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:

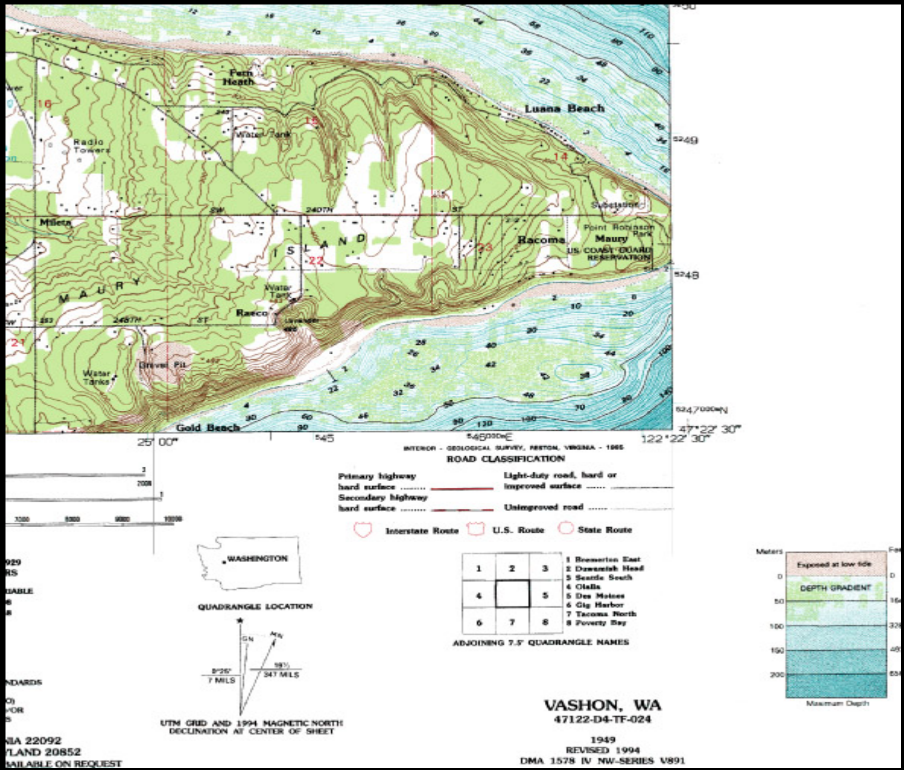
not easy to carry

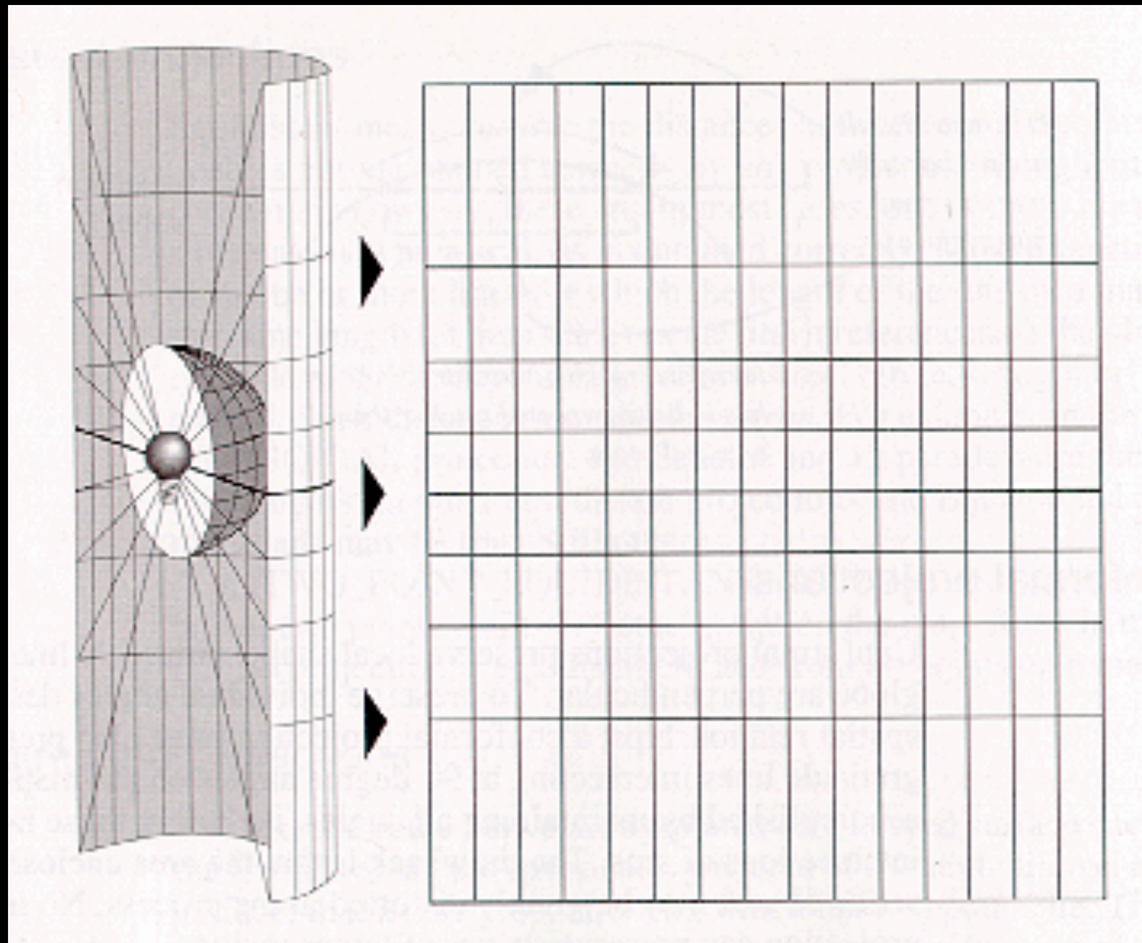
not good for making planimetric measurement (distance, area, angle)

Maps are flat

- easy to carry
- good for measurement
- scaleable

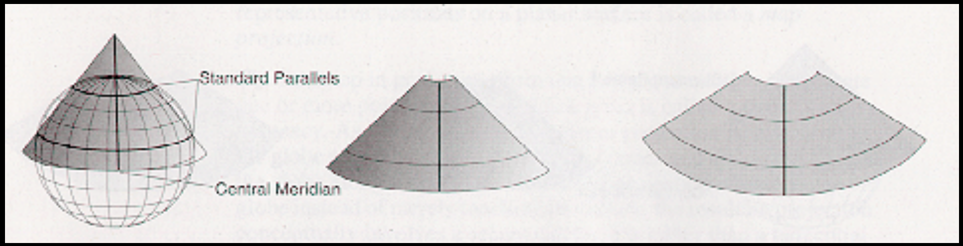
Map projections are used to “project” data from a sphere onto a planar surface



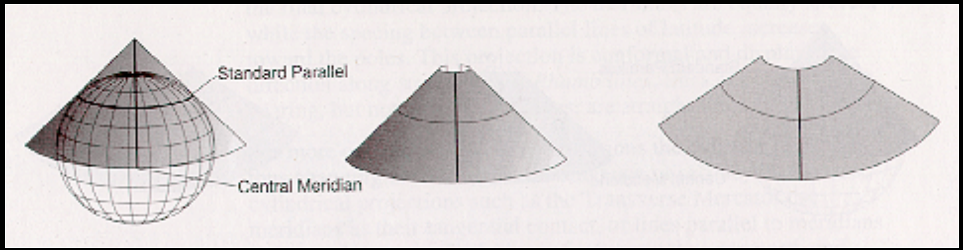


- an imaginary light is “projected” onto a “developable surface”
- a variety of different projection models exist

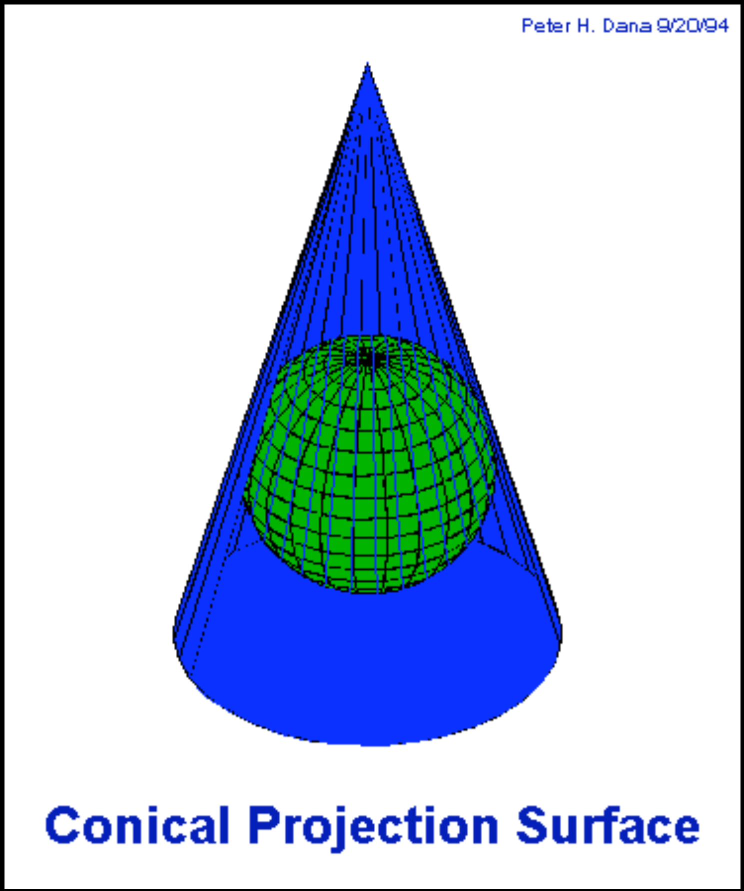
cone as developable surface



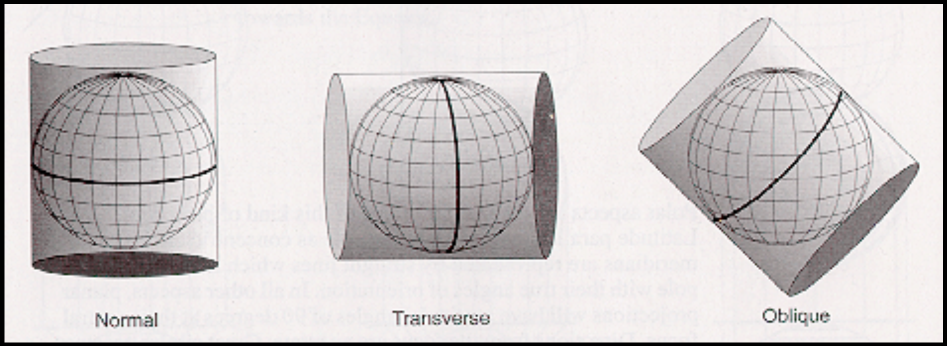
secant cone



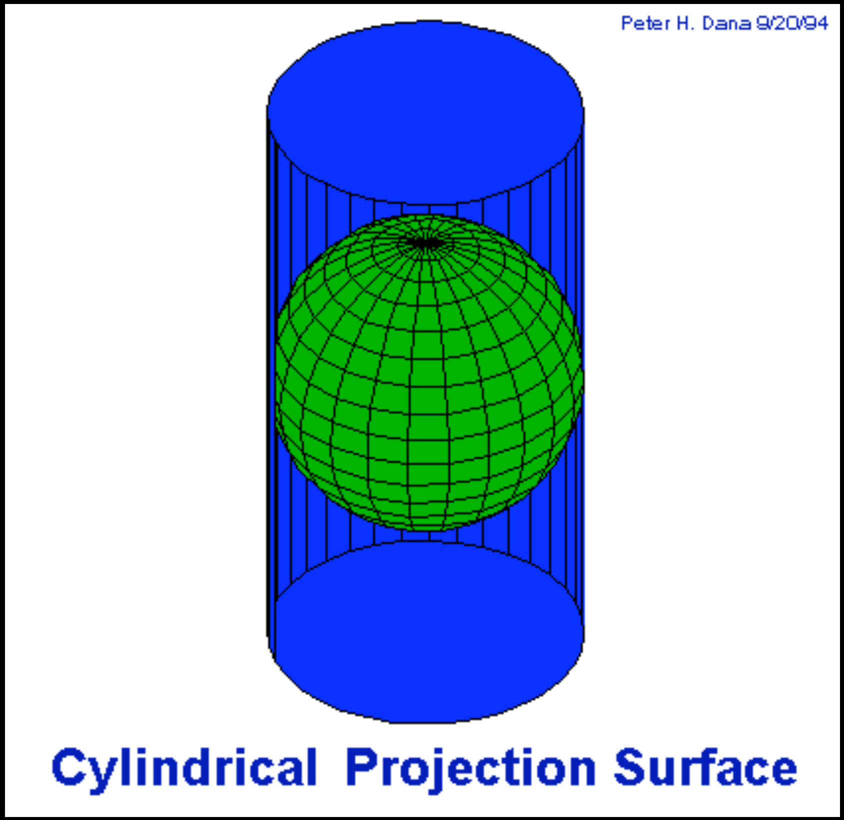
tangent cone



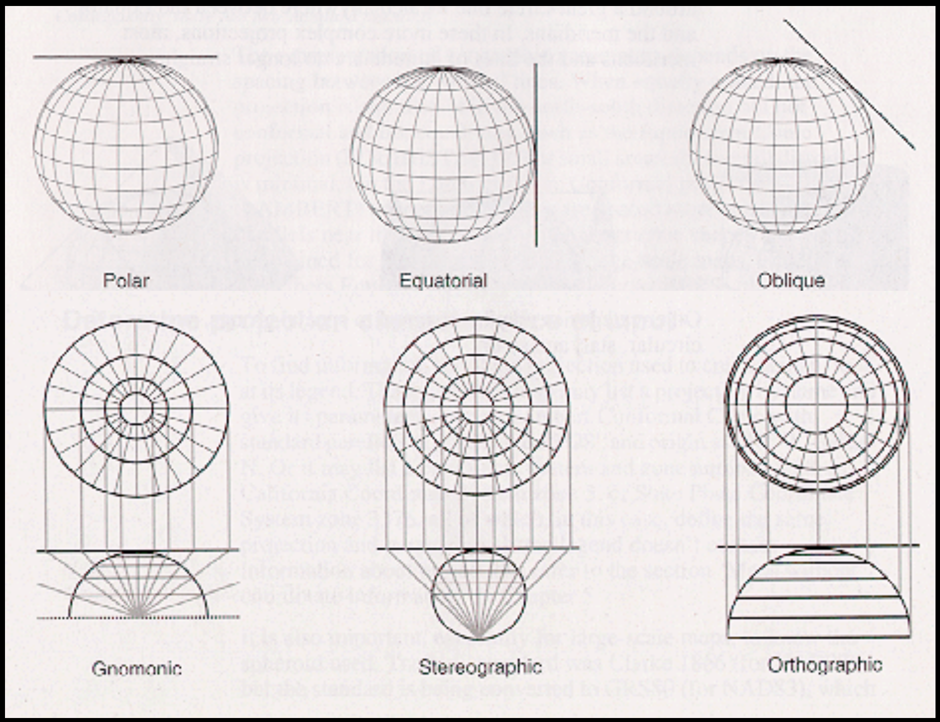
cylinder as developable surface

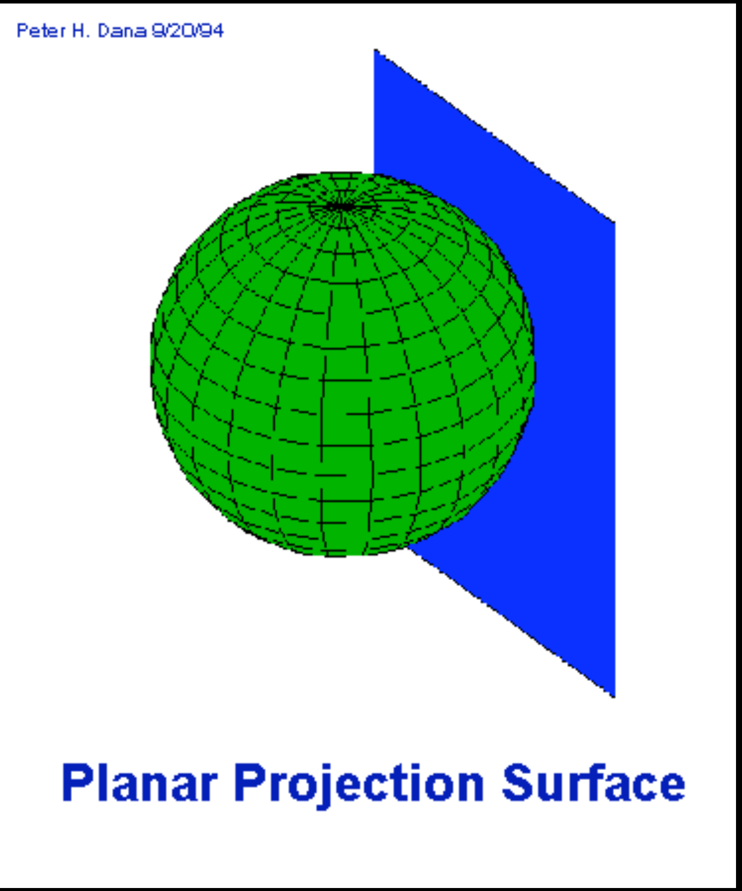


tangent cylinders

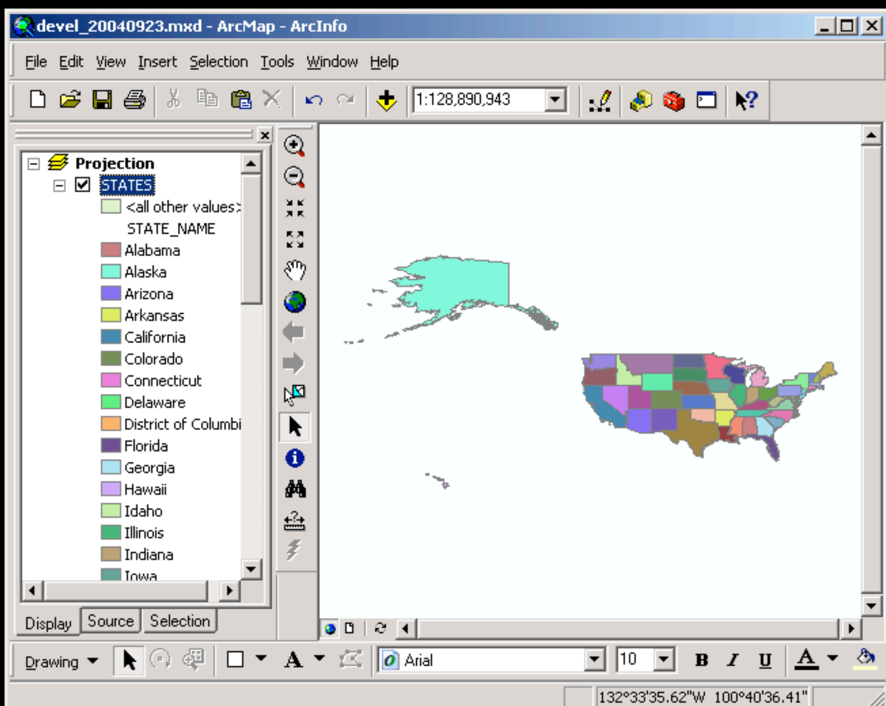


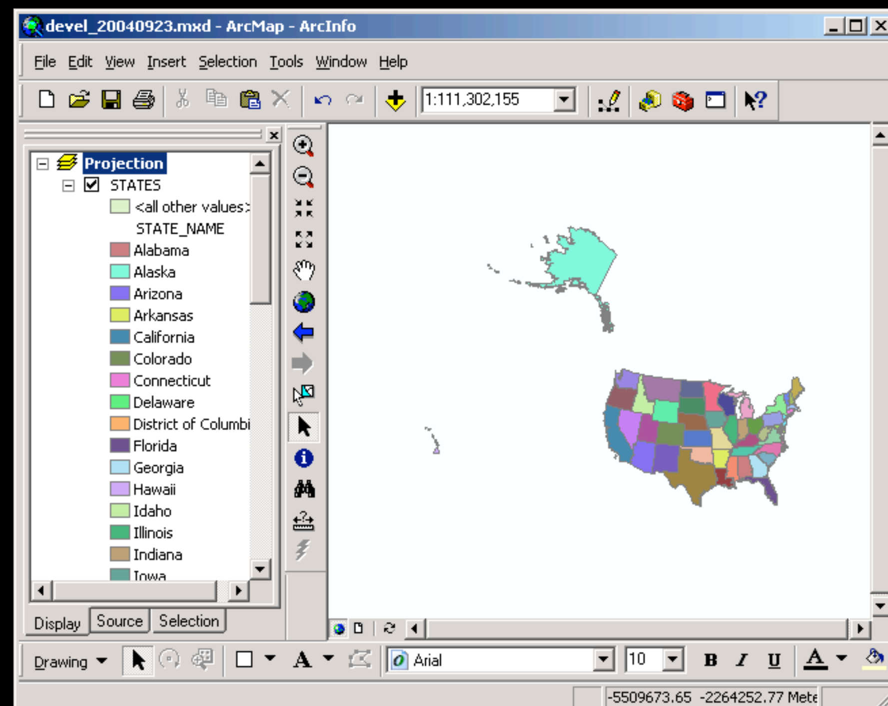
plane as developable surface



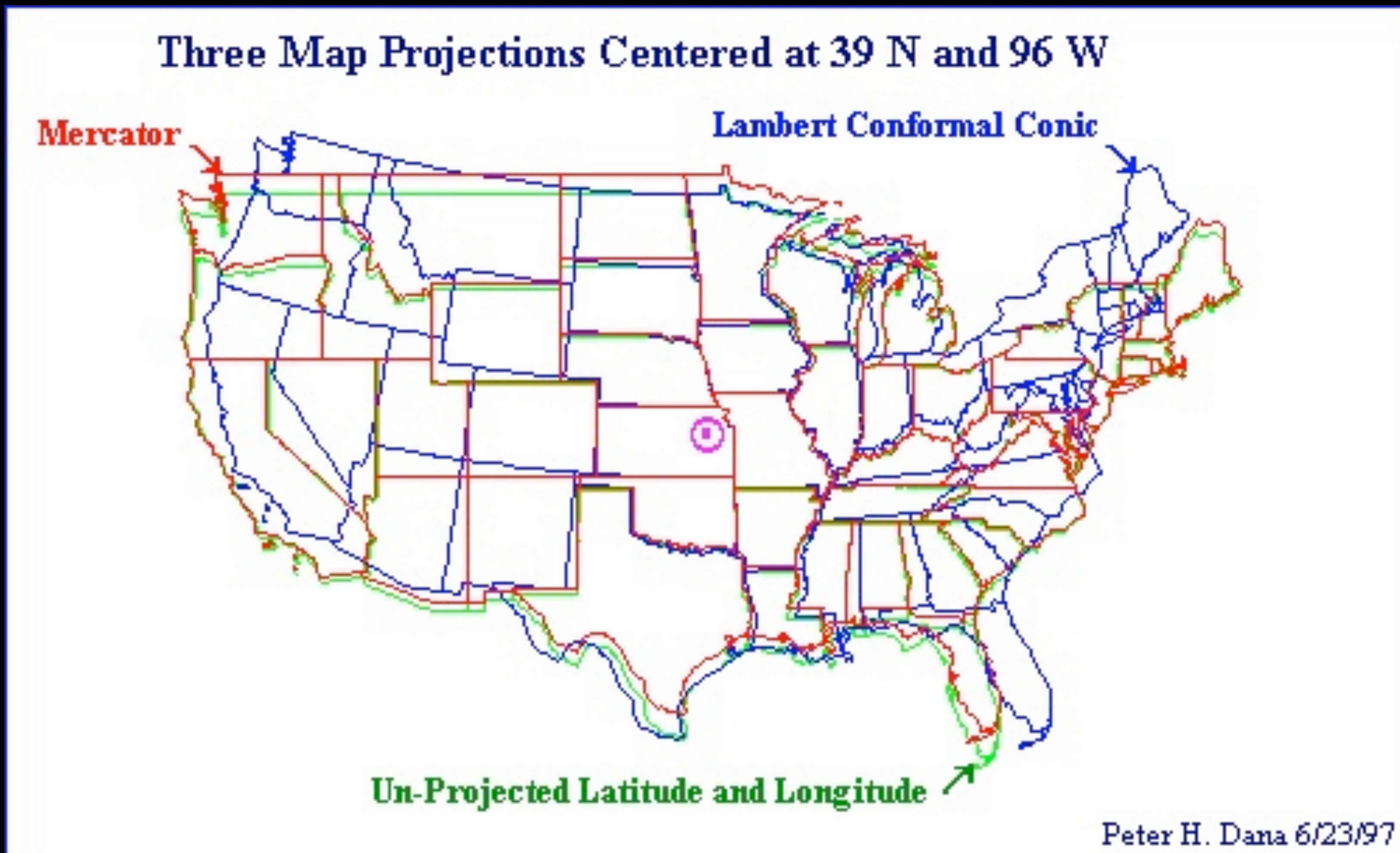


Map projections *always* introduce error and distortion

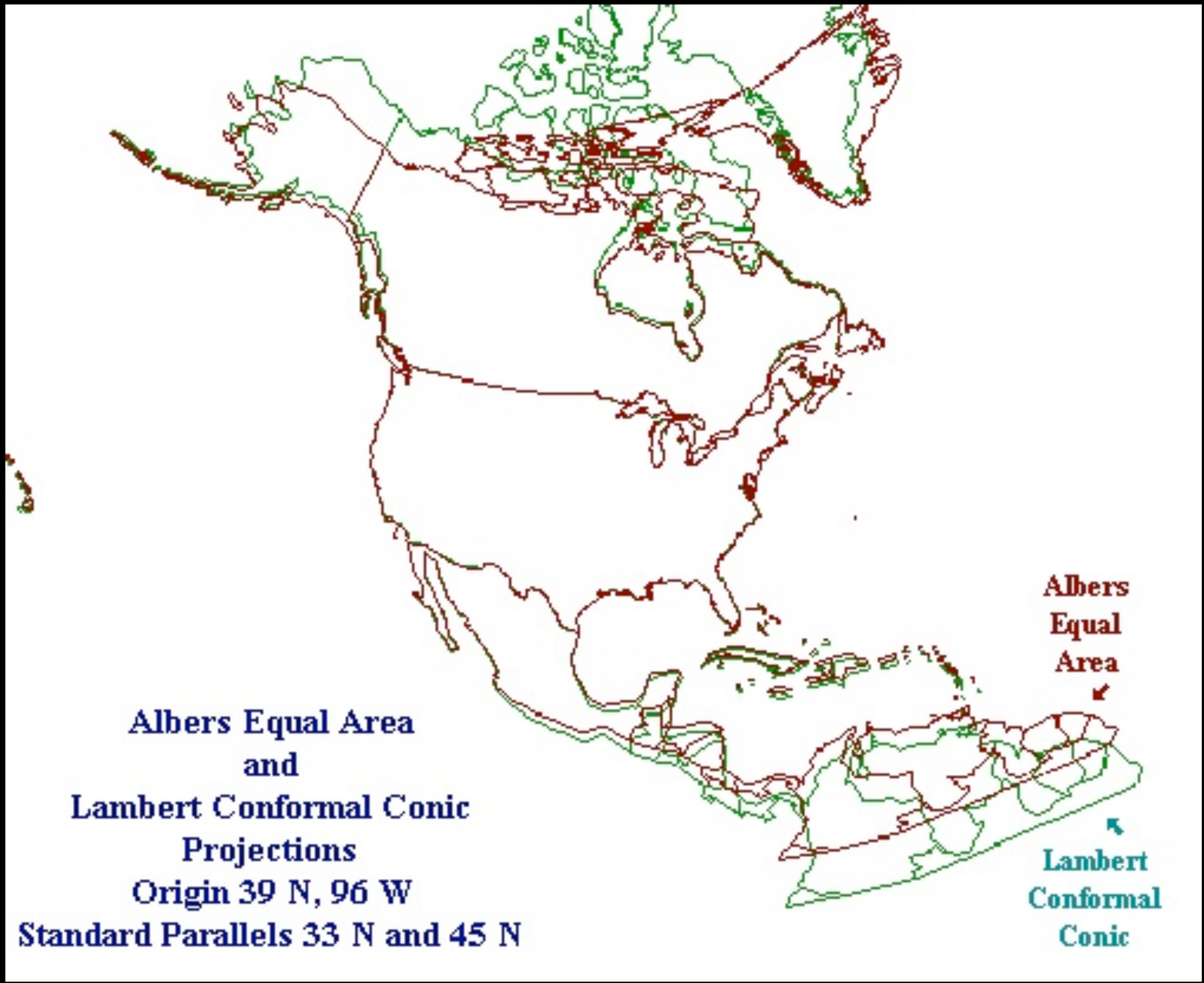




Map projections *always* introduce error and distortion



Map projections *always* introduce error and distortion



Map projections *always* 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

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

input
unprojected
angles (lat/long)

output
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

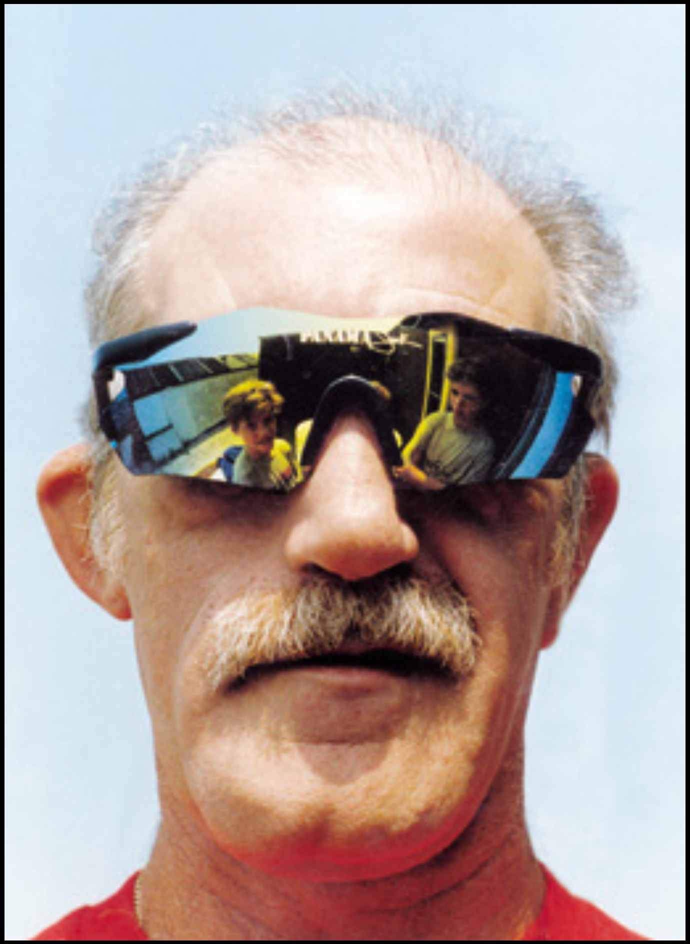
Projection, zone, datum (units)	X	Y
geographic, NAD27 (decimal degrees)	-122.35°	47.62°
UTM, Zone 10, NAD27 (meters)	548843.5049	5274052.0957
State Plane, WA-N, NAD83 (feet)	1266092.5471	229783.3093

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

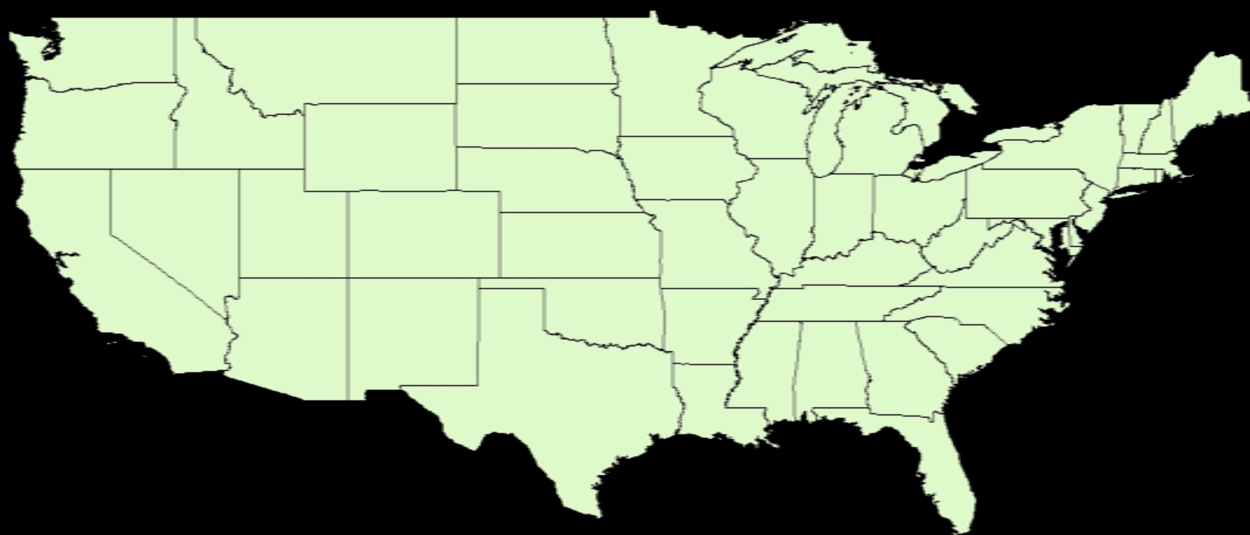
You see the map differently, but the data have not changed



How does ArcGIS handle map projections for *data*?

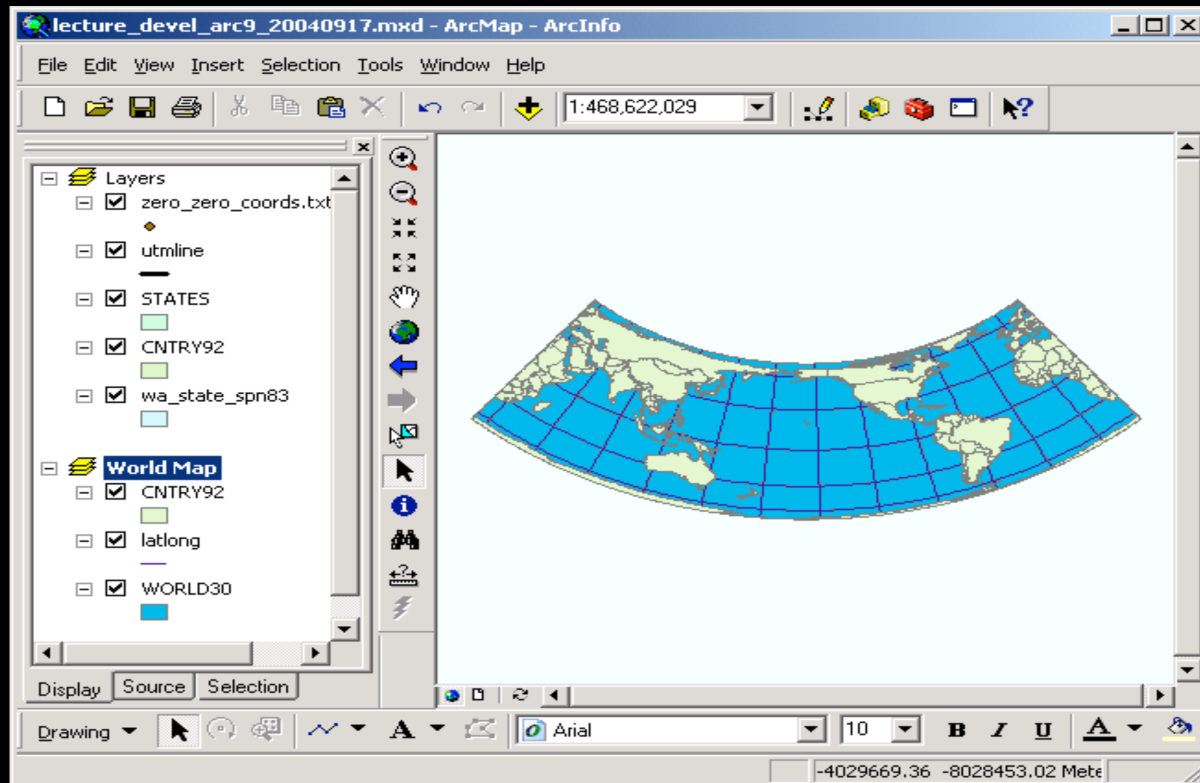
- Projecting data creates a new data set on the file system
- Data can be projected so that incompatibly projected data sets can be made to match.
- ArcGIS's projection engine can go in and out of a large number of different projections, coordinate systems, and datums.

Geographic “projection”



Examples of different projections

- Albers (Conic)

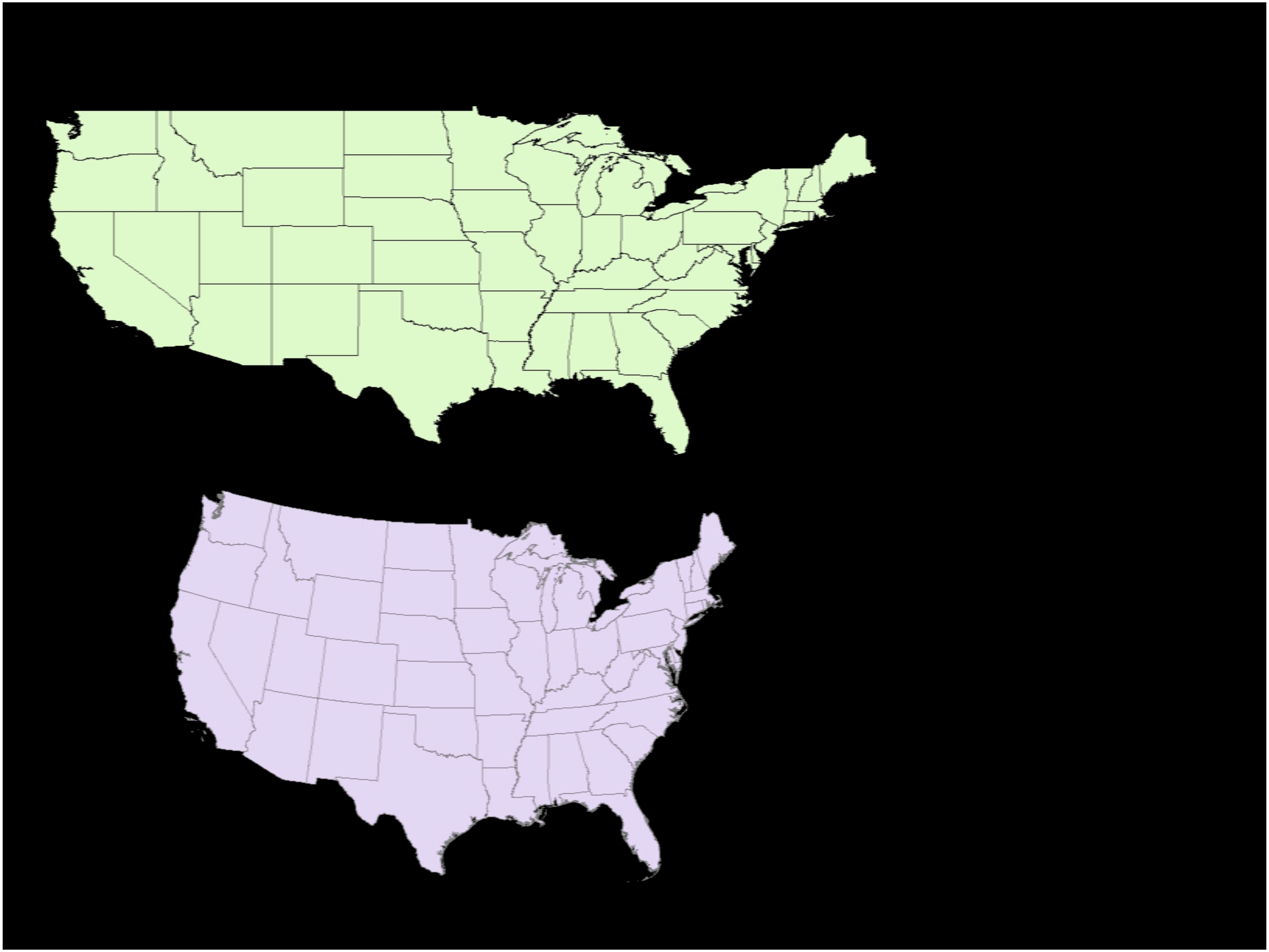


Shape — Shape along the standard parallels is accurate and minimally distorted in the region between the standard parallels and those regions just beyond. The 90-degree angles between meridians and parallels are preserved, but because the scale along the lines of longitude does not match the scale along lines of latitude, the final projection is not conformal.

Area — All areas are proportional to the same areas on the Earth.

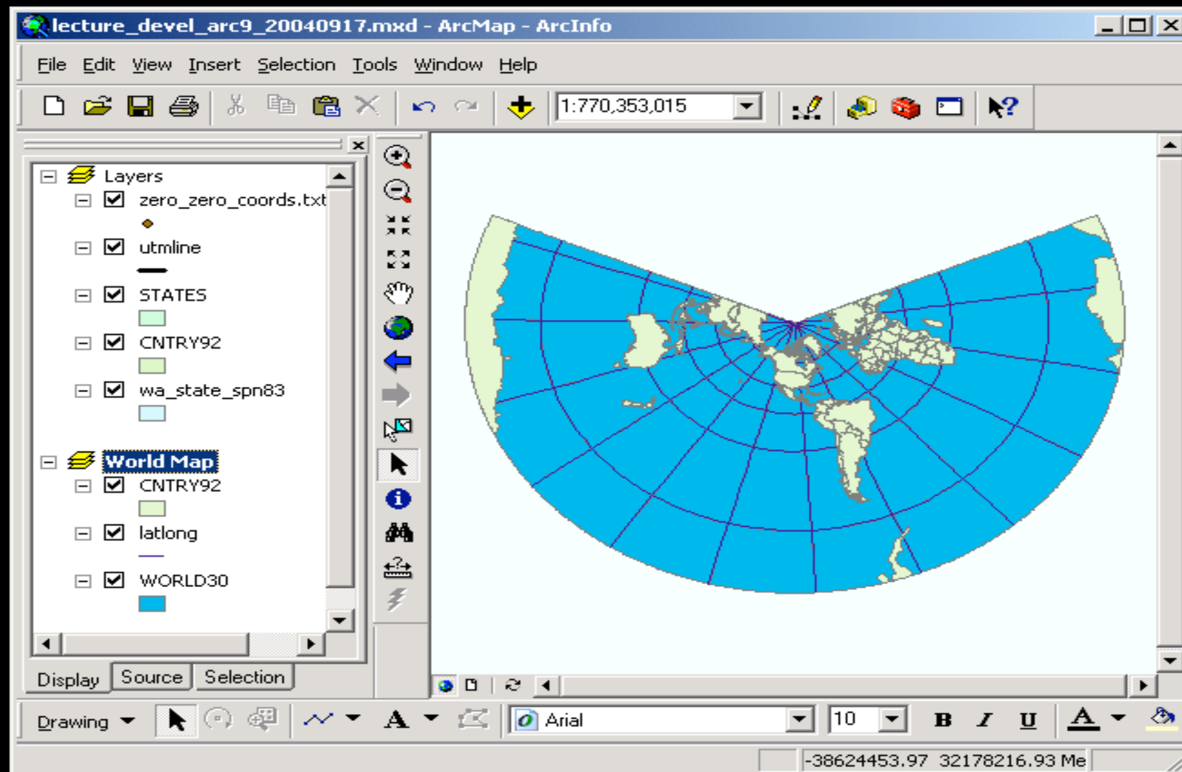
Direction — Locally true along the standard parallels.

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)

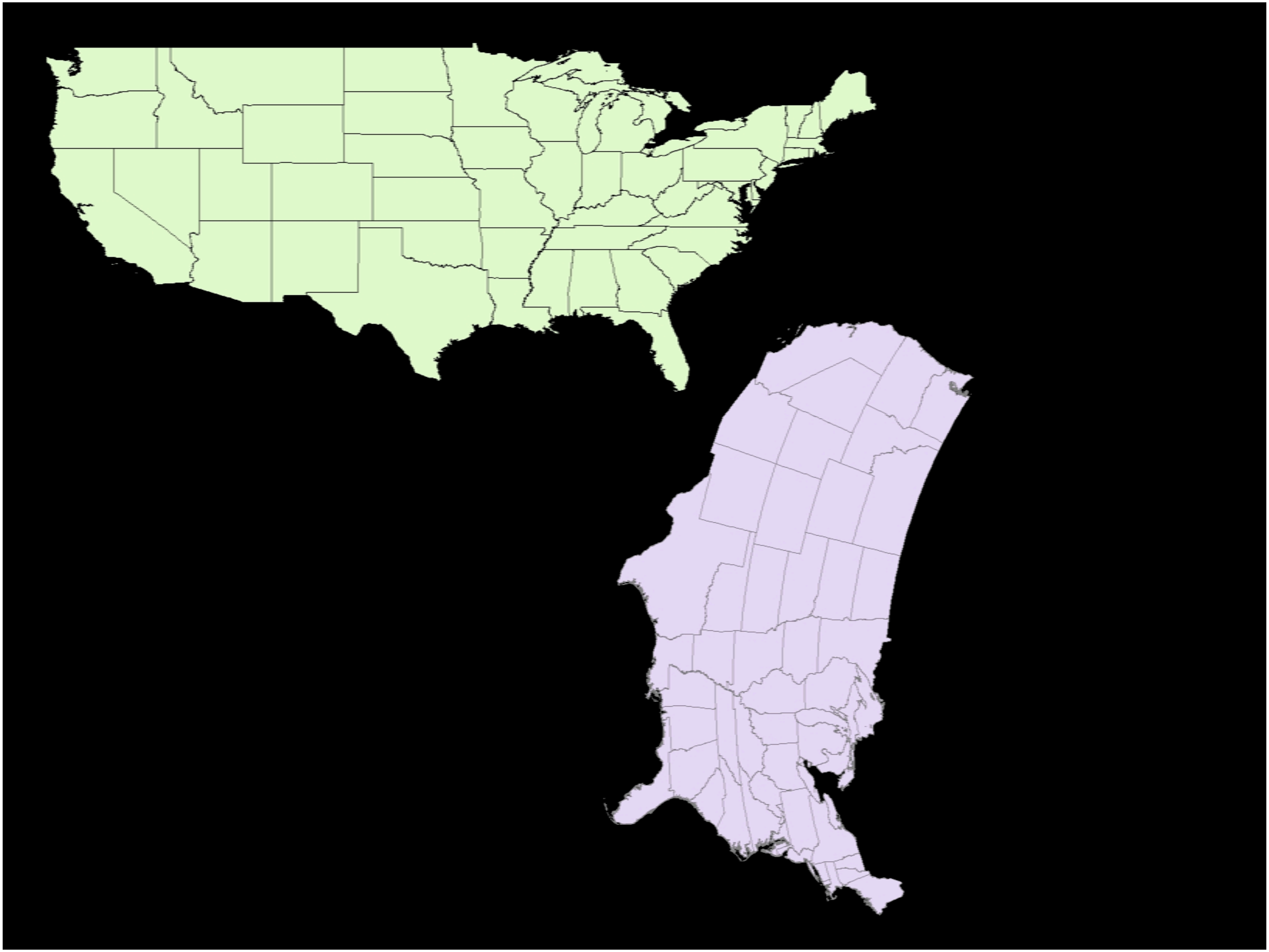


Shape Shape is true along the standard parallels of the normal aspect (Type 1), or the standard lines of the transverse and oblique aspects (Types 2 and 3). Distortion is severe near the poles of the normal aspect or 90° from the central line in the transverse and oblique aspects.

Area There is no area distortion on any of the projections.

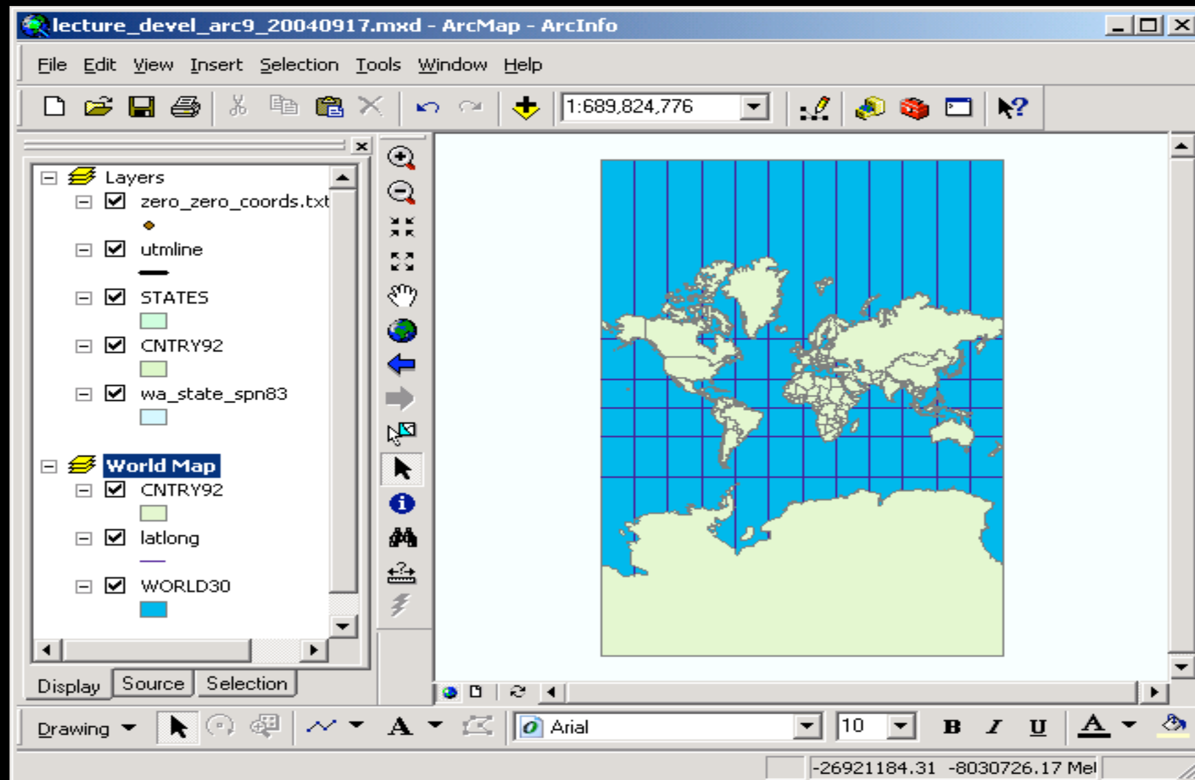
Direction Local angles are correct along standard parallels or standard lines. Direction is distorted elsewhere.

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)

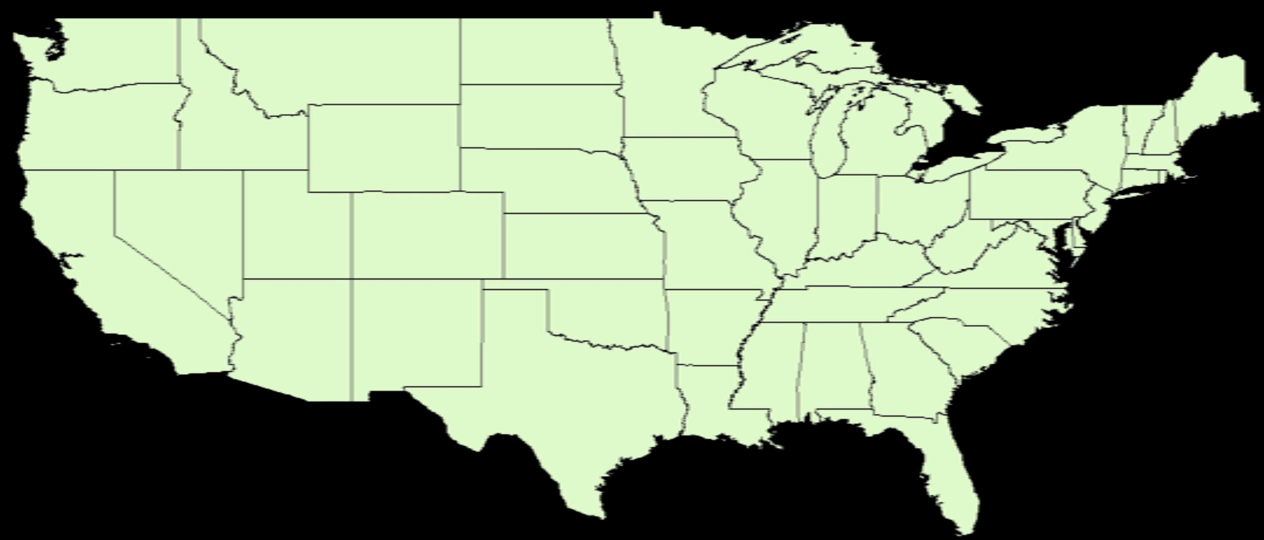


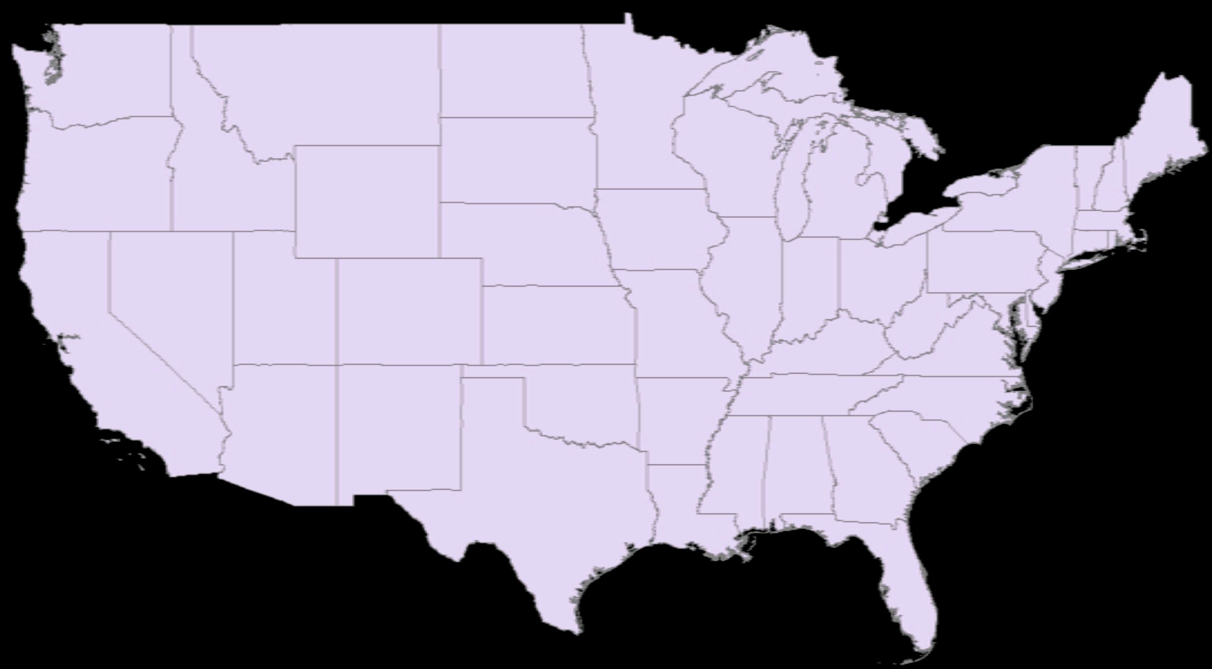
Shape Conformal. Small shapes are well represented because this projection maintains the local angular relationships.

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.

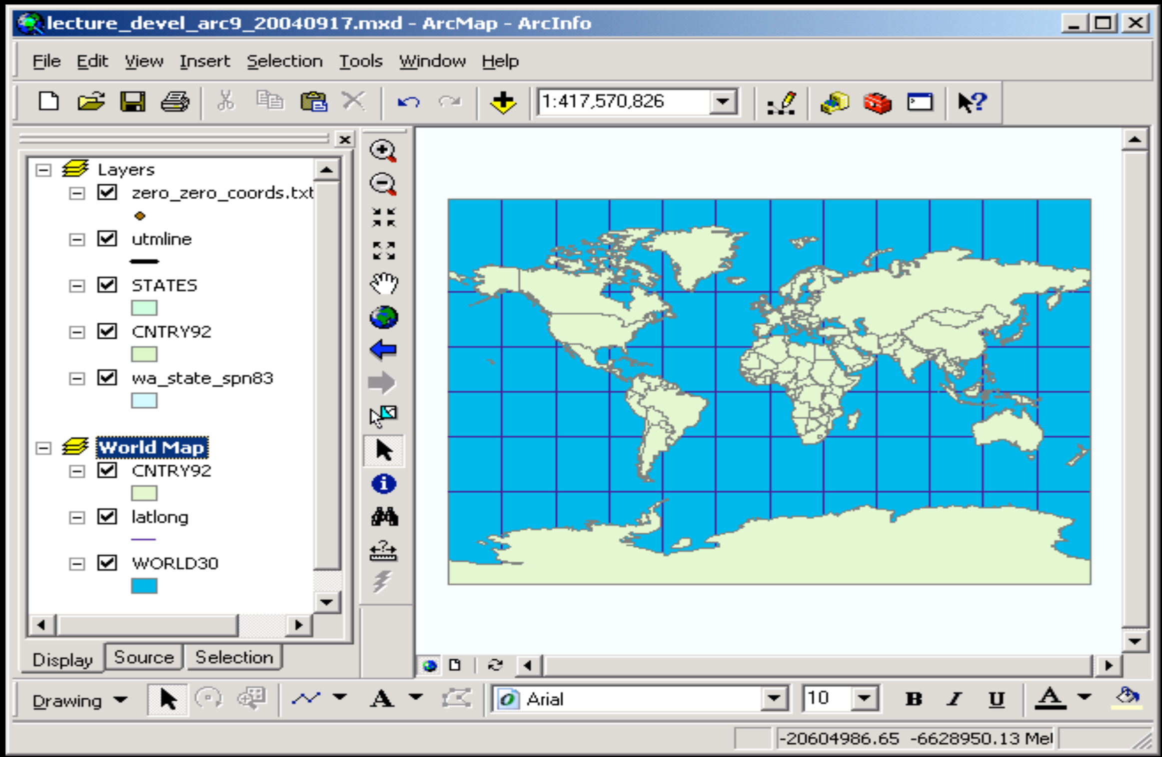
Distance Scale is true along the Equator, or along the secant latitudes.



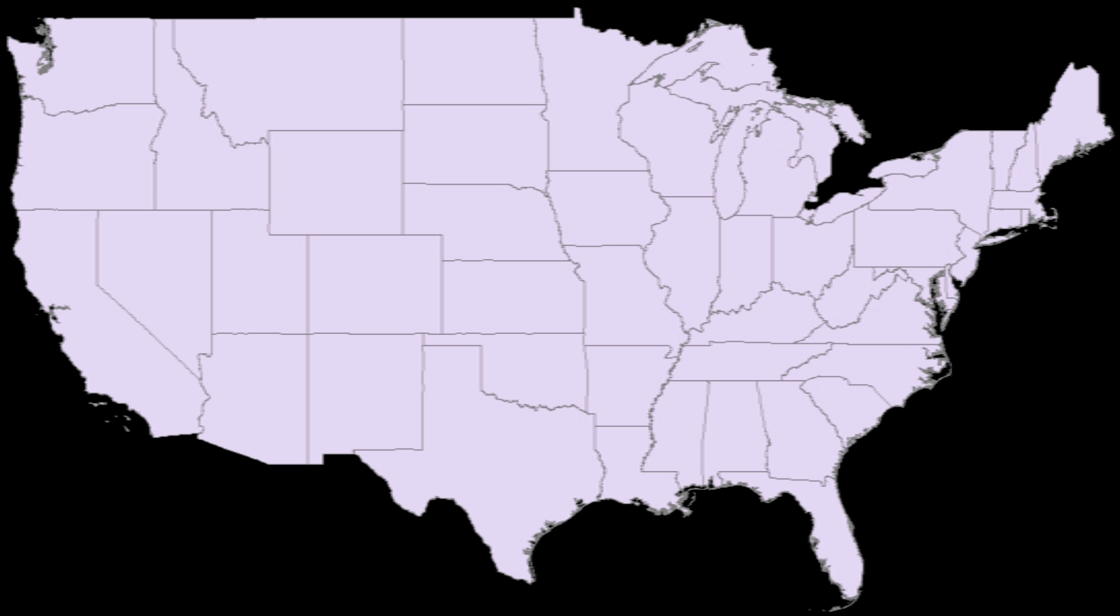
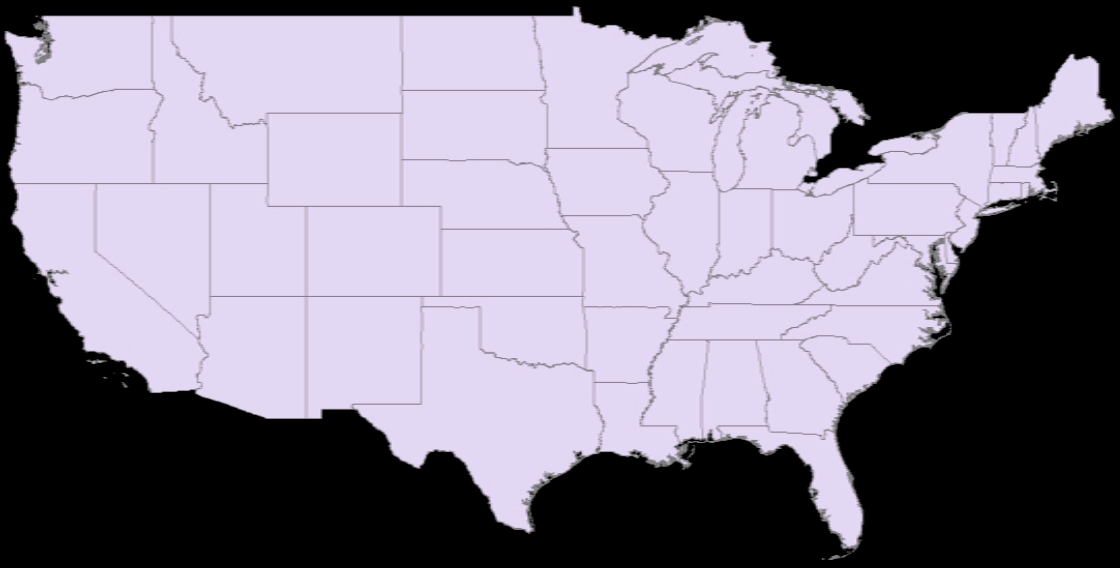


Examples of different projections

- Miller (Cylindrical)

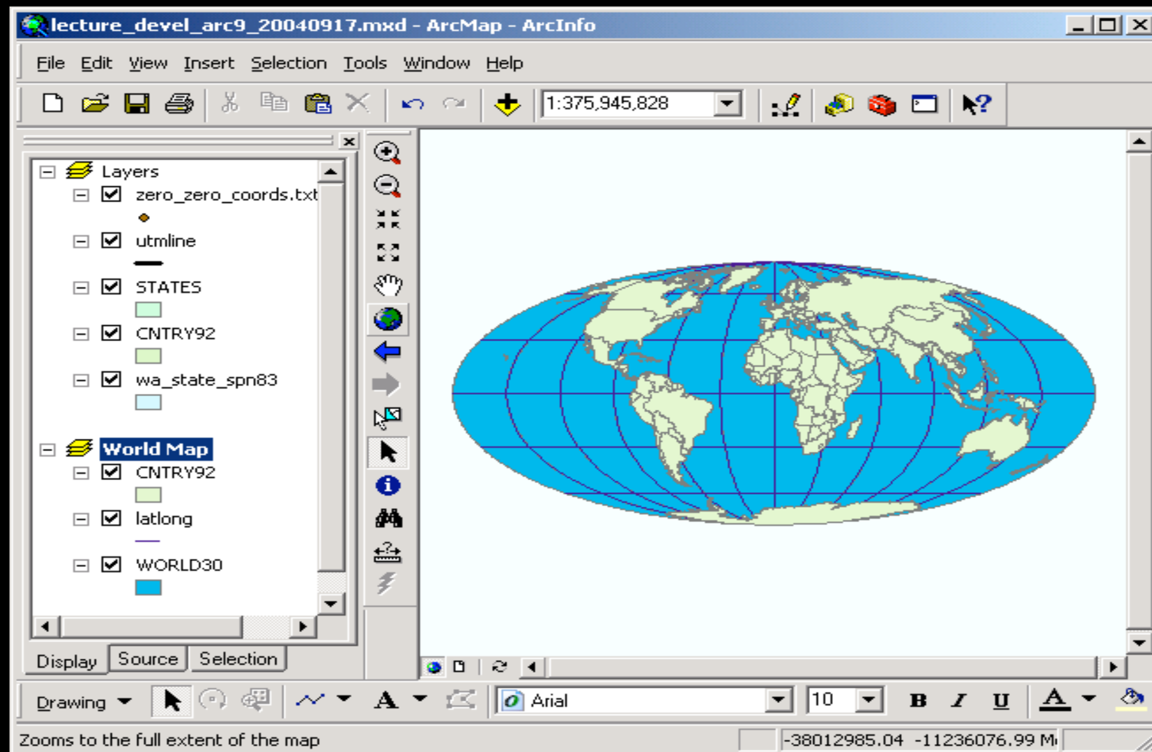


Shape	**Minimally distorted between 45th parallels, increasingly toward the poles. Land masses are stretched more east to west than they are north to south.**
Area	**Distortion increases from the Equator toward the poles.**
Direction	**Local angles are correct only along the Equator.**
Distance	**Correct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

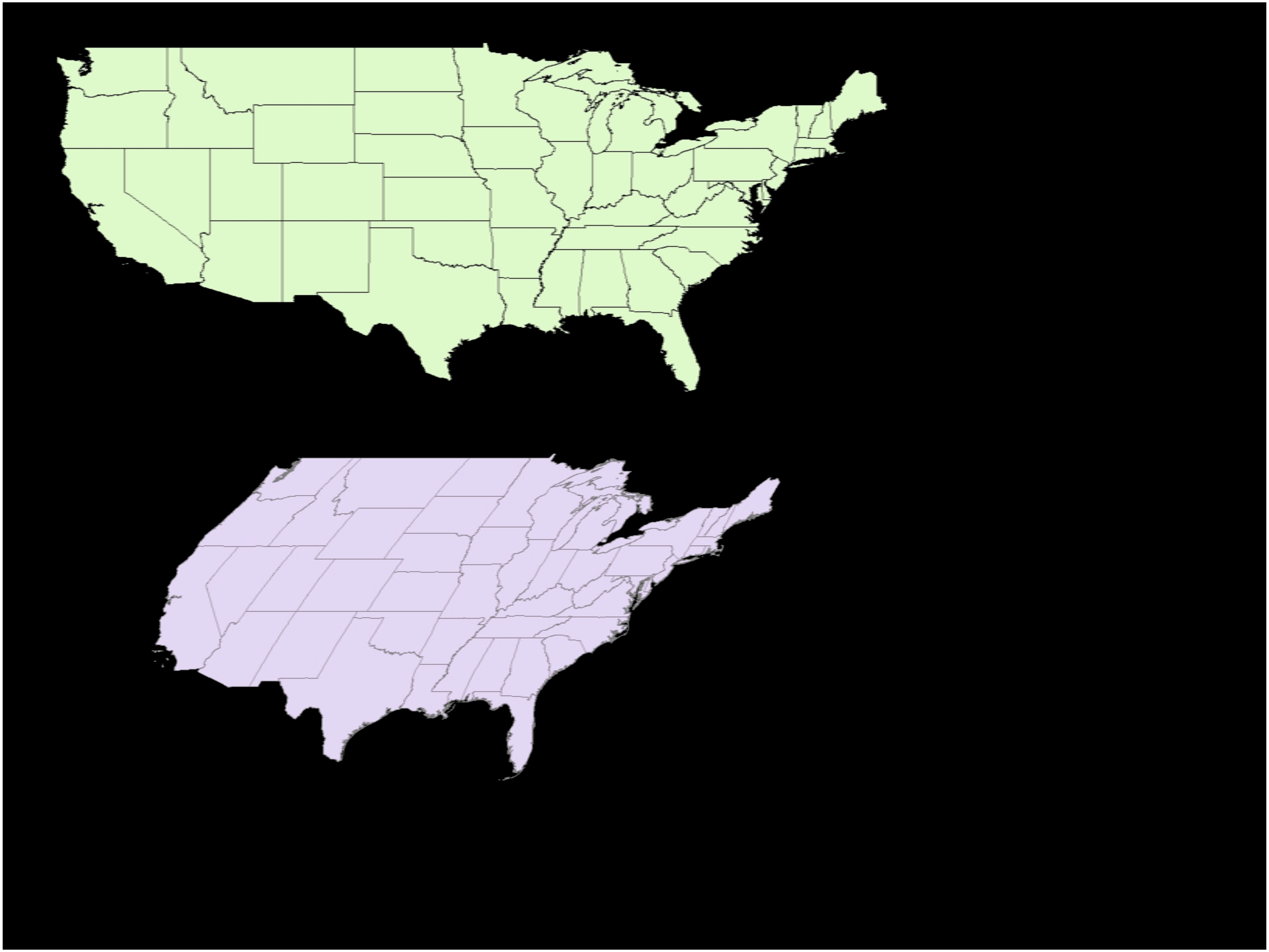



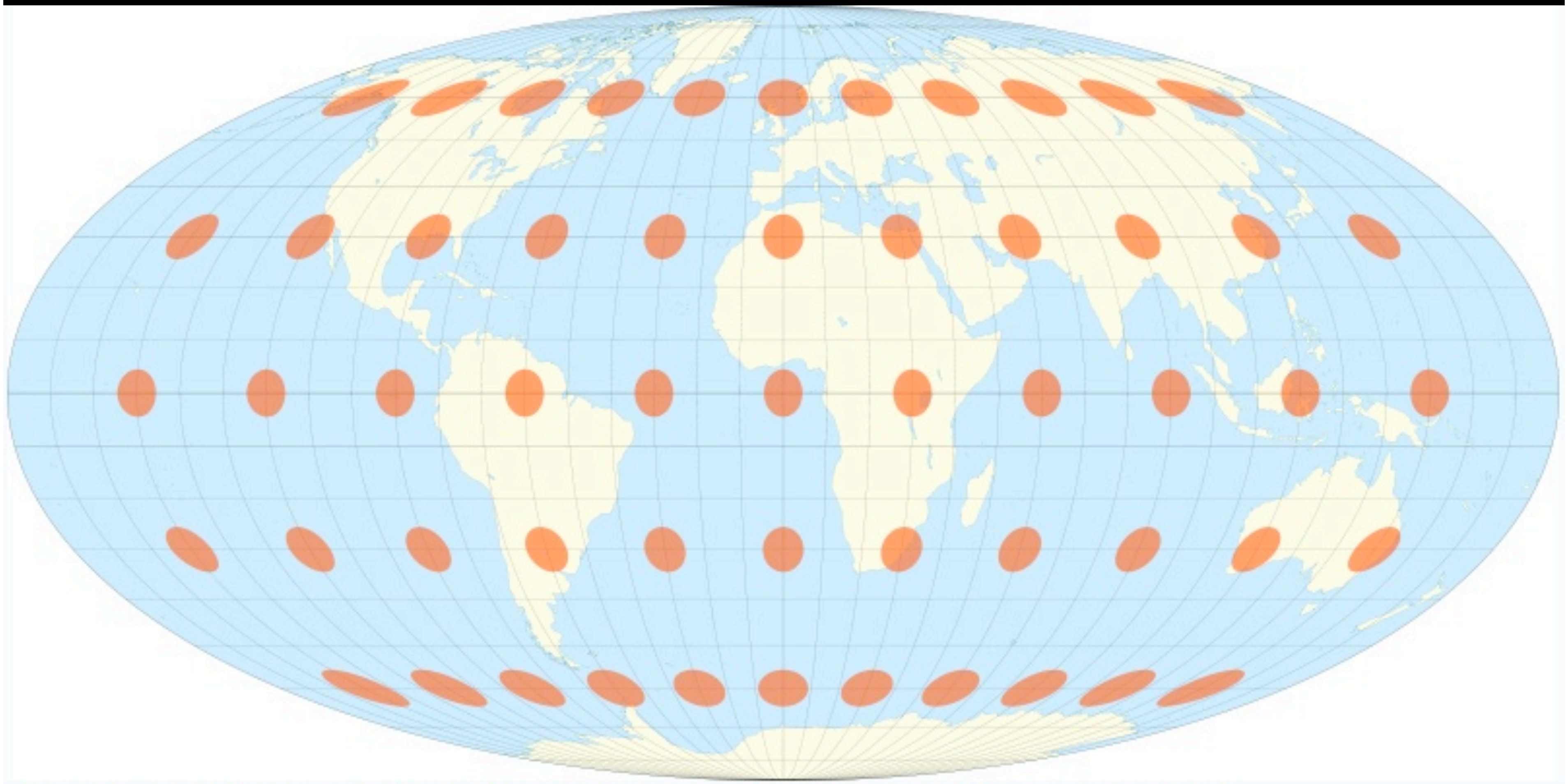
Examples of different projections

- 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.**

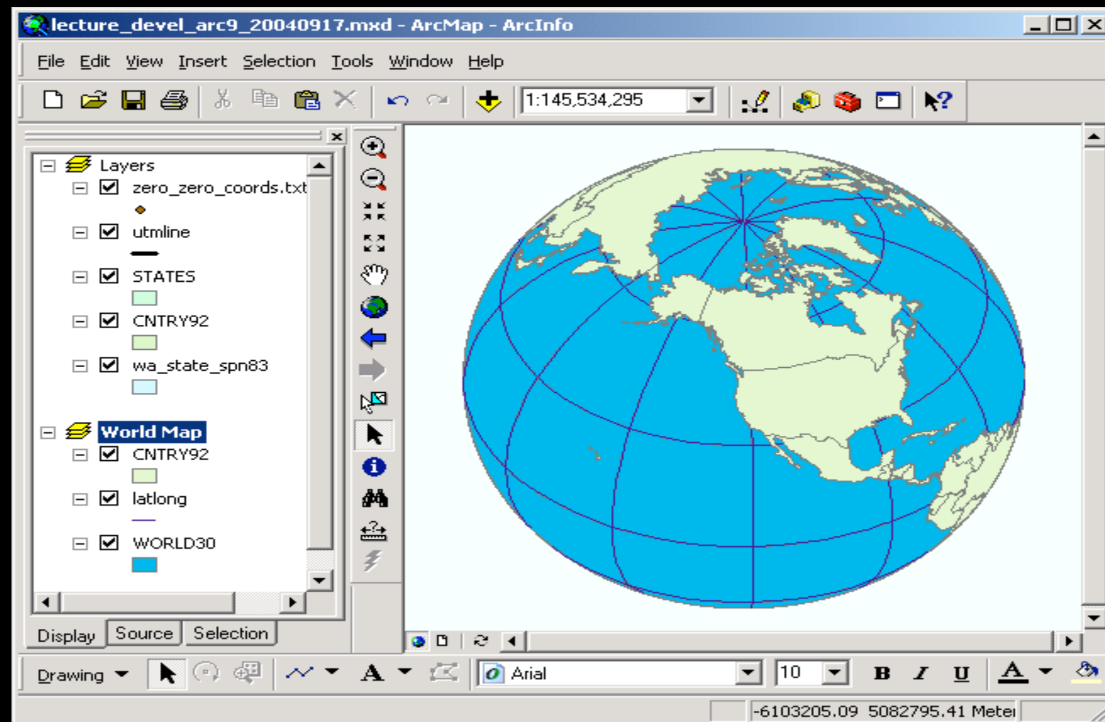




Tissot_indicatrix_world_map_Mollweide_proj.svg (SVG file, nominally 3,000 × 1,500 pixels, file size: 1.53 MB)

Examples of different projections

- Orthographic

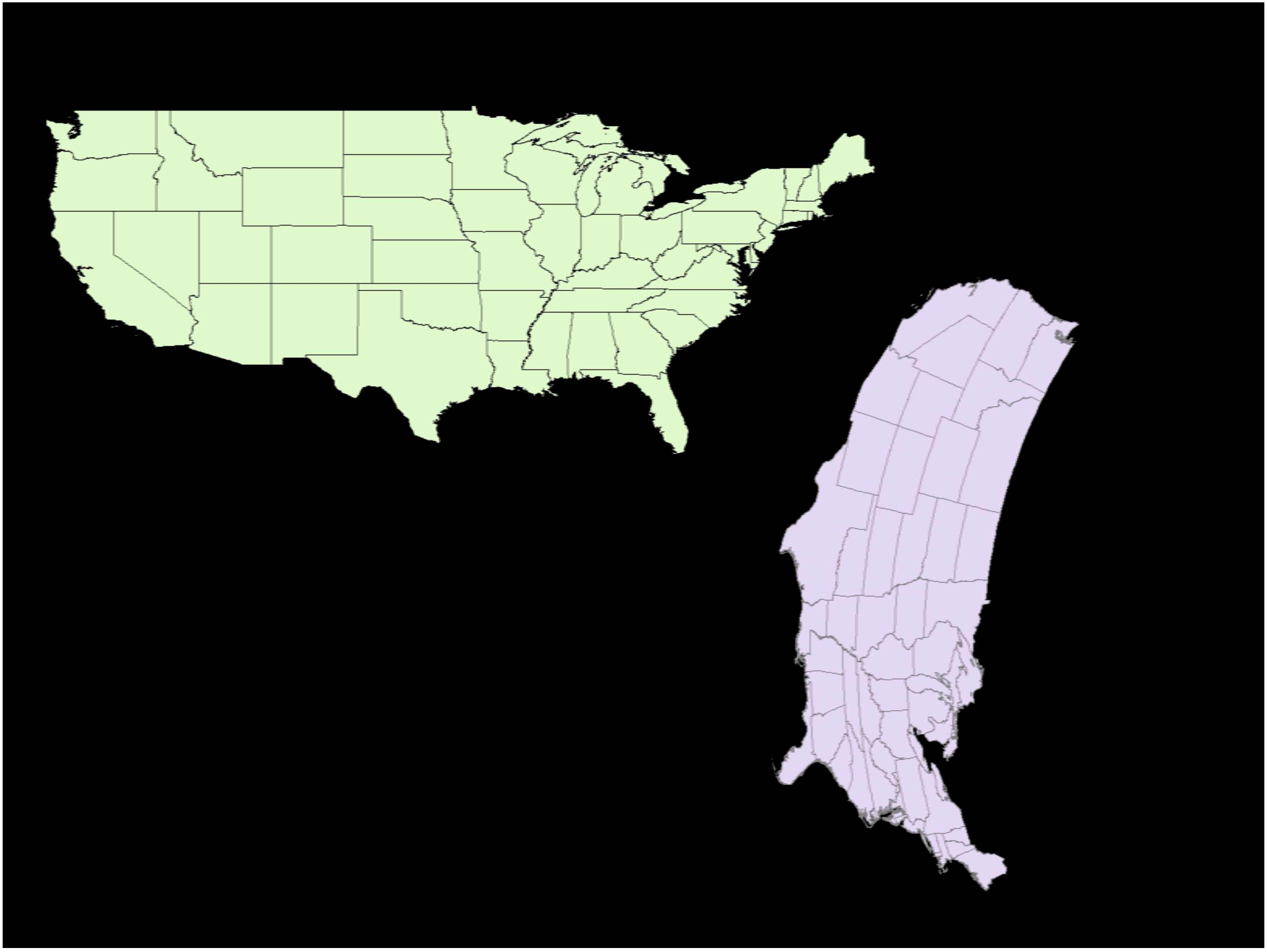


Shape Minimal distortion near the center; maximal distortion near the edge.

Area The areal scale decreases with distance from the center. Areal scale is zero at the edge of the hemisphere.

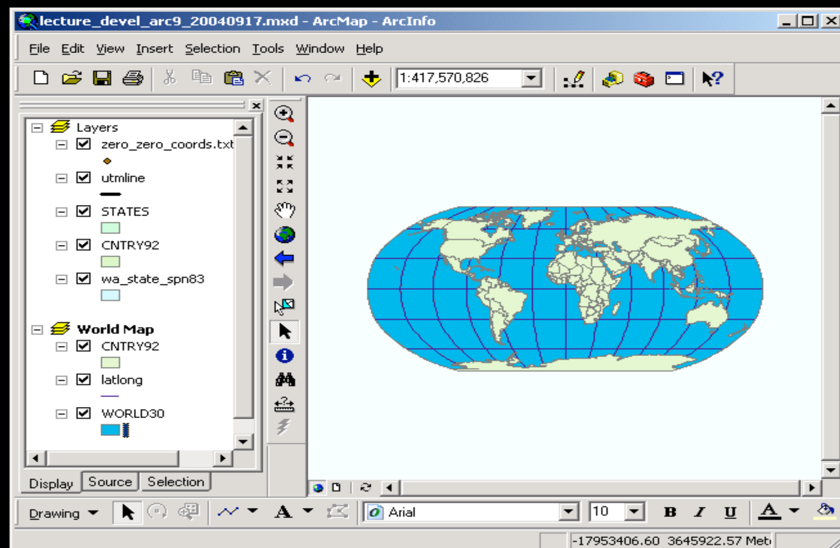
Direction True direction from the central point.

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

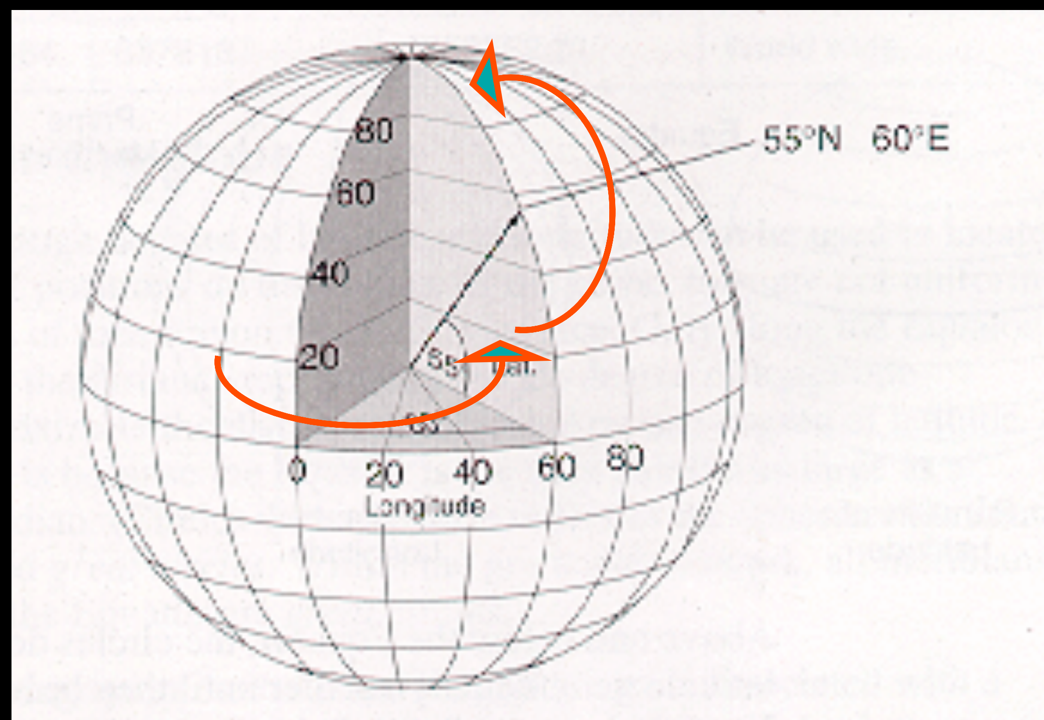
Coordinate systems

- 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

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

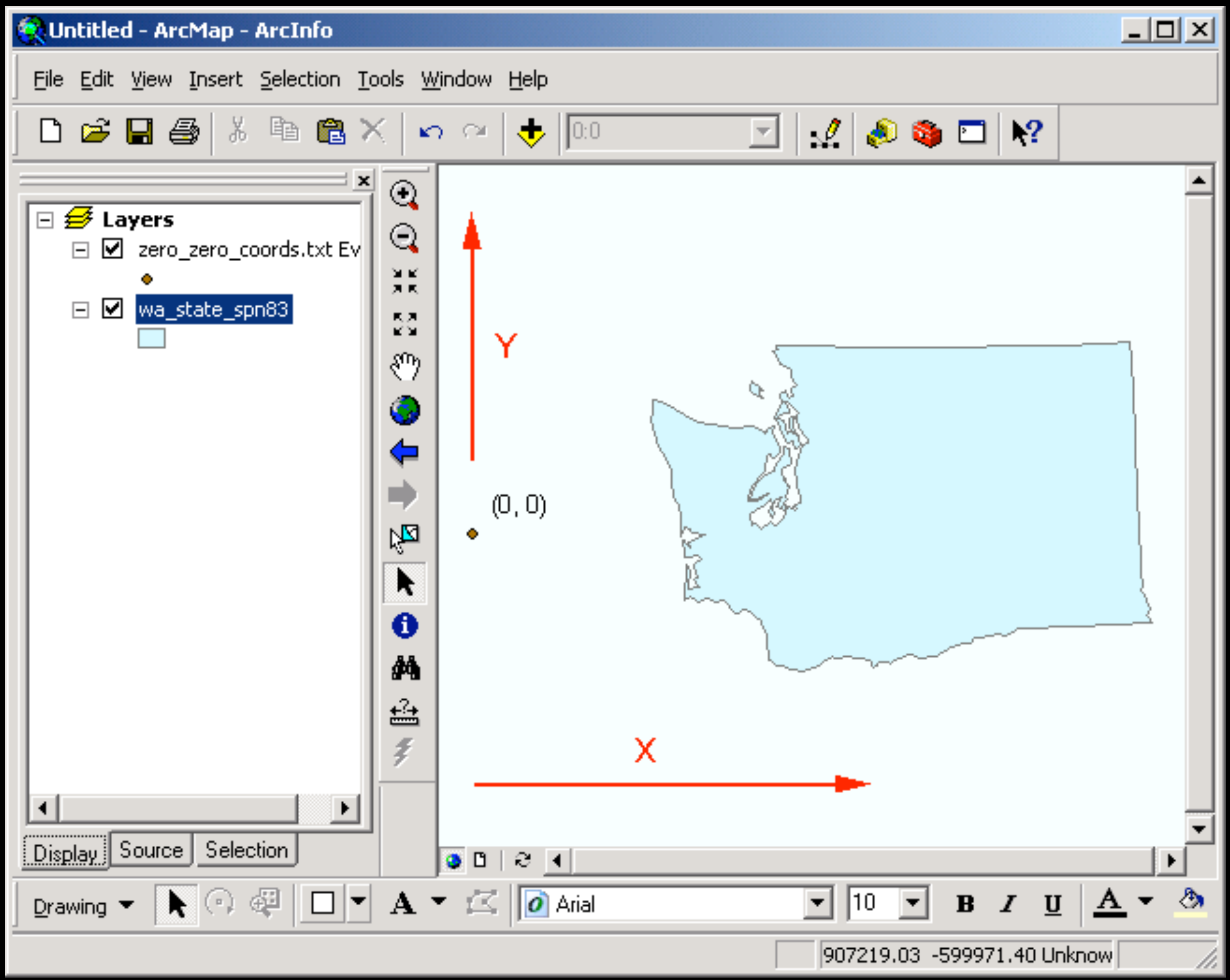


Lat/long values are NOT Cartesian (X, Y) coordinates

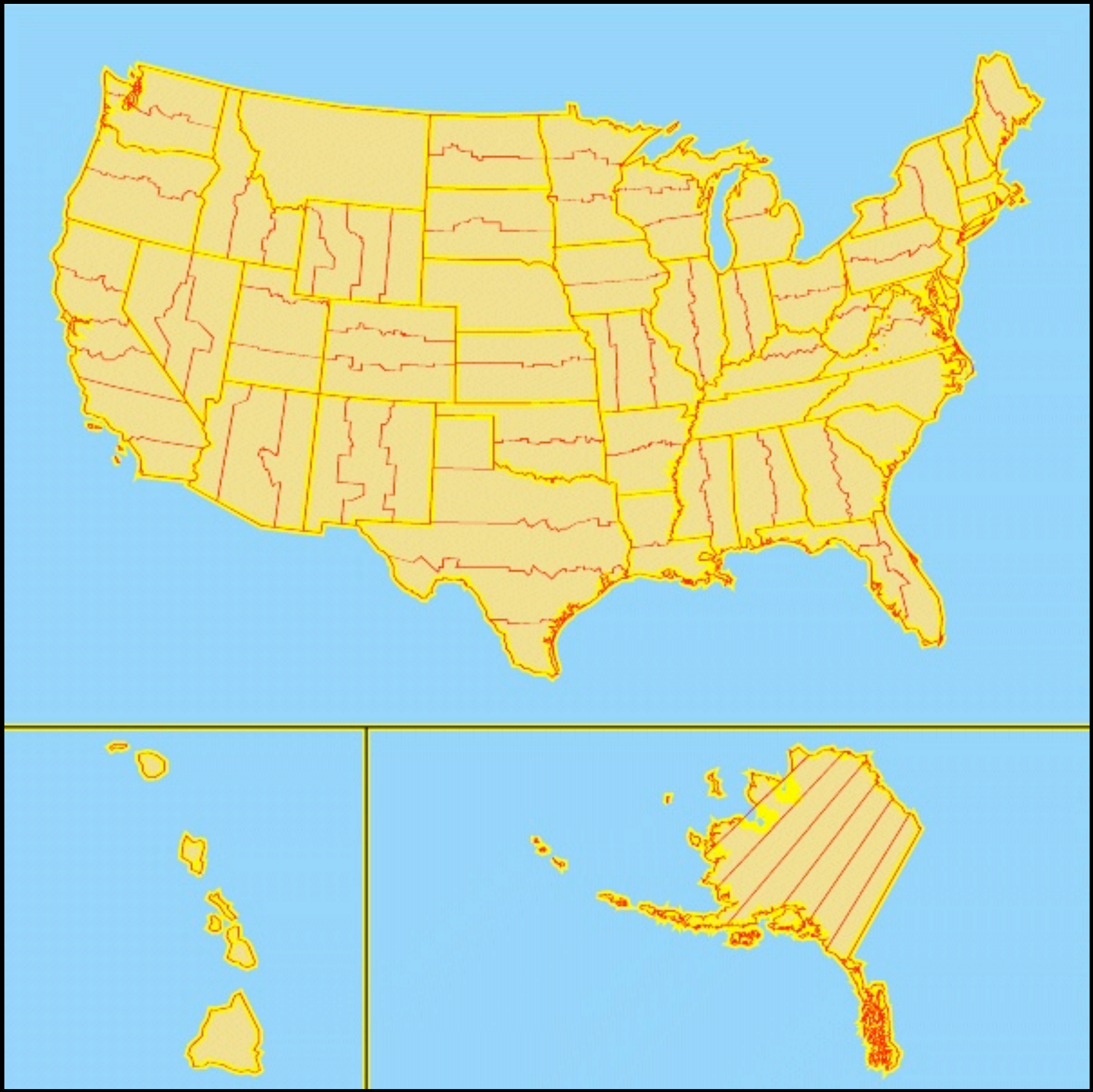
constant angular deviations do not have constant distance deviations

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

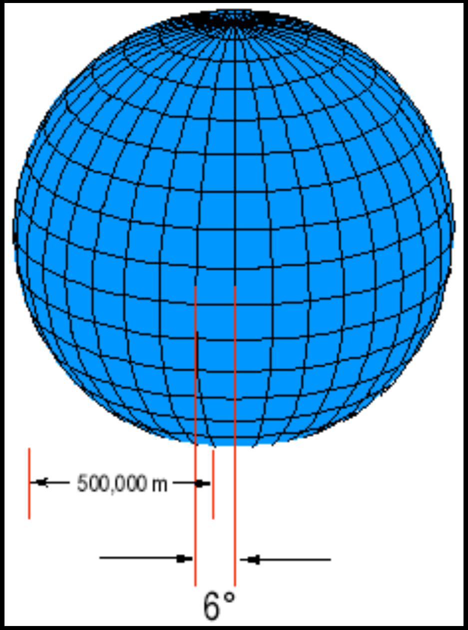
State Plane

- 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)

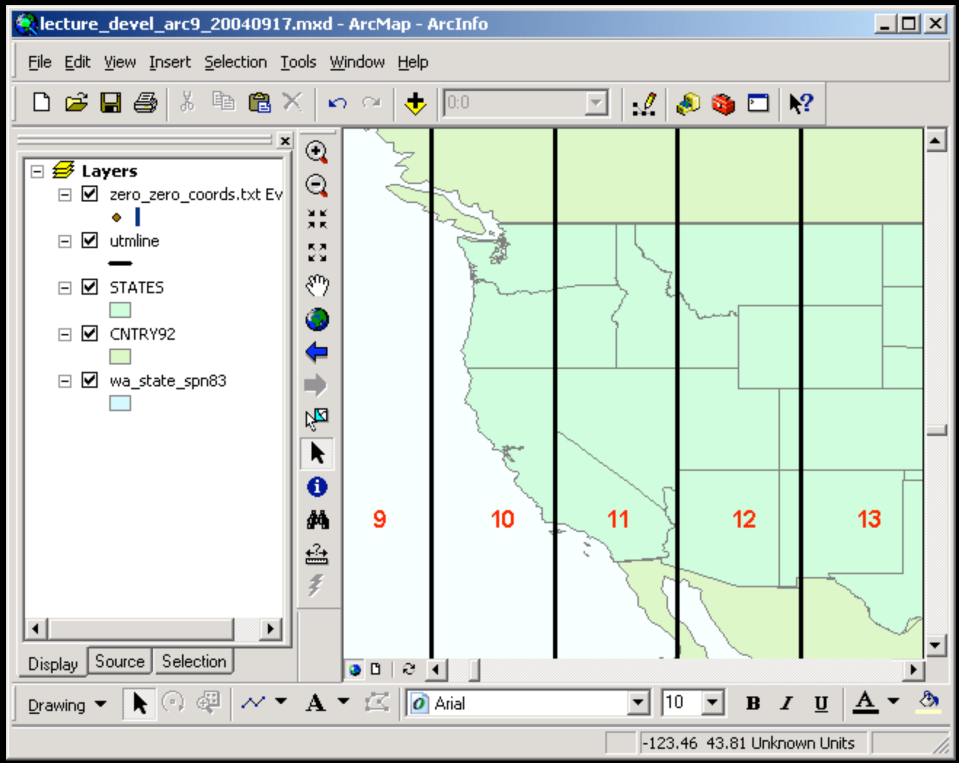
Coordinate systems

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

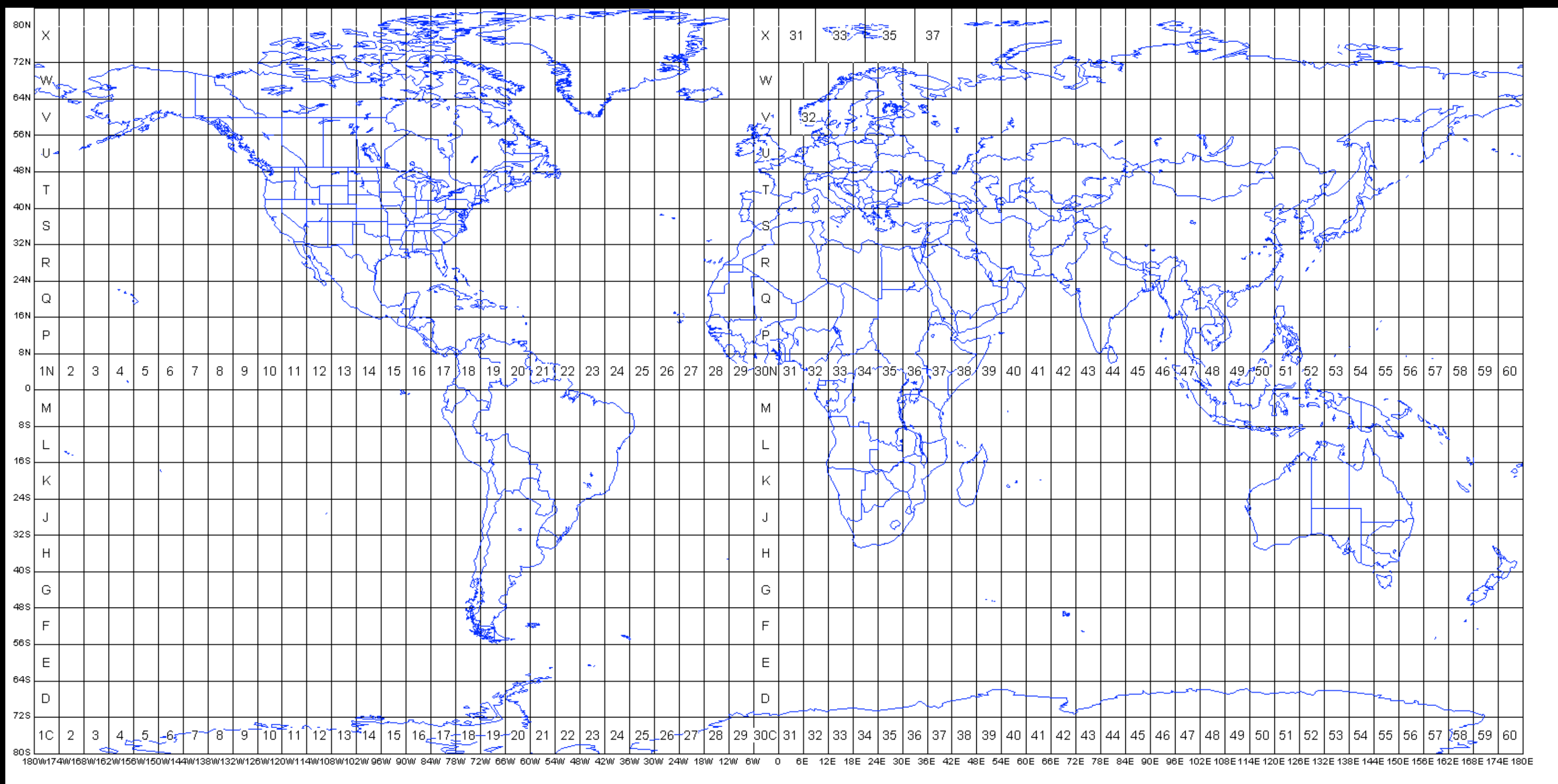


Universal Transverse Mercator (UTM)



Washington state is in Zones 10 & 11

Coordinate systems



Every place on earth falls in a particular zone

Datums

Datums

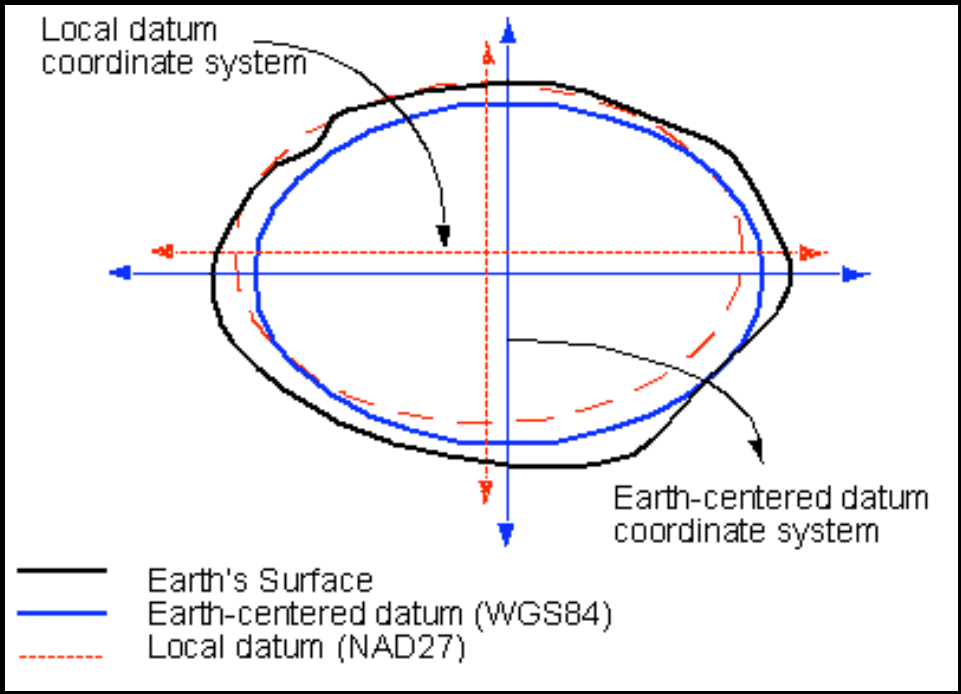
A system that allows us to place a coordinate system on the earth's surface

Initial point

Secondary point

Model of the earth

Known geoidal separation at the initial point

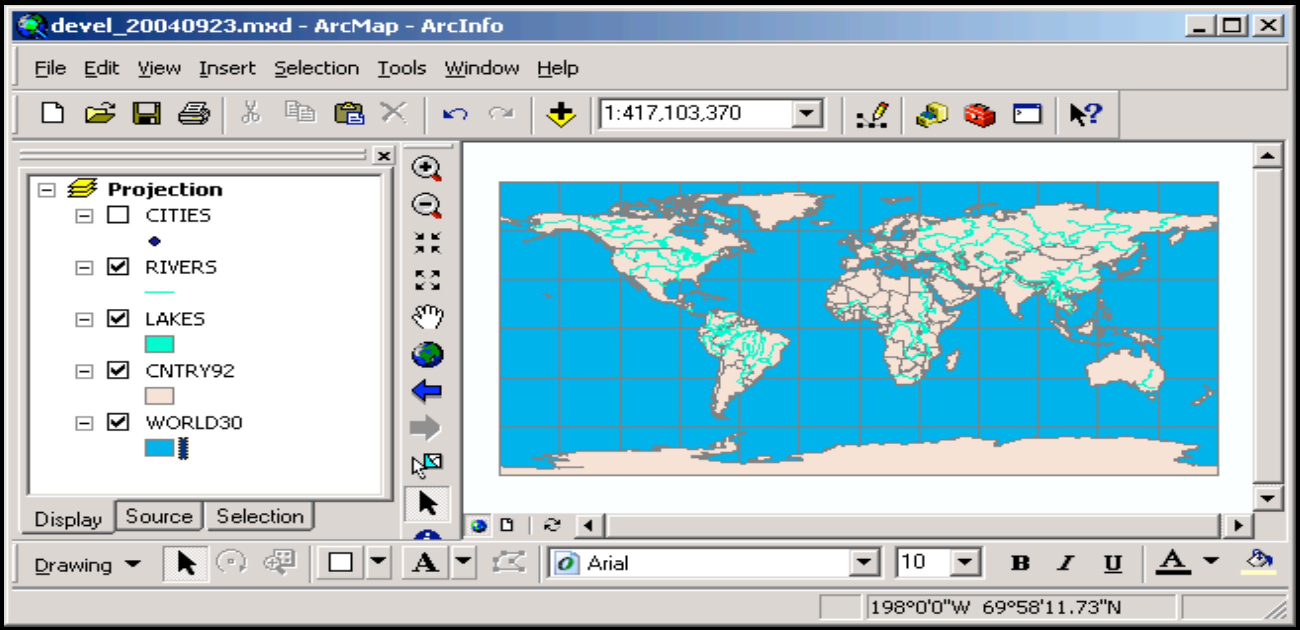


Datums

Commonly used datums in North America

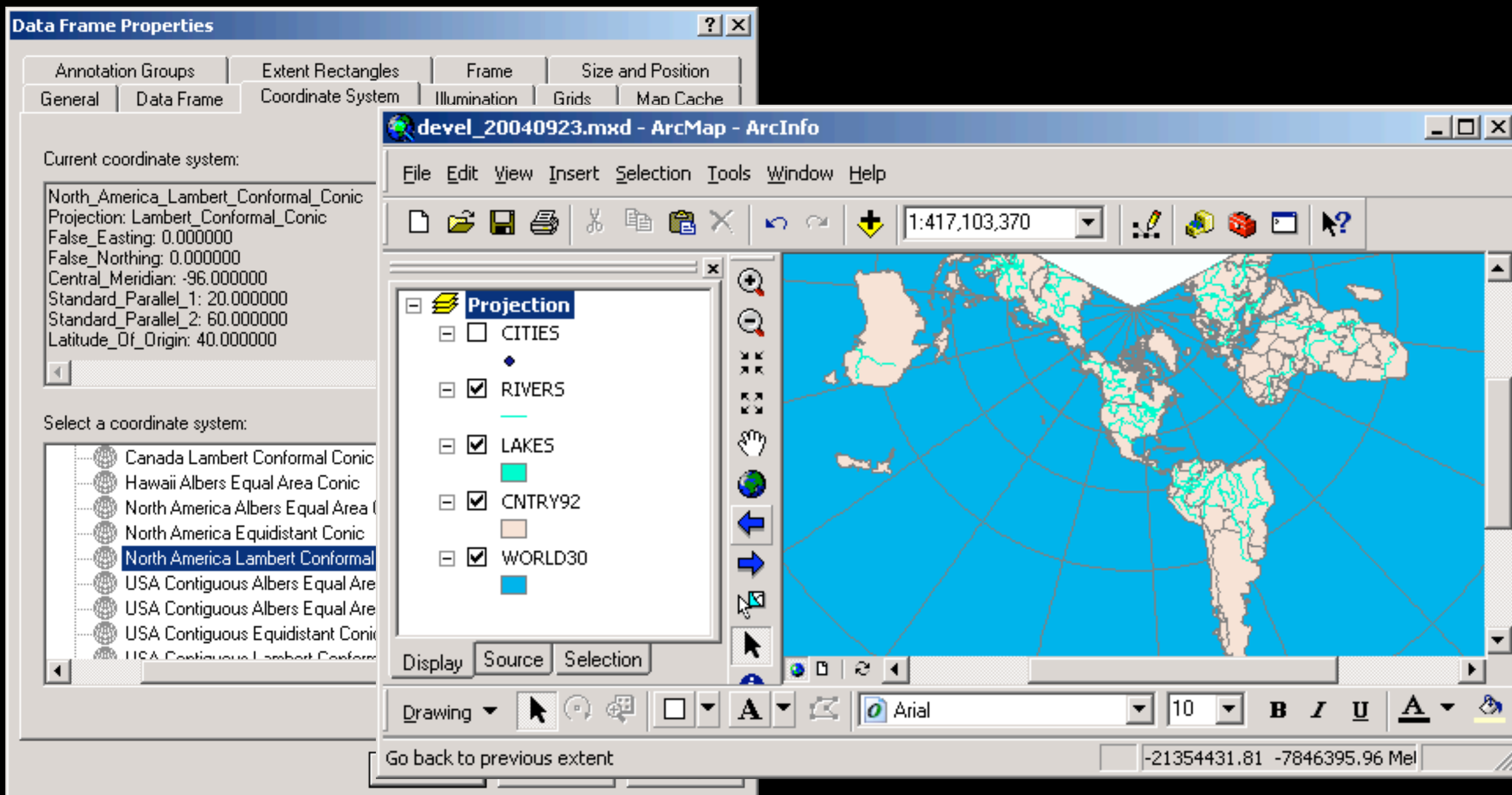
- North American Datum of 1927 (NAD27)
- NAD83
- World Geodetic System of 1984 (WGS84)

Projecting data frames



start with unprojected data

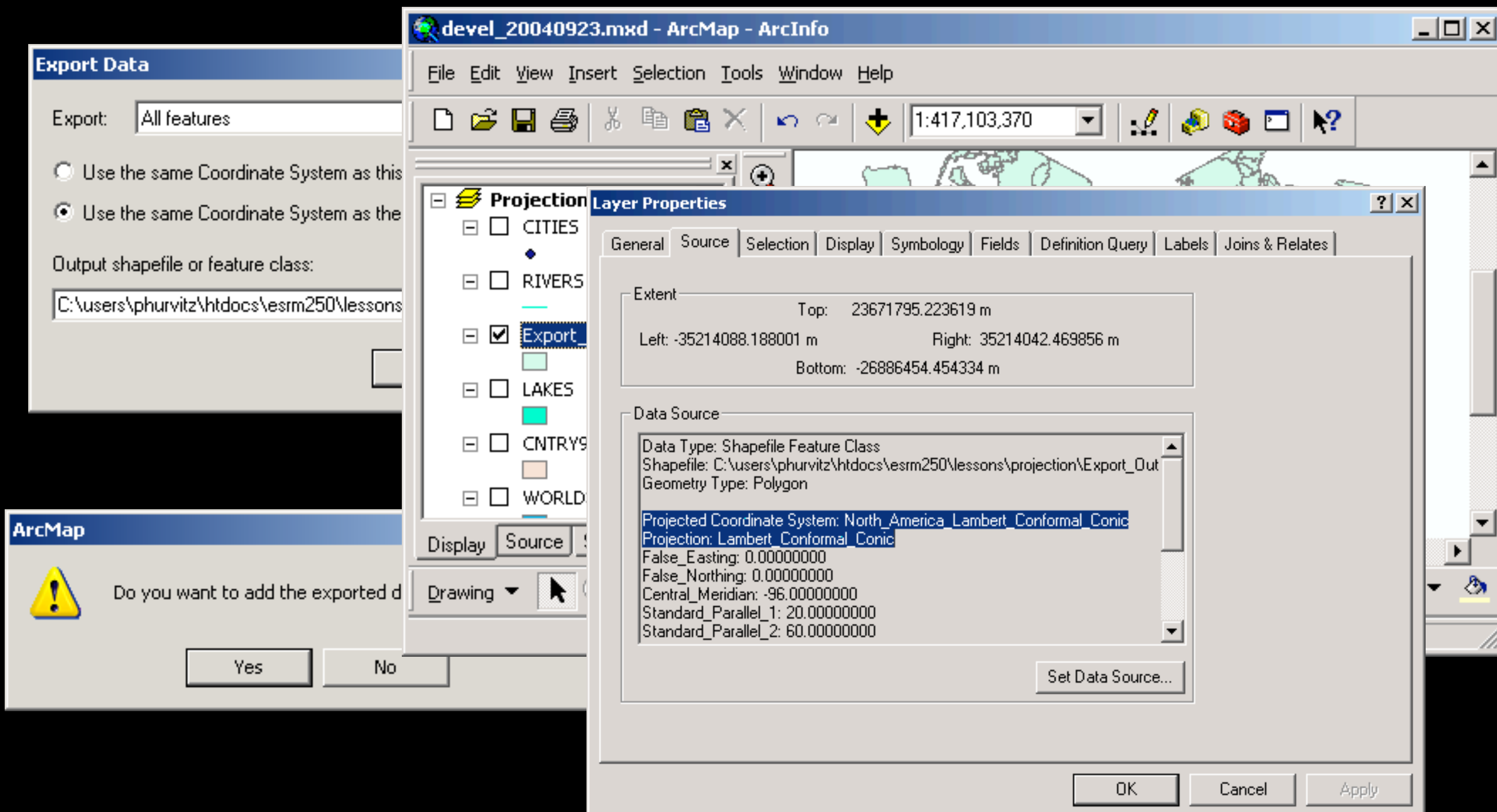
Projecting data frames

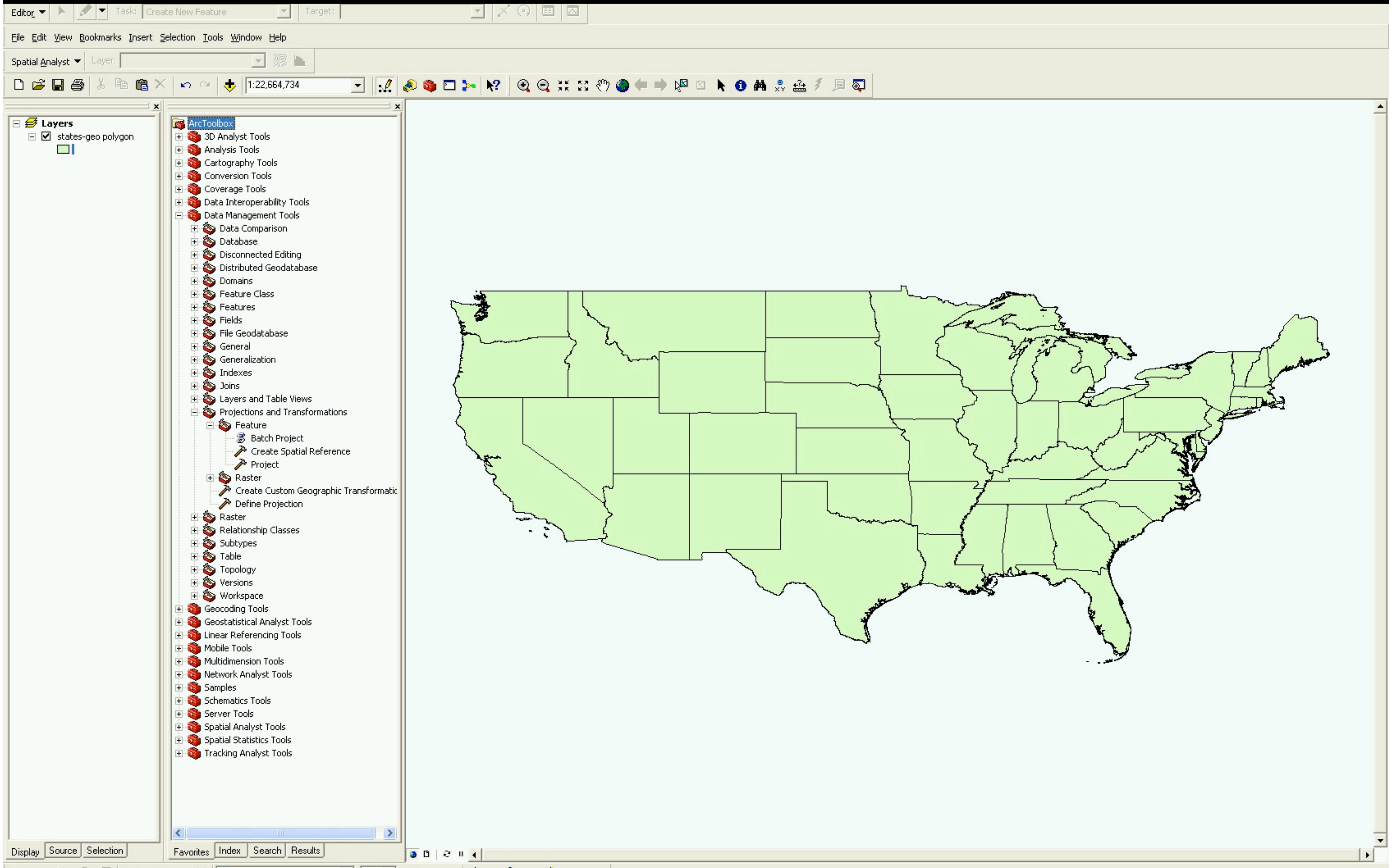


then apply a projection to the data frame

Projecting data frames: saving data sets in projected units

- Export from a projected data frame




Editor
Task: Create New Feature
Target:
File Edit View Bookmarks Insert Selection Tools Window Help
Spatial Analyst
Layer:
1:22,664,734
Layers
states-geo polygon
ArcToolbox
3D Analyst Tools
Analysis Tools
Cartography Tools
Conversion Tools
Coverage Tools
Data Interoperability Tools
Data Management Tools
Data Comparison
Database
Disconnected Editing
Distributed Geodatabase
Domains
Feature Class
Features
Fields
File Geodatabase
General
Generalization
Indexes
Joins
Layers and Table Views
Projections and Transformations
Feature
Batch Project
Create Spatial Reference
Project
Raster
Create Custom Geographic Transformatic
Define Projection
Raster
Relationship Classes
Subtypes
Table
Topology
Versions
Workspace
Geocoding Tools
Geostatistical Analyst Tools
Linear Referencing Tools
Mobile Tools
Multidimension Tools
Network Analyst Tools
Samples
Schematics Tools
Server Tools
Spatial Analyst Tools
Spatial Statistics Tools
Tracking Analyst Tools
Display Source Selection
Favorites Index Search Results

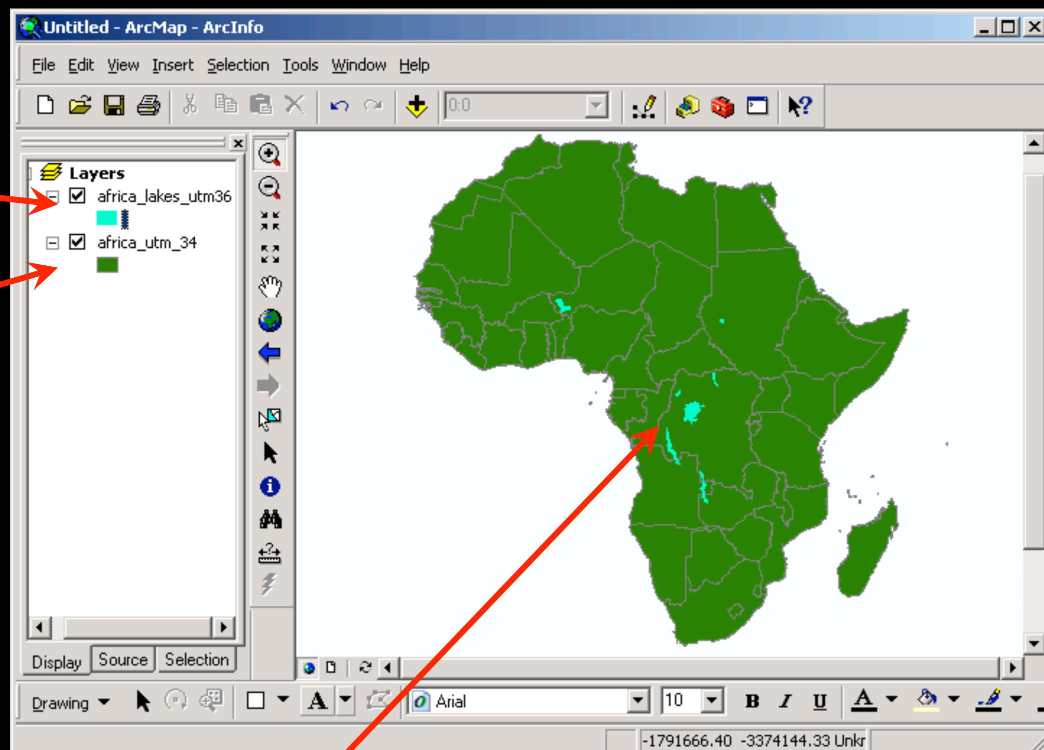
Projecting spatial data sets

Used for going **between** projections

Source data sources may not be compatible

UTM 36

UTM 34

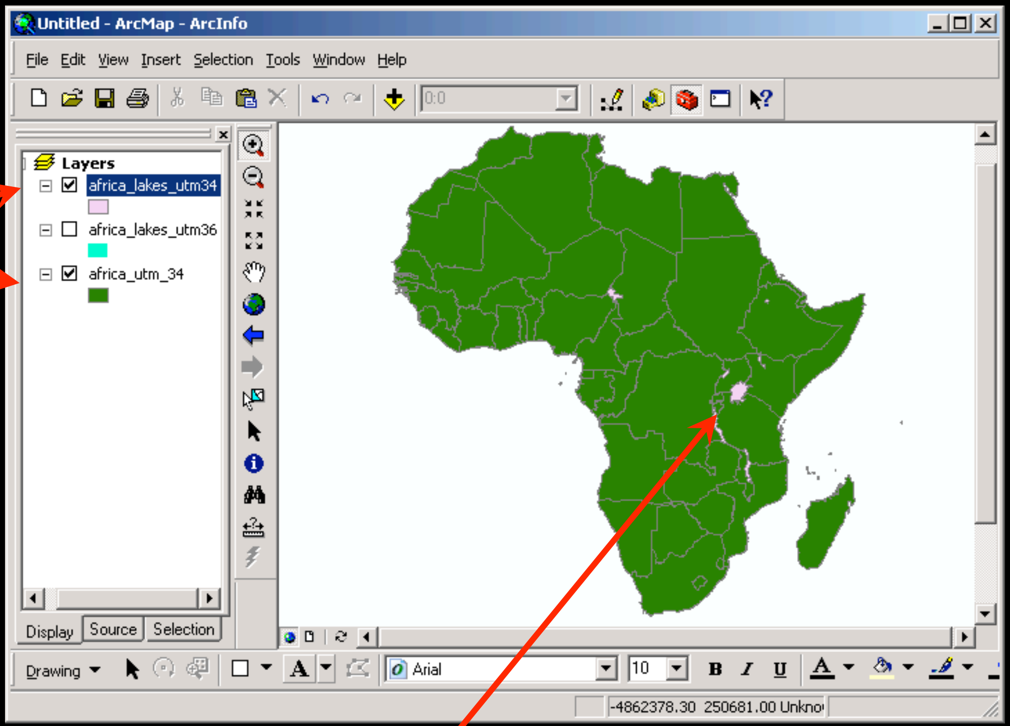


Lake Victoria is **not** in central Africa

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 20