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Climate Change And Indiana

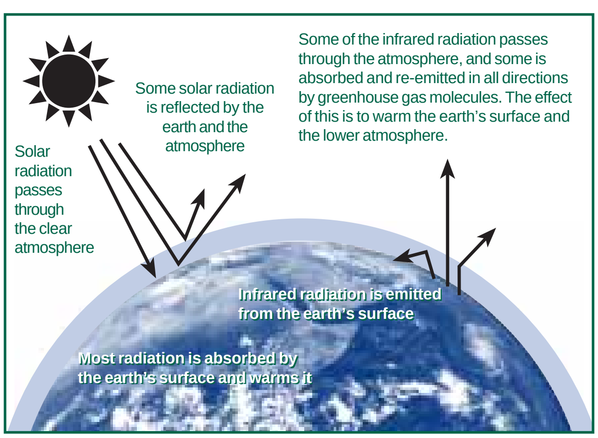
The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases — primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The heat-trapping property of these greenhouse gases is undisputed.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

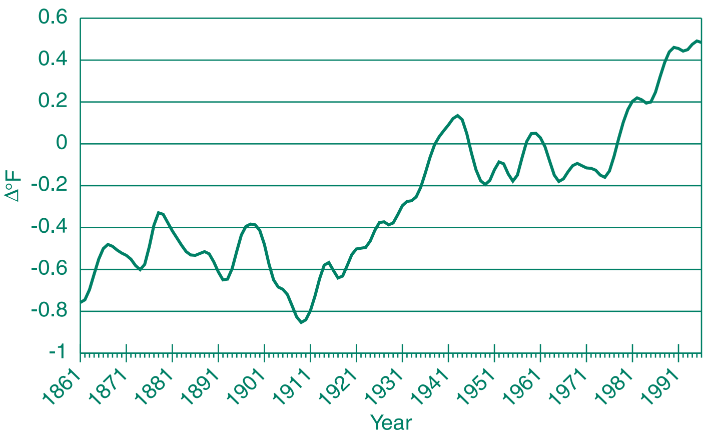
Although many greenhouse gases already are present in the atmosphere, oceans, and vegetation, their concentrations in the future will depend in part on present and future emissions. Estimating future emissions is difficult, because they will depend on demographic, economic, technological, policy, and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

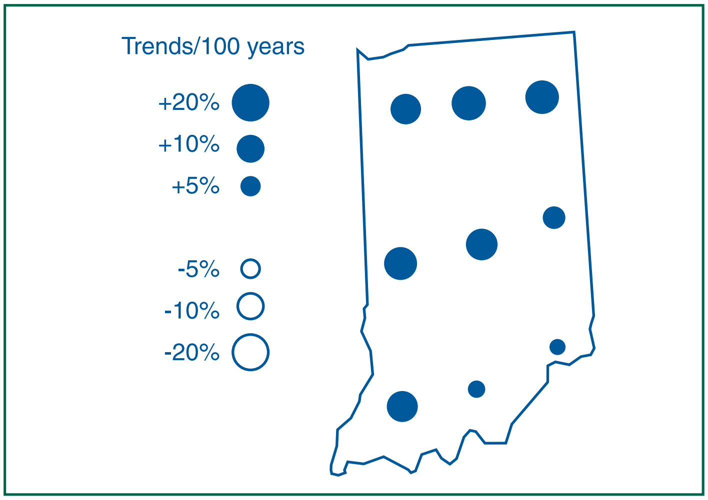
Calculations of regional climate change are much less reliable than global ones, and it is unclear whether regional climate will become more variable. The frequency and intensity of some extreme weather of critical importance to ecological systems (droughts, floods, frosts, cloudiness, the frequency 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 Bloomington, Indiana, has increased 1.8°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 Indiana 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 Indiana could increase by 2°F in summer (with a range of 1-4°F), 3°F in winter and spring (with a range of 1-6°F), and 4°F (with a range of 2-7°F) in fall. Precipitation is estimated to increase by 10% in winter and spring (with a range of 5-20%), 20% in fall (with a range of 10-40%), and 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 is expected to increase along with 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. Indiana, with its irregular, intense heat waves, could be susceptible.

One study projects that heat-related deaths in Indianapolis could increase by about 90% with a warming of 4°F, from about 35 to about 65 (although increased air conditioning use may not have been fully accounted for). This study also shows that winter-related deaths in Indianapolis could double with a warming of 2-3°F. 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 in the Midwest, with no other change in weather or emissions, could increase concentrations of ozone, a major component of smog, by as much as 8%. Perhaps more important, however, is that the area exceeding national health standards for ozone could increase. Currently, Gary is classified as a "severe" nonattainment area for ozone, and increased temperatures could increase ozone concentrations further. Ground-level ozone is associated with respiratory illnesses such as asthma, reduced lung function, and respiratory inflammation.

Infected individuals can bring malaria to places where it does not occur naturally. Also, some mosquitoes in Indiana can carry malaria, and others can carry St. Louis and eastern equine encephalitis, which can be lethal or cause neurological damage. If conditions become warmer and wetter, mosquito populations could increase, thus increasing the risk of transmission if these 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

Runoff in the state is largely determined by rainfall and to a lesser degree by spring snowmelt. Earlier snowmelt would result in higher streamflows in winter and spring. Lower streamflows, lake levels, and groundwater levels in the summer could reduce water availability for municipal, industrial, and agricultural uses, particularly in southern Indiana where streamflow is variable and groundwater supplies are not dependable. In the northern part of the state, groundwater withdrawals for crop irrigation have grown significantly. Lower groundwater levels in the summer, when water demand is highest, could increase competition between urban and agricultural uses. Higher summer temperatures and lower flows also could harm water quality by concentrating pollutant levels. This could increase water quality concerns in, for example, highly industrialized and urbanized areas, where improperly treated waste discharges have resulted in low dissolved oxygen and high levels of fecal coliform bacteria, heavy metals, and organic compounds such as polychlorinated biphenyls (PCBs).

Wetter conditions would increase streamflows and recharge aquifers, but could increase flooding. The Maumee River basin, and especially Fort Wayne, is vulnerable to major urban flood damage. During wet periods, the numerous lakes in northeastern Indiana are susceptible to shoreline damage. Higher rainfall also could increase levels of pesticides and fertilizers in runoff. About 70% of the land in Indiana is used for agriculture, and runoff containing fertilizers and pesticides can be problematic. These problems could be exacerbated by greater runoff and flooding.

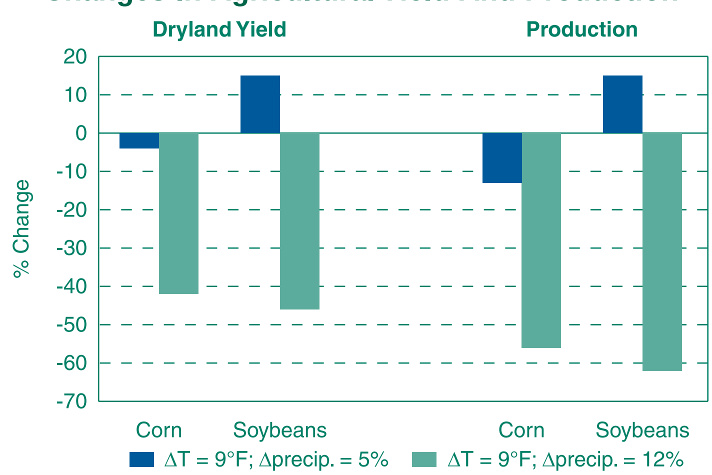
The southern shore of Lake Michigan is heavily industrialized in Indiana. In a warmer climate, increased temperature and higher evaporation could reduce freshwater inflows into the Great Lakes and lower lake levels (studies suggest a foot or more for a 4°F warming). Shorelines could be more susceptible to erosion damage from wind and rain, but flood damage could be reduced. Harbors and channels could require more dredging. Although shipping could be adversely affected by lower water levels in the channels connecting the lakes, reduced ice cover would lengthen the shipping season. Warmer water temperatures could alter lake water quality.

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 farmers

Changes In Agricultural Yield And Production



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

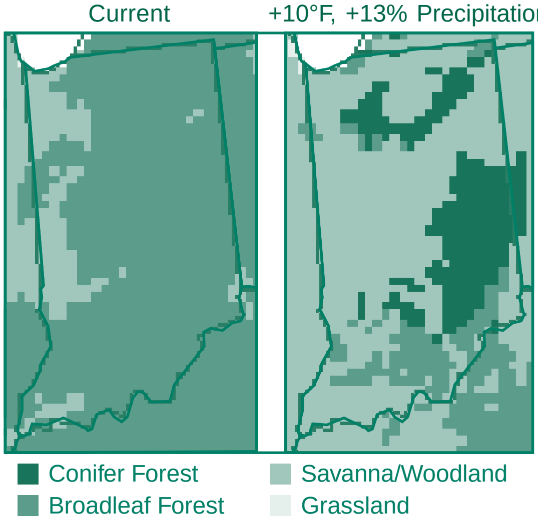
In Indiana, production agriculture is a $5 billion annual industry, 60% of which comes from crops. Very few of the farmed acres are irrigated. The major crops in the state are corn and soybeans. Corn yields could fall 4-42% as temperatures rise beyond the tolerance levels of the crop. Depending on how climate changes, soybean yields could fall by 46% or rise by 15%. Farmed acres could remain fairly constant, or they could decrease by as much as 15%.

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 Indiana could change little or decline by as much as 60-75%. However, the types of trees dominating those forests and woodlands are likely to change. Forested areas would be increasingly dominated by pine and scrub oaks, replacing many of the eastern hardwoods common throughout Indiana forests. 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 Indiana's forests, scrub oaks of little commercial value (e.g., post oak and blackjack oak) could increase their range. Decreases in soil moisture and on water supplies for irrigation could adversely affect urban and suburban forests, where the migration of species better adapted to new climate conditions would be impaired by fragmented forest landscapes.

Changes In Forest Cover



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

Ecosystems

The Indiana Dunes National Lakeshore, along Lake Michigan's shoreline, ranks third of all U.S. national parks in plant diversity, even though its acreage is less than 3% of that of the top two (Great Smoky Mountains and Grand Canyon). These dunes support some of the most extensive oak savannas remaining in the United States and are home to such rare animals as the plains pocket gopher, the blue spotted salamander, and several species of endangered butterflies, including one of the world's only populations of the Karner blue butterfly. The bottomland and flood plain forests, bald cypress swamps, and oak-dominated flatwoods of southwestern Indiana are known for their ecological richness. Fish Creek contains one of the most diverse assemblages of freshwater mussels and fish in the Great Lakes basin, and is the only place in the world where the white cat's paw pearly mussel and two other federally endangered mussels are found. The Wabash-Ohio lowlands natural system is on the Mississippi flyway. It is an especially productive breeding ground and an important stopover point for waterfowl, including wood ducks. Indiana is well-known for its extensive limestone cave systems, which support species such as caves salamanders, blind cavefish, blind crayfish, and the endangered Indiana bat. 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 9ºF during winter hibernation has been associated with a 42% increase in the rate of body mass loss).

Changes in climate threaten remaining wetlands, particularly for ecosystems that lie within the Great Lakes basin. Recent studies have shown that the largest hydrological impacts from warming temperatures will be in the southern portion of the basin. If runoff is reduced, wetland habitats that depend on inundation of freshwater from the lake could be adversely affected. An increase in climatic variability suggests that frequency and severity of wildfires could increase, which could affect already dry sites such as sand dune and oak savannah habitats. The small area and history of fire suppression in these ecosystems could increase their vulnerability. Wetlands play a major role in river basin hydrology and serve as important wildlife habitats. Changes in water levels brought about by a changing climate could dramatically alter the extent of these ecosystems and endanger resident flora and fauna. For example, warmer air temperatures could lead to reduced stream flow and warmer water temperatures, which would significantly impair reproduction of fish and other animals and favor the spread of exotic species that exhibit a high tolerance for extreme environmental 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.