- **Key Card access to Stone 218/219**
  - Email name/NetID/course number to support@cfc.umt.edu
  - Enter through Stone 219; access Stone 218 through door between the rooms.

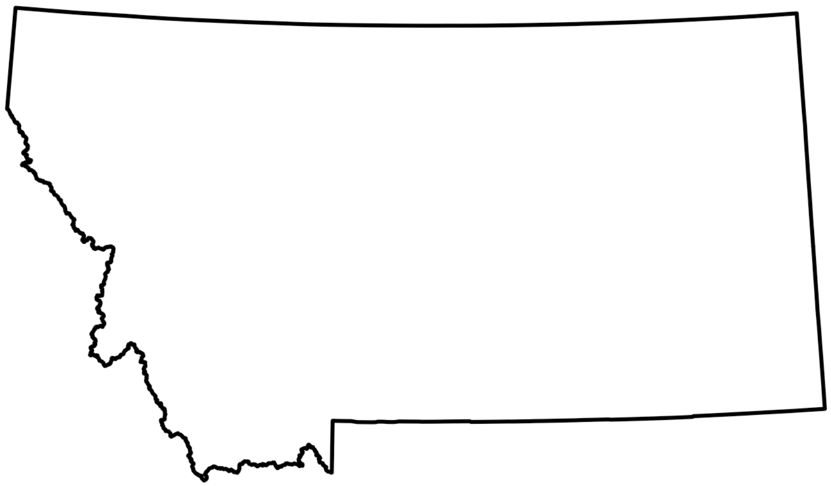
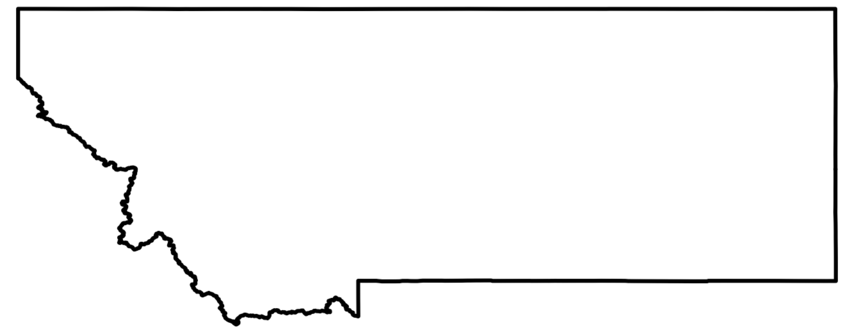
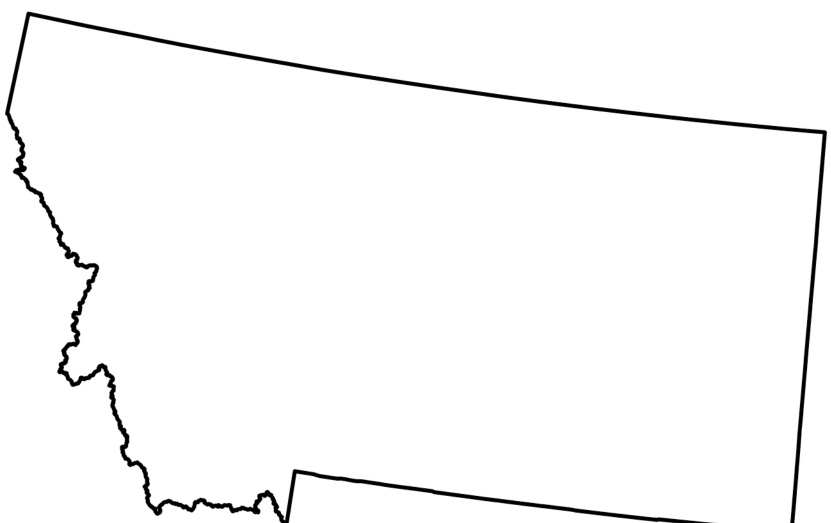
- **Join MAGIP list-serve** https://www.magip.org
  - Resources -> E-mail List-Serve

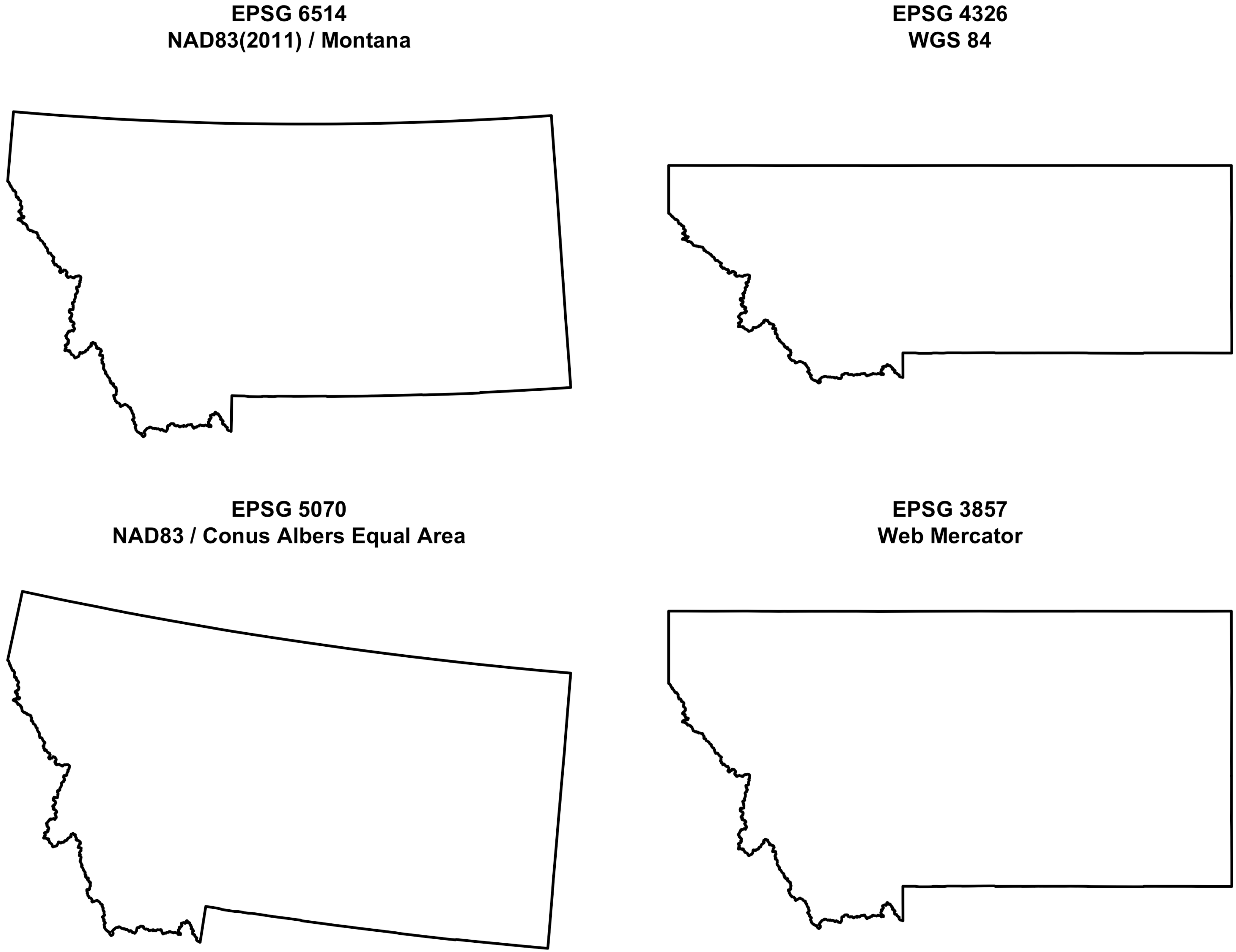
- **Syllabus Quiz on Tuesday**
  - https://umtgis.github.io/apps/syllabus/

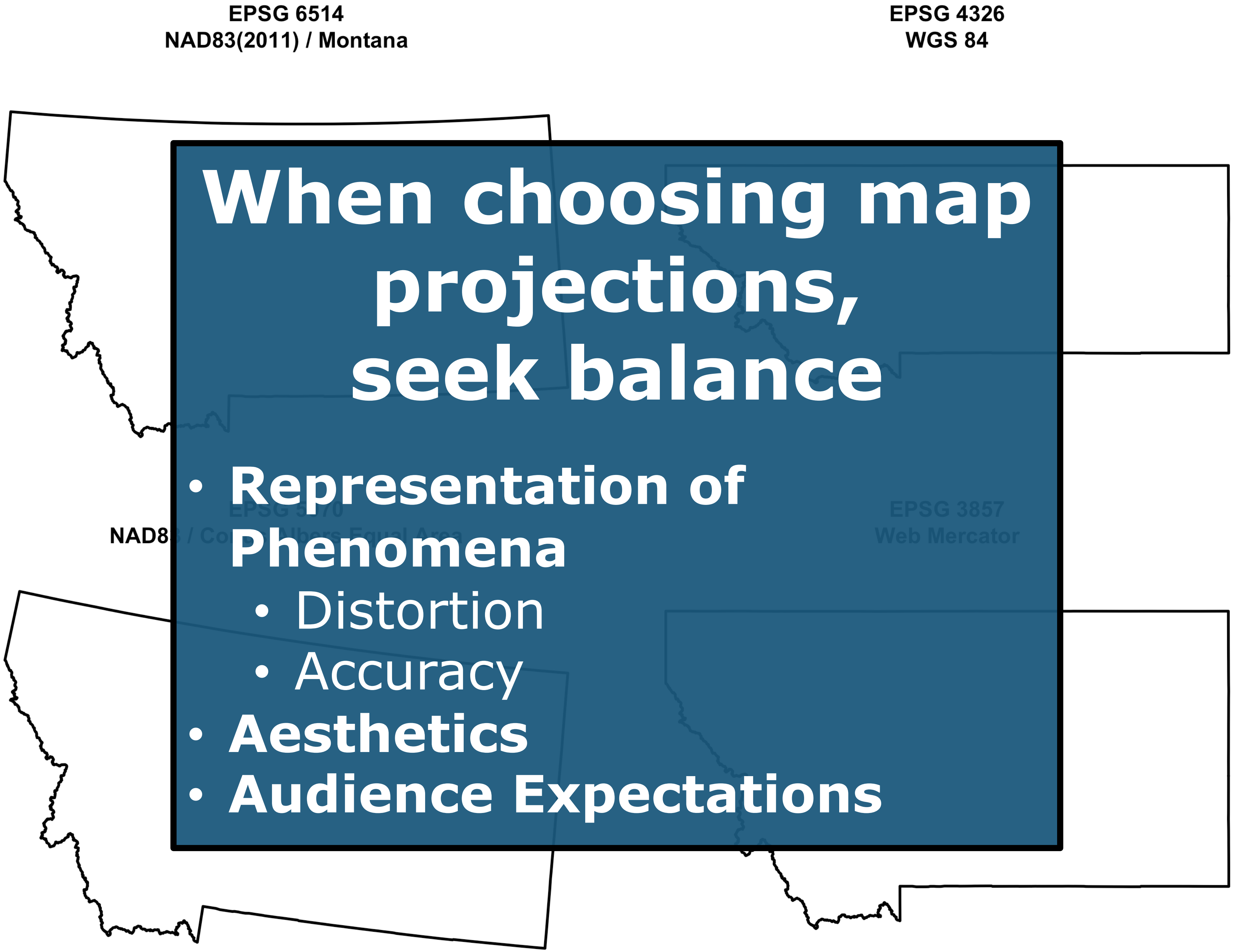
Coordinate Systems, Map Projections, Scale and GDBs

A Concise Review,

Without All the Fat!

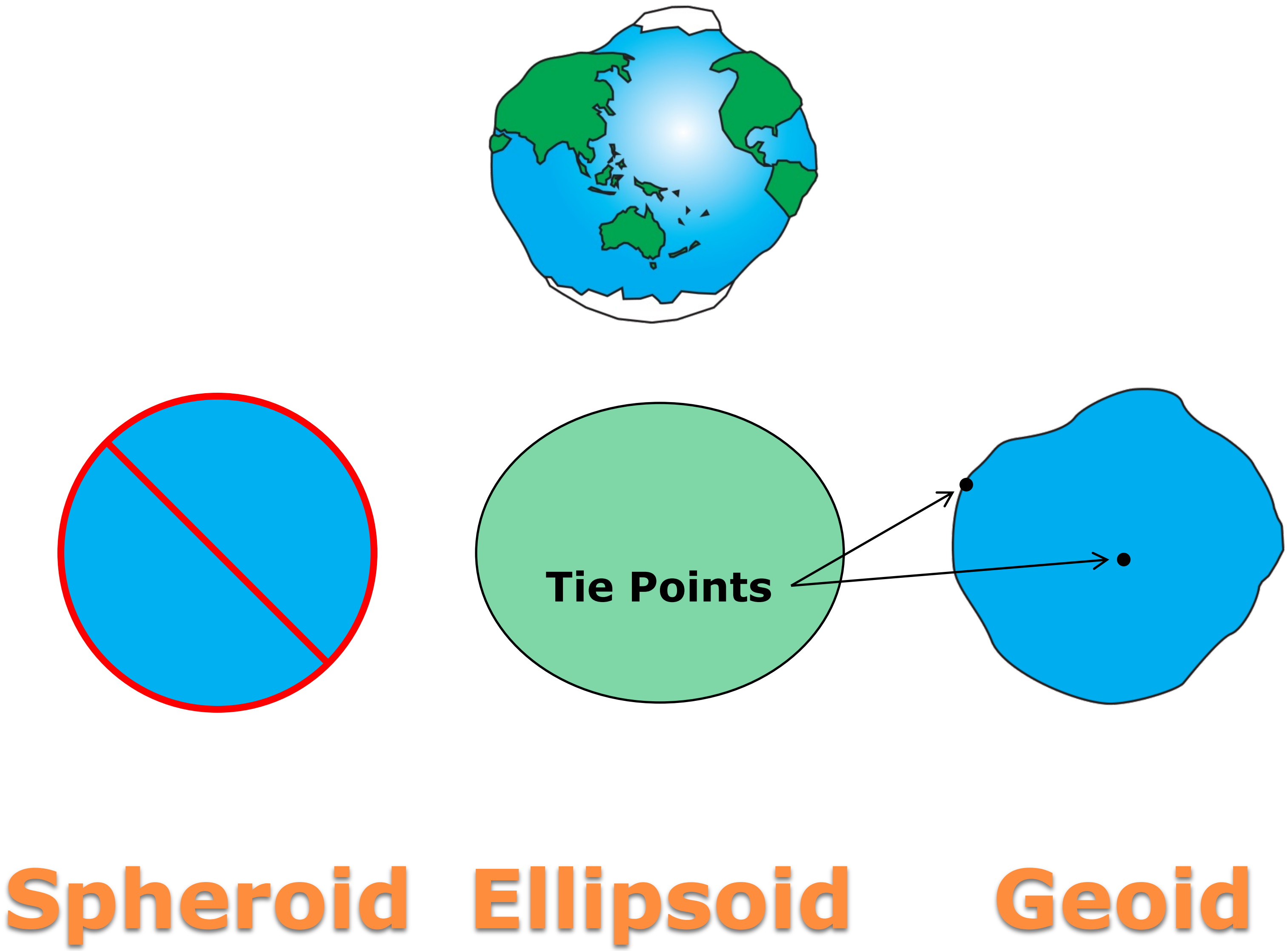




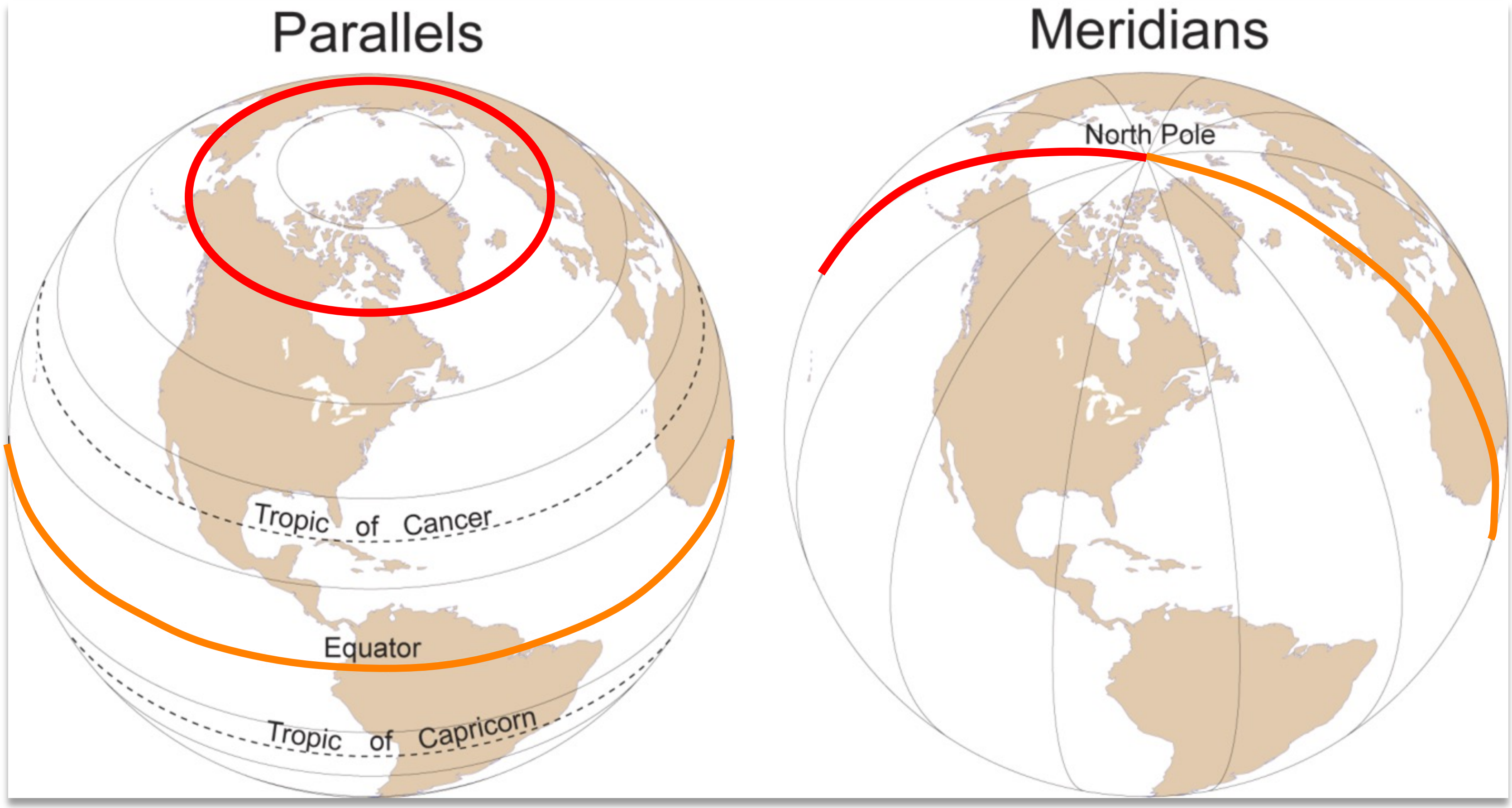


EPSG 6514
NAD83(2011) / Montana
EPSG 4326
WGS 84
EPSG 5070
NAD83 / Conus Albers Equal Area
EPSG 3857
Web Mercator



When choosing map projections, seek balance

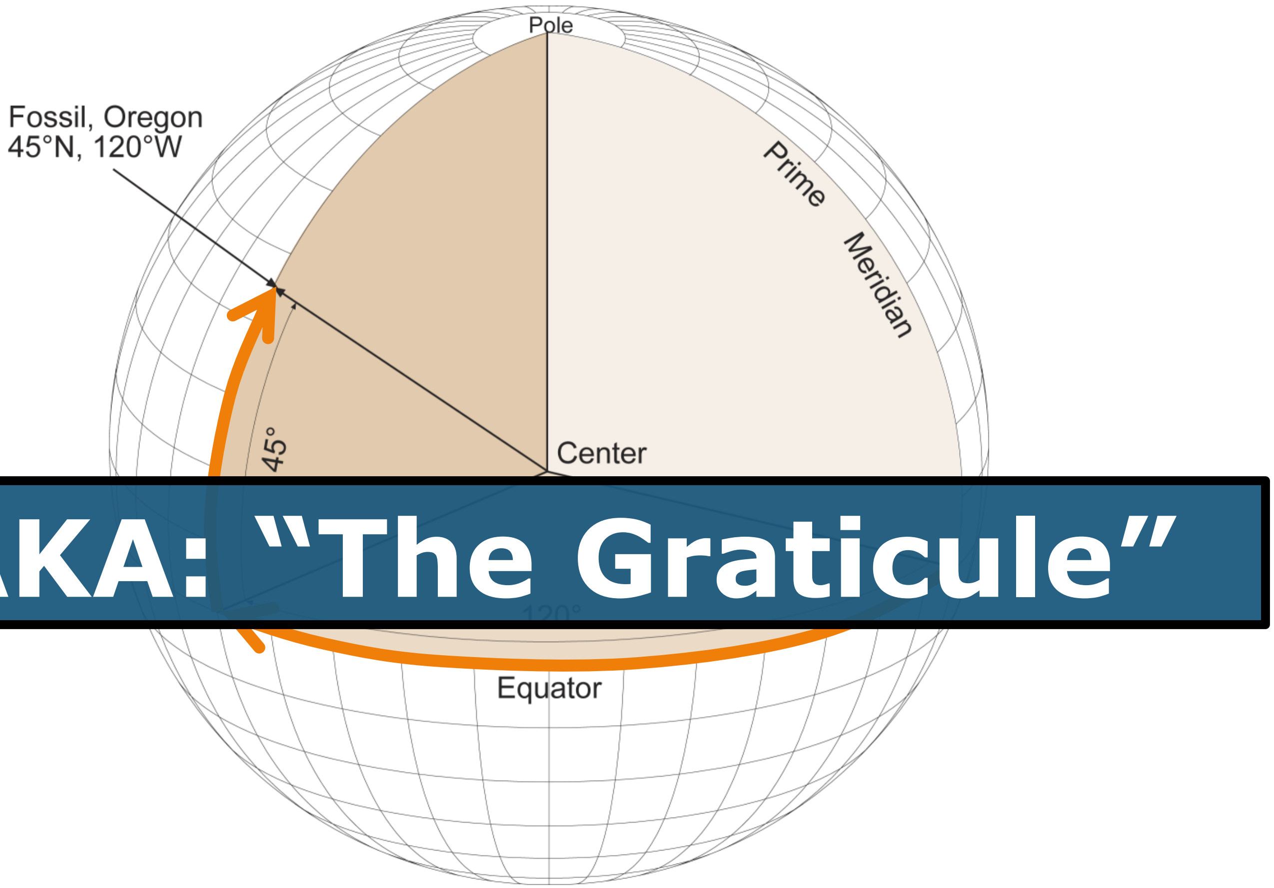
- **Representation of Phenomena**
  - Distortion
  - Accuracy
- **Aesthetics**
- **Audience Expectations**


Tie Points
Spheroid
Ellipsoid
Geoid



Latitude **Longitude**

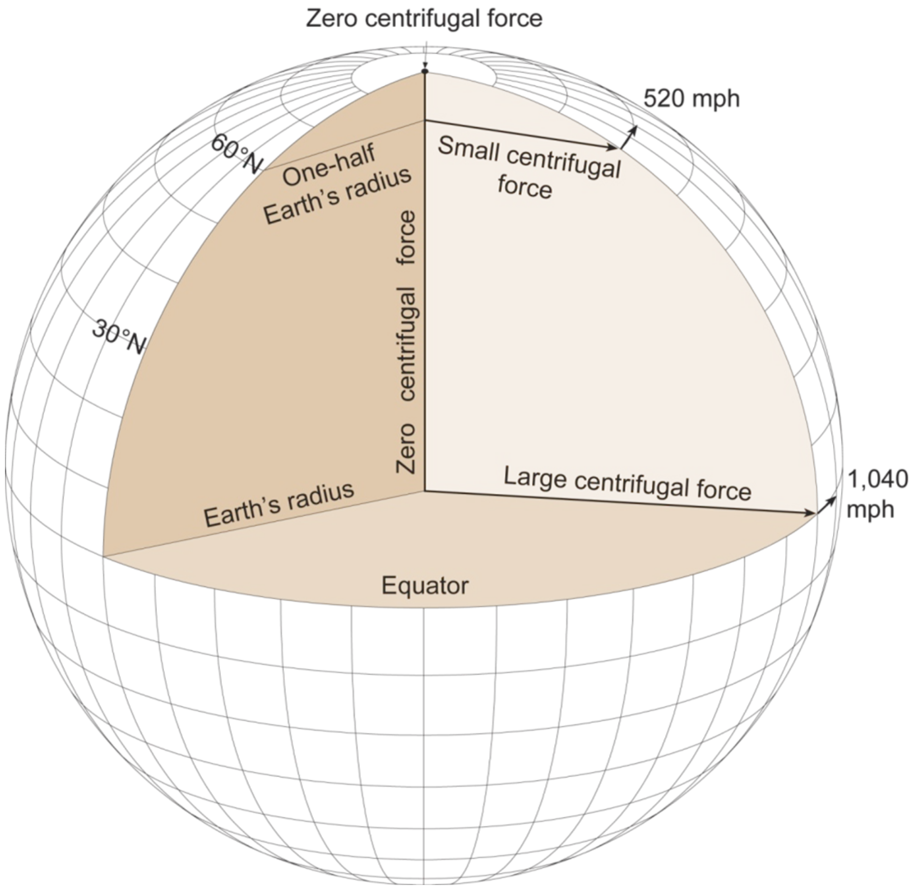
Coordinate Systems



AKA: “The Graticule”

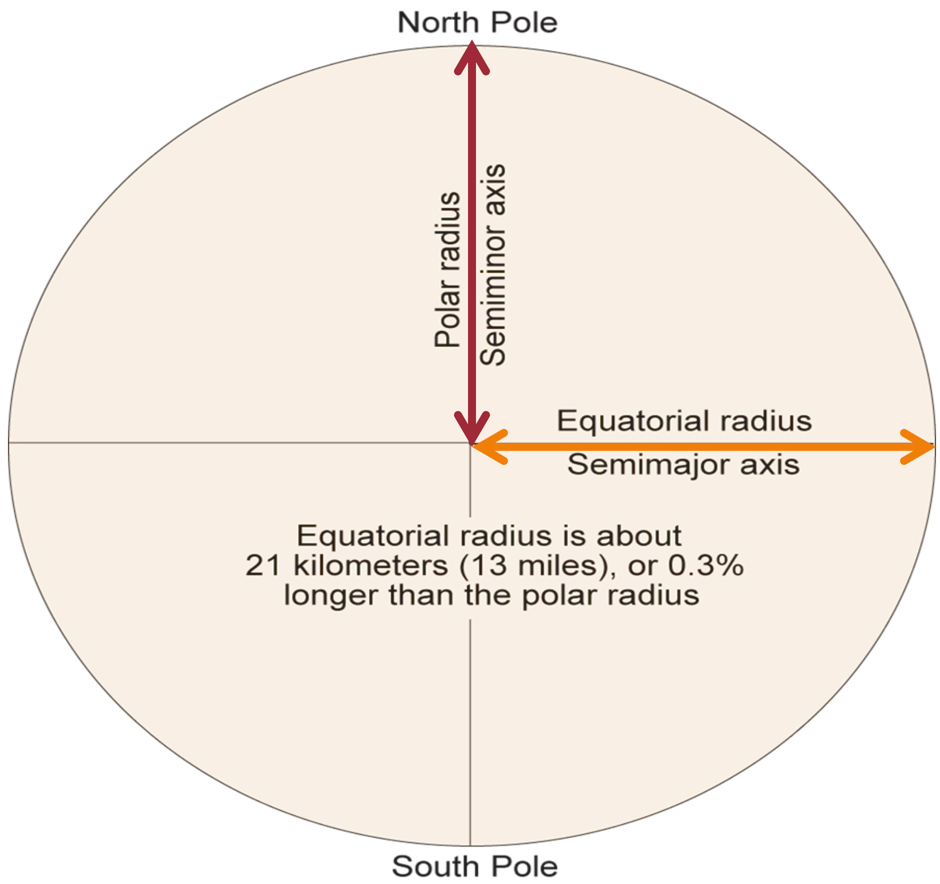
Coordinate Systems

Is 45°N positive or negative?   Is 120°W positive or negative?   45, -120

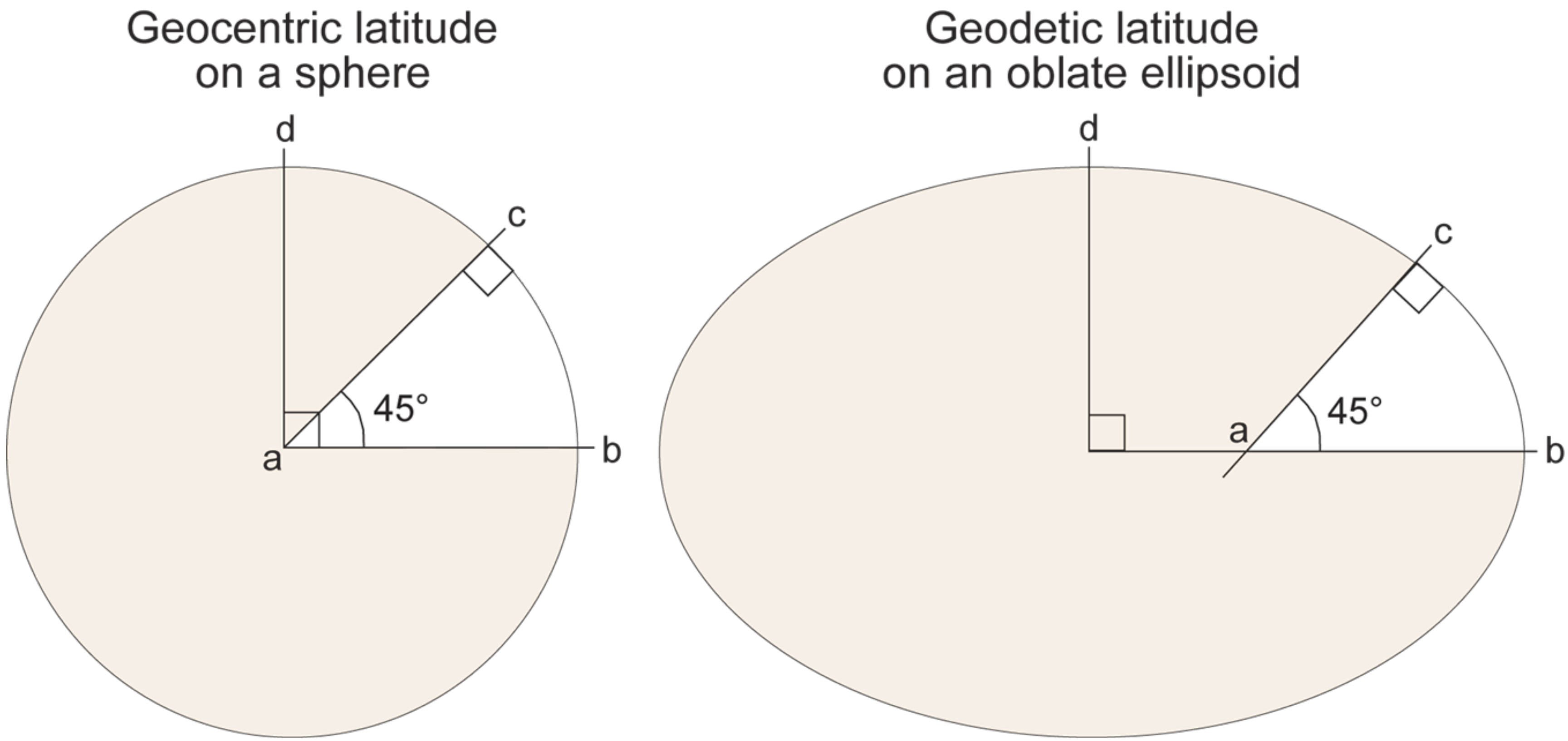


Zero centrifugal force
520 mph
60°N
One-half
Earth's radius
Small centrifugal
force
Zero centrifugal force
30°N
Earth's radius
Large centrifugal force
1,040
mph
Equator

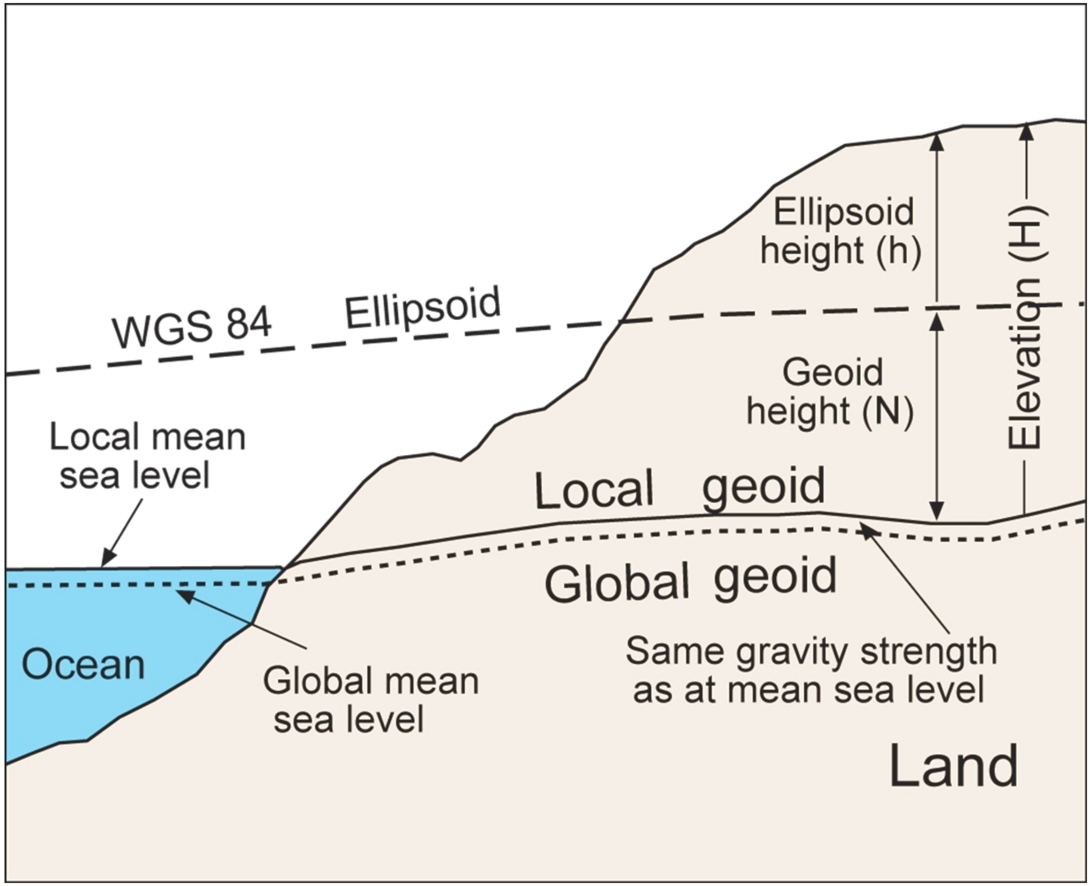
Ellipsoid


North Pole
Polar radius
Semiminor axis
Equatorial radius
Semimajor axis
Equatorial radius is about
21 kilometers (13 miles), or 0.3%
longer than the polar radius
South Pole

Ellipsoid


Geocentric latitude
on a sphere
d
c
45°
a
b
Geodetic latitude
on an oblate ellipsoid
d
c
a
45°
b

Ellipsoid


Ellipsoid
height (h)
Elevation (H)
WGS 84 Ellipsoid
Geoid
height (N)
Local mean
sea level
Local geoid
Global geoid
Ocean
Global mean
sea level
Same gravity strength
as at mean sea level
Land

Geoid

What the Heck is a Datum?

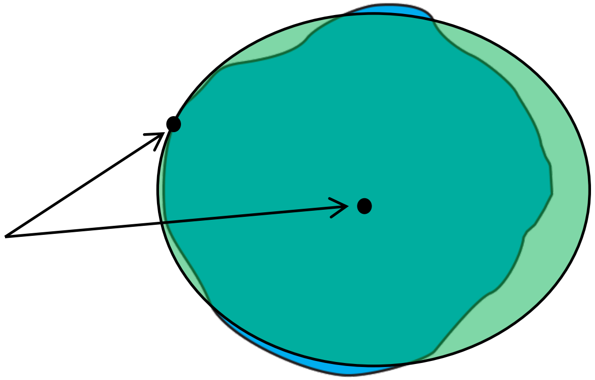
Ellipsoid

+

Geoid

+

(Coordinates) Tie Points



=

Datum

Also called:

Geographic Coordinate System

So… Where's the Beef?

The ellipsoid and geoid only matter if you are building\customizing reference systems……

In common use, just know that they are incorporated within the datum (GCS):

- NAD 27 uses the Clarke 1866 Ellipsoid
- NAD 83 uses the GRS 1980 Ellipsoid
- WGS 84 uses the EGM 1996 Ellipsoid

Etc….

TAKE HOME: These 3 Datums are what you will use 90% of the time. If you need another, look it up! https://epsg.io

National Geodetic Survey Positioning America for the Future geodesy.noaa.gov

New Datums Are Coming!

New Datums

NOAA is Replacing NAD 83 and NAVD 88.
NOAA's National Geodetic Survey (NGS) will be replacing the datums of the National Spatial Reference System (NSRS), including **the North American Datum of 1983 (NAD 83) and the North American Vertical Datum of 1988 (NAVD 88)**. NGS will provide the tools to easily transform between the new and old datums. Read the NGS Ten-Year Plan and visit the **New Datums Web page** on our site to learn more.

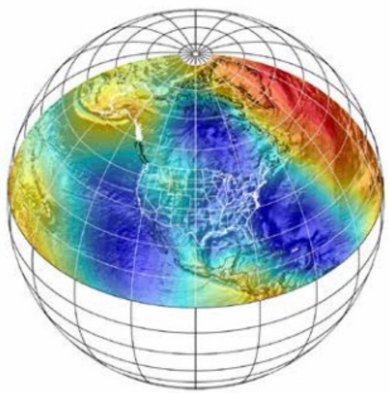
Benefits
The new reference frames (geometric and geopotential) will rely primarily on **Global Navigation Satellite Systems (GNSS)**, such as the Global Positioning System (GPS), as well as on a gravimetric geoid model resulting from NGS' **Gravity for the Redefinition of the American Vertical Datum (GRAV-D)** Project.

The target accuracy of differential orthometric heights (heights relative to sea level) in the geopotential reference frame will be 2 centimeters over any distance, where possible.

What You Can Expect
The magnitude of change with the new datums will vary depending on the datum you are using and your geographic location. The new geometric datum will change latitude, longitude, and ellipsoid height between 1 and 4 meters. In the conterminous United States (CONUS), the new vertical datum will change heights on average 50 centimeters, with approximately a 1-meter tilt towards the Pacific Northwest.

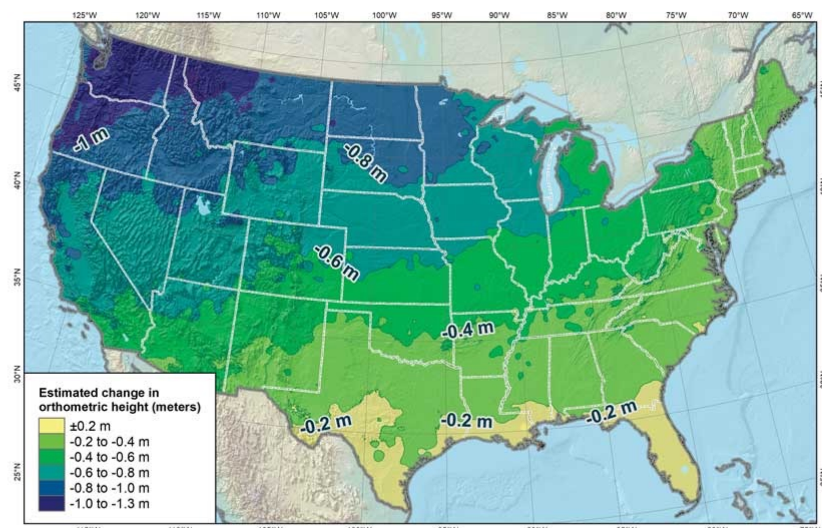
How You Can Prepare

- Learn if **legislation** or other formal documents referencing NAD 83 and NAVD 88 need to be changed in your state.
- **Transform existing data** to the latest NSRS datums and realizations; i.e. NAD 83 (2011), GEOID18, and NAVD 88.
- **Obtain precise ellipsoidal heights** on NAVD 88 bench marks, and visit the GPS on Bench Marks Web page to learn more.
- Require and provide **complete metadata** on all mapping contracts. See our website for more details.



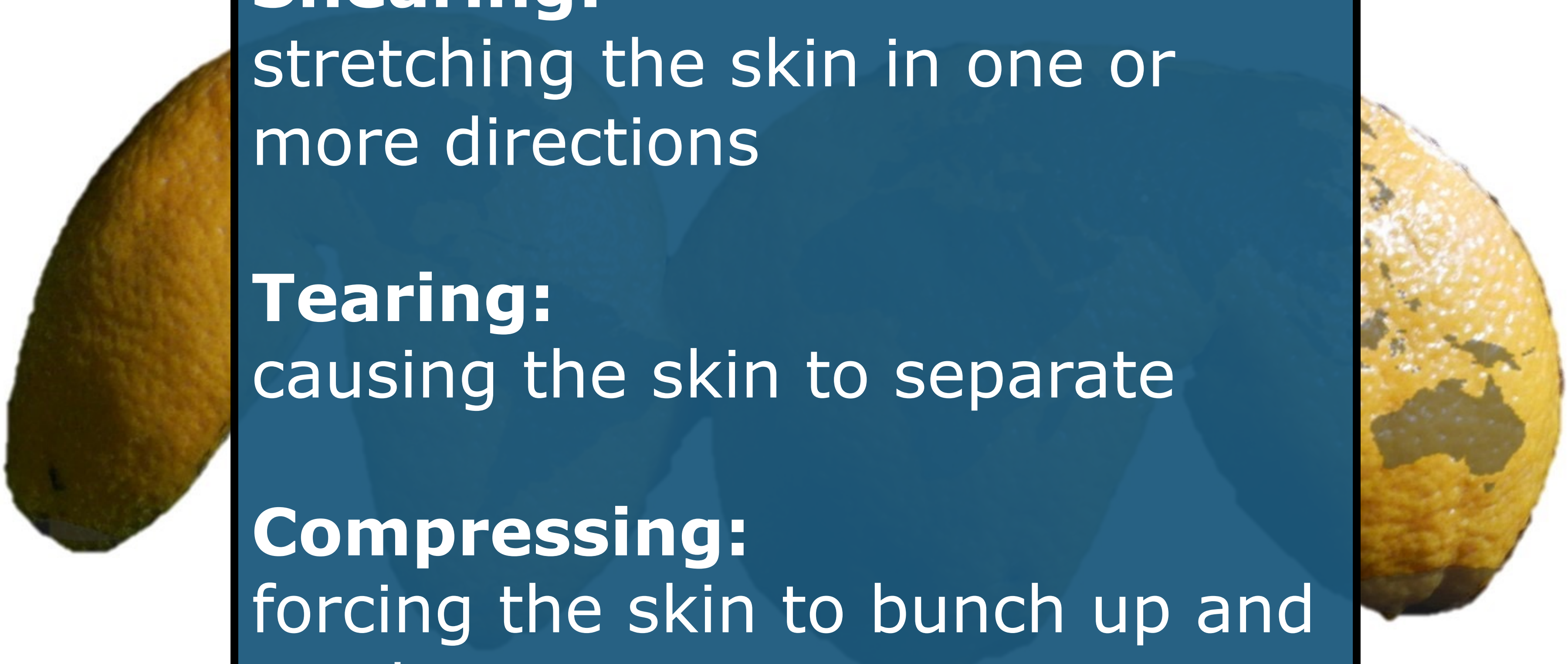
The new datums will extend across CONUS and U.S. territories. The terrestrial reference frames replacing NAD 83 will be consistent with geocentric global reference frames defining latitude and longitude. The geopotential datum replacing NAVD 88 will be based on a gravimetric geoid model, enhanced by data from NGS' Gravity for the Redefinition of the American Vertical Datum (GRAV-D) Project.

National Oceanic and Atmospheric Administration • National Geodetic Survey



NOAA ESRI

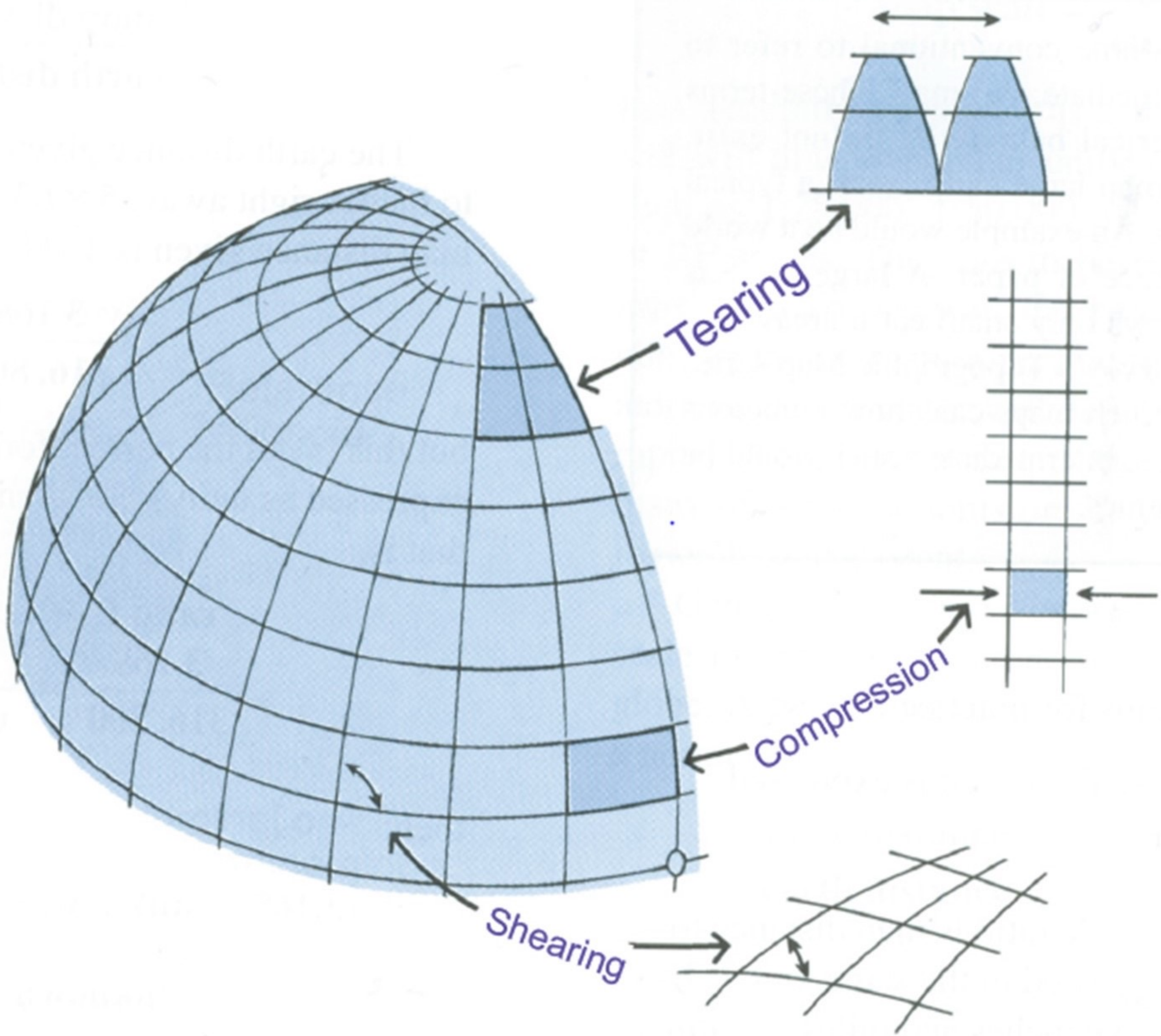
Projections – Distilled

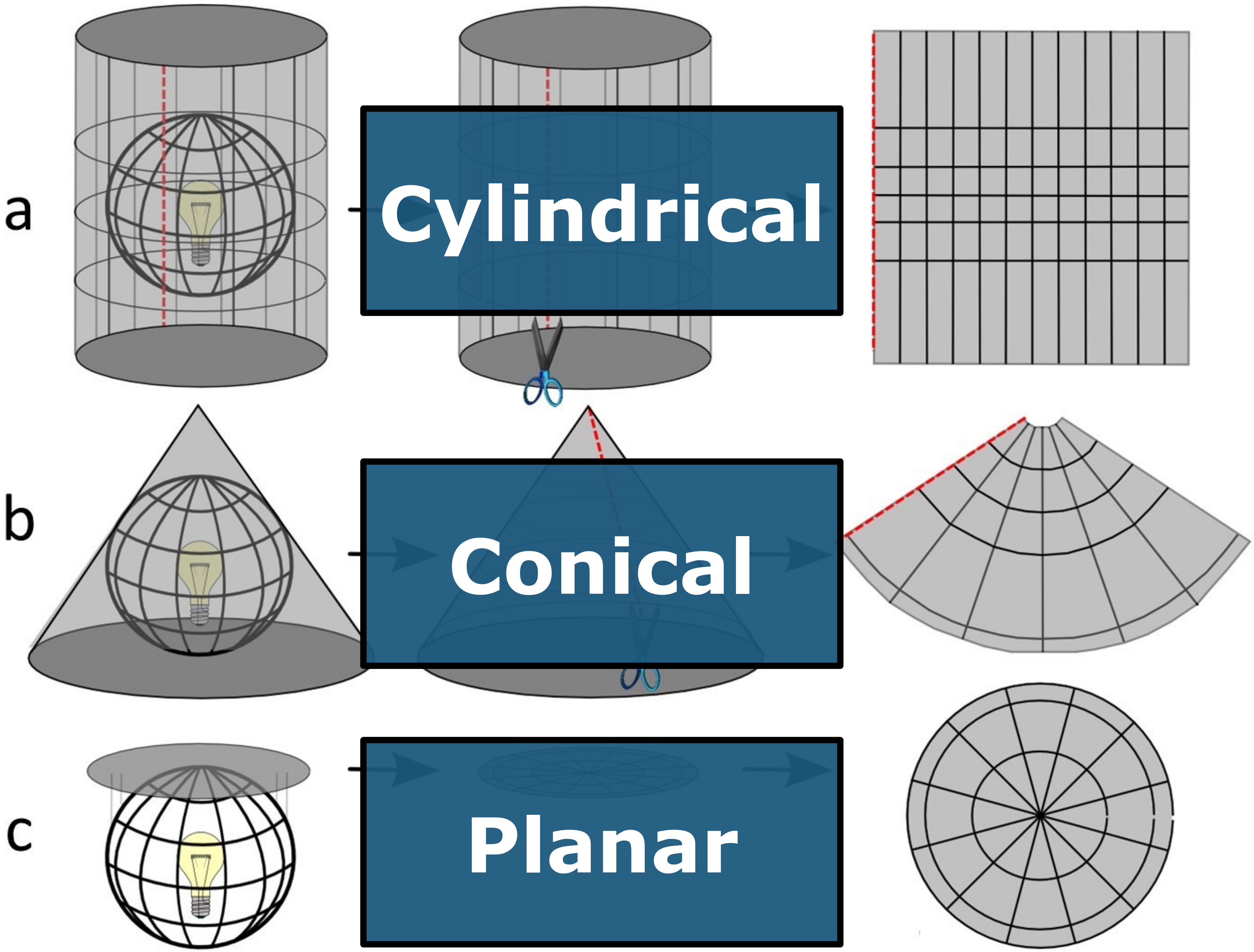


Shearing:
stretching the skin in one or more directions

Tearing:
causing the skin to separate

Compressing:
forcing the skin to bunch up and condense

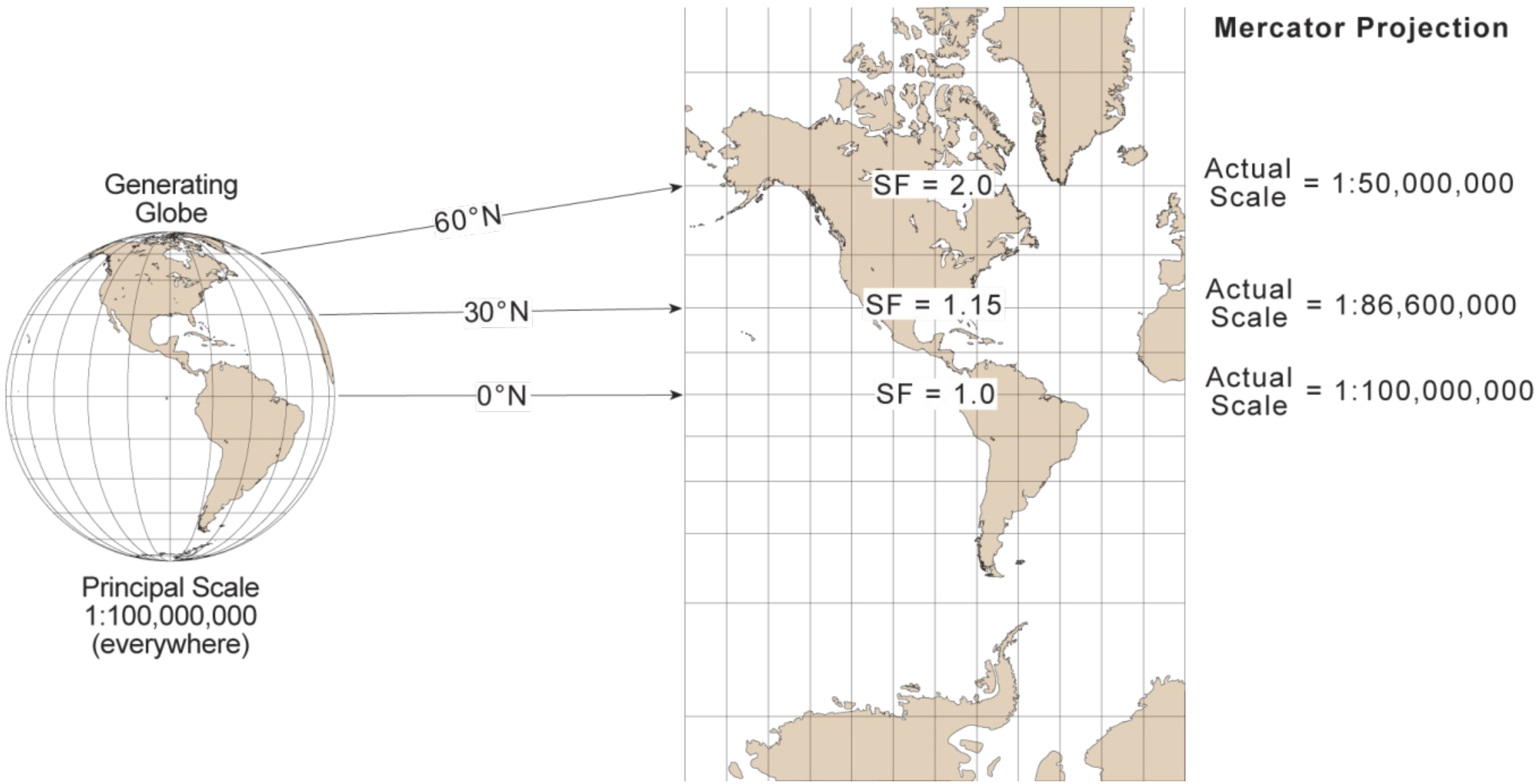

Tearing
Compression
Shearing


a
Cylindrical
b
Conical
c
Planar

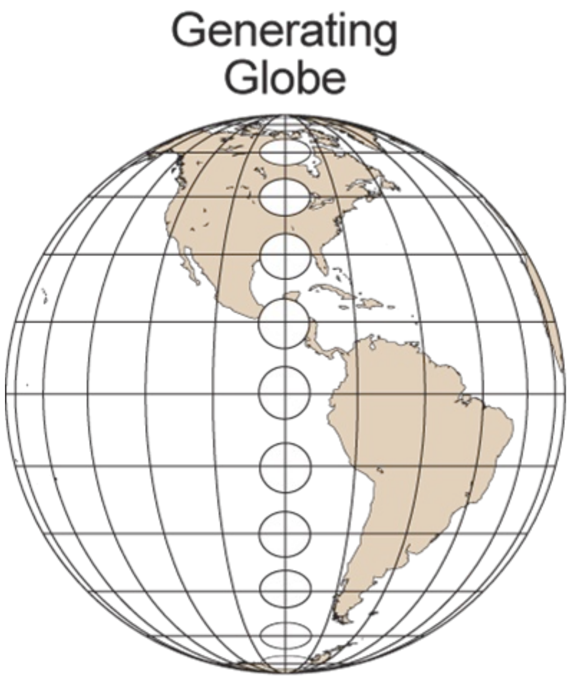
a

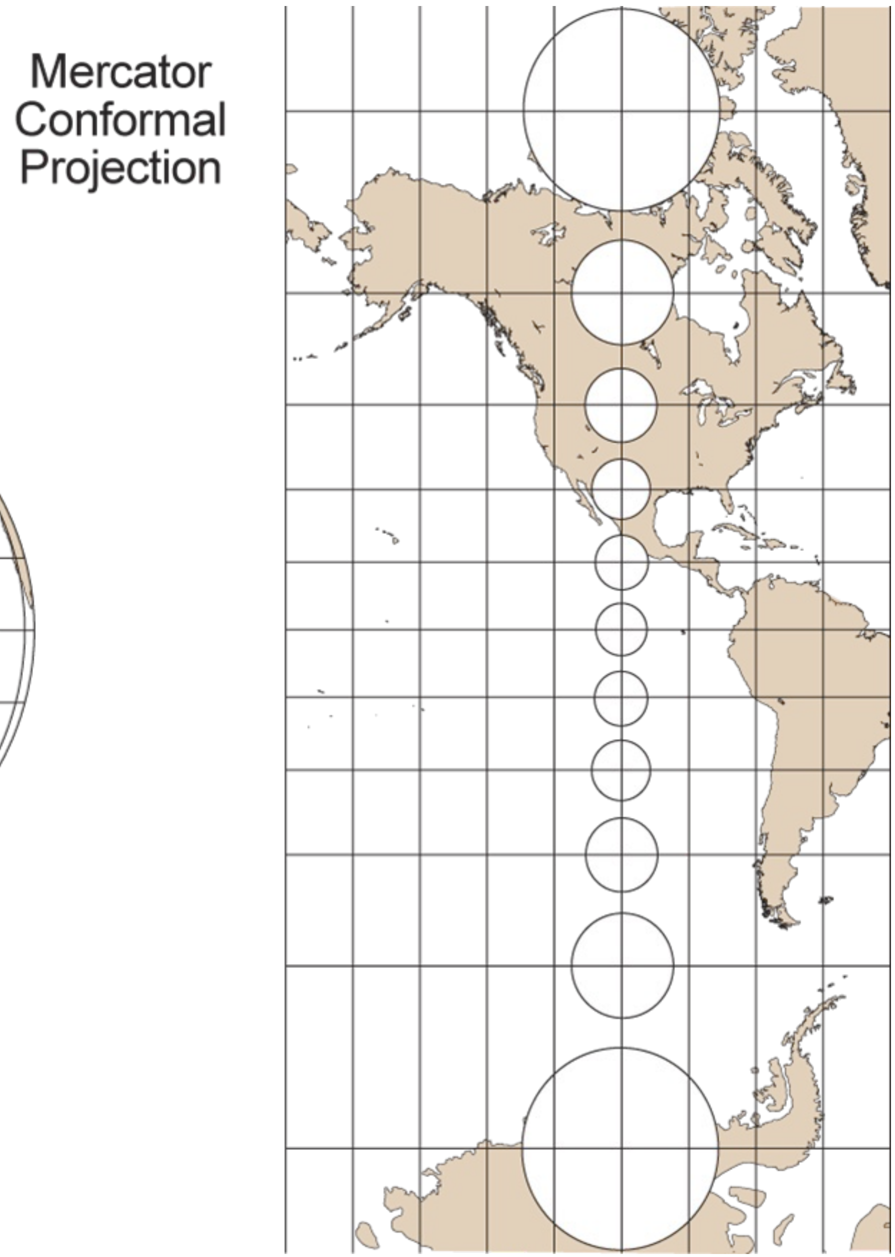
c

b

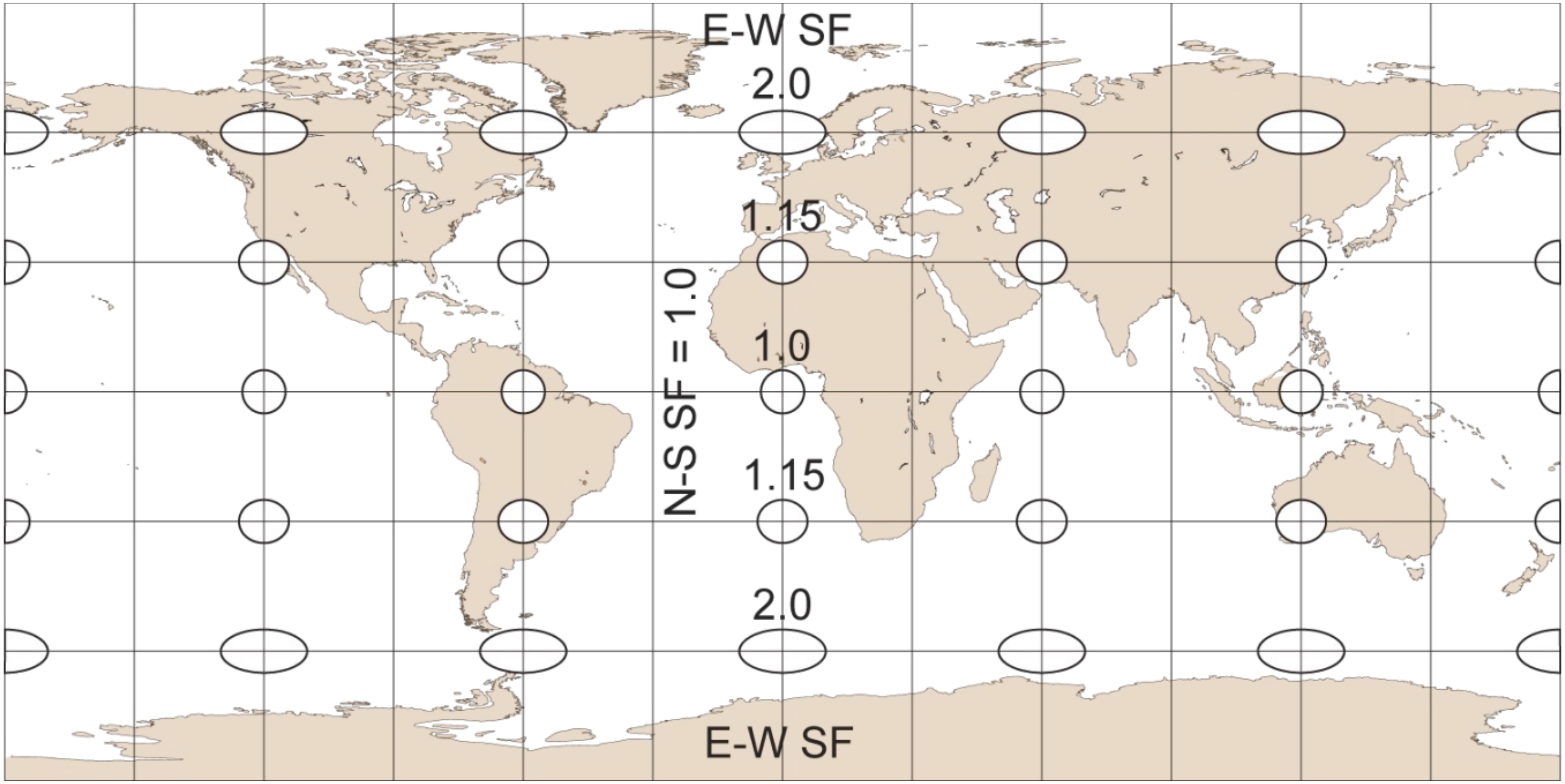


Projections



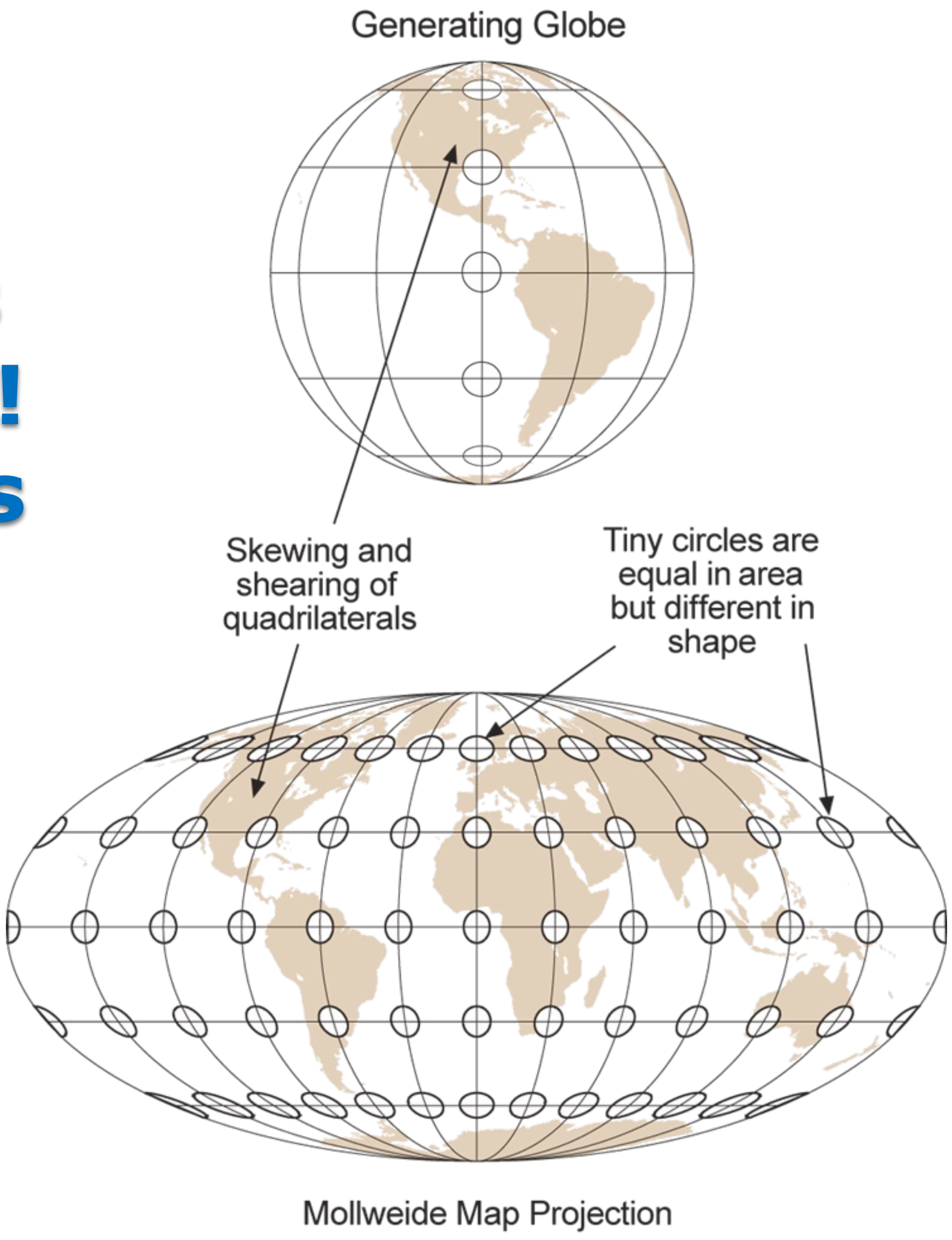


Projections



Projections

All Projections are Distortions! All we can do is compromise what gets distorted.



Projections

To Choose a Projection Ask…

What is the nature of the phenomena to be analyzed?

In other words, do you want to compare:

Area,

Distance,

Shape,

or

Direction

Projections – Distilled

Projections – You Have to Choose One

- **Azimuthal** — Direction from a given central point to any other point is shown correctly. Use to evaluate the **direction** phenomena move from a location.
- **Conformal** — Angles and shapes at each point are preserved. Use to compare the **shape** of phenomena in relation to one another.
- **Equal-area** — All areas have the same relative area as the corresponding part on the Earth. Use to compare the **area** of phenomena in relation to one another.
- **Equidistant** — Shows true distances from a center point or along a special set of lines. Use to measure the **distance** between phenomena, either spreading from a point or along a route.

https://map-projections.net/

Projections

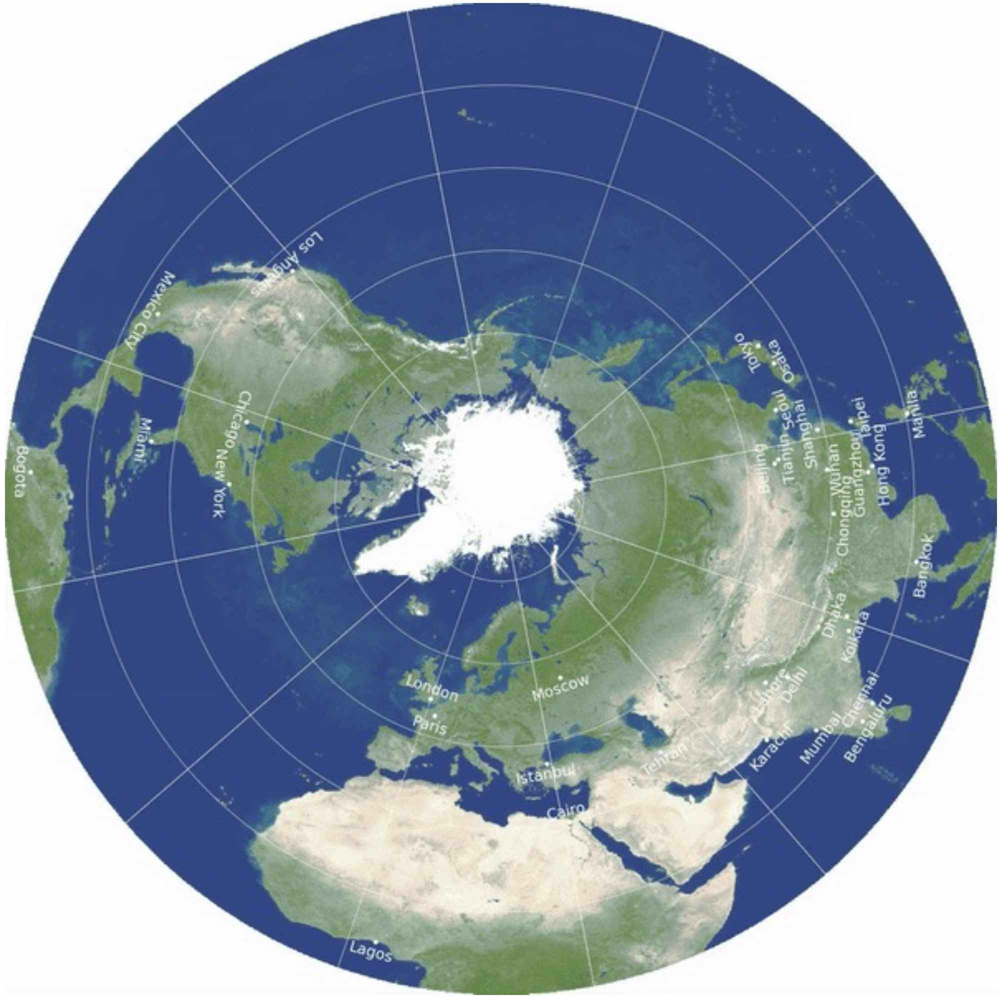
Projections – Choose Map Extent

TABLE 3.2 GUIDE TO THE EMPLOYMENT OF PROJECTIONS FOR WORLD-, CONTINENTAL-, AND COUNTRY-SCALE THEMATIC MAPS

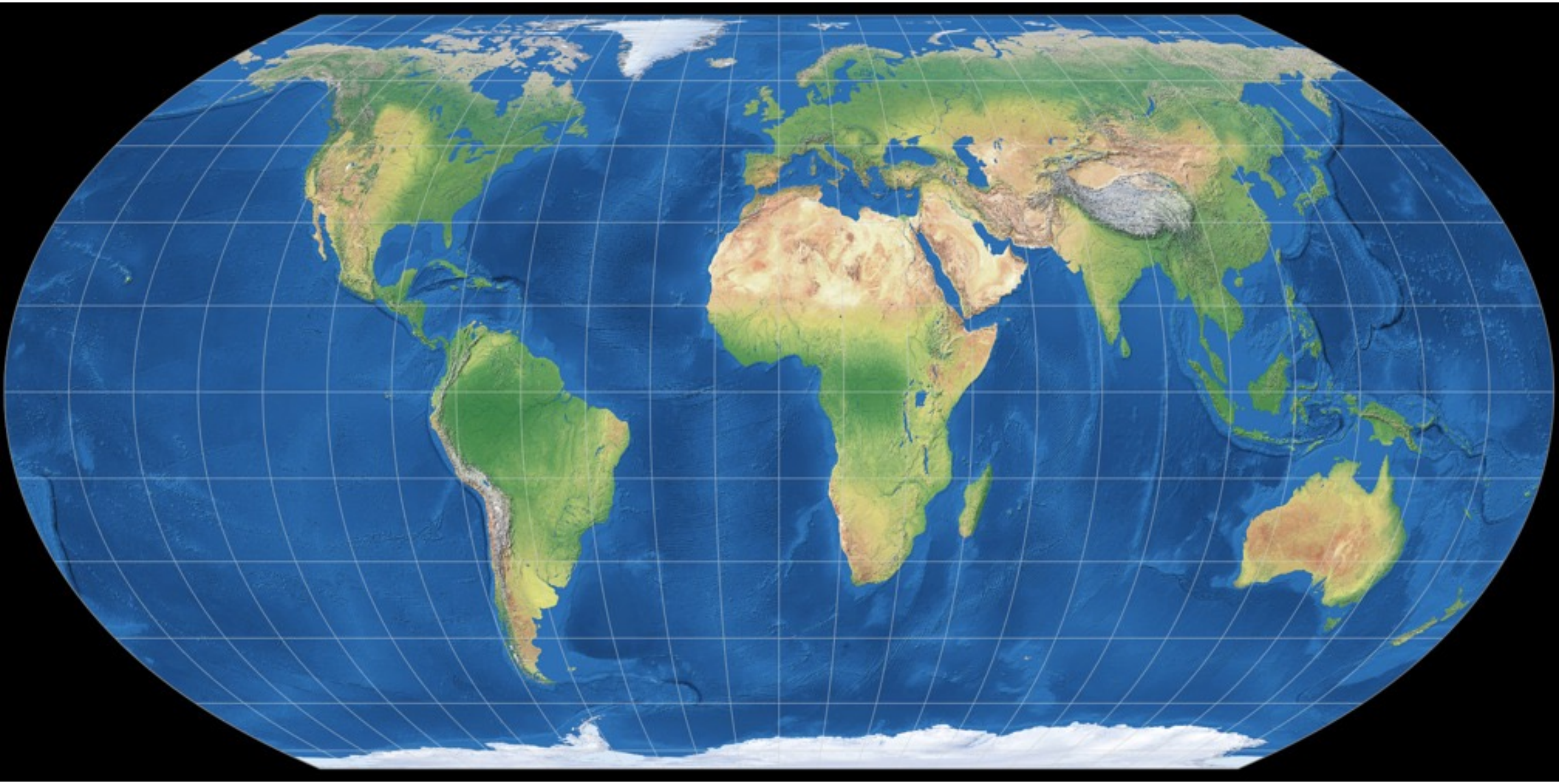
Principal Use	Suitable Projections	Notes
1. Maps of the world		
Equal area	Sinusoidal (Sanson-Flamsteed)	Awkard shape
Equal area	Mollweide	Pleasing shape
Equal area	Hammer	Sometimes called Hammer-Aitoff in software
Compromise	Robinson	Pleasing shape, balances extremes
Compromise	Winkel Tripel	May be most accurate compromise
2. Continental areas		
A. Asia and North America		
Equal area	Bonne*	Considerable distortion in NE and NW corners
Equal area	Lambert Azimuthal Equal Area	Bearings true from center
B. Europe and Australia		
Equal area	Lambert Azimuthal Equal Area*	
	Bonne*	
	Albers Equal Area Conic; ideal for United States	
Conformal	Lambert Conformal Conic	
C. Africa and South America		
Equal area	Lambert Azimuthal Equal Area*	
Equal area	Mollweide*	
Equal area	Sinusoidal*	
Equal area	Homolosine*	
3. Large countries in mid-latitudes		
A. United States, Russia, China		
Equal area	Lambert Azimuthal*	
Equal area	Albers Equal Area Conic	
Equal area	Bonne*	
Conformal	Lambert Conformal Conic	
4. Small countries in mid-latitudes		
Equal area	Albers Equal Area*	
Equal area	Bonne*	
Equal area	Lambert Azimuthal*	
Conformal	Lambert Conformal Conic*	
5. Polar regions		
Equal area	Lambert Azimuthal	
6. Hemispheres and continents		
Visual	Orthographic	View of Earth as if from space; neither equal area nor conformal

***Must take special care to scale (zoom in) and re-center projection parameters to the particular area of interest.**

Sources: Compiled from a variety of sources listed in the references, especially Raisz 1962; Steers 1962; Snyder 1987; Dana 1999; and Environmental Systems Research Institute 2007.



Double sided disk by J. Richard Gott, Robert Vanderbei and David Goldberg



Equal Earth projection by Bojan Savric, Tom Patterson, Bernhard Jenny (2018)

Natural Earth II projection by Tom Patterson, Bojan Savric, Bernhard Jenny (2015) https://map-projections.net/singleview.php

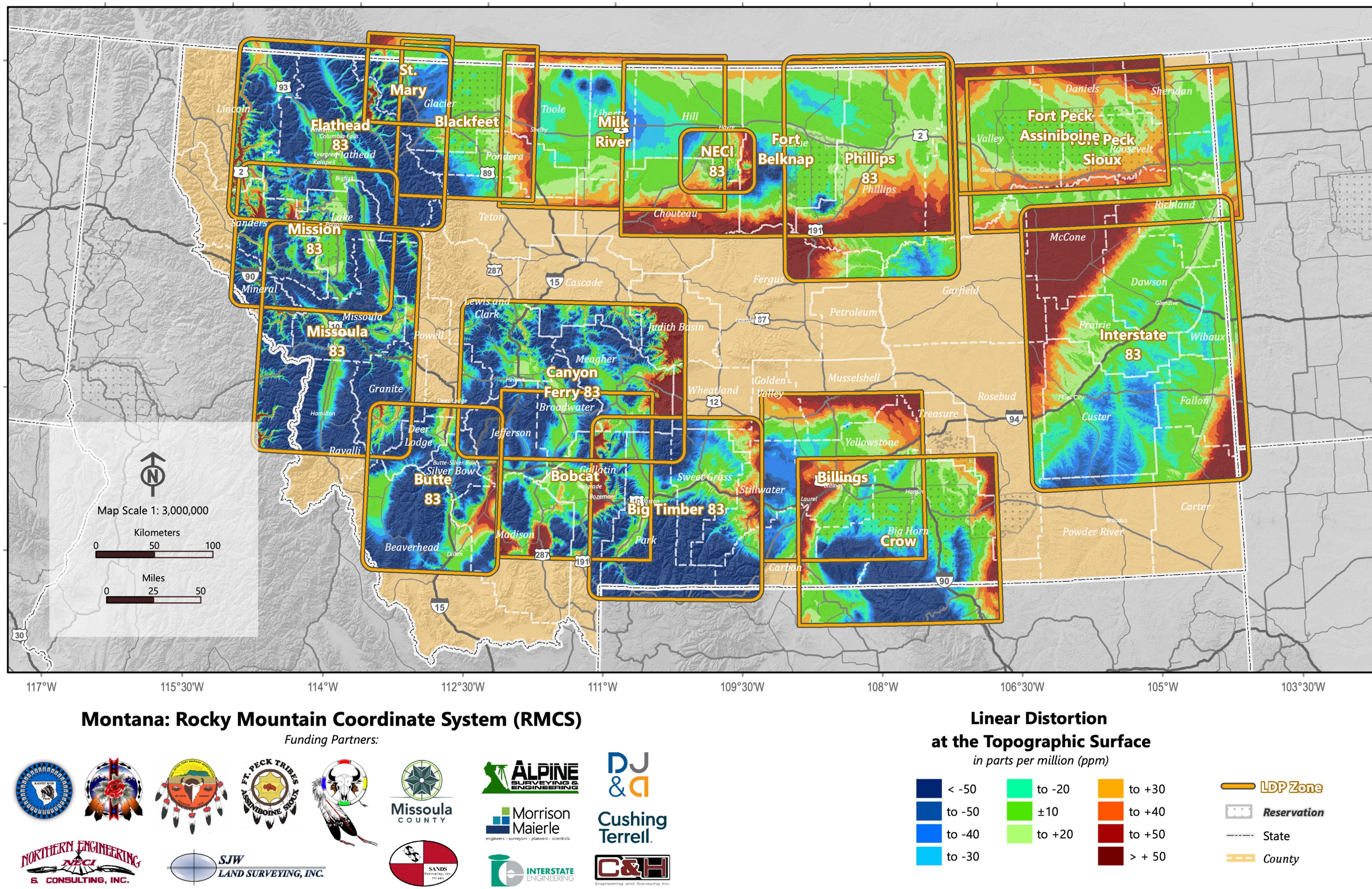
Projections – In 3 East Steps

1. Determine if your data is best analyzed by area, distance, shape, or direction.

2. Choose the best projection compromise for your data type.

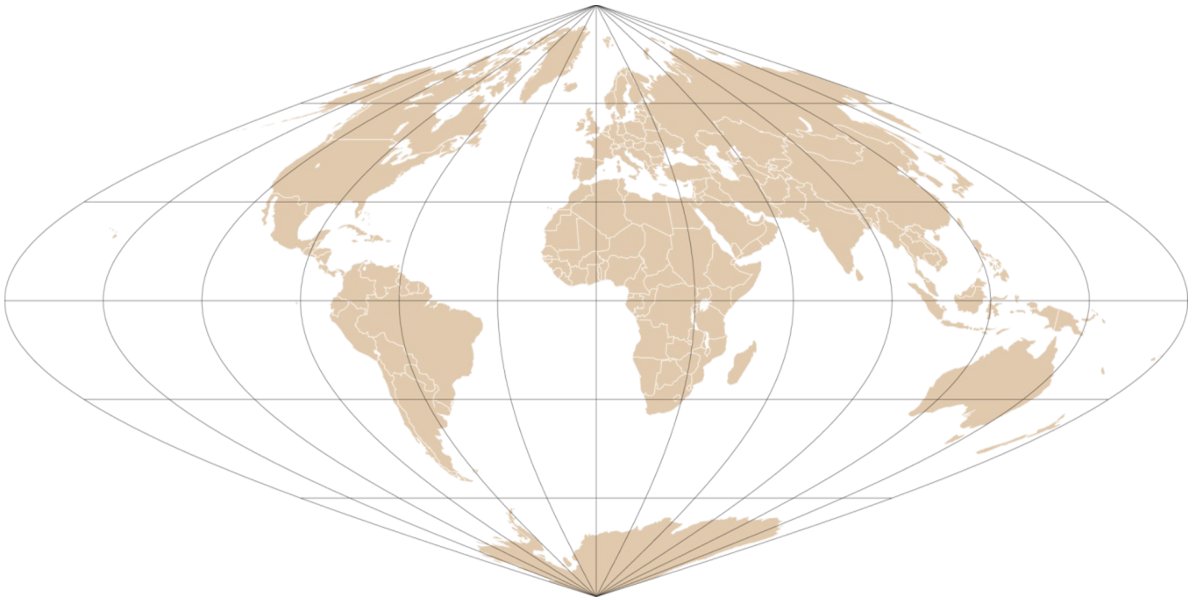
3. Select the best projection for the geographic extent being mapped.

TAKE HOME: The Equal-area projection is by far the most popular for thematic mapping.



https://www.marls.com/resources/rmtcrs-information/

Scale—The relationship between a distance on a map and the corresponding distance on the Earth.

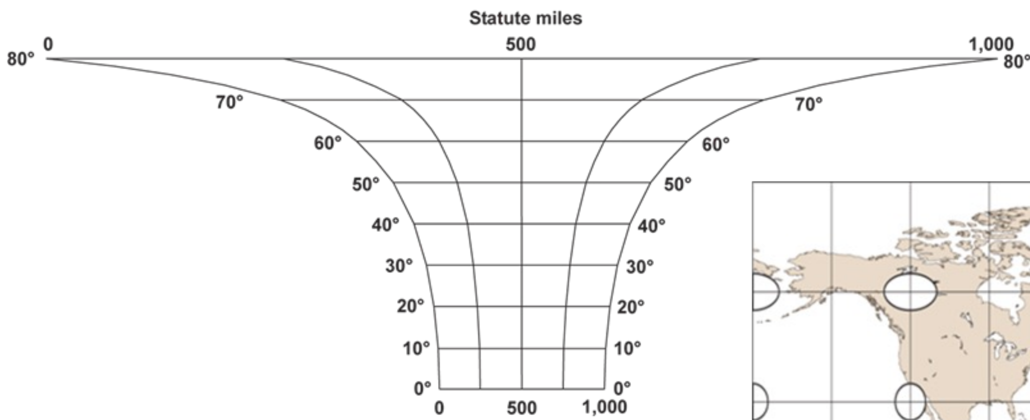


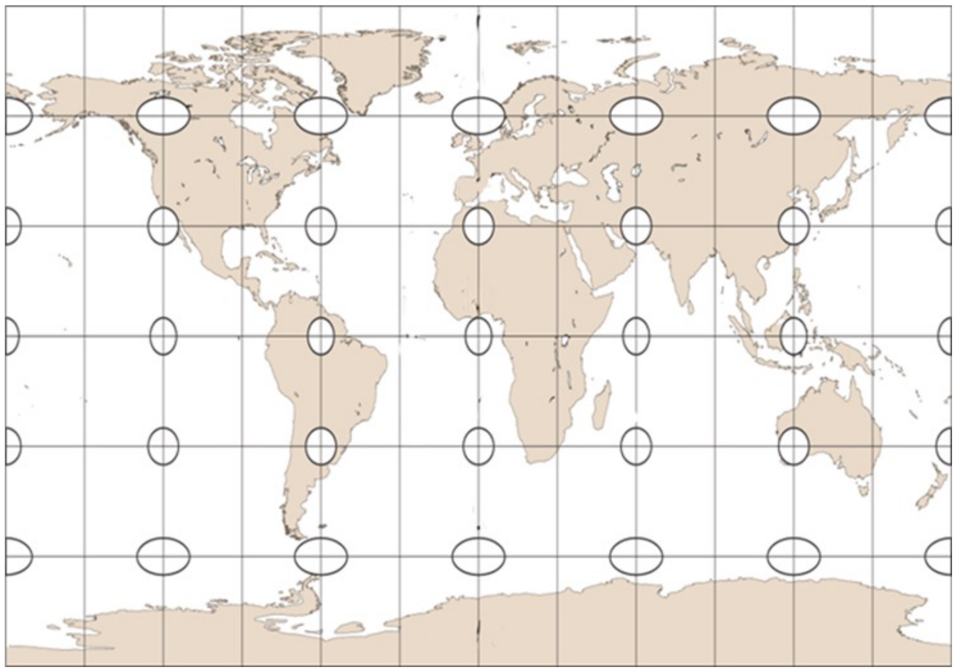
Three Types

- Representative Fraction – 1:100,000
- Verbal Scale – 1 inch to the Mile
- Graphic Scale – Scale Bar

Scale

Scale varies across Small Scale Maps of the World





This would be the correct scale on a Mercator World Map.

Scale

Large Scale
1:25,000

IT's

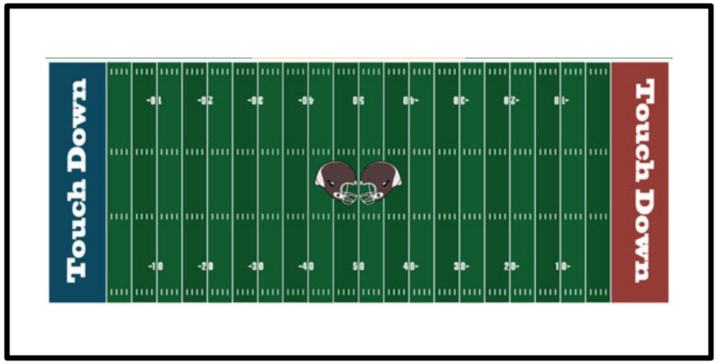
1:250,000

RELATIVE

1:25,000,000
Small Scale

Scale

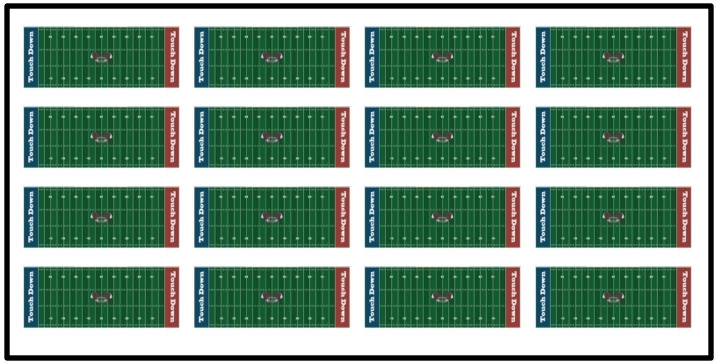
Large Scale **Smaller Number** **Larger Features** **Smaller Area**



11" x 17"

1:1,800

Small Scale **Larger Number** **Smaller Features** **Larger Area**



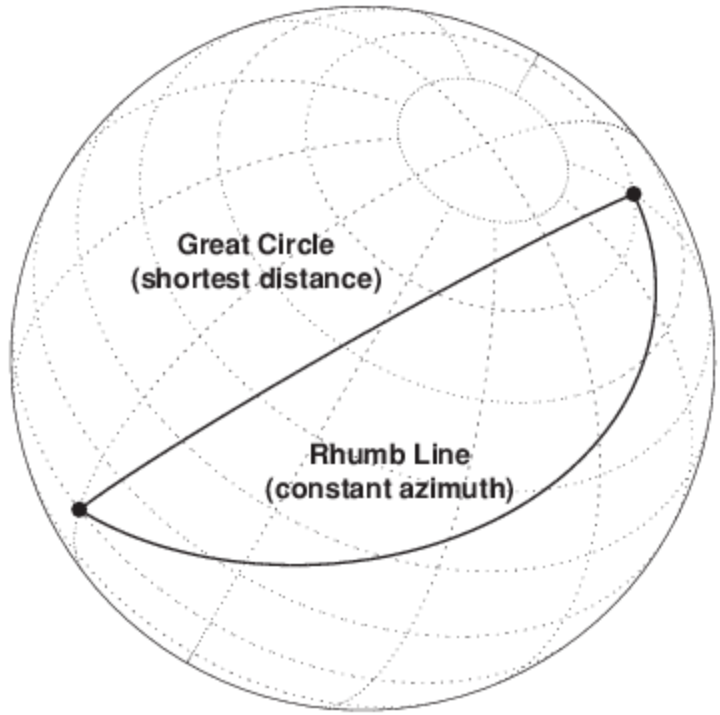
11" x 17"

1:72,000

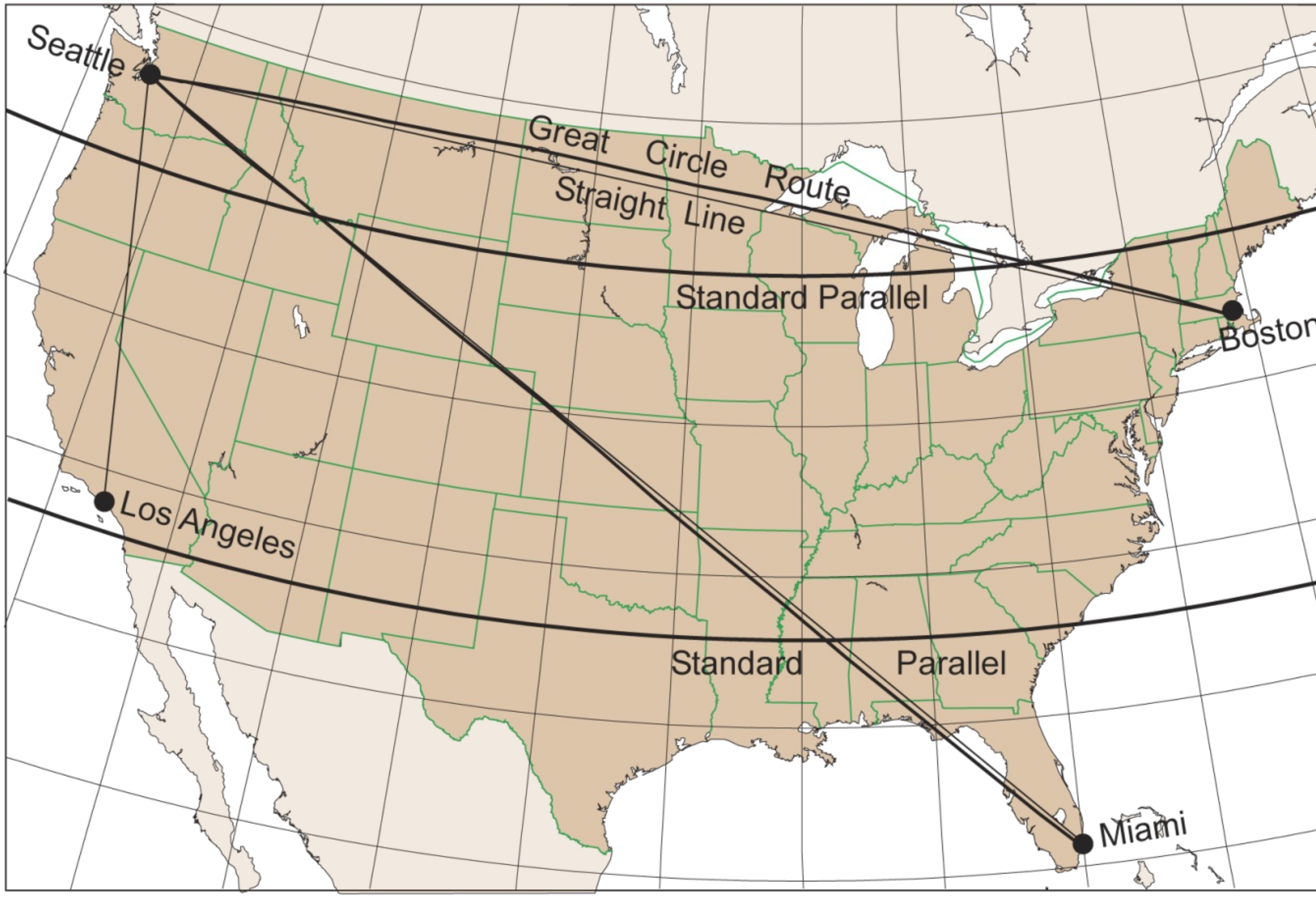
Scale

TAKE HOME: Scale is not equal across all areas of a small scale projection. On world maps, a static scale bar is virtually useless. A Conic Projection is a good compromise for true scale when mapping mid-latitude continents.

Scale

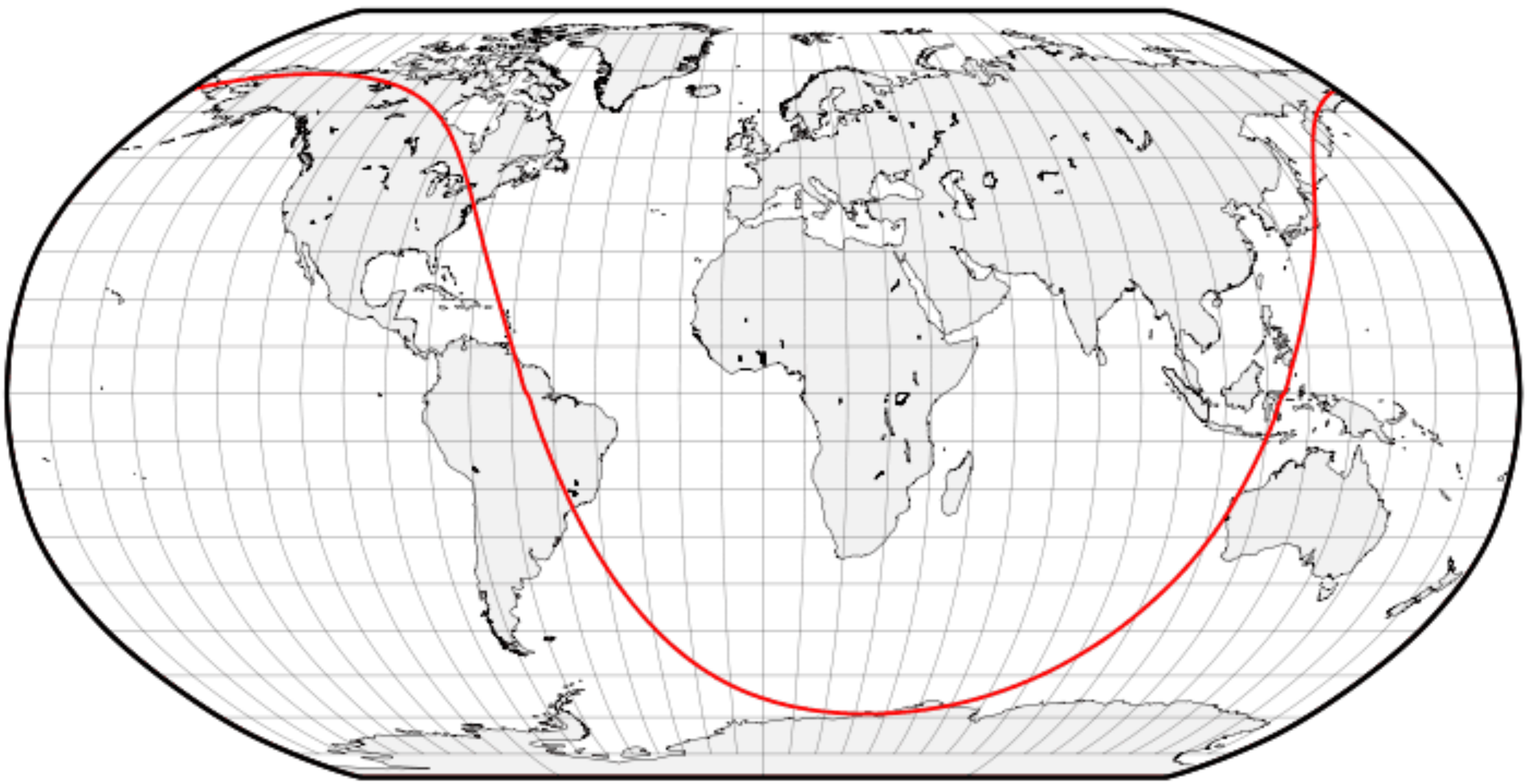


Great Circles Vs Rhumb Lines



Great Circles Vs Rhumb Lines

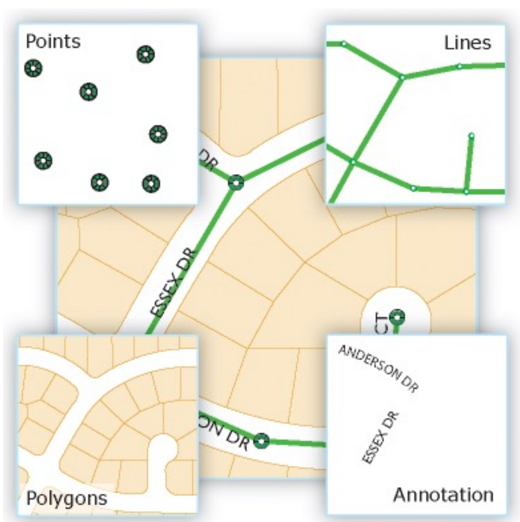
Great Circles Vs Rhumb Lines

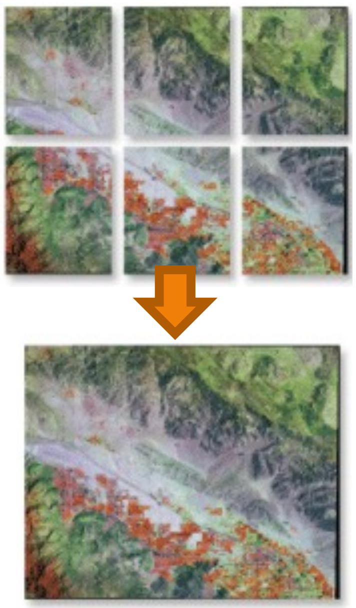


https://beta.observablehq.com/@jake-low/satellite-ground-track-visualizer

The Geodatabase

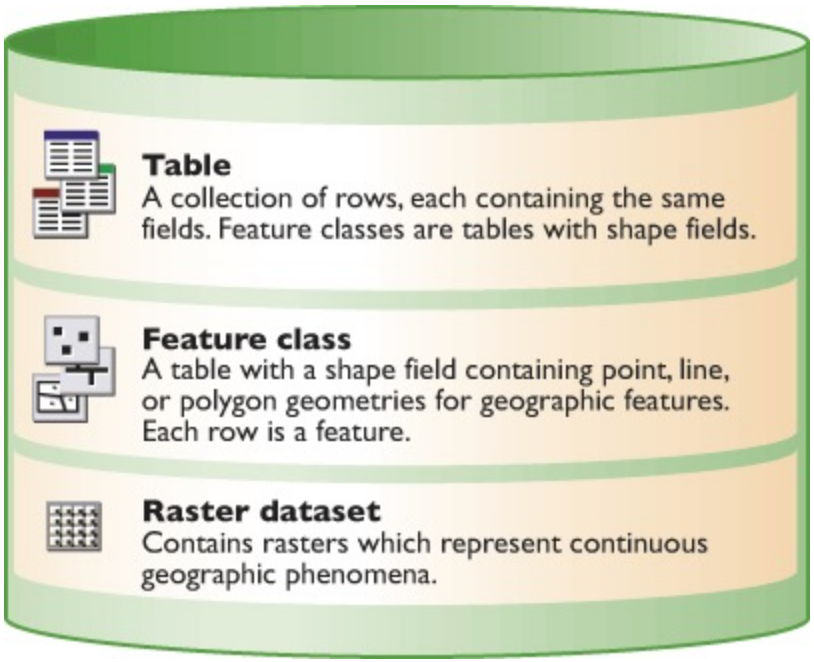
What is a Geodatabase?





The Geodatabase

- The geodatabase is the basic building block and storage vessel for all data management in GIS.
- Many agencies still store layers as shapfiles, but they are missing the power and convenience of the GDB



The Geodatabase

- The power of a GDB lies in the file hierarchy and the ability to normalize the layers in a single projection:

- Feature Dataset (set projection that all imported layers inherit)
  - Feature Class (exp. Gauging Stations points)
  - Feature Class (exp. River lines)
  - Feature Class (exp. Lakes polygons)

- Feature Datasets also allow you to set up Topologies
  - A Topology is a rule that governs interactions between layers
  - For Example, you could say that adjacent layers can’t have gaps.

Staying Organized

Remember:

- Data come in many different formats
- Data come in many different coordinate systems
- Data come in many different projections

A Geodatabase is the best way to normalize the data:

- But individual feature classes imported retain their reference system
- So… you **MUST** use the Feature Dataset to normalize the coordinates
- Always decide on a geographic coordinate system for the Feature Dataset
- Then choose a projection from within the ArcGIS Pro Map Frame … **ALWAYS!**

EXCEPTION: Set the projection within the GDB only if you plan to use a Geospatial Analysis tool that requires it (e.g., Geographically Weighted Regression)
Or… Your required to project in the GDB by an employer or professor

- Rasters need to be normalized by using the Reproject Raster tool or creating a Mosaic Dataset, choosing the coordinate system, and importing rasters into it.