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THE CLIMATE OF 2011 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 2011 climate conditions across the United States and around the planet. As the scientific community continues to work 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 cyclones. Our primary focus is to give the recent climate record a historical perspective based on 132 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 2011 extreme events. Data for the final part of 2011 are preliminary and slight changes in the reported numbers and rankings are possible.

The 2011 annual report can be found online at: http://www.ncdc.noaa.gov/sotc/.

1. GLOBAL CLIMATE ANOMALIES IN 2011

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 and is through 2011, making a 132-year record. The 2011 (land and ocean combined) average temperature anomaly was 0.51 °C, which tied with 1997 as the 11th warmest year on record (Figure 1). The global land surface temperature was the 8th warmest on record, and the global ocean temperature tied for 11th warmest. The spatial pattern of 2011 temperature anomalies, with respect to the 1971-2000 base period, is shown in Figure 2. The warmest anomalies occurred over high latitudes of the Northern Hemisphere, much of eastern North America, and Europe, and cooler than average anomalies occurred over the equatorial Pacific, western North America, eastern Asia, and much of Australia. The global and hemispheric annual temperature ranks are summarized in Table 1.

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The year 2011 began and ended with the cool phase of the El Niño – South Oscillation (ENSO), also known as La Niña. The first four months of 2011 were marked by La Niña conditions across the equatorial Pacific. This episode ended during May 2011, and ENSO neutral conditions were present from May through September. However, during October, sea surface temperature anomalies again dropped below the La Niña threshold and La Niña conditions strengthened through the Northern Hemisphere fall and into the Northern Hemisphere winter.

Consistent with the effects of La Niña's presence for over half of the year, the globally averaged temperature during each month and during 2011 as a whole, were lower than the same period during 2010. 2011 began and ended with a La Niña, while 2010 began with a strong El Niño and ended with La Niña. The global land surface temperature anomalies were among the ten warmest on record, ranking as the 8th warmest on record. While the ocean surface temperature was the 11th warmest on record, and the combined land and ocean value being the 11th warmest on record.

Several notable monthly and seasonal temperature extremes occurred during 2011. Australia experienced its coolest March-May (autumn) on record, with temperatures 1.15 °C below average (1961-90 base period). Conversely, the United Kingdom tied with 2007 as the warmest such period on record, with temperatures 1.8 °C above average (1971-2000 base period). During the Northern Hemisphere summer (June-August), much above average temperatures dominated the high latitudes; Finland experienced its

2011 Annual Temperature	Anomaly vs. 1901-2000 avg	1880-2010 Rank (131years)
Global		
Land	+0.83 °C	8th warmest
Ocean	+0.40 °C	11th warmest
Land & Ocean	+0.51 °C	11th warmest
Northern Hemisphere		
Land	+0.94 °C	6th warmest
Ocean	+0.39 °C	13th warmest
Land & Ocean	+0.60 °C	10th warmest
Southern Hemisphere		
Land	+0.52 °C	14th warmest
Ocean	+0.41 °C	11th warmest
Land & Ocean	+0.43 °C	12th warmest

Table 1. 2011 surface temperature anomaly (°C) and rank Source: NOAA/NCDC

fourth warmest summer on record. For the year, both Norway and Spain were record warm, while the United Kingdom had its second warmest year on record.

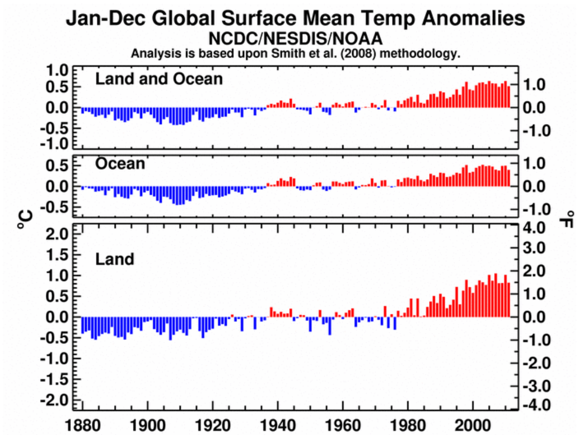
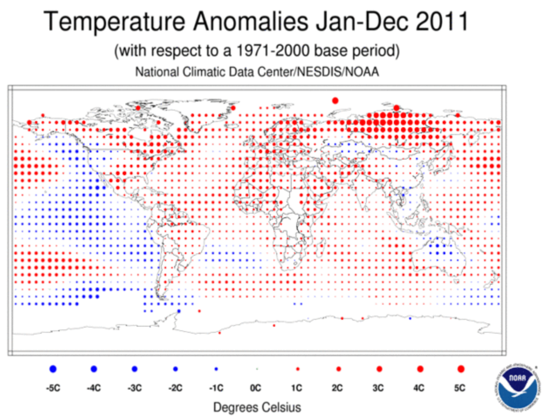


Fig. **2** Global surface temperature anomalies for 1880-2011. Source: NOAA/NCDC.



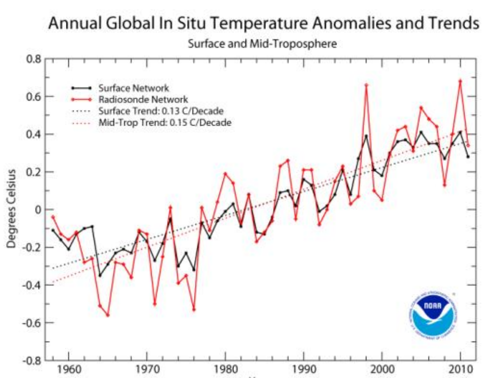


Fig. 1 Global mid-tropospheric mean temperature anomalies (red) for 1958-2011, based on radiosonde (RATPAC) data, compared to the NCDC surface temperature record (black). Source: NOAA/NCDC.

Fig. 3 2011 surface temperature anomalies relative to a 1971-2000 base period. Source: NOAA/NCDC.

1.2 Tropospheric Temperatures

Temperatures above the surface are measured using in-situ (radiosonde) instruments 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, measurement practices, and changes in orbital features over time (Free et al., 2005). NCDC uses 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. 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 2011, temperatures in the mid-troposphere were near the 1981-2010 average, resulting in the 9th warmest calendar year in the 54-year record (Table 2). The four methods NCDC uses to assess mid-tropospheric temperatures using satellite (Microwave Sounding Unit) data gave a range of ranks for the 2011 mid-tropospheric temperatures between the 16th coolest and 23rd coolest (11th-18th warmest). For each of these data sets, 1998 was the warmest year on record.

	Anomaly (vs. 1981-2010 average	1979-2011 Rank (33 yrs)
Lower Troposphere		
UAH	+0.15 °C	9th warmest
RSS	+0.05 °C	12th warmest
Middle Troposphere		
UAH	0.0 °C	16th coolest
RSS	-0.01 °C	16th warmest
UW-UAH	+0.08 °C	10th warmest
UW-RSS	+0.07 °C	11th warmest
RATPAC	+0.34 °C	9th warmest

Table 2. 2011 global tropospheric temperature anomaly (°C) and rank. Source: NOAA/NCDC, UAH, UW, RSS.

1.3 Global Precipitation and Drought

The spatial pattern of 2011 precipitation consisted of very large wet anomalies over the northeastern United States, Central America, much of coastal South America, Australia, and northwestern China. It was particularly drier than normal in far southwestern Canada, the south central United States, northern Mexico, southern and northeastern China, Mongolia, Hawaii, and French Polynesia and Kiribati in the South Pacific Ocean. When data for the land-based precipitation stations are averaged globally, 2011 was the second wettest year on record, behind 2010.

Record-breaking precipitation which occurred across Australia during the end of 2010 continued into 2011. The Australian state of Queensland was particularly hard hit during January 2011. Widespread flooding was reported for the city of Brisbane. Impacts were widespread and felt from delicate ecosystems to the mining industry. Severe Tropical Cyclone Yasi affected the region in February 2011, exacerbating the flooding conditions. Yasi was estimated to be the second costliest tropical cyclone to impact Australia on record.

Heavy rains hit Brazil in early January causing widespread flooding and landslides in the southeastern parts of the country. Nearly a thousand people were reportedly killed due to the flooding, marking the deadliest natural disaster on record to impact Brazil.

Heavy rains across Southeast Asia impacted Cambodia, Myanmar, and Thailand from July to October which led severe flooding across the region. Some regions in Thailand were under as much as two meters of water. The city of Bangkok was particularly hard hit, as flood waters made their way southward toward the Gulf of Thailand, essentially cutting off the city. Over 500 people were reported to have perished due to the flood waters.

A crippling drought impacted the horn of Africa during summer 2011. Consecutive seasons of below-normal precipitation were associated with La Niña across the Equatorial Pacific. The drought caused extreme food shortages in the region, where an estimated 11 million people were without a reliable source of food. As much as 80 percent of the livestock population was destroyed.

In October, two separate storm systems—a tropical depression from the Pacific and another system from the Caribbean—dumped nearly five feet (1520 mm) of rain in some areas across Central America. Honduras, Costa Rica, Guatemala, El Salvador, and Nicaragua were significantly impacted, where hundreds of fatalities were reported.

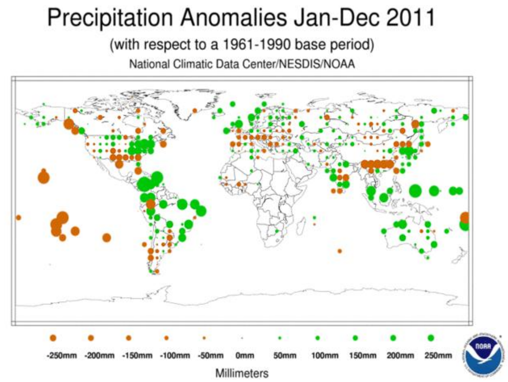


Fig. 4 Gridded global precipitation anomalies relative to a 1961-90 base period. Source: NOAA/NCDC/GHCN.

1.4 Arctic Sea Ice Extent

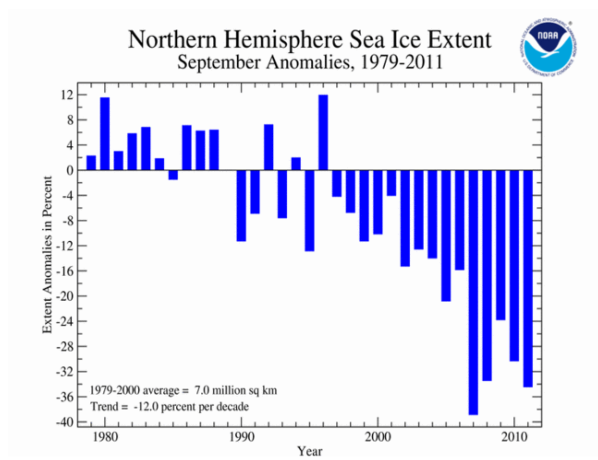


Fig. 5 Northern Hemisphere sea ice anomalies, September 1979-2011. Source: National Snow/Ice Data Center

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 7 March 2011, which is near the median date of the historical annual maximum extents. The annual maximum extent of 15.86 million square km was within 1 percent of the smallest annual maximum on record, which occurred in 2006. The March 2011 extent of 14.56 million square km was about 7.5 percent less than the 1979-2000 average of 15.8 million square km, and represented the second-lowest March Arctic sea ice extent in the satellite record.

The 2011 minimum sea ice extent of 4.33 million square km occurred on 9 September, and was the second smallest of the satellite era. The last five smallest Arctic ice extents have occurred over the past five years (2007-2011), with the smallest extent on record occurring in 2007. The average September sea ice extent was also the second-smallest on record. September Arctic sea ice extent has decreased at a rate of 12 percent per decade. Individually, the months of January and July set new monthly records for the smallest average sea ice extent on record. No month saw average Arctic sea ice extent above the long-term average, and the last month with above average ice extent was May 2001.

1.5 Northern Hemisphere Snow Cover

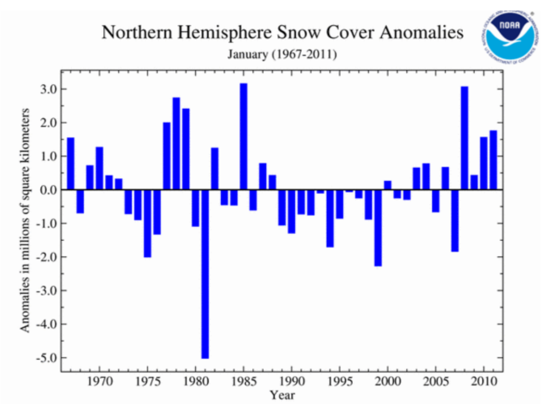


Fig. 6. Northern Hemisphere snow cover anomalies for January 1967-2011. Source: Rutgers University.

Satellite observations of snow cover extent began in late 1966. For the fourth consecutive year, the average Northern Hemisphere January (mid-season) snow cover extent was above average. The average January 2011 snow cover extent of 48.5 million square km was the sixth largest January snow cover extent on record. This above-average January extent held for both North America (fourth largest extent) and Eurasia (11th largest). The North American snow cover extent for January, where cooler-than-normal temperatures and numerous storms affected the eastern United States during January, was the largest since 1985. The above-average snow cover extent for the Northern Hemisphere, as well as North America and Eurasia continued through March. The North American snow cover extent anomalies were consistently larger than those for Eurasia. Cool temperatures and an active storm pattern across the western and northern United States and southern Canada, contributed to the Northern Hemisphere having a top ten snow cover extent for February and March. In April, the Northern Hemisphere had below average snow cover extent, with below average snow extent observed across Eurasia and above average snow extent across North America.

1.6 Tropical Cyclones

Global tropical cyclone activity was well below average during 2011, reprising the global totals of 2010. The six major basins had 76 tropical cyclones, below the long-term (1979-2008) average of 85.6. Of these, 38 reached hurricane (or, alternatively, typhoon or cyclone) strength. This is below the long-term average of 45.7. Tropical cyclone activity by ocean basin is summarized in Table 3. 2010-11 tropical cyclone data is preliminary.

The North Atlantic basin saw significantly above-average activity, consistent with the general expectations of La Niña, which tends to produce more favorable shear conditions during a season. The season's 18 named storms, ties as the 6th busiest Atlantic hurricane season with 1969, since records keeping began. Only six of the named storms reached hurricane strength, which is near average for the basin. This only accounted for a third of the named storms, less than the typical 55 percent of named storms becoming hurricane strength in the basin. During the season, one hurricane – Irene – made landfall in the United States. Hurricane Irene was the first hurricane to make landfall in the U.S. since Hurricane Ike in 2008. The Northeast Pacific basin had a below-average season, with 11 named storms, 10 hurricanes, and 5 major hurricanes.

The Northwest Pacific basin also had a below average typhoon season, with 20 named storms and 10 typhoons. Numerous tropical cyclones impacted the Filipino Archipelago during 2011, causing significant flooding and damage across the nation. Typhoon Talas, which hit Japan in early September, killed over 70 people marking the deadliest tropical cyclone to affect the nation in seven years.

Ocean Basin	2011 Tropical Storms (with 1979-2008 Average)	2011 Cyclones/Hurricanes/Typhoons (with 1978-2008 average)
Atlantic	19 (12.1)	7 (6.7)
Eastern North Pacific	11 (21.0)	10 (12.1)
Western North Pacific	20 (26.1)	10 (15.9)
South Pacific	9 (11.0)	5 (1.8)
North Indian	6 (6.3)	1 (1.8)
South Indian	11 (11.8)	5 (6.4)
Global	76† (85.6)	38† (45.7)

Table 3. Tropical cyclone activity during the 2011 season by ocean basin. Values for southern hemisphere basins are tallied for the year ending June 30, 2011to capture the seasonal offset. Source: NCDC preliminary best track data. †*Global totals may not match the sum of basin totals due to sharing of storms between basins*

2. U.S. CLIMATE ANOMALIES IN 2011

2.1 U.S. Temperatures

Continuing the long-term trend, temperatures during 2011 in the contiguous United States (CONUS) were above the 20th century average. The CONUS 2011 annual temperature of 53.9 °F was 1.1 °F above normal and the 22nd warmest year on record. Since 1895, the CONUS has observed a long-term temperature increase of about 0.12 °F per decade.

The spatial pattern was dominated by above-normal temperatures across the Southwest, Southern Plains, and along the Eastern Seaboard. Below normal temperatures were observed across the Pacific Northwest.

On a statewide level, Texas had its second warmest year in the 117-year period of record, and Delaware had its warmest year on record. The summer period (June-August) was the second warmest three month period on record for the nation. Oklahoma and Texas had the two warmest three month periods of any state on record, surpassing the long-standing warm summers of the 1930s. Washington and Oregon were the only states with summer temperatures in the lowest tercile of their historical distribution. The near- record warmth during the summer, extended to most of the warm season (April-September), which was the 7th warmest such period on record for the CONUS.

In contrast to the warm summer, the preceding winter season (Dec 2010-Feb 2011) was cooler than average for the CONUS. The eastern two-thirds of the nation had temperatures below average, while California and Nevada were warmer than average. A strong negative phase of the Arctic Oscillation during most of the winter contributed to the cool temperatures in the East.

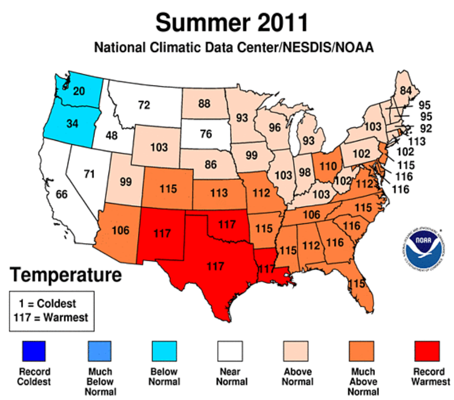


Fig. 7. Summer (June-August) temperature ranks, by state, for the contiguous United States. Source: NOAA/NCDC.

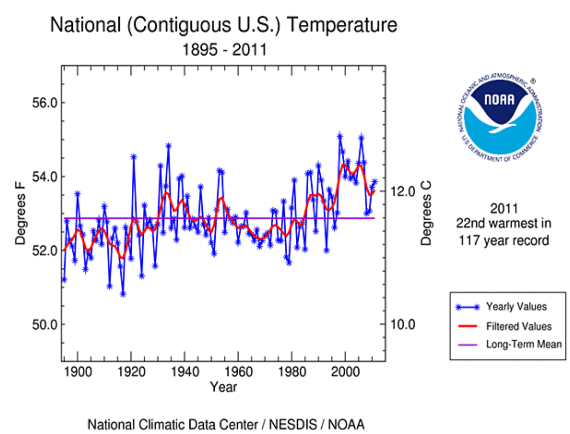


Fig. 8. Contiguous U.S. average annual temperatures, 1895-2011. Source: NOAA/NCDC.

2.2 U.S. Precipitation and Drought

After three consecutive years of above-normal values, nationally-averaged precipitation was near the long-term mean, masking regional extremes. Record-breaking drought across the southern CONUS counterbalanced record-breaking precipitation in the Northeast and Ohio Valley, causing the CONUS to have near-average annual precipitation.

The northern tier of the country tended to be wetter than average, with several states across the Northeast and Ohio Valley – Connecticut, Indiana, Kentucky, New Jersey, New York, Ohio, and Pennsylvania -- having their wettest year on record. Six other states had years which were among their ten wettest. This wet pattern was associated with a persistent northerly storm track during the year, and two tropical cyclones (Irene and Lee), bringing heavy rainfall to the Northeast.

The above-normal precipitation across the northern U.S. was associated with record flooding along several major waterways. Above-average snowpack across the Ohio Valley and Northern Rockies, combined with above-average spring precipitation, led to record flooding along the Missouri, Mississippi, Souris, and James rivers. Thousands of acres of farmland were devastated from the Canadian border to the Gulf of Mexico. Much of the flooding expanded into southern Canada, and impacted the city of Winnipeg. Lake Champlain, in Vermont, also reached record levels during 2011, flooding shoreline villages.

In contrast, the Southern Plains and Southeast received below-average precipitation during the year. New Mexico, South Carolina, Louisiana, and Georgia had a top-ten-dry year, while Texas had its second driest year on record. The dryness across the South was most notable the first 8 months of the year. For every month from February through September, Texas had one of its ten driest such periods.

One of the most notable national-scale events was the expansion of exceptional drought across the southern United States. The previous year (2010) was marked by above-normal precipitation for the nation, and by the end of the 2010 warm season drought was nearly eradicated for the CONUS, according to the U.S. Drought Monitor (USDM). However, persistent dryness during 2011 erased all precipitation gains made against drought during the previous year. By early October 2011, nearly 12 percent of the CONUS was under exceptional drought conditions, the worst classification in the USDM. During September, nearly all of Texas experienced extreme-to-exceptional drought. Parts of the Southern Plains observed their most extreme drought in the 1900-present record, according to the Palmer Hydrological Drought Index (PHDI).

The 2011 drought in Texas broke records of severity, but the 1950s drought holds the record in terms of duration. The 2011 summer statewide Palmer Drought Severity Index (PDSI) value for Texas was the lowest summer value in the 1900-present record, with the summer of 1956 ranking second lowest. Analysis of tree-ring records dating back to 1550 AD indicates that: (1) droughts as severe as 2011 and 1956 occur in about 1 in 40 years in both the 20th century instrumental and pre-20th century reconstructed paleo records; (2) the 1789 drought was comparable to the 2011 drought in terms of severity; and (3) droughts which occurred in 1859-1864 and 1785-1790 had durations comparable to the 1950s drought.

During the year there were 14 Billion Dollar Disaster Events. Most of the events were associated with severe convective weather across the U.S. and flooding events. Total damage from these events is expected to exceed 55 billion U.S. dollars.

The Climate Extremes Index (CEI) (Gleason et al., 2008) was above normal for the annual period for the country. For the second straight summer, the areal extent of extremely warm minimum temperatures was larger than any summer prior to 2010. Regionally, the Northeast had its second highest Regional CEI (RCEI) on record, driven by extremes in wet PDSI, days with precipitation, 1-day precipitation totals, and warm daily minimum temperatures. Meanwhile, the South also had its second highest RCEI on record, due to warm maximum temperatures and dry PDSI values.

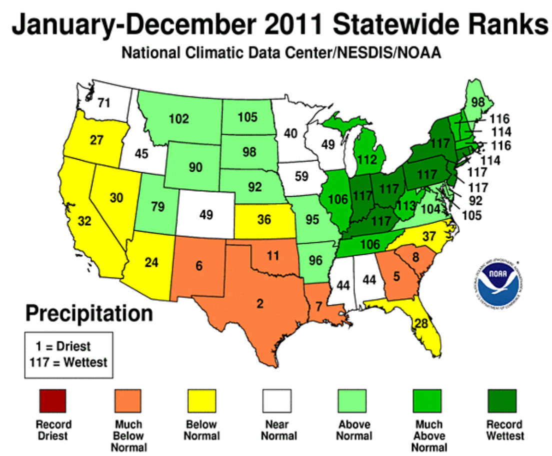


Fig. 9. Annual precipitation ranks, by state, for the contiguous United States. Source: NOAA/NCDC**.**

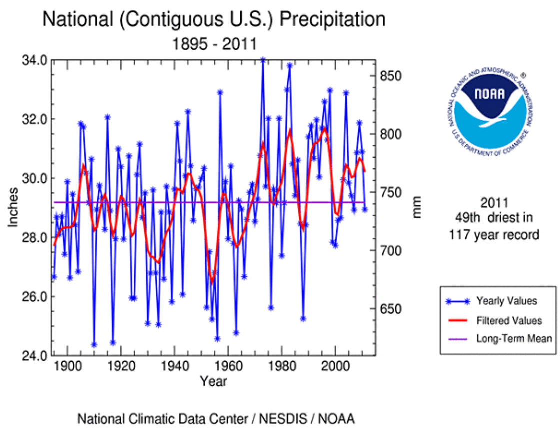


Fig. 10. Contiguous U.S. average annual temperatures, 1895-2011. Source: NOAA/NCDC.

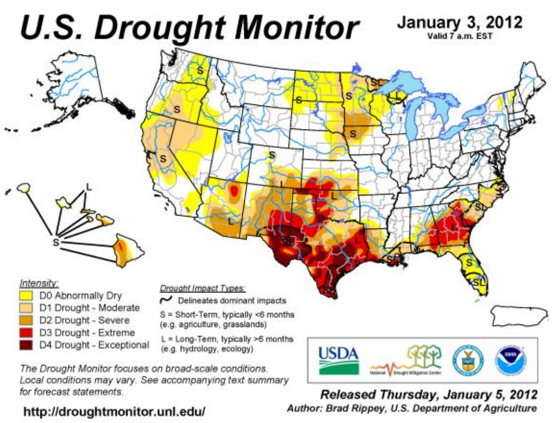


Fig. 11. U.S. Drought Monitor depicting conditions at the end of the year (3 January, 2012). Source: National Drought Mitigation Center.

2.3 U.S. Tornadoes

The preliminary tornado count for 2011 was 1,676, with 33 preliminary reports still pending for December, at the time this report was written. It should be noted that not all reported tornadoes are confirmed (see Ray et al., 2003). Regardless, 2011 will finish as one of the most active, deadly, and destructive tornado years on record. The most active tornado year on record was 2004, when there were 1,817 confirmed tornadoes. April was the most active tornado month during 2011, when approximately 758 tornadoes were confirmed during the month. This surpasses May 2003, when 550 tornadoes were confirmed, as the most tornadoes to occur during a single month, since the modern record began in 1950.

There were four significant tornado outbreaks during the month of April, each with economic impacts exceeding one billion U.S. dollars. The hardest hit areas were the southeastern states of Mississippi, Alabama, Tennessee, Georgia, and North Carolina. There were an estimated 360 tornado related fatalities during April 2011. The April 25-27 tornado outbreak had over 300 individual tornadoes – one of the largest tornado outbreaks in U.S. history. The deadliest single tornado of the year occurred on May 22 when an EF-5 tornado ripped through Joplin, Missouri, killing an estimated 158 people. The tornado caused significant damage to the town, with economic impacts expected to exceed three billion U.S. dollars. The Joplin tornado is the deadliest tornado to strike the nation since the modern record began in 1950. Total economic losses due to tornadoes and severe weather alone during 2011 are expected to exceed 28 billion U.S. dollars.

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Seasonal Rank Maps