Understanding Projections for GIS

Presented by

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Understanding Projections for GIS

Presentation Objectives

To understand basic concepts on projections and coordinate systems for the GIS user. To do this we'll talk about:

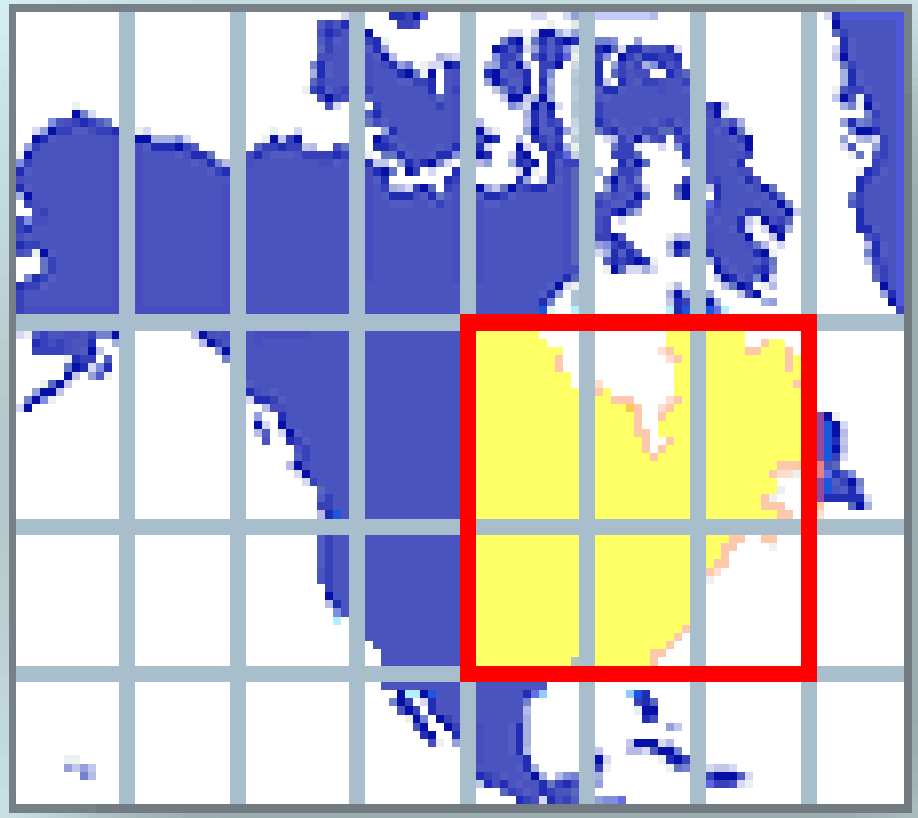
- Terminology – What all those terms really mean
- Geodesy – The shape of the Earth
- Map projections – How we get from a round world to a flat map.
- Map based grid systems – How we locate features on the map from an origin point.
- Working with Projections in ArcGIS

Understanding Projections for GIS

Projection Terminology - *From the ArcGIS Glossary*

Projection(Map Projection) – A method by which the curved surface of the earth is portrayed on a flat surface.

This generally requires a systematic mathematical transformation of the earth's graticule of lines of longitude and latitude onto a plane.



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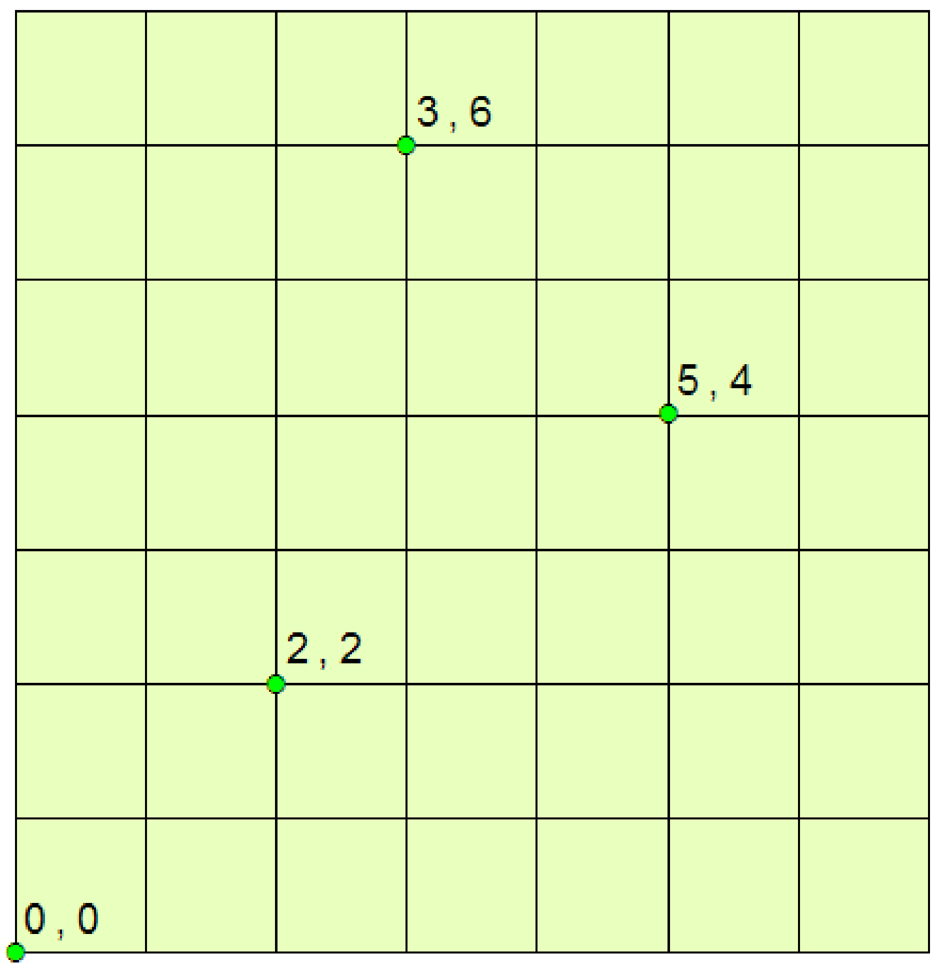
Projection Terminology - *From the ArcGIS Glossary*

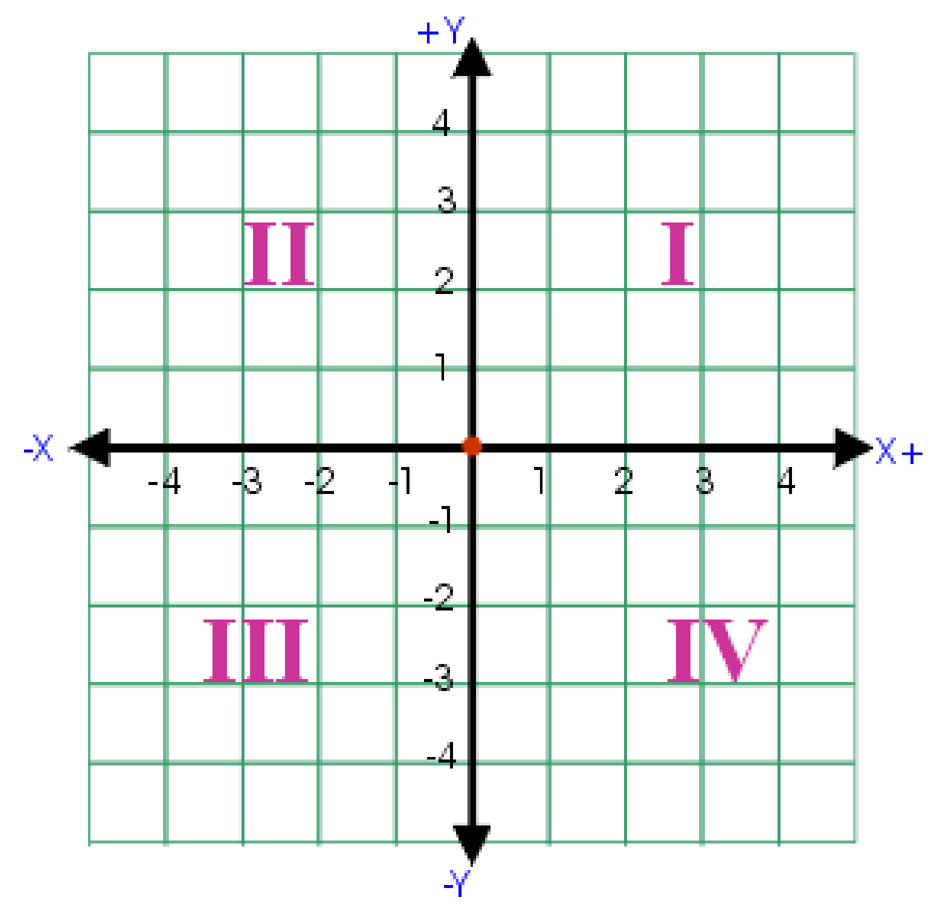
Coordinate System – A reference framework consisting of a set of points, Lines and/or surfaces, and a set of rules, used to define the positions of points in space in either two or three dimensions.

Planar Coordinate System – A two-dimensional measurement system that locates features on a plane based on their distance from an origin (0,0) along two perpendicular axes.



Projection Terminology - *From the ArcGIS Glossary*

Cartesian Coordinate System – A two-dimensional, planar coordinate system in which horizontal distance is measured along an x-axis and vertical distance is measured along a y-axis. Each point on the plane is defined by an x,y coordinate. Relative measures of distance, area, and direction are constant.

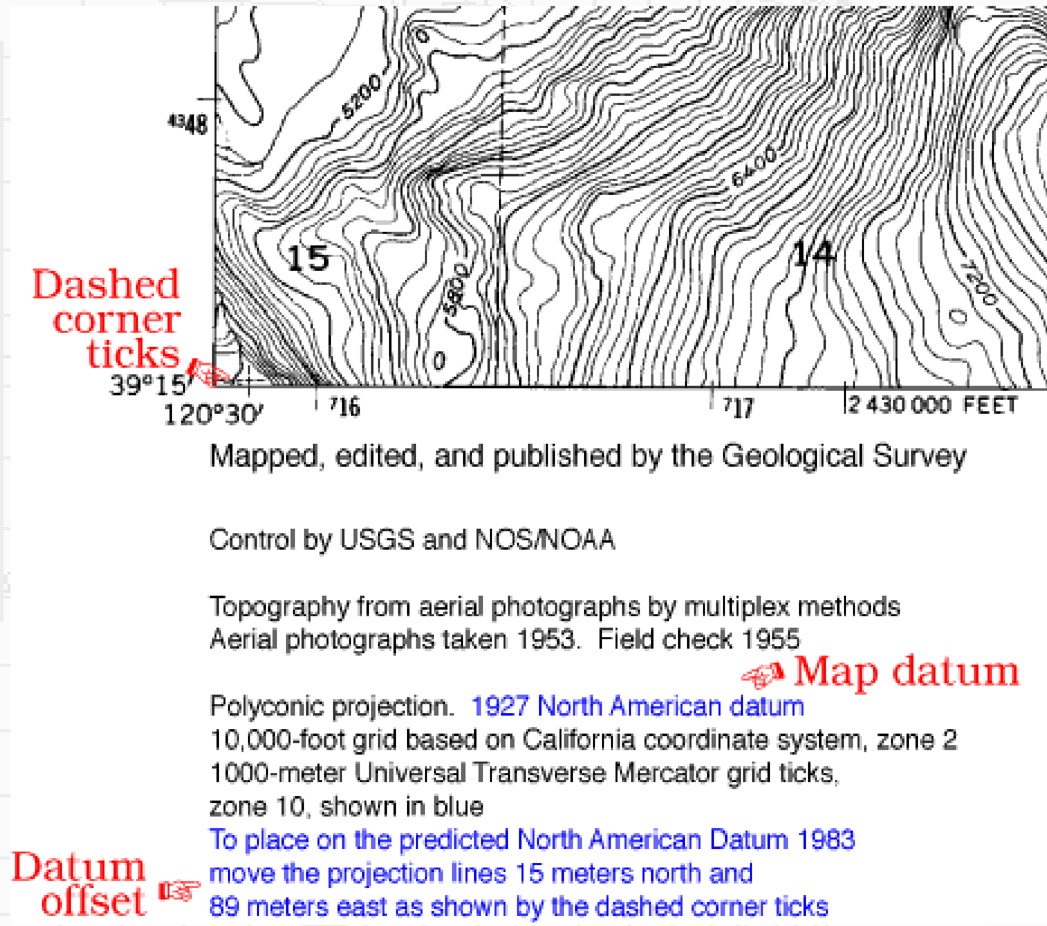


Projection Terminology - *From the ArcGIS Glossary*

Datum – The reference specifications of a measurement system, usually a system of coordinate positions on a surface (a horizontal datum) or heights above or below a surface (a vertical datum).

Geodetic Datum – A datum that is the basis for calculating positions on the earth's surface or heights above or below the earth's surface.

Datums are based on specific Ellipsoids and sometimes have the same name as the ellipsoid.



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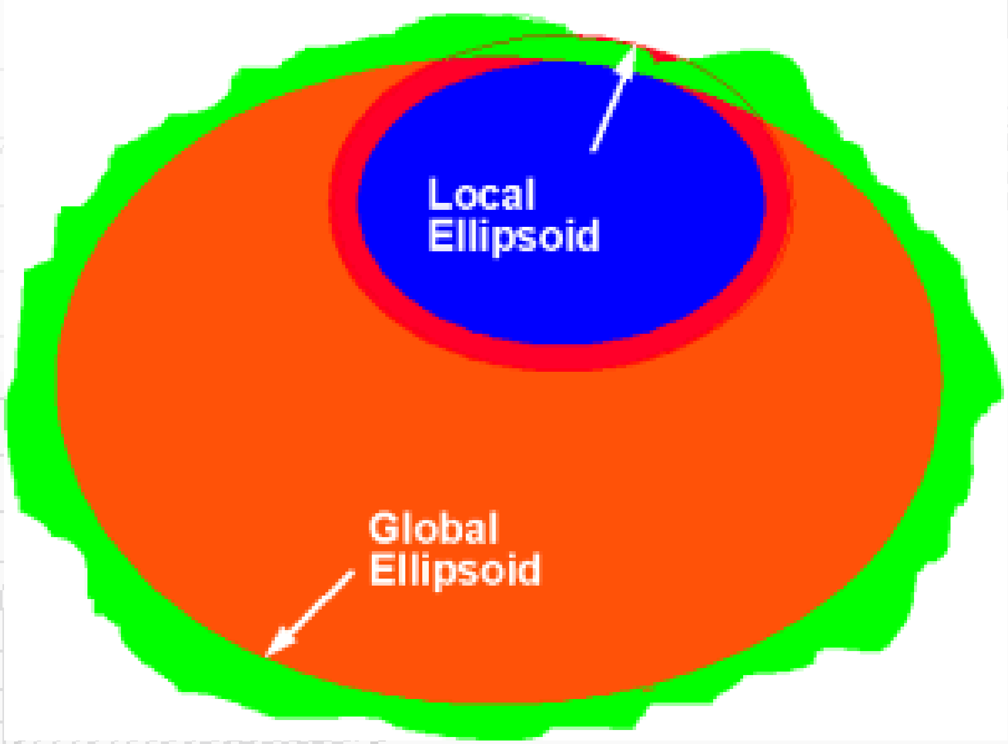
Projection Terminology - *From the ArcGIS Glossary*

Geocentric Datum – A horizontal geodetic datum based on an ellipsoid that has its origin at the earth's center of mass.

Examples are the World Geodetic System of 1984, the North American Datum of 1983, and the Geodetic Datum of Australia of 1994. The first uses the WGS84 ellipsoid; the latter two use the GRS80 ellipsoid.

Geocentric datums are more compatible with satellite positioning systems, such as GPS.

Local Datum – A horizontal geodetic datum based on an ellipsoid that has its origin on the surface of the earth, such as the North American Datum of 1927.



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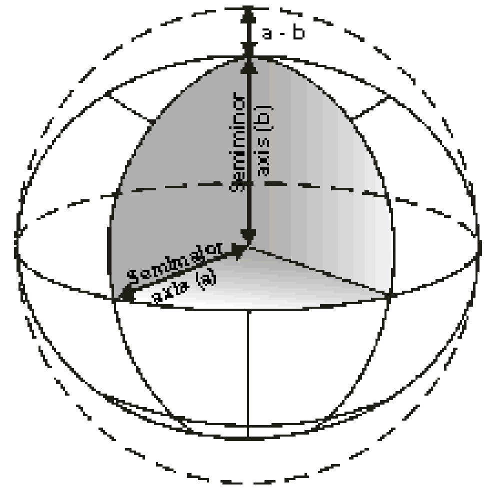
Projection Terminology - *From the ArcGIS Glossary*

Ellipsoid/Spheriod – A three-dimensional, closed geometric shape, all planar sections of which are ellipses or circles.

A three-dimensional shape obtained by rotating an ellipse about its minor axis, with dimensions that either approximate the earth as a whole, or with a part that approximates the corresponding portion of the geoid.

A mathematical figure that approximates the shape of the Earth in form and size, and which is used as a reference surface for geodetic surveys. Used interchangeably with Spheriod. (From Nationalatlas.gov)



Ellipsoid	a (m)	b (m)	*1/f
Airy	6,377,563.396	6,356,256.910	
Australian national	6,378,160		298.25
Bessel	6,377,397.155		299.1528128
Clarke 1866	6,378,206.4	6,356,583.8	
Clarke 1880	6,378,249.145		293.465
Everest	6,377,276.345		300.8017
Hough	6,378,270		297
International	6,378,388		297
Modified Airy	6,377,340.189		
Modified Everest	6,377,304.063		300.8017
South American 1969	6,378,160		298.25
WGS 72	6,378,135		298.26

*Flattening is the ratio of the difference between the semimajor axis and the semiminor axis of the spheroid and its major axis $\frac{(a-b)}{a}$ and may be stated by the numerical value of the reciprocal of the flattening (1/f).

Projection Terminology - *From the ArcGIS Glossary*

Transformation – The process of converting the coordinates of a map or an image from one system to another, typically by shifting, rotating, scaling, skewing, or projecting them.

Geographic Transformation – A systematic conversion of the latitude-longitude values for a set of points from one geographic coordinate system to equivalent values in another geographic coordinate system.

Sometimes called the "**Datum Shift**"

$$\Delta\phi'' = [-\Delta X\sin\phi\cos\lambda - \Delta Y\sin\phi\sin\lambda + \Delta Z\cos\phi + (a\Delta f + f\Delta a)\sin 2\phi]/[R_M \sin 1'']$$

$$\Delta\lambda'' = [-\Delta X\sin\lambda + \Delta Y\cos\lambda]/[R_N\cos\phi\sin 1'']$$

$$\Delta H = \Delta X\cos\phi\cos\lambda + \Delta Y\cos\phi\sin\lambda + \Delta Z\sin\phi + (a\Delta f + f\Delta a)\sin^2\phi - \Delta a$$

Geodesy – Study of the shape of the Earth

The earth was initially thought to be flat.

Later thought to be a sphere.

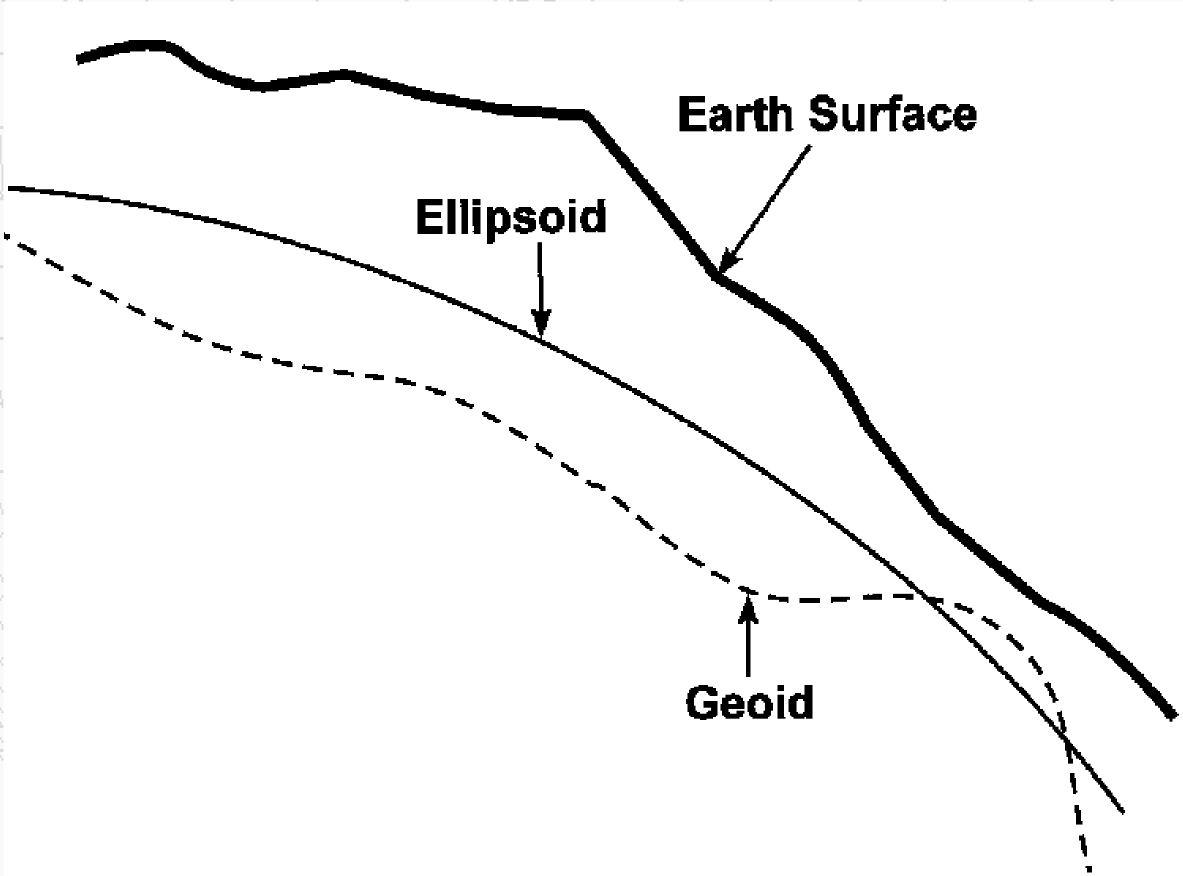
French geographers in the 1730's proved that the earth is an ellipsoid\spheroid.

- Common ellipsoids used now are Clarke 1866, the Geodetic Reference System of 1980(GRS80) and more recently the WGS84 ellipsoid.
- These are just different measurements of the "flattening" at the poles.

Geodesy–Study of the shape of the Earth

...And then there's the Geoid

This is a hypothetical figure of the earth that represents the surface as being at mean sea level, but still influenced by gravitational pull, density of earth's materials, and hydrostatic forces.



Geodesy–Study of the shape of the Earth

Ellipsoid or Geoid??

This effects how elevation is measured, and also can effect the location of a point on the earth.

When working between different coordinate systems, you may need to know how elevation is being measured:

- Height above Ellipsoid (HAE)
- Height above Geoid (HAG)
- In Bend, Oregon the ellipsoid is about 64’ below the geoid.

Measuring the Earth in 3D–Latitude and Longitude

Latitude/Longitude measures in degrees — not in distance. The actual length of a degree changes over different parts of the earth.

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Measuring the Earth in 3D–Latitude and Longitude

Location North or South (Latitude) is measured from the Equator

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Measuring the Earth in 3D–Latitude and Longitude

Location East or West (Longitude) is measured from the Prime Meridian

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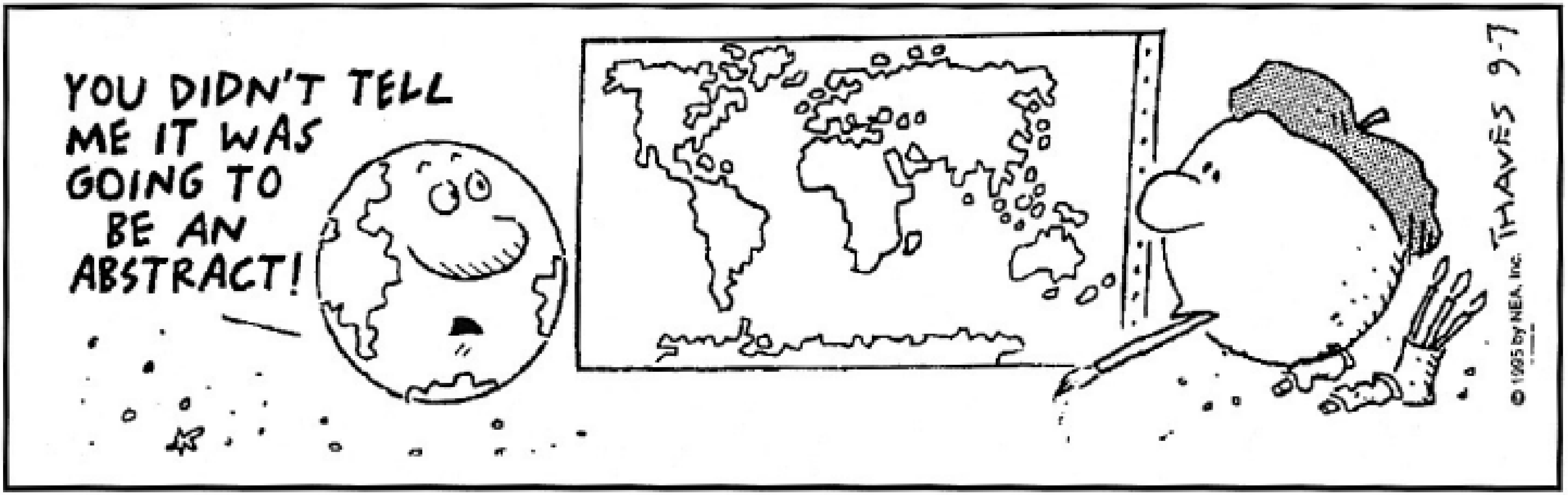
Projections–Going from 3D to Flat Maps

“The transformation of the round earth onto a flat surface using Latitude and Longitude as a reference.”

FRANK & ERNEST by Bob Thaves



Projections–Going from 3D to Flat Maps

Distortion – Impossible to flatten a round object without distortion.

Projections try to preserve one or more of the following properties:

- Area – sometimes referred to as equivalence
- Shape – usually referred to as “conformality”
- Direction – or “azimuthality”
- Distance

When choosing a projection, consider what type of measurement is important.

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Projections–Going from 3D to Flat Maps

The World as seen from Space in 3D

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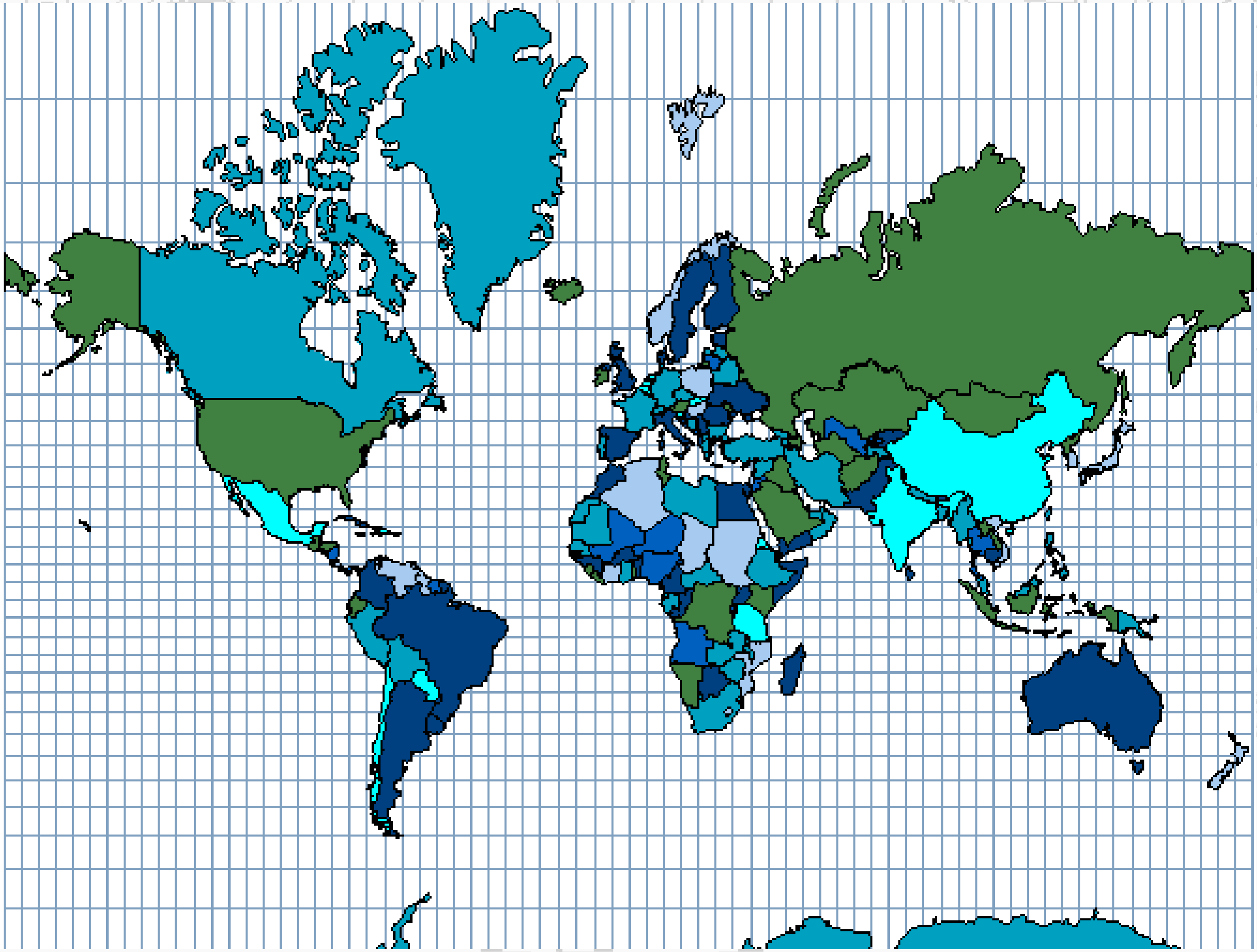
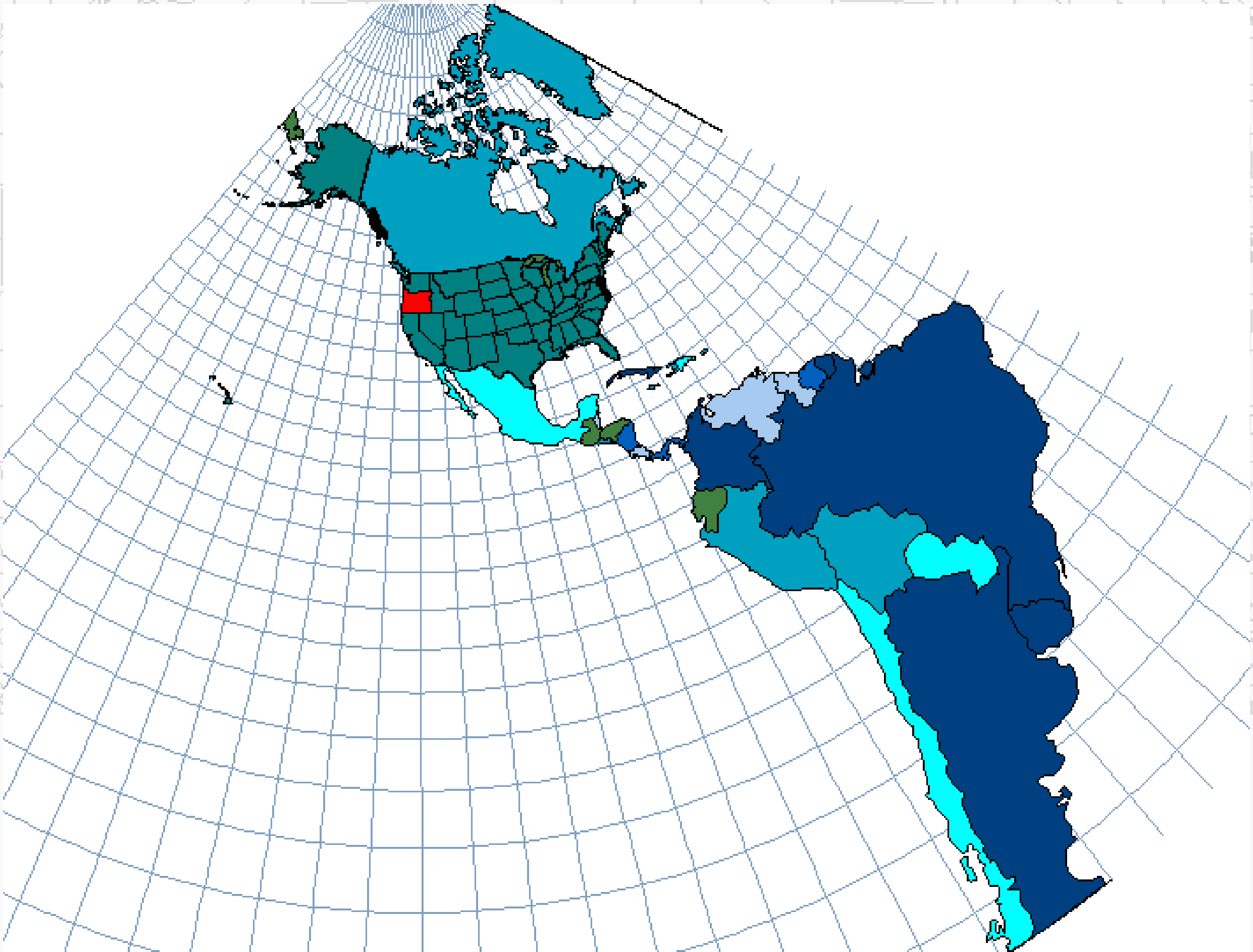
Projections–Going from 3D to Flat Maps

The World Projected onto a Flat Surface



Projections–Going from 3D to Flat Maps

The World as seen from an Oregon perspective



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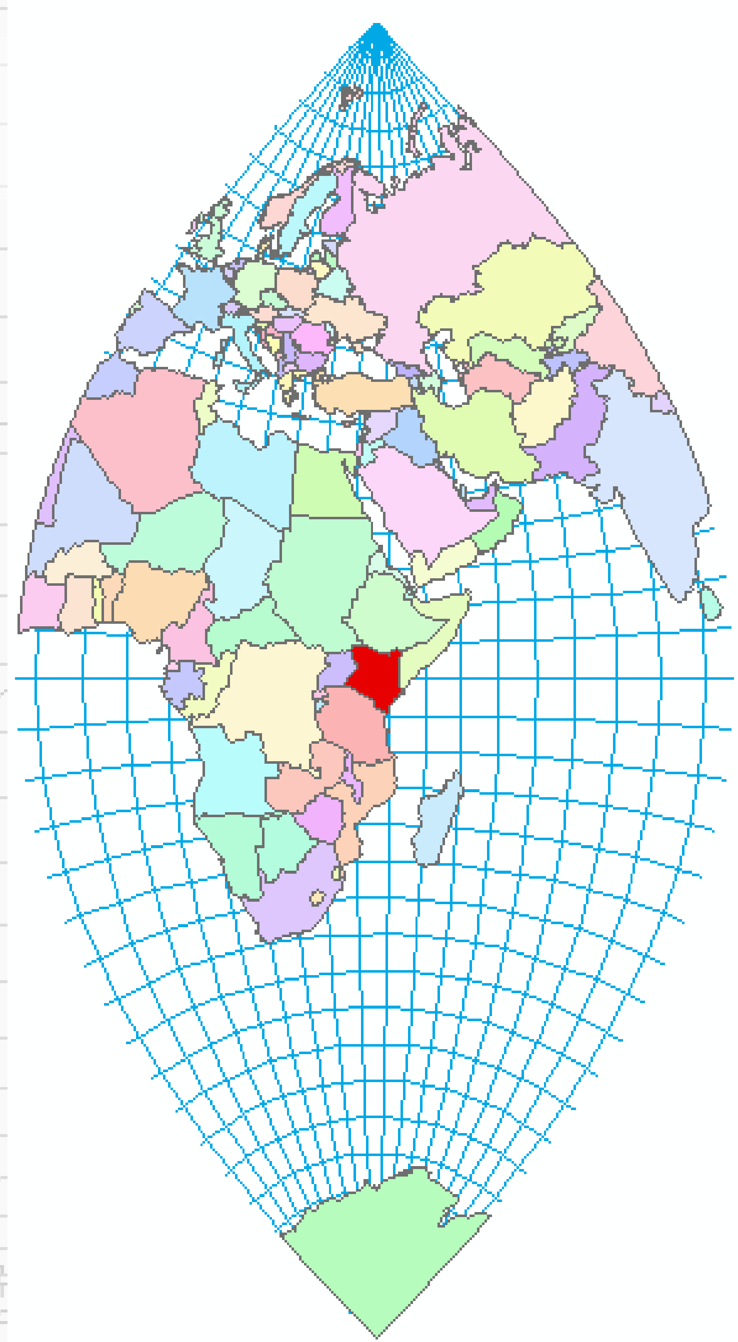
Projections–Going from 3D to Flat Maps

The World as seen from a Kenyan perspective



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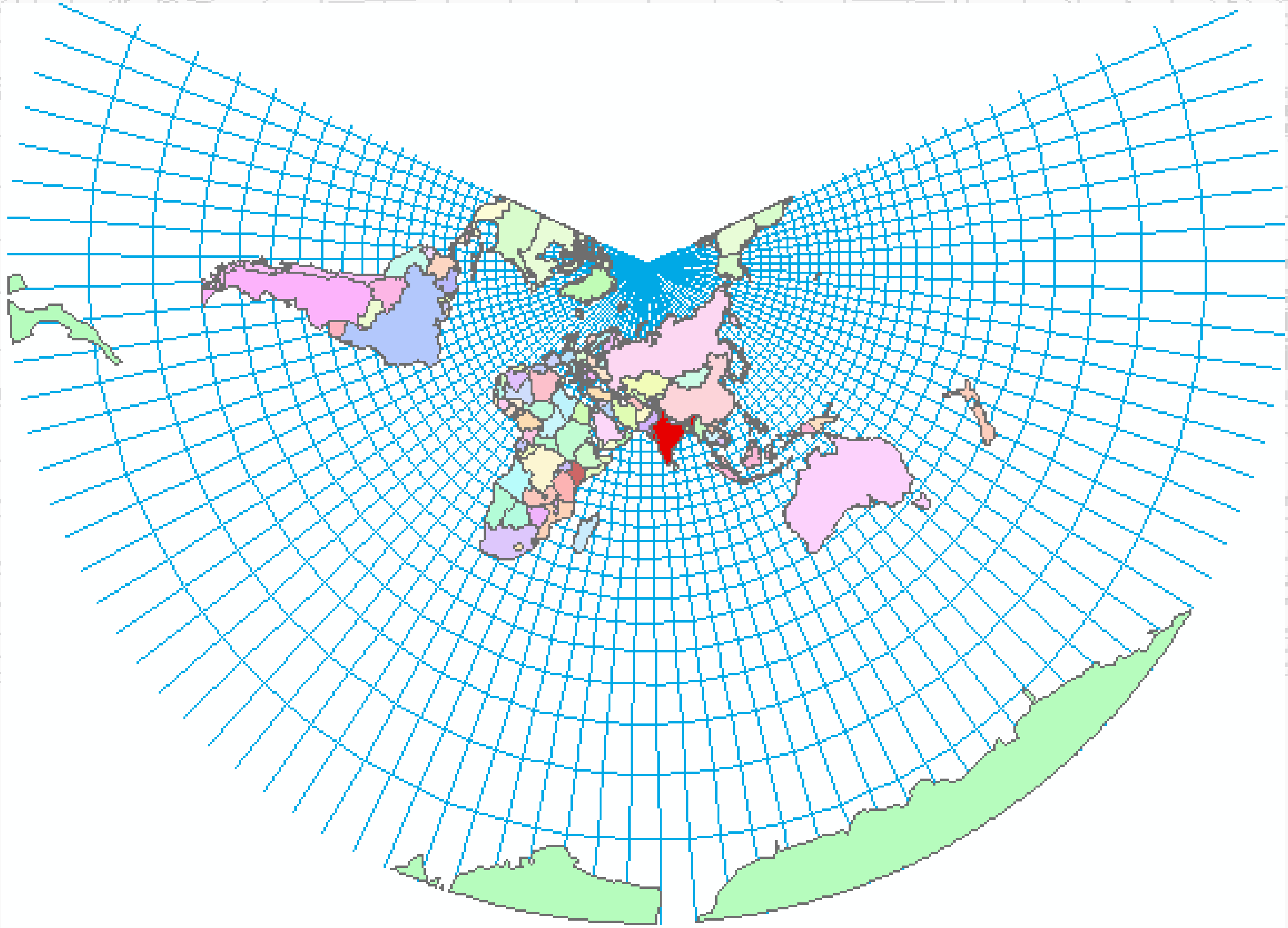
Projections–Going from 3D to Flat Maps

The World as seen from an Indian perspective



Projections–Going from 3D to Flat Maps

Projections are created by transferring points on the earth onto a flat surface.

Think of this as having a light in the middle of the earth, shining through the earth's surface, onto the projection surface. There are three basic methods for doing this:

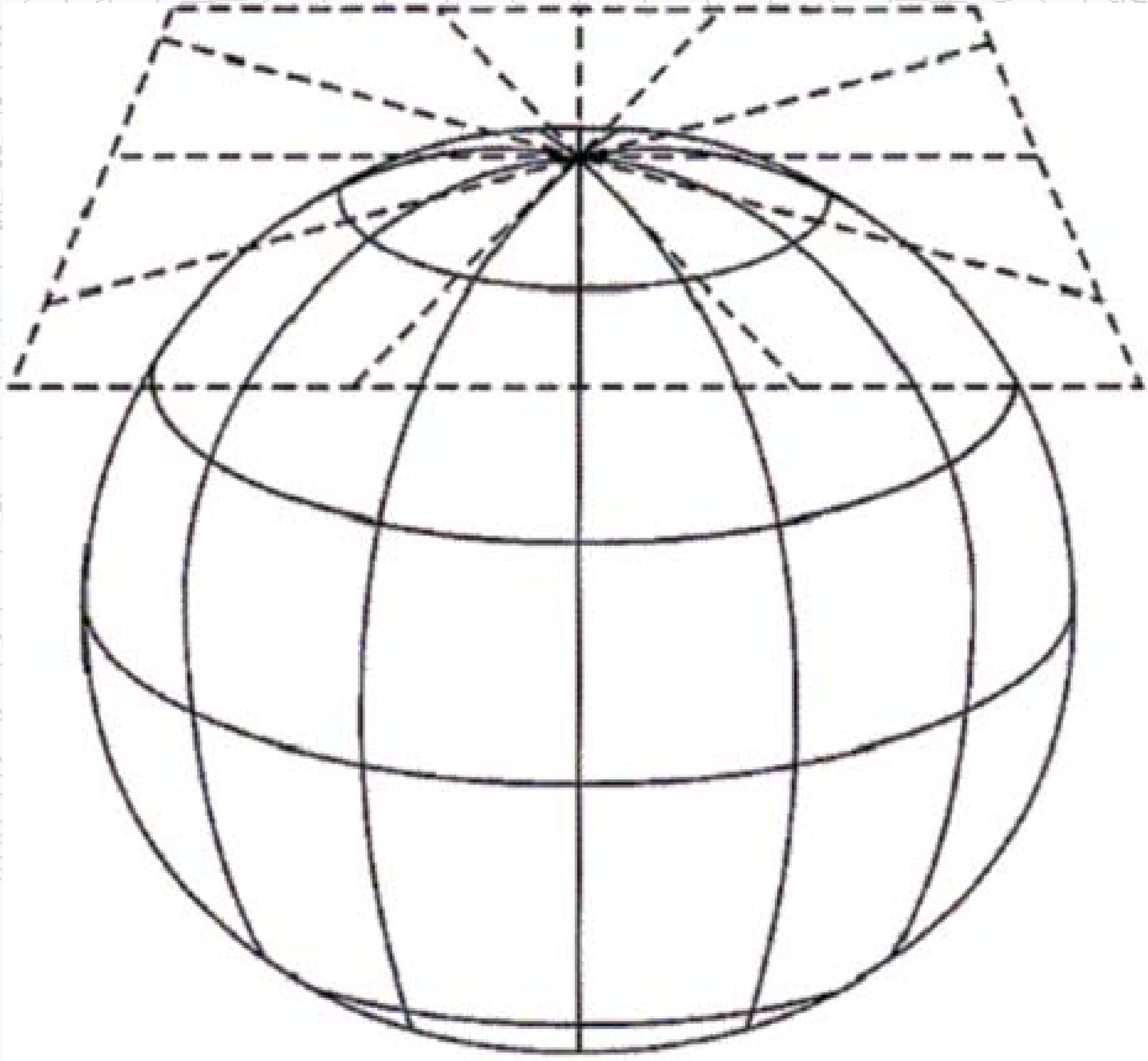
Planar – projection surface laid flat against the earth

Conic – cone is placed on or through the surface of the earth

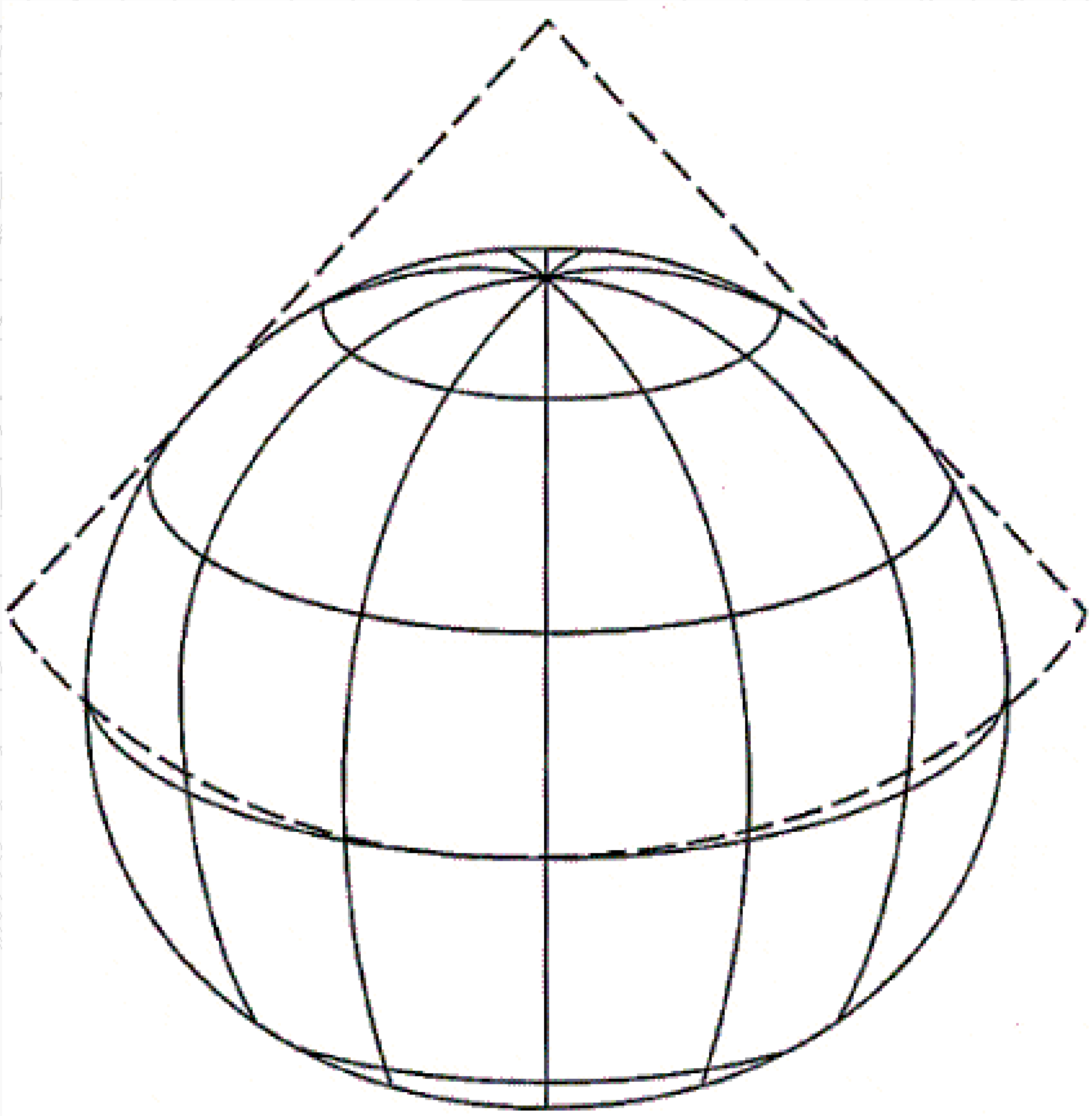
Cylindrical – projection surface wrapped around the earth

Where the projection surface touches the earth is called the "Standard Line."

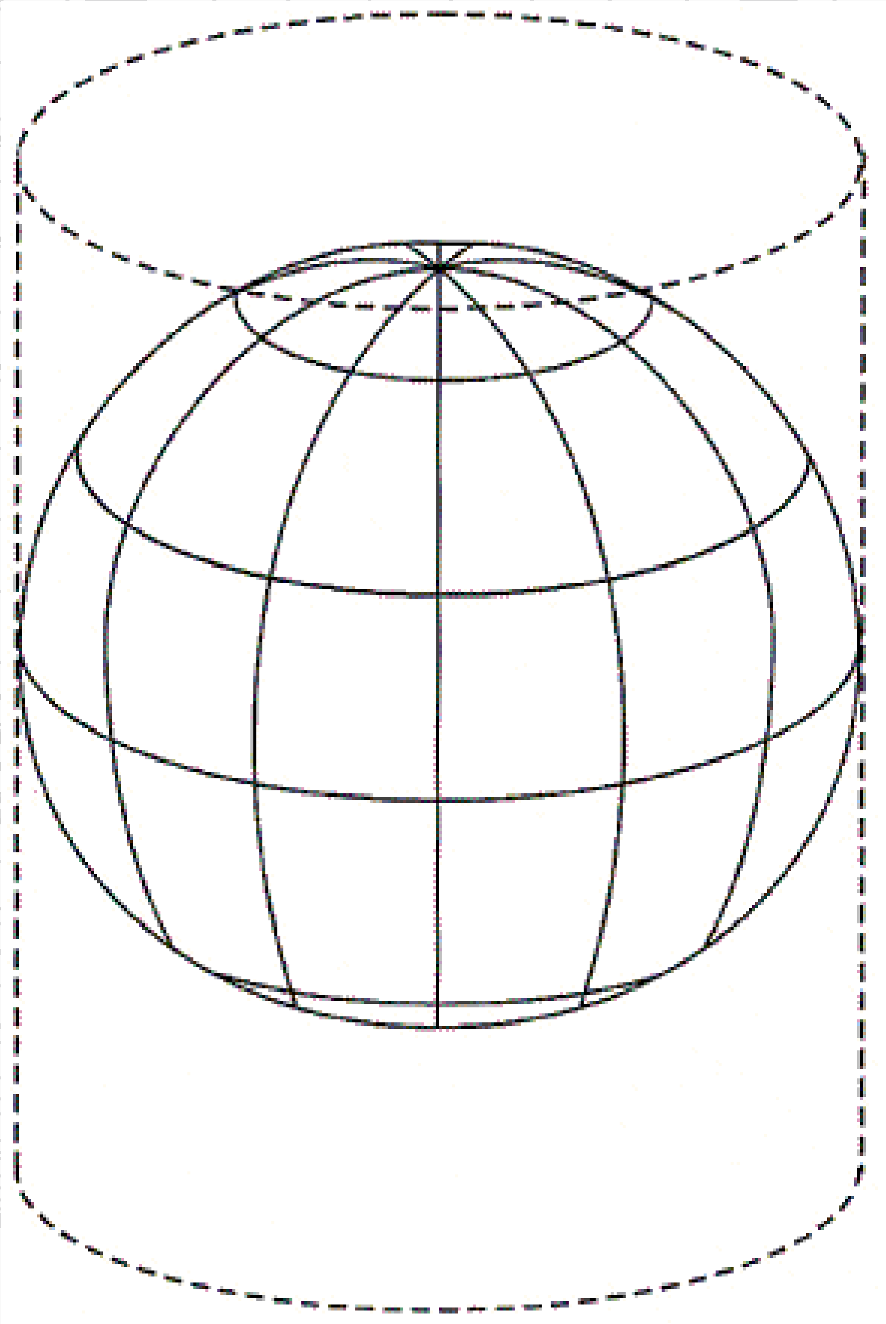
Projections – Polar Planar Projection



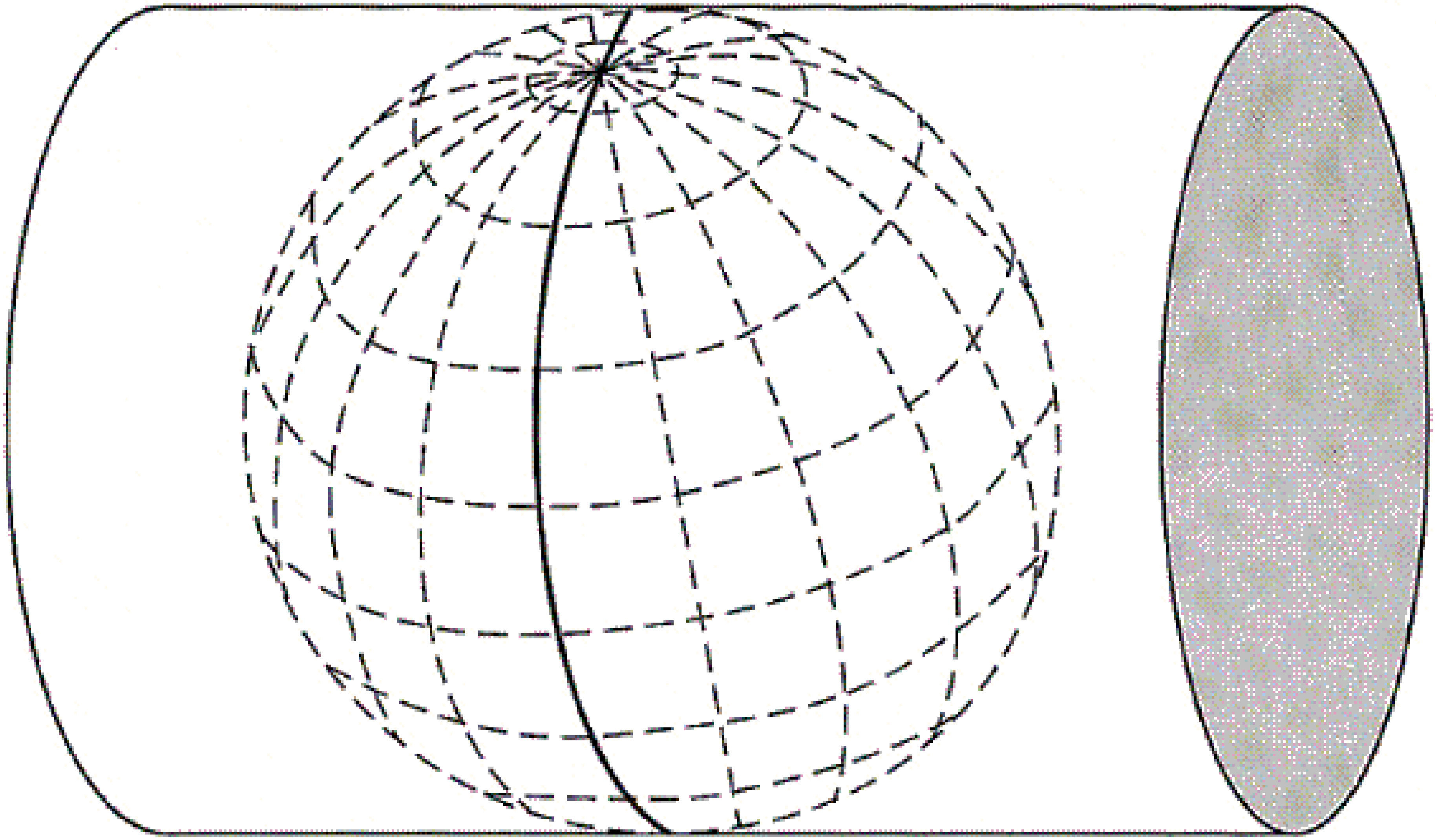
Projections – Conic Projection



Projections – Cylindrical Projection



Projections –Transverse Mercator



The transverse Mercator projection is projected onto a cylinder that is tangent along a meridian.

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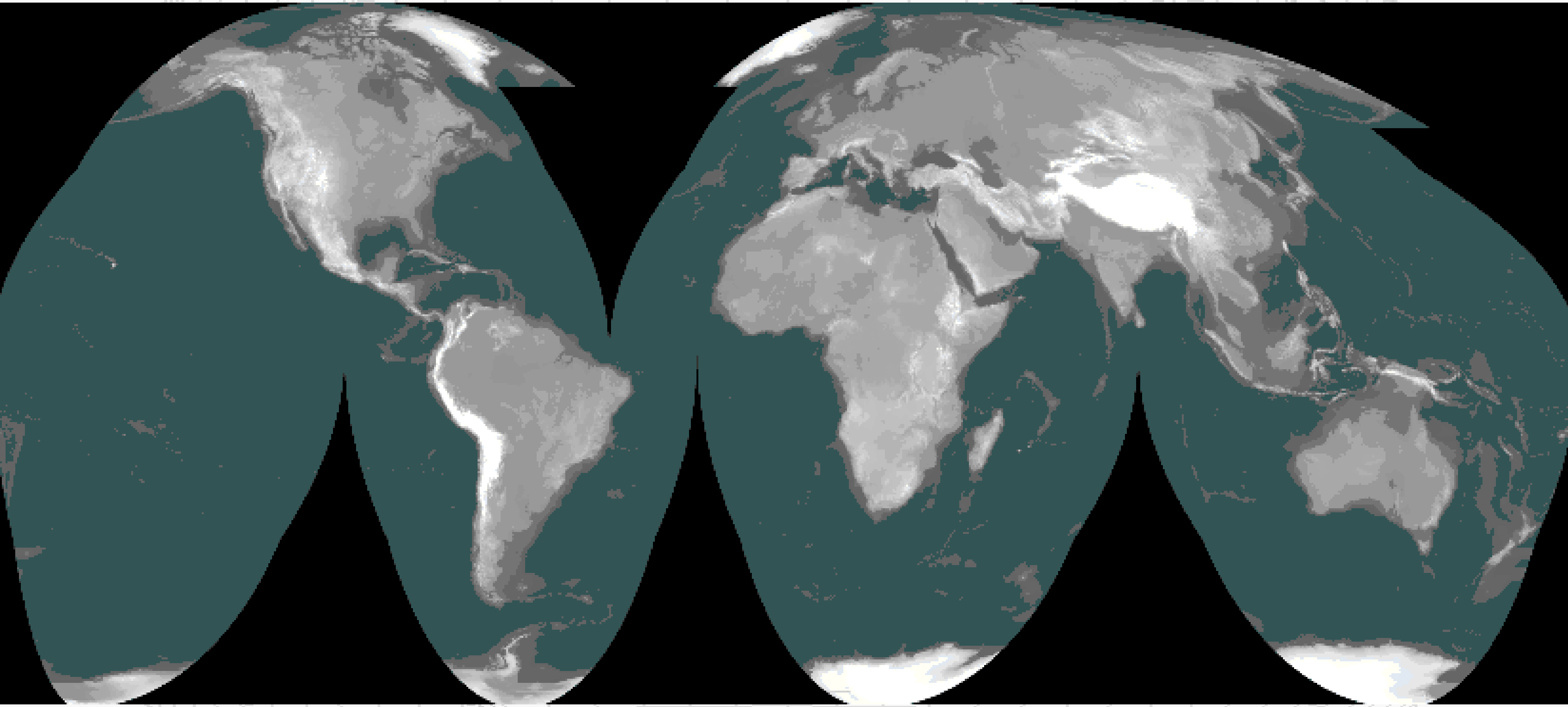
Projections – Origami Projection



For the official descriptions of projection types,
see http://erg.usgs.gov/isb/pubs/MapProjections/projections.html
or Google on USGS Projections Poster

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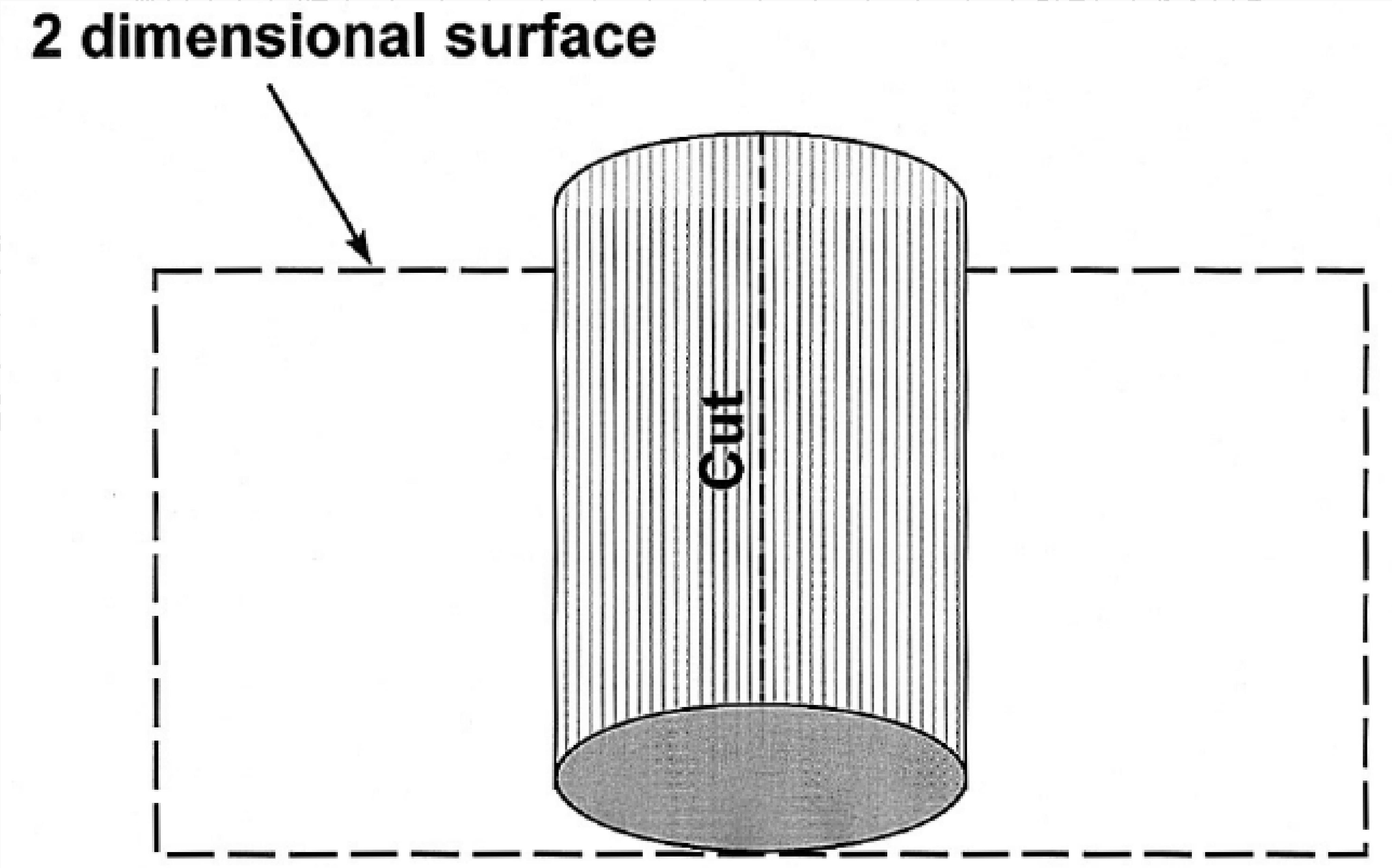
Projections – "Developing" a Cylindrical Projection



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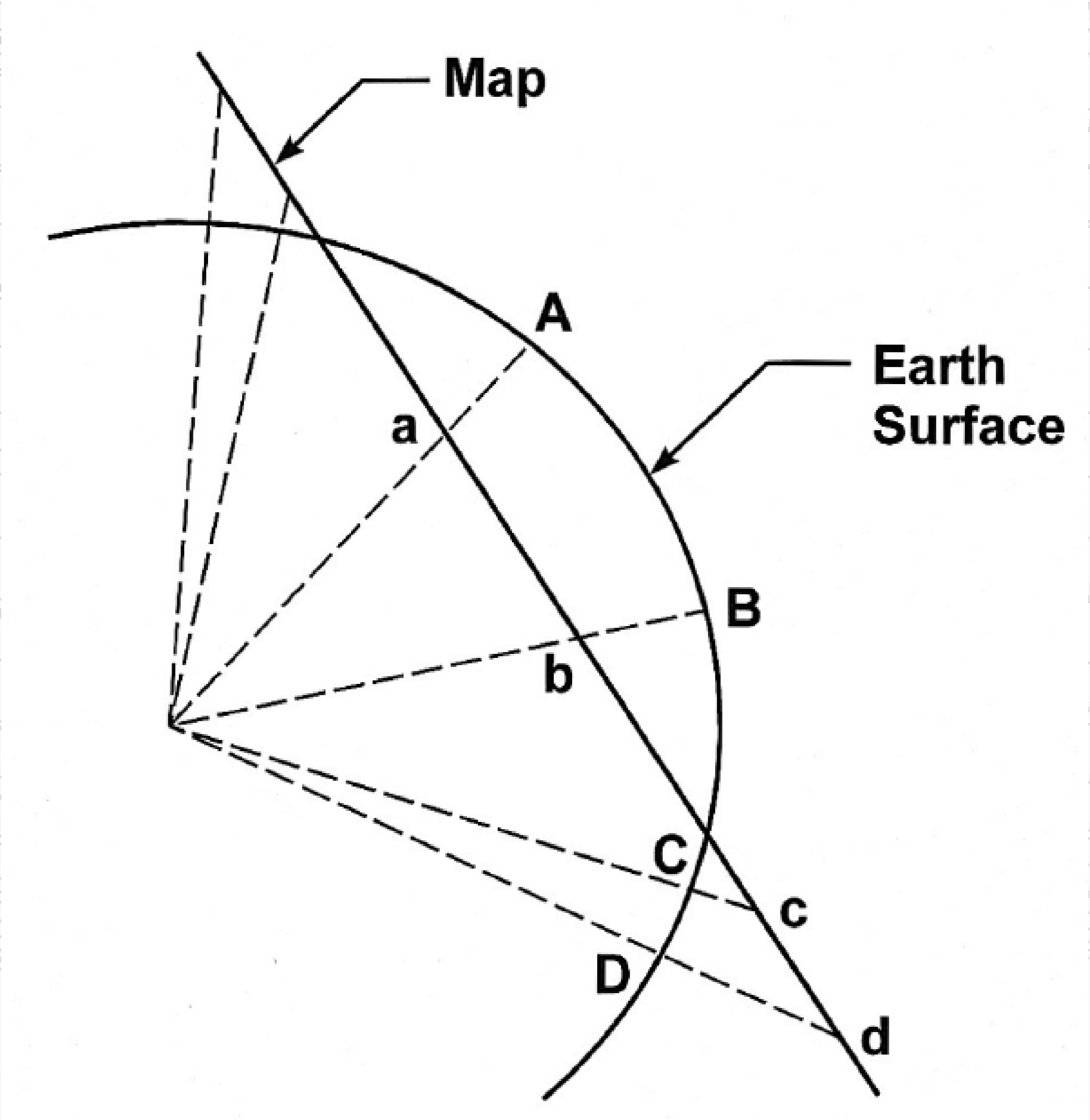
Projection Distortion –

Conic Projection cutting through the earth's surface at 2 parallels



Coordinate Systems – Plotting Location on a Map

Once reference points have been projected from the earth's surface to a flat plane,a coordinate system is established that provides a common reference on the ground.

These are also sometimes called "Map Grids" and are usually based on the Cartesian Coordinate system.

Coordinate Systems – Plotting Location on a Map

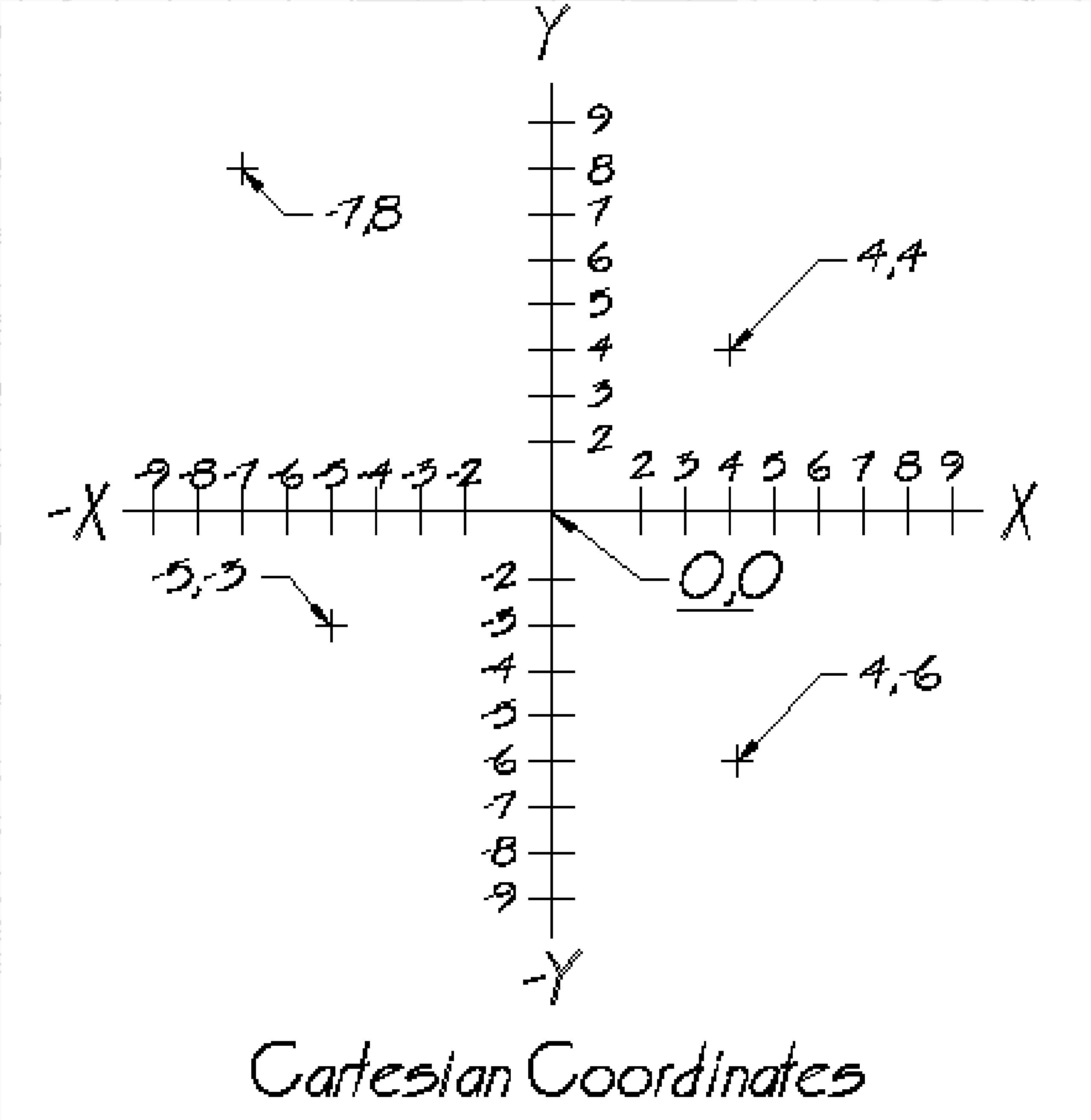
Coordinate systems have a baseline running East-West, and a baseline running North-South, used to measure distance in two directions from the origin.

The origin, with a given value of 0,0 is where the baselines intersect.

The location of any point can then be described by listing two coordinates, one showing the distance from the East-West baseline and one showing the distance from the North-South baseline.

Most CAD and mapping systems refer to the coordinates as “X,Y” but sometimes the coordinates are also referred to as “Easting” and “Northing.”

Coordinate Systems – Plotting Location on a Map



Coordinate Systems – Plotting Location on a Map

The two most common types of projected coordinate systems in use in the United States are:

State Plane Coordinate System

UTM (Universal Transverse Mercator) Coordinate System

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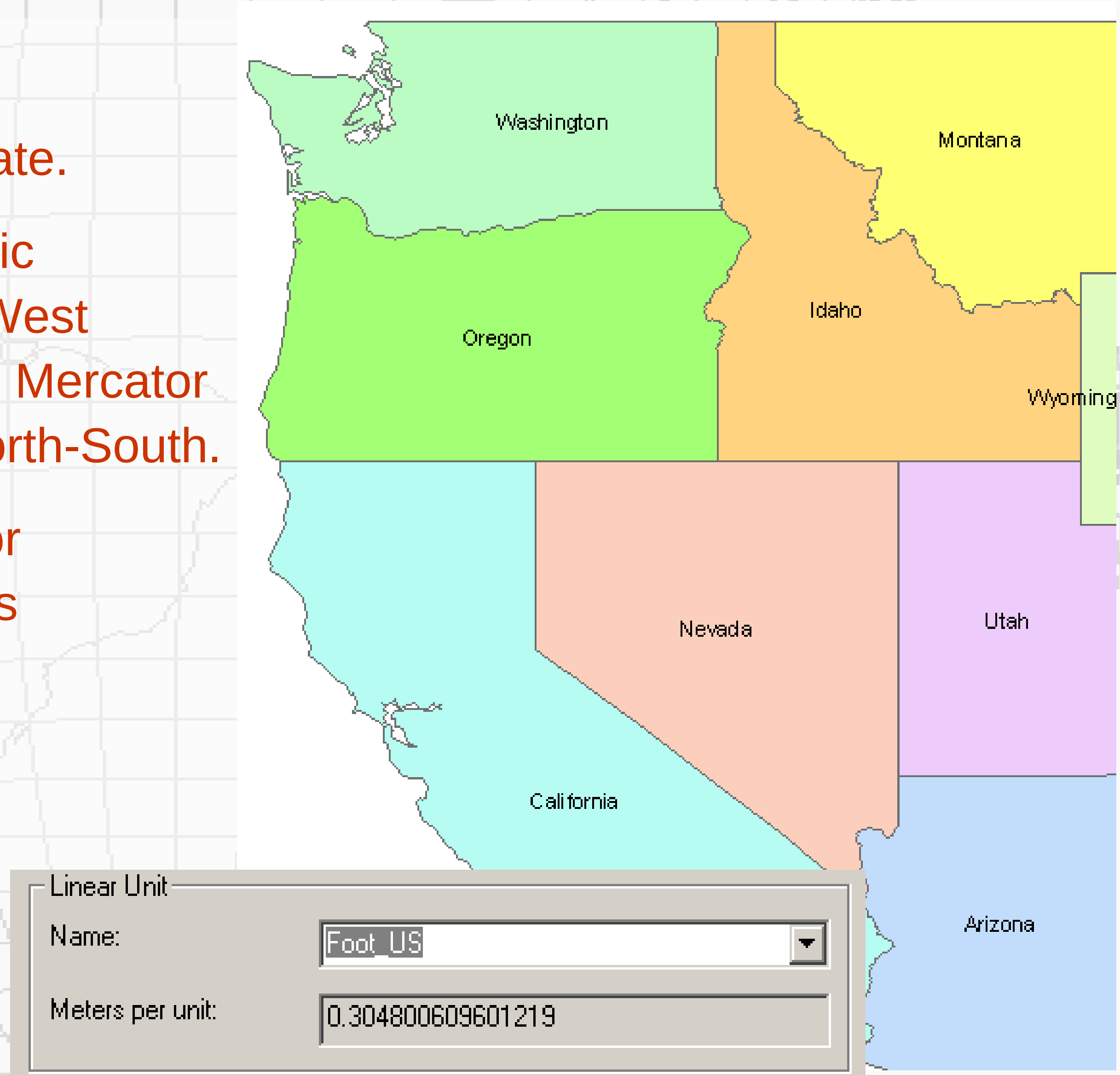
Coordinate Systems – Plotting Location on a Map

State Plane Coordinate System

- One or more zones for each state.
- Usually based on Lambert Conic Conformal projection for East-West trending states and Transverse Mercator projection for states running North-South.
- Usually has a “False Easting” or “False Northing” so that all units are positive.
- Units are usually in feet.
  - Survey Feet, Int’l feet, US Feet



Coordinate Systems – Plotting Location on a Map

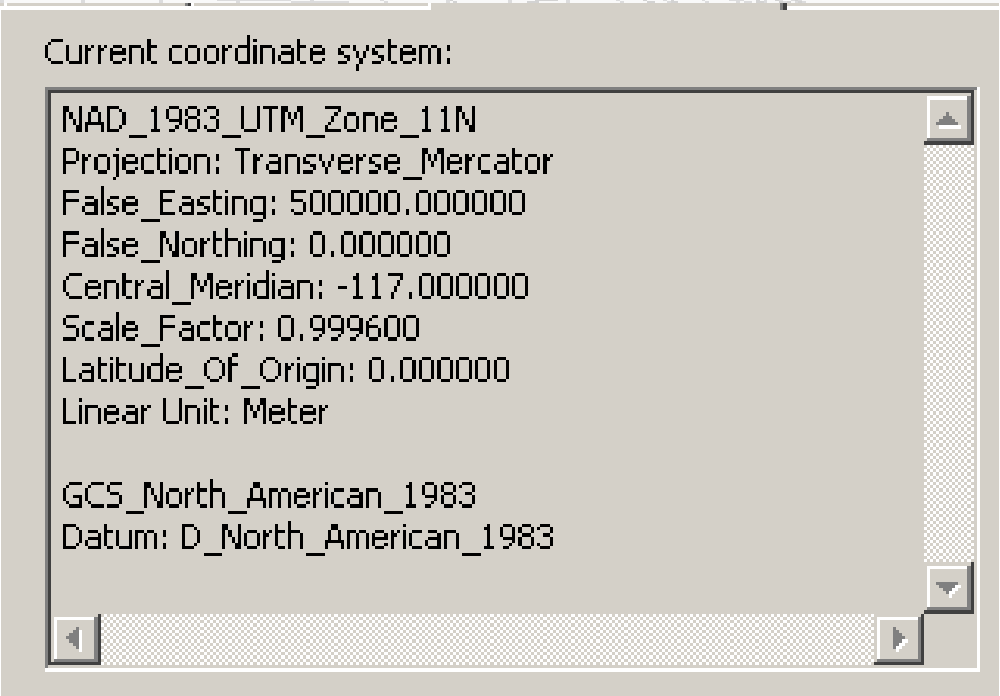
UTM Coordinate System

Used often by federal agencies.

Units are usually in meters.

Based on
Transverse Mercator projection.

Usually has a “False Northing”
and “False Easting” so that all units are positive.



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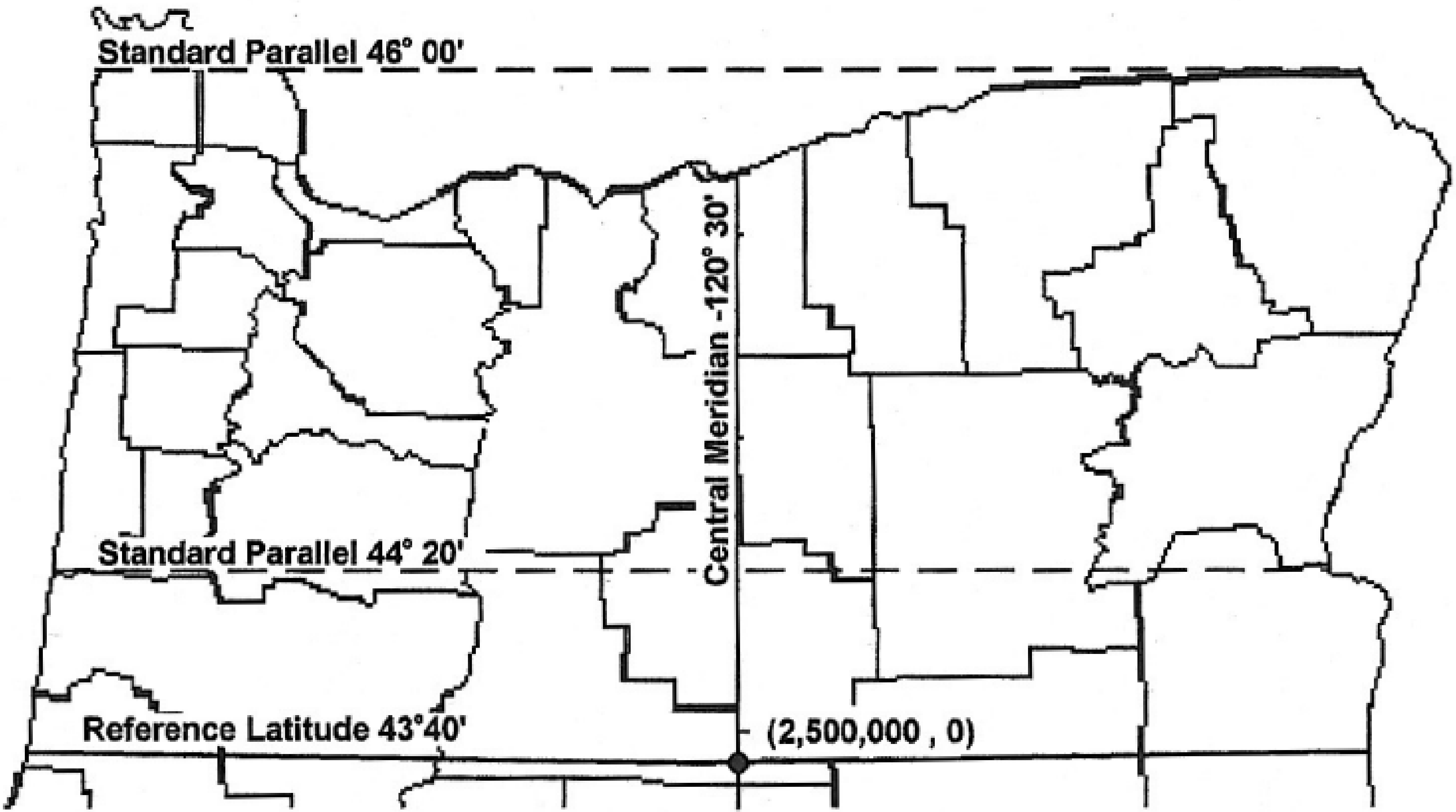
Coordinate Systems – State Plane, Oregon North NAD 83

Based on a Conic Conformal Projection that with two points of tangency



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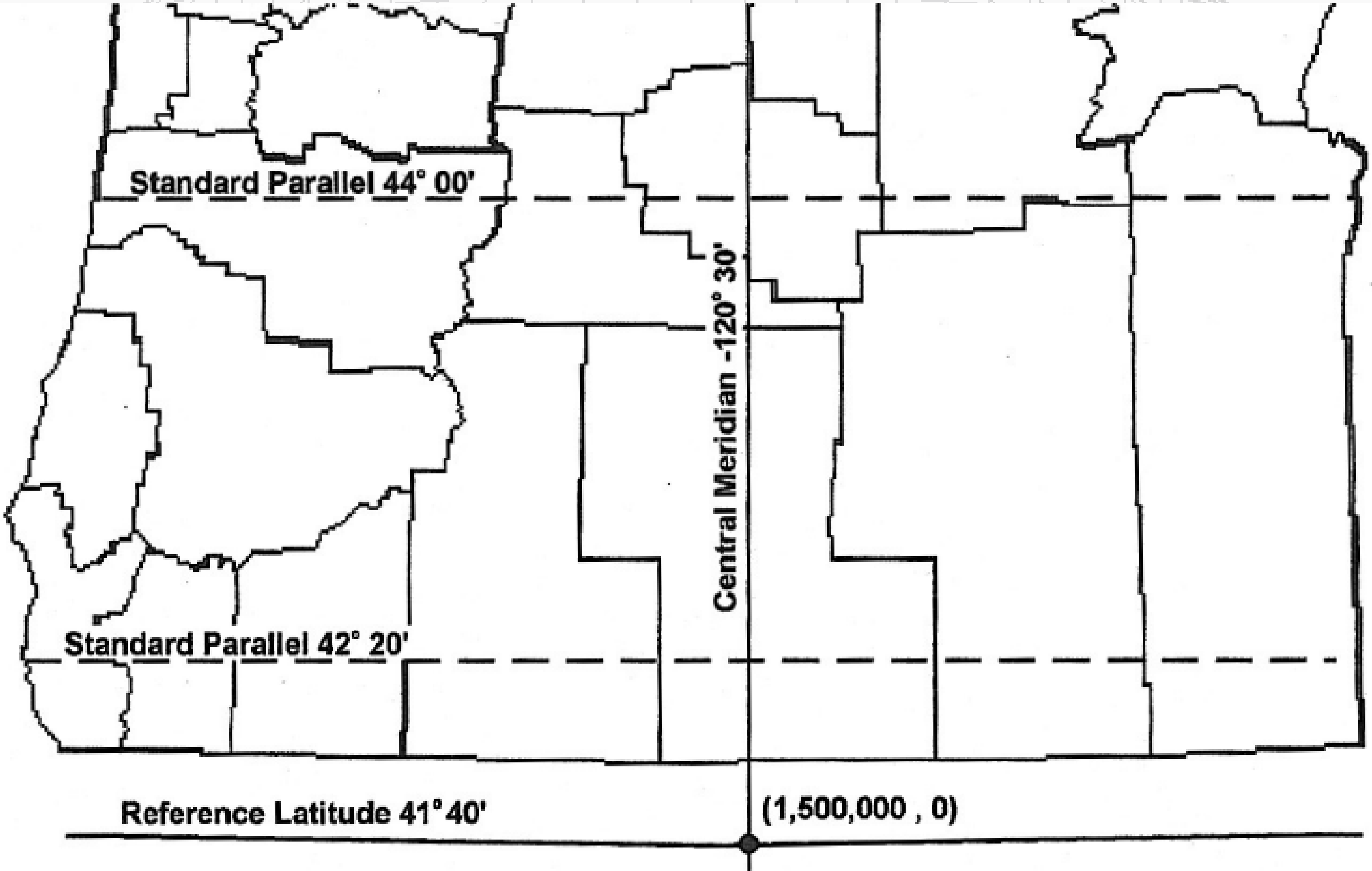
Coordinate Systems – State Plane, Oregon South NAD 83



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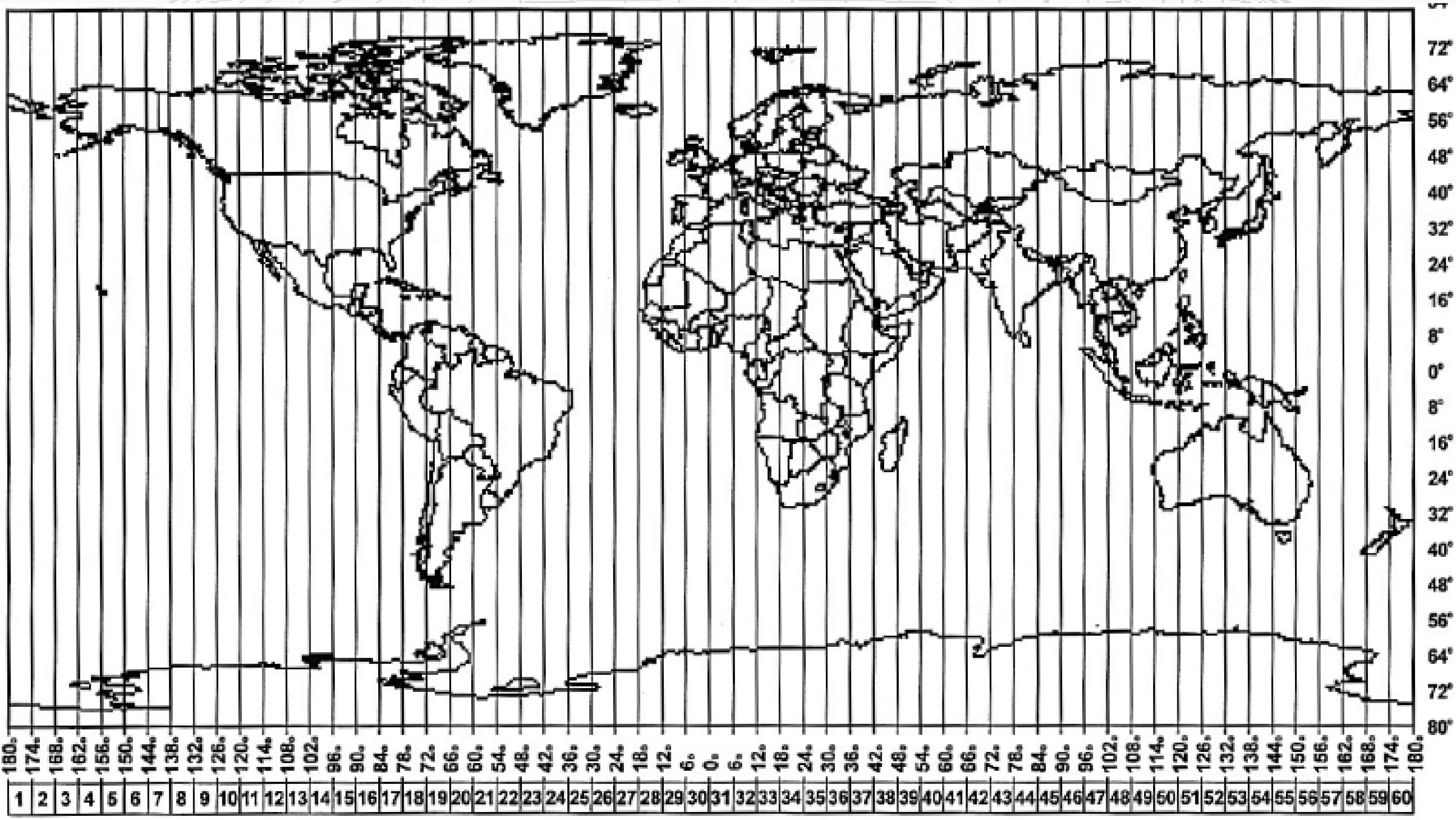
Coordinate Systems – UTM Zones (60 6° wide zones)



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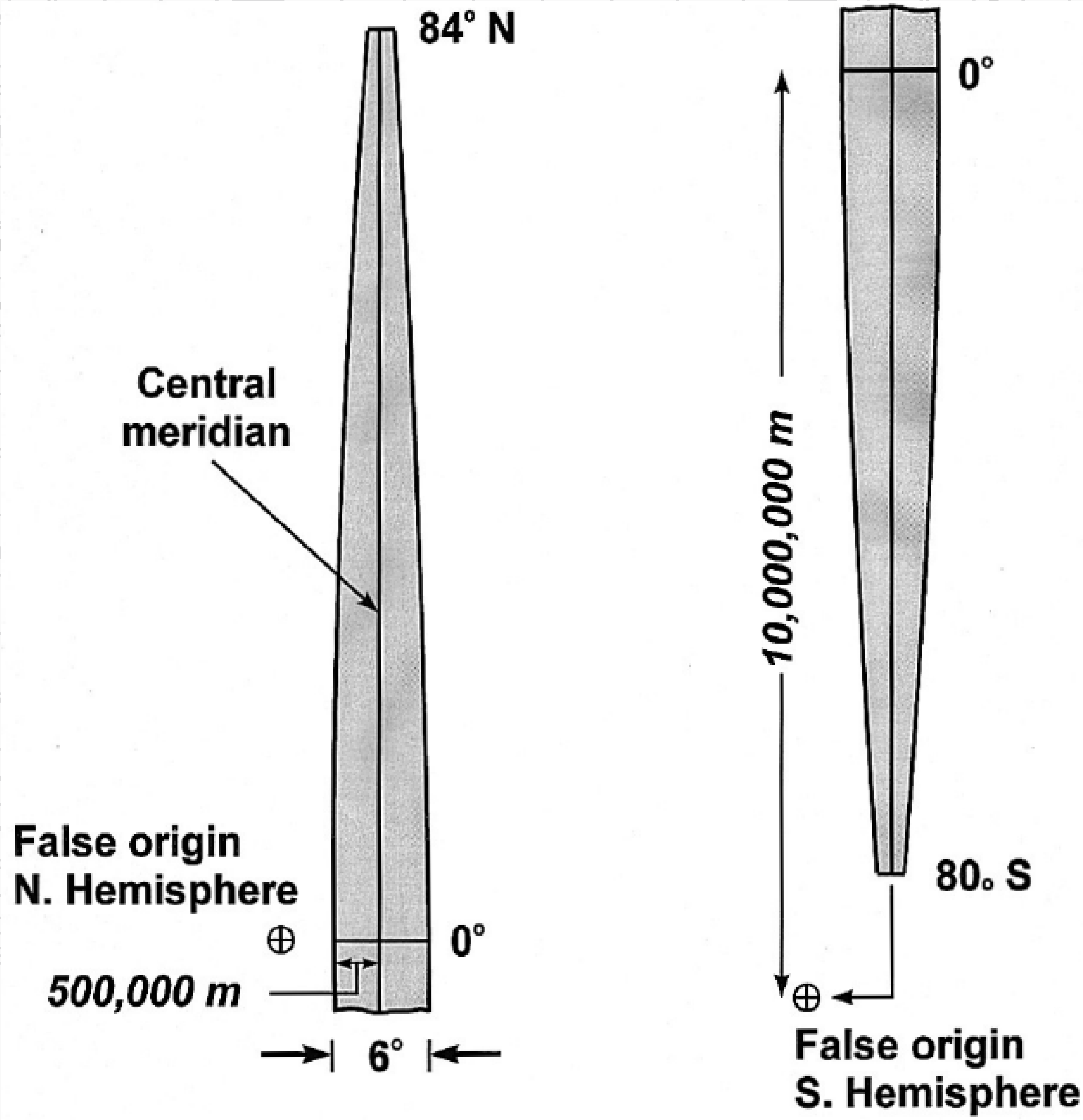
Coordinate Systems – UTM Zone Origins and Meridians

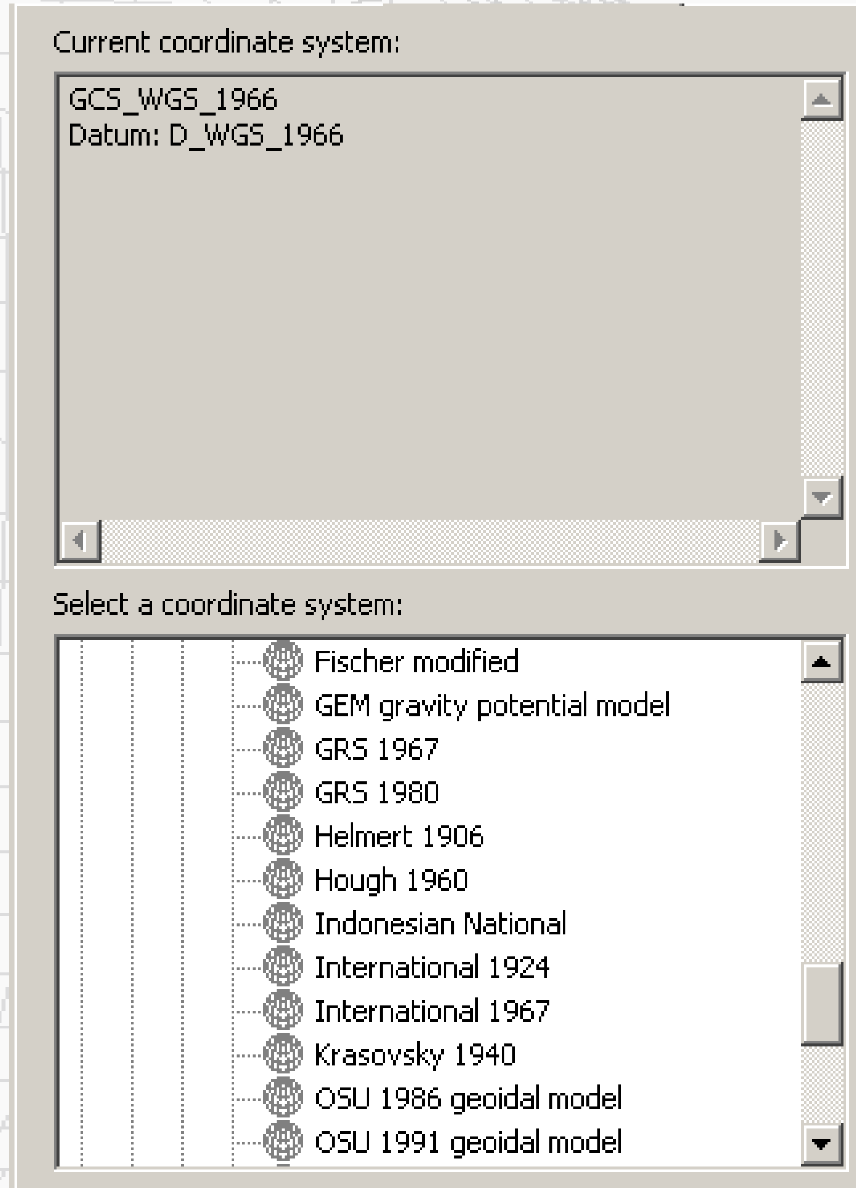


Coordinate Systems – Plotting Location on a Map

Geographic and Projected Coordinate systems are tied to Datums – which are a set of established reference points.

Datums are usually based on Geographic Coordinate Systems (GCS), which are based on different spheroids. In many cases a datum may be named the same as a GCS.

Datums reflect different ways of measuring the shape of the earth and thus impact both coordinate systems using Latitude/Longitude **and** projected coordinate systems.



Coordinate Systems – Plotting Location on a Map

The two datums widely used in the US are:

North American Datum 1927 (NAD 27)

Based on Clarke Ellipsoid of 1866

North American Datum 1983 (NAD 83)

Based on the GRS80 Ellipsoid

High-Accuracy Reference Networks (HARN), also called High Precision Geodetic Networks (HPGN) are starting to be used by most states,usually called NAD83_Harn. This is based on the GRS80 Ellipsoid but uses the GPS satellites for control.

Difference between NAD27 and NAD83 in the western US is about 100 meters.
Difference between NAD83 and HARN or WGS is about 16 feet.

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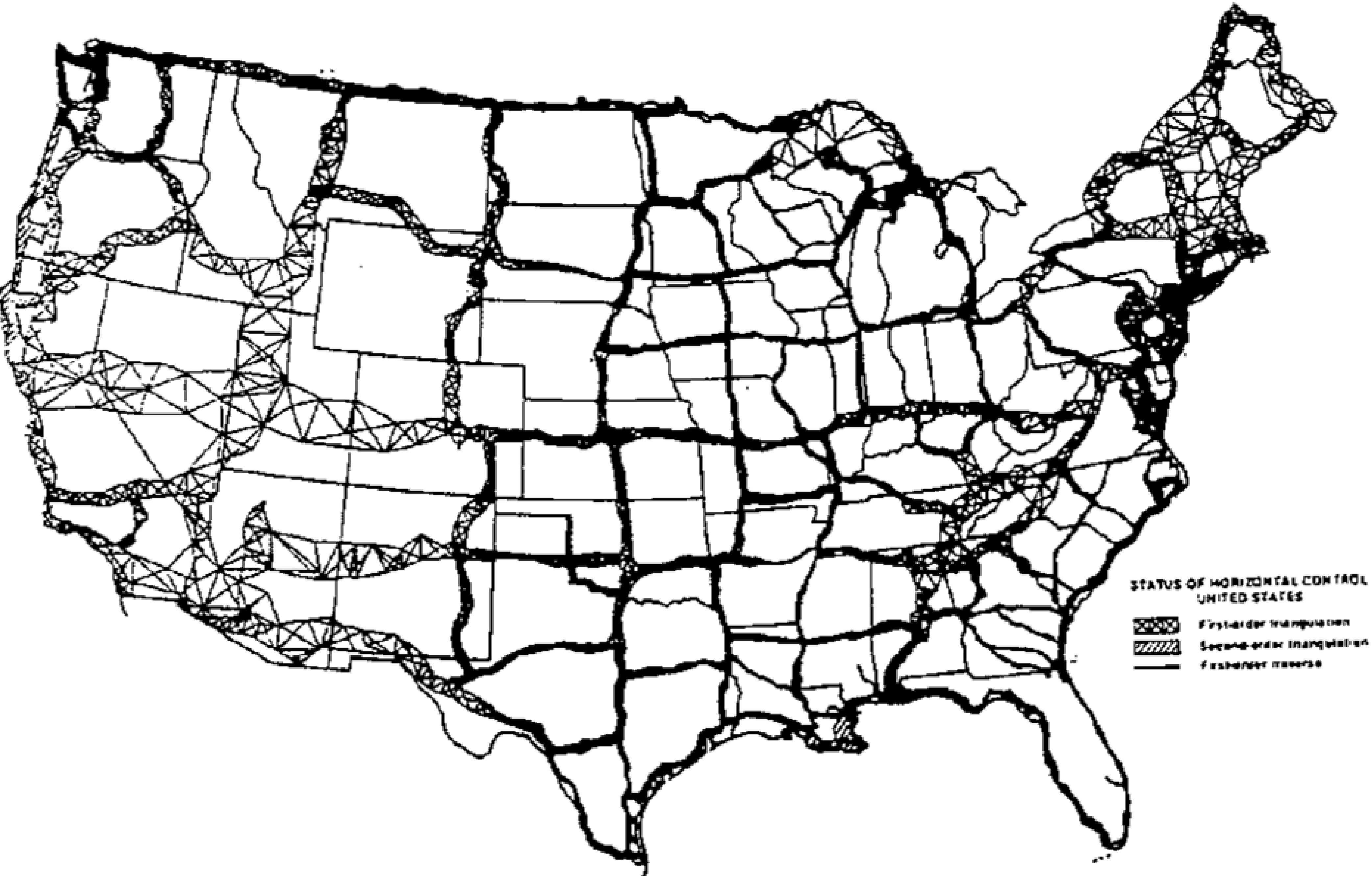
Coordinate Systems – 1927 Datum Control Points



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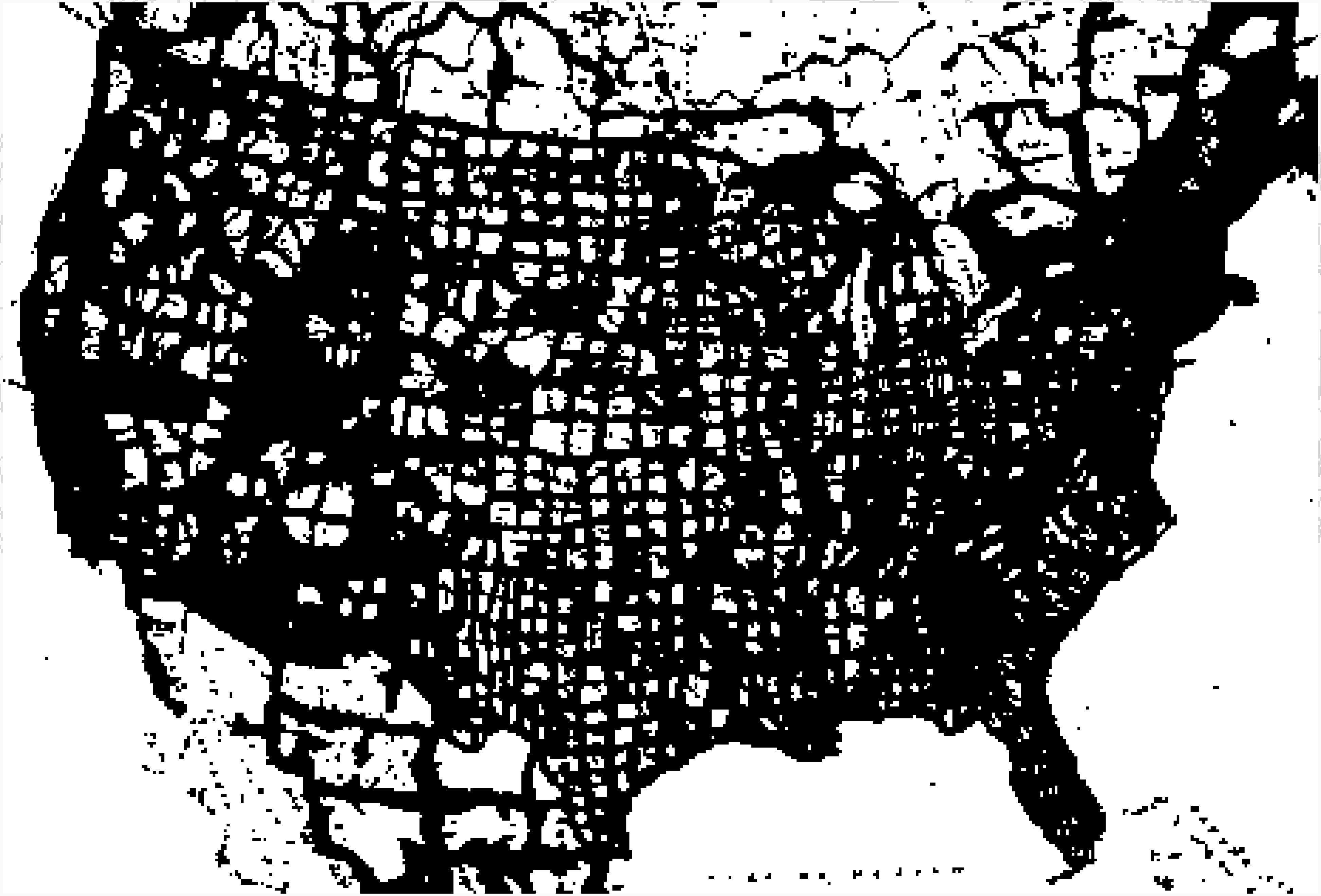
Coordinate Systems – 1983 Datum Control Points



So what do we do with this information?

Hopefully you now know enough about ellipsoids, projections, datums, and coordinate systems to understand why some systems have been used.

And how to determine the parameters needed to project data from one system to another. Key parameters to look for are:

- Projection or coordinate system
- Type of Datum\ Type of Spheroid
- Standard parallel(s) and or meridians
- False Easting/Northing
- Units

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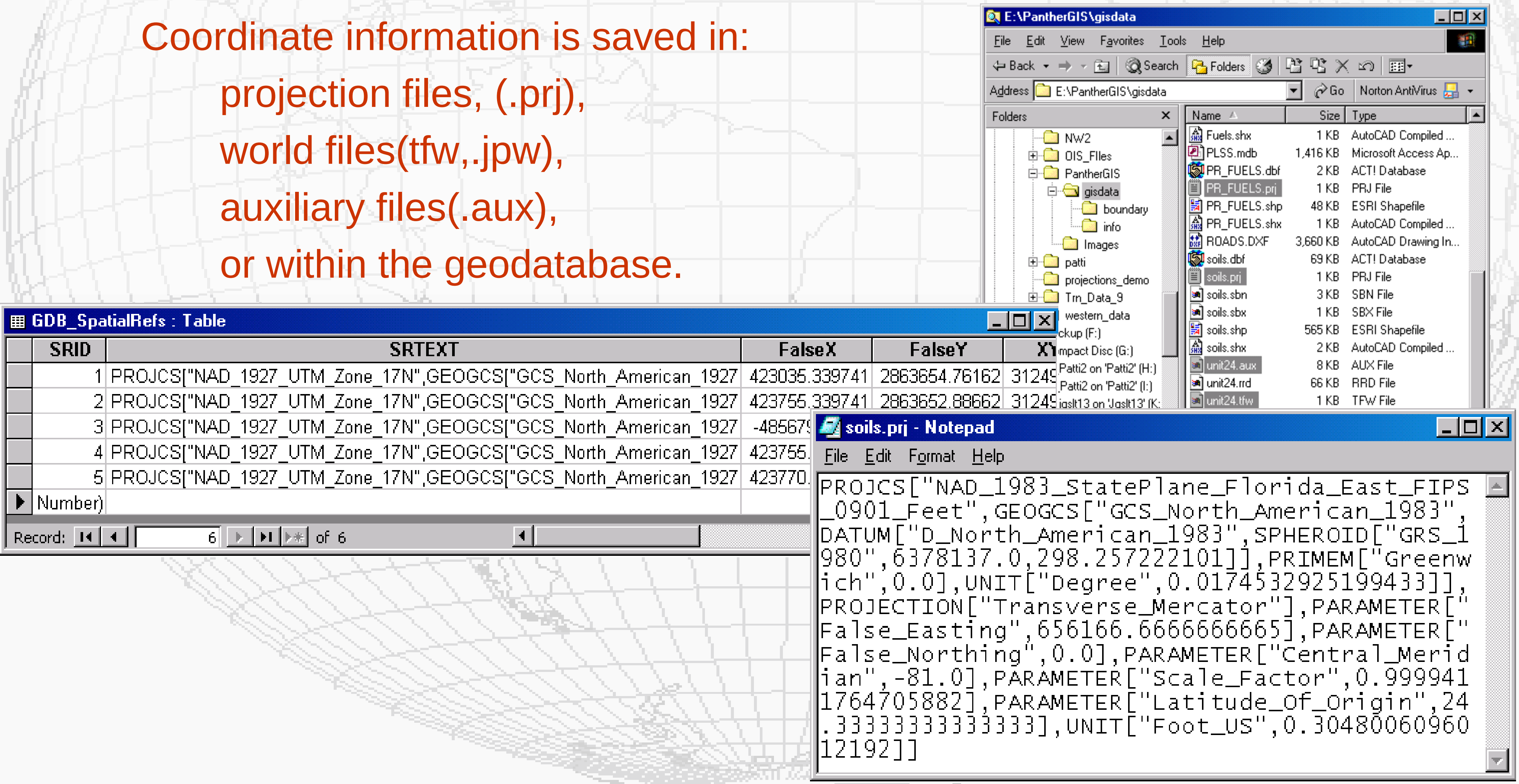
Working with Projections in ArcGIS

Data needs to be in the same coordinate system for display and analysis.

ArcGIS needs to know the coordinate system of the data.

Coordinate information is saved in:

- projection files, (.prj),
- world files(tfw,.jpw),
- auxiliary files(.aux),
- or within the geodatabase.



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Working with Projections in ArcGIS

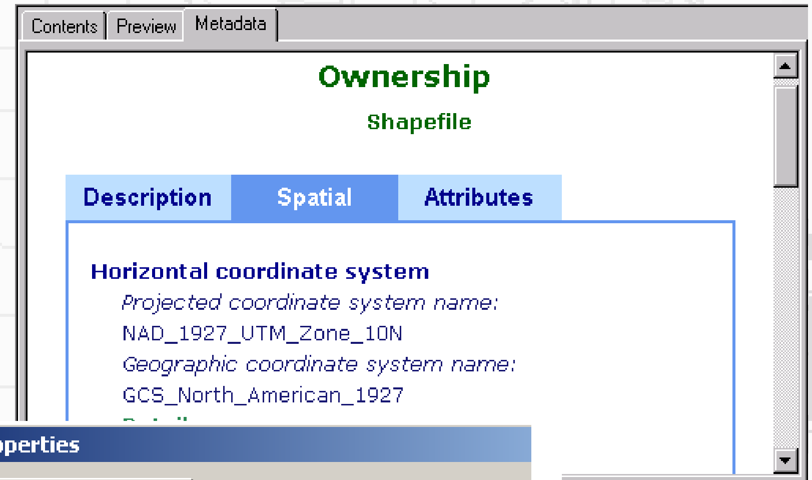
Coordinate information can be viewed in several places.

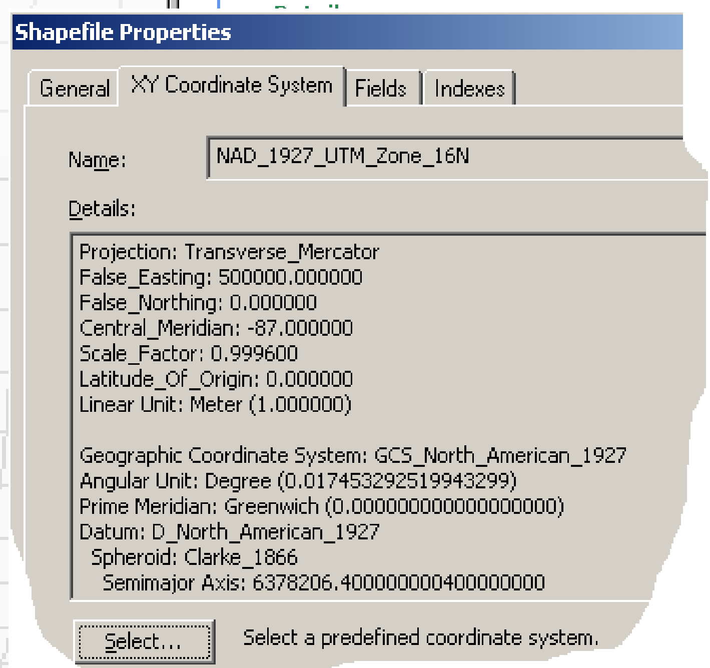
ArcCatalog>Metadata>Spatial

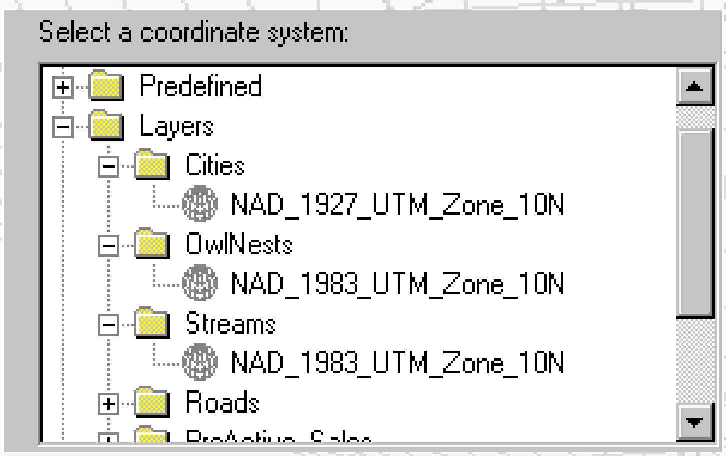
ArcMap>Layer>Properties…>Source

ArcCatalog>Properties…>XY Coordinate System

ArcMap>DataFrame Properties…> Coordinate Systems>Layers







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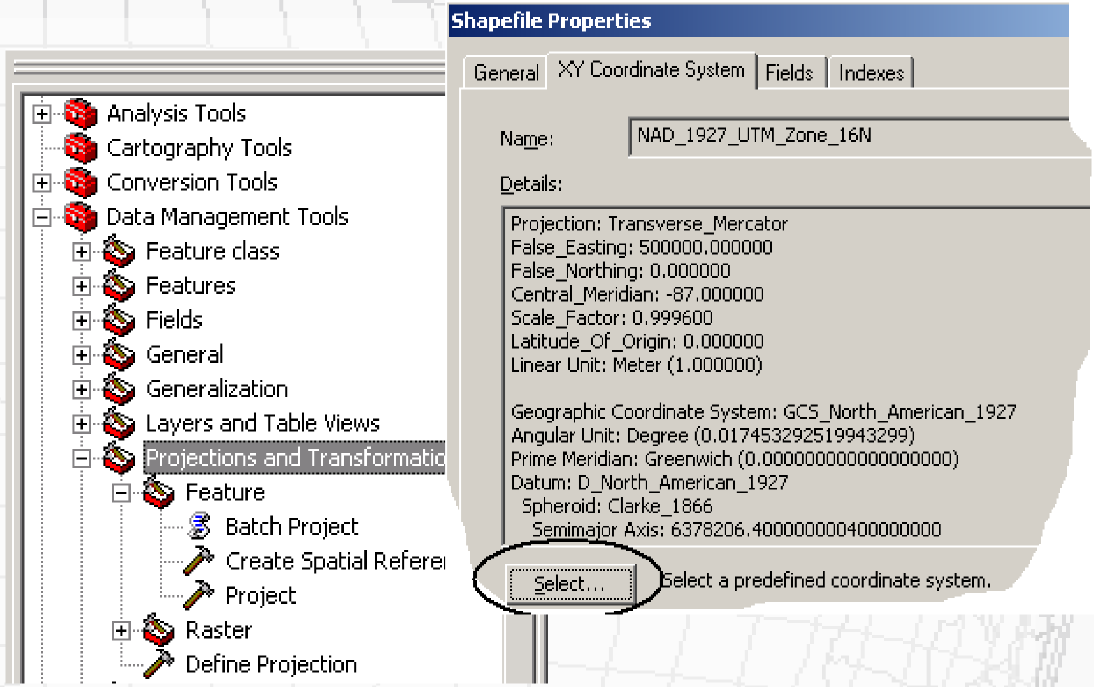
Working with Projections in ArcGIS

Coordinate system can be set in ArcCatalog, as a property of the data, or in ArcToolbox using Projections…> Define Projection Tool.

The coordinate system can be changed using ArcToolbox with Projections…>Project Tool.



Important to understand the difference between setting the coordinate system and projecting the data to a different coordinate system.

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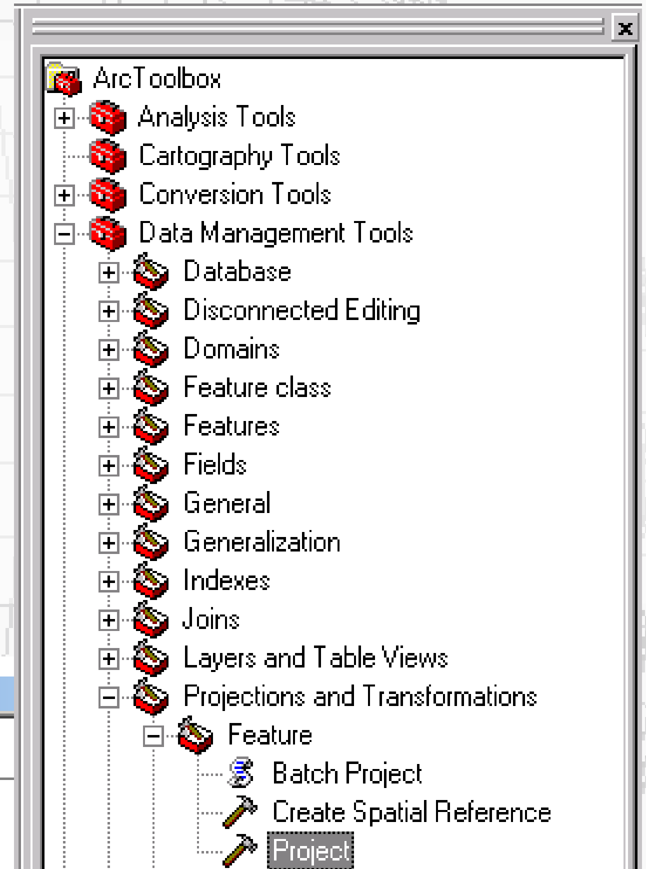
Working with Projections in ArcGIS

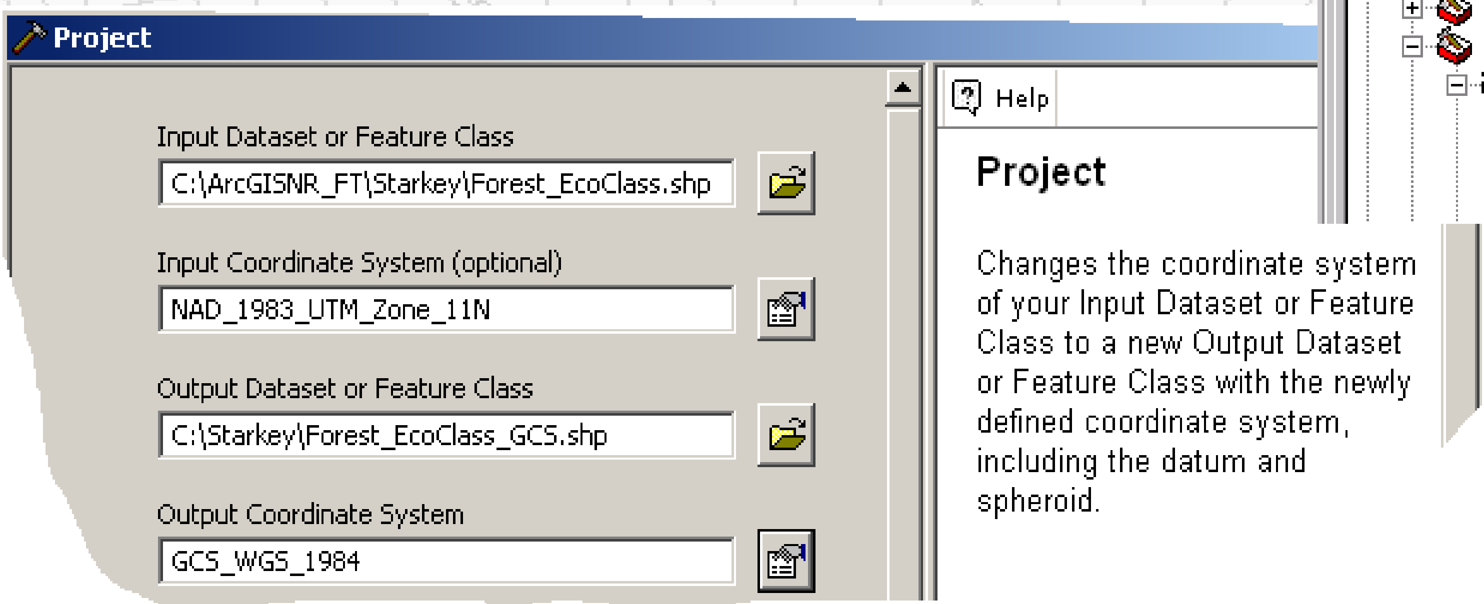
Projecting Data in ArcGIS

The correct coordinate system must be defined before data can be projected.

In 9.2 this can be done in the Project tool.

Projecting data is done through with the Project tool in the Data Management Tools> Projections and Transformations>Feature toolset.





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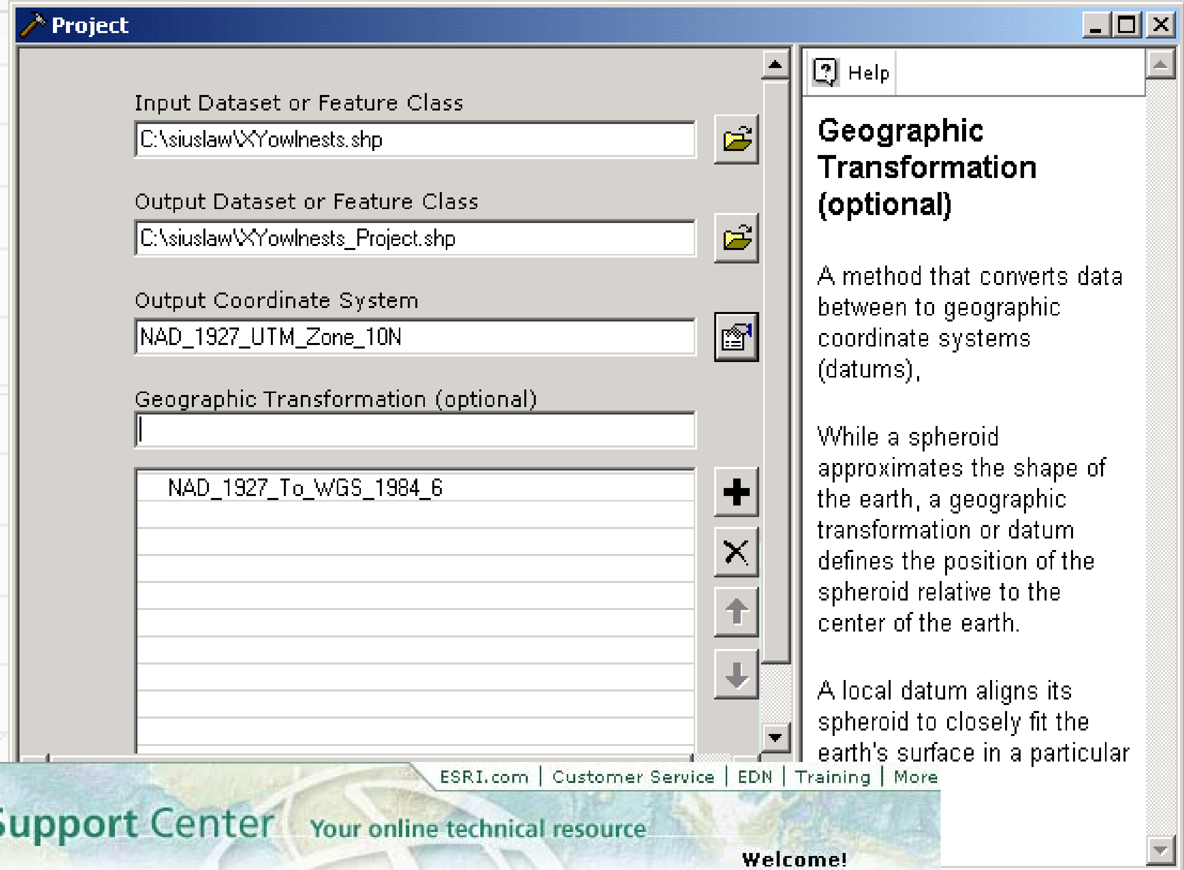
Working with Projections in ArcGIS

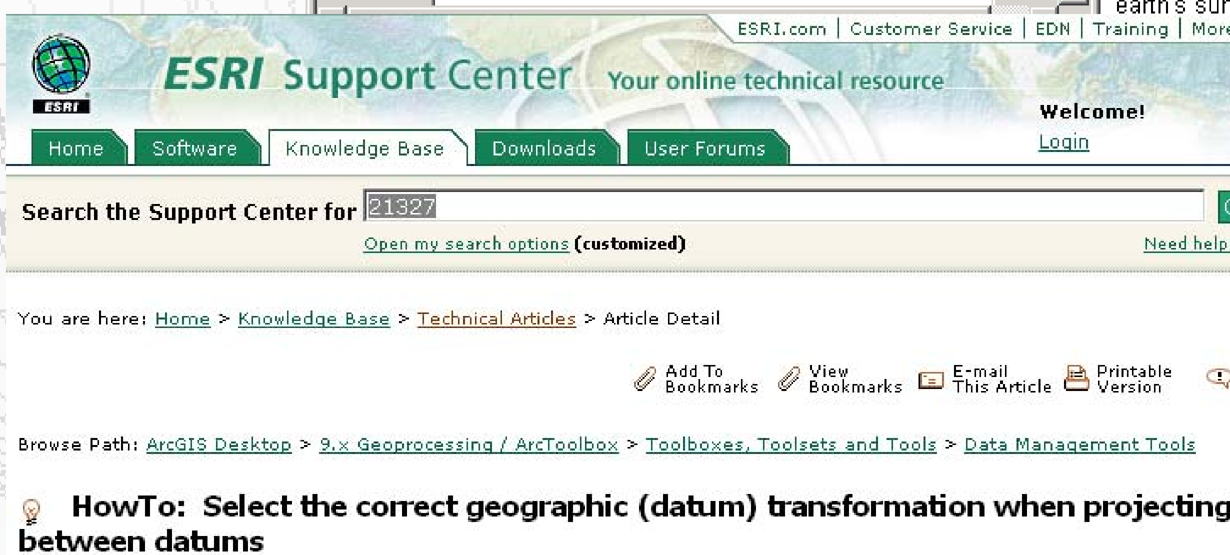
Projecting Data in ArcGIS

Projecting data might also mean changing the datum by using a specific transformation.

When changing datums, you might have a choice of transformation methods.

http://downloads.esri.com/support/techArticles/PEgeoareas.doc or search for article 21327





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Working with Projections in ArcGIS

Projecting Data in ArcGIS – Transformation Methods

Projection Methods For NAD27 to WGS84 from Pegt_namewhere.doc

ArcGIS Projection Engine version 9.x Datum transformations available and geographic areas for which each transfor
method should be applied. From Pegt_Namewhere.doc

Geographic transformations—area of interest

name	code	area of use
NAD_1927_To_WGS_1984_1	1170	Antigua
NAD_1927_To_WGS_1984_1	1170	Barbados
NAD_1927_To_WGS_1984_1	1170	Barbuda
NAD_1927_To_WGS_1984_1	1170	Caicos Islands
NAD_1927_To_WGS_1984_1	1170	Cuba
NAD_1927_To_WGS_1984_1	1170	Dominican Republic
NAD_1927_To_WGS_1984_1	1170	Grand Cayman
NAD_1927_To_WGS_1984_1	1170	Jamaica
NAD_1927_To_WGS_1984_1	8070	Turks Islands
NAD_1927_To_WGS_1984_10	1179	Alberta
NAD_1927_To_WGS_1984_10	1179	British Columbia
NAD_1927_To_WGS_1984_11	1180	Manitoba
NAD_1927_To_WGS_1984_11	1180	Ontario
NAD_1927_To_WGS_1984_12	1181	New Brunswick
NAD_1927_To_WGS_1984_12	1181	Newfoundland
NAD_1927_To_WGS_1984_12	1181	Nova Scotia
NAD_1927_To_WGS_1984_12	1181	Quebec
NAD_1927_To_WGS_1984_13	1182	Northwest Territories
NAD_1927_To_WGS_1984_13	1182	Saskatchewan
NAD_1927_To_WGS_1984_14	1183	Yukon
NAD_1927_To_WGS_1984_15	1184	Panama (Canal Zone)
NAD_1927_To_WGS_1984_16	1185	Cuba
NAD_1927_To_WGS_1984_17	1186	Greenland (Hayes Peninsula)
NAD_1927_To_WGS_1984_18	1187	Mexico
NAD_1927_To_WGS_1984_2	1171	Belize
NAD_1927_To_WGS_1984_2	1171	Costa Rica
NAD_1927_To_WGS_1984_2	1171	El Salvador
NAD_1927_To_WGS_1984_2	1171	Guatemala
NAD_1927_To_WGS_1984_2	1171	Honduras
NAD_1927_To_WGS_1984_2	1171	Nicaragua
NAD_1927_To_WGS_1984_21	1249	Alaska - Aleutians east of 180 E
NAD_1927_To_WGS_1984_22	1250	Alaska - Aleutians west of 180 E
NAD_1927_To_WGS_1984_3	1172	Canada
NAD_1927_To_WGS_1984_30	1530	Cuba
NAD_1927_To_WGS_1984_4	1173	United States (contiguous 48 states)
NAD_1927_To_WGS_1984_5	1174	United States (contiguous states east of Mississippi River including MN, M
NAD_1927_To_WGS_1984_6	1175	United States (contiguous states west of Mississippi River)
NAD_1927_To_WGS_1984_7	1176	Alaska
NAD_1927_To_WGS_1984_8	1177	Bahamas (except San Salvador Island)
NAD_1927_To_WGS_1984_9	1178	Bahamas (San Salvador Island)

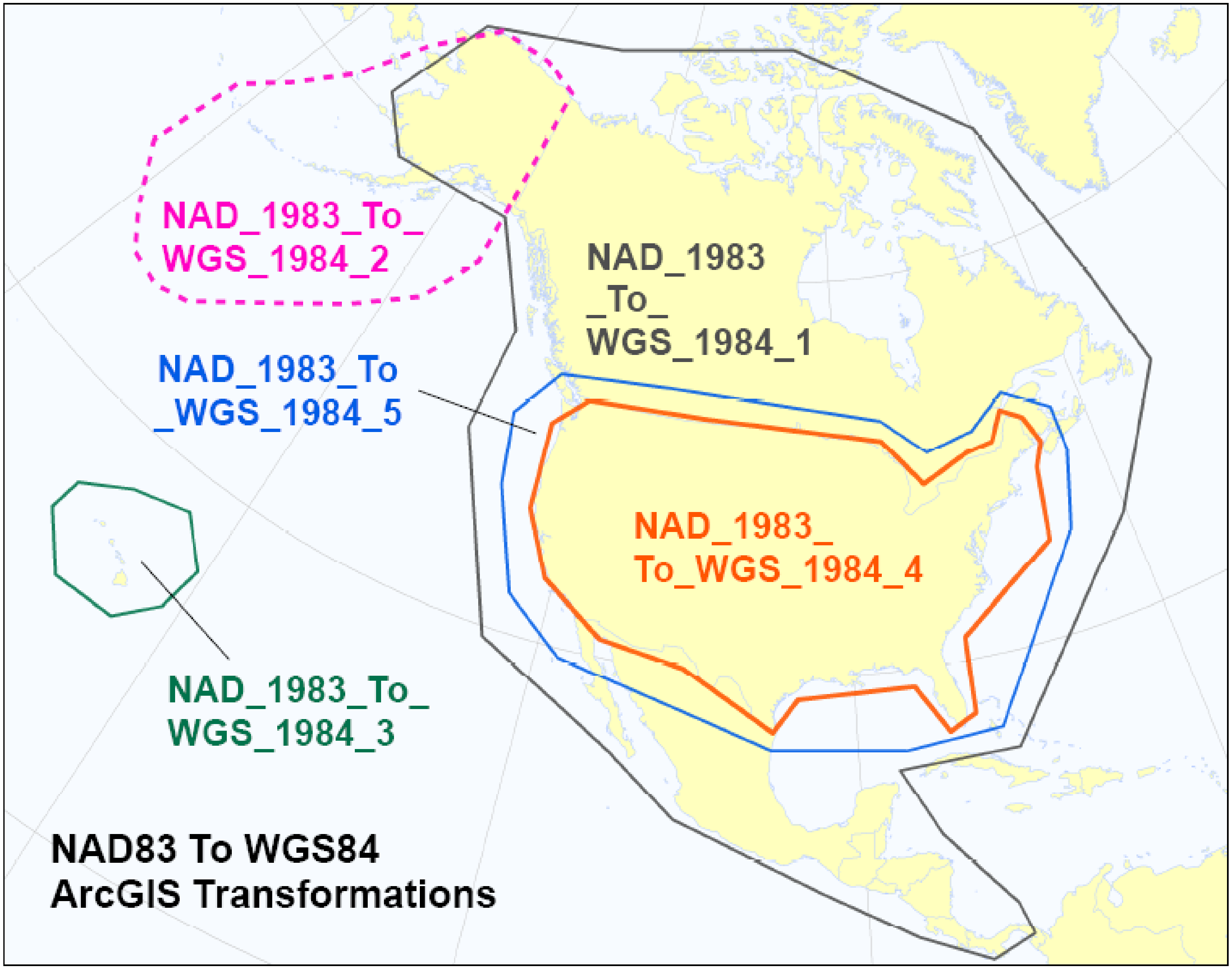
Understanding Projections for GIS

Working with Projections in ArcGIS

Projecting Data in ArcGIS – Transformation methods NAD83/WGS84

These maps are available from ArcScripts. The script is named ***Geographic Transformation Formula Maps*** and were created by Rob Burke. Search for "wgs84"

http://arcscripts.esri.com/details.asp?dbid=15287



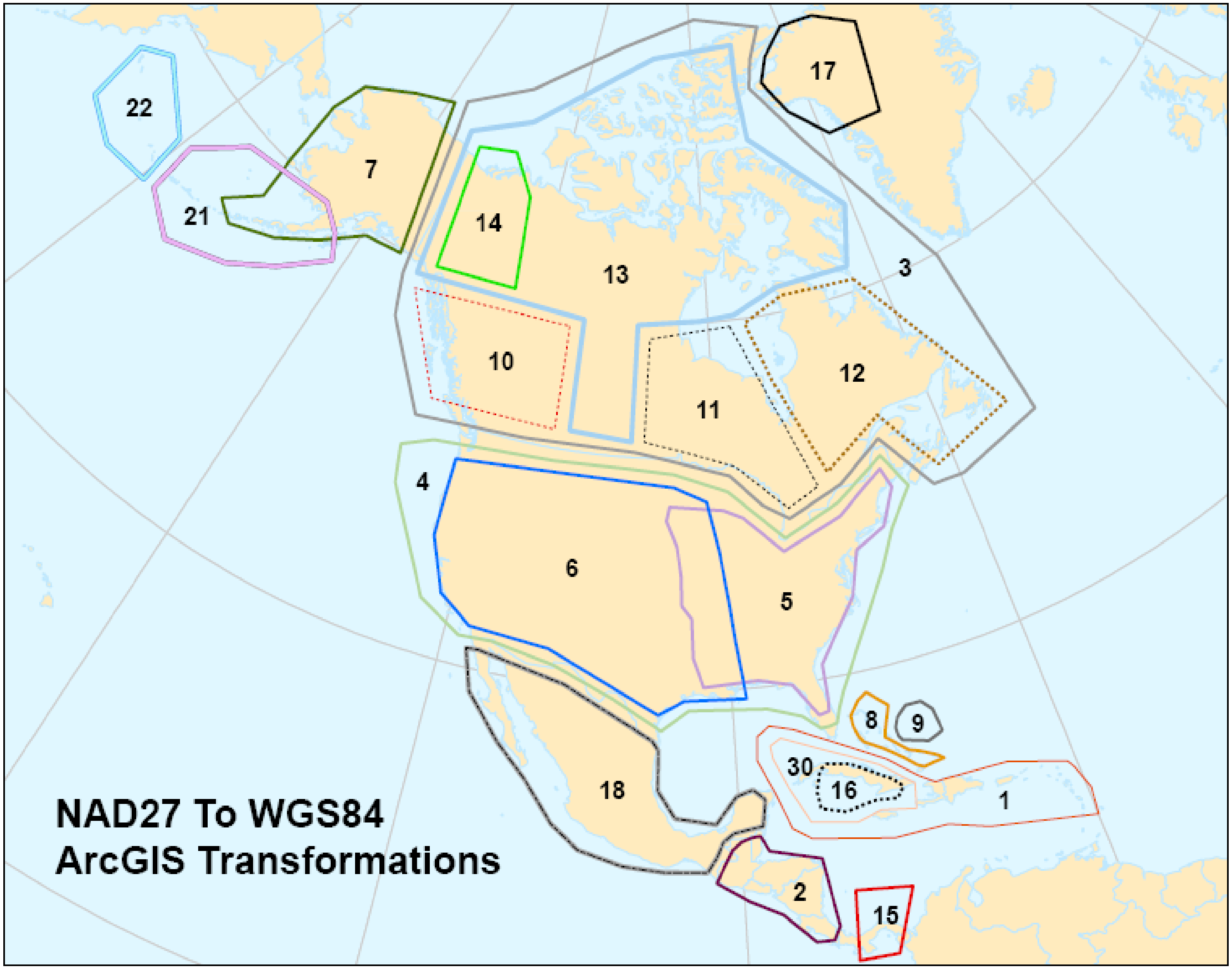
Understanding Projections for GIS

Working with Projections in ArcGIS

Projecting Data in ArcGIS – Transformation methods NAD27/WGS84

These maps are available from ArcScripts. The script is named ***Geographic Transformation Formula Maps*** and were created by Rob Burke. Search for "wgs84"

http://arcscripts.esri.com/details.asp?dbid=15287



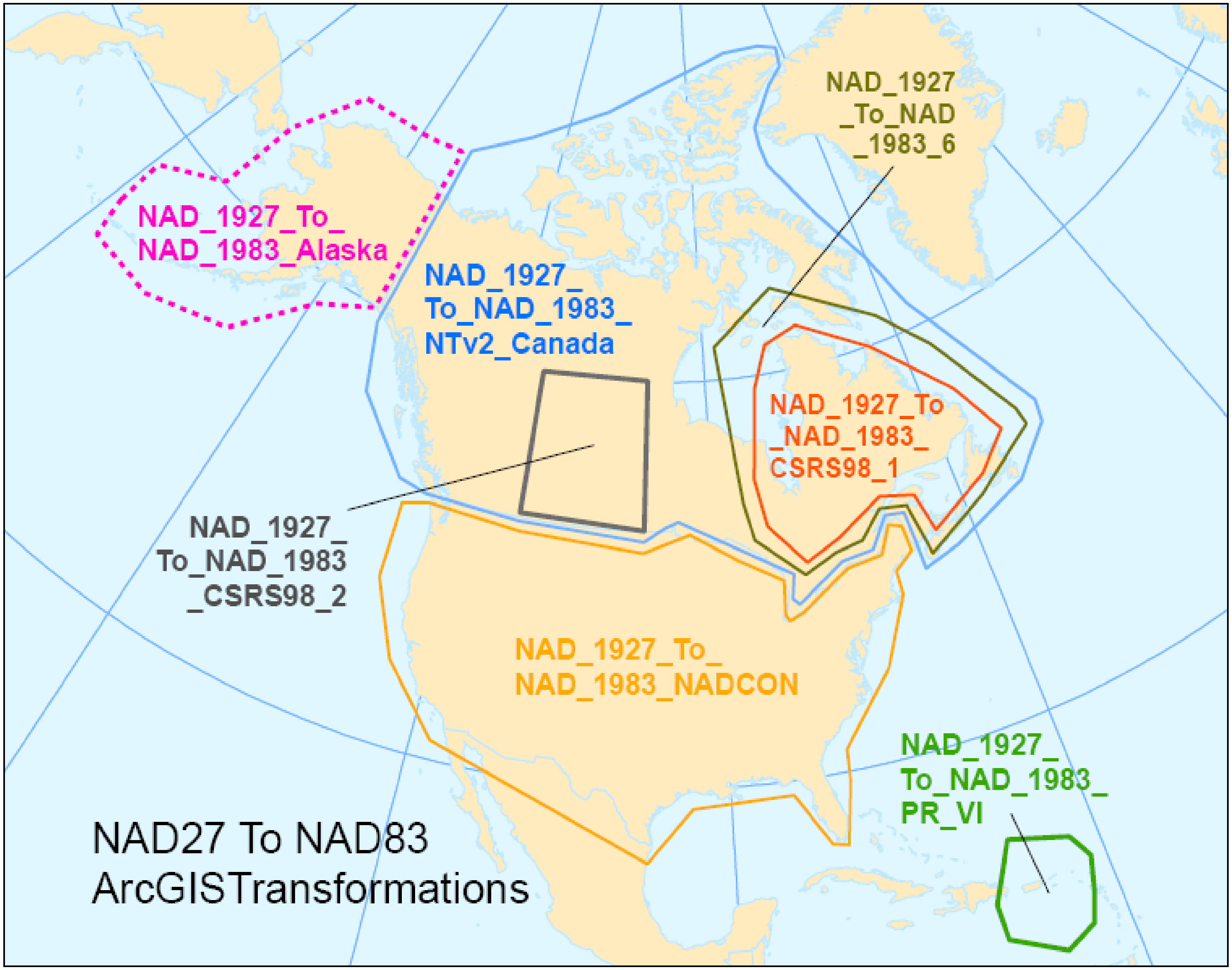
Understanding Projections for GIS

Working with Projections in ArcGIS

Projecting Data in ArcGIS – Transformation methods NAD27/NAD83

These maps are available from ArcScripts. The script is named ***Geographic Transformation Formula Maps*** and were created by Rob Burke. Search for "wgs84"

http://arcscripts.esri.com/details.asp?dbid=15287



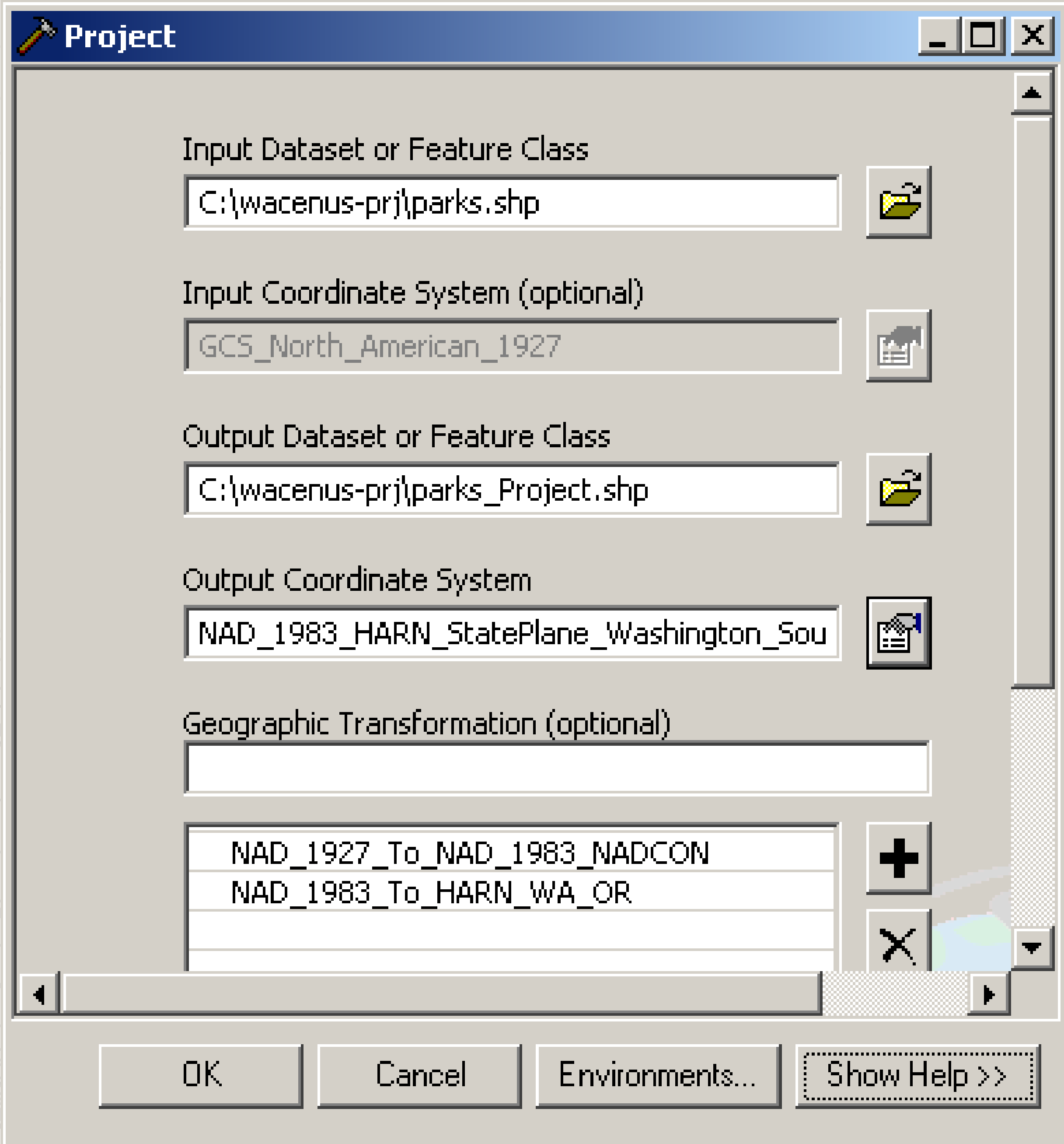
Understanding Projections for GIS

Working with Projections in ArcGIS

Projecting Data in ArcGIS

In some cases, you might need to do two transformations.

The dialog box is smart enough to keep the Geographic Transformation drop-down button "active" if you haven't selected all the needed transformations.



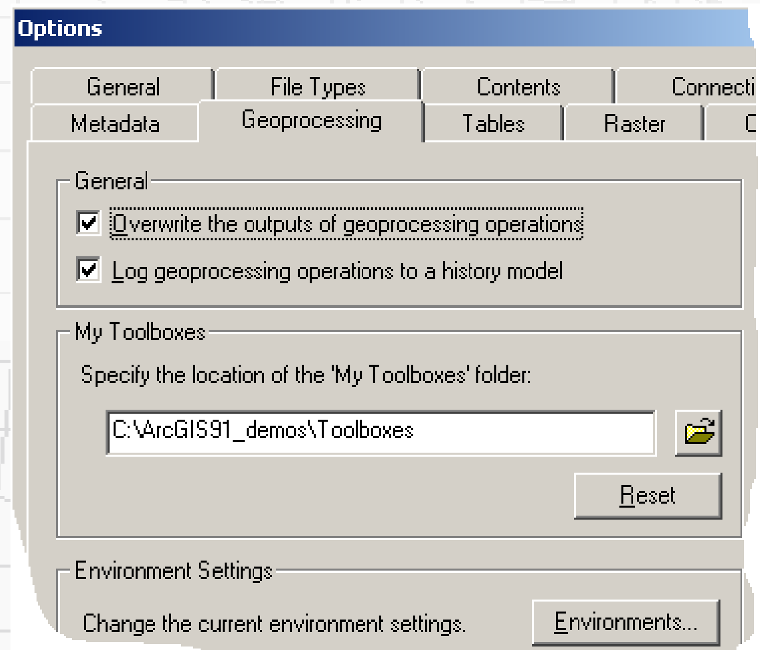
Understanding Projections for GIS

Working with Projections in ArcGIS

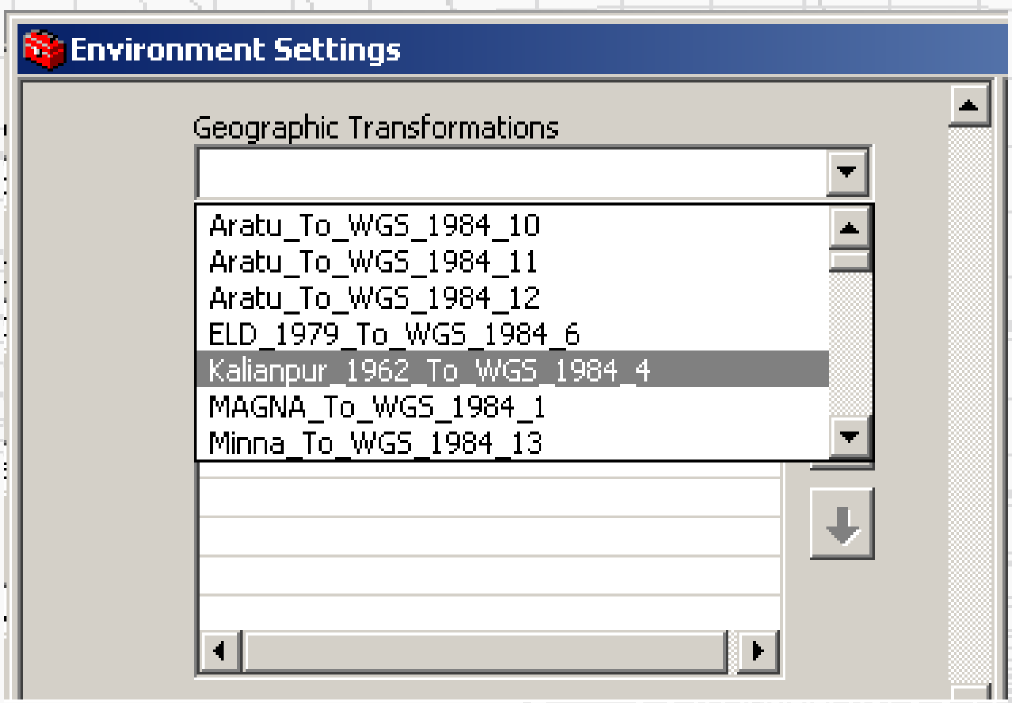
Projecting Data in ArcGIS

ArcGIS will also project data as part of most Geoprocessing operations –

But you must set the transformation methods in the Geoprocessing Environments or this may yield inaccurate results when datum changes are necessary. *Geoprocessing>Environments>General*



The transformation cannot be set in 9.1



Understanding Projections for GIS

Working with Projections in ArcGIS

ArcGIS will project data "on the fly" when you add data to ArcMap.

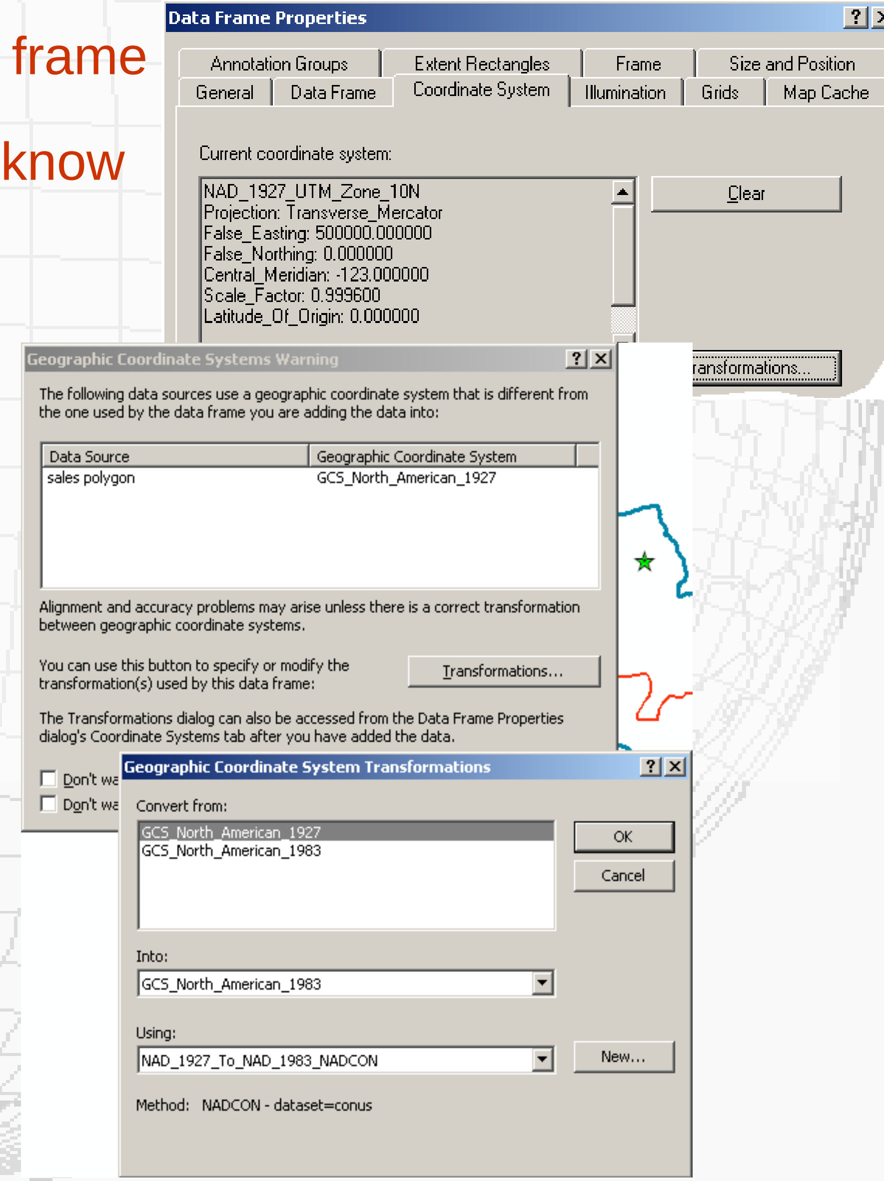
Coordinate system must be set for the data frame

Transformations methods can be set if you know the specifics of the data being added.

Works on raster data (images) and vector data.

Project on the fly is not as "mathematically rigorous" as using the project tool.

Best procedure for highest accuracy:
Do all projections through the Project Tool

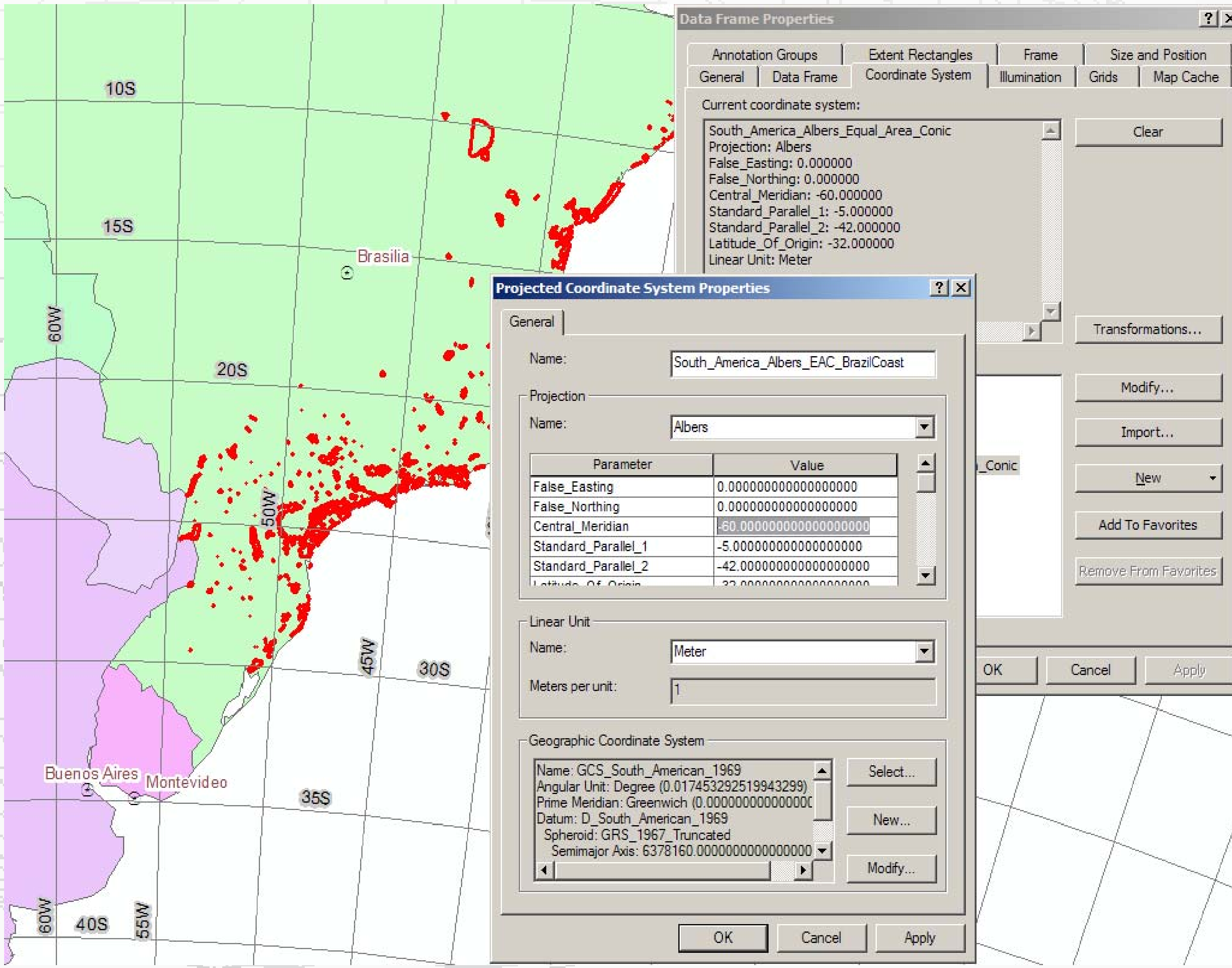


Understanding Projections for GIS

Working with Projections in ArcGIS

Modifying a Projection in ArcGIS

Projections can be modified to align with the area of interest.



Understanding Projections for GIS

Working with Projections in ArcGIS

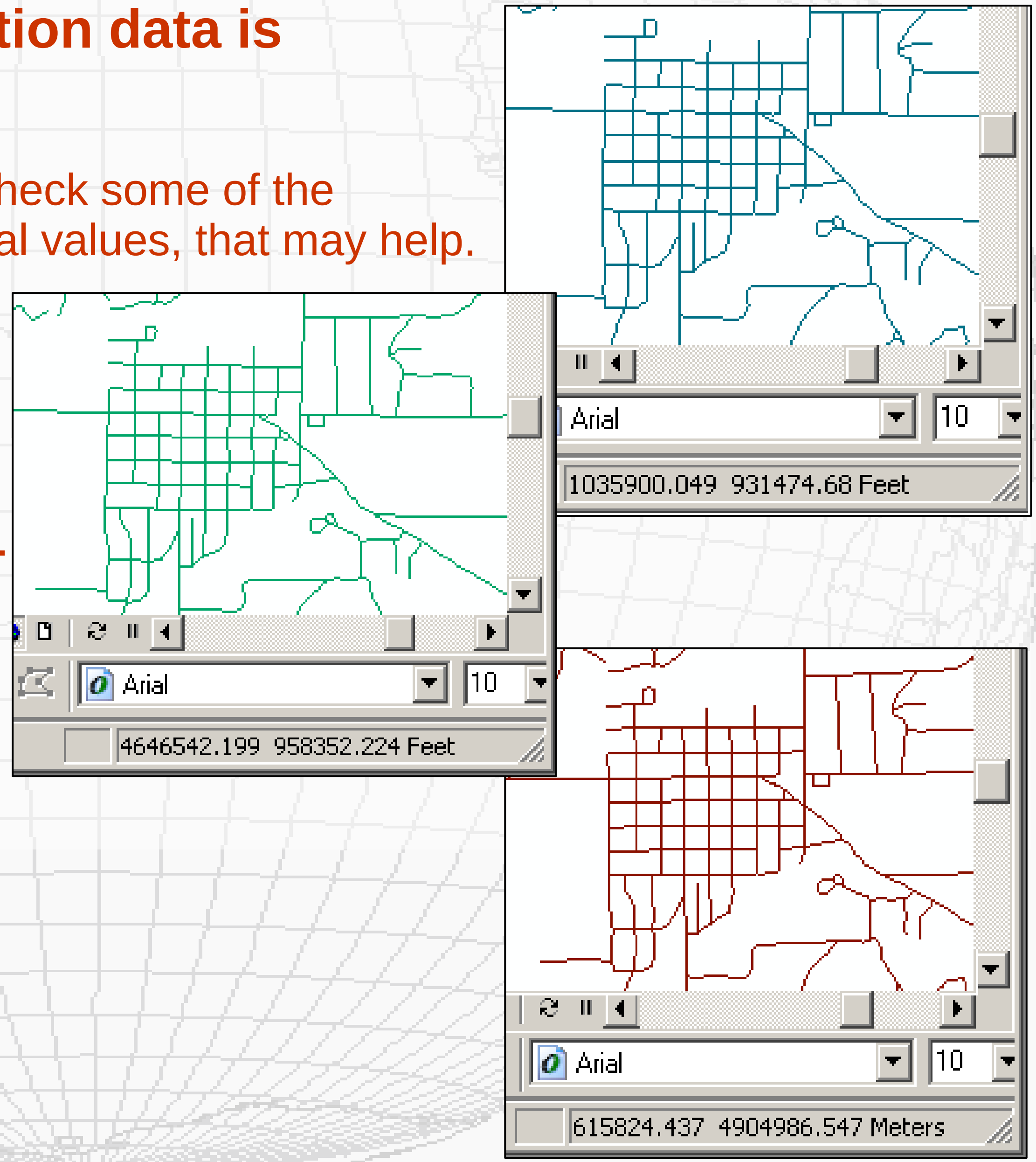
How to determine what projection data is in when there is no metadata

Bring data into an <u>empty</u> map and check some of the coordinate values. If you know typical values, that may help.

Can be hard to tell difference between NAD27 and NAD83 for UTM or NAD83 and Harn for State Plane because those numbers only vary a few feet to a 100 meters.

Compare unknown data to a known reference layer.

Check ESRI help for article 24893 – this has some some suggestions.



Working with Projections in ArcGIS

Demonstrations

- Working with "Project on the Fly" and transformations
- Modifying Projections
- Projections with double datum transformations