7. REGIONAL CLIMATES

a. *Overview*—A. B. Watkins and L. A. Vincent

This chapter provides the local perspective of the global climate in 2008. Analyses have been made for a number of individual nations, most broad geographic regions, and all continents. In the vast majority of cases, information for a specific region has been compiled by local scientists, and hence the source of the data used is typically the agency affiliated with the lead author, unless otherwise noted. While acknowledging that the recommended World Meteorological Organization's standard reference period is 1961–90, a number of other reference periods are also used in this chapter for the computation of local climate normals. This is largely due to insufficient data being available in some regions to cover one selected reference period, while in some cases local reference periods are more suitable for domestic purposes. Please also note that while this chapter covers the climate of 2008, information may include data from the previous year to accurately cover appropriate climate events. For example, in southern Africa, the rainy season is from October until the following April, and hence information is provided for the entire period and not just the months from 2008. Likewise, descriptions of the austral summer and boreal winter seasons include data from December 2007.

Annual mean temperatures were generally well above average in Canada, South America, northern and southern Africa, Iceland, Europe, Russia, South Asia, and Australia. Winter 2008 (December 2007 to February 2008) was remarkably mild in most northern European regions. In contrast, an exceptional cold outbreak occurred during January across Eurasia, over southern European Russia, and southern western Siberia.

The year 2008 was also characterized by heavy precipitation in a number of regions including South America, Africa, and South Asia. In contrast, a prolonged and intense drought occurred during most of 2008 in northern Argentina, Paraguay, Uruguay, and southern Brazil, causing severe impacts to agriculture and affecting many communities.

Where not explicitly described in the following text, the background atmospheric state for this local perspective is provided in chapter 2.

b. *North America*

1) Canada—R. Whitewood and D. Phillips

The year 2008 was another warm year (relative to the 1951–80 reference period). It was wet across Canada, especially in southern regions of Ontario and Quebec where some locations set records for both the wettest winter and summer. It was another year of significant ice loss in the Arctic. For several growers from British Columbia to Ontario, hail storms took a significant toll on grain and fruit crops and properties.

(i) Temperature

Canada experienced its 16th-warmest year in 2008, 0.7°C above normal (Fig. 7.1). The warmest year remains 1998 at 2.5°C above normal, since reliable nationwide records began in 1948. Although not as warm as recent years, most of the warming occurred in the arctic region (Fig. 7.2a) where temperatures were more than 1°C above normal north of 60°N. Most of the populated south was within half a degree of normal.

Temperatures have shown a pronounced warming since records began. Figure 7.1 shows that temperatures have been above the 1951–80 normal period for 12 consecutive years, with 5 of the warmest 10 years occurring in the last decade. The dashed line indicates a trend of 1.3°C for the 1948–2008 period.

Seasonally, anomalies for summer and fall were higher than for the cold seasons. Summer temperatures were 1.0°C above normal, ranking it the third warmest since records began in 1948. Fall ranked sixth warmest with temperatures 1.4°C above normal. For both seasons, most of the above-normal temperatures occurred in the north. Nunavut averaged about 2°C above normal. Nationally, winter and spring were closer to normal, within about half a degree above normal.

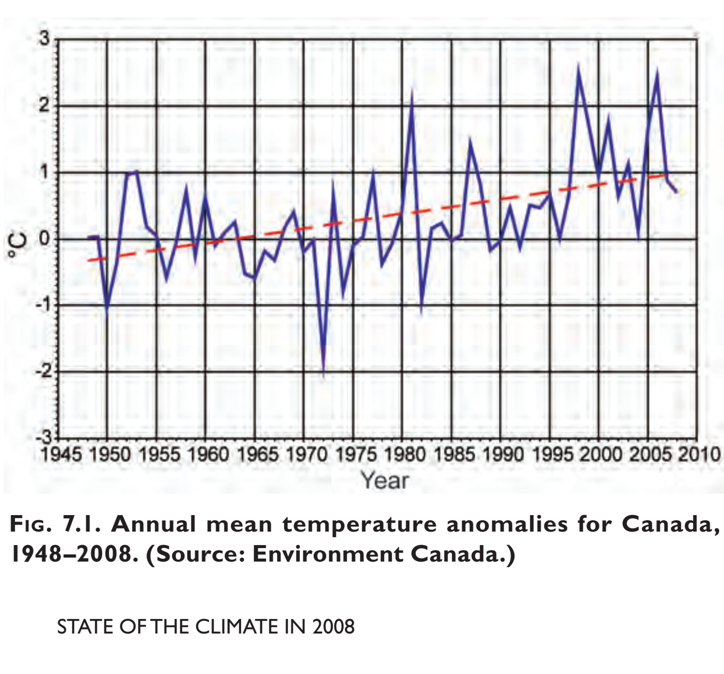

Fig. 7.1. Annual mean temperature anomalies for Canada, 1948–2008. (Source: Environment Canada.)

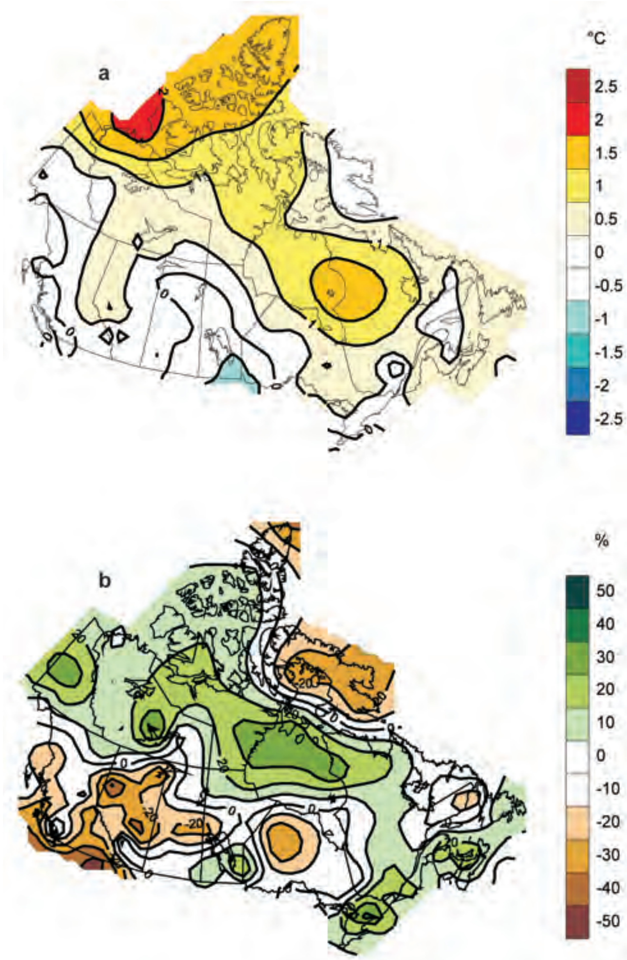

Fig. 7.2. (a) 2008 annual mean temperature anomalies and (b) 2008 annual total precipitation anomalies (percent of 1951–80 average) for Canada. (Source: Environment Canada.)

(ii) Precipitation

Nationwide, Canada experienced its 13th-wettest year in 2008, 4.6% above average. The wettest regions (>20% wetter than normal) included the Arctic, and from southern Ontario through the Maritimes (Fig. 7.2b). In the west, British Columbia through Saskatchewan, it was at least 20% drier than normal. Of note, southern Ontario and southern Quebec experienced their wettest year, 20.4% above normal. Conversely, the region covering the interior mountains of British Columbia was 18.5% below normal, ranking as the fifth-driest year on record (1948–2008).

Since the 1970s, precipitation across Canada has tended to be less than the 1951–80 average. The last drier-than-normal year was 2001. The wettest year on record occurred in 2005 (13.4% above normal), and the driest was 1956 (7.3% below normal).

Seasonally, the summer was exceptionally wet nationally, 13.3% above normal, ranking this season the third-wettest on record. Autumn, on the other hand, was on the dry side, 1.0% below normal, ranking as the 22nd driest on record. Both winter and spring were close to normal (0.5% above normal, and 0.5% below normal, respectively).

(iii) Notable events

The loss of sea ice in the Arctic meant that 2008 was the first time in the satellite era that both the Northwest and the Northeast Passages were open simultaneously, with Arctic sea ice melting to the second-lowest coverage (4.13 million km^2) since records began in 1979 (see chapter 5).

Although not a single event, the total amount of snow that fell during the winter of 2007/08 eclipsed many records across eastern Canada. Snow totals for several locations were in excess of 500 cm, including Quebec City, Quebec (558 cm), Muskoka, Ontario (558 cm), and Gander, Newfoundland (534 cm). The excessive amount of snow led to large snow removal costs, the collapse of several buildings leading to four deaths, and near-record floods.

Costly hail storms damaged crops across Canada during the spring–summer of 2008, despite the lack of hot, humid weather normally associated with such events. Crop damage across the prairies amounted to $341 million (Canadian), the most ever reported. A July storm damaged the fruit-growing region of British Columbia, with some orchards experiencing losses of up to 40% of their tender fruit. Southern Ontario had a series of hail storms that bruised and battered fruit and crops, amounting to 4 times the previous 5-yr average for both number of reports and acreage damaged.

2) United States—S. E. Stephens, R. R. Heim, Jr., K. L. Gleason, C. Fenimore, G. D. Bell, M. Shulski, and R. A. Ballard

Reliable monthly, seasonal, and annual weather records for the United States exist from 1895 to the present, enabling the climate of 2008 to be placed in a 114-yr context for the contiguous United States. Based on preliminary data, the year 2008 was near the twentieth-century mean, with a nationally averaged temperature of 11.7°C. This ended a string of 10 consecutive much-warmer-than-average years. Spatial distribution of annual temperature anomalies included above-average temperatures in the northeast and southwest, with below-average temperatures in the central states and Pacific Northwest.

The year was characterized by dry conditions in the West, portions of Texas, and the Southeast, with unusually wet conditions from the plains into the Northeast. New Hampshire and Missouri experienced their wettest year on record, punctuated by historic flooding in June in the Midwest. Exceptional drought, as defined by the U.S. Drought Monitor (Svoboda et al. 2002), was ameliorated in the Southeast by late in the year, while areas affected by drought expanded in parts of south-central Texas. Above-average snowpack in the West provided relief to some areas experiencing multiyear drought.

(i) Temperature

For the contiguous United States, 2008 was the coolest year since 1997 with an annual temperature that was 0.1°C above the twentieth-century (1901–2000) mean (Fig. 7.3).

The contiguous United States had the 53rd-warmest winter season (December 2007–February 2008), 45th-coolest spring (March–May), 30th-warmest summer (June–August), and 32nd-warmest fall (September–November) in 2008. A persistent trough brought below-normal temperatures to the West Coast into the central plains, with warmer-than-average temperatures from the Deep South into the Northeast. Below-average spring temperatures occurred across the plains and westward, with only Texas, New Jersey, Delaware, Connecticut, and Rhode Island warmer than normal. Indicative of a weakening La Niña, temperature anomalies during the summer season were much above average in the West, where California experienced its sixth-warmest summer on record. New Jersey and Rhode Island experienced their eighth- and sixth-warmest summers, respectively. The western United States had a warmer-than-normal fall, while the eastern United States was cooler than average. California experienced its third-warmest fall on record, while Georgia observed the eighth coolest.

California and the Southwest experienced above-normal annual temperatures, while New Jersey and Delaware had their 10th- and 11th-warmest annual period, respectively. Temperatures across the Midwest were below average for 2008, with Iowa recording its 11th-coolest year (Fig. 7.4a).

The annual temperature for Alaska in 2008 was 0.4°C below average, representing a return to cool anomalies after above-normal conditions for eight consecutive years. The strongest negative tempera-

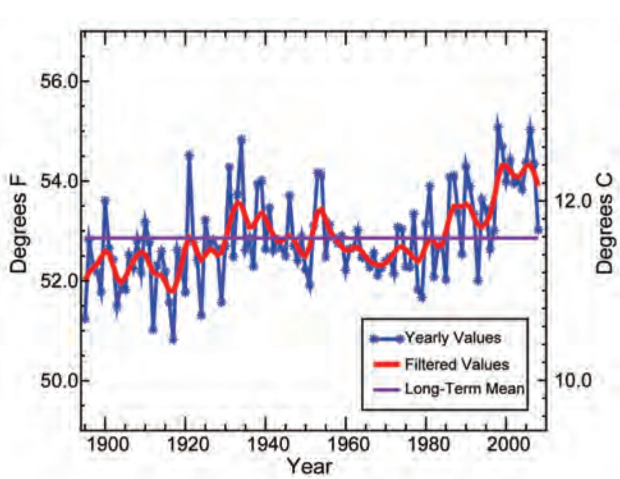

Fig. 7.3. Annual mean temperature for the contiguous United States, 1895–2008. (Source: NOAA/NCDC.)

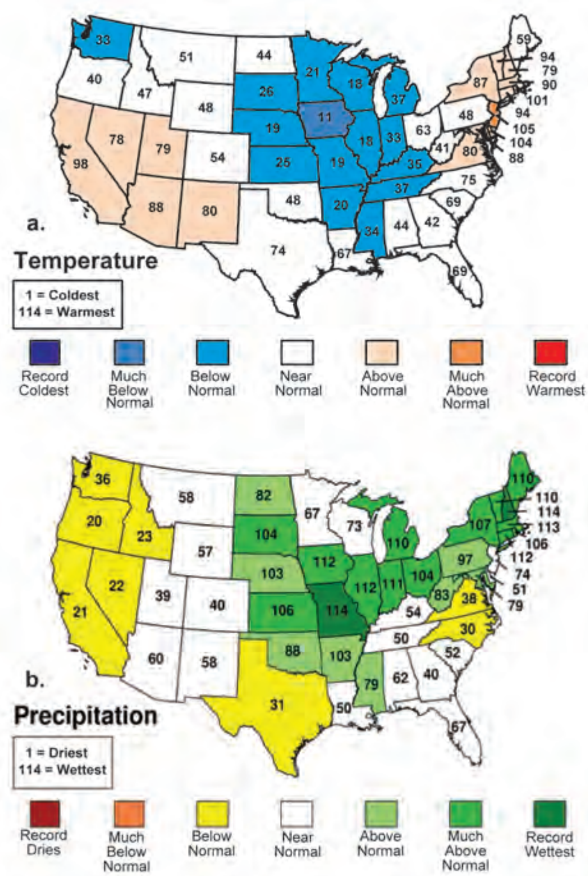

Fig. 7.4. Statewide ranks of (a) annual 2008 temperatures and (b) annual 2008 precipitation. A rank of 114 represents the warmest/wettest year since 1895. Much-above-normal temperature/precipitation is defined as occurring in the top 10% of recorded years, which corresponds to a rank of 104–113. Above-normal temperature/precipitation is defined as occurring in the warmest/wettest third of recorded years (ranks 77–103). Much-below-normal temperature/precipitation is likewise the bottom 10% of coolest/driest years since 1895, and below normal is defined as the remaining coolest/driest third of the distribution. (Source: NOAA/NCDC.)

ture anomalies were in the southwest portion of the state, with a notable warmer-than-normal exception along the central Arctic coast. Alaskan temperatures in winter (December–February) were near the 1971–2000 average. Spring temperatures were above average, while summer and fall both averaged below the 1971–2000 mean.

(ii) Precipitation and snowpack

Record amounts of rainfall in the Northeast and historic flooding in the Mississippi and Ohio River valley regions occurred during 2008 (Fig. 7.4b). Nationally, four months were wetter than average, contributing to the 27th-wettest year on record. Persistent precipitation events throughout the year resulted in record precipitation for the Northeast. Connecticut, Massachusetts, Rhode Island, and Vermont each had the wettest February, while New York experienced its wettest winter. New Hampshire ranked wettest for the summer and annual periods.

During June, significant flooding affected the states of Illinois, Indiana, Michigan, Minnesota, Missouri, and Wisconsin. Record-high flows were recorded in major rivers, including the Des Moines, Cedar, and Wisconsin Rivers, with peak levels in some locations exceeding the 500-yr return interval. The Cedar River crested at over 9.8 m, flooding 1,300 city blocks of Cedar Rapids, Iowa. Local flash floods also occurred as rainfall totals at times exceeded 127 mm day^{-1}, with more than 1,100 daily rainfall records broken during the month. Factors contributing to the floods included well-above-average precipitation during January–May, followed by significant rainfall for nearly two weeks in June as a persistent area of low pressure and well-defined cold and warm fronts affected the central plains. Preconditioning heavy rainfall events earlier in 2008, culminating with the heavy June rainfall, occurred while the convection patterns associated with the MJO and La Niña were in-phase (Bell 2008). Additionally, excess soil moisture and elevated river levels preceded the floods. The atmospheric circulation during the main flood event was typical of other major floods, including the great Midwest floods of 1993 (Bell and Janowiak 1995).

During winter 2007/08, snowpack levels were above average in much of the Rockies, Cascades, and Sierra Nevada. Some areas in Oregon, Washington, Arizona, New Mexico, Nevada, and southern Colorado had levels above 180% of normal. Conversely, parts of Wyoming, Montana, and Nevada had levels below normal, as did much of eastern Alaska and southern New Mexico. Mountain snowpack remained substantial with most of the intermountain region and Pacific Northwest reporting above-normal snowpack at the end of the winter season. February brought a series of large winter storms across much of the northern two-thirds of the nation. Madison, Wisconsin, set a new record for seasonal snowfall with 257.6 cm. Snowfall at Caribou, Maine, was 502.4 cm, a new seasonal record.

The beginning of the 2008/09 snow season was below normal in the Sierra Nevada and many California reservoirs were at their lowest levels in over 30 years. Snow conditions in the rest of the West were near normal. In October, a major snowstorm over the western United States dumped as much as 124 cm of snow in Cole Creek, Montana, and 76 cm of snow in Lander, Wyoming. In Alaska, Barrow reported the heaviest October snowfall on record with 58.9 cm. During the month of December, more than 2,200 daily and monthly snowfall records were broken across the United States, with the most notable events in the upper Midwest, southern Nevada, and southwest Louisiana.

(iii) Drought and wildfires

The year was characterized by persistently dry conditions across much of the West, Southeast, northwestern Great Lakes, southern plains, and Hawaii. For California, which had its driest spring (March–May) and March–August periods on record, October 2007–September 2008 was the second consecutive dry hydrological year. Nevada had its driest March–September period on record.

Three-quarters of the Southeast was in moderate-to-exceptional drought when the year began, with low stream flows and water restrictions affecting many communities. Beneficial precipitation in the waning months of the year contracted the drought area to about 15% of the region. Drought plagued the southern plains for most of 2008, depleting soil

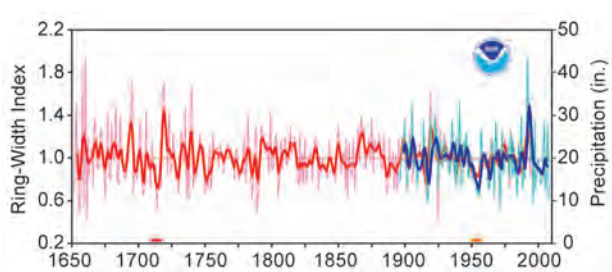

Fig. 7.5. South-central Texas Dec–Jun precipitation (1896–2008, blue curves) and proxy precipitation from tree rings (1652–1995, red curves). Annual values are shown as thin curve; 5-yr smoothed values are shown as thick curves. (Source: NOAA/NCDC/Paleoclimatology Branch.)

FACTORS CAUSING THE 2008 U.S. COOLNESS—NOAA CSI TEAM

The near-normal 2008 U.S. annual temperature was a departure from the unusual warmth of the previous 10 years (Fig. 7.6). However, the decline relative to 2007 was only about one standard deviation of the historical interannual variability. Two sets of climate models—CMIP model data and atmospheric general circulation models forced with the monthly evolution of observed SSTs (AMIP experiments)—were used to assess the influence of external climate forcings (greenhouse gas concentrations and other forcings) and SSTs on U.S. temperatures.

Figure 7.6 (middle) shows the time series of the CMIP ensemble mean annual U.S. temperatures for 1895–2008 and the 2008 projection of +0.73°C, which is considerably warmer than the observed anomaly. Further, the observed coolness appears to have been a low-probability outcome: only 5% of the model runs (7 of 144) are as cold as observed for 2008, despite the considerable spread among ensemble members.

The 2008 ocean conditions were persistently cool in the tropical Pacific, which was not predicted due to external forcing (CMIP runs). Global SSTs as a whole have cooled in recent years, possibly due to strong natural internal coupled variability. The time series of AMIP ensemble mean annual U.S. temperatures for 1895–2008 is shown in Fig. 7.6 (bottom). The observed anomaly was also colder than the expected SST-forced signal (+0.45°C), though the probability of exceedence of such coolness in the AMIP realizations was 15% (23 of 150), threefold greater than implied by the CMIP runs.

This preliminary assessment has not taken other potentially important factors into account (e.g., land surface conditions, uncertainties in external climate forcings in the CMIP runs, observed values of solar forcing for 2008). Nonetheless, a key outcome of the model diagnosis is that the average spread among individual simulations for both CMIP and AMIP runs is roughly 0.50°C, a value close to the observed historical interannual variability. As such, the observed coolness over the United States appears consistent with a scenario of moderate-intensity atmospheric internal variability masking the warming influences of boundary forcings. In other words, although the United States was colder than many recent years, temperatures in 2008 were well within the range of variability associated within natural internal climate fluctuations. Indeed, the model simulations suggest that even stronger cooling could have resulted—one AMIP run using observed SSTs for 2008 generated colder U.S. temperatures than any prior observed year since 1895.

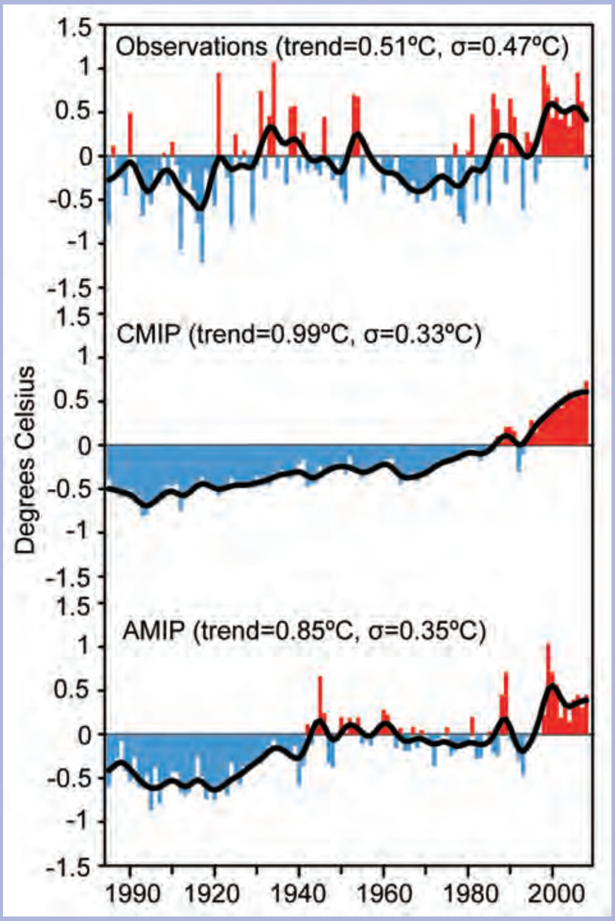

Fig. 7.6. Time series of annual land temperature departures (°C) for the contiguous United States during 1895–2008 based on (top) NCDC climate division observational analyses, (middle) the ensemble of CMIP simulations forced with observed greenhouse gas, aerosol, solar, and volcanic aerosol variability, and (bottom) the ensemble of AMIP simulations forced with observed global sea surface temperature variability. Bars plot the annual departure, computed relative to a 1971–2000 reference period, and the black curve is a 9-point Gaussian filter applied to the annual values.

moisture, lowering river and lake levels, and ravaging crops. Southern Texas had the driest October–June in its 114-yr record. December 2007–June 2008 ranked as the fourth-driest December–June in the 114-yr precipitation record for south-central Texas. A precipitation index for this region based on tree-ring data covers the period 1652–1995. In the approximately 250 years prior to 1896, the tree-ring record shows about a dozen individual years that likely had very low December–June precipitation similar to the lowest values in the past century, such as 2008 (Fig. 7.5). The 1950s drought is the drought of record for the twentieth century, with seven consecutive years (1950–56: orange bar) having below-normal December–June precipitation. The 1950s drought appears to have been matched and possibly exceeded by one that occurred in the early 1700s (red bar), in which the ring-width index was below average for seven years in a row (1711–17) and the cumulative ring-width anomaly for those seven years was slightly lower than that for 1950–56.

Although there were heavy rains and serious flooding over Hawaii in February and again in mid-December, these episodes were separated by a long, severe dry spell that produced significant drought conditions by late summer. Although beneficial rains did fall by year's end, some areas in Hawaii continued to suffer from lingering drought conditions.

The United States had a relatively mild wildfire season in 2008 when compared to 2007 and 2006. However, some areas of the nation—primarily in the western and southeastern regions—experienced significant and costly fire activity in 2008. The majority of fire activity occurred during the months of July and August. For the year as a whole, nearly 80,000 wildland fires burned more than 2 million hectares, according to preliminary year-end statistics from the NIFC. These values rank 2008 near average in terms of the number of fires and above average for area burned.

(iv) Tornadoes

Across the United States, 2008 was a very active year for tornadoes. As of January 2009, confirmed tornado reports and estimates for the end of 2008 indicated that there were 1,630 tornadoes from January–December 2008, which is above the 10-yr average of 1,270 and the second-highest total in the 1953–2008 record. In 2004, 1,817 tornadoes were confirmed across the contiguous United States. The number of strong-to-violent tornadoes (rated EF3–EF5)[1] reported in 2008 was 36, which is equivalent to the average number reported over the period 1950–2008. (See: www.spc.noaa.gov/faq/tornado/ef-ttu.pdf for additional details.) The total number of tornado-related fatalities for 2008 was 125, the 10th highest in the 1953–2008 record. Nearly all of these fatalities occurred during the first five months of the year.

The beginning of 2008 was an active severe weather period. There were 54 confirmed reports of tornadoes and five deaths across the Midwest on 7–8 January 2008, making it the second-largest January tornado outbreak on record. On 5 February, 87 tornadoes were confirmed. This deadly event, nicknamed the "Super Tuesday Outbreak," was responsible for 57 deaths in the southeastern United States. The number of tornado-related fatalities reported in February across the United States was the second highest on record for the month.

May was also an active month with 460 confirmed tornadoes, making it the third-most-active May on record. For the period January–May, a total of 112 tornado fatalities were reported, which ties 2008 and 1968 for the eighth-deadliest January through May period since reliable records began in 1953. Severe weather continued into June when two outbreaks spawned 289 confirmed tornadoes. The severe weather season began to slow down over the summer months and into the fall with over 300 tornadoes confirmed from July–October and only five additional fatalities reported during the remainder of the year.

3) Mexico—V. Davydova-Belitskaya and F. Romero-Cruz

For Mexico, 2008 was slightly warmer than normal, with an annual mean temperature of 21.4°C, 0.7°C above the long-term climate average. Annual total precipitation was the 17th wettest since records began in 1941, with 900.7 mm, compared with the long-term (1941–2000) average of 771 mm. Extreme weather took a toll with several deaths and monetary losses in the millions (USD) across the agricultural sector. Hardest hit were areas near Coahuila, north of Chihuahua and Tamaulipas, Durango, Nayarit, south of Sinaloa, and west of Jalisco, which started the year with severe drought conditions and continued with extended wildfires through the spring. In contrast, Aguascalientes, Zacatecas, San Luis Potosi, Durango, south of Tamaulipas, Chihuahua, and Veracruz registered heavy rain and flooding during July and August, with dam levels in these zones more than 100% of capacity at year's end.

(i) Temperature

The annual mean temperature anomaly over much of Mexico was near 0°C, however across the northwestern region temperatures were 1° to 3°C above normal (Fig. 7.7a). During the spring and the begin-

[1] Prior to 2007, statistics were compiled using the original Fujita scale, which classified tornadoes based on wind strength, estimated by associated damage. The Enhanced F-scale is also a set of wind estimates based on damage. It uses 3-second gusts estimated at the point of damage based on a judgment of 8 levels of damage to 28 specified indicators.

U.S. RIVER DISCHARGE FOR 2008—A. MACDONALD, L. BOWLING, B. FEKETE, R. LAMMERS, AND R. LAWFORD

For the 2008 water year (1 October 2007 through 30 September 2008), streamflow across the contiguous United States was slightly above the long-term annual median (1930–2008), with pronounced regional differences (Jian et al. 2009). Annual streamflow was much above normal throughout the upper Midwest and central Plains, due primarily to wet winter and early spring conditions. Wet winter and summer conditions led to above-normal annual streamflow in New England. Much-below-average annual flows existed in the Southeast, due to low flows in the fall and winter that slowly recovered in the spring and summer (Jian et al. 2009). Streamflow in Alaska was low in all seasons, with record-low values in the spring, summer, and annual totals.

Transporting nutrients, pollutants, heat, and low salinities, river discharge is important to the ocean on both regional and basin scales. Milliman et al. (1995) identified 61 rivers in the contiguous United States that discharge directly into ocean basins. Of these, 40 are active USGS stations with record lengths sufficient to compute 2008 streamflow as a percentile of normal flow (1964–2008). As illustrated (Table 7.1), total discharge into the Gulf of Mexico was higher than normal in 2008 (84th percentile) due to summer flooding in the U.S. Midwest, while discharge into the Pacific and Atlantic Oceans was lower than normal (32nd and 36th percentiles, respectively).

Table 7.1. Estimates of observed and extrapolated discharge volume.

Basin receiving water	U.S. land area (km^2)[a]	Gauged land area (km^2)	Observed 2008 discharge volume (km^3)	Percentile (1964–2008)	Extrapolated 2008 discharge volume (km^3)[b]
Atlantic Ocean[c]	795,256	277,847	102	36th	292
Pacific Ocean[d]	1,022,605	749,933	215	32nd	293
Gulf of Mexico[e]	4,053,225	3,251,813	588	84th	733

[a] Estimated using the published areas of the 21 USGS water resources regions (Seaber et al. 1987)

[b] Calculated from observed annual runoff (observed discharge/gauged land area) times the total land area draining to each water body.

[c] Excludes Great Lakes drainage through the St. Lawrence River.

[d] Includes the Canadian portion of the Columbia River basin.

[e] Excludes the Rio Grande.

ning of summer, anomalies from +1° to +4°C were observed in the northwestern, northern, northeastern, and the southern Pacific Coast regions. Monsoon conditions starting in the north and moving eastward brought heavy rain from July to September. This was accompanied by temperatures 2° to 4°C below normal in the northern, central, southern, and southeastern regions of Mexico. The northwestern and western regions of the country experienced temperatures 1° to 3°C above normal during the rainy season (June–September). During the fall, in the southeast and the Yucatán Peninsula, unusually low temperatures were reported (11°C and 13°C in Campeche and Yucatán, respectively), resulting in low mean temperatures for these regions during October and November.

(ii) Precipitation

The year started drier than normal during the winter and spring, but significant precipitation occurred during the rainy season. Normal precipitation started in July, particularly in the north and northeast of Mexico and the central part of the country. The rainy

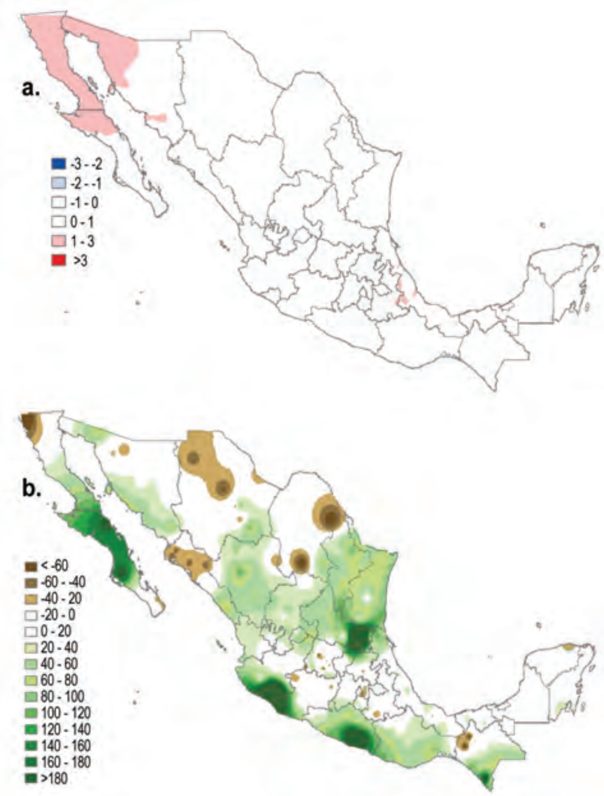

Fig. 7.7. (a) Annual mean temperature anomalies for Mexico (°C, based on 1971–2000); (b) seasonal total precipitation anomalies (May–Oct) (percent of 1971–2000). (Source: National Meteorological Service of Mexico.)

season ended abruptly at the beginning of October, and the end of the year was exceptionally dry.

Annual total precipitation for Mexico was 116.8% of the 1941–2000 mean. The largest anomalies were registered in Aguascalientes and Coahuila (49% above normal), Nayarit (48%), San Luis Potosi (47%), Baja California (44%), Nuevo Leon (43%), Campeche (40%), Chihuahua (35%), Tamaulipas (34%), Durango (33%), and Guanajuato and Chiapas (25%). Four of the 32 states of Mexico reported some rainfall deficit: Mexico City (23% below normal), Yucatán (14%), Tlaxcala (3%), and Sinaloa (2%). The rainy season in Mexico was mostly wet. Only the northern regions of the country and the Yucatán Peninsula reported precipitation slightly below normal (Fig. 7.7b).

(iii) Wildfires

According to the CONAFOR reports, less than 10,000 wildfires were detected during 2008. Most of them were registered during the period from February through June. May had the most wildfires, almost 26% of the total, while April and March accounted for 24% and 21% of the annual total, respectively. Wildfires occurred mainly in the western, northern, southeastern, and northeastern parts of the country, as well as along the Gulf of Mexico and the Yucatán Peninsula. In the north, northwest, and west regions of the country, the North American monsoon helped extinguish these fires during the 2008 rainy season.

c. Central America and the Caribbean

1) Central America—J. A. Amador, E. J. Alfaro, E. R. Rivera, and B. Calderon

(i) Temperature

To illustrate the behavior of the 2008 climate across Central America in the context of its long-term mean, four stations were analyzed for the Pacific region, namely San José (Guatemala), Choluteca (Honduras), Liberia (Costa Rica), and David (Panamá), and three along the Caribbean Sea; Philip Goldson (Belize), Puerto Lempira (Honduras), and Puerto Limón (Costa Rica). All four Pacific stations recorded below-normal annual mean temperature with respect to their climatological values (1971–2000 average). Of all the stations, the largest anomaly was for Liberia, whose annual mean temperature was about 2°C below normal. In contrast, two stations on the Caribbean side (Philip Goldson and Puerto Limón) reported above-normal mean temperatures, while Puerto Lempira was near normal. Puerto Limón recorded an annual mean temperature of about 1°C above normal.

(ii) Precipitation

All stations reported below-normal annual total precipitation for 2008, though it is worth noting that most stations had some missing data. In most regions, daily precipitation was generally less than 20 mm, with very few events recording totals above 40 to 50 mm. The start and end dates of the Caribbean rainy season were near normal; however, a slightly late start was observed for Choluteca and David.

(iii) Notable events

2008 was very active for tropical storms. From 16 named storms observed in the Atlantic, 10 entered the Caribbean basin, four of which were very strong. Despite the fact that Pacific hurricanes rarely affect Central America, the first hurricane of the season, Alma, reached land in Leon (Nicaragua), producing significant economic and social damage.

2) Cuba—C. Fonseca, R. Pérez, B. Lapinel, V. Cutié, I. Gonzáles, D. Boudet, and M. Hernandez.

(i) Temperature

The annual mean temperature for Cuba was 0.3°C above its long-term average, with 2008 being

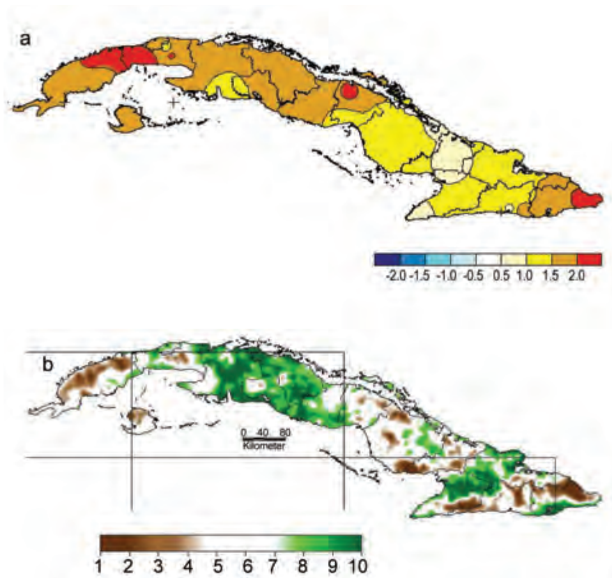

Fig. 7.8. (a) Feb mean temperature anomalies for Cuba (°C; based on 1971–2000); (b) annual total rainfall expressed as deciles (based on 1971–2000; preliminary analysis). (Source: Institute of Meteorology of Cuba.)

its ninth-warmest year since records began in 1951. February was much warmer than normal, with an anomaly of +1.8°C; the second warmest on record (Fig. 7.8a). The summer season was also very warm. November was the only month below average, with temperatures of 0.9°C below normal. Several weather stations reported new record-low nighttime during that month.

(ii) Precipitation

Annual total precipitation for 2008 was either above or near normal for most provinces across the country, with only a few small regions recording below-normal precipitation (Fig. 7.8b). During the first seven months of the year, rainfall deficits were recorded across the country, contributing to a significant drought event over eastern Cuba; however, rainfall associated with hurricanes during August, September, and November ended this drought.

(iii) Notable events

Cuba was affected by four tropical cyclones, which included one tropical storm (Fay) and three hurricanes (Gustav, Ike, and Paloma). Ike was the sixth major hurricane (Category 3 or above) to impact Cuba since 2001, a record for any 8-yr period. The three hurricanes caused extensive damage, estimated at about $10 million (USD), and while seven deaths were reported, actions taken to mitigate the impact of hurricanes on Cuba prevented many more.

3) Jamaica—T. S. Stephenson, M. A. Taylor, and J. M. Spence

(i) Temperature

Positive surface air temperature anomalies were recorded at coastal stations during most of 2008, consistent with the warmer-than-average ocean temperatures. Some inland stations, however, experienced below-normal temperatures over the same period.

(ii) Precipitation

The annual total rainfall for 2008 was slightly above average. This was the cumulative effect of negative anomalies for half of the year, near-normal precipitation for four months, and well-above-normal precipitation for two months (August and November) (Fig. 7.9). August rainfall was the highest August total (357 mm) since 1971. It was primarily attributed to the passage of TS Gustav, and to a lesser extent to tropical waves and surface troughs. Other notable rainfall features included February being the fourth driest since 1971 and the delay of the characteristic May peak in rainfall to June. December rains were below the 1971–2000 mean, but this may be related to a reduction in station density across the island.

(iii) Notable events

The main event in 2008 was the passage of TS Gustav in late August, which produced considerable rainfall over the island. The Mavis Bank station in rural St. Andrew recorded 419 mm of rain on 28 August (495% of the 1951–80 climatological monthly mean) and a 3-day total of 534.6 mm between 27 and 29 August. The rainfall rate at this station peaked at 80 mm h^{-1}. Jamaica also experienced the effects of Hurricane Fay (August) and TSs Ike and Paloma (September and November, respectively).

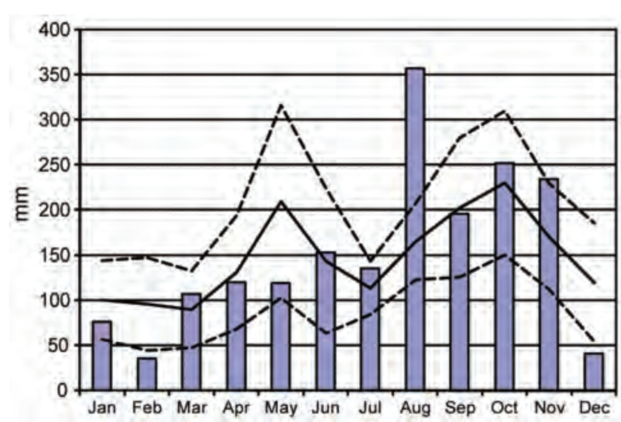

Fig. 7.9. Monthly Jamaican rainfall for 2008 (bars), climatology (black), and one std dev from climatology (dashed). The reference period is 1971–2000. (Source: Meteorological Service of Jamaica.)

4) Puerto Rico and the U.S. Virgin Islands—S. Rossi and J. P. Cupo

(i) Temperature

Annual mean temperatures in San Juan (Puerto Rico) during 2008 were 0.2°C below the 1971–2000 mean. The average maximum temperature of 29.8°C was the coolest recorded since 1996. The highest daily maximum temperature occurred in Juana Diaz, on the south coast, where the temperature reached 37.2°C on 18 July. The lowest daily minimum temperature occurred in Aibonito, over the central interior, where the temperature fell to 6.1°C on 30 January. The temperatures in San Juan were fairly consistent with those observed across the U.S. Virgin Islands, with both the Cyril E. King Airport on Saint Thomas and the Henry E. Rohlsen Airport on Saint Croix reporting their coolest average maximum temperatures of the decade (29.6°C and 29.8°C, respectively). Minimum temperatures were also below their 30-yr means across the U.S. Virgin Islands, resulting in an annual mean temperature anomaly of −0.7°C.

(ii) Precipitation

The annual total precipitation across Puerto Rico (average of 30 sites) was near normal during 2008, with 98% of the expected yearly rainfall for the island (100% was recorded for the U.S. Virgin Islands). San Juan recorded 1,389 mm of rain, nearly identical to the accumulated rainfall of the previous year, and marking its sixth consecutive year of above-normal precipitation. This recent string of wet years in San Juan has resulted in a total rainfall surplus of 1,554 mm recorded so far this decade, exceeding one year's worth of precipitation; the 30-yr annual average rainfall in San Juan is about 1,289 mm.

Of the six geographical sectors that make up Puerto Rico, the driest sector was the eastern interior, which received only 81% of its average precipitation in 2008. The wettest sector was the south coast, which received 132% of its average precipitation in 2008 (Fig. 7.10). There were several spikes in the averaged weekly rainfall across Puerto Rico in 2008, with each of these spikes representing a significant weather event that affected the island.

(iii) Notable events

The first significant weather event of the year was associated with a pair of fragmented cold fronts during the month of January that brought widespread rainfall to much of the northern half of the island. The remnants of two additional fragmented frontal boundaries, combined with a weakening of the persistent upper-level ridge across the region, led to an additional pair of significant rainfall events in the spring. However, these rainfall events were not enough to prevent large sections of the southern and eastern regions from entering into dry-to-moderate drought conditions by late March, which persisted until mid-September.

Relief from heavy rainfall associated with three strong tropical waves during the second half of August (which eventually developed into Tropical Storm Fay, Hurricane Gustav, and Hurricane Hanna), helped to relieve the drought conditions across the region. However, short-term drought conditions did not end until the passage of a strong tropical disturbance, which meandered around Puerto Rico for several days during September, dropping torrential rainfall across much of the southern and eastern sections of the island. Specifically, an unprecedented 560 mm fell in Patillas, 559 mm in Guayama, 406 mm in Cabo Rojo, and 377 mm in Yabucoa, all within a 24-hr period ending at 1200 UTC 22 September.

The only named tropical system that directly impacted Puerto Rico and the U.S. Virgin Islands came in mid-October when Hurricane Omar moved across the Caribbean, eventually tracking northeast through the Anegada Passage. While a spike in rainfall associated with this storm can be seen across Puerto Rico in Fig. 7.10, Puerto Rico was largely spared the brunt of Hurricane Omar. Across the U.S. Virgin Islands, however, damage from the hurricane-force winds, heavy rainfall, and large surf was reported on the island of Saint Croix, with less damage reported across Saint Thomas and Saint John.

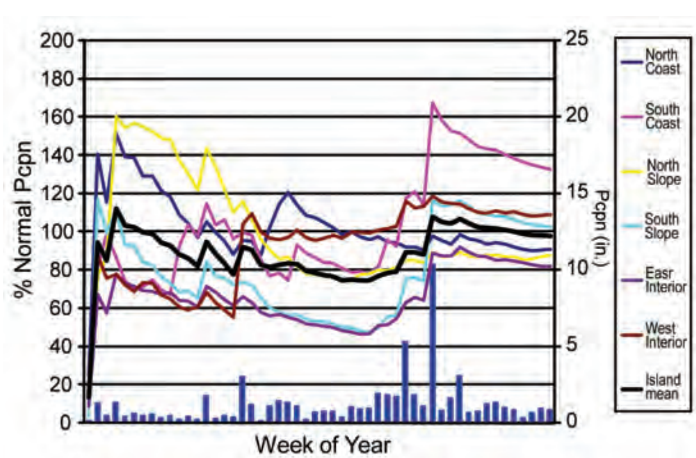

Fig. 7.10. Weekly precipitation expressed as percentage of normal rainfall (left-hand side) for six distinct sectors of Puerto Rico. The average for the island is in bold and the weekly average totals are given on the bottom.

d. South America

1) Northern South America and Tropical Andes

—R. Martínez, D. Pabón, G. León, E. Jaimes, A. Quintero, and A. Mascarenhas

(i) Temperature

2008 was characterized by mean temperatures below the 1971–2000 normal for the coast of Suriname, Guyana, Columbia, Ecuador, and Peru, while elsewhere temperatures were near normal (Fig. 7.11a). Temperatures were generally above normal from January to May in most countries, while from July to September temperatures were above normal in the coastal regions. From October to December, the temperatures along the coastal zone were below normal, while they were above normal in the highlands and Amazonia. Temperatures in Peru were near normal with highly localized cold anomalies. In the Galapagos Islands, temperatures were predominantly above normal, except in March when monthly anomalies of −0.5°C were observed.

(ii) Precipitation

Annual total rainfalls were mainly above normal along the coast of Suriname, Guyana, Columbia, and Ecuador, while they were below normal in the north of Venezuela, northeast Columbia, and south of Peru (Fig. 7.11b).

In Venezuela, most of the country experienced below normal precipitation during 2008; however, locally intense rainfall occurred during February, April, and May, while above-normal precipitation occurred over most of the country in October and November. Despite some positive precipitation anomalies in May, the start of the rainy season was delayed. Positive precipitation anomalies in October were mainly associated to the passage of Tropical Storm Omar. This event produced floods and landslides in different parts of the country, with emergency actions taking place in several states and in the Capital District. In November, heavy rainfall caused eight deaths and damaged houses and other infrastructures in Ocumare in Aragua state.

For Colombia, 2008 showed above-normal precipitation. From January to March, most areas experienced positive anomalies, with the wetter conditions contributing to fewer bushfires than expected at that time of year. During the remaining months, generally above-normal precipitation predominated, with the exception of April, September, and December. In the north, central, and west, May, August, October, and November saw many extreme events such as sudden storms, floods, and landslides. The landslides and floods in October and November had considerable human and economic impacts. According to the institution of the National System for Disaster Prevention, 165 people were killed, 213 were wounded, and nearly 1.8 million people

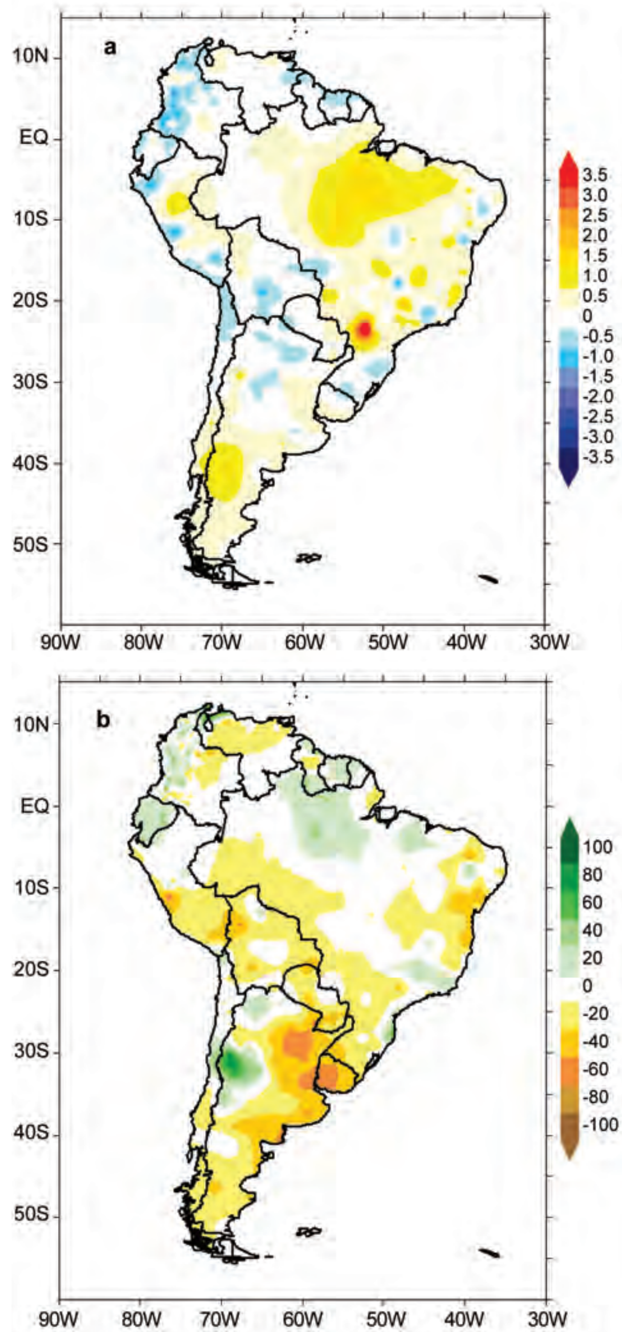

Fig. 7.11. (a) Annual mean temperature anomalies for South America for 2008 (°C); (b) annual total precipitation anomalies (% normal). The reference period is 1971–2000. [Sources: National Meteorological Services of Argentina, Brazil, Bolivia, Chile, Columbia, Ecuador, Guyana, Paraguay, Peru, Uruguay, Venezuela, and CPTEC (Brazil). Data compilation and processing by CIIFEN 2008.]

(approximately 360,000 families) experienced damage to their houses. Losses were estimated at over $26 million (USD).

In Ecuador, the annual total precipitation anomalies were about 20% above normal during 2008. With the La Niña event peaking during December 2007, the rainy season over Ecuador experienced its earliest start in the last seven years. During January and February 2008, while La Niña was diminishing, heavy rainfall was registered over most of the country with the coastal regions affected by floods and the central and northern highlands affected by landslides, leading to a state of emergency being declared across the country. During March and April, rainfall remained above normal along the coast and the Andean region, but it was below normal in Amazonia. In May and June, conditions in the coastal region switched to a rainfall deficit, while in the southern and northern highlands heavy rainfall was reported. The second half of the year was characterized by normal conditions in the coastal zone. During the last trimester of 2008, rainfall was above normal in the central highlands and southeastern Ecuador. In the Galapagos Islands, precipitation was significantly below normal in January and February, mostly associated with negative sea surface temperature anomalies; however, precipitation was twice the monthly normal in March and 27% above normal in April. The rest of the year was characterized by normal to slightly below-normal precipitation.

In Peru, significant rainfall was observed in January. Heavy rainfall occurred in the coastal area of Ica (17 mm in 5 days; 4 mm is usually observed for the month) and in the highlands of Arequipa, where more than 80 mm of rain was observed in the first 20 days of the month. In February and March, there was significant rainfall along the northern coast of Peru, resulting in an emergency declared in the flooded areas. In April, cold and dry air moved into the tropical latitudes inducing rainfall and thunderstorms over the southern jungle of Peru, Bolivia, and Amazonia. This also resulted in a significant drop in air temperature over the tropics. In the remaining months, the precipitation was slightly below normal. During 2008, the precipitation over Peru showed a deficit of about 20% compared to the long-term average (1971–2000).

(iii) Notable events

Of 16 tropical cyclones, only Omar passed near the Caribbean coast of Venezuela on 13 and 14 October, intensifying precipitation over much of the country.

2) Tropical South America East of the Andes—J. A. Marengo, J. Baez, and J. Ronchail

(i) Temperature

Most of tropical South America east of the Andes and south of 23°S experienced a warm 2008, with annual mean temperatures 2° to 3°C warmer than normal. Likewise, warm conditions (1° to 2°C above normal) were observed in northern Venezuela, interior Brazil between Amazonia and Northeast Brazil, and in eastern Peru (Fig. 7.11a). Cooler-than-normal conditions (anomalies of −0.5 to −1°C) were observed in southeast Brazil. From January to April, warm temperature anomalies were detected in eastern Amazonia, Northeast Brazil, southern Paraguay, and northern Argentina. In the interior of Northeast Brazil, mean temperatures reached 32° to 34°C, exceeding the mean by more than 4°C. Negative daily maximum temperature anomalies of 2° to 3°C were reported in Uruguay, southern Brazil, and the Brazilian highlands, associated with the penetration of a cold air mass.

In May, negative air temperature anomalies (−1° to −2°C) were observed in the Peruvian Andes and western Bolivia. A cold outbreak, due to an early northward penetration of a polar air mass, occurred in May in southern South America. Very cold temperatures were registered over the Peruvian–Bolivian Altiplano from March to May 2008. Mean minimum temperatures fell considerably to 2.7°, −0.2°, and 3.9°C in La Paz in March, April, and May, respectively. Early frosts and hail resulted in poor harvests in Andean crops (30%–40% below normal) and affected high-altitude hay making, leaving breeders with no alternative food for their herds. Mean maximum temperatures dropped by 3° to 4°C in those regions while minimum temperatures dropped by 1° to 2°C. The sharp falls in temperature were related to two episodes of cold-air penetration, which occurred at the beginning and end of May, with lower temperatures in the highlands of southern Brazil.

In June, colder temperatures (1° to 2°C below normal) were reported over a large area between Paraguay, northern Argentina, and northern Brazil. In July, positive temperature anomalies were detected across almost all tropical South America, east of the Andes. Temperatures 4°C warmer than normal were recorded in eastern Bolivia, Paraguay, northern Argentina, and southern Brazil, making it the warmest July in the last 50 years for many locations. In July, maximum and minimum air temperature anomalies reached 4°C above normal over most of central and southeastern South America, including Brazil. Clearer-than-normal skies also favored intense overnight heat losses, which in turn lowered minimum air temperatures, especially in west-central and southeastern Brazil. In Campos de Jordão, in the highlands of São Paulo, the temperature fell to −0.2°C on 14 July, and in southern Brazil, some cities experienced three consecutive days with minimums near 0°C from 17 to 19 July.

From August to October almost all of tropical South America was about 1°C warmer than normal, while in September and October, negative maximum and minimum temperature anomalies (1° to 3°C below normal) were detected in southern Brazil and eastern South America. High daily maximum temperatures were detected on 26 August in west-central Brazil (38.4°C at Cacoal; 39.3°C at Diamantino; and 39.6°C at Cáceres). In other regions, minimum temperatures were near normal due to the cloudiness associated with a cold front. However, in November warm temperatures were detected in regions of southern Bolivia, Paraguay, southern Brazil, and northern Argentina, with temperatures 3°C warmer than normal. In November, maximum mean temperature anomalies reached +2° to +3°C over large parts of tropical South America while mean minimum temperatures were 3°C warmer than normal.

(ii) Precipitation

In the tropical region east of the Andes, rainfall was 40% to 60% above normal in the Amazon region and central-southeastern Brazil (Fig. 7.11b), a situation fairly typical of La Niña years. The opposite was observed in central and southern Paraguay, with rainfall 20% to 80% below normal. In Bolivia, heavy rainfall, which began in November 2007, continued into January, causing floods that affected around 25,000 people and resulted in 30 fatalities. More than 10,000 hectares of crops were damaged by the floods, causing an estimated $30 million (USD) in losses. Mudslides destroyed many homes in the capital city of La Paz. In Rio de Janeiro, torrential rain produced floods that affected around 50,000 people and caused four deaths.

As for January, most of the summer and autumn months were characterized by episodes of intense rainfall and floods in large cities such as São Paulo and Rio de Janeiro. In the Peruvian upper Amazon, excessive rains in February produced floods and landslides in various states. The heights of the Ucayali and Madre de Dios Rivers, as well as the Beni and Mamoré Rivers in the lowlands of Bolivia, were all above normal. On the Altiplano, severe flooding and high river levels were detected in the Desaguadero and Pilcomayo Rivers. In tropical Brazil, wetter conditions in the austral summer of 2007/08 resulted in above-normal river levels for the Amazon, Tocantins, and São Francisco Rivers. In northern Paraguay, rainfall was almost twice the normal amount in February 2008; however, for the rest of summer and fall rainfall was deficient.

In Northeast Brazil, the pre–rainy season between January and February was wetter than normal, while the peak of the rainy season from March to May was also normal to above normal. Both March and April were between 20% and 40% wetter than normal. As a consequence, widespread floods killed 15 people, displaced more than 30,000 from their homes, and destroyed corn and bean crops in the Piaui state of Northeast Brazil. In June and July, wetter conditions were observed in northern Brazil and French Guiana, while drier conditions persisted in eastern Colombia and western Venezuela. In August, hailstorms were observed in southern Brazil due to the penetration of a cold front.

Rainfall in the Andean region of Colombia was about 40%–60% above normal between January and September 2008, and, as a consequence of the intense rainfall, about 56% of the country suffered the impacts of the rainfall excesses. Landslides accounted for 70% of deaths and 46% of injuries. In May, dangerous floods caused by torrential rains affected more than 100,000 people, damaged thousands of homes, and were responsible for nine fatalities. In December, rainfall was 20% to 60% above normal over the entire region, and the subsequent overflowing of the Magdalena River broke the retaining wall in the town of Plato (580 km north of Bogotá) and affected about 20,000 people. Power systems and drinking water were restricted in several areas of the municipality.

In areas east of the Andes, a large part of northern Argentina, Paraguay, Uruguay, and southern Brazil experienced a prolonged and intense drought during most of 2008, causing severe impacts to agriculture. From April to August 2008 (including September for Paraguay), Bolivia, Paraguay, and most of northern Argentina were affected by severe rainfall deficits, in some cases 60% to 80% below normal. The presence of a dry air mass that covered most of central and northern South America inhibited the formation of rain and produced above-normal maximum temperatures and, in some areas, a reduction in minimum (overnight) temperatures.

In August 2008, two cold fronts produced intense rainfall in southern and southeastern Brazil. In Paraguay, the states of Alto Paraguay, Boquerón, and Presidente Hayes were affected by a severe drought (rainfall

INTENSE RAINFALL AND FLOODS CLAIM AT LEAST 120 LIVES IN SOUTHERN BRAZIL—J. A. MARENGO

In southern Brazil, 22 to 24 November saw heavy rainfall over Santa Catarina state, which caused severe floods and deadly mudslides. Around 1.5 million people (a quarter of Santa Catarina's total population) were directly impacted, with 69,000 people left homeless, 120 fatalities reported, and a state of emergency declared. Mudslides and flooding caused by the storms blocked almost all highways in the region and cut off water and electricity to many thousands of homes. Most of the fatalities were caused by mudslides that swept away homes and businesses. The storms broke a stretch of pipeline that carries Bolivian natural gas to southern Brazil and forced the suspension of the fuel supply to part of Santa Catarina and to the entire neighboring Rio Grande do Sul state. Some cities reported looting of supermarkets and pharmacies by hungry and desperate flood victims. This event has been described as the region's worst hydrometeorological disaster since at least 1862.

The meteorological causes were associated with an atmospheric blocking over the South Atlantic that formed in the preceding week. High rainfall was linked to the intensification of the subtropical Atlantic high, which produced a steep pressure gradient along the coast that favored strong moisture transport from the ocean to the continent. Over land, a cyclonic vortex at the middle levels of the atmosphere between eastern Paraná and Santa Catarina favored the ascent of the moist air along the Sierra do Mar mountains. This unusual combination of phenomena favored the intensification of rainfall along the coastal region of Santa Catarina (Fig. 7.12). Unofficial estimates of the losses due to this extreme rainfall event and subsequent floods and landslides are of the order of $350 million (USD).

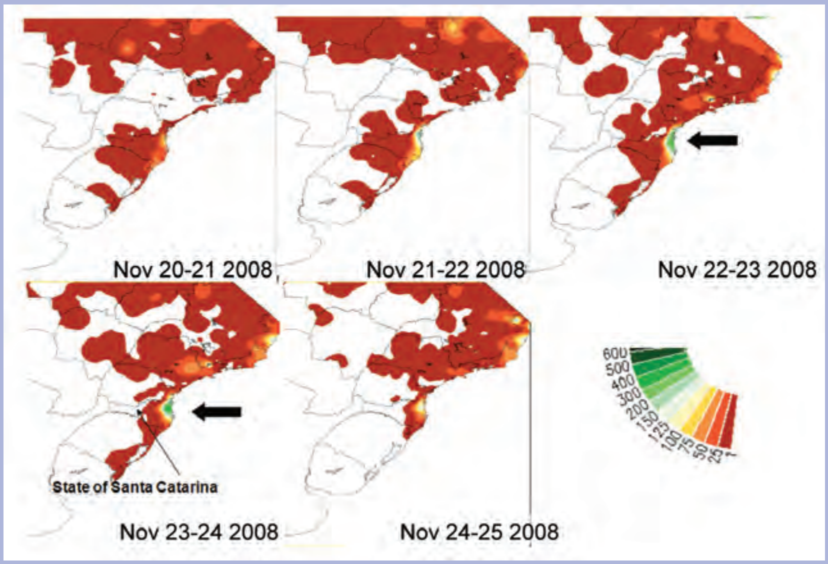

Fig. 7.12. Accumulated precipitation (mm) in southern Brazil during 20–25 Nov 2008. (Source: CPTEC/INPE.)

80%–100% below normal), and by September 2008 the government had declared a regional emergency (Paraguayan Chaco), with thousands of families, as well as cattle and agriculture, strongly affected.

3) Southern South America—P. Aceituno, M. Bidegain, J. Quintana, M. Skansi, and M. Rusticucci

(i) Temperature

Temperatures above the 1971–2000 average were observed over most of southern South America during 2008, with mean anomalies of between +0.5 and +1°C (Fig. 7.11a). Mean temperatures in July were more than 3°C above average over large parts of northern Argentina, Paraguay, northern Uruguay, and southern Brazil, making this month the warmest of the last 50 years for many locations. Mean temperature anomalies larger than 3°C were also reported during November, when the average daily maximum temperature in central Argentina and southwestern Uruguay was more than 4°C above the climatological mean. For many cities in southeastern South America, including Montevideo and Buenos Aires, this was the warmest November in the last 50 years.

The annual mean temperature for 2008 was also above average along the extratropical west coast of the continent southward from 30°S, with annual mean anomalies of 1.0°C in the region from 35° to 41°S. Above-average daily maximum temperatures were prevalent during the early (January to March) and late (September to December) parts of the year. Most were associated with rainfall deficits and clear sky conditions. In the region from 39° to 46°S, monthly mean maximum temperature anomalies were above +2.0°C during January and March and above 4.0°C in February. However, the most extreme conditions occurred during January when maximum temperatures on some days exceeded 35°C in southern Chile for some days. In particular, 37.3°C was registered at Temuco (38.8°S) on 28 January, which was the highest daytime temperature in 37 years. The beginning of the 2008/09 austral summer was anomalously warm in the southern region of Chile, with daily maximum temperature anomalies greater than +3.0°C reported during December (4.7°C above the 1971–2000 average at Coyhaique, 46°S). As a result of strong positive anomalies in daily minimum temperature for central Chile during winter, a relatively low incidence of freezing days was reported for this rich agricultural region during 2008.

(ii) Precipitation

Large and persistent rainfall anomalies in southern South America are typically associated with the occurrence of La Niña or El Niño episodes. During the first quarter of 2008, the regional climate was strongly affected by La Niña conditions.

Southeastern South America, including a large part of Argentina, Uruguay, Paraguay, and southern Brazil, experienced a prolonged and intense drought during most of 2008 (Fig. 7.11b). This caused severe impacts to agriculture and hydropower generation. Dry conditions in Uruguay reinforced a drought that started in November 2007, with the western province of Soriano experiencing its driest annual total in 65 years. These conditions exacerbated water shortages for agriculture in this main crop-growing area of the country, with the annual rainfall deficit reaching 57% below average in Mercedes, Soriano (Fig. 7.13). In the rest of the country the rainfall ranged from 20% to 40% below the 1971–2000 mean. Further exceptionally dry conditions occurred in March and November when mean rainfall deficits of 71% and 86%, respectively, were reported for the whole country. All months during 2008 were drier than average in Uruguay, resulting in the driest year in the past 65 years.

In Argentina, annual total precipitation was 40% to 60% below average in the eastern region of the country, including the province of Entre Rios and part of the provinces of Corrientes, Santa Fe, and Buenos Aires. In some areas, the precipitation during 2008 was the lowest recorded in the last 50 years.

Along the western margin of the continent, dry conditions that had prevailed in Chile during 2007 continued during the 2007/08 summer, with rainfall deficits around 50% occurring from 37° to 46°S. Early uncertainty about the evolution of a La Niña event raised concerns about drought and hence about a severe shortage of energy in Chile, where hydroelectrical power plants have a large share in the industry of energy production. However, the relatively abrupt weakening of La Niña during the autumn saw intense storms in central Chile during May, producing considerable damage due to extensive flooding, and an autumn surplus of rainfall at most stations. The 127.6 mm of rainfall measured at Concepción (36.9°S) on 18 May was the largest daily value for this month since 1971. The rainfall regime during winter was characterized by a large intraseasonal variability with a marked contrast between anomalously dry conditions during June and July and above the 1971–2000 average rainfall in August, mainly as the result of an intense storm that affected the central portion of the country around the middle of the month. The 103.4 mm of rainfall registered at Valparaiso (33°S) on 15 August was the highest daily value since 1971. Winter ended with near-average rainfall, except at the southernmost station of Punta Arenas (53.3°S), where a surplus of 39% was recorded.

As for other regions in the southern portion of the continent, very dry conditions prevailed over Chile during the spring, with rainfall ranging from 40% to 90% below average. As the drought was intensified by a very warm austral fall and winter, considerable impacts on agriculture and a large number of forest fires were reported for central and southern portions of the country.

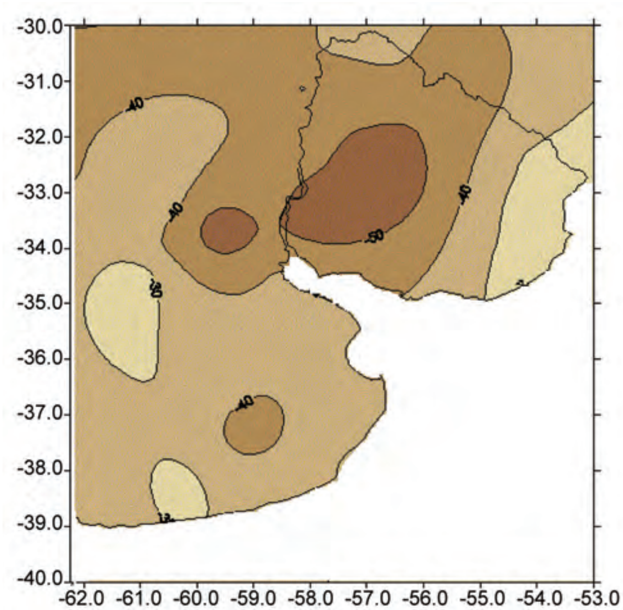

Fig. 7.13. Annual total rainfall deficit in central-east Argentina and Uruguay during 2008. The reference period is 1961 to 1990. (Source: CIIFEN 2008.)

SEVERE DROUGHT IN CENTRAL ARGENTINA AND URUGUAY—M. BIDEGAIN

Precipitation was below the 1971–2000 mean during the period November 2007 to December 2008 over a large region in central-east Argentina and Uruguay. This severe drought, which is considered the worst in the last 65 years, affected key agricultural areas in Argentina and Uruguay, producing a sharp decline in grain and meat output. The drought especially hit the 600,000 km^2 of grassland in the Pampas region. The Rural Association estimated that Argentinean grain production would drop by 39% and 1.5 million livestock would be lost, with poor meat and dairy production from the surviving animals. Drought assistance measures adopted by the governments of Argentina and Uruguay included delivery of livestock fodder.

The severe rainfall deficit in this region was illustrated by the record of daily and accumulated precipitation at Salto, located near the border with Argentina in northern Uruguay, where 2008 ended with an annual rainfall total that was 47% below the 1971–2000 mean (Fig. 7.14).

In Uruguay, the hydroelectric sector was also severely affected, with precipitation more than 60% below the long-term mean over the Uruguay (reference period 1979–2005) and Negro (reference period 1950–2000) river basins. During 2008, the level of the reservoirs, which normally are responsible for 80% of the country's energy production along these basins, reached values lower than 20% of their long-term mean. During the 2007 winter, hydroelectric plants satisfied all domestic demand; however, in 2008 the continuing drought forced oil-fired plants into full operation, burning expensive imported oil to feed the power grid.

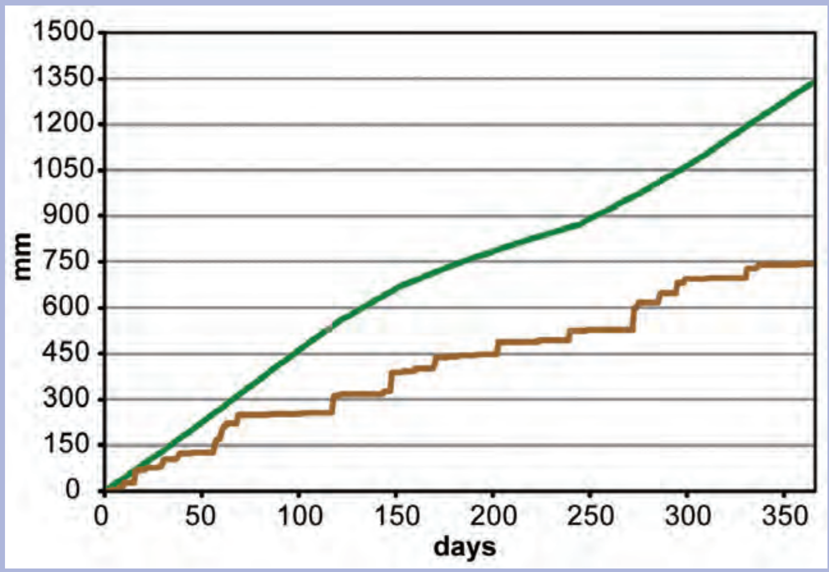

Fig. 7.14. Accumulated rainfall at Salto (Uruguay) during 2008 (brown) an accumulated normal (green). (Source: CIIFEN 2008.)

e. *Africa*

1) Northern Africa—K. Kabidi, A. Sayouri, R. Sebbari, S. Attaher, A. Khalil, and M. Medany

The year 2008 was characterized by several extreme weather events, including periods of heavy rainfall, heat waves, cold outbreaks, and strong winds. Several records were broken and the annual mean temperature for northern Africa continued to rise.

(i) Temperature

In northwest Africa (mainly Morocco, Algeria, Tunisia, and Libya), the annual mean temperature was 1° to 2°C above the 1968–96 normal in many regions. Winter was exceptionally cold with temperatures generally 0.5° to 3°C below normal and daily minimum temperature records broken at many locations. In contrast, spring was more than 2°C above the long-term average over most parts of Morocco. During the summer, exceptional heat waves occurred across the region, with above-average maximum temperatures in several locations. Tanger (Morocco) experienced summer temperatures 3.3°C above normal.

In Egypt, the annual mean temperature was 1.9°C above the 1961–90 reference period (Fig. 7.15). All weather stations across Egypt indicated an annual mean minimum temperature of 1.3° to 5.7°C above normal. Stations on the northern coast recorded annual mean temperature anomalies of –0.5° to –1.2°C, whereas all other stations indicated annual mean temperatures that were 1.2° to 5.6°C above normal. Annual mean maximum temperatures were below normal for northern Egypt with anomalies ranging from –0.2° to –3.9°C. In the central region, the annual mean maximum temperature was 1.3° to 5.5°C above normal.

(ii) Precipitation

In northwest Africa, spring and summer 2008 were characterized by low rainfall totals, with March expe-

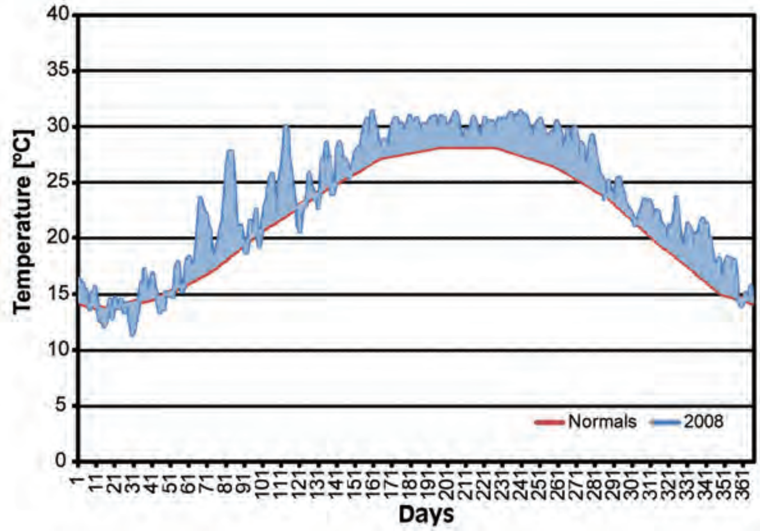

Fig. 7.15. Daily mean temperature for 2008 and the long-term average for Egypt. (Source: Weather Service in Egypt.)

riencing a deficit of more than 90%. However, autumn and winter 2007/08 were characterized by significant rainfall, especially across the northern regions. For October, many weather stations in Morocco, Algeria, and Tunisia reported 24-hr rainfall totals exceeding 200 mm. In Algeria, September, October, and November saw many locations registering monthly rainfalls 4 to 7 times their monthly average. Similarly in Morocco, October and November brought rainfall that was more than 300% of the monthly means. However, in Egypt both the number of the rainy days and the total precipitation for 2008 were near normal.

(iii) Notable events

Several high daytime temperature records were set over the region in 2008. New records were set for Kenitra (Morocco) with a temperature of 49.8°C on 1 July (Fig. 7.16), Tanger Aero with 37°C on 27 June, and 24.4°C on 3 April for Tanger Port. A number of low nighttime records were also broken. For example, Tanger Port recorded 9.7°C on 13 April, and Housaima and Taourirte had a minimum temperature of 7.6°C and 6.8°C, respectively, in October. Heavy precipitation occurred in October, with 24-hr rainfall records set in Larache and Chefchaouen at 108 and 117 mm, respectively, on 31 October, while 200 mm was observed at Tanger Port on 23 October.

In Egypt, strong winds (known as "The Khamaseen") and sandstorms typically occur during February to April. In 2008, there was a large number of these events, with an average wind speed of 8 m s^{-1} and an average horizontal visibility of 4 to 6 km. On 8 June, a sandstorm hit Cairo at noon with wind speeds reaching 11 m s^{-1} and maximum temperatures around 4°C above normal.

2) Western Africa—L. N. Njau, M. A. Bell, and W. M. Thiaw

Western Africa extends from the Guinea coast to Chad and the Central African Republic. 2008 was characterized by above-average rainfall in the west, while below-average rainfall was observed in the southeast.

(i) Temperature

Overall, the annual mean temperature for most of the western Africa countries was near average in 2008. In August 2008, mean temperature anomalies above 1.5°C were observed in northeast Niger, northwest Chad, and western Nigeria and across into Benin, while mean temperature anomalies below –1.5°C were observed in south Mauritania across into Mali.

(ii) Precipitation

Precipitation totals during the May–October 2008 rainy season were mostly near or above the 1971–2000 average in the western sections of the region, except for southeastern Côte d'Ivoire and central Guinea. However, they were below average in several areas farther east, including southeastern Nigeria, Cameroon, eastern Chad, and the central region of the Central African Republic (Fig. 7.17).

The evolution of the rainy season in western Africa was extremely variable. Areas with precipitation deficits during one month would often receive above-

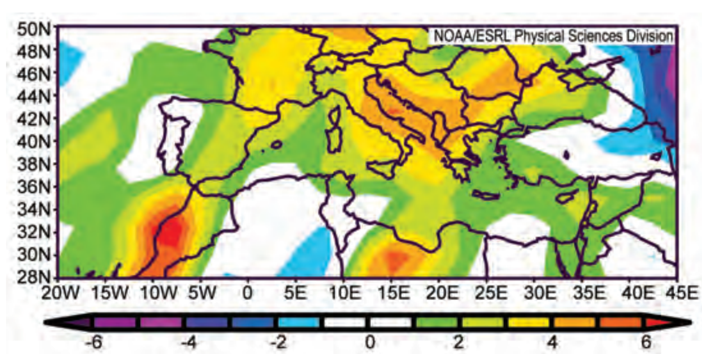

Fig. 7.16. Daily maximum temperature anomalies on 1 Jul 2008 for northern Africa (°C, 1968–96 reference period). (Source: CDC, NOAA.)

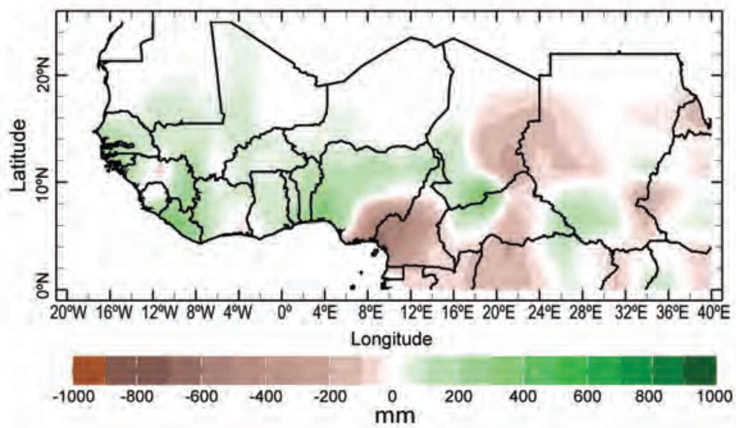

Fig. 7.17. May to Oct 2008 accumulated precipitation anomalies (mm) for western African (1971–2000 reference period). (Source: GPCC, Version 2 Monitoring Product.)

average rainfall during the following month. In April, at the start of the rainy season, monthly precipitation values were as much as 50 mm below the 1971–2000 normal in southern Benin and neighboring areas of Nigeria and Togo. In May, there was a general increase in precipitation totals in the western regions of the Guinea coast (with the exception of southeastern Liberia), with mixed anomalies observed farther east. With the exception of southern Benin and surrounding areas, where precipitation was as much as 150 mm above average at some stations, precipitation along the Guinea coast was below average in June. In contrast, rainfall in the western Sahel, and particularly in Senegal, was well above average, with some stations receiving two and one-half times their mean June total. July also brought significant rainfall to much of western Africa, with notably large accumulations, and some flooding in southern Chad, the western sections of the Central African Republic, and Senegal. Dry conditions continued to develop in July in southeastern Nigeria and much of Cameroon. In August, above-average precipitation was observed across the region but was followed by mixed conditions in September, including another round of heavy precipitation in southern Chad and a general reinforcement of dry conditions in eastern Nigeria and much of Cameroon that persisted into October.

3) Eastern Africa—B. Osman-Elasha, C. Oludhe, and L. Ogallo

Eastern Africa can be divided into three main sectors: southern, equatorial, and northern. The southern sector, which comprises central and southern Tanzania, normally experiences a unimodal type of rainfall regime, with rainfall occurring between December and April. The equatorial sector, made up of northern Tanzania, Kenya, southern Ethiopia, southern Sudan, and southern Somalia, generally exhibits a bimodal rainfall regime, with the "Long Rains" season occurring from March to May and the "Short Rains" occurring between October and December. In the northern sector, comprising central and northern Sudan, northern Ethiopia, Eritrea, and Djibouti, the major rainy season occurs during the months of June to September.

(i) Temperature

In Sudan, the mean temperature was near to below normal from January to April. For the rest of

HEAVY RAINS AND FLOODS IN WESTERN AFRICA—L. N. NJAU

Heavy rainfall across western Africa brought flooding to the region, threatening the homes and livelihoods of more than 50,000 people in seven western African countries during the period from 15 July to 4 August. Six fatalities were reported in Mali, while the rising waters of the Senegal River displaced about 4,600 people in southern Mauritania. In Togo, 10,000 people were displaced by the swollen Hao and Zio Rivers. At least nine deaths were reported as floods submerged several villages in Togo.

In early July, the Red Cross estimated 7,000 people in Benin were affected by floods. Storms during the last week of July affected 9 out of 13 districts in Benin with entire neighborhoods under water. From 30 July to 3 September, the World Health Organization reported 192 cases of cholera in three districts of Cotonou with more than 10,000 people displaced by floods.

On 18 July, at least seven deaths were reported and 2,000 displaced after heavy rains in the Zinder region in Niger, while on 8 August, 30 people died in Burkina Faso after a landslide. In Chad, during the period 20 July to 25 August, over 10,000 people were displaced by floods around the southern town of Sahr.

On 20 July, intense rainfall over the Liberian capital Monrovia resulted in one of the worst floods on record, with nearly 1,000 people forced out of their houses.

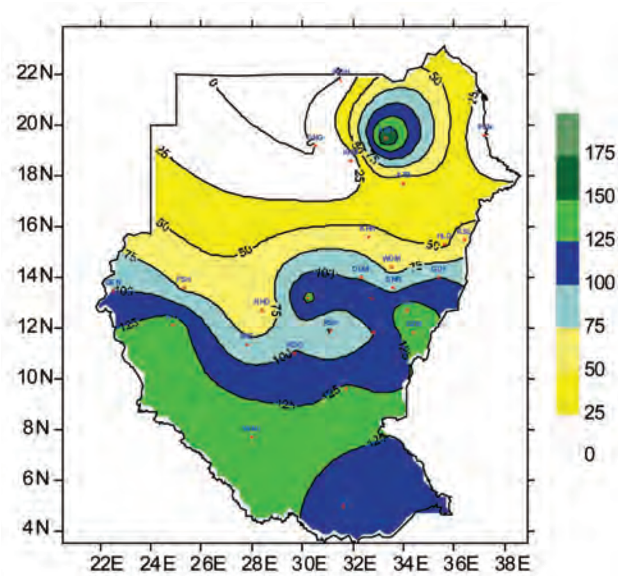

Fig. 7.18. Jun to Sep 2008 Sudan total rainfall expressed in percentage of normal (1971–2000 reference period). (Source: National Weather Service of Sudan.)

the year, mean temperatures were near to above the 1971–2000 average. The highest temperature for the year (48.0°C) was recorded in July at Dongola, located in the northern region, and at Port Sudan on the Red Sea coast. The lowest temperature was 4.0°C reported in February at Dongola.

(ii) Precipitation

In Sudan, the rainy season usually extends from June to September. Rainfall started early in some regions and late in others. From mid-July to mid-August, delayed below-average rains were recorded in the western regions of Kordofan, Gezira, and Kassala states. This resulted in negative impacts to agricultural crops, particularly those planted after the onset of the rains. Timely rainfall with good distribution was experienced in many areas of eastern Sudan, including the Blue Nile, Sennar, and Gadaref states. From mid-August onward, most areas received normal-to-above-normal rainfall, largely compensating for the low rainfall in July and enabling a late planting of crops and hence a general improvement in food security. Normal-to-above-normal rainfall continued until mid-September but shifted to drier-than-average conditions toward the end of the season (Fig. 7.18). Overall, the June to September total rainfall was above the 1971–2000 average in the south, while it was below average in the north of Sudan. In Djibouti, only 3.5 mm of rain was received for the year until 29 October, after which 136 mm fell in the next six days, including 110 mm in the two days 3–4 November, exceeding the annual average.

The GHA consists of southern Sudan, Ethiopia, Uganda, Kenya, Somalia, and Tanzania. In January, much of the southern region (including Uganda, Kenya, and Tanzania) received from 10 mm to over 100 mm of rainfall. March marked the beginning of the "Long Rains" season over the equatorial sector, while most rainfall for the northern GHA occurred in the period from June to August. This season was marked by wet conditions over the central areas of the northern GHA, namely western Ethiopia and southwestern Sudan, where more than 100 mm was recorded during the month of August.

The accumulated totals for selected stations indicate near-average rainfall for the northern sector (Fig. 7.19a), below-average rainfall for the equatorial sector (Fig. 7.19b), and above-average rainfall for the southern sector (Fig. 7.19c). These cumulative rainfalls are used to evaluate water stress over various parts of the GHA regions.

In September, rainfall conditions were associated with poor pastures and water stress for livestock in the eastern and northern regions, improved agricultural

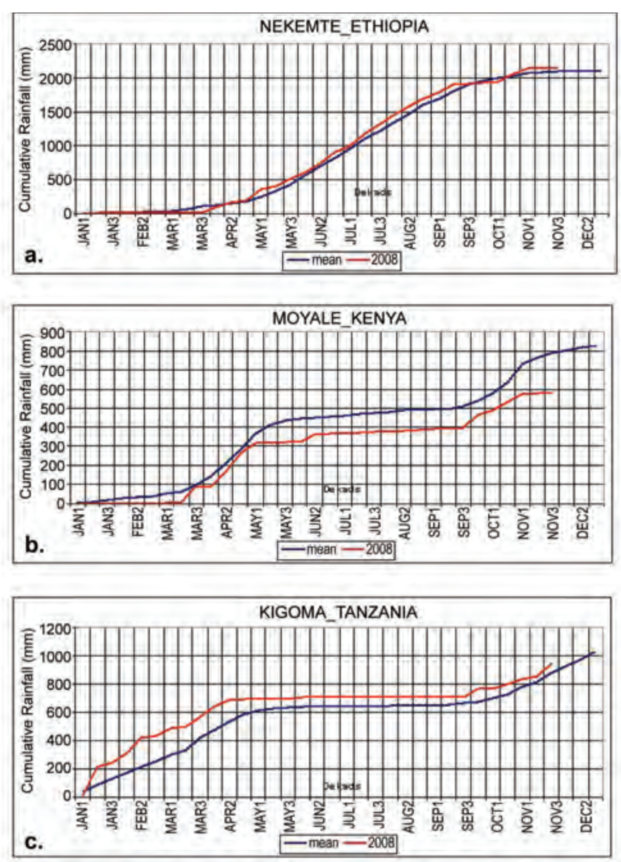

Fig. 7.19. Cumulative rainfall over (a) the northern sector (Nekmite, Ethiopia), (b) the equatorial sector (Moyale, Kenya), and (c) the southern sector (Kigoma, Tanzania). (Source: ICPAC 2008.)

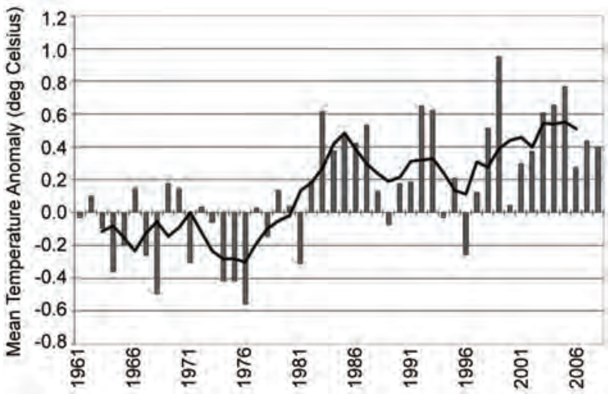

Fig. 7.20. Annual mean temperature anomalies for South Africa, 1961–2008 (1961–90 reference period). The dark line represents a 5-yr running mean. (Source: South African Weather Service.)

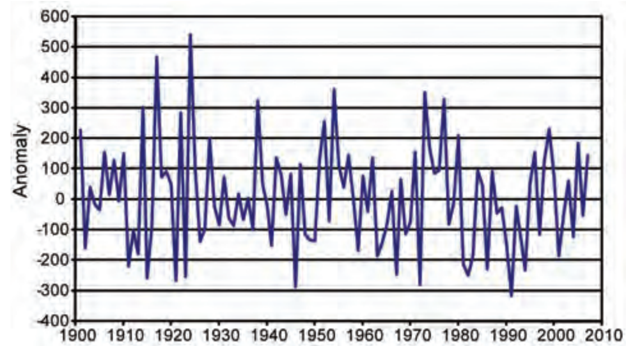

Fig. 7.21. Annual total rainfall anomalies for Zimbabwe, 1900–2008 (mm; 1971–2000 reference period). (Source: Meteorological Service Department of Zimbabwe.)

productivity over the western and northern regions, floods in most parts of the northern and western equatorial regions, and increasing cases of malaria in the western equatorial sector and parts of the northern regions due to an increase in moisture availability and breeding places for mosquitoes.

4) Southern Africa—A. Mhanda, W. Zhakata, C. Mutasa, M. S. Gamedze, A. Kruger, W. M. Thiaw, and C. McBride

(i) Temperature

In Zimbabwe, monthly mean temperatures were close to their long-term (1971–2000) average with no records broken in 2008. However, in Swaziland, the temperatures were warmer than average over most parts of the country. In Lesotho, the year was generally warm, with the annual mean temperature about 0.3°C above normal.

For South Africa, 2008 was approximately the 13th-warmest year since nationwide averages began in 1961 (Fig. 7.20). Monthly mean temperatures were near the 1971–2000 average in most regions. In March, the maximum temperature anomalies were mostly negative over the greater part of the country. Extremely cold conditions over the western and northern interior resulted in numerous new lowest maximum and minimum temperature records for the month. In contrast, May brought mostly positive temperature anomalies over the country. In September, temperatures followed the rainfall pattern with mostly below-average temperatures in the wetter western regions, and above-normal temperatures over the remainder of the country where it was dry. With the exception of the southern and eastern coastal regions, the country experienced above-average temperatures during December.

(ii) Precipitation

In Zimbabwe, the rainy season extends from October to the following April. The Zimbabwe national average rainfall for October 2007 to April 2008 of 795.8 mm was well above the 1971 to 2000 average of 650.7 mm (Fig. 7.21). Although most of the country received normal-to-above-normal rainfall, the temporal distribution was skewed, with the bulk of the rain falling in the first part of the season (October to December 2007), with the second part of the season (February to April) recording below-average totals.

In Swaziland, the rainy season is typically from October until April. The 2007/08 rainy season started late, with drier-than-average conditions during the

Fig. 7.22. Annual total rainfall anomalies for South Africa (expressed as percentage of the 1961–90 average) for Jul 2007 to Jun 2008. (Source: South African Weather Service.)

EXTREME WEATHER IN SOUTH AFRICA—A. KRUGER AND C. MCBRIDE

A number of significant weather events took place in South Africa during 2008 with associated humanitarian and economic consequences. Strong winds with associated wildfires occurred in the Western Cape in January and February. Heavy rains with flooding occurred in the eastern interior in January and cases of heavy rainfall and gale-force winds occurred in February, causing loss of life and building collapses. February also saw one person killed and more than 500 left homeless when a suspected tornado struck in the Eastern Cape, while freak waves on the east coast at Durban drowned one person with 18 others rescued. Incidents of heavy rainfall and flooding in the east continued in March, while in Cape Town a gale-force southeasterly wind fanned wildfires, leaving more than 100 people homeless. In June, floods in the Western Cape displaced a number of residents, while in the eastern province of KwaZulu-Natal, rivers burst their banks and media reported that four people perished. Incidents of heavy rainfall and flooding in the Western Cape continued throughout July.

In August, incidents of wildfires increased over the dry central and eastern regions. In October, unseasonable hailstorms caused widespread destruction in the east in the Mpumalanga province, with significant impacts on the fruit export industry. Several devastating storms, including reports of a tornado, hit the Free State province during November. Eight people died, homes were destroyed, and roads damaged. In December at least 10 wildfires raged over the Cape peninsula, causing extensive damage.

months of December 2007 and January 2008. As this dry spell coincided with the warmest months of the season, a major crop failure occurred in the eastern half of the country. In Lesotho, rainfall amounts were near normal.

In South Africa, the rainy season is October to March over much of the country, but May to September in the southwest. The rainy season from July 2007 to June 2008 was near average for most of the country, with the noteworthy exception of the southwest, which received 150%–200% of its average rainfall. In contrast, locations in the east received less than 75% of their rainy season totals (Fig. 7.22).

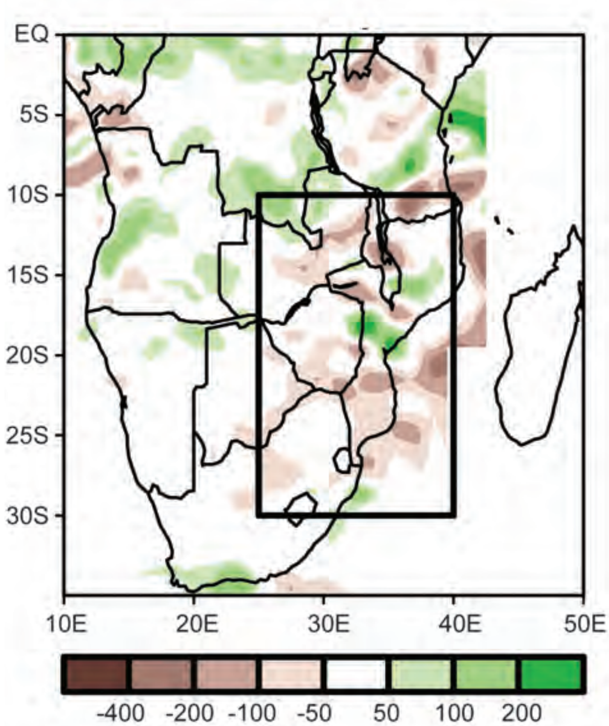

Fig. 7.23. Total rainfall anomalies over southern Africa for Nov 2007 to Apr 2008 (mm). The black box denotes areas that are climatologically wet during summer. (Source: NOAA.)

The southern Africa summer features two basic climate zones. The climatologically wet zone (shown as a box in Fig. 7.23) registered rainfall amounts between 300 and 1,200 mm. Rainfall in the climatologically dry zone, the area that encompasses western South Africa, much of Namibia, and western Botswana, received 100 to 300 mm. Overall, the November to April rainfall season for southern Africa did not exhibit a significant departure from climatology during the 2007–08 season (Fig. 7.23). However, the southern areas of Mozambique and Zimbabwe, southern Zambia, Malawi, and southern Tanzania recorded rainfall totals 50 to 200 mm below normal, while areas of central Mozambique received amounts about 200 mm above average.

f. Europe

1) Overview—A. Obregón, P. Bissolli, J. J. Kennedy, and D. E. Parker

Europe commenced the year under a strong zonal (positive) North Atlantic Oscillation (NAO) pattern, which continued until March, when a blocking pattern developed over Russia resulting in a strong meridional pattern during April. May saw high pressures dominate northern and central Europe, followed by cyclonic conditions during summer across central Europe with frequent thunderstorms. A negative phase of the Arctic Oscillation brought cold Arctic air into

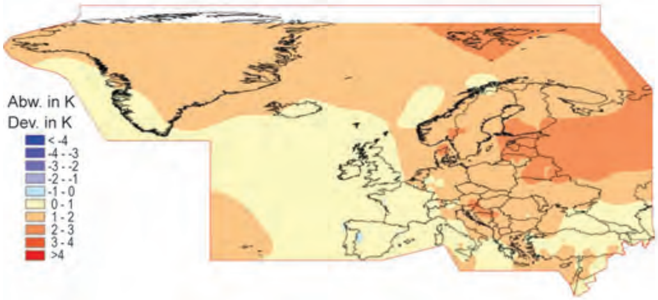

Fig. 7.24. Annual mean temperature anomalies in Europe and over the North Atlantic, 2008 (°C, 1961–90 base period) based on CLIMAT and ship observations. [Source: DWD.]

northeastern, and at times central and southern, Europe from April to September. Conversely, southwesterly flow during summer across southeastern Europe resulted in several heat waves. In October, a blocking pattern established over Russia and remained for much of the year, producing mild conditions over eastern Europe and colder air masses over western Europe. In November, a deep trough extended from Scandinavia to Iberia. The year ended with very cold air flowing from the high latitudes to southeastern Europe and the Middle East on the eastern flank of a central European high pressure system.

Overall, warmer-than-average conditions in 2008 extended across most of Europe.[2] The mean land surface temperature for the European region (35°–75°N, 10°W–30°E), derived from the CRUTEM3 dataset (Brohan et al. 2006), was 1.16° ± 0.17°C above the 1961–90 mean. This made 2008 (with 2006) the fourth-warmest year for Europe since 1850. The highest temperature anomalies occurred in Svalbard, the Baltic countries, eastern Europe, and parts of southern Fennoscandia, where anomalies exceeded +2°C (Fig. 7.24). Lithuania reported its warmest year, while Latvia and Denmark experienced their second-warmest year since records began. Only a few places in southwestern Europe reported a cooler-than-average temperature in 2008.

Rainfall for Europe during 2008 was unevenly distributed both spatially and temporally (Figs. 7.25a–d), and the year was characterized by several notable storm events with some extremely intense and heavy precipitation. Annual precipitation (Fig. 7.26) was mainly above the long-term (1951–2000) average in northern and western parts of Europe and below average in southern Europe. Less than 80% of normal precipitation was observed in Bulgaria, Greece, and the Middle East. Some areas of Finland, Sweden, the United Kingdom, and Ireland received over 125% of normal precipitation.

Winter featured a dipole structure, with warmer-than-normal conditions and above-average rainfall in northern parts of Europe and closer-to-average temperatures and very dry conditions in southern Europe (Figs 7.27a, 7.25a). Iberia in particular was affected by severe drought conditions during February. Southwesterly winds were predominant during the winter and coincided with anomalously high sea surface temperatures in the North Atlantic. This led to an exceptionally warm winter in most of northern Europe with many temperature records broken. In contrast, unusually cold and dry conditions prevailed during winter across the Middle East (see section 7g).

During spring, temperatures were mostly above average across Europe with the highest positive anomalies over eastern Europe (Fig. 7.27b). Temperatures during May were well above average in central and western Europe (Fig. 7.28). Eastern Europe, France, and Iberia received above-normal rainfall during the spring, while precipitation in central Europe and

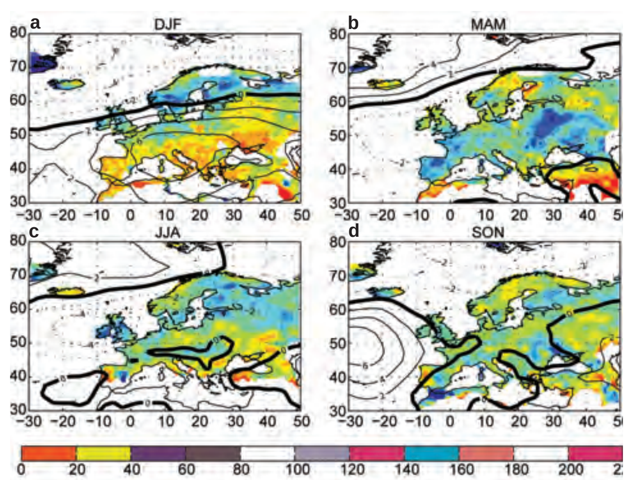

Fig. 7.25. Seasonal anomalies (1961–90 reference period) of sea level pressure (contour, hPa) using data from the NCAR–NCEP reanalysis. The colored shading represents percentage of accumulated seasonal precipitation compared with the 1951–2000 climatology using the seasonal GPCC precipitation data set: (a) winter (Dec 2007–Feb 2008), (b) spring (Mar–May 2008), (c) summer (Jun–Aug 2008), and (d) autumn (Sep–Nov 2008). Some intense precipitation anomalies in the southern Mediterranean during seasons when it usually rains very small amounts are filtered out.

[2] The standard reference period used for European averages is 1961–90 for temperature, and 1951–2000 for precipitation, unless otherwise expressly identified.

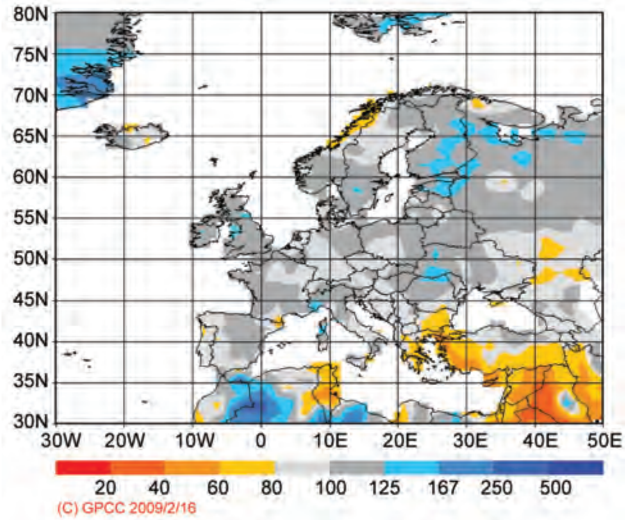

Fig. 7.26. European precipitation totals (percentages of normal, 1951–2000 base period) for the whole year 2008. (Source: GPCC; Rudolf et al. 2005.)

parts of northern Europe was close to or below the long-term average. Precipitation was particularly low in central Europe during May (Fig. 7.29).

During summer 2008, eastern Europe and northern parts of the Balkan Peninsula experienced well-above-average temperatures, with August being a particularly hot month. Conversely, August was colder than normal over northeastern Europe, particularly in Finland and northern Russia (Fig. 7.30). Summer was dry for the southern parts of Europe, particularly over western Iberia and Turkey [see section 7g4(iii)], while northern European regions received mainly above-average rainfall.

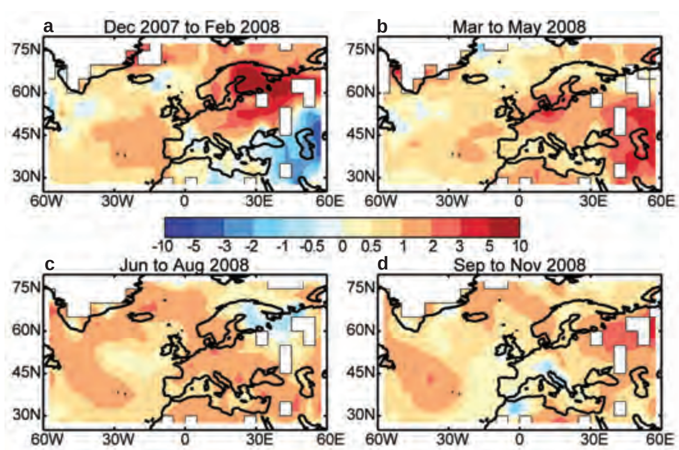

Fig. 7.27. European surface air temperature anomalies (°C, 1961–90 base period) from HadCRUT3 for (a) Dec 2007–Feb 2008, (b) Mar–May 2008, (c) Jun–Aug 2008, and (d) Sep–Nov 2008.

During autumn, the highest temperature anomalies occurred over the Arctic and the eastern and southeastern parts of Europe, while western Europe was average to colder than average. Iberia in particular had an extremely cold November.

The year ended with colder-than-average conditions over virtually all of western Europe and the Middle East. Anomalous warmth was widespread over northern, eastern, and southeastern Europe. December was drier than normal in most parts of Europe, but very wet south of the Alps and over the central Mediterranean.

2) Central and Western Europe—A. Obregón, P. Bissolli, J. J. Kennedy, and D. E. Parker

(i) Temperature

Warmer-than-average temperatures affected central Europe during 2008. At stations in Slovakia, 2008 was the warmest year since records began in 1871. In most parts of Austria, 2008 ranked among the five warmest years. Due to frequent southerly foehn events, valleys in the northern Alpine region experienced temperature anomalies above +1.3°C. In Germany, Austria, Switzerland, and the Czech Republic, September was the only month that recorded below-average temperatures.

Over western Europe, annual temperature anomalies were generally lower than in central regions. For the United Kingdom and Ireland, despite temperatures 0.6°C above normal, 2008 was one of the coldest years in the last decade. France experienced mean temperature anomalies of around +0.4°C, while the Netherlands recorded +0.8°C.

In Germany, the mean winter anomaly of +2.7°C was the sixth warmest on record. Belgium reported its fourth-warmest winter (+2.1°C anomaly), while the winter temperature anomaly for the United Kingdom was +1.6°C, which, although high, was cooler than in 2006/07. January was particularly mild throughout western and central Europe.

Much of Europe was also warmer than average during May (Fig. 7.28). It was the warmest May on record in the United Kingdom, at most stations in Ireland, Uccle (Belgium), and Luxembourg. May was also exceptionally warm across Switzerland and the Netherlands—it was the warmest May in De Bilt for more than a century—and it was the fourth-warmest May on record for France. On 28 May, a heat wave in Graz (Austria) saw a new May record temperature of 34.9°C.

In contrast, summer was one of the coldest since the turn of the century, particularly over

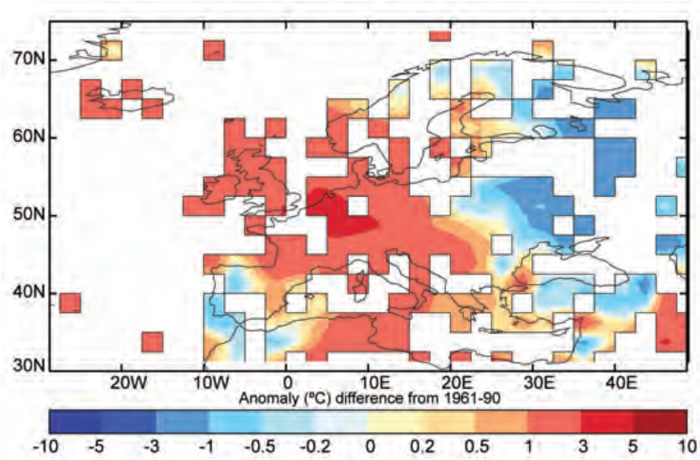

Fig. 7.28. May 2008 mean temperature anomalies in Europe, (°C, 1961–90 base period), based on CRUTEM3 dataset (Source: Brohan et al. 2006).

western Europe. Despite such relatively cold conditions, temperatures were still above the 1961–90 average throughout most of central and western Europe, with anomalies generally around +1°C.

In September, most countries were approximately 1°C cooler than average. In western Europe, the cold conditions continued into October. It was the coldest autumn at many stations in Ireland for 10 years and in the United Kingdom for 15 years. During the last week of October, some stations in the United Kingdom set new October records for low maximum temperatures. In contrast, Switzerland was warmer than average, with temperatures up to 20°C on the plains and 15°C at elevations of 1500 m. November ended with a cold spell across western and central Europe. On 29 November, the average Northern Ireland maximum temperature (1.9°C) was the lowest November maximum temperature since such records began in 1960.

December 2008 was colder than normal over western Europe (–2°C and below in western France) and up to +3°C warmer than normal in the east. It was the coldest December since 1996 for Northern Ireland. It was also a sunny month especially in northern parts of central Europe. In the Netherlands (station De Bilt) it was the sunniest December since records began in 1901.

(ii) Precipitation

In 2008, above-average precipitation was recorded over most of western Europe and northern parts of central Europe. The United Kingdom experienced its third-wettest year in a national rainfall series that begins in 1914, with 118% of the 1961–90 annual mean rainfall. Rainfall totals in Ireland were well above average. Shannon Airport recorded its highest precipitation total since observations began in 1945. In central Europe, precipitation was close to or slightly below average, with the exceptions being eastern Austria (>110%) and the southern Alpine region (120%–140%).

Due to mild temperatures during the winter, no snowfall was measured during all three winter months at most locations in central and western lowland parts of Switzerland. Basel and Geneva registered their first snowfall of the year at the end of March, the latest arrival of snow since measurements began in 1931. Austria, too, received little snow, just 10%–30% of the winter average.

During January, precipitation exceeded 250% of average in parts of northern England and southern Scotland. It was the wettest January in eastern Scotland and the second wettest in Northern Ireland since 1914. Poland was also exceptionally wet during January. In contrast, February was dry over Austria, especially in the southeast (<25% of the 1961–90 mean) and in parts of Switzerland and southern France (around 50% or less).

England experienced its wettest March since 1981, Scotland since 1994. Luxembourg reported 185% of normal rainfall in March, the Czech Republic 153%, northeastern Poland and parts of upper Austria more than 200%, while March brought more snow to Austria than the preceding winter months. In contrast, May was exceptionally dry in Ireland, most of the United Kingdom except the south, and most of central Europe. It was the third-driest May in Germany since 1901 and the driest since 1919.

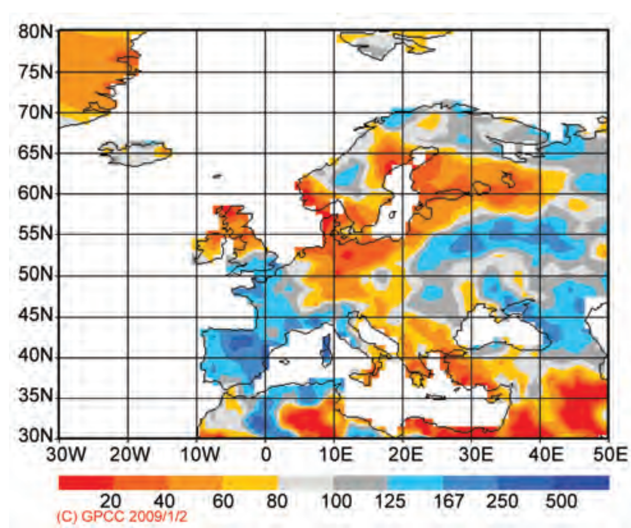

Fig. 7.29. European precipitation anomalies (percentages of normal, 1951–2000 base period) in May 2008. (Source: GPCC; Rudolf et al. 2005.)

Summer precipitation was more than 167% of normal in eastern Ireland. Dublin Airport experienced its wettest summer in 50 years. In June, 300% of the 1961–90 normal precipitation fell south of Vienna and parts of eastern Austria registered their wettest summer on record. Poland was very dry in June. In Lugano, Switzerland, it was the second-wettest July since 1864 (359 mm). The Netherlands reported 111 mm of rainfall in July (70 mm average) and 100 mm in August (82 mm average). August was very wet across northern and central France, much of the United Kingdom (154%), and Ireland. In Northern Ireland, it was the wettest August since records began in 1914 (anomaly 213%).

In September, some stations in England recorded around 300% of their monthly normal (1961–90) rainfall. Scotland experienced its fourth-wettest October on record and the wettest since 1954. Luxembourg Airport reported 162% of average (1971–2000) precipitation in September and set new records for hourly and daily rainfall amounts. During a cold spell at the end of October, snow was registered in many places. London received snow in October for the first time since 1934. New record fresh snow depths for this month were also measured on 30 October in many places in Switzerland; October snow events are extremely rare in the lowlands of Switzerland. A fresh snow depth of 20 cm in Zurich beat the previous October record of 14 cm set in 1931. Between 31 October and 2 November, France was affected by flooding after up to 500 mm of precipitation fell in the region west of the Rhône River in the southeast of the country.

December brought a record snow depth for that month of 38 cm in Switzerland's capital Bern. In Austria, a new record snow depth for December of 125 cm was reported from eastern Tyrol's capital Lienz. December precipitation was also well above average in southeast France and was up to 400% of normal over southern Austria, largely due to persistent low pressure in the Gulf of Genoa. Southern Alpine regions experienced heavy snowfalls until the middle of the month.

(iii) Notable events

Heavy storms occurred over central Europe between 26 and 28 January. Gusts of up to 46 m s^{-1} were measured in Austria, where the storm Paula caused massive forestry losses. On 1 March, another storm, Emma, brought strong winds to western and central areas, reaching hurricane strength over the mountains and bringing heavy precipitation with local flooding. Infrastructure disruptions and at least 14 fatalities were reported. Strong winds also affected the United Kingdom, France, and Germany on 10–12 March and a pressure of 953.6 hPa was recorded in Northern Ireland, the lowest since 1995.

Snow fell over much of the region during a cold spell on 20–26 March. In some places over central Europe, it was the coldest Easter on record. Temperatures remained below 0°C at many stations in Germany and Switzerland on Easter Sunday.

Tennis-ball-size hail was reported in western Germany on 30 May. On 22 June, thundery showers with strong gusts and hailstones of approximately 5-cm diameter caused much damage in the eastern Netherlands. Unusually heavy thunderstorms with hailstorms occurred in Austria in all three summer months, causing flooding and large agricultural losses. During August, several tornadoes occurred in northern Germany and France, Belgium, and the Netherlands.

3) The Nordic and Baltic countries—C. Achberger, A. Walther, D. Chen, A. Obregón, P. Bissolli, J. J. Kennedy, and D. E. Parker

(i) Temperature

Similar to recent years, annual temperatures over the Nordic region (Denmark, Finland, Iceland, Norway, and Sweden, including the European Arctic) and the Baltic countries were characterized by positive anomalies. They ranged between 0° and +1°C for Iceland and the Faroe Islands, +1° and +2°C in most of Fennoscandia and Denmark, and +2° and +3°C for Svalbard, southeastern Norway, southern Finland, and most of the Baltic States (Fig. 7.24). This was mainly due to exceptionally high temperatures during the winter of 2007/08 (Fig. 7.27).

Widespread anomalous warmth was present over the European Arctic in 2008. The island Hopen, in the Svalbard archipelago, experienced a temperature anomaly of +2.8°C. The island of Jan Mayen (northeast of Iceland) had an annual average temperature of 0.7°C, 2.1°C above normal.

For Iceland, 2008 was the 13th consecutive warmer-than-average year. The Icelandic capital Reykjavik reported an annual temperature anomaly of +1.0°C. Temperatures during May to September were unusually high in the south and west. Reykjavik reported a new all-time record of daily maximum temperature at 25.7°C on 30 July. In September, Reykjavik was more than 3°C warmer than normal. October was the only colder-than-average month on Iceland.

In Norway, Sweden, and Denmark, annual mean temperatures were well above normal (Norway:

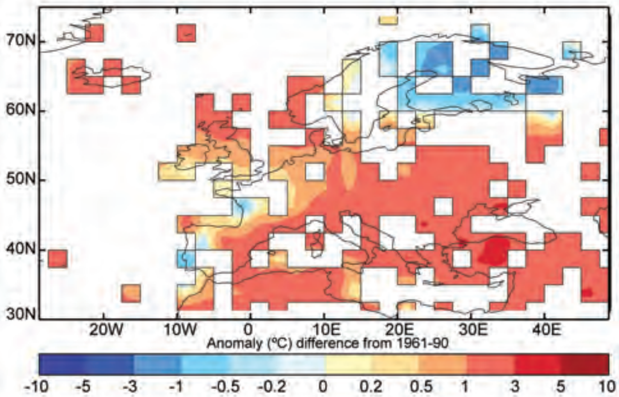

Fig. 7.30. Aug 2008 mean temperature anomalies in Europe (°C, 1961–90 base period), based on CRUTEM3 dataset (Source: Brohan et al. 2006).

+1.4°C; Sweden: +1° to +2.5°C). It was the second-warmest year in Denmark (along with 2006), with an annual mean temperature of 9.4°C, +1.7°C above normal. The last three years were the warmest ever recorded in Denmark.

For Finland, 2008 was among the six warmest years since measurements started in 1850. Southwestern and most of southern Finland experienced the warmest year in those areas since 1961, while the capital, Helsinki, set a new mean temperature record (7.6°C). For the first time since temperature measurements started in Helsinki in 1829, all monthly mean temperatures were above 0°C.

It was the warmest year in Lithuania, where the annual mean air temperature of 8.2°C was 2°C higher than the 1961–90 average. Latvia reported its second-warmest year over the last 85 years (+1.8°C anomaly).

(ii) Precipitation

Precipitation during 2008 was mostly above the long-term average. The highest anomalies occurred in southeastern and southwestern Finland, where precipitation was 150%–200% of the 1961–90 normal. In Kemiö, 1,064 mm of precipitation was recorded, the second-highest total recorded in Finland in the last hundred years. However, due to mild temperatures, only 20–30 snow days (where a snow day is a day with at least 1 cm of snow lying on the ground) were recorded in southern and southwestern Finland during winter, well below the normal of more than 70 days. Latvia had an annual precipitation total of 757 mm (115% of normal). In Sweden, precipitation totals locally reached 175% of normal partly due to a wet winter. Denmark received 110% of normal precipitation; a very dry May partly compensated for wet conditions during January, March, and August. Annual precipitation was close to normal in Norway, although some southern parts received 50% more than normal. Parts of the European Arctic experienced well-above-average precipitation. Ny-Ålesund on Svalbard reported 128% of average precipitation. On Iceland, precipitation was close to normal in the north and east, but for the southwest of the island, 2008 was a wet year (Reykjavik 117%). Tórshavn on the Faroe Islands had 115% of the 1961–90 normal rainfall.

Winter 2007/08 proved to be much wetter than normal across the Nordic countries. Norway experienced over 145% of normal, parts of eastern and northern Norway over 200%; Denmark received 125% of normal. Lithuania recorded more than 150% of the normal (1961–90) monthly total in both January and February. April was dry in Iceland, with Stykkishólmur experiencing its driest April since 1951. May was a significantly dry month in most of the Nordic region, especially Denmark, southern Finland, and the Baltic States (Fig. 7.29). Denmark had its fourth-driest May on record with only 13 mm of precipitation averaged over the country (normal 48 mm).

Summer was wetter than average in Finland, most of Sweden, and Denmark, mainly due to an exceptionally wet August (218% anomaly from 1961–90 in Denmark, the wettest August in 40 years). June was exceptionally dry in Reykjavik (30% of normal).

Large parts of Sweden received less than 25 mm of precipitation in September, which is less than 40% of normal. Lithuania saw less than half its normal (1961–90) precipitation in September. In contrast, September was a very wet month for Reykjavik (>250% of the normal), and Stykkishólmur on the west coast recorded its wettest September since 1856.

The year ended with a drier-than-normal December, especially on the west coasts of Norway, Sweden, and Denmark.

(iii) Notable events

Norway's capital Oslo was affected by some heavy storms in 2008. On 1 February, a snowstorm forced Oslo's airport to close for several hours. On 5 July, the city was again affected by an intense thunderstorm causing heavy rainfall and flooding. Gusts up to 27 m s^{-1} were reported. Gothenburg, Sweden, was hit by a heavy storm with hurricane-strength winds on 22 February, disrupting power for many hours. The severe storm also reached the coast of Lithuania with local wind speeds of 28–30 m s^{-1}.

MILD WINTER IN NORTHERN EUROPE—C. ACHBERGER, A. WALTHER, D. CHEN, A. OBREGÓN, P. BISSOLLI, J. J. KENNEDY, AND D. E. PARKER

Winter (December 2007–February 2008) was remarkably mild in the northern European region, mainly due to a dominant southwesterly flow, in conjunction with anomalously high sea surface temperatures in the North Atlantic. This was consistent with an ongoing positive phase of the winter North Atlantic Oscillation, which was +1.37 for December 2007–March 2008 (Jones et al. 1997; Fig. 7.31).

Mean temperature anomalies ranged between +3° and +4°C in southern Scandinavia and exceeded +4°C in eastern Sweden and most parts of Finland and the Baltic countries (Fig. 7.27a; please note the inclusion of SST anomalies in this map is likely to have diluted the coastal land air temperature anomalies in cases of sharp local anomaly contrasts, e.g., Norway). Finland experienced temperatures 4° to 6.5°C above the 1971–2000 average, some 1°C higher than the previous record set in 1925. The number of winter days (daily mean temperature below 0°C) was significantly lower than normal through central and southern Finland. There was hardly any ice cover in the Baltic Sea and no permanent snow cover in most of southern Finland. Average temperatures in Latvia were 5°C above the long-term mean. Svalbard Airport reported temperature anomalies of +7.8° and +7.3°C in January and February, respectively.

In most parts of Finland, Sweden, and the Baltic States, winter 2007/08 was the warmest in recorded history. In Norway, it was the third-warmest winter on record for the country as a whole; Denmark experienced its fourth-warmest winter and had only 18 frost days on an areal average (normal is 53). In the vicinity of Stockholm, winter was the warmest in some local series going back to the eighteenth century.

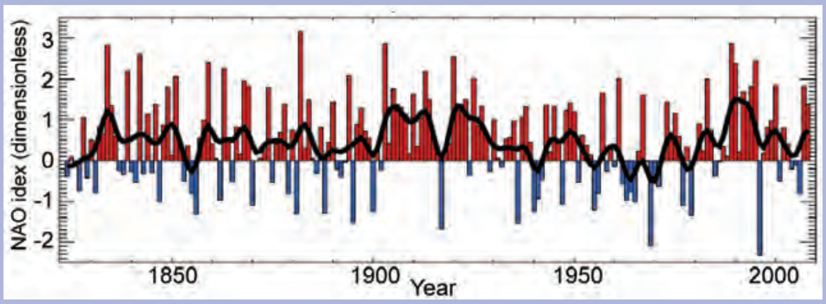

Fig. 7.31. Time series of winter NAO (after Jones et al. 1997, Dec to Mar average). Image from www.cru.uea.ac.uk/~timo/projpages/nao_update.htm, updated 27 Jan 2009.

4) Iberia—R. M. Trigo, D. Barriopedro, C. C. Gouveia, A. Obregón, P. Bissolli, J. J. Kennedy, and D. E. Parker

(i) Temperature

Although annual temperatures in Spain were slightly above average, it was the coldest year since 1996. Portugal was about 0.2°C cooler than the 1971–2000 average.

However, these annual anomalies conceal important spatial and seasonal differences. Winter 2007/08, for instance, was much warmer than average, with Seville experiencing its warmest winter since 1951. January was a particularly warm month throughout Iberia. For Portugal, the January anomaly of +1.5°C was the second warmest since 1931 (Instituto de Meteorologia 2009). Averaged over continental Spain, January mean temperatures were 1.7°C above the 1971–2000 average. The month of February was extremely mild for the southern Spanish cities of Seville, Cordoba, and Cadiz as well as for the northwestern (Galicia) stations of Santiago and La Coruña, which registered new monthly records in time series longer than 60 years.

In contrast, autumn brought significant negative anomalies with minimum temperatures in Portugal being the third coolest since 1931 (Instituto de Meteorologia 2009), largely dominated by an extremely cold November, particularly in the later days of the month. Monthly mean temperature anomalies in Portugal generally ranged between −1.5° and −2.5°C, while Spain experienced its coldest autumn since 1993.

Spring was relatively warm (+0.44°C) over Iberia and was followed by a slightly warmer-than-average summer (+0.22°C). In Portugal, it was the 15th consecutive spring with temperature anomalies above the 1971–2000 average. June was exceptionally warm over the Atlantic Spanish archipelago of Canary Islands. Monthly records were broken, including in the approximately 90-yr series of Santa Cruz de Tenerife.

(ii) Precipitation

The Iberian Peninsula generally experienced below-average rainfall in 2008, with the largest anomalies more than 20% below the long-term mean over the northern half of Portugal. In the northeastern regions of Spain, annual precipitation was slightly above average. The 2008 accumulated precipitation over the Iberian Peninsula was slightly less (around 5%) than the 1961–90 average. The year was generally characterized by periods of drought interspersed with local heavy rainfalls. From April to June and September to November, a new record daily precipitation for the respective month was set for at least one Spanish station.

Iberia experienced drier-than-average conditions during winter 2007/08, with large areas receiving less than 60% of the average (Fig. 7.25). These conditions were related to positive mean sea level pressure anomalies over western Europe and northern Africa, which, combined with 500-hPa geopotential height anomalies, suggested the northern European blocking pattern was shifted slightly southward, a feature that limits the natural progression of Atlantic low pressure systems bound for southern Europe (Trigo et al. 2004). Portugal suffered its most severe winter drought since 1917. Drought conditions in Spain prevailed until mid-April, making it Spain's worst drought for over half a century.

The following seasons revealed a very different pattern, with most of Iberia recording above-average spring rainfall (Fig. 7.25b), while there were below-(above) normal values over western (eastern) Iberia in summer and autumn. Most of the rainfall in spring occurred in the latter part of the season, although northeastern Spain was wet during March. Spring rainfall exceeded 125% of normal over most parts of Iberia, with several new records of monthly precipitation. Records set in March were largely confined to the Basque country stations of Bilbao (215 mm) and San Sebastián (238 mm); however, during the following months several new all-time records of accumulated monthly precipitation were observed over a wider area of southern (April) and coastal Mediterranean (May) provinces, including stations with more than 100 years of data (e.g., Tortosa). May was the wettest since 1971 in Spain. Heavy precipitation caused flooding in the northeast of the country.

Summer in the southwestern half of Iberia was markedly dry. Southern Portugal received less than 10 mm of precipitation, less than 20% of average. In contrast, parts of eastern Iberia were characterized by above-average summer precipitation totals, although it must be remembered that Iberia is typically extremely dry in summer.

During autumn, Portugal experienced locally very heavy rainfalls. Faro on the southern Atlantic coast set a new record of 80.4 mm within 24 hr from 28 to 29 September, while its monthly total of 147.3 mm was also its highest rainfall for September since records began in 1965. At the end of September, the heaviest rainfall for 30 years in eastern Spain caused local flooding. Valencia received an hourly rainfall amount of 144 mm, and 390 mm over 24 hr. The Gibraltar Strait also registered an extremely wet period during autumn. New daily records were set for the Spanish enclave city of Melilla (60-yr time series), with 92.7 mm on 26 September far surpassing the previous maximum of 29.4 mm. New monthly record values were also set in September (Melilla and Cadiz) and October (Melilla; see also section 7e for details on Morocco).

Despite locally heavy rainfall in Portugal, it was generally very dry between October and December. From 28 November to 3 December, there was snow during a cold spell in areas above 600 m in Portugal. The southernmost coast of Iberia was (relative to normal) much drier than the rest of Iberia in spring and much wetter in autumn.

5) Mediterranean, Italian, and Balkan Peninsulas and Eastern Europe—A. Obregón, P. Bissolli, J. J. Kennedy, and D. E. Parker

(i) Temperature

2008 was 1° to 2°C warmer than normal over most of eastern and southeastern Europe. In Belarus, anomalies exceeded +2°C, while anomalies in southern Greece, Sicily, and parts of the Italian peninsula were below +1°C. On the Balkan Peninsula, the highest departures from the normal were observed in Bosnia and Herzegovina and northern parts of Croatia. Across most of Croatia, temperatures exceeded the 98th percentile of the 1961–90 distribution. In Zagreb, 2008 was the third-warmest year after 2000 and 2007, and in Split, it was the fifth. New records of absolute maxima were recorded in Serbia in February, May, and September for several locations throughout the country.

In winter, anomalies exceeded +2°C in northern parts of Ukraine and +3°C in Belarus and northern Russia (Fig. 7.27a). Temperatures across Italy and the Balkan Peninsula were closer to the long-term mean. However, an exceptionally low number of freezing days was recorded during January in Serbia, while January was also the mildest in Moscow for 130 years (see section 7g).

Over the rest of the year, the highest temperature anomalies generally occurred over eastern Europe and northern parts of the Balkan Peninsula, while anomalies farther to the south were less pronounced. March was a particularly warm month in parts of the Balkan Peninsula and eastern Europe. In most parts of eastern Europe, monthly mean temperature anomalies exceeded +3°C. Out of all months in Athens, the highest positive anomaly was observed in March (>3°C). In Italy, the cities of Verona (27.2°C) and Ferrara (27.6°C) reported new record high March temperatures. Spring temperatures in Montenegro were in the upper decile of the 1961–90 distribution in coastal areas and northeastern parts. Farther south, a maximum temperature of 37.4°C was recorded on Crete on 22 April, one of the highest April temperatures ever measured there. At the end of May, warm Saharan air led to high temperatures in southeastern Europe. Chirpan, Bulgaria, experienced 36.2°C, and Palermo, Sicily, 38.9°C.

The summer was very warm in parts of the northern Balkan Peninsula, although heat waves were less severe than in 2007. Serbia recorded heat waves from 26 May to 3 June and from 20–27 June, while in August, its number of tropical days (>20ºC) was twice the long-term average. Mean temperature anomalies in Serbia, Bosnia, and Herzegovina as well as in Montenegro ranged around +2°C and exceeded the 98th percentile in most parts. Summer temperatures were also well above average in Athens, with highest deviations in August, which was also particularly hot in Ukraine, Romania, and Bulgaria (Fig. 7.30).

For many areas, September was the only cooler-than-average month of 2008. However, Serbia experienced a heat wave at the beginning of the month with widespread new record maximum September temperatures of more than 37°C, although cooler conditions prevailed in the second half of the month. October was unusually warm across eastern Europe. Unusually high temperatures of around 30°C occurred in southern Greece on 2 November. In December, monthly mean temperature anomalies of more than +2°C were observed across most of the Balkan Peninsula, locally reaching more than +3°C.

(ii) Precipitation

In 2008, rainfall deficits were observed across the Italian and Balkan Peninsulas, while precipitation was above average in Belarus and parts of Russia and Romania. Corsica in the western Mediterranean was wet in 2008; annual rainfall totals were the highest in more than 40 years. The annual total rainfall in Athens was 87% of the 1961–90 average. Croatia, too, had a deficit in annual rainfall, especially in northern parts and southern coastal areas. Precipitation in Dubrovnik was below the 10th percentile (1961–90 base period). It was also dry in most parts of Serbia, where the annual total, as well as the number of rain and snow days, was low.

Winter was characterized by significantly below-normal rainfall across most of the region (Fig. 7.25a). At some locations in Montenegro and Croatia, seasonal rainfall was 40% of average. February was exceptionally dry in Romania and parts of Bulgaria, Greece, Serbia, and Croatia, where less than 20% of normal precipitation fell in many places. Much of Romania received less than 10%, while Sofia received only 1 mm during the whole month. Monthly precipitation in Athens was about 25% of normal.

April was exceptionally wet across the Ukraine and large parts of Bulgaria and Greece. Precipitation across Bulgaria was mainly above 150% of normal, while Athens received double the normal amount of rainfall. Northern Italy experienced two very intense rain periods in May and June. It was the fifth-wettest May in Bologna since 1937. Summer was very dry in the south of the region, particularly in Bulgaria and Greece (Fig. 7.25c). September was exceptionally wet in the Ukraine (>200% of the 1961–90 normal over most of the country), Bulgaria, and parts of Greece. Athens received 300% of the September normal. Precipitation from October onward was generally closer to average, except for anomalously high totals in Italy and Croatia during December.

(iii) Notable events

Southeastern Europe was hit by an intense storm with heavy snowfall on 3 January, with the Black Sea harbors and the main airports of Romania closed. On 17 February, more than 25 villages in Greece were cut off by heavy snowfall, and Athens was covered by several centimeters of snow. During 22–29 July, torrential rainfall affected parts of Ukraine and Romania. Farmland was destroyed and 50,000 houses were affected by flooding. Thirty-four fatalities were reported, while 350 mm of precipitation fell over northern Italy close to Bologna between 28 October and 1 November.

Between 10 and 12 December, a storm system brought heavy rainfall and strong winds to Italy causing flooding in several places. Rainfall around Rome was particularly high. Cumulative rainfall totals over three days exceeded the monthly average.

6) Middle East—A. Obregón, P. Bissolli, J. J. Kennedy, and D. E. Parker

Detailed summaries for Turkey, Iran, and Iraq may be found in part 4 (Southwest Asia) of section g (Asia) of this chapter.

(i) Temperature

Annual temperatures across the Middle East were generally 0° to 1°C above normal, although anomalies in Cyprus, southern Turkey, and parts of Syria, Lebanon, and Israel exceeded +1°C.

In contrast to most of continental Europe, the Middle East region experienced well-below-average temperatures during winter (Fig. 7.27a). Mean temperature anomalies were generally between –2° and –1°C in Georgia and Armenia, with local values in some areas below –2°C. In parts of Syria, Israel, and Jordan, mean temperatures were between 0° and 1°C below the long-term average. During the first weeks of the year, extreme low temperatures prevailed across much of the Middle East region. In January, parts of Georgia experienced one of the coldest nights for 10 years, with temperatures dropping to –10°C in the capital Tbilisi and to –25°C in mountainous areas. Severe frost was also reported in southern Israel and Jordan. In Syria's capital Damascus (608 m above sea level) nighttime temperatures fell to –11°C in mid-January, 11.5°C below the average minimum temperature for January and the lowest January temperature since 1982. Mean temperatures across Cyprus were around 1°C below normal in January, with widespread ground frost during the first half of the month causing damage to crops.

Spring temperature anomalies were generally positive across the region and exceeded +2°C in the eastern Caucasus, Syria, and Jordan. March temperatures were around 4°C above normal in Cyprus, where temperatures reached 33°C at the end of the month. In April, several heat waves occurred across the Middle East, while temperatures exceeding 40°C affected Cyprus in the second half of July and during the last week of August. The remainder of the year was generally warmer than average across the region, though anomalies tended to be smaller than at other times of the year.

(ii) Precipitation

Drier-than-average conditions affected most of the Middle East region in 2008 (Fig. 7.26). Precipitation anomalies ranged between 40% and 60% of normal in Cyprus and in parts of Jordan and Syria. For Cyprus, it was its second-driest year since 1901, with the country now suffering three consecutive years of drought and, as a result, severe water shortages. Long dry spells in Cyprus during winter caused a decrease in crop production, while snow fell in areas above 100 m elevation several times in January and February. Annual rainfall was 60%–80% of average in Lebanon, Israel, and parts of Turkey. In other areas of Turkey and in the Caucasus region, annual precipitation was generally close to the long-term mean, while December was particularly dry across much of the Middle East.

(iii) Notable events

During a storm on 30 January, Jerusalem was covered by snow, with a recorded depth of 20 cm. Likewise, Jordan's capital Amman received 30 cm of snow, while Lebanon, Syria, and even Cyprus were affected by severe cold conditions.

On 17 February, heavy snowfall across much of Turkey led to thousands of villages becoming isolated, while on 18 February the storm reached Israel, bringing snow, hail, rain, and strong winds. Five centimeters of snow was reported in Jerusalem. Thunderstorms with hail affected southern Lebanon.

On 8 May and again in October, severe hailstorms with heavy rainfall affected Cyprus, causing floods.

g. Asia

1) Russia—O. N. Bulygina, N. N. Korshunova, and V. N. Razuvaev.

2008 was very warm over Russia, with a mean air temperature anomaly (relative to 1961–90) of 1.9°C; the second warmest since observations began in 1891 (Fig. 7.32). Anomalies of mean air temperatures were positive for all seasons: winter, +2.4°C; spring, +2.0°C; summer, +0.9°C; and autumn, +2.1°C (second only to 2005).

January air temperature anomalies were in the range from –9° to +12°C (Fig. 7.33). Conditions were very warm in the north of the country, including most of the Yakutia-Sakha Republic, the Amur region, and the southern Khabarovsk Territory. Maximum temperature anomalies in excess of 12°C were recorded on the Arctic coast, where records were set at a number of stations. These large anomalies are associated with significant deviations from the normal surface pressure field. The Icelandic low, which slightly shifted northeastward, was considerably deeper than normal, as was the trough going from

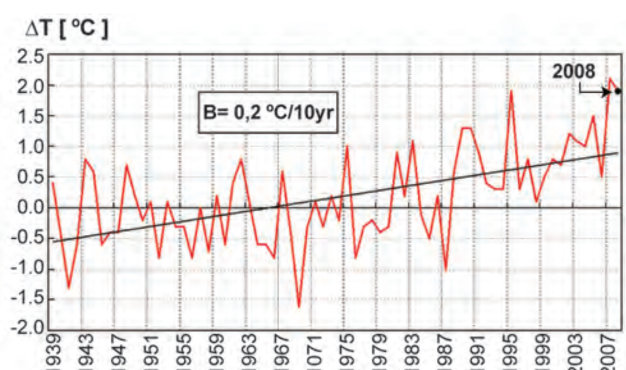

Fig. 7.32. Anomalies of mean annual air temperatures averaged over the Russian Territory, 1939–2008 (against 1961–90 normals).

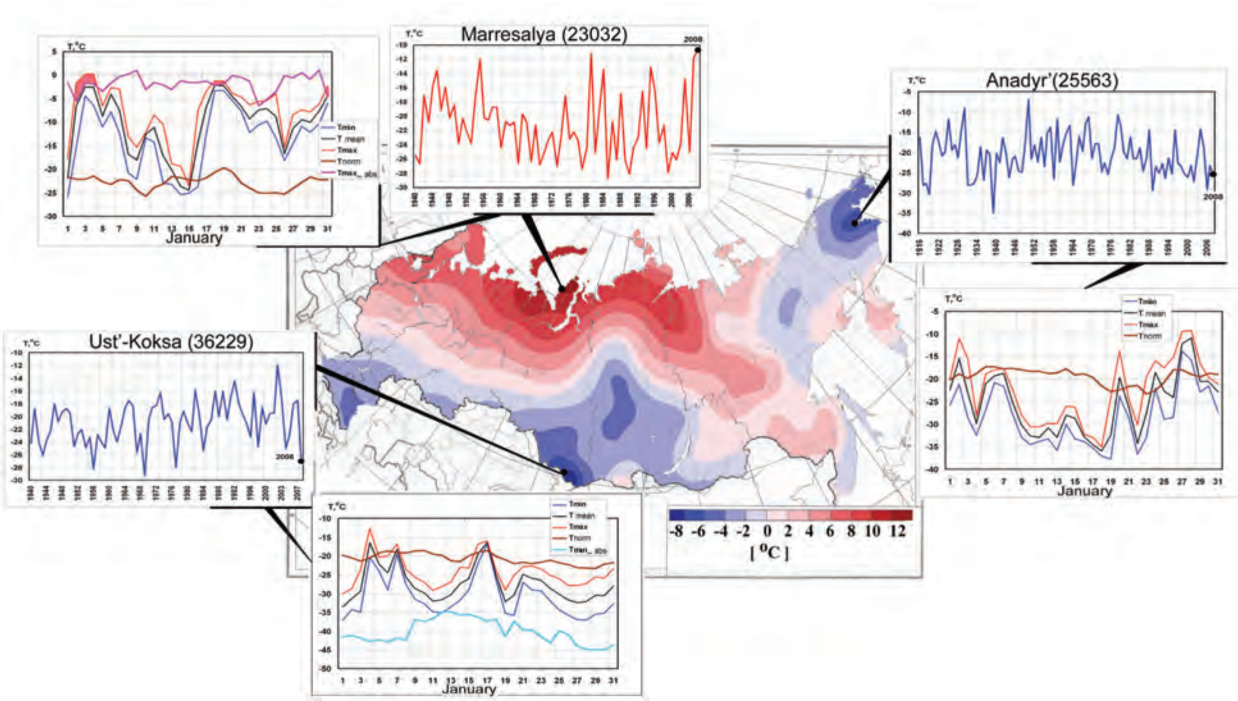

Fig. 7.33. Air temperature anomalies in Jan 2008. Insets show mean monthly and mean daily air temperatures in Jan 2008 at meteorological stations Marresalya, Anadyr', and Ust'-Koksa.

the Iceland depression along the northern coast of Eurasia. Throughout January, the Atlantic cyclones passed over the northern seas around Eurasia, contributing to the formation of warm and wet air masses in the coastal regions.

In contrast, over southern European Russia and southern western Siberia it was very cold. Such cold weather was due to the Siberian anticyclone being southwest of its climatological position, being more intense, covering a larger area than normal, and forming a common high with the Azores anticyclone. In the first 10 days of January, abnormally cold weather with mean daily air temperatures 7°–15°C below normal was recorded in central Chernozem regions. In the Volgograd region, the Stavropol Territory, and the Chechen Republic, minimum air temperatures were as low as –25° to –28°C. In the south of western Siberia, severe frosts (–35° to –42°C) were recorded in the second 10-day period of January. On the coldest days, the mean daily air temperature was 7°–16°C below normal. In some areas of the Krasnoyarsk Territory, the Irkutsk region, and Transbaikalia, the air temperature reached –46° to –50°C.

In European Russia, with the exception of the Black Sea coast, and over most of Siberia, mean February temperatures were above normal. Maximum anomalies (in excess of 10°C) were recorded in southwestern Yakutia. The warmest weather in European Russia was recorded in the west, where mean monthly air temperatures were 6°–7°C above normal. In eastern Siberia, mean monthly temperature anomalies around Evenkia were +8 to +9°C. Precipitation was also twice the monthly mean over the northwestern region, the southwestern Arkhangelsk region, and the southern Urals. At the beginning of the second 10-day period, the Sverdlovsk region and Bashkortostan experienced severe snow storms, with wind speed attaining 24 m s^{-1} and visibility being as poor as 300–500 m. In the southern Far East, the Maritime Territory and the Amur region recorded no precipitation for two months.

Mean monthly air temperatures in March were 1°–2°C below normal in northern European Russia and northern western Siberia. In the rest of the Russian Territory, March was very warm. In the east of the country, mean monthly temperatures were up to 10°C above normal over the eastern Yakutia-Sakha Republic, while in the southern Khabarovsk Territory, mean monthly air temperature anomalies were 7°–8°C. High temperatures in these regions were accompanied by a large amount of precipitation. In the vicinity of Yakutsk and Khabarovsk, precipitation was 3 times as high as the monthly average.

In April, the largest temperature anomalies were recorded over European Russia, where mean monthly air temperatures were generally above normal.

FIG. 7.34. Precipitation total in Jul 2008 against normal. Insets show monthly precipitation total series in Jul and daily precipitation in 2008 at meteorological stations Moscow, Chertkovo, Kislokan, and Srednekolymsk.

Significant precipitation deficits were recorded in the southern Far East (western Amur region, eastern Maritime Territory, and southern Sakhalin) against the background of positive temperature anomalies (3°–4°C).

In May, the division between negative and positive anomalies in the temperature field coincided with the border between the two continents. In European Russia, mean monthly temperatures were below normal, with some regions recording record low daily minima. In contrast, nearly the whole of the territory east of the Urals experienced warmer weather than the long-term average, with many regions of Siberia and the Far East setting new daily maximum air temperature records. In late May, air temperatures rose to +25°C in Yakutia and to +35°C in southern Siberia.

In June, negative temperature anomalies persisted in European Russia. In the first 10-day period, ground and air frosts were recorded in most locations. June was very warm in Eastern Siberia and southern Yakutia. Very hot weather, predominantly without precipitation, also prevailed in the Amur region and the southern Khabarovsk Territory. These weather conditions caused railway accidents and numerous forest fires. The city of Khabarovsk was wrapped with dense smog from forest fires that gave rise to poor visibility. In the republics of Northern Caucasia, the Krasnodar, and Stavropol Territories precipitation of 75–96 mm occurred in one to three hours.

In July, no significant broadscale temperature anomalies were recorded; however, precipitation in some regions exceeded long-term records (Fig. 7.34). Heavy rains were reported in the central region of European Russia and in the northwestern Rostov region (200%–300% of monthly average). In contrast, August was warm over most of the Russian Territory. Hot winds were observed in the Altai Territory by the end of the first 10-day period, while very hot and dry weather occurred in the second half of August in southern European Russia. In some regions maximum air temperatures were above 30°C for 24–25 days, peaking at 36°–40°C. Drought conditions, defined as a period with precipitation of less than 5 mm, persisted for 31 days.

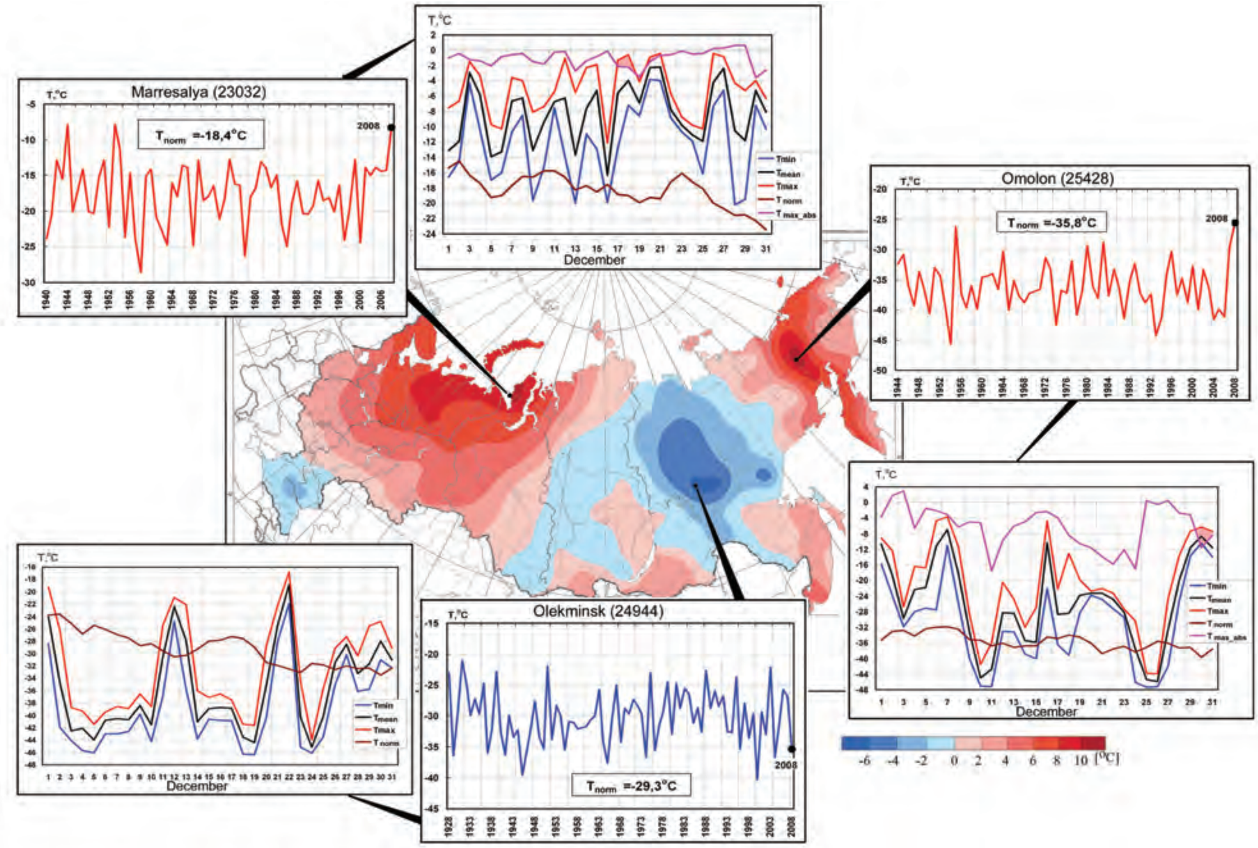

Fig. 7.35. Air temperature anomalies in Dec 2008. Insets show mean monthly and mean daily air temperatures in Dec 2008 at meteorological stations Marresalya, Omolon, and Olekminsk.

September 2008 in European Russia will be remembered for both abnormal heat and cold. For example, on 11 September, Voronezh city reached a record-high temperature, 30.7°C, and in the neighboring city of Tambov, on 27 September, air temperature dropped to a record-breaking low value of –2.6°C. In the Magadan region, Chukotka, and Kamchatka, the weather was considerably warmer throughout the month, as compared with normal values.

October 2008 was the warmest October on record for Russia, with a mean air temperature anomaly of 2.9°C. This record was achieved despite few individual stations reaching record levels (maximum anomalies were no higher than 6°C), but rather by the fact that virtually the entire country was consistently warm. Over most of European Russia, warm weather in October was generally accompanied by below-normal precipitation. Conversely, Transbaikalia received above-average precipitation, with monthly averages exceeded by 2 to 3 times, and heavy snowfalls producing a snow cover as deep as 30–35 cm. Heavy snowstorms also took place on Taimyr and in Khakassia.

November also proved warm for Russia, with abnormally warm weather prevailing over European Russia, particularly in the Urals, with mean monthly air temperature anomalies reaching 6–7°C. Western Siberia experienced anomalies of more than 8°C. Central regions of Sakhalin received precipitation that was twice the monthly mean.

In December, northern regions of European Russia and western Siberia and continental regions of the Magadan and Chukotka all recorded exceptional warm anomalies—up to 10°C in places. For example, at Omolon, whose normal value is –35.8°C, mean monthly air temperatures rose to –25.6°C. Conversely, over western Yakutia (Fig. 7.35), daily air temperatures were below normal for most of the month, with anomalies reaching –15° to –20°C.

2) East Asia—Y. Guo, Y. Sakai, S. Zhao, X. Wang, and H. Lee

(i) Overview

Over most of East Asia, the annual mean surface air temperature during 2008 was near or above normal (Fig. 7.37). Temperatures were significantly below normal for most of East Asia during winter

THE EURASIAN COLD EVENT OF JANUARY 2008—M. ROGERS, S. SENSOY, O. BULYGINA, F. RAHIMZADEH, Y. GUO, S. ATTAHER, AND A. B. WATKINS

During January 2008, an exceptional cold outbreak occurred across Eurasia (Fig. 7.36). Mean monthly temperatures were as low as −8.0°C in Turkey, with nearly 50 extreme weather events recorded. Cold stretched south into Israel, Jordan, and Egypt, where temperatures 5° to 8°C below normal had a severe impact on many vegetable and fruit crops. Jerusalem was covered by 20 cm of snow, Amman received 30 cm of snow, while Lebanon, Syria, and even Cyprus were affected by severe cold conditions. Iraq experienced record cold, with snow being reported on at least six days at Mosul in northern Iraq and temperatures near record lows in many areas. On 11 January, snow fell in Baghdad for the first time in living memory. The lowest recorded temperature was −10°C at Al Qaim in the western desert. Over northern Iran, mean January temperatures were generally 5° to 10°C below normal. Some areas that had not observed minimum temperatures below freezing since records began in 1951, experienced subzero temperatures on multiple days. In the south of western Siberia, severe frosts (−35° to −42°C) were recorded in mid-January, with temperatures generally 7° to 16°C below normal. In some areas of the Krasnoyarsk Territory, the Irkutsk region, and Transbaikalia, temperatures dropped to between −46° and −50°C. Western regions of Afghanistan experienced their coldest winter in nearly 30 years. Nearly two-thirds of China was affected by the event, with southern China experiencing a once-in-a-hundred-year cold snap. Maximum temperatures were 2° to 6°C below average. Averaged across southern China, 19 successive days occurred with a daily mean temperature of below 1°C. This, and an accumulated mean snowfall of 42.4 mm, were both records since observations began in 1952. Snow cover for Eurasia was at all-time record levels for the month of January. Snow coverage exceeded 32 million km^2, just over 3 million km^2 above the long-term average; further details in chapter 2. Sadly, many hundreds died from the extremely cold conditions across Eurasia in early 2008.

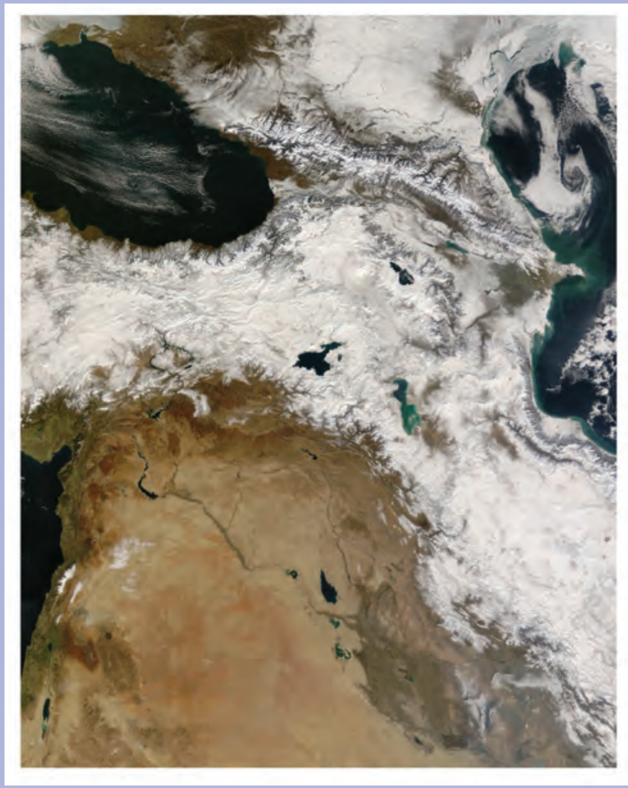

FIG. 7.36. Snow covers the region of southwest Asia, from Turkey in the west to Iran in the east, on 15 Jan 2008. NASA image courtesy Jeff Schmaltz, MODIS Rapid Response Team at NASA GSFC (http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=19555).

(December 2007–February 2008) and were above normal in the spring (March–May 2008) and autumn (September–November 2008). In China, the mean temperature in spring was the warmest since national average records commenced in 1951. In Japan, 2008 was the 11th-warmest year since 1898. Annual precipitation totals were above normal in eastern northwest China, the Tibetan Plateau, and the regions from southern China to the northeastern Indochina peninsula, while it was below normal in the regions from western northwest China to western Mongolia and the northeast part of East Asia (Fig. 7.38). Two extreme floods occurred in southern China in late May to June, and again during late October to early November. Widespread droughts expanded across most of northern China from January to March 2008. Parts of Japan were affected by localized torrential rainfall during summer.

(ii) Temperature

The average temperature over China for 2008 was 9.5°C, 0.7°C above the 1971–2000 normal and the seventh highest since 1952, and the 12th above-average year since 1997. Annual mean temperatures for 2008

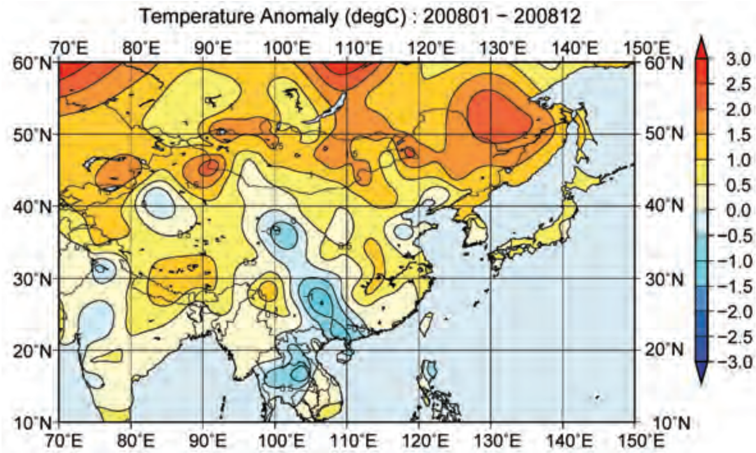

FIG. 7.37. Annual mean temperature anomalies (°C; 1971–2000 base period) over East Asia in 2008. (Source: JMA.)

were near normal over most of China, and 1°–2°C above normal in northeastern and northwestern China. The average temperature in China for winter 2007/08 was −4.4°C, which was 0.2°C below normal and the coolest winter since 1986/87. Extreme low temperatures, freezing rain, and snow persisted over most of southern China from 10 January to 2 February, resulting in the worst severe weather event in five decades, the loss of 107 people, and over $15 billion (USD) in damage (Gao 2009; Wang et al. 2008b). For spring, the average temperature was 11.4°C, 1.8°C above normal and the warmest spring since 1951. The seasonal mean temperatures for summer and autumn were 0.5°C and 1.0°C above normal, respectively.

The average temperature over Japan (averaged over 17 observatories confirmed as being relatively unaffected by urbanization) in 2008 was 0.46°C above normal (based on the 1971–2000 average), making it the 11th warmest year since 1898. Area-averaged annual mean temperature anomalies were +0.6°C in northern and eastern Japan, +0.5°C in western Japan, and +0.4°C in Okinawa/Amami.

(iii) Precipitation

Total precipitation for 2008 in China was 651.3 mm, which was 38.4 mm above normal and the highest since 1999. The spatial and seasonal precipitation distributions were uneven across the country. Summer rainfall was the third highest since 1955. Annual precipitation was 20%–50% above normal in western Inner Mongolia, southwestern, and southern China, while deficits of 20%–50% were recorded in parts of northwestern China. From 26 May to 19 June, heavy rainfall persisted over southern China, causing severe flooding. From 21 October to 8 November, heavy rains occurred frequently in southern China, resulting in an average precipitation of 94.9 mm, 160% above normal and the highest value since regional records began in 1951. In contrast, from 1 January to 18 March, widespread droughts expanded across much of northwest and North China, with precipitation 30% to 80% below normal.

Annual precipitation amounts over Japan were near normal nationwide, except for northern Japan and over parts of eastern Japan, where totals were significantly below normal. Some mainland areas experienced localized torrential rainfall in summer.

(iv) Atmospheric circulation

In winter, both the polar front jet and the subtropical jet were stronger than normal over Eurasia. Blocking highs were prevalent around western Siberia, and the Siberian high developed in January and February, when cold spells affected East Asia, and particularly China. Extremely low temperature anomalies were observed in the lower troposphere over China.

During spring and summer, positive 500-hPa height anomalies occurred over the Arctic Ocean and the midlatitudes of Asia, while negative anomalies

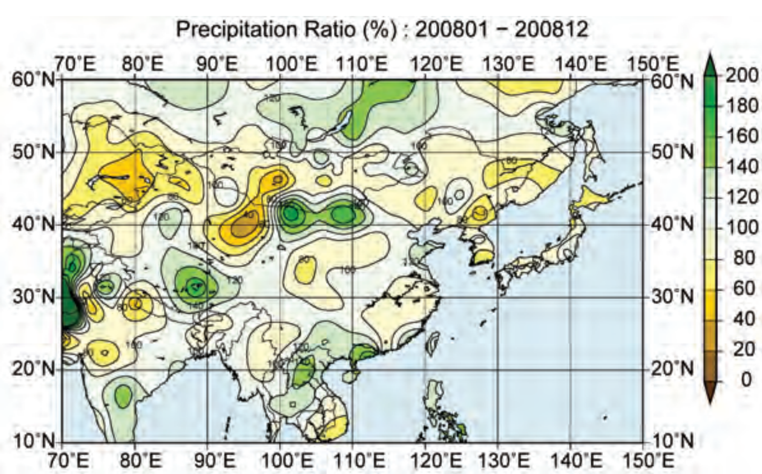

FIG. 7.38. Annual precipitation ratio as percentage of normal (1971–2000 base period) over East Asia in 2008. (Source: JMA.)

occurred from Europe to central Siberia. A stationary ridge over eastern Siberia was also observed. These features were consistent with the southward-shifted polar front jet and the weaker-than-normal or slightly northward–shifted subtropical jet, corresponding to most parts of East Asia experiencing a warm spring and a hot summer. Though the Okhotsk high appeared over the Sea of Okhotsk several times, it brought a cool wind to northern Japan only in late August. The Pacific high was weaker than normal over the northwestern Pacific during August.

In September and November, positive 500-hPa height anomalies prevailed over East Asia. Southerly winds were dominant in the lower troposphere, resulting in a warm autumn for most parts of East Asia. In November and December, westerly jets meandered and the trough stayed over the East China Sea. Wet weather was observed at the south and east side of the trough, while dry conditions were observed to the north and west.

(v) Monsoon

The onset of the SCS summer monsoon was in the first pentad of May and earlier than normal. Subsequently, southwesterlies moved northward to regions south of the Yangtze River. During mid-June, southwesterlies extended northward to the Jianghuai area, and warm and humid air was prevalent south of the Huanghuai area. Southwesterlies moved northward to North China during mid-July. After mid-August, warm and moist air swiftly withdrew southward and moved back to the middle to lower reaches of the Yangtze River, withdrawing further to South China by mid-September and remaining until early October. The summer monsoon withdrew from the SCS during the second pentad[3] of October 2008, two pentads later than normal. Overall, the SCS summer monsoon index during 2008 was –1.37 and weaker than normal. Pentad intensities of the SCS summer monsoon were stronger than normal during May and the period from the third pentad of September to the first pentad of October, but they were weaker than normal during most of the period June–August (Fig. 7.39). Over eastern China, precipitation totals for summer (June–August) were more than 30% above normal in the Jianghan area, the eastern Huanghuai area, and South China.

Onsets of the Bai-u (the rainy season over Japan during the late spring and summer) were earlier than

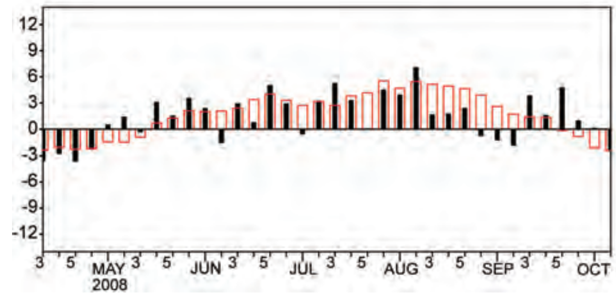

Fig. 7.39. Variation of pentad zonal wind index over monitoring region(10°–20°N, 110°~120°E), red open bars stand for climatology (Unit: m s^{-1}) (Source: CMA.)

normal in western and eastern Japan. In western Japan, the Bai-u withdrew on 6 July, one to two weeks earlier than normal. This was followed by sunny and hot days until mid-August. Over western Japan, July received only 29% of its normal rainfall, which was the least recorded since 1946. Meanwhile, isolated heavy rains caused by developed cumulonimbus were sporadically observed in eastern and western Japan from the end of July to the beginning of September. Total precipitation amounts exceeded 400 mm in the Tokai region resulting in floods and land slides.

(vi) Aeolian dust

In spring 2008, China was affected by nine dust and sand events, far fewer than in 2007 (15). The average number of dust days in northern China was 1.7 days (3.8 days less than normal). During 26–28 May, the worst event of 2008 saw a 3-day dust storm blanketed northern China.

The Republic of Korea was affected by six dust events in spring (March, April, May) 2008, with the strongest peaking on 2 March, affecting most of Korea over a 2-day period. The average number of dust days over the 28 recording stations was 4 days, which was near normal (3.6 days). The number of dust days in April was 0.3 days, which was significantly below normal (2 days) and is likely to be due to anomalous easterlies and southwesterlies. The last dust event was observed on 29–31 May, which was the latest occurrence observed since 1979.

In Japan, the number of days when yellow sand, or aeolian dust, was observed was 10 from January to May 2008, which was the lowest number since 1987. The total number of days that meteorological stations recorded aeolian dust during 2008 was 125, which was also the lowest number since 1997. Of special interest is that the total number of days when yellow sand was observed during April (one) was far below the normal value of 7.9.

[3] Pentad refers to blocks of five days, starting on the first day of the month.

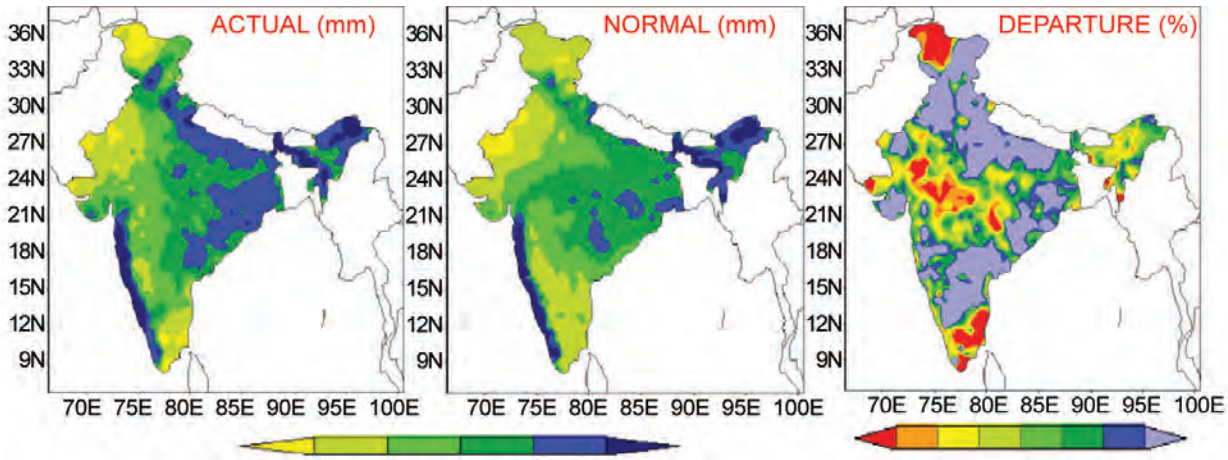

Fig. 7.40. Monsoonal (Jun–Sep) rainfall (mm) and anomalies (percentage departure from normal) over India in 2008.

3) South Asia—M. Rajeevan and J. Revadekar

(i) Overview

During 2008, South Asia experienced many extreme precipitation and temperature events. During the last week of January, parts of northern India experienced severe cold-wave conditions. Delhi, the capital city of India, recorded a minimum of 2.5°C on 28 January, its lowest temperature in five years. During the premonsoon season (March to May), a severe heat wave affected many parts of northern India and Pakistan. During March, unprecedented heavy rainfall occurred over southern parts of India and Sri Lanka associated with the passage of easterly waves in the lower troposphere. The area-weighted average rainfall over the southern peninsular India was 915% of its long period average value, an all-time record. Record-high rainfall was reported at more than 20 stations over southern India. In Sri Lanka, flash floods associated with heavy rains affected more than 50,000 families.

A cyclonic storm (Nargis) developed over the Bay of Bengal during the last week of April, which intensified into a very severe cyclonic storm (Category 4) on 29 April. Along with its intensification, it recurved and moved toward Myanmar. On 2 May, it crossed the southwest coast of Myanmar, resulting in the worst disaster ever for that country. Nargis was the most devastating cyclonic storm to strike South Asia since 1991. According to reports, the storm left nearly 78,000 people dead and almost 56,000 missing.

(ii) South Asian summer monsoon (June to September)

The summer monsoon season (June to September) typically contributes 60%–90% of the annual mean rainfall over major portions of South Asia. The onset phase of the monsoon in 2008 was characterized by a normal onset over southern peninsular India. Further progress of the monsoon over the country was satisfactory, except for a brief hiatus during the third week of June. The monsoon covered the whole country by 10 July, about five days ahead of normal.

The all-India summer monsoon rainfall (June to September) was 2% below its long-term (1901–2000) mean of 890 mm. However, rainfall was unevenly distributed over both space and time (Fig. 7.40). Seasonal rainfall was above normal over the far northern parts of India and its north peninsula, while totals were deficient over most of central and extreme southern parts of India. The 2008 summer monsoon was also characterized by strong intraseasonal variability as seen in Fig. 7.41. During the month of June, area-weighted rainfall over the country as a whole was 24% above average. However, rainfall activity was confined to the extreme northern parts of India, in association with the interaction between the midlatitude westerly system and the monsoon

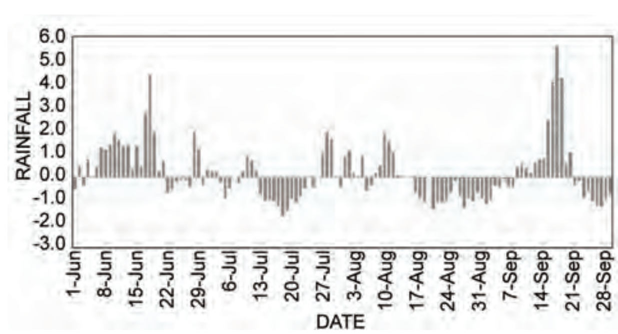

Fig. 7.41. Daily standardized rainfall time series averaged over the monsoon zone over India (1 Jun to 30 Sep 2008).

circulation. Conversely, during the second and third weeks of July, the monsoon circulation was weak, most likely due to enhanced convection over the equatorial eastern Indian Ocean and midlatitude circulation anomalies.

During the summer monsoon season, 2 of the 36 meteorological subdivisions in India recorded excess rainfall, 31 subdivisions received normal rainfall, and the remaining 3 subdivisions received deficient rainfall. Out of 516 meteorological districts for which rainfall data were available, 76% of the meteorological districts received excess/normal rainfall, and the remaining 24% of districts received deficient rainfall (rainfall deficiency more than 19%). During the season, 65 districts (13%) experienced moderate drought conditions (rainfall 26% to 50% below normal) and 17 districts (3%) experienced severe drought conditions (rainfall deficiency 51% or more).

A notable feature during the monsoon season was less-frequent occurrence of cyclonic disturbances such as monsoon depressions, although this suppressed activity is consistent with the observed decreasing trend in the frequency of monsoon depressions over the Indian region during recent decades. Only four monsoon depressions formed during the season, against the long-term average of around seven. Depressions that did occur were short lived with an average life period of only 2.2 days.

The area-weighted seasonal (July to September) rainfall over Pakistan was slightly below normal. Rainfall in July was deficient, while it was in excess during August. Seasonal rainfall was above normal over northwest Frontier Province and Punjab. Over the Sindh region, seasonal monsoon rainfall was largely deficient. Monsoon rainfall over western Nepal was consistently above normal until August.

During the monsoon season, heavy rainfall and flash floods affected many parts of India, Bangladesh, Nepal, and Pakistan, impacting hundreds of thousands of people and causing more than 2,000 deaths. Record rainfall was reported in many cities and towns in India. On 2 July, the city of Varanasi recorded 330 mm of rainfall in just 24 hr, an all-time record for the city. In neighboring Nepal, heavy rainfall in August caused the Kosi River to spill over its banks, flooding villages and leaving several people missing. During September, in eastern Orissa, heavy monsoon rains triggered widespread floods that affected nearly 2.4 million people and damaged crops and property.

Another notable feature was the strong zonal dipole structure of precipitation observed over the tropical Indian Ocean, with positive anomalies over the west and negative anomalies over the east. This pattern was consistent with the strong and persistent dipole structure in the SST pattern observed during the same period. This favorable SST pattern may be responsible for the observed excess of monsoon rainfall along the west coast of India and the northern peninsula, at least during August.

(iii) Northeast monsoon

The NEM sets in over southern peninsular India in October and in Sri Lanka in late November. The NEM contributes 30%–50% of the annual average rainfall over southern peninsular India and Sri Lanka as a whole, and up to 70% of the annual rainfall in the dry northern and eastern regions of Sri Lanka.

During the season, the storm activity over the North Indian Ocean was above normal with three cyclonic storms and one deep depression. In November, Tropical Storm Nisha caused disaster in Sri Lanka and India and resulted in fatalities of at least 200 people. The storm caused heavy rain and flooding that displaced more than 50,000 people in Vanni and Jaffna districts in Sri Lanka. Associated with this storm, Jaffna recorded 520.1 mm of rainfall, which is an all-time record. Orathanadu, a small town in Tamil Nadu received more than 990 mm of rainfall in just 48 hr. On 28 November, Chennai airport recorded 280 mm of rainfall in just 24 hr. The NEM seasonal rainfall was, however, above normal only over the eastern parts of the south peninsula, while it was deficient over the western parts of the region.

4) Southwest Asia

(i) Iraq—M. Rogers

(a) Overview

The main features of the climate of Iraq in 2008 were the cold January, the very dry winter and spring, and the relatively wet autumn. The dry spring, and overall dry year, has extended one of the worst droughts in the past 10 years and has had a massive effect on the wheat and barley production within the country.

(b) Seasonal Review

The winter period, Iraq's wet season, was drier than normal with most locations receiving less than 50% of their normal winter rainfall (see Fig. 7.42). December and February were drier than average with generally near-normal temperatures. January, however, had near-normal rainfall in many central and southern areas, locally above-normal in the west, but mean temperatures were between 2° and 3°C below normal. Basra Airport was 3.3°C colder

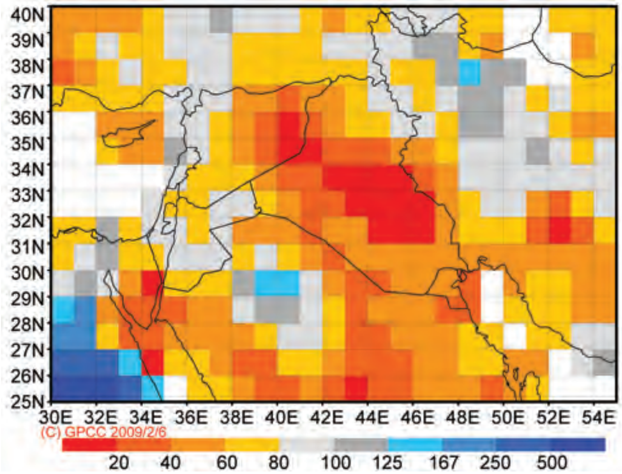

Fig. 7.42. Percentage of normal precipitation (base period 1951–2000) for seasons Dec–Feb. (Source: GPCC.)

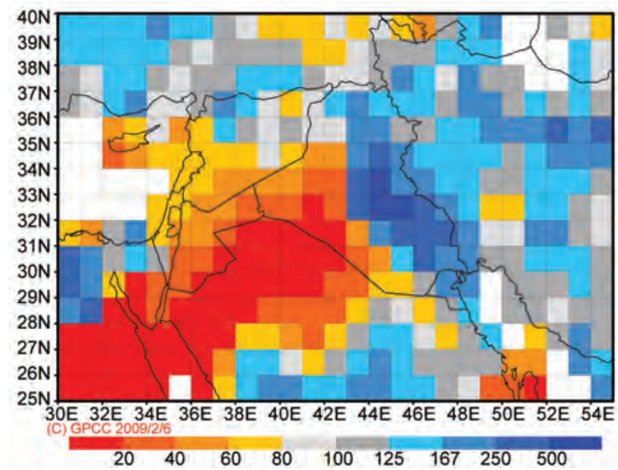

Fig. 7.43. Percentage of normal precipitation (base period 1951–2000) for seasons Sep–Nov. (Source: GPCC.)

than average during January and 1.8°C colder for the winter as a whole.

Temperatures recovered during the spring, with most areas experiencing mean temperatures between 2° and 4°C above the 1961–90 normal, with many places reaching record-breaking temperatures during March (e.g., 39.4°C at Basra Airport). The high temperatures, brought about by generally settled weather conditions across the country, led to an extension of the very dry conditions experienced during winter. Most areas received less than 40% of their normal rainfall with some places having less than 10% (e.g., around 6% at Baghdad). With the drier-than-normal ground and the lack of crops in the fields due to their failure through lack of irrigation, there was a higher occurrence of dense lifted dust.

Summer in Iraq was fairly typical with fine, dry, and dusty conditions across most areas, although temperatures were generally above normal. The northwesterly Shamal winds dominated conditions, bringing occasional dense lifted dust.

An unsettled period of weather during October and November led to above-average rainfall in many places, especially in central and eastern areas (see Fig. 7.43), with Baghdad receiving nearly 180% of the normal rainfall during the September to November period. Temperatures were generally between 1° and 2°C above normal. A drier-than-average December with near-normal temperatures ended the year.

(c) Annual Review

Overall, 2008 in Iraq was drier and warmer than average. On the whole temperatures were between 1° and 2°C above normal with rainfall less than 65% of the expected levels (Table 7.2).

(ii) Iran—M. Khoshkam and F. Rahimzadeh

Temperature anomalies during 2008 in Iran were mixed (Table 7.3). Cooler-than-average conditions prevailed during winter, when Iran experienced temperatures generally 0°–4°C below the long-term mean, with areas in the northeast of the country recording temperatures up to 6°C below average (Fig. 7.44). During spring, temperatures were generally up to 4°C above long-term average over most parts of Iran, though some regions experienced maximums up to 6.3°C above the mean. During summer, below-average temperatures were observed in the south, southeast, and northwest. In autumn, cooler-than-average temperatures persisted across the northwest, southern, and central parts of the

Table 7.2. Precipitation anomaly (percentage of 1951–2000 normal). (Source: USAF, 14th Weather Squadron.)

	Mar–May	Sep–Nov	Annual
Mosul	32.0	188.9	62.4
Baghdad	5.9	179.9	58.5
Basra	32.9	118.6	53.8

Parameter	Season		Winter	Spring	Summer	Autumn
Precipitation	Average (mm)		69	14	9.5	56.2
	Respect to (%)	Long term	−42%	−76%	−15%	−14%
		Previous year	−27%	−84%	−37%	49%
	Range from–to (mm)		6 to 578	0 to 180	0 to 227	0 to 954
Temperature	Respect to long term (°C)		−6 to 0	2 to +4	0 to 1	−2 to −1
	Range from–to (°C)		−10 to 25	10 to 35	15 to 45	3 to 28

Table 7.3. Seasonal amount of precipitation and temperature over Iran.

country, while warmer-than-average conditions were limited to the east and some parts of the northwest and central regions.

Iran experienced drier-than-normal conditions in all four seasons of 2008 (Table 7.3), with the country receiving only 58%, 24%, 85%, and 86% of its long-term winter, spring, summer, and autumn rainfall, respectively. Winter, spring, and summer also received less rainfall in 2008 than that received in the previous year, the only exception (autumn) being due to exceptionally low rainfall in 2007. Areas with above-average winter rainfall were confined to the southeast and small parts over the northwest, while the rest of the country received precipitation amounts that were at most 75% of the long-term mean. Total rainfall for winter 2008 across the Caspian Sea and through the western parts of the country was generally more than 200 mm. The largest total of 578 mm was observed in Bandar Anzali (northern Iran). Through the middle of the country, and through isolated regions in other parts, rainfall was less than 35 mm. Averaged precipitation over the country was below the long-term mean during the spring of 2008 (Fig. 7.45).

During the summer, most parts of the eastern half of the country received below-normal precipitation, while areas in the south received no rainfall at all. During autumn, northwest, northeast, south, and southeast parts of the country received 60% of their long-term mean rainfall.

During winter, spring, and summer, significant dust storms spread out over large parts of the southern half of Iran. While this is fairly typical for the southeastern regions, it is only in the past few years that these conditions have spread into the southwest of the country, although it is worth noting that the source region differs for the two areas.

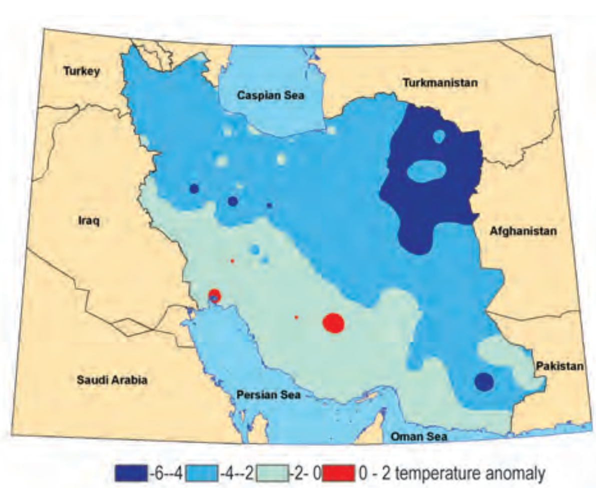

Fig. 7.44. Winter mean temperature anomaly (°C) for Iran. (Source: IRIMO.)

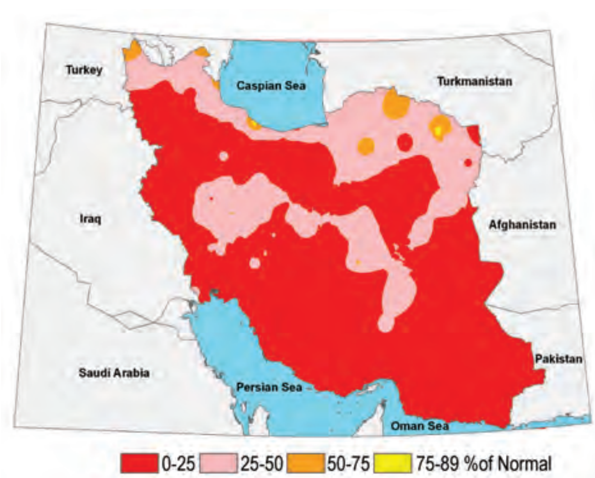

Fig. 7.45. Spring precipitation anomaly (percentage of normal) for Iran. (Source: IRIMO.)

(iii) Turkey—S. Sensoy

The annual surface temperature anomaly averaged over Turkey in 2008 was 0.8°C above the 1961–90 average (13.6°C). Coastal areas and the western part of the country recorded temperatures above the mean, while areas around Sivas, Erzurum, and Kars experienced below-average temperatures. Positive temperature anomalies for Turkey have now occurred over all years (with the exception of 1997) since 1994. This increase is observed not only in the mean temperature but also in maximum and minimum temperatures. Middle East and Turkish climate indices studies show that the number of summer days (Tmax ≥ 25°C) and tropical nights (Tmin ≥ 20°C) has been increasing over Turkey, while cool nights (Tmin < 10th percentile) and cool days (Tmax < 10th percentile) have been decreasing (Sensoy et al. 2008; Zhang et al. 2005).

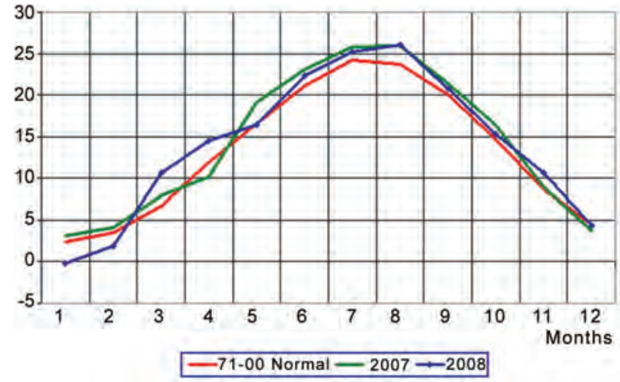

Fig. 7.46. Monthly mean temperatures (°C) for Turkey in 2008.

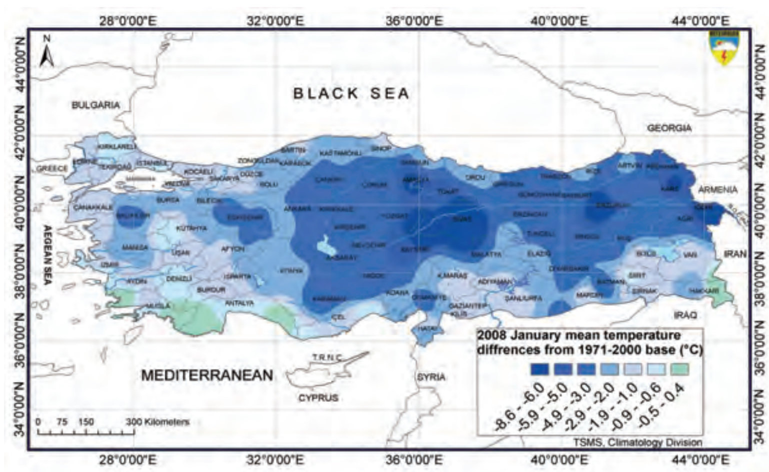

Fig. 7.47. Jan 2008 temperature anomalies (°C; base period 1971–2000) for Turkey.

In 2008, January and February mean temperatures were below the 1971–2000 mean, while March, April, June, July, August, and November were above it. All other months saw mean temperatures that were near normal (Fig. 7.46). January 2008 mean temperatures were significantly below the 1971–2000 mean, reaching −8.0°C in areas around Sivas, Erzurum, and Kars (Fig. 7.47). Forty-nine extreme events, including heavy snowfall, storms, and frosts, were reported in January and February 2008. This exceptional cold was thought to be due to the Siberian high-pressure system that affected Turkey, combined with prevailing La Niña conditions.

Total precipitation was below the mean in Antalya, Muğla, Mardin, and Bitlis, which all broke records in 2008. In contrast, slightly above-average precipitation occurred in the central Black Sea region, Sivas, Bayburt, and Kars. Overall, total precipitation for the country was 128 mm below the 1961–90 mean, and hence large areas suffered drought conditions during all seasons of 2008 except autumn. Despite the drought conditions, 42 extreme rainfall and flood events occurred during 2008.

h. Oceania

1) Australia—B. C. Trewin and A. B. Watkins

(i) Overview

Australia in 2008 was generally warmer than normal, with near-normal rainfall, despite the presence of a strong La Niña early in the year (see chapter 4 for a description of the ENSO state, and chapter 3 gives a broader view of oceans), something that historically brings above-normal rainfall to northern and eastern Australia. Rainfall averaged over Australia for 2008 was 466 mm (44th highest of 109 years, 1% below normal),[4] and, while much of the north and east was wet, dry conditions in the southeast reinforced long-term drought over much of that region. This exacerbated severe water shortages in the agriculturally important Murray-Darling basin.

[4] Anomalies are calculated with respect to the 1961 to 1990 average. High-quality *annual* Australia-wide temperature anomalies have been calculated for all years since 1910 (Della-Marta et al. 2004), while high-quality *monthly* anomalies are available from 1950. This report's rankings use the monthly values. High-quality nationwide rainfall measurements commenced in 1900 (Lavery et al. 1997).

Mean temperatures for the year were 0.41°C above normal, making 2008 the 14th-warmest year on record, despite being the coolest year since 2001. Australian temperatures are generally below average in years in which a La Niña event finishes. Unusual for a La Niña year, the Australian mean diurnal temperature range was larger than normal.

(ii) Temperature

Temperatures were above normal for much of Australia during 2008, but to a lesser extent than they have been in some recent years, with the largest anomalies in the central and western interior.

Only the south-central Northern Territory and the eastern interior of western Australia experienced maximum temperature anomalies of more than +1°C through the year (Fig. 7.48), while only a few areas had below-normal maxima. Averaged over Australia, the mean maximum temperature was 0.52°C above normal (13th highest on record), with positive anomalies in all states. However, only the Northern Territory (10th) ranked in the top 10.

Minima were closer to normal, with the national average anomaly of +0.29°C ranking 19th highest. Only a few areas had annual anomalies with a magnitude of more than 1°C. The most consistent signals were in northern parts of the Northern Territory and western Australia, where annual anomalies were between −0.5° and −1.0°C, and in the northern half of New South Wales, which was similarly cool.

While the annual temperatures were mostly unexceptional, there were some notable monthly and seasonal anomalies. January was Australia's warmest on record and was particularly hot in the central and western interior, which missed out on wet season rains. Maximum temperatures in March were exceptionally warm over much of southern Australia, largely due to a prolonged heat wave [see section 7h1(iv)]. However the early end to the wet season and persistent southerly flow saw low autumn minimum temperatures over much of northern Australia.

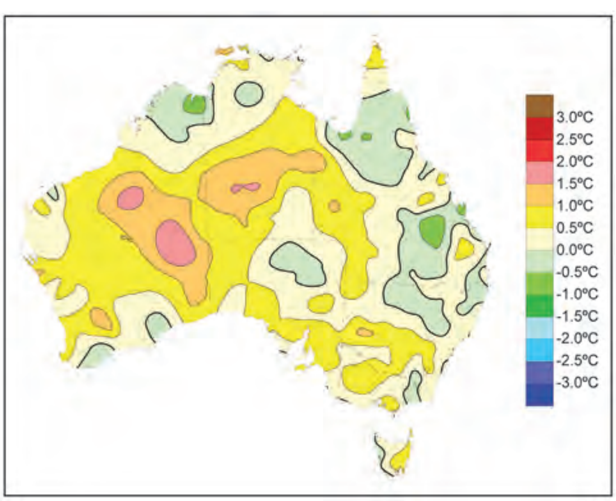

Fig. 7.48. Australian mean annual maximum temperature anomalies (°C; 1961–80 base period) for 2008.

Winter temperatures were generally close to normal, with a cold August offsetting a mild June. Parts of the southeast had their lowest winter mean maximum temperatures since 1998, although anomalies were still near zero. Mount Hotham set an Australian record when the temperature failed to rise above 0°C for 53 consecutive days between 7 July and 28 August, and Eyre set a western Australian state record with −7.2°C on 17 August.

September and October were generally warm, continuing the pattern of recent years (September maximum temperature anomalies have been +0.8°C or above in 13 of the last 15 years, and positive in all 15), with Victoria and South Australia setting October records for mean maxima and minima, respectively. The year had a reasonably cool finish, especially in the west, although December was hot in much of Queensland.

(iii) Precipitation

Australian precipitation was generally close to normal during 2008. While some areas affected by long-term drought had their best rains for several years, others saw a continued deterioration of conditions during the year.

The tropical wet season in the first part of 2008 was one of contrasts. In the northern tropics, much of the eastern half of Queensland, and NSW, it was wet with flooding at times, although only limited areas had January–March totals in the highest decile. Conversely, with no significant incursions of tropical moisture into the interior, rainfall was well below normal in the Northern Territory south of 18°S, the far west of Queensland, and all of South Australia. The wet conditions around the NSW/Queensland border, following heavy rains at the end of 2007, provided the northern Murray-Darling basin with its best inflows since 2000/01, although little of this water reached lower parts of the basin.

The tropical wet season came to an early end and dry conditions dominated over most of the country from March to October, with 87% of the country experiencing below-median rainfall. Autumn was especially dry, with the national average the eighth lowest on record, May was the driest on record, and all states and territories were below normal in all three months.

The winter rainfall areas of southeastern Australia experienced near-normal totals in July and August but were otherwise dry, especially in September and October, which were the driest on record over large parts of Victoria and South Australia.

There was a marked shift in the rainfall regime in November, with above-normal rains extending through most of the continent. The contrast was especially marked in South Australia and the southern half of the Northern Territory, much of which experienced its driest January–October on record, with many stations below 50 mm for the period (and a few below 20 mm). South Australia followed its second-driest January–October on record, with its wettest November–December.

For the year as a whole (Fig. 7.49), rainfall was above normal in northern New South Wales and eastern Queensland, the Top End of the Northern Territory and the Kimberley region of western Australia, and most of the western half of western Australia. The most consistent below-normal values were in the central Northern Territory and adjoining western Queensland, as well as in the southeast, covering Victoria, Tasmania, and southern South Australia. In the latter region, the low rainfall exacerbated long-term rainfall deficits. The last 12 years have now been the driest such period on record in much of southern Victoria, while record 3-yr rainfall deficits have also developed in many areas, particularly on the northwest slopes of the Australian Alps, which are critical for inflows into the Murray-Darling basin.

(iv) Notable events

The most significant feature of the early weeks of 2008 in Australia was flooding in the north and east. While several regions were affected, the two most severe events affected the Emerald area in eastern Queensland in mid-January and Mackay in mid-February. The Emerald floods resulted from several days of heavy rain associated with the remnants of Tropical Cyclone Helen. The Mackay event, in contrast, was mostly flash flooding, which resulted from extremely heavy rain in a low-level convergence zone. East Mackay received 625 mm on 15 February, most of it in five hours. A full description of Australian and southwest Pacific basin cyclones is given in chapter 4.

Perhaps the most notable event of 2008 was the exceptional prolonged heat wave that affected southern Australia during March (National Climate Centre 2008). Adelaide experienced 15 consecutive days above 35°C from 3 to 17 March (including a run of 13 consecutive days above 37.8°C/100°F), nearly double the previous record of 8 days. The heat wave was more exceptional for its duration than any individual extreme days, but a Tasmanian state record for March was still set when Campania reached 38.0°C on 14 March.

There were several severe thunderstorm outbreaks in southeastern Queensland in the second half of November. The most damaging occurred on 16 November, when storms crossed metropolitan Brisbane and a suspected microburst caused major damage in the northwestern suburbs.

Tropical cyclone activity in the Australian region in the 2007/08 season was close to normal with a total of 10 systems (including those of late 2007).

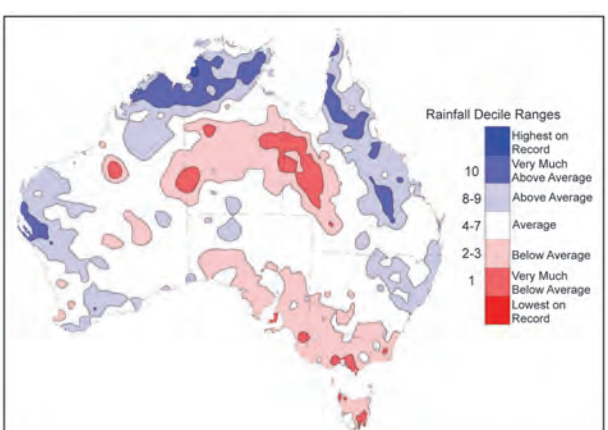

Fig. 7.49. Australian annual rainfall deciles for 2008.

2) New Zealand—M. J. Salinger

New Zealand's climate for 2008 was sunny and warm with many extremes. Most significantly, drought from January to March in the west of the North Island was estimated to have cost at least $1 billion (NZ), while floods in central North Island areas caused loss of life.

Overall, mean sea level pressures were near average over New Zealand, with more anticyclones than average to the east of the country, resulting in frequent winds from the north and northeast. Warmer-than-normal sea surface temperatures prevailed around New Zealand from January to May, becoming cooler during late spring before warming up again by early summer.

The national average temperature in 2008 was 12.9°C, 0.3°C above the 1971–2000 normal (Fig. 7.50). Temperatures were generally between 0.5° and 1.0°C above average in the west of the North Island and Nelson. The warmest location was Leigh (northeast North Island), with a mean temperature for the year of 16.5°C, 0.3°C above normal.

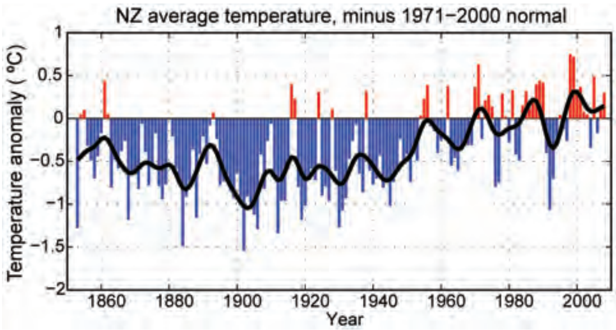

Fig. 7.50. Mean annual temperature anomalies (°C) over New Zealand, from 1853 to 2008 inclusive, based on between 2 (from 1853) and 7 (from 1908) long-term station records. The blue and red bars show annual differences from the 1971–2000 average; the solid black line is a smoothed time series.

Rainfall was close to normal in many areas of New Zealand. Annual rainfall was more than 135% of normal at the northern tip of New Zealand and in central New Zealand (Wellington and in central Marlborough), and more than 120% of normal in the far northern areas of the country, central New Zealand, and parts of the east of South Island. Annual rainfall was less than 90% of normal in the southwest of South Island, and the east of North Island, with parts of Fiordland, eastern Otago, and southern Hawke's Bay recording less than 80% of normal.

It was a sunny year everywhere, with nowhere in New Zealand recording below-normal sunshine totals. Sunshine hours were more than 115% of normal in central areas of North Island, the east of North Island, and in the east and south of South Island, with Turangi, Dannevirke, Waipawa, and Invercargill experiencing their sunniest years on record.

From January–March it was very extremely dry, with monthly totals of less than 10 mm in many areas. In Waikato it was the driest January in over 100 years of records. The dryness continued through February and March, and as a result, severe soil moisture deficits persisted in Waikato, parts of Bay of Plenty, South Taranaki, and northern Manawatu, Hawke's Bay, Wairarapa, and Marlborough, as well as parts of south Canterbury, Otago, and Southland. January also saw heat wave conditions occur across inland areas of South Island, sometimes reaching the coast.

April was a month of extremes, with floods in northern New Zealand, while it remained dry in the south. Heavy rainfalls alleviated the significant soil moisture deficits for most of North Island. It was the coldest May since 1992, with the national average temperature of 9.6°C being 1.1°C below average.

May to August were stormy months. Late June saw thunderstorms, hail, lightning, and high winds affecting much of North Island. In the last week of July, New Zealand was hit by two intense storms that caused flooding and the loss of five lives. Winter rainfall was over twice as high as normal in the northeast of South Island, with several high rainfall/flood-producing events. On 26 July heavy rainfall in Northland and Coromandel (166 mm was recorded in Paeroa, the highest 1-day total for July since records commenced in 1914) caused severe flooding. On 29 July, heavy rainfall caused more flooding, slips, and damage in Thames/Coromandel, Auckland, Nelson, and Marlborough. More severe flooding occurred on 26 August, when 126 mm of rain fell at Kaikoura, the second-highest 1-day August rainfall for this location since 1898, resulting in several landslides, damage, and the death of many livestock. Rainfall totals were greater than 150% of normal for much of North Island in August. Mt. Ruapehu in the central North Island recorded a snowpack of 3.5 m, the deepest since records began in 1992.

September brought a shift back to much more settled weather conditions for the country. Temperatures were above average, while rainfall was less than 50% of normal for many areas.

The period October to December was dry, with the southeast of South Island recording its highest October sunshine values on record. November and December were sunny months over much of the country, and rainfall was once again less than 50% of normal in eastern areas and between 50% and 80% of normal for much of North Island. Soil moisture levels in eastern areas and in Waikato were between 30 and 50 mm lower than normal at the end of December. Double the normal rainfall for November fell in the northwest of South Island and for December in inland Canterbury and Banks peninsula.

The highest New Zealand temperature of the year (34.8°C) occurred in the east of South Island at Timaru Airport on 12 January and 19 March and at Waione (eastern North Island) on 22 January, while the lowest temperature was −9.5°C recorded at Mt. Cook on 20 August. The highest-recorded wind gust was 183 km h^{-1} at Mokohinau Island on 11 May and at Hicks Bay on 18 June. The driest location was Alexandra in Central Otago with 376 mm of rain for the year, while, of the regularly reporting gauges, Cropp River in the Hokitika River catchment in the west of South Island recorded the highest rainfall with 10,940 mm. Of the major cities, Wellington was by far the wettest with 1,662 mm; in contrast, Christchurch and Dunedin were the driest of the five main centers with a mere 704 and 705 mm, respectively. Auckland received 1,226 mm and Hamilton 1,220 mm.

3) Southwest Pacific—S. McGree

The year began with La Niña conditions firmly established in the equatorial Pacific (see chapter 4), the event reaching maturity in February, with the first signs of weakening apparent in March. Neutral conditions existed in May and continued for the rest of 2008, although some indices were more typical of a weak La Niña in November and December. The surface equatorial (trade) winds were generally enhanced from January to April, and again later in the year between September and December. Sea surface temperature anomalies along the equator in January were the coolest since 2000. Broadscale anomalies were as low as −2°C, with small areas of −3°C, and extended along the equator from the South American coast to west of the date line central; eastern equatorial SSTs increased from March to August. In September, slight cooling took place with further cooling from October to December, especially in the eastern Pacific.

From early January, the SPCZ was southwest of its normal position, typical of a cool ENSO phase. In March to May the SPCZ was well south, over Vanuatu and occasionally south of Fiji (Fig. 7.51). In June it extended from PNG over northern Fiji to Niue and across to the southern Cook and Austral Islands. Over the next five months, the SPCZ was generally north of Fiji, but it was usually weak and inactive; however, there were instances when troughs of low pressure would merge with the SPCZ, resulting in enhanced activity. In late December, the SPCZ was again south of its climatological position, particularly in the areas near Samoa and the Cook Islands. From January to May a large region of suppressed convection existed near the equator, including western and eastern Kiribati, Nauru, Tokelau, Tuvalu, and northern Cook and Marquesas Islands. Over the next three months the area of suppressed convection contracted but still included Kiribati and the region immediately to the south of these islands. Suppressed convection covering an area similar to that from January to May also existed from October to December.

Positive sea surface temperature anomalies existed around Vanuatu, New Caledonia, west of Fiji, eastern French Polynesia, and Pitcairn Island in January. These positive SST anomalies expanded in February to cover the band from PNG to Vanuatu, south of Fiji, to a large region south of the Cook and Austral Islands. Anomalies above +2.0°C existed at the center of this large region. The area of positive SST anomalies increased in March to include the Solomon Islands, Fiji, Tonga, and the southern Cook Islands. Cooling occurred from April to June. Warming resumed in July, and by November positive SST anomalies existed from northern PNG to French Polynesia. Positive SST anomalies extended as far north as Tuvalu and Samoa in December and were greater than +2.0°C from southern Vanuatu to south of Fiji and in a large region south of the Cook Islands. This pattern is typical of positive (cool) ENSO conditions caused by a strengthening of the South Pacific high and the southwest displacement of the SPCZ.

Annual rainfall was greater than 120% of normal across most of the Solomon Islands, central Vanuatu, most of Fiji, and Tonga. Near-normal rainfall was received elsewhere in these countries and the southern parts of Tuvalu, Niue, American Samoa, and the southern Cook Islands. Below-normal rainfall was recorded at Nanumea in northern Tuvalu (36% of normal, lowest in 68 years), the whole of Kiribati (44%–59%), and Penrhyn in the northern Cook Islands (56%). This pattern of drier conditions in

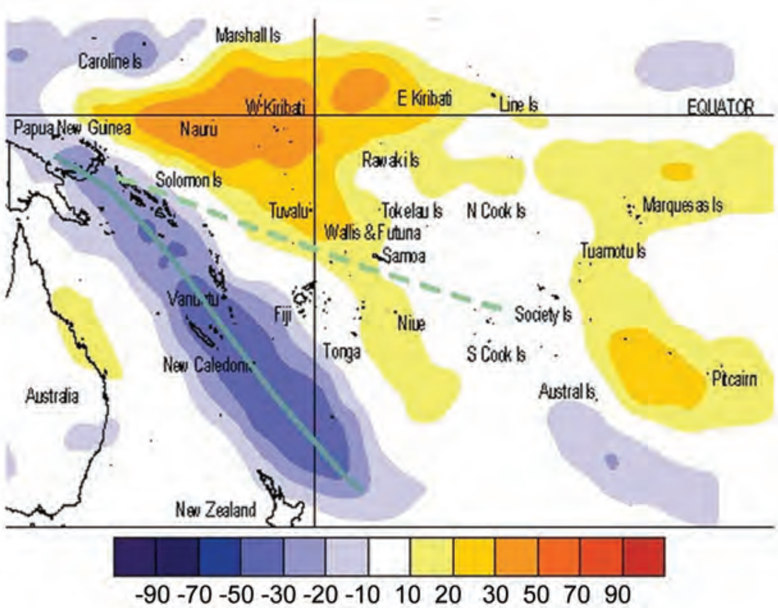

Fig. 7.51. Outgoing longwave radiation anomalies (W m^{-2}) in the southwest Pacific for Apr 2008. Solid line indicates the location of the SPCZ. Dashed line indicates the normal location of the SPCZ in Apr.

the north and east, and wetter conditions in the south and west, is broadly consistent with the neutral-to-cool ENSO conditions that were experienced through 2008.

Maximum and minimum air temperatures in American Samoa were above normal year-round. In Fiji, maximum and minimum temperatures were normal or above normal, except in January and May—and March in the case of minimum temperatures.

Three tropical cyclones formed in the southwest Pacific in 2008 (for full details see chapter 4). TC Funa developed near northern Vanuatu on 16 January, resulting in maximum winds to 195 km h^{-1}, causing damage to agricultural crops, villages, and tourist resorts in the provinces of Torba, Sanma, and Penama. TC Gene developed over Fiji on 28 January with winds to 185 km h^{-1}, resulting in significant damage to agricultural crops and the loss of seven lives. The financial cost of the damage in Fiji exceeded $22 million (USD). More than 50% of agricultural crops were damaged by high winds as the cyclone passed close to the island of Futuna in Vanuatu.

Satellite observations show generally positive sea level in the western South Pacific throughout the year. In March, the region of +20-cm anomalies had expanded east as far as Tuvalu, with all-time monthly mean sea level records set in the PNG and the Solomon Islands region. Reasonably large tidal ranges were observed early in May and June due to the astronomical positions of the moon and the sun. Record-high sea level was observed by the Vanuatu Tide Gauge in November, with the monthly mean exceeding the October 2008 record by 5 cm. Large waves generated by weather systems in the far North Pacific caused flooding along coastlines of a number of Pacific Island countries in December. By the end of the month, positive sea level anomalies existed across much of the region, from 160°E–160°W and 5°–22°S, with the highest +20-cm anomalies off the PNG coastline.

Other notable meteorological events included hail on three separate days and a small 15-min tornado during November in Fiji. Incidences of hail and tornados are very rare in the southwest Pacific and are usually associated with afternoon thunderstorm activity.

4) Northwest Pacific, Micronesia—C. Guard and M. A. Lander

(i) Overview

This assessment covers the area from the date line west to 130°E, between the equator and 20°N. It includes the U.S.-affiliated islands of Micronesia but excludes the western islands of Kiribati. The weather throughout Micronesia was generally tranquil, with no destructive wind events and few extremes of rainfall. This is generally typical of the weather experienced during La Niña, although the prevailing state of the climate was ENSO neutral. As in 2007, trade winds and low-latitude easterly winds were stronger than normal, while the monsoon trough spent most of the boreal summer and fall west of Micronesia, rarely pushing eastward beyond Palau and Yap. This caused a shift of tropical cyclone activity in the basin, with most tropical cyclones developing west of Guam and north of Yap, and not significantly intensifying until they were nearer to the Philippines, Taiwan, or East Asia. In addition, sea levels were significantly higher than normal across all of Micronesia. In fact, the most dramatic climate extreme of the year occurred during the week of 8–15 December 2008, when an unusual pattern of gale-force winds located in the subtropics of the western North Pacific near the date line generated an oceanic swell that traveled to the south and caused phenomenal surf throughout eastern Micronesia and the northern coast of Papua New Guinea.

(ii) Temperature

Except for the Mariana Islands (e.g., Guam and Saipan), average monthly maximum temperatures across most of Micronesia were lower than normal. At the Guam International Airport, monthly average maximum temperature anomalies were +0.40°C from January through June and +0.19°C for the entire year. For Palau, at the western end of the area, the average monthly maximum temperature anomalies were −0.35°C for the first six months and −0.27°C for the entire year. Values at Yap were −0.34°C for the first six months and −0.42°C for the entire year. In central Micronesia, south of 10°N, Chuuk had average monthly maximum temperature anomalies of −0.22°C for the first 6 months and 12-month anomalies of −0.28°C. Farther east, Pohnpei experienced January through June anomalies of −0.15°C and for the year they were −0.16°C. Still farther east, maximum temperature anomalies at Kosrae were larger, with 6-month and 12-month values being −0.74°C and −0.65°C, respectively.

The cause of the persistently below-normal maximum temperatures across most of Micronesia may have been related to the persistent tongue of colder-than-normal SSTs that extended from California to south of Hawaii, and then to Micronesia, for much of the year. In addition, trade winds were much stronger than normal over Micronesia, likely increasing cooling via evaporation. Temperature anomalies for the first six months and for all of 2008 for selected Micronesian locations are summarized in Table 7.4.

(iii) Precipitation

Precipitation at the major island stations during the first half of 2008 was fairly typical of La Niña conditions. The stronger-than-normal and converging northeast and southeast trade winds allowed the trade wind trough to become well developed, keeping the western North Pacific islands between 4° and 8°N wet during the first half of the year. The trough axis typically passes very close to Kosrae, which had 3101.1 mm or 112% of normal rainfall during the first half of 2008. In general, rainfall for the first six months of 2008 in Micronesia fell between 75% and 125% of average throughout most of the area. With the exception of the Marshall Islands, locations north of 8°N were drier than normal, while those south of 8°N were generally wetter than normal. In the Marshall Islands, locations north of 6°N were drier than normal and those south of 6°N were wetter. During the third quarter (July–September), almost all locations in Micronesia were considerably drier than normal. This was the result of monsoon and tropical cyclone activity being displaced well to the north and west, and high pressure generally dominating Micronesia. The annual rainfall for the major islands in Micronesia ranged from a high of 5,661.7 mm or 108% of normal at Kosrae to a low of 1,697.2 mm or 88% of normal at Saipan in the Commonwealth of the Northern Mariana Islands. Palau at the western edge of the area had 4,038.3 mm or 107% of normal, while Majuro at the eastern edge of the area had 2,933.7 mm, 88% of normal for the year. Generally, islands north of 8°–9°N and east of 165°E were drier than normal, while those to the south and west were wetter than normal. The six-month and annual rainfall for selected locations are summarized in Table 7.4. Figure 7.52 shows the annual rainfall amount and percent of normal for American Samoa and the major Micronesian islands.

(iv) Tropical cyclone activity

Tropical cyclone activity in 2008 in the western North Pacific and across Micronesia was below nor-

Table 7.4. Maximum (max) temperature (temp) anomalies and rainfall anomalies for selected Micronesian locations for Jan–Jun and Jan–Dec 2008. "N" is the normal rainfall taken from the NCDC 1971–2000 base period. Locations (lat and lon) are approximate.

		Max Temp		Rainfall					
		Jan–Jun	Jan–Dec	Jan–Jun			Jan–Dec		
Station	**Location**	°C	°C	N mm	2008 mm	2008 %	N mm	2008 mm	2008 %
Guam	13°N, 145°E	+0.40	+0.19	612.1	618.2	99	2167.6	1838.2	81
Yap	9°N, 138°E	−0.34	−0.42	1168.9	950.7	81	2987.5	2710.4	89
Palau	7°N, 134°E	−0.35	−0.27	1724.7	1841.8	107	3768.6	4038.3	107
Chuuk	7°N, 152°E	−0.22	−0.28	1538.0	1801.4	117	3402.8	3262.1	97
Pohnpei	7°N, 158°E	−0.15	−0.16	2277.6	2794.8	123	4689.1	4767.1	100
Kosrae	5°N, 163°E	−0.74	−0.65	2765.3	3101.1	112	5236.7	5661.7	108
Kwajalein	9°N, 168°E	−0.69	−0.63	959.6	822.5	86	2550.2	2164.6	83
Majuro	7°N, 171°E	+0.62	+0.25	1455.4	1289.6	89	3344.2	2933.7	88

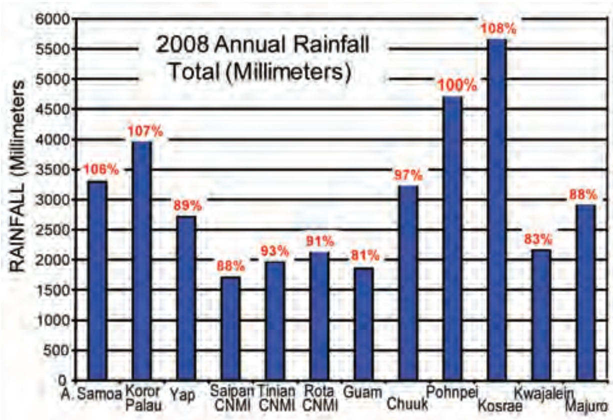

Fig. 7.52. Annual rainfall (mm) for American Samoa and selected Micronesian islands for Jan through Dec 2008. Numbers above the bars indicate the annual rainfall as a percent of normal as determined from the NCDC 1971–2000 base period.

mal (see chapter 4d4), and was even more meager than in 2007. For nearly the entire year, low-level easterly wind anomalies dominated low latitudes of the western North Pacific. The monsoon trough was weak and displaced to the west, and as a result, tropical cyclone genesis was affected in two fundamental ways: a reduction of the number of tropical cyclones that developed in the deep tropics and a major shift to the west and north of the tropical cyclone genesis area. It was not until the first week of December that a midlatitude cyclone east of Japan intensified and developed a warm-cored vortex and became the seed for Typhoon Dolphin. Prior to Dolphin, every 2008 storm that began to develop in Micronesia never intensified beyond tropical depression intensity until it passed west of Palau, Yap, Guam, or the Commonwealth of the Northern Mariana Islands.

(v) Sea level

The high sea levels of 2007 that occurred across Micronesia continued through all of 2008. The persistent La Niña–like conditions kept trade winds strong, and hence the wind stress caused water to mound up in the west of the basin. In addition, clearer-than-normal skies allowed the ocean to absorb abundant incoming solar radiation, which added heat content, and hence thermal expansion, to the upper 300 m of the western North Pacific Ocean. As a result, coastal flooding and inundation affected many of the low islands from the Marshall Islands in the east to Palau in the west. Sea levels were highest from January through April and in November and December. From January 2008 through the end of the year, sea levels averaged 15 to 25 cm above their normal monthly averages, but during full and new moon phases, the high tide levels were sometimes as high as 80–110 cm above expected high tide levels. The high astronomical tides coupled with the affect of La Niña caused considerable coastal inundation in the Chuuk and Pohnpei states, contaminating drinking water and destroying food crops.