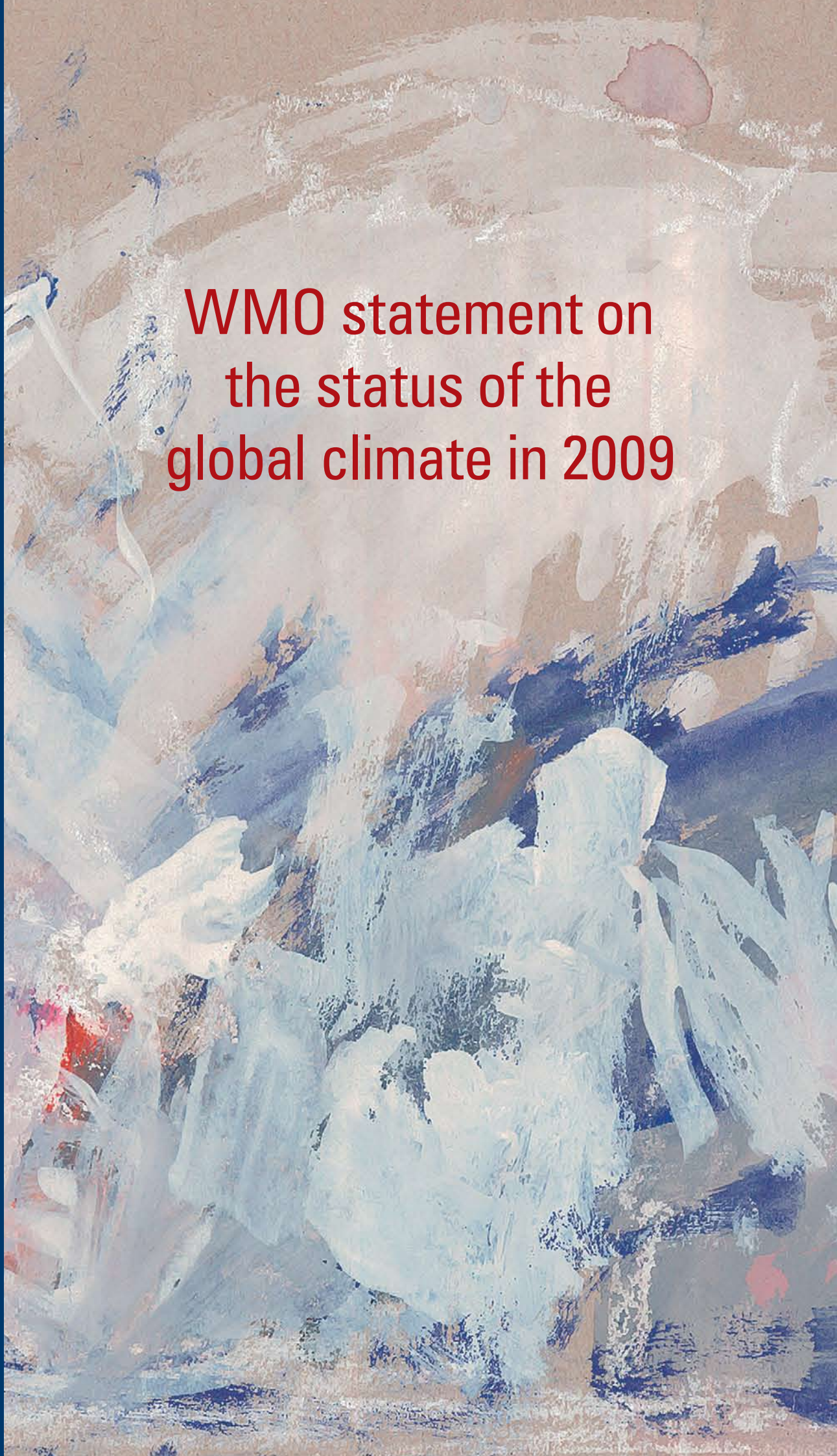
WMO statement on the status of the global climate in 2009



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Chair, Publications Board
World Meteorological Organization (WMO)
7 bis, avenue de la Paix
P.O. Box 2300
CH-1211 Geneva 2, Switzerland

Tel.: +41 (0) 22 730 84 03
Fax: +41 (0) 22 730 80 40
E-mail: publications@wmo.int

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Cover: The beauty and variety of the weather. Illustration by Felix Jegenberg, 8 years old, Sweden

Foreword

Since 1993, the World Meteorological Organization (WMO) has been issuing its annual "WMO Statement on the Status of the Global Climate", which has become an authoritative regular source of information, eagerly sought by the scientific community and the media.

The present Statement is the latest addition to this successful series, and a key result is that the period 2000–2009 was the warmest decade on record since the beginning of modern instrumental measurements around 1850.

A number of extreme weather and climate events were recorded in 2009, including in particular heatwaves in China, India and southern Europe, as well as in Australia. Severe droughts, intense storms and flooding were also registered in different parts of the world, and the end of 2009 was notably cold in the northern hemisphere, with heavy snowfall in Europe, North America and northern Asia.

Furthermore, the year concluded with a moderate El Niño event, which is being continuously monitored.

It is essential to underscore the vital role of the National Meteorological Services of the 189 Members of WMO and of many WMO partners for their key efforts to maintain the necessary observing infrastructure and the information systems, which permitted the exchange of data and analyses of temperature and precipitation variations, tropical cyclones, drought and flooding, snow cover and sea ice, the ozone layer and many other critical weather, climate and water parameters monitored across the world over the year which has concluded.

Equally outstanding were the continuing efforts of several climate centres to develop the long-term homogeneous datasets required to support the authoritative assessments that contributed to the work of WMO, the United Nations Framework Convention on Climate Change, the Intergovernmental Panel on Climate Change, the World Climate Research Programme and other key scientific activities across the world.

I therefore wish to express the gratitude of the World Meteorological Organization to all contributors to the *WMO Statement on the Status of the Global Climate in 2009.*

(M. Jarraud)
Secretary-General

Global temperature during 2009

The year 2009 is nominally ranked as the fifth warmest year on record since the beginning of instrumental climate records around 1850. On the decadal scale, the analysis shows that the 2000s decade (2000–2009) was warmer than the 1990s (1990–1999), which in turn were warmer than the 1980s (1980–1989) and earlier decades.

Global temperature assessment is provided with an uncertainty margin that affects the global surface temperature figures and consequently their ranking, mainly as a result of the existing gaps in data coverage. The magnitude of the uncertainty in assessing the global surface temperature in 2009 is estimated at 0.10°C. Therefore, the most likely value of the global surface temperature anomaly for 2009 is between +0.34°C and +0.56°C.

The southern hemisphere was particularly warmer than the long-term average, especially during the austral winter and late spring.

Note: There are three independent datasets used for the analysis of the global temperature anomaly. Based on two global datasets maintained independently by the Met Office Hadley Centre and Climatic Research Unit, University of East Anglia in the United Kingdom and the National Climatic Data Center of the National Oceanic and Atmospheric Administration (NCDC–NOAA) in the United States, the analysis of the global surface temperature for the year 2009 shows anomalies of +0.44°C (+0.59°F) and +0.46°C (+0.63°F) in the two datasets, respectively, with reference to the 1961–1990 long-term average of 14°C (57.2°F). A third dataset, which is maintained by the Goddard Institute for Space Studies operated by the National Aeronautics and

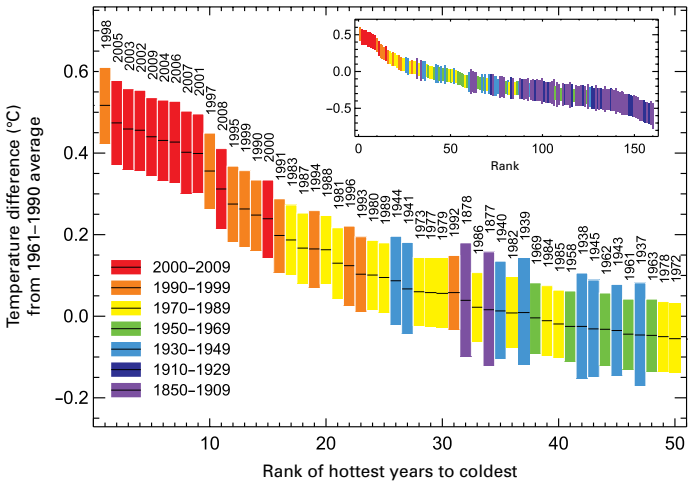


Figure 1. Global ranked surface temperatures for the warmest 50 years. Inset shows global ranked surface temperatures from 1850. The size of the bars indicates the 95 per cent confident limits associated with each year. The source data are blended land surface air temperature and sea surface temperature from HadCRUT3 series (Brohan and others, 2006). Values are simple area-weighted averages for the whole year. *(Source: Met Office Hadley Centre, UK, and Climatic Research Unit, University of East Anglia, UK)*

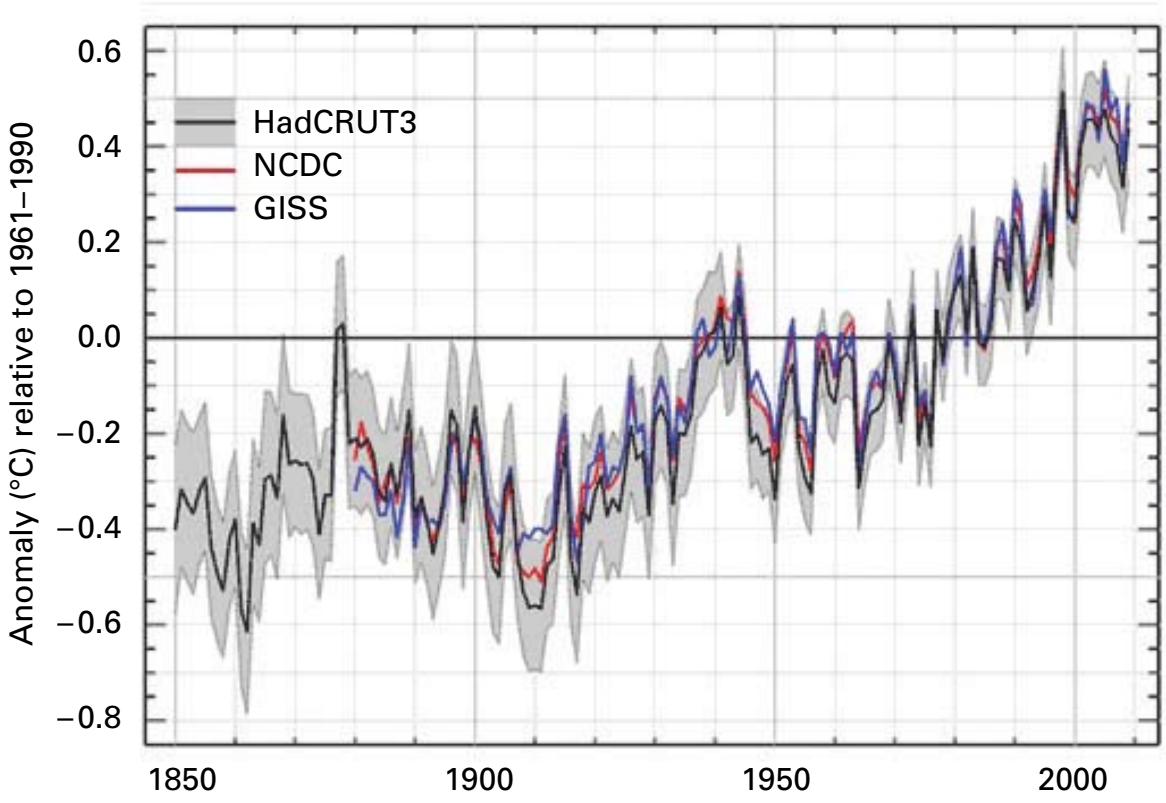


Figure 2. Annual global average temperature anomalies (relative to 1961–1990) from 1850 to 2009 from HadCRUT3 (black line and grey area, representing mean and 95 per cent uncertainty range), the NOAA National Climatic Data Center (red) and the NASA Goddard Institute for Space Studies (blue) *(Source: Met Office Hadley Centre, UK, and Climatic Research Unit, University of East Anglia, UK)*

Space Administration (NASA) in the United States, shows a global surface temperature anomaly of +0.50°C for 2009, which is in the same range as above. Information on source and methodology for global surface temperature assessment is provided on page 12.

Regional temperature anomalies

According to the reports provided by the National Meteorological and Hydrological Services, above-normal annual temperatures were recorded in 2009 in most parts of the continents. However, parts of the United States and Canada, and central Siberia experienced cooler temperatures than average. During the year, extreme warm episodes were frequently recorded in southern South America, Australia and southern Asia. In the southern hemisphere, August and November set new temperature records.

Europe

In Europe, warmer-than-average temperatures were recorded during most of the year. In some parts of western and central Europe, colder-than-average conditions were recorded at the beginning of the year. Spring was very warm in Europe. April was particularly mild in Germany, the Czech Republic and Austria with monthly mean temperature anomalies of more than +5°C in some places. The mean April temperatures ranged between 10°C and 15°C compared to the long-term average values ranging between 5°C and 10°C. The summer was also warmer than the long-term average, particularly over southern Europe. Spain had the third warmest summer after the very hot summers of 2003 and 2005. However, a very cold October was reported in Scandinavia, with mean temperature anomalies ranging from –2°C to –4°C. Early winter 2009/2010 started with an extended cold wave of more than a week in most of Europe. On some days in December, the minimum temperature dropped to –40°C in some locations in Scandinavia, –17°C in northern Italy and below –20 °C in the

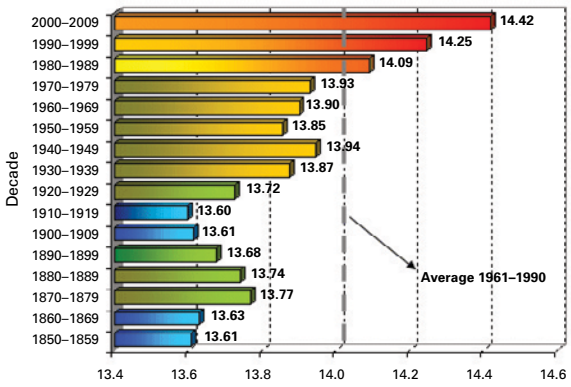


Figure 3. Decadal global average combined land–ocean surface temperature (°C) combining two global temperature datasets *(Sources: (a) Met Office Hadley Centre, UK, and Climatic Research Unit, University of East Anglia, UK; (b) National Climatic Data Center, NOAA, United States. The only dataset available for decades 1850–1859, 1860–1869 and 1970–1979 is (a)).*

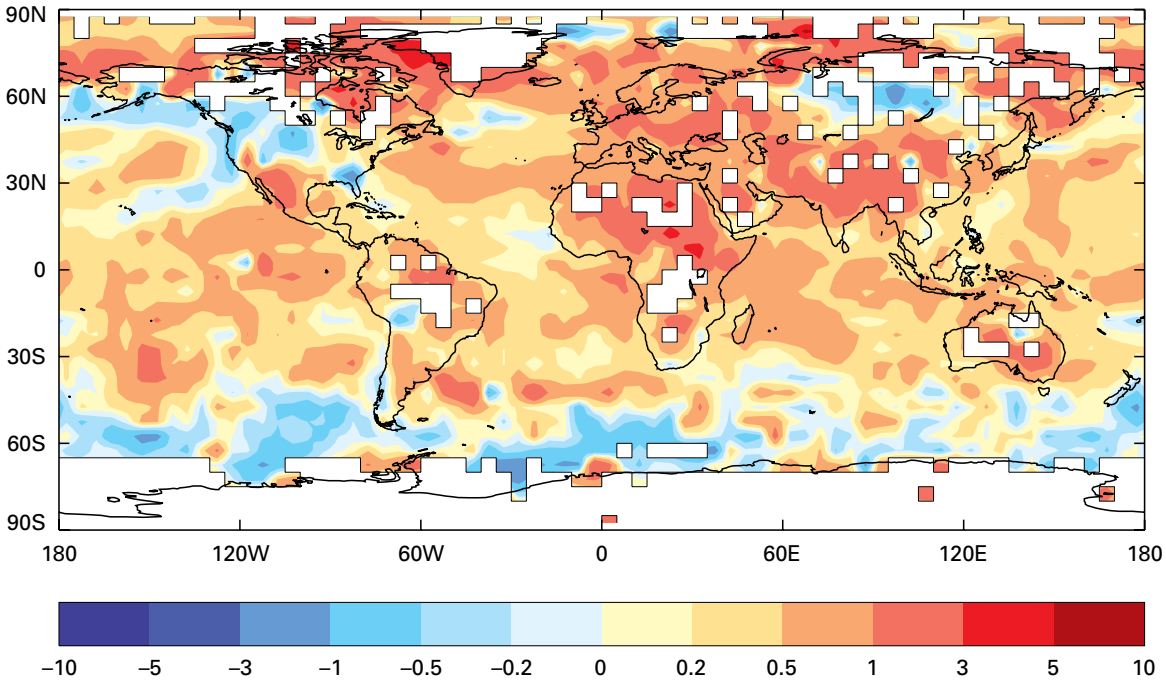
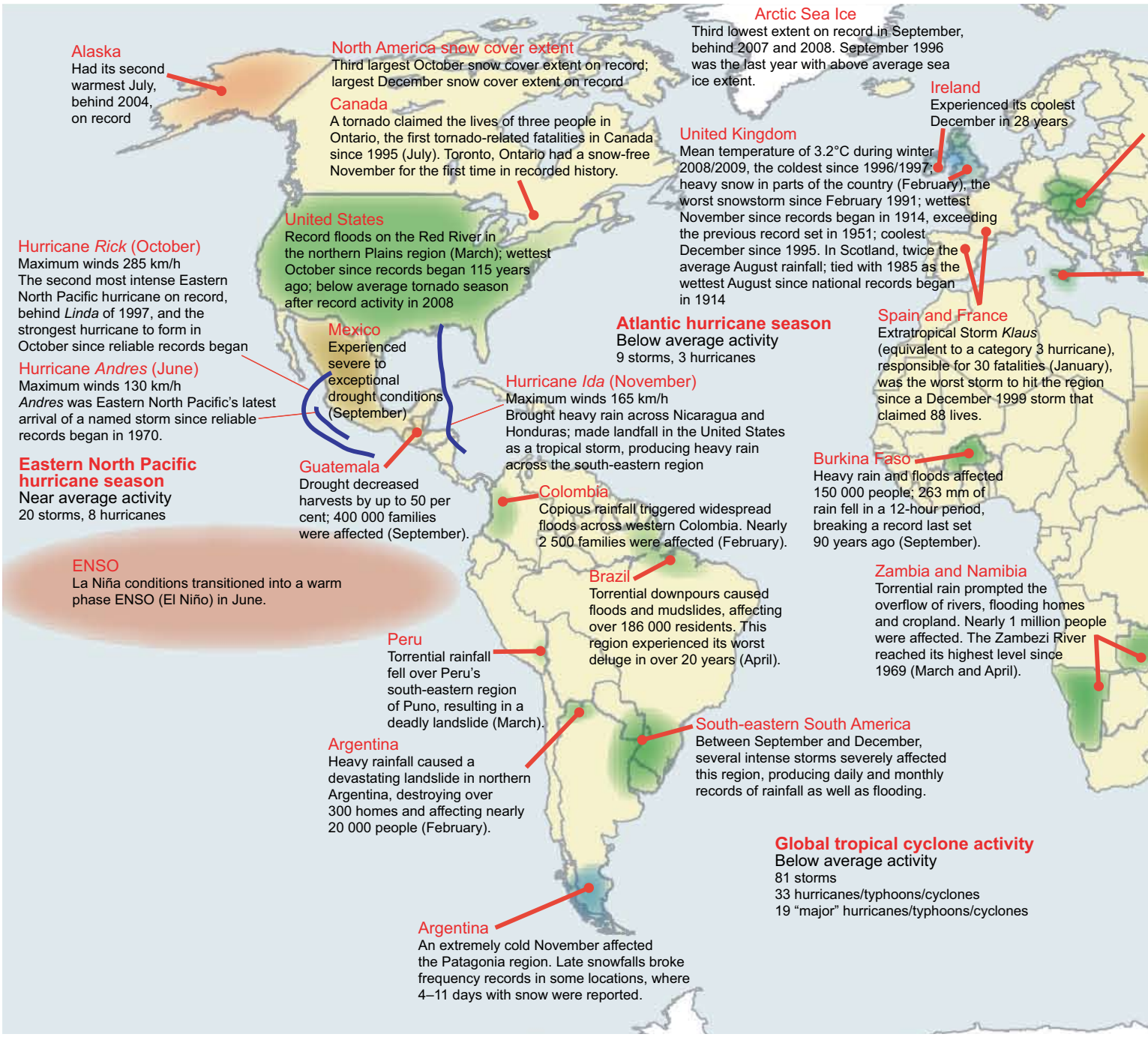


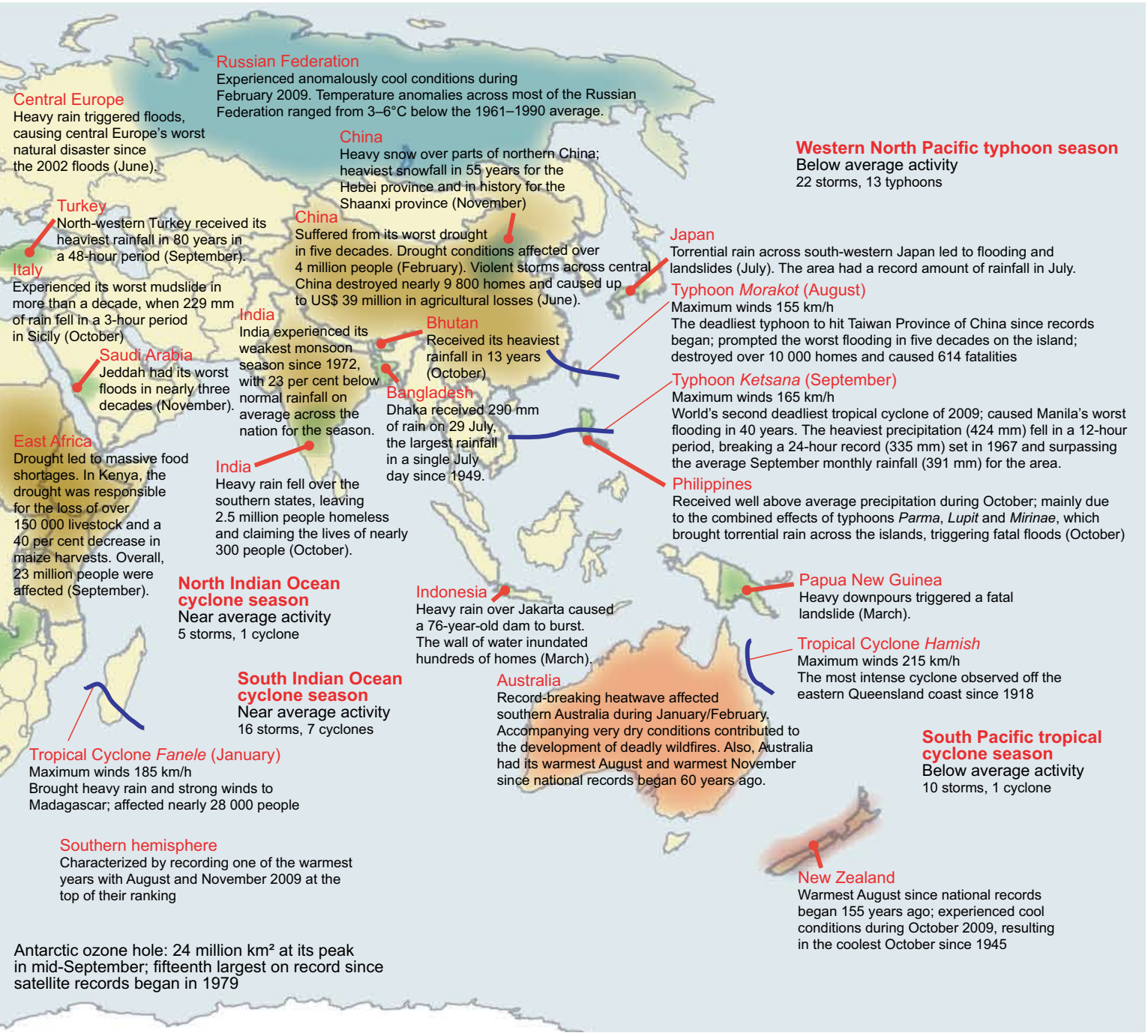
Figure 4. Global field of land surface and sea surface temperature anomalies (°C), relative to 1961–1990 for 2009 *(Source: Met Office Hadley Centre, UK, and Climatic Research Unit, University of East Anglia, UK)*



north-east of France. The combination of cold weather and extensive snowfalls was unusual in the United Kingdom, which experienced the most prolonged spell of freezing temperatures and snowfall across the country since winter 1981/1982.

Asia

Apart from some areas in northern Asia, the rest of the continent experienced higher-than-average temperatures. India recorded its warmest year since 1901 with a mean temperature anomaly of +0.93°C. China had its fourth warmest year since 1951. The year started with a very mild January in large parts of the continent, although February was particularly cold in the Russian Federation. Spring was warmer than average across the whole continent, as was summer in most parts of the region. Temperatures during December



were well below average over northern Asia with monthly temperature anomalies ranging between –4°C and –8°C.

North America

The year started with colder-than-normal weather conditions over the Great Lakes region in Canada, as well as the north-east of the United States and Alaska. The rest of the United States and Mexico experienced a mild January and February. Spring presented a similar pattern to that observed in the winter, with a predominance of below-normal temperatures in Canada and above-normal temperatures in the rest of the region. In late July, many cities in Canada recorded their warmest daily temperatures; for example, Victoria set a new record of 35°C on 29 July. Conversely, October was colder than the long-term average across the United States. For the nation

Figure 5. Significant climate anomalies and events in 2009 *(Source: National Climatic Data Center, NOAA, United States)*

as a whole, it was the third coolest October on record, with an average temperature anomaly of –2.2°C (–4°F). Oklahoma recorded the lowest monthly mean temperature for October (12.3°C); the previous record (12.4°C) was set in 1925. December was also colder than normal across most of the United States with monthly temperature anomalies around –5°C in the central and western regions.

South America

During 2009, warmer-than-normal conditions predominated across the region, with the south most affected. Argentina had its warmest year of the last five decades. The austral summer was warmer than normal in Chile, Argentina and eastern Brazil, while the north-east of the region experienced cooler-than-normal conditions. Autumn (March to May) was particularly warm in Argentina, Uruguay, Paraguay and southern Brazil. In fact, a large part of central Argentina recorded the warmest autumn since 1961 with seasonal temperature anomalies ranging between +2°C and +3°C. August was exceptionally warm in southern South America and many new daily maximum temperature records were set; for example, Buenos Aires set a new record of 34.4°C on 30 August. However, in June and July below-normal temperatures were recorded in Paraguay, Uruguay and southern Brazil. Abnormally cold conditions also prevailed in the southern part of Argentina, with several late snowfalls and frosts in November.

Australia

In Australia, 2009 was the second warmest year in a temperature series that began in 1910. The average temperature was 0.9°C above the 1961–1990 long-term average. Summer was very warm, except in the north, which experienced colder-than-normal conditions in conjunction with an active monsoon. Winter was exceptionally mild over much of Australia. In August, maximum temperatures were well above normal across the entire continent, recording up to 7°C above the monthly long-term average in some places; the national mean maximum temperature anomaly of +3.2°C was the highest ever recorded for any month. November was also very warm across the south-eastern region with mean maximum temperature anomalies between +4°C and +8°C.

Heatwaves and cold waves

Italy recorded two heatwaves in the second half of July with maximum daily temperatures above 40°C; some local temperatures soared to 45°C. An extreme heatwave also hit India during May, which caused 150 deaths. Northern China also experienced a heatwave during June when daily maximum temperatures rose above 40°C; historical maximum temperature records were broken for the summer in some locations. Australia was marked by exceptional heatwaves, which affected the south-eastern part of the country in

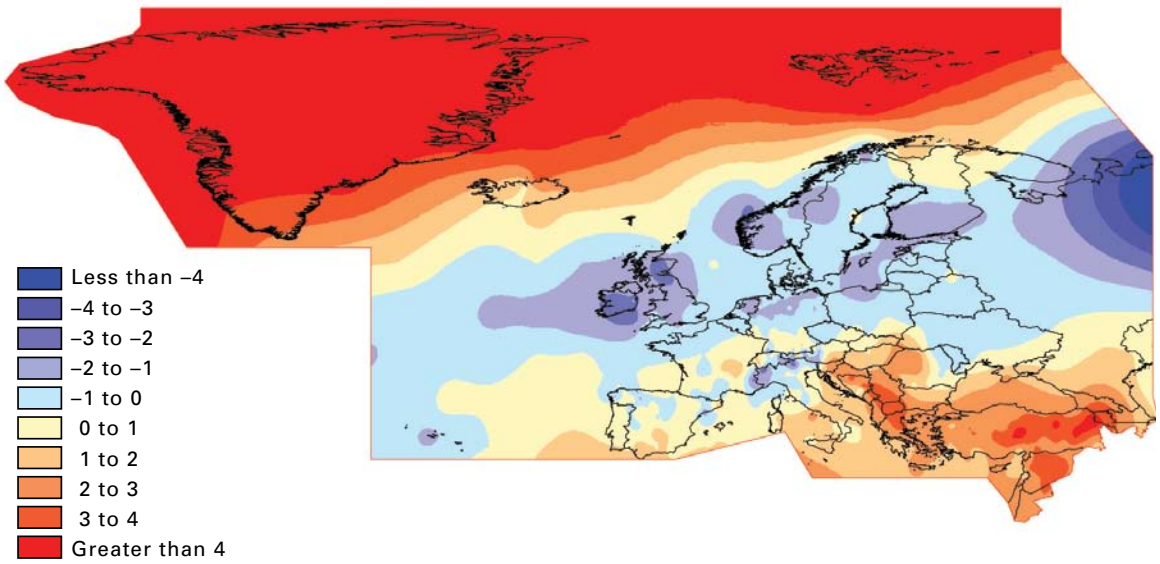


Figure 6. Monthly air surface temperature anomalies over Europe showing departures in degrees Celsius, 1961–1990 base for December 2009 *(Source: Deutscher Wetterdienst, Germany)*

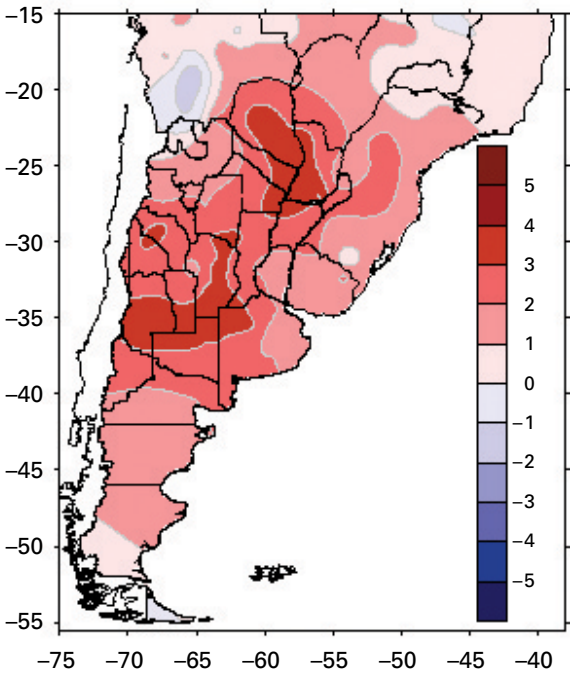


Figure 7. Mean maximum temperature anomalies (°C) over southern South America during austral autumn 2009 *(Source: National Meteorological Service of Argentina)*

January/February and November, and the subtropical eastern part in August. The January/February heatwave was associated with disastrous bushfires that caused more than 173 fatalities. Victoria recorded its highest temperature with 48.8°C at Hopetoun, the highest temperature ever recorded so far south anywhere in the world.

Argentina was affected by an exceptional heatwave affecting the northern and central part of the country at the end of October and beginning of November. Unusually high temperatures of above 40°C were recorded in many places and for several consecutive days. Several daily temperature records were broken, often by a wide margin; in some locations the annual absolute maximum temperature records were also broken, such as the 47°C temperature recorded in Catamarca.

Northern China was affected by very low temperatures during the first half of November as part of an early cold wave. Large parts of the United States, central and northern Europe and northern Asia were affected by an extended cold wave during the second half of December, the intensity varying with geographical location. For example, Germany reported daily minimum temperatures ranging between –10°C and –25°C with several locations setting new daily minimum records in at least six decades. In Switzerland, Geneva recorded –12.6°C, the lowest temperature for December since the temperature dropped to –14°C in 1968. Some minimum daily temperature records were also tied or broken in the United States.

Global precipitation

Global precipitation during 2009 was near the 1961–1990 average. However, regionally, drier-than-average conditions were recorded across Alaska's panhandle, southern Australia, southern South America, and parts of Western

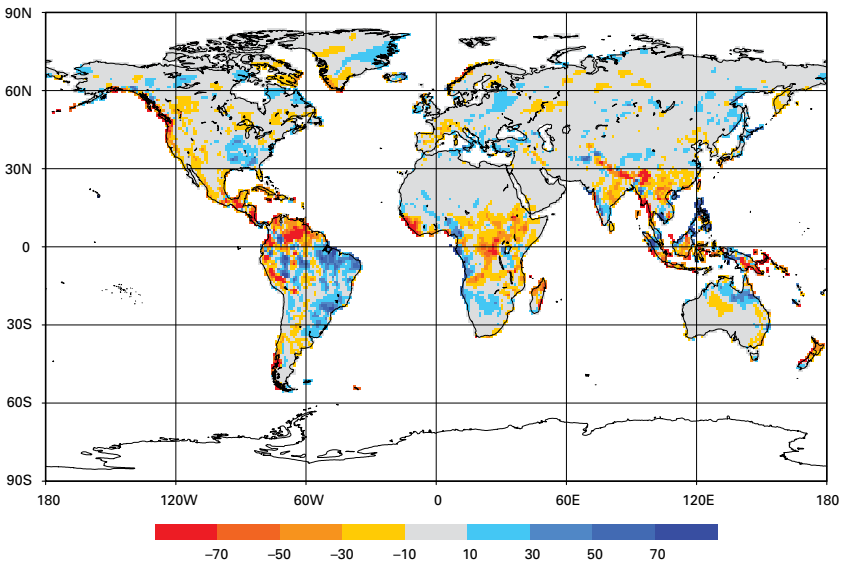


Figure 8. Annual precipitation anomalies for global land areas for 2009; gridded 1.0-degree raingauge-base analysis as normalized departures in mm/month from normal focusing on 1951–2000 base period *(Source: Global Precipitation Climatology Centre, Deutscher Wetterdienst, Germany)*

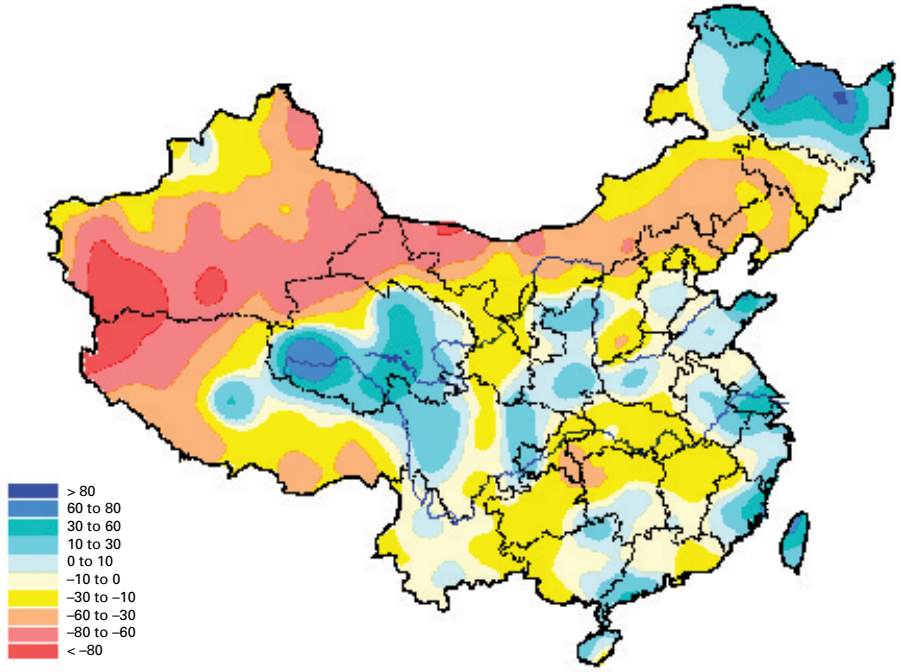


Figure 9. Percentage of precipitation anomaly (%) over China during summer 2009
(Source: China Meteorological Administration)

Europe and southern Asia. On the other hand, south-eastern Brazil, Uruguay, parts of eastern and south-eastern Asia, most of Europe and the eastern half of the contiguous United States experienced wetter conditions than the long-term average.

Severe droughts

China suffered from severe drought during most of the seasons in 2009. Water levels in parts of the Gan and Xiangjiang Rivers were the lowest in 50 years. In India, the poor monsoon season was reported to be one of the weakest since 1972. It caused severe drought impacts in 40 per cent of the districts and the north-western and north-eastern parts of the country were severely affected.

In East Africa the drought led to massive food shortages. In Kenya the drought was responsible for severe damage to livestock and a 40 per cent decline in the maize harvest.

In North America, Mexico experienced severe-to-exceptional drought conditions by September. In the United States, the western region was the most affected by a moderate-to-exceptional drought by the end of October. Nevertheless, the total area affected by drought in the United States during October was the second smallest value recorded during the decade.

Drought in central Argentina caused severe damage to agriculture, livestock and water resources. The situation was most severe at the end of October, in combination with the recorded high temperatures.

Intense storm events and flooding

At the end of January, Spain and France were severely affected by winter storm *Klaus*, the worst extra-tropical storm in a decade, with wind speeds equivalent to a Category 3 hurricane. During the same month, a wintry storm combined with heavy snowfall caused severe damage in Western Europe and resulted in serious disruptions to air and rail traffic in several countries. In late spring and summer, a large number of thunderstorms with heavy rain, hail and tornadoes caused local flooding and significant damage across Germany. In September, several parts of the Mediterranean region were affected by extreme rainfall events. Total rainfall of more than 300 mm was recorded in less than

48 hours in one location in south-eastern Spain, where the long-term average of total annual precipitation does not exceed 450 mm. During the same month, intense rainfall caused devastating damage to infrastructure in several parts of northern Africa, including Algeria, Morocco and Tunisia. In Turkey the extreme weather events recorded during 2009, including severe storms, tornadoes, frosts, hail storms, floods and landslides, marked a record high since 1941. November brought severe flooding to areas of the northern United Kingdom, with daily rainfall of more than 200 mm in Seathwaite, totalling 379 mm in 48 hours. It was the wettest November for the United Kingdom as a whole since 1914. The year ended with significant snowstorms and extreme frosts all over Europe, which resulted in some damage and transport disruptions. A record-breaking 13-month-long storm-free period in Swedish coastal waters ended on 25 December when local storm winds swept the Swedish east coast.

During the beginning of the year heavy rainfall was observed in Colombia, producing landslides and widespread floods. Northeast Brazil was severely affected by heavy rainfall and flooding in April and May. In July, a severe snowstorm – the worst in 15 years – hit the southern part of Argentina. During the austral spring, particularly in November, continuous, heavy and intense rainfall in north-eastern Argentina, southern Brazil and Uruguay caused flooding in many places, affecting more than 15 000 people. Total monthly precipitation records were broken, with rainfall exceeding 500 mm in many locations.

In Canada, Ontario experienced a record number of witnessed tornadoes and a record number of related fatalities. Canadian avalanches were almost double the yearly average for the past decade and the worst since 2002/2003. A total of 25 deaths made it one of the deadliest seasons. The northern plains region of the United States was affected by record flooding during March. As a whole, the United States recorded the wettest October in 115 years. A major snowstorm hit the northeast region of the country in the second half of December, setting new snowfall records from Washington to Boston. Travel of every type was disrupted; airports, interstate highways and local roads were closed, and rail lines were shut down.

In Central America, an intense storm in El Salvador in November, associated in part

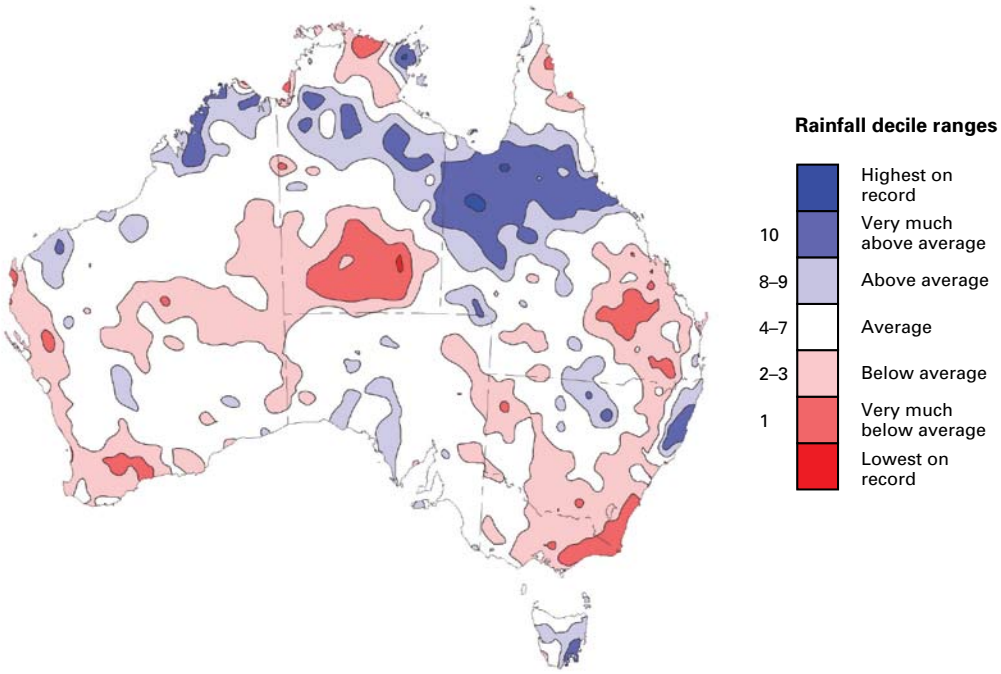


Figure 10. Australian rainfall deciles for the year 2009. Deciles are calculated relative to the period 1900–2009, with distribution based on gridded data from the National Climate Centre. *(Source: Commonwealth of Australia, Australian Bureau of Meteorology)*

with Hurricane *Ida*, produced deadly floods and landslides that claimed 192 lives.

In Asia, after the weak 2009 monsoon season, southern India recorded severe flooding due to incessant rain in late September and the first week of October, and around 300 lives were lost. Northern China was severely affected by a snowstorm that occurred during the first half of November as part of a strong cold air mass outbreak. The snow fell one month earlier than normal, breaking local weather records.

In western Africa, heavy and intense rainfall in September caused flooding that affected more than 100 000 people. The worst flooding was observed in Burkina Faso, where 263 mm of rain was recorded in less than 12 hours, breaking a record set 90 years ago. Further south on the continent, nearly 1 million people in Zambia and Namibia were affected by torrential rain that caused rivers to overflow their banks, flooding homes and cropland.

Australia was also affected by local flooding. Heavy monsoon rains caused widespread flooding in north-eastern Australia in January and early February. Subsequently, coastal Queensland and New South Wales were the hardest hit by several heavy rains, with daily rainfall totals in excess of 300 mm. Conversely, numerous duststorms affected eastern Australia in the second half of September and early October. The most severe duststorm occurred on 22–23 September and covered large parts of New South Wales and Queensland, where the visibility was reduced to 100–200 m in both Sydney and Brisbane.

End of La Niña and development of El Niño

La Niña-like conditions were present in early 2009, followed by the development of El Niño patterns starting in June 2009. During June–September 2009, sea surface temperatures were generally about 1°C warmer than the long-term average across the central and eastern equatorial Pacific. There was a rapid intensification of the event to moderate levels during October, with the peak of the mature phase being reached in late December. Most equatorial regions east of the Date Line were more than 1°C warmer than average by that time, with a few regions more than 2°C above average.

Tropical cyclone season

The 2009 Atlantic hurricane season closed with the fewest named storms and hurricanes since 1997, most likely owing to the unfavourable cyclonic conditions caused in part by El Niño. A total of nine named tropical storms were formed, including three hurricanes, two of which were major hurricanes at Category 3 strength or higher, compared with averages of 11, 6 and 2, respectively.

In the Eastern North Pacific, 20 named tropical storms were recorded, 8 of which evolved into hurricanes and 5 of which became major hurricanes, compared with averages of 16, 9 and 4, respectively.

In the western North Pacific, 22 named tropical storms were recorded, 13 of which reached the intensity of typhoon, compared with the long-term averages of 27 and 14, respectively. Heavy precipitation associated with typhoons *Ketsana* and *Parma* was observed across the south of Luzon Island in the Philippines. The resulting flood disaster caused more than 900 fatalities. In August, Typhoon *Morakot* swept across Taiwan Province of China and caused more than 600 deaths and severe damage to agriculture and infrastructure. Hundreds of roads and bridges on the island were destroyed by floods.

The Australian and South Pacific Ocean cyclone seasons recorded near-average activity. In the Australian region, there were 10 systems during the season. Although it did not make landfall, *Hamish* was the most significant, reaching Category 5 intensity. It was the most intense cyclone observed off the eastern Queensland coast since 1918.

The South Indian Ocean cyclone season recorded near-average activity with 16 storms, 7 of which were cyclones. Tropical Cylcone *Fanele* made landfall in Madagascar in January and brought heavy rain and strong winds and affected nearly 28 000 people.

Arctic sea ice

The National Snow and Ice Data Center near-real-time Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager (SSM/I) Daily Polar Gridded Sea Ice

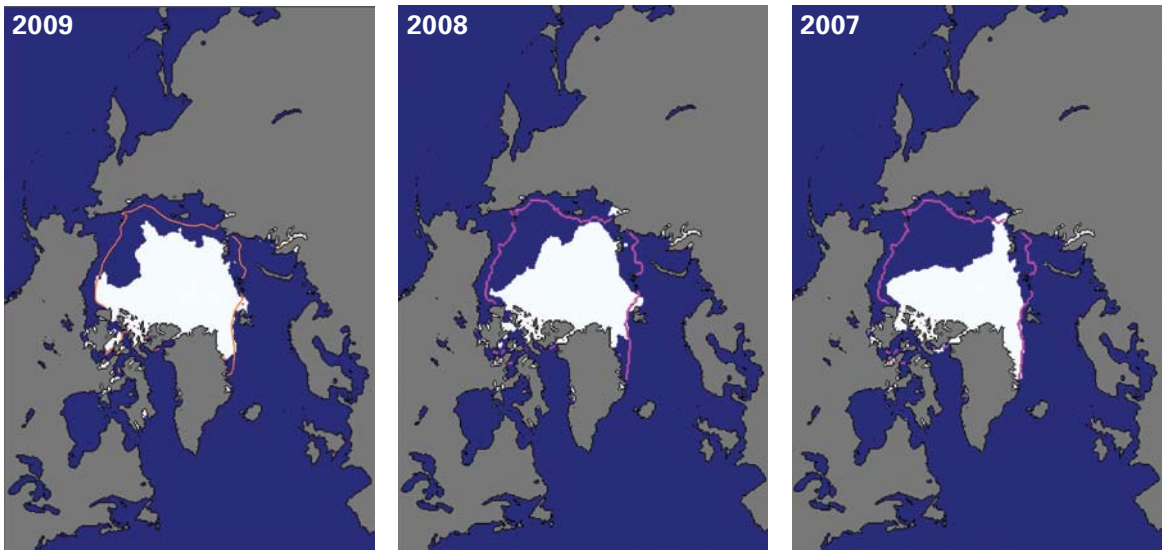


Figure 11. Sea-ice extent for September 2009 (third lowest on record), September 2008 (second lowest on record) and September 2007 (lowest on record). The magenta/orange line indicates the long-term median from the 1979–2000 base period.
(Source: National Snow and Ice Data Center, United States)

Concentrations and the Sea Ice Concentrations from the Nimbus-7 Scanning Multichannel Microwave Radiometer (SSMR) and DMSP SSM/I Passive Microwave Data datasets are used to generate the monthly records of sea-ice extent and sea-ice concentration for the Arctic and Antarctica from satellite passive microwave data.

Arctic sea-ice extent during the 2009 melt season was a minimum extent of 5.10 million km^2, ranking third lowest on record after 2007 (4.13 million km^2) and 2008 (4.52 million km^2) since satellite measurements began in 1979. Compared with the long-term average of the reference period 1979–2000, the Arctic sea ice at the end of the melt season in 2009 was 76 per cent of the long-term average of 6.71 million km^2 compared with 67 per cent in 2008 and 62 per cent in 2007. According to scientific measurements, Arctic sea ice has declined dramatically over the past 30 years, with the most extreme decline seen in the summer melt season.

Antarctic ozone hole

The daily maximum ozone hole for 2009 was 24.1 million km^2 on 17 September. This is

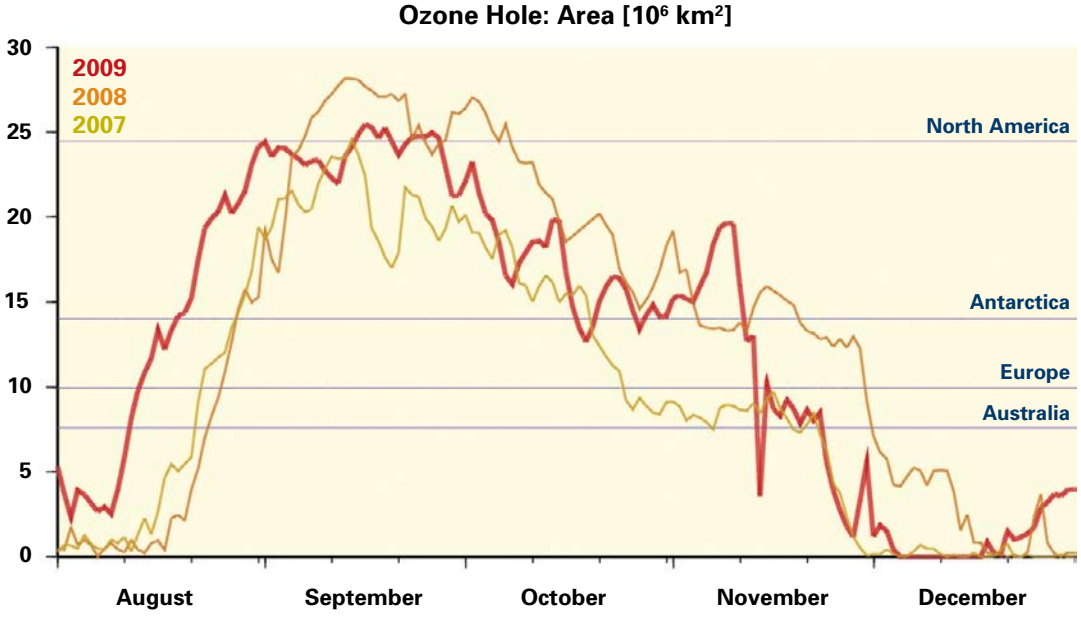


Figure 12. The plot shows the daily evolution of the surface area of the Antarctic ozone hole over the course of the ozone hole season. The blue horizontal lines show the surface area of the various regions for comparison.
(Source: The graph was prepared by the World Data Centre for Remote Sensing of the Atmosphere, one of the Global Atmosphere Watch World Data Centres, hosted by the German Aerospace Center in Germany. The data used to produce this graph were derived from the METOP-A/GOME-2 and ENVISAT/SCIAMACHY sensors and are the result of several algorithms.)

5.5 million km² more than the 1979–2000 long-term average and about 6 million km² less than the record of almost 30 million km² in 2000. Compared with the average size over the 7 September–13 October time period, the ozone hole in 2009 was the fifteenth largest on record since satellite records began in 1979. Measured in Dobson Units (DU), the minimum daily minimum ozone during 2009 was reached on 26 September with 94.0 DU. This is below the 1979–2000 long-term average of 125.4 DU. This ranks 2009 (together with 1991) as the seventh lowest daily minimum ozone on record in the southern hemisphere. The record low was observed in 1994 with 73.0 DU.

Source and methodology for global surface temperature assessment

Global average temperature records are essential to help understand how the climate is changing. To understand changes and variations in the climate it is essential to know how the surface temperature changes – from month to month, up to decade to decade. Global average temperature records provide this vital information. From these records it can be seen how warm specific months, years or decades are, and trends can be discerned in the climate system over longer periods of time.

The global surface temperature assessment is based on the instrumental records of the air temperature measured at 1.25 to 2 metres above the surface level on the land. Sea surface temperature measurements are recorded by various observation platforms, including ships and buoys. The annual assessment is based on these measurements after they have been quality controlled to filter data errors and homogenized.

There are three centres that maintain global climate datasets and calculate global average temperature and related anomalies at monthly and annual timescales:

- Met Office, UK, in collaboration with the Climatic Research Unit at the University of East Anglia (United Kingdom);
- National Climatic Data Center, which is part of NOAA (United States);
- Goddard Institute for Space Studies, which is part of NASA (United States).

The development of climate datasets is based on the following:

- Routinely disseminated daily and monthly weather and climate observations by the National Meteorological and Hydrological Services of the 189 WMO Members following the WMO standards for data collection, quality control and exchange;
- Historical climate records dating back to 1850, including those available from marine climate summaries;
- Recovered old climate records worldwide as part of continuous data rescue efforts promoted by WMO and its Members;
- Peer reviewed scientific methods for quality control, homogenization and interpolation to constitute high-quality global climate datasets.

Temperature anomalies

Absolute temperatures are not used directly to calculate the global average temperature. They are first converted into anomalies, which are the difference in temperature from the normal level. The normal level is calculated for each observation location by taking the long-term average for that area over a base period. One of the main reasons for using anomalies is that they remain fairly constant over large areas. The anomaly method also helps to avoid biases. For example, if actual temperatures were

used and information from an Arctic observation station were missing for that month, the global temperature record therefore would seem warmer. Thus, when anomalies are used such missing data will not bias the temperature record.

Accuracy of the observations

Each observation station follows international standards for taking observations set out by WMO. Each National Meteorological Service provides reports on how its data are collected and processed to ensure consistency. This includes recording information about the local environment around the observation station and any changes to that environment. This is important for ensuring the required data accuracy and performing homogeneity tests and adjustments. There are additional uncertainties because temperatures over large areas of the Earth are not observed as a matter of routine. These elements are taken into account by factoring the uncertainty into global average temperature calculations, thereby producing a temperature range rather than one uniquely definite figure.

For more information, please contact:

World Meteorological Organization

Communications and Public Affairs Office

Tel.: +41 (0) 22 730 83 14 – Fax: +41 (0) 22 730 80 27

E-mail: cpa@wmo.int

7 bis, avenue de la Paix – P.O. Box 2300 – CH 1211 Geneva 2 – Switzerland

www.wmo.int

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