Visualizing Environmental Science

Global Atmospheric Changes

Chapter 9

Molnia, Bruce F. 2004 Muir Glacier: From the Glacier Photograph Collection. Boulder, Colorado USA: National Snow and Ice Data Center/World Data Center for Glaciology. Digital Media.

C. L. Andrews/NG Image Collection

The Atmosphere and Climate

- Weather
  - Conditions in the atmosphere *at a given place and time*
  - Includes temperature, atmospheric pressure, precipitation, cloudiness, humidity, and wind
  - Can vary hour to hour and day to day

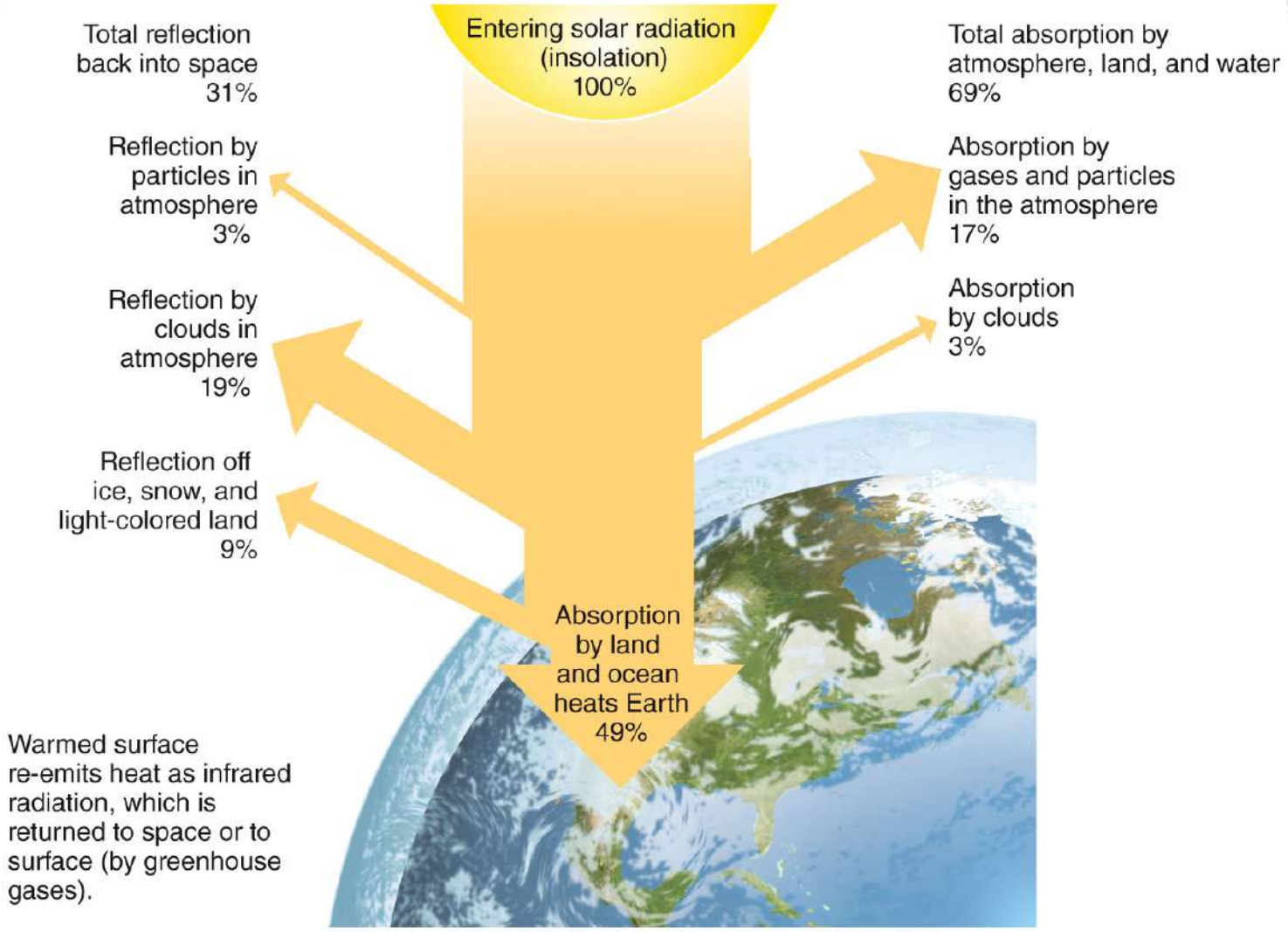
The Atmosphere and Climate

- Climate
  - Weather patterns that occur in a place over a period of years
  - Determined by Earth's distance from sun; its tilt relative to its rotational axis; distribution of water and landmasses on its surface, and composition of gasses in the atmosphere
  - All change very slowly *except* solar intensity and atmospheric composition
  - Temperature and precipitation are the two most important factors that define an area's overall climate
  - Because climate normally changes slowly, over hundreds or thousands of years, organisms in a given area have adapted to these factors

Solar Radiation and Climate

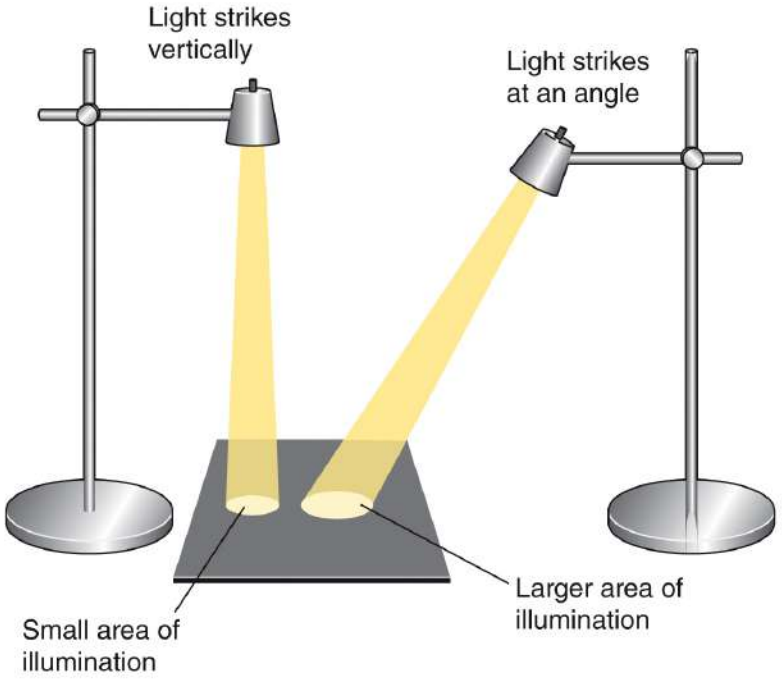
- Sunshine warms the planet and makes life on Earth possible
  - Without the sun, all water on Earth would be frozen
  - Photosynthetic organisms use the sun's energy to make compounds necessary for most other forms of life
  - 69% of solar energy is absorbed and runs the hydrologic, carbon and other biogeochemical cycles
    - Clouds, snow, ice, and the ocean reflect away the remaining 31% of solar energy that reaches the Earth
  - Infrared radiation is the final form of energy that solar energy is converted to as it returns to space from Earth.

Solar Radiation and Climate



Temperature Changes With Latitude and Season

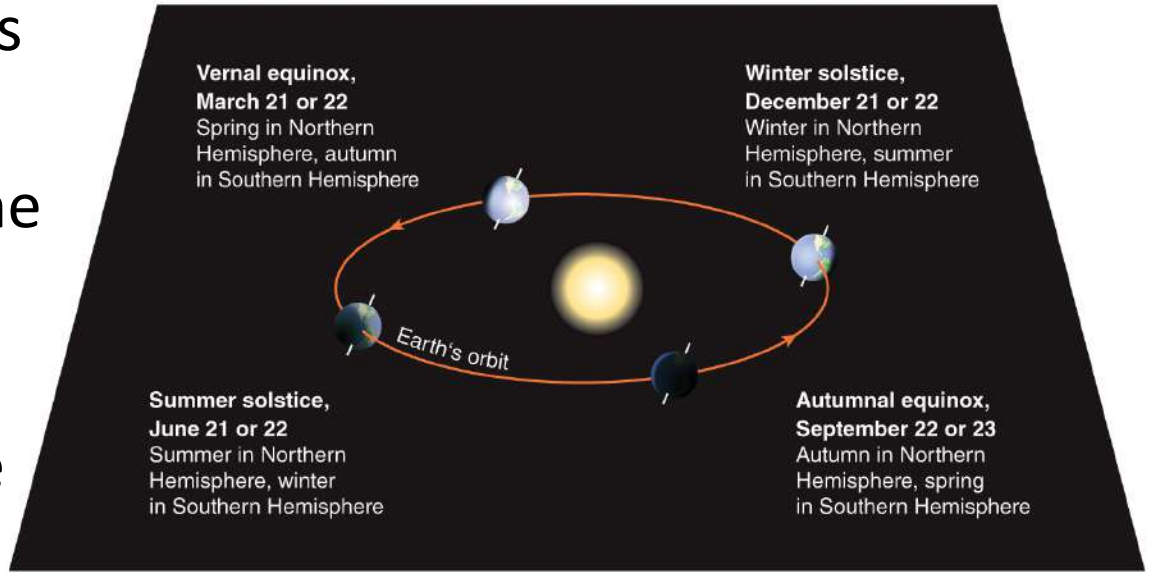
- Most of the energy produced by the sun never reaches the Earth
- Exposure to solar energy varies due to Earth's shape and the tilt of its axis
- Sunlight hitting the equator vertically (left lamp) is concentrated on Earth's surface
- As you move towards the poles, light hits more indirectly and covers larger area (right lamp)



Solar intensity and latitude

Temperature Changes With Latitude and Season

- Earth's tilt on its axis is 23.5 degrees
- This tilt determines the seasons
- Half the year the Northern Hemisphere tilts towards the sun (March – Sept), the other half it tilts away

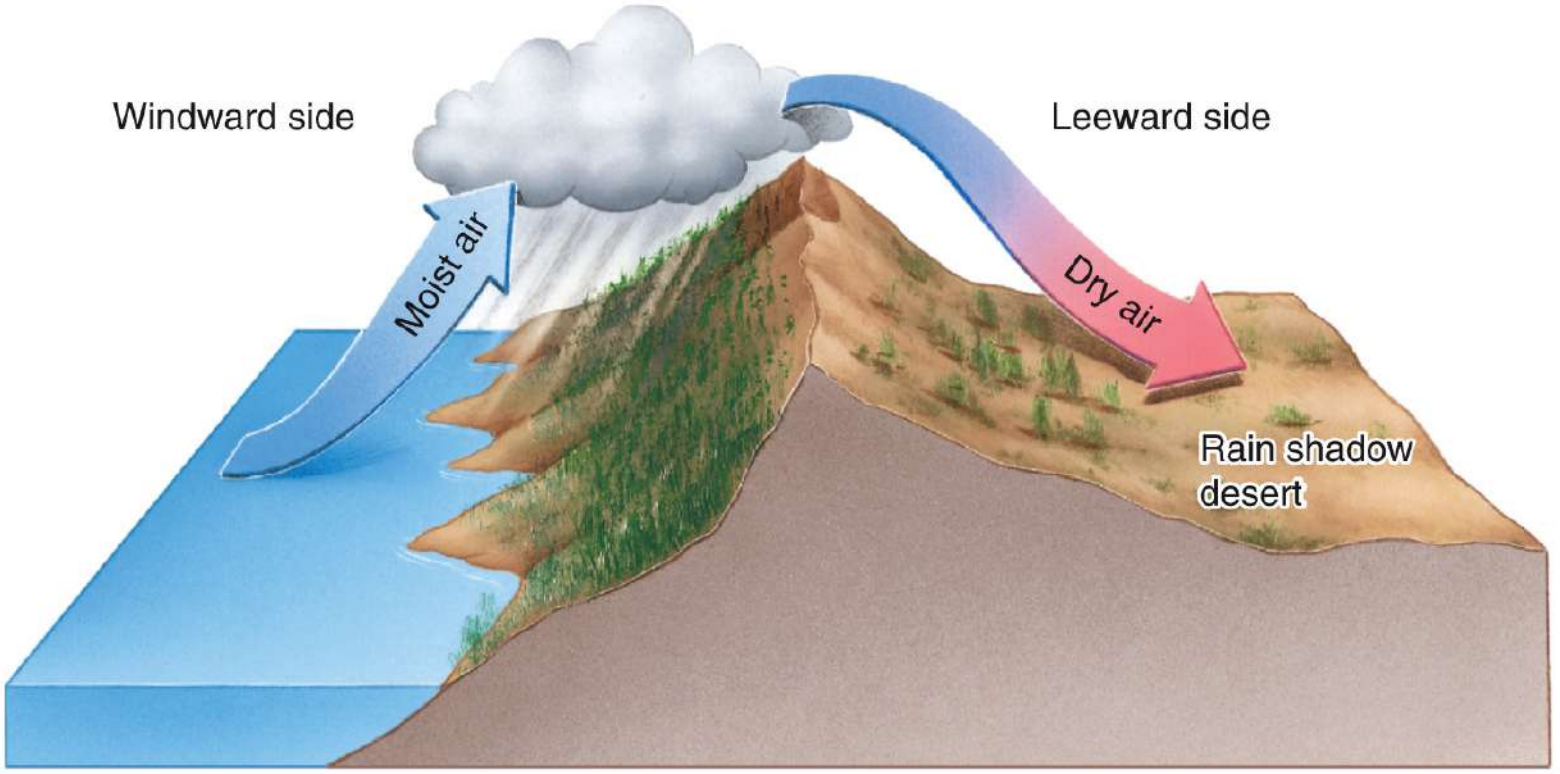


Progression of seasons

Precipitation

- Precipitation
  - Water falling from the atmosphere in any form—rain, snow, hail
- Differences in precipitation depend on three factors
  - Amount of water in the atmosphere
    - Equatorial uplift
      - Water evaporates from warm areas of the ocean.
  - Geographic location
  - Topographic features
    - Rain shadows
      - Dry on one side of mountain, away from wind, while raining on other side

What a Scientist Sees: Rain Shadow



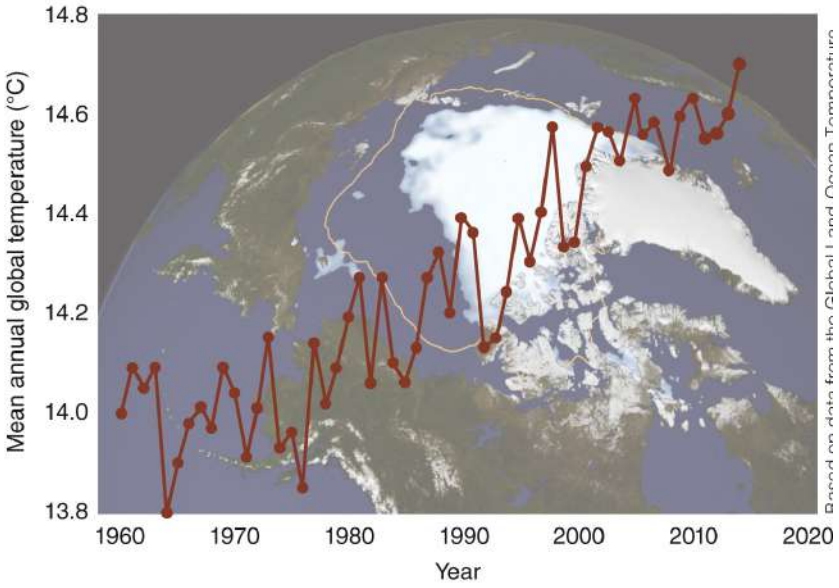
A rain shadow refers to arid or semiarid land that occurs on the far side (leeward side) of a mountain. Prevailing winds blow warm, moist air from the windward side. Air temperature cools as it rises, releasing precipitation, so dry air descends on the leeward side. Such a rain shadow exists east of the Cascades.

Global Climate Change

- Earth's average temperature is increasing
  - Daily measurements taken by meteorological stations, weather balloons, orbiting satellites, transoceanic ships, sea surface buoys
  - Data from these global sources show that every year since 1995 has been hotter than any year between 1800 (earliest records) and 1985.
  - Seven of the hottest years on record occurred in the past decade

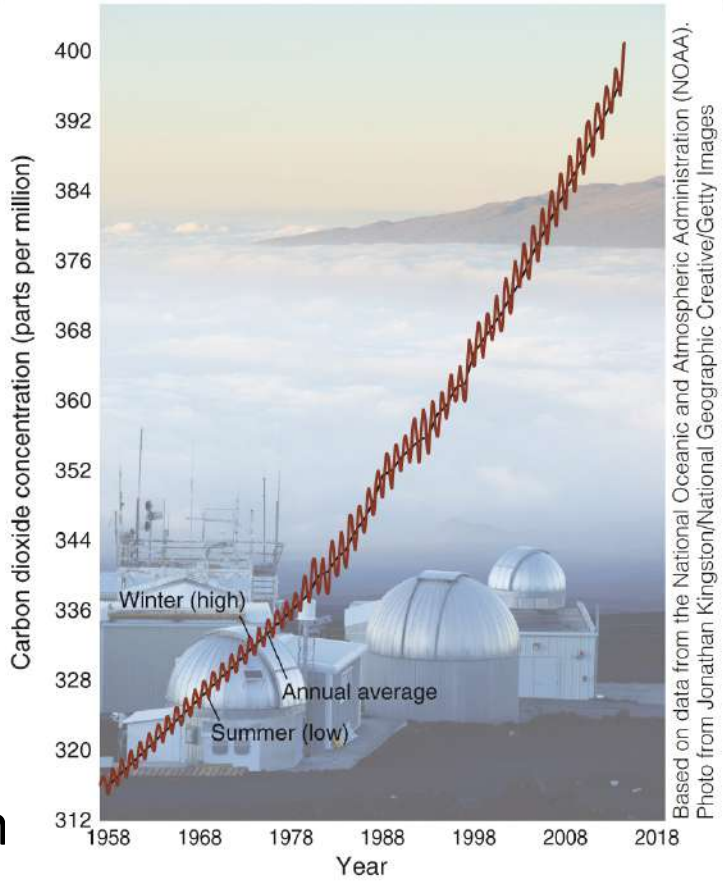
Global Climate Change

- NOAA: global temperatures since 2010 have been the highest in the last millennium
  - Last two decades of the 20th century were its warmest
  - Increase in heat waves, heat-related deaths
  - Sea levels rising, glaciers retreating, more severe hurricanes
- Spring in the Northern Hemisphere comes six days earlier than in 1959; autumn comes five days later



Global Climate Change

- Significant climate change due to human activities that release greenhouse gases will occur in the 21st century
- United Nations has charged the Intergovernmental Panel on Climate Change (IPCC) to provide scientific assessment of climate change
  - Predict a 2.0–5.5°C (3.6° to 9.9°F) increase in global temperature by the year 2100
  - Predict higher maximum and minimum temperatures, and increased precipitation and risk of drought, depending on location



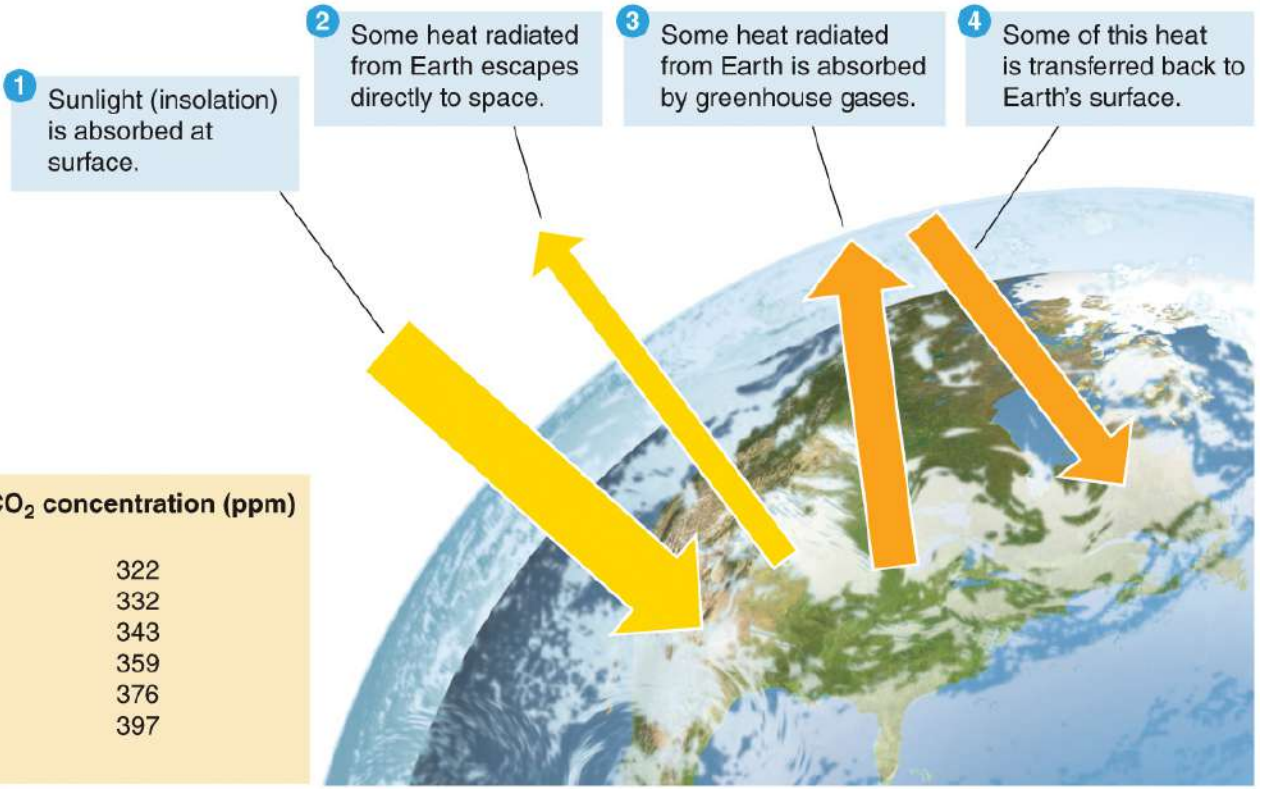
Carbon dioxide (CO_2) in the atmosphere, 1958–2015

Causes of Global Climate Change

- Greenhouse gases accumulate in the atmosphere as a result of human activities.
  - Carbon dioxide (CO_2)
    - Burning fossil fuels accounts for >70% of CO_2 increase
    - Deforestation accounts for the remainder of the increase
  - Methane (CH_4)
    - Produced by decomposition of organic material
  - Nitrous oxide (N_2O)
    - Car engines release N_2O and CO_2
  - Chlorofluorocarbons (CFCs)
    - Chemicals released by older leaking refrigerators and air conditioners
  - Tropospheric ozone (O_3)
    - Produced by chemical reactions with N_2O released by internal combustion (cars)
- CO_2 has increased from 288ppm 200 years ago to 401 ppm in 2015

Causes of Global Climate Change

Enhanced Greenhouse Effect



Year	Temperature (°C)	CO_2 concentration (ppm)
1964	13.79	322
1974	13.92	332
1984	14.16	343
1994	14.32	359
2004	14.55	376
2014	14.75	397

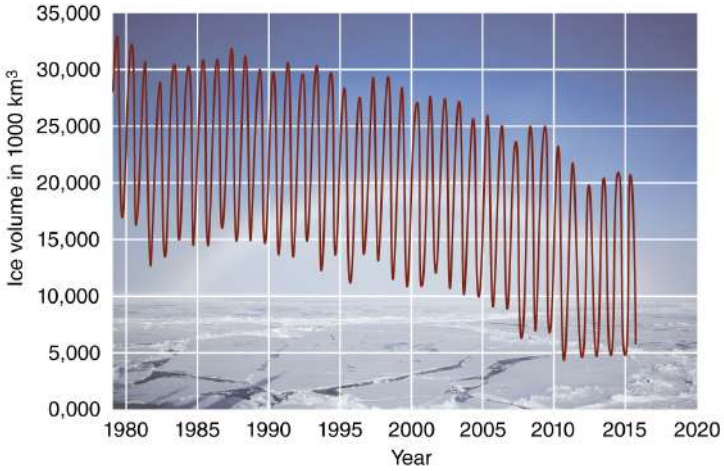
The buildup of carbon dioxide (CO_2) and other greenhouse gases warms the atmosphere by absorbing some of the outgoing infrared (heat) radiation. Some of the heat in the warmed atmosphere is transferred back to Earth's surface, warming the land and ocean.

Causes of Global Climate Change

- CO_2 and other gases are called *greenhouse gases* because they trap the sun's infrared radiation like glass in a greenhouse
- Additional atmospheric warming, due to the presence of increased concentrations of greenhouse gases produced by human activities, is called the *enhanced greenhouse effect*

Effects of Global Climate Change

- Global climate change effects include:
  - Melting land and ocean ice
  - Ice cap at North Pole decreased consistently over the past three decades
  - Sea-level rise
    - Antarctic ice cap and continental glaciers melting
    - Water expands as it heats
    - The sea level rose 10 to 20 cm (4 to 8 in) during the 20th century. It is estimated to rise an additional 20 to 50 cm (7.9 to 20 in) by 2100



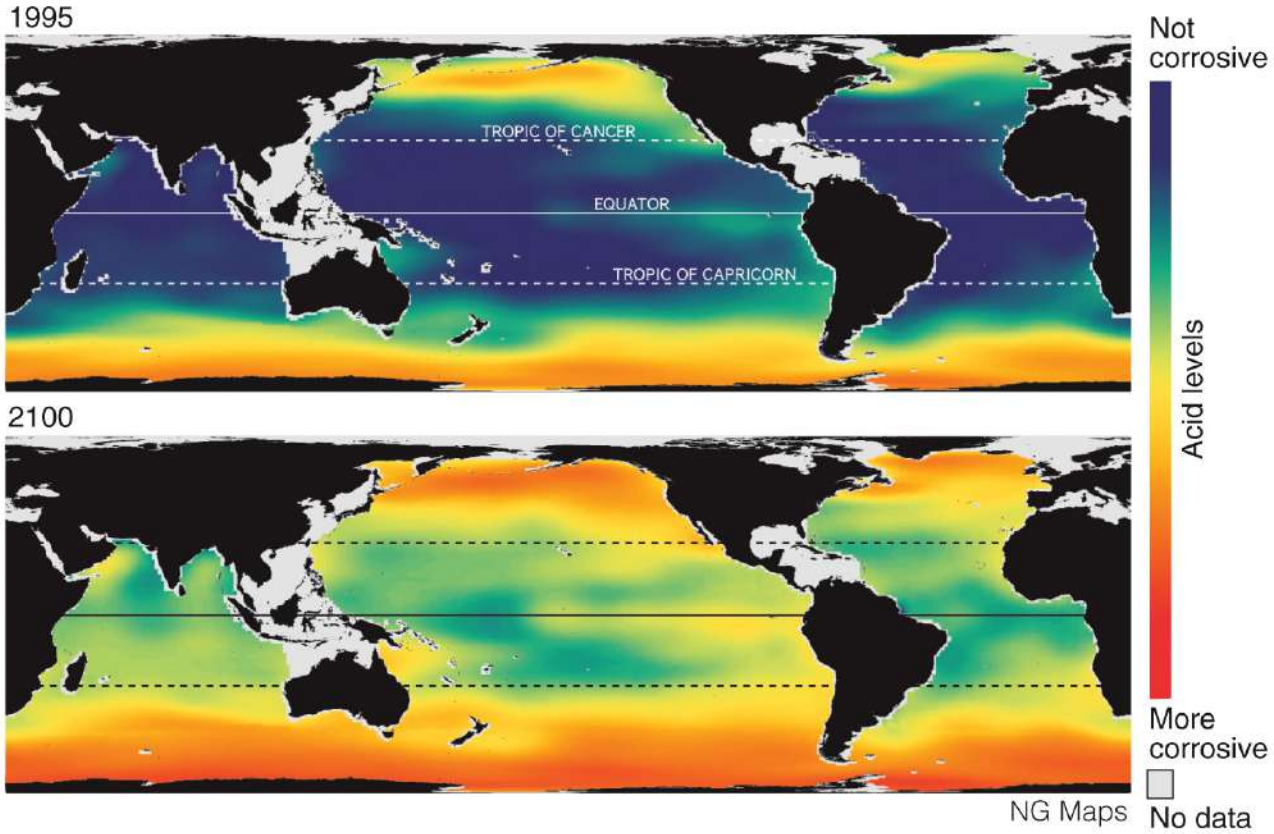
Effects of Global Climate Change

- Global climate change effects include:
  - Changes in precipitation patterns
  - Impacts on agriculture and human health
    - Mixed effects on agriculture; some areas will be wetter, some drier
  - Residents of coastal areas and low-lying islands and will be increasingly vulnerable to saltwater intrusion and storm surges

Effects of Global Climate Change

- Impacts on human health
  - Increases in heat-related illnesses and deaths
  - Mosquitoes and other disease-carrying organisms will expand their range and spread malaria and yellow fever
- Impacts on populations, communities and ecosystems
  - Measurable changes in the biology of plant and animal species
  - Decline in Antarctic silverfish and krill
  - Global decline in frog populations
  - Coral reef bleaching
  - Ocean acidification could kill zooplankton, affecting entire marine food web

Environmental InSight
The Effects of Global Climate Change



Scientific models project that ocean water will become increasingly acidic if human-produced CO_2 levels continue to rise. Shown are computer models for 1995 and 2100 from the NOAA Pacific Marine Environmental Laboratory.

Dealing With Global Climate Change: Mitigation and Adaptation

- Mitigation is the moderation of global climate change by taking measures that reduce greenhouse gas emissions
- Adaptation is a planned response to changes caused by global climate change
- Approach will require a combination of both mitigation and adaptation
  - The sooner we implement mitigation and adaptation strategies, the more effective they will be

Mitigation of Global Climate Change

- Focus is on CO_2 reduction
  - All greenhouse gases are important, but CO_2 is produced in the greatest quantity and has the largest total effect
- CO_2 reduction strategies include developing alternatives to fossil fuels (renewable energy), reduce energy use and increase energy efficiency
  - Plant and maintain forests as carbon sinks
  - Increase fuel economy of motor vehicles
  - Carbon management—separate and capture CO_2 produced during fossil fuel combustion

Mitigation of Global Climate Change

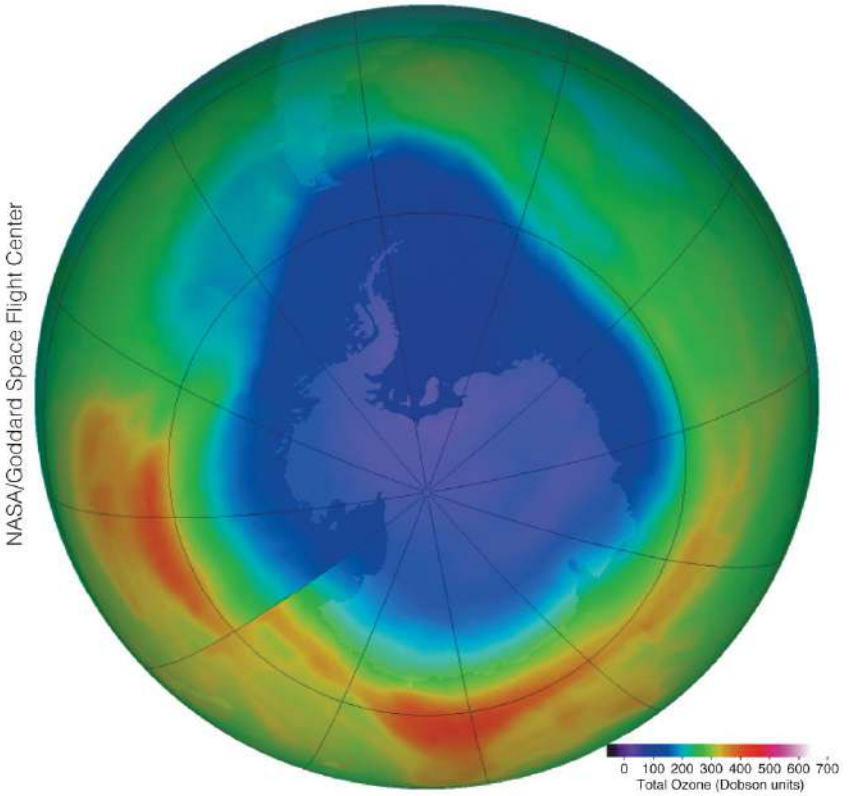
- Other mitigation strategies that can be used along with fossil fuel reduction:
  - Plant trees on degraded land
  - Increase efficiency of coal-fired power plants
  - Replace coal-fired power plants with nuclear, hydro, wind, or even natural gas plants
  - Redesign cities to reduce reliance on single-occupant vehicles
  - Insulate buildings to reduce winter heating and summer cooling needs
  - Improve management of agricultural soils

Adaptation to Global Climate Change

- Most pressing issue is rising sea level
  - Solution is to move coastal settlements inland or construct sea walls on coastal areas—both expensive options
  - Rivers could be channeled to prevent saltwater intrusion into fresh water and agricultural land
  - Adapt to shifting agricultural zones
    - Find substitute crops to grow on warming land
    - Develop heat and drought resistant crops/trees
  - City planning
    - Rebuild storm runoff system to prevent flooding due to higher tide levels

Ozone Depletion in the Stratosphere

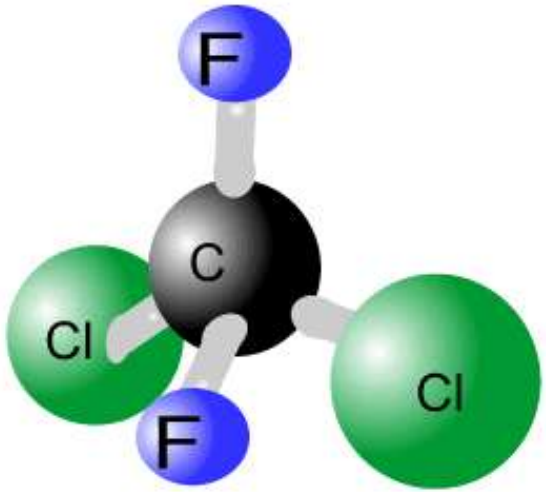
- Ozone (O_3) is a natural component of the stratosphere but a human-made pollutant in troposphere
- Ozone layer in stratosphere shields the Earth from UV radiation
- Without the ozone layer, Earth would be uninhabitable
- Unnatural thinning of ozone, referred to as the 'ozone hole' where levels decrease up to 70% each year, was first noticed in 1985



A computer-generated image of part of the Southern Hemisphere, taken in September 2012, reveals ozone thinning (the purple area over Antarctica).

Causes of Ozone Depletion

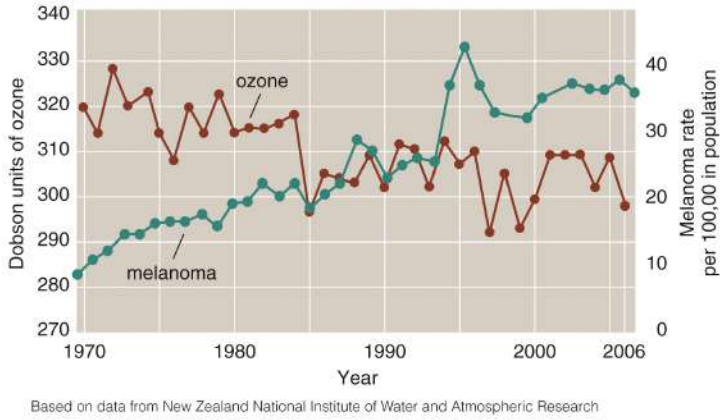
- Chlorofluorocarbons (CFCs) are the primary chemicals responsible for ozone loss in the stratosphere
  - CFCs are human-made organic compounds that contain chlorine and fluorine
  - Used primarily as coolants in refrigerators and air conditioners, and also as propellants in aerosol cans



Effects of Ozone Depletion

- Ozone depletion allows more UV radiation to reach the Earth's surface
  - Disrupts ecosystems
  - Linked to ocular cataracts, weakened immunity and skin cancer
  - Exposure to any amount of UV radiation increases the risk of skin cancer
    - Rates of occurrence of malignant melanoma, the most dangerous skin cancer, are increasing faster than those of any other type of cancer

This graph shows the average yearly ozone column over New Zealand and the correlation with annual melanoma rate

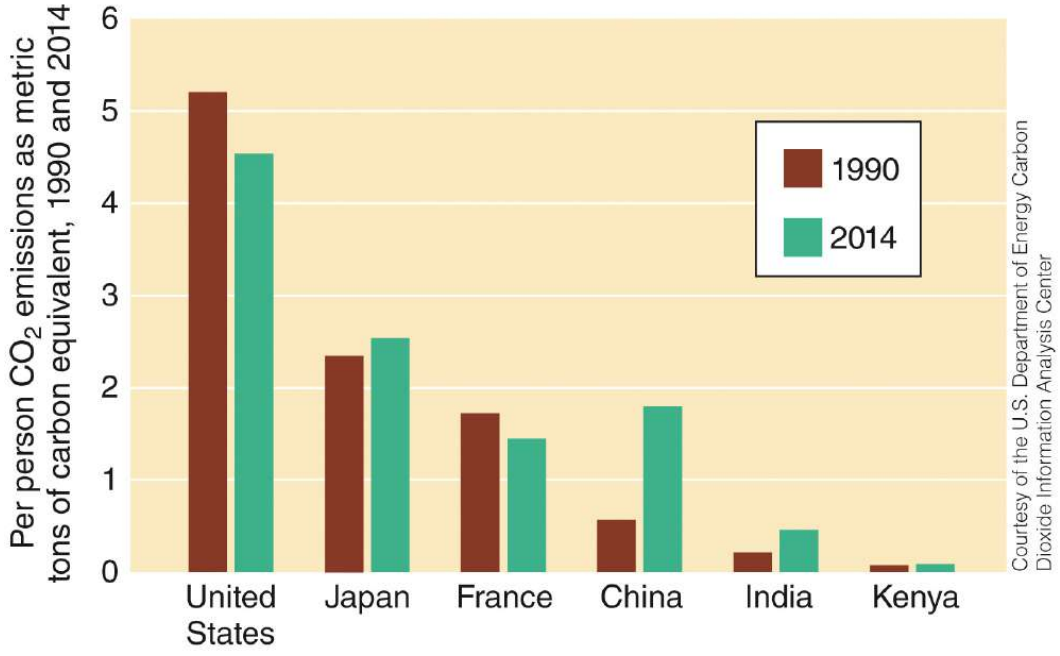


Reversing Ozone Layer Thinning

- CFC production was phased out in the United States and other highly developed countries in 1996
- Developing countries phased out use of CFC in 2005
- Unfortunately, since CFCs are very stable, they will continue to deplete stratospheric ozone for decades
  - Full ozone recovery should take place after 2050

Case Study: International Implications of Global Climate Change

- Social, economic, political factors complicate efforts to manage global climate change
  - Per capita emissions higher in developed than developing countries, however emissions increase with industrialization



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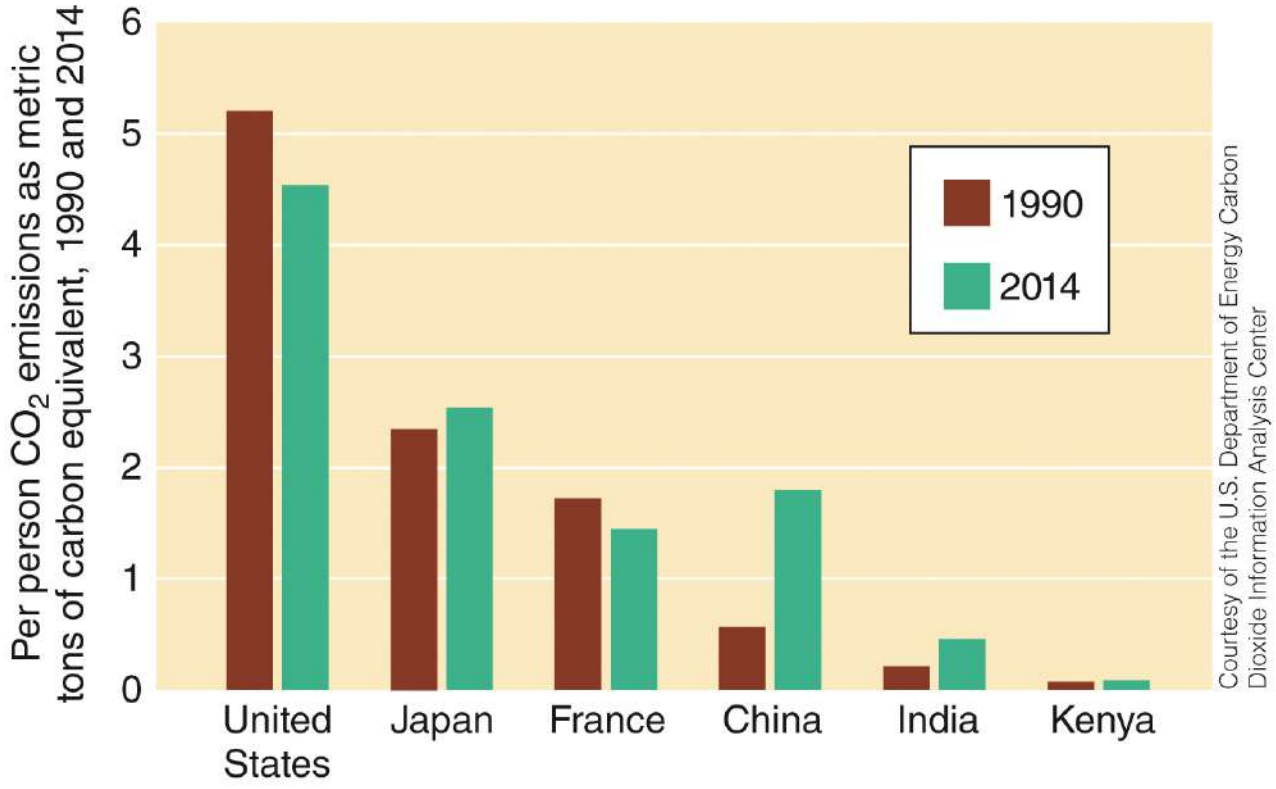

Per person carbon dioxide (CO_2) emission estimates for selected countries, 1990 and 2014

Currently, industrialized nations produce a disproportionate share of CO_2 emissions. As developing nations such as China and India industrialize, however, their per person CO_2 emissions increase.