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Air and Atmosphere

Climate Change

Key Findings

- During the last few decades, the earth's climate has been disrupted by the rising temperature of the earth's surface. This global warming very likely stems from increases in atmospheric greenhouse gas (GHG) concentrations produced by human activities.
- In North America, the largest source of GHG emissions is energy-related activities, including electric power generation, transportation and industrial fuel use. Some of these emissions are offset by factors such as forest and agricultural carbon sinks.
- North America is responsible for about a quarter of global GHG emissions.
- Since 1990, North American GHG emissions have increased by almost 18 percent, or at roughly the same rate as total energy use.

Climate change **refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be caused by natural internal processes or external forcings, or by persistent anthropogenic changes in the composition of the atmosphere or in land use.**

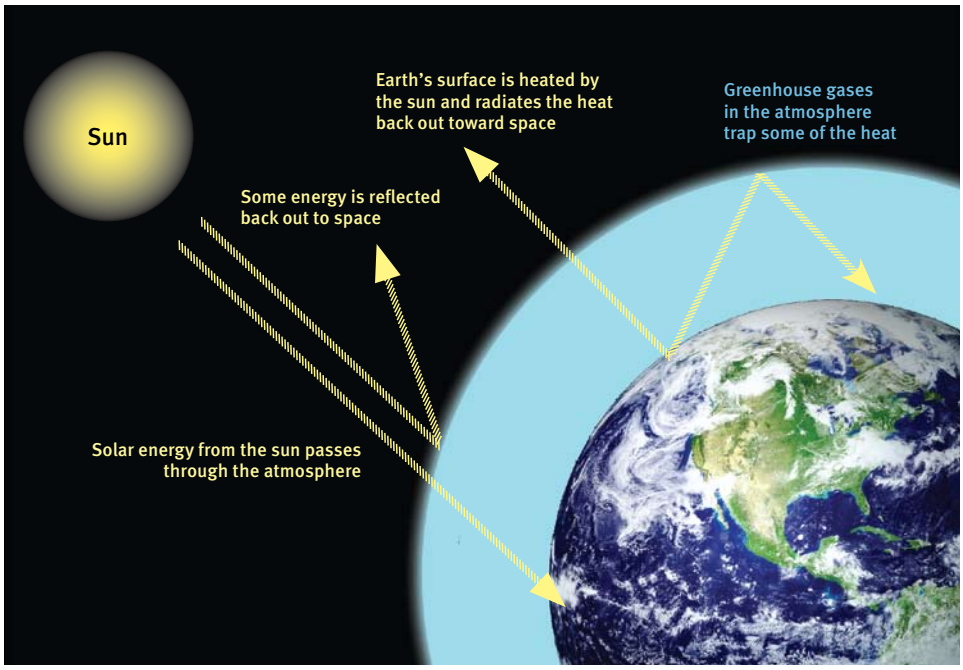
What Is the Environmental Issue?

Climate change is any change in climate properties that can be measured statistically (such as mean temperature, precipitation or wind) caused by natural internal processes, external forcings or human activities and lasting decades or longer. The global climate has experienced substantial variability over the history of the planet, but during the last few decades the climate has been disrupted in an unprecedented fashion. This disruption consists of an exceptionally rapid increase in the global average temperatures of the earth's near-surface air and oceans. Unless current policies and practices change, this warming trend and a variety of associated climate impacts are projected to continue.

The Greenhouse Effect

Energy from the sun, which arrives mainly in the form of visible light, drives global climate and is the basis for life on earth. About 30 percent of the sun's energy arriving at earth is scattered back into space by the outer atmosphere, but the rest reaches the surface, where it is reflected back in the form of infrared radiation. The eventual escape of this infrared radiation into space is delayed by greenhouse gases such as water vapor, carbon dioxide,

The Greenhouse Effect



ozone and methane. These gases make up only about 1 percent of the atmosphere, but they act like the glass roof of a greenhouse, trapping heat and keeping the planet warmer than it would be otherwise. Without the natural greenhouse effect, the average temperature at earth's surface would be below the freezing point of water. The natural greenhouse effect is therefore a prerequisite for life on earth.

Human activities are, however, very likely intensifying the natural greenhouse effect. Natural levels of greenhouse gases are being supplemented by emissions of carbon dioxide from the burning of fossil fuels, by the additional methane and nitrous oxide produced by farming activities and changes in land use, and by releases of long-lived industrial gases that do not occur naturally. As a result, global greenhouse gas emissions have grown since preindustrial times—70 percent between 1970 and 2004 alone.

Because of these emissions, global atmospheric concentrations of greenhouse gases have increased markedly and now far exceed preindustrial values. The concentration of carbon dioxide in the atmosphere has reached a record high relative to the last half-million years, and it has done so at an exceptionally fast rate.

Global Climate Change

The impact of additional greenhouse gases on global climate is evident in increases in the average global air and ocean temperatures (especially at the higher latitudes), the widespread melting of snow and ice, and the rising average sea level globally. Eleven of the last twelve years (1995–2006) are among the twelve warmest years since 1850. Over the last 30 years, the Arctic ice pack has shrunk on average each year by an area equivalent to Texas and Arizona combined, and the melting trend is accelerating.

Most of the observed increase in the globally averaged temperatures of the last 50 years is very likely attributable to the observed increase in concentrations of anthropogenic greenhouse gases. Indeed, the human impact on climate greatly exceeds that of known changes in natural processes, such as solar changes and volcanic eruptions. The current global temperatures are warmer than those of at least the past five centuries, perhaps those of more than a millennium. If warming continues unabated, the resulting climate change within this century would be extremely unusual in geological terms.

Why Is This Issue Important to North America?

North America is already experiencing locally severe economic damage and substantial ecosystem, social and cultural disruption from weather-related events, including hurricanes, other severe storms, floods, droughts, heat waves and larger and more frequent wildfires. Although climate change does not account for all weather extremes, it exacerbates the risk from these events by affecting the frequency, intensity and duration of extreme climate events and associated natural disasters. The economic damage from the severe weather is growing dramatically, largely because of the rising value of the infrastructure at risk. The annual costs to North America have now reached tens of billions of dollars in property damage and lost economic productivity, as well as lives disrupted and lost. These patterns of climate change will continue unless the greenhouse gas emissions and the related greenhouse gas concentrations in the atmosphere that are causing global warming are substantially reduced.

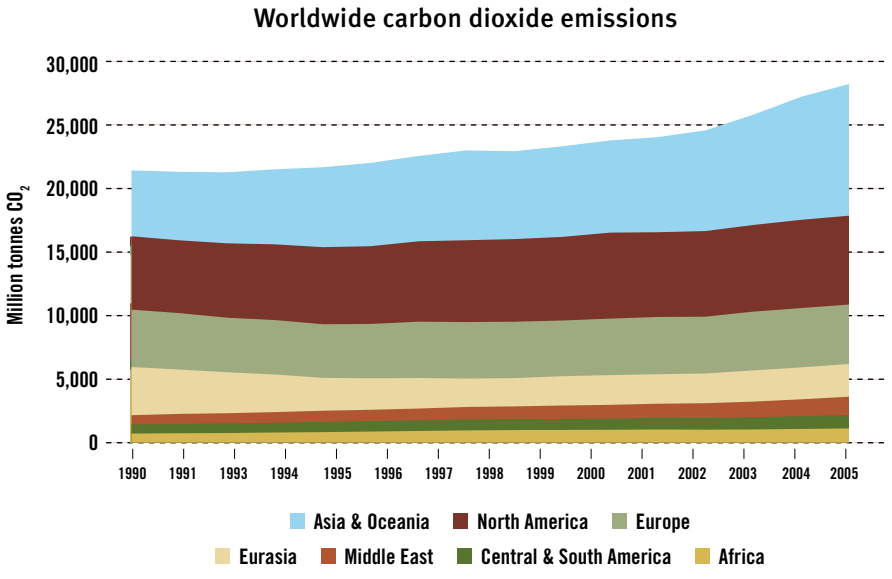
Trees ravaged by insect infestation.

Greenhouse Gas Emissions in North America

Home to some 7 percent of the world's population, North America is responsible for 25 percent of the total emissions of the most important greenhouse gas, carbon dioxide (see graph). Per person, North America emits twice as much carbon dioxide as Europe, over five times as much as Asia, and over 13 times as much as Africa. Per capita emissions are several times higher in Canada and the United States than in Mexico. These high rates are a result of higher per capita levels of economic activity, which drive greenhouse gas emissions, especially those related to energy consumption.

Sources of Emissions

Since 1990, North American greenhouse gas emissions have increased by almost 18 percent (see graph)—or at roughly the same rate as total energy use, but more slower than the



Worldwide carbon dioxide emissions, 1990–2005. Source: US Energy Information Administration.

overall gross domestic product. Without significant advances in energy efficiency and productivity over this period, this rate would have been even higher.

Similar to the global picture, carbon dioxide constitutes over 80 percent of total greenhouse gas emissions in North America. The largest source of that gas, and of overall greenhouse gas emissions, is energy-related activities, including electric power generation, transportation and industrial fuel use.

The conversion of fossil fuels to energy (primarily electricity) is the single largest contributor to North American emissions of carbon dioxide. More than half of the electricity produced in North America is consumed in buildings, making that single use one of the largest factors in North American emissions. As of 2003, the carbon dioxide emissions from US buildings alone were greater than the total carbon dioxide emissions of any country, except China.

The transportation sector is the second-largest contributor to emissions of carbon dioxide in North America. This sector and its associated carbon dioxide emissions have grown steadily during the past 40 years. Growth has been the most rapid in Mexico, the country most dependent on road transport.

Important contributors to the remaining 20 percent of greenhouse gas emissions are releases of methane from natural gas systems, landfills and agricultural sources; nitrous oxide from nitrogen fertilization and fuel combustion; and certain fluorinated industrial gases.

The fluorinated industrial gases—hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6)—are potent greenhouse gases with long atmospheric lifetimes. Although they add only about 2 percent to the overall North American total greenhouse gas contribution, releases of these gases have increased sharply, up 72 percent between 1990 and 2005. Some industrial releases have fallen, but this achievement has been more than offset by the rapid switch to HFCs and PFCs as substitutes for chlorofluorocarbons and other ozone-depleting substances, in particular the introduction of HFC-134a as a chlorofluorocarbon (CFC) substitute in refrigeration and air-conditioning applications.

Recapture of Carbon

Land management activities can remove some portion of industrial greenhouse gas emissions. Forests and other vegetation act as a natural sink through carbon sequestration, but their net impact varies across North America. In 2005 land use, land use change and forestry activities captured more than 11 percent of US greenhouse gas emissions. Net carbon sequestration—primarily through a higher rate of net carbon accumulation in growing forests—was 16 percent greater than in 1990. In Canada, the contribution of land management activities is highly variable: over 20 percent net carbon accumulation in 1990, but only 2 percent in 2005. This fluctuation is attributable to the large and variable impact of emissions from wildfires. In Mexico, land management activities *added* to total greenhouse gas emissions because of deforestation and land clearing. In 2002 land use, land use change and forestry activities accounted for 14 percent of Mexico's total greenhouse gas emissions.

What Are the Linkages to Other North American Environmental Issues?

As climate change continues, North America is expected to face additional challenges, some of which are described in the *Fourth Assessment Report* of the Intergovernmental Panel on Climate Change.

Human Health

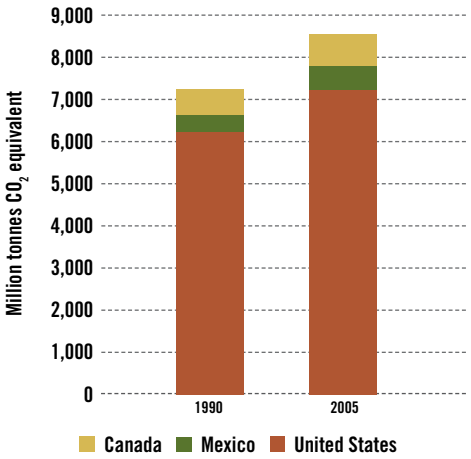
By the end of the twenty-first century, climate change, with its higher temperatures and extreme weather in the form of longer and more intense heat waves, will have pronounced effects on human health, especially that of the elderly. Warming and climate extremes, including added exposure to pollen and ozone, are likely to lead to more respiratory illnesses. Periods of extreme weather and intense rainfall may spark as well an increase in water-borne diseases and degrade water quality. Climate change is also likely to hasten the spread of vector-borne infectious diseases, including Lyme disease and West Nile virus. In Mexico, the *Instituto Nacional de Ecología* has established a direct link between higher temperatures and an increase in the incidence of dengue fever since 1995.

More than half of the electricity produced in North America is consumed in buildings, making that single use one of the largest factors in North American emissions.

Water Quantity and Quality

In making their projections, scientists are less certain about future precipitation patterns than about future temperatures. They do, however, project that warming in western mountains will reduce the snow pack, increase evaporation, produce more winter flooding and reduce summer flows, exacerbating the competition among agricultural, municipal, industrial and ecological uses of water in the west. In the Great Lakes and major river systems, lower water levels are likely to spur adaptation challenges related to water quality, navigation, recreation, hydropower generation, water transfers and binational relationships. Some studies project widespread increases in extreme precipitation with greater risks of not only flooding, but also drought. In Mexico, studies indicate that almost 97 percent of the

North American greenhouse gas emissions



Greenhouse gas emissions in North America, excluding land management, 1990 and 2005 (latest data from Mexico from 2002, not 2005). Source: United Nations Framework Convention on Climate Change.

country is susceptible to a moderate or high degree of desertification and reduction in precipitation as a result of climate change.

Oceans, Coasts and Fisheries

Coastal communities and habitats are especially vulnerable to climate change. Sea levels are rising along much of the coast, and the rate of change will accelerate in the future, worsening the impacts of progressive inundation, storm surge flooding and shoreline erosion. The destruction inflicted by storms is likely to grow, especially along the Gulf and Atlantic coasts. As for wildlife, coastal habitats and dependent species are threatened by rising sea levels, changes in vegetation and a built environment that blocks landward migration.

Habitat Change and Disturbances

Climate change is a factor in the growing number of climate-related disturbances in North America such as wildfire and insect outbreaks, which are only likely to intensify with the drier soils and longer growing seasons that appear to lie ahead. Although in some areas vegetation growth may respond positively to recent climate trends, a rising incidence of disturbances is likely to limit carbon storage, enable the proliferation of invasive species and disrupt ecosystem services. As summers grow warmer, the window of high fire risk is expected to widen (see case study).

Over time, species will respond to climate pressures by moving north and to higher elevations in search of more suitable habitats, thereby rearranging North American ecosystems. The structure, function and services of ecosystems will change in response to the various capacities of species to shift ranges and from the constraints imposed by development, habitat fragmentation, invasive species and other pressures. This ecosystem alteration will be enhanced where high disturbance rates leave large areas open to recolonization by vegetation. In Mexico, half of the national vegetative cover may suffer alterations, including the disappearance of some zones and changes in others. In central and southern Mexico, climate change and land use patterns are projected to replace tropical forests with savannas, and the semiarid vegetation in most of central and northern Mexico with arid vegetation. Change in habitat distribution is expected to affect the species that inhabit these ecosystems. In tropical areas of Mexico, some species may become extinct altogether.

Case Study – Accelerating Forest Ecosystem Disturbances

North American forests are indirectly influenced by climate through effects on natural disturbances such as wildfire, insects, and disease.

Wildfires

The area consumed by wildfires in the United States and Canada has increased dramatically over the last three decades. The intensity of wildfires is closely related to the availability of the dry, dead biomass they use as fuel. A warming climate produces longer summer periods that dry fuels, thereby promoting the easier ignition and faster spread of wildfires. Since 1980, US wildfires have consumed an average of 22,000 square kilometers (km^2) a year, or almost twice the 1920–1980 average of 13,000 km^2 a year. From 1987 to 2003 in the western United States, the forested area burned was 6.7 times that burned from 1970 to 1986. In Canada, the burned area has exceeded 60,000 km^2 a year three times since 1990, or twice the long-term average. The wildfire-burned area in the North American boreal region increased from 6,500 km^2 a year in the 1960s to 29,700 km^2 a year in the 1990s. The human vulnerability to wildfires has also increased with rising population and housing development in forested areas.

Insects and disease

Insects and disease are a natural part of ecosystems. In forests, periodic insect epidemics kill trees over large areas. Recent epidemics have been related to the climate-sensitive stages in insect life cycles. Many northern insects have a two-year life cycle, and warmer winter temperatures allow a larger fraction of overwintering larvae to survive. Recently, spruce budworm in Alaska completed its life cycle in one year rather than the normal two. The mountain pine beetle has expanded its range in British Columbia into areas previously too cold. The susceptibility of trees to insects is increased when multiyear droughts degrade the ability of trees to generate defensive chemicals. The recent dieback of aspen stands in Alberta was caused by light snowpacks and drought in the 1980s, which triggered defoliation by tent caterpillars, followed by wood-boring insects and fungal pathogens. Extensive areas of dead, standing dry trees exacerbate the risk of large wildfires.

California wildfire.