EXTREME RAINFALL IN NOVEMBER 2009 IN SOUTHEASTERN SOUTH AMERICA—M. BIDEGAIN, M. SKANSI, AND J.A. MARENGO

Portions of northern Uruguay, southern Brazil and northeastern Argentina experienced significant positive precipitation anomalies during November (Fig. 7.15). Northern and western Uruguay, Rio Grande do Sul (state in Brazil), and Entre Rios (province in Argentina) felt the impacts of the flooding that affected all cities along the lower basin of Rio Uruguay River. Estimates indicated that more than 5000 people were evacuated from Uruguay alone.

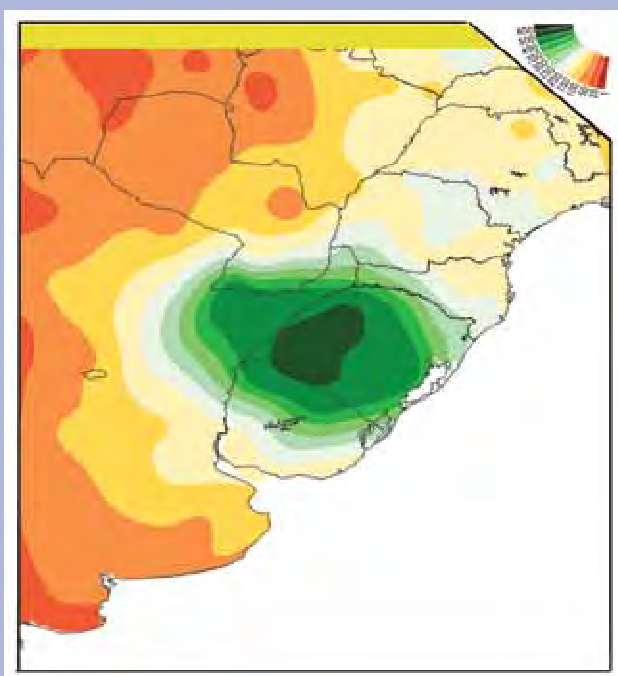

Fig. 7.15. November 2009 rainfall (mm) in Southeastern South America. (Source: CPTEC/INPE.)

November 2009 was the wettest November in the last 30 years, since the Salto Grande dam was built (Fig. 7.16). Overall, more than 350 mm of rain felt in the region between 25°S-35°S and 50°W-60°W. The monthly average is 150 mm, but in some places the record exceeded 600 mm.

The National Institute of Meteorology of Brazil (INMET) and the National Institute for Space Research (INPE) reported that the November precipitation surpassed 400 mm at 19 meteorological stations of Rio Grande do Sul State, and average rainfall in all states was about 300 mm above normal. In Sao Luiz Gonzaga, the rainfall was 640 mm while the historical monthly average was 154 mm, a record for November since observations began in 1912.

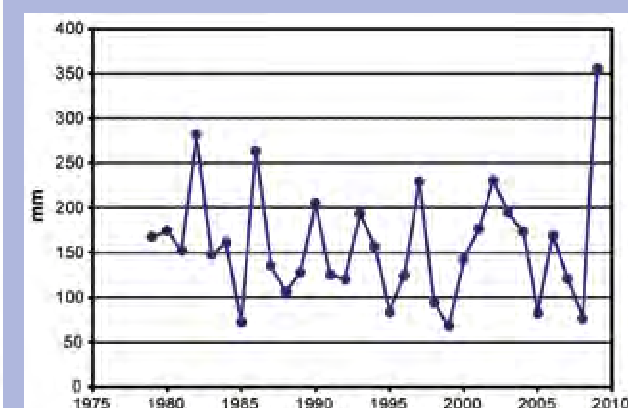

Fig. 7.16. November mean rainfall for Southeastern South America, 1979–2009. (Source: GPCP.)

In November, there were exceptional rains in eastern Argentina, causing flooding and high levels of the Parana and Uruguay rivers. In many cities located over Rio Uruguay, people were evacuated (more than 5000 in Uruguay and 15 000 in Argentina. Excesses as large as 200% of normal rainfall and associated floods affected the southern and northern part of the Buenos Aires province (Gualeguaychú +334.8%, Laboulaye +246.8%, Junin +210.7%.), with the precipitation registered at Gualeguaychú (430 mm) and Laboulaye (377 mm) being the largest since 1940. San Antonio de Areco in the northern part of the province of Buenos Aires was the city with the most damage and evacuees.

e. *Africa*

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

Countries considered in this region include: Morocco, Algeria, Tunisia, and Egypt.

(i) Temperature

In northwest Africa (Morocco, Algeria, and Tunisia), the annual mean temperature was mainly above normal in 2009, with the anomalies between +0.4°C and +2.5°C. Winter and autumn were exceptionally cold over the region with monthly mean minimum temperatures 0.1°C to 3°C below normal. January anomalies of -2.0°C and -2.2°C were found in Algeria and Morocco, respectively. Spring temperature

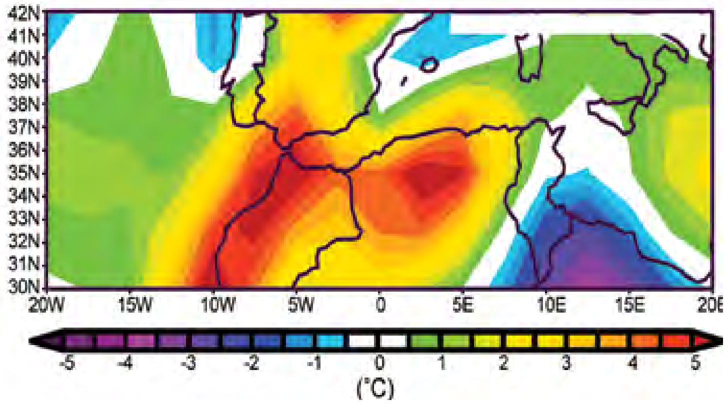

Fig. 7.17. Daily maximum temperature anomalies (°C) on July 21st 2009 for northwest Africa (based on 1968–96). (Source: NOAA/ESRL.)

reached 1.5°C above average over most parts of Morocco; the temperature ranged from 7°C in the north to 23°C in the south. During the summer, exceptional heat waves occurred. The monthly mean temperatures exceeded the normal; for example, the anomaly was +2.4°C in Tetouan in July. On 21 July, the daily maximum temperature reached between 47°C and 50°C in the Saharien City, Maskara in Algeria, Agadir, Tiznit, and Tan Tan in Morocco (Fig. 7.17).

In Egypt, 2009 can be described as a year with more stable and moderate weather than the previous years, with less temperature fluctuations and extreme events. For the 2000–09 decade, the annual mean temperature of Egypt remained above the normal by about 1.1°C. Fig. 7.18 shows a continued increasing trend from 1975. Only two years were below the average, 1982 and 1983. The warmest and second warmest years were 2008 and 2005 with anomalies of +1.9 and +1.7°C, respectively.

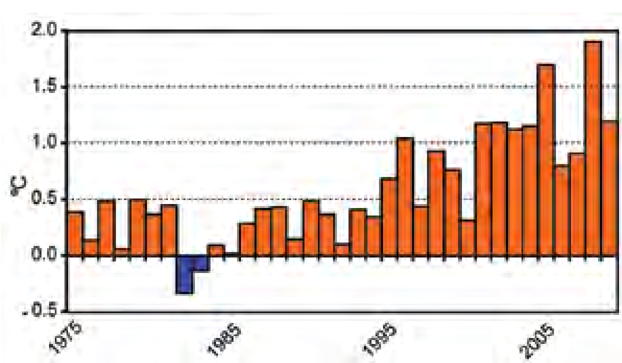

Fig. 7.18. Annual mean temperature anomalies (based on 1961–90) for Egypt, 1975–2009. (Source: Egyptian Meteorological Authority.)

(ii) Precipitation

In northwest Africa, annual 2009 precipitation was near normal to above normal. Large positive deviations also occurred in some regions and seasons, especially during the winter 2008/09 and the beginning of winter 2009/10, where rainfall was between 45% and 280% of average for most locations. Precipitation records during December 2009 represented 31% of the annual total. Many weather stations in Morocco, Algeria, and Tunisia reported rainfall exceeding 150 mm in less than 24 hours. Heavy storms that occurred from 20 to 25 December produced heavy rains causing floods. Rainfall amounts up to 200 mm in 48 hours were recorded, especially in the extreme north of Morocco. For example, Chefchaouen City recorded 834.9 mm in December for which the monthly normal is 265.4 mm (calculated from 1994 to 2000). The fall was variable spatially and temporally, but overall it was wetter than normal; October and November were considerably below average but September total rainfall exceeded the monthly mean by more than +800% in some areas of Morocco (for example in Rabat). In Tunisia, more than 90 mm was recorded in less than four hours at Zarzis, Gribis, and Souihel during the same month. Spring and summer were characterized by reduced rainfall activity over most of northwest Africa reaching more than 90% deficit, especially in August due to anticyclonic conditions.

In Egypt, the annual number of rainy days and the annual total precipitation for 2009 were near the historical average (based on 1961–90). The relative humidity was also around the historical average, with a variation range of ±5%.

(iii) Notable events

The year 2009 was characterized by heavy rainfall events, especially during winter, that affected Algeria, Tunisia, and Morocco. These events caused important infrastructure damages and human life loss in many cities and villages when many daily rainfall records for September and December were broken. Record wind speeds also occurred; for example, 140 km hr^{-1} in Khouribga City in May and 115 km hr^{-1} in Tangier in December. Several forest fires occurred in July and August, especially when the daily temperature exceeded 50°C for some locations in Algeria and 49°C in Morocco.

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

Western Africa is the region which extends from the Guinea coast and Côte d'Ivoire to Chad and the Central African Republic. The year was characterized by above-normal rainfall in the extreme western region, while dry conditions were found in the Côte d'Ivoire and Gabon areas.

(i) Temperature

January 2009 temperature anomalies (based on 1971–2000) were above normal with anomalies greater than 3°C in eastern Niger, western Chad, and part of northern Nigeria. The positive temperature anomalies continued in February, with anomalies greater than +3°C covering most of Niger, eastern Mali, northern Burkina Faso, and all of northern Nigeria. From March to June, the positive temperature anomalies decreased and became near normal in July, August and September. In October, the temperature once again became much above normal with anomalies reaching above +3.5°C over northern Niger. In November and December, the positive temperature anomalies continued over most of Western Africa. At Bilma, located in northern Niger, monthly mean temperatures were above normal for every month of the year (Figure 7.19). Negative temperature anomalies were almost nonexistent in the region, except in January when significant negative anomalies (less than -1.5°C) were observed over south Mauritania, western Mali, northern Guinea and Senegal.

(ii) Precipitation

In Western Africa, the rainfall anomalies (based on 1971–2000) showed significant deficits in April and May over Guinea, Liberia, southwest Côte d'Ivoire, and south Mali. In contrast, excessive rainfall was recorded over southeast Ghana, south Togo, southwest Benin, and parts of the central African countries. In June, rainfall deficits were observed over Guinea while heavy rains and floods hit most of the coastal settlements in the subregion.

In July, the Sahel rainfall increased with peaks ranging from150 mm–300 mm over western Senegal, the Gambia, and Guinea Bissau. The eastern Gulf of Guinea and northwestern part of the central African countries had a rainfall increase, with peaks ranging from 300 mm–400 mm over Nigeria and Cameroon.

In August, the peak rainfall for the Sahel ranged from 300 mm–400 mm over Burkina Faso, southern Mali, and southern Chad, intensifying to about 700 mm over Senegal and the Gambia and resulting in flooding. The southern Gulf of Guinea had a rainfall deficit. Above-normal rainfall was observed over the central African countries with peaks ranging from 300 mm–500 mm, intensifying to about 600 mm over Guinea Bissau, Guinea, and Sierra Leone.

In September, the rainfall in the Sahel generally decreased, but high accumulations ranging from 250 mm–500 mm were observed over central Burkina Faso, southern Mali, and Senegal. The Gulf of Guinea countries observed, similarly, a general decrease in rainfall, but observed high amounts of about 400 mm over Guinea Bissau, Guinea, and Nigeria spreading over parts of the central African countries.

Compared to the base period 1971–2000, July, August, and September 2009 had significant positive rainfall anomalies with severe rainfall deficits over most of the Gulf of Guinea countries and central African countries (Fig. 7.20). Positive rainfall anomalies were found in September with the maximum amount observed over south Mauritania, Senegal, Gambia, and central and western Mali.

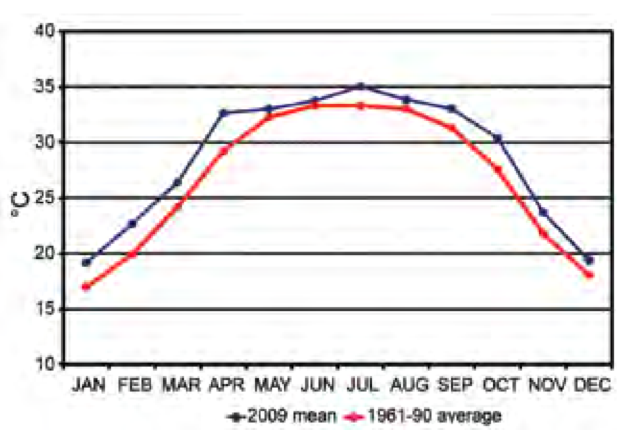

Fig. 7.19. Monthly mean temperature in 2009 and 1961–90 average for Bilma, Niger. (Source: African Centre of Meteorological Applications for Development.)

(iii) Notable events

According to UN Integrated Regional Information Networks (IRIN) 9 October report, more than 60 schools in Senegal were flooded due to the heavy rains in July, August, and September. The spokesperson for Senegal's Interior Ministry confirmed a $4.5 million U.S. emergency plan to pump out the water from flooded zones, rid standing water of mosquito larvae, and provide free health services at medical posts set up in affected areas.

3) Eastern Africa—C. Oludhe, L. Ogallo, P. Ambenje, Z. Athery, and W. Gitau

The Great Horn of Africa (GHA) region can be divided into three main sectors. The northern sector

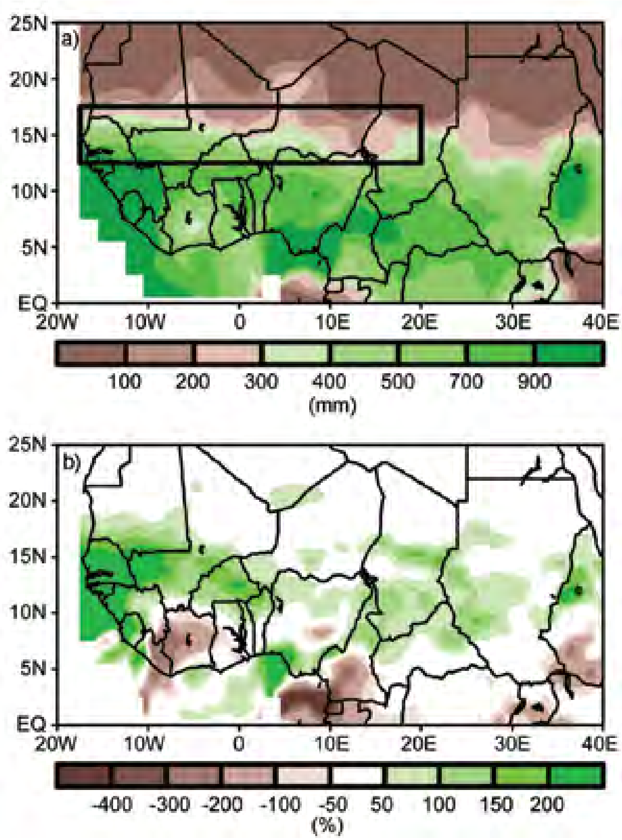

Fig. 7.20. (a) July to September 2009 rainfall (mm) for Western and Central Africa and (b) July to September 2009 anomalies (expressed as percentage of 1971–2000.) (Source: NOAA/NCEP.)

covers Sudan, Ethiopia, Eritrea, Djibouti, and northern Somalia; the equatorial sector includes Uganda, Kenya, Burundi, Rwanda, southern Somalia, and northern Tanzania; and the southern sector refers to central and southern Tanzania. The base period is 1961–90.

(i) Temperature

Overall, the temperature was warmer than average over most of the GHA. In June, the minimum temperatures were warmer than normal over western and northern Sudan; localized parts of western, central, and southern Ethiopia; coastal parts of Kenya; and eastern Tanzania. They were cooler than average only over a smaller area including central Somalia and southeastern Ethiopia. During the same month, the maximum temperatures followed a similar pattern; however, the below-average area was larger, extending to south Somalia and eastern Kenya. The patterns of above-average maximum and minimum temperatures in western and central GHA and of below-average maximum and minimum temperatures in the east were generally found throughout the year.

(ii) Precipitation

December to February marks the main rainfall season over the southern sector and the hottest season over the equatorial sector. During December 2008–February 2009, most of the northern and equatorial sectors received less than 75% of their long-term average (Fig. 7.21a). Isolated small areas over southern

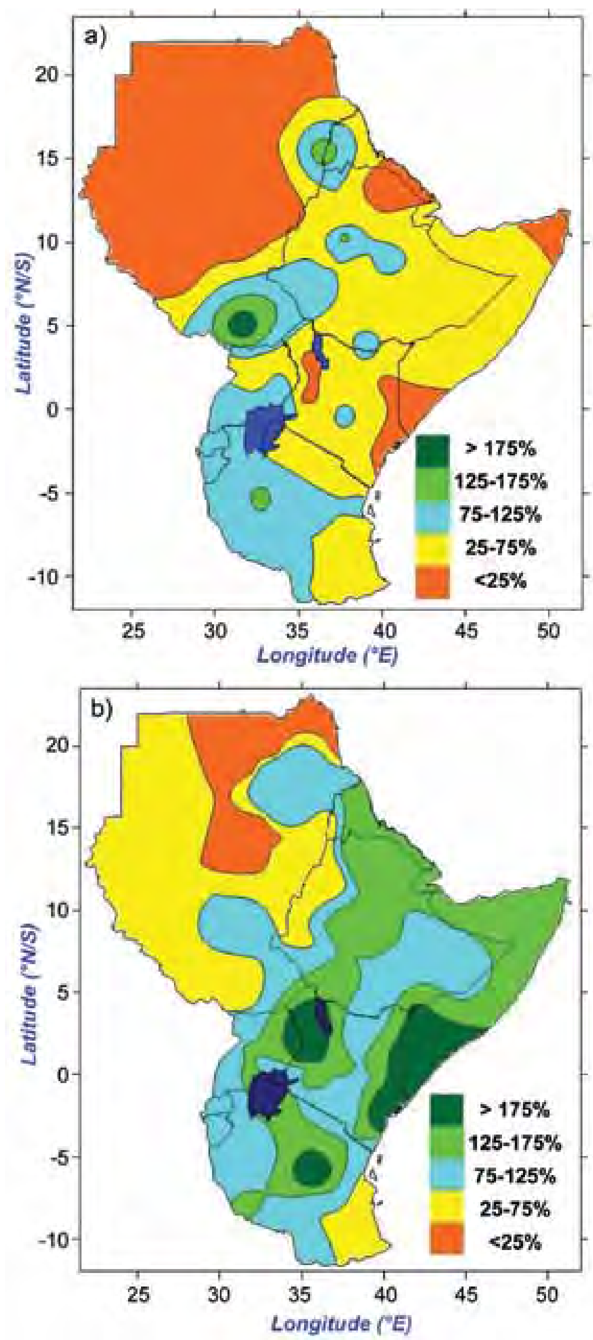

Fig. 7.21. (a) December 2008 to February 2009 rainfall anomalies and (b) October to December 2009 rainfall anomalies (expressed as percentage of 1961–90) for the Great Horn of Africa. (Source: ICPAC, 2009.)

and eastern Sudan, western and central Ethiopia, western Eritrea, central Kenya, and central Tanzania received more than 75% for the period.

March to May (MAM) is the main rainfall season over the equatorial sector. The onset of the MAM 2009 seasonal rainfall was rather late and the ending early. The western areas of both southern and equatorial sectors received 75%–125% of their long-term average. The rest of the GHA received less than 75% of their long-term average. The poor rainfall distribution resulted in crop failure and loss of livestock and wildlife due to drought conditions.

June to August is the main rainfall season over the northern sector and also the coldest period over the equatorial sector. The western parts of the equatorial sector received substantive rainfall over this period. The northern sector and northern parts of the equatorial sector received less than 75% of their long-term average. Localized areas over northern Uganda, northern and central Ethiopia, and central Sudan received near-normal precipitation.

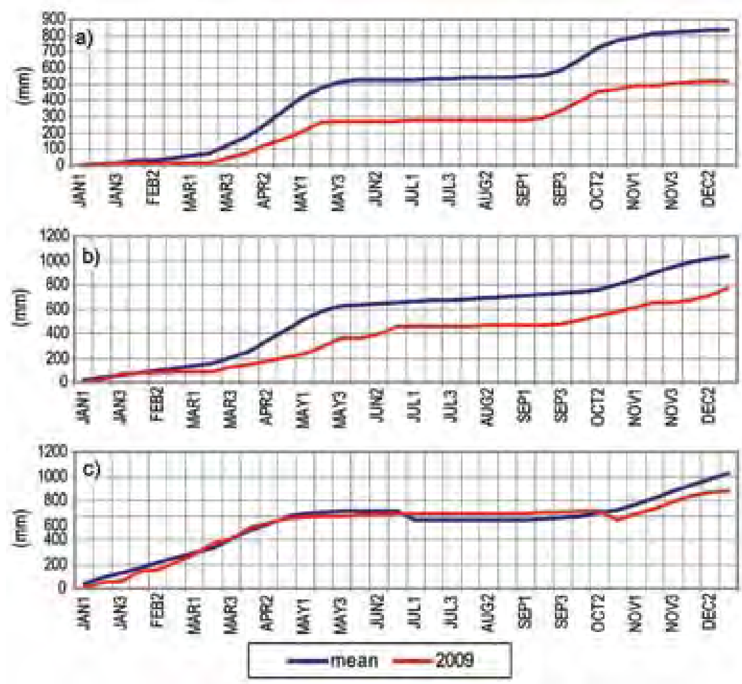

Fig. 7.22. Cumulative rainfall for (a) Neghelle, Ethiopia, (b) Dagoretti, Kenya and (c) Kigoma, Tanzania. (Source: ICPAC, 2009.)

September to December marks the second rainfall season (short rainfall season) over the equatorial sector. GHA, especially the equatorial sector, has one of the strongest climatic signals of ENSO events in terms of rainfall. The onset of ENSO for the short rainfall season was timely. However, over several locations, the distribution was not uniform with prolonged periods of dryness immediately followed by the onset of the rainfall season. Much of the GHA received between 75% and 125% of their long-term average, with eastern and northwestern Kenya, southern parts of Somalia, and central Tanzania receiving more than 175% of their long-term average (Fig. 7.21b). Episodic rainfall events towards the end of the period resulted in localized flooding in several parts of the central equatorial sector.

Fig. 7.22 compares the cumulative 10-day rainfall totals for 2009 with their long-term average. Neghelle, in southern Ethiopia, represents northern sector; Dagoretti, in central Kenya, represents equatorial sector; and Kigoma, in western Tanzania, represents the southern sector. The figure shows the rainfall deficit in the northern and equatorial sectors and adequate rainfall in the southern sector. The rainfall deficits resulted in cumulative climate stress which had both direct and indirect impacts on the climate-dependent sectors. Such impacts that were observed in 2009 include loss of livestock due to inadequate pastures, crop failure resulting in food insecurity, scarcity of the water resources resulting in rationing of hydropower and limited water for domestic and industrial uses, poor health resulting from malnutrition, and contamination of the water sources among other socioeconomic challenges.

4) Southern Africa—A. Kruger, C. McBride, A. Mhanda, J. Banda, and W. M. Thiaw

This region includes the countries south of 15°S with more focus on South Africa and Zimbabwe.

(i) Temperature

For South Africa, the annual mean temperature anomalies for 2009, based on 27 climatological stations, was about 0.4°C above the reference period (1961–90). This made 2009 the 15th warmest year since 1961. Fig. 7.23 shows that the past 13 years were all above normal. For Zimbabwe, the temperatures were near normal with no records broken throughout the year.

(ii) Precipitation

The mean rainfall of South Africa is temporally and spatially very diverse. The main features are the fairly regular decrease in rainfall from east to west and also the marked influence of orographic features

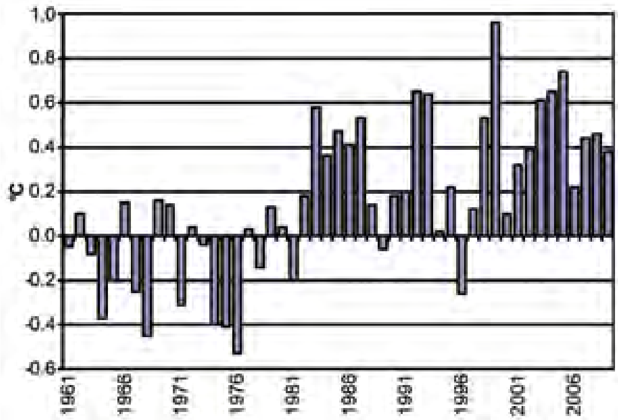

Fig. 7.23. Annual mean temperature anomalies (based on 1961–90) average over 27 stations in South Africa, 1961–2009. (Source: South African Weather Service.)

on the rainfall. The latter is most pronounced over the northeastern escarpment, the area around the northern border with Lesotho, and the southwestern and southern Cape. The average annual rainfall over the coastal plateau of the southwestern Cape is about 400 mm but in the mountains it ranges to more than 2000 mm in some locations. Although it is clear that there is a relationship between rainfall and elevation, other factors such as distance from the sea, rain-bearing winds, and type of rainfall (convective or frontal) also play a role.

The 2009 rainfall anomalies (Fig. 7.24) reflected the mean rainfall pattern, as most places in South Africa measured 75%–150% of the 1961–90 average. The most notable exception was the south and south-eastern coast and adjacent interior, which received mainly less than 75% of its annual mean.

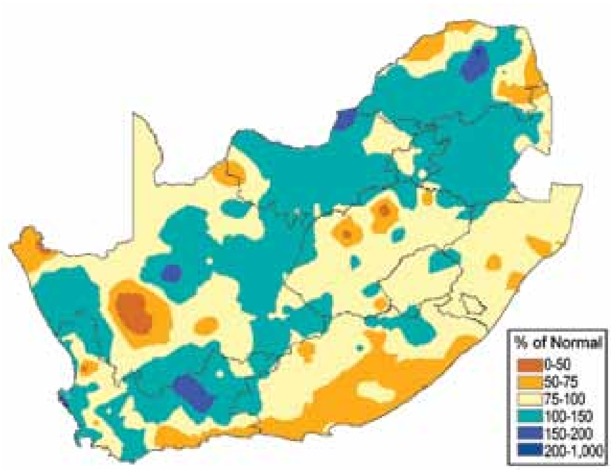

Fig. 7.24. Rainfall anomalies (expressed as percentage of 1961–90) for South Africa for 2009. (Source: South African Weather Service.)

For Zimbabwe, the rainfall season, from November 2008–March 2009, was characterized by normal to above-normal rainfall in most parts of the country. Rainfall amounts were generally moderate with no outstanding daily totals. The last two weeks of the season were very dry across the whole country. Overall, the December 2008–February 2009 rainfall anomalies for Southern Africa were near normal (Fig. 7.25).

(iii) Notable events

On 2 January, 45 families were left homeless when a storm accompanied by strong winds destroyed areas of Taung in the northwest. Villages that were affected include

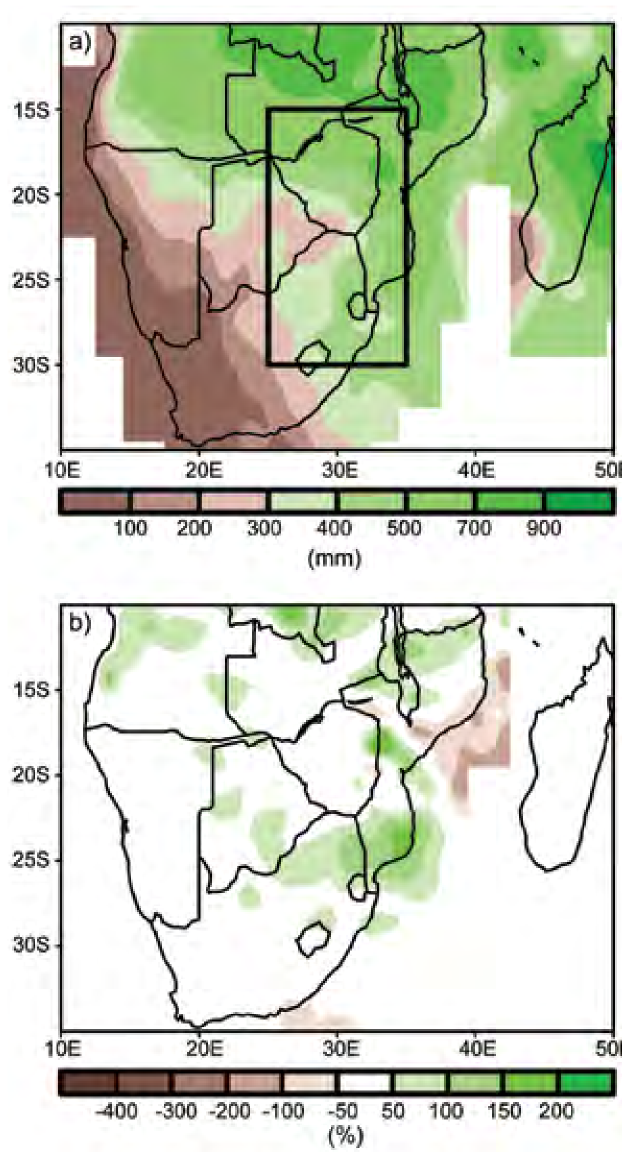

Fig. 7.25. (a) December 2008 to February 2009 rainfall (mm) for Southern Africa and (b) December 2008 to February 2009 anomalies (expressed as percentage of 1971–2000). (Source: NOAA/NCEP.)

Vergenoeg, Molelema, Kokomeng, and Longaneng. The storm left more than 500 people homeless and disaster management had to provide the affected families with blankets, mattresses, food parcels, and tents. The damage was estimated at more than R2 million ($264 000 U.S.).

A man died in his sleep when his mud hut collapsed on him during heavy rains at Mohlabaneng village in the Limpopo Province on 5 January, and 123 villagers were injured when their houses collapsed. Three hundred houses were destroyed and more than 1500 people were left homeless in the storm. The affected villages include Jamela, Mohlabaneng, Phaphadi, and Shawela.

Heavy rain that fell over the northern coastal areas of KwaZulu-Natal during the weekend of 7 March claimed the lives of at least five people and flooded hundreds of houses. KwaDukuza was also left without water after their water pumps and the pumps of the reservoir at Gledhow (which are used in emergency situations) were washed away. All rivers in the KwaDukuza area burst their banks causing extensive damage to houses in all 20 wards of the municipality.

Nearly 500 houses, affecting more than 1700 people in 28 informal settlements in Cape Town, were flooded during the weekend of the 16–17 May when the first of the annual Cape winter storms with intermittent rain and strong winds hit the Western Cape. Swells of about nine meters also occurred along the coastal regions.

Thousands were left homeless after heavy rains on 12 July caused flooding in the Western Cape, while rock- and mudslides caused damage to the infrastructure. The Lourens River in Strand and the Liesbeek River outside Cape Town burst their banks adding to the flooding problem. The Cape Flats seemed to be worst hit with people from 20 informal settlements having to be housed in community halls. About 9000 people from 2500 shacks were left homeless but there were no injuries reported. In Grabouw, 143 people had to leave their flooded homes while about 19 families from Jamestown and about 25 families near Cloetesville in Stellenbosch had to be evacuated because of rising flood waters.

Kimberley was hit by two heavy storms on 3–4 November causing extensive damage to houses, cars, and businesses; uprooting trees; ripping off roofs; and flooding several streets. The storms struck across the Northern Cape, including areas of Barkly West, Kuruman, and Longlands. Hundreds of houses were flooded in Galeshewe and some were completely washed away as water ripped through the low-lying areas of these informal settlements. An ecological disaster occurred at the swamped Kamfers Dam outside Kimberley where the third breeding season of the small flamingos started about a month earlier. Hundreds of both chicks and eggs were lost. This is one of four breeding spots in Africa and one of six in the world.

Hundreds of families were left homeless after heavy rains accompanied by golf ball-sized hail and strong winds affected Newcastle in northern KwaZulu-Natal on 11 December. Another storm hit the area seven days earlier and left 300 homes flattened. Six hundred families were left homeless after roofs were blown away, trees uprooted, and livestock destroyed in a damage estimated at millions of rands (hundreds of thousands of U.S. dollars). The municipality provided the victims with tents and food parcels. There were no injuries or deaths reported in both the storms.

5) Western Indian Ocean countries—L. A. Vincent, E. Aguilar, M. Saindou, A. F. Hassane, G. Jumaux, D. Schueller, P. Booneeady, R. Virasami, L. Y. A. Randriamarolaza, S. Andrianiafinirina, V. Amelie, and B. Montfraix

The analysis for the Western Indian Ocean countries is included for the first time in the *State of the Climate* report. This region is made of many islands grouped into five countries, namely République des Comoros, République de Madagascar, Republic of Mauritius, La Reunion (France), and République des Seychelles. Overall, the 2009 land surface temperature was well above normal (relative to 1971–2000) at most locations (Fig. 7.26a), while precipitation was generally near or slightly below normal (Fig. 7.26b).

(i) Temperature

In Comoros, the 2009 temperature was above normal every month with the exception of April when it was slightly below normal; the annual anomaly was +0.4°C. For Madagascar, the monthly mean temperatures were also near normal to above normal resulting in an above-normal annual mean temperature across the country (Fig. 7.27a). The highest monthly anomaly was +2°C observed in the northwest in October. The April temperature was also slightly below normal with a departure of -1.1°C in the south highlands. For the Republic of Mauritius, the 2009 temperature was above the 1971–2000 average by 1.0°C for Mauritius, 0.8°C for Agalega, and 0.6°C for Rodrigues islands. Every month stayed above normal at these locations except for Rodrigues when the temperatures were slightly below normal from July to September. For

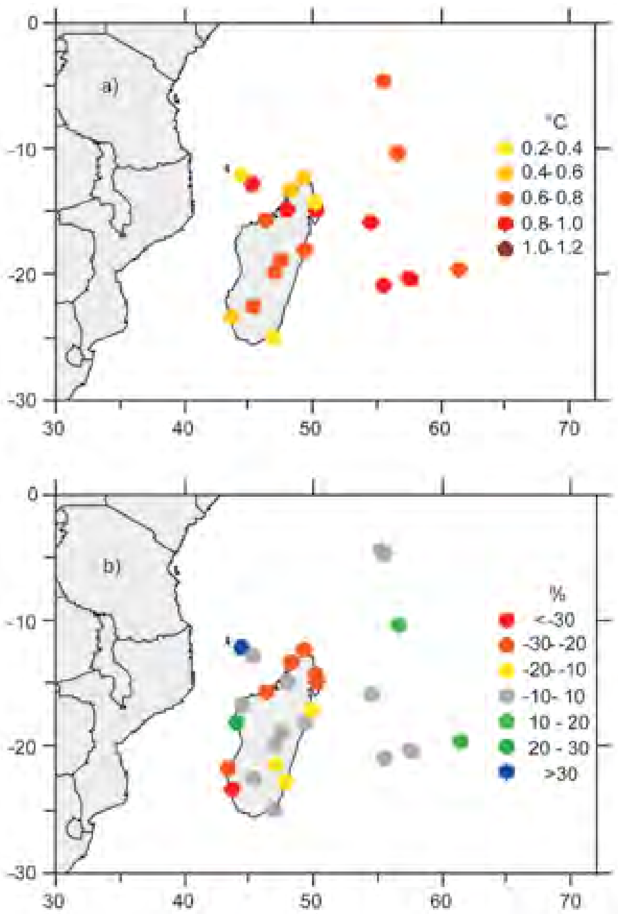

Fig. 7.26. (a) Annual mean temperature anomalies (°C; based on 1971–2000) and (b) annual precipitation anomalies (% of 1971–2000) for the countries of the Western Indian Ocean for 2009. (Source: Météo Nationale Comorienne, Service Météorologique de Madagascar, Météo-France, Mauritius Meteorological Services and Seychelles National Meteorological Services.)

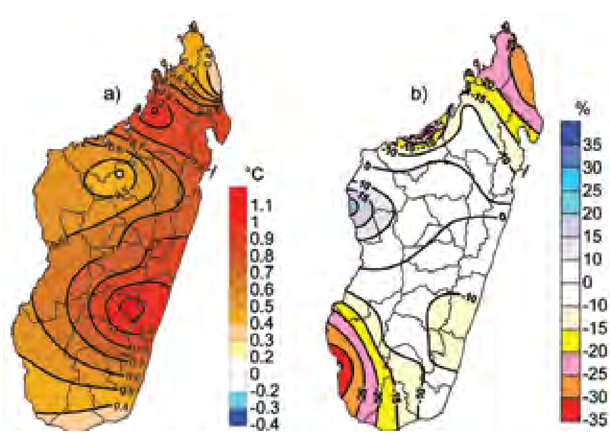

Fig. 7.27. (a) Annual mean temperature anomalies (°C; based on 1971–2000) and (b) annual precipitation anomalies (% of 1971–90) in Madagascar for 2009. (Source: Service Météorologique de Madagascar.)

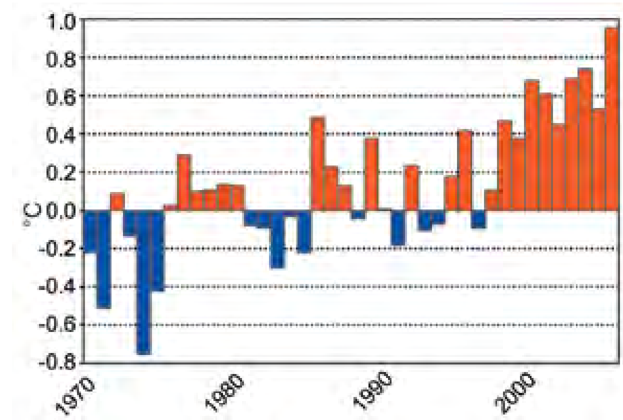

Fig. 7.28. Annual mean temperature anomalies for La Reunion (average of 10 stations observations), 1970–2009. (Source: Météo-France.)

La Reunion, 2009 was the warmest year since 1970 (Fig. 7.28) with an anomaly of +0.95°C (+0.84°C for minimum temperature and +1.07°C for maximum). Fig. 7.28 shows that the temperature has been above the 1971–2000 average for 10 consecutive years, with 8 of the warmest 10 years occurring in the last decade. For Seychelles, above-normal temperatures occurred every month with the exception of February. The annual anomaly was +0.6°C.

(ii) Precipitation

For Comoros, the 2009 annual total anomaly was +41.2% even though rainfall was below normal for nine months. April was very wet, as more than 1700 mm of rain was observed in 23 days. For Madagascar, the annual total was mainly near normal while some small regions in the north and south had below-normal precipitation (Fig. 7.27b). The accumulated annual rain over Mauritius, Agalega, and Rodrigues islands was near normal or slightly above normal. However, October 2009 was the wettest October on record in Mauritius with 250% of the long-term average (1971–2000). For La Reunion, the annual anomaly was +10% over the island (13th wettest year since 1970) although a contrast of -19% in the west to +53% in the southeast was observed. April was also a very wet month in La Reunion. The annual total precipitation was generally near normal for Seychelles.

(iii) Notable events

April 2009 was marked by significant heavy rainfall in Comoros, Madagascar, Agalega (part of Republic of Mauritius), and La Reunion. This was due to Tropical Storm Jade, which appeared on 5 April. Wind gusts of 170 km hr^{-1} were observed on the east coast of Madagascar and heavy precipitation led to several floods. More than 100 houses were flooded in southeast La Reunion.

Heavy precipitation was also observed in July in Comoros and Seychelles. Although it brought landslides and flooding in Seychelles, the rain was a relief for the country since it was experiencing very dry conditions and government-imposed restrictions on water use. The increase in precipitation was associated with an easterly wave which brought more than 150 mm of rain over a time period of 12 hours. This type of weather is rare in Seychelles.

f. Europe

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

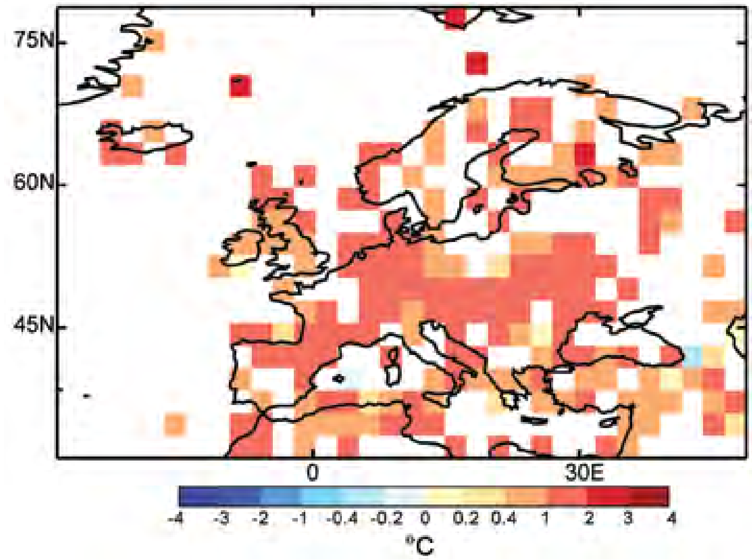

Fig. 7.29. Annual mean anomalies of surface air temperature in Europe and over the North Atlantic, 2009 (°C, 1961–90 base period), CRUTEM3 data updated from Brohan et al. 2006. (Source: UK Met Office.)

Widespread anomalous warmth affected much of continental Europe in 2009. The annual-average land surface air temperature anomaly from the CRUTEM3 dataset (Brohan et al. 2006), relative to 1961–90, was +1.05[1]±0.07°C for the European region (35°N–75°N, 10°W–30°E). This ranked 2009 as between the third and tenth warmest year since 1850, with a nominal ranking of seventh. Notably, 2000–09 was the warmest decade on record for Europe, with an anomaly of +1.0±0.12°C, significantly warmer than previous decades (1990s: +0.58±0.11, 1980s: +0.06±0.10).

The highest temperature anomalies of 2009 were recorded in the Mediterranean countries, Eastern and parts of Central Europe, Fennoscandia (Norway, Sweden, Finland) and the Arctic region (including Iceland and Greenland), all with annual mean temperature anomalies in the range from +1°C to +2°C (Fig. 7.29). Svalbard (Arctic Norway), which has recorded the highest anomalies in greater Europe in recent years, again exceeded +2°C.

Total precipitation for the year 2009 (Fig. 7.30; Schneider et al. 2008) was above average over most of Eastern and Southeastern Europe, Ireland, northern and southern parts of the UK, Iceland, and in parts of Fennoscandia. It was particularly wet in Austria, where new record annual precipitation totals were set in several places, and in Belarus. Drier-than-average conditions occurred over the Low Countries (Netherlands, Belgium, and Luxembourg), western parts of Germany, much of France and central parts of England, where totals were 80%–100% of normal. Some smaller parts of Iberia, southern France, Scandinavia, Russia, the Middle East, and Greenland received rainfall totals below 80% of the long-term average over the year 2009.

The year commenced with below-average 500-hPa heights over Southern Europe and large positive anomalies over Fennoscandia and Russia (Fig. 7.31, DJF). This large-scale circulation mode is similar to the Eastern Atlantic/Western Russia pattern (Barn-

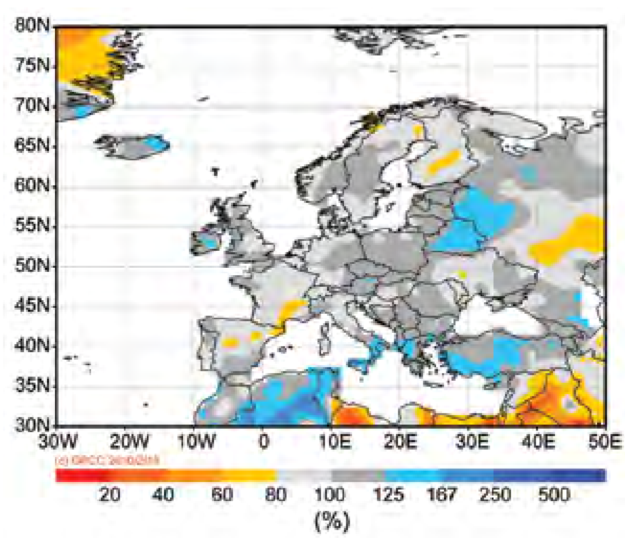

Fig. 7.30. European precipitation totals (% of normal, 1951–2000 base) for 2009. (Source: Global Precipitation Climatology Centre [GPCC], Schneider et al. 2008.)

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

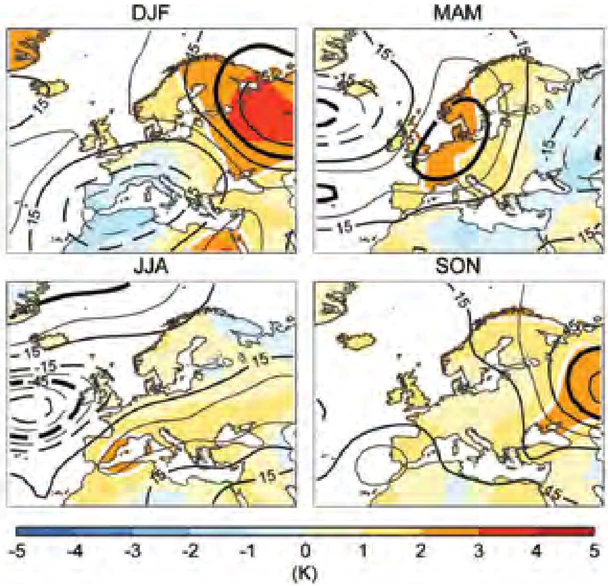

Fig. 7.31. Seasonal anomalies (1961–90 reference) of 500 hPa geopotential height (contour, gpm) and 850 hPa temperature (shading, K) using data from the NCEP/NCAR reanalysis. (DJF) winter (Dec 2008–Feb 2009), (MAM) spring (Mar–May 2009), (JJA) summer (Jun–Aug 2009) and (SON) autumn (Sep–Nov 2009). Black (white) thick lines highlight those geopotential height (temperature) contours with all the encircled grid points having absolute anomalies above their 1-sigma level of the base period.

ston and Livezey 1987). As a consequence, western and southwestern parts of Europe were significantly colder than normal (Fig. 7.32a), with monthly mean anomalies during January as low as -3°C in France and parts of Germany. Southern and Southeastern Europe experienced above-average precipitation (Fig. 7.33, DJF) and increased winter storm activity. In contrast, mild temperatures prevailed over Eastern Europe during winter 2008/09 with peak anomalies > +4°C in northwest Russia and Finland. Spring was very warm, particularly in Western and Central Europe (Fig. 7.32b), largely due to an anomalous ridge of high pressure which remained dominant throughout the season (Fig. 7.31, MAM). Temperature anomalies peaked during April, when they exceeded +5°C in places in Germany, Austria, and the Czech Republic (Fig. 7.34). Mean temperature records for April were broken in several locations.

Summer was also warmer than normal over Europe, though with smaller anomalies than spring (Fig. 32c). This was largely the result of a dipole pattern of near- to below-average 500-hPa height anomalies over the Atlantic and Fennoscandia, and above-average 500-hPa heights over the Mediterranean and Southern Europe (Fig. 7.31, JJA). Consequently, above-average precipitation was observed across Northwestern Europe and Fennoscandia (Fig. 7.33, JJA), and above-average temperatures were observed across Southern Europe with anomalies exceeding +2°C in southern France and Spain (Fig. 7.32c). A heat wave affected Italy in July, with temperatures locally reaching 45°C, while Iberia also experienced several heat waves during the summer. Some stations in Norway reported new daily maximum temperature records. Western and Central Europe were affected by severe thunderstorms, accompanied by heavy rain and hail, causing local flooding.

Autumn temperatures were well above average across Europe, particularly in the central and eastern regions (Fig. 7.32d). Precipitation showed extreme temporal and spatial variation during autumn (Fig. 7.33, SON). Positive 500-hPa height anomalies across Northern Europe and a broad trough across Southern Europe during September (Fig. 7.31, SON) were associated with above-average temperatures across much of Europe and western Russia. Southern Europe and the Mediterranean experienced very high precipitation totals (Fig. 7.33, SON). October precipitation was exceptionally high in Eastern and Southeastern Europe, and October temperatures were low in Scandinavia and Northeastern Europe. During November, an extensive flow of marine air into the European continent resulted in generally above-average temperatures with the largest departures in Fennoscandia

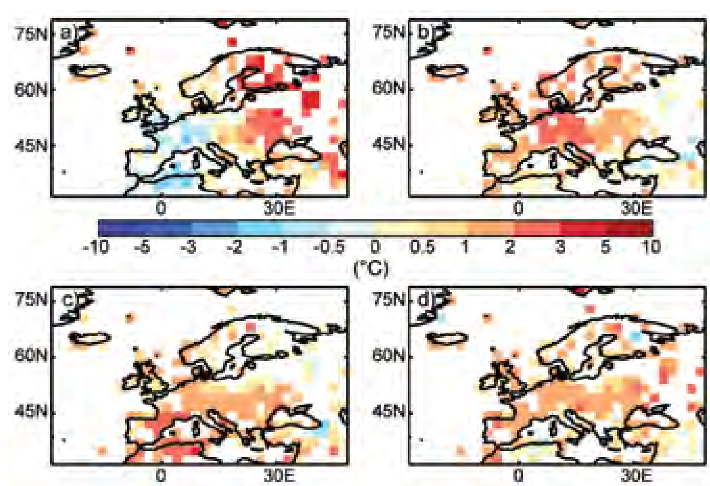

Fig. 7.32. European land surface air temperature anomalies (°C, 1961–90 base period), CRUTEM3 updated from Brohan et al. 2006. (a) December 2008 to February 2009; (b) March to May 2009; (c) June to August 2009; (d) September to November 2009.

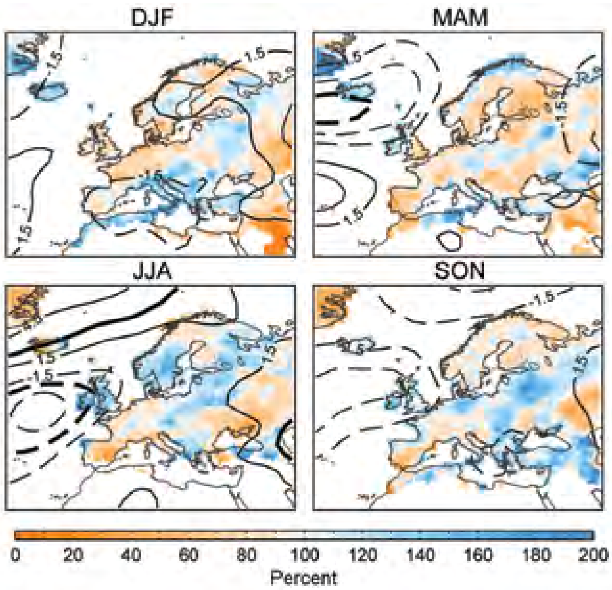

Fig. 7.33. Seasonal anomalies, with respect to the 1961-90 mean, of sea level pressure (hPa) from NCAR/NCEP reanalyses. Colored shading represents the percentage of accumulated seasonal precipitation compared with the 1951–2000 climatology from the seasonal GPCC precipitation data set (only values above 15 mm per season are represented). Thick black lines highlight those sea level pressure anomalies which are greater than one standard deviation above the mean.

and western Russia, where temperature anomalies exceeded +3°C. Increased cyclonicity led to well-above-average November precipitation, particularly in the northern half of Europe with new records set across Ireland and the UK.

The end of the year was characterized by an extremely negative phase of the Arctic Oscillation (AO) with high pressures dominating the higher latitudes of the Northern Hemisphere, affecting the weather in Europe. The AO Index in December 2009 was -3.4, the lowest value observed for that month in 60 years (Fig. 2.30b in Section 2d), with extremely negative values in the second half of the month. Most of Europe was under the influence of a strong high pressure system over the Arctic and Scandinavia that favored intense advection of cold polar air far into the middle latitudes (Trigo et al. 2004). The negative North American Oscillation index in December also contributed to a starkly contrasting temperature pattern over Europe. While Southeastern Europe and parts of the polar region (Greenland, Iceland, Svalbard) experienced mild temperatures—Greenland was 7°C warmer than average—colder-than-average conditions prevailed over the northern half of Europe with heavy snowfall in places. The Scandinavian high pressure also caused a dry December in Northern Europe, while most of the rest of Europe, particularly the South, experienced a very wet end of the year.

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

Countries considered in this section include: Ireland, the United Kingdom, the Netherlands, Belgium, Luxembourg, France, Germany, Switzerland, Austria, Poland, Czech Republic, Slovakia, and Hungary.

(i) Temperature

Annual mean temperatures in Central Europe were 1°C–2°C above the 1961–90 average throughout most of the region (Fig. 7.29). Over Western Europe, anomalies were mostly below +1°C.

Winter 2008/09 was the coldest in the UK since 1996/97. In France, it was the third coldest winter in 20 years. Severe cold waves during January and February brought temperatures below -25°C to Germany and Poland. The lowest recorded daily minimum temperature in 2009 in Poland was -28.2°C in the southwest of the country on 7 January. A private weather service station in Saxony, eastern Germany, recorded -29.1°C on the same day. In contrast, winter was warmer than average in the easternmost regions (Poland, Czech Republic, Slovakia, Austria, and Hungary; Fig. 7.32a).

Spring temperatures were well above average, mainly due to an exceptionally warm April (Fig. 7.34). Belgium and Switzerland each reported their second warmest spring on record. April was the second warmest on record for De Bilt in the Netherlands

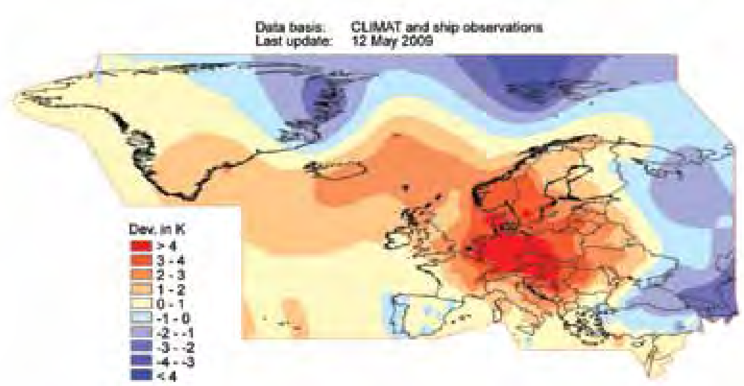

Fig. 7.34. Monthly mean anomalies of surface air temperature across Europe and over the North Atlantic, April 2009 (1961–90 base period) based on CLIMAT and ship observations. [Source: Deutscher Wetterdienst (DWD).]

(1706–2009), and new national records were set for mean anomalies in Hungary (+4.2°C) and Germany (+4.5°C; 1901–2009).

Summer temperatures were generally above average (Fig. 7.32c), most notably in southern France and Switzerland where anomalies were more than +2°C. A significant heat wave affected Western Europe during July, while a heat wave in France from 15–20 August resulted in temperatures above 36°C in the North and 40°C in the South.

Monthly mean temperatures for November were among the three warmest in the last century across the United Kingdom, Netherlands, Belgium, France, and Germany. In southern Germany, maximum temperatures of around 20°C were reached as a result of foehn winds; such high temperatures are unusual during November.

December was cold especially in the UK and Ireland but also in northern Central Europe and on both sides of the Alps, with anomalies below -1°C. This was mainly due to a long cold spell in the second half of the month.

(ii) Precipitation

Annual precipitation amounts were normal or above normal in Central Europe (Fig. 7.30), though some regions in southern France received only 70–80% of their normal totals. The United Kingdom and Ireland experienced a wet year. Valentia Observatory in Ireland reported its highest annual rainfall total since records began in 1866.

Winter was mainly dry throughout Central and Western Europe (around 60%–80% of normal, Fig. 7.33, DJF), but with heavy snowfall in some areas particularly during February. In February and March, heavy snowfall in parts of the northern Alpine region resulted in peak snow depths of over four meters.

It was the driest spring since 1997 in England and Wales, while March was exceptionally wet in eastern Central Europe; the Czech Republic reported almost double its average March rainfall. April was very dry in eastern Central Europe. Hungary recorded only 23% of its average 1971–2000 April rainfall, while Poland experienced rainfall in the 10th percentile of its 1961–90 distribution.

England and Wales had their wettest July on record, while western Scotland had its wettest August since records began in 1910. This was the third consecutive wet summer in the UK and Ireland (Fig. 33, JJA). In Switzerland, the city of Lugano reported its highest July precipitation (397 mm) since records began in 1864, mainly due to two large thunderstorms during the middle of the month. In contrast, dry conditions in August and September prevailed over Western and Central Europe.

November was the wettest in recorded history across the UK and most of Ireland. The Alps had received intense snowfalls by the end of November. December again was a wet month in most of Western and Central Europe but very dry in Ireland and Scotland.

(iii) Notable events

A severe North Atlantic storm with strong winds up to 174 km hr^{-1} affected the UK and Ireland on 17 January. Another Atlantic storm, with gusts of hurricane force, affected Western Europe on 23–24 January. Southern Ireland saw heavy rain with severe flooding on 29–30 January.

Unusual snow events affected Western Europe at the beginning of the year. On 6–7 January, a Mediterranean storm dropped 20 cm–40 cm of snow across southeastern France for the first time since 1987. At the beginning of February, the United Kingdom experienced its most widespread snowfalls since 1991, resulting in peak snow depths of up to 30 cm. London received its heaviest snowfalls in 18 years. In the Alpine region, the snows lasted until the end of February even at low elevations, which was unusual, especially south of the Alps.

Various episodes of heavy rainfall occurred during summer. On 6 June and 16–17 July, the United Kingdom experienced daily totals of more than 90 mm. Likewise, heavy precipitation, flooding, and mudslides affected Central Europe on 21 June. On 2 July, Dublin was affected by flooding after torrential rainfall. A severe storm on 23 July affected Germany, Poland, and the Czech Republic.

Autumn also had some noteworthy heavy rain events with flooding. On 3 September in northeast Scotland, daily totals exceeded 120 mm. Parts of Aberdeen city centre were flooded with disruptions to roads and rail services. A frontal system moving across the Atlantic Ocean caused record precipitation and widespread flooding in northwestern England on 18–20 November (see sidebar). Central Europe experienced gusts of hurricane force on 23–24 November.

A severe cold spell and heavy snowfall 15–22 December affected most of the region. Temperatures below -20°C were reported in Germany and France. The Netherlands experienced unusually heavy snowfall, with snow depths up to 30 cm. Cold and snowy conditions continued into 2010.