

2014 NATIONAL CLIMATE ASSESSMENT – FINAL REPORT (6 MAY 2014)

KEY FINDINGS & MESSAGES

Compiled by Nick Sundt, WWF

8 May 2014

The following information is extracted from the final draft of the 2014 National Climate Assessment (full report). Download the full report or individual chapters at <http://nca2014.globalchange.gov/downloads>.

Chapters of the Report

1. Overview
2. Our Changing Climate

Sectors

3. Water Resources
4. Energy Supply and Use
5. Transportation
6. Agriculture
7. Forests
8. Ecosystems, Biodiversity, and Ecosystem Services
9. Human Health
10. Energy, Water, and Land Use
11. Urban Systems, Infrastructure, and Vulnerability
12. Indigenous Peoples, Lands and Resources
13. Land Use and Land Cover Change
14. Rural Communities
15. Biogeochemical Cycles

Introduction to Regions

16. Northeast
17. Southeast and Caribbean
18. Midwest
19. Great Plains
20. Southwest
21. Northwest
22. Alaska and the Arctic
23. Hawaii and the U.S. Affiliated Pacific Islands
24. Oceans and Marine Resources
25. Coastal Zone Development and Ecosystems

Introduction to Response Strategies

26. Decision Support: Connecting Science, Risk Perception, and Decisions
27. Mitigation
28. Adaptation
29. Research Needs for Climate and Global Change Assessments
30. Sustained Assessment: A New Vision for Future U.S. Assessments

Appendices

1. Report Development Process
2. Information Quality Assurance Process
3. Climate Science
4. Frequently Asked Questions
5. Scenarios and Models
6. Topics for Consideration in Future Assessments

Chapter 1. Overview

These findings distill important results that arise from this National Climate Assessment. They do not represent a full summary of all of the chapters' findings, but rather a synthesis of particularly noteworthy conclusions.

1. Global climate is changing and this is apparent across the United States in a wide range of observations. The global warming of the past 50 years is primarily due to human activities, predominantly the burning of fossil fuels.

Many independent lines of evidence confirm that human activities are affecting climate in unprecedented ways. U.S. average temperature has increased by 1.3°F to 1.9°F since record keeping began in 1895; most of this increase has occurred since about 1970. The most recent decade was the warmest on record. Because human-induced warming is superimposed on a naturally varying climate, rising temperatures are not evenly distributed across the country or over time.²¹ See page 18.

2. Some extreme weather and climate events have increased in recent decades, and new and stronger evidence confirms that some of these increases are related to human activities.

Changes in extreme weather events are the primary way that most people experience climate change. Human-induced climate change has already increased the number and strength of some of these extreme events. Over the last 50 years, much of the United States has seen an increase in prolonged periods of excessively high temperatures, more heavy downpours, and in some regions, more severe droughts.²² See page 24.

3. Human-induced climate change is projected to continue, and it will accelerate significantly if global emissions of heat-trapping gases continue to increase.

Heat-trapping gases already in the atmosphere have committed us to a hotter future with more climate-related impacts over the next few decades. The magnitude of climate change beyond

the next few decades depends primarily on the amount of heat-trapping gases that human activities emit globally, now and in the future.²³ See page 28.

4. Impacts related to climate change are already evident in many sectors and are expected to become increasingly disruptive across the nation throughout this century and beyond.

Climate change is already affecting societies and the natural world. Climate change interacts with other environmental and societal factors in ways that can either moderate or intensify these impacts. The types and magnitudes of impacts vary across the nation and through time. Children, the elderly, the sick, and the poor are especially vulnerable. There is mounting evidence that harm to the nation will increase substantially in the future unless global emissions of heat-trapping gases are greatly reduced.²⁴ See page 32.

5. Climate change threatens human health and well-being in many ways, including through more extreme weather events and wildfire, decreased air quality, and diseases transmitted by insects, food, and water.

Climate change is increasing the risks of heat stress, respiratory stress from poor air quality, and the spread of waterborne diseases. Extreme weather events often lead to fatalities and a variety of health impacts on vulnerable populations, including impacts on mental health, such as anxiety and post-traumatic stress disorder. Large-scale changes in the environment due to climate change and extreme weather events are increasing the risk of the emergence or reemergence of health threats that are currently uncommon in the United States, such as dengue fever.²⁵ See page 34.

6. Infrastructure is being damaged by sea level rise, heavy downpours, and extreme heat; damages are projected to increase with continued climate change.

Sea level rise, storm surge, and heavy downpours, in combination with the pattern of continued development in coastal areas, are increasing damage to U.S. infrastructure including roads, buildings, and industrial facilities, and are also increasing risks to ports and coastal military installations. Flooding along rivers, lakes, and in cities following heavy downpours, prolonged rains, and rapid melting of snowpack is exceeding the limits of flood protection infrastructure designed for historical conditions. Extreme heat is damaging transportation infrastructure such as roads, rail lines, and airport runways.²⁶ See page 38.

7. Water quality and water supply reliability are jeopardized by climate change in a variety of ways that affect ecosystems and livelihoods.

Surface and groundwater supplies in some regions are already stressed by increasing demand for water as well as declining runoff and groundwater recharge. In some regions, particularly the southern part of the country and the Caribbean and Pacific Islands, climate change is increasing the likelihood of water shortages and competition for water among its many uses. Water quality is diminishing in many areas, particularly due to increasing sediment and contaminant concentrations after heavy downpours.²⁷ See page 42.

8. Climate disruptions to agriculture have been increasing and are projected to become more severe over this century.

Some areas are already experiencing climate-related disruptions, particularly due to extreme weather events. While some U.S. regions and some types of agricultural production will be relatively resilient to climate change over the next 25 years or so, others will increasingly suffer from stresses due to extreme heat, drought, disease, and heavy downpours. From mid-century on, climate change is projected to have more negative impacts on crops and livestock across the country – a trend that could diminish the security of our food supply.²⁸ See page 46.

9. Climate change poses particular threats to Indigenous Peoples' health, well-being, and ways of life.

Chronic stresses such as extreme poverty are being exacerbated by climate change impacts such as reduced access to traditional foods, decreased water quality, and increasing exposure to health and safety hazards. In parts of Alaska, Louisiana, the Pacific Islands, and other coastal locations, climate change impacts (through erosion and inundation) are so severe that some communities are already relocating from historical homelands to which their traditions and cultural identities are tied. Particularly in Alaska, the rapid pace of temperature rise, ice and snow melt, and permafrost thaw are significantly affecting critical infrastructure and traditional livelihoods.²⁹ See page 48.

10. Ecosystems and the benefits they provide to society are being affected by climate change. The capacity of ecosystems to buffer the impacts of extreme events like fires, floods, and severe storms is being overwhelmed.

Climate change impacts on biodiversity are already being observed in alteration of the timing of critical biological events such as spring bud burst and substantial range shifts of many species. In the longer term, there is an increased risk of species extinction. These changes have social, cultural, and economic effects. Events such as droughts, floods, wildfires, and pest outbreaks associated with climate change (for example, bark beetles in the West) are already disrupting ecosystems. These changes limit the capacity of ecosystems, such as forests, barrier beaches, and wetlands, to continue to play important roles in reducing the impacts of these extreme events on infrastructure, human communities, and other valued resources.³⁰ See page 50.











11. Ocean waters are becoming warmer and more acidic, broadly affecting ocean circulation, chemistry, ecosystems, and marine life.

More acidic waters inhibit the formation of shells, skeletons, and coral reefs. Warmer waters harm coral reefs and alter the distribution, abundance, and productivity of many marine species. The rising temperature and changing chemistry of ocean water combine with other stresses, such as overfishing and coastal and marine pollution, to alter marine-based food production and harm fishing communities.³¹ See page 58.

12. Planning for adaptation (to address and prepare for impacts) and mitigation (to reduce future climate change, for example by cutting emissions) is becoming more widespread, but current implementation efforts are insufficient to avoid increasingly negative social, environmental, and economic consequences.

Actions to reduce emissions, increase carbon uptake, adapt to a changing climate, and increase resilience to impacts that are unavoidable can improve public health, economic development, ecosystem protection, and quality of life.³² See page 62.

Observed and projected climate change impacts vary across the regions of the United States. Selected impacts emphasized in the regional chapters are shown below, and many more are explored in detail in this report.

	Northeast	Communities are affected by heat waves, more extreme precipitation events, and coastal flooding due to sea level rise and storm surge.
	Southeast and Caribbean	Decreased water availability, exacerbated by population growth and land-use change, causes increased competition for water. There are increased risks associated with extreme events such as hurricanes.
	Midwest	Longer growing seasons and rising carbon dioxide levels increase yields of some crops, although these benefits have already been offset in some instances by occurrence of extreme events such as heat waves, droughts, and floods.
	Great Plains	Rising temperatures lead to increased demand for water and energy and impacts on agricultural practices.
	Southwest	Drought and increased warming foster wildfires and increased competition for scarce water resources for people and ecosystems.
	Northwest	Changes in the timing of streamflow related to earlier snowmelt reduce the supply of water in summer, causing far-reaching ecological and socioeconomic consequences.
	Alaska	Rapidly receding summer sea ice, shrinking glaciers, and thawing permafrost cause damage to infrastructure and major changes to ecosystems. Impacts to Alaska Native communities increase.
	Hawai'i and Pacific Islands	Increasingly constrained freshwater supplies, coupled with increased temperatures, stress both people and ecosystems and decrease food and water security.
	Coasts	Coastal lifelines, such as water supply infrastructure and evacuation routes, are increasingly vulnerable to higher sea levels and storm surges, inland flooding, and other climate-related changes.
	Oceans	The oceans are currently absorbing about a quarter of human-caused carbon dioxide emissions to the atmosphere and over 90% of the heat associated with global warming, leading to ocean acidification and the alteration of marine ecosystems.

Chapter 2. Our Changing Climate

Key Messages

1. Global climate is changing and this change is apparent across a wide range of observations. The global warming of the past 50 years is primarily due to human activities.
2. Global climate is projected to continue to change over this century and beyond. The magnitude of climate change beyond the next few decades depends primarily on the amount of heat-trapping gases emitted globally, and how sensitive the Earth's climate is to those emissions.
3. U.S. average temperature has increased by 1.3°F to 1.9°F since record keeping began in 1895; most of this increase has occurred since about 1970. The most recent decade was the nation's warmest on record. Temperatures in the United States are expected to continue to rise. Because human-induced warming is superimposed on a naturally varying climate, the temperature rise has not been, and will not be, uniform or smooth across the country or over time.
4. The length of the frost-free season (and the corresponding growing season) has been increasing nationally since the 1980s, with the largest increases occurring in the western United States, affecting ecosystems and agriculture. Across the United States, the growing season is projected to continue to lengthen.
5. Average U.S. precipitation has increased since 1900, but some areas have had increases greater than the national average, and some areas have had decreases. More winter and spring precipitation is projected for the northern United States, and less for the Southwest, over this century.
6. Heavy downpours are increasing nationally, especially over the last three to five decades. Largest increases are in the Midwest and Northeast. Increases in the frequency and intensity of extreme precipitation events are projected for all U.S. regions.
7. There have been changes in some types of extreme weather events over the last several decades. Heat waves have become more frequent and intense, especially in the West. Cold waves have become less frequent and intense across the nation. There have been regional trends in floods and droughts. Droughts in the Southwest and heat waves everywhere are projected to become more intense, and cold waves less intense everywhere.
8. The intensity, frequency, and duration of North Atlantic hurricanes, as well as the frequency of the strongest (Category 4 and 5) hurricanes, have all increased since the early 1980s. The relative contributions of human and natural causes to these increases are still uncertain. Hurricane-associated storm intensity and rainfall rates are projected to increase as the climate continues to warm.
9. Winter storms have increased in frequency and intensity since the 1950s, and their tracks have shifted northward over the United States. Other trends in severe storms,

including the intensity and frequency of tornadoes, hail, and damaging thunderstorm winds, are uncertain and are being studied intensively.

10. Global sea level has risen by about 8 inches since reliable record keeping began in 1880. It is projected to rise another 1 to 4 feet by 2100.
11. Rising temperatures are reducing ice volume and surface extent on land, lakes, and sea. This loss of ice is expected to continue. The Arctic Ocean is expected to become essentially ice free in summer before mid-century.
12. The oceans are currently absorbing about a quarter of the carbon dioxide emitted to the atmosphere annually and are becoming more acidic as a result, leading to concerns about intensifying impacts on marine ecosystems.

Chapter 3. Water Resources

Key Messages

Climate Change Impacts on the Water Cycle

1. Annual precipitation and river-flow increases are observed now in the Midwest and the Northeast regions. Very heavy precipitation events have increased nationally and are projected to increase in all regions. The length of dry spells is projected to increase in most areas, especially the southern and northwestern portions of the contiguous United States.
2. Short-term (seasonal or shorter) droughts are expected to intensify in most U.S. regions. Longer-term droughts are expected to intensify in large areas of the Southwest, southern Great Plains, and Southeast.
3. Flooding may intensify in many U.S. regions, even in areas where total precipitation is projected to decline.
4. Climate change is expected to affect water demand, groundwater withdrawals, and aquifer recharge, reducing groundwater availability in some areas.
5. Sea level rise, storms and storm surges, and changes in surface and groundwater use patterns are expected to compromise the sustainability of coastal freshwater aquifers and wetlands.
6. Increasing air and water temperatures, more intense precipitation and runoff, and intensifying droughts can decrease river and lake water quality in many ways, including increases in sediment, nitrogen, and other pollutant loads.

Climate Change Impacts on Water Resources Use and Management

7. Climate change affects water demand and the ways water is used within and across regions and economic sectors. The Southwest, Great Plains, and Southeast are particularly vulnerable to changes in water supply and demand.

8. Changes in precipitation and runoff, combined with changes in consumption and withdrawal, have reduced surface and groundwater supplies in many areas. These trends are expected to continue, increasing the likelihood of water shortages for many uses.
9. Increasing flooding risk affects human safety and health, property, infrastructure, economies, and ecology in many basins across the United States.

Adaptation and Institutional Responses

10. In most U.S. regions, water resources managers and planners will encounter new risks, vulnerabilities, and opportunities that may not be properly managed within existing practices.
11. Increasing resilience and enhancing adaptive capacity provide opportunities to strengthen water resources management and plan for climate change impacts. Many institutional, scientific, economic, and political barriers present challenges to implementing adaptive strategies.

Chapter 4. Energy Supply and Use

Key Messages

1. Extreme weather events are affecting energy production and delivery facilities, causing supply disruptions of varying lengths and magnitudes and affecting other infrastructure that depends on energy supply. The frequency and intensity of certain types of extreme weather events are expected to change.
2. Higher summer temperatures will increase electricity use, causing higher summer peak loads, while warmer winters will decrease energy demands for heating. Net electricity use is projected to increase.
3. Changes in water availability, both episodic and long-lasting, will constrain different forms of energy production.
4. In the longer term, sea level rise, extreme storm surge events, and high tides will affect coastal facilities and infrastructure on which many energy systems, markets, and consumers depend.
5. As new investments in energy technologies occur, future energy systems will differ from today's in uncertain ways. Depending on the character of changes in the energy mix, climate change will introduce new risks as well as opportunities.

Chapter 5. Transportation

Key Messages

1. The impacts from sea level rise and storm surge, extreme weather events, higher temperatures and heat waves, precipitation changes, Arctic warming, and other climatic conditions are affecting the reliability and capacity of the U.S. transportation system in many ways.

2. Sea level rise, coupled with storm surge, will continue to increase the risk of major coastal impacts on transportation infrastructure, including both temporary and permanent flooding of airports, ports and harbors, roads, rail lines, tunnels, and bridges.
3. Extreme weather events currently disrupt transportation networks in all areas of the country; projections indicate that such disruptions will increase.
4. Climate change impacts will increase the total costs to the nation's transportation systems and their users, but these impacts can be reduced through rerouting, mode change, and a wide range of adaptive actions.

Chapter 6. Agriculture

Key Messages

1. Climate disruptions to agricultural production have increased in the past 40 years and are projected to increase over the next 25 years. By mid-century and beyond, these impacts will be increasingly negative on most crops and livestock.
2. Many agricultural regions will experience declines in crop and livestock production from increased stress due to weeds, diseases, insect pests, and other climate change induced stresses.
3. Current loss and degradation of critical agricultural soil and water assets due to increasing extremes in precipitation will continue to challenge both rainfed and irrigated agriculture unless innovative conservation methods are implemented.
4. The rising incidence of weather extremes will have increasingly negative impacts on crop and livestock productivity because critical thresholds are already being exceeded.
5. Agriculture has been able to adapt to recent changes in climate; however, increased innovation will be needed to ensure the rate of adaptation of agriculture and the associated socioeconomic system can keep pace with climate change over the next 25 years.
6. Climate change effects on agriculture will have consequences for food security, both in the U.S. and globally, through changes in crop yields and food prices and effects on food processing, storage, transportation, and retailing. Adaptation measures can help delay and reduce some of these impacts.

Chapter 7. Forests

Key Messages

1. Climate change is increasing the vulnerability of many forests to ecosystem changes and tree mortality through fire, insect infestations, drought, and disease outbreaks.
2. U.S. forests and associated wood products currently absorb and store the equivalent of about 16% of all carbon dioxide (CO₂) emitted by fossil fuel burning in the U.S. each

year. Climate change, combined with current societal trends in land use and forest management, is projected to reduce this rate of forest CO₂ uptake.

3. Bioenergy could emerge as a new market for wood and could aid in the restoration of forests killed by drought, insects, and fire.
4. Forest management responses to climate change will be influenced by the changing nature of private forestland ownership, globalization of forestry markets, emerging markets for bioenergy, and U.S. climate change policy.

Chapter 8. Ecosystems, Biodiversity, and Ecosystem Services

Key Messages

1. Climate change impacts on ecosystems reduce their ability to improve water quality and regulate water flows.
2. Climate change, combined with other stressors, is overwhelming the capacity of ecosystems to buffer the impacts from extreme events like fires, floods, and storms.
3. Landscapes and seascapes are changing rapidly, and species, including many iconic species, may disappear from regions where they have been prevalent or become extinct, altering some regions so much that their mix of plant and animal life will become almost unrecognizable.
4. Timing of critical biological events, such as spring bud burst, emergence from overwintering, and the start of migrations, has shifted, leading to important impacts on species and habitats.
5. Whole system management is often more effective than focusing on one species at a time, and can help reduce the harm to wildlife, natural assets, and human well-being that climate disruption might cause.

Chapter 9. Human Health

Key Messages

1. Climate change threatens human health and well-being in many ways, including impacts from increased extreme weather events, wildfire, decreased air quality, threats to mental health, and illnesses transmitted by food, water, and disease-carriers such as mosquitoes and ticks. Some of these health impacts are already underway in the United States.
2. Climate change will, absent other changes, amplify some of the existing health threats the nation now faces. Certain people and communities are especially vulnerable, including children, the elderly, the sick, the poor, and some communities of color.
3. Public health actions, especially preparedness and prevention, can do much to protect people from some of the impacts of climate change. Early action provides the largest

health benefits. As threats increase, our ability to adapt to future changes may be limited.

4. Responding to climate change provides opportunities to improve human health and well-being across many sectors, including energy, agriculture, and transportation. Many of these strategies offer a variety of benefits, protecting people while combating climate change and providing other societal benefits.

Chapter 10. Energy, Water, and Land Use

Key Messages

1. Energy, water, and land systems interact in many ways. Climate change affects the individual sectors and their interactions; the combination of these factors affects climate change vulnerability as well as adaptation and mitigation options for different regions of the country.
2. The dependence of energy systems on land and water supplies will influence the development of these systems and options for reducing greenhouse gas emissions, as well as their climate change vulnerability.
3. Jointly considering risks, vulnerabilities, and opportunities associated with energy, water, and land use is challenging, but can improve the identification and evaluation of options for reducing climate change impacts.

Chapter 11. Urban Systems, Infrastructure, and Vulnerability

Key Messages

1. Climate change and its impacts threaten the well-being of urban residents in all U.S. regions. Essential infrastructure systems such as water, energy supply, and transportation will increasingly be compromised by interrelated climate change impacts. The nation's economy, security, and culture all depend on the resilience of urban infrastructure systems.
2. In urban settings, climate-related disruptions of services in one infrastructure system will almost always result in disruptions in one or more other infrastructure systems.
3. Climate vulnerability and adaptive capacity of urban residents and communities are influenced by pronounced social inequalities that reflect age, ethnicity, gender, income, health, and (dis)ability differences.
4. City government agencies and organizations have started adaptation plans that focus on infrastructure systems and public health. To be successful, these adaptation efforts require cooperative private sector and governmental activities, but institutions face many barriers to implementing coordinated efforts.

Chapter 12. Indigenous Peoples, and Lands and Resources

Key Messages

1. Observed and future impacts from climate change threaten Native Peoples' access to traditional foods such as fish, game, and wild and cultivated crops, which have provided sustenance as well as cultural, economic, medicinal, and community health for generations.
2. A significant decrease in water quality and quantity due to a variety of factors, including climate change, is affecting drinking water, food, and cultures. Native communities' vulnerabilities and limited capacity to adapt to water-related challenges are exacerbated by historical and contemporary government policies and poor socioeconomic conditions.
3. Declining sea ice in Alaska is causing significant impacts to Native communities, including increasingly risky travel and hunting conditions, damage and loss to settlements, food insecurity, and socioeconomic and health impacts from loss of cultures, traditional knowledge, and homelands.
4. Alaska Native communities are increasingly exposed to health and livelihood hazards from increasing temperatures and thawing permafrost, which are damaging critical infrastructure, adding to other stressors on traditional lifestyles.
5. Climate change related impacts are forcing relocation of tribal and indigenous communities, especially in coastal locations. These relocations, and the lack of governance mechanisms or funding to support them, are causing loss of community and culture, health impacts, and economic decline, further exacerbating tribal impoverishment.

Chapter 13. Land Use and Land Cover Change

Key Messages

1. Choices about land-use and land-cover patterns have affected and will continue to affect how vulnerable or resilient human communities and ecosystems are to the effects of climate change.
2. Land-use and land-cover changes affect local, regional, and global climate processes.
3. Individuals, businesses, non-profits, and governments have the capacity to make land-use decisions to adapt to the effects of climate change.
4. Choices about land use and land management may provide a means of reducing atmospheric greenhouse gas levels.

Chapter 14. Rural Communities

Key Messages

1. Rural communities are highly dependent upon natural resources for their livelihoods and social structures. Climate change related impacts are currently affecting rural communities. These impacts will progressively increase over this century and will shift the locations where rural economic activities (like agriculture, forestry, and recreation) can thrive.
2. Rural communities face particular geographic and demographic obstacles in responding to and preparing for climate change risks. In particular, physical isolation, limited economic diversity, and higher poverty rates, combined with an aging population, increase the vulnerability of rural communities. Systems of fundamental importance to rural populations are already stressed by remoteness and limited access.
3. Responding to additional challenges from climate change impacts will require significant adaptation within rural transportation and infrastructure systems, as well as health and emergency response systems. Governments in rural communities have limited institutional capacity to respond to, plan for, and anticipate climate change impacts.

Chapter 15. Biogeochemical Cycles

Key Messages

1. Human activities have increased atmospheric carbon dioxide by about 40% over pre-industrial levels and more than doubled the amount of nitrogen available to ecosystems. Similar trends have been observed for phosphorus and other elements, and these changes have major consequences for biogeochemical cycles and climate change.
2. In total, land in the United States absorbs and stores an amount of carbon equivalent to about 17% of annual U.S. fossil fuel emissions. U.S. forests and associated wood products account for most of this land sink. The effect of this carbon storage is to partially offset warming from emissions of CO₂ and other greenhouse gases.
3. Altered biogeochemical cycles together with climate change increase the vulnerability of biodiversity, food security, human health, and water quality to changing climate. However, natural and managed shifts in major biogeochemical cycles can help limit rates of climate change.

Chapter 16. Northeast

Key Messages

1. Heat waves, coastal flooding, and river flooding will pose a growing challenge to the region's environmental, social, and economic systems. This will increase the vulnerability of the region's residents, especially its most disadvantaged populations.
2. Infrastructure will be increasingly compromised by climate-related hazards, including sea level rise, coastal flooding, and intense precipitation events.
3. Agriculture, fisheries, and ecosystems will be increasingly compromised over the next century by climate change impacts. Farmers can explore new crop options, but these adaptations are not cost- or risk-free. Moreover, adaptive capacity, which varies throughout the region, could be overwhelmed by a changing climate.
4. While a majority of states and a rapidly growing number of municipalities have begun to incorporate the risk of climate change into their planning activities, implementation of adaptation measures is still at early stages.

Chapter 17. Southeast and Caribbean

Key Messages

1. Sea level rise poses widespread and continuing threats to both natural and built environments and to the regional economy.
2. Increasing temperatures and the associated increase in frequency, intensity, and duration of extreme heat events will affect public health, natural and built environments, energy, agriculture, and forestry.
3. Decreased water availability, exacerbated by population growth and land-use change, will continue to increase competition for water and affect the region's economy and unique ecosystems.

Chapter 18. Midwest

Key Messages:

1. In the next few decades, longer growing seasons and rising carbon dioxide levels will increase yields of some crops, though those benefits will be progressively offset by extreme weather events. Though adaptation options can reduce some of the detrimental effects, in the long term, the combined stresses associated with climate change are expected to decrease agricultural productivity.
2. The composition of the region's forests is expected to change as rising temperatures drive habitats for many tree species northward. The role of the region's forests as a net absorber of carbon is at risk from disruptions to forest ecosystems, in part due to climate change.
3. Increased heat wave intensity and frequency, increased humidity, degraded air quality, and reduced water quality will increase public health risks.

4. The Midwest has a highly energy-intensive economy with per capita emissions of greenhouse gases more than 20% higher than the national average. The region also has a large and increasingly utilized potential to reduce emissions that cause climate change.
5. Extreme rainfall events and flooding have increased during the last century, and these trends are expected to continue, causing erosion, declining water quality, and negative impacts on transportation, agriculture, human health, and infrastructure.
6. Climate change will exacerbate a range of risks to the Great Lakes, including changes in the range and distribution of certain fish species, increased invasive species and harmful blooms of algae, and declining beach health. Ice cover declines will lengthen the commercial navigation season.

Chapter 19. Great Plains

Key Messages:

1. Rising temperatures are leading to increased demand for water and energy. In parts of the region, this will constrain development, stress natural resources, and increase competition for water among communities, agriculture, energy production, and ecological needs.
2. Changes to crop growth cycles due to warming winters and alterations in the timing and magnitude of rainfall events have already been observed; as these trends continue, they will require new agriculture and livestock management practices.
3. Landscape fragmentation is increasing, for example, in the context of energy development activities in the northern Great Plains. A highly fragmented landscape will hinder adaptation of species when climate change alters habitat composition and timing of plant development cycles.
4. Communities that are already the most vulnerable to weather and climate extremes will be stressed even further by more frequent extreme events occurring within an already highly variable climate system.
5. The magnitude of expected changes will exceed those experienced in the last century. Existing adaptation and planning efforts are inadequate to respond to these projected impacts.

Chapter 20. Southwest

Key Messages:

1. Snowpack and streamflow amounts are projected to decline in parts of the Southwest, decreasing surface water supply reliability for cities, agriculture, and ecosystems.
2. The Southwest produces more than half of the nation's high-value specialty crops, which are irrigation-dependent and particularly vulnerable to extremes of moisture,

- cold, and heat. Reduced yields from increasing temperatures and increasing competition for scarce water supplies will displace jobs in some rural communities.
3. Increased warming, drought, and insect outbreaks, all caused by or linked to climate change, have increased wildfires and impacts to people and ecosystems in the Southwest. Fire models project more wildfire and increased risks to communities across extensive areas.
 4. Flooding and erosion in coastal areas are already occurring even at existing sea levels and damaging some California coastal areas during storms and extreme high tides. Sea level rise is projected to increase as Earth continues to warm, resulting in major damage as wind-driven waves ride upon higher seas and reach farther inland.
 5. Projected regional temperature increases, combined with the way cities amplify heat, will pose increased threats and costs to public health in southwestern cities, which are home to more than 90% of the region's population. Disruptions to urban electricity and water supplies will exacerbate these health problems.

Chapter 21. Northwest

Key Messages:

1. Changes in the timing of streamflow related to changing snowmelt are already observed and will continue, reducing the supply of water for many competing demands and causing far-reaching ecological and socioeconomic consequences.
2. In the coastal zone, the effects of sea level rise, erosion, inundation, threats to infrastructure and habitat, and increasing ocean acidity collectively pose a major threat to the region.
3. The combined impacts of increasing wildfire, insect outbreaks, and tree diseases are already causing widespread tree die-off and are virtually certain to cause additional forest mortality by the 2040s and long-term transformation of forest landscapes. Under higher emissions scenarios, extensive conversion of subalpine forests to other forest types is projected by the 2080s.
4. While the agriculture sector's technical ability to adapt to changing conditions can offset some adverse impacts of a changing climate, there remain critical concerns for agriculture with respect to costs of adaptation, development of more climate resilient technologies and management, and availability and timing of water.

Chapter 22. Alaska and the Arctic

Key Messages

1. Arctic summer sea ice is receding faster than previously projected and is expected to virtually disappear before mid-century. This is altering marine ecosystems and leading to greater ship access, offshore development opportunity, and increased community vulnerability to coastal erosion.

2. Most glaciers in Alaska and British Columbia are shrinking substantially. This trend is expected to continue and has implications for hydropower production, ocean circulation patterns, fisheries, and global sea level rise.
3. Permafrost temperatures in Alaska are rising, a thawing trend that is expected to continue, causing multiple vulnerabilities through drier landscapes, more wildfire, altered wildlife habitat, increased cost of maintaining infrastructure, and the release of heat-trapping gases that increase climate warming.
4. Current and projected increases in Alaska's ocean temperatures and changes in ocean chemistry are expected to alter the distribution and productivity of Alaska's marine fisheries, which lead the U.S. in commercial value.
5. The cumulative effects of climate change in Alaska strongly affect Native communities, which are highly vulnerable to these rapid changes but have a deep cultural history of adapting to change.

Chapter 23. Hawaii and the U.S. Affiliated Pacific Islands

Key Messages

1. Warmer oceans are leading to increased coral bleaching events and disease outbreaks in coral reefs, as well as changed distribution patterns of tuna fisheries. Ocean acidification will reduce coral growth and health. Warming and acidification, combined with existing stresses, will strongly affect coral reef fish communities.
2. Freshwater supplies are already constrained and will become more limited on many islands. Saltwater intrusion associated with sea level rise will reduce the quantity and quality of freshwater in coastal aquifers, especially on low islands. In areas where precipitation does not increase, freshwater supplies will be adversely affected as air temperature rises.
3. Increasing temperatures, and in some areas reduced rainfall, will stress native Pacific Island plants and animals, especially in high-elevation ecosystems with increasing exposure to invasive species, increasing the risk of extinctions.
4. Rising sea levels, coupled with high water levels caused by storms, will incrementally increase coastal flooding and erosion, damaging coastal ecosystems, infrastructure, and agriculture, and negatively affecting tourism.
5. Mounting threats to food and water security, infrastructure, health, and safety are expected to lead to increasing human migration, making it increasingly difficult for Pacific Islanders to sustain the region's many unique customs, beliefs, and languages.

Chapter 24. Oceans and Marine Resources

Key Messages

1. The rise in ocean temperature over the last century will persist into the future, with continued large impacts on climate, ocean circulation, chemistry, and ecosystems.
2. The ocean currently absorbs about a quarter of human-caused carbon dioxide emissions to the atmosphere, leading to ocean acidification that will alter marine ecosystems in dramatic yet uncertain ways.
3. Significant habitat loss will continue to occur due to climate change for many species and areas, including Arctic and coral reef ecosystems, while habitat in other areas and for other species will expand. These changes will consequently alter the distribution, abundance, and productivity of many marine species.
4. Rising sea surface temperatures have been linked with increasing levels and ranges of diseases in humans and marine life, including corals, abalones, oysters, fishes, and marine mammals.
5. Climate changes that result in conditions substantially different from recent history may significantly increase costs to businesses as well as disrupt public access and enjoyment of ocean areas.
6. In response to observed and projected climate impacts, some existing ocean policies, practices, and management efforts are incorporating climate change impacts. These initiatives can serve as models for other efforts and ultimately enable people and communities to adapt to changing ocean conditions.

Chapter 25. Coastal Zone Development and Ecosystems

Key Messages

1. Coastal lifelines, such as water supply and energy infrastructure and evacuation routes, are increasingly vulnerable to higher sea levels and storm surges, inland flooding, erosion, and other climate-related changes.
2. Nationally important assets, such as ports, tourism and fishing sites, in already-vulnerable coastal locations, are increasingly exposed to sea level rise and related hazards. This threatens to disrupt economic activity within coastal areas and the regions they serve and results in significant costs from protecting or moving these assets.
3. Socioeconomic disparities create uneven exposures and sensitivities to growing coastal risks and limit adaptation options for some coastal communities, resulting in the displacement of the most vulnerable people from coastal areas.
4. Coastal ecosystems are particularly vulnerable to climate change because many have already been dramatically altered by human stresses; climate change will result in further reduction or loss of the services that these ecosystems provide, including potentially irreversible impacts.
5. Leaders and residents of coastal regions are increasingly aware of the high vulnerability of coasts to climate change and are developing plans to prepare for potential impacts on citizens, businesses, and environmental assets. Significant institutional, political, social, and economic obstacles to implementing adaptation actions remain.

Chapter 26. Decision Support: Connecting Science, Risk Perception, and Decisions

Key Messages

1. Decisions about how to address climate change can be complex, and responses will require a combination of adaptation and mitigation actions. Decision-makers – whether individuals, public officials, or others – may need help integrating scientific information into adaptation and mitigation decisions.
2. To be effective, decision support processes need to take account of the values and goals of the key stakeholders, evolving scientific information, and the perceptions of risk.
3. Many decision support processes and tools are available. They can enable decision-makers to identify and assess response options, apply complex and uncertain information, clarify tradeoffs, strengthen transparency, and generate information on the costs and benefits of different choices.
4. Ongoing assessment processes should incorporate evaluation of decision support tools, their accessibility to decision-makers, and their application in decision processes in different sectors and regions.
5. Steps to improve collaborative decision processes include developing new decision support tools and building human capacity to bridge science and decision-making.

Chapter 27. Mitigation

Key Messages

1. Carbon dioxide is removed from the atmosphere by natural processes at a rate that is roughly half of the current rate of emissions from human activities. Therefore, mitigation efforts that only stabilize global emissions will not reduce atmospheric concentrations of carbon dioxide, but will only limit their rate of increase. The same is true for other long-lived greenhouse gases.
2. To meet the lower emissions scenario (B1) used in this assessment, global mitigation actions would need to limit global carbon dioxide emissions to a peak of around 44 billion tons per year within the next 25 years and decline thereafter. In 2011, global emissions were around 34 billion tons, and have been rising by about 0.9 billion tons per year for the past decade. Therefore, the world is on a path to exceed 44 billion tons per year within a decade.
3. Over recent decades, the U.S. economy has emitted a decreasing amount of carbon dioxide per dollar of gross domestic product. Between 2008 and 2012, there was also a decline in the total amount of carbon dioxide emitted annually from energy use in the United States as a result of a variety of factors, including changes in the economy, the development of new energy production technologies, and various government policies.

4. Carbon storage in land ecosystems, especially forests, has offset around 17% of annual U.S. fossil fuel emissions of greenhouse gases over the past several decades, but this carbon “sink” may not be sustainable.
5. Both voluntary activities and a variety of policies and measures that lower emissions are currently in place at federal, state, and local levels in the United States, even though there is no comprehensive national climate legislation. Over the remainder of this century, aggressive and sustained greenhouse gas emission reductions by the United States and by other nations would be needed to reduce global emissions to a level consistent with the lower scenario (B1) analyzed in this assessment.

Chapter 28. Adaptation

Key Messages

1. Substantial adaptation planning is occurring in the public and private sectors and at all levels of government; however, few measures have been implemented and those that have appear to be incremental changes.
2. Barriers to implementation of adaptation include limited funding, policy and legal impediments, and difficulty in anticipating climate-related changes at local scales.
3. There is no “one-size fits all” adaptation, but there are similarities in approaches across regions and sectors. Sharing best practices, learning by doing, and iterative and collaborative processes including stakeholder involvement, can help support progress.
4. Climate change adaptation actions often fulfill other societal goals, such as sustainable development, disaster risk reduction, or improvements in quality of life, and can therefore be incorporated into existing decision-making processes.
5. Vulnerability to climate change is exacerbated by other stresses such as pollution, habitat fragmentation, and poverty. Adaptation to multiple stresses requires assessment of the composite threats as well as tradeoffs among costs, benefits, and risks of available options.
6. The effectiveness of climate change adaptation has seldom been evaluated, because actions have only recently been initiated and comprehensive evaluation metrics do not yet exist.

Chapter 29. Research Needs for Climate and Global Change Assessments

Five Research Goals

1. Improve understanding of the climate system and its drivers
2. Improve understanding of climate impacts and vulnerability
3. Increase understanding of adaptation pathways
4. Identify the mitigation options that reduce the risk of longer-term climate change
5. Improve decision support and integrated assessment

Five Foundational Cross-Cutting Research Capabilities

1. Integrate natural and social science, engineering, and other disciplinary approaches
2. Ensure availability of observations, monitoring, and infrastructure for critical data collection and analysis
3. Build capacity for climate assessment through training, education, and workforce development
4. Enhance the development and use of scenarios
5. Promote international research and collaboration

Chapter 30. Sustained Assessment: A New Vision for Future U.S. Assessments

[no key issue bullets]

Appendix 3: The Science of Climate Change

Supplemental Messages

1. Although climate changes in the past have been caused by natural factors, human activities are now the dominant agents of change. Human activities are affecting climate through increasing atmospheric levels of heat-trapping gases and other substances, including particles.
2. Global trends in temperature and many other climate variables provide consistent evidence of a warming planet. These trends are based on a wide range of observations, analyzed by many independent research groups around the world.
3. Natural variability, including El Niño events and other recurring patterns of ocean-atmosphere interactions, influences global and regional temperature and precipitation over timescales ranging from months up to a decade or more.
4. Human-induced increases in atmospheric levels of heat-trapping gases are the main cause of observed climate change over the past 50 years. The “fingerprints” of human-induced change also have been identified in many other aspects of the climate system, including changes in ocean heat content, precipitation, atmospheric moisture, and Arctic sea ice.

5. Past emissions of heat-trapping gases have already committed the world to a certain amount of future climate change. How much more the climate will change depends on future emissions and the sensitivity of the climate system to those emissions.
6. Different kinds of physical and statistical models are used to study aspects of past climate and develop projections of future change. No model is perfect, but many of them provide useful information. By combining and averaging multiple models, many clear trends emerge.
7. Scientific understanding of observed temperature changes in the United States has greatly improved, confirming that the U.S. is warming due to heat-trapping gas emissions, consistent with the climate change observed globally.
8. Many other indicators of rising temperatures have been observed in the United States. These include reduced lake ice, glacier retreat, earlier melting of snowpack, reduced lake levels, and a longer growing season. These and other indicators are expected to continue to reflect higher temperatures.
9. Trends in some types of extreme weather events have been observed in recent decades, consistent with rising temperatures. These include increases in heavy precipitation nationwide, especially in the Midwest and Northeast; heat waves, especially in the West; and the intensity of Atlantic hurricanes. These trends are expected to continue. Research on climate change's effects on other types of extreme events continues.
10. Drought and fire risk are increasing in many regions as temperatures and evaporation rates rise. The greater the future warming, the more these risks will increase, potentially affecting the entire United States.

Appendix 4: Frequently Asked Questions

- A. How can we predict what climate will be like in 100 years if we can't even predict the weather next week?
- B. Is the climate changing? How do we know?
- C. Climate is always changing. How is recent change different than in the past?
- D. Is the globally averaged surface temperature still increasing? Isn't there recent evidence that it is actually cooling?
- E. Is it getting warmer at the same rate everywhere? Will the warming continue?
- F. How long have scientists been investigating human influences on climate?
- G. How can the small proportion of carbon dioxide in the atmosphere have such a large effect on our climate?
- H. Could the sun or other natural factors explain the observed warming of the past 50 years?
- I. How do we know that human activities are the primary cause of recent climate change?
- J. What is and is not debated among climate scientists about climate change?
- K. Is the global surface temperature record good enough to determine whether climate is changing?
- L. Is Antarctica gaining or losing ice? What about Greenland?
- M. Weren't there predictions of global cooling in the 1970s?
- N. How is climate projected to change in the future?
- O. Does climate change affect severe weather?
- P. How are the oceans affected by climate change?

- Q. What is ocean acidification?
- R. How reliable are the computer models of the Earth's climate?
- S. What are the key uncertainties about climate change?
- T. Are there tipping points in the climate system?
- U. How is climate change affecting society?
- V. Are there benefits to warming?
- W. Are some people more vulnerable than others?
- X. Are there ways to reduce climate change?
- Y. Are there advantages to acting sooner rather than later?
- Z. Can we reverse global warming?

Appendix 6: Topics for Consideration in Future Assessments

- Economic Analyses
- National Security
- Interactions between Adaptation and Mitigation Activities