Global Climate Change
The Greenhouse Effect

Framework Text

Earth and Human Activity

How do Earth's surface processes and human activities affect each other?

Earth's surface processes affect and are affected by human activities. Humans depend on all of the planet's systems for a variety of resources, some of which are renewable or replaceable and some of which are not. Natural hazards and other geological events can significantly alter human populations and activities. Human activities, in turn, can contribute to the frequency and intensity of some natural hazards. Indeed, humans have become one of the most significant agents of change in Earth's surface systems. In particular, it has been shown that climate change—which could have large consequences for all of Earth's surface systems, including the biosphere—is driven not only by natural effects but also by human activities. Sustaining the biosphere will require detailed knowledge and modeling of the factors that affect climate, coupled with the responsible management of natural resources.

Global Climate Change

How do people model and predict the effects of human activities on Earth's climate?

Global climate change, shown to be driven by both natural phenomena and by human activities, could have large consequences for all of Earth's surface systems, including the biosphere. Humans are now so numerous and resource dependent that their activities affect every part of the environment, from outer space and the stratosphere to the deepest ocean.

However, by using science-based predictive models, humans can anticipate long-term change more effectively than ever before and plan accordingly.

Global changes usually happen too slowly for individuals to recognize, but accumulated human knowledge, together with further scientific research, can help people learn more about these challenges and guide their responses. For example, there are historical records of weather conditions and of the times when plants bloom, animals give birth or migrate, and lakes and rivers freeze and thaw. And scientists can deduce long-past climate conditions from such sources as fossils, pollen grains found in sediments, and isotope ratios in samples of ancient materials.

Scientists build mathematical climate models that simulate the underlying physics and chemistry of the many Earth systems and their complex interactions with each other. These computational models summarize the existing evidence, are tested for their ability to match past patterns, and are then used (together with other kinds of computer models) to forecast how the future may be affected by human activities. The impacts of climate change are uneven and may affect some regions, species, or human populations more severely than others.

Climate models are important tools for predicting, for example, when and where new water supplies will be needed, when and which natural resources will become scarce, how weather patterns may change and with what consequences, whether proposed technological concepts for controlling greenhouse gases will work, and how soon people will have to leave low-lying coastal areas if sea levels continue to rise. Meanwhile, important discoveries are being made—for example, about how the biosphere is responding to the climate changes that have already occurred, how the atmosphere is responding to changes in anthropogenic greenhouse gas emissions, and how greenhouse gases move between the ocean and the atmosphere over long periods. Such information, from models and other scientific and engineering efforts, will continue to be essential to planning for humanity's—and the global climate's—future.

It is important to note that although forecasting the consequences of environmental change is crucial to society, it involves so many complex phenomena and uncertainties that predictions, particularly long-term predictions, always have uncertainties. These arise not only from uncertainties in the underlying science but also from uncertainties about behavioral, economic, and political factors that affect human activity and changes in activity in response to recognition of the problem. However, it is clear not only that human activities play a major role in climate change but also that impacts of climate change—for example, increased frequency of severe storms due to ocean warming—have begun to influence human activities. The prospect of future impacts of climate change due to further increases in atmospheric carbon is prompting consideration of how to avoid or restrict such increases.

Main Concepts (You MUST cover at least five of these in your game)

The focus here is on how the greenhouse effect works.

- Earth has a natural greenhouse effect, which is important in keeping the surface warm.
    - Energy travels through space to Earth as electromagnetic radiation. Sunlight is primarily visible light, but also includes some ultraviolet and some infrared.
    - Once sunlight reaches Earth, some is reflected and some is absorbed, primarily by the ground and oceans, and to a small extent directly by the atmosphere.
    - When the ground and oceans absorb sunlight, they heat up.
    - Everything with a temperature above absolute zero emits infrared radiation. The warmer something is, the more infrared it emits.
    - Thus, when the land, oceans, and air molecules heat up, they emit some of that energy back out as infrared radiation.
    - Some of this infrared radiation travels directly back out to space. Some is absorbed by certain molecules in the atmosphere. These molecules are known as greenhouse gases.
    - When greenhouse gases absorb infrared radiation, they heat up, thus keeping the atmosphere warm.
    - The atmosphere also emits infrared. The warmer it is, the more it emits. Eventually, the energy is emitted out to space.
- Without an atmosphere, Earth would not be warm enough for life. The moon, for example, is the same distance from the sun, but cannot support life in part because of temperature extremes.
- Air is heated primarily from infrared radiation from the ground and oceans, not from direct absorption of sunlight.
- The greenhouse effect is a global phenomenon, not a local phenomenon.
- Greenhouse gases transmit visible light but absorb infrared.

- The main greenhouse gases are CO_2, CH_4 (methane), and water vapor. All of these exist naturally in the atmosphere.
    - Natural sources of CO2 today include respiration, decomposition, degasing from ocean water, and volcanism (very small portion). Natural sources of methane include decomposition and animal digestion. Most water vapor comes from evaporation from oceans.
- If the amount of radiation absorbed by the atmosphere is equal to the amount emitted to space, the system is in balance and the temperature does not change.
    - If the amount of energy coming in from the sun is not changing and the composition of the atmosphere is not changing, the system is in balance. Atmospheric temperature does not change.
- However, if the amount of solar radiation changes or the composition of the atmosphere does change, the amount of infrared absorbed by the atmosphere will change and will continue to change until a new balance is reached.
    - If a pulse of greenhouse gases is added to the atmosphere, increasing the concentration to a certain new level, temperature will rise until the new balance is reached.
- In the natural system, the amount of CO_2 added to the atmosphere through respiration and decomposition is balanced by the amount removed during photosynthesis.
    - Burning fossil fuels and making concrete releases additional CO_2. Some of this is absorbed by oceans and some is taken out of the atmosphere through photosynthesis, but not all. As a result, the concentration of CO_2 in the atmosphere is increasing, causing intensifying the greenhouse effect.
    - Cows emit methane, which also intensifies the greenhouse effect.
- Although sources of greenhouse gases may be local (factories, farms), because air gets mixed by the wind systems, the effects are global.
- Positive feedback loops can exacerbate greenhouse conditions. For example,
    - Water vapor in the air increases as temperatures increases. Since water vapor is a greenhouse gas, an increase in water vapor causes further temperature increase.
    - The amount of CO_2 that can be dissolved in ocean water decreases with ocean temperature. Thus as temperature increases, more CO_2 moves from the oceans to the atmosphere, increasing the concentration of CO_2 and increasing the temperatures.
    - When ice melts, Earth becomes less reflective. Less sunlight is reflected back to space and more is absorbed by the oceans and ground. More is emitted, warming up the atmosphere more.