The Earth

Question

How do we know the internal structure of the Earth?

Data Table

Table 8-1 Earth Data

Average distance from the Sun:	1.000 AU = 1.496×10^8 km
Maximum distance from the Sun:	1.017 AU = 1.521×10^8 km
Minimum distance from the Sun:	0.983 AU = 1.471×10^8 km
Eccentricity of orbit:	0.017
Average orbital speed:	29.79 km/s
Orbital period:	365.256 days
Rotation period:	23.9345 hours
Inclination of equator to orbit:	23.45°
Diameter (equatorial):	12,756 km
Mass:	5.974×10^{24} kg
Average density:	5515 kg/m^3
Escape speed:	11.2 km/s
Albedo:	0.39
Surface temperature range:	Maximum: 60°C = 140°F = 333 K Mean: 9°C = 48°F = 282 K Minimum: −90°C = −130°F = 183 K

(NASA) R I V U X G

Regions to Investigate

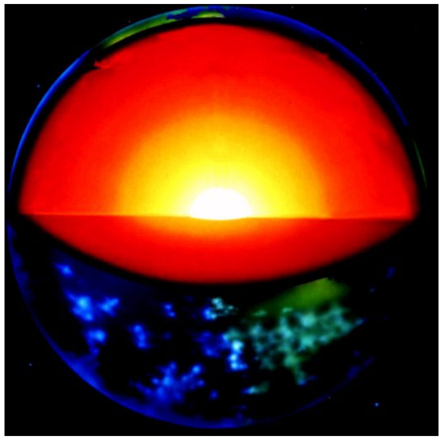
The Interior

The Surface

The Atmosphere

The Magnetosphere

The Interior

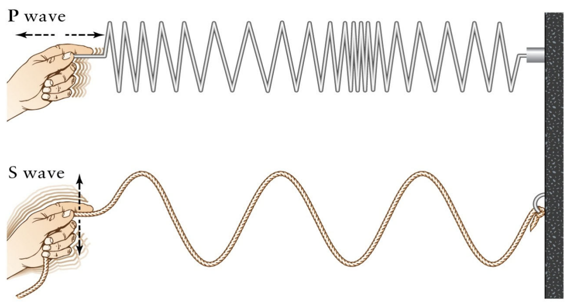


Density

The density of surface rocks is 2.5 to 3.0 g/cm^3.
The average density of the planet is 5.5 g/cm^3.
Hence the interior must be very dense.

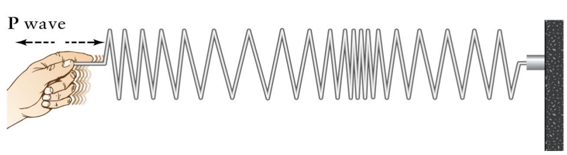
Seismic Waves

P waves – longitudinal, pressure waves
S waves – transverse waves
L waves – rolling



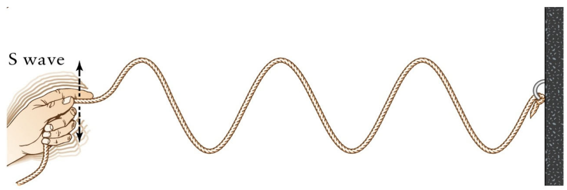
P Waves

P waves – Pressure waves
(Primary waves)
Faster of the Two Waves
Travels thru **Solids & Liquids**

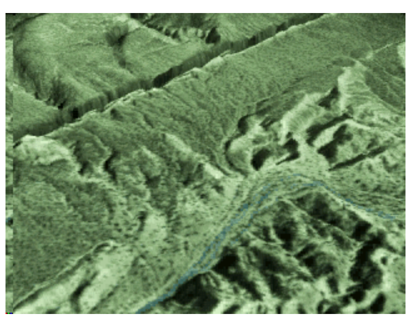


S Waves

S waves – Transverse waves
(Secondary waves)
Slower of the Two Waves
Travels thru **Solids ONLY**

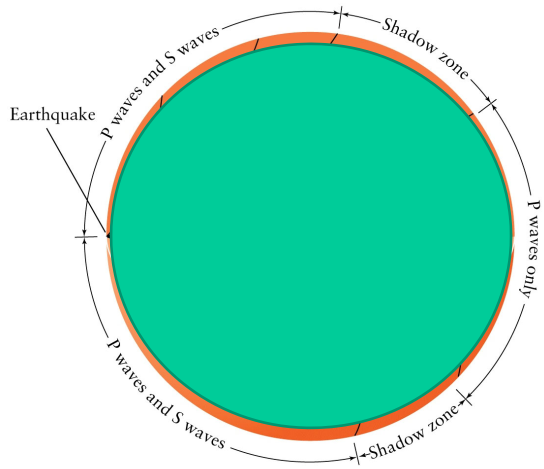


Earthquakes

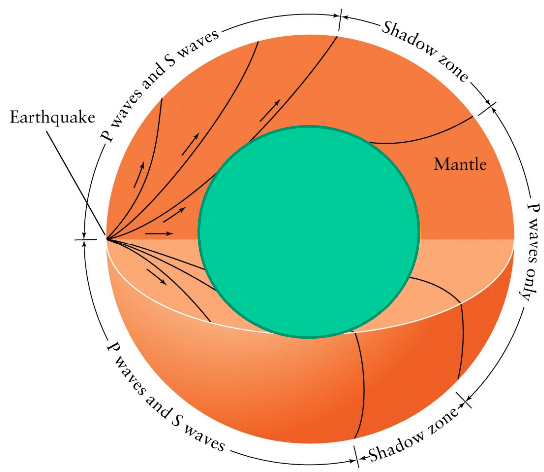


Epicenter

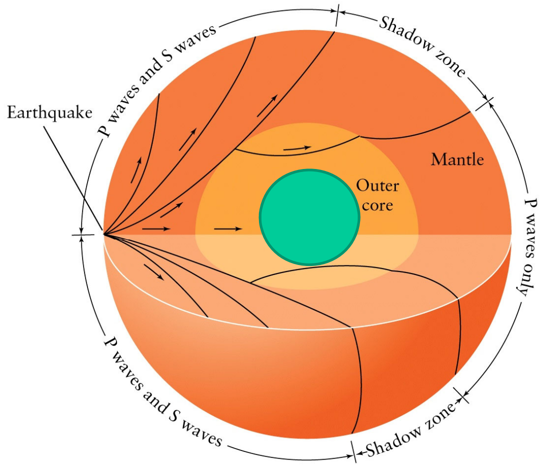
Seismic Results



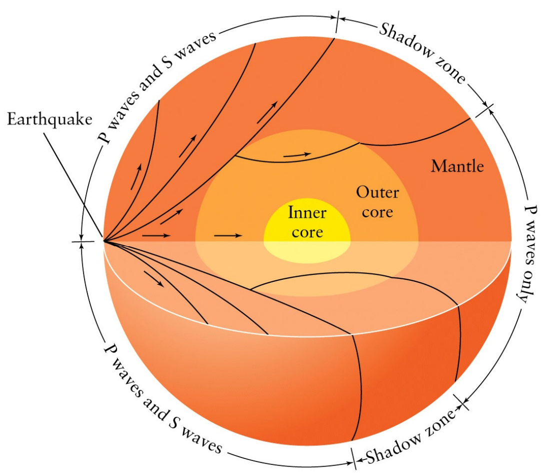
Seismic Results



Seismic Results



Seismic Results



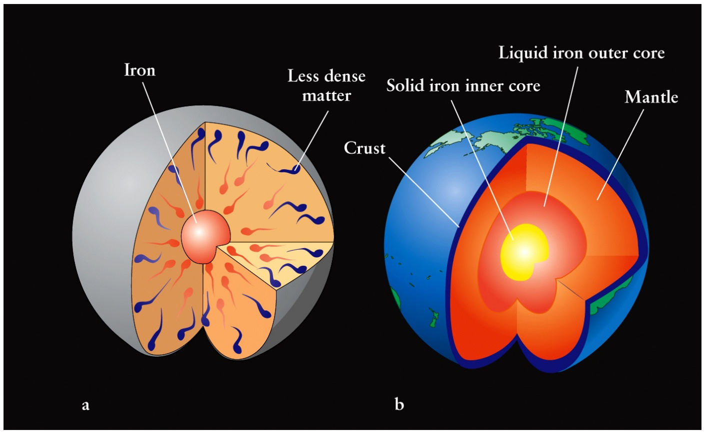
Structure

Inner core	solid (iron, nickel)	0000 to 1200 km	19%	13 g/cm^3
Outer core	liquid (iron, nickel)	1200 to 3500 km	55%	11 g/cm^3
Mantle	ooze (iron, Mg, Si)	3500 to 6400 km	99%	4.5 g/cm^3
Crust	ocean (basalt)	8 km thick		
	continental (granite)	20 to 70 km thick		3.5 g/cm^3

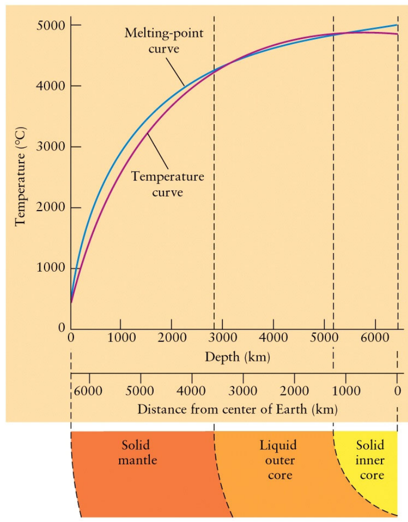
Excellent Homework Problem:

Calculate the Volumes and Masses of the Inner Core, the Outer Core, and the Mantle.

Differentiation



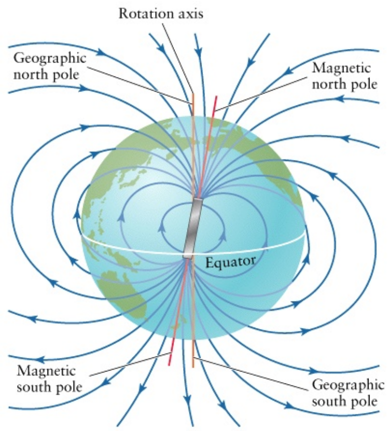
Temperature of the Interior



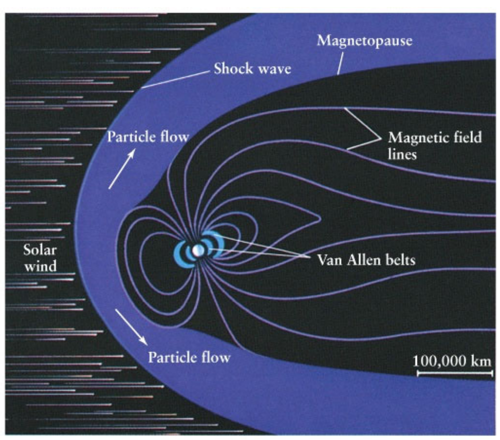
Why is the Earth's Core Hot?

1. Heat left over from the formation of the Earth.
2. Gravitational pressure by tidal forces and the rotation of the Earth.
3. Radioactive decay of elements in the inner part of the Earth.

The Magnetosphere



The Magnetosphere



What Generates the Magnetic Field?

There are two components necessary for a strong magnetic field:

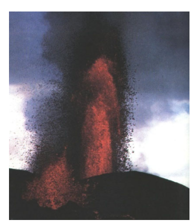
1. There has to be fluid motion to generate the field. The Earth's magnetic field is produced by the electric currents found in the *liquid, outer core*.

2. Rapid rotation is necessary. The Earth's 24 hour rotation is slower than that of the Jovian planets, but nevertheless it is considered to be a rapid rotator.

Aurora

The Surface

Geologic Processes



Endogenic source is from internal activity (e.g., volcanism)

Exogenic source is from external processes (e.g., impacts)

Initial Evidence for Motion

Alfred Wegener, 1880 - 1930

Plate Tectonics

Lithosphere mobile, top, crust
Asthenosphere convective zone in the mantle

Continents Granite
Oceans Basalt

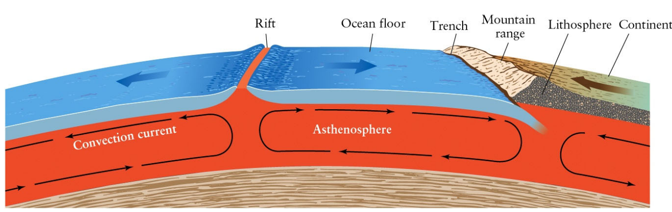
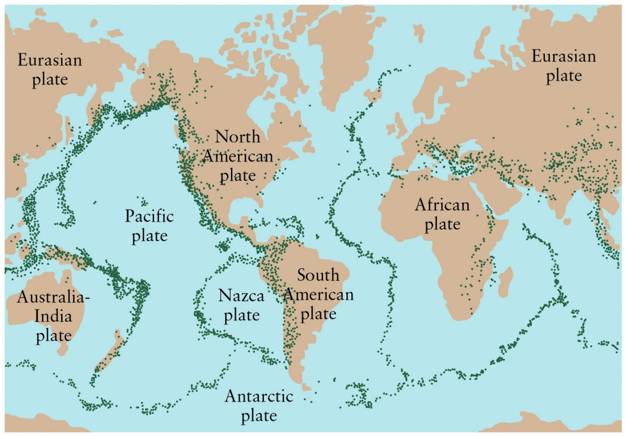
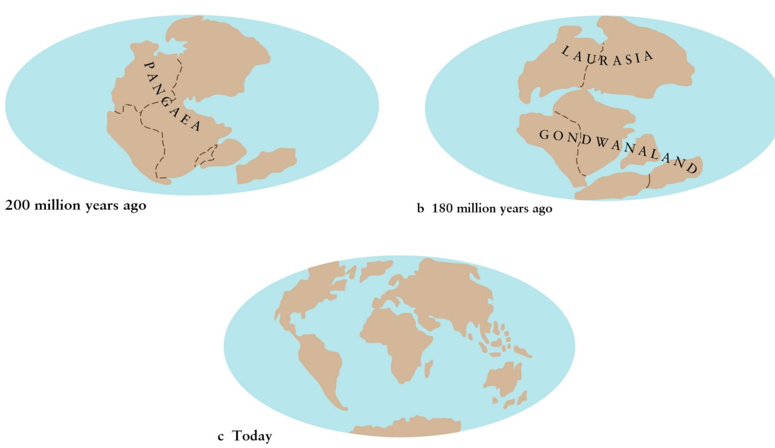


Plate Boundaries



The green dots indicate sites of major earth-quake activity. These are the plate boundaries.

Breakup of the Supercontinent



a 200 million years ago

b 180 million years ago

c Today

Plate Interactions

Rift Zones

Two plates get pushed apart.

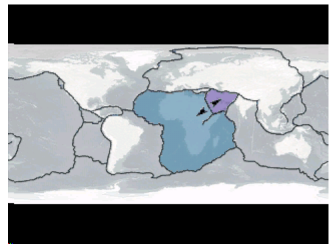


Plate Interactions

Subduction Zones

An oceanic plate is pushed under a continental plate.

Much of the Earth's surface has been destroyed and recycled by this process.

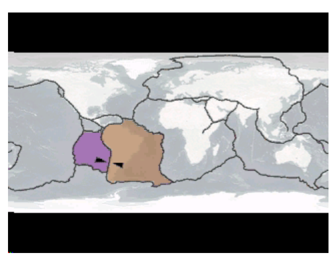


Plate Interactions

Fault Zones

Two plates move along side of each other.

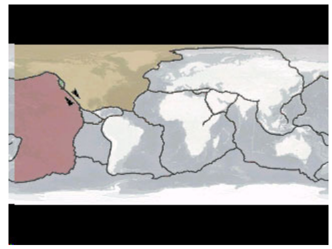
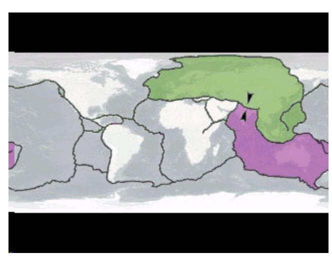


Plate Interactions

Mountain Building Zones

Two continental plates move into each other.



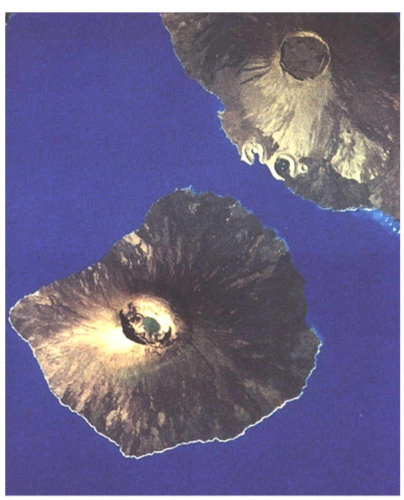
Three Types of Volcanoes

Shield

Eruptive

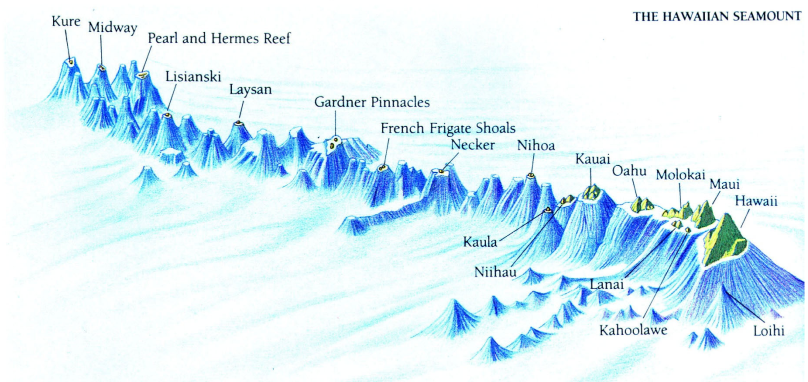
Flood Plain

Volcanoes – Shield



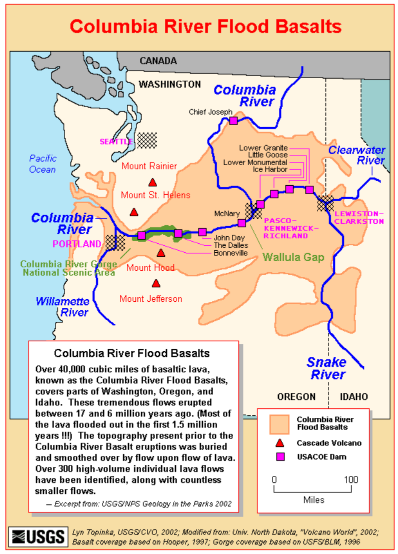
Caldera

Volcanoes – Shield Chains



Volcanoes – Eruptive

Volcanoes – Flood Plains



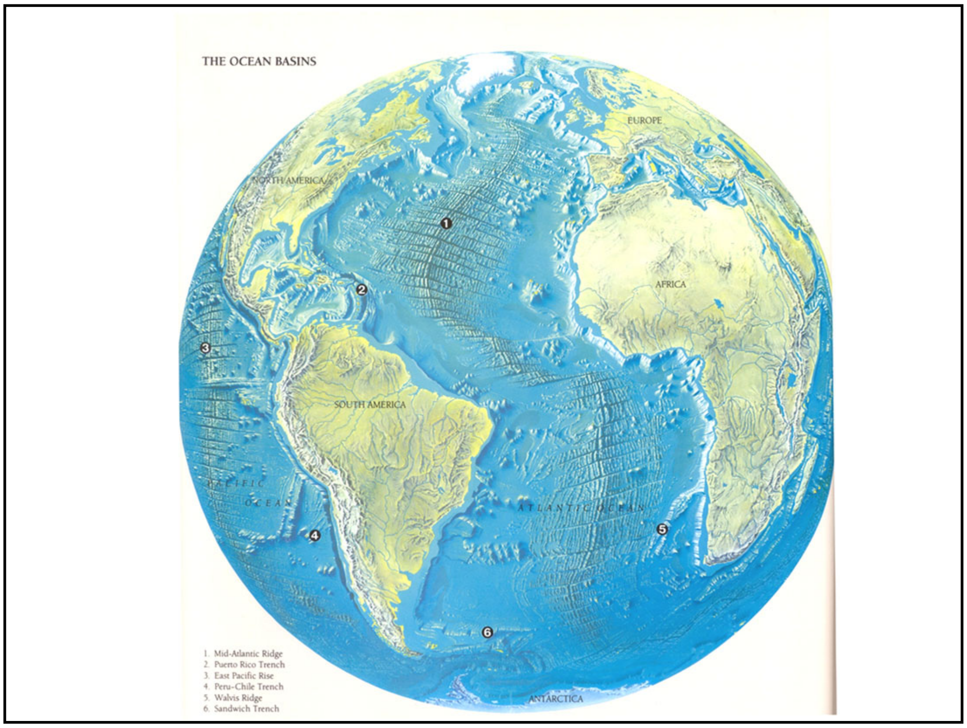
Oceans

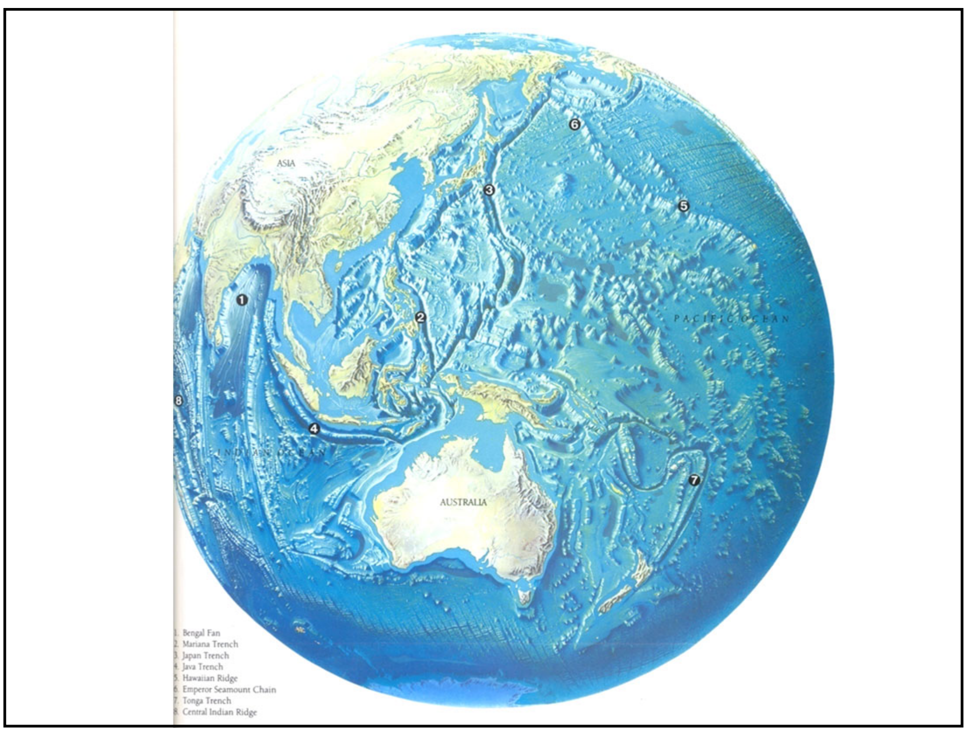
Creation of the Oceans

The oceans were formed over the millennia from steam given off from the interior of the Earth by the action of volcanoes, and they acquired their salty composition by the continual weathering and leaching of the rocks through countless cycles of evaporation and precipitation.

This has resulted in the composition of sea water being 3.5% by weight of dissolved salts, a percentage that remains constant within very narrow limits throughout the world's oceans.

Today, the oceans cover 70% of the Earth's surface.


THE OCEAN BASINS
EUROPE
NORTH AMERICA
AFRICA
SOUTH AMERICA
ATLANTIC OCEAN
ANTARCTICA
1. Mid-Atlantic Ridge
2. Puerto Rico Trench
3. East Pacific Rise
4. Peru-Chile Trench
5. Walvis Ridge
6. Sandwich Trench


ASIA
PACIFIC OCEAN
AUSTRALIA
1. Bengal Fan
2. Mariana Trench
3. Japan Trench
4. Java Trench
5. Hawaiian Ridge
6. Emperor Seamount Chain
7. Tonga Trench
8. Central Indian Ridge

Ocean Currents

Navigators have known for thousands of years that the oceans have variable winds and variable currents. However, it has only been during the last half-century that a reasonable picture has emerged of the patterns of ocean currents and their underlying causes.

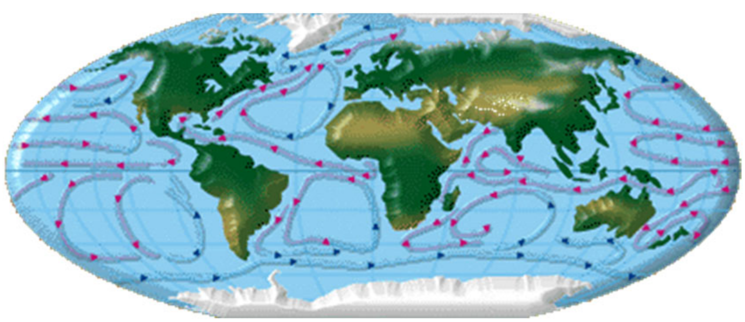
(1) The major force setting up and maintaining the oceanic current system is that of the prevailing winds.

(2) The direction of the current flow is governed by

(a) the winds and

(b) the rotation of the Earth.

Surface Circulation

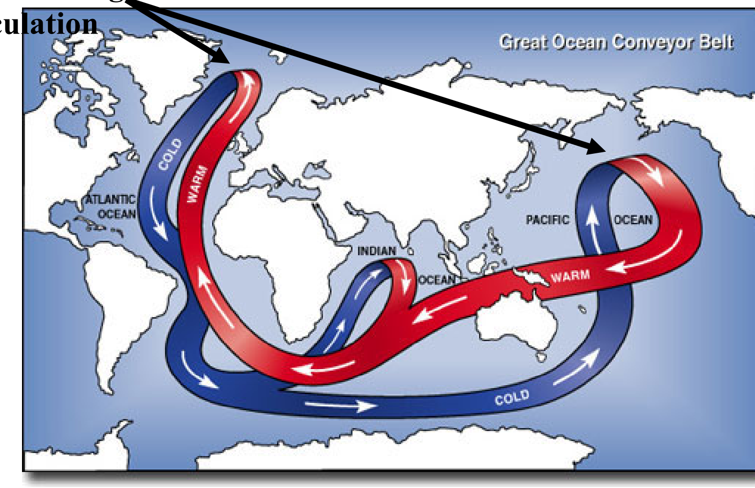


http://oceansjsu.com/105/exped_circulation/1.html

Oceanic Conveyor Belt of Heat

A conceptual model of global ocean circulation.

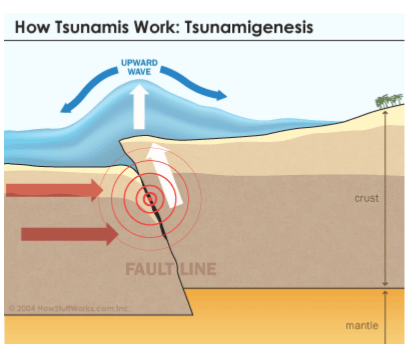
Overturning circulation

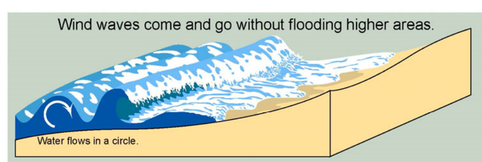


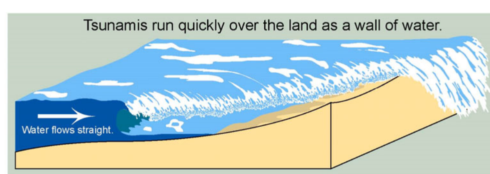
W.Broecker (Columbia U.); http://www.anl.gov/Media_Center/Frontiers/2003/

Tsunamis

Tsunamis are often no taller than normal wind waves, but they are much more dangerous.



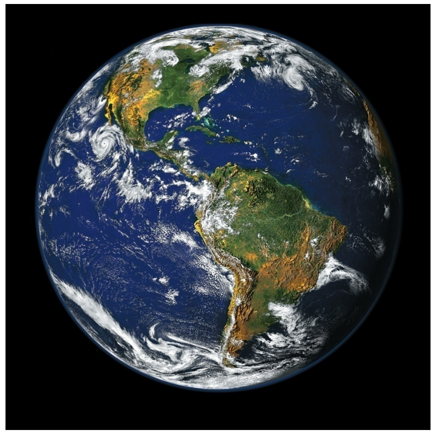




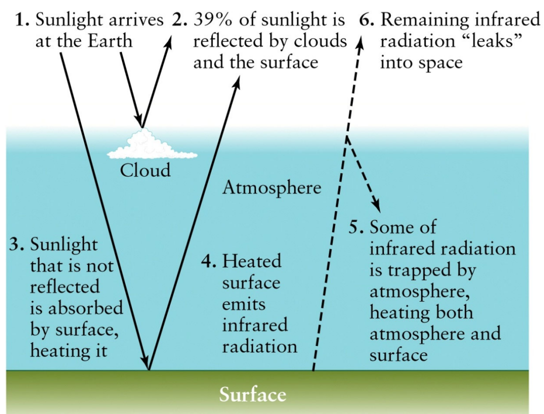
Even a tsunami that looks small can be dangerous!

Any time you feel a large earthquake, or see a disturbance in the ocean that might be a tsunami, head to high ground or inland.

The Atmosphere



Greenhouse Effect



Albedo: Percent of sunlight that is reflected.

Theories of Formation

1. Was formed with the rest of the planet
2. Was released via volcanoes later
3. Was derived from impacts by comets

History of the Atmosphere

1. Original gases had the same composition as the solar nebula. The gases were at first trapped, but as the Earth heated and became molten, the gases were released from the rocks. The Earth's gravity was too weak to retain free Hydrogen and Helium, but the Hydrogen combined with Oxygen to produce water (H_2O).

2. As the Earth cooled, the water vapor condensed into raindrops and fell to the surface, creating the oceans. (If the only atmospheric constituent was water, then the oceans would have frozen. Because this is not the case, there must have been other, greenhouse gases that kept the Earth warm.)

History of the Atmosphere

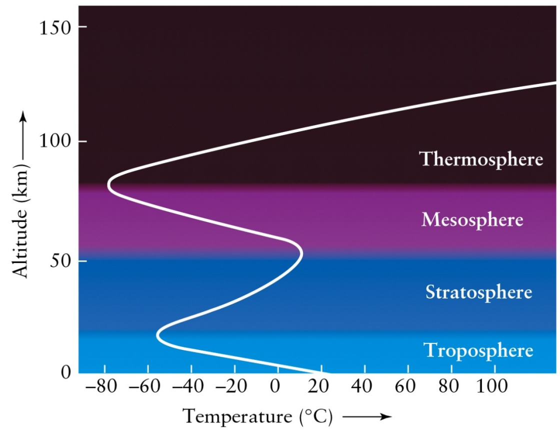
3. The other gas is carbon dioxide (CO_2), which must have been very abundant. Most of the CO_2 was not lost to space (it is too heavy), but it was removed from the atmosphere by the rain. Most of the Earth's CO_2 is now trapped in ocean rocks. [Some CO_2 is returned to the atmosphere by subduction zones that melt the ocean rocks.]

4. Once plant life began and flourished, CO_2 was converted via photo-synthesis into O_2. Later, animal life converted the O_2 back to CO_2.

Composition of the Atmosphere

Gas	%
Nitrogen (N_2)	78.1
Oxygen (O_2)	21.0
Argon (Ar)	0.93
Carbon Dioxide	0.03
Neon	0.002

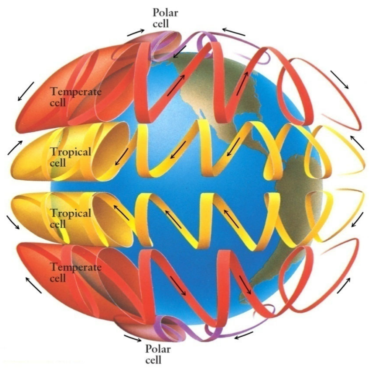
Temperature of the Atmosphere

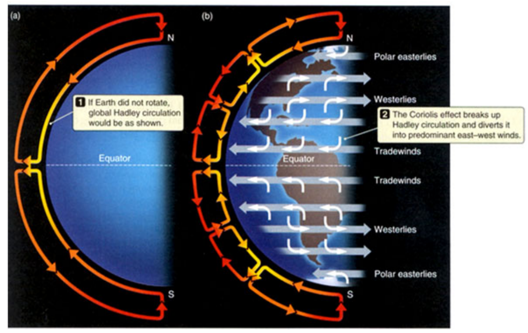


Structure of the Atmosphere

1. Troposphere	00 - 10 km
2. Stratosphere	10 - 65 km
3. Mesosphere	65 - 85 km
4. Thermosphere	80 - 400 km

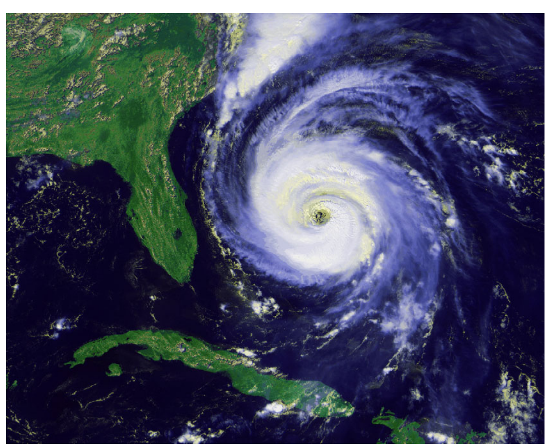
Wind Circulation Patterns





Hadley cells are circulation flows. The dominant circulation in our atmosphere consists of six convection cells. The poleward-equatorward flow is diverted into zonal flow by the **Coriolis effect.**

Hurricanes



NOAA Hurricane Center

Hurricanes

A tropical cyclone is a rapidly rotating storm system characterized by a low-pressure center, strong winds, and a spiral arrangement of thunder-storms that produce heavy rain.

Depending on its location and strength, a tropical cyclone is referred to by names such as

> hurricane, typhoon, tropical storm, cyclonic storm,
> tropical depression, and simply cyclone.

Hurricanes

The term "tropical" refers to the geographical origin of these systems, which form almost exclusively over tropical seas.

The term "cyclone" refers to their cyclonic nature, with wind blowing counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.

The opposite direction of circulation is due to the Coriolis effect.

Hurricanes

Tropical cyclones typically form over large bodies of relatively warm water. They derive their energy from the evaporation of water from the ocean surface, which ultimately re-condenses into clouds and rain when moist air rises and cools to saturation.

The strong rotating winds of a tropical cyclone are a result of the (partial) conservation of angular momentum imparted by the Earth's rotation as air flows inwards toward the axis of rotation.

Cyclones are between 100 and 4,000 km (62 and 2,485 mi) in diameter.

Weather and Climate

Weather – short term

Climate – long term

Causes for Climate Change

I. Internal Forcing Mechanisms
- Ocean variability
- Volcanism
- Plate tectonics
- Life & Human influences

II. External Forcing Mechanisms
- Orbital variations
- Solar output