Climate Change

Weather and Climate

- Weather
  - The state of the atmosphere at a specific time and place
- Components of weather
  - Temperature, pressure, humidity, wind, clouds, visibility, etc.
- Climate
  - The average state of the atmosphere over a long period of time
  - Climate averages are calculated from data over a 30-year period

Gases of the Atmosphere

- Nitrogen
  - Added by decaying plant matter and removed by bacteria in soil
  - Important for supporting plant and ocean life
- Oxygen
  - Produced by plants through photosynthesis
- Carbon Dioxide
  - Responsible for climate change
  - Removed by atmosphere by plants through photosynthesis
  - Enters atmosphere from burning fossil fuels (coal, oil)
  - Global levels have steadily risen over the past century as have global air temperatures
- Water vapour
  - Highly variable in concentration (highest in humid area ie. Rainforests)
  - Water in atmosphere forms clouds by condensation and may eventually for precipitation
- Ozone
  - Mostly found in the stratosphere
  - Protects us from the Sun's ultraviolet (UV) rays
- Methane
  - Occurs naturally from bacterial decay and in the intestinal track of cows, sheep
  - Anthropogenic sources include mines, oil wells, gas pipelines, rice cultivation and landfills
- Halocarbons
  - Include CFCs and are almost entirely anthropogenic, found in refrigerants and industrial processes

Aerosols

- Tiny particles that are small enough to remain suspended in the atmosphere for an extended period of time
- Contribute to the formation of smog
- Prolonged exposure may be harmful to those with weakened immune systems

Health Effects of Aerosols

- Removal time from the atmosphere is a function of the size of the particle
- Gravitational settling
  - Larger particles fall more quickly due to gravity
- Health concerns
  - Aerosols enter lungs and damage tissues
  - Finer particles are more dangerous

The Climate System

- Climate is a function of the interaction of many spheres
- Atmosphere: gases

- Hydrosphere: oceans, large bodies of water
- Lithosphere: plate tectonics, orogeny (mountain building)
- Cryosphere: glaciers, ice sheets, snow cover
- Biosphere: vegetation, animals, humans

Climate Change

- Through Earth's entire history (4.6 billion years) the climate has always been changing
- Over the last billion years, there have been several worldwide ice ages
- Between ice ages, the global climate was at times slightly warmer than it is today
- The concern today is not the actual temperatures, it's the rate of temperature change

The Last Glacial Period

- All of Canada was covered with ice 18 000 years ago (except northern Yukon)
- Lower sea levels at that time exposed the Bering land bridge

The Holocene Epoch

- Name given to the time period from 10 000 years ago to today
- Represents a time of warming
- The medieval warm period : a time of mild temperatures
- The little ice age: a widespread cooling

Climate in Recent History

- There has been a rapid ride in temperature over the past 100 years
- Corresponds to human industry and the increase of greenhouse gases

Causes of Climate Change

- Four general causes
    - Variations in solar radiation
    - Changes in composition of the atmosphere
    - Changes in Earth's surface
    - Variations in Earth's orbit

Variations in Solar Radiation

- Sun tends to emit more energy during periods of high sunspot activity
- Sunspot: a cool region of high magnetism on the Sun
- Sunspots occur in cycles and reach a maximum every 11 years
- Sunspots are cool areas on the Sun that are surrounded by faculae (bright areas that emit high amounts of energy)
- Solar output regularly changes on the order of 0.1-0.2% in relation to sunspot cycles
- With more sunspots, there is increased solar output
- Maunder minimum
    - A time period with no sunspots; this corresponds to a time period known as the little ice age

Changes in Composition of the Atmosphere

- The addition of greenhouse gases (CO_2, water vapour, methane) increases global temperature
- CO_2 has long residence time in atmosphere (100 years)
- Even if we reduce CO_2 today, the effects will not be felt for decades
- Warming climate appears to be inevitable during our lifetime

The Greenhouse Effect

- Greenhouse gases allow solar radiation to pass through but they absorb infrared radiation
- Main gases: CO2, water vapour, methane

Enhancement of the Greenhouse Effect

- The greenhouse effect itself is not a concern, however the enhancement of the greenhouse effect by humans is a concern
- Adding greenhouse gases results in climate change
- Increasing the amount of CO2 enhances the effect
- More infrared radiation from the Earth is absorbed by the atmosphere
- CO2 emissions are rapidly increasing in China and India as the economies in these countries industrialize

Determining Past Climates

- Ice Cores
  - The width of an ice layer provides insight on the temperature and snowfall of that year
  - Each year, a new layer of ice forms
  - Bubbles of air are trapped in the ice
  - Provide climate data for up to 600 000 years in the past
- Dendrochronology
  - Study of tree rings
  - Wider tree rings correspond to warmer or wetter years
  - Tree rings provide climate data for up to 1000 years in the past

Changes in the Earth's Surface

- Theory of plate tectonics
  - The continents have moved over time
- The collision of converging plates results in uplift and the creation of mountains
- Implications
  - This affects wind, temperatures and precipitation patterns of the surrounding landscape

Variations in Earth's Orbit

- Milankovitch theory
  - Theory proposes that three separate phenomena relating to Earth's orbit lead to climate change
- Referred to as 3 milankovitch cycles
  - Eccentricity
  - Precession
  - Obliquity

Milankovitch Cycles

- Eccentricity
  - Changes in the shape of Earth's orbit from circular to elliptical
  - 100 000 year cycle
  - Accounts for ice ages
- Precession
  - The wobble of the Earth's axis
  - 23 000 year cycle
- Obliquity
  - Changes in the tilt of the Earth's axis
  - 42 000 year cycle

Ozone

- Gas composed of oxygen with an odour similar to chlorine
- Forms naturally in the stratosphere
- Forms in the troposphere by chemical reaction with other gases

Ozone in the Stratosphere

- Important because 7% of some of the Sun's radiation is ultraviolet, harmful to humans
- Ozone layer protects us from the UV rays
- UV rays can cause great damage to unprotected skin

Destruction of the Ozone Layer

- CFCs are the major reason for the depletion of the ozone layer during the 1900s
- CFCs were found in inefficient appliances, spray cans, and industrial processes
- Non-essential uses of CFCs were banned in North American in the 70s
- Montreal protocol: highly successful worldwide agreement among countries to reduce CFC concentrations
- UV breaks up CFC molecules causing the release of chlorine
- Chlorine rapidly destroys ozone
- CFC molecule can remain in the atmosphere for many decades
- Though CFC emissions have declined since 1970, there is little decline recognized in the atmosphere because of the high residence time
- Decreased amounts of stratospheric ozone have resulted in increased cases of skin cancer
- Skin cancer rates have doubled since 1950

Acid Precipitation

- Precipitation that combines with pollutants that turn the precipitation acidic
- Main sources: sulfur oxides, nitrogen oxides
- Effect: slows tree growth, reduced fish population in lakes, erodes materials
- Currently 14 000 lakes are acidified
- pH measures acidity: 0-14 where 7 is neutral and below 7 is acidic
- precipitation is naturally 5.5
- acid precipitation is most common in eastern North America
- nitrogen oxides and sulfur oxides combine with water vapour to form nitric and sulfuric acid
- aquatic life cannot survive when pH <4.8

Positive Feedback

- process in a system that encourages the continuation of the original process
- example: less snow/ice decreases in the reflectivity of solar radiation (snow is reflective)
- therefore after snow/ice melts, more solar radiation is absorbed rather than reflected
- this process leads to continually warmer conditions
- reason why the polar regions are warming the fastest

Climate Models

- estimating by how much the Earth will warm is achieved by climate models
- climate models predict that over the next 100 years, the Earth will warm by at least 1.5deg
- models through equations where there are greenhouse gases, solar radiation and other climatological components
- the best estimate observed temperatures, a climate model must incorporate many different variables

Slowing Climate Change

- Kyoto Protocol: global agreement aiming to slow climate change
- Objective: to reduce greenhouse gas emissions to 5% below 1990 levels by 2010

Impacts of Climate Change

- Polar regions will warm the most
- Boreal forests will expand northward, agriculture will shift northward
- Precipitation patterns will change thus affecting habitats
- There may be increased intensity of tropical storms and hurricanes

Impacts on Humans

- Climate change affects food production, tourism and human health
- The most serious impact of climate change to humans is the spread of malaria

Impacts on Biodiversity

- Warming temperature will affect plant and animal habitats
    - Bleaching of corals
    - Loss of flora and fauna
    - Extinction risk for polar bears

Deaths from Climate Change

- Since the 70s is contributing to the cause of over 160 000 deaths a year
- Mainly because of malaria and malnutrition in less developed countries