

Heat Waves and Climate Change

A Science Update from Climate Communication



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Expert Reviewers:

- Kevin Trenberth, National Center for Atmospheric Research
- Jerry Meehl, National Center for Atmospheric Research
- Jeff Masters, Weather Underground
- Richard Somerville, Scripps Institution of Oceanography, University of California, San Diego

There has been a remarkable run of record-shattering heat waves in recent years, from the Russian heat wave of 2010 that set forests ablaze to the historic heat wave in Texas in 2011 and the “Summer in March” in the U.S. Midwest in 2012. These events typify the on-going trend driven by climate change.

This report, *Heat Waves and Climate Change*, summarizes our current scientific understanding of the connection between climate change and the recent increase in extreme temperatures, as reported in peer-reviewed research articles published through May 2012.

Summary:

Climate change is already affecting extreme weather. The National Academy of Sciences reports that the hottest days are now hotter.¹ And the fingerprint of global warming behind this change has been firmly identified.^{2 3 4}

Since 1950 the number of heat waves worldwide has increased, and heat waves have become longer.⁵ The hottest days and nights have become hotter and more frequent.^{6 7} In the past several years, the global area hit by extremely unusual hot summertime temperatures has increased 50-fold.⁸ Over the contiguous United States, new record high temperatures over the past decade have consistently outnumbered new record lows by a ratio of 2:1.⁹ In 2012, the ratio for the year through June 18 stands at nearly 10:1.¹⁰ Though this ratio is not expected to remain at that level for the rest of the year, it illustrates how unusual 2012 has been, and how these types of extremes are becoming more likely.

The significant increase in heat extremes we have witnessed associated with a small shift in the global average temperature is consistent with climate change. The percentage change in the number of very hot days can be quite large.¹¹ Global warming boosts the probability of very extreme events, like the recent “Summer in March” episode in the U.S. in which thousands of new record highs were set, far more than it changes the likelihood of more moderate events.¹²

Higher spring and summer temperatures, along with an earlier spring melt, are also the primary factors driving the increasing frequency of large wildfires and lengthening the fire season in the western U.S. over recent decades.¹³ The record-breaking fires this year in the Southwest and Rocky Mountain Region are consistent with these trends.

The impact of these changes can be devastating. The drought, heat wave and associated record wildfires that hit Texas and the Southern plains in the summer of 2011 cost \$12 billion.¹⁴

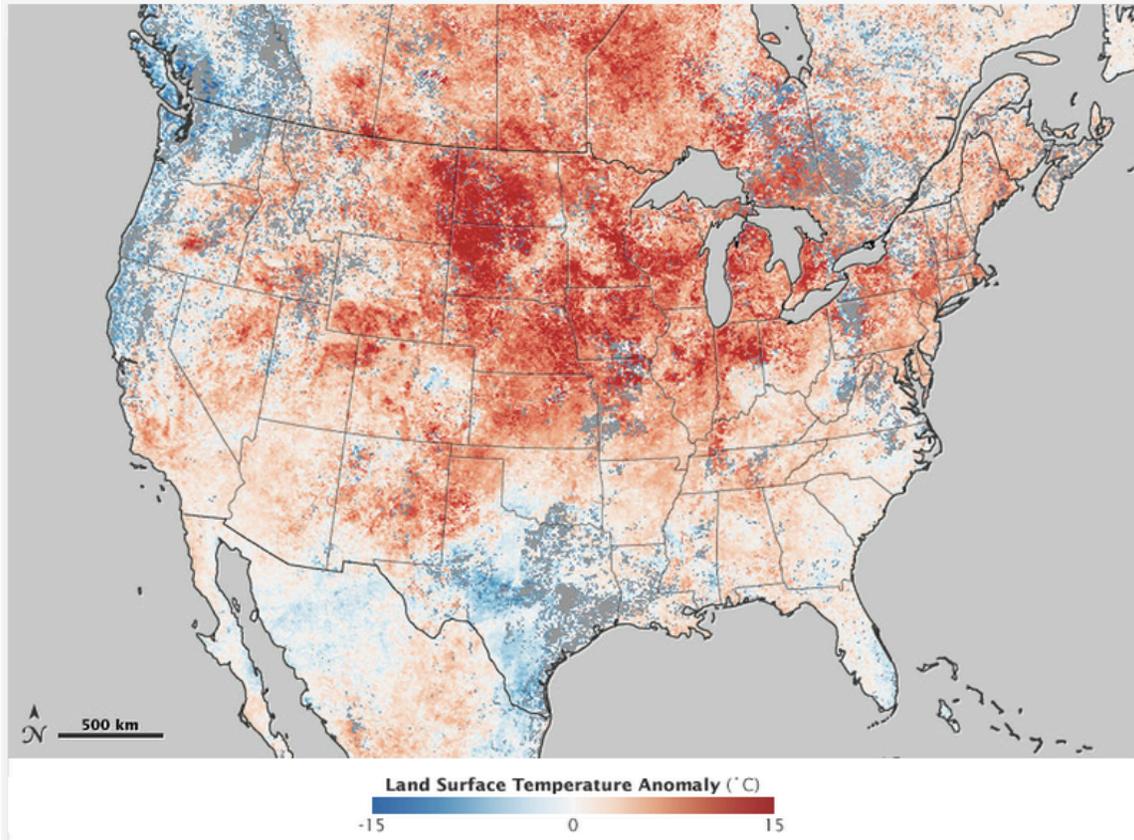


Fig. 1: Summer in March. The colors show the difference from average temperatures from March 13-19, 2012 in degrees C. The dark red areas were 15° C (27°F) above average for this period. Source: NASA

Looking Forward:

Confidence has risen in computer model projections of future changes in hot extremes because recent observations are consistent with the results of past model predictions.¹⁵

Models predict that the same summertime temperatures that ranked among the top 5% in 1950–1979 will occur at least 70% of the time by 2035–2064 in the U.S. if global emissions of greenhouse gases grow at a moderate rate (as modeled under the IPCC SRES A2 scenario). Such a growth rate would require a decline from the current high rate of growth.¹⁶

The South, Southwest, and Northeast may be especially prone to large increases in unusually hot summers.¹⁷ Parts of the South that currently have about 60 days per year with temperatures over 90 degrees are projected to experience 150 or more days a year above 90 degrees by the end of this century.¹⁸

By the end of this century, a once-every-20 year heat wave is projected to occur every other year.¹⁹

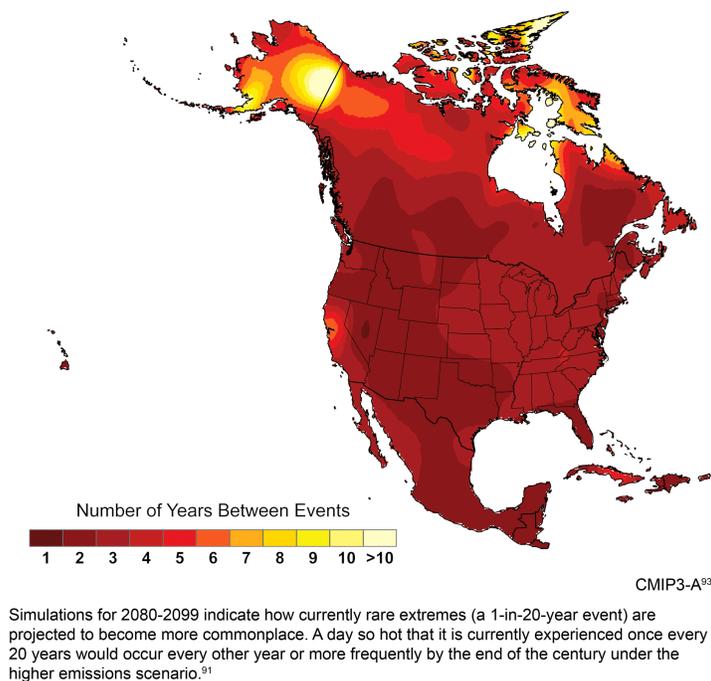


Figure 2: Projected Frequency of Extreme Heat: 1-in-20 Year Events. Source: U.S. Global Change Research Program

Heat Waves: The Details

A heat wave is generally defined as a period of several days to weeks of abnormally hot weather.

In the past 3-4 decades, there has been an increasing trend in high-humidity heat waves, which are characterized by the persistence of extremely high night-time temperature.²⁰ The combination of high humidity and high night-time temperature can make for a deadly pairing, offering no relief and posing a particular threat for the elderly. Extreme heat events are responsible for more deaths annually than hurricanes, lightning, tornadoes, floods, and earthquakes combined.²¹

At the same time, low-humidity heat waves associated with droughts and fueled in part by climate change contribute to the dry conditions that are driving wild fires.^{22 23}

Numerous studies have documented that human-induced climate change has increased the frequency and severity of heat waves across the globe.^{24 25 26 27 28}

For instance, a thorough statistical analysis of the Russian heat wave suggests that there was an

approximate 80% probability that the 2010 July Russian heat record would not have occurred without climate warming, or alternatively the probability increased by a factor of five.^{29 30}

Globally, extremely warm nights that used to come once in 20 years now occur every 10 years.³¹ And extremely hot summers, those more than three standard deviations above the historic average, are now observed in about 10% of the global land area, compared to 0.1-0.2% for the period 1951-1980.³²

These trends cannot be explained by natural variation alone. Only with the inclusion of human influences can computer models of the climate reproduce the observed changes. These changes include an increase in the number of warm nights, unusually hot days, and heat waves, as well as warming of the warmest night of the year, warming of the coldest nights and days of the year, and warming of the hottest day of the year.^{33 34 35 36 37 38}

While natural variability continues to play a key role in extreme weather, climate change has shifted the odds and changed the natural limits, making heat waves more frequent and more intense. In an unchanging climate both new record highs and new record lows are set regularly, even while the total number of new records set each year may decrease as time goes on. However, the new records would be, on average, evenly balanced between record highs and record lows. In contrast, the balance shifts in a warming climate, and on average more new records highs than new record lows are set over any time period. It is worth noting that even in a warming climate new record lows are still set, though fewer in number, due to natural variation even as the climate warms.

Sixty years ago in the continental United States, the number of new record high temperatures recorded around the country each year was roughly equal to the number of new record lows. Over the past decade, however, the number of new record highs recorded each year has been twice the number of new record lows, a signature of a warming climate, and a clear example of its impact on extreme weather.³⁹ (See Figure 3 below.)

NOAA's National Climatic Data Center reports that from January 1 – June 18 of 2012 new high temperature records outnumbered cold records across the United States by nearly 10:1. As noted above, this ratio cannot be expected to remain at that level for the rest of the year, but it illustrates how unusual 2012 has been, and how these types of extremes are becoming more likely.

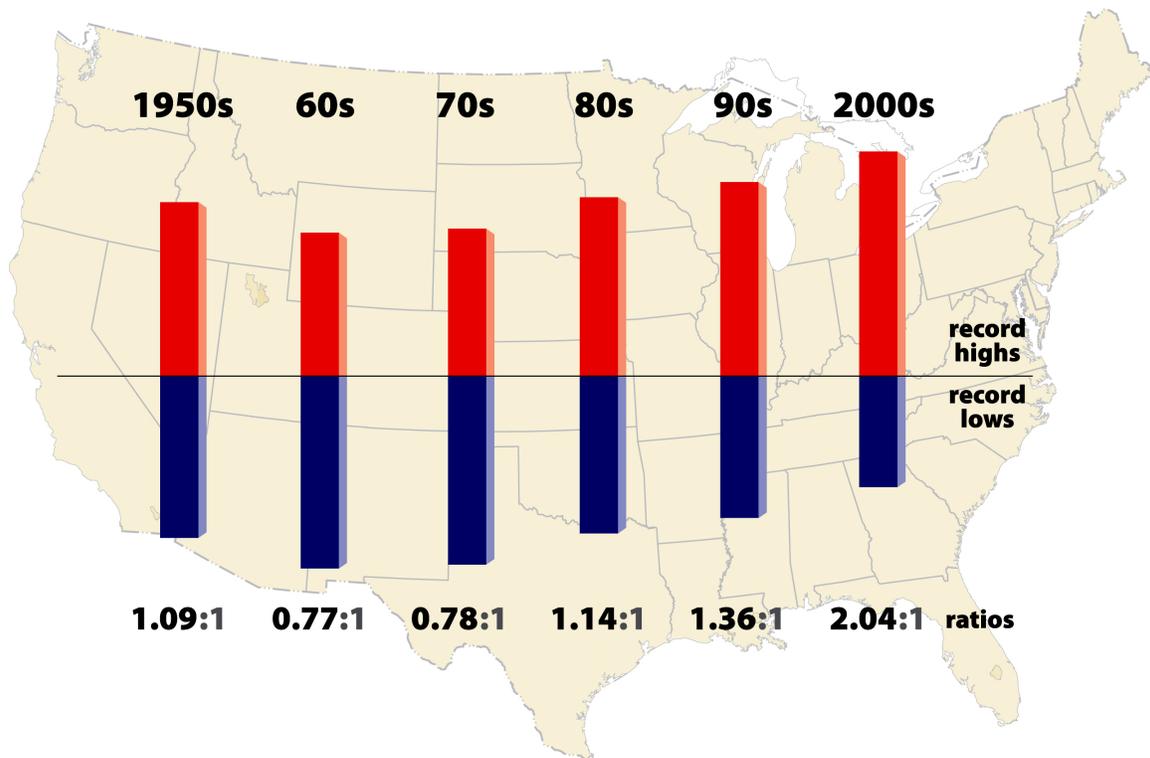
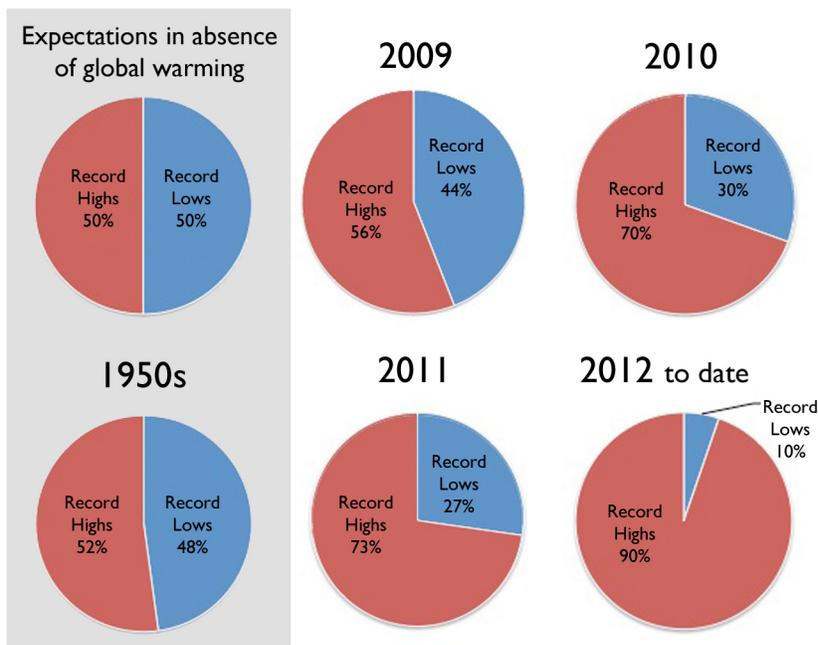


Figure 3: The ratio of record daily temperature highs to record daily lows observed at about 1,800 weather stations in the 48 contiguous United States from January 1950 through September 2009. Source: Meehl et al. 2009

For the U.S., the rise in heat-trapping gases in the atmosphere has increased the probability of record-breaking temperatures 15-fold.⁴⁰ In Europe, global warming is now responsible for an estimated 29% of the new record highs set each year.⁴¹

Figure 4 (below) illustrates that during the 1950s in the U.S. about as many new record highs were recorded as new record lows, roughly consistent with expectations of an unchanging climate. However, in 2009, 2010, and 2011, roughly twice as many new record highs were recorded compared to record lows, qualitatively consistent with a warming climate. The data for the year-to-date in 2012 reflect a very high ratio, much more than 2 to 1, and that highlights the fact that in any given year, a region as small as the U.S. can have very large departures from the global average. Atmospheric circulation variability, El Niños and La Niñas, and many other phenomena are involved in determining which regions will experience extremes in any given year.

More New Record High Than Low Temps in U.S.



1950s data from Meehl et al., all other data from NOAA

Figure 4: Ratios of Record High Temperatures to Record Low Temperatures.

A small change in average global temperature leads to a dramatic change in the frequency of extreme events.^{42 43 44} The following graphs (Figures 5 and 6) help to illustrate this point. In a normal climate the probability for extreme events can be visualized like a traditional bell curve, as illustrated in Figure 6.

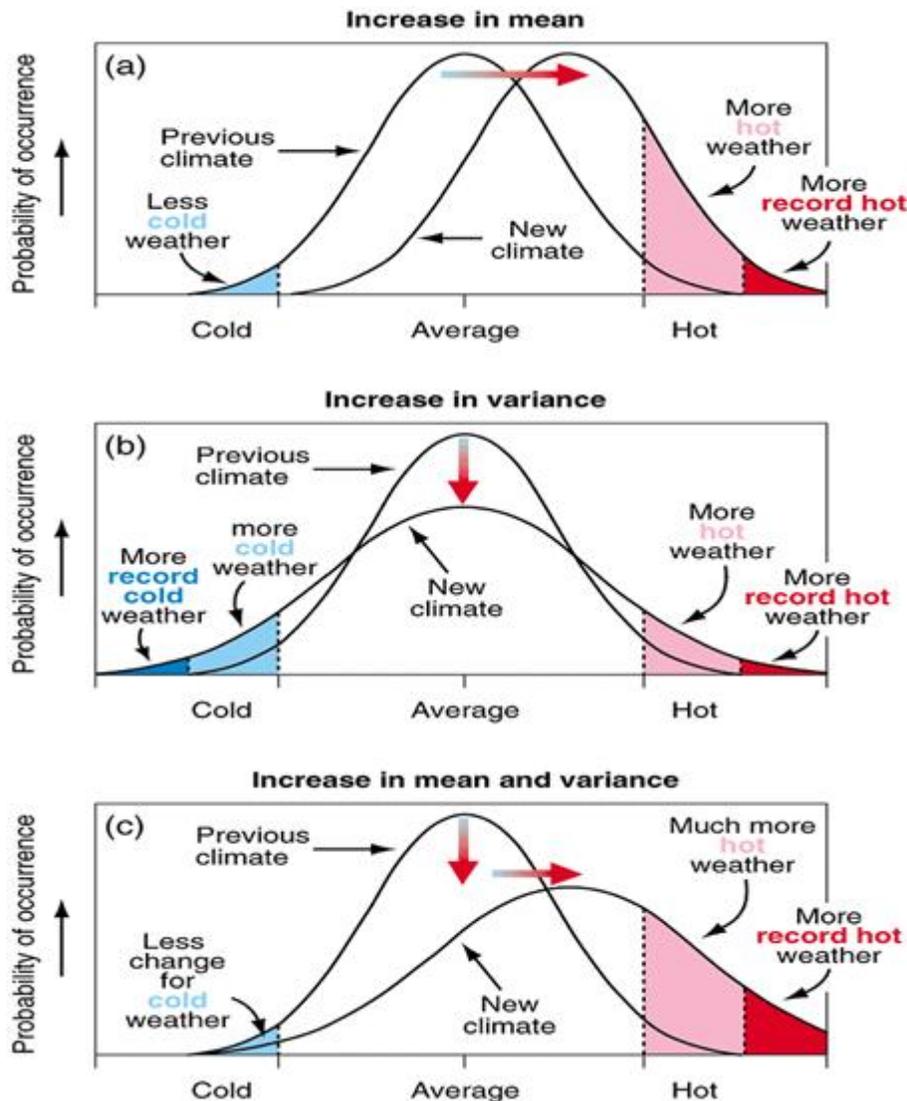


Figure 5: IPCC (2001) graph illustrating how a shift and/or widening of a probability distribution of temperatures affects the probability of extremes.

Moderate weather events are much more common than extreme events. So a small shift in temperature has an outsized effect on the frequency of extreme events due to relative impact of this shift.⁴⁵

Climate change shifts the curve to the hotter side, moving the average over. Climate change also flattens the curve, providing for a greater spread of events, an increase in variability. The combination provides for a dramatic increase in record hot weather.⁴⁶ Here “variance” is a measure of the spread of temperatures around the “mean” or average temperature.

The graph below, Figure 6, plots historical temperature data from the Northern Hemisphere, with each colored line representing a different decade. A “positive temperature anomaly” means temperatures are higher than the long-term average, while a “negative temperature

anomaly” means they are lower. Thus, the graph illustrates both the shift and the flattening of the curve representing the distribution of unusual temperatures.⁴⁷ The overall effect corresponds with graph (c) in Figure 5 above.

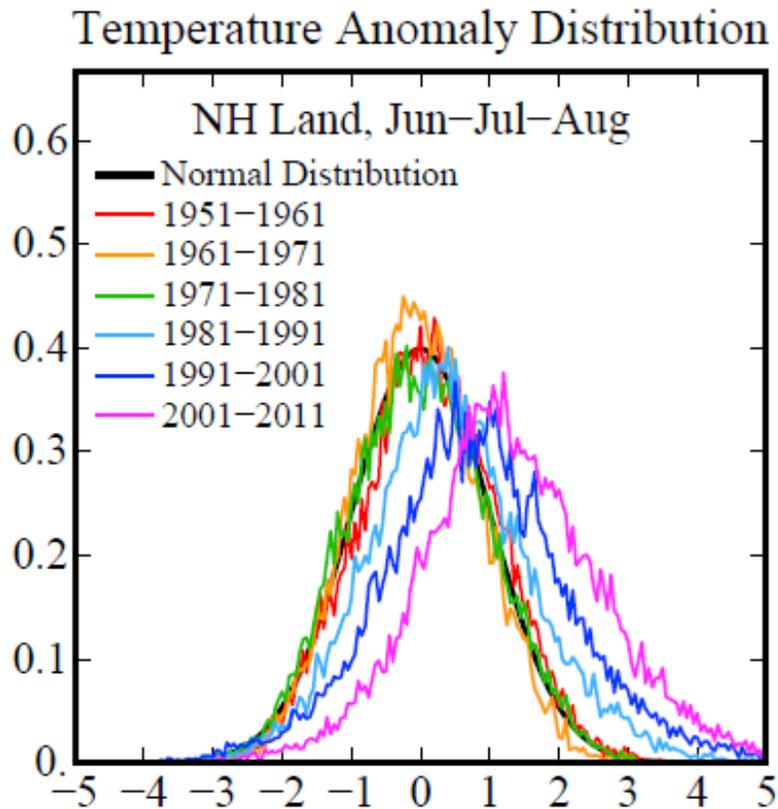


Figure 6: Frequency of summer temperature anomalies (how often they deviated from the historical normal of 1951-1980) over the summer months in the northern hemisphere. Source: NASA/ Hansen et al. 2012

Heat Waves and Wildfires

For many heat waves, there are also important feedbacks that come into play that amplify drought and heat and set the stage for wildfires. There is a direct local contribution to the drying and high temperatures in the absence of evaporative cooling.⁴⁸ While heat waves with high humidity are oppressive and give no relief at night, heat waves often form in association with drought. In these cases, the prevailing dry conditions set the stage for the heat since the land is dried out, the vegetation is wilted, and all of the heat from the sun goes into raising temperatures, whereas ordinarily, in the process of evaporative cooling, surface water or wetness acts as an evaporative cooler (swamp cooler) of sorts.

Some extreme examples have occurred in recent years in south Australia in January 2009, in Russia in summer 2010, and in Texas and Oklahoma in summer 2011. The record high temperatures in each case, along with the tinder dry conditions, led to extensive wildfires that were extremely costly in terms of lives, structures, human displacements, and costs.^{49 50} The exceptionally warm March in the U. S. is but part of record warmth for the first five months of the year (see Figure 8 below) and, along with an absence of snow, the rapid snow melt has left the Rocky Mountains almost without snow by 1 June 2012. The very hot and dry conditions throughout the Southwest and Rocky Mountain Region have led to exceptionally high risk of wildfire. Multiple wildfires have already occurred, and several in Colorado and Utah have expanded into huge burn areas, resulting in loss of life and structures.

As emissions of heat-trapping gases continue to rise, and global average temperatures continue to increase, we can expect even more of the of extreme heat and related impacts we've been witnessing in recent years.

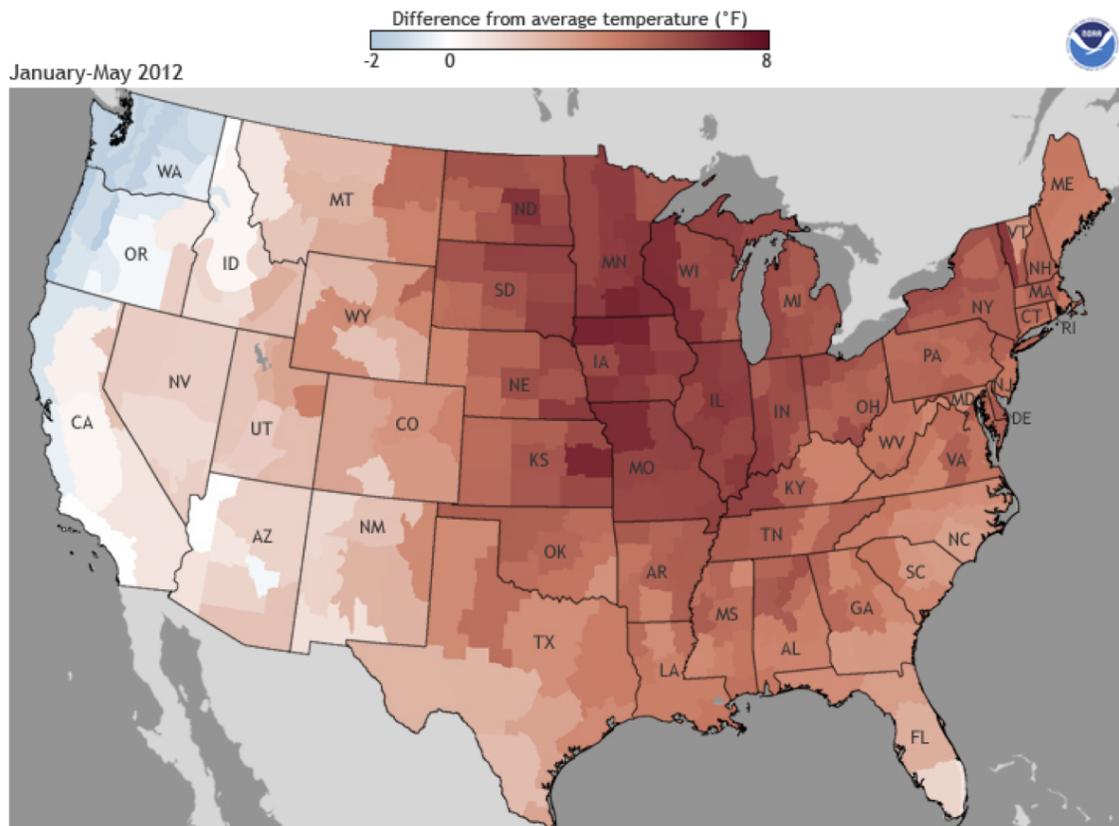


Figure 7: Difference from average temperature over the contiguous U.S., January – May, 2012. Source: NCDC/NOAA.

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See also:

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