ANNOUNCEMENTS

- Midterm tomorrow (February 26th)
  - **LRW B1007– Last name range (A – I)**
  - **T 34 – Last name range (J - O)**
  - **MDCL 1305 – Last name range (P – Z)**
- **Articles to read (not for midterm but for the class after)**
  - https://www.theguardian.com/science/2019/feb/24/climate-change-is-central-to-geography-lessons
  - https://www.theatlantic.com/science/archive/2019/02/ticks-can-take-down-800-pound-moose/583189/
  - https://business.financialpost.com/pmn/business-pmn/consumer-goods-companies-preparing-for-climate-change-impact


Climate Change

Learning Objectives

- Understand the difference between climate and weather
- Know the basic concepts of atmospheric science, specifically the structure, composition, and dynamics of the atmosphere
- Understand the causes of climate change
- Understand how climate has changed in the recent geologic past, and how human activity may be altering climate
- Know how climate change can affect the frequency or severity of some natural hazards
- Know how we can adjust to the problems climate change may cause

Global Change and Earth System Science

- The effect of humans on Earth are extensive

- To recognize and modify the changes we have initiated, we need to understand how the Earth works as a system

- **Earth system science**
  - The aim is to study how the components of the system are linked on a global scale and how these complex links affect life on Earth
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Climate and Weather

- refers to the characteristic atmospheric conditions of a region over years or decades
  - Characterized by average temperature and precipitation

- refers to the atmospheric conditions of a region for days or weeks

Composition of the Atmosphere

-
  - Concentrations of which do not change
  - Ex: nitrogen, oxygen
-
  - Concentrations of which vary in time and space
  - Ex: carbon dioxide, water vapour, ozone, methane

TABLE 14.1 Composition of the Atmosphere

Permanent Gases		Variable Gases	
Nitrogen	78.08%	Water Vapour	0.2–4%
Oxygen	20.95%	Carbon Dioxide	0.038%
Argon	0.93%	Methane	0.00017%
Neon	0.0018%	Nitrous Oxides	0.000032%
Helium	0.00052%	Ozone	0.000004%
Krypton	0.00011%	Halocarbons	0.00000002%
Xenon	0.00009%		
Hydrogen	0.00005%		

Note: Percentage by volume.

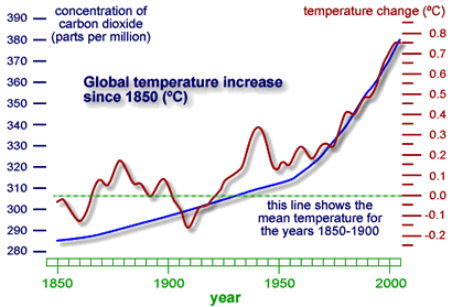
Source: Data in part from Bryant, E. 1997. Climate Process and Change. *New York, NY: Cambridge University Press.*

Permanent Gases

- Constitute about ___ by volume of all atmospheric gases
  - nitrogen, oxygen, and argon
- Nitrogen composes about ___ of the volume of all permanent gases
  - Relatively unimportant to atmospheric dynamics
- Oxygen composes about ___ of atmospheric gases by volume

Carbon Dioxide (CO_2)

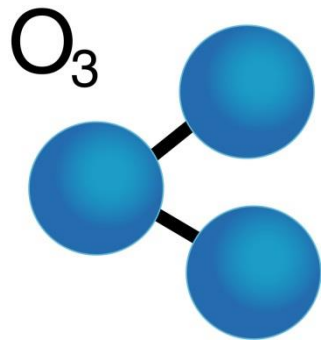
- Makes up a very small percentage of the atmosphere
- Released naturally by volcanic activity, plant and animal respiration, wildfires, and decay of organic material
- Removed through photosynthesis, chemical weathering, and absorption by sea water seawater
- It also enters the atmosphere through the burning of fossil fuels by people
  - Increased greatly since the Industrial Revolution



Water Vapour (H_2O)

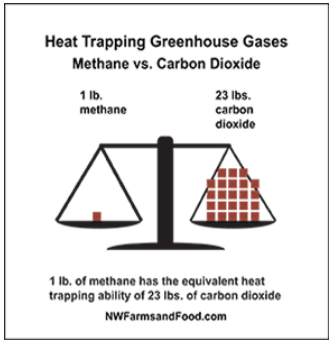
- Produced by the evaporation at Earth's surface
- Condenses to form clouds and eventually returns to the surface as precipitation as part of the **hydrologic cycle**
- Air temperature is the primary control of the amount of water vapour in the atmosphere
  - Warm air increases evaporation

Ozone (O_3)



- Found in small amounts in the stratosphere
- Partially shields Earth from ultraviolet radiation from the sun
- Smaller concentrations are found in the troposphere near Earth's surface
  - Produced by chemical reactions during the _____
  - Irritates lungs and eyes and aggravates _____

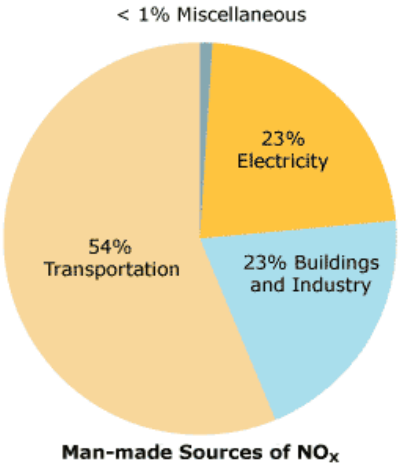
Methane (CH_4)



- A major component of natural gas
- Forms naturally by bacterial decay, and in the intestinal tracks of termites, cows, and sheep
- Anthropogenic sources include coal mines, oil wells, leaking natural gas pipelines, rice paddies, landfills, and livestock
- Levels in the atmosphere have doubled _____

Nitrogen Oxide Gases (NO_x)

- Sometimes referred to as nitrous oxides
- Natural sources include microbiological processes in soils and oceans, wildfires, and lightning strikes
- Anthropogenic sources include automobiles, power plants, jet aircraft, and fertilizers

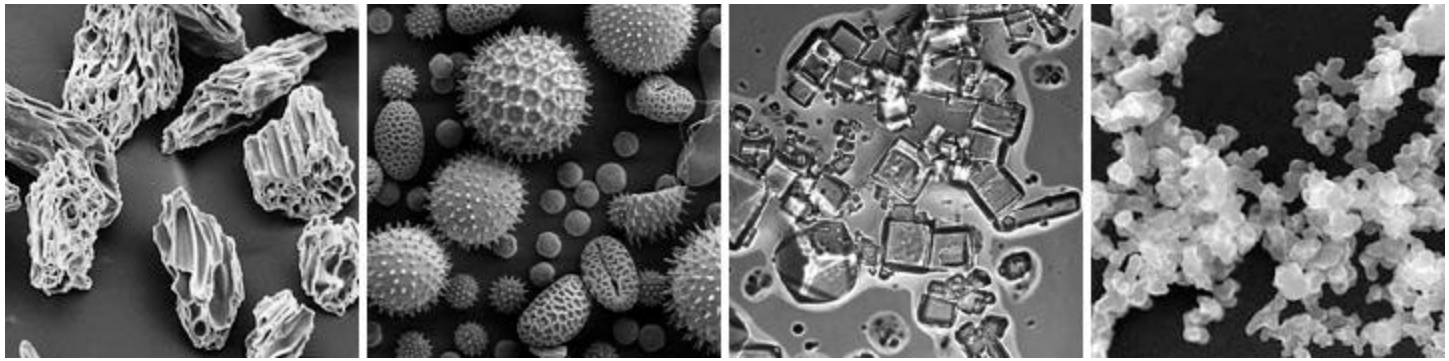


Halocarbons

- Chemical compounds that contain carbon and halogen elements
- Include CFCs and are almost entirely anthropogenic
- Used in industrial processes, firefighting, and as fumigants, refrigerants, and propellants
- Contribute to warming of the troposphere and ozone depletion in the stratosphere

Aerosols

- Microscopic liquid and solid particles in the atmosphere
  - The nuclei around which droplets _____
- Natural sources of aerosols include desert dust, wildfires, sea spray, and volcanic eruptions
- Anthropogenic sources include the burning of forests to clear land and the consumption of _____

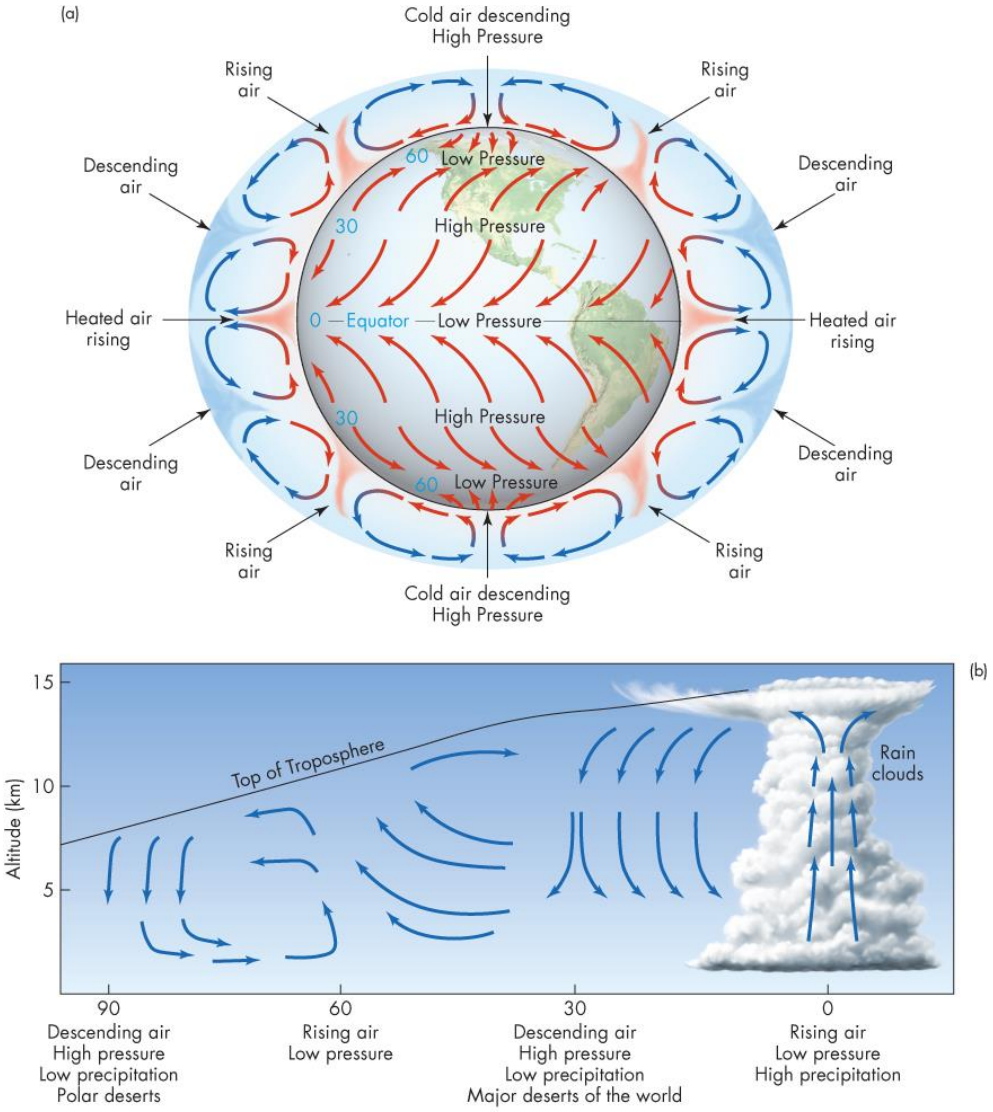


Structure of the Atmosphere

- Much of the heat radiating from Earth's surface is absorbed in the troposphere
  - Lowest layer of the atmosphere
- The stratosphere is a dry layer where water vapour occurs as ice crystals
  - Aerosols rapidly disperse around the world in the stratosphere
- Uppermost layers (mesosphere and thermosphere) have little effect on climate

Atmospheric Circulation

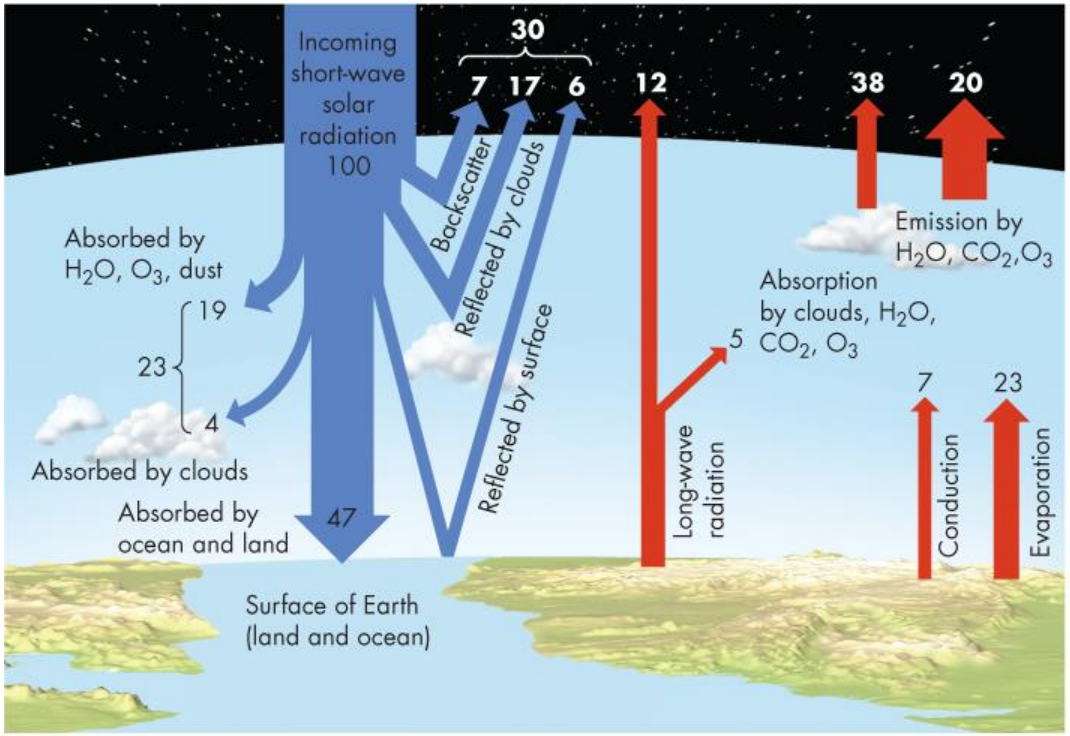
- At the equator, warm moist air rises and moves toward the poles
  - As it rises, it cools and loses moisture as rain
- Dry air descends between _____
  - Descending air produces high pressure and little rainfall
- Circulation cells create regions of high pressure and low precipitation near the North and South poles
  - Land areas there are referred to as polar deserts



▲ **FIGURE 14.4 ATMOSPHERIC CIRCULATION** (a) The general circulation of the lower atmosphere, showing zones of rising and descending air masses and corresponding areas of low and high air pressure. (b) An idealized diagram showing atmospheric circulation along a transect from the equator to a pole.

The Greenhouse Effect

- The surface temperature of Earth is determined by:
  - Amount of sunlight Earth receives
    - Most of this has short wavelengths
    - About 2/3 reaches the surface of the Earth where most of it is absorbed
  - Amount of sunlight reflected from Earth's surface
    - Radiated back into the atmosphere as infrared radiation
  - The degree to which the atmosphere retains heat radiated from Earth
    - Water vapour, carbon dioxide, methane, nitrogen oxides absorb infrared radiation
    - The heat-trapping effect of these gases is analogous to the trapping of heat by a greenhouse for growing plants



◄ **FIGURE 14.5 THE GREENHOUSE EFFECT** An idealized diagram showing Earth's energy balance. Earth absorbs approximately 47 percent of the incoming short-wave solar radiation (visible light, ultraviolet light, and some infrared radiation). Some of this energy is radiated back into the atmosphere as long-wave infrared (heat) radiation. Water vapour, water, carbon dioxide, methane, and other gases in the atmosphere absorb a portion of the long-wave radiation. These greenhouse gases reradiate some of the infrared energy to Earth and warm the atmosphere. Global warming has been attributed to increases in the concentrations of carbon dioxide and methane because of human activities. *(Based on Trujillo, A. P., and H. V. Thurman. 2005.* Essentials of Oceanography, *8th ed. Upper Saddle River, NJ: Pearson Prentice Hall; and Lutgens, F. K., and E. J. Tarbuck. 2004.* The Atmosphere: An Introduction to Meteorology, *9th ed. Upper Saddle River, NJ: Pearson Prentice Hall)*

The Greenhouse Effect, cont.

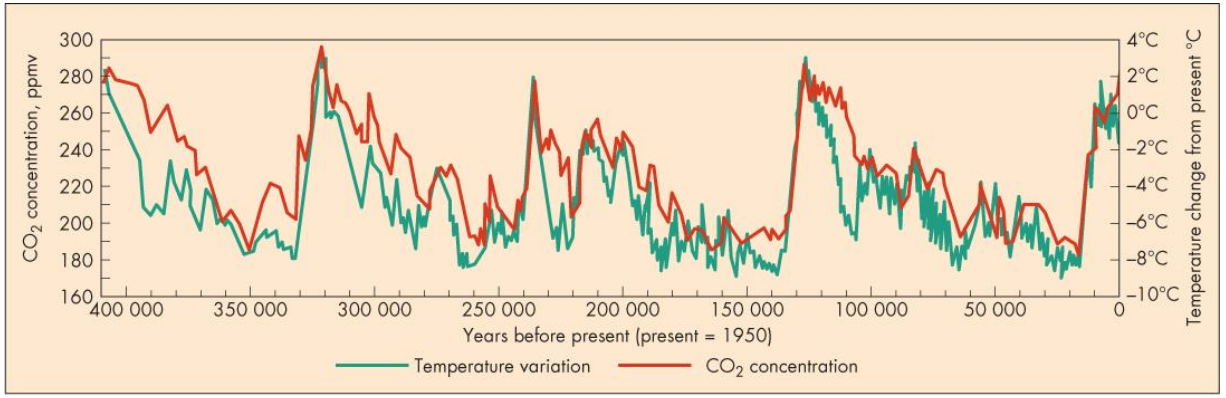
- Without the greenhouse effect, Earth's surface would be much cooler than it is
  - All surface _____
  - Little, if any, life would exist

- Some of the climate warming is due to absorption by **greenhouse gases**
  -

Carbon Dioxide and The Greenhouse Effect

- Carbon dioxide is the most studied of the greenhouse gases

- Changes in its concentration are measured from ice cores



▲ **FIGURE 14.6 AIR TEMPERATURE CHANGES CORRESPOND CLOSELY TO CHANGES IN ATMOSPHERIC CARBON DIOXIDE** Measurements of the carbon dioxide content of air bubbles and oxygen isotope ratios in glacier ice from a core taken at Vostok, Antarctica, show that atmospheric CO_2 levels have corresponded closely to air temperatures for 420 000 years. Records from other ice cores show a similar pattern extending back more than 800 000 years. *(Based on Petit, J. R., J. Jouzel, et al. 1999. "Climate and atmospheric history of the past 420,000 years from the Vostok ice core in Antarctica." Nature 399:429–436)*

Effects of Climate Change

- Glacier Ice and Sea-Level Rise
  - Sea level is currently rising at over _____per year due to melting glaciers and thermal expansion of ocean waters
  - Threatening some small island nations in the Pacific Ocean

- _____
  - Could advance rapidly producing a temporary lake
    - After the advance ends, the lake might drain catastrophically
  - Ice avalanches can occur at the terminus of a valley glacier when it retreats up a steep bedrock slope
  - Calving produces icebergs

Effects of Climate Change

-
  - Release of carbon dioxide into the atmosphere from the decay of organic sediments
-
  - Temperature and precipitation patterns, soil moisture
  - Increase in the frequency or intensity of violent storms
  - Change in the frequency and strength of El Niño and La Niña events

Effects of Climate Change, cont.

-
  - Reduction in species and shifts in plant and animal habitats
  - Migration of malaria, dengue fever, and other diseases
  - Major changes in natural vegetation zones
  - Ocean acidification
    - Carbon dioxide dissolved in the water
-
  - Human-induced degradation of productive land
  - Preceded and accompanied by loss of vegetation and soil erosion
  - Land may lose productiveness and not recover for decades or centuries

Effects of Climate Change, cont.

-
  - Could increase in length and severity
  - Areas that become drier and warmer will have more droughts
  - Drought in Canada could be exacerbated by a reduction in the amount of snow and glacier ice
    - Will have an effect on summer streamflow in many areas
-
  - An increase in wildfires in many regions
  - Accelerate replacement of ecosystems that are poorly adapted to a warmer climate with ones that can tolerate more warmth