CLIMATE CHANGE and GLOBAL WARMING

Climate Change and Feedback Loops

- **Part of the reason climate change is so complex is that there can be many positive and negative feedback loops.**
- **Negative feedbacks are self-inhacing and help stabilize a system.**
- **Positive feedbacks are self-regulating, so a greater change now will result in an even greater change in the future.**

Possible Negative Feedback Loops for Climate Change

- As global warming occurs, the warmth and additional carbon dioxide could stimulate algae growth. This, in turn, could absorb carbon dioxide, reducing the concentration of CO2 in the atmosphere and cooling Earth's climate.
- Increased CO2 concentration with warming might similarly stimulate growth of land plants, leading to increased CO2 absorption and reducing the greenhouse effect.
- If polar regions receive more precipitation from warmer air carrying more moisture, the increasing snowpack and ice buildup could reflect solar energy away from Earth's surface, causing cooling.
- Increases in water evaporation with warming from the ocean and the land could lead to cloudier conditions (the water vapor condenses), and the clouds would reflect more sunlight and cool the surface.

Possible Positive Feedback Loops for Climate Change

- The warming Earth increases water evaporation from the oceans, adding water vapor to the atmosphere. Water vapor is a major greenhouse gas that, as it increases, causes additional warming. If more clouds form from the increased water vapor, and more solar radiation is reflected this would cause cooling as discussed with negative feedback above. Thus water vapor is associated with both positive and negative feedback. This makes study of clouds and global climate change complex.
- The warming Earth could melt a large amount of permafrost at high latitudes, which would in turn release the greenhouse gas methane, a by-product of decomposition of organic material in the melted permafrost layer. This would cause additional warming.
- Replacing some of the summer snowpack or glacial ice with darker vegetation and soil surfaces decreases the albedo (reflectivity) increasing the absorption of solar energy, further warming surface. This is a powerful positive feedback explaining, in part, why the Arctic is warming faster than at lower latitudes.
- In warming climates, people use more air-conditioning and thus more fossil fuels. The resulting increase in carbon dioxide could lead to additional global warming.

- Since negative and positive feedback can occur simultaneously in the atmosphere, the dynamics of climate change are all the more complex. Research is ongoing to better understand negative feedback processes associated with clouds and their water vapor.

Causes of Climate Change

- The realization that there had been glacial and interglacial episodes began in 1815
- The glaciers changed their limits at previous times
- But this idea did not accepted at first
- When Agassiz saw the evidence and agreed with the climate change through time, he formulated a theory of continental glaciation.
- The evidence was debris— rocks and soils—at the edges of existing mountain glaciers and the same kinds of deposits at lower elevations. Agassiz realized that only glaciers could have produced the kinds of debris now far below the ice.

Milankovitch cycles

- describes the collective effects of changes in the Earth's movements upon its climate, named after Serbian geophysicist and astronomer Milutin Milankovic who in the 1920s had theorized that variations in the Earth's orbit strongly influenced climatic patterns on Earth through orbital forcing.

Solar Cycles

- the sun goes through cycles too, sometimes growing hotter, sometimes colder. Today, solar intensity is observed directly with telescopes and other instruments. Variations in the sun's intensity in the past can be determined because hotter and cooler sun periods emit different amounts of radionuclides—atoms with unstable nuclei that undergo radioactive decay (such as beryllium-10 and carbon-14), which are trapped in glacial ice and can then be measured.

Atmospheric Transparency Affects Climate and Weather

- How transparent the atmosphere is to the radiation coming to it, from both the sun and Earth's surface, affects the temperature of the Earth. Dust and aerosols absorb light, cooling the Earth's surfaces. Volcanoes and large forest fires put dust into the atmosphere, as do various human activities, such as plowing large areas. Each gas compound has its own absorption spectrum (the electromagnetic radiation that is absorbed by a gas as it passes through the atmosphere). Thus the chemical and physical composition of the atmosphere can make things warmer or cooler.

The Surface of Earth and Albedo (reflectivity) Affects

Albedo is the reflectivity of an object that is measured as the percentage of incoming radiation that is reflected. A dark rock surface exposed near the North Pole absorbs more of the sunlight it receives than it reflects in the summer, warming the surface and the air passing over it. When a glacier spreads out and covers that rock, it reflects more of the incoming sunlight than the darker rock cooling both the surface and the air that comes in contact with it. Vegetation also affects the climate and weather in the same way. If vegetation is a darker color than the soil, it warms the surface. If it is a lighter color than the soil, it cools the surface.

Roughness of the Earth's Surface Affects the Atmosphere

- Above a completely smooth surface, air flows smoothly—a flow called "laminar." A rough surface causes air to become turbulent—to spin, rotate, reverse, and so forth. Turbulent air gives up some of the energy in its motion (its kinetic energy), and that energy is turned into heat. This affects the weather above. Forests are a much rougher surface than smooth rock or glaciers, so in this way, too, vegetation affects weather and climate.

The Chemistry of Life Affects the Atmosphere

- The emission and uptake of chemicals by living things affect the weather and climate. Thus, a planet with water vapor, liquid water, frozen water, and living things has a much more complex energy-exchange system than a lifeless, waterless planet. This is one reason (of many) why it is difficult to forecast climate change.

The Oceans and Climate Change

- The oceans play an important role in climate because two thirds of the Earth is covered by water. Moreover, water has the highest heat-storage capacity of any compound, so a very large amount of heat energy can be stored in the world's oceans. There is a complex, dynamic, and ongoing relationship between the oceans and the atmosphere. If carbon dioxide increases in the atmosphere, it will also increase in the oceans, and, over time the oceans can absorb a very large quantity of CO2. This can cause seawater to become more acidic (H2O CO2 H2CO3) as carbonic acid increases.

El Niño and Climate

- **important climate change linked to variations in ocean currents - the Southern Oscillation, informally as El Niño.**
- **Observed every 7 years from the time of early Spanish settlement of the west coast of South America,**
- **the ocean waters would warm up, fishing would become poor, and seabirds would disappear.**
- **Under normal conditions, there are strong vertical, rising currents, called upwelling, off the shore of Peru. These are caused by prevailing winds coming westward off the South American Continent, which move the surface water away from the shore and allow cold water to rise from the depths, along with important nutrients that promote the growth of algae (the base of the food chain) and thus produce lots of fish. Seabirds feed on those fish and live in great numbers, nesting on small islands just offshore. El Niño occurs when those cold upwellings weaken or stop rising altogether.**

- As a result, nutrients decline, algae grow poorly, and so do the fish, which either die, fail to reproduce, or move away. The seabirds, too, either leave or die.
- Because rainfall follows warm water eastward during El Niño years, there are high rates of precipitation and flooding in Peru, while droughts and fires are common in Australia and Indonesia.
- Because warm ocean water provides an atmospheric heat source, El Niño changes global atmospheric circulation, which causes changes in weather in regions that are far removed from the tropical Pacific.

Forecasting Climate Change

- **Past Observations and Laboratory Research**
- **Computer Simulations**

Potential Environmental, Ecological, and Human Effects of Global Warming

- **Changes in River Flow**

With a continuation of global warming, melting of glacial ice and reductions in snow cover are anticipated to accelerate throughout the twenty-first century. This is also projected to reduce water availability and hydropower potential, and change the seasonality of flows in regions supplied by meltwater from major mountain ranges (e.g., Hindu-Kush, Himalaya, Andes), where more than one sixth of the world population currently lives.

- **Rise in Sea Level**

The sea level reached a minimum during the most recent glacial maximum. Since then, the sea level has risen slowly.

Sea level rises from two causes: (1) **Liquid water expands as it warms**; and (2**) ice sheets on land that melt increase the amount of water in the oceans**.

Since the end of the last ice age, the sea level has risen approximately 23 cm per century. Climatologists forecast that global warming could about double that rate.

Various models predict that the sea level may rise anywhere from 20 cm to approximately 2 m in the next century; the most likely rise is probably 20–40 cm.

The rising sea level particularly threatens island nations and could worsen coastal erosion on open beaches, making structures more vulnerable to damage from waves.

- **Glaciers and Sea Ice**

The amount of ice on the Earth's surface changes in complicated ways. A major concern is whether global warming will lead to a great decline in the volume of water stored as ice, especially because melting of glacial ice raises the mean sea level and because mountain glaciers are often significant sources of water for lower-elevation ecosystems. At present, many more glaciers in North America, Europe, and other areas are retreating, than are advancing.

In the Cascades of the Pacific Northwest and the Alps in Switzerland and Italy, retreats are accelerating. For example, on Mt. Baker in the Northern Cascades of Washington, all eight glaciers on the mountain were advancing in 1976. Today all eight are retreating. If present trends continue, all glaciers in Glacier National Park in Montana could be gone by 2030 and most glaciers in the European Alps could be gone by the end of the century. Not all melting of glacial ice is due to global warming. The ice is disappearing not from warmer temperatures at the top of the mountain, which are almost always below freezing, but because less snowfall is occurring and ice is being depleted by solar radiation and sublimation (ice is transformed from solid state to water vapor without melting). More arid conditions in the past century led to air that contained less moisture and thus favored sublimation. This may be due to land use changes from native vegetation to agriculture. Much of the ice depletion had occurred by the mid-1950s. In addition to many glaciers melting back, the Northern Hemisphere sea ice coverage in September, the time of the ice minimum, has declined an average of 10.7% per decade since satellite remote sensing became possible in the 1970s.

- If present trends were to continue, the Arctic Ocean might be seasonally rise ice-free by 2030.

- **Changes in Biological Diversity**

Some of the greatest uncertainties about the consequence of global warming have to do with changes in biodiversity. This is because organisms are complex and so their responses to change can be complex. Warming is one change, but others—such as availability of nutrients, relations with other organisms (predator and prey), and competition for habitat and niches in ecosystems—also affect biodiversity. Surprisingly few species went extinct as a result of climate change during the past 2.5 million years, even though the amount of changes was about the same as that forecast for today and the next few decades. Warming will certainly change some areas, and plants and animals will experience stress. Many will adapt, as apparently occurred during the Medieval Warm Period. For example, polar bears were undoubtedly stressed during this period but did not become extinct.

On the other hand, black guillemots, birds that nest on Cooper Island, Alaska, illustrate the concerns some scientists have about global warming and certain species. The abundance of this species has declined since temperature increases in the 1990s caused the sea ice to recede farther from Cooper Island each spring. The parent birds feed on Arctic cod found under the sea ice and must then return to the nest to feed their chicks, who are not yet mature enough to survive on their own. For the parents to do this, the distance from feeding grounds to nest must be less than about 30 km, but in recent years the ice in the spring has been receding as much as 250 km from the island. As a result, the black guillemots on the island have lost an important source of food. The future of black guillemots on Cooper Island depends on future springtime weather. Too warm and the birds may disappear; Too cold and there may be too few snow-free days for breeding, in which case they also will disappear.

- **Agricultural Productivity**

Globally, agricultural production will likely increase in some regions and decline in others. In the Northern Hemisphere, some of the more northern areas, such as Canada and Russia, may become more productive.

A climate shift could have serious negative effects on mid-latitude food production. Meanwhile, lands in the southern part of the Northern Hemisphere may become more arid. Prolonged drought as a result of future warming as evidently occurred during the Medieval warming period with loss of agricultural productivity could be one of the serious impacts of global warming.

- **Human Health Effects**

Like other biological and ecological responses, the effects of global warrning on human health are difficult to forecast. The IPCC (Intergovernmental Panel on Climate Change) 2007: Synthesis Report is cautious about these possible effects, stating only that one needs to be thinking about "some aspects of human health, such as excess heat-related mortality in Europe, changes in infectious disease vectors in parts of Europe, and earlier onset of and increases in seasonal production of allergenic pollen in Northern Hemisphere high and mid-latitudes." Some have suggested that global warming might increase the incidence of malaria. However, this has been shown not to be the case in past and present circumstances because temperature alone is not a good correlate for malaria. The same has been found for tick borne encephalitis, another disease that some thought might increase from global warming.