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EPA Climate Change And Tennessee

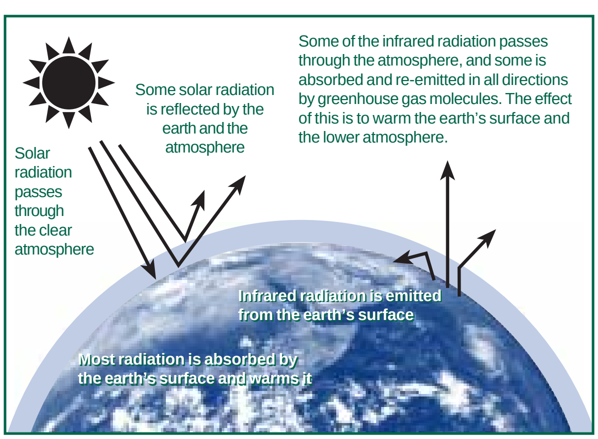
The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases — primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The heat-trapping property of these greenhouse gases is undisputed. 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.

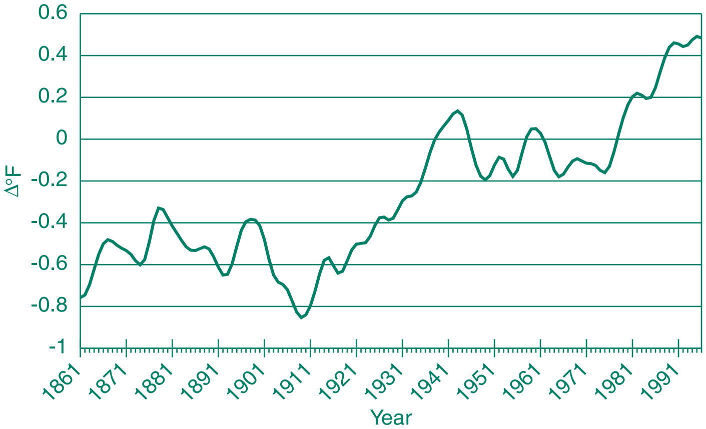
Although many greenhouse gases already are present in the atmosphere, oceans, and vegetation, their concentrations in the future will depend in part on present and future emissions. Estimating future emissions is difficult, because they will depend on demographic, economic, technological, policy, and 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 10 warmest years in this century all have occurred in the last 15 years. Of these, 1998 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

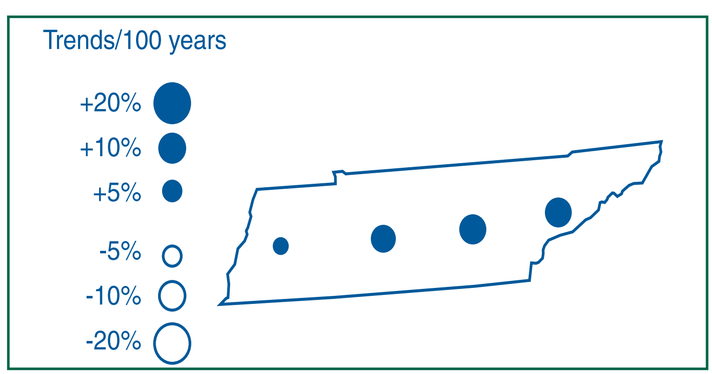
Over the last century, the average temperature in Nashville, Tennessee, has increased nearly 1°F, and precipitation has increased by up to 10% in many parts of the state. These past trends may or may not continue into the future.

Over the next century, climate in Tennessee may change even more. 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 Tennessee could increase by 2-3°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.

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. Although Tennessee is exposed to regular, intense heat during a typical summer, one study suggests that the population could still be sensitive to heat waves.

Precipitation Trends From 1900 To Present



Source: Karl et al. (1996)

In Memphis, a city historically vulnerable to heat-related deaths, a warming of 3-4°F during a typical summer is projected to cause heat-related deaths to increase by about 60% from the current 40 to 65 (although increased air conditioning use may not have been fully accounted for). The elderly, especially those living alone, are at greatest risk. This study also projects little change in winter-related deaths in Tennessee.

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. 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 most likely increase.

Upper and lower respiratory allergies are influenced by humidity. A 2°F warming and wetter conditions could increase respiratory allergies.

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. Infected individuals can bring malaria to places where it does not occur naturally. Warmer temperatures could increase the incidence of Lyme disease and other tick-borne diseases in Tennessee, because populations of ticks, and their rodent hosts, could increase under warmer temperatures and increased vegetation. 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

Surface and groundwater resources in Tennessee are abundant. The Tennessee and Cumberland rivers are the major rivers in the eastern and central regions of the state, where they are the principal source of water. These rivers contain a well-developed system of dams and lakes that provide flood control, navigation, power generation, recreation, and minimum flows for water quality maintenance. In western Tennessee, the Mississippi River forms the border between Tennessee and Arkansas. Most public and industrial water supplies in this part of the state, however, depend on groundwater sources.

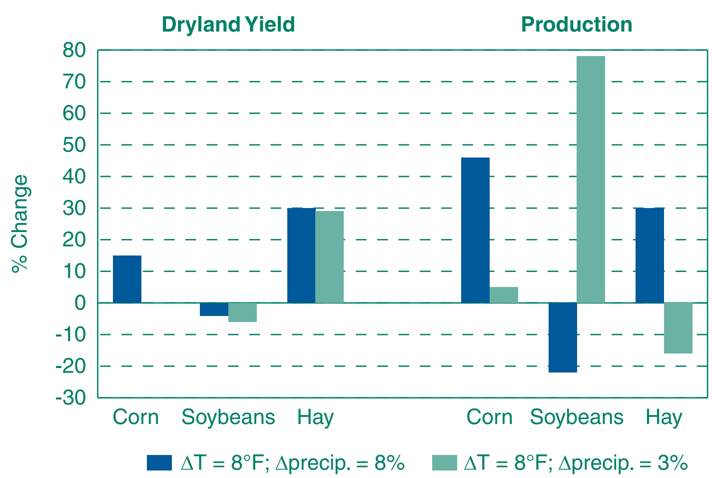
Snow accumulation is minimal in Tennessee, so in a warmer climate, runoff would be influenced primarily by higher temperatures, increased evaporation, and changes in precipitation. If runoff decreases, the reservoir systems of the Tennessee and Cumberland rivers could experience declines in hydropower generation, disruptions to navigation, degraded recreational opportunities, and decreased water availability for water supplies. Lower flows and higher water temperatures also could degrade water quality by lowering dissolved oxygen levels and concentrating pollutant levels. This could be problematic for urban areas such as Knoxville, Chattanooga, Nashville, and Memphis, which discharge their treated municipal and industrial wastes into rivers. Higher water temperatures could also impair the cold water fisheries that have been established below many dams. In addition, higher water temperatures could reduce the efficiency of industrial and power plant cooling systems. They also could make it increasingly difficult to meet regulatory standards for acceptable downstream water temperatures, particularly during extremely warm periods.

If rainfall and runoff increase in the Tennessee region, then higher streamflows and lake levels could benefit hydropower production, enhance recreational opportunities, and improve water availability for water supplies. Although higher flows would dilute pollutants, erosion and levels of pesticides and fertilizers in runoff from agricultural areas could increase. It also could increase pollution in runoff from mining areas. Many river basins in western Tennessee are susceptible to sedimentation and nutrient enrichment from farming activities. Increased rainfall also could increase flooding, which is currently a problem in the steep terrain in eastern Tennessee, along the many unregulated streams throughout the state, and in growing urban areas such as Chattanooga-Hamilton, Nashville-Davidson, and Memphis-Shelby counties. Increased rainfall also could disrupt navigation during periods of high flow.

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.

Changes In Agricultural Yield And Production



Sources: Mendelsohn and Neumann (in press); McCarl (personal communication)

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

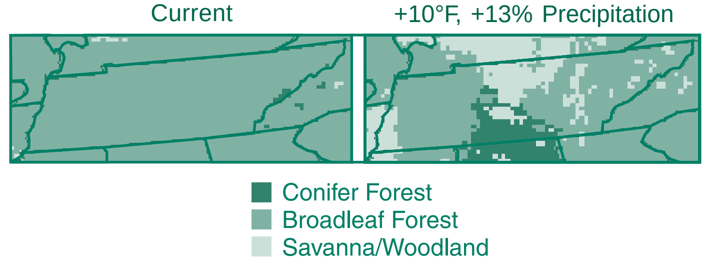
In Tennessee, production agriculture is a $2 billion annual industry, almost split evenly between crops and livestock. Very few of the farmed acres are irrigated. The major crops in the state are corn, soybeans, hay, and tobacco. Corn yields could increase 1-15% as a result of climate change. Hay and pasture yields could rise by 30%, and soybean yields could fall by 5%. Estimated changes in yield vary, depending on whether land is irrigated. Farmed acres are estimated 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. Commercial timber production could also be affected by resulting changes in growth rates, plantation acreage and management, and market conditions.

With changes in climate, the extent of forested areas in Tennessee could change little or decline by as much as 5-15%. 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 Tennessee. The forests in and around the Great Smoky Mountains National Park support a rich variety of plants and animals, and they are important recreation areas. Composition changes in these forests could adversely affect diversity and recreation. 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 Tennessee's forests, scrub oaks of little commercial value (e.g., post oak and blackjack oak) could increase their range. As a result, the character of forests in Tennessee 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

Tennessee contains diverse ecosystems, including wetlands, high-elevation forests and glades, oak-hickory forest, grasslands, cedar glades, mussel shoals, and caves. The waterways of the Mississippi Delta reach into the western part of the state and contain remnants of rich bottomland hardwood forests, a habitat that supports almost five times the biodiversity of upland areas. Migratory and wintering waterfowl frequent these areas, which also support the greatest diversity and number of freshwater mollusk and fish species in the country. Grasslands in the Highland Rim and Central Basin are home to hundreds of specially adapted plants and animals, including several rare plants. The Smoky Mountains have long been recognized as a global center of biodiversity, including the southern limit of spruce-fir forests found in the highest elevations. The southern Appalachians also contain a diverse array of salamanders, which are very sensitive to climatic factors.

Exotic species invasions, excess nutrient and toxic loading, and sedimentation in freshwater systems of the state are expected to increase as a result of climate change. If increased evaporation exceeds any increase in rainfall during the summer months, streamflows could become intermittent, and thus favor plants and animals adapted to ephemeral 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 is expected to decrease, thus limiting their abundance and range. Habitat for warmwater fish could also be reduced by hotter temperatures. Higher flood peaks, a result of greater clustering of storms, could increase erosion and sediment loading to stream channels. The Appalachian spruce-fir forests already are threatened by air pollution (acid rain and ground-level ozone) and exotic pests (hemlock wooly adelgid). Climate change could add significantly to the stresses of these forests as conditions suitable for the growth of red spruce and Fraser fir disappear under warmer and drier conditions.

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.