Lecture Outlines

Physical Geology, 15/e

Plummer, Carlson & Hammersley

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Global Climate Change

Physical Geology 15/e, Chapter 21

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Weather, Climate and Climate Change

Weather– describes what the atmosphere is doing over short timescales

Climate– the average weather pattern in a region over long periods of time

Anthropogenic Climate Change– climate change related to human activities

Concerns Over Modern Climate Change

•Rapid rate of climate change makes adaptability less likely

•Increased human population limits the ability of humans to easily move away from problems

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Understanding the Atmosphere

Composition– the atmosphere is composed of many different gases

- Nitrogen and oxygen: >99% in clean dry air
- Argon, carbon dioxide, neon, helium, water vapor (0.0001 – 4%)

Structure– atmosphere divided into 4 layers

- *Troposphere:* lowest layer
- *Stratosphere*: ozone layer occurs here
- *Mesosphere*
- *Thermosphere:* also called the *ionosphere*

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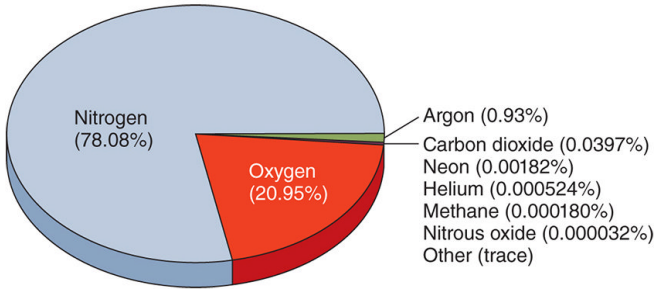

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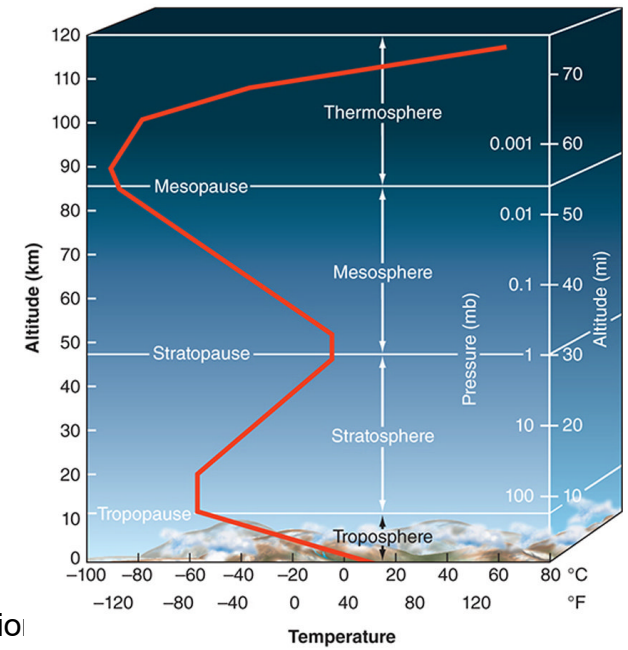

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Understanding the Atmosphere

Energy from the Sun– Earth's primary source of energy (electromagnetic radiation)

- *Albedo:* percentage of radiation reflected from the surface

Blackbody radiation– the intensity and wavelength of emitted electromagnetic radiation

- Infrared radiation: terrestrial radiation or long-wave radiation

The Greenhouse Effect– keep Earth warm

- Greenhouse gases absorb long-wave radiation
- Heats atmosphere
- Act as a blanket

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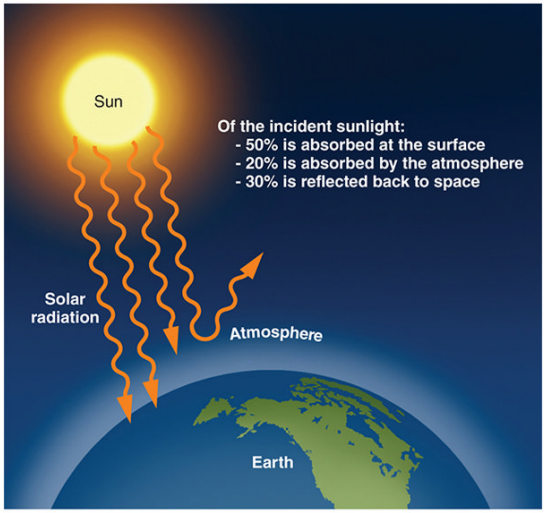

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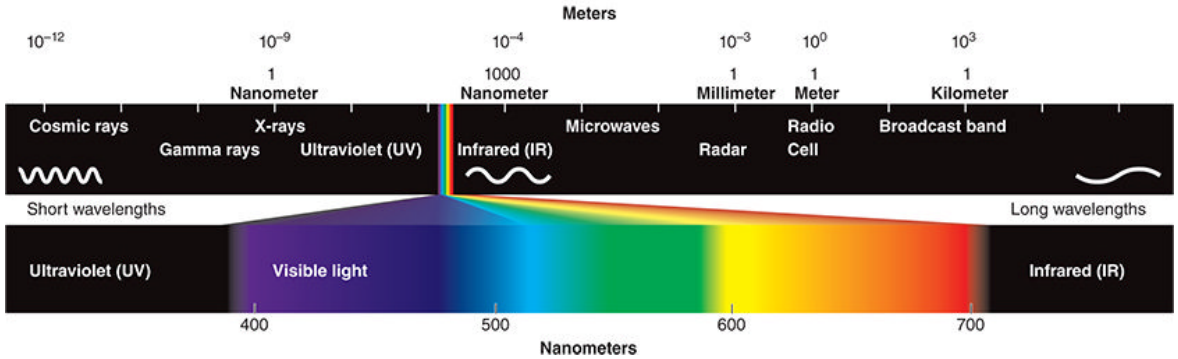

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Causes of Climate Change

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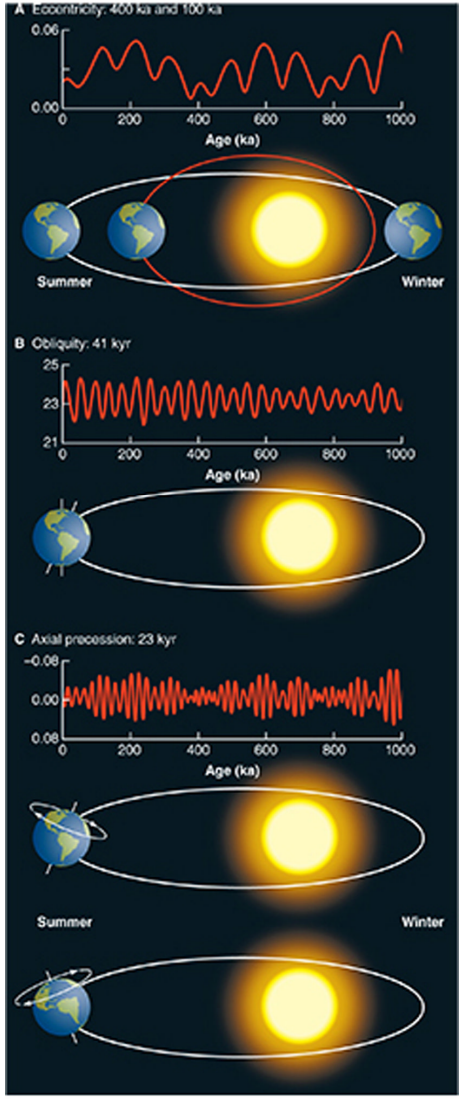

Earth's average climate is determined by its *radiative balance*

- Amount of energy entering the Earth system
- Amount of solar energy absorbed by the Earth system
- Amount of long-wave radiation emitted to space

Solar Variability and the Orbital Theory of Climate

- Amount of solar energy reaching Earth varies
- ***Milankovitch Theory***
    - *Orbital Eccentricity, Axial Obliquity and Axial Precession* determine input and distribution of solar radiation over long time scales.
- ***Sunspot Cycle***

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Causes of Climate Change

Variations in Earth's Albedo

Approximately 30% of the Sun's radiation is reflected back into space

- Albedo varies based on surface materials
    - Snow and Ice have high albedos
    - Darker surfaces have lower albedos
- *Climate feedback:* conversion of high albedo snow and ice to lower albedo surfaces

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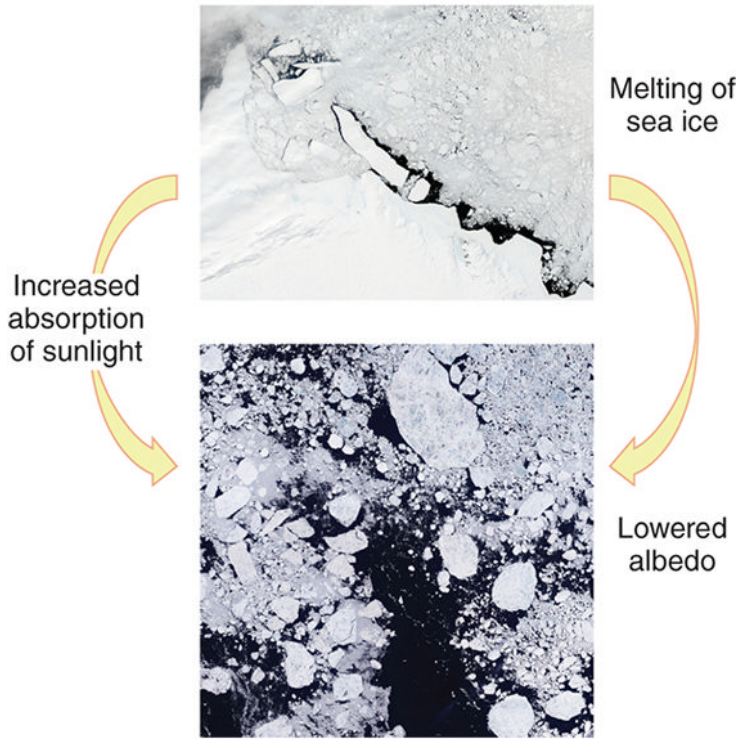

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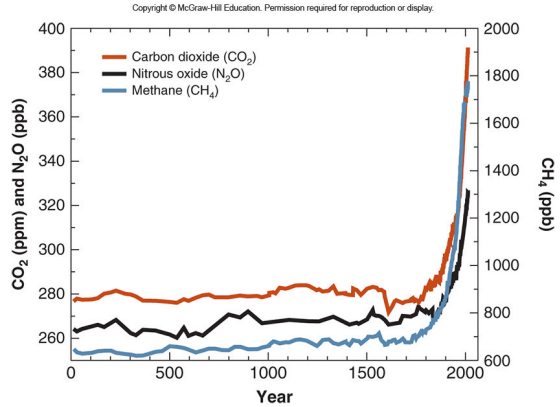
Causes of Climate Change

Greenhouse gases– each different gas has a different ability to affect Earth's climate

•Each greenhouse gas absorbs radiation with varying efficiencies

•*Atmospheric lifetime*: each greenhouse gas survives in the atmosphere for different amounts of time

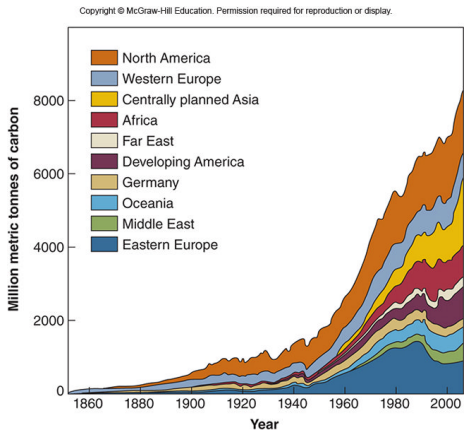
•*Global Warming Potential:* a relative measure of each gases ability to trap heat in the atmosphere



Clouds and particles

•*Aerosols* – small particles suspended in the atmosphere

•Cloud droplets and aerosols reflect approximately 23% of incident solar radiation back to space



Volcanoes– releases particles and gases into the atmosphere

Plate tectonics– alters surface albedo and ocean circulation over million-year timescales

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A Brief History of Earth's Climate

Paleoclimatology— the study of ancient climates

Climate Millions of Years Ago

- Prior to 2.6 million years ago temperatures and CO2 levels were higher
- CO2 levels reconstructed from isotopic content of carbon in fossils and density of plant stomata

Climate Over the Last Million Years

- The Milankovitch Theory
    - Oxygen isotopes in foraminifera correlate to past temperatures and revealed a clear periodicity in accordance with Milankovitch
- Ice Cores reveal CO2 variations; CO2 variations correlate closely with temperature
- Major changes in temperatures have varied on 100,000 year cycles that correlate to periods of glaciation and subsequent warmer interglacial periods

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A Brief History of Earth's Climate

Paleoclimatology— the study of ancient climates

Climate Over the Last Few Thousand Years to Present

- Last glacial maximum ended about 15,000 years ago due to orbital variation forces and amplified by changes in CO2 and methane concentrations
- Several proxies are used to assess temperature variations
    - Borehole thermometry – measuring temperatures deep in the ground to infer what temperatures must have been in the past
    - Tree Rings and Direct Measurement
- Global temperatures began to rise substantially at time of industrial revolution

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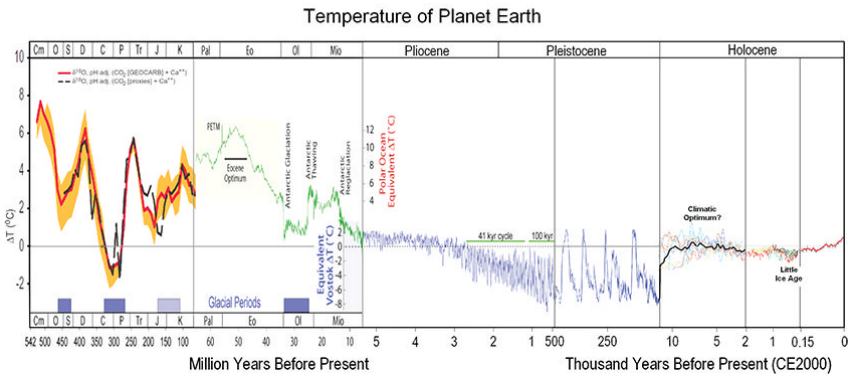

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Climate Change in the Modern Age

Temperature

•Increased approximately 0.74 degrees Celsius between 1901 and 2012

•Rate of increase is increasing

•However, global mean temperatures have been constant over the last decade

•Computer models suggest that warming is due to greenhouse gases

Precipitation - increasing regional differences

Sea Ice & Glacier Melt - decreasing sea ice, increasing glacial melting

Sea-Level Rise - melting of glaciers and ice sheets responsible for a 0.19 m rise between 1901 and 2010

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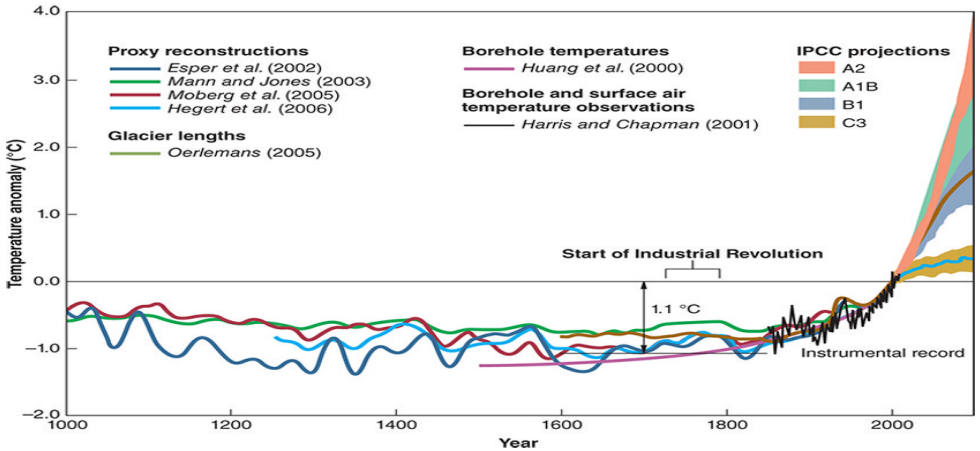

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Climate Models

Earth's climate is complex and challenging to predict

Global-scale computer models indicate that increases in greenhouse gas concentrations are responsible for the vast majority of warming over the last century

The IPCC Intergovernmental Panel on Climate Change

- 2013 report concluded that "Warming of the climate system is unequivocal" and that "Human influence on the climate system is clear…"

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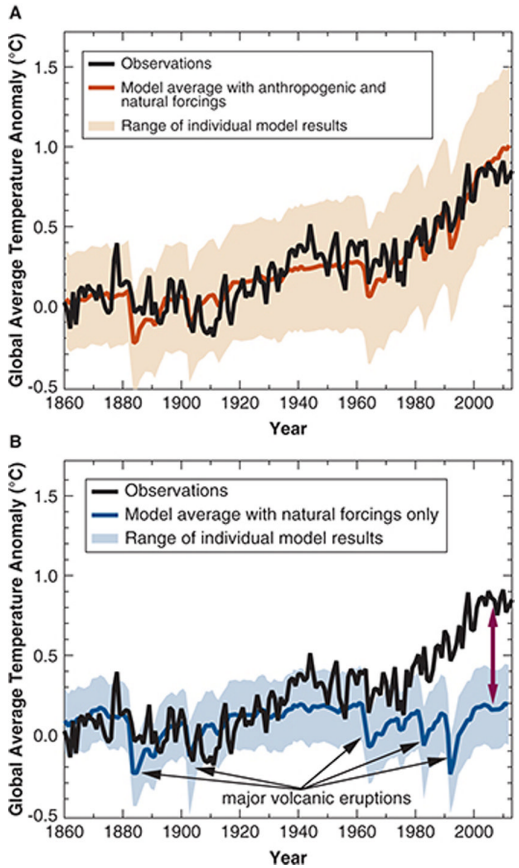

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Impacts & Consequences

Biodiversity and Agriculture

- Biodiversity - could be reduced as habitats become more limited.
- Agriculture – crops become more susceptible to extreme weather events

Ocean Acidification—as more CO_2 dissolves in the ocean, the ocean will become more acidic

Coastal regions and Sea Level rise

- >600 million people live <10 m above sea level
- Aquifers flooded with sea water

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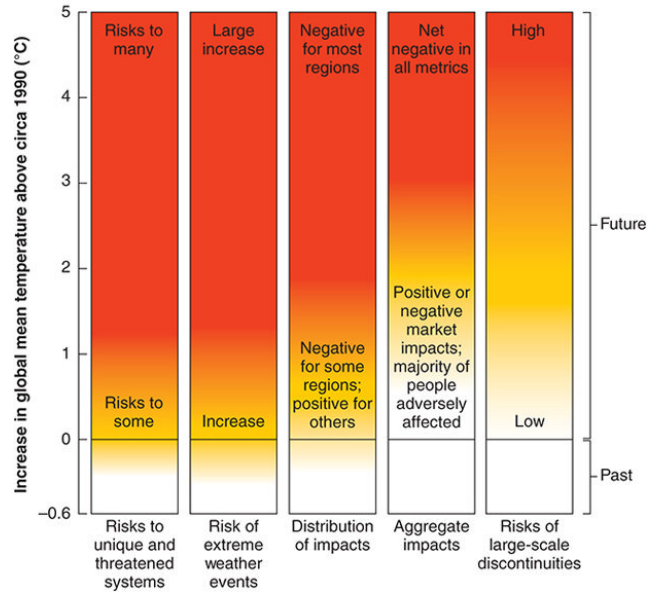

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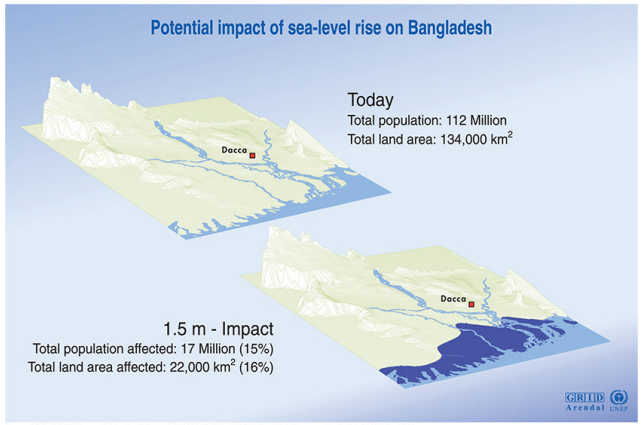

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Geoengineering

Geoengineering

Large-scale intentional efforts to modify Earth's climate

- **Solar Radiation Management**
  - Reflecting more back into space
  - Should be considered temporary fixes
- **Carbon Management**
  - Accelerating the reduction of CO_2 concentrations
  - *Carbon Capture and Sequestration:* capture and storage of CO_2

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Decreasing Emissions of Greenhouse Gases

Future reductions must include:

- Reducing use of fossil fuels by increasing efficiency
- Switch to alternative energy sources
- Wide-spread usage of low-energy appliances
- Cultural shifts to reduce demand for energy and natural resources is decreased

Fate of Atmospheric Carbon Dioxide

- Different Processes remove CO2 on various time-scales
    - Uptake by the land biosphere
    - Dissolution into the oceans
    - Reaction with calcium carbonate

Scientific Consensus

- Link between greenhouse gases and planetary temperatures is well established
- Broad agreement that negative consequences are already being felt and will continue without action

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End of Chapter 21

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