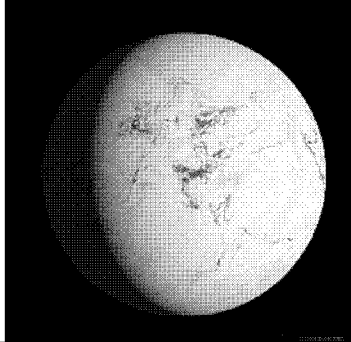


Thursday, October 7
Climate Change



Climate Change Key Concepts

- 1) The CO₂ cycle, driven by plate tectonics, regulates the amount of atmospheric CO₂.
- 2) The CO₂ cycle and the greenhouse effect, taken together, act as a global thermostat.
- 3) In the Proterozoic Eon, long deep Ice Ages occurred, causing a **Snowball Earth**.

The CO₂ cycle:

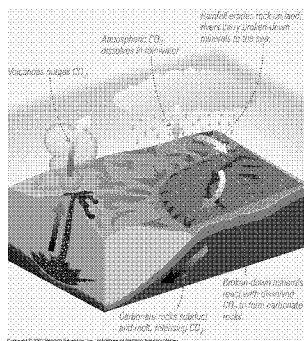
Raindrops dissolve CO₂ & form a mild acid.

Rain erodes rock, washing calcium into oceans.

Dissolved CO₂ reacts with calcium to make limestone.

Limestone **subducts** into the mantle and melts.

Liberated CO₂ is outgassed by volcanoes.



The CO₂ Cycle depends critically on having liquid water and plate tectonics.

Liquid water (raindrops & oceans) is required to dissolve CO₂.

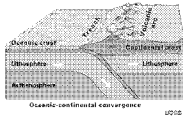
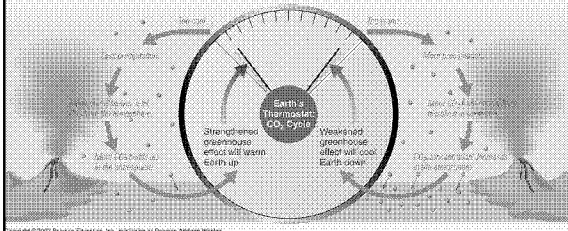


Plate tectonics is required to drag limestone into the mantle, where melting releases CO₂.

CO₂ cycle + greenhouse effect = thermostat.



A classic example of a “negative feedback loop”.

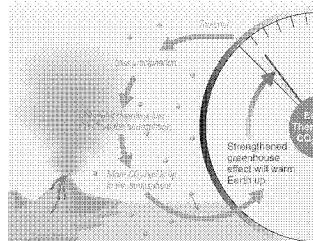
If the temperature drops, more CO₂ is left in the atmosphere, strengthening greenhouse heating.

Cooler temperatures mean less rainfall.

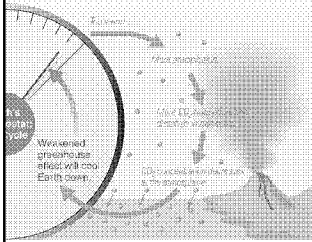
Less CO₂ is scrubbed out of the atmosphere.

Build-up of CO₂ in the atmosphere increases the greenhouse effect.

Atmosphere warms back up, restoring balance.



If the temperature rises, less CO₂ is left in the atmosphere, weakening greenhouse heating.



Warmer temperatures mean more rainfall.

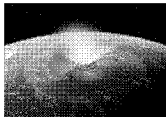
More CO₂ is scrubbed out of the atmosphere.

Decrease of CO₂ in the atmosphere weakens the greenhouse effect.

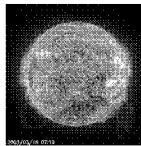
Atmosphere cools back down, restoring balance.

The balance can be upset by outside influences.

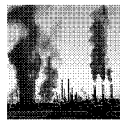
Changes in the Sun's luminosity.



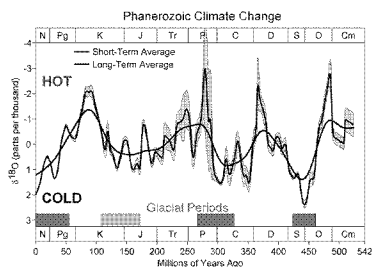
An asteroid impact kicking up dust.



Human activity injecting massive amounts of CO₂.

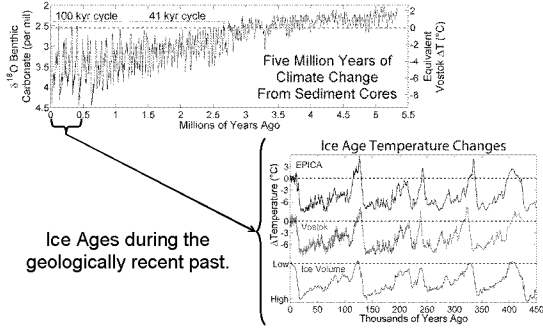


The geological record contains evidence for long periods of cold weather, or "Ice Ages".



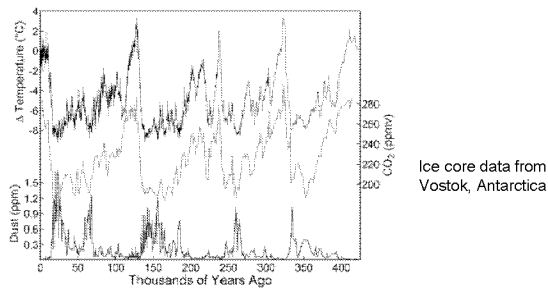
Long-term trends may be related to changes in the Sun's luminosity & the arrangement of continents.

Recent Ice Ages have occurred in repeating patterns of 40,000 to 100,000 years.



Ice Ages during the geologically recent past.

Ice Ages are correlated with the CO₂ content of the atmosphere (low CO₂ ↔ low temperature).



Ice core data from Vostok, Antarctica

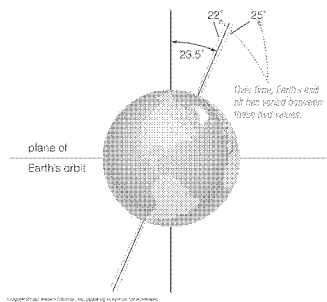
Recent Ice Ages are correlated with changes in the Earth's orbit and tilt.

Earth's axis tilt causes the seasons.

The tilt varies on a 41,000 cycle.

Less tilt = mild seasonal variation.

More tilt = big seasonal variation.



In the Proterozoic Eon, very long, deep ice ages occurred that caused the oceans to freeze.

Two episodes:

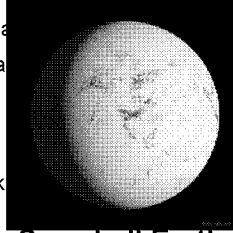
Late Proterozoic 750 - 580 Myr ago

Early Proterozoic 2.4 - 2.2 Gyr ago

Very deep freezes:

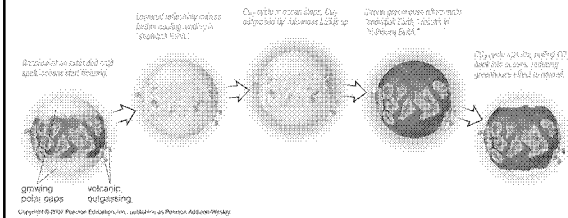
-50°C average temperatures

Oceans frozen to a depth of 1 km



Snowball Earth

Snowball Earth is caused by runaway cooling in polar-ocean ice caps (positive feedback).



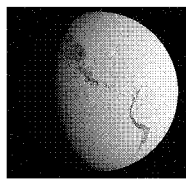
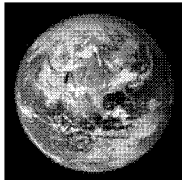
Frozen oceans stop CO₂ cycle, but volcanic outgassing continues, and CO₂ builds up to ~1000× current levels.

Subsequent strong CO₂ greenhouse effect melts the ice.

The Earth has experienced repeated changes in its climate over its long history.

Negative and positive feedback cycles at work.

Interplay among plate tectonics, atmospheric composition, and astronomical effects.



Has numerous implications for understanding the history of life, and the habitability of the Earth.

Quiz Tomorrow
Bring your number 2 pencil!
