Adaptive Composite Map Projections

Adapting your map projection to the view as it changes to always minimize distortion.

Oregon State University OSU

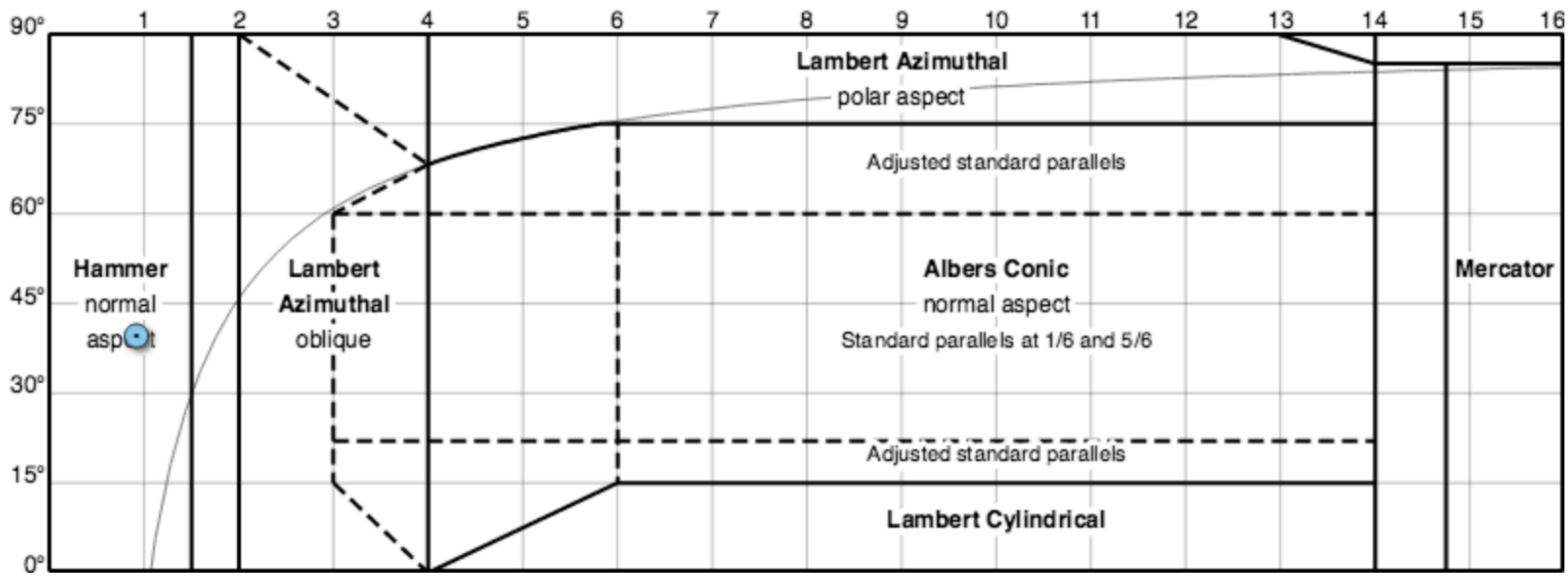
CARTOGRAPHY & GEOVISUALIZATION GROUP

ADAPTIVE COMPOSITE MAP PROJECTIONS

Do try it yourself! Demo at:
http://cartography.oregonstate.edu/demos/AdaptiveCompositeMapProjections/

Adaptive Composite Map Projections

Horizontal axis: map zoom factor.
Vertical axis: central latitude of map.
Click in the diagram or drag the button to change scale and central latitude.



Do try it yourself! Demo at:
http://cartography.oregonstate.edu/demos/AdaptiveCompositeMapProjections/

Geography 360
October 26, 2016

How GIS understands both shapes and properties of entities on the Earth

1. *Questions and Announcements*
   - Field Paper outage [resolved]
   - New (first part of a) project up: Data, near and FAR

2. *How does GIS represent and present features on the Earth?*
   (continued.)
   - Projections: What they are. When to use which one.
   - Datums
   - Data in well-specified spatial reference systems:
     Coordinates with a specific datum in a projection.
   - Some basic data models, with a focus on ‘vector’ data.

REVISITING *the best and worst part of 2D projections:*

Different projections are better at 'preserving' different 'properties'

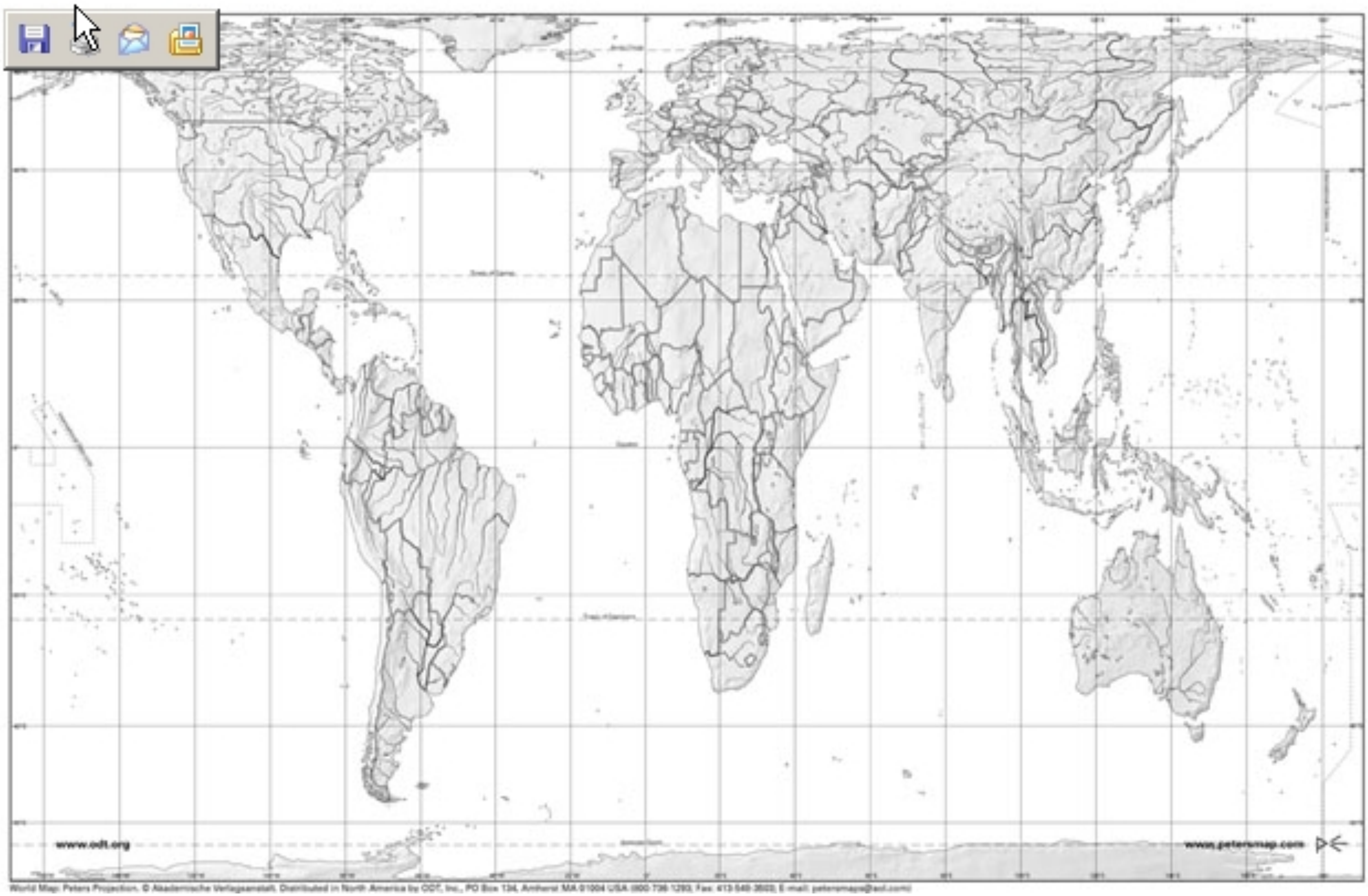
- Projections distort in different ways
- Projections can *preserve* various ***properties***.

  A map that preserves a property is one that has that property appear the same way across the map.

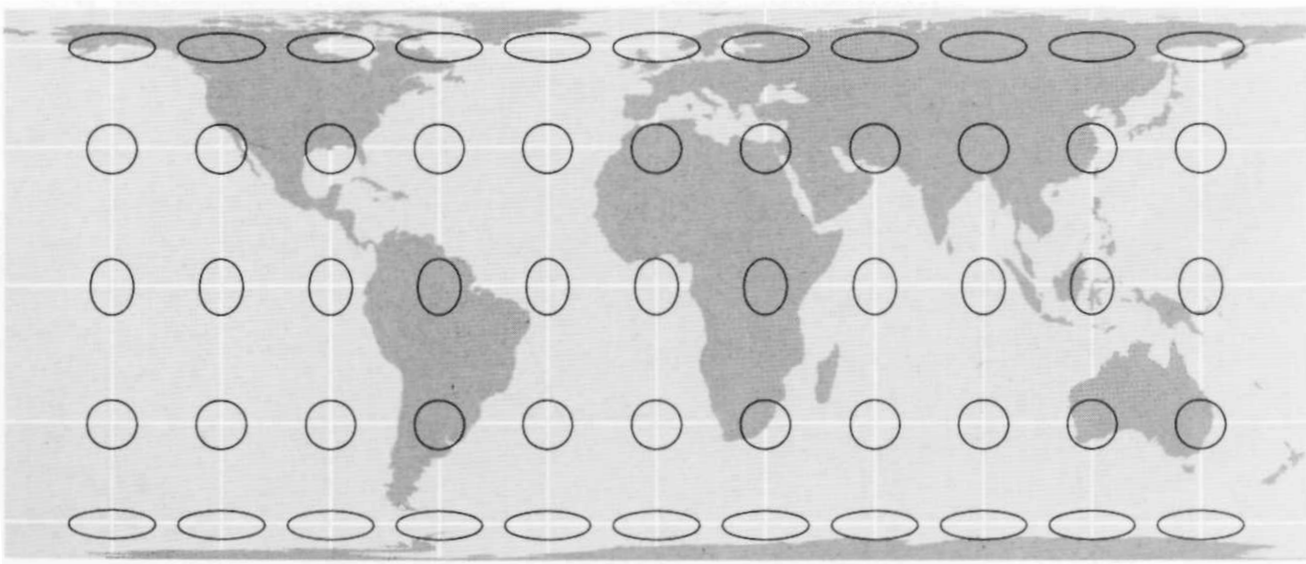
  - ***Property preserved:*** What we call this sort of projection
  - ***Area:*** "Equal Area" or "Equivalent" projections
  - ***Angle / (small) Shapes:*** "Conformal" projections
  - ***Distance from a line or point or two:*** "Equidistant" projections
  - ***Direction from the center:*** "Azimuthal" projections
- But no map preserves all properties, perfectly, at once!
- This is simultaneously a representational lack and an analytical opportunity.
- You want to tell particular stories about your data and not mislead.

  Use a projection that preserves the properties appropriate to the characteristics of your data and to the types of perspectives you are taking on your data.

  Projections themselves modify how you are conveying information through the visual variables of location, orientation and pattern, among others.

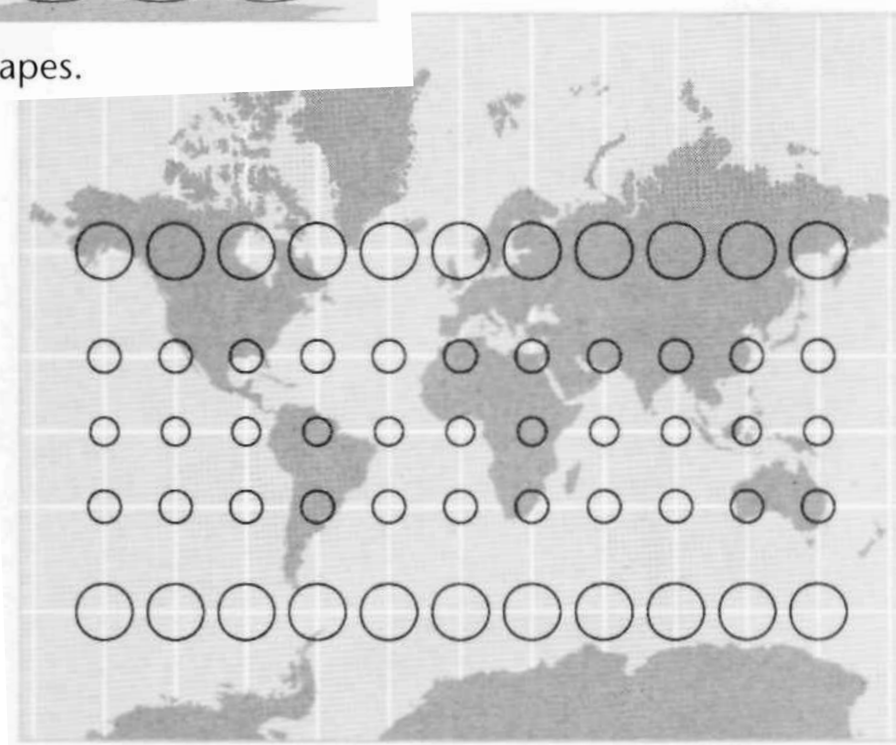


Peters: equal area, poor shape, politically significant historically.



Equal-area map projection: Preserves areas, distorts shapes.

This is actually a Peters projection,
though **not** all equal area projections are Peters.
Generally, choose a different one.



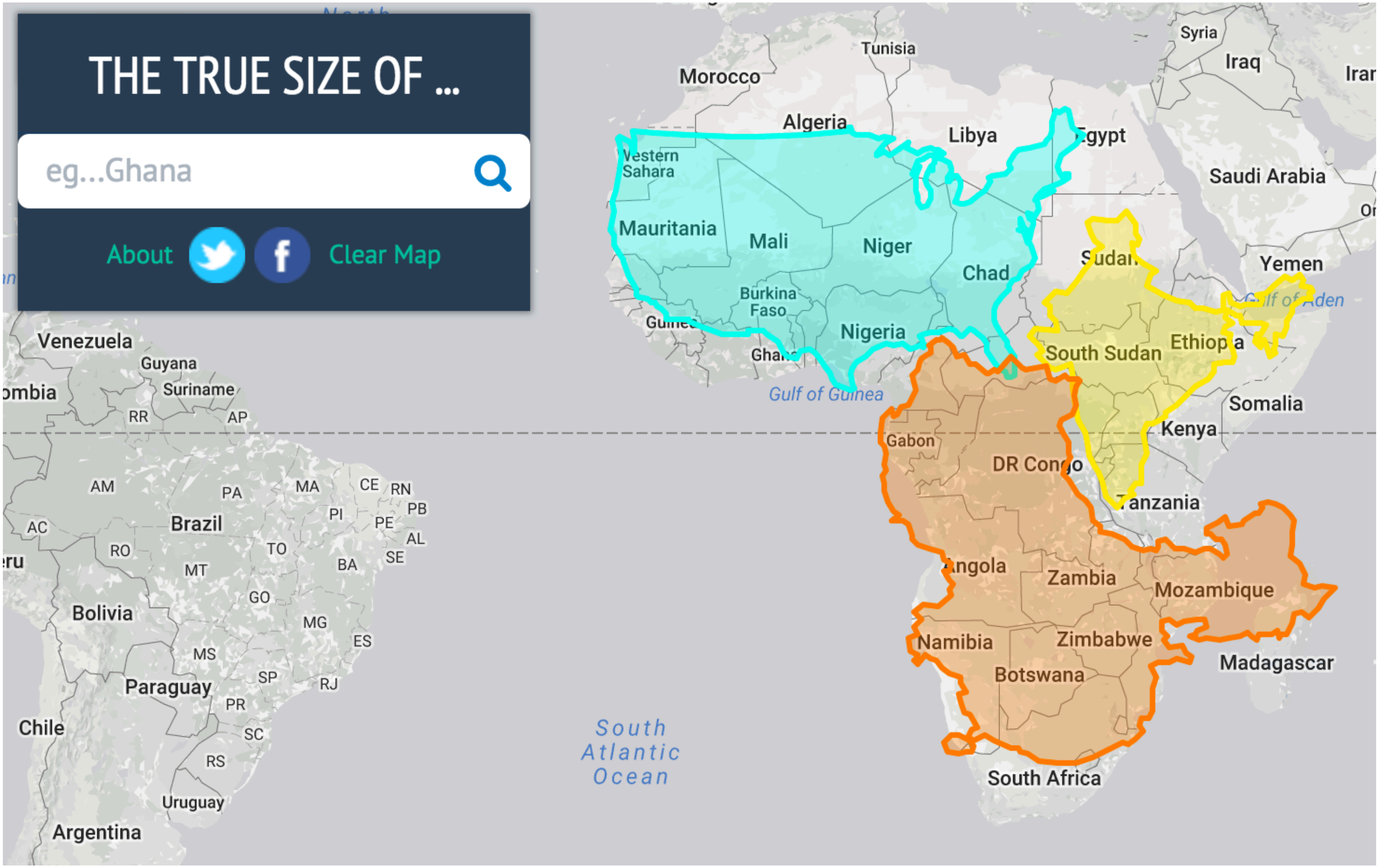
Mercator map projection:
Preserves shapes, distorts areas.

Krygier and Wood 2011

These little circles are *all the same size* on the Earth's surface.

In a grid form centered at intersections of lines of lat and long, they are called *Tissot's indicatrices*.

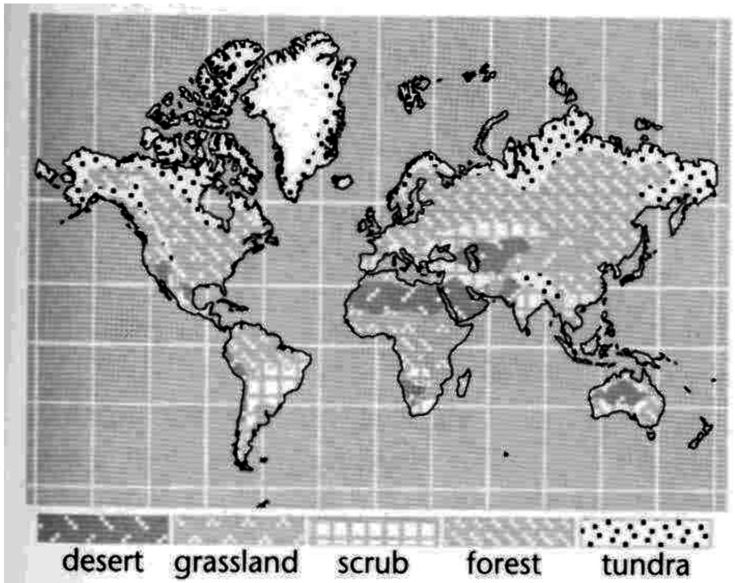
They are useful for understanding map projection distortions.



http://thetruesize.com/#/aboutModal?borders=1~!MTcyNTAyNTM.MTM4MjkxMA*MzYwMDAwMDA(MA~!CONTIGUOUS_US*MTAwMjQwNzU.MjUwMjM1MTc(MTc1)MA~!IN*NTI2NDA1MQ.Nzg2MzQyMQ)MQ~!CN*OTkyMTY5Nw.NzMxNDcwNQ(MjI1)Mg

If you fold different parts of a map in the Mercator projection onto themselves, you get a clearer visual sense for how regions actually compare in size.

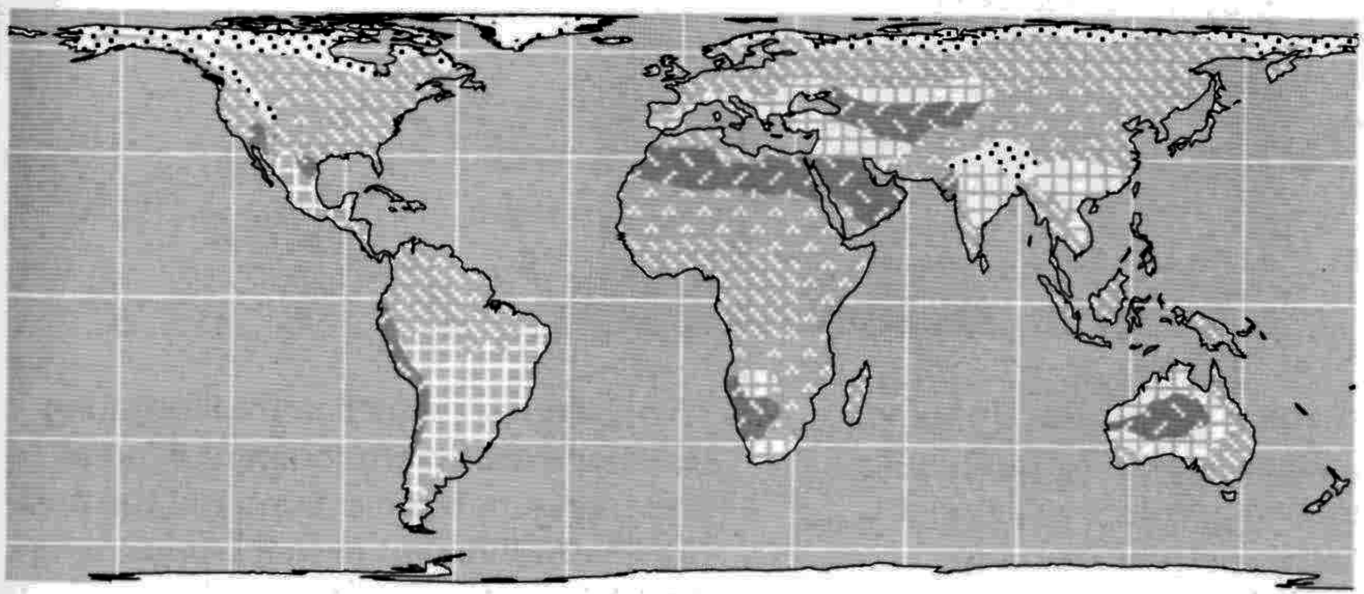
And remember—whether area is preserved or not can be crucial for thematic mapping, too......



Mercator map projection:
Preserves shapes, distorts areas.

A map of vegetation on a Mercator (left) distorts the data. Northern types are greatly expanded in area compared to those near the equator. This suggests the global dominance of northern vegetation types, which is wrong.

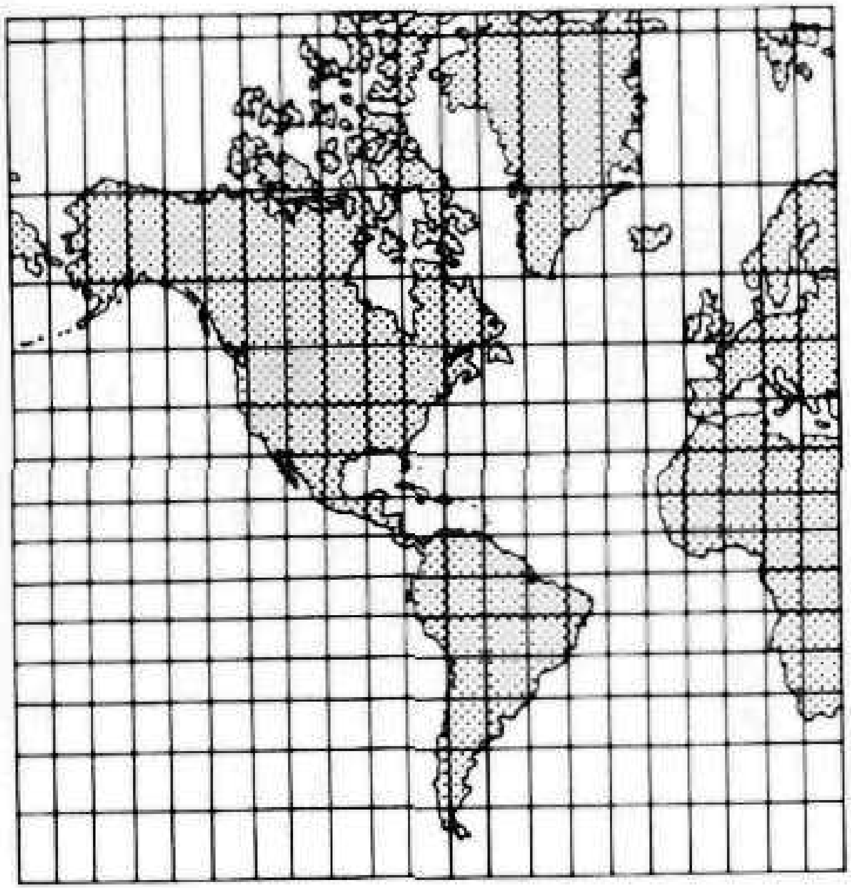
The same data on a map projection (below) that doesn't distort areas. But now shape is distorted! You must be smart with projections and understand tradeoffs. In this case, with area vegetation data, you are better to distort shapes and not areas.



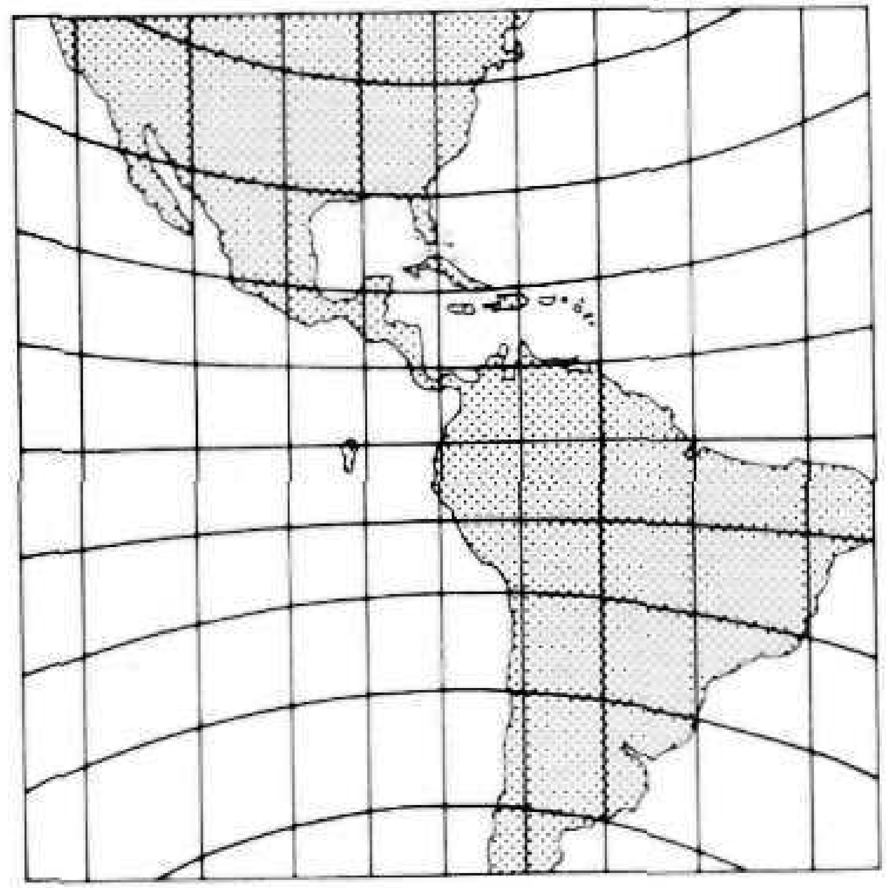
Equal-area map projection: Preserves areas, distorts shapes.

So, what kind of projections would you use to map spatial distributions when the **relative areas of phenomena** are important to convey?

Krygier and Wood 2011



Mercator projection

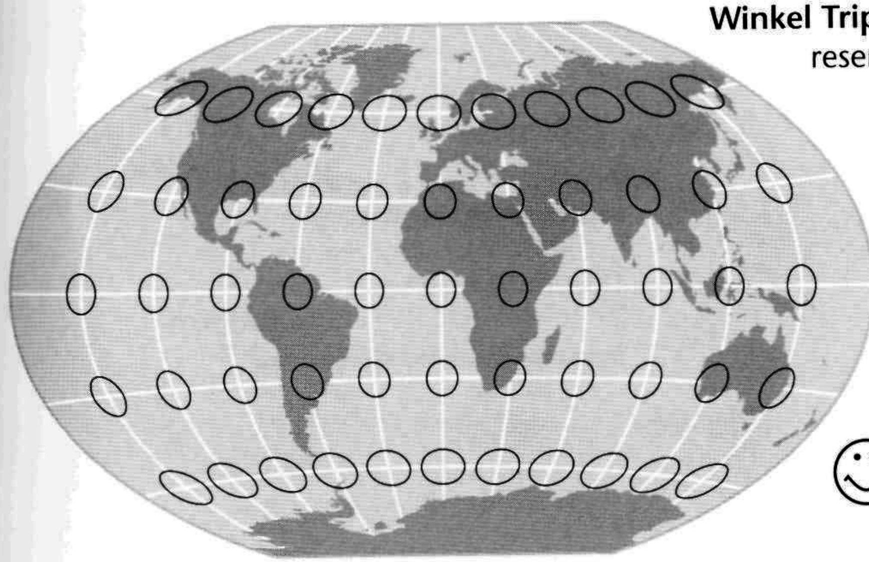


Gnomonic projection

FIGURE 2.7. Straight lines on an equatorially based Mercator projection (left) are rhumb lines, which show constant geographic direction, whereas straight lines on a gnomonic projection (right) are great circles, which show the shortest route between two points.

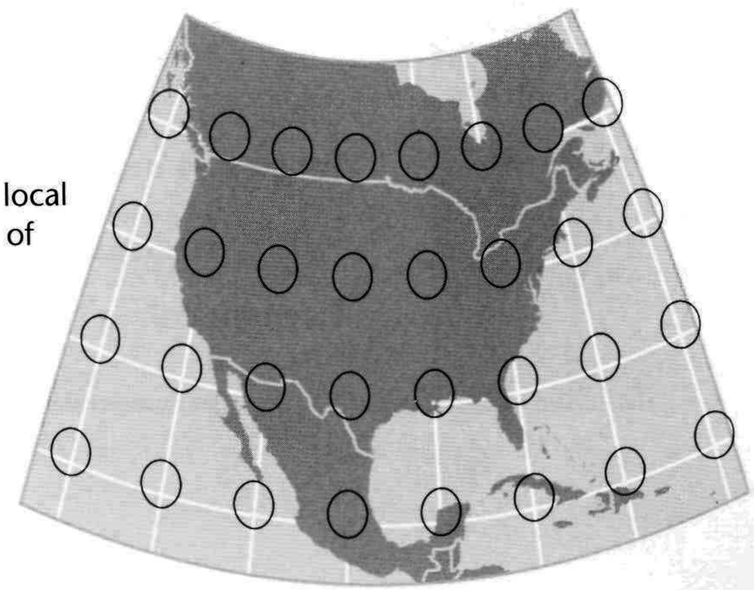
Monmonier 1996

Compromise Projections!



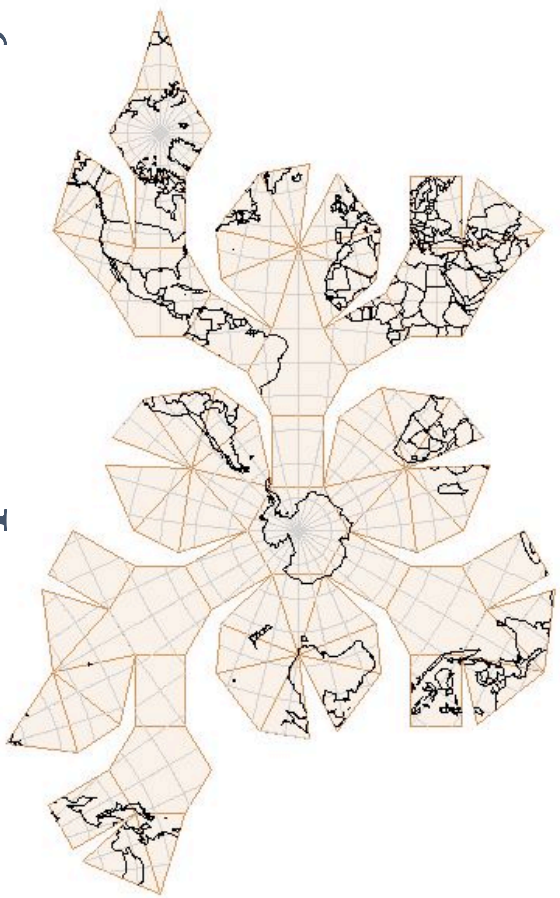
Winkel Tripel projection: This projection resembles the Robinson, but it has less area exaggeration in the polar regions. The Winkel Tripel is the default map projection of the National Geographic Society.

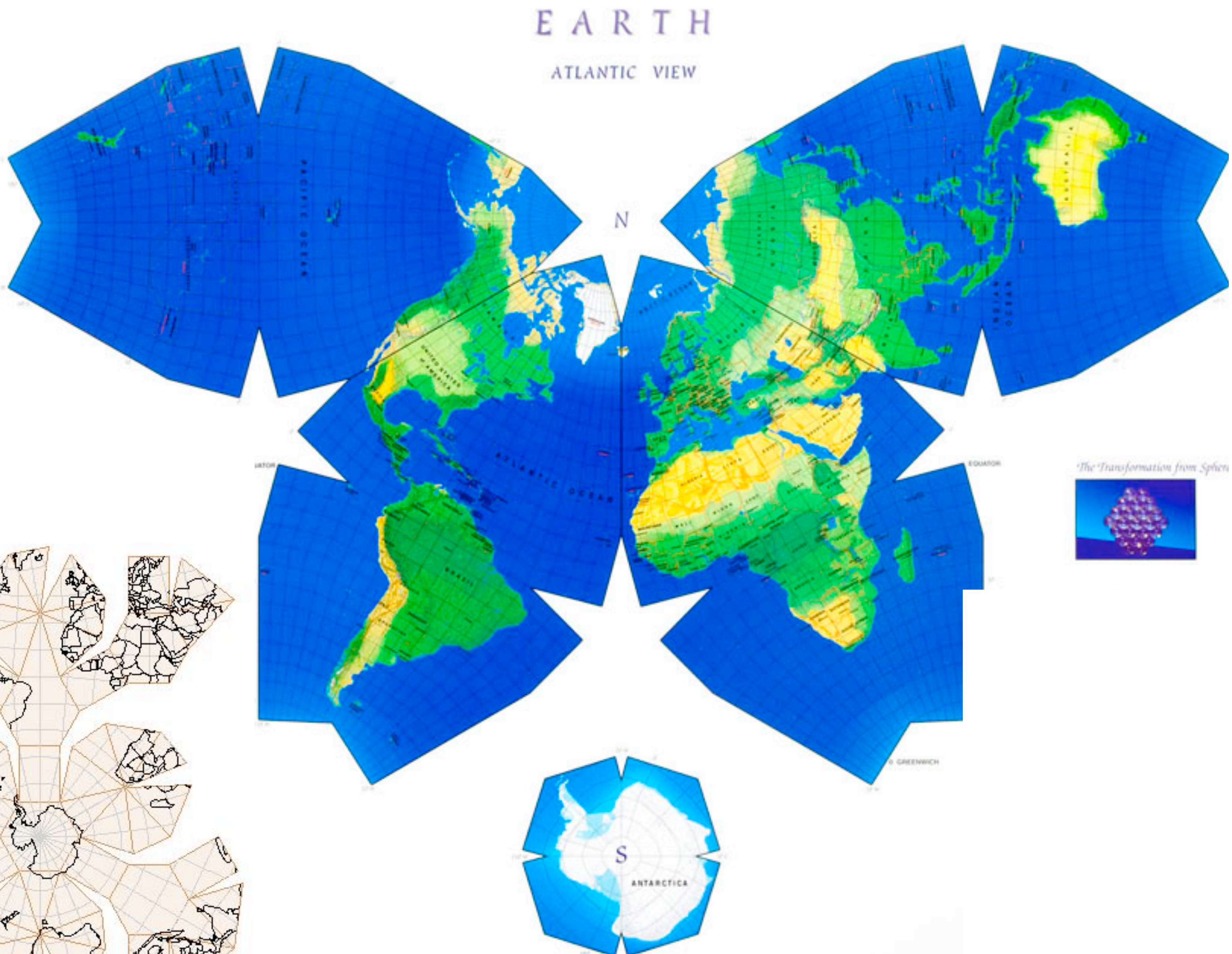
Good for a general world map and for mapping global phenomena.



Poor for regional or local scale maps because of area and shape distortion.

Compromise Projections!





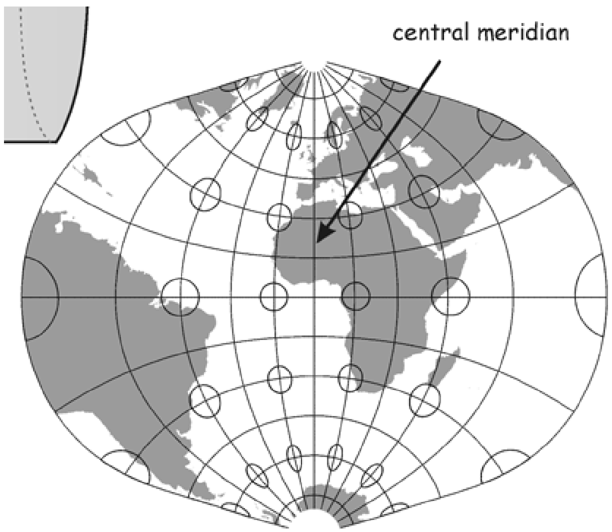
Waterman Butterfly Projection

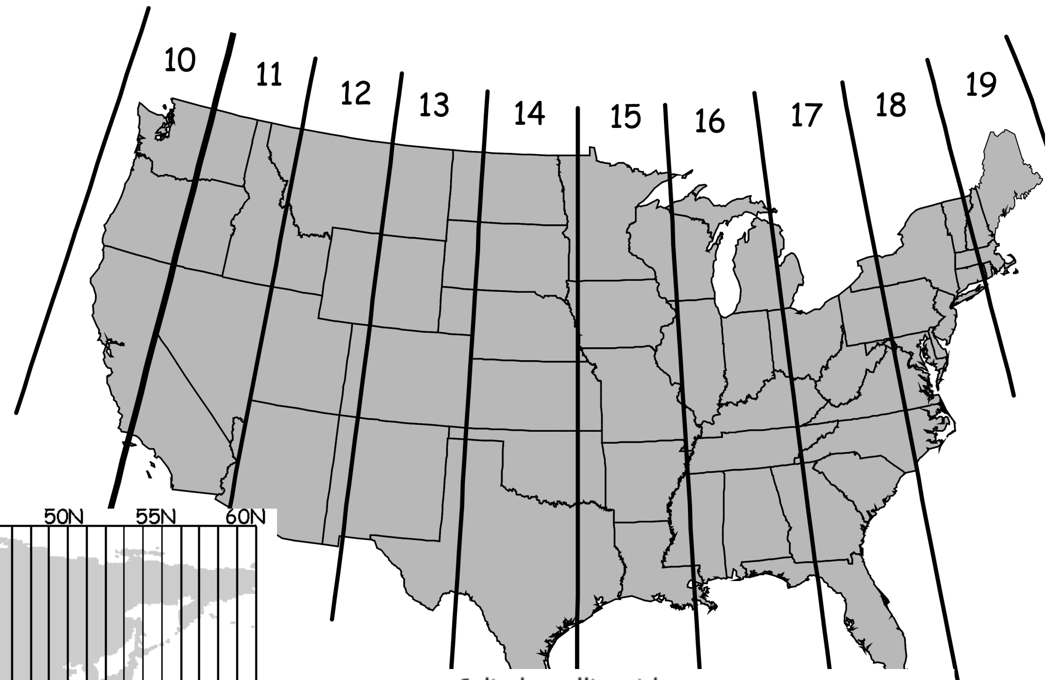
It’s simpler when you only have a known, small area. It used to be very common to see data in one of the zones (e.g. 10N) from the…

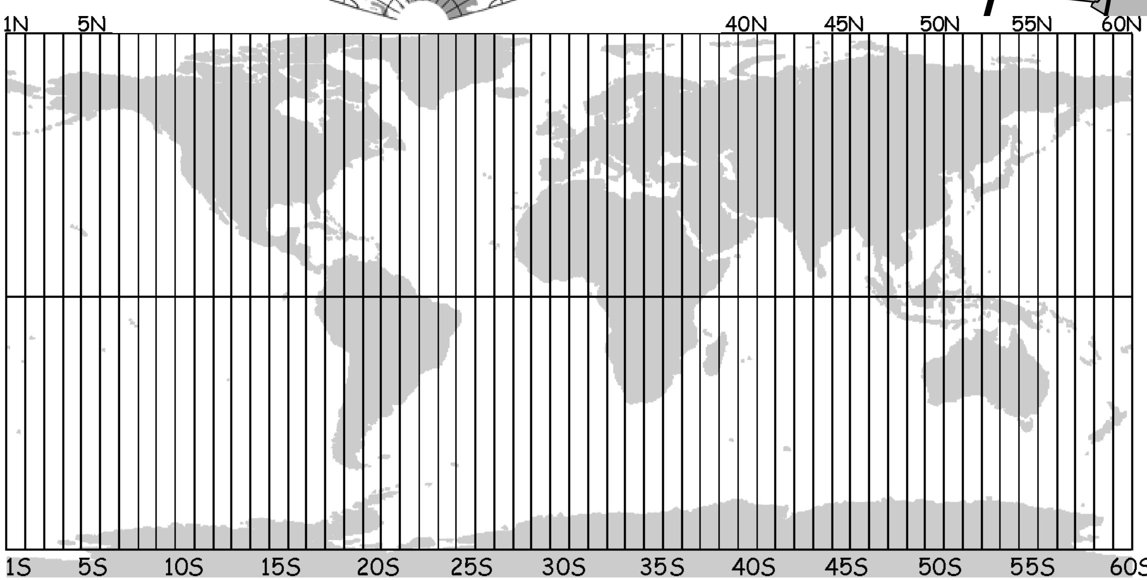
Universal Transverse *Mercator* (UTM) Coordinate System.

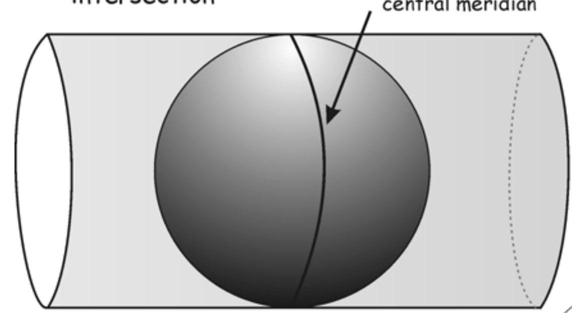
(Does this have the same weaknesses as Mercator? Why?)

Compromise Projections!



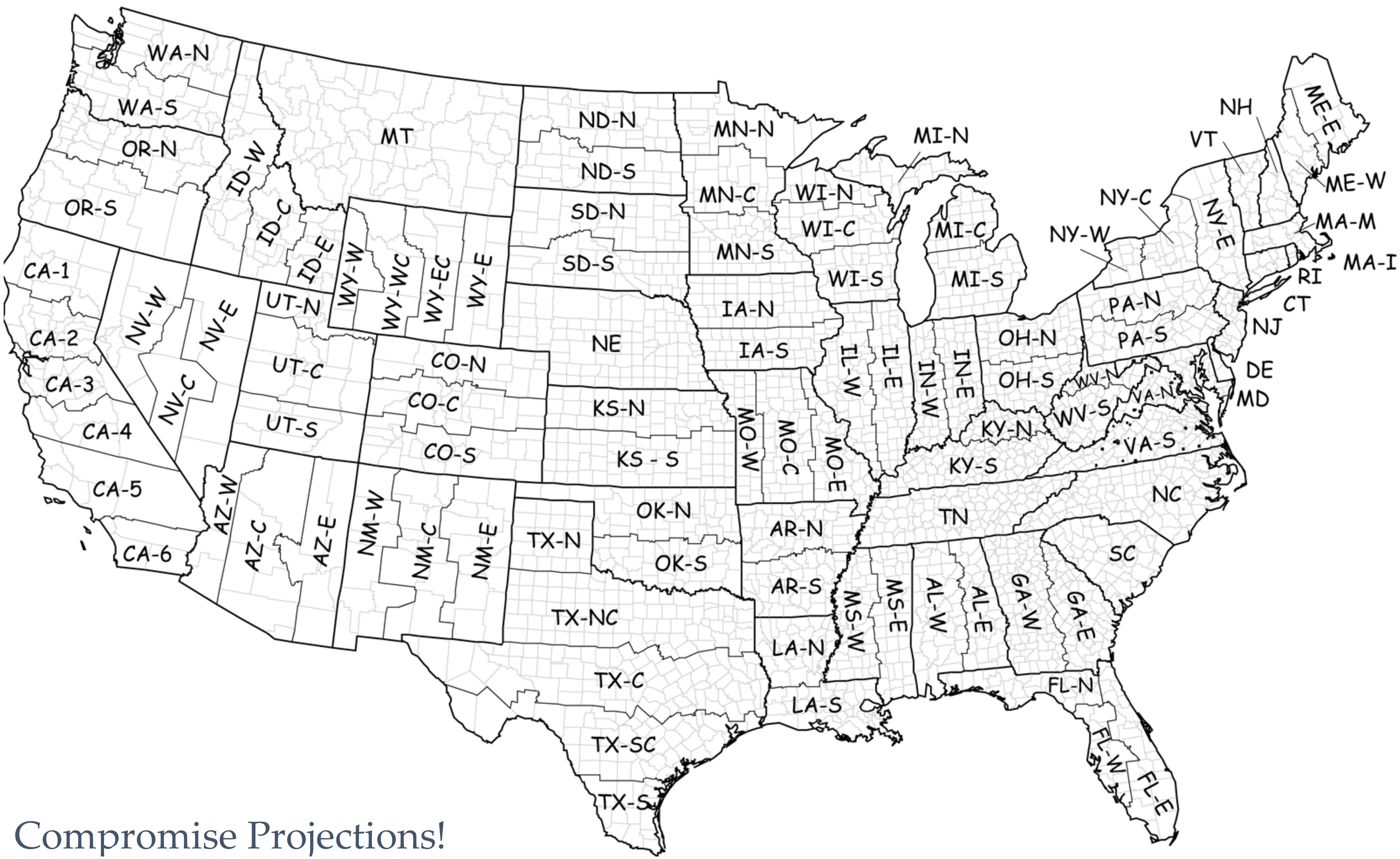






It's simpler when you only have a known, small area. In the US, State and Local governments often use the:

State Plane Coordinate System



Compromise Projections!

Many detailed guides available to consult when implementing these basic principles of selecting projections…

ArcGIS Supported Map Projections

		Properties							Suitable Extent						Location or Shape						General Purpose					
Projection	**Type**	Conformal	Equal Area	Equidistant*	True Direction*	Perspective	Compromise	Straight Rhumbs	World	Hemisphere	Continent/Ocean	Region/Sea	Medium Scale	Large Scale	North/South	East/West	Oblique	Equatorial	Midlatitude	Polar/Circular	Topographic	Geologic	Thematic	Presentation	Navigation	USGS
Aitoff	Modified Azimuthal	~	~				√		√										√					√		
Alaska Grid[1]	Modified Planar	√	~		√							√							√				√			√
Alaska Series E	Pseudocylindrical												√								√					√
Albers equal area conic	Conic		√								√	√	√			√			√				√	√		√
Azimuthal equidistant	Planar			√	√				~	√	√	√		~			√	√	√	√	√				√	√
Behrmann equal area cylindrical	Cylindrical		√						√															√		
Berghaus Star	Interrupted, faceted				√		√		√								√							√		
Bipolar oblique conformal conic	Conic (Oblique)	√									√											√		√		√
Bonne	Pseudoconic		√								√				~											
Cassini-Soldner	Cylindrical													√	√						√					
Chamberlin Trimetric	Modified Planar			~							√															
Craster Parabolic	Pseudocylindrical		√						√																	
Cube[2]	Faceted						√																			
Cylindrical equal area	Cylindrical		√		√											√		√						√		
Double Stereographic	Planar	√			√	√				√	√	√					√	√	√	√		√			√	
Eckert I	Pseudocylindrical								√																	
Eckert II	Pseudocylindrical		√						√																	
Eckert III	Pseudocylindrical								√														√			
Eckert IV	Pseudocylindrical		√						√														√			
Eckert V	Pseudocylindrical								√														√			
Eckert VI	Pseudocylindrical		√						√														√			
Equidistant conic	Conic			√							~	√				√			√					√		
Equidistant cylindrical[3]	Cylindrical			√										√												√
Fuller	Faceted						√		√														√	√		
Gall's Stereographic	Cylindrical					√			~															√		
Gauss-Kruger	Cylindrical (Transverse)	√									√	√	√	√	√			√	√		√	√				
Geocentric[4]	Spherical								√																	
Geographic[4]	Spherical								√																	
Gnomonic	Planar				√	√						~					√	√	√	√				√	√	
Goode Homolosine[5]	Interrupted Pseudo-cylindrical Equal-Area		√						√														√	√		
Great Britain National Grid	Cylindrical	√										√	√	√	√						√	√				
Hammer-Aitoff	Modified Planar		√						√														√	√		
Hotine Oblique Mercator	Cylindrical (Oblique)	√									√	√	√	√			√				√					√
Krovak	Conic	√										√	√	√			√				√	√		√	√	
Lambert Azimuthal equal area	Planar		√		√					√	√	√					√	√	√	√			√	√	√	√
Lambert conformal conic	Conic	√									√	√	√	√		√			√		√	√		√	√	√
Local Cartesian System	Planar													√												
Loximuthal	Pseudocylindrical							√																	√	
McBryde-Thomas Flat Polar Quartic	Pseudocylindrical		√						√																	
Mercator	Cylindrical	√						√	~			√	√	√		√		√			√	√			√	√
Miller Cylindrical	Cylindrical						√		√														√			√
Mollweide	Pseudocylindrical		√						√														√			
New Zealand Grid	Modified Cylindrical	√											√	√			√				√	√				
Oblique Mercator	Cylindrical (Oblique)	√									√	√	√	√			√				√					√
Orthographic	Planar				√	√				√	√						√	√	√	√				√		√
Perspective[5]					√	√					√	√					√	√	√	√				√		
Plate-Carée	Cylindrical			√										√												√
Polar Stereographic	Planar	√			√	~				√	√		√							√	√			√		√
Polyconic	Conic			~			√						~	~	√						√					√
Quartic Authalic	Pseudocylindrical		√						√														√			
Robinson	Pseudocylindrical						√		√														√	√		
Rectified Skew Orthomorphic	Cylindrical (Oblique)	√											√	√			√				√					
Simple Conic	Conic			√							~	√				√			√					√		
Sinusoidal	Pseudocylindrical		√	~					√		√				√			√					√			√
Space Oblique Mercator	Modified Cylindrical	~												√							√					√
State Plane[6]		√											√	√							√	√		√		√
Stereographic	Planar	√			√	√				√	√	√					√	√	√	√		√			√	√
Times	Pseudocylindrical						√		√														√	√		
Transverse Mercator	Cylindrical (Transverse)	√										√	√	√	√			√	√		√	√				√
Two Point Equidistant	Modified Planar			√					~		√	√					√						√		~	
Universal Polar Stereographic	Planar	√			√	~					√	√	√	√						√	√	√		√		√
Universal Transverse Mercator (UTM)	Cylindrical (Transverse)	√										√	√	√	√			√	√		√					√
Van der Grinten I	Circular						√		~															√		√
Vertical Near-side Perspective[7]	Planar				√	√					√	√					√	√	√	√				√		
Winkel I	Pseudocylindrical								√															√		
Winkel II	Pseudocylindrical								√															√		
Winkel Tripel	Modified Planar						√		√														√	√		

1 Modified Stereographic Conformal
2 Used in ArcGlobe - true direction in limited areas
3 Also known as Equirectangular
4 Not a map projection. The earth is modeled as a sphere or spheroid
5 Combination of the Mollweide and Sinusoidal projections
6 See Lambert Conformal Conic, Transverse Mercator, and Hotine Oblique Mercator
7 Also known as Perspective or Vertical Perspective

√ = Minimal Distortion
~ = Distortion is moderate for most of the area
* = Distortion is minimal in certain directions or at particular points

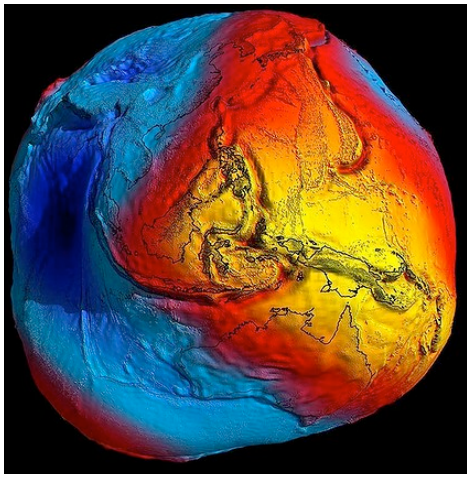
Adapted from *Map Projections*, a USGS poster

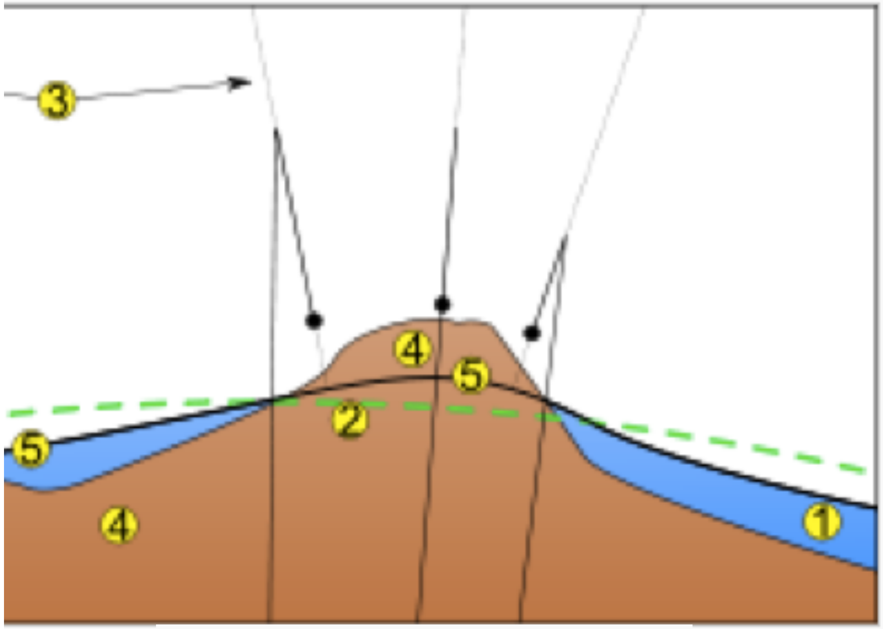
G37891 9/09sp

Knowing where something is on the Earth is not easy, as the Earth is not actually a sphere…

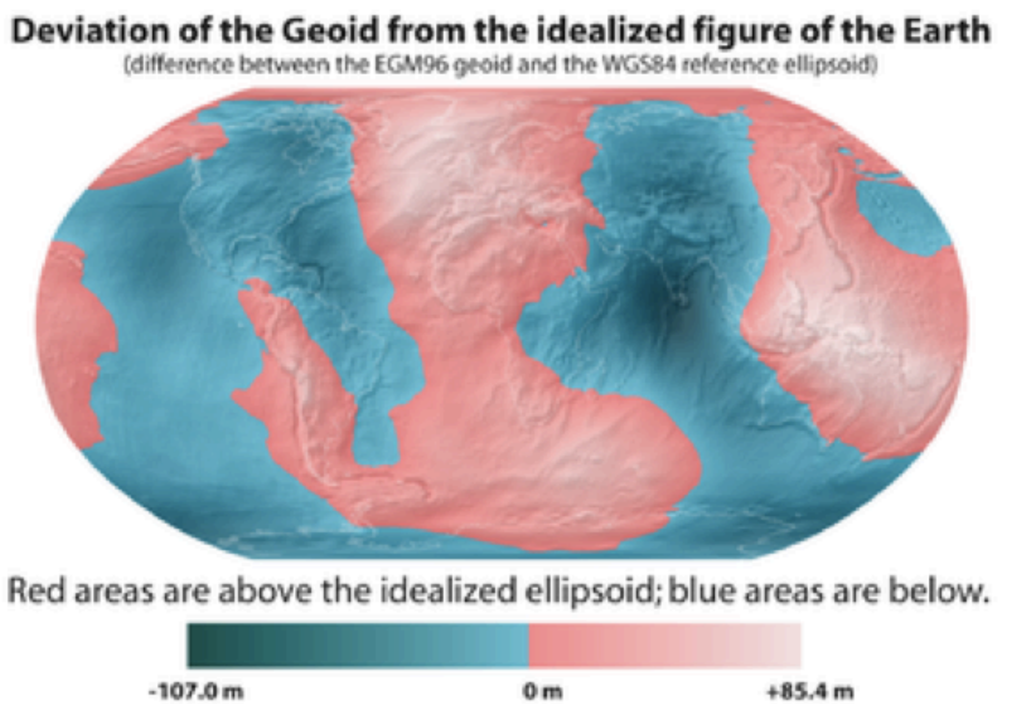
Thus lat-long coordinates also have a ‘**datum**’ which indicates what sort of shape the coordinates assume the Earth has.

From ESA's GOCE satellite, 2011





1. Ocean
2. Reference ellipsoid
3. Local plumb line
4. Continent
5. Geoid



Map of the undulation of the geoid, in meters (based on the EGM96 gravity model and the WGS84 reference ellipsoid).[1]

http://en.wikipedia.org/wiki/Geoid

Danger in Using the Wrong Datum

Did you know that using the wrong datum can create an error of up to 200 or 300 meters on your map? In this fact sheet we explain what a datum is and make some recommendations about managing datums.

An example of datum error:

- In the map at the right, two teams have mapped minefield perimeters using GPS. They are for the same minefield, but when they are displayed on an air photo in a GIS, it is obvious that one of them is wrong.
- In this case, the lower one is in the wrong location. Why? Because the team that mapped it used the wrong datum. Their perimeter is 200 meters south of the correct location.
- Using the wrong datum usually results in errors of a few meters to several hundred meters. These kinds of errors are not as obvious as errors of 10,000 meters, so they may not be noticed, but they are important!

Geneva International Centre for Humanitarian Demining
Centre International de Déminage Humanitaire - Genève

How GIS quantifies location (revisited)

GIS locates things with (groups of) tuples of coordinates.

- Example: You could say Seattle is at (-122,48).

But all coordinates are measured with respect to an underlying framework called a:

- "Spatial Reference System" (SRS), or
- "Coordinate Reference System" (CRS), or
- Most simply, just called by a datum and a projection.

How GIS quantifies location (revisited)

So, it would be more complete to say that Seattle is:

- At (-122,48) in unprojected WGS84,
    - Or at (-122,48) in EPSG:4326
    - Or, as 'WKT' would describe the projection, at (-122,48) in:

```
GEOGCS["WGS 84",
    DATUM["WGS_1984",
        SPHEROID["WGS 84",6378137,298.257223563,
            AUTHORITY["EPSG","7030"]],
        AUTHORITY["EPSG","6326"]],
    PRIMEM["Greenwich",0,
        AUTHORITY["EPSG","8901"]],
    UNIT["degree",0.01745329251994328,
        AUTHORITY["EPSG","9122"]],
    AUTHORITY["EPSG","4326"]]
```

How GIS quantifies location (revisited)

But it would be equally good to say that Seattle is:

- At (1269000, 237000) feet in:
  - a Washington State Plane North projection that is
  - using a NAD1983 HARN datum.
  - Or, as WKT would have it:

```
PROJCS["NAD_1983_HARN_StatePlane_Washington_North_FIPS_4601",
    GEOGCS["GCS_North_American_1983_HARN",
        DATUM["NAD83_High_Accuracy_Regional_Network",
            SPHEROID["GRS_1980",6378137,298.257222101]],
        PRIMEM["Greenwich",0],
        UNIT["Degree",0.017453292519943295]],
    PROJECTION["Lambert_Conformal_Conic_2SP"],
    PARAMETER["False_Easting",500000],
    PARAMETER["False_Northing",0],
    PARAMETER["Central_Meridian",-120.8333333333333],
    PARAMETER["Standard_Parallel_1",47.5],
    PARAMETER["Standard_Parallel_2",48.73333333333333],
    PARAMETER["Latitude_Of_Origin",47],
    UNIT["Meter",1],
    AUTHORITY["EPSG","102348"]]
```

How GIS quantifies location (revisited)

When using GIS, there may be many different coordinate systems in play at the same time:

- Original data coordinate system stored on web or in files.
  (Sometimes the coordinate system isn't set or is set incorrectly and you have to [re-]set it yourself.)
- 'Data frame' coordinate system
  (GIS usually temporarily reproject all the coordinates of different data layers you have loaded into one single coordinate system so data can be compared! In ArcGIS Online, it is the coordinate system of the first data you loaded, but in most GIS, it can be set by you.)
- Analysis coordinate system
  (Make sure that the GIS has reprojected all the data into the same coordinate system before calculating anything…and make sure that the coordinate system preserves the properties that the calculation needs!)
- Visualization/graphical coordinate system
  (Make sure that you and your project's viewers are seeing data displayed in a coordinate system that is appropriate to the properties, phenomena, and message you want to convey!)