12.1 **THE CLIMATE OF 2004 IN HISTORICAL PERSPECTIVE**

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1. INTRODUCTION

The Climate Monitoring Branch at NOAA's National Climatic Data Center (NCDC) routinely produces climate assessments on a monthly, seasonal, and annual basis. The purpose of these assessment reports is to put the observed climatic conditions into historical perspective. In this paper, we present the major climate and weather events of 2004, focusing on the temperature and precipitation patterns observed during the past year and their relationship to inter-annual trends in these parameters across the U.S. and the globe.

It is important to note that this article is being written and submitted to the AMS before the end of 2004. Therefore, the products and analyses presented emphasize the year-to-date conditions (Jan–Sep) and seasonal values during the past winter (DJF), spring (MAM) and summer (JJA). In addition to the standard parameters of temperature and precipitation, other important regional and global climatic conditions will be included, such as the ongoing drought conditions in the western U.S., and the observed Atlantic basin tropical storms and hurricanes during 2004. Other large-scale influences on global climate, such as the El Niño/Southern Oscillation (ENSO), will also be addressed.

2. GLOBAL CLIMATE

The year-to-date (Jan-Sep) globally averaged temperature anomalies for both land and ocean surfaces using data from the Global Historical Climatology Network (GHCN) are shown in Figure 1. The observed global surface temperature anomaly so far in 2004 was +0.51°C (+0.92°F). This ranks 2004 as the fourth warmest on record, when compared with the January to August nine-month period over the entire 1880-2004 record in the GHCN dataset. The year-to-date sea-surface temperatures (SSTs) also ranked as fourth warmest in 2004, with a globally averaged anomaly of +0.39°C (+0.70°F), while land areas have been fifth warmest so far in 2004, with an anomaly of +0.79°C (+1.42°F).

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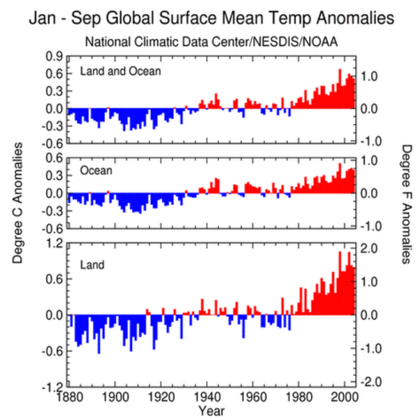


Figure 1. Global surface mean temperature anomalies (°C left and °F right) averaged over January-September for the period 1880-2004: (Top) land and ocean surfaces, (middle) oceans surfaces only, and (bottom) land surfaces only.

From a seasonal perspective, above average temperature anomalies have dominated the Northern Hemisphere during the winter, spring and summer of 2004. Figure 2 shows the land surface temperature anomalies for those three seasons compared with the 1961-1990 base period. The largest temperature anomalies during the winter of 2004 (Dec-Feb) occurred across Eurasia, where the observed departures reached 4-5°C across central Asia and Siberia. The spring (Mar-May) was exceptionally warm across the contiguous U.S., the northern parts of Europe (Scandinavia and the U.K.), Iceland and western Alaska, with 3-5°C anomalies in these regions. The observed anomalies in summer (Jun-Aug) were mixed, with continued above normal temperatures across Europe and the northwestern parts of North America (Alaska and the Yukon Territory of Canada) and cold anomalies 3-4 °C below normal across the central U.S., including the upper Midwest and plains states (see U.S. section below).

The observed seasonal precipitation patterns over land surfaces in 2004 are shown in Figure 3. During winter 2004 (DJF), significant dry anomalies were present across the Indian subcontinent, the Iberian Peninsula, South Africa, most of western Alaska, and the Patagonia region of Argentina, while significant large-scale wet anomalies were present over northeast Brazil, western Africa and most of western Europe and

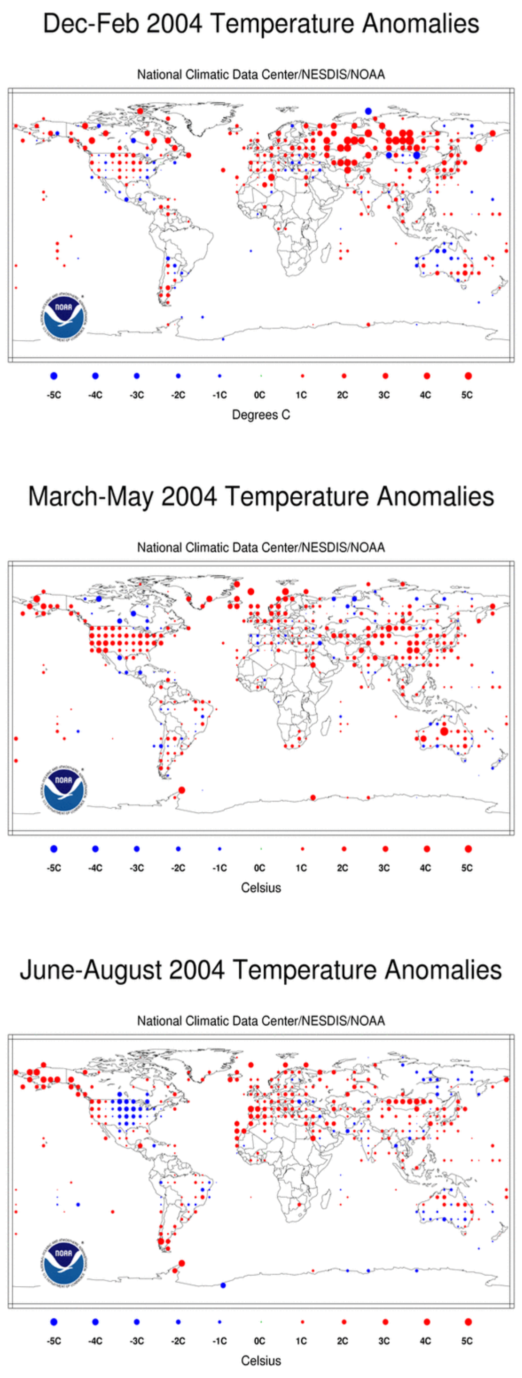


Figure 2. Seasonal global land surface mean temperature anomalies (in °C) for 2004: (Top) winter, (middle) spring, and (bottom) summer. Anomalies were determined relative to the 1961-1990 base period normals.

Scandinavia. The spatial pattern of anomalies was different during the spring (MAM) in the Northern Hemisphere, with the largest wet anomalies observed

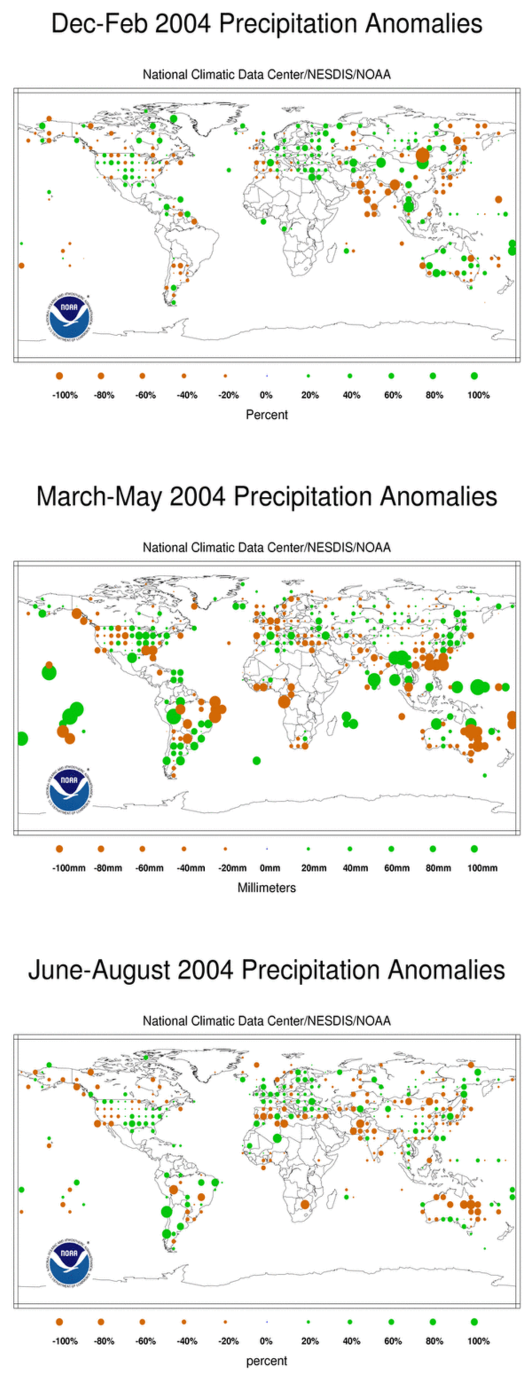


Figure 3. Seasonal global land surface precipitation anomalies (% of normal relative to the 1961-1990 base period) for 2004: (Top) winter, (middle) spring, and (bottom) summer.

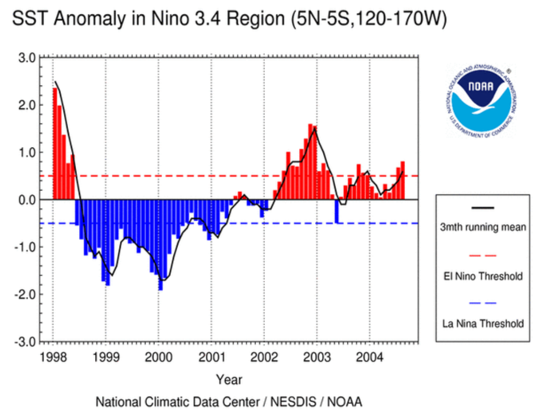
across western Alaska, southern India, and the northwest part of Asia, and abnormally dry conditions over most of Europe, the east coast of Australia, the southwestern U.S. and parts of southern Asia (Afganistan and Pakistan). The largest precipitation anomalies during the Northern Hemisphere summer (JJA) were the persistence of the anomalously dry conditions over the eastern coast and interior sections of Australia, southern Asia (Afganistan and Pakistan), the Iberian Peninsula, and the southwest U.S., with anomalously wet conditions over Chile and the southwest coast of South America, the U.K., Finland and the Baltic states, as well as Texas and areas along the Gulf of Mexico coastline.

3. ENSO AND THE TROPICAL PACIFIC

Atmospheric and oceanic conditions related to the El Niño/Southern Oscillation (ENSO) were neutral during most of 2004, with a sharp increase in sea surface temperatures (SSTs) in July. In general, SSTs have shown significant variability in 2004, especially in the central and eastern parts of the equatorial Pacific basin. In the western Pacific basin, SSTs have been consistently warmer than average since the middle of 2001, before the onset of the 2002-2003 El Niño warm event. In the Niño 4 region, a warming trend occurred in 2004 during the Northern Hemisphere summer months. SST anomalies have also increased relative to the long-term mean in the central and eastern equatorial Pacific, with a rapid warming trend observed in the Niño 3.4 region in July and August.

Figure 4 shows the monthly averaged SST anomalies in the Niño 3.4 and Niño 4 regions in the central and western Pacific, respectively. The observed warming of SSTs across the equatorial Pacific was due to the passage of an oceanic Kelvin wave, which was generated by anomalous westerly winds and convection over the western Pacific in late June and early July. As with many past events, the effect of this Kelvin wave was to suppress the depth of the thermocline and decrease equatorial upwelling in the oceanic mixed-layer, which resulted in an increase in the observed SSTs in all of the Niño regions during July and August, 2004. At the end of September 2004, conditions showed signs of a transition to a weak or moderate El Niño event as above average SST anomalies spread eastward into the central and eastern equatorial Pacific basin.

Both the Southern Oscillation Index (SOI) and the Outgoing Long-wave Radiation (OLR) Index had no persistent positive or negative trend during the first half of 2004, reflecting the near-neutral conditions associated with ENSO during this time. The OLR Index switched signs from positive to negative almost every month, while the monthly averaged SOI also switched sign several times. This situation appears to have changed during the Northern Hemisphere summer (JJA), with negative index values of the SOI for all three months in the equatorial Pacific (negative values of both indices are related to El Niño conditions). Therefore, despite the warming conditions in the oceanic mixed-layer and a transition toward El Niño conditions in the oceanic indices during the Boreal summer, the atmospheric signal has been mixed. As of the end of September, deep tropical convection had not formed in association with the SST anomalies along the equator in the western and central Pacific, but the sea-level pressure pattern had begun to show signs of shifting toward an El Niño as the SOI remained negative during the June-September 2004 period.



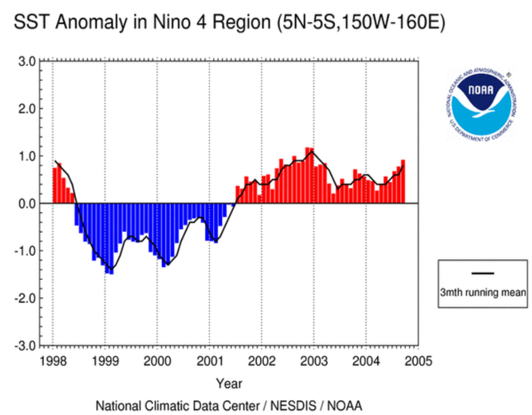


Figure 4. The monthly averaged sea surface temperature (SST) anomaly (red/blue bars in °C), and the three-month running mean SST anomaly (black line in °C), in the Niño 3.4 (top) and Niño 4 (bottom) regions during the period January 1998 to August 2004.

4. U.S. CLIMATE AND WESTERN DROUGHT

Temperatures across the U.S. have been consistently above average for most of 2004, with several notable exceptions. During winter 2004 (DJF), temperatures were anomalously warm across the contiguous U.S., with above average temperatures in the western and Midwest states, and below average temperatures in the northeast and southeast states. Anomalous warmth developed during the spring (MAM), as the U.S. as a whole was above or much above normal (see top map in Figure 5). Generally zonal flow at 500 hPa (not shown) was present during the spring, generating subsidence and above normal temperatures for the season.

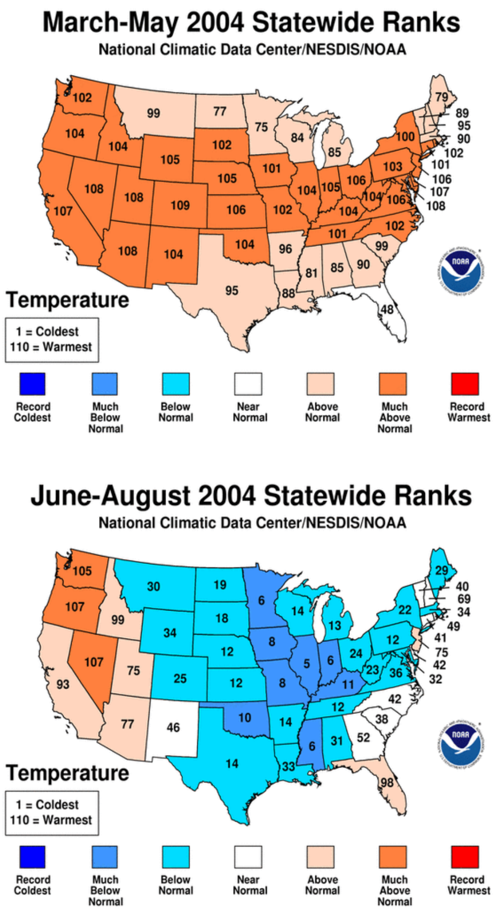


Figure 5. (Top) Statewide temperature ranks for the contigous U.S. during the spring (MAM), and (bottom) statewide temperature ranks for the summer 2004 (JJA).

In contrast to the spring, a major shift in the upper-tropospheric flow occurred in summer 2004. The mean 500 hPa geopotential heights were anomalously amplified during the summer months, as a strong ridge of high pressure developed over Alaska and an associated trough of low pressure developed downstream and persisted over the central U.S. (Figure 6), which brought unseasonably cold air southward into the upper Midwest and Great Plains states. Record and near-record cold temperatures were observed over most of this region, with significant cold anomalies across many states in the Midwest and Great Lakes, with states as far south as the Gulf of Mexico coast experiencing much below normal temperatures for the season. Of particular note was the coldest August on record in Minnesota.

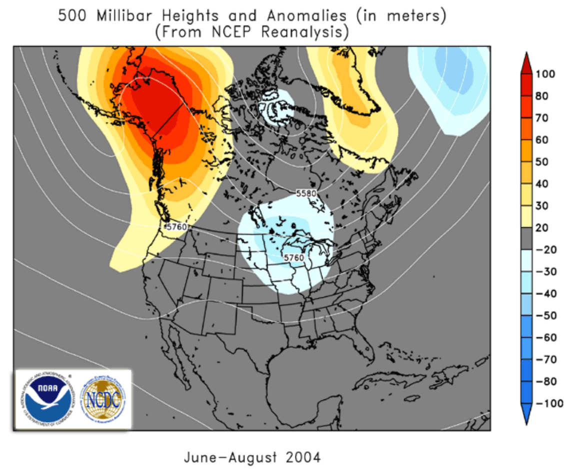


Figure 6. Summer 2004 (JJA) mean 500 hPA geopotential heights (isopleths) and height anomalies (shaded contours in meters) analyzed from NCEP Reanalysis data.

As mentioned, the amplified ridge of high pressure persisted over Alaska for most of the summer, which generated anomalously warm conditions across the state. The exceptional warmth can be seen in Figure 7, which shows the statewide temperatures averaged across Alaska for the summer. The observed temperature anomaly for the three month period in summer 2004 was 2.6°C (4.6°F) above the 1971-2000 mean, while the monthly anomaly reached 2.97°C (5.34°F) for August (not shown).

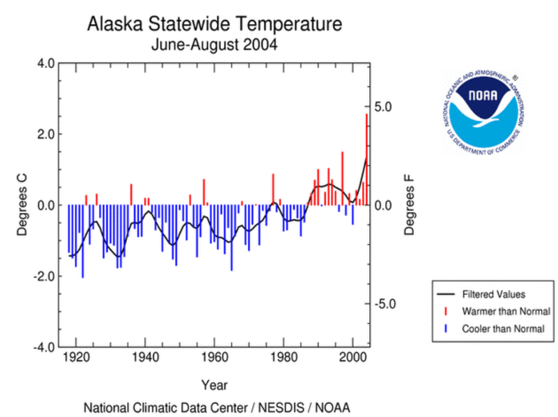


Figure 7. Summer 2004 (JJA) mean statewide temperatures across Alaska relative to the 1971-2000 base period. Alaskan data are from the Global Historical Climatological Network (GHCN).

The record warm conditions across Alaska, combined with long-term dry conditions and anomalous precipitation deficits during the spring and summer months, generated the worst fire season in the state's history. As of the end of September, over 6.3 million acres had burned across Alaska in 2004. The extent and severity of the fires across the state, and the adjacent Yukon Territory in Canada, generated a persistent smoke pall across the region. Limited mixing due to a stagnant airmass trapped smoke within the boundary layer causing hazardous air quality conditions over a large area of Alaska and Canadian arctic. In addition, long-range transport brought smoke as far south as the Gulf of Mexico and as far east as the Canadian Maritimes and the Atlantic coast of Newfoundland during late June and early July.

Long-term precipitation deficits have generated extensive drought conditions in the western U.S., which have persisted for five to six years across a large area along and west of the Rocky Mountains. In 2004, the severity and extent of the U.S. drought peaked in July in the western U.S. The primary indicator used for analyzing drought severity is the Palmer Drought Index (PDI), which is really a suite of three indices that depict the impacts of drought on a variety of temporal scales (Palmer 1965; see Heim 2002 for an overview of drought indices). The Palmer Hydrological Drought Index (PHDI), the primary indicator of long-term drought conditions, is shown in Figure 8 for July 2004. Long-term drought conditions remained severe to extreme across a large portion of the West, with indices below -4.0 (i.e. severe drought) across most of Montana and Wyoming, and parts of Nevada, Utah and California.

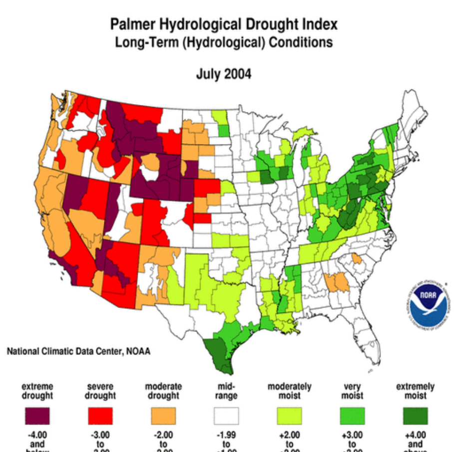


Figure 8. The Palmer Hydrological Drought Index (PHDI) analyzed for all U.S. climate divisions in July 2004.

The percent area of the western U.S. in moderate to extreme drought, which includes all areas with Palmer Drought Index (PDI) values below -2, is shown in Figure 9. The magnitude of the current drought in the West rivals the worst droughts of the 20th century, including the Dust Bowl years of the 1930's. However, the current drought is still less in percent area compared with the maximum extent of the 1930's drought, although it's clear that the current drought conditions are some of the worst of the past 100 years.

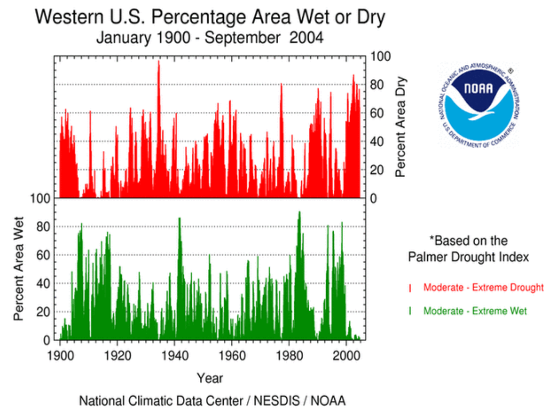


Figure 9. The percent area of the western U.S. (Rocky Mountains and westward) that had moderate to severe Palmer Drought Index (PDI) values: (top) moderate to extreme drought (PDI < -2.0), and (bottom) moderate to extreme wet (PDI > 2.0) for the period January 1900 to September 2004.

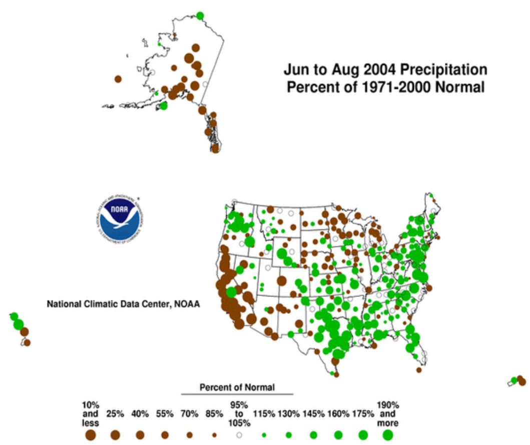


Figure 10. The percent of normal precipitation for the U.S., including Alaska and Hawaii, using data from the Automated Surface Observing System (ASOS) stations (anomalies were determined from the 1971-2000 base period).

One characteristic of the current drought is the persistence and duration of the large area of the western U.S. in moderate to extreme drought. What is also noticeable with the current drought is the lack of any areas in the moderate-extremely wet category of PDI (values greater than 2.0). This indicates that the entire western U.S. has experienced long-term precipitation deficits during a majority of the current drought that began in 1999. The precipitation deficits continued across much of the southwest and Great

Basin regions during the summer of 2004, as shown in Figure 10. The precipitation deficits in Alaska during the summer contributed to the severity of the fire season across the state.

The long-term drought conditions that are currently affecting the western U.S. can be put into a longer historical context using paleoclimate reconstructions. Figure 11 shows the Palmer Drought Severity Index (PDSI) since 1234 using a tree-ring reconstruction of wet and dry conditions in southwestern Montana, which is at the center of the severest drought conditions in the West. The current dry spell is severe, it is clear from the paleo data that extensive dry periods are common in this region, and the length of the current drought is still much shorter that many similar periods during the past 770 years of this reconstructed record.

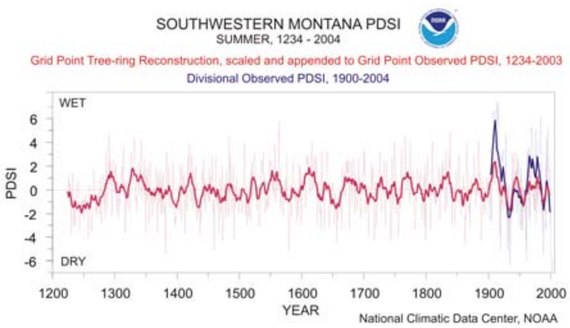


Figure 11. Tree-ring reconstruction of the Palmer Drought Severity Index (PDSI) over the period 1234-2003 compared with the PDSI for the climate division in southwestern Montana (courtesy of Connie Woodhouse, NOAA-NCDC).

5. NORTH ATLANTIC TROPICAL CYCLONES

The hurricane season was above normal in the Atlantic Basin in 2004, with 14 named storms and 6 major hurricanes as of mid-October (see Table 1). Of particular note is the severity of the season in 2004, which will be remembered for the number of tropical cyclones that made landfall or generated significant impacts in the Caribbean Islands and along the eastern coast of the U.S. during August, September and early October.

The season began later than normal with no named storms in June or July (June 1 is the “official” start date of the Atlantic Hurricane season). The season finally started with the development of tropical storm Alex off the coast of the Carolinas on the first day of August. Alex rapidly intensified into a hurricane on August 3, and into a major hurricane on August 5. The NOAA National Hurricane Center’s 1944-1996 climatology has July 11 as the average development date for the first named storm of the season, although the average date of formation of the first hurricane is August 14 and the average date of formation for the first major hurricane is September 4. Therefore, despite the late date of the first named storm, the 2004 season was actually earlier than normal with respect to intensity, as measured by the early development of Alex as both the first hurricane and major hurricane of the season.

Figure 12 shows the annual number of named storms and major hurricanes observed in the North Atlantic Basin from 1944-2004. The annual number for 2004 is preliminary, and includes all named storms as of mid-October (Alex through Nicole). Despite the preliminary numbers, 2004 ranks as one of the most active years in modern times, and is a continuation of the above average activity in the North Atlantic that began in 1995. In addition, the six major hurricanes (Category 3-5 on the Saffir-Simpson scale) so far in 2004 has been the second most annual total on record, tied with 1996 and 1961, and second only to 1950 which had seven major hurricanes.

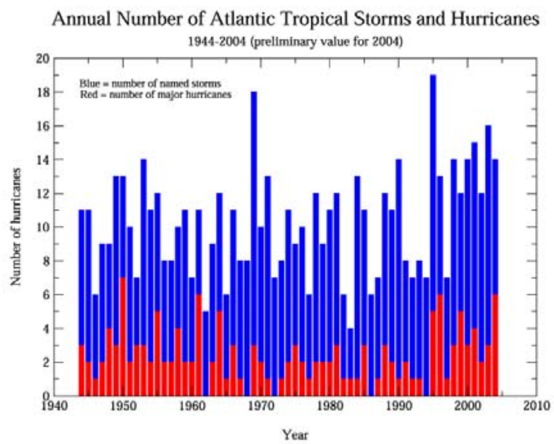


Figure 12. The annual number of tropical storms and hurricanes in the Atlantic Basin from 1944-2004 (data from 2004 are preliminary through mid-October). The blue bars indicate all named storms, while the red bars indicate only major hurricanes (i.e. Category 3-5 on the Saffir-Simpson scale).

Significant impacts were felt in the Caribbean Islands and the east coast of the U.S. in 2004 due to the above average number of land-falling tropical storms and hurricanes. In fact, of the 14 named storms so far in 2004, nine of these either made landfall or had significant impacts on the U.S. mainland, with four of these affecting Florida: Alex impacted the Outer Banks of North Carolina as a Category 2 hurricane; Tropical Storm Bonnie came ashore along the Florida panhandle; Hurricane Charley made landfall along the west coast of Florida as a Category 2 system; Hurricane Frances made landfall on the east coast of Florida also as a Category 2 storm; Tropical Storm Gaston moved onshore along the coast of South Carolina; Tropical Storm Hermine came ashore along the coast of Massachusetts; Hurricane Ivan made landfall along the coast of Alabama as a Category 3 system; Hurricane Jeanne was also a Category 3 storm when it made landfall on the east coast of Florida; and Tropical Storm Matthew made landfall along the Louisiana coast in October.

6. SUMMARY

This paper summarized the global and U.S. climate conditions in 2004, focusing on year-to-date and seasonal values of temperature and precipitation. It should be noted that this work is a prelude to the much larger effort of preparing the State of the Climate section that appears in the *Bulletin of the American Meteorological Society* each June. Therefore, a number of important climate parameters and related issues were not included, but will be addressed in the State of the Climate in 2004 article.

On a global scale, anomalously warm global temperatures continued in 2004, with many regions experiencing record or near-record high seasonal and year-to-date values. Over the January-September period, surface temperatures in 2004 remained well-above the 1961-1990 average, with the January-September globally averaged temperature ranking fourth warmest on record. The ocean temperatures were also fourth warmest so far in 2004, while land areas were fifth warmest. In addition, the Northern Hemisphere continued to be well above normal, ranking third warmest for the January-September period, while the Southern Hemisphere was sixth warmest over the first nine months of 2004.

The oceanic and atmospheric conditions in the tropical Pacific Ocean related to the El Niño/Southern Oscillation (ENSO) were neutral during most of 2004, with a sharp increase in sea surface temperatures (SSTs) during July-September. The running three-month mean anomaly of SSTs in the Niño 3.4 region were above 0.5°C at the end of August, while the September monthly SST anomaly for the Niño 3.4 region reached 0.84°C. By the end of September the monthly averaged values for the Southern Oscillation index (SOI) were negative for the fourth consecutive month (negative SOI values are indicative of El Niño warm event conditions). However, large-scale impacts typically related to past El Niños, such as changes in precipitation patterns that are due to shifts in the Walker circulation, had not yet developed across the Pacific Basin as of mid-October 2004.

The climate of the U.S. in 2004 has been extremely variable, with exceptionally warm temperatures across the contiguous U.S. during spring and below normal temperatures across the middle of the country during summer. Widespread drought conditions continued to plague a large portion of the western U.S. in 2004. Precipitation deficits reached record levels in many areas of the West, with the observed deficits in 2004 contributing to 5-6 years of below normal precipitation in the Great Basin and parts of the Northern Rockies. In addition, anomalous warmth coupled with below normal precipitation during the Boreal summer generated the worst fire season in terms of acreage burned in Alaska.

The Atlantic Basin hurricane season was above average in 2004, with 14 named storms and 6 major hurricanes as of mid-October. Nine of the 14 named storms impacted the U.S. mainland, and four of these made landfall in Florida. Significant damage and flooding occurred from these land-falling tropical systems due to the extreme precipitation and high winds observed across the southeast and mid-Atlantic states in August and September.

7. REFERENCES

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Tropical Cyclone	Cyclogenesis Date	Cyclolysis Date	Saffir-Simpson Category	Maximum 6-hr Sustained Wind (kt)	Maximum 6-hr Wind Gust (kt)	Accumulated Cyclone Energy (ACE) Index (kt^2)
Alex	7/31/04	8/5/04	Category 3	105	130	11.17×10^4
Bonnie	8/9/04	8/12/04	Tropical Storm	55	65	2.5×10^4
Charley	8/9/04	8/15/04	Category 4	125	150	10.44×10^4
Danielle	8/13/04	8/21/04	Category 2	90	110	11.95×10^4
Earl	8/13/04	8/16/04	Tropical Storm	40	50	1.05×10^4
Frances	8/25/04	9/7/04	Category 4	125	155	46.80×10^4
Gaston	8/27/04	9/1/04	Tropical Storm	60	75	2.18×10^4
Hermine	8/28/04	8/31/04	Tropical Storm	45	55	1.01×10^4
Ivan	9/3/04 9/22/04	9/17/04 9/24/04	Category 5	145	175	69.86×10^4
Jeanne	9/14/04	9/27/04	Category 3	100	120	24.80×10^4
Karl	9/17/04	9/24/04	Category 4	120	145	27.99×10^4
Lisa	9/20/04	10/3/04	Category 1	65	80	9.27×10^4
Matthew	10/8/04	10/10/04	Tropical Storm	40	50	0.77×10^4
Nicole	10/10/04	10/11/04	Sub-tropical Storm	45	55	1.16×10^4

Table 1. All named tropical cyclones in 2004 in the Atlantic basin as of mid-October, with their dates of formation and dissipation, Saffir-Simpson category, maximum sustained wind and wind gusts, and the Accumulated Cyclone Energy (ACE) Index (Bell et al. 2000) for each tropical cyclone.