Climate Change Information Resources
New York Metropolitan Region
(CCIR-NYC)

What causes global climate change?

Key Points
There is a scientific consensus that concentrations of greenhouse gases in the atmosphere are increasing and that this is causing global climate change. Human-driven emissions of carbon dioxide and other greenhouse gases, as well as land-use change, are the processes primarily responsible for the increase. Emissions of black carbon (soot) may also be contributing to the warming. Emissions of reflective sulfate aerosols have been associated with a net cooling effect.

Defining Weather and Climate
Weather is the state of the atmosphere at a specific time in a specific place. Temperature, cloudiness, humidity, precipitation, and winds are examples of weather elements. Thunderstorms, tornadoes, and monsoons are also part of the weather of some places during some seasons.

Climate is defined as long-term weather patterns that describe a region. For example, the New York metropolitan region's climate is temperate, with rain evenly distributed throughout the year, cold winters, and hot summers.

Climate Variability and Climate Change
Climate variability refers to variations in the prevailing state of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system, or to variations in natural or anthropogenic (human-driven) external forcing. Global climate change indicates a change in either the mean state of the climate or in its variability, persisting for several decades or longer. This includes changes in average weather conditions on Earth, such as a change in average global temperature, as well as changes in how frequently regions experience heat waves, droughts, floods, storms, and other extreme weather. It is important to note that changes in individual weather events will potentially contribute substantially to changes in climate variability.

Climate change could occur naturally as a result of a change in the sun's energy or Earth's orbital cycle (natural climate forcing), or it could occur as a result of persistent anthropogenic forcing, such as the addition of greenhouse gases, sulfate aerosols, or black carbon to the atmosphere, or through land-use change.

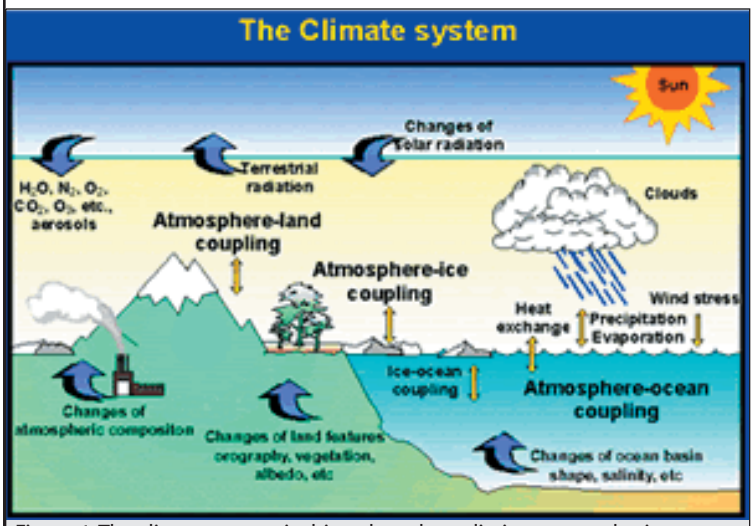

Figure 1. The climate system is driven by solar radiation, atmospheric composition, and interaction with ocean and land processes. Source: Commonwealth Scientific and Industrial Research Organisation (CSIRO), *Modelling Climate: CSIRO Atmospheric Research Greenhouse Information Paper.* Australia 1996. http://www.dar.csiro.au/publications/info98_4.htm

The Climate System and the Carbon Cycle
The climate system is driven by the sun's energy and regulated by natural processes and cycles in the Earth system (Figure 1). These include the carbon cycle and greenhouse effect, orbital cycles, ocean currents that distribute warmer and colder water around the globe, and atmosphere-ocean interactions that moderate temperature. Humans are principally affecting the climate system through alterations to the carbon cycle, which regulates the flow of carbon among living and non-living parts of the Earth system (Figure 2). Carbon is found in all living things, in soils and rocks, in fossil fuels, in ocean sediments and corals, and as carbon dioxide in the atmosphere. Each of these carbon reservoirs stores a percentage of the Earth's total carbon and carbon moves at varying rates among the reservoirs. In some cases, the carbon may remain in a reservoir for millions of years, as in the case of fossil fuels before the Industrial Revolution. As humans burn fossil fuels to produce energy and as they clear natural ecosystems, carbon dioxide is released into the atmosphere, where it acts as a greenhouse gas.

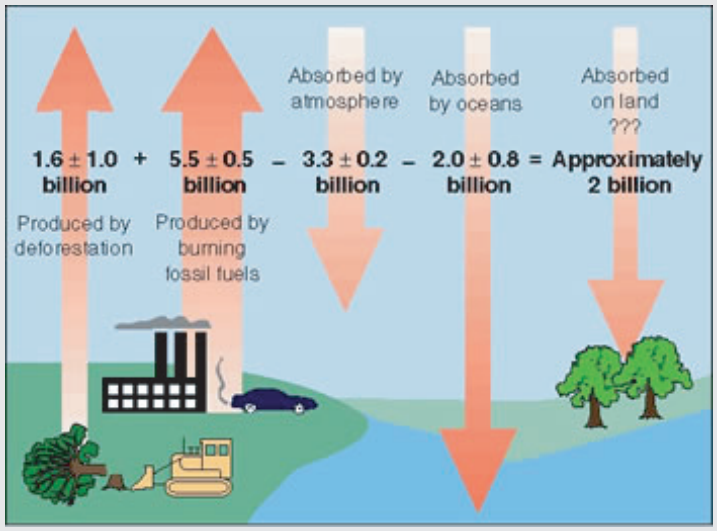

Figure 2. Carbon cycles through all living things and can be found in the ocean, atmosphere, rocks, and soil. Units are in metric tonnes of carbon per year. Source: United States Geological Survey (USGS). Global Environmental Change and the Carbon Cycle. USGS Fact Sheet137-97 1997. http://geochange.er.usgs.gov/pub/carbon/fs97137/co2bdgt90.jpg

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Greenhouse Gases

The presence of greenhouse gases in the atmosphere is a natural component of the climate system and helps to maintain the Earth as a habitable planet (Figure 3). Greenhouse gases are relatively transparent to incoming solar radiation, allowing the sun's energy to pass through the atmosphere to the surface of the Earth. The energy is then absorbed by the Earth's surface, used in processes like photosynthesis, or emitted back to space as infrared radiation. Some of the emitted radiation passes through the atmosphere and travels back to space, but some is absorbed by greenhouse gas molecules and then re-emitted in all directions. The effect of this is to warm the Earth's surface and the lower atmosphere. Water vapor (H_2O) and carbon dioxide (CO_2) are the two largest contributors to the greenhouse effect. Methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs) and other greenhouse gases are present only in trace amounts, but can still have a powerful warming effect due to their heat-trapping abilities and their long residence time in the atmosphere. Without the greenhouse effect, Earth's average temperature would be -0.4°F (-18°C), rather than the present 59°F (15°C).

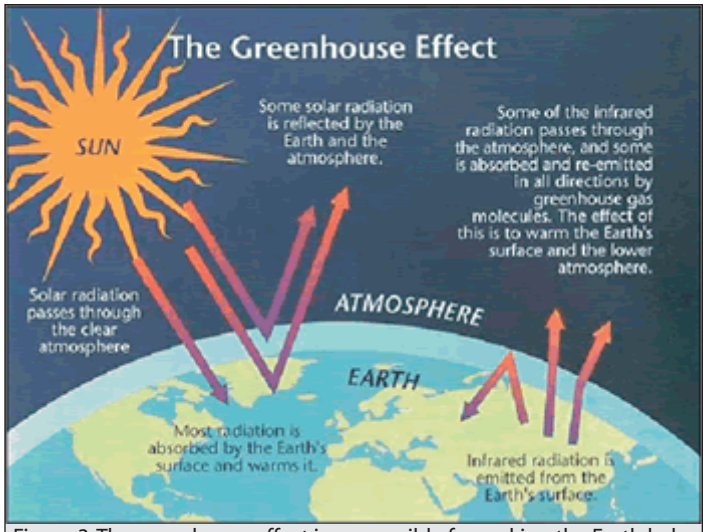

Figure 3. The greenhouse effect is responsible for making the Earth habitable. Source: United States Global Change Research Information Office, United States Global Change Research Program, 1996. http://www.gcrio.org/ocp96/p30box.html

Concentrations of greenhouse gases – and especially carbon dioxide – have risen over the past two hundred and fifty years, largely due to the combustion of fossil fuels for energy production. Since the Industrial Revolution in the eighteenth century the concentration of carbon dioxide in the atmosphere has risen from about 270 parts per million (ppm) to about 370 ppm. Concentrations of methane have also risen due to cattle production, the cultivation of rice, and release from landfills. Nearly one-third of human-induced nitrous oxide emissions are a result of industrial processes and automobile emissions.

Land-use Change

The combustion of fossil fuels is not the only anthropogenic source of carbon dioxide. When ecosystems are altered and vegetation is either burned or removed, the carbon stored in them is released to the atmosphere as carbon dioxide. The principal reasons for deforestation are agriculture and urban growth, and harvesting timber for fuel, construction, and paper. Currently, up to a quarter of the carbon dioxide emissions to the atmosphere can be attributed to land-use change.

Sulfate Aerosols and Black Carbon

Sulfate aerosols and black carbon are two important additional examples of anthropogenic forcings. Sulfate aerosols, which enter the atmosphere naturally during volcanic eruptions, are tiny airborne particles that reflect sunlight back to space. Industrial activity has recently increased their concentration in the atmosphere primarily through the burning of fossil fuels containing sulfur. Anthropogenic emissions of sulfate aerosols have been associated with a net cooling effect.

Black carbon is soot generated from industrial pollution, traffic, outdoor fires, and the burning of coal and biomass fuels. Black carbon is formed by incomplete combustion especially of coal, diesel fuels, biofuels and outdoor biomass burning. Soot particles absorb sunlight, both heating the air and reducing the amount of sunlight reaching the ground.

Global Climate Change in the Twentieth Century

The climate system includes a great deal of natural variability, and climate fluctuations have always been part of the Earth's 4.6 billion year history. However, over the past century changes in concentrations of greenhouse gases in the atmosphere are of an unprecedented rate and magnitude. Human population growth has led to increasing demands for energy and land resources. Through the burning of fossil fuels to produce energy for industrial use, transportation, and domestic power, and through land-use change for agriculture and forest products, humans have been altering the Earth's energy balance. Scientists believe that these changes may have already begun to alter the global climate.

References

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National Academy of Sciences (NAS). 2001. "Climate Change Science: An Analysis of Some Key Questions." *National Academies Press*. 42 pp.

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