HEALTH SECTOR

Certain health outcomes are known to be associated with weather and/or climate, including:illnesses and deaths associated with temperature; extreme precipitation events;air pollution; water contamination;and diseases carried by mosquitoes,ticks,and rodents. Because human health is intricately bound to weather and the many complex natural systems it affects,it is possible that projected climate change will have measurable impacts,both beneficial and adverse,on health. Projections of the extent and direction of potential impacts of climate variability and change on health are extremely difficult to make because of many confounding and poorly understood factors associated with potential health outcomes,population vulnerability, and adaptation. For example,not enough is yet known about particulate matter to project how levels of this air pollutant might change in projected future climate scenarios. Basic information on the sensitivity of human health to aspects of weather and climate is limited,and it is difficult to anticipate what adaptive measures might be taken in the future to mitigate risks of adverse health outcomes,such as vaccines or improved use of weather forecasting.

KEY ISSUES

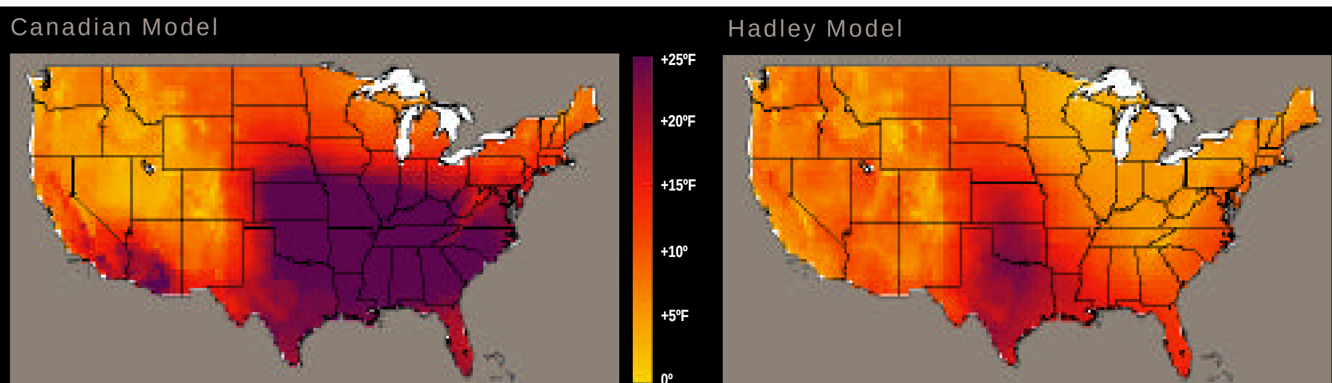
- **Temperature-related Illnesses and Deaths**
- **Health Effects Related to Extreme Weather Events**
- **Air Pollution-related Health Effects**
- **Water- and Food-borne Diseases**
- **Insect-, Tick- and Rodent-borne Diseases**

Health outcomes in response to climate change are highly uncertain. Currently available information suggests that a range of negative health impacts is possible. These have been the focus of much of the public health research on climate change to date. Some positive health outcomes,notably reduced cold-weather mortality, are possible,although the balance between increased risk of heat-related illnesses and death and changes in winter illnesses and death cannot yet be confidently assessed. At present, much of the US population is protected against adverse health outcomes associated with weather and/or climate, although certain demographic and geographic populations are at greater risk. Adaptation, primarily through the maintenance and improvement of public health systems and their responsiveness to changing climate conditions and to identified vulnerable subpopulations should help to protect the US population from adverse health outcomes of projected climate change. The costs,benefits,and availability of resources for such adaptation must be considered,and further research into key knowledge gaps on the relationships between climate/weather and health is needed.

Temperature-related Illnesses and Deaths

Episodes of extreme heat already pose a health threat in parts of the US. For example, following a five-day heat wave in 1995 in which maximum temperatures in Chicago,

July Heat Index Change - 21st century



Both models project substantial increases in the July heat index (which combines heat and humidity) over the 21st Century. These maps show the projected increase in average daily July heat index relative to the present. The largest increases are in the southeastern states, where the Canadian model projects increases of more than 25˚F. For example, a July day in Atlanta that now reaches a heat index of 105˚F would reach a heat index of 115˚F in the Hadley model, and 130˚F in the Canadian model.

Illinois ranged from 93 to 104ºF, the number of deaths increased 85% over the number recorded during the same period of the preceding year. At least 700 excess deaths (deaths in that population beyond those expected for that period of time) were recorded,most of which were directly attributable to heat. Studies in certain urban areas show a strong association between increases in mortality and increases in heat,measured by maximum or minimum daily temperature and heat index (a measure of temperature and humidity).Some of these studies adjust for other weather conditions.

...following a five-day heat wave in 1995 in which maximum temperatures in Chicago, Illinois ranged from 93° to 104°F, the number of deaths increased 85% over the number recorded during the same period of the preceding year.

Heat stroke and other health effects associated with exposure to extreme and prolonged heat appear to be related to environmental temperatures above those to which the population is accustomed. Thus,the regions most sensitive to projected increases in severity and frequency of heatwaves are likely to be those in which extremely high temperatures occur only irregularly.

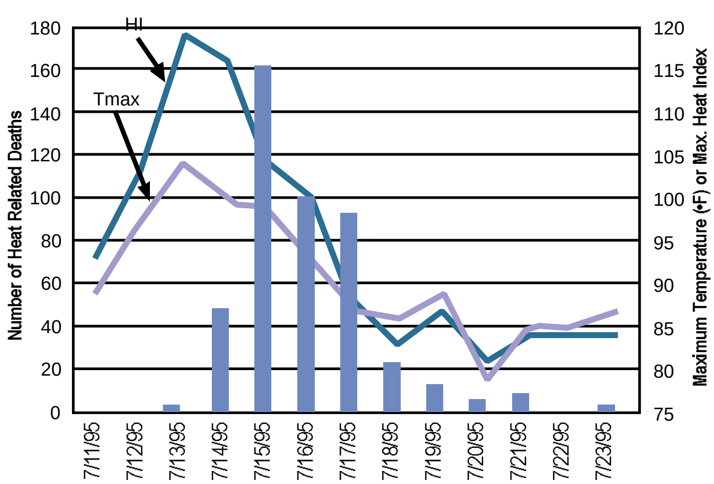
Within heat-sensitive regions,populations in urban areas are most vulnerable to adverse heat-related health outcomes.Heat indices and heat-related mortality rates are higher in the urban core than in surrounding areas. Urban areas remain warmer throughout the night compared to outlying suburban and rural areas. The absence of nighttime relief from heat for urban residents is a factor in excessive heat-related deaths. The elderly, young children,the poor, and people who are bedridden,on certain medications,or who have certain underlying medical conditions are at particular risk.

Overall death rates are higher in winter than in summer, and it is possible that milder winters could reduce deaths in winter months. However, the relationship between winter weather and mortality is difficult to interpret. For example,many winter deaths are due to respiratory infections such as influenza,and it is unclear how influenza transmission would be affected by higher winter temperatures. The net effect on winter mortality from climate change is therefore extremely uncertain.

Deaths due to summer heat are projected to increase in US cities, in a study using several climate models. Mortality rates (number of deaths per 100,000 population) are shown for the Max-Planck Institute model, the results from which lie roughly in the middle of the models examined. Because heat-related illness and death appear to be related to temperatures much hotter than those to which the population is accustomed, cities that experience extreme heat only infrequently appear to be at greatest risk. For example, Philadelphia, New York, Chicago, and St. Louis have experienced heat waves that resulted in a large number of heat-related deaths, while heat-related deaths in Atlanta and Los Angeles are much lower. In this study, statistical relationships between heat waves and increased death rates are constructed for each city based on historical experience. Deaths under a city's future climate are then projected by applying that city's projected incidence of extreme heat waves to the statistical relationship that was estimated for the city whose present climate is most similar to the projected future climate for the city in question. This approach attempts to represent how people will acclimate to the new average climate they experience.

Heat Related Deaths - Chicago, July 1995

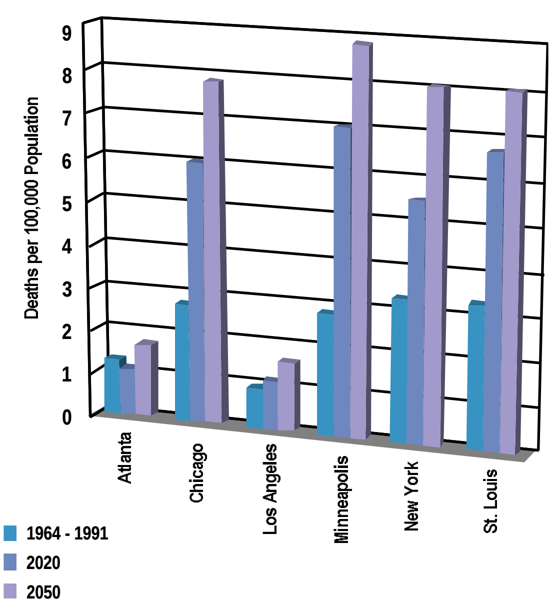
Maximum Temperature and Heat Index



This graph tracks maximum temperature (Tmax), heat index (HI), and heat-related deaths in Chicago each day from July 11 to 23, 1995. The gray line shows maximum daily temperature, the blue line shows the heat index, and the bars indicate number of deaths for the day.

Average Summer Mortality Rates

Attributed to hot weather episodes



HEALTH KEY ISSUES

Changes in precipitation, temperature, humidity, salinity, and wind have a measurable effect on water quality. In 1993, the Milwaukee, Wisconsin drinking water supply became contaminated by Cryptosporidium, and as a result 400,000 people became ill and 54 died.

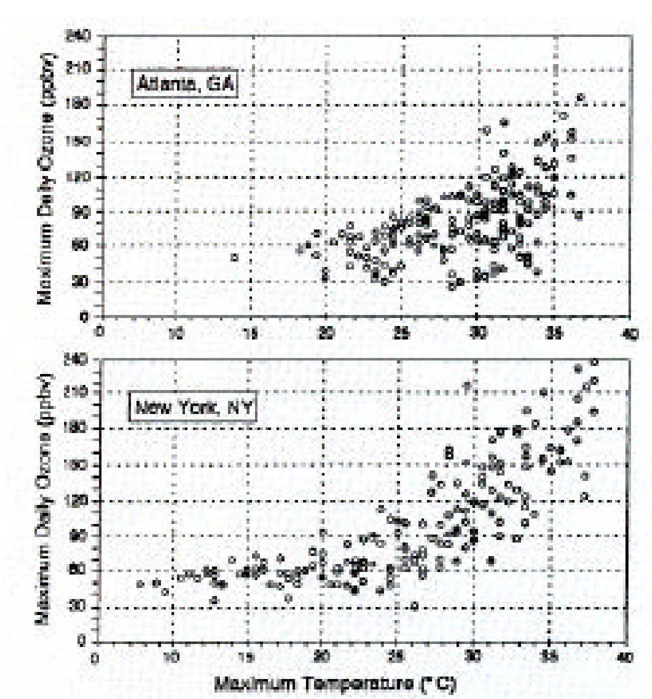
Heat and heat waves are very likely to increase in severity and frequency with increasing global average temperatures. The climate scenarios used in this Assessment show increases in average summer temperatures and relatively larger increases in average winter temperatures,leading to new record high temperatures, both in summer and winter. The size of US cities and the proportion of US residents living in them are also projected to increase over the next century, so it is possible that the population at risk from heat events will increase.

Heat-related illnesses and deaths are largely preventable through behavioral adaptations,including use of air conditioning and increased fluid intake. However, the degree to which these adaptations might be broadly adopted or economically available to sensitive populations has not been assessed.

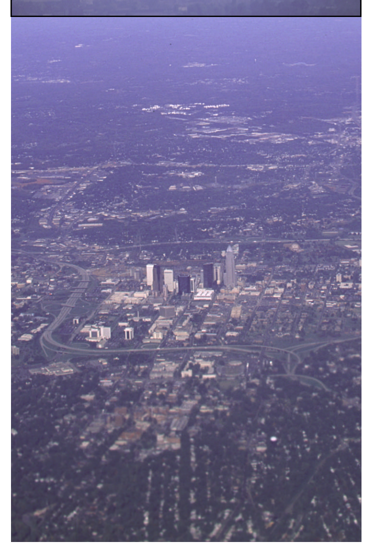
Health Effects Related to Extreme Weather Events

Injury and death are the direct health impacts most often associated with natural disasters such as floods and hurricanes.Secondary health effects have also been observed. These effects are mediated by changes in ecological systems (such as bacterial and fungal proliferation) and in public health infrastructures (such as the availability of safe drinking water). The health impacts of extreme weather events such as floods and storms therefore hinge on the vulnerabilities and recovery capacities of the natural environment and the local population. There is controversy about the incidence and continuation of significant mental problems,such as post traumatic stress disorder, following disasters. However, a rise in mental disorders has been observed following several natural disasters in the US.

Maximum Daily Ozone Concentrations
and Maximum Daily Temperature - Atlanta & New York



These graphs illustrate the observed association between ground-level ozone concentrations and temperature in Atlanta and New York City (May to October 1988-1990). The projected higher temperatures across the US in the 21st century are likely to increase the occurence of high ozone concentrations, especially since extremely hot days frequently have stagnant air circulation patterns, although this will also depend on emissions of ozone precursors and meteorological factors. Ground-level ozone can exacerbate respiratory diseases and cause short-term reductions in lung function.

Atlanta

Increases in heavy precipitation have occurred in the US over the past century. Future climate scenarios show likely increases in the frequency of extreme precipitation events,including precipitation during hurricanes. This poses an increased risk of floods and associated health impacts.

Air Pollution-related Health Effects

Current exposures to air pollution have serious public health consequences. Ground-level ozone can exacerbate respiratory diseases and cause short-term reductions in lung function. Exposure to particulate matter can aggravate existing respiratory and cardiovascular diseases,alter the body's defense systems against foreign materials,damage lung tissue,lead to premature death,and possibly contribute to cancer. Health effects of exposure to carbon monoxide,sulfur dioxide,and nitrogen dioxide can include reduced work capacity, aggravation of existing cardiovascular diseases,effects on breathing, respiratory illnesses,lung irritation,and alterations in the lung's defense systems.

The mechanisms by which climate change affects exposures to air pollutants include 1) affecting weather and thereby local and regional pollution concentrations;2) affecting human-caused emissions,including adaptive responses involving increased fuel combustion for power generation;3) affecting natural sources of air pollutant emissions;and 4) changing the distribution and types of airborne allergens. Analyses show that higher surface air temperatures are conducive to increased concentrations of ground-level ozone. Since it is very likely that temperatures will increase significantly across the US by the end of the 21st century, this creates a risk of higher concentrations of ground-level ozone,especially because higher temperatures are frequently accompanied by stagnating circulation patterns. However, without knowledge of future emissions in specific places,the success of air pollution policies,and local and regional meteorological scenarios,more specific predictions of exposure to air pollutants and health effects cannot be made with confidence.

In addition to affecting exposure to air pollutants,there is some chance that climate change will play a role in exposure to airborne allergens. Climate change will possibly alter pollen production in some plants and the geographic distribution of plant species. Consequently, there is some chance that climate change will affect the timing or duration of seasonal allergies. The impact of pollen and of pollen changes on the occurrence and severity of asthma,the most common chronic disease of childhood,is currently very uncertain.

Water- and Food-borne Diseases

Exposure to water-borne disease can result from drinking contaminated water, eating seafood from contaminated water, eating fresh produce irrigated or processed with contaminated water, or from activities such as fishing or swimming in contaminated water. Water-borne pathogens of current concern include viruses,bacteria (such as *Vibrio vulnificus*, a naturally-occurring estuarine bacterium responsible for a high percentage of the deaths associated with shellfish consumption),and protozoa (such as *Cryptosporidium*, associated with gastrointestinal illnesses).Changes in precipitation,temperature,humidity, salinity, and wind have a measurable effect on water quality. In 1993,the Milwaukee,Wisconsin drinking water supply became contaminated by *Cryptosporidium*, and as a result 400,000 people became ill.Of the 54 individuals who died,most had compromised immune systems because of HIV infection or other illness. A contributing factor in the contamination,in addition to treat-

Injury and death are the direct health impacts most often associated with natural disasters such as floods and hurricanes. Future climate scenarios show likely increases in the frequency of extreme precipitation events, including precipitation during hurricanes. This poses an increased risk of floods and associated health impacts.

Since it is very likely that temperatures will increase significantly across the US by the end of the 21st century, this creates a risk of higher concentrations of ground-level ozone, especially since higher temperatures are frequently accompanied by stagnating circulation patterns.

HEALTH KEY ISSUES

ment system malfunctions, was heavy rainfall and runoff that resulted in a decline in the quality of raw surface water arriving at the Milwaukee drinking water plants. In Florida during the strong El Niño winter of 1997-1998, heavy precipitation and runoff greatly elevated the counts of fecal bacteria and infectious viruses in local coastal waters. In Gulf Coast waters, *Vibrio vulnificus* bacteria are especially sensitive to water temperature, which dictates their seasonality and geographic distribution. In addition, toxic red tides proliferate as seawater temperatures increase. Reports of marine-related illnesses have risen over the past two and a half decades along the East Coast, in correlation with El Niño events.

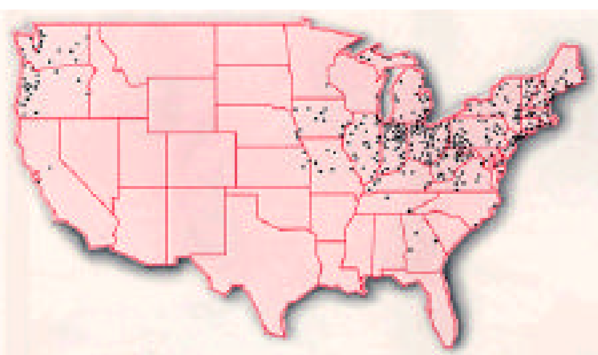
Climate changes projected to occur in the next several decades, in particular the likely increase in extreme precipitation events, will probably raise the risk of contamination events.

Insect-, Tick-, and Rodent-borne Diseases

Malaria, yellow fever, dengue fever, and other diseases transmitted between humans by blood-feeding insects, ticks, and mites were once common in the US. Many of these diseases are no longer present, mainly because of changes in land use, agricultural methods, residential patterns, human behavior, and vector control. However, diseases that may be transmitted to humans from wild animals continue to circulate in nature in many parts of the country. Humans may become infected with the pathogens that cause these diseases through transmission by insects or ticks (such as Lyme disease, which is tick-borne) or by direct contact with the host animals or their body fluids (such as hantaviruses, which are carried by numerous rodent species and transmitted to humans through contact with rodent urine, droppings, and saliva). The organisms that directly transmit these diseases are known as vectors.

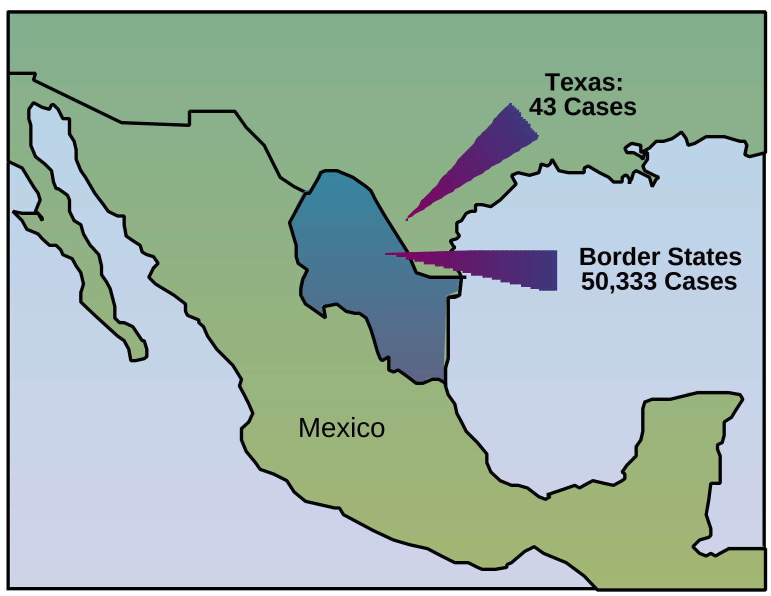
The ecology and transmission dynamics of these vector-borne infections are complex, and the factors that influence transmission are unique for each pathogen. Most vector-borne diseases exhibit a distinct seasonal

Combined Wastewater Systems



Wastewater systems that combine storm drains, sewage and industrial waste are still used in about 950 communities, mostly in the Northeast and Great Lakes regions. During rainstorms or spring snowmelt, when the volume of water being discharged can exceed the capacity of the sewage treatment system, these systems are designed to overflow and discharge untreated sewage into surface waters. In 1994, EPA developed a framework to control such combined-sewer overflows under the federal Clean Water Act's water discharge permit program. If combined sewer systems remain in place and continue to discharge untreated wastewater during storms, they will very likely pose an increased health risk under projected increases in intense precipitation events.

Reported Cases of Dengue 1980-1996



Dengue along the US-Mexico border. Dengue, a mosquito-borne viral disease, was once common in Texas (where there were an estimated 500,000 cases in 1922), and the mosquito that transmits it remains abundant. The striking contrast in the incidence of dengue in Texas versus three Mexican states that border Texas (43 cases vs. 50,333) in the period from 1980-1996 provides a graphic illustration of the importance of factors other than temperature, such as public health infrastructure, use of air conditioning and window screens, in the transmission of vector-borne diseases.

pattern, which clearly suggests that they are weather sensitive. Rainfall, temperature, and other weather variables affect both vectors and the pathogens they transmit in many ways. For example, epidemics of malaria are associated with rainy periods in some parts of the world, but with drought in others. Higher temperatures may increase or reduce vector survival rate, depending on each specific vector, its behavior, ecology, and many other factors.

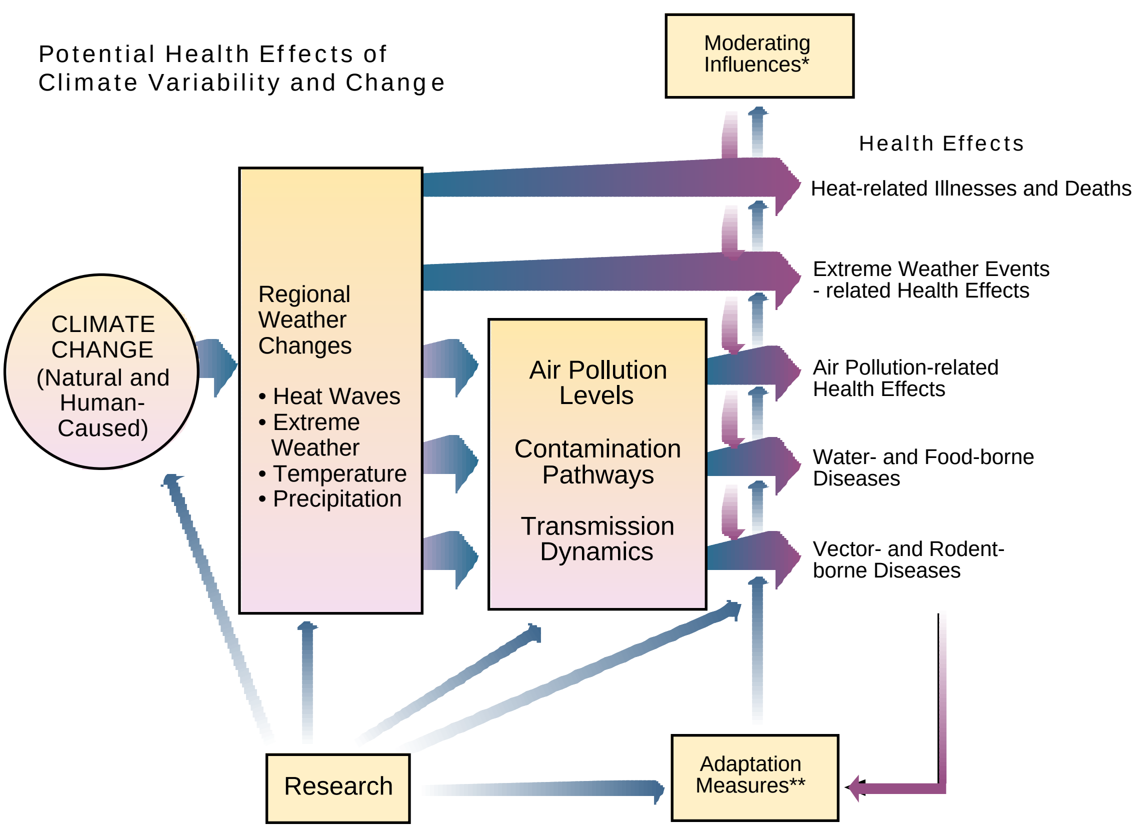
In some cases, specific weather patterns over several seasons appear to be associated with increased transmission rates. For example, in the midwestern US, outbreaks of St. Louis encephalitis (a viral infection of birds that can also infect and cause disease in humans) appear to be associated with the sequence of warm, wet winters, cold springs, and hot dry summers. The factors underlying this association are complex and require more investigation.

Adaptation Strategies

The future vulnerability of the US population to the health impacts of climate change largely depends on the magnitude of the increase in potential health impacts and on our capacity to adapt to potential adverse changes through legislative, administrative, institutional, technological, educational, and research-related measures. Examples include building codes and zoning to prevent storm or flood damage, severe weather warning systems, improved disease surveillance and prevention programs, improved sanitation systems, education of health professionals and the public, and research addressing key knowledge gaps in climate/health relationships.

Many of these adaptive responses are desirable from a public health perspective irrespective of climate change. For example, reducing air pollution obviously has both short- and long-term health benefits. Improving warning systems for extreme weather events and eliminating existing combined sewer and storm water drainage systems are other measures that can ameliorate some of the potential adverse impacts of current climate extremes and of the possible impacts of climate change. Improved disease surveillance, prevention systems, and other public health infrastructure at the state and local levels are already needed. Adaptation is a complex undertaking, as demonstrated by the varying degrees of effectiveness of current efforts to cope with climate variability. Considerable work still needs to be done to assess the feasibility (for example, the ability of a community to incur the costs) and the effectiveness of alternative adaptive responses, and to develop improved mechanisms for coping with climate variability and change.

Potential Health Effects of Climate Variability and Change



***Moderating influences include non-climate factors that affect climate-related health outcomes, such as population growth and demographic change, standards of living, access to health care, improvements in health care, and public health infrastructure.**

****Adaptation measures include actions to reduce risks of adverse health outcomes, such as vaccination programs, disease surveillance, monitoring, use of protective technologies, such as air conditioning, pesticides, water filtration/treatment, use of climate forecasts and development of weather warning systems, emergency management and disaster preparedness programs, and public education.**