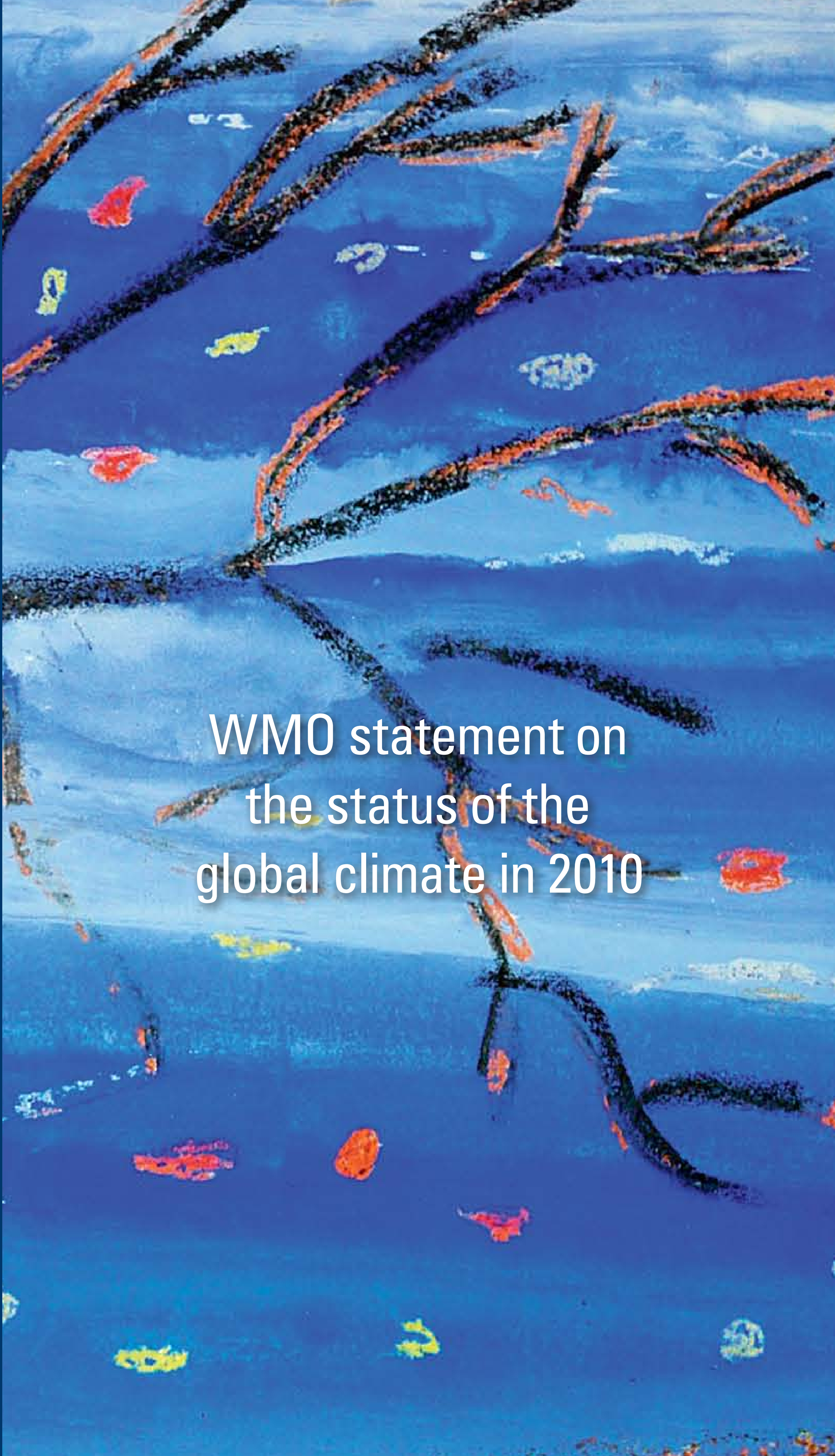

WMO statement on the status of the global climate in 2010

World Meteorological Organization
Weather • Climate • Water

WMO-No. 1074

WMO-No. 1074

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ISBN 978-92-63-11074-9

WMO in collaboration with Members issues since 1993 annual statements on the status of the global climate. This publication was issued in collaboration with the Hadley Centre of the UK Meteorological Office, United Kingdom of Great Britain and Northern Ireland; the Climatic Research Unit (CRU), University of East Anglia, United Kingdom; the Climate Prediction Center (CPC), the National Climatic Data Center (NCDC), the National Environmental Satellite, Data, and Information Service (NESDIS), the National Hurricane Center (NHC) and the National Weather Service (NWS) of the National Oceanic and Atmospheric Administration (NOAA), United States of America; the Goddard Institute for Space Studies (GISS) operated by the National Aeronautics and Space Administration (NASA), United States; the National Snow and Ice Data Center (NSIDC), United States; the European Centre for Medium-Range Weather Forecasts (ECMWF), United Kingdom; the Global Precipitation Climatology Centre (GPCC), Germany; and the Dartmouth Flood Observatory, United States. Other contributors are the National Meteorological and Hydrological Services or equivalent climate institutions of Algeria, Argentina, Australia, Austria, Belarus, Belgium, Benin, Brazil, Canada, China, Colombia, Croatia, Denmark, Fiji, Finland, France, Germany, Hungary, Iceland, India, Indonesia, Ireland, Israel, Japan, Kenya, Latvia, Lithuania, Moldova, Morocco, Netherlands, New Zealand, Norway, Pakistan, Portugal, Russian Federation, Serbia, Spain, Sweden, Switzerland, Tunisia, Turkey, United Kingdom, United States, and Venezuela (Bolivarian Republic of). The WMO Regional Association VI (Europe) Regional Climate Centre on Climate Monitoring, the African Centre of Meteorological Applications for Development (ACMAD, Niamey), the International Research Centre on El Niño (CIIFEN, Guayaquil, Ecuador), the Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre (ICPAC, Nairobi), the Global Atmosphere Watch (GAW) and the World Climate Research Programme (WCRP) also contributed.

Cover: Autumn wind. Illustration by Roisin Manning, 10 years old, United Kingdom

Foreword

In 1993 the World Meteorological Organization (WMO) launched its annual "WMO Statement on the Status of the Global Climate" series, in the wake of climate awareness generated by the Second World Climate Conference, which WMO organized with its scientific partners in 1990. The report has continued to gain in popularity and is today a recognized authoritative source of information for the scientific community, the media and the public at large. The present *WMO Statement on the Status of the Global Climate in 2010* is the latest member of this successful sequence.

The year 2010 was especially notable in that global surface temperatures reached record values at the same level as in 1998 and 2005, consistent with the acceleration of the warming experienced over the last 50 years. The year also signalled the closure of the warmest decade on record. Over this decade, warming was markedly more pronounced in some regions, notably so in North Africa and the Arabian Peninsula, South Asia and the Arctic.

Moreover, large and extended climate extremes were recorded in several parts of the world, causing significant socio-economic impacts. In particular, the flooding in Pakistan and Australia as well as the summer heatwave in the Russian Federation were among the most remarkable climate extremes of the year.

Furthermore, 2010 was also special as the year in which a High-level Taskforce developed recommendations for the structure, priorities and governance of a Global Framework for Climate Services, in response to the unanimous decision of the World Climate Conference-3, which WMO convened in 2009 in partnership with the United Nations system. Through the development of the Framework, WMO is committed to further improve its climate products, information and service delivery to serve all climate-sensitive socioeconomic sectors.

The year 2010 was WMO's Diamond Jubilee, since on 23 March 1950 the new Organization took over the global responsibilities of the International Meteorological Organization, established in 1873 as an outcome of the First International Meteorological Congress held in Vienna.

I wish to express the appreciation of WMO to all the Centres and the National Meteorological and Hydrological Services of its 189 Members that collaborated with WMO and contributed to this key publication. As with the previous editions, I would like to underscore the importance of your feedback. WMO looks forward to your comments on the *WMO Statement on the Status of the Global Climate in 2010* and to your welcome suggestions for its further improvement.

(M. Jarraud)
Secretary-General

Global temperatures in 2010

Average global temperatures were estimated to be 0.53°C ± 0.09°C above the 1961–1990 annual average of 14°C. This makes 2010 tied for warmest year on record in records dating back to 1880. The 2010 nominal value of +0.53°C ranks just ahead of those of 2005 (+0.52°C) and 1998 (+0.51°C), although the differences between the three years are not statistically significant, due to uncertainties mainly associated with sampling the Earth's land and sea surface temperatures using only a finite number of observation sites, and the way estimates are interpolated between those sites. Data from the ECMWF Interim Reanalysis (ERA) indicate that 2010 ranks as the world's second warmest year, with the difference between it and 2005 within the margin of uncertainty.

The decade 2001–2010 was also the warmest on record. Temperatures over the decade averaged 0.46°C above the 1961–1990 mean, 0.21°C warmer than the previous record decade 1991–2000. In turn, 1991–2000 was warmer than previous decades, consistent with a long-term warming trend.

Note: The analysis is based on three independent datasets, maintained by the Hadley Centre of the Meteorological Office, UK, and the Climatic Research Unit of the University of East Anglia (HadCRU) in the United Kingdom, the National Climatic Data Center of the National Oceanic and Atmospheric Administration (NCDC–NOAA) in the United States, and the Goddard Institute for Space Studies (GISS) operated by the National Aeronautics and Space Administration (NASA) in the United States.

Major large-scale influences on the global climate in 2010

The year 2010 began with an El Niño event well established in the Pacific Ocean. This

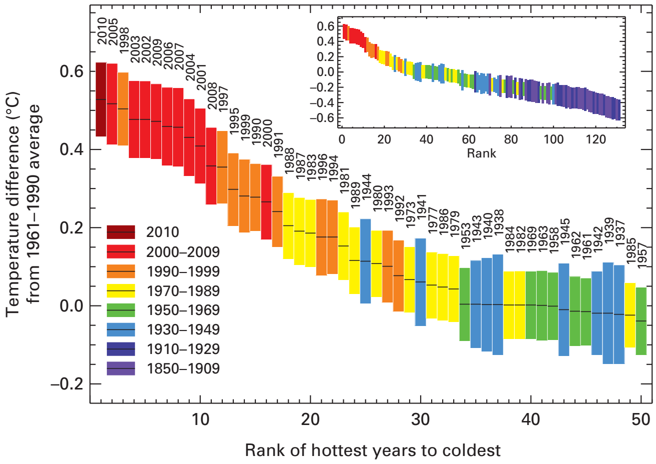


Figure 1. Global ranked surface temperatures for the warmest 50 years. Inset shows global ranked surface temperatures from 1880. The size of the bars indicates the 95 per cent confidence limits associated with each year. Values are simple area-weighted averages for the whole year. *(Source: Met Office Hadley Centre, UK, and Climatic Research Unit, University of East Anglia, United Kingdom)*

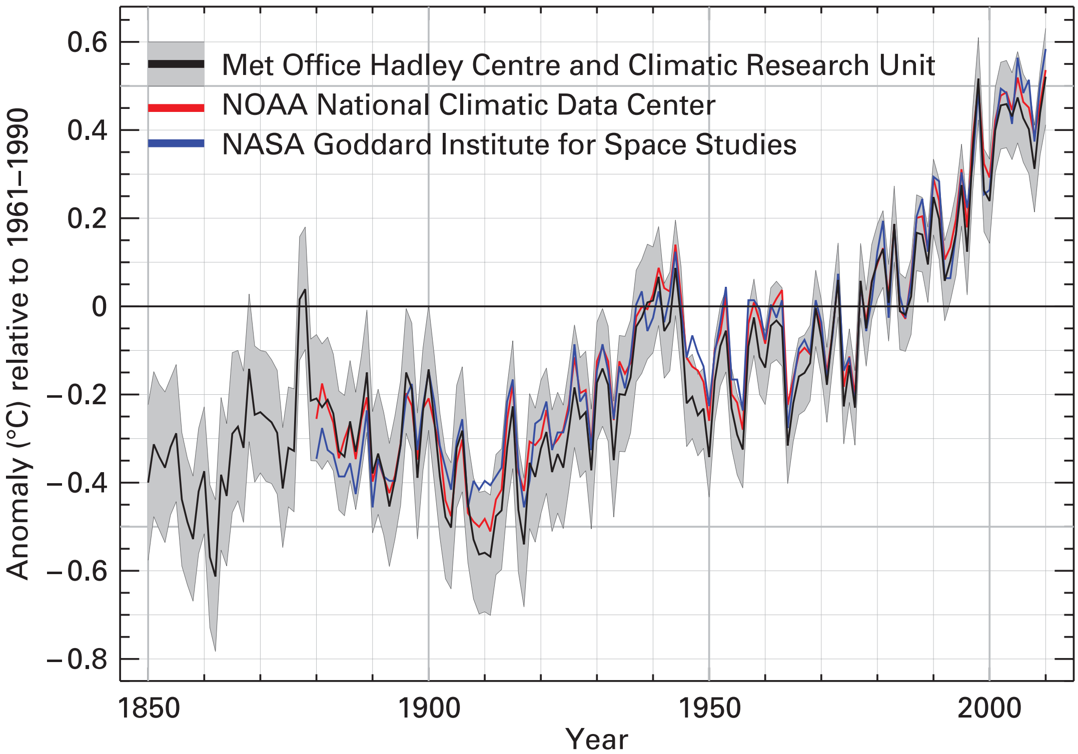


Figure 2. Annual global average temperature anomalies (relative to 1961–1990) from 1850 to 2010 from the Hadley Centre/CRU (HadCRUT3) (black line and grey area, representing mean and 95 per cent uncertainty range), the NOAA National Climatic Data Center (red); and the NASA Goddard Institute for Space Studies (blue) *(Source: Met Office Hadley Centre, UK, and Climatic Research Unit, University of East Anglia, United Kingdom)*

broke down quickly in the early months of the year. A rapid transition took place and La Niña conditions were in place by August. By some measures the La Niña event in progress at the end of 2010 is the strongest since at least the mid-1970s, and among the five strongest of the last century. The atmospheric response has been especially strong, with the Southern Oscillation Index reaching its highest monthly values since 1973 in September and December, and its highest six-month mean since 1917. The El Niño-to-La Niña transition is similar to that which occurred in 1998, another very warm year, although in 2010 the El Niño was weaker, and the La Niña stronger, than was the case in 1998.

The eastern tropical Indian Ocean was also significantly warmer than average during the second half of 2010 (negative Indian Ocean Dipole), in contrast with the previous La Niña event in 2007/2008 when it was generally cooler than average. The Arctic Oscillation (AO) and North Atlantic Oscillation (NAO) were in a negative phase for most of the year, exceptionally so in the 2009/2010 northern hemisphere winter, which on most indicators had the most strongly negative seasonal AO/NAO on record. They returned to a strongly negative phase in late 2010 with December 2010 values only

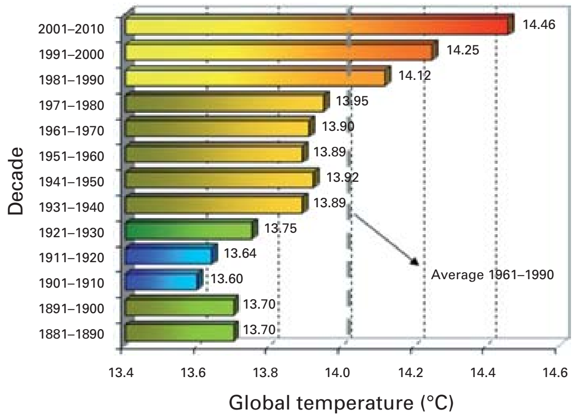


Figure 3. Decadal global average combined land-ocean surface temperature (°C), combining three global temperature datasets *(Source: Met Office Hadley Centre, UK, and Climatic Research Unit, University of East Anglia, United Kingdom)*

slightly less extreme than those recorded the previous winter. The Antarctic Oscillation, also known as the Southern Annular Mode, was in positive mode for most of the year, reaching its highest monthly values since 1989 in July and August.

Regional temperatures

For both the northern hemisphere and Africa, 2010 was the warmest year on record. It was also the warmest year on record for six subregions: West Africa, the Saharan/Arabian region, the Mediterranean, South Asia, Central/

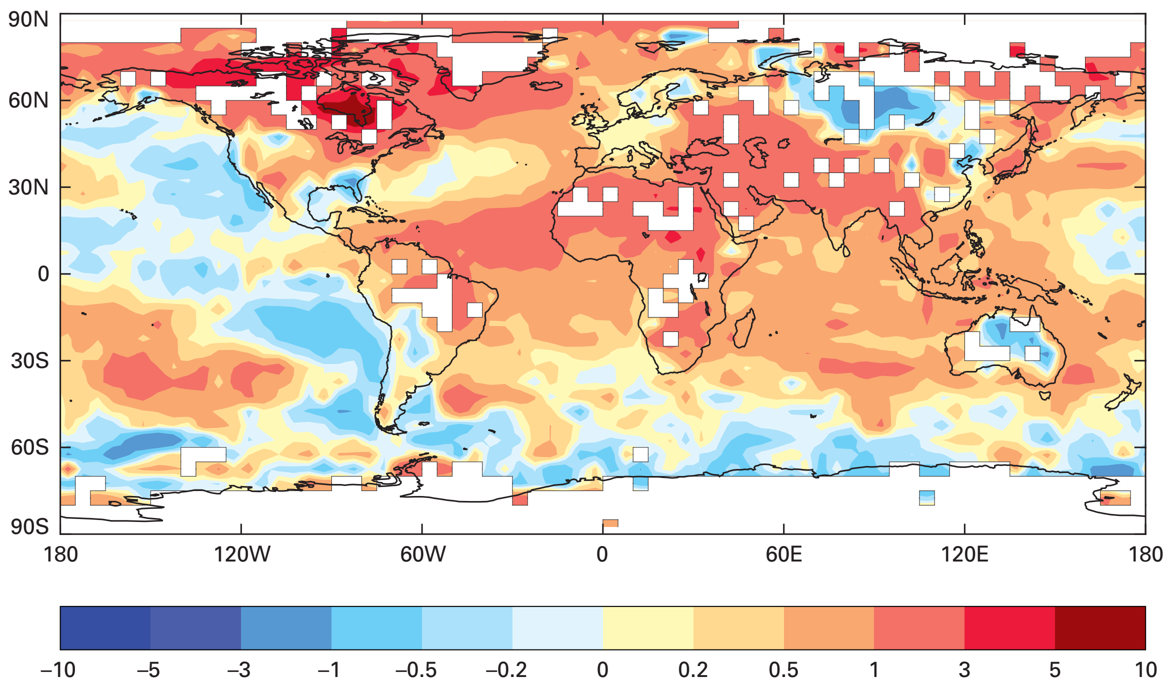
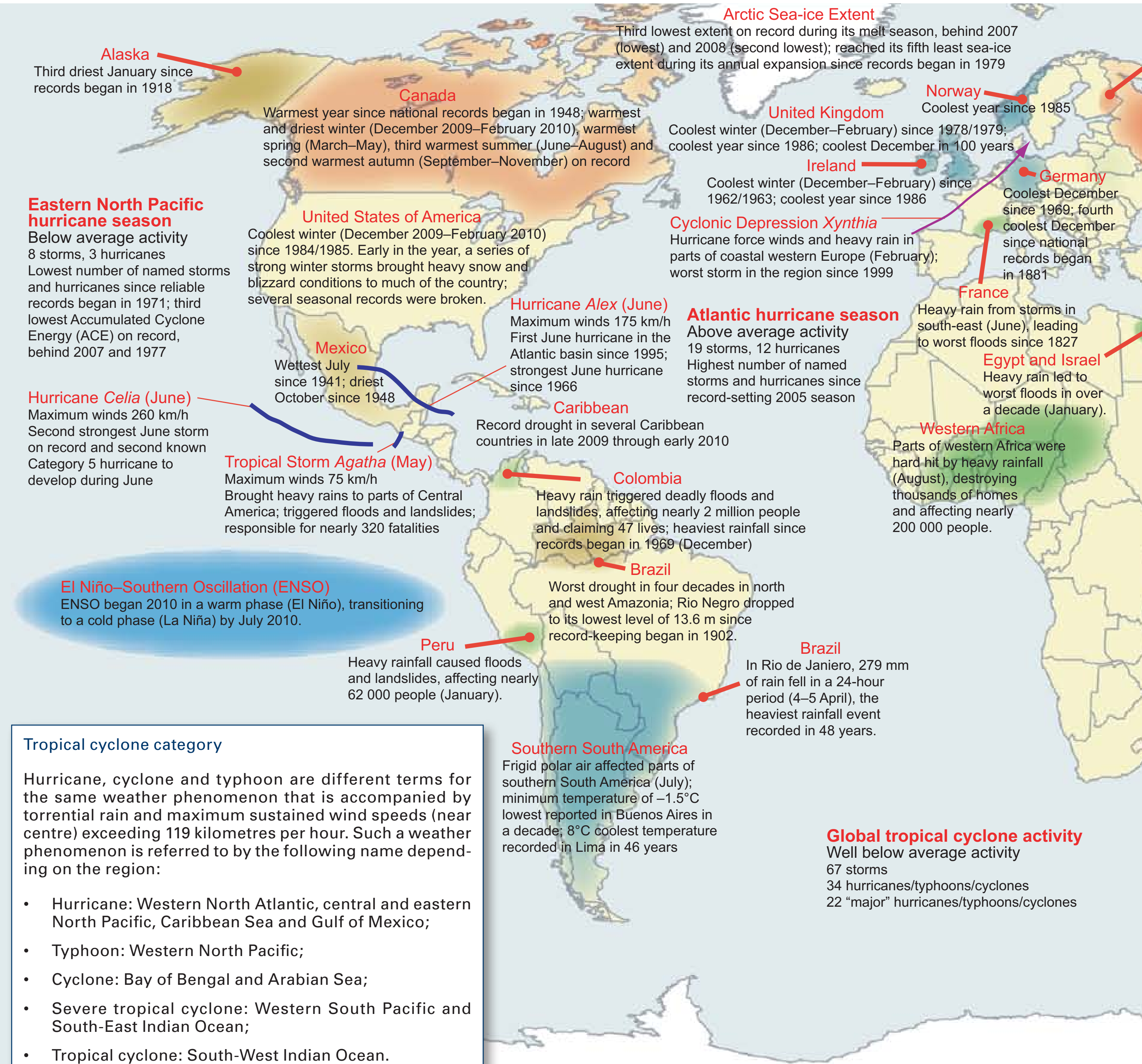


Figure 4. Global land surface and sea surface temperature anomalies (°C) for 2010, relative to 1961–1990 *(Source: Met Office Hadley Centre, UK, and Climatic Research Unit, University of East Anglia, United Kingdom)*



Tropical cyclone category

Hurricane, cyclone and typhoon are different terms for the same weather phenomenon that is accompanied by torrential rain and maximum sustained wind speeds (near centre) exceeding 119 kilometres per hour. Such a weather phenomenon is referred to by the following name depending on the region:

- Hurricane: Western North Atlantic, central and eastern North Pacific, Caribbean Sea and Gulf of Mexico;
- Typhoon: Western North Pacific;
- Cyclone: Bay of Bengal and Arabian Sea;
- Severe tropical cyclone: Western South Pacific and South-East Indian Ocean;
- Tropical cyclone: South-West Indian Ocean.

South-West Asia and Greenland/Arctic Canada, with records broken by nearly a degree in some places. Below-average temperatures on land were limited in spatial extent, with the most significant areas covering western and central Siberia, northern and central Australia, parts of Northern Europe, the south-eastern United States, and an area centred on Beijing in north-eastern China.

Ocean temperatures were below average in the eastern Pacific, associated with the development of La Niña, but were above average in most other regions. The tropical Atlantic was especially warm, with a large part of the region experiencing its highest sea surface temperatures on record. Sea surface temperatures in the region surrounding Australia were also the highest on record.

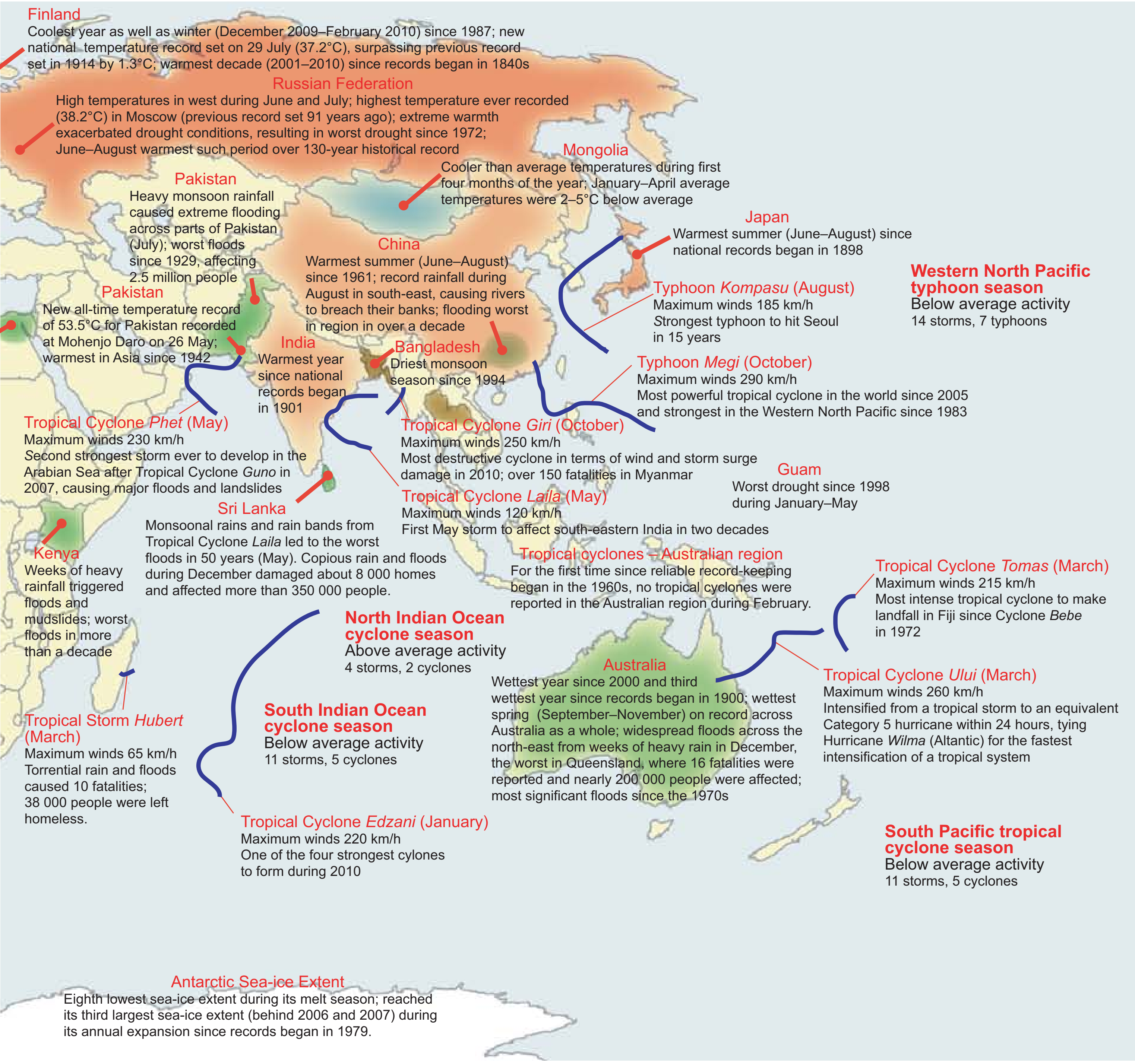


Figure 5. Significant climate anomalies and events in 2010 *(Source: National Climatic Data Center, NOAA, United States)*

Africa and the Arabian Peninsula

The year was exceptionally warm in most of Africa and southern Asia, as far east as the Indian subcontinent. Temperatures averaged over Africa were 1.29°C above the long-term average, breaking the previous record by 0.35°C. Continental monthly anomalies exceeded +1.5°C in each of the five months from December 2009 to April 2010, peaking at +2.12°C in February; the previous largest monthly anomaly on record was +1.44°C in April 1998. All twelve months of 2010 were at least 0.7°C above normal. While temperatures were well above average throughout Africa, they were especially exceptional in the northern half of the continent (extending into the Arabian Peninsula), where the Saharan/Arabian region was 2.22°C above normal, 0.89°C above the previous record and the largest annual anomaly ever recorded for any subregion outside the Arctic. The Mediterranean region also had its warmest year on record with Tunisia equalling its previous warmest year.

Recent warming has been especially strong in Africa. Temperatures for the 2001–2010 decade averaged 0.85°C above normal, 0.49°C warmer than any previous decade, and the five hottest years on record for the continent have all occurred since 2003. East Africa, which had never had a year as much as 1°C above normal prior to 2003, has now reached this threshold in eight successive years.

Asia and the Pacific

The very warm conditions in Africa and the Arabian Peninsula extended northwards and eastwards into aouthern and central Asia as far east as the Indian subcontinent. India and Turkey had their hottest years on record, as did the broader south and south-west/central Asian regions.

Further south, South-East Asia had its second hottest year on record, behind 1998. Temperatures in that region were more than a degree above normal in the first half of the year but returned closer to average later in the year as El Niño conditions, strongly associated with high temperatures in the region, transitioned to a strong La Niña.

Most parts of northern and eastern Asia were warmer than average in 2010, except for parts of western and central Siberia. Annual temperatures were mostly unexceptional, with a very hot summer being partially offset by near-average conditions early and late in the year.

Summer 2010 was Asia's hottest on record, narrowly breaking the previous mark set in 1998. China, Japan and the Russian Federation all had their hottest summers on record, with the Russian Far East being especially warm.

Australia, influenced by wet conditions through much of the year, had its coolest year since 2001, with temperatures below average through much of the central and eastern interior, although they were well above average near the tropical coast with some northern locations having their hottest year on record. New Zealand had its fifth-warmest year on record and records were set locally in the South Island and around Auckland.

Europe

The year saw a wide range of conditions in Europe. Temperatures were below average in many parts of northern and western Europe, where it was widely the coldest year since at least 1996. Norway had its coldest year since 1985 and the United Kingdom and Ireland their coldest since 1986, while other countries with annual mean temperatures below the long-term average (most of them for the first

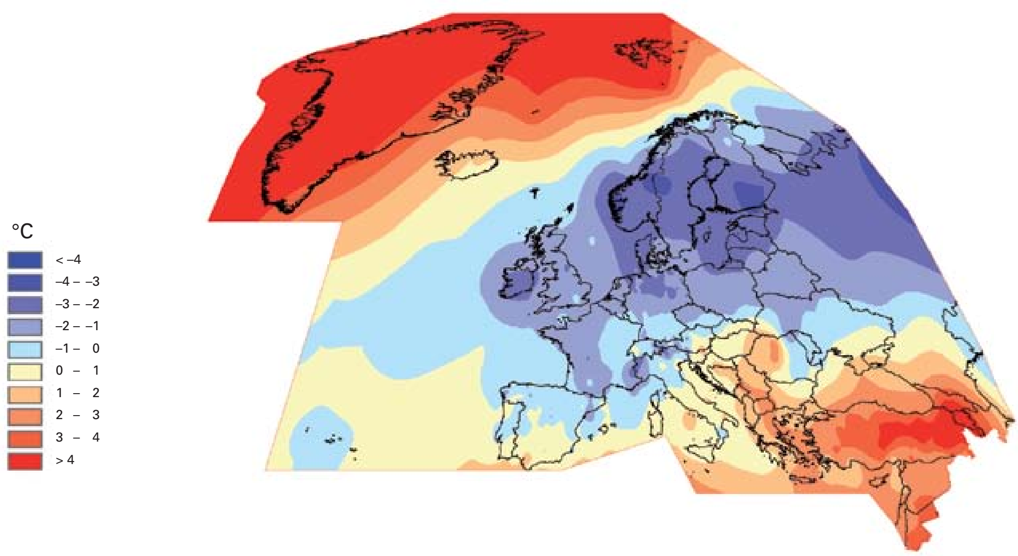


Figure 6. European temperature anomalies (°C) relative to 1961–1990 for (left) December 2009–February 2010 and (right) December 2010 *(Source: WMO Regional Association VI (Europe) Regional Climate Centre on Climate Monitoring, Deutscher Wetterdienst, Germany)*

time since 1996) included Sweden, Finland, the Netherlands, Germany, France, Denmark and Latvia. At the other end of the scale, many parts of south-eastern Europe had annual mean temperatures 1–3°C above normal, with Turkey having its warmest year on record and Athens its warmest year since at least 1897. It was also a warm year in the high latitudes of the North Atlantic, with Svalbard in Norway 2.5°C above normal and Reykjavik 1.6°C above normal, its second-warmest year on record.

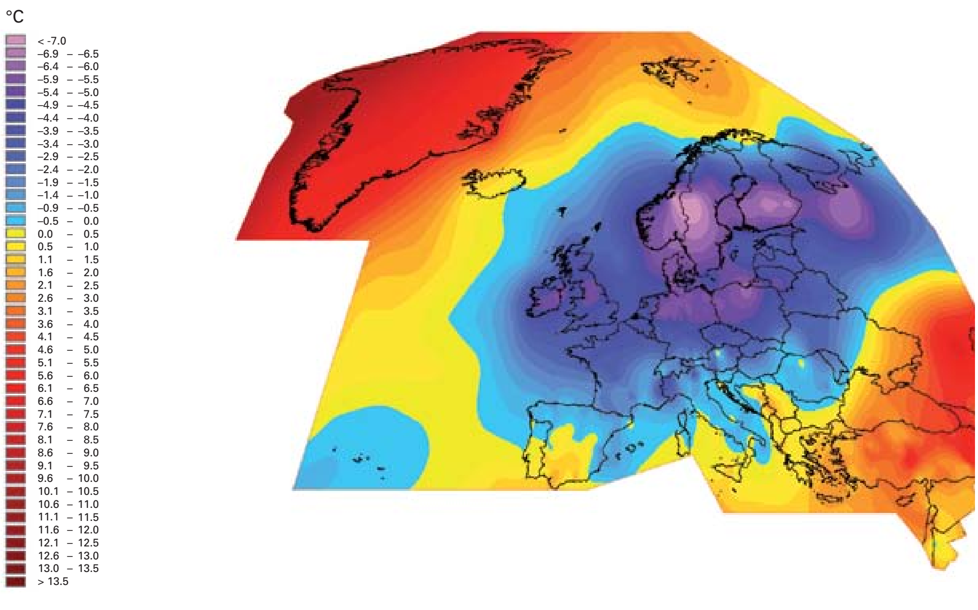
Europe from the Alps northwards was cold both early and late in the year, with the lack of the normal winter westerlies (associated with the extreme negative phase of the North Atlantic Oscillation) allowing cold continental air to become established as far as the continent's western periphery. The most unusual conditions in the 2009/2010 winter were in the westernmost parts of Europe, where Ireland and Scotland both experienced their coldest winter since 1962/1963. Many other parts of northern and central Europe had their coldest winter since 1978/1979, 1986/1987 or 1995/1996, although conditions still fell well short of those experienced in numerous winters in the 1960s and earlier. Many of the same regions then saw even stronger temperature anomalies in December.

The summer was unusually hot over most of Europe and was the hottest on record averaged over the continent, breaking the previous record set in 2003 by 0.62°C. The most extreme conditions were in the western Russian Federation, but summer temperatures were above average virtually throughout the continent. July was especially hot and broke the previous continental record by nearly a degree, with temperatures at least 1°C above normal almost everywhere except the United Kingdom, Ireland and parts of Bulgaria.

North America and Greenland

It was an exceptionally warm year in northern North America, especially the Arctic. It was Canada's warmest year on record with temperatures averaging 3.0°C above the 1961–1990 mean, with both winter and spring also being the country's warmest on record. Annual anomalies reached +5°C around the north of Hudson Bay; the annual mean temperature of −4.3°C at Iqaluit, on Baffin Island, was 2.3°C above the previous record. It was also the warmest year on record at most Greenland stations, except in the north-east, with annual anomalies of +4.9°C at Ilulissat and +4.0°C at Nuuk. For the Greenland/Arctic Canada region as a whole, temperatures were 2.99°C above normal, 0.75°C above the previous record. The decade 2001–2010 has also been extremely warm with decadal temperatures 1.39°C above normal, and 0.92°C warmer than the next warmest decade.

Further south, temperatures were relatively close to average through most parts of the



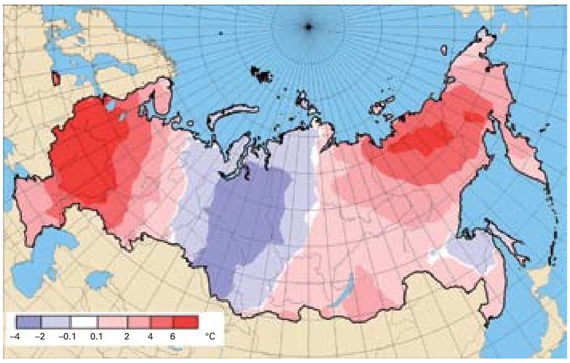


Figure 7. Russian Federation temperature anomalies (°C) relative to 1961–1990 for July 2010 *(Source: Roshydromet, Russian Federation)*

United States, except its northern fringe, and Central America. The south-eastern United States was colder than average, due mostly to abnormally cold conditions in winter, with Florida experiencing its coldest January–March on record and then its coldest December. The United States as a whole had its coldest winter since 1984/1985, and most southern areas from Texas eastwards had one of their 10 coldest winters on record. These cold conditions were accompanied by unusually extensive snow cover and very heavy seasonal snowfall amounts in some eastern cities, including a record seasonal total in Washington, D.C. However, most of the country had above average temperatures in summer, which was the fourth hottest on record.

South America

Temperatures in South America were mostly above average in the north of the continent and close to average in the south. In northern South America, where 2010 temperatures rank second behind those of 1998, the first half of the year was very warm before temperatures returned closer to average levels from July onwards. In the south, warm conditions early and late in the year were separated by a rather cold winter and early spring; the northern half of Argentina was especially warm in December.

Heatwaves and cold waves

Exceptional heatwaves were recorded in several parts of Eurasia during the northern hemisphere summer. The most extreme heat was centred over the western Russian Federation, with the peak extending from early July to mid-August, although temperatures were well above average from May onwards. In Moscow, July mean temperatures were 7.6°C above normal, making it the city's hottest month on record by more than 2°C, and similar anomalies continued until cooler conditions developed in the last 10 days of August. A new record high temperature for the city of 38.2°C was set on 29 July, and it reached 30°C or above on 33 consecutive days (in comparison, there was not one day with temperatures above 30°C in the summer of 2009). About 11 000 excess deaths during the summer were attributed to the extreme heat in Moscow alone. Some parts of central European Russian Federation had average temperatures more than 5°C above normal for the summer. The heat was accompanied by destructive forest fires, while severe drought, especially in the Volga region, led to widespread crop failures. Nearby countries were also affected. The Russian Federation, Belarus and Finland all had their highest temperatures on record, and a number of stations in Serbia set records for the greatest number of nights above 20°C.

Earlier in the year, there was exceptional pre-monsoon heat in southern Asia, which included a temperature of 53.5°C at Mohenjo Daro on 26 May, a national record for Pakistan and the highest temperature in Asia since at least 1942. Extreme heat affected northern Africa, Turkey and the Arabian Peninsula at times during the summer, with notable readings including 52.0°C at Jeddah (Saudi Arabia), 50.4°C at Doha, 47.7°C at Taroudant (Morocco) and 46.7°C at Mut (Turkey).

Much of northern and western Europe experienced abnormal cold both early and late in 2010. The temperature fell to –57.0°C at Hoseda-Hard (Russian Federation) on 19 February, the second-lowest temperature on record in Europe. Outside the Russian Federation, the 2009/2010 European winter was more exceptional for the persistence of cold conditions than individual extreme events; for example, a number of locations in central Sweden experienced their longest-ever period of unbroken temperatures below 0°C.

Extreme cold returned to northern and western Europe in late November and persisted through most of December. It was the second-coldest December in more than 350 years of observations in central England. Mean monthly temperatures were as much as 10°C below

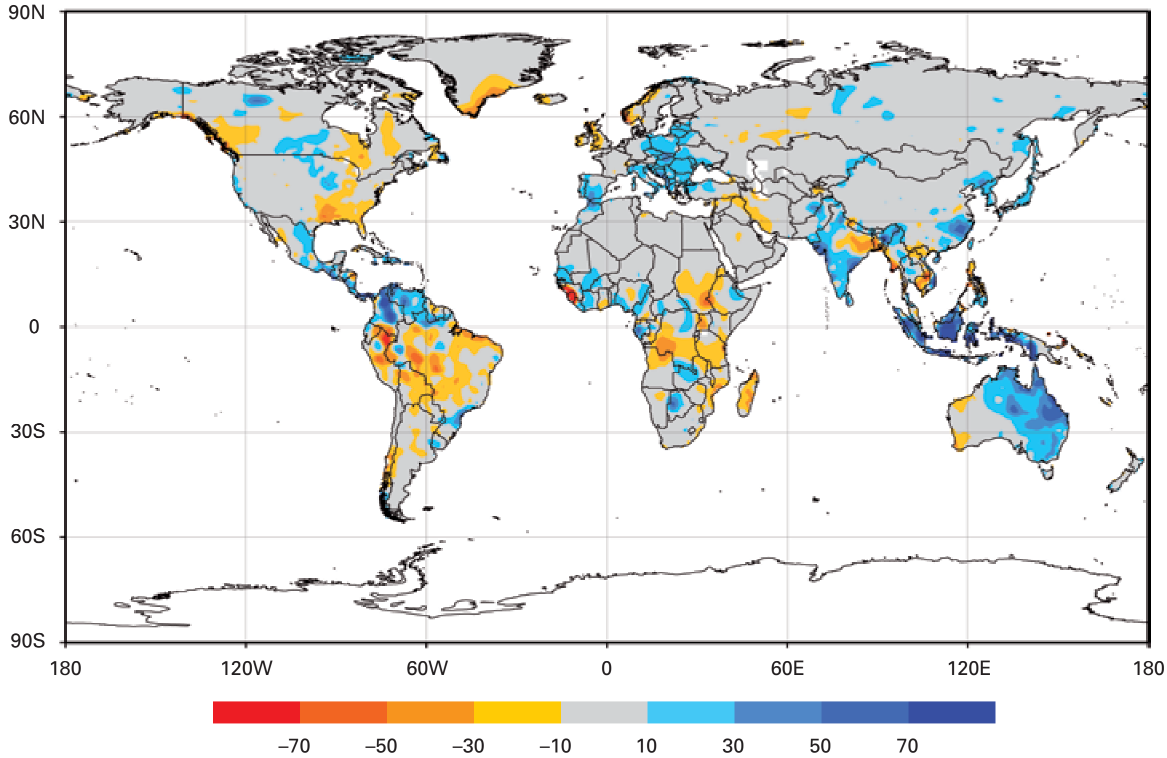


Figure 8. Annual precipitation anomalies for global land areas for 2010; gridded 1.0-degree raingauge-based analysis as normalized departures in mm/month focusing on 1951–2000 base period *(Source: Global Precipitation Climatology Centre, Deutscher Wetterdienst, Germany)*

normal in parts of Norway and Sweden, and were more than 5°C below normal over large parts of northern Europe. Snowfalls badly disrupted transport on a number of occasions, as did freezing rain in Moscow in the last week of December. Castlederg set a record low for Northern Ireland with –18.7°C on 23 December, while –23.0°C in Holbæk on 22 December was Denmark's lowest temperature since 1987.

The unusual atmospheric circulation that caused extreme cold in northern Europe also caused unusual warmth in other areas, notably the Canadian Arctic, Greenland and the south-easternmost parts of Europe. Some stations in northern Canada had December mean temperatures as much as 14°C above normal, while in the Russian Federation, Vladikavkaz reached 27.1°C on 6 December, surpassing the record for the highest winter temperature in the country (set at Sochi in February 2010) by 3.3°C.

Precipitation

According to an analysis by the United States National Climatic Data Center, globally-averaged land precipitation in 2010 was the highest on record, 52 mm above the 1961–1990 average of 1 033 mm. The previous highest years, 1956 and 2000, also coincided with strong La Niña events.

It was a very wet year over much of East Asia and Australia. Australia had its second-wettest year on record (52 per cent above the 1961–1990 average), associated with the strong La Niña event (there was also a strong La Niña in the record year of 1974), and rainfall was also well above average over most of Indonesia, Japan and south-eastern China. It was also wet in Pakistan, which had its fourth-highest monsoon season rainfall on record, and in western India.

It was also a very wet year in large parts of central and south-east Europe and adjacent areas of Asia, with parts of the region experiencing rainfall 50 per cent or more above normal. Hungary had its wettest year since 1901, while it was the wettest year on record at a number of locations, including Bursa (Turkey), Novi Sad (Serbia) and several stations in Moldova. In contrast with many recent years, it was also wet in most of the Iberian Peninsula. Portugal had its wettest year of the past decade (20 per cent above normal),

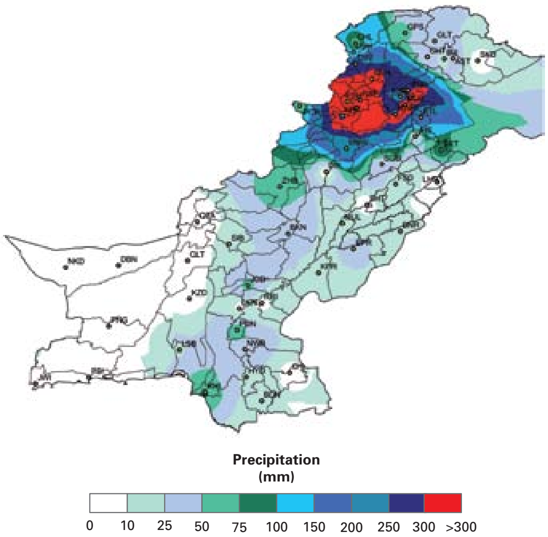


Figure 9. Rainfall (mm) over Pakistan for the period 26–29 July 2010 *(Source: Pakistan Meteorological Department)*

while rainfall was more than 50 per cent above normal in parts of south-western Spain.

Rainfall in 2010 was above average over large parts of West Africa, including the Sahel. It was also well above average in parts of north-western South America and nearby areas, especially in northern and western Colombia and northern Bolivarian Republic of Venezuela, with Cartagena receiving 2 485 mm (150 per cent above normal) between May and December, and numerous Colombian centres having their wettest year on record. Other significant regions that were wetter than average included much of the northern and western United States, the Canadian Prairies and south-east Brazil.

There were fewer regions that experienced dry conditions over the year as a whole, although some suffered from severe drought for parts of the year. Regions that had annual rainfall significantly below average in 2010 included north-western Europe, most of Argentina and Chile, many islands in the central and eastern Pacific, and the south-west corner of Australia.

Floods in many parts of the world

Pakistan experienced the worst flooding in its history as a result of exceptionally heavy monsoon rains. The event principally responsible for the floods occurred from 26 to 29 July, when four-day rainfall totals exceeded 300 mm over a large area of northern Pakistan centred on Peshawar. There were additional heavy rains further south from 2 to 8 August that reinforced the flooding. More than 1 500 lives were lost, and over 20 million people were

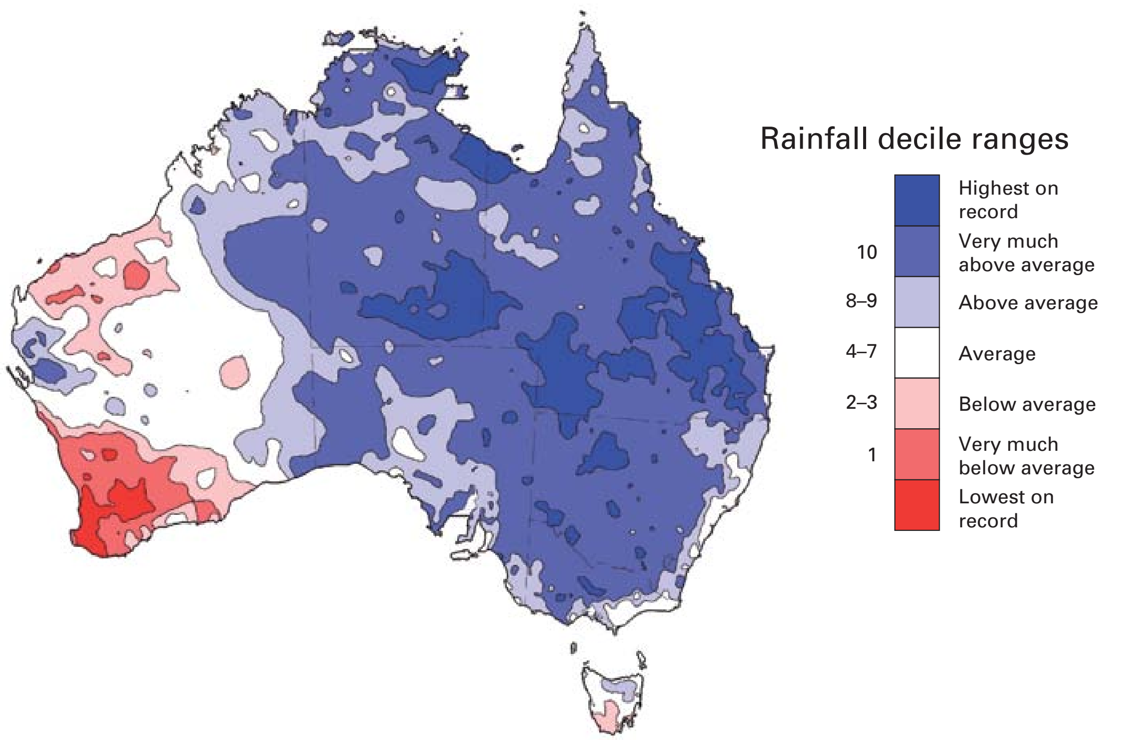


Figure 10. Australian rainfall deciles for the year 2010; deciles are calculated relative to the period 1900–2010, based on gridded data. *(Source: Australian Bureau of Meteorology)*

displaced as large parts of the country's agricultural land were inundated. In terms of the number of people affected, the United Nations rated the flood as the greatest humanitarian crisis in recent history. The total monsoon season rainfall for Pakistan was the fourth highest on record, and the highest since 1994.

Summer rainfall was also well above average in western India, and China experienced its most significant monsoon flooding since 1998, with south-eastern China and parts of the north-east most severely affected. The latter floods also extended to the Korean Peninsula. A number of these floods led to significant loss of life, directly as well as through landslides in China, which left more than 1 700 people dead or missing in Gansu Province. There was also significant flooding later in the year that affected parts of Thailand and Viet Nam in October. However, monsoon season rainfall averaged over India was only 2 per cent above normal, and it was well below average in north-eastern India and Bangladesh, which had its driest monsoon season since 1994.

There were numerous episodes of flooding in eastern Australia during the second half of 2010 as a result of regular heavy rains. The most severe floods occurred in central and southern Queensland in the last week of December, extending into early 2011, with hundreds of buildings inundated and severe disruption to agriculture, mining and transport. Rockhampton, Emerald and Bundaberg were among the worst-affected centres.

Floods occurred on several occasions during the year in central and south-eastern Europe. Central Europe had major floods in May, particularly in eastern Germany, Poland and Slovakia. Flooding occurred in Romania, the Ukraine and Moldova in late June, and in Germany, Poland and the Czech Republic in August. Major flooding then returned to south-east Europe in early December after widespread three-day rainfalls of 100–200 mm in Montenegro and Bosnia and Herzegovina at the end of November, with the worst impacts being downstream in Serbia. Record peaks occurred on the Drina River.

An active wet summer monsoon season in the West African Sahel was accompanied by floods from time to time, with Benin and Niger the countries most severely affected. In Benin, this caused the worst flooding on record in terms of impact, causing severe losses to the agriculture sector and severe disturbances to public services, including cutting access to health centres, although rainfall amounts themselves were mostly not record-breaking. Significant flooding also occurred in Kenya during the early months of 2010.

Repeated heavy rains in Colombia resulted in persistent flooding, most severe in November and December, which was described as the most severe natural disaster in the country's history, with over 300 deaths and major damage to agriculture, buildings and infrastructure. The Bolivarian Republic of Venezuela and Panama were also affected, with the Panama Canal closed due to weather conditions on 8–9 December for the first time in its history.

More localized flash floods caused severe damage and loss of life in numerous other locations, including Rio de Janeiro, Brazil (April), Madeira (February), Arkansas, United States (June), southern France (June) and Casablanca, Morocco (November).

Drought in the Amazon and elsewhere

Parts of the Amazon basin were badly affected by drought during the later part of 2010. An unusually dry July–September period in north-western Brazil resulted in sharply reduced streamflow in many parts of the Amazon catchment, with the Rio Negro, a major Amazon tributary, falling to its lowest level on record. Earlier in the year, the eastern Caribbean islands were badly affected by drought, with rainfall for the period from October 2009 to March 2010 widely in the driest 10 per cent of recorded years. The northernmost parts of mainland South America – many of which were to experience severe flooding later in the year – were also very dry, with large parts of the Bolivarian Republic of Venezuela experiencing their driest January–March period in over 100 years; Colombia and Guyana were also badly affected.

In Asia, parts of south-western China experienced severe drought through late 2009 and early 2010. Yunnan and Guizhou provinces both had their lowest rainfalls on record during the period from September 2009 to mid-March 2010 with totals widely 30 to 80 per cent below normal. The dry conditions were also accompanied by above-average temperatures and numerous forest fires. Conditions there eased with good rains during the summer. Pakistan also experienced drought in the early months of 2010 before the onset of the monsoon. Summer rains also eliminated developing drought conditions in parts of western Europe, where the United Kingdom had its driest January–June period since 1929. The dry conditions were especially marked in exposed coastal regions, which normally receive heavy precipitation in westerly flow, with western Norway having its driest winter on record.

Some other parts of southern Asia, including north-eastern India, Bangladesh, and parts of Thailand and Viet Nam, were relatively dry during the main monsoon season, although Thailand and Viet Nam were then hit by floods in October. While widespread above-average rains eased long-term drought in many parts of Australia, the south-west was a marked exception, experiencing its driest year on record in 2010.

Dry conditions developed during the later months of the year in parts of East Africa, particularly in equatorial regions of Kenya and the United Republic of Tanzania, with a number of locations in the region receiving less than half their usual rainfall for the September–December period. This had adverse impacts on agriculture and water supply in the region. Dry conditions also developed late in the year in key grain-growing areas of eastern China, where October–January rainfall over a six-province region south of Beijing was the second-lowest since 1961, and in the River Plate region of Argentina and Uruguay where October–December rainfall was more than 50 per cent below normal.

Tropical cyclones

Global tropical cyclone activity in 2010 was the lowest recorded in the modern satellite era (from 1970 to the present). A total of 67 storms occurred, 34 of which reached hurricane/typhoon intensity (sustained winds of 120 km/h or greater). This total surpassed the 68 observed in 1976 and 1977 as the lowest total of the post-1970 period, and is about 20 per cent below the 1970–2009 mean of 85, while the number of hurricanes/typhoons was also well short of the long-term average of 44. The North Atlantic was the only basin with above-normal activity.

It was an exceptionally quiet season in both the North-West and North-East Pacific. The North-West Pacific's total of 14 storms (7 typhoons) was the lowest recorded in the satellite era, while the North-East Pacific (8 storms, 3 hurricanes) equalled its previous record low. In both cases the number of storms was only about half the long-term average. North Indian (4 storms, 2 cyclones) and South Indian (11 storms, 5 cyclones) activity was also well below average, while the South-West Pacific (11 storms, 5 cyclones) was close to average.

By contrast, the Atlantic had a very active season, with 19 storms, well above the average of 10, equalling the third-highest total on record. Of these, 12 reached hurricane intensity, ranking only behind the 2005 season, when there were 28 storms, including 15 hurricanes. There were, however, no landfalls on the continental United States during the year.

The four strongest cyclones during the year were *Edzani* (January, South Indian), *Ului* (March, South-West Pacific), *Celia* (June, North-East Pacific) and *Megi* (October, North-West Pacific). All four had maximum sustained 10-minute winds of at least 215 km/h. Particularly notable was *Megi*, which was the year's most intense tropical cyclone with a minimum central pressure of 885 hPa, making it the strongest anywhere in the world since 2005 and the strongest in the North-West Pacific since 1983. It was also the year's strongest landfall when it struck the island of Luzon in the Philippines at near-peak intensity; casualties were relatively modest for such an intense cyclone with 19 deaths reported, although agricultural damage was severe. The year's most destructive cyclone, in terms of wind and storm surge damage, was *Giri*, which killed at least 150 people in Myanmar in October. Numerous other tropical cyclones contributed to destructive floods with substantial loss of life, notably *Agatha*, *Alex* and *Matthew* in Central America, *Conson* in the Philippines and *Fanapi* in southern China.

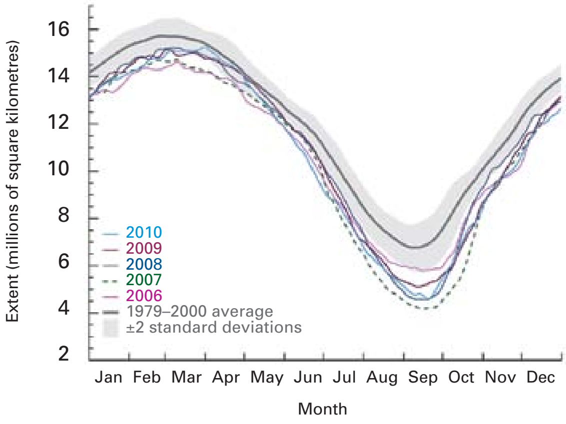


Figure 11. Northern hemisphere sea-ice extent in 2010, compared with previous years and the 1979–2000 average *(Source: National Snow and Ice Data Center, United States)*

Other extreme weather events during the year

A severe extratropical storm (*Xynthia*) crossed north-western Europe at the end of February, with widespread wind and storm surge damage. More than 60 lives were lost, mostly as a result of storm surges in western France, which reached 1.5 m at La Rochelle. Insured losses in France and Germany exceeded US$ 4 billion, and there was also substantial damage in Spain, Belgium, the Netherlands, Switzerland and Austria. A wind gust of 238 km/h was recorded at Pic du Midi in the French Pyrenees, and 120–140 km/h gusts were common on low ground in France and Switzerland.

Israel experienced the worst forest fire in recorded history in early December, with more than 40 lives lost in a blaze in the Carmel Mountains near Haifa. This followed an extremely dry and warm period, with the August–November period being the driest on record in the Haifa area, and the warmest on record for Israel as a whole.

The largest hailstone recorded in the United States, 20 cm in diameter, came from a storm at Vivian, South Dakota, on 23 July. There were also two very damaging hailstorms in Australia in March, with hailstones up to 10 cm in diameter in Melbourne on 6 March and 6 cm in Perth on 22 March. Both were the most significant hailstorms on record in their respective cities in terms of both hail size and impact, with damage exceeding US$ 1 billion in both cities. Canada also experienced its most damaging hailstorm, with over US$ 400 million in damage in Calgary on 12 July.

Polar regions: third-lowest Arctic summer sea-ice minimum

Arctic sea-ice extent was again well below average in 2010. The minimum extent of Arctic sea ice was reached on 19 September with an area of 4.60 million km^2, the third-lowest

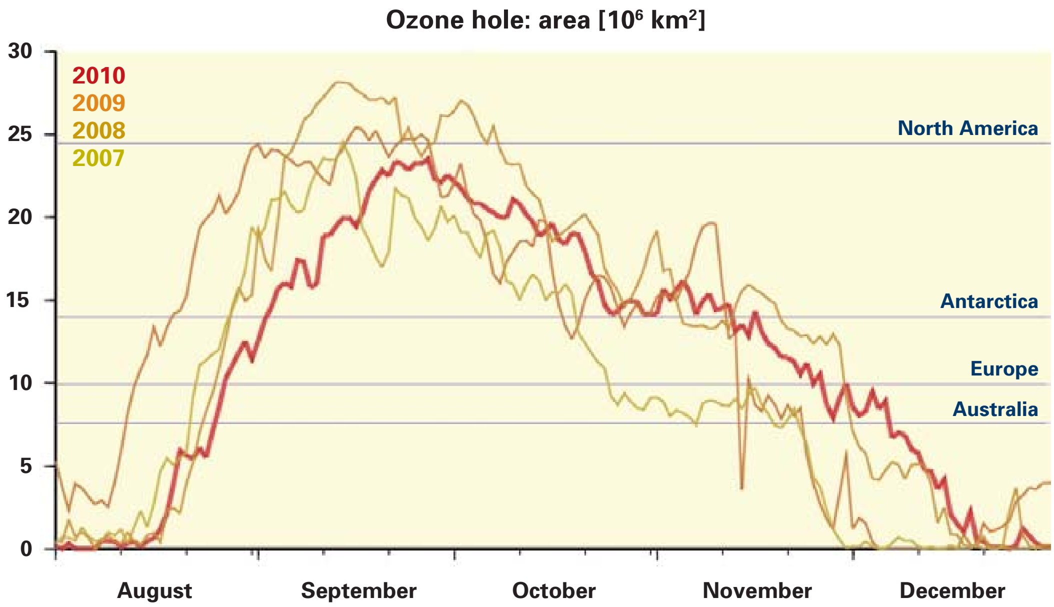


Figure 12. Daily evolution of the surface area of the Antarctic ozone hole over the course of the ozone hole season; the blue horizontal lines show the surface area of the various regions for comparison. *(Source: World Data Centre for Remote Sensing of the Atmosphere, one of the Global Atmosphere Watch World Data Centres, hosted by the German Aerospace Centre. 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.)*

seasonal minimum in the satellite record after 2007 and 2008, and more than 2 million km^2 below the long-term average of 6.74 million km^2. The Canadian sector had its lowest summer ice extent on record. The largest ice breakup in the Arctic since 1962 occurred on 5 August when an ice mass of 251 km^2 broke off the Petermann Glacier in north-west Greenland.

The autumn 2010 freeze-up was also abnormally slow, and the mean December 2010 ice cover (12 million km^2) was the lowest on record, 0.27 million km^2 below the previous record set in 2006. The conditions were particularly exceptional in the Canadian sector, with Hudson Bay not freezing over totally until mid-January 2011, more than a month after the usual date.

The Arctic low ice cover was consistent with well-above-average temperatures over most of the Arctic, with numerous stations in Greenland, as well as the Greenland/Arctic Canada region as a whole, having their warmest year on record with annual mean temperatures 3–5°C above normal.

By contrast, Antarctic sea-ice extent was generally slightly above average for most of 2010, with the lowest monthly average being 3.16 million km^2 in February, 0.22 million km^2 above the long-term average. It fell to near-average levels by the end of the year. Temperatures averaged over the Antarctic region were also slightly above average.

Antarctic ozone

The peak Antarctic ozone hole in 2010, while larger and more intense than the long-term average, was less significant than in most recent years.

The daily maximum ozone hole for 2010 was 22.2 million km^2 on 25 September. This is 3.6 million km^2 more than the 1979–2000 average but about 8 million km^2 less than the record of almost 30 million km^2 set in 2000. Averaged over the full period of peak ozone hole extent (7 September–13 October), the ozone hole in 2010 was the twelfth smallest since satellite records began in 1979, and the second-smallest since 1989.

The minimum daily average ozone during 2010 was reached on 1 October with 118.0 Dobson Units (DU). This is below the 1979–2000 average of 125.4 DU, but ranks as the eleventh highest value since 1979, and the second highest since 1988. The record low was observed in 1994 with 73.0 DU.

The use of reanalysis data for monitoring the state of the climate

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Reanalysis provides a coherent multivariate reconstruction of the global atmosphere over an extended period of time, based on information from a wide range of observations. The reconstructions are created with model-based data assimilation methods similar to those employed for numerical weather prediction. Reanalyses rely on a forecast model to propagate information in space and time, and to impose physically meaningful constraints on the estimates produced. In this way it is possible, for example, to extract useful information about rainfall from satellite observations of temperature and humidity, or to infer large-scale features of the global circulation in the early twentieth century from surface pressure observations available at the time.

Since first produced in the 1980s, reanalysis data have been widely used for research in the atmospheric sciences. Reanalysis is a rapidly evolving field; successive generations of products have improved in quality and diversity, reflecting major advances in modelling and data assimilation achieved in recent decades. New reanalysis products additionally benefit from improvements in the observations and other required input datasets, such as specifications of sea surface temperature and sea-ice concentration. These are the result of ongoing efforts in data reprocessing and recalibration by satellite agencies and other data providers, as well as recovery and digitization of early instrumental data that have not previously been used. The value and appeal of reanalyses arises from the accumulation of these benefits and their expression in a comprehensive dataset conveniently provided on global grids.

Evaluation of the quality of reanalysis products is often provided by users, based on many different measures depending on the application. Producers of reanalyses closely monitor the quality of fit to observations used, the ability of the assimilating model to predict those observations, and the adjustments made to the predictions by the data assimilation procedure. These so-called analysis increments represent the net impact of the observations on the reanalysed atmospheric fields. Systematic increments may be due to residual biases in observations, in the forecast model, or both. They can introduce artificial sources and sinks of heat, energy and water in the reanalysis, and hence affect the global budgets for these quantities. Changes in the mean increments, for example, associated with changes in the observing system, can affect trend estimates for basic climate variables derived from reanalysis data.

Several centres now routinely extend their latest reanalyses close to real time and provide product updates to users at a short delay. Timely, comprehensive estimates of global climate variables, consistently produced with an unchanged data assimilation system, can be very useful for climate monitoring. It is clearly necessary, however, to evaluate uncertainties before presenting assessments of year-to-year changes in climate based on reanalysis data. The accuracy of estimated trends and variability for any given variable depends on the strength of the observational constraint, on the variation of this constraint in time and space and, ultimately, on the uncertainties in the models and observations used. Where possible, estimates from reanalysis data must be compared with independent estimates based on observations alone. This is especially important for variables (such as precipitation) that are only indirectly constrained by the assimilated observations, and hence depend crucially on the quality of the assimilating forecast model.

Data sources and other background information

The three temperature datasets used in this publication are:

- The HadCRUT3 dataset, developed by the Hadley Centre at the UK Meteorological Office and the Climatic Research Unit (CRU) at the University of East Anglia.
- A dataset produced by the National Climatic Data Center (United States), using land surface temperature data from the Global Historical Climatology Network (GHCN) and version 3b of the Extended Reconstructed Sea Surface Temperature (ERSST) dataset.
- The GISTEMP analysis produced by the Goddard Institute for Space Studies (GISS) at the National Aeronautics and Space Administration (NASA), United States.

In this publication a common base period of 1961–1990 is used for global temperature data.

The individual datasets and further background material on the data can be obtained at the respective institution web pages:

Hadley Centre: www.hadobs.org

National Climatic Data Center: www.ncdc.noaa.gov

Goddard Institute for Space Studies: data.giss.nasa.gov/gistemp/

Other sources of data used in this publication include:

Climate Prediction Center, United States (El Niño/La Niña, Arctic Oscillation, North Atlantic Oscillation): www.cpc.ncep.noaa.gov

National Snow and Ice Data Center, United States (sea ice): www.nsidc.org

National Climate Centre, Australian Bureau of Meteorology (El Niño/La Niña, Indian Ocean Dipole): www.bom.gov.au/climate

Global Precipitation Climatology Centre, Deutscher Wetterdienst, Germany: gpcc.dwd.de

WMO Regional Association VI (Europe) Regional Climate Centre on Climate Monitoring, Deutscher Wetterdienst, Germany: www.dwd.de

Climatic Research Unit, University of East Anglia (temperature, precipitation, circulation indices): www.cru.uea.ac.uk

The subregions used in this publication are those defined in the IPCC Third Assessment Report. Their boundaries can be seen in various figures of the IPCC report at: www.grida.no/climate/ipcc_tar/wg1/384.htm

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