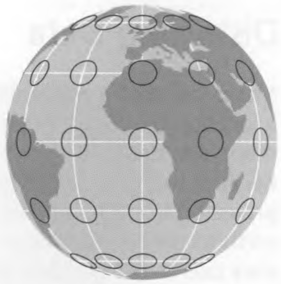
# What Map Projections Preserve

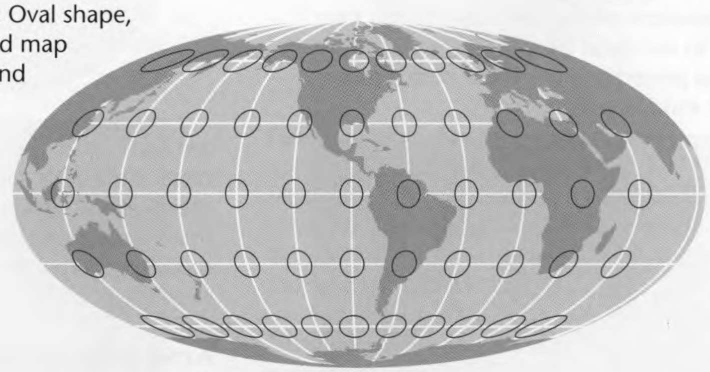
No map projection preserves the attributes of a globe, which does preserve the earth's relative sizes, shapes, distances, and directions. Map projections can preserve one or two of these attributes of the globe, but not all four together. Select a map projection that makes the best sense for your data.

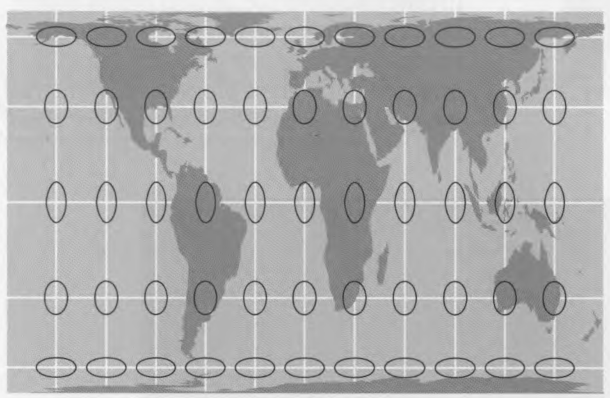
## Preserving Sizes or Area

Some projections preserve area. This means that areas of the same size on the globe have the same relative size on the map. Such size, or area-preserving (equal-area) map projections are a good default for maps showing area data.



**Mollweide projection:** Oval shape, preserves area. Rounded map shape suggests the round earth. The Mollweide can be recentered to minimize shape distortions of regions of greatest interest.

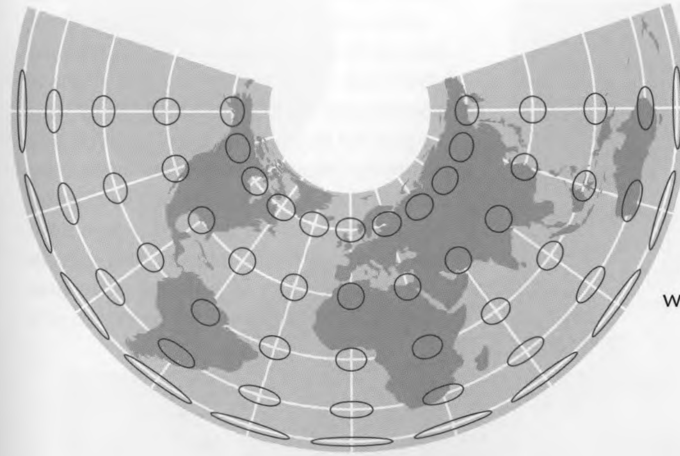




**Peters (Gall-Peters) projection:** To some map experts, what garlic is to vampires. This equal-area map projection's straight grid makes north-south relationships straightforward. As with any rectangular map projection, it fits into page layouts.

This is a good projection for illustrating the shape distortions inherent in equal-area map projections and the area distortions inherent in shape-preserving projections. Also good as a symbol of affinity with the Global South.





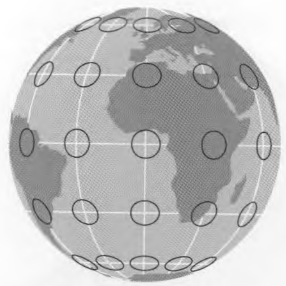
**Albers equal-area projection:** A common equal-area map projection. Poor for world scale maps because of shape distortion and peculiar form. However, recentering on an area of interest (the U.S., below) and selecting part of the earth (continent, country) results in an equal-area map with minimal shape distortion.

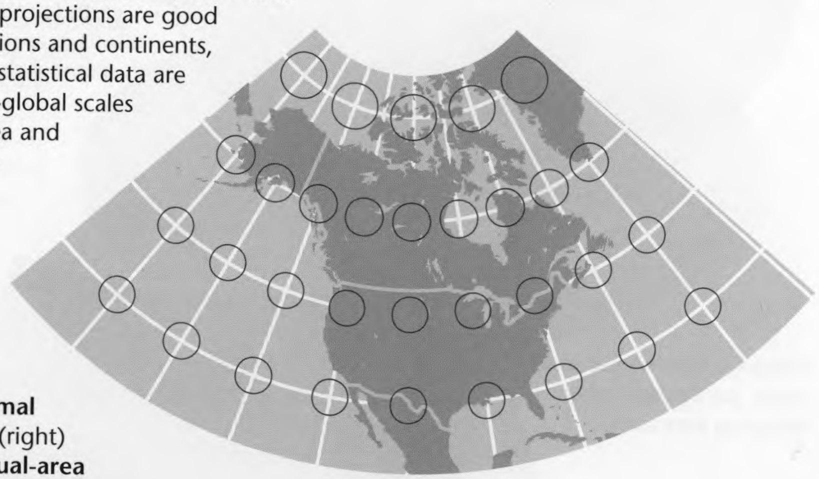
Good for continental scale maps, particularly when mapping area data.

If you zoom in and isolate one area, you may have to recenter again: in this case, center the projection on Nevada (116.67° W).

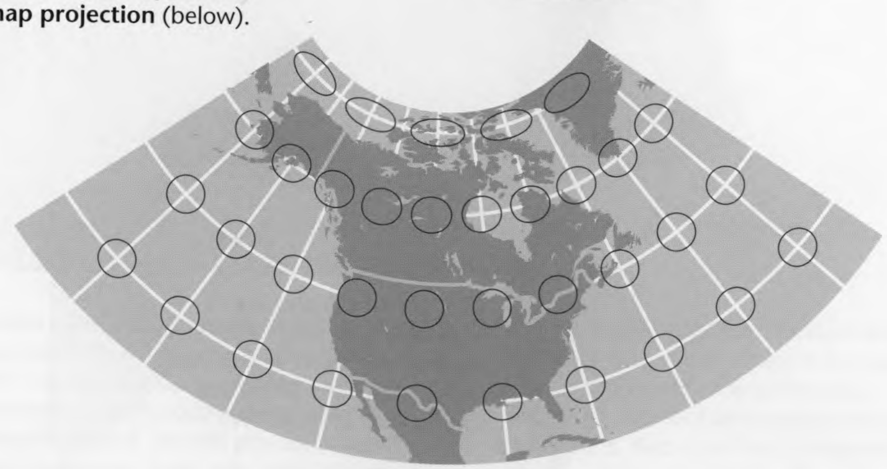
## Preserving Shape (Angles)

Preserving shape (or angles) on a map projection means the projection is *conformal.* Conformal map projections preserve angles (around points) and therefore shape in small areas. As long as you are away from areas of high distortion, the shapes of continents look OK in comparison to shapes on the globe. Areas are, however, distorted. Conformal map projections are good for mapping regions and continents, especially when statistical data are involved. At sub-global scales distortions of area and shape are not as evident.



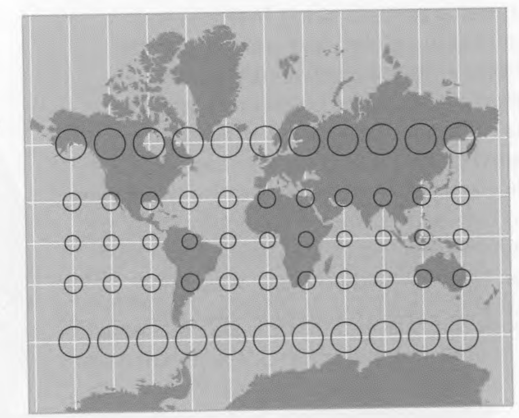


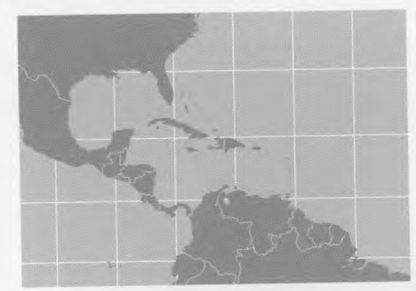
Compare the distortion ellipses on the **Lambert conformal map projection** (right) and **Lambert equal-area map projection** (below).

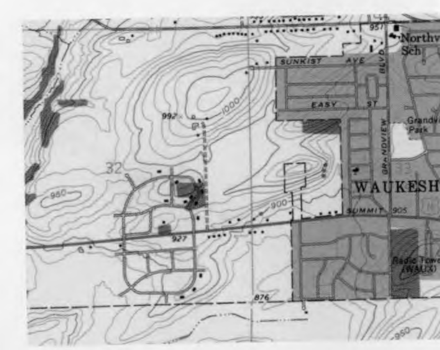


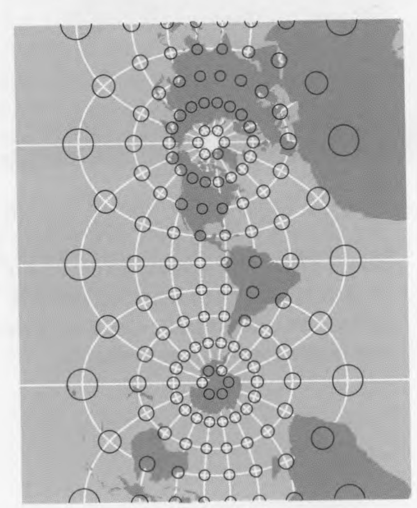


**Mercator projection:** One of the few conformal world projections. Its distortions of sizes are nasty, and it is a poor choice for a world map. Good for equatorial maps (below) where the area distortion is small. A Mercator with the distorted north and south lopped off was chosen for the Voyager map. Also good for maps of very small areas (below, right). A modified version of the Mercator is used for most web maps, because north is always up, eliminating angular distortion of streets and other features as you move away from the center of the projection.





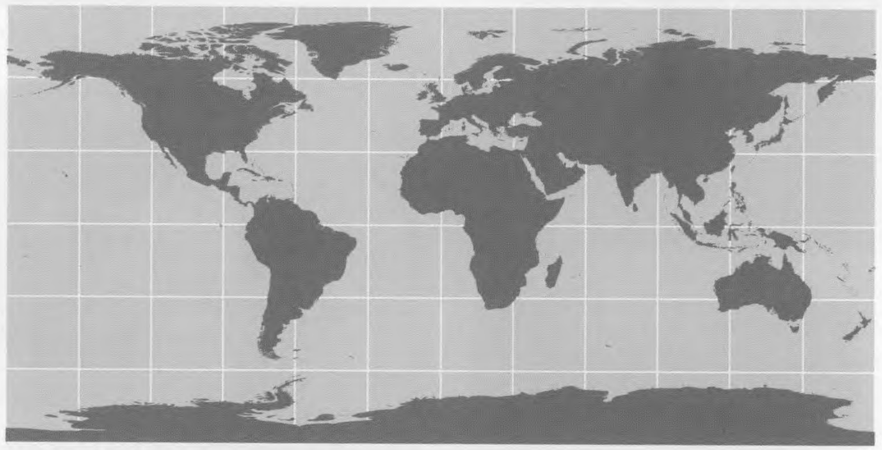


**Transverse Mercator:** On the Mercator projection, scale is true along the equator. When that projection is recentered sideways along a meridian (or line of longitude), scale is true along that meridian. This recentered projection is known as the Transverse Mercator and is the basis for the Universal Transverse Mercator coordinate system. When areas a few square miles in size are mapped using this projection, they are effectively free of all distortion.

## Preserving Distance, Direction

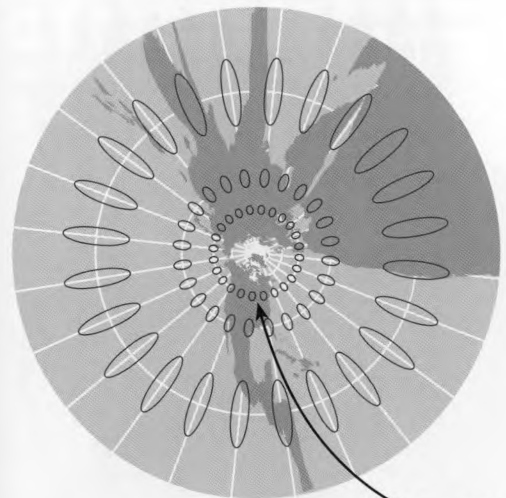
Stretch a piece of string between two points on a globe, and you will get the shortest distance between the points (a great circle). Some projections preserve such distance relations: a straight line between two points on the map is the shortest distance between those two points on the earth. Distance relations cannot be preserved on equal-area maps. Direction can be preserved on area-, shape-, or distance-preserving map projections.



**The Geographic Coordinate System,** aka the **Geographic** or **Equirectangular projection**, is similar to the **Plate Carrée projection**. Invented by Marinus of Tyre in 100 AD, it "maps meridians to equally spaced vertical straight lines, and circles of latitude to evenly spread horizontal straight lines."

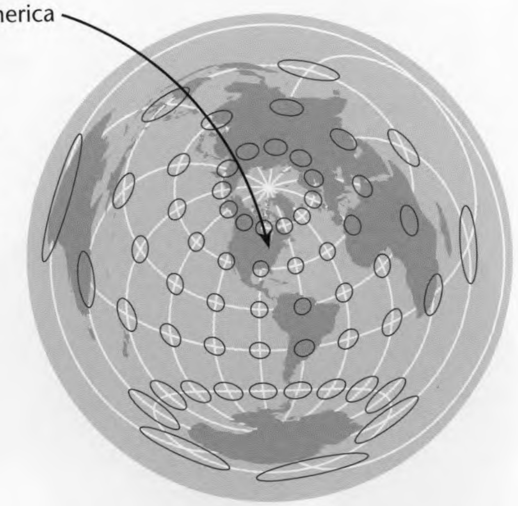
The Geographic Coordinate System is a common default for GIS software and some internet mapping sites, where it distorts the data mapped on it. It preserves nothing but distance, principally for north-south measurements.





**Gnomonic projection:** A straight line anywhere on a Gnomonic projection is a great circle route, the shortest distance between two points. Terrifying distortions of area and shape and the inability to show more than half the earth at a time limit other uses of this projection.

North America



**Azimuthal equidistant projection:** Planar (azimuthal) map projections preserve directions (azimuths) from their center to all other points. The azimuthal equidistant projection also preserves distance. A straight line from the projection center to any other point represents accurate distance in addition to correct direction and the shortest route. Great for travel agencies when centered on their city.

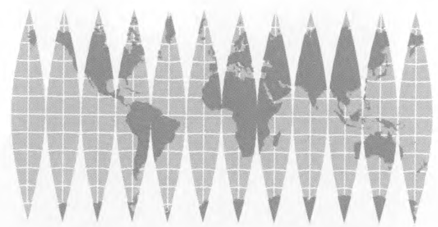
Poor for showing anything but distances from a particular point. Areas are wildly exaggerated and shapes distorted as you move from the center.

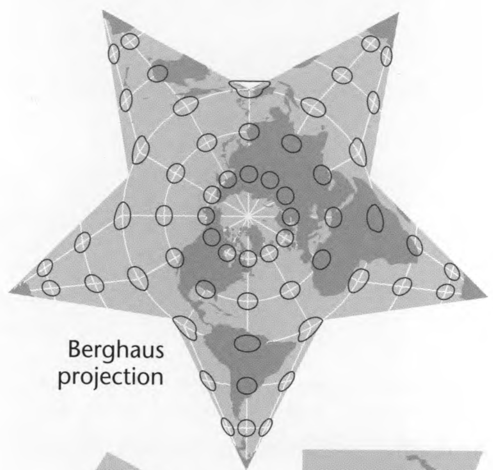
## Preserving Interruptions

Globe gores, peeled from a globe and flattened, are akin to interrupted map projections. Interrupted map projections minimize distortions on the uninterrupted part of the map, and are typically used on maps of the entire earth.

Interrupted map projections are commonly used for maps of global statistical data. They are also used as icons (Berghaus "star") and as the basis of "cut and assemble" do-it-yourself globes (Fuller).

A Berghaus centered on the north pole is equidistant north of the equator. The Fuller has constant scale along the edges of all 20 of the triangular pieces. Within each of these triangles, area and shape are well preserved.





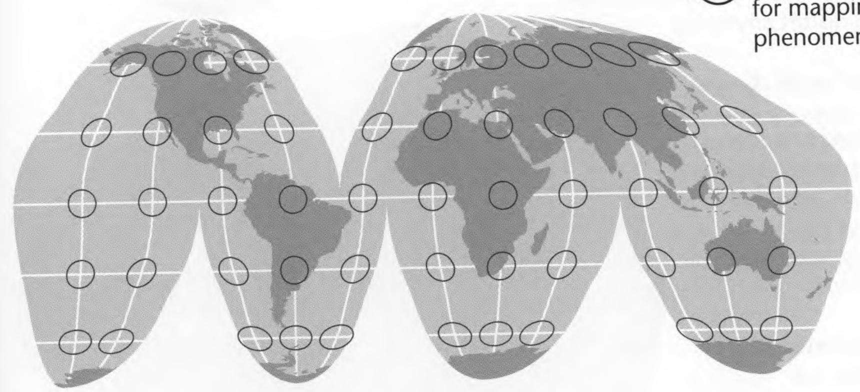
Berghaus projection

Fuller projection



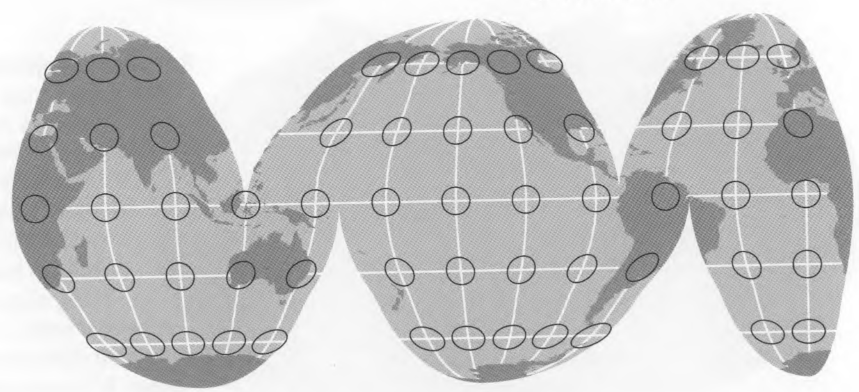
**Goode's homolosine projection:** Goode's is a common interrupted map projection used for world maps of statistical data. The projection does not distort areas, and shape distortions in the uninterrupted areas of the map are minimized.

Poor interruptions for mapping ocean phenomena

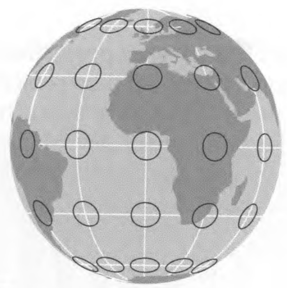


Interruptions can be moved. A map for ocean phenomena can interrupt land areas, for example.

Goode interruptions for mapping ocean phenomena



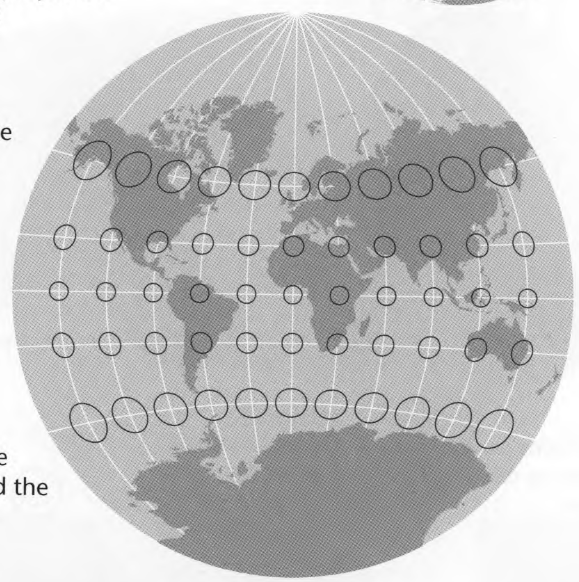
## Preserving Everything, Almost



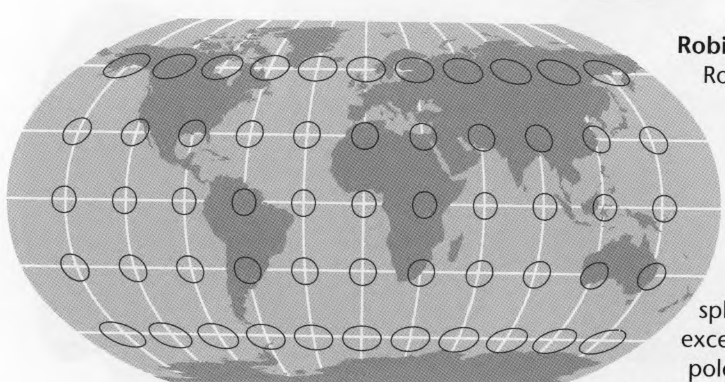
Map projection is most visible at a global scale, where distortions of areas and shape are most evident. Area-preserving projections often badly distort shapes; and shape-preserving projections, area. But there is an alternative – a map projection that does not distort anything!

But that doesn't exist. Crap.

However, instead consider some compromise map projections that distort both area and shape a bit, but neither too badly. They preserve everything, almost.



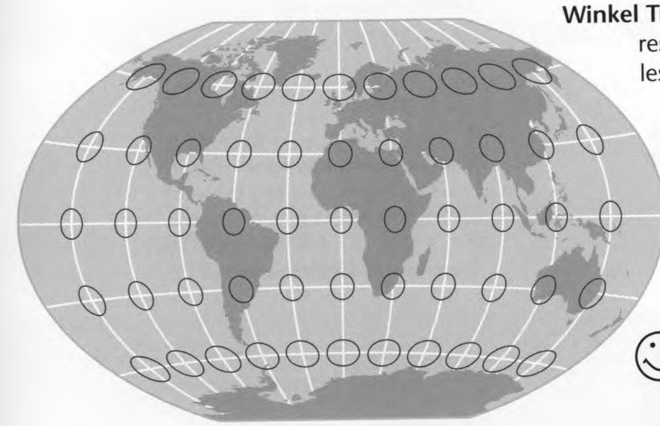
**The Van der Grinten projection** does not preserve shape or area, but minimizes their distortions in all but polar regions. Usually the polar regions are lopped off and the map presented as a rectangle.



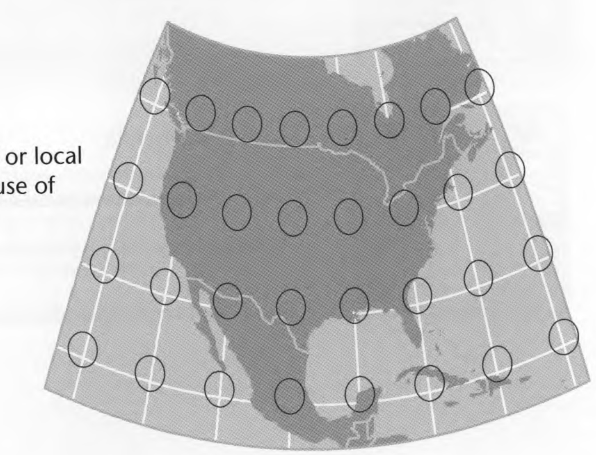
**Robinson projection:** Arthur Robinson's map projection preserves neither area nor shape, but reduces the distortion of both. Mapping area data on it is OK. The Robinson has rounded sides, suggesting the spherical earth, and avoids excessive distortion near the poles. It's a wholesome and handsome choice for world maps.



**Winkel Tripel projection:** This projection resembles the Robinson, but it has less area exaggeration in the polar regions. The Winkel Tripel is the map projection used by 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.

# Map Scale

The earth is big. Maps are small. Map scale describes the difference, verbally, visually, or with numbers. Map scale will be determined by your goals for your map. Map scale affects how much of the earth, and how much detail, can be shown on a map.

Verbal

Visual

Small Scale

1 inch = 2500 miles

0 3000 mi

1 cm = 1584 kilometers

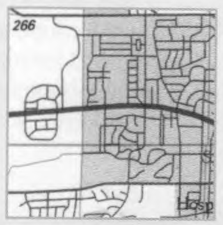
0 4000 km

1 inch = 350 miles

0 400 mi

1 cm = 220 kilometers

0 800 km




1 inch = 1.6 miles

0 2 mi

1 cm = 1 kilometer

0 3 km


1 inch = .4 mile

0 1/2 mi

1 centimeter = .25 kilometer

0 1 km

Large Scale



Numerical

Small Scale

**1 : 155,000,000**

A representative fraction (RF) shows the proportion between map distance and earth distance for any unit of measure. 1 inch on the map is 155 million inches on the earth. 1 cm on the map is 155 million cm on the earth.

**1 : 22,000,000**

Distortions from map projections become less visually noticeable at regional and local scales. These distortions may become evident when combining map layers with different projections in GIS.

**1 : 100,000**

Divide a representative fraction:

| | |
|---|---|
| 1 / 100,000 | = .00001 |
| 1 / 24,000 | = .00004 |

The former is smaller than the latter: thus 1:100,000 is smaller scale than 1:24,000 (larger scale).


**1 : 24,000**

Larger-scale maps show more detail, but of a limited area. Map projection distortions are less evident and distance is relatively accurate over the entire map.


Large Scale

# Earth's Shape and Georeferencing

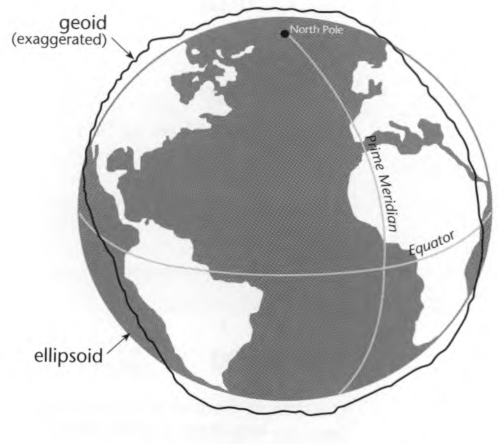
The earth is a geoid, an imperfect 3D object. An ellipsoid is a slightly squished-down sphere that approximates our geoid-shaped earth. Mapping things requires a system for locating those things (georeferencing), typically based on a pair of coordinates. Latitude and longitude are based on our 3D earth. Other systems operate in a projected 2D world.

## Ellipsoids and Datums

There are a diversity of ellipsoids that can serve as an approximation of our earth. Many were created to best fit the earth in specific countries. Maps and data sets based on different ellipsoids will not work together.

A datum is based on a single common point shared by the geoid (our imperfect earth) and a particular ellipsoid. All spatial relationships (locations, directions, scales) derive from this single point. Maps and data sets based on different datums will not work together.

Ellipsoids, datums, projections, and georeferencing systems combine in strange ways with great diversity. Expect to convert your geographic data sets in order to get them to work together.




The World Geodetic System of 1984 (WGS84) is the modern standard ellipsoid. The North American Datum of 1983 (NAD83), closely approximating WGS84, has been widely adopted in North America.

## Map Coordinates

Map coordinates – also known as georeferences – typically consist of a pair of numbers or letters that locate data, tying them to the grid. Geographic data are distinguished from other data by the fact that they can be located. There are many different map coordinate systems and means of georeferencing. You need to pay attention to which system is associated with your data. Coordinate systems can be converted from one to another, and often have to be when making maps with GIS.

**Where is (0, 0)?** Where, on earth, should the origin (0, 0) be? If Washington, DC, is the origin, then all other locations are in relation to Washington. Different coordinate systems have different origins.

**Area covered?** How much of the earth is covered by the coordinate system? Coordinate systems may cover all or only part of the earth.

**Flat or spherical?** Coordinate systems covering part of the earth assume a flat earth, to take advantage of easier planar geometry. Coordinate systems covering the entire earth assume spherical geometry.

**Units?** Coordinate systems can be in English units (feet), metric units (meters), or degrees. Different coordinate systems have different units of measurement.

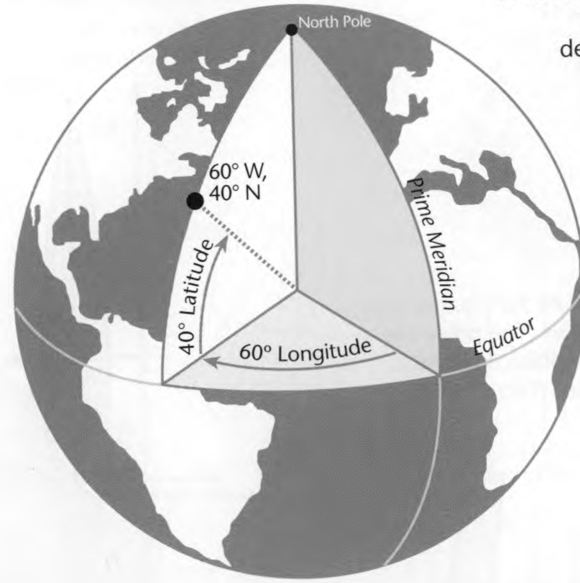


## Latitude and Longitude

Latitude and longitude cover the entire earth with one system and a single origin. It's used when you need a single coordinate system for our 3D earth. In this system, locations are specified in degrees, which can be subdivided. There are 60 minutes in 1 degree and 60 seconds in 1 minute. Decimal degrees are increasingly common.

The equator is the origin for **latitude**. Lines of latitude are called parallels. Parallels run east-west, measuring 90° north and 90° south of the equator. Parallels never converge: one degree of latitude is always 69 miles or 111 km.

Greenwich, England, is the origin (prime meridian) for **longitude**. Lines of longitude are called meridians. Meridians run north-south, measuring 180° east and 180° west of the prime meridian. Meridians converge at the poles. One degree of longitude at the equator is 69 miles or 111 kilometers. One degree of longitude at the poles is 0 miles or km (a point).



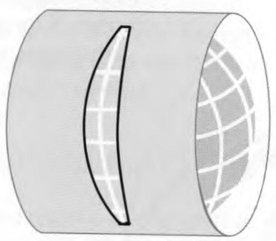

The single origin (0, 0) is off the coast of Africa. Coordinates fall into one of four quadrants to the N/S (latitude) and E/W (longitude) of this origin.

Latitude and longitude can operate in a 3D or 2D world. Map projections flatten and distort the grid of latitude and longitude.

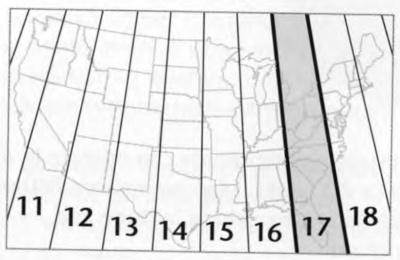
## Universal Transverse Mercator (UTM)

**The Universal Transverse Mercator** (UTM) is a projected coordinate system. UTM, based on the "transverse" (sideways) Mercator projection, covers most of the earth, which is divided into 60 zones, each 6° wide, running from 84° north to 80° south. Planar geometry (a flat earth) makes computations easy. UTM is measured in meters. A point is located in terms of how many meters east and north it is from the origin. UTM is used by environmental scientists, the military, and any other professionals who work at a regional or local scale but need their maps to coordinate with maps of other areas on the earth.

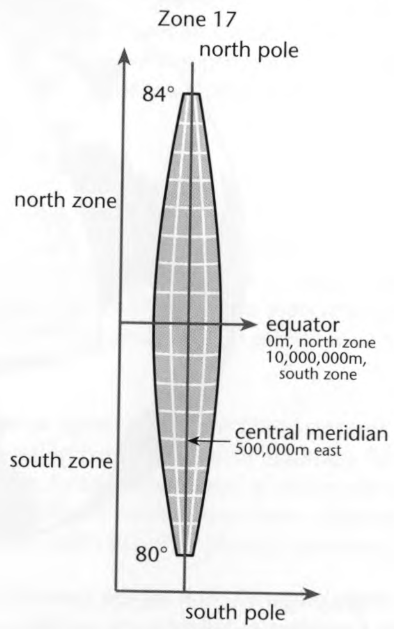
Zone 17



UTM zones are widest at the equator and narrow toward the poles. The poles use the universal stereographic coordinate system. Ten UTM zones (10 to 19) cover the continental U.S.




Each 6°-wide zone has a north and south zone. The central meridian of each zone is assigned a value of 500,000 meters (not tied to any earth feature; thus east-west measurements are called *false eastings*). North-south measurements are in terms of the equator. In the south zone, the equator is assigned a value of 10,000,000 meters to avoid negative coordinates.





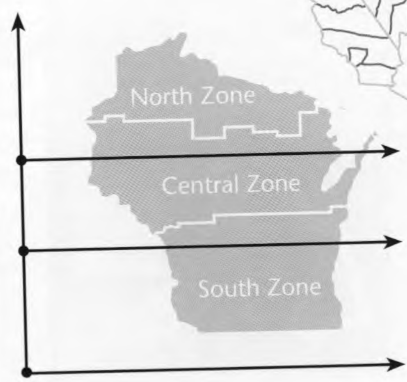

## State Plane Coordinate System (SPCS)

The **State Plane Coordinate System** (SPCS) is also based on a flat 2D earth. SPCS is used only in the United States, which is divided into over a hundred areas, each with its own coordinate system. Since each area is relatively small, distortions from projection are minimal. The most recent version of SPCS is based on the NAD83 datum.

SPCS is measured in feet, meters, or both. A point is located in terms of how many units east and north it is from the origin. Where the false origin is set varies. Some states use a central meridian as a false *easting*, as with UTM. Others establish the false origin outside of the bounds of the state (but only coordinates within state boundaries are used).

SPCS is used by planners, urban utilities, and environmental engineers. Similar coordinate systems are used in other parts of the world.

Small U.S. states have a single SPCS zone; larger states (excepting Montana) are divided into several zones. No SPCS zone crosses a state boundary.




Wisconsin has three SPCS zones. An origin (0, 0) is established to the southwest of each zone, so that all coordinates in the zone are positive.