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THE CLIMATE OF 2009 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 2009 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 about 130 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 2009's extreme events.

The 2009 annual report can be found online at: http://www.ncdc.noaa.gov/sotc/?year=2009

1. Global Climate Anomalies in 2009

1.1 Global Temperature

The data set of record for this manuscript is NOAA's Merged Land & Ocean Surface Temperature (Smith et al., 2008). Data for 2009 were available through October

Jan-Oct 2009 Temperature	Anomaly (vs. 1901-2000 avg)	1880-2009 Rank (130 years)	
Global			
Land	+0.80°C	5th warmest	
Ocean	+0.47°C	6th warmest	
Land & Ocean	+0.56°C	5th warmest	tied 2007
Northern Hemisphere			
Land	+0.84°C	6th warmest	tied 2008
Ocean	+0.47°C	5th warmest	
Land & Ocean	+0.61°C	5th warmest	tied 2003, 2006
Southern Hemisphere			
Land	+0.70°C	3rd warmest	
Ocean	+0.49°C	4th warmest	
Land & Ocean	+0.52°C	4th warmest	tied 2005

Table 1. January-October 2009 surface temperature anomaly (°C) and rank. Source: NOAA/NCDC.

as of this writing. The 2009 global (land and ocean) annual (January-October) average temperature anomaly was +0.56 °C, which tied 2007 as the 5th warmest such period of the record (Fig. 1). The global land temperature rank was also 5th warmest and the global ocean temperature rank was 6th warmest. The spatial pattern of January-October 2009 temperature anomalies, relative to a 1971-2000 base period, is shown in Figure 2. The warmest anomalies occurred in a long (roughly 10,000 km) belt from central Africa through the Middle East, southern and eastern Asia and into Siberia, with additional notable warmth in eastern and northern Europe and high-latitude North America. Cool anomalies occurred over the interior of North America and in the southern oceans. The global and hemispheric January-October temperature ranks are summarized in Table 1.

As the ENSO status evolved from La Niña early in the year to an emerging El Niño by early summer, ocean surface temperatures responded accordingly. The boreal summer (June - August) was the warmest on record for ocean surface temperature. The global oceans were the warmest on record for the months of July and August.

Notable monthly temperature extremes include a severe heatwave during January and February across southern Australia. The extreme heat was accompanied by very dry conditions that contributed to the development of wildfires which claimed 210 lives. Also, Australia had its warmest August since national temperature records began 60 years ago. The average temperature for the nation as a whole was 2.47˚C above the 1961-90 average, breaking the previous record by 0.98˚C. New Zealand also experienced its warmest

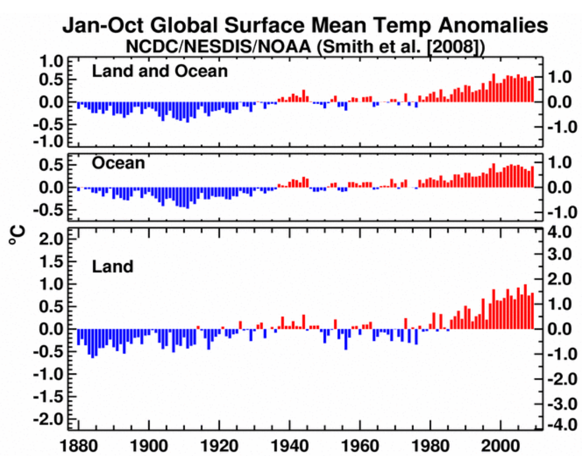

Fig.1. Global surface temperature anomalies for Jan-Oct, 1880-2009. Source: NOAA/NCDC.

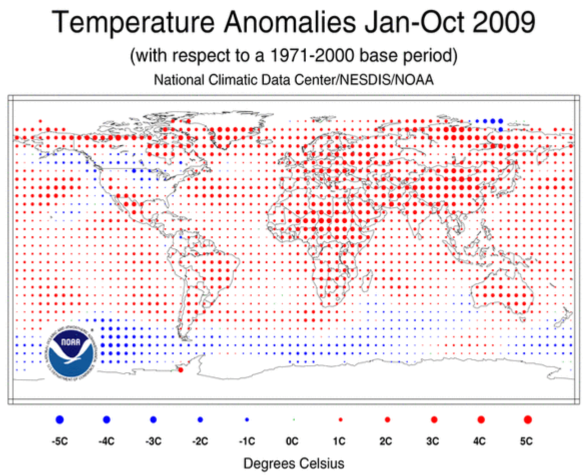

Fig. 2. Global surface temperature anomalies relative to a 1971-2000 base period, for Jan-Oct 2009. Source: NOAA/NCDC.

August since national records began 155 years ago.

Conversely, New Zealand had its coolest October since 1945. The national average was 1.4˚C below the long-term October average. The United Kingdom had its coolest winter since the winter of 1996-97.

1.2 Tropospheric Temperatures

Temperatures above the surface of the earth are measured using in-situ balloon-borne instruments (radiosondes) and polar-orbiting satellites (NOAA's TIROS-N). The radiosonde (RATPAC) and satellite records have been adjusted to remove time-dependent biases (artificialities caused by changes in radiosonde instruments and measurement practices as well as changes in satellite instruments and orbital features through time). Several different adjustment algorithms are applied to the satellite data. NCDC's monitoring activities utilize 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 to present, while satellite measurements began in 1979. It is important to note that the length of record can affect the period of record means, the resulting sign of the anomalies, period of record trends, and, therefore, one's perception of the importance and meaning of the ranks and time series for each analysis.

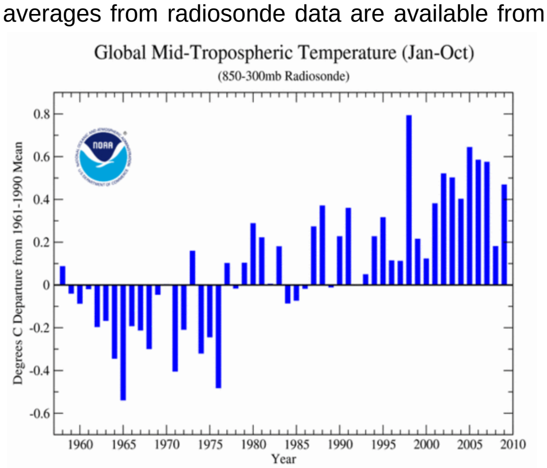

Fig. 3. Global mid-tropospheric mean temperature anomalies for Jan-Oct, 1959-2009, based on radiosonde (RATPAC) data. Source: NOAA/NCDC.

Radiosonde measurements indicate that for January-October 2009, temperatures in the mid-troposphere were 0.47°C above the 1958-2009 average, resulting in the 7th warmest January-October period in the 52-year record (Fig. 3). Satellite measurements of January-October 2009 mid-tropospheric temperatures, based on the shorter 1979-2009 period, varied from 7th warmest to 12th warmest, depending on the analysis.

Jan-Oct 2009	Anomaly (vs. 1979-2009 average)	1979-2009 Rank (31 yrs)
Lower Troposphere		
UAH	+0.24°C	7th warmest
RSS	+0.25°C	8th warmest
Middle Troposphere		
UAH	+0.08°C	12th warmest
RSS	+0.13°C	11th warmest
UW-UAH	+0.18°C	7th warmest
UW-RSS	+0.21°C	9th warmest
RATPAC	+0.47°C †	7th warmest †

***† RATPAC (radiosonde) anomalies and ranks are based upon a 52-year (1958-2009) dataset*.**

Table 2. January-October 2009 global tropospheric temperature anomaly (°C) and rank. Source: NOAA/NCDC, UAH, UW, RSS.

1.3 Global Precipitation and Drought

The spatial pattern of January-October 2009 precipitation consisted of large wet anomalies over southeastern Brazil, parts of eastern Asia, most of Europe and the eastern United States. Dry anomalies dominated Alaska's panhandle, Australia, southern South America, and parts of southern Asia.

Precipitation in the Philippines was well-above-average, mainly due to the combined effects of repeated typhoons that impacted the islands. During June, central Europe had heavy rains that triggered floods and mudslides. The floods killed at least 17 and destroyed the historic center of Prague. The southeastern United States received heavy rainfall in September, leading to a 500-year flood in Atlanta, Georgia. November brought some of the worst flooding in the United Kingdom's history, when more than 30 cm of rain fell in Cumbria in 24 hours, a new all-time U.K. record.

The Indian Monsoon was notably weak in 2009. The country reported just 77% of normal monsoon season rainfall, according to the India Meteorological Department, the lowest value of the decade. Parts of China experienced their worst drought in 50 years, leaving over 4 million people with inadequate drinking water and destroying 24 million acres of crops. Extreme heat and drought across southern Australia in January and February led to the worst wildfires in Australia's history, killing 210 people in Victoria.

1.4 Northern Hemisphere Snow Cover

Satellite observations of snow cover extent began in late 1966. The January 2009 (mid-season) Northern Hemisphere snow cover extent was very near the 43-year average (Fig. 4). This near-average January extent held for both North America (18th largest extent) and Eurasia (22nd largest / 22nd smallest). However, by March (late season), the Northern Hemisphere snow extent was below average, ranking as the 12th smallest (smallest tercile) of the record. This was attributable partly to a warmer-than-normal late winter in Eurasia, where the March snow extent was the 9th smallest (smallest quartile) of the 43-year record. North American snow cover extent for March was near average. March 2009 was the fourth consecutive March, and the 17th of the last 22, with below-normal snow extent in Eurasia.

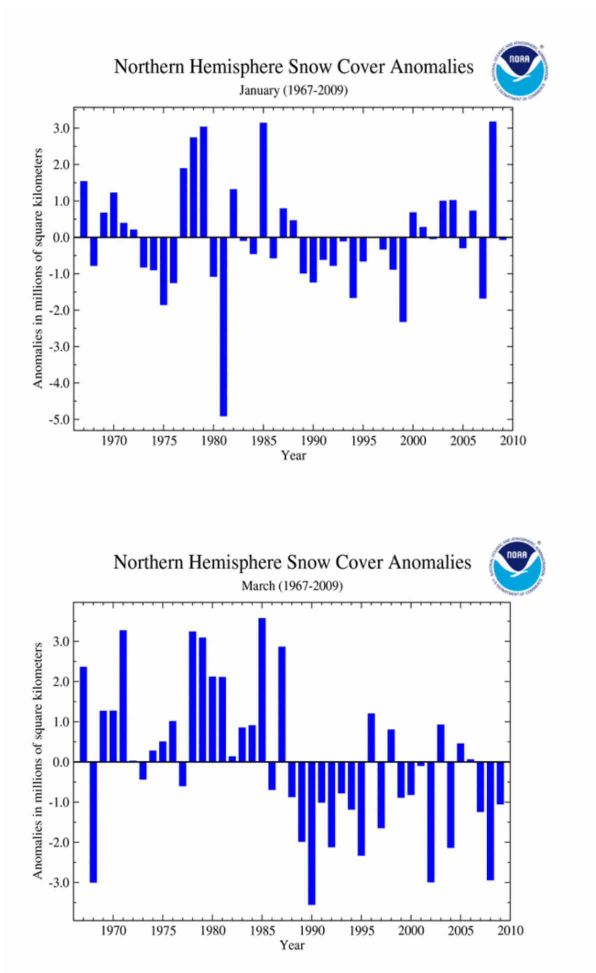

Fig. 4. Northern Hemisphere snow cover anomalies for January, 1967-2009 (left) and March 1967-2009 (right). Source: Rutgers University.

In January, a rare snowfall in Spain left 6-10 cm of accumulation and was the heaviest snow event in decades for Madrid. A strong January ice storm hit the U.S. Midwest, particularly the state of Kentucky, where it was described as the biggest natural disaster to ever affect the state. The worst snowstorm since 1991 affected The U.K. in February with 25 cm of snow observed in parts of southern England. A series of strong winter storms during the last week of March and left up to 90 cm of snow on parts of the U.S. Plains.

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 a minimum in 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 28 February 2009, at 15.1 million square km. This is 0.7 million square km below the 1979-2000 average of 15.9 million square km, the 5th-lowest maximum extent during the satellite record. The six lowest maximum extents have all occurred in the last six years.

The 2009 monthly sea ice extent was third lowest for both August and for September (Fig. 5), and the second-lowest value for the post-minimum (growth) month of October. In all three months, the lowest extent occurred in 2007. September arctic sea ice extent has decreased at a rate of 11.2 percent per decade.

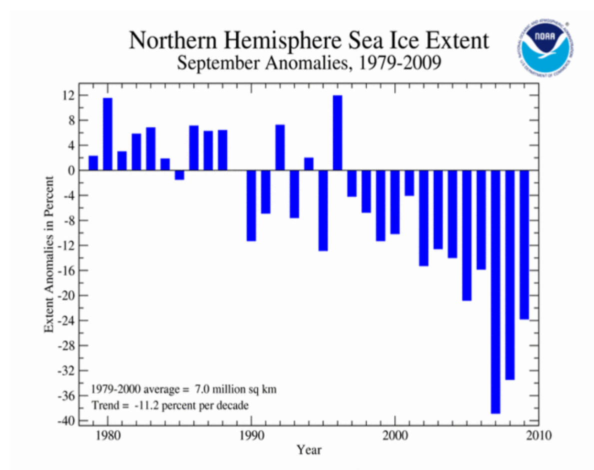

Fig. 5. Northern Hemisphere sea ice anomalies, September, 1979-2009. Source: NSIDC.

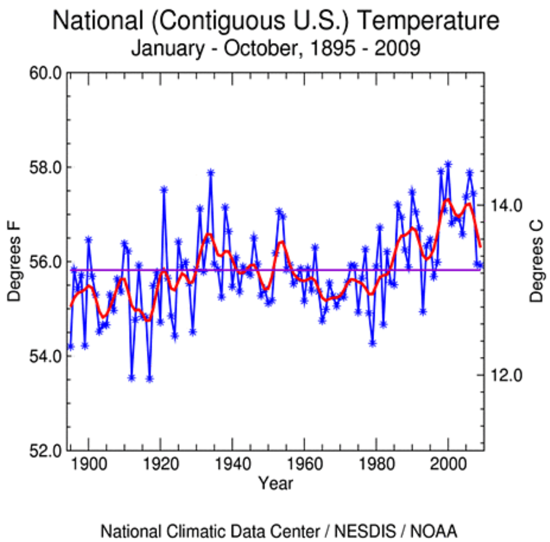

Fig. 6. Contiguous U.S. temperatures, January-October, 1895-2009. Source: NOAA/NCDC.

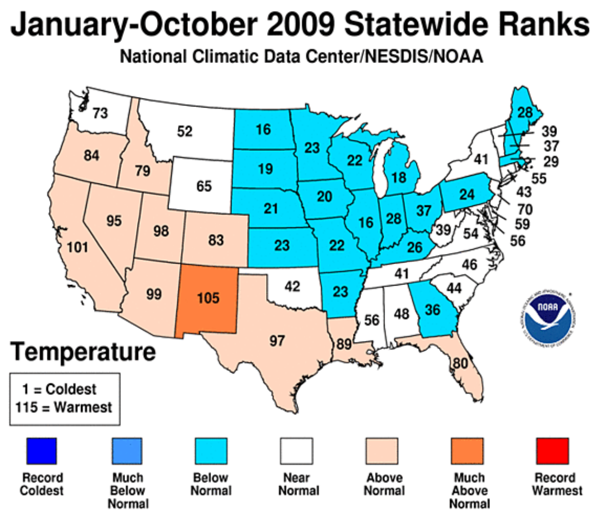

Fig. 7. Statewide temperature ranks for January-October 2009. Source: NOAA/NCDC.

1.6 Tropical Cyclones

Global tropical cyclone activity was below average during the 2009 season (the southern hemisphere's annual counts ended 30 June 2009). 82 tropical storms occurred in the six major basins, slightly below the long-term (1979-2008) average of 85.6. Of these, 35 reached hurricane/typhoon/cyclone strength. This is below the long-term average of 45.7. Tropical cyclone activity by ocean basin is summarized in Table 3. All 2008-09 tropical cyclone data are preliminary.

Overall activity in the North Atlantic basin was light, consistent with the general understanding of the impact of El Niño-related shear during the season. The nine named storms in the basin is the lowest number since 1997, and the three reaching hurricane strength is the lowest since 1987. The Philippines were hit hard by successive tropical cyclones, resulting in hundreds of fatalities. In the Eastern Pacific, Andres became the first named storm of the season on 21 June, the latest arrival of a named storm in the basin. Hurricane Rick was the basin's strongest October storm and its second strongest storm during any month (behind Linda, 1997).

2. U.S. Climate Anomalies in 2009

2.1 U.S. Temperatures

In contrast to the continued unusual warmth on a global scale, 2009 temperatures in the contiguous United States were near the 20th century average (Fig. 6) for the second consecutive year, following ten consecutive much-warmer-than-average years. The spatial temperature pattern consisted of cool anomalies in the northern and central U.S. Plains and Midwest, with warm anomalies in the Southwest and Florida (Fig. 7). A persistent cool anomaly was entrenched in the U.S. Plains and Upper Midwest during summer and fall. Preliminary attribution exercises from NOAA CSI (see http://www.esrl.noaa.gov/psd/csi/images/IAP_18NOV2009.ppt) suggest that this pattern is not inconsistent with those expected during a summer-onset El Nino. According to preliminary data, October 2009 was the 3rd coolest October on record (since 1895; 115-year record).

Ocean Basin	2009 Trop. Storms (with 1979-2008 Average)	2009 Cyclones / Hurricanes / Typhoons (with 1979-2008 Average)
Atlantic	9 (12.1)	3 (6.7)
Eastern North Pacific	20 (21.0)	8 (12.1)
Western North Pacific	24 (26.1)	15 (15.9)
South Pacific	9 (11.0)	1 (1.8)
North Indian	4 (6.3)	1 (1.8)
South Indian	17 (11.8)	7 (6.4)
Global	**83‡ (85.6)**	**35‡ (45.7)**

Table 3. Tropical cyclone activity during the 2009 season by ocean basin. Values for southern hemisphere basins are tallied for the year ending June 30, 2009 to capture the seasonal offset. Source: NCDC preliminary best track (IB TRACS) data. ‡ *Global totals may not match the sum of basin totals due to sharing of storms between basins*

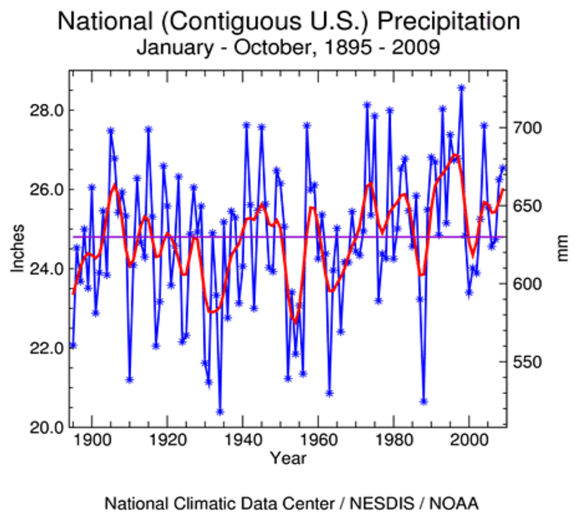

Fig. 8. Contiguous U.S. precipitation, Jan-Oct, 1895-2009. Source: NOAA/NCDC.

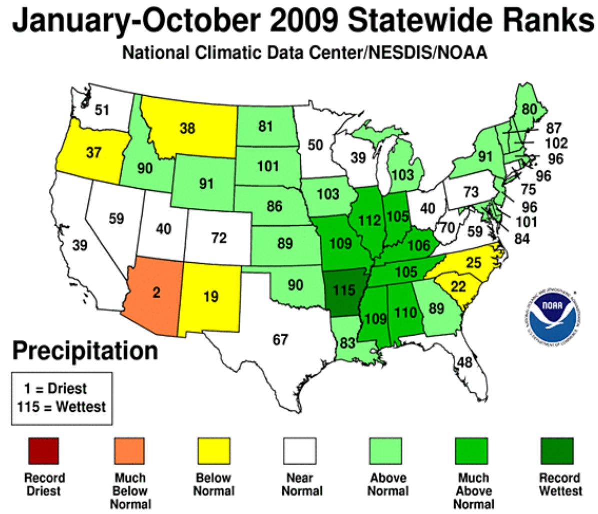

Fig. 9. Statewide precipitation ranks for January-October 2009. Source: NOAA/NCDC.

2.2 U.S. Precipitation and Drought

The below-average temperature anomalies in the central U.S. were associated with above-average precipitation anomalies (Fig. 8). Overall, according to preliminary data, the Contiguous U.S. had its 20th wettest January-through-October period on record. The wet 2009 is not inconsistent with a decades-long trend of increasing January-October precipitation.

Spatially, the most abnormally wet areas were located in the lower and middle Mississippi Valley (Fig. 9). Arkansas had its wettest year (January-October 2009) of the 115-year record, and Illinois its 4th wettest. August-through-October rainfall was record-setting for along the Gulf Coast, including many adjacent divisions in Texas, Louisiana, Arkansas, Mississippi, Alabama, and Georgia. It is noteworthy that this occurred despite only one tropical cyclone (Claudette, in August) making landfall in the region during this period.

The overall U.S. drought footprint was relatively small during 2009 (Fig. 10). Late October drought coverage of 11.9% was the second-smallest weekly footprint this decade, according to the U.S. Drought Monitor. Nevertheless, significant drought episodes plagued parts of the nation during 2009. The most intense episode occurred across central and southern Texas. By late summer, conditions reached near-historic proportions, and a combination of instrumental data and tree-ring reconstructions (Fig. 11) suggest that the extremely low precipitation during January-June 2009 has only about 15 peers since 1650. Autumn rains alleviated the intensity and size of the drought episode.

Drought in California persisted through much of 2009, briefly growing in late summer to threaten much of the Pacific Northwest and Great Basin areas. Late-summer brought drought to Arizona, chiefly due to the failure of the North American Monsoon to deliver typical rains. Hawaii dealt with persistent dryness focused on its easternmost islands. Another smaller episode persisted in the western Great Lakes region, centered on northern Wisconsin and eastern Minnesota.

A combination of exceptionally heavy snowfall, rapid melt, and antecedent soil moisture led to near-historic flooding on parts of the Red River bordering North Dakota and Minnesota in late March. At the same time, a late-season blizzard delivered more than two feet of snow across parts of the Southern Plains, breaking all-time record 24-hour snow totals for the states of Kansas (30 inches at Pratt), Oklahoma (26 inches at Freedom and Woodward), and Texas (25 inches at Follett).

2.3 U.S. Tornadoes

The 2009 preliminary tornado count at the end of November was 1109, which will represent one of the quietest tornado years this decade. June was the most active tornado-producing month with 268 confirmed tornado reports. April, June and July were the only months to experience tornado counts greater than the running three-year (2006-08) average. The 22 tornado-related fatalities in 2009 is less than each of the last four years. The deadliest single tornado for the year occurred on 10 February when an EF4 tornado killed eight in Oklahoma. It was the first February EF4 tornado for Oklahoma. The largest tornado outbreak of 2009 occurred 10 April when 73 tornadoes were reported across the southeastern U.S., killing two people.

3. References

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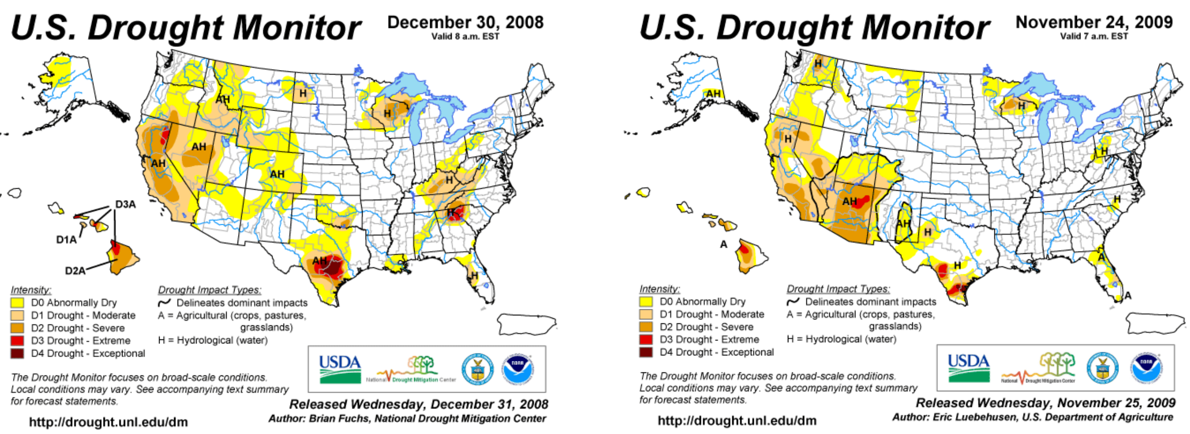

Fig. 10. U.S. Drought Monitor depicting drought conditions at the beginning of the year (December 30, 2008; left) and near the end of the year (November 24, 2009; right). Source: National Drought Mitigation Center.

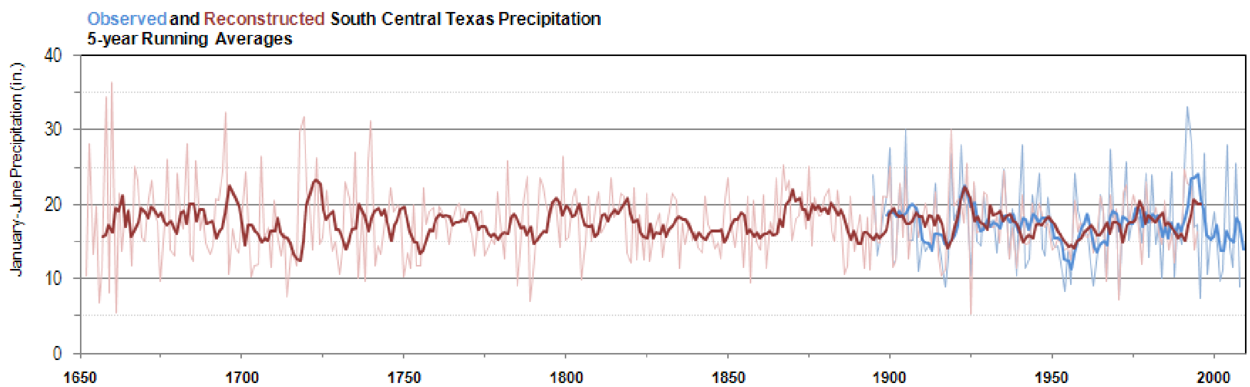

Fig. 11. January-June precipitation for 1895-2009 for South Central Texas (Climate Division 7) (annual values in light blue, 5-year weighted average in dark blue), with a 344-year tree-ring record (1652-1995; annual values in light red; 5-year smoothed values in dark red). This record is a composite of six post oak (*Quercus stellata*) tree-ring chronologies from south Texas.

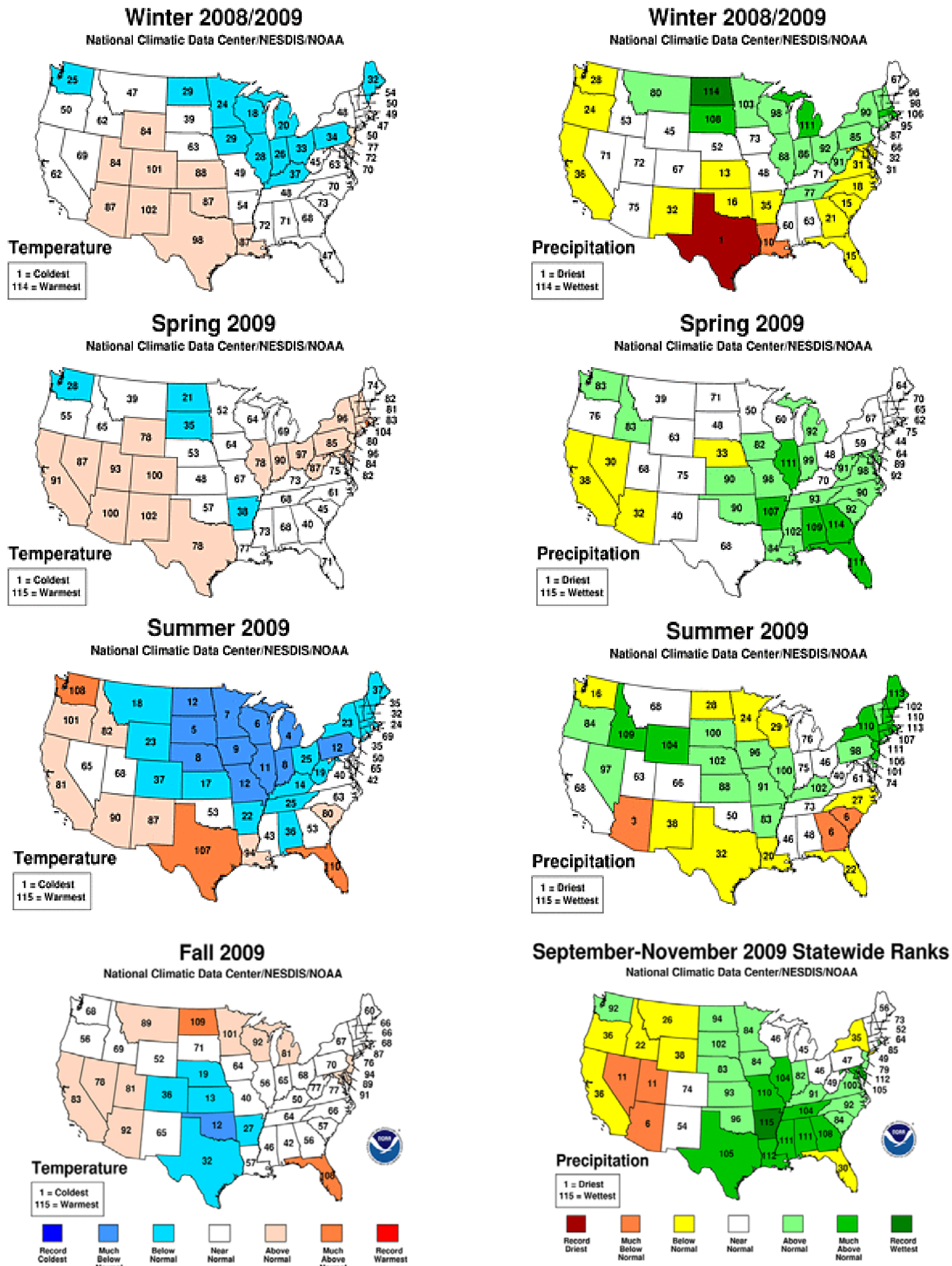

Fig. 11. State Temperature (left) and precipitation (right) ranks for each of 2009's climatological seasons: winter (December 2008 – February 2009; top row), spring (March-May 2009; second row), summer (June-August 2009; third row), and autumn (September-November 2009; bottom row).