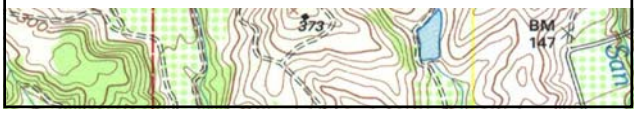
Geography 12: Maps and Spatial Reasoning

Lecture1: The Size and Shape of the Earth

Professor Keith Clarke



Non-scientific quiz #1

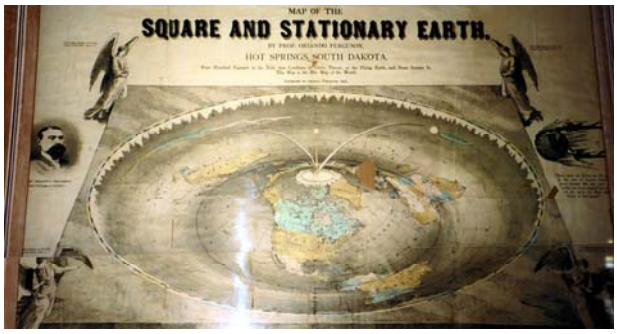
- What shape is the earth?

a. Flat
b. Round
c. Square Bowl-shaped
d. Prolate Ellipsoid
e. Disk-shaped, balanced on the back of four elephants, standing on a turtle's back

Discworld

Discworld is a comedic fantasy book series by the British author Terry Pratchett, set on the Discworld, a flat world balanced on the backs of four elephants which, in turn, stand on the back of a giant turtle

Orlando Ferguson 1893



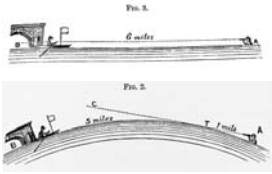
Aristotle: 3 Proofs by observation

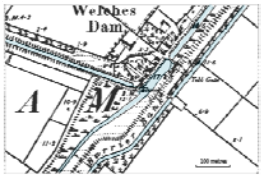
"After the 5th century BC, no Greek writer of repute thought the world was anything but round."

•Every portion of the Earth tends toward the center until by compression and convergence they form a sphere.
•Travelers going south see southern constellations rise higher above the horizon
•The shadow of Earth on the Moon during a lunar eclipse is round.

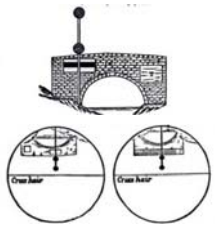
Parallax

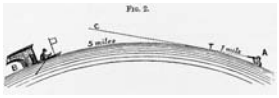
- Samuel Birley Rowbotham
- Lectured for two decades up and down Britain promoting his unique flat earth theory *Zetetic Astronomy*
- 16 page pamphlet published in 1849 "Earth not a Globe"
- Rowbotham supporter John Hampden lost a bet to Alfred Russel Wallace about the Bedford Level Experiment in 1870





The Bedford Level Experiment

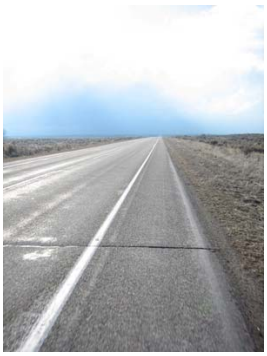




Definitive Proof

- Ferdinand Magellan's circumnavigation (1519-1521)
- Oldham, H. Yule (1904). The Experimental Demonstration of the Curvature of the Earth's Surface, as Recorded by Photography. *Year Book of the Royal Society of London*. 148.
- Curvature first seen by direct observation from a balloon at 15 787m in 1931 (Lynch, 2008)
- Can we get proof by our own observation?

“Round”: How can we prove it?



Platform Holly: Where are the legs?

3km

15km

Non-scientific quiz #2

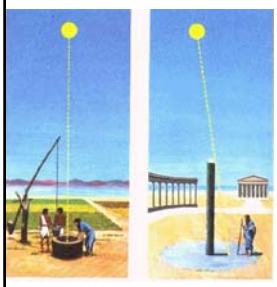
- How far is it around the earth?
- A. 5000 stadions
- B. 57,437.9 toises
- C. 150 * 10^6 km
- D. 4653 m
- E. 40 000 000m

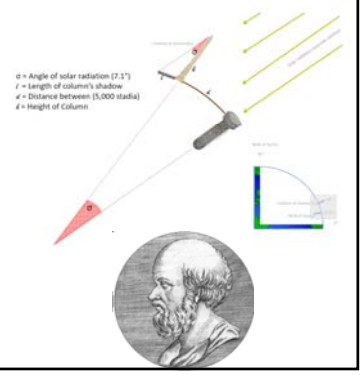
How far around?

The Well at Syene (Edfu)

Eratosthenes (276-194 BC)

The Principle





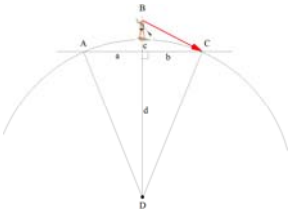
How many days by camel train?

5000 stadia (about 800km)

46,250 kilometers (15% too big)

1. Although it is true that the sun at noon is directly overhead at the Tropic of Cancer on the day of the summer solstice, Syene is not exactly on the tropic of Cancer but 37 miles to the north
2. The true distance between Alexandria and Syene is somewhat smaller than Eratosthenes had measured (453 miles instead of the reported 500)
3. Nobody really knows exactly what the unit (stadion) length was
4. Syene lies 3° 30' east of the meridian of Alexandria
5. The difference of latitude between Alexandria and Syene is 7° 5' rather than the rounded (1/50 of a circle) value of 7° 12' that Eratosthenes obtained
6. Camel trains are an inexact means of measuring distance

How far is 40 000 000m? How far can I see?

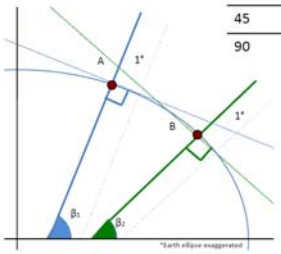


d = sqrt (2 R h) , where h is the height of the observer's eyes (1.7m)
Radius correction is *R = R / (1 – k)* *k* is given as a value of 0.13.
d = sqrt (2h R /0.87)
This gives a horizon at 4,998 meters or about 3.1 miles.
Without the correction for refraction the answer is only 4,653 m.

But…..

- The Earth is NOT a perfect sphere!

How to tell the difference

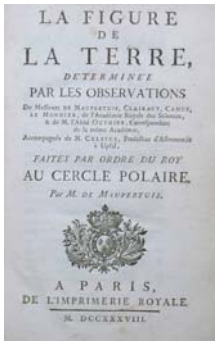


Latitude	Length of 1° of Latitude
0	110574.27m
45	111131.75m
90	111693.92m

Which way was the flattening?

- Oblate ellipsoid predicted by Newton
- French Academy of sciences already had Cassini's data for the Paris meridian
- Sent expeditions to Lapland and Peru (now in Ecuador) to measure the length of a degree along a meridian
- Charles La Condamine and Pierre Bouguer sent to Mitad del Mundo (1735)
- Moreau de Maupertius sent to Tornio River Valley (1736)

Pierre-Louis Moreau de MAUPERTUIS (1698-1759)



Maupertuis's Map

- River Tornio in modern Finland
- 14.3 km base line laid out on the ice

Charles Marie de la Condamine

Measuring the Ellipsoid

- Maupertuis reported a meridian degree as 57,437.9 toises (1 toise = 1.949 m)
- Meridian degree at Paris was 57,060 toises
- Concluded Earth was flatter at poles
- Measures were erroneous but conclusions were correct
- Published as “La Figure de la Terre” (1738)

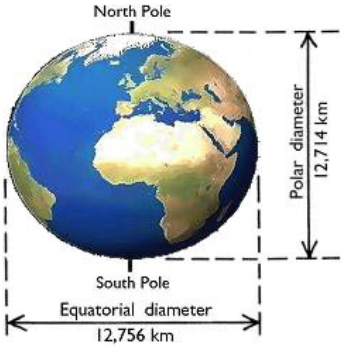
Measurements in the US?

1763 to 1767 by Charles Mason and Jeremiah Dixon

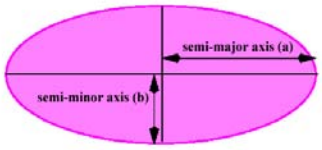
The Spheroid and Ellipsoid

- The sphere is about 40 million meters in circumference.
- An ellipsoid is an ellipse rotated in three dimensions about its shorter axis.
- The earth's ellipsoid is only about 1/297 off from a sphere.
- Many ellipsoids have been measured, and maps based on each. Examples are WGS84 and GRS80.

What shape is the earth?



WGS84



$$f = 1 - \frac{b}{a}$$

For the WGS84
$a = 6{,}378{,}137$
$b = 6{,}356{,}752.3$, so $f = 1/298.257$

Figure 2.3 The ellipsoid. The long axis is the major axis, the short the minor axis. Half of each of these lengths is used to calculate the flattening of the ellipsoid.

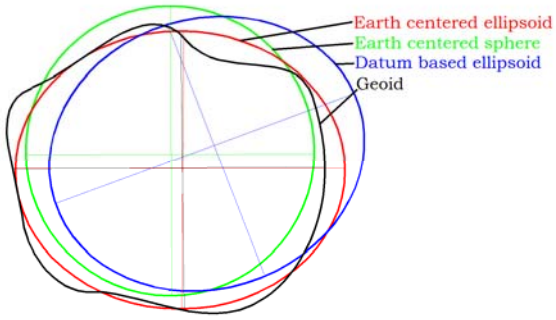
The Datum

- An ellipsoid gives the base elevation for mapping, called a datum.
- First US national mapping efforts used NAD27, changed over to NAD83
- US mapping standardized in the 1920s at Meades Ranch, Kansas

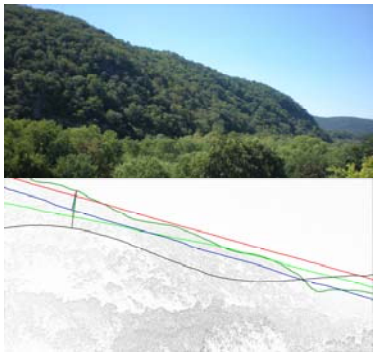
A lumpy ellipsoid

- The geoid is a figure that adjusts the best ellipsoid and the variation of gravity locally
- It is the most accurate, and is used more in geodesy than GIS and cartography

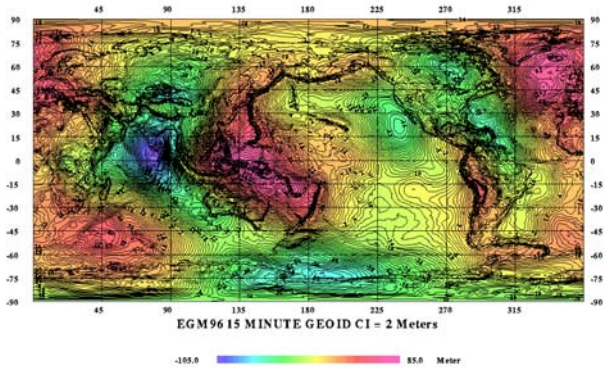
Earth Models and Datums



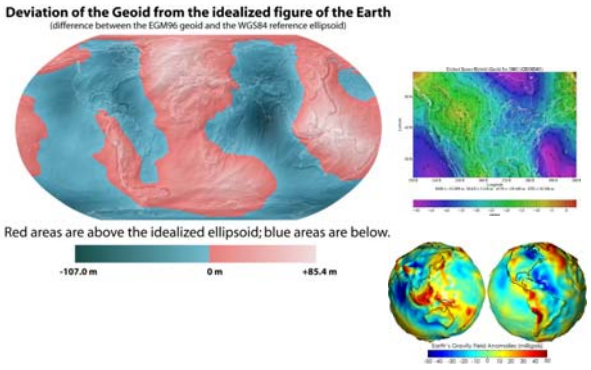
Which height?



Geoid



Geoid as a surface of equal gravity



The bottom line

- For maps showing the whole earth, a sphere is fine
- For detailed mapping, the ellipsoid is necessary
- For extreme mapping, the geoid is necessary
- This impacts the map's DATUM
- Location of places and their height change with the datum
- In the USA, we usually use NAD83 (very similar to WGS84) based on GRS80