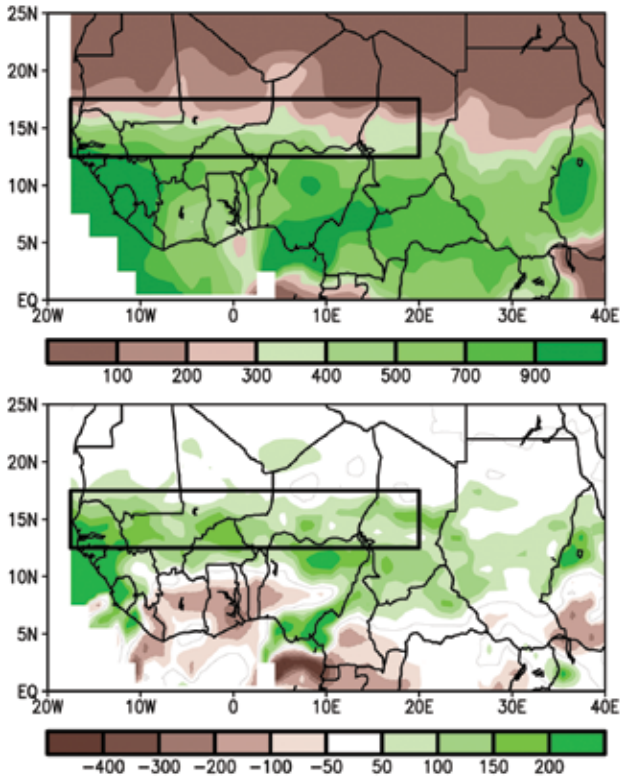

Fig. 6.8. June–September 2006 (a) total rainfall and (b) anomalies (mm; 1971–2000 base) for western Africa. The boxed region denotes the approximate boundaries of the Sahel.

mulative rainfall totals were near or above average across many areas in the Sahel. In the west, the formation of tropical depressions (some of them later developed into Atlantic tropical storms and hurricanes) along the coastlines of southern Senegal and Guinea, resulted in strong rainfall anomalies exceeding 200 mm. In contrast, seasonal rainfall totals across most of the Gulf of Guinea region were below normal. Rainfall deficits ranged between 100 and 300 mm across the central and southern areas of Benin, Togo, Ghana, most of the Cote d'Ivoire, and the eastern half of Guinea. The exceptions were the northern and southeastern areas of Nigeria, Liberia, and Sierra Leone, where rainfall totals exceeded 900 mm.

(ii) Atmospheric circulation

The above-average 2006 rainy season resulted from an enhanced West African monsoon in the latter part of the season. In August–September 2006, strong southwesterly winds at 925 hPa averaging 3–6 m s^{-1} extended well northward into the Sahel region. This enhanced monsoonal inflow was also evident at 850 hPa with Atlantic westerly wind anomalies exceeding 3 m s^{-1}, contributing to a deep penetration of moist, unstable air well into the Sahel region. The enhanced monsoon was also associated with an anomalous low-level cyclonic circulation across the northern and central Sahel, characterized by enhanced cyclonic shear along the equatorward flank of the AEJ. The mean position of the AEJ across the western Sahel was at about 15°N.

c. North America

1) Canada—R. Whitewood and D. Phillips

The climate of Canada in 2006 was characterized by near-record temperatures (Fig. 6.9) and near-normal precipitation relative to the 1951–80 base period (Fig. 6.10). Extreme weather took a toll this year with several deaths and millions of dollars in property damage. British Columbia suffered the most in 2006, starting the year with a near-record number of days with precipitation, experiencing drought-like conditions through the summer, and concluding with some of the most powerful storms ever to hit the province.

(i) Temperature

Canada, as a whole, experienced its second warmest year—2.4°C above normal (Fig. 6.11), with 1998 remaining the warmest at 2.5°C above normal—since reliable nationwide records started in 1948. Most of Canada had temperatures at least 2°C above normal, with the northern territories experiencing the greatest anomaly of about 4°C. Only an area in northern British Columbia had near-normal temperatures. This marks the 10th straight year of above-normal temperatures, with 6 of the warmest 10 years occurring in the last 10 years. Over the period of record (1948–2006) the national trend is +1.3°C.

Nine of the eleven Canadian climate regions had temperatures that ranked among the 10 warmest, with three climate regions having their warmest year: two covering Nunavut (+3.4° and +2.3°C), and one covering northern Ontario and Quebec (+2.3°C). Three other regions experienced their second warmest year: the region covering much of the Northwest Territories (+3.2°C), Atlantic Canada (+1.8°C), and southern Ontario and Quebec (+1.8°C). Over the 59 years of record, all the climate regions show a positive trend, with the region covering much of the Northwest Territories showing the largest trend of +2.2°C, and the Atlantic Canada region the smallest trend of +0.3°C.

(ii) Precipitation

Nationally, 2006 was unremarkable with regard to precipitation totals, ranking 21st wettest, out of

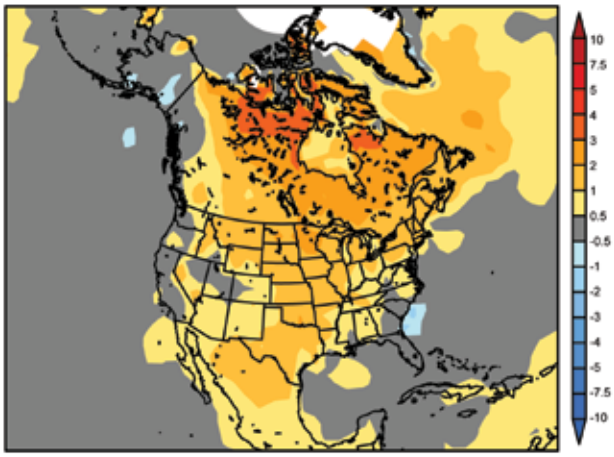

Fig. 6.9. North American 2006 annual temperature anomalies (°C, 1971–2000 base) from CAMS-OPI.

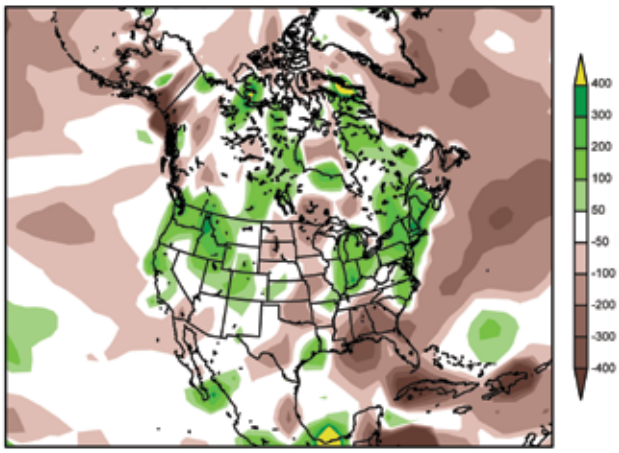

Fig. 6.10. North American 2006 annual precipitation anomalies (mm, 1979–2000 base) from CAMS-OPI.

59 years of nationwide records, 2.2% above the 1951–80 normal. This is in sharp contrast to 2005, which was the wettest on record, 13.4% above normal. Wetter areas of the country, those with more than 20% above normal, include the Arctic Islands, southwest British Columbia, central Saskatchewan, northern Manitoba and Quebec, and southern Ontario. Drier areas, those more than 20% below normal, include the western edge of the Northwest Territories, northern British Columbia, a few areas throughout Alberta, southern Manitoba, and northwest Ontario. One climate region, southern Ontario and Quebec, experienced its second wettest year (17.6% above normal); no climate region ranked among its 10 driest years. The southern prairies provinces experienced the driest value, –5.8% (22d driest).

(iii) Notable events

Vancouver, British Columbia, set a couple of records in January: the most rainfall for the month (283.6 mm, the normal is 154 mm) and the most number of days with rain (29). The warm season had the opposite effect, with a dearth of rain across much of Vancouver Island. The resort town of Tofino, on the west coast of the island and normally one of the wettest spots in Canada, received no significant rain between 14 July and 16 September. Consequently, the town's reservoir fell to record-low levels. November brought three notable storms to British Columbia's coast. The first, on 5 and 6 November, brought intense rains, at times 10–15 mm of rain an hour for 15 hours. A storm on the 15 November brought heavy rains to the Vancouver area, causing so much turbidity in the drinking water that an estimated two million people were advised to boil their tapwater before drinking. Then, on 25 November, a storm brought 40 cm of snow to Vancouver and Victoria, the amount they normally receive in a year. Three wind storms (greater than 100 km h^{-1}), all aimed at Vancouver Island and the lower mainland, were the hallmark of December.

Several tornadoes were reported across central Canada, resulting in one death and costing thousands in property damage. The death was the result of a tornado that hit Gull Lake, Manitoba, on a stormy day on 5 August. One storm system on 17 July generated a series of tornadoes and microbursts that affected areas from Lake Huron through Quebec, one of the longest storm tracks in Ontario's history. Another storm system hit Ontario in early August affecting cottage country, north of Toronto. Remarkably, nobody was killed in the 14 tornadoes that were

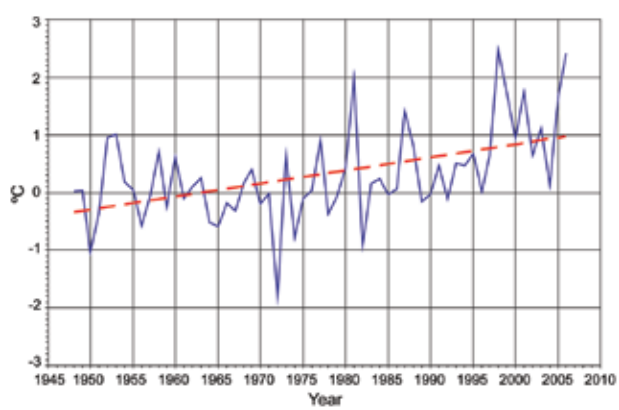

Fig. 6.11. Annual average air temperature anomalies (°C; blue; 1951–80 base) and the 1948–2006 linear trend showing a +1.3°C increase (red). [Source: Environment Canada.]

generated, two of which had winds speeds greater than 180 km h^{-1}. The Canadian Interagency Forest Fire Centre reported an active wildfire season. At the end of the fire season, 1 October, the center reported a total of 9,482 fires (27% more than normal), covering an area of 2,031,705 ha (4% more than normal) for all of Canada.

2) United States—R. R. Heim Jr., D. H. Levinson, N. B. Guttman, and A. M. Sanchez-Lugo

(i) Overview

Reliable monthly, seasonal, and annual weather records for the United States exist since 1895, enabling the climate of 2006 to be placed in a 112-year context. The nationally averaged temperature for 2006 was 12.72°C, ranking this year as the second warmest on record. The 2006 annual average temperature was only 0.04°C cooler than the record that occurred in 1998, and ~0.01°C warmer than 1934, making these three years nearly identical in rank (Fig. 6.12). These rankings are based on version 2 of the U.S. Historical Climatology Network. Note that ties are not indicated in figures; ties are labeled as duplicates of the more extreme ranking (e.g., a tie for ranking two and three is listed as two for both).

Nationally, annual precipitation was near the long-term mean, giving 2006 a rank of 55th driest year in the 112-year record. Considerable variability in precipitation occurred across the country and throughout the year. Florida had the driest March–December season on record in 2006, while Indiana ranked as the wettest on record for the same season. Significant drought expanded during the first half of the year, affecting ~52% of the country at its peak in July. The dry conditions were accompanied by a record wildfire season, with almost 10 million acres (~4 million ha) burned during 2006.

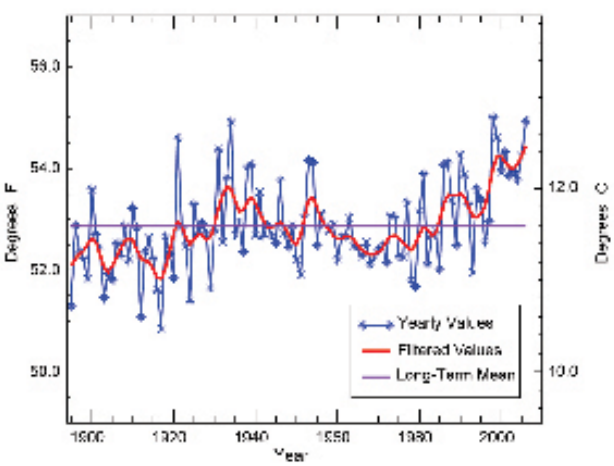

Fig. 6.12. Annual temperature (°F and °C) averaged across the contiguous United States from 1895 to 2006.

(ii) Temperature

For the contiguous United States, 2006 marked the ninth consecutive year with temperatures much warmer than the long-term average (Fig. 6.12). The past nine years have all been among the 25th warmest years on record, a streak that is unprecedented in the historical record. The long-term warming trend for annual temperatures is approximately 0.56°C (1.0°F) warmer than at the start of the twentieth century. National temperatures persisted at warm or record warm levels throughout 2006 with only two months (September and October) that were cool exceptions.

The 2005/06 winter season (December–February) temperatures were above average across most of the nation with near-average temperatures limited to parts of the Northwest and Southeast and no state ranking below average. The warmer-than-average winter season was due in part to record-warm temperatures that affected the nation in January. The nationally averaged temperature for January 2006 was 3.9°C, which is 1°C warmer than the previous January record set in 1953. All states within the contiguous United States were warmer than average during January, with 13 states, mostly located in the central and northern plains and Great Lakes, ranking as their record warmest.

Cold-air outbreaks affected the western states during March and the Southeast during May, but warm temperatures dominated the nation during the 2006 spring season (March–May). Much warmer-than-average temperatures affected most of the central states, with Texas and Oklahoma having the warmest spring on record. April ranked second warmest in the 1895–present record for the nation, with an average temperature of 13.4°C.

The summer (June–August) months were characterized by an intense and long-lasting heat wave that began in mid-July in the northern plains and upper Midwest, breaking records that stood since the Dust Bowl years in some locations. The heat spread across the plains and moved into the West before returning to the northern plains by late July, then spreading to the East Coast by the first week of August. More than 2,300 daily temperature records were broken in the United States during the last two weeks of July and several more during the first half of August; more than 50 records for the highest temperatures in any July were established. Many locations from the West

Coast to the central plains broke records for the most days above 32.2° (90°F) and 37.8°C (100°F). The month of July 2006 ranked as the second hottest month ever in the 112-year record, with a nationally averaged temperature of 25.1°C, only 0.24°C cooler than the record-hottest month—July 1936. Nationally averaged temperatures gave summer 2006 a rank of second warmest on record just behind 1934 (second warmest) and 1936 (warmest).

The persistent widespread warmth for much of the year resulted in the warmest January–August period on record. Colder weather during September and October brought a brief respite before unusual warmth returned to much of the country during November and December. December 2006 ranked fourth warmest on record.

For the year as a whole, New Jersey, Vermont, Oklahoma, and Texas were second warmest on record (Fig. 6.13a). Another 13 states had one of their top-five warmest years. All of the 48 contiguous states were either record warmest, warmer, or much warmer than average. No state ranked near or below average during 2006. This contrasts with the spatial pattern during the warmest and third warmest years, 1998 and 1934, when at least one state ranked colder than average for the year (Figs. 6.13b,c). The 2006 annual temperature for Alaska ranked near the 1918–2006 average, breaking a string of persistently warm years dating back to 2000. Winter temperatures in 2006 were above average for the seventh consecutive year. Both spring and summer were slightly cooler than average and fall was slightly warmer.

(iii) Precipitation and drought

Precipitation in the contiguous United States during 2006 was variable throughout much of the country, with periods of excessive rainfall, especially across the Northwest, Great Lakes, and Northeast, and persistent and developing drought in other areas. Winter storms in the Northwest contributed to the ranking of 10th wettest winter for the region. The Southwest had its second driest winter, with Arizona and New Mexico having their driest winters on record. Precipitation averaged across the nation was below average during spring. Regionally, the Southeast had the third driest spring, whereas the West ranked as the sixth wettest. The Northeast had its wettest summer, exceeding the previous record by more than 25.4 mm (1 in.), while the region consisting of the Northern Great Plains and northern Rockies states had its ninth driest summer. Three states (New Hampshire, New York, and Rhode Island) had the wettest summer on record. Fall was generally wet across the contiguous United States, resulting in a rank of 15th wettest for the nation. Regionally, the Northwest and Northeast ranked as having the 10th and 4th wettest autumn periods, respectively.

Five of the first seven months of the year were drier than average for the contiguous United States as a whole. Combined with unusually warm temperatures, this exacerbated drought across much of the country. By late July, half of the contiguous

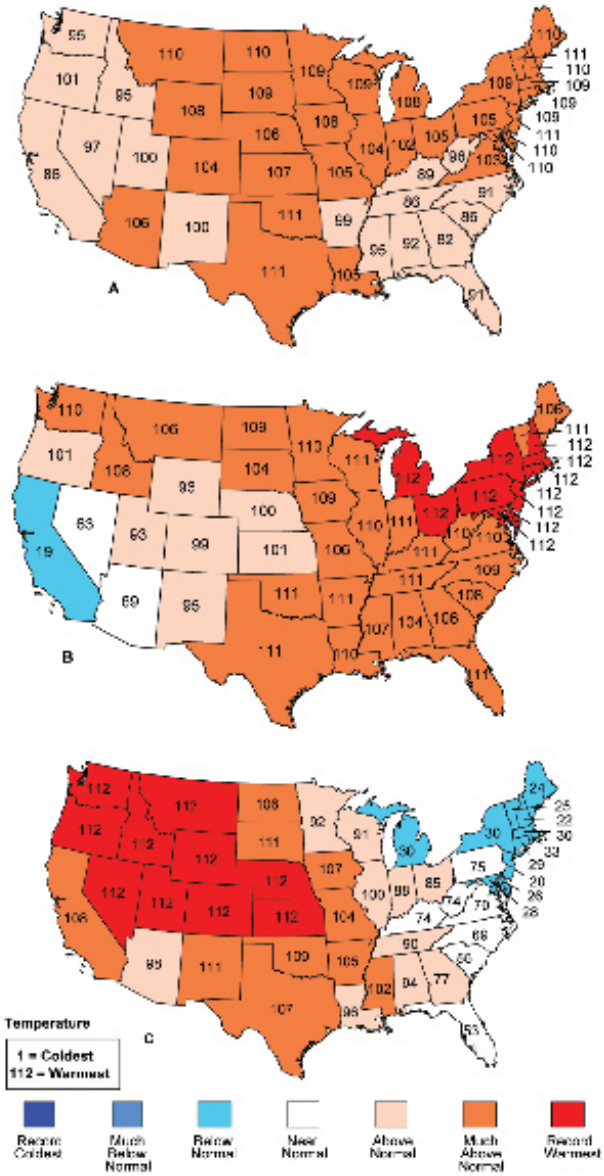

Fig. 6.13. Statewide rankings (as of 2006) of annual temperature as measured across the contiguous United States for (a) 2006, (b) 1998, and (c) 1934. A rank of 112 (1) in the record represents the warmest (coldest) year in the 1895–2006 period. Ties are included as duplicates of the more extreme ranking. [Source: NOAA/NCDC.]

United States was in moderate to exceptional drought. Annual precipitation ranks ranged from third driest in Florida and fifth driest in Wyoming and Georgia, to second wettest in New Hampshire and third wettest in Indiana. The Northeast had another wet year, ranking sixth wettest in 2006 and marking the fifth consecutive year with above-average precipitation. In fact, the top two wettest annual periods in New Hampshire occurred during the past two years. Nationally, annual precipitation was near the long-term mean, ranking as the 55th driest year on record.

The year began drier than average across a broad swath of the country from the Southwest to the Great Plains, across much of the Gulf Coast, and into the coastal Southeast. Above-average precipitation continued to erode the drought areas in the Pacific Northwest. This pattern continued throughout the spring and into the summer (Fig. 6.14). By fall, drought was concentrated in the plains, especially in Texas and Oklahoma. By the end of the year, drought subsided in much of the Southeast, but was prominent across parts of the plains.

Several short-lived dry episodes occurred in other regions throughout the year, notably in the mid-Atlantic in February and March, the Northeast coast in March, the Pacific Northwest in July and August, and Florida for much of the year. The percent area of the contiguous United States experiencing moderate to extreme drought (as defined by the Palmer Drought Index) grew steadily from 20% in January, to a peak of about 52% by July, and then declined during the second half of the year. Impacts from the 2006 droughts were felt especially hard by the agricultural and hydrological communities. The South Platte River was nearly dry during the summer, low water levels in the Mississippi and Missouri Rivers forced an early end to barge transportation, several municipalities imposed water use restrictions, livestock was prematurely sold, and crops died before harvest. In some areas, such as in South Dakota and Nebraska, recovery of grazing lands from drought is not expected for at least two years.

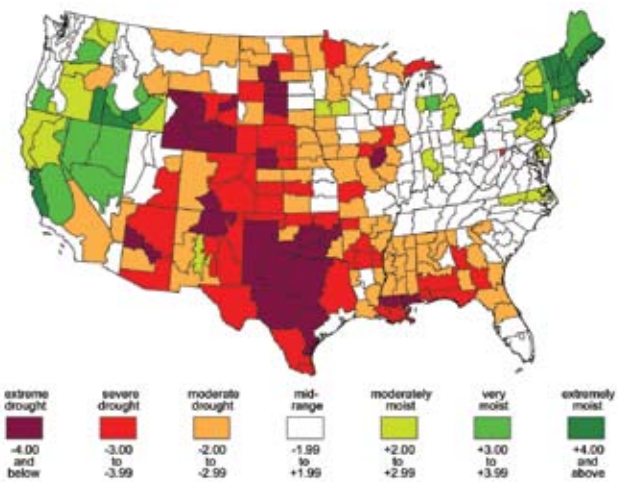

Fig. 6.14. Palmer Hydrological Drought Index showing the spatial pattern of drought across the contiguous United States during July 2006. [Source: NOAA/NCDC.]

(iv) Snowpack

The 2005/06 snow season was generally above average across parts of the Northwest and below average across the Southwest. The snow cover extent was below average for the North American continent as a whole during the winter season, in which January 2006 had the second lowest snow cover extent behind 1981, as well as during the spring season. This is consistent with a trend toward reduced spring snow cover for North America since 1986. By the end of the spring season, snowpack was above average across the western mountains from the Sierra Nevada in California to the Washington Cascades, and into the interior Northwest.

Notable snow storms in 2006 include a blizzard during the month of February that affected areas of the Mid-Atlantic and the Northeast on 11–12 February. This storm produced 68.3 cm (26.9 in.) of snow in New York City's Central Park. This amount broke the all-time storm total record of 67.1 cm (26.4 in.) set during the 26–27 December 1947 storm. The NESIS classified the February blizzard as a category 3 (major) storm and ranked it as the 20th most intense on record for the Northeast. In Hartford, Connecticut, a snowfall total of 55.6 cm (21.9 in.) broke the old storm total record of 53.3 cm (21 in.), set in 1983. Many locations in the region reported 25–51 cm (10–20 in.) during this event.

An active Pacific storm track during the winter and spring brought a steady supply of snow to the West, Northwest, and Intermountain West. On the other hand, snowfall across Arizona and New Mexico was exceptionally low throughout the season, with most basins reporting less than 40% of normal snowpack at the end of spring.

The 2006/07 snow season started with above-average snowfall across parts of the West. Snowfall accumulations of up to 60 cm (2 ft) fell across the Cascades in late November. During December 2006, two major winter snow storms impacted Colorado and parts of the High Plains. Denver, Colorado, had its third snowiest December on record and endured a major blizzard, which brought the city to a standstill

during the holiday travel season. Snowfall in excess of 90 cm (3 ft) fell across portions of the Colorado Front Range and western High Plains during these two events.

(v) Wildfires

Continuing a pattern of increased large fire activity that extends back to the early 1990s, wildland fires reached record levels in 2006. According to the NIFC, preliminary estimates of the area burned exceeded 9.8 million acres (~4 million ha) across the United States this past year. In contrast to the total acreage burned, the annual number of wildfires has decreased steadily since the 1980s; over 96,000 fires were reported in 2006, which was the sixth consecutive year that the annual number of fires for the entire United States has been below 100,000. As discussed by Westerling et al. (2006), there has been an increasing trend of larger wildfires across the West, where the inverse relationship between increasing area burned and decreasing number of fires has been the most pronounced.

There were several notable aspects to the record fire season in 2006, in terms of its timing and severity. Wildfires that initially began across the southern plains in December 2005 persisted into early 2006. Below-normal precipitation and extreme drought conditions aided in the development of numerous wildfires across Oklahoma, Texas, and Arkansas, with over 1.5 million acres (~600,000 ha) burned over the first three months of the year in the southern area (which encompasses 13 states, Puerto Rico, the Virgin Islands, and the District of Columbia). During the spring, fire activity spread to the Southwest, with the most severe activity concentrated in New Mexico and southern California. By summer, wildfires had spread into the Great Basin and Pacific Northwest, with large fires affecting most of the West by the end of July. Large fire activity spread northward, because the Pacific Northwest was the focal area in August and early September, while during the fall, activity shifted again into southern California.

(vi) Severe extratropical storms

Several severe extratropical cyclones affected the United States in 2006. The first of these occurred early in the year on 18 January, when a powerful winter storm brought heavy rainfall, strong winds, and heavy snowfall to sections of the East Coast. During the spring peak in severe weather, several tornado outbreaks occurred in the southern plains, as well as the Tennessee and Ohio valleys, which produced over 500 tornadoes and nearly 50 fatalities during March and April combined. Northwestern Tennessee was the hardest hit region, with 23 fatalities attributed to the storms. According to preliminary statistics compiled by NOAA's Storm Prediction Center, there were 1333 tornadoes reported across the United States in 2006, with April having the most of any month (324). The most severe day of the year was 12 March when 142 tornadoes were reported.

Two large extratropical storms of note occurred toward the end of 2006. On 21–22 November, a strong extratropical cyclone developed off the southeastern coast of the United States, producing a variety of severe weather events in the Southeast and Mid-Atlantic. Heavy rainfall and strong winds were reported along the coastline from South Carolina northward through Virginia. Winds gusting over 115 km h^{-1} (70 mph) were reported along the coast of North Carolina. On 13–15 December, a powerful storm system came ashore along the Pacific Northwest coast and generated strong winds, heavy rainfall, and high-elevation snows. Wind gusts reaching hurricane force caused power outages across Washington and Oregon.

3) Mexico—V. Davydova Belitskaya and A. Douglas

Mexico was on average 5% wetter than normal in 2006, with much warmer than normal temperatures. Mexico's SMN reported a national precipitation average of 808 mm, compared with an historical average of 771 mm (1941–2000). The nationwide annual mean temperature was 21.9°C, which was a 1.2°C above the long-term climate average. However, it should be noted that most of the stations used to create the nationwide temperature values are in large urban centers. In light of inherent heat island biases in the underlying data, which are currently unaccounted for, care should be taken in interpreting the 1.2°C climate anomaly.

The rainfall distribution was not homogeneous throughout the year or across large sections of the country. The year started abnormally dry but it quickly recovered with a good rainy season from May to October (total rain or warm-season precipitation was 111% of normal according to the SMN; see Fig. 6.15). The summer of 2006 was typified by widespread and consistent monsoon rainfall through much of the country; this helped to raise reservoir levels throughout the western states following a long series of dry winters in that region.

Some states reported major rainfall deficits for the year. These include Baja California (46% below the long-term mean), San Luis Potosí (25% below), México and Yucatan (19% below), Oaxaca and Sonora (16% below), Hidalgo (15% below), Zacatecas

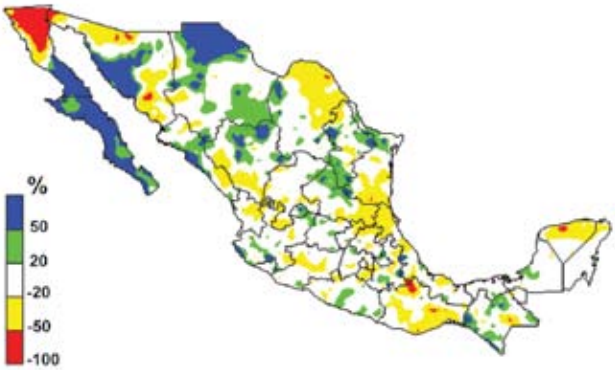

Fig. 6.15. Precipitation anomalies (%) during the May–October 2006 rainy season in Mexico.

and Tamaulipas (12% below), Quintana Roo (10% below), and Sinaloa (7% below). The deficits in the northwest were associated with a poor winter rainy season in early 2006 and again in late 2006. The development of El Niño conditions during the later half of the year was associated with four east Pacific tropical storms that recurved toward the west coast of Mexico: John, Lane, Norman, and Paul. In contrast, there were no landfalling tropical storms on the east coast of Mexico; this helped to contribute to the observed dryness in the Yucatan Peninsula and northeast Mexico.

Despite the very warm annual mean temperature; a notable cold outbreak occurred in northern Mexico on 17 January when Temosachic and La Rosilla recorded –15°C, Yecora recorded –10°C, Pabillon recorded –7°C, and Saltillo recorded –4.5°C. An exceptionally early winter cold outbreak occurred in the northwest on 1 December, with La Rosilla falling to –13.5°C and Temosachic to –12°C. One of the most significant and highly unusual meteorological events occurred during the last week of the year in the states of Chihuahua and Durango when very heavy snows covered the western section of the these two states, with mountainous areas exceeding well over 10 in. of snow.

d. Central America and the Caribbean—P. Ramírez and J. Peréz Fernández

1) Precipitation

Most of the Central American isthmus and the Caribbean experienced drier-than-normal conditions in 2006 (Fig. 6.16). Precipitation deficits were severe and more persistent over what is known as the "dry corridor" of Central America (western Guatemala, central Honduras, northern and central Nicaragua, and western El Salvador). August had the highest precipitation deficits compared to the 1971–2000 period. Precipitation deficits continued during September and October along the dry corridor. In parts of Nicaragua and Honduras, deficits between 35% and 55% of the long-term mean were observed in September and October. October is when most tropical cyclones form close to Central America, generating very intense rains or "temporales" on the Pacific side of the isthmus. The temporales were lacking in autumn 2006, because El Niño conditions were observed in the tropical Pacific. In November, the Caribbean side of Central America was affected by a cold front that brought strong rains to the northern Honduras coast and central Panama. Late-year rains, associated with the divergent phase of the MJO, were observed on the Pacific side of Central America through the middle of December.

2) Temperature

Annual mean surface temperature in 2006 was above normal across much of Central America and parts of the Caribbean (Fig. 6.17). Positive anomalies of between 0.3° and 0.4°C were found over Central America (south and west of Honduras and El Salvador, Nicaragua, and northern Costa Rica), and were near normal across Panama. Temperatures that were near normal predominated the first two months of the year. In March, resulting from a late intrusion of cold fronts into the region, below-normal monthly means were observed in Belize, western Guatemala and Honduras, and western Panama. At the same time, positive anomalies were registered in Costa Rica and Nicaragua. Positive anomalies dominated along

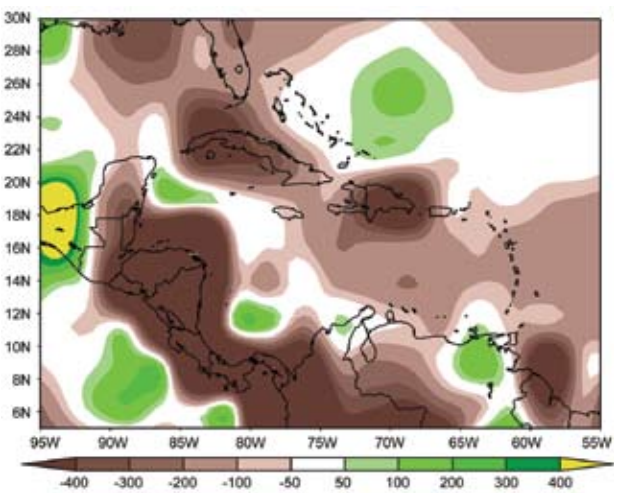

Fig. 6.16. Central American and Caribbean 2006 annual precipitation anomalies (mm, 1979–2000 base) from CAMS-OPI.