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Climate Change And Virginia

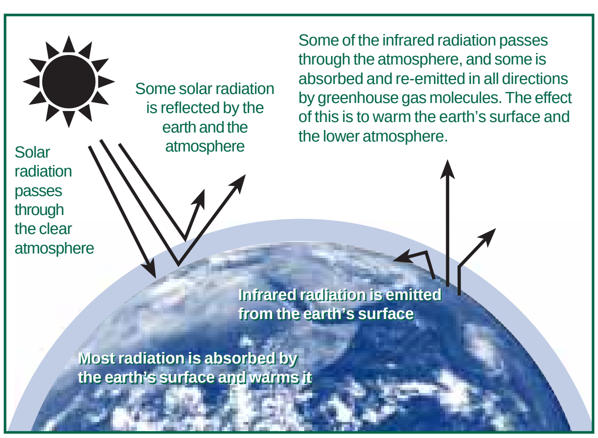
The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases — primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The heat-trapping property of these greenhouse gases is undisputed.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

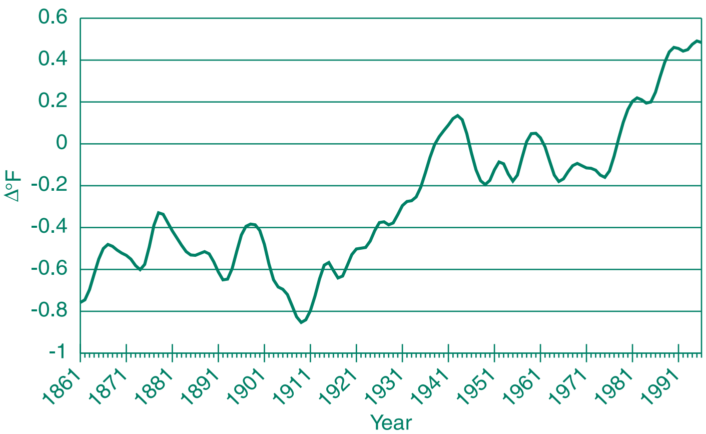
Although many greenhouse gases already are present in the atmosphere, oceans, and vegetation, their concentrations in the future will depend in part on present and future emissions. Estimating future emissions is difficult, because they will depend on demographic, economic, technological, policy, and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

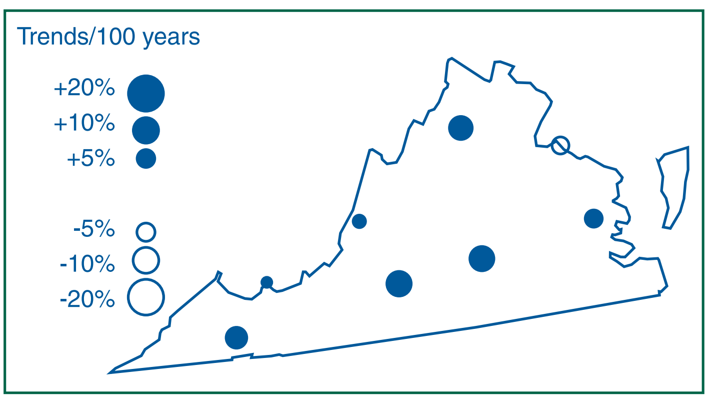
Calculations of regional climate change are much less reliable than global ones, and it is unclear whether regional climate will become more variable. The frequency and intensity of some extreme weather of critical importance to ecological systems (droughts, floods, frosts, cloudiness, the frequency 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 near Richmond, Virginia, has increased 0.2°F, and precipitation has increased by up to 10% in many parts of the state. However, trends in other parts of Virginia show decreases in temperature. The exact reasons for these differences in trends are unknown. However, there are regional differences in the concentrations of particulates and aerosols in the atmosphere that affect the amount of heat that is trapped or reflected. These past trends may or may not continue into the future.

Over the next century, Virginia'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 Virginia could increase by 3°F in winter, spring, and summer (with a range of 1-6°F), and 4°F in fall (with a range of 2-8°F). Precipitation is estimated to increase by 20% in all seasons (with a range of 10-30%). Other climate models may show different results, especially regarding estimated changes in precipitation. The impacts described in the sections that follow take into account estimates from different models. The frequency of extreme hot days in summer would increase because of the general warming trend. Although it is not clear how the severity of storms such as hurricanes might be affected, an increase in the frequency and intensity of winter storms is possible.

Precipitation Trends From 1900 To Present



Source: Karl et al. (1996)

Human Health

Higher temperatures and increased frequency of heat waves may increase the number of heat-related deaths and the incidence of heat-related illnesses. Virginia, with its irregular, intense heat waves, could be susceptible. To the south, one study projects increases of nearly 70% given a warming of 3-4°F (although increased air conditioning use may not have been fully accounted for). However, heat-related deaths could increase slightly around and north of Washington, D.C. This study also projects that winter-related deaths could remain unaffected in the southern part of the state, but could rise by a third in the northern part of the state near Washington, D.C. The elderly, especially those living alone, are at greatest risk. The exact reasons for these differences are unknown.

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 at several locations throughout the state. These areas include the "serious nonattainment areas" near Washington, D.C. Ground-level ozone is associated with respiratory illnesses such as asthma, reduced lung function, and respiratory inflammation.

Warm waters encourage a shift in species from plankton to toxic algae associated with human shellfish poisoning and fish kills. Mosquitos carrying malaria, dengue fever, and St. Louis encephalitis are present in Virginia. Warm, wet conditions could increase mosquito populations, increase biting rates, and reduce the incubation rate of the viruses and parasites within them, perhaps leading to increased risk of disease transmission where these diseases are introduced into the area. Rodent populations that carry hantavirus and leptospirosis (a bacterium) are sensitive to climatic factors. Drought can reduce rodent predators (owls, snakes, coyotes), and sudden rains can increase the number of rodents.

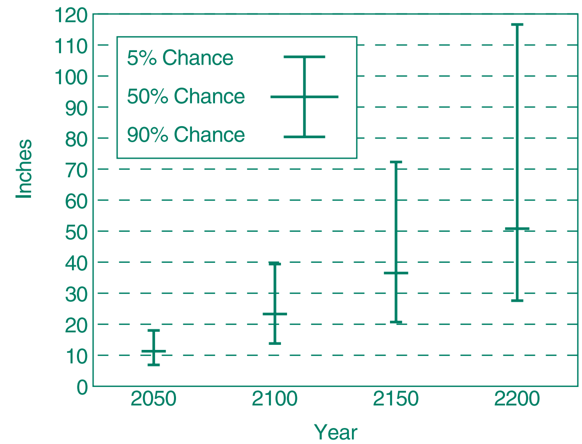
Developed countries such as the United States should be able to minimize the impacts of these diseases through existing disease prevention and control methods.

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.

Virginia is endowed with over 3,300 miles of tidally influenced shoreline. It consists of barrier islands, the sandy beaches of the Delmarva peninsula, as well as the western shore of Chesapeake Bay, the nation's largest estuary. The western shore of Chesapeake Bay features a diversity of tidally influenced wetlands, including freshwater and flooded hardwood marshes, brackish marshes, and riverine wetlands. Because of human activities such as dredging, as well as a slow natural rate of sediment accretion, rising sea levels are likely to increase inundation and salinity intrusion in these ecosystems. Virginia's existing barrier beaches are currently eroding rapidly (tens of feet per year). If sea level were to rise 3 feet or more, Virginia's existing barrier beaches could disappear, causing further erosion of salt marshes.

Future Sea Level Rise At Newport News



Source: EPA (1995)

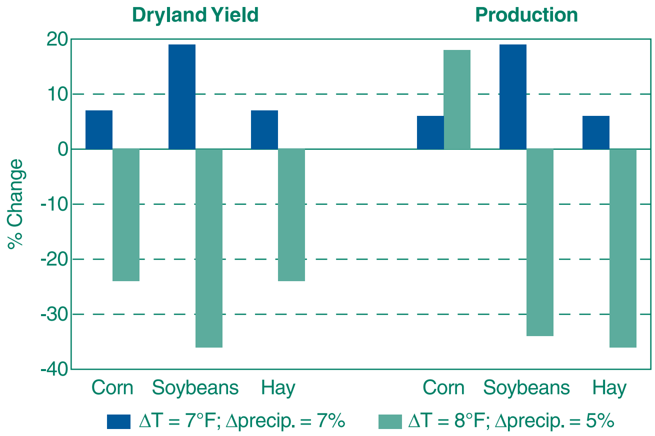
At Newport News, sea level already is rising by 12 inches per century, and it is likely to rise another 23.3 inches by 2100. The cumulative cost of sand replenishment to protect Virginia's coastline from a 20-inch sea level rise by 2100 is estimated at $200 million to $1.2 billion.

Water Resources

In the mountainous portions of the state, winter warming could cause more of the precipitation to fall as rain. In other areas of the state, without increases in rainfall, higher temperatures and evaporation in the summer would also cause drier summer conditions. This could result in lower streamflows, lake levels, and groundwater levels. In densely populated areas along the James and Roanoke rivers, competition for water to meet public and industrial needs could increase. Groundwater levels in the coastal plain also could decline further. Warmer temperatures could increase water quality problems such as algae and eutrophication.

If rainfall and runoff increase with a warmer climate, many of these problems would be reduced. However, this could lead to increased problems from flooding, particularly in the Appalachian region. Higher rainfall also could increase erosion and runoff of pollutants from agricultural, urban, and mining areas, and could increase concentrations of fertilizers, heavy metals, and organic substances. The rivers of Virginia currently receive large amounts of chemicals from farming, including fertilizers. These chemicals reduce oxygen and limit the types of species that can live in the rivers. Increased runoff from farmlands would exacerbate this effect. These already are a concern in the sediments of the James and Shenandoah rivers and in estuaries along Chesapeake Bay.

Changes In Agricultural Yield And Production



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

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 Virginia, production agriculture is a $2 billion annual industry, two-thirds of which comes from livestock. Very few of the farmed acres are irrigated. The major crops in the state are corn, soybeans, hay, and tobacco. Crop and pasture yields could fall by as much as 36% under severe conditions where temperatures rise beyond the tolerance levels of the crop, or could rise by 19%, depending on how climate changes. Farmed acres are projected to remain fairly constant. Estimated changes in yield vary, depending on whether land is irrigated. Livestock and dairy production may not be affected, unless summer temperature rises significantly and conditions become significantly drier. Under these conditions, livestock tends to gain less weight and pasture yields decline, limiting forage.

Forests

Trees and forests are adapted to specific climate conditions, and as climate warms, forests will change. These changes could include changes in species composition, geographic range, and health and productivity. If conditions also become drier, the current range of forests could be reduced and replaced by grasslands and pasture. Even a warmer and wetter climate could lead to changes; trees that are better adapted to warmer conditions, such as 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 Virginia could change little or decline by as much as 5-10%. However, the types of trees dominating those 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).

Ecosystems

High-elevation sites of the southern Appalachians in Virginia contain remnants of northern forests such as red spruce and Fraser fir trees. Birds normally associated with forests far to the north, such as the Canada and Blackburnian warblers, inhabit these forest types. Another valuable ecosystem is the eastern shore, which has been designated a priority watershed. This coastal area contains barrier reefs and tidal marshes, which are important habitat for three endangered species (loggerhead sea turtles, peregrine falcons, and piping plovers).

The Appalachian spruce-fir forests are already threatened by air pollution (acid rain and ground-level ozone) and exotic pests (hemlock wooly adelgid). These forests could be further stressed by climate change as conditions suitable for growth of red spruce and Fraser fir decline with warmer and drier conditions. The southern Appalachians are a globally important center of diversity for salamanders, which are very sensitive to climatic factors. Recent changes in salamander community structure have already been documented on Hawksbill Mountain in the Shenandoah National Park, where the red-backed salamander (widely distributed in North America) is increasing its range at the expense of the endangered Shenandoah salamander. Climate change could hasten this change. Warmer air temperatures could lead to reduced stream flow and warmer water temperatures, which could impair reproduction of fish such as the brook trout. In coastal habitats, one consequence of rising sea levels will be the inundation and salinization of vital wildlife habitats.

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.