direction (cont.)

- Loxodrome
  - A path formed by keeping a constant bearing from points A to B
  - Useful for navigation

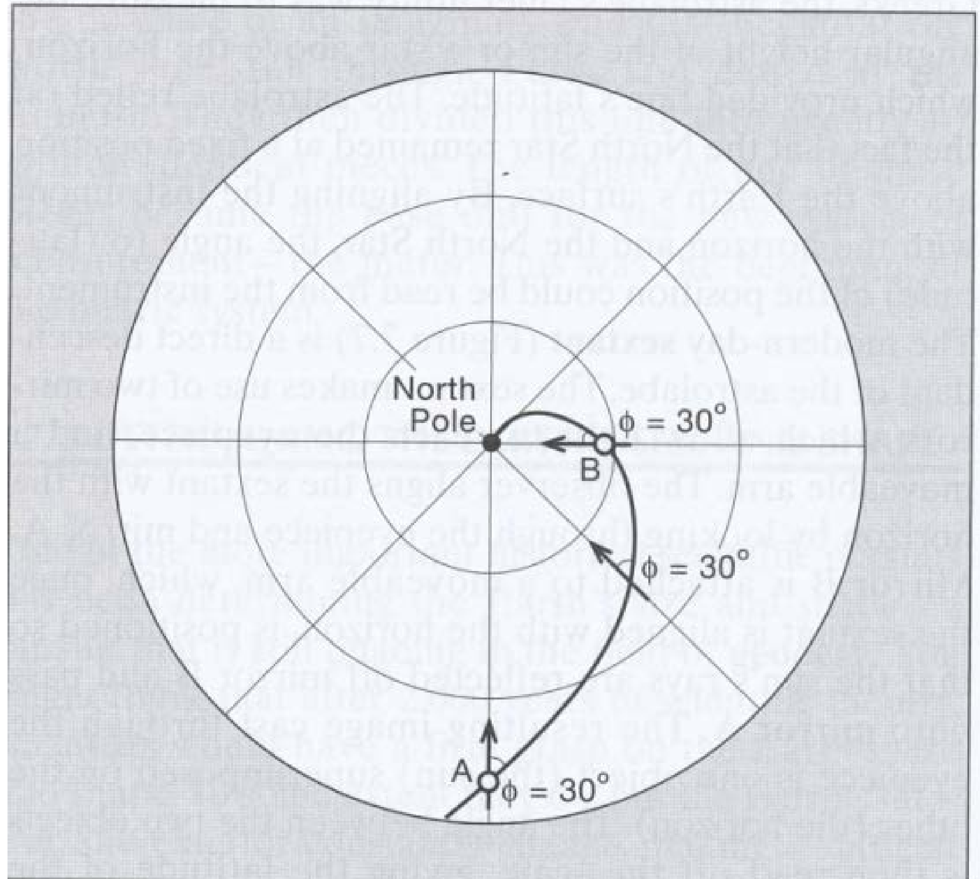


FIGURE 7.6 A line drawn from point A to point B crossing each meridian at a constant angle is called a loxodrome. If extended, this line will continue to spiral toward the North Pole.

(Source: Slocum et al. 2009)

The Earth is not precisely round

- Earth's rotation and differences in geology/density results in a non-spherical shape
- Geodesy refers to Earth's true shape as the geoid
  - Average ocean surface of the Earth
- To calculate locations easier a reference ellipsoid is used that approximates the geoid
- This introduces some distortions

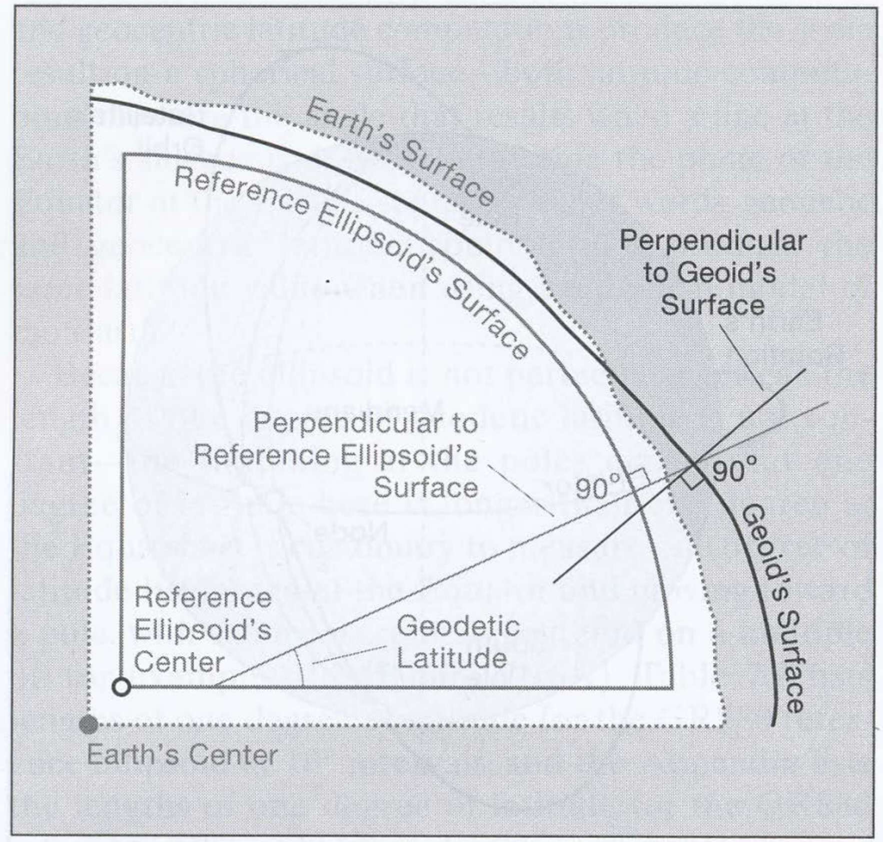
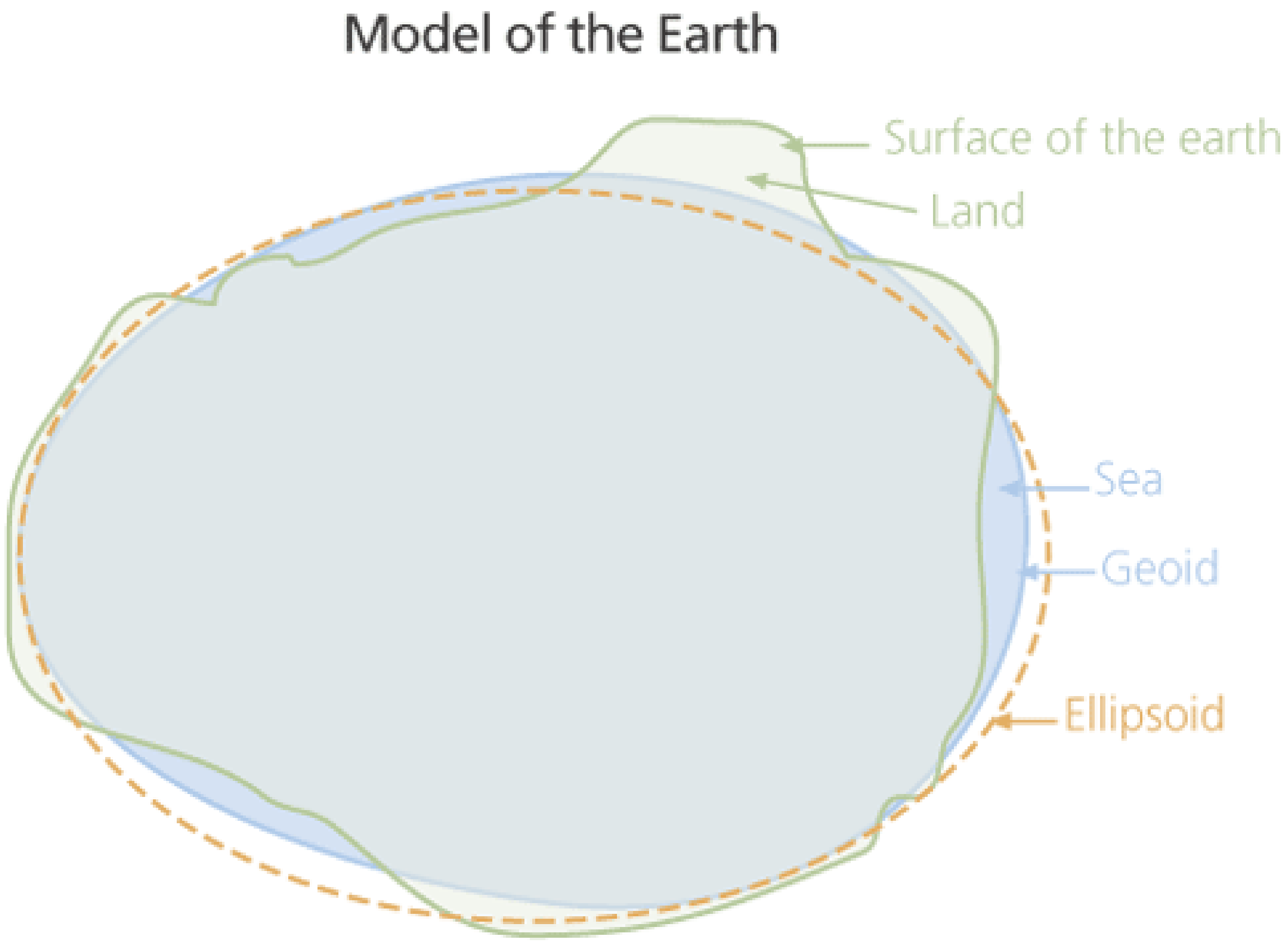


FIGURE 7.18 The relationship among surfaces representing the Earth, a reference ellipsoid, and a geoid. Note that when determining geodetic latitude, a line perpendicular to the reference ellipsoid is not perpendicular to the geoid.

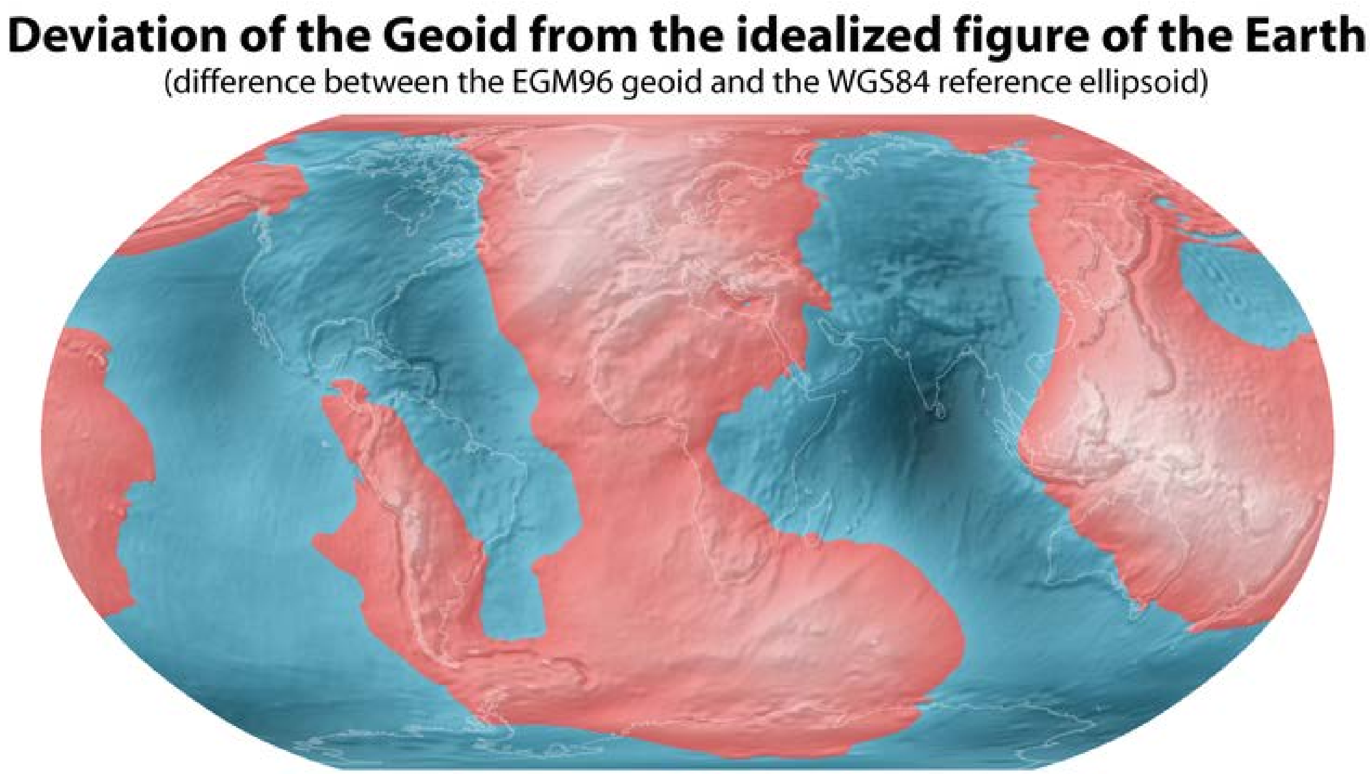
(Source: Slocum et al. 2009)

The Earth is not precisely round

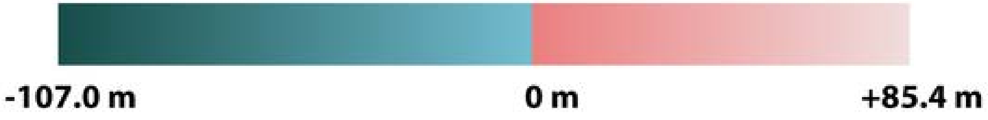


- (Source: physics.stackexchange.com)

The Earth is not precisely round (cont.)



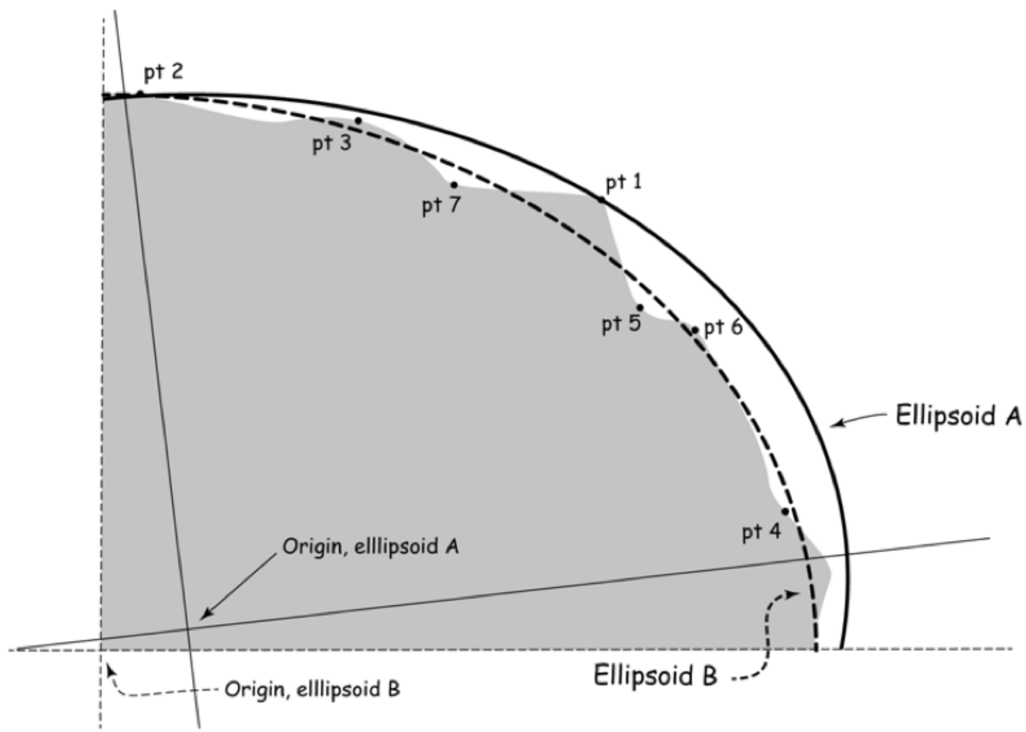
Red areas: the geoid (average ocean surface) above the ellipsoid; blue areas: below



- (Source: http://earth-info.nga.mil/GandG/wgs84/gravitymod/wgs84_180/wgs84_180.html)

Datum

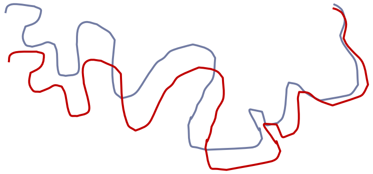
- A mathematical model of the earth which approximates the shape of the earth
- Different regions on the earth have different datums
- Calculations in a consistent and more accurate manner for a specific region
- If comparing GPS coordinates to a chart or map…
  - the map datum in the GPS unit must be set to match the chart for accurate comparison



(http://www8.garmin.com/support/faqs/faq.jsp?faq=17; Bolstad, 2012)

Why bother?

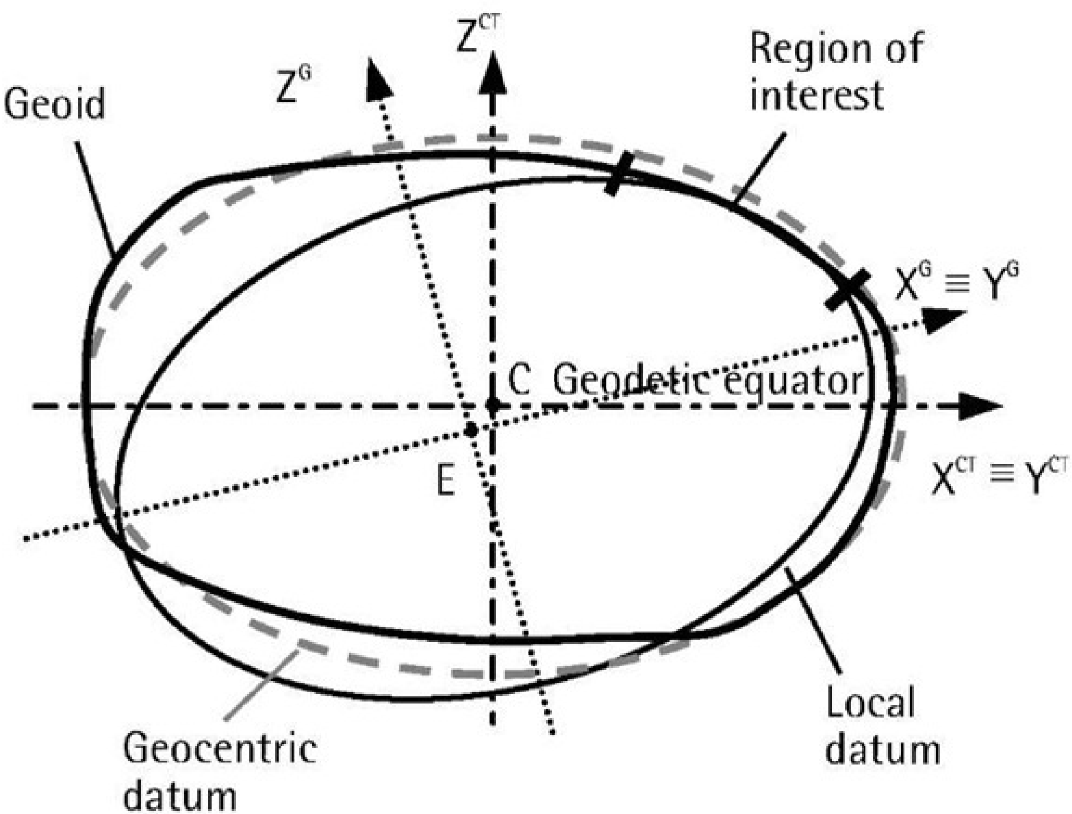
- Well, a lot of position readings today are done using a GPS and this requires specifying what datum to use.
  - (Map's datum = GPS's datum)
  - e.g. scuba diving (this link provides a useful example of applied GPS and earth coordinate knowledge)



- But, for most medium of small-scale thematic mapping we can ignore these details

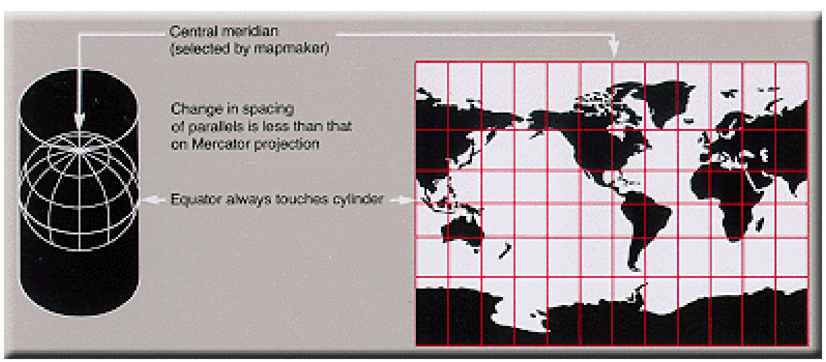
(source: http://www.wannadive.net/help/index.html?wdaction=lib.WDPageHelp.gps)

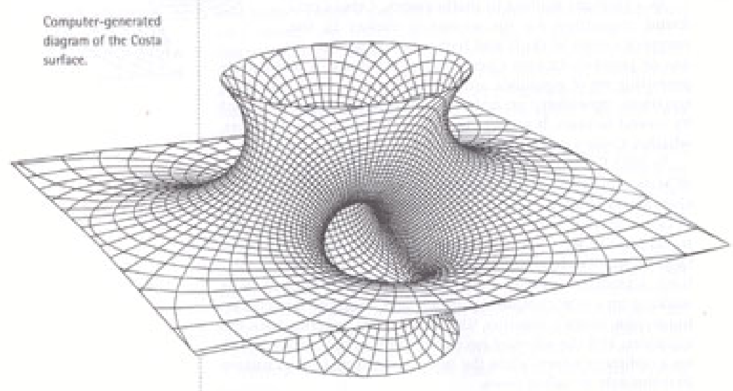
Choose datum that better matches to geoid



The projection concept

- *Any map projection is the systematic arrangement of the earth's meridians and parallels onto a plane surface (Dent 1999).*
- The basic steps
  - Choose a scale reduction
  - Choose a projection type
    - Direct - developable surfaces (ex. somewhere on Earth)
    - Indirect – purely mathematically defined surfaces





- Ex. A projected map (http://www.answers.com/topic/map-projection) and The Costa surface (http://www.philosophy.umd.edu/Faculty/jhbrown/BtyAdds/)

The scale reduction

- The amount of spatial reduction from real world to the map
- Expressed
  - Numerically
  - Graphically
  - Verbally

Scale 1:700,000 (or 1/700,000)

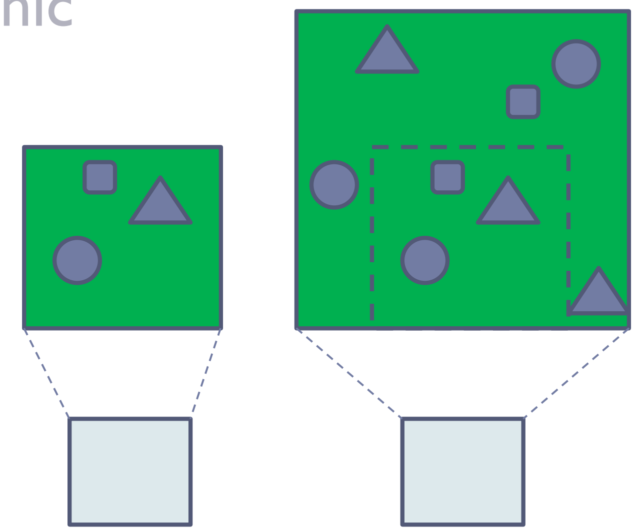
"1mm on the map represents 700,000 mm on the earth"

$$\text{map scale} = \frac{\text{map distance}}{\text{earth distance}}$$

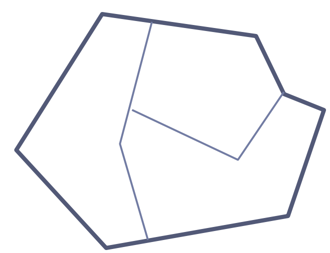
- Generally:
  - Important to use same units when comparing different maps!

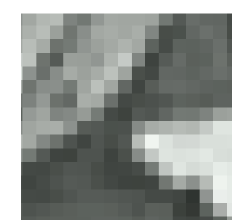
Other statements of scale

- Cartographic
  - Verbal, representative fraction (RF), graphic
- Geographic
  - "Large" scale, Vs. "small" scale (extents)

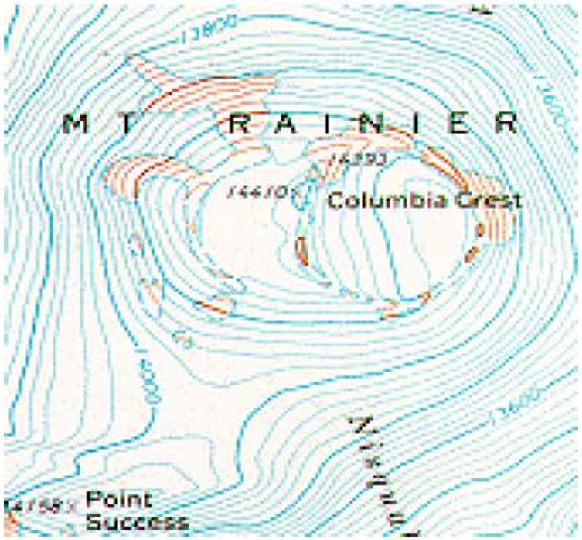


- Resolution
  - "Minimum mapping unit"
    - Ex. a census block-group (vector data) or a pixel size (raster data)

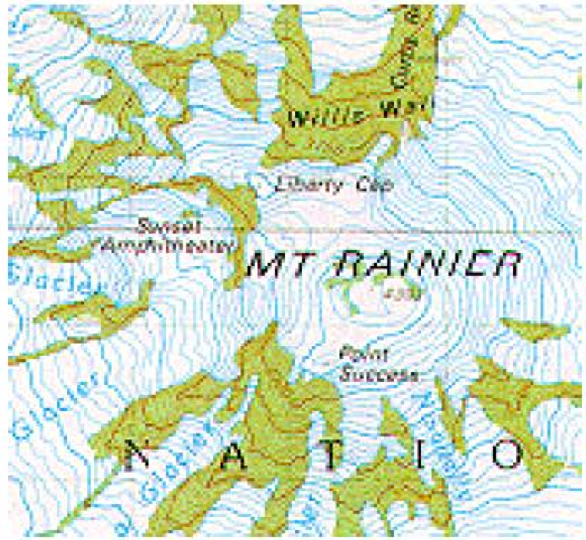




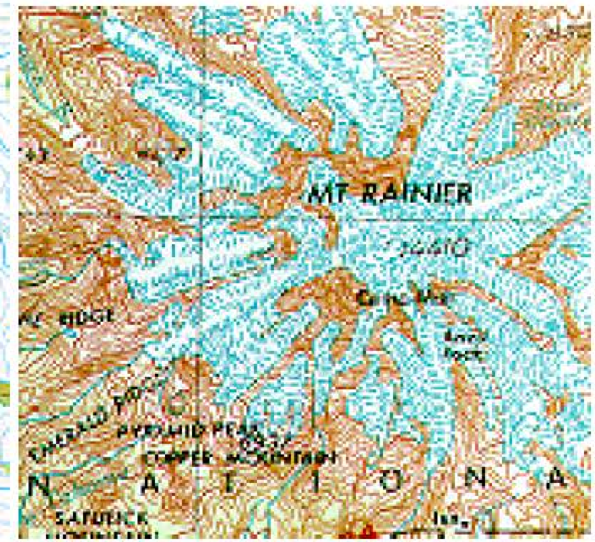
Some common mapping scales



1:24,000 scale,
1 inch represents
2,000 feet



1:100,000 scale,
1 inch represents about
1.6 miles (8,448 feet)



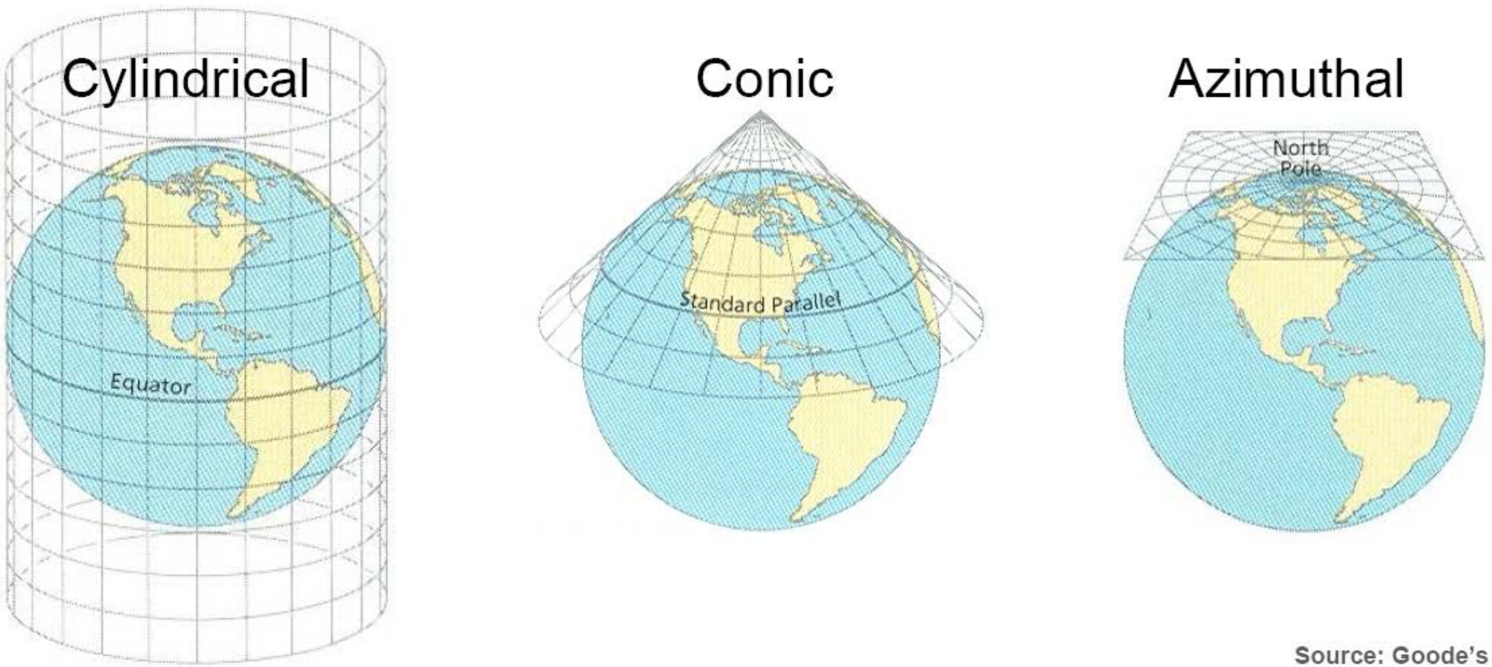
1:250,000 scale,
1 inch represents about
4 miles (21,120 feet)

- Q. Using calculator or whatever, answer A, B, and C:

1/24,000 = A 1/100,000 = B 1/250,000 = C

Selecting map projections

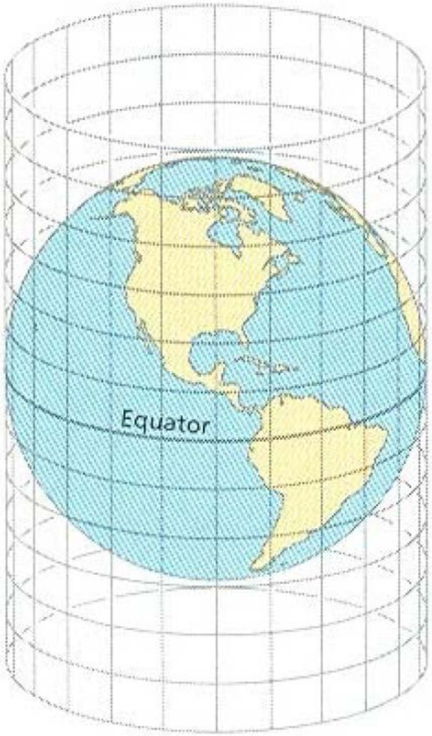
- Three basic rules (after Maling, 1992)
  - A country in the tropics asks for a cylindrical projection.
  - A country in the temperate zone asks for a conical projection.
  - A polar area asks for an azimuthal projection.

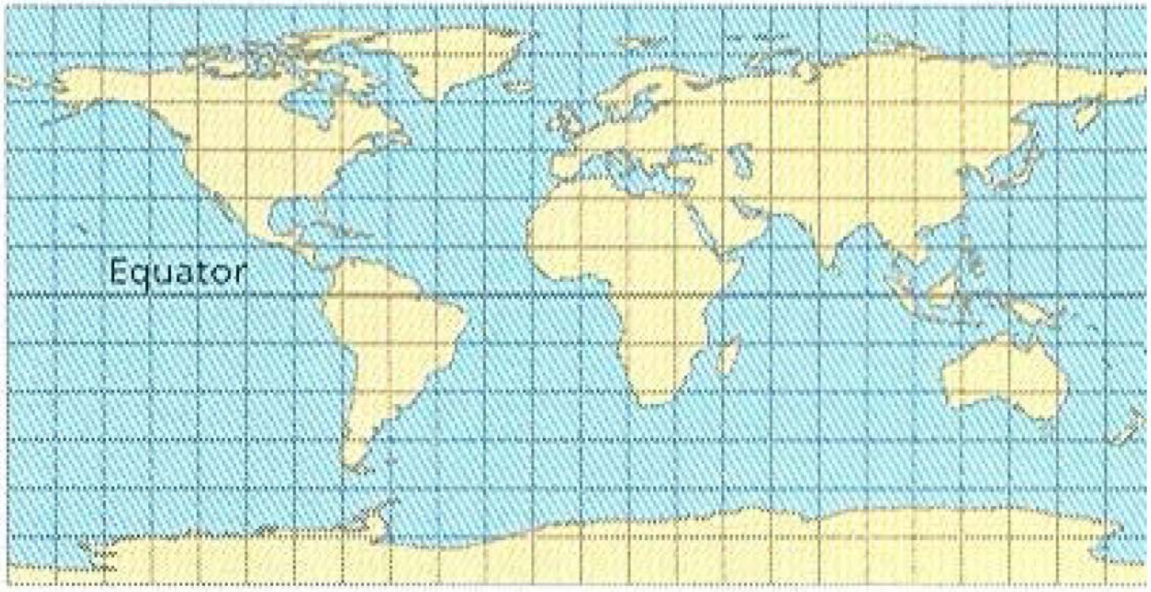


Source: Goode's World Atlas

Cylindrical projections

- Cylindricals are true at the equator and distortion increases toward the poles

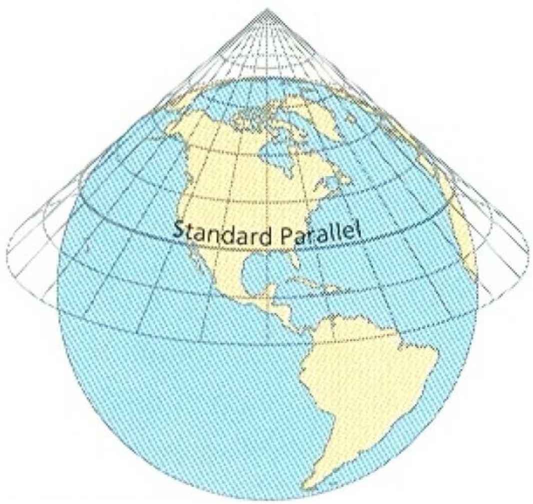


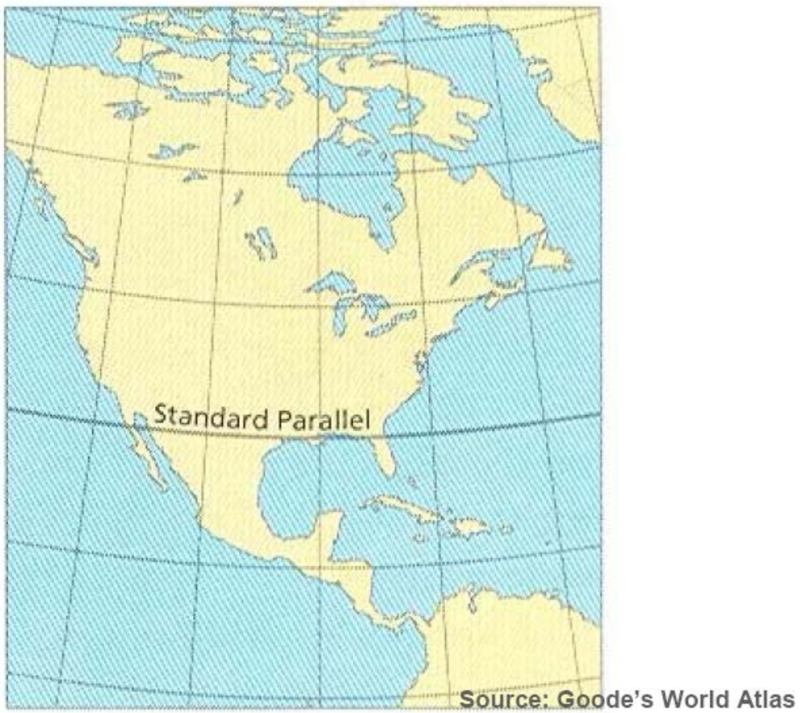


Source: Goode's World Atlas

Conical projections

- Conics are true along some parallel somewhere between the equator and a pole and distortion increases away from this standard.

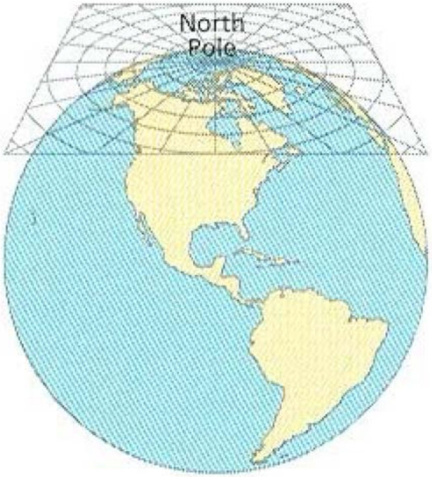


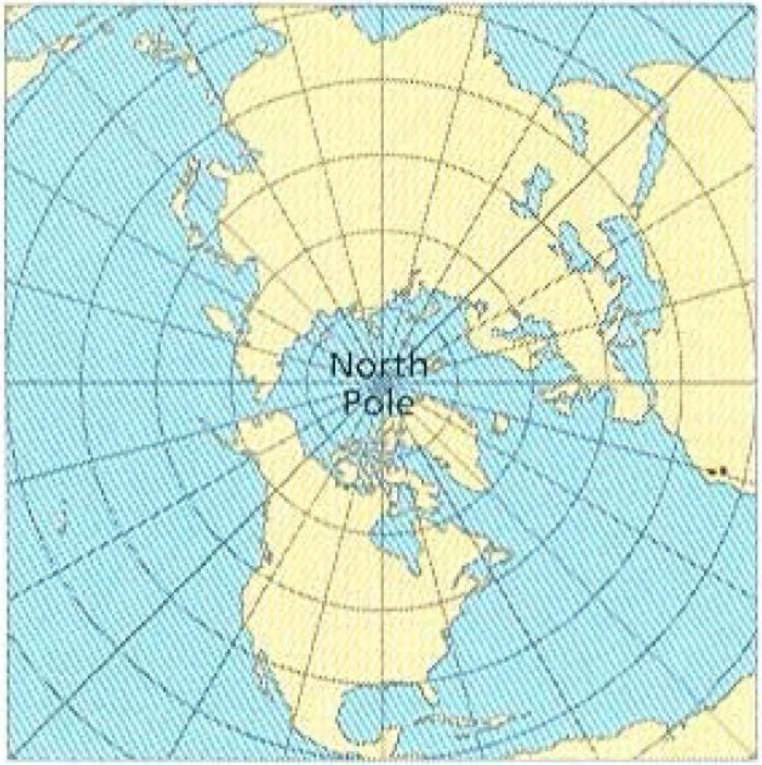


- Standard Parallel: A parallel on a map along which the scale is as stated for that map.

Azimuthal projections

- Azimuthals are true at some point and distortion increases away from this standard.





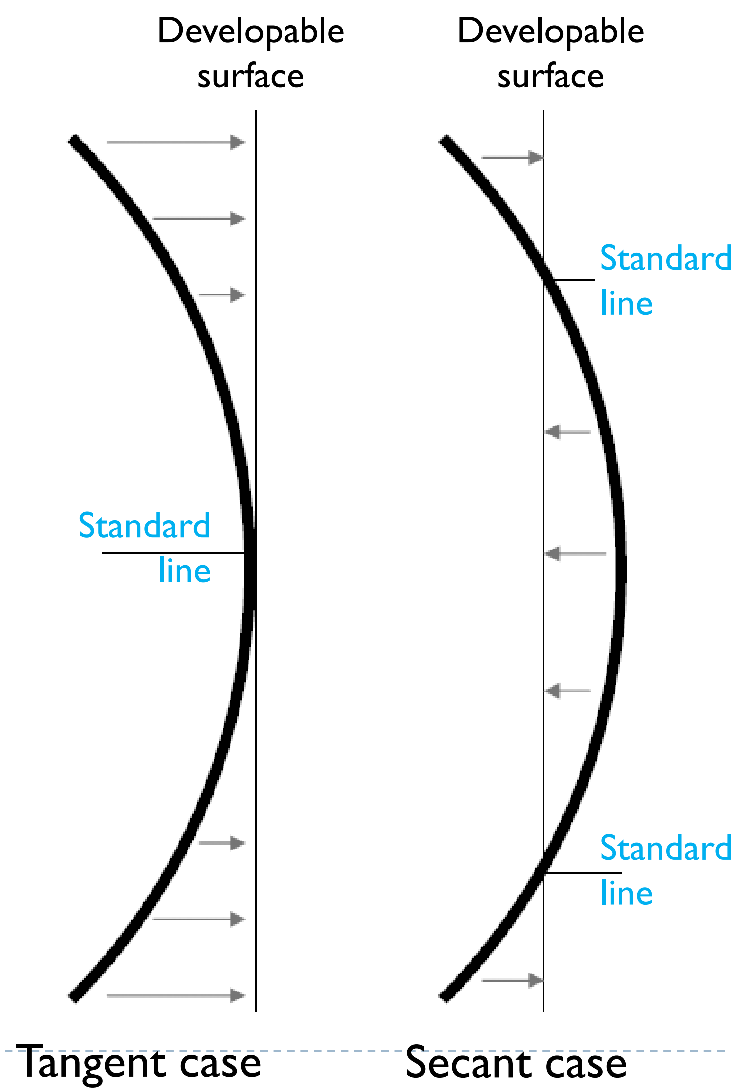
Source: Goode's World Atlas

Projection and distortion

- Each projection creates specific distortions
- Typically we can choose to preserve one or two spatial properties but not all:
  - Areas – *Equivalent proj.*
  - Angles – *Conformal proj.*
  - Distances – *Equidistant proj.*
  - Directions – *Azimuthal proj.*
  - *See Table 9.1 (p.155) on the textbook for details of Named Projection for each Property of projection*

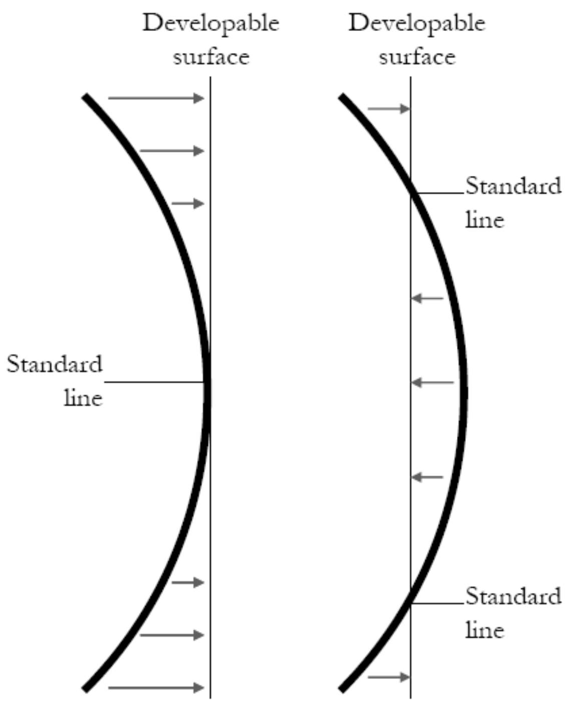
A closer look at distortion

- Distortion increases away from the standard line
  - Scale on reference globe equals to scale on developable surface *only at the standard line(s)!*
- Ways to mitigate distortion
  - Secant *case (intersect 2 points)*
  - Modify *aspect of projection (following slide)*

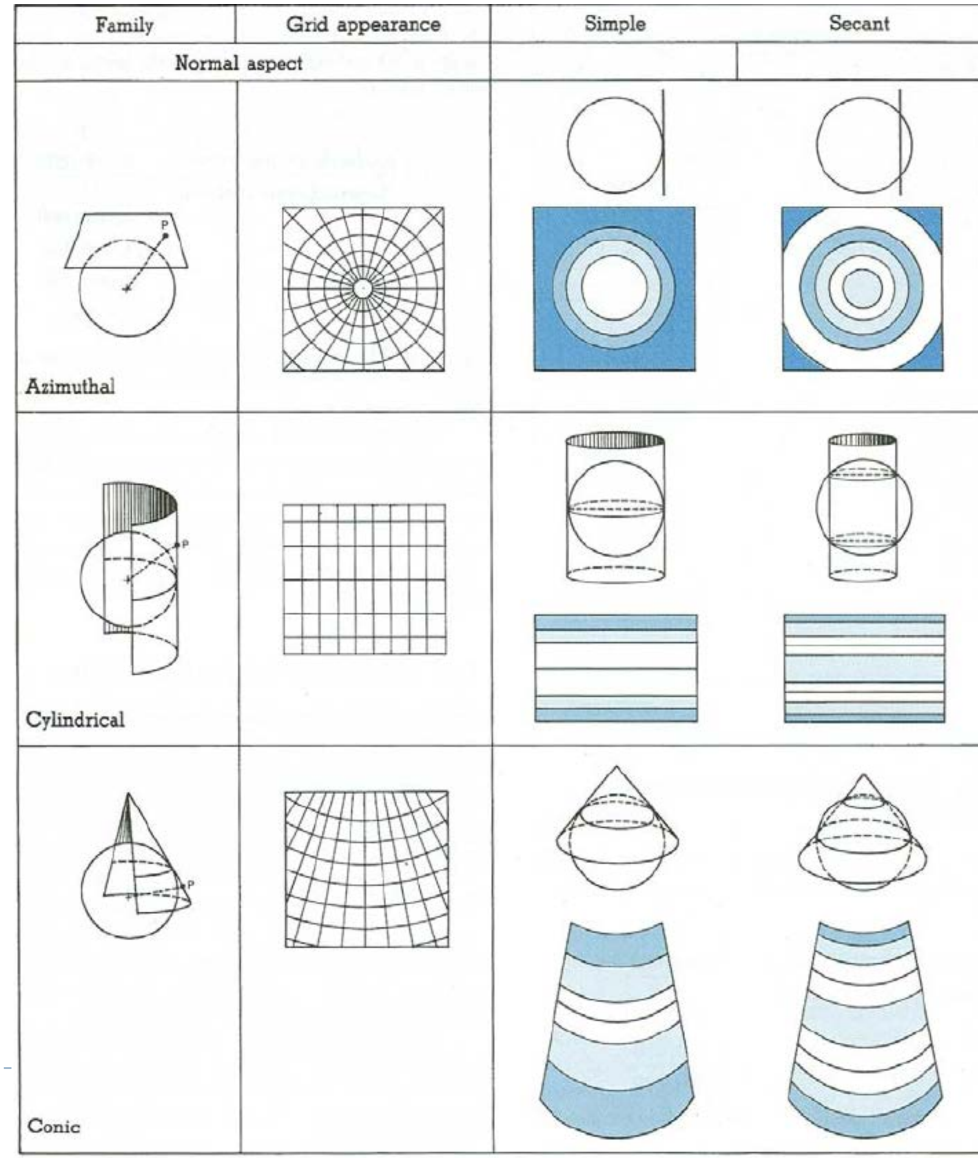


Scale factor varies across a projected map

- A mathematical measure of distortion
- Depends on
  - Type of projection
  - Case
  - Aspect



- Tangent case
  Secant case



Aspects by latitude

- Equatorial
- Oblique
- Polar

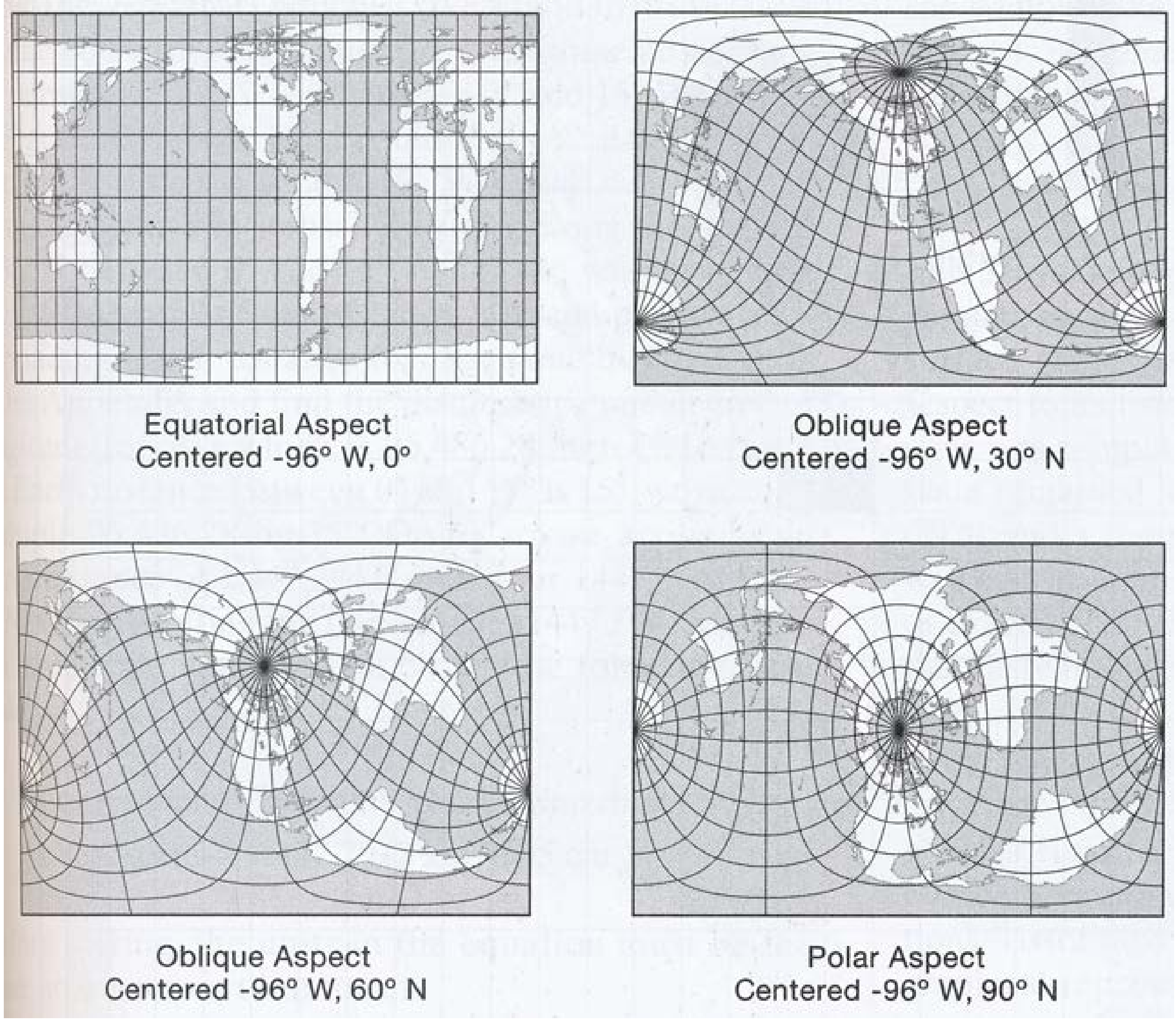


Figure 8.14 (Solcum et al. 2009)

- *"…there is no such thing as a bad projection – there are only good and bad choices."*

Arthur Robinson

Choosing a projection

- Projection properties (Equivalency, conformality, equidistance, azimuthality)
  - Suitable to the map's purpose?
  - Which ones must be preserved, and which can be sacrificed? Or, is compromise of all for the best choice?
- Deformational patterns across mapped area
  - Is amount and location of deformation acceptable?
- Projection center
  - Can the projection be centered easily on the mapped area?
- Familiarity
  - Is appearance recognizable to map reader or will it confuse?

Questions?

- For next time…
  - Revisit Chapters 7&8 in the textbook
  - Lab1