EPA United States Environmental Protection Agency

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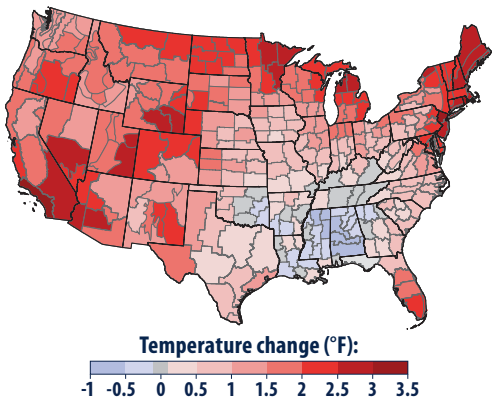
EPA 430-F-16-003

What Climate Change *Means for* Alabama

In the coming decades, **Alabama** will become warmer, and the state will probably experience more severe floods and drought. Unlike most of the nation, Alabama has not become warmer during the last 50 years. But soils have become drier, annual rainfall has increased in most of the state, more rain arrives in heavy downpours, and sea level is rising about one inch every eight years. Changing the climate is likely to increase damages from tropical storms, reduce crop yields, harm livestock, increase the number of unpleasantly hot days, and increase the risk of heat stroke and other heat-related illnesses.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree (F) during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others. While most of the earth warmed, natural cycles and sulfates in the air cooled Alabama. Sulfates are air pollutants that reflect sunlight back into space. Now sulfate emissions are declining, and the factors that once prevented the state from warming are unlikely to persist.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has warmed about one degree during the last 80 years. Warming is causing snow to melt earlier in spring, and mountain glaciers are retreating. Even the great ice sheets on Greenland and Antarctica are shrinking. Thus the sea is rising at an increasing rate.



Changing temperatures in the last century. While most of the nation has warmed, Alabama and a few other states have cooled. Source: EPA, Climate Change Indicators in the United States.

Rising Seas and Retreating Shores

Sea level is rising more rapidly in Alabama than most coastal areas because the land is sinking. If the oceans and atmosphere continue to warm, sea level along the Alabama coast is likely to rise eighteen inches to four feet in the next century. Rising sea level submerges wetlands and dry land, erodes beaches, and exacerbates coastal flooding.

Coastal Storms, Homes, and Infrastructure

Tropical storms and hurricanes have become more intense during the past 20 years. Although warming oceans provide these storms with more potential energy, scientists are not sure whether the recent intensification reflects a long-term trend. Nevertheless, hurricane wind speeds and rainfall rates are likely to increase as the climate continues to warm.

Whether or not storms become more intense, coastal homes and infrastructure will flood more often as sea level rises, because storm surges will become higher as well. Rising sea level is likely to increase flood insurance rates, while more frequent storms could increase the deductible for wind damage in homeowner insurance policies. Many cities, roads, railways, ports, airports, and oil and gas facilities along the Gulf Coast are vulnerable to the combined impacts of storms and sea level rise. People may move from vulnerable coastal communities and stress the infrastructure of the communities that receive them.

Hurricane Katrina's storm surge destroyed homes and roads on Dauphin Island in 2005. Credit: FEMA.

Precipitation and Water Resources

Annual precipitation in Alabama has increased 5 to 10 percent since the first half of the 20th century. Although rainfall during spring is likely to increase during the next 40 to 50 years, the total amount of water running off into rivers or recharging ground water is likely to decline 2.5 to 5 percent, as increased evaporation offsets the greater rainfall. Droughts are likely to be more severe, because periods without rain may be longer and very hot days will be more frequent.

Flooding, River Transportation, and Hydroelectric Power

Flooding is becoming more severe in the Southeast. Since 1958, the amount of precipitation during heavy rainstorms has increased by 27 percent in the Southeast, and the trend toward increasingly heavy rainstorms is likely to continue. While some rivers such as the Tennessee have dams to help prevent flooding, other rivers either have no dams or have dams with too little capacity to significantly reduce flooding. Heavy rains have caused the Pea River to flood Elba several times, and the Alabama River flooded two thousand homes in Selma and Montgomery during 1990.

Droughts create a different set of challenges. When reservoirs release water for navigation along the Tennessee or Black Warrior rivers, too little water may be available for lake recreation or hydropower. Low flows from drought occasionally limit navigation along the Alabama River. During severe droughts in the Mississippi River's watershed, however, navigation can potentially increase on the Tennessee-Tombigbee Waterway, which provides an alternative route to the Gulf of Mexico.

Flooding of a small stream in June 2014 destroyed this roadbed in Foley. Credit: Patsy Lynch, FEMA.

Droughts also affect the amount of electricity that Alabama Power and the Tennessee Valley Authority (TVA) can produce from their hydroelectric dams, which account for about 8 percent of the electricity produced in the state. During the 2007 drought, total production from the TVA's hydroelectric plants fell by more than 30 percent, which forced the TVA to meet customer demand by using more expensive fuel-burning power plants.

Agriculture and Forest Resources

Changing the climate will have both harmful and beneficial effects on farming. Seventy years from now, Alabama is likely to have 30 to 60 days per year with temperatures above 95°F, compared with about 15 days today. Even during the next few decades, hotter summers are likely to reduce yields of corn. But higher concentrations of atmospheric carbon dioxide increase crop yields, and that fertilizing effect is likely to offset the harmful effects of heat on soybeans, cotton, wheat, and peanuts—if adequate water is available. More severe droughts, however, could cause crop failures. Higher temperatures are also likely to reduce livestock productivity, because heat stress disrupts the animals' metabolism.

Higher temperatures and changes in rainfall are unlikely to substantially reduce forest cover in Alabama, although the composition of trees in the forests may change. More droughts would reduce forest productivity, and climate change is also likely to increase the damage from insects and disease. But longer growing seasons and increased carbon dioxide concentrations could more than offset the losses from those factors. Forests cover more than two-thirds of the state. Oak, hickory, and white pine trees tend to be most common in the northern part of the state, while loblolly pines are more common in the southern forests. As the climate warms, forests in southern Alabama are likely to have more white pines and oaks, and fewer loblolly pines.

Human Health

Hot days can be unhealthy—even dangerous. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor. High air temperatures can cause heat stroke and dehydration and affect people's cardiovascular and nervous systems. Warmer air can also increase the formation of ground-level ozone, a key component of smog. Ozone has a variety of health effects, aggravates lung diseases such as asthma, and increases the risk of premature death from heart or lung disease. EPA and the Alabama Department of Environmental Management have been working to reduce ozone concentrations. As the climate changes, continued progress toward clean air will become more difficult.

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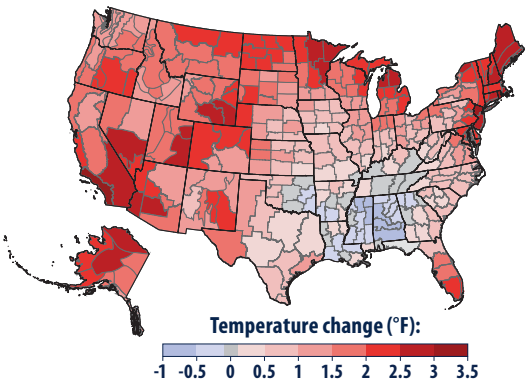
What Climate Change *Means for* Alaska

Alaska's climate is changing. Over the past 60 years, most of the state has warmed three degrees (F) on average and six degrees during winter. As a result, Arctic sea ice is retreating, shores are eroding, glaciers are shrinking, permafrost is thawing, and insect outbreaks and wildfires are becoming more common. In the coming decades, these effects are likely to accelerate.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has warmed about one degree during the last 80 years. Warming is causing snow to melt earlier in spring, and mountain glaciers are retreating. Even the great ice sheets on Greenland and Antarctica are shrinking. Thus the sea is rising at an increasing rate.



Rising temperatures in the last century. Alaska has warmed more than most of the United States. Source: EPA, Climate Change Indicators in the United States.

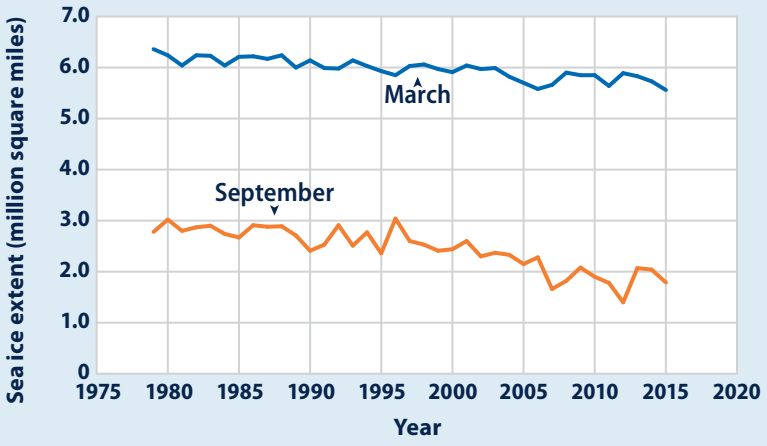
Glaciers and Sea Ice

Rising temperatures have reduced the area of land covered by glaciers and water covered by sea ice, and will continue to do so. Glaciers have retreated dramatically during the last century in southeast Alaska, in the Alaska Range, and along the south central coast. In Glacier Bay National Park, for example, Muir Glacier has retreated more than 31 miles since it was first observed in the late 19th century.

Toboggan Glacier near Prince William Sound in August 1905 (top) and August 2008 (bottom). The glacier has thinned by nearly 500 feet and retreated by about 0.3 miles. Credits: Sidney Paige, USGS (top); Bruce F. Molnia, USGS (bottom).

Sea ice covers almost all of the Arctic Ocean in winter, and, until recently, ice covered most of this ocean during summer as well. During the last few decades, the ice has retreated. The area covered by ice at the end of summer 2012 was nearly 50 percent smaller than the historical average. The ice is likely to melt entirely most summers within a few decades.

Sea ice provides habitat for polar bears, walruses, and other animals; hunting grounds for Alaska Native communities; and a buffer against storm damage. But all of that is threatened by rising temperatures.



Average Arctic sea ice coverage has declined since 1979. Source: EPA.

Permafrost, Infrastructure, and Energy Production

Permafrost soil lies beneath about 80 percent of Alaska's land surface. Much of this land could shift or sink if rising temperatures thaw the permafrost. That can damage pipelines, buildings, roads and other transportation infrastructure, water supplies, and sewer systems. Thawing permafrost is likely to increase the cost of maintaining public infrastructure by 10 to 20 percent in the next 20 years.

Energy production depends on vehicles that must drive on frozen tundra and ice roadways to support oil and gas exploration activities in areas without conventional highways. Because of melting, the travel season has shrunk from more than 200 days in 1970 to around 100 days in 2002. Energy production and transportation could benefit from warming in other ways, though. For example, less sea ice could allow more ship travel and oil and gas exploration in the Arctic Ocean.

Fisheries and Wildlife

Increasing ocean acidity threatens fishing, which is Alaska's third largest industry and a key source of food for many native communities. Higher acidity harms shellfish and certain types of plankton that depend on minerals in the water to build their skeletons and shells. Less plankton means less food available to support populations of salmon and other fish.

Climate change is likely to affect Alaska's animal biodiversity. Declining Arctic sea ice can harm polar bear populations, by reducing their ability to hunting seals. Polar bear, walrus, and seal populations are expected to decline further, due to loss of snow and ice cover—especially walrus, which bear and nurse their calves on summer sea ice. Higher evaporation, permafrost thaw, and other factors have decreased the area of lakes in the past half-century, particularly in southern Alaska. Continued loss of lake and wetland areas in Alaska is likely to reduce habitat for the millions of migratory birds that rely on these areas for breeding.

Forests and Tundra

Rising temperatures in interior Alaska have increased the length of the growing season by 45 percent during the last century, and the growing season will continue to lengthen. While a longer growing season could boost agriculture and plant growth, other changes could harm Alaska's forest and tundra plants. Wetland drying; warmer, drier summers; and more frequent thunderstorms have led to more large forest and tundra fires in the last 10 years than in any decade since recordkeeping began in the 1940s. The number of acres burned each year is likely to double by 2050 and triple by 2100.

"Drunken forests" occur when the permafrost under trees thaws, causing them to lean. Credit: NOAA.

In south-central Alaska, during the 1990s, milder winters and warmer temperatures increased the winter survival of the spruce bark beetle and allowed it to complete its life cycle in one year instead of the normal two years. Nine years of drought stress weakened spruce trees' normal defense mechanisms against the beetles. This combination of ecological factors—all related to climate change—led to the largest reported outbreak of spruce bark beetles in the world, which killed many trees.

Alaska Native Communities

Many of Alaska's native communities are vulnerable to climate change, because their travel, hunting, food, and infrastructure depend on a landscape that is frozen for at least part of the year. The loss of sea ice restricts the subsistence lifestyle of groups such as the Yup'ik, Iñupiat, and Inuit by limiting hunting grounds and reducing habitat for traditional food sources such as walrus. Erosion and thawing permafrost are forcing some coastal communities to consider relocating to more stable land. Jobs in the general economy are scarce in these villages, so threats to the resources on which Alaska Natives rely make them particularly vulnerable to the impacts of climate change.

Health and Vulnerable People

Climate change is likely to amplify some threats to health in Alaska. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor.

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What Climate Change *Means for* Arizona

Arizona's climate is changing. The state has warmed about two degrees (F) in the last century. Throughout the southwestern United States, heat waves are becoming more common, and snow is melting earlier in spring. In the coming decades, changing the climate is likely to decrease the flow of water in the Colorado River, threaten the health of livestock, increase the frequency and intensity of wildfires, and convert some rangelands to desert.

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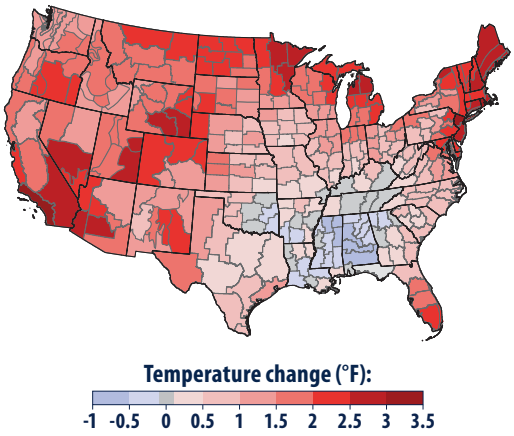
Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has warmed about one degree during the last 80 years. Warming is causing snow to melt earlier in spring.



Rising temperatures in the last century. The last decade was the warmest on record in the Southwest. Source: EPA, Climate Change Indicators in the United States.

Snowpack

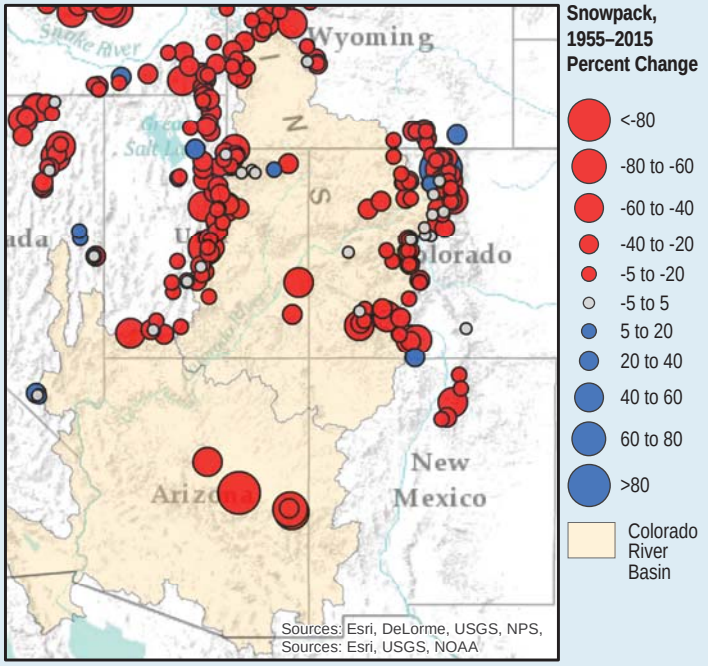
As the climate warms, less precipitation falls as snow, and more snow melts during the winter. That decreases snowpack—the amount of snow that accumulates over the winter. Since the 1950s, the snowpack has been decreasing in Arizona, as well as most mountainous areas in the Colorado River Basin. Diminishing snowpack can decrease water supplies and shorten the season for skiing and other forms of winter tourism and recreation.

Water Availability

The changing climate is likely to increase the need for water but reduce the supply. Rising temperatures increase the rate at which water evaporates (or transpires) into the air from soils, plants, and surface waters. Irrigated farmland would thus need more water. But less water is likely to be available, because precipitation is unlikely to increase enough to make up for the additional water lost to evaporation. Annual precipitation has decreased in Arizona during the last century, and it may continue to decrease. So soils are likely to be drier, and periods without rain are likely to become longer, making droughts more severe.

Lake Mead viewed from Hoover Dam in 2009. The white area reveals the drop in water levels over the last decade, during which drought has reduced flows of the Colorado River into the lake. Low lake levels threaten water supplies and hydroelectric power. © Chris Lamie; used by permission.

The decline in snowpack could further limit the supply of water for some purposes. Mountain snowpacks are natural reservoirs. They collect the snow that falls during winter and release water when the snow melts during spring and summer. Over the past 50 years, the snowpack throughout the Colorado River Basin has been melting earlier in the year (see map on back page). Dams capture most meltwater and retain it for use later in the year. But upstream of these reservoirs, less water is available during droughts for ecosystems, fish, water-based recreation, and landowners who draw water directly from a flowing river.



Trends in April snowpack in the Colorado River Basin, 1955–2013. Snowpack has decreased at most sites in the basin and all sites in Arizona. Source: EPA.

Agriculture

Increasing droughts and higher temperatures are likely to affect Arizona's top agricultural products: cattle, dairy, and vegetables. Hot temperatures threaten cows' health and cause them to eat less, grow more slowly, and produce less milk. Livestock operations could also be impaired by fire, the lack of water, and changes in the landscape from grassland to woody shrubs more typical of a desert. Reduced availability of water would also create challenges for irrigated farms, which account for two-thirds of the water used in the state.

Wildfires and Changing Landscapes

Higher temperatures and drought are likely to increase the severity, frequency, and extent of wildfires, which could harm property, livelihoods, and human health. On average, more than 2 percent of the land in Arizona has burned per decade since 1984. Wildfire smoke can reduce air quality and increase medical visits for chest pains, respiratory problems, and heart problems.

The combination of more fires and drier conditions may expand deserts and otherwise change parts of Arizona's landscape. Many plants and animals living in arid lands are already near the limits of what they can tolerate. A warmer and drier climate would generally extend the Sonoran and Chihuahuan deserts to higher elevations and expand their geographic ranges. In some cases, native vegetation may persist and delay or prevent expansion of the desert. In other cases, fires or livestock grazing may accelerate the conversion of grassland to desert in response to a changing climate. For similar reasons, some forests may change to desert or grassland.

In 2011, Arizona experienced the largest wildfire in the state's recorded history, the Wallow Fire (pictured here). It burned more than half a million acres. Two years later, the Yarnell Hill Fire became the state's deadliest wildfire when it took the lives of 19 firefighters. Credit: Eastern Arizona Incident Management Team.

Pests

Warmer and drier conditions make forests more susceptible to pests. Drought reduces the ability of trees to mount a defense against attacks from pests such as bark beetles, which have infested 100,000 acres in Arizona. Temperature controls the life cycle and winter mortality rates of many pests. With higher winter temperatures, some pests can persist year-round, and new pests and diseases may become established.

Human Health

Hot days can be unhealthy—even dangerous. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor. High air temperatures can cause heat stroke and dehydration, and affect people's cardiovascular, respiratory, and nervous systems. Higher temperatures are amplified in urban settings where paved and other surfaces tend to store heat. Construction crews may have to increasingly operate on altered time schedules to avoid the heat of the day.

Rising temperatures can increase the formation of ground-level ozone, a key component of smog. Ozone has a variety of health effects, aggravates lung diseases such as asthma, and increases the risk of premature death from heart or lung disease. EPA and the Arizona Department of Environmental Quality have been working to reduce ozone concentrations. As the climate changes, continued progress toward clean air will be more difficult.

Tribal Communities

Changing the climate threatens natural resources and public health of tribal communities. Rising temperatures and increasing drought are likely to decrease the availability of certain fish, game, and wild plants on which the Navajo and other tribes have relied for generations. Water may be less available for domestic consumption, especially for those who are not served by either municipal systems or reliable wells, which includes about 30 percent of the people on the Navajo Nation, who must haul water to meet daily needs. Recurring drought and rising temperatures may degrade the land itself. In the Navajo Nation, for example, the Great Falls Dune Field has advanced almost a mile in the last 60 years, threatening roads, homes, and grazing areas. Extreme heat may also create health problems for those without electricity, including about 40 percent of the people on the Navajo reservation.

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What Climate Change *Means for* Arkansas

In the coming decades, **Arkansas** will become warmer, and the state will probably experience more severe floods and drought. Unlike most of the nation, Arkansas has not become warmer during the last 50 to 100 years. But annual rainfall has increased in much of the state, and more rain arrives in heavy downpours. Changing the climate is likely to increase damage from storms, reduce crop yields, harm livestock, increase the number of unpleasantly hot days, and increase the risk of heat stroke and other heat-related illnesses.

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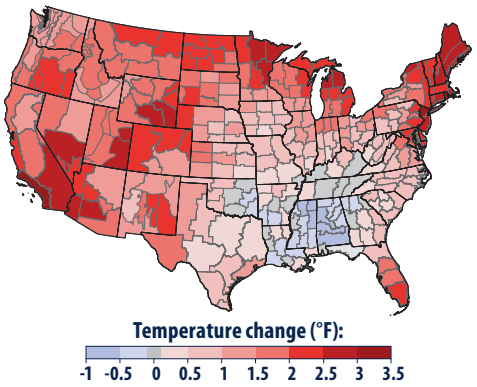
Natural cycles and sulfates in the air prevented much of Arkansas from warming during the last century. Sulfates are air pollutants that reflect sunlight back into space. Now sulfate emissions are declining, and the factors that once prevented Arkansas from warming are unlikely to persist.



Rising temperatures in the last century. Arkansas has warmed less than most of the United States, and some parts have cooled. Source: EPA, Climate Change Indicators in the United States.

Heavy Precipitation and Flooding

Changing the climate is likely to increase inland flooding, particularly in communities along major rivers. Since 1958, the amount of precipitation falling during heavy rainstorms has increased by 27 percent in the Southeast, and the trend toward increasingly heavy rainstorms is likely to continue. The risk of flooding along the Mississippi River may also increase because the Midwest, which drains into that river, is also becoming wetter. Both annual rainfall and stream flows in the Midwest are increasing, and that trend is likely to continue. The U.S. Army Corps of Engineers manages dams and reservoirs to control flooding, but these dams cannot prevent all floods.

Floodwaters overwhelmed Bald Knob National Wildlife Refuge after the White River overtopped a levee during the historic floods of May 2011. Credit: U.S. Fish and Wildlife Service.

Drought and Water Resources

Although climate change is likely to increase the risk of flooding, droughts are also likely to become more severe. Average rainfall is likely to decrease during the 21st century, especially in spring and summer. In addition, rising temperatures increase evaporation, which dries the soil and decreases the amount of rain that runs off into rivers. The total amount of water running off into rivers or recharging ground water each year is likely to decline by 5 percent or more. Droughts are likely to be more severe, because periods without rain will be longer and very hot days will be more frequent.

Droughts pose challenges for water management and river transportation. If the spring is unexpectedly dry, reservoirs may have too little water during summer. During droughts, the Corps of Engineers releases water from dams to maintain navigation on the Arkansas River, where barges carry freight worth more than $4 billion during a typical year. The Corps of Engineers tries to keep channels at least nine feet deep, because lower river levels can force barges to carry smaller loads, leading to increased transportation costs. If droughts become more severe, the Corps of Engineers will face this type of problem more often. Droughts can also restrict shipping on the Mississippi River. The drought of 2012 narrowed navigation channels, forced lock closures, and caused dozens of barges to run aground on the river. The resulting impact on navigation cost the region more than $275 million.

Aquatic Ecosystems

Changing the climate can harm aquatic ecosystems. Warmer water lowers the level of dissolved oxygen in surface water, which can severely limit fish populations. Because fish cannot regulate their body temperatures, warmer water can make a stream uninhabitable for fish that require cooler water. Warmer temperatures can also increase the frequency of algal blooms, which can be toxic and further reduce dissolved oxygen. Summer droughts may amplify these effects, while periods of extreme rainfall can increase the impacts of pollution on streams.

Agriculture

Changing the atmosphere will have both harmful and beneficial effects on farming. Seventy years from now, Arkansas is likely to have 30 to 60 days per year with temperatures above 95°F, compared with 15 to 30 days today. Hot weather causes cows to eat less and grow more slowly, and it can threaten their health. Even during the next few decades, hotter summers are likely to reduce yields of corn and rice. But the higher concentrations of atmospheric carbon dioxide wil increase crop yields, and that fertilizing effect is likely to offset the harmful effects of heat on soybeans and cotton, assuming that adequate water is available. On farms without irrigation, however, increasingly severe droughts could cause more crop failures.

A corn crop in Arkansas is stunted and sparse due to drought conditions. Credit: Tim McCabe, USDA Natural Resources Conservation Service.

Forests

Higher temperatures and changes in rainfall are unlikely to substantially reduce forest cover in Arkansas, although the composition of those forests may change. More droughts would reduce forest productivity, and climate change is also likely to increase the damage from insects and diseases. But longer growing seasons and increased carbon dioxide concentrations could more than offset the losses from those factors. In northern Arkansas, forests are likely to have more pine and fewer hickory trees.

Human Health

Hot days can be unhealthy—even dangerous. High air temperatures can cause heat stroke and dehydration, and affect people's cardiovascular and nervous systems. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor. Warmer temperatures can also increase the formation of ground-level ozone, a key component of smog. Ozone has a variety of health effects, aggravates lung diseases such as asthma, and increases the risk of premature death from heart or lung disease. EPA and the Arkansas Department of Environmental Quality have been working to reduce ozone concentrations. As the climate changes, continued progress toward clean air will become more difficult.

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What Climate Change *Means for* California

California's climate is changing. Southern California has warmed about three degrees (F) in the last century and all of the state is becoming warmer. Heat waves are becoming more common, snow is melting earlier in spring—and in southern California, less rain is falling as well. In the coming decades, the changing climate is likely to further decrease the supply of water, increase the risk of wildfires, and threaten coastal development and ecosystems.

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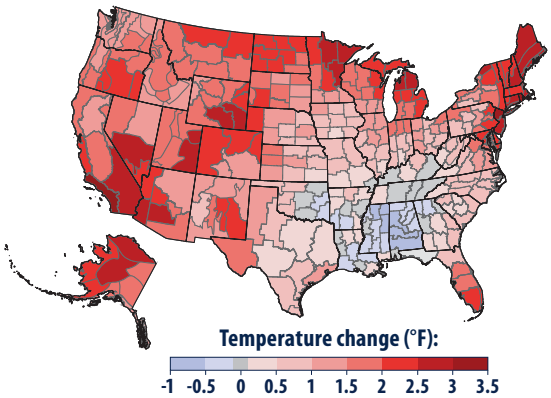


Rising temperatures in the last century. Southern California has warmed more than the rest of the state. Source: EPA, Climate Change Indicators in the United States.

Snowpack

As the climate warms, less precipitation falls as snow, and more snow melts during the winter. That decreases snowpack—the amount of snow that accumulates over the winter. Since the 1950s, the snowpack has declined in California and the nearby states that drain into the Colorado River.

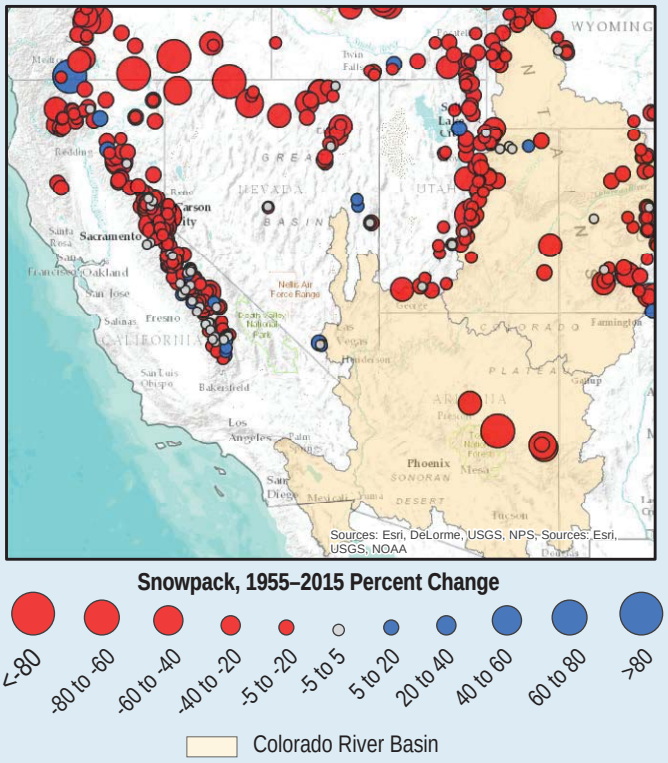
Diminishing snowpack can shorten the season for skiing and other forms of winter tourism and recreation. The tree line may shift, as mountain hemlock and other high-altitude trees become able to grow at higher elevations. A higher tree line would decrease the extent of alpine tundra ecosystems, which could threaten some species.

Water Availability

The changing climate is likely to increase the need for water but reduce the supply. Rising temperatures increase the rate at which water evaporates into the air from soils and surface waters. Rising temperatures also increase the rate at which plants transpire water into the air to keep cool, so irrigated farmland would need more water. But less water is likely to be available, because precipitation is unlikely to increase as much as evaporation. Soils are likely to be drier, and periods without rain are likely to become longer, making droughts more severe. Increasing temperatures and declining rainfall in nearby states have reduced the flow of water in the Colorado River, a key source of irrigation water in southern California.

This 2014 photo shows the dramatic effect of a multi-year drought on Lake Oroville. Credit: Kelly Grow, California Department of Water Resources.

The decline in snowpack could further limit the supply of water for some purposes. Mountain snowpacks are natural reservoirs. They collect the snow that falls during winter and release water when the snow melts during spring and summer. Over the past 50 years, snowpack has been melting earlier in the year. Dams capture most meltwater and retain it for use later in the year. But upstream of these reservoirs, less water is available during droughts for ecosystems, fish, water-based recreation, and landowners who draw water directly from a flowing river.



Trends in April snowpack in California and the Colorado River Basin, 1955–2013. Snowpack has decreased at most monitoring sites in California and the basin. Source: EPA.

Agriculture

About 90 percent of crops harvested in California are grown on farms that are entirely irrigated, so a sustained decrease in the amount of water available for irrigation would force farmers to either reduce the acreage under cultivation or shift away from the most water-intensive crops. But even if sufficient water is available, rising temperatures could transform California's agriculture. Fruit trees and grape vines need a certain number of "chilling hours" during which temperatures are between 32° and 50°F in the winter before they can flower. Suitable areas for growing wine grapes are likely to shift north, and the area capable of consistently producing grapes for the highest-quality wines is likely to shrink by more than 50 percent during the next 75 years. Chilling will be insufficient in much of California for the types of fruit trees found in the state today. The yields of most grain crops currently grown in the state are likely to decline as well. Livestock may also be affected: higher temperatures cause cows to eat less, grow more slowly, and produce less milk, and in extreme cases, it may threaten their health.

Warming and drought threaten economically vital California crops, such as grapes. Credit: Caitlyn Kennedy, NOAA Climate.gov.

Wildfires and Changing Landscapes

Higher temperatures and drought are likely to increase the severity, frequency, and extent of wildfires, which could harm property, livelihoods, and human health. On average, 4 percent of the land in California has burned per decade since 1984. In 2003, the Old, Grand Prix, and Padua wildfires destroyed 800 homes in southern California, forced 100,000 residents to be evacuated, and cost $1.3 billion. Wildfire smoke can reduce air quality and increase medical visits for chest pains, respiratory problems, and heart problems.

The combination of more fires and drier conditions may expand deserts and otherwise change parts of California's landscape. Many plants and animals living in arid lands are already near the limits of what they can tolerate. A warmer and drier climate would generally expand the geographic ranges of the Sonoran, Mojave, and Great Basin deserts. In some cases, native vegetation may persist and delay or prevent expansion of the desert. In other cases, fires or livestock grazing may accelerate the conversion of grassland to desert in response to a changing climate. For similar reasons, some forests may change to desert or grassland.

Human Health

Hot days can be unhealthy—even dangerous. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor. High air temperatures can cause heat stroke and dehydration, and affect people's cardiovascular, respiratory, and nervous systems. Higher temperatures are amplified in urban settings where paved and other surfaces tend to store heat. Warming can also increase the formation of ground-level ozone, a component of smog that can contribute to respiratory problems. EPA and the California Air Resources Board have been working to reduce ozone concentrations. As the climate changes, continued progress toward clean air will be more difficult.

Sea Level Rise

Sea level is likely to rise between one and four feet in the next century. Even a 16-inch rise could threaten coastal highways, bridges, and the San Francisco and Oakland airports. A rise of three feet would increase the number of Californians living in places that are flooded by a 100-year storm from about 250,000 today to about 400,000. Along some ocean shores, homes will fall into the water as beaches, bluffs, and cliffs erode; but along shores where seawalls protect shorefront homes from erosion, beaches may erode up to the seawall and then vanish. The sea could also submerge wetlands in San Francisco Bay and other estuaries, which would harm local fisheries and potentially remove key intertidal feeding habitat for migratory birds.

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EPA United States Environmental Protection Agency

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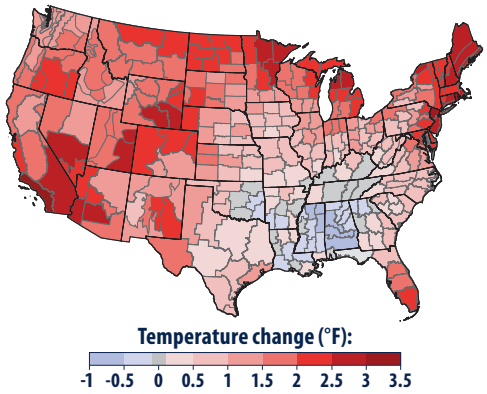
What Climate Change Means for Colorado

Colorado's climate is changing. Most of the state has warmed one or two degrees (F) in the last century. Throughout the western United States, heat waves are becoming more common, snow is melting earlier in spring, and less water flows through the Colorado River. Rising temperatures and recent droughts in the region have killed many trees by drying out soils, increasing the risk of forest fires, or enabling outbreaks of forest insects. In the coming decades, the changing climate is likely to decrease water availability and agricultural yields in Colorado, and further increase the risk of wildfires.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has warmed about one degree during the last 80 years. Warming is causing snow to melt earlier in spring.



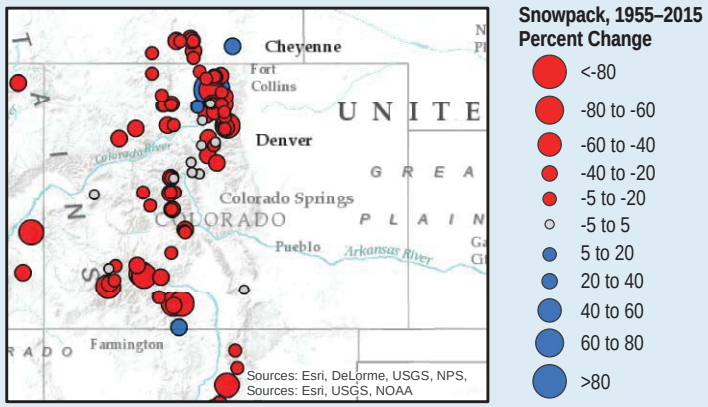
Rising temperatures in the last century. The last decade was the warmest on record throughout the West. Source: EPA, Climate Change Indicators in the United States.

Snowpack

Changes in temperature and precipitation are affecting snowpack—the amount of snow that accumulates on the ground. In most of the West, snowpack has decreased since the 1950s, due to earlier melting and less precipitation falling as snow. The amount of snowpack measured in April has declined by 20 to 60 percent at most monitoring sites in Colorado.

Diminishing snowpack can shorten the season for skiing and other forms of winter tourism and recreation. It also enables subalpine fir and other high-altitude trees to grow at higher elevations. The upward movement of the tree line will shrink the extent of alpine tundra and fragment these ecosystems, possibly causing the loss of some species.

Mount Evans in late August with Summit Lake in the foreground. During the winter, the mountain is covered by snowpack, which melts during spring and summer. The water runs off the mountain into streams that eventually flow into the South Platte River. These streams are an important part of the water supply for cities and towns along the Front Range. By August, little of the snowpack remains, as shown in the photo. As climate warms, even less snow will remain at this time of year. Credit: Boilerinbtown, Creative Commons.



Trends in April snowpack in Colorado, 1955–2013. The snowpack has declined at most monitoring sites in Colorado. Source: EPA.

Water Availability

Throughout the West, much of the water needed for agriculture, public supplies, and other uses comes from mountain snowpack, which melts in spring and summer and runs off into rivers and fills reservoirs. Over the past 50 years, snow has been melting earlier in the year, and more late-winter precipitation has been falling as rain instead of snow. Thus, water drains from the mountains earlier in the year. In many cases, dams capture the meltwater and retain it for use later in the year. But upstream of these dams, less water is available during droughts for ecosystems, fish, water-based recreation, and landowners who draw water directly from a flowing river.

Rising temperatures also increase the rate at which water evaporates (or transpires) into the air from soils and plants. Unless rainfall increases to the same extent as evaporation, soils become drier. As a result, the soil retains more water when it rains, and thus less water runs off into rivers, streams, and reservoirs. During the last few decades, soils have become drier in most of the state, especially during summer. In the decades to come, rainfall during summer is more likely to decrease than increase in Colorado, and periods without rain are likely to become longer. All of these factors would tend to make droughts more severe in the future.

Agriculture

Changing the climate is likely to have both positive and negative effects on Colorado's farms and ranches. Livestock and field crops in the eastern part of the state rely primarily on ground water pumped from the High Plains Aquifer, which is becoming depleted. About 20 percent of crop land in eastern Colorado is irrigated. Higher evaporation rates will increase irrigation demands and reduce natural recharge of the aquifer, further lowering the water table. Reduced water availability will force some farms to switch from irrigation to dry land farming, which typically cuts yields in half. Increasingly severe heat waves would harm livestock. Even where ample water is available, higher temperatures would reduce yields of corn.

Shorter winters are likely to reduce yields of winter wheat. Colorado is currently the fourth largest grower of winter wheat, which is an important source of food for livestock. Increased concentrations of carbon dioxide, however, may increase yields of wheat enough to offset the impact of higher temperatures. Warmer and shorter winters may allow for a longer growing season, which could allow two crops per year instead of one in some instances.

Wildfires

Higher temperatures and drought are likely to increase the severity, frequency, and extent of wildfires in Colorado, which could harm property, livelihoods, and human health. In 2013, the Black Forest Fire burned 14,000 acres and destroyed over 500 homes. Wildfire smoke can reduce air quality and increase medical visits for chest pains, respiratory problems, and heart problems. The size and number of western forest fires have increased substantially since 1985.

In 2013, Colorado experienced the most destructive wildfire (the Black Forest Fire, shown here) and the second-largest wildfire (the West Fork Fire Complex) in the state's recorded history. Credit: National Wildfire Coordinating Group.

Pests

Warmer, drier conditions also make forests more susceptible to pests. Temperature controls the life cycle and winter mortality rates of pests such as the mountain pine beetle. With higher winter temperatures, some pests can persist year-round, and new pests and diseases may become established. Drought also reduces the ability of trees to mount a defense against attacks from beetles and other pests. A mountain pine beetle outbreak in 2006 covered nearly half of Colorado's forests and killed nearly five million lodgepole pines.

In the northern Williams Range Mountains, beetles have killed more than 80 percent of mature lodgepole pines over many square kilometers. Credit: USGS.

Human Health

Extreme temperatures and heat events can cause heat stroke and dehydration, and affect people's cardiovascular, respiratory, and nervous systems. Higher temperatures are amplified in urban settings where paved and other surfaces tend to store heat. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor.

Rising temperatures also increase the formation of ground-level ozone, a key component of smog. Ozone has a variety of health effects, aggravates lung diseases such as asthma, and increases the risk of premature death from heart or lung disease. EPA and the Colorado Department of Public Health and Environment have been working to reduce ozone concentrations. As the climate changes, continued progress toward clean air will be more difficult.

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United States Environmental Protection Agency

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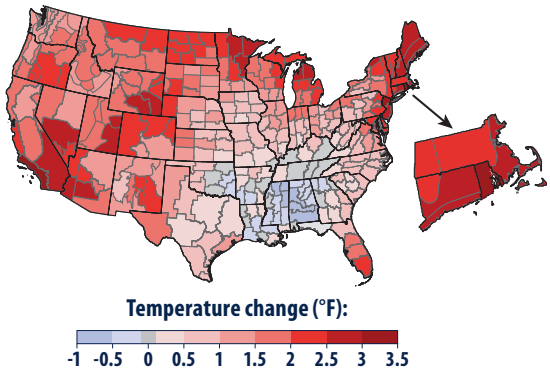
What Climate Change *Means for* Connecticut

Connecticut's climate is changing. The state has warmed two to three degrees (F) in the last century. Throughout the northeastern United States, spring is arriving earlier and bringing more precipitation, heavy rainstorms are more frequent, and summers are hotter and drier. Sea level is rising, and severe storms increasingly cause floods that damage property and infrastructure. In the coming decades, changing the climate is likely to increase flooding, harm ecosystems, disrupt farming, and increase some risks to human health.

Our climate is changing because the earth is warming. Since the late 1700s, people have increased the amount of carbon dioxide in the air by 40 percent. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has warmed about one degree during the last 80 years. Warming is causing snow to melt earlier in spring, and mountain glaciers are retreating. Even the great ice sheets on Greenland and Antarctica are shrinking. Thus the sea is rising at an increasing rate.



Rising temperatures in the last century. Connecticut has warmed twice as much as the rest of the contiguous 48 states. Source: EPA, Climate Change Indicators in the United States.

Increasing Temperature and Changing Precipitation Patterns

Rising temperatures and shifting rainfall patterns are likely to increase the intensity of both floods and droughts. Average annual precipitation in the Northeast increased 10 percent from 1895 to 2011, and precipitation from extremely heavy storms has increased 70 percent since 1958. During the next century, average annual precipitation and the frequency of heavy downpours are likely to keep rising. Average precipitation is likely to increase during winter and spring, but not change significantly during summer and fall. Rising temperatures will melt snow earlier in spring and increase evaporation, and thereby dry the soil during summer and fall. So flooding is likely to be worse during winter and spring, and droughts worse during summer and fall.

In 2011, Hurricane Irene filled the Connecticut River with muddy sediment as a result of erosion upstream. Heavy storms are becoming more common as a result of climate change. Credit: NASA.

Sea Level Rise, Wetland Loss, and Coastal Flooding

Rising sea level erodes wetlands and beaches and increases damage from coastal storms. Tidal wetlands are inherently vulnerable because of their low elevations, and shoreline development prevents them from migrating inland onto higher ground. Human activities such as filling wetlands have destroyed about one third of New England's coastal wetlands since the early 1800s. Wetlands provide habitat for many bird species, such as osprey and heron, as well as several fish species. Losing coastal wetlands would harm coastal ecosystems and remove an important line of defense against coastal flooding.

Coastal cities and towns will become more vulnerable to storms in the coming century as sea level rises, shorelines erode, and storm surges become higher. Storms can destroy coastal homes, wash out highways and rail lines, and damage essential communication, energy, and wastewater management infrastructure.

Coastal marshes in Old Saybrook and nearby properties are at risk from sea level rise. © James G. Titus; used by permission.

Ecosystems and Agriculture

Changing the climate threatens ecosystems by disrupting relationships between species. Wildflowers and woody perennials are blooming—and migratory birds are arriving—sooner in spring. Not all species adjust in the same way, however, so the food that one species needs may no longer be available when that species arrives on its migration. Warmer temperatures allow deer populations to increase, leading to a loss of forest underbrush, which makes some animals more vulnerable to predators. Rising temperatures also enable invasive species to move into areas that were previously too cold.

Climate change may also pose challenges for agriculture: Warmer temperatures cause cows to eat less and produce less milk. That could reduce the output of Connecticut's $70-million dairy industry, which provides 13 percent of the state's farm revenue. Some farms may be harmed if more hot days and droughts reduce crop yields, or if more flooding and wetter springs delay their planting dates. Other farms may benefit from a longer growing season and the fertilizing effect of carbon dioxide.

Human Health

Changes in temperature and precipitation could increase the incidence of acute and chronic respiratory conditions such as asthma. Higher temperatures can increase the formation of ground-level ozone (smog), a pollutant that can contribute to respiratory problems. Rising temperatures may also increase the length and severity of the pollen season for plants such as ragweed—which has already been observed in other regions. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor.

The risk of some diseases carried by insects may also increase. The ticks that transmit Lyme disease are active when temperatures are above 45°F, so warmer winters could lengthen the season during which ticks can become infected or people can be exposed to the ticks. Higher temperatures would also make more of New England warm enough for the Asian tiger mosquito, a common carrier of West Nile virus. The number of cases may or may not increase, depending on what people do to control insect populations and avoid insect bites.

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EPA United States Environmental Protection Agency

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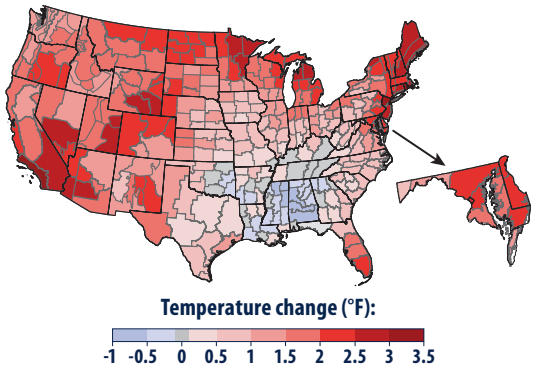
What Climate Change Means for Delaware

Delaware's climate is changing. The state has warmed two degrees (F) in the last century, heavy rainstorms are more frequent, and the sea is rising about one inch every seven years. Higher water levels are eroding beaches, submerging low lands, exacerbating coastal flooding, and increasing the salinity of estuaries and aquifers. In the coming decades, changing the climate is likely to increase coastal flooding; harm marine, wetland, and inland ecosystems; disrupt farming; and increase some risks to human health.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has warmed about one degree during the last 80 years. Warming is causing snow to melt earlier in spring, and mountain glaciers are retreating. Even the great ice sheets on Greenland and Antarctica are shrinking. Thus the sea is rising at an increasing rate.



Rising temperatures in the last century. Delaware has warmed more than most of the nation. Source: EPA, Climate Change Indicators in the United States.

Increasing Temperature and Changing Precipitation Patterns

Rising temperatures and shifting rainfall patterns are likely to increase the intensity of both floods and droughts. Average annual precipitation in Delaware has increased a few percent in the last century, and precipitation from extremely heavy storms has increased in the eastern United States by more than 25 percent since 1958. During the next century, annual precipitation and the frequency of heavy downpours are likely to keep rising. Precipitation is likely to increase during winter and spring, but not change significantly during summer and fall. Rising temperatures will melt snow earlier in spring and increase evaporation, and thereby dry the soil during summer and fall. As a result, climate change is likely to intensify flooding during winter and spring, and drought during summer and fall.

Rising Seas and Retreating Shores

Sea level is rising more rapidly along the Delaware coast than in most coastal areas because Delaware is sinking. If the oceans and atmosphere continue to warm, sea level is likely to rise between sixteen inches and four feet along the Delaware coast in the next century.

As sea level rises, the lowest dry lands are submerged and become either tidal wetland or open water. Wetlands can create their own land and keep pace with a slowly rising sea. But if sea level rises three feet or more in the next century, most existing tidal wetlands in Delaware are unlikely to keep pace but will instead become tidal mud flats or shallow open water. Existing tidal flats will generally convert to open water as they are submerged.

Beaches also erode as sea level rises. A higher ocean level makes it more likely that storm waters will wash over a barrier island or open new inlets. The United States Geological Survey estimates that Fenwick Island could be broken up by new inlets or lost to erosion if sea level rises three feet by the year 2100, unless people take measures to reduce erosion. Estuarine beaches may also be eliminated in some areas. Many of Delaware Bay's beaches are narrow, with wetlands immediately inland. Along parts of Delaware Bay and the Delaware River, people have built walls or other shore protection structures that eliminate the beach once the shore erodes up to them.

Homes and Infrastructure

Houses along Broadkill Beach are vulnerable to severe storms, flooding, and coastal erosion. Credit: U.S. Army Corps of Engineers.

Towns along the Delaware shore shore will be increasingly vulnerable to storms and erosion as sea level rises. While hurricanes are rare, their wind speeds and rainfall intensities are likely to increase as the climate warms. Rising sea level is likely to increase flood insurance rates, while more frequent storms could increase deductibles for wind damage in homeowner insurance policies. Storms can destroy coastal homes, wash out highways and rail lines, and damage essential communication, energy, and wastewater management infrastructure.

Ecosystems

The loss of tidal marshes could harm fish, reptiles, and birds that depend on a marsh for food or shelter. Blue crab, perch, weakfish, flounder, and rockfish rely on the tidal marshes in Delaware Bay to hide from predators and to feed on mussels, fiddler crabs, and other species. Sea turtles and shorebirds feed on some of the species that inhabit these marshes. Great blue herons, black ducks, ospreys, red-winged blackbirds, and several other bird species also use the salt marshes in Delaware Bay. As marshes erode, fish may benefit initially as more tidal channels form, which would make more marsh accessible. But after a point, erosion would make less marsh available, and populations of fish and birds would decline.

The loss of bay beaches and tidal flats would also threaten some species. Delaware Bay is a major stopover area for six species of migratory shorebirds that feed on its beaches and tidal flats, including most of the Western Hemisphere's red knot population. Nearly a million birds feed on the horseshoe crab eggs on the bay's sandy beaches. Diamondback terrapin nest on estuarine beaches along Delaware's inland bays.

Changing temperatures could also disrupt ecosystems. If water temperatures exceed 86°F during summer, eelgrass could be lost, which would remove a key source of food for many fish. Wildflowers and woody perennials are blooming—and migratory birds are arriving—sooner in spring. Not all species adjust in the same way, however, so the food that one species needs may no longer be available when that species arrives on its migration.

Saltwater Intrusion

As sea level rises, salt water can mix farther inland or upstream in bays, rivers, and wetlands. Because water on the surface is connected to ground water, salt water can also intrude into aquifers near the coast. Soils may become too salty for the crops and trees that currently grow in low-lying areas.

Agriculture

Changing the climate will have both harmful and beneficial effects on farming. Hotter summers are likely to reduce yields of corn. But higher concentrations of atmospheric carbon dioxide increase crop yields, and that fertilizing effect is likely to offset the harmful effects of heat on soybeans, assuming that adequate water is available. Although most chickens are raised indoors, warmer temperatures could reduce the productivity of livestock raised outside.

Human Health

Hot days can be unhealthy—even dangerous. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor. High air temperatures can cause heat stroke and dehydration, and affect people's cardiovascular and nervous systems. Warmer temperatures can also increase the formation of ground-level ozone, a key component of smog that can contribute to respiratory problems. Rising temperatures may also increase the length and severity of the pollen season for plants such as ragweed, which has already been observed in other regions.

The risk of some diseases carried by insects may also increase. The ticks that transmit Lyme disease are active when temperatures are above 45°F, so warmer winters could lengthen the season during which ticks can become infected or people can be exposed to the ticks. The number of cases may or may not increase, depending on what people do to control insect populations and avoid insect bites.

As sea level rises, the water table rises as well, which can prevent ordinary septic systems from working properly. The owner of this house in Pickering Beach responded by shifting to a mounds-based system, which provides the required separation between the drain field and the water table. © James G. Titus; used by permission.

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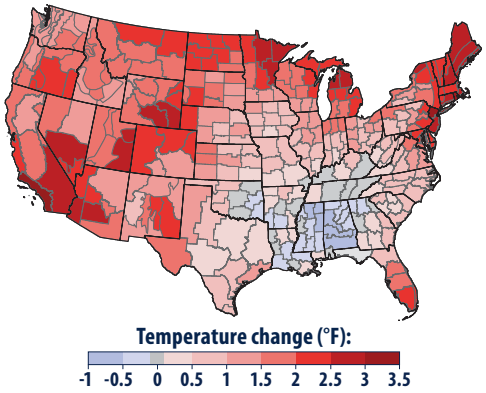
What Climate Change Means for Florida

Florida's climate is changing. The Florida peninsula has warmed more than one degree (F) during the last century. The sea is rising about one inch every decade, and heavy rainstorms are becoming more severe. In the coming decades, rising temperatures are likely to increase storm damages, harm coral reefs, increase the frequency of unpleasantly hot days, and reduce the risk of freezing to Florida's agriculture.

Climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has warmed about one degree during the last 80 years. Warming is causing snow to melt earlier in spring, and mountain glaciers are retreating. Even the great ice sheets on Greenland and Antarctica are shrinking. Thus the sea is rising at an increasing rate.



Rising temperatures in the last century. South Florida has warmed more than the rest of the state. Source: EPA, Climate Change Indicators in the United States.

Rising Seas and Retreating Shores

Along the Atlantic and Gulf Coasts of Florida, the land surface is also sinking. If the oceans and atmosphere continue to warm, sea level along the Florida coast is likely to rise one to four feet in the next century. Rising sea level submerges wetlands and dry land, erodes beaches, and exacerbates coastal flooding.

Coastal cities like West Palm Beach will likely need to take adaptive measures, such as building larger seawalls, elevating structures, and nourishing beaches, to avoid damage from sea level rise. Credit: Peter G. Merritt, Treasure Coast Regional Planning Council.

Storms, Homes, and Infrastructure

Tropical storms and hurricanes have become more intense during the past 20 years. Although warming oceans provide these storms with more potential energy, scientists are not sure whether the recent intensification reflects a long-term trend. Nevertheless, hurricane wind speeds and rainfall rates are likely to increase as the climate continues to warm.

Cities, roads, railways, ports, and water supplies in Florida are vulnerable to the impacts of storms and sea level rise. Greater wind speeds and the resulting damages can make insurance for wind damage more expensive or difficult to obtain. Whether or not storms become more intense, coastal homes and infrastructure will flood more often as sea level rises, because storm surges will become higher as well. As a result, rising sea level is likely to increase flood insurance premiums.

Changing climate is also likely to increase inland flooding. Since 1958, the amount of precipitation during heavy rainstorms has increased by 27 percent in the Southeast, and the trend toward increasingly heavy rainstorms is likely to continue. More intense rainstorms can increase flooding because rivers overtop their banks more frequently, and more water accumulates in low-lying areas that drain slowly.

Coral Reefs and Ocean Acidification

Florida's coral reefs are susceptible to warming waters and ocean acidification. Rising water temperatures can harm the algae that live inside corals and provide food for them. This loss of algae weakens corals and can eventually kill them. This process is commonly known as coral bleaching, because the loss of the algae also causes the corals to turn white.

Increasing ocean acidity can also damage corals, as well as fish and other marine species. Ocean acidity has increased by about 25 percent in the past three centuries, and it is likely to increase another 40 to 50 percent by 2100. As the ocean becomes more acidic, corals are less able to remove minerals from the water to build their skeletons. Shellfish and other organisms also depend on these minerals, and acidity interferes with their ability to build skeletons and shells. Coral reefs provide critical habitat for a diverse range of species, and small shell-producing animals are important sources of food for larger animals. Warming and acidification could harm Florida's marine ecosystems, fisheries, and tourism.

Water Resources and the Everglades

Changing climate is likely to increase the need for water. Higher air temperatures increase the rate at which water evaporates (or transpires) into the air from soils, plants, and surface waters. Because irrigated farmland would need more water, the total demand for water is likely to increase more than 25 percent during the next half century. But the amount of available water is unlikely to increase significantly—and it may decrease.

The Everglades are vulnerable to both changing climate and rising sea level. Human activities have impaired this ecosystem by diverting the natural flow of water away from the Everglades to prevent flooding or to supply farmers and municipalities with water. Ongoing efforts to restore the historical flow of water will be more difficult if rising temperatures increase competing demands for water.

Sea level rise poses a particular risk for the Everglades—a vast, ecologically rich area, much of which is within a few feet of sea level. © Chris Lamie; used by permission.

Much of the Everglades are less than three feet above sea level. The rising sea may submerge the low-lying portions. Moreover, as sea level rises, salt water can mix farther inland or upstream into the Everglades, which allows salt-tolerant species like mangroves to spread inland but threatens cypress swamps and other species that do not tolerate salt water. Increasing salinity may also threaten the Biscayne Aquifer, which is the primary source of drinking water for South Florida. The aquifer is recharged by surface water in the Everglades, so saltier water in the Everglades would reach the aquifer as well. The city of Hallandale Beach has abandoned six of its eight drinking water wells, because the water was becoming too salty to drink.

Agriculture

Changing climate will have both harmful and beneficial effects on farming. Freezing temperatures will become very rare in most of the state, which would benefit citrus trees and other fruits and vegetables grown during winter. During summer, however, hotter temperatures are likely to reduce yields of corn and may also reduce yields of sugar, peanuts, and cotton, depending on whether sufficient water is available for irrigation. Higher temperatures are also likely to reduce livestock productivity, because heat stress disrupts the animals' metabolism.

Human Health

Hot days can be unhealthy—even dangerous. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor. High air temperatures can cause heat stroke and dehydration and affect people's cardiovascular and nervous systems. Seventy years from now, temperatures in most of the state are likely to rise above 95°F between 45 and 90 days per year, compared with less than 15 days per year today. Higher humidity will further increase the heat index and associated impacts on health.

Warmer air can also increase the formation of ground-level ozone, a key component of smog. Ozone has a variety of health effects, aggravates lung diseases such as asthma, and increases the risk of premature death from heart or lung disease. EPA and the Florida Department of Environmental Protection have been working to reduce ozone concentrations. As the climate changes, continued progress toward clean air will be more difficult.

The sources of information about climate and the impacts of climate change in this publication are: the national climate assessments by the U.S. Global Change Research Program, synthesis and assessment products by the U.S. Climate Change Science Program, assessment reports by the Intergovernmental Panel on Climate Change, and EPA's *Climate Change Indicators in the United States*. Mention of a particular season, location, species, or any other aspect of an impact does not imply anything about the likelihood or importance of aspects that are not mentioned. For more information about climate change science, impacts, responses, and what you can do, visit EPA's Climate Change website at www.epa.gov/climatechange.

United States Environmental Protection Agency

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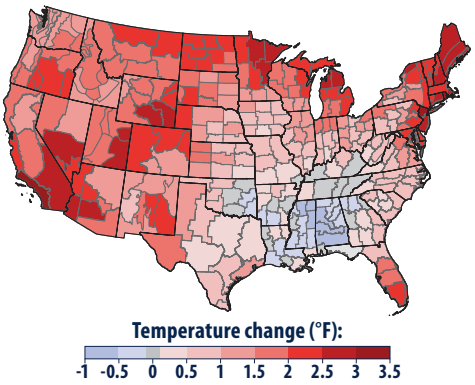
What Climate Change Means for Georgia

In the coming decades, **Georgia** will become warmer, and the state will probably experience more severe floods and drought. Even today, more rain is falling in heavy downpours, and sea level is rising about one inch every decade. Higher water levels are eroding beaches, submerging low lands, and exacerbating coastal flooding. Like other southeastern states, Georgia has warmed less than most of the nation during the last century. But during the next few decades, the changing climate is likely to harm livestock, increase the number of unpleasantly hot days, and increase the risk of heat stroke and other heat-related illnesses.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree (F) during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has warmed about one degree during the last 80 years. Warming is causing snow to melt earlier in spring, and mountain glaciers are retreating. Even the great ice sheets on Greenland and Antarctica are shrinking. Thus the sea is rising at an increasing rate.



Rising temperatures in the last century. Georgia has warmed less than most of the United States. Source: EPA, Climate Change Indicators in the United States.

Rising Seas and Retreating Shores

Sea level is rising more rapidly in Georgia than along most coasts because the land is sinking. If the oceans and atmosphere continue to warm, sea level is likely to rise one to four feet in the next century along the coast of Georgia. Rising sea level submerges wetlands and dry land, erodes beaches, and exacerbates coastal flooding.

Coastal Storms, Homes, and Infrastructure

Tropical storms and hurricanes have become more intense during the past 20 years. Although warming oceans provide these storms with more potential energy, scientists are not sure whether the recent intensification reflects a long-term trend. Nevertheless, hurricane wind speeds and rainfall rates are likely to increase as the climate continues to warm.

Whether or not storms become more intense, coastal homes and infrastructure will flood more often as sea level rises, because storm surges will become higher as well. Rising sea level is likely to increase flood insurance rates, while more frequent storms could increase the deductible for wind damage in homeowner insurance policies. Parts of Savannah and Brunswick are vulnerable to coastal flooding, which is likely to become more severe as sea level rises.

Water Resources, Flooding, and Drought

Changing the climate is likely to increase the severity of both inland flooding and droughts. Since 1958, the amount of precipitation falling during heavy rainstorms has increased by 27 percent in the Southeast, and the trend toward increasingly heavy rainstorms is likely to continue.

Rising temperatures are likely to increase the demand for water but make it less available. Warmer temperatures increase the rate at which water evaporates (or transpires) into the air from soils, plants, and surface waters. Because irrigated farmland would need more water, the total demand for water is likely to increase 10 to 50 percent during the

A drought in 2007 lowered water levels in Lake Lanier, which threatened metropolitan Atlanta's water supply and interfered with recreational activities. Droughts could become more severe as the climate warms. Credit: Bill Kinsland, National Weather Service.

next half century. But the amount of available water is likely to decrease, and soils are likely to become drier in most of the state, except along the coast.

As temperatures rise, less water is likely to flow into the Chattahoochee and other major rivers. Decreased river flows can lower the water level in Lake Lanier and other reservoirs, which may limit municipal water supplies for Atlanta and other cities. Lower water levels may also impair ecosystems, swimming, and other recreational activities, and reduce hydroelectric power generation.

Agriculture and Forest Resources

Changing the climate will have both harmful and beneficial effects on farming. Although hotter temperatures alone would tend to depress crop yields, higher concentrations of atmospheric carbon dioxide increase yields, and that fertilizing effect is likely to offset the harmful effects of heat on cotton, peanuts, soybeans, and wheat—if adequate water is available. More severe droughts, however, could cause crop failures. Higher temperatures are likely to reduce livestock productivity, because heat stress disrupts the animals' metabolism.

Warmer temperatures and changes in rainfall are unlikely to substantially reduce forest cover in Georgia, although the composition of trees in the forests may change. More droughts would reduce forest productivity, and climate change is also likely to increase the damage from insects and disease. But longer growing seasons and increased carbon dioxide concentrations could more than offset the losses from those factors. Forests cover about half of the state, with oak-pine forests common in the north, loblolly-shortleaf pine forests common in the center, and longleaf-slash pine forests common in the south. Changing the climate may enable oak-pine forests to become the most common forest type throughout the state.

Human Health

Hot days can be unhealthy—even dangerous. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor. High air temperatures can cause heat stroke and dehydration and affect people's cardiovascular and nervous systems. Seventy years from now, most of Georgia is likely to have 45 to 75 days per year with temperatures above 95°F, compared with about 15 to 30 such days today.

Warmer air can also increase the formation of ground-level ozone, a key component of smog. Ozone has a variety of health effects, aggravates lung diseases such as asthma, and increases the risk of premature death from heart or lung disease. EPA and the Georgia Environmental Protection Division have been working to reduce ozone concentrations. As the climate changes, continued progress toward clean air will be more difficult.

In large metropolitan areas like Atlanta, buildings and paved surfaces create an "urban heat island" that raises temperatures above surrounding areas and can worsen the health impacts of a heat wave. Stock photo.

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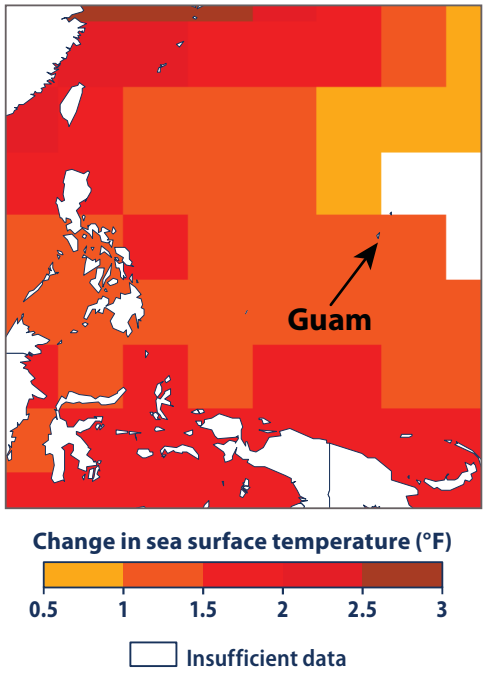
What Climate Change *Means for* Guam

In the coming decades, changes in the earth's atmosphere are likely to alter several aspects of life in **Guam**. The air and ocean are warming, sea level is rising, and the ocean is becoming more acidic. These changes are likely to damage or destroy much of Guam's coral reef ecosystems, increase damages from flooding and typhoons, reduce the availability of fresh water during the dry season, and make air temperatures uncomfortably hot more often than they are today.

Our planet is warming and the climate is changing. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of the earth about one degree (F) during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. Worldwide, the surface of the ocean has warmed about one degree during the last 80 years. Mountain glaciers are retreating and even the great ice sheets on Greenland and Antarctica are shrinking. Thus the sea is rising at an increasing rate.



Rising sea surface temperatures since 1901. The waters around Guam have warmed by more than one degree. Source: EPA, Climate Change Indicators in the United States.

Climate Change and Coral Loss

Warming waters are likely to damage much of the coral around Guam. Average water temperatures around Guam have risen more than one degree over the last century, in addition to the year-to-year changes associated with the El Niño-Southern Oscillation ("El Niño"). Rising water temperatures harm the algae that live inside corals and provide food for them. The loss of algae weakens corals and can eventually kill them. This process is commonly known as "coral bleaching" because the loss of the algae also causes the corals to turn white. Coral bleaching is becoming more common around Guam, including record-breaking bleaching that has occurred throughout the western Pacific since 2013. Elevated water temperatures also cause outbreaks of diseases that can harm or kill corals.

Increasing ocean acidity also damages corals. By changing the balance of minerals in sea water, higher acidity decreases the ability of corals to produce calcium carbonate, which is the primary component of their skeletons. The Pacific Ocean has become about 25 percent more acidic in the past three centuries, and acidity is likely to increase another 40 to 50 percent by 2100. Over the next 50 to 60 years, warming and acidification are likely to harm coral reefs around Guam and throughout the world, and widespread loss of coral is likely.

Warming and acidification could result in widespread damage to marine ecosystems. Guam is home to a diverse array of fish species. Sharks, rays, grouper, snapper, and hundreds of other fish species rely on healthy coral reefs for habitat. Reefs also protect nearshore fish nurseries and feeding grounds. A significant fraction of reef-dwelling fish are likely to lose their habitats by 2100. Increasing acidity would also reduce populations of shellfish and other organisms that depend on minerals in the water to build their skeletons and shells.

Bleached corals in the Tumon Bay Marine Preserve in 2007. Credit: Dave Burdick, NOAA.

Tropical Storms

As the climate changes, typhoons may cause more damage. Guam lies in one of the world's most active regions for tropical storms. In 2002, Typhoon Pongsona caused $700 million in damages, destroyed 1,300 homes, and left the island without power. In just the last few years, neighboring islands have suffered from some of the strongest and most damaging tropical cyclones ever recorded, including Super Typhoons Haiyan (2013), Maysak (2015), and Soudelor (2015). Although warming oceans provide typhoons with more potential energy, scientists are not yet sure whether typhoons have become stronger or more frequent. Nevertheless, wind speeds and rainfall rates during typhoons are likely to increase as the climate continues to warm. Higher wind speeds and the resulting damages can make insurance for wind damage more expensive or difficult to obtain.

Damage caused by Typhoon Pongsona in 2002. Credit: Andrea Booher, FEMA.

Rising Sea Level and Coastal Flooding

Sea level has risen by about four inches relative to Guam's shoreline since 1993. If the oceans and atmosphere continue to warm, sea level around Guam is likely to rise one to three feet in the next century. Sea level rise submerges low-lying areas, erodes beaches, and exacerbates coastal flooding from typhoons and tsunamis. Coastal homes and infrastructure will flood more often as sea level rises because storm surges will become higher as well. Homes, businesses, roads, and the Port of Guam are vulnerable to the impacts of storms and sea level rise.

The loss of coral reefs compounds this problem because reefs help protect the shore from waves and storm damage. As reefs die, they lose their structural integrity and provide less protection to the shore. If larger waves strike the shore, beaches will erode more rapidly.

Rainfall and Water Supplies

Average rainfall in Guam has increased slightly since 1950, but scientists are not sure whether total rainfall here will increase in the future. Nevertheless, Guam's wet season may become wetter, while dry periods may become drier. Warmer temperatures tend to make both rainstorms and droughts more intense. Moreover, Guam's climate tends to be dry during El Niño years and wet during La Niña years, and scientists generally expect the differences between El Niño and La Niña years to become greater in most places.

Inland flooding in Guam may increase as the climate changes. Heavy rainstorms occasionally overwhelm Guam's rivers, streams, and urban storm drains, leading to damaging floods. Flooding is most common in the southern part of Guam, where the local bedrock is less permeable than the limestone in the north. This means that rainfall in the south runs off into rivers and streams instead of filtering into the ground. Flooding during the wet season could become worse as rainstorms become more intense.

Conversely, water may be less available in the dry season. Less rainfall occurs during El Niño years, such as during the drought that affected the island in 2015–2016. Thus, if the El Niño cycle becomes more intense, less rain might fall during the dry season. Moreover, rising temperatures increase the rate at which water evaporates (or transpires) into the air from soils, plants, and reservoirs, which would further exacerbate drought conditions.

During droughts, rising sea level could make fresh water less available—particularly groundwater, which provides 80 percent of Guam's water supply. Most of Guam's fresh water comes from the northern part of the island, which has a "lens" of fresh groundwater floating on top of the heavier, saltier water. Some wells already produce salty water during dry periods when the freshwater lens becomes thinner; prolonged drought could make more of Guam's wells salty. Rising sea level could also cause salt water to infiltrate farther into the island's groundwater.

Inland Plants and Animals

Warmer temperatures and changes in rainfall could expand, shrink, or shift the ranges of various plants and animals in Guam's forests, depending on the conditions that each species requires. Many tropical plants and animals could be threatened by warming, as they are accustomed to the temperatures that currently prevail in Guam, which are fairly steady year-round. It is unclear whether species could tolerate the weather often being warmer than it ever is today. Some native species could be crowded out by invasive species better adapted to the changing climate, and some could face extinction.

Human Health

Hot days can be unhealthy—even dangerous. Rising temperatures will increase the frequency of hot days and warm nights. High air temperatures can cause heat stroke and dehydration and affect people's cardiovascular and nervous systems. Warm nights are especially dangerous because they prevent the human body from cooling off after a hot day. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor. Military personnel also face a higher risk of heat-related illness because they perform intense physical activities outdoors, they often wear layers of protective equipment, and many are from cooler climates and not acclimated to Guam's warm and humid climate.

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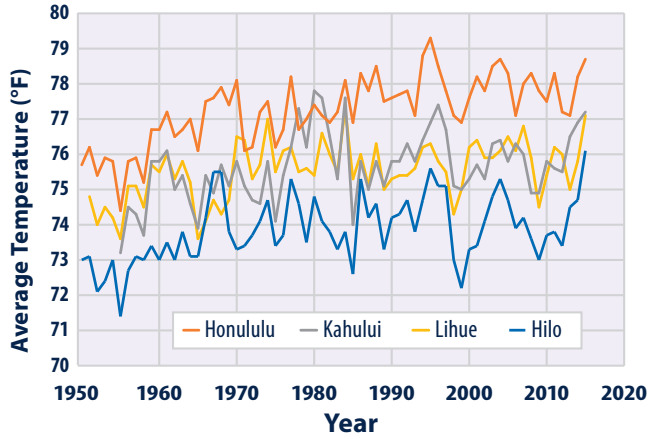
What Climate Change Means for Hawaii

Hawaii's climate is changing. In the last century, air temperatures have increased between one-half and one degree (F). Warming in the oceans around Hawaii has damaged coral reefs, and, in recent decades, increased ocean acidity has threatened reefs and other marine ecosystems. Average precipitation decreased in the last century, reducing freshwater availability on some islands and affecting delicate land-based ecosystems, often harming native species. In the last 50 years, sea level has risen along Hawaii's shores, increasing erosion and threatening coastal communities and infrastructure.

Climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has warmed about one degree during the last 80 years. Warming is causing snow to melt earlier in spring, and mountain glaciers are retreating. Even the great ice sheets on Greenland and Antarctica are shrinking. Thus the sea is rising at an increasing rate.



Average annual temperatures have increased across Hawaii since 1950. Source: NOAA

Ocean Warming and Acidification

The waters around Hawaii are warming, which is harming Hawaii's coral reefs and marine ecosystems. The El Niño-Southern Oscillation ("El Niño") and other natural cycles cause ocean temperatures in the Pacific to fluctuate from year to year and from decade to decade. Even after accounting for these natural patterns, the waters around Hawaii have been warming since the 1950s, with temperatures rising by several degrees from the ocean surface down to at least 600 feet. Rising water temperatures can harm the algae that live inside corals. Because algae provide food for the coral, a loss of algae weakens corals and can eventually kill them. This process is commonly known as "coral bleaching," because the loss of the algae also causes the corals to turn white. Mass bleaching events are becoming more common, with documented cases in the north-western Hawaiian Islands in 1996 and 2002. Water temperature spikes in Hawaii have also been linked to coral disease outbreaks.

Bleached corals in Kaneohe Bay, Oahu, in the fall of 2014. Credit: XL Catlin Seaview Survey

Increasing ocean acidity can also damage corals, as well as shellfish and other organisms that depend on minerals in the water to build their skeletons and shells. The acidity of the Pacific Ocean has increased by about 25 percent in the past three centuries, and it is likely to increase another 40 to 50 percent by 2100.

Warming and acidification could result in widespread damage to the entire marine ecosystem in the waters off Hawaii. Hawaii's isolation in the Central Pacific makes it home to a wide range of fish species not found anywhere else in the world. Many of these fish rely on healthy coral reefs for habitat, and even with substantial cuts to greenhouse gas emissions, up to 40 percent of coral

Tourism infrastructure and nearshore coral reefs, both threatened by climate change, in Maui. Credit: Hudson Slay, EPA Region 9.

reef fish could lose their habitats by 2100. Reefs also protect nearshore fish nurseries and feeding grounds. Damage to coral and reduced fish populations could negatively impact the state's economy, as these natural resources bring an estimated $385 million to Hawaii each year through tourism, direct consumption, and commercial fisheries.

Water Availability

Rainfall in Hawaii has been decreasing, but scientists do not know whether that trend will continue. El Niño will probably continue to dominate precipitation patterns from year to year in the tropical Pacific. Climate change-related increases in air temperatures will lead to more evaporation and more moisture in the air. As a result, the variability in El Niño-related precipitation is likely to increase, making rainfall predictions difficult.

Although projections of future rainfall are uncertain, streams and rivers on the Hawaiian Islands have experienced a reduction in flow over the last century, resulting in less fresh water available for people and ecosystems. Additionally, increased drought may threaten taro and breadfruit, which are important traditional food sources for Hawaii's native peoples.

Land Ecosystem Changes

Ecosystems on land are also experiencing impacts from a warming climate. Many native plant species could lose ground to invasive species better adapted to the changing climate, or simply fail to thrive in altered habitats. For example, higher temperatures and increased drought have caused dramatic declines among native plant species such as Haleakalā silversword. Some native species display the ability to adapt to climate change, such as a few types of fire-adapted grasses that have shifted to higher altitudes in Hawaii Volcanoes National Park. However, some insects such as mosquitoes have also been able to expand their ranges into higher elevations, infecting native birds with diseases like avian malaria.

Shoreline Loss

Since 1960, sea level has risen between two and eight inches relative to Hawaii's shoreline. Sea level rise can make Hawaii's existing coastal hazards—such as waves, hurricanes, tsunamis, and extreme tides—even worse. Additionally, rising sea level has accelerated coastal erosion, which has resulted in wetland migration and cliff collapse. Chronic erosion has affected more than 70 percent of Kauai and Maui's beaches over the last century.

Sea level rise and the associated coastal impacts due to increased flooding, elevated ground water tables, storm surge, and erosion have the potential to harm an array of natural and built environments in Hawaii. Dying coral reefs add to this problem, as they leave the shoreline more vulnerable to erosion and damage from waves. In the Northwestern Hawaiian Islands Marine National Monument, sea level rise threatens native species, especially those that nest on beaches, such as green sea turtles, Hawaiian monk seals, and the endangered Laysan finch. Damage to coastal infrastructure may also hurt Hawaii's economy, more than a quarter of which stems from tourism. Waikīkī Beach alone brings in $2 billion per year in visitor spending. Furthermore, many of Hawaii's native communities are in vulnerable coastal areas. Sea level rise and associated flooding are expected to destroy land, coastal artifacts, and structures of significant cultural value, and may force these communities to relocate.

A seawall built in Ukumehame, Maui, to protect the shoreline and coastal infrastructure from erosion. Credit: Hudson Slay, EPA Region 9.

Health and Vulnerable People

Climate change is likely to amplify some threats to health in Hawaii. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor.

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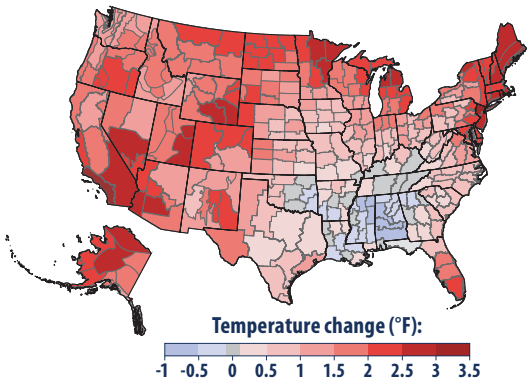
What Climate Change *Means for* Idaho

Idaho's climate is changing. Over the past century, most of the state has warmed one to two degrees (F). Snowpack is melting earlier in the year, and the flow of meltwater into streams during summer is declining. In the coming decades, streams will be warmer, populations of several fish species may decline, wildfires may be more common, deserts may expand, and water may be less available for irrigation.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has warmed about one degree during the last 80 years. Warming is causing snow to melt earlier in spring.



Rising temperatures in the last century. The warming in Idaho has been similar to the average warming nationwide. Source: EPA, Climate Change Indicators in the United States.

Snowpack, Streamflows, and Water Availability

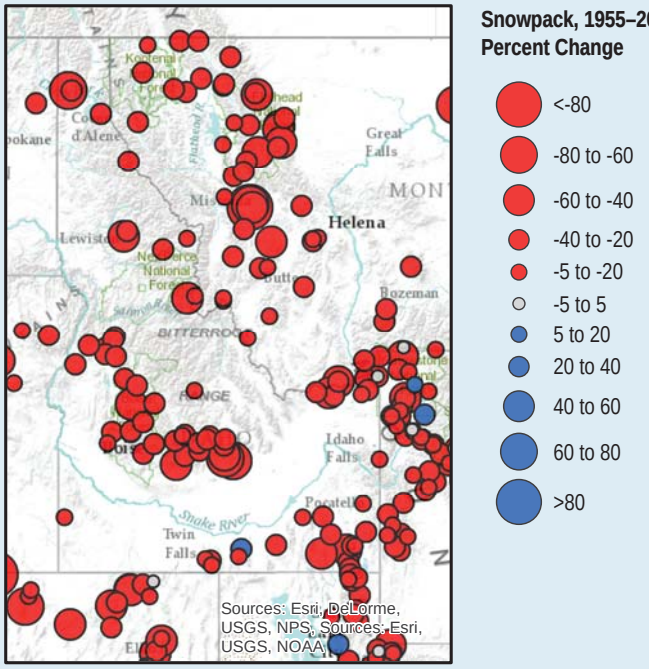
Much of the water needed for agriculture, public supplies, and other uses comes from mountain snowpack, which melts in spring and summer and runs off into rivers and fills reservoirs. As the climate warms, less precipitation falls as snow, and more snow melts during the winter, which decreases the snowpack. Since the 1950s, Idaho's snowpack has been decreasing in most locations.

Diminishing snowpack may shorten the season for skiing and other forms of winter tourism and recreation. The tree line may shift, as subalpine fir and other high-altitude trees become able to grow at higher elevations. A higher tree line would decrease the extent of alpine tundra ecosystems, which could threaten some species.

Mountain snowpack at Galena Summit, close to one of the long-term measuring sites shown in the map on the next page. April snowpack depth has decreased here and at another site in the valley below. Credit: G. Ingersoll, USGS.

A warming climate makes water less available during summer. As snowpack melts earlier, flows of fresh water in rivers and streams increase during late winter and early spring, but decrease during summer. This trend is likely to continue. Moreover, rising temperatures increase the rate at which water evaporates (or transpires) into the air from soils, plants, and surface waters, which will further reduce the amount of water draining into streams. While the impact on some streams may be negligible, in other streams, the flow of water during summer may be 50 percent less by mid-century than it is today.

Declining snowpack and streamflow are likely to harm aquatic ecosystems and water-dependent economic activities. With less melting snow to feed the streams during summer, water temperatures will rise. The combination of warmer water and lower flows would threaten salmon, steelhead, trout, and other coldwater fish. Lower flows would also mean less hydroelectric power.



Trends in April snowpack, 1955–2013. The snowpack has declined at most monitoring sites in Idaho. Source: EPA.

Drought and Wildfires

Climate change can increase the frequency and severity of fires that burn forests, grasslands, and desert vegetation. On average, nearly 1 percent of the land in Idaho has burned per year since 1984, making it the most heavily burned state in the nation. Changing the climate is likely to more than double the area in the Northwest burned by forest fires during an average year by the end of the 21st century. Although drier soils alone increase the risk of wildfire, many other factors also contribute.

Higher temperatures and a lack of water can also make trees more susceptible to pests and disease, and trees damaged or killed burn more readily than living trees. Changing the climate is likely to increase the area of pine forests in the Northwest infested with mountain pine beetles over the next few decades. Pine beetles and wildfires are each likely to decrease timber harvests. Increasing wildfires also threaten homes and pollute the air.

The combination of more fires and drier conditions may expand deserts and otherwise change the landscape in southern Idaho. Many plants and animals living in arid lands are already near the limits of what they can tolerate. Higher temperatures and a drier climate would generally extend the geographic range of the Great Basin desert. In some cases, native vegetation may persist and delay or prevent expansion of the desert. In other cases, fires or livestock grazing may accelerate the conversion of grassland to desert in response to changing climate. For similar reasons, some forests may change to desert or grassland.

A few charred tree trunks are all that remains after a section of forest was burned by the Motorway Complex Fire near Syringa and Lowell in 2015. Credit: Idaho Department of Lands.

Agriculture

Climate change may also pose challenges for livestock and crops. Hot weather causes cows to eat less, grow more slowly, and produce less milk; and in extreme cases it may threaten their health. Higher emperatures might also decrease potato yields and potato quality in the Northwest. Some farms may be harmed if more hot days reduce crop yields, or if the decline in summer streamflow reduces the water available for irrigation. Other farms may benefit from a longer growing season and the fertilizing effect of carbon dioxide.

Health and Vulnerable People

Climate change is likely to amplify some threats to health in Idaho. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor.

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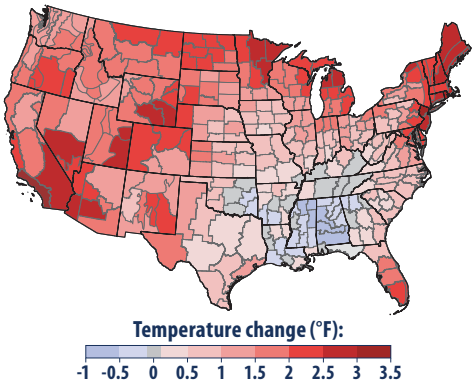
EPA 430-F-16-015

What Climate Change *Means for* Illinois

Illinois's climate is changing. Most of the state has warmed by about one degree (F) in the last century. Floods are becoming more frequent, and ice cover on the Great Lakes is forming later or melting sooner. In the coming decades, the state will have more extremely hot days, which may harm public health in urban areas and corn harvests in rural areas.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has also warmed about one degree during the last 80 years. Although warmer temperatures cause sea level to rise, the impact on water levels in the Great Lakes is not yet known. Warmer air also melts ice and snow earlier in spring.



Rising temperatures in the last century. Northern Illinois has warmed more than southern Illinois. Source: EPA, Climate Change Indicators in the United States.

Heavy Precipitation and Flooding

Changing climate is likely to increase the frequency of floods in Illinois. Over the last half century, average annual precipitation in most of the Midwest has increased by 5 to 10 percent. But rainfall during the four wettest days of the year has increased about 35 percent, and the amount of water flowing in most streams during the worst flood of the year has increased by more than 20 percent. During the next century, spring rainfall and average precipitation are likely to increase, and severe rainstorms are likely to intensify. Each of these factors will tend to further increase the risk of flooding.

Illinois, Ohio, and Mississippi Rivers

Flooding occasionally threatens both navigation and riverfront communities, and greater river flows could increase these threats. In 2011, a combination of heavy rainfall and melting snow caused a flood that closed the Ohio and Mississippi rivers to navigation and prompted evacuation of Cairo due to concerns that its flood protection levees might fail. To protect Cairo, the U.S. Army Corps of Engineers opened the Birds Point-New Madrid Floodway, which lowered the Mississippi River by flooding more than 100,000 acres of farmland in Missouri. The flood caused $360 million of damage to infrastructure, property, and agricultural yields upstream.

The Mississippi River flooding at the Quincy Lock and Dam 21 in Quincy in June 2008. The lock is submerged in the foreground and the dam is visible to the left. Credit: USGS, Advanced Hydrological Prediction Service.

Although springtime in Illinois is likely to be wetter, summer droughts are likely to be more severe. Higher evaporation and lower summer rainfall are likely to reduce river flows. The drought of 2012 narrowed navigation channels, forced lock closures, and caused dozens of barges to run aground along the Illinois shoreline of the Mississippi River, all of which delayed shipping. The Corps of Engineers estimates that the drought's impact on navigation cost the region more than $275 million. Both floods and drought can cause problems for the Illinois Waterway, which carries 25 million tons of cargo per year between Chicago and the Mississippi River.

One advantage of climate change is that warmer winters reduce the number of days that ice prevents navigation.

Great Lakes

The ice-free season along the Great Lakes is also becoming longer. Between 1994 and 2011, reduced ice cover lengthened the shipping season on the lakes by eight days. The Great Lakes are likely to warm another 3° to 7°F in the next 70 years, which will further extend the shipping season.

In Lake Michigan, changing climate is likely to harm water quality. Warmer water tends to cause more algal blooms, which can be unsightly, harm fish, and degrade water quality. Severe storms also increase the amount of pollutants that run off from land to water, so the risk of algal blooms will be greater if storms become more severe. Increasingly severe rainstorms could also cause sewers to overflow into the lake more often, threatening beach safety and drinking water supplies.

Agriculture

Changing climate will have both beneficial and harmful effects on farming. Longer frost-free growing seasons and higher concentrations of atmospheric carbon dioxide would increase yields for some crops during an average year. But increasingly hot summers are likely to reduce yields of corn and possibly soybeans. Seventy years from now, southern Illinois is likely to have 15 to 20 more days with temperatures above 95°F than it has today. More severe droughts or floods would also hurt crop yields.

Parched and stunted corn during a summer drought in Illinois. Credit: USGS.

Air Pollution and Human Health

Rising temperatures can harm air quality and amplify existing threats to human health. Warmer weather can increase the production of ground-level ozone, a pollutant that causes lung and heart problems. Ozone also harms plants. In rural Illinois, ozone levels are high enough to significantly reduce yields of soybeans and winter wheat. U.S. EPA and the Illinois EPA have been working to reduce ozone concentrations. As the climate changes, continued progress toward clean air will become more difficult.

Hot days can be unhealthy, even dangerous. High air temperatures can cause heat stroke and dehydration, and affect people's cardiovascular and nervous systems. Northern cities like Chicago are vulnerable to heat waves, because many houses and apartments lack air conditioning, and urban areas are typically warmer than their rural surroundings. Heat waves kill approximately 50 people per year in Chicago. In the next 70 years, climate change is likely to substantially increase heat-related deaths. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor.

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United States Environmental Protection Agency

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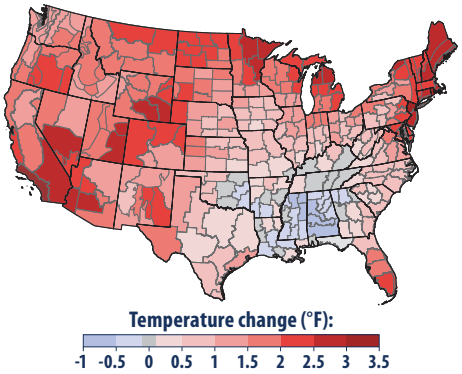
What Climate Change Means for Indiana

Indiana's climate is changing. Most of the state has warmed about one degree (F) in the last century. Floods are becoming more frequent, and ice cover on the Great Lakes is forming later or melting sooner. In the coming decades, the state will have more extremely hot days, which may harm public health in urban areas and corn harvests in rural areas.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has also warmed about one degree during the last 80 years. Although warmer temperatures cause sea level to rise, the impact on water levels in the Great Lakes is not yet known. Warmer air also melts ice and snow earlier in spring.



Rising temperatures in the last century. Northern Indiana has warmed more than southern Indiana. Source: EPA, Climate Change Indicators in the United States.

Heavy Precipitation and Flooding

Changing the climate is likely to increase the frequency of floods in Indiana. Over the last half century, average annual precipitation in most of the Midwest has increased by 5 to 10 percent. But rainfall during the four wettest days of the year has increased about 35 percent, and the amount of water flowing in most streams during the worst flood of the year has increased by more than 20 percent. During the next century, spring rainfall and average precipitation are likely to increase, and severe rainstorms are likely to intensify. Each of these factors will tend to further increase the risk of flooding.

Ohio River

Flooding occasionally threatens both navigation and riverfront communities, and greater river flows could increase these threats. In 2011, a combination of heavy rainfall and melting snow caused flooding along the Ohio and Wabash rivers in Southern Indiana and closed the lower Ohio River to navigation.

Heavy rain flooded the Wabash River in March 2009, including this section north of Lafayette. Credit: Ashley Brooks, National Weather Service.

Although springtime in Indiana is likely to be wetter, summer droughts are likely to be more severe. Higher evaporation and lower summer rainfall are likely to reduce river flows. The drought of 2005 caused portions of the lower Ohio River to be closed to commercial navigation, which delayed shipments of crops and other products to and from upstream states like Indiana. In 2012, a drought caused navigation restrictions on the lower Mississippi River, which cost the region more than $275 million.

One advantage of climate change is that warmer winters reduce the number of days that ice prevents navigation.

Great Lakes

The ice-free season along the Great Lakes is also becoming longer. Between 1994 and 2011, reduced ice cover lengthened the shipping season on the lakes by eight days. The Great Lakes are likely to warm another 3° to 7°F in the next 70 years, which will further extend the shipping season.

In Lake Michigan, the changing climate is likely to harm water quality. Warmer water tends to cause more algal blooms, which can be unsightly, harm fish, and degrade water quality. Severe storms also increase the amount of pollutants that run off from land to water, so the risk of algal blooms will be greater if storms become more severe. Increasingly severe rainstorms could also cause sewers to overflow into the lake more often, threatening beach safety and drinking water supplies.

Agriculture

Changing the climate will have both beneficial and harmful effects on farming. Longer frost-free growing seasons and higher concentrations of atmospheric carbon dioxide would increase yields for some crops during an average year. But increasingly hot summers are likely to reduce yields of corn and possibly soybeans. Seventy years from now, much of Indiana is likely to have 5 to 15 more days per year with temperatures above 95°F than it has today. More severe droughts or floods would also hurt crop yields.

Increasingly hot summers and droughts could reduce yields of corn. Credit: USDA Natural Resources Conservation Service.

Air Pollution and Human Health

Rising temperatures can harm air quality and amplify existing threats to human health. Warmer weather can increase the production of ground-level ozone, a pollutant that causes lung and heart problems. Ozone also harms plants. In rural Indiana, ozone levels are high enough to significantly reduce yields of soybeans and winter wheat. EPA and the Indiana Department of Environmental Management have been working to reduce ozone concentrations. As the climate changes, continued progress toward clean air will become more difficult.

Hot days can be unhealthy—even dangerous. High air temperatures can cause heat stroke and dehydration, and affect people's cardiovascular and nervous systems. Midwestern cities like Indianapolis are vulnerable to heat waves, because many houses and apartments lack air conditioning, and urban areas are typically warmer than their rural surroundings. In recent decades, severe heat waves have killed hundreds of people across the Midwest. Heat stress is expected to increase as climate change brings hotter summer temperatures and more humidity. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor.

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EPA United States Environmental Protection Agency

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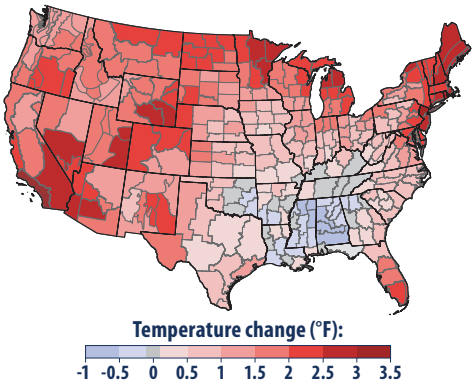
What Climate Change Means for Iowa

Iowa's climate is changing. Most of the state has warmed one-half to one degree (F) in the last century, and floods are becoming more frequent. In the coming decades, the state will have more extremely hot days, which may harm public health in urban areas and corn harvests in rural areas.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.



Rising temperatures in the last century. All regions of Iowa have warmed. Source: EPA, Climate Change Indicators in the United States.

Heavy Precipitation and Flooding

Changing the climate is likely to increase the frequency of floods in Iowa. Over the last half century, average annual precipitation in most of the Midwest has increased by 5 to 10 percent. But rainfall during the four wettest days of the year has increased about 35 percent, and the amount of water flowing in most streams during the worst flood of the year has increased by more than 20 percent. During the next century, spring rainfall and average precipitation are likely to increase, and severe rainstorms are likely to intensify. Each of these factors will tend to further increase the risk of flooding.

Flooding of the Cedar River in 2008 damaged this section of U.S. Highway 6 east of Atalissa. Credit: Iowa Department of Transportation.

Mississippi and Missouri Rivers

Flooding occasionally threatens both navigation and riverfront communities, and greater river flows could increase these threats. In April and May 2011, a combination of heavy rainfall and melting snow caused a flood that closed the Mississippi River to navigation and caused billions of dollars in damage downstream. Later that spring, heavy rains and rapid snowmelt upstream led to flooding along the Missouri River, which damaged property and closed the river to navigation. These floods caused $85 million in direct damages along the Missouri, with the most extensive property damage and crop loss occurring between Sioux City and Council Bluffs.

Although springtime in Iowa is likely to be wetter, summer droughts are likely to be more severe. Higher evaporation and lower summer rainfall are likely to reduce river flows. The drought of 2012 narrowed navigation channels, forced lock closures, and caused dozens of barges to run aground on the Mississippi River, which cost the region more than $275 million.

Tornadoes

Scientists do not know how the frequency and severity of tornadoes will change. Rising concentrations of greenhouse gases tend to increase humidity, and thus, atmospheric instability, which would encourage tornadoes. But wind shear is likely to decrease, which would discourage tornadoes. Research is ongoing to learn whether tornadoes will be more or less frequent in the future. Because Iowa experiences about 50 tornadoes a year, such research is closely followed by meteorologists in the state.

Agriculture

Changing the climate will have favorable and harmful effects on farming, although the net effect is unknown. Longer frost-free growing seasons and higher concentrations of atmospheric carbon dioxide would increase yields for many crops during an average year. But increasingly hot summers are likely to reduce yields of corn and possibly soybeans. Higher temperatures are also likely to reduce livestock productivity, because heat stress disrupts the animals' metabolism. Seventy years from now, Iowa is likely to have 10 to 20 more days per year with temperatures above 95°F than it has today. More severe droughts or floods would also hurt crop yields.

Drought-stricken corn in Missouri Valley in August 2012. Credit: Dave Kosling, USDA.

Air Pollution and Human Health

Changing the climate can harm air quality and amplify existing threats to human health. Higher temperatures can increase the production of ground-level ozone, a pollutant that can cause lung and heart problems. Ozone also harms plants. In rural Iowa, ozone levels are high enough to reduce yields of soybeans. EPA and the Iowa Department of Natural Resources have been working to reduce ozone concentrations. As the climate changes, continued progress toward clean air will become more difficult.

Climate change may also increase the length and severity of the pollen season for allergy sufferers. For example, the ragweed season in the northern Great Plains and Upper Midwest is now 10 to 21 days longer than it was in 1995, because the first frost in fall is later.

Hot days can be unhealthy—even dangerous. High air temperatures can cause heat stroke and dehydration, and affect people's cardiovascular and nervous systems. Midwestern cities are vulnerable to heat waves, because many houses and apartments lack air conditioning, and urban areas are typically warmer than their rural surroundings. In recent decades, severe heat waves have killed hundreds of people across the Midwest. Heat stress is expected to increase as climate change brings hotter summer temperatures and more humidity. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor.

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EPA United States Environmental Protection Agency

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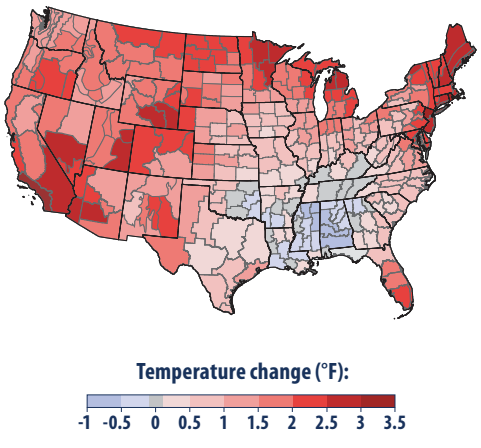
What Climate Change *Means for* Kansas

Kansas's climate is changing. In the past century, most of the state has warmed by at least half a degree (F). The soil is becoming drier. Rainstorms are becoming more intense, and floods are becoming more severe. Warming winters and changes in the timing and size of rainfall events have altered crop yields. In the coming decades, summers are likely to become increasingly hot and dry, creating problems for agriculture and possibly human health.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.



Rising temperatures in the last century. All parts of Kansas have warmed. Source: EPA, Climate Change Indicators in the United States.

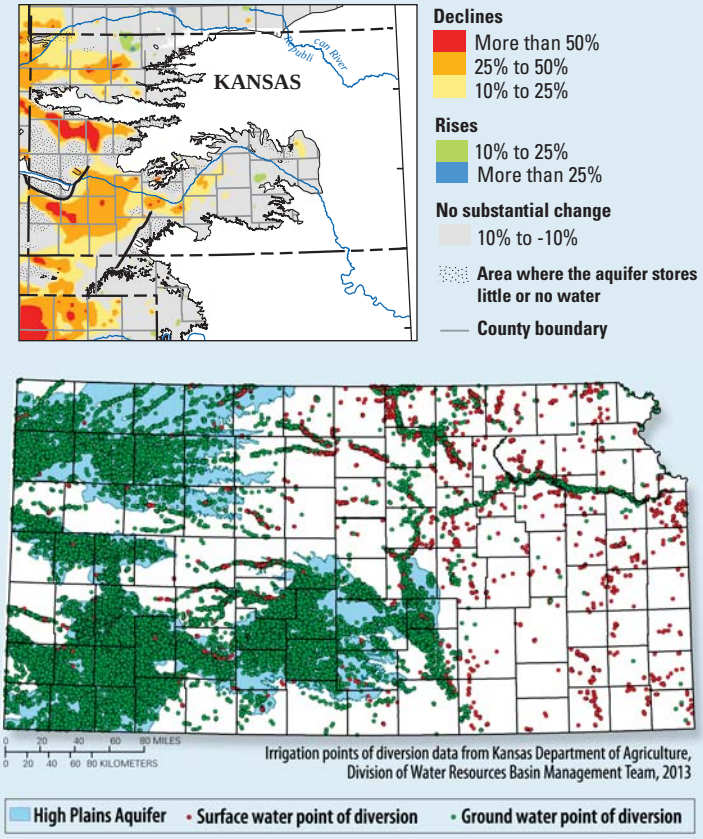
Precipitation and Water Resources

Changing climate is likely to increase the demand for water but make it less available. Soils have become drier over the last several decades, and they are likely to continue to become drier as warmer temperatures increase evaporation and water use by plants. Average rainfall during the summer is likely to decrease. Seventy years from now, the longest period without rain each year is likely to be three or four days longer than today. Warmer temperatures and drier soils are also likely to decrease the average flow of rivers and streams, because drier soil retains more water when it rains.

Drier soils will increase the need for farmers to irrigate their crops, but sufficient water might not be available. Approximately 22 percent of the farmland in Kansas is irrigated, mostly with ground water from the High Plains Aquifer System. As a result, this aquifer is becoming depleted. Since the 1950s, the amount of water stored in the aquifer has declined by more than 25 percent in many parts of the state. (See map on back page.)

Decreased river flows can create problems for navigation, recreation, public water supplies, and electric power generation. Commercial navigation can be suspended during droughts when there is too little water to keep channels deep enough for barge traffic. Decreased river flows can also lower the water level in lakes and reservoirs, which may limit municipal water supplies and impair swimming, fishing, and other recreational activities. Although the state has only one hydroelectric dam, conventional power plants also need adequate water for cooling. Compounding the problem, rising temperatures are expected to increase the demand for electricity for air conditioning.

A very low flow of water on the Arkansas River at Great Bend during a drought. July 12, 2013. Credit: Nathan Sullivan, USGS.



Ground water accounts for 96 percent of the water used for irrigation in Kansas. Most of it comes from the High Plains Aquifer. Top: Percent depletion of ground water in the High Plains Aquifer, 1950–2013. Bottom: Irrigation trends in Kansas, 1991–2011. Source: USGS.

Agriculture

Rising temperatures, drier soils, and decreasing water availability are likely to present challenges for Kansas's farms. Yields would decline by about 50 percent in fields that can no longer be irrigated. Even where ample water is available, higher temperatures would reduce yields of corn. Increased concentrations of carbon dioxide, however, may increase yields of wheat and soybean enough to offset the impact of higher temperature. Although warmer and shorter winters may allow for a longer growing season, they may also promote the growth of weeds and pests, and shorten the dormancy for many winter crops, which could increase crop losses during spring freezes.

A center-pivot irrigation system in western Kansas. Credit: Lori Marintzer, USGS.

The early flowering of winter wheat could have negative repercussions on livestock farmers who depend on it for feed. Livestock themselves may also be affected by more intense heat waves and lack of water. Hot weather causes cows to eat less, grow more slowly, and produce less milk, and it can threaten their health.

Rainstorms and Tornadoes

Although summer droughts are likely to become more severe, floods may also intensify. During the last 50 years, the amount of rain falling during the wettest four days of the year has increased about 15 percent in the Great Plains. River levels associated with flooding have increased in eastern Kansas. Over the next several decades, the amount of rainfall during the wettest days of the year is likely to continue to increase, which would increase flooding.

A worker measures the overflow of the Smoky Hill River along old U.S. Route 40 during a record flood near New Cambria. May 25, 2007. Credit: USGS, Kansas Water Science Center.

Scientists do not know how the frequency and severity of tornadoes will change. Rising concentrations of greenhouse gases tend to increase humidity, and thus atmospheric instability, which would encourage tornadoes. But wind shear is likely to decrease, which would discourage tornadoes. Research is ongoing to learn whether tornadoes will be more or less frequent in the future. Because Kansas experiences about 100 tornadoes a year, such research is closely followed by meteorologists in the state.

Hot Weather and Human Health

Hot days can be unhealthy—even dangerous. By 2050, Kansas is likely to have four times as many days above 100°F. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor. The elderly may be particularly prone to heat stress and other heat-related health problems, including dehydration, cardiovascular strain, and respiratory problems. Those with low incomes may be particularly vulnerable due to a lack of air conditioning. Power failures due to severe weather can also present risks, especially in lightly populated areas where access to the necessary support services may be limited.

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United States Environmental Protection Agency

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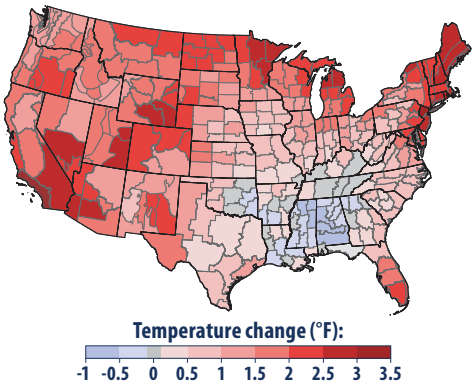
What Climate Change *Means for* Kentucky

Kentucky's climate is changing. Although the average temperature did not change much during the 20th century, most of the commonwealth has warmed in the last 20 years. Average annual rainfall is increasing, and a rising percentage of that rain is falling on the four wettest days of the year. In the coming decades, the changing climate is likely to reduce crop yields and threaten some aquatic ecosystems. Floods may be more frequent, and droughts may be longer, which would increase the difficulty of meeting the competing demands for water in the Ohio, Tennessee, and Cumberland rivers.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree (F) during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Natural cycles and sulfates in the air prevented much of Kentucky from warming during the last century. Sulfates are air pollutants that reflect sunlight back into space. Now sulfate emissions are declining, and the factors that once prevented Kentucky from warming are unlikely to persist.



Rising temperatures in the last century. Kentucky has warmed less than most of the United States. Source: EPA, Climate Change Indicators in the United States.

Precipitation and Water Resources

Annual precipitation in Kentucky has increased approximately 5 percent since the first half of the 20th century. But rising temperatures increase evaporation, which dries the soil and decreases the amount of rain that runs off into rivers. Although rainfall during spring is likely to increase during the next 40 to 50 years, the total amount of water running off into rivers or recharging ground water each year is likely to decline 2.5 to 5 percent, as increased evaporation offsets the greater rainfall. Droughts are likely to be more severe, because periods without rain will be longer and very hot days will be more frequent.

Flooding, Navigation, and Hydroelectric Power

Flooding is becoming more severe in the Southeast. Since 1958, the amount of precipitation during heavy rainstorms has increased by 27 percent in the Southeast, and the trend toward increasingly heavy rainstorms is likely to continue. The Tennessee Valley Authority (TVA) and the U.S. Army Corps of Engineers operate Kentucky Dam, Wolf Creek Dam, and other dams to prevent serious floods on the Ohio, Tennessee, and Cumberland rivers. The agencies release water from the reservoirs behind these dams before the winter flood season. By lowering water levels, these releases provide greater capacity for the reservoirs behind those dams to prevent flooding. Nevertheless, dams and other flood control structures cannot prevent all floods. The Ohio River has flooded Louisville several times, for example, and flash floods have caused property destruction and deaths throughout Kentucky.

Flooding at Third and Magnolia Streets in Louisville after heavy rains in August 2009. Credit: Mike Howard, courtesy of the National Weather Service and the Louisville and Jefferson County Metropolitan Sewer District.

Increasingly severe droughts could pose challenges for river transportation. The drought of 2005 closed portions of the lower Ohio River to commercial navigation, which delayed shipments of crops and other products between Kentucky and the Mississippi River. In 2012, a drought caused navigation restrictions on the lower Mississippi River, which cost the region more than $275 million.

A barge passes by Paducah during a period of low water on the Ohio River in summer 2005. Drought conditions caused shipping delays throughout the region. Credit: National Weather Service.

Droughts also affect the amount of electricity from hydroelectric dams. During the 2007 drought, total production from the TVA's hydroelectric plants fell by more than 30 percent, which forced the TVA to meet customer demand by using more expensive fuel-burning power plants.

Aquatic Ecosystems

Changing climate can harm aquatic ecosystems. Warmer water lowers the level of dissolved oxygen in surface water, which can severely limit fish populations. Because fish cannot regulate their body temperatures, warmer water can make a stream uninhabitable for fish that require cooler water. Warmer temperatures can also increase the frequency of algal blooms, which can be toxic and further reduce dissolved oxygen. Summer droughts may amplify these effects, while periods of extreme rainfall can increase the impacts of pollution on streams.

Agriculture

Longer frost-free growing seasons and increased concentrations of atmospheric carbon dioxide tend to increase yields for many crops during an average year. But more severe droughts and more hot days are likely to reduce yields, especially in the western half of Kentucky, which in seventy years is likely to have 15 to 30 more days with temperatures above 95°F than it has today. Even on irrigated fields, higher temperatures are likely to reduce yields of corn, and possibly soybeans. Higher temperatures are also likely to reduce livestock productivity: hot weather causes cows to eat less, grow more slowly, and produce less milk, and it can threaten their health.

Forest Resources

Higher temperatures and changes in rainfall are unlikely to substantially reduce forest cover in Kentucky, but the composition of those forests may change. More droughts would reduce forest productivity, and climate change is also likely to increase the damage that insects and diseases cause to forests. Yet longer growing seasons and increased carbon dioxide concentrations could more than offset the losses from those factors. In central Kentucky, the population of maple, beech, and birch trees is likely to decline, in favor of the oak and hickory trees that dominate forests in most of the state.

Human Health

Hot days can be unhealthy—even dangerous. High air temperatures can cause heat stroke and dehydration, and affect people's cardiovascular and nervous systems. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor. Higher temperatures can also increase the formation of ground-level ozone, a key component of smog. Ozone has a variety of health effects, aggravates lung diseases such as asthma, and increases the risk of premature death from heart or lung disease. EPA and the Kentucky Department for Environmental Protection have been working to reduce ozone concentrations. As the climate changes, continued progress toward clean air will require even more reductions in the air pollutants that contribute to ozone.

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EPA United States Environmental Protection Agency

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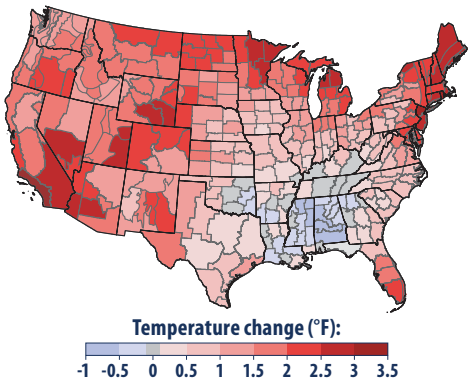
What Climate Change *Means for* Louisiana

In the coming decades, **Louisiana** will become warmer, and both floods and droughts may become more severe. Unlike most of the nation, Louisiana did not become warmer during the last century. But soils have become drier, annual rainfall has increased, more rain arrives in heavy downpours, and sea level is rising. Our changing climate is likely to increase damages from floods, reduce crop yields and harm fisheries, increase the number of unpleasantly hot days, and increase the risk of heat stroke and other heat-related illnesses.

The climate is changing because our planet is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of the earth about one degree (F) during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others. While most of the earth warmed, natural cycles and sulfates in the air cooled Louisiana. Sulfates are air pollutants that reflect sunlight back into space. Now sulfate emissions are declining, and the factors that once prevented the state from warming are unlikely to persist.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has warmed about one degree during the last 80 years. Warming is causing snow to melt earlier in spring, and mountain glaciers are retreating. Even the great ice sheets on Greenland and Antarctica are shrinking. Thus the sea is rising at an increasing rate.



Rising temperatures in the last century. Louisiana has warmed less than most of the United States, and part of the state has cooled. Source: EPA, Climate Change Indicators in the United States.

Rising Seas and Retreating Shores

Rising sea level is likely to accelerate coastal erosion caused today by sinking land and human activities. The sediment washing down the Mississippi River created the river delta that comprises most of coastal Louisiana. These sediments gradually compact, so the land sinks about one inch every three years. Historically, the river would occasionally overflow its banks and deposit enough new sediment to allow the land surface to keep pace with rising sea level and the delta's tendency to sink. But today, river levees, navigation channels, and other human activities thwart this natural land-building process, so coastal lands are being submerged. Louisiana has been losing about 25 square miles of land per year in recent decades.

If temperatures continue to warm, sea level is likely to rise one to three feet during the next century. Rising sea level has the same effect as sinking land, so changing climate is likely to accelerate coastal erosion and land loss. Federal, state, and local governments have ongoing projects to slow land loss in Louisiana, but if the sea rises more rapidly in the future, these efforts will become increasingly difficult.

Tropical Storms

Tropical storms and hurricanes have become more intense during the past 20 years. Although warming oceans provide these storms with more potential energy, scientists are not sure whether the recent intensification reflects a long-term trend. Nevertheless, hurricane wind speeds and rainfall rates are likely to increase as the climate continues to warm.

Most of New Orleans was flooded when rising water overtopped levees and floodwalls during Hurricane Katrina in 2005. Credit: LtCdr. Mark Moran, NOAA Corps

Increased Flooding

Whether or not tropical storms become more frequent, rising sea level makes low-lying areas more prone to flooding. Many coastal roads, railways, airports, and oil and gas facilities are vulnerable to the impacts of storms and sea level rise. Louisiana is especially vulnerable, because much of New Orleans and other populated areas are below sea level, protected by levees and pumping systems that remove rainwater, which cannot drain naturally. With a higher sea level, these levees may be overtopped more readily during storms. Severe flooding can disrupt the economy of a city by inducing people to move away, which occurred after Hurricane Katrina in New Orleans. The greater flood risk is also likely to increase flood insurance rates.

Changing climate is also likely to increase the risk of inland flooding. Since 1958, the amount of precipitation falling during heavy rainstorms has increased by 27 percent in the Southeast, and the trend toward increasingly heavy rainstorms is likely to continue. Moreover, the amount of rainfall in the Midwest is also likely to increase, which could worsen flooding in Louisiana, because most of the Midwest drains into the Mississippi River.

The Port of New Orleans is vulnerable to river floods that shut down traffic on the Mississippi River, as well as coastal storms that can flood port facilities. In 2011, high water levels on the Mississippi River led the U.S. Army Corps of Engineers to divert water through the Morganza Spillway to the Atchafalaya River to prevent serious flooding of Baton Rouge and New Orleans. The resulting high water on the Atchafalaya flooded small towns and about 1,000 square miles of agricultural land, and required temporary levees to protect Morgan City. Although major flooding on the Mississippi River was avoided, high water levels still caused a barge collision that led the Corps to close the river near Baton Rouge for four days.

Heavy rains flooded Franklinton in March 2016. Credit: Sgt. Cody Westmoreland, Louisiana Army National Guard.

Agriculture, Forests, and Fisheries

Changing climate will have both harmful and beneficial effects on farming. Seventy years from now, Louisiana is likely to have 35 to 70 days with temperatures above 95°F, compared with about 15 days today. Even during the next few decades, hotter summers are likely to reduce yields of corn and rice. But higher concentrations of atmospheric carbon dioxide increase crop yields, and that fertilizing effect is likely to offset the harmful effects of heat on soybeans and cotton—if adequate water is available. On farms without irrigation, however, increasingly severe droughts could cause more crop failures. Higher temperatures are also likely to reduce livestock productivity, because heat stress disrupts the animals' metabolism.

Higher temperatures and changes in rainfall are unlikely to substantially reduce forest cover in Louisiana, although the composition of trees in the forests may change. More droughts would reduce forest productivity, and climate change is also likely to increase the damage from insects and disease. But longer growing seasons and increased concentrations of carbon dioxide could more than offset the losses from those factors. Forests cover about half of the state, with loblolly-shortleaf pine forests most common outside of wetland areas. Changing climate may cause the loblolly and shortleaf pine trees to give way to oak-pine forests.

Rising sea level and higher temperatures threaten Louisiana's fisheries. Coastal wetlands account for most of the land that the state has been losing. Those wetlands support shrimp, oyster, crab, crawfish, menhaden, and other fisheries–about 75 percent of the state's total commercial fisheries. Rising temperatures may also harm fish by reducing levels of dissolved oxygen in the water, promoting harmful algal blooms, bacteria, and other factors that contribute to diseases in coastal waters.

Human Health

Hot days can be unhealthy, even dangerous. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor. High air temperatures can cause heat stroke and dehydration and affect people's cardiovascular and nervous systems. Warmer air can also increase the formation of ground-level ozone, a key component of smog. Ozone has a variety of health effects, aggravates lung diseases such as asthma, and increases the risk of premature death from heart or lung disease. EPA and the Louisiana Department of Environmental Quality have been working to reduce ozone concentrations. As the climate changes, continued progress toward clean air will become more difficult.

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EPA United States Environmental Protection Agency

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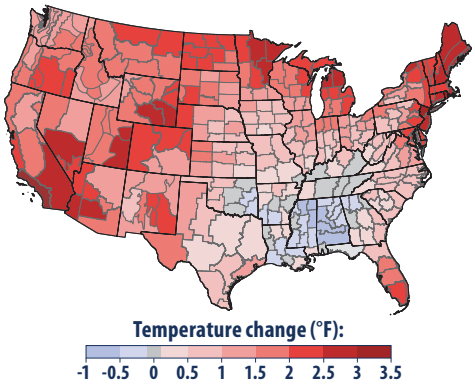
What Climate Change Means for Maine

Maine's climate is changing. The state has warmed about three degrees (F) since the year 1900. Throughout the northeastern United States, spring is arriving earlier and bringing more precipitation, heavy rainstorms are more frequent, and summers are hotter and drier. Sea level is rising, and severe storms increasingly cause floods that damage property and infrastructure. In the coming decades, changing the climate is likely to increase flooding; harm ecosystems; disrupt fishing, agriculture, and winter recreation; and increase some risks to human health.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has warmed about one degree during the last 80 years. Warming is causing snow to melt earlier in spring, and mountain glaciers are retreating. Even the great ice sheets on Greenland and Antarctica are shrinking. Thus the sea is rising at an increasing rate.



Rising temperatures in the last century. Maine has warmed twice as much as the rest of the contiguous 48 states. Source: EPA, Climate Change Indicators in the United States.

Increasing Temperature and Changing Precipitation Patterns

Rising temperatures and shifting rainfall patterns are likely to increase the intensity of both floods and droughts. Average annual precipitation in the Northeast increased 10 percent from 1895 to 2011, and precipitation from extremely heavy storms has increased 70 percent since 1958. During the next century, average annual precipitation and the frequency of heavy downpours are likely to keep rising. Average precipitation is likely to increase during winter and spring, but not change significantly during summer and fall. Rising temperatures will melt snow earlier in spring and increase evaporation, and thereby dry the soil during summer and fall. So flooding is likely to be worse during winter and spring, and droughts worse during summer and fall.

The Sandy River flooded Farmington in January 2006. Credit: Franklin County Emergency Management Agency.

Sea Level Rise, Wetland Loss, and Coastal Flooding

Rising sea level erodes wetlands and beaches and increases damage from coastal storms. Tidal wetlands are inherently vulnerable because of their low elevations, and shoreline development prevents them from migrating inland onto higher ground. Human activities such as filling wetlands have destroyed about one third of New England's coastal wetlands since the early 1800s. Wetlands provide habitat for many bird species, such as osprey and heron, as well as several fish species. Losing coastal wetlands would harm coastal ecosystems and remove an important line of defense against coastal flooding.

Coastal cities and towns will become more vulnerable to storms in the coming century as sea level rises, shorelines erode, and storm surges become higher. Storms can destroy coastal homes, wash out highways and rail lines, and damage essential communication, energy, and wastewater management infrastructure.

Sea level rise threatens salt marshes like Scarborough Marsh, which is Maine's largest. Credit: Robert Pos, U.S. Fish and Wildlife Service.

Ecosystems

Changing the climate threatens ecosystems by disrupting relationships between species. Wildflowers and woody perennials are blooming—and migratory birds are arriving—sooner in spring. Not all species adjust in the same way, however, so the food that one species needs may no longer be available when that species arrives on its migration. Warmer temperatures allow deer populations to increase, leading to a loss of forest underbrush, which makes some animals more vulnerable to predators.

Climate change can allow invasive species to expand their ranges. For example, the hemlock woolly adelgid has recently infested hemlock trees near the coast in southern Maine. Infestation eventually kills almost all hemlock trees, which are replaced by black oaks, black birch, and other hardwoods. Warmer temperatures are likely to enable the woolly adelgid to expand inland and up the coast. The loss of hemlock trees would remove the primary habitat for the blue-headed vireo and Blackburnian warbler. It could also cause streams to run dry or become excessively warm more often, harming brook trout and brown trout.

Fishing and Farms

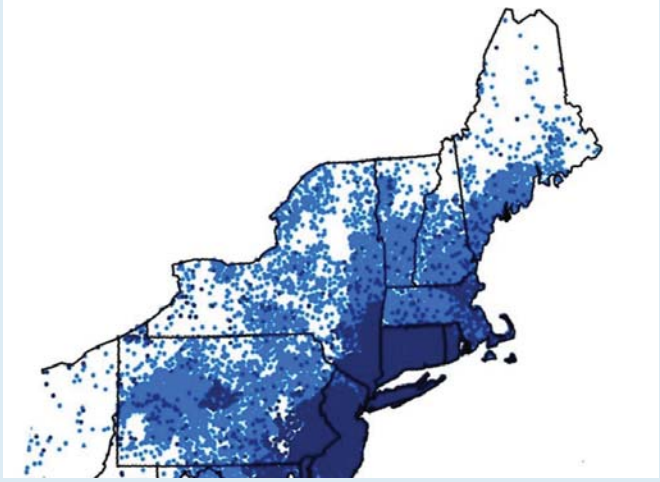
Parts of Maine's fishing and agriculture sectors may suffer as the climate changes. Rising water temperatures can lower oxygen levels and otherwise alter freshwater and marine ecosystems. Lobsters and other shellfish are vulnerable to increased ocean acidity, especially during early life stages when acidity impairs their ability to build shells. As ocean temperatures rise, some fish species are moving northward or into deeper waters to remain within their normal temperature range. The loss of coastal wetlands could harm clams, bass, and other commercially important fish.

Climate change may also pose challenges for agriculture. Some farms may be harmed if more hot days and droughts reduce crop yields, or if more flooding and wetter springs delay their planting dates. Other farms may benefit from a longer growing season and the fertilizing effect of carbon dioxide. Rising temperatures may also affect maple syrup production, but the likely impact over the next few decades is unknown.

Human Health

Climate change is likely to amplify some of the existing threats to health in Maine. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor.

Warmer weather could increase the incidence of some diseases carried by insects and some respiratory conditions. The ticks that transmit Lyme disease are active when temperatures are above 45°F, so warmer winters could lengthen the season during which ticks can become infected or people can be exposed to the ticks. Higher temperatures can also increase the formation of ground-level ozone (smog), a pollutant that can contribute to respiratory problems such as asthma. Finally, rising temperatures may increase the length and severity of the pollen season for plants such as ragweed, which has already been observed in other regions.



Increase in Lyme disease between 1996 and 2013. Each dark dot shows one case reported in 1996; light dots show 2013. The increased range shown here has been attributed to factors other than climate change. Nevertheless, additional warming will lengthen the season during which people are exposed to Lyme disease and may allow the disease to spread to colder areas. Source: CDC.

Winter Recreation

Warmer winters may bring more rain and less snow to Maine. A decline in snowfall would shorten the season during which the ground is covered with snow, which could harm recreational industries like skiing, snowboarding, and snowmobiling, and the local economies that depend on them.

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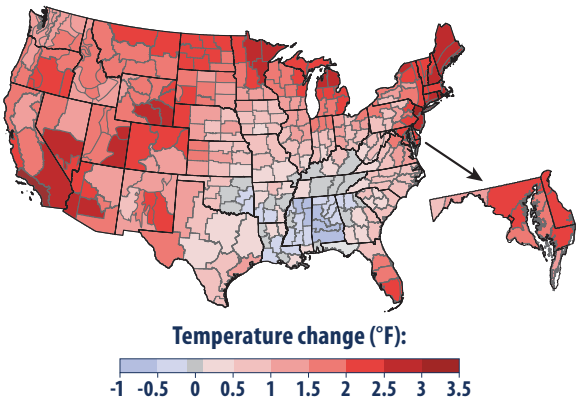
What Climate Change *Means for* Maryland

Maryland's climate is changing. Most of the state has warmed one to two degrees (F) in the last century, heavy rainstorms are more frequent, and the sea is rising about one inch every seven to eight years. Higher water levels are eroding beaches, submerging low lands, exacerbating coastal flooding, and increasing the salinity of estuaries and aquifers. In the coming decades, changing the climate is likely to increase coastal and inland flooding; harm marine, wetland, and inland ecosystems; disrupt fishing and farming; and increase some risks to human health.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has warmed about one degree during the last 80 years. Warming is causing snow to melt earlier in spring, and mountain glaciers are retreating. Even the great ice sheets on Greenland and Antarctica are shrinking. Thus the sea is rising at an increasing rate.



Rising temperatures in the last century. Except for western Maryland, the state has warmed more than most of the nation. Source: EPA, Climate Change Indicators in the United States.

Increasing Temperature and Changing Precipitation Patterns

Rising temperatures and shifting rainfall patterns are likely to increase the intensity of both floods and droughts. Average annual precipitation in Maryland has increased about 5 percent in the last century, but precipitation from extremely heavy storms has increased in the eastern United States by more than 25 percent since 1958. During the next century, average annual precipitation and the frequency of heavy downpours are likely to keep rising. Average precipitation is likely to increase during winter and spring, but not change significantly during summer and fall. Rising temperatures will melt snow earlier in spring and increase evaporation, and thereby dry the soil during summer and fall. As a result, changing the climate is likely to intensify flooding during winter and spring, and drought during summer and fall.

Rising Seas and Retreating Shores

Sea level is rising more rapidly in Maryland than in most coastal areas because the land is sinking. If the oceans and atmosphere continue to warm, sea level along the Maryland coast is likely to rise sixteen inches to four feet in the next century.

As sea level rises, the lowest dry lands are submerged and become either tidal wetland or open water. The freshwater wetlands in the upper tidal portions of the Potomac, Patuxent, Choptank, and Nanticoke rivers build their own land by capturing floating sediments, and they are likely to keep pace with the rising sea during the next century. But most salt marshes elsewhere in the state are unlikely to keep pace if sea level rises three feet. The wetlands along the Eastern Shore south of the Bay Bridge are even more vulnerable, and likely to be lost if the sea rises two feet. Wetlands in Dorchester County are already being submerged by rising sea level.

Beaches also erode as sea level rises. A higher ocean level makes it more likely that storm waters will wash over a barrier island or open new inlets. The United States Geological Survey estimates that Assateague Island is likely to be broken up by new inlets or lost to erosion if sea level rises two feet by the year 2100. Eroding beaches along Chesapeake Bay and its tributaries are likely to be squeezed between the advancing water and stone revetments erected to protect development along the shore. Even towns with "Beach" in their names are seeing their beaches replaced with hard shore protection structures.

Sea level rise threatens coastal wetlands like this marsh at Blackwater Wildlife Refuge, along with the ecosystems and fisheries they support. © James G. Titus; used by permission.

Saltwater Intrusion

As sea level rises, salt water can mix farther inland or upstream in bays, rivers, and wetlands. Because water on the surface is connected to ground water, salt water can also intrude into aquifers near the coast. Soils may become too salty for the crops and trees that currently grow in low-lying areas.

Homes and Infrastructure

Storms can destroy coastal homes, wash out highways and rail lines, and damage essential communication, energy, and wastewater management infrastructure. In 2003, the storm surge in Chesapeake Bay from Hurricane Isabel flooded downtown Annapolis, North Beach, and several communities on the Eastern Shore, causing about $400 million in damages. While recent hurricanes have had minimal impacts on Ocean City, about 25 percent of its structures are vulnerable to flooding. On the lower Eastern Shore, communities like Hooper's Island, Smith Island, and parts of Crisfield are so low that water in ditches along the streets rises and falls with the tides. These towns will become more vulnerable to storms and erosion as sea level rises.

Although hurricanes are rare, their wind speeds and rainfall rates are likely to increase as the climate continues to warm. Rising sea level is likely to increase flood insurance rates, while more frequent storms could increase the deductible for wind damage in homeowner insurance policies.

Downtown Annapolis the day after Hurricane Isabel struck the Atlantic coast on September 18, 2003. © James G. Titus; used by permission.

Ecosystems

The loss of tidal marshes could harm fish and birds that depend on a marsh for food or shelter. Small insects and marine organisms that feed in the marsh are a key source of food for crabs, rockfish, and other commercially important fisheries. Striped bass, bluefish, sea trout, and summer flounder also move into and out of the marsh for feeding and shelter. The most vulnerable marshes along Chesapeake Bay are inhabited by great blue heron, bald eagle, American black duck, and snowy egret. The marshes near Ocean City and Assateague Island provide forage for shorebirds, such as sandpipers and plovers, and several species of ducks and geese spend the winter in these marshes.

The loss of bay beaches would remove key habitat for diamondback terrapin that nest on these beaches. Other species that depend on bay beaches include horseshoe crabs, tiger beetles, sand fleas, snails, and several crab species. The loss of those species would remove important sources of food for birds.

Changing temperatures could also disrupt ecosystems. If water temperatures exceed 86°F during summer, eelgrass could be lost. Blue crabs would lose an important hiding place during spring when they are changing shells and vulnerable to predators, and the sea turtles that feed on those crabs in the eelgrass might lose that food source. Wildflowers and woody perennials are blooming—and migratory birds are arriving—sooner in spring. Not all species adjust in the same way, however, so the food that one species needs may no longer be available when that species arrives on its migration.

Fishing and Farms

Parts of Maryland's fishing and agriculture sectors may suffer as the climate changes. Blue crabs and other shellfish are vulnerable to increased acidity in the water, especially during early life stages when acidity impairs their ability to build shells. As sea level rises, the Chesapeake Bay region is expected to lose some of the wetlands that fish and shellfish depend on for nursery grounds. Warmer waters are expected to increase harmful algae, lower oxygen levels, and change the mix of species that thrive in the bay.

Climate change may also pose challenges for agriculture: some farms may be harmed if more hot days and droughts reduce crop yields, or if more flooding and wetter springs delay their planting dates. Other farms may benefit from a longer growing season and the fertilizing effect of carbon dioxide.

Human Health

Hot days can be unhealthy—even dangerous. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor. High air temperatures can cause heat stroke and dehydration, and affect people's cardiovascular and nervous systems. Warmer temperatures can also increase the formation of ground-level ozone, a component of smog that can contribute to respiratory problems. Rising temperatures may also increase the length and severity of the pollen season for plants such as ragweed,which has already been observed in other regions.

The risk of some diseases carried by insects may also increase. The ticks that transmit Lyme disease are active when temperatures are above 45°F, so warmer winters could lengthen the season during which ticks can become infected or people can be exposed to the ticks. The number of cases may or may not increase, depending on what people do to control insect populations and avoid insect bites.

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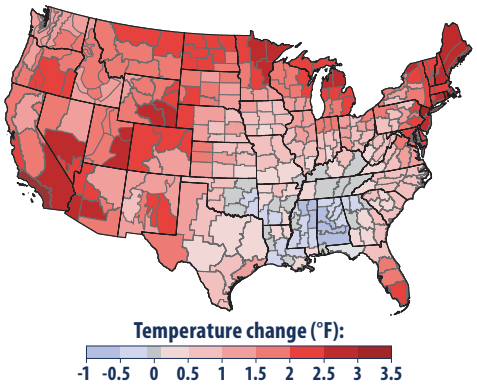
What Climate Change *Means for* Massachusetts

The climate of **Massachusetts** is changing. The commonwealth has warmed by more than two degrees (F) in the last century. Throughout the northeastern United States, spring is arriving earlier and bringing more precipitation, heavy rainstorms are more frequent, and summers are hotter and drier. Sea level is rising, and severe storms increasingly cause floods that damage property and infrastructure. In the coming decades, the changing climate is likely to increase flooding, harm ecosystems, disrupt fishing and farming, and increase some risks to human health.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has warmed about one degree during the last 80 years. Warming is causing snow to melt earlier in spring, and mountain glaciers are retreating. Even the great ice sheets on Greenland and Antarctica are shrinking. Thus the sea is rising at an increasing rate.



Rising temperatures in the last century. Massachusetts has warmed almost twice as much as the rest of the contiguous 48 states. Source: EPA, Climate Change Indicators in the United States.

Increasing Temperature and Changing Precipitation Patterns

Rising temperatures and shifting rainfall patterns are likely to increase the intensity of both floods and droughts. Average annual precipitation in the Northeast increased 10 percent from 1895 to 2011, and precipitation from extremely heavy storms has increased 70 percent since 1958. During the next century, average annual precipitation and the frequency of heavy downpours are likely to keep rising. Average precipitation is likely to increase during winter and spring, but not change significantly during summer and fall. Rising temperatures will melt snow earlier in spring and increase evaporation, and thereby dry the soil during summer and fall. So flooding is likely to be worse during winter and spring, and droughts worse during summer and fall.

Sea Level Rise, Wetland Loss, and Coastal Flooding

Rising sea level erodes wetlands and beaches and increases damage from coastal storms. Tidal wetlands are inherently vulnerable because of their low elevations, and shoreline development prevents them from migrating inland onto higher ground. Human activities such as filling wetlands have destroyed about one third of New England's coastal wetlands since the early 1800s. Wetlands provide habitat for many bird species, such as osprey and heron, as well as several fish species. Losing coastal wetlands would harm coastal ecosystems and remove an important line of defense against coastal flooding.

The marshes of Plum Island Estuary are among those predicted to submerge in the next century. Credit: Matthew Kirwan, USGS.

Sea level rise, stronger storms, and coastal erosion threaten parts of the New England coastline such as these homes in Newburyport. Credit: Trish Garrigan, EPA.

Coastal cities and towns will become more vulnerable to storms in the coming century as sea level rises, shorelines erode, and storm surges become higher. Storms can destroy coastal homes, wash out highways and rail lines, and damage essential communication, energy, and wastewater management infrastructure. In the city of Boston alone, the total cost of storm damages during the 21st century could be between $5 and $100 billion, depending on how the city responds to rising sea level.

Ecosystems and Natural Resources

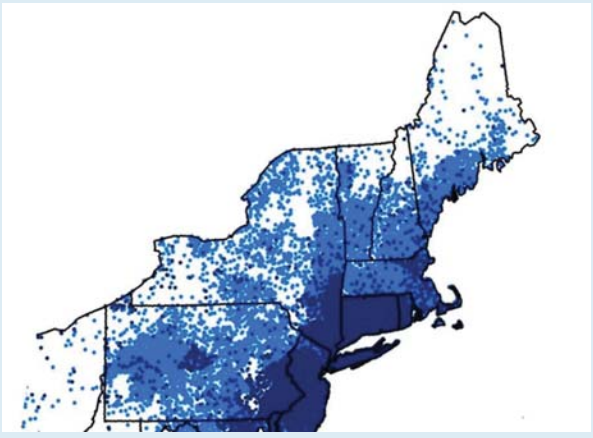
Changing the climate threatens ecosystems by disrupting relationships between species. Wildflowers and woody perennials are blooming—and migratory birds are arriving—sooner in spring. Not all species adjust in the same way, however, so the food that one species needs may no longer be available when that species arrives on its migration. Warmer temperatures allow deer populations to increase, leading to a loss of forest underbrush, which makes some animals more vulnerable to predators. Rising temperatures also enable invasive species to move into areas that were previously too cold.

Parts of Massachusetts's fishing and farming sectors may suffer as the climate changes. Rising water temperatures can lower oxygen levels and otherwise alter freshwater and marine ecosystems. Some species such as bass may flourish more readily in the Northeast's warming waters, but key ocean fisheries, such as cod and lobster south of Cape Cod, are expected to decline. The loss of coastal wetlands could harm bass, clams, and other commercially important fish. Climate change may also pose challenges for agriculture: Some farms may be harmed if more hot days and droughts reduce crop yields, or if more flooding and wetter springs delay their planting dates. Other farms may benefit from a longer growing season and the fertilizing effect of carbon dioxide.

Human Health

Changes in temperature and precipitation could increase the incidence of acute and chronic respiratory conditions such as asthma. Higher temperatures can increase the formation of ground-level ozone (smog), a pollutant that can contribute to respiratory problems. Rising temperatures may also increase the length and severity of the pollen season for plants such as ragweed. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor.

The risk of some diseases carried by insects may also increase. The ticks that transmit Lyme disease are active when temperatures are above 45°F, so warmer winters could lengthen the season during which ticks can become infected or people are exposed to the ticks. Higher temperatures would also make more of New England warm enough for the Asian tiger mosquito, a common carrier of West Nile virus. The number of cases may or may not increase, depending on what people do to control insect populations and avoid insect bites.



Increase in Lyme disease between 1996 and 2013. Each dark dot shows one case reported in 1996; light dots show 2013. The increased range shown here has been attributed to factors other than climate change. Nevertheless, additional warming will lengthen the season during which people are exposed to Lyme disease and may allow the disease to spread to colder areas. Source: CDC.

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EPA United States Environmental Protection Agency

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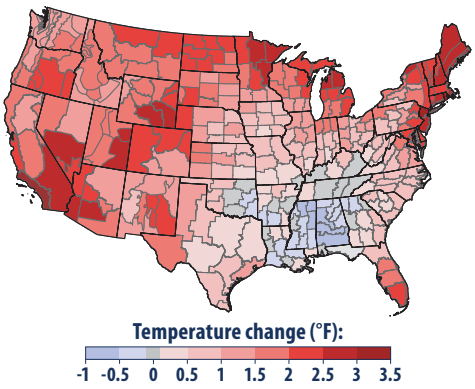
What Climate Change *Means for* Michigan

Michigan's climate is changing. Most of the state has warmed two to three degrees (F) in the last century. Heavy rainstorms are becoming more frequent, and ice cover on the Great Lakes is forming later or melting sooner. In the coming decades, the state will have more extremely hot days, which may harm public health in urban areas and corn harvests in rural areas.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has also warmed about one degree during the last 80 years. Although warmer temperatures cause sea level to rise, the impact on water levels in the Great Lakes is not yet known. Warmer air also melts ice and snow earlier in spring.



Rising temperatures in the last century. Northern Michigan has warmed more than southern Michigan. Source: EPA, Climate Change Indicators in the United States.

Heavy Precipitation and Flooding

Changing the climate is likely to increase the frequency of floods in Michigan. Over the last half century, average annual precipitation in most of the Midwest has increased by 5 to 10 percent. But rainfall during the four wettest days of the year has increased about 35 percent. During the next century, spring rainfall and annual precipitation are likely to increase, and severe rainstorms are likely to intensify. Each of these factors will tend to further increase the risk of flooding.

Heavy rains and snowmelt flooded the Tittabawassee River in Midland in April 2015. Credit: City of Midland.

Great Lakes

Changing the climate is likely to harm water quality in Lake Erie and Lake Michigan. Warmer water tends to cause more algal blooms, which can be unsightly, harm fish, and degrade water quality. During August 2014, an algal bloom in Lake Erie prompted the Monroe County Health Department to advise residents in four townships to avoid using tap water for cooking and drinking. Severe storms increase the amount of pollutants that run off from land to water, so the risk of algal blooms will be greater if storms become more severe. Severe rainstorms can also cause sewers to overflow into lakes and rivers, which can threaten beach safety and drinking water supplies. For example, heavy rains in August 2014 led to nearly 10 billion gallons of sewer overflows in southeastern Michigan, much of which ended up in Lake St. Clair and eventually Lake Erie. More severe rainstorms could also cause sewers in Milwaukee and Chicago to overflow into Lake Michigan more often, which could pollute beaches in Michigan.

One advantage of climate change is that warmer winters reduce the number of days that ice prevents navigation. Between 1994 and 2011, the decline in ice cover lengthened the shipping season on the Great Lakes by eight days. The lakes are likely to warm another 3° to 7°F in the next 70 years, which will further extend the shipping season.

Ice forming on Lake Michigan near St. Joseph. Credit: M. McCormick, NOAA Great Lakes Environmental Research Laboratory.

Winter Recreation

Warmer winters are likely to shorten the season for recreational activities like ice fishing, snowmobiling, snowboarding, and skiing, which could harm the local economies that depend on them. Small lakes are freezing later and thawing earlier than a century ago, which shortens the season for ice fishing and ice skating. Since the early 1970s, winter ice coverage in the Great Lakes has decreased by 63 percent. Warmer temperatures are likely to shorten the season when the ground is covered by snow, and thereby shorten the season for activities that take place on snow. Nevertheless, annual snowfall has increased in much of the Great Lakes region, which could benefit winter recreation at certain times and locations.

Ecosystems

The ranges of plants and animals are likely to as the climate changes. For example, warmer weather could change the composition of Michigan's forests. As the climate warms, the population of paper birch, quaking aspen, balsam fir, and black spruce may decline in the Upper Peninsula and northern Lower Peninsula, while oak, hickory, and pine trees may become more numerous. Climate change will also transform fish habitat. Rising water temperatures will increase the available habitat for warmwater fish such as bass, while shrinking the available habitat for coldwater fish such as trout. Declining ice cover and increasingly severe storms would harm both types of fish habitat through erosion and flooding.

Warming could also harm ecosystems by changing the timing of natural processes such as migration, reproduction, and flower blooming. Migratory birds are arriving in the Midwest earlier in spring today than 40 years ago. Along with range shifts, changes in timing can disrupt the intricate web of relationships between animals and their food sources and between plants and pollinators. Because not all species adjust to climate change in the same way, the food that one species eats may no longer be available when that species needs it (for example, when migrating birds arrive). Some types of animals may no longer be able to find enough food.

Agriculture

Changing the climate will have both beneficial and harmful effects on farming. Higher concentrations of atmospheric carbon dioxide and longer frost-free growing seasons would increase yields of wheat during an average year. But increasingly hot summers are likely to reduce yields of corn and possibly soybeans. Seventy years from now, Michigan's Lower Peninsula is likely to have 5 to 15 more days per year with temperatures above 95°F than it has today. More severe droughts or floods would also hurt crop yields.

Air Pollution and Human Health

Changing the climate can harm air quality and amplify existing threats to human health. Higher temperatures increase the formation of ground-level ozone, a pollutant that causes lung and heart problems. Ozone also harms plants. In some rural parts of Michigan, ozone levels are high enough to significantly reduce yields of soybeans and winter wheat. EPA and the Michigan Department of Environmental Quality have been working to reduce ozone concentrations. As the climate changes, continued progress toward clean air will become more difficult.

Hot days can be unhealthy—even dangerous. High temperatures can cause heat stroke and dehydration, and affect people's cardiovascular and nervous systems. Northern cities like Detroit are vulnerable to heat waves, because many houses and apartments lack air conditioning, and urban areas are typically warmer than their rural surroundings. In recent decades, severe heat waves have killed hundreds of people across the Midwest. Heat stress is expected to increase as climate change brings hotter summer temperatures and more humidity. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor.

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EPA United States Environmental Protection Agency

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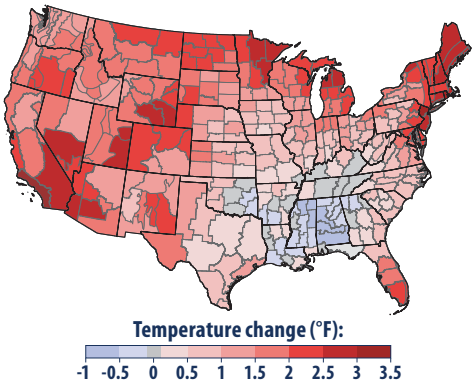
What Climate Change *Means for* Minnesota

Minnesota's climate is changing. The state has warmed one to three degrees (F) in the last century. Floods are becoming more frequent, and ice cover on lakes is forming later and melting sooner. In the coming decades, these trends are likely to continue. Rising temperatures may interfere with winter recreation, extend the growing season, change the composition of trees in the North Woods, and increase water pollution problems in lakes and rivers. The state will have more extremely hot days, which may harm public health in urban areas and corn harvests in rural areas.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has also warmed about one degree during the last 80 years. Although warmer temperatures cause sea level to rise, the impact on water levels in the Great Lakes is not yet known. Warmer air also melts ice and snow earlier in spring.



Rising temperatures in the last century. Northern Minnesota has warmed more than twice as much as southern Minnesota. Source: EPA, Climate Change Indicators in the United States.

Heavy Precipitation and Flooding

Changing the climate is likely to increase the frequency of floods in Minnesota. Over the last half century, average annual precipitation in most of the Midwest has increased by 5 to 10 percent. But rainfall during the four wettest days of the year has increased about 35 percent. During the next century, spring rainfall and annual precipitation are likely to increase, and severe rainstorms are likely to intensify. Each of these factors will tend to further increase the risk of flooding.

Lakes and Rivers

Flooding of the Red River in East Grand Forks in 1997. Credit: Dave Saville, FEMA.

Flooding is occasionally a problem for both navigation and riverfront communities, and greater river flows could make these problems worse. In the Red River watershed, river flows during the worst flood of the year have been increasing about 10 percent per decade since the 1920s. Floods are also becoming more severe in the upper Mississippi watershed. In June 2014, a flood forced two port facilities in St. Paul to stop operating, and barges waiting to unload had to be temporarily parked in Pigs Eye Lake until the river receded. Increasingly severe droughts elsewhere in the Mississippi River Basin could also pose problems for navigation in Minnesota. For example, a drought in 2012 led the U.S. Army Corps of Engineers to restrict navigation on the lower Mississippi River, which affected shipping upstream.

One advantage of climate change is that warmer winters reduce the number of days that ice prevents navigation. Between 1994 and 2011, the decline in ice cover lengthened the shipping season on the Great Lakes by eight days. The Great Lakes are likely to warm another 3° to 7°F in the next 70 years, which will further extend the shipping season.

Higher temperatures and heavier storms could harm water quality in Minnesota's lakes and rivers. Warmer water tends to cause more algal blooms, which can be unsightly, harm fish, and degrade water quality. Severe storms increase the amount of pollutants that run off from land to water, so the risk of algal blooms will be greater if storms become more severe. Increasingly severe storms could also cause sewers to overflow into lakes or rivers more often, threatening beach safety and drinking water supplies.

Ecosystems

The ranges of plants and animals are likely to shift as the climate changes. For example, warmer weather could change the composition of Minnesota's forests. As the climate warms, the populations of paper birch, quaking aspen, balsam fir, and black spruce trees may decline in the North Woods, while oak, hickory, and pine trees may become more numerous. Climate change will also transform fish habitat. Rising water temperatures will increase the available habitat for warmwater fish such as bass, while shrinking the available habitat for coldwater fish such as trout. Declining ice cover and increasingly severe storms would harm both types of fish habitat through erosion and flooding.

Warming could also harm ecosystems by changing the timing of natural processes such as migration, reproduction, and flower blooming. Migratory birds are arriving in Minnesota earlier in spring today than 40 years ago. Along with range shifts, changes in timing can disrupt the intricate web of relationships between animals and their food sources and between plants and pollinators. Because not all species adjust to climate change in the same way, the food that one species eats may no longer be available when that species needs it (for example, when migrating birds arrive). Some types of animals may no longer be able to find enough food.

Winter Recreation

Warmer winters are likely to shorten the season for recreational activities like ice fishing, snowmobiling, skiing, and snowboarding, which could harm the local economies that depend on them. Small lakes are freezing later and thawing earlier than a century ago, which shortens the season for ice fishing and ice skating. Since the early 1970s, winter ice coverage in the Great Lakes has decreased by 63 percent. Warmer temperatures are likely to shorten the season when the ground is covered by snow, and thereby shorten the season for activities that take place on snow. Nevertheless, annual snowfall has increased in much of the Great Lakes region, which could benefit winter recreation at certain times and locations.

Agriculture

Changing the climate is likely to have both positive and negative effects on agriculture in Minnesota. Warmer weather has extended the growing season by about 15 days since the beginning of the 20th century. Longer frost-free growing seasons and higher concentrations of atmospheric carbon dioxide would increase yields of soybeans and wheat during an average year. But increasingly hot summers may reduce yields of corn. In seventy years, southern Minnesota is likely to have 5 to 15 more days per year with temperatures above 95°F than it has today. More severe droughts or floods would also hurt crop yields.

Air Pollution and Human Health

Changing the climate can harm air quality and amplify existing threats to human health. Higher temperatures increase the formation of ground-level ozone, a pollutant that causes lung and heart problems. Ozone also harms plants. In some rural parts of Minnesota, ozone levels are high enough to reduce yields of soybeans and winter wheat. EPA and the Minnesota Pollution Control Agency have been working to reduce ozone concentrations. As the climate changes, continued progress toward clean air will become more difficult.

Climate change may also increase the length and severity of the pollen season for allergy sufferers. For example, the ragweed season in Minneapolis is 21 days longer than in 1995, because the first frost in fall is later. The risk of some diseases carried by insects may also increase. The ticks that transmit Lyme disease are active when temperatures are above 45°F, so warmer winters could lengthen the season during which ticks can become infected or people can be exposed to the ticks.

Hot days can be unhealthy, even dangerous. High air temperatures can cause heat stroke and dehydration, and affect people's cardiovascular and nervous systems. Northern cities like Minneapolis and St. Paul are vulnerable to heat waves, because many houses and apartments lack air conditioning, and urban areas are typically warmer than their rural surroundings. In recent decades, severe heat waves have killed hundreds of people across the Midwest. Heat stress is expected to increase as climate change brings hotter summer temperatures and more humidity. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor.

A photo of a ragweed plant, a common source of allergens in Minnesota. Like many crops and pollen sources, ragweed will have a longer growing season as temperatures rise. Stock photo.

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EPA United States Environmental Protection Agency

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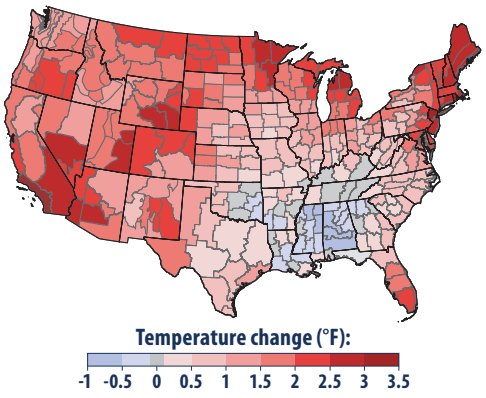
What Climate Change *Means for* Mississippi

In the coming decades, **Mississippi** will become warmer, and both floods and droughts may be more severe. Unlike most of the nation, Mississippi did not become warmer during the last 50 to 100 years. But soils have become drier, annual rainfall has increased, more rain arrives in heavy downpours, and sea level is rising about one inch every seven years. The changing climate is likely to increase damages from tropical storms, reduce crop yields, harm livestock, increase the number of unpleasantly hot days, and increase the risk of heat stroke and other heat-related illnesses.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree (F) during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others. While most of the earth warmed, natural cycles and sulfates in the air cooled Mississippi. Sulfates are air pollutants that reflect sunlight back into space. Now sulfate emissions are declining, and the factors that once prevented the state from warming are unlikely to persist.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has warmed about one degree during the last 80 years. Warming is causing snow to melt earlier in spring, and mountain glaciers are retreating. Even the great ice sheets on Greenland and Antarctica are shrinking. Thus the sea is rising at an increasing rate.



Changing temperatures in the last century. While most of the nation has warmed, Mississippi and a few other states have cooled. Source: EPA, Climate Change Indicators in the United States.

Rising Seas and Retreating Shores

Sea level is rising more rapidly in Mississippi than most coastal areas because the land is sinking. If the oceans and atmosphere continue to warm, sea level along the Mississippi coast is likely to rise between twenty inches and four feet in the next century. Rising sea level submerges wetlands and dry land, erodes beaches, and exacerbates coastal flooding. Coastal communities along Mississippi Sound are protected by undeveloped barrier islands, so erosion of those islands could threaten communities on the mainland.

Storms, Homes, and Infrastructure

Tropical storms and hurricanes have become more intense during the past 20 years. Although warming oceans provide these storms with more potential energy, scientists are not sure whether the recent intensification reflects a long-term trend. Nevertheless, hurricane wind speeds and rainfall rates are likely to increase as the climate continues to warm.

Hurricane Katrina's storm surge and high winds destroyed the homes on these three lots in Long Beach, and many others. Credit: John Fleck, FEMA.

Whether or not storms become more intense, coastal homes and infrastructure will flood more often as sea level rises, because storm surges will become higher as well. Rising sea level is likely to increase flood insurance rates, while more frequent storms could increase the deductible for wind damage in homeowner insurance policies. Many cities, roads, railways, ports, airports, and oil and gas facilities along the Gulf Coast are vulnerable to the combined impacts of storms and sea level rise. People may move from vulnerable coastal communities and stress the infrastructure of the communities that receive them.

Flooding and River Transportation

Changing the climate is also likely to increase inland flooding. Vicksburg and Natchez are vulnerable to high water levels on the Mississippi River. Since 1958, the amount of precipitation during heavy rainstorms has increased by 27 percent in the Southeast, and the trend toward increasingly heavy rainstorms is likely to continue. Moreover, streamflows in the Midwest are increasing, and the amount of rainfall there is also likely to increase, which could increase flooding in Mississippi, because most of the Midwest drains into the Mississippi River.

Droughts create a different set of challenges. During severe droughts in the Mississippi River's watershed, low flows can restrict commercial navigation. For example, low water in 2012 forced the U.S. Army Corps of Engineers to reduce allowable barge sizes on the Mississippi River and close the river at Greenville for more than a week, which delayed approximately 100 barges.

The Mississippi River flooded parts of Vicksburg in May 2011, including the old railroad depot shown here. Credit: Patrick Moes, U.S. Army Corps of Engineers.

Agriculture

Changing the climate will have both harmful and beneficial effects on farming. Seventy years from now, Mississippi is likely to have 30 to 60 days per year with temperatures above 95°F, compared with about 15 days today. Even during the next few decades, hotter summers are likely to reduce yields of corn. But higher concentrations of atmospheric carbon dioxide increase crop yields, and that fertilizing effect is likely to offset the harmful effects of heat on soybeans, cotton, wheat, and peanuts—if enough water is available. More severe droughts, however, could cause crop failures. Higher temperatures are also likely to reduce livestock productivity, because heat stress disrupts the animals' metabolism.

Forest Resources

Higher temperatures and changes in rainfall are unlikely to substantially reduce forest cover in Mississippi, although the composition of trees in the forests may change. More droughts would reduce forest productivity, and climate change is also likely to increase the damage from insects and disease. But longer growing seasons and higher carbon dioxide concentrations could more than offset the losses from those factors. Forests cover almost two-thirds of the state. Oak, hickory, and white pine trees are most common in the northern part of the state, except along the Mississippi River delta. In the southern part of the state, loblolly and longleaf pines are most common. As the climate warms, forests in southern Mississippi are likely to have more oaks and white pines, and fewer loblolly and longleaf pines.

Human Health

Hot days can be unhealthy—even dangerous. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor. High air temperatures can cause heat stroke and dehydration and affect people's cardio-vascular and nervous systems. Warmer air can also increase the formation of ground-level ozone, a key component of smog. Ozone has a variety of health effects, aggravates lung diseases such as asthma, and increases the risk of premature death from heart or lung disease. EPA and the Mississippi Department of Environmental Quality have been working to reduce ozone concentrations. As the climate changes, continued progress toward clean air will become more difficult.

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United States Environmental Protection Agency

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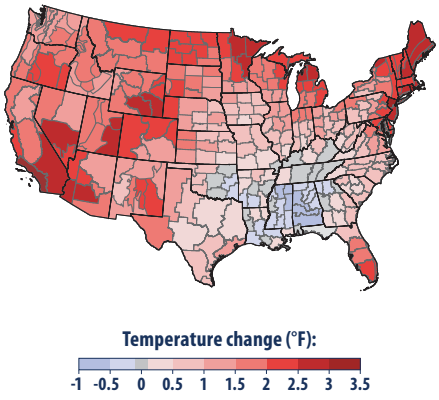
What Climate Change *Means for* Missouri

Missouri's climate is changing. Most of the state has warmed one-half to one degree (F) in the last century, and floods are becoming more frequent. In the coming decades, the state will have more extremely hot days, which may harm public health in urban areas and corn harvests in rural areas.

Our climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.



Rising temperatures in the last century. Missouri has warmed less than most of the United States. Source: EPA, Climate Change Indicators in the United States.

Heavy Precipitation and Flooding

Changing the climate is likely to increase the frequency of floods in Missouri. Over the last half century, average annual precipitation in most of the Midwest has increased by 5 to 10 percent. But rainfall during the four wettest days of the year has increased about 35 percent, and the amount of water flowing in most streams during the worst flood of the year has increased by more than 20 percent. During the next century, spring rainfall and average precipitation are likely to increase, and severe rainstorms are likely to intensify. Each of these factors will tend to further increase the risk of flooding.

Mississippi and Missouri Rivers

Flooding occasionally threatens navigation and riverfront communities, and greater river flows could increase these threats. In April and May 2011, a combination of heavy rainfall and melting snow caused a flood that closed the Mississippi River to navigation, threatened Caruthersville, and prompted evacuation of Cairo, Illinois, due to concerns that its flood protection levees might fail. To protect Cairo, the U.S. Army Corps of Engineers opened the Birds Point-New Madrid Floodway, which lowered the river by flooding more than 100,000 acres of farmland in Missouri. Later that spring, heavy rains and rapid snowmelt upstream led to flooding along the Missouri River, which damaged property and closed the river to navigation.

Heavy rain led to flooding around St. Louis in December 2015, including this area in Valley Park. Credit: Cpl. Alex Flynn, Missouri Army National Guard.

Although springtime in Missouri is likely to be wetter, summer droughts are likely to be more severe. Higher evaporation and lower summer rainfall are likely to reduce river flows. The drought of 2012 narrowed navigation channels, forced lock closures, and caused dozens of barges to run aground on the Mississippi River along the Missouri shoreline. The resulting impact on navigation cost the region more than $275 million. The drought of 2012–2013 also threatened municipal and industrial water users along the Missouri River.

Tornadoes

Scientists do not know how the frequency and severity of tornadoes will change. Increasing concentrations of greenhouse gases tend to increase humidity, and thus, atmospheric instability, which would encourage tornadoes. But wind shear is likely to decrease, which would discourage tornadoes. Research is ongoing to learn whether tornadoes will be more or less frequent in the future. Because Missouri experiences about 50 tornadoes a year, such research is closely followed by meteorologists in the state.

Forests

Higher temperatures and changes in rainfall are unlikely to substantially reduce forest cover in Missouri, although the composition of trees in the forests may change. More droughts would reduce forest productivity, and climate change is also likely to increase the damage from insects and diseases. But longer growing seasons and increased carbon dioxide concentrations could more than offset the losses from those factors. Forests cover about one-third of the state, dominated by oak and hickory trees. As the climate changes, the abundance of pines in Missouri's forests is likely to increase, while the population of hickory trees is likely to decrease.

Agriculture

Changing the climate will have both harmful and beneficial effects on farming. Seventy years from now, Missouri is likely to have more than 25 days per year with temperatures above 95°F, compared with 5 to 15 today. Hot weather causes cows to eat less, produce less milk, and grow more slowly—and it could threaten their health. Even during the next few decades, hotter summers are likely to reduce yields of corn. But higher concentrations of atmospheric carbon dioxide increase crop yields, and that fertilizing effect is likely to offset the harmful effects of heat on soybeans, assuming that adequate water is available. On farms without irrigation, however, increasingly severe droughts could cause more crop failures. More severe droughts or floods would also hurt crop yields.

Air Pollution and Human Health

Changing the climate can harm air quality and amplify existing threats to human health. Higher temperatures can increase the production of ground-level ozone, a pollutant that can cause lung and heart problems. Ozone also harms plants. In some rural parts of Missouri, ozone levels are high enough to significantly reduce yields of soybeans and winter wheat. EPA and the Missouri Department of Natural Resources have been working to reduce ozone concentrations. As the climate changes, continued progress toward clean air will become more difficult.

Climate change may also increase the length and severity of the pollen season for allergy sufferers. For example, the ragweed season in Kansas City has grown 18 days longer since 1995, because the first frost in fall is later.

A photo of a ragweed plant, a common source of allergens in Missouri. Like many crops and pollen sources, ragweed will have a longer growing season as temperatures rise. Stock photo.

Hot days can be unhealthy—even dangerous. High air temperatures can cause heat stroke and dehydration, and affect people's cardiovascular and nervous systems. Midwestern cities like St. Louis are vulnerable to heat waves, because many houses and apartments lack air conditioning, and urban areas are typically warmer than their rural surroundings. In recent decades, severe heat waves have killed hundreds of people across the Midwest. Heat stress is expected to increase as climate change brings hotter summer temperatures and more humidity. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor.

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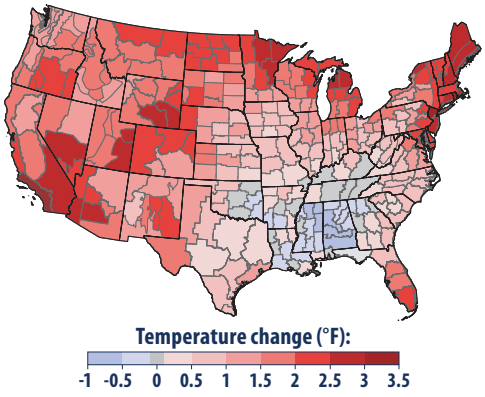
What Climate Change *Means for* Montana

Montana's climate is changing. In the past century, most of the state has warmed about two degrees (F). Heat waves are becoming more common, and snow is melting earlier in spring. Rising temperatures and recent droughts have killed many trees by drying out soils, increasing the risk of forest fires, or enabling outbreaks of forest insects. In the coming decades, the changing climate is likely to decrease the availability of water in Montana, affect agricultural yields, and further increase the risk of wildfires.

The climate is changing because Earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

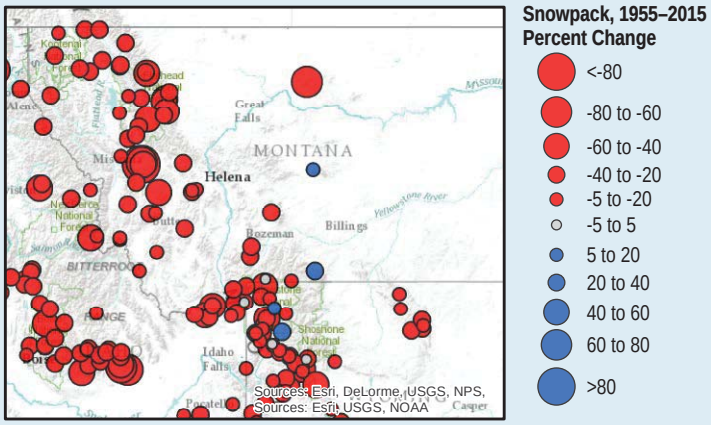
Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has warmed about one degree during the last 80 years, and sea level is rising at an increasing rate. Warming is causing snow to melt earlier in spring.



Rising temperatures in the last century. Montana has warmed more than most of the contiguous United States. Source: EPA, Climate Change Indicators in the United States.

Snowpack and Glaciers

As the climate warms, less precipitation falls as snow, and more snow melts during winter. That decreases snowpack—the amount of snow that accumulates over the winter. Since the 1950s, the snowpack in Montana has been decreasing. Diminishing snowpack can shorten the season for skiing and other forms of winter tourism and recreation. The tree line may shift, as higher temperatures and a longer season without snow on the ground allow subalpine fir and other high-altitude trees to grow at higher elevations. A higher tree line would decrease the extent of alpine tundra ecosystems, which could threaten some species.



Trends in April snowpack in Montana, 1955–2013. The snowpack has declined at most monitoring sites in Montana. Source: EPA.

More than one thousand glaciers cover about 26 square miles of mountains in Montana, but that area is decreasing in response to rising temperatures. Glacier National Park's glaciers receded rapidly during the last century. Several of these glaciers are likely to disappear by 2030 if current trends continue. Areas that are no longer covered by glaciers may still accumulate snowpack, but the snow will no longer remain year-round.

Repeat photographs of Sperry Glacier in Glacier National Park. Source: USGS.

Precipitation and Water Resources

Changing the climate is likely to increase the demand for water and make it more available. Warmer temperatures increase evaporation and water use by plants. Increases in rainfall, however, are likely to offset these losses so that soil moisture increases slightly or remains about the same as today. More water is likely to run off into the upper Missouri River and its tributaries.

In areas that depend on melting snow, however, the supply of water is likely to decline. Mountain snowpacks are natural reservoirs that collect the snow that falls during winter and release water when the snow melts during spring and summer. Dams capture meltwater and retain it for use later in the year. But upstream of these dams, as the snowpack declines, less water is available during droughts for ecosystems, water-based recreation, and landowners who draw water directly from a natural lake or flowing river.

Agriculture

Rising temperatures and changes in rainfall are likely to have both positive and negative effects on Montana's farms and ranches, and the net effect is unknown. Higher temperatures reduce yields of wheat, but higher concentrations of carbon dioxide are likely to increase yields by a similar amount. Warmer and shorter winters may allow for a longer growing season, which could allow two crops per year instead of one in some instances. But warmer winters may also promote the growth of weeds and pests.

Rising carbon dioxide concentrations are likely to increase the productivity of rangelands. Provided that the quality of forage does not deteriorate, the higher range productivity would increase cattle production.

Warmer winters could also benefit ranches by reducing losses to winter storms. During the winter of 1996–1997, for example, high winds and heavy snow killed half of the newborn calves and 100,000 adult cows in the Northern Great Plains. But warmer summers would at least partly offset the benefit of warmer winters, because hot weather causes cows to eat less and grow more slowly, and it can threaten their health. Over the next 70 years, the number of days above 100°F in Montana is likely to double.

Wildfires

Higher temperatures and drought are likely to increase the severity, frequency, and extent of wildfires in Montana, which could harm property, livelihoods, and human health. On average, about 2 percent of the land in the state has burned per decade since 1984. Wildfire smoke pollutes the air and can increase medical visits for respiratory and heart problems.

Firefighters battle the Taylor Creek blaze in southeastern Montana in 2012. Credit: Gerald Vickers, National Wildfire Coordinating Group.

Forests

Longer growing seasons and increased carbon dioxide concentrations could increase the productivity of forests, but warmer conditions also make forests more susceptible to pests. Temperature controls the life cycle and winter mortality rates of pests such as bark beetles, which have infested millions of acres and killed millions of trees across the West in recent decades. With higher winter temperatures, some pests can persist year-round, and new pests and diseases may become established. Drought also reduces the ability of trees to mount a defense against attacks from beetles and other pests.

Human Health

Extremely hot and cold days can be unhealthy—even dangerous. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor. The elderly may be particularly prone to heat stress and other heat-related health problems, including dehydration, cardiovascular strain, and respiratory problems. Those with low incomes may be particularly vulnerable if they lack air conditioning. Power failures due to severe weather can also present risks, especially in lightly populated areas where access to the necessary support services may be limited. While these risks will increase as the climate becomes warmer, illnesses and deaths due to cold weather and snow are likely to decline.

The sources of information about climate and the impacts of climate change in this publication are: the national climate assessments by the U.S. Global Change Research Program, synthesis and assessment products by the U.S. Climate Change Science Program, assessment reports by the Intergovernmental Panel on Climate Change, and EPA's *Climate Change Indicators in the United States.* Mention of a particular season, location, species, or any other aspect of an impact does not imply anything about the likelihood or importance of aspects that are not mentioned. For more information about climate change science, impacts, responses, and what you can do, visit EPA's Climate Change website at www.epa.gov/climatechange.