6. REGIONAL CLIMATES—K. A. Shein,[82] Ed.

a. Overview—K. A. Shein[82]

While the anomalous global warmth of 2005 is generally reflected in regional temperatures, various regions of the planet respond differently to climate forcings at many scales, both spatial and temporal. An analysis of globally averaged climate may mask a number of important climatic conditions that have impacted some areas more than others. This section chronicles regional climatic conditions relative to their historical context, and highlights notable atmospheric events of 2005. In fact, most regions experienced some form of record-breaking weather or climate conditions in 2005.

This section is distributed by continent or major land region, and each regional subsection is further divided into logical climatic divisions, either geographic or political. The use of national names in no way implies political preference or precedence. Also, it should be noted that while the large-scale temperature and precipitation anomaly maps (i.e., Figs. 6.1, 6.7, 6.16, 6.17, 6.24, 6.29, and 6.39) all use a 1971–2000 base period for temperature and a 1979–2000 base period for precipitation, discussions of anomalies in individual regions may refer to alternate base periods.

b. Africa

1) Eastern Africa—C. Oludhe,[61] P. Ambenje,[2] and L. Ogallo[60]

The rainy seasons in the Greater Horn of Africa (GHA) are influenced by the intra-annual north–south migration of the ITCZ. In the GHA region, rainfall exhibits strong variability both in space and time. Much of the variability is strongly accounted for by the existence of complex topographic features, including the East African lakes, and is also partly influenced by the movement of the ITCZ. The subregion can, however, be divided into three sectors (Southern, Equatorial, and Northern) based on rainfall onsets and withdrawals. The Southern sector (central and southern Tanzania) experiences a unimodal precipitation regime, with rain occurring between December and April. The Equatorial sector (northern Tanzania, Kenya, southern and extreme eastern Ethiopia, southern Sudan, and the southern half of Somalia) generally exhibits a bimodal rainfall regime, with the "Long Rains" season from March to May and the "Short Rains" extending from October to December. However, both the western and coastal areas also receive substantial rainfall during July and August. In the Northern sector (central and northern Ethiopia, Eritrea, Djibouti, and the northern half of Sudan), the major rainy season is between June and September, but a few areas receive a secondary peak from March to May.

The climate over the GHA is largely regulated by sea surface temperatures in the Indian and Atlantic

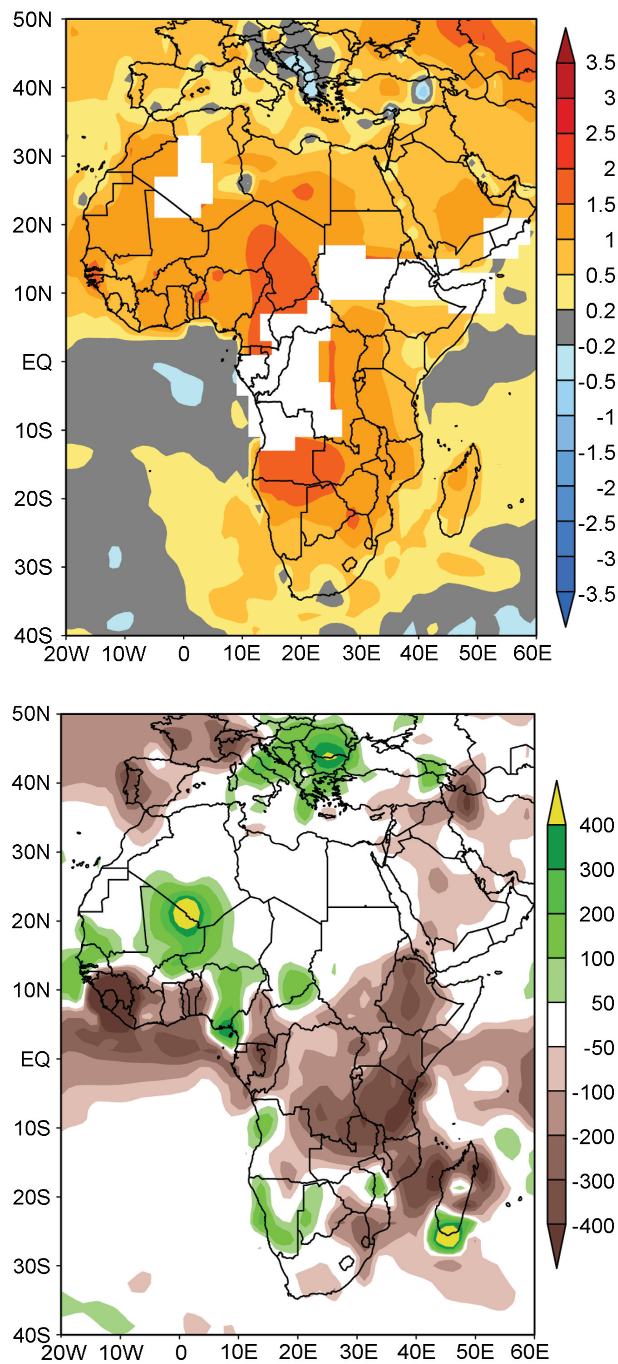


Fig. 6.1. African 2005 annual (top) temperature anomalies (°C; 1971–2000 base), and (bottom) precipitation anomalies (mm; 1979–2000 base) from the CAMS–OPI dataset (Janowiak and Xie 1999). [Source: NOAA/NCDC]

Oceans, general atmospheric circulation and large-scale anomalies (e.g., ENSO, Indian Ocean dipole), Indian Ocean tropical cyclone activity, and the variability of the monsoon.

(i) Climate patterns in the GHA in 2005

Parts of the GHA were under persistent drought throughout the year with most stations recording rainfall much below their long-term mean (Fig. 6.1). In some of the arid and semiarid lands (ASALs), no significant rainfall was recorded for the year. Erratic rainfall and poor temporal distribution was common during the rainy seasons, even in areas that recorded normal to above-normal precipitation.

Most socioeconomic and subsistence activities in the GHA depend directly or indirectly on rainfall. Below-average rainfall during the year had far-reaching socioeconomic impacts, including the loss of life, livestock, and property.

The Southern sector experienced abundant rainfall between December 2004 and February 2005, providing relief, especially in areas such as central and southern Tanzania that had experienced extremely dry conditions during the 2003/04 rainfall season.

From March to May 2005 (Long Rains), most locations over the Equatorial sector received near-normal to below-normal rainfall amounts. There was a general late onset and early withdrawal as well as poor temporal and spatial distribution of the seasonal rainfall in most areas of the sector, especially the ASALs.

The month-by-month evolution of the Drought Severity Index for the Long Rains season indicates that although near-normal to wet conditions were observed at some locations during March and May, long dry spells were predominant, especially during the peak rainfall month of April, which was relatively dry at many locations within the Equatorial sector. Occasional short-lived heavy rainfall events, some exceeding 50 mm in 24 h, significantly contributed to seasonal rainfall totals in some areas. Unfortunately, these events generated flash flooding in some parts of the GHA, displacing thousands of people.

Western and coastal areas of the Equatorial sector recorded significant rainfall from June to August, although totals were slightly below the seasonal average in some areas (Fig. 6.2).

From October to December (Short Rains), most parts of the Equatorial sector received between 25% and 75% of long-term seasonal mean precipitation (Fig. 6.2). Like the Long Rains, the Short Rains were also characterized by poor temporal distribution, and were devoid of the heavy rainfall events common during tropical rainy seasons. The rains ceased in the second half of November instead of the usual mid-December. Performance was extremely poor in the ASALs, enhancing the cumulative rainfall deficiencies these areas had been experiencing for several consecutive seasons. As a result, an estimated five million people in Kenya and Tanzania were affected by famine.

The Northern sector had one major rainfall peak concentrated in June–September, with few areas receiving the usual secondary rainfall peak between March and May. Near- to above-normal rainfall was observed in parts of western and northern areas of the subregion during June–August 2005 (Fig. 6.2). Most locations recorded June–September rainfall totals of 75%–125% of the long-term average. Much of the eastern and central parts of the Northern sector experienced dry conditions, with most locations recording rainfall below 75% of the long-term average.

II) NORTHERN AFRICA—M. A. Bell[6] and K. Kabidi[36]

(i) Temperature

For 2005, mean temperature anomalies were generally between 0.25° and 1.5°C above normal throughout most of North Africa (Fig. 6.1). The year started with below-normal monthly mean tempera-

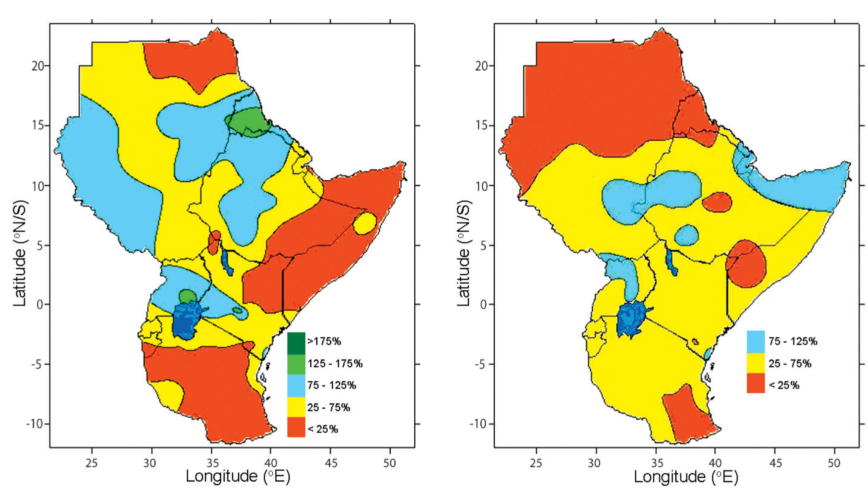


FIG 6.2. East African rainfall anomaly percentages for (left) June to August and (right) October to December 2005. [Source: Kenya Meteorological Service]

tures in January, and particularly in February. Chefchaouen, Morocco, recorded 18 below-freezing days in January. Subfreezing temperatures were recorded in many other areas and broke numerous records. A low of −14°C was recorded in a mountainous area of Morocco. By April, positive temperature anomalies had begun to dominate, and a heat wave in mid-July resulted in at least 13 deaths in Algeria due to sunstroke, according to the British Broadcasting Corporation (BBC). In Algeria, the heat wave pushed July temperatures as high as 50°C.

(ii) Precipitation

The Mediterranean coast of North Africa receives the majority of its rainfall during October–April, largely from midlatitude cyclones and associated cold fronts. In the Atlas Mountains of northern Morocco, Algeria, and Tunisia, cold-frontal passages can bring subfreezing temperatures and heavy rain or snow, occasionally causing floods and landslides.

Accumulated precipitation anomalies for the October 2004–April 2005 rainy season indicate below-normal precipitation totals in most of Morocco (particularly in the north), northwestern Algeria, the southern half of Tunisia, and much of northern Libya, and above-normal precipitation in northeastern Algeria and northern Tunisia (Fig. 6.3).

The precipitation deficits in Morocco developed in November 2004, in concert with the genesis of the severe drought that would plague the Iberian Peninsula and other sections of southwestern Europe for much of the year. Although rain in mid- to late-February provided some relief, dry conditions persisted throughout most of the remainder of the 2004/05 boreal winter rainy season in Morocco. October–December 2005 began the winter rainy season with near-normal precipitation throughout North Africa.

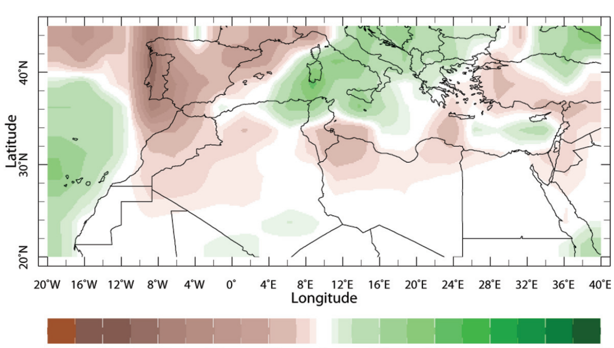


Fig. 6.3. October 2004–April 2005 precipitation anomalies (mm; 1979–2000 monthly means base) for northern Africa from CAMS–OPI.

As discussed in the CPC/Famine Early Warning System Network (FEWS NET) Africa Weekly Weather Hazards Assessments in 2005, although the cooler-than-normal temperatures early in the year may have temporarily reduced moisture demand and partially mitigated precipitation deficits in the major wheat-growing areas of North Africa, the persistence of below-normal rainfall and the development of positive temperature anomalies had a detrimental effect on the region's winter wheat crop, with grain production (including wheat) in 2005 was well below the previous year's record levels in Morocco, Algeria, and Tunisia, and also below the average of the past 5 yr in Morocco and Algeria [Source: U.S. Department of Agriculture (USDA) and United Nations (UN) Food and Agriculture Organization (FAO).]

(iii) Notable events

A winter storm in late January 2005 produced the heaviest snowfall seen in Algiers in "more than 50 years," according to the BBC, and was responsible for at least 10 deaths, primarily due to traffic accidents.

During February, a synoptic low pressure system brought heavy rainfall to the region, with a record of 193 mm falling in less than 24 h at Tetuan, Morocco. This system also brought high wind speeds exceeding 31 m s^{-1} in some places, and waves up to 10 m were recorded along the northwestern Atlantic coast (Fig. 6.4).

The most unusual climatic event recorded during 2005 was the landfall of Tropical Storm Delta. On 29 November, Delta passed to the north of the Canary Islands, where widespread damage and seven fatalities were reported. Soon after, Delta crossed over the southern coast of Morocco in the area of Tantan and Layoune Ports, where it quickly dissipated, but not before delivering much-needed rain to the area.

iii) Southern Africa—W. M. Thiaw,[85] T. Gill,[27] and W. A. Landman[43]

(i) Temperature

Annual mean temperatures across southern Africa for 2005 were generally 0.5°–1.5°C above the 1971–2000 mean (Fig. 6.1). Most of Madagascar was 0.5°–1.0°C above normal. Temperatures were up to 2°C above normal in an area including northern Namibia, southern Angola, northwestern Botswana, and western Zambia. In South Africa, June–August mean temperatures were 2°–3°C above normal over the northeastern parts of the country, 1°–2°C above normal over central regions, and near normal in southern and western sections.

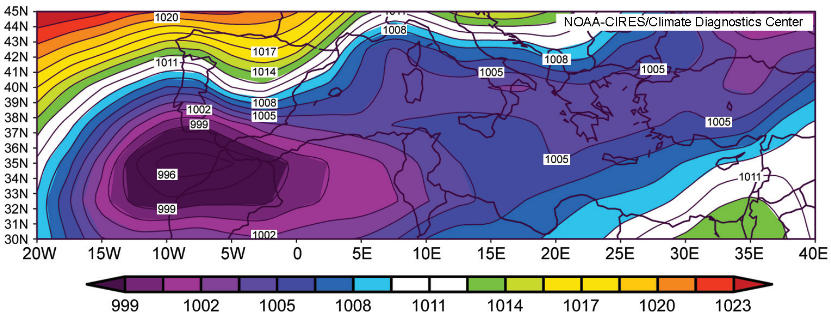


Fig. 6.4. Mean sea level pressure (hPa) over North Africa on 28 February. [Source: NOAA/Cooperative Institute for Research in Environmental Science (CIRES)/Climate Diagnostics Center (CDC)]

(ii) Precipitation

The rainy season in southern Africa extends from October to April, with the greatest amounts typically observed between December and March. In general, ENSO conditions play an important role in the variability of southern Africa rainfall, which tends to be drier than average during El Niño and wetter than average during La Niña.

Overall, the 2004/05 southern Africa rainy season was characterized by near-average rainfall (Fig. 6.1), although delayed onset of the rains in October 2004 and inconsistent rainfall led to deficits in January and February. Rainfall anomalies were quite variable in the wet zone (east of 25°E; Fig. 6.5 boxed region). In this area, 200–400 mm of rain fell during the period of November 2004–April 2005, ranking in the 10th–30th percentile across northeastern Botswana, the eastern half of Zimbabwe, and northeastern South Africa. Rainfall was also below normal in pockets along the east coast of Madagascar. In contrast, central Mozambique and southern Madagascar received from 700 to over 900 mm of rainfall, which ranked in the 70th–90th percentile. Average conditions prevailed in most of interior South Africa, eastern Zimbabwe, and southern Mozambique. Climatologically dry areas of the region registered near- to above-normal rainfall, with amounts in the 70th–90th percentile across southern Namibia.

The low-level atmospheric circulation for the 2004/05 rainy season featured near normal easterly winds (~4 m s^{-1}) along the equatorward flank of the Mascarene high. A significant reduction in low-level easterlies associated with the presence of an anomalous anticyclonic flow in the southwestern Indian Ocean contributed to rainfall deficits in November 2004 and February 2005. In addition, an elongated ridge extending from high latitudes into the continent contributed to strong subsidence in southern Africa.

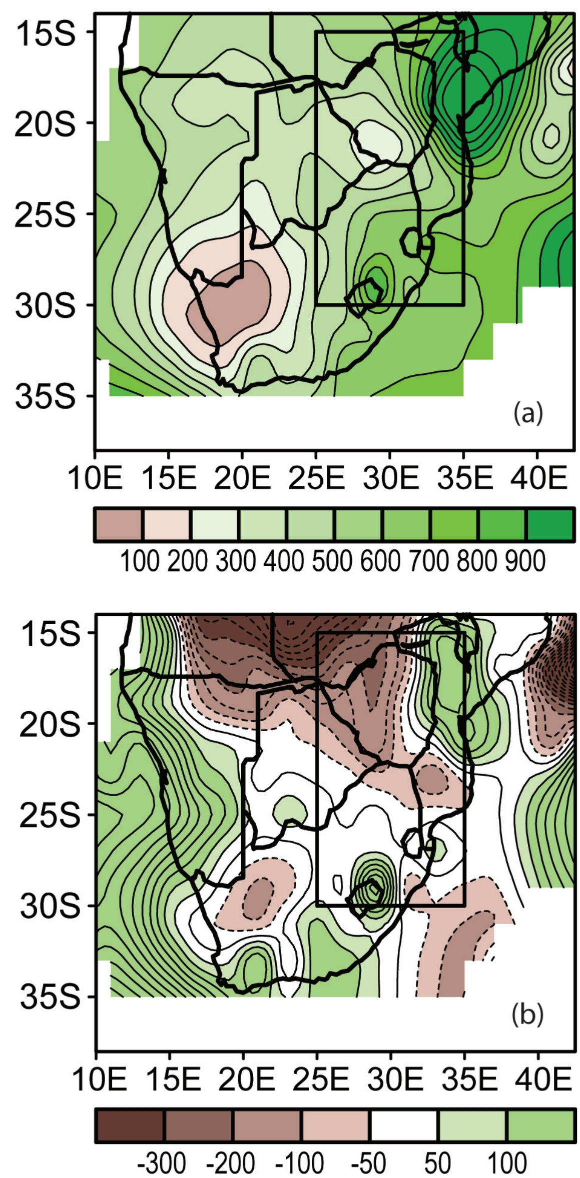


Fig. 6.5. November 2004–April 2005 (a) total rain and (b) precipitation anomaly (mm; 1971–2000 base) for southern Africa. Boxed region is considered the "wet zone."

IV) Western Africa—W. M. Thiaw[85] and M. A. Bell[6]

(i) West African Monsoon

West African rainfall can be divided into two quasi-homogeneous regions: the Sahel and the Gulf of Guinea. Rainfall in both areas is controlled by the annual progression of the ITCZ over the region. The African Sahel, defined here as the region between 12°–20°N, 18°W–20°E (Fig. 6.6, boxed region), receives approximately 90% of its mean annual rainfall during June–September. The rainfall is monsoonal and its penetration into the region is closely related to the position of the mid- and upper-level jets, and to the ITCZ, which starts its northward progression in March and reaches its northernmost position in August. Seasonal precipitation exhibits a strong meridional gradient, with average totals exceeding 600 mm in the south, and 100–300 mm in the north. These larger-scale circulation features are fairly sensitive to changes in the global monsoon circulation on both interannual and interdecadal time scales.

Further south, along the central Gulf of Guinea coast, the rainy season is bimodal and runs from about April to October, typically with a "little dry season" in July–August. This configuration produces an extremely marked north-to-south gradient in annual precipitation totals across the region.

(ii) Precipitation

The 2005 rainy season featured above-normal rainfall across most of the Sahel (Fig. 6.6). Rainfall totals exceeded 100 mm above average across most of the central and western areas of the Sahel. Overall, the 2005 rainy season was the second wettest since 1994.

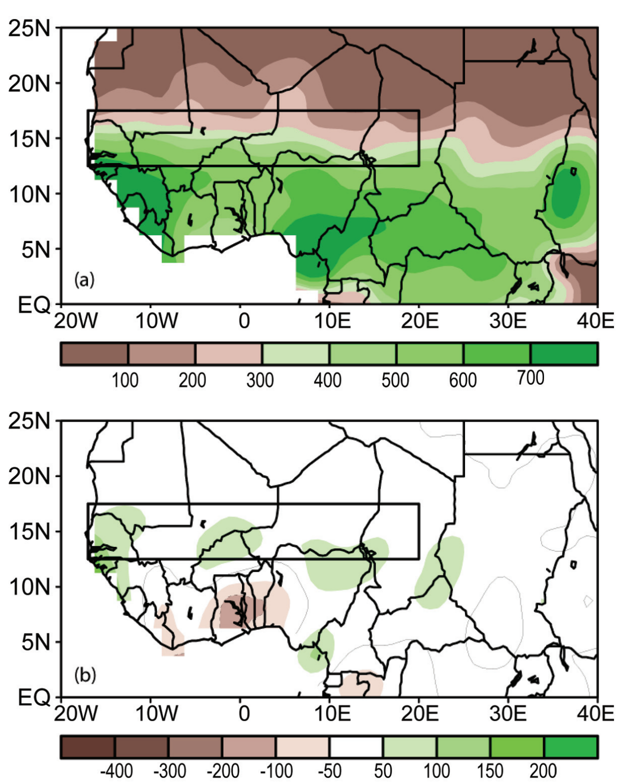


Fig. 6.6. June–September 2005 (a) total rainfall and (b) anomalies (mm; 1971–2000 base) for western Africa. Boxed region is the Sahel.

In particular, most of Senegal and southern areas of Mauritania, northern Burkina Faso, eastern Mali, southern and western Niger, and southeastern Nigeria received above-normal rainfall throughout most of the rainy season, with the exception of July precipitation in southeastern Nigeria. Rainfall anomalies were extremely strong over western Senegal, which received around 700 mm of rainfall between July and September (Fig. 6.6). That is about 300 mm above the long-term mean, making 2005 the rainiest season in this area since 1970. Seasonal totals along most of the Gulf of Guinea coast, from Côte d'Ivoire to western Nigeria were below normal, particularly in central Benin and Côte d'Ivoire. Rainfall deficits ranged between 50 and 200 mm below the climatological mean in the central areas of Ghana, Togo, and Benin.

Heavy rainfall in June, near the start of the rainy season in Guinea and Guinea-Bissau, reportedly sparked a severe cholera epidemic that would eventually spread to at least nine countries in West Africa over the course of the last half of the year, according to the World Health Organization (WHO). Initially, cases were largely confined to the capital city of Bissau, but it spread quickly. Heavy rainfall in Dakar, Senegal, from mid-August through early September not only flooded areas of the city's outer suburbs and forced the evacuation of approximately 60,000 people, but it also triggered a sharp increase in the number of local cholera cases. According to WHO statistics available in late September 2005, at least 43,638 cases of the disease and 759 deaths had been reported throughout West Africa. The end of the rainy season and a lack of new reported cases by the end of December allowed the Ministry of Health in Guinea-Bissau to declare an end to the epidemic in that country, according to the UN Integrated Regional Information Networks (IRIN).

c. North America

1) Canada—C. Kocot,[39] D. Phillips,[67] and R. Whitewood[92]

The climate of Canada in 2005 was characterized by warmer and wetter conditions than normal (relative to the 1951–80 base period). Although Canada was spared much of the extreme weather that impacted other regions of Earth, it was not totally immune. Anomalous winter warmth adversely impacted snowpack in British Columbia (BC). Several tornadoes and heavy flooding in three provinces contributed to 2005 being the costliest year to date, weatherwise, for insurers.

(i) Temperature

Above-normal temperatures were observed throughout the country, with most areas at least 1°C above normal (Fig. 6.7). Departures of 3°C above normal were experienced in the southwest corner of the Yukon Territory. The 1.7°C above-normal (1951–80 mean) average national temperature experienced by Canada in 2005 marked it as the ninth consecutive year of above-normal temperatures (Fig. 6.8). Overall, 2005 tied 2001 and 1999 as the third warmest year since reliable nationwide records began in 1948. The year's national average is exceeded only by 1998 (+2.5°C) and 1981 (+2.0°C).

Ten of the 11 Canadian climate regions had temperatures that ranked among the 10 warmest years in their records. However, of those, only the north BC mountains/Yukon region tied 1981 for its warmest year (+2.8°C). The remaining nine regions were the following: Arctic mountains and fjords (second warmest, +2.0°C); Pacific coast (fifth warmest, +1.2°C); northwestern forest (sixth warmest, +2.0°C); Arctic tundra (sixth warmest, +1.7°C); northeastern forest (sixth warmest, +1.4°C); Mackenzie district (seventh warmest, +2.1°C); Atlantic Canada (seventh warmest, +0.9°C); south BC mountains (eighth warmest, +1.1°C); and Great Lakes/St. Lawrence (ninth warmest, +1.1°C). The lowest-ranked region, the prairies, experienced its 11th warmest year (+1.2°C). Over the 58-yr period of record (1948–2005), all 11 regions show a positive annual temperature trend, with the greatest increase (+2.2°C) in the north BC mountains/Yukon and the smallest (+0.1°C) in Atlantic Canada.

(ii) Precipitation

In 2005, Canada experienced its wettest year in the 58 years since reliable nationwide records commenced (Fig. 6.7). The 13.4% above the 1951–80 mean displaced the previous record of +9.1% (1996). Areas with precipitation values over 20% above normal in 2005 were most of Yukon, some of the southern Northwest Territories, most of Nunavut, the southwest coast of BC, southern Alberta, most of Saskatchewan and Manitoba, the extreme north of Quebec, and the western part of Nova Scotia. Areas with precipitation amounts at least 20% below normal were along the west coast of BC, the eastern edge of BC, and the western edge of Alberta. The remainder of the country was close to normal.

Regionally, six climate regions experienced conditions in 2005 that would rank them among the 10 wettest years: Arctic tundra (second wettest, +23.1%); northwestern forest (second wettest, +12.8%); Arctic mountains and fjords (fifth wettest, +32.0%); Mackenzie district (fifth wettest, +19.9%); north BC mountains/Yukon (fifth wettest; +19.1%); prairies (seventh wettest, +18.2%). While no region ranked 2005 as the record wettest, a sufficient portion of the country was enough above normal to collectively produce Canada's wettest year on record. The three driest regions of the country were south BC mountains (–3.8%), Pacific coast (–5.5%), and Great Lakes/St. Lawrence (–3.5%). These three regions recorded only slightly drier-than-normal conditions.

(iii) Notable events

Although 2005 started out dry across the province, a series of June storms drenched portions of southern Alberta, resulting in widespread flooding as rain-swollen rivers escaped their banks. Extensive damage was reported to dwellings and infrastructure in over 40 municipalities. At 247.6 mm, Calgary recorded its wettest June on record (79.8 mm is normal). Outside

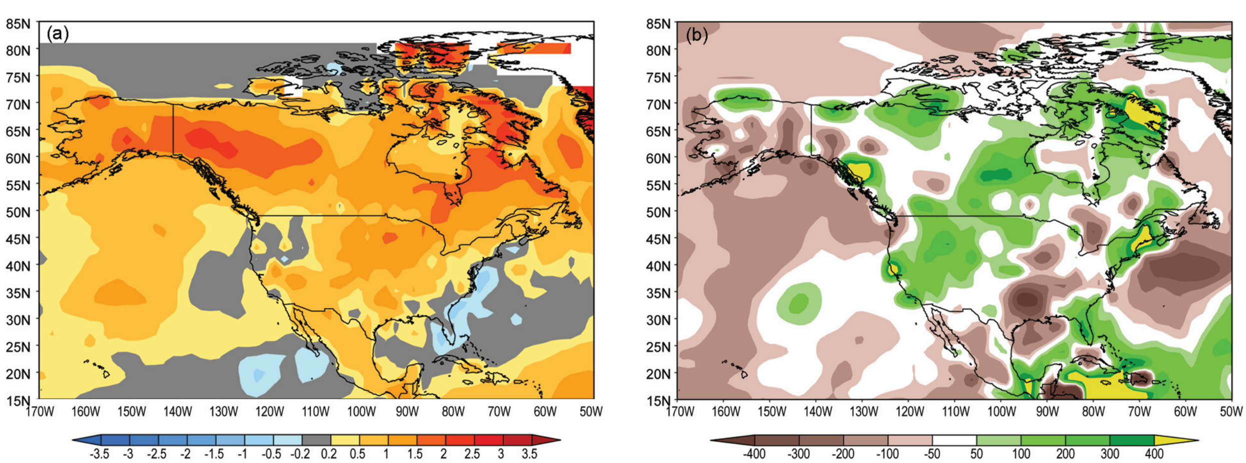


Fig. 6.7. North American 2005 annual (left) temperature anomalies (°C; 1971–2000 base), and (right) precipitation anomalies (mm; 1979–2000 base) from CAMS–OPI.

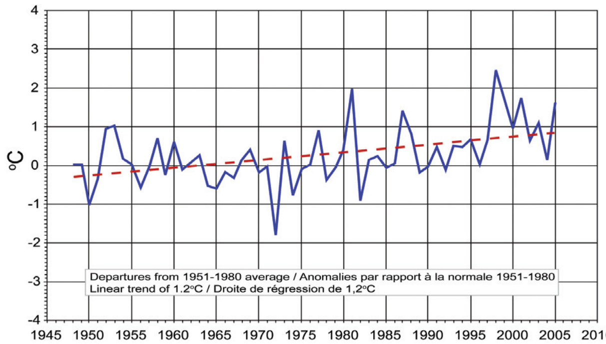


Fig. 6.8. Annual average air temperature anomalies (°C; blue) and 1948–2004 trend (red) for Canada. [Source: Environment Canada]

the city, monthly rainfall approached 400 mm. Total losses are estimated at $400M (million) Canadian dollars (CAD; $344M USD) of which $275M CAD ($232M USD) was insured, making this weather event one of the costliest in Alberta's history.

Manitoba was treated to rare and record widespread flooding as the result of frequent and intense June and July thunderstorms. The Churchill River crested at its highest levels ever recorded and Manitoba Agriculture estimated more than a quarter of the province's farmland was inundated during the flooding.

A line of severe thunderstorms tracked across southern Ontario on 19 August, leaving record damage estimated at over $500M CAD ($430M USD). The storms spawned two F2 tornadoes and a rare tornado warning was issued for Toronto. In and around Toronto, ~45 mm diameter hail, straight line winds with gusts reaching 72 km h^{-1}, and rainfall rates exceeding 100 mm h^{-1} generated the most damage.

The 2005 sea ice extent in Canadian Arctic waters dropped to its lowest level on record, 5.3 million km^2; down 20% from 1978 when satellite observations began. The previous record minimum of slightly less than 6 million km^2, was set in 2002. Since the 1970s the geographical extent has been decreasing by around 8% decade^{-1}.

The Canadian International Forest Fire Centre (CIFFC) reported a near average fire year in Canada in terms of the number of fires (7438; –1.3% of normal), but with significantly fewer hectares (ha) of forest consumed, 1.7 million ha, or ~68% of the 1995–2004 mean. The total number of fires in 2005 was down in most provinces and territories, with notable exceptions in Ontario (1961 fires; +51% of normal) and Quebec (1374 fires, +57% of normal). In contrast, and with respect to the total area affected, all provinces and territories, with the exception of Quebec, reported lower than average area burned. The total area burned within the province of Quebec in 2005 (831,022 ha) however, accounted for ~49% of the national total.

ii) United States of America—K. L. Gleason[28]

(i) Overview

Reliable weather records for the United States exist from 1895 to the present, enabling the climate of 2005 to be placed in a 111-yr context for the contiguous United States. The nationally averaged temperature in 2005 was the seventh (105 of 111 years) warmest on record, with an annual mean of 12.3°C (+0.8°C relative to the period of record). The linear temperature trend for the 111-yr record over the contiguous United States is 0.056°C decade^{-1}, with an increase to 0.32°C decade^{-1} since 1976. Seven of the ten warmest years on record for the United States have occurred since 1986.

Precipitation in the United States in 2005 was variable throughout much of the country, with periods of excessive rainfall in the Southwest and Northeast, persistent drought in portions of the Northwest, and developing drought from the Southern Plains to the Great Lakes. Nationally, it was the 43rd wettest year on record, which is near the long-term mean. Maine and New Hampshire had their wettest year on record, surpassing 1909 and 1954, respectively. Conversely, Arkansas had its second driest year since 1895.

Temperature and precipitation anomalies for the United States are based upon the 1895–2005 data record, rather than on any particular 30-yr normal statistics (e.g., 1971–2000 mean). With respect to the United States, temperature or precipitation is described as "much above" or "much below" normal when the value falls within the top or bottom 10% (decile) of the historical record distribution. Temperatures are simply "above" ("below") normal if they fall within the upper (lower) third, or tercile, of the distribution, but are not in the top (bottom) decile. Values falling within the middle tercile are considered near normal.

(ii) Temperature

Temperatures were above average across most of the contiguous United States from December 2004 to February 2005, with no state ranking below average. Colorado, Wyoming, and Utah were much above normal for the season. From March to May (spring) was exceptionally cool from Texas to Florida and along the entire eastern seaboard. Eleven states had below-average seasonal temperatures. Three additional states reported much-below-average temperatures for the season (Fig. 6.9, left). Extremely cool May temperatures covered the Northeast and Mid-Atlantic coast, with seven states (Connecticut, Rhode Island, Massachusetts, Pennsylvania, Delaware, Maryland, and South Carolina) experiencing one of their 10 coldest Mays on record.

In contrast, record to near-record summer (June–August) heat occurred from the Great Lakes into the Northeast with record seasonal heat in New Hampshire and New Jersey. Much-above-average temperatures in the southwestern United States during July resulted from an upper-level ridge situated over the region for most of the month. Temperatures exceeded 38°C (100°F) and broke more than 200 daily records in six western states. A new record of seven consecutive days at or above 52°C (125°F) was observed in July at Death Valley, California (previous record of five days). A persistent upper-level cyclonic circulation positioned over the central United States into August contributed to above-average summer temperatures across the eastern United States, where August temperature records were set in New Jersey and Rhode Island. No state in the contiguous United States reported below-average temperatures during the season.

An uncharacteristic blocking ridge over Alaska fostered an exceptionally warm and dry summer throughout the state. Statewide June–August 2005 temperatures were third warmest since reliable records began in 1918. Overall, 2005 was Alaska's sixth warmest year on record, and was the sixth consecutive above-average year for the state (Fig. 6.10).

Autumn (September–November) temperatures were much above average across large parts of the southern and central United States and portions of the Northeast and Mid-Atlantic, with warmer-than-average temperatures present throughout all but three states in the Pacific Northwest (Fig. 6.9, right). The contiguous United States recorded its fourth warmest autumn in the last 111 years. This near-record heat resulted from a quasi-stationary 500-hPa ridge situated across eastern North America. No state in the contiguous United States was cooler than average during this season.

(iii)Precipitation and drought

Average precipitation for the contiguous United States in 2005 was 755 mm, slightly above the long-term (1895–2005) mean of 740 mm. Precipitation across the United States in 2005 was characterized by persistent moderate wetness in the Northeast and Southwest, below-average precipitation in some parts of the Northwest, and developing dryness from the Southern Plains into the Great Lakes (Fig. 6.9). An area from Texas to parts of the Midwest and Ohio Valley was drier than normal. Also, despite the significant rainfall associated with Hurricanes Katrina and Rita, Arkansas and Louisiana reported much-below-normal precipitation for the year. Conversely, Maine and New Hampshire had their wettest year on record, and most states had above- or much-above-normal precipitation.

December 2004 through February 2005 was very wet from the California coast, through the Plains, and into the Great Lakes and Northeast. There also was much-above-normal precipitation around the Great Lakes. A strong blocking high over the Gulf of Alaska in conjunction with an amplified trough over the southwestern United States generated an active storm season along the West Coast. However, March marked the beginning of a very dry period across the central United States, extending from

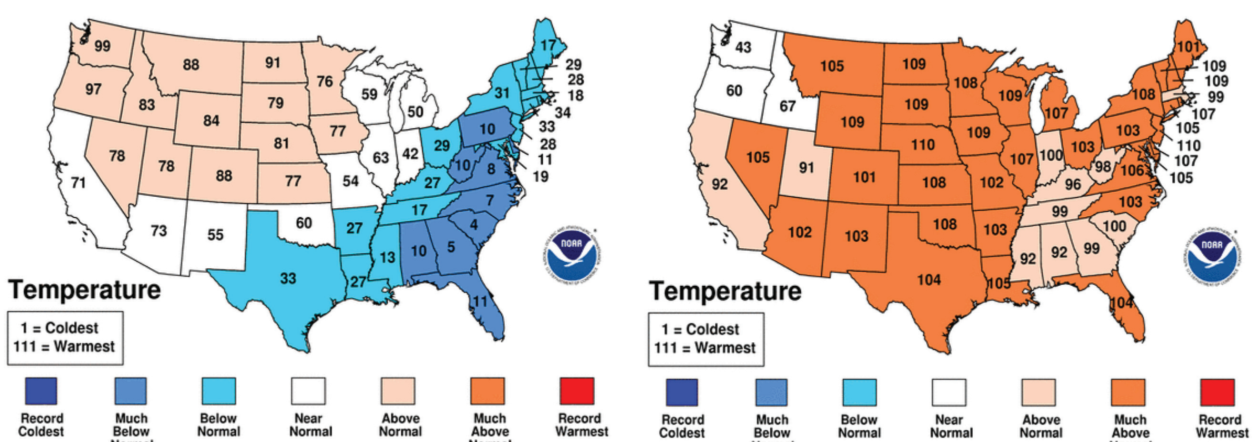


Fig. 6.9. Statewide rankings of temperature as measured across the contiguous United States in 2005: (left) March–May and (right) September–November. A rank of 111 (1) in the U.S. Historical Climatology Network (USHCN) record represents the warmest (coldest) season since 1895.

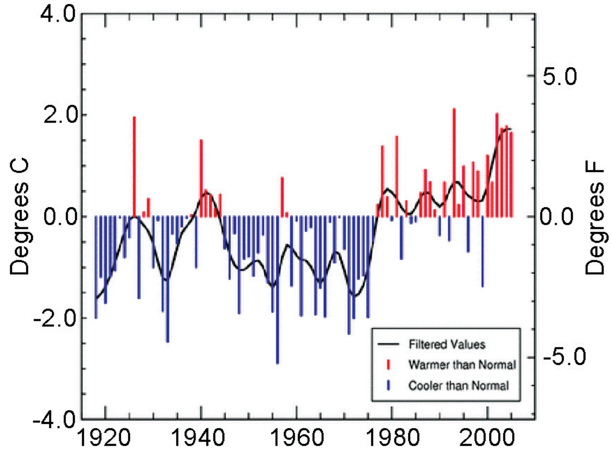


FIG. 6.10. Alaska statewide average annual temperature anomalies (°C), 1919–2005. [Source: NOAA/NCDC]

Texas to the Great Lakes (Fig. 6.11). An active storm track across the western United States led to above to much-above-normal precipitation in the West, the Northern Plains, the Southeast, and the far Northeast.

Boreal summer (June–August) brought much-above-normal rainfall to the Southeast and parts of the central and northern Great Plains. Only nine states experienced below-normal precipitation, and just one state (New Mexico) much-below-normal summer precipitation. Stormy conditions contributed to a record wet October and fall season across much of the region. Six states (Maine, Vermont, New Hampshire, Connecticut, Rhode Island, and Massachsetts) reported their wettest fall on record, and nine states set a record for the wettest October, with two additional states reaching their second wettest. Mt. Washington, New Hampshire, set a record for the greatest October snowfall on record (200 cm), exceeding the previous record set back in 2000 by 102 cm.

The year ended with a very dry December from the Southwest, across the Southern Plains, to the Ohio Valley and eastern Great Lakes. Several states from the Southwest to the Lower Mississippi Delta had one of their 10 driest Decembers; Arizona and Arkansas had their driest December on record. December capped a three-month period of much-drier-than-normal weather in the Southern Plains, with Arkansas and the Arklatex region (nexus of Arkansas, Texas, Louisiana, and Oklahoma) all experiencing the driest October–December on record.

At the beginning of the year, approximately 8% of the contiguous United States was in moderate to extreme drought, as defined by the Palmer Hydrological Drought Index (PHDI; Palmer 1965; Heim 2002). The areal extent of moderate to extreme drought grew to reach a peak of 21% of the contiguous United States in December 2005 (Fig. 6.12). Precipitation deficiencies from March to June and again from September to December resulted in the emergence and intensification of drought conditions from the Texas Gulf Coast to the Great Lakes. Northeastern Illinois and the Arklatex region were significantly impacted by the emerging drought.

The development of drought conditions in parts of the Midwest and Southern Plains can be attributed to a pronounced shift in synoptic circulation in March–June and October–December. During both periods, the northern branch of the polar jet was active across the western United States, while the southern branch was active over the United States. Southeast and Atlantic coast. The resulting absence of storms from the Deep South to the Great Lakes created substantial precipitation deficits. The lack of precipitation from October to December left Arkansas with its driest of such periods on record and Louisiana with its third driest.

The same synoptic conditions brought above to much-above-normal rainfall to the northwestern United States during the spring and the last two months of 2005, contributing to a significant reduction in total drought area across parts of the Northwest by the end of the year. The western United States drought of 1999–2004 was one of the most severe droughts in this region over the last 100 years. More than five years of precipitation deficits lowered streamflows and depleted reservoirs. Some reservoirs recovered during 2005, but aggregated reservoir levels were still below average at the end of the year.

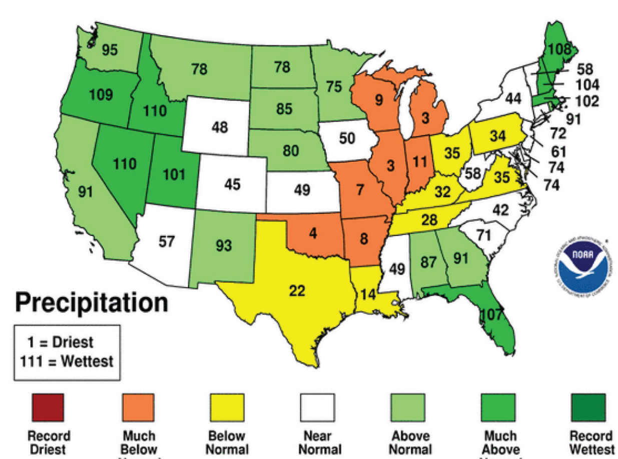


FIG. 6.11. March–May 2005 statewide ranks of precipitation for the contiguous United States. A rank of 111 (1) in the USHCN record represents the wettest (driest) year since 1895.

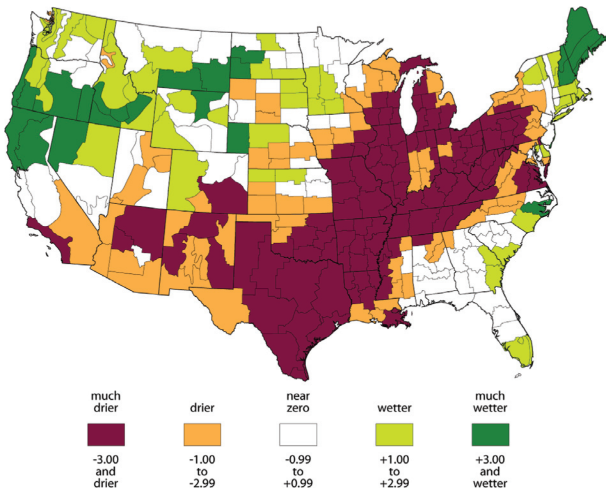


Fig. 6.12. Change in the PHDI between 1 January–31 December shown by U.S. Climate Division. [Source: NOAA/NCDC]

(iv) Snowpack and wildfires

(a) Snow

The 2004/05 snow season and snowpack was generally above average across the Southwest and much below average across the northern Rockies and Pacific Northwest. By the end of the 2004/05 winter, the Northwest snowpack was just 50% of normal. Snow cover was slightly below average for the North American continent as a whole over the winter, and much below average for the spring. This is consistent with a trend toward reduced spring snow cover over North America (Mote et al. 2005). Snow cover has been below average in all but four years since the mid-1980s.

Notable snow storms in 2005 include a major winter storm, referred to as the "Blizzard of 2005," which deposited well over 30 cm of snow across much of southern New England in January. Boston, Massachusetts, had its snowiest January on record partly as a result of that storm. NOAA's operational Northeast Snowfall Impact Scale (NESIS), developed by Kocin and Uccellini (2004) to characterize and rank high-impact northeastern U.S. snowstorms, ranked this January snow storm as the seventh most intense on record for the region. In other regions, a late-season (April) snow event produced over 61 cm of accumulation in the mountains west of Denver, Colorado, and a significant snow storm on 27–28 November generated blizzard conditions across the northern High Plains, accumulating up to 61 cm of snow in parts of Nebraska and the Dakotas.

In contrast to the above-average snowfall season in 2004/05, the beginning of the 2005/06 snow season in the Southwest was nearly nonexistent. An examination of USDA snowcourse/snow telemetry (snotel) station data in Arizona revealed that 31 of 33 sites (94%) were snow free at the end of 2005—the most snow-free locations in at least the past 40 years.

(b) Wildfires

Preliminary estimates from the National Interagency Fire Center suggest that 2005 will break the record set in 2000 with over 3.45 million ha (8.53 million acres) burned. During the 2000 fire season, roughly 3.41 million ha were consumed across the entire United States, with over 2.83 million ha burned in the contiguous United States. Despite the record area burned, the total number of fires across the country continued to decline in 2005, suggesting the average size of individual fires has increased over the past 20 years.

In Alaska, over 1.78 million ha burned in 2005, compared to nearly 2.43 million ha consumed in 2004, which was the worst fire season on record for the state. Above-average temperatures coupled with below-normal precipitation during the summer months contributed to the above-average wildfire season across Alaska in 2005.

Atypical wildfire activity erupted across parts of the central United States during December 2005. Numerous large fires, enhanced by extreme drought conditions, developed across parts of Oklahoma, Texas, and the Southern Plains. Many of these fires continued to burn into early January 2006. Over 162,000 ha had burned across the Southern Plains during the first week of the New Year, normally a time of very low fire activity.

(v) Severe extratropical storms

Preliminary estimates indicate there were only nine very strong to violent tornadoes (F3–F5 on the Fujita scale) during the 2005 official tornado season (March–August), all of F3 intensity. This was significantly below the 1971–2000 mean of 37, contributing to a slight negative trend in very strong to violent tornadoes observed since 1950. However, two late-year (out of season) tornado outbreaks increased the annual total.

A severe weather outbreak accompanied by over 30 reported tornadoes occurred across Mississippi and Louisiana in April. In June, tornadoes ripped through the town of Hammond, Wisconsin, causing over $3 million USD in damage. Severe thunderstorms in August generated tornadoes that killed at least three people in Wisconsin and Wyoming. Tornadoes also touched down in September across parts of the central United States between Oklahoma and Wisconsin. On

6 November, a deadly Midwestern tornado outbreak claimed 24 lives in and around Evansville, Indiana. This was the deadliest United States outbreak since 1998. Additional severe weather impacted the same region on 15 November, with over 30 tornadoes reported. Among these was the strongest tornado of the year, an F4 twister that reached a higher intensity than any of the tornadoes that developed during the official season.

iii) Mexico—M. Cortez Vázquez[18]

(i) Temperature

In 2005, the areally averaged annual mean temperature for Mexico was 21.4°C, which is 0.7°C warmer than normal (based on the period of record, 1980–2004). The year, 2005, was ranked as the second warmest, behind 1998, since the start of the national temperature dataset in 1980 (Fig. 6.14). The warmth in 2005 continued the trend of above normal temperatures in Mexico since the mid-1980s. Nationally, the lowest minimum temperature for the year was –17°C, reported in the mountains of Durango in northwest Mexico, the same area that holds the long-term historical record minimum temperature of –25°C reported in December 1997 (based on 1980–2005 data). In 2005, maximum temperatures of 49.5°C were reported in Chihuahua and Michoacán, and these temperatures were only 0.5°C less than the national all-time historical record temperature of 50°C.

(ii) Precipitation

Nationwide, the areally averaged rainfall was 778 mm, which was 14.5 mm (2%) above the long-

U.S. CLIMATE EXTREMES INDEX (CEI)—K. L. Gleason[28]

How has the climate changed over the past century? In what ways is it changing and by how much? Many people, including climatologists, have been struggling with these questions for some time now, not only for scientific interest, but also to aid in policy decisions (Houghton et al. 2001) and to inform the general public. In order to answer these questions, it is important to obtain comprehensive and intuitive information that allows interested parties to understand the scientific basis for confidence, or lack thereof, in the present understanding of the climate system. One tool, first developed as a framework for quantifying observed changes in climate within the contiguous Unites States, is the United States Climate Extremes Index (CEI).

The CEI was first introduced in early 1996 (Karl et al. 1996), with the goal of summarizing and presenting a complex set of climate changes in the United States so that the results could be easily understood and used to aid decision making by policy makers. The CEI initially consisted of a combination of five separate climate change indicators. Recent revisions include a sixth indicator related to extremes in landfalling tropical system wind speed. The CEI is also now evaluated for nine standard periods or seasons including: spring (MAM), summer (JJA), autumn (SON), winter [December–February (DJF)], warm (April–September), cold (October–March), hurricane (June–November), year to date, and annual (January–December). The CEI conveys the percentage area of the United States that has been affected by climate extremes as they relate to monthly maximum and minimum temperatures, daily precipitation, and the Palmer Drought Severity Index (PDSI) within a given period.

The annual CEI for 2005 was about 41%, which is much above the expected value of 20% and is the second largest value since reliable records began in 1910 (Fig. 6.13). This high 2005 CEI was due to the combined impacts from a record active Atlantic hurricane season, extremes in monthly maximum and minimum temperature, much-above-normal wet PDSI, and extremes in daily precipitation. In addition, the 2005 hurricane and cold seasons had record CEI percentages. Approximately 44% of the United States was affected by climate extremes during the hurricane season and nearly 38% during the cold season. All six indicators were well above the expected percentage during the hurricane season. Extremes in much-above-average mean minimum temperature were more than five times the expected value. Much-above-average mean maximum and minimum temperatures, a wet PDSI, and the large number of days with precipitation all contributed significantly to the record extreme 2005 cold season. A more detailed explanation of the CEI and graphs of the most current CEI and the individual indicators that comprise the CEI may be viewed at the NCDC CEI Web site at www.ncdc.noaa.gov/oa/climate/research/cei/cei.html.

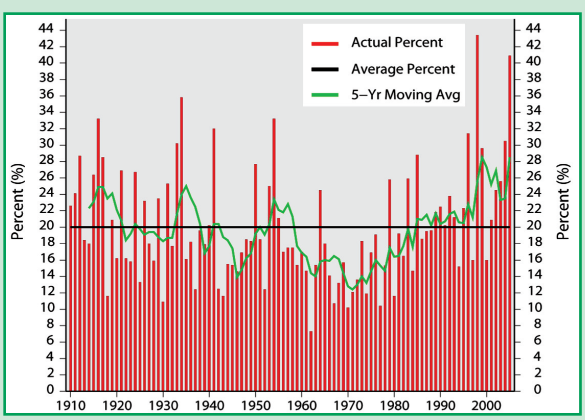


Fig. 6.13. Annual U.S. Climate Extremes Index values (1910–2005). [Source: NOAA/NCDC]

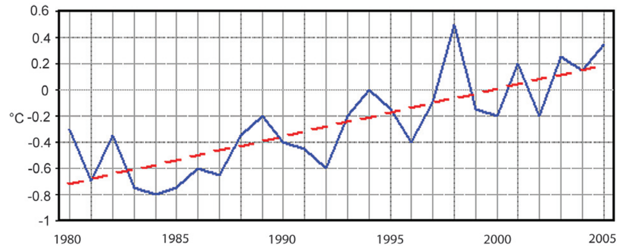


Fig. 6.14. Annual temperature anomalies (°C) over Mexico (1980–2005).

term climatological mean defined by the period of 1941–2004. The year ranks as the 25th wettest on record. Although the annual rainfall total was slightly above average, rainfall distribution was very irregular throughout the year. The rainy season (June–October) was characterized by short events of heavy rainfall, which were mainly associated with tropical cyclones that approached Mexico from the Atlantic side of the continent. Wet conditions were observed in February, followed by a dry trend from March to May. The onset of the summer rainy season started 3–4 weeks later than normal in southern Mexico, and this delay influenced the northward progression of the monsoon during the early summer. The 2005 rainy season was finally established after mid-June, with exceptionally wet conditions being recorded in July and again in October. Large rainfall deficits developed in September, which is normally the wettest month on average for Mexico. Although the total amount of rainfall was slightly above normal, precipitation was localized over small areas in the south and southeast, around the tracks of landfalling tropical cyclones.

Portions of northern Mexico also received significant amounts of rain during February, associated with midlatitude systems. However, an early withdrawal of the summer monsoon in northern Mexico, along with a persistent meteorological drought in the western part of the country during the entire summer, resulted in limited water storage at all dams and hydrological drought declarations by year-end along the Lerma–Chapala and Cutzamala Basins.

(iii)Notable events

Climatologically, the annual rainfall distribution in Mexico clearly reflects the influence of tropical cyclone activity on both sides of the country (Fig. 6.15). The southwest coast and western Mexico typically receive appreciable rainfall from Pacific tropical storms, but during the 2005 season the storms developed and tracked farther offshore than normal (see section 4c). This helped to depress rainfall totals in western and northwest Mexico, with only two systems (Dora and Otis) approaching the Pacific coast states. In contrast, a very active season was observed in the Atlantic and Caribbean basins, with seven systems making landfall in Mexico: Hurricanes Emily, Stan and Wilma; Tropical Storms Bret, Gert, and Jose; and Tropical Depression Cindy. The number of landfalling tropical cyclones in Mexico in 2005 represented a new record since the start of the satellite era. In southeast Mexico, Stan produced abundant rainfall across the Yucatan Peninsula on 2–3 October before moving into the states of Veracruz and Oaxaca. Pentad and monthly rainfall totals exceeded 200% of normal along and to the right of Stan's track into mainland Mexico, with heavy flooding in portions of northern Veracruz and Oaxaca. Stan developed a large moisture tap across the Pacific slope of Chiapas and this promoted widespread flooding along the Pacific slope of Chiapas, and sections of Central America. By far the most destructive tropical cyclone during the 2005 season was Wilma, which moved slowly across the Yucatan Peninsula on 20–23 October causing severe economic loss and several fatalities in the Cozumel and Cancun areas. Based upon wind speeds and sea level pressure readings, Wilma was the most powerful hurricane on record to make landfall in Mexico.

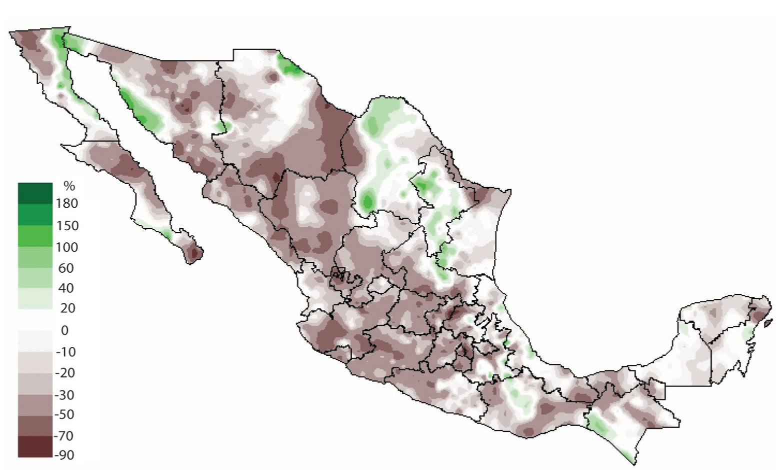


Fig. 6.15. Percent of normal precipitation across Mexico during the 2005 rainy season (May–October) relative to the 1941–2005 mean.

d. *Central America and the Caribbean*—E. K. Grover-Kopec[31]

I) Temperature

Annual mean surface temperatures were slightly above average across Central America and the Caribbean during 2005 (Fig. 6.16). Temperatures were at least 0.5°C above normal for the year over the entire region except for western Cuba and the Pacific coastal regions of Costa Rica and Panama. The warmest conditions, relative to climatology, were observed in Guatemala and Belize, where annual departures from the 1971–2000 mean exceeded 1°C.

II) Precipitation

Most of the Central American isthmus experienced drier-than-normal conditions in 2005, though precipitation deficits were not as severe and widespread as those seen in recent years. The most significant standardized 12-month precipitation anomalies occurred across Honduras, Nicaragua, central Costa Rica, and southern Panama (Fig. 6.16). The largest absolute annual precipitation deficits compared to the 1979–2000 base period were observed in this same region. Negative anomalies exceeding 1000 mm were observed in eastern Honduras and Nicaragua, accounting for approximately half of the climatological mean annual precipitation in these areas, typically among the wettest regions in Central America.

The largest contrast between the precipitation regime of 2005 and that of recent years was observed in the Caribbean, particularly in Jamaica, eastern Cuba, and western Haiti. Drought conditions, which have had a large impact on water resources and agriculture over the past few years in Cuba (Levinson 2005), eased a bit as the eastern portion of the island received 25% more precipitation than normal during the year. Much of this excess precipitation came during May, June, and October, which are among the wettest months of the year in that area. The climatological precipitation distribution across most of the Caribbean and Central American region is bimodal, with relative maxima occurring in May–June and September–October.

III) Notable events

The record-breaking 2005 Atlantic hurricane season (see section 4 sidebar) caused devastating losses across the region from July to November. Most damage came from Hurricanes Dennis, Emily, Stan and Beta, and Tropical Storm Gamma, which primarily affected the countries of Cuba, Grenada, Guatemala, Nicaragua, and Honduras, respectively.

While all of these storms had tremendous localized impacts, Stan was arguably the most destructive and certainly the deadliest in the region, affecting eight countries in early October. The storm brought 150–400 mm of precipitation to western Guatemala. One-third of the population of Guatemala was affected by Stan and more than 1000 deaths were reported. Agence France-Presse and Reuters reported that most of these deaths occurred when mudslides buried the villages of Panabaj and Tzanchal in the southwestern department of San Marcos, where some of the largest precipitation accumulations were reported.

e. *South America*

I) Overview—M. Rusticucci[78] and J. L. Camacho[13]

South America experienced below-normal precipitation anomalies across a majority of the conti-

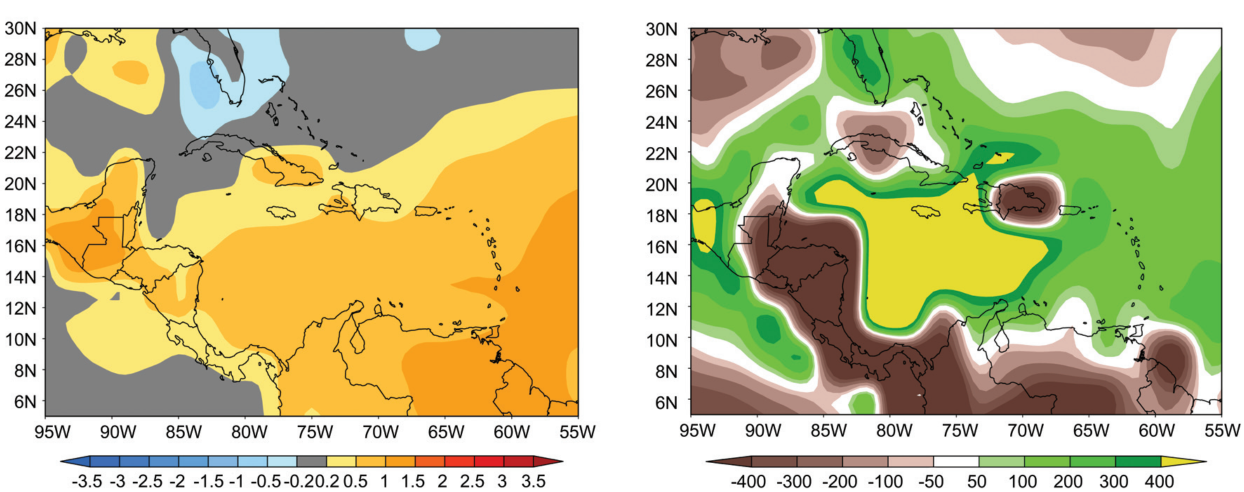


Fig. 6.16. Central American and Caribbean 2005 annual (left) temperature anomalies (°C; 1971–2000 base), and (right) precipitation anomalies (mm; 1979–2000 base) from CAMS–OPI.

nent in 2005, with some excesses in the northwest and southwest (Fig. 6.17). However, despite overall deficits, extreme but inconsistent and widely scattered precipitation events over most of the continent adversely impacted the population. Additionally, anomalously frequent cold air advection from higher latitudes was experienced by both the north and south sides of the continent.

Most of northern and eastern South America experienced temperatures above the 1961–90 normal, while western parts were below average. This is generally reflected in Fig. 6.17.

One important recent improvement in the climatic analysis of South America has been the addition of annual or monthly averages from up to 516 individual stations, as provided by the National Meteorological and Hydrometeorological Services of Argentina, Bolivia, Chile, Colombia, Ecuador, Uruguay, Paraguay, Peru, and Venezuela, and also from the Brazilian Centre de Provisão de Tempo Estudos Climáticos (CPTEC). Attention has been given to minimizing excessive local-scale influence to better establish the regional behavior of extreme climatic events. These data are the primary source for subsequent precipitation analyses, and they have been blended with the NCDC/GHCN database for temperatures; the reference period is 1961–90.

ii) Northern South America and the Southern Caribbean—J. D. Pabón[63]

Typical responses to equatorial Pacific cold conditions were observed in northern and northwestern South America in 2005, with precipitation generally above normal except in the Colombian–Venezuelan Amazonia region, where precipitation deficits occurred. Intense rainfall, particularly from March to May and during the second half of the year caused flash flooding and landslides that resulted in death and considerable damage. Around 1 million people were affected during intense October–December rainfall events in Colombia, which caused more than 500 deaths, destroyed over 1,000 houses, and heavily damaged infrastructure.

Although average temperatures for several months were below normal over several regions of Colombia, northeastern parts of Columbia and Venezuela experienced annual average air temperature up to 1.0°C above normal, while western regions were slightly below normal. Northern Hemisphere midlatitude synoptic activity penetrated further south than normal, generating perturbations in the ITCZ and producing considerable precipitation over the Caribbean and northern South America. The Caribbean also was affected by the increased tropical cyclone activity in the Atlantic basin in 2005 (see section 4c).

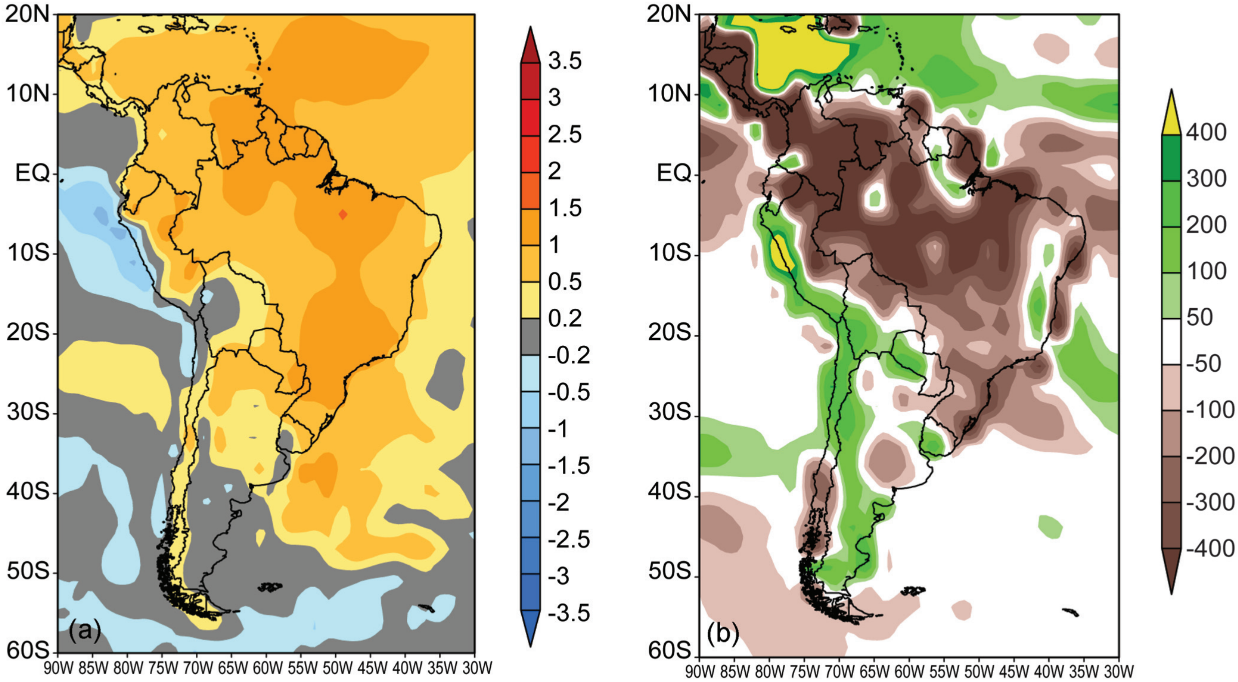


Fig. 6.17. South American 2005 annual (left) temperature anomalies (°C; 1971–2000 base), and (right) precipitation anomalies (mm; 1979–2000 base) from CAMS–OPI.

III) Tropical South America East of the Andes—J. A. Marengo[50]

Heavy rain in January caused flooding in Georgetown, Guyana, and surrounding areas, affecting an estimated 290,000 people. Conversely, large negative rainfall anomalies were measured east of the Andes in the Amazon, northeast and southern Brazil, and in the South American monsoon–Pantanal regions. The rainy season in northeast Brazil during February–May was below normal, reaching drought levels in some semiarid interior regions, and severely impacting over two million inhabitants. Amazonia also experienced intense drought during most of 2005, especially in southern and western sections of the basin (see sidebar). More than 167,000 people have been affected by the drought, both directly and indirectly. Low river levels impacted the region's main source of transport and contributed to the deaths of large numbers of already endangered manatees and river dolphins.

In west-central and southeastern Brazil, the rainy season was from below to slightly below the normal. Drought conditions were present in the Chaco region of Bolivia and Paraguay during January and February 2005. Low water levels on the Paraguay River significantly reduced barge traffic in 2005.

Rainfall in southeastern Brazil was primarily in the form of intense events that lasted several days. Several of Brazil's large cities were flooded by these events, leaving much of the population without power or shelter. In and around São Paulo and Rio de Janeiro, dozens of people died due to landslides and flooding.

Annual air temperature anomalies reached almost 3°C above normal in eastern Brazil, with every month above normal and the warmest months being April, August and October. In October, typically the onset of the rainy season in the southern areas, temperature anomalies were up to 5°C above normal. From Octo-

DROUGHT IN AMAZONIA—J. Marengo[50]

In 2005, large sections of the western part of the Amazon Basin endured the worst drought in 40 years and also one of the most intense since the beginning of the twentieth century. While the Amazon normally rises and falls in conjunction with seasonal precipitation, 2005 rainfall was well below normal (Fig. 6.18), which allowed rivers to drop to record low levels. Levels of the Madeira and Solimões Rivers, two of the Amazon's major tributaries, dropped to record and 38-yr lows, respectively. In the Brazilian states of Rio Branco, Rondonia, southern Para, and southern Amazonas, rainfall was 30%–50% below normal in January–April 2005, 33% below normal in June and August, and 65% below normal in July. According to the meteorological service of Peru, the hydrological year of 2004/05 exhibited rainfall well below normal in Peruvian Amazonia, with mean rainfall for the hydrological year September 2004–August 2005 up to 39% below normal. Rainfall on the basins of the Bolivian Beni and Mamoré Rivers was about 20%–30% below normal for January–April. Drought conditions favored the occurrence of forest fires, and in September the number of fires was about 300% more than those detected in September 2004.

Levels of the Amazonas River at Iquitos, Peru, and Leticia, Colombia; the Solimões River at Tabatinga and Fonte Boa, Brazil; the Acre River at Rio Branco, Brazil; the Mamoré at Puerto Varador, Bolivia; and the Ibaré River at Puerto Almacén, Bolivia all were well below the normal during most of 2005 until September, in some cases as much as 2 m below normal monthly means. At daily time scales, the situation was even more dramatic. The level of the Solimões River at Tabatinga and Fonte Boa decreased from 11.5 and 21 m (respectively) in May to near 1 and 11 m (respectively) in September. Rainfall started by the end of October 2005, reached a November mean of almost 107% above normal, and recharged the Rio Amazonas in Iquitos to a normal level by November. By January 2006 the Acre and Madeiras Rivers achieved anomalously high levels (11.08 and 12.34 m, respectively) due to the intense rains. In contrast to the intense drought of the 1982/83 and 1997/98 El Niño years, the 2005 drought was concentrated in western and southern Amazonia and was not related to El Niño, which brings drought to central and eastern Amazonia, but rather to a warming of the tropical North Atlantic during most of 2004 and 2005.

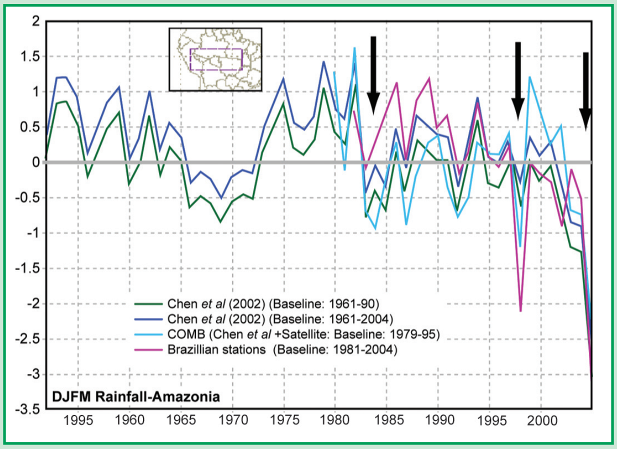


Fig. 6.18. Rainfall anomalies (mm day^{-1}) in central Amazonia during the peak season (December–May) 1951–2005. Black arrows represent drought years 1983, 1998, and 2005.

ber to December, temperatures were over 3°C above normal in far western Amazonia. Air temperatures in Bolivia and northern Paraguay were 1°–4°C below normal from September to November.

iv) Tropical South America West of the Andes—R. Martínez[51]

As in northern South America, rainfall in Ecuador and Peru was strongly influenced by SST over the Niño-1+2 region during 2005. Despite weak warming in the tropical Pacific, cold coastal SST anomalies led to negative rainfall anomalies along the Ecuadorian coast. Mean temperature also was below normal during 2005. In November 2005, a strong frost caused significant damage in the central and southern highland of Ecuador. In Peru, rainfall was below normal along the central and southern highlands, continuing several years of drought in this region. Bolivia also experienced drier-than-normal conditions in 2005, except for October and November when intense rains generated flooding and damage. The mean temperature in Bolivia was above normal across most of the country.

v) Southern South America—M. Bidegain[7] and M. Rusticucci[78]

Annual precipitation anomalies over southern South America show light deficits over the east and surplus over central Chile and western and southern Argentina. Above-normal precipitation for several months contributed to the positive anomalies in these regions. A series of intense summer (June–August) precipitation events also contributed, with some local anomalies exceeding 700% of the normal. On 26 June, 162.4 mm of rain fell over Concepción, Chile, generating landslides that killed 5 and injured 4,800. Between 26 and 28 August, 120 mm of rain fell in 48 h in Santiago, Chile, resulting in 1,153 injured, 755 houses damaged, and an estimated economic cost of $10 million USD.

The regional core of negative precipitation anomalies was in the Chaco region and southern Paraguay, where intense drought prevailed to spring 2005. Precipitation deficits produced livestock losses and reduced water levels on the Uruguay River, impacting hydroelectric generation. Strong negative October–December rainfall anomalies dominated the southern part of the region, affecting agriculture in this productive region. In southern Brazil, seasonal (December 2004–March 2005) rainfall 100–500 mm below normal produced intense drought and heavy agricultural losses. The southern state of Rio Grande do Sul was the most affected, and while May rainfall alleviated the drought, it produced flooding in some cities. Damage attributed to the drought of 2005 in southern Brazil was considerable: 2 million people were affected by water shortages, 13 million tons of agricultural products were lost, and economic losses were on the order of $3 billion USD.

Annual air temperature anomalies were generally near normal, with eastern regions above normal and central and western region slightly below normal. Uruguay experienced temperatures above the normal (up to +1.2°C), especially near the Brazilian border. From January to August most monthly temperatures were above normal, with May–August having the largest anomalies. June temperature broke records (for the 1961–2004 period) over northeastern Argentina, and winter was 2°C warmer than normal in Uruguay. In contrast, cold air advection in September affected the eastern part of the region. October–December temperature anomalies were up to 3°C below normal, with early December frosts, including a few intense frosts in the Andes that killed thousands of sheep. Annual air temperatures in Chile were slightly above normal in the central region, and slightly below normal in the south. April, May, and June temperatures were below normal, especially in southern Chile. The week of 26 June, a severe cold air outbreak between 34° and 36°S left 30,000 injured and affected 12,000 homes.

On 23–24 August 2005, an exceptionally strong midlatitude cyclone occurred over Rio de la Plata and southern Uruguay. The gale was characterized by unforced rapid deepening to a near–record (locally) low mean sea level pressure, very high winds, and anomalous cold surface temperatures. High winds contributed to extensive damage and 10 deaths along the Uruguayan riverside.

f. Asia

i) Russia—O. N. Bulygina,[11] N. N. Korshunova,[40] and V. N. Razuvaev[72]

(i) Temperature

Russia experienced very warm conditions in 2005. The mean annual air temperature anomaly relative to the period of record (1936–2005) was +1.6°C, which is the second highest value since 1936 (Fig. 6.19).

The year began with January temperatures above normal across all of Russia, although very cold weather was observed in places. Northeast European Russia experienced particularly warm conditions, with mean monthly temperature anomalies exceeding +8°C. Anomalies reached +7°C over central regions. Moscow's January 2005 temperature ranked third highest on record, with record maximum daily

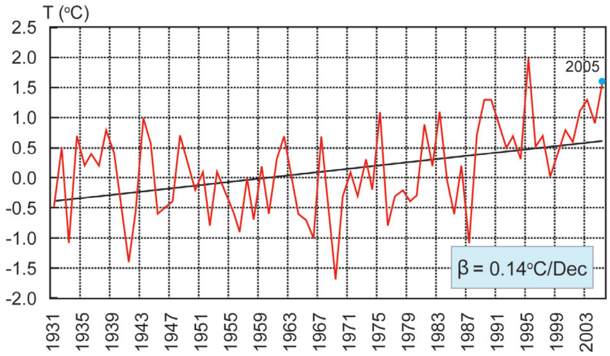


Fig. 6.19. Departures of mean annual air temperatures (red) over the Russian territory for the period 1931–2005. A linear trend of +0.14°C decade^{-1} (black) is also shown.

air temperatures observed on five days (e.g., 5.2°C on the 9th). February temperatures in north European Russia and western Siberia were up to 10°C above normal.

Interestingly, January and February air temperatures in the north of Asian Russia were often higher than those to the south. At Turukhansk, the 12 January mean air temperature was –5.5°C, which is 21.5°C above normal. In contrast, at the end of January the Novosibirsk and Kemerovo regions experienced temperatures as low as –38°C, and temperatures in the Republic of Altai reached –47°C. Particularly strong February frosts occurred between the 15th and 18th in Altai (–40° to –43°C), and from the 1st to the 10th in Trans-Baikal (–38° to –44°C), while true "Siberian" frosts (–35° to –40°C) were recorded during 14–19 February in the Krasnoyarsk Territory and Khakasia (south-central Siberia). The Republic of Tuva experienced its most severe and persistent frosts in the past 20 yr, as temperatures fell to –48°C in the Tuva hollow.

March brought bitter cold across much of European Russia, with record cold mean monthly temperature anomalies (–5° to –6°C) set in several northeastern areas, and colder-than-normal (–3° to –4°C anomaly) conditions in central and western regions. However, April countered with positive temperature anomalies over most of Russia. Western parts of the Sakha Republic (northeast Siberia) were particularly warm, with mean monthly anomalies from +7° to +8°C. Anomalous warmth continued into May, with the mean May temperature for Russia tying the record set in 1943. May 2005 was the hottest May in the 105-yr temperature record for the Ural Federal District.

During the first 20 days of June, central and southern regions of European Russia recorded anomalously cold air temperatures (0° to –2°C) as a result of frequent cold air intrusion. Concurrently, temperatures ran 1° to 2°C above normal across most of the Russian Far East. In early July, western and southern-central regions of Siberia experienced a heat wave, with diurnal temperatures climbing to 39°C in places.

A strong anticyclone centered over European Russia caused very dry and hot weather in August. The Novosibirsk region and Altai in western Siberia experienced mid-August diurnal temperatures between 28° and 38°C. At 40°C, Zmeinogorsk exceeded the previous August maximum temperature record by 2°C. For the whole of Russia, summer 2005 was one of the warmest on record.

With a temperature anomaly of +2.7°C, autumn 2005 was the hottest autumn on record for Russia (Fig. 6.20). While September was warm, eastern Siberia experienced its warmest October in the past 65 yr, with October temperatures 2°–5°C above normal. Record November temperatures were also reported at several meteorological stations in northeastern European Russia and in the southeast of the Sakha Republic as two large heat domes formed over those regions (Fig. 6.20). Temperatures near the centers of these areas of heat were 9° and 11°C above normal, respectively.

The warm weather over European Russia and the Sakha Republic persisted into December, with monthly temperatures being 1°–4°C above normal. However, December temperatures were 4°–5°C below normal in southern Siberia (Krasnoyarsk Territory and Irkutsk region) as a cold pool formed in the Siberian anticyclone zone following the warm autumn.

(ii) Precipitation

The warm winter temperatures also led to above-normal January precipitation in places. Moscow reported a new record January precipitation total of 98 mm (232% of monthly average). Heavy March precipitation was recorded in the eastern regions of European Russia and in the Urals, in some regions exceeding normal values threefold. Frequent March snowstorms with heavy snow were observed across European Russia (from the Nenets Autonomous District to northern Caucasia). The Taimyr Peninsula experienced strong winter blizzards with heavy snow and winds exceeding 25 m s^{-1}. In the east, Trans-Baikal, Sakhalin, and Kamchatka were repeatedly attacked by strong cyclones that brought heavy snow and blizzard conditions. March precipitation in these regions was more than double that of normal amounts.

Heavy April precipitation (200% to > 300% of normal) was recorded in central and southern regions of

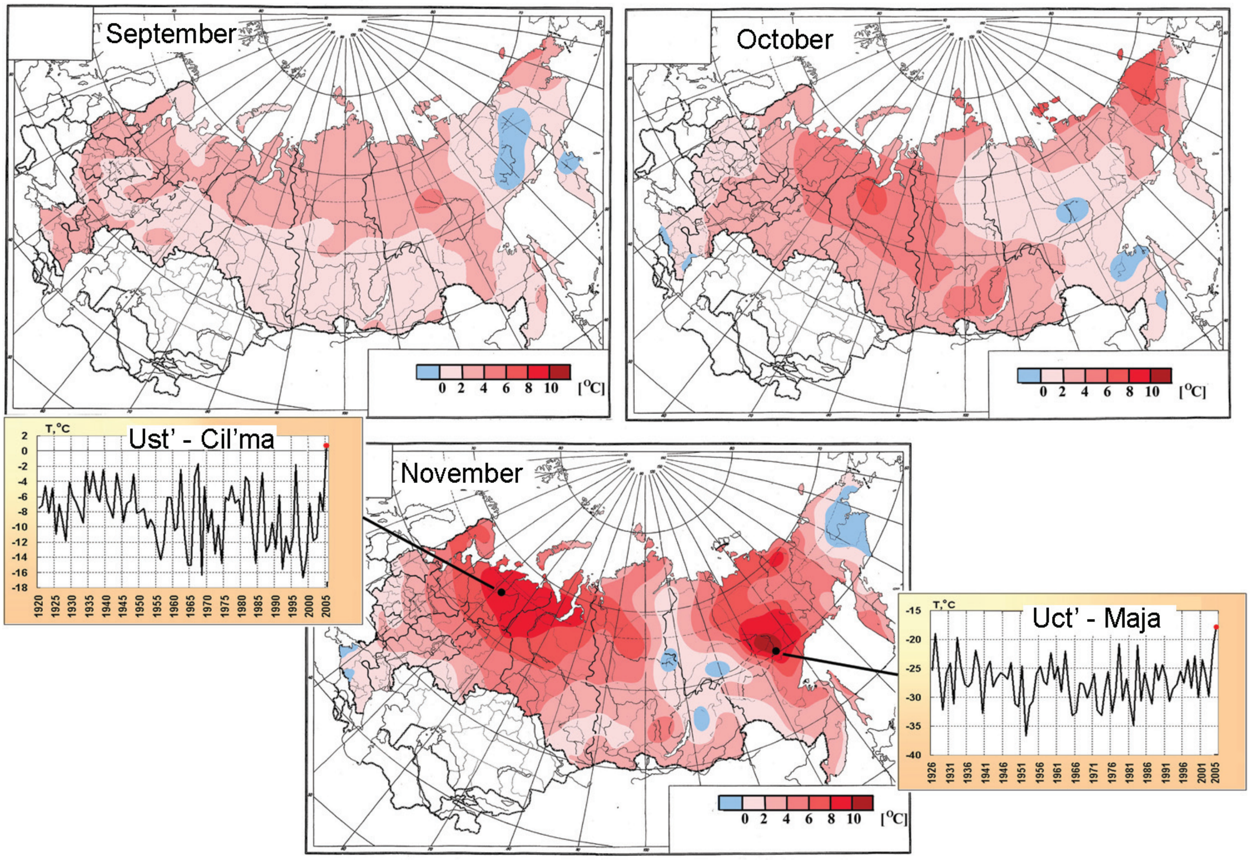


Fig. 6.20. Russian air temperature anomalies (°C) in autumn 2005. Insets show November mean monthly air temperatures at meteorological stations Ust'-Cil'ma (1920–2005) and Uct'-Maja (1926–2005).

Siberia (Krasnoyarsk Territory, Khakasia, Cis-Baikal, and Trans-Baikal). From 12 to 16 days of precipitation fell in Khabarovsk Territory and the Amur region, more than double the normal frequency and totaling over 200% of the normal precipitation for the month. Wet conditions continued into May in Khabarovsk, Maritime Territories, and Sakhalin, resulting in high river levels.

Summer precipitation across Russia was often accompanied by severe thunderstorms with hail and wind squalls. Hail to 35 mm was recorded in the Krasnodar Territory. In early June, the Arkhara River (Amur region) flooded to a record June level of 4.1 m after a 2-day, 100-mm rainfall. However, the hot June was accompanied by precipitation deficits over western Siberia (20%–30% of monthly normals). July precipitation in European Russia was inconsistent, with heavy thunderstorms in places and precipitation deficits in others. August precipitation was just 8%–30% of normal across European Russia, although the Kaliningrad region in the far west received over 300% of normal monthly precipitation.

Precipitation deficits continued into September. Moscow experienced one of its driest Septembers on record (12.2 mm, 18% of normal). With the high temperatures, fire hazard increased over much of European Russia, and several peat bogs caught fire. Near-normal precipitation returned to Russia by December, with the exception of the south of the Central Federal District, where around 200% of monthly normal snow fell.

ii) China—F. Ren[73] and G. Gao[23]

(i) Temperature

In 2005, the annual mean temperature of China was 0.6°C above the 1971–2000 mean (Fig. 6.21). It was the ninth consecutive year of warmer-than-normal temperature since 1997. Regionally, temperatures were above or near normal across most of China, with 1°–2°C above normal in the middle Tibetan Plateau and eastern Xinjiang.

The 2004/05 winter (December–February) mean temperature was near normal for China, but it ranked the third lowest since the 1986/87 winter. In mid-February, rare icing events occurred in some provinces

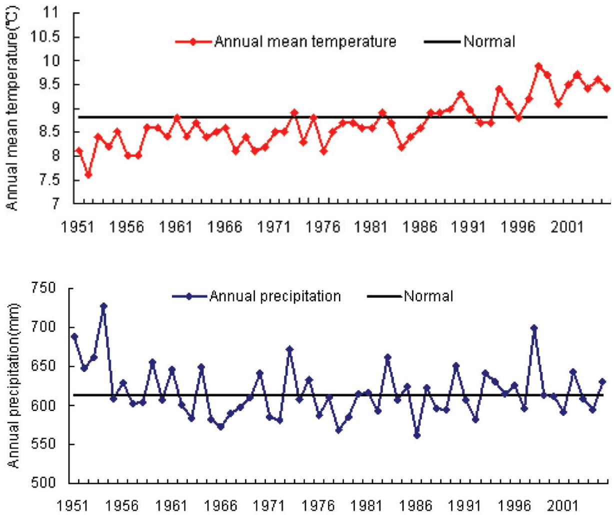


Fig. 6.21. Mean annual (top) temperature (°C) and (bottom) precipitation (mm) averaged over China relative to the 1971–2000 mean.

in southern China (e.g., Hunan, Hubei, Guizhou). In Hunan Province, the power grid was the most heavily affected by icing since 1954.

Summer seasonal mean temperature tied 2000 and 2001 as the highest ranked since 1951. Heat waves occurred frequently in central-eastern China and Xinjiang. Southeastern China experienced 5–15 days more than normal (20–40 days) with maximum temperatures at or above 35°C. Seasonal extreme daily maximum temperatures were 38°–42°C in North China, western Huanghuai Region, and South China, while records (1951–2005) of seasonal extreme daily maximum temperature were broken in parts of Hebei, Shanxi, Shandong, Zhejiang, and Inner Mongolia.

China also experienced a warm autumn, and the seasonal mean temperature ranks second in the historical record (1951–2005). In southeastern China, heat waves returned during the middle of September, and daily maximum temperatures soared to 35°–39°C.

(ii) Precipitation

In 2005, annual precipitation was 17.7 mm above the 1971–2000 mean across China (Fig. 6.21). Regionally, precipitation was 30%–100% above normal in the Huanghuai region, southern and northern Xinjiang, Qinghai, northwestern Tibet, and the southeast coast, and 30%–80% below normal in northern Heilongjiang, the middle of Inner Mongolia, and northern Ningxia (Fig. 6.22).

Regional and short-term drought was a major characteristic in 2005. In southern South China, precipitation was only 300–600 mm from September 2004 to May 2005, or about 30%–80% below normal, resulting in severe persistent drought. From April to May, rare spring drought occurred in Yunnan Province as a result of long-term rainfall deficiency. Early summer drought occurred in middle and lower reaches of the Yangtze River due to a delay in the onset and shortened duration of the plum rain season generating below-normal precipitation. Summer–autumn drought occurred in northeast part of northwest China and Inner Mongolia, and autumn drought affected Hunan and western South China.

(iii) Notable events

An above-normal eight tropical storms or typhoons made landfall in China, of which six (Haitang, Matsa, Talim, Khanun, Damrey, and Longwang) were severe, with winds over 162 km h^{-1} (see section 4c). Heavy rain and high winds generated mudflows and widespread flooding. About 92 million people were affected (386 dead), and economic losses of over 82 billion yuan Renminbi (RMB; $10 billion USD) were exceeded only by losses in the 1996 typhoon season.

From 17 to 25 June, consecutive heavy rainstorms impacted South China with 300–600 mm of rain falling in parts of Fujian, Guangdong and Guangxi Provinces. The Xijiang River in Guangxi and the Minjiang River in Fujian exceeded flood stage. About 21 million people were affected by the floods—171 people lost their lives and direct economic loss was over 18 billion RMB ($2.2 billion USD).

During early and middle July, heavy rain and flooding occurred in the upper reaches of the Huaihe River Basin. Between late September and early October heavy flooding occurred in the Hanjiang River and the Weihe River as the result of frequent and

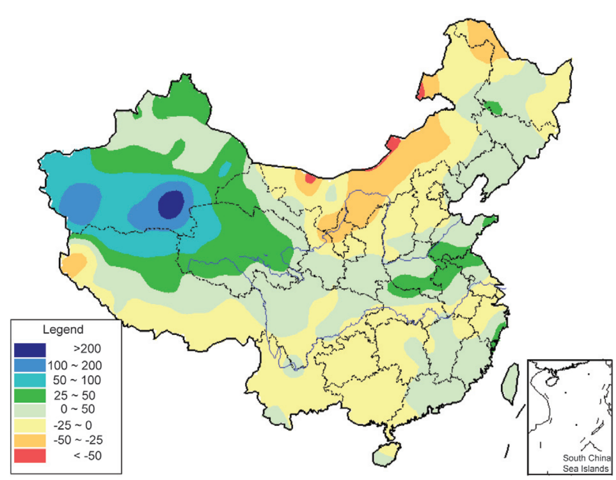


Fig. 6.22. Precipitation anomalies (%) across China (1971–2000 base).

widespread rainfall in the southeast part of northwest China and the Huanghuai region. About 5.52 million people were affected, with 14 dead in Shanxi, Hubei, and Gansu Provinces and 2.5 billion RMB ($311 million USD) of direct economic loss.

Although fewer dust storms affected China than in 2004, and 2005 had the lowest number since 1954, 13 storms occurred. The most widespread occurred from 16 to 21 April, affecting 12 provinces in northern China, while the most intense storm occurred on 27–28 April, impacting nine northern provinces or regions, including Beijing.

iii) Southeast Asia—F. Ren[73] and G. Gao[23]

(i) East Asian monsoon

Onset commenced over the South China Sea (SCS) in the sixth pentad of May, about two pentads later than normal. Stronger-than-normal southwesterly flow advanced to and persisted over South China until the fourth pentad of June. In the last 10 days of June, the monsoon advanced to the region between the Yellow and Huaihe Rivers. In mid-August, rapid retreat occurred to around 30°N where it remained until mid-September. In the sixth pentad of September the warm and humid air had withdrawn from East Asia, and wind direction in the SCS shifted from the southwest to northeast, signifying a near-normal closing date to the East Asian summer monsoon.

The SCS summer monsoon index (–1.42) was weaker than normal. Intensity of the SCS monsoon also was weaker than normal during summer except for the periods from the sixth pentad of May to the third pentad of June and from the second pentad of August to the third pentad of August (Fig. 6.23). Precipitation was above normal in most of South China in June and in the Upper Huaihe River from July to September.

(ii) Temperature

Annual air temperature anomalies were generally 0.5°–1°C above the 1971–2000 mean. However, annual temperatures over the SCS were near to slightly below normal (Fig. 6.24). Seasonal mean surface air temperatures were above average in most of southeast Asia during December 2004–February 2005, with anomalies exceeding 1°C in the northern and southeastern Indo–China Peninsula. Generally, temperatures were close to normal across southeast Asia through the remainder of the year.

(iii) Precipitation

Precipitation was generally below normal across most of continental Southeast Asia in 2005. Northern and western Myanmar, southern Vietnam, and portions of Malaysia observed annual anomalies more than 400 mm below normal. The Philippines, western Thailand, and the northern Malay Peninsula received above-normal precipitation, with northeastern Malaysia, central Vietnam, and Mindanao all receiving over 400 mm above normal for the year (Fig. 6.24).

December 2004–February 2005 rainfall was below average over most of Southeast Asia, and more than 80% below normal in the western Indo–China Peninsula. March–May rainfall totals were well below normal in the northern Indo–China Peninsula and close to normal over the remainder of Southeast Asia. In April, Thailand experienced its worst drought in seven years. June–August precipitation was close to normal, though heavy rainfall caused flooding in northern Thailand. In Myanmar, heavy monsoon-related rainfall affected the southern coastal areas during the second week of September. Otherwise, September–November rainfall was near normal.

(iv) Notable events

In Indonesia, heavy January rains hampered tsunami (December 2004) relief efforts, and continued heavy rain in February generated landsides that left 61 dead and 90 missing. On 9 June, continuous heavy rain brought mudslides with 12 deaths and 11 missing in northern Vietnam. In West Sumatra, Indonesia, heavy rainfall produced landslides near Padang on 2 September. There were 16 fatalities and at least 10 injuries. Heavy October rains across central Vietnam produced flooding with at least 67 fatalities. The most severely affected area was Binh Dinh Province, where 3,200 houses were damaged and most of the fatalities occurred.

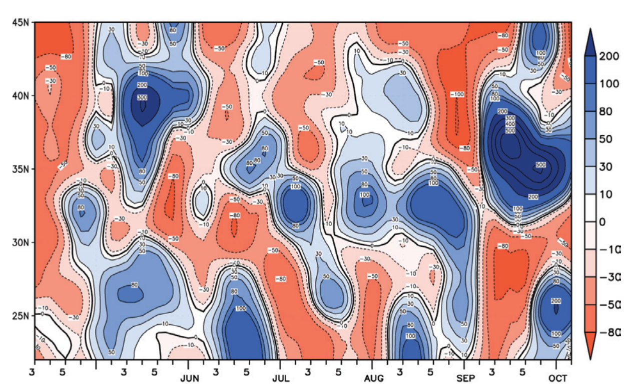


Fig. 6.23. Time–latitude cross section of pentad precipitation anomalies (%) for 110°–120°E. [Source: National Climate Center (NCC) China Meteorological Administration (CMA)]

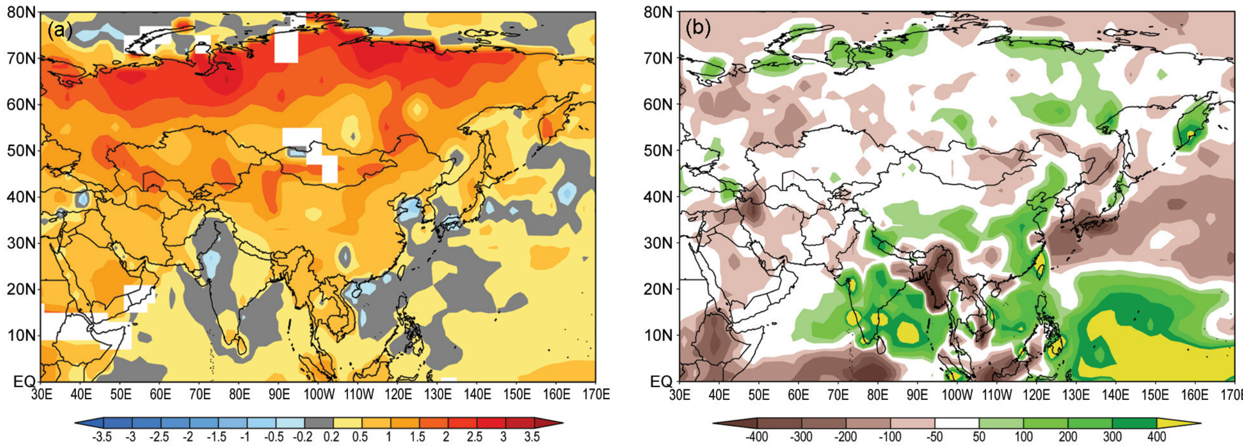


Fig. 6.24. Asian 2005 annual (left) temperature anomalies (°C; 1971–2000 base), and (right) precipitation anomalies (mm; 1979–2000 base) from CAMS–OPI.

iv) India and Southern Asia—M. Rajeevan[71] and K. R. Kumar[42]

(i) Temperature

This year was marked by extreme weather all across South Asia, both in terms of temperature and precipitation. At the beginning of the year, parts of Afghanistan and adjoining Pakistan experienced extreme cold weather, with temperatures more than 5°C below normal in February. Severe cold also prevailed over northern India and adjoining regions in late February. During the postmonsoon season and toward the end of the year, heavy snow and extreme low temperatures occurred over northern parts of South Asia, causing several casualties and seriously affecting the rescue and rehabilitation work in Pakistan following the destructive earthquake of 8 October.

On the other extreme, May and June brought scorching heat waves, with maximum temperatures around 45°–50°C in India, Pakistan, and Bangladesh. Delayed southwest monsoon rains allowed the heat to persist into June, claiming at least 400 lives in India. An anomalous anticyclone and northwesterly winds created a severe heat wave over central and northeastern India, with maximum temperatures 6°–8°C above normal.

(ii) Precipitation

During the third week of February, sections of northern Pakistan and neighboring areas of northern India received heavy snowfall, described as the worst in two decades. Snowfall accumulations reached almost 2 m in some parts of Jammu and Kashmir in India. In Pakistan, heavy rains in the south and snow in the north triggered flooding and avalanches, causing the extensive loss of life and property. Heavy rains in March also caused flooding in parts of western Pakistan and Afghanistan; Balochistan Province was the worst affected. Over Pakistan, the 2005 January–March seasonal rainfall was 121% of its long-term average.

(a) *South Asian Summer monsoon*

The summer monsoon this year was marked by unprecedented heavy rains and extensive flooding in parts of western and southern India, affecting more than 20 million people and resulting in more than 1,800 deaths. Rainfall activity in Nepal and Bangladesh was, however, below normal. Central and southern parts of India received excess rainfall during the season (Fig. 6.25). While northwest India received normal rainfall, seasonal rainfall over

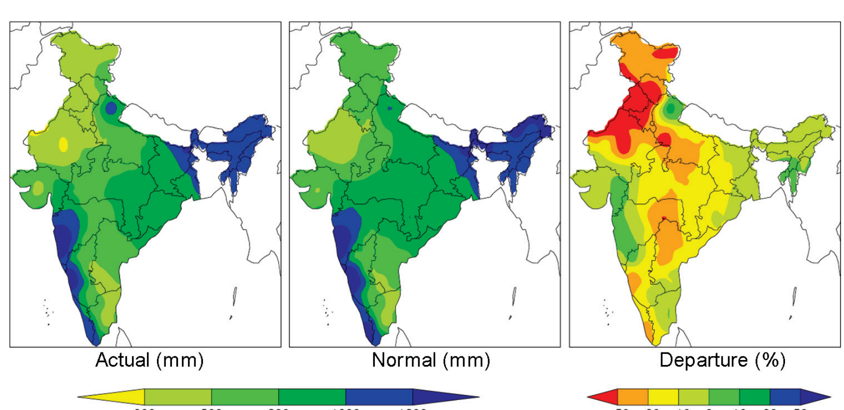


Fig. 6.25. June–September precipitation (mm) over India in 2005: (left) actual; (center) normal; and (right) percentage anomaly.

northeastern parts of India was below normal by more than 20%.

Onset of the 2005 southwest monsoon was delayed to 5 June, when it arrived over the south peninsula and northeastern parts of India. Despite unfavorable synoptic conditions, the monsoon advanced more quickly over northwestern India and Pakistan, covering the entire subcontinent by 30 June, 15 days ahead of the normal.

Countering declining trends of recent years, 12 low pressure systems formed (the most since 1998), of which five developed into monsoon depressions and one into a cyclonic storm (the first in September since 1997). The storm tracked from the Bay of Bengal across central India and the Gangetic Plains, resulting in widespread flooding.

While the spatial distribution of rainfall this season was normal, it was intermittent. There were prolonged dry spells in June and August, though excess rainfall in July and September ultimately helped the season end with near-normal rainfall. Due to the late onset and sluggish advance of the monsoon, rainfall during much of June was limited. In August, monsoonal rainfall was 27% below normal over India. Precipitation deficits lead to moderate drought for 25% of India's meteorological districts (2% severe drought). For the season, average rainfall over India was near normal (–1%).

(b) *Northeast monsoon*

Heavy rainfall continued unabated in southeastern parts of India and Sri Lanka during the northeast monsoon season of October–December. Five low pressure systems (four depressions and one cyclonic storm) affected southern parts of India and Sri Lanka. In India, Tamil Nadu and Andhra Pradesh were the most affected states. The northeast monsoon seasonal rainfall over south India was 165% of normal, the highest since 1901. Associated flooding affected more than 3 million people, with at least 300 fatalities and considerable socioeconomic impact. In Sri Lanka, approximately 29,000 families in 10 districts were affected and at least six deaths were reported.

(iii) Notable events

The most notable event of 2005 occurred on 27 July, when Mumbai (Bombay) received its greatest-ever recorded 24-h rainfall of 944.2 mm (most of it in just 6 h, between 1430 and 2030 local time) at Santacruz, an observatory at the airport (Fig. 6.26). The previous record of 575.6 mm was set at Colaba on 5 July 1974. Interestingly, in the 2005 event Colaba, just 20 km from Santacruz, recorded only 73.4 mm of rain. This localized event was confined to a region of a 20–30 km radius. Although a warning for regionally heavy rainfall had been issued, torrential rain severely disrupted life in the city, with numerous fatalities, heavy damage, and large economic losses.

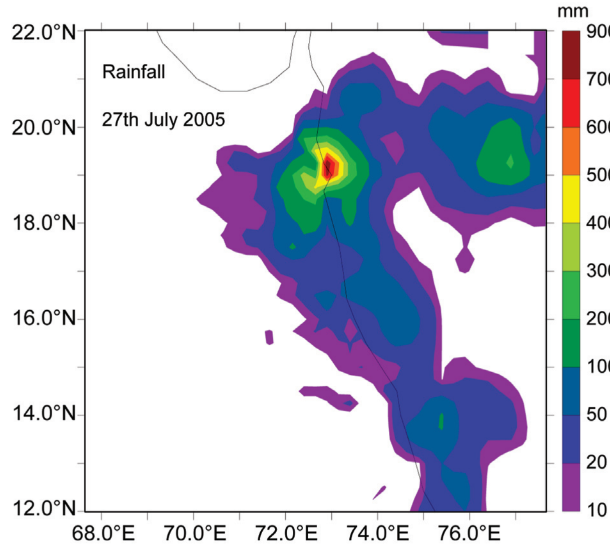


Fig. 6.26. Rainfall totals (mm) on 27 July around Mumbai, India.

v) Southwestern Asia—F. Rahimzadeh,[70] M. Khoshkam,[41] and E. K. Grover-Kopec[31]

(i) Temperature

All of southwest Asia experienced above-normal temperature in 2005, with annual temperature anomalies of 0.5°–2°C. North and northeastern Iran were 3°C warmer than normal for the year. Despite these positive 12-month departures, the northern half of the region experienced cooler-than-normal conditions during February, when mean temperatures ranged from 5°C in western Turkmenistan to –18°C in the highlands of Tajikistan and Kyrgyzstan. Temperatures were 1°–6°C below normal in these areas. Northern Iran experienced winter temperatures 3°C below normal. Northern Afghanistan, where hypothermia and other cold-related illnesses claimed more than 100 deaths, recorded temperatures of 1°–2°C below normal during February.

In contrast, temperatures were above the 90th percentile across the central portion of Southwest Asia during March (2°–7°C above the long-term average; Fig. 6.27). Afghanistan, Kyrgyzstan, Tajikistan, and Pakistan experienced temperatures 1°–2°C above normal in June. Spring temperatures in Iran were split between cooler-than-average conditions in areas of the east, center, and northeast of the country, and warmer-than-normal conditions elsewhere.

Seasonal mean temperatures in southern Iran were 10°–35°C.

Most of Iran saw positive summer temperature anomalies exceeding 2°C. A heat wave that affected Iran in July produced monthly anomalies up to 4°C above normal. Autumn remained on average 2°C above normal across Iran, although cooler-than-normal conditions were observed over the Persian Gulf.

(ii) Precipitation

Southwest Asia generally receives most of its annual precipitation from extratropical disturbances traveling eastward from the Mediterranean Sea between November and April. From July through August, the South Asian monsoon generally brings precipitation to southeastern Afghanistan, but tends to suppress summer precipitation in areas farther north and west.

Annual precipitation accumulations were slightly below normal across the majority of the region during 2005, and most of these negative annual anomalies were 25–75 mm below normal (Fig. 6.27). These departures were modest, however, and generally accounted for less than 25% of normal annual precipitation (i.e., 2005 annual totals were about 75%–100% of normal). A few areas received above-average precipitation during 2005, including portions of southern Afghanistan, western and northern Pakistan, and south-central Kazakhstan. However, these departures were also relatively small (10–50 mm) compared to long-term mean accumulations.

Despite the relative precipitation deficits across Southwest Asia, portions of the region experienced record snow amounts during January and February. As much as 200 cm of snow fell in just 2 weeks in parts of Tajikistan, contributing to more than 475 avalanches in the mountainous country. Similar impacts were reported in northeastern Afghanistan where avalanches claimed approximately 160 lives. The heavy snowfall in January and February, and above-average precipitation in late 2004 (Levinson 2005), contributed to a healthy snowpack in the highland areas of Southwest Asia, which is responsible for providing most of the region's water supply later in the year.

The 2004/05 winter was also wetter than normal across most of Iran, averaging 154.1 mm, or 14% above 2004 levels and 24% above the long-term mean. The largest anomalies were in southeast Iran, where some locations received up to 3.5 times the normal seasonal amounts. Also, early winter snow alleviated a 7-yr drought in the region. Tehran experienced record February snowfall, and in northern Iran, heavy late-February snow damaged or destroyed over 7,000 homes.

Unfortunately, abnormally warm conditions in March hastened the melting of the highland snowpack and swelled rivers across the region. Heavy rainfall in central and western Afghanistan during March exacerbated conditions and caused extensive flooding in those areas. The June heat wave melted remaining snowpacks in Afghanistan, Kyrgyzstan, Tajikistan, and Pakistan. Pakistan's northern provinces in were extremely hard hit by the resulting flooding. More than 460,000 people were affected and nearly 1 million ha of crops suffered damage.

Although spring is generally the rainy season for Iran, and wetter-than-average (100%–200%) spring conditions prevailed over northern Iran, it was much drier than normal (0%–10%) across southern areas,

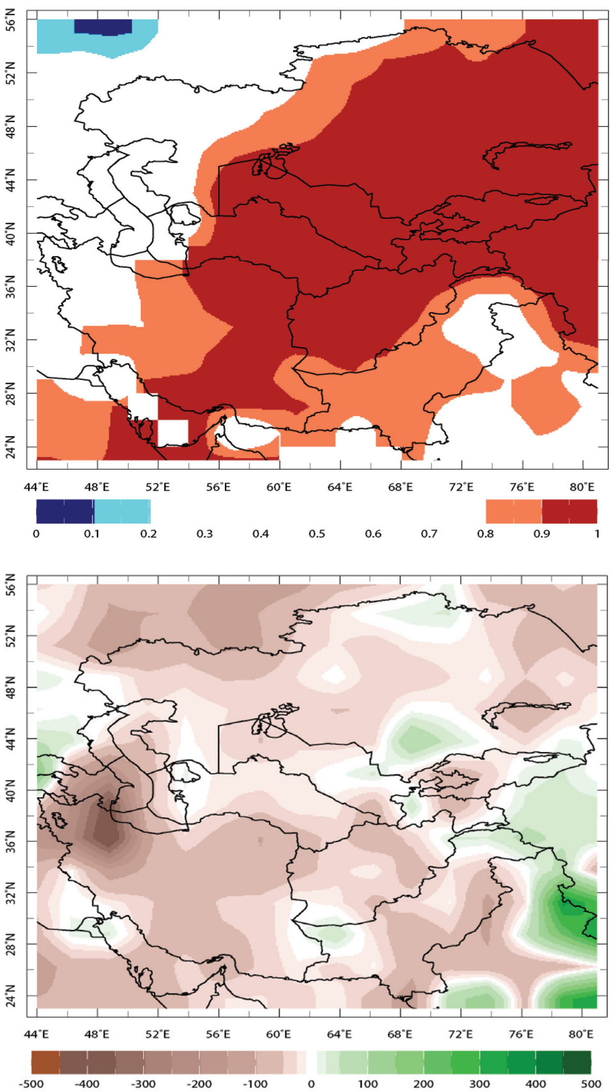


Fig. 6.27. Annual average (top) temperature deciles and (bottom) precipitation anomalies (mm; 1971–2000 base) for southwest Asia.

and also (50% of normal) in central regions. Overall, spring precipitation in Iran was just 42% of the normal. Summer precipitation in Iran was 20% below normal, with especially dry conditions in the west half of the country. However, heavy rains in the east did result in flooding. Below-normal precipitation continued into the autumn across much of Iran. Autumn precipitation in Iran was 37% below the long-term mean, and some parts in the east received just 0%–25% of the normal seasonal precipitation due to the delayed onset of late-season precipitation.

g. Europe

1) Overview—J. J. Kennedy[38]

The annual surface temperature anomaly (Brohan et al. 2006) averaged over Europe in 2005 was 0.71 ±0.07°C above the 1961–90 average (Fig. 6.28). Only a small area extending north from Greece had annual temperatures below average (Fig. 6.29), and that was only by around 0.1°C. Annual average temperatures in the United Kingdom and northern Norway and Finland were above the 90th percentile of occurrence according to statistics based on the period 1961–90 (all European temperature and precipitation percentiles herein refer to this period).

Temperatures during the first three months of 2005 were significantly (meaning in the upper or lower decile of the distribution) below average in southern Europe, through Spain and the Mediterranean and into Italy. In the same period, above-average temperatures observed in the north and east exceeded the 90th percentile only over Scotland. Between April and June, temperatures were above average in all areas and significantly above normal over much of Europe west of 15°E and south of 55°N.

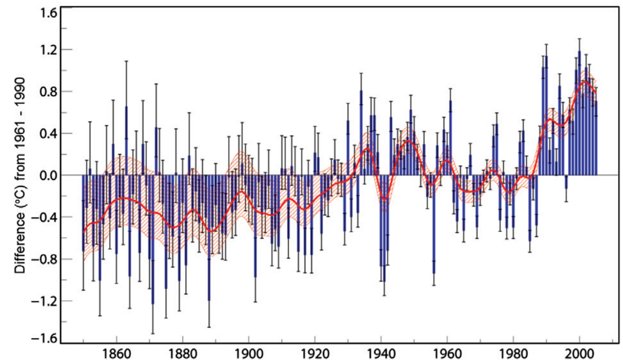
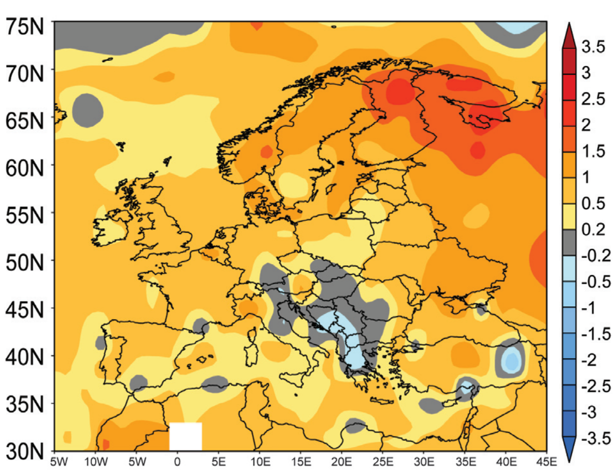


Fig. 6.28. European average temperature anomalies (°C; relative to 1961–90 mean) 1850–2005. Blue bars show the annual values with uncertainties represented by the black bars. The red curves show the annual anomalies and uncertainties after smoothing with a 21-term binomial filter. [Source: Brohan et al. 2006]

Temperatures in Spain and France exceeded the 98th percentile. From July to September temperatures once again were above average in most areas, although temperatures were close to average in southeastern Europe. Scandinavia and Eastern Europe were significantly above normal. Cooler conditions in southeastern and central Europe coincided with the largest regional rainfall totals for the season. October–December brought a north–south split, with much of the Mediterranean and southern Europe experiencing below-average temperatures, while in the north temperatures were generally above average with areas of the United Kingdom and Scandinavia significantly above average.

Total precipitation (Rudolf et al. 1994, 2005; Rudolf and Schneider 2005; Beck et al. 2005) between January and November 2005 (Fig. 6.29) was below



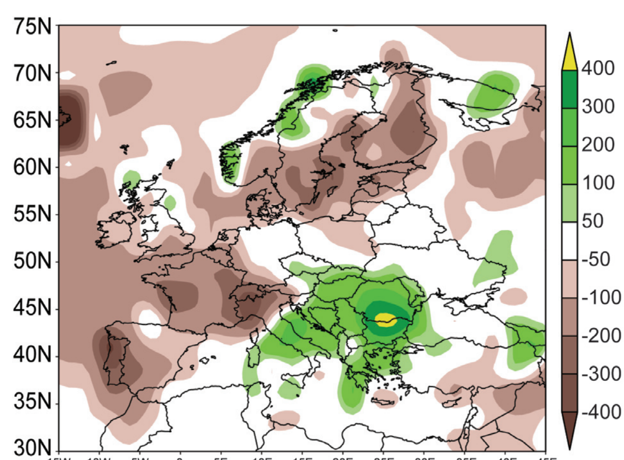


Fig. 6.29. European 2005 annual (left) temperature anomalies (°C; 1971–2000 base), and (right) precipitation anomalies (mm; 1979–2000 base) from CAMS–OPI.

average in southwestern Europe, with parts of France and the Iberian Peninsula receiving less than 40% of the 11-month 1961–90 average. Precipitation in southeastern Europe was above the 1961–90 average. Romania and Bulgaria received significant rainfall excesses during the year, with August totals in some areas approaching 500% of the monthly average.

II) Central and Eastern Europe—J. J. Kennedy[38]

Annual average temperatures in the region ranged from near average in Hungary and neighboring countries to over 2°C above average in eastern Ukraine (Fig. 6.29). January–November rainfall was significantly above average in Romania (Fig. 6.29).

A warm January, with areas of eastern Ukraine more than 5°C above average, gave way to colder conditions in February and March. Precipitation was generally below average in the southwest, but further north and east exceeded the average, with the largest excesses occurring in January and February. March rainfall was below average in most areas.

April–June temperatures in parts of Austria and the Czech Republic were significantly above average, and in Switzerland some western areas experienced temperatures above the 98th percentile. Further east, however, temperatures were nearer the average. Rainfall anomalies were generally higher in the east than the west, with the highest anomalies in Romania and Moldova.

In June, temperatures were significantly above normal in Austria and Switzerland and, in the far west, were high enough to exceed the 98th percentile. At the same time, temperatures in Ukraine and Romania fell below average. With only eastern Ukraine experiencing below-average rainfall, April precipitation was above average in most areas and the excess rainfall led to flooding in Romania. May precipitation was close to average in many areas, but Romania again experienced above-average totals. Most areas were drier than usual in June, with only eastern Romania and Ukraine experiencing wetter-than-normal conditions.

Temperatures were above average between July and September everywhere. The largest anomalies were in the east where temperatures were significantly above average. Smaller positive temperature anomalies further to the west coincided with the largest rainfall anomalies. Some areas of southern Romania received more than three times the seasonal average, generating widespread flooding in July and August. July temperatures were above average in all areas, but above-average precipitation contributed to depressed temperature anomalies in central Europe. Only Ukraine, where precipitation levels were below normal, showed significant warmth. August brought above-average rainfall to all but the most easterly areas, and temperatures fell below average in the west. Ukraine showed the highest temperature anomalies, with temperatures significantly above normal in parts.

October and November were mainly drier than usual in western areas, with wetter-than-average conditions confined to eastern Romania and Ukraine. Cold anomalies spread from the southeast in October to cover the central and western states in November. In December, cold anomalies were confined to the westernmost regions, with some parts of Austria significantly below normal.

III) Fennoscandinavia, Iceland, and Greenland—C. Achberger[1] and D. Chen[16]

Fennoscandinavia's (here Norway, Sweden, Finland, and Denmark) climate is to a large extent controlled by the atmospheric circulation over the European and North Atlantic region. Objective synoptic classification based on the Lamb scheme (Lamb 1950) has been extensively used in Sweden to quantify impacts of atmospheric circulation (e.g., Chen 2000). In 2005, occurrences of the four dominant weather types—anticyclonic (A), cyclonic (C), westerly (W), and southwesterly (SW)—were all above the 1961–90 mean. The generally warmer than normal conditions over Fennoscandinavia in 2005 correspond well to increased frequencies of W and SW types.

(i) Temperature

Annual mean temperatures for 2005 in the Nordic countries (including Greenland and Iceland) were around 0.5° to 4.5°C above the 1961–90 mean (Fig. 6.30), depending on geographical location. At Svalbard on Spitsbergen, annual mean temperatures reached −3.0°C, which is 3.6°C above normal, ranking 2005 as the warmest year since 1912. Danmarkshavn, in northeastern Greenland, reported an annual mean temperature of −9.5°C, placing 2005 as the warmest year since reliable measurements started in 1949. Parts of Finland were also unusually warm, at around 2.3°C above the long-term mean. Sweden, Denmark, and Norway, however, experienced more moderate temperature deviations, ranging between 1.1° and 1.7°C above normal, while the annual mean temperature for Iceland was about 1°C warmer than the 1961–90 mean. The warmer-than-normal temperatures were most profound at the highest latitudes.

Autumn (September–November) was extraordinarily warm at many Nordic locations, several of

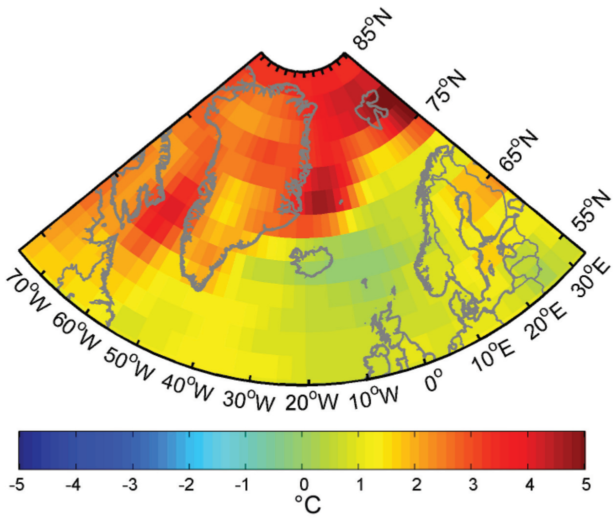


Fig. 6.30. Annual temperature anomalies (°C) across Fennoscandinavia, the North Atlantic, and Greenland in 2005 (1961–90 base). [Source: NCAR–NCEP Reanalysis]

which broke existing records. For example, on 11 October 2005 several Norwegian stations reported daytime temperatures well above 20°C. Of these, Molde Airport recorded the highest temperature (25.6°C), which is a new Norwegian record for October. Finland also experienced two unusually warm spells in autumn, making November 2005 the warmest November since 1900 in the central regions. For Denmark, 2005 was the fourth sunniest year on record and Reykjavik, Iceland, experienced 280 more sunshine hours compared to the 1961–90 mean. In all, 2005 is ranked as the fifth to eight warmest year since the second half of the eighteenth century, when regular measurements commenced in many Nordic countries.

(ii) Precipitation

Annual precipitation amounts across the region were both above and below the 1961–90 average (Fig. 6.31). Across much of Finland, northern regions of Norway and Sweden, the Färö Islands, and along the southern half of the Norwegian west coast, annual precipitation was above average (Fig. 6.31, right), where positive departures reached up to 40% of the long-term mean. Greenland also experienced remarkable precipitation deviations from the long-term mean (Fig. 6.31, left). However, while large regions of southernmost, western, and northern Greenland received from 50% to over 100% more precipitation than the 1961–90 mean, parts of eastern and southern Greenland were considerably drier than normal (Fig. 6.31, left).

Southern Sweden, Denmark, and Iceland received annual precipitation amounts either somewhat below or close to the long-term average. Many locations across Fennoscandinavia, though, reported record or near-record precipitation in 2005: Nuuk, Greenland, received 1219 mm, ranking 2005 as the wettest year there since 1958. For Norway, 2005 was among the second to third wettest year since measurements began. Parts of Finland experienced a very wet May, with precipitation 200%–300% above normal. Severe flooding occurred along several rivers in northern Finland as a result of snowmelt. Also, Sweden experienced heavy rainfall in July and August.

(iii) Notable events

For much of the region, 2005 started with an extremely severe storm. On 8–9 January an intense low pressure system formed west of the British Isles and intensified on its way toward Fennoscandinavia. Mean sea level pressure dropped as low as 960 hPa when the system, named Gudrun, reached Sweden, causing major damage. Mean wind speeds and maximum gusts reached 33 and 42 m s^{-1}, respectively. In addition to widespread power failure and infrastructure damage, Gudrun was responsible for several fatalities, and became the worst tree-felling storm in Sweden since 1930, when statistics on storm-related forest damage started. In addition, record sea levels and coastal flooding occurred along parts of

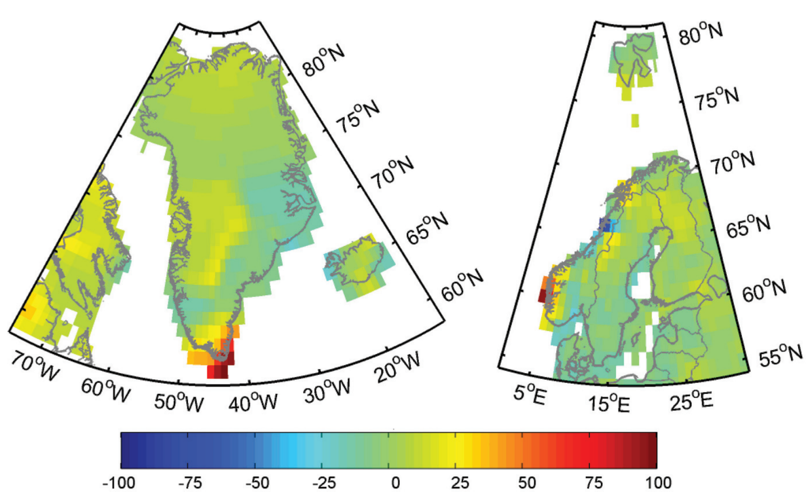


Fig. 6.31. Annual precipitation departures from normal (mm yr^{-1}) across (left) Greenland and (right) Fennoscandinavia (1961–90 base). [Source: Global Precipitation Climatology Center (GPCC)]

the Swedish, Norwegian, and Finnish west coasts. Swedish insurance companies rank Gudrun as the costliest natural event in their history.

Remnants of Hurricane Katrina reached Greenland as an extratropical low pressure system in early September. The low brought several thunderstorms and frequent lightning to southwest Greenland.

On 14 November, an exceptionally strong low pressure system named Loke reached Norway and brought over 200 mm of precipitation over 24 h to several locations. In addition to one fatality, the storm generated landslides across Norway, closing many roads and the train line between Oslo and Bergen. Loke produced the country's second highest daily precipitation amount (223 mm) on record, measured near Bergen.

iv) Central northern Europe—J. J. Kennedy[38]

Annually averaged temperatures in 2005 were above average throughout the region (Fig. 6.29). Precipitation totals for January–November were near average in the west and east, but somewhat drier than average in Poland (Fig. 6.29).

January temperatures and precipitation were above average everywhere, with the largest temperature anomalies (more than 5.3°C) in the east. February temperatures fell to below average everywhere except the far northeast. These northeastern areas were also drier than normal, but most areas experienced above-average rainfall in February. March temperatures were more than 3°C below average in Estonia and Latvia, and only western Germany experienced warmer-than-average temperatures. Rainfall totals in March were anomalously large in Belarus, Lithuania, and eastern Poland, but were lower than average in other areas.

April–June temperatures in some areas of Poland and Germany were significantly above average. Temperatures were above average everywhere in April, with significant warmth (> 2°C) in parts of Germany and Poland. May anomalies were generally lower than those in April, with below-average temperatures in the east. After a dry April, May rainfall was above average. Precipitation was particularly heavy in the east with many areas receiving more than twice the usual monthly amount. One area in Belarus received nearly three times its average monthly total. In June, temperature anomalies fell again in the east, with temperatures dropping below average everywhere east of central Poland. Temperature anomalies in southwestern Germany, however, rose above 2.8°C (98th percentile).

July–September was another warm period. Temperature anomalies were highest in the east, exceeding the 90th percentile in large parts of Poland, Belarus, and Estonia. Precipitation was below average except in Germany. July saw above-average temperatures in all areas, although significant positive anomalies were found in only a few areas of Poland, Belarus and Lithuania. Above average rainfall in Germany and Poland may have acted to reduce temperature anomalies in those regions. Below-average August temperatures occurred in Germany and much of Poland, and wetter-than-average conditions existed in the east. September was drier and warmer than average in most areas, with Belarus, northern Germany, and western Poland experiencing significant warmth. Only central parts of Germany received above-average rainfall.

Temperatures between October and December were above average and precipitation totals were below average in all regions. October temperature anomalies were highest in Germany, where temperatures were significantly above normal over much of the country, and even rose above the 98th percentile in the west (+2.5°C anomaly). Some areas of Poland received less than 20% of the average October precipitation. In November southern Germany and Poland had below-average temperatures, but anomalies increased to the north. November was another dry month, and no area experienced above-average rainfall. In December, temperatures were above average in most areas, although southern Germany had temperatures that were more than 1.6°C below the average.

v) Northwestern Europe—J. J. Kennedy[38]

Annually averaged temperatures in northwestern Europe in 2005 were above average in all areas. The United Kingdom and Netherlands experienced significantly above-normal temperatures, and anomalies in Scotland exceeded the 98th percentile for the year. France and the south of the United Kingdom were drier than average between January and November 2005 and some areas of France received less than 60% of the average rainfall.

January saw significantly above-average temperatures in the United Kingdom. Most areas were dry, but the north of the United Kingdom received above-average rainfall, which led to flooding in a number of areas. Temperatures fell below average in most areas in February. In the south of France both temperatures and rainfall were significantly below average, with some areas receiving less than 20% of normal precipitation. Drier-than-average conditions continued in March across France and the United Kingdom. March temperatures were above average in most areas, and significantly so in Scotland and Ireland.

April–June average temperatures were significantly above normal everywhere except Scotland and Ireland. Temperatures in France exceeded the 98th percentile. April was warmer than average in all regions, but significant warmth was confined to the Low Countries, southeast England, and western Scotland. Precipitation was above average in most areas. Temperatures in May were below average only in Ireland and Scotland, while the south of France experienced significantly high temperatures. Rainfall was below average in England, Wales, and France, but above average in Scotland and Ireland. Significantly high June temperatures covered all areas except central England, where subzero temperatures were experienced near the start of the month and the central England minimum temperature index (Parker and Horton 2005) dropped below the 5th percentile of occurrence (3.6°C on 7 June). Contrastingly, temperatures in the southeast of France exceeded the 98th percentile. Precipitation totals were below average over continental regions.

July was warmer than average in all areas, with the highest anomalies over continental areas. Rainfall deficits were observed in the south of France and Scotland, but other areas experienced above-average rainfall. August was warmer and drier than usual in the west, but cooler and wetter than normal in the east. Anomalies increased in September with above-average temperatures in all areas. Southern France had the lowest temperature anomalies and highest rainfall anomalies, but other areas were predominantly dry.

In October temperatures in central areas exceeded the 98th percentile. On 12 October the highest ever October minimum central England temperature (15.2°C) was recorded. October precipitation was above average in the United Kingdom and northwest France, but below average in other areas. November temperatures in France and England were below average, and it was drier than average over most of the region. Temperatures in December were below average in France, particularly in the south of the country, where it was significantly below normal (< –2°C anomaly).

VI) Iberia—R. Trigo,[86] R. Garcia-Herrera,[24] and D. Paredes[64]

(i) Temperature

The average 850-hPa temperature across Iberia in 2005 was 0.3°C above normal (1961–90 base period mean). However, this relatively moderate annual anomaly conceals considerably larger cold and warm temperature anomalies observed in winter (-1.6°C) and summer (+1.7°C).

Wintertime upper-level 500-hPa geopotential height anomaly fields confirm the overall structure observed at surface, with intense positive anomalies centered between the Azores and Iceland (Fig. 6.32, left). As a consequence of this strong northwest–southeast geopotential height gradient, Western Europe was under the influence of strong cold air advection from higher latitudes. Several consecutive cold wave outbreaks were observed between the end of January and early March affecting all of Iberia as well as France and central Europe (Garcia-Herrera et al. 2006, manuscript submitted to *J. Hydrometeor.*). Daily maximum and minimum temperatures for Lisbon, Portugal, reveal that these cold waves reached the western coast of Iberia, producing a number of days with temperatures in the coldest decile (lowest 10%) of daily long-term records (Fig. 6.33). Interestingly, soon after the last cold wave, a circulation shift to North African air penetration resulted in late-March/early April daily temperatures within the highest decile (hottest 10%) of long-term temperature records for those days (Fig. 6.33).

Spring and summer months were characterized by warmer-than-normal temperature values, particularly between late May and August, with most of Iberia impacted by two intense heat waves in June and August (Fig. 6.33). Positive SLP anomalies over Europe, due to the extended Azores anticyclone, contributed to the anomalous warmth in these months. The summer 500-hPa geopotential height anomaly field was dominated by a positive anomaly maximum centered between Iberia and the United Kingdom (Fig. 6.32, right). This large-scale feature not only impeded the natural eastward progression of low pressure systems that frequently cross northern Europe in the summer, but contributed to the advec-

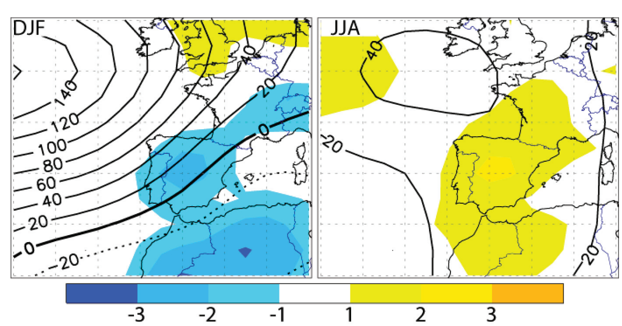


Fig. 6.32. (left) Winter (DJF) and (right) summer (JJA) anomalies of 500-hPa geopotential height (contours; gpm) and corresponding 850-hPa temperature anomaly field (color; °C) over southwest Europe and North Africa. [Source: NCAR NCEP reanalyses; 1961–90 base]

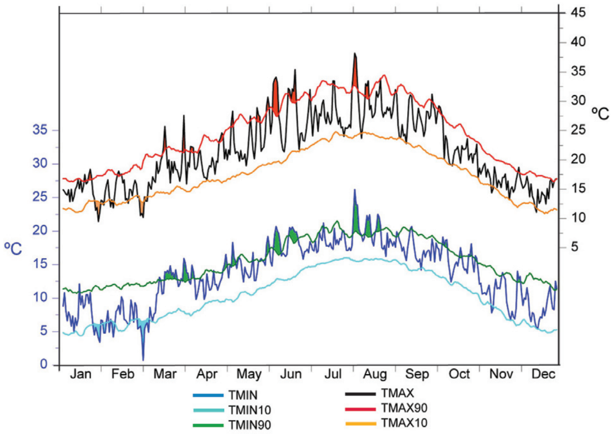


FIG. 6.33. Daily Tmax (black) and Tmin (dark blue) temperature (°C) in Lisbon during 2005. Red (green) and orange (light blue) lines correspond to the 90th and 10th percentiles, respectively, of the Tmax (Tmin) for each day of the year (10-day moving window), and were computed using the period 1941–2000.

tion of warm air masses in the south as well as enhanced adiabatic heating through subsidence (Trigo et al. 2004). Furthermore, extended periods of clear skies associated with anticyclonic conditions contributed to increased solar radiative heating over the region.

(ii) Precipitation

The Iberian Peninsula experienced drier-than-normal conditions during 2005 relative to the 1961–90 base period mean (Fig. 6.29). The hydrological year of 2004/05 (October 2004–September 2005) was among the driest since regular precipitation records started in both Portugal and Spain (see sidebar). In fact, based on the monthly Global Precipitation Climatology Center (GPCC)-gridded dataset (Rudolf and Schneider 2005), drought conditions prevailed in 2005 over a large area of Western Europe, including the southern United Kingdom, France, and Northern Italy (Fig. 6.29). During winter and spring, usually the wettest seasons, dry conditions prevailed over much of Iberia, with precipitation less than 50% (and in places < 25%) of 1961–90 mean values. Winter months were characterized by the presence of intense anticyclonic circulation, located northward of its usual latitude (Azores). Drought conditions continued through the spring months, although with less intensity than in winter. However, unlike winter, several storm tracks progressed from the Atlantic toward Iberia and France, but were stopped from penetrating the European continent by the development of extensive blocking events.

The summer season of 2005 was also characterized by reduced precipitation over Western Europe and northern Africa, with the maximum amplitude over Iberia. Precipitation totals rebounded across the northeastern sector of the Iberian Peninsula during autumn 2005, but normal precipitation fell in the remaining areas, particularly in the southern sector.

Major climatic anomalies are often driven by enhanced values of large-scale atmospheric circulation indices [e.g., ENSO, PNA, NAO, east Atlantic (EA)]. Interestingly, this record-breaking drought is only partially associated with extreme values of teleconnection indices, particularly those that are known to have a significant impact upon winter Iberian precipitation (NAO and EA). Moderately positive (negative) values of NAO (EA) recorded between November and February are clearly associated with the scarce precipitation observed over Iberia. However, the similarly dry conditions observed in March are more difficult to associate with the intense negative NAO (–1.8) and moderately positive EA (+1.1) indices. Instead, an extremely intense blocking event positioned over unusually southern latitudes contributed to the widespread March precipitation anomaly over Europe.

VII) MEDITERRANEAN AND SOUTHERN EUROPE—J. J. Kennedy[38]

Temperatures in the Mediterranean were above average in most areas in 2005. Greece was one of the few countries that experienced below-average temperatures for the year as a whole. Precipitation was generally below average in the west, but above average further east.

January–March temperatures were below average in all regions and significantly below average in Italy. In the western Mediterranean, temperatures fell below the 2nd percentile of occurrence. The north of Italy and the western Mediterranean were drier than average, while southern Italy and Greece were wetter. January temperatures were above average only in Greece, and in the western Mediterranean temperatures were below the 2nd percentile. Cold conditions continued into February and the whole of the Mediterranean area west of 25°E experienced significant cold. The south and west were the coolest areas, with temperature anomalies of –3.7°C in the Balearic Islands falling below the 2nd percentile. January was drier than average in the west, but above-average January precipitation in Greece and Italy spread westward in February, when only northern Italy experienced below-average rainfall. March was much drier, with most areas experiencing below-average rainfall.

In April–June, average temperatures were significantly above normal in all areas except Greece. West of Sardinia, temperatures exceeded the 98th percentile. Precipitation was below average in most regions, with the exception of southern Italy and Sicily. April temperatures were near average in most regions. May was warmer with large areas in the west showing significant warmth. Heating continued through June, with significantly above-normal temperatures in all areas except Greece. Parts of northern Italy exceeded the 98th percentile. Anomalous rainfall occurred in southern Italy and Sicily, where totals were above average in all three months.

Significant heat continued into July over large areas of the region. Above-normal precipitation fell over Greece, with eastern areas receiving more than twice the monthly average. Temperature anomalies were somewhat lower in August, dropping below average in northeastern areas, but high temperatures in the western Mediterranean brought large numbers of jellyfish to Spanish beaches. Most areas saw above-average rainfall, and northern Greece again received significant excesses of precipitation. Temperature anomalies in the west fell in September, and most areas experienced above-average rainfall.

Average October–December temperatures were below average in most areas. October temperatures were below average in the east, and above average in the west. In November, cold anomalies spread over much of the Mediterranean and by December temperatures had dropped significantly below normal in central areas. In December, Greece was the only country in the region to experience above-average temperatures. October was mainly a dry month, with northern Italy the only place to receive above-average precipitation. November in contrast was wetter than average in most areas.

viii) Southeastern Europe—J. J. Kennedy[38]

Temperatures in southeastern Europe in 2005 were within 0.2°C of the 1961–90 average. Eastern areas, particularly Bulgaria, received significantly

THE EXTREME IBERIAN DROUGHT OF 2004/05—R. Trigo,[86] R. Garcia-Herrera,[24] and D. Paredes[64]

The year 2005 was characterized by one of the worst droughts ever recorded in the Iberian Peninsula, particularly in its southern half. The hydrological year that spans between October 2004 and September 2005 was the driest on record for several locations throughout Iberia, namely in the capital cities of Lisbon, Portugal, and Madrid, Spain, where reliable precipitation records have been kept since 1865 and 1859, respectively (Fig. 6.34). In particular, in Lisbon the 2004/05 event surpassed the previous record drought of the 1944/45 hydrological year (Fig. 6.35).

The precipitation regime over Iberia is characterized by strong seasonal behavior, with a unimodal rainy season concentrated between October and March and relatively arid conditions at other times. Therefore, all major droughts in this region are characterized by lack of rainfall during several months of the winter half of the year (Trigo et al. 2004). Using data from the GPCC (Rudolf and Schneider 2005) the spatially averaged precipitation over Iberia, between October 2004 and September 2005, was roughly 45% less than the 1961–90 climatological average (Garcia-Herrera et al. 2006, manuscript submitted to *J. Hydrometeor.*). However, regionally, the drought was most intense in the southern and southwestern sectors of the Iberian Peninsula, where rainfall was as little as 40% of normal during that period (Fig. 6.34)

The 2004/05 drought had major socioeconomic impacts in both Iberian countries, particularly for hydroelectricity and cereals production, which decreased to 40% and 60%, respectively, of their long-term average values. Agricultural losses due to scarce water resources and diminished pasture land during this season have been estimated to be on the order of $2 billion USD.

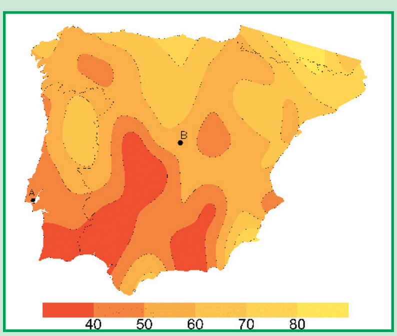


Fig. 6.34. Percentage of normal (1961–90 base) precipitation accumulated between October 2004 and September 2005. [Source: GPCC] Lisbon (A) and Madrid (B) are shown.

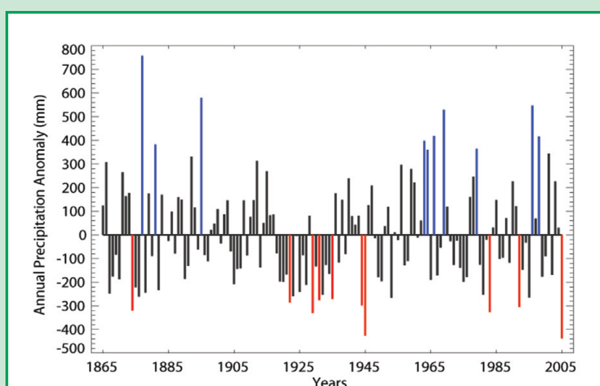


Fig. 6.35. Annual precipitation anomaly (mm) for Lisbon from 1865 to 2005 (1865–2005 mean). Anomalies correspond to the hydrological year that spans between October of year *n*-1 and September of year *n*.

above-average precipitation totals for the year, causing flooding in many areas.

The January–March period was colder than average in all but eastern Bulgaria. January was generally warmer than average, but February saw significant cold in most areas, with temperatures in Serbia more than 3°C below average. Temperatures in March were also below average, but not significantly so. The greatest precipitation anomalies occurred in Bulgaria in all three months, which led to flooding there in February.

April saw the end of the anomalously cold weather, with above-average temperatures in all areas. May and June temperatures were above average in most areas, significantly warmer than normal in Croatia and Bosnia-Herzegovina, but below average for June in Bulgaria. Rainfall totals in April and June were close to average in most parts, but in Bulgaria significant May rainfall once again brought flooding.

Although July temperature anomalies in southeastern Europe were positive, they were lower than in most areas of Europe. Even so, temperatures along the Adriatic coast were significantly above normal. Temperatures in August were below average except in eastern Bulgaria, which experienced significant warmth. September was warmer than average. July, August, and September rainfall totals were far above average, with Bulgaria receiving more than twice the seasonal average, and large areas recording more than three times the average. In August, 500% above-normal monthly rainfall in Bulgaria produced flooding that continued into September and left more than 30 dead.

Excessive rains continued in the east into October, but November totals were close to average in all areas. October and November temperatures were below average in the south and east, but December saw the colder weather shifting to the west. Temperatures in the north were above average in October, but fell below average for the last two months of the year.

h. Oceania

1) Australia—A. B. Watkins[90]

Despite the notable absence of an active basin-wide El Niño event, 2005 was the hottest year on meteorological record for Australia.[2] Neutral to slightly warm conditions in the equatorial Indian and Pacific Oceans at the start of 2005 persisted until June, returning to near normal in the latter half of the year. Correspondingly, pressure over Australia was higher than normal during the first half of the year, and from normal to below normal during the remainder of 2005. The anomalously high pressure over the country during early 2005 greatly reduced rainfall over the interior and inhibited the northward penetration of frontal systems from the Southern Ocean. High pressure also contributed to a sporadic Australian monsoon, which failed to extend far inland, resulting in anomalously warm and dry conditions in the north.

(i) Temperature

Due in part to the inconsistent Australian monsoon, the tropical wet season (October 2004–April 2005) was relatively warm. Northern Australia experienced a +1.5°C maximum temperature (Tmax) anomaly (0.6°C above the previous wet season record). Additionally, April, ordinarily the start of the main winter cropping season, was climatologically one of the most remarkable months on record for Australia. Australia-wide, April mean Tmax was 3.11°C above normal (Fig. 6.36). Not only was this 0.7°C above the previous April record, but it was the largest anomaly recorded for any month since Australia-wide temperature records began in 1950, which is substantially higher than the previous record (+2.68°C) set in October 1988. Combined with record high minimum temperatures (Tmin), the April mean temperature anomaly of +2.58°C was 0.85°C above the previous April record set in 2002 and 0.26°C above the previous record for any month (June 1996). Notably, the April mean temperature was the highest on record over 66% of the continent, with 86% of the continent experiencing mean temperatures for the month in the highest 10% the of recorded totals.

June–December Tmax and Tmin remained above average across virtually the entire country (+0.75° and +0.94°C anomalies, respectively). When combined with the hot start to the year, temperatures for 2005 were exceptional. The Australia-wide Tmax anomaly for 2005 was +1.21°C, equal to the record set in 2002, while the Australia-wide Tmin anomaly

[2] For Australia-wide, as well as large-scale regional averages, high-quality monthly temperature data is available from 1950, with high-quality annual temperature data starting 1910. For rainfall, high-quality area-averaged data commences in 1900. All records and percentile values are calculated with respect to these years. Anomalies are calculated with respect to the 1961 to 1990 average, in accordance with World Meteorological Organization guidelines (WMO Publication No. 100: www.wmo.ch/web/wcp/ccl/ GuideHome/html/wmo100.html).

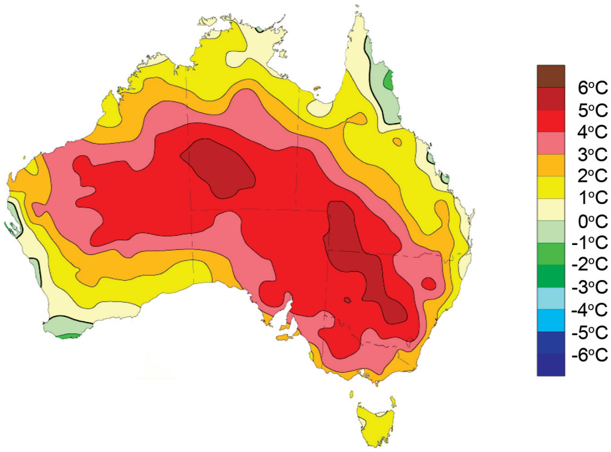


Fig. 6.36. Australian maximum April temperature (Tmax) anomalies (°C) for 2005 (1961–90 base).

of +0.91°C was the third warmest on record behind 1998 (+1.12°C).

Overall, the mean temperature anomaly for 2005 of +1.06°C was 0.23°C above the previous hottest year (1998). Consequently, Australia experienced its hottest mean temperature since annual mean records commenced in 1910. In total, 95% of the continent experienced above-average mean temperatures during 2005 (Fig. 6.37). With the absence of a decaying El Niño event, the record Australian heat of 2005 clearly highlights the impact of the long-term warming trend of the global and Australian climate upon the natural variability of year-to-year fluctuations.

(ii) Precipitation

High pressure over the continent and the weak Australian monsoon contributed to extremely dry conditions during the first five months of the year (Watkins 2005), with 44% of the country experiencing rainfall in the lowest 10% of recorded totals (decile 1). Australia-wide, April was the eighth driest April on record, with only 10.7 mm for the month (average of 31.1 mm). The Australia-wide average rainfall of 168 mm was the second lowest January–May total (after 1965) since Australia-wide monthly records began in 1900. While short-term dry spells are not unusual for Australia, it hindered the limited recovery from the devastating 2002/03 El Niño–related Australian drought (Coughlan et al. 2003), one of the worst droughts in Australia's recorded meteorological history (Nicholls 2004).

In a remarkable turnaround, 80% of the country experienced above-average rainfall between June and December, which corresponded to a change in ocean conditions in the equatorial Pacific. June–December precipitation over many previously drought-affected parts of New South Wales was in the top 10% (decile 10) of recorded totals. Australia-wide, 23% of the country experienced decile-10 precipitation between June and December, compared to only 0.6% for the January–May period.

Despite the average to above-average rainfall totals in the second half of the year, the extremely dry conditions during the first five months contributed to a generally below-average rainfall year for Australia (Fig. 6.37). The 2005 Australia-wide average rainfall of 407.2 mm was the 33rd driest such period since all-Australian records commenced in 1910, which is 65 mm below the 1961–90 mean of 472 mm. Overall, 63% of Australia experienced below-average rainfall during 2005.

(iii) Notable events

In January, Nyang Station, in the Gascoyne region of inland Western Australia, measured Australia's

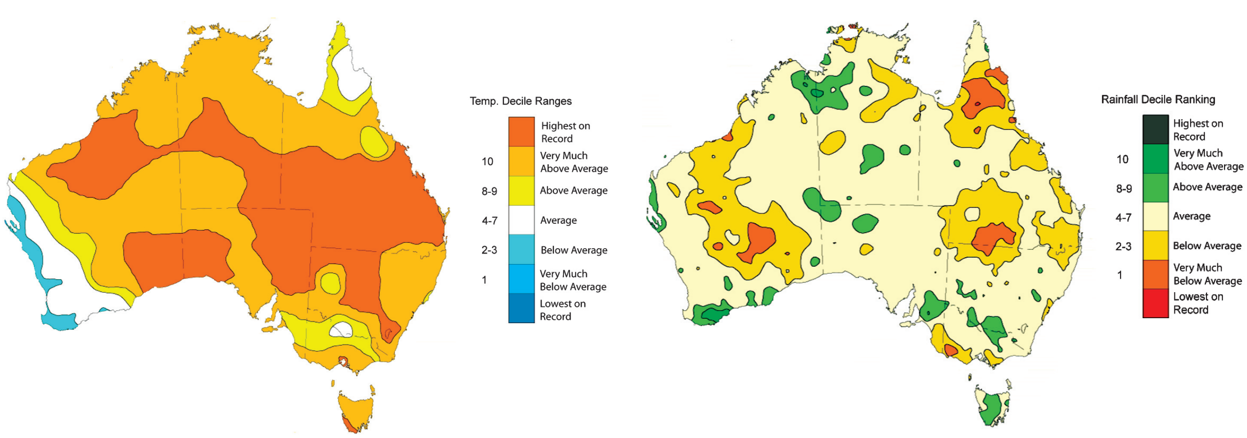


Fig. 6.37. Australian mean (left) temperature and (right) precipitation accumulation deciles for 2005 (relative to 1950–2005 for temperature and 1900–2005 for precipitation). [Source: Australian BOM]

hottest month on record, when its average maximum temperature of 44.8°C equaled the previous record, also set at Nyang, from February 1998.

An intense low pressure system developed over Eastern Bass Strait on 2 February, resulting in substantial rainfall and low temperatures for Victoria, southern New South Wales, South Australia, and Tasmania. The event made February 2005 Victoria's wettest February since 1973. Despite the 2-day event supplying 22% of Melbourne's annual mean rainfall (638.8 mm), the city's 2005 total precipitation of 589.8 mm was below average for the ninth year in succession.

Tropical Cyclone Ingrid, which occurred between 5 and 16 March (see section 4c), reached category 5 (Australian scale; information online at www.bom.gov.au/catalogue/warnings/WarningsInformation_TC_Ed.shtml) on at least two occasions, and is the only TC in Australia's recorded history to impact three different states or territories (Queensland, Northern Territory, Western Australia) as a severe tropical cyclone (category 3 or above).

Despite the generally mild winter, three major low-elevation snow events occurred during the season. These affected the Northern Tablelands of New South Wales and adjoining southern Queensland (22–23 June), the Monaro district of New South Wales (8–9 July), and southern Victoria and Tasmania (10 August). The August event brought snow to sea level in Victoria for the first time since 9 August 1951.

A notable heat wave affected large parts of central and eastern Australia during late December 2005 and early January 2006. The most abnormal conditions occurred in the period from 30 December 2005 to 1 January 2006, when northwesterly winds brought extreme heat to southeastern Australia. Arguably, the most exceptional record occurred at Montague Island (New South Wales), where a reading of 41.0°C broke its previous all-time record by 3.8°C. Sydney reached 44.2°C on 1 January 2006, second only to the 45.3°C reached there on 14 January 1939.

II) New Zealand—M. J. Salinger[80]

New Zealand's climate of 2005 was influenced by more frequent anticyclonic activity in the Tasman Sea and to the east of the South Island, resulting in less wind, warmer temperatures, and generally decreased precipitation for much of New Zealand. However, more cyclonic activity was present in February, March, May, and December, and the northeast of the North Island experienced more frequent easterlies at times (Fig. 6.38). Notable climate features in various parts of the country included heat waves, low soil moisture, localized flooding, the Greymouth tornado, an unseasonable snowstorm, and damaging hailstorms.

(i) Temperature

The national average temperature in 2005 was 13.1°C, 0.5°C above the 1971–2000 normal. It was the fourth warmest year nationally since reliable records commenced in the 1860s. Only 1971, 1998, and 1999 have been warmer with temperatures of 13.2°, 13.3°, and 13.3°C, respectively. For New Zealand as a whole, there were seven warmer-than-normal months (February, March, May, July through September, and December), two cooler months (January and April), and three months with mean temperatures close to the climatological average (June, October, and November).

A combination of anticyclones and northeasterlies brought one of the warmest Februaries on record, with maximum temperatures of 30°C or more in many locations throughout New Zealand, and temperatures of 35°C or more in sheltered inland areas of the South Island during the first 10 days. The highest recorded extreme air temperature for the year was 38.7°C at Alexandra on 5 February (the highest temperature there for any month, in records back to 1929). Overall, February was the eighth warmest on record, with a mean temperature of 18.6°C (+1.3°C anomaly).

Halfway through the year, more frequent anticyclones over the North Island and northwesterlies over the South Island produced the sixth warmest winter (June–August) on record, even though June

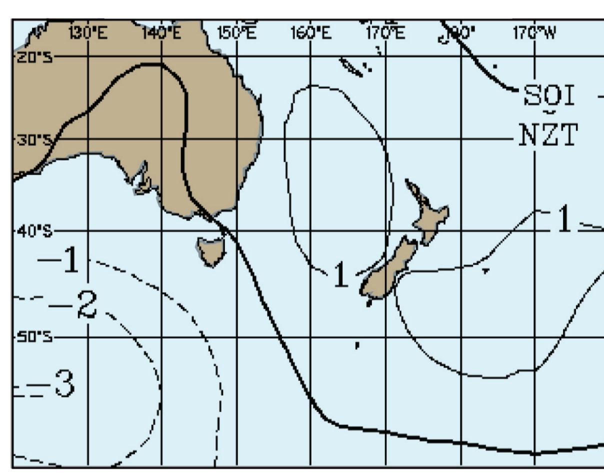


Fig. 6.38. 2005 mean sea level pressure anomaly map for the New Zealand region showing departures from average (hPa). Anticyclones were more frequent than normal east of the South Island and in the Tasman Sea.

was the coldest in a decade. With a mean temperature of 9.1°C (+1.2°C), July was the third warmest on record. Record high August maximum temperatures were recorded at Hanmer Forest (25.1°C on the 30th) and Amberley (25.4°C on the 31st). August's 9.8°C (+1.1°C) made it the fourth warmest on record. Mild conditions accompanied continued anticyclonic activity into spring (September–November). A changing atmospheric pattern to warm northerlies produced the third warmest December on record, with 17.5°C (+1.9°C).

Mean temperatures in 2005 were at least 0.3°C above average in most regions, and 0.5°–0.9°C above average in parts of Auckland, Coromandel, western Bay of Plenty, and western North Island from Wanganui to Wellington, as well as Wairarapa and much of the South Island. Temperatures were near average in coastal Wairarapa, along the Kaikoura Coast, and in coastal areas of south Canterbury. The warmest locales were Cape Reinga and Whangarei Airport, both with a mean temperature for the year of 16.1°C (0.2° and 0.5 °C above normal, respectively). Several locations observed record warmest annual average temperature in 2005.

(ii) Precipitation

New Zealand's climate for 2005 was marked by too little rain in some places, and too much in others. Annual rainfall during the year was less than 75% of normal over much of the South Island, and 75%–90% of normal in the north and west of the North Island (excluding Wanganui) and southern Wairarapa (Fig. 6.39). Clyde recorded the least annual precipitation at 348 mm (76% of normal). Near-record to record low precipitation was observed at numerous locations. Conversely, well-above-average precipitation (> 125%) fell in the western Bay of Plenty, Hawke's Bay, and the far southwest of the South Island. Precipitation was near normal elsewhere. The wettest location was Cropp River in Westland, with an annual total of 9290 mm.

Anticyclones in January commenced the trend of low rainfall and severe or significant soil moisture deficits in the northern half of the North Island and Canterbury; these conditions persisting into April. March was wetter in the North Island, but more anticyclones in April kept conditions dry. However, weather patterns changed abruptly in May, resulting in widespread flooding in the Bay of Plenty.

Frequent winter anticyclones over the North Island and northwesterlies over the South Island produced extremely dry conditions in the east of the South Island between June and September. Winter snowfall was much less frequent than normal. However, an early spring snow (19 September) down to sea level in Canterbury was unusual for the month.

Below-average spring rainfall resulted in significant soil moisture deficits developing much earlier than usual from Southland to Marlborough. Deficits spread to Nelson and the southwest of the North Island in November, and developed in Hawke's Bay, Auckland, and parts of Northland in December. However, southeasterlies in both October and November produced significant flooding in Gisborne.

(iii) Notable events

For the year, there were at least 26 heavy rainfall events, half of which produced floods. There were also 7 damaging hailstorms and 12 damaging tornadoes (or events attributed to tornadoes) in 2005. The Greymouth tornado of 10 March was particularly

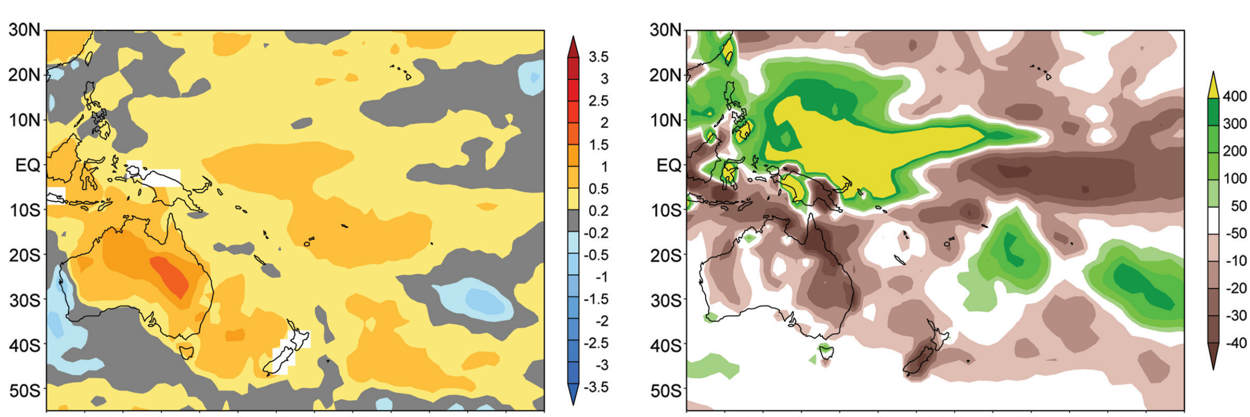


Fig. 6.39. South Pacific 2005 annual (left) temperature anomalies (°C; 1971–2000 base) and (right) precipitation anomalies (mm; 1979–2000 base) from CAMS–OPI.

destructive, leaving 30 people homeless and resulting in damage worth at least $10 million New Zealand dollars (NZD; $6.3 million USD). Wellington Airport was closed for many more hours than usual in 2005. There were 52 h with fog there, the highest for any year in 45 years of measurement.

The Bay of Plenty floods of 3–4 May and 17–18 May were most disastrous, with the earlier of the two causing widespread damage in parts of Tauranga, and the later being phenomenal, with unprecedented high rainfall for the district and a state of emergency declaration from Tauranga to Matata. Hundreds of people were evacuated. Homes were destroyed by mudslides and flooding, and rising waters threatened hundreds of others, especially in Matata.

The extremely high temperatures during the first 10 days of February are notable because there are very few instances prior to this event where temperatures anywhere in New Zealand have exceeded 38°C (100°F).

In Canterbury, the Christchurch airport, schools, and universities were closed due to an unusual early spring snow (19 September) in Canterbury. Snow depths of 5–10 cm were recorded in the region.

III) South Pacific Islands—M. J. Salinger[80] and S. M. Burgess[12]

A high frequency of surface equatorial westerlies occurred near the date line in February (the most since the last El Niño in 2002). Trade winds generally were near normal in strength at other times of the year. There was also some ENSO influence on the location of the SPCZ during the year. West of the date line, the SPCZ was further north than usual from January through August, and further south than usual from November through December. East of the date line, the SPCZ was very weak from March through August. It was further south than usual from October through December (see section 4d). Above-average equatorial SSTs occurred with the weakly negative El Niño; however, the region of positive SST anomalies drifted west as the El Niño faded. From August through December OLR anomalies showed enhanced convection over Papua New Guinea, and suppressed convection over Western and Eastern Kiribati, Tokelau, Tuvalu, and the North Cook Islands. For much of the year, mean sea level pressures were above average west of the date line, and below average in the east.

(i) Temperature

Overall, 2005 was warmer than normal (1971–2000 mean) across much of the region (Fig. 6.39). Above-average SSTs occurred throughout much of the tropical Southwest Pacific during 2005 (Fig. 6.40). Notably, SSTs were about +1.0°C above average around western Kiribati, and at least +0.5°C above average in many other island nations, especially those north of 20°S. New Caledonia, the Southern Cook Islands, the Austral Islands, and Pitcairn Island were surrounded by near-average SSTs. Southwest Pacific island surface air temperature anomalies for 2005 were consistent with the SST anomalies throughout the region. It was an extremely warm year in Tahiti-Faa'a, central French Polynesia, where the annual mean temperature was 27.0°C (+0.8°C above the 1971–2000 normal), and equal the highest since measurements commenced in 1957.

Locally, a heat wave occurred from 4 to 7 January in La Tontouta, New Caledonia, with maximum temperatures between 36° and 37°C. New Caledonia's mean temperatures were 1.3°C above normal for the month. In general, southern locations such as Vanuatu, Fiji, New Caledonia, and southern French Polynesia experienced a cooler-than-normal July and August. Tahiti-Faa'a recorded its hottest November and December maximum temperatures in 2005 (33.9° and 28.1°C, respectively).

(ii) Precipitation

Southwest Pacific 2005 OLR anomalies showed a region of enhanced convection over Papua New Guinea extending toward the Solomon Islands (Fig. 6.41). There was also an area of weakly enhanced convection over Niue and the Southern Cook Islands, as well as Pitcairn Island. Convection was suppressed in 2005 over western and eastern Kiribati, Tokelau,

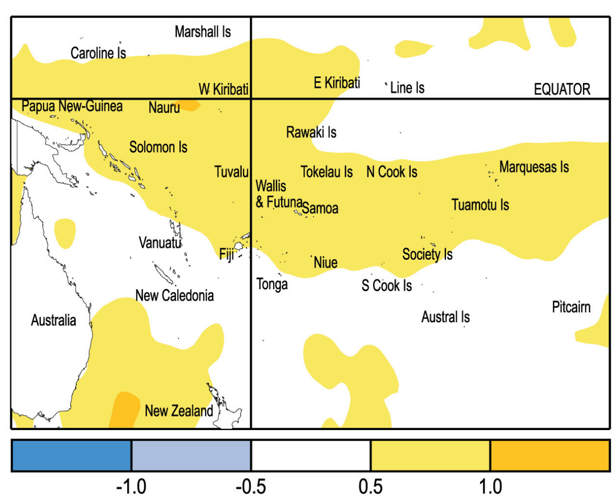


Fig. 6.40. South Pacific annual SST anomalies (relative to 1971–2000 mean; °C). Yellow or orange areas represent above-average temperatures.

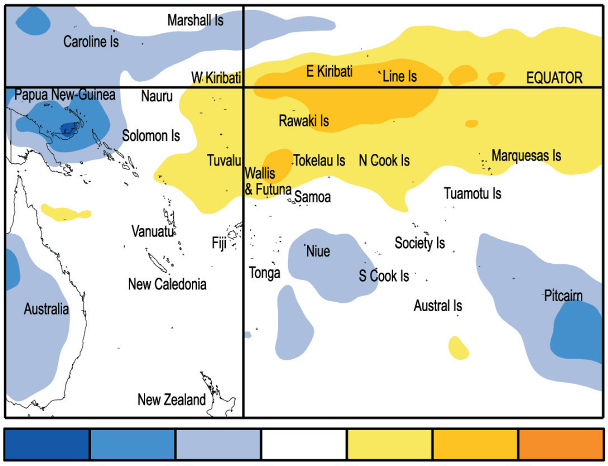


Fig. 6.41. Annual South Pacific outgoing longwave radiation anomalies (W m^{-2}). High radiation levels (yellow or orange) are typically associated with clearer skies and lower rainfall, while low values (blue) often indicate cloudy conditions and more rain for the region.

Tuvalu, Wallis and Futuna, the North Cook Islands, and the Marquesas Islands. The year's rainfall distribution shows similarities to the OLR pattern. However, for rainfall there were not many significant anomalies. Annual rainfall was at least 110% of normal in an area affecting a region extending from Niue to the north and east of Fiji, and also parts of Southern French Polynesia. In contrast, 2005 rainfall was less than 90% of the average throughout much of New Caledonia.

One location, Gambier, Rikitea, French Polynesia, recorded an extremely high 2005 precipitation anomaly of 127% of normal (2505 mm). Several locations received record monthly rainfall amounts: Vunisea, Fiji (786 mm, April), Viwa (205 mm, June), Monasavu (640 mm, June), Navua (587 mm, June), Nausori Airport (474 mm, September), Vatukoula (353 mm, November), and at Lupepau'u, Tonga (440 mm, June). On 4 March, Vunisea set a record for daily rainfall of 251 mm, and on 18 November, Vatukoula received a record 119 mm of precipitation. Record low monthly precipitation was also recorded at Udu Point, Fiji (84 mm), and Tuamotu, Takaroa, French Polynesia (25 mm), in March, Nadi Airport and Penang Mill, Fiji (1 and 7.8 mm, respectively), in May, and Bora Bora, French Polynesia (23 mm) in October.

Rainfall occurred almost every day from 6 to 20 April in Fiji's Western Division. Extensive flooding occurred in the Northern and Western Divisions over 16–20 April, closing almost 50 roads. There was one fatality. Vanuatu, Pekoa, recorded 950 mm for April, including 5 days exceeding 100 mm. Torrential rainfall occurred in Fiji's Central Division during the last week of September, leading to flooding in parts of Suva, Nausori, and Tailevu. A large number of villages were evacuated and there was one fatality. Nausori Airport recorded 187 mm of rain on the 28th.

(iii) Notable events

In February, a record four intense tropical cyclones (Meena, Nancy, Olaf, and Percy) impacted the South Pacific Islands (see section 4c). All four occurred east of the date line, with most being triggered during an active phase of the Madden–Julian oscillation. On the Saffir–Simpson scale, Meena and Nancy reached category 4 status, while Olaf and Percy were category 5 at their height.

The first of the cyclones, Meena, passed close to Rarotonga on 6 February, with wind gusts exceeding 115 km h^{-1}. Cyclone Nancy tracked through the Northern Cook Islands from 13 to 15 February with winds gusting to 163 km h^{-1} in Rarotonga and to 185 km h^{-1} elsewhere. In Aitutaki, trees were uprooted, roofs damaged, and low-lying areas flooded. Wind and storm surge caused widespread damage along the northern and eastern coasts of Rarotonga. On 16 February, Olaf's storm surge destroyed numerous coastal structures and high winds lifted many roofs in both Samoa and American Samoa. Rarotonga's west coast received substantial damage. Late in the month, Percy, with maximum sustained winds reaching 260 km h^{-1}, caused widespread damage and destruction on Pukapuka, Nassau, Swain, and Tokelau Islands. In Tokelau, Percy destroyed most of the island's agriculture and was reportedly the worst tropical cyclone in living memory. Fortunately, despite the intense nature of these four cyclones, and reconstruction estimates exceeding $25 million USD, there were no confirmed fatalities from these storms (two listed as missing at sea following Olaf).