



Climate Change And Pennsylvania

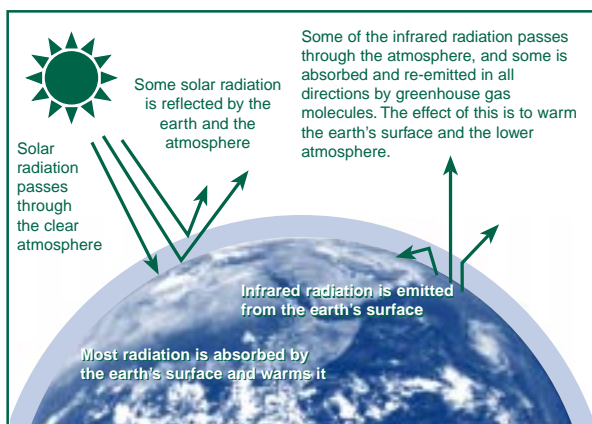
The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases — primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The heat-trapping property of these greenhouse gases is undisputed. 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, common air pollutants, cool the atmosphere by reflecting incoming solar radiation. However, sulfates are short-lived and vary regionally.

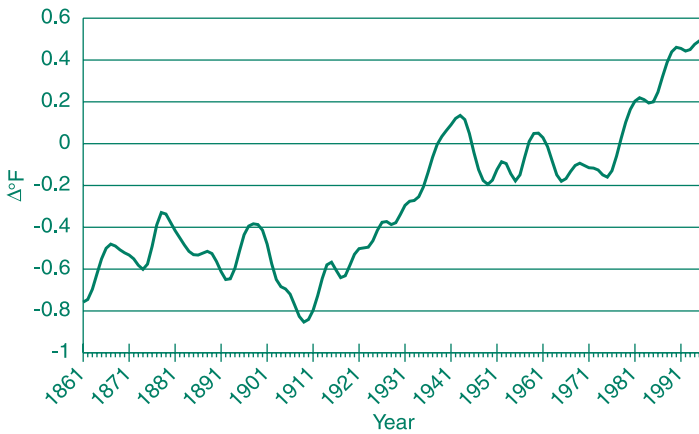
Although many greenhouse gases already are present in the atmosphere, oceans, and vegetation, their concentrations in the future will depend in part on present and future emissions. Estimating future emissions is difficult, because they will depend on demographic, economic, technological, policy, and 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

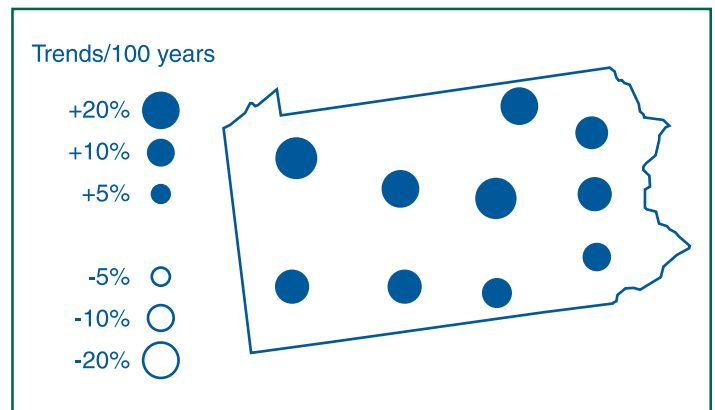
Over the last century, the average temperature in Harrisburg, Pennsylvania, has increased 1.2°F, and precipitation has increased by up to 20% in many parts of the state.

Over the next century, climate in Pennsylvania 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 Pennsylvania could increase by about 4°F (with a range of 2-9°F), slightly less in summer and fall, and slightly more in winter and spring. Precipitation is estimated to increase by about 10% in spring, by about 20% in winter and summer, and by as much as 50% in fall. Other climate models may show different seasonal changes in rainfall. The amount of precipitation on extreme wet or snowy days is likely to increase. The frequency of extreme hot days in summer would increase because of the general warming trend. Although it is not clear how severe storms would change, an increase in the frequency and intensity of summer thunderstorms is possible.

Climate Change Impacts

Global climate change poses risks to human health and to terrestrial and aquatic ecosystems. Important economic resources such as agriculture, forestry, fisheries, and water resources also

Precipitation Trends From 1900 To Present



Source: Karl et al. (1996)

may be affected. Warmer temperatures, more severe droughts and floods, and sea level rise could have a wide range of impacts. All these stresses can add to existing stresses on resources caused by other influences such as population growth, land-use changes, and pollution.

Similar temperature changes have occurred in the past, but the previous changes took place over centuries or millennia instead of decades. The ability of some plants and animals to migrate and adapt appears to be much slower than the predicted rate of climate change.

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. Pennsylvania, with its irregular, intense heat waves, could be especially susceptible.

In Philadelphia, one study projects that by 2050 heat-related deaths during a typical summer could increase 90%, from close to 130 heat-related deaths per summer to over 240 (although increased air conditioning use may not have been fully accounted for). Similar but smaller increases have been projected for Pittsburgh, from about 40 heat-related deaths to 60, or a 50% increase. Winter-related deaths could drop from 85 in Philadelphia per winter to about 35 if winter temperatures warm. In Pittsburgh, winter-related deaths are expected to change very little. The elderly, particularly 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. Air pollution also is made worse by increases in natural hydrocarbon emissions during hot weather. If a warmed climate causes increased use of air conditioners, air pollutant emissions from power plants also will increase.

A preliminary modeling study of the Midwest, which included the area around Pittsburgh, found that a 4°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, ground-level ozone concentrations exceed national ozone health standards in several areas throughout the state, with the Philadelphia area classified as a “severe” nonattainment area for ozone. Ground-level ozone has been shown to aggravate respiratory illnesses such as asthma, reduce existing lung function, and induce respiratory inflammation. In addition, ambient ozone reduces crop yields and impairs ecosystem health.

Warming and other climate changes may 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. Mosquitos flourish in some areas around Pennsylvania. Some can carry malaria, while others can carry encephalitis, which can be lethal or cause neurological damage. Incidents of Lyme disease, which is carried by ticks, have increased in the Northeast. If conditions become warmer

and wetter, mosquito and tick populations could increase in Pennsylvania, thereby increasing the risk of transmission of these diseases.

Water Resources

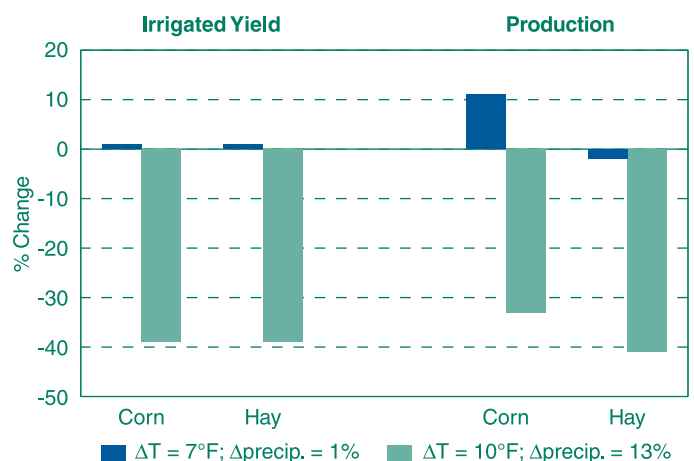
Water resources are affected by changes in precipitation as well as by temperature, humidity, wind, and sunshine. Changes in streamflow tend to magnify changes in precipitation. Water resources in drier climates tend to be more sensitive to climate changes. Because evaporation is likely to increase with warmer climate, it could result in lower river flow and lower lake levels, particularly in the summer. If streamflow and lake levels drop, groundwater also could be reduced. In addition, more intense precipitation could increase flooding.

Pennsylvania’s Susquehanna River drains much of the eastern two-thirds of the state, and the Allegheny and the upper Ohio rivers drain most of the western third. A warmer climate would lead to earlier spring snowmelt, and could result in higher streamflows in winter and spring and lower streamflows in summer and fall. However, changes in rainfall also could have significant effects on streamflow and runoff and, if summer precipitation falls, could affect adversely downstream uses such as navigation on the Ohio River. Increased precipitation in winter or summer could offset losses from increased evaporation, but also could lead to increased flood risk. Some of the most intense flooding on record in the United States has occurred in Pennsylvania.

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

Changes In Agricultural Yield And Production



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

conditions could decrease water supplies, which also may be needed by natural ecosystems, urban populations, industry, and other sectors.

Understandably, most studies have not fully accounted for changes in climate variability, water availability, and imperfect responses 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.

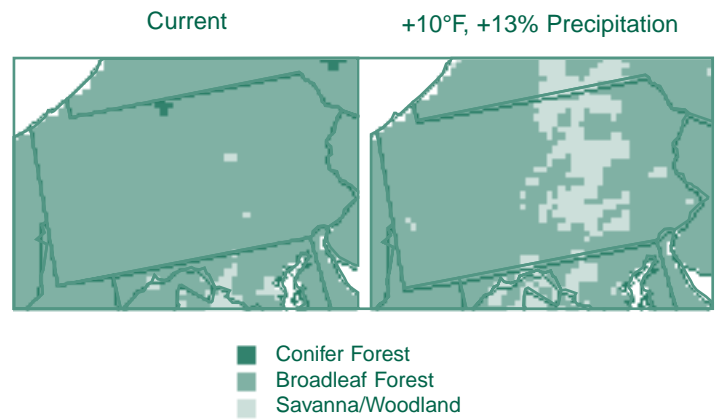
In Pennsylvania, agriculture is a \$3.8 billion annual industry, two-thirds of which comes from livestock, most of which is dairy. About 6% of the crop acreage is irrigated. The major crops in the state are corn and hay. Climate change could change crop yields very little or by as much as 39%, leading to changes in acres farmed and production. For example, hay yields could rise while production falls because of a decrease in hay acres farmed.

Forests

Trees and forests are adapted to specific climate conditions, and as climate warms, forests will change. These changes could include changes in species, 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 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 Pennsylvania could change little or decline by as much as 15-25%. However, the types of trees dominating Pennsylvania forests and woodlands are likely to change. The maple, beech, and birch forests found in northern Pennsylvania would retreat northward. Forest areas would become dominated by oak, ash, hickory, and pine, and the brilliant autumn foliage associated with maples would be diminished. In areas where richer soils are prevalent, southern pines could increase their range and density,

Changes In Forest Cover



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

and in areas with poorer soils, which are more common in Pennsylvania'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 Pennsylvania may change.

Ecosystems

Ecosystems in Pennsylvania consist of forests, woodlands, wetlands, peatland, and riparian habitats. The Two Mile Run wetlands in the Pocono Mountains are the largest undisturbed peatland ecosystem in Pennsylvania. This is also the site of the largest and healthiest native spruce forest in Pennsylvania. The peatlands are an important habitat for black bears, which use them for denning and feeding. Snowshoe hare, osprey, beaver, river otter, and waterfowl also live in the Two Mile Run wetlands area. Climate change could alter the range and location of these habitats, and fragmented land use patterns could impede migration of plants and animals.

Climate change could adversely affect ecosystems such as the Erie National Wildlife Refuge and French Creek, which flows for 117 miles through northwestern Pennsylvania. This area provides habitat for approximately 70 species of fish and 25 species of freshwater mussels. Many of the aquatic species in French Creek (for example, the clubshell mussel) are already endangered. The refuge system also provides important habitat for birds, including the threatened bald eagle.

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.

