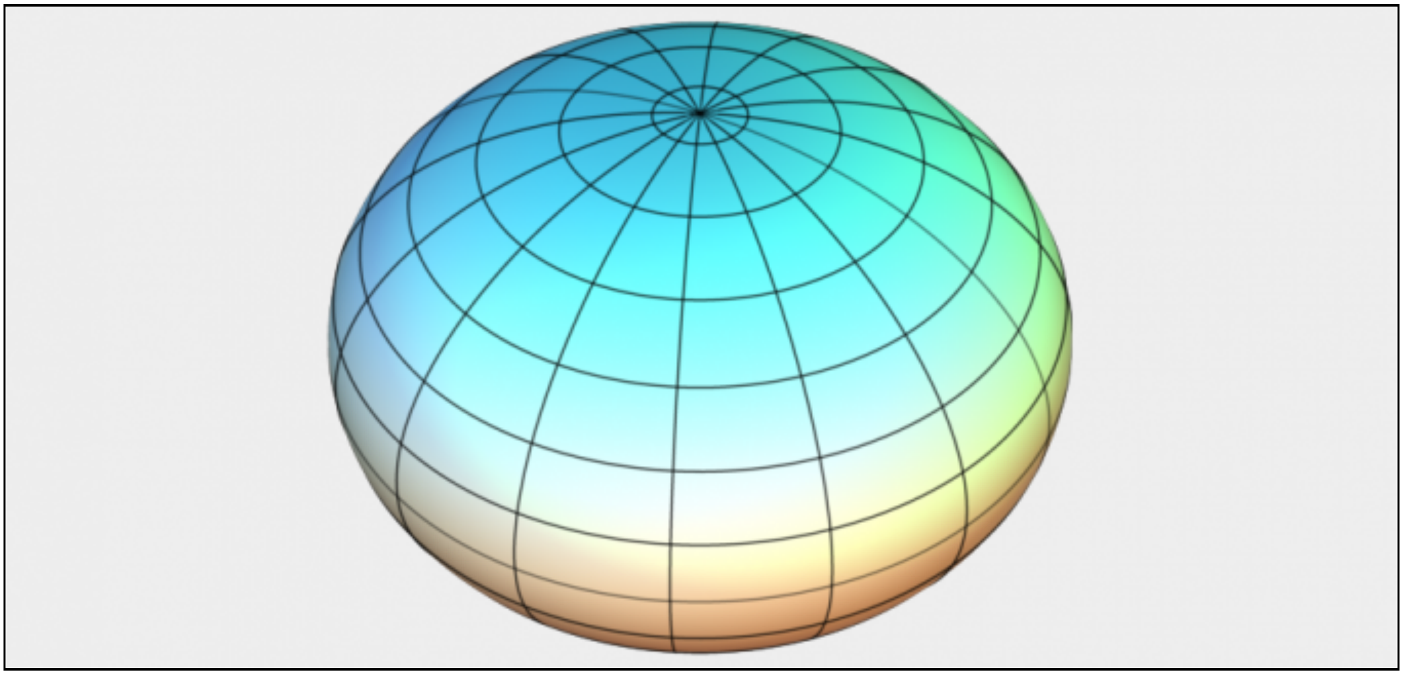
Ellipsoid/Spheroid – Our Oblate Spheroid Planet Earth



By: GIS Geography · Last Updated: April 29, 2020

Earth Bulges at the Equator

We say Earth is a sphere… But it's not exactly a perfect one.

It's an oblate spheroid that bulges at the equator and is somewhat squashed at the poles.

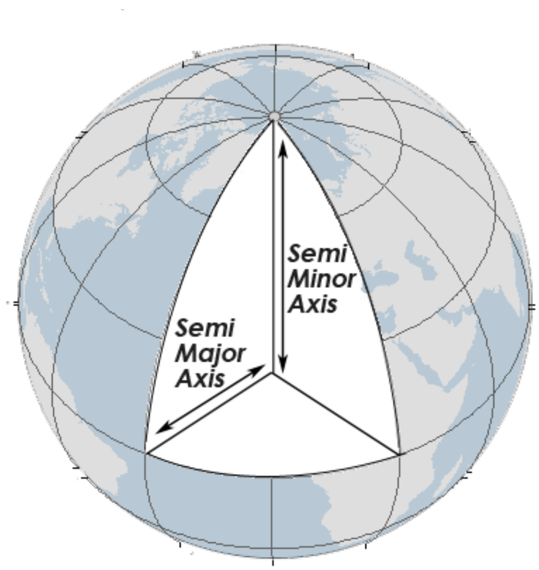
In fact, it bulges about 14 miles out more at the equator compared to pole-to-pole.

Because of the **field of geodesy**, the shape of our planet has become well-known. Let's delve into this a little deeper.

What is an Ellipsoid in GIS?

Geodesists have adopted an ellipsoid model to determine **latitude and longitude coordinates**.

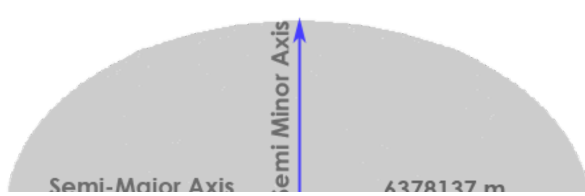
The major axis of an ellipse is the equatorial radius. The minor axis is from the poles to the center.

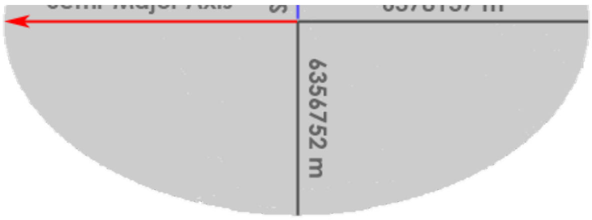


Reference ellipsoids are primarily used as a surface to specify point coordinates such as latitudes (north/south), longitudes (east/west) and elevations (height).

The most common reference ellipsoid in cartography and surveying is the **World Geodetic System (WGS84)**. The Clarke Ellipsoid of 1866 and was recomputed for the **North American Datum of 1927 (NAD27)**.

When comparing NAD27 and NAD84, latitude and longitude coordinates can be displaced on the degree of tens of meters (with the same latitude and longitude coordinates).

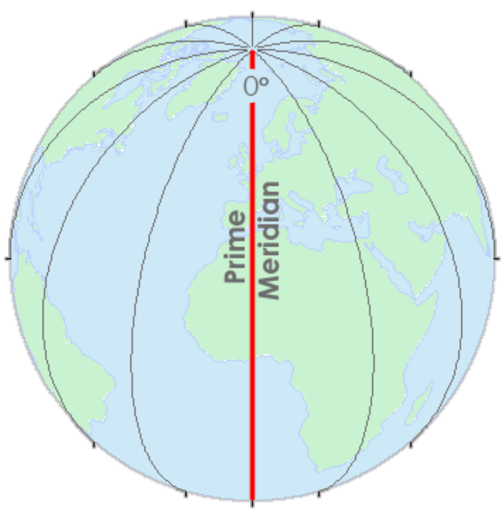




How Do Horizontal Datums Relate to Ellipsoids?

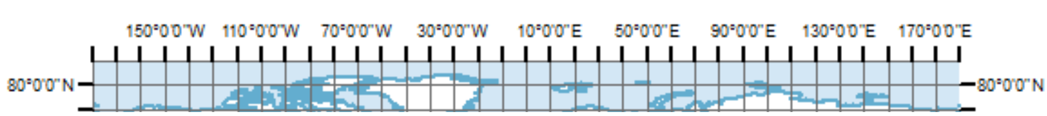
Horizontal datums give us the capability to measure distances and directions across the surface of the earth. Most **horizontal datums** define a zero line at the equator from which we measure north and south (latitudes).

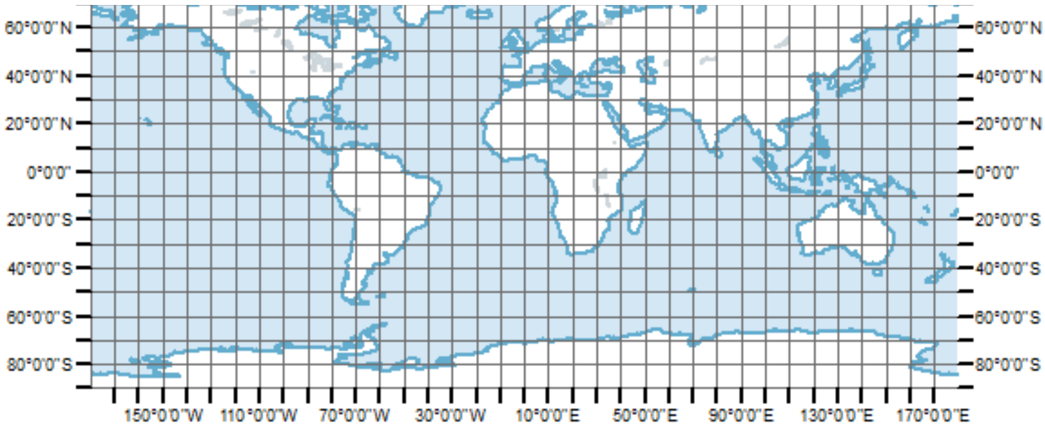
There is also a zero line at the **Greenwich Meridian** from which we measure east and west (longitudes).



Together these lines provide a reference for **latitude and longitude** expressed in decimal degrees. These latitudes and longitude positions (Geographic Coordinate Systems) are based on a spheroid or ellipsoid surfaces that approximate the surface of the earth – a datum.

All coordinates are referenced to a datum such and the ones in the image below:





A datum describes the shape of the Earth in mathematical terms. A datum defines the radius, inverse flattening, semi-major axis and semi-minor axis for an ellipsoid.

Here is the WGS84 datum:

- Semi-major axis: 6,378,137.0 m
- Semi-minor axis: 6,356,752.3 m
- Inverse flattening: 294.978698214

Name	Year	Semi-Major Axis (Equator Radius)	Semi-Minor Axis (Polar Radius)	Users
Clarke	1866	6,378,206.4 m	6,356,583.8 m	North America
International (Hayford) Ellipsoid	1924	6,378,388.0 m	6,356,911.9 m	Most of the World
WGS72	1972	6,378,135.0 m	6,356,750.5 m	NASA
GRS80	1980	6,378,137.0 m	6,356,752.3 m	Worldwide
WGS84	1984	6,378,137.0 m	6,356,752.3 m	Current Worldwide

Earth is Flattened Because of Rotational Forces

Sir Isaac Newton proposed that the Earth flattens at the poles because of rotational forces. As the Earth spins on its axis, the centrifugal force causes the Earth to bulge out at the equator. This is why the Earth is better modeled as an ellipsoid, which is a sphere slightly flattened at the poles.

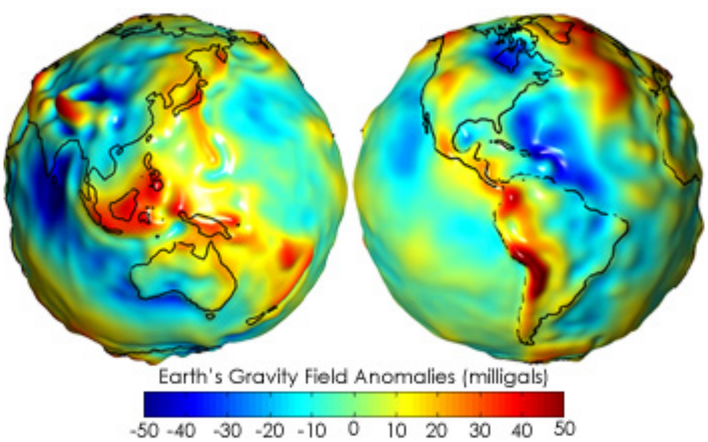
In the 19th and 20th centuries, different ellipsoids were adopted in various parts of the world. Surveys were being performed on different continents. Each survey produced different ellipsoidal parameters.

For example, surveys in Australia yielded a “best” ellipsoid. Europe’s “best” ellipsoid was different from South America and Asia. There wasn’t a unifying global ellipsoid. Each continental survey was isolated with it’s own ellipsoid parameters. There was no clear way how to combine these global survey measurements. There was a scarcity of survey points in specific areas and a lack of computational resources that prevented a global ellipsoid.

Fitting the Ellipsoid with the Geoid

A horizontal coordinate system gives us the side-by-side that is our latitude and longitude. On the other hand, a vertical datum is another component of your typical horizontal coordinate system.

We are on a three-dimensional planet which has ups-and-downs in addition to the side-to-side in a horizontal coordinate system on the surface. To handle the ups-and-downs, we have the vertical datum which gives a place to put the zero measurement. Mean sea level is often understood as the basis for our ups-and-downs. This is called the **geoid**.



Geoid (Image courtesy of NASA/JPL)

Vertical datums are lumpy and irregular. This is because of the varying densities in the Earth in different places. There are gravity anomalies such as mountainous areas have more mass.

This means that mean sea level is not as smooth as everyone thinks it is. Geoids are not constant and they differ from place-to-place. Geoids have undulations as you move around on the Earth. The Earth is not as round as we like to pretend it is. We have lumps or undulations on them as they come back to us in the form of a geoid. The geoids put the lumps back into our nice smooth horizontal datum coordinate system.

Ellipsoid height is the most basic version of up-and-down. The ellipsoid uses the size and shape of the **horizontal datum** such as WGS84. It gives a smooth surface without bumps or irregularities. The geoid is complex to describe it mathematically. Therefore, we fit different Ellipsoids to approximate it such as WGS84.

The Varying Historical Accuracy of the Ellipsoid

Earth bulges out more at the equator than at the poles by about 70,000 feet.

And since the beginning of the 19th century, the dimensions of the ellipsoid have been calculated at least 20 different times with considerably different accuracy.

The early attempts at measuring the ellipsoid used small amounts of data and did not represent the true shape of the Earth. In 1880, the Clarke ellipsoid was adopted as a basis for its triangulation computations.

The first geodetic datum adopted for the United States was based on the Clarke ellipsoid with its starting point in Kansas known as Meade’s Ranch.

…and now we have geocentric datums like WGS84 and NAD83 with their major and minor axis

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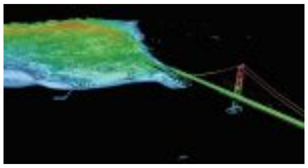

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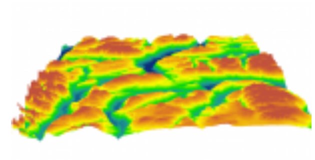

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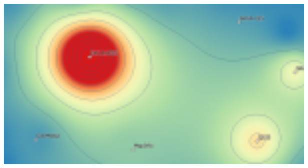

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