PROJECTED COORDINATE SYSTEMS

Introduction to GIS| Winter 2015

How do we represent the Earth's ellipsoid on a flat surface?

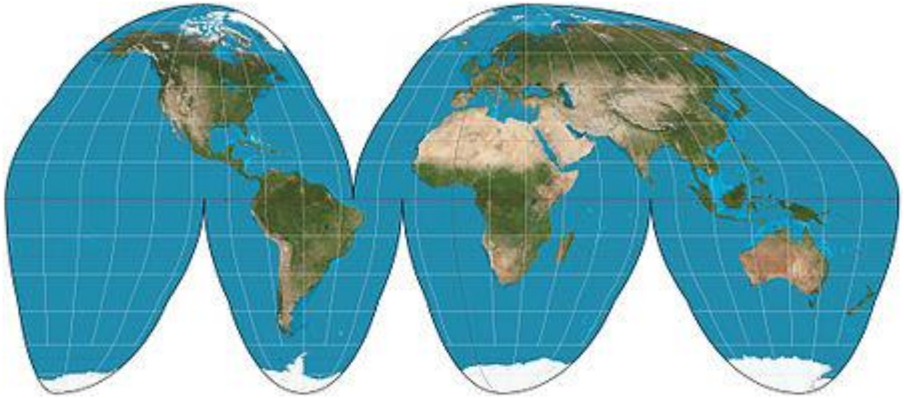
Projected Coordinate Systems

Enter: Projections

- Projected coordinate systems (PCS) transform the spherical Earth on to a flat surface
  - All projections attempt to maintain spatial relationships
  - All projections will result in some degree of distortion

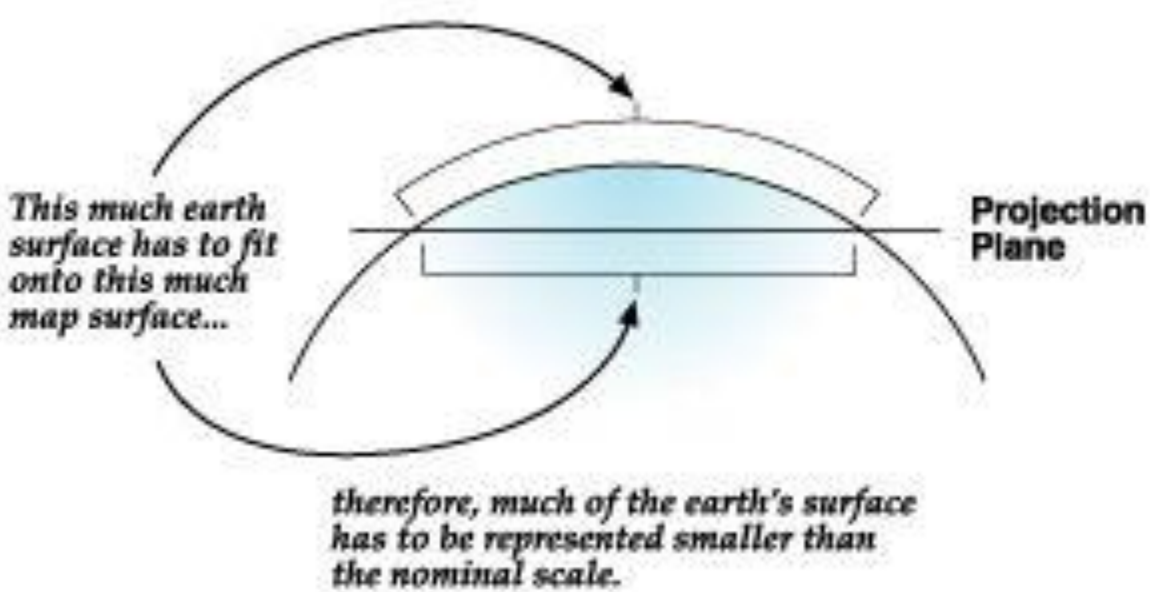
Map projections = peeling an orange

- Like making an orange peel flat, one must stretch and distort the round surface to make it flat



Map projections = distortion

- Something's gotta give…
- Area, shape, distance, or direction



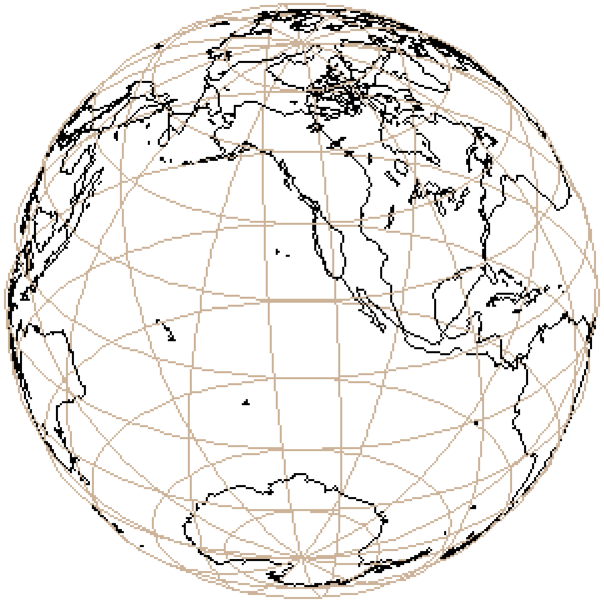
Why do projections matter?

[The West Wing and Map Projections]

The most accurate map

- The good….
  - Accurately displays lines of latitude and longitude
  - Scale is uniform across the entire surface

- The bad….
  - Difficult to travel with
  - Expensive
  - Measuring can be tricky



How do map projections work?

- Transforms lat/long (Geographic coordinates) to an x/y Cartesian coordinate system using mathematical equations
- i.e. Mercator projection mapping equation:

$$x = R(\lambda - \lambda_0)$$

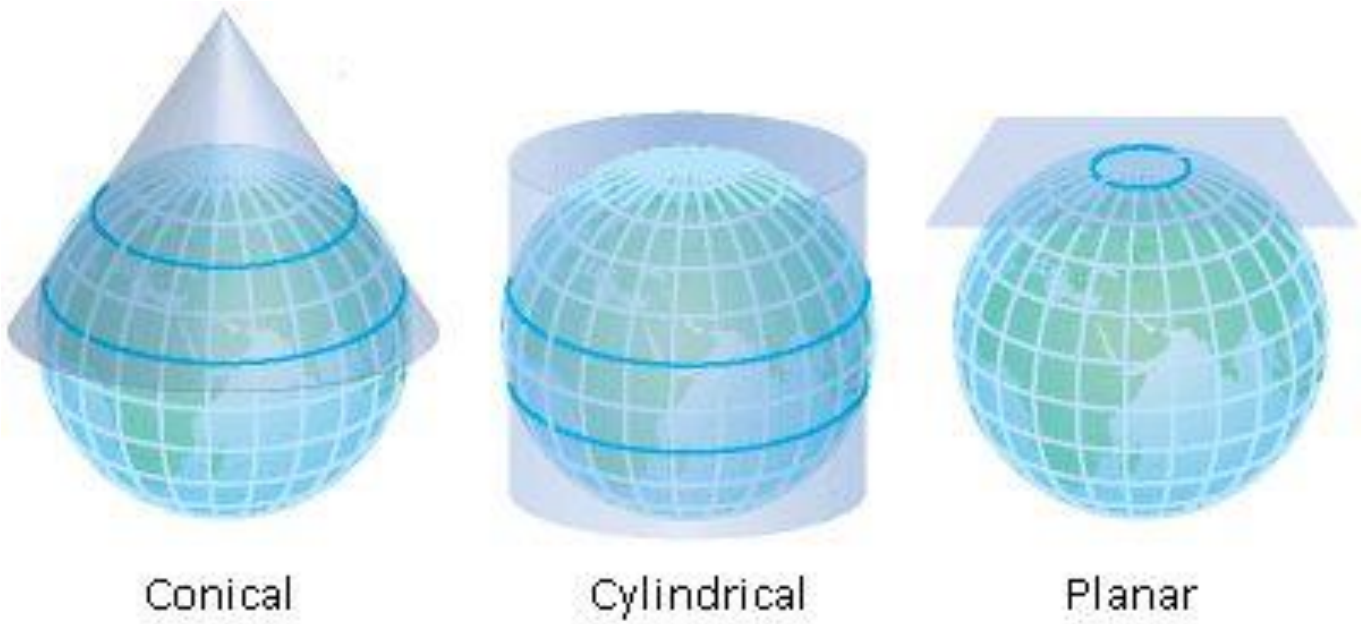
$$y = R(ln(tan(\frac{\pi}{4} + \frac{\phi}{2})))$$

Components of map projections

- Surface type (or developable surface)
  - Planar, conical or cylindrical
- Lines of tangency or secancy
- Orientation
  - Normal, transverse, oblique
- Location and direction of false illumination source
  - Center, opposite, infinity
- Characteristics of distortion

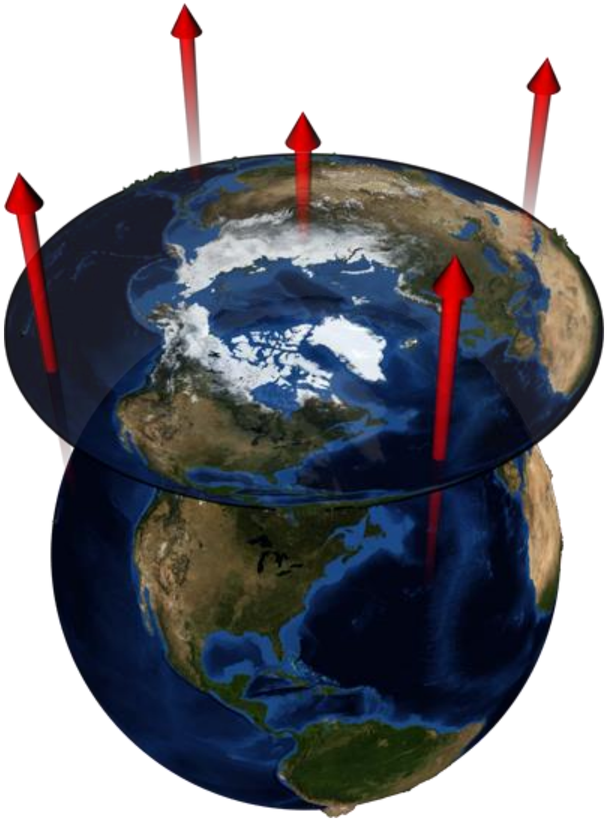
Map projection surface types

Map projection surface types

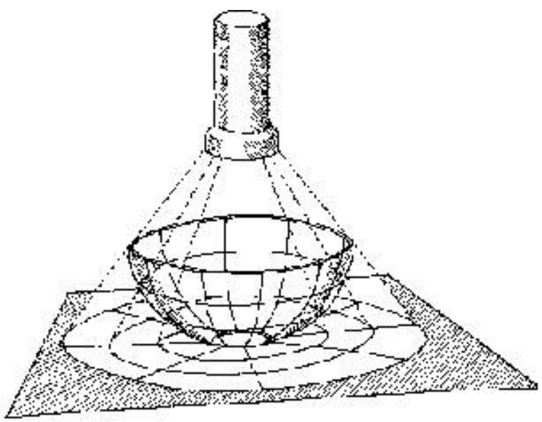


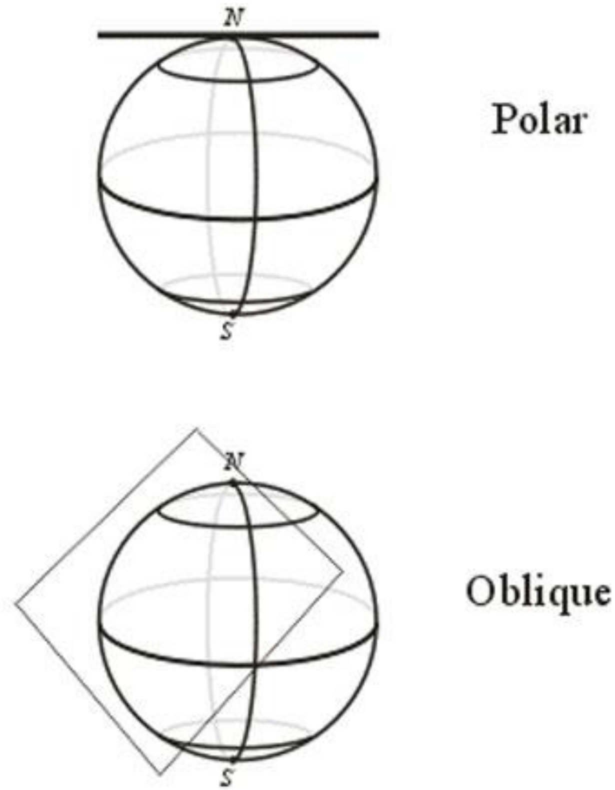
Planar / Azimuthal projection

- The transformation from one perspective point to a flat surface



Planar / Azimuthal projection



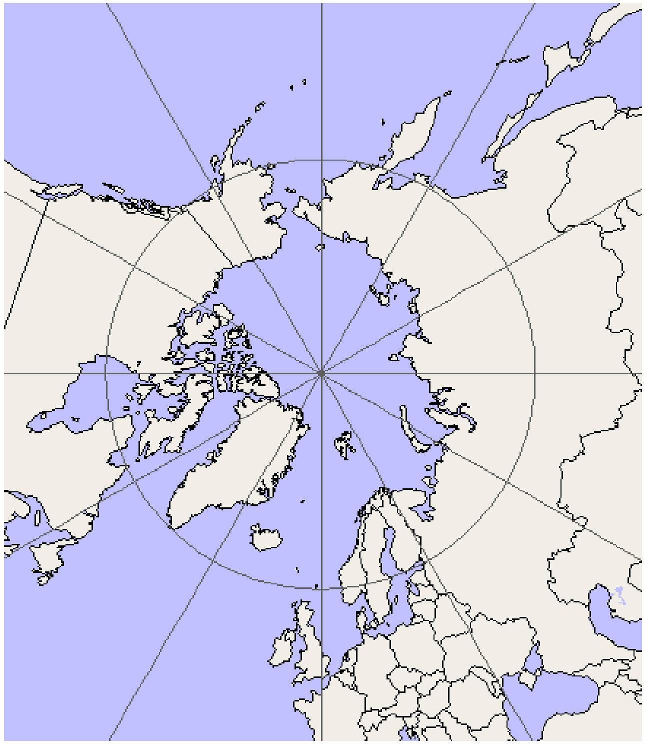


Planar / Azimuthal projection

- Used for mapping polar regions
- True direction from center and other locations
- Straight lines from Point of Tangency (POT) are great circle routes
- Uses:
  - Commercial atlases
  - Navigation (i.e. airports)

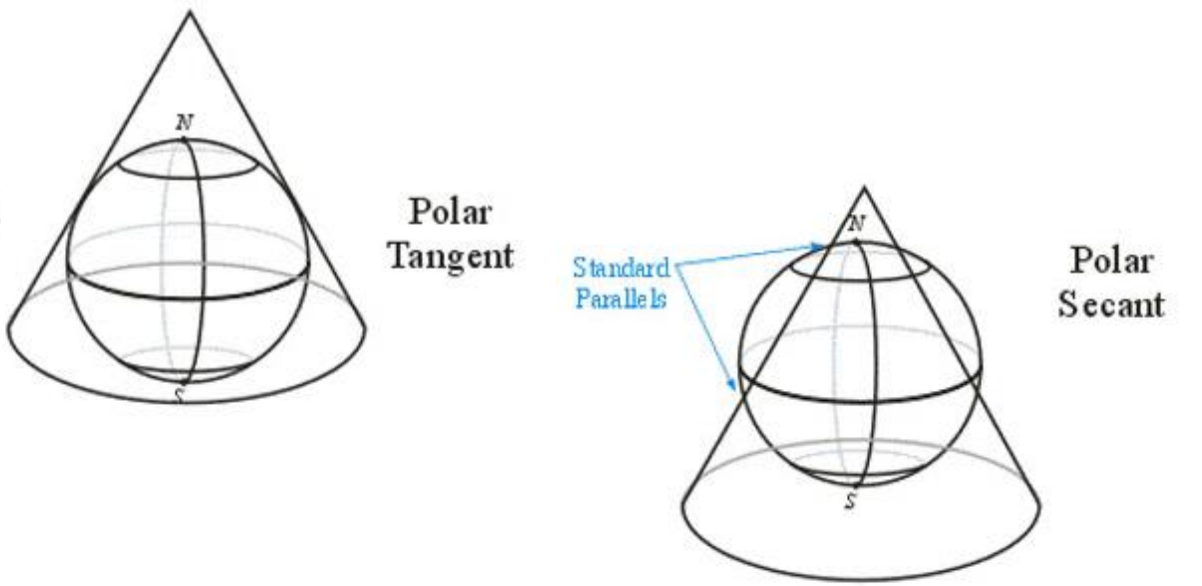
Planar / Azimuthal projections

- Parallels are shown as circles around the globe
- Meridians radiate from poles like wheel spokes
- Distorts equator (when in normal aspect)



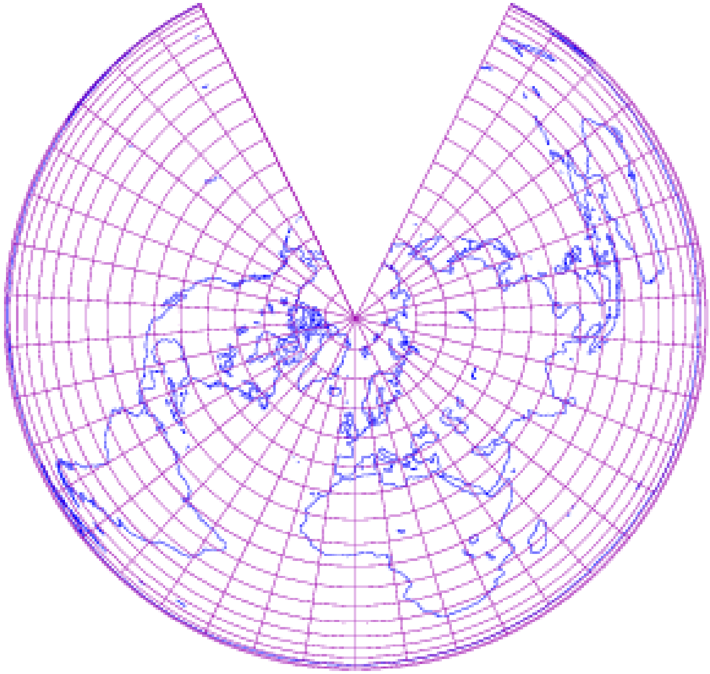
Conical projections

- A global snow cone, where the cones touches a predetermined line of latitude (normal aspect)
- Becomes developable one ‘unrolled’



Conical projections

- Parallels are concentric circular arcs
- Meridians are straight, equally spaced lines that converge towards the poles
- Exceptional for mid-latitudes



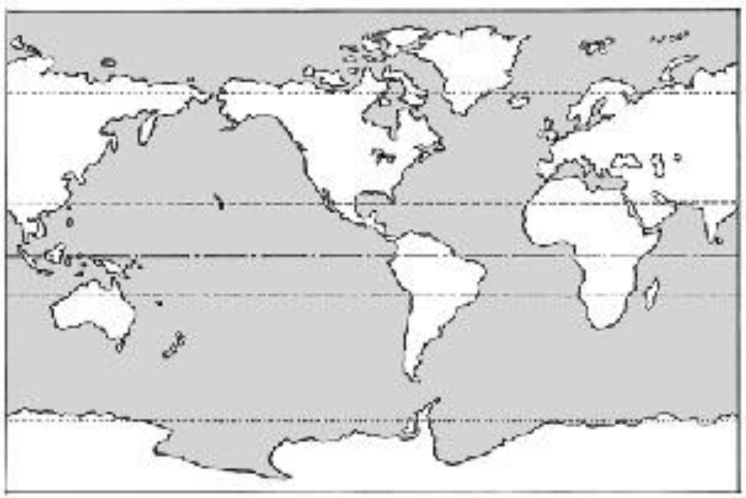
Conical projections

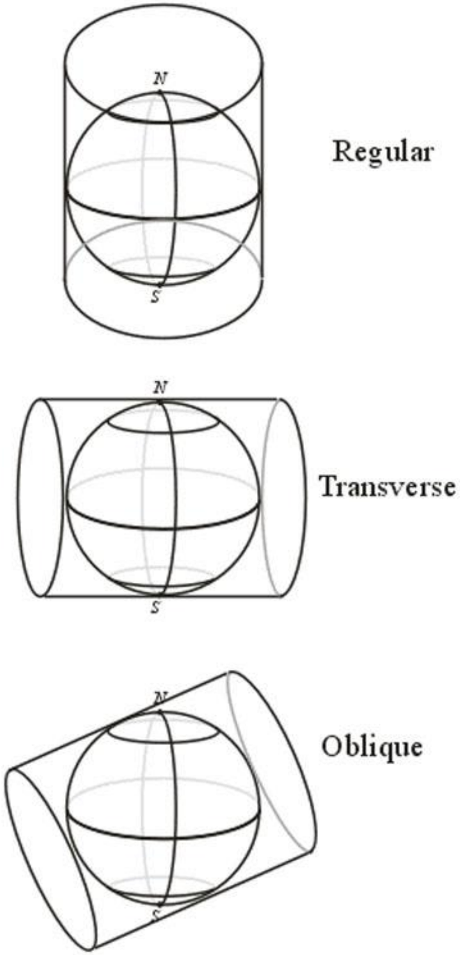
- Often have two lines of tangency
  - Lambert: 45N & 33N
  - Albers: 45.5N & 29.5N
- Central Meridian is midpoint between east and west extent
- Particularly good for mapping North America

Cylindrical projections

- A cylinder wrapped around the globe and unwrapped
- Parallels and meridians are evenly spaced and straight
  - Meridians are vertical
  - Parallels are horizontal
- Distortions occur at high latitudes

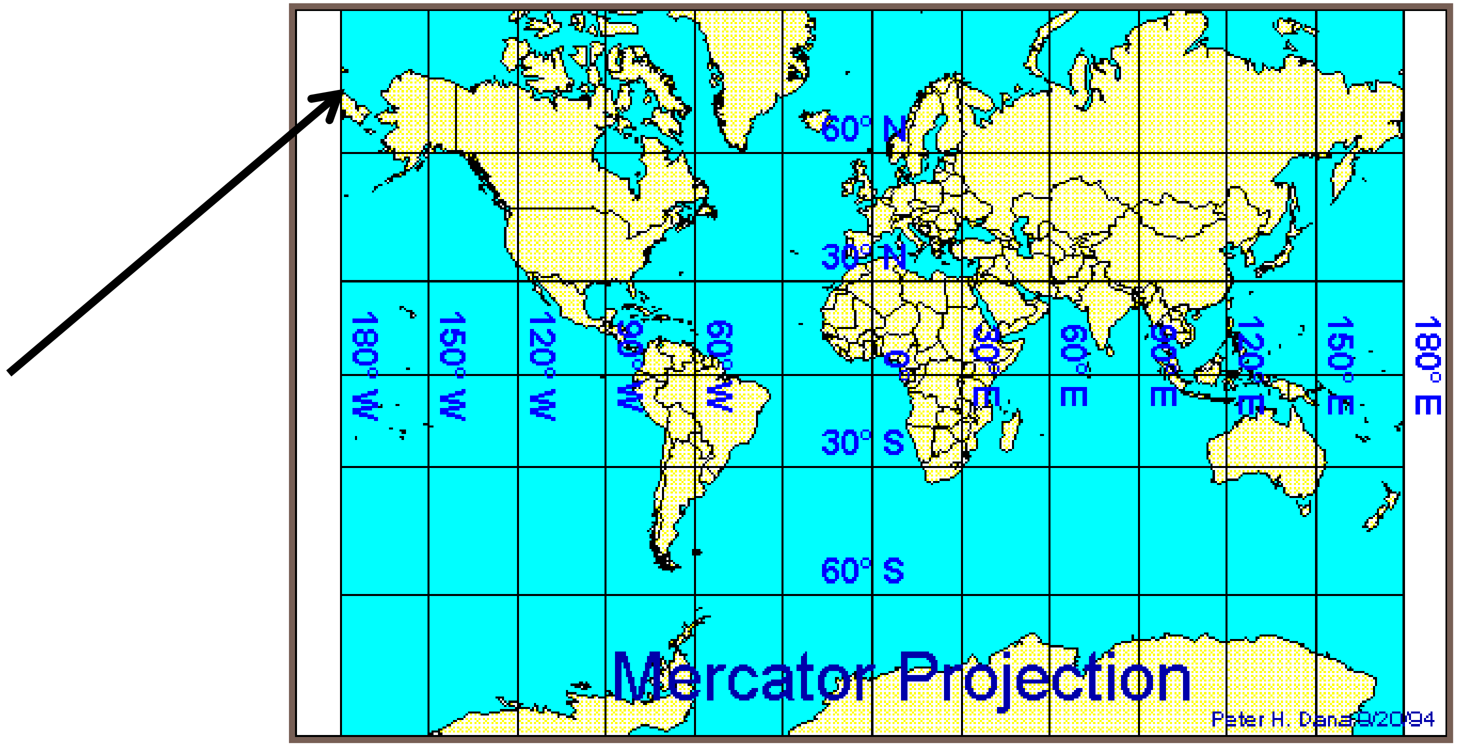
Cylindrical projection





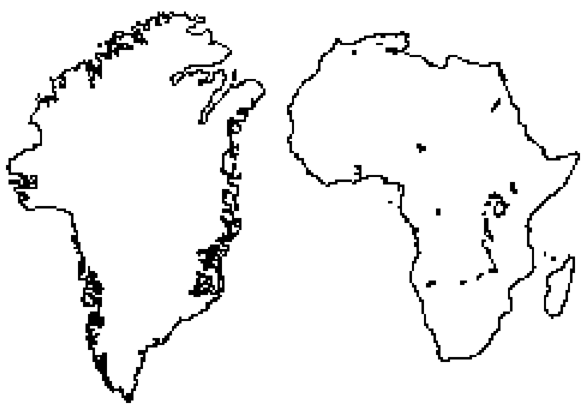
Cylindrical distortion

- Meridians should be convergent at poles, hence the distortion to the north and south



Cylindrical projection

- The Greenland/Africa example



Mercator Projection

True Size

Cylindrical projection

- Particularly good for navigation because a straight line between any two points follows a single direction (rhumb line)
- Makes navigation simple

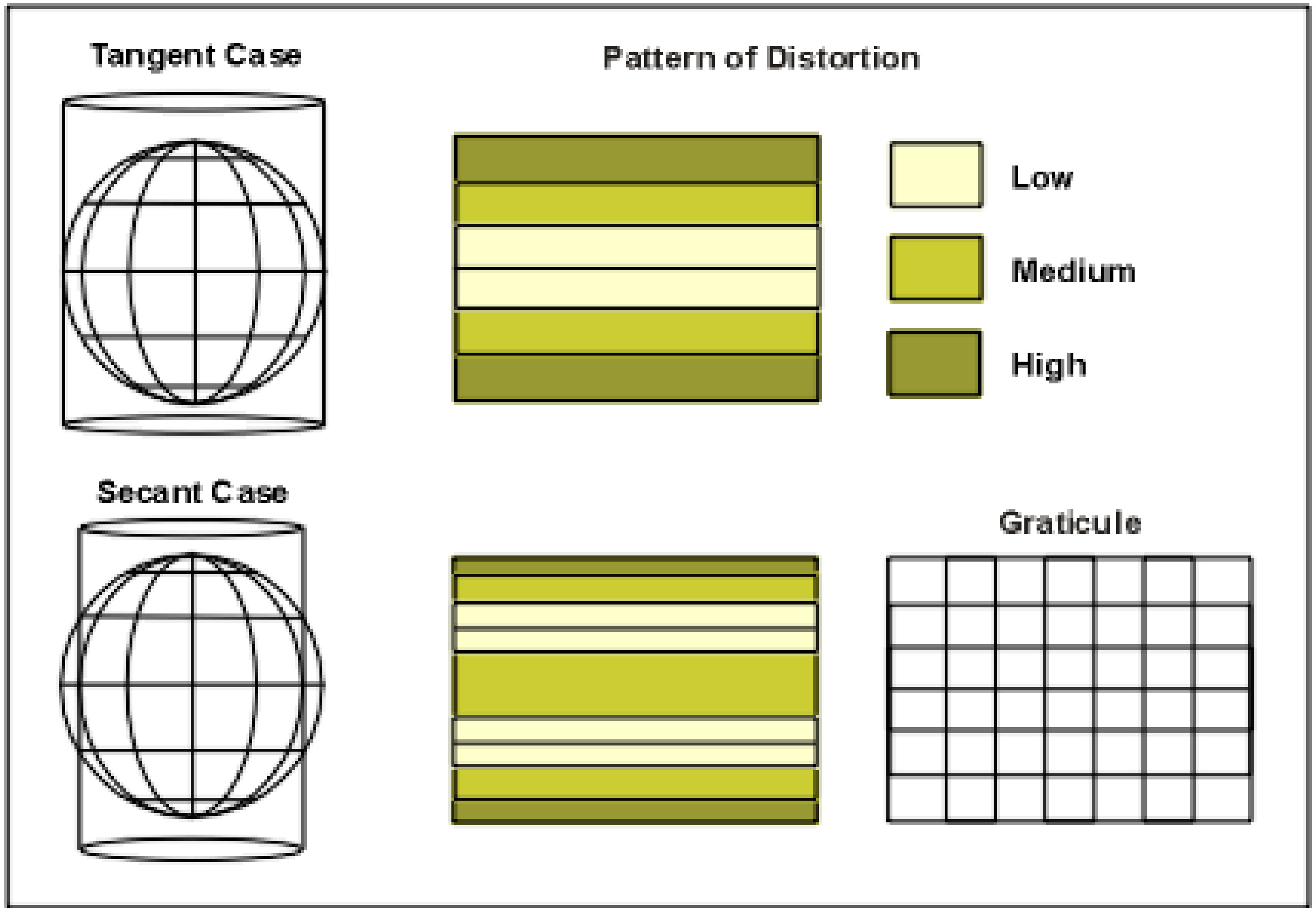
Tangency & Secancy

And distortions

Tangents & Secants

- Map projections contact the Earth's surface along a point or line (Tangent) or two lines (Secant)
- Represents locations on the map projection where there is no distortion
- The further you move away from the tangent or secant (north or south), distortion increases

Tangents & secants



What properties are distorted?

Area – Shape – Distance – Direction

- Conformal – preserves shape
  - Meridians & parallels intersect at right angles
- Equal Area – preserves area
  - Used primarily for GIS Analysis
- Equidistant – preserves distance
  - Equal area projections can also be equidistant
- Equi-azimuthal – preserves direction
  - North is always north

Projection & distortions

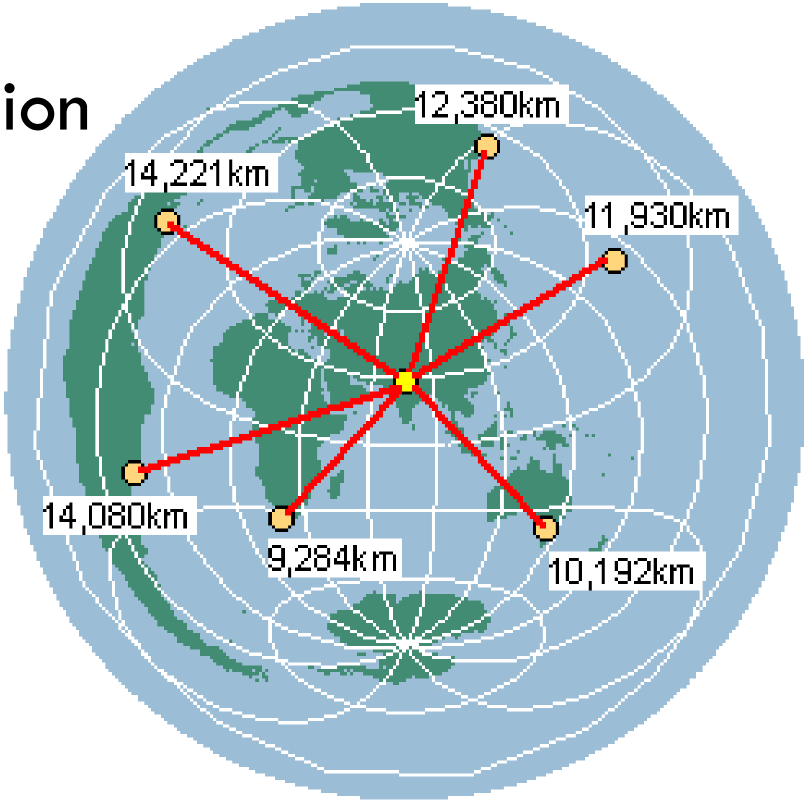
- When choosing a projections, choose it base on what you would like to distort LEAST

Area

- AKA: Equal area or equivalent projections
- Area sizes are correct throughout the map
- Tends to distort shape

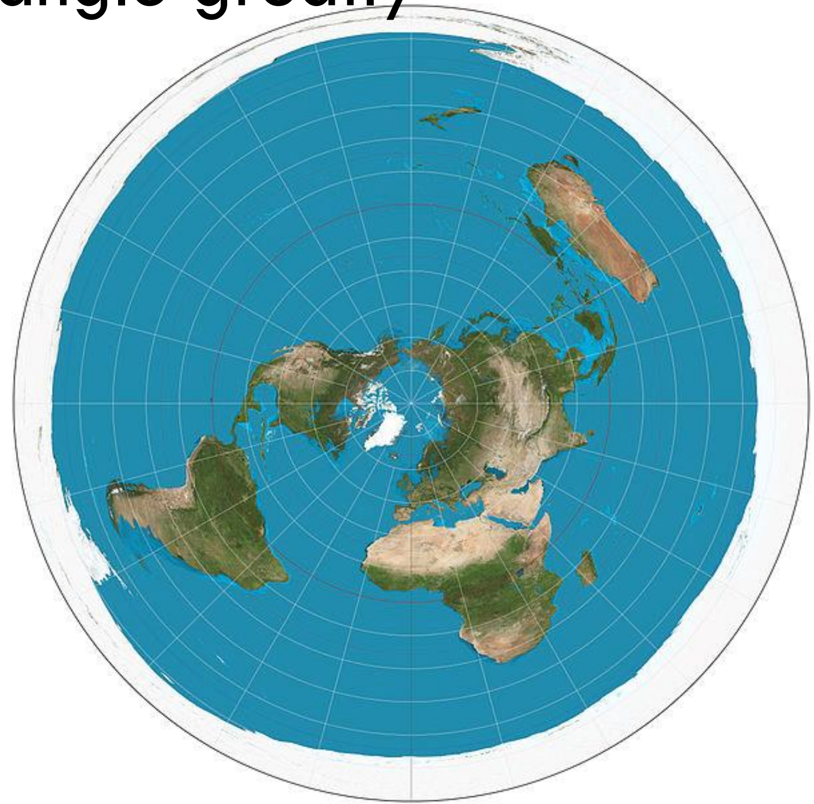
Distance

- AKA: Equidistant
- From centered point (focal point), distance is correct in all directions
- Tends to distort area /direction



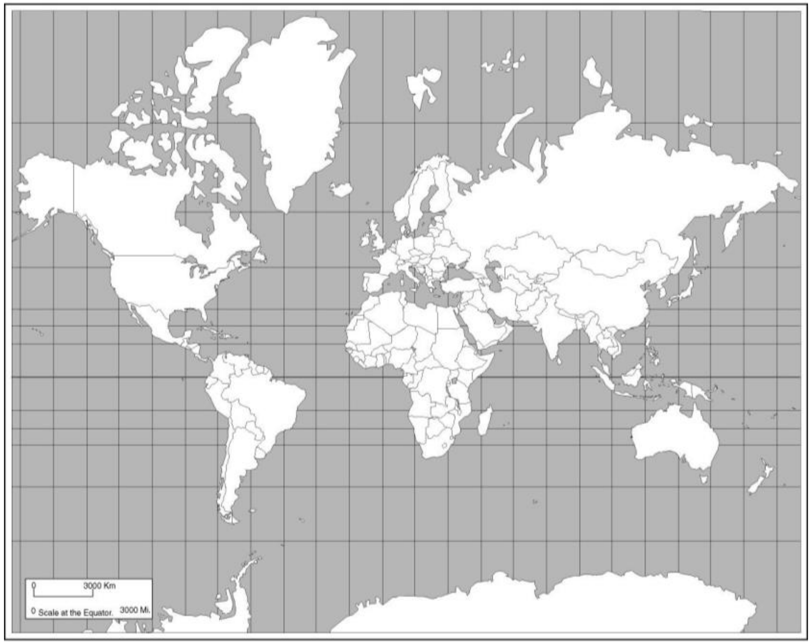
Direction

- AKA: Azimuthal
- From center point, all directions are accurate
- Distorts shape, area, and angle greatly



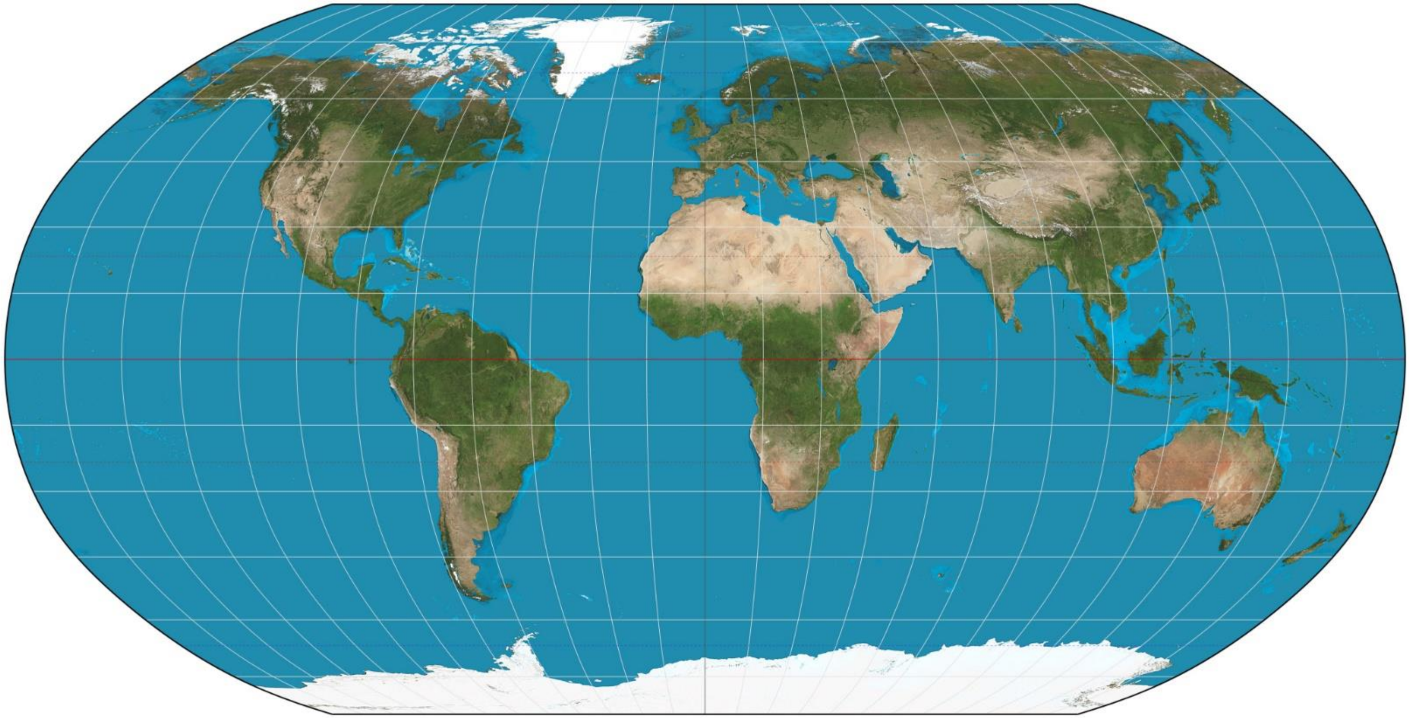
Shape

- AKA: Conformal
- Shape is maintained across the map, while area is distorted
- Latitude and longitude cross at right angles
- Used for navigation



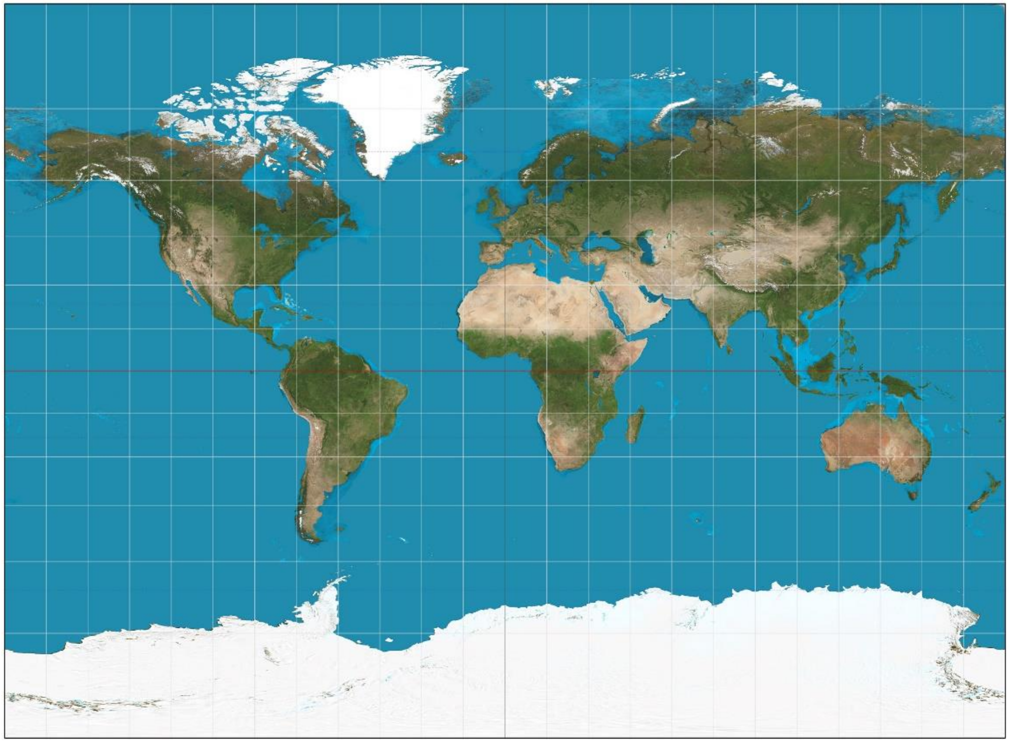
Compromise Projections

- Pseudoconic and Pseudocylindrical
  - Use curved meridians
  - i.e. Robinson Projection



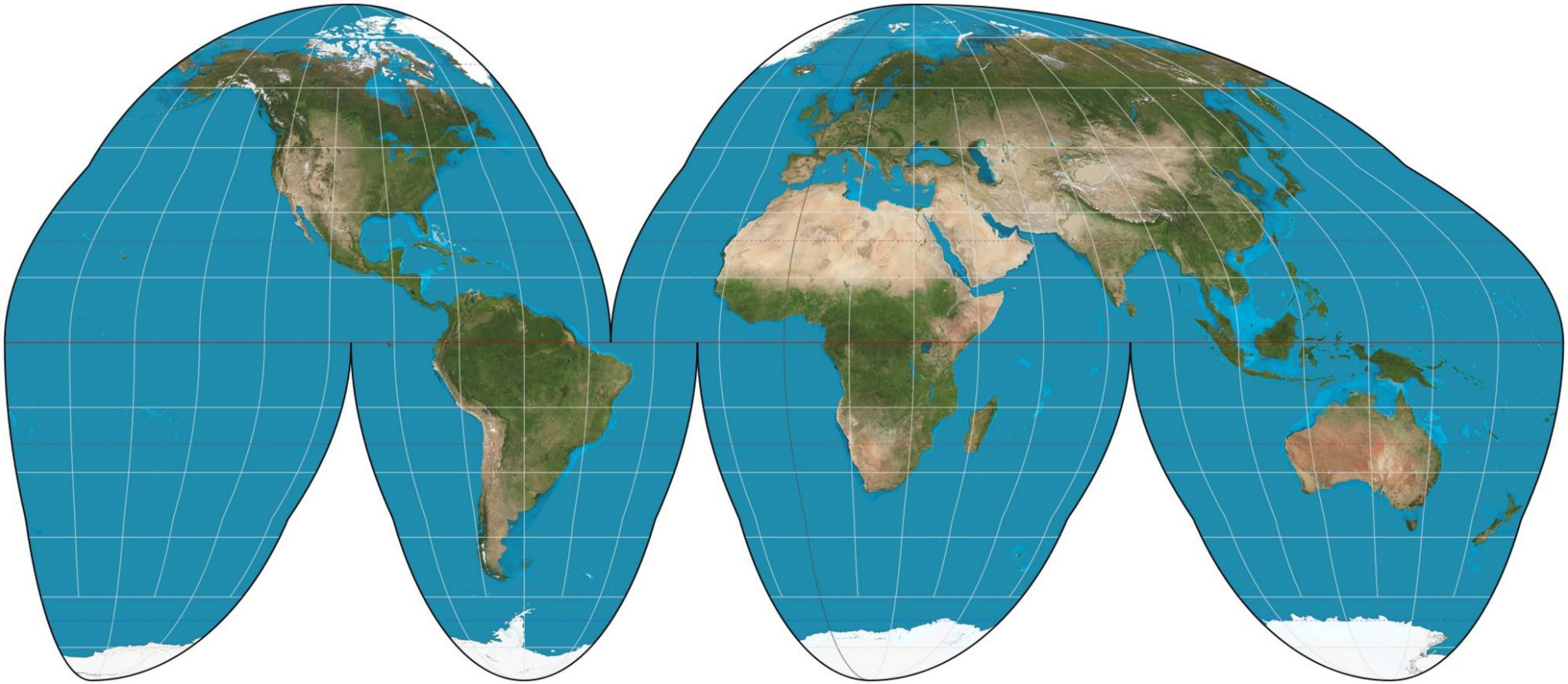
Compromise Projections

- Modified projections
  - Add more standard parallels to reduce distortion and size of areas
  - i.e. Miller Cylindrical



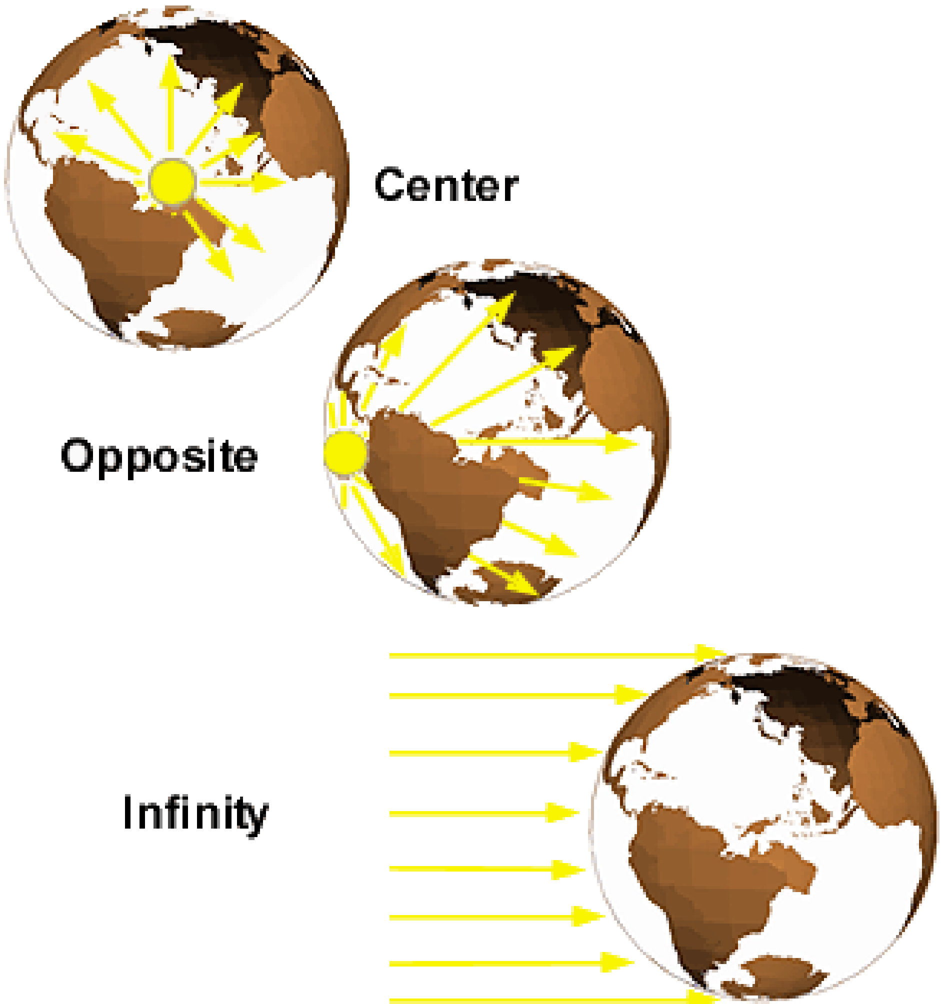
Compromise Projections

- Unique projections
  - The Goode Projection



Light Source

Light source origins

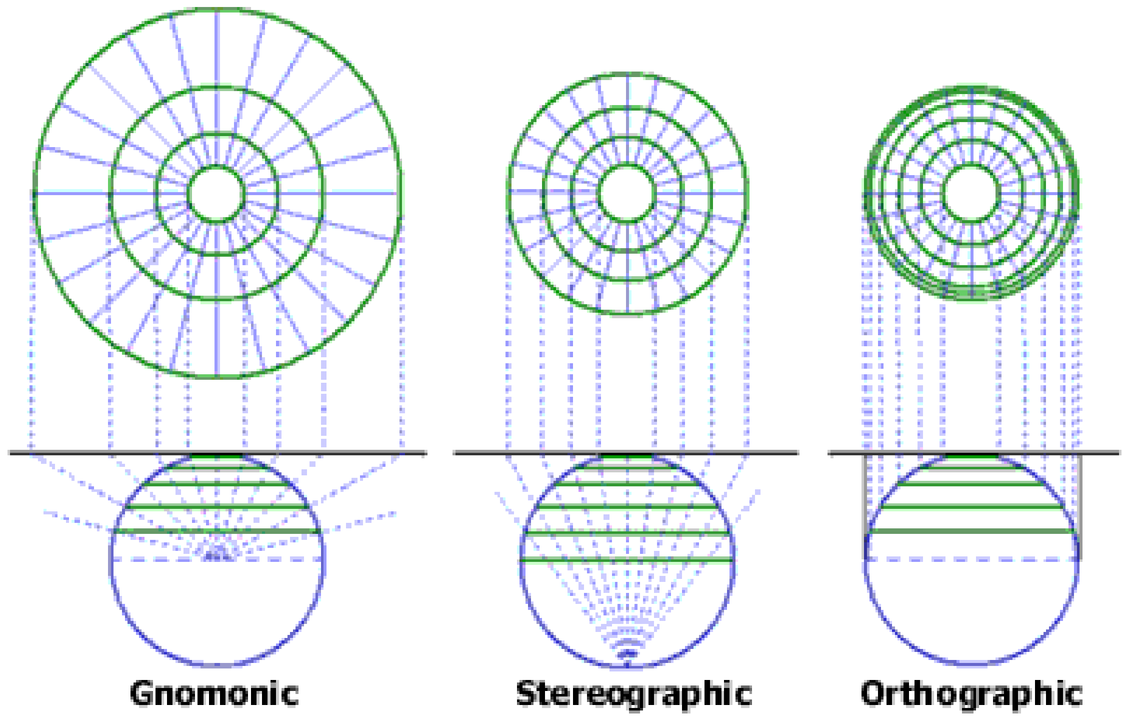


Light source origins

- Results in different perspectives for the map projection
- Conic & Cylindrical projections usually have a light source from the center of the Earth
- Planar projections are most affected by the light source origin; affects meridians & parallels
- Distance between parallels varies greatly

Light source & Planar projections

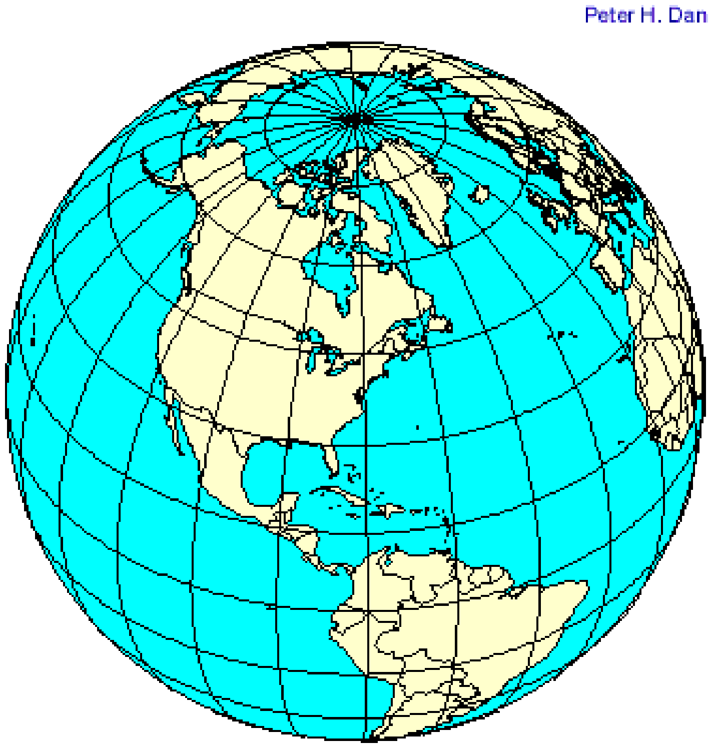
- Gnonomic – center of the Earth
- Stereographic – from one pole to the opposite
- Orthographic – infinite point in space



Common Projected Coordinate Systems

Planar Orthographic Projection

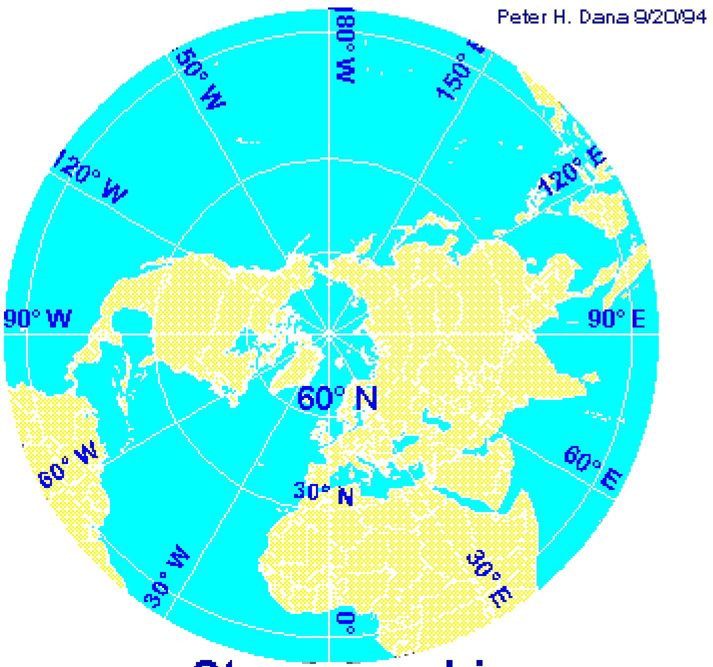
- How earth would be seen from a distant planet
- Light source from infinitely far away
- Used for Remote sensing land cover
- Can only show 1 hemisphere at a time



Orthographic Projection
Centered on Washington, DC

Planar Stereographic

- Light source from opposite the point of tangency
- Conformal
- Often used to map the poles
- Can only show 1 hemisphere



Stereographic
North Polar Aspect

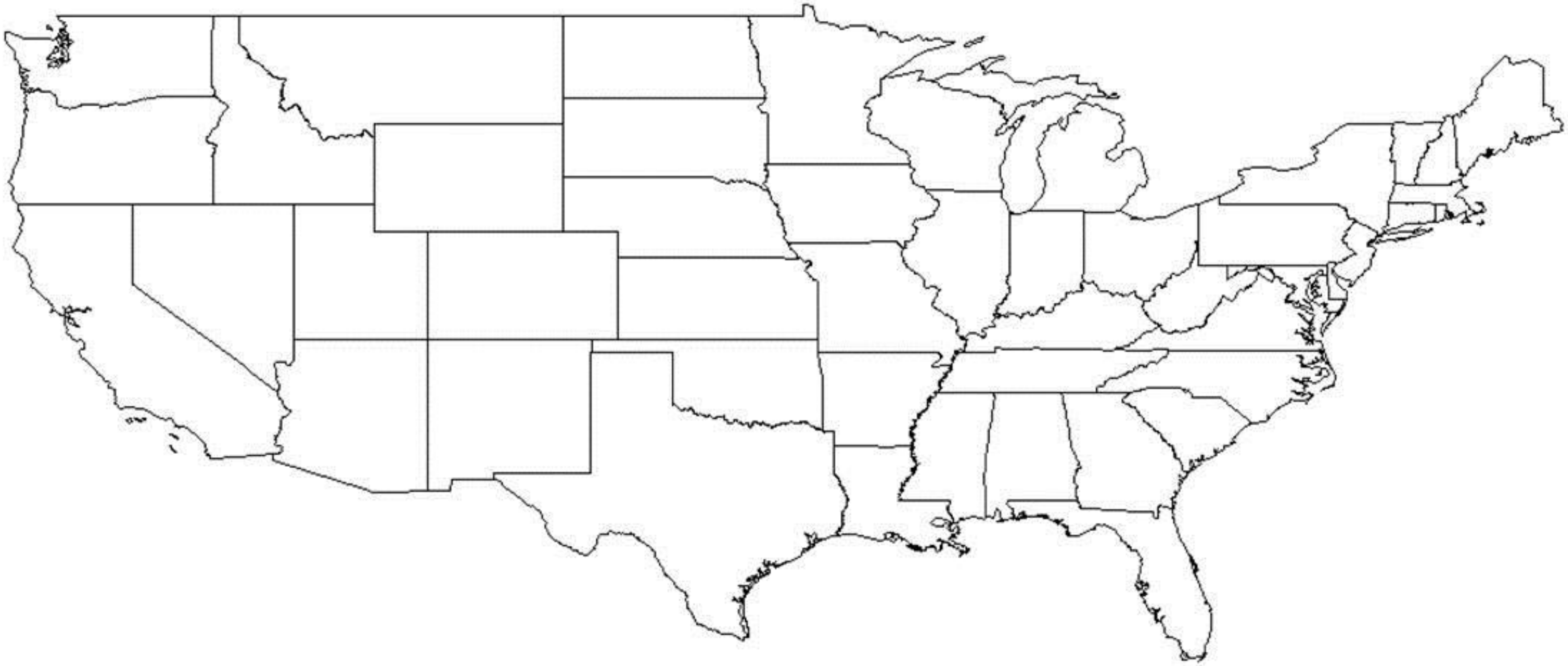
Planar Gnomonic Projection

- Light source from the center of Earth
- Originally used for celestial observations
- Oldest map projection; developed in the 6th century BC
- Meridians & equator are great circles and shown as straight lines

Plate Caree (Cylindrical)

- Geographic Projection
- Create a grid of equal rectangles
- Map is twice as wide as it is high
- Used for satellite imagery and aerial photos
- Simplistic

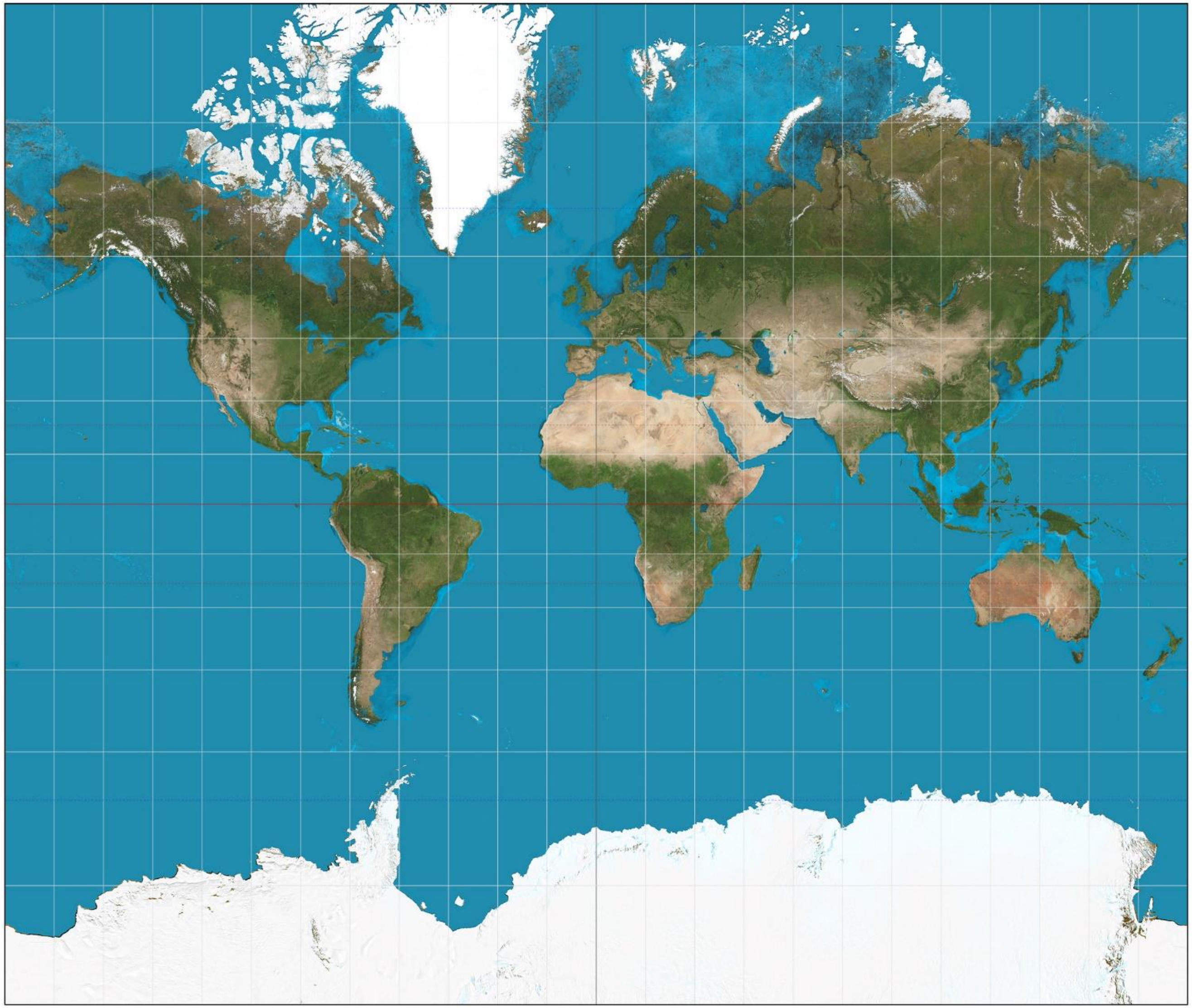
Plate Caree



Mercator Projection

- Cylindrical & conformal
- Equal meridian spacing; parallels increase from N-S poles
- Begins and ends at 80 degrees
- Rhumb lines (compass directions are straight on the map)
- Cannot show great circles
- Distorts middle to upper latitudes

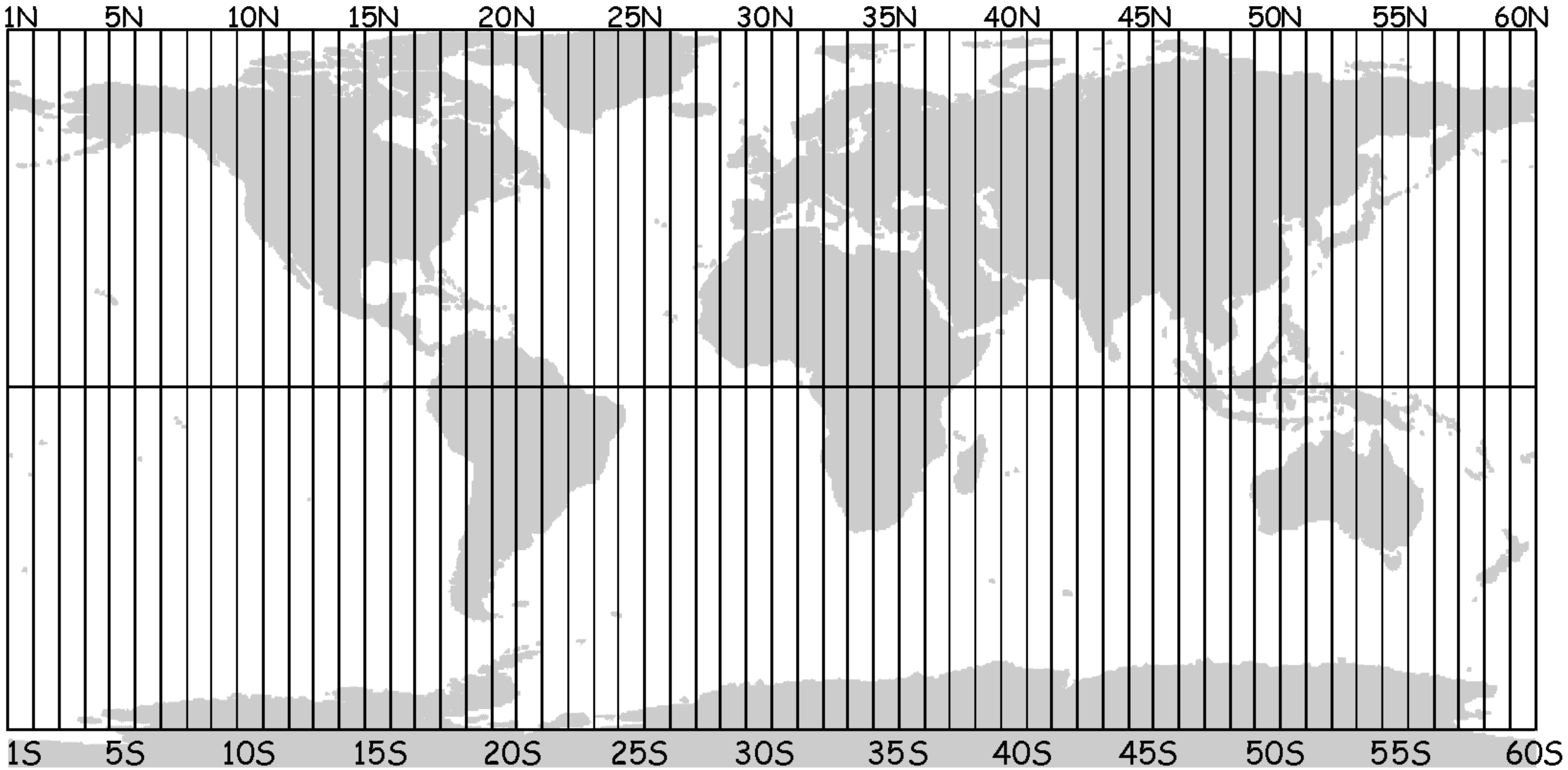
Mercator Projection



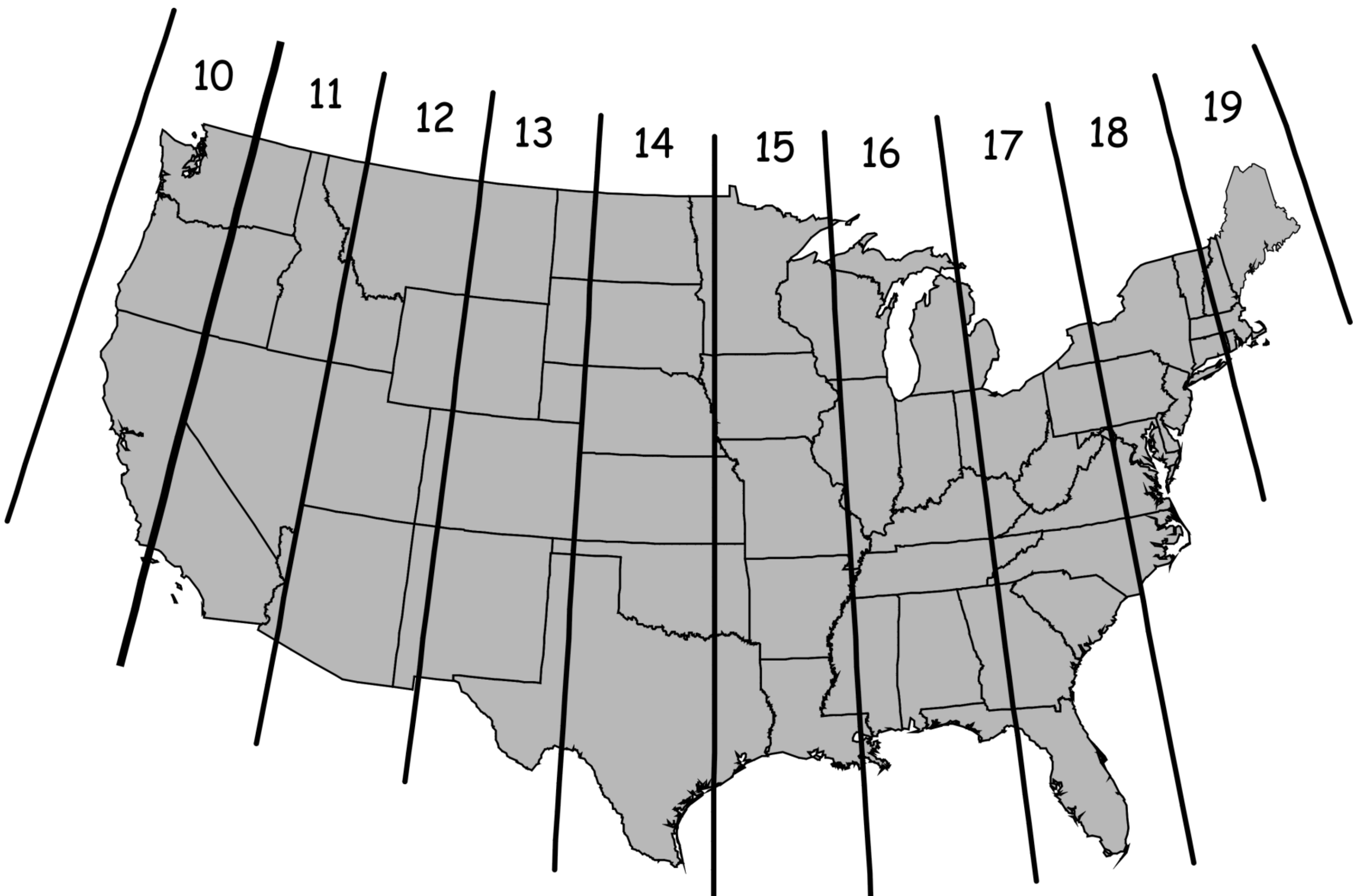
Universal Transverse Mercator (UTM)

- Standard map projection for most US state governments
- N-S strips projected with no local shape distortion and minimal area distortion
- Best suited for N-S extents
- Series of 60 UTM zones around the globe
  - Each zone is 6° longitude wide
  - Narrow strips of Transverse Mercator projection
  - 80°S to 80°N
  - Meters

UTM Zones

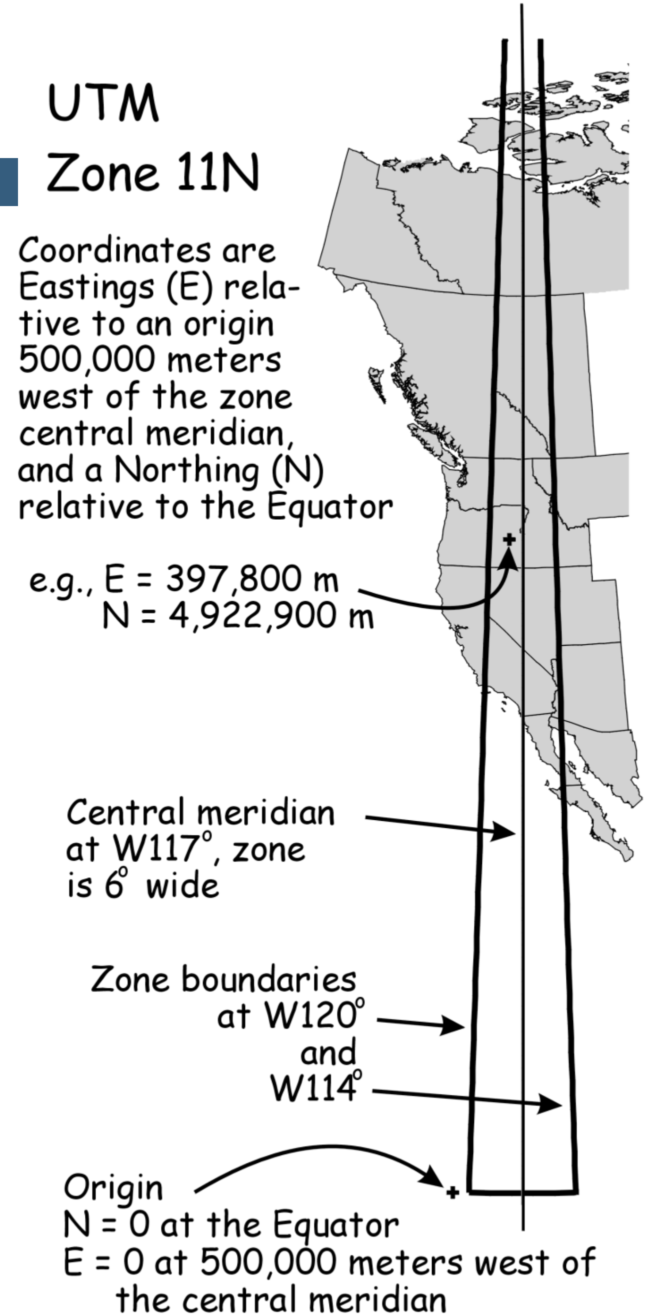

1N
5N
10N
15N
20N
25N
30N
35N
40N
45N
50N
55N
60N
1S
5S
10S
15S
20S
25S
30S
35S
40S
45S
50S
55S
60S

UTM Zones in U.S.

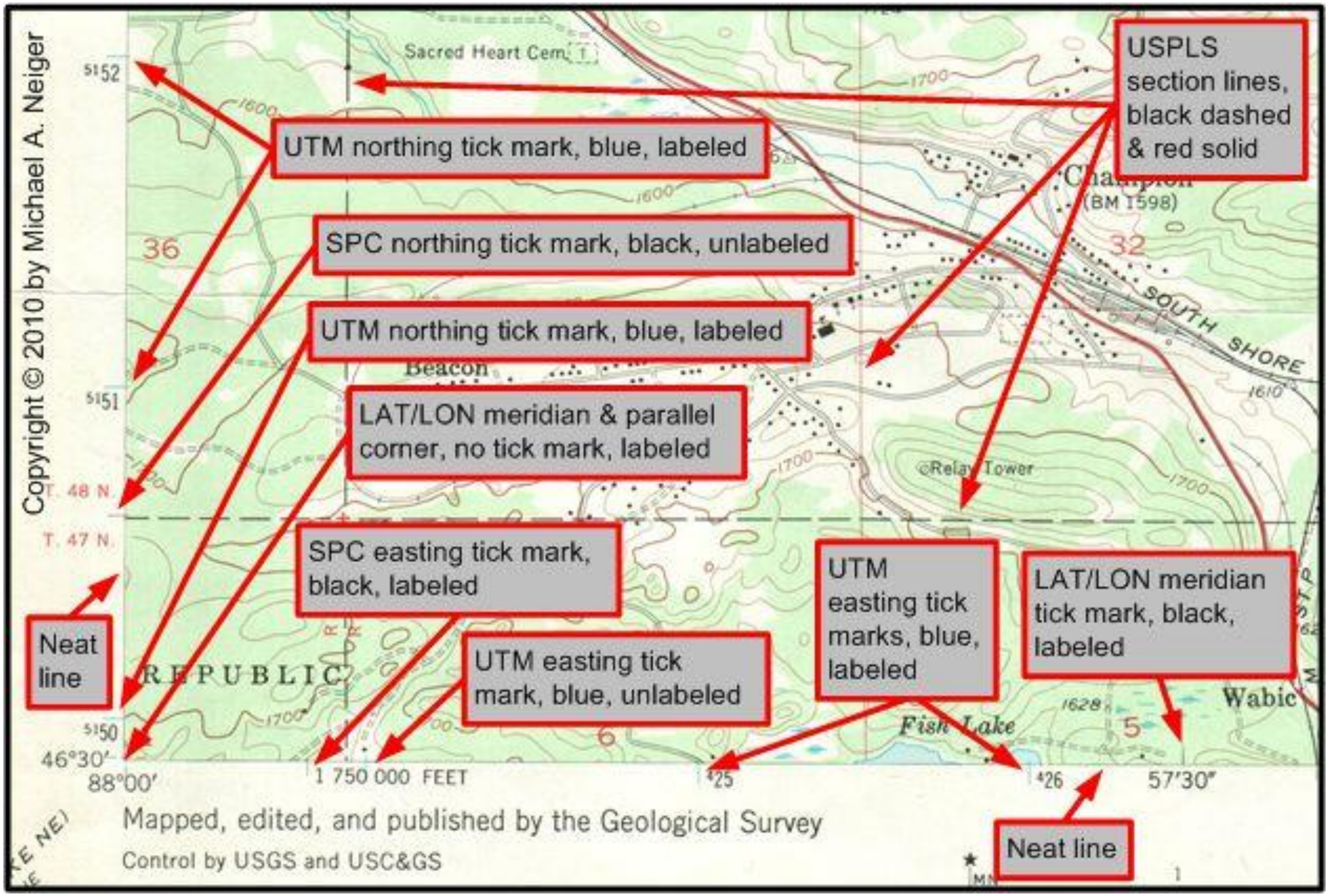


UTM

- Coordinates are in 'Northings' and 'Eastings'
  - Northings are relative to the equator
  - Eastings are relative to a false origin 500,000 meters west of the zone's central meridian



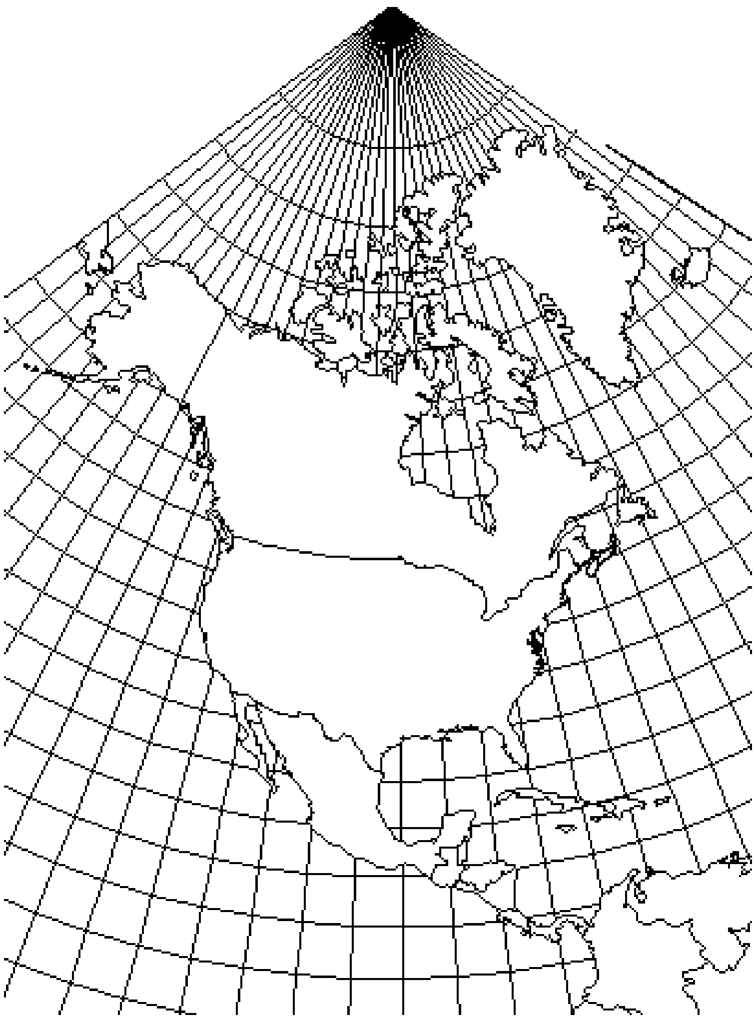
UTM & the USGS Topo Map

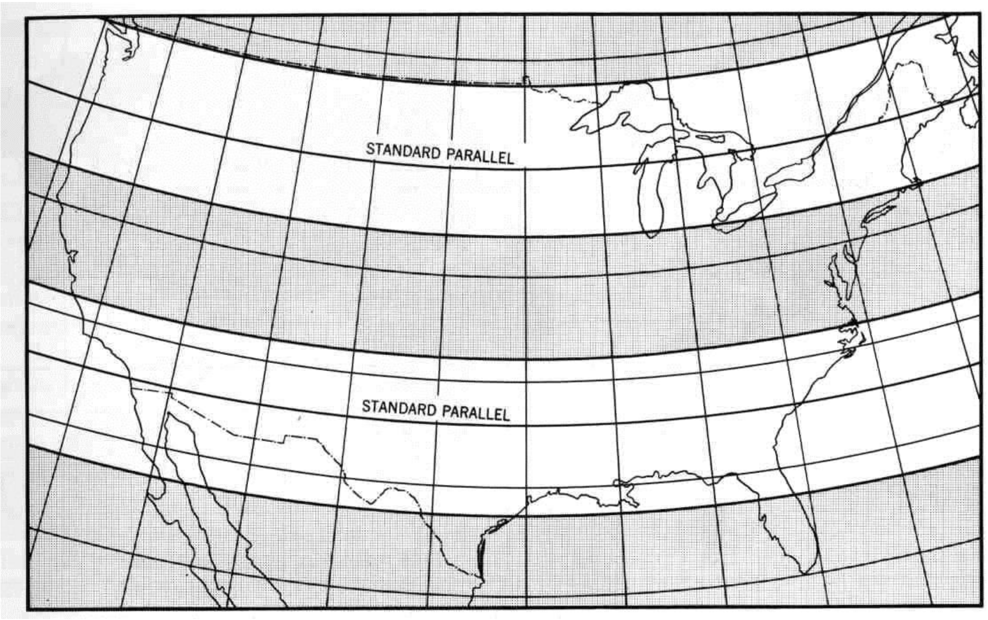


Lambert Conformal Conic

- Secant case, normal aspect
- Parallels for U.S. typically at 33N & 45N
- Used for E-W trending zones
- Preserves shapes and direction

Lambert Conformal Conic

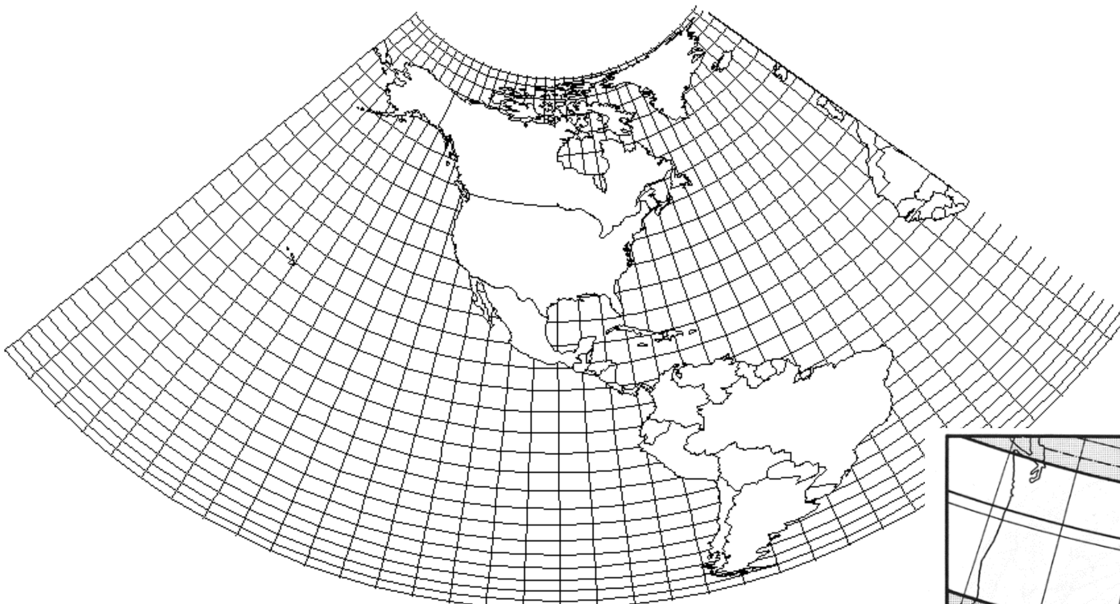


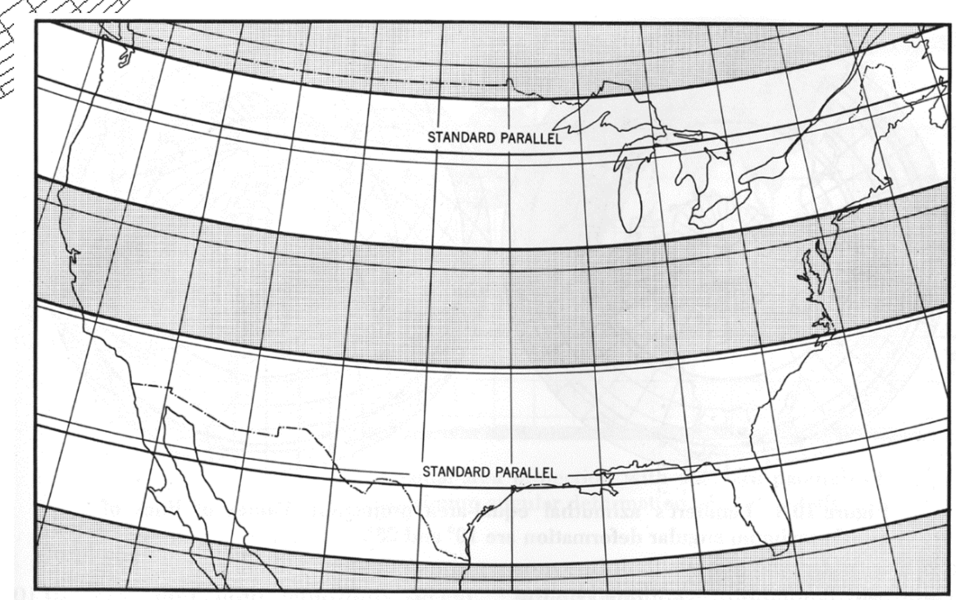


Albers Equal Area Conic

- Shows mid-latitudes
- Used for statistics & analysis
- US Standard parallels: 29.5N & 45.5N
- Preserves areas

Albers Equal Area Conic

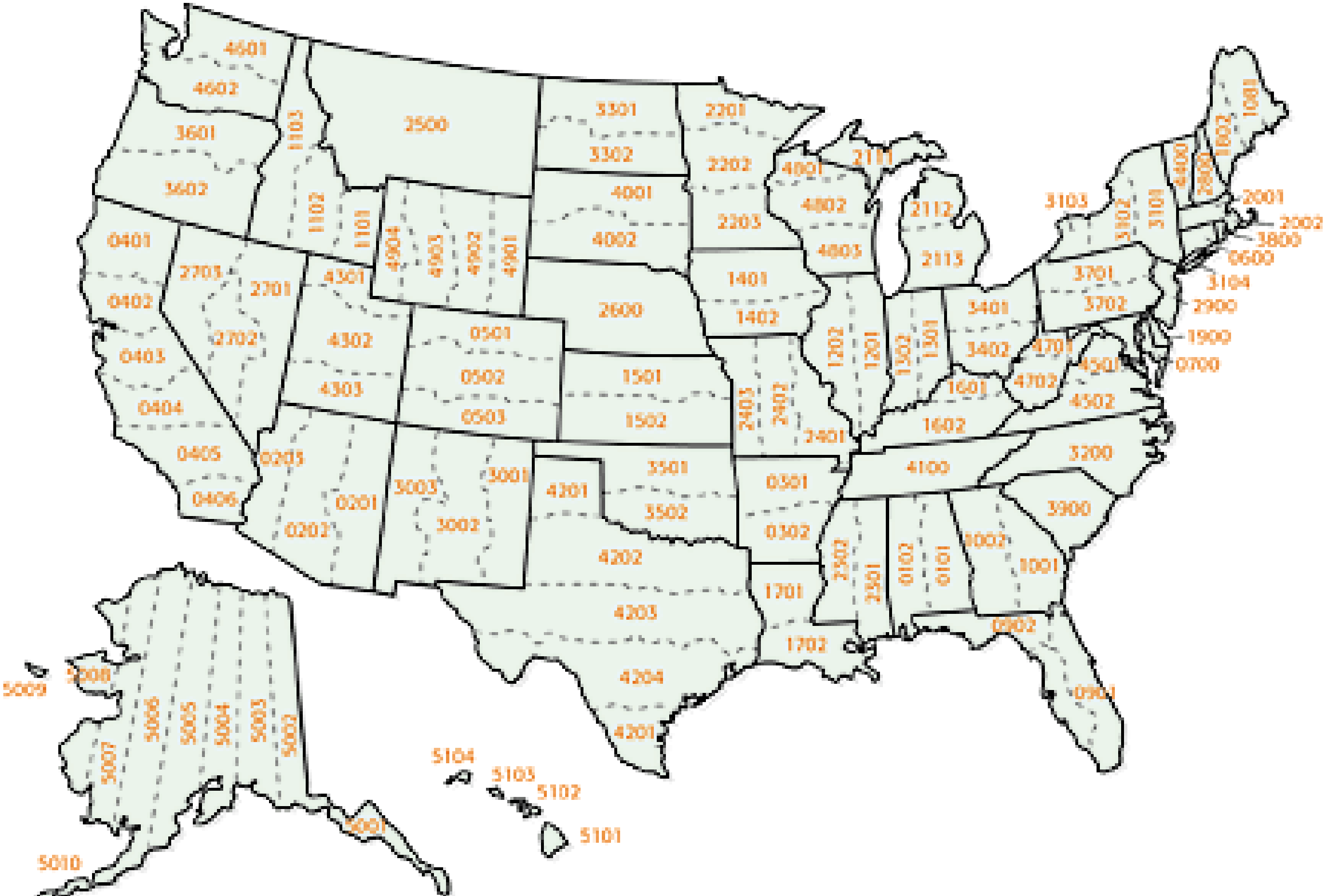




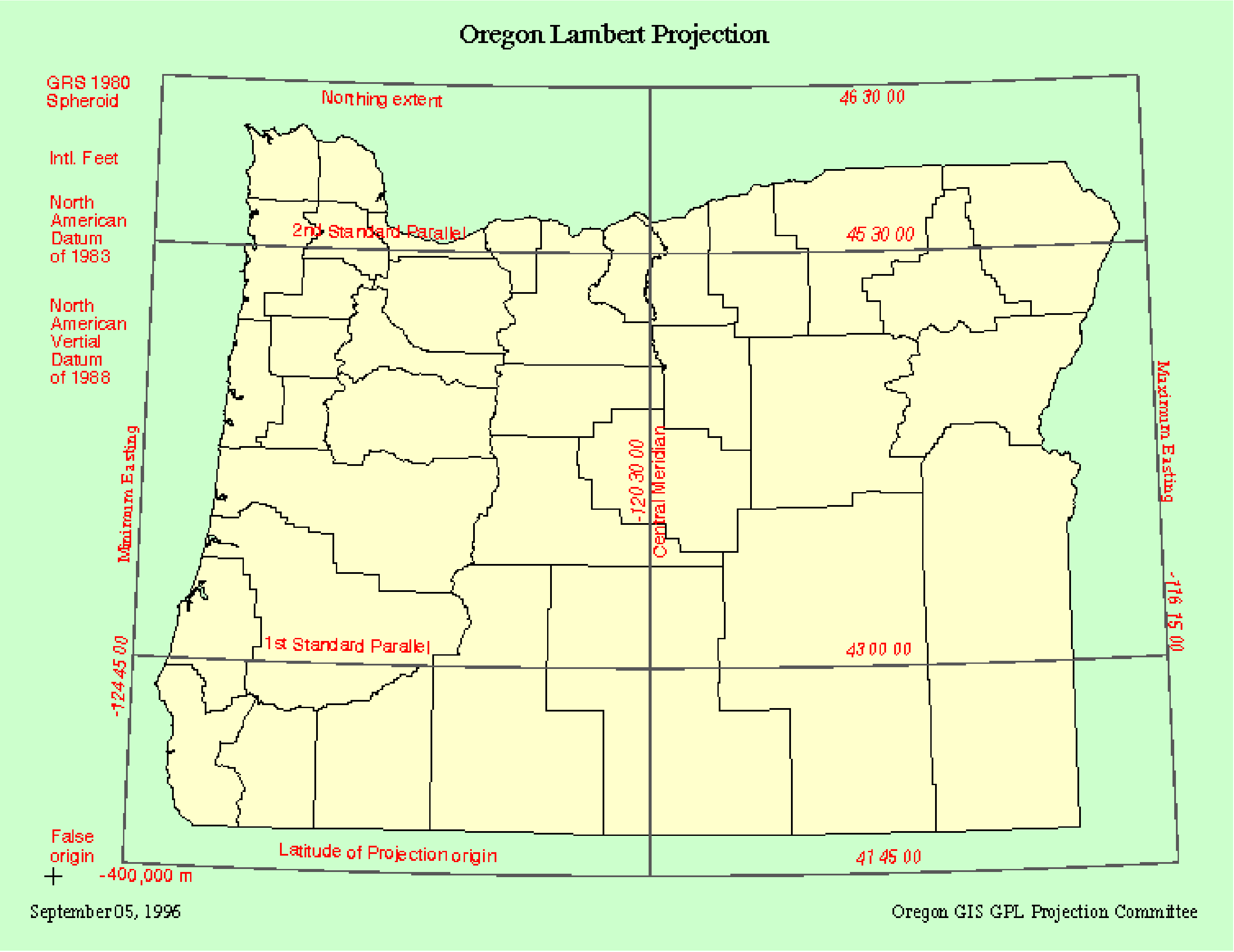
State Plane Coordinate System

- A system in the US that divides the country into 120 zones based on state boundaries
- Specific projection for each zone; chosen to minimize distortion based on the state's shape
- Smaller states may only use a single zone; larger states may be divided into several zones
- Units are usually in feet, but can also be in meters
- NOT a projection itself; it's a system where each zone is based on a different projection

State Plane Zones



Oregon Statewide PCS

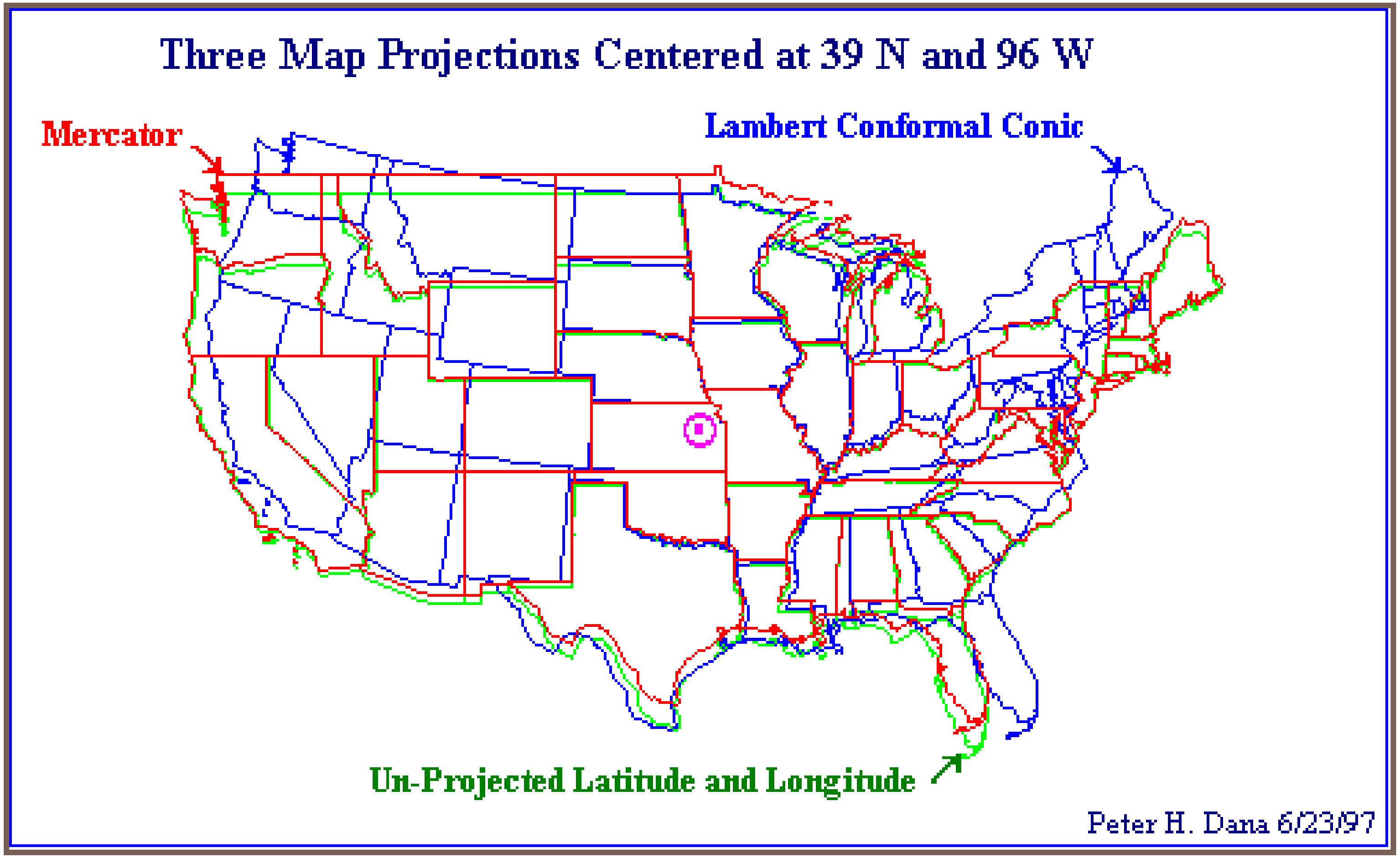


What projection do I use?

What Projection to Use?

- 1. What area will you use?
  - The smaller the area, the less distortion will exist
  - For micro areas, any projection can work
- 2. Latitude
  - Cylindrical work well for low latitudes
  - Conical works for mid latitudes
  - Planar works best for poles

- 3. Shape of your area
  - East to West extents are suited for conical or cylindrical
  - North to South are suited for cylindrical
  - Circular or square extents can use planar
- 4. Purpose
  - Navigation?
  - Comparing areas throughout the globe?


Three Map Projections Centered at 39 N and 96 W
Mercator
Lambert Conformal Conic
Un-Projected Latitude and Longitude
Peter H. Dana 6/23/97

Coordinate Systems in ArcGIS

Geographic Coordinate Systems

- Latitude/ Longitude is always based on a particular datum (i.e. NAD83)
- Name in ArcGIS:
  - GCS_{datum name}
  - i.e. GCS_North_America_1983
- Uses spherical units
  - Degrees, minutes, seconds (DMS)
  - Decimal degrees (DD)

Projected Coordinate Systems

- Based on a projection, geographic coordinate system, & datum
- Name in ArcGIS:
  - {datum name}_{projection type}_{projection name}
  - i.e. NAD_1983_UTM_Zone_10N
- Uses real-world units
  - Feet, meters, international feet

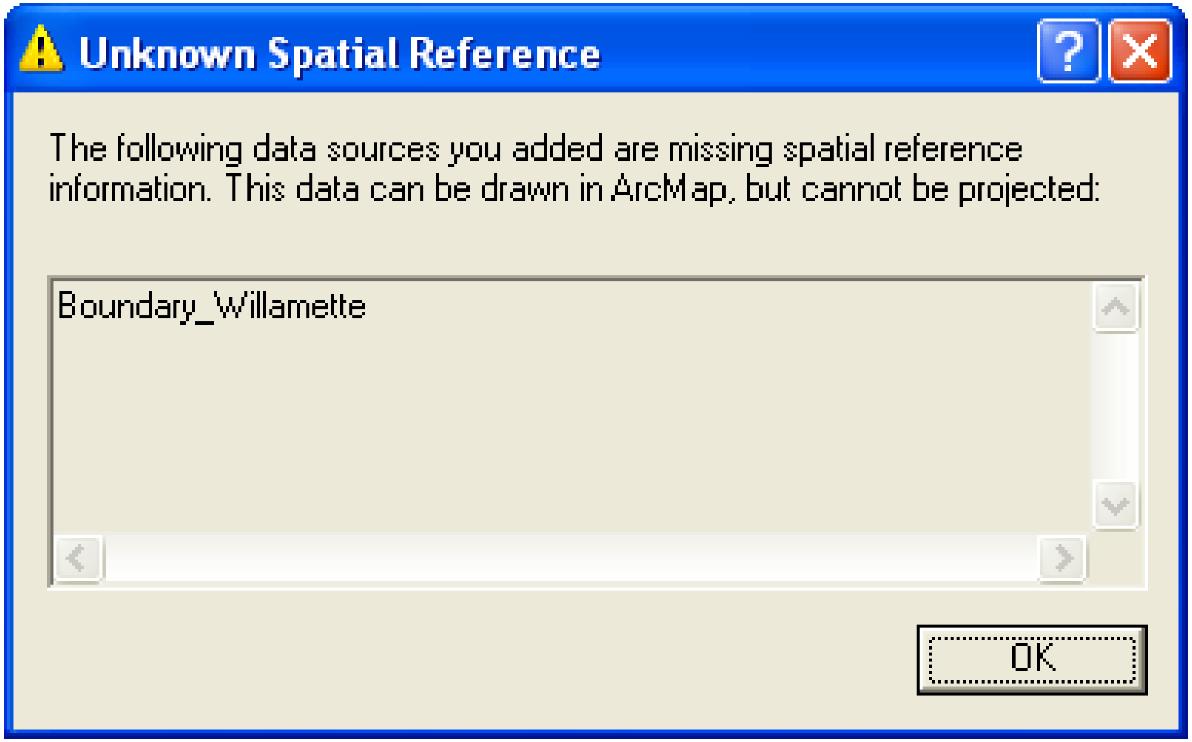
How does ArcGIS properly align my data?

- GIS software has the ability to manipulate coordinate systems
  - Temporarily change coordinate system using '***on-the-fly projection***' defined by the data frame properites
  - Permanently change coordinate system through 'projecting' coordinates using tools in ArcToolbox
- Both methods require that all your layers have a projection definition file
- Projections or coordinate systems can be created, selected from a predefine list or imported from another dataset

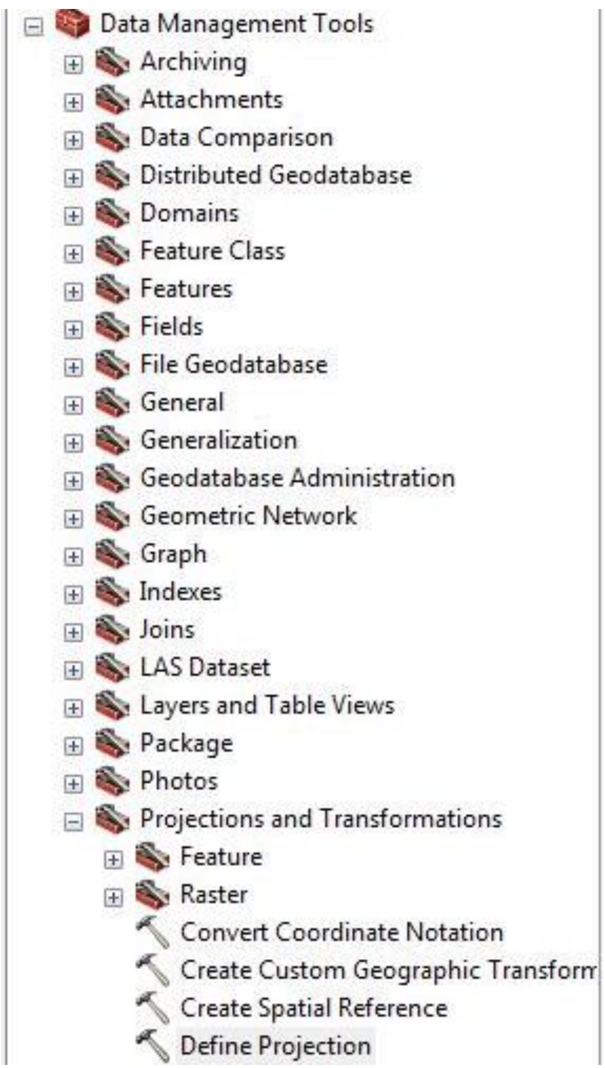
Projection information in a GIS file

- Projection definition file stores coordinate system parameters
  - Coverages/GRID: prj.adf
  - Shapefile: .prj
  - Geodatabases: database property

What if your GIS file has no projection information?



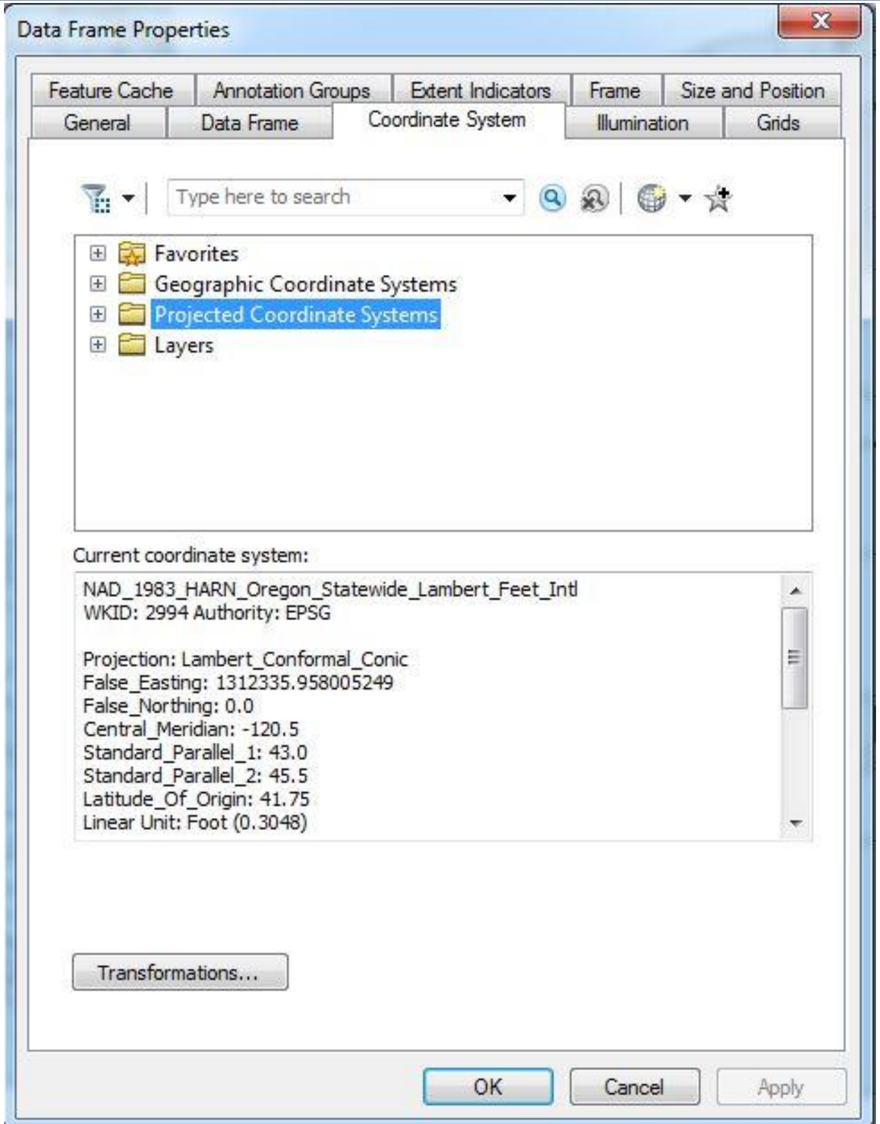
Use the “Define Projection” tool



Projection information for a map data frame

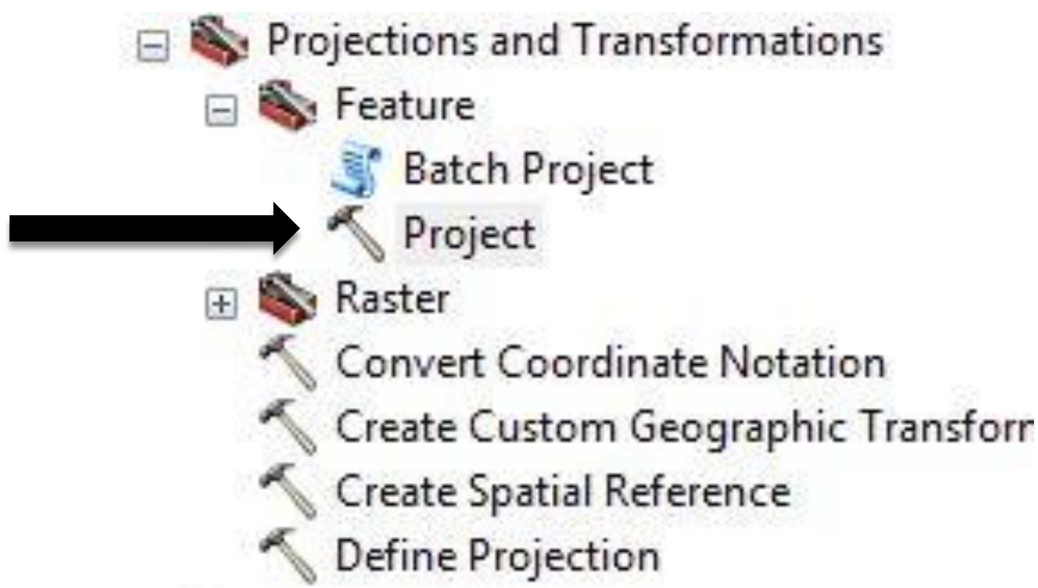
- Each data frame on your map has its own coordinate system for displaying data
- It takes on the coordinate system of the ***first dataset added*** to the data frame (i.e. read the projection definition file)
- ***All other datasets added to the map are then projected 'on-the-fly'*** to match (but only if they have a defined projection)
- Changing the coordinate system of the data frame, changes the ***appearance*** of the map data
- Changing the coordinate system of the data frame ***DOES NOT*** change the data set coordinates

Where can I change the data frame coordinate system?



Changing the Projection Definition file

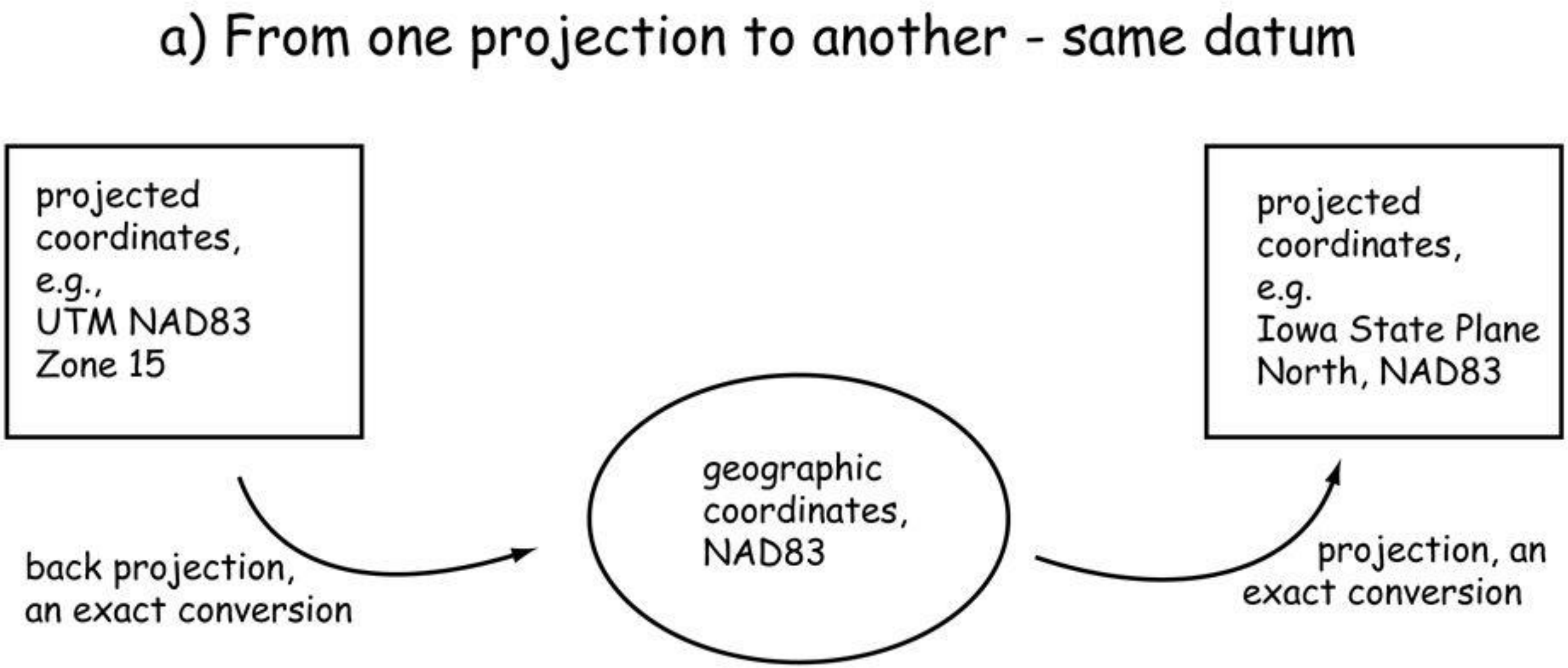
- What if my GIS data set already has a projection definition file, but I want to change it?
- Use the 'Project tool'



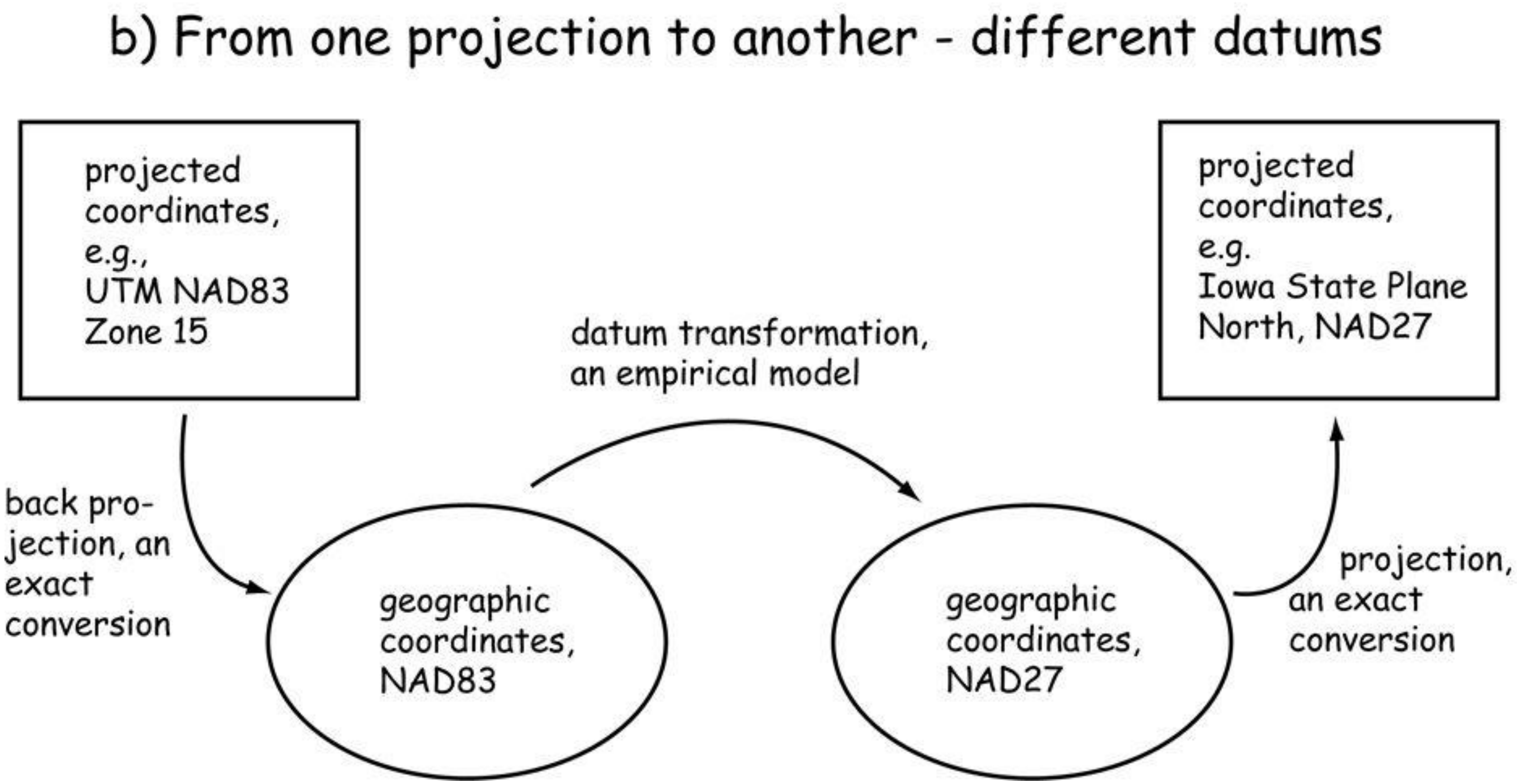
What does the ‘Project’ tool do?

- ***Creates a new dataset*** (user specifies name & storage location on computer) with a new projection definition file
- Why use this?
  - You want to ***permanently*** change the ***already - defined*** coordinate system of a dataset
- If there is a change in the datum from its original coordinate system to the one you are choosing to convert – a ***datum transformation*** is required.

'Project' with same datum



‘Project’ with different datums



What does this mean?

- The datasets on your map have different coordinate systems