



Union of  
Concerned  
Scientists

# Climate Change in the United States

## The Prohibitive Costs of Inaction

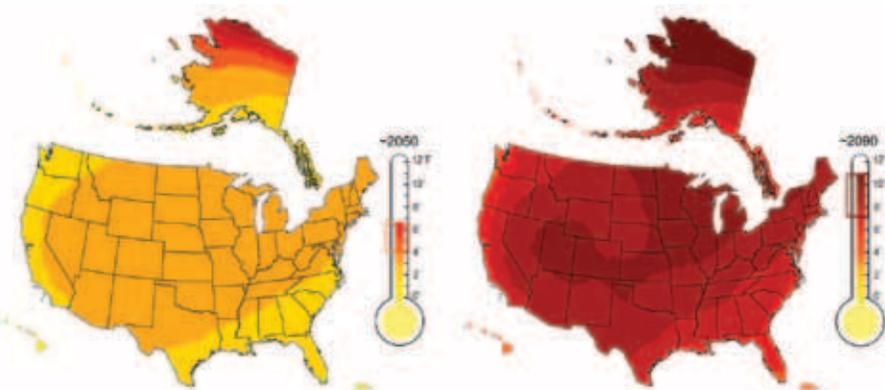
The United States is already experiencing the effects of climate change, and these effects will be much worse without action to sharply curtail our global warming emissions. Average U.S. temperatures have already risen by 2°F over the past 50 years, and are projected to rise another 7–11°F by the end of this century under a high-emissions scenario, and 4–6.5°F under a low-emissions scenario (see Figure 1).

Recognizing the urgency of global warming, policy makers are beginning to pursue solutions to help us avoid the worst effects of climate change, while transitioning the nation to a clean energy economy. However, the debate over comprehensive climate and energy policy often focuses on the costs of climate *action*, rather than on the serious economic and environmental consequences if we *fail to act*. One study shows that if global warming emissions continue to grow unabated—a high-emissions scenario—the annual economic impact of more severe hurricanes, residential real-estate losses to sea-level rise, and growing water and energy costs could reach 1.4 percent of GDP by 2025, and 1.9 percent by 2100 (Ackerman and Stanton 2008).

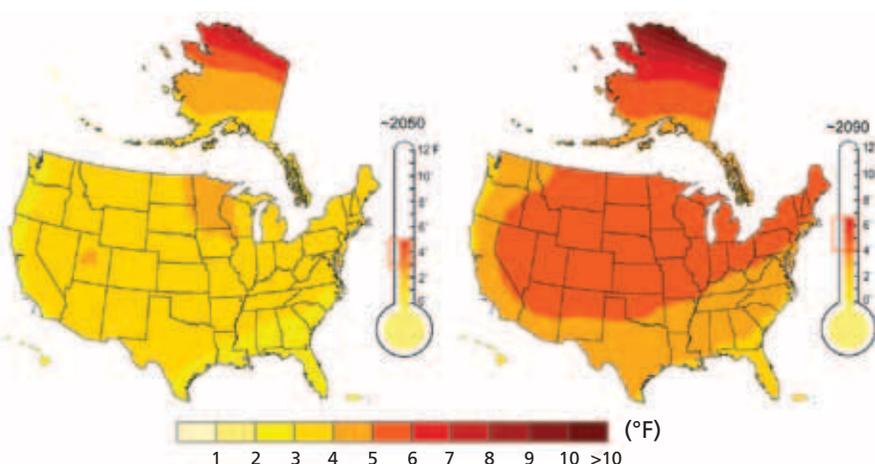
The U.S. Global Change Research Program, a consortium of 13 federal departments and agencies, recently released a comprehensive report describing some of the major impacts of climate change in the United States (Karl, Melillo, and Peterson 2009). That report bolstered a growing consensus that the nation can reap significant economic, public health, and environmental benefits from moving quickly to dramatically reduce our global warming emissions.

**FIGURE 1. Nationwide Projected Temperature Increases**

Mid-century (higher-emissions scenario)    End-of-century (higher-emissions scenario)



Mid-century (lower-emissions scenario)    End-of-century (lower-emissions scenario)



1 2 3 4 5 6 7 8 9 10 >10 (°F)

Source: Adapted from Karl, Melillo, and Peterson 2009.

**Temperatures have already risen an average 2°F over the past 50 years in the United States. By the end of the century, the average U.S. temperature is projected to increase approximately 7 to 11°F from the 1961–1979 baseline under a high-emissions scenario, and approximately 4 to 6.5°F under a low-emissions scenario.**

This fact sheet provides specific examples from that and numerous other studies of the projected damages from climate change, and their costs. These studies show that climate change will

have costly effects on our coasts, our health, our energy and water resources, our agriculture, our transportation infrastructure, and our recreational resources. There are other costs, not included here,

that are hard to quantify or project. The costs presented here also do not include the considerable effects on other countries. Past emissions of heat-trapping gases have already committed us to many near-term costs. However, swift and deep emissions reductions can greatly curtail longer-term costs.

Even a partial accounting of the costs sends a clear message: *Climate inaction is simply too costly.* The prudent response is to aggressively reduce carbon emissions—at least 80 percent from 2005 levels by 2050.

### Impacts on Coastal Communities

Most of the U.S. coast has seen rising sea levels over the past 50 years, and that trend will likely continue under a warming climate. A two-foot rise in global sea levels by the end of this century—within the range of recent estimates—would mean that the ocean would rise another 2.3 feet at New York City, 2.9 feet at Hampton Roads, VA, 3.5 feet at Galveston, TX, and one foot at Neah Bay, WA (Karl, Melillo, and Peterson 2009). These changes would have serious economic consequences for coastal communities.

**Flood damage.** One-sixth of the U.S. population—53 million people—lives in the coastal counties of the Northeast. A sea-level rise of 13–20 inches by 2100 would threaten insured property in these counties valued at \$4.7 trillion—accounting for half of the value of all insured coastal property in the United States (Frumhoff et al. 2007).

In Boston alone, 18 inches of sea-level rise are projected to exact cumulative costs of \$13 billion by 2100—on top of \$7 billion in “normal” flooding costs. And if sea-level rise reaches 33 inches by 2100, today’s 100-year coastal flood will likely occur every one to two years in Boston and Atlantic City, and every 11 to 22 years in New York City (Frumhoff et al. 2007).

In Florida, with 45 inches of sea-levels rise projected under a high-emissions scenario, losses of residential real estate are projected to reach \$60 billion



AP Photo/Michael Dwyer

**Climate change and ensuing sea-level rise threaten to increase the severity of flooding and to damage the infrastructure of coastal communities.**

annually by 2100 (Stanton and Ackerman 2007). In North Carolina, 18 inches of sea-level rise would cause \$2 billion in cumulative property damage by that date (Karetnikov et al. 2008a).

In Florida, under a high-emissions scenario, 9 percent of the state’s land area, 70 percent of Miami-Dade County, half of the state’s existing beaches, and 99 percent of its mangroves would fall into the zone most vulnerable to year-round flooding in 2060 (Stanton and Ackerman 2007). With more coastline than the other 49 states combined, Alaska also stands to experience steep costs from rising sea levels.

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### Even a partial accounting of the costs sends a clear message: Climate inaction is simply too costly.

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**Hurricane intensity.** With all other factors being equal, experts expect higher ocean temperatures to strengthen

hurricanes, which can strike almost anywhere in the Southeast and Gulf Coast region, taking lives and causing enormous damage. A major northeastern hurricane like the one that struck Long Island and New England in 1938 would cause \$20 billion in damages were it to strike today (Frumhoff et al. 2007).

In Florida, the annual costs of more extensive hurricane damage under a high-emissions scenario are projected to reach \$111 billion by 2100. Climate change is also projected to cause an additional 37 hurricane-related deaths per year in that state by 2100—on top of today’s annual average of eight deaths (Stanton and Ackerman 2007).

**Adaptation costs.** Protective measures to head off coastal flooding from rapidly rising sea levels will be costly. Most coastal communities will have to choose among several options: elevating existing structures, constructing seawalls or dykes, and relocating the most vulnerable families and businesses to higher ground (Titus et al. 1991). In California alone, protecting low-lying coastal property from sea-level rise and the resulting storm surges, particularly around San Francisco Bay,

could cost \$6 billion–\$30 billion annually by 2100 under a high-emissions scenario (Kahrl and Roland-Holst 2008).

Elevating a single-family home by 24 inches could cost \$22–\$62 per square foot, while raising larger structures would be far more costly. Estimates of the cost of protecting vulnerable coastal areas with seawalls vary considerably. By one estimate, seawalls could cost \$5 million per linear mile, totaling \$1.2 billion for urban areas in the Northeast, \$3.4 billion for all urban waterfront in the United States, and \$60 billion to protect the entire vulnerable U.S. coastline (USGS 2000; Burby and Nelson 1991). Another study estimates that building seawalls to protect the nation from coastal flooding would cost \$46 billion–\$146 billion (Stanton and Ackerman 2007). However, seawalls would be ineffective against permanent flooding caused by sea-level rise without constant pumping of rain and groundwater within the walled areas (Burby and Nelson 1991; Titus et al. 1991).

In many coastal communities, the only viable option in the face of several feet of sea-level rise will be to gradually abandon properties and relocate further

inland. The Army Corps of Engineers recently estimated that relocating just three Alaskan towns threatened by rising sea levels—Shismaref, Kivalina, and the village of Newtok—would cost \$405 million (Ruth, Coelho, and Karetnikov 2007).

### Impacts on Public Health

If emissions continue to grow unabated, extreme heat waves that now occur once every 20 years are projected to occur about every other year in much of the country by the end of this century. And these very hot days will likely be about 10°F hotter than they are today (Gutowski et al. 2008).

In July 1993, a two-week-long heat wave in Philadelphia with high temperatures between 93°F and 101°F killed more than 100 people (Frumhoff et al. 2007). Such impacts will increase dramatically with climate change, especially affecting vulnerable populations such as children, the elderly, the sick, and the poor. Although deaths from extreme cold are expected to drop, this decline will be substantially smaller than the increase in deaths from heat waves (Medina-Ramon and Schwartz 2007). And higher temperatures will create the conditions for rising

levels of lung-damaging low-altitude ozone and respiratory allergies in urban areas (Twilley et al. 2001).

**Heat waves.** Northeast cities have historically had fewer than two days each year with temperatures above 100°F, and 5 to 20 days with temperatures above 90°F, depending on the city. Under a high-emissions scenario, many cities in this region can expect 60 or more days above 90°F by 2100, and 14–28 days above 100°F, with some of the hottest temperatures expected in large cities such as Philadelphia and New York (Frumhoff et al. 2007).

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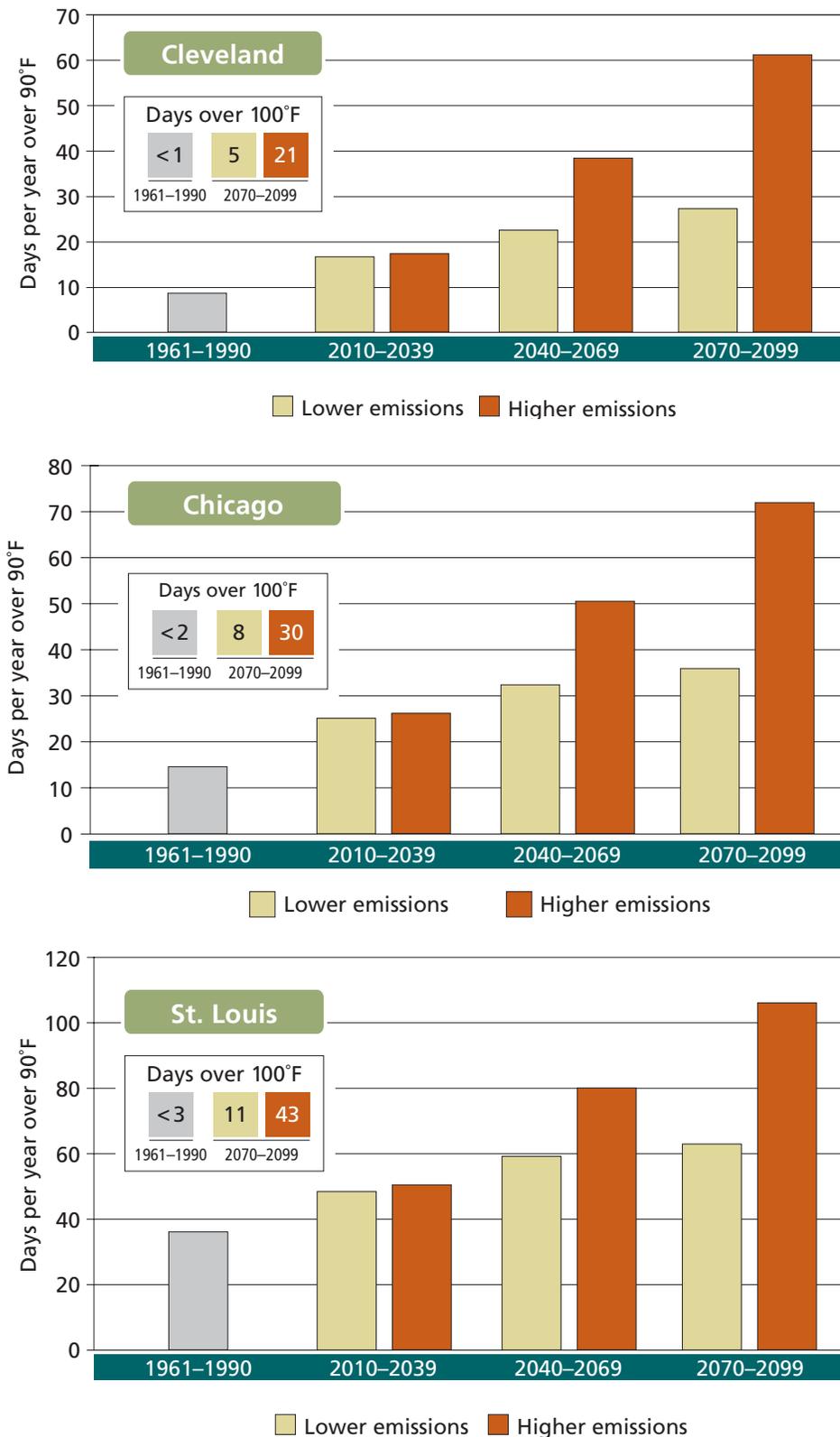
AP Photo/Franck Previl

**Children and the elderly are particularly vulnerable to illness during heat waves. Urban areas across the country will experience the worst effects of heat waves, stressing hospital capacity.**

The Midwest is also vulnerable to much hotter summers under both high-emissions and low-emissions scenarios, with some of the highest temperatures occurring in urban areas such as Cleveland and St. Louis (see Figure 2, p. 4). During the peak of the Chicago heat wave of 1995, admissions to Cook County hospitals rose 11 percent, to 1,072 patients (Semenza et al. 1999). A heat wave of that magnitude 10 years later would cost \$18 million, given the average cost per hospitalized patient in 2005 (HCUP n.d.). Accounting for lost work days and productivity among patients and their caregivers, as well as follow-up medical appointments, would bring this cost even higher (Srinivasan 2008).

Heat waves will also become more severe and common in the Southeast and Gulf states. Miami will become

**FIGURE 2. Extreme Heat in Midwestern Cities**



**Under a high-emissions scenario, Midwest cities will spend most of the summer sweltering in heat over 90°F, including dramatic increases in the number of days over 100°F. Making the choice to pursue a lower-emissions pathway can significantly lessen these effects.**

several degrees hotter than Bangkok today—now the world’s hottest, most humid major city—and daily highs in many Florida cities could exceed 90°F nearly two-thirds of the year (Stanton and Ackerman 2007). In Baton Rouge, Birmingham, Dallas, Houston, and Tampa, deaths from extreme heat now average 28 per year. Even moderate temperature increases would raise this figure to 60 to 75 deaths every year in each of those cities (Twilley et al. 2001).

**Higher ozone levels.** Given the same level of air pollution as today, analysts project a 68 percent increase in the number of Red Ozone Alert Days—when the air is unhealthy for everyone—in the 50 largest eastern U.S. cities by the middle of this century (Bell et al. 2007).

In New Mexico, annual health costs from low-altitude ozone and heat waves combined are expected to jump by \$1.6 billion by 2080 (Niemi 2009a). In California, heat-related health costs could total \$14 billion by 2100 under a high-emissions scenario, while rising ozone levels could increase medical costs by another \$10 billion (Kahrl and Roland-Holst 2008).

### Impacts on Water Resources

Climate change will make storms, floods, and droughts more likely and more intense, and the timing of precipitation could be seriously altered around the country. For example, precipitation and runoff are likely to increase in the Northeast and Midwest in winter and spring, and decrease in the West, especially the Southwest, in spring and summer (Karl, Melillo, and Peterson 2009).

**Flooding.** With its major river systems and relatively high precipitation, the Midwest is prone to flooding, with heavy rainstorms and rapid snowmelt, in particular, causing widespread damage. For example, in May and June 2008, thunderstorms, tornadoes, and flooding caused more than \$18 billion in damage and 55 deaths nationwide, primarily in the Midwest (Lott et al. 2009). And in 1996, a 17-inch rainstorm caused flash flooding over more than 12,000 square

miles of Illinois, Wisconsin, and Indiana in a matter of hours (Changnon 2005).

The record-breaking 1993 midwestern flood caused \$30 billion of damages (Lott et al. 2009), with Iowa, Illinois and Missouri the most heavily hit states (Changnon 2005). The flood inundated 20 million acres in nine states, causing crop losses of 12 percent in Missouri, 11 percent in Minnesota, and 7 percent in Iowa (Mattoon 2008). That flood also caused an estimated 52 deaths, damaged 70,000 homes and buildings, and left 74,000 people homeless. Damages to infrastructure included 1,000 miles of roads closed, 500 miles of railroad track underwater, and nine non-railroad bridges damaged and closed. The flood also idled more than 2,000 barges on the Mississippi for two months (Mattoon 2008; Daniels and Trebilcock 2006).

A senior official at the U.S. Department of Agriculture's Risk Management Agency estimated that payments from the Federal Crop Insurance Program (FCIP) for crops damaged by a similar flood today would be five times the \$2 billion paid in 1993—and not all farmers were insured through FCIP for that flood (USGAO 2007).

**Water scarcity.** Water shortages, already a critical issue in the Southwest, are likely to become far worse with climate change. Such shortages will make agricultural production more expensive, force cut-backs in the amount of land under cultivation, and increase the cost of living in the urban Southwest (see Figure 3). Rivers such as the Colorado—primarily supplied by snowmelt and already over-allocated—are especially vulnerable. In New Mexico alone, reduced stream flows could cost farmers \$21 million per year by 2080, according to one analysis (Niemi 2009a).

In the Southeast, annual rainfall will likely become more variable and could drop, with longer dry spells worsening today's drought conditions (Stanton and Ackerman 2007). Yet hotter and drier conditions will mean that agricultural and domestic users need more water. That means climate change will

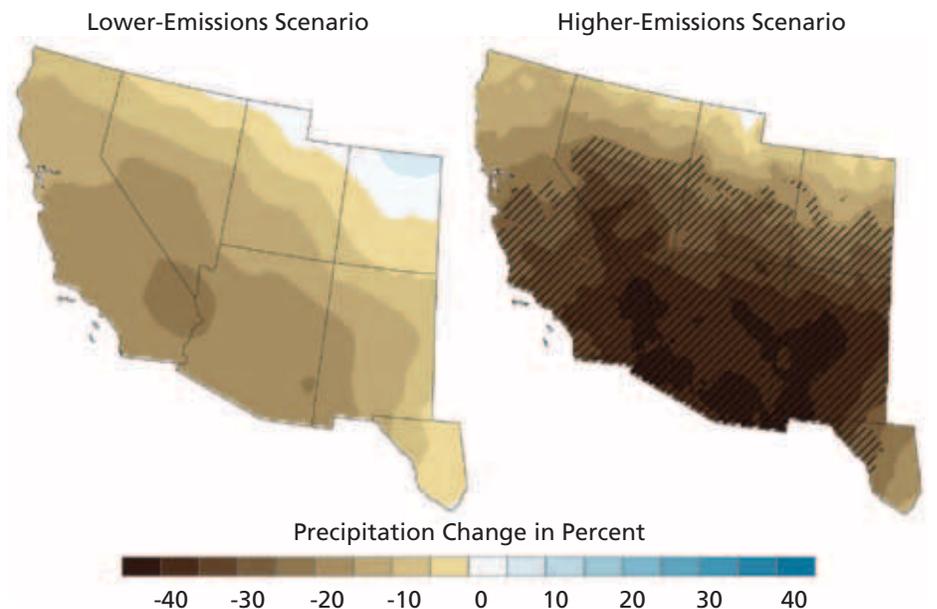
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U.S. Army Corps of Engineers

**Flooding in Fort Wayne, IN. Higher rainfall in the Midwest and the Northeast owing to climate change will lead to more flash flooding that can damage property and infrastructure.**

**FIGURE 3. Projected Drop in Spring Precipitation in the Southwest**



**Percentage change in end-of-century spring precipitation, compared with the 1961–1979 baseline. Lower water levels in the Southwest will create water shortages, impair hydropower generation, lower tourism revenues, and cause water to be more expensive for businesses, farmers, and households alike.**

Source: Adapted from Karl, Melillo, and Peterson 2009.

# The Impacts of Climate Change across the United States



**Flooding:** Under climate change, areas around rivers, lakes, and coastlines are more vulnerable to flooding, which can damage real estate, infrastructure, and crops.



**Hurricane intensity:** These areas are subject to more intense hurricanes, causing property damage and loss of life.



**Beach tourism:** Changing water levels and eroding beaches threaten jobs and require costly adaptive measures such as sand replenishment.



**Public health:** Hotter days and rising ozone levels threaten public health, particularly among at-risk populations such as children and the elderly.



**Water scarcity:** Changing weather patterns reduce water supplies, increasing the cost for farmers, businesses, and households. Water scarcity also limits the effectiveness of hydropower and the cooling systems needed for nuclear, coal-, and natural-gas-fired power plants.



**Shipping:** Lower water levels make shipping routes on rivers and the Great Lakes less viable. Both farmers and industries depend on those routes to transport goods relatively cheaply.



**Winter tourism:** Rising temperatures and declining snowpack shorten the skiing and snowmobiling season and require ski operators to make more snow.



**Agriculture:** Changing weather patterns, lower water levels along shipping routes, and flooding all threaten to make farming more costly and risky.



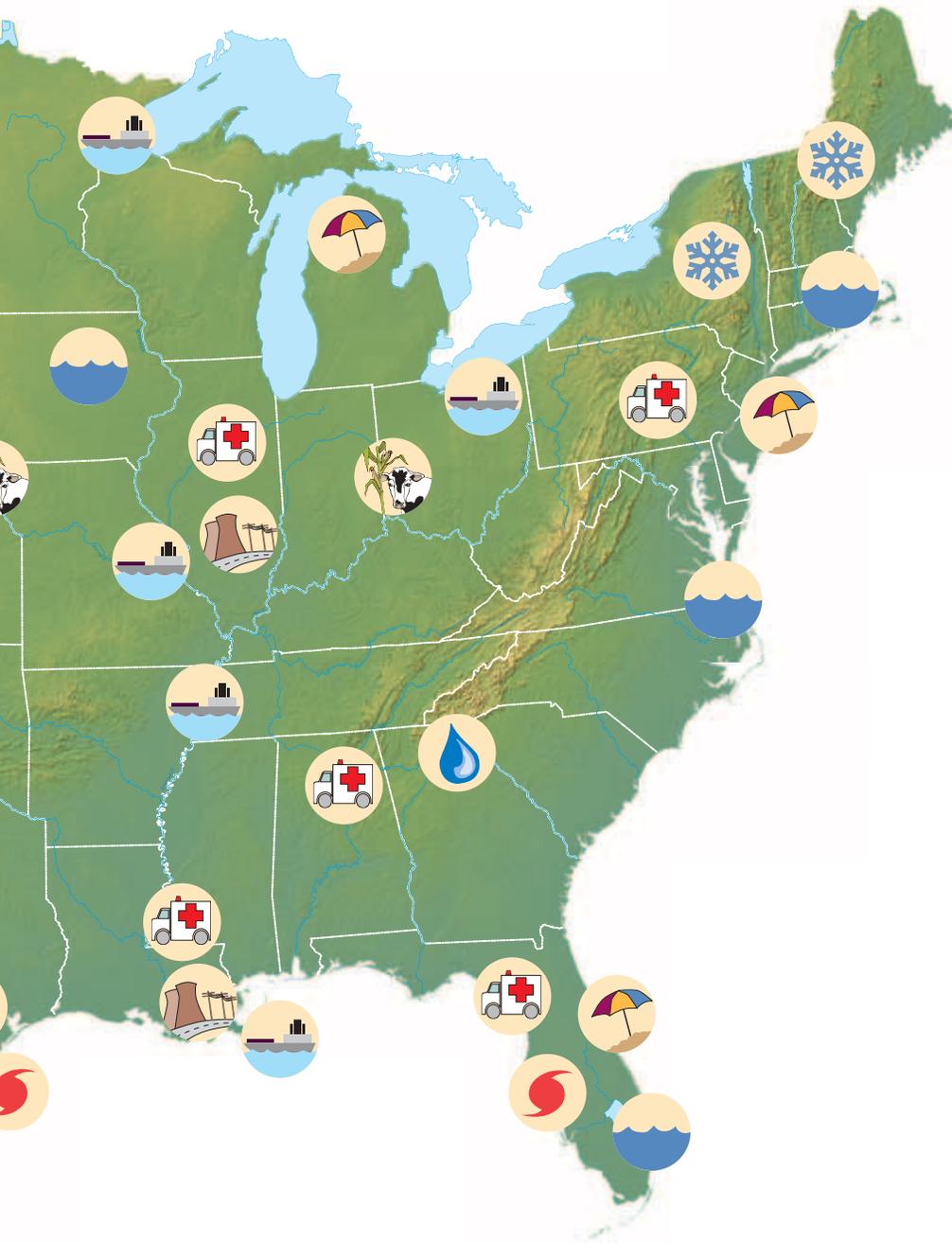
**Energy and infrastructure stress:** Changing climate patterns threaten our transportation and energy infrastructure.



**Wildfires:** Changing weather patterns will bring more frequent wildfires.



If global warming emissions continue to rise unabated, we will see growing costs related to climate change. This map shows some of the projected damages—to our coasts, our health, our energy and water resources, our agriculture, our transportation infrastructure, and our recreational resources—that will occur in states and regions throughout the United States. Making the choice to dramatically lower our emissions at least 80 percent from 2005 levels by 2050 will help avoid some of the worst consequences of climate change.



Climate Impacts in Specific States/Regions	
<b>Northeast</b>	    
CT, DE, ME, MD, MA, NH, NJ, NY, PA, RI, VT	
<b>Southeast</b>	       
AL, AR, FL, GA, KY, LA, MS, NC, SC, TN, VA, WV	
<b>Midwest</b>	     
IL, IN, IA, MI, MN, MO, OH, WI	
<b>Mountains/Great Plains</b>	     
CO, ID, KS, MT, NE, ND, OK, SD, UT, WY	
<b>Southwest</b>	      
AZ, NV, NM, TX	
<b>West Coast</b>	     
CA, OR, WA	
<b>Alaska</b>	  
<b>Hawaii</b>	 



U.S. Geological Survey

**Water scarcity, already a problem in many parts of the Southwest, will worsen under climate change, and irrigation costs will skyrocket.**



University of Minnesota

**Projected increases in rainfall and runoff in the spring, followed by a drier growing season and more rain during harvest times, will be especially challenging for midwestern farmers.**

threaten the survival of irrigated winter agriculture in the region.

Higher temperatures, changes in water levels, and changes in precipitation will also undermine water quality in streams, lakes, and reservoirs, with rising numbers of waterways considered by the U.S. Environmental Protection Agency to be “impaired” by pollution. Sustaining drinking water supplies, wastewater treatment, and storm-water management will require higher expenditures on infrastructure (USEPA 2008).

### **Impacts on Agriculture**

The impact of climate change on agriculture is both complex and uncertain. Higher levels of carbon dioxide will benefit some crops. However, other crops—such as corn, sorghum, and sugar cane—already use carbon dioxide so efficiently that higher levels are unlikely to help.

Higher temperatures will mean higher crop yields in some northern areas. For example, the fruit-growing season around the Great Lakes may be longer (Field et al. 2007). However, in other parts of the country, the effects of climate change on agriculture will be predominantly negative, especially if farmers try to grow the same crops in the same manner as before. While farmers can try to adapt by

changing crop types, planting dates, and irrigation and fertilizer practices, such changes will likely come at a cost.

In the Midwest, climate change is already contributing to wetter springs, which can delay the planting of crops. Hot, dry summers will stress crops and reduce yields, while warmer winters mean that crop pests and pathogens normally kept in check by cold temperatures are projected to expand their ranges northward, causing crop damages beyond the \$78.5 billion already lost to such pests each year. One study projected a 7 percent increase in precipitation in Illinois, which was expected to increase soil erosion by 19–38 percent, making agricultural production more expensive. When combined with a 4.5°F increase in annual temperatures, the yearly costs of climate change for the state’s agricultural sector could reach \$9.3 billion (Karetnikov et al. 2008b).

In California, annual losses to agriculture, forestry, and fisheries could reach \$4.3 billion under a high-emissions scenario. Hotter conditions will slow production and reduce the quality of many of the state’s agricultural products. For example, milk production is expected to fall 22 percent by 2100 under a high-emissions scenario (Kahrl and Roland-Holst 2008). Cooling systems will be

expensive but essential to enable livestock farmers to compensate for higher summer temperatures.

Lower rainfall during the growing season threatens the vital agricultural sector in Great Plains states such as the Dakotas. The 2006 drought cost North Dakota’s livestock industry \$32 million, primarily because of higher feed prices, while crop damage cost farmers \$425 million (Karetnikov et al. 2008d).

The lack of a long winter chill in Massachusetts and New Jersey—which now supply nearly half the nation’s cranberry crop—will likely mean that those states can no longer produce cranberries by the middle of the century under a high-emissions scenario (Frumhoff et al. 2007; Wolfe et al. 2007).

One study found that the average value of farmland in the rain-fed, non-irrigated areas of the eastern and central United States would fall 25 percent by mid-century, and 69 percent by the end of the century, under a high-emissions scenario. Almost all of that loss would stem from the rising number of days above 93°F, when most crops start to suffer (Schlenker et al. 2006).

### **Impacts on Transportation**

Because they will inundate roads, railroads, airports, seaports, and pipelines,

rising sea levels and more severe storm surges could cost commercial transportation hundreds of billions of dollars annually (Karl, Melillo, and Peterson 2009).

**Roads and rail.** Some 60,000 miles of coastal highway already experience periodic flooding from coastal storms, including high waves (NRC 2008). Global warming will likely worsen such flooding. More intense rainstorms also mean that flooding rivers could wash out or degrade railroad beds and roads.

Longer periods of extreme heat could also damage roads in several ways, such as by softening asphalt, which occurs with sustained temperatures above 90°F. Extreme heat can also cause deformities in railroad tracks, requiring trains to run at slower speeds and even causing derailments, and temperatures above 100°F can lead to equipment failure.

Extreme heat also causes bridge joints to expand, stressing the structures and increasing maintenance costs, as well as adversely affecting bridge operations during such maintenance.

**Air travel.** Flooding at airports in coastal areas will affect air travel, and aircraft will need higher takeoff speeds and longer runways to obtain the extra lift required at higher temperatures. Recent hot summers have forced companies to cancel

flights, especially at high-altitude locations. One analysis projects a 17 percent reduction in the freight-carrying capacity of a Boeing 747 at the Denver airport by 2030, and a 9 percent reduction for such an aircraft at the Phoenix airport, because of higher temperatures and more water vapor (NRC 2008).

**Water.** Some 200 million tons of bulk commodities, including iron ore and coal, move through Great Lakes ports such as Duluth-Superior each year (Lindeberg and Albercook 2004). This activity supports more than 30,000 U.S. and Canadian jobs, and provides income totaling more than \$3 billion per year. For example, Ohio's ports on Lake Erie handle 55 million tons of cargo annually, including iron ore from Minnesota and Michigan, coal from Ohio and nearby states, and numerous other goods (LCA n.d.). The ships are designed and loaded to just barely clear the shallowest points along their routes. Every lost inch of water depth can mean that freighters must reduce their cargo by 50 to 270 tons (Lydersen 2008).

The Midwest also relies heavily on shipping on the Mississippi River and its tributaries, which transport almost 500 million tons of cargo—including coal, petroleum products, farm products, and other bulk materials—every year (USACE

2006). Without access to barge transportation on the upper Mississippi (above St. Louis) and the Illinois River, producers of corn, soybean, and wheat would see their revenues drop by \$350 million per year, with Iowa (\$152 million), Minnesota (\$78 million), and Illinois (\$50 million) seeing the heaviest losses (FAPRI 2004).

Both too much and too little water can make river navigation more difficult. Low water conditions mean that barges must carry smaller, less profitable loads, or cannot operate at all. Given those conditions, dredging costing \$85 million—\$142 million annually may be the only way to keep these routes viable (Ruth, Coehlo, and Karetnikov 2007).

Alaska has warmed more than twice as fast as the rest of the nation over the last 50 years, and the thawing permafrost has damaged roads, runways, water and sewer systems, and other infrastructure. Continued thawing will add \$3.6 billion—\$6.1 billion to the cost of publicly owned infrastructure by 2030, and \$5.6 billion—\$7.6 billion by 2080 (Larsen et al. 2008).

## Impacts on Energy Infrastructure

**Oil and gas infrastructure.** Sea-level rise and more severe hurricanes stemming from global warming could cause



Changing water levels in the Great Lakes will lead to economic losses for farmers and industrialists who rely on shipping as an inexpensive way to move crops and other cargo.

Michigan Travel Bureau



Thunder Horse, an offshore oil platform, damaged in 2005 as a result of Hurricane Dennis. Hurricanes often damage oil and gas infrastructure in the Gulf Coast region, creating gasoline shortages and higher gas prices, particularly in the South.

U.S. Coast Guard

huge disruptions along the Gulf Coast, home to 30 percent of the nation's crude oil production and 20 percent of its natural gas production. Such disruptions could also occur in the nearby coastal plains (home to one-third of the nation's refining and processing facilities) and the Gulf of Mexico, which hosts offshore drilling platforms, refineries, and pipelines. Aon Corp., the world's second largest insurance broker, and Willis Group Holdings, the third largest, separately estimated damage to oil and gas producers, drillers, pipeline operators, and

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## More frequent wildfires could represent one of the most costly impacts of climate change in the Rocky Mountain and West Coast regions.

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refiners from two recent hurricanes—Katrina and Rita—at \$15 billion (Kennett 2006).

Oil and gas operations in Alaska are also vulnerable to the effects of global warming. Much of the Trans-Alaska Pipeline is built on permafrost, and thawing of the ground beneath the pipeline creates structural instability that could lead to spills and expensive repairs (Ruth, Coelho, and Karetnikov 2007). The number of days in which the tundra is firm enough to allow the transport and operation of drilling and exploration equipment has already dropped from 200 to 100 during the last 30 years (Hinzman et al. 2005; ACIA 2004).

**Electricity supply.** Water shortages are projected to constrain electricity production in Arizona, Utah, Texas, Louisiana, Georgia, Alabama, Florida, California, Oregon, and Washington state by 2025 (Bull et al. 2007). Washington and Oregon will together lose \$1.7 billion in annual revenues from hydropower by 2080 because of declining snowpack and

water shortages. Even if the most severe climate change does not occur, analysts project that California could lose 10–20 percent of its hydropower at a cost of \$440 million–\$880 million annually (Franco and Sanstad 2006).

**Rising energy demand.** Air conditioning is critical to preventing heat-related illness, yet heat waves can stress and disrupt the electricity supply, as consumers require more power just when demand is highest. For example, during Chicago's 1995 heat wave, a surge in electricity demand led to power outages, depriving even those who had air conditioners of relief. Government, utilities, and power producers can invest in energy efficiency, better energy planning, and new power plants. However, any generating capacity built to avoid power outages on the hottest days typically sits idle for the rest of the year, making it an expensive addition to the electricity system.

In California, analysts expect energy demand to rise 3–20 percent by the end of the century, primarily because of greater use of air conditioning. The added cost in energy bills could total \$1 billion–\$8 billion each year in today's dollars (Franco and Sanstad 2006).

Rising temperatures also make power generation and transmission systems function less efficiently. One analysis projects that inefficient energy transmission during heat waves will cost New Mexico consumers \$1 billion per year by 2080, and that the added cost of air conditioning will cost them \$1.6 billion (Niemi 2009a).

In Florida, the annual cost to generate power for extra air conditioning under a high-emissions scenario is projected to be \$19 billion in 2100. Temperature increases will also make power generation and transmission systems function less efficiently; partly as a result, every additional degree Fahrenheit of warming could cost Florida consumers \$3 billion in electricity costs per year by 2100 (Stanton and Ackerman 2007).

## Impacts on Recreational Resources

Rising temperatures and precipitation changes threaten the skiing and snowmobiling industries. Ski areas will require far more snowmaking to remain viable, and in many cases—especially in the highest-emissions scenarios—the ski season may become too short for snowmaking to be profitable, and resorts will close. Snowmobiling, the nation's largest



**A warming climate threatens recreational activities such as skiing, snowmobiling, and ice angling, which represent billions of dollars in tourism revenues and thousands of jobs across the country.**

Jodi Hillon

winter recreation industry, will see its season shrink 80 percent by 2100 under those scenarios (Frumhoff et al. 2007).

Sea-level rise and other climate changes threaten beach-related tourism. For example, rising ocean temperatures and acidity levels cause coral bleaching and disease, harming the many marine species that depend on coral ecosystems, and thus tourism.

**West.** Climate change under a high-emissions scenario could spur an 80 percent loss of Sierra snowpack by the end of the century. California's ski season would disappear, and with it 15,000 jobs and \$500 million in annual industry revenues. California's tourism assets at risk total \$98 billion, while annual losses to tourism revenues could reach \$7.5 billion. Reduced snowfall will also harm the ski industry in Washington and Oregon, at an annual cost of \$525 million by 2080. Those states could further see a \$1.1 billion-per-year decline in their cold-water angling industries by 2080 (Niemi 2009b; Niemi 2009c).

**Northeast.** Tourism revenues throughout the Northeast are closely tied to maple sugaring, fall foliage, winter sports, hunting, beaches, and many other activities that rely on today's climate. Under high-emissions scenarios, the Northeast stands to lose \$5.3 million–\$12.1 million per year from maple sugar losses alone. Vermont's sugar maples and other important fall foliage trees will rapidly lose their U.S. habitat under high-emissions, high-temperature scenarios. The region also stands to lose \$405 million–\$810 million in annual skiing revenues (Ruth, Coelho, and Karetnikov 2007).

**Midwest.** The Midwest tourism industry stands to lose revenue as water levels in the Great Lakes fall by several feet, curbing water and wetland-based recreational activities such as pleasure boating, fishing, and bird-watching. Rising temperatures in rivers and streams in Michigan and other states will likely reduce sportfishing for trout and other cold-water species (Karetnikov et al. 2008c; Easterling and Karl 2001).



John McColgan/Bureau of Land Management/Alaska Fire Service

**Wildfire in the Bitterroot National Forest, MT. Wildfires are expected to become more frequent in the Rocky Mountain and West Coast regions, adding to firefighting costs, property damage, and lost timber.**

**Southwest.** Revenue from activities in the Southwest such as boating, kayaking, and skiing will likely drop because of falling water levels and rising temperatures. For example, the 5.4 percent drop in water level at Lake Powell from 1999

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## If we act quickly and decisively, we can avoid the worst of the costs associated with global warming.

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to 2003 cut the number of visitors to the Glen Canyon National Recreation Area by half a million in 2003. The result was a loss of \$32.1 million in visitor spending, 758 jobs, and \$13.4 million in personal income (Ponnaluru 2005).

**Southeast and Hawaii.** With severe beach erosion, flooding of the Everglades, and coral bleaching under a high-emissions scenario, Florida's tourism industry will lose \$178 billion annually by

2100. In North Carolina, a sea-level rise of 18 inches by 2080 is expected to cost the beach recreation industry \$11 billion in cumulative damages (Karetnikov et al. 2008a). And in Georgia, a sea-level rise of 20 inches could require \$1.3 billion in sand replenishment costs by 2100, and lead to a loss of 5,000 jobs in the tourism industry (Horin et al. 2008). Meanwhile, in Hawaii, coral bleaching and sea-level rise threaten that state's \$800 million-per-year marine tourism industry (Cesar et al. 2002).

### Wildfires

More frequent wildfires could represent one of the most costly impacts of climate change in the Rocky Mountain and West Coast regions. For example, under a high-emissions scenario, Washington will face added annual costs of \$380 million by 2080 for property damage from wildfires, and Oregon \$497 million (Niemi 2009b). New Mexico stands to lose \$2.2 billion annually in lost timber value and additional fire control expenditures by 2080 (Niemi 2009a).

Fire suppression costs on federal lands alone totaled \$1.9 billion in 2006 and \$1.8 billion in 2007 (Blazer et al. 2008). And the federal government spent almost



**Effective climate legislation will protect businesses and jobs, and ensure a safer environment for generations to come.**

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\$200 million just in California in 2008, including three fires that cost \$50 million each (USDA 2009). California is likely to see a 12–53 percent increase in the annual number of large wildfires by 2100 (Kahrl and Roland-Holst 2008), while annual wildfires in Alaska are expected to triple under a moderate-emissions scenario and quadruple under a high-emissions scenario (Balshi et al. 2008).

Estimates show that states pay another 25 percent on top of federal firefighting expenditures, and that damages to real estate and infrastructure impose further costs on governments, insurers, and homeowners (Rasker 2008).

## Conclusion

If global warming emissions continue unabated, every region in the country will confront large costs from climate change in the form of damages to infrastructure, diminished public health, and threats to vital industries employing millions of Americans. No region can expect a costless adaptation to a rapidly changing climate. Indeed, climate change threatens our very way of life and our legacy to future generations.

The minimum costs presented here will likely outweigh the costs of dramatically reducing carbon emissions starting today. And these projected costs of climate change do not include those that are critical but hard to quantify, such as

costs stemming from changes to ecosystems and the need to relocate coastal communities.

Fortunately, if we act quickly and decisively, we can avoid the worst of these costs. A recent UCS analysis, *Climate 2030: A National Blueprint for a Clean Energy Economy*, shows that immediate implementation of a comprehensive suite of climate, energy, and transportation policies can dramatically lower U.S. global warming emissions while saving consumers and businesses money. Congress needs to enact strong climate legislation that includes such policies to safeguard our economy, our environment, and our future.



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Citizens and Scientists for Environmental Solutions

The Union of Concerned Scientists is the leading science-based nonprofit working for a healthy environment and a safer world.

This fact sheet is a collaborative effort between the Union of Concerned Scientists and independent researchers Frank Ackerman and Elizabeth A. Stanton of the Stockholm Environment Institute at Tufts University. To download a copy or view the list of references, visit [www.ucsusa.org/climatecosts](http://www.ucsusa.org/climatecosts).



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## REFERENCES

- Ackerman, F., and E.A. Stanton. 2008. *Climate change and the U.S. economy: The costs of inaction*. Medford, MA: Global Development and Environment Institute, Tufts University; and Stockholm Environment Institute. Online at: [http://www.sei-us.org/climate-and-energy/US\\_Costs\\_of\\_Inaction.doc](http://www.sei-us.org/climate-and-energy/US_Costs_of_Inaction.doc).
- AIR Worldwide Corporation. 2008. *The coastline at risk: 2008 update to the estimated insured value of U.S. coastal properties*. Boston. Online at: [http://www.air-worldwide.com/\\_public/images/pdf/AIR2008\\_Coastline\\_at\\_Risk.pdf](http://www.air-worldwide.com/_public/images/pdf/AIR2008_Coastline_at_Risk.pdf).
- Arctic Climate Impact Assessment (ACIA). 2004. *Impacts of a warming Arctic*. Cambridge, UK: Cambridge University Press. Online at: <http://www.acia.uaf.edu>. Cited in *Global climate change impacts in the United States*, edited by T.R. Karl, J.M. Melillo, and T.C. Peterson. U.S. Global Change Research Program. Washington, DC: Cambridge University Press, 2009. Online at: <http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf>.
- Balshi, M.S., A.D. McGuire, P. Duffy, M. Flannigan, J. Walsh, and J.M. Melillo. 2008. Assessing the response of area burned to changing climate in western boreal North America using a multivariate adaptive regression splines (MARS) approach. *Global Change Biology* 15(3):578–600. Cited in *Global climate change impacts in the United States*, edited by T.R. Karl, J.M. Melillo, and T.C. Peterson. U.S. Global Change Research Program. Washington, DC: Cambridge University Press, 2009. Online at: <http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf>.
- Bell, M.L., R. Goldberg, C. Hogrefe, P. Kinney, K. Knowlton, B. Lynn, J. Rosenthal, C. Rosenzweig, and J.A. Patz. 2007. Climate change, ambient ozone, and health in 50 U.S. cities. *Climatic Change* 82(1–2):61–76. Cited in *Global climate change impacts in the United States*, edited by T.R. Karl, J.M. Melillo, and T.C. Peterson. U.S. Global Change Research Program. Washington, DC: Cambridge University Press, 2009. Online at: <http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf>.
- Blazer, A., S. Caudle, R.E. Clevette, J.R. Shelley, T. Szayna, and A.C. Hyde. 2008. *2007 U.S. Forest Service and Department of Interior large wildfire cost review*. Online at: <http://www.fs.fed.us/fire/publications/ilwc-panel/report-2007.pdf>.
- Bull, S.R., D.E. Bilello, J. Ekmann, M.J. Sale, and D.K. Schmalzer. 2007. Effects of climate change on energy production and distribution in the United States. In *Effects of climate change on energy production and use in the United States*, edited by T.J. Wilbanks, V. Bhatt, D.E. Bilello, S.R. Bull, J. Ekmann, W.C. Horak, Y.J. Huang, M.D. Levine, M.J. Sale, D.K. Schmalzer, and M.J. Scott. Washington, DC: U.S. Climate Change Science Program. Online at: <http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf>.
- Burby, R.J., and A.C. Nelson. 1991. Local government and public adaptation to sea-level rise. *Journal of Urban Planning and Development* 117(4):140–153.
- Cesar, H., P. van Beukering, S. Pintz, and J. Dierking. 2002. *Economic valuation of Hawaiian reefs*. Arnhem, The Netherlands: Cesar Environment Economics Consulting.
- Changnon, S.A. 2005. The 1993 flood's aftermath: Risks, root causes, and lessons for the future. *Journal of Contemporary Water Research and Education* 130:70–74.
- Daniels, R.J., and M.J. Trebilcock. 2006. *Rationales and instruments for government intervention in natural disasters*. Philadelphia: University of Pennsylvania Press, 89–107. Online at: [http://repository.upenn.edu/cgi/viewcontent.cgi?article=1018&context=law\\_series](http://repository.upenn.edu/cgi/viewcontent.cgi?article=1018&context=law_series).
- Easterling, D.R., and T.R. Karl. 2001. Potential consequences of climate variability and change for the midwestern United States. In *Climate change impacts on the United States: The potential consequences of climate variability and change*. Cambridge, UK: Cambridge University Press, 167–188.
- Federal Emergency Management Agency (FEMA). 1998. *Homeowner's guide to retrofitting: Six ways to protect your house from flooding*. Washington, DC. Online at: <http://www.fema.gov/library/viewRecord.do?id=1420>.
- Field, C.B., L.D. Mortsch, M. Brklacich, D.L. Forbes, P. Kovacs, J.A. Patz, S.W. Running, and M.J. Scott. 2007. North America. Cited in *Climate change 2007: Impacts, adaptation, and vulnerability*, edited by M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson. Cambridge, UK: Cambridge University Press, 617–652. Online at: <http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf>.
- Food and Agricultural Policy Research Institute (FAPRI). 2004. *The upper Mississippi and Illinois Rivers: Value and importance of these transport arteries for U.S. agriculture*. FAPRI-UMC briefing paper 03-04. Columbia, MO: University of Missouri; and Ames, IA: Iowa State University. Online at: [http://fapri.missouri.edu/outreach/publications/2004/FAPRI-UMC\\_Briefing\\_Paper\\_03\\_04.pdf](http://fapri.missouri.edu/outreach/publications/2004/FAPRI-UMC_Briefing_Paper_03_04.pdf).
- Franco, G., and A.H. Sanstad. 2006. *Climate change and electricity demand in California*. Berkeley, CA: California Climate Change Center.
- Frumhoff, P.C., J.J. McCarthy, J.M. Melillo, S.C. Moser, and D.J. Wuebbles. 2007. *Confronting climate change in the U.S. Northeast: Science, impacts, and solutions*. Synthesis report of the Northeast Climate Impacts Assessment. Cambridge, MA: Union of Concerned Scientists. Online at: <http://www.climatechoices.org/assets/documents/climatechoices/confronting-climate-change-in-the-u-s-northeast.pdf>.
- Gude, P.H., J.A. Cookson, M.C. Greenwood, M. Haggerty. 2009. *Homes in wildfire-prone areas: An empirical analysis of wildfire suppression costs and climate change*. Bozeman, MT: Headwaters Economics. Online at: [http://www.headwaterseconomics.org/wildfire/Gude\\_JWF-Manuscript\\_4-24-09\\_Color.pdf](http://www.headwaterseconomics.org/wildfire/Gude_JWF-Manuscript_4-24-09_Color.pdf).
- Gutowski, W.J., G.C. Hegerl, G.J. Holland, T.R. Knutson, L.O. Mearns, R.J. Stouffer, P.J. Webster, M.F. Wehner, and F.W. Zwiers. 2008. Causes of observed changes in extremes and projections of future changes. In *Weather and climate extremes in a changing climate: Regions of focus—North America, Hawaii, Caribbean, and U.S. Pacific Islands*, edited by T.R. Karl, G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple, and W.L. Murray. Washington, DC: U.S. Climate Change Science Program, 81–116.
- Hayhoe, K., J. VanDorn, V. Naik, and D. Wuebbles. 2009. *Climate change in the Midwest: Projections of future temperature and precipitation*. Cambridge, MA: Union of Concerned Scientists.
- Healthcare Cost and Utilization Project (HCUP). No date. Rockville, MD: Agency for Healthcare Research and Quality. Online at: <http://hcupnet.ahrq.gov/>, accessed June 30, 2009.
- Hinzman, L.D., N.D. Bettez, W.R. Bolton, F.S. Chapin, M.B. Dyurgerov, C.L. Fastie, B. Griffith, R.D. Hollister, A. Hope, H.P. Huntington, A.M. Jensen, G.J. Jia, T. Jorgenson, D.L. Kane, D.R. Klein, G. Kofinas, A.H. Lynch, A.H. Lloyd, A.D. McGuire, F.E. Nelson, M. Nolan, W.C. Oechel, T.E. Osterkamp, C.H. Racine, V.E. Romanovsky, R.S. Stone, D.A. Stow, M. Sturm, C.E. Tweedie, G.L. Vourlitis, M.D. Walker, D.A. Walker, P.J. Webber, J.M. Welker, K.S. Winker, and K. Yoshikawa. 2005. Evidence and implications of recent climate change in northern Alaska and other Arctic regions. *Climatic Change* 72(3):251–298. Cited in *Global climate change impacts in the United States*, edited by T.R. Karl, J.M. Melillo, and T.C. Peterson. U.S. Global Change Research Program. Washington, DC: Cambridge University Press, 2009. Online at: <http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf>.
- Horin, C., M. Ruth, K. Ross, and D. Irani. 2008. *Economic impacts of climate change on Georgia*. College Park, MD: Center for Integrative Environmental Research, University of Maryland. Online at: <http://www.cier.umd.edu/climateadaptation/Georgia%20Economic%20Impacts%20of%20Climate%20Change.pdf>.
- Jorgenson, J.D. 2006. *Minerals yearbook: Iron ore*. Washington, DC: U.S. Geological Survey. Online at: [http://minerals.usgs.gov/minerals/pubs/commodity/iron\\_ore/myb1-2006-feore.pdf](http://minerals.usgs.gov/minerals/pubs/commodity/iron_ore/myb1-2006-feore.pdf).
- Kahl, F., and D. Roland-Holst. 2008. *California climate risk and response*. Research paper #08102801. Berkeley, CA: University of California. Online at: [http://www.next10.org/pdfreport\\_CCRR/California\\_Climate\\_Risk\\_and\\_Response.pdf](http://www.next10.org/pdfreport_CCRR/California_Climate_Risk_and_Response.pdf).
- Karetnikov, D., S. Lakhey, C. Horin, B. Bell, M. Ruth, K. Ross, and D. Irani. 2008a. *Economic impacts of climate change on North Carolina*. College Park, MD: Center for Integrative Environmental Research, University of Maryland. Online at: <http://www.cier.umd.edu/climateadaptation/North%20Carolina%20Economic%20Impacts%20of%20Climate%20Change%20Full%20Report.pdf>.

- Karetnikov, D., M. Ruth, K. Ross, and D. Irani. 2008b. *Economic impacts of climate change on Illinois*. College Park, MD: Center for Integrative Environmental Research, University of Maryland. Online at: <http://www.cier.umd.edu/climateadaptation/Illinois%20Economic%20Impacts%20of%20Climate%20Change.pdf>.
- Karetnikov, D., M. Ruth, K. Ross, and D. Irani. 2008c. *Economic impacts of climate change on Michigan*. College Park, MD: Center for Integrative Environmental Research, University of Maryland. Online at: <http://www.cier.umd.edu/climateadaptation/Michigan%20Economic%20Impacts%20of%20Climate%20Change.pdf>.
- Karetnikov, D., S. Lakhey, C. Horin, B. Bell, M. Ruth, K. Ross, and D. Irani. 2008d. *Economic impacts of climate change on North Dakota*. College Park, MD: Center for Integrative Environmental Research, University of Maryland. Online at: <http://www.cier.umd.edu/climateadaptation/North%20Dakota%20Economic%20Impacts%20of%20Climate%20Change%20Full%20Report.pdf>.
- Karl, T.R., J.M. Melillo, and T.C. Peterson, eds. 2009. *Global climate change impacts in the United States*. U.S. Global Change Research Program (USGCRP). Washington, DC: Cambridge University Press. Online at: <http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf>.
- Kennett, J. 2006. Katrina, Rita cost to oil industry rises to record \$17 billion. Online at: <http://www.bloomberg.com/apps/news?pid=20601109&sid=aZjgqqrTSgrs&refer=exclusive>, accessed June 26, 2009.
- Konieczki, A.D., and J.A. Heilman. 2004. *Water-use trends in the desert Southwest, 1950–2000*. Scientific Investigations Report 2004-5148. Washington, DC: U.S. Geological Survey.
- Lake Carriers' Association (LCA). No date. Great Lakes shipping: The vital link for Ohio industry. West Cleveland, OH. Online at: <http://lcaships.com/ohio/>, accessed June 29, 2009.
- Larsen, P.H., S. Goldsmith, O. Smith, M.L. Wilson, K. Strzepek, P. Chinowsky, and B. Saylor. 2008. Estimating future costs for Alaska public infrastructure at risk from climate change. *Global Environmental Change* 18(3):442–457.
- Lindeberg, J.D., and G.M. Albercook. 2004. *Climate change and Great Lakes shipping/boating: Great Lakes regional assessment*. Washington, DC: U.S. Environmental Protection Agency. Online at: [http://www.geo.msu.edu/gbra/PDF\\_files/Regional%20Summary/04F\\_WRES\\_F.boating.pdf](http://www.geo.msu.edu/gbra/PDF_files/Regional%20Summary/04F_WRES_F.boating.pdf).
- Lott, N., T. Ross, T. Houston, A. Smith, and K. Shein. 2009. *Billion dollar U.S. weather disasters, 1980–2008*. Washington, DC: National Climatic Data Center. Online at: <http://www.ncdc.noaa.gov/img/reports/billion/billionz-2008.pdf>.
- Lydersen, K. 2008. Great Lakes' lower water levels propel a cascade of hardships. *Washington Post*, January 27, A04. Online at: <http://www.washingtonpost.com/wp-dyn/content/article/2008/01/26/AR2008012601748.html>.
- Mattoon, R. 2008. Assessing the Midwest floods of 2008 (and 1993). Chicago: Federal Reserve Bank of Chicago. Online at: [http://midwest.chicagofedblogs.org/archives/2008/07/mattoon\\_flood\\_b.html](http://midwest.chicagofedblogs.org/archives/2008/07/mattoon_flood_b.html).
- Medina-Ramon, M., and J. Schwartz. 2007. Temperature, temperature extremes, and mortality: A study of acclimatisation and effect modification in 50 U.S. cities. *Occupational and Environmental Medicine* 64(12):827–833.
- Moser, S., G. Franco, S. Pittiglio, W. Chou, and D. Cayan. 2009. *The future is now: An update on climate change science impacts and response options for California*. Sacramento: California Climate Action Center. Online at: <http://www.energy.ca.gov/2008publications/CEC-500-2008-071/CEC-500-2008-071.PDF>.
- National Research Council (NRC). 2008. *Potential impacts of climate change on U.S. transportation*. Transportation Research Board special report #290. Washington, DC. Online at: <http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf>.
- Niemi, E. 2009a. *An overview of potential economic costs to New Mexico of a business-as-usual approach to climate change*. Eugene, OR: Climate Leadership Initiative, University of Oregon. Online at: [http://climlead.uoregon.edu/pdfs/Inaction\\_NM\\_FnlRpt.pdf](http://climlead.uoregon.edu/pdfs/Inaction_NM_FnlRpt.pdf).
- Niemi, E. 2009b. *An overview of potential economic costs to Oregon of a business-as-usual approach to climate change*. Eugene, OR: Climate Leadership Initiative, University of Oregon. Online at: <http://climlead.uoregon.edu/pdfs/FinalOReconomicreport.pdf>.
- Niemi, E. 2009c. *An overview of potential economic costs to Washington of a business-as-usual approach to climate change*. Eugene, OR: Climate Leadership Initiative, University of Oregon. Online at: [http://climlead.uoregon.edu/pdfs/Inaction\\_WA\\_FnlRpt.pdf](http://climlead.uoregon.edu/pdfs/Inaction_WA_FnlRpt.pdf).
- Pimentel, D., S. McNair, J. Janecka, J. Wightman, C. Simmonds, C. O'Connell, E. Wong, L. Russel, J. Zern, T. Aquino, and T. Tsomondo. 2001. Economic and environmental threat of alien plant, animal, and microbe invasions. *Agriculture, Ecosystems, and the Environment* 84:1–20.
- Ponnaluru, S. 2005. *Visitation to the national parks of the Southwest: The influence of economic and climate variables*. Master's thesis. Tucson, AZ: Department of Agricultural and Resource Economics, University of Arizona.
- Rahmstorf, S. 2007. A semi-empirical approach to projecting future sea-level rise. *Science* 315:368–370.
- Rasker, R. 2008. *Montana wildfire cost study technical assessment*. Bozeman, MT: Headwaters Economics. Online at: [http://www.headwaterseconomics.org/wildfire/HeadwatersEconomics\\_FireCostStudy\\_TechnicalReport.pdf](http://www.headwaterseconomics.org/wildfire/HeadwatersEconomics_FireCostStudy_TechnicalReport.pdf).
- Ruth, M., D. Coelho, and D. Karetnikov. 2007. *The U.S. economic impacts of climate change and the costs of inaction*. College Park, MD: Center for Integrative Environmental Research, University of Maryland. Online at: <http://www.cier.umd.edu/documents/US%20Economic%20Impacts%20of%20Climate%20Change%20and%20the%20Costs%20of%20Inaction.pdf>.
- Schlenker, W., W.M. Hanemann, and A.C. Fisher. 2006. The impact of global warming on U.S. agriculture: An econometric analysis of optimal growing conditions. *Review of Economics and Statistics* 88(1).
- Semenza, J.C., J.E. McCullough, W.D. Flanders, M.A. McGeehin, and J.R. Lumpkin. 1999. Excess hospital admissions during the July 1995 heat wave in Chicago. *American Journal of Preventive Medicine* 16(4):269–277.
- Srinivasan, T. 2008. *Cost of excess hospitalizations and emergency department visits for the 2006 California heat wave*. Washington, DC: Natural Resources Defense Council. Online at: [http://docs.nrdc.org/health/files/hea\\_08082601A.pdf](http://docs.nrdc.org/health/files/hea_08082601A.pdf).
- Stanton, E.A., and F. Ackerman. 2007. *Florida and climate change: The costs of inaction*. Medford, MA: Global Development and Environment Institute, Tufts University; and Stockholm Environment Institute. Online at: [http://www.sei.se/mediamanager/documents/Publications/Climate/inaction\\_florida.pdf](http://www.sei.se/mediamanager/documents/Publications/Climate/inaction_florida.pdf).
- Stern, N. 2006. *The Stern review: The economics of climate change*. London: HM Treasury. Online at: [http://www.hm-treasury.gov.uk/stern\\_review\\_report.htm](http://www.hm-treasury.gov.uk/stern_review_report.htm).
- Titus, J.G., R.A. Parke, S.P. Leatherman, J.R. Weggel, M.S. Greene, P.W. Mousel, S. Brown, G. Gaunt, M. Trehan, and G. Yohe. 1991. Greenhouse effect and sea level rise: The cost of holding back the sea. *Coastal Management* 19:171–204.
- Twilley, R.R., E.J. Barron, H.L. Gholz, M.A. Harwell, R.L. Miller, D.J. Reed, J.B. Rose, E.H. Siemann, R.G. Wetzel, and R.J. Zimmerman. 2001. *Confronting climate change in the Gulf Coast region: Prospects for sustaining our ecological heritage*. Cambridge, MA: Union of Concerned Scientists.
- U.S. Army Corps of Engineers (USACE). 2006. *Waterborne commerce of the United States, Part 2: Waterways and harbors of the Gulf Coast, Mississippi River System, and Antilles*. IWR-WCUS-06-2. Online at: <http://www.iwr.usace.army.mil/ndc/wcs/pdf/wcuscumvc06.pdf>.
- U.S. Department of Agriculture (USDA). 2009. *Fire and aviation management fiscal year 2008 accountability report*. Online at: [http://www.fs.fed.us/fire/management/reports/fam\\_fy2008\\_accountability\\_report.pdf](http://www.fs.fed.us/fire/management/reports/fam_fy2008_accountability_report.pdf).
- U.S. Environmental Protection Agency (USEPA). 2008. *National water program strategy: Response to climate change*. Washington, DC.
- U.S. Geological Survey (USGS). 2000. *National assessment of coastal vulnerability to future sea-level rise*. USGS fact sheet FS-076-00. Washington, DC.
- U.S. Government Accountability Office (USGAO). 2007. *Climate change: Financial risks to federal and private insurers in the coming decades are potentially significant*. GAO 07-285. Washington, DC.
- Wolfe, W., L. Ziska, C. Petzoldt, A. Seaman, L. Chase, and K. Hayhoe. 2007. Projected change in climate thresholds in the northeastern U.S.: Implications for crops, pests, livestock, and farmers. *Mitigation and Adaptation Strategies for Global Change* 13(5–6):555–575.
- Yin, J., M.E. Schlesinger, and R.J. Stouffer. 2009. Model projections of rapid sea-level rise on the northeast coast of the United States. *Nature Geoscience* 2:262–266.