

# The Extremes Become the Norm

By Sonia Aggarwal and Hallie Kennan

June 2013

Extremes in weather and climate affect every sector of the global economy; from infrastructure stability such as energy and water delivery, to disaster relief, refugees, and human health.

The National Weather Service redefines normal temperatures at the end of each decade, using temperatures from the previous 30 years.<sup>i</sup> This means there is a progression of temperatures that can be considered “normal” as the climate changes gradually over time. Still, above-average temperatures have been observed more and more frequently in recent years, even compared to this progressing normal temperature distribution. In fact, this April marked the 338<sup>th</sup> consecutive month that has recorded an above-average temperature. The last below-average temperature for any month was in February of 1985, more than 28 years ago.<sup>ii</sup> Further, in 2012 alone, 362 sites in the United States experienced all-time record high temperatures, while zero sites recorded all-time low temperatures.<sup>iii</sup> If we’ve been using these methods of measuring and recording temperatures for more than a century now<sup>iv</sup>, why have we hit so many above-average temperatures recently?

Of course, Earth has always experienced a range of temperatures, and ecosystems have evolved to accommodate that specific range. The spread has also always included some extremes, which have become integrated into natural rhythms. For example, infrequent extremes have been necessary in some systems to keep pest populations under control. It is critical to think about this full range of possible temperatures--as well as their relative likelihood--in order to understand how climate change will impact temperature and precipitation over the next 100 years.

## What’s normal?

An understanding of probability curves is critical in order to envision the way our climate will shift over the next century. Probability is a measure of the likelihood that a given event will occur. It is useful to think of probability as relative rather than absolute; the most likely event is the norm, but events closely related to the norm have a much higher chance of happening than the events that are far from the norm. This is called a “normal probability curve,” or a “bell curve.”

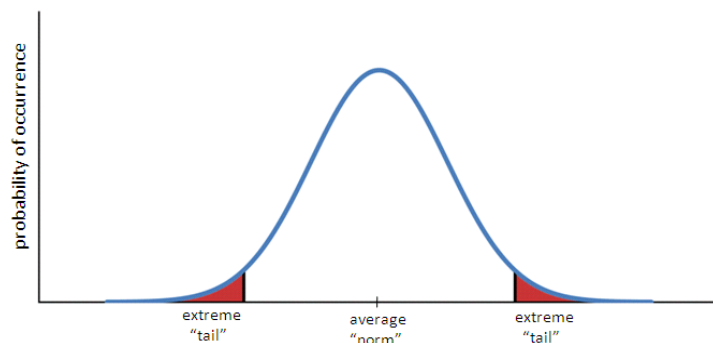


Figure 1: The normal probability curve

To use a real example, average temperatures in the United States currently follow a relatively normal probability curve. The 20<sup>th</sup> century’s July temperature norm in the U.S. was 23 degrees Celsius (74° Fahrenheit). Because July temperatures follow this normal probability curve, it is more likely that an average temperature will be close to 74°, and less likely that it will be much hotter or colder than 74°. In fact, only once did the average July temperature hit 76° F in the thirty years between 1950 and 1980.<sup>v</sup>

When that particularly hot summer occurred in 1980, there were 1700 heat-related deaths in the U.S. and domestic agricultural losses reached \$20 billion.<sup>vi</sup>

### A shift in perception

A recent World Bank report estimates that the world will warm by approximately 4 degrees Celsius (or about 8° Fahrenheit), within in the next 100 years given current greenhouse gas mitigation efforts. If we do not meet our current mitigation commitments, the world may become 4°C warmer by as early as 2060.<sup>vii</sup> But what does that actually mean? Four degrees sounds completely nonthreatening, and almost pleasant. After all, temperatures can fluctuate by as much as 10 or 20 degrees in one day. So, understandably, warnings of a 4 degree rise in the average global temperature have been largely ignored. However, this interpretation misses the importance of the probability curve for temperature. The increasing global average temperature itself will have little effect on our everyday lives; it's the tails of the probability curve that will profoundly affect the way we live, the decisions we make, and the ecosystems on which we rely.

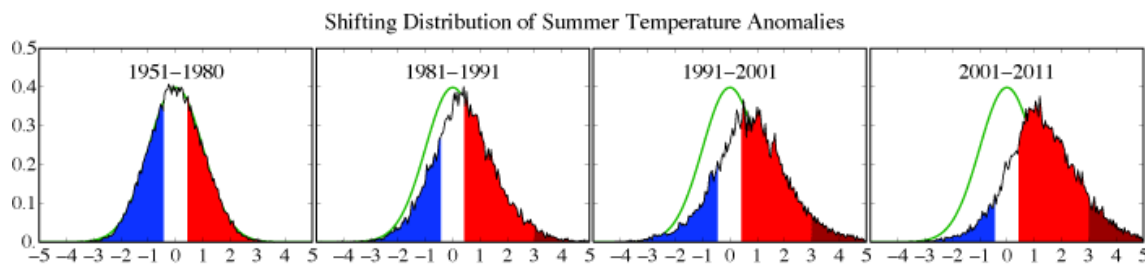


Figure 2: Shifting distribution of temperature anomalies for summer months<sup>viii</sup>

As Figure 2 shows, a very small shift in the average translates to a much larger probability of extreme events. The small upward shift in global average temperature described above will result in a much higher frequency and intensity of extreme high temperatures (the dark red part of the graph at the bottom right will continue to grow) and much lower frequency of extreme low temperatures (the blue part of the graph will continue to shrink).

In certain regions, the shift may be much more pronounced. Figure 3 compares average July temperatures in the United States from 1950-1980 and those same average temperatures projected for 2050-2080. The rarest historical average temperatures are shown far in the right-side tail of the red curve. According to climate predictions, an average July in the second part of this century will be considerably warmer than past Julys. High temperatures that were once extremely rare will become the norm within just 100 years. Since 2000, the U.S. has already experienced four July's with average temperatures exceeding 76° F (a temperature only once reached between 1950 and 1980). So far, this century's average July temperature is 75.5° F, already more than 1 degree warmer than the month's 20<sup>th</sup> century norm. The average July temperature in 2012 was 77.6° Fahrenheit, marking it the warmest July, and the all-time warmest month, on record in the U.S. During that month, more than 60 percent of the continental U.S. experienced moderate to extreme drought conditions, which devastated crop and livestock yields and caused wildfires that covered more than 2 million acres of land.<sup>ix</sup>

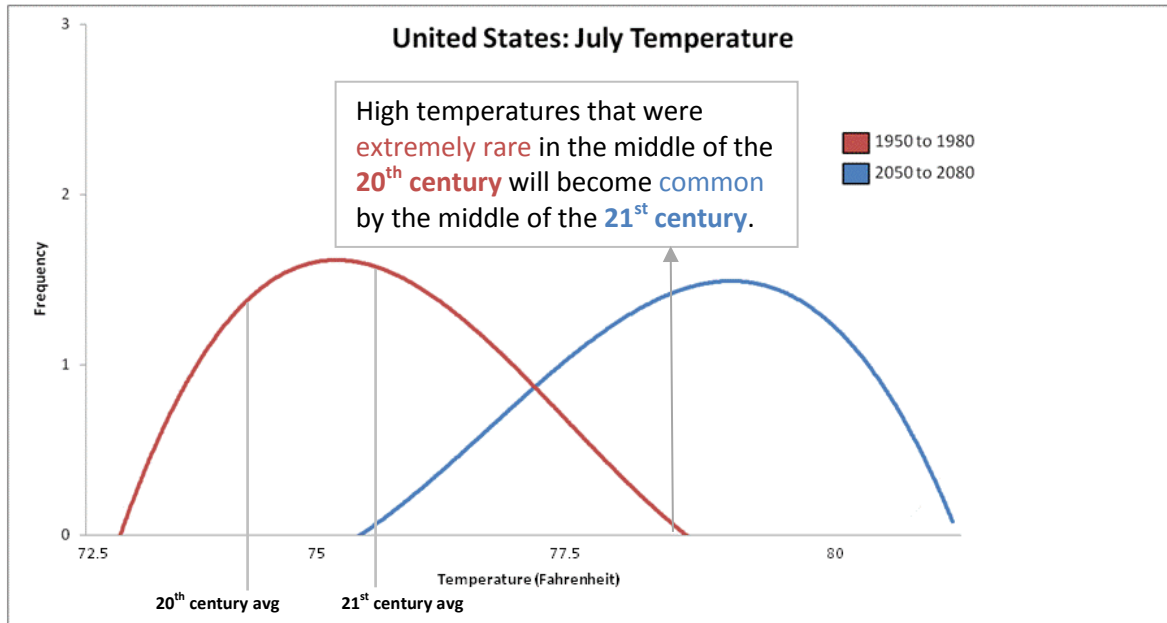


Figure 3: Historical and projected average U.S. temperatures for the month of July<sup>x,xi</sup>

This shift in the average temperature probability curve causes once-extreme events to become much more likely, and occur much more frequently. The “heat wave of the century” will become the “heat wave of the decade.” For example, under current climate change trends, an area in Texas that usually experiences 10-20 days over 100° Fahrenheit (37.7 degrees Celsius) each year will instead experience temperatures higher than 100° F for nearly *four months* every year by the end of the century.<sup>xii</sup> These projections are consistent with findings from the National Climate Impact Assessment Report, which predict that the United States will experience significant mid-continental drying, while the coasts will experience wetter weather.

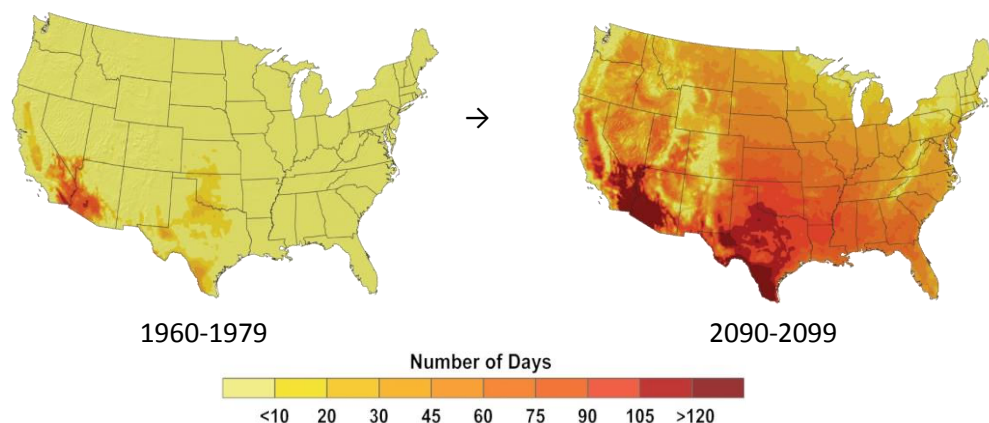


Figure 4: Historical and projected number of days per year breaking 100° Fahrenheit (37.7 degrees Celsius)<sup>xiii</sup>

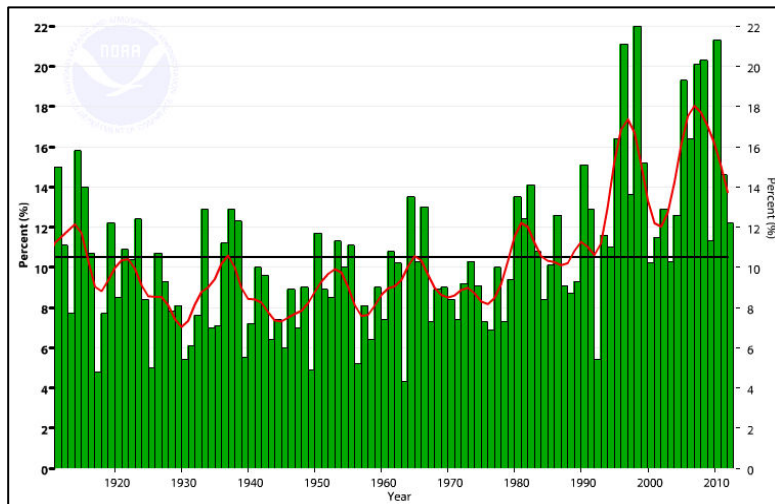
Increasing average temperatures are already taking place on a global scale; the decade from 2002 - 2012 was the warmest decade on record<sup>xiv</sup>, with temperatures rising approximately .2° C (.38° F) per decade for the last 30 years.<sup>xv</sup> Parts of the United States, Russia, and other European and Asian countries were

impacted by heat waves during the summer of 2010. June and July of that year set the record temperatures for the entire northern hemisphere. Wildfires, heat stroke, and crop loss all resulted from the extreme temperatures.<sup>xvi</sup> Climate scientists believe this event was made three-times more likely due to man-made climate change activity.<sup>xvii</sup>

### Whether the weather will get wetter

In 2012, a drought throughout the southern U.S. had drastic effects on over 1,000 counties across 26 states.<sup>xviii</sup> Economists estimate that this drought will cost over \$12 billion to cover crop insurance, disaster-relief loans, and other economic costs.<sup>xix</sup> As the probability curve for average rainfall changes, droughts like this will likely become much more common, and will be interspersed with equally extreme precipitation leading to floods of similar magnitudes. These changes in rainfall patterns will have profound effects on global food security, health, and water access.

The strength and frequency of precipitation has already increased in several flood-prone regions over the last several decades. Figure 5 shows that the number of extreme one-day precipitation events has



increased in the last century, with nine of the top ten years with extreme one-day precipitation events occurring since 1990.<sup>xx</sup> This increase in heavy precipitation partially contributes to the overall increase in average rainfall over the last century. Precipitation in the continental United States increased nearly 6 percent over the last century.<sup>xxi</sup>

Figure 5: Extreme One-Day Precipitation Events in the Contiguous 48 States, 1910-2012

Global climate models describe the rainfall probability curve as less “normal” than the temperature curve. In addition to shifting right, the rainfall probability curve is also likely to flatten as the climate changes (see Figure 2). This morphing of the rainfall probability curve implies that both ends of the curve, the “tails,” will become thicker in the future; which means that extreme weather events, major droughts and floods, will become much more frequent.



Figure 6: Precipitation anomalies and their impacts, 2010

This broadening and morphing of the rainfall probability curve will have profound impacts on our ability to plan for crops and harvests. Between extreme droughts and flood-induced landslides, food scarcity is likely to become an even larger global problem. For example, as shown in Figure 6, catastrophic precipitation events occurred throughout the world in 2010, which is both the hottest and wettest year on record.<sup>xxii</sup> Russia experienced a record heat wave that killed thousands of people and destroyed a quarter of the country's crop yield.<sup>xxiii</sup> That very same year, flooding overtook an area of Queensland the size of Germany and France combined, devastating the country's agriculture and mining sectors.<sup>xxiv</sup> These anomalous events affected millions of people and cost billions of dollars in damages. As the climate continues to shift, the "100 year drought" will become the "5 year drought" while floods that used to merit international attention will become commonplace. Munich RE's natural catastrophe database demonstrates that the frequency of natural catastrophes has nearly tripled since 1980, with the greatest increase in weather-related climatological (extreme temperatures, drought, fire) and hydrological (flood, mass movement) events.<sup>xxv</sup> In 2012, the world experienced more than 900 natural disaster events, many of which occurred in densely populated, coastal regions (see Figure 7).

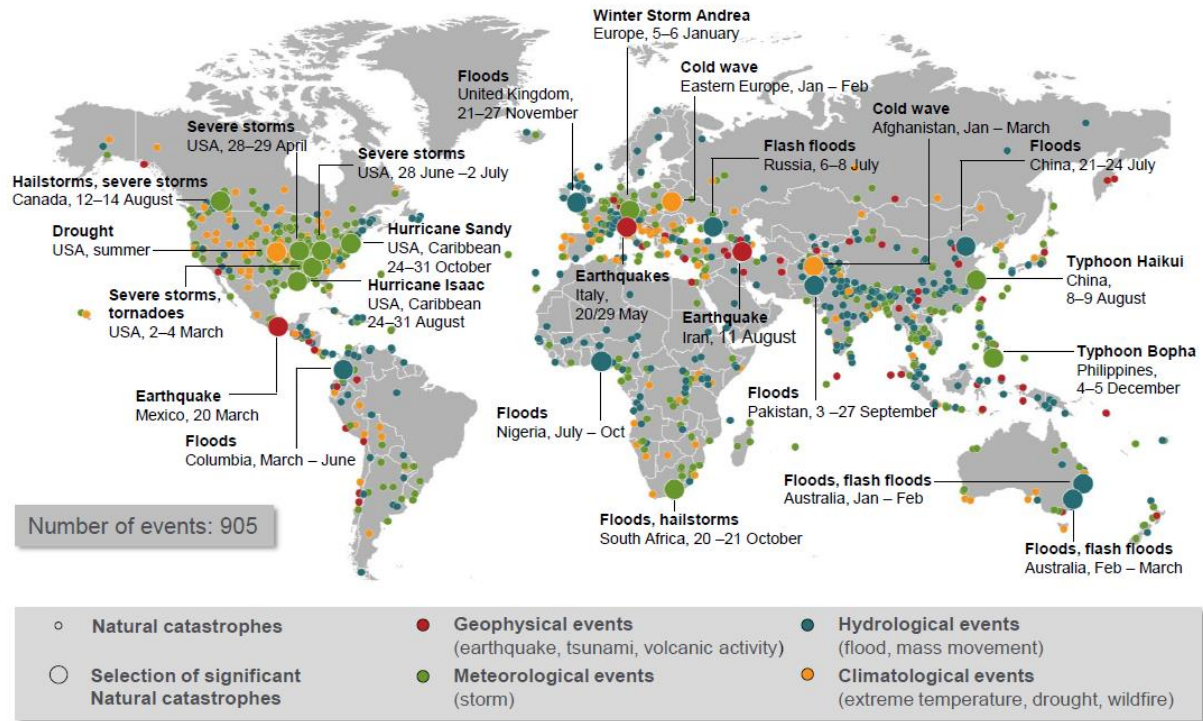


Figure 7: World Map of Natural Catastrophes, 2012

### Are we to blame for these extremes?

The composition of gases in the earth's atmosphere is one of the primary factors of climate change. Since the earth was formed billions of years ago, its climate has never been perfectly stagnant. Throughout history, there have been periods of severe heat as well as severe cold, as atmospheric gas concentrations have fluctuated over time. Carbon dioxide is a well-known example of a greenhouse gas. "Sources" of carbon dioxide, such as burning organic material, release carbon dioxide into the atmosphere. At the same time, oceans and forests act as "sinks" and absorb the emitted carbon dioxide, thus maintaining a steady concentration.<sup>xxvi</sup> For millions of years, the earth has played this balancing act, which has kept carbon dioxide concentrations between approximately 170 and 300 parts per million (ppm).<sup>xxvii</sup> However, change in human activity since the Industrial Revolution has increased the emission of carbon dioxide and other greenhouse gases. As more carbon dioxide (along with other greenhouse gases) enters the atmosphere, it contributes to a phenomenon known as the "greenhouse effect," in which the gas absorbs heat and reflects it back to the earth's surface, causing the planet to warm. Recent human activities have not only *increased* carbon dioxide **sources** through the combustion of long-buried gas and oil, but have also *decreased* carbon dioxide **sinks** through logging and agriculture, which eliminate CO<sub>2</sub>-absorbing forests. In the last 150 years, carbon dioxide concentrations have increased by nearly 40 percent and, this May, surpassed 400ppm for the first time in human history.<sup>xxviii</sup> The Fourth Assessment Report by the Intergovernmental Panel on Climate Change attributes 90 percent of global warming to human activity throughout the last 250 years and states that this rate of warming is likely unprecedented in the last 10,000 years.<sup>xxix</sup>

### Extremes will continue to cost us, but there are solutions

As history and experience have shown, the damages from isolated extreme weather events can be massive, but as the earth's climate continues to change we will begin to experience these kinds of events more often: a record heat wave, a prolonged drought, and a deadly flood simultaneously. In combination, these weather events present immense economic, social, and political risk. The economic cost of worldwide natural disasters in 2011 reached a record-breaking \$380 billion<sup>xxx</sup>, though this record will likely be broken in the near future as the globe experiences even more extreme weather events.

We have the potential to lessen the impact of these extremes by cutting emissions now. If we aggressively deploy emissions-reduction technologies today, we still have a chance of slowing the effects of climate change and limiting the global average temperature increase. Starting now—and starting fast—can minimize our risk exposure. Of course, this will not prevent all statistical anomalies, but building resilience to extreme climate events now will help us in the future, regardless of how many extreme events we end up having to face. We can also reduce our vulnerability by investing now in climate adaptation measures such as water-use efficiency, disaster preparedness, and appropriate building codes.

---

Special thank you to Andrew Batjiaka, who contributed research for the original version of this article, released in 2009.

<sup>i</sup> National Oceanic and Atmospheric Administration. *What is "Normal" Temperature?* <http://www.wrh.noaa.gov/tfx/pdfs/NORMALS.pdf>

<sup>ii</sup> National Climatic Data Center. "NCDC Releases April 2013 Global Climate Report." NOAA. 2013. <<http://www.ncdc.noaa.gov/news/ncdc-releases-april-2013-global-climate-report>>..

<sup>iii</sup> Romm, Joe. "2012 Saw 362 All-Time Record High Temperatures In U.S. But Zero All-Time Record Lows." *Climate Progress*. ThinkProgress, 5 Jan. 2013. <<http://thinkprogress.org/climate/2013/01/05/1394711/2012-saw-362-all-time-record-high-temperatures-in-us-but-zero-all-time-record-lows/>>.

<sup>iv</sup> Smith, Cathy. "The Statewide, Regional, and National Data." *Earth System Research Laboratory: Physical Sciences Division*. National Oceanic & Atmospheric Administration. Web. 6 Aug. 2009. <<http://www.cdc.noaa.gov/data/usclimdivs/data/>>.

<sup>v</sup> "U.S. Climate at a Glance." *National Temperature Data*. National Climatic Data Center, 7 Aug. 2009. Web. 7 Aug. 2009. <<http://www.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html>>.

<sup>vi</sup> Wilson, Charlie. "Weather History." *San Francisco Examiner*. 12 July 2009. Web. 7 Aug. 2009. <<http://www.examiner.com/x-4645-Wilmington-Weather-Examiner~y2009m7d12-Weather-History--July-13-Record-Heat-1980--1995-Heat-Wave-Severe-Storms-and-Flooding>>.

<sup>vii</sup> *Turn Down the Heat: Why a 4C Warmer World Must Be Avoided*. The World Bank, Nov. 2012. Web. <[http://climatechange.worldbank.org/sites/default/files/Turn\\_Down\\_the\\_heat\\_Why\\_a\\_4\\_degree\\_centigrade\\_warmer\\_world\\_must\\_be\\_avoided.pdf](http://climatechange.worldbank.org/sites/default/files/Turn_Down_the_heat_Why_a_4_degree_centigrade_warmer_world_must_be_avoided.pdf)>.

<sup>viii</sup> [http://www.giss.nasa.gov/research/briefs/hansen\\_17/](http://www.giss.nasa.gov/research/briefs/hansen_17/)

<sup>ix</sup> National Climatic Data Center. "State of the Climate." *National Overview: July 2012*. National Oceanic and Atmospheric Administration, Aug. 2012. Web. <<http://www.ncdc.noaa.gov/sotc/national/2012/7>>.

---

<sup>x</sup> "U.S. Climate at a Glance." *National Temperature Data*. National Climatic Data Center, 7 Aug. 2009. Web. 7 Aug. 2009. <<http://www.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html>>.

<sup>xi</sup> Historical data: CDC. Projected data: COSMIC2 GFSD model.

<sup>xii</sup> Karl, Thomas R., Jerry M. Melillo, and Thomas C. Peterson. *Global Climate Change Impacts in the United States*. Tech. United States Global Change Research Program, Cambridge University Press, 2009. Web. 11 Aug. 2009. <<http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts>>.

<sup>xiii</sup> Karl, Thomas R., Jerry M. Melillo, and Thomas C. Peterson. *Global Climate Change Impacts in the United States*. Tech. United States Global Change Research Program, Cambridge University Press, 2009. Web. 11 Aug. 2009. <<http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts>>.

<sup>xiv</sup> Stone, Dan. "Globe Continues Hottest Decade Ever." *National Geographic*. 1/15/13. <<http://newswatch.nationalgeographic.com/2013/01/15/globe-continues-hottest-decade-ever/>>.

<sup>xv</sup> "NASA Research Finds Last Decade Was Warmest on Record, 2009 One of Warmest Years." *Features*. National Aeronautics and Space Administration, Jan. 2010. Web. <[http://www.nasa.gov/home/hqnews/2010/jan/HQ\\_10-017\\_Warmest\\_temps.html](http://www.nasa.gov/home/hqnews/2010/jan/HQ_10-017_Warmest_temps.html)>.

<sup>xvi</sup> "Heatwaves Hit Northern Hemisphere." *China Daily*. N.p., July 2010. Web. <[http://www.chinadaily.com.cn/world/2010-07/30/content\\_11075022.htm](http://www.chinadaily.com.cn/world/2010-07/30/content_11075022.htm)>.

<sup>xvii</sup> Jha, Alok. "Climate Change Increased Likelihood of Russian 2010 Heatwave – Study." *The Guardian*. N.p., Feb. 2012. Web. <<http://www.guardian.co.uk/environment/2012/feb/21/climate-change-russian-heatwave>>.

<sup>xviii</sup> Bjerga, Alan. "Disaster Declared in 26 States as Drought Sears U.S." *Bloomberg*. 7/12/12. <<http://www.bloomberg.com/news/2012-07-11/usda-declares-disaster-in-26-states-as-drought-sears-midwest.html>>.

<sup>xix</sup> Rice, Doyle and Raasch, Chuck. "Drought could cost \$12 billion, most since 1988." *USA Today*. 7/26/12. <<http://usatoday30.usatoday.com/weather/drought/story/2012-07-25/drought-crops-loss-costs/56491296/1>>.

<sup>xx</sup> NOAA. "Contiguous U.S. Extremes in 1-Day Precipitation (Step 4\*) Annual (January-December) 1910-2012." *U.S. Climate Extremes Index (CEI)*. 2012. <<http://www.ncdc.noaa.gov/extremes/cei/graph/4/01-12>>.

<sup>xxi</sup> NOAA. "U.S. and Global Precipitation." *Climate Change Indicators in the United States*. U.S. Environmental Protection Agency, 2012. <<http://www.epa.gov/climatechange/science/indicators/weather-climate/precipitation.html>>.

<sup>xxii</sup> "2010 Wettest Year, Tied for Hottest - NOAA." Weblog post. *The Carbon Brief*. N.p., Jan. 2011. Web. <<http://www.carbonbrief.org/blog/2011/01/noaa-2010-tied-for-hottest-year-on-record>>.

<sup>xxiii</sup> Jha, 2010.

<sup>xxiv</sup> Harwood, Jonathan. "Queensland Floods: The Effects Could Go Global." *The Week*. N.p., Jan. 2011. Web. <<http://www.theweek.co.uk/politics/8617/queensland-floods-effects-could-go-global#>>.

<sup>xxv</sup> "The GENI-us Letter: Climate Change - Connecting the Dots." *GENI*. Global Energy Network Institute, Apr. 2012. Web. <<http://www.geni.org/globalenergy/library/GENI-us/2012/geni-us-letter-2012-04.shtml>>.



---

<sup>xxvi</sup> "Sources and Sinks." Environmental Literacy Council, 2002. Web.  
<<http://www.enviroliteracy.org/article.php/439.html>>.

<sup>xxvii</sup> Karl, Thomas R., Jerry M. Melillo, and Thomas C. Peterson. *Global Climate Change Impacts in the United States*. Publication. U.S. Global Change Research Program, 2009. Web.  
<<http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf>>.

<sup>xxviii</sup> Gerken, James. "Atmospheric CO2 Concentrations Surpass 400 PPM Milestone." *The Huffington Post*. 5/10/13.  
< [http://www.huffingtonpost.com/2013/05/10/atmospheric-co2-concentrations\\_n\\_3253757.html](http://www.huffingtonpost.com/2013/05/10/atmospheric-co2-concentrations_n_3253757.html)>.

<sup>xxix</sup> "Causes." *Global Climate Change*. Ed. Amber Jenkins. National Aeronautics and Space Administration, n.d. Web.  
<<http://climate.nasa.gov/causes/>>.

<sup>xxx</sup> "Natural Disasters in 2011 Made for Costliest Year Ever." *The Huffington Post*. 3/5/12. <  
[http://www.huffingtonpost.com/2012/03/05/natural-disasters-2011-costliest-year\\_n\\_1321580.html](http://www.huffingtonpost.com/2012/03/05/natural-disasters-2011-costliest-year_n_1321580.html)>.