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Climate Change And Maryland

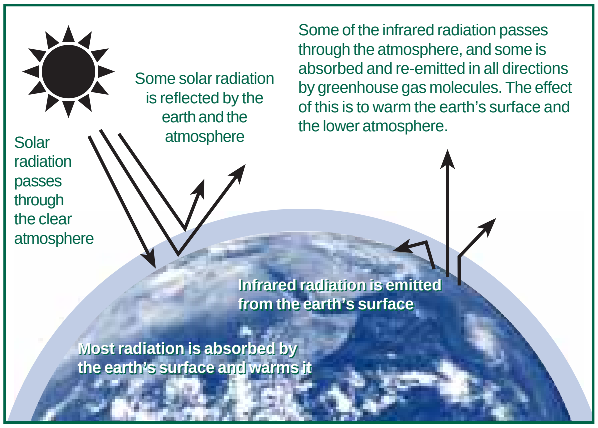
The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases — primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The heat-trapping property of these greenhouse gases is undisputed.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

The Climate System

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

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

The Greenhouse Effect



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

Emissions Of Greenhouse Gases

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

Concentrations Of Greenhouse Gases

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

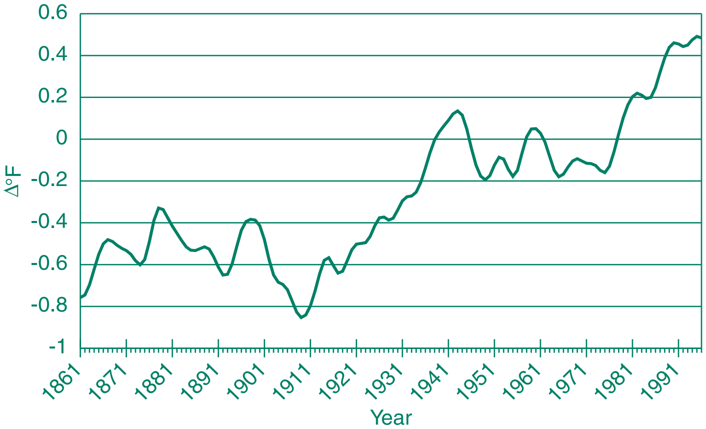
Although many greenhouse gases already are present in the atmosphere, oceans, and vegetation, their concentrations in the future will depend in part on present and future emissions. Estimating future emissions is difficult, because they will depend on demographic, economic, technological, policy, and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

Current Climatic Changes

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

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

Global Temperature Changes (1861–1996)



Source: IPCC (1995), updated

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

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

Future Climatic Changes

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

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

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

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

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

Local Climate Changes

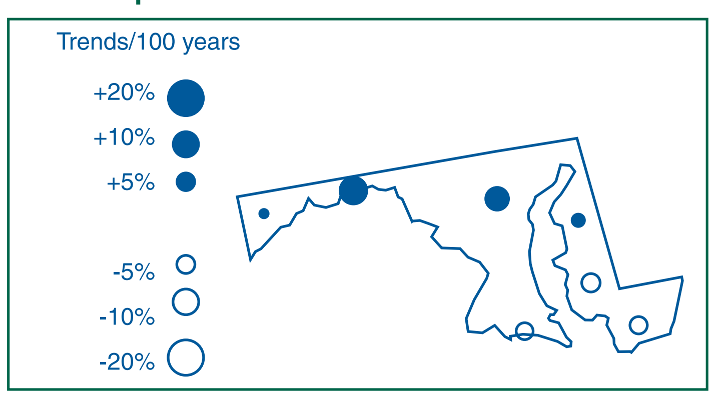
Over the last century, the average temperature in College Park, Maryland, has increased 2.4°F, and precipitation has increased by up to 10% in many parts of the state. These past trends may or may not continue into the future.

Over the next century, Maryland's climate may change even more. For example, based on projections made by the Intergovernmental Panel on Climate Change and results from the United Kingdom Hadley Centre climate model (HadCM2), a model that accounts for both greenhouse gases and aerosols, by 2100 temperatures in Maryland could increase by 3°F (with a range of 1-7°F) in spring and 4°F (with a range of 2-9°F) in the other seasons. Precipitation is projected to increase by 20% (with a range of 10-40%) in all seasons, probably slightly less in spring and fall and slightly more in winter. Other climate models may show different results, especially regarding estimated changes in precipitation. The impacts described in the sections that follow take into account estimates from different models. The amount of precipitation on extreme wet or snowy days in winter is likely to increase. The frequency of extreme hot days in summer would increase because of the general warming trend. Although it is not clear how the severity of storms might be affected, an increase in the frequency and intensity of winter storms is possible.

Human Health

Higher temperatures and increased frequency of heat waves may increase the number of heat-related deaths and the incidence of heat-related illnesses. Maryland, with its irregular, intense heat

Precipitation Trends From 1900 To Present



Source: Karl et al. (1996)

waves, could be susceptible. One study projects that in Baltimore, a warming of 3°F could increase heat-related deaths by 50% from the current 85 to 130, and in Washington, D.C., results indicate slightly smaller increases (although increased air conditioning use may not have been fully accounted for in both estimates). This study also projects that winter-related deaths in Baltimore should remain unaffected, but could increase by a third in Washington, D.C. The exact reasons for these differences are unknown. The elderly, especially those living alone, are at greatest risk.

Climate change could increase concentrations of ground-level ozone. For example, high temperatures, strong sunlight, and stable air masses tend to increase urban ozone levels. In the eastern mid-Atlantic region, a 4°F warming, with no other change in weather or emissions, could increase concentrations of ozone, a major component of smog, by 4%. Currently, ground-level concentrations exceed the national ozone health standard throughout the state. Nearly all of Maryland is classified as a nonattainment area for ozone. Serious to severe nonattainment areas include Baltimore and the suburbs of Washington, D.C. Ground-level ozone is associated with respiratory illnesses such as asthma, reduced lung function, and respiratory inflammation.

Mosquitos carrying malaria, dengue fever, and St. Louis encephalitis are present in Maryland. Warm, wet conditions could increase mosquito populations, increase biting rates, and reduce the incubation rate of the viruses and parasites within them. The incidence of Lyme disease could also increase as warmer temperatures and increased precipitation enhance the habitat for ticks and their rodent hosts. Warmer winters, warmer temperatures, and heavy precipitation also can increase harmful algal blooms, that is, red tides; reduce water quality; and increase the potential for outbreaks of cryptosporidiosis and giardia. These impacts, however, can be minimized through existing disease prevention and control methods.

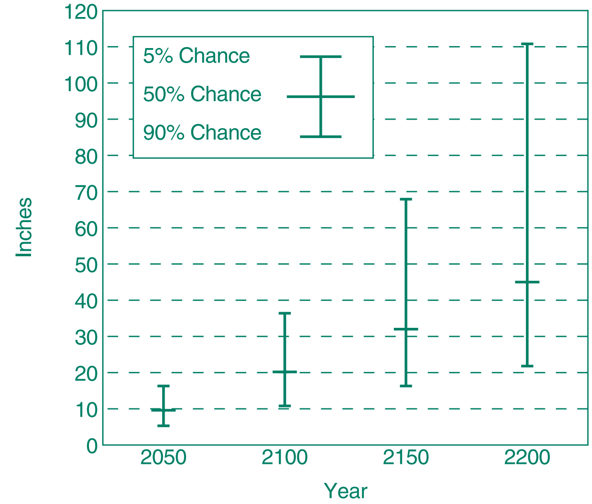
Coastal Areas

Sea level rise could lead to flooding of low-lying property, loss of coastal wetlands, erosion of beaches, saltwater contamination of drinking water, and decreased longevity of low-lying roads, causeways, and bridges. In addition, sea level rise could increase the vulnerability of coastal areas to storms and associated flooding.

Maryland has 3,100 miles of tidally influenced shoreline. It consists of barrier islands such as Assateague Island, the highly urbanized and developed oceanfront of Ocean City, and the extensive eastern shore of Chesapeake Bay. The eastern shore of Chesapeake Bay in Maryland has an extensive array of tidally influenced freshwater and salt marshes, forested wetlands, riverine wetlands, and open water.

At Baltimore, sea level already is rising by 7 inches per century, and it is likely to rise another 19 inches by 2100. Human activities such as impounding and dredging as well as sea level rise have caused extensive losses of coastal wetlands and marshes in both the Chesapeake Bay and Assateague Island regions. With higher

Future Sea Level Rise At Easton



Sources: Lyles et al. (1988); EPA (1995)

sea levels, Assateague Island is likely to migrate toward the mainland as sand is eroded on the ocean side and deposited on the mainland side, and the island's native plant communities, which include some threatened species, are likely to change in distribution and diversity. The 9-mile coastline of Ocean City, which was nourished by a $30 million beach nourishment project in the late 1980s, could be threatened by a rise in sea level.

The cumulative cost of additional sand replenishment to protect Maryland's coastline from a 20-inch sea level rise by 2100 is estimated at $35-$200 million. However, sand replenishment may not be cost-effective for all coastal areas in the state and, therefore, some savings could be possible.

Water Resources

Without increases in precipitation, higher temperatures and increased evaporation would lower streamflows, lake levels, and groundwater levels in the summer and fall. This could adversely affect the many instream uses of water in Maryland, including hydroelectric power generation, navigation, marine commerce, commercial and sport fishing, and recreation. Water supplies for the large and growing metropolitan areas surrounding Baltimore and the District of Columbia could suffer from lower summer streamflows. Drier summer conditions also could reduce groundwater levels, which could be significant for parts of Charles and Prince Georges counties in southern Maryland, which are already experiencing declines in groundwater levels. Groundwater is also the primary source of water for domestic use and irrigated agriculture on the Eastern Shore. Additionally, low flows and higher temperatures in the summer could affect water quality, further aggravating problems with nuisance algae, low dissolved-oxygen levels, and bacterial contamination in urban streams.

If, however, rainfall and runoff increase in the Maryland region, the resulting higher streamflows could alleviate water supply problems and dilute pollutants, although more flooding could occur. Higher runoff also could increase erosion and levels of pesticides and fertilizers from agricultural areas. These chemicals reduce oxygen and limit the types of species that can live in the rivers. Increased runoff from farmlands would exacerbate this effect. It also could increase erosion and pollution from urban and strip mining areas. Although many sources of pollution into Chesapeake Bay have been controlled, runoff containing nutrients, heavy metals, and sediment remains a problem in many tidal areas. Acid mine drainage is also a concern in westernmost Maryland.

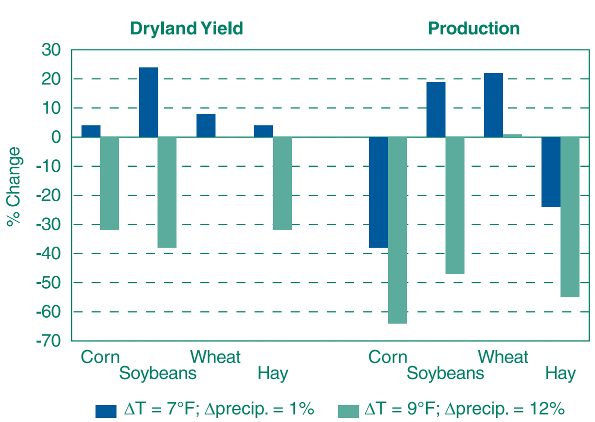
Agriculture

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

Understandably, most studies have not fully accounted for changes in climate variability, water availability, crop pests, changes in air pollution such as ozone, and adaptation by farmers to changing climate. Including these factors could change modeling results substantially. Analyses that assume changes in average climate and effective adaptation by farmers suggest that aggregate U.S. food production would not be harmed, although there may be significant regional changes.

In Maryland, production agriculture is a $1.3 billion annual industry, 60% of which comes from livestock, mainly cattle. Very few of the farmed acres are irrigated. Climate changes could reduce the farmed acres of major crops such as corn, soybeans, wheat, and hay by 24-43%, in response to changes in yields and resulting economic conditions. Projected changes in yields vary widely, depending on how climate changes and whether land is irrigated. For example, under severe conditions, corn and hay yields could fall by 32% and soybeans by 38% as temperatures rise beyond tolerance levels of the crop. Less severe changes, however, could result in increases of 4% and 24%, respectively, as soil moisture and carbon dioxide levels rise.

Changes In Agricultural Yield And Production



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

Forests

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

With changes in climate, the extent and density of forested areas in Maryland could change little or decline by as much as 5-10%. However, the types of trees dominating Maryland forests are likely to change. The warmer mixed forests, dominated by southern pines and oaks, would spread northward, replacing the predominantly hardwood forests currently found in the northern and western sections of the state. Maritime forests, important for their recreational and aesthetic value and for their role in coastal hydrology, could be affected adversely by changes in the frequencies of large storms associated with climate change (hurricanes in the late summer and fall, nor'easters in the winter and spring). Coastal estuaries are breeding grounds for important commercial fish and shellfish species, and changes in the hydrology of upland forests in Maryland could have profound effects on these sensitive coastal systems.

Ecosystems

The diverse habitats of Maryland's Chesapeake Bay (including underwater grass beds, salt marshes, forested wetlands, and upland forests) provide a home for more than 2,700 species of animals and plants. The Blackwater Wildlife Refuge on the eastern shore of the bay has the largest concentration of nesting bald eagles on the east coast north of Florida, and is vital for migratory waterfowl and shorebirds. These wetlands are also important agents of flood control and water quality.

Chesapeake Bay has already begun to feel the effects of sea level rise. Rising sea level enables saltwater to penetrate farther inland and upstream, and the more than 150 streams and rivers that flow into the bay could be affected. Intruding salt water and increasing sedimentation are choking many marshes. Since 1938, the rising sea has destroyed one-third of the marsh at Blackwater. Most of the remaining marsh in this area is projected to disappear within 30 years. Inundation of lowland habitats surrounding the marshes could result in the disappearance of habitat for migratory birds and other species, for example, the endangered Delmarva fox squirrel.

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