C2ES CENTER FOR CLIMATE AND ENERGY SOLUTIONS

A Climate of Extreme Weather Events

U.S. Impacts and Vulnerability

Introduction:

Much of the discussion of climate change focuses on slow changes in average temperatures and precipitation over time. But this focus masks the larger changes in weather variability and extreme weather events that will accompany modest changes in averages. Damages aren't typically associated with average rainfall events or gradual increases in temperatures but are driven by extreme flooding events, periods of extended drought or prolonged, intense heat waves.

Extreme weather events have always been an important part of our climate history. The Dust Bowl drought of the 1930s, the 1927 Mississippi River flood, and the 1980 Heat Wave that blanketed much of the Midwest are just a few examples of extreme events that are etched in our nation's history. By its very nature our climate system produces variable weather including an occasional extreme event. By increasing greenhouse gases in the atmosphere, however, we are loading the dice toward more favorable climate conditions for extreme weather and are very likely to experience more frequent extreme events over time.

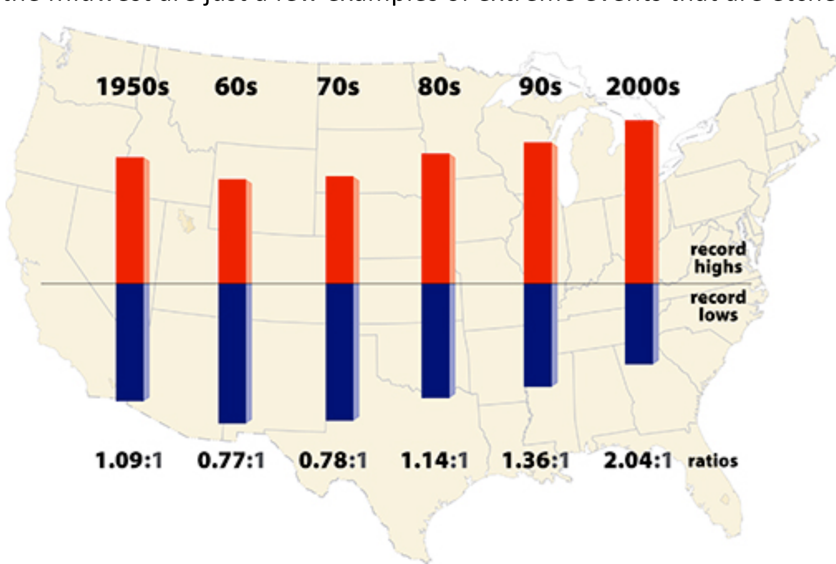

Figure 1: Ratio of record highs to record lows. Source: ©UCAR, Mike Shibao (2009)

A large body of scientific evidence suggests that droughts, floods and heat waves are likely to become more frequent and/or intense. Recent data suggests we are experiencing this trend already.[1] For example, the amount of rain that falls during intense precipitation events has increased by 20 percent in the United States over the last century.[2] Over the past decade, record high

[1] Global Climate Change Impacts in the United States, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009. (p.32)
(eds.). Cambridge University Press, 2009. (p.32) [2] Global Climate Change Impacts in the United States, op. cit. (p.44)
[2] Global Climate Change Impacts in the United States, op. cit. (p.44)

temperatures now occur about twice as often as record lows; the ratio was about one-to-one in the 1950s (Figure 1).[3] Recent floods in Tennessee, the lower Mississippi and North Dakota, droughts and wildfires in the southwest, and intense, humid heat waves in the Midwest, illustrate the high costs of extreme weather events. These types of changes are fully consistent with what scientists have long warned would be the consequences of increasing greenhouse gas concentrations in our atmosphere. A large body of scientific evidence makes it clear that the risk of such events has increased and should be expected to continue to increase as the climate warms.

The events we have experienced in recent years provide important information about our vulnerability to extreme weather, the human and economic costs that could result, and most importantly, actions we can take today to minimize the risks of more frequent extreme weather events. This information is useful regardless of why any particular event happened and whether climate change made it worse or not. The often asked question about whether climate change caused a particular weather event cannot be answered definitively. Individual events are caused by the interaction of many factors and efforts to isolate the role of climate change will not be resolved cleanly in the years to come. What virtually all climate scientists agree on, however, is that the climate is already changing, that all weather events now form under different conditions than they used to, and that this change is increasing the probability of extreme weather events happening. Moreover, scientists agree that severe heat and heavy downpours are already more frequent and intense than they used to be. Since the rising risk of extreme weather is well established, it makes sense to learn what we can from actual events and avoid getting caught up in an irresolvable debate about why a particular event happened.

The interactive extreme events map focuses on the types of extreme weather events that scientists say are already more frequent and/or intense and the risk of which can be expected to rise in the future as a result of climate change. The map shows where historically some of the most significant heat waves, floods, droughts, and wildfires have occurred across the United States since 1995. These events impact all parts of the country and provide opportunities to learn about the potential economic and human impacts from extreme weather events and the actions needed to build resilience for the future.

Other types of weather events, such as tornadoes, are excluded from the map because current scientific understanding provides inadequate prediction of how they might respond to climate change. The reader should take care, however, not to interpret this lack of information as evidence that there isn't a link; we simply don't know yet. Indeed, one could easily argue that it is prudent to increase resilience to tornadoes based on current vulnerabilities alone.

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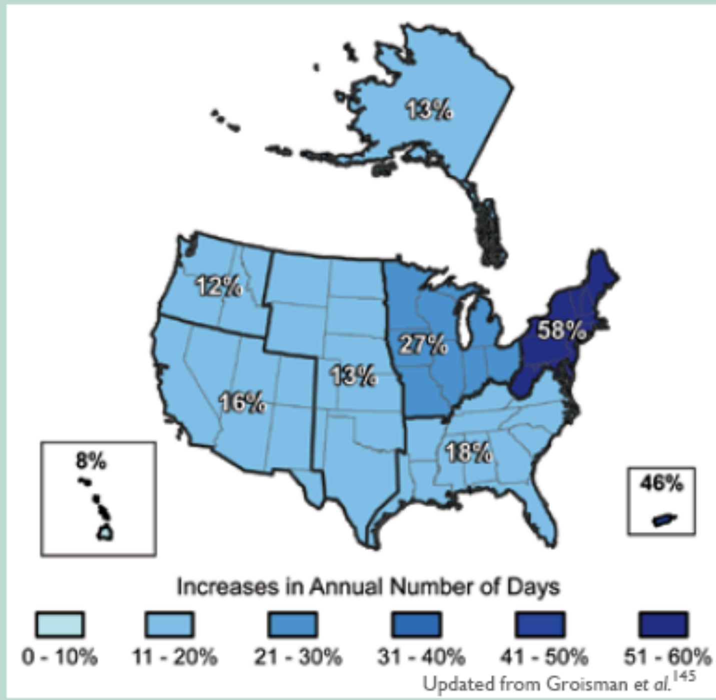
[3] Meehl, G. A., C. Tebaldi, G. Walton, D. Easterling, and L. McDaniel (2009), Relative increase of record high maximum temperatures compared to record low minimum temperatures in the U.S., *Geophys. Res. Lett.*, *36*, L23701, doi:10.1029/2009GL040736.

Flooding

Extended periods of heavy precipitation have increased significantly over the past few decades.[4] In the U.S., total precipitation has increased by about 7 percent and the frequency of heavy downpours (defined as the top 1 percent of rainfall amounts) has increased by almost 20 percent on average.[5] The largest increase in heavy downpours has occurred in the Northeast and Midwest (Figure 2).[6] Recently, five-hundred year flooding events have impacted the Midwest twice, during 1993 and 2008, due to extended periods of heavy precipitation.[7] These events coincide with a 50 percent increase in the Midwest of the number of days with precipitation over 4 inches.[8] Similar events have plagued parts of the United States in 2010 and 2011.

Increases in the Number of Days with Very Heavy Precipitation (1958 to 2007)



The map shows the percentage increases in the average number of days with very heavy precipitation (defined as the heaviest 1 percent of all events) from 1958 to 2007 for each region. There are clear trends toward more days with very heavy precipitation for the nation as a whole, and particularly in the Northeast and Midwest.

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[4] Global Climate Change Impacts in the United

[5] Gutowski, W.J., G.C. Hegerl, G.J. Holland, T.R. Knutson, L.O. Mearns, R.J. Stouffer, P.J. Webster, M.F. Wehner, F.W. Zwiers, 2008: Causes of Obser ved 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. T.R. Karl, G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple, and W.L. Murray (eds.). A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC.

[6] Global Climate Change Impacts in the United States, op. cit. (p.44)

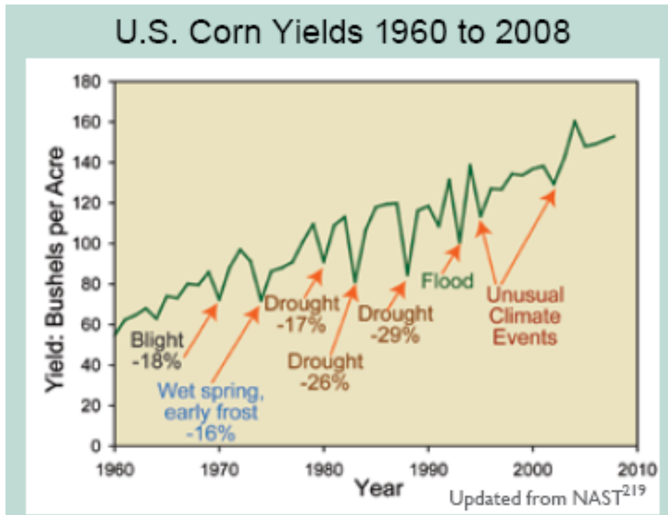
[7] Global Climate Change Impacts in the United States, op. cit. (p.64)

[8] Kunkel, K.E., P.D. Bromirski, H.E. Brooks, T. Cavazos, A.V. Douglas, D.R. Easterling, K.A. Emanuel, P.Ya. Groisman, G.J. Holland, T.R. Knutson, J.P. Kossin, P.D. Komar, D.H. Levinson, R.L. Smith, 2008: Observed Changes in Weather and Climate Extremes in Weather and Climate Extremes in a Changing Climate. Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands. T.R. Karl, G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple, and W.L. Murray (eds.). A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC.

A warmer world is expected to produce changes in the distribution and frequency of precipitation events. The increased moisture in the atmosphere as a result of global warming (a warmer atmosphere can hold more water) increases the capacity for the atmosphere to generate heavy rainfall events. These heavy events become climatically favored over light rainfall events, and thus increase the risk of flooding. Into the future, precipitation intensity is projected to increase everywhere, with the largest increases occurring in areas that already have the highest rainfall.[9] Therefore, the Midwest and Northeast, where total precipitation has already increased the most, is likely to suffer from the even greater increases in extreme precipitation in the future.

Figure 2: Increases in heavy precipitation

The impact of extreme floods can be substantial, especially when they overwhelm existing defenses. During the 2008 Midwest flood, dozens of levees were breached across the region, inundating huge areas, including the city of Cedar Rapids, Iowa. Transport was brought to a standstill as normally navigable waterways became impassable and railroads were flooded. Interstate 80 was closed for more than five days, disrupting east-west shipping for the entire country.[10] The 2008 floods also drowned hundreds of thousands of acres of cropland, just as farmers were preparing to harvest wheat and plant corn, soybeans and cotton, slashing agricultural output. Agricultural losses were estimated at $8 billion, driving many farmers out of business.[11] As seen in Figure 3, climate extremes can have a large impact on crop yield.



While technological improvements have resulted in a general increase in corn yields, extreme weather events have caused dramatic reductions in yields in particular years. Increased variation in yield is likely to occur as temperatures increase and rainfall becomes more variable during the growing season. Without dramatic technological breakthroughs, yields are unlikely to continue their historical upward trend as temperatures rise above the optimum level for vegetative and reproductive growth.

Figure 3: Corn Yields

In areas where the precipitation is expected to increase, excessive winter snowpacks could increase the risk of flooding during the spring snowmelt and increasing temperatures could cause rivers to swell earlier in the year. Levees that are built to withstand the expected runoff based on historical records may prove inadequate under new climate conditions, especially when a heavy winter snowpack is combined with warm, intense spring rainfall. That combination has plagued the Midwest and West in recent years, including the spring of 2011 when North Dakota experienced its worst flooding since record keeping began in the 19th century.

[9] Global Climate Change Impacts in the United States, op. cit. (p.44)
[10] Global Climate Change Impacts in the United States, op. cit. (p.66)
[11] National Climatic Data Center, Climate of 2008: Midwestern U.S. Flood Overview. Retrieved June 22, 2011, from http://www.ncdc.noaa.gov/oa/climate/research/2008/flood08.html

Flooding can have serious public health effects as well. Many cities including New York, Chicago, Washington D.C., and Milwaukee have combined sewer systems that carry storm water and sewage in the same pipes. When extreme rainfall events happen, these systems become overwhelmed and discharge raw sewage into lakes and waterways, including into drinking water supplies and places where people swim and catch fish.[12] If 2.5 inches of rain is the threshold for an overflow event, the frequency of these events would be projected to rise between 50 and 100 percent in Chicago by the end of the century.[13]

Coastal flooding caused by rising sea levels is another risk that is currently increasing due to climate change. Estimates of sea level rise have increased based on new scientific evidence developed over the past few years. A recent scientific assessment estimates that the global average sea level could rise by 3-5 feet by the end of this century.[14] Coastal erosion combined with the higher water level reduces shoreline defenses against storm surges, unusually high tides or waves. This increased vulnerability has implications for coastal property values and the economic viability of coastal towns. In places like Norfolk, Virginia, millions of dollars are being spent to raise roads and buildings to reduce exposure to flooding. After Hurricane Katrina in New Orleans, attempts are being made to restore wetlands that can act as a buffer and strengthen existing infrastructure to prevent flooding during future storms.

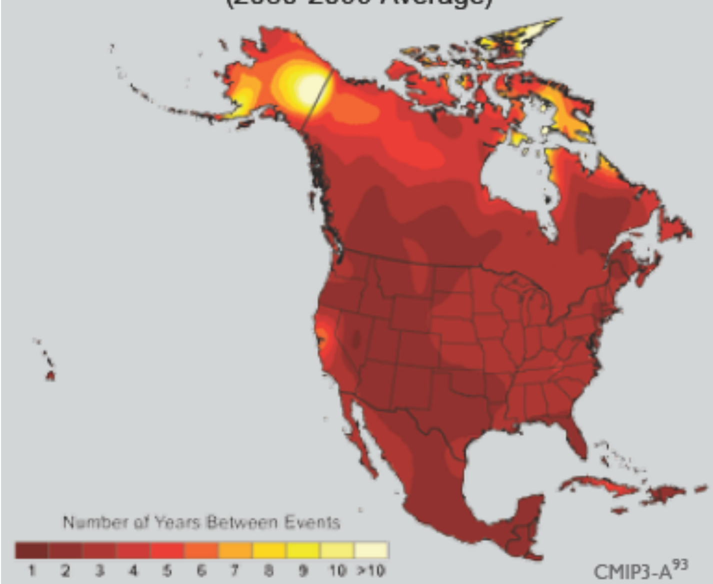
[12] v Peterson, T.C., D.M. Anderson, S.J. Cohen, M. Cortez-Vázquez, R.J. Murnane, C. Parmesan, D. Phillips, R.S. Pulwarty, J.M.R. Stone, 2008: Why Weather and Climate Extremes Matter in Weather and Climate Extremes in a Changing Climate. Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands. T.R. Karl, G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple, and W.L. Murray (eds.). A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC.

[13] Jonathan A. Patz, Stephen J. Vavrus, Christopher K. Uejio, Sandra L. McLellan (2008) Climate Change and Waterborne Disease Risk in the Great Lakes Region of the U.S. in *American Journal of Preventive Medicine*, Vol. 35:5 P. 451-458 DOI: 10.1016/j.amepre.2008.08.026)

[14] K. Ritter, "New report confirms Arctic melt accelerating." Associated Press, May 3, 2011, Retrieved on June 23, 2011 from http://apne.ws/kXN5j3

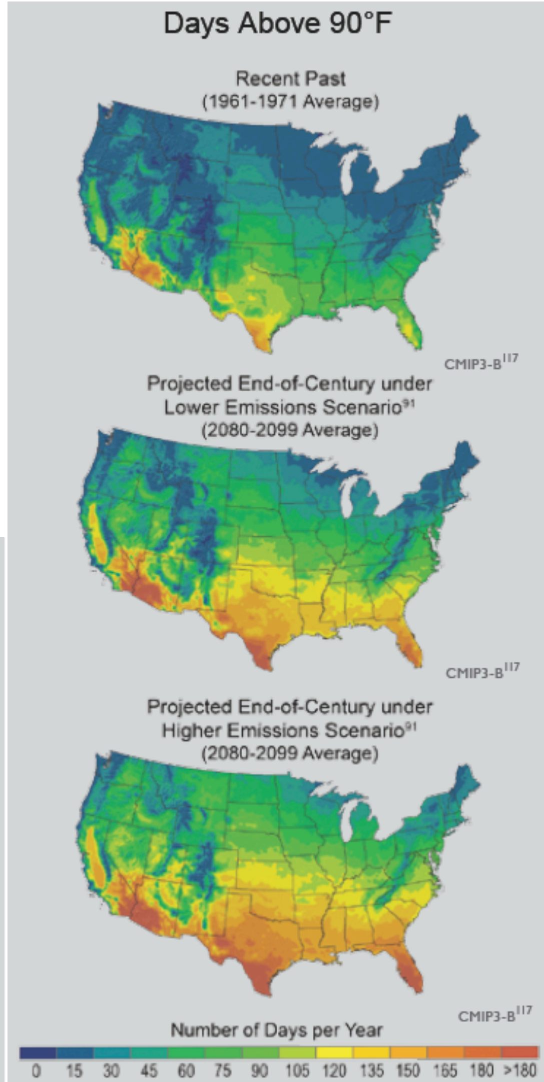
Heat Waves

Average temperatures in the U.S. have increased by 2°F over the past 50 years.[15] Accompanying these changes in average temperature have been far more record high temperatures than record lows, and that trend is expected to grow in proportion with future warming. Figures 4 and 5 show the expected changes in the frequency of extreme heat by the end of the century. Days with high temperatures that only occur once every 20 years could occur every other year by the end of the century. Temperatures in excess of 90°F could become commonplace in the northern tier of the nation.



Simulations for 2080-2099 indicate how currently rare extremes (a 1-in-20-year event) are projected to become more commonplace.

Figure 4: Frequency of extreme heat

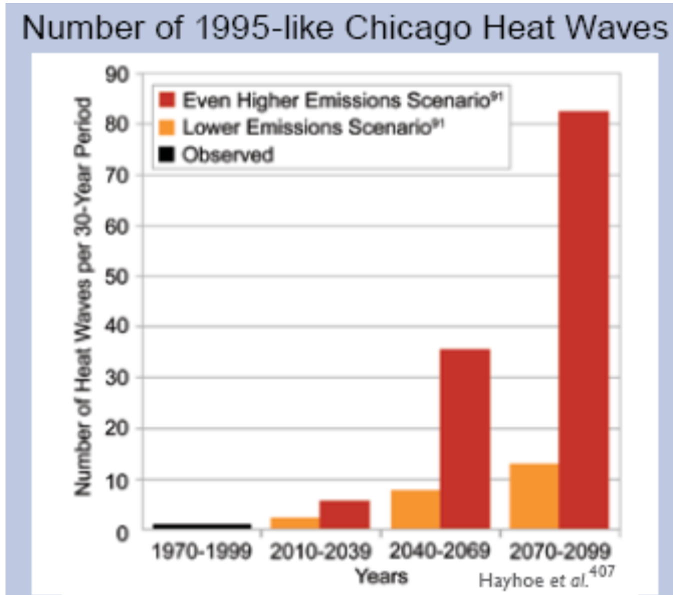


The average number of days per year when the maximum temperature exceeded 90°F from 1961-1979 (top) and the projected number of days per year above 90°F by the 2080s and 2090s for lower emissions (middle) and higher emissions (bottom).[91] Much of the southern United States is projected to have more than twice as many days per year above 90°F by the end of this century.

Figure 5: Days over 90°F

[15] Global Climate Change Impacts in the United States, op. cit. (p.27)

In addition to the temperature changes, high-humidity heat waves have become more common.[16] These moist heat waves are differentiated from dry heat waves by the persistence of high nighttime temperatures.[17] This high nighttime humidity can place additional stress on people already suffering from high daytime temperatures and cause additional deaths.[18] As temperatures continue to rise throughout the next century, climate models indicate that there will be an increased risk of more intense, more frequent and longer lasting heat waves.[19] The number of days above 90°F is projected to increase across the country and in areas of the southeastern United States, the number of days above 90°F could top 150 by the end of the century.[20]



Over the last three decades of this century, heat waves like the one that occurred in Chicago in 1995 are projected to occur about once every three years under the lower emissions scenario.[91] Under the even higher emissions scenario, such events are projected to occur an average of nearly three times a year. In this analysis, heat waves were defined as at least one week of daily maximum temperatures greater than 90°F and nighttime minimum temperatures greater than 70°F, with at least two consecutive days with daily temperatures greater than 100°F and nighttime temperatures greater than 80°F.

Figure 4: Heat wave frequency

This adjustment could be difficult for areas that are already under threat from heat waves. During 1998, 200 people were killed in the Southeast by a heat wave—the kind of event that is predicted to become stronger and more frequent in the future. The 1995 Chicago heat wave that killed over 600 people is another example of the deadly toll highly unusual heat waves can have on a population that is historically unprepared for the long stretch of extreme temperatures. The Chicago heat wave was highly abnormal not only for the temperatures but also for its high-humidity, denying residents a much needed overnight cooling break.

Heat is already the leading cause of weather-related deaths in the United States, with a disproportionate effect on

[16] Global Climate Change Impacts in the United States, op. cit. (p.33)
[17] Kunkel, et al. Observed changes in weather and climate extremes, op. cit.
[18] Ebi, K.L. and Meehl, G.A. (2007) The Heat is On: Climate Change & Heatwaves in the Midwest. In [Gulledge, J. and Smith, J., Eds.] *Regional Impacts of Climate Change: Four Case Studies in the United States*. Pew Center on Global Climate Change, Arlington, Virginia USA. http://goo.gl/fpY9l.
[19] Meehl, G.A. et al. (2007) Global Climate Projections. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
[20] Global Climate Change Impacts in the United States, op. cit. (p.34); Diffenbaugh, N.S. and M. Ashfaq (2010) Intensification of hot extremes in the United States. Geophysical Research Letters, 37, L15701, doi:10.1029/2010GL043888

the elderly.[21] Heat waves don't only affect human health, during a 2006 heat wave in the eastern U.S., electric transformers failed in Missouri and New York, interrupting power supplies to the region and exacerbating heat stress impacts by eliminating air conditioning as a coping mechanism.[22] Today such intense heat waves are relatively rare. However, events like the Chicago heat wave are projected to occur once every other year by the end of the century under low greenhouse gas emission scenarios or 2-3 times per year under high ones.[23] (Figure 6) In addition, these frequent heat waves are projected to be as much as 10°F hotter than today.[24] Other projections for Chicago suggest that unless public health measures are implemented, the average number of deaths due to heat waves could double by 2050 under a low emissions scenario and quadruple under high emissions.[25]

[21] Global Climate Change Impacts in the United States, op. cit. (p.90)
[22] Global Climate Change Impacts in the United States, op. cit. (p.59)
[23] Ebi and Meehl, Heat Waves & Global Climate Change, op. cit.
[24] Global Climate Change Impacts in the United States, op. cit. (p.34); Gutowski, et al. Causes of observed changes in extremes and projections of future changes, op. cit.
[25] Katharine Hayhoe, Jeff VanDorn, Thomas Croley II, Nicole Schlegal, Donald Wuebbles, Regional climate change projections for Chicago and the US Great Lakes, Journal of Great Lakes Research, Volume 36, Supplement 2, Potential Climate Impacts on Chicago and Midwest, 2010, Pages 7-21, ISSN 0380-1330, DOI: 10.1016/j.jglr.2010.03.012.

Wildfire

In recent decades, the frequency and size of wildfires as well as the length of the fire season have increased dramatically in the western United States. (Figure 7) The length of wildfire season has increased by 78 days compared to the 1970-1986 period, with the season starting earlier and ending later.[26] Individual large fires burn on average one month longer before firefighters can bring them under control. The average annual number of large fires has increased by fourfold and the area burned by those fires has grown by sixfold.[27]

Alaska has also experienced an increase in the occurrence of forest fires, with the area burned more than doubling in recent decades.[28] Of the three largest wildfire seasons in Alaska's 56 year record, two occurred in 2004 and 2005, and half of the most severe fire seasons have occurred since 1990.[29] Across the entire northern tier forests of Alaska and Canada, the area burned tripled from the 1960s to the 1990s.[30]

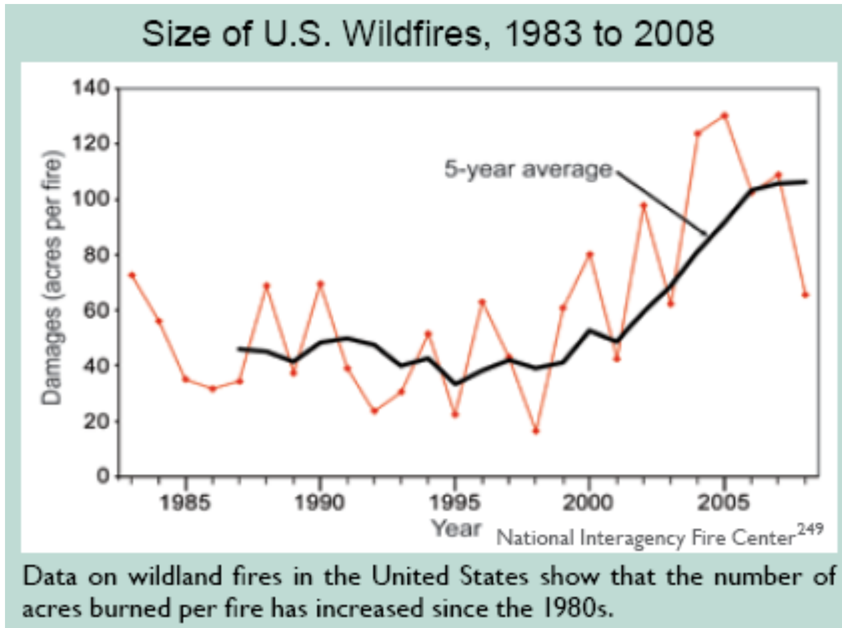


Figure 5: Wildfire size

While climate change cannot be said to be the sole cause of any of the wildfires listed on the map or any recent fire, earlier spring snowmelt and hotter drier summers have made weather conditions more conducive to burning.[31] Changes in climate have reduced the availability of moisture, resulting in drier soils and vegetation that is more prone to fire. In Alaska, one study found that a third of the responsibility for the increase in area burned by fire between 1950 and 2003 is attributed to higher June air temperatures alone.[32] The Pacific Northwest has already observed an increase in wildfire due to

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[26] A. L. Westerling, H. G. Hidalgo, D. R. Cayan, and T. W. Swetnam. Warming and earlier spring increase western U.S. forest wildfire activity. *Science*, 313(5789):940–943, August 2006.
[27] Global Climate Change Impacts in the United States, op. cit. (p.95)
[28] Global Climate Change Impacts in the United States, op. cit. (p.82)
[29] Kasischke, E. S. and M. R. Turetsky (2006), Recent changes in the fire regime across the North American boreal region—Spatial and temporal patterns of burning across Canada and Alaska,*Geophys. Res. Lett.*, *33*, L09703, doi:10.1029/2006GL025677.
[30] Global Climate Change Impacts in the United States, op. cit. (p.141)
[31] Westerling, et al, Warming and earlier spring increase western U.S. forest wildfire activity, op. cit.
[32] CCSP, 2008: The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. P. Backlund, A. Janetos, D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T.

increasing summer moisture deficits that can be tied directly to rising temperatures.[33] Hence, climate change clearly has increased the risk of wildfires and this trend is likely to grow as climate change proceeds in the future.[34]

Alaska is at risk of a doubling of the area burned by fire by mid-century with a three-to-four fold increase by the end of the century depending on future greenhouse gas emissions scenarios. These increases would correspondingly increase public health hazards such as the poor air quality suffered by people in Fairbanks during the fire outbreaks in 2004 and 2005. Fire related air pollution is known to cause eye and respiratory illness in addition to direct injuries due to burns.[35] In addition to human injuries, wildfires destroy buildings and decrease tourism and recreation, impacting economic activity in communities.

In the Southwest, fires in areas that are currently wet are projected to become more frequent, while fires in areas that are drier and thus limited by fuel availability are not likely to increase.[36] The economic and human risks that these fires engender will depend on future emissions as well as on the rate of continued development in forested areas.

Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M.G. Ryan, S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, W. Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, R. Shaw. U.S. Department of Agriculture, Washington, DC., USA, 362 pp

[33] Global Climate Change Impacts in the United States, op. cit. (p.136)

[34] Bachelet, D., J.M . Lenihan and R.P. Neilson (2007) The Importance of Climate Change for Future Wildfire Scenarios in the Western United States. Pew Center on Global Climate Change, Arlington, Virginia: http://goo.gl/hilwH.

[35] CCSP, 2008: Analyses of the effects of global change on human health and welfare and human systems. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [Gamble, J.L.(ed.), K.L. Ebi, F.G. Sussman, T.J. Wilbanks, (Authors)]. U.S. Environmental Protection Agency, Washington, DC, USA.

[36] Westerling, A.L. and Bryant, B.P. (2008) Climate change and wildfire in California. *Climatic Change* 87 (Suppl 1):S231-S249 DOI 10.1007/s10584-007-9363-z

Drought

Over the past 50 years, drought has been increasing in many parts of the Southeast and Western United States,[37] while much of the Northeast and upper Midwest has experienced less frequent drought. (Figures 8 and 9) This shifting rainfall pattern is consistent with what is expected from climate change. In arid regions, these changes can have major impacts on agriculture as longer periods between rainfalls and higher air temperatures dry out soils and vegetation, causing drought. The desert Southwest is one region that scientists expect to become drier with a much higher risk for drought.[38] Decreasing snowpack and soil moisture is likely to further stress water supplies and contribute to wildfire risk.

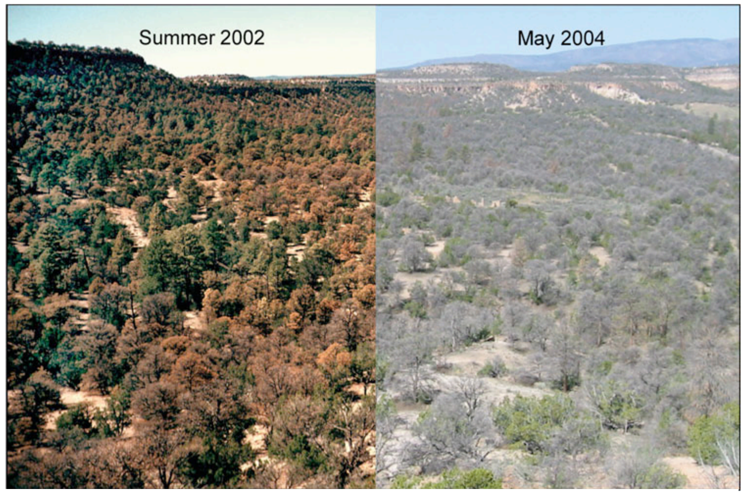

Figure 8: Los Alamos, NM

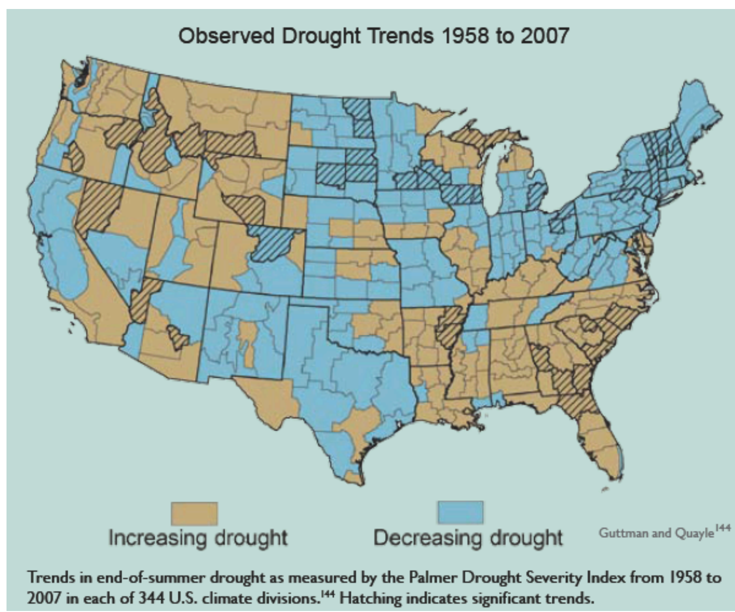

Figure 9: Drought trends

One important aspect of drought in the West is the impact on snowfall and the resulting spring runoff. Snowpack in the west has been decreasing, particularly at low elevations.[39] Correspondingly, summer stream-flow is decreasing and peak flow is occurring earlier in the year. A majority of western rivers have already observed earlier peak stream-flow over the past 50 years.[40] In the future, stream-flow is projected to peak earlier across the nation, meaning that low water conditions occur earlier and for longer during the

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[37] Global Climate Change Impacts in the United States, op. cit. (p.30)

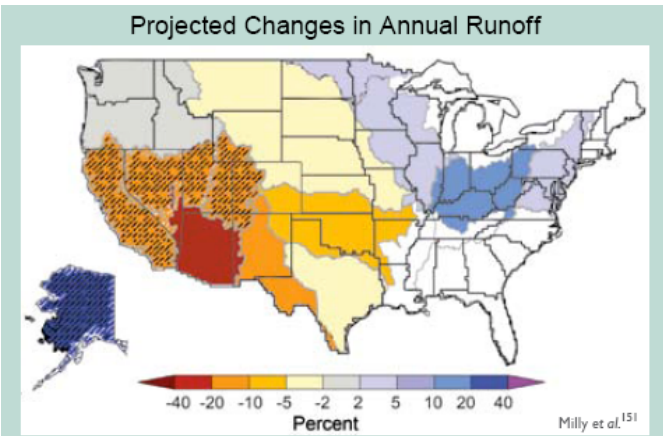
[38] Cook, E.R., P.J. Bartlein, N. Diffenbaugh, R. Seager, B.N. Shuman, R.S. Webb, J.W. Williams, and C. Woodhouse, 2008: Hydrological variability and change. In: Abrupt Climate Change. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. U.S. Geological Survey, Reston, VA, pp. 143–257; A. Thompson (2007) "Southwest Forecast: Expect 90 Years of Drought" *LiveScience*, April 5. Retrieved on June 23, 2011 from: http://goo.gl/6mjWl.

[39] Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds., 2008: Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp

[40] Global Climate Change Impacts in the United States, op. cit. (p.43)

summer and fall. This amplifies the risk of drought as less water is available in general and can lengthen the wildfire season as well as increasing stress on groundwater resources.

The total runoff volume is projected to decrease in the Southwest and Southern Rockies, while rivers in the Northwest may experience increases in total stream flow by the end of the century.[41] At Lees Ferry in the Colorado River basin, 2000-2010 was the lowest 11-year period since 1906 in terms of annual natural flow.[42] These changes in timing and flow volume make events like the western drought of 2002 more likely. The severity of the 2002 drought was deepened by the lack of available water during the summer from runoff, and as a result, three rivers set new record low stream-flows.[43]



Projected changes in median runoff for 2041-2060, relative to a 1901-1970 baseline, are mapped by water-resource region. Colors indicate percentage changes in runoff. Hatched areas indicate greater confidence due to strong agreement among model projections. White areas indicate divergence among model projections. Results are based on emissions in between the lower and higher emissions scenarios.[91]

Figure 10: Projected runoff change

Many of the problems associated with future decreases in water availability are exacerbated by increased human use. In the Southwest, the most water-stressed region of the U.S., a growing population is placing ever increasing demands on water resources.[44] It is this same area of the country that is most at risk of decreased snowpacks and increased drought in the future as a result of climate change.[45] Much of the west relies on snowpacks instead of reservoirs to store water, so a decrease in the size of the snowpack could have substantial consequences. (Figure 10) Already, the Colorado River does supplies insufficient water to meet usage agreements between the southwestern states. This situation has led to a series of legal conflicts between states, sectors, and nations.[46] Competing demands from treaties, development, and agriculture combined with years of drought could cause significant future conflicts over an already over-allocated resource. The situation is similar in the Southeast, where Alabama, Florida, and Georgia, have been locked in legal battles over access to water for years.[47]

[41] Reclamation, SECURE Water Act Section 9503(c), Reclamation Climate Change and Water, Report to Congress, (2011) (p.179)
[42] Ibid. (p.23)
[43] United States Geological Survey, 2003: Drought Conditions in Utah, 1999-2002: A Historical Perspective. http://pubs.usgs.gov/fs/fs-037-03/resources/drought.pdf
[44] Global Climate Change Impacts in the United States, op. cit. (p.129)
[45] Global Climate Change Impacts in the United States, op. cit. (p.45)
[46] Global Climate Change Impacts in the United States, op. cit. (p.131)
[47] "Tri-state water wars: Don't end up high and dry," *Atlanta Journal Constitution*, Friday, June 17, 2011. Retrieved on June 23, 2011 from: http://www.ajc.com/opinion/tri-state-water-wars-980243.html