

Global Climate Change

Milankovitch Cycles

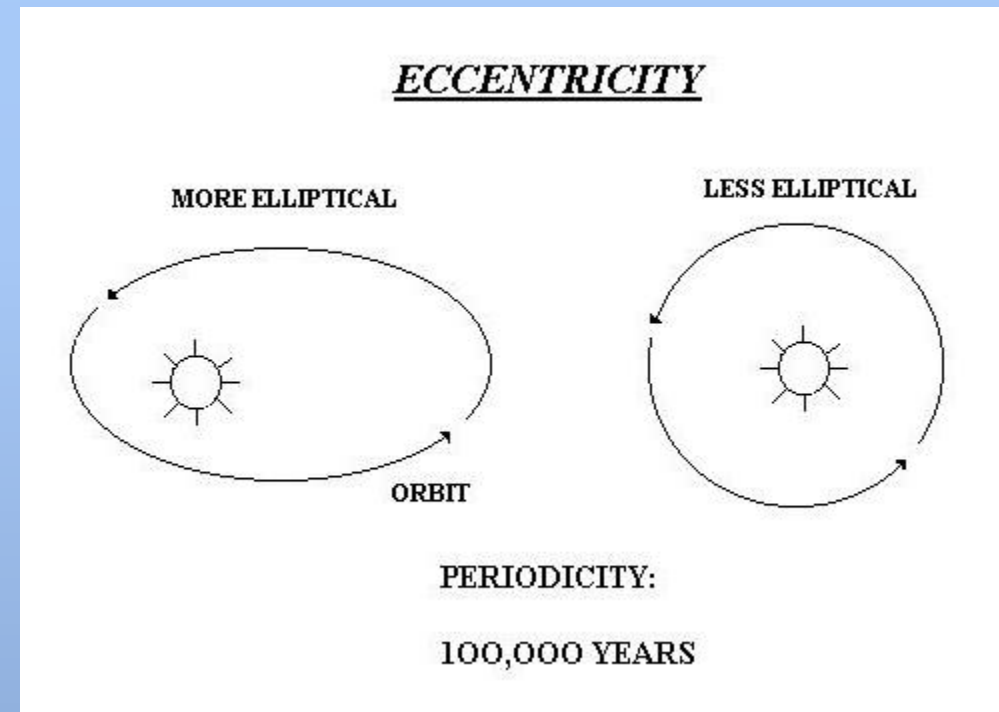
- Comprised of 3 dominant cycles:
 1. Eccentricity
 2. Axial Tilt
 3. Precession
- Named after Milutin Milankovitch. Serbian astronomer/mathematician. Credited with calculating their magnitude.
- Changes in the these 3 cycles creates alterations in the seasonality of solar radiation reaching the Earth's surface.

Milankovitch Cycles and Glaciation

- Times of increased or decreased solar radiation directly influence the Earth's climate system.
- Impacts the advance and retreat of Earth's glaciers.
- Climate change and resulting periods of glaciation resulting from the cycles is **not due to the total amount of solar energy reaching Earth.**
- The 3 cycles impact the **seasonality and location of solar energy** around Earth.
- Impacts the contrasts between seasons.

Eccentricity

- The shape of the Earth's orbit around the Sun.
- Constantly changing orbital shape.
- On a cycle of $\sim 100,000$ yrs
- Alters the distance from the Earth to the Sun
- Reduces or increases the amount of radiation received at the Earth's surface in different seasons.

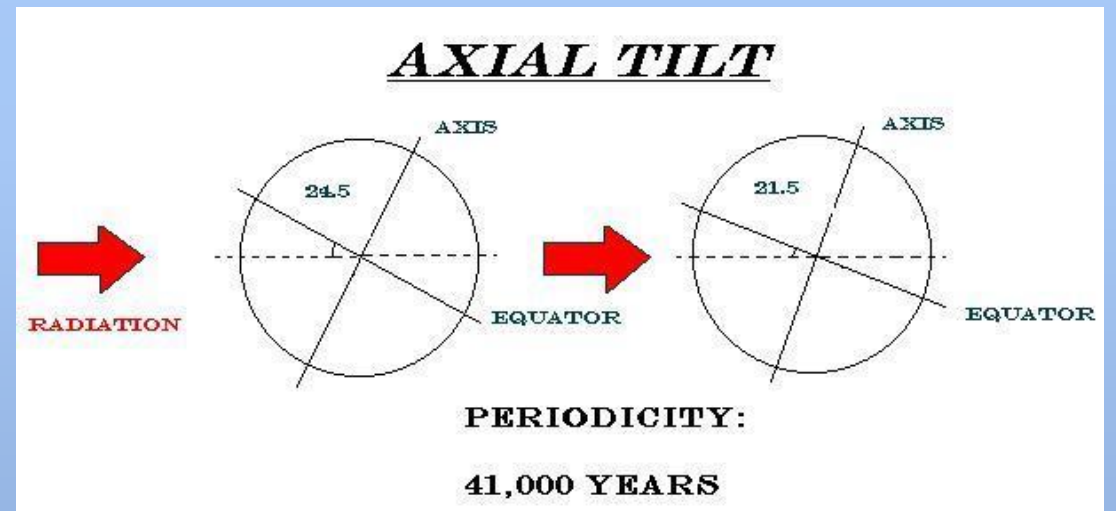


Eccentricity

- Only a 3% difference between the **aphelion** (farthest point) and the **perihelion** (closest point)
- When Earth's orbit is most elliptical the amount of solar energy received at the perihelion would be ~ 20-30% more than at the aphelion.
- These continually altering amounts of received solar energy result in big changes in the Earth's climate and glacial regimes.
- The orbital eccentricity is nearly at the minimum of its cycle.

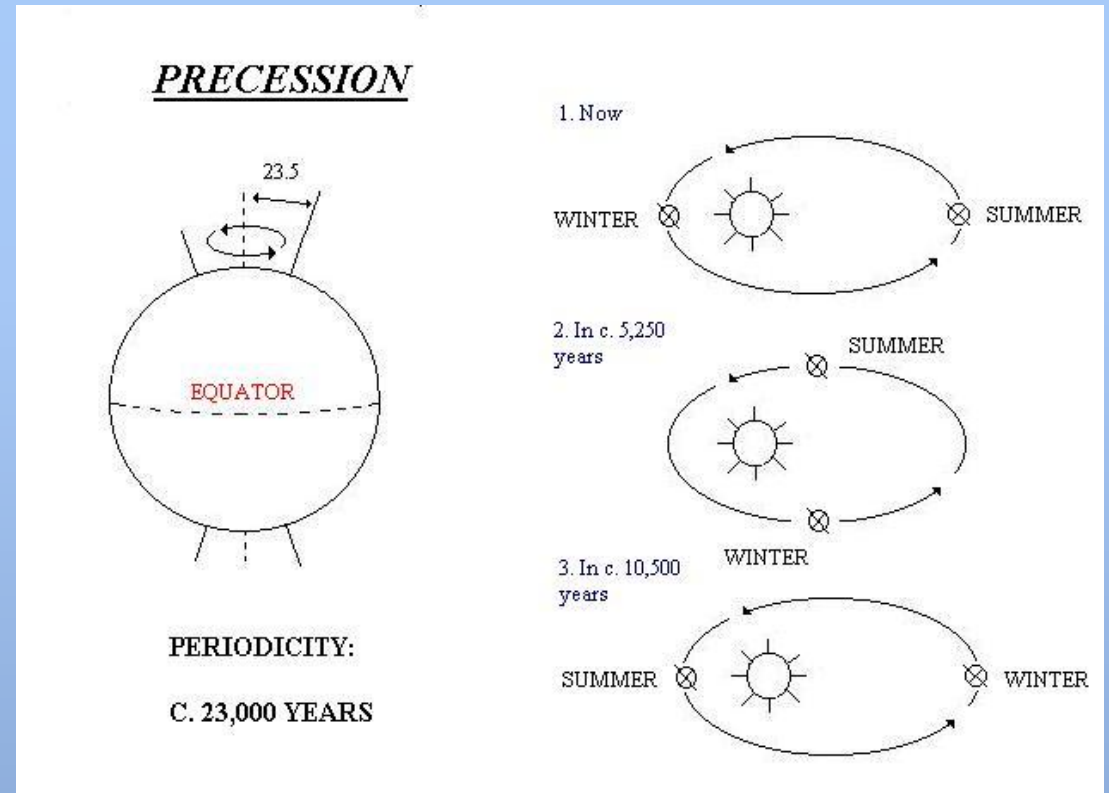
Axial Tilt

- The inclination of the Earth's axis in relation to its plane of orbit around the sun.
- Can change between 21.5° – 24.5°
- Currently it is 23.5°
- Accounts for our seasons.
- Less tilt = more even distribution of radiation between winter and summer.
- Less tilt = also increases the difference in radiation between the equator and polar regions.



Precession

- The Earth's slow wobble as it spins on its axis.
- Wobbles from pointing at the North star to pointing to Vega.
- Vega = Northern hemisphere will experience winter when the Earth is furthest from the sun and summer when the Earth is closest.
- Results in greater seasonal contrasts
- [this additional animation](#)

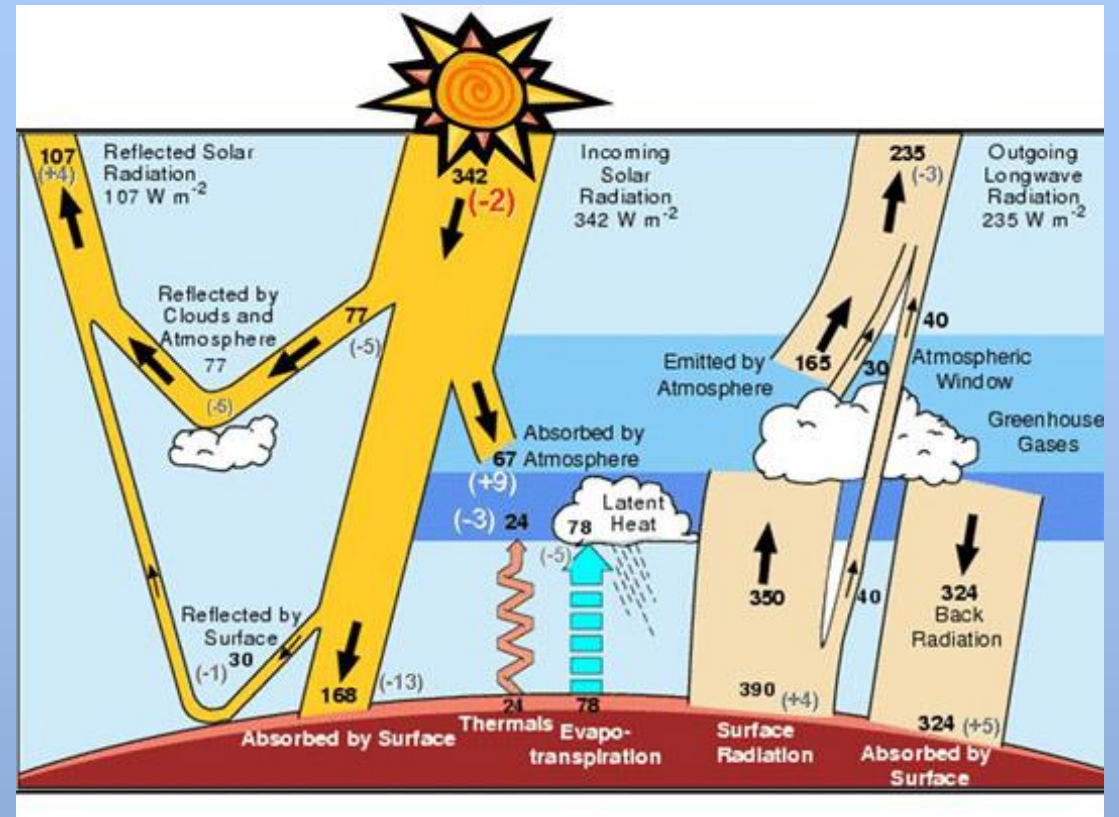


Milankovitch Cycles

- Simulation

Insolation

- It is a measure of the solar energy striking a specified area over a set period of time.
- The amount of energy that hits an area.
- Not all of the solar energy that reaches the Earth actually reaches the surface of the Earth.

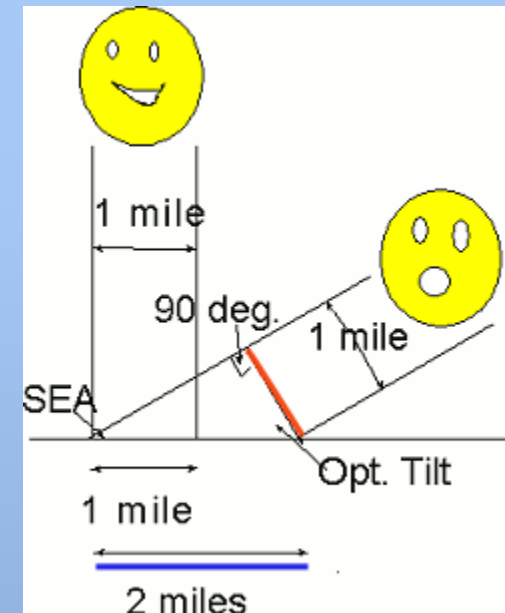


<http://solarinsolation.org/wp-content/uploads/2012/01/SolarRadiation.jpg>

Insolation

- Factors affecting how much sunlight reaches a given area:

1. Sun Angle
2. Air Mass
3. Day length
4. Cloud Coverage
5. Pollution Levels



<http://solarinsolation.org/wp-content/uploads/2012/01/suns.gif>

Natural Climate Change and External Forcings

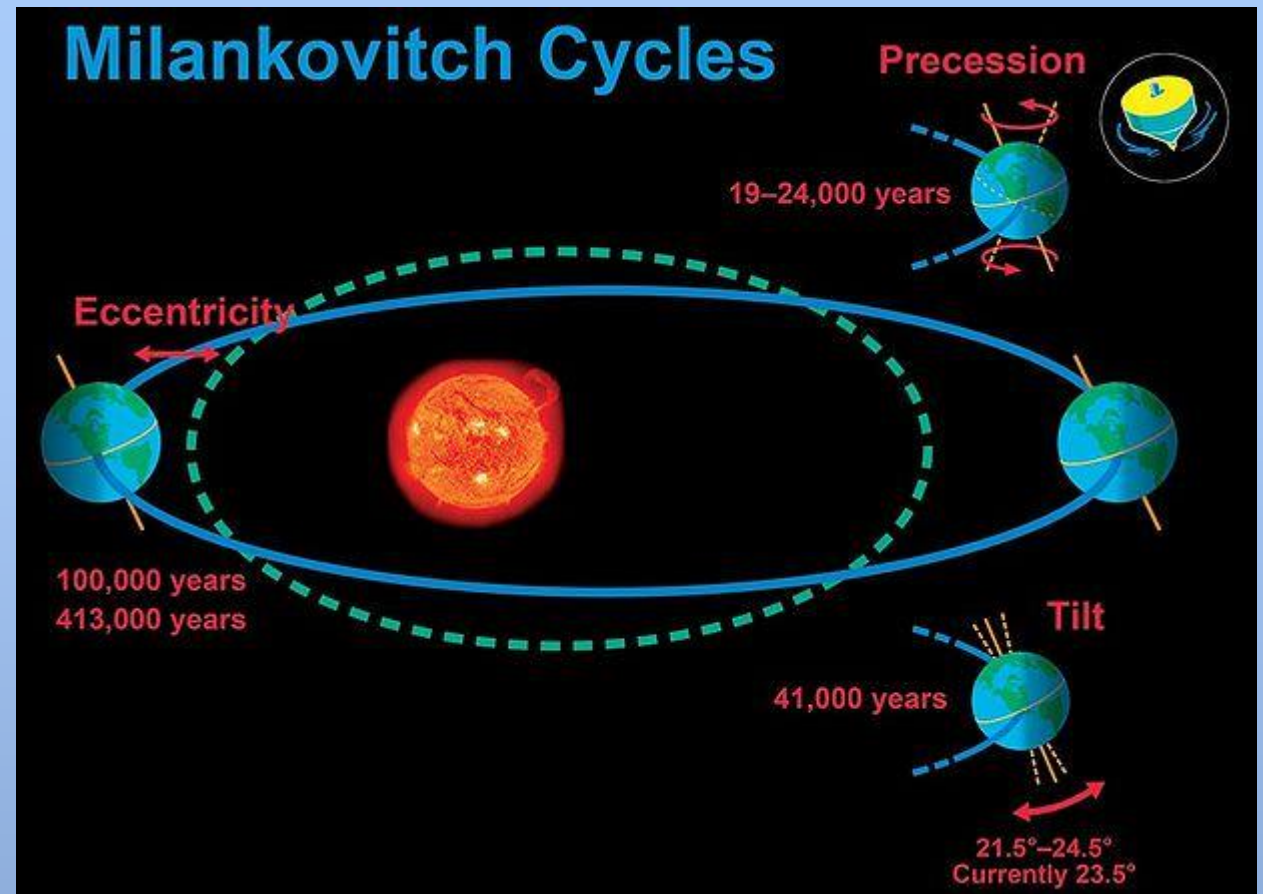
- **External Forcings:** changes in the amount of solar radiation and changes in the characteristics of the atmosphere.
- These naturally occurring processes contribute to long-term climate changes.

1. Long term changes – Milankovitch Cycles

Change in solar radiation

For Example:

- If the Earth is more tilted then the summers are warmer. This means ice melts and does not build up in the poles.
- If the Earth is less tilted the summers are cooler so ice builds up the poles.
- According to the Milankovitch cycles, if you take out all other factors, we should be in the middle of a **COOLING** period which started 6000 years ago and will continue for the next 23,000 years.

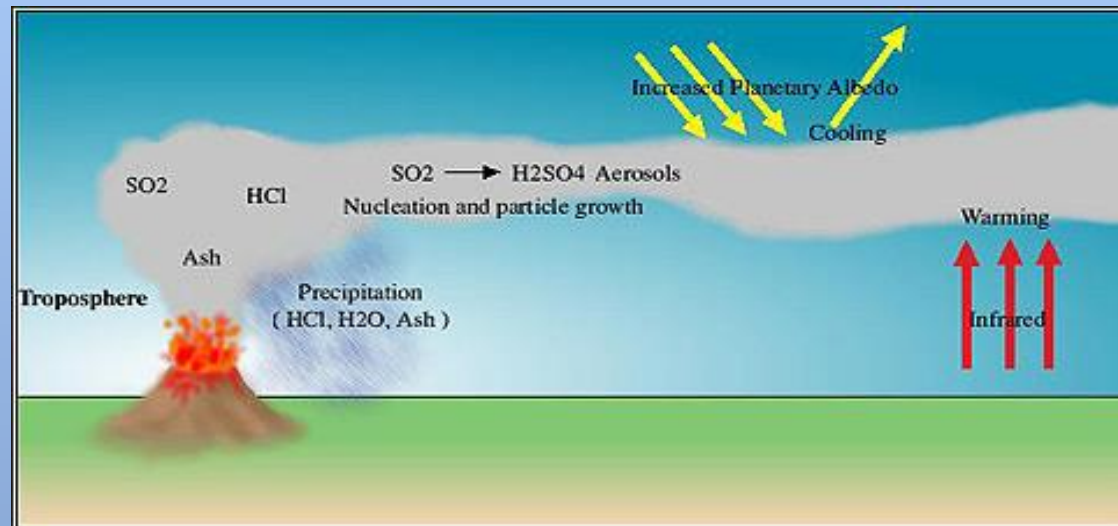


2. Variations in Solar Energy Sunspots change in solar radiation

- Sunspots are huge magnetic storms on the sun's surface which release increased solar radiation to Earth.
- During the last ice age (1645 – 1715) a decrease in sunspot activity was recorded.
- Sunspots have been recorded for over 400 years, and an 11 year cycle has been identified.
- Solar variation could account for up to 20% of the warming experienced in the twentieth century (IPCC, 2007).
- Recent (post 1978) measurements show that the earth has warmed but there has been **no** corresponding increase in sunspot activity therefore its short-term effects are disregarded.

3. Change in Atmosphere Albedo

- Large explosive volcanoes have a short term (1-3 year) cooling effect on the Earth's atmosphere because they release carbon dioxide, sulphur dioxide and particles of dust and ash into the atmosphere which increases atmospheric albedo (**reflecting incoming solar radiation**). Also there will be more absorption of solar radiation leading to a **reduction in solar radiation reaching the surface**

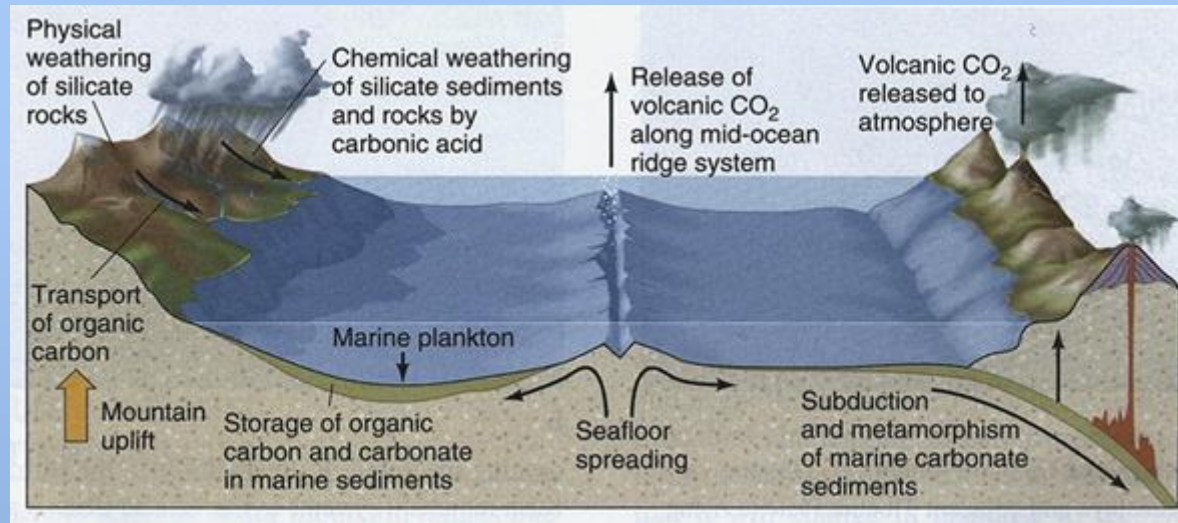


4. The Long term Carbon Cycle

Change in the Albedo of the Atmosphere

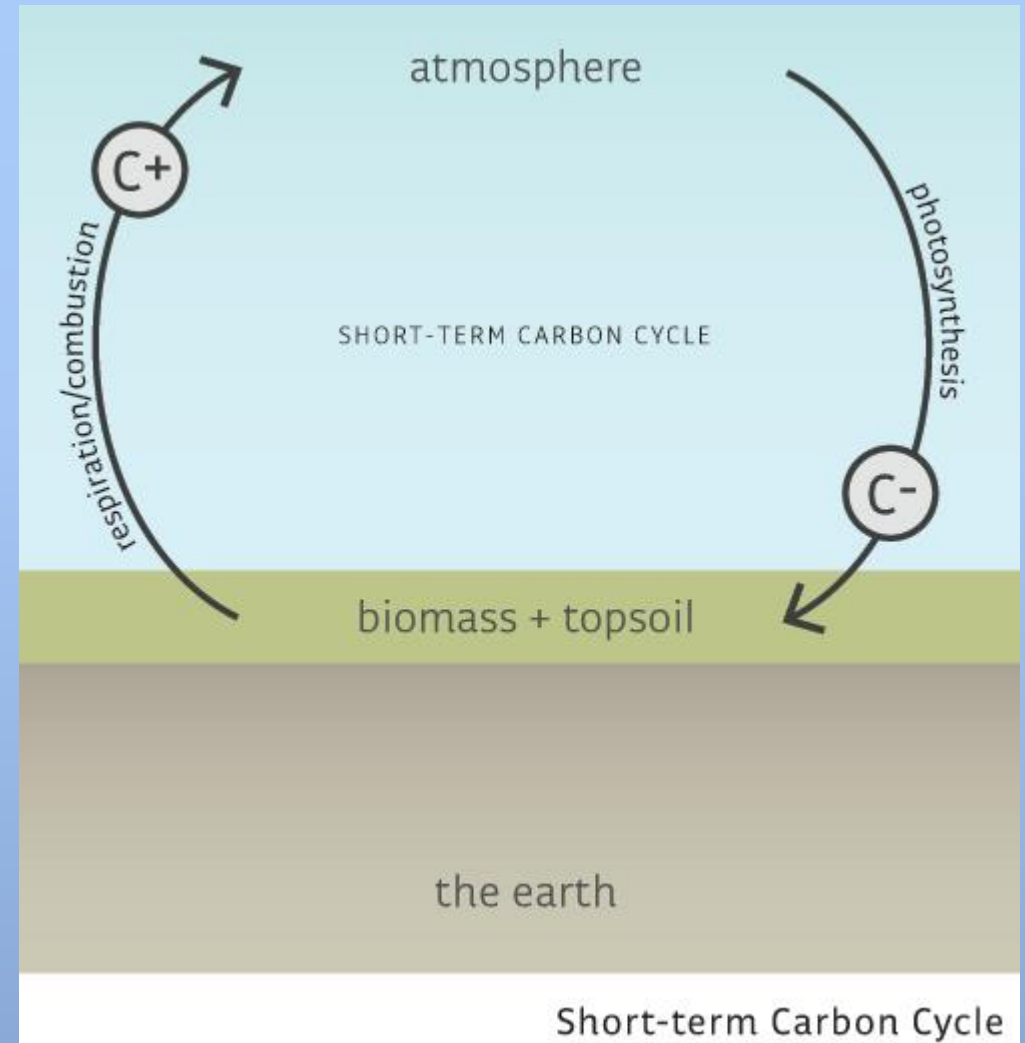
- Carbon dioxide is outgassed/released into the atmosphere from the lithosphere through tectonic activity. (Volcanic eruptions)
- Carbon dioxide stays in the atmosphere until it is washed out of the atmosphere by rain.
- This mildly acid rainwater dissolves rocks in a process of chemical weathering forming calcium carbonate in solution.
- The calcium carbonate in solution goes into rivers and then into the sea.
- In the sea the calcium carbonate in solution is removed from the water by coral and other sea organisms.
- When the coral dies it falls to the sea bed and slowly forms limestone.
- Through tectonic processes the limestone is slowly moved to a destructive plate boundary where it is finally pushed down into a subduction zone and re – released into the atmosphere in a volcanic eruption.

This would lead to long-term variations in the amount of CO₂ in the atmosphere. We are literally talking millions of years here. This **does not** explain recent change in the last few decades.



The Short Term Carbon Cycle

- Plants 'fix' or 'sequester' carbon out of the atmosphere through the process of photosynthesis.
- When plants die they decompose and the carbon is re-released into the atmosphere as the decomposers respire.

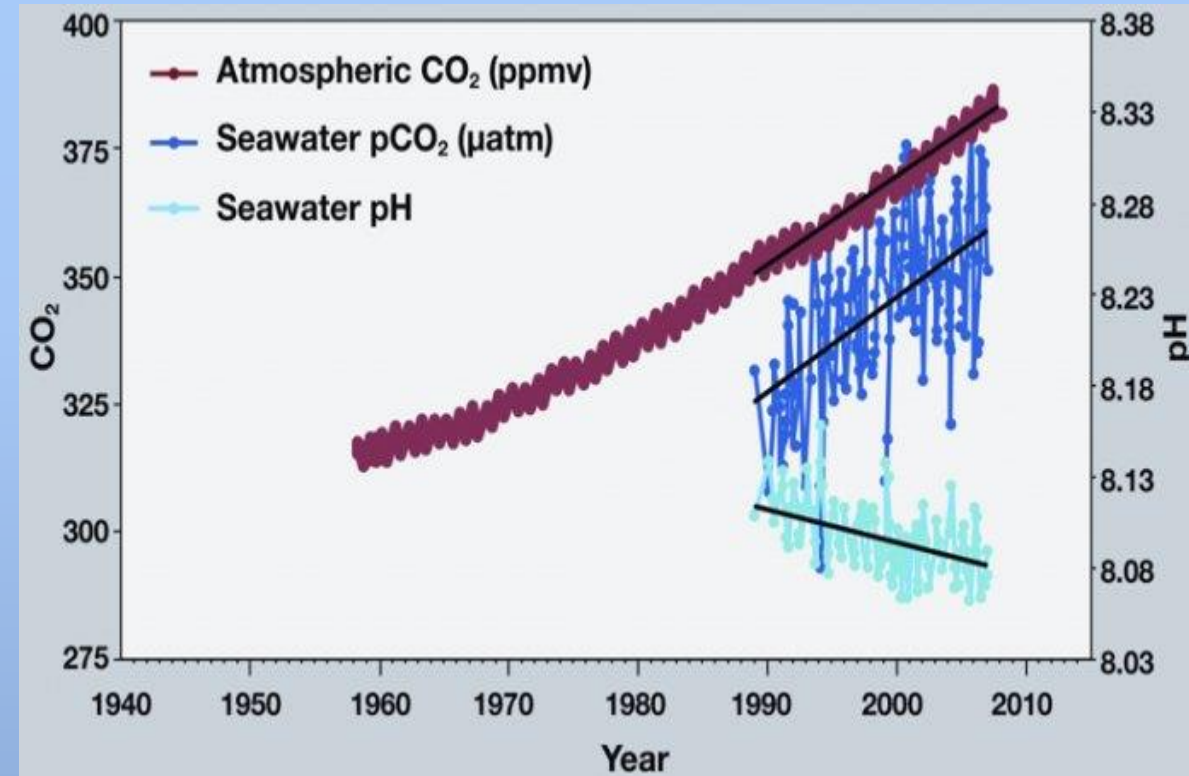


But what happens if, over millions of years, that carbon gets locked into the lithosphere and forms coal (in the case of plants) or oil and natural gas (in the case of sea creatures)?

and then if in a few hundred years we burn huge amounts of it...

A Rapid Warming!!!

video



video link

ice cores

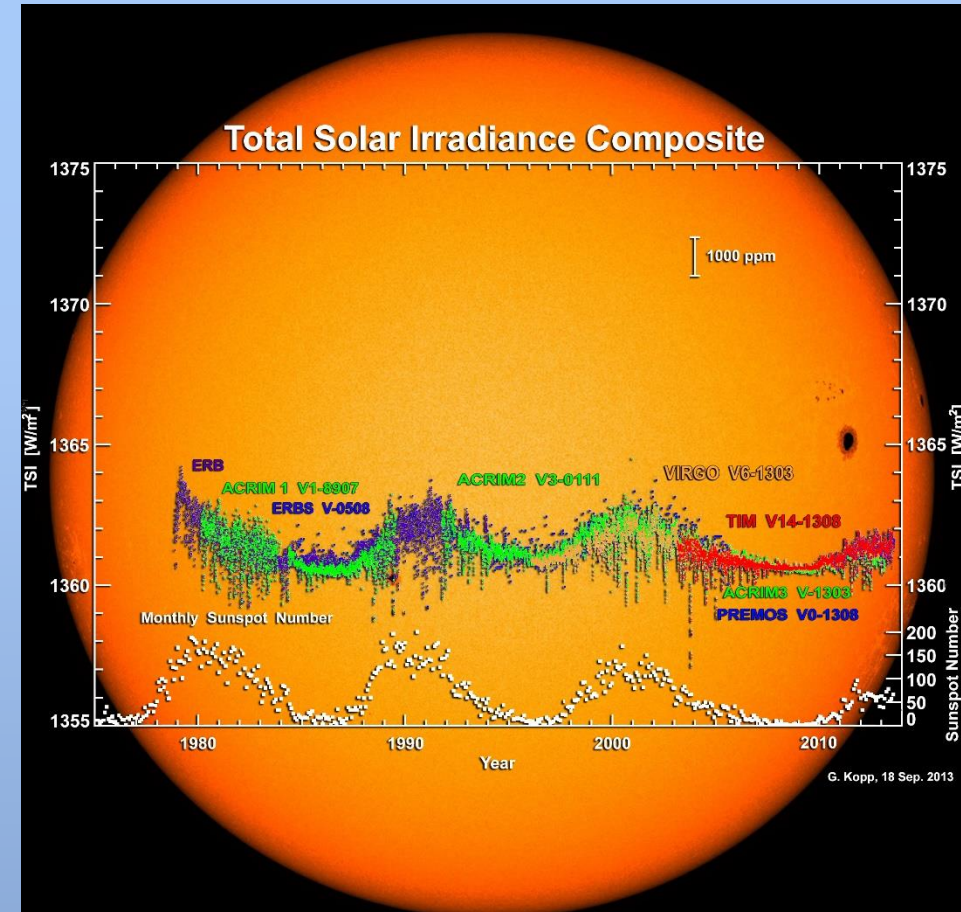
simulation

review of tilt

Solar Irradiance

- Refers to the amount of energy emitted by the Sun over all wavelengths that fall per second on 11 sq ft outside the Earth's atmosphere.
- In simpler terms, it is the amount of radiant energy coming from the Sun which human beings are able to see.
- It is the radiant energy which is sent directly towards the Earth.

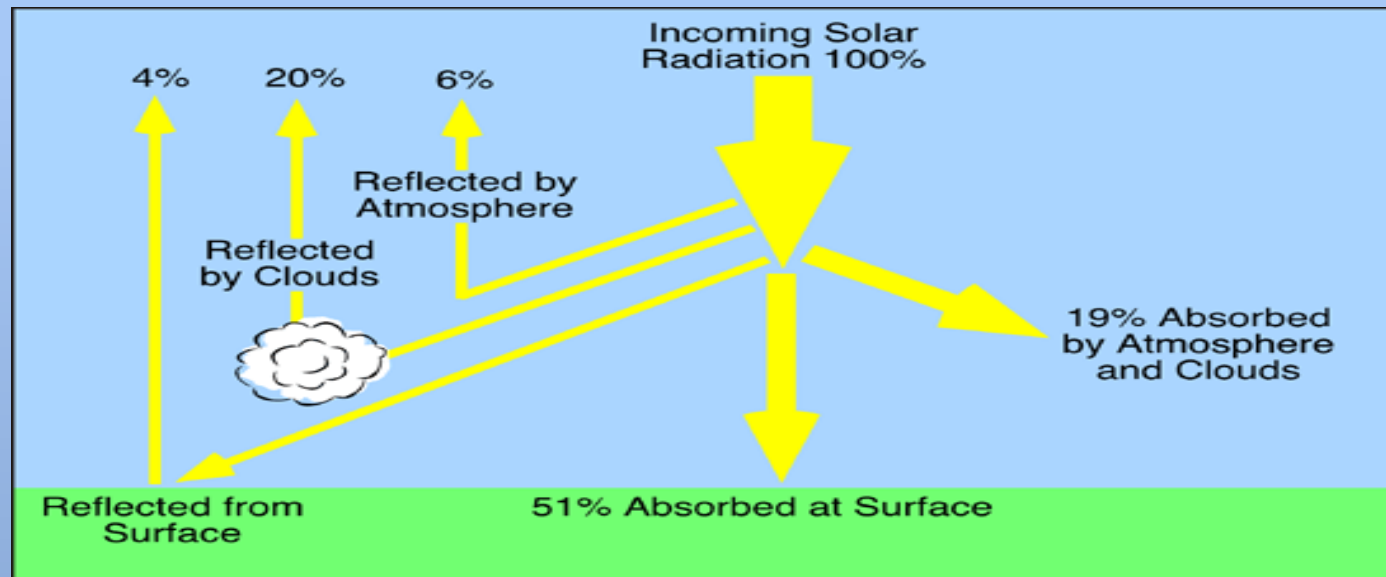
<http://planetfacts.org/solar-irradiance>



<https://3c1703fe8d.site.internapcdn.net/newman/gfx/news/hires/2013/2-newinstrumen.jpg>

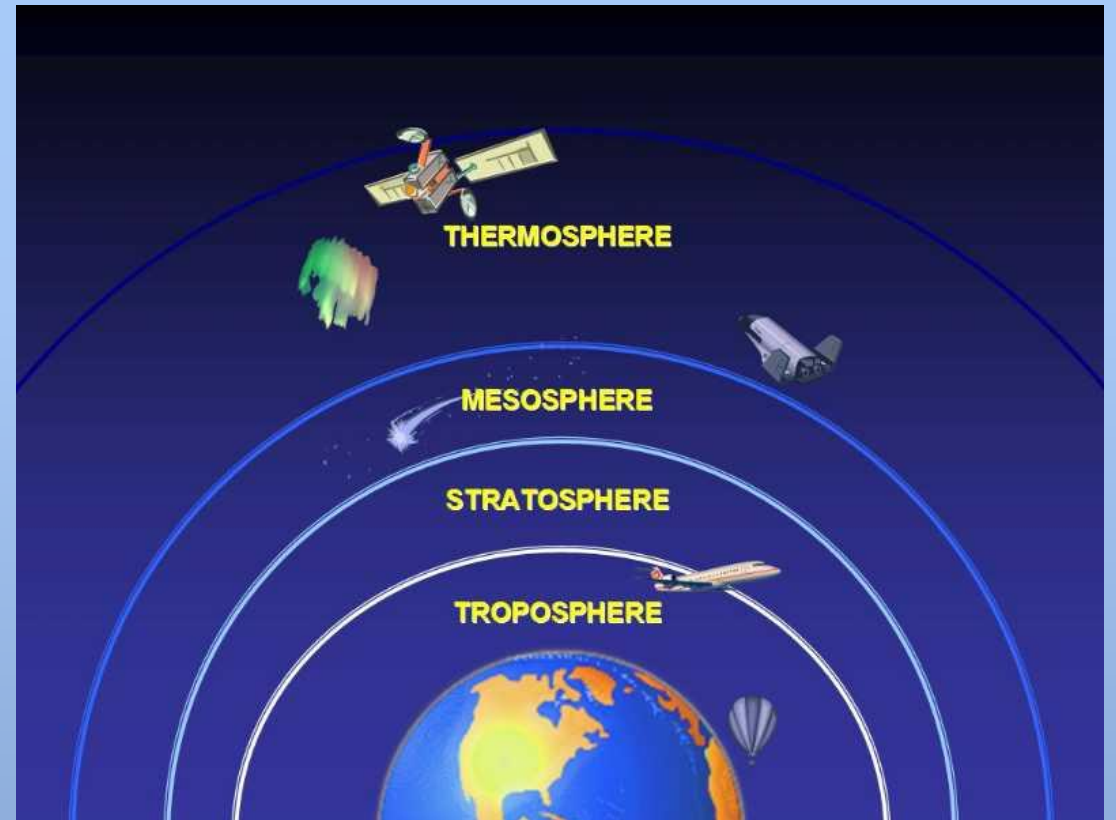
INcoming SOLar RadiATION

- Energy from the sun that interacts with our atmosphere, hydrosphere, and lithosphere.
- Most is in the form of visible light.



Earth's Atmosphere

- Troposphere: Layer closest to Earth. Where weather occurs. Densest because of weight of all other layers.
- Stratosphere: Layer above troposphere. Contains the ozone layer.
- Mesosphere: Coldest layer.
- Thermosphere: Warmest layer.
- Exosphere: Outermost portion of thermosphere.



How does the Earth's atmosphere affect Insolation?

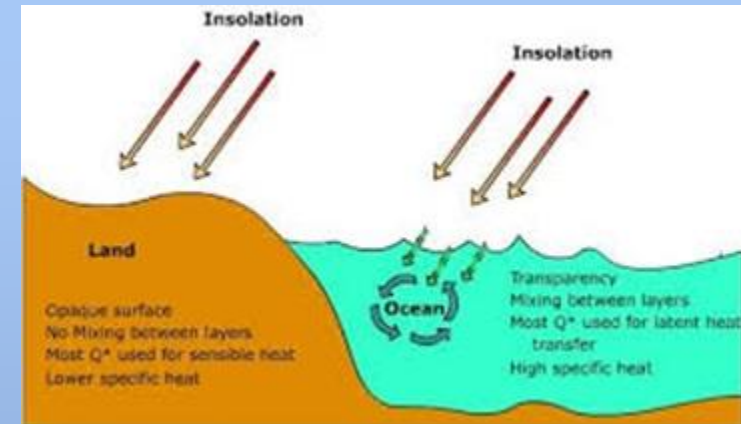
- Most incoming ultraviolet radiation and other shortwave radiation are **absorbed** by the atmosphere.
- Most U-V is absorbed by the **ozone (O₃)** layer found in the stratosphere.
- The longer waves such as infrared radiation (heat) are absorbed by other gases such as **carbon dioxide (CO₂)**, **methane**, and **water vapor**. This warms the atmosphere.

Radiative Balance

- Clouds in the lower atmosphere (Troposphere) reflect *insolation* back out into space.
- Insolation can be *scattered* by gases and aerosols (pollutants)
- Example- O₂ scatters the blue portion of visible light making the sky appear blue, aerosols and other gases cause sunsets.
- The amount of insolation absorbed by the Earth's atmosphere and surface over time is EQUAL to the amount of reradiation produced by the Earth.

What factors affect insolation?

- The angle of insolation.
- The duration of insolation.
- The nature of the Earth's surface.
- Change of phase and photosynthesis.



Angle

- The Earth is a sphere and insolation doesn't strike the Earth's surface at the same angle at different locations.
- Latitude – For example, at the equator it hits directly and at the poles it comes in at an angle.

Duration

- The amount of time the sun is out.
- Changes with season and latitude.

Nature of Earth's Surface

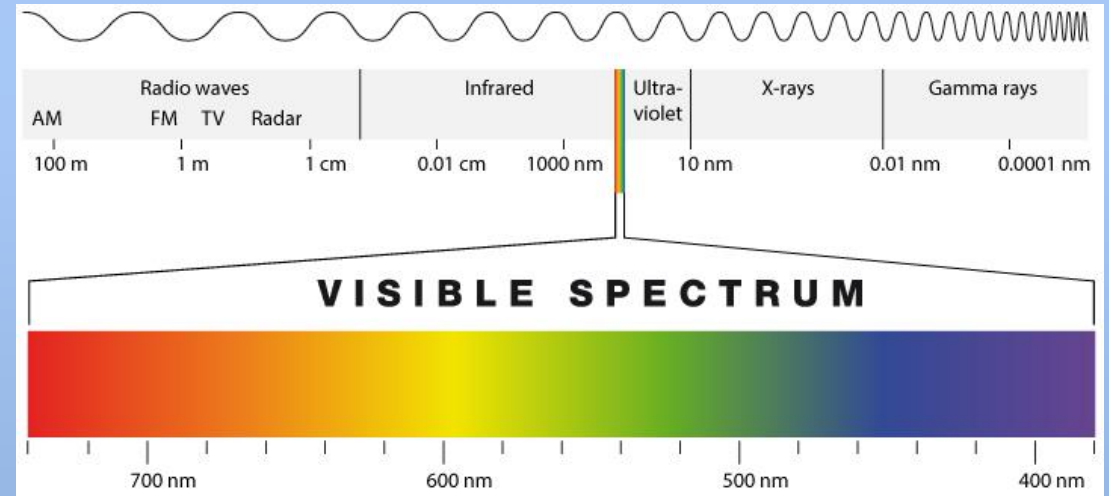
- Insolation that the Earth receives reacts differently because of texture and color.
- Due to the Earth having many different types of surface features.

Phases and Photosynthesis

- Insolation that is used to change the phase of a material does not raise the temperature.
- Plants use insolation to live and this does not raise the temperature.

Electromagnetic Radiation

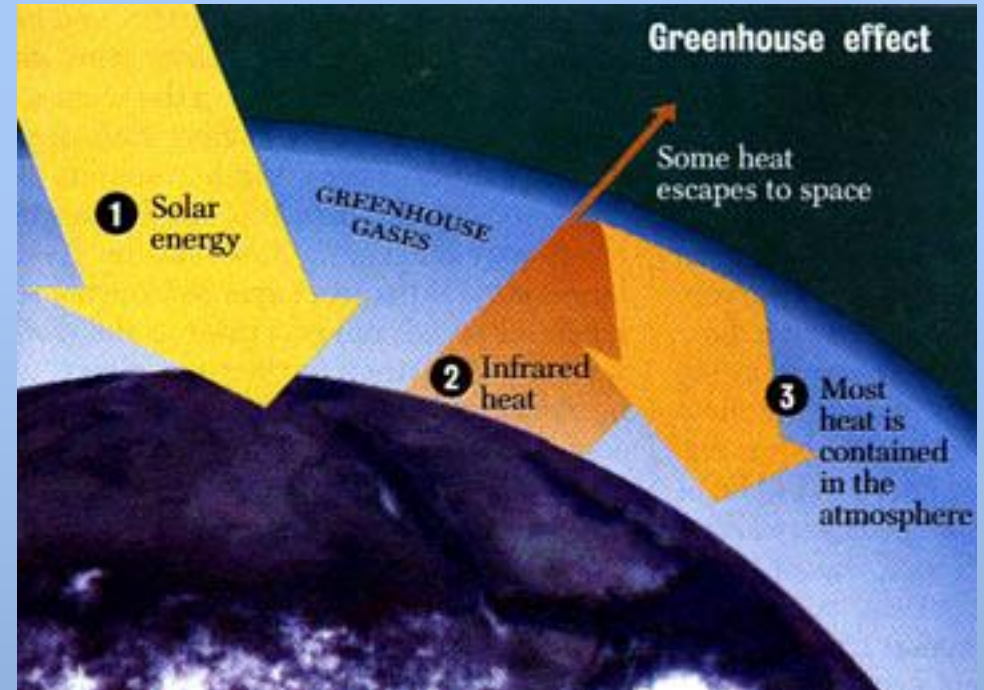
- The transfer of energy by electromagnetic waves
- Characterized by the amount of energy they carry.
- Electromagnetic Spectrum: ranges from low energy radio waves to high energy gamma rays.
- Black: absorb/release more radiation than light/shiny objects.
- Shiny objects tend to reflect energy.



<https://www.extremetech.com/wp-content/uploads/2017/07/Electromagnetic-spectrum.jpg>

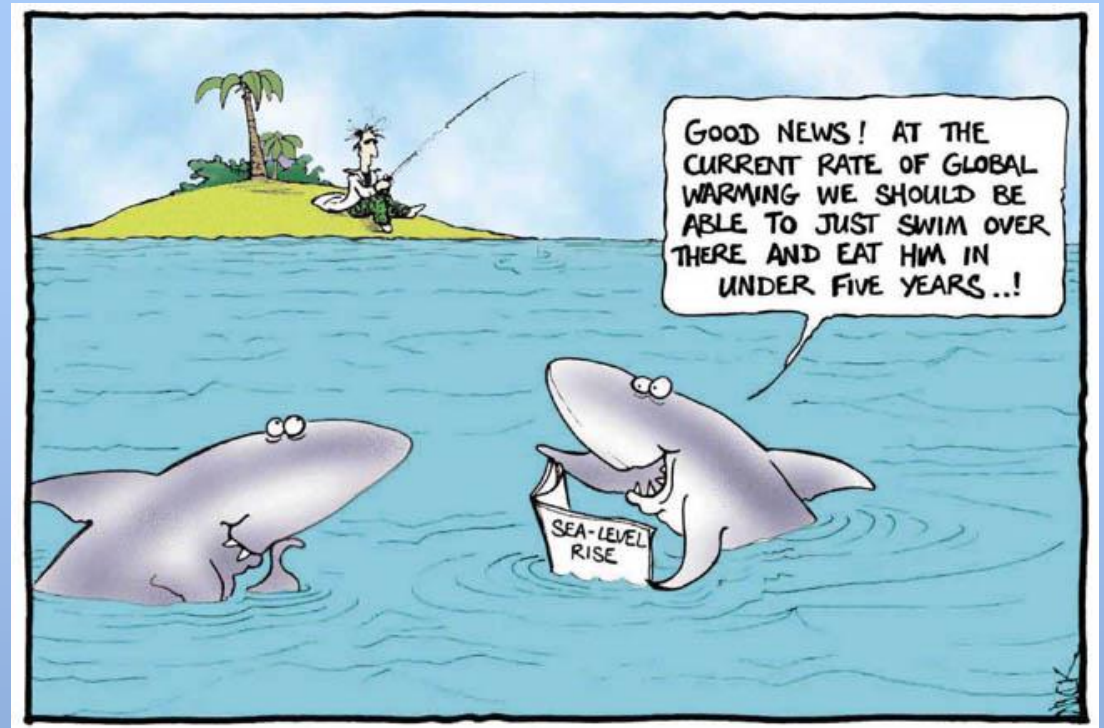
Greenhouse Effect

- Atmosphere allows sunlight to reach Earth's surface but prevent the heat from escaping back into space.
- Shortwave insolation from the sun is absorbed at the surface and the surface reradiates a longer wave, called **infrared**.
- Water Vapor
- Carbon Dioxide
- Methane
- Other Gases



Global Warming

- Since the 1800's CO₂ has increased, by 2020 it will be 2x its present level.
- An increase in Earth's temperature due to an increase in greenhouse gases.
- Due to the combustion of fossil fuels.



Effects of Global Warming

- Ice caps/glaciers melting
- Sea levels rise
- More severe storms
- Change in climate patterns
- Deforestation



Specific Heat

- The amount of energy required to raise the temp of 1 kg of a substance by 1 kelvin.
- SI unit = $\text{J/kg}^\circ\text{K}$
- Quantity to measure the relationship between heat and temp change
- Materials with a high specific heat can absorb a great deal of energy w/o a great change in temp. Example = water
- Energy(heat) flow = mass x specific heat x temp change

Heat Islands

- As urban areas develop, changes occur in their landscape.
- Buildings, roads, parking lots, and other infrastructure replace open land and vegetation.
- Causes urban regions to become warmer than rural surroundings.
- Forms an “island” of higher temperatures.
- Can occur on the surface and atmosphere.
- Parks, open land, bodies of water can create cooler areas within a city.
- http://www.ei.lehigh.edu/learners/luc/heat_island.mov

Heat Islands

Surface

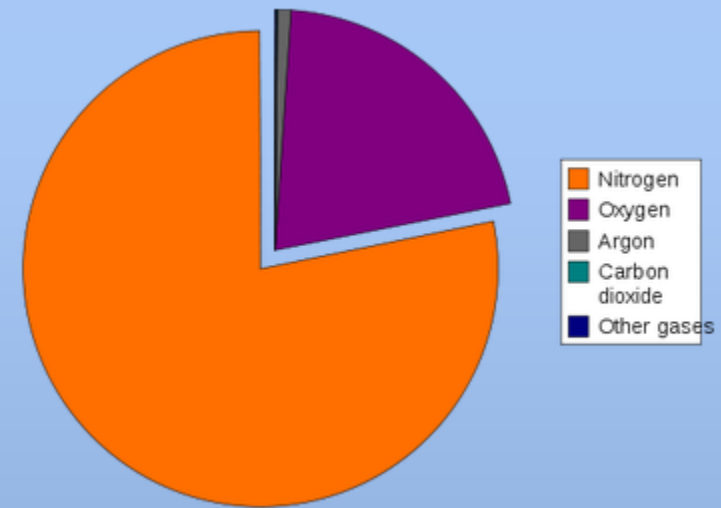
- Present day and night
- Strongest during day when sun is shining.
- Temps vary more during day

Atmospheric

- Weak during the day
- Stronger at night b/c of slow release of heat from infrastructure.

What is in the atmosphere?

- Constant Gases: Nitrogen (78%)
Oxygen (21%)
Argon (1%)
- Variable Gases: Carbon Dioxide
Water Vapor
Methane
Sulfur Dioxide
Ozone
Nitrogen Oxides



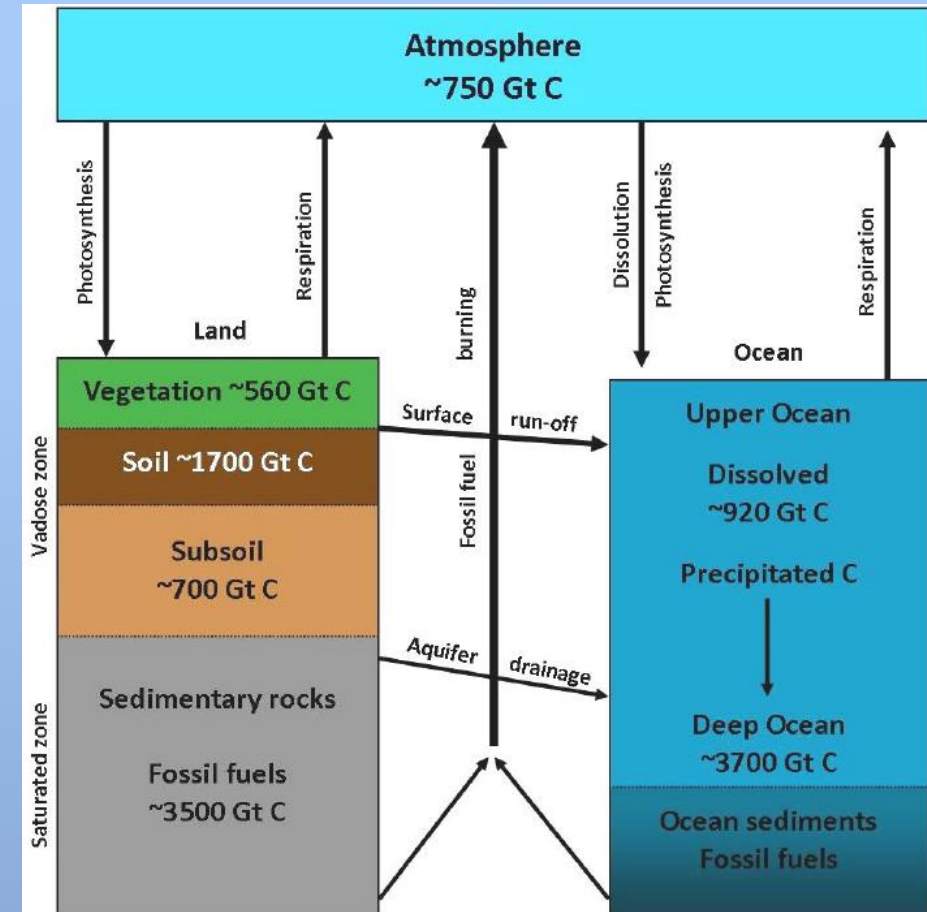
<http://www.opengeography.org/uploads/1/7/4/1/17412073/988871251.png?360>

Carbon Pools/Reserves

- Places that store carbon in different forms.
- Global Carbon Pools: vegetation
 - soil
 - fossil fuels (hydrocarbons)
 - atmosphere (CO_2 and CH_4)
 - upper ocean and marine life (H_2CO_3 , CaCO_3 , organic matter)
 - deep ocean
 - sedimentary rock (CaCO_3)
- Measured in gigatonnes (Gt) It is equal to 1 billion metric tonnes

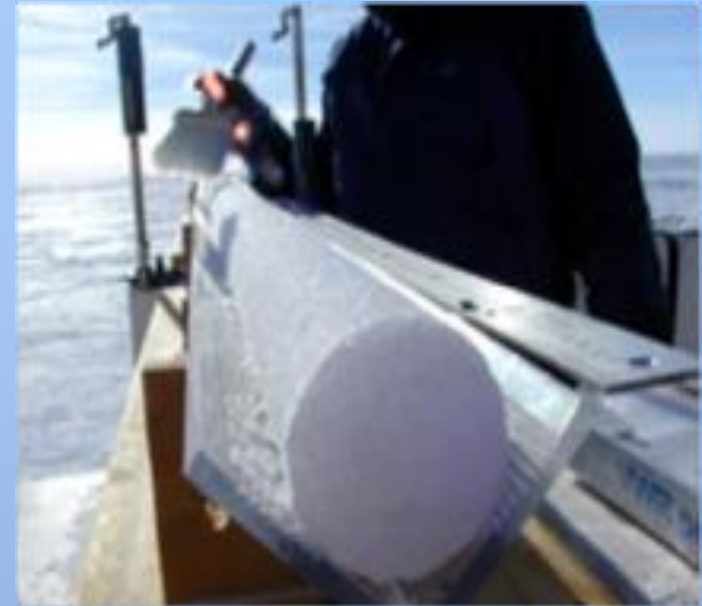
Carbon Fluxes – movement of carbon from one pool to another

- Photosynthesis
- Respiration
- Combustion
- Erosion/weathering
- Diffusion
- Ocean mixing
- Sedimentation
- volcanism



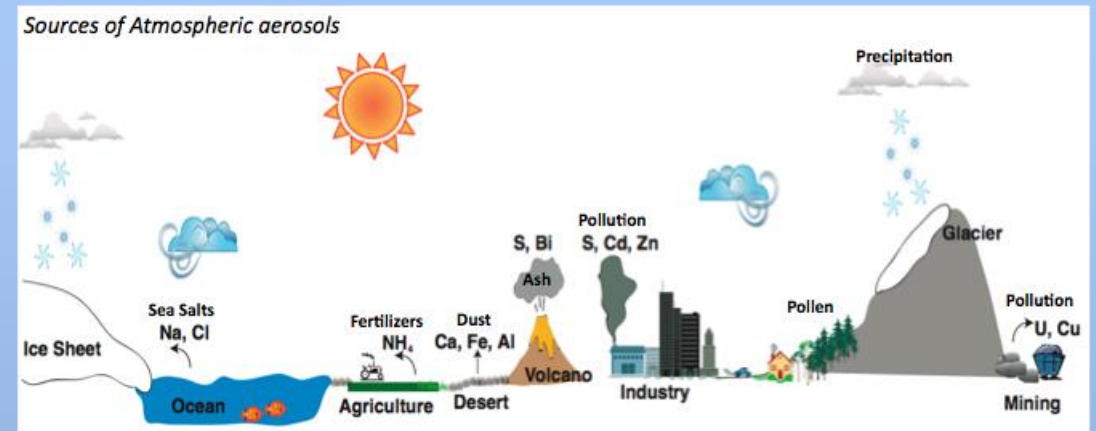
Ice Cores

- A cylinder shaped sample of ice drilled from a glacier.
- Show past climate conditions
- Snowfall that falls on glaciers captures atmospheric concentrations of:
 - dust
 - sea – salts
 - ash
 - gas bubbles
 - pollutants
- Can reveal changes in seasons all the way to hundreds of thousands of years.



Ice Core Uses

- Can reconstruct:
 1. Temperature
 2. Atmospheric circulation strength
 3. Precipitation
 4. Ocean volume
 5. Dust
 6. Volcanic eruptions
 7. Solar variability
 8. Forest fires
 9. Marine biological productivity



Ice Core Dating Techniques

- Seasonal markers (dust storms, stable water isotopes)
- Dating Horizons (volcanic eruptions, radioactivity)
- Radiometric dating
- Flow modeling

[video link](#)



How is climate change affecting, transforming and connected to the following.....

- ❖ International Politics

- ❖ Wildfires

- ❖ Glaciers

- ❖ Marine Life