

# 1A.1 THE CLIMATE OF 2010 IN HISTORICAL PERSPECTIVE

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## ABSTRACT

This annual summary of the climate, by NOAA's National Climatic Data Center, provides an overview of 2010 climate conditions across the United States and around the planet. As the scientific community works to better understand our changing climate, continual monitoring provides vital information about climate variability and trends. It also helps assess the incidence, impact and behavior of short-term and weather-scale events, such as droughts, tornado activity and tropical storms. Our primary focus is to give the recent climate record a historical perspective based on 131 years of atmospheric measurements as well as paleoclimate records that extend understanding of the Earth's climate to the more distant past. A discussion of century-scale variability and trends in temperature and precipitation is included, as is discussion of 2010 extreme events.

The 2010 annual report can be found online at: <http://www.ncdc.noaa.gov/sotc>

## 1. GLOBAL CLIMATE ANOMALIES IN 2010

### 1.1 Global Temperature

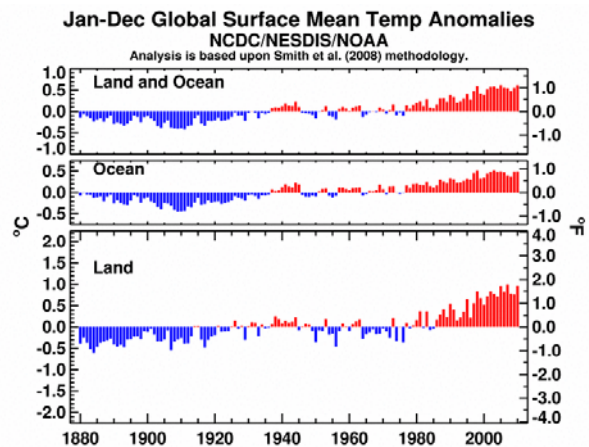
The data set of record for this manuscript is NOAA's Merged Land & Ocean Surface Temperature (Smith et al., 2008). It begins in 1880, making for a 131-year record, through 2010. The 2010 global (land and ocean combined) annual average temperature anomaly was +0.62 °C, which tied 2005 as the warmest calendar year of the record (Fig. 1). The global land temperature tied with 2005 as the 2<sup>nd</sup> warmest year on record, and the global ocean temperature also tied with 2005, but for 3<sup>rd</sup> warmest. The spatial pattern of 2010 temperature anomalies, relative to a 1971-2000 base period, is shown in Figure 2. The warmest anomalies occurred across Canada, southern Greenland, and a large area spanning land regions of Africa (especially north of the equator), the Middle East, and into South Asia. The tropical Atlantic Ocean was also quite warm. Cool anomalies occurred over Siberia and Mongolia, the southern oceans, and parts of the eastern Pacific. The global and hemispheric annual temperature ranks are summarized in Table 1.

In a similar (but opposite) way as 2009, the year 2010 began and ended in opposite phases of ENSO status. El Niño prevailed for the first few months of the year, then faded during May. By autumn, La Niña had developed and persisted or strengthened through the year's remaining months.

Consistent with the effects of El Niño superimposed on long-term (interdecadal) warming, the first six months of the year were among the warmest on record. According to NOAA's global surface temperature (Smith et al., 2008), each of the four months of March through May were the warmest on record for the respective month. This tied 2010 with 1998 as the calendar years with the most such "warmest months" on record, with three each. December 2010 was the coolest December since 2000.

2010 Annual Temperature	Anomaly vs. 1901-2000 avg	1880-2010 Rank (131 years)	
<b>Global</b>			
Land	+0.96°C	2 <sup>nd</sup> warmest	tied 2005
Ocean	+0.49°C	2 <sup>nd</sup> warmest	tied 2005
Land & Ocean	+0.62°C	Warmest	tied 2005
<b>Northern Hemisphere</b>			
Land	+1.08°C	2 <sup>nd</sup> warmest	
Ocean	+0.51°C	3 <sup>rd</sup> warmest	tied 2003
Land & Ocean	+0.73°C	Warmest	
<b>Southern Hemisphere</b>			
Land	+0.65°C	5 <sup>th</sup> warmest	tied 2003
Ocean	+0.49°C	5 <sup>th</sup> warmest	
Land & Ocean	+0.51 °C	6 <sup>th</sup> warmest	

**Table 1.** 2010 surface temperature anomaly (°C) and rank. Source: NOAA/NCDC.

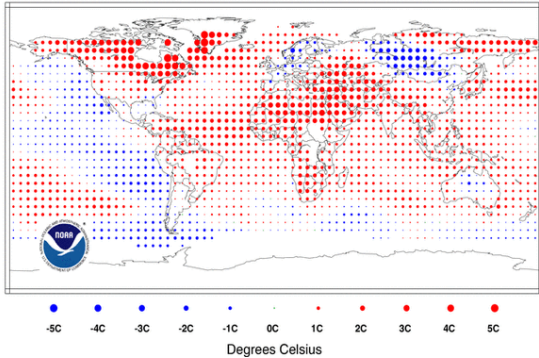


**Fig.1.** Global surface temperature anomalies for 1880-2010. Source: NOAA/NCDC.

## Temperature Anomalies Jan-Dec 2010

(with respect to a 1971-2000 base period)

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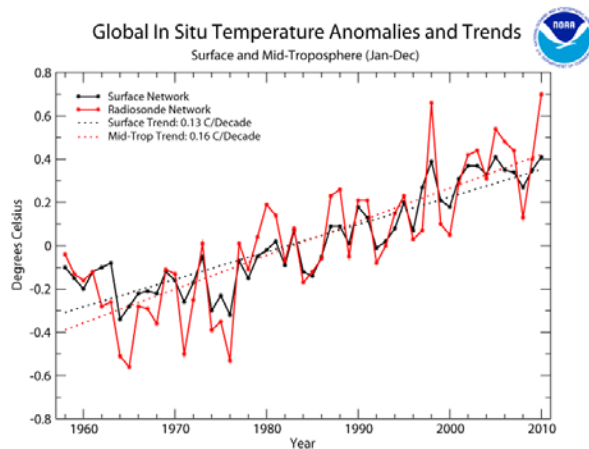


**Fig. 2.** Global surface temperature anomalies relative to a 1971-2000 base period, for 2010. Source: NOAA/NCDC.

Several notable monthly and seasonal temperature extremes occurred during 2010. The United Kingdom's average winter (DJF) temperature was the coolest since 1978-79. The Irish Republic experienced its coolest winter since 1962-63. Much of central Asia also endured near-historic January cold. Conversely, Canada had its warmest winter since national records began in 1948. Delhi, India recorded its highest April temperature in nearly 60 years. A record-breaking heatwave affected portions South Asia in late May, with a temperature of 53.5°C in MahenjuDaro establishing a new all-time record for Pakistan. A severe cold snap claimed lives and crops in southern South America in July. Much of Europe and western Russia endured record-breaking summer heat in July and August. Moscow recorded its all-time highest temperature on 30 July.

### 1.2 Tropospheric Temperatures

Temperatures above the surface of the earth are measured using in-situ balloon-borne instruments



**Fig. 3.** Global mid-tropospheric mean temperature anomalies (red) for 1958-2010, based on radiosonde (RATPAC) data, compared to the NCDC surface temperature record (black). Source: NOAA/NCDC.

(radiosondes) and polar-orbiting satellites (NOAA's TIROS-N). Radiosonde (RATPAC) and satellite records are adjusted to remove time-dependent biases caused by changes in radiosonde instruments and measurement practices as well as changes in satellite instruments and orbital features over time (see Free et al., 2005). NCDC utilizes adjustments by the University of Alabama in Huntsville (UAH), Remote Sensing Systems (RSS), and University of Washington (UW). Global averages from radiosonde data are available from 1958, while satellite measurements began in 1979. It is important to note that the length of record can affect period-of-record means and trends, the resulting sign of anomalies, and one's perception of the importance and meaning of the ranks and time series for each analysis.

Radiosonde measurements indicate that for 2010, temperatures in the mid-troposphere were 0.78°C above the period of record (1958-2010) average, resulting in the warmest calendar year in the 53-year record (Fig. 3). Each of the four methods NCDC uses to assess mid-tropospheric temperatures using satellite (Microwave Sounding Unit) data ranks the 2010 mid-tropospheric temperatures as the 2<sup>nd</sup> warmest of the shorter (1979-2010) period of record. For each of these data sets, 1998 was the warmest year on record.

	Anomaly (versus 1979-98 average)	1979-2010 Rank (32 yrs)
<b>Lower Troposphere</b>		
<b>UAH</b>	+0.41°C	2 <sup>nd</sup> warmest
<b>RSS</b>	+0.51°C	2 <sup>nd</sup> warmest
<b>Middle Troposphere</b>		
<b>UAH</b>	+0.32°C	2 <sup>nd</sup> warmest
<b>RSS</b>	+0.38°C	2 <sup>nd</sup> warmest
<b>UW-UAH</b>	+0.47°C	2 <sup>nd</sup> warmest
<b>UW-RSS</b>	+0.49°C	2 <sup>nd</sup> warmest
<b>RATPAC</b>	+0.86°C †	Warmest †

† RATPAC (radiosonde) ranks reflect a 52-year (1958-2010) dataset. Its anomalies refer to a 1961-1990 base period.

**Table 2.** 2010 global tropospheric temperature anomaly (°C) and rank. Source: NOAA/NCDC, UAH, UW, RSS.

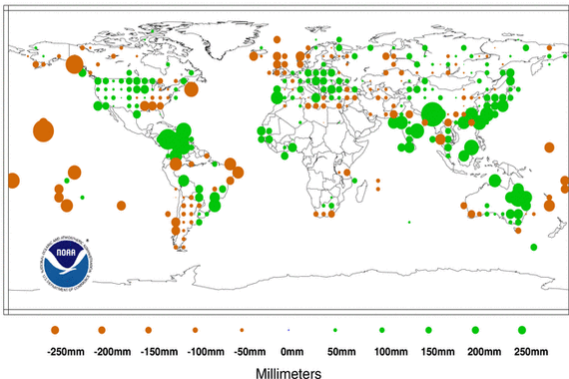
### 1.3 Global Precipitation and Drought

According to the GHCN globally-averaged precipitation, 2010 was the wettest year since reliable records began in 1900. The spatial pattern (Fig. 4) consisted of very large wet anomalies over East Asia, South Asia, tropical Central America and northeastern Australia. Very large deficits spanned much of Oceania in the Pacific.

Pakistan's upper Indus Valley experienced historic rainfall and flooding in July and August. At least 1,600 people were killed and about 6 million were forced to

## Precipitation Anomalies Jan-Dec 2010

(with respect to a 1961-1990 base period)  
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**Fig. 4.** Gridded global precipitation anomalies relative to a 1961-90 base period Source: NOAA/NCDC/GHCN.

evacuate. The flooding progressed downstream toward the Arabian Sea, and as much as one-fifth of the country was submerged at some time during the weeks-long episode. Enhanced seasonal rains caused widespread flooding in West Africa during the summer (JJA) months.

The drought associated with a summer heatwave in western Russia contributed to widespread wildfires and crop failures. Thousands of deaths were attributed to the combination of heat and wildfire. Bangladesh reported its driest monsoon season since 1994. Brazil's north and west Amazonia was in the midst of one of its worst droughts in the past 40 years. The Rio Negro at Manaus, where it flows into the Amazon, fell to its lowest level (13.6 meters) since record keeping began in 1902.

### 1.4 Northern Hemisphere Snow Cover

Satellite observations of snow cover extent began in late 1966. For the third consecutive year, the average Northern Hemisphere January (mid-season) snow cover extent during was above average. The average January 2010 snow extent of 48.3 million square km (Fig. 5) was the sixth largest January snow cover extent on record. This above-average January extent held for both North America (sixth largest extent) and Eurasia (11<sup>th</sup> largest). January and February brought significant winter storms to much of the eastern United States.

However, a warm and dry early 2010 led to record snow cover retreat across North America. Toronto, Ontario, Canada, which receives an average of 22 cm snow during March, recorded no March snow for the first time of a record dating to 1898. By March (late season), the North American snow extent was below average, ranking as the eighth smallest of the record. Large Eurasian (10<sup>th</sup> largest) snow cover kept the hemispheric total (Fig. 5) above normal (18<sup>th</sup> largest).

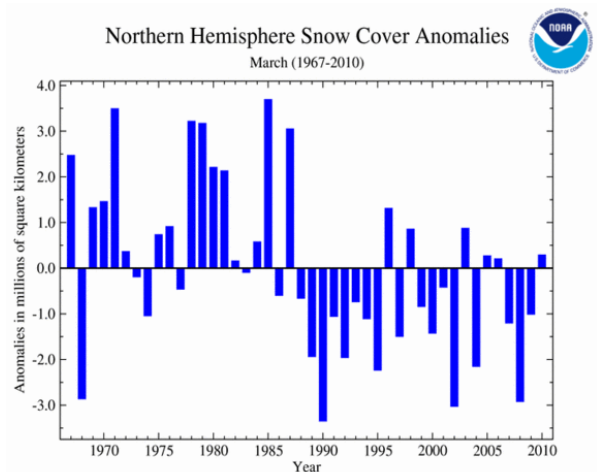
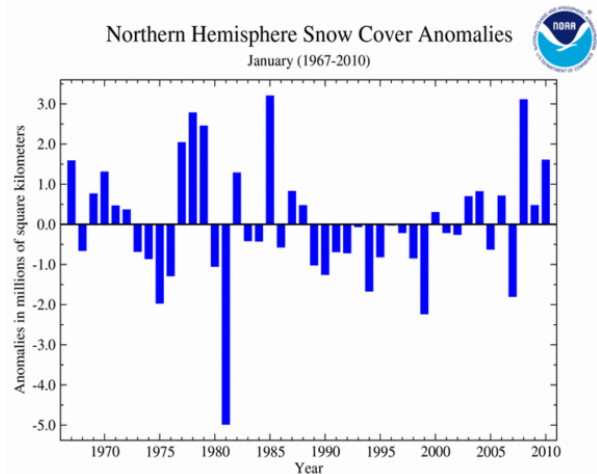
April 2010 saw record small North American snow cover extent. May and June followed with record small North American, Eurasian and Northern Hemisphere snow extent.

For the Northern Hemisphere as a whole and for the North American component, the snow retreat, as measured from January through May was the largest of the record.

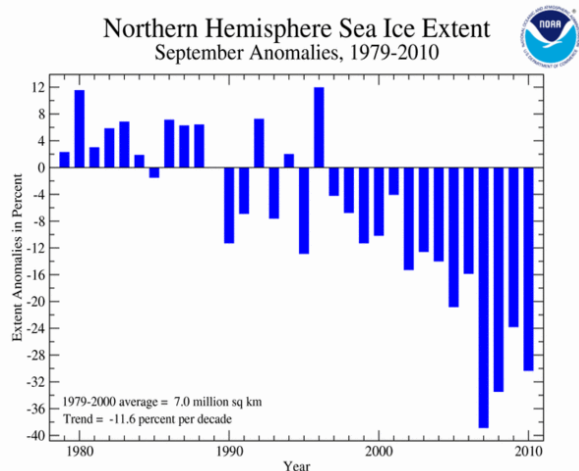
### 1.5 Arctic Sea Ice Extent

Northern Hemisphere sea ice extent is measured from passive microwave instruments onboard NOAA satellites, with a record dating to 1979. The seasonal cycle of expanding ice in the cold season and contracting ice in the warm season (typically reaching maximum/minimum in March/September) should be considered when examining arctic sea ice extent trends. Long-term variations in sea ice extent reveal a significant decreasing trend since 1979 in all months.

Arctic sea ice reached its annual maximum extent on 31 March 2010, the latest such date of the ice extent



**Fig. 5.** Northern Hemisphere snow cover anomalies for January, 1967-2010 (top) and March 1967-2010 (bottom). Source: Rutgers University.



**Fig. 6** Northern Hemisphere sea ice anomalies, September 1979-2010. Source: National Snow & Ice Data Center.

record. The average March 2010 extent of 15.1 million square km was about 4% less than the 1979-2000 average of 15.8 million square km, and represented the fifth-lowest March Arctic sea ice extent of the satellite record.

Despite the shortened melt season, the 2010 minimum sea ice extent of 4.6 million square km occurred on 19 September, and was the third smallest of the satellite era. The last four years (2007-2010) are the four smallest on record. The average September sea ice extent (Fig. 6) was also the third-lowest on record. September arctic sea ice extent has decreased at a rate of 11.6 percent per decade.

Individually, the months of June and December set new monthly records for smallest average sea ice extent of the record. No month saw average Arctic sea ice extent above the long-term average.

### 1.6 Tropical Cyclones

Global tropical cyclone activity was well below average during the 2010 season for the second consecutive year (the southern hemisphere's annual

counts ended 30 June 2010). The six major basins had 65 tropical storms, well below the long-term (1979-2008) average of 85.6. Of these, 35 reached hurricane (or, alternatively, typhoon or cyclone) strength. This is below the long-term average of 45.7, and the same as 2009's total of 35. Tropical cyclone activity by ocean basin is summarized in Table 3. All 2009-10 tropical cyclone data are preliminary.

Only the North Atlantic basin saw significantly above-normal activity, consistent with general expectations during La Niña, which tends to produce more favorable shear conditions during a season. The season's 19 named storms is the most in the basin since the 2005 season, and tied with 1995 for the second most during the modern record (since 1971). The 1995 and 2005 seasons also occurred during La Niña. The twelve storms reaching hurricane strength is second-most of the modern era, behind 2005's fifteen. Despite the extremely active Atlantic storm season, only one tropical system made U.S. landfall at tropical storm or greater strength. This occurred when a relatively minimal Tropical Storm Bonnie brushed southern Florida in late July.

The Northeast Pacific Basin had one of its least active seasons in history. Its seven named storms and three hurricanes represent the lowest totals of the modern era. The Northwest Pacific basin also experienced lower-than-average activity, although October's Megi was the world's strongest tropical cyclone of 2010, and the basin's most intense since Vanessa (1984).

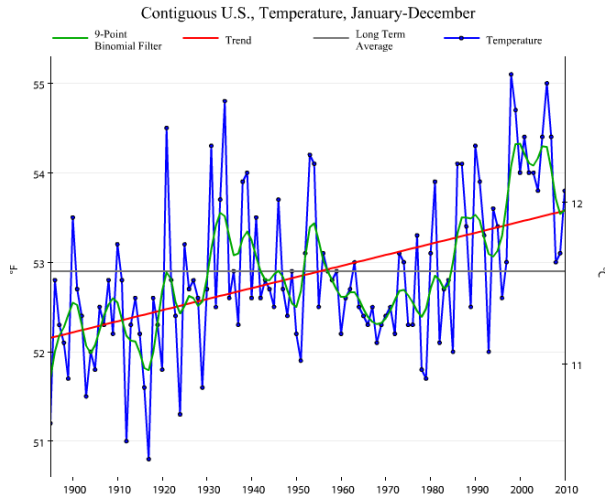
## 2. U.S. CLIMATE ANOMALIES IN 2010

### 2.1 U.S. Temperatures

After two consecutive years of near-average values, 2010 temperatures in the contiguous United States (CONUS) were easily above the 20<sup>th</sup> century average (Fig. 7), reviving a consistent trend that spanned most of the previous decade. The CONUS average annual temperature of 53.8 °F (12.1 °C) was 1.0 °F (0.6 °C) above normal, and was the 23<sup>rd</sup> warmest year on record. Since 1895, the CONUS has observed a long-term temperature increase of about 0.12 °F (0.07 °C) per decade. The spatial pattern was dominated by above-average to record temperatures across the Upper

Ocean Basin	2010 Trop. Storms (with 1979-2008 Average)	2010 Cyclones / Hurricanes / Typhoons (with 1979-2008 Average)
Atlantic	19 (12.1)	12 (6.7)
Eastern North Pacific	7 (21.0)	3 (12.1)
Western North Pacific	14 (26.1)	8 (15.9)
South Pacific	9 (11.0)	5 (1.8)
North Indian	5 (6.3)	4 (1.8)
South Indian	13 (11.8)	6 (6.4)
<b>Global</b>	<b>67<sup>‡</sup> (85.6)</b>	<b>38<sup>‡</sup> (45.7)</b>

**Table 3.** Tropical cyclone activity during the 2010 season by ocean basin. Values for southern hemisphere basins are tallied for the year ending June 30, 2010 to capture the seasonal offset. Source: NCDCE preliminary best track (IBTRACS) data. <sup>‡</sup>Global totals may not match the sum of basin totals due to sharing of storms between basins



**Fig. 7.** Contiguous U.S. average annual temperatures, 1895-2010. Source: NOAA/NCDC.

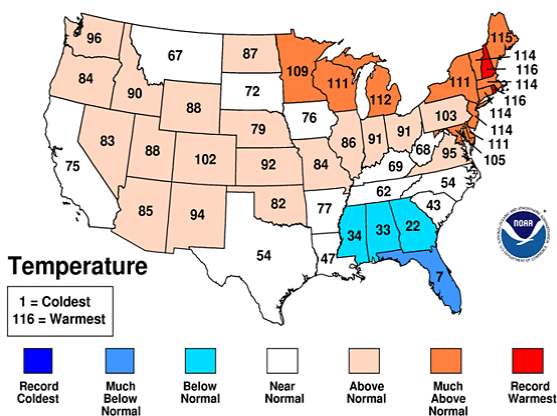
Midwest and Northeast (Fig. 8), and above average temperatures across much of the central and western United States.

Among states, Rhode Island and New Hampshire each had their warmest year on record, which spans the 116 years from 1895 through 2010. Only Florida, Alabama, Georgia and Mississippi had annual temperatures in their coolest tercile. According to preliminary data, the warm season (April-September) was the warmest on record (since 1895; 116-year period of record) for three of the nine climate regions (Southeast, Northeast, Central) in the CONUS (Fig. 9). Several notable heat waves afflicted the east coast of the United States during this period.

The Climate Extremes Index (Gleason et al., 2008) for the JJA summer period was well above normal, primarily due to a large footprint of extreme warmth during the

### January-December 2010 Statewide Ranks

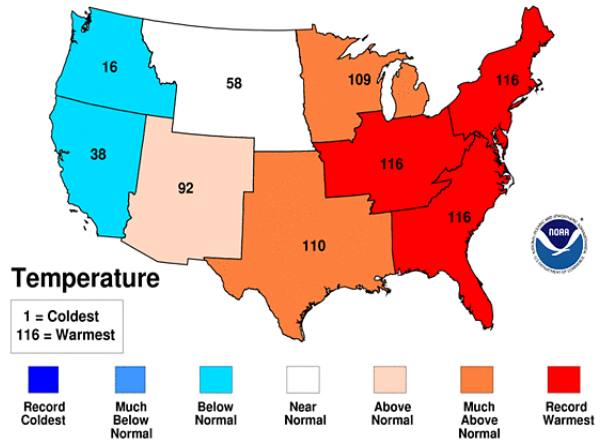
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**Fig. 7.** Statewide average annual temperature ranks for 2010. Source: NOAA/NCDC.

### April-September 2010 Regional Ranks

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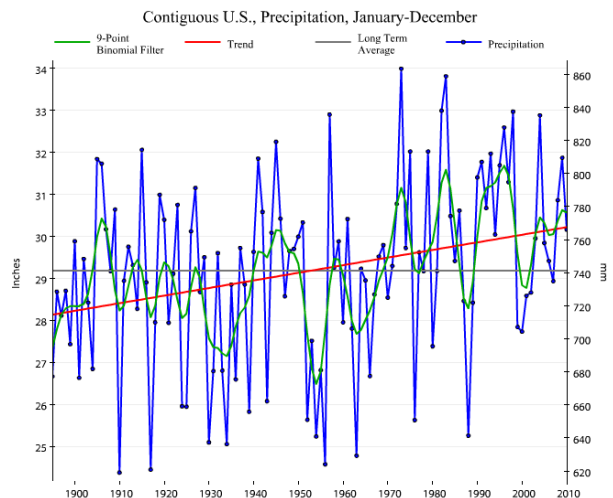
**Fig. 9.** Warm-season (March through September) temperature ranks, by climate region, for the contiguous United States. Source: NOAA/NCDC.

period. The subcomponent related to extremely-warm minimum temperatures had its largest JJA value on record, with up to 60 percent of the country experiencing overnight lows in the extreme (warmest 10% of the historical record).

### 2.2 U.S. Precipitation and Drought

For the third consecutive year, the CONUS precipitation was above-normal (Fig. 10). According to preliminary data, the CONUS-averaged precipitation was marginally in the wettest tercile of history (about 33<sup>rd</sup> wettest of 116 years). The wet 2010 is consistent with a decades-long trend of increasing CONUS precipitation.

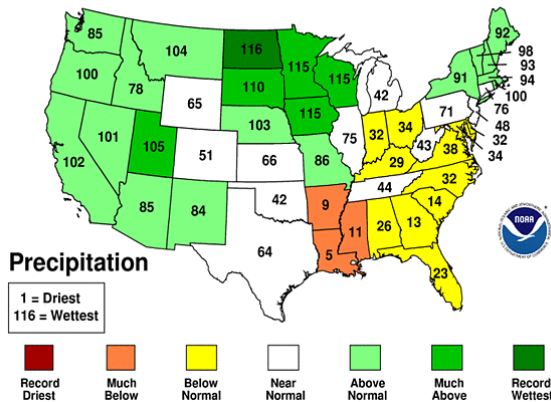
As is typical, precipitation, relative to average, was



**Fig. 10.** Contiguous U.S. annual average precipitation, 1895-2010. Source: NOAA/NCDC.

# January-December 2010 Statewide Ranks

National Climatic Data Center/NESDIS/NOAA



**Fig. 11.** Statewide average annual precipitation ranks for 2010. Source: NOAA/NCDC.

quite variable over space and time. Spatially, the Upper Midwest was very wet throughout the year (Fig. 11). North Dakota had its wettest year on record, while Iowa, Minnesota and Wisconsin had calendar years among their five wettest. This wet pattern was especially evident during summer, when a persistent upper level pattern steered many storms through the Northern Plains across the Great Lakes and into the Northeast.

In contrast, much of the Southeast received below-average precipitation, most notably Louisiana, which had its fifth-driest year on record. Arkansas and Mississippi both had annual average precipitation among their driest decile. As with the Upper Midwest wetness, the dryness in the Southeast strengthened in the warm season.

The most notable national-scale precipitation event was the near-eradication of drought conditions from the CONUS during the warm season. By late summer, the area depicted in drought by the U.S. Drought Monitor (Svoboda et al., 2002) was the smallest of the record, which began in 2000. Long-lasting drought was largely eliminated from the western CONUS and Upper

Midwest. Near-historic drought, however, continued in Hawaii. By year's end, a large region of drought and abnormally dry conditions had emerged along the Gulf Coast and across the Ohio and Lower Mississippi Valleys (Fig. 12).

In January and February, a series of strong winter storms brought very heavy snow and blizzard conditions to much of the U.S. eastern seaboard. Several seasonal snowfall records were felled. The seasonal pattern was attributed to a combination of El Niño and an intensely negative Arctic Oscillation Index (L'Heureux et al., 2010).

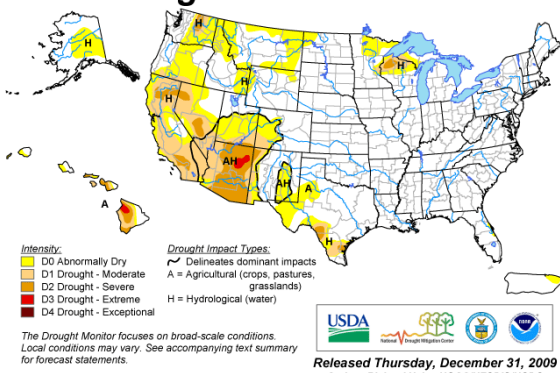
Central Tennessee experienced record one- and two-day rainfall and associated flooding and flash-flooding in early May. By May 2<sup>nd</sup>, many locations in Tennessee, including Nashville, had already recorded their greatest monthly totals (for May) on record. The Cumberland River escaped its banks and caused millions of dollars in damage to downtown Nashville.

## 2.3 U.S. Tornadoes

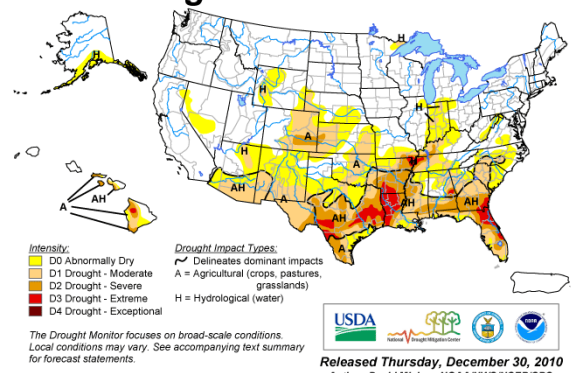
The 2010 preliminary tornado count through November was 1,302, with 122 preliminary reports still pending for November and December. It should be noted that not all reported tornadoes are confirmed (see Ray et al., 2003). Regardless, this will likely finish as one of the ten most active tornado years on record, roughly near the median for the previous decade. June was the most active tornado-producing month (for the second consecutive year) with 325 confirmed tornado reports, nearly 100 more than the running three-year average for the month. July and October were also more active than in recent years. In contrast, the first three months of the year were very much below normal in tornado activity. The 45 tornado-related fatalities in 2010 were more than in 2009, but less the previous three years.

The deadliest single tornado for the year occurred on 24 April when a long-track (100 miles) tornado killed ten people across central Mississippi. The largest tornado outbreak of 2010 occurred on 17 June in the Upper Midwest. There were 115 preliminary tornado reports across North Dakota, Minnesota, extreme northern Iowa

## U.S. Drought Monitor December 29, 2009



## U.S. Drought Monitor December 28, 2010



**Fig. 11.** U.S. Drought Monitor depicting drought conditions at the beginning of the year (29 December, 2009; left) and near the end of the year (28 December 2010; right). Source: National Drought Mitigation Center.

and extreme western Wisconsin. Three EF-4 tornadoes occurred in Minnesota and one occurred in North Dakota. This was the first time an outbreak produced four EF-4s since the "Super Tuesday" outbreak of February 2008.

Nine persons were killed in four different tornadoes in Arkansas and Missouri on 31 December 2010. This was the largest number of December fatalities on a single day, and for the month, since 2000.

### **2.4 Extreme Events in the United States**

The National Climatic Data Center has established a database (Shein, 2010) to store national and statewide records for five standard climate variables (maximum and minimum daily temperature, 24-hour precipitation, 24-hour snowfall and snow depth). These values are reviewed and adjudicated by the National Climate Extremes Committee and State Climate Extremes Committee, respectively. Other variables are established and assessed on a state-by-state basis when NCDC's climate services partners (such as State Climatologist Offices or local NWS Weather Forecast Offices) request their review on behalf of the public interest. Several state records and a national record for climate extremes were established in 2010. Those mentioned below were reviewed and found to be valid by their respective Committees.

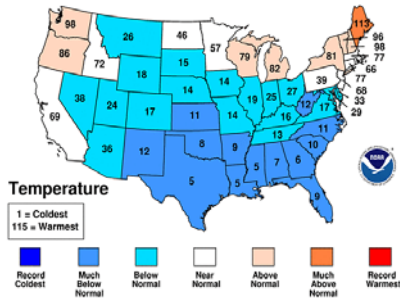
On the evening of 23 July, a hailstone measuring 8.0 inches in diameter and weighing 1 lb., 15 oz (0.88 kg) fell in Vivian, SD. These were confirmed as new national records for hailstone diameter and weight. These broke marks of 7.0 inches (22 June 2003, Aurora, NE) and 0.74 kg (3 September 1970, Coffeyville, KS) respectively.

On 15 September, a hailstone measuring 7.75 inches in diameter fell in Wichita, Kansas. This broke the state record for hailstone diameter (previous record: 7.0 inches on 2 September 1970 at Coffeyville, KS). Had the Vivian, SD hailstone not occurred two months earlier, the Wichita hailstone's diameter would have been the national record.

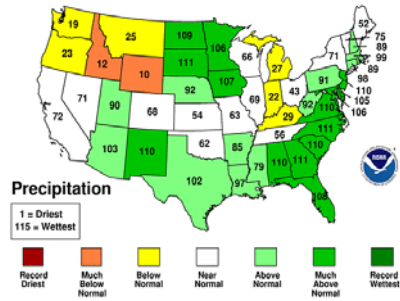
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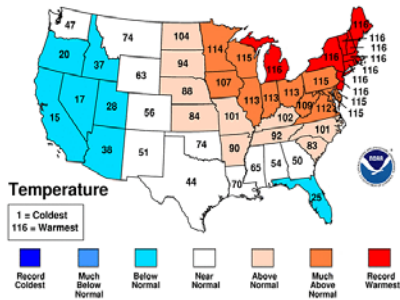
**Statewide Ranks Dec 2009 - Feb 2010**  
National Climatic Data Center/NESDIS/NOAA



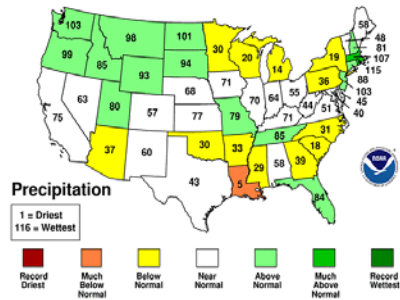
**Statewide Ranks Dec 2009 - Feb 2010**  
National Climatic Data Center/NESDIS/NOAA



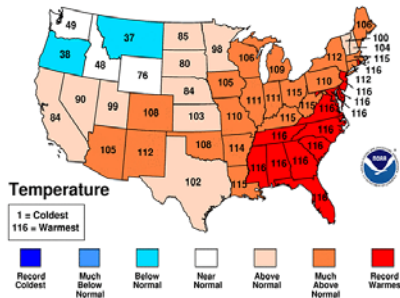
**Statewide Ranks March-May 2010**  
National Climatic Data Center/NESDIS/NOAA



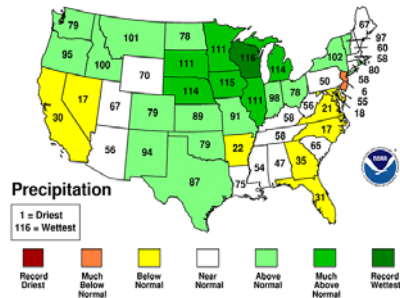
**Statewide Ranks March-May 2010**  
National Climatic Data Center/NESDIS/NOAA



**Statewide Ranks June-August 2010**  
National Climatic Data Center/NESDIS/NOAA

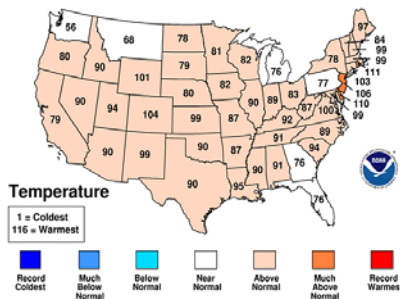


**Statewide Ranks June-August 2010**  
National Climatic Data Center/NESDIS/NOAA



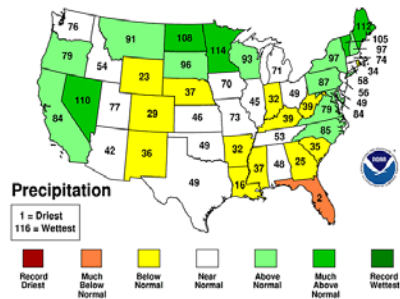
**Fall 2010**

National Climatic Data Center/NESDIS/NOAA



**Fall 2010**

National Climatic Data Center/NESDIS/NOAA



**Fig. 11.** State Temperature (left) and precipitation (right) ranks for each of 2010's climatological seasons: winter (December 2009 – February 2010; top row), spring (March-May 2010; second row), summer (June-August 2010; third row), and autumn (September-November 2010; bottom row).