CHAPTER 16

Oceans & Climate Change

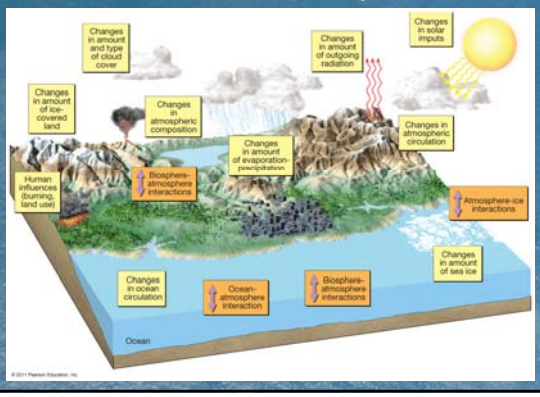
Chapter Overview

- Humans are adding greenhouse gases to Earth's atmosphere.
- Climate change will cause many severe problems in the ocean environment.
- It is necessary to reduce and mitigate the effects of these changes.

Earth's Climate System

- Climate – long term atmospheric conditions in a region
- Earth's climate includes interactions of:
  - Atmosphere
  - Hydrosphere
  - Geosphere
  - Biosphere
  - Cryosphere
- Climate system – exchanges of energy and moisture between these spheres

Earth's Climate System

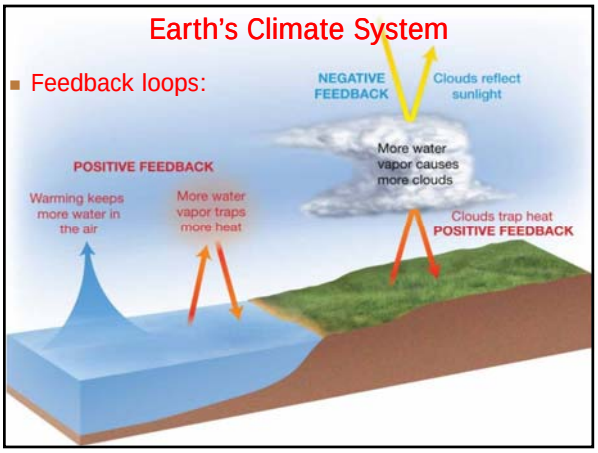


Earth's Climate System

- Feedback loops – modify atmospheric processes
  - Positive feedback loops – enhance initial change
  - Negative feedback loops – counteract initial change

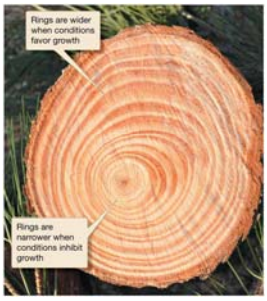
Earth's Climate System

- Feedback loops:



Determining Causes of Earth's Climate Change

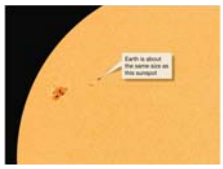
- Paleoclimatology
- Proxy data – indirect evidence using natural recorders of climate variability
  - Sea floor sediments
  - Coral deposits
  - Glacial ice rings
  - Tree rings
  - Pollen
  - Historical documents

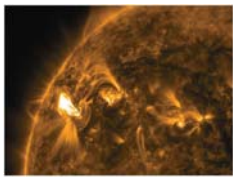


Proxy Data: Ice Cores

Natural Causes of Climate Change

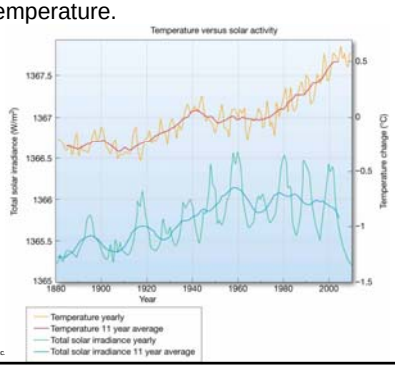
- Solar energy changes
  - Variable energy from the Sun over time
  - Luminosity
  - Sunspots – cooler, episodic dark areas on Sun
  - Faculae – bright spots on Sun





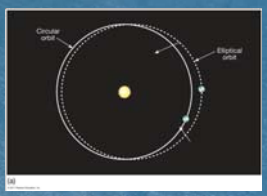
Natural Causes of Climate Change

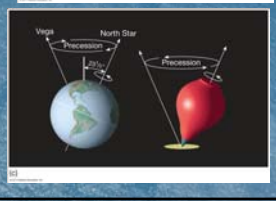
- Lack of correlation between solar activity and average Earth temperature.



Natural Causes of Climate Change

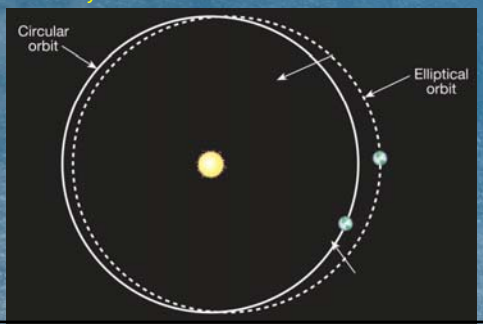
- Variations in Earth's Orbit
- Milankovitch Theories
  - Eccentricity of Earth's orbit
  - Obliquity of Earth's axis
  - Precession of Earth's axis





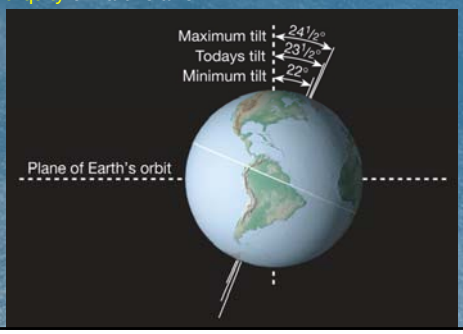
Natural Causes of Climate Change

- Milankovitch Theory 1
  - Eccentricity of Earth's orbit



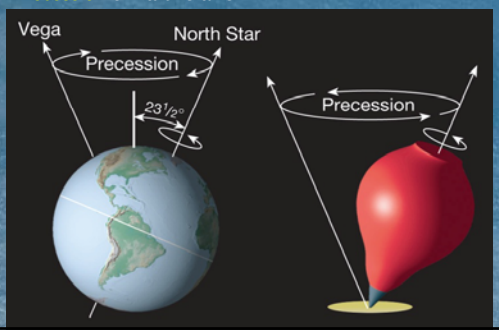
Natural Causes of Climate Change

- Milankovitch Theory 2
  - Obliquity of Earth's axis



Natural Causes of Climate Change

- Milankovitch Theory 3
  - Precession of Earth's axis



Natural Causes of Climate Change

- Volcanic eruptions
- Volcanic ejecta may block sunlight
- Need many eruptions in short time period
- Not observed in recent history

Natural Causes of Climate Change

- Movement of Earth's Plates
  - Change ocean circulation
  - Extremely slow process
  - Climate change would be very gradual over millions of years

Natural Causes of Climate Change

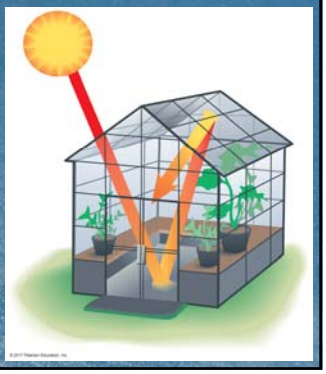
- Linked to Pleistocene Ice Age, Little Ice Age, Medieval Warm Period
- Recent change unprecedented
  - More likely result of human activity than natural causes

Documenting Human-Caused Climate Change

- Intergovernmental Panel on Climate Change (IPCC)
  - Global group of scientists
  - Published assessments since 1990
  - Predict global temperature changes of 1.4–5.8°C (2.5–10.4°F)
- Climate change models can mimic modern conditions only if human emissions are taken into account.

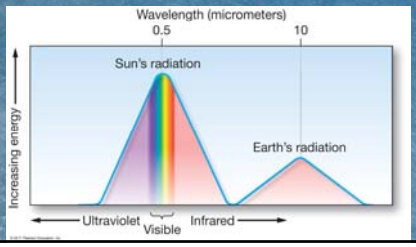
Atmosphere's Greenhouse Effect

- Global warming – increase in Earth's global temperatures
- Greenhouse effect – keeps Earth's surface habitable
  - Incoming heat energy is shorter wavelengths
  - Longer wavelengths – some trapped, some escape, net warming effect

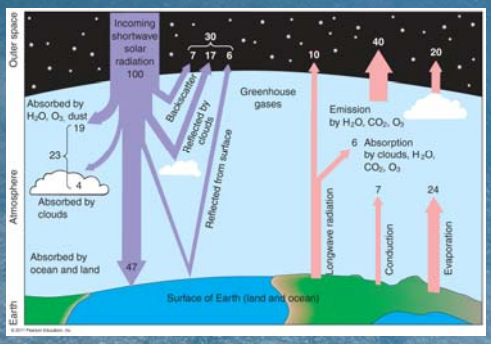


Earth's Heat Budget

- Addition to or subtraction from heat on Earth
- Incoming radiation from Sun shorter wavelengths
- Outgoing radiation from Earth longer wavelengths
- Rates of energy absorption and re-radiation must be equal



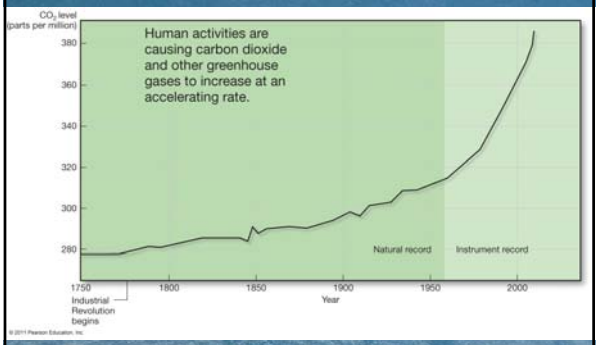
Earth's Heat Budget



Greenhouse Gases

- Water vapor
  - Most important
  - 66–85% of greenhouse effect
- Carbon dioxide
  - Natural part of atmosphere
  - Greatest relative contribution from human activities
  - Burning of *fossil fuels*

Atmospheric Carbon Dioxide



Greenhouse Gases

- Methane
  - Second most abundant human-caused greenhouse gas
  - Great warming power per molecule
  - Landfill decomposition
  - Cattle
- Other trace gases
  - Nitrous oxide, CFCs, ozone

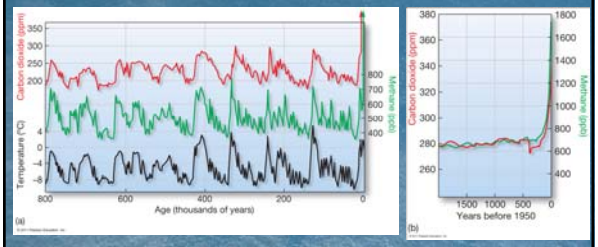
Human-Caused Greenhouse Gases

TABLE 16.1 HUMAN-CAUSED GREENHOUSE GASES AND THEIR CONTRIBUTION TO INCREASING THE GREENHOUSE EFFECT

Atmospheric gas	Human-caused sources of gas	Pre-industrial (circa 1750) concentration (ppbv*)	Present concentration (ppbv*)	Current rate of increase or decrease (% per year)	Relative contribution to increasing the greenhouse effect (%)	Infrared radiation absorption per molecule (number of times greater than CO_2)
Carbon dioxide (CO_2)	Combustion of fossil fuels	280,000	387,0000	+0.5	60	1
Methane (CH_4)	Leakage, domestic cattle, rice agriculture	700	1750	+1.0	15	25
Nitrous oxide (N_2O)	Combustion of fossil fuels, industrial processes	270	315	+0.2	5	200
Tropospheric ozone (O_3)	Byproduct of combustion	0	10–80	+0.5	8	2000
Chlorofluorocarbon (CFC-11)	Refrigerants, industrial uses	0	0.26	−1.0	4	12,000
Chlorofluorocarbon (CFC-12)	Refrigerants, industrial uses	0	0.54	0.0	8	15,000
Total					100	

*ppbv = parts per billion by volume (not by weight).

Ice Core Data

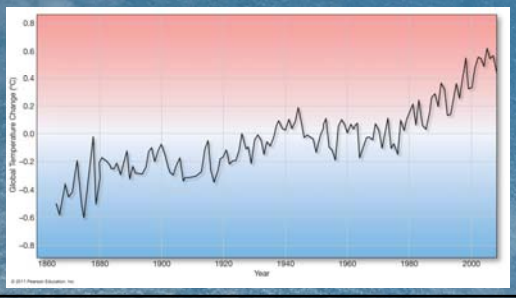


Changes from Global Warming

- Melting glaciers and ice caps
- Shorter winters
- Species distribution shifts
- Global temperature rise
- Sea surface temperature increases

Changes from Global Warming

- The 8 warmest years have occurred since 1998
- Earth's surface temperature has risen 0.8°C (1.4°F) in last 140 years.



Changes from Global Warming

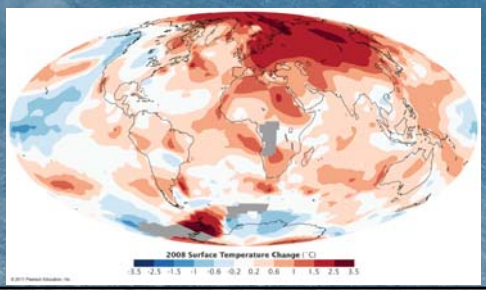
Predicted Changes:

- Earlier, hotter summers
- More severe droughts in some places, flooding in others
- Retreat of mountain glaciers
- Water contamination issues
- Ecosystem changes and extinctions

Changes in the Oceans

Increasing ocean temperatures

- Sea surface temperatures risen mostly since 1970
- Deep waters showing increases



Changes in the Oceans

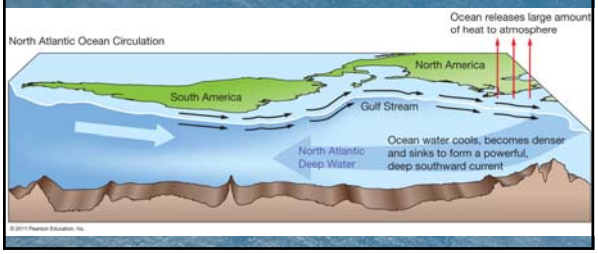
Increased hurricane activity

- Warmer water fuels hurricanes
- Severity of recent Atlantic hurricanes
- Number of global tropical storms have not increased worldwide
- Intensity of storms has increased
  - More Category 4 and 5 hurricanes

Changes in the Oceans

Changes in deep-water circulation

- North Atlantic especially sensitive
- Melting glaciers
- Warmer surface waters



Changes in the Oceans

Polar Ice Melting

- *Arctic amplification*
- Loss of more than 2 million square kilometers (800,000 square miles) of Arctic sea ice in last decade
- Loss of ice = enhanced warming due to lower albedo

Changes in the Oceans

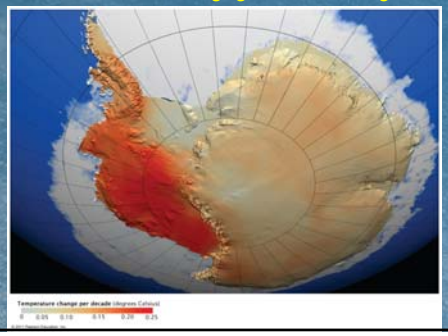
Polar Ice Melting

- Arctic ice melting affects polar bear survival.
- Food sources are dwindling for human Arctic dwellers.
  - Marine species migration

Changes in the Oceans

Polar Ice Melting

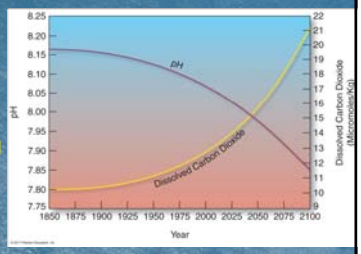
- Antarctica shrinking, glaciers thinning



Changes in the Oceans

Ocean acidity increase

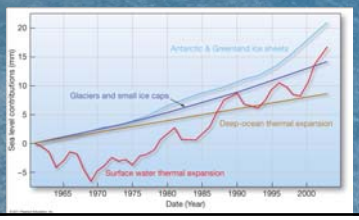
- Some atmospheric carbon dioxide dissolves in ocean water.
  - Acidifies ocean
- Threatens calcifying organisms
  - Coccolithophores
  - Foraminifers
  - Sea urchins
  - Corals



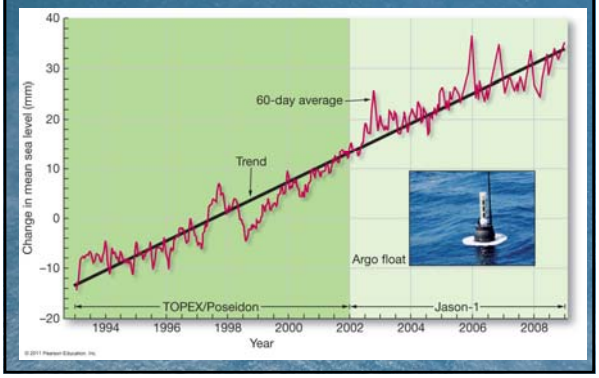
Organisms Threatened by Increased Marine Acidity

Changes in the Oceans

- Rising Sea Level – already occurring
- Main contributors:
  - Melting of Antarctic and Greenland ice sheets
  - Thermal expansion of ocean surface waters
  - Melting of land glaciers and ice caps
  - Thermal expansion of deep-ocean waters

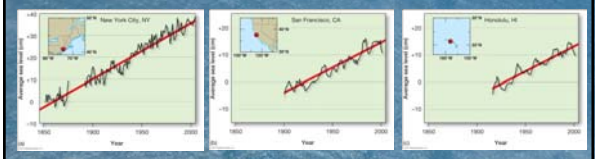


Global Sea Level Rise



Rising Sea Level

- Severely affect areas with gently sloping coastlines
  - U.S. Atlantic and Gulf Coasts
- Models predict rise between 0.5 and 1.4 meters (1.6 and 4.6 feet) by year 2100



Changes in the Oceans

Other predicted changes

- Sound transmission in ocean
- Reduced dissolved oxygen – marine dead zones
- Change in ocean productivity
- Marine organisms unable to adapt to temperature changes

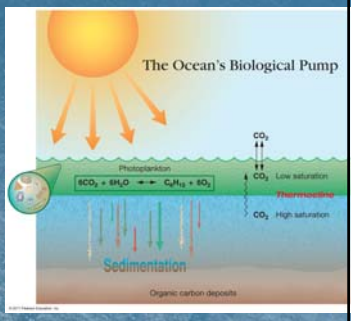
Reducing Greenhouse Gases

- Human emissions contributing excessive CO^2
- Global engineering – attempts to counteract human-caused climate change
  - Reducing sunlight reaching earth
  - Removing human-caused greenhouse gases

Reducing Greenhouse Gases

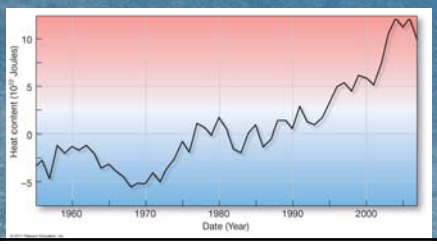
Ocean's Role

- Ocean's biological pump
  - "sink" for carbon dioxide
  - Pumps from surface to deep waters



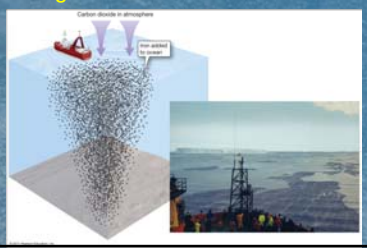
Reducing Greenhouse Gases

- Ocean as thermal sponge
  - Unique thermal properties of water
  - Oceans absorb much heat without changing temperature
  - Oceans still warming



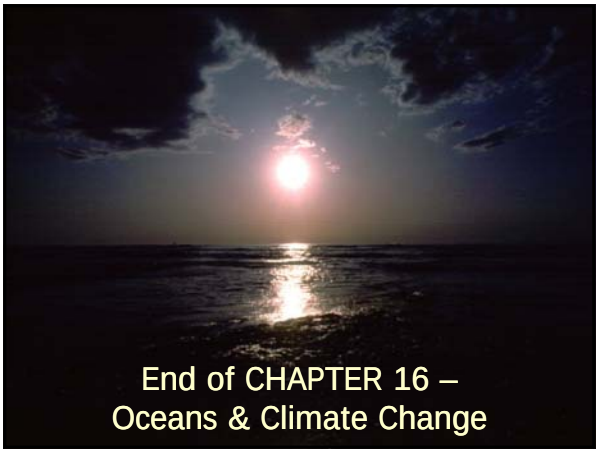
Possibilities for Reducing Greenhouse Gases

- Iron hypothesis
  - Fertilize ocean to increase productivity
  - Increase phytoplankton, increase carbon dioxide removal from atmosphere
- Sequestering excess carbon dioxide in oceans



Kyoto Protocol: Limiting Greenhouse Gas Emissions

- International agreement – 60 nations
- Voluntarily limit greenhouse gases
- Even if gas emissions stabilize, Earth will continue to warm.
  - *Commitment to warming*
- Human activities are altering the global environment.



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