

2019

## Unit 4

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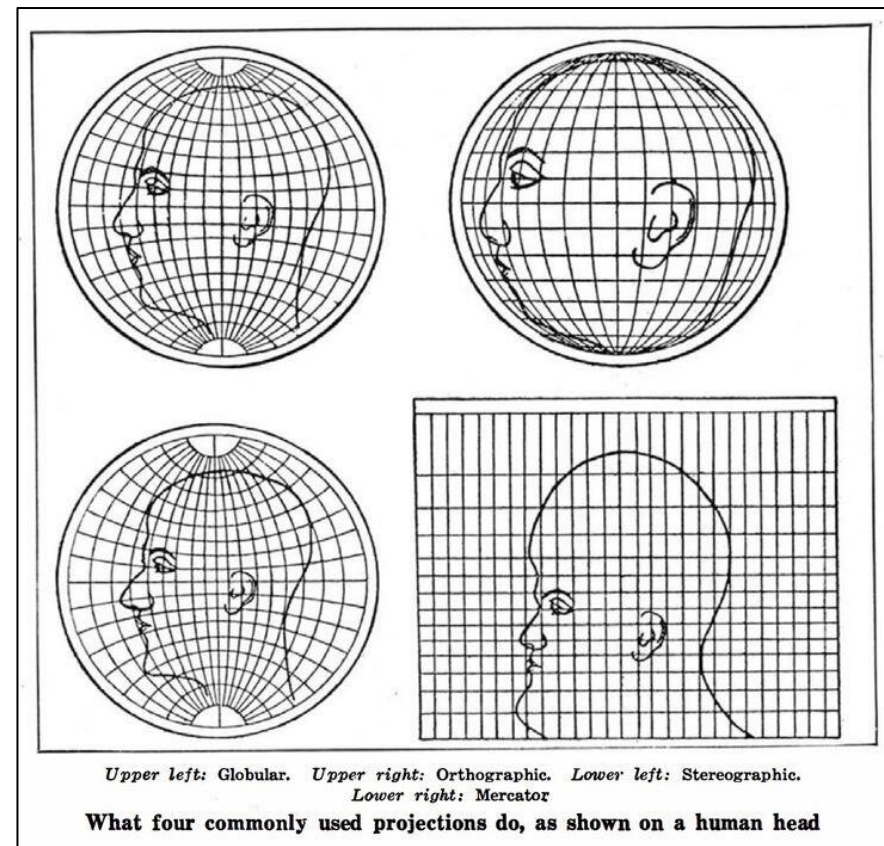
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# Map Projections



Upper left: Globular. Upper right: Orthographic. Lower left: Stereographic.  
Lower right: Mercator

What four commonly used projections do, as shown on a human head

From *Elements in Map Projection*

<http://io9.gizmodo.com/buckminster-fullers-dymaxion-map-reveals-the-near-cont-461490890>

Forrest J. Bowlick, Intro to GIS  
Univ. of Mass. – Amherst

# When you are Confused

- Ask questions
  - I will stop a lot more this time around to look for questions. Ask out!
  - Use the form here: **tx.ag/what**
    - Anonymous! Great if you are shy, can't get a word in, etc.

# The Spatial Trail

- We began our investigation of GIS understanding that 'spatial is special'.
- To have spatial data, we need some system that allows us to build coordinates linking attributes with their spatiality.

# Location

- To capitalize on spatial data, we must first have data that is spatial.

| Nominal location  | Absolute location (DMS)      | Absolute location (DD) |
|-------------------|------------------------------|------------------------|
| Los Angeles, US   | 34° 3' North, 118° 15' West  | +34.05, -118.25        |
| Mumbai, India     | 18° 58' North, 72° 49' East  | +18.975, +72.8258      |
| Sydney, Australia | 33° 51' South, 151° 12' East | -33.859, 151.211       |
| Sao Paulo, Brazil | 23° 33' South, 46° 38' West  | -23.550, -46.634       |

# Location Data

- Having data that is spatial is nice, but to plot and place that data we need to match to some system of coordinates.
- But to abstract coordinates from the planet, we need to know what shape it is.



# The Earth Is Flat, Explained



Ashley Feinberg

Today 4:30pm · Filed to: FLAT EARTHERS ▾



59.9K



432



13



**Earlier today**, rapper B.o.B. declared to his millions of Twitter followers that, despite everything they've been led to believe their entire lives, the earth is flat. And the weirdest part isn't just that he believes the earth is flat, but that he's not even remotely alone.

# Kyrie Irving Really, Actually, Earnestly Believes The Earth Is Flat



Emma Baccellieri

Saturday 10:30am · Filed to: KYRIE IRVING ▾



128.7K



519



15



Photo Credit: Ronald Martinez/Getty



# Kyrie Irving on flat-Earth comments: 'I'm sorry'

Oct 1, 2018 9:10 PM ET



Kyrie Irving said he has learned that certain thoughts are best kept in "intimate conversations."

**BOSTON (AP)** -- Kyrie Irving offered a simple message to science teachers Monday.

"I'm sorry," the Boston Celtics star said.

And with that, Irving made clear that he regrets publicly saying that the Earth is flat.

**IF THE EARTH WAS FLAT**



**CATS WOULD HAVE PUSHED  
EVERYTHING OFF IT BY NOW**

Believe in something...

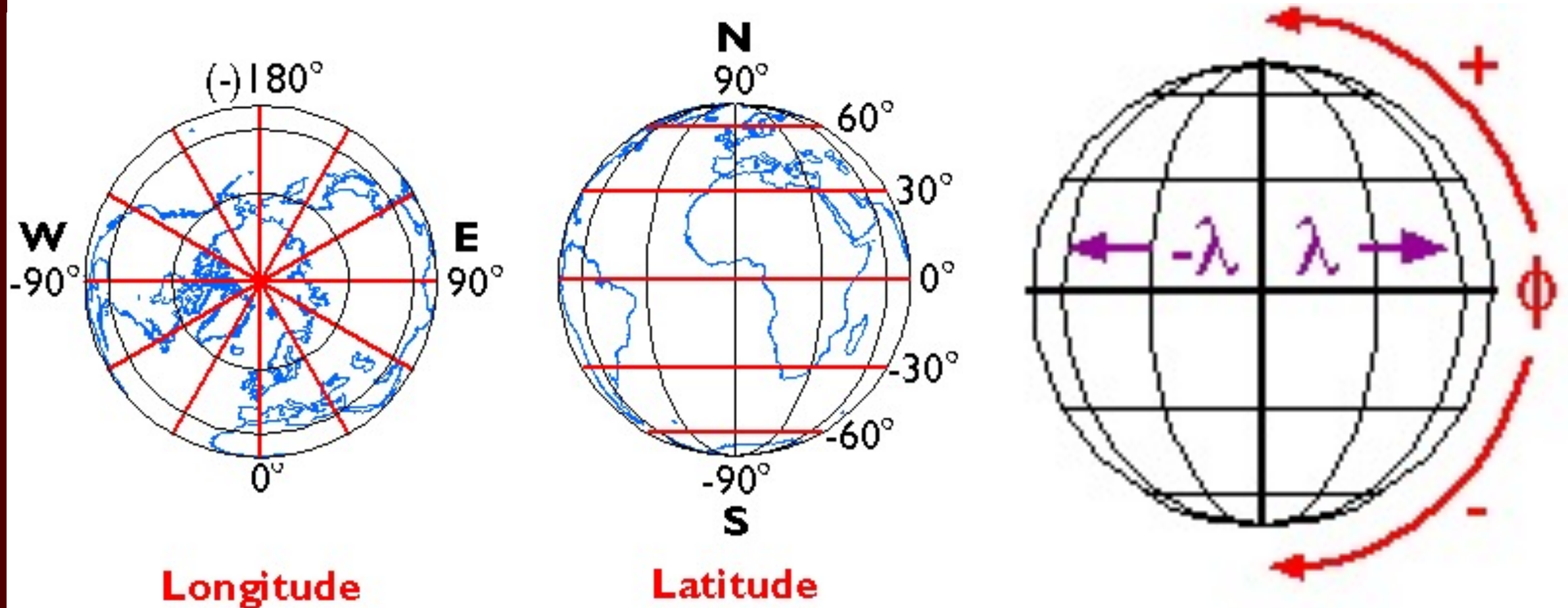


Wait, no...not that. What are you,  
an idiot??

# Why Spatial Works

- The Earth's surface is continuous.
- We can generally refer to the Earth as a sphere\*.

# The Earth is Not Flat

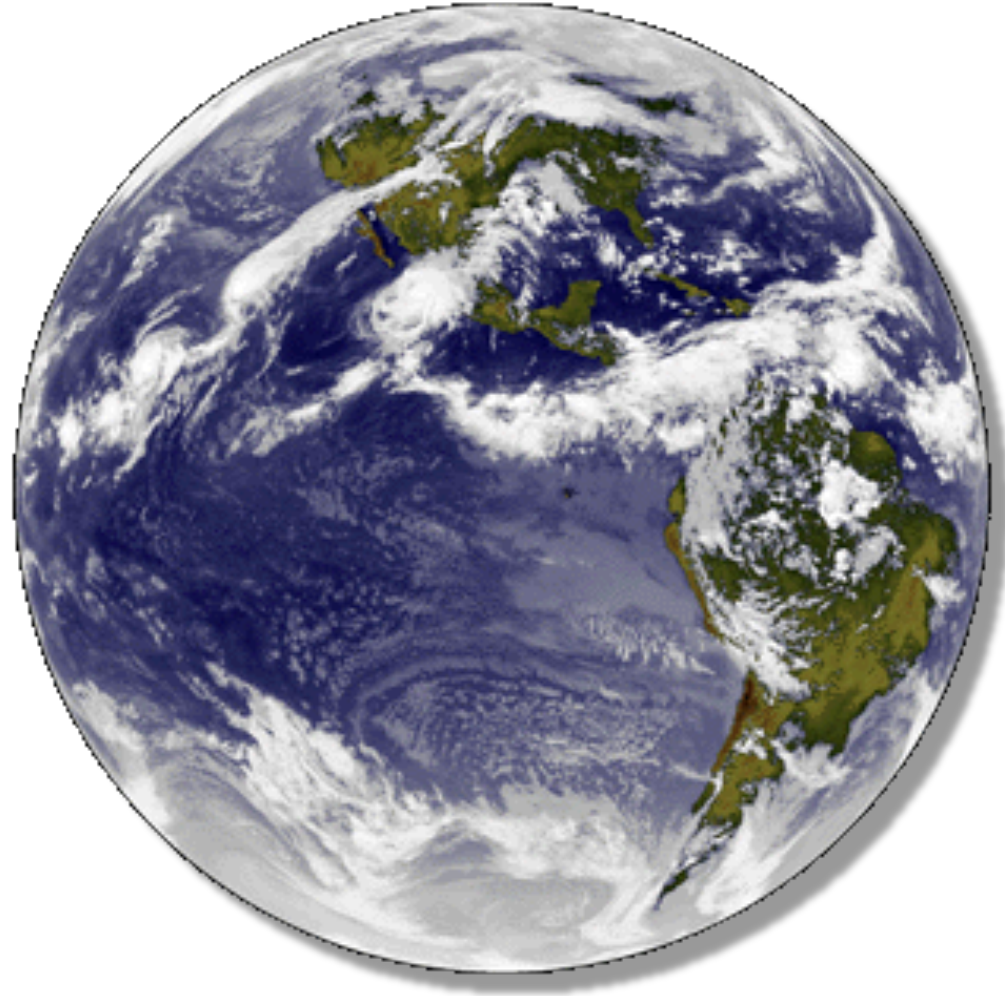


# A Spherical\* Earth

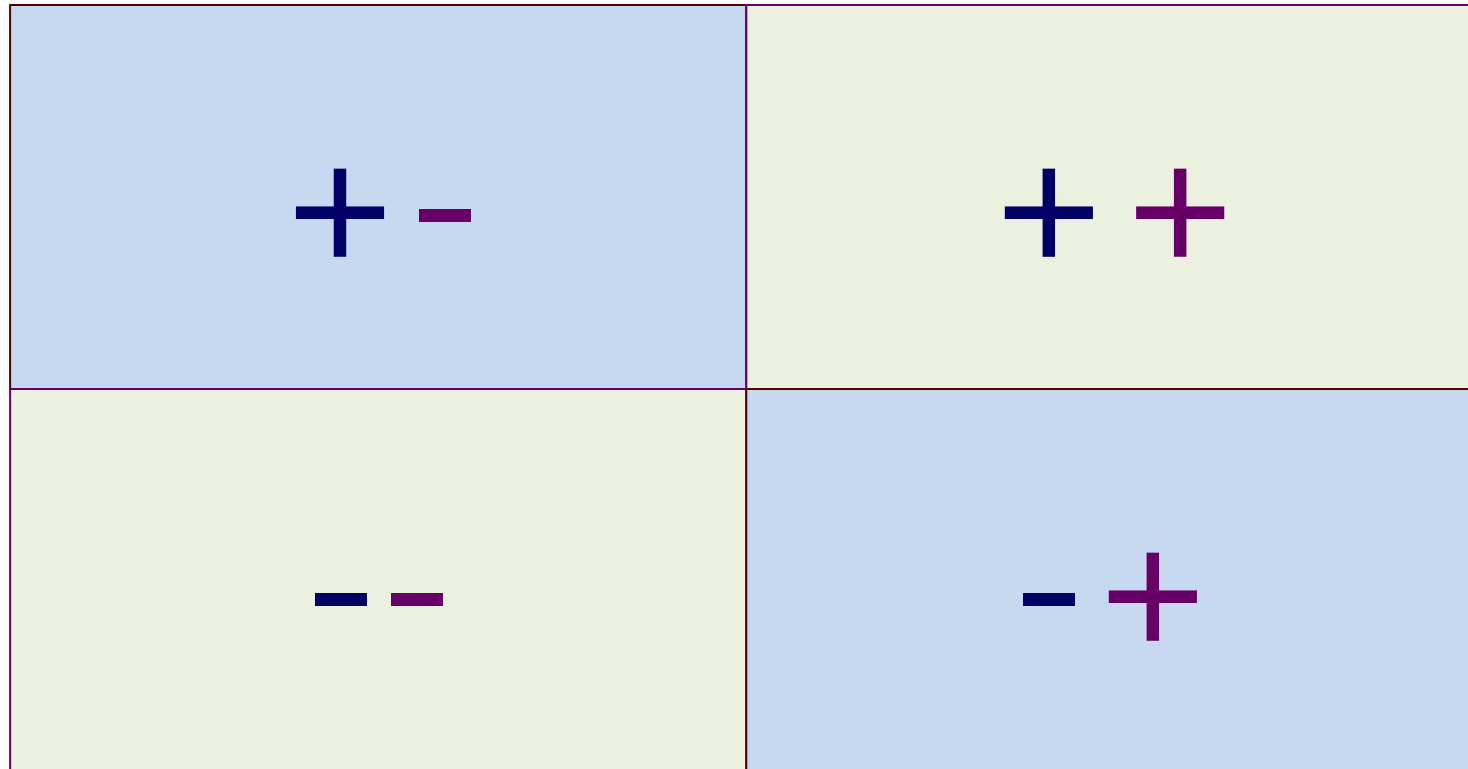
- When we measure a position on the earth (a globe) we use **spherical** coordinates
  - Latitude
    - degrees ( $^{\circ}$ ) North or South of the Equator
  - Longitude
    - degrees ( $^{\circ}$ ) East or West of The Prime Meridian



# The Spherical\* Earth



# Sign Convention



0° Latitude  
Equator

0° Longitude  
(Prime Meridian)

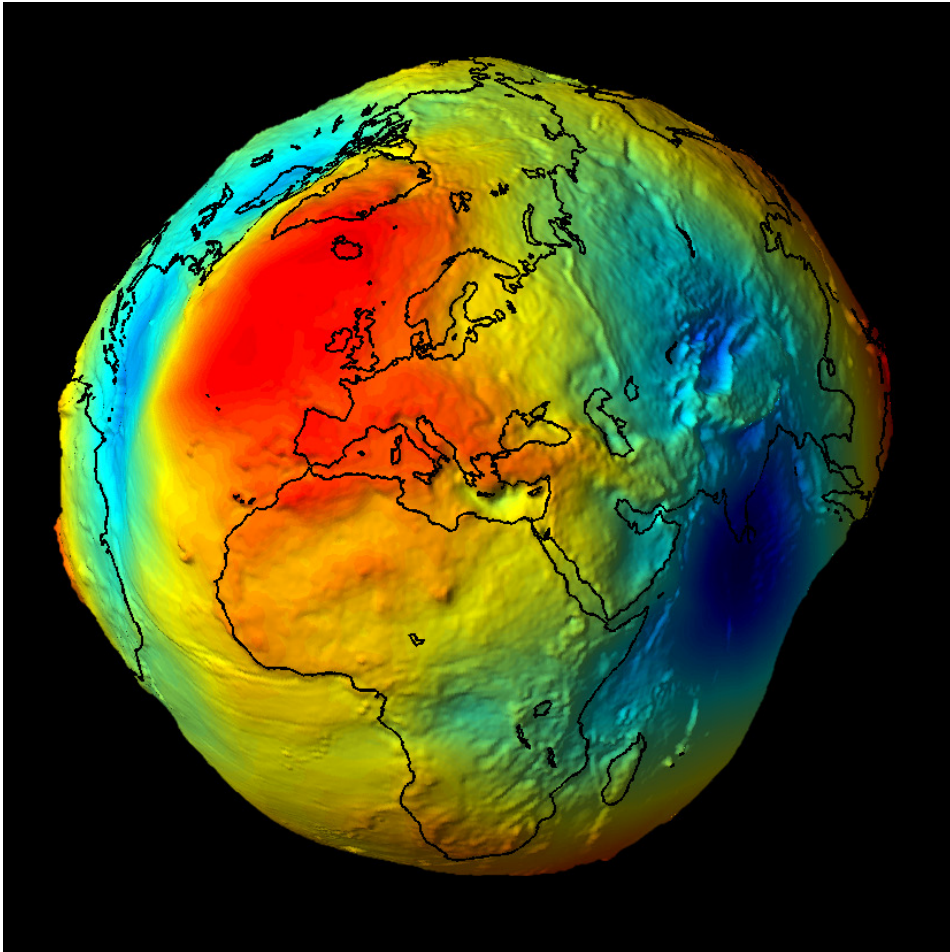
# Test Yourself

- <https://play.kahoot.it/#/k/6102f00a-1552-4ddf-85cc-e358b53d5f18>

# The Spatial Trail II

- And while Lat/Long or other systems provide that spatiality, we still need to represent the Earth digitally.
- Taking the geoid to the map requires significant care and attention.

# Geoid



[http://en.es-static.us/upl/2011/04/geoid\\_bumpy.jpg](http://en.es-static.us/upl/2011/04/geoid_bumpy.jpg)

- Shape is called an 'oblate spheroid'.
- True shape of the Earth.
- Definitely not flat!
  - Definitely not a sphere.

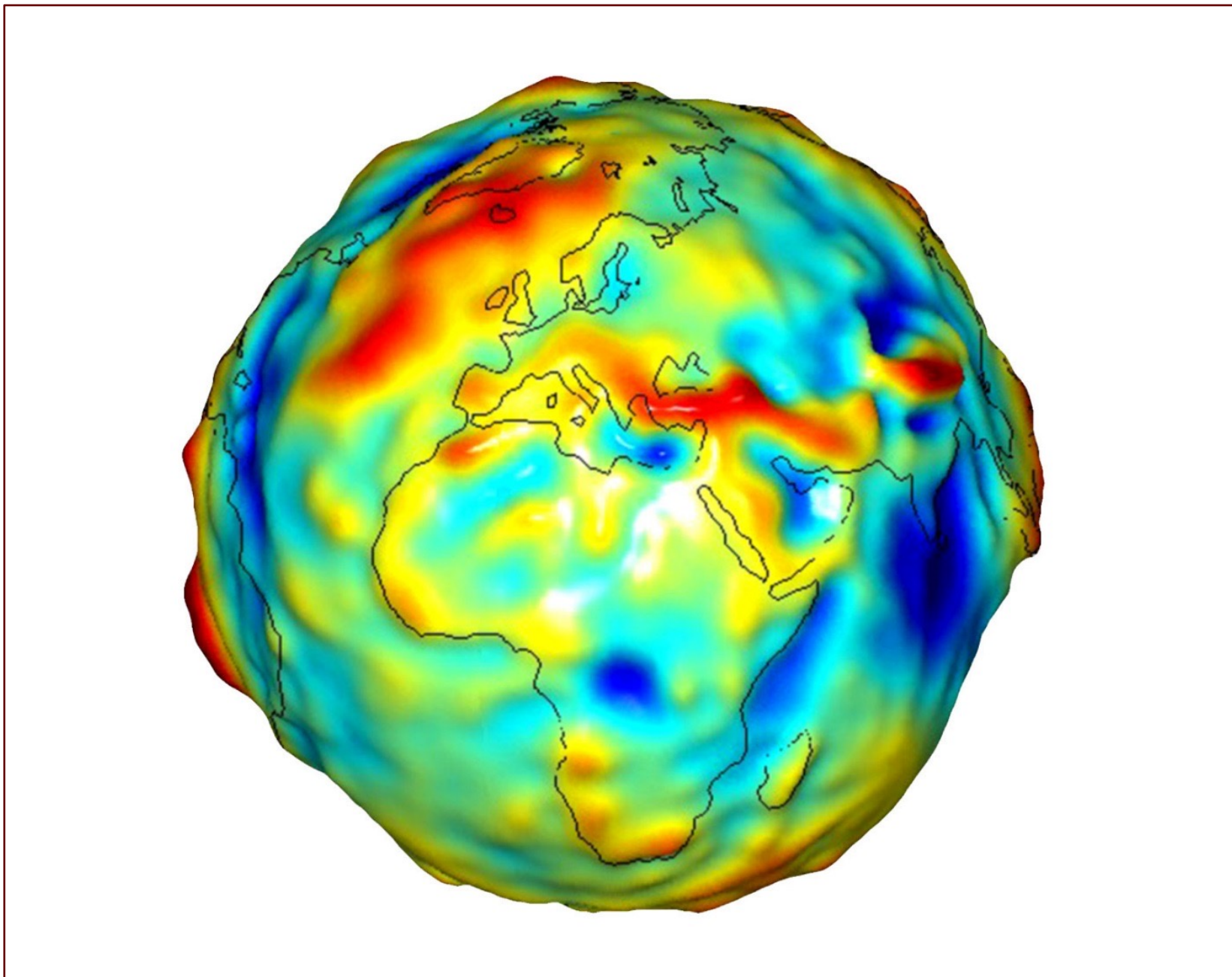


# What is the Actual Shape of the Earth?

- The actual shape of the Earth is a Geoid .
- This means literally "Earth Shaped".
- The Geoid is earth's **mean-sea-level** surface.
- For the oceans this is pretty easy to imagine, but for land the geoid would be the height to which water would rise in a well that is connected to the ocean.

# Lumpy Space Potato

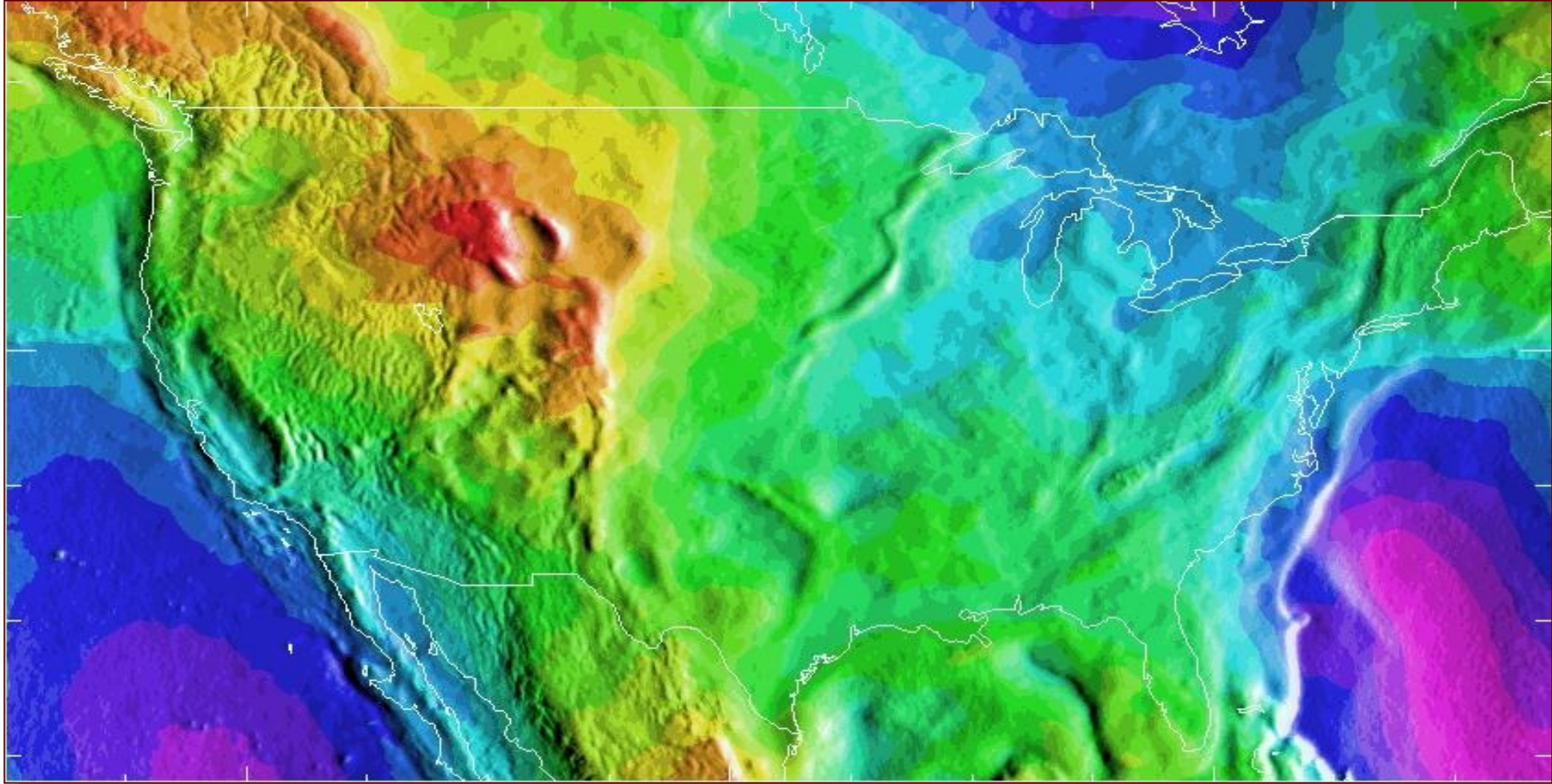
- The true shape of the earth is like a lumpy potato with undulations from the ellipsoid as much as 100 m.
- There is also a large bulge in the earth of 10 to 15m in the Southern Hemisphere giving rise to the description of earth as **pear shaped.**



Source: Paul Bolstad. 2012. GIS Fundamentals – A first text on Geographic Information Systems. 4<sup>th</sup> ed.



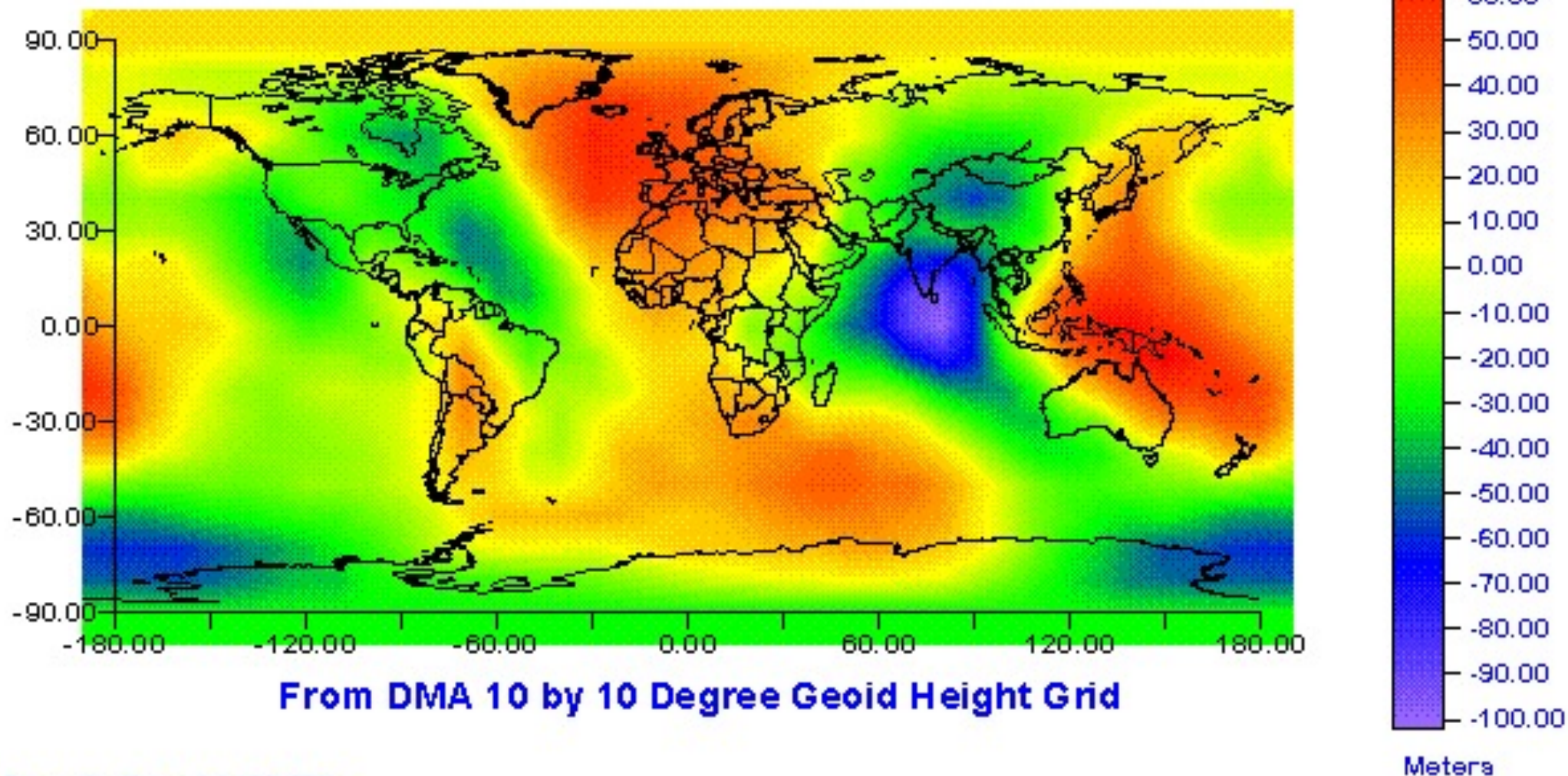
# A graphical representation of the Geoid



- Geoid 1996 of the conterminous US
- Geoid heights range from -51.6 meters (magenta (Atlantic)) to -7.2 m (red (Rockies))

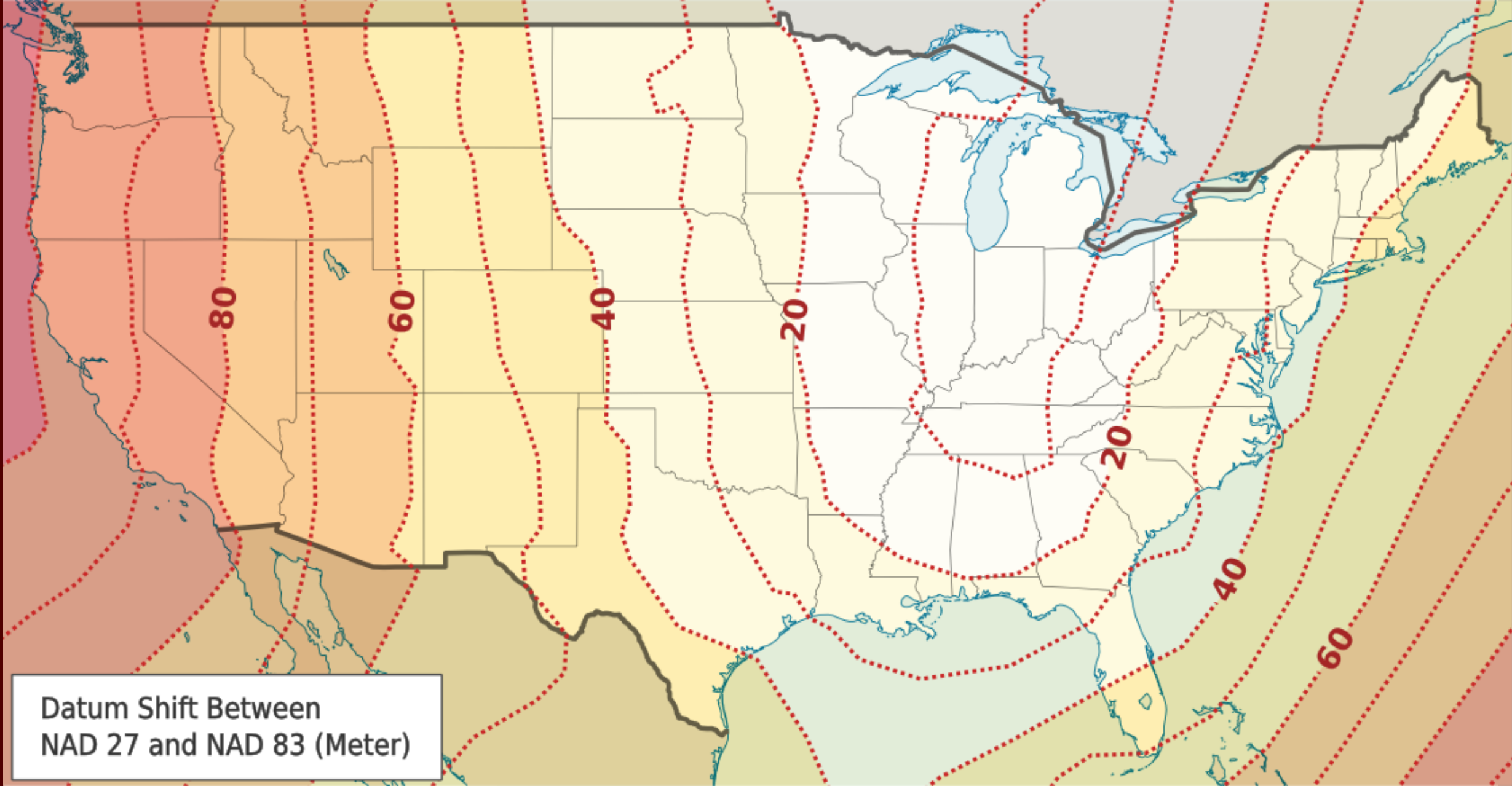


# WGS-84 Geoid Height



Peter H. Dana 11/05/95

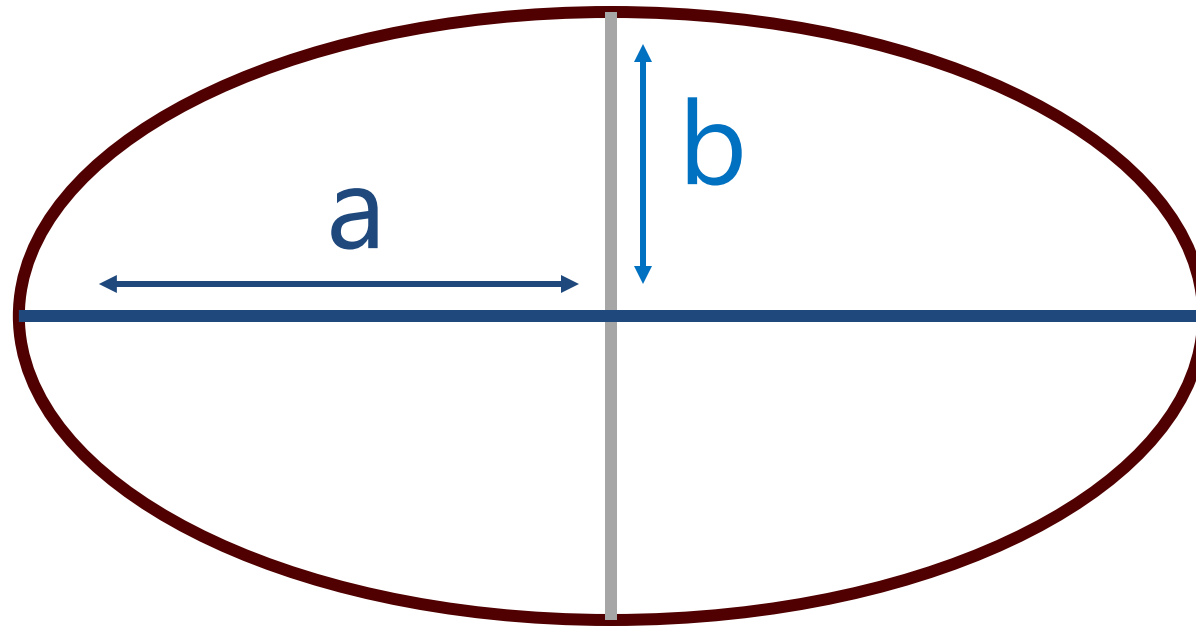




# Limiting Complexity

- The Geoid, while a much simpler shape than the earth's topographic surface is still very complex.
- For most uses, a simpler model of the shape of the earth will work fine...this model is the **ellipsoid** or **spheroid**

# The Ellipsoid

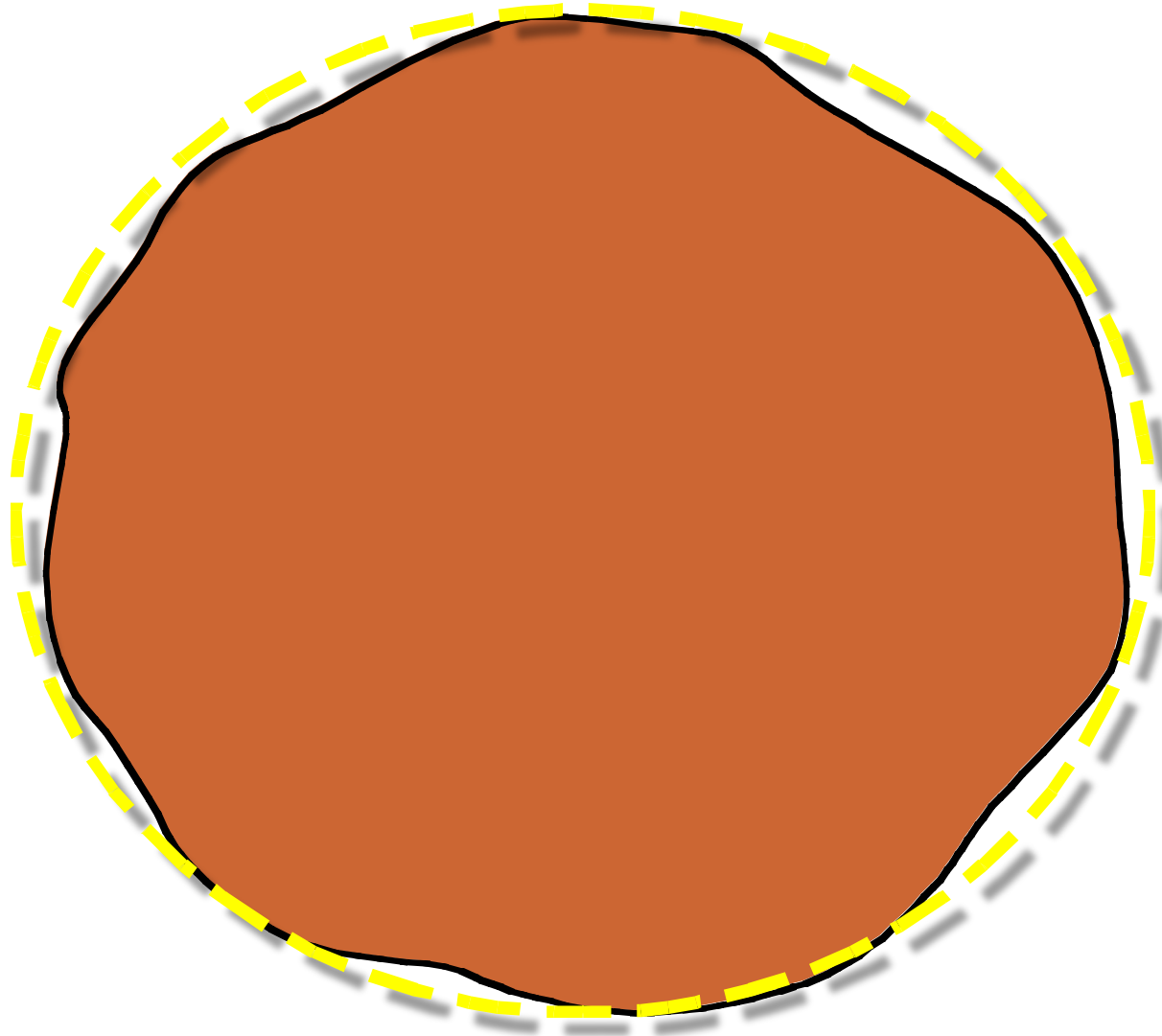


a - semi major axis (equatorial radius)

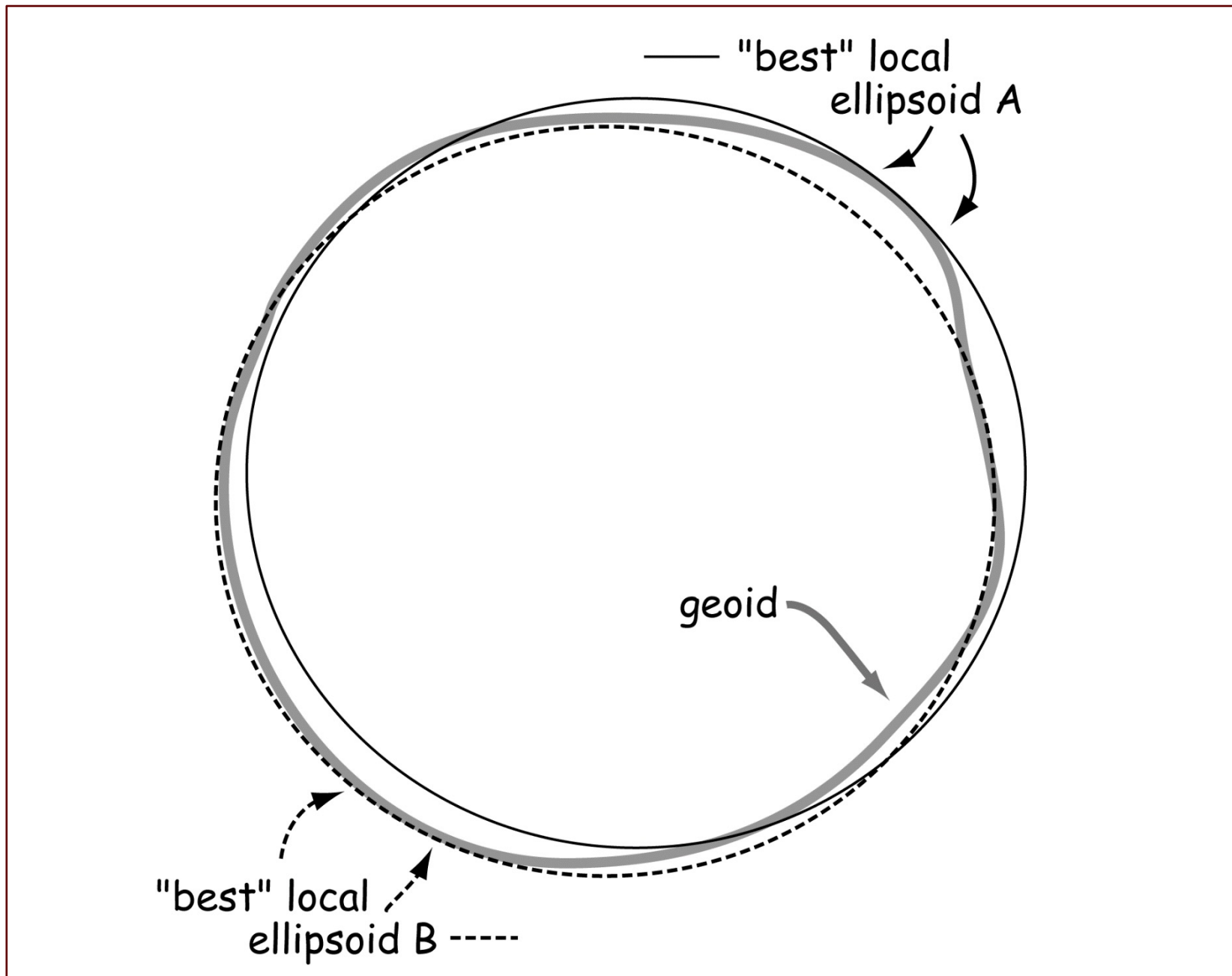
b - semi minor axis (parallel to the rotation axis)

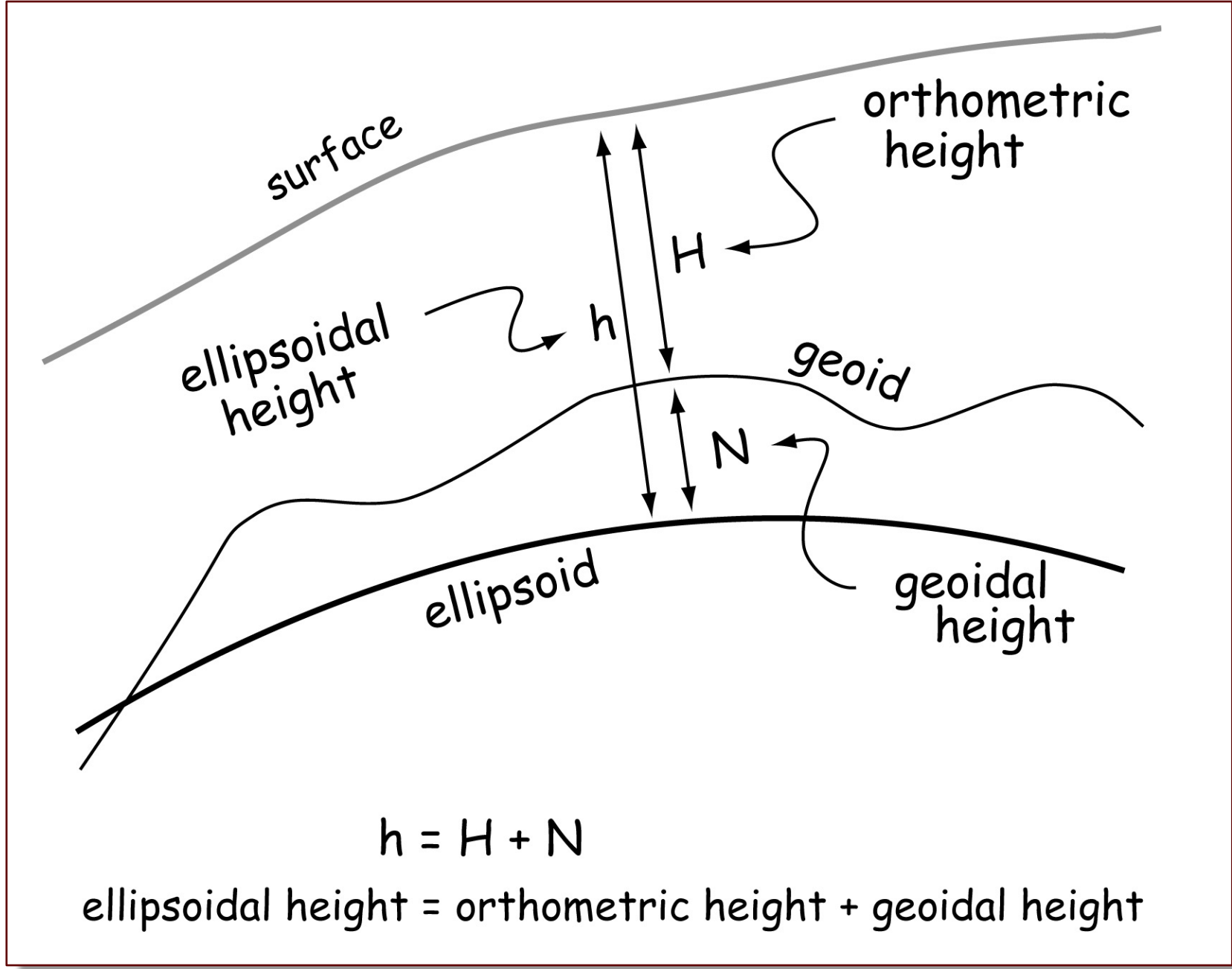
$f = (a-b)/a$  or flattening

# A Geoid and an Ellipsoid



An Ellipsoid is the closest fit of an ellipse to the geoid, but remember the “best fitting” ellipsoid for one location, may not be the same as for another

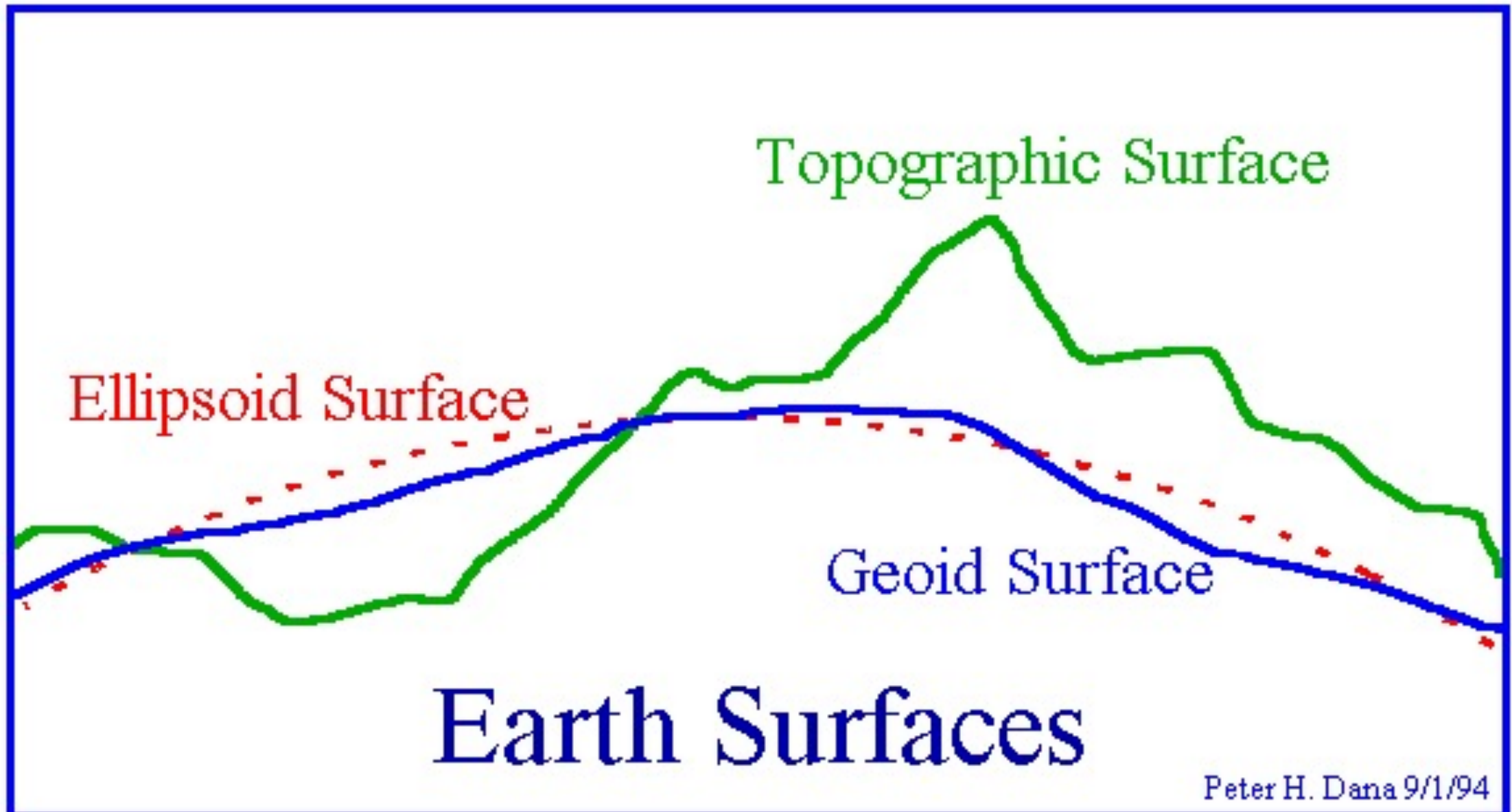


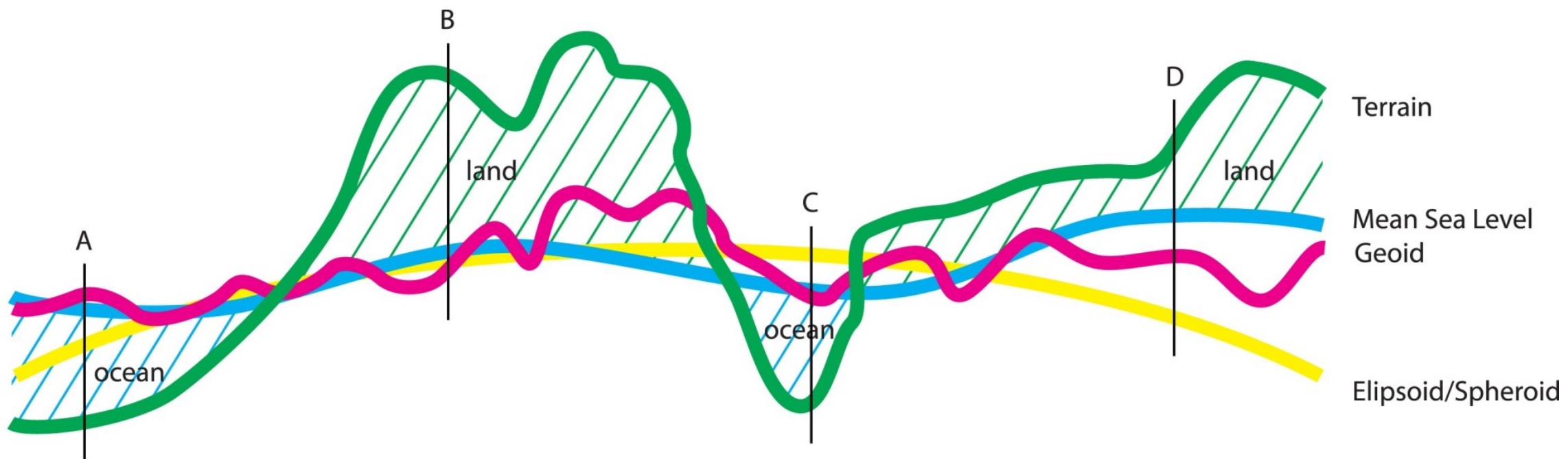


Source: Paul Bolstad. 2012. GIS Fundamentals – A first text on Geographic Information Systems. 4<sup>th</sup> ed.



# A closer look





A  
 Geoid  
 Mean Sea Level  
 Elipsoid/Spheroid  
 Terrain

B  
 Terrain  
 Mean Sea Level  
 Elipsoid/Spheroid  
 Geoid

C  
 Elipsoid/Spheroid  
 Mean Sea Level  
 Geoid  
 Terrain

D  
 Terrain  
 Mean Sea Level  
 Geoid  
 Elipsoid/Spheroid

# Kahoot II

- <https://play.kahoot.it/#/k/1f32ae82-0c9b-41bc-a693-9a50dc2c729c>

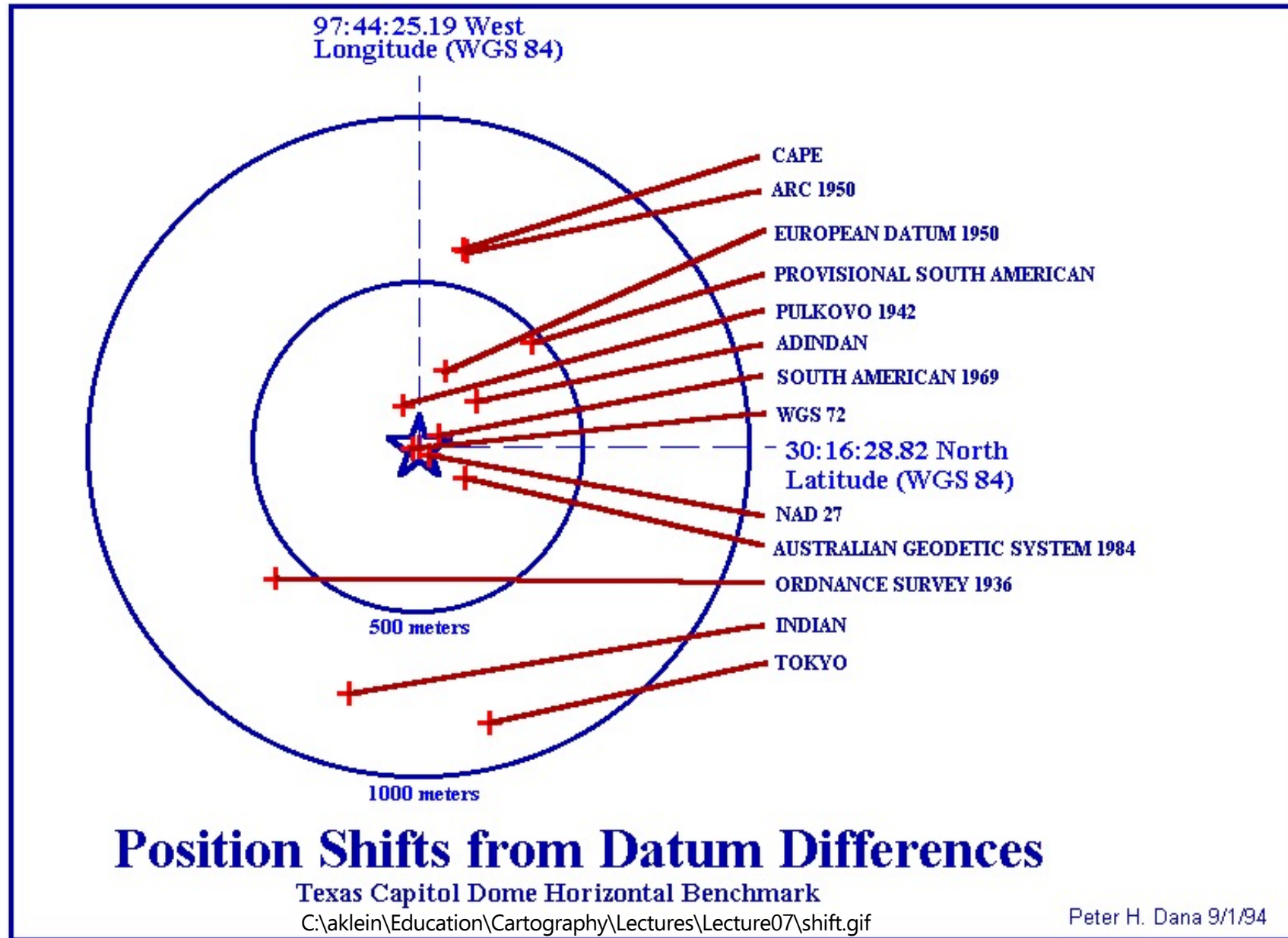
# What is a Datum?

*In surveying and geodesy, a **datum** is a reference point or surface against which position measurements are made, and an associated model of the shape of the earth for computing positions*

[http://en.wikipedia.org/wiki/Geodetic\\_system](http://en.wikipedia.org/wiki/Geodetic_system)

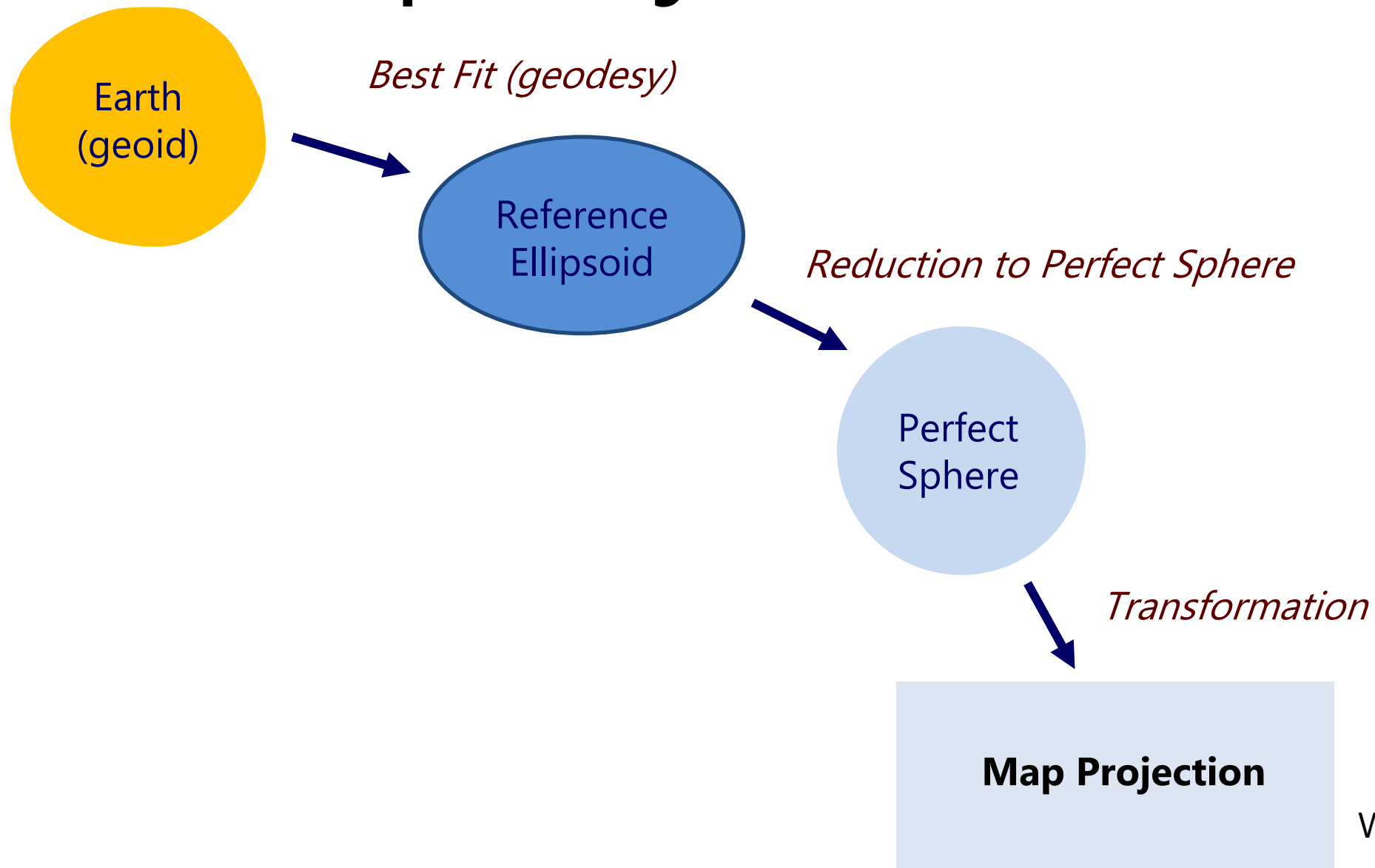
- A geodetic datum is a mathematical model of the earth upon which geodetic computations are based.
- A datum is a reference system with two components:
  - A specified ellipsoid with a spherical coordinate system and an origin
  - A set of highly accurate surveyed points and lines
- There are *Regional* and *Global* Datums.

# Does it Make a Difference?





# The Map Projection Process



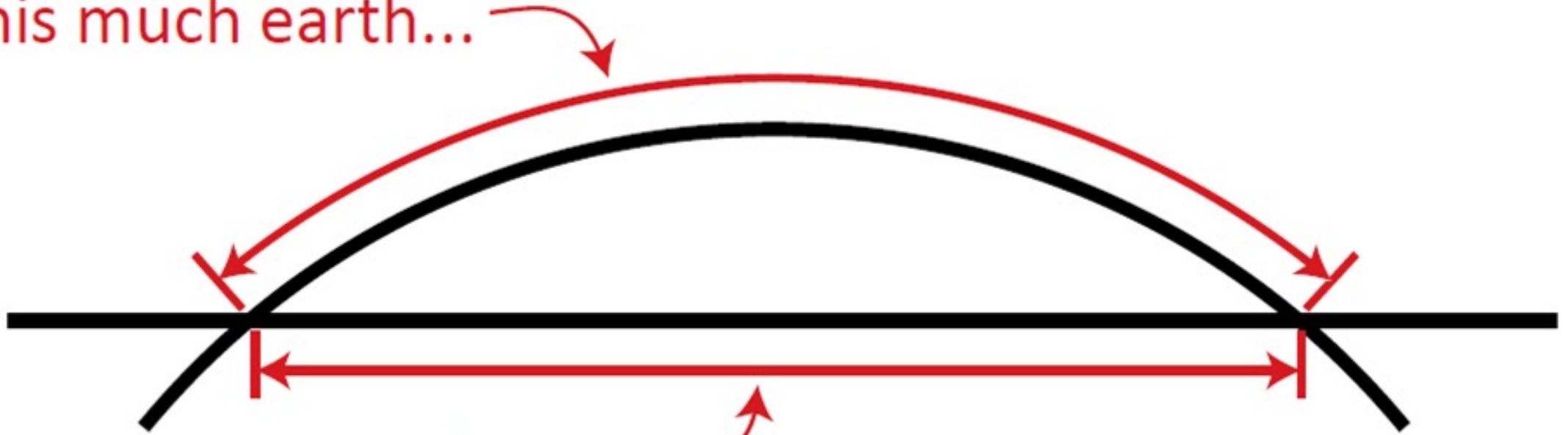
# What is a Projection?

The systematic representation of all or part of the surface of a round body, especially the earth, onto a flat or plane surface

John P. Snyder in *Flattening the Earth*

<http://bl.ocks.org/mbostock/3711652>

This much earth...



...has to fit onto this much map surface.

<http://mjfoster83.github.io/projections/#/>

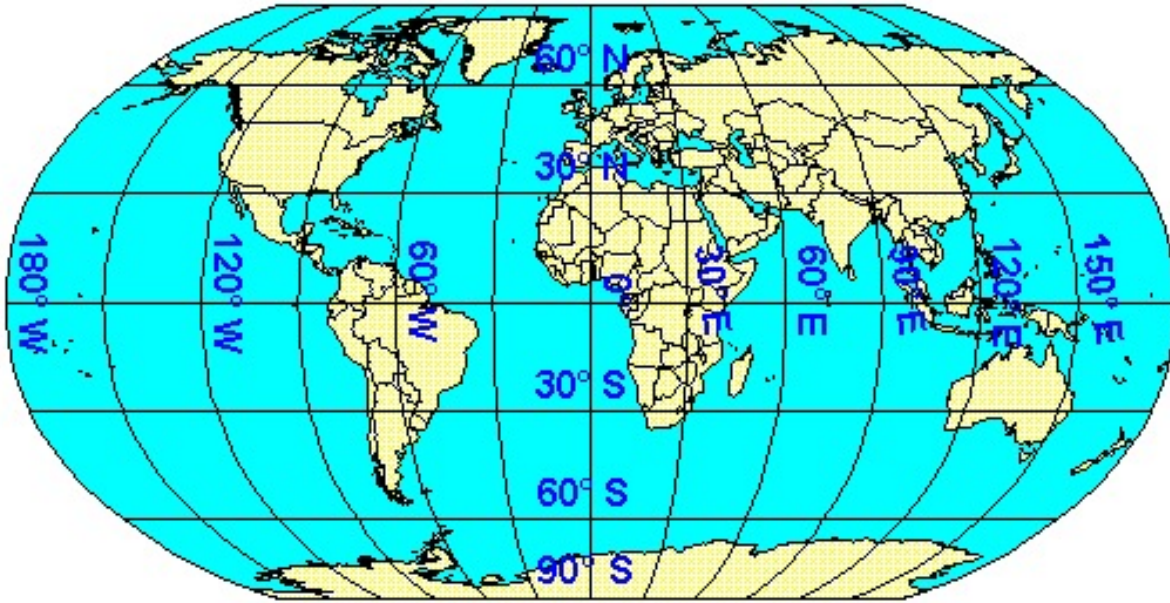
# The Map Projection Process II

- Projecting GIS data from one map projection to another is accomplished via *exact* mathematical transformations.
- Vector data can be projected “on the fly” (in real time) and does not necessarily result in loss of information.
- Projecting raster data is computationally intensive and can result in loss of information.

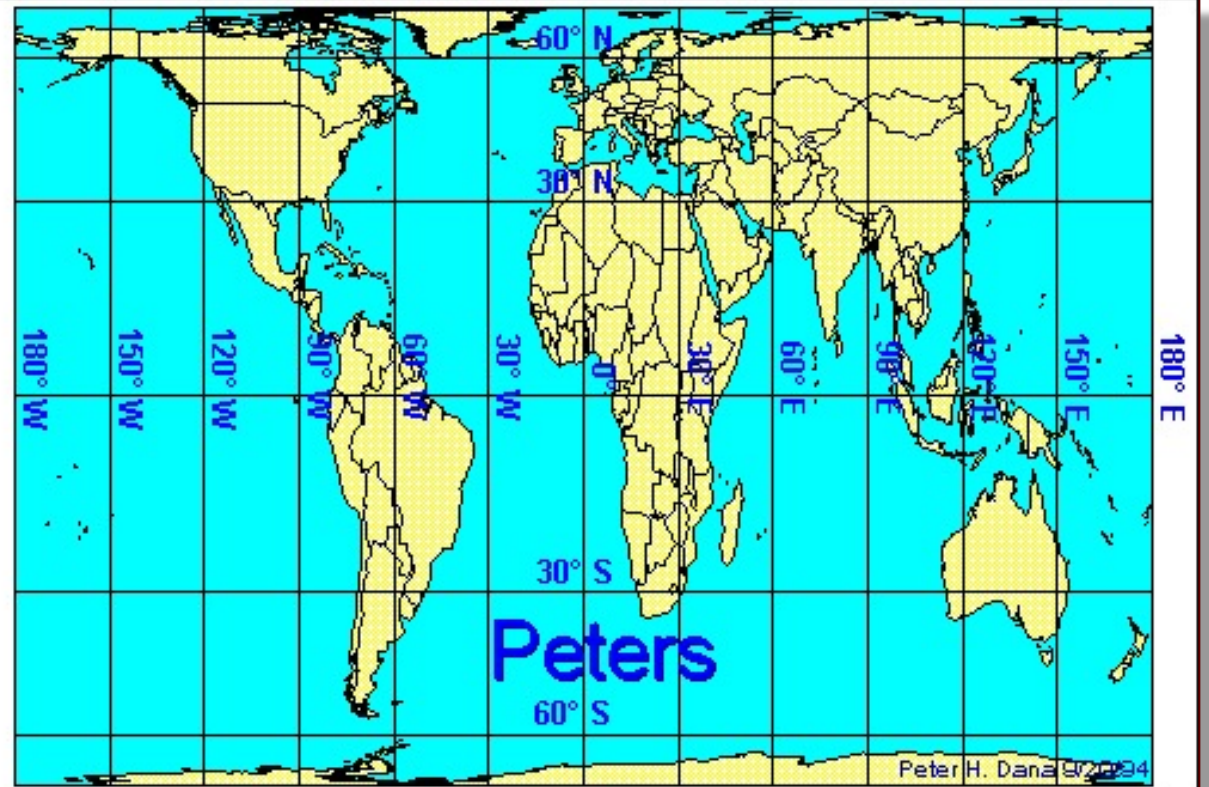
# Why Map Projections Matter

They literally affect our  
"world view"

Peter H. Dana 9/20/94



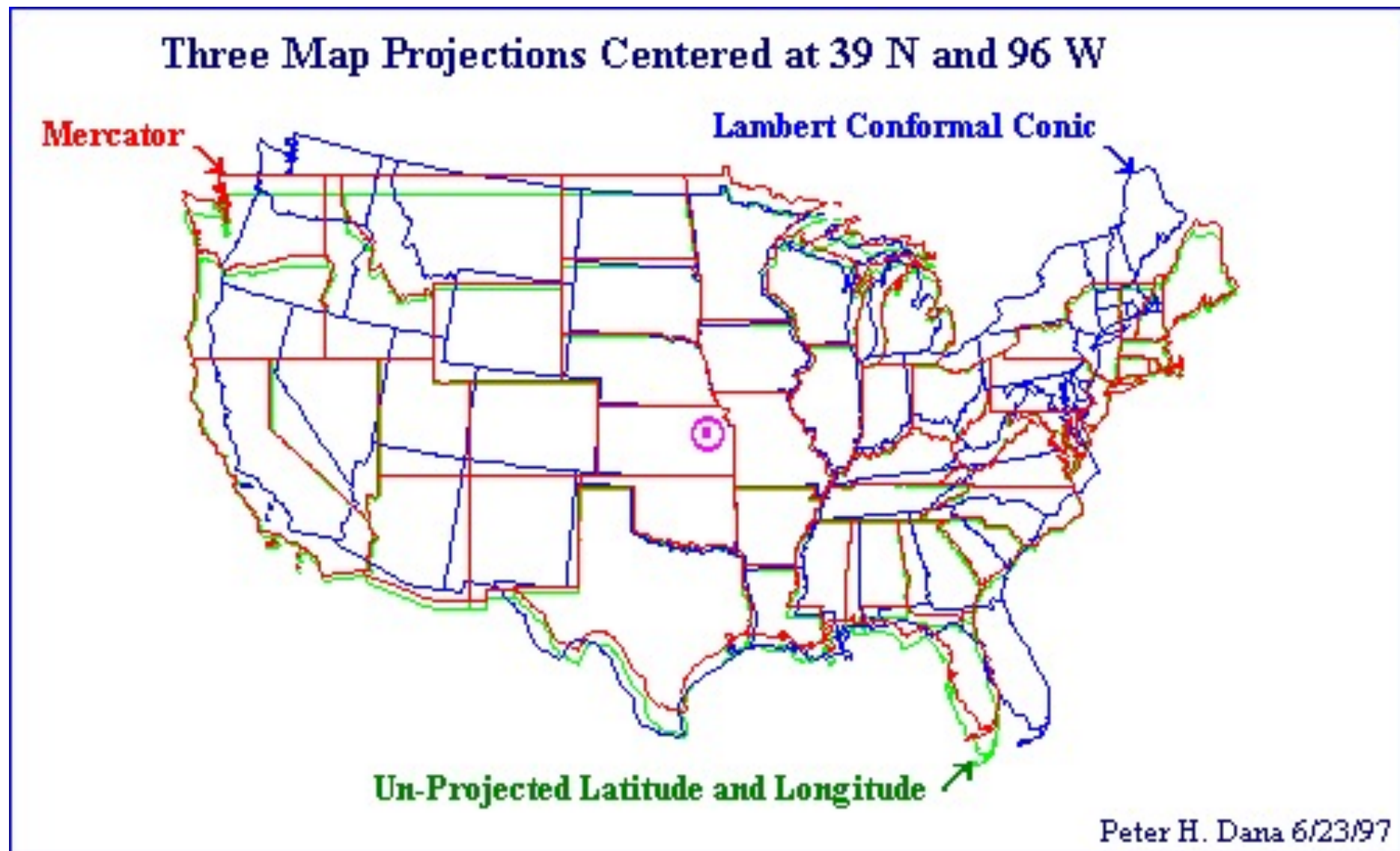
Robinson Projection



Peter H. Dana 9/20/94

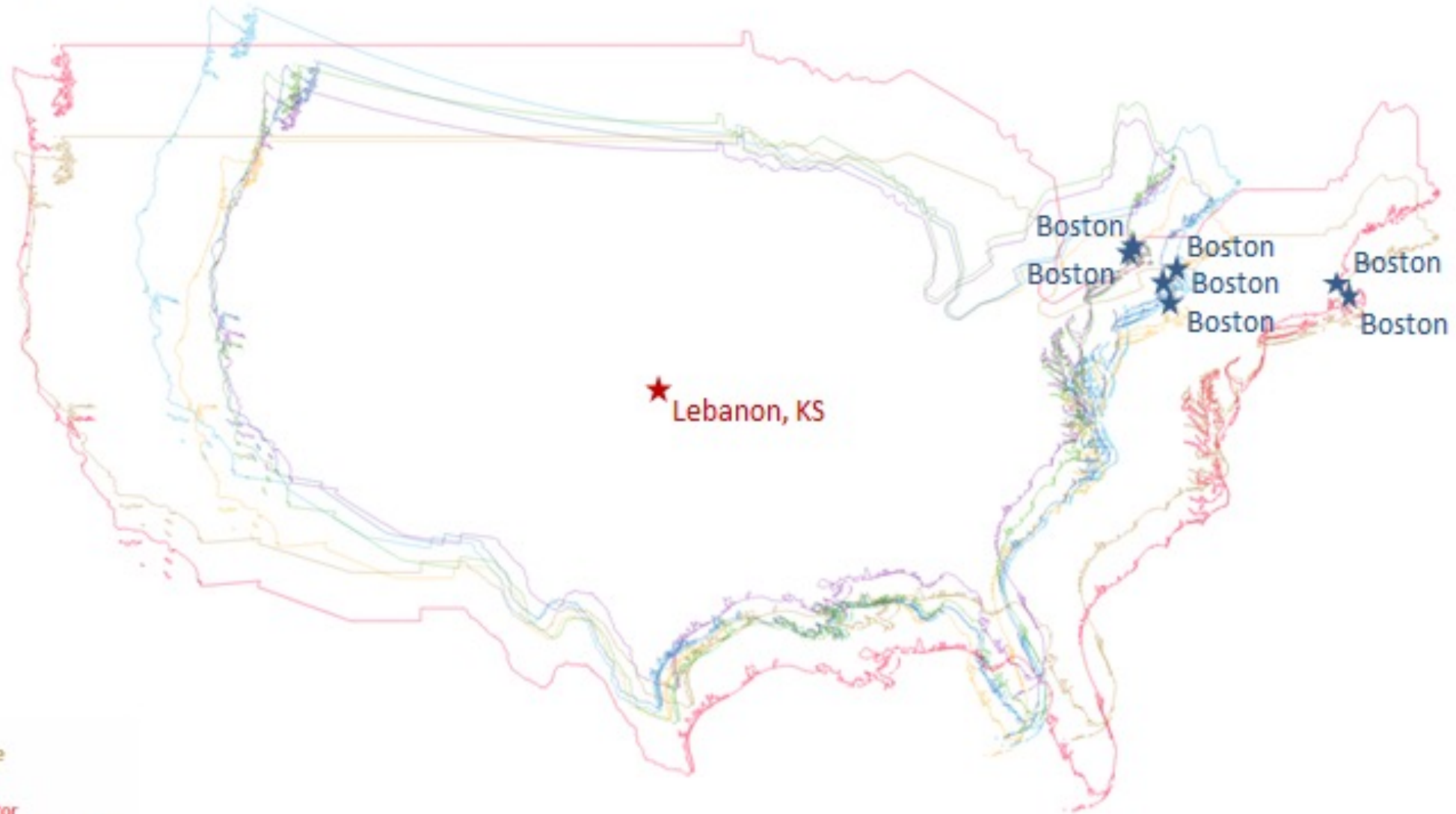


# Or your "regional view"



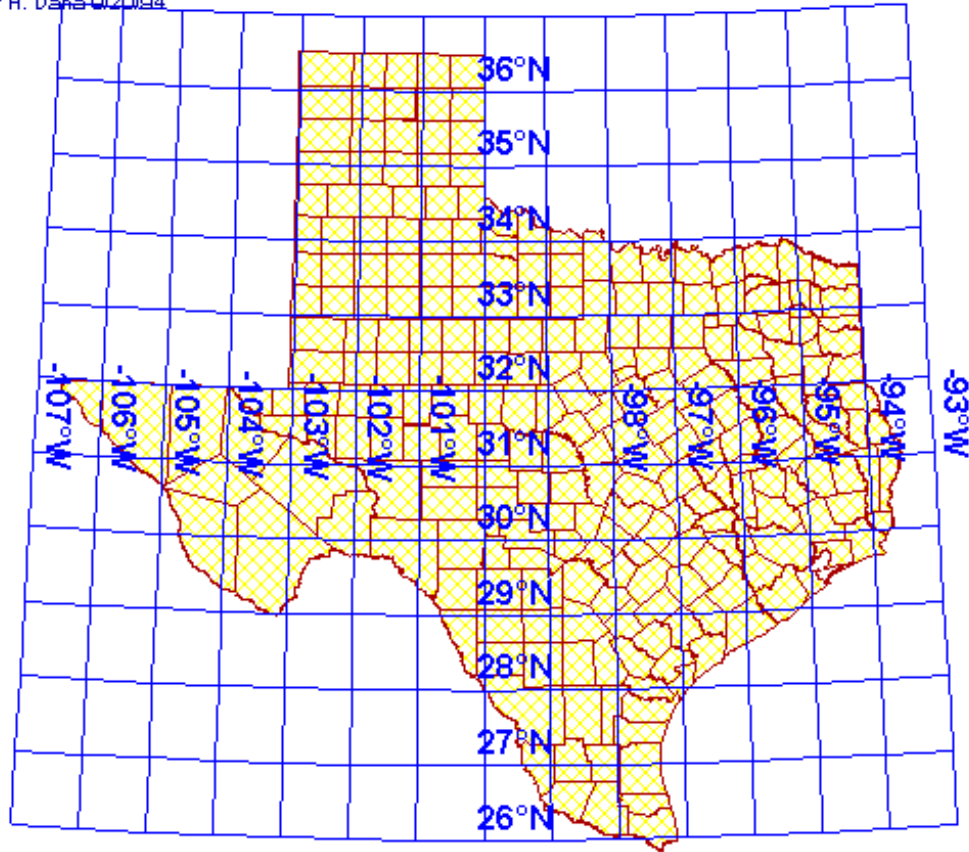
# Continental USA in Eight Projections

All shapes drawn at the same scale, with the same center



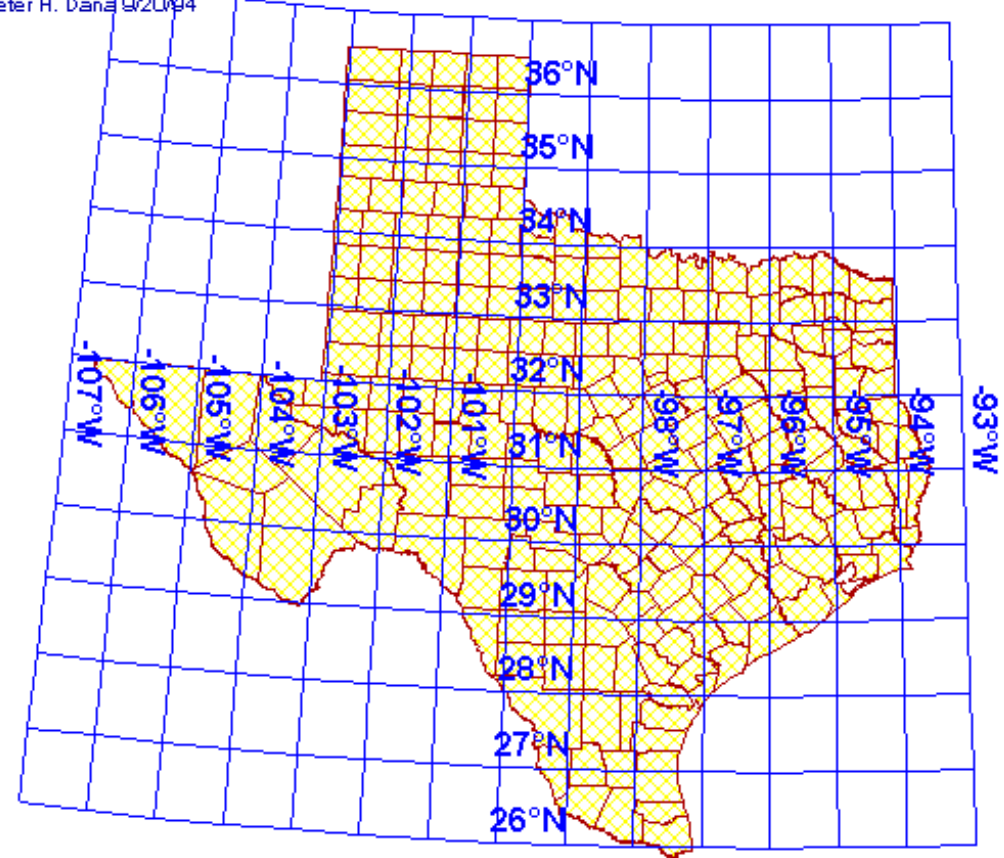
# Or if you live in a big state like Texas...Your Local View

Peter H. Dana 9/20/94

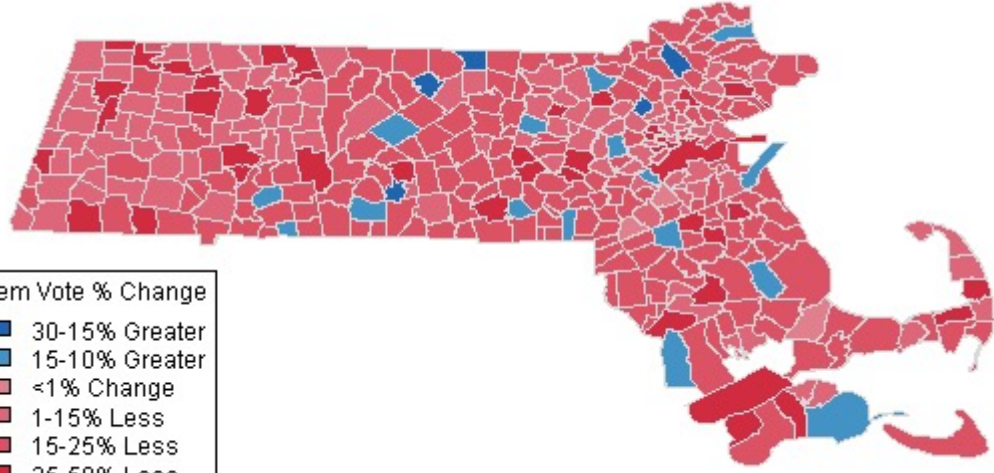


Texas State-Wide Map Projection

Peter H. Dana 9/20/94



Lambert Conformal Conic (Cont. US)

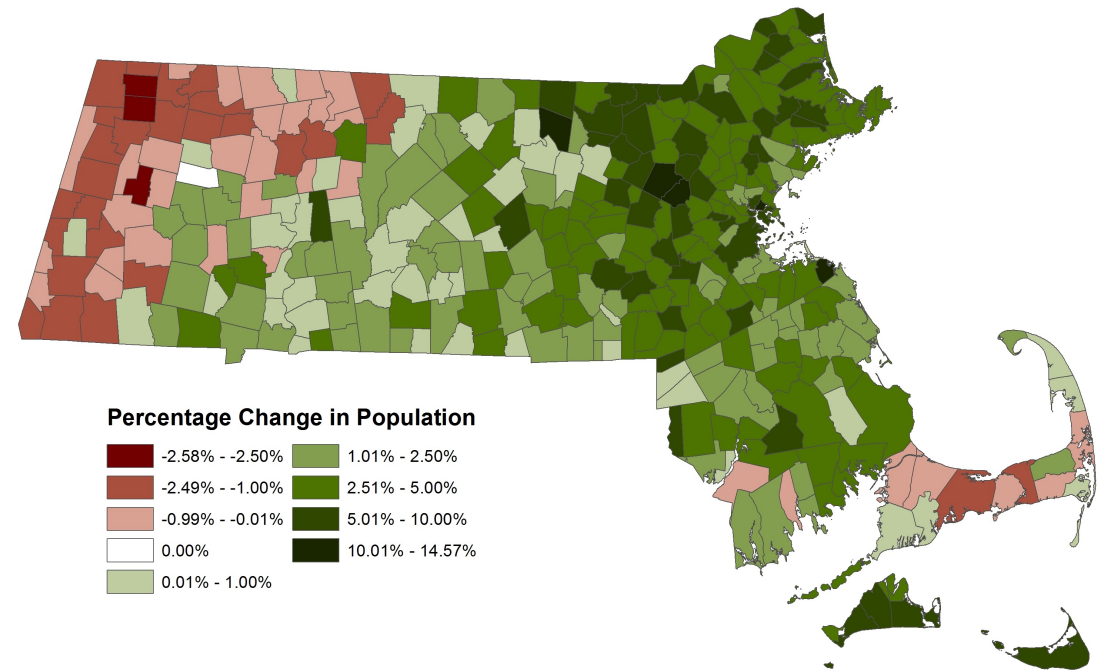


**Dem Vote % Change**

- 30-15% Greater
- 15-10% Greater
- <1% Change
- 1-15% Less
- 15-25% Less
- 25-50% Less

<http://blog.revolutionanalytics.com/2010/01/mapping-the-massachusetts-election-upset-with-r.html>

**Massachusetts 2014 Sub-County Population Estimates - Percentage Change April 1, 2010 Base to July 1, 2014**



**Percentage Change in Population**

- 2.58% - -2.50%
- 2.49% - -1.00%
- 0.99% - -0.01%
- 0.00%
- 0.01% - 1.00%
- 1.01% - 2.50%
- 2.51% - 5.00%
- 5.01% - 10.00%
- 10.01% - 14.57%

UMass Donahue Institute Population Estimates Program.  
 Source data: Annual Estimates of the Resident Population: April 1, 2010 to July 1, 2014.  
 U.S. Census Bureau Population Division. May 21, 2015.

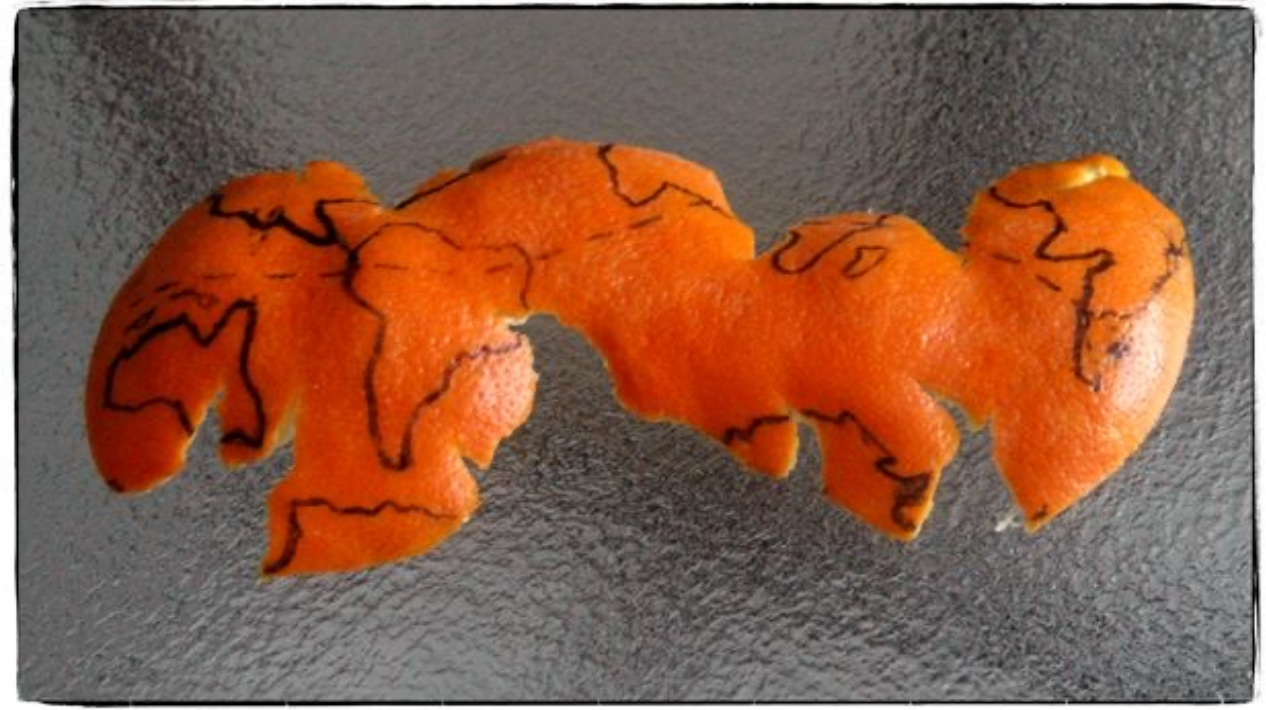


<https://www.youtube.com/watch?v=vVX-PrBRtTY>



# Much Like Thermodynamics, You Can't Win

- When going from a 3-D sphere to a 2-D piece of paper it is inevitable that distortion will occur.
- To maintain one of the properties, you have to give up the others.
- Selection of a map projection means deciding what to save and what to give up.



The Classic Orange Peel

<https://s-media-cache-ak0.pinimg.com/736x/2d/81/fc/2d81fcfacdc11ec04f34d1b1c587954.jpg>

# Properties of a Globe

The Globe Preserves:

Area

Shape

Distance

Direction

Maps Can Be:

Equal Area

Conformal

Equidistant

Azimuthal

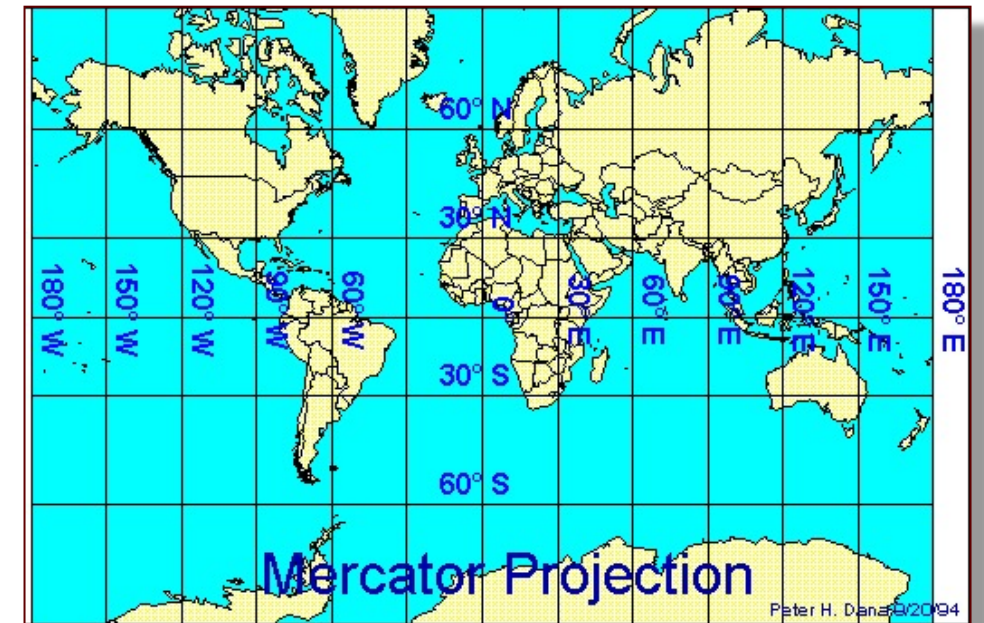
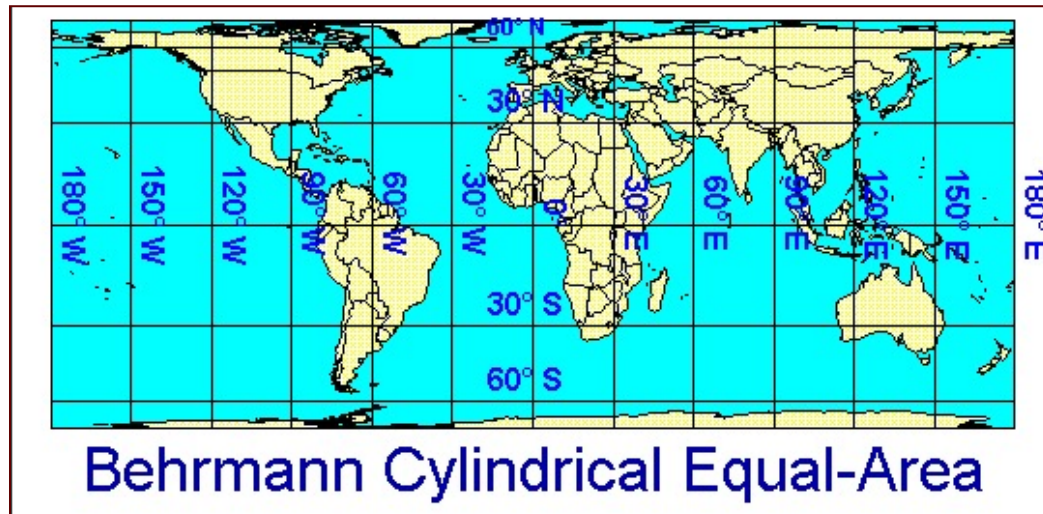
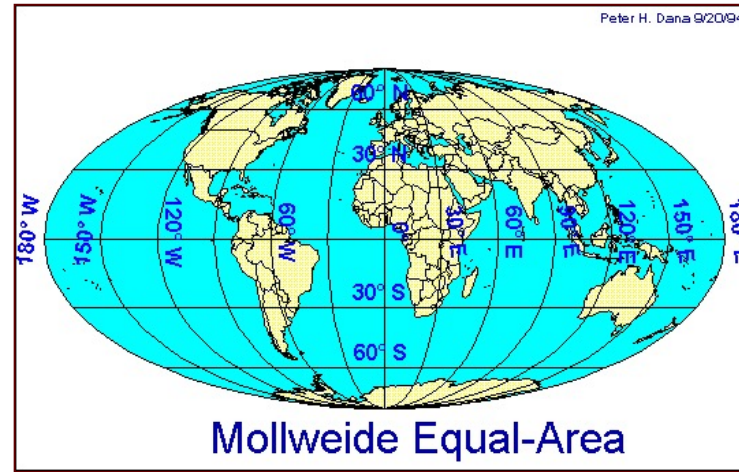
# The Four Classes of Maps

There are four general classes of map. Each of these four types is designed to preserve one of the four major properties of a globe, but to accomplish this it is necessary to make accommodations in the other three...

*The art of selecting an appropriate map projection is determining which property of the globe is most important to preserve while striving to minimize distortions in the others for your area of interest*

# Equal Area

Areas are preserved at the expense of other properties.

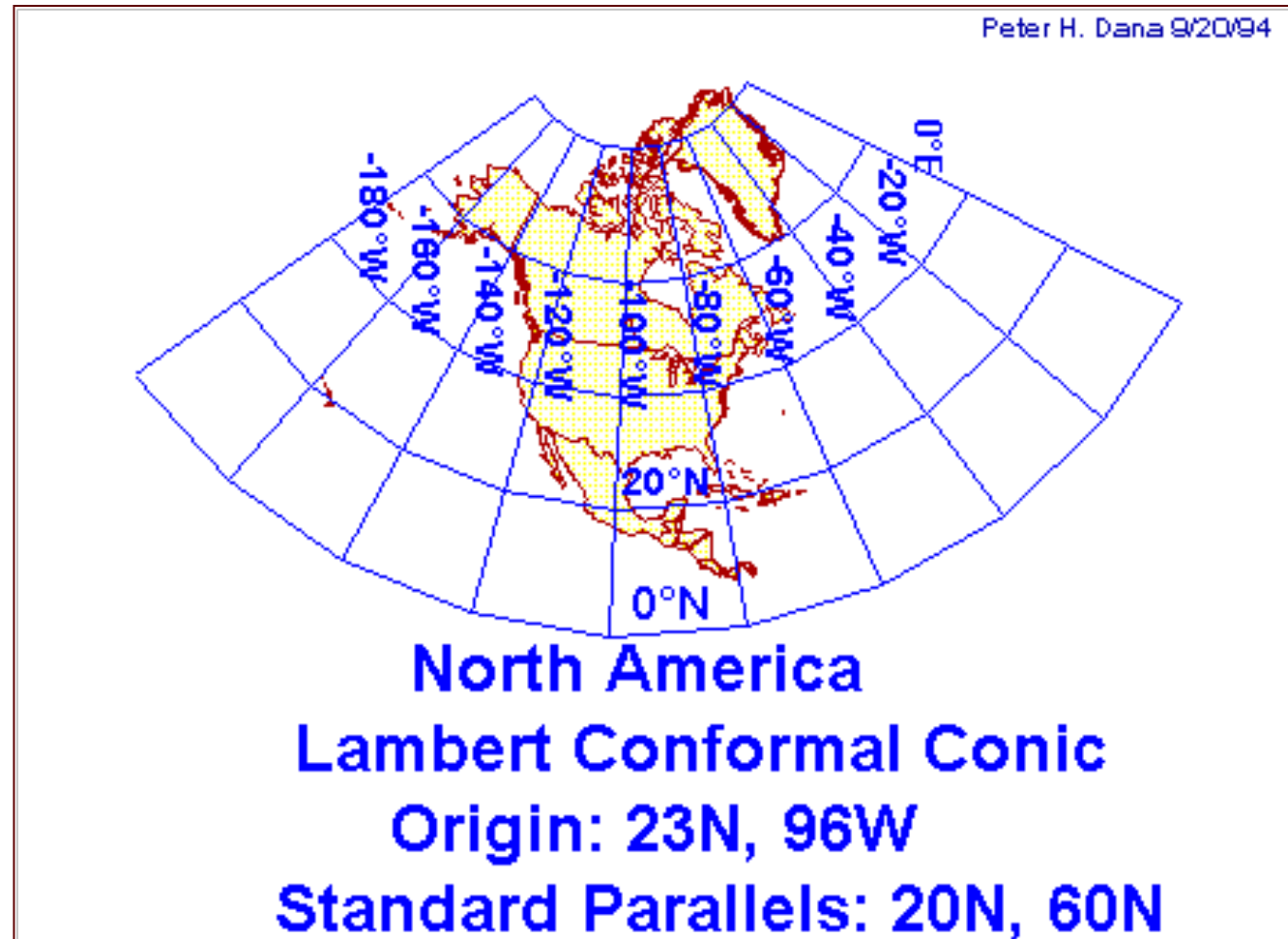


Which of these is not equal area?



# Conformal

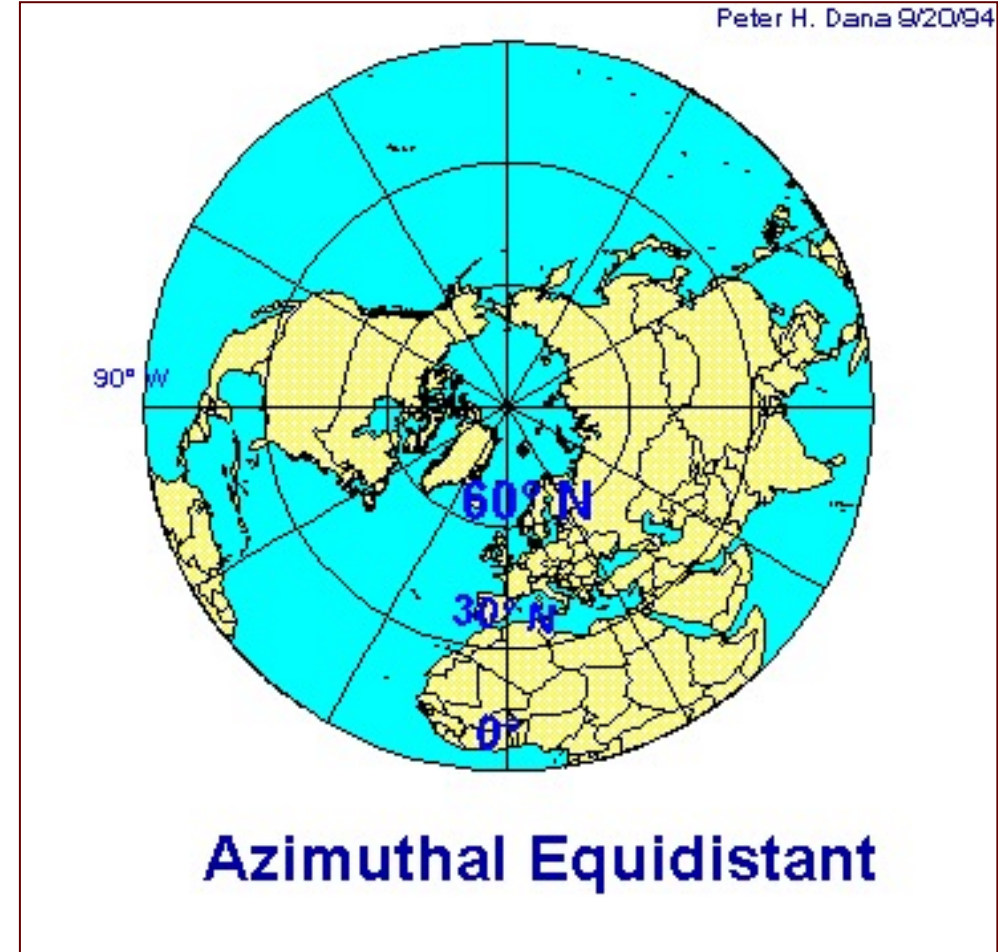
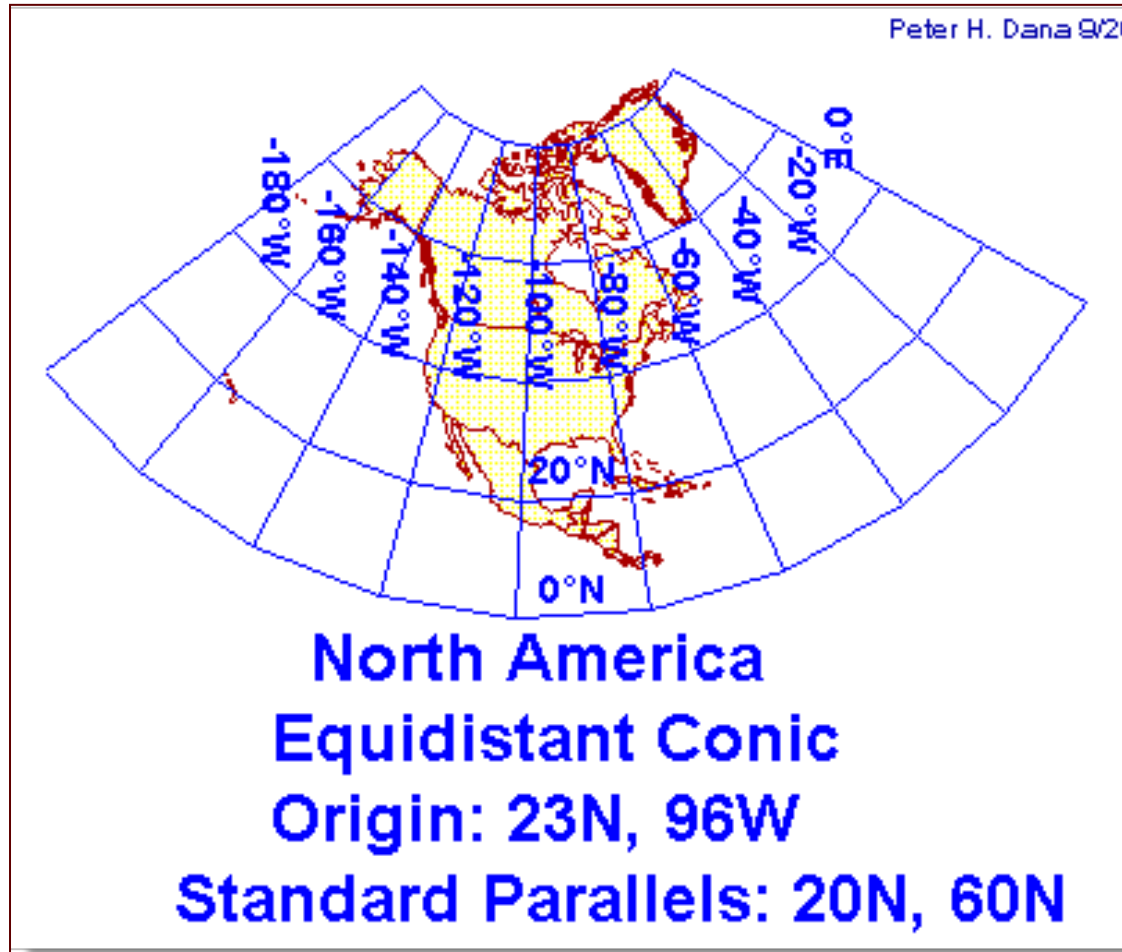
- Shape (of small areas) are preserved.
- Preserves local angles.
- Ideal for navigation.





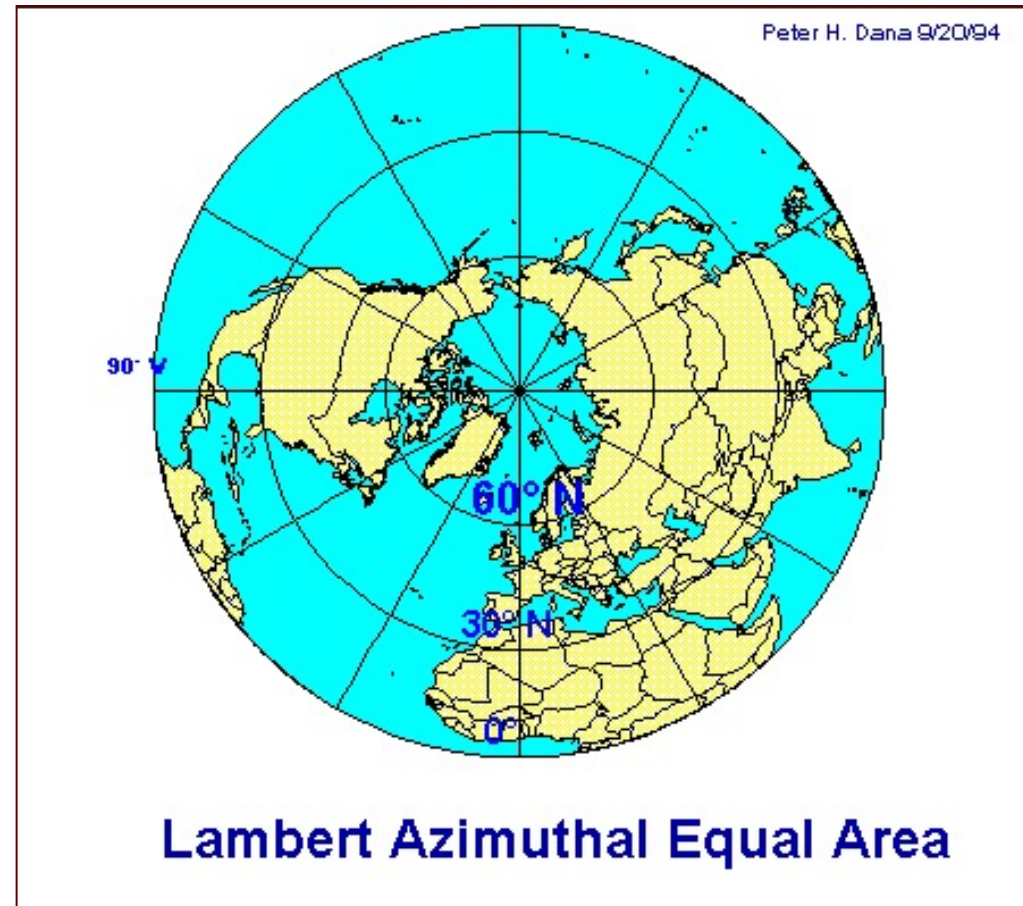
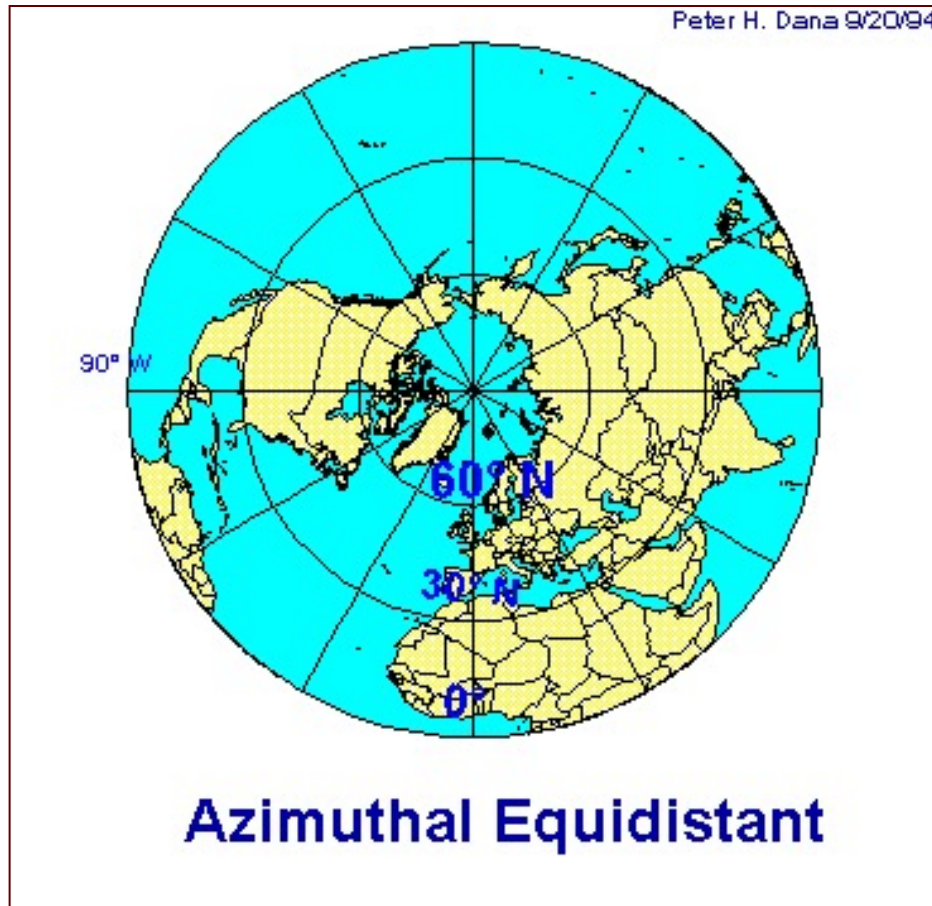
# Equidistant

- Distance along designated great circles are true; or:
- Distances from one point to all others is true.



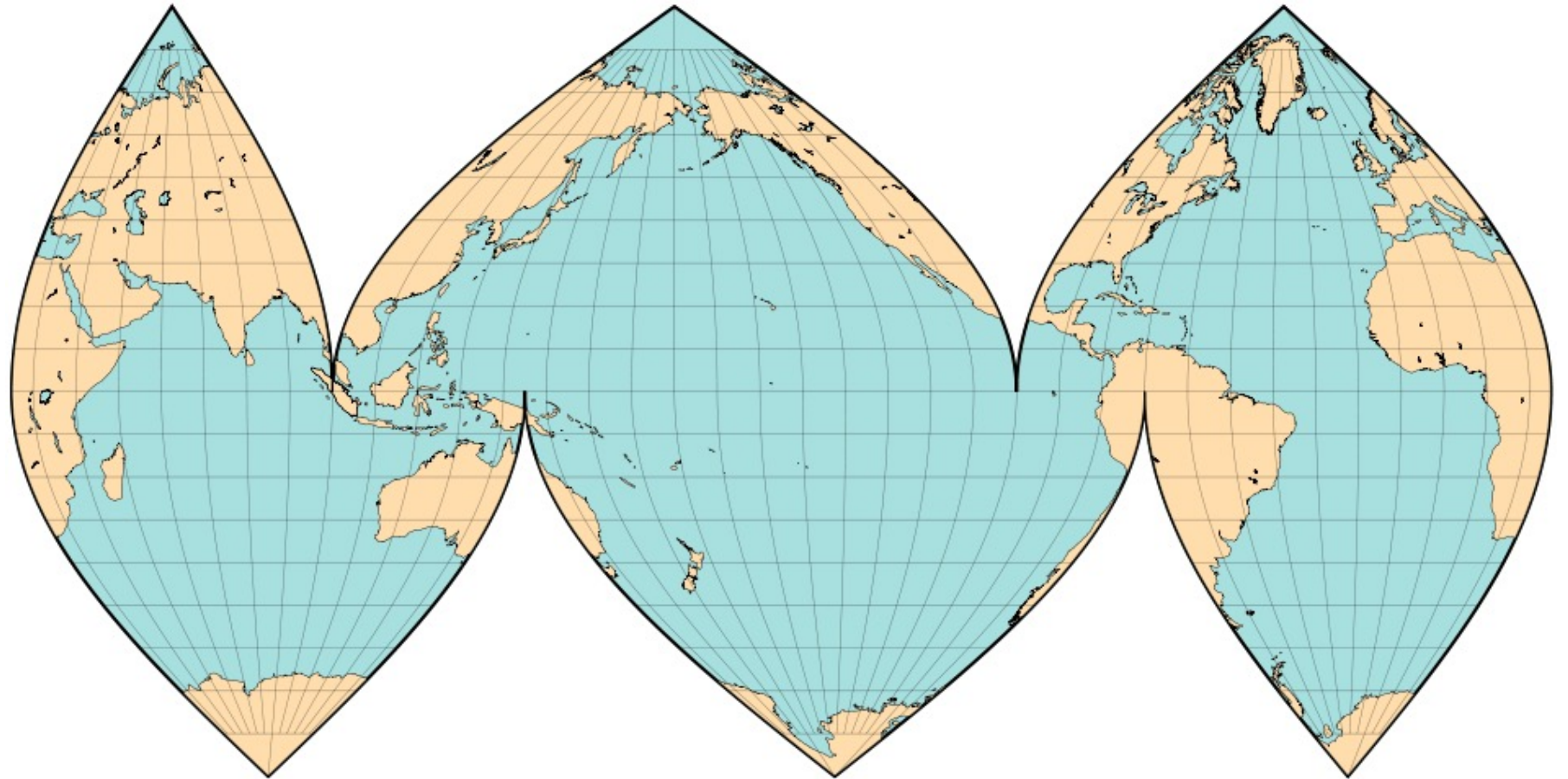
# Azimuthal

True direction is shown from one central point to all other points



# Interrupted Projections

- Balance distortions by splitting the surface.





# Know Your Rat Projections



Conic Rat



Robinson Rat



Sinusoidal Rat



Mercator Rat



Peters Rat



Dymaxion Rat

# Consider the Following

- The Mercator projection vastly distorts area, but is the basis for the 'Web Mercator' used by online systems.
- Answer: Why is Mercator the basis for online mapping?

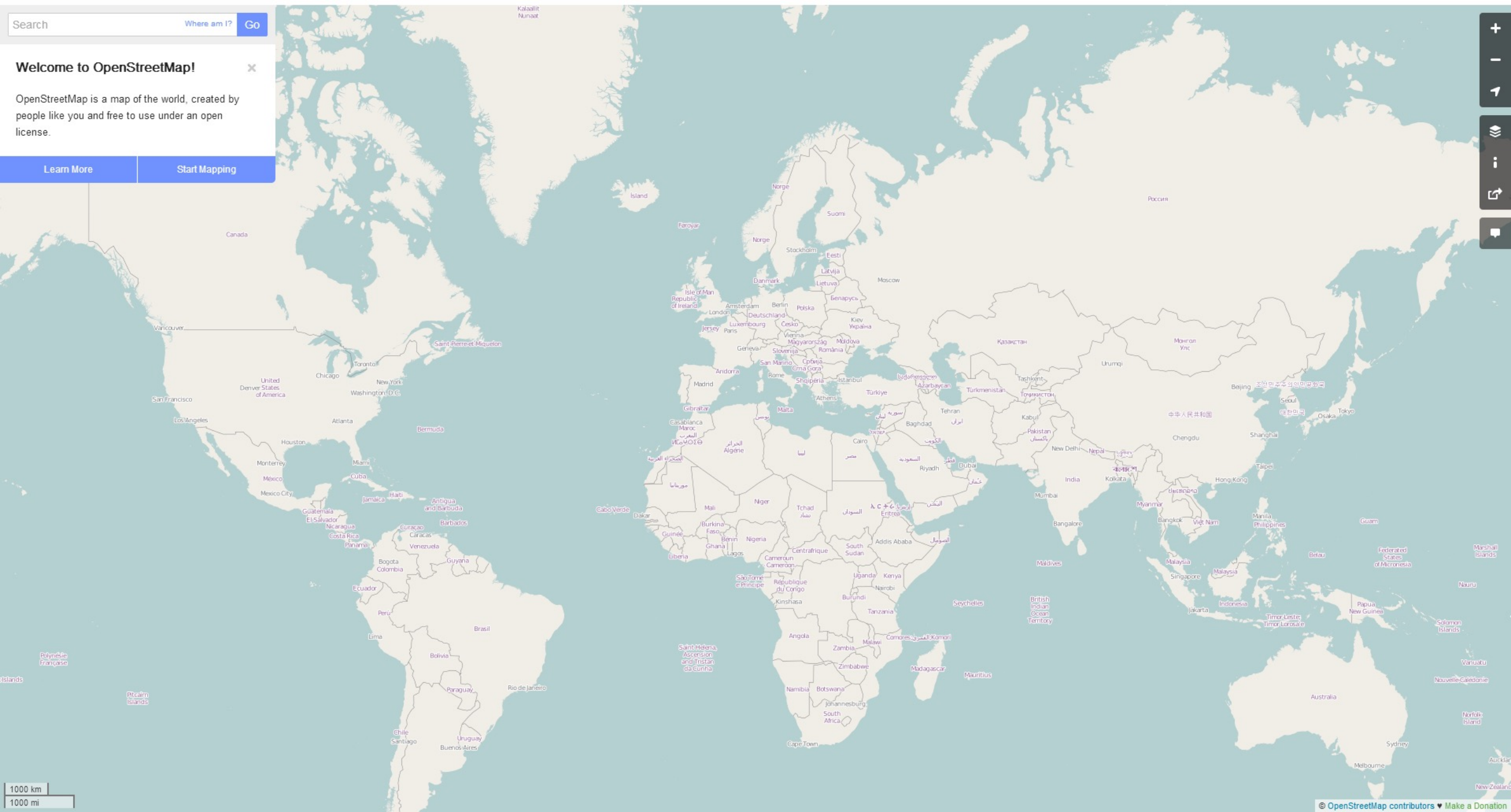


Search Where am I? Go

**Welcome to OpenStreetMap!** ✕

OpenStreetMap is a map of the world, created by people like you and free to use under an open license.

[Learn More](#) [Start Mapping](#)

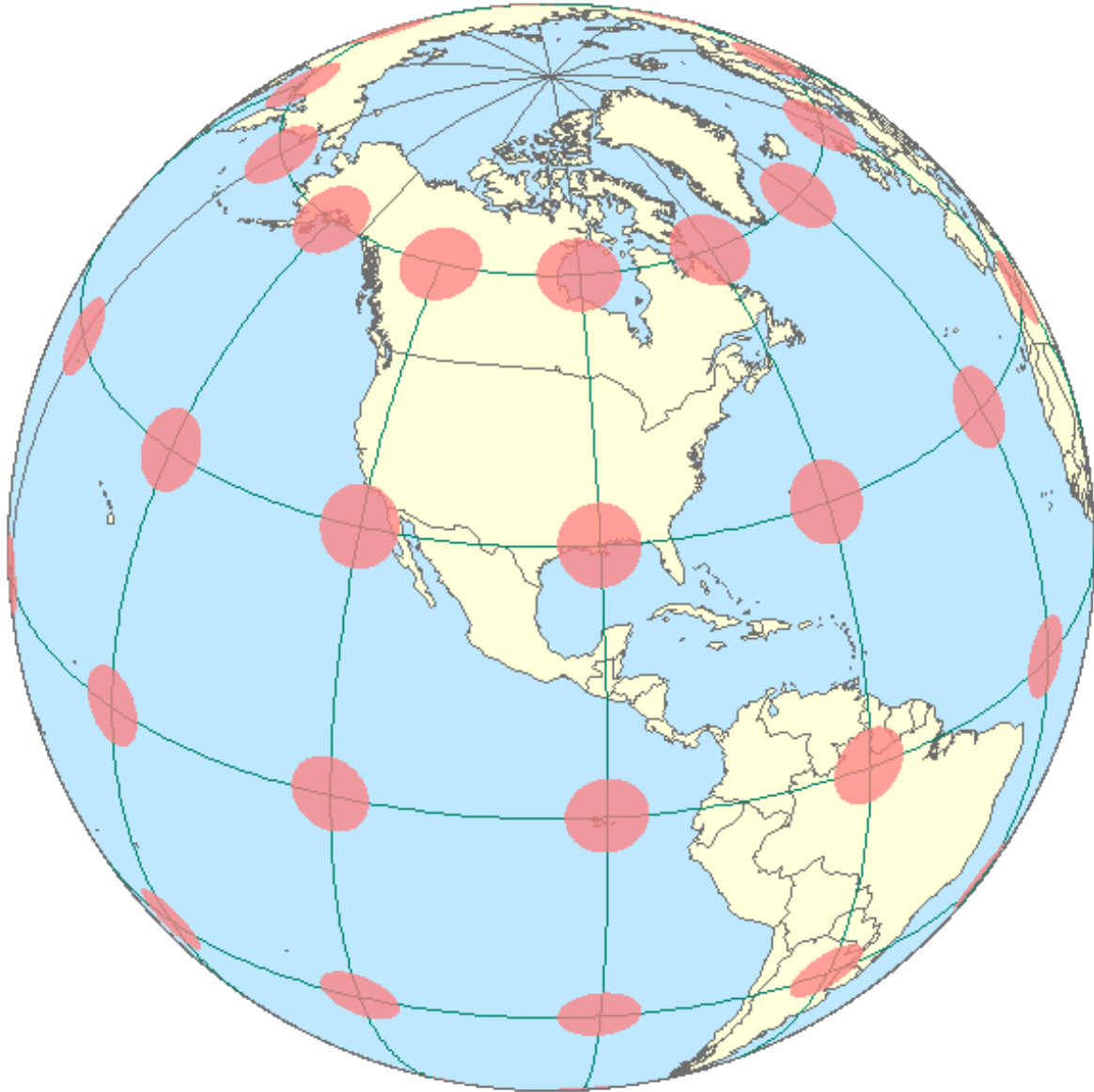


Map navigation controls including zoom in (+), zoom out (-), home (house icon), full screen (maximize icon), and a speech bubble icon.

1000 km  
1000 mi

[Tx.ag/GIS4](https://www.tx.ag/GIS4)

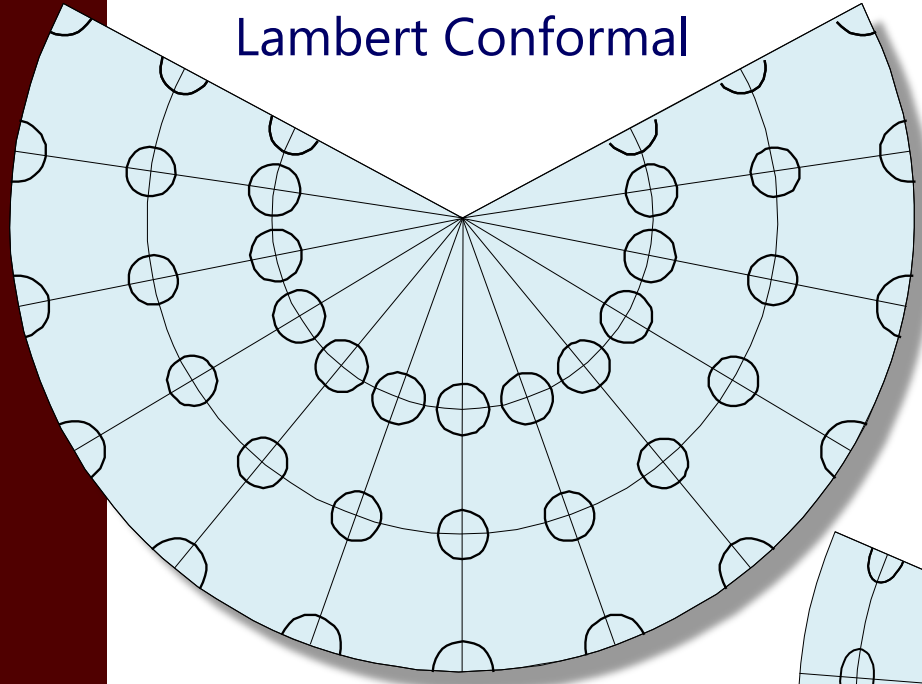
# Orthographic Projection



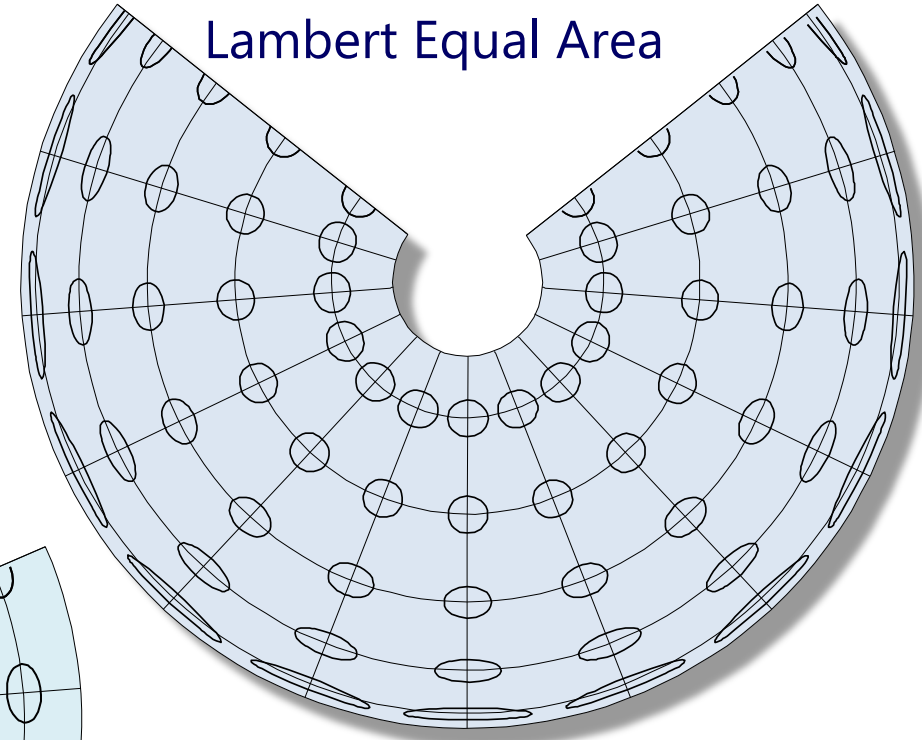
*Note that on a globe all Tissot Ellipses are the same size and are circular since on a globe both area and shape are preserved correctly*

# Projections and Tissot's Indicatrix

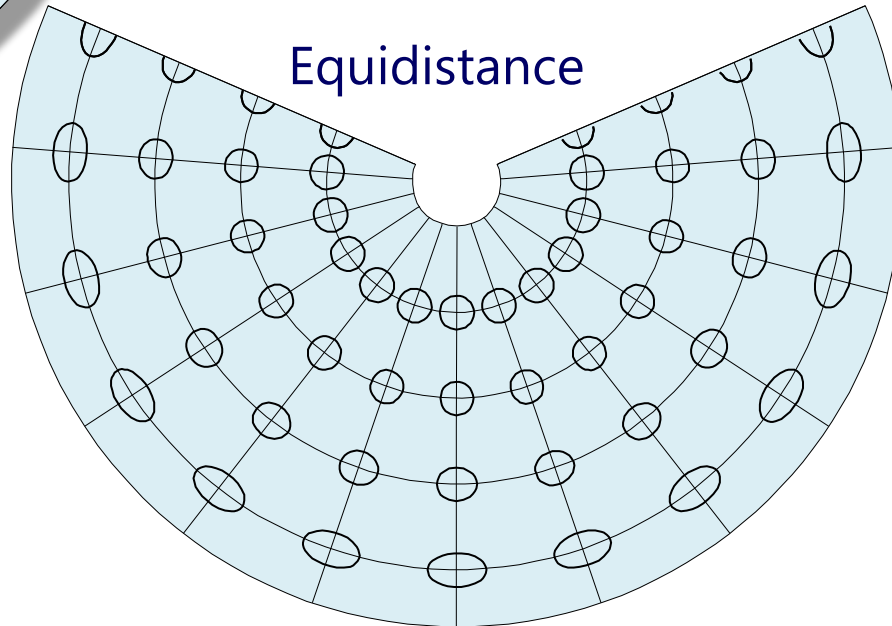
Lambert Conformal



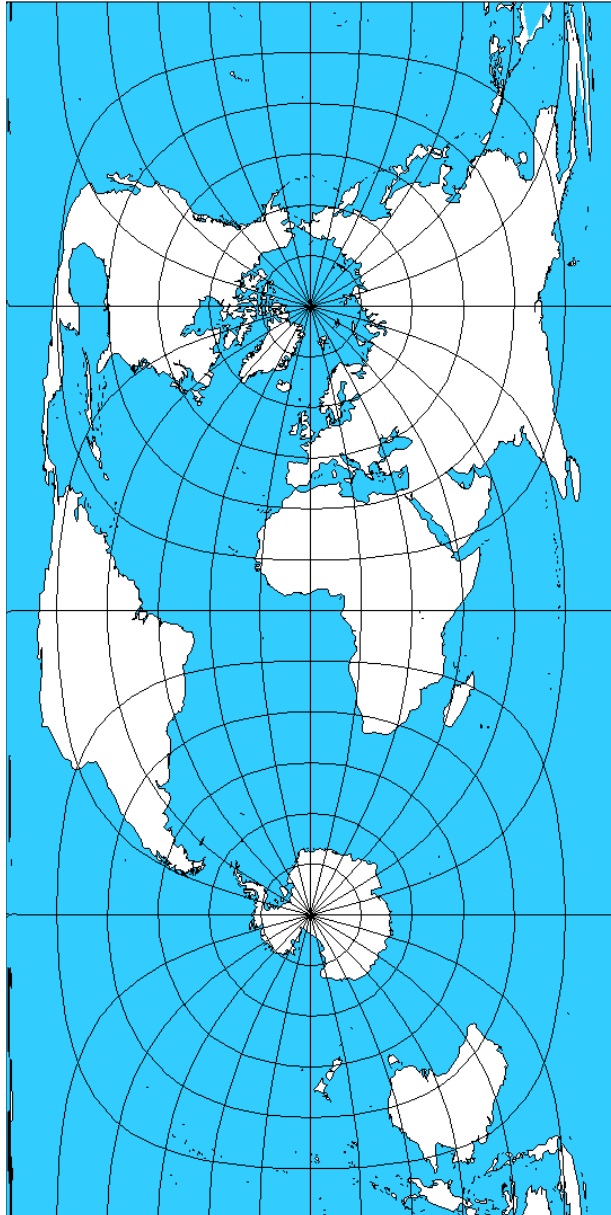
Lambert Equal Area



Equidistance



# Identifying Distortion Using Tissot's Indicatrix



Cassini  
Projection

