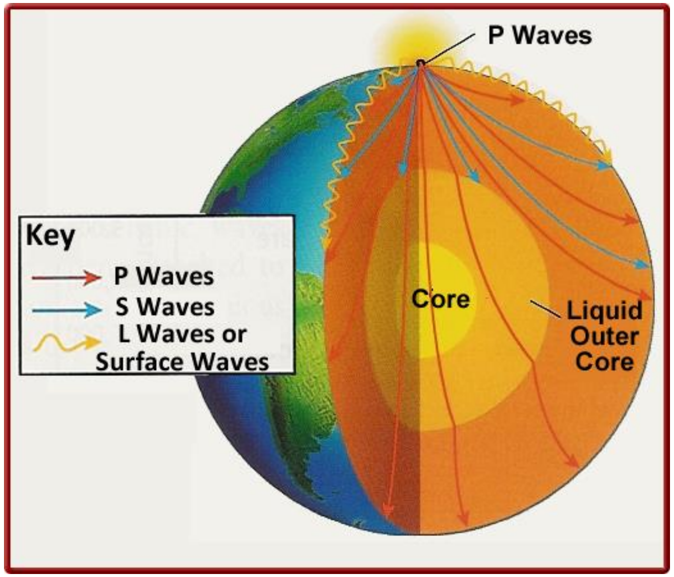
EARTH'S STRUCUTRE

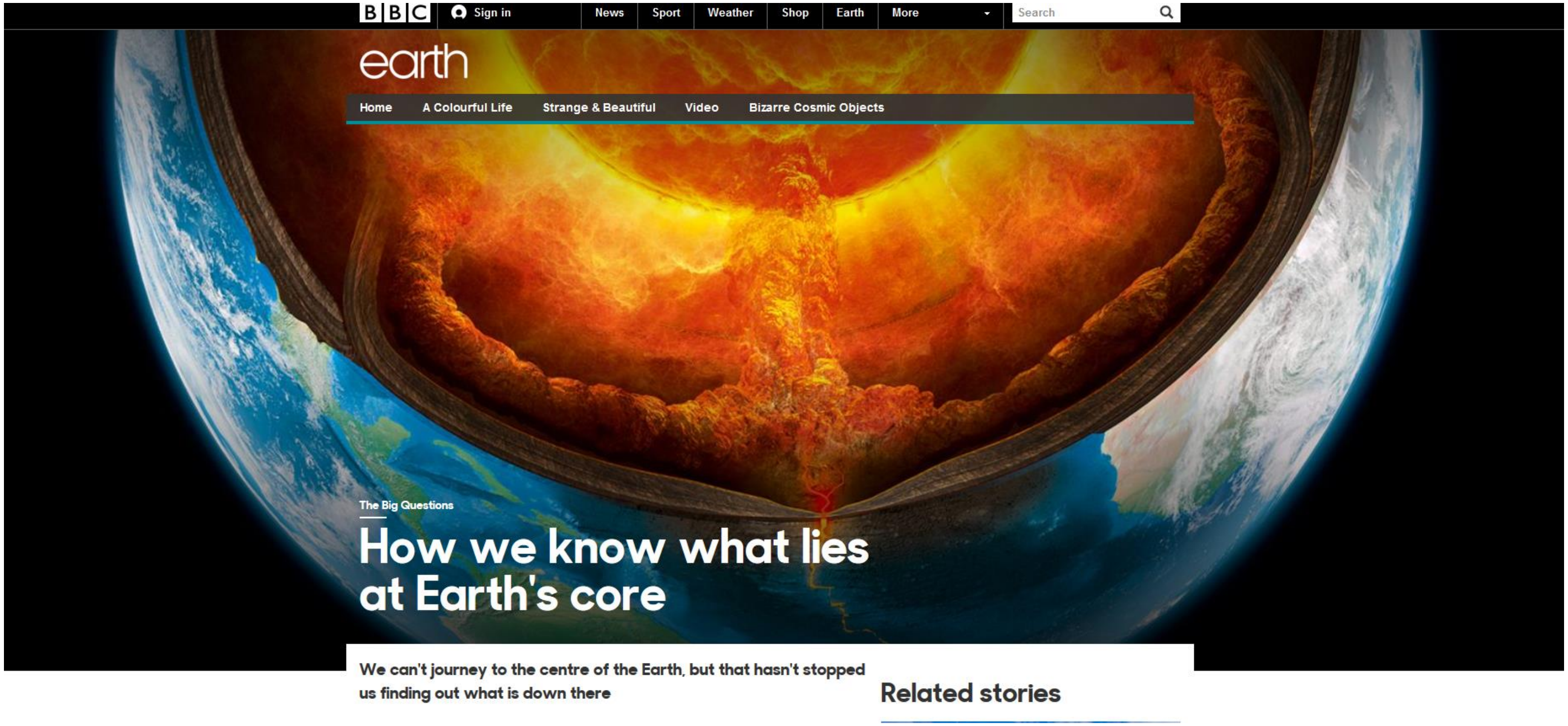
May 26th, 2021

HOW DO WE GET KNOWLEDGE ON EARTH'S STRUCTURE ?

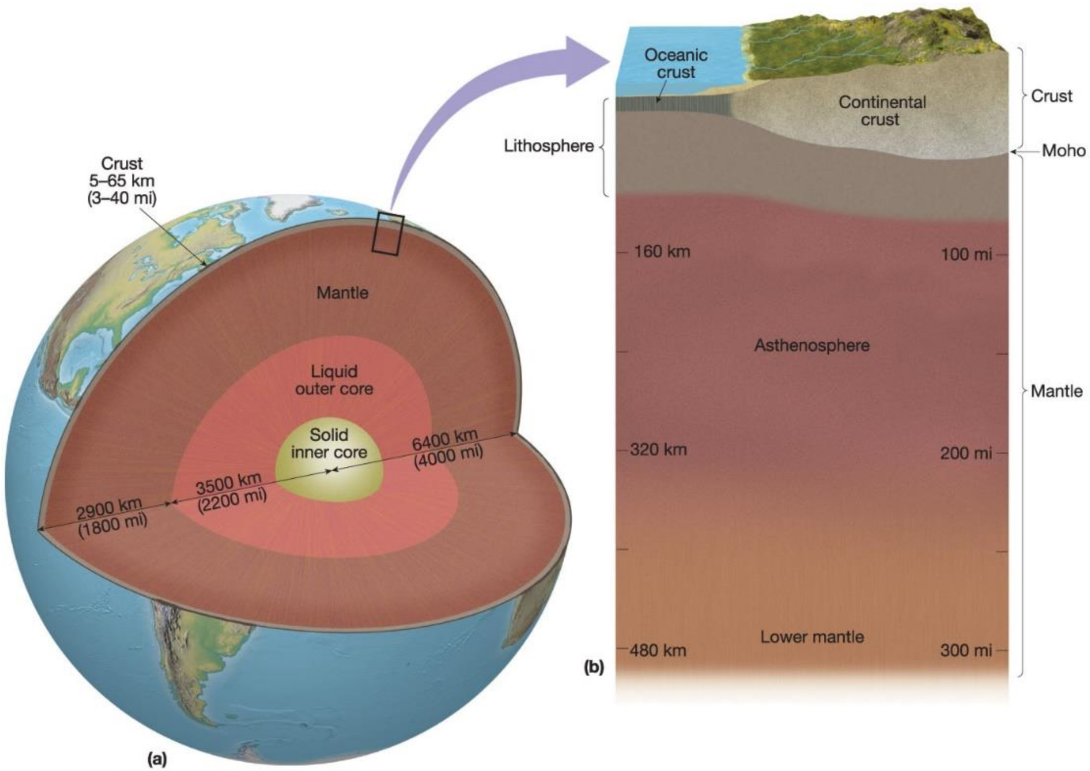
Earthquakes, volcanic eruptions, deep mines and bore holes, all provide clues to the nature of the earth's interior.



How we know what lies at Earth's core?



http://www.bbc.com/earth/story/20150814-what-is-at-the-centre-of-earth

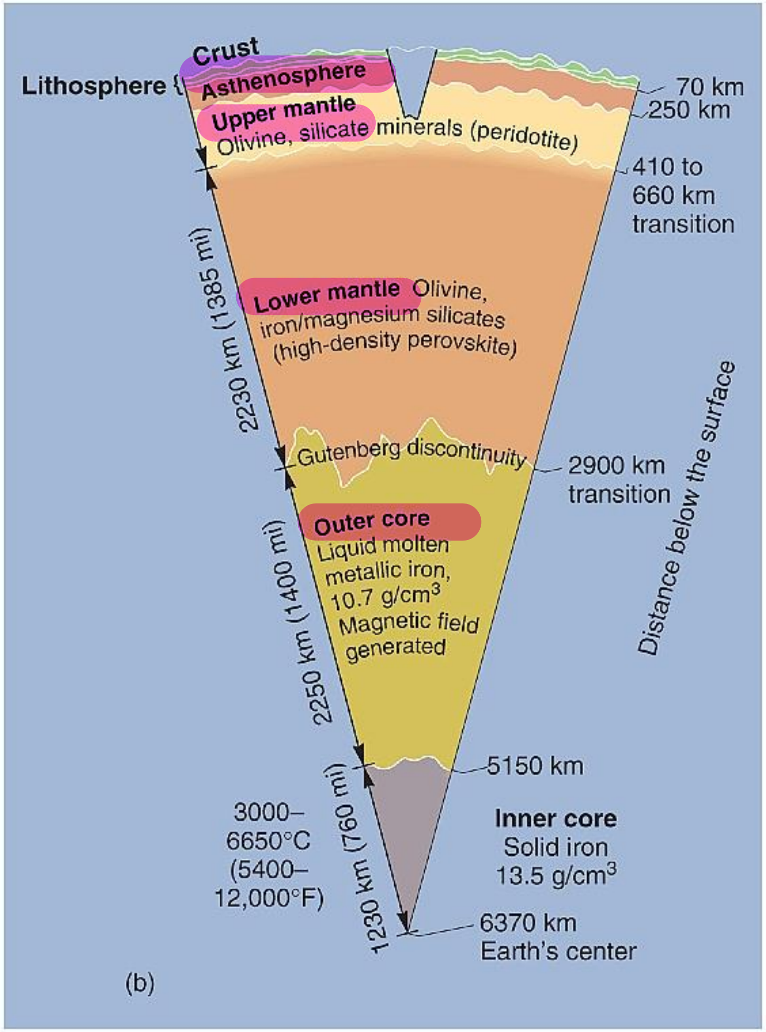


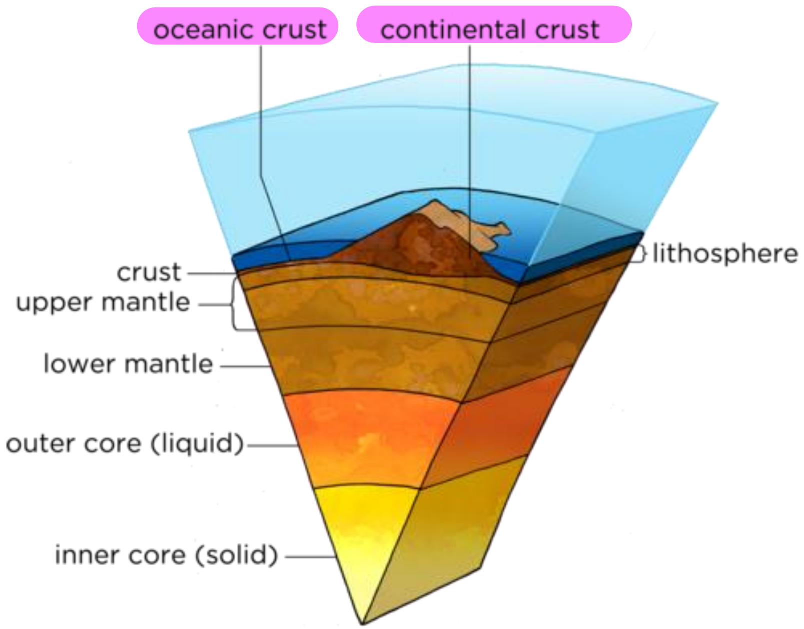
Cross-Section Through the Earth

The earth is made up of three main parts:

- **The Crust:** density increases with depth
- **The Mantle:** 80% of the Earth's volume – 2800ºC – 1800ºC
- **The Core**: 3000-5000 ºC

Temperature and pressure increases with depth.


Crust
Lithosphere
Asthenosphere
Upper mantle
Olivine, silicate minerals (peridotite)
70 km
250 km
410 to
660 km
transition
Lower mantle Olivine,
iron/magnesium silicates
(high-density perovskite)
2230 km (1385 mi)
Gutenberg discontinuity
2900 km
transition
Distance below the surface
Outer core
Liquid molten
metallic iron,
10.7 g/cm3
Magnetic field
generated
2250 km (1400 mi)
5150 km
3000–
6650°C
(5400–
12,000°F)
1230 km (760 mi)
Inner core
Solid iron
13.5 g/cm3
6370 km
Earth's center
(b)


oceanic crust
continental crust
lithosphere
crust
upper mantle
lower mantle
outer core (liquid)
inner core (solid)

6 primary layers (for convenience)

1. ***Crust***: 10-70 km thick, also called the Earth's Crust - rigid.
   a. Continental – lower zone of dense mafic rock (magnesium and iron-bearing) and upper zone of lighter felsic rock (feldspar and silica)
   b. Oceanic Crust – mafic rocks
2. ***Asthenosphere***: ***part of the mantle***
   a. ~70 – 250 km below the earth surface – not completely solid – not truly liquid ---*it's plastic* –like tar.
   b. There is motion in this part of the earth that accounts for the movement above – earthquakes and volcanic activity seen at the earth's surface.
3. ***Upper Mantle:*** olivine and silicate minerals

pressure increse, more dense minerals

6 main layers

4. ***Lower Mantle***: very hot rock - molten magma
   a. parts are rigid and parts are molten
5. ***Outer Core:*** Liquid (molten)
   a. under less pressure than inner core
   b. currents gives the earth's magnetic field
   c. high in iron – density: 10.7 g/cm^3
6. ***Inner Core:*** Solid
   a. very hot
   b. heated by radioactive decay
   c. almost entirely iron, with some nickel
   d. due to high pressure it is solid; without this high pressure it would be molten

block the harmful solar wave

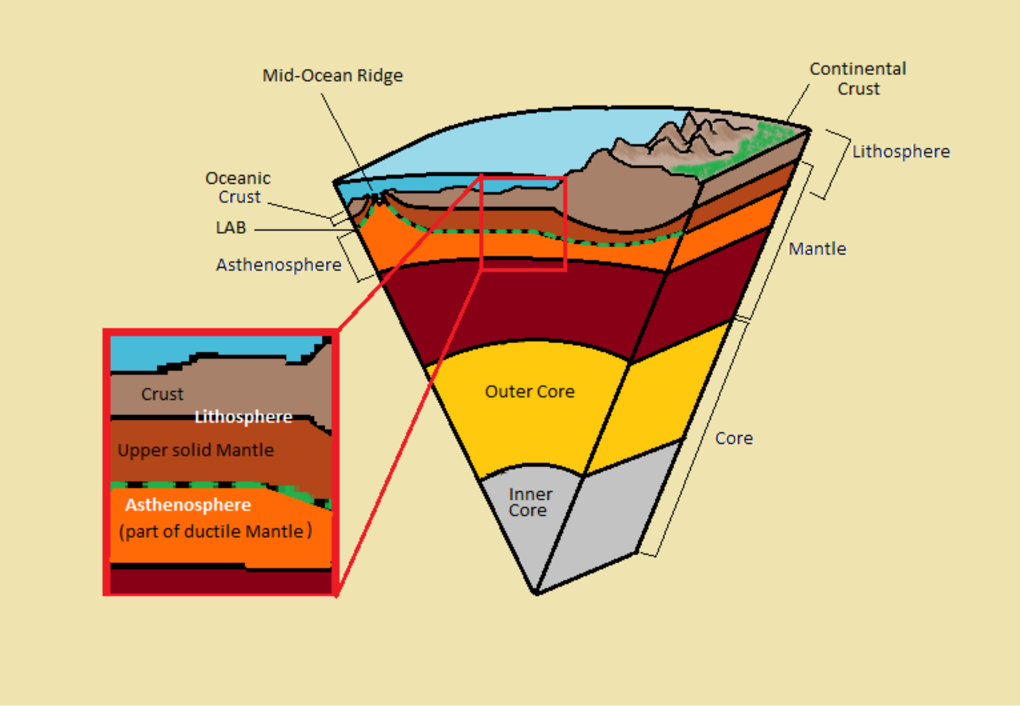
very thick

use the seismic waves to determine the form(liquid or solid)

20% of earth' volume, expanding slowly

We are interested in.....

- **Lithosphere**....
  - Earth's solid part
  - Lithosphere – ***Greek word for Stone***.
  - Lithosphere consists of Oceanic Crust, Continental Crust and to some extent Asthenosphere.



Lithosphere...

Floats on the asthenosphere

The lithospheric shell is divided into large pieces called **lithospheric** plates.

Plates can be as large as continents and move independently of the plates that surround it

Plates can therefore collide or separate from each other, leading to the formation of mountains and valleys, movements we describe as **PLATE TECTONICS.**

geoid

The Geographic Grid

- The way to depict the globe on a flat surface
- Divided into ***degrees, minutes and seconds***
- Provides a “grid” of imaginary lines (parallels and meridians)

PARALLELS AND MERIDIANS

Meridians and parallels define geographic directions.

- **Meridian** – north/south
- **Parallel** – east/west

Infinite number of parallels & meridians.

Every point on the Earth has a combination of one parallel and one meridian, **defined by the intersection**

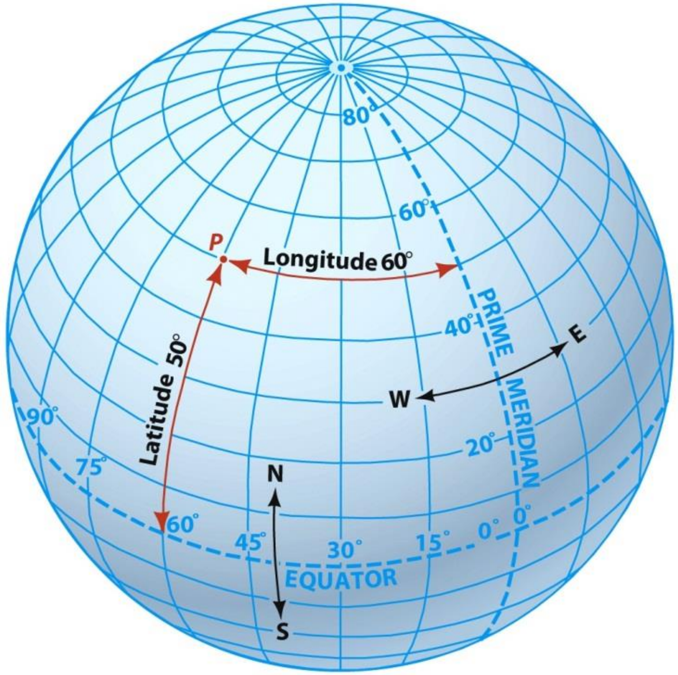


Figure 1.8

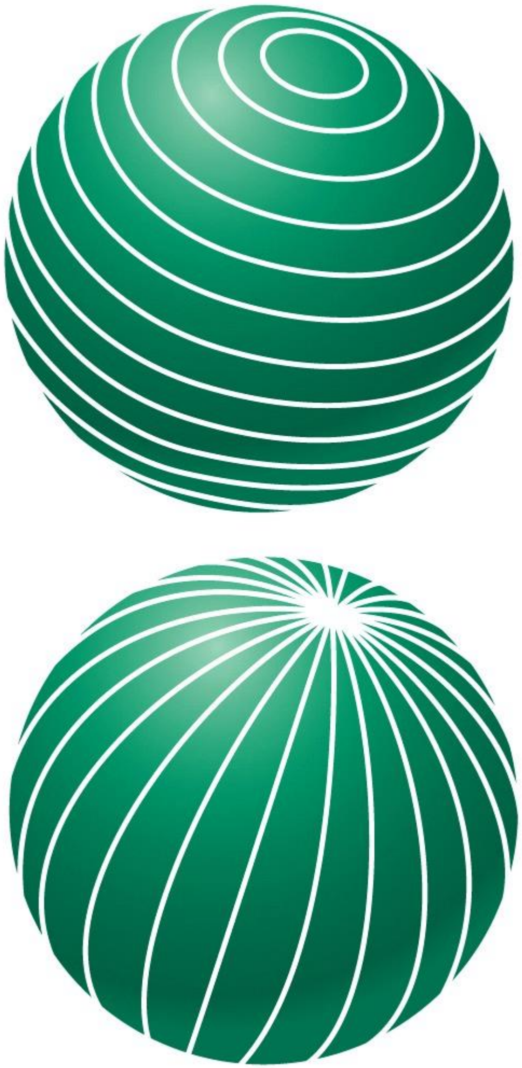


Figure 1.4

LATITUDE AND LONGITUDE

Latitude **(Parallels)**

1 degree latitude

constant 111 km

Longitude **(Meridians)**

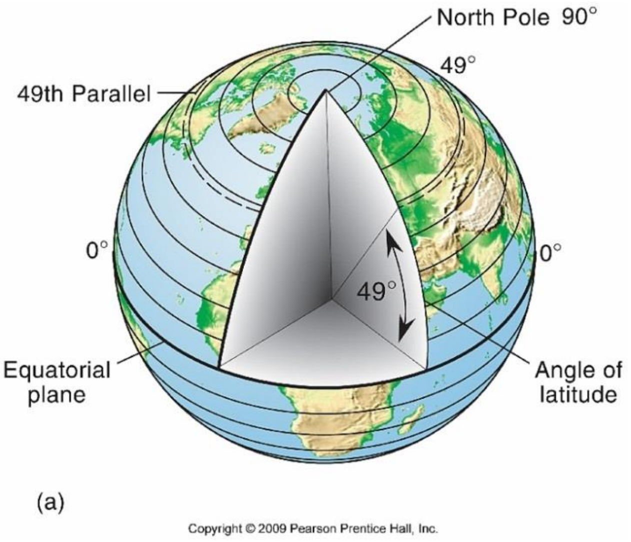
1 degree of longitude

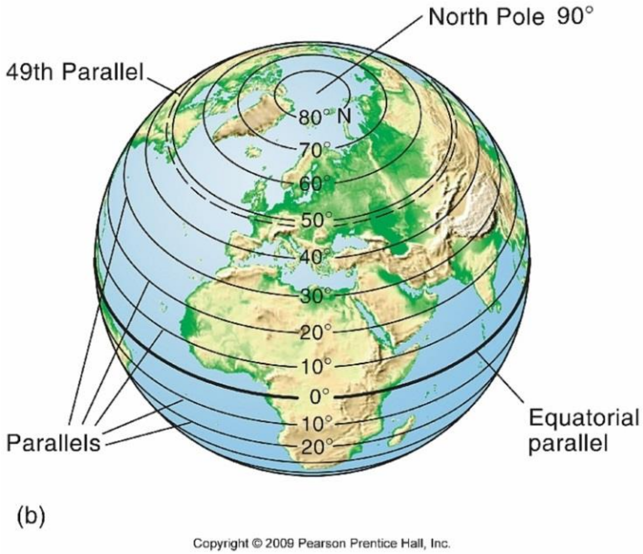
111 km at the equator and 0 at the poles

LATITUDE

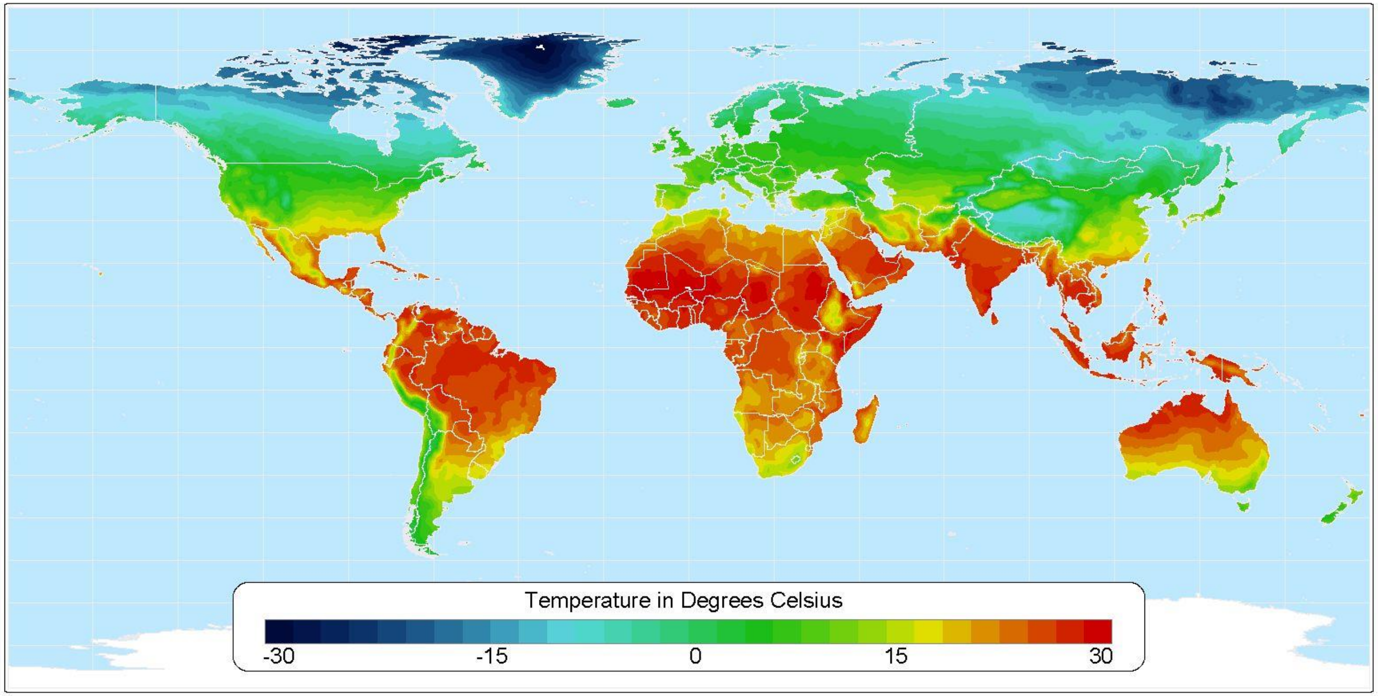
Equator is halfway between the poles

1. North Pole: 90 degrees **N**
2. Arctic Circle: 66.5 degrees **N**
3. Tropic of Cancer: 23.6 degrees **N**
4. **Equator: 0 degrees**
5. Tropic of Capricorn: 23.6 degrees **S**
6. Antarctic Circle: 66.5 degrees **S**
7. South Pole: 90 degrees **S**





Average Annual Temperature



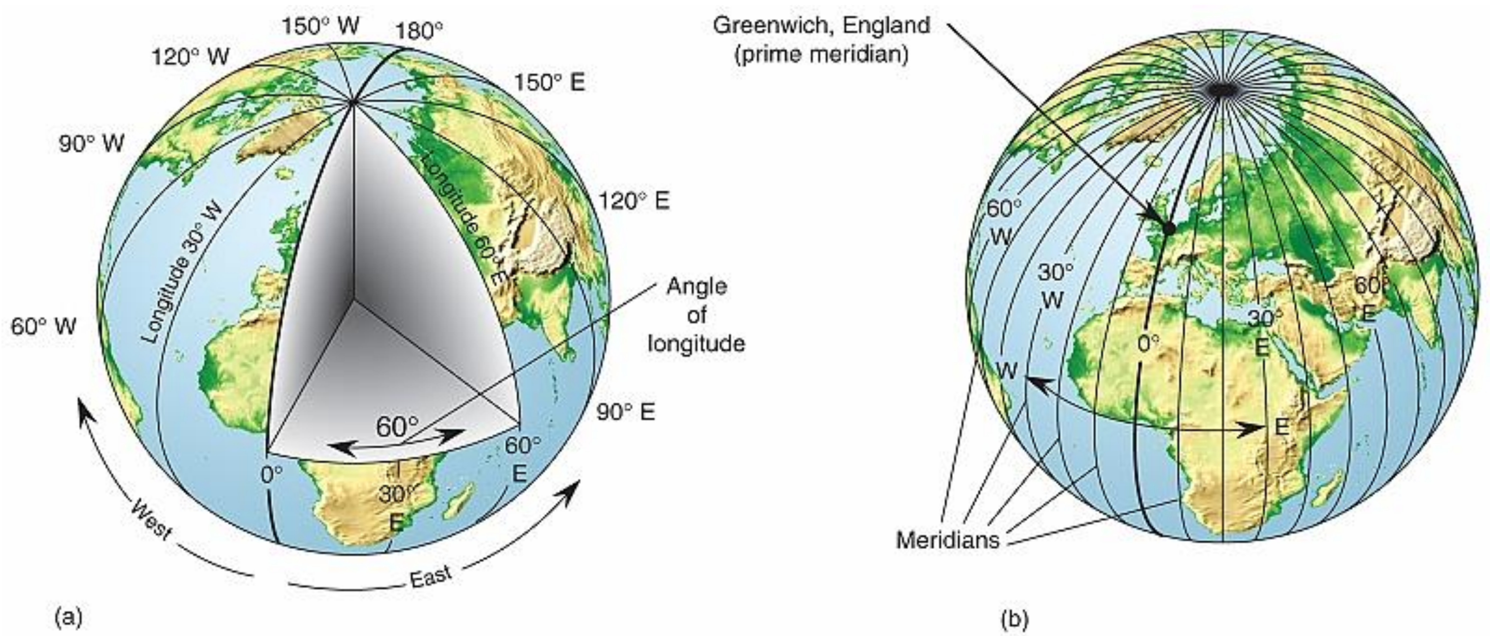
Data taken from: CRU 0.5 Degree Dataset (New, et al.)

Atlas of the Biosphere
Center for Sustainability and the Global Environment
University of Wisconsin - Madison

LONGITUDE

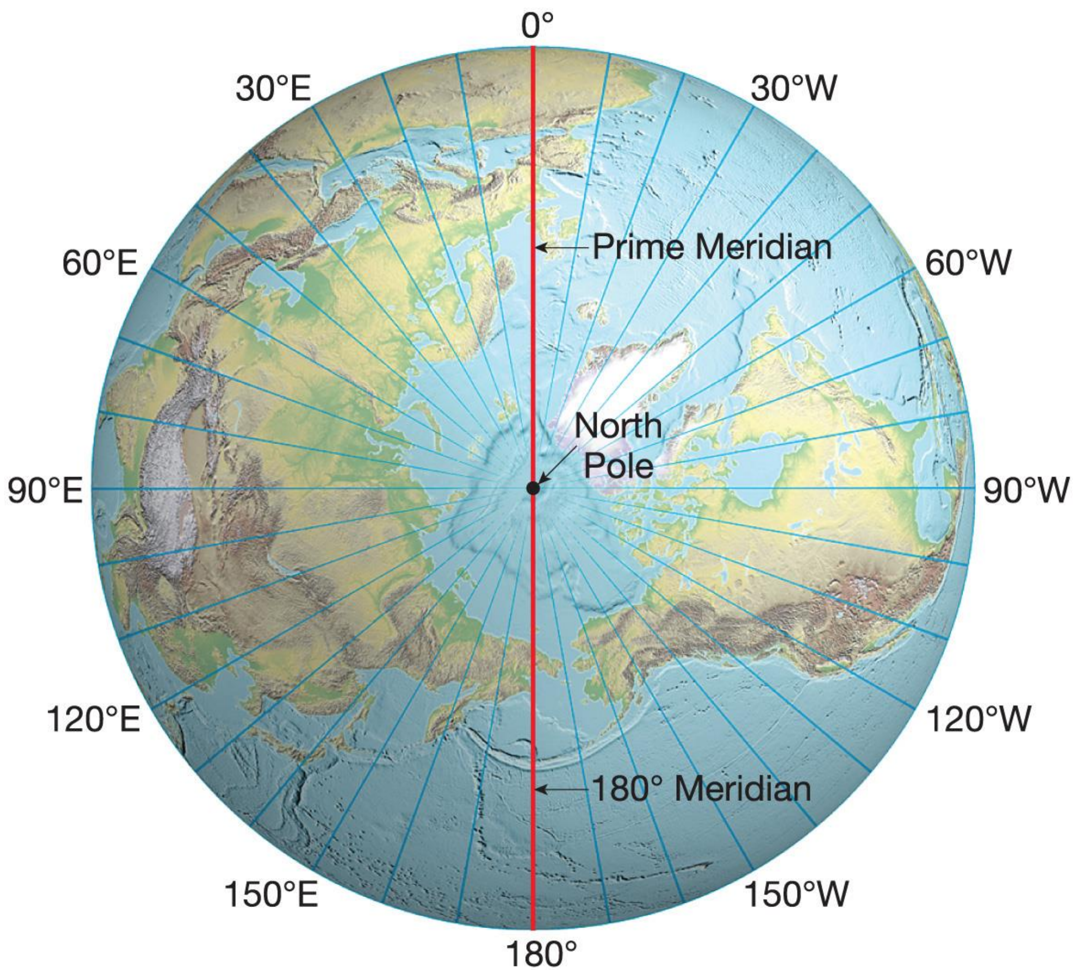
Lines of longitude (meridians) connect one pole to another

- Greenwich meridian was arbitrarily labeled 0 degrees

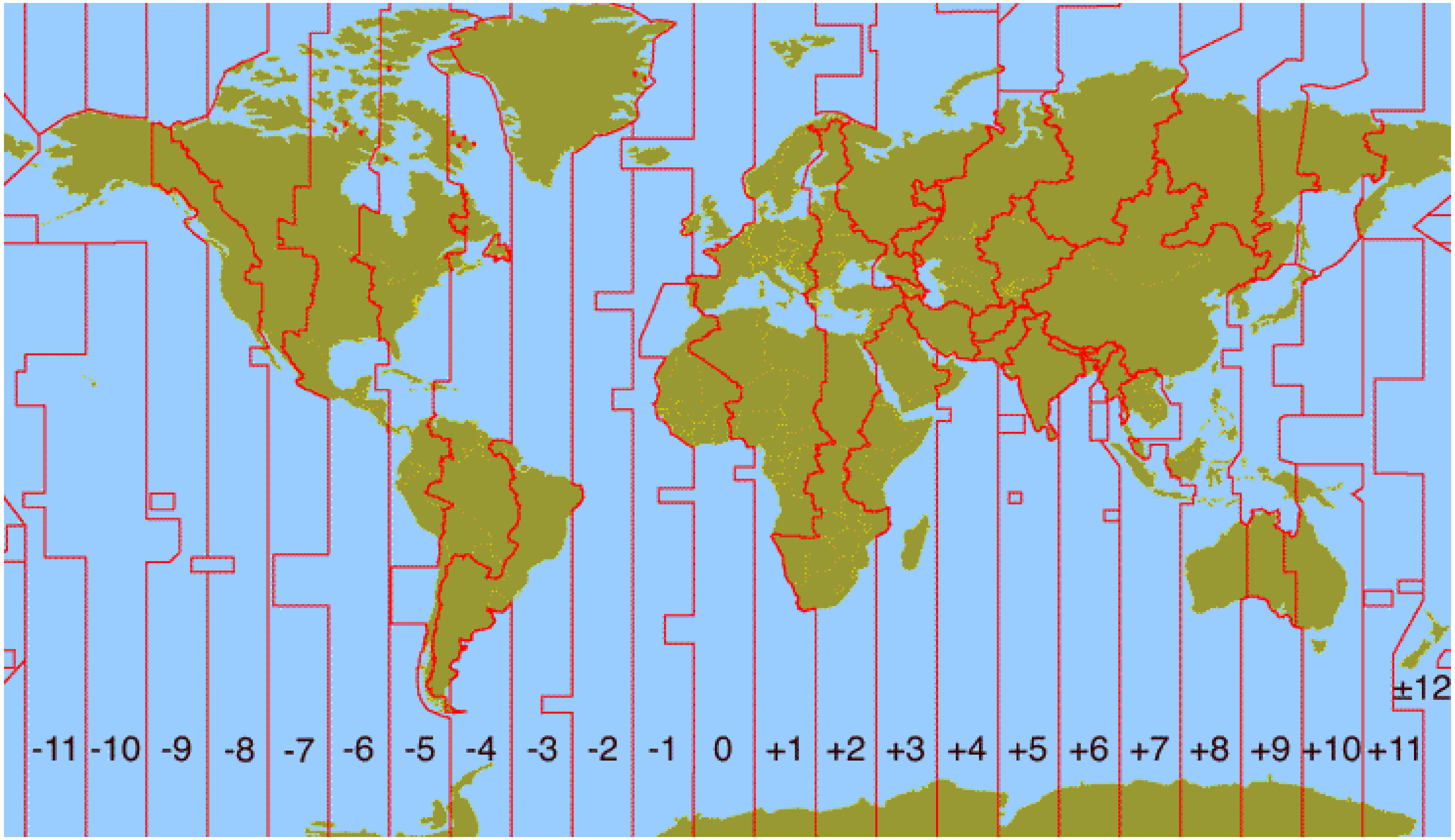


Earth rotates from the west towards east. As viewed from North Star or polestar Polaris, the Earth turns counter-clockwise.

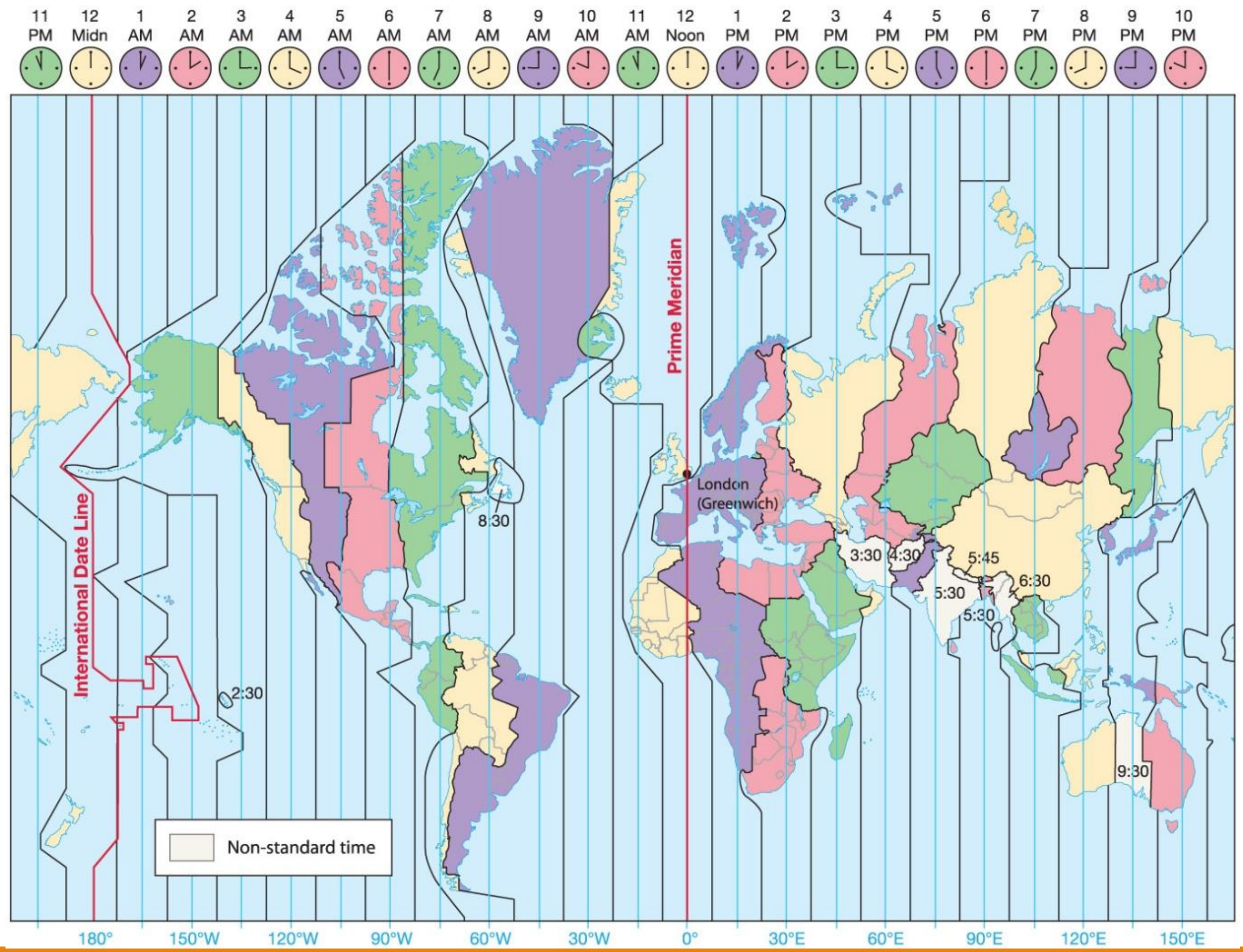
The Prime Meridian and International dateline separates the planet into Eastern and Western hemispheres.



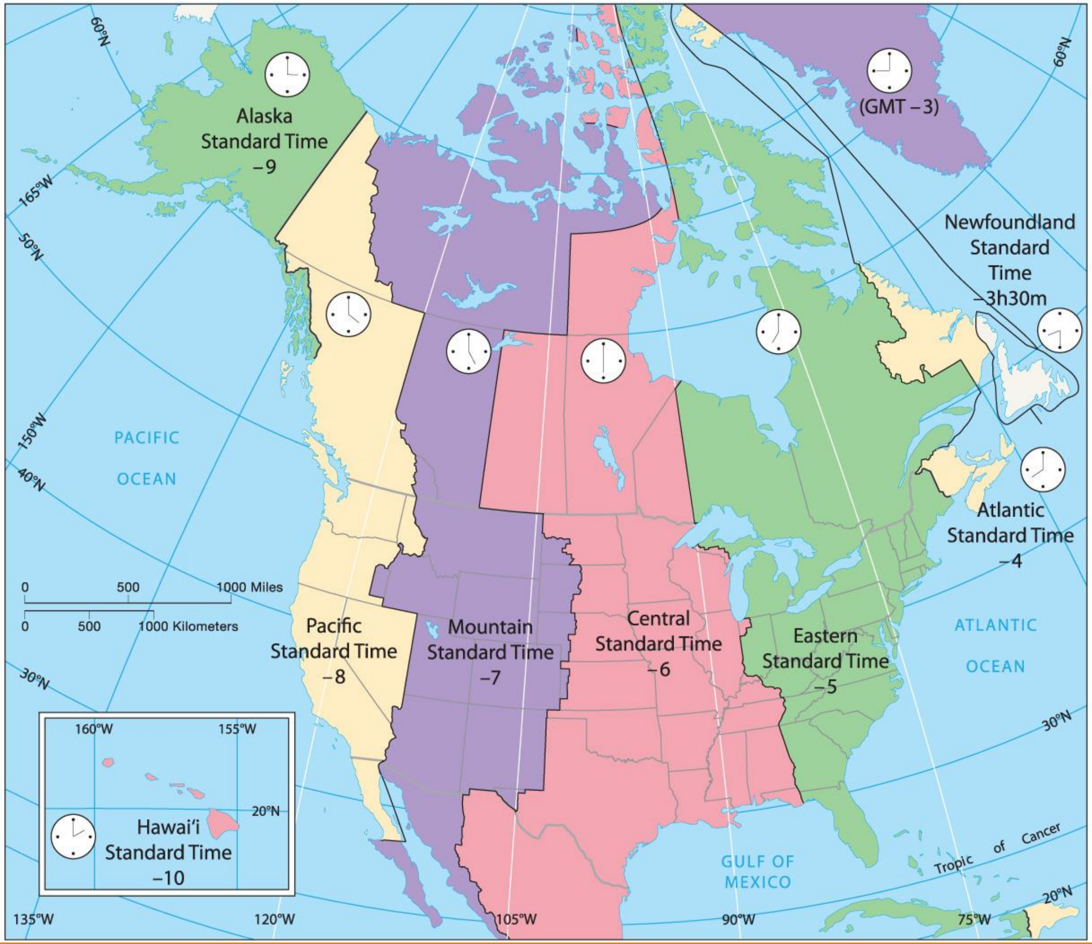
24 time zones, each 15 degrees of longitude in width



Telling Time: Time zones of the world



Telling Time: Time zones of the United States



Projections

Latitude and longitude define locations on the Earth's surface with respect to three well-defined references

- the prime meridian
- the center of mass
- the axis of rotation

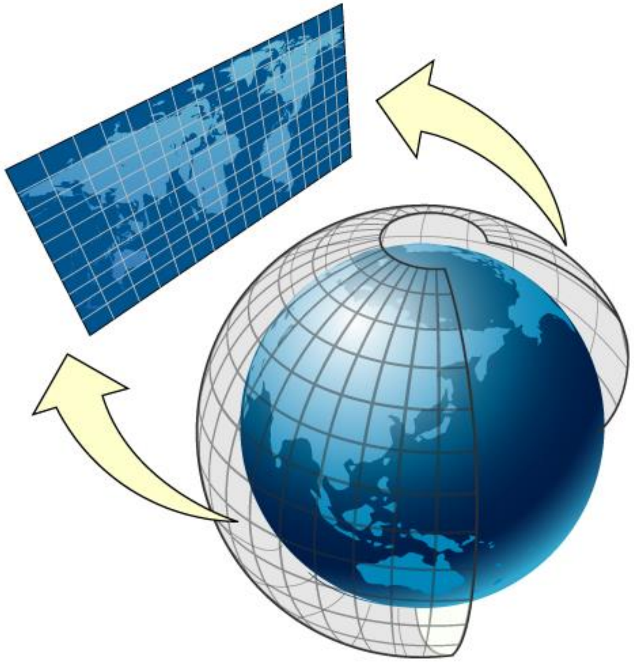
But Earth's surface is curved; how are real world coordinates reflected onto maps?

A projected coordinate system redefines 3-D geographic locations onto a flat, 2-D surfaces.

- Much work in GIS deals with a flattened or projected Earth

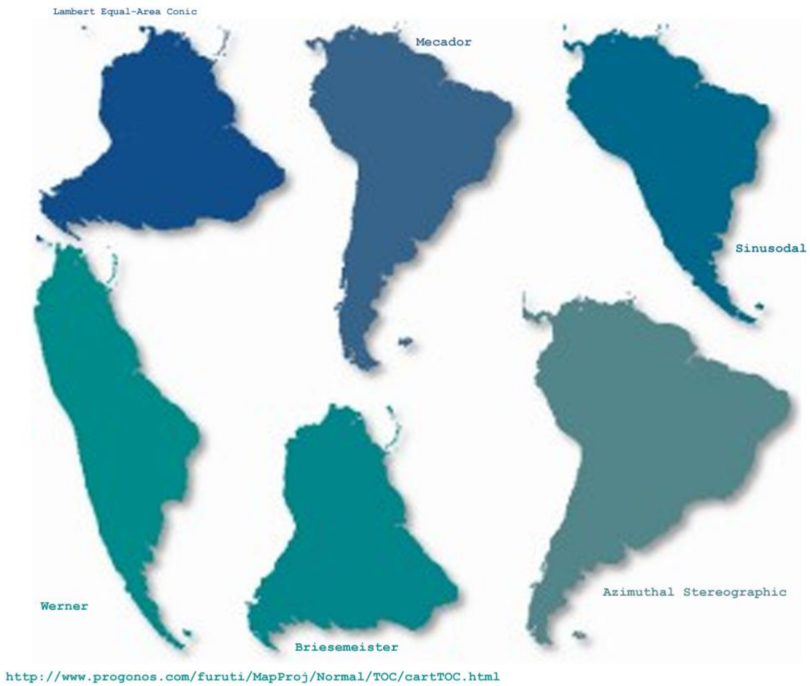
Projections

- Geographic information is often "flattened"
- Cartesian coordinate system
  - Assigns two coordinates to every point
  - Often x and y
  - Transforms a position on Earth identified by latitude and longitude (ϕ, λ) into a position in Cartesian coordinates (x, y)
    - $x = f(\phi, \lambda)$
    - $y = g(\phi, \lambda)$
- Distortions are inevitable consequences of "flattening" 3-D location coordinates to map coordinates



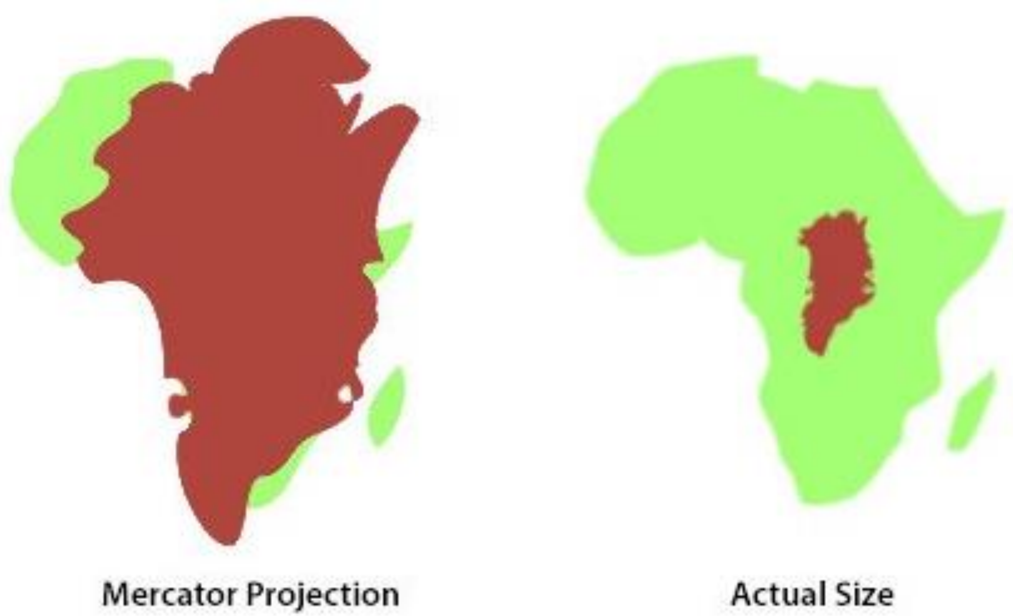
Example 1: South America in different projections at the same scale

Distortions in projecting the continent with different coordinate systems



Source: http://www.hiker.org/map_errors/

Example 2: Greenland vs. Africa

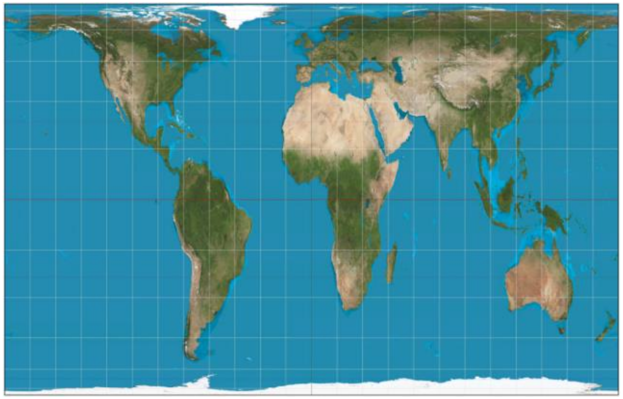


Source: https://geoffboeing.com/2015/08/map-projections-that-lie/

Example 3

https://youtu.be/OH1bZ0F3zVU

peters projection, preserve size



Preserving properties in projections

Flattening must contain a distortion

- Trying to represent a curved surface (3-D) to a flat space (2-D)

Some properties can be preserved

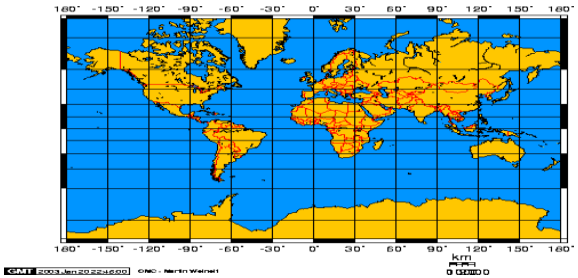
- Conformal property: angles and shapes are preserved
- Equal area property: ensures that areas measured on the map maintain the same proportion to areas measured on Earth

Types of projections

Conformal

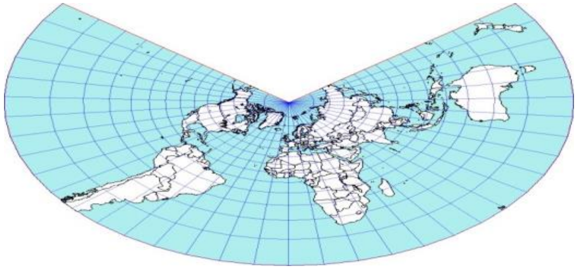
Equal-Area

Mercator

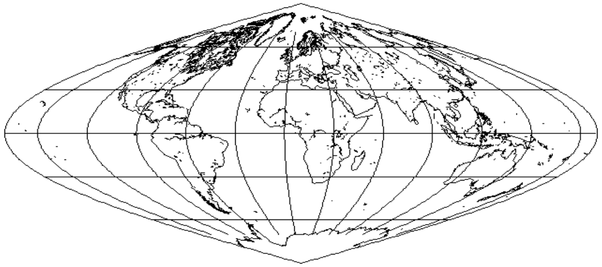


Albers Equal Area

Lambert conformal conic



Sinusoidal



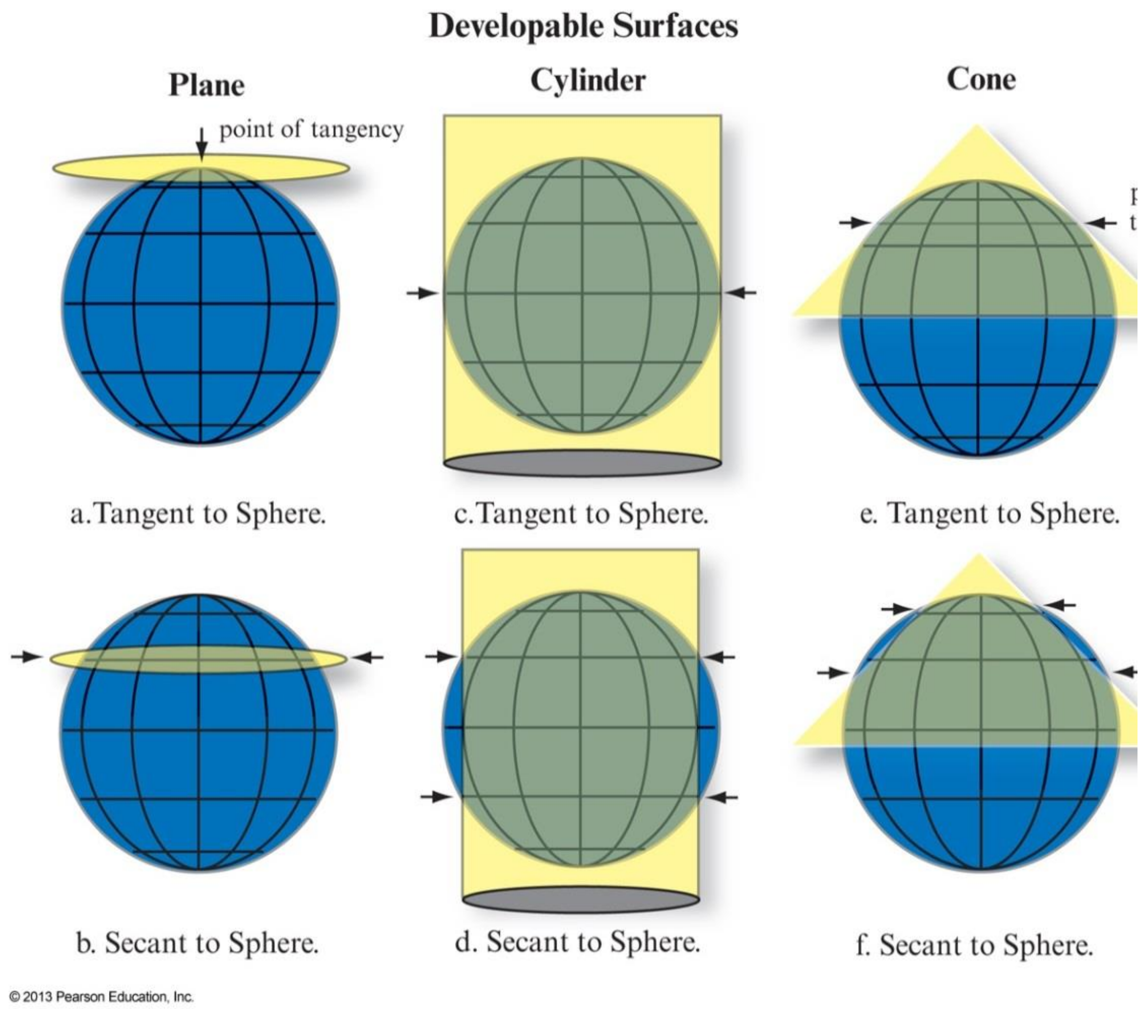
Types of projections:

How positions of the map's flat surface are related to positions on the curved Earth

- Azimuthal (planar)
- Cylindrical
- Conic

They can preserve conformal or equal area properties, but not both

- alternatively, instead of preserving metric properties compromise projections seek to strike a balance between distortions or to simply make things "look right"



Types of projections

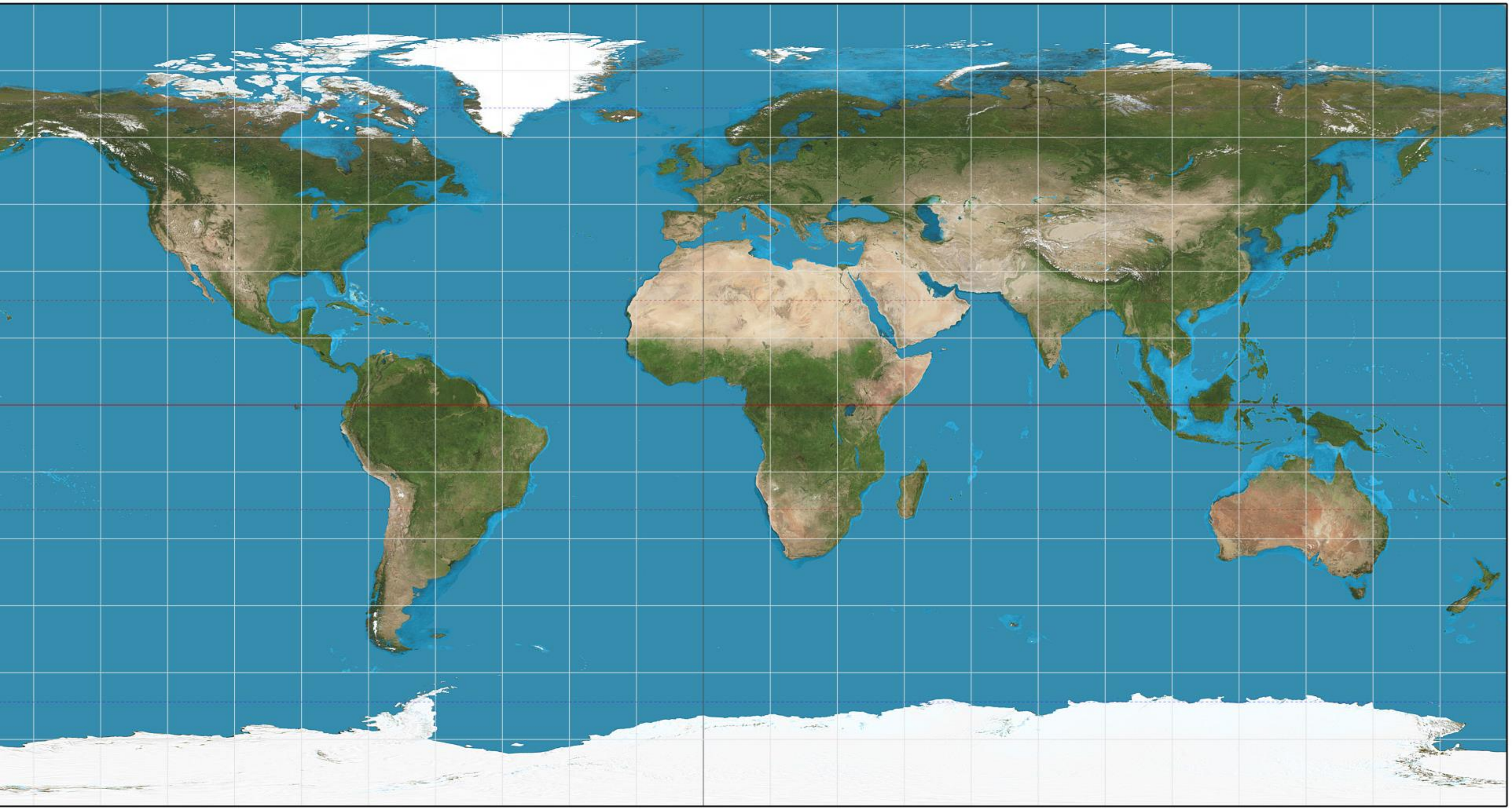
The Plate Carrée (Cylindrical equidistant projection)

x = longitude, y = latitude

Simplest of all projections; known as the unprojected projection

Because of its simple calculations, its usage was more common in the past

- widely used in satellite images, world maps
- normally used for the whole Earth



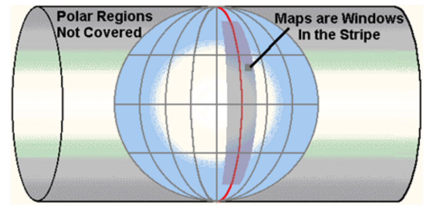
The Plate Carrée
(Cylindrical equidistant projection)

The Plate Carrée (Cylindrical equidistant projection)

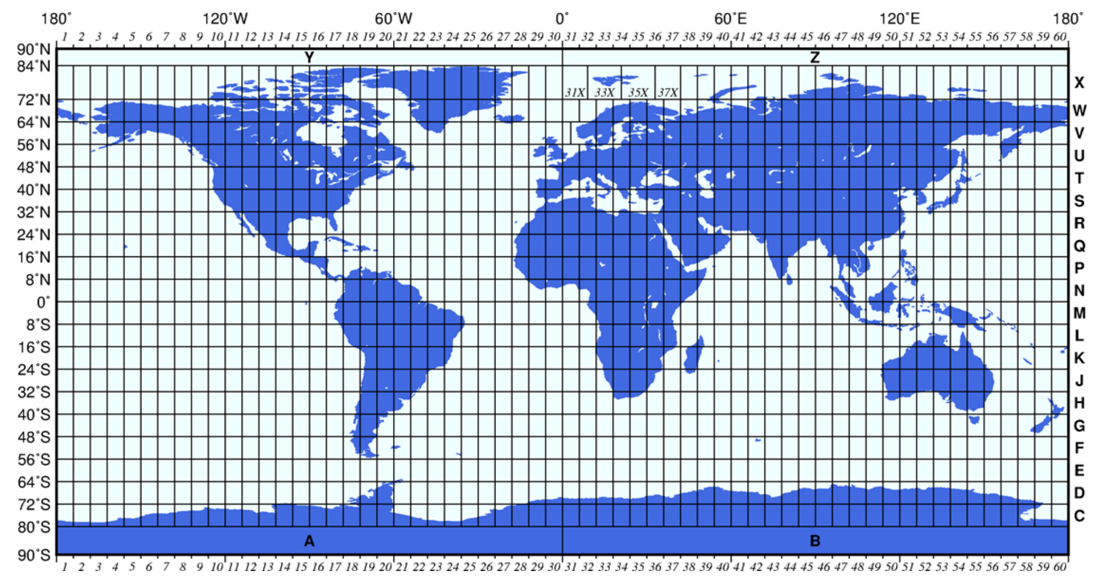
Limitations:

- not conformal and not equal area; only distances between points on the equator are correct
- the same problems as an analysis with unprojected maps in GIS
- a straight line on a map with this projection is not the shortest path

The Universal Transverse Mercator Projection (UTM)



equal area



Source: http://www.drillingformulas.com/universal-transverse-mercator-application-in-directional-drilling/

The Universal Transverse Mercator Projection (UTM)

- Based on Mercator projection
  - Transverse means that a cylinder wraps Earth around the poles rather than the equator
- 60 zones with 6 degrees width
  - Each zone has different projection
- Conformal (preserve shapes)
- Represented in Northings and Eastings.
- Widely used in
  - Military applications
  - Datasets with global or national coverage

The Universal Transverse Mercator Projection (UTM)

Limitations:

- more problematic at higher latitudes
  - above 80°
- more critical for cities that cross zone boundaries e.g., Calgary Alberta, Canada (between Zone 11 and 12)
  - one zone can be extended to cover the entire city but that will cause size distortions; defining a special zone might help reduce inaccuracy (e.g. Italy is split into Zones 32 and 33)

Exercise 1

LOCATIONS ON EARTH – LATITUDE AND LONGITUDE