CCSP-6

U.S. Climate Change Science Program

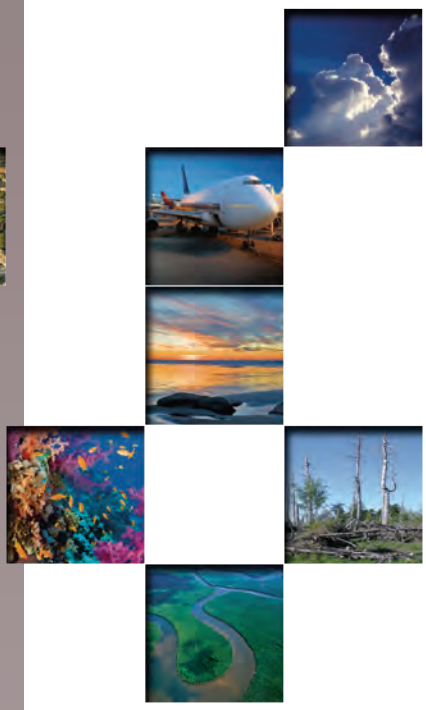
Scientific Assessment of the Effects of Global Change on the United States

Summary and Findings

Our environment, and especially our climate, is changing. In order to deal with the changes that are taking place now and to prepare for those that are likely to happen in the future, decisionmakers need information about global environmental change and its effects on the Nation.

Over the past several years, our understanding of global environmental change and our ability to estimate its future effects has improved significantly. In order to summarize the key conclusions of this research, the U.S. Climate Change Science Program (CCSP) has undertaken a national scale "Scientific Assessment of the Effects of Global Change on the United States."The conclusions in this assessment build on the vast body of observations, modeling, decision-support, and other types of activities conducted under the auspices of CCSP. It draws on findings from previous assessments of the science, including reports and products by the Intergovernmental Panel on Climate Change (IPCC), CCSP, and others. Together with CCSP's 21 Synthesis and Assessment Products, this is arguably the most comprehensive assessment to date of the effects of global change, and especially climate, on the United States.This fact sheet summarizes the key findings of the Assessment.

How has the Climate Changed in the United States?



Like global average temperatures, U.S. average temperatures increased during the 20th and into the 21st century, and the last decade is the warmest in more than a century of direct observations in the United States. Some other critical U.S. climate changes already observed include:

- **Temperature**
  - An increase in the number of U.S. heat waves since 1950.
  - Fewer unusually cold days during the last few decades [the last 10 years have seen fewer severe cold waves than for any other 10-year period in the historical record, which dates back to 1895].

- **Precipitation and Drought**
  - An overall increase in annual precipitation for the continental United States, though with significant regional variability.
  - An increase in the proportion of heavy precipitation events, especially in the last three decades and especially in the eastern half of the country.
  - An increase in the fraction of annual precipitation falling as rain (rather than snow) in the last half century.
  - A tendency towards a decrease in the severity and duration of drought over the latter half of the 20th century, though several droughts have been severe.

- **Snow and Ice**
  - Large decreases in Arctic summer sea ice between 1978 and 2005 [the 2007 Arctic sea ice extent was approximately 23% below the previous all-time minimum observed in 2005].

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WHAT IS CAUSING CLIMATE CHANGE IN THE UNITED STATES?

Studies that rigorously quantify the effect of different external influences on observed changes (attribution studies) conclude that most of the recent global warming is very likely due to human-generated increases in greenhouse gas concentrations.

IT IS LIKELY THAT THERE HAS BEEN A SUBSTANTIAL HUMAN CONTRIBUTION TO SURFACE TEMPERATURE INCREASES IN NORTH AMERICA.

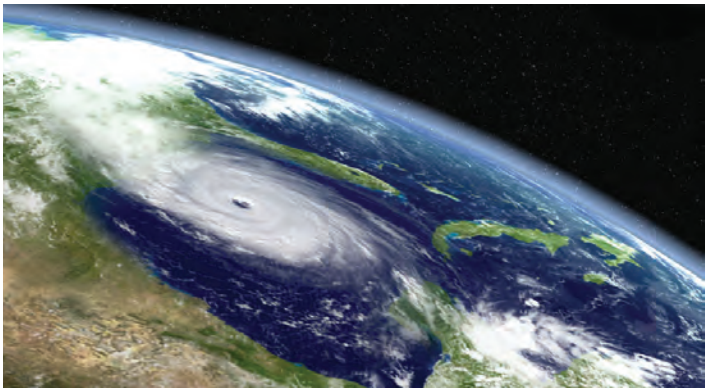
Attribution studies also show that it is likely that there has been a substantial human contribution to surface temperature increases in North America, though attribution of the drivers of long-term temperature changes on time scales of less than 50 years and at regional scales, with limited exceptions, has not yet been established.

Discernible human influences also extend to additional aspects of climate, including the recent decreases in Arctic sea ice extent, patterns of sea-level pressure and winds, and the global scale pattern of land precipitation.

  - An increase in the snow-covered area of North America in the November to January season from 1915 to 2004 due to increases in precipitation; however, a general decrease in spring snow cover in mountainous regions of the western United States during the latter half of the 20th century.

- **Sea-Level Rise**
  - Reflecting a global rise in sea level, U.S. sea-level data show that along most of the U.S. Atlantic and Gulf Coasts, sea level has been rising 0.08 to 0.12 inches per year. The rate of sea-level rise varies from a few inches per decade along the Louisiana Coast (due to sinking land) to a drop of a few inches per decade in parts of Alaska (due to rising land).

- **Atlantic Hurricanes**
  - It is likely that the annual numbers of tropical storms, hurricanes, and major hurricanes in the North Atlantic have increased over the past 100 years, a time in which Atlantic sea-surface temperatures have also increased.



How is Climate Expected to Change in the Future?

Continued greenhouse gas emissions at or above current rates are expected to cause further warming and to induce many changes during the 21st century that will very likely be larger than those of the last century.

- **Temperature**
  - All of North America is very likely to warm during this century, and to warm more than the global average increase in most areas.
  - Nearly all the models used in the IPCC assessment project that average warming in the United States will exceed 3.6°F, with five out of 21 models projecting that average warming will exceed 7.2°F.
  - Abnormally hot days and nights and heat waves are very likely to become more frequent, and cold days and cold nights are very likely to become much less frequent over North America.

- **Precipitation and Drought**
  - In the 21st century, precipitation over North America is projected to be less frequent but more intense.
  - Most climate models project an increase in winter precipitation in the northern tier of states and a decrease in portions of the Southwest.
  - It is likely that droughts will continue to be exacerbated by earlier and possibly lower spring snowmelt runoff in the mountainous West, which results in less water available in late summer.

- **Snow and Ice**
  - Snow cover is projected to continue to decrease as the climate warms.
  - Results from multiple model simulations indicate that an Arctic Ocean free of summer ice is likely by the end of the century, with some models suggesting that this could occur as soon as 2040.
  - Glaciers and terrestrial ice sheets are projected to continue to lose mass. This will contribute to sea-level rise.

- **Sea-Level Rise**
  - Future sea-level rise is virtually certain to cause some areas of dry land in the United States to become inundated.
  - The IPCC projects that global sea level will rise between 7 and 23 inches by the end of the century (2090-2099).
  - Potential accelerations in ice flow of the kind recently observed in some Greenland outlet glaciers and West Antarctic ice streams could substantially increase the contribution from the ice sheets to sea level, a possibility not reflected in the aforementioned projections. Understanding of these processes is limited and there is no consensus on their magnitude and thus on the upper bound of sea-level rise rates.
  - Storm surge levels are expected to increase due to projected sea-level rise.

- **Atlantic Hurricanes**
  - For North Atlantic, it is likely that hurricane rainfall and wind speeds will increase in response to human-caused warming. There is less confidence in the projected changes in the number of hurricanes.

What are the Major Impacts of Climate Change for the United States?

It is very likely that temperature increases, increasing carbon dioxide levels, and altered patterns of precipitation are already affecting U.S. water resources, agriculture, land resources, biodiversity, and human health, among other things. And it is very likely that climate change will continue to have significant effects on these resources over the next few decades and beyond. A very brief summary of the key findings of climate impacts on the United States follows.

The Natural Environment

Ecosystems provide society with a number of goods (e.g., food, fiber, fuel, pharmaceutical products) and services (e.g., cycling of water and nutrients, removal of waste products, sustaining biological diversity) and are essential to human health and well-being:

- The resilience of many ecosystems is likely to be exceeded this century by an unprecedented combination of climate change, associated disturbances (e.g., flooding, drought, wildfire, insects, ocean acidification), and other global change drivers (e.g., land-use change, pollution).
- In North America, warming has generally resulted in and is expected to continue to result in shifts of species ranges poleward and to higher altitudes.

Agriculture

The many U.S. crops and livestock (valued at about $200 billion in 2002) are strongly affected by climate:

- The marketable yield of many horticultural crops (e.g., tomatoes, onions, and fruits) is very likely to be more sensitive to climate change than grain and oilseed crops.

CLIMATE EXTREMES

Human activities have also likely influenced extremes in temperature. Many indicators of climate extremes – including the annual numbers of frost days, warm and cold days, and warm and cold nights – show changes that are consistent with warming. Studies for North America suggest that, in the future, abnormally hot days and nights and heat waves are very likely to become more frequent and that cold days and cold nights are very likely to become much less frequent.

In addition to temperature extremes, analyses indicate that, on average for North America, precipitation is likely to be less frequent but more intense. It is also likely that future hurricanes will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases in tropical sea surface temperatures. However, projections of changes in hurricane frequency remain very uncertain.

- Higher temperatures will very likely reduce livestock production during the summer season, but these losses will very likely be partially offset by warmer temperatures during the winter season.

Water

Although U.S. water management practices are generally quite advanced, particularly in the West, the reliance on past conditions as the foundation for current and future planning and practice will no longer be tenable as climate change and variability increasingly create conditions that are well outside of historical parameters, eroding predictability:

- Stream temperatures are likely to increase as the climate warms and are very likely to have effects on aquatic ecosystems and water quality.
- Where earlier snowmelt peaks and reduced low flows in the summer and fall have already been detected, continuing shifts in this direction are very likely and may substantially affect the performance of reservoir systems.

Population and Society

While it may appear that industrialized countries like the United States are well equipped to cope with gradual climate change at a national level, at a local level there may be substantial variability in climate effects and capacities to adapt; on the other hand, some U.S. communities may find opportunities in climate change:

- Population growth is generally shifting toward areas (e.g., coastal regions) more likely to be vulnerable to the effects of climate change.
- For small islands, particularly in the Pacific, some studies suggest that sea-level rise could reduce island size, raising concerns for parts of Hawaii and other U.S. territories.
- Wildfires have increased in extent and severity in recent years and are very likely to intensify in a warmer future. At the same time, the population has been expanding into fire-prone areas.

Health

Climate variability and change can affect health through the effects of temperature changes on the body. Climate change can also make it possible for animal-, water-, and food-borne diseases to spread or emerge in areas where they had been limited or had not existed, or it can make it possible for such diseases to disappear by making areas less hospitable to the disease carrier or pathogen:

- An increased frequency and severity of heat waves is expected, leading to more illness and death, particularly among the young, elderly, frail, and poor.
- Increases in extreme weather (e.g., storms, flooding) and accompanying events (e.g., wildfire resulting from prolonged drought) may lead to increases in deaths, injuries, infectious diseases, interruptions of medical care for chronic disease treatment, and stress-related disorders and other adverse effects associated with social disruption and migration.

Energy

To date, most discussions on energy and climate change have focused on mitigating human effects on climate. However, along with this role as a driver of climate change, the energy sector will be subject to the effects of climate change:

- Direct impacts from increased intensity of extreme weather events.
- Reduced water supplies in regions dependent on water resources for hydropower and/or thermal power plant cooling.
- Positive or negative impacts on production of biomass, wind power, or solar energy where climate conditions change.

Transportation

Increasing global temperatures, rising sea levels, and changing weather patterns pose significant challenges to the Nation's roads, airports, railways, transit systems, and ports. The transportation network is vital to the U.S. economy and quality of life:

- Increasing frequency, intensity, or duration of heat spells could cause railroad tracks to buckle or kink and could affect roads through softening and traffic-related rutting.
- Coastal and riverine flooding and landslides are very likely to cause negative impacts on roads, rails, and ports.
- Warmer or less snowy winters are likely to improve ground and air transportation reliability, and decrease the need for winter road maintenance. However, more intense winter storms could increase risks for traveler safety and require increased localized snow removal.

This fact sheet was generated by the Climate Change Science Program Office
For further information, see <www.climatescience.gov>.