## 6. REGIONAL CLIMATES

### a. Overview—A. Arguez

This section provides a localized perspective of global climates in 2007, offering analyses of individual continents, nations, and subregions. Consistent with the remainder of the report, the year 2007 is described and placed in a historical context to the extent possible. The vast majority of contributions to this section are authored by scientists that hail from the respective region for which they cover. The remainder of this section is divided into seven parts: Africa, North America, Central America and the Caribbean, South America, Asia, Europe, and Oceania. These regions are further divided into pragmatic subdivisions. Naming conventions in this section do not reflect any particular sympathies, political or otherwise. Please note that varying reference periods are utilized in the computation of climate anomalies. Please also note that seasonal averages (boreal winter or austral summer) sometimes include data from December 2006, and in some cases annual anomalies are defined for December 2006 to November 2007, due to lags in acquiring data. Where omitted, the source of data used in analyses is typically the agency that the section's lead author is affiliated with.

### b. Africa

#### 1) Eastern Africa—C. Oludhe, L. Ogallo, L. Njau, M. Kadi, and S. Tinni

The GHA subregion can be divided into three sectors (southern, equatorial, and northern) based on periods of rainfall onsets and withdrawals associated with the movement of the ITCZ. The southern sector, consisting of central and southern Tanzania, experiences a unimodal rainfall regime, with rainfall occurring from December to April. The equatorial sector is made up of northern Tanzania, Rwanda, Burundi, Uganda, Kenya, southern and extreme eastern Ethiopia, southern Sudan, and the southern half of Somalia; it exhibits a bimodal rainfall regime, with the "long rains" season occurring in March–May and the "short rains" being experienced in October–December. In the northern sector, composed of central and northern Ethiopia, Eritrea, Djibouti, and the northern half of Sudan, the major rainy season is June–September, but a few areas receive a secondary peak from March to May.

Most of the southern and equatorial sectors as well as much of Ethiopia received rainfall amounts ranging from 75% to 125% of their LTM in 2007 during the usually dry months of January–March. Rainfall in north-central Tanzania was over 25% greater than normal. The remaining parts of the region received less than 75% of their LTM rainfall. March marks the beginning of the long rains over the equatorial sector, and March 2007 was marked with reduced rainfall activity and poor distribution over most parts of the GHA. Specifically, much of the northern half of the GHA received less than 100 mm of rainfall while most of the southern sector received more than 100 mm of rainfall during March .

The period JJA marks the summer rainfall season over many parts of the northern sector, and is also important for the western and coastal parts of the equatorial sector. In 2007, the season was marked by very wet conditions with rainfall totals that were 25% to over 75% greater than the LTM, with extremely wet conditions in northeast Sudan, Somalia, northern Kenya, and western Tanzania. Severe floods ravaged the GHA during the 2007 rainy season. The Mpeketoni and Witu divisions of Kenya were hit by floods in early June. In late July, Sudan's Humanitarian Aid Commission reported that the level of the Blue Nile at Khartoum, the capital, was "far above" the record levels seen at this time of year in 1988. August brought flooding to western Kenya's Budalangi region and the Teso subregion of Uganda. A major flood event also affected Rwanda on 12 September.

Climatologically, the various stages of the life cycle of the short rains are associated with specific months by sector. September marks the withdrawal of rainfall over the northern sector. October marks the onset of the seasonal rainfall over the equatorial sector. November marks the peak of the rainfall season over the equatorial sector. December marks the cessation of the rainfall season over the equatorial sector. During 2007, rainfall in September was mainly concentrated over the southern and central parts of the northern sector. In October, a delayed onset of the seasonal rainfall over most parts of the equatorial sector was observed, while rainfall activity was confined to the central and western equatorial sector. In November, rainfall activity was depressed over most parts of the northern and southern sectors and above average over the equatorial sector.

#### 2) Northern Africa

##### (i) Northwest Africa—K. Kabidi and A. Sayouri

Most of northwest Africa's rainfall occurs during the period of October–May as the result of extratropical weather system incursions from the Atlantic Ocean and Europe, bringing cold air and cloudiness. The typical rainfall distribution is characterized by a positive gradient from south to north and the topographic influence exerted by the Atlas Mountains. The dry season extends from June to

Table 6.1. Daily minimum temperature records for March.

| Station | Record value (°C) and date | Previous record (°C) and date | Record period |
|---|---|---|---|
| Rabat Sale<br>Lat: 34°3´N<br>Lon: 6°46´W | 1°C on 23 Mar 2007 | 1.9°C on 6 Mar 1967 | 1957–2007 |
| Sidi Slimane<br>Lat: 34°14´N<br>Lon: 6°3´W | –0.5°C on 23 Mar 2007 | 0.4°C on Mar 2004 | 1980–2007 |
| Chefchaouen<br>Lat: 35°5´N<br>Lon: 5°18´W | –3.5°C on 23 Mar 2007 | –1°C on 6 Mar 2005 | 1995–2007 |
| Tanger Aero<br>Lat: 35°43´N<br>Lon: 5°53´W | 1°C on 23 Mar 2007 | 1.4°C on 6 Mar 2005 | 1931–2007 |

early September, influenced by hot, dry air originating from the Sahara. Nevertheless, some convective clouds develop occasionally during the dry season when subtropical maritime air masses converge in the region. Summer is generally dry and hot; daily maximum temperatures exceeding 40°C is a common feature of the continental areas.

The year 2007 was characterized by several extreme weather events including heavy rainfall, heat waves, cold spells, and strong winds.[1] Several records were broken and the annual mean temperature continued to rise. northwest Africa experienced windy conditions across the region during February and March, with wind speeds exceeding 31 m s$^{-1}$ in some areas. The maximum wind speed was recorded at Khouribga, Morocco (~36 m s$^{-1}$). On 23 March, very low temperatures were recorded in several locations (Table 6.1). The daily temperature anomalies are plotted in Fig. 6.1.

At the beginning of spring, there was significant rainfall activity over northwest Africa. In April, many stations in Morocco, Algeria, and Tunisia reported rainfall exceeding 100 mm. A total of 73.6 mm of rainfall fell on 21 April in Nador in northern Morocco. These extreme rainfall events caused damage to property and infrastructure and claimed numerous lives, mainly because of the resulting springtime flooding in Algeria.

Several heat wave events occurred in the summer of 2007, contributing to forest fires in the Rif Mountains of northern Morocco in July. Tunisia and Algeria withstood a severe heat wave during June and July, where the daily maximum temperature exceeded 47°C (117°F), breaking all-time high temperature records in some locations (Fig. 6.2).

During autumn, northwest Africa experienced a succession of weather systems. Region wide the mean rainfall exceeded 100% of the normal for the season, and daily rainfall records for November were broken. For example, 94 mm of rain fell at Tetouan City in the extreme north of Morocco on 24 November, breaking the previous daily record of 90 mm on 19 November 1969. Flooding in parts of Algeria occurred throughout the fall, causing additional damage and loss of life.

[1] Based on observations from the Direction de la Météorologie Nationale in Morocco.

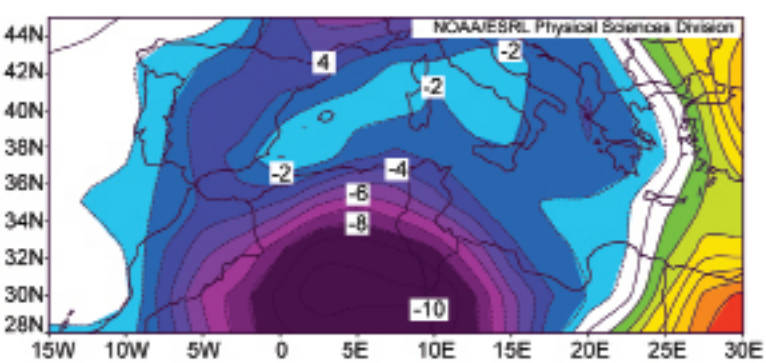


**Fig. 6.1. Daily temperature anomalies (°C; 1968–96 base period) over northwest Africa on 23 Mar 2007. [Source: NOAA/ESRL.]**

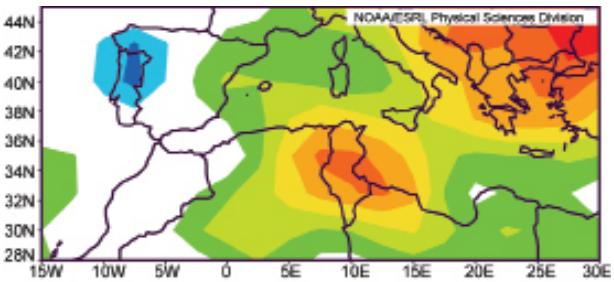


**Fig. 6.2. Monthly temperature anomalies (°C; 1968–96 base period) for Jun 2007 over northwest Africa. [Source: NOAA/ESRL.]**

(ii) Egypt—S. M. Attaher and M. A. Medany

Egypt is located in the northeast corner of the African continent, with 3,500 km of coastline facing the Mediterranean in the north and the Red Sea in the east. Egypt is divided into four major geographic zones: 1) the Nile Valley and Delta, 2) the Western Desert, 3) the Eastern Desert, and 4) the Sinai Peninsula. Egypt is composed of two climatic zones, the Mediterranean zone and the arid zone of the North Africa region. In general, Egypt's climate is semiarid to arid, characterized by hot dry summers, moderate winters, and very little rainfall. Temperatures average between 27° and 32°C in summer and 13° and 21°C in winter, and most rainfall occurs in the winter months. Snow periodically falls on Sinai's mountains, and on rare occasions in the northern coastal cities. Several prominent wind regimes affect Egypt, including the Khamaseen, which is a seasonal southeasterly wind that blows every spring. The Khamaseen advects sand and dust, and can be associated with temperatures that exceed 38°C.

The average annual surface temperature in 2007 was 0.9°C above the 1961–90 average (Fig. 6.3). For the year, all stations indicated an increase in minimum temperature in the range of 1.0°–2.1°C, with an increase in average temperature of 0.5°–1.3°C. Approximately six cold waves occurred in winter, during which the temperature decreased by 3°–7°C below normal, with each event lasting 3–6 days. Several heat waves with daily temperature anomalies exceeding +2°–6°C were observed during January, February, March, and December, with each heat wave lasting about 2–7 days. From May–November, temperatures were near normal or above the average by 2°–6°C, with an increased frequency of heat waves. Although the number of the rainy days was near the annual average, the total precipitation in 2007 was below the normal by about 8%–17%.

Strong winds and dust and sand storms typically occur in February–April in Egypt. During February and March 2007, there were a limited number of these events, with an average wind speed less than 6 m $s^{-1}$, whereas the recorded average horizontal visibility was 4–6 km. On 17 April, a strong sand storm associated with the Khamaseen hit Egypt with wind speeds reaching 17 m $s^{-1}$ coupled with temperatures reaching 36°C (~8°C above normal). This sand storm decreased the horizontal visibility to less than 100 m, effectively shutting down all transportation activities for a day and a half. The National Meteorological Authority declared that this sand storm was the strongest in 30 yr.

3) Southern Africa—W. M. Thiaw, A. C. Kruger, D. M. Patricio, L. Njau, M. Kadi, and S. Tinni

(i) Precipitation

During the 2006–07 rainfall season, the climatologically wet region of southern Africa (the eastern half of the region) registered amounts that ranged between 300 mm in central South Africa to over 1200 mm in northern Madagascar and parts of northern Zambia (Fig. 6.4a). In the climatologically dry zone (the western part from Namibia and Botswana southward into western South Africa) rainfall totals ranged between less than 100 mm along coastal Namibia and South Africa to 400 mm in the northern areas of Namibia and Botswana. The rainfall season featured a north–south dipole structure with enhanced rainfall in the northeastern part of the region from central Mozambique and eastern Zimbabwe northward into eastern Zambia (Fig. 6.4b). Rainfall was particularly enhanced over central Mozambique, where anomalies exceeded 200 mm in some localities. The area of suppression was in the southern part of the region, and mainly over South Africa, Botswana, and Namibia, where rainfall anomalies averaged 50–200 mm below the mean.

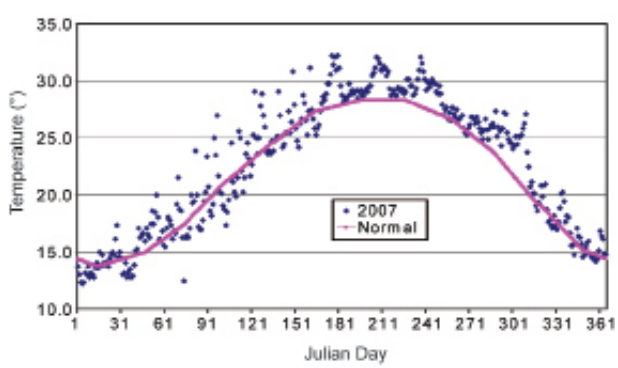


**Fig. 6.3. Average annual surface temperature (°C) of 2007 for Egypt (blue diamonds) compared with the average normals for 1961–90 (pink line).**

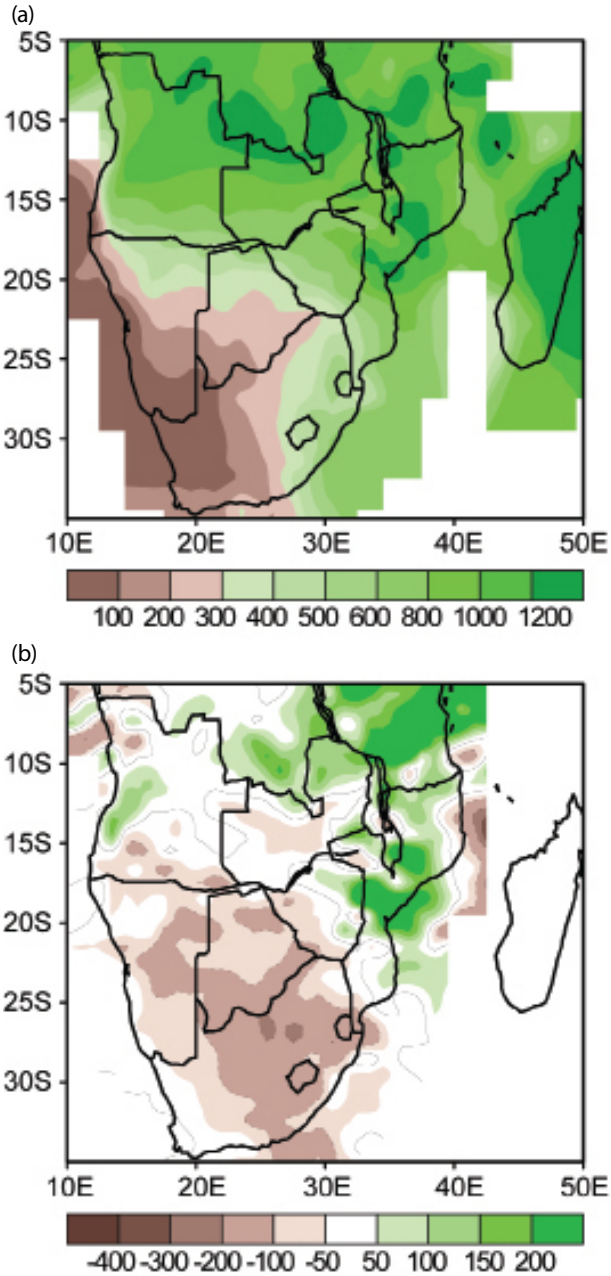


**Fig. 6.4. (a) Total precipitation (mm) and (b) anomalies (mm; 1971–2000 base period) for Nov–Apr 2006/07 over southern Africa.**

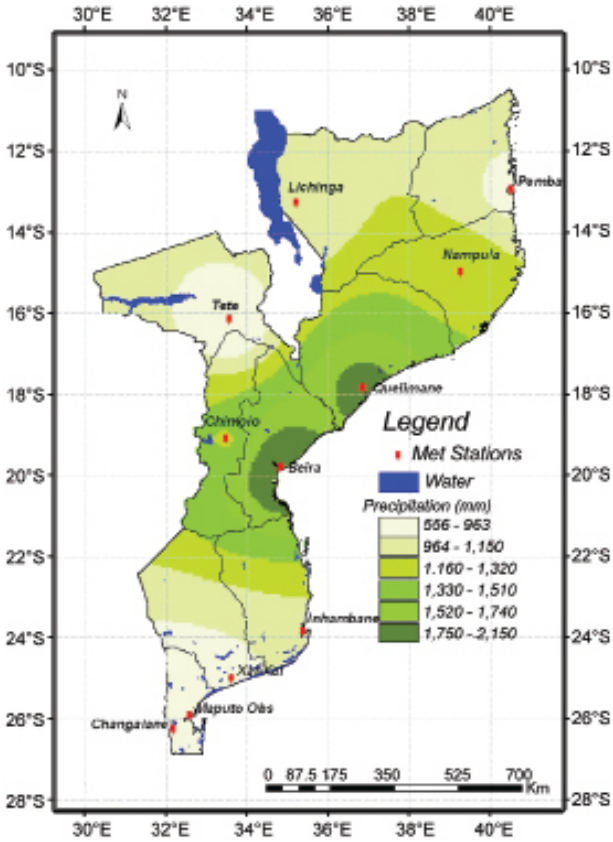


**Fig. 6.5. Annual total rainfall (mm) for 2007 over Mozambique.**

The rainfall season was once again marked by sharp intraseasonal variability. In the area of enhancement, rainfall was off to a quick start early in November, and the months of December and January ranked above the 90th percentiles based on the 1971–2000 mean. In response to a warm Indian Ocean, and especially to the Agulhas Current, strong tropical cyclones brought extremely heavy rainfall to central Mozambique and caused flooding along many river basins, including the Save River. In contrast, in the area of suppression (Fig. 6.4b), while the rainfall was near average in November, and December ranked in the 70th percentile, the period from January to March 2007 was extremely dry, with both January and February ranking only in the 10th percentile and March in the 30th percentile.

Annual rainfall in 2007 over southern Africa was highly variable. The most noteworthy deviations from normal were dry conditions over the central and eastern parts of South Africa, the southeastern coast of Madagascar, and southern parts of the Democratic Republic of the Congo. Very high rainfall was received along the coasts and adjacent interiors of Angola into northern Namibia, central Mozambique into eastern Zimbabwe, and along the west coast of Madagascar, mostly during the latter part of the year from October to December. South Africa suffered from drought and wildfires in July, ravaging swaths of KwaZulu-Natal, Mpumalanga, and Swaziland.

Rainfall over Mozambique, in particular, was significantly above average in 2007. In southern Mozambique, rainfall was 31.5% above normal. In

December, 333 mm fell in Inhambane. In central Mozambique, 2007 rainfall was 26% above normal, with 640 mm of rain falling in January in Quelimane and 2,153 mm falling for the year in Beira (Fig. 6.5). Northern Mozambique was near normal for 2007, but heavy rainfall (430 mm) fell in Pemba in February.

(ii) Temperature

Annual mean temperatures[2] over southern Africa were generally very close to the 1971–2000 mean. However, areas in northern South Africa, northern Madagascar, and a wide area in southern Angola and in northwestern Zambia were 1°–2°C above normal. The near-normal temperature conditions in the southern parts is reflected by the mean temperature anomalies of 28 South African climate stations, which show that temperatures in South Africa in general were about 0.44°C above the 1961–90 mean, making 2007 approximately the 11th warmest year since 1961.

(iii) Atmospheric circulation

Consistent with warming in the equatorial Pacific and in the midlatitudes of the South Atlantic and south Indian Oceans, the low-level atmospheric circulation associated with the 2006–07 rainy season featured weaker-than-normal westerlies south of about 35°–40°S. As a result, midlatitude frontal systems from the southwest were less active, setting up unfavorable conditions for rainband disturbances to develop and move across southern Africa. These socalled tropical temperate troughs result from the coupling between midlatitude systems and tropical lows and account for much of the synoptic rainfall in southeastern Africa. In addition, the 500-hPa geopotential height pattern (Fig. 6.6) revealed the presence of a persistent anomalous high pressure system of 70–210 m above average, mostly located over southern Africa for much of the peak of the Southern Hemisphere summer. In contrast, on the equatorward flank of the Mascarene high pressure system, an easterly wind anomaly indicated by magnitudes of 2–8 m $s^{-1}$ converged over the Mozambique Channel north of Madagascar with a northeasterly flow that originated from the Congo. These conditions, in addition to an active south Indian Ocean tropical cyclone season, contributed to enhanced rainfall in the northeastern sector of southern Africa.

[2] Some of the temperature data used in the southern Africa section are from the forthcoming climate data bank of the South African Weather Service.

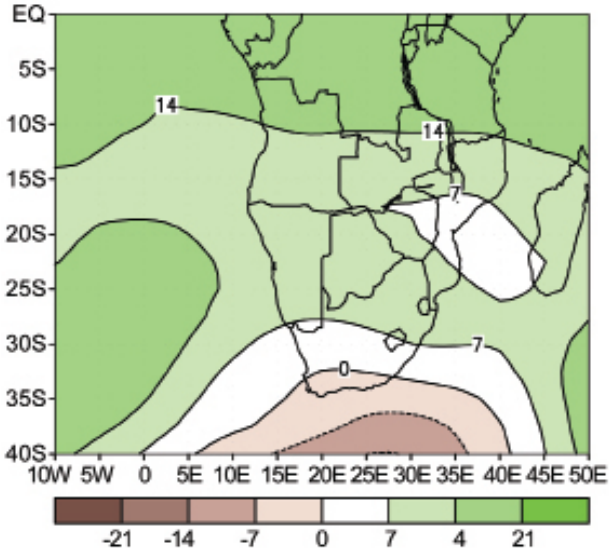


**Fig. 6.6. Geopotential height anomalies (tens of meters) at 500 hPa for Dec–Feb 2006–07. Green (brown) shades indicate areas of anomalous anticyclonic (cyclonic) flow.**

4) West Africa—W.M.Thiaw, L.Njau, M.Kadi, and S.Tinni

(i) Precipitation

Rainfall totals (from numerous rain gauges) during the period July–September 2007 ranged between less than 100 mm in the northern part of the Sahel to over 900 mm in the areas of maximum precipitation, including the western Guinean coast, and the southern boundary between Nigeria and Cameroon (Fig. 6.7a). The 300-mm isoline stretched from northern Senegal to eastern Chad almost continuously along 15°N. The position of this isoline is critical in determining the strength of the monsoon system.

The 2007 rainy season once again featured above-average rainfall across most areas in the Sahel and portions of the Gulf of Guinea region. Rainfall totals exceeded 100 mm above average across southern Mauritania, Senegal, western Mali, Burkina Faso, most areas in southern Niger, and central Chad (Fig. 6.7b). Anomalies of over 200 mm above the mean exacerbated flooding in many areas from Niger to Senegal. Overall, the 2007 rainy season was the second wettest since 1968, but as in 2006, the rainfall season was marked by a late onset in June. As of July, rainfall was significant enough to offset the delayed onset of the monsoon, and flooding occurred in many areas, especially in Mali. This change in the rainfall pattern was associated with an abrupt northward shift of the position of the ITCZ. As of August, positive rainfall anomalies extended well north of 20°N to encompass areas including central Mauritania and the northern areas of Mali and western Niger. These

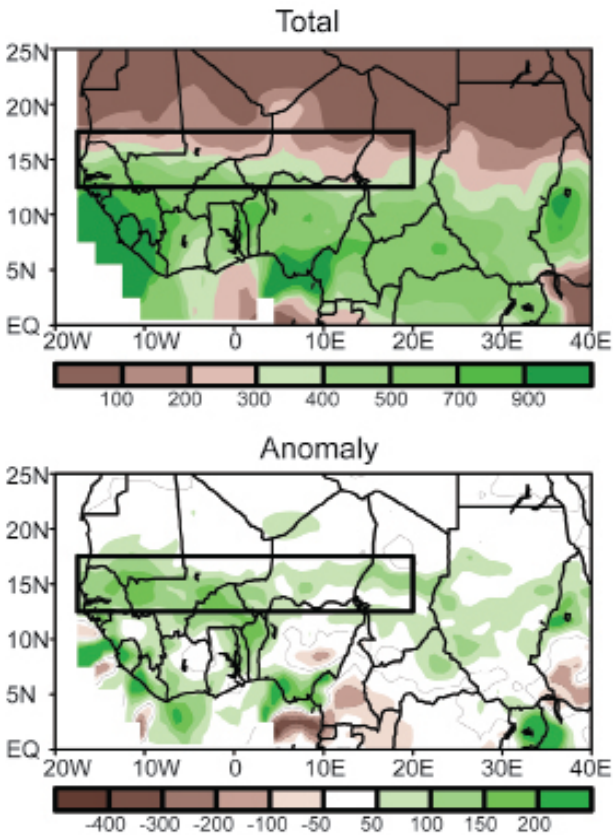


**Fig. 6.7. (a) Total precipitation (mm) and (b) anomalies (mm; 1971–2000 base period) for Jul–Sep 2007. The boxed region denotes the approximate boundaries of the Sahel region.**

positive rainfall anomalies persisted through September 2007. In contrast to the 2006 rainfall season, and despite sporadic dry spells in various parts of the region, including central Cote d'Ivoire, Ghana, and the southern portions of Togo and Benin, the Gulf of Guinea region also received near- to above-average rainfall for the period July–September 2007. The largest anomalies exceeded 150 mm and were observed over southern Nigeria, northern Benin, and along the western Guinean coastline.

Severe flooding events occurred across the region. In Burkina Faso, two-thirds of all houses in the village of Banh were washed away by flood waters in early August. Concurrently, flood events occurred in many parts of Nigeria, Niger, and Chad.

(ii) Atmospheric circulation

The Sahel and the Gulf of Guinea regions' rainfall is controlled by the depth and northward penetration of the West African monsoon, which in turn is related to the position of the mid- and upper-level jets, the AEJ and the TEJ, respectively. These larger-scale circulation features are fairly sensitive to changes in the global monsoon circulation on both the interannual and interdecadal time scales. The above-average 2007 rainfall resulted from an enhanced global monsoon circulation with a direct impact on West Africa. In fact, the composite map of the 200-hPa velocity potential anomaly overlaid with divergent wind (Fig. 6.8) during August–September 2007 revealed a wavenumber 1 pattern featuring divergence across Africa and Indonesia, and subsidence from the central Atlantic to the western Pacific. Consistent with this pattern, strong southwesterly winds at 925 hPa averaging 3–6 m $s^{-1}$ extended well northward into the Sahel region. This enhanced monsoonal inflow was also evident at 850 hPa, with cross Atlantic westerly wind anomalies exceeding 3 m $s^{-1}$ contributing to a deep penetration of moist, unstable air well into the Sahel region. The enhanced monsoon was also associated with an anomalous enhanced cyclonic shear along the equatorward flank of the AEJ.

## c. North America

### 1) Canada—R. Whitewood and D. Phillips

In Canada, 2007 was a warmer- and wetter-than-normal year (relative to the 1951–80 base period). The summer was especially hot and humid on the prairies and warm and dry across southern Ontario. Also of interest was the record low of Arctic sea ice during the summer, possibly a result of many warmer-than-normal years across the north. Meanwhile, BC dealt with springtime flooding.

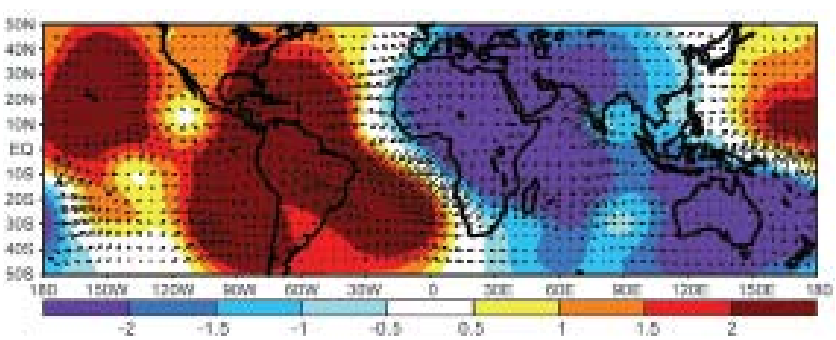


**Fig. 6.8. The 200-hPa velocity potential anomaly overlaid with divergent winds at the same level for Aug–Sep 2007. Blue (red) shades indicate areas of upper-level divergence (convergence) and enhanced (suppressed) surface rainfall.**

(i) Temperature

Canada, as a whole, experienced its 13th warmest year in 2007, 0.9°C above normal. The year 1998 remains as the warmest year, with 2.5°C above normal, since reliable nationwide records began in 1948. In 2007, temperatures were at least 1°C above normal north of 60°N, with the extreme northern regions experiencing temperatures more than 2°C above normal. Elsewhere in Canada, temperatures were generally 0.5°C warmer than normal. A notable exception was the Atlantic Canada region where temperatures were within half a degree of normal over the year. 2007 marked the 11th straight year of above normal temperatures, with six of the warmest 10 years occurring in the last decade.

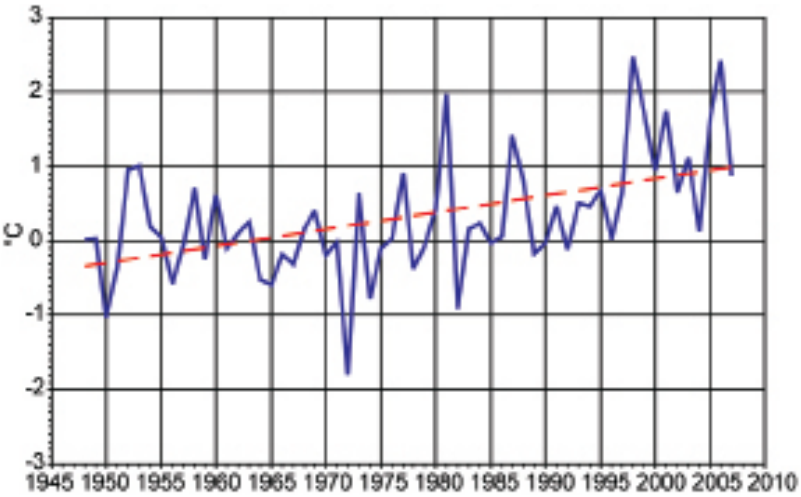


**Fig. 6.9. Annual mean temperature anomalies 1948–2007 (°C; blue; 1951–80 base period) with a linear trend of +1.4°C (red) for Canada. [Source: Environment Canada.]**

Regionally, annual temperatures were generally reflective of the nation's temperature, with anomalies that were 0.5°–1.0°C above normal. The easternmost part of the Arctic Islands was exceptionally warm, with 2007 ranking among the 10 warmest years (sixth warmest, 1.6°C above normal ). The east coast (26th warmest, 0.1°C above normal) and the west coast (27th warmest, 0.3°C above normal) experienced temperature anomalies that were below the 0.5°–1.0°C range. The national temperature trend over the period of record (1948–2007) is +1.4°C (Fig. 6.9). The northern regions, specifically the Yukon and the Northwest Territories, have seen the largest trend of +2.1°C, whereas the Atlantic Canada region had the least temperature trend of +0.2°C.

(ii) Precipitation

As a whole, Canada experienced its 15th wettest year in 2007, 3.3% above normal. The wettest region (>20% wetter than normal) included southwestern and northern BC, southeastern Yukon, southern Northwest Territories, western Nunavut, most of Saskatchewan, southern Manitoba, and northern Quebec (Fig. 6.10). This was partially offset by areas that were at least 20% drier than normal, which included northwestern Northwest Territories, eastern BC, large parts of Alberta, and the eastern Arctic Islands.

Two of Canada's climate regions experienced wetter-than-normal conditions, causing 2007 to rank among the 10 wettest years in the 60-yr record. Most of Nunavut had its eighth wettest year (16.7% above normal), and the northern half of the prairie provinces, had its ninth wettest year (7.8% above normal). The regions with the driest conditions were southern Ontario and Quebec, which had its 13th driest year

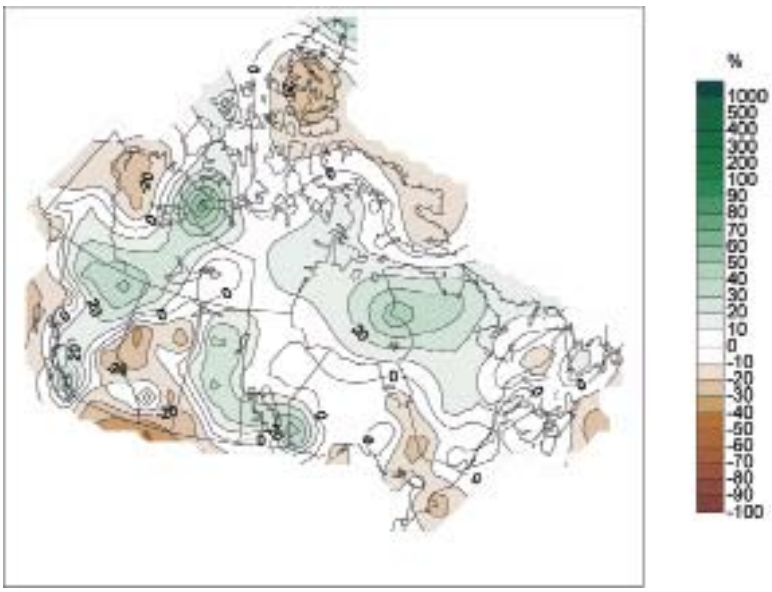


**Fig. 6.10. Canadian 2007 annual total precipitation anomalies (percent of the 1951–80 normal). [Source: Environment Canada.]**

(6.6% below normal). Southern BC experienced its 14th driest year, 9% below normal.

(iii) Notable events

Winter 2007 over the west coast of British Columbia was exceptionally good for the ski industry; however, record snowpacks created ongoing concern for flood managers and residents near rivers. A cooler-than-normal April contributed to the slow melting of the large mountain snowpack. In May, a 5-day warm spell started a rapid snow melt. River basins in west-central British Columbia were drenched with some of the worst flooding ever, swamping several communities including Terrace, Price Rupert, and Smithers.

July was hot across the prairies, with many locations experiencing near-record heat. Calgary experienced its warmest July since 1936, and Regina had its warmest July since 1937. Prolonged record high humidity exacerbated the situation across the normally semiarid prairies. Remarkably, on 30 July, Carman, Manitoba, recorded a humidex rating of 53. Humidex is a metric of felt air temperature based on temperature and dewpoint, analogous to the "heat index." The reading of 53 is a record for Canada, surpassing the previous record of 52.1 set in Windsor, Ontario, back in 1953.

During the summer, southern Ontario experienced 30–40 "hot days" (days where the temperature exceeded 30°C), 2 to 3 times the normal number . Accompanying the heat were very dry conditions. From July to September, Toronto received only 45% of its normal amount of rain. The drought in southern Ontario extended from the beginning of the year through October. Toronto experienced its second driest January–October period on record. The hot and dry conditions helped reduce river flows and Great Lake levels to near-record lows throughout the region.

Canada witnessed its first F5 tornado (EF5 using the Enhanced Fujita Scale) on record, according to the Fujita intensity scale. The tornado was spotted near Elie, Manitoba (about 40 km west of Winnipeg), on 22 June. Winds near Elie were likely in excess of 116 m $s^{-1}$.

2) United States—R. R. Heim Jr., K. L. Gleason, M. C.Kruk,D.H.Levinson,A.M.Sánchez-Lugo,R.Fritsch, R. Thoman, J. Papineau, and S. Lindsey

(i) Overview

Reliable monthly, seasonal, and annual weather records for the United States exist from 1895 to the present, enabling the climate of 2007 to be placed in a 113-yr context for the contiguous United States. Based on preliminary data available at the end of the year, 2007 tied with 2005 as the ninth warmest year on record with a nationally averaged temperature of 12.4°C (54.3°F). Considerable variability in temperatures and precipitation occurred throughout the year for the nation as a whole and regionally, with record warmth occurring in March and record cold following in April. Unseasonably warm temperatures dominated in the western United States and cold in the east under a strong upper-level ridge/trough pattern during July. A heat wave in August broke numerous record high temperatures, stressing residential energy systems.

The year was characterized by dry conditions in the West and a historic drought in the Southeast, with unusually wet conditions in the plains, especially during the first nine months of the year. Texas and Oklahoma had the wettest June–August on record, while Georgia and Mississippi experienced the driest March–May and Tennessee had the driest January–August. Drought persisted for much of the year in the western Great Lakes. Nationally, seven months were drier than average, with 2007 ranking as the 47th driest year on record. Moderate-to-extreme drought, as defined by the U.S. Drought Monitor (Svoboda et al. 2002), expanded from a fourth of the contiguous United States at the beginning of the year to nearly half by the end of summer before decreasing to a third of the country by year's end. Above-normal temperatures and below-normal precipitation during the spring contributed to a below-normal snowpack in the West. The persistently dry conditions, coupled with excessive summer heat, contributed to a near-record wildfire year.

(ii) Temperature

For the contiguous United States, 2007 ranked as the ninth warmest year on record and marked the 10th consecutive year with temperatures much warmer than the long-term average (Fig. 6.11). The past 10 yr have all been among the 25 warmest years on record, a feat which is unparalleled in the historical record. The annual average temperature in 2007 was 0.8°C (1.5°F) warmer than the twentieth century mean, yet was 0.4°C (0.7°F) cooler than 2006 (third warmest). The long-term warming trend for annual temperatures is approximately 0.56°C (1.0°F) per century. Temperature ranks for the contiguous United States were second warmest on record in March and third warmest in August. Large regions of below-average temperatures were present during January, February, April, and July.

Collectively, the 2006–07 winter (December–February) temperatures were near average across most of the nation. December 2006 was marked by above-average to record warm temperatures across a large portion of the Northeast. January was cold across most of the western and southern states and above average in the eastern United States. A persistent trough positioned over the eastern United States in February was responsible for cold temperatures from the Great Plains to the Atlantic coast. The central region ranked ninth coldest on record and was near the center of the coldest anomalies with departures from average less than –3.9°C (–7°F) for the month. The Northeast region was more than 3.1°C (5.5°F) below average and ranked 14th coldest.

After a relatively cool beginning to the year, March rebounded and ranked second warmest for the contiguous United States. Temperatures were much above average across 22 states from the West Coast to the Ohio Valley. Oklahoma had its warmest March on record during 2007. In fact, March statewide-averaged temperatures in Oklahoma had not been within 1.1°C (2°F) of the 2007 average since the late-1930s. The prolonged warm spell during March led to a premature leaf and bloom for many plants and trees across the central, southern, and southeastern United States. In early April, temperatures plummeted as Arctic air brought record-breaking cold temperatures and a cold freeze event to much of the central plains, the South, and parts of the East. Over 1,200 daily minimum temperature records were broken across the contiguous United States during this event. Nonetheless, the spring season (March–May) temperatures ranked eighth warmest nationally, reflecting the dominance of the March warmth during the season.

The summer (June–August) months were characterized by a near-record to record warm July across portions of the West, and below to much below-average temperatures across much of the remainder of the contiguous United States. In addition, widespread warmth blanketing a majority of the contiguous United States resulted in a rank of third warmest August on record for the nation. A severe and persistent heat wave moved across the country from the Intermountain West to the Southeast and Ohio Valley during August 2007. More than 50 deaths were attributed to the excessive heat. Over 70 all-time record highs were set in August, along with scores of new daily high temperatures. Average temperatures during the warmest periods from the 7th–11th, and again from the 15th–17th, were more than 5.6°C (10°F) warmer than average in many parts of the country. Seven states (Utah, Kentucky, Tennessee, Alabama, Georgia, South Carolina, and Florida) had a record warm August and an additional 17 states had temperatures that ranked much above average for the month (Fig. 6.12a). For the season, the summer of 2007 was sixth warmest across the nation despite the colder-than-average anomalies present over Texas and Oklahoma, which resulted from persistent cloud cover and rainfall during much of June and July. Both July and August were exceedingly warm across Utah and ranked second warmest and warmest, respectively, giving the state a record warmest ranking for the summer season.

Autumn (September–November) was marked by persistent near- to above-average temperatures. October ranked fifth warmest for the contiguous United States, with much above-average temperatures observed across most of the eastern third of the nation. Record warmth during October occurred in New Jersey, Maryland, and Delaware. For the season as a whole, national temperatures ranked sixth warmest.

For the year, the only state where temperatures ranked below average was Maine. Thirteen states had temperatures that ranked much above average, and the remaining states were near or above average (Fig. 6.12b).

The annual temperature for Alaska in 2007 ranked as the 15th warmest in the 1918–2007 record, representing a return to warm anomalies after near-normal conditions in 2006. Only 10 of the last 31 yr had annual temperatures near to or below the long-term mean for the state. Winter temperatures in 2007 were above average for the eighth consecutive year, although a severe Arctic outbreak affected southeast Alaska in late February to early March. For the greater Fairbanks area, 15 February–15 March was the coldest ever on record during that time of year.

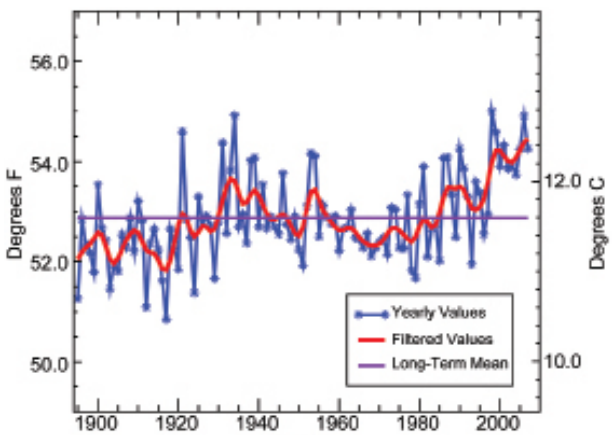


**Fig. 6.11. Annual temperature for the contiguous United States over the period 1895–2007. [Source: NOAA/NCDC.]**

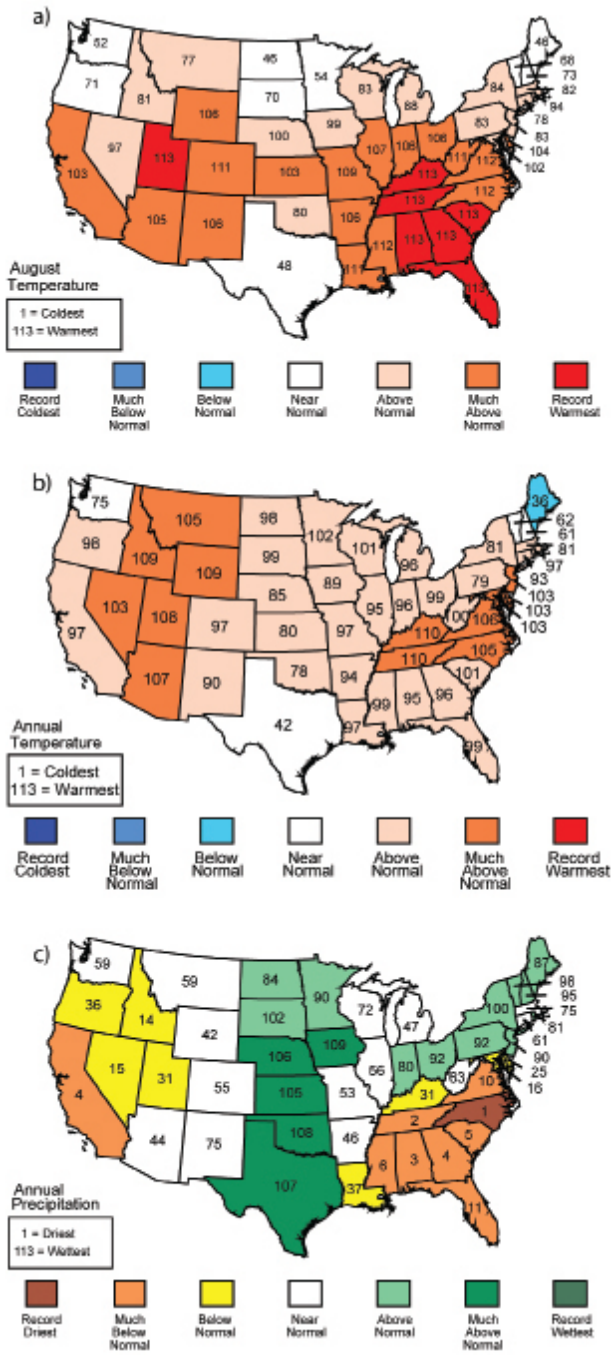


**Fig. 6.12. Statewide ranks of (a) Aug 2007 temperatures, (b) annual 2007 temperatures, and (c) annual 2007 Precipitation. A rank of 113 represents the warmest/wettest year since 1895. Much above-normal temperature/precipitation is defined as occurring in the top 10% of recorded years, which corresponds to a rank of 103–112. Above-normal temperature/precipitation is defined as occurring in the warmest/wettest third of recorded years (ranks 76–102). 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.]**

The average high was –19.9°C and the average low was –33.5°C. Spring was slightly below average, summer was warmer than average, and fall was significantly warmer than the 1918–2000 average.

### (iii) Precipitation and drought

Precipitation in the United States during 2007, although variable, was characterized by periods of excessive rainfall across the central third of the United States, and persistent and developing drought in the southeastern quarter of the country and the far western states. This pattern dominated during the winter and spring months, with the Southeast and West regions having the driest and sixth driest spring, respectively, while the west-north central region of the northern plains ranked third wettest. A series of severe storms caused flooding, extensive damage, and loss of life from Texas to Kansas and Missouri in June and July. This was followed by the remnants of Tropical Storm Erin, which produced heavy rainfall in the same area in August, giving the South region (composed of Mississippi, Louisiana, Texas, Arkansas, Oklahoma, and Kansas; see Karl and Koss 1984) its wettest summer on record. Precipitation during fall was below normal for much of the nation, although widespread extreme anomalies were absent.

Severe to exceptional drought affected the Southeast and western United States throughout much of the year. After a slight contraction during 2005–06, the drought area in the West expanded this year, covering half or more of the region beginning in late spring. The persistent dryness in the Southeast started in December 2006 and resulted in an expanding drought area with time, with more than two-thirds of the region in drought from midsummer 2007 through the end of the year. Unusually warm temperatures and scarce rainfall exacerbated conditions. Drought also affected large parts of the upper Midwest for much of the year. Several short-lived dry episodes occurred in other regions throughout the year, notably in the Ohio Valley and Northeast in May and the northern plains in July.

The cumulative effects of the drought resulted in the driest year in the 113-yr record for North Carolina, second driest for Tennessee, third driest for Alabama, and fourth driest for Georgia and California (Fig. 6.12c). Note the sharp gradient between the severe drought in the Southeast, above normal to much above normal precipitation in the country's midsection and Northeast, and the intervening regions from Louisiana north to Missouri and east to the Potomac, where conditions were near normal. Conditions in the southern plains went from extremely wet to extremely

dry during September, with Texas having the wettest January–September on record, followed by the 11th driest October–December. Water conservation measures and drought disasters, or states of emergency, were declared by governors in five southeastern states, along with California, Oregon, Maryland, Connecticut, and Delaware at some point during the year. Unusually dry conditions during May–October of this year and for the last several years resulted in a record low level for Lake Superior, impacting shipping and recreational activities. Also noteworthy is that, in contrast to the severe drought in the Southeast, heavy precipitation was noted from the Ohio Valley and Great Lakes into the Northeast for the year.

### (iv) Snowpack

The 2006–07 snow season was variable in many areas across the United States. Parts of the Northern Cascades, Big Horn Mountains in Wyoming, and the Colorado Front Range had generally near- to above-average snowfall, while the Sierra Nevada, Wasatch, and the mountains of Arizona experienced below-average snow accumulations. The snow cover extent was slightly above average for the North American continent as a whole over the winter season, but well below average during the spring, consistent with a trend over the last 40 yr toward reduced spring snow cover for North America (Fig. 6.13). The below-average snowpack during the spring can be associated with the anomalous warmth that engulfed most of the contiguous United States during March (when monthly mean temperatures were more than 3°C above average in many places) and May.

Notable snow storms that affected the contiguous United States in 2007 include the deadly ice storm that occurred 11–16 January, affecting areas from the Rio Grande Valley to New England and southeastern Canada. Two subsequent storms affected the southern United States and later the southern plains and mid-Atlantic states. During mid-February, a major snow storm deposited 10–50 cm of snow across much of the central United States, while parts of eastern New York and northern Vermont received up to 76 cm. The Northeast Snowfall Impact Scale (Kocin and Uccellini 2004; Squires and Lawrimore 2006) classified this as a category 3 (major) storm and ranked it as the 14th most intense on record for the Northeast. This event was preceded by a 10-day lake effect storm that produced over 254 cm of snow on New York's Tug Hill Plateau, with a total of 358 cm reported at Redfield in Oswego County. In southeast Alaska, all stations saw well above-normal snowfall in March, with many locations breaking March snowfall records.

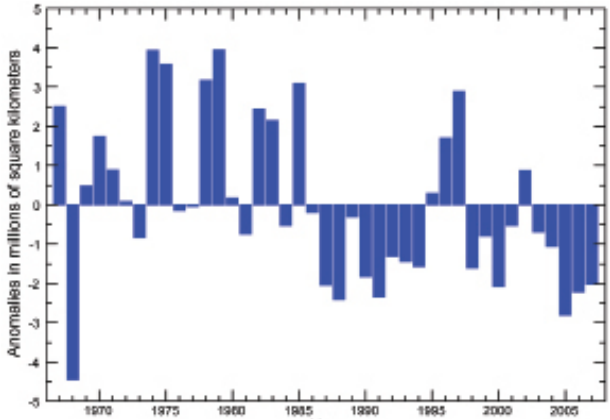


**Fig. 6.13. North America snow cover extent anomalies for spring (Mar–May), 1967–2007, as derived from visible satellite observations.**

Near the end of spring, few areas in the contiguous United States had above-average snowpack, while snowpack water content less than 50% of average was widespread from Oregon to the Southwest.

The beginning of the 2007–08 snow season was above average across parts of the Southwest, with well below-normal amounts in the Sierra Nevada, Cascades, the Bear River, and Salt River Ranges. A severe winter storm in the second week of December covered Missouri and Oklahoma in a thick layer of ice. Several back-to-back midlatitude cyclones brought significant snowfall from the Great Plains through New England in mid- and late December.

### (v) Wildfires

The 2007 fire season continued a string of record or near-record wildfire seasons across the United States. Long-term precipitation deficits played a critical role in the severity of the 2007 wildfire season, especially in the Southeast and West, where drought conditions persisted or worsened during the year.

According to preliminary data from the NIFC, the 2007 fire season had the second most acres burned in the historical record, with more than 9.3 million acres (~3.8 million hectares) for the United States as a whole, about 500,000 acres (~200,000 hectares) less than was reported in 2006 (the record year). Based on annual statistics that extend back to 1960 (source: NIFC in Boise, Idaho, www.nifc.com/fire_info/fire_stats.htm), the number of fires reported each year has shown a steady decline since the early 1980s for the entire United States, and since the early 1990s for Alaska. However, the total number of acres burned each year has increased steadily since about 1995 (Fig. 6.14). As a result, there has been an increasing

trend in the size of wildfires (Westerling et al. 2006), with 6 of the 10 worst seasons in terms of acres burned having occurred since 2000.

Wildfire activity started earlier than usual in 2007, as wildfires affected portions of the Tennessee Valley and the Southeast in March, eventually spreading to northern Minnesota in April and southern Florida in May. In the West, the fire season started slowly in June, except in central California, where numerous blazes affected the Lake Tahoe area. Fire activity increased dramatically in July, as large portions of the Intermountain West were affected by wildfires. The most severe fire activity during the summer occurred in the northern Rockies, where numerous large fires burned in July and August. Fire activity persisted into September across Idaho and Montana, but eventually shifted southward into

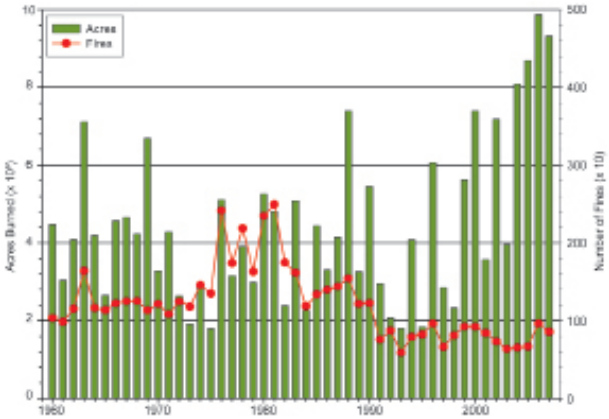


**Fig. 6.14. The annual number of wildland fires (curve, right axis) and acres burned (bars, left axis) for the contiguous United States for 1960–2007.**

## DIAGNOSIS OF CAUSE(S) FOR 2007 U.S. PRECIPITATION EXTREMES—
## M. P. HOERLING IN CONJUNCTION WITH THE NOAA CSI TEAM

For the contiguous United States, large precipitation deficits occurred in the Southwest and Southeast regions during all seasons in 2007, with annual departures exceeding –30% of the 1971–2000 climatologies (Fig. 6.15, top). The concurrent oceanic conditions consisted of a lingering El Niño during winter/early spring 2007 followed by a La Niña event in late summer and fall of 2007. Three different atmospheric climate models were used to assess whether such dryness was related to global SST conditions. The models (NCEP GFS, NCAR CCM3, and GFDL AM2.1, with nominal resolution of ~200 km) were forced with the monthly varying global 2007 SSTs. For these so-called GOGA runs, 50 separate realizations were conducted for each model. The multimodel ensemble mean precipitation anomaly (percent of climatology), computed relative to control simulations that had used climatological global SSTs of 1971–2000, consists of a dry signal over much of the southern United States (Fig. 6.15, middle).

In a further suite of runs, SSTs were specified over the region 20°N–20°S, 160°E to the South American coast only (i.e. the ENSO domain), while climatological SSTs were specified elsewhere over the world's oceans. For these so-called EPOGA runs, 50 separate realizations were again conducted for each model. A strong wet signal occurs over the Southwest (Fig. 6.15, bottom left), opposite of the observed drought conditions. The simulated wet signal is especially strong during winter/spring 2007 when El Niño conditions prevailed, and is also consistent with historical observations that reveal ENSO impacts to be largest during that time of year (Kiladis and Diaz 1989). It is evident, however, that the expected wet signal failed to emerge during 2007; both the empirically derived wet signal expected from historical ENSO impacts, and the simulated signal from these EPOGA simulations are opposite to the observed drought conditions. It thus appears that ENSO was not a critical factor with respect to the droughts of 2007.

The principal anomalies in global SSTs during 2007, outside the ENSO region, were characterized by warmth in the tropical Indian and Atlantic Oceans, and warmth across much of the extratropical North Pacific and North Atlantic Oceans (see section 3). The effect of the "non-ENSO region" SST forcing was estimated by constructing the differences "GOGA-EPOGA" (subsequently referred to as global/non-ENSO). To the extent that the U.S. response can be viewed as the simple linear superposition of various ocean-forced signals, this analysis is one estimate for the SST-forced signal from the ocean conditions outside of the tropical eastern Pacific. The global/non-ENSO results (Fig. 6.15, bottom right) reveal a strong U.S. precipitation sensitivity to this non-ENSO region forcing. In particular, a dry signal occurs along the entire southern tier of states, having a maximum percentage reduction in precipitation over the Southwest akin to the observed anomalies. Over the United States as a whole, this dry signal overwhelms the east Pacific induced wet signal. Thus, the modest U.S. drying emerging in response to the full global SST conditions of 2007 (Fig. 6.15, middle) reflects the cancellation between two mutually exclusive SST influences—a wet ENSO effect and a stronger drying effect due to non-ENSO SST conditions.

The preliminary diagnosis presented above provides some attribution of key features of the observed 2007 U.S. climate conditions. The text uses subjective language to interpret the likelihood that certain conditions were caused by certain forcings, but at this point that should be viewed as a qualitative, expert assessment. Regarding the anomalously low precipitation within

California later in the month. The most destructive fires of the year occurred in Southern California during the fall, as severe-to-exceptional drought and strong Santa Ana winds exacerbated brush and forest fires, destroying homes across the region in October and November.

The 2007 fire season was not an especially severe one in Alaska, which had just over half a million acres (~202,000 hectares) burned during the year. However, in September the Anaktuvuk River wildfire, which was caused by lightning, burned over 250,000 acres (~100,000 hectares) and set a record for the largest fire on Alaska's North Slope.

(vi) Severe extratropical storms

Several severe extratropical cyclones affected the United States in 2007. The first major system moved across parts of the Midwest and the Northeast on 13–15 February. The intense storm produced significant accumulations of ice and snow in these areas, with some locales in Illinois receiving more than 30 cm of snow. In upstate New York more than 100 cm of snow was reported. During 15–17 April, a nor'easter moved up the eastern seaboard, bringing strong winds, high seas, and heavy rains from South Carolina to Maine. Some locations across the Northeast received over 190 mm of rain in a single day, producing widespread flooding, while on the cold side of the storm, more than 40 cm of snow fell across Vermont and New Hampshire.

During the normal spring peak in severe weather, several tornado outbreaks occurred across the plains, producing over 400 tornadoes during April and May combined. The worst of these outbreaks occurred

the two drought regions, this diagnosis suggests the following main conclusion:

The droughts were inconsistent with east tropical Pacific SST variability during 2007, and thus were unlikely caused by the ENSO cycle occurring during January–December 2007. We estimate less than a 5% probability that the observed droughts were consistent with climate conditions driven from the tropical east Pacific in 2007.

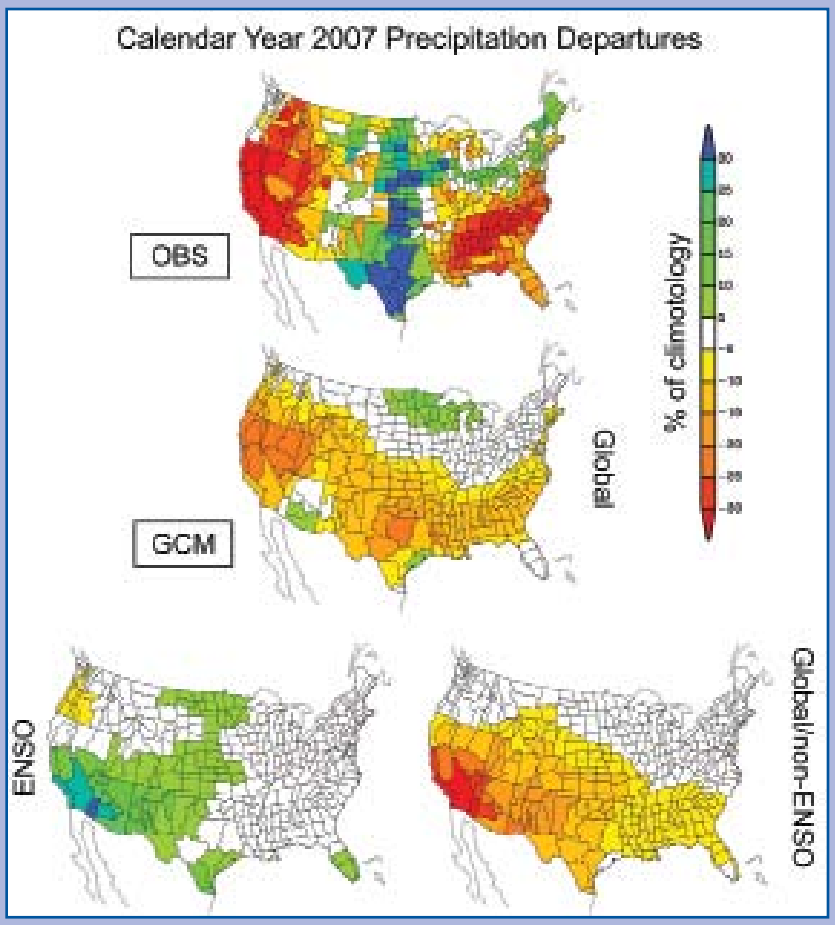


**Fig. 6.15. The U.S. 2007 annually averaged (Jan–Dec) precipitation departures expressed as a percentage of the 1971–2000 climatologies for (top) observations (OBS), for (middle) simulations based on global SST forcing (contour interval half as for OBS), (bottom left) for simulations based on tropical east Pacific SST forcing (same contour interval as for OBS), and (bottom right) for simulations based on global SST forcing excluding the tropical east Pacific (global/non-ENSO; same contour interval as for OBS). [Source: NOAA CSI Team.]**

on 4–5 May, when an EF5[3] tornado devastated the town of Greensburg, Kansas, killing 10 people and destroying nearly 95% of the town. This was the first category 5 tornado since the Oklahoma City, Oklahoma, tornado in May 1999. According to preliminary statistics compiled by NOAA's Storm Prediction Center, there were 1,074 tornadoes reported in 2007, with May having the most of any month (251). The most severe day was 3 April, when 594 reports of severe weather (tornadoes, wind, and hail combined) were documented.

Although the summer and much of the fall were relatively quiet for much of the United States, there were two major extratropical storms of note to end the year. The first was a strong Kona Low which brought heavy rains greater than 25 cm and flooding to Maui and the Big Island of Hawaii during the first week of December. The second was a storm system that battered the coasts of Washington and Oregon from 1 to 3 December. Several locations along the northern Oregon coast received more than 250 mm of rain for the period, along with peak wind gusts exceeding 45 m $s^{-1}$.

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

Mexico was on average 5.3% wetter than normal in 2007, with much warmer-than-normal temperatures. Mexico's SMN reported a national precipitation average of 812.2 mm, compared with a historical average of 771 mm (1941–2000). The nationwide annual mean temperature was 21.8°C, 1.1°C above the long-term climate average. Tabasco suffered heavy rain and flooding in January, experienced severe drought conditions and wildfires through the summer, and ended the year with some of the most powerful storms and flooding ever to hit the state.

#### (i) Precipitation

The rainfall distribution was inhomogeneous spatially and temporally. The year 2007 began wetter than normal, but the March–July period was considerably below average. A partial recovery of precipitation totals, particularly in southern and southeastern Mexico, began in August. The total annual precipitation reported by the Mexican SMN was 53% above normal. However, many states reported rainfall deficits. These include Baja California (48% below the long-term mean), Oaxaca (23.7% below), Zacatecas (19.4% below), Sinaloa (17% below), Durango (14.1% below), Quintana Roo (13.3% below), Morelos (12.5% below), Yucatan (8.9% below), Baja California Sur (6.4% below), and Tlaxcala (4.5% below). Considering the May–October rainy season, precipitation deficits abounded across the country (Fig. 6.16a). Only the northeast region of the country reported above-normal precipitation.

#### (ii) Temperature

Mexico experienced its second warmest year, 1.1°C above normal (Fig. 6.16b), with 2006 being the warmest (1.2°C above normal), since reliable records began nearly three decades ago. Most of Mexico had temperatures at least 1°C above normal. The warmest states were San Luis Potosí (3.2°C above the long-term mean), Oaxaca (3.1°C above), Distrito Federal (2.1°C above), Nayarit (1.9°C above), Chihuahua (1.7°C above), and Morelos (1.5°C above). Only three states had near or below normal temperatures. These were Durango (0°C), Estado de México (–0.7°C below) and Michoacan (–1.9°C below).

#### (iii) Extreme events

Despite the very warm annual mean temperature, a notable cold outbreak occurred across northern Mexico on 4 January when La Rosilla, Durango, recorded a minimum temperature of –16.5°C; Guachochi, Chihuahua, recorded –10.3°C; and Yecora recorded –10°C. An exceptionally early winter cold outbreak occurred in the northwest on 30 October with temperatures in La Rosilla plummeting to –12.5°C and Santa Barbara, Durango, to –12°C.

Events of extreme precipitation were recorded due to the landfalling Hurricanes Dean (13–23 August) and Lorenzo (25–28 September), which formed in the Atlantic Ocean, and Henriette (30 August–6 September), which formed in the Pacific Ocean. Precipitation reached record levels in the states of Veracruz, Tamaulipas, Puebla, San Luis Potosí, Tlaxcala, Baja California Sur, and some regions of Sonora. Heavy precipitation caused severe flooding in the Rio Panuco basin, where areas remained inundated from 23 August (the passing of Dean) through the first week of October, when the passing of Lorenzo reinforced the flooding. By the end of October, the passing of the fourth cold front over Mexico and its interaction with Tropical Storm Noel (28 October–2 November) caused heavy precipitation in Chiapas and Tabasco. This resulted in record accumulated values (700–1000 mm in the period from 28 to 31 October) and Tabasco's worst flooding in history, with 80% of

[3] The National Weather Service switched to the Enhanced Fujita Scale from the Fujita Scale on 1 February 2007. (for more information on the EF Scale, please see www.spc.noaa.gov/efscale/).

the territory inundated until the end of the year.

(iv) Wildfires

During 2007, more than 80,000 wildfires were reported in Mexico. Most of them were recorded during March–June. May accounted for almost 45% of the total fires. Wildfires mainly affected the west, northwest, along the Gulf of Mexico, the southeast, and the Yucatan Peninsula. Due to severe drought conditions in the area of Campeche and Tabasco, these fires continued unabated until the passing of Hurricane Dean in late August. In the northwestern and western parts of Mexico, the development of the North American monsoon helped extinguish these fires during the 2007 rainy season.

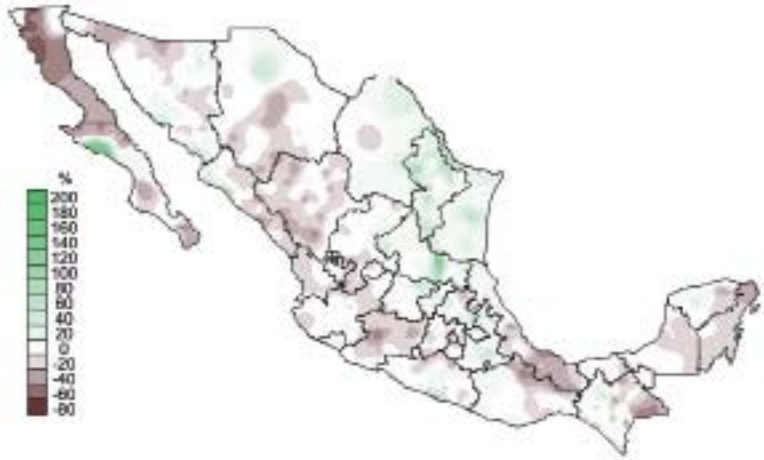


**Fig. 6.16a. Mexican seasonal rainfall anomalies (May–Oct) in 2007.**

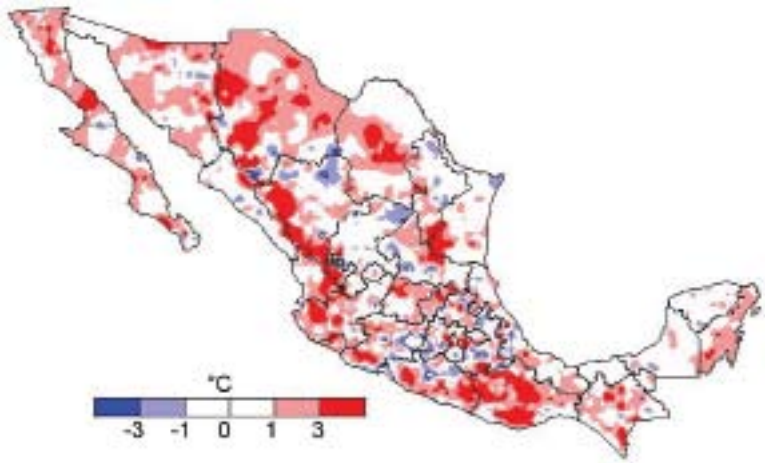


**Fig. 6.16b. Mexican annual mean temperature anomalies in 2007 (°C; 1981–2005 base).**

d. Central America and the Caribbean

1) Central America—P. Ramírez

(i) Temperature

Annual mean surface temperatures in 2007 were slightly above normal across Central America, with anomalies between 0.1° and 0.4°C. Monthly temperatures slightly above normal predominated during winter. April temperatures were near normal, although positive anomalies were found in the southern part of the isthmus, and summer months were also above average. The highest temperature anomalies were observed in the northern part (Guatemala and Honduras) in July and September. Fall was also warmer than normal, except for October when near-normal temperatures were observed across the region.

(ii) Precipitation

In Central America, 2007 was influenced by two primary features: the La Niña event that developed in the central Pacific in the middle of the year and the persistence of above-normal SSTs in the Caribbean. This situation created an SST dipole that enhanced the flow of humid air from the Pacific to the Caribbean, which generally increased humidity, particularly over southern Central America.

Monthly distributions of accumulated rain, however, varied over the region. Dry anomalies affected the Caribbean basin from Honduras to Panamá in January and February. From March to May an above-normal rainfall pattern prevailed over the southern part of the region with the highest anomalies over Costa Rica and Panamá. A late season cold front that reached the northern part of the region brought above-normal springtime rains to the Caribbean plains of Honduras and to northern and central Guatemala. A precipitation deficit occurred in June over the Pacific basin, especially over the "Dry Corridor" (El Salvador, western and southern Honduras, western Nicaragua, and northwestern Costa Rica). The region had above-normal rainfall during October. In November, as the transition to the dry season was evolving in the Pacific basin, above-normal rainfall was observed on the Caribbean side from Honduras to Panamá as the first cold fronts of the winter moved into the Caribbean. In the southern part of the isthmus, the rainy season ended later than normal.

(iii) Notable events

Hurricane Dean brought heavy rains to Nicaragua and El Salvador in August. However, the total accumulation of rainfall was limited due to the rapid propagation of the system. In early September, Hurricane Felix struck Nicaragua, causing more than 100 deaths and damages to infrastructure exceeding $30 million (U.S. dollars). Also in September, a low pressure system near the Yucatan Peninsula induced another low off the Pacific coast of the isthmus; the combination of both systems generated a period of continued and heavy rains known as "temporal." During the second half of October a persistent disturbance over southern Central America and northern South America produced several days of very heavy rainfall and storms. Impacts from this event were also felt in Costa Rica, where floods and landslides affected many parts of the country, causing extensive damage to houses and roads.

2) Belize—R. Frutos and A. Gordon

Frontal activity during the winter 2006–07 was above normal.[4] A total of 14 cold fronts reached Belize, with the first one crossing the country around mid-October, and the last one making its entry in early May 2007. Two strong cold air incursions were experienced during the winter period 2006–07. The first was in mid-December 2006, which lasted about five days, while the second cold episode occurred in late January 2007 and lasted about four days.

The dry season in 2007 began in February, with signs of an early onset during the first week of the month. The dry period intensified in late March through mid-May, generating widespread bush fires that burned hundreds of acres in the coastal savannah and inland areas. About three major forest fires burned in the Mountain Pine Ridge Forest Reserve.

The weather was warmer than normal across Belize in 2007. Figure 6.17 depicts 2007 monthly maximum and minimum temperatures compared to the 1961–90 averages. The annual maximum (minimum) temperature for 2007 was 30.8°C (23.7°C), 0.8°C (1.2°C) higher than normal and tied for the second highest on record with 1997 (2002). For the year, all months were warmer than normal except November (and March for minimum temperature).

The 2007 rainy season began during the period of 15–23 May, about a week earlier than usual. A combination of a late-season frontal incursion and a trough in the easterlies moving through the western Caribbean generated rainfall across Belize during 17–23 May 2007. After the initial onset of the rains, showers continued intermittently during the rest of May through June. Nonetheless, rainfall at most places during June was well below normal (Fig. 6.18), as well as in July, September, October, and December. However, intense rainfall occurred along the central coast of Belize during the period of 28–30 August, when 299.7 mm of rain fell, which made August 2007 the wettest in the historical record. The rainfall total for August 2007 was 550.7 mm, approximately 200% above normal. In addition, January was 74% above normal. The main airport in Belize City recorded a total of 83 days with rain during the 2007 rainy season, compared to a normal of 103 days.

[4] The data used in the Belize section are the property of the National Meteorological Service of Belize from its national meteorological and hydrological surface network.

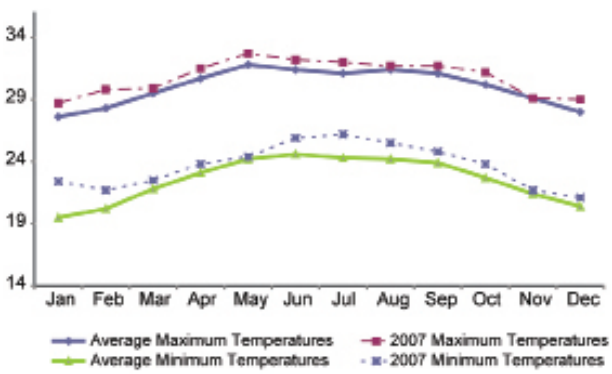


**Fig. 6.17. Average maximum and minimum temperatures (°C) in 2007 and the 1961–90 base period normals for Belize.**

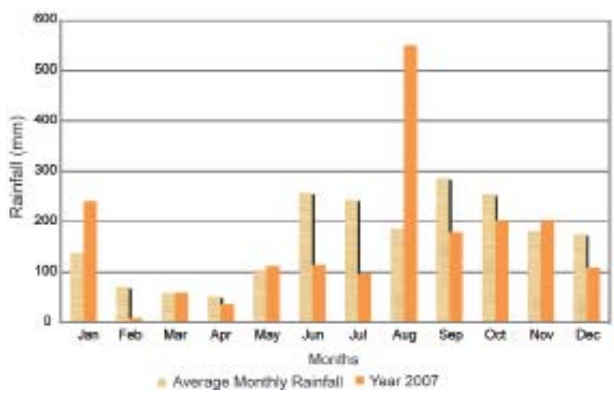


**Fig. 6.18. Average rainfall (mm) in 2007 vs the 1961–90 normals for Belize.**

3) Cuba—C. Fonseca Rivera, B. Lapinel Pedroso, V. Cutié Cansino, D. Boudet-Roco, A. M. Carrión Romero, and R. Pérez Suárez (translated by A. Arguez)

Consistent with observed trends, Cuban temperatures in 2007 were warm, ranking as the eighth warmest year since 1951. The annual mean temperature was 26.0°C, about 0.5°C above normal. January and February were much warmer than normal over the island. January, climatologically the coldest month, was 1.6°C above normal while February was the 10th warmest since 1951 with an anomaly of 1.1°C. The period from March to November was near normal as a whole, although most months exhibited positive anomalies, including anomalies of about 0.5°C in August and October. In December, typically the second coldest month in Cuba, the temperature anomaly was 1.1°C.

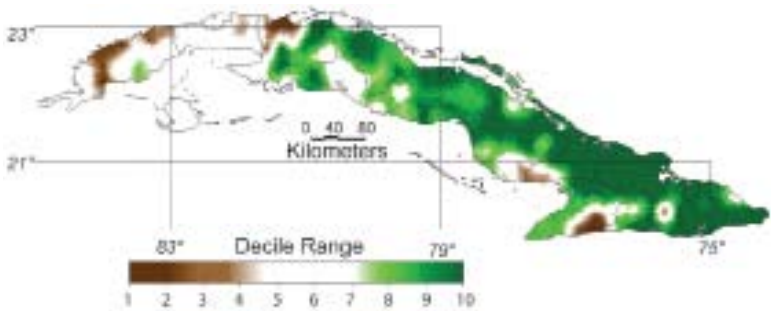


**Fig. 6.19. Annual rainfall expressed as a decile ranking, based on the 1971–90 reference period (preliminary analysis).**

Precipitation totals for the year were either above normal or near normal for the vast majority of the island (Fig. 6.19). Most of the eastern two-thirds of the country received rainfall amounts exceeding the 80th percentile. A few regions experienced below-normal precipitation: northern and central Pinal del Río, northern Matanzas, the southern coast of Las Tunas, as well as the border between Granma and Santiago de Cuba. Cuba was impacted by Tropical Storm Noel in October, bringing torrential rains and flooding to eastern Cuba.

4) Jamaica—J. M. Spence and M. A. Taylor

Jamaican rainfall in 2007 reflected the influence of warm anomalies in the tropical North Atlantic through June and cold anomalies in the equatorial Pacific through December. Respectively, the temperature anomalies contributed to wetter-than-normal conditions in both May (the early rainfall peak; Fig. 6.20) and between August and November (the primary rainfall period). For both periods, most parishes equaled or exceeded the 30-yr mean, with some (Trelawny in the north; St. Catherine and Clarendon in the south) in excess of twice the normal rainfall during October–November. Intense and persistent island-wide rainfall during the latter half of March contributed to the wettest March on record, which is climatologically the driest month. Frontal systems stayed well north of Jamaica during December, resulting in most parishes falling below their 30-yr mean. The impact was most severe for southern regions, which constitute the main agricultural belt. The December rainfall deficits were consistent with the north (dry)–south (wet) gradient in Caribbean rainfall associated with La Niña conditions.

Prevailing warm Caribbean ocean temperatures resulted in positive air temperature anomalies of up to 1°C for most stations for the first five months of the year. Thereafter, the traditionally warmer months saw negative anomalies, especially over southern parishes, likely because of the long periods of persistent cloudiness and rain. By the end of the year, positive temperature anomalies were again reported by some stations while others tended to be near normal. The aforementioned lack of frontal systems in the vicinity of the islands precluded the reduction in temperature that normally accompanies them.

The island was affected by the passage of category 4 Hurricane Dean on 19 August 2007. Its passage just south of the island resulted in extensive wind and flood damage over the southern parishes. Hurricane Felix in September generated swells on the south coast, and in December tropical storm Olga impacted Ja-

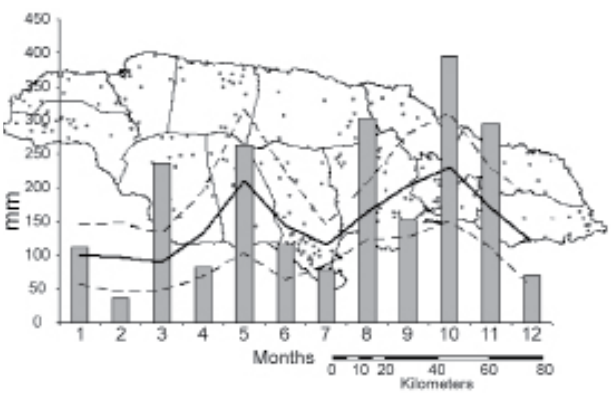


**Fig. 6.20. Monthly Jamaican rainfall for 2007 (bars). Data are for a composite index derived from station data. Also shown are the climatology (black) and one standard deviation from climatology (dashed). Baseline period: 1971–2000. Map background shows Jamaica and location of stations used in analysis.**

maica. Also noteworthy were the prolonged periods of rainfall, which affected the island during October and November, as flash flood warnings and watches were issued for 18 days in October and 13 days in November. Wet conditions in 2007 continued the trend of above-average rainfall, which began in the late 1990s.

5) Puerto Rico—J. P. Cupo and E. Morales

The Puerto Rican climate in 2007 was affected by the neutral ENSO to moderate La Niña conditions that were observed for much of the year. Both precipitation and temperature measurements were generally slightly above normal island-wide, with few exceptions. When distributed by month, temperature readings were found to be slightly to moderately above normal every month of the year. The annual mean temperature at the San Juan International Airport was 26.7°C, whereas the overall average temperature was 27.3°C for 2007.

Precipitation was slightly above normal for the year, with the exception of the eastern interior and the southern slopes of Puerto Rico. At the end of 2006, the eastern interior and southern slopes were already experiencing below-normal precipitation. Since the Puerto Rican dry season normally occurs between the latter half of January through April, these areas experienced drier-than-normal soil conditions as a result. The dry season extended through most of the Puerto Rican rainy season as well. The National Drought Mitigation Center classified this event as a D1. Tropical Storm Noel ended the dry spell over these regions when it produced 12–17 in. of rain across the eastern half of Puerto Rico at the end of October. Meanwhile, normal to above-normal rainfall conditions were reported for the rest of the island, with convection and other local effects the main source of the precipitation.

Rainfall across the eastern portions of Puerto Rico is normally generated by tropical waves that typically move across the area every 3–5 days. A normal number of tropical waves were noted for 2007, but rainfall associated with these systems was below normal. The eastern portions of Puerto Rico experienced dry conditions similar to that of other smaller Caribbean islands that also depend on showers generated by these tropical waves. The observed precipitation across Puerto Rico for 2007 was near normal.

Puerto Rico was affected by three tropical cyclones during the year. Tropical Cyclone Dean brushed the southern coast of the island as it developed into a category 5 hurricane in mid-August. Impacts included torrential rains across the southern and western coastline. In October, Tropical Storm Noel moved very slowly as it traversed the local waters of the Caribbean along the periphery of the island, generating very heavy rainfall across the southeastern portions of the island. Rainfall in excess of 17 in. (432 mm) was reported at the Lago Carite near Cayey. Finally, subtropical storm Olga, which eventually transitioned into a tropical storm, impacted the island in mid-December. Due to its development outside of the normal tropical cyclone season, it ended up shattering the normally drier month's records for precipitation at numerous stations across the island. One such record was at the San Juan International Airport, where 2.26 in. of rain fell, breaking the old record of 1.29 in. in 1965. Despite these three tropical cyclones, the 2007 hurricane season was relatively quiet for Puerto Rico, considering the above-average activity over the past decade.

e. South America

1) Overview—P. López Carmona and M. Rusticucci

The data used in this section were acquired from 300 meteorological stations by the National Meteorological and Hydrological Services of Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Perú, Surinam, Uruguay, and Venezuela. The data were compiled by CIIFEN.

In general terms, climate conditions over South America during 2007 were drier than normal in the southern and eastern parts of the continent, very dry over the west, and near normal to wetter than normal in the region north of the equator and parts of the Amazon basin (Fig. 6.21). With regard to temperatures, an unusually cold winter was reported over the southern portion of the continent, while warmer-than-normal conditions prevailed in the Amazonian region. This marked meridional contrast in temperature, between the anomalously warm conditions in the tropics and the lower-than-normal temperature over the southern half of the continent, was observed for 2007 as a whole in terms of mean, maximum, and minimum temperatures (Fig. 6.22).

The weak El Niño conditions in January quickly dissipated in early February, shifting to La Niña conditions by April. The negative SST anomalies in the equatorial Pacific strengthened in the following months until reaching the mature stage by the end of the year. Modulation by the MJO and upper-level conditions were also factors in 2007, as were dynamic changes in the SWJ. The SWJ was anomalously intense and displaced northward over the continent during January, resulting in the strengthening of the SACZ and the development of intense convec-

tive activity and enhanced rainfall in west-central Brazil, southern Amazonia, and eastern Bolivia. The impacts were particularly severe in Bolivia, where flooding events and associated damages were similar in magnitude to those associated with the 1997–98 El Niño event. The rainfall anomaly pattern along the west coast of South America was generally coherent with typical cold episodes in the equatorial Pacific, particularly the above-normal precipitation in Colombia and the dry conditions in central Chile (Fig. 6.21). In Ecuador, precipitation during the rainy season (February–March) was the lowest in the last 50 yr. The deficient rainy season in northeastern Brazil was linked to an anomalous displacement of the ITCZ toward the north from March to June, with generally a rainfall surplus in Colombia, Venezuela, Guyana, and Surinam. The southern half of South America experienced mostly below-average annual rainfall, excluding Uruguay, southern Brazil, and large areas of the northern half of Argentina.

Regarding extreme precipitation events, very intense rainfall episodes occurred in Bolivia and southern Brazil in early 2007. A flood event between 4 and 6 May in Uruguay dropped over 300 mm of rainfall, the most intense rainfall event since April 1959. The interaction between the ITCZ and the anomalously warm North Atlantic conditions were associated with intense rainfall in Colombia from March to May and during the second half of the year. La Niña conditions that developed during 2007 partially explain some of the rainfall anomalies across the continent during this year, particularly the relatively wet conditions in Colombia and the below-average precipitation in central Chile.

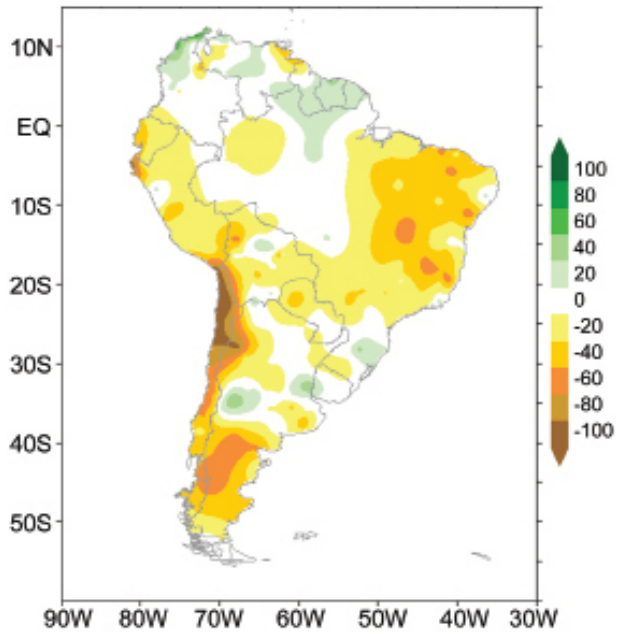


**Fig. 6.21. Annual precipitation anomalies during 2007 (percent of 1961–90 normal) in South America. [Source: National Meteorological Services of Argentina, Brazil, Bolivia, Chile, Colombia, Ecuador, Guyana, Surinam, Uruguay, Paraguay, Peru, and Venezuela. Data compilation and processing: CIIFEN.]**

Other very unusual weather episodes were observed during 2007. A snowfall episode in Buenos Aires and the surrounding areas on 9 July was the first one since 1928. The first snowfall event in a decade affected the rich agricultural region of central Chile on 9 August, exacerbating the damage caused by numerous freezing days during an anomalously

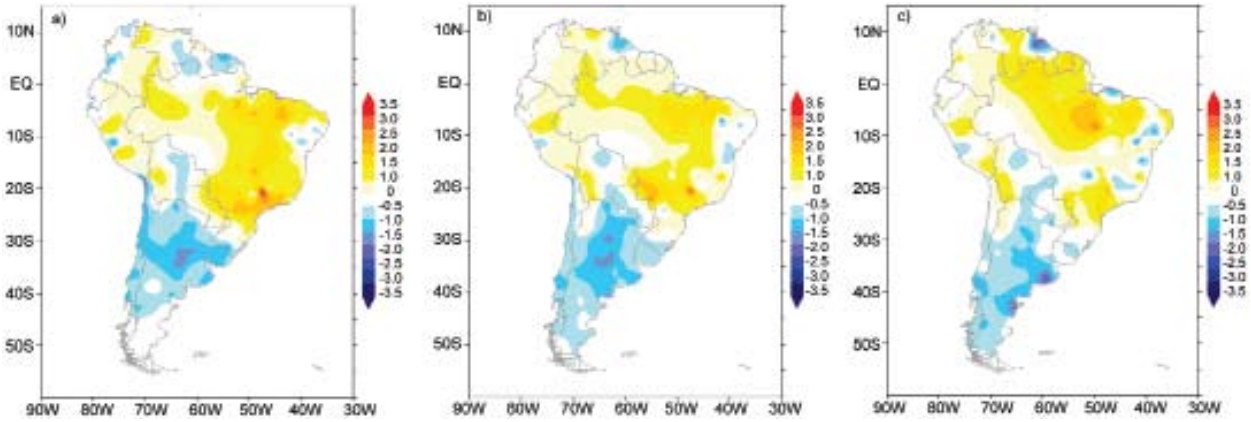


**Fig. 6.22. Annual (a) mean, (b) maximum, and (c) minimum temperature anomalies for 2007 (°C; base period is 1961–90) over South America. [Source: National Meteorological Services of Argentina, Brazil, Bolivia, Chile, Colombia, Ecuador, Guyana, Surinam, Uruguay, Paraguay, Peru, and Venezuela. Data compilation and processing: CIIFEN.]**

cold winter. A couple of waterspouts were observed during August in Venezuela near Margarita Island and in Lake Valencia. Last, an extremely intense 1-h long hail storm hit Bogotá, Colombia, on 3 November, producing severe damage and effectively bringing the city to a halt.

### 2) Northern South America and the Tropical Andes—R. Martínez Güingla, A. Quintero Mercardo, G. Hurtado, and E. Jaimes Espinoza

#### (i) Guyana, Surinam, and Venezuela

Monthly precipitation anomalies for January–February in Venezuela, Guyana, and Surinam were slightly below normal for a large portion of this region. Over Guyana and Surinam, rainfall was 20–40 mm below normal. Following the intensification of the ITCZ during March, a slight increase in rainfall was observed across the region, particularly in southern Venezuela, Guyana, and Surinam. The agricultural region in central and western Llanos—the grassland east of the Andes in northwestern South America—registered anomalies near –40 mm. The drier-than-normal conditions were also evident in northern Guyana. In Venezuela, a 140-mm deficit was observed in the state of Guárico and affected the farming communities in Bolívar, Anzoátegui, and Maturín.

During the third quarter of 2007, positive precipitation anomalies were observed in Surinam and central and southern parts of Guyana. In Venezuela, positive precipitation anomalies (up to 200 mm) were registered in August over Guarico and Anzoategui states and over the northern part of the country, while anomalies from 60 to 180 mm were observed in the south. However, for the entire season the precipitation anomalies in the western, central, and eastern regions were below average.

During August, two exceptional occurrences of waterspouts were observed in Venezuela, one on 6 August near the airport on Margarita Island (11°N, 64°W), and the second one on 8 August in Lake Valencia (Caraboo state), specifically in the small barren island of Chambergo.

The tropical cyclone season in the Caribbean Sea was less active than usual, and the cyclones that were observed did not affect the Caribbean sector of northern South America. Only tropical easterly waves over the Caribbean Sea influenced the weather of the Caribbean sector. A total of 50 tropical easterly waves moved from the Caribbean Sea to the north of Venezuela, interacting with the ITCZ and generating cloudiness and precipitation, as is typical during the rainy season.

Precipitation during the last quarter of 2007 was above the average in Venezuela, Guyana, and Surinam, with the exception of northern Guyana, where a 60 mm deficit was observed in November. Nevertheless, for December, positive precipitation anomalies reached near 100 mm in the region.

An analysis of precipitation records for different stations in Venezuela during recent years, including 2007, reveals a general negative trend in the frequency of rainy days. The development of large convective systems was common during 2007 in different regions, especially in central Llanos and southern Venezuela. These systems, characterized by the development of multiple convective cells, produced intense rainfall, storms, and showers.

Regarding temperature, an anomaly of +0.5°C was observed in the annual mean value of maximum daily temperature over northern Venezuela, where most of the populated cities are located, and +1.0°C over the northwest. The average minimum daily temperature was above normal in most of the territory in Venezuela, with an anomaly of +1.0°C over the northern portion of the country. Over Guyana, negative temperature anomalies on the order of –1.0°C were observed in the northern part of the country, in contrast with positive anomalies of +1.0°C in the southern region; this was also the case in Surinam. With respect to annual mean temperatures, anomalies of +1.0°C were observed in northern Venezuela and +0.5°C in the rest of the country, Guyana, and Surinam.

#### (ii) Colombia

During January and February, the displacement of warm waters toward the Colombian coast (from Kelvin waves) in response to the 2006–07 El Niño, combined with an anomalous northward displacement of the frontal systems over the Caribbean Sea, favored below-normal precipitation over most of the country and temperature anomalies around +2.0°C over isolated areas in eastern Colombia. Furthermore, during the first week of February, most of the highland regions located above 2500 m experienced very low minimum temperatures, with freezing conditions generated by extremely intense and rare nocturnal radiative cooling. From March to May, the ITCZ interacted with frontal systems that originated over the North Atlantic and produced favorable conditions for dense cloud generation and above-normal precipitation amounts in most of Colombia. Beginning in June, widespread above-normal rainfall was observed over the Andes, Caribbean, and Pacific regions. Rainfall was below average over the eastern part of Colombia in the second half of 2007.

(iii) Ecuador

The observed climate pattern over Ecuador during January showed limited influence from the 2006–07 El Niño event, as rainfall was slightly below normal along the northern coast and central highlands. In February, as the El Niño dissipated, the whole country experienced the most significant precipitation deficit of the last 50 yr, which was mostly associated with atypical circulation patterns in the upper troposphere over Amazonia and the Caribbean. During March, the rainy season became more intense, with above-normal precipitation in most of the highlands and along the central and northern coast. In April and May, the rainy season was characterized by significant rainfall episodes primarily along the northern coast, while precipitation deficits were observed in the rest of the country.

The second half of 2007 was characterized by dry conditions in most of the country. However, above-normal precipitation was recorded in highland areas and the Amazon region from August to October. The ITCZ exhibited weak-to-moderate convective activity and very limited influence over the continent between 2°N and 1°S. This behavior was due to the blocking of cold air advection from the Caribbean, among other factors, in the upper troposphere over Colombia and northern Ecuador. This inhibited the development of convection over the ITCZ, mainly in the coastal region.

The temperature was above normal during January and February over the Ecuadorean territory. From March to May and October to December, temperature was below normal. During the first quarter, although negative SLP anomalies were present in the equatorial Pacific, the above-average SLP offshore of the Peruvian coast favored fair weather conditions. The SPA was displaced slightly to the south and exhibited anomalies up to +3.0 hPa.

(iv) Perú

The first four months of 2007 were characterized by enhanced humidity convergence over the Amazonian portion of the Peruvian territory, sustained by a persistent transport of water vapor from the northeast. This process, combined with upper-level divergence, favored the development of intense deep convection and associated intense precipitation over Amazonia and the highlands. Humidity transport led to the development of rainfall events along the central coast and northern Perú. Migratory high pressure systems routinely formed over the continent, shifting quickly toward the South Atlantic and displacing the frontal systems to southeast Brazil. A ridge located near northeast Brazil favored the advection of warm and wet air masses from the north.

During the first 10 days of February, a change in the regional atmospheric circulation pattern favored the advection of humidity toward the eastern slopes of the Andes, producing moderate-to-intense rainfall over the Amazon region in Perú. During the second week of February, an intense episode of the LLJ, with winds up to 22 m $s^{-1}$, produced some light damage in the Department of San Martin. Furthermore, advection of warm and moist air from the north favored the development of intense convection over the jungle, while over the highlands westerly winds generated convection and intense hail storms that caused extensive agricultural damage.

At the beginning of May, the southeast Pacific subtropical anticyclone was anomalously intense (anomalies up to +10 hPa) and displaced southward from its mean position. A ridge over El Chaco, which is characteristic of this season, inhibited precipitation. However, the presence of easterly winds over tropical South America aided the development of convection and rainfall over the Peruvian jungle and the eastern slopes of the Andes. In contrast, several episodes of cold air advection were associated with the passage of migratory high pressure systems.

During July–September, an episode of intense winds occurred along the Peruvian coastal strip (called Paracas winds) that was associated with the intensification of the zonal pressure gradient and the southern configuration of the SPA. The strong winds lifted dust and sand from Ica to the north, and generated persistent drizzle along the coast, including in Lima. At low levels (950 hPa) offshore of the central coast of Perú, winds surpassed 25 m $s^{-1}$.

During the first part of October, an upper-level anticyclone predominated over southern Perú. The associated divergence over the central and northern part of the Peruvian Amazon supported the development of several episodes of moderate-to-strong convection and precipitation, as was observed over Loreto (northeast Perú) on 4 October when 140 mm of rainfall was recorded.

During December, subsidence was predominant over the Peruvian territory, and convection was restricted to isolated episodes over the eastern slope of the Peruvian Andes. Rainfall events that occurred mainly in the central and southern part of the Amazon region of Perú, during the second week of the month, were forced by advection of warm and moist air associated with an intense LLJ episode. Southerly winds over Argentina, Paraguay and Bolivia, associated with migratory highs, generated intense

convergence over northern Bolivia, leading to strong convection and rainfall.

3) Tropical South America, east of the Andes—J. A. Marengo and J. Báez

(i) Regional precipitation

In general, the most important features of summer rainfall in the region were the intense rainfall and flooding episodes in January–February in Bolivia, eastern Perú, central Chaco and eastern Paraguay, and western and southeastern Brazil. In Bolivia, floods affected nearly 200,000 people and 70,000 hectares of cropland. According to SENAMHI (www.senamhi.gov.bo), during January and February 2007 rainfall in the lowlands was 57% above normal in January and 23% above normal in February. However, during the whole year, the lowlands of Bolivia east of the Andes, from Pando to Santa Cruz, experienced moderate drought conditions while the Andean region experienced intense drought from La Paz to Potosi. In Paraguay, from April until the first half of October, rainfall deficits predominated over the country. In cities such as San Pedro, San Estanislao, Concepción, and others in the north, rainfall was absent for 40 consecutive days, prompting the most prolonged and extensive forest fires ever recorded in the country. In the upper Amazon region of Perú, floods in San Ramón affected 90% of the city, while intense rains over the Huallaga Valley produced floods that affected crops and left hundreds homeless. In Brazil, large areas in the southeastern and west-central regions were affected by abundant rainfall that produced landslides; rainfall was almost 80% above normal in many cities in those regions during January 2007. northeast Brazil's prerainy season was below normal, similar to most of the Amazon and southern Brazil regions. This was due to the configuration of the SACZ and a lack of cold fronts. January 2007 was among the five wettest over the past 46 yr. The upper-level circulation in January was characterized by a subtropical westerly jet stronger than normal and displaced anomalously northward over South America. The upper-tropospheric Bolivian anticyclone was very intense and positioned over southeastern Bolivia; its presence led to the amplification of convective activity over its diffluent region, bringing moisture and favoring rainfall over eastern Bolivia, central Chaco in Paraguay, and west-central Brazil and the southern Amazon, with intense rainfall events over these regions. In the Amazon region, rainfall in January was 100 mm above normal in northern and southwestern zones, while in the rest of the region rainfall was below normal.

As in January, most of the summer and autumn months were characterized by episodes of intense rainfall. In some cities of the Amazon and northeast Brazil regions in March, the accumulated rain in 2–3 days was larger than the long-term means by at least 100 mm. However, in the same month a dry air mass was stationary over large regions of southeastern and southern Brazil, and the relative humidity reached values of about 30% or less. For instance, in Resende-Rio de Janeiro, Curitiba-Parana, and the Sao Paulo International Airport, relative humidity reached 20% on 4 March. In the austral winter (June–August), the dry season in most of tropical and subtropical Brazil was interrupted by intense rainfall events due to the presence of cold fronts and extratropical cyclones that produced storms and hail in southern Brazil. During spring (September–November), rainfall was above

## DRY CONDITIONS IN BOLIVIA IN 2007: BLAME IT ON EL NIÑO?—J. A. MARENGO

The brief El Niño event of late 2006 quickly dissipated in January 2007, and La Niña conditions became well established across the central and eastern equatorial Pacific in the latter half of 2007. According to Bolivian Government sources, early 2007 dryness in Bolivia was attributable to the 2006–07 El Niño. The warming of the tropical Pacific was considerably weaker than in other El Niño events, as in 1982–83 and 1997–98. Compared to the 1997–98 El Niño, when 34% of the country was affected, conditions linked to the 2006–07 El Niño affected almost 60% of the country. Total losses in this year were about $405 million (U.S. dollars), compared to $570 million (U.S. dollars) during the 1997–98 El Niño.

Ronchail et al. (2002) have suggested that drought conditions in the regions that experienced rainfall deficits in early 2007 in Bolivia have occurred in the past not only in El Niño years, but also in years that experienced anomalous warming in both the tropical North and South Atlantic, and also in La Niña years accompanied by anomalously warm surface waters in the tropical North Atlantic. They argue that El Niño–induced droughts typically affect the provinces of Pando and Beni, as well as Potosi and Tarija, while above-normal rainfall may be detected from La Paz to Santa Cruz. The rainfall anomaly pattern observed in 2007 over Bolivia compares more favorably with the pattern characterized by warming in the tropical Atlantic than that of a typical El Niño. Therefore, it is likely that the 2006–07 El Niño was not the main cause of dry conditions in Bolivia in 2007.

normal along the eastern coast of Brazil, while in the interior a dry air mass persisted, with lower values of relative humidity (13% in Goiânia-Goias). Rainfall was above normal in the Amazon and southern Brazil regions, associated with the presence of the SACZ. Consequently, rainfall was above normal in some cities of southeastern Brazil, including in Ubatuba-São Paulo, where it rained 235 mm during 22–26 October, 13 mm above the climatological average for all of October.

The rainy season March–May in northeast Brazil in 2007 was deficient, about 200 mm lower than normal, in contrast to 2005 and 2006, both of which had rainfall surpluses (Fig. 6.23). The region most affected by drought was the semiarid region, as well as the northern region of northeast Brazil. The 2006–07 El Niño event was weak during the austral summer and had dissipated during autumn, so the most important dynamic cause of dry conditions in northeast Brazil in 2007 was the behavior of the tropical Atlantic. The tropical Atlantic oscillated between normal and relatively warm north of the equator; therefore, the ITCZ was located northward of its climatological position during summer and autumn. Even though the whole season was considered as rainfall deficient, some intense rainfall events were reported.

(ii) Regional temperatures

Most of tropical South America east of the Andes experienced a warm 2007, with temperatures about 2°–3°C warmer than normal in January–February. In the Amazon and northeast Brazil regions, temperature anomalies were above 3°C in January. Unusually warm temperatures approximately 3°–6°C above average were also observed during September–October in Paraguay, extending into west-central and southeastern Brazil and into northern Argentina, southern Brazil, and Uruguay.

South America experienced an unusually cold winter (June–August), bringing winds, blizzards and rare snowfall to various provinces with temperatures falling to –22°C in Argentina and –18°C in Chile in early July. May 2007 was unusually cold, and in southern Brazil the temperatures reached values as low as –5°C on 29 May in São Joaquim-Santa Catarina. In the Amazon region, temperatures fell as low as 13.5°C on 9 May and 9°C on 10 May in Vilhena-Rondonia, where the average temperatures are greater than 20°C. The penetration of a polar air mass associated with a cold front affected the Amazon region in late June, when minimum temperatures reached 14.9°C on 26 June, with a drop in temperature of 7.6°C from the previous day. In southern Brazil, minimum temperatures reached –5°C in the highlands. Monthly temperature anomalies were 2°–3°C below normal in southern Brazil, Paraguay and northeast Argentina during July and August, while tropical Brazil experienced temperatures about 1°–3°C warmer than normal from April to August.

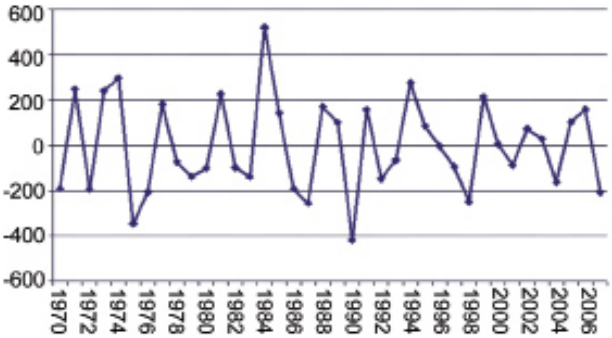


**Fig. 6.23. Rainfall anomalies (mm; base period in 1970–2000) during the peak season Mar–May in northeast Brazil during 1970–2007. [Source: CPTEC/INPE and INMET.]**

4) Southern South America: Argentina, Chile, Paraguay, and Uruguay—M. Bidegain, M. Skansi, P. Aceituno, and J. M. Quintana

(i) Regional temperatures

Temperature anomalies were negative during 2007 throughout a great portion of SSA, and anomalously low along the extratropical west coast of the continent. Annual temperatures between 0.5° and 1.0°C below normal were observed in Argentina, Chile, Paraguay, and Uruguay.

The beginning of 2007 was relatively hot in Chile, Paraguay, Uruguay, and Argentina (north of 40°S), where mean temperature was above normal (0.2°–0.5°C). Below-normal temperatures (anomalies from +0.2° to –1.0°C) were observed over Uruguay and the eastern portion of Argentina during the austral autumn. The winter was extremely cold over the entire region with temperatures 0.5°–4.0°C below normal. July was exceptionally cold, and record minimum temperatures were broken at many stations in northeastern Argentina, southern Paraguay, and northern Uruguay, where monthly anomalies of up to –5°C were observed. A strong cold spell after the passage of a cold front that affected the region from 6 to 12 July produced extremely low minimum and maximum temperatures and covered a large part of Chile and Argentina with snow, including Buenos Aires, where a rare snowfall episode was observed on 9 July, the first one since 1928. The winter's end was abrupt, and September was anomalously hot, particularly over

## WINTER IN ARGENTINA—M. SKANSI

The winter of 2007 was extremely cold in almost all of Argentina, breaking a recent pattern of very warm winters. Mean temperature anomalies in the center and north of the country were below –1.0°, while those in the Pampas (30°–45°S) reached –2°C to –3.5°C (Fig. 6.24). Many locations recorded their lowest mean temperatures in the last 45 yr. The negative anomalies for the daily minimum temperatures were even more significant. The only exception was the southernmost region of Tierra del Fuego, where temperatures were above normal. In the Pampean region, anomalies ranged from –2° to below –4°C in the southern portion of Buenos Aires province. Mean daily maximum temperatures were on the order of 1°–2°C below normal in the central and northern portions of the country, while the southern part of Patagonia recorded anomalies that were slightly positive.

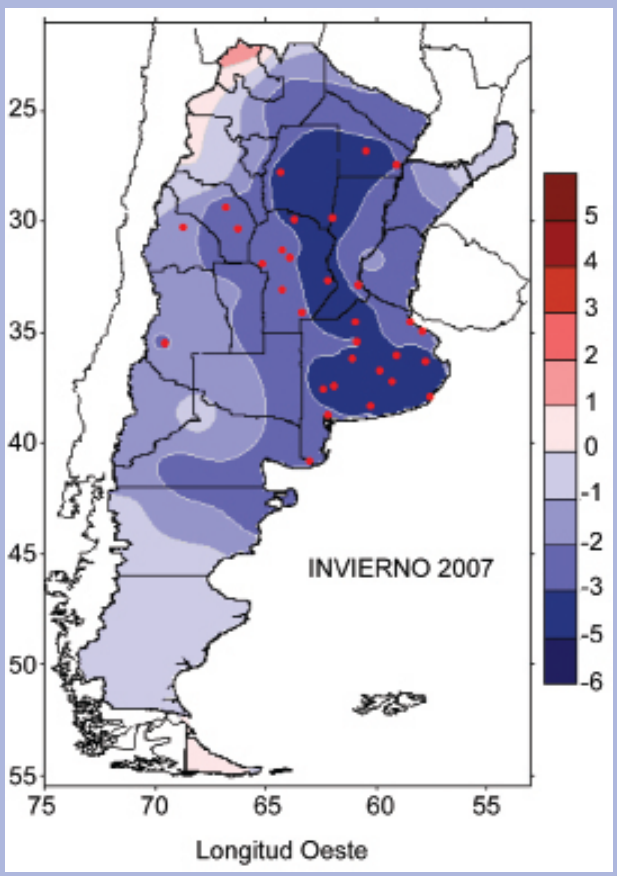


**Fig. 6.24. Average minimum temperature anomalies (°C; 1961–90 base period) over Argentina in winter (Jun–Aug) 2007. Red dots depict stations that reported record cold minimum temperatures (since 1961) averaged over winter in 2007.**

eastern Argentina and Uruguay (>2°C), where the hottest conditions of the last 45 yr were observed in some sectors. The spring showed positive temperature anomalies from 0.5° to 1.0°C above the mean.

As elsewhere in SSA, anomalously cold conditions characterized the austral winter and spring in central Chile, as shown in Fig. 6.25, which shows the evolution of daily minimum temperature in Santiago (33.5°S). The large frequency of freezing days during June–August produced considerable damage to agriculture along the central valley in the region from 30° to 40°S. In fact, the mean daily minimum temperature of 2.6°C in Santiago during August was the lowest since 1914, and the snowfall episode observed in central Chile during the night of 9 August was the first one in a decade.

### (ii) Regional precipitation

Beginning in February 2007, heavy rainfall and storms caused severe flooding in SSA, affecting mainly the Argentine provinces of Entre Ríos and Santa Fe, located on the lower basin of the Paraná River. During the last week of March, 500 mm of rain was registered over this region, almost 4 times the climatological average for the entire month. It was estimated that more than 80,000 people were affected by the flooding.

The year 2007 was characterized by below-normal rainfall along the extratropical west coast of the continent. The deficit in annual rainfall in Chile, associated with an intensified SE Pacific subtropical anticyclone during the development of a La Niña event in the tropical Pacific, was 60% below average in the semiarid territory between 25° and 30°S and was of the order of 40% below average in the rich agricultural region between 33° and 37°S (Fig. 6.26).

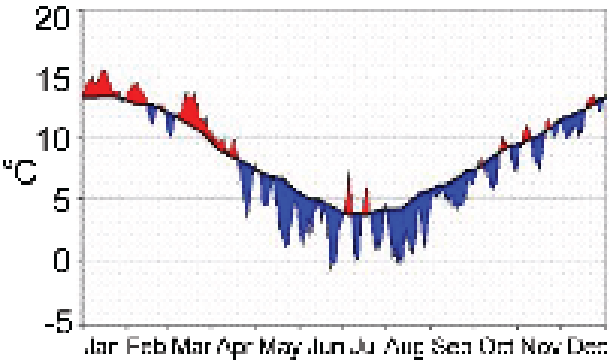


**Fig. 6.25. Evolution of 5-day moving average of daily minimum temperature at Santiago (33.5°S) during 2007. The black line indicates the 1961–90 climatological mean.**

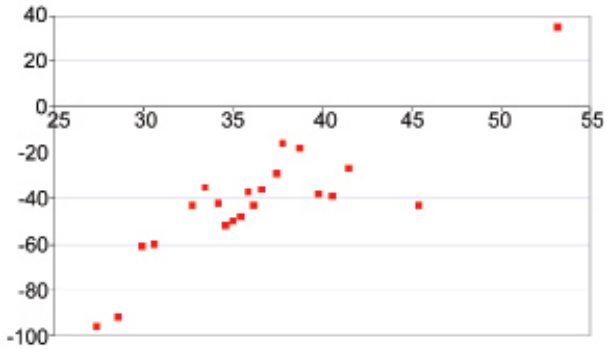


**Fig. 6.26. Annual rainfall anomalies (percent of 1961–90 normal) for various Chilean stations. The *x* axis depicts latitude (28°–53°S).**

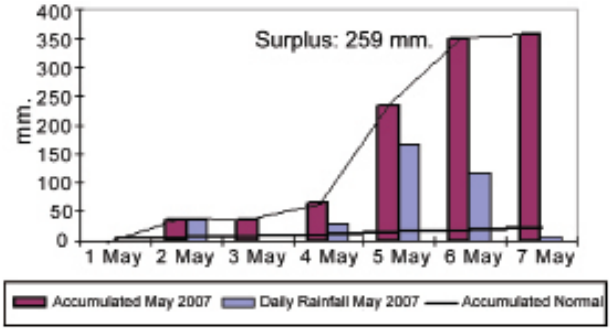


**Fig. 6.27. Daily rainfall (mm) during 1–7 May in Treinta y Tres, Uruguay. The solid line represents the cumulative rainfall during this period in 2007, while the solid line depicts normal conditions.**

In Uruguay, a heavy rainfall event during 4–6 May 2007 caused severe floods in the central part of the country (Fig. 6.27). It was the most intense rainfall episode (>300 mm) since April 1959. More than 110,000 people were affected in the cities of Treinta y Tres, Durazno, and Mercedes. Consistent with the mature phase of the La Niña episode at the end of 2007, rainfall deficits were observed in the southeastern portion of the continent during November and December, including southern Brazil, Uruguay, and eastern Argentina.

### f. Asia

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

The year 2007 was the warmest on record in Russia, where regular meteorological observations date back to 1891. The mean annual air temperature anomaly averaged over the Russian territory was +2.0°C (1961–90 base period). Winter (December 2006–February 2007) and summer (June–August) were the warmest on record, registering anomalies of +3.2° and +1.8°C, respectively. In spring (March–May) and fall (September–November), mean seasonal air temperature anomalies were second-warmest on record, with anomalies of +2.2° and +1.8°C, respectively.

January 2007 proved to be abnormally warm over most of Russia. The vast territory of Russia, from its western boundaries to the Lena River, had not experienced such high temperatures in the entire instrumental record. Severe Atlantic storms moved eastward and brought warm and wet air masses, effectively weakening the Siberian anticyclone and displacing it to the northeast. The largest mean monthly air temperature anomalies (Fig. 6.28) were recorded in the northern Krasnoyarsk Territory (>14°C) and in the southwest of the Yakutia-Sakha Republic (>12°C). In European Russia, the positive mean monthly air temperature anomalies in the Volga Region and the Southern Urals exceeded +10°C. In the center of European Russia, the first half of January was particularly warm. Many meteorological stations, including those in Moscow, reported air temperatures that exceeded their maximum daily records. Over most of European Russia, February brought very cold weather, with mean monthly air temperatures of 8°–10°C below normal.

Spring air temperatures over the Russian territory were higher than the long-term average. In March (especially the second half), many meteorological stations in central European Russia exceeded their maximum daily record air temperatures. For most stations, March was the warmest in the entire period of record. In the southern Far East, cool and humid weather was generated by unusually deep cyclones that, while moving from the south, brought heavy snowfall and strong winds. The Maritime Territory (extreme southeast Russian territory whose principal city is Vladivostok), which experiences heavy snow nearly every year, received record snowfall in March when the all-time daily precipitation maximum was exceeded at 24 meteorological stations (Fig. 6.29). For March, the Maritime Territory received 300%–400% of the monthly precipitation norms, the southern Khabarovsk Territory received 200%–300%, and Sakhalin received 200%. Okhotsk, in the southern Khabarovsk Territory, received 62 mm of precipitation, 5 times the average amount. April was warm over most of the country, especially over the Asian territory. The largest mean monthly air temperature anomalies (higher than 10°C) were recorded in the

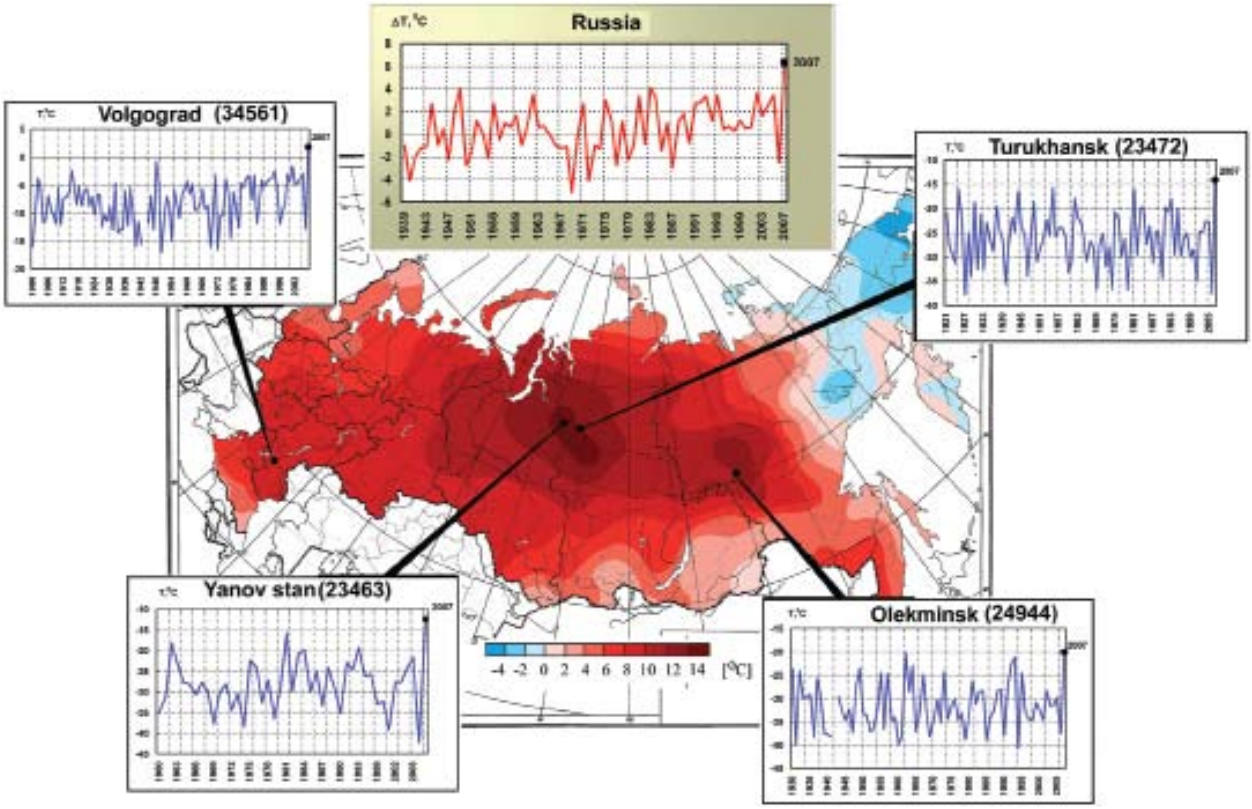


**Fig. 6.28. Air temperature anomalies in Jan 2007. Insets show the series of the Jan air temperature anomaly averaged over the Russian territory and the series of mean Jan air temperature at meteorological stations Volgograd, Yanov stan, Turukhansk, and Olekminsk.**

north of eastern Siberia and in the Taimyr Autonomous Area. Over virtually all of Russia, except Sakhalin and the Southern Federal District, mean monthly air temperatures were above normal, making April 2007 the second warmest on record. During the last week of May, abnormally hot and dry weather set in over central and southern European Russia. On the last days of the month, the air temperature reached 30°–37°C. Record-breaking daily air temperatures, 38°–39°C, were recorded in the south of the Volgograd Region and in the north of the Astrakhan Region, which were 1°–3°C above the previous records. Hot weather, combined with significant precipitation deficits, low relative air humidity, and strong winds, affected these regions. Beginning on 20 May, soil drought spread into the steppe and submountain regions of the Republic of North Ossetia-Alaniya.

Summer over the Russian territory was also much warmer than normal. In June, the Southern Federal District experienced a precipitation deficit in conjunction with warm temperature anomalies, which contributed to the rapid development of drought that persisted for 30–45 days. Unusually hot weather was recorded in the Southern Federal District during most of July. A vast region of very warm air temperatures formed in Chukotka, where mean monthly air temperature anomalies were greater than +6°C. For the Russian territory as a whole, August was the warmest on record (Fig. 6.30).

The fall in 2007 was also abnormally warm, particularly on the Arctic coast of Asian Russia. September brought above-average air temperature anomalies nearly everywhere in the Russian territory. The mean September air temperature was only slightly lower than the record-breaking value of 2005. September air temperature records were broken in some parts, such as northern Chukotka (Pevek), where mean monthly air temperature anomalies were higher than +6°C. In October, mean monthly air temperatures were above normal throughout the Russian territory, except the southern regions of western and eastern Siberia and the southwestern coast of Kamchatka. The highest mean monthly temperatures in the Far East were recorded in Chukotka, greater than +7°C above normal. In October, it was very warm on the Arctic coast and in southeastern Yakutia.

The positive temperature anomalies over the Asian territory persisted into November. The center of maximum anomalies (>8°C) remained in the vicinity of Kolyma and

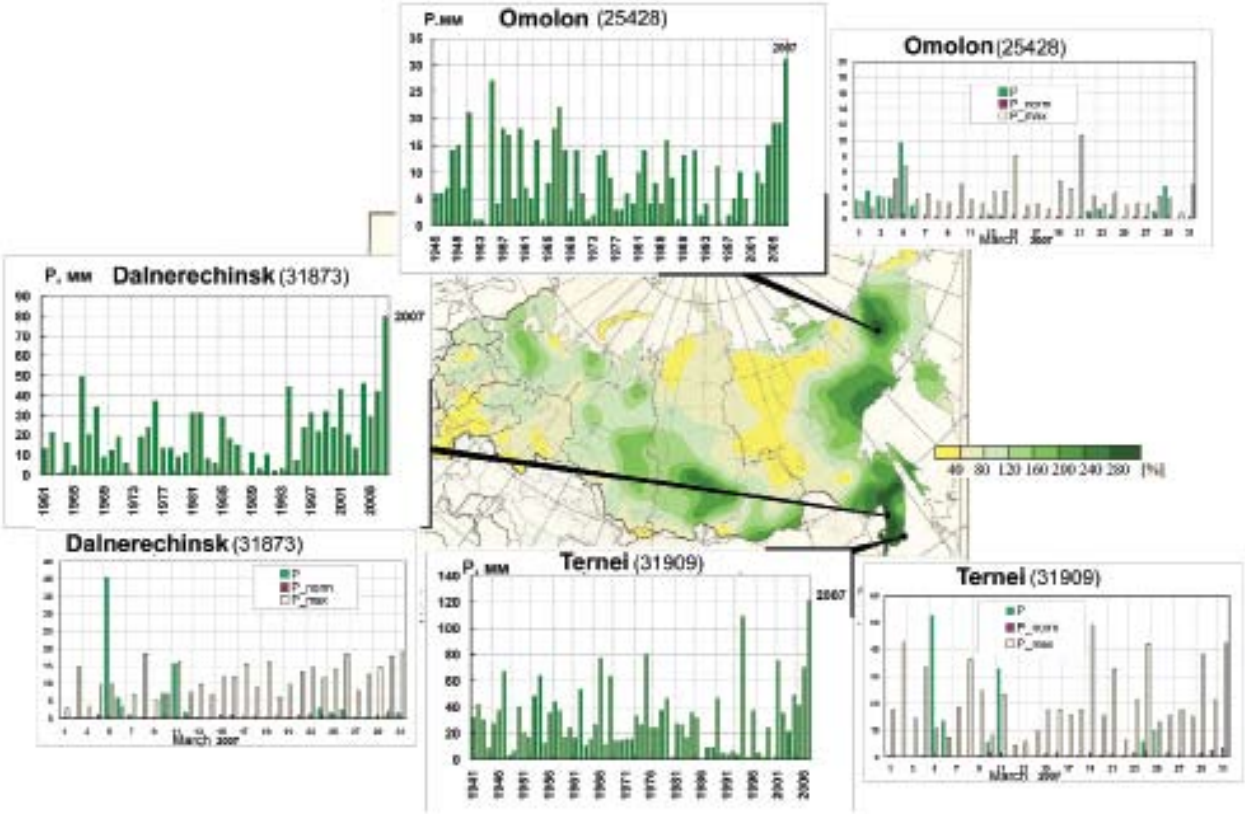


**Fig. 6.29. Precipitation total vs the normal value in Mar 2007. Insets show the series of monthly and daily precipitation totals at meteorological stations Dalnerechinsk, Ternei, and Omolon.**

in northern Chukotka. In November, record-breaking temperatures were observed in Oimyakon (Yakutia). On 7 November, the maximum air temperature reached –10.5°C, which was nearly 20°C above normal. December also proved to be warmer than usual over most of Russia. Large areas of above average temperatures developed in the north of European Russia and in the northeast of the Asian territory of the country, where monthly means were 8° and 10°C above normal, respectively. In Chukotka, where the monthly mean was warmer than normal for the fourth consecutive month, several stations (Shmidt Cape, Valkarai) had their warmest December on record.

2) East Asia—K. Suda, X. Zou, X. Liang, Y. Chen, Y. Guo, J.-E. Kim, and P. Gomboluudev

(i) Overview

Surface air temperatures over most of East Asia during 2007 were near or above normal (based on the 1971–2000 average), and were significantly above normal in winter (December 2006–February 2007) and spring (March–May 2007). Meanwhile, temperatures in parts of northwestern Mongolia and parts of southern China in autumn (September–November 2007) were slightly below normal. The annual temperature in China for 2007 was 1.3°C above normal (all four seasons were warmer than average), making 2007 the warmest year since reliable records began in 1951. In August, unusually high temperatures hit Japan, breaking the long-term monthly record. Considerable variability in precipitation occurred across East Asia throughout the year. In China, heavy rains caused devastating floods in the Huaihe River Valley in late June and July, while significant droughts affected much of southern China from late September to mid-December. In the Democratic People's Republic of Korea, heavy rains caused severe floods in August. Severe drought conditions persisted across Mongolia.

(ii) Temperature

The average temperature in China for 2007 was 10.1°C, which was 1.3°C above normal, ranking this year as the warmest since reliable national records began in 1951 (Fig. 6.31). Annual mean temperatures for 2007 were above normal over most of China, and 1°–2°C above normal in the northern and eastern

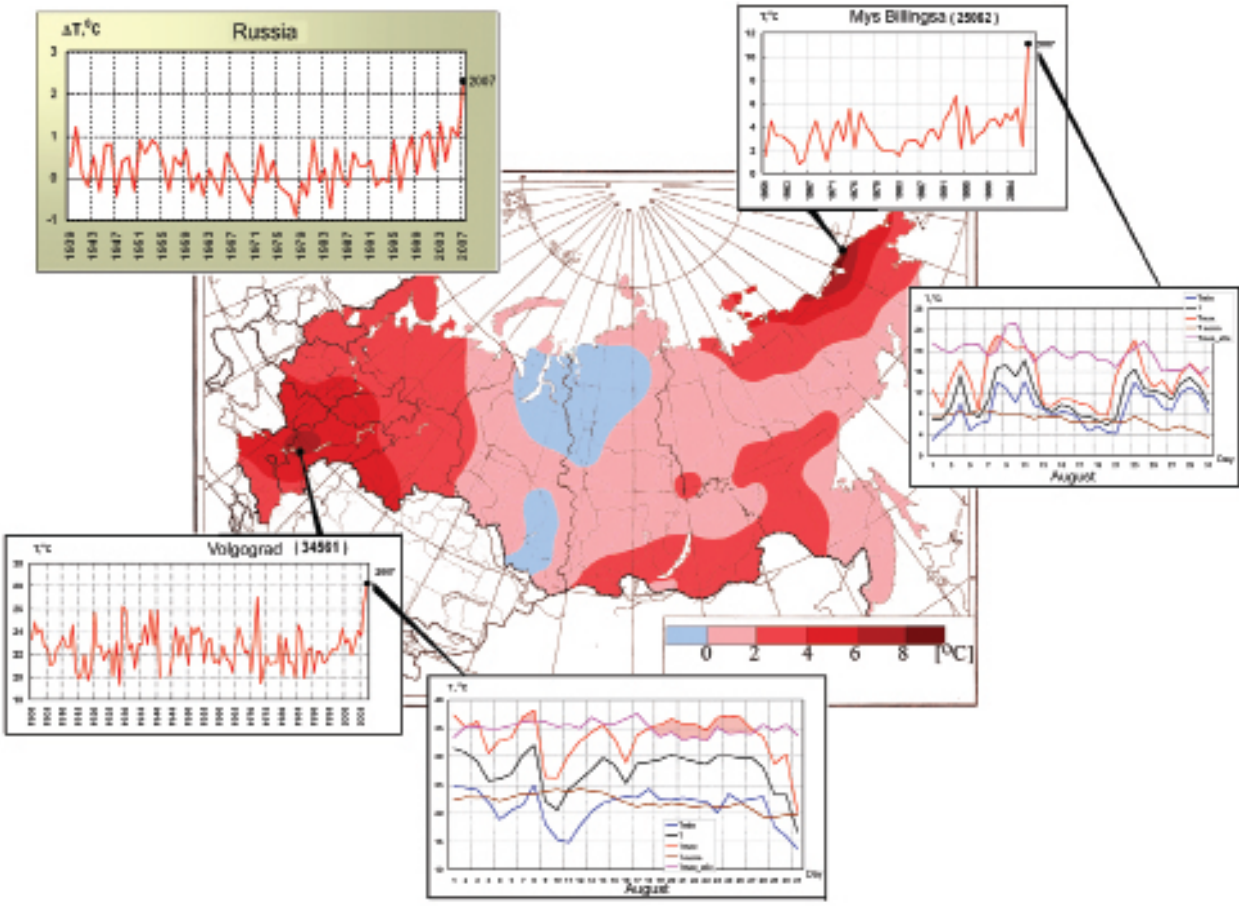


**Fig. 6.30. Air temperature anomalies in Aug 2007. Insets show the series of the Aug air temperature anomalies averaged over the Russian territory and the series of mean monthly and daily air temperatures in Aug 2007 at meteorological stations Volgograd and Mys Billingsa.**

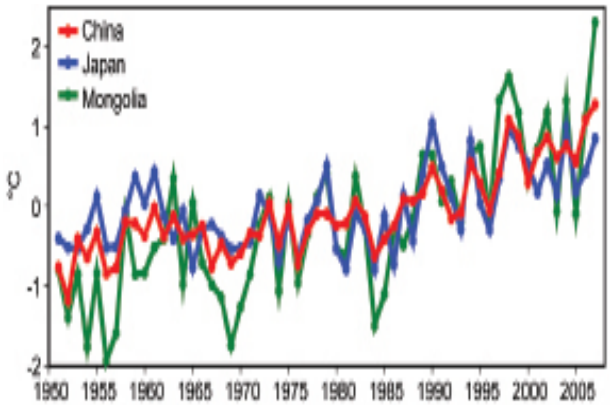


**Fig. 6.31. Time series of annual mean temperature anomalies (°C; 1971–2000 base period) in East Asia from 1951 to 2007. [Source: CMA, JMA, and NAMHEM of Mongolia.]**

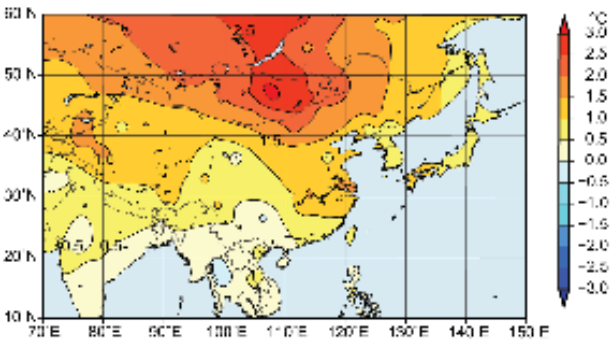


**Fig. 6.32. Annual mean temperature anomalies (°C; 1971–2000 base period) over East Asia in 2007. [Source: JMA.]**

parts of the country (Fig. 6.32). The 2006/07 winter season was the second warmest winter for China during the past half century. For spring, the average temperature for the whole country was 10.9°C, which was 1.2°C above normal and the warmest spring since 1951. The average temperature for summer (June–August 2007) in China was 21.3°C, which was the second warmest in the 1951–2007 record. The

autumn temperature in 2007 in China was 10.1° and 0.8°C above normal.

The annual mean temperature of the Republic of Korea in 2007 was 13.4°C (1.0°C above normal), making 2007 the second warmest year since 1973. The mean temperature during winter was the highest since 1973. Anomalously warm conditions occurred in September, as daily minimum temperatures did not drop below 25°C in some of the southern parts of the Republic of Korea.

The annual mean temperature in Japan was 0.85°C above normal, the fourth highest on record since 1898. In winter, all-time seasonal mean temperature records were broken at 63 out of 153 observatories. The regional mean temperatures in many parts of Japan were the highest since the winter of 1946/47, when reliable historical records began. In August and September, monthly mean temperatures were significantly above normal in many parts of Japan. A number of stations broke their all-time high temperature records in mid-August. On 16 August 2007, a new national record of 40.9°C was measured concurrently at Kumagaya near Tokyo and Tajimi near Nagoya.

The annual mean temperature in Mongolia was 2.4°C, which was the warmest year since 1940. The winter temperature was –15.4°C, about 3.1°C higher than normal and also the warmest winter in the entire observational record. The summer temperature was the second highest and the spring and autumn temperatures were also above normal.

### (iii) Precipitation

Total precipitation for 2007 in China was near normal, ranking as the 27th driest out of 57 yr of nationwide records. The spatial and seasonal precipitation distributions were uneven across the country. Precipitation values were 20%–100% above normal in most of northwest China and the Huaihe River Valley, while deficits of 20%–50% were recorded over Northeast China and the areas south to the Yangtze River (Fig. 6.33). In late June and July, heavy rainfall continued in the Huaihe Valley, which caused the most severe flood since 1954, with more than 1 million evacuees. Anhui province was especially hard hit. During late September to mid-October, successive rains occurred in eastern northwest China and north China, with above-average counts of rainy days, marking the longest autumn rain event on record in northern China. In summer, widespread droughts expanded across much of southern China and northeast China. From late September to mid-December, a 1-in-50-yr drought impacted most of southern China, which rapidly intensified and caused a shortage of potable water for about 3 million people.

The Republic of Korea had an average rainfall of 1,515 mm in 2007, which was 15% above normal. This was punctuated by a very wet September, when Korea received 2.8 times its September normal.

In Japan, annual precipitation amounts were below average in most areas. The amounts were less than 60% of their normal in parts of western Japan, and three observatories reported their driest conditions on record. During winter, the snowfall amounts were significantly less than normal across all of Japan. Some regional mean winter snowfall amounts were the least since the winter of 1961/62, when the historical records began. In a part of eastern Japan, the total snowfall amount was 91% less than normal. In autumn, seasonal precipitation amounts were extremely below average in western Japan.

In Mongolia, a period of dry conditions continued; the annual precipitation was 170 mm, which was 23% lower than normal. Drought persisted from May to July, with the only exceptions of the southwestern and southern parts of the country.

### (iv) Atmospheric circulation

In winter, the center of the Aleutian low shifted eastward from its normal position, and the Siberian high was weaker than normal. This type of pattern indicates that the northeastern Asian winter monsoon was weaker than normal with less frequent cold surges. In the upper troposphere, the intensity of the seasonal mean polar front jet was stronger than normal from Europe to Lake Baikal, which brought an extremely warm winter to northeastern Asia. In spring, upper-level ridges over central Asia and troughs from Japan to the western Pacific were observed partly as quasi-stationary Rossby waves

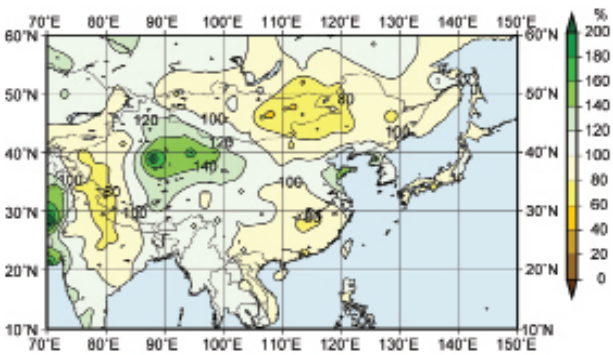


**Fig. 6.33. Annual precipitation anomalies (1971–2000 base period) as percentage of normal over East Asia in 2007. [Source: JMA.]**

that propagated from Europe. High pressure systems did not develop pesistently in the Sea of Okhotsk in summer, while the North Pacific anticyclone was stronger than normal around Japan in August and September. In the upper troposphere, the Tibetan high was stronger than normal in its northeastern periphery as the Asian jet meandered frequently in August and September. In connection with these synoptic patterns, a barotropic high pressure system brought extremely high temperatures to Japan.

(v) Monsoon

The onset of the SCS summer monsoon began at the end of May, which was later than normal. Subsequently, warm and wet air controlled the SCS as southwesterly flow set in. During mid-June, southwesterlies moved northward to the Jianghuai area together with a northward movement of the northwest Pacific subtropical high. The mei-yu[5] also prevailed in the area, and warm and wet air dominated south of the Huanghuai area. During late July, warm and wet air moved northward to north China. After mid-August, warm and wet air swiftly withdrew southward, and moved back to South China during early September and lingered until late October. At this point, the winds shifted to the northeast, bringing the SCS summer monsoon season to an end. Overall, the SCS summer monsoon index was −1.3 in 2007, which was weaker than average.

The national average of precipitation during the Changma period (the Korean rainy season, roughly 21 June through 29 July) was 322.7 mm, which was close to the climatological normal (346.1 mm). The number of rainy days during the Changma period (20.8 days) was 4.2 days above normal.

The onset of baiu (the rainy season over Japan during the late spring and summer) was later than normal and water shortages occurred in parts of western Japan, due to migratory anticyclones and a delay in the northward migration of the baiu front. The baiu front tended to stay near the mainland of Japan through July, which brought rainy and cool days. Monthly precipitation amounts during July were above normal due to the active baiu front enhanced by Super Typhoon Man-Yi (see section 4b for additional details on the west North Pacific typhoon season). The end of baiu season was later than normal in most areas of Japan. However, the North Pacific anticyclone intensified around Japan in August, and hot days continued nationwide with dry weather on the Pacific side of the country.

(vi) Aeolian dust

In spring 2007, China was affected by 15 dust and sand events, which was fewer than in 2006. The average number of dust days in northern China was 2.0 days, which was 3.6 days less than normal. On 30–31 March, a severe dust storm blanketed much of northwest and north China, regarded by some as the worst dust storm in 2007. The Republic of Korea was affected by 13 Asian dust events, and the strongest one peaked on 31 March, affecting most of Korea over a 3-day period. In Japan, the number of days when "yellow sand" (i.e., aeolian dust) was observed was 34 from January to May 2007, which was the eighth most since 1967. The number of stations that observed aeolian dust was 75 on 2 April, and 72 on 26 May, which were the second and third largest counts on record, respectively.

3) South Asia—M. Rajeevan, J. Revadekar, and L. Zubair

(i) Overview

In 2007, South Asia experienced extremes, both in terms of precipitation and temperature. In January, many parts of north India had severely cold conditions, with a few stations reporting minimum temperatures below the freezing point. The cold outbreak also affected northern districts of Bangladesh, where the reported temperatures were the coldest in 38 yr. Heat waves are common in May and June over northern parts of India and Pakistan, before the onset of the summer monsoon. During May and early June, severe heat wave conditions prevailed over parts of Pakistan, northern India, and south peninsular India with temperatures reaching 45°C. The harsh heat wave conditions claimed the lives of at least 100 people in India and Pakistan. During the first week of May, heavy rainfall triggered landslides and flooding along the southwest coast of Sri Lanka, affecting more than 1 million people. Colombo, the capital city of Sri Lanka, received about 10 in. of rain in 48 hr.

(ii) South Asian summer monsoon

Summer monsoon (June to September) contributes 60%–90% of the annual rainfall over major portions of South Asia. The 2007 monsoon was characterized by an early onset over south peninsular India. Immediately after onset, there was a 10 day stall in the monsoon's advancement as a disruption of monsoon flow accompanied the formation of Cyclone Gonu (see tropics chapter) over the Arabian Sea. However, the southwest monsoon ultimately

[5] Mei-yu ("plum rains") refers to the June–July rainy season in southern China, also referred to as baiu in Japan.

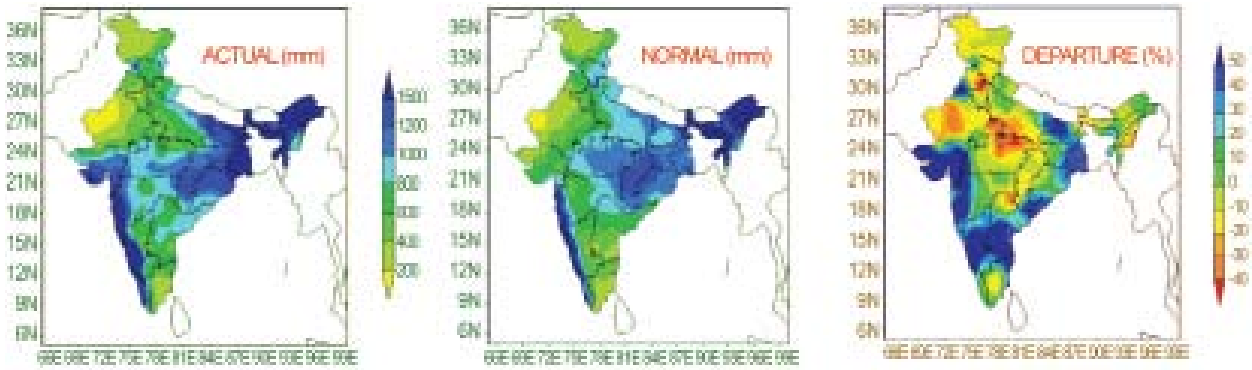


**Fig. 6.34. Monsoon rainfall (mm) and anomalies (percentage of normal) over India in 2007.**

covered India on 4 July, about 10 days ahead of its normal date.

During the 2007 summer monsoon, storm activity was slightly above normal. The formation of two intense cyclonic storms over the Arabian Sea in the month of June was the unique feature of the season. In addition, 11 low pressure systems, including five deep monsoon depressions, formed over the Bay of Bengal. During the season, the monsoon trough (continental tropical convergence zone) was positioned south of its normal position, causing low pressure systems to move south of their normal tracks and resulting in copious amounts of rainfall and flooding over many southern parts of the peninsula. As a result, severe landslides and floods claimed at least 100 lives. From 21 June to 4 July, three depressions formed over the Bay of Bengal in succession. On 23 June, Kurnool in the semiarid area of the southern peninsula received a record rainfall total of 393 mm in 24 h. The previous record was 81.3 mm, recorded on 4 June 1901.

The India-wide summer monsoon rainfall was 6% above its long-term average of 89 cm. However, rainfall activity was not well distributed over space and time (Fig. 6.34). It exhibited strong intraseasonal activity during the season (Fig. 6.35). Active monsoon conditions prevailed on many days in June, September, and during the first week of July and August. However, monsoon breaks prevailed for several days in July and August. After an early onset, the monsoon was less active until the third week of June, partly due to the disruption of the monsoon circulation by Cyclone Gonu over the Arabian Sea. However, with the formation of a deep depression over the west-central Bay of Bengal on 21 June, monsoon conditions revived and active monsoon conditions continued until 10 July. During the second half of July, a monsoon break prevailed over the country. The monsoon was again less active in August, except for a brief period during the first week of the month. However, with the rapid development of La Niña and the positive Indian Ocean dipole conditions (see tropics chapter), the monsoon revived again during the second week of September causing heavy rains over many parts of the country.

Over the country, the monsoon rainfall was deficient over northwest India and parts of central India. However, it was in excess over the south peninsula, where strong monsoon activity continued throughout the season. Out of 36 meteorological subdivisions, 13 received excess rainfall, 18 received normal rainfall, and 5 received deficient rainfall. Out of 504 meteorological districts for which rainfall data were available, 73% of the meteorological districts received excess rainfall and 27% received deficient rainfall. During the season, 74 districts (15%) experienced moderate drought conditions (a rainfall deficiency of 26% to 50%) and 29 districts (6%) experienced severe drought conditions (a rainfall deficiency of 51% and more).

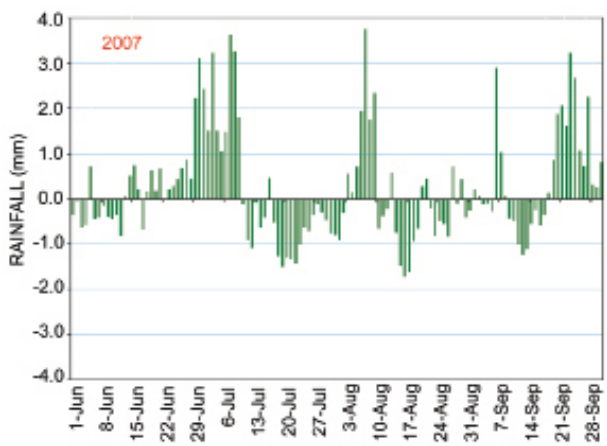


**Fig. 6.35. Daily standardized rainfall time series averaged over the monsoon zone (1 Jun–30 Sep 2007).**

The 2007 summer monsoon rainfall was deficient over Pakistan. The largest rainfall deficiency was observed in Northwest Frontier Province (–16.4%), followed by Balochistan (–14.1%). In general, normal to above-normal rainfall was recorded in most parts of Nepal, except in the eastern region and the Kathmandu and Dipayal Valleys. As in previous years, many parts of South Asia experienced heavy rainfall and associated floods during the season. More than 25 million people were affected by the floods in South Asia with more than 2,000 fatalities. During August, Bangladesh and Nepal were affected by the heaviest rainfall in decades.

(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 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 2007, the rainfall during NEM over southern peninsular India and Sri Lanka was within 5% of its long-term average. Regionally, the seasonal temperature was near normal. The northern regions of peninsular India of Andhra Pradesh and Karnataka and Eastern Sri Lanka received anomalously lower rainfall. The rainfall from November to mid-December was dramatically low. However, Tamil Nadu experienced above-normal rainfall activity during the second half of December. During the last half of the year, La Niña and positive IOD conditions prevailed (see tropics chapter). This is a rare combination with La Niña typically leading to depressed NEM rainfall and positive IOD enhancing the NEM rainfall. Neither the influence of the La Niña nor the influence of the IOD appears to have been dominant during the 2007 NEM season.

4) Southwest Asia

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

(a) Overview

Most parts of Iran were cooler than average during both winter and summer, while warmer-than-average conditions prevailed in spring and autumn (1°–2°C above average). Spring was wetter than average over much of Iran, while in early June, Super Cyclonic Storm Gonu brought heavy rainfall to Oman and the arid regions of southeastern Iran.

(b) Seasonal review

Most of Iran was up to 2°C below normal during winter. Some parts in the east, southeast, and northeast portions of the country were up to 2°C warmer than normal. Areas with near- or above-normal precipitation were the north, northeast, and a narrow band in the northwest. Half of the country experienced precipitation amounts 25% or more below normal during winter 2007. Winter rainfall surpassed 100 mm near the Alborz and Zagros Mountains, and eclipsed 200 mm on the western and southeastern slopes of Zagros. The maximum value of 533 mm was observed in Koohrang. The rest of the country experienced rainfall accumulations between 0 and 50 mm. Winter precipitation across Iran as a whole was 25% below normal and 14% less than in 2006.

Springtime temperatures of up to 2°C above the long-term average were observed over most parts of Iran. The range of spring temperatures varied from 10°C in the northwest to 35°C in the southeast. Precipitation was above normal during spring 2007. Precipitation totals across the southeast (Sistan and Baluchestan Province) were 200% above the long-term mean (Fig. 6.36), primarily due to the impacts of Cyclone Gonu (see below), which first made landfall in Oman and caused severe damage there. Overall, wetter-than-average conditions prevailed over a majority of the country. The Hormozgan Province and some smaller areas received 50%–100% of normal rainfall totals. From a seasonal perspective, the amount of precipitation over Iran was 34% higher than normal.

Summer was cooler than average across much of Iran (up to 2°C below normal), although intraseasonal temperature variability was quite high. During typical summers, the southwest, northeast, and parts of

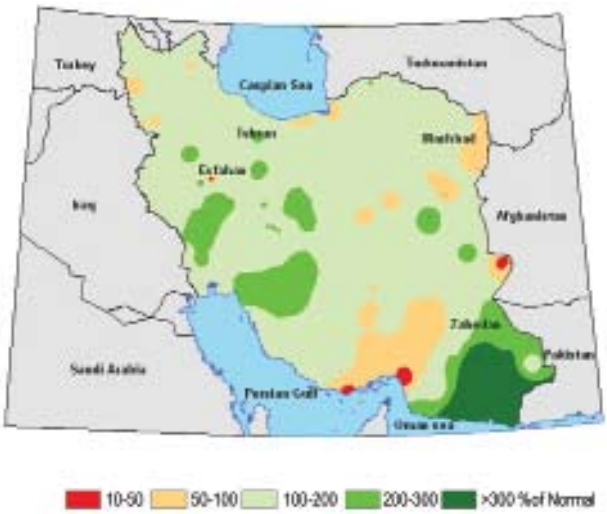


**Fig. 6.36. Spring precipitation anomaly (percentage of normal) for Iran. [Source: IRIMO.]**

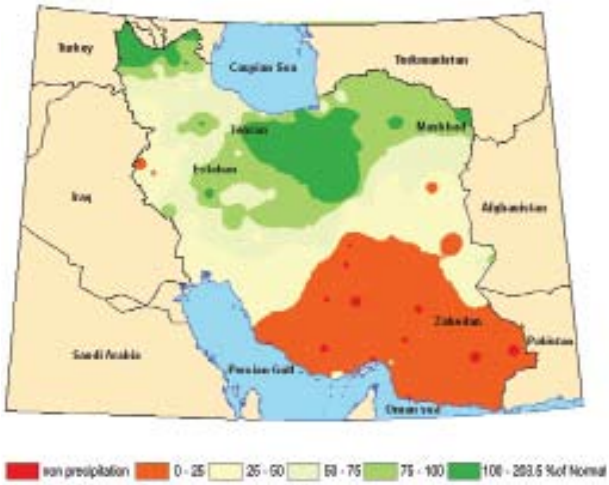


**Fig. 6.37. Autumn precipitation anomaly (percentage of normal) for Iran. [Source: IRIMO.]**

the south receive limited rainfall. In 2007, however, the Sistan and Baluchestan Province (which experienced drought conditions in association with dust and sand storms in recent summers) received 2 to 3 times their long-term average summer precipitation. Area-averaged precipitation over Iran was above normal in the summer of 2007, 83% higher than the long-term mean and the 2006 summer.

In autumn, warmer-than-average conditions persisted across most of the country; cooler-than-average conditions were limited to the east and northeast of the country. Autumn area-averaged precipitation was 39 mm, 43% less than normal and 52% less than autumn 2006. The southeast and southern regions received very little rainfall. Only parts of northern Iran received near-or above-normal rainfall in autumn (Fig. 6.37).

### (c) Rainfall Impact of Gonu on Iran

Super Cyclonic Storm Gonu dropped heavy rainfall in early June near the eastern coastline of Iran, causing flooding and heavy damage. Chabahar, Jask, and other stations in Sistan and Baluchestan Province and Hormozgan Province normally receive less than 200 mm annually; rainfall associated with Gonu on 7 June alone brought as much as 60–120 mm to these areas (see Table 6.2). In the aftermath of this very atypical rain event, the southeastern part of Sistan and Baluchestan Province experienced severe problems associated with transportation, telecommunications, and access to drinking water.

Table 6.2. Total precipitation caused by Gonu for several Iranian stations (from Torbali et al. 2007).

| Province | Station | Precipitation (mm) |
|---|---|---|
| Sistan and Baluchestan | Chanbahr | >160 |
| Hormozgan | Jask | >160 |
| Hormozgan | Bashgerd | >100 |
| Hormozgan | BandarAbas | >11 |
| Hormozgan | Minab and Roudan | >15 |
| Kerman | Kerman | >50 |

### (ii) Turkey—S. Sensoy

The annual surface temperature anomaly averaged over Turkey in 2007 was 0.92°C above the 1961–90 average. Only one station (Bingol in the eastern part of Turkey) had an annual temperature anomaly of less than –2.3°C. Generally the western three-fourths of the country had annual temperatures above the mean while the eastern parts were near average (Fig. 6.38). This continued a trend of positive temperature anomalies that have been reported since 1994 (except 1997). Temperatures in April and December were below average, while temperatures were above average in all other months. Significant positive temperature (maximum, minimum, and mean) anomalies ($p \leq 0.05$) occurred between May and October. Recent studies show that the number of summer days (defined as $T$max≥25°C) and tropical nights ($T$min≥20°C) have been increasing all over Turkey while cool nights ($T$min<10th percentile) and cool days ($T$max<10th percentile) have been decreasing (Sensoy et al. 2007; Zhang et al. 2005).

Due to Turkey's topography, rain clouds seldom penetrate the country's interior. Rain clouds deposit most of their water on the slopes facing the sea. For this reason, central Anatolia does not receive very much precipitation. While Rize receives 2,200-mm precipitation annually, Konya receives only 320 mm

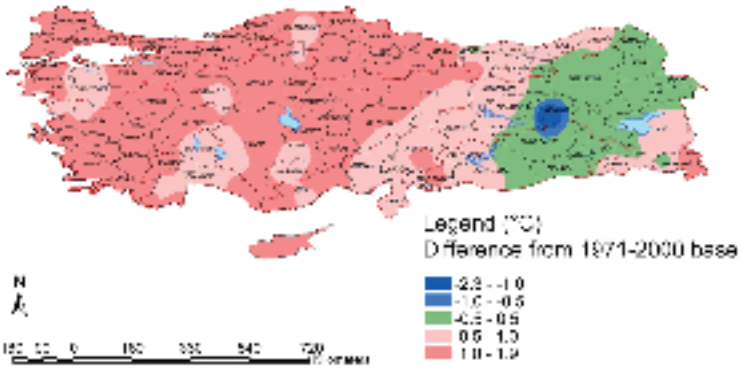


**Fig. 6.38. Annual temperature anomalies (°C; 1971–2000 base period) for Turkey in 2007.**

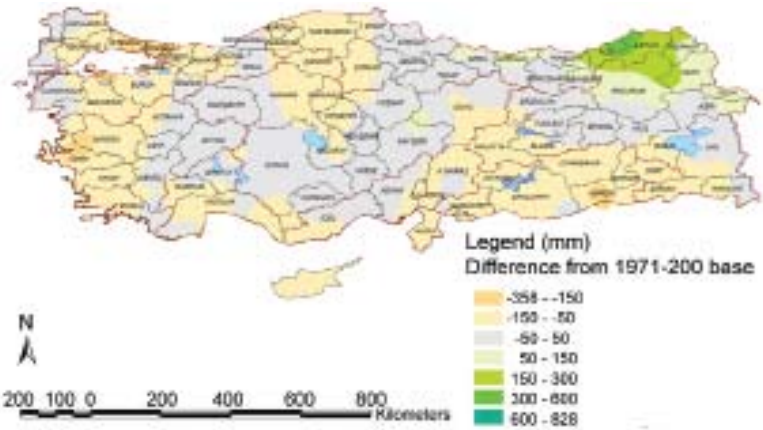


**Fig. 6.39. Annual precipitation anomalies (mm; 1971–2000 base period) for Turkey in 2007.**

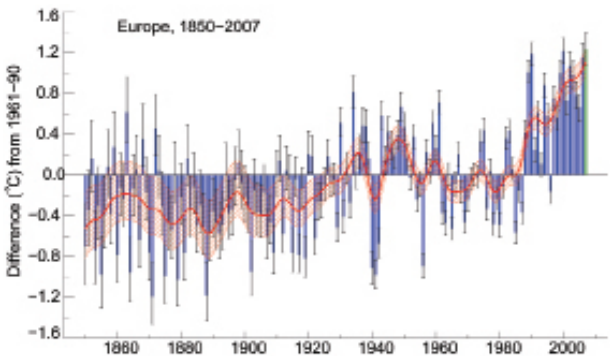


**Fig. 6.40. Annual average land surface air temperature anomaly for Europe (35°–75°N, 10°W–30°E). The blue bars show the annual average values and the black error bars indicate the 95% confidence range of the uncertainties. The green bar is the annual value for 2007. The smooth red line shows the annual values after smoothing with a 21-point binomial filter. The hatched red area indicates the 95% confidence range on the smoothed values. Data are taken from the HadCRUT3 dataset (Brohan et al. 2006).**

(Arguez et al. 2007; Sensoy 2004). The average annual total precipitation for Turkey is 647.6 mm according to 1961–90 base period. The average total precipitation in 2007 was 618 mm, which was slightly below average. Only northeastern parts of the country (Ordu, Giresun, Rize, Artvin, Erzurum, Kars, Ardahan, and Iğdır) had precipitation surpluses. Western, southern, and north-central regions of Turkey suffered prolonged drought conditions during 2007 (Fig. 6.39). Approximately 60 stations out of 130 across Turkey received below-normal precipitation in 2007, while 20 were above average and about 50 stations were near normal.

## g. Europe

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

Warmer-than-average conditions covered most of Europe, including the European Arctic, the North Atlantic, and the Middle East, in 2007. Surface air temperature anomalies were 1°–2°C above the 1961–90 average over most of the continent (Figs. 6.40 and 6.41). In the North Atlantic, the warmth was coincident with the continuing warm phase of the Atlantic multidecadal oscillation, which began in the mid-1990s. The annual average land surface temperature derived from the CRUTEM3 dataset (Brohan et al. 2006) was +1.23 ± 0.08°C for the European region between 35°–75°N and 10°W–30°E (Fig. 6.40) and is virtually certain to be one of the five

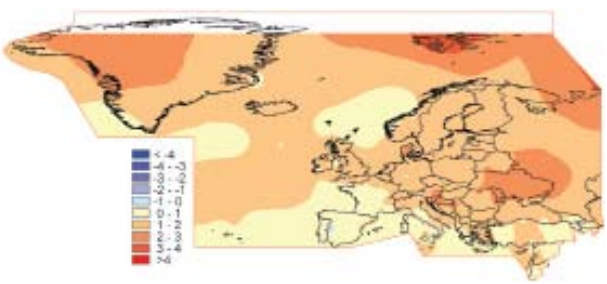

**Fig. 6.41. Annual mean temperature anomalies in Europe and over the North Atlantic, 2007 (°C, relative to the 1961–90 average) based on CLIMAT and ship observations. [Source: Deutscher Wetterdienst (DWD).]**

warmest years in the 1850–2007 series. The year 2007 was the warmest year on record in the Netherlands, Belgium, the Czech Republic, Denmark, and several countries in eastern and southeastern Europe.

Total precipitation for the year 2007 (Fig 6.42a; Rudolf et al. 2005) was below average in most of Mediterranean Europe. Northwest Italy, the south of France, and parts of Spain received locally less than 60% of the 1961–90 average. Near- or slightly above-average rainfall occurred throughout much of the rest of Europe. Exceptions included central parts of Sweden and Norway, western coastal areas of

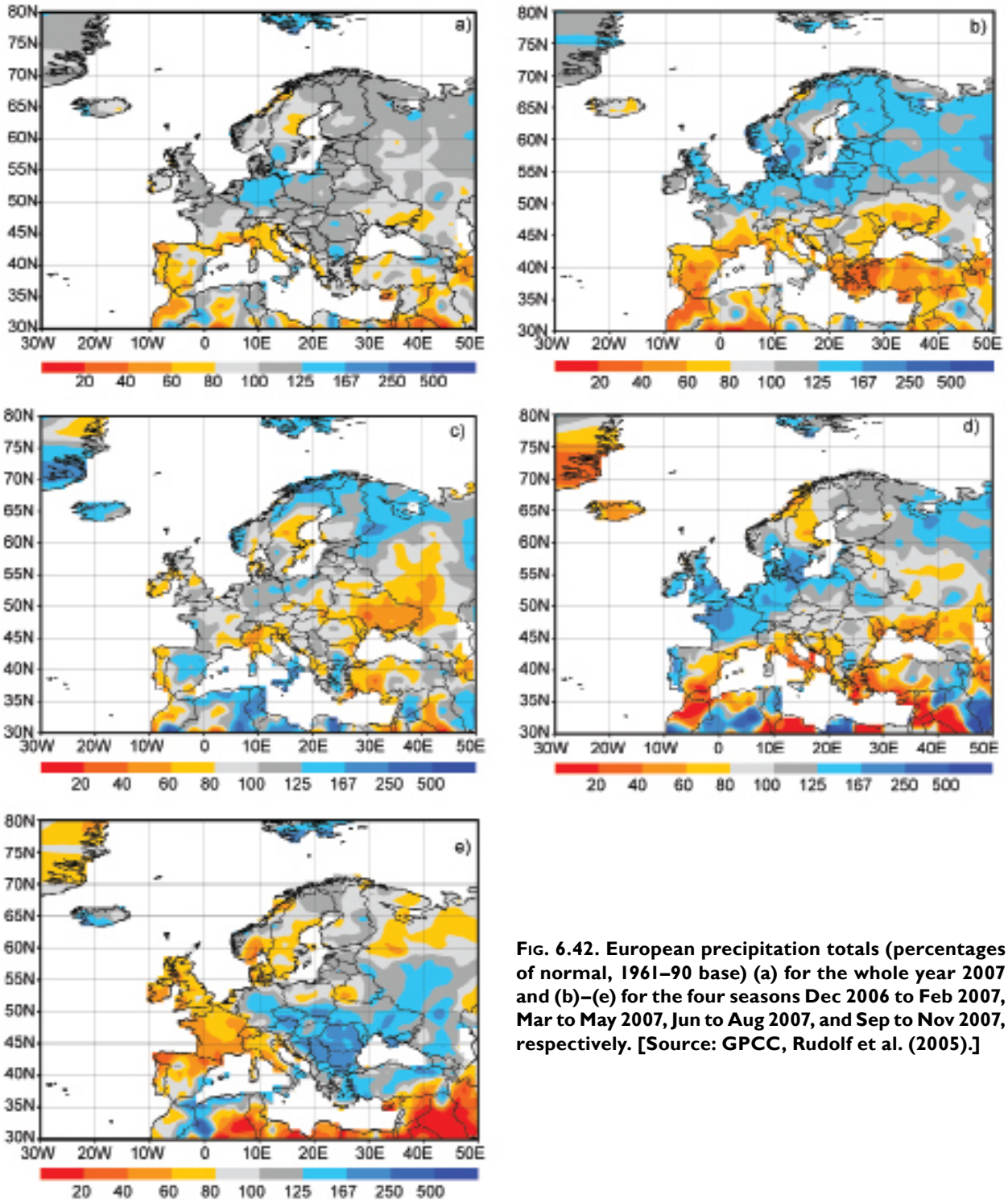


**Fig. 6.42. European precipitation totals (percentages of normal, 1961–90 base) (a) for the whole year 2007 and (b)–(e) for the four seasons Dec 2006 to Feb 2007, Mar to May 2007, Jun to Aug 2007, and Sep to Nov 2007, respectively. [Source: GPCC, Rudolf et al. (2005).]**

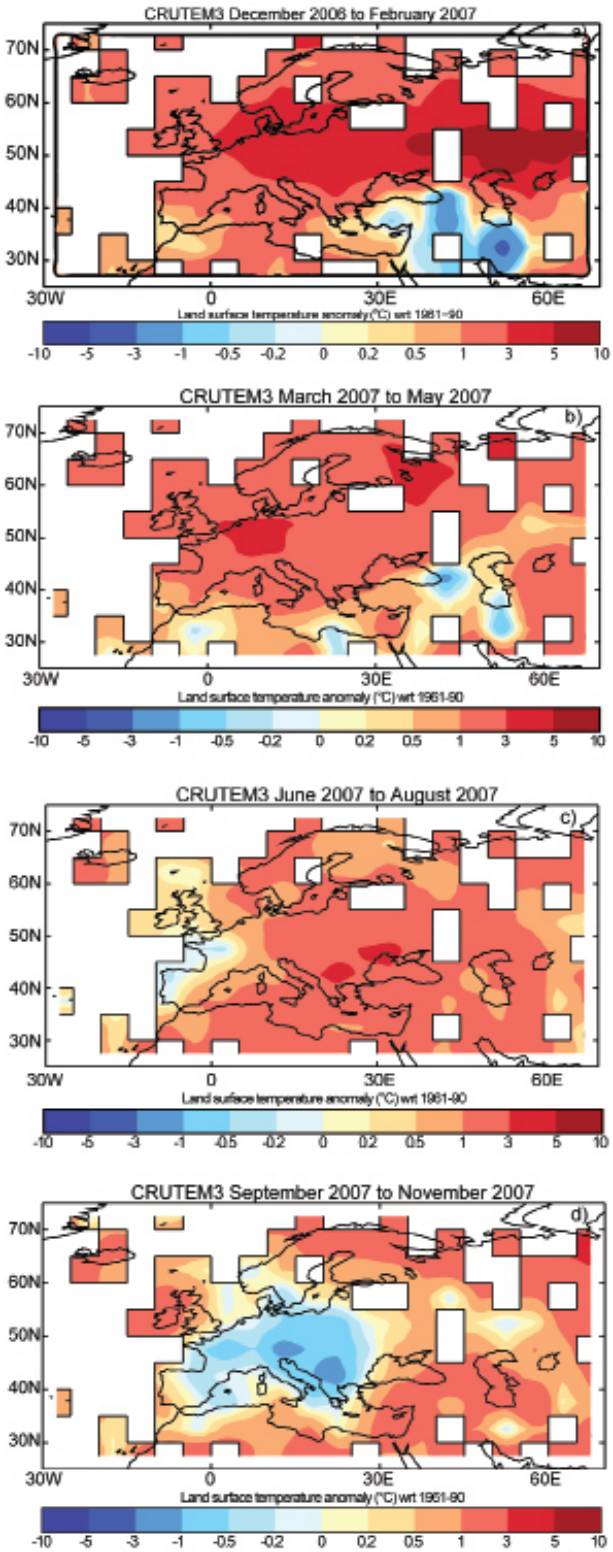


**Fig. 6.43. European land surface air temperature anomalies (°C; relative to 1961–90) from the CRUTEM3 dataset (Brohan et al. 2006) for (a) Dec 2006 to Feb 2007, (b) Mar to May 2007, (c) Jun to Aug 2007, and (d) Sep to Nov 2007.**

Scotland and Ireland, and some parts of southeastern Europe and the Middle East, where precipitation totals were less than 80% of the average. The highest rainfall anomalies, exceeding 125% of the long-term mean, occurred in northern areas of central Europe, southern Scandinavia, Svalbard, and a few locations in eastern Europe (Fig. 6.42a).

The beginning of 2007 was extraordinarily mild throughout Europe, leading to an early start to the growing season. Several countries experienced their mildest winter (December 2006–February 2007) on record. The winter in central and eastern Europe was unusually warm with anomalies exceeding +3°C (Fig. 6.43a). A recent study (Luterbacher et al. 2007) indicated that the winter of 2006–07 was extremely likely the warmest for more than 500 yr. In January, temperature anomalies reached more than +11°C in far eastern Europe. During the winter season, the 500-hPa height pattern featured positive anomalies (relative to 1971–2000) over southern Europe and negative anomalies over Fennoscandia (Fig. 6.44). This pattern was associated with an almost constant westerly flow that advected mild, marine air from the Atlantic Ocean into Europe. This contributed to exceptionally high surface temperatures in central and eastern Europe and positive rainfall anomalies throughout northern areas of the continent, while

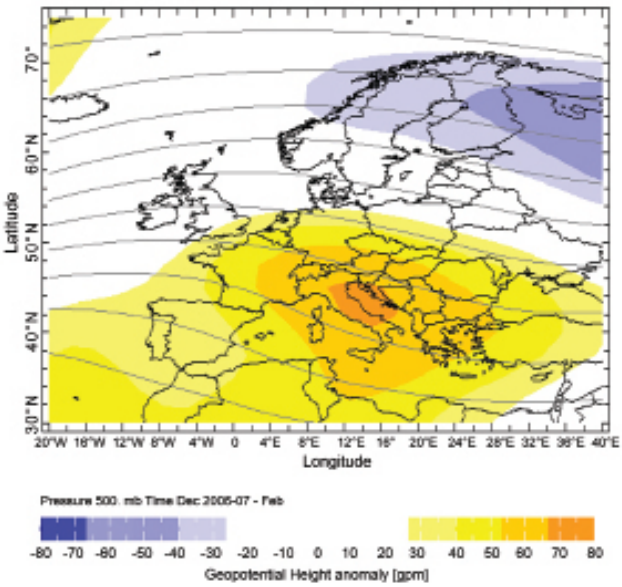


**Fig. 6.44. Winter 2006–07 500-hPa geopotential height, seasonal averages (gray contours, contour interval 60 gpm) and anomalies (color-shaded areas, relative to 1971–2000, legend below). Based on NCEP reanalysis data. [Source: IRI Data Library, http://iridl.ldeo.columbia.edu/maproom/.Global/.Atm_Circulation/Seasonal_Height.html.]**

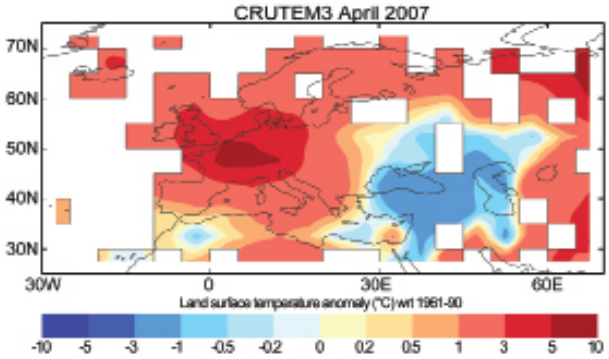


**Fig. 6.45. European land surface air temperature anomalies (°C; relative to 1961–90) for Apr 2007 from the CRUTEM3 dataset (Brohan et al. 2006).**

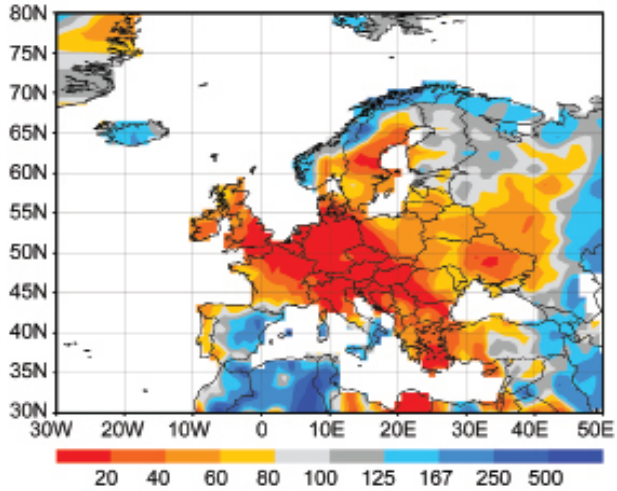


**Fig. 6.46. European precipitation anomalies (percentages of normal, 1961–90 base) in Apr 2007. [Source: GPCC, Rudolf et al. (2005).]**

southern Europe had a drier-than-average winter (Fig 6.42b). This was consistent with a strong positive phase of the winter NAO (+1.83) for the period December 2006 to March 2007 [based on pressures at Gibraltar and Stykkisholmur (Iceland); Jones et al. 1997]. Other contributing factors included significantly increased cloud cover during winter months and unusually warm SSTs in the North Sea, which developed as a result of the exceptional warmth of summer and autumn 2006. The estimated return period of the extremely high winter temperatures exceeded 100 yr in a large part of Europe.

Temperatures in spring also ranked among the highest ever recorded in several European countries (Fig. 6.43b). Temperature anomalies were unusually high in March (>7°C) with the largest departures over eastern Europe and in Svalbard. April was particularly warm in western and central Europe (>5°C, Fig. 6.45). It was the warmest April on record in some of these areas and many new records of daily mean temperatures were set. In contrast, April was colder than average in southeastern Europe and the Middle East. May was warmer than normal nearly everywhere in Europe, but the anomalies did not exceed +4°C. Spring was drier than average (Fig. 6.42c), and many countries in Europe had their driest April on record (Fig. 6.46), followed by an extremely wet May for all but eastern Europe.

In summer 2007, the jet stream was farther south than normal and low pressure systems were directed to central and southern areas of the United Kingdom, leading to heavy rainfall and severe flooding (Fig. 6.42d) as well as cooler-than-average temperatures (Fig. 6.43c) in much of northwestern Europe. In contrast, southeastern Europe was affected by two severe heat waves in the last weeks of June and July (Fig. 6.47) due to the stronger influence of warm, dry air masses from Africa. Several countries in this part of Europe had their warmest summer since records began, with many new records of daily maximum temperatures exceeding 40°C.

Despite record high SSTs in the North Atlantic, large parts of central Europe were colder than normal in autumn 2007 (September–November; Fig. 6.43d). In contrast, positive mean temperature anomalies in autumn were recorded across the United Kingdom, the southeast, and far northern Scandinavia. Precipitation totals above the long-term mean occurred in southeastern Europe, while western and northern Europe experienced drier-than-normal conditions (Fig. 6.42e). The year ended with a very mild December (anomalies up to +4°C) in the northern half of Europe and colder-than-normal temperatures in

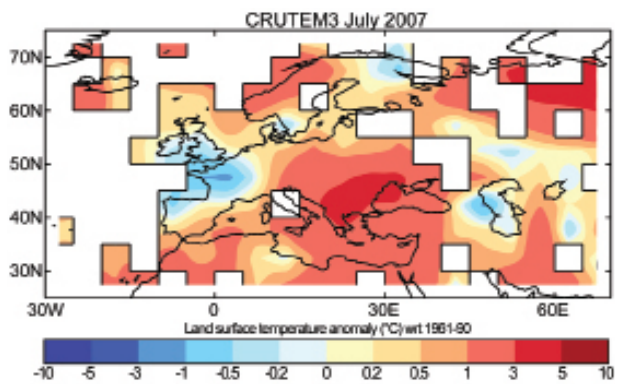


**Fig. 6.47. European land surface air temperature anomalies (°C; relative to 1961–90) for Jul 2007 from the CRUTEM3 dataset (Brohan et al. 2006).**

the southern half. December precipitation in Europe was mostly below or close to normal.

2) Central and western Europe—A. Obregón, P. Bissolli, J. J. Kennedy, D. E. Parker, S. Bader, M. Beswick, D. Buchel, M. Croci-Maspoli, H. Derka, F. Grooters, J. Hardwick, P. Hechler, E. Hotanova, P. Lennon, G. Müller-Westermeier, M. Perry, J. Prior, O. Svabik, F. Vinit, and J. Zimmer

(i) Temperature

The largest annual 2007 temperature anomalies occurred in Belgium (+2.0°C). The year 2007 was the warmest on record in the Netherlands, Belgium, Luxembourg, eastern Austria, the Czech Republic, and parts of Ireland. The United Kingdom and Germany had their second warmest year on record, and it was also one of the warmest years on record in Austria and the fourth warmest year in Switzerland. However, while the first half of 2007 was exceptionally warmer than normal in all western and central European countries, the last six months were close to or slightly below normal, except in northwestern Europe.

Winter and spring were record-breaking seasons in nearly all central and western European countries, with exceptional warmth in January and April (Fig. 6.45). The winter of 2006–07 was the warmest on record in most of central Europe and the second warmest in the United Kingdom. In the De Bilt, Netherlands, series that begins in 1706, January 2007 was the warmest ever with an average temperature of 6.6°C (3.3°C above average). It was also the warmest January on record in Germany (4.6°C above average), Luxemburg, France, the Alpine region, and the Low Countries. The mean January temperature in Belgium was 7.2°C (+5°C), and monthly anomalies in Austria exceeded +6°C in the east. On the night of 18–19 January, temperatures rose to 20°C in eastern Austria; conditions that are more typical of summer. It was the second warmest January in the United Kingdom as a whole since 1914. February was generally mild but a short period of very cold weather affected northwestern Europe on 5–8 February.

Spring 2007 was the warmest on record in Germany, Switzerland, the Netherlands, Belgium, and France. April was particularly warm with many new temperature and sunshine records established throughout the region. In Germany, which had more than twice the average number of sunshine hours, the monthly mean temperature in April was 11.6°C (+4.2°C). Monthly anomalies of +5.5°C were widespread in Switzerland with larger values (+7.5°C) at higher elevations. In Belgium, the April temperature was 5.8°C above the 1961–90 average of 8.5°C, exceeding the previous record set in 1987 by more than 2°C. The highest anomalies in France, southern England and parts of eastern Scotland were also greater than +5°C. April was also the warmest April in the 349-yr CET (Parker et al. 1992) series (11.2°C, 3.3°C above average).

Most areas in western and central Europe recorded their first negative monthly temperature anomalies of 2007 in July. In contrast, a heat wave affected much of southeast central Europe in mid-July and new daily maximum temperature records were established in many stations in Austria.

(ii) Precipitation

Precipitation totals in 2007 were generally close to or above average in most of central and western Europe (Fig. 6.42a), but southeastern parts of Switzerland received about 75% of normal precipitation and the year 2007 was one of the 10 driest years in Lugano, Switzerland, where regular measurements started in 1864.

January was very wet in north-central Europe and in southwestern and northwestern Austria (up to more than 250% of the normal). A short, but intense, snow storm affected central and western Europe on 22–24 January. Snow depths of 20–30 cm were registered even in the lowlands of southern Germany and France. Another period of heavy snowfall occurred on 19–24 March in the Alpine region due to the formation of a strong low over northern Italy. Fifty centimeters of snow fell within a few hours in southern Austria. More snow fell in this short period in large parts of Austria than in the whole of the preceding winter. Parts of northern Switzerland had almost 30 cm of snow on 22–23 March, while some areas of the northern Alps received 1 m.

April was exceptionally dry throughout the region (Fig. 6.46) due to a blocking high over western Europe. In the England–Wales precipitation series (1766–2007, Alexander and Jones 2001), only 10 mm of rain (15% of the 1961–90 normal) was recorded, the lowest since 1938. Many stations over southeastern England and East Anglia received less than 3 mm (5%–6% of the normal). Some eastern areas of Ireland also had April totals of less than 10 mm. In the Netherlands, little or no precipitation fell during the period from 22 March to 6 May, which was the driest in at least 100 yr. In Uccle, Belgium, no rainfall occurred during the 36 days from 31 March to 5 May. It was the longest period without rainfall on the whole record (for all seasons) since 1833. Only 2 mm of precipitation fell in the city of Luxemburg during the month of April. Germany experienced its driest April since records began in 1901 with a country-wide average

of 4 mm (7% of the 1961–90 normal). In Austria and Switzerland, monthly precipitation amounts were generally below 30% of the normal with some areas receiving no rainfall.

In stark contrast, May 2007 was the wettest May on record in Germany since measurements began in 1901 (126 mm; 177% of average). In northern France, 200% of normal monthly precipitation fell in many places during summer, and Zurich, Switzerland, had its fourth wettest summer since measurements began in 1864. In England and Wales the May–July period was the wettest (406 mm) since records began in 1766, breaking the previous record of 349 mm set in 1789. In June and July (Fig. 6.48) many parts of the United Kingdom were affected by severe flooding. Some stations in northeast England reported totals exceeding 500% of the June average, and the south Midlands and Wales had 300%–400% of the July average. In Ireland, Kilkenny and Dublin Casement Aerodrome had their wettest summer since rainfall records began in 1957 and 1954, respectively. July 2007 was the second wettest July (behind 1942) in the Netherlands since records began in 1906 (155 mm; 200% of normal). Switzerland and Austria experienced unusually heavy thunderstorms in summer with hailstones of up to tennis ball size.

Heavy rains from 5 to 7 September in Austria along the main ridge of the Alps caused flooding. Rainfall rates of up to 245 mm in 72 h were recorded. Autumn precipitation totals exceeded 200% of normal in eastern Austria. The beginning of winter 2007/08 brought early snow cover to the Alps. During November, Switzerland experienced its heaviest snowfall in more than 50 yr. In Davos, 62 cm of snow fell in 24 h, setting a new record.

### (iii) Notable events

Winter storm "Kyrill" hit the Irish and British coasts on 17 January, then made landfall on the coasts of Germany and the Netherlands on 18 January and moved toward Poland and the Baltic Sea (also affecting the Czech Republic along the way). Precipitation amounts of 80–90 mm fell on the Harz Mountains in Germany. A gust of 56 m $s^{-1}$ was recorded at Wendelstein (southern Germany), and gusts of more than 38 m $s^{-1}$ occurred in the lowlands. A rare winter tornado was observed in Wittenberg, Germany, near the cold front. The United Kingdom had its strongest measured winds since 1990. In Ireland, a gust of 41 m $s^{-1}$ was measured at Dublin Airport on 18 January, the highest at the station since it opened in 1941.

On 8–9 November, a heavy winter storm caused a storm surge in the North Sea. The coastlines of the

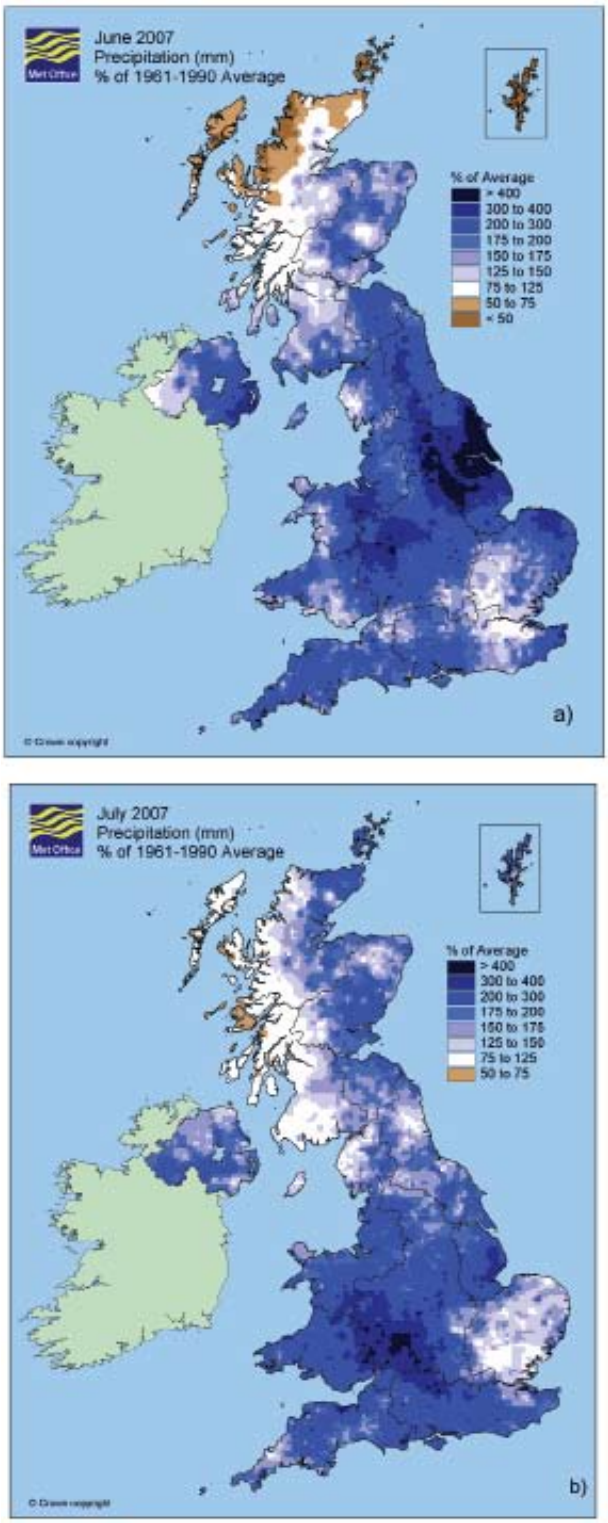


**Fig. 6.48. Precipitation anomalies (percentages of normal, 1961–90 base) in the United Kingdom during Jun and Jul 2007. [Source: Met Office.]**

United Kingdom, the Netherlands, Belgium, and Germany were most affected. Damage was relatively minor because the flooding did not coincide with high tide. However, at the East Anglian coast, the storm surge was one of the highest since 1953.

On 9 December, just after midnight, a slow-moving depression (966-hPa central pressure) brought stormy conditions and an exceptionally high wave of over 17 m to the west coast of Ireland. It was the highest wave ever measured by the Irish buoy network.

### 3) The Nordic countries—C. Achberger, D. Chen, J. Cappelen, S. Hellström, K. A. Iden, M. Jonsson, and S. Saku

#### (i) Temperature

Annual temperatures over the Nordic region (Sweden, Norway, Denmark, Finland, and Iceland) were above the 1961–90 long-term mean in 2007 (Fig. 6.41). Denmark had its warmest and sunniest year on record, 1.8°C above the 1961–90 mean and 0.1°C above the 2006 annual mean. Since 1870, Danish temperatures (low-pass filtered) have increased by 1.5°C. In addition, the number of sunshine hours (low-pass filtered) in Denmark has increased considerably since 1980. Annual mean temperatures in Sweden exceeded the long-term mean by 1.5°–2°C, making 2007 the seventh warmest year. In Norway the annual temperature was 1.3°C above normal, making 2007 the 10th warmest year since 1900. Furthermore, on the Svalbard Archipelago, annual mean temperatures were an extremely high –2.5°C, which is 4.2°C above normal. Finland reported annual mean temperatures ranging from 1.0°–1.6°C above the 1971–90 long-term mean, with the strongest positive anomalies in northern areas of the country. For Iceland, the spell of warm years dominating its climate since the turn of the century continued in 2007.

The positive annual temperature deviations over the Nordic region are to a considerable extent explained by the mild winter December 2006 to February 2007 (Fig. 6.43a). Around Svalbard, winter temperatures were 9°–10°C above normal. For the Scandinavian countries, winter temperature anomalies ranged between 1° and 4°C, with the highest anomalies over southern Sweden and Denmark. These anomalies followed the extremely warm autumn of 2006. On the Swedish west coast, the first frost of the season was reported as late as 22 January, which is the latest date for a first frost ever reported by a Swedish station. Furthermore, the Finnish winter was characterized by a mild January (2°–3°C above normal). Although February was generally colder than normal in Finland, spring started at the beginning of March, about one month earlier than usual. Spring was generally warm throughout the Nordic region (Fig. 6.43b). Due to the mild winter conditions, the Baltic Sea ice season started very late (Vainio et al. 2008). Only near the end of January did ice begin to form in all sea areas. The largest ice extent was reached on 23 February, and two months later the Baltic Sea was ice free.

On average, summer temperatures over the Nordic region were 0.5°–2.0°C above the long-term mean in 2007 (Fig. 6.43c). In Denmark and Sweden, summer started with a very warm and sunny spell in the first half of June, but the rest of the summer was dominated by unsettled weather. Summer temperatures in Norway were 1°C above normal, making summer 2007 the 19th warmest since 1900. Large positive deviations from the long-term mean occurred locally in the northernmost part of the Nordic region. At the airport of Svalbard, the summer mean temperature was more than 2°C higher than normal and resulted in the warmest summer since the start of measurements in 1912. In many parts of Finland, the spring season was unusually warm (mean spring temperature ranked as the fifth warmest since 1900), while unsettled weather dominated the Finnish summer. Still, mean summer temperatures were 0.5°–1.5°C above normal there, mainly due to unusually high temperatures in early August.

December 2007 was the warmest December in more than 70 yr locally in the northernmost parts of Norway and Sweden. An extensive high over southern Scandinavia maintained strong and persistent westerly winds that transported warm and humid air masses into northern Fennoscandia.

#### (ii) Precipitation

On average, annual precipitation over the Nordic region in 2007 was close to or slightly above normal, but large deviations from the long-term mean occurred in some regions and seasons, especially during the summer (Fig. 6.42d). In Iceland, an extended period of warm and dry weather in June and July caused local water shortages and the southeastern region of the country had its driest summer since 1873. This unusual dry spell was followed by an exceptional wet period beginning in the second half of August. The rest of the year was the wettest ever registered in southern and western Iceland. Annual precipitation in Denmark was 155 mm above the normal amount of 712 mm. Much of the annual surplus was due to an extraordinarily wet summer, which ranked third since 1874. Station records in Denmark show that annual precipitation (low-pass filtered) has increased approximately 100 mm since measurements started in 1870.

Annual precipitation for Sweden as a whole was not exceptional, but large regional deviations from the long-term mean occurred. In southern Sweden, several stations reported the rainiest summer since records began, and some records for monthly and annual precipitation were broken. Norwegian annual precipitation was about 15% above normal, making 2007 the fifth wettest year since 1900. Considerable positive deviations occurred in the southern part of Norway's west coast where annual precipitation in 2007 exceeded the long-term mean by 25%–50%. However, central parts of the west coast had less than 80% of normal rainfall in 2007 (Fig. 6.42a). In contrast to Sweden and Denmark, the wettest seasons (relative to normals) in Norway were winter and spring with seasonal precipitation amounts 40%–50% above the normal value. Annual precipitation amounts in Finland were close to or slightly above normal. However, large regional precipitation deviations occurred during the summer season when the southeastern part of the country received 383 mm, 50% more than usual. Due to higher-than-normal winter temperatures, only the northern and eastern parts of Finland had persistent snow cover.

(iii) Atmospheric circulation

Large-scale atmospheric circulation over northern Europe and the North Atlantic control the regional temperature and precipitation patterns. Using Lamb's (1950) synoptic weather typing, the impact of the large-scale atmospheric circulation on the surface weather conditions in this region has been estimated (e.g., Chen 2000). In 2007, the annual frequencies of C days, days with mixed directional and cyclonic flow conditions (CNW, CW, and CE), and W and NW days were higher than the 1961–90 mean. These conditions contributed to the warmer-than-normal conditions in 2007, especially in winter when the frequency of A days, often associated with cold weather conditions, were about 40% lower than normal. In the summer season, C days as well as days with mixed directional and cyclonic flow conditions occurred more frequently at the expense of A days. The seasonal flow conditions were thus consistent with the warmer weather in winter and wetter conditions prevailing in summer in extended parts of Fennoscandia.

(iv) Notable events

On 14 January a severe winter storm named "Per" brought unusually strong winds to coastal areas of Sweden and Norway. In late August, the eastern coast of Sweden was hit by a storm with winds as high as 35 m $s^{-1}$ at the station of Örskär. The storm was the first in August in Swedish coastal areas since 1975. Kiruna, the northernmost city of Sweden, reported a snow depth of 2 cm on 30 August, the first measurable snow depth in August at any Swedish station since 1994. December was very stormy in Iceland, causing interrupted air and land communication on several occasions.

4) Iberia—R. M. Trigo, C. C. Gouveia, R. García-Herrera, A. Obregón, P. Bissolli, J. J. Kennedy, D. E. Parker, and O. Pires

(i) Temperature

On the Iberian Peninsula, warmer-than-average seasonal temperatures occurred in winter (+0.75°C), spring (+0.63°C), and fall (+0.19°C). Only the summer season was cooler than average, –0.19°C below the 1971–2000 mean. For the year as a whole the eastern half of Iberia was generally warmer than average while the western half was near average. The annual temperature averaged over the Spanish mainland and the Balearic Islands was 0.4°C above the 1971–2000 mean. The annual temperature was also above average for Portugal (0.2°C above the 1961–90 mean).

February was a particularly warm month throughout Iberia, ranking as the fourth warmest in Spain. During spring, slight negative anomalies in the 500-hPa geopotential height over northern Africa (not shown) reflected the passage of several low pressure systems that induced relatively high precipitation values over Spain and northern Africa in spring (Fig. 6.49, upper right). Summer was characterized by colder-than-normal temperatures and negative 500-hPa geopotential height anomalies in northern Iberia and adjacent Atlantic areas. These anomalies were associated with summer storms that affected the western and northern sectors of Iberia, particularly in July and August. By contrast, positive 500-hPa geopotential height anomalies were present over the Atlantic region in autumn with a large region of maximum values (above 100 gpm) located west of the British Islands. This pattern contributed to a highly asymmetric 850-hPa temperature anomaly field over Iberia. While the western sector was considerably warmer than normal, the eastern provinces were under the influence of cold air advection.

(ii) Precipitation

Drier-than-average conditions affected the Iberian Peninsula during the 2006–07 winter (DJF), with most of the central, southern, and eastern sectors of Iberia receiving less than 60% of 1961–90 average precipitation (Fig. 6.49, upper left). The winter dryness was consistent with positive SLP anomalies over southwestern Europe and northern Africa, a

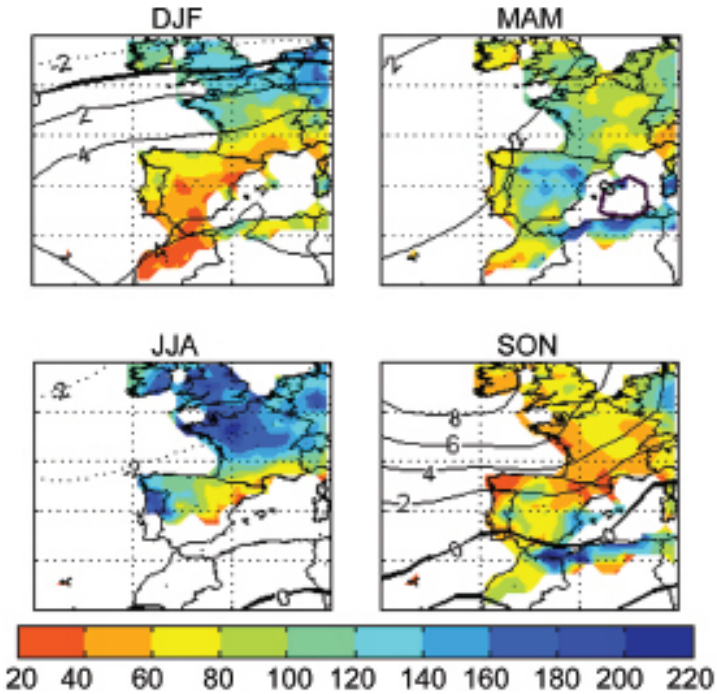


**Fig. 6.49. Seasonal anomalies of sea level pressure (contour, hPa) using data from NCAR–NCEP reanalyses. The colored shading represents percentage of accumulated seasonal precipitation compared with climatology using the monthly GPCC precipitation dataset. All climatological averages are computed for the 1961–90 period. Only areas with seasonal rainfall normals above 30 mm are shown. Negative anomalies are dotted while the zero line is bold.**

feature that has been shown to limit the progression of Atlantic low pressure systems into southern Europe (Garcia-Herrera et al. 2007). Precipitation was generally above average across Spain and below average in Portugal during spring (Fig. 6.49, upper right). During summer, precipitation totals were above (below) normal in western (eastern) Iberia (Fig. 6.49, lower left). Positive SLP anomalies were predominant during autumn over western Europe, promoting widespread dry conditions over southwestern Europe, with several sectors of northwestern and northeastern Iberia receiving less than 40% of the seasonal average (Fig. 6.49, lower right). December was extraordinarily dry in the northwest with precipitation in most of Portugal and adjacent Spanish regions below the 10th percentile of the 1961–90 distribution. Most of Portugal and also parts of Spain received less than 20% of the normal precipitation.

Summer is a climatologically dry time of year on the Iberian Peninsula. Despite a wetter-than-average summer in western Iberia, the absolute precipitation totals were relatively low. By contrast, the spring and fall seasons are climatologically wetter seasons, and they are the wettest seasons of the year in northern and eastern sectors of Iberia (Trigo and Palutikof 2001). With an anomalously dry winter, spring, and autumn, Iberia received only 75% of annual average rainfall leading to moderate-to-severe drought in several highly populated coastal regions. This was the case for western Iberia, including Portugal and Galicia (Espirito-Santo et al. 2008), as well as Spain's northeastern province of Catalonia. Vigo received only 1038 mm of rainfall (54.4% of the 1971–2000 average), which is the lowest since observations began in 1951. Santiago de Compostela received 58.7% of the annual average precipitation, ranking 2007 as the third driest year since 1944. Overall, Spain received only 80% of the 1971–2000 mean rainfall in 2007. In Portugal, many parts of the country received rainfall amounts below 80%, and for the country as a whole it was the second driest year (behind 2005) since 1931.

(iii) Notable events

On 28 January a rare snowfall occurred in coastal and low altitude regions of Portugal for the second consecutive year. On 21 September, Andalucía (southern Spain) was hit by thunderstorms with severe hail and rainfall producing floods and crop damage. The region around Valencia was also affected by torrential rainfall on 11–12 October. Two-day precipitation totals exceeded 400 mm in the mountainous regions of the Marina Alta Province, more than 50% of the annual average. In Valencia, 170 mm was registered on 11 October alone, making this the second wettest day since records began.

April was exceptionally warm in northern Spain, and in several locations in northeastern parts of the country it was the warmest April on record. A new national record for April daily maximum temperature was set in Oviedo (28.3°C). The month of May was extremely hot for the entire Mediterranean coastal region, with several stations breaking monthly mean temperature (Murcia and Alicante) and monthly maximum temperature records (Valencia, Murcia, Alicante, and Reus). June was also extremely hot throughout the Mediterranean coast and the nearby Balearic Islands, with monthly records broken at several stations in Catalonia and Valencia Provinces. In contrast, for the first time since 1997, there was not a single recorded heat wave (defined as five consecutive

days that exceed the average maximum temperature by 5°C based on the 1961–90 base period) during the summer in Portugal. New records for the lowest mean temperature in November were set in Murcia and Alicante. A new record for the lowest all-time daily minimum temperature in Portugal was set on 18 November in Mirandela (–10.9°C).

### 5) Mediterranean, Eastern, and Southeastern Europe—A. Obregón, P. Bissolli, J. J. Kennedy, D. E. Parker, A. Busuioc, T. Cegnar, T. Colombo, S. Djordjevic, P. Hechler, J. Karkozas, Z. Katusin, M. Kulbida, I. Lukac, and V. Pavan

#### (i) Temperature

Parts of Romania and Bulgaria exceeded the 98th percentile of annual temperature in 2007, and anomalies exceeded +2°C in Ukraine, Moldova, and eastern parts of Romania (Fig. 6.41). The winter was extraordinarily warm in the Baltic States, mainly due to an exceptionally warm January (+6.3°C averaged over Lithuania; +4.6°C in Tallinn, Estonia). Romania, Croatia, and Slovenia had their warmest winters on record. In Romania, it was the warmest January on record with local anomalies up to +9°C. There was a record-breaking warm January in Italy, and farmers were surprised by the early flowering of many species of fruit trees. A record January high maximum temperature of 21.3°C was recorded on 21 January in Bologna, where records began in 1948. This warmth was associated with a strong alpine foehn event during the passage of the storm "Kyrill" over central Europe (see section 6g2 above).

In Slovenia and parts of Croatia spring season anomalies exceeded +3°C making it the warmest spring in many regions. Italy and Slovenia, in common with other areas of Europe, experienced their warmest April ever (Fig. 6.45). During summer, exceptional warmth was widespread, with mean air temperatures exceeding the 90th percentile. In northeast Romania, Moldova, and southern Ukraine, departures from normal reached or exceeded +3°C. Extreme heat waves affected much of southeastern Europe in the last 10 days of June and during mid- to late July with many places registering their highest recorded maximum temperatures (Table 6.3).

The July heat wave contributed to an exceptionally warm month in southeastern Europe (Fig. 6.47). The largest anomalies were in Bulgaria (3.7°C in Sofia). The July average maximum temperature for Italy was 34.7°C, the warmest July in at least 30 yr. In Serbia and adjacent countries, temperatures in July were above the 98th percentile of the 1961–90 distribution.

During a warm spell at the end of August, the daily maximum temperature in Bosnia and Herzegovina (Mostar, 43.1°C) exceeded the temperature record set during the July heat wave. August anomalies between 2° and 3°C occurred in the Baltic States, western parts of Belarus and the Ukraine, and eastern Hungary, and anomalies exceeded +3°C in eastern parts of Belarus and Ukraine. In December, temperature anomalies exceeded +5°C in Vilnius and Tallinn, while in Romania, local monthly anomalies were as low as –4°C.

#### (ii) Precipitation

The northern Balkan Peninsula experienced above-average precipitation in 2007 with the largest anomalies in Romania, Serbia, and Bulgaria (e.g., 148% of average fell in Sofia). In contrast, in the Italian region of Emilia-Romagna (near Bologna), the lowest annual precipitation total since 1925 was recorded, with less than two-thirds of the normal.

Table 6.3. Record temperatures reported in Jun and Jul in southeast Europe.

| Location | Date | Temperature |
|---|---|---|
| Froggia/Amendola, Southern Italy | 25 Jun | 47.0°C |
| Athens, Greece | 26 Jun | 46.2°C |
| Negotin, Serbia | 26 Jun | 41.2°C |
| Kiskunhalas, Hungary | 20 Jul | 41.9°C |
| Hurbanovo, Slovakia | 20 Jul | 40.3°C |
| Slobodzya, Moldova | 21 Jul | 41.9°C |
| Odessa, Ukraine | 23 Jul | 39.3°C |
| Chisinau, Moldova | 23 Jul | 39.4°C |
| Prizren, Kosovo | 24 Jul | 42.0°C |
| Demir Kapija, Macedonia | 24 Jul | 45.7°C |
| Smederevska Palanka, Serbia | 24 Jul | 44.9°C |

Owing to a lack of snow in the Alps and the Apennines and the dry spring, the water level of the Po River reached its lowest level on record on 23 April. It was also a very dry April on the Balkan Peninsula and in Slovenia (Fig. 6.46). In contrast, Sicily had record precipitation during March and was also extraordinarily wet in April and June. Summer brought drought to most of southeastern Europe. There was no rainfall in Athens from July until September. Southern Italy was also affected by severe drought in July and August with water deficits less than 60% of normal. However, the Baltic States had a very wet July, with more than 200% of the average rainfall in Lithuania. Autumn was extraordinarily wet throughout most of the Ukraine, Bulgaria, the Balkan Peninsula, and southern Italy (Fig. 6.42e). Sofia received more than double the average amount of rainfall in every month from August to November.

(iii) Notable events

Intense thunderstorms affected northern Italy in the summer. One west of Bologna on 12 June had a peak rainfall rate of 159 mm $h^{-1}$ and a total accumulation of 59 mm. The extreme heat waves and severe drought in June and July led to massive forest fires across the Balkan Peninsula, Serbia, Croatia, Romania, and Bulgaria. From late June through early September, over 3,000 fires were reported in Greece, causing 79 fatalities and destroying more than 2,700 $km^2$ of forest and farmland.

6) Middle East—A. Obregón, P. Bissolli, J. J. Kennedy, D. E. Parker, M. Demircan, A. Hovsepyan, H. Ozcan, and S. Pashiardis

(i) Temperature

Winter temperature anomalies exceeded +4°C in western Kazakhstan, but minimum temperatures in January in parts of the Ararat Valley (Armenia) reached record lows near –25°C. Temperatures in spring were generally above average, but significant cold conditions occurred in March (below the 10th percentile) in eastern Turkey and northern Syria. Temperatures in Lebanon, Cyprus, and most of Syria exceeded the 90th percentile during the summer months. Heat waves with temperatures above 40°C on 24–29 June and 24–31 July contributed to several large forest fires. September and October was 2.0°–2.5°C warmer than normal in Armenia, owing to two strong heat waves on 4–9 September and 14–17 October.

(ii) Precipitation

Parts of Cyprus and Azerbaijan received less than 50% of average annual rainfall, but 125%–150% of normal precipitation fell in northeastern parts of Turkey. Winter and spring were particularly wet in western Kazakhstan, while Azerbaijan was drier than normal. In May, precipitation in Georgia and Azerbaijan was below the 10th percentile. In summer, parts of Syria, Lebanon, and Cyprus received less than 50% of the normal rainfall, while Armenia was unusually wet, especially in July. Autumn was very dry in Cyprus (below 25%), while November precipitation exceeded the 90th percentile in Georgia. It was also very wet in Armenia, 200%–270% of normal precipitation. A dry December followed with only 20% of the normal precipitation in the lowlands of Armenia and in the Ararat Valley.

(iii) Notable events

A hailstorm with hailstones of 25 mm in diameter affected central Armenia on 7 June. Tornadoes and severe hailstorms also affected Cyprus in March, May, and in the autumn. On 1 July and 5 December, heavy rainfall with flooding occurred in Cyprus.

h. Oceania

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

Large parts of Australia were in the grip of both long- and short-term drought leading into 2007. Early trends away from El Niño conditions in the equatorial Pacific led to an Australian area-average rainfall for 2007 of 497 mm, ranking 30th wettest out of the 108 yr of record. The mean for the 1961–90 standard reference period is 472 mm. However, in line with the trends observed over the past 50 yr, the greatest rainfall totals were in Australia's sparsely inhabited northwest. In the densely populated and major agricultural regions, rainfall was generally average to below average. For much of the agricultural sector, promising autumn rains were countered by a severe short-term drought in the crucial late winter and early spring period, greatly reducing crop and pasture growth.

While most areas were generally not as severely dry as they were during 2006, the recovery was only partial and water resources remained very low in most areas. Water demand was high, driven by warm daytime temperatures. Maximum temperatures were the fifth warmest on record,[6] some +0.7°C above

[6] 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. High-quality nationwide rainfall measurements commenced in 1900 (Lavery et al. 1997). Anomalies are calculated with respect to the 1961–90 average.

the mean, with just over 37% of the continent in the warmest decile. In terms of mean temperatures it was Australia's sixth warmest year since high quality Australia-wide records commenced in 1950, 0.7°C above the 1961–90 mean.

(i) Temperature

Many of the regions that experienced acute dry conditions during the year, including large areas under long-term drought conditions, were also warmer than average during 2007. Maximum temperatures (Fig. 6.50) over much of the southern half of the continent were at least 1.0°C above normal, with large portions of southern Australia more than 1.5°C above the 1961–90 mean. In decile terms, much of southern Australia was in the highest 10% of recorded temperatures (decile 10), with large parts of southern South Australia and virtually all of Victoria warmest on record. This was reflected in the statewide values. Victorian maximum temperatures were the hottest on record, 1.4°C above the 1961–90 mean, and only the second time (after 1914) that the anomaly surpassed +1°C. Southern Australia as a whole was third warmest on record, only fractionally cooler than 2005. The warmest year remains 2002. For Australia as a whole, the average maximum temperature was the fifth warmest on record behind 2005 (warmest), 2001, 1980, and 1991. Maximum temperatures in 2007 averaged 0.7°C above the mean, with just over 37% of the continent in the warmest decile, and 0% in the coolest decile.

Minimum temperatures were generally 0.5°–1.5°C above average for much of southern, and particularly southeastern, Australia, resulting in southern Australia's warmest nights on record (+0.8°C), marginally above the previous record set in 1973. Conditions were up to 1°C below average in some areas of the north; however, when summed over all of northern Australia, minimum temperatures were still, on average, +0.5°C above average. For Australia as a whole, the average minimum temperature was fifth warmest, 0.6°C above the average. Only 2% of the continent experienced temperatures in the bottom three deciles, yet over 60% of the continent was in the top three deciles.

With warmer-than-average days and nights in the southeastern area of the continent, the states of South Australia (+1.1°C), Victoria (+1.2°C) and New South Wales (+1.1°C), as well as the agriculturally vital Murray–Darling Basin (+1.1°C) region, all recorded their warmest annual mean temperatures on record, while Tasmania (+0.8°C) was second warmest.

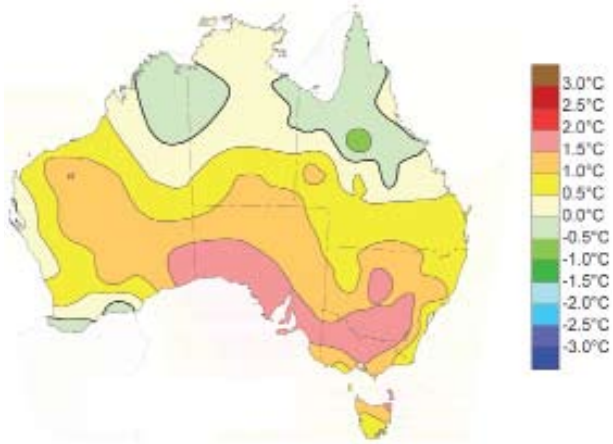


**Fig. 6.50. Australian maximum temperature anomalies (°C; 1961–90 base period) for 2007.**

(ii) Precipitation

In contrast to the previous year, 2007 started with a wetter-than-average month for much of the continent. Rainfall on just two days (21–22 January) in the South Australian towns of Bedourie (206 mm), Boulia (130 mm), and Hawker (176 mm) were greater than the totals they recorded for the entire 2006 calendar year (54, 95, and 156 mm, respectively). Furthermore, wet months in March, May, and for many areas along the east coast and north, June, heightened expectations of a wetter-than-average year.

However, July–September was particularly dry in the eastern half of the continent, and it was not until November, and the final breakdown of cool conditions to Australia's north and the emergence of La Niña in the equatorial Pacific, that rain returned to much of the continent. December rains again brought flooding in some areas of northern inland New South Wales, with 48-h totals approaching 200 mm.

The result of this varying pattern—from very dry to generally wet months—meant that Australia-wide, the year as a whole was not exceptional (Fig. 6.51). Australian rainfall (497 mm) was 30th wettest out of the 108 yr of record, only 25 mm above the normal 472 mm. In total, 43% of the continent experienced rainfall totals above the 66th percentile for the year. In contrast, only 2.3% of the continent was in the lowest 10% of recorded totals for the year, in stark contrast to 2006 when over 18% of the continent experienced similar conditions.

Despite some rain, long-term dry conditions persisted in southeast Queensland, southwest western Australia, and the southeast corner of the continent. For southeastern Australia (including Tasmania) as a whole, the 11-yr period ending October 2007

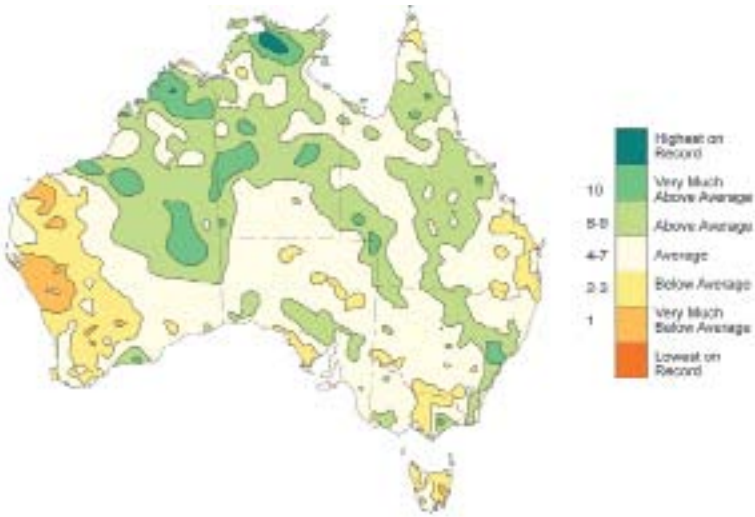


**Fig. 6.51. Australian rainfall deciles (1961–90 base period) for 2007.**

brought just 6,006 mm of precipitation. Compared to the normal amount of 6,650 mm (605 mm $yr^{-1}$), southeastern Australia missed out on over one year of normal rainfall when summed over the duration of the 11-yr drought event.

(iii) Notable events

While Australia was consistently warm throughout the year, the average was constrained by its coldest ever June (1.5°C below average). This was almost solely the result of an exceptional cold and wet event in tropical Australia in what is ordinarily the region's dry season. On 20 June, 31% of the land area of Australia experienced its lowest recorded daily maximum temperature for June (over the post-1941 period), with maximum temperatures <10°C observed at 14 tropical stations. Previously there had only been 12 recorded cases of individual tropical stations not reaching 10°C. The low temperatures included maxima of 8.0°C at Tennant Creek (19°39′S), the northernmost ever sub-10°C maximum in Australia.

February was exceptionally hot throughout southern and Western Australia, with western Australia, South Australia, and Tasmania all recording their hottest February on record. For large parts of western Australia, temperatures were >5°C above average. Marble Bar in the western Australian Pilbara region exceeded 40°C on 52 consecutive days from 5 January to 27 February, and had a mean daily maximum of 44.9°C for February, the highest monthly mean ever recorded at an Australian station.

Southeastern Australia was affected by abnormal warmth for late winter in the last week of the season. The South Australian capital of Adelaide reached 30.4°C on 30 August, breaking its previous record for the earliest 30° day by more than two weeks, while Mildura's 29.9°C on the same day equaled the Victorian record for August. The West Australian capital of Perth recorded 44.2°C on Boxing Day, its hottest December day since records began in 1897, exceeding the previous record of 42.3°C on 31 December 1968 by almost 2°C.

A succession of east coast lows developed during June off the New South Wales coast. Major flooding occurred in the Hunter River. Moisture associated with another east coast low brought severe flooding in eastern Victoria at the end of June, with rainfall totals including a 319-mm reading at Mount Wellington on 28 June, the second highest daily rainfall recorded in Victoria. A later event in early November, with daily rainfall of ~100 mm, brought renewed flooding to the same region.

Exceptionally heavy rainfall occurred in the Sunshine Coast region of Queensland on 24–25 August. The most extreme totals occurred on the early morning of the 24th, with 24-h totals of up to 772 mm at Coops Corner, which set a new Australian daily record for August. While these extreme rainfalls were localized, rainfalls in the 100–200-mm range were more widespread, causing significant local flooding, especially in the Noosa area.

Extensive wildfires, which began in early December 2006 in the mountains of northeastern Victoria, continued to burn into early February 2007. It was the most long-lived fire in the state's history. The fire was finally contained on 7 February after 69 days, having burned over 11,000 $km^2$.

2) New Zealand—M. J. Salinger

(i) General conditions

The national average temperature in 2007 was 12.7°C, 0.1°C above the 1971–2000 normal (Fig. 6.52).[7] The year ended very near the 1971–2000 normal as a consequence of several warm months offsetting some cooler months. Temperatures were near normal in most regions.

Annual rainfall in 2007 was below average throughout much of New Zealand. Annual rain-

[7] New Zealand data are from the National Climate Database archived for New Zealand with NIWA.

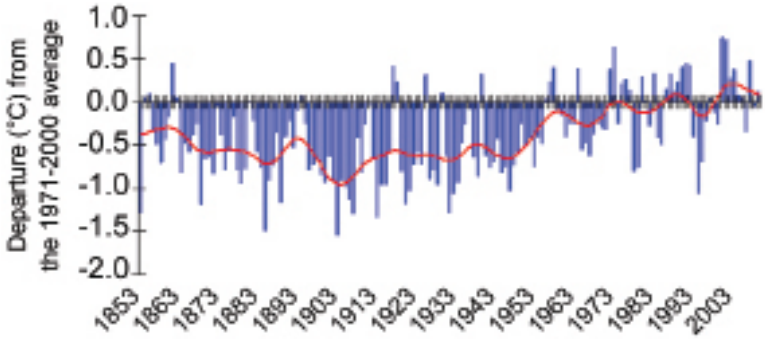


**Fig. 6.52. New Zealand annual mean temperature anomalies (°C; 1971–2000 base period) for 1853–2007.**

fall was less than 75% of normal in the east from Wairarapa to Otago, as well as eastern Bay of Plenty, Taranaki, Gisborne, Manawatu, Wellington, and Nelson. Rainfall totals were less than 60% of normal in parts of Marlborough, Canterbury, and Central Otago, as many locations recorded their driest year on record. Lauder recorded its driest year in more than 60 yr, with only 291 mm for the year.

Sunshine hours were more than 115% of normal in inland South Canterbury and Otago, with Tekapo, Dunedin, and Invercargill recording one of their sunniest years on record. Totals were at least 110% of normal in eastern Bay of Plenty, Southland, and Westland, and near normal elsewhere. Blenheim was the sunniest location in 2007, recording 2,567 h, followed by Lake Tekapo (2,554 h), and Whakatane (2,551 h).

### (ii) Notable events

Notable climate features in various parts of the country were disastrous floods in Northland under very dry conditions, as well as drought in the east of the North Island. There was an unprecedented swarm of tornadoes in Taranaki, as well as destructive windstorms in Northland and in eastern New Zealand in October. There were numerous heavy rainfall events during 2007, of which nine produced flooding. Notable snowfall events occurred on relatively few occasions. There were 14 damaging tornado events for New Zealand for the year, an early autumn and late spring hot spell, two severe hailstorms, and seven damaging electrical storms.

The year began with low rainfall and significant soil moisture deficits, especially in the east, which persisted in the east of the North Island until May. The most disastrous Northland floods for many decades occurred in the Far North and Whangarei districts, especially in the Bay of Islands area at the end of March, due to exceptionally high rainfall ranging from 250 to more than 400 mm in eastern Northland. Warmer-than-normal seas to the west, anticyclones to the east, and frequent warm northwesterlies over New Zealand produced record high mean May temperatures for New Zealand overall and the driest May on record in the northernmost and eastern parts of the country. The national average temperature in May was 12.4°C (1.7°C above normal), the highest for New Zealand as a whole in reliable records dating back to the 1860s.

July was a month of extremes and contrasts with depressions often tracking over, or to the north of, the North Island. They produced floods in parts of Northland (over 400 mm in some areas), Hawke's Bay, coastal South Canterbury, and Otago; damaging windstorms in Northland, Auckland, and the Coromandel; and thunderstorms and damaging tornadoes in Taranaki (severe), Auckland, and Bay of Plenty. More settled, although rather cold, conditions existed for much of the month in Central Otago and inland Southland, often with periods of freezing fog. At Lauder, air temperatures were constantly below zero from 12 to 21 July, and there were 13 days from 7 to 22 July with minimum air temperatures below –10.0°C.

October was rather stormy and generally cold with deep depressions tracking south of New Zealand and frequent westerly gales. This was the fourth windiest October overall with regard to westerlies based on measurements that began in 1966. Wind gusts over 36 m $s^{-1}$ occurred on 13 days (42%) in the month. Many stations had at least 7 more days than average for the time of year with strong winds (gusts to 16 m $s^{-1}$ or more).

Low rainfall totals occurred in many regions in November 2007, especially in the South Island, with totals less than 10 mm throughout much of Nelson, Marlborough, and Central Otago. Severe soil moisture deficits resulted from the lack of rainfall in parts of Hawke's Bay, Marlborough, Canterbury, and Otago. These persisted until the end of the year. Additional extremes included the following:

- Extreme temperatures: The highest recorded extreme temperature of the year was 33.5°C and was recorded at Napier Airport in Hawke's Bay (33.5°C) on 22 January during hot dry northwesterly conditions. The lowest air temperature

for the year was –15.4°C recorded at Lauder on 18 July. This was the lowest reading there since July 1995 (–19.7°C), with numerous other inland South Island locations recording minimum air temperatures below –10.0°C at times between 7 and 22 July.

- Winds and tornadoes: The highest recorded wind gust for the year (as archived in the NIWA climate database) was 47 m $s^{-1}$. This reading was for a westerly wind at Taiaroa Head (Otago coast) during violent storm conditions on 23 October. A higher wind gust of 50 m $s^{-1}$ was reported on the offshore island of Tititiri Matangi between 9 and 11 July. An extraordinary outbreak of damaging tornadoes caused severe damage throughout Taranaki over 4–5 July.
- Rainfall: The lowest annual precipitation totals occurred in Alexandra in Central Otago (272 mm), followed by Lauder (291 mm), and Clyde (294 mm). Of the regularly reporting gauges, the Cropp River gauge in Westland, inland in the headwaters of the Hokitika River, recorded the highest rainfall with a 2007 annual total of 8,940 mm. This region typically receives on the order of 10,000 mm of rainfall per year as it is situated in an area of moderate uplift of moist westerly air.
- Christchurch was the driest of the five main regions with 510 mm and Auckland the wettest with 1096 mm. Hamilton received 952 mm, Wellington 1070 mm, and Dunedin 599 mm.

### 3) Southwest Pacific—M. J. Salinger

The first quarter of the year was influenced by decaying El Niño conditions (see chapter 4), followed by a neutral period. La Niña conditions developed by September, and matured in December. There were ENSO-related influences on the location of the SPCZ, with the SPCZ tending to be north of its normal location during the first part of the year, and farther south than usual from July to December. Surface equatorial easterlies became very persistent near the date line from April onward. Above average equatorial SSTs occurred in January around Western and Eastern Kiribati with the decaying warm episode (+1°C anomalies); however, warm anomalies moved south of the equator through October, dissipating after that time. Negative SST anomalies (–0.5°C) developed east of the date line in July, gradually spreading west to reach the date line in October. Temperatures cooled to 1.0°–1.5°C below average in the seas around Eastern Kiribati for the remainder of the year.

Typical of an El Niño event, January's OLR anomalies showed enhanced convection over Kiribati southeast to the Northern Cook Islands, with suppressed convection farther south. However, this was short lived. From June through December a reversal to suppressed convection occurred there in association with La Niña's development. Mean sea level pressures were above average in the subtropics west of the date line until April. Negative anomalies developed in the tropical western Pacific between Papua New Guinea and Fiji from June onward.

For 2007 as a whole, above average SSTs occurred throughout much of the tropical southwest Pacific south and west of the date line (Fig. 6.53), which were at least +1.5°C above average around the Solomon Islands, Vanuatu, Fiji, Samoa, and central French Polynesia. SSTs were below average in the equatorial region near and east of the Line Islands. southwest Pacific island surface air temperature anomalies for 2007 were generally consistent with the SST anomalies throughout the region. It was an extremely warm year in Fiji and Tonga where the mean temperatures were about 1.0°C above historical averages.

OLR anomalies in 2007 (Fig. 6.54) showed a region of enhanced convection over Papua New Guinea and west of the Caroline Islands, as well as between Fiji and central French Polynesia, including Tonga, Samoa, Niue, and the southern Cook Islands. Convection was

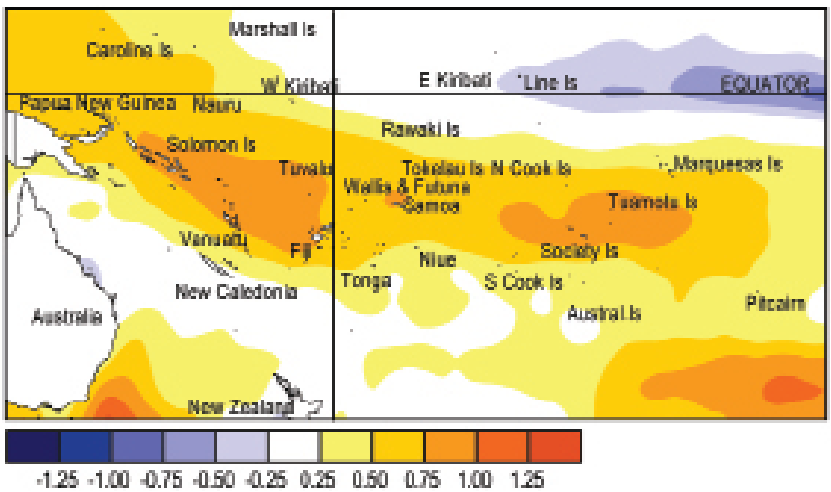


**Fig. 6.53. SST anomalies (°C; 1971–2000 base period). Yellow or orange areas represent a warmer-than-average sea surface.**

suppressed in 2007 over Kiribati, extending to northern French Polynesia. The year's rainfall anomaly pattern is similar to the OLR pattern, with above-average rainfall between Fiji and central French Polynesia, including Tonga, and below-average rainfall in Kiribati, extending to northern French Polynesia.

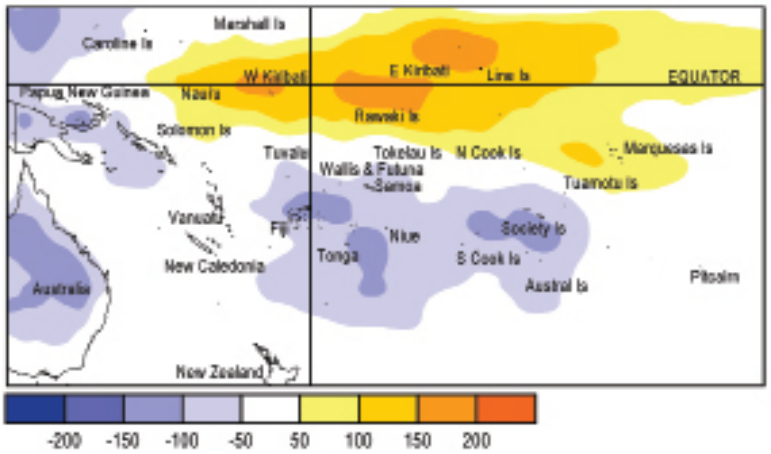


**Fig. 6.54. OLR anomalies (W m$^{-2}$; 1971–2000 base period). High radiation levels (yellow or orange) are typically associated with clearer skies and lower rainfall, while cloudy conditions lower the OLR (blue) and typically mean higher rainfall.**

4) Micronesia—C. Guard and M. A. Lander

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. During 2007, Micronesia was initially dominated by a mild post–El Niño drought and later by the effects of La Niña. In early 2007, the 2006 El Niño waned and gave way to ENSO-neutral conditions. In the middle third of the year, equatorial oceanic conditions vacillated between ENSO-neutral and weak La Niña. Atmospheric conditions, however, had distinct La Niña characteristics in Micronesia during much of the year. Trade winds and low-latitude easterly winds were stronger than normal. The monsoon trough spent most of the boreal summer and fall in the western part of Micronesia, rarely pushing eastward. In fact, it only penetrated to 155°E once during the year and to 145°E 3 times during the year. This caused the tropical cyclone season to start late, with most tropical cyclones developing west of Guam and north of Yap, and not significantly intensifying until they were well on their way to the Philippines, Taiwan, or northeast Asia. In addition, sea levels were significantly higher than normal across all of Micronesia.

(i) Temperature

Average monthly maximum temperatures were higher than normal across most of Micronesia. This was especially the case during the first six months of the year, when many locations were affected by a mild post–El Niño drought (Table 6.4). At the Guam International Airport, monthly average maximum temperature anomalies were +0.8°C for January–June and also +0.8°C for the entire year. All months either had normal or above normal maximum temperatures. For Palau at the western end of the area, the average monthly maximum temperature anomaly was +0.9°C for the first six months and +0.7°C for the entire year, with all months having higher than normal maximum temperatures. At the eastern end of the area, maximum temperatures at Majuro (central Marshall Islands) were warmer than average for 8 of the 12 months, but for the first 6 months and for the entire year, the anomalies only averaged 0.1° and 0.2°C, respectively. Pohnpei in the central part of the Micronesian area had a maximum temperatures anomaly of +0.3°C for the first six months and +0.2°C for the entire year. Only Chuuk, also in the central part of the area, exhibited cooler-than-normal maximum temperatures during 2007, with anomalies of –0.4°C for the first six months and –0.3°C for the entire year. The higher-than-normal maximum temperatures can, for the most part, be attributed to increased incoming solar radiation as a result of increased early year subsidence associated with the post–El Niño drought and reduced monsoon and tropical cyclone activity in the second half of the year.

(ii) Precipitation

Precipitation at the major island stations in Micronesia was drier than normal during the first one to four months of 2007. Widespread subsidence frequently produces drought conditions in the region during the post–El Niño period. The severity of the drought usually corresponds to the severity of the El Niño. Weak El Niño events can produce mixed precipitation patterns with wet and dry areas across the region, as was the case in early 2007. For the most part, rainfall for the first six months of 2007 in Micronesia was between 75% and 125% of average for most locations (Table 6.4). Exceptions occurred

in the Marshall Islands, Palau and Guam, where values were 20%–50%, 40%–60%, and 60%–70% of average, respectively, for at least three of the six months. Extremely dry conditions affected the northern Marshall Islands, where winter rainfall was 20% of normal. Guam was also dry for several months, exacerbating the dry-season wildfire threat. Very dry conditions also affected several of the low islands of Chuuk State. The abrupt change from El Niño to ENSO-neutral conditions and the trend toward La Niña early in the year may have prevented more severe and widespread subsidence and drier conditions early in the year. Despite ENSO-neutral conditions in the boreal spring and summer, the atmospheric patterns over Micronesia were largely La Niña–like and the weather could be described as tranquil, with fewer than normal tropical cyclones, a weak monsoon, and a general suppression of large-scale convective activity.

The stronger-than-normal trade winds and general lack of strong widespread subsidence allowed the convectively active, narrow trade wind trough to develop, keeping the islands between 4° and 8°N wet during most of the months of the first half of the year. Palau at the western edge of the area, Guam on the northern edge of the area, and Kwajalein at the northeast edge of the area had rainfall that was 28%, 14%, and 20% below normal, respectively, for the January–June period. As the trend toward La Niña increased, rainfall increased in the western part of the Micronesian area. Yap maintained its wet pattern during the second half of the year, and Palau was able to make up much of its first half-year deficit (Table 6.4). The high islands of Guam and Pohnpei had sufficient convective activity to produce rainfall values slightly above normal by the end of the year, despite the lack of monsoon and tropical cyclone activity. The La Niña pattern is often accompanied with a strong, persistent TUTT that contains embedded upper cold-core low pressure systems that move east to west. High-level divergent flow equatorward of these low pressure systems produced widespread shower activity over the northern islands (Guam, Yap, Kwajalein) of the area that helped increase rainfall there during the second half of 2007.

### (iii) Tropical cyclone impacts

Tropical cyclone activity in 2007 in the western North Pacific and across Micronesia was below normal in almost every category of activity (see chapter 4). Tropical cyclone Kong-rey brought much needed rainfall to parts of Pohnpei and Chuuk States, and to the CNMI. The peak wind recorded in the sparsely populated northern islands of the CNMI was 34.5 m $s^{-1}$, and it only produced about 91 mm of rain. Yutu passed near Yap as a weak tropical storm. A peak wind of only 18.5 m $s^{-1}$ was recorded on Yap with 115 mm of storm-total rain. In July, Tropical Storm Man-yi passed north of Yap and west of Guam, producing peak winds of about 25 m $s^{-1}$ in Yap State.

Table 6.4. Temperature and precipitation summaries for locations in Micronesia.

| | | Max. temperature anomaly (°C) | | Rainfall (mm) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Jan–Jun | | Annual | |
| Station | Location | Jan–Jun | Annual | 2007 | % Normal | 2007 | % Normal |
| Guam | 13°N, 145°E | +0.8 | −0.8 | 523.5 | 86 | 2,235.7 | 103 |
| Yap | 9°N, 138°E | +0.2 | +0.1 | 1,326.9 | 114 | 3,496.3 | 117 |
| Palau | 7°N, 134°E | −0.9 | +0.7 | 1,238.8 | 72 | 3,230.1 | 86 |
| Chuuk | 7°N, 152°E | −0.4 | −0.3 | 1,571.8 | 102 | 3,216.7 | 95 |
| Pohnpei | 7°N, 158°E | −0.3 | +0.2 | 2,390.1 | 105 | 4,921.5 | 105 |
| Kwajalein | 9°N, 168°E | +0.1 | −0.1 | 772.2 | 80 | 2,266.4 | 89 |
| Majuro | 7°N, 171°E | +0.1 | +0.2 | 1,419.6 | 98 | 3,014.0 | 90 |

A strong gradient between the storm and a strong high pressure system several hundred kilometers northeast of Guam produced gale-force winds that battered Guam and the CNMI for 24 h. Tropical Storm Usagi produced peak winds of 21.6 m $s^{-1}$ over the northern islands of the CNMI and a 24-h rainfall total of 236 mm.

(iv) Sea level

The late start of the weak El Niño of 2006 and its abrupt ending near the beginning of February 2007 produced only a small sea level drop over the easternmost parts of Micronesia in the early part of 2007. Western parts of Micronesia never experienced the sea level falls that normally accompany, even weak, El Niño events. With the abrupt demise of El Niño and the trend toward La Niña conditions early in 2007, strong trade winds began to elevate the sea levels across Micronesia. High wave events caused several episodes of coastal flooding in Chuuk State in the boreal spring, fall, and winter. From November 2007 through the end of the year, sea levels averaged 15–20 cm above their normal monthly averages, but during full and new moon phases, the highest sea levels were 60–80 cm above normal heights. The high astronomical tides coupled with the affect of La Niña caused considerable coastal inundation in Chuuk and Pohnpei States.