1 **CHAPTER 16**

Oceans & Climate Change

2 **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.

3 **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

4 **Earth's Climate System**

5 **Earth's Climate System**

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

6 **Earth's Climate System**

- Feedback loops:

7 **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  - Historical documents
  -

8 **Proxy Data: Ice Cores**

9 **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

10 **Natural Causes of Climate Change**

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

11 **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

12 **Natural Causes of Climate Change**

- Milankovitch Theory 1

- Eccentricity of Earth's orbit

13 **Natural Causes of Climate Change**
- Milankovitch Theory 2
  - Obliquity of Earth's axis

14 **Natural Causes of Climate Change**
- Milankovitch Theory 3
  - Precession of Earth's axis

15 **Natural Causes of Climate Change**
- Volcanic eruptions
- Volcanic ejecta may block sunlight
- Need many eruptions in short time period
- Not observed in recent history

16 **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

17 **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

18 **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.

19 **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

20 **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

21 **Earth's Heat Budget**

22 **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*
  -

23 **Atmospheric Carbon Dioxide**

24 **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
  -

25 **Human-Caused Greenhouse Gases**

26 **Ice Core Data**

27 **Changes from Global Warming**

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

28 **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.

29 **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

30 **Changes in the Oceans**

Increasing ocean temperatures

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

31 **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

32 **Changes in the Oceans**

Changes in deep-water circulation

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

33 **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

34 **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

35 **Changes in the Oceans**

Polar Ice Melting

- Antarctica shrinking, glaciers thinning

36 **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

37 **Organisms Threatened by Increased Marine Acidity**

38 **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

39 **Global Sea Level Rise**

40 **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

41 **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
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42 **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

43 **Reducing Greenhouse Gases**

Ocean's Role

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

44 **Reducing Greenhouse Gases**

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

45 **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

46 **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.

47 **End of CHAPTER 16 –**
Oceans & Climate Change