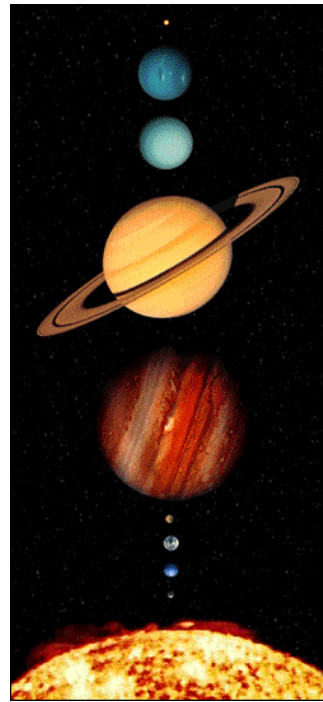


The Earth—10 Feb

- Policy on absences
 - You may miss classes for a university sanctioned event if you bring me a letter from your sponsor or coach.
 - You may miss class if you are really sick if you bring me a note from your doctor.
 - If you miss class for either of these two reasons, you will not be penalized for missing clicker questions.
 - Of course you will need to learn the material that you missed.
- Test 1 will be released on Wed afternoon.
 - Need to fix ambiguous bubbles & wrong codes
 - Look for announcement on angel
- Homework 3 will be due 6:00am on Wed, Feb 18 (next week)

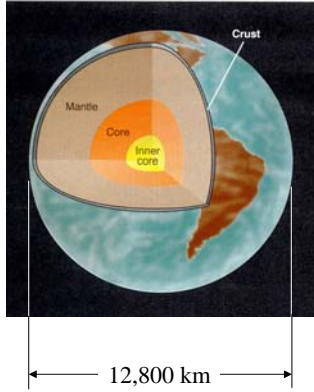
The Earth

- Big questions
 - What determines planets size, temperature, composition?
 - The proto solar system was made mostly of hydrogen & helium, like the sun. How did Earth form with such an unusual composition?
 - What makes a planet support life?
 - Earth, Venus, and Mars formed in similar ways. What processes caused them to become so different?
- Q1: Besides Earth, ___ is rocky. A Venus, B Jupiter, C Saturn, D Uranus.
- Q2: In composition, which planet is most unlike the sun? Same foils.
- Processes that shape earth
 - Plate tectonics
 - Volcanism
 - Energy trapping: Greenhouse effect
 - Carbon dioxide cycle
 - Erosion
 - Loss of gases



Interior of the Earth

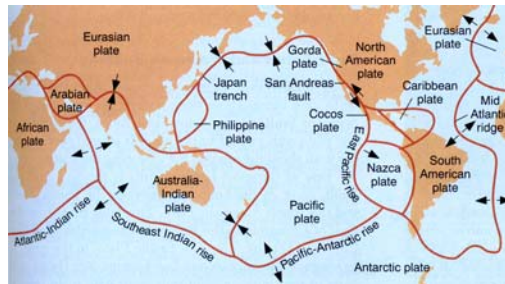
[see Fig 7.2]



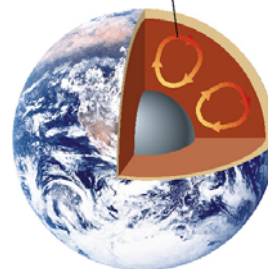
- Crust
 - ~6 km thick under oceans.
 - 20-70 km thick under continents.
 - Rocks composed of silicon, oxygen, etc.
 - 0.3% of mass.
- Mantle
 - Slowly flowing semi-solid rock.
- Core
 - 7000 km diameter.
 - Metallic (iron, nickel, sulfur)
 - Outer core is liquid.
 - Inner core probably solid.
- Q: Why is there much iron in the core and much silicon on the crust?
- Q: What is the key difference between iron & silicon that explains the reason?
 - A. Abundance
 - B. Ability to react with oxygen
 - C. Density
 - D. Emissivity

Plate Tectonics

- Crust split into huge *plates* drifting around on top of the mantle.
- Driven by *convection* (same as bubbles in boiling water). Convection time is 200Myears.
- Plates pushed apart in *rift* zones
 - Mid-Atlantic Ridge
- Plates bash together in *subduction* zones.
 - e.g. "Rim of Fire" around Pacific Ocean.
- Plates can slide at the boundaries
 - San Andreas Fault in California

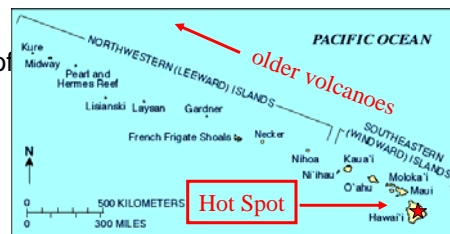
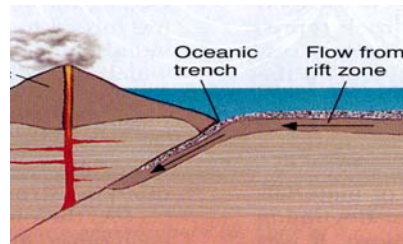


Mantle convection: hot rock rises and cooler rock falls.



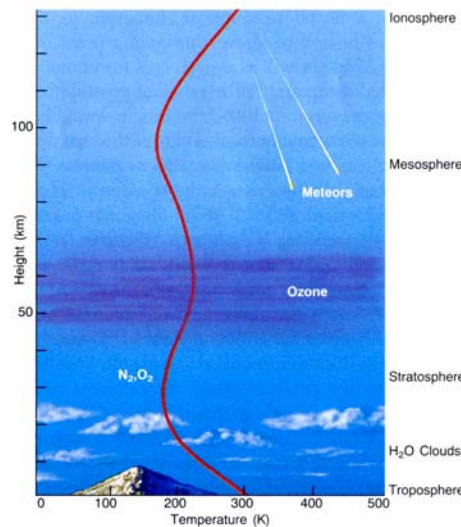
Geological Activity on Earth

- Plate collisions → mountain building
 - Light continental plate collides with light continental plate; eg, Himalayas.
 - Heavy oceanic plate collides with light continental plate; eg, Andes.
- Volcanoes
 - *Magma* (molten rock) forced upwards from mantle.
 - Along mid-ocean ridges.
 - Around subduction zones (Rim of Fire)
- Plate drifts over a hot spot
 - Hawaiian Island chain

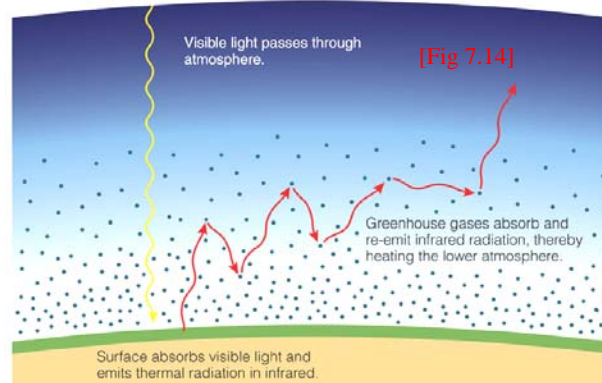


The Earth's Atmosphere [7.5]

- Weighs 13.6 pounds per square inch
- 78% nitrogen, 21% oxygen, + argon, H₂O, CO₂, etc.
- Unusual mixture
 - Oxygen "should not" be present because it reacts easily.
 - Hydrogen & helium "should be" dominant because they are the most abundant elements in the universe.
- Ozone (O₃) is critical for life
 - blocks Sun's ultraviolet radiation
 - *Ozone hole*: over Antarctica, where ozone destroyed by man-made pollutants.



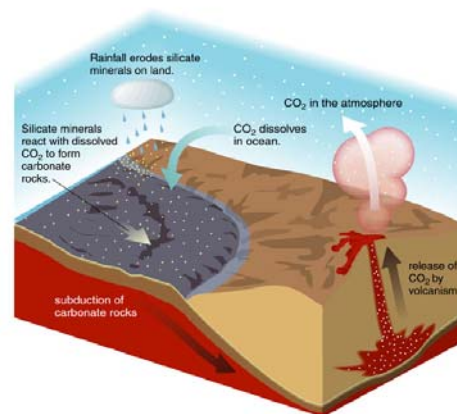
Greenhouse Effect



- Incoming sunlight passes through atmosphere.
- Absorbed by ground.
- Re-emitted as infrared radiation.
- Water & CO₂ gas absorbs infrared light. Reradiated.
- Infrared light is trapped, so heats surface.

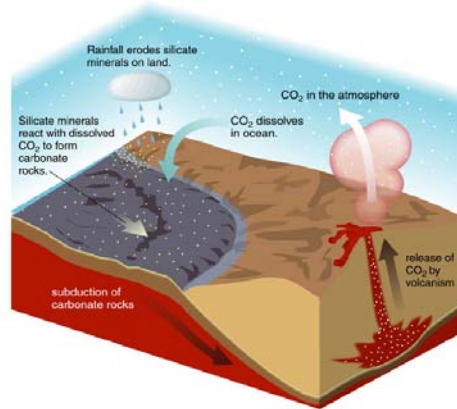
Carbon Dioxide Cycle

- Removal of CO₂ from atmosphere
 - Rain dissolves CO₂
 - Rivers carry CO₂ into the oceans
 - Carbonate rocks lock up carbon
- Introduction of CO₂ into the atmosphere
 - Subduction of oceanic plate carries carbonate rocks underneath continent
 - Volcanoes release CO₂



Faint-sun Problem

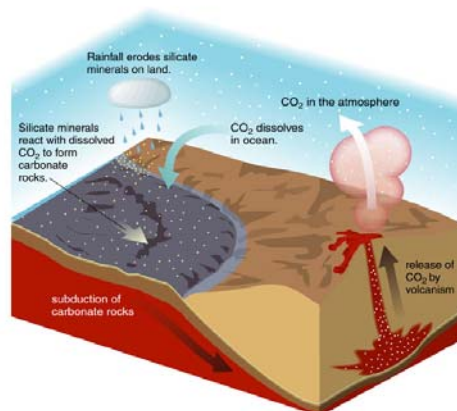
- Removal of CO₂ from atmosphere
 - Rain dissolves CO₂
 - Rivers carry CO₂ into the oceans
 - Carbonate rocks lock up carbon
- Introduction of CO₂ into the atmosphere
 - Subduction of oceanic plate carries carbonate rocks underneath continent
 - Volcanoes release CO₂
- The sun was fainter when it was younger.
 - The earth should have been frozen.
 - Fossils show earth was warm, instead.
- Carbon dioxide is a feedback that maintains temperature.
 - Less solar radiation ⇒ cooler ⇒ less rain ⇒ more CO₂ ⇒ more effective greenhouse ⇒ warmer



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Q

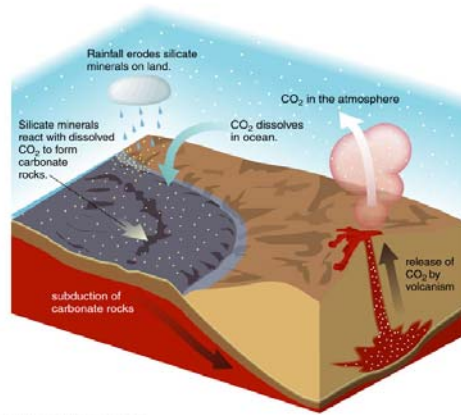
- Removal of CO₂ from atmosphere
 - Rain dissolves CO₂
 - Rivers carry CO₂ into the oceans
 - Carbonate rocks lock up carbon
- Introduction of CO₂ into the atmosphere
 - Subduction of oceanic plate carries carbonate rocks underneath continent
 - Volcanoes release CO₂
- Q: What would happen if a giant hand stopped the plates from moving?
 - A. The earth would cool.
 - B. The earth would get hotter.



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Carbon Dioxide Cycle

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 - Rain dissolves CO₂
 - Rivers carry CO₂ into the oceans
 - Carbonate rocks lock up carbon
- Introduction of CO₂ into the atmosphere
 - Subduction of oceanic plate carries carbonate rocks underneath continent
 - Volcanoes release CO₂
- Assignment for Thurs: Which is the main reason Venus so hot?
 - a. CO₂ traps heat
 - b. It is close to the sun
 - c. Its atmosphere has so much CO₂
 - d. Its atmosphere has so much water.
- Assignment for Thurs: Venus and Earth are nearly twins. What went wrong on Venus?



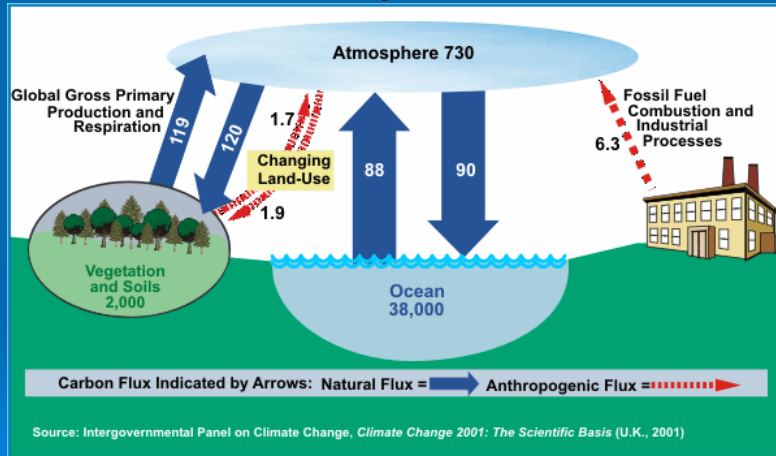
The Science of Climate Change: Part 1--Overview

**Presented at Michigan State University
22 March 2006**

*Dr. Michael MacCracken
Climate Institute
Washington DC*

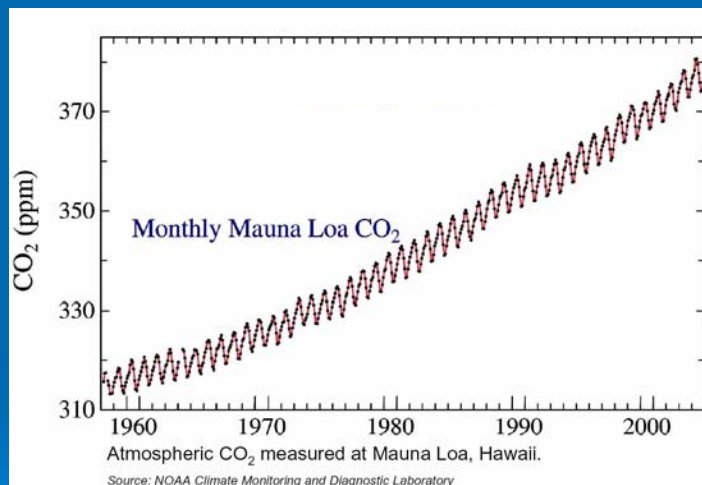
*Photo taken from first
Apollo flight to the Moon,
December, 1968*

Emissions from human activities alter the natural carbon cycle, increasing the amount of carbon in the air, the oceans, and the living biosphere



Source: EIA, Greenhouse Gas brochure

CO₂ Emissions are Significantly Increasing its Atmospheric Concentration



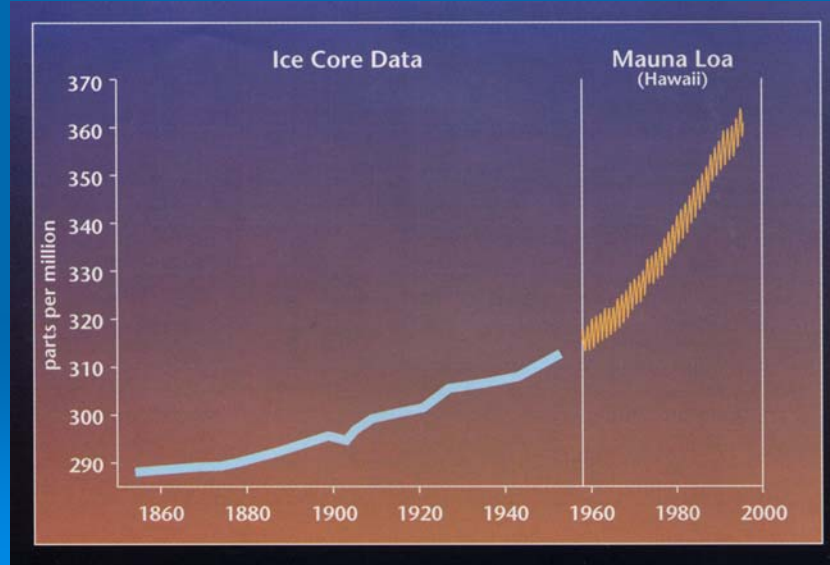
The current value is about 380 ppmv, over 35% above the preindustrial value, which had not varied significantly since the end of the last glacial (i.e., roughly 8000 years).

ppm=parts per million (by volume)

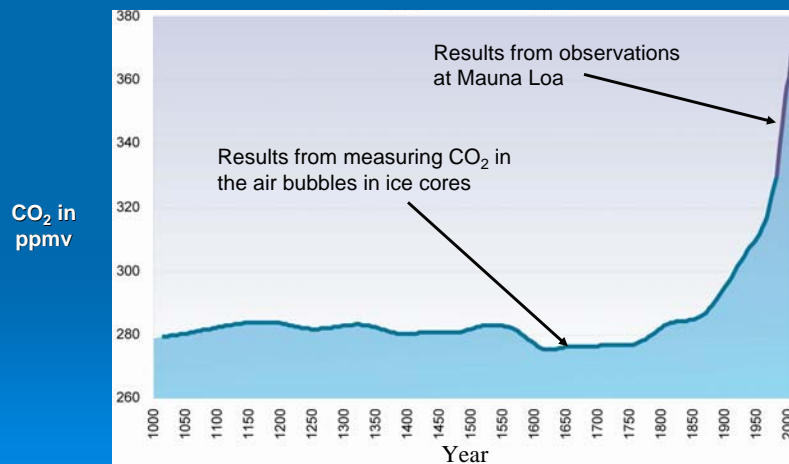
Observations by C. David Keeling

That the magnitude of the seasonal cycle has increased suggests that, even with a reduced amount of vegetation, the higher CO₂ concentration is enhancing the seasonal growth of global vegetation

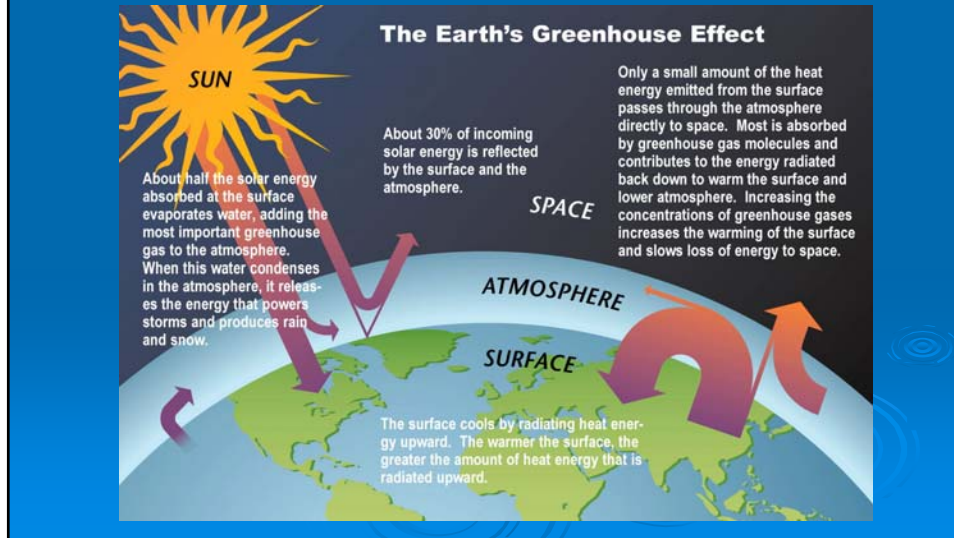
The CO₂ concentration is now about 35% higher than its preindustrial level



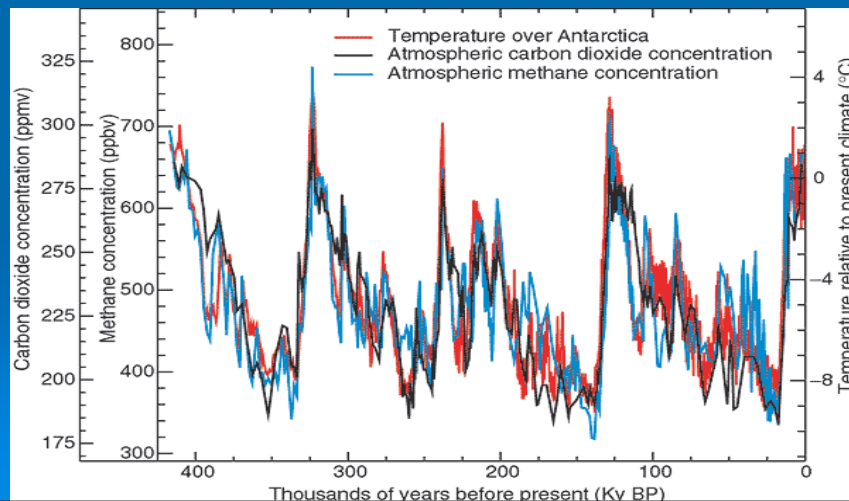
The CO₂ concentration had been roughly steady over the centuries (and millennia) preceding the Industrial Revolution



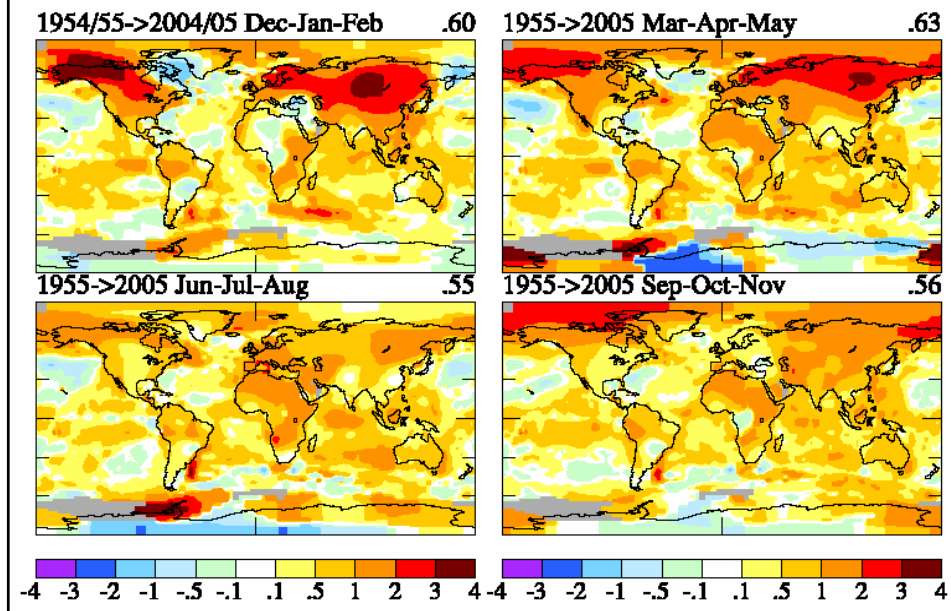
The Earth's natural *Greenhouse Effect* occurs because the atmosphere recycles most of the infrared (heat) energy that is emitted by the surface, providing energy that significantly augments incoming solar radiation



The timing of glacial advances and retreats over the past 400,000 years seems to be driven by changes in the shape, tilt, and timing of the Earth's orbit--with associated changes in CO_2 and CH_4 concentrations providing an important amplifying effect



Warming has occurred in all four seasons over the past 50 years



Extensive Additional Evidence Confirms that Climate Change is Occurring

- **Ground (subsurface) temperatures**, which respond to long-term average conditions at the surface, are rising
- **Ocean temperatures** are rising, at the surface and through the upper kilometer of ocean depth
- **Sea ice cover** is decreasing, particularly in the Arctic
- **Mountain glaciers and the Greenland Ice Sheet** are melting, snow cover extent is reduced, and the snow line is rising
- **Sea level** is rising due to added meltwater from glaciers and expansion caused by warming
- **Atmospheric water vapor** concentrations are rising (in the lower and upper troposphere) and rainfall events are becoming more intense
- **Distributions of a large fraction of studied species** are shifting poleward (except where they run out of habitat)

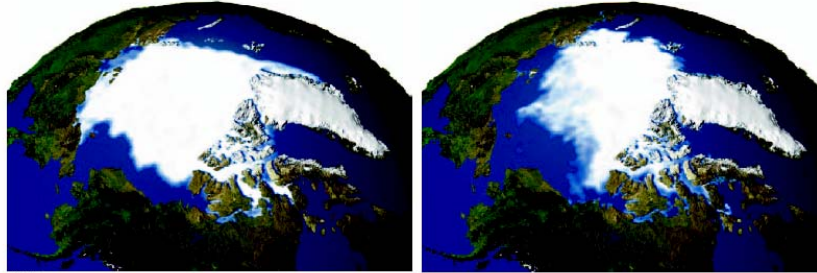
Minimum Extent of Arctic Ocean Sea Ice Cover

September 1979

September 2003

Observed sea ice September 1979

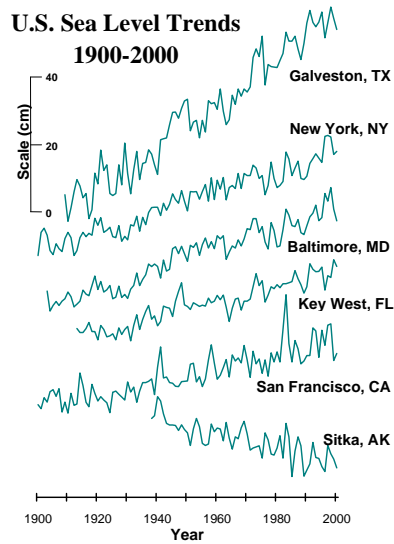
Observed sea ice September 2003



©NASA

The two images above, constructed from satellite data, compare arctic sea ice concentrations in September of 1979 and 2003. September is the month in which sea ice is at its yearly minimum and 1979 marks the first year that data of this kind became available in meaningful form. The lowest concentration of sea ice on record was in September 2002.

Global sea level rose by about 10 to 20 cm (4 to 8 inches) during the 20th century



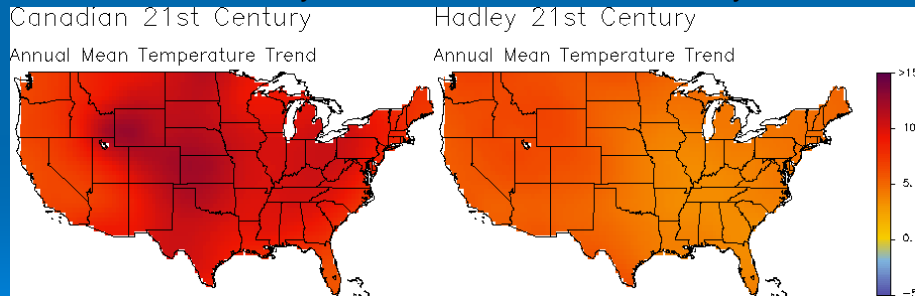
Contributions to increases in global sea level occur as a result of thermal expansion of warming ocean waters, melting of mountain glaciers, and net losses from the Greenland and Antarctica Ice Sheets. Changes in land stored on land in reservoirs and aquifers can also be important.

Changes in local sea level (relative sea level) are also determined by coastal subsidence or emergence due to long-term (e.g., glacial rebound) and short-term (e.g. aquifer pumping) factors.

**Climate model simulations used in the
US National Assessment project a
21st century warming of about 5 - 10°F**

Canadian model scenario
for increase by 2100

Hadley (UK) model scenario
for increase by 2100



Plots show the projected change in annual average temperature (°F) over the 21st century