Establishing a Georeferencing Framework for Mapping Locations on Earth

DATUMS & PROJECTIONS

"Every map user and maker should have a basic understanding of projections no matter how much computers seem to have automated the process."

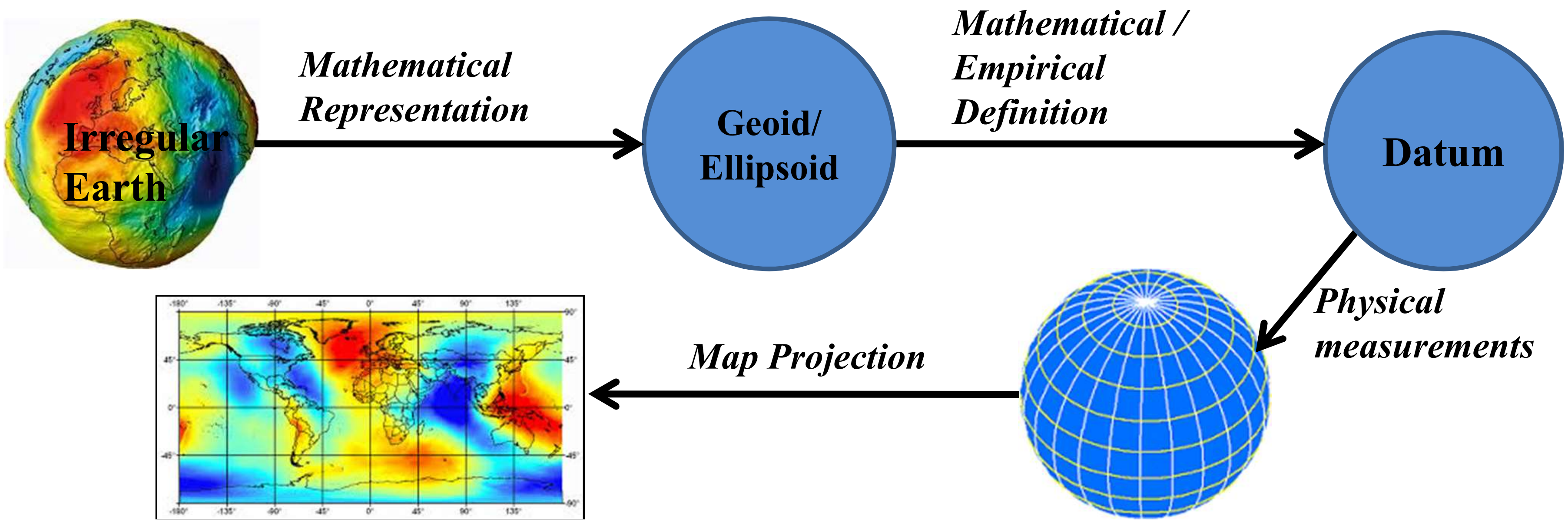
- John P. Snyder

Why is this important?

- Creating spatial data (collecting GPS data)
- Import into GIS and overlay with other layers
- Acquiring spatial data from other sources
- Display your GPS data using maps

GEOREFERENCING

- Defined as the fixing of locations of real-world features within the spatial framework of a particular coordinate system
- Can be seen as a series of concepts and techniques that progressively transform measurements carried out on the irregular surface of the Earth to a flat surface of a map, and make it easily and readily measurable on this flat surface by means of a coordinate system.
- Fundamental to georeferencing are:
  - Representation of the physical shape of the Earth by means of a mathematical surface
  - The realization of this concept by the definitions of the geoid and the ellipsoid

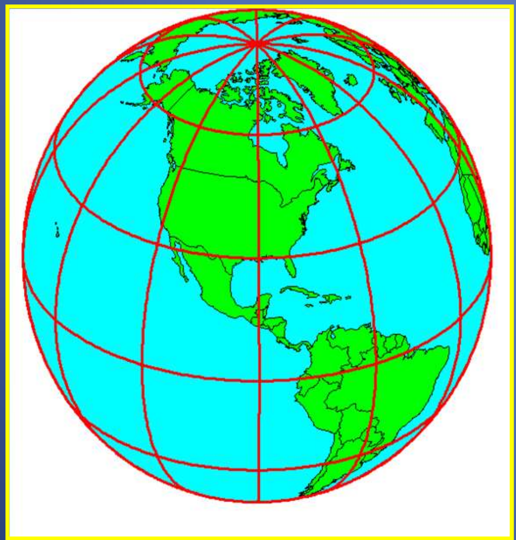


The terrestrial spatial description in coordinates within a frame of reference is defined in terms of

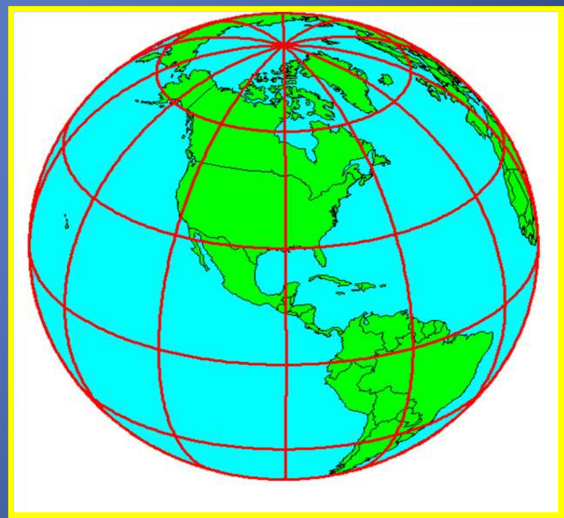
- Datum – Horizontal/ Vertical
- Reference Ellipsoid and Fundamental Point
- Type of Coordinates – Geographic/ Plane
- Map projection
- Map Scale
- Transformation parameters from global datum to local datum

How Do We Define the Shape of the Earth?

We think of the earth as a *sphere*

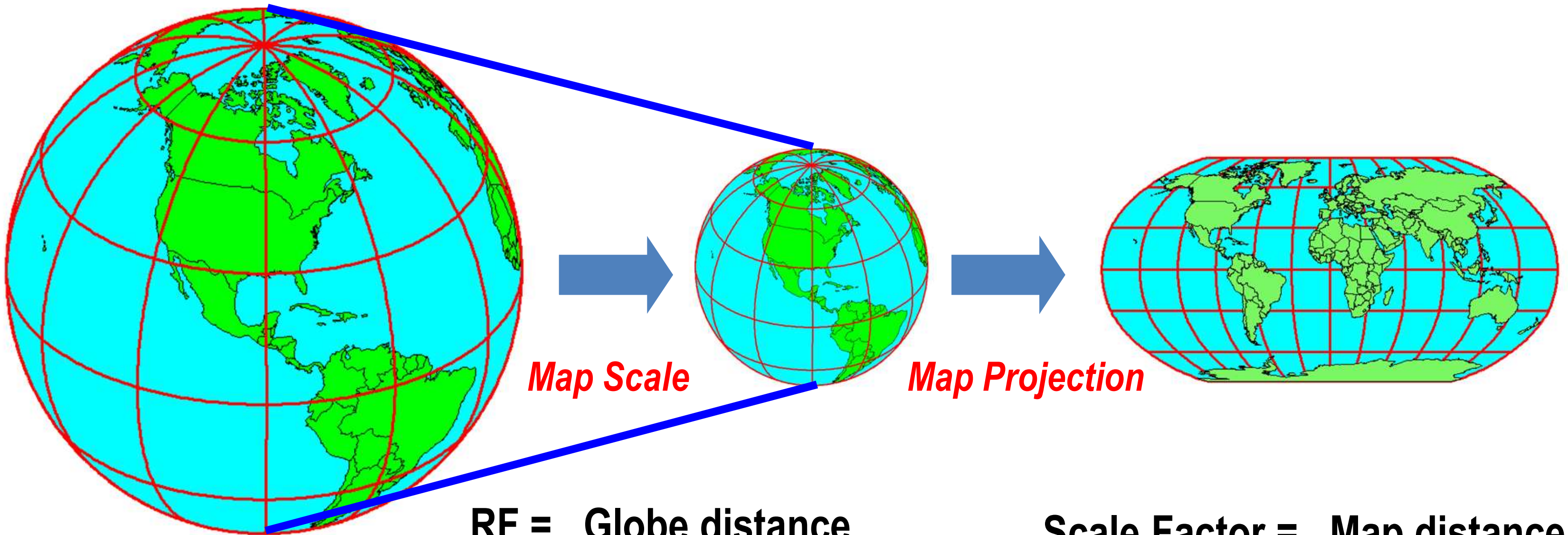


It is actually a *spheroid*, slightly larger in radius at the equator than at the poles



MATHEMATICAL REPRESENTATION OF THE SHAPE OF THE EARTH

- The first step to map spatial features on the Earth's surface is to **select a model that approximates the shape and size of the Earth**
- The simplest model is **sphere**, which is typically used in map projections
- In context of georeferencing, the **Ellipsoid –Geoid model** is the commonly used mathematical surface that represents the shape of the Earth

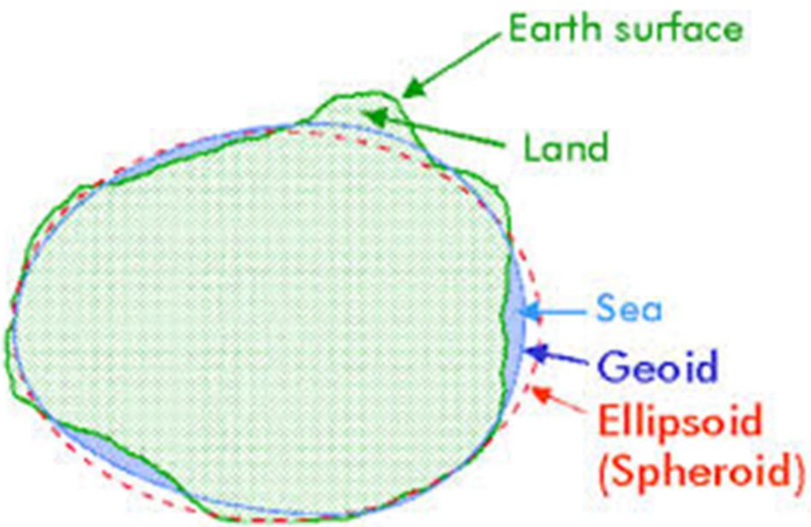


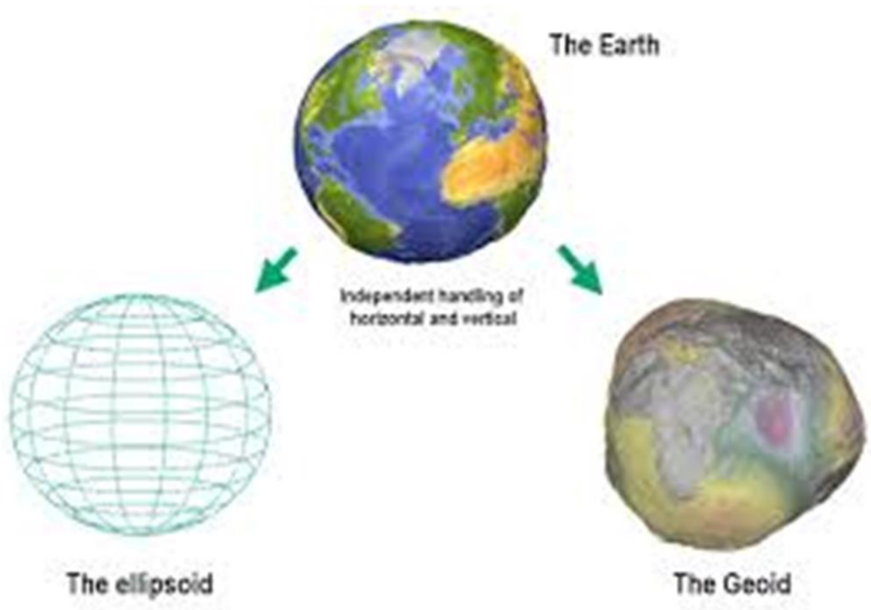
$$RF = \frac{\text{Globe distance}}{\text{Earth distance}}$$

$$\text{Scale Factor} = \frac{\text{Map distance}}{\text{Globe distance}}$$

THE ELLIPSOID-GEOID MODEL

- The Geoid and the Ellipsoid are two distinct surfaces which serve different purposes
- The Ellipsoid is the reference surface for horizontal positions
- The Geoid is the reference surface for elevations





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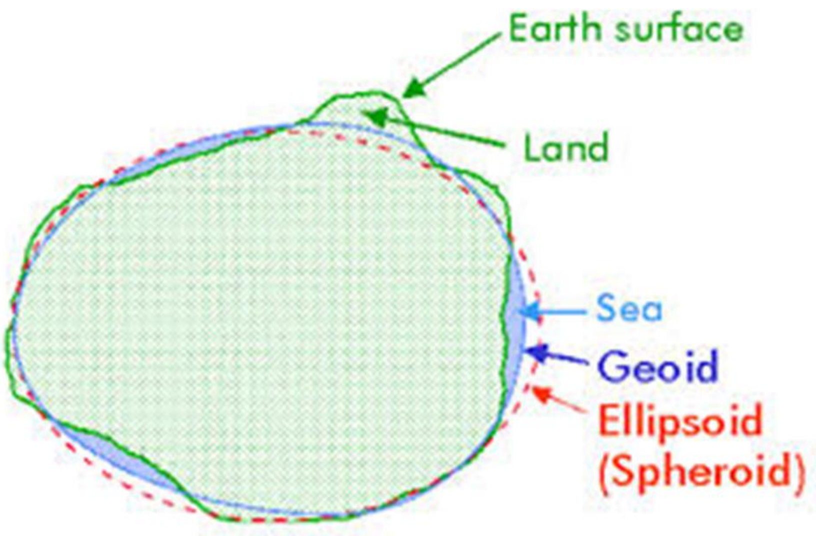
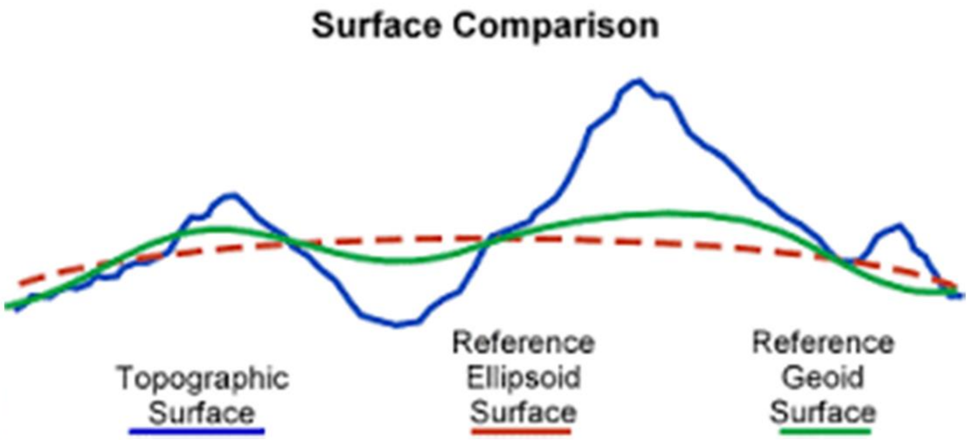




THE ELLIPSOID

- A closer approximation of the physical shape of the real Earth, than a sphere, accounting for the slight flattening at the poles is a Spheroid also called Ellipsoid.
- Closely approximated by the mathematical surface of the rotational ellipsoid or the solid obtained by rotating an ellipse on its minor axis
- Because flattening occurs at Poles, the figure may be further defined as oblate spheroid.
- Ellipsoid allows variable radii
- The flattening is very close to 1/300
- The difference in length between the equatorial and polar radii is about 11.5 km, hence Polar Axis is about 23 kms. shorter than Equatorial Axis

Ellipsoid or Spheroid

Rotate an ellipse around an axis

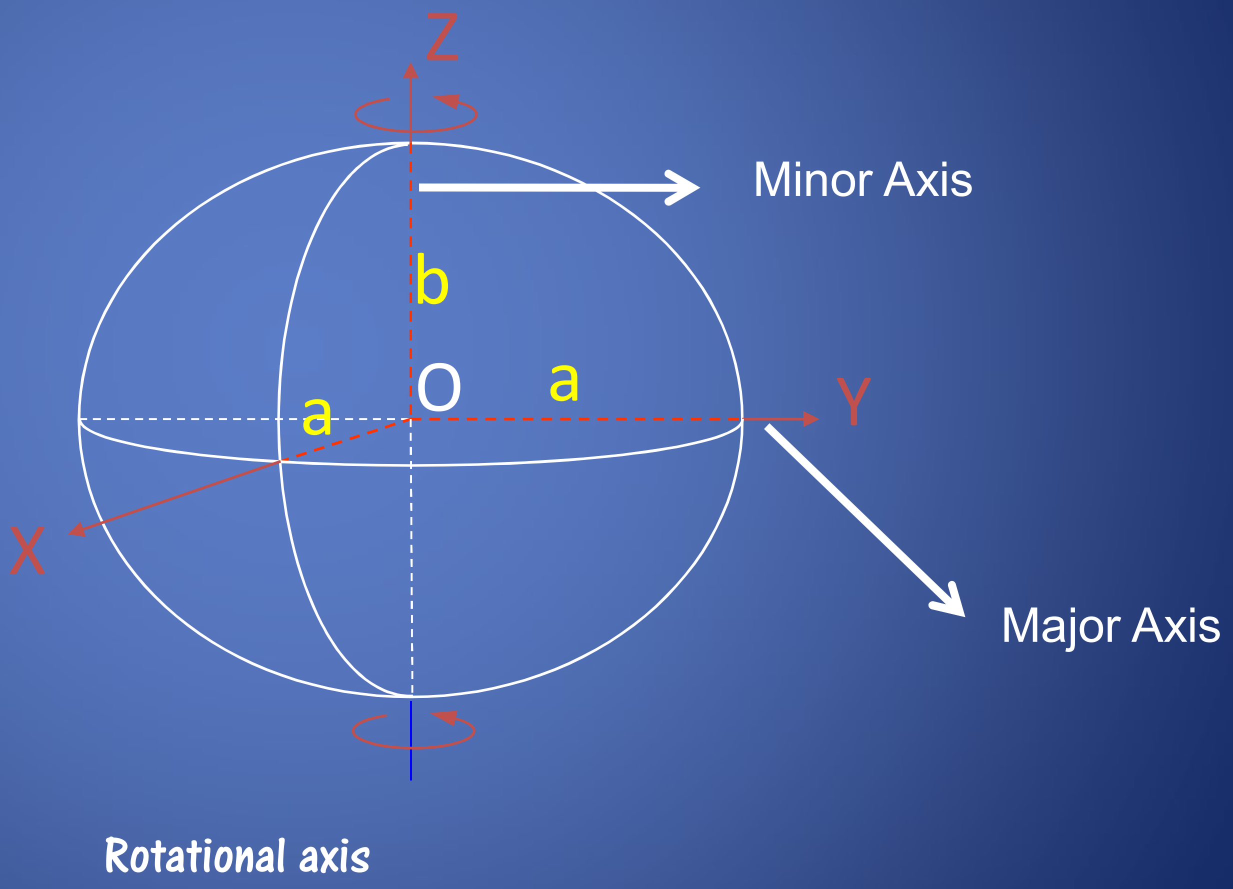
ffden-2.phys.uaf.edu/211_fall2010.web.dir/Jocelyn_Simpson/Slide4.htm

Ellipsoid or Spheroid

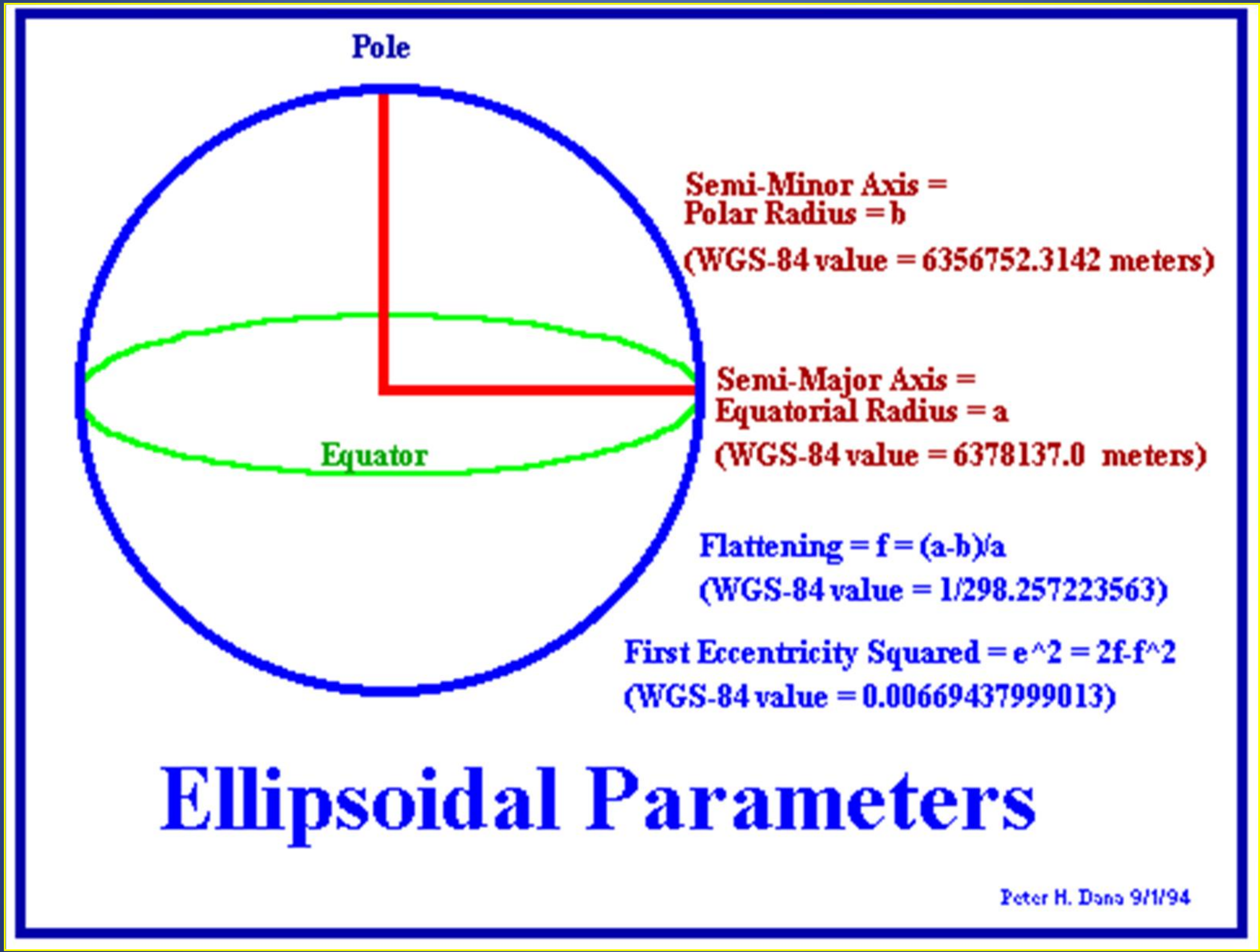
Selection of the Spheroid determines the SIZE of the Earth

With reference to Earth

- Semi major axis (a) is the radius from center of the Earth to the Equator .
- Semi Minor axis (b) is the radius from the center of the Earth to the Pole.
- Flattening (f) defined by (a-b)/a measures the difference between two axes of a spheroid
- Geographic coordinates based on a spheroid are c/a Geodetic Coordinates



Selection of the Spheroid is what determines the SIZE of the Earth



THE HISTORY OF ELLIPSOIDS

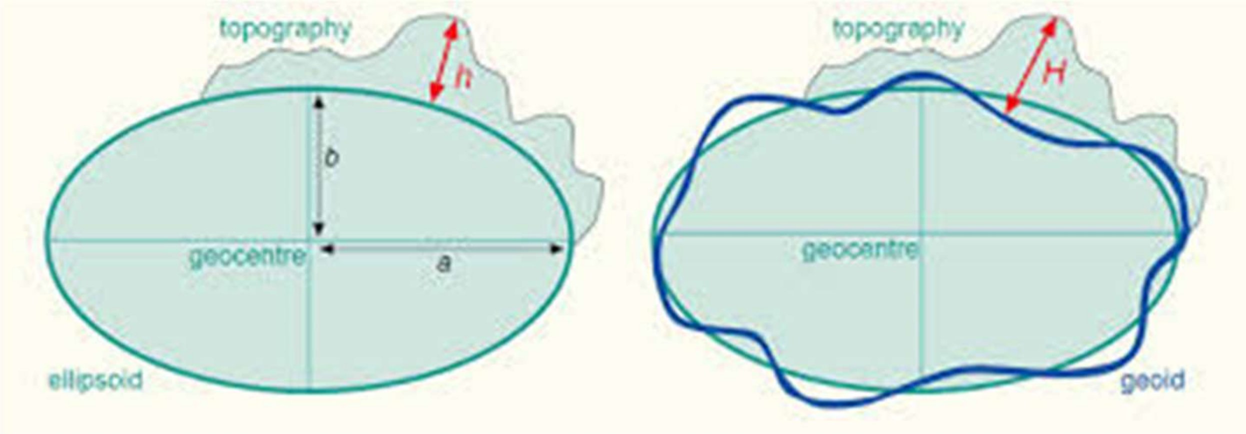
- Since eighteenth century geodesists have been attempting to determine the polar flattening value that would produce a best Earth-fitting Ellipsoid. They came up with many different ellipsoids because many different values of equatorial and polar radii were used in computations.
- Practically all early ellipsoids were defined using constants determined by measurements in a particular area of interest (a country or a continent)
- Each country felt free to adopt its own as the most accurate approximation to its own part of the Earth
- Ellipsoids defined in this way fitted well in that part of the Earth's surface in and around the area of interest but not necessarily other parts of the world.
- Without a single standard the maps produced by different countries using different ellipsoids could never be made to fit together
- Around 30 ellipsoids are in common use today

THE HISTORY OF ELLIPSOIDS

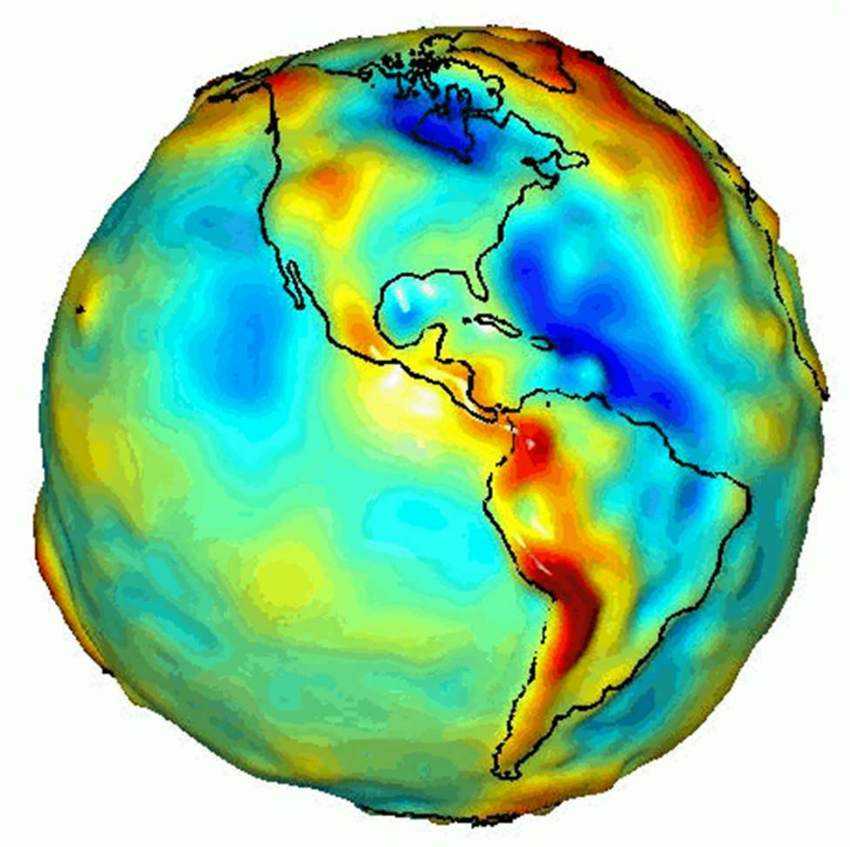
- Since 1960s, new values of equatorial and polar radii have been obtained by satellite based observations. International collaborative efforts have gained strength (Eg. International Union of Geodesy and Geophysics)
- Unlike ground determined ellipsoids defined by using a physical origin on Earth's surface, satellite determined ellipsoids are defined by using center of mass of the whole planet Earth as the Origin.
- These ellipsoids are called as geocentric or Earth-centered ellipsoids
- These newly proposed ellipsoids are able to represent the entire Earth more precisely.
- Many countries have adopted them in their geo-referencing systems

THE GEOID

- Geoid means 'Earth like'.
- Geophysically defined as an equi-potential surface, (a surface on which the gravity potential is everywhere constant) to which direction of gravity is everywhere perpendicular
- Geoidal Modelling is based on precise measurements of gravity across the continents and around the world.
- Since gravity measurements tend to vary from place to place on the Earth's surface. Thus the geoidal surface is an irregular surface.
- Geoid generally rises over the continents and is depressed over the oceans



NASA - GRACE MISSION
(Earth's Gravity Recovery and Climate Experiment)



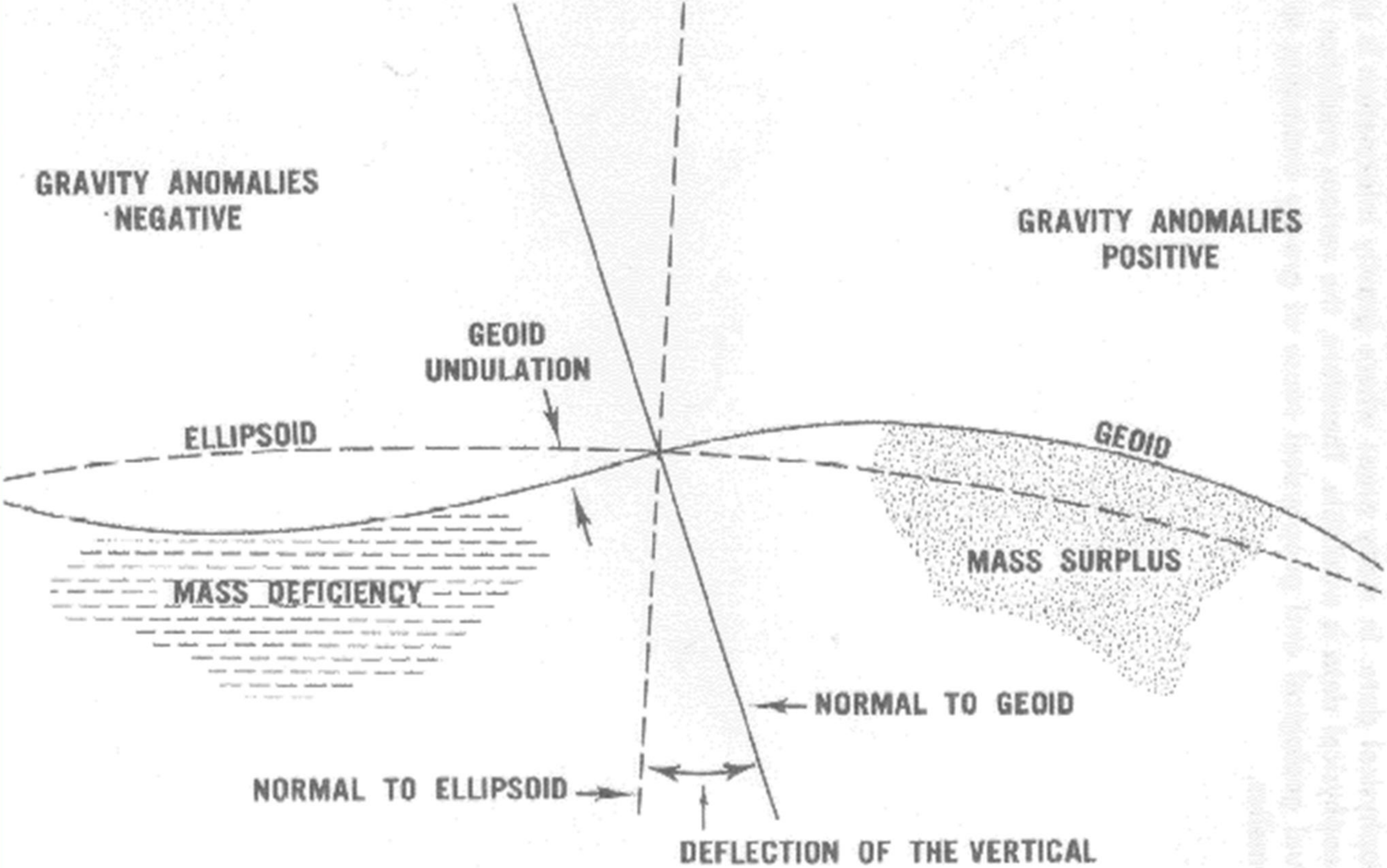
GRACE is a collaborative endeavor involving the Center for Space Research at the University of Texas, Austin; NASA's Jet Propulsion Laboratory, Pasadena, Calif.; the German Space Agency and the German Research Center for Geosciences, Potsdam.

This visualization of a gravity model was created with data from NASA's Gravity Recovery and Climate Experiment (GRACE) and shows variations in Earth's gravity field.

Gravity is determined by mass. Earth's mass is not distributed equally, and it also changes over time.

The colors in this image represent the gravity anomalies measured by GRACE. One can define standard gravity as the value of gravity for a perfectly smooth 'idealized' Earth, and the gravity 'anomaly' is a measure of how actual gravity deviates from this standard. Red shows the areas where gravity is stronger than the smooth, standard value, and blue reveals areas where gravity is weaker

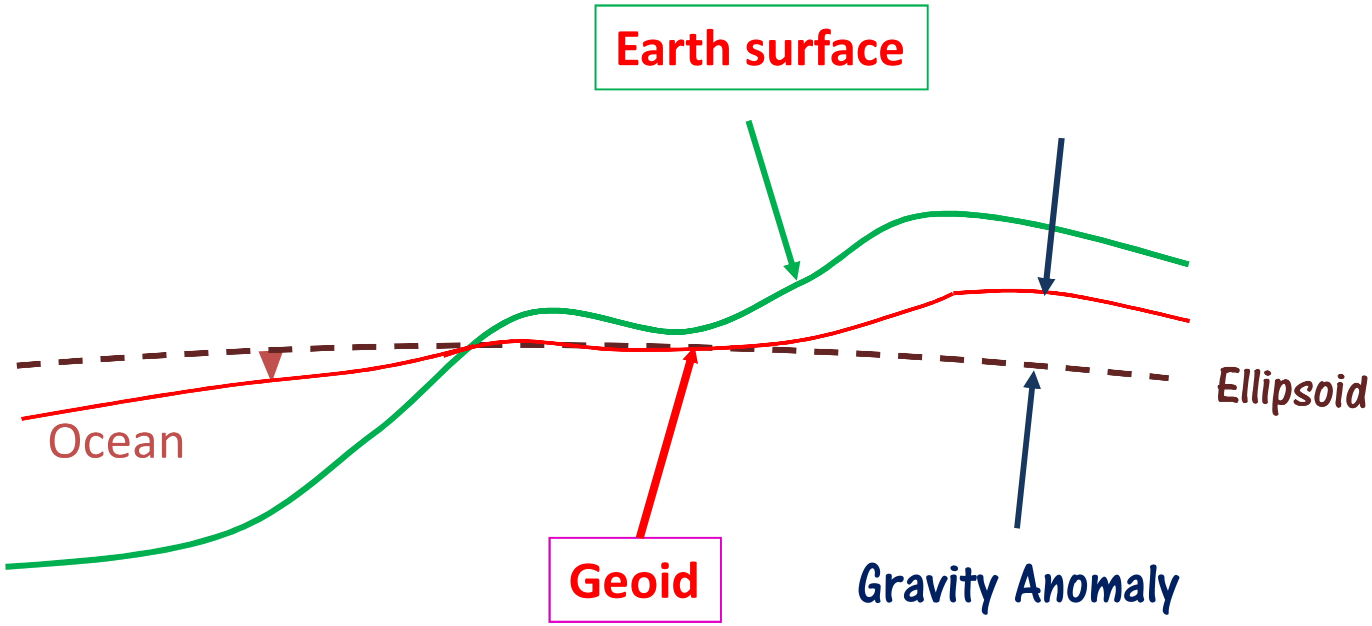
Source: http://grace.jpl.nasa.gov/



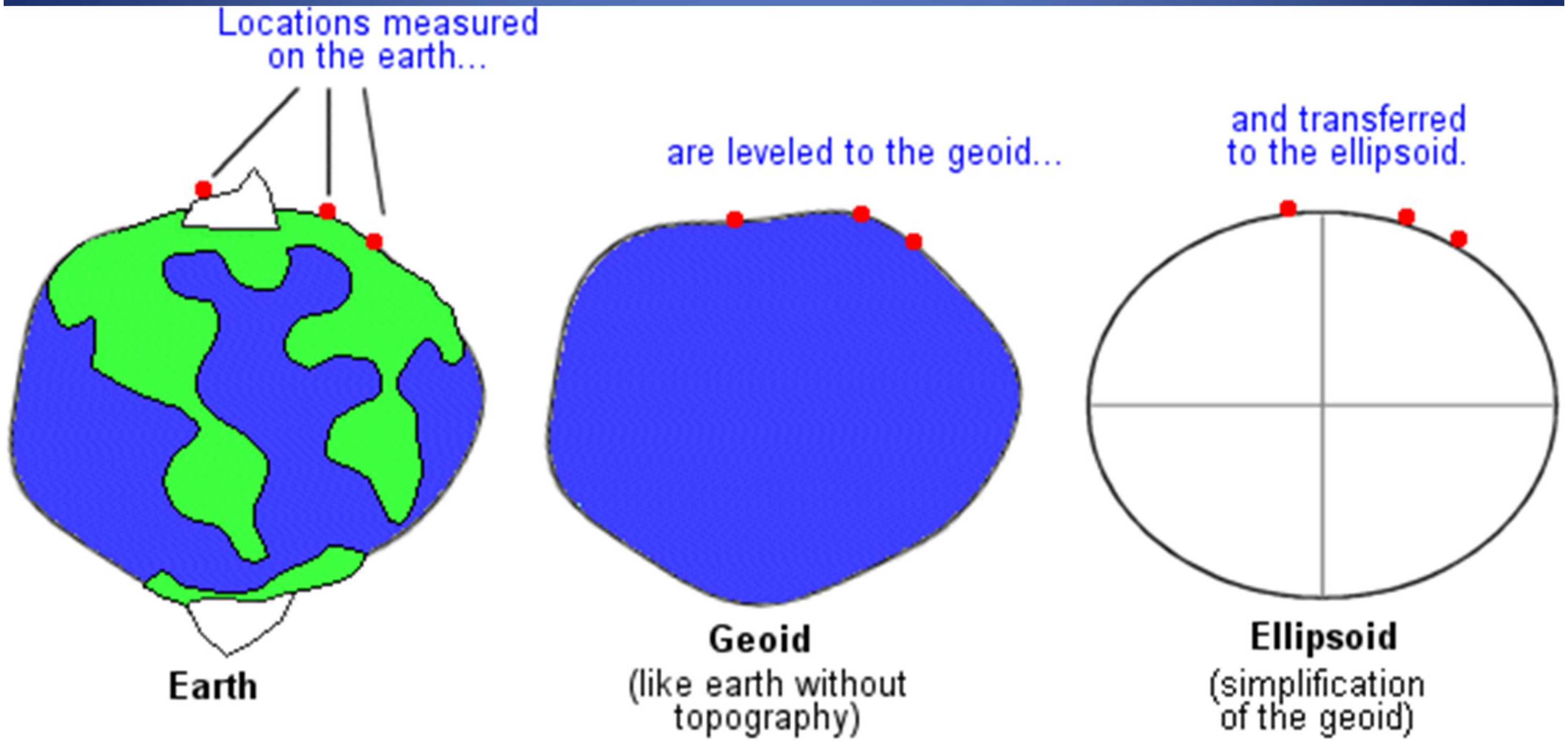
THE EFFECT OF MASS ANOMALIES
ON THE GEOID

THE GEOID

- An imaginary surface of zero height all over the world.
- In general, the geoid coincides very well with Mean Sea Level (MSL) in the open oceans that make up most of the Earth's surface
- Therefore all elevations in surveying and mapping are computed relative to Geoid as represented by MSL.
- Thus, geoid is a reference surface for vertical coordinates.

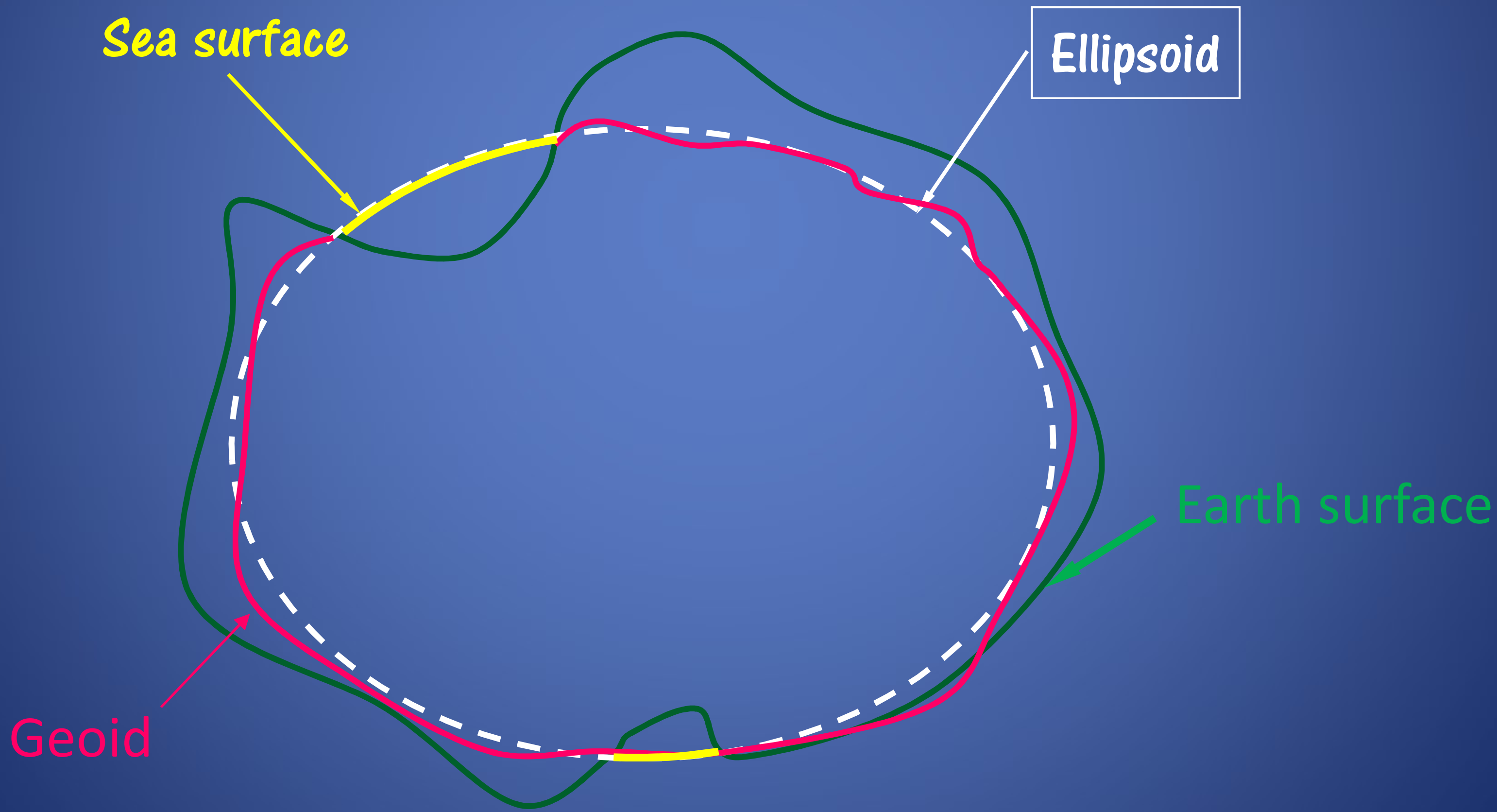


THEREFORE…..



Locations measured
on the earth...
are leveled to the geoid...
and transferred
to the ellipsoid.
Earth
Geoid
(like earth without
topography)
Ellipsoid
(simplification
of the geoid)

REPRESENTATIONS OF THE EARTH



Since the Geoid varies due to local anomalies, we must approximate it with an ellipsoid

GEOID....

- *Since ellipsoid is defined entirely by the mathematical method, it is a smooth surface which is different from the Geoid obtained by gravity measurements.*
- *The separation between these two surfaces at a particular point on Earth's surface is called Geoid Undulation, Geoid Separation or Geoid Height.*
- *The angle between the perpendicular to the Ellipsoid and the perpendicular to the Geoid (i.e. the Plumb Line) is called the vertical deflection*