Climate Change
The Climate System

- The climate system includes the:
  - Atmosphere
  - Hydrosphere
  - Geosphere
  - Biosphere
  - Cryosphere (Ice & Snow)
How Is Climate Change Detected?

• Techniques for analyzing Earth’s climate history
  • Seafloor sediments—Numbers and types of organic remains are indicative of past sea-surface temperatures.
  • Oxygen isotope analysis—The ratio of \(^{18}\text{O}/^{16}\text{O}\) in shells of microorganisms reflect past temperatures.
How Is Climate Change Detected?

• Techniques for analyzing Earth’s climate history
  • Other sources of data for studying past climates include:
    – Growth of tree rings
    – Drill cores in glacial ice
    – Pollen contained in sediment and coral reefs
    – Information found in historical documents
Deep Sediment Drilling & Core Analysis
Tree Rings Are Useful Recorders of Past Climates
Oxygen ratios ($O^{18}$ & $O^{16}$) in Foram shells

Warm Water = High $O^{18}$  Cold Water = Low High $O^{18}$
Same Thing for Ice Cores!

A.

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B.

Higher $O^{18}$

Lower $O^{18}$

Temperature ($^\circ$C)

Thousands of years before present

0 5 10 15 20 25 30 35 40
Abundance of Pollen Spores (Dinosaurs??)
Composition of Earth’s Atmosphere

- **Nitrogen (78.084%)**
- **Oxygen (20.946%)**
- **Argon (0.934%)**
- **Carbon dioxide (0.0387% or 387 ppm)**
- **All others**

Concentration in parts per million (ppm)

- Neon (Ne) 18.2
- Helium (He) 5.24
- Methane (CH₄) 1.5
- Krypton (Kr) 1.14
- Hydrogen (H₂) 0.5
$\text{CO}_2$ Concentrations Over the Past 400,000 Years

(Famous “Hockey Stick” Graph)
Thermal Structure of the Atmosphere
Incoming Solar Radiation

- 100% of solar radiation
- 5% backscattered to space by the atmosphere
- 20% of radiation absorbed by atmosphere and clouds
- 30% lost to space by reflection and scattering
- 5% reflected from land-sea surface
- 50% of direct and diffused radiation absorbed by land and sea
Some Atmospheric Basics

• The greenhouse effect
  • Radiant energy that is absorbed heats Earth and eventually is reradiated skyward.
    – Radiation is in the form of longwave infrared radiation.
    – Atmospheric gases, primarily $\text{H}_2\text{O}$ and $\text{CO}_2$, are more efficient absorbers of longwave radiation.
    – This selective absorption, called the greenhouse effect, results in warming of the atmosphere.
The Greenhouse Effect

Short-wave solar radiation passes through the atmosphere and is absorbed by Earth’s surface.

Earth’s surface emits longwave radiation which is absorbed by greenhouse gases.

Greenhouse gases reradiate some energy Earthward, thus trapping heat in the lower atmosphere.
Natural Causes of Climate Change

• Several explanations have been formulated to explain climate change, including:
  • Exposed Land Surface Changes
  • Variations in Earth’s orbit—eccentricity, obliquity, and precession
  • Volcanic activity
  • Changes in the Sun’s output associated with sunspots
Changing Land Surface Elevation
Orbit & Tilt Changes

VARIATION IN EARTH'S ORBIT CYCLE
ABOUT 100,000 YEARS
Effect of Volcanic Activity on Solar Radiation
More Sun Spots = Warmer Climates
Human Influences

- 17,000 pounds of CO₂ by using 1,100 kilowatt-hours of electricity per month
- 8,800 pounds of CO₂ by using 6,300 cubic feet of natural gas per month
- 1,000 pounds of CO₂ by creating 4.5 pounds of trash per day
- 8,900 pounds of CO₂ by driving 160 miles per week
- 1,000 pounds of CO₂ by flying 1,900 miles per year
Air Pollution Haze from China
A. Less than 15% Methane

B. More than 50% Natural Sources
Net Effect: Changes in Arctic Sea Ice
Warming for 100 years or 10,000 years?

Ice Cores-Temps

CO₂ Studies
Some Possible Consequences of Climate Change

• Although complex to predict, some possible consequences include:
  • Probable rise in sea level
  • Greater intensity of tropical cyclones
  • Changes in the extent of Arctic sea ice and permafrost
  • Sudden unexpected changes in climate are possible.
  • A constant state of change is very likely.