Environmental Geology
Chapter 18 GLOBAL CLIMATE CHANGE

- ***Climate* –** characteristic atmospheric conditions (precipitation and temperature) over seasons, years, and decades.
  - Climate changes: Contributing to the complex evolutionary history of the Earth system
  - Earth system: Interactions between the atmosphere, the oceans, solid Earth, and the biosphere
  - The effects of human activities: Extensive on a global scale

- ***Climate Change Study***
  - Seeks to understand how our planet works, including the interactions of the atmosphere, hydrosphere, biosphere and solid earth
  - Multidisciplinary – chemistry, physics, meteorology, geology, biology
  - Ultimate goal is to be able to predict how changes in one part of the system do and will affect the others, and how climate is likely to change moving forward in time
  - Extremely challenging due to highly complex nature of atmospheric processes

- **Climate change is important to society because it involves:**
  - Changing weather patterns (intensity/frequency of storms, droughts, floods)
  - Changing sea level (coastal flooding in highly populated areas)
  - Changes in habitat for animals and plants (ecological/agricultural effects)
  - Potential changes in patterns of disease and famine

- **Tools for Studying Global Change**
  - Uses of the geologic records
  - e.g., carbon dioxide concentration in glacial ice, sediment cores, tree rings
  - Real-time monitoring
  - Mathematical models
    - e.g., global circulation models (GCMs)
    - Predicting changes in global climate

- **Atmosphere and Climate Change**
  - Climate change: Change of atmosphere conditions and its relationships with lithosphere, hydrosphere, and biosphere
  - Atmosphere as a complex chemical factory: With many little-understood chemical reactions
  - Changes in greenhouse gases, variable temp, and water vapor

- **Global Heat Budget -**Temp of the Earth: Depends on 3 factors
  - The amount of sunlight received

  - The amount of solar energy reflected and absorbed
  - The amount of retention by atmosphere

- **Annual Energy Flow to Earth from the Sun** – For the past 50 years-incoming solar energy has exceeded outgoing solar energy

- **Global Warming**
  - Earth absorbs the short wavelength solar energy-warming it
  - Earth radiates long wavelength infrared (IR) radiation
  - Most is absorbed by greenhouse gases at troposphere-then emitted to outer space
  - Some is not emitted. This small imbalance maintains the greenhouse effect & warms the atmosphere and oceans, and melts glaciers

- **The Greenhouse Effect**
  - Several atmospheric gases, such as carbon dioxide ($CO_{2)}$, methane (CH_4), chlorofluorocarbons (CFCs) trapping more heat and warming up the lower atmosphere, similar to the effect of a greenhouse
  - The concentration of greenhouse gases increased recently due to human activities (anthropogenic gases)
  - "Visible" light is a narrow wavelength range our eyes have evolved to detect
  - Major atmospheric gases Nitrogen (N_2) and Oxygen (O_2) are transparent at these wavelengths
  - CO_2 is *not* transparent to IR (heat) radiation
  - Sun's energy output peaks at these wavelengths
  - Greenhouse gases block escape of IR radiation to space
  - Heat is held in, as by a blanket
  - Carbon Dioxide ($CO_{2)}$ and Methane ($CH_{4)}$ are main greenhouse gases (Ozone (O_3) and chlorofluorocarbons (CFCs) contribute)
  - Human activity produces these gases in large quantities

- **Carbon Dioxide, Methane & Temperature Correlation.** Although this is not the hottest time ever in history, in the past century, temperatures have risen globally about 1 degree Celsius. During the same time, carbon dioxide and methane concentrations have risen dramatically.

- **Fossil Fuels and Atmospheric CO_2 Rise**
  - Burning of fuel for transportation (and heating) is largest culprit
  - Coal burning for generation of electricity contributes
  - Burning natural gas only somewhat better

- **Global Temperature Change**
  - The Pleistocene Ice Age: ~ 2 Million yeasrs ago
  - Numerous changes in Earth's mean annual temperature since then

- Warming trend over the last 150 years, especially since 1940s with the warmest in 1980s, 1990s & 2000s (decades)
- Mean temp increased about .8° C (1.36° F) in the past 100 years
- Maximum extent of glacial ice at ~ 21,000 years ago
- Last 18,000 years – interglacial period
- Last 1,000 years – Medieval Warm Period and the Little Ice Age (Washington crosses the Delaware River – late 1700's surprising the enemy on a cold winter night)

- **Why Climate Change?**
  - Changes in long cycles (100,000 yrs) separated by short cycles (20,000 to 40,000 yrs)
  - First identified in 1920s, Milankovitch hypothesis
  - Long cycle: The variability in Earth's orbit around the Sun
  - Short cycle: The wobble effect of Earth's axis
  - Natural contributors to climate changes (i.e., non-human causes) include:
    - Orbital/Milankovitch cycles (ice ages vs. warm times)
    - Solar output
      - Currently on the rise – partly responsible for recent global warming
    - Volcanic activity
      - Rare, massive eruptions cause global cooling for months to years
  - Climate system can even be unstable in shorter cycles, a few decades
  - The ocean conveyor belt, global circulation of ocean water, contribute to the change**. Northern Europe – Is habitable due to warm Atlantic Ocean currents**
  - Global warming: Need to consider major forcing variables—solar, volcanic, and anthropogenic gases

- **Can global warming cause an ice age?**
  - **One View** ---- Shifting ocean circulation patterns. "Ocean currents are partially responsible for distributing heat around the Earth. The Gulf Stream, for example, is a current that directs warm water to northern Europe from the Gulf of Mexico. By doing so, the Gulf Stream makes temperatures in Great Britain and the rest of northwestern Europe warmer than they otherwise would be. As global temperatures rise, Arctic ice melts and massive amounts of fresh water pour into the North Atlantic and slow the Gulf Stream down. By slowing or stopping this ocean current, global warming actually would cool Europe down dramatically. If other ocean currents were disrupted, the entire planet could experience the same cooling effect and cause an ice age"….. From Discovery.com

- **Another** ---- Others suggest that global warming could just as easily "runaway" and create a planet like Venus.

Some things create added forces that effect climate change……

- **Solar Forcing**
  - Medieval warm period corresponded to a time of increased solar radiation
  - The little ice age (14th century) corresponded to minimum solar activity – it was **primarily due to this**

- **Volcanic Forcing**
  - Volcanic eruption: Vast amount of aerosol particles put into the air
  - Aerosols: Reduce solar radiation to the Earth surface
    - **Episodes of volcanic eruptions made a *significant contribution* to the cooling of the Little Ice Age**

- **Anthropogenic Forcing**
  - Natural variability-failing to explain the warming at end of the 20th century
  - Mathematical modeling on the anthropogenic forcing: Increase of temperature is due to the doubling of CO_2
  - Has been significant global warming as a result of human activities
  - CO_2 is *by far* the most abundant greenhouse gas we emit
  - Other human-generated gases are also significant!

- **Anthropogenic Effects: Ozone Layer**
  - Chlorofluorocarbons (CFCs) used in aerosol cans and as coolants (freon/halon)
  - Chemically stable at Earth's surface, but attack ozone in upper atmosphere **http://en.wikipedia.org/wiki/Ozone_depletion**
  - Problem *may* have just begun to lessen as a result of CFC ban (1987 Montreal Protocol)

- **Complex Effects on Climate Change**
  - Human effects can cause warming *and* cooling
  - Volcanic emissions can also produce both effects
  - Net effects since last Ice Age have been positive (warmer)
  - Cumulative human effect is a net temperature increase

- **Changes since the industrial age 1750** -
  - Positive forcings (warm)
  - Negative forcings (cool)
  - Human causes exceed natural causes in recent years
  - Human activity is contributing to climate change

- Release of greenhouse gases, such as CO_2, methane, and *chlorofluorocarbons* (CFCs) traps heat near Earth's surface, increasing global temperatures
    - CFCs also have depleted ozone in Earth's upper atmosphere
- ~1°C of global warming has occurred over the past two centuries
- CO_2 levels have been rapidly increasing over this time-frame
- *Future human-induced climate change may accelerate due to the vastly increased CO_2* **(about 35% more now than in 1800) in our atmosphere**
- CO_2 increase is due to massive burning of fossil fuels (coal, oil, natural gas) since the start of the "industrial revolution" in the early 1800s
- Burning of fossil fuels continues to increase, with latest spike due largely to increased development of economies in Asia (India, China, S. Korea)
- At the most basic level, *human population increase* (and the associated increase in energy needed to sustain society) is the primary cause
- **China and the U.S.** are by far the **two largest emitters of greenhouse gases**
- Even after greenhouse gas (e.g., CO_2) emissions max out and begin to decrease, it will likely take centuries (or more) for global climatic and sea level conditions to stabilize

- **Of all fossil fuels, burning of *coal* produces the most greenhouse gases per unit of energy, burning *oil* produces 23% less per unit energy, and burning of *natural gas* produces 28% less per unit of energy**
    - **However, burning of *any* carbon compound (including renewable biofuels like ethanol and biodiesel) produces CO_2/geenhouse gas!**

- Use of corn or other food-staple based biofuels is more sustainable (renewable), but it can have widespread negative effects on global food availability and commodity prices that are immediately felt by the human population
    - Already food shortages, riots and economic hardship has been occurring in various places around the world

- **Potential Effects of Global Climate**
    - Doubling the greenhouse gases may result in a 1.5–6˚C (2.6–10.2˚F) increase in average global temp
    - Significant rise of sea level and melting of glacial ice due to the increase in temp (warmer oceans "expand" and glacial melt water adds to the volume)
    - The number of retreating glaciers accelerating in many areas of the world
    - Global warming produces sea level rise, as a result of melting of land-based polar ice caps (Greenland and Antarctica)

  - Greenland ice sheet is melting at an increasing rate; Antarctic ice sheet seems to be stable overall (East Antarctica). West Antarctica – experiencing more melting.
  - Seal level rise threatens low-elevation coastal cities (e.g., Miami, New York, New Orleans) with flooding and increased storm damage
- Warming at higher lattitudes (toward the poles) may exceed other areas- as glaciers melt and land is exposed-land absorbs the heat more
- In an ice age, added snow/ice reflects more of the Sun's energy – it increases the reflectance of energy into Space.

- **Sea Level Rise and Global Warming**
  - An estimated 40 cm (16 in.) rise in sea level (minimum) for the next century. Actual rise may greatly exceed this. Many climate scientist predict a rise closer to 1 meter (39 in.) or more.
  - Increases in coastal erosion: Up to 260 ft or more on open beaches
  - Landward shift of existing estuaries
  - Disastrous impact on some existing developments along coastal zones
  - Many glaciers have changed (e.g. Grinnell Glacier Glacier National Park)-majority are shrinking
  - Changes Already Apparent Near Poles
    Loss of Arctic Sea Ice

- **Potential Effects of Global Climate**
  - Global warming leads to significant changes of rainfall, soil moisture
  - Agricultural activities and world food supplies affected greatly by climatic factors
  - Global warming affects the frequency, intensity, and distribution of natural hazards, such as hurricane and other storms
  - More extreme versions of natural cycles (e.g., El Niño and La Niña)

- **Biosphere and Global Warming**
  - Causing a number of changes in biosphere, both people and overall ecosystem
  - Risk of species extinction due to land-use change and habitat shift
  - Spread of infectious and other diseases due to migration of organisms

- **Reducing the Impact of Global Warming**
  - Identify the historic changes that have occurred
  - Predict the potential changes in the future
  - Reduce greenhouse gases
  - Political commitment: Reconciling the conflicts between the environmental need for reduction of greenhouse gases and the economic demands for more fossil fuel

- Reduce the emission of CO_2

- Use fossil fuels releasing less CO_2 (e.g., natural gas)
- Conservation of energy (CFL bulbs, more efficient appliances)
- Store CO_2 in forests, soils and rocks (sequestration of CO_2)
- Use alternative energy (i.e., *not* fossil fuels)

- Human response/adjustments can/should involve:
  - Reduction in use/burning of carbon-based fossil fuels
  - Sequestering carbon from atmosphere (e.g., "clean coal" technology)
  - Adapting to change
    - Coastal levees/barriers to flooding
    - Increasing efficiency of energy use
    - More renewable, non-greenhouse-gas-producing energy usage
    - Conservation and recycling
    - Changes in location and/or nature of croplands
  - Moving cities from endangered low coast areas(?)

- **Coupling of Global Change Processes**
  - The coupling of the greenhouse and ozone depletion problems from CFCs
  - Burning of fossil fuels and acid rain problems
  - Volcanic eruptions and atmospheric cooling
  - Emphasis on the principle of global environmental unity in action – e.g. Kyoto Treaty; Montreál Protocol and Paris agreement (2015)

- The sooner we adjust our activities to mitigate/reduce future negative effects from continued climate change/warming (sea level rise, flooding, drought, etc.), the easier it will be for us to possibly reduce or reverse the recent climate shift and reduce the negative effects on the human population

- Because of dwindling fossil fuel supplies (we have several decades to a few centuries of supply left), increasing sea level, increasing human population, increasing pollution and habitat destruction, and a lack of sufficient alternative energy source development at the present time, we are living in a highly *unsustainable* manner at the moment

- It is only through increased scientific understanding, public awareness, and societal attitude changes that we can hope to overcome the challenges of global climate change now and in the future

- Regardless of whether the current climate change is entirely, primarily, or secondarily due to human activities, it is still necessary to make significant changes in the way we produce and use energy and other resources, if we are to ensure the long term health of our planet's biosphere and the survival of humans as a species

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