Projections and Coordinate Systems

Overview

- Projections
- Examples of different projections
- Coordinate systems
- Datums

Projections

The earth is a spheroid

The best model of the earth is a globe

Drawbacks:

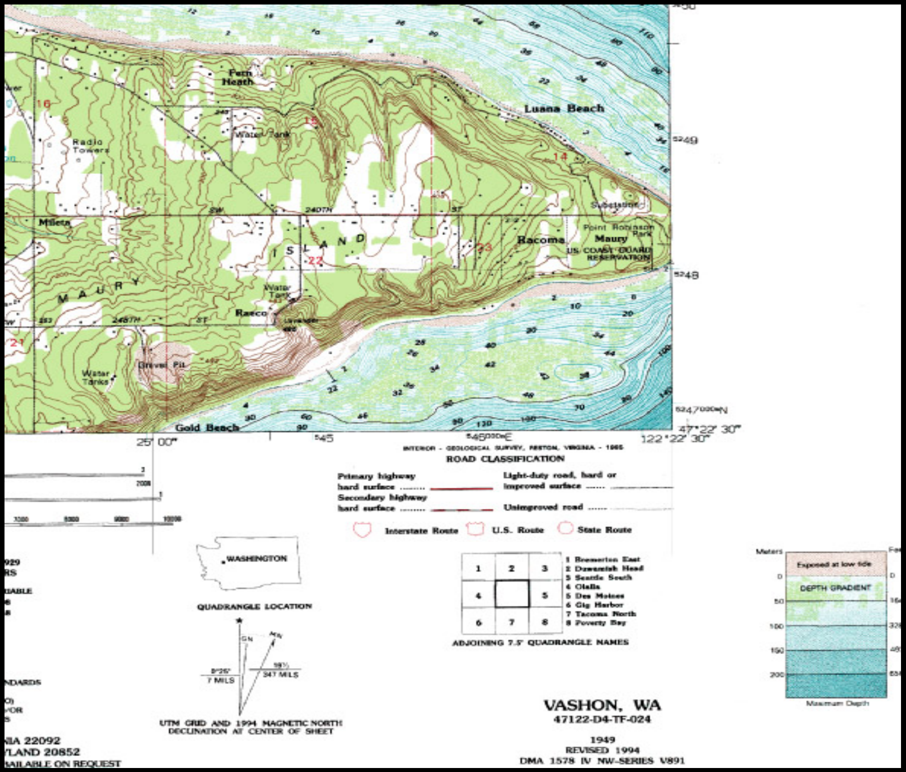
- not easy to carry
- not good for making planimetric measurement (distance, area, angle)

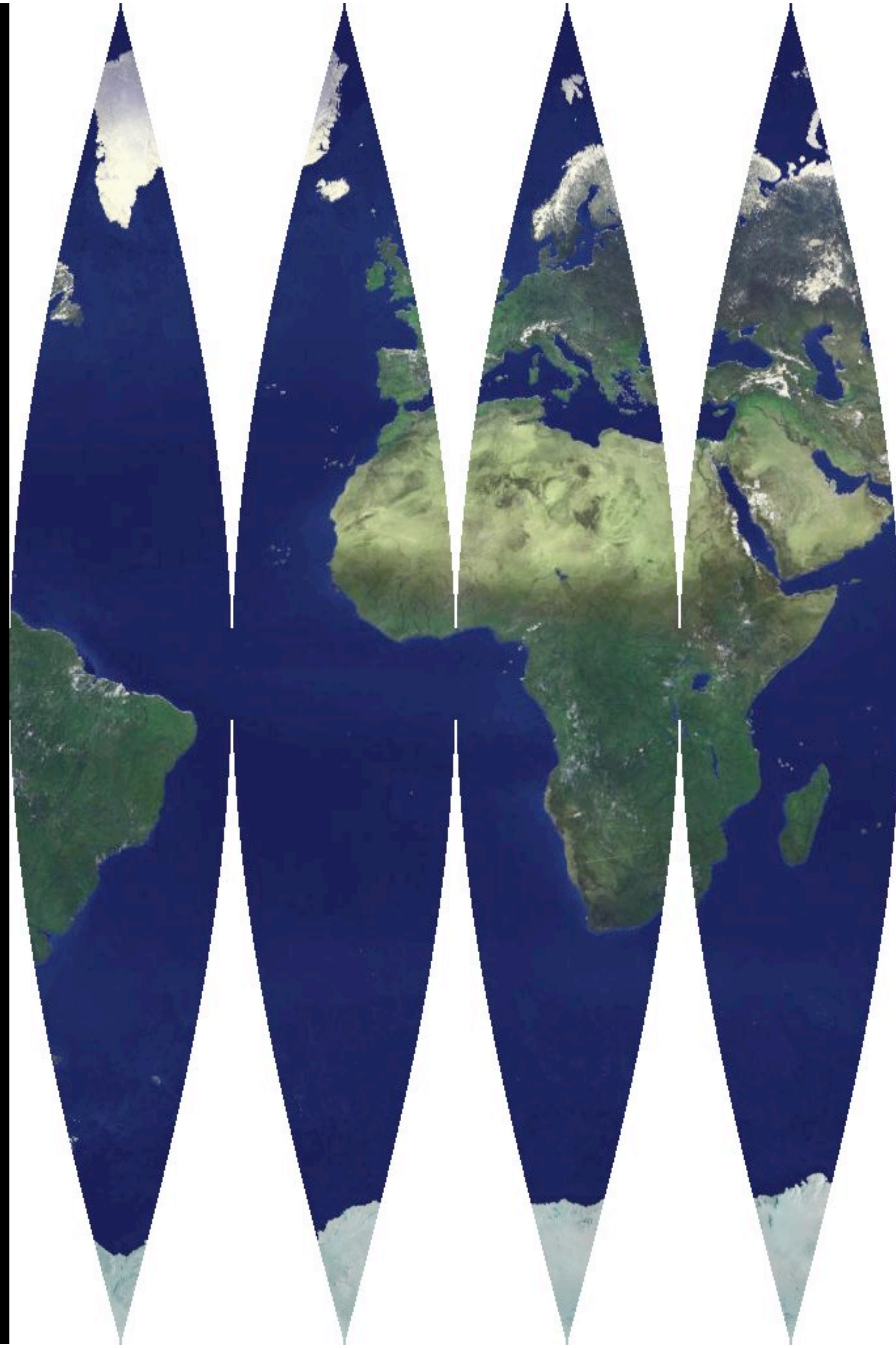
Maps are flat

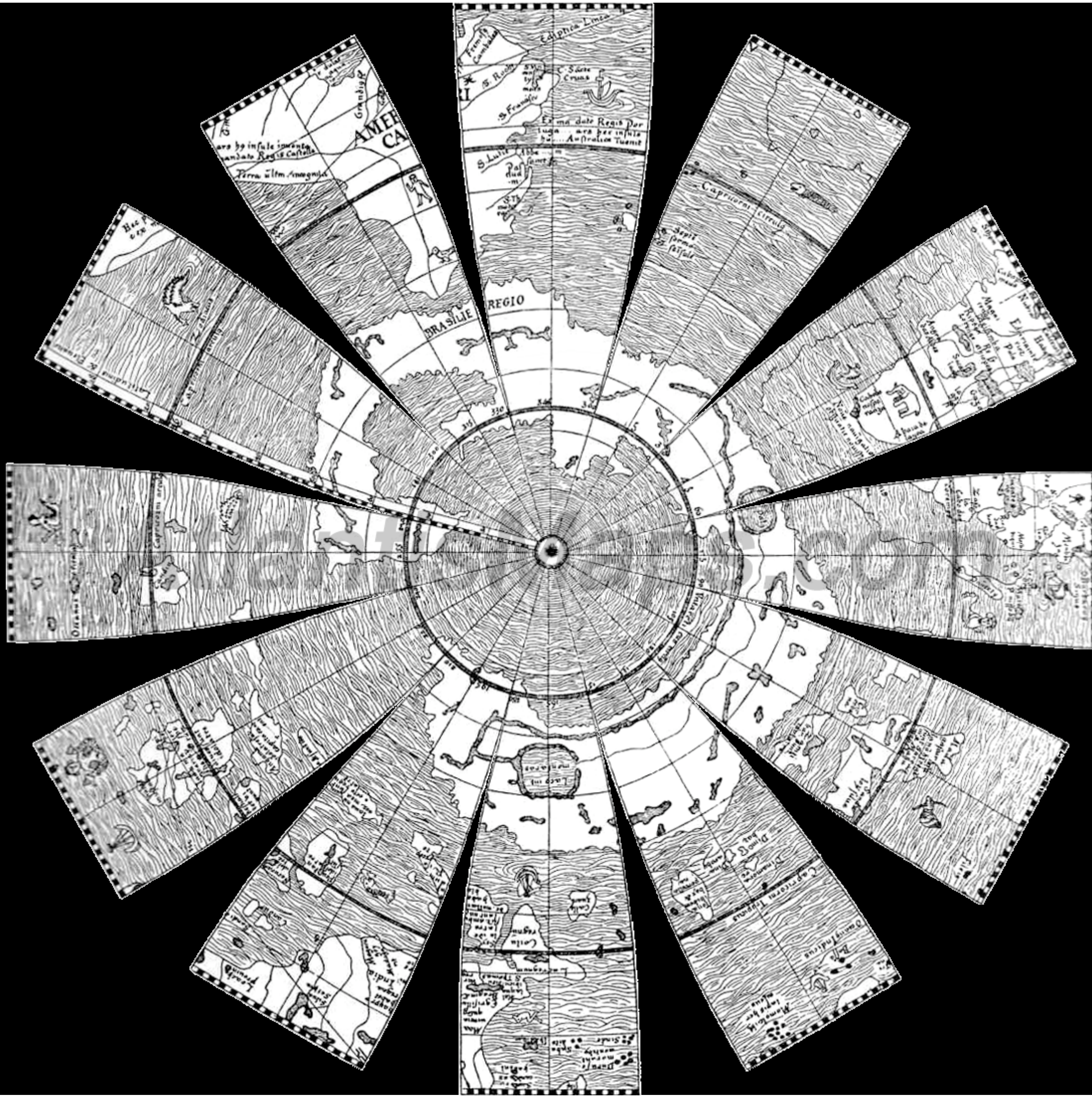
easy to carry

good for measurement

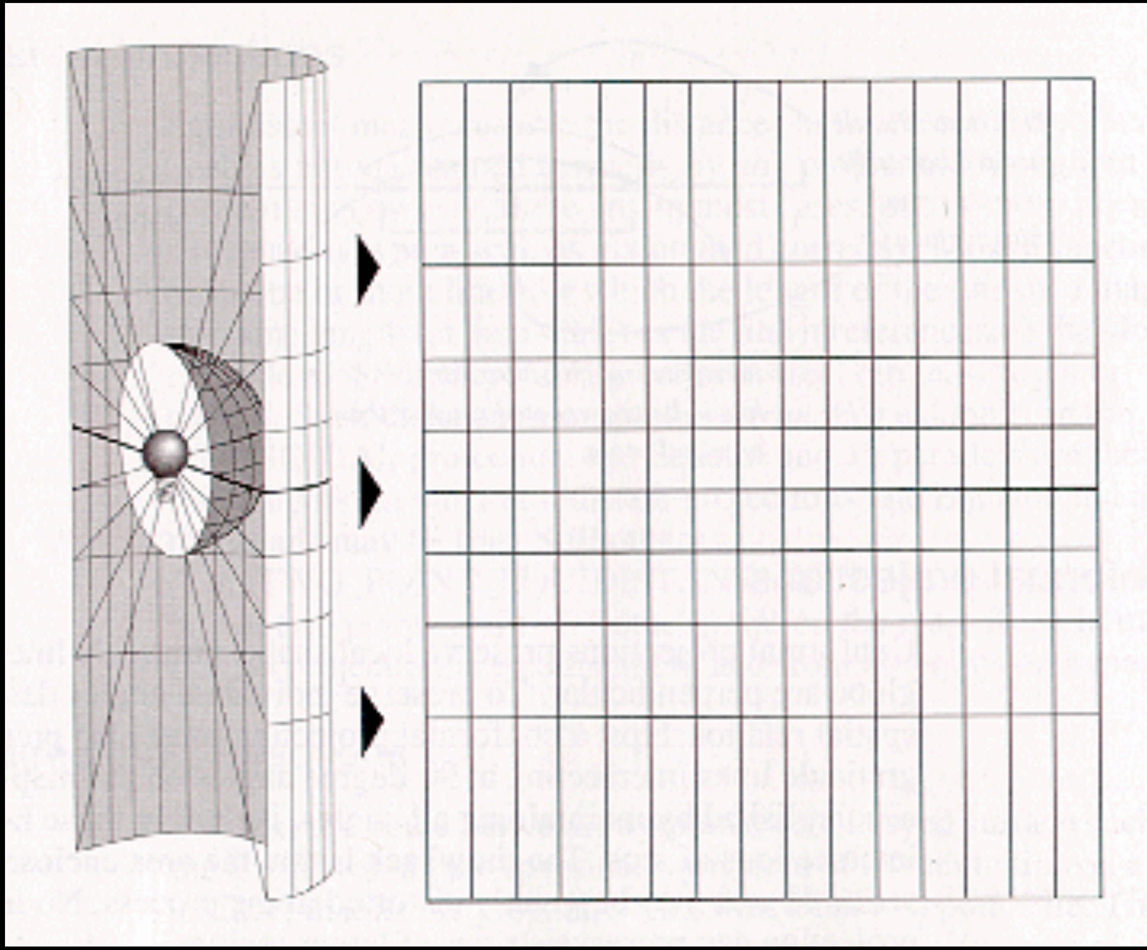
scaleable





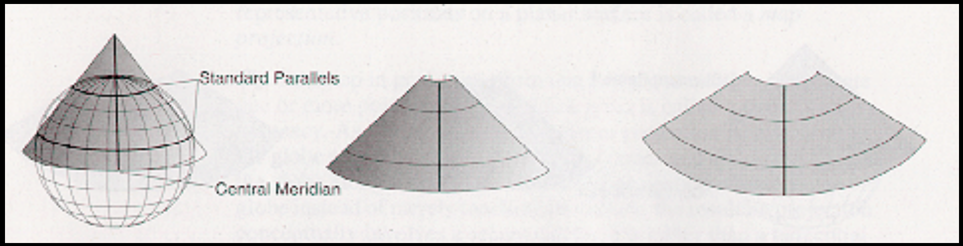

BRASILIE REGIO
Ecliptica Linea
Capricorni circulus

A map projection is a method for mapping spatial patterns on a curved surface (the Earth’s surface) to a flat surface.

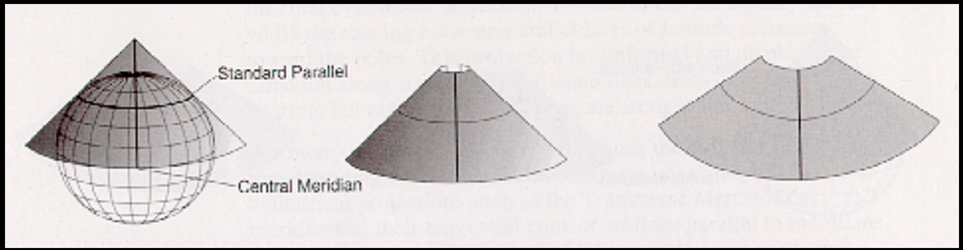


- an imaginary light is “projected” onto a “developable surface”
- a variety of different projection models exist

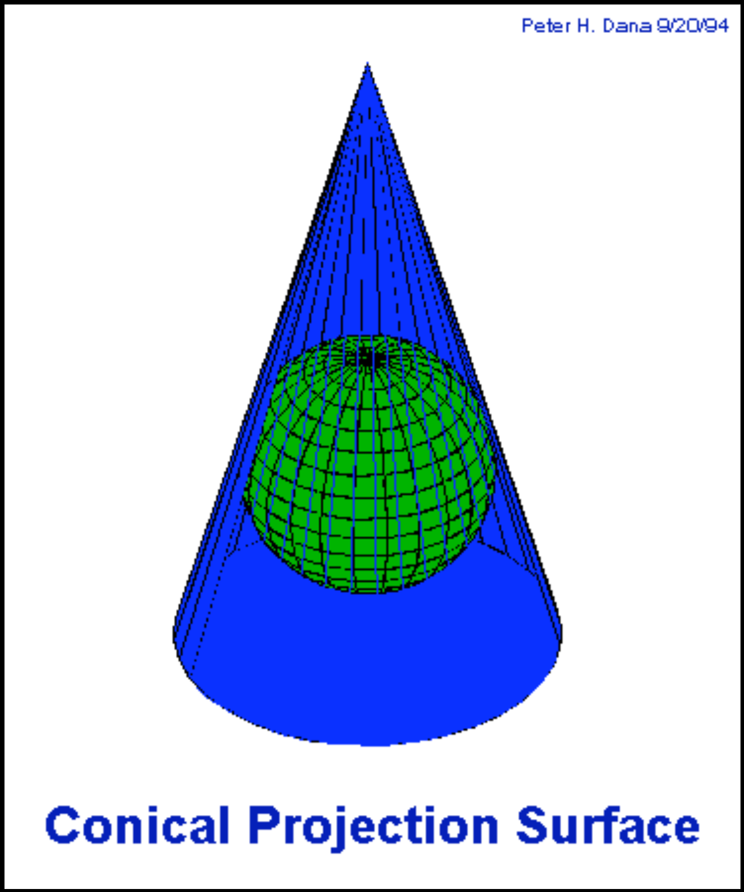
cone as developable surface



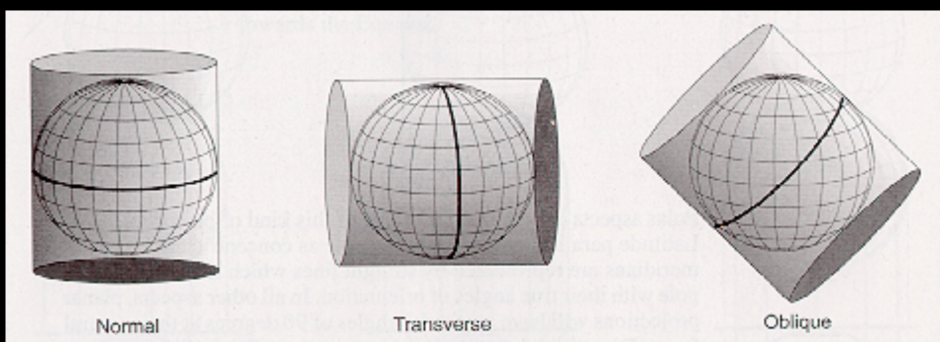
secant cone



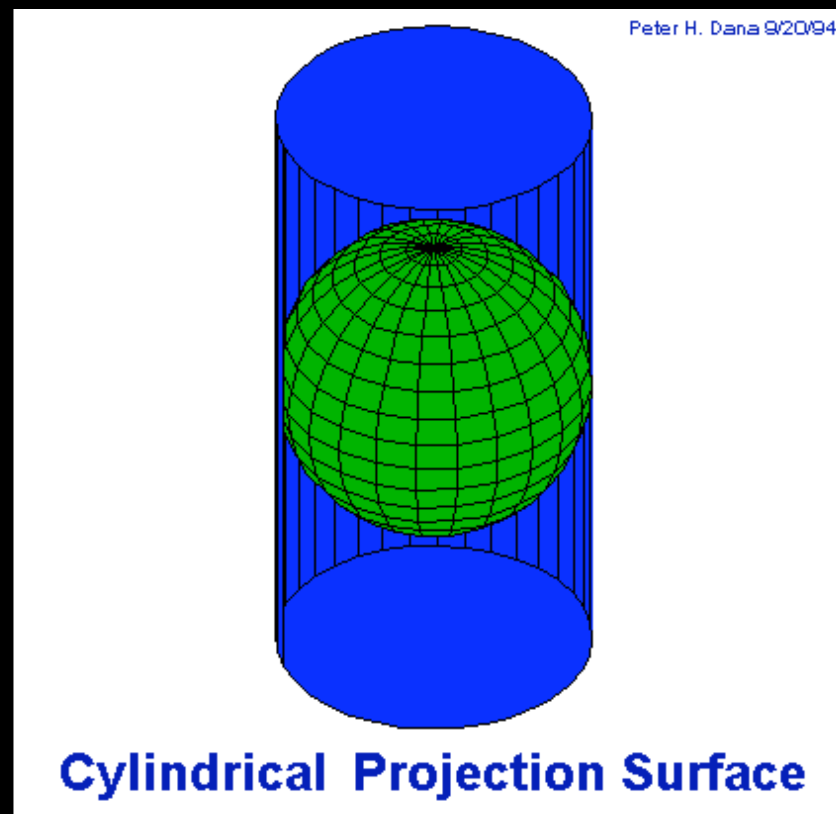
tangent cone



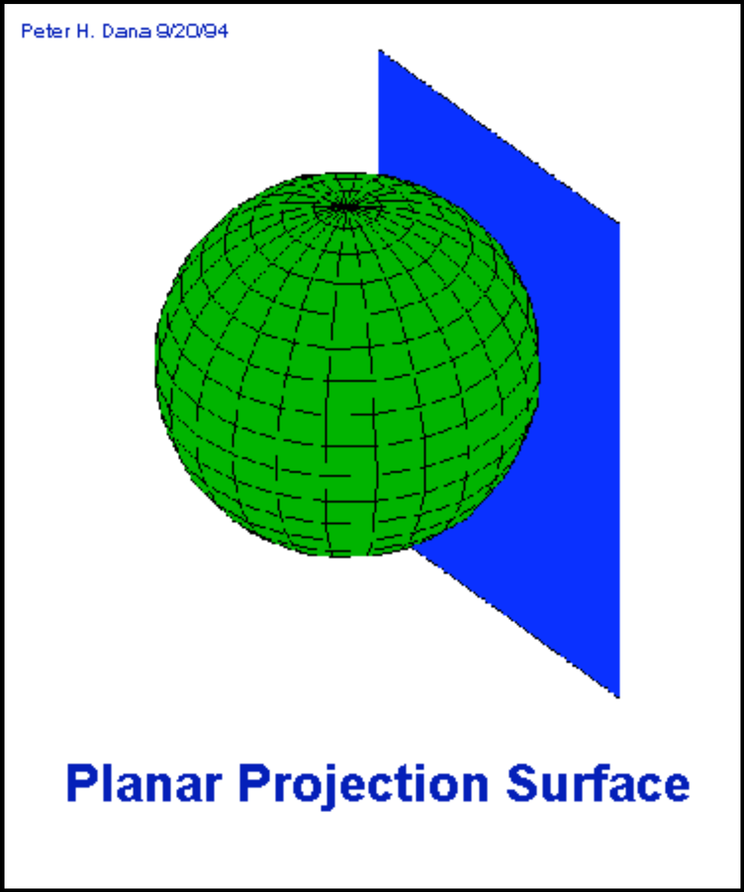
cylinder as developable surface

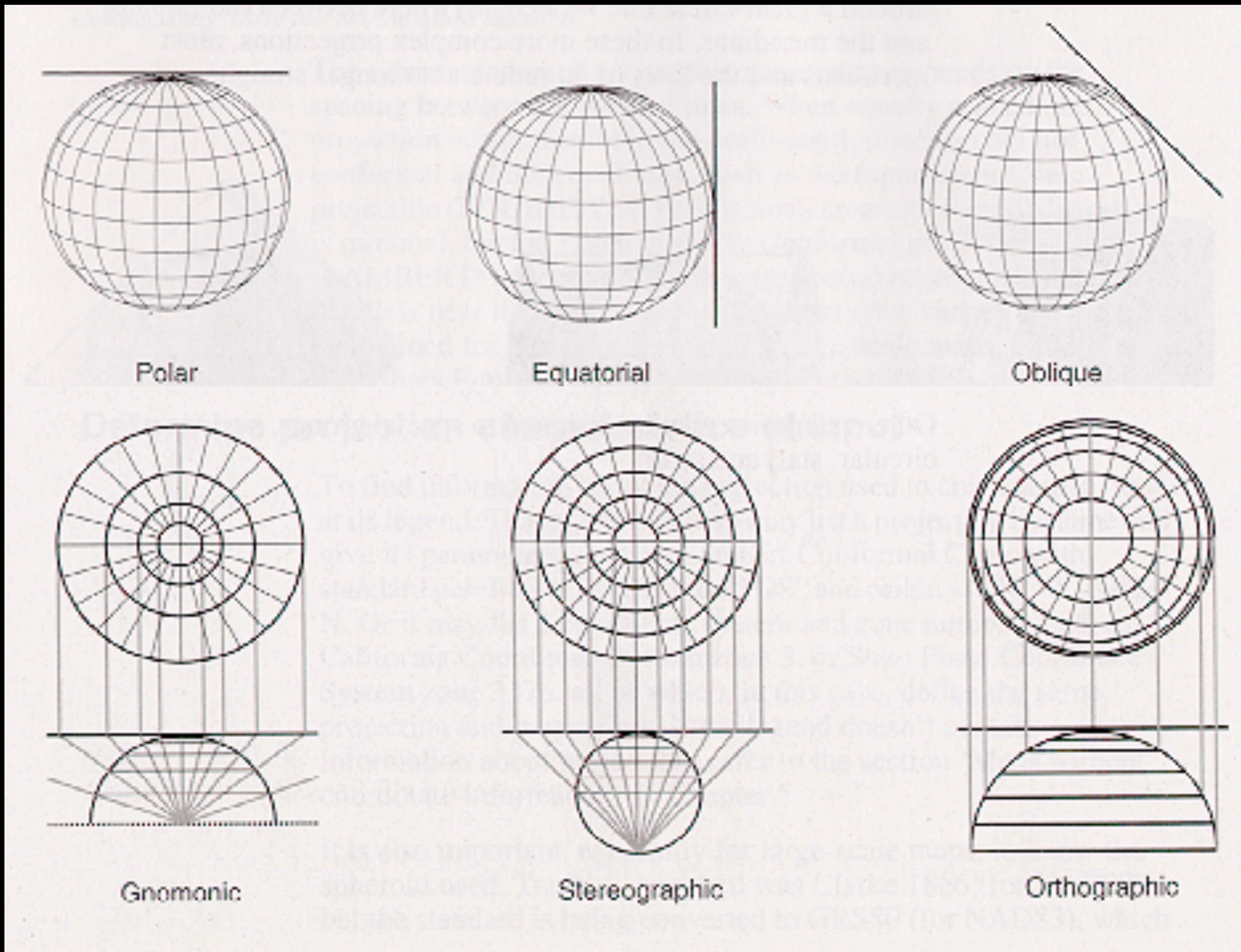


tangent cylinders

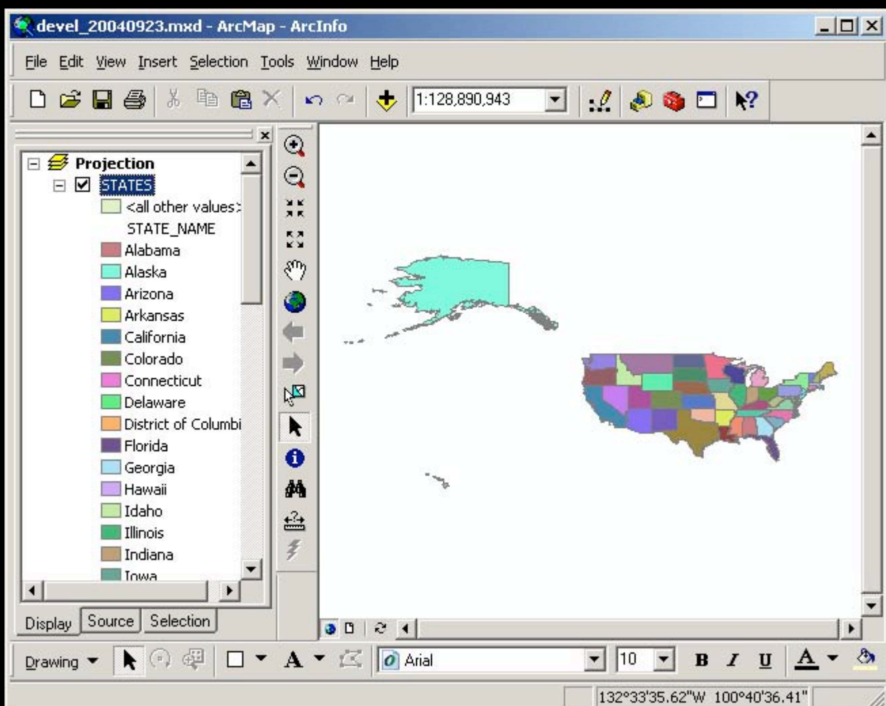


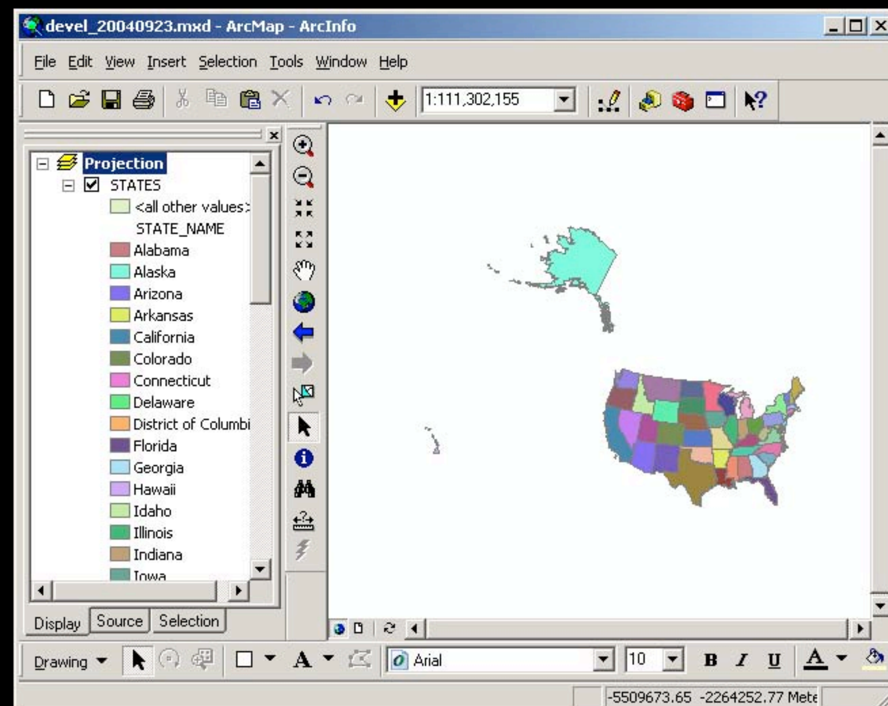
plane as developable surface



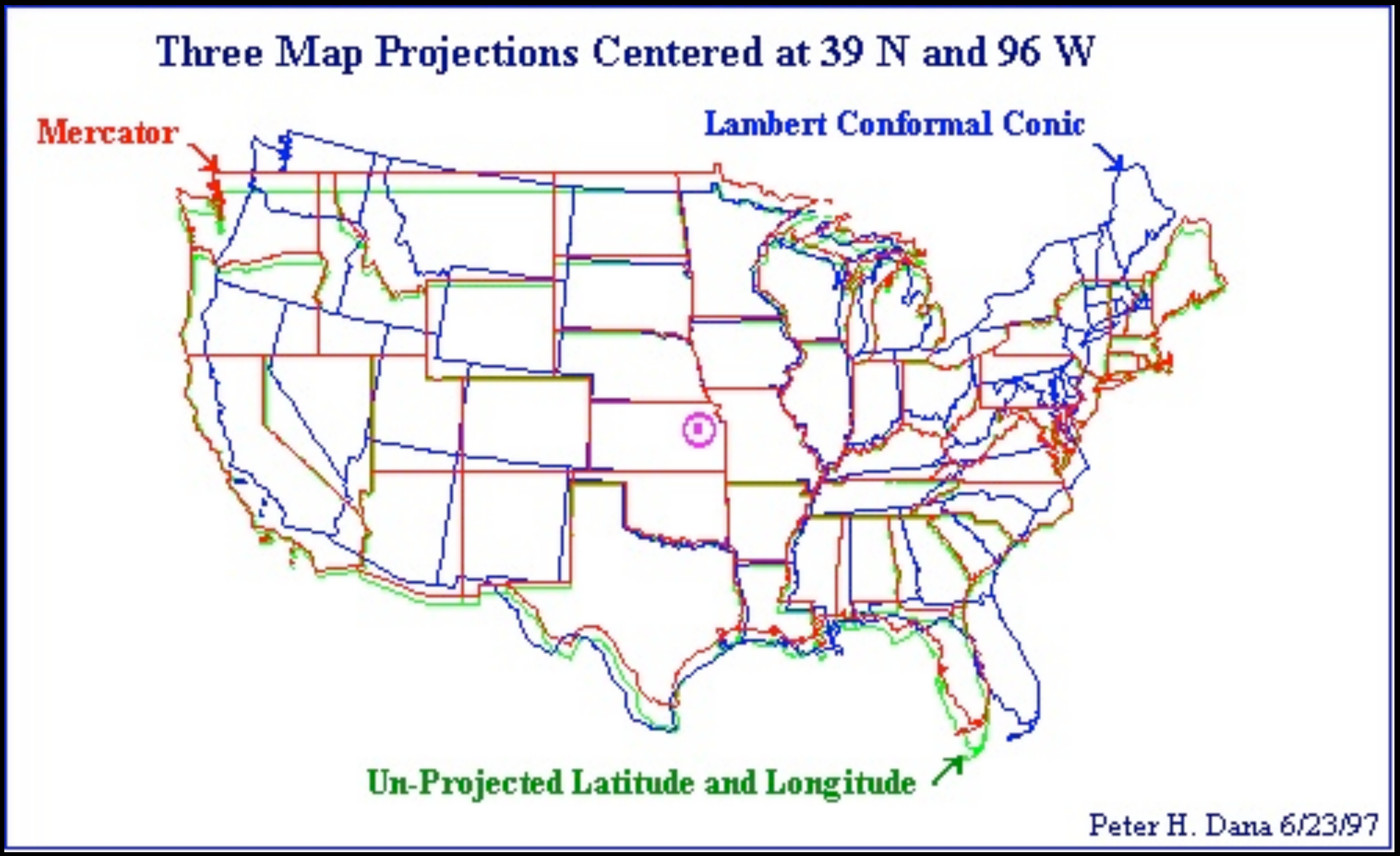

Polar
Equatorial
Oblique
Gnomonic
Stereographic
Orthographic

Map projections *always* introduce error and distortion

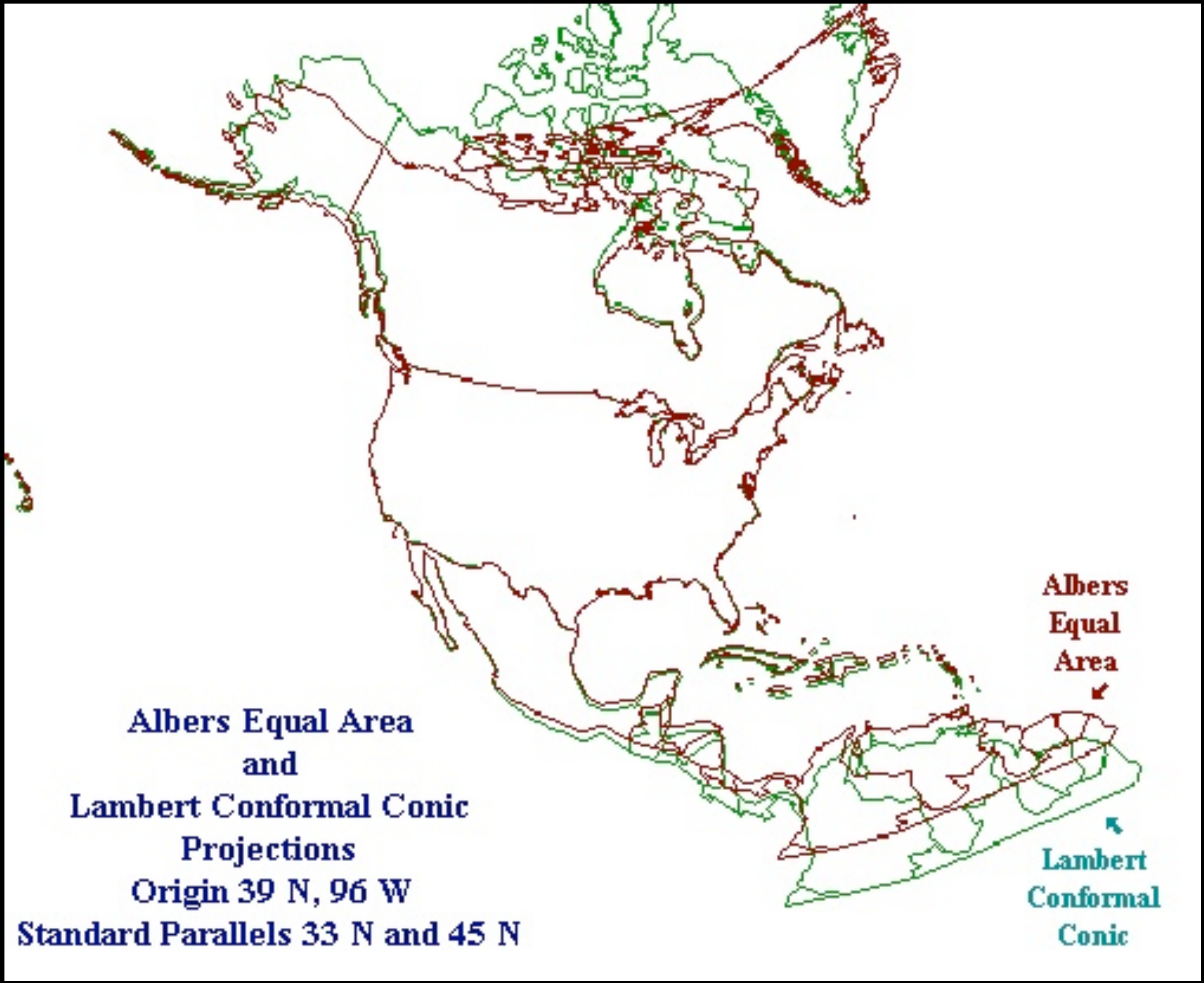




Map projections *always* introduce error and distortion



Map projections *always* introduce error and distortion



Map projections *<u>always</u>* introduce error and distortion

Distortion may be minimized in one or more of the following properties:

- Shape > conformal
- Distance > equidistant
- True Direction > true direction
- Area > equal area

Exactly what are map projections?

Sets of mathematical equations that convert coordinates from one system to another

$$(x, y) \xrightarrow{f} f(x, y)$$

<u>input</u>
unprojected
angles (lat/long)

<u>output</u>
projected
Cartesian coordinates

How do projections work on a programmatic level?

- each set of "coordinates" is transformed using a specific projection equation from one system to another
- angular measurements can be converted to Cartesian coordinates
- one set of Cartesian coordinates can be converted to a different measurement framework

Projection, zone, datum (units)	X	Y
geographic, NAD27 (decimal degrees)	-122.35°	47.62°
UTM, Zone 10, NAD27 (meters)	548843.5049	5274052.0957
State Plane, WA-N, NAD83 (feet)	1266092.5471	229783.3093

How does ArcGIS handle map projections in *data frames*?

- Project data frames to see or measure features under different projection parameters
- Applying a projection on a data frame projects data “on the fly.”
- ArcGIS’s data frame projection equations can handle any input projection.
- However, sometimes on-the-fly projected data do not properly overlap.

Applying a projection to a data frame is like putting on a pair of glasses



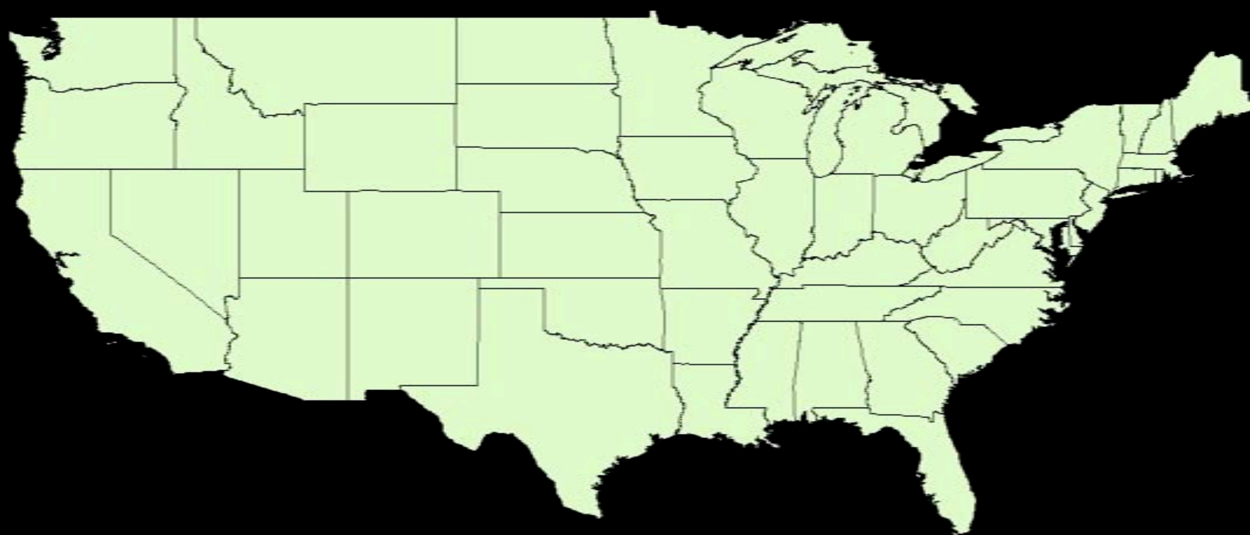


You see the map differently, but the data have not changed

How does ArcGIS handle map projections for *data*?

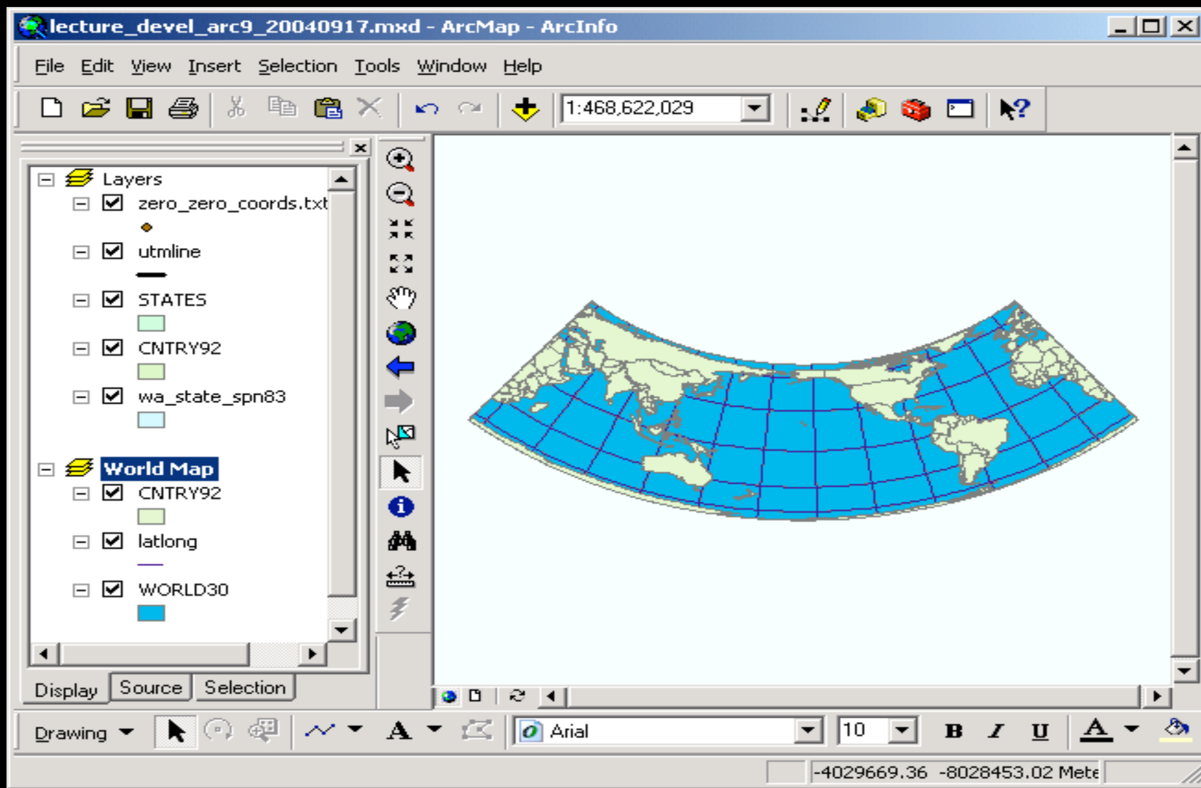
- Projecting data creates a new data set on the file system
- Data can be projected so that incompatibly projected data sets can be made to match.
- ArcGIS's projection engine can go in and out of a large number of different projections, coordinate systems, and datums.

Geographic “projection”

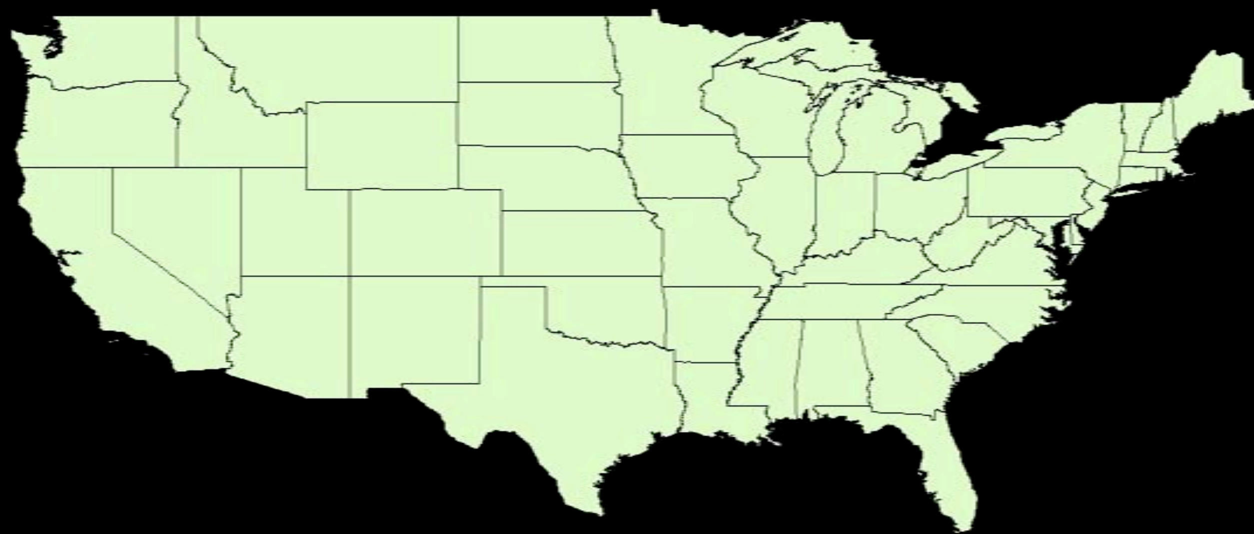


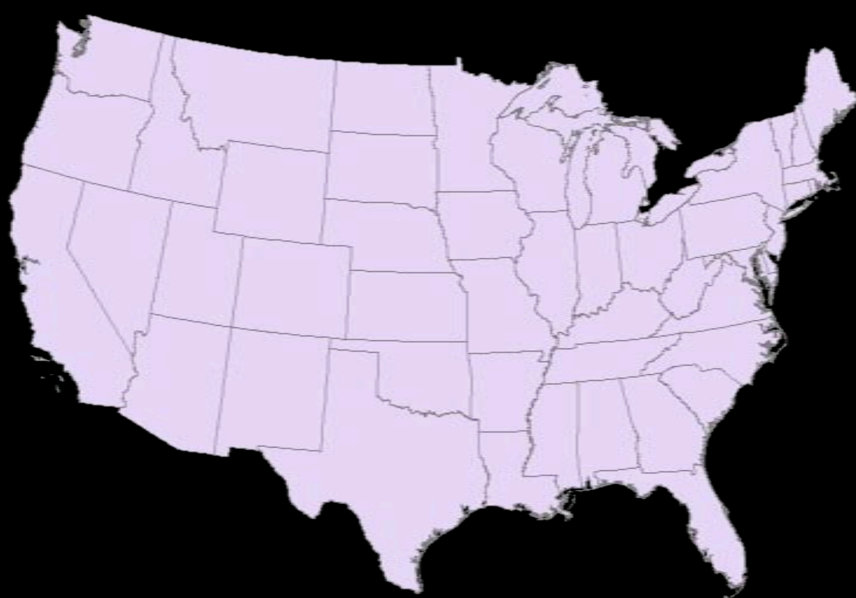
Examples of different projections

- Albers (Conic)



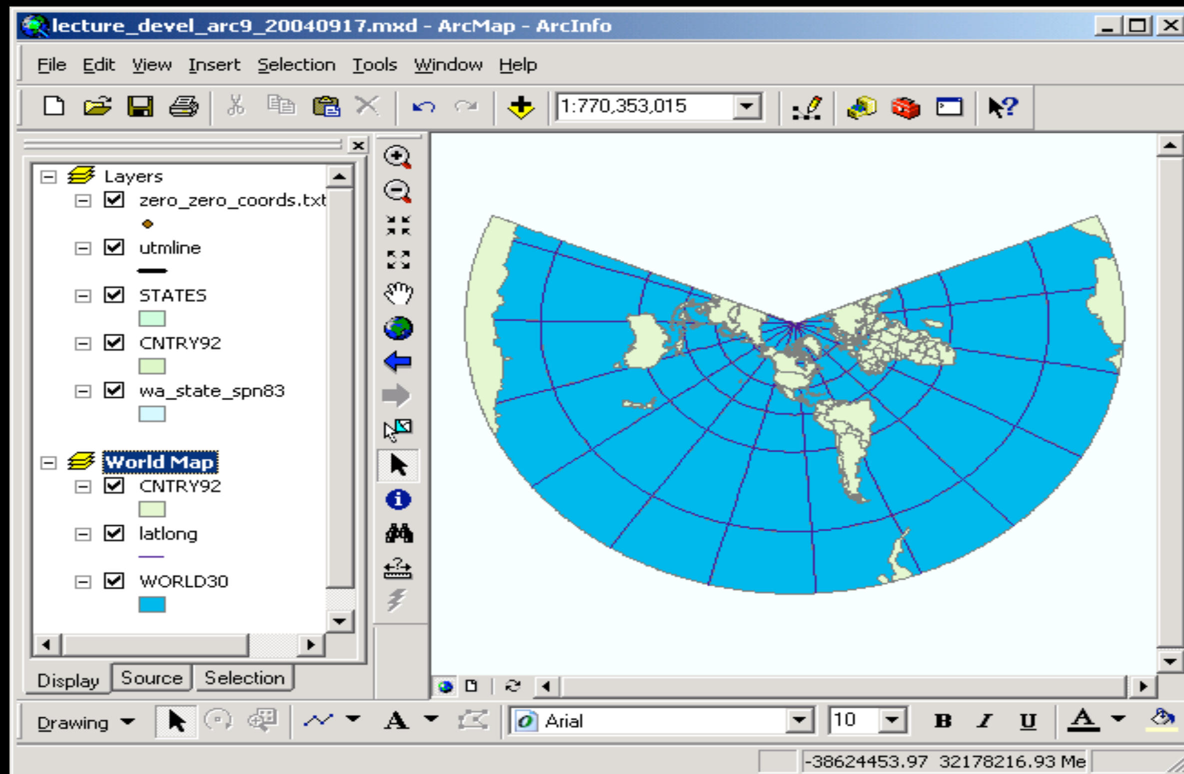
Shape	**Shape along the standard parallels is accurate and minimally distorted in the region between the standard parallels and those regions just beyond. The 90-degree angles between meridians and parallels are preserved, but because the scale along the lines of longitude does not match the scale along lines of latitude, the final projection is not conformal.**
Area	**All areas are proportional to the same areas on the Earth.**
Direction	**Locally true along the standard parallels.**
Distance	**Distances are best in the middle latitudes. Along parallels, scale is reduced between the standard parallels and increased beyond them. Along meridians, scale follows an opposite pattern.**



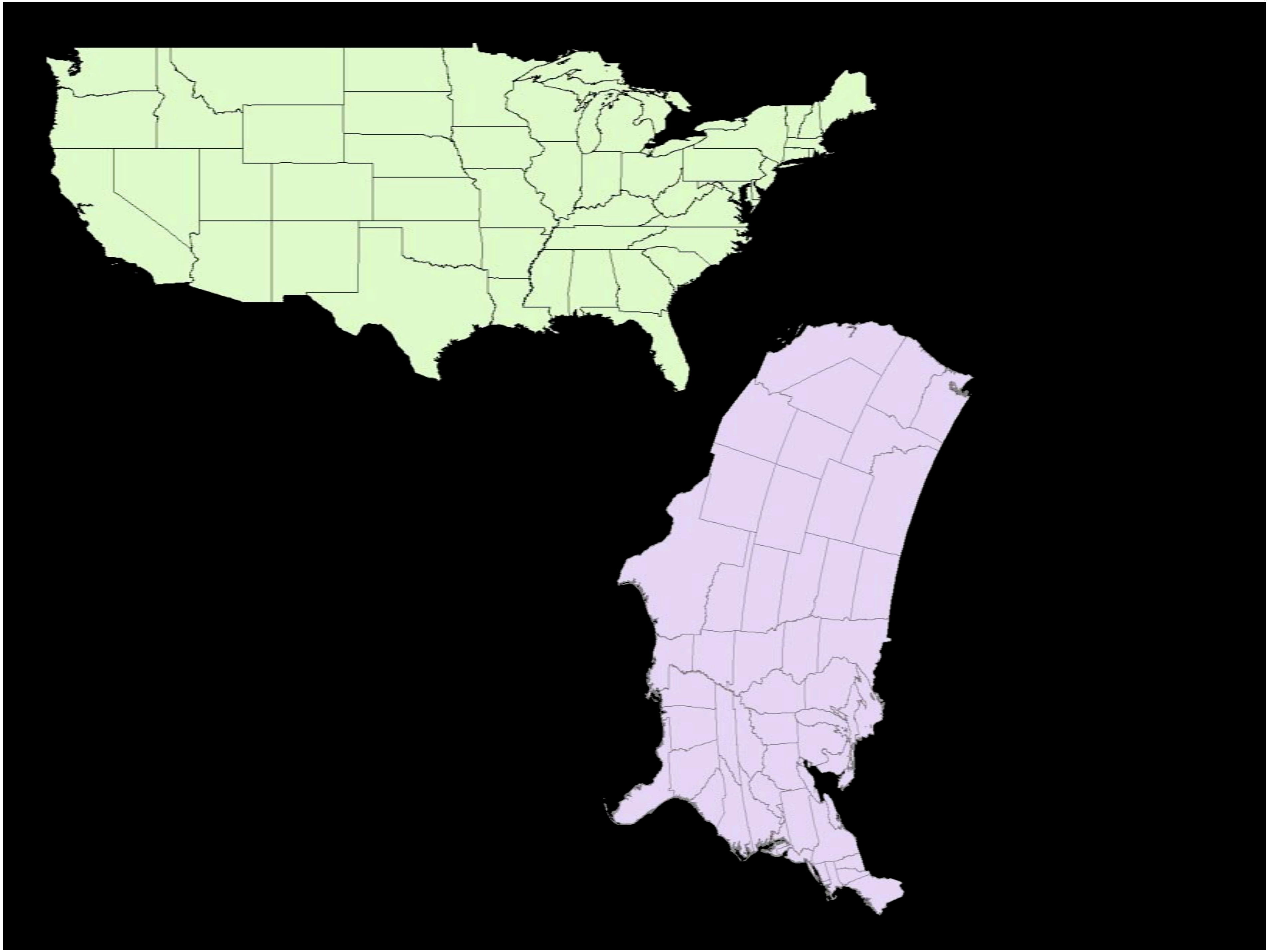


Examples of different projections

- Lambert Azimuthal Equal Area (Planar)

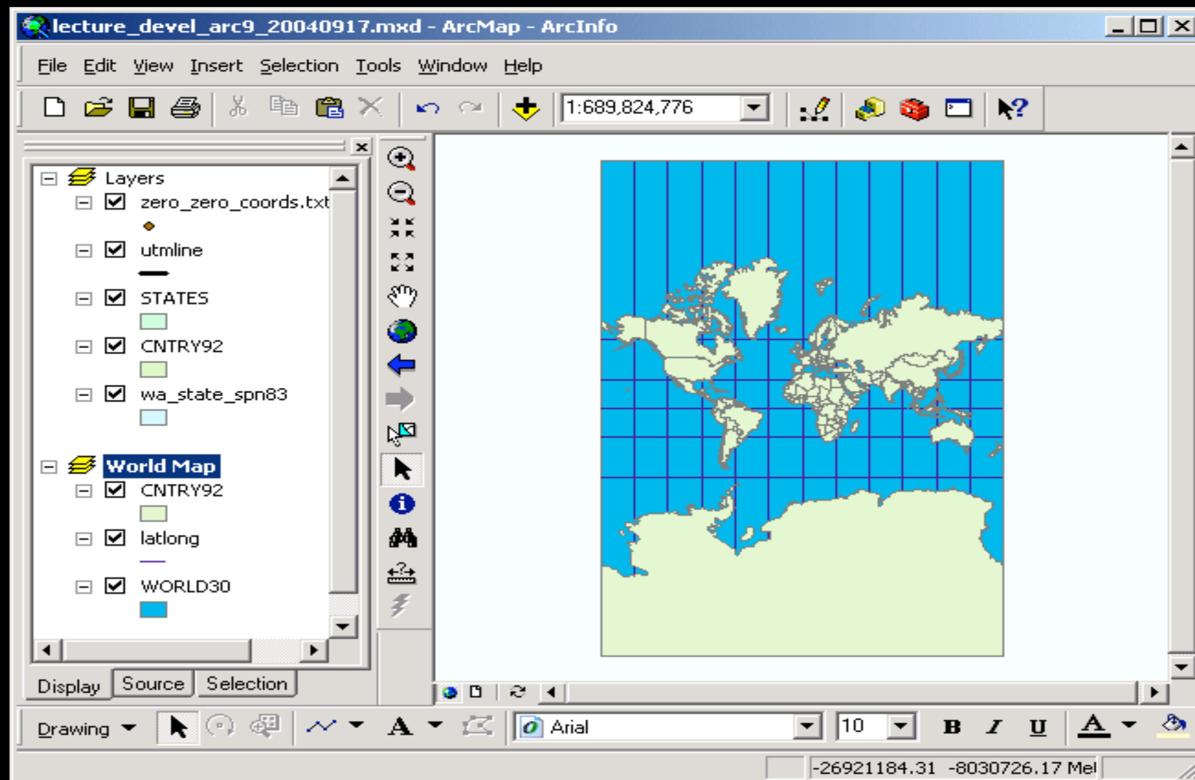


Shape	**Shape is true along the standard parallels of the normal aspect (Type 1), or the standard lines of the transverse and oblique aspects (Types 2 and 3). Distortion is severe near the poles of the normal aspect or 90° from the central line in the transverse and oblique aspects.**
Area	**There is no area distortion on any of the projections.**
Direction	**Local angles are correct along standard parallels or standard lines. Direction is distorted elsewhere.**
Distance	**Scale is true along the Equator (Type 1), or the standard lines of the transverse and oblique aspects (Types 2 and 3). Scale distortion is severe near the poles of the normal aspect or 90° from the central line in the transverse and oblique aspects.**



Examples of different projections

- Mercator (Cylindrical)

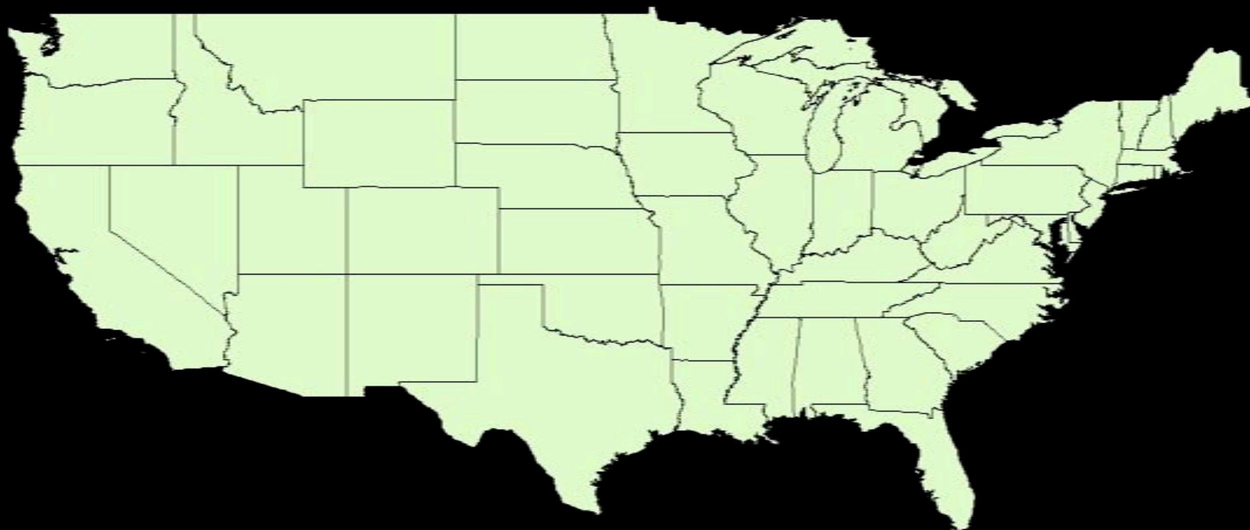
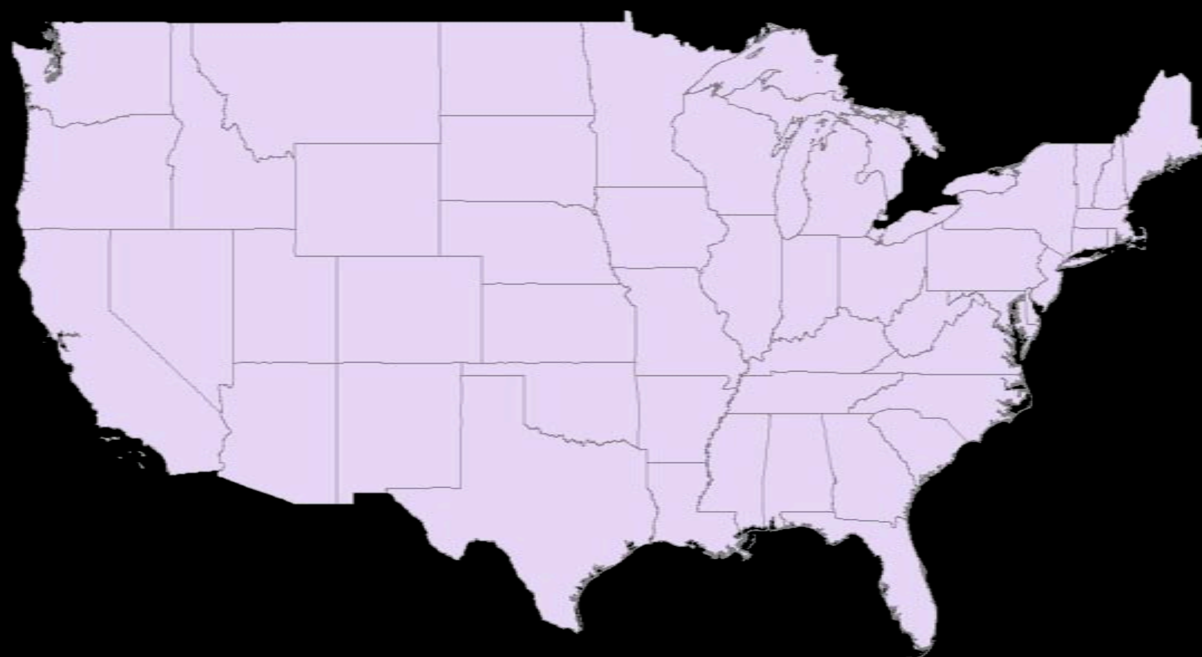


Shape Conformal. Small shapes are well represented because this projection maintains the local angular relationships.

Area Increasingly distorted toward the polar regions. For example, in the Mercator projection, although Greenland is only one-eighth the size of South America, Greenland appears to be larger.

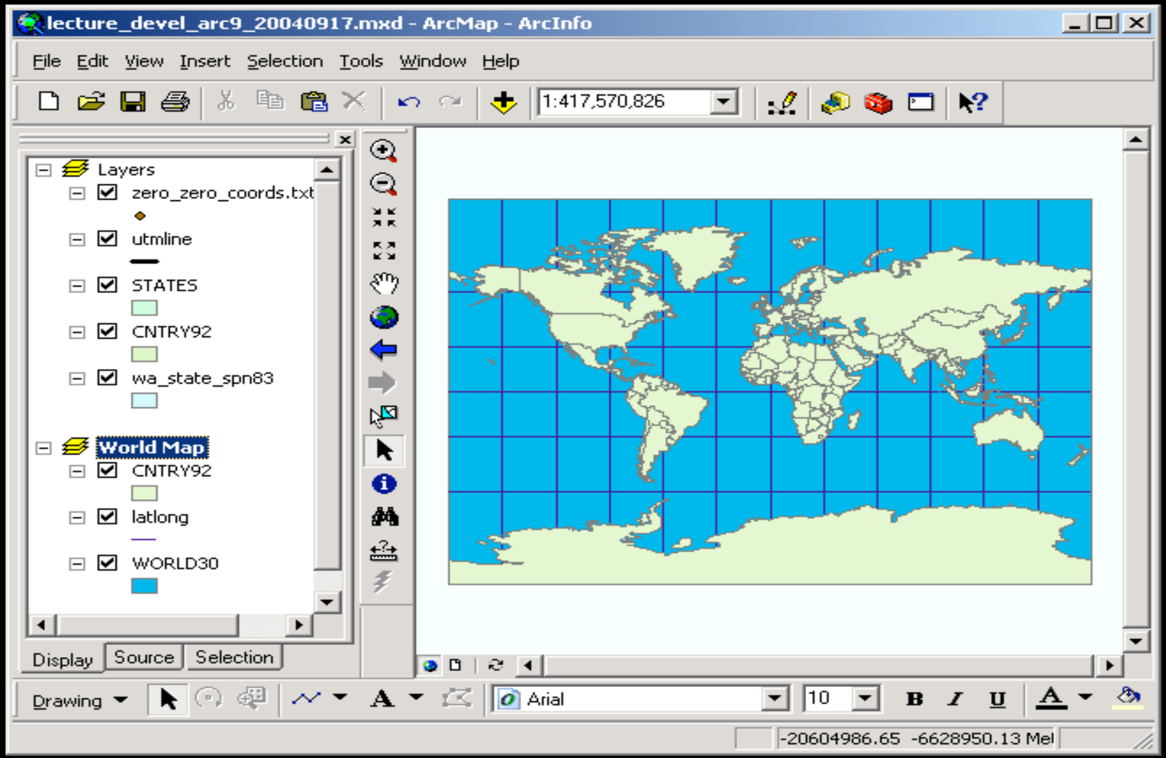
Direction Any straight line drawn on this projection represents an actual compass bearing. These true direction lines are rhumb lines, and generally do not describe the shortest distance between points.

Distance Scale is true along the Equator, or along the secant latitudes.

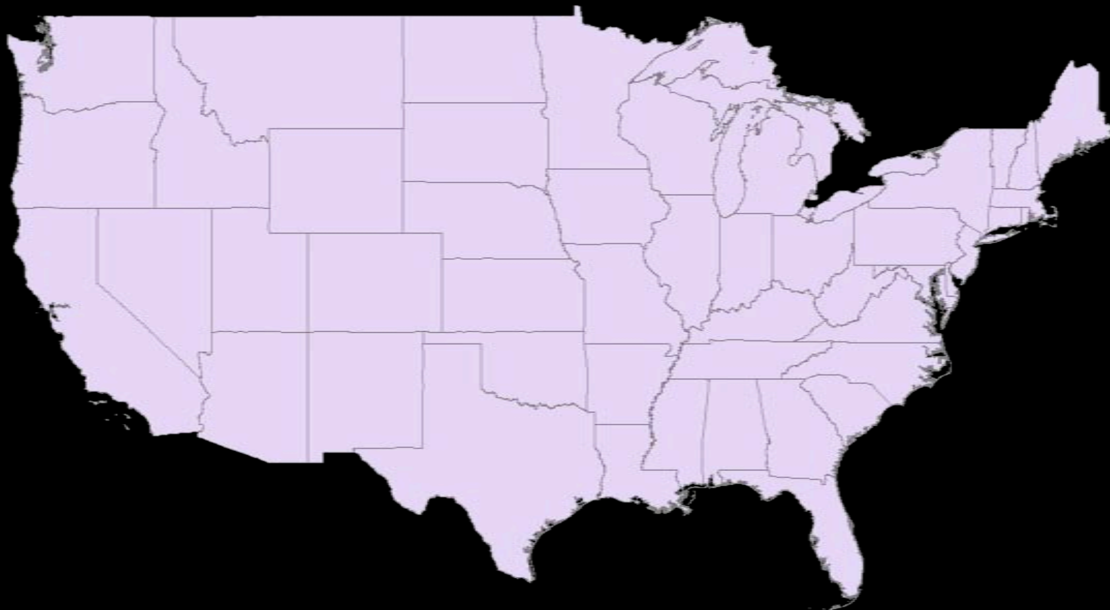



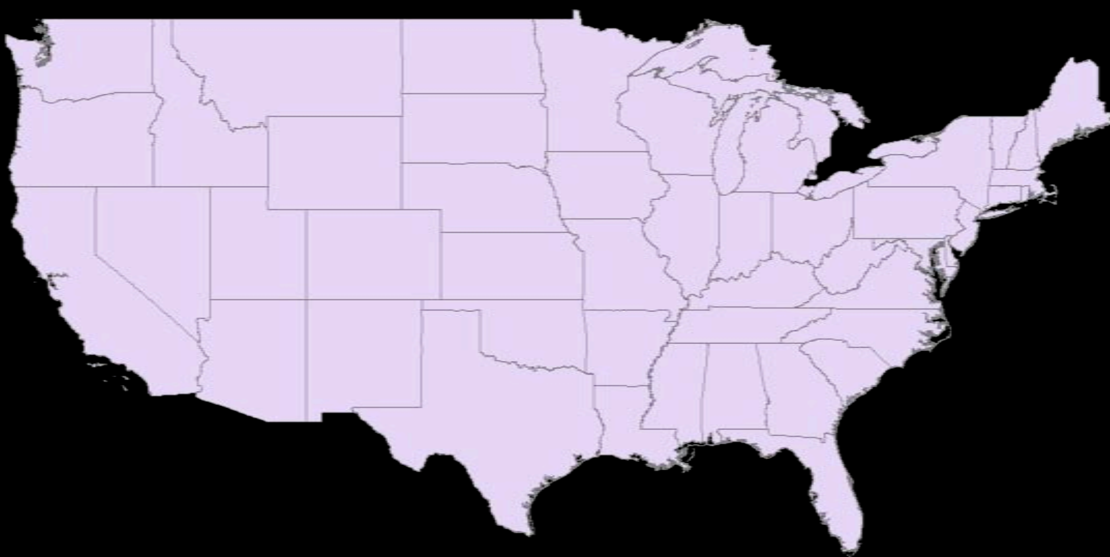
Examples of different projections

- Miller (Cylindrical)



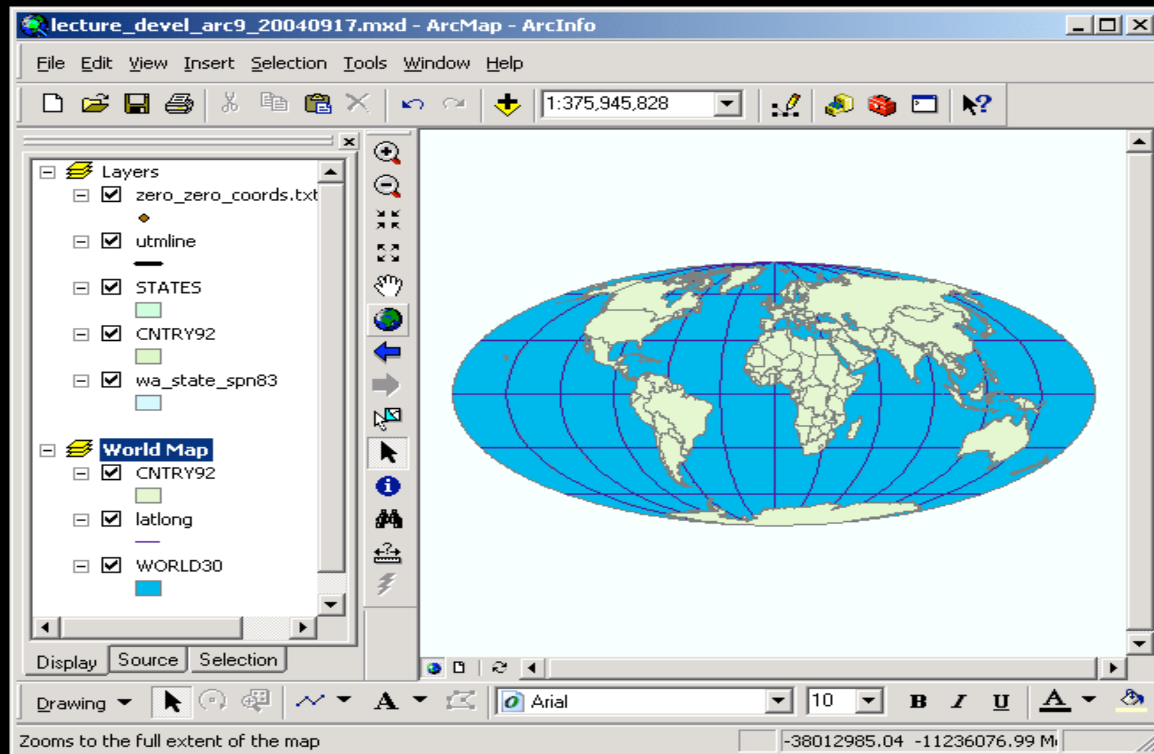
Shape	**Minimally distorted between 45th parallels, increasingly toward the poles. Land masses are stretched more east to west than they are north to south.**
Area	**Distortion increases from the Equator toward the poles.**
Direction	**Local angles are correct only along the Equator.**
Distance	**Correct distance is measured along the Equator.**



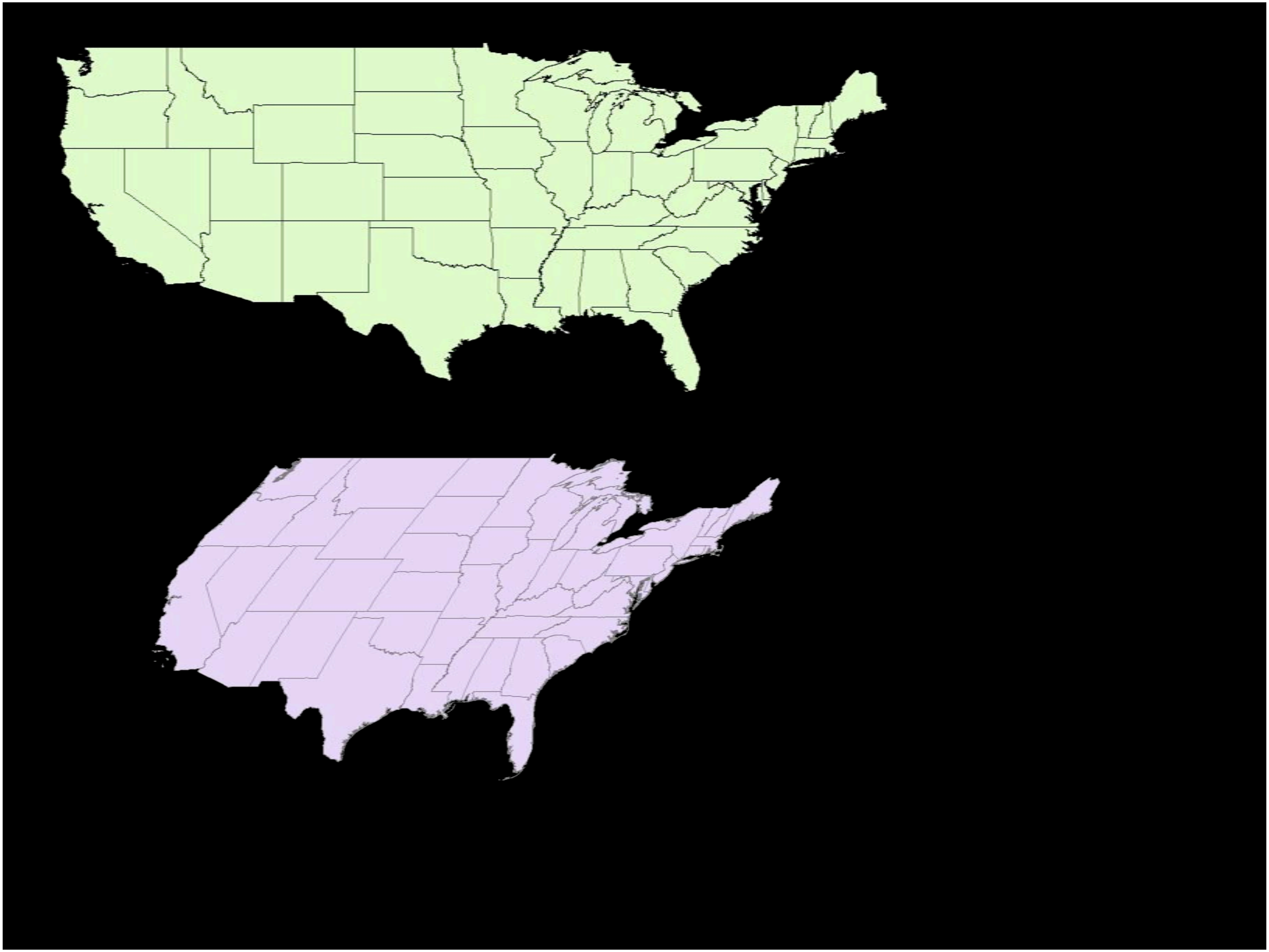


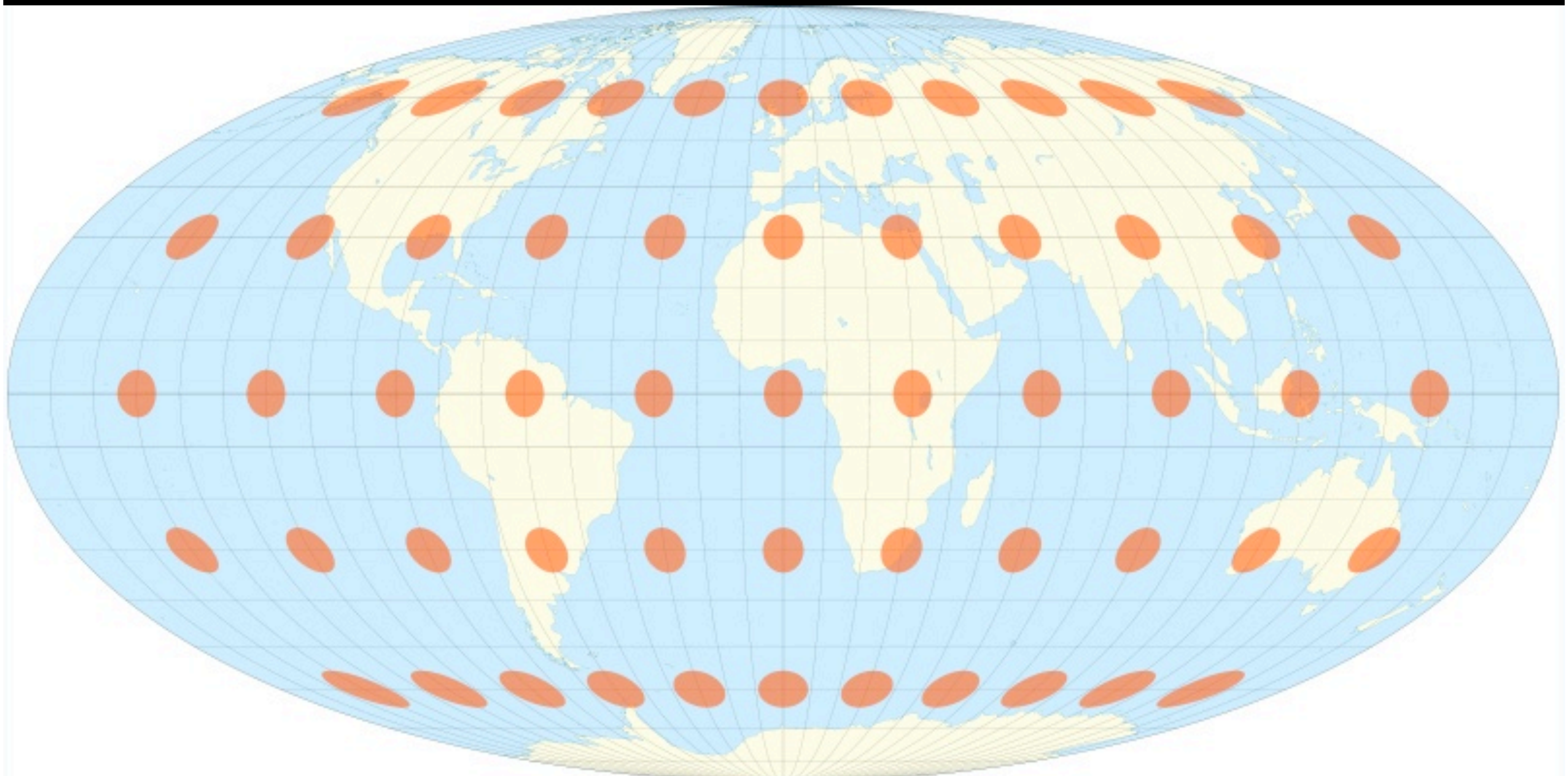
Examples of different projections

- Mollweide (Pseudo-cylindrical)



Shape	**Shape is not distorted at the intersection of the central meridian and latitudes 40° 44' N and S. Distortion increases outward from these points and becomes severe at the edges of the projection.**
Area	**Equal-area.**
Direction	**Local angles are true only at the intersection of the central meridian and latitudes 40° 44' N and S. Direction is distorted elsewhere.**
Distance	**Scale is true along latitudes 40°44' N and S. Distortion increases with distance from these lines and becomes severe at the edges of the projection.**

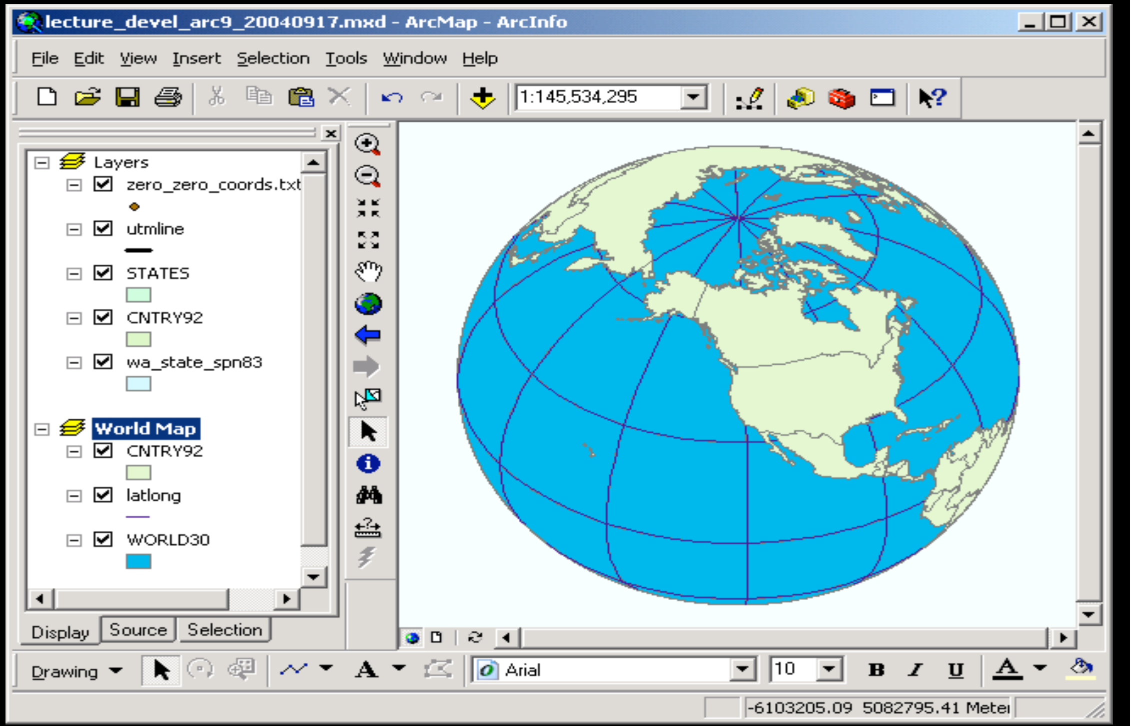




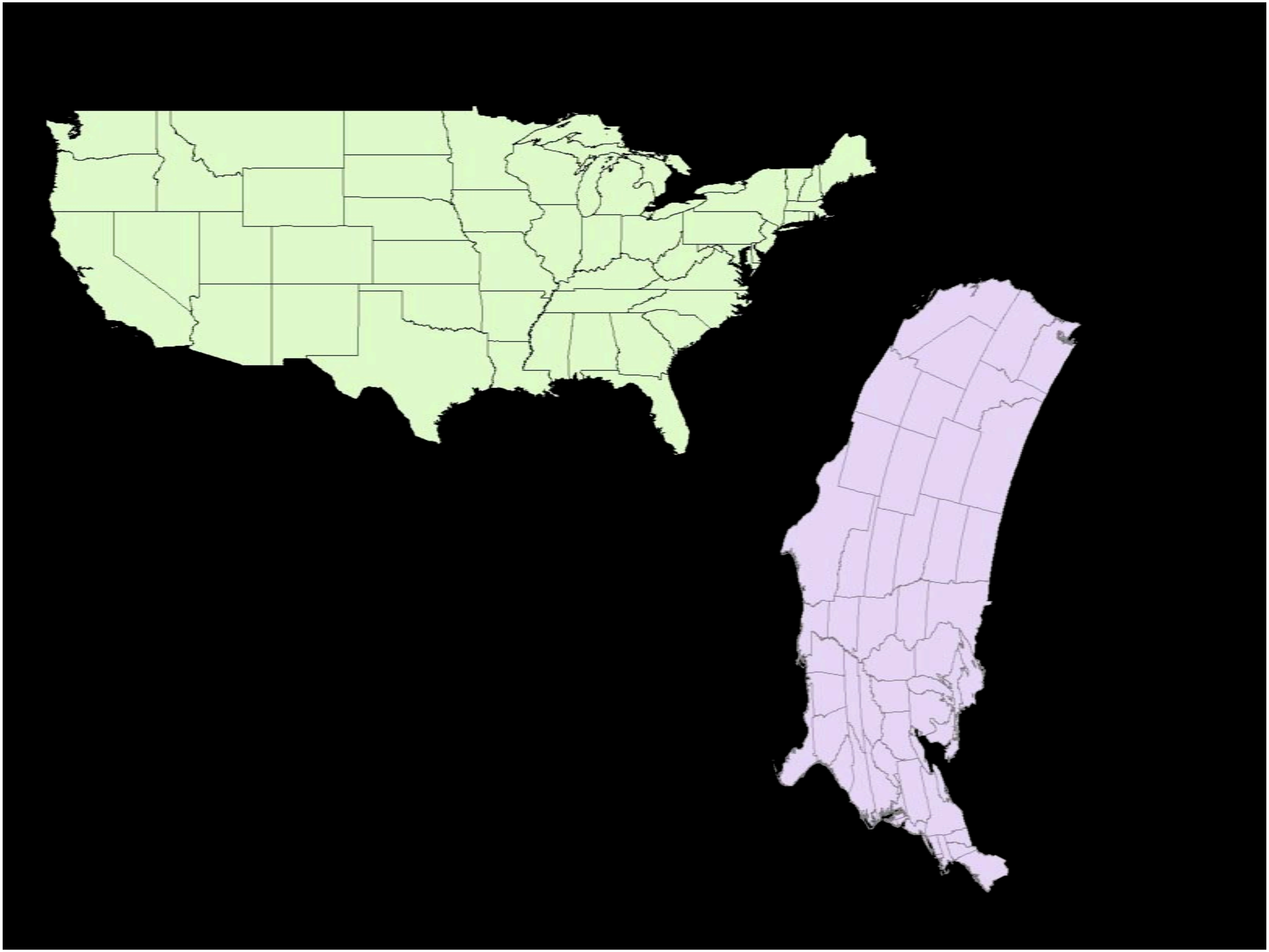
Tissot_indicatrix_world_map_Mollweide_proj.svg (SVG file, nominally 3,000 × 1,500 pixels, file size: 1.53 MB)

Examples of different projections

- Orthographic

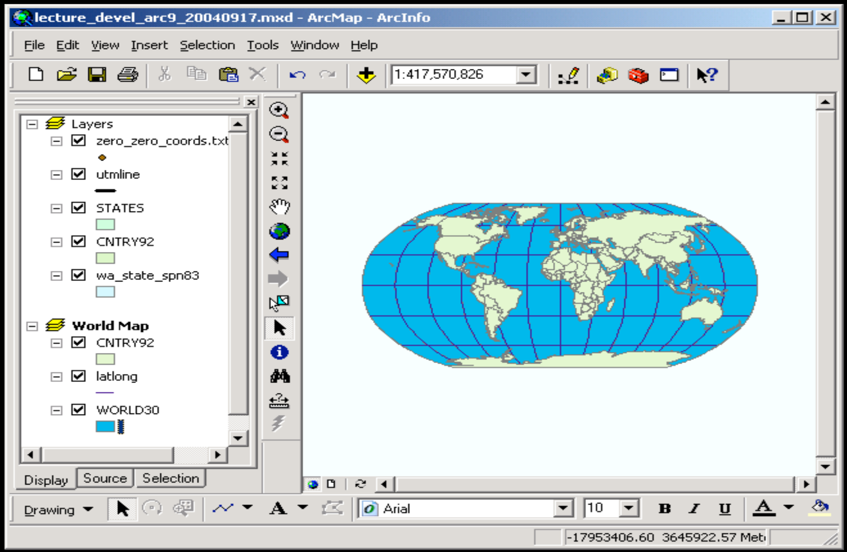


Shape	**Minimal distortion near the center; maximal distortion near the edge.**
Area	**The areal scale decreases with distance from the center. Areal scale is zero at the edge of the hemisphere.**
Direction	**True direction from the central point.**
Distance	**The radial scale decreases with distance from the center and becomes zero on the edges. The scale perpendicular to the radii, along the parallels of the polar aspect, is accurate.**



Examples of different projections

- Robinson (Pseudo-cylindrical)



Shape	**Shape distortion is very low within 45° of the origin and along the Equator.**
Area	**Distortion is very low within 45° of the origin and along the Equator.**
Direction	**Generally distorted.**
Distance	**Generally, scale is made true along latitudes 38° N and S. Scale is constant along any given latitude, and for the latitude of opposite sign.**

Coordinate Systems

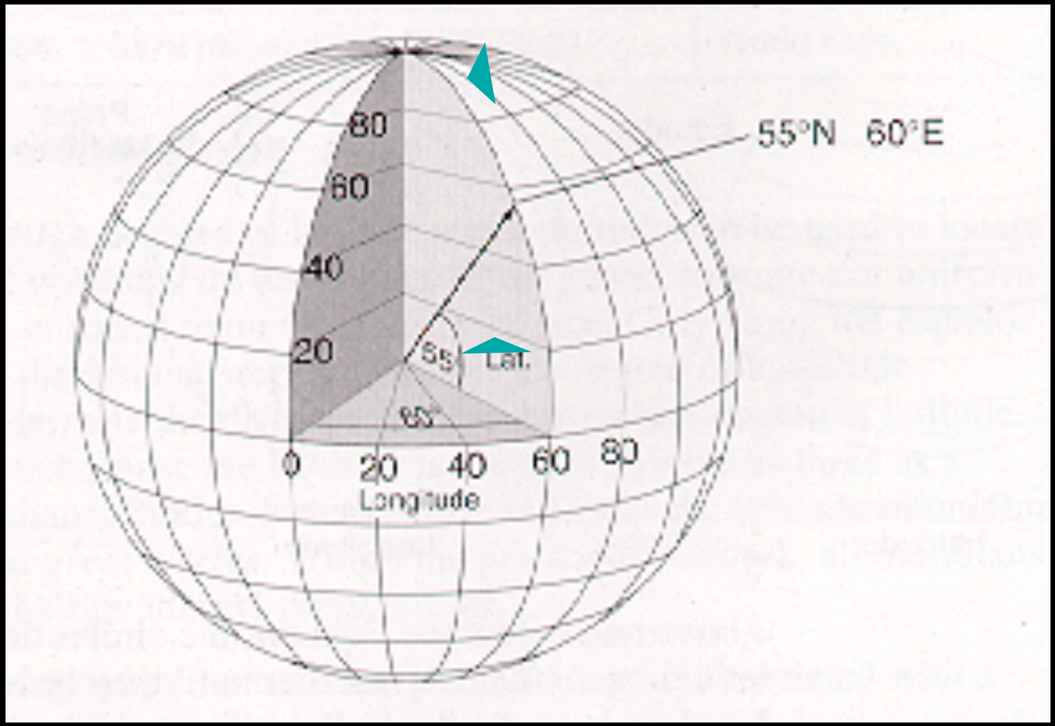
Coordinate systems

- Features on spherical surfaces are not easy to measure
- Features on planes are easy to measure and calculate
  - distance
  - angle
  - area
- Coordinate systems provide a measurement framework

Coordinate systems

- Lat/long system measures angles on spherical surfaces

- 60º east of PM
- 55º north of equator

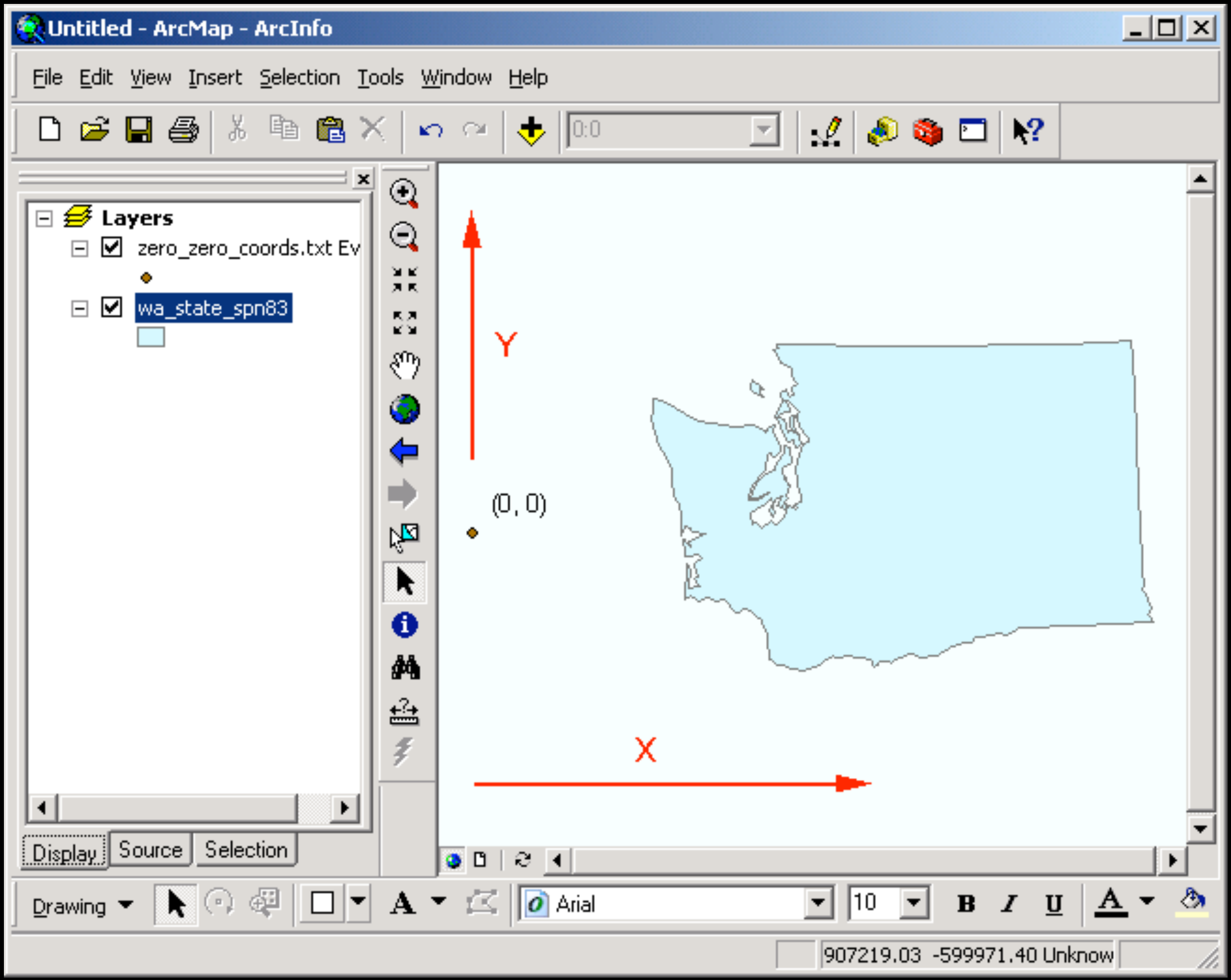


Lat/long values are NOT Cartesian (X, Y) coordinates

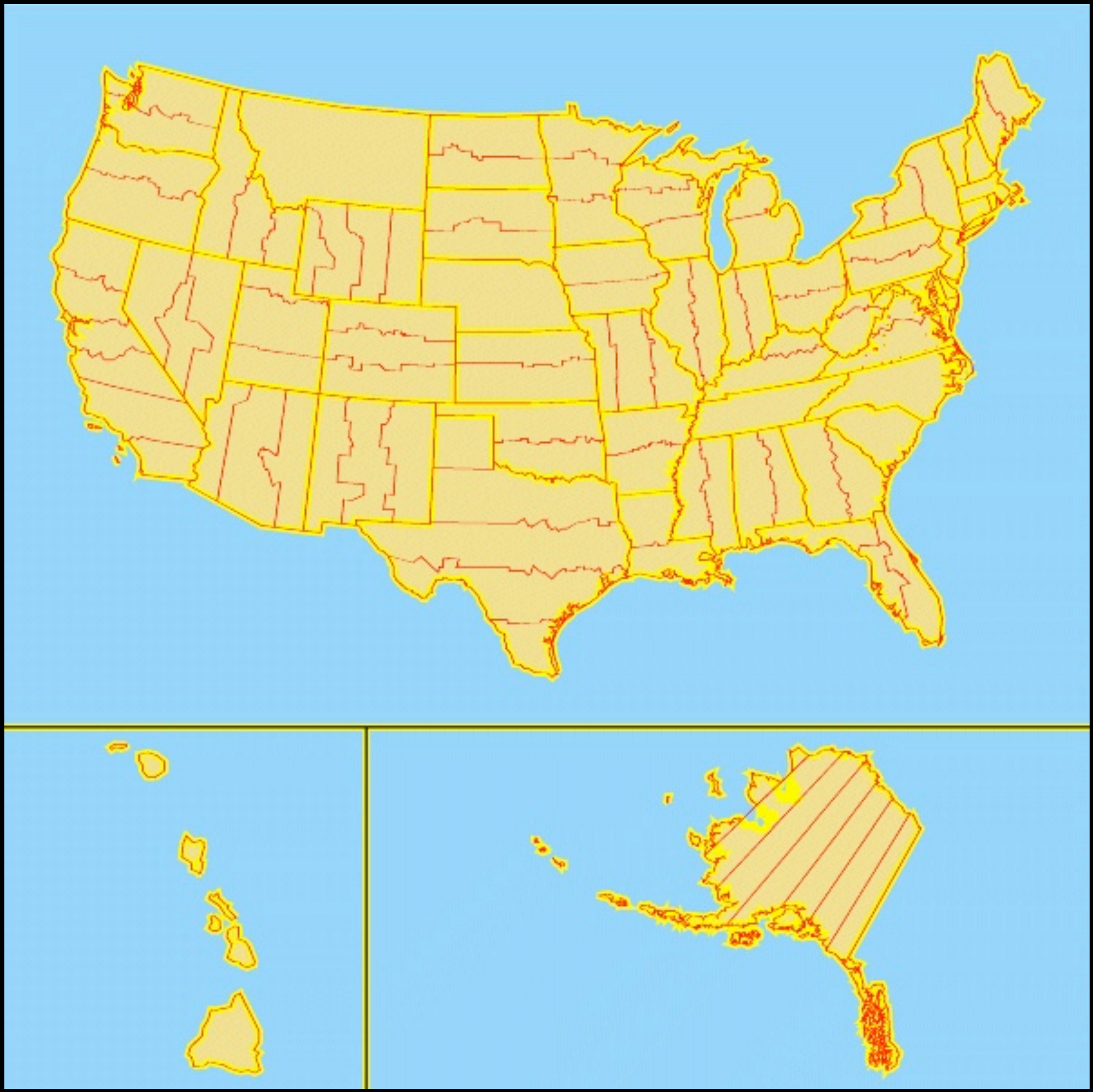
constant angular deviations do not have constant distance deviations

1° of longitude at the equator ≠ 1° of longitude near the poles

GIS software uses planar measurements on Cartesian planes



Coordinate systems



Coordinate systems

Examples of different coordinate/ projection systems

- State Plane
- Universal Transverse Mercator (UTM)

Coordinate systems

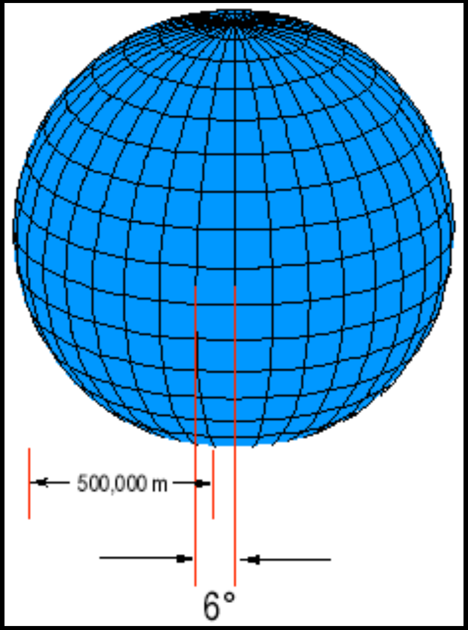
State Plane

- Codified in 1930s
- Use of numeric zones for shorthand
  - SPCS (State Plane Coordinate System)
  - FIPS (Federal Information Processing System)
- Uses one or more of 3 different projections:
  - Lambert Conformal Conic (east-west orientation)
  - Transverse Mercator (north-south orientation)
  - Oblique Mercator (nw-se or ne-sw orientation)

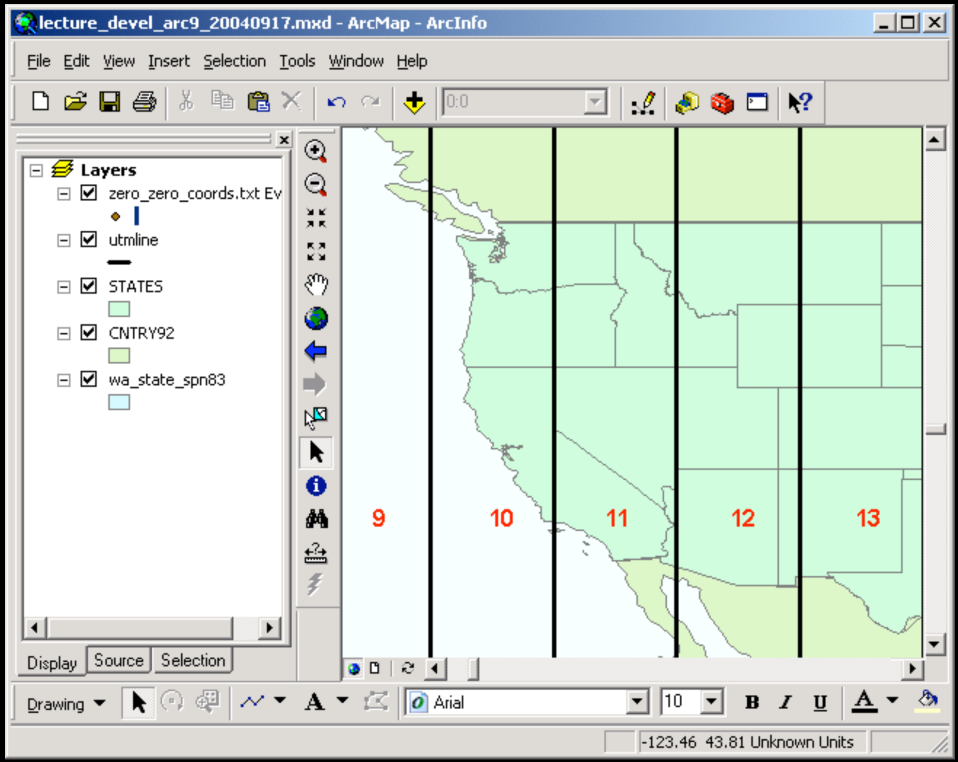
Coordinate systems

Universal Transverse Mercator (UTM)

- Based on the Transverse Mercator projection
- 60 zones (each 6° wide)
- false eastings
- Y-0 set at south pole or equator

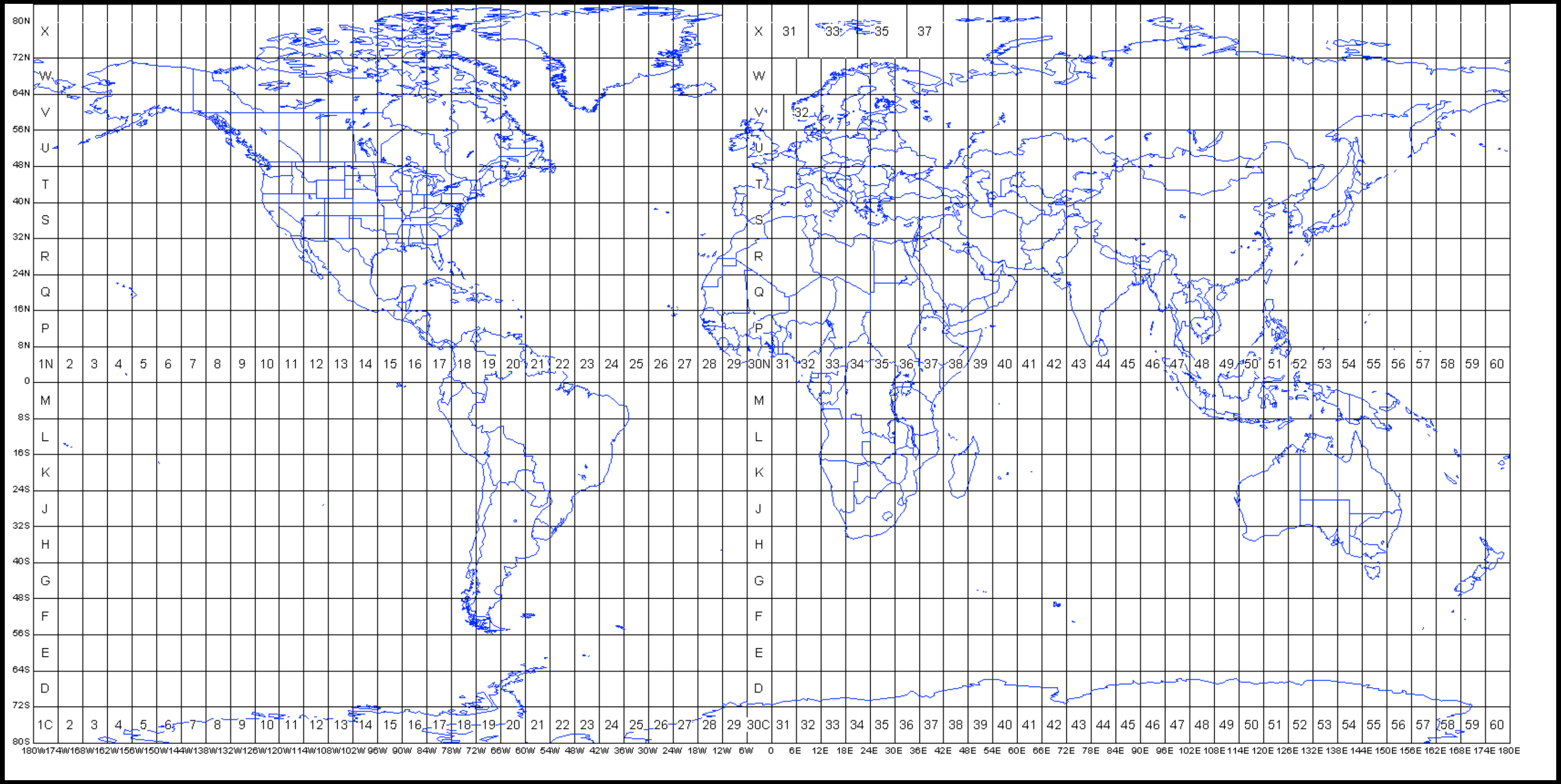


Universal Transverse Mercator (UTM)



Washington state is in Zones 10 & 11

Coordinate systems



Every place on earth falls in a particular zone

Datums

Datums

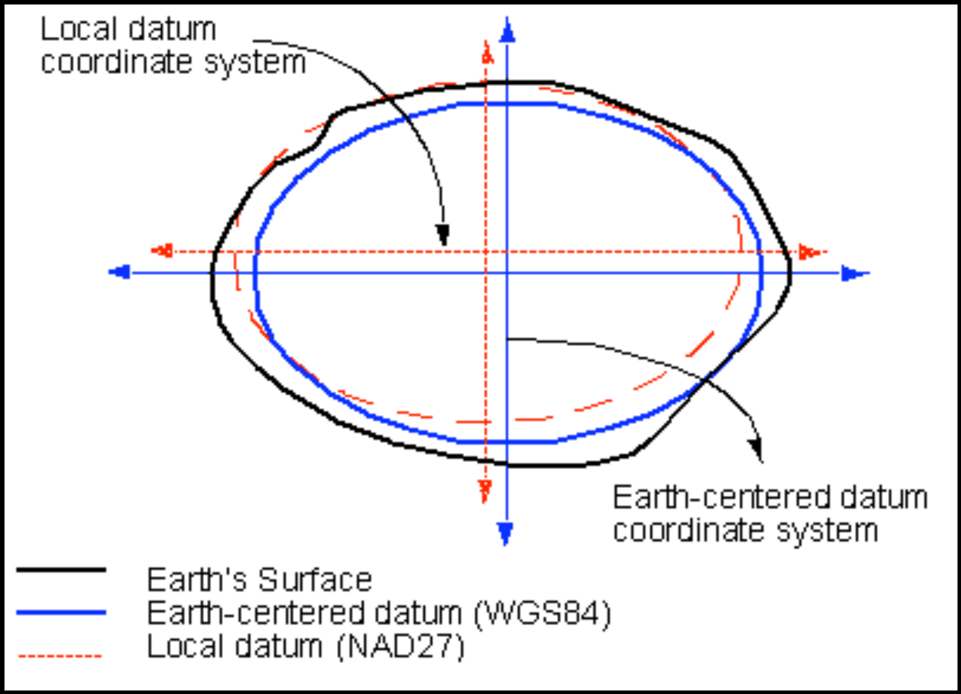
A system that allows us to place a coordinate system on the earth's surface

Initial point

Secondary point

Model of the earth

Known geoidal separation at the initial point



Datums

Commonly used datums in North America

- North American Datum of 1927 (NAD27)
- NAD83
- World Geodetic System of 1984 (WGS84)

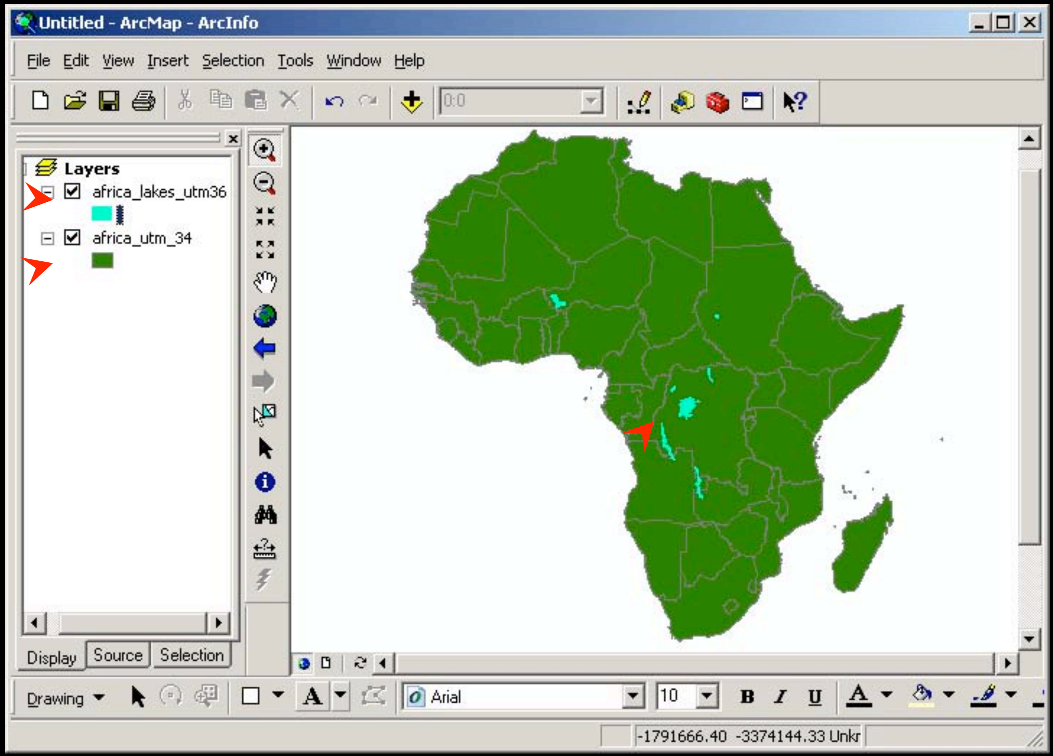
Projecting spatial data sets

Used for going between projections

Source data sources may not be compatible

UTM 36

UTM 34

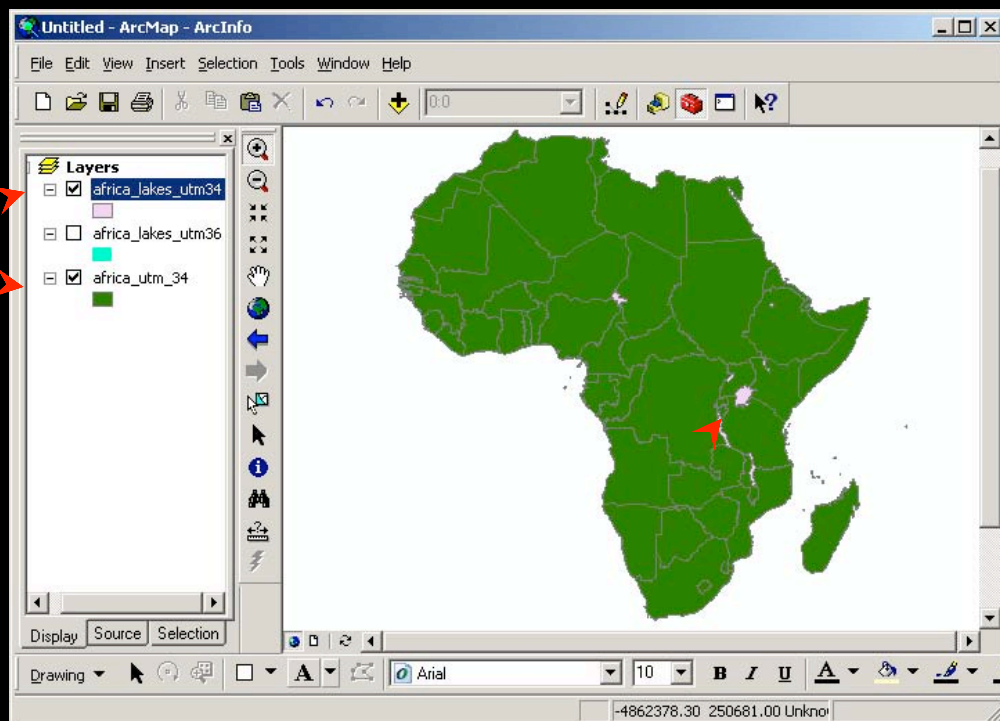


Lake Victoria is not in central Africa

Projecting spatial data sets

- Used for going between projections
  - Data sets are now compatible

both are now UTM 34



Lake Victoria really is in east Africa

Homework

Read “Projections and Coordinate Systems”, “Creating feature datasets and vector editing”, “scale issues”

Do assignment 3 -- Due April 18