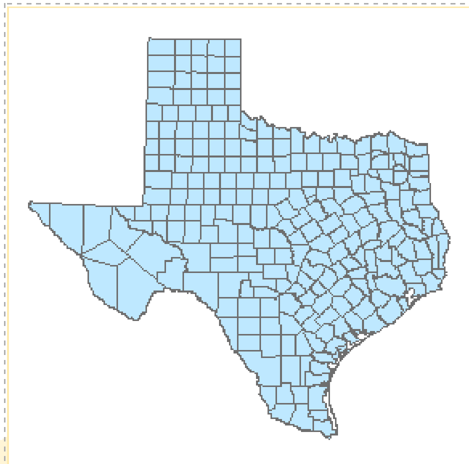
Projections

Today’s Agenda

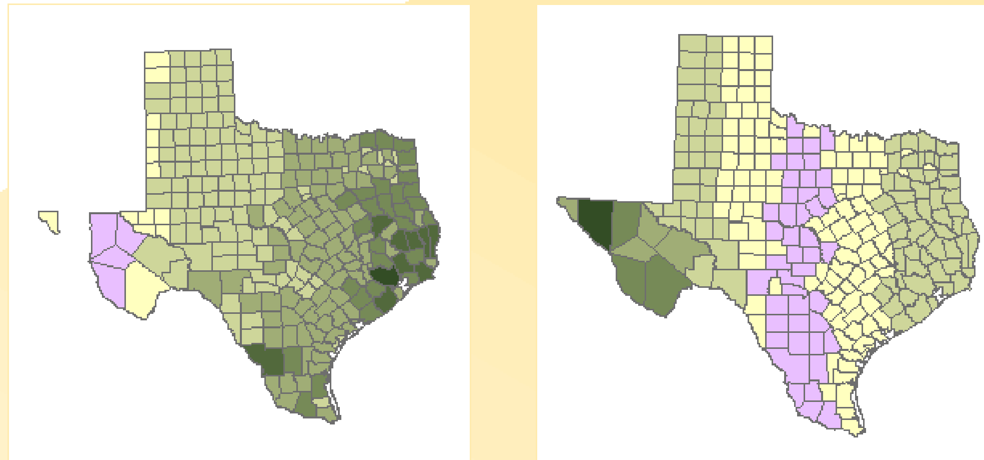
- Review last week’s exercise
- Map Projections

Understanding map projections and coordinate systems.

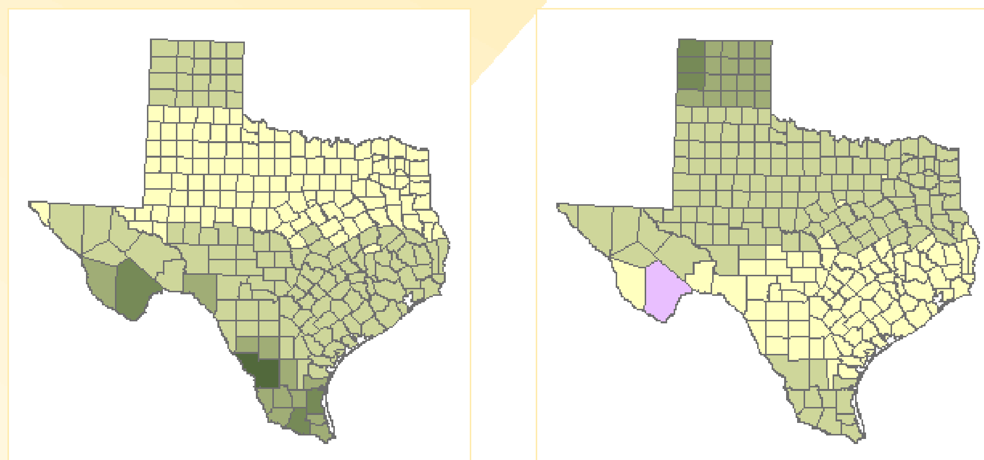
Replace text with your name



Equal Area projections ensure GIS-based polygon areas approximate geodetic areas.



Two different Transverse Mercator map projections were used to project county polygons onto the UTM Zone 13N (left) and UTM Zone 14N (right) coordinate grids. Although useful, neither preserves geodetic areas for all counties.



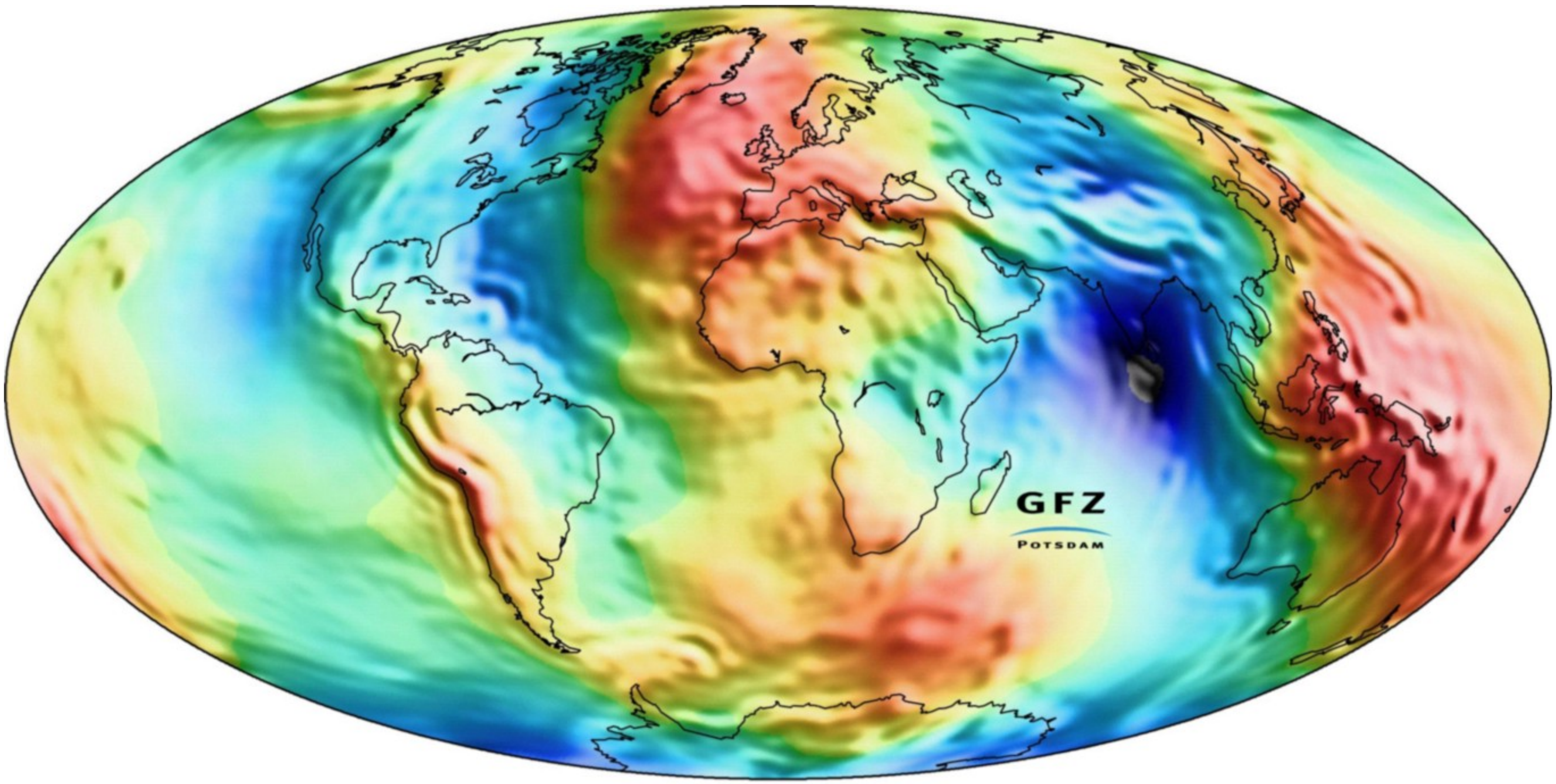
Two different Lambert Conformal Conic map projections were used to project county polygons onto the State Plane Texas Northcentral (left) and Southcentral (right) coordinate grids. Most projections minimize distortions in limited regions only.

diff_UTM13

- 80.1 to 100 km (Highly exaggerated)
- 60.1 to 80 km
- 40.1 to 60 km
- 20.1 to 40 km
- 1.6 to 20 km (Scale exaggerated)
- -1.5 to 1.5 km (Minimal distortion)
- -8.8 to -1.6 km (Scale reduced)

Recap from last class

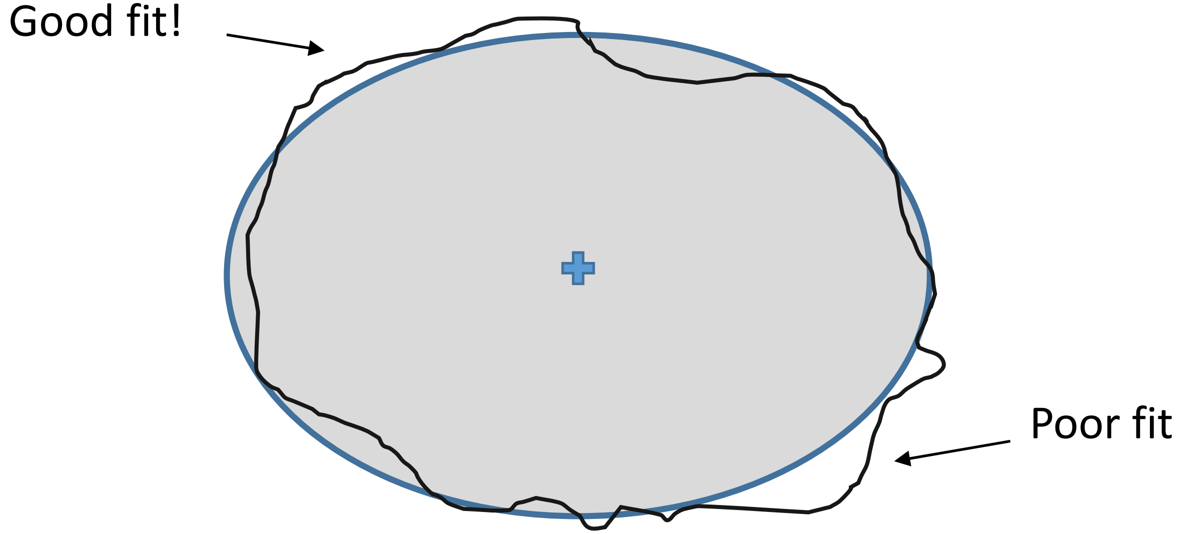
Earth’s Geoid



How to we assign an X, Y, and Z location to a point on the geoid?

Let’s use ellipsoids to approximate the geoid

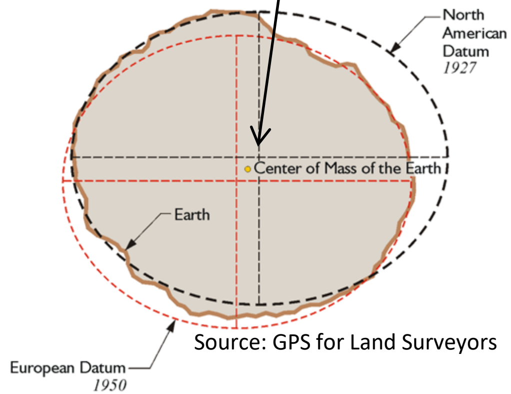
Let’s use an ellipsoid and shift it to the left and tilt it so part of it overlays with the geoid



An ellipsoid <u>and</u> its shift is a **datum**

An ellipsoid and its shift is a datum

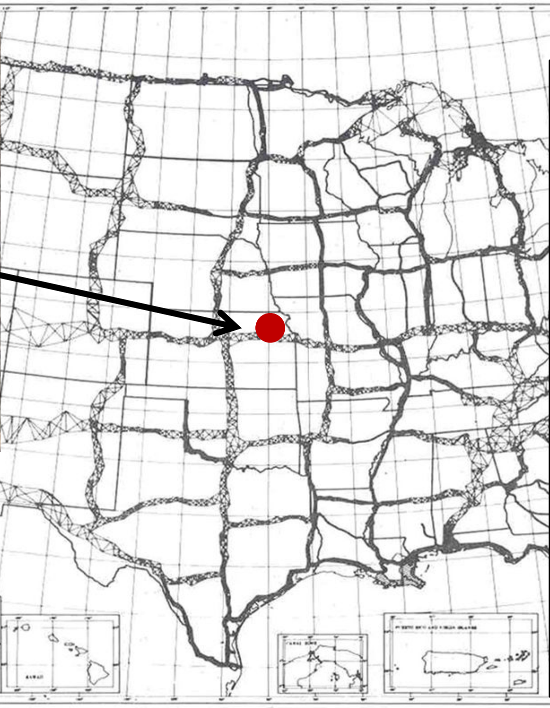
Clarke 1866 Ellipsoid

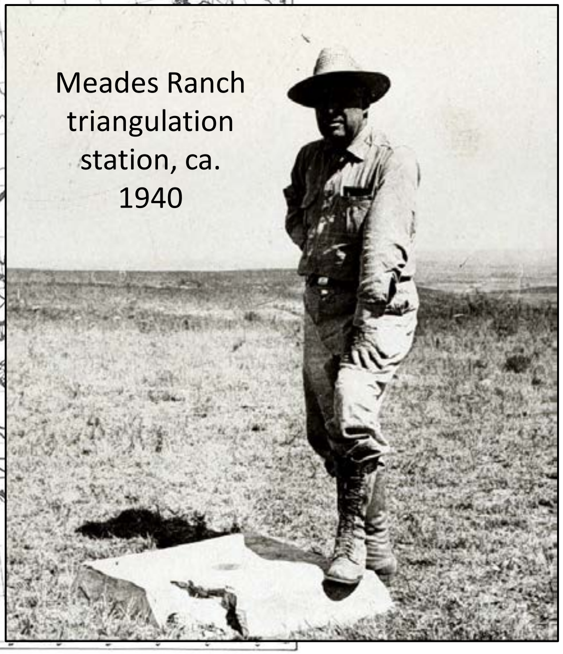


Source: GPS for Land Surveyors

NAD27

Clarke 1866: Based on triangulations on earth's surface. Center at Meads Ranch





Meades Ranch triangulation station, ca. 1940

NAD27 vs NAD83

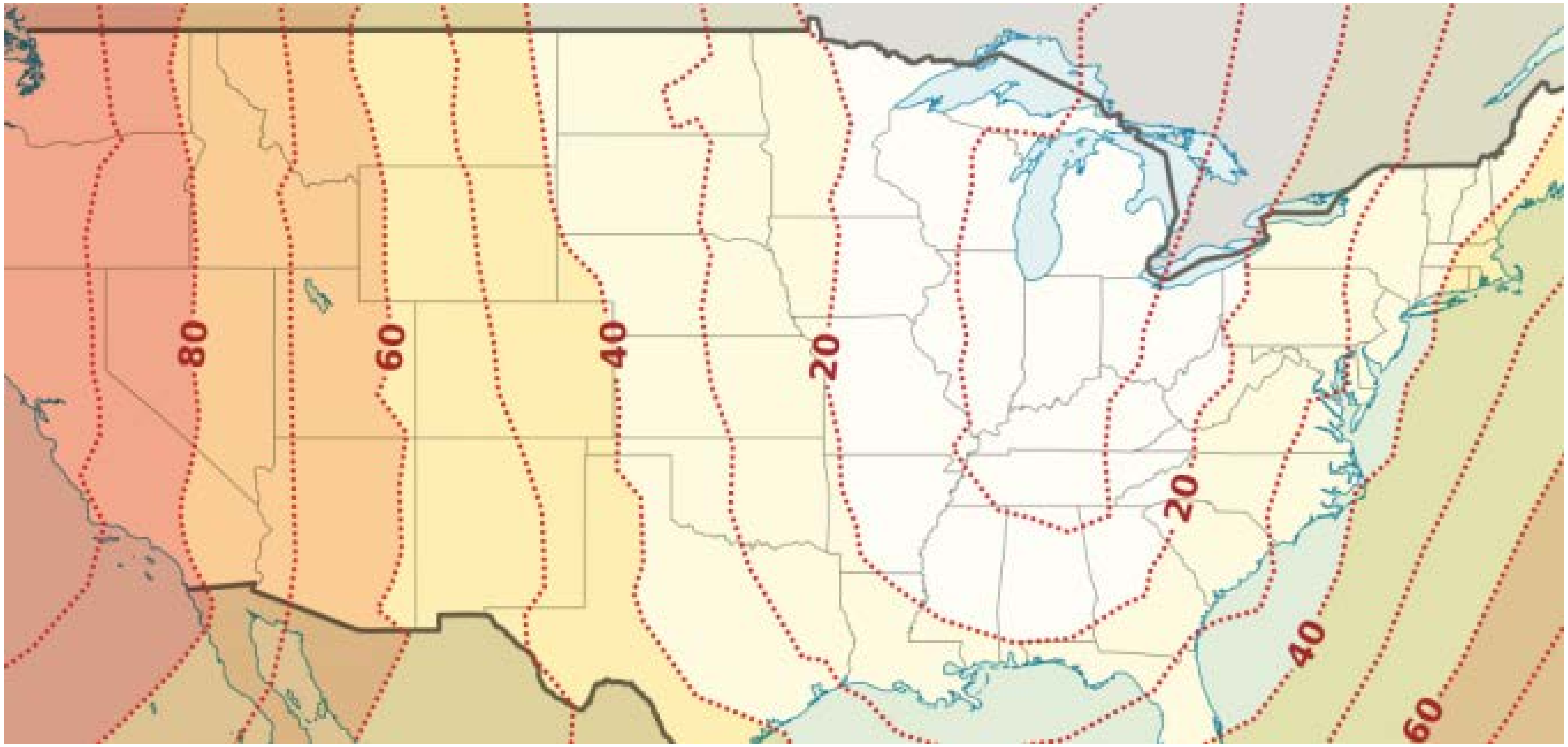


Image credit: NADCON

An ellipsoid <u>and</u> its shift is a datum

There are three key datums to be aware of:

- **NAD27** – North American Datumn of 1927 - Origin is shifted from Earth's center
- **NAD83** – – North American Datumn of 1983 - Origin is shifted from Earth's center
- **WGS84** – Center of earth's mass as origin

These are not projections!

Coordinate System - a reference system used to represent the locations of geographic features, imagery, and observations such as GPS locations. There are 2 types:

Global coordinate systems (3D); Units of degrees (latitude and longitude)

Projected coordinate systems (2D); Units of length (meters, feet)

Projection - two-dimensional surface. Unlike a geographic coordinate system, a projected coordinate system has constant lengths, angles, and areas across the two dimensions. A projected coordinate system is always based on a geographic coordinate system that is based on a sphere or spheroid.
Locations are identified by x,y coordinates on a grid, with the origin at the center of the grid. Each position has two values (x and y) that reference it to that central location.

Datum – An ellipsoid and its shift (if applicable) that approximates the geoid. There are two types.

Geocentric datum; Ellipsoid is centered on earth's center of mass (ex: WGS84)

Local datum; Ellipsoid is off center relative to earth's center of mass so that the ellipsoid fits closely to the geoid in one specifc area (ex: NAD83)

Spatial Reference – a complete description of a dataset’s coordinate system. It includes:

Coordinate system

Datum

Projection (if one is used)

Storage units used to store the x-y values (degrees, feet, etc.)

Extent, or maximum allowable x-y values

Resolution, or the x-y precision

Permanently Projecting Data

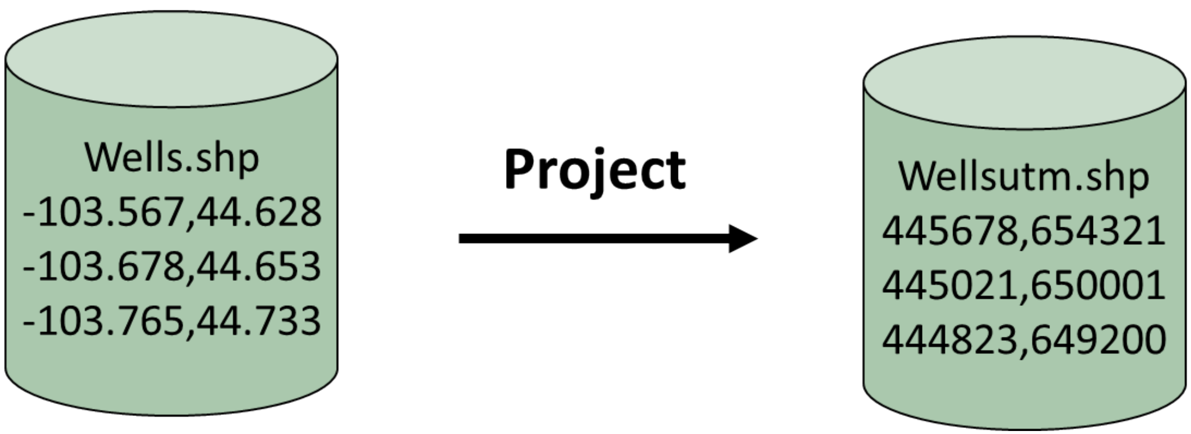
Creates a **new** spatial data file

Does not change the original file

Recalculates each lat long point into the new coordinate system and units (x and y)

Labels the new file with the new CS

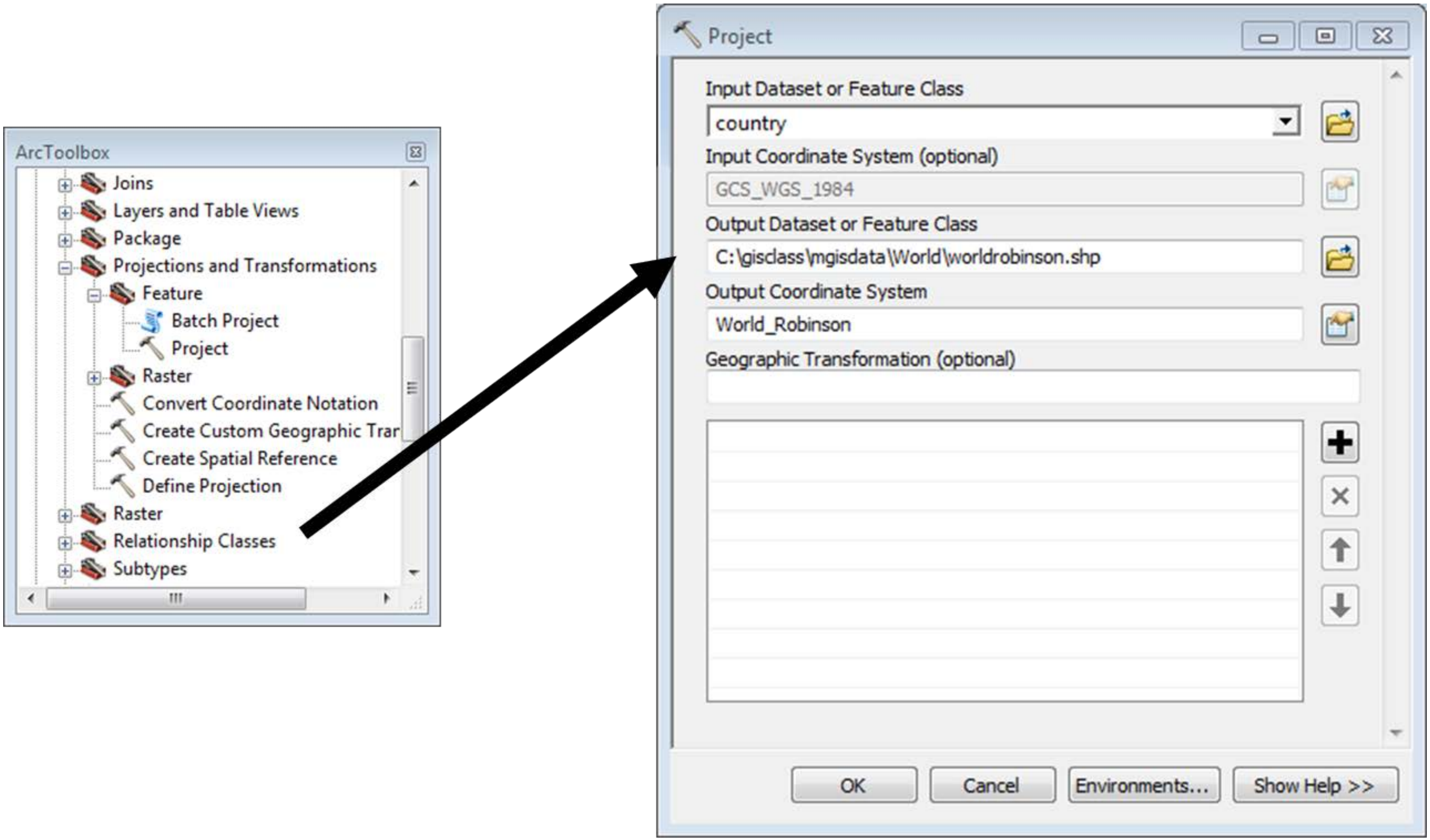
Several ways to do it



Units in decimal degrees (GCS)

Units in meters (projected)

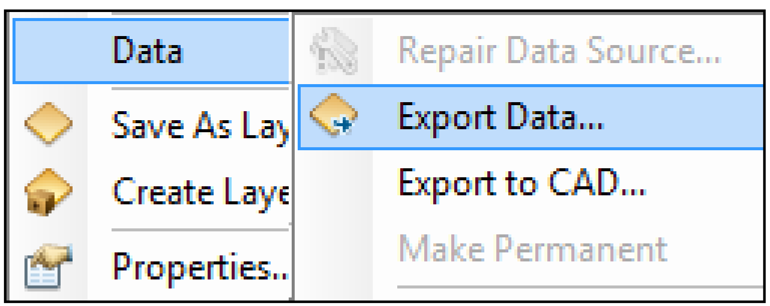
Using the Project tool

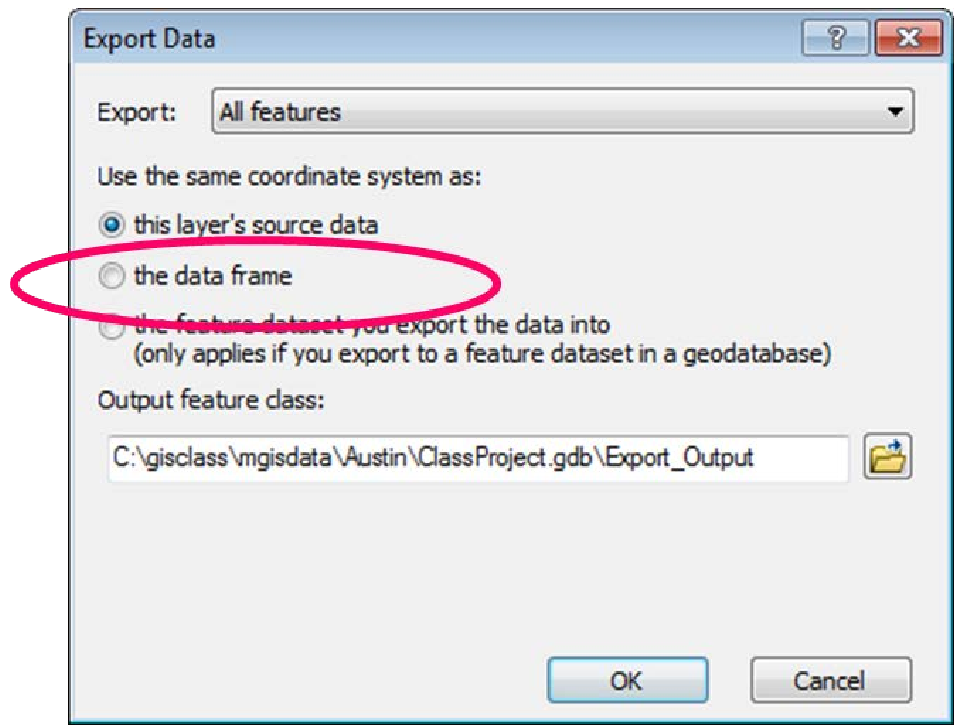


Using Export in ArcMap

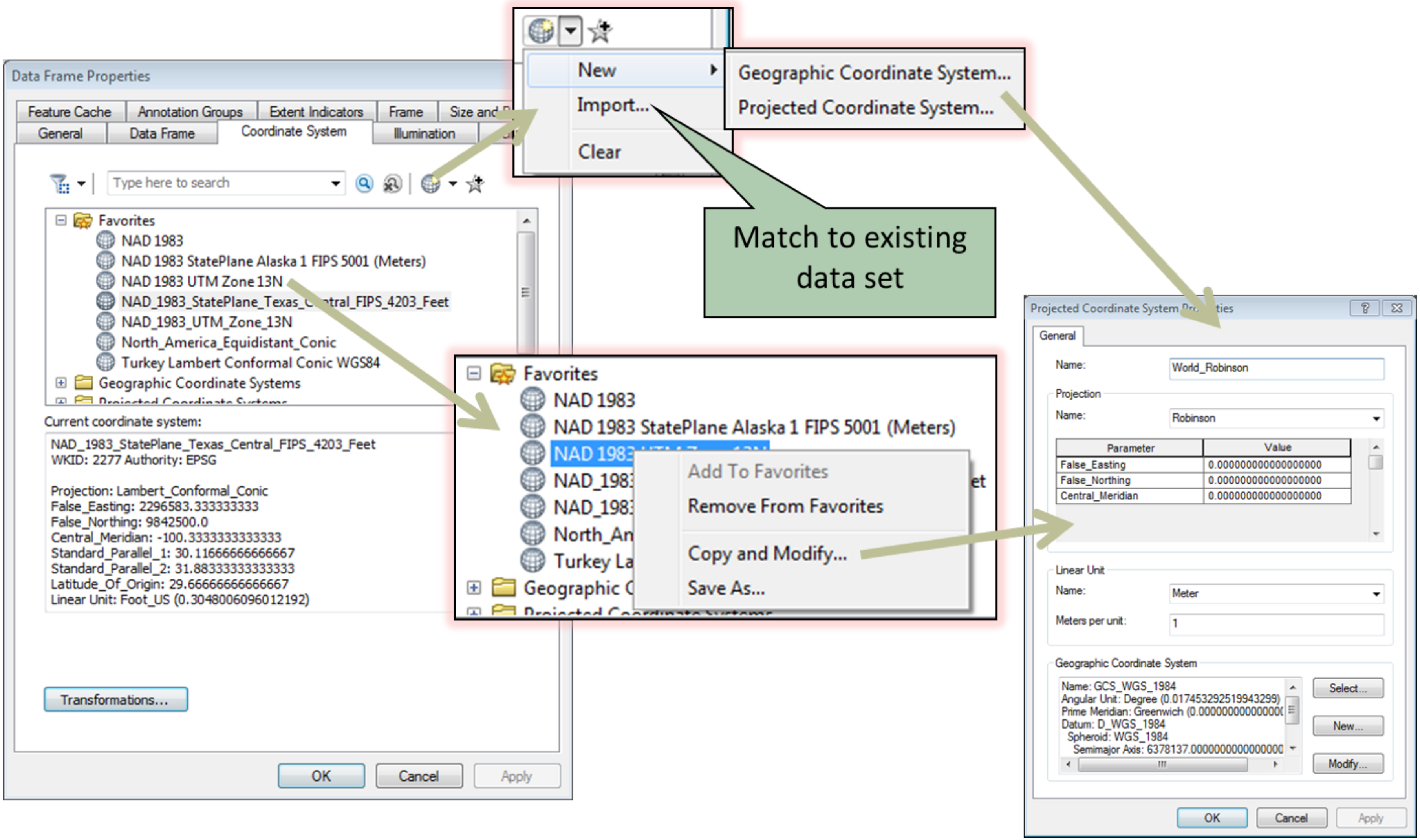
Set the data frame coordinate system to the desired output CS

Export and choose to use the data frame CS

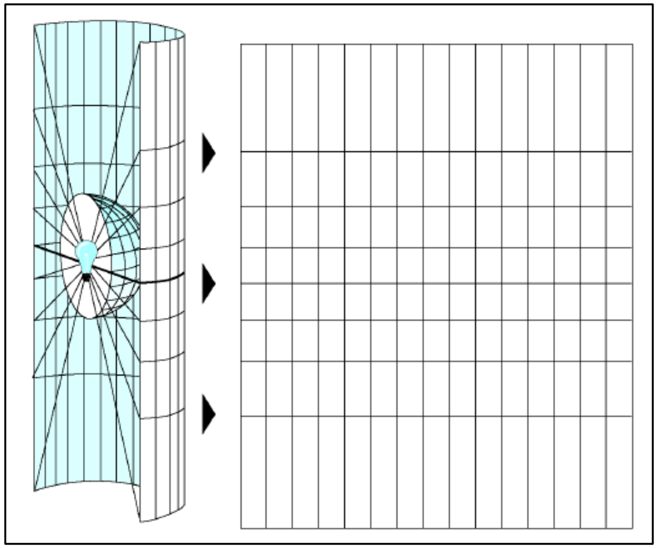




Ways to set the spatial reference (coordinate system, extent, origin, etc.)

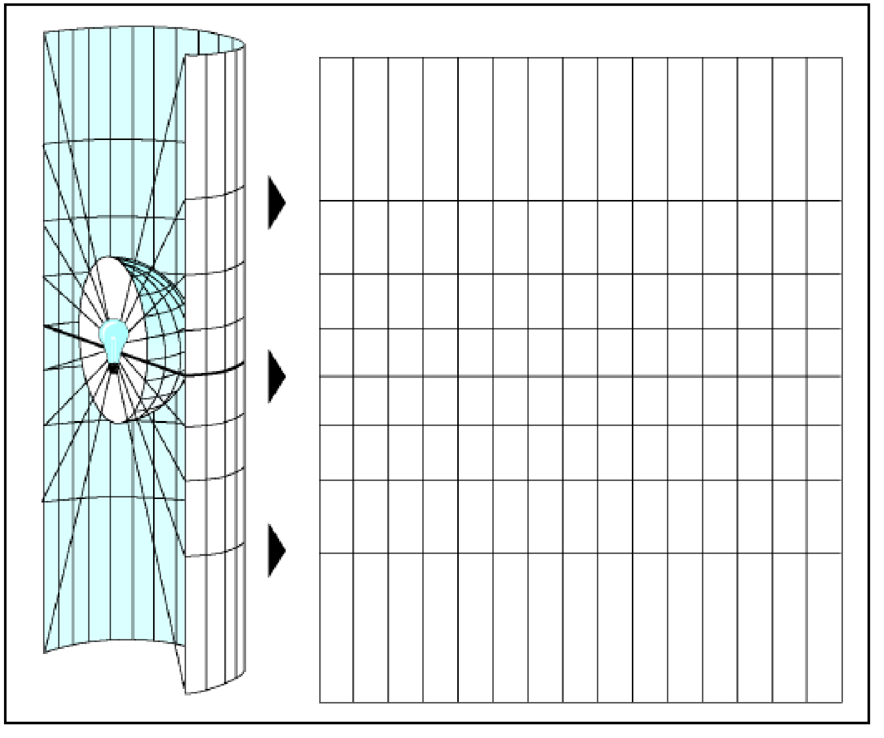


Projected Coordinate Systems



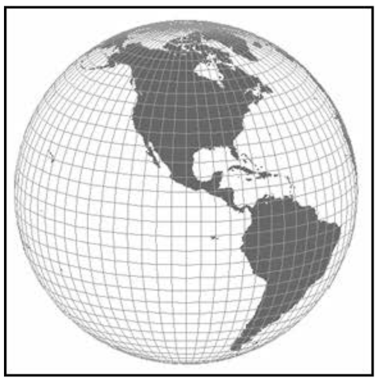
Projections

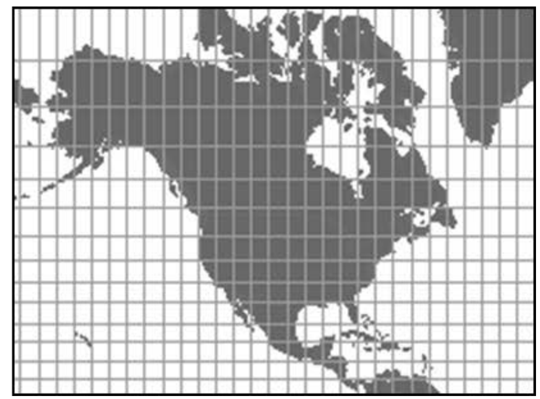
A projection is a mathematical conversion of a 3D object to a 2D surface



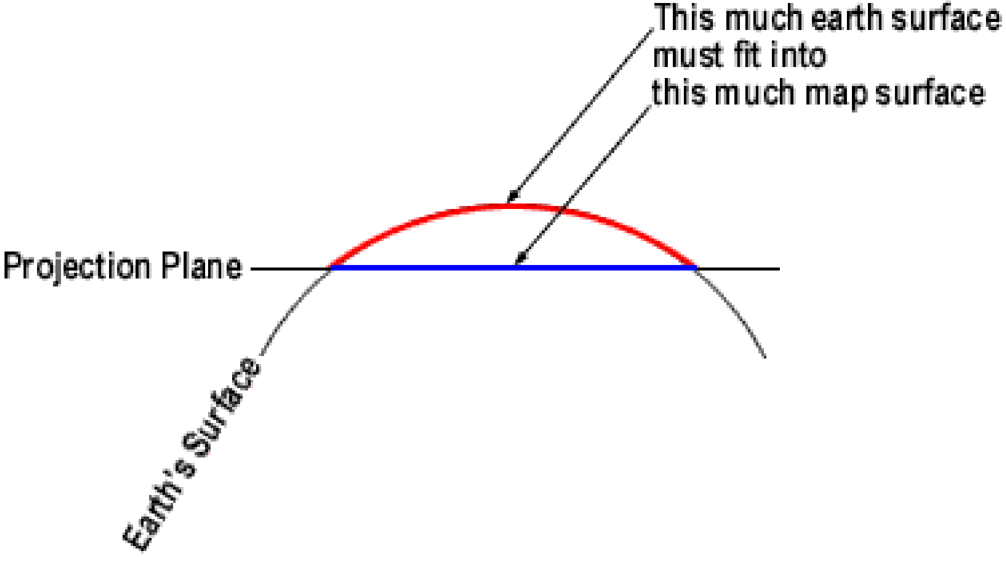
What is a Projection?

Projecting changes the x-y values from degrees to meters or feet



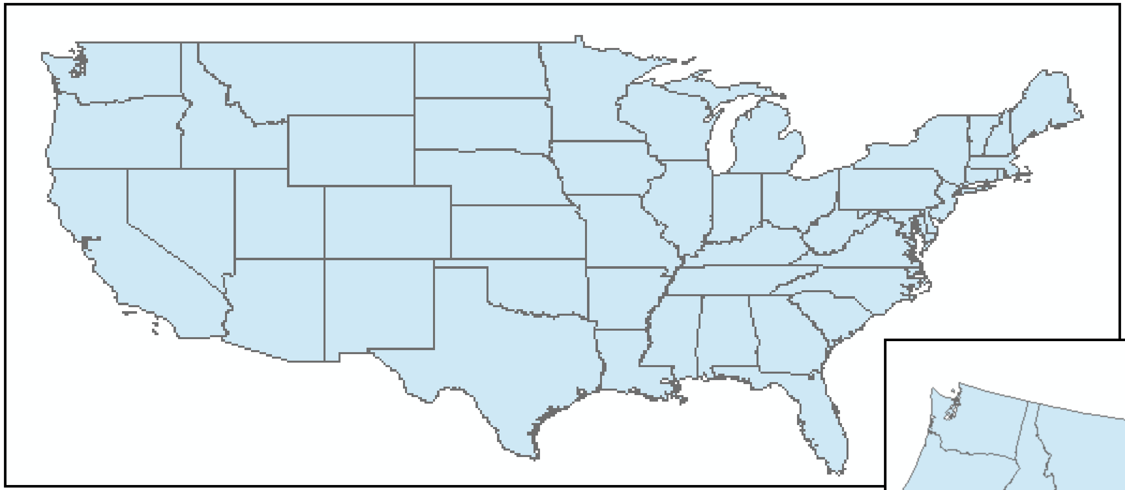


-103.567,44.628	2445678,654321
-103.678,44.653	2445021,650001
-103.765,44.732	2444823,649200
…	….
Units in decimal degrees	Units in meters

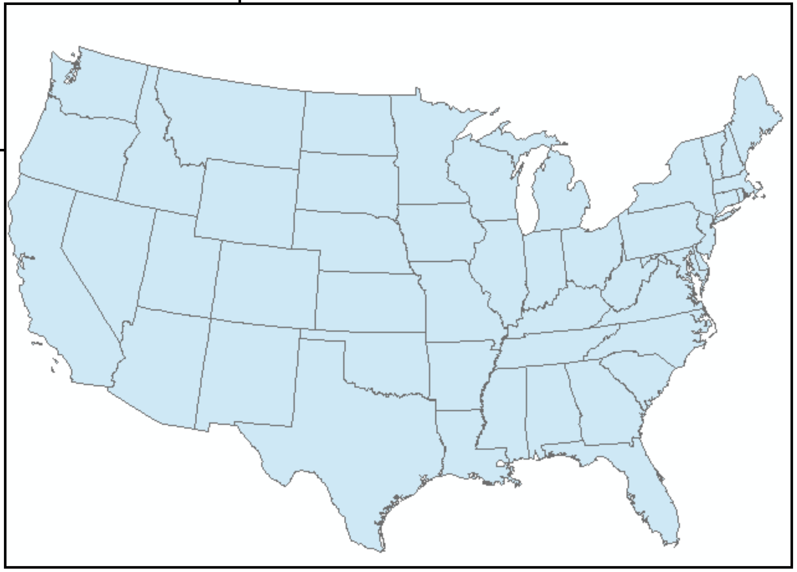


It is impossible to fit a 3D surface onto a 2D surface without creating distortion

Selecting a projection

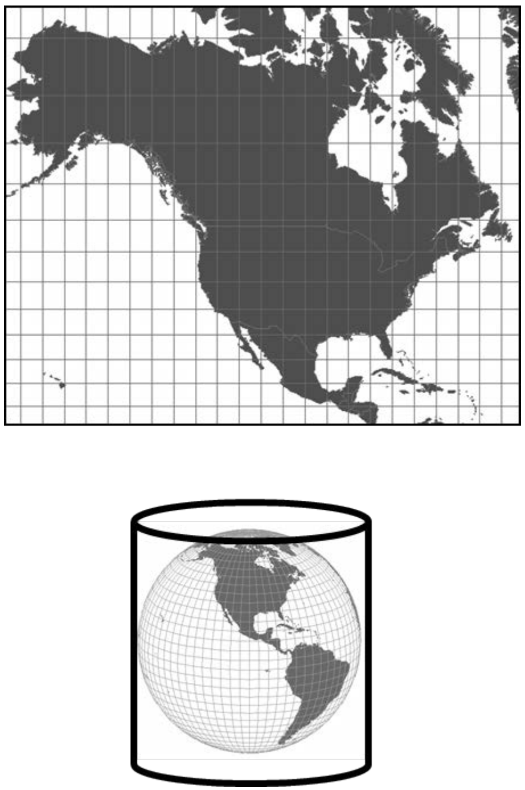


A map using a Geographic Coordinate system (GCS) appears distorted.

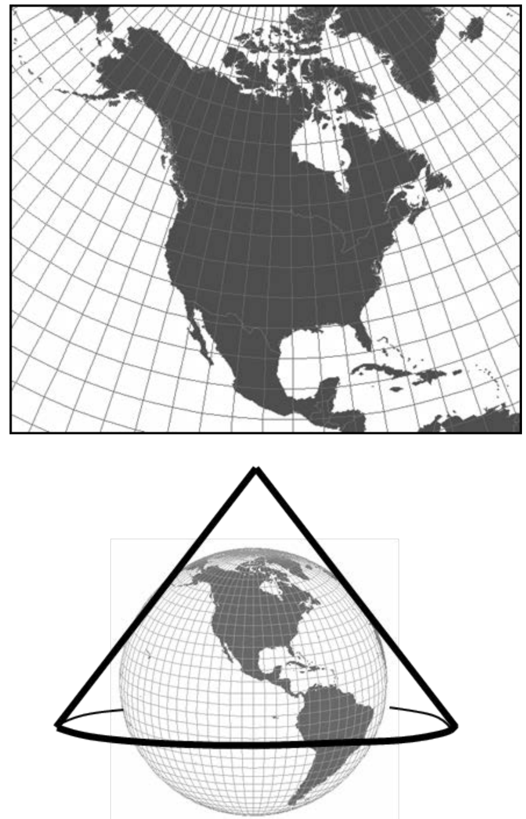


Always use a projected coordinate system for mapping.

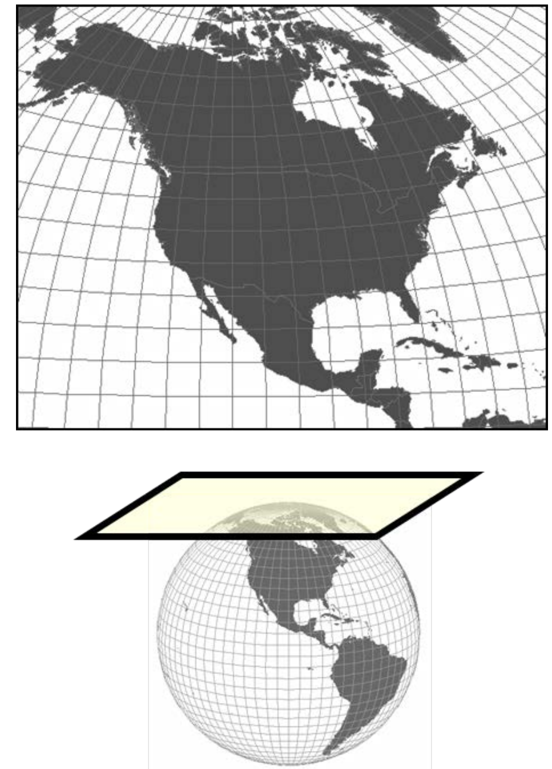
Types of projections



Cylindrical



Conic



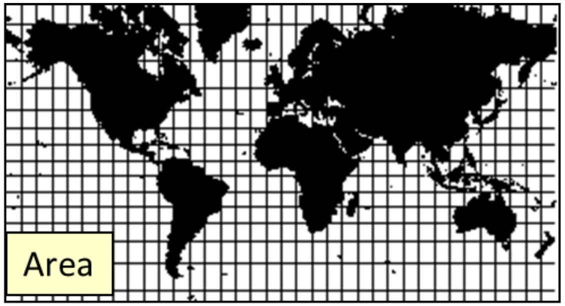
Azimuthal

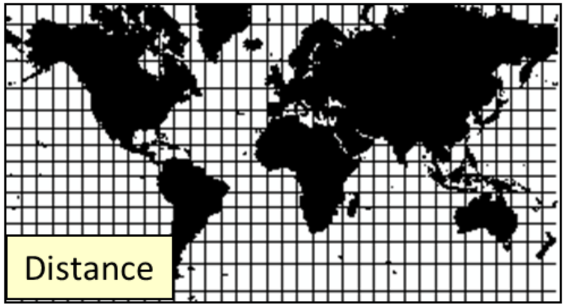
Distortion

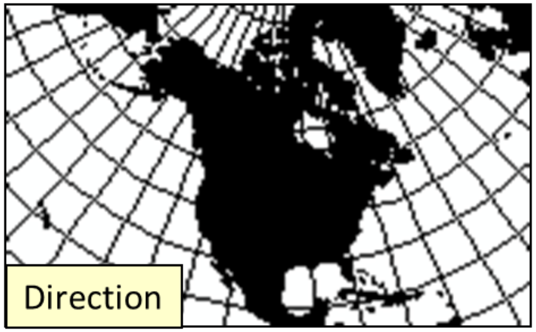
All map projections introduce distortion

Type and degree of distortion varies with map projection

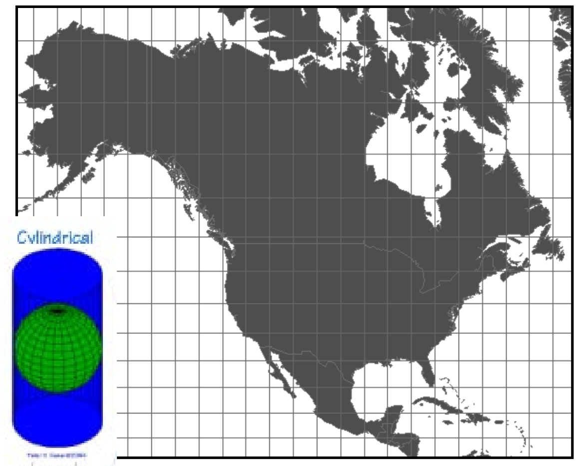
When using a projection, one must take care to choose one with suitable properties



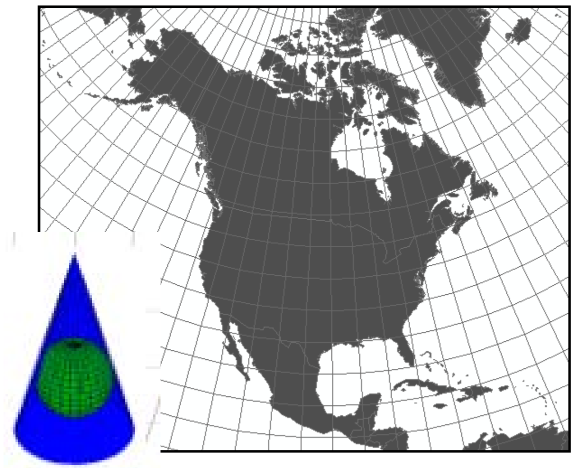




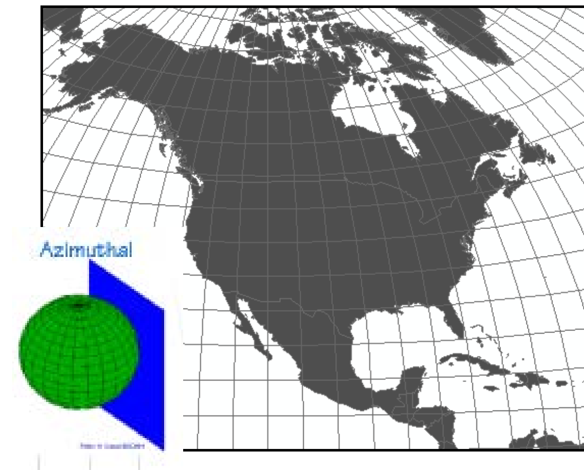
Types of projections



Conformal



Equal area



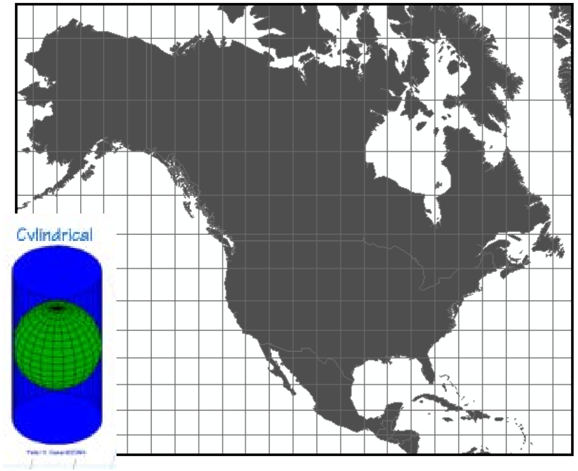
Equidistant

Generally preserve **direction** and **shape**.

Preserve **area**

Generally preserve **distance**.
Commonly used for navigation

Types of projections



Conformal

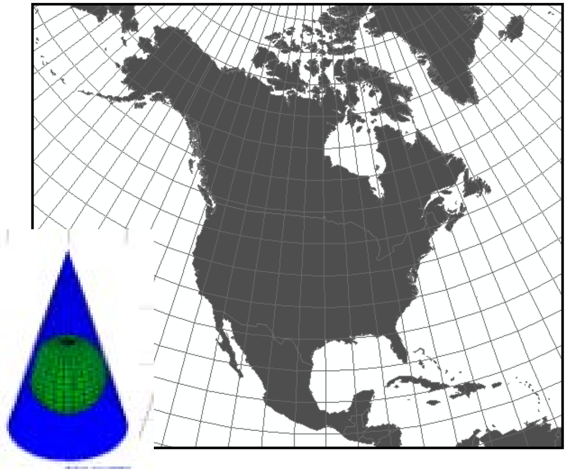
Generally preserve **direction** and **shape**.

Lat and long lines meet at right angles

Linear scale change in one direction must be the *same* as linear scale change in the perpendicular direction

It must be obvious that the map is not equal area

Types of projections



Equal area

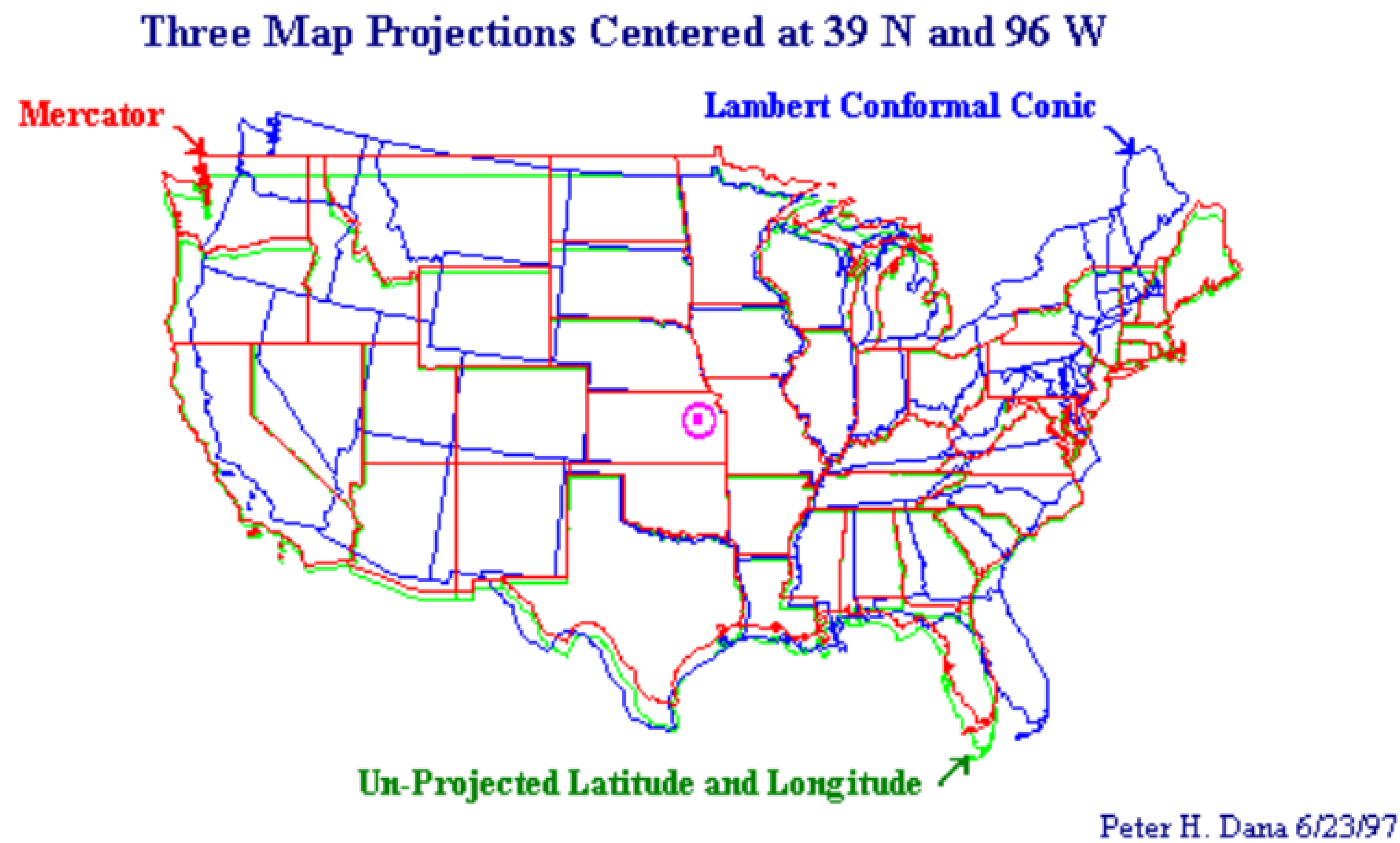
Preserve **area**

Lat and long cells decrease in size as you go toward the poles
There are other characteristics... See handout.

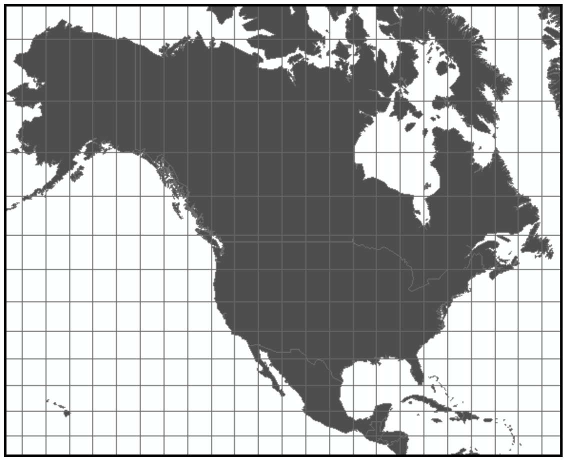
First test if Equal Area then test of Conformal. If no to both, then the projection is neither

What is getting distorted and how do you know?

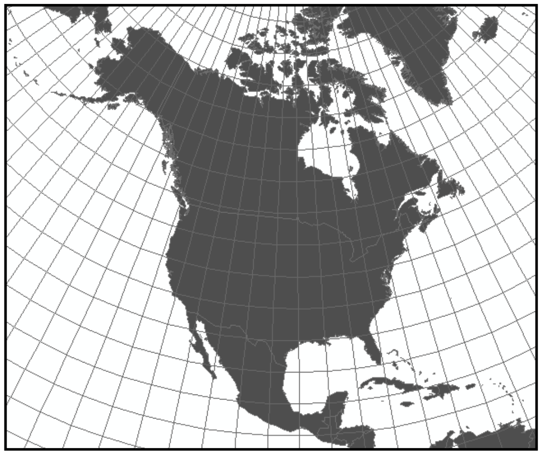
Visualizing Projections



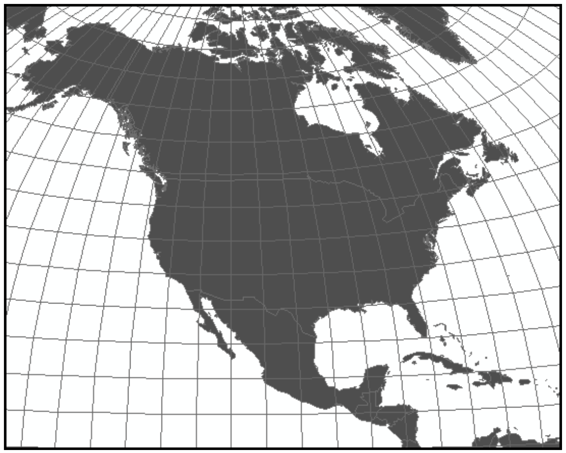
Types of projections



Cylindrical



Conic

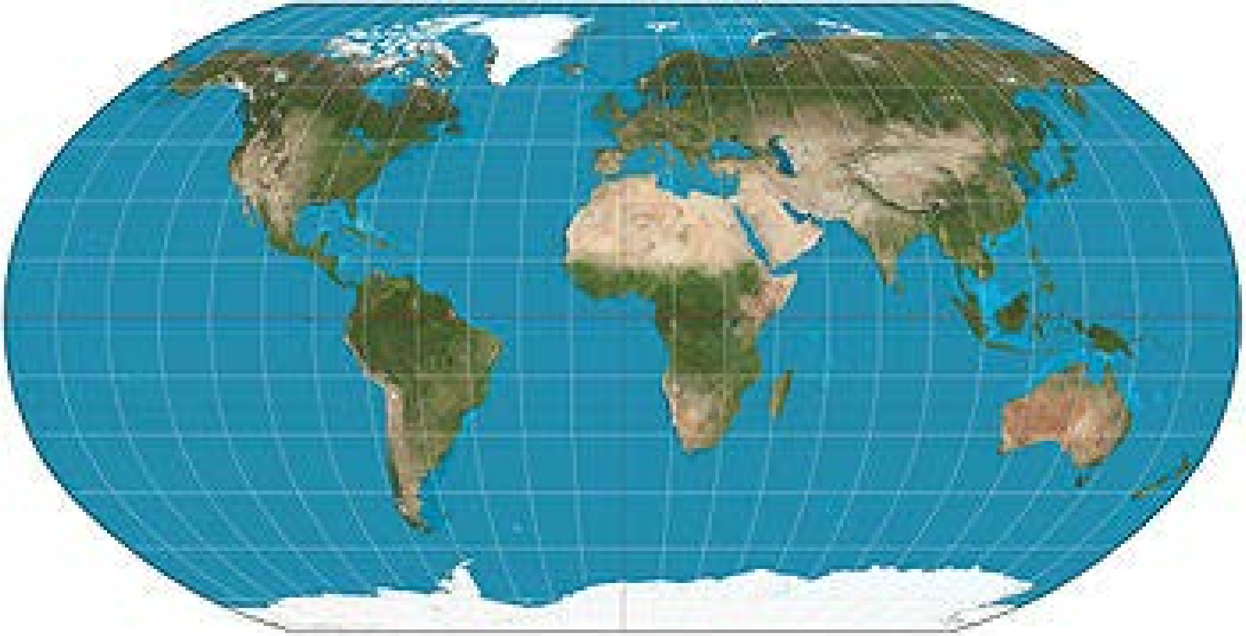


Preserve area

Generally preserve **direction** and **shape**. Transverse cylindrical good for N-S oriented areas.

Generally preserve **area** and **distance**. Preferred for E-W oriented areas.

Generally preserve **area** and **distance**. Commonly used for satellite data and polar regions.



Robinson Projection: A compromise

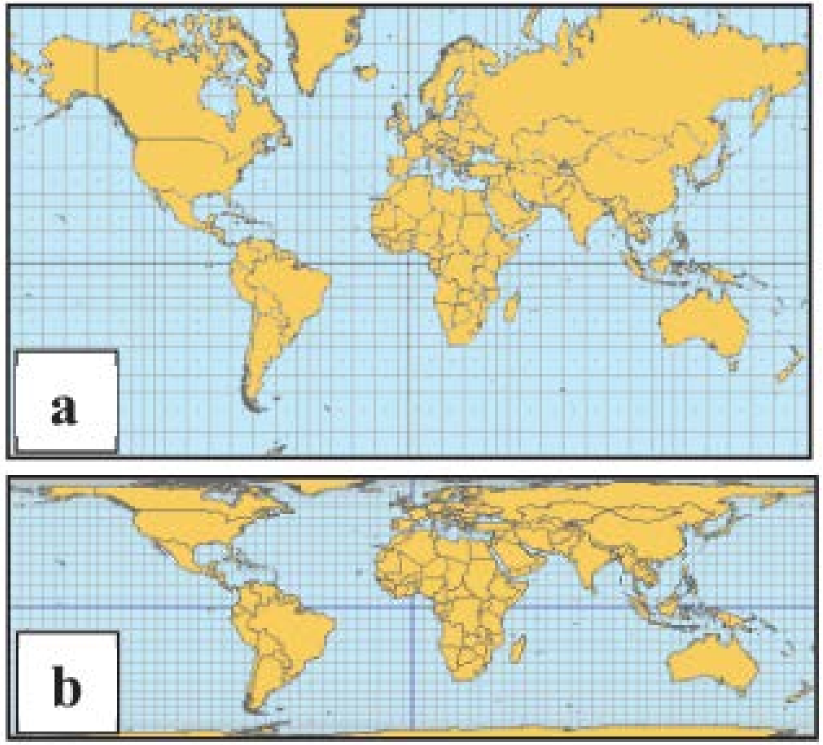


Fig. 5.3. (a) A Mercator and (b) an equal-area cylindrical projection

Mercator Projection: Preserves direction

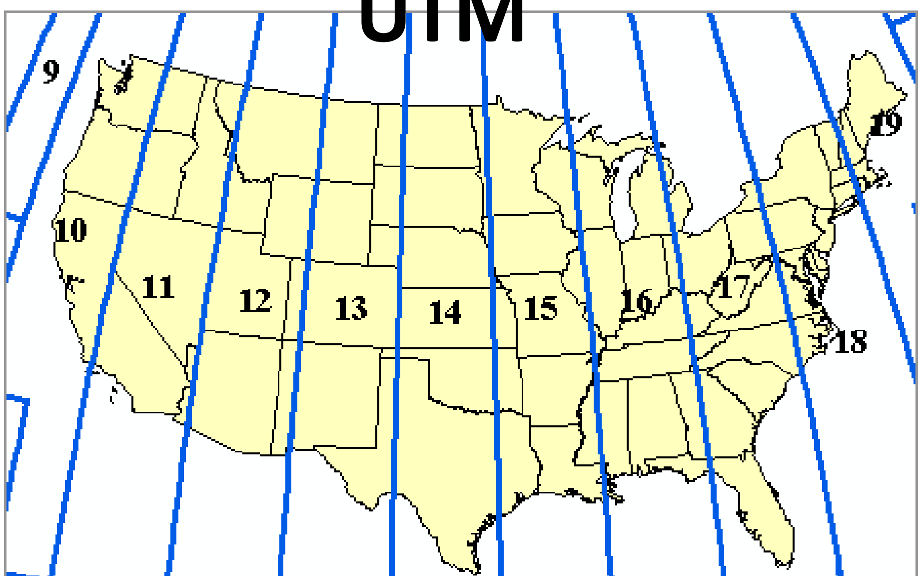
Projections for large scale maps

Large scale maps cover small areas

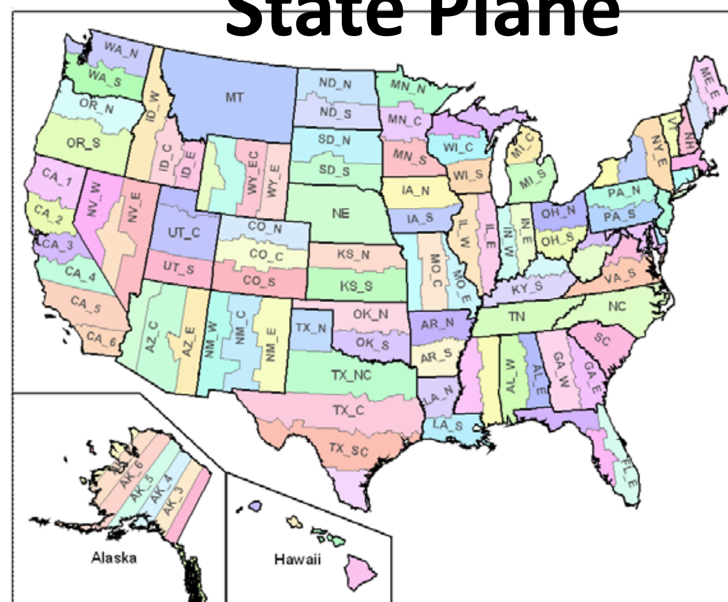
Local, city, county maps, smaller states

- Projection systems virtually eliminate distortion
- Choose appropriate **Universal Transverse Mercator (UTM)** or **State Plane zone**
- For best results, map should lie in a single zone

UTM

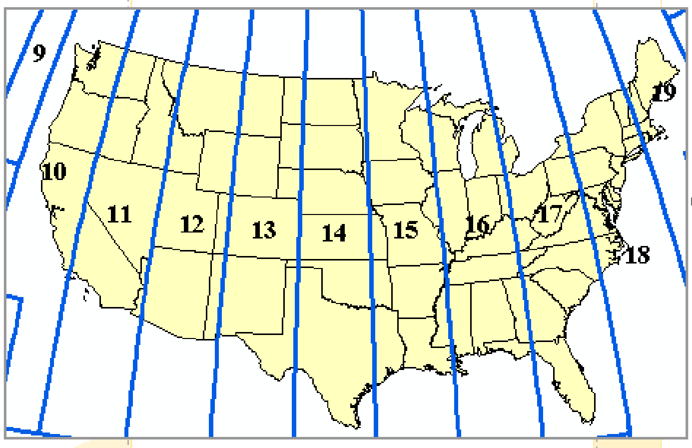


State Plane



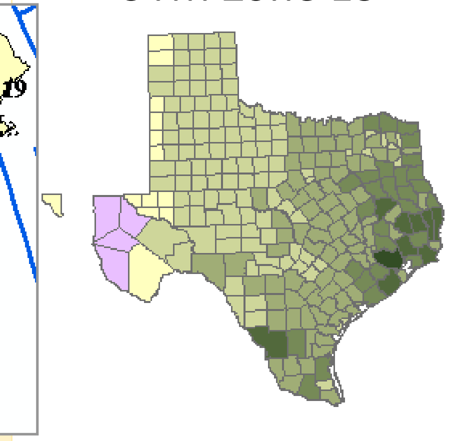
Understanding map projections and coordinate systems.

Replace text with your name

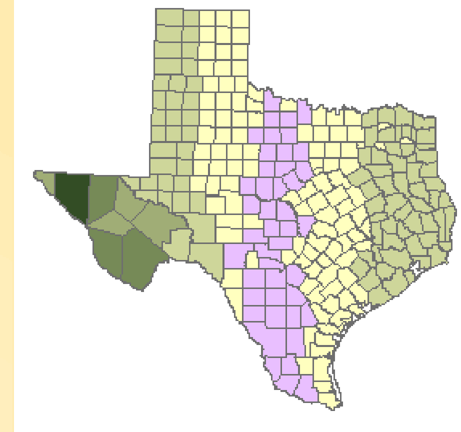


Equal Area projections ensure GIS-based polygon areas approximate geodetic areas.

UTM Zone 13



UTM Zone 14



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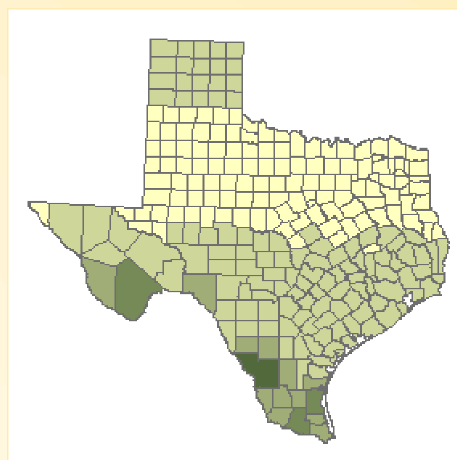

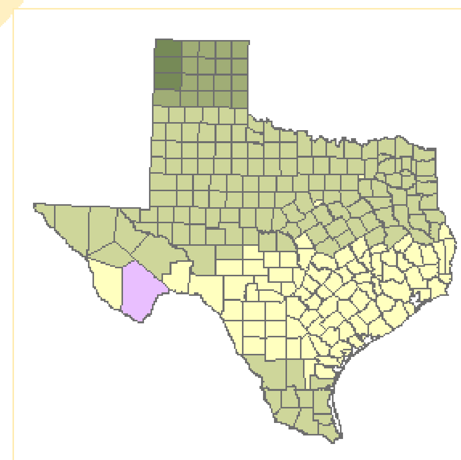

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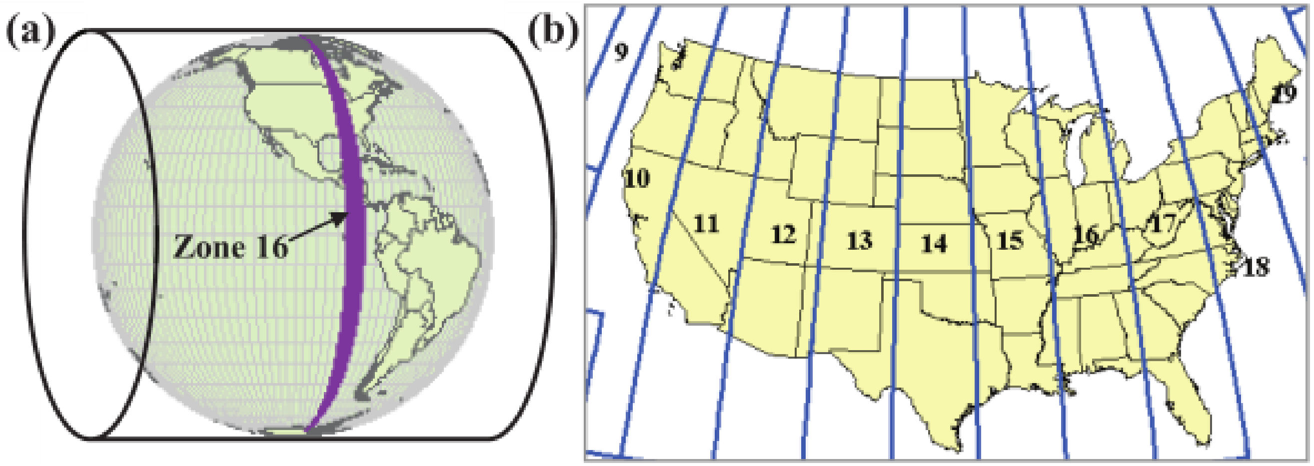
Universal Transverse Mercator projection



There is no distortion where the projection surface intersects the earth

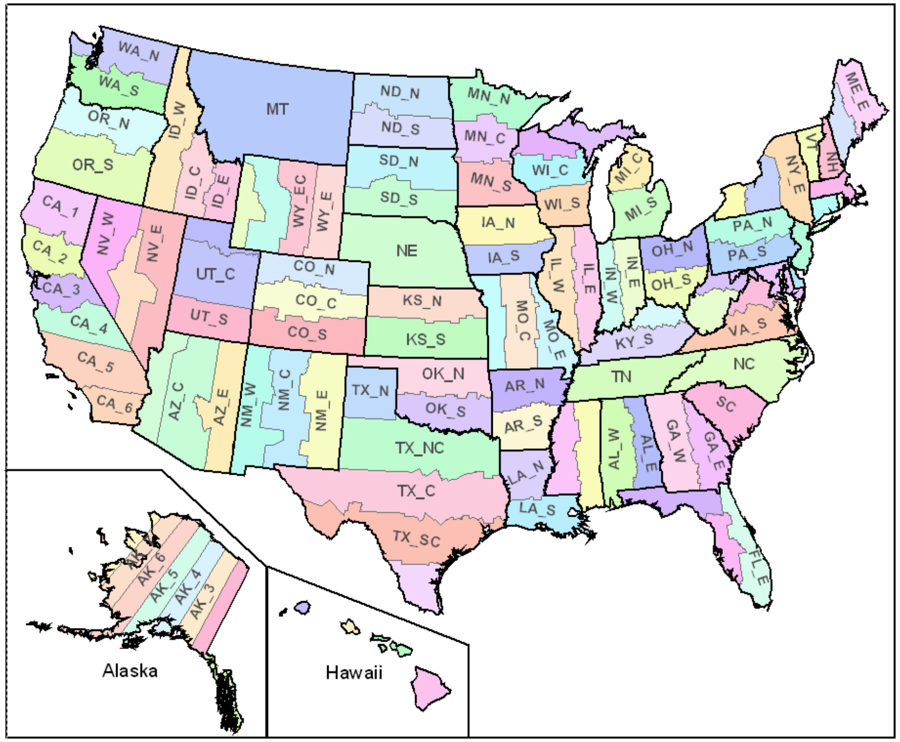
Distortion increases with distance from the two points of intersection

Distortion between two intersection lines is minimal

The earth is rotated within a cylinder in 6 degree intervals to produce 60 zones around the world

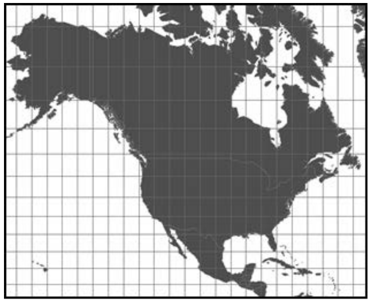
State Plane Coordinate System

Uses multiple projections depending on state, size of area, and area orientation (E-W vs N-S)



Projections for small scales

Small scale maps cover large areas



Coordinate system names generally indicate the locale and purpose it is optimized for. Use for clues to choice.

Continents and countries

Distortion is inevitable, so purpose drives the choice

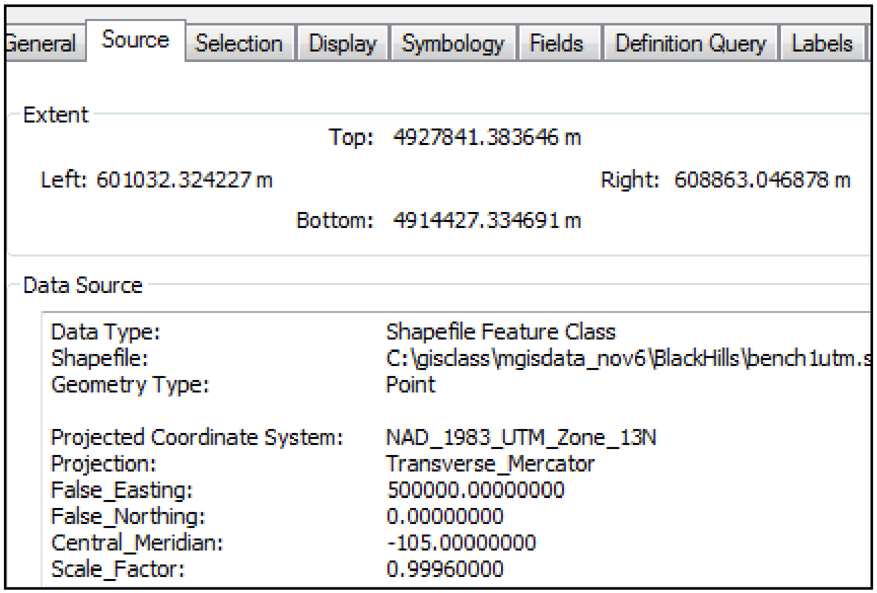
- Equidistant maps when distances are important
- Equal area maps when areas are important
- Conformal or compromise projections for general purpose maps

Not so fast!

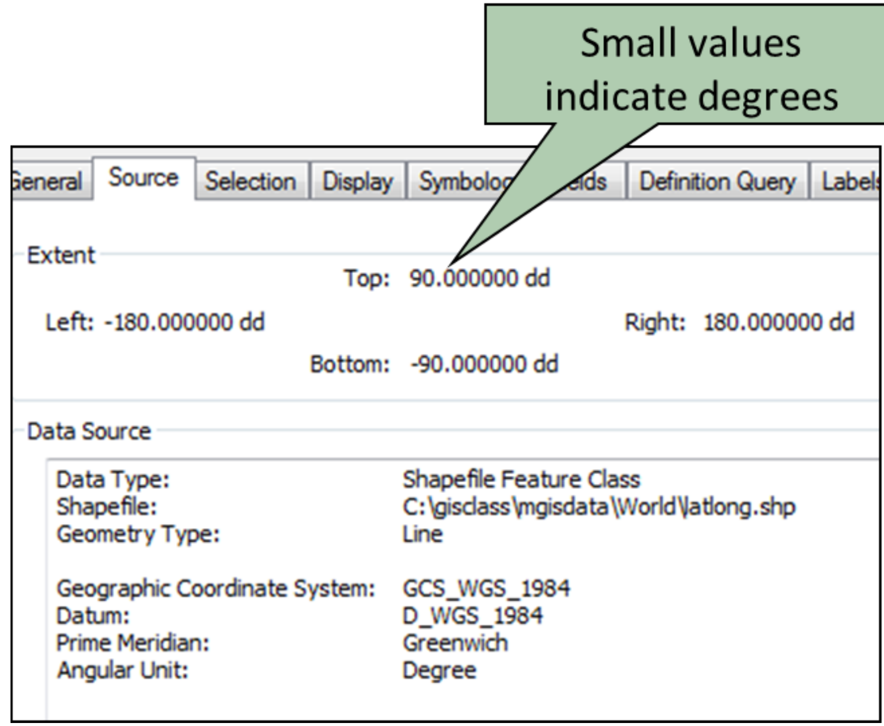
These solutions will give you somewhat better accuracy for your maps, but there are some considerations.

- You will need to take care to convert all data to your chosen coordinate system.
- GPS units will not be able to collect data directly in your coordinate system.
- When using non-standard projections you must be extra careful with your metadata so that users understand the differences.

Projected/unprojected data



Projected coordinate system



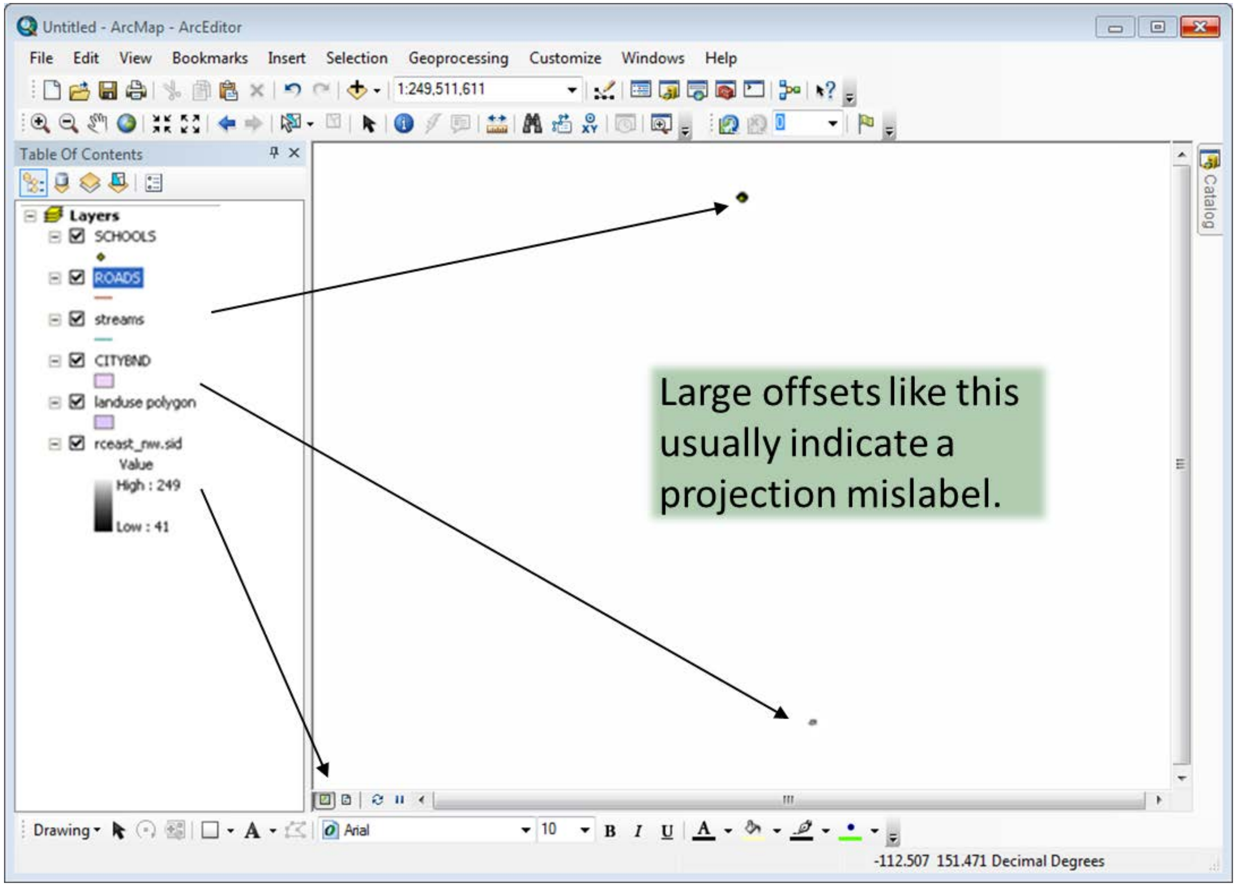
Unprojected coordinate system

Troubleshooting coordinate systems

Troubleshooting coordinate systems

These layers are all from Rapid City and should align, but they don't. One or more has a coordinate system problem.

What should you do?



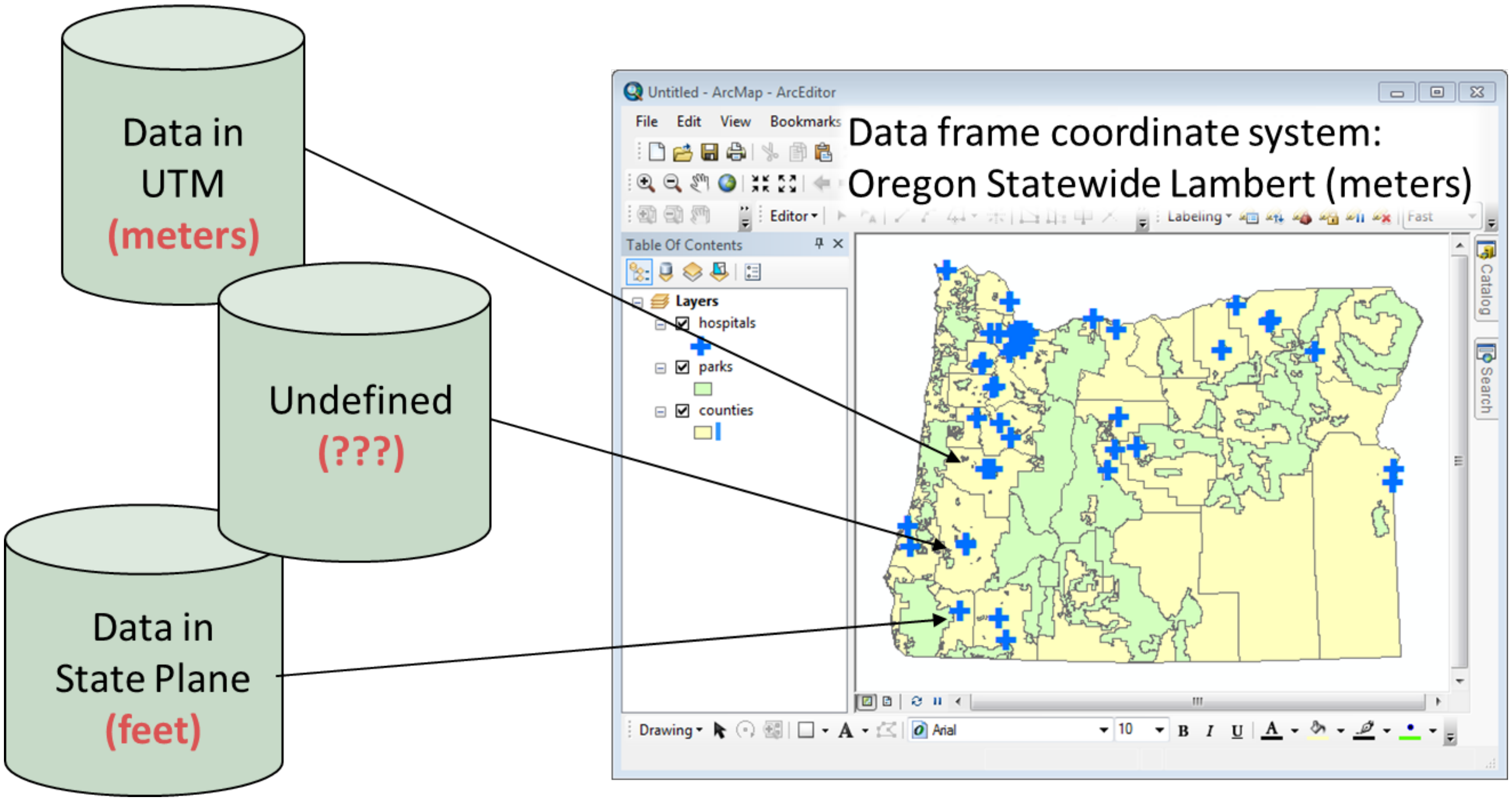
Coordinate problems

Coordinate problems occur when two data sets that should map on top of each other…don't.

Most coordinate system problem arise from two causes

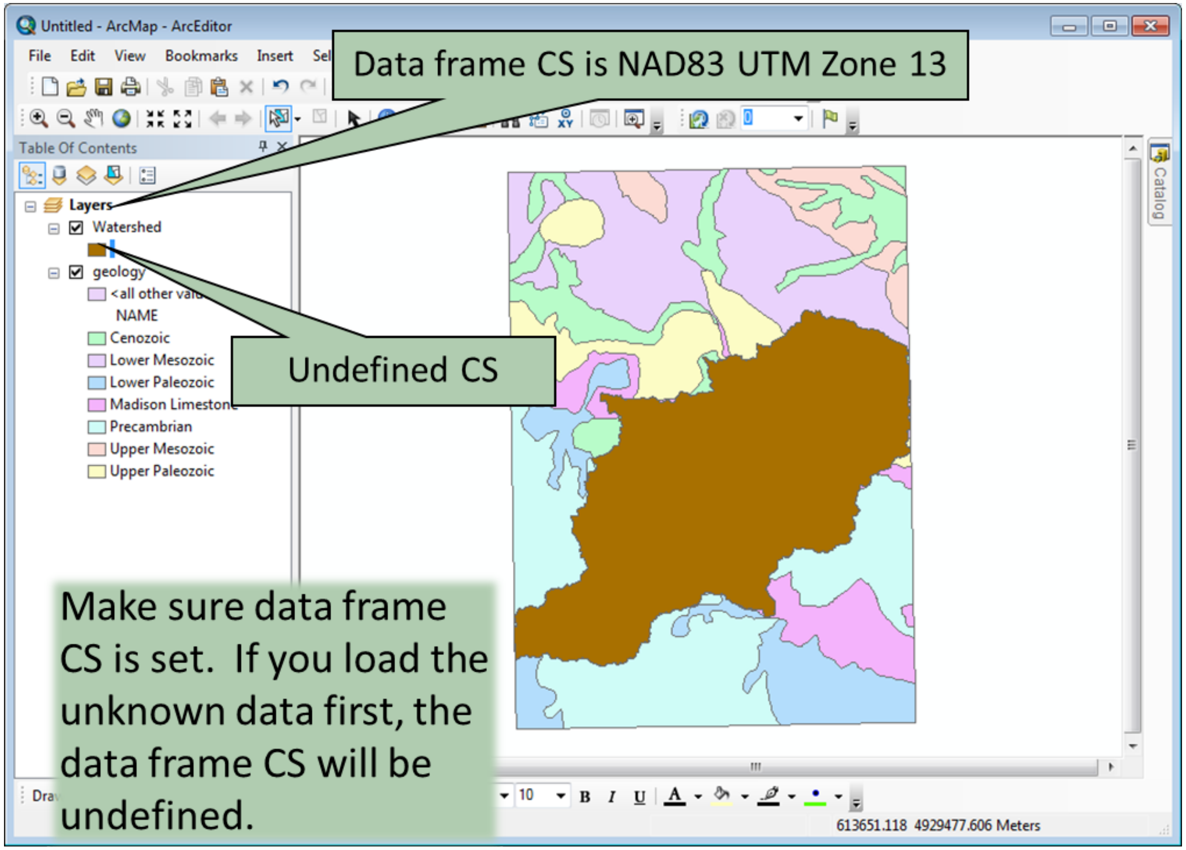
- You are trying to use a data set with a missing coordinate system label
- You are trying to use a data set with an incorrect coordinate system label

Undefined coordinate systems



Undefined data sets are not projected on the fly. Whatever x-y values are in the file appear unchanged in the data frame coordinate system.

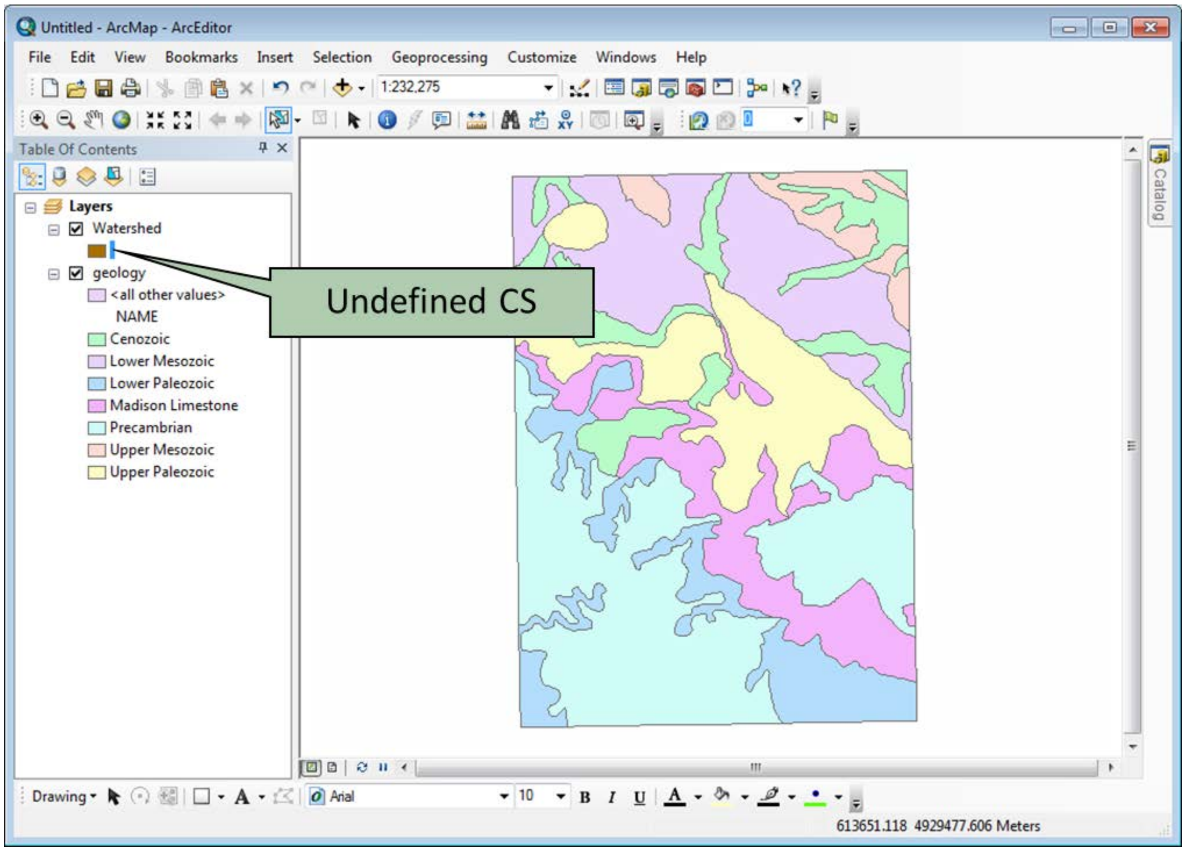
Undefined layer appears correctly



If the undefined data set appears in place, then you know that its coordinate system is the same as the data frame coordinate system.

You can then create a label for it, making it fully usable.

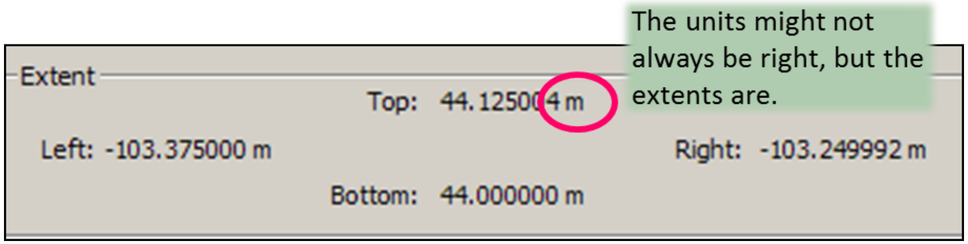
Undefined layer does not appear



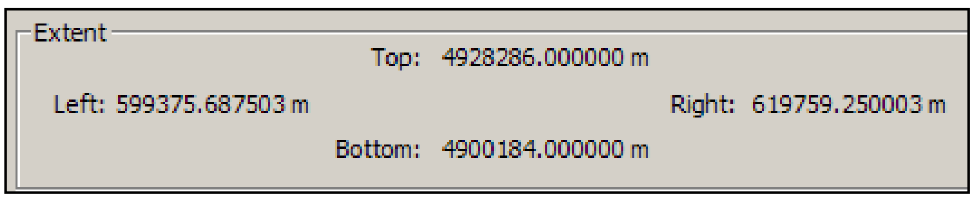
If it does NOT appear, then you know that the undefined CS is not the same as the CS of your data frame.

You must do some investigating to see if you can find out what it is.

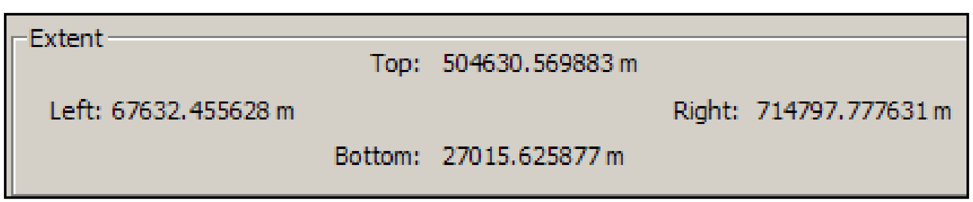
What is the extent?



This extent clearly belongs to a GCS in degrees.



This is projected data. If you work with UTM a lot you might recognize these as UTM coords



This is projected data, but not easy to see what kind.

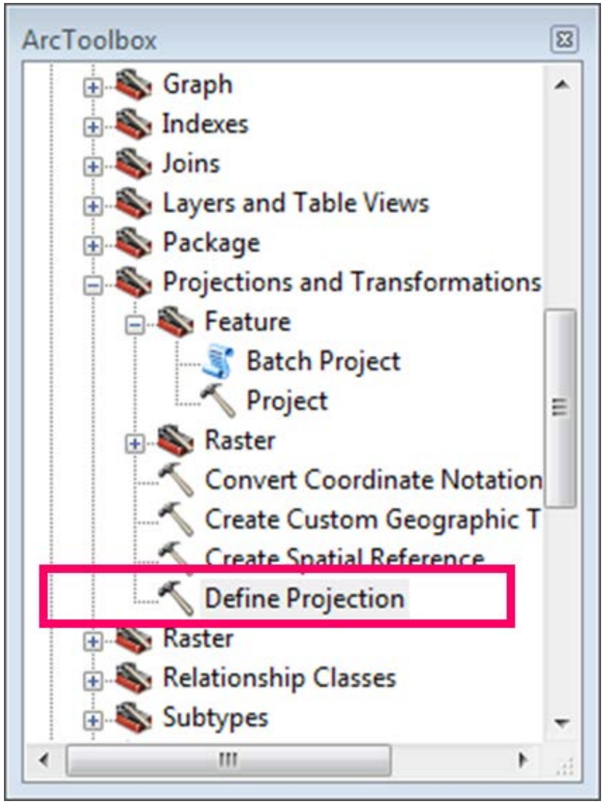
The Extent in the layer properties always lists what range of x-y coordinates are stored in the file.

With a problem data set, always check the properties.

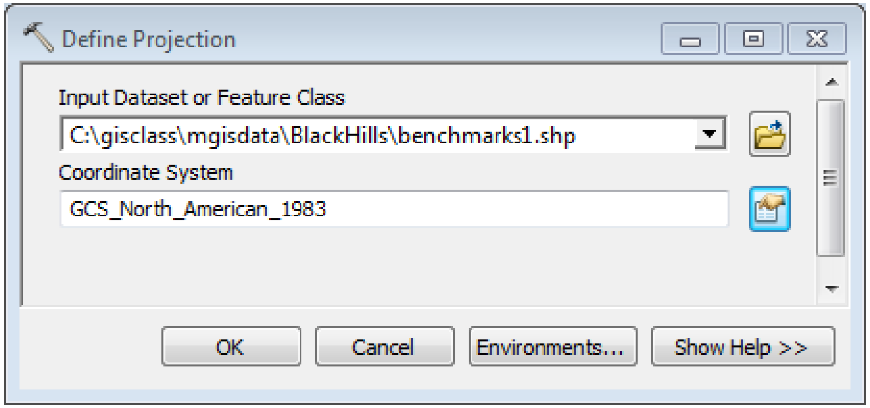
You may get a clue what the CS is.

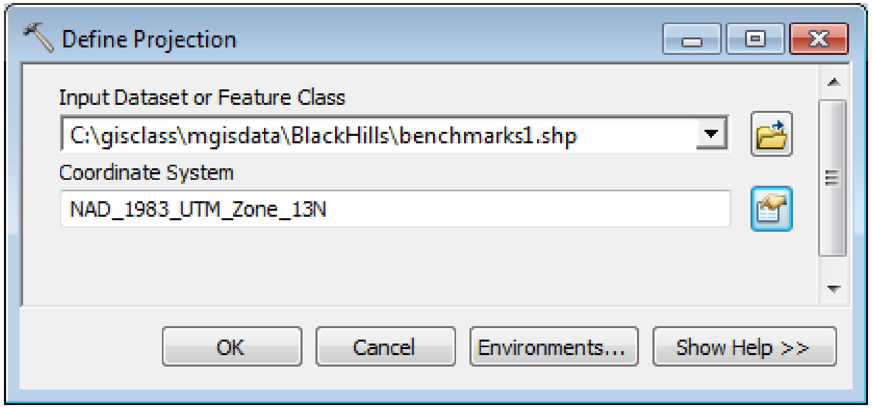
Fixing the problem

Create CS labels using the **Define Projection** tool.



Set it to the CS you *think* it is in.

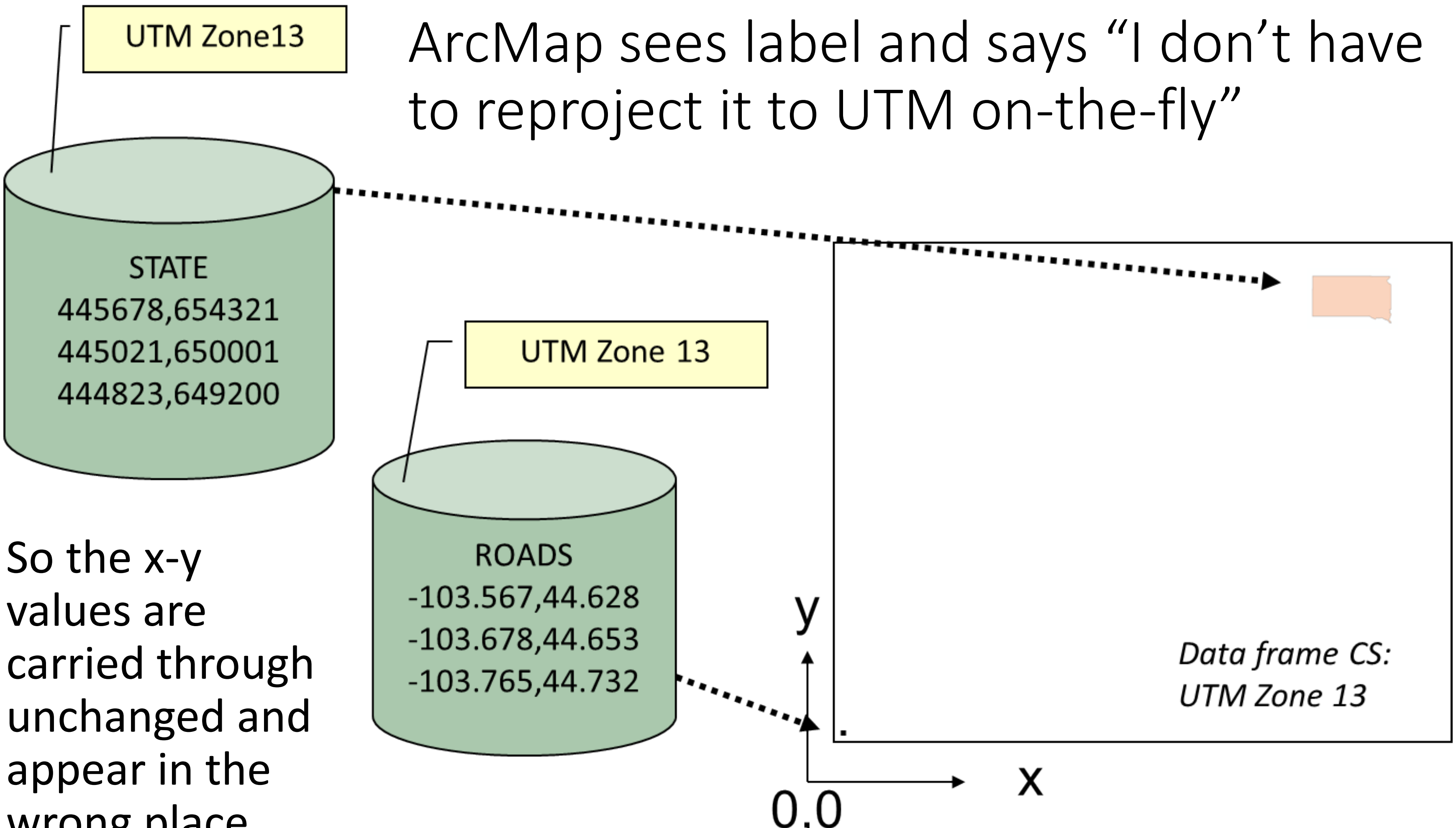




If you guessed correctly, the data set will appear in the right place on the map.

2. Incorrectly labeled data

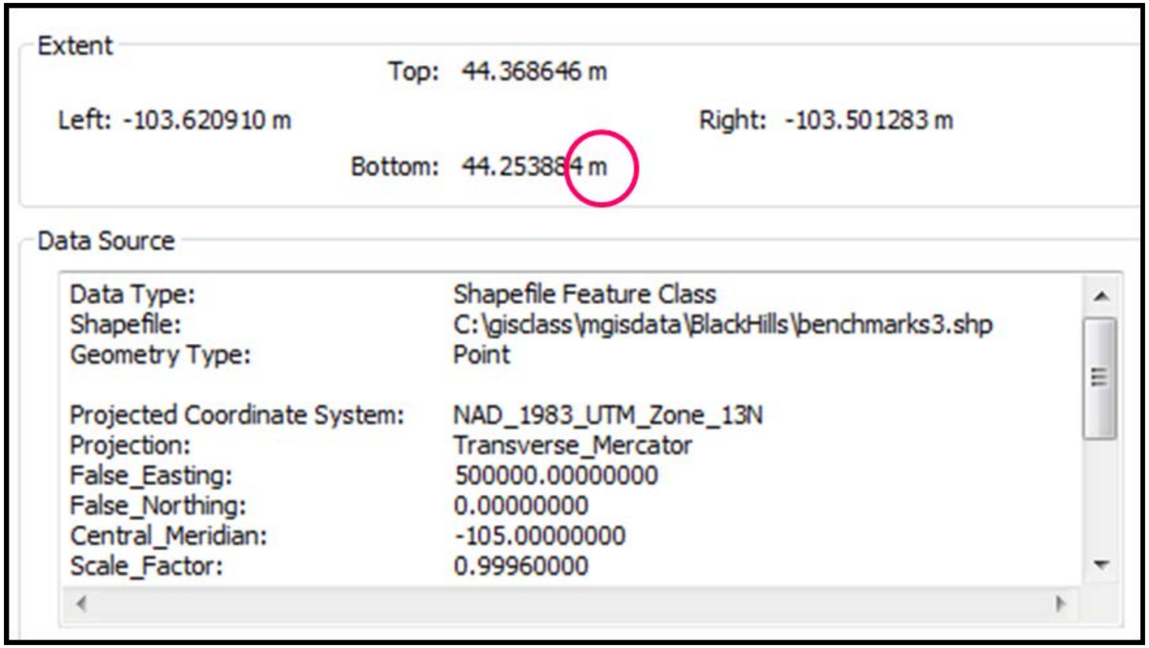
ArcMap sees label and says “I don’t have to reproject it to UTM on-the-fly”



So the x-y values are carried through unchanged and appear in the wrong place.

Checking for mislabeled data

The units might not always be right, but the extents are.



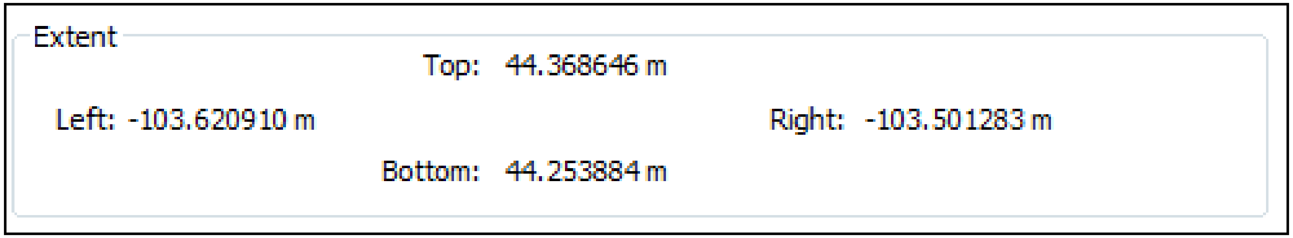
This is a GCS data set incorrectly labeled with a UTM coordinate system.

Compare the extent and the coordinate system information

Do the extent units and values appear to match the defined CS?

May be corrected… **IF** you can identify the actual CS represented by the extent.

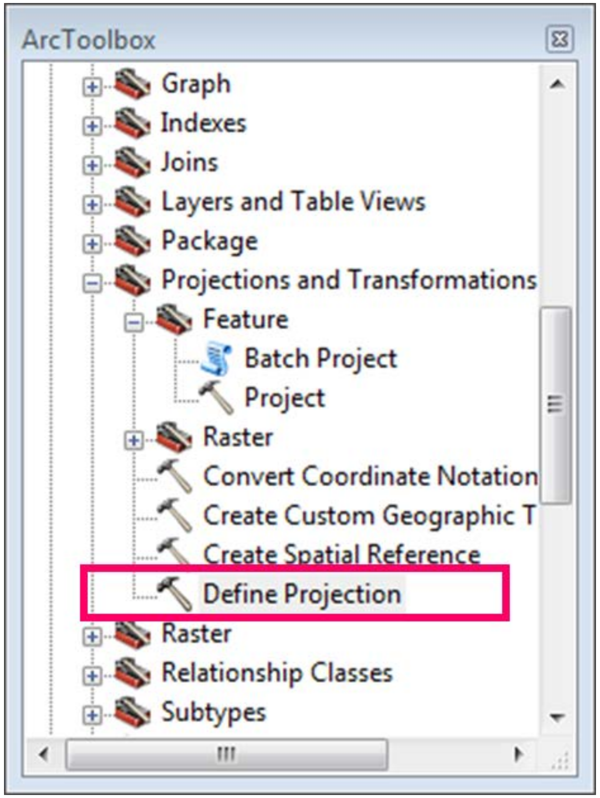
Fixing the problem$_2$



Same routine as for an unlabeled data set.

You must determine the actual coordinate system if you can.

You must correct the label.

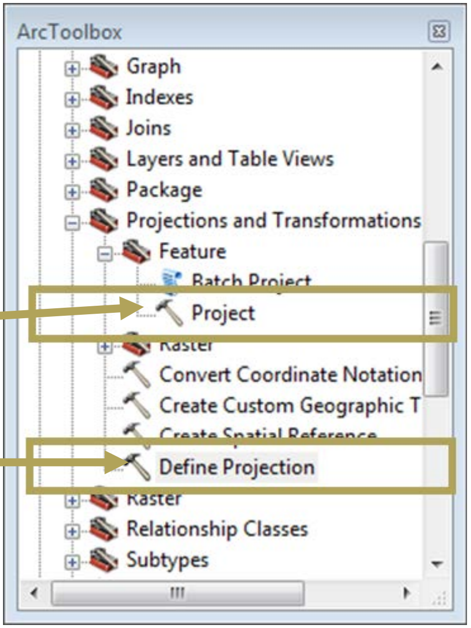


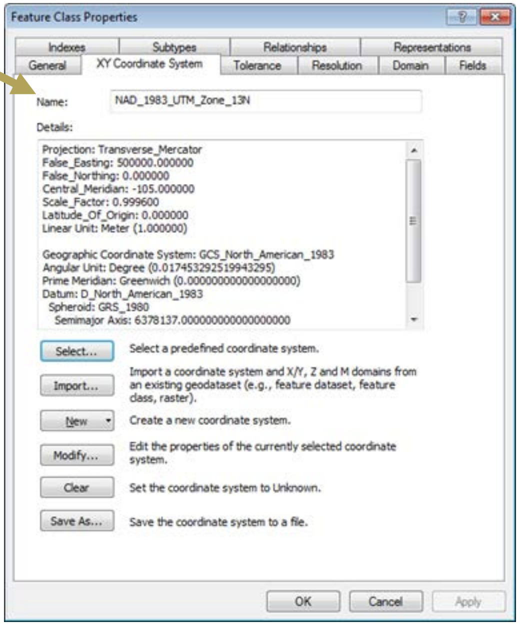
CAUTION!

DO NOT confuse

- Projecting
- Defining a projection
- Setting the CS in ArcCatalog

Most common cause of CS problems





Remember!

Do not confuse these two functions!

Define Projection

ArcCatalog Properties

- Changes only the CS label
- Does not change the coordinates
- Keeps original data set
- Use only when CS is unknown or incorrect

Project tool

- Changes coordinates in file
- Changes definition also
- Creates new data set
- Use when changing a CS permanently
- Use to assemble collections of data with the same stored CS

Troubleshooting Summary

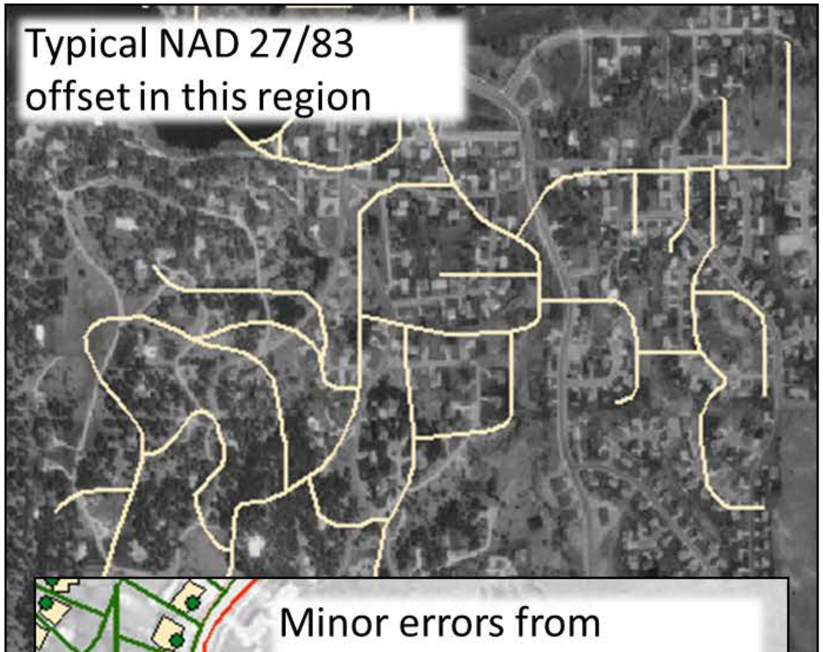
The most common problem is a mismatch between the label and the actual CS.

- Determine if a mismatch exists
- Determine the actual CS, if possible
- Define the label correctly
- Test to see if the alignment problem is fixed.

It is helpful to have a feature class or raster that is known to be correctly defined, so that comparisons can be made.

Other common issues

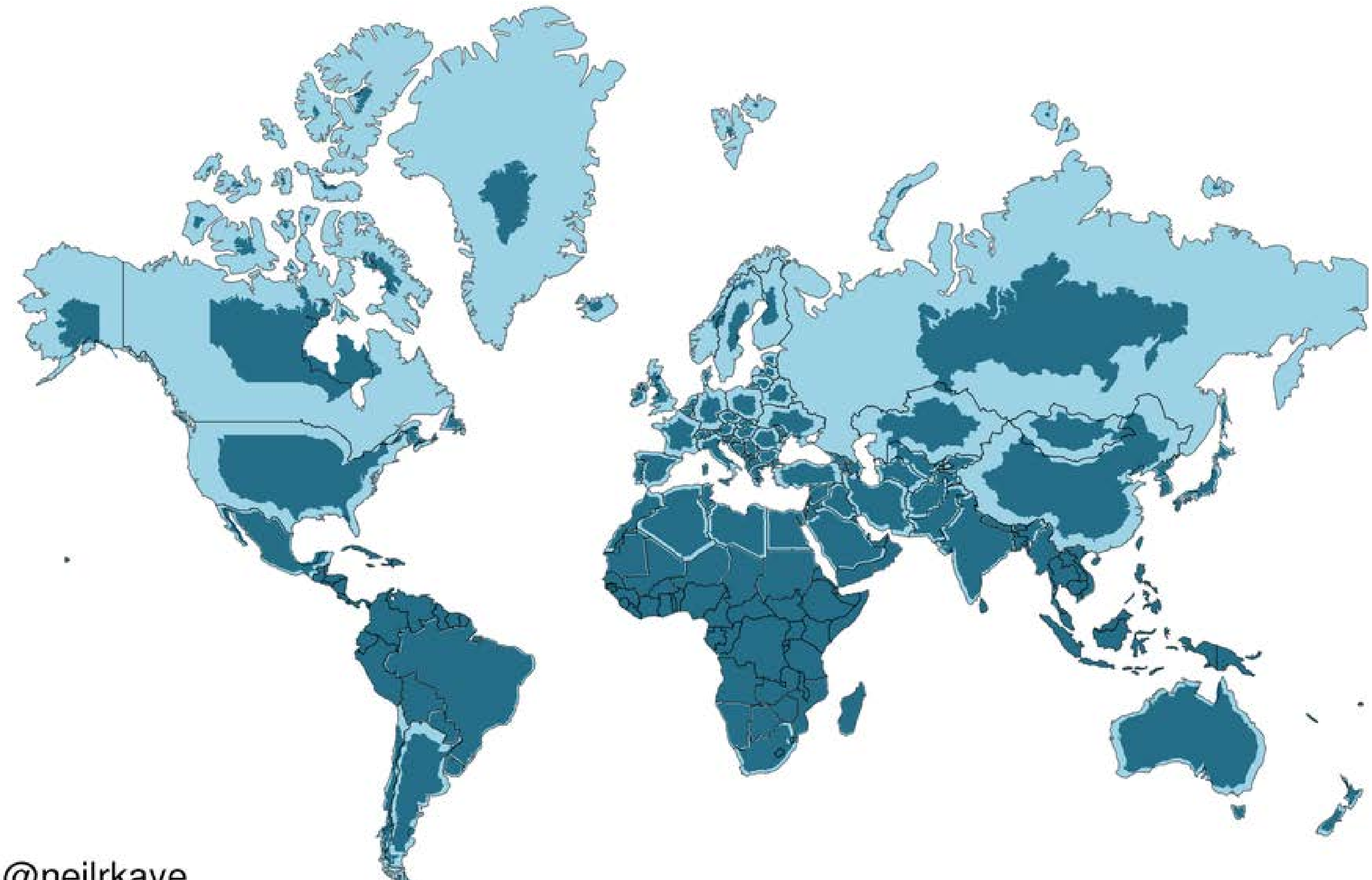
This is fixed by setting CS label to correct datum.



These will usually be fixed by editing: shifting all streets to closer match with a known base layer, and/or editing minor offsets.

https://thetruesize.com

World Mercator projection with true country size added



@neilrkaye

Map Transitions