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Climate Change And Kentucky

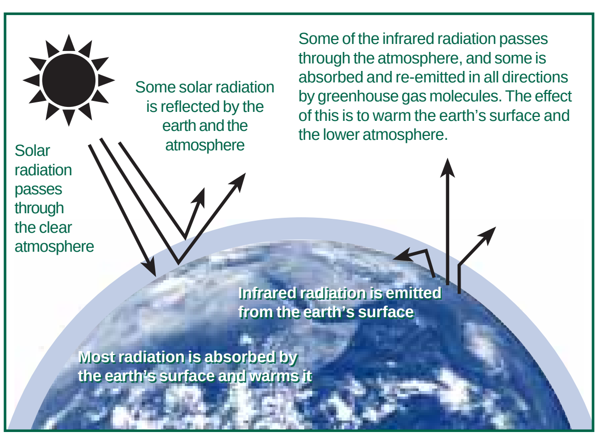
The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases — primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The heat-trapping property of these greenhouse gases is undisputed. Although there is uncertainty about exactly how and when the earth's climate will respond to enhanced concentrations of greenhouse gases, observations indicate that detectable changes are under way. There most likely will be increases in temperature and changes in precipitation, soil moisture, and sea level, which could have adverse effects on many ecological systems, as well as on human health and the economy.

The Climate System

Energy from the sun drives the earth's weather and climate. Atmospheric greenhouse gases (water vapor, carbon dioxide, and other gases) trap some of the energy from the sun, creating a natural "greenhouse effect." Without this effect, temperatures would be much lower than they are now, and life as known today would not be possible. Instead, thanks to greenhouse gases, the earth's average temperature is a more hospitable 60°F. However, problems arise when the greenhouse effect is ***enhanced*** by human-generated emissions of greenhouse gases.

Global warming would do more than add a few degrees to today's average temperatures. Cold spells still would occur in winter, but heat waves would be more common. Some places would be drier, others wetter. Perhaps more important, more precipitation may come in short, intense bursts (e.g., more than 2 inches of rain in a day), which could lead to more flooding. Sea levels would be higher than they would have been without global warming, although the actual changes may vary from place to place because coastal lands are themselves sinking or rising.

The Greenhouse Effect



Source: U.S. Department of State (1992)

Emissions Of Greenhouse Gases

Since the beginning of the industrial revolution, human activities have been adding measurably to natural background levels of greenhouse gases. The burning of fossil fuels — coal, oil, and natural gas — for energy is the primary source of emissions. Energy burned to run cars and trucks, heat homes and businesses, and power factories is responsible for about 80% of global carbon dioxide emissions, about 25% of U.S. methane emissions, and about 20% of global nitrous oxide emissions. Increased agriculture and deforestation, landfills, and industrial production and mining also contribute a significant share of emissions. In 1994, the United States emitted about one-fifth of total global greenhouse gases.

Concentrations Of Greenhouse Gases

Since the pre-industrial era, atmospheric concentrations of carbon dioxide have increased nearly 30%, methane concentrations have more than doubled, and nitrous oxide concentrations have risen by about 15%. These increases have enhanced the heat-trapping capability of the earth's atmosphere. Sulfate aerosols, a common air pollutant, cool the atmosphere by reflecting incoming solar radiation. However, sulfates are short-lived and vary regionally, so they do not offset greenhouse gas warming.

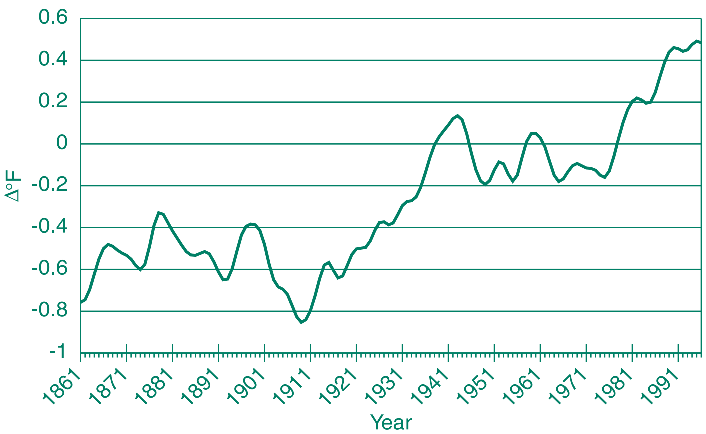
Although many greenhouse gases already are present in the atmosphere, oceans, and vegetation, their concentrations in the future will depend in part on present and future emissions. Estimating future emissions is difficult, because they will depend on demographic, economic, technological, policy, and institutional developments. Several emissions scenarios have been developed based on differing projections of these underlying factors. For example, by 2100, in the absence of emissions control policies, carbon dioxide concentrations are projected to be 30-150% higher than today's levels.

Current Climatic Changes

Global mean surface temperatures have increased 0.6-1.2°F between 1890 and 1996. The 9 warmest years in this century all have occurred in the last 14 years. Of these, 1995 was the warmest year on record, suggesting the atmosphere has rebounded from the temporary cooling caused by the eruption of Mt. Pinatubo in the Philippines.

Several pieces of additional evidence consistent with warming, such as a decrease in Northern Hemisphere snow cover, a decrease in Arctic Sea ice, and continued melting of alpine glaciers, have been corroborated. Globally, sea levels have risen

Global Temperature Changes (1861–1996)



Source: IPCC (1995), updated

4-10 inches over the past century, and precipitation over land has increased slightly. The frequency of extreme rainfall events also has increased throughout much of the United States.

A new international scientific assessment by the Intergovernmental Panel on Climate Change recently concluded that ***"the balance of evidence suggests a discernible human influence on global climate."***

Future Climatic Changes

For a given concentration of greenhouse gases, the resulting increase in the atmosphere's heat-trapping ability can be predicted with precision, but the resulting impact on climate is more uncertain. The climate system is complex and dynamic, with constant interaction between the atmosphere, land, ice, and oceans. Further, humans have never experienced such a rapid rise in greenhouse gases. In effect, a large and uncontrolled planet-wide experiment is being conducted.

General circulation models are complex computer simulations that describe the circulation of air and ocean currents and how energy is transported within the climate system. While uncertainties remain, these models are a powerful tool for studying climate. As a result of continuous model improvements over the last few decades, scientists are reasonably confident about the link between global greenhouse gas concentrations and temperature and about the ability of models to characterize future climate at continental scales.

Recent model calculations suggest that the global surface temperature could increase an average of 1.6-6.3°F by 2100, with significant regional variation. These temperature changes would be far greater than recent natural fluctuations, and they would occur significantly faster than any known changes in the last 10,000 years. The United States is projected to warm more than the global average, especially as fewer sulfate aerosols are produced.

The models suggest that the rate of evaporation will increase as the climate warms, which will increase average global precipitation. They also suggest increased frequency of intense rainfall as well as a marked decrease in soil moisture over some mid-continental regions during the summer. Sea level is projected to increase by 6-38 inches by 2100.

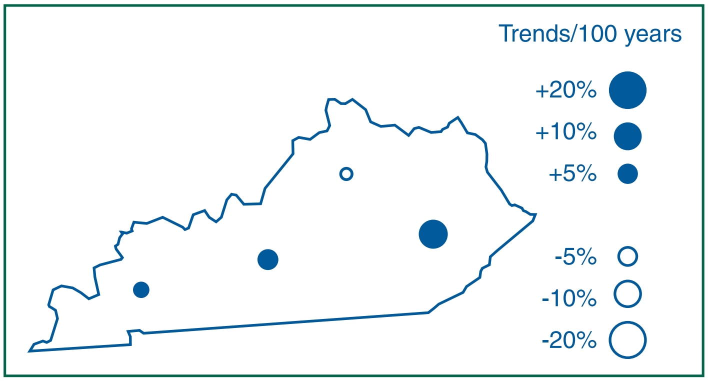
Calculations of regional climate change are much less reliable than global ones, and it is unclear whether regional climate will become more variable. The frequency and intensity of some extreme weather of critical importance to ecological systems (droughts, floods, frosts, cloudiness, the frequency of hot or cold spells, and the intensity of associated fire and pest outbreaks) could increase.

Local Climate Changes

Over the last century, the average temperature in Frankfort, Kentucky, has decreased 1.4°F, and precipitation has increased by up to 10% in many parts of the state. These past trends may or may not continue into the future.

Over the next century, climate in Kentucky could experience additional changes. For example, based on projections made by the Intergovernmental Panel on Climate Change and results from the United Kingdom Hadley Centre's climate model (HadCM2), a model that accounts for both greenhouse gases and aerosols, by 2100 temperatures in Kentucky could increase by 3°F (with a range of 1-5°F) in all seasons (slightly less in summer, slightly more in fall). Precipitation is estimated to increase only slightly in winter (with a range of 0-10%), by 20% in spring and fall (with a range of 10-30%), and by 30% (with a range of 10-50%) in summer. Other climate models may show different results, especially regarding estimated changes in precipitation. The impacts described in the sections that follow take into account estimates from different models. The frequency of extreme hot days in summer would increase because of the general warming trend. It is not clear how the severity of storms might be affected, although an increase in the frequency and intensity of summer thunderstorms is possible.

Precipitation Trends From 1900 To Present



Source: Karl et al. (1996)

Human Health

Higher temperatures and increased frequency of heat waves may increase the number of heat-related deaths and the incidence of heat-related illnesses. However, some southern states appear less susceptible to heat waves, perhaps because the population is better adapted to the regular, intense heat.

In Louisville, one study projected a summer warming of 4-5°F is likely to cause little change in heat-related deaths. This study also shows that a temperature increase of 8°F could cause winter-related deaths to increase by 20%. However, the exact reasons for this increase are unknown. The elderly, especially those living alone, are at greatest risk.

Climate change could increase concentrations of ground-level ozone. For example, high temperatures, strong sunlight, and stable air masses tend to increase urban ozone levels. A 2°F warming, with no other change in weather or emissions, could increase concentrations of ozone, a major component of smog, by as much as 8%. Currently, Louisville is classified as a “moderate” nonattainment area for ozone. Ground-level ozone is associated with respiratory illnesses such as asthma, reduced lung function, and respiratory inflammation. Air pollution also is made worse by increases in natural hydrocarbon emissions such as emissions of terpenes by trees and shrubs during hot weather. If a warmed climate causes increased use of air conditioners, air pollutant emissions from power plants also will increase.

Warming and other climate changes could expand the habitat and infectivity of disease-carrying insects, thus increasing the potential for transmission of diseases such as malaria and dengue (“break bone”) fever. Warmer temperatures could increase the incidence of Lyme disease and other tick-borne diseases in Kentucky, because populations of ticks, and their rodent hosts, could increase under warmer temperatures and increased vegetation.

Infected individuals can bring malaria to places where it does not occur naturally. Also, some mosquitoes in Kentucky can carry malaria. If conditions become warmer and wetter, mosquito populations could increase, thus increasing the potential for transmission if this and other diseases are introduced into the area. Increased runoff from heavy rainfall could increase water-borne diseases such as giardia, cryptosporidia, and viral and bacterial gastroenteritides. Developed countries such as the United States should be able to minimize the impacts of these diseases through existing disease prevention and control methods.

Water Resources

The Ohio River, which forms the 644-mile northern boundary of Kentucky, is the major river in the state. Important tributaries of the Ohio in the state include the Big Sandy, Kentucky, and Green rivers. The Cumberland and Tennessee rivers drain small areas along the state’s southern border. These surface waters supply most of the water needs in Kentucky. In some of the more densely populated drainage basins, streamflows are not sufficient to meet water requirements during dry years. Where available, reservoir releases are needed during these low flow periods. This situation could be exacerbated in a warmer climate. If summer rainfall remains the same or declines, then increases in temperature and evaporation could further reduce streamflows, lake levels, and groundwater levels during the critical summer months. Cities such as Frankfort and Lexington, which depend on the Kentucky River for water supplies, could be particularly vulnerable. Lower groundwater levels also could be detrimental for the one-third of the population that depends on groundwater for drinking water. Low flows and higher temperatures could worsen water quality, which has been adversely affected in various regions of the state by coal mining, oil and gas operations, agriculture, and domestic-waste discharges.

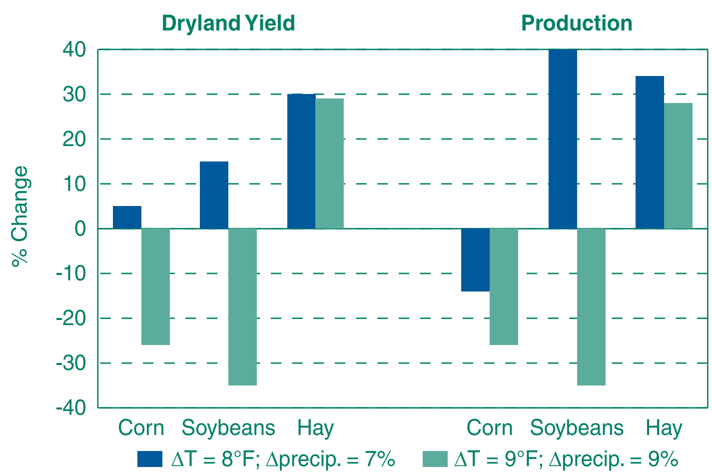
Increased precipitation could alleviate water shortages and provide more water for dilution of pollutants. However, flooding is a recurring problem along many streams in Kentucky. Major floods are frequent from November to May, whereas flash floods can occur at any time. Rising groundwater levels also have contributed to flooding in the Louisville area. Higher rainfall, particularly during the traditional flood season, would increase the flood risk. Increased rainfall also could increase landslides, erosion, and levels of pesticides and fertilizers in runoff from agricultural areas. It could also increase pollution in runoff from mining and urban areas.

Agriculture

The mix of crop and livestock production in a state is influenced by climatic conditions and water availability. As climate warms, production patterns could shift northward. Increases in climate variability could make adaptation by farmers more difficult. Warmer climates and less soil moisture due to increased evaporation may increase the need for irrigation. However, these same conditions could decrease water supplies, which also may be needed by natural ecosystems, urban populations, industry, and other users.

Understandably, most studies have not fully accounted for changes in climate variability, water availability, crop pests, changes in air pollution such as ozone, and adaptation by

Changes In Agricultural Yield And Production



Sources: Mendelsohn and Neumann (in press); McCarl (personal communication) farmers to changing climate. Including these factors could change modeling results substantially. Analyses that assume changes in average climate and effective adaptation by farmers suggest that aggregate U.S. food production would not be harmed, although there may be significant regional changes.

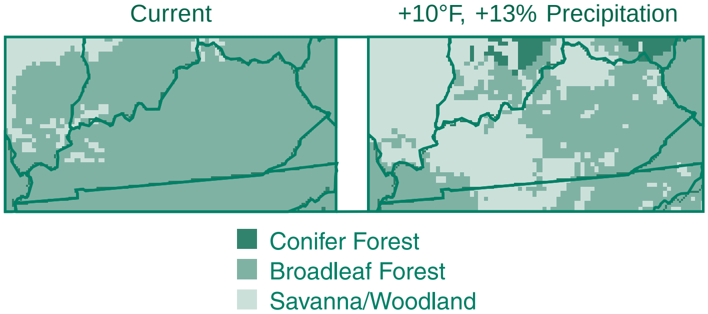
In Kentucky, production agriculture is a $3.3 billion annual industry, almost split evenly between crops and livestock. Very few of the farmed acres are irrigated. The major crops in the state are corn, soybeans, and hay. Corn and soybean yields could fall by 35% under severe conditions where temperature rises beyond the temperature tolerance of the crop. However, under less severe change, yields could rise by 15%. Hay and pasture yields could rise by 30%. Estimated changes in yield vary, depending on whether land is irrigated. Farmed acres are projected to remain fairly constant. Livestock and dairy production may not be affected, unless summer temperatures rise significantly and conditions become significantly drier. Under these conditions, livestock tend to gain less weight and pasture yields decline, limiting forage.

Forests

Trees and forests are adapted to specific climate conditions, and as climate warms, forests will change. These changes could include changes in species composition, geographic range, and health and productivity. If conditions also become drier, the current range of forests could be reduced and replaced by grasslands and pasture. Even a warmer and wetter climate could lead to changes; trees that are better adapted to warmer conditions, such as oaks and pines, would prevail. Under these conditions, forests could become more dense. These changes could occur during the lifetimes of today's children, particularly if the change is accelerated by other stresses such as fire, pests, and diseases. Some of these stresses would themselves be worsened by a warmer and drier climate.

With changes in climate, the extent of forested areas in Kentucky could change little or decline by as much as 10-25%. However, the types of trees dominating those forests and woodlands are likely to change. Forested areas could be increasingly dominated by pine and scrub oaks, replacing many of the eastern hardwoods common throughout eastern Kentucky. In areas where richer soils are prevalent, southern pines could increase their range and density, and in areas with poorer soils, which are more common in Kentucky's forests, scrub oaks of little commercial value (e.g., post oak and blackjack oak) could increase their range. As a result, the character and diversity of Kentucky forests could change. Climate change could also affect the success of tree plantings to stabilize open-face mining sites.

Changes In Forest Cover



Sources: VEMAP Participants (1995); Neilson (1995)

Ecosystems

Kentucky consists of three major geographic areas and has more running water than any other state except Alaska. As a result, Kentucky is home to many diverse ecosystems. In the west, the Gulf Coastal Plain is bounded by the Mississippi, Ohio, and Tennessee rivers (the last is now Kentucky Lake). The bottomland hardwood forests of this area include some of the Mississippi Delta's last intact bald cypress-tupelo swamps, and are home to many rare, threatened, or endangered plants and animals, including the globally imperiled Rockcastle aster and a diverse array of freshwater mussels. Thousands of waterfowl, particularly wood ducks, overwinter in this region. Climate change could exacerbate the current threats to ecosystems of this region, including increases in exotic species invasions, nutrient and toxic loading, and sedimentation. If increases in evaporation exceed increases in precipitation during the summer months, streams could shift from constant to intermittent flows, thereby favoring plants and animals adapted to these conditions (e.g., chironomids and mayflies), rather than those with relatively long life cycles (e.g., caddisflies and mollusks). Under a warmer climate, the habitat available to coldwater fish species such as trout could decrease, thus limiting their abundance and distribution. Higher flood peaks, caused by greater clustering of storms, could increase erosion and sediment loading to stream channels. The extent and duration of inundation is crucial to the health of wetlands, including productivity, decomposition, and cycling of major nutrients and pollutants.

The southeastern border of the state is characterized by Appalachian oak forests. The oaks of high-elevation forests are already declining because of the increasing incidence of several pests. An example is the shoestring fungus, which appears to be associated with drought conditions. Climate change could accelerate these declines. A native grassland region called the Big Barrens is another well-known ecological community. In this ecosystem, climate change could favor the spread of exotic weedy species, which spread and adapt easily.

Kentucky is also well known for its karst features, including Mammoth Cave, the world's longest cave. Caves are important geological, hydrological, and biological resources that provide habitat for huge populations of bats (including the endangered gray and Indiana bats) and numerous invertebrate species. Higher-than-normal winter temperatures could boost temperatures inside cave bat roosting sites, which has been shown to cause higher mortality due to increased winter body weight loss in endangered Indiana bats (e.g., an increase of 9°F during winter hibernation has been associated with a 42% increase in the rate of body mass loss).

For further information about the potential impacts of climate change, contact the Climate and Policy Assessment Division (2174), U.S. EPA, 401 M Street SW, Washington, DC 20460, or visit http://www.epa.gov/globalwarming/impacts.