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Weather • Climate • Water

Global temperatures continue to set new records

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Global mean temperatures near the Earth's surface continued to set new records between 2011 and 2015, consistent with rising levels of greenhouse gases in the atmosphere. The year 2014 was nominally the world's warmest on record: global mean temperatures were 0.61°C* above the mean for the 1961–1990 reference period. The year 2015 is continuing on a similar track, with temperatures for the period January to July at 0.70°C* above the 1961–1990 mean.

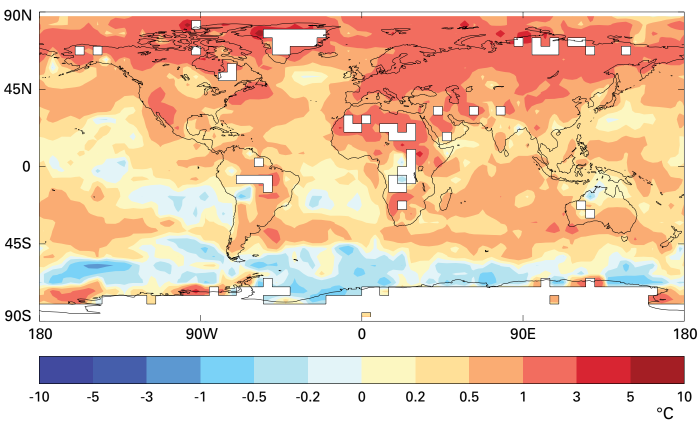

Figure 1. Global temperature anomalies from January 2011 to July 2015 (Reference period: 1961–1990)

(Source: Met Office, United Kingdom)

Concentrations of the various main greenhouse gases in the atmosphere continued to increase during the 2011–2015 period. Hemispherically averaged atmospheric levels of carbon dioxide in the northern hemisphere temporarily passed 400 parts per million for the first time during the spring of 2013. The 2014 annual mean of about 398 parts per million was the highest on record and 43% above pre-industrial levels. Methane and nitrous oxide levels also reached new records in 2014.

Global temperatures in 2011, 2012 and 2013 were not as high as in 2014 or 2015, but each of those three years was still warmer than any year before 1998. The year 2011 was relatively less warm compared with the preceding 15 years (0.46°C above the 1961–1990 mean) – it was influenced by the strong 2010–2011 La Niña – but was still warmer than any previous La Niña year. During the full period from 2011 to June 2015, global temperatures averaged 0.56°C above the 1961–1990 mean, and so are above the mean global temperature for the world's warmest decade (2001–2010), which was 0.50°C* above the 1961–1990 mean.

Between 2011 and 2015, many land areas set annual high-temperature records. Large parts of Europe had their warmest year on record in 2014, with several places likely to set new records in 2015. For Australia, 2013 was the warmest year on record, while records were set for the continental United States of America and Argentina in 2012. In Africa, 2013 ranked as the second-warmest year behind 2010. Some local regions experienced below-normal temperatures for one or more years during the period: for example, northern Australia in 2011 and 2012, central North America in 2013 and 2014, and central Asia and Alaska in 2012. However, no land areas were consistently cool thoughout the full five-year period.

Global temperatures over the sea surface in 2014 were the highest on record. Ocean heat content for the upper 700 metres of the ocean has also continued to set new records over the 2011–2015 period.

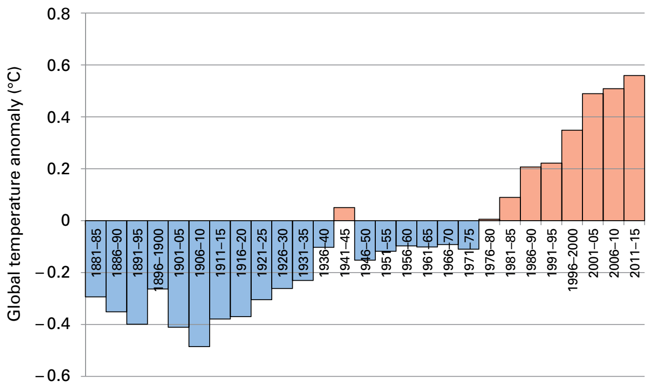

*Figure 2. Five-year moving average global temperature anomaly time series**

* Temperature anomalies are computed using three global datasets: HadCRUT4.4, jointly produced by the Met Office Hadley Centre and the Climatic Research Unit at the University of East Anglia; the GISTEMP Analysis (2015 version), produced by the NASA Goddard Institute for Space Studies; and the NOAA Global Surface Temperature dataset (version 4.0), produced by the NOAA National Centers for Environmental Information.

The El Niño/Southern Oscillation and other large-scale climate drivers

The 2011–2015 period began with a strong La Niña event, which was already in progress in the tropical Pacific Ocean. The event broke down during the first half of 2011 and redeveloped later that year, with weak to moderate La Niña conditions in place in late 2011 and early 2012. The El Niño/Southern Oscillation conditions then remained generally neutral for the next three years before the rapid development of an El Niño event during the northern hemisphere spring of 2015. As of September 2015, this event is still maturing and is likely to strengthen to become one of the four strongest events since 1950.

The markedly negative phases of the Arctic Oscillation and North Atlantic Oscillation during the winters of 2009–2010 and 2010–2011 led to very cold conditions in much of Europe through early 2011. The North Atlantic Oscillation and Arctic Oscillation then remained mostly positive throughout the northern hemisphere winters of the 2011–2015 period, although there was a notable negative phase during March 2013, which contributed to that month being very cold in Europe.

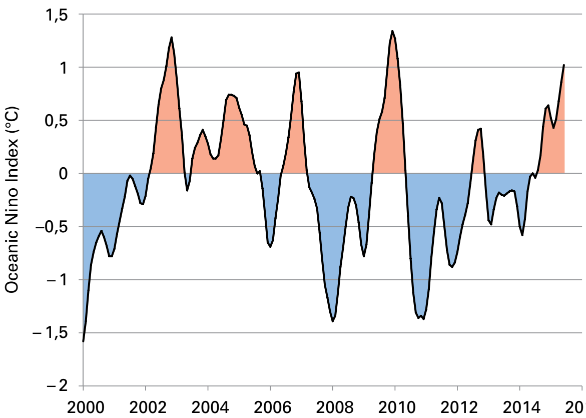

Figure 3. Oceanic Niño Index (3-month running mean of Niño 3.4 index) from 2000 to 2015

(Source: NOAA Climate Prediction Center, United States)

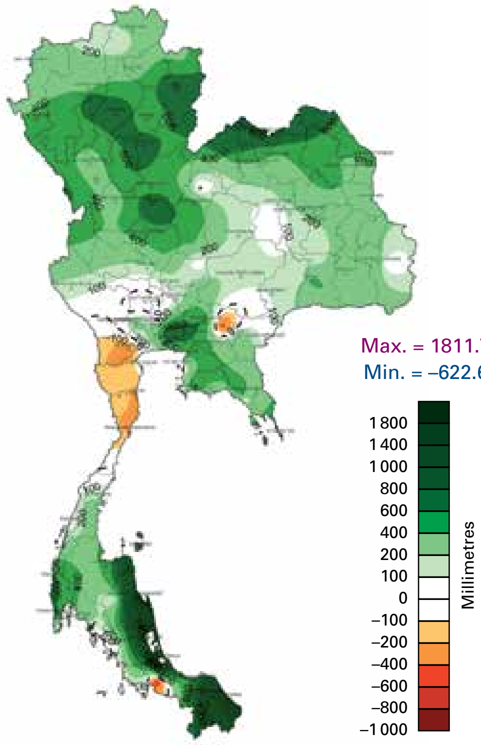

Figure 4. Annual rainfall anomalies in Thailand for 2011, expressed as millimetres above or below the long-term average

(Source: Thai Meteorological Department)

Selected extreme events

Flooding and flash floods have been a regular feature of the climate in recent years. Large-scale and prolonged flooding has affected large areas and intense local rainfalls have resulted in flash floods. One of the most significant flooding events of the period occurred in South-East Asia as a result of consistently high seasonal rainfall, which peaked in October 2011. Thailand was hardest-hit but there were also major impacts in neighbouring countries, especially Cambodia and Viet Nam. About 1 000 deaths were attributed to the flooding; economic losses in Thailand were estimated by the World Bank to be US$ 45 billion. Other major flooding events included those in eastern Pakistan (2011), eastern Australia (2011 and 2013), central Canada (2011), West Africa (2012), and the Parana basin of Paraguay, western Brazil and northern Argentina (2014). The most severe flash flood in terms of casualties occurred in January 2011 north of Rio de Janeiro in Brazil: more than 900 lives were lost.

The United States and Brazil were both affected by major multi-year droughts during the 2011–2015 period. Intense drought developed in 2011, centred on Texas and adjacent areas of northern Mexico, and spread to large parts of the central and western United States in 2012. Conditions improved east of the Rockies from 2013 onwards. However, major rainfall deficits have been affecting the western United States since 2012, especially in California where rainfall has generally been well below normal in each of the last three years. Drought conditions have also prevailed over many parts of eastern Brazil since 2013, reaching a peak in early 2015. The region around Brazil's largest city, São Paulo, was especially badly affected, with water storages dropping below 10% of capacity during the summer of 2014–2015.

Numerous shorter-term droughts have also affected many parts of the world. The most severe of these in terms of humanitarian impact occurred in East Africa in 2011. The failure of two successive rainy seasons in late 2010 and early 2011 caused major stock and crop losses, food shortages

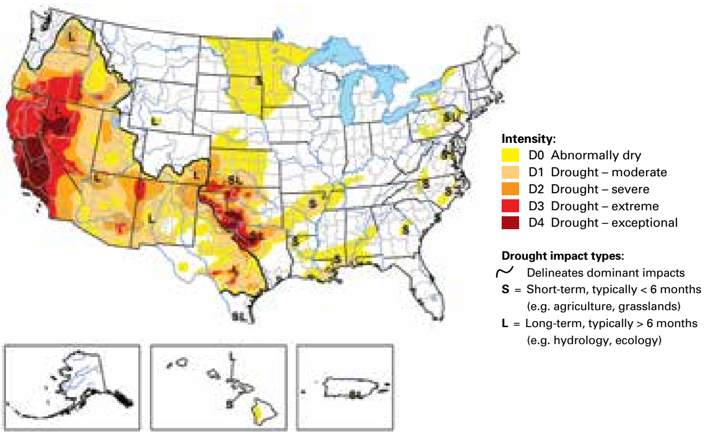

Figure 5. Drought conditions in the United States at the end of 2014

(Source: United States Drought Monitor)

and large-scale displacement of the population, especially in Somalia and adjacent areas of Kenya. The United Nations Office for the Coordination of Humanitarian Affairs estimated that 13 million people required humanitarian aid.

Typhoon *Haiyan*/*Yolanda* hit the Philippines in November 2013. It was assessed as one of the most intense tropical cyclone landfalls ever recorded, with estimated maximum 10-minute winds of 230 km/h when it reached land near the city of Tacloban. The sea level near the Philippines has observed some of the highest rising sea-level rates over the past half century. This contributed to the devastating impact of storm surges triggered by Typhoon *Haiyan*/*Yolanda*, which caused more than 6 200 deaths. While there were many other noteworthy tropical cyclones during the 2011–2015 period, another especially destructive event was Hurricane *Sandy* in October 2012. It reached land in New Jersey, United States, as a transitioning extratropical storm and caused major damage across a large area of the eastern United States and the Caribbean. New York City and the surrounding region was especially hard-hit, with extensive storm surge flooding in many areas, including lower Manhattan. Total damage was estimated at US$ 65 billion, making it the second most costly weather-related disaster on record after Hurricane *Katrina* in 2005. Rising sea levels contribute to increased risks of storm-surge flooding such as that seen during *Haiyan*/*Yolanda* and *Sandy*.

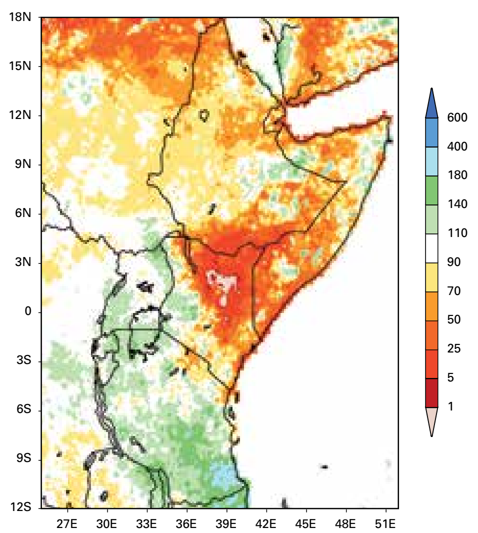

Figure 6. Rainfall for East Africa for February–September 2011, as a percentage of the estimated 1983–2009 average, calculated using blended station and satellite data

(Source: NOAA Climate Prediction Center, United States)

The past five years also saw numerous major heatwaves, including in the southern United States in 2011 and 2012, eastern Asia in 2013, Australia in 2013 and 2014, and India, Pakistan, the Middle East and southern and central Europe in 2015. However, no single heatwave during the 2011–2015 period had the extreme impact of the heatwaves which previously occurred in central Europe in 2003 or in the Russian Federation in 2010.

Meanwhile, parts of eastern and central North America experienced notably cold winters in both 2014 and 2015. Many parts of Europe experienced their most significant cold spell since the 1980s in February 2012, while Eurasia recorded extreme cold conditions during the following winter of 2012–2013. Large-scale deviations in atmospheric circulation can result in sharp geographical contrasts in temperature anomalies; in the North Atlantic region, these are often associated with extreme values of the North Atlantic Oscillation or Arctic Oscillation. Temperatures can be well above normal in regions with southerly to westerly flow anomalies, and at the same time, well below normal in regions with northerly to easterly flow anomalies. Potential long-term changes in the behaviour of the Arctic Oscillation, and any links that those changes may have to variations in Arctic sea ice, are an active area of research.

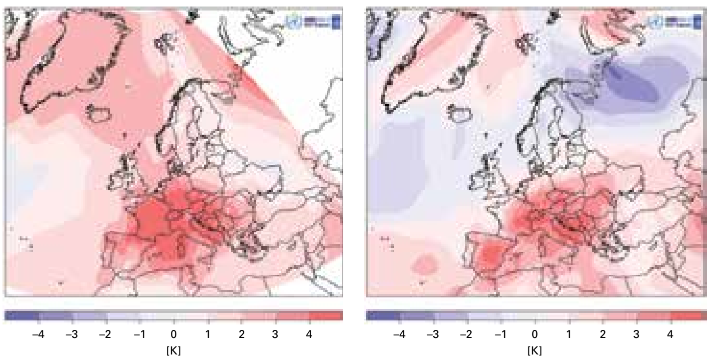

Figure 7. European heatwaves: temperature anomalies in August 2003 (left) and July 2015 (right) (Reference period: 1961–1990)

(Source: Regional Climate Centre for Europe; Climate Monitoring Node, Deutscher Wetterdienst, Germany)

Assessment of the extent to which anthropogenic climate change contributes to the risk of various observed extreme events is also an active area of research. Such studies are published annually in a supplement to the State of the Climate Reports published in the *Bulletin of the American Meteorological Society*. The findings of the studies were that long-term climate change has substantially increased the risk of many extreme events occurring, especially those relating to extreme heat.

The polar regions

Sea-ice extent showed opposite tendencies in the Arctic and Antarctic. In the Arctic, sea-ice extent at the end of the summer melt season was well below the 1981–2010 mean in all five years of the 2011–2015 period. In 2012, the lowest recorded Arctic sea-ice extent was observed, with a seasonal minimum of 3.41 million km^2, compared with the 1981–2010 average of 6.22 million km^2. The years 2011, 2013 and 2014 all ranked among the 10 years of lowest sea-ice extent. As of August 2015, Arctic sea-ice extent is the fourth-lowest on record for the time of year. While the decline in winter maximum extent has been much slower than the decline in summer minimum extent, 2015 had the lowest winter maximum extent on record. All five years from 2011–2015 had maximum extents below the 1981–2010 mean.

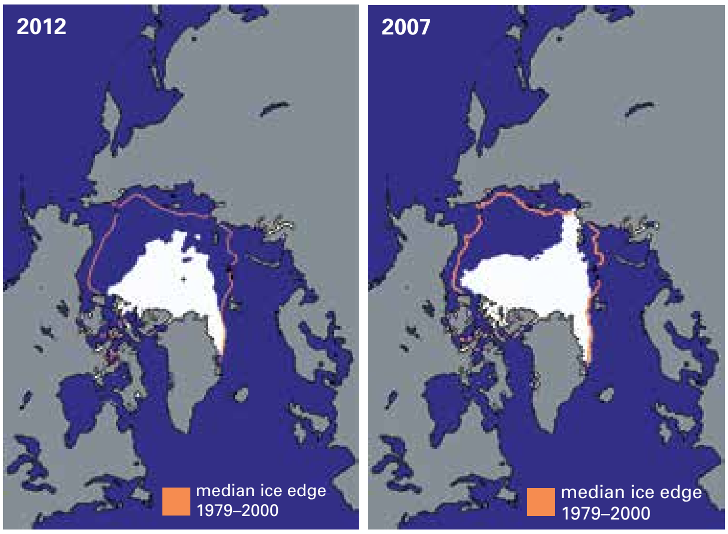

Figure 8. Arctic sea-ice extent – continued depletion
(Source: National Snow and Ice Data Center, United States)

By contrast, Antarctic sea-ice extent was above the 1981–2010 average for most of the 2011–2015 period. In September 2014, Antarctic sea-ice extent reached 20.11 million km^2, the highest value on record since satellite observations began in 1979, and 1.54 million km^2 above the 1981–2010 average maximum extent. Antarctic sea-ice extent was at record levels for the time of year for most of the second half of 2014 and the first half of 2015. However, very slow ice growth during the winter of 2015 led to sea-ice extent being slightly below normal by August 2015.

The observed long-term increase in Antarctic sea ice since 1979 is the subject of continuing research. The roles of stratospheric ozone depletion and resultant changes in the atmospheric circulation around the Antarctic have been suggested as possible causes that are under investigation.

Sea levels

Global sea levels continued to rise over the 2011–2015 period. In general, sea levels over the period were consistent with a continuing upward trend of approximately 3 mm per year. That trend has prevailed since satellite observations began in 1993. Some regions of the globe are experiencing greater sea-level rises than others. This is the case in the western Pacific Ocean near the Philippines and Indonesia and in the eastern Indian Ocean near Australia where the sea-level rise shows maximum sea-level trends.

There was significant interannual variability in global sea levels over the 2011–2015 period by the standards of the satellite era. The period began with global sea levels about 10 mm below the long-term trend value in early 2011. That was due to a strong La Niña which was then in progress and the resulting high rainfall over some land areas, which in turn led to above-normal water storage on land (especially in Australia). Sea levels quickly rebounded as the La Niña ended and had returned to levels that were at or above trend by mid-2012. There was a further marked rise in early 2015 as an El Niño developed, with sea levels 6-7 mm above trend by mid-2015. Both the 2010–2011 and 2015 departures from trend were larger than anything observed between 1993 and 2009, including during the very strong 1997–1998 El Niño.

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