CRP 4080: Introduction to Geographic Information Systems for planners

Lecture 3: Coordinate System & Projection

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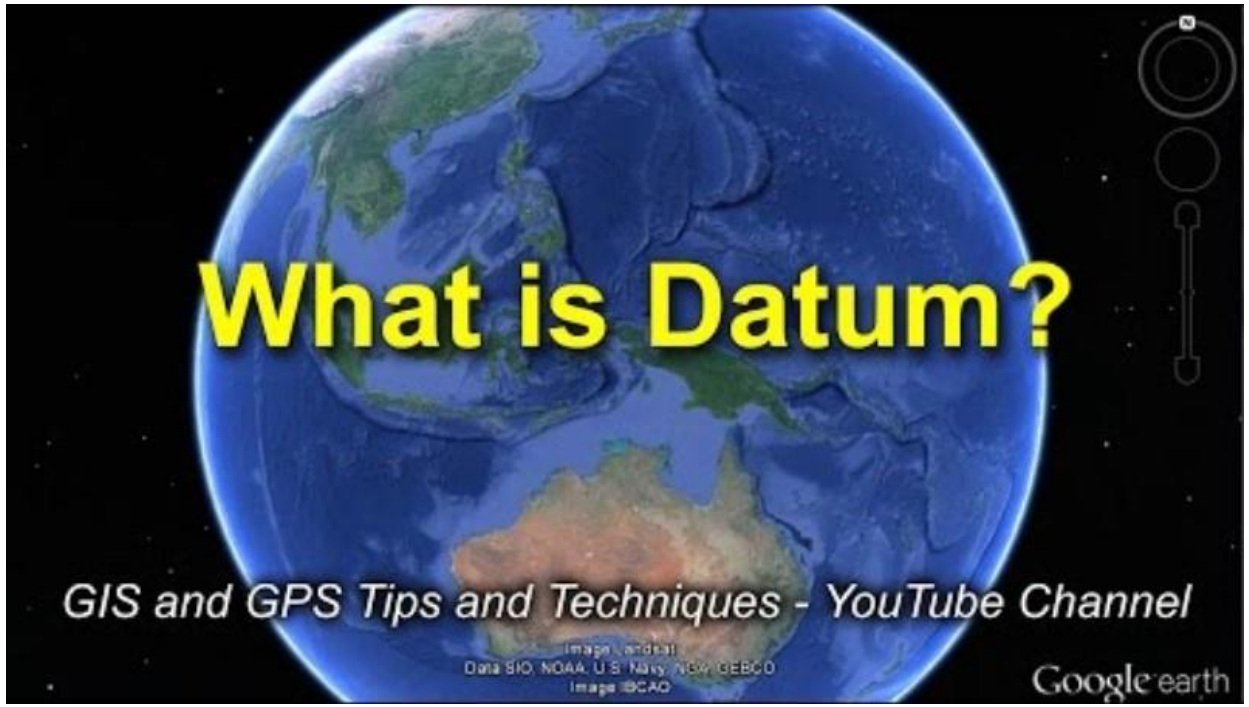
Recap

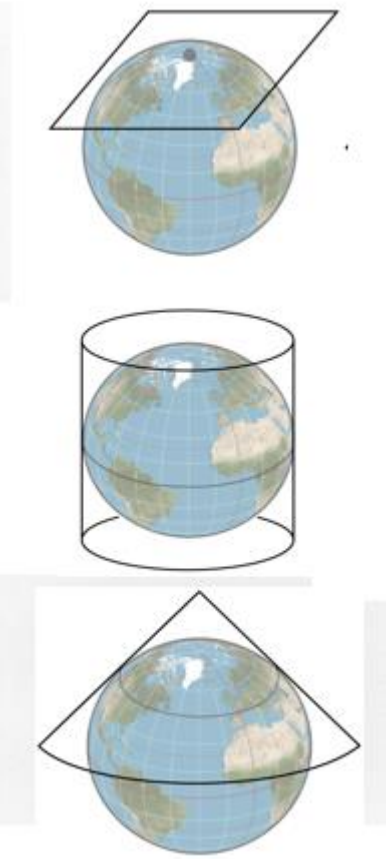
- What is the key element in a datum?
- https://www.youtube.com/watch?v=xKGIMp__jog



Recap

- Projection?
  - a mathematical method used to represent the 3D curved surface of the Earth on a 2D flat surface.

- Tell me a feature of projection?
  - All projections distort some combination of either the shape, size, distance or direction of land masses.
    - Mercator Puzzle: http://bramus.github.io/mercator-puzzle-redux/
  - Common Types of Projections
    - Azimuthal (Planar): uses a flat plane
    - Conic: uses a cone
    - Cylindrical: uses a cylinder
  - Projection orientation/Aspect
    - Normal, transverse, oblique



What is a Coordinate System?

A geographic coordinate system (GCS) is a reference framework that defines the locations of features on a spherical model of the earth.

- uses latitude-longitude, Decimal Degrees or degrees, minutes, seconds (DMS)
- **No projection**

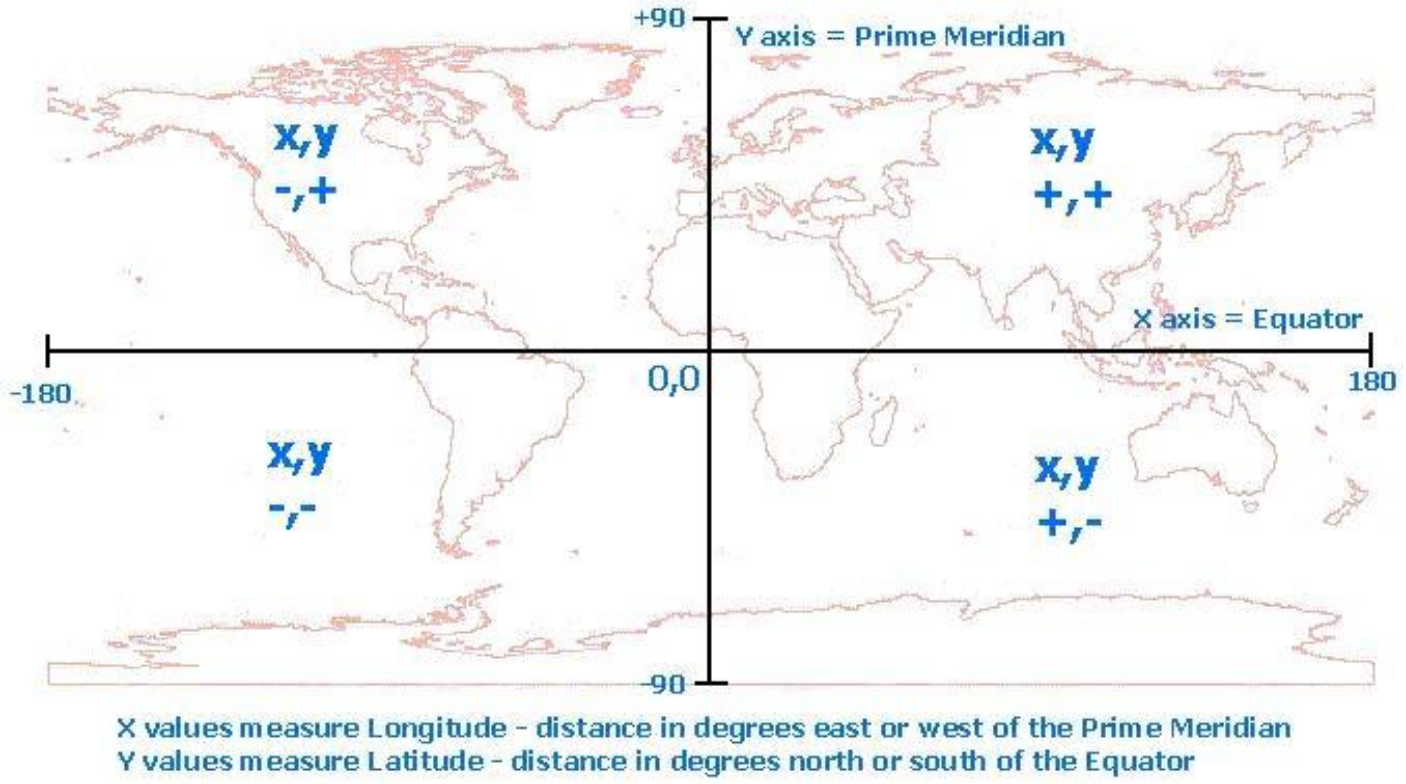
Projected coordinate systems (PCS)—any coordinate system designed to transform **from sphere to a flat surface**

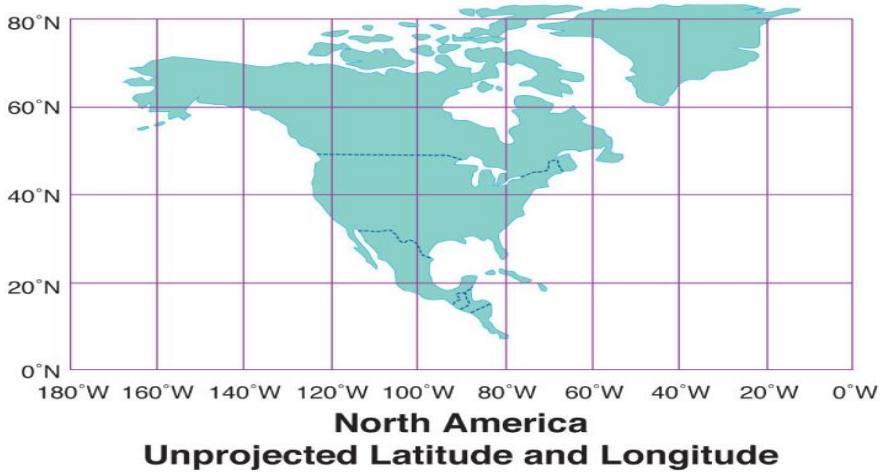
- Employs mathematical formulas to convert a three-dimensional geographic coordinate system to a two-dimensional flat projected coordinate system
- **Based on a geographic coordinate system (GCS)**, but it uses linear units of measure for coordinates (e.g., **meters, feet**), so that calculations of distance and area are easily done in terms of those same units.
- Continental, Polar, US National Grids, **UTM, State Plane.**

GCS (Geographic coordinate systems): no projection

latitude-longitude (degrees, minutes, seconds) converted to Decimal Degrees and assigned to (x,y) coordinates system (cartesian coordinate system) – plot lng/lat as grid.

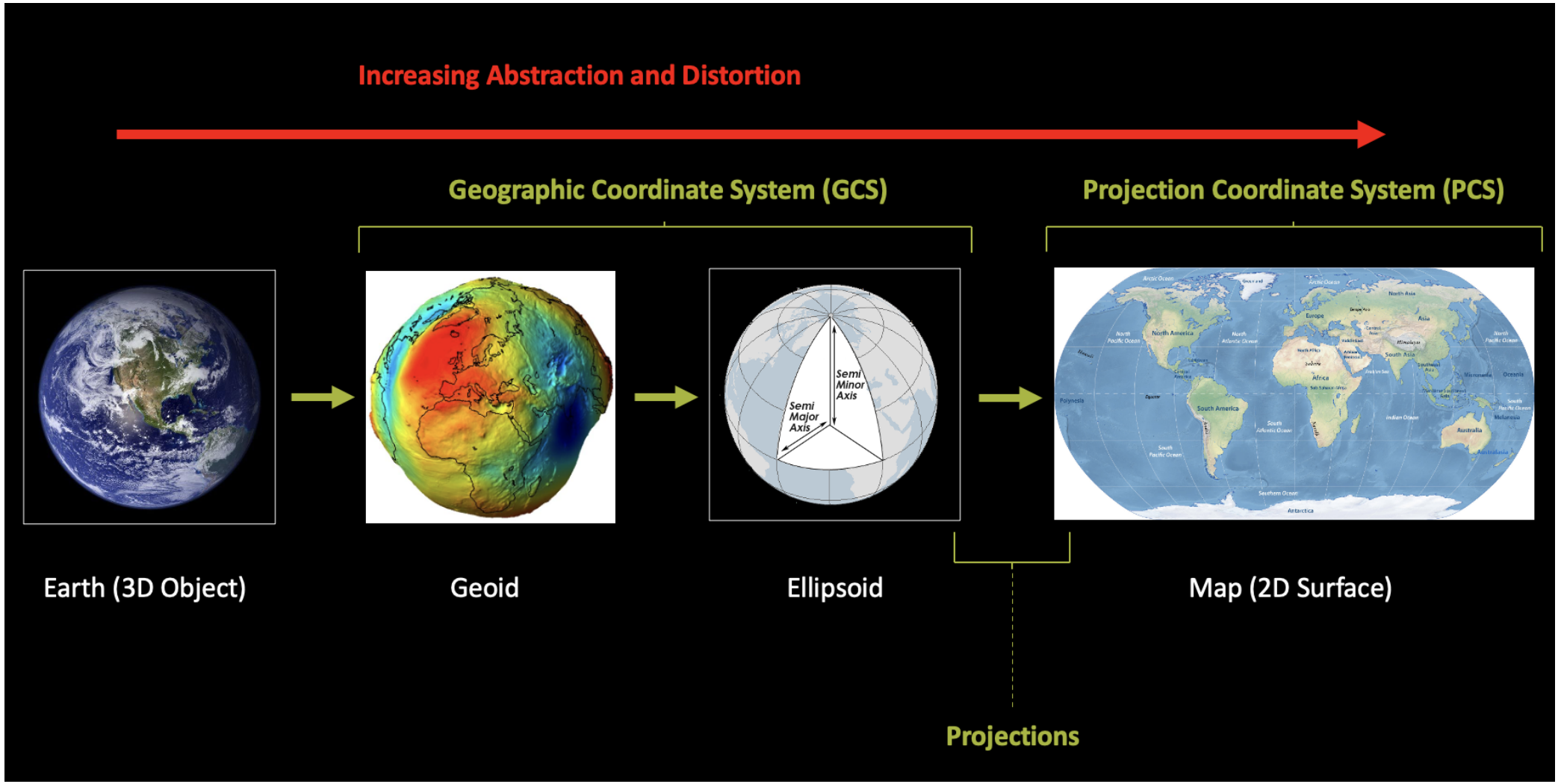
Pseudo-Projection: Plate Carrée projection





Unprojected geographic coordinates on a plane : 1 degree of longitude = 1 degree of latitude

From Earth to GCS to PCS



PCS (Projected coordinate systems)

- based on GCS, but it uses linear units of measure for coordinates, so that calculations of distance and area are easily done in terms of those same units.

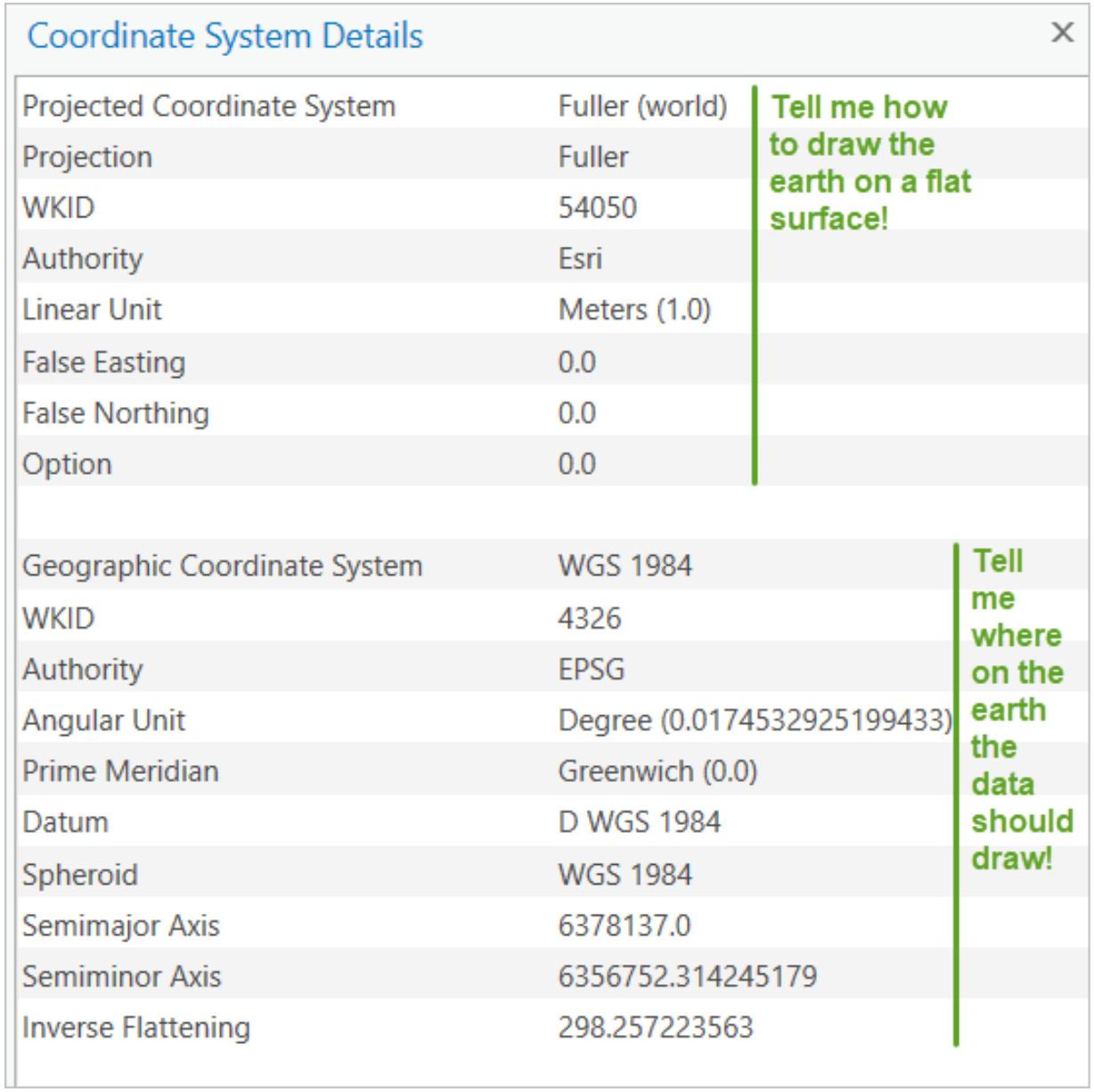
- Key components of a PCS:
  - **Datum**: Defines the model of the Earth's shape used in the projection (e.g., WGS 84, NAD 83).
  - **Projection**: The mathematical transformation that flattens the Earth's surface.
  - **Units of Measurement**: Specifies the linear units (e.g., meters, feet) used to define distances on the flat map.
  - **False Easting/Northin**g: Adjusts the origin point (0,0) to avoid negative coordinates, often for convenience in local regions.

Don’t be confused
GCS and PCS

	GCS	PCS
Surface	3D (Curved surface of the Earth)	2D (Flattened surface)
Coordinate Units	Angular (degrees, minutes, seconds)	Linear (meters, feet, etc.)
Datum	Defines the shape of the Earth (e.g., WGS 84, NAD 83)	Uses a datum + projection
Measurement Accuracy	Not accurate for distances and areas on a flat map	Accurate for distance, area, and angle measurements
Distortion	No distortion but doesn't work well on flat maps	Distortion in shape, area, or distance, depending on projection
Use	Global or large-area representation	Local/regional, precise mapping, measurement

Don’t be confused
GCS and PCS

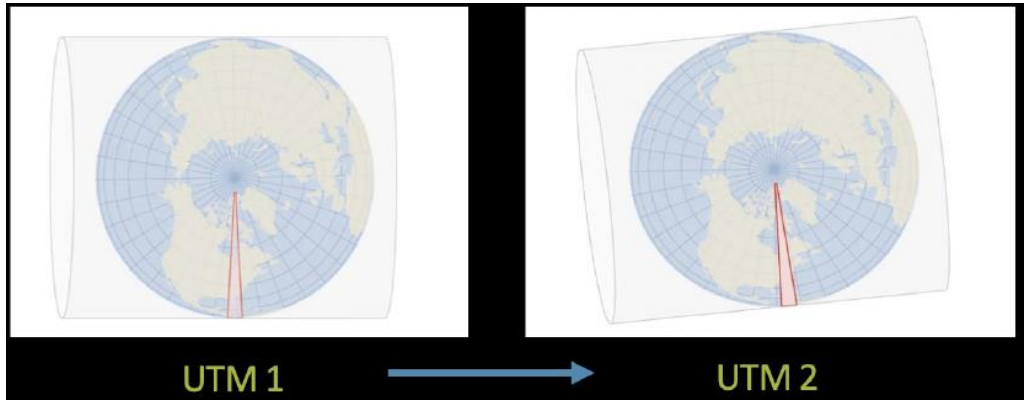
- A PCS is a **GCS** that has been flattened using a map projection.
- Your data must have a GCS before it knows where it is on earth. **There has to be GCS first, and then a PCS**
- Projecting your data is optional, but projecting your map is not. Maps are flat, so your map must have a PCS in order to know how to draw.



Common PCS - Universal Transverse Mercator (UTM)

- Each UTM zone is of 6° of longitude, and there are total 60 UTM zones (North and South).

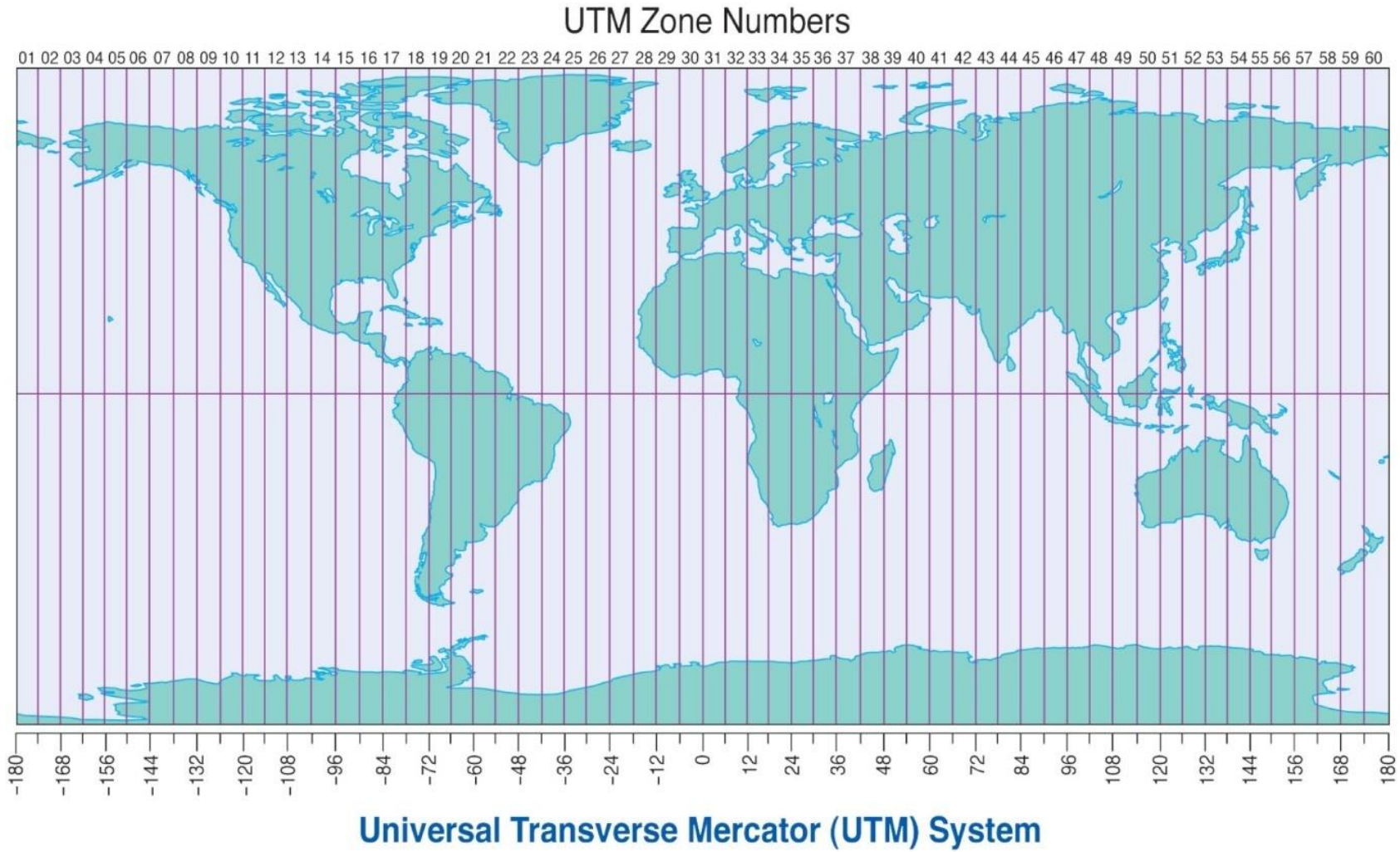
Beginning at 180º, Transverse Mercator projections are obtained every 6 degrees of longitude, along a central meridian.



- The meridian is the line of tangency and the central line of each zone.
- There is no distortion at the meridian line
- Works great for large scale data sets and satellite image rectification, though some areas cross zones (PA, NC, TN, etc.).
- Linear unit: Meters

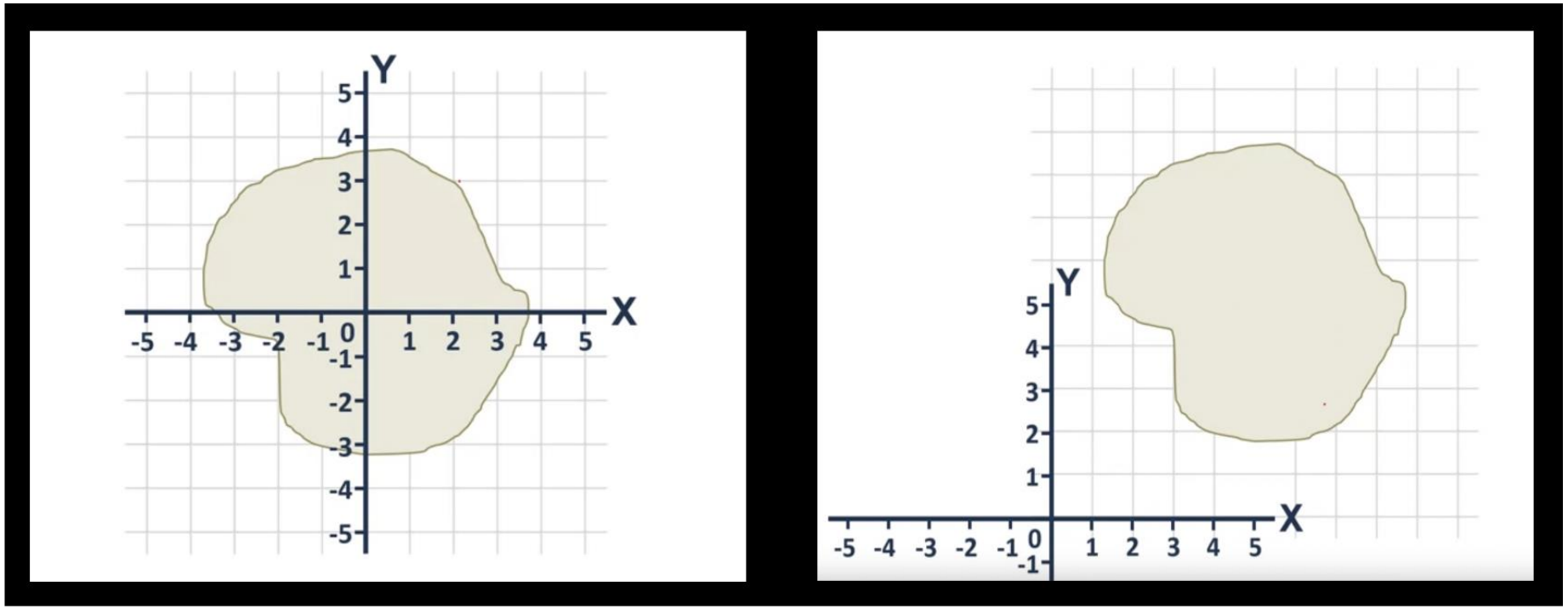
Common PCS - Universal Transverse Mercator (UTM)

- 60 N-S zones spanning 6^{o} of longitude each (0.5^{o} overlap each side) from 84^{o} N - 80^{o} S.
- Zones begin at 180^{o} and are numbered eastward, 1-60.
- Ithaca: Zone 18N



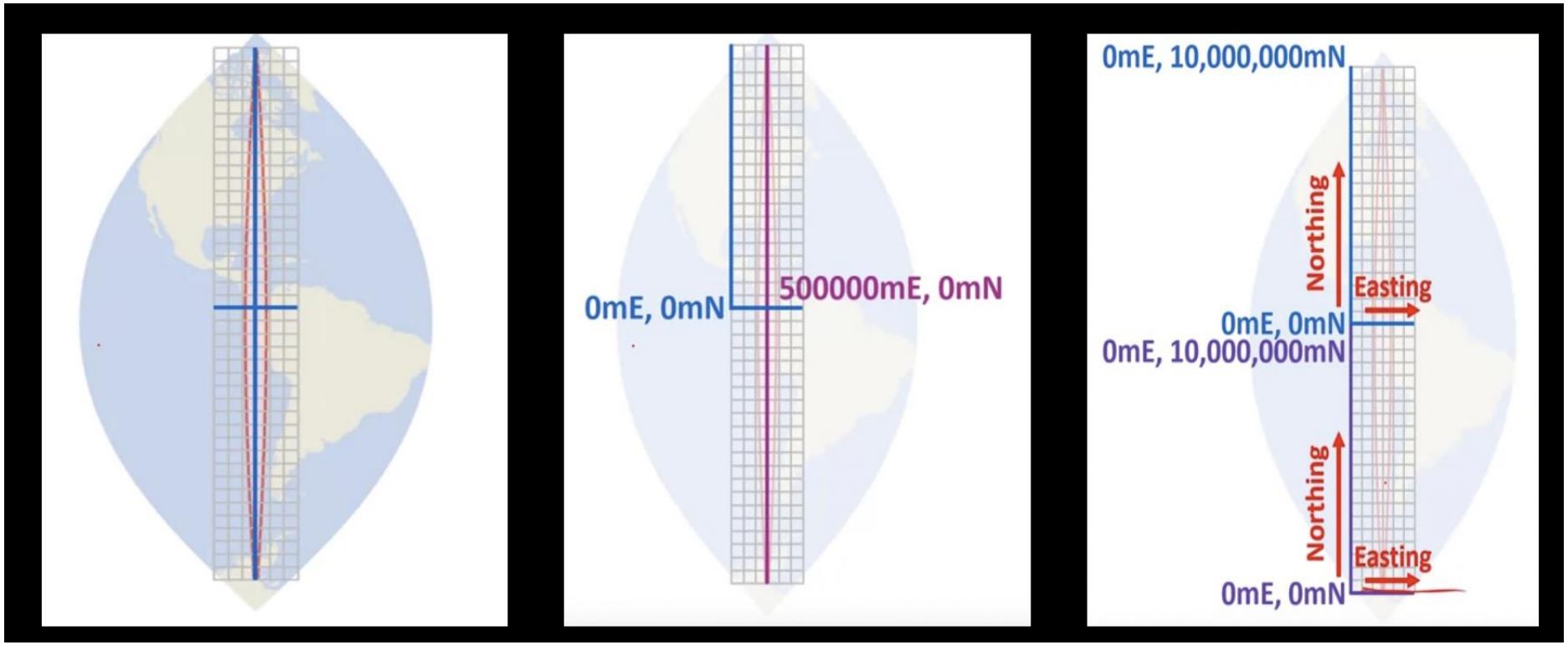
Common PCS - Universal Transverse Mercator (UTM)

- After the UTM projection, a Cartesian Coordinate System is placed on top of it, make it easier for us to measure distance!



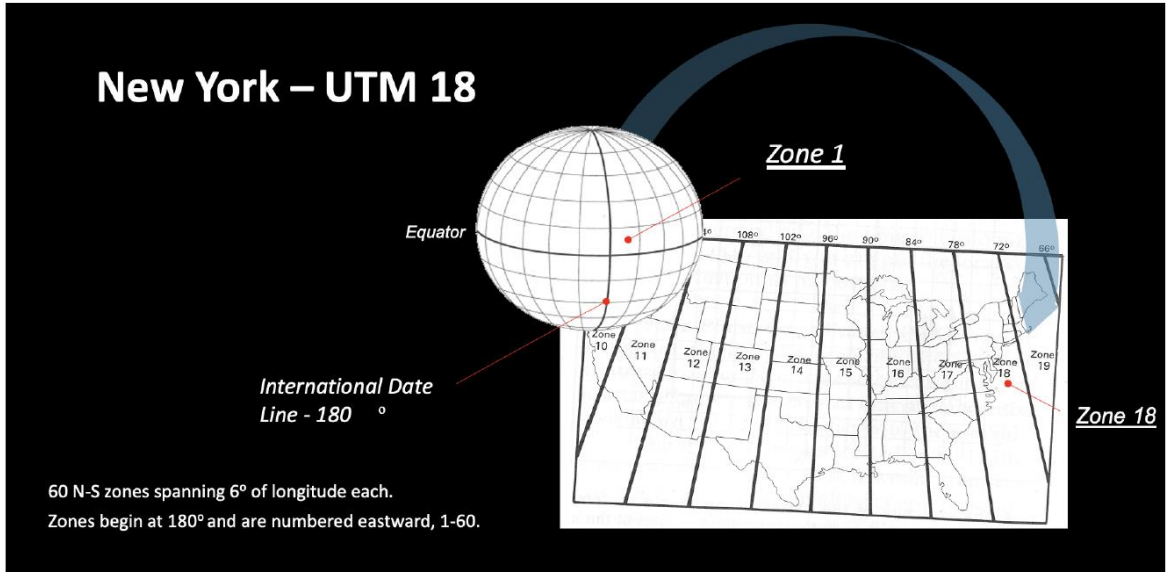
Common PCS - Universal Transverse Mercator (UTM)

- In order to avoid negative value within the Cartesian Coordinate System, a false easting value of 500,000 meters is applied for all regions, and a false northing value of 10,000,000 meters is applied for only regions in the southern hemisphere.



Common PCS - Universal Transverse Mercator (UTM)

Example of NYS



NYS: Zone 18N

Spatial Reference

Projected Coordinate System	NAD 1983 (2011) UTM Zone 18N
Projection	Transverse Mercator
WKID	6347
Previous WKID	102387
Authority	EPSG
Linear Unit	Meters (1.0)
False Easting	500000.0
False Northing	0.0
Central Meridian	-75.0
Scale Factor	0.9996
Latitude Of Origin	0.0

PCS (projection) + GCS

Geographic Coordinate System	NAD 1983 (2011)
WKID	6318
Previous WKID	104145
Authority	EPSG
Angular Unit	Degree (0.0174532925199433)
Prime Meridian	Greenwich (0.0)
Datum	D NAD 1983 2011
Spheroid	GRS 1980
Semimajor Axis	6378137.0
Semiminor Axis	6356752.314140356
Inverse Flattening	298.257222101

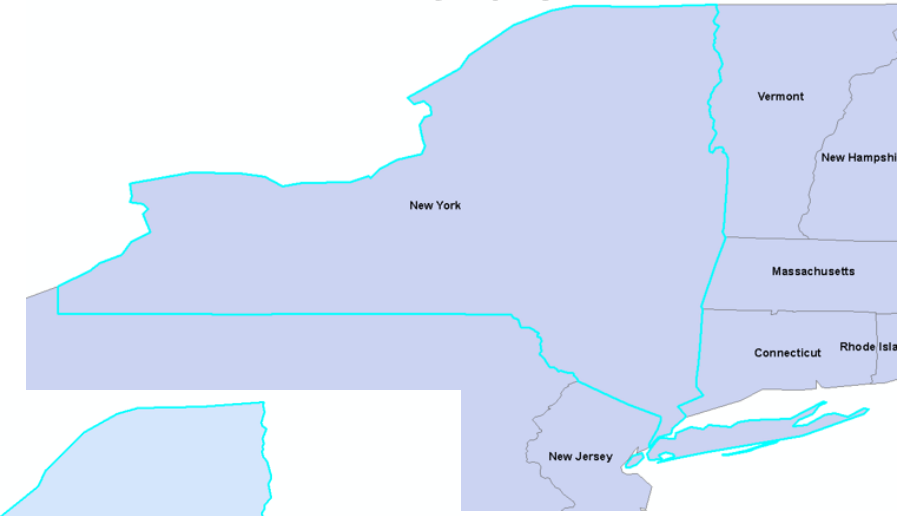
GCS

Define UTM Zone 18N in ArcGIS Pro

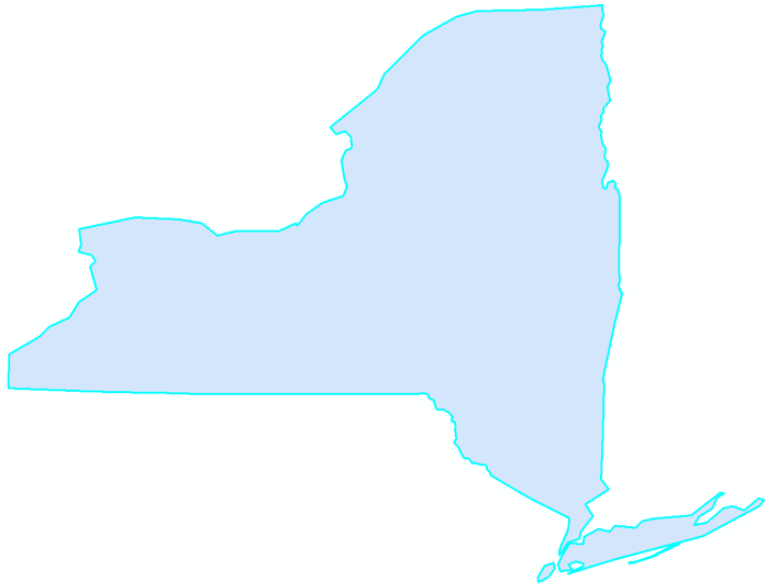
Common PCS - Universal Transverse Mercator (UTM)

PCS - Albers Equal Area Conic

GCS



PCS –UTM Zone 18N



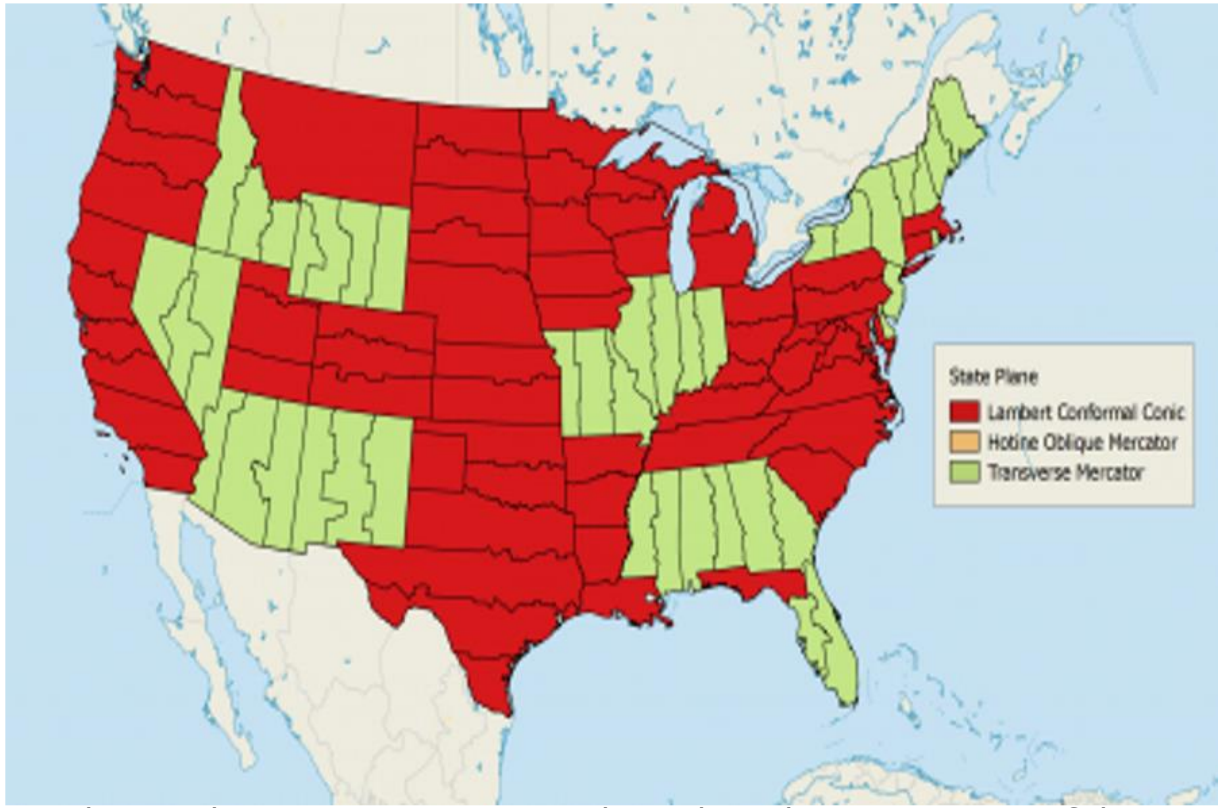
Common PCS - Universal Transverse Mercator (UTM)

Choose the right projection…

Common PCS - State Plane (U.S only)

The State Plane **Coordinate System** (SPCS): a set of 125 (not including one for Puerto Rico and US Virgin Island) geographic zones designed for specific regions of the United States.

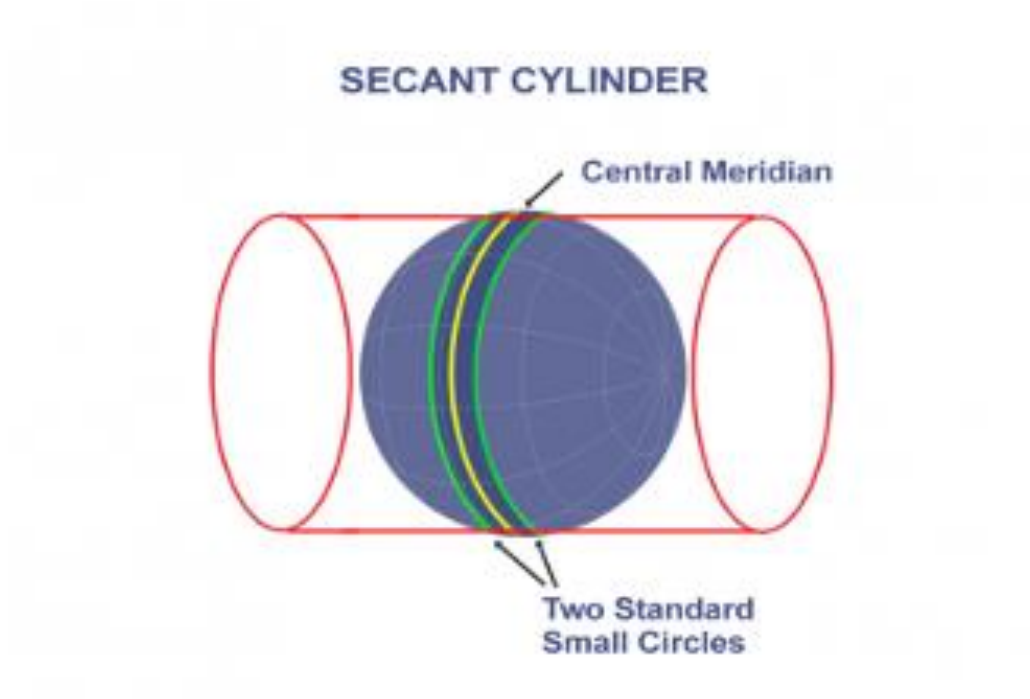
- Each state contains **one or more state plane zones**,.
- There are 110 zones in the contiguous US, with 10 more in Alaska, 5 in Hawaii, and one for Puerto Rico and US Virgin Islands.
- **Distortion over small areas is minimal (high level of accuracy)**
- **Linear unit: US feet**



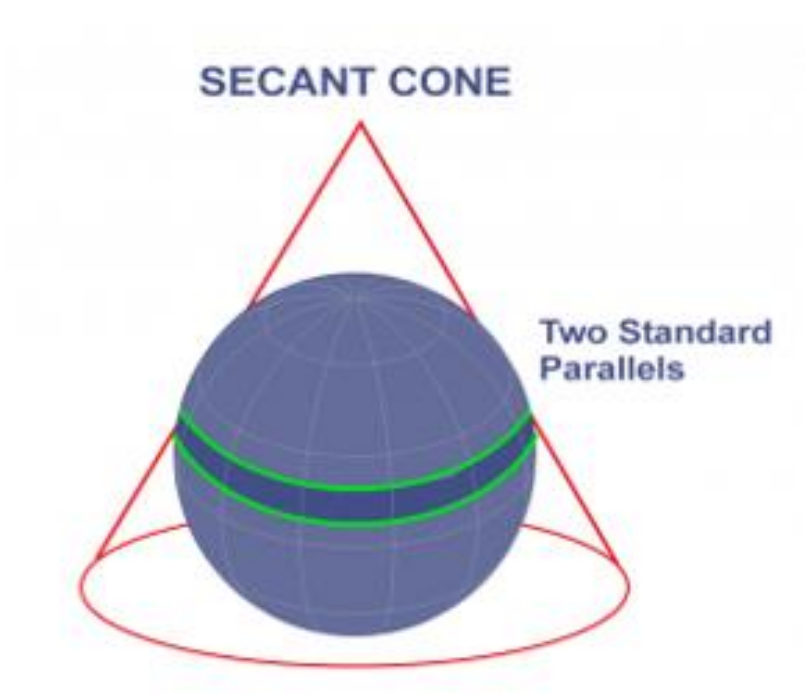
Each zone has its own projection based on the orientation of the state.

Common PCS - State Plane (U.S only)

North-south orientation: Transverse Mercator Projection



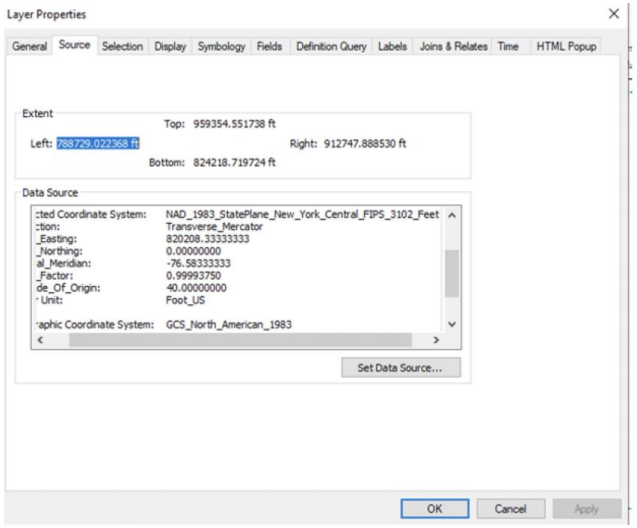
East-west orientation: Lambert Conformal Conic Projection

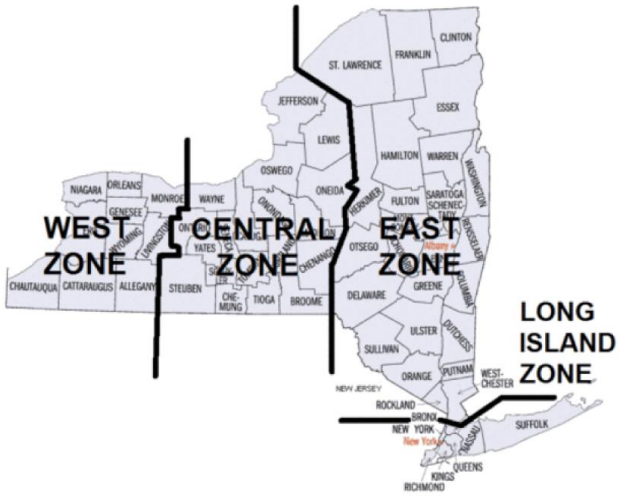


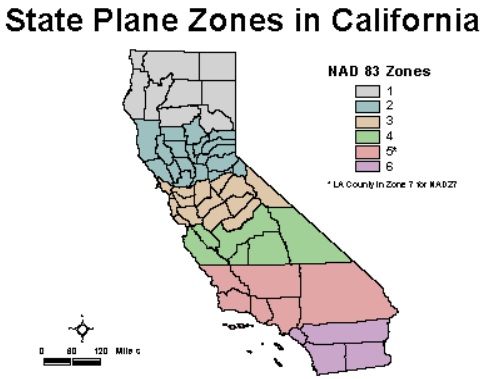
Common PCS - State Plane (U.S only)

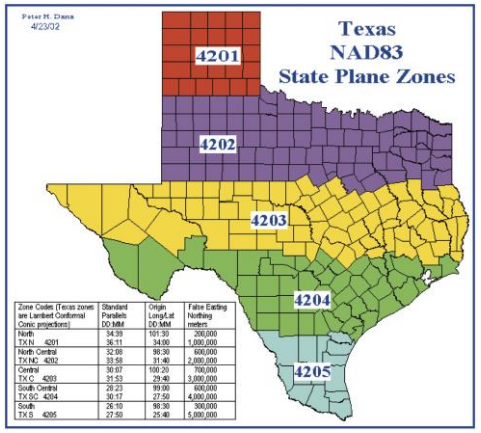
the boundaries of SPCS usually follow county and state lines

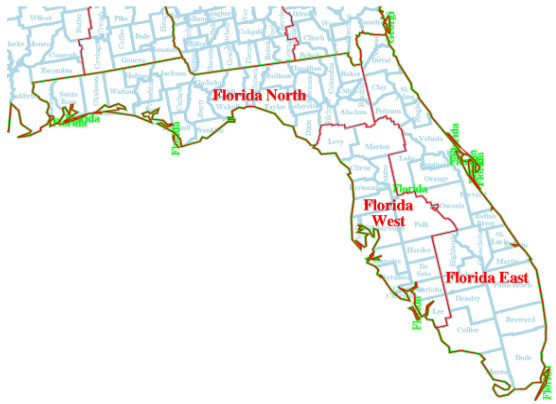
- For Tompkins County: NAD_1983_StatePlane_New_York_Central_FIPS_3102_Feet











Identifying Coordinate Systems in ArcGIS Pro

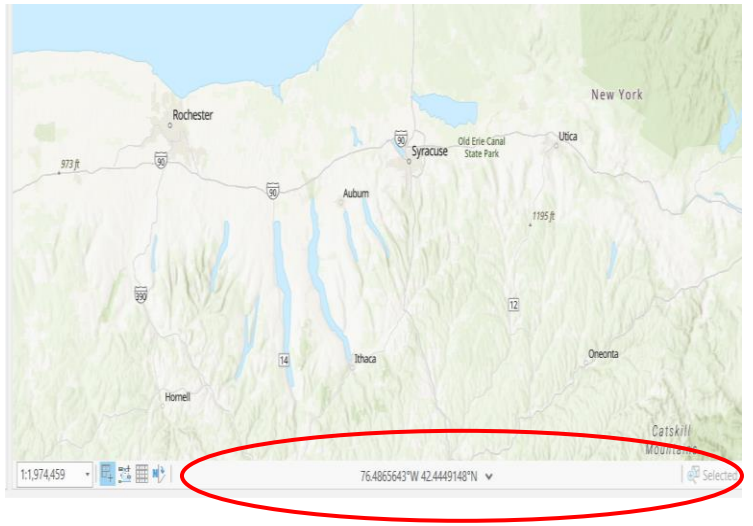
project vs. define projection

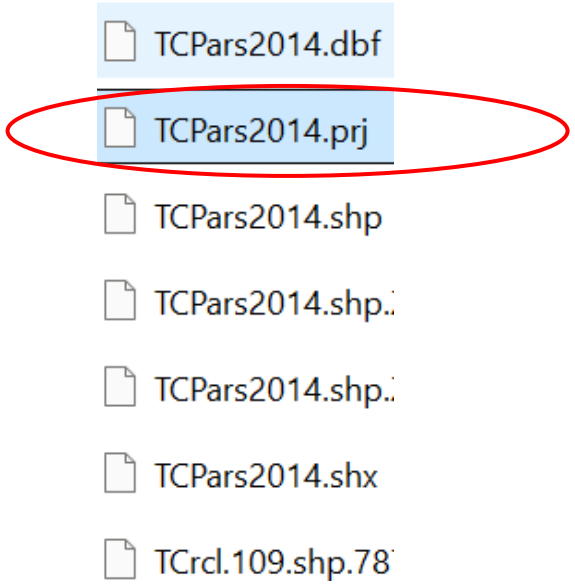
Projection information is stored in a prj file

- Check projection in the Map properties

Projected Coordinate System	NAD 1983 StatePlane New York Central FIPS 3102 (US Feet)
Projection	Transverse Mercator
WKID	2261
Previous WKID	102716
Authority	EPSG
Linear Unit	US Survey Feet (0.3048006096012192)
False Easting	820208.3333333333
False Northing	0.0
Central Meridian	-76.58333333333333
Scale Factor	0.9999375
Latitude Of Origin	40.0

Geographic Coordinate System	NAD 1983
WKID	4269
Authority	EPSG
Angular Unit	Degree (0.0174532925199433)
Prime Meridian	Greenwich (0.0)
Datum	D North American 1983
Spheroid	GRS 1980
Semimajor Axis	6378137.0
Semiminor Axis	6356752.314140356
Inverse Flattening	298.257222101



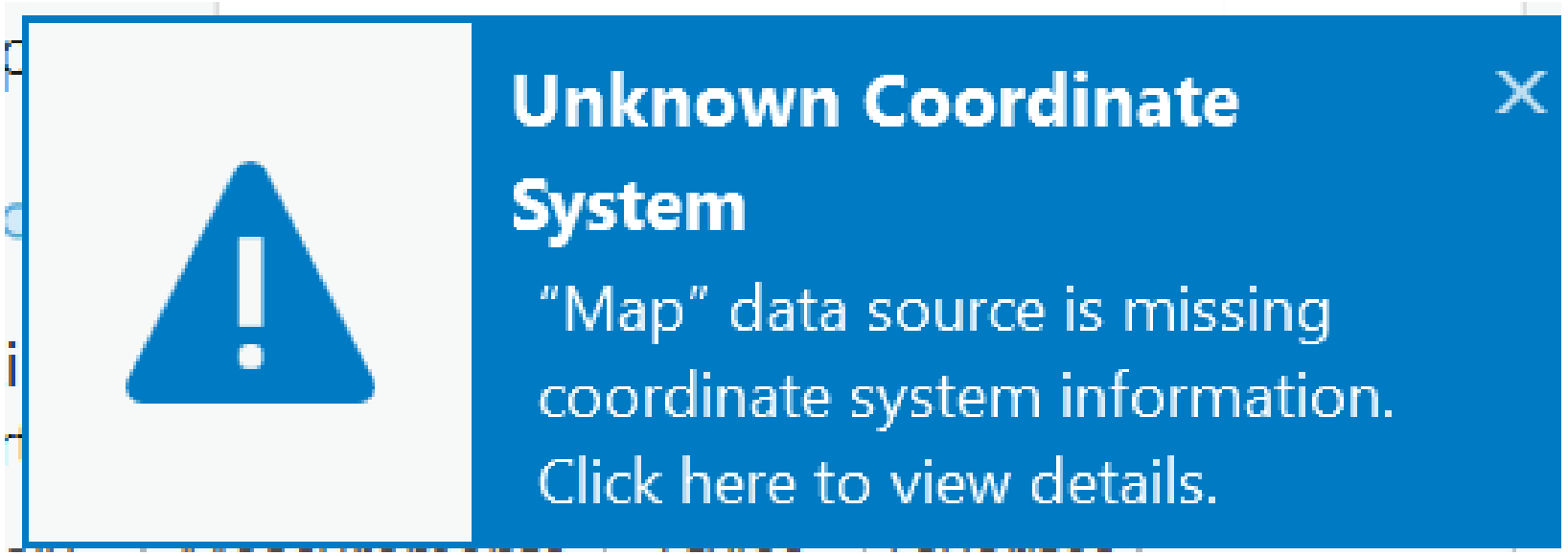


Define projection: if the .prj file is missing

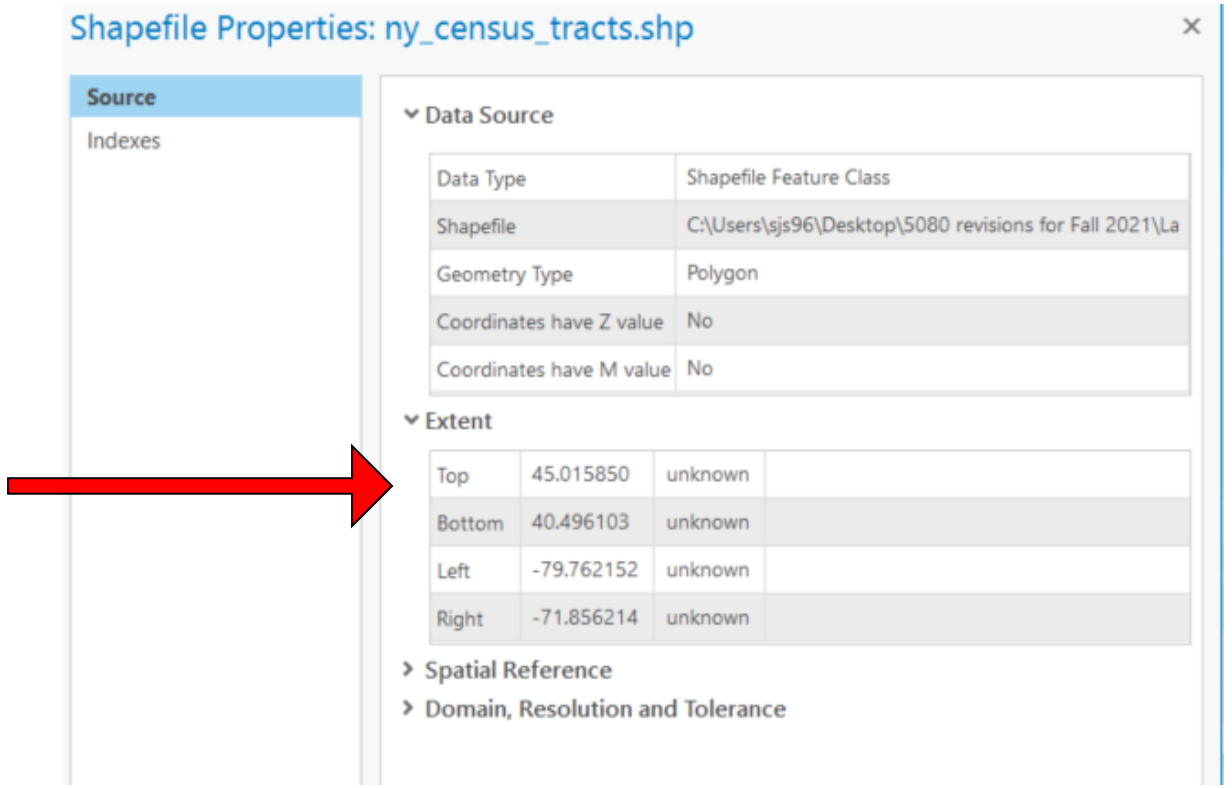
If .prj file is missing, then we must ‘Define Projection’

Use “Define projection” to create a .prj file that tells ArcGIS the coordinate system, projection is otherwise ‘undefined’

Note: All georeferenced data already has a projection!!



How do we know what the projection is if we don't have a prj file?

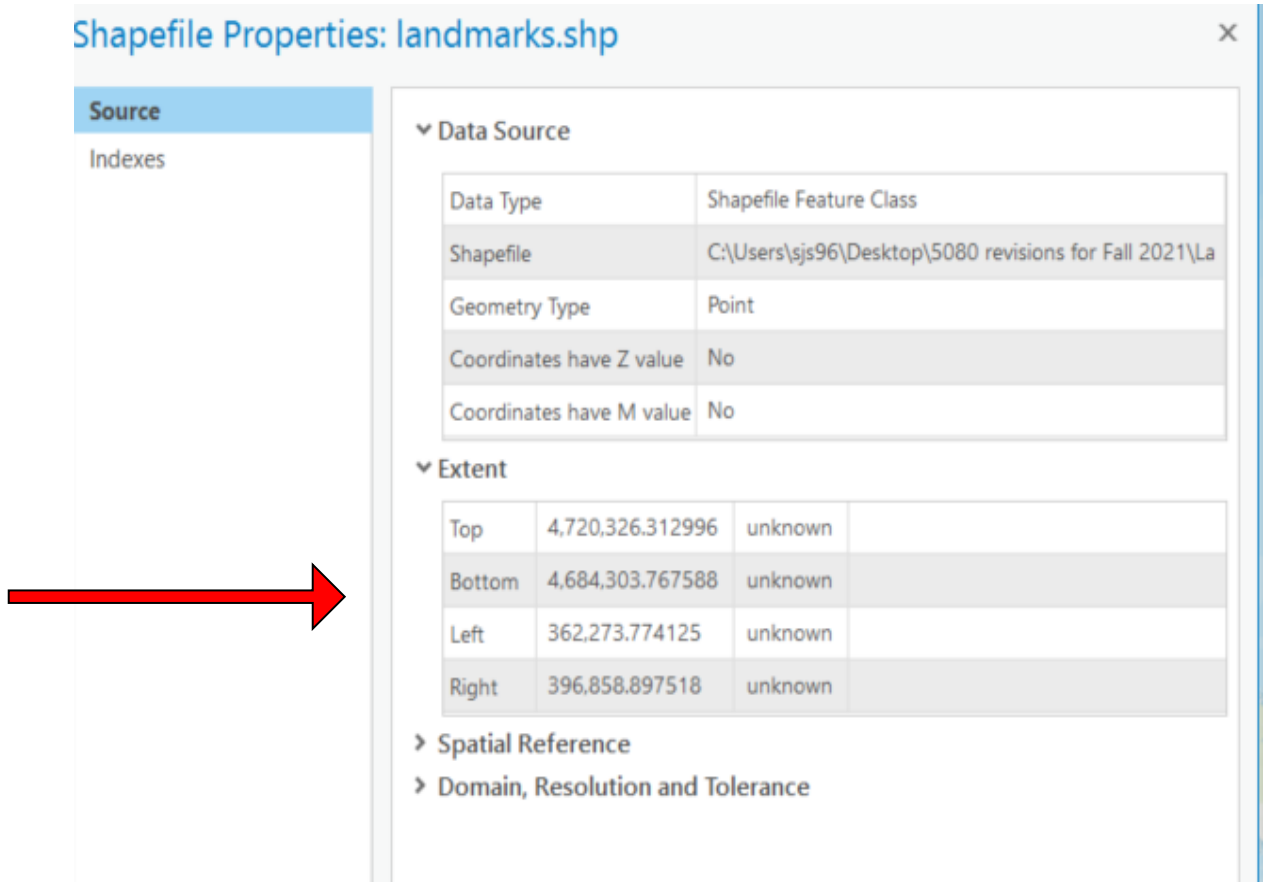


Check the 'source' tab under Shapefile Properties

Coordinate system reads "undefined", but the coordinates listed in the Extent box provide some clues.

If the coordinates are between longitude -180 and +180 and latitude -90 and +90 – this implies that they are in Decimal degrees.

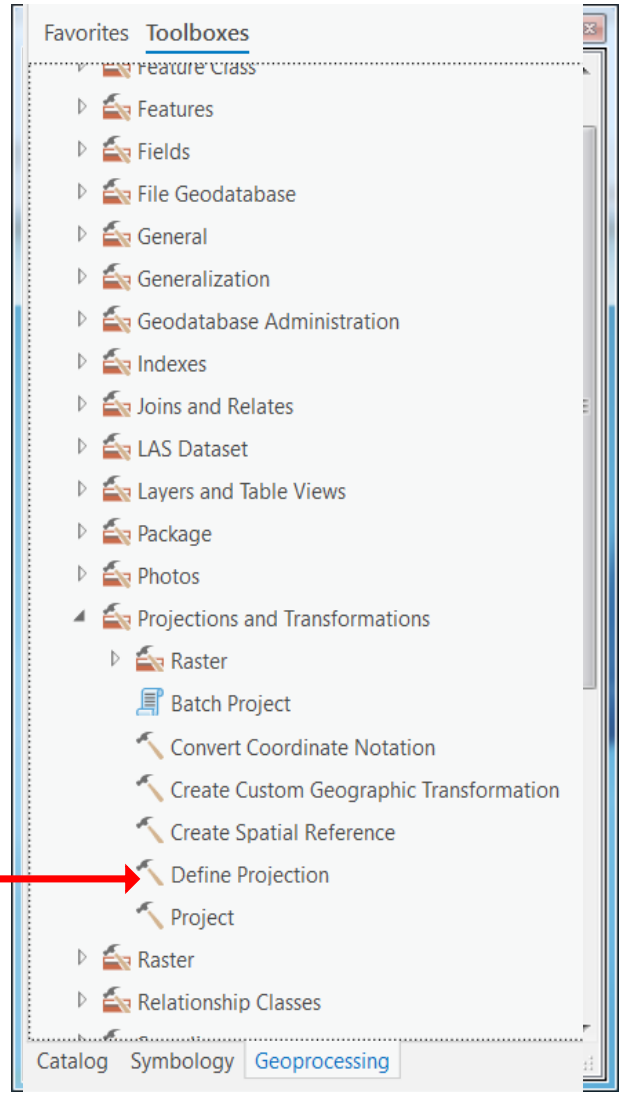
How do we know what the projection is if we don't have a prj file?

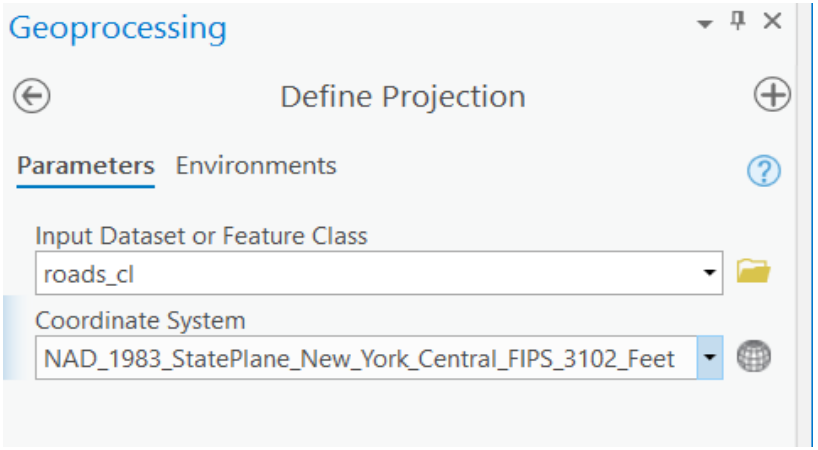


If the coordinates to the left of the decimal are six, seven, or eight digits, the data is probably in State Plane or Universal Transverse Mercator (UTM) coordinate systems

How to tell? Examine properties for data with defined projection

‘Define Projection’ in ArcToolbox



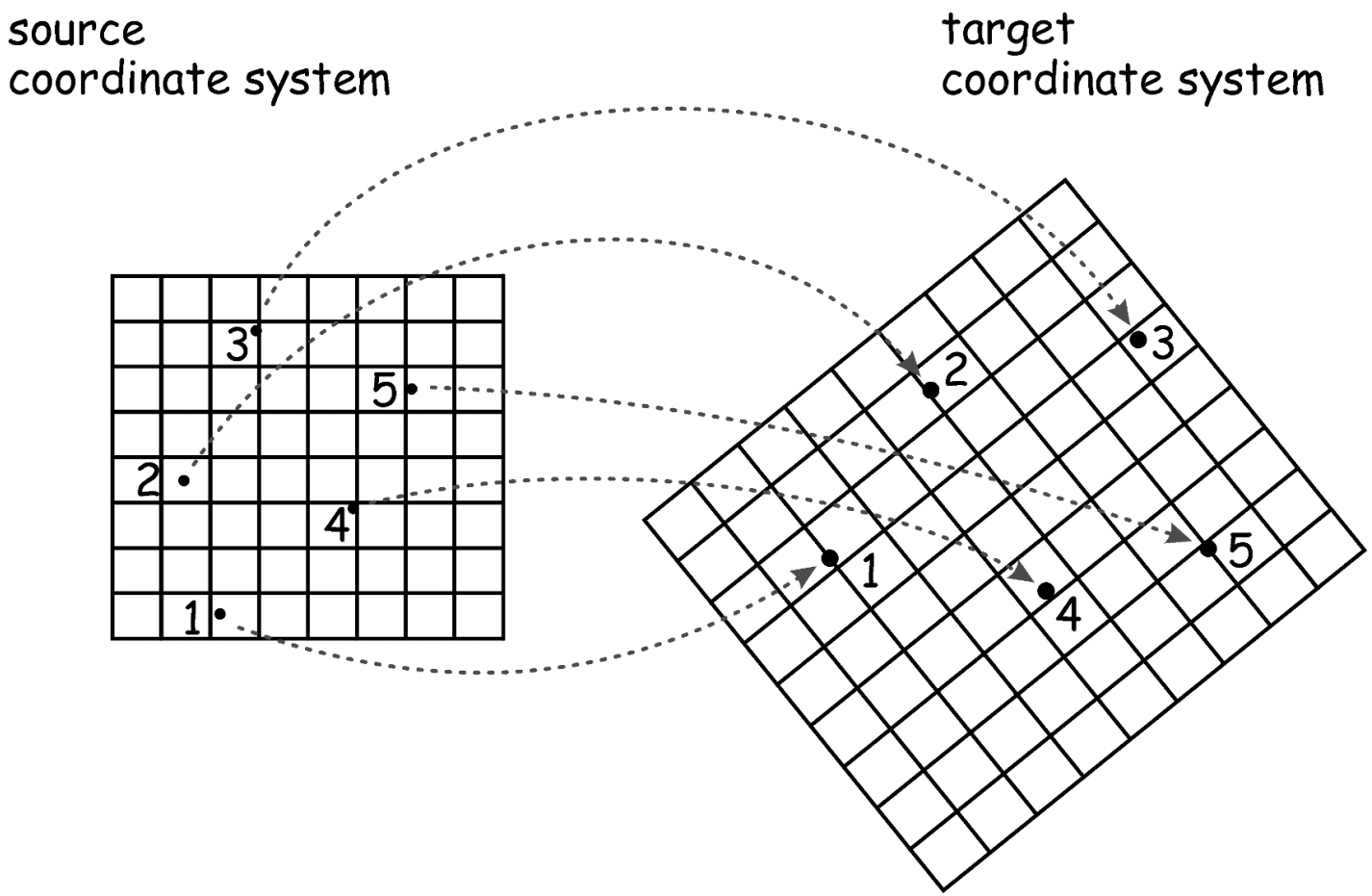


you must specify the **original** or **correct** projection for the dataset based on the clue!!!

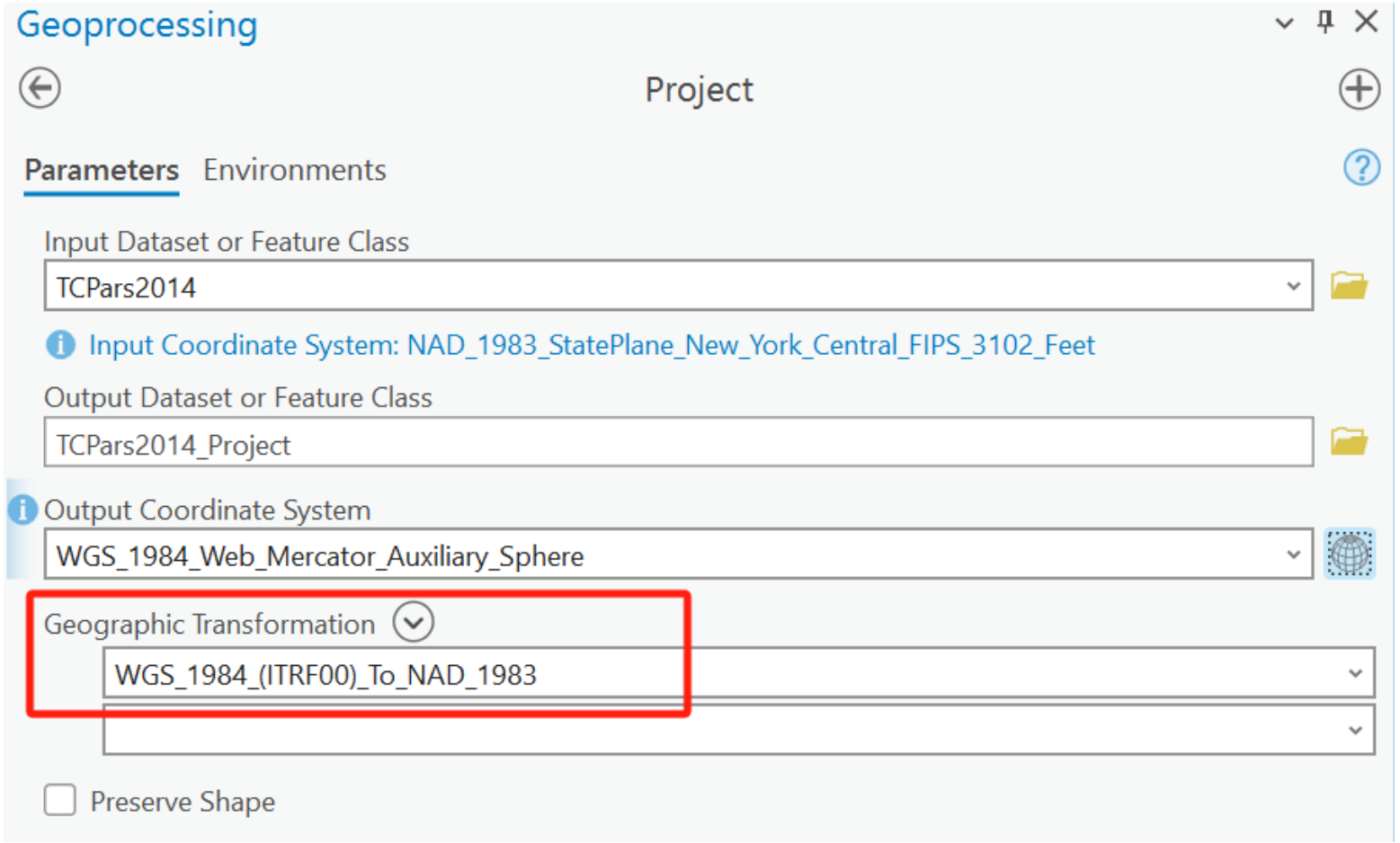
This tool doesn't change the coordinates or reproject the data

Changing a projection: Map Transformations

From one two-dimensional coordinate system to another



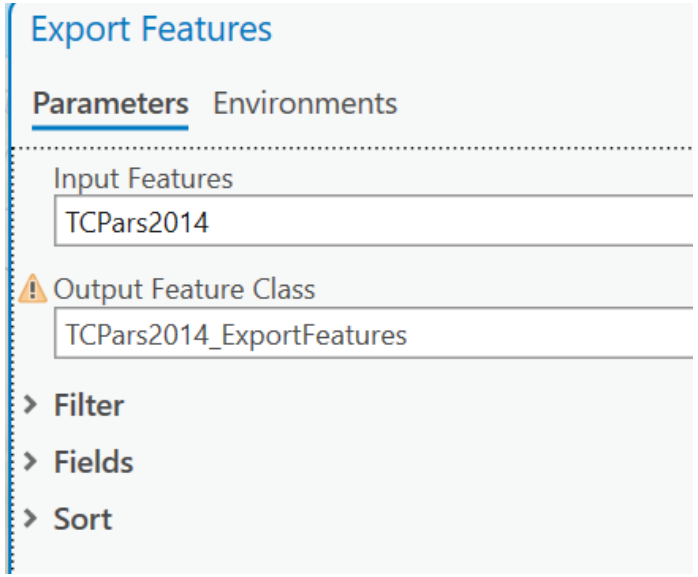
Changing a projection: Method 1

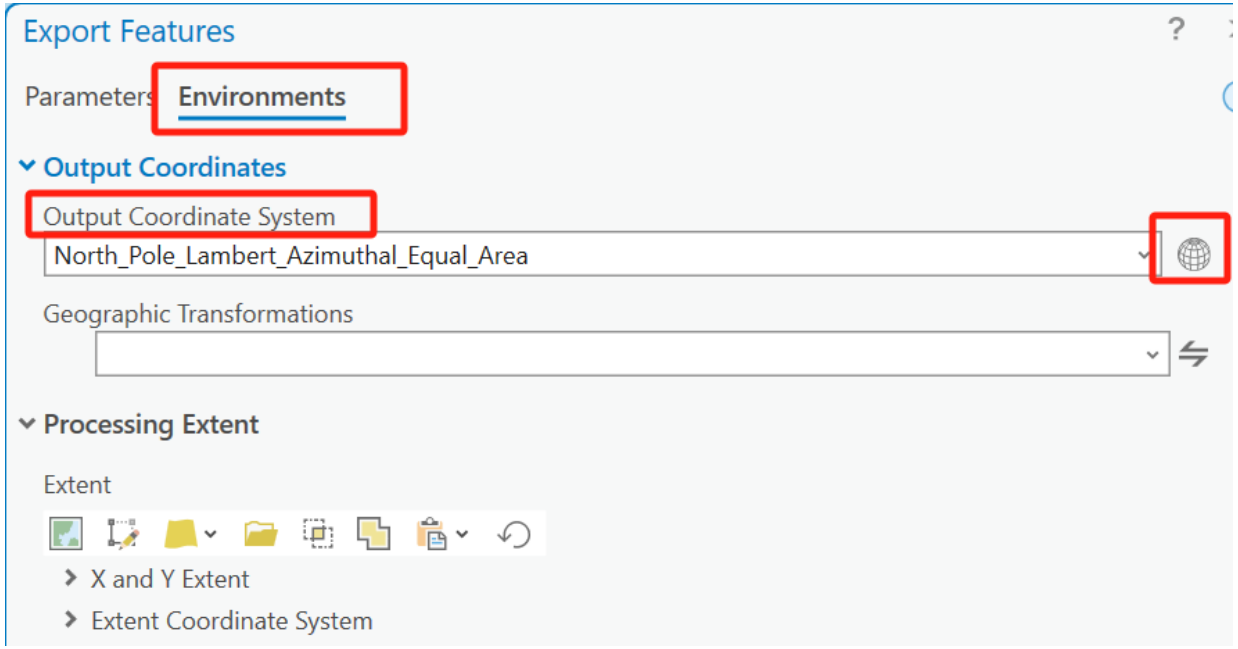


- ArcToolbox Project Tool makes new copies of data sources in a new projection.
- A new .prj file created automatically

Method #2: exporting a layer with a new projection (not recommend)

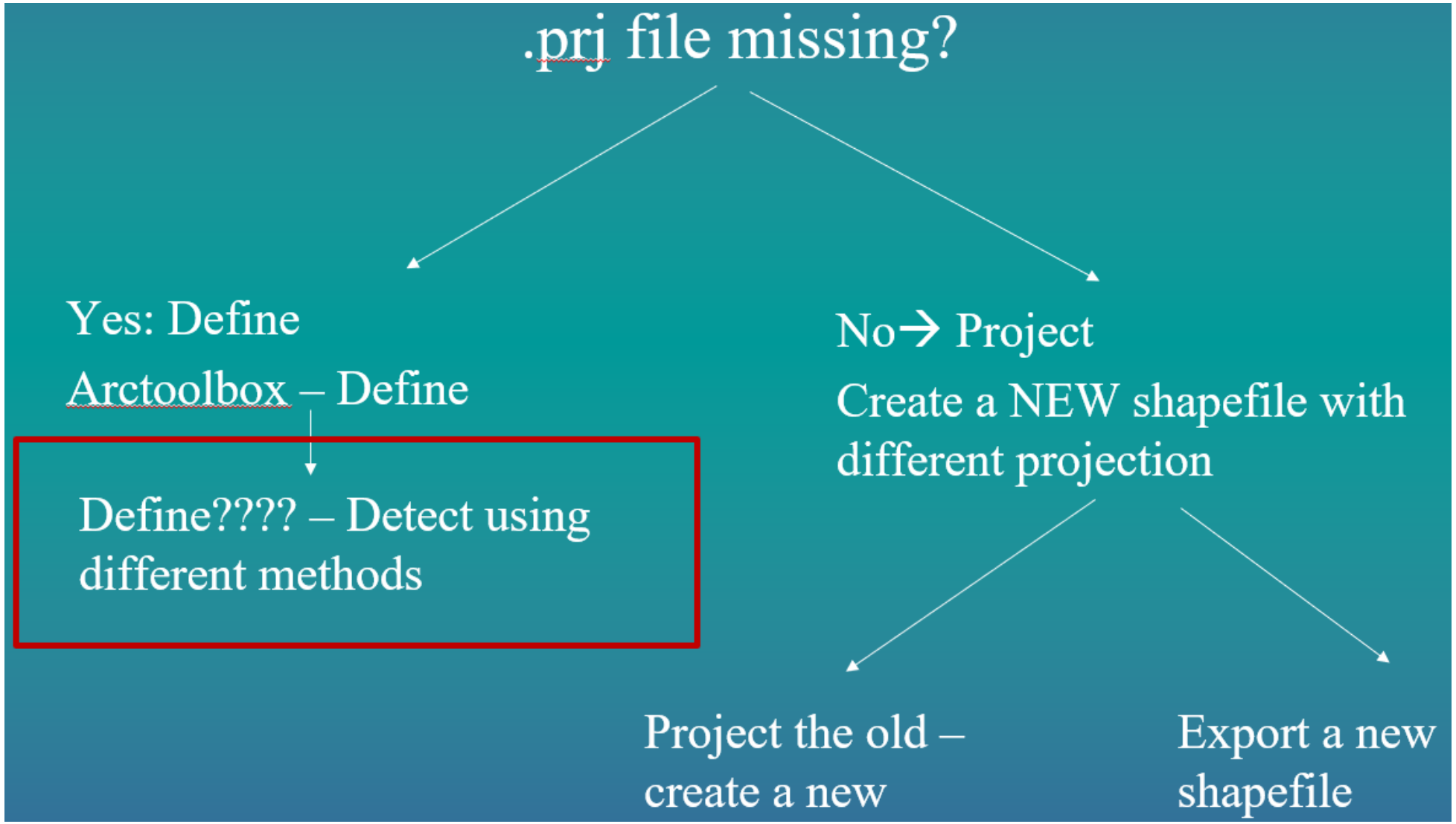
Export the data and set the output coordinate system. as the current dataframe





reprojecting data via Export Features may not prompt you to geographic transformation options - could affect accuracy when you change between datums.

Define a projection or Project



Detect Tompkins County as Example:

GCS or PCS?

Long/Lat or 6,7,8 digits numbers (no negative)

GCS: e.g., (-77, 44) – long/lat - NAD27, NAD83, WGS1984

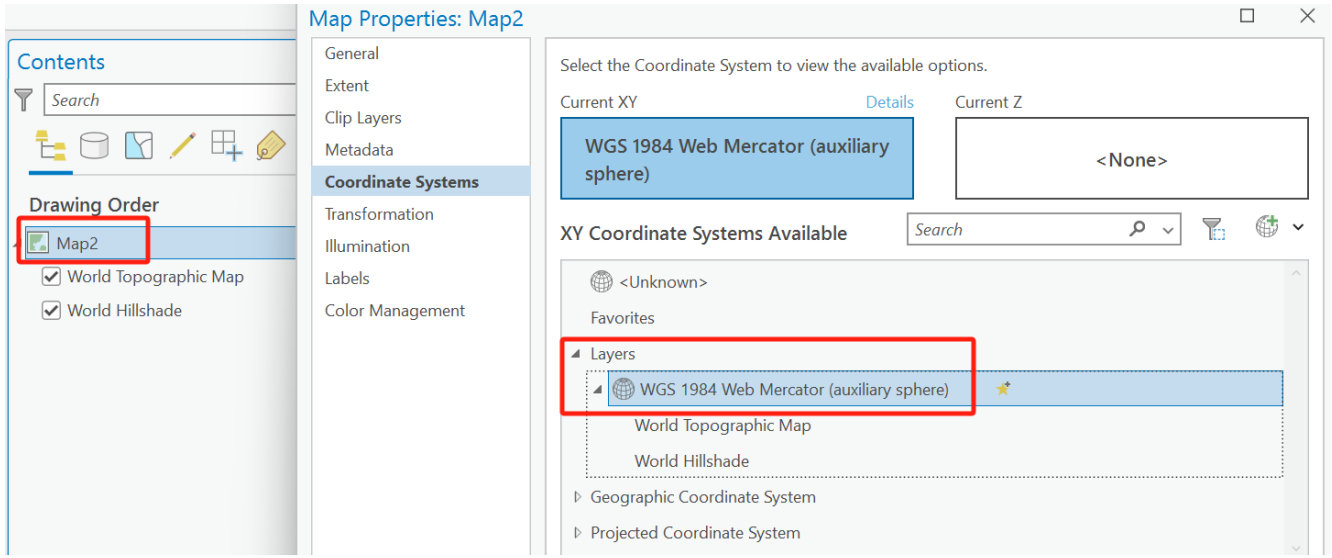
PCS: e.g.,6,7,8 digits of numbers, no negative

??? 800,000, 800,000 → State Plane (feet)

??? 300,000, 4,000,000 → UTM (meter)

Project on the fly

- display layers with different coordinate systems together in the same map without actually changing the underlying data's coordinate system (No Data Modification).



Scenario to use "Project on the Fly"

- Layer 1: A shapefile of roads in Ithaca, NY, using the NAD 1983 StatePlane New York coordinate system.
- Layer 2: A satellite image of the same area using the WGS 1984 Web Mercator coordinate system.

Features:

- **Temporary Display:** layers with different projections temporarily reprojected to the same projection
- **No Data Change:** actual data remains in original coordinate system
- **Not a way to change/define original projection – no .prj created or modified.**

Cool Resources for Map Projection

- Map Projection Transitions: https://www.jasondavies.com/maps/transition/
- Mercator Puzzle: http://bramus.github.io/mercator-puzzle-redux/
- **Why Map Projection?** Why all world maps are wrong (youtube.com)

Identifying Coordinate Systems in ArcGIS Pro

project v.s. define project

Map properties:

Map Unit: The coordinate units in which the geographic data are stored, such as inches, feet, or meters or degrees, minutes and seconds.

Display Unit: The units that ArcGIS will display when the measuring tool is used or the scale bar is created.