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WORLD METEOROLOGICAL ORGANIZATION

WMO Statement on the State of the Global Climate in 2017
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Executive Summary

Whilst 2017 has been a cooler year than the record-setting 2016, it is very likely to be one of the three warmest years on record, and the warmest not influenced by an El Niño event. The five-year average 2013-2017 global average temperature is currently close to 1°C above the average for 1880-1900 and is likely to be the highest five-year average on record. The world also continues to see rising sea levels, with some level of acceleration and increasing concentrations of greenhouse gases. The cryosphere continued its contraction, in particular in the Arctic where sea ice extent continued shrinking, and Antarctic sea ice extent started shrinking since last year after a multi-year period of stable or even slight expansion

The overall risk of heat-related illness or death has climbed steadily since 1980, with around 30% of the world's population now living in climatic conditions with extreme hot temperatures persisting several days a year. Between 2000 and 2016, the number of vulnerable people exposed to heatwave events has increased by approximately 125 million**.**

According to the international Monetary Fund (IMF), for the median low-income developing country, with annual average temperature conditions around 25°C, a 1°C increase in temperature could lower per capita economic output by about 1.2 percent.

There were many significant weather and climate events in 2017, including a very active North Atlantic hurricane season, major monsoon floods in the Indian subcontinent, and continuing severe drought in parts of east Africa.

In September 2017, the three major and devastating hurricanes that made landfall in the southern United States and in several Caribbean islands in rapid succession broke modern records for such weather extremes and for associated loss and damage.

Massive internal displacement in context of drought and food insecurity continues across Somalia. From November 2016 to mid-June 2017, nearly 761 000 drought-related internal displacements were recorded by the United Nations High Commissioner for Refugees (UNHCR).

Information used in this report is sourced from a large number of National Meteorological and Hydrological Services (NMHSs) and associated institutions, as well as the World Climate Research Programme (WCRP) and the Global Atmosphere Watch (GAW). Information has also been supplied by a number of other United Nations and other international agencies, including the Food and Agriculture Organization (FAO), the World Food Program (WFP), the World Health Organization (WHO), UNHCR, the International Organization for Migration (IOM), the International Monetary Fund (IMF), the UN International Strategy for Disaster Reduction (UNISDR) and the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO).

Global temperatures in 2017

Global mean temperature for the period January to September 2017 was 0.47°±0.08°C above the 1981-2010 average[1] This estimate is based on five independently-maintained global temperature data sets, and the range represents the spread of those estimates.

2017 is on course to be the second or third warmest year on record. The previous year, 2016, which was influenced by a strong El Niño, is likely to remain the warmest at 0.56±0.10°C above the 1981-2010 average. Continuing global warmth means that 2015, 2016 and 2017 are now the three warmest years on record, according to data available to date for 2017. 2014 was fourth warmest in four of five data sets considered, although a number of other years were comparable.

The exceptional warmth in 2016 and, to an extent 2015, were caused by the long-term global warming trend with temperatures further boosted by one of the three strongest El Niño events of the past 50 years. El Niño events tend to increase global temperature when they occur, due to the associated ocean warming in the tropical Pacific and the subsequent enhanced heat release in the atmosphere. With the absence of El Niño conditions throughout 2017, the year's temperatures have not remained at record levels. However, 2017 has been considerably warmer than 2014, the previous year to experience ENSO-neutral conditions throughout the year.

January to September 2017 is approximately 1.1±0.1°C above the average for 1880-1900 (see box for additional information on baselines). The five-year average 2013-2017, provisionally 0.40°C warmer than the 1981-2010 average (compared with 0.35°C for 2012-2016 and 0.27°C for 2011-2015), which currently represents near 1°C increase since the pre-industrial period. It is likely to be the highest five-year average on record.

Small differences between the five datasets used in the assessment (see Box) principally arise from differences in the handling of data from poorly observed regions. In particular, unusually warm conditions in the Arctic in late 2016 and early 2017 have led to recent differences among the data sets. Because the reanalysis-based data sets have full global coverage, and include more data from the rapidly warming poles, they show a stronger warming signal than do the conventional data sets.

All continents, except Antarctica, have had one of their 10 warmest January-to-September periods on record, although none has had record warmth. A number of areas in the first nine months of 2017 were unusually warm, notably parts of southern Europe, including Italy, and North Africa. January to September has been the warmest on record for the Asian part of Russia and equal to the warmest on record for China. Much of North America was warmer than average, but parts of the northwestern US and western Canada were cooler than the 1981-2010 average. Parts of eastern Africa were record warm, as were parts of southern Africa. Much of South America has been warmer this year than the 1981-2010 average. Although only limited areas neared record levels, large areas of the continent were much warmer than average. A large part of the Antarctic continent has been colder than average so far in 2017, but there have been large changes from month-to-month.

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1 WMO has started using the 30 year period 1981-2010 for computing long term averages of climate quantities and their departures from the average. This allows the analysis to benefit from satellite observations and reanalysis which started in late 1970s. The change in the baselines has no influence on the trend analysis.

Greenhouse gases

Globally averaged greenhouse gas (GHG) concentrations are key drivers of climate change. Atmospheric concentrations form as a budget between emissions due to human activities and the uptake from biosphere and oceans. Concentrations are expressed in terms of surface mole fractions calculated from a global in-situ monitoring network, for carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). GHG concentrations reached new highs in 2016, with CO_2 at 403.3±0.1 ppm (parts per million), CH_4 at 1853±2 ppb (parts per billion) and N_2O at 328.9±0.1 ppb. These values constitute, respectively, 145%, 257% and 122% of pre-industrial (before 1750) levels.

The increase in CO_2 from 2015 to 2016 was larger than the increase observed from 2014 to 2015. It was the largest annual increase observed in the post-1984 period. The previous largest annual increase was in 1998, also at the end of a strong El Niño event. The 2015 – 2016 El Niño event contributed to the increased growth rate through complex two-way interactions between climate change and the carbon cycle. During strong El Niño events the increase in net emissions are likely due to increased droughts in the tropical regions, leading to less carbon uptake by vegetation and increased CO_2 emissions from fires. For CH_4, the increase from 2015 to 2016 was slightly smaller than that observed from 2014 to 2015 but larger than the average over the past decade. For N_2O, the increase from 2015 to 2016 was also slightly smaller than that observed from 2014 to 2015 and the average growth rate over the past 10 years.

Global average GHG concentration figures for 2017 will not be available until late 2018. Real-time data from a number of specific locations indicate that levels of CO_2, CH_4 and N_2O continued to increase in 2017, but it is not yet clear how the rate of increase compares with that in 2016 or in previous years.

Ozone

The 2017 Antarctic ozone hole season is still in progress at the time of writing, however the ozone hole area did reach a maximum, of 19.6 million km^2, on 11 September.

During the first part of the season, up until the second week of September, the size of the Antarctic ozone hole was close to the 1979-2016 average. However, the polar vortex became unstable and elliptical in the third week of September, with temperatures at the polar cap (60-90°S) rising 5-7°C above the long-term mean. This resulted in a rapid decrease in the size of the ozone hole before a small increase around the end of September. The average area of the ozone hole through the peak of the season (7 September to 13 October) was 16.8 million km^2. This is the smallest value since 2002 (9.9 million km^2) , slightly smaller than in 2012, the lowest value in the 2003-2016 period (19.8 million km^2). If one averages the ozone hole over the 30 worst consecutive days, the area was 17.5 million km^2. This is also the lowest value observed since 2002 (15.3 million km^2) and again somewhat smaller than in 2012 (18.8 million km^2).

The oceans in 2017

Sea level

The global mean sea level (GMSL) is one of the best indicators of global climate change. It integrates the response of several components of the Earth system (ocean, atmosphere, cryosphere and hydrosphere) to anthropogenic and natural forcing factors as well as the effect of direct human intervention on the hydrological cycle. The GMSL budget, which is almost balanced over the satellite altimetry era, also places bounds on poorly known components, such as deep ocean warming below 2000 metres.

Global mean sea level has been relatively stable in 2017 to date, similar to levels first reached in late 2015. This is because the temporary influence of the 2015-16 El Niño on GMSL (during which GMSL peaked in early 2016 at around 10 millimetres above the 2004-2015 trend) continues to diminish and GMSL is reverting to values closer to the long-term trend. Preliminary data indicate that a rise in GMSL may have started to resume from July-August 2017 onwards.

The long-term trend in GMSL remains consistently upwards, with some level of acceleration. Whilst there are some differences between data sets, observed trends in GMSL range from 3.3 to 3.7 mm/year for 2004-2015, and 2.5 to 2.9 mm/year for 1993-2004.

Sea surface temperatures and ocean heat content

Global sea surface temperatures to date have been well above average and provisionally estimated at 0.38C[2] above the 1981-2010 average for January-September and are on track to make 2017 one of the three warmest years on record. The January- September period was the warmest on record for much of the tropical western Pacific as well as for the western Indian Ocean along the African coast and east of Madagascar. Over most of the tropical and subtropical Atlantic, temperatures were well above average but not record-breaking. Sea surface temperatures were slightly below the 1981-2010 average in much of the eastern Indian Ocean, in parts of the Southern Ocean south of Africa and South America, and in an area of the North Atlantic south of Greenland (a region that has seen cool anomalies regularly in recent years). Temperatures over most of the oceans adjacent to Antarctica have been warmer than average for almost all areas.

Global ocean heat content in 2017 to date has been at or near record high levels. The total global ocean heat content for the 0-700 metre layer for January to June 2017 (NOAA) has been 161 zetajoules (ZJ)[3], and the mean for the 12 months ending in June (149 ZJ) is just below the 151 ZJ for January to December 2015 as the highest 12-month average on record. 162 ZJ for January to March 2017 is the highest quarterly value on record. Comparable records have also been set or approached for the 0-2000 metre layer, with a quarterly record (238 ZJ) also being set for this layer in the January to March.

Ocean acidification

The ocean absorbs up to 30% of the annual emissions of anthropogenic CO2 into the atmosphere, helping to alleviate the impacts of climate change on the planet. However, this comes at a steep ecological cost, as the absorbed CO2 reacts in seawater and changes acidity levels in the ocean. More precisely, this involves a decrease in seawater pH together with closely linked shifts in the carbonate chemistry of the waters, including the saturation state of aragonite, which is the main form of calcium carbonate used by key species to form shells and skeletal material (e.g. reef-building corals and shelled molluscs). Observations of marine acidity at open ocean and coastal locations have revealed that present-day conditions are often outside preindustrial bounds. In some regions, the changes are amplified by natural processes such as upwelling (where cold water that is CO2 and nutrient-rich rises from the deep toward the sea surface), resulting in conditions that exceed critical biological thresholds.

Projections of future ocean conditions show that ocean acidification affects all areas of the ocean, while consequences for marine species, ecosystems, and their functioning vary. Over the past 10 years, various studies have confirmed that ocean acidification is directly influencing the health of coral reefs; aquaculture success, sea food quality and taste. It also changes survival prospects and calcification of several key organisms. These alterations often affect species at lower trophic levels

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2 Computed by WMO using Met Office HadSST and NOAA ERSST analyses.

3 1 ZJ = 10^{21} joules.

and have cascading effects within the food web, which are expected to result in increasing impacts on coastal economies.

Further, ocean acidification does not impact marine ecosystems in isolation. Multiple other environmental stressors can interact with ocean acidification, such as ocean warming and stratification, de-oxygenation, and extreme events, as well as other anthropogenic perturbations such as overfishing and pollution.

There has been a consistent trend in ocean acidification over time. Since records at Aloha station (north of Hawaii) began in the late 1980s, seawater pH has progressively fallen, from values above 8.10 in the early 1980s to between 8.04 and 8.09 in the last five years.

Other significant ocean events

Elevated sea surface temperatures in tropical regions, conducive to coral bleaching, became less widespread during 2017 than they had been during and after the 2015-16 El Niño. Nevertheless, some significant coral bleaching still occurred during 2017. The Great Barrier Reef off Australia experienced major bleaching for the second successive year; the main area affected was further south than it had been in 2016, with the greatest damage in central areas between Cooktown and Townsville.

UNESCO reported[4] in June that all but three of the 29 coral reefs with World Heritage listing had been subjected to temperatures consistent with bleaching at some point in the 2014-2017 period.

The El Niño-Southern Oscillation (ENSO) and other large-scale features of the climate system

The El Niño-Southern Oscillation (ENSO) has been in a neutral phase in 2017 to date, with monthly mean sea-surface temperatures in the equatorial central Pacific within 0.5°C of their average values throughout the year. However, despite the lack of a basin-wide El Niño, temperatures were 2°C or more above average near the equatorial South American coast in early 2017, resulting in climate anomalies more typically associated with El Niño on the west coasts of both South America and North America.

The Indian Ocean Dipole (IOD) was also in a neutral phase throughout 2017, although cool conditions prevailed in the eastern Indian Ocean south of the Equator. The Arctic Oscillation (AO) and Antarctic Oscillation (AAO)[5] were both in a predominantly positive phase during relevant periods of the year, although both had stronger positive signals during 2015.

Precipitation in 2017

With the El Niño-Southern Oscillation in a neutral state throughout the year to date, major precipitation anomalies have been more localized than they were in 2015 or 2016.

Areas with precipitation totals above the 90th percentile for the January to September period include southern South America (particularly in Argentina), parts of the southern and eastern United States and Ontario in Canada, northwest Russia, locally in southern and western Africa, western China, and parts of southeast Asia (especially Thailand – which had its second-wettest January to September on record - Malaysia and eastern Indonesia). The January to September period was the wettest on record for the contiguous United States.

4 Heron et al. 2017. Impacts of Climate Change on World Heritage Coral Reefs : A First Global Scientific Assessment. Paris, UNESCO World Heritage Centre. http://unesdoc.unesco.org/images/0025/002505/250596e.pdf

5 Also known as the Northern and Southern Annular Modes respectively.

Large regions with precipitation amounts below the 10th percentile are located in the Canadian Prairies and adjacent northern border areas of the United States; the Mediterranean region, especially Tunisia, Italy and the Levant region; and in Somalia, Mongolia, Gabon and southwestern South Africa. Italy suffered particularly severe rainfall deficits and had its driest January to September on record. Smaller regions with precipitation amounts below the 10th percentile are found in Brazil, Cuba, Madagascar, India, South Korea, Japan, Australia and the Baltic region.

Rainfall was generally close to average in Brazil, and near to above average in northwest South America and Central America, supporting the recovery of these areas from droughts associated with the 2015-16 El Niño (although dry conditions persisted locally in northeast Brazil). Rainfall was also near- to above-average over most of southern Africa, except the far southwest. The 2017 rainy season (May to September) saw above-average rainfall over many parts of the Sahel, with significant flooding in some regions (especially in Niger), although streamflows in most parts of the Niger basin have been lower than they were in 2016.

Averaged over India as a whole, rainfall for the 2017 monsoon season (June to September) was slightly below average, with all-India rainfall 5% below average. However, above-average rainfall in some parts of India, especially the northeast, and adjacent countries led to significant flooding in those regions. Rainfall over the majority of eastern China was fairly close to average, but there were also some locally wet and dry areas.

A wetter-than-average start to the year in many parts of Australia, especially the western half, was followed by dry conditions from April onwards, with the June to September period being especially dry away from the south coast. It was a wet year in many parts of New Zealand, with significant flooding in the North Island in March and April, and parts of the South Island in July.

The cryosphere in 2017

Arctic sea-ice extent was well below average throughout 2017. It reached record-low levels for the first four months of the year according to sea-ice extent datasets from both the National Snow and Ice Data Center (NSIDC) and the Copernicus Climate Change Service. The Arctic annual maximum extent occurred in early March, measuring 6-8% (depending on the dataset) below the 1981-2010 average. This ranked among the five lowest maximum extents in the 1979-2017 satellite record and, according to NSIDC data, was lowest on record . The five lowest maximum extents have all occurred since 2006.

Following the very low winter levels, the melting of Arctic sea-ice became slower than in most recent years. The position of a strong and persistent low-pressure system over the central Arctic helped to inhibit ice loss, especially during the summer months. Arctic sea-ice extent reached its minimum in mid-September at 25-31% below the 1981-2010 average. This ranked among the eight smallest minimum extents on record. The ten smallest minimum extents have all occurred since 2007.

Consistent with temperatures warmer than average over the oceans adjacent to Antarctica the Antarctic sea-ice extent was also well below average throughout 2017. Monthly extents through August were either record or near-record smallest since the satellite record began in 1979. Record low sea ice was observed for the first several months of the year, with record-low daily extents starting in late 2016 and persisting until spring 2017. The annual minimum extent occurred in early March at 26-32% below the 1981-2010 average and was ranked a record low in both datasets that were analyzed. The record-low Antarctic sea-ice extent was driven in large part by a nearly complete lack of ice in the Amundsen Sea, with adjacent areas of western Antarctica experiencing persistent above-average temperatures. Sea-ice conditions in the Antarctic have been highly variable over the past several years, with the record-large sea-ice extents occurring as recently as 2015.

Following the minimum extent in early March, sea ice expanded at a faster-than-average rate during the austral autumn, but it slowed to near-average and below-average rates during winter and into spring. The Antarctic sea-ice extent reached its annual maximum extent in mid-October between 4 and 6% below the 1981-2010 average and was at or near record-low levels for the region. Below-average sea-ice coverage was observed in the Indian Ocean sector and the northern Ross and Weddell Seas.

For the January-August 2017 period, the average Northern Hemisphere snow cover extent was 10.54 million square km. This was 74 000 square km greater than the 1981-2010 average, the largest January-August snow cover extent since 2013, and near the median value in the 1967-2017 satellite record. Above-average snow cover was observed for most of this period, with slightly below-average snow cover during March, June and July.

The Greenland ice sheet has been losing ice mass nearly every year over the past two decades. However, 2017 will likely see an increase of more than 40 billion tons of ice due to above-average snowfall and a short melt season. The remnants of Hurricane Nicole in October 2016, a June 2017 snow storm, and an early end to the melt season in August 2017 contributed to the overall additional snow. Despite the gain in overall ice mass this year, it is only a small departure from the trend over the past two decades, with the Greenland ice sheet having lost approximately 3 600 billion tons of ice mass since 2002.

Climate risks and related impacts

Climate-related extreme events and disasters exert a heavy toll on human well-being, various sectors and national economies.

Agriculture and Food Security

Exposure and vulnerability to extreme events can destroy agricultural assets and infrastructure, causing serious damage to the livelihoods and food security of millions of people. The assessment of the World Food Programme (WFP) is that more than 80% of the world's food-insecure people live in countries with degraded environments prone to natural hazards. When climate-related disasters occur, the situation of already-vulnerable people can quickly deteriorate into food and nutrition crises.

The disruption of agricultural production in rural areas of developing countries affects the already fragile livelihoods of the poorest and most vulnerable people in particular. A review of the Food and Agriculture Organisation (FAO) found that, during the period of 2006-2016, agriculture in developing countries (crops, livestock, fisheries, aquaculture and forestry) accounted for 26% of all the damage and loss associated with medium to large-scale storms, floods and drought. [6]

In the Philippines over the last two decades, 15 times as many infants died in the 24 months after typhoons as died in the typhoons themselves, of which 80% were infant girls.[7] In Ethiopia, children born in an area affected by disasters are 35.5% more likely to be malnourished and 41% more likely to be stunted.[8]

Health

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6 FAO,2017. The Impact of Disasters on Agriculture. Addressing the information gap. http://www.fao.org/3/a-i7279e.pdf

7 Anttila-Hughes and Hsiang. 2013. Destruction, Disinvestment, and Death: Economic and Human Losses Following Environmental Disaster. http://ssrn.com/abstract=2220501

8 IPCC, 2007. Fourth Assessment Report. https://www.ipcc.ch/report/ar4/

According to the World Health Organisation (WHO), the global health impacts of heatwaves depend not only on the overall warming trend, but on how heatwaves are distributed across where people live. Recent research shows that the overall risk of heat-related illness or death has climbed steadily since 1980, with around 30% of the world's population now living in climatic conditions that deliver extreme hot temperatures persisting several days to weeks a year.[9] Between 2000 and 2016, the number of vulnerable people exposed to heatwave events has increased by approximately 125 million.[10]

An estimated 1.3 billion people are at risk from cholera in cholera-endemic countries, while in Africa alone about 40 million people live in cholera "hotspots".[11] The latter have been identified across most endemic countries facing recurrent and predictable cholera outbreaks, which often coincide with the rainy season. WHO has recognized that large cholera outbreaks in eastern and central, and later southern Africa were likely aided by El Niño-related weather conditions that accelerated transmission across the region starting in mid-2015, with control efforts still underway in several countries in 2017. Flood events are also often associated with outbreaks of water-borne diseases or those linked to poor sanitation.

Population displacement

Population displacement linked to disasters, including the adverse impacts of climate variability and change, is a current reality. Most of such displacement is internal and linked to sudden onset extreme weather events. However, slow onset effects of climate change, such as droughts, desertification, coastal erosion and sea-level rise, can also lead to internal and cross-border displacement. These slow-onset events can act as a "threat multiplier," including by exacerbating conflict which, in turn, can give rise to flows of refugees and internally displaced persons (IDPs). Regardless of whether climate change plays a primary or secondary role as a driver of displacement, the affected populations have unique protection needs and vulnerabilities that must be addressed.

In 2016, 23.5 million people were displaced during weather-related disasters.[12] Consistent with previous years, the majority of these internal displacements were associated with floods or storms and occurred in the Asia-Pacific region. In the Greater Horn of Africa, including Somalia, Ethiopia and Kenya, more than 1 million people were recorded as displaced by drought in 2017[13]. The most striking current example of displacement due to major climate events is occurring in Somalia, where 761 000 internal displacements have been reported (see further details below). Of the displaced people who were surveyed, approximately 90% indicated that drought was the primary reason for displacement, while the remaining 10% gave reasons closely related to drought or cited drought as a contributing factor, such as food or livelihood insecurity.[14]

Economic impacts

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9 Mora et al. Global risk of deadly heat. Nature Climate Change.7,501-506. DOI:10.1038/nclimate3322.

10 Watts et al. 2017 Report of The Lancet Countdown on Health and Climate Change: From 25 years of inaction to a global transformation for public health. The Lancet .

11 World Health Organization.2017. Weekly epidemiological record. June 2017. http://apps.who.int/iris/bitstream/10665/255611/1/WER9222.pdf?ua=1.

12 IDMC.2017.Global Report on Internal Displacement 2017. http://www.internal-displacement.org/global-report/grid2017/pdfs/2017-GRID.pdf

13 International Organization for Migration (IOM). (2017). Somali Region, Ethiopia, Round III: January to February 2017. Displacement Tracking Matrix. http://www.globalprotectioncluster.org/_assets/ files/field_protection_clusters/Etiophia/files/dtm-round-iii-report-somali-region.pdf. International Organization for Migration (IOM). (2017). Somalia Drought-related Displacements April 2017. http://www.globaldtm.info/somalia-drought-related-displacements-april-2017/

14 As of 23 June, 687,906 Somali IDPs interviewed by UNHCR PRMN indicated drought was primary reason for displacement, while 72,688 IDPs indicated that drought was a contributing factor. https://data2.unhcr.org/en/documents/download/58290

The International Monetary Fund (IMF) World Economic Outlook published in October 2017[15] indicates that increases in temperature have uneven macroeconomic effects. Adverse consequences are concentrated in countries with relatively hot climates, such as most low-income countries. Examining data from 180 countries, the study confirms the existence of a statistically significant nonlinear relationship between temperature and per capita economic growth. In countries with relatively cool climates, a small increase in temperature can boost economic activity, whereas it has the opposite effect in countries with hot climates. In these countries, an increase in temperature reduces per capita output, in both the short and medium term, by reducing agricultural output, suppressing the productivity of workers exposed to heat, slowing investment, and damaging health.

For the median emerging market economy, a 1°C increase from a annual average temperature of 22°C, lowers output per capita in the same year by 0.9 percent. For a median low-income developing country, with annual average temperature of 25°C, the effect of a 1°C increase in temperature is even larger: per capita output falls by 1.2 percent . Even though countries whose economies are projected to be significantly adversely affected by an increase in temperature produced only about one-fifth of global GDP in 2016, they are home to close to 60% of current global population and to more than 75% of the global population projected for the end of the century.

Extreme events and impacts observed in 2017

The best documented impacts of weather and climate are associated with extreme events. These can be short-term (such as a storm) or they can extend over months or years (such as a drought). Moreover, whilst formal attribution studies have not yet been carried out for most of the 2017 events described in this section, a previous analysis found that more than half of 79 published studies covering events between 2011 and 2014 concluded that anthropogenic climate change contributed to the extreme event under consideration, either directly or indirectly, for example through the influence of abnormal sea-surface temperatures on circulation patterns.

Tropical cyclones

Global tropical cyclone activity for 2017 to date has been slightly below average, with a total of 73 cyclones observed.[16] The number of cyclones has been above average in the North Atlantic, but below average in the Northwest Pacific and in all Southern Hemisphere basins.

The North Atlantic has had a very active season. The Accumulated Cyclone Energy (ACE) index, a measure of the aggregate intensity and duration of cyclones, had its highest monthly value on record in September. The seasonal total ACE as of 18 October is more than double the 1981-2010 average and is already amongst the 10 highest values on record. Conversely, in the Northwest Pacific, although the total number of cyclones was only slightly below average, there was a notable lack of intense cyclones – with only three (as of 22 October) reaching central pressures below 950 hPa – and seasonal ACE is currently only about half the average. The 2016-17 Southern Hemisphere season was notable for its late start, with only one short-lived cyclone occurring before the start of February.

Three major and high-impact hurricanes occurred in the North Atlantic in rapid succession, with Harvey in August being closely followed by Irma and Maria in September. Harvey made landfall in Texas as a category 4 system, then remained near-stationary near the coast for several days, producing extreme rainfall around and east of the Houston metropolitan area and causing severe

15 International Monetary Fund. 2017.Seeking Sustainable Growth: Short term Recovery, Long term Challenges. Washington, DC, October 2017. https://www.imf.org/en/Publications/WEO/Issues/2017/09/19/world-economic-outlook-october-2017.

16 This is the total number of cyclones in 2017 for Northern Hemisphere basins, and the 2016-17 season for Southern Hemisphere basins.

flooding. Provisional seven-day rainfall totals reached as high as 1539 mm at a gauge near Nederland, Texas, the largest ever recorded for a single event in the mainland United States. Combined in-situ and satellite data show that over 23-31 August 2017, mean daily precipitation averaged over the period exceeded two to four times the 99 percentile of daily precipitation in parts of the region. The WMO Expert Team on Climate Impacts on Tropical Cyclones found[17] that, whilst there is no clear evidence that climate change is making the occurrence of slow-moving, land-falling hurricanes more or less frequent, it is likely that anthropogenic climate change made rainfall rates more intense, and that ongoing sea-level rise exacerbated storm surge impacts.

Irma and Maria both reached category 5 intensity. Both were associated with major destruction on a number of Caribbean islands, principally Barbuda, Anguilla, Saint Martin/Sint Maarten, the Virgin Islands and Cuba for Irma, and Dominica and Puerto Rico for Maria. Irma was also associated with significant impacts in Florida, especially its southwest. Later, in mid-October, Ophelia reached major hurricane (category 3) status more than 1 000 kilometres further northeast than any previous North Atlantic hurricane. It was associated with substantial damage in Ireland as a transitioning post-tropical storm, whilst winds associated with its circulation contributed to severe wildfires in Portugal and northwest Spain. Nate also caused significant flooding in Central America, especially Costa Rica and Nicaragua.

Other noteworthy tropical cyclones of 2017 included Dineo (February) and Enamo (March) in the Southwest Indian basin, Debbie (March) in the Southwest Pacific, and Nanmadol (June-July), Hato (August), Talim (September) and Lan (October) in the Northwest Pacific. The remnant low of Dineo led to major flooding and significant crop losses in Mozambique[18] and Zimbabwe, whilst Enamo had major impacts on Madagascar,[19] with at least 81 associated deaths reported and extensive damage to houses, infrastructure and crops. Agricultural losses were estimated by the World Bank at USD 207 million, mostly from the destruction of vanilla plantations. Debbie was associated with significant wind damage on the central Queensland coast in Australia, before producing major flooding as a remnant low in southern Queensland, northern New South Wales, and later on the North Island of New Zealand. Hato led to significant damage in Macao, and to a lesser extent in nearby coastal regions, including Hong Kong. Nanmadol, Talim and Lan were all associated with significant flooding and other damage in Japan.

Flooding (non-tropical cyclone) and associated phenomena

One of the most significant weather-related disasters of 2017, in terms of casualties, was a landslide in Freetown, Sierra Leone, on 14 August, in which at least 500 deaths occurred.[20] Exceptionally heavy rain was a major contributor to this disaster; Freetown received 1459.2 mm in the period from 1 to 14 August, about four times their average rainfall for this period. Another major landslide associated with heavy rainfall occurred in Mocoa, in southern Colombia, on 1 April, with at least 273 deaths reported.[21]

Many parts of the Indian subcontinent were affected by flooding during the monsoon season between June and September, despite overall seasonal rainfall being near average over the region. The most serious flooding occurred in mid-August, after extremely heavy rainfall over a region centered on eastern Nepal, northern Bangladesh and adjacent areas of northern and northeastern India. Mawsynram (India), near the Bangladesh border, received more than 1 400 mm in the four days 9 to

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17 https://public.wmo.int/en/media/news/wmo-expert-team-statement-hurricane-harvey.

18 IFRC.2017. Emergency Plan of Action Operation Update. Mozambique: Tropical Cyclone Dineo. http://reliefweb.int/sites/reliefweb.int/files/resources/MDRMZ01301ou.pdf

19 World Bank.2017. Estimation of Economic Losses from Tropical Cyclone Enawo. http://reliefweb.int/sites/reliefweb.int/files/resources/MG-Report-on-the-Estimation-of-Economic-Losses.pdf

20 IOM.2017.Sierra Leone Flood Response. Situation Report. 28 August 2017. http://reliefweb.int/sites/reliefweb.int/files/resources/SL%20Floods%20Sitrep%201.pdf

21 EM-DAT database. Centre for Research on the Epidemiology of Disasters, Université catholique de Louvain, Belgium, http://www.emdat.be/database.

12 August, whilst daily totals in excess of 400 mm also occurred near the India-Nepal border, and the Rangpur region of northern Bangladesh received 360 mm, about their normal monthly total, on 11-12 August. Across the period as a whole, more than 1 200 deaths were reported in India, Bangladesh and Nepal,[22] whilst more than 40 million people were displaced or otherwise affected. WHO indicated that in Bangladesh alone, more than 13 000 cases of waterborne diseases and respiratory infections were reported during three weeks in August,[23] whilst extensive damage was reported to public health facilities in Nepal.[24]

Earlier in the season, 292 deaths were reported in Sri Lanka in late May, principally in southern and western parts of the country, due to heavy rains from the precursor low to Cyclone Mora. Ratnapura received 384 mm of rain in 24 hours on 25-26 May. Some 650 000 people were affected in some way by the floods, but the rains did little to alleviate significant drought in northern and eastern parts of Sri Lanka.[25] Cyclone Mora went on to cause significant impacts in Bangladesh and Myanmar.[26] Heavy rains flooded thousands of crop hectares and damaged poultry sheds, fishing nets and boats, severely eroding the livelihoods of agriculture and fisheries-dependent communities in the affected rural districts.

Flooding affected many parts of Peru in March, after sustained heavy rains. At least 75 deaths[27] were reported, and over 625 000 people were affected including more than 70 000 who lost their homes. FAO reported that there were significant crop production losses,[28] particularly maize, in the main producing regions of Lambayeque, Piura and Ica. Flooding of this type typically affects Peru during the late phase of El Niño events. Whilst there was no Pacific-wide El Niño during 2017, sea surface temperatures near the Peruvian coast in March were 2°C or more above average, values which would be more typical of an El Niño year than of a neutral year such as 2017. (In contrast, during the El Niño of early 2016, coastal sea-surface temperatures were less warm than is typical during an El Niño, and coastal rainfall was not significantly above average.)

Major flooding occurred mid-year in parts of southern China, especially within the Yangtze River basin. The heaviest rain fell in the provinces of Hunan, Jiangxi, Guizhou and Guangxi. Peak totals during the period from 29 June to 2 July were in excess of 250 mm. Fifty-six deaths were reported and economic losses were estimated at more than USD 5 billion.[29]

A number of heavy rain events in the western United States during January and February caused substantial flooding and numerous landslides. Tens of thousands of people were relocated from areas downstream of the Oroville Dam, in northern California, in February due to fears that a dam spillway could fail under the high flows being experienced. It was the wettest winter on record for Nevada, and the second-wettest for California.

Drought

Parts of east Africa continued to be seriously affected by drought in 2017. Following well-below-average rainfall over many parts of Somalia, Kenya and the United Republic of Tanzania in 2016, the

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22 World Meteorological Organization. Rainfall extremes cause widespread socio-economic impacts. 2017. https://public.wmo.int/en/media/news/rainfall-extremes-cause-widespread-socio-economic-impacts.
23 IFRC 2017. South Asia flood crisis: Disease outbreaks, funding shortages compound suffering of flood survivors. https://media.ifrc.org/ifrc/press-release/south-asia-flood-crisis-disease-outbreaks-funding-shortages-compound-suffering-flood-survivors/.
24 World Health Organization. 2017. Situation Report #5, Nepal Flood 2017. https://reliefweb.int/sites/reliefweb.int/files/resources/who_sitrep-06sept2017.pdf
25 FAO and WFP.2017. Special Report. FAO/WFP Crop and Food Security Assessment Mission to Sri Lanka. http://www.fao.org/3/a-i7450e.pdf
26 IFRC .2017. Emergency appeal revision. Bangladesh: Cyclone Mora. http://reliefweb.int/sites/reliefweb.int/files/resources/MDRBD019_RevEA.pdf
27 From information supplied by UNISDR.
28 FAO.2017. GIEWS Country Brief: Peru. http://www.fao.org/giews/countrybrief/country.jsp?code=PER
29 From information supplied by China Meteorological Administration.

2017 “long rains” season (March to May) was also dry in most of Somalia, the northern half of Kenya, and southeastern Ethiopia. Seasonal rainfall over most of this region was at least 20% below average, reaching 50% or more below average over large parts of northern Kenya and in central Somalia and adjacent border areas of Ethiopia. The most affected areas include southern and south-eastern Ethiopia, northern and coastal Kenya, almost all of Somalia, south-eastern areas of South Sudan and north-eastern areas of Uganda.

FAO reported[30] that in Somalia, as of June 2017, more than half of the cropland was affected by drought, and herds had been reduced by 40-60% since December 2016 due to increased mortality and to distress sales. WFP estimates that the number of people on the brink of famine in Somalia has doubled to 800 000 since February 2017, with the 2017 main harvest season (April-June) being 37% below average. WFP has confirmed that more than 11 million people are experiencing severe food insecurity in Somalia, Ethiopia and Kenya. Massive internal displacement in the context of drought and food insecurity continues across Somalia. From November 2016 to mid-June 2017, nearly 761 000 drought-related internal displacements were recorded by the Protection and Return Monitoring Network (PRMN),[31] a United Nations High Commissioner for Refugees (UNHCR) led project which acts as a platform for identifying and reporting on displacement and return of populations in Somalia as well as protection-related incidents occurring during such movements. In Somalia alone, the number of people needing assistance has risen from 5 million in September 2015 to over 6.2 million in February 2017 – more than half the country’s population. This included a drastic increase in those facing “crisis” and “emergency” situations, from 1.1 million in the third quarter of 2016 to a projected 3 million between February and June 2017.[32] There have also been major impacts in Kenya, southern and eastern Ethiopia, leading to appeals for international support to address emergency needs for 5.6 million people in 2017. While improved conditions in northern Ethiopia led to an almost 50% reduction in the number of food-insecure people throughout Ethiopia, which reached 10.2 million in 2016, it remained much higher than the average of the previous three-year period.

Kenya declared the current 2017 drought – affecting 23 counties and pockets of other areas – a national disaster. Nairobi faced water shortages that have compelled city authorities to ration water until the dams that supply the capital are replenished, whilst cereal prices rose and first quarter 2017 GDP figures showed a significant negative economic impact. The government’s drought mitigation measures included provision of cash transfers and allowing maize importation to stabilize high prices for cereals. Somalia and South Sudan also declared emergencies, while Uganda shifted some of its development resources to address food insecurity and livelihood protection, mostly in the dry northern region of Karamoja.

A generally above-average wet summer season in 2016-2017 significantly eased drought conditions, which had been in place since 2014, over most of southern Africa. Rainfall for October 2016 – May 2017 was at least 20% above average over most of Botswana and Zimbabwe, the southern half of Mozambique, and the northern provinces of South Africa. However, more localized drought intensified in the southwest of South Africa, particularly the Cape Province. After rainfall for the two years 2015 and 2016 was about 30% below average at Cape Town, in 2017, only 223 mm has fallen to the end of September, about half the average for that period. This has led to severe water shortages.

Heavy winter rains in early 2017 also substantially eased long-term drought conditions in California, although they resulted in some flooding, and contributed to vegetation growth which may have influenced the severity of wildfires later in the year.

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30 FAO.2017. Global Information and Early Warning System on Food and Agriculture (GIEWS). Special Alert N. 339. Region: East Africa. http://www.fao.org/3/a-i7537e.pdf

31 More information available here: https://data2.unhcr.org/redirect/?url=http://data.unhcr.org/horn-of-africa/download.php%3fid=1994.

32 From information supplied by UNISDR.

Many parts of the Mediterranean region experienced dry conditions in 2017. The most severe drought focused on Italy. Rainfall averaged over Italy for January-August 2017 was 36% below average, more than 10% below the previous record low in the post-1961 period, although a wet September saw a limited recovery. It was also Italy's hottest January-August on record, with temperatures 1.31°C above the 1981-2010 average. Other dry areas included many parts of Spain and Portugal and coastal areas of the eastern Mediterranean. Significant agricultural production losses were reported, especially in Italy, where olive oil production was 62% lower than in 2016.[33]

The Democratic People's Republic of Korea was also affected by recurrent periods of below‑average rains, particularly between April and June, which negatively affected the area planted and yields of key staple crops such as paddy and maize, with negative impacts on food security. FAO reported[34] that around 20% of the herds (cattle, pigs, sheep, goats, poultry) were severely affected in the areas hit by drought. Drought also significantly affected the Republic of Korea, where nationally-averaged rainfall from January to June was 51% below average, the lowest since national records began in 1973.

Major heatwaves

An extreme heatwave affected parts of South America in January. In Chile, numerous locations had their highest temperature on record, including Santiago (37.4°C), whilst temperatures at locations including Linares (42.6°C) and Los Angeles (42.2°C) exceeded previous national records for Chile. In Argentina, the temperature reached 43.5°C on 27 January at Puerto Madryn, the highest ever recorded so far south (43°S) anywhere in the world.

Much of eastern Australia experienced extreme heat in January and February, peaking on 11-12 February when temperatures reached 47°C in the western suburbs of Sydney and at a number of locations near the coast north from Sydney, as well as at numerous locations inland. Some locations reached their highest temperatures on record, including Dubbo, Bathurst, Moree, Scone and Port Macquarie.

Exceptional heat affected parts of southwest Asia in late May. On 28 May, temperatures reached 54.0°C in Turbat, in the far west of Pakistan near the Iranian border,[35] and record high temperatures also occurred at a number of other sites in Pakistan. Temperatures also exceeded 50°C during this event in Iran and Oman. There was further extreme heat in the region throughout the summer, with 53.7°C recorded at Ahwaz, Iran on 29 June, and Bahrain experiencing its hottest August on record.

The Mediterranean region experienced a number of major heatwaves during the summer. In southern Spain, record high temperatures occurred at Cordoba (46.9°C on 12 July) and Granada (45.7°C on 13 July), whilst a more extensive heatwave in early August led to setting temperature records in northern and central Italy, Croatia and southern France. Marignana (Corsica) had an overnight minimum temperature of 30.5°C on 1 August, the highest on record for metropolitan France. Extreme heat also affected eastern Asia at times during the summer, with Shanghai (40.9°C on 21 July) and the Hong Kong Observatory (36.6 °C on 22 August) both reaching their highest temperatures on record, the latter associated with offshore flow in the circulation of Typhoon Hato.

It was also a very hot summer in parts of western North America, with California having its hottest summer on record and extreme heat also affecting a number of other western states. This culminated in a major heatwave at the end of August and early September, which included a record high temperature (41.1°C) at San Francisco.

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33 European Commission (2017). Short-term Outlook for EU Agricultural Markets in 2017 and 2018. Summer 2017. https://ec.europa.eu/agriculture/sites/agriculture/files/markets-and-prices/short-term-outlook/current_en.pdf

34 FAO.2017. Global Information and Early Warning System on Food and Agriculture (GIEWS). Special Alert N. 340. Country: The Democratic People's Republic of Korea. http://www.fao.org/3/a-i7544e.pdf

35 This observation is currently being evaluated by a WMO committee. If confirmed, it will be an equal record for Asia.

Ref.: 39082/2017-1.3 CLW/DMA

Heat and drought contribute to numerous destructive wildfires

Extreme heat and drought contributed to many destructive wildfires in various parts of the world in 2017. Whilst a return to near- or above-average rainfall contributed to reduced fire activity (compared with recent years) in various tropical regions, numerous mid-latitude regions had severe fire seasons.

Chile had the most significant forest fires in its history during the 2016-2017 summer, after exceptionally dry conditions during 2016 followed by extreme heat in December and January. 11 deaths were reported, and a total of 614 000 hectares of forest were burnt, easily the highest seasonal total on record and eight times the long-term average.[36] There were also significant fires during the 2016-2017 Southern Hemisphere summer in various parts of eastern Australia, especially eastern New South Wales, and in the Christchurch region of New Zealand, whilst the southern South African town of Knysna was badly affected by fire in June.

It was a very active fire season in the Mediterranean region. The worst single incident occurred in central Portugal in June, where 64 deaths occurred in a fire near Pedrogao Grande. There were further major fire outbreaks in Portugal and northwestern Spain in mid-October, exacerbated by strong winds associated with the circulation of Hurricane Ophelia. The area burned in Portugal during January- September [37] was about three times the 2007-2016 median, with further substantial areas burned in the mid-October event. Other significant fires affected countries including Croatia, Italy and France.

It was also an active fire season in western North America, both in the United States and Canada. The total area burned in the contiguous United States from January to 19 October was 46% above the 2007-2016 average,[38] whilst the area burned in Canada was about 51% above the seasonal average. according to the Canadian Forest Service. A wet winter, which allowed the heavy growth of ground fuels, followed by a dry and hot summer, provided ideal conditions for high-intensity fires, the worst of which occurred north of San Francisco in early October. At least 41 deaths were reported, the worst loss of life in a wildfire in the United States since 1918. Long-lived fires in Canada and the northwest United States also contributed to heavy smoke pollution.

Other noteworthy events

Severe cold and snow affected parts of Argentina in July. After heavy snow had fallen the previous day, the temperature reached −25.4°C in Bariloche on 16 July, 4.3°C below the previous lowest temperature on record there. Other regions where record low temperatures occurred in 2017 included some locations in inland southeastern Australia in early July, where Canberra had its lowest temperature (−8.7°C) since 1971, and the Gulf region in the Middle East in early February.

The United States had its most active tornado season since 2011, with a preliminary total of 1 321 tornadoes in the January to August period, including the second-most active January on record. Despite this, the number of tornado-related fatalities in 2017 has been below the long-term average. Noteworthy severe local storms have occurred in many parts of the world, with particularly significant events affecting western Russia on 30 May with 11 deaths reported in the Moscow region, most from falling trees in high winds; Poland on 11-12 August, and South Africa in early October.

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36 From information supplied by the Dirección Meteorológica de Chile.

37 Instituto de Conservação da Natureza e das Florestas. 2017 Relatório Provisório de Incêndios Florestais http://www.icnf.pt/portal/florestas/dfci/Resource/doc/rel/2017/8-rel-prov-1jan-30set-2017.pdf

38 National Interagency Fire Center.2017. Incident Management Report, Wednesday, October 25, 2017. https://www.nifc.gov/nicc/sitreprt.pdf.

Box

Temperature data sets and baseline

Five data sets are used in the WMO assessment, of two kinds: surface temperature data sets and reanalyses. The latter are being explicitly incorporated into the WMO statement for the first time in this 2017 assessment.

The three conventional surface temperature data sets – NOAA's NOAAGlobalTemp data set[39], Met Office Hadley Centre and Climatic Research Unit HadCRUT.4.6.0.0 data set[40] and NASA GISS's GISTEMP data set[41] – use measurements of air temperature over land and sea-water temperature measurements over oceans to estimate temperatures around the globe. In parts of the world there are few weather stations; in these, statistical methods are used to estimate temperatures in the gaps. The three groups which maintain these datasets approach this issue in different ways and thus obtain slightly different estimates of the global average temperature, but agreement between the three surface temperature data sets is good.

Reanalyses use a much wider range of input data, including measurements from satellites. The input data are combined using a weather forecasting system, which provides a globally complete, physically consistent estimate of surface temperatures for each day. They provide better coverage of regions, such as polar regions, where observations are historically sparse. The two reanalyses used in the statement are ERA-Interim[42] produced by the European Centre for Medium-Range Weather Forecasts and JRA-55[43] produced by the Japan Meteorological Agency. Despite the very different approach, the estimates of global average temperature produced by these reanalyses are in good agreement with the surface temperature datasets.

The provisional statement now uses 1981-2010 as a baseline. This takes the place of the 1961-1990 baseline used in previous reports. The 1981-2010 period is recommended by WMO to compute the climatological standard normal for climate monitoring purposes as it is more representative of current conditions. It allows a consistent reporting of information from satellite and reanalysis systems, some of which do not extend back to 1960, alongside with traditional data sets based on surface-observations. For global average temperatures, the 1981-2010 period is approximately 0.31±0.02°C warmer than that of 1961-1990.

39 NOAAGlobalTemp: Smith, T.M., R.W. Reynolds, T.C. Peterson, and J. Lawrimore, 2008: Improvements to NOAA's historical merged land–ocean surface temperatures analysis (1880–2006); Journal of Climate, 21, 2283–2296, doi:10.1175/2007JCLI2100.1

40 HadCRUT.4.6.0.0: Morice, C. P., J. J. Kennedy, N. A. Rayner, and P. D. Jones (2012), Quantifying uncertainties in global and regional temperature change using an ensemble of observational estimates: The HadCRUT4 dataset, J. Geophys. Res., 117, D08101, doi:10.1029/2011JD017187.

41 NASA GISTEMP: GISTEMP Team, 2017: GISS Surface Temperature Analysis (GISTEMP). NASA Goddard Institute for Space Studies. Dataset accessed 2017-10-25 at https://data.giss.nasa.gov/gistemp/. Hansen, J., R. Ruedy, M. Sato, and K. Lo, 2010: Global surface temperature change, Rev. Geophys., 48, RG4004, doi:10.1029/2010RG000345.

42 ERA-Interim: Dee, D. P., Uppala, S. M., Simmons, A. J., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M. A., Balsamo, G., Bauer, P., Bechtold, P., Beljaars, A. C. M., van de Berg, L., Bidlot, J., Bormann, N., Delsol, C., Dragani, R., Fuentes, M., Geer, A. J., Haimberger, L., Healy, S. B., Hersbach, H., Hólm, E. V., Isaksen, L., Kållberg, P., Köhler, M., Matricardi, M., McNally, A. P., Monge-Sanz, B. M., Morcrette, J.-J., Park, B.-K., Peubey, C., de Rosnay, P., Tavolato, C., Thépaut, J.-N. and Vitart, F. (2011), The ERA-Interim reanalysis: configuration and performance of the data assimilation system. Q.J.R. Meteorol. Soc., 137: 553–597. doi:10.1002/qj.828

43 RA-55: Kobayashi, S., Y. Ota, Y. Harada, A. Ebita, M. Moriya, H. Onoda, K. Onogi, H. Kamahori, C. Kobayashi, H. Endo, K. Miyaoka, and K. Takahashi , 2015: The JRA-55 Reanalysis: General specifications and basic characteristics. J. Meteor. Soc. Japan, 93, 5-48, doi:10.2151/jmsj.2015-001.
Harada, Y., H. Kamahori, C. Kobayashi, H. Endo, S. Kobayashi, Y. Ota, H. Onoda, K. Onogi, K. Miyaoka, and K. Takahashi, 2016: The JRA-55 Reanalysis: Representation of atmospheric circulation and climate variability, J. Meteor. Soc. Japan, 94, 269-302, doi:10.2151/jmsj.2016-015.

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Pre-industrial temperatures

The Paris Agreement's central aim is "to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius.[44]

In this WMO statement, the period 1880-1900 has been used as a reference period for pre-industrial conditions allowing early instrumental observations to be used for estimating pre-industrial temperature conditions. Other periods have also been proposed, and provide broadly similar results. For example, a study by Hawkins et al.[45] suggests that the period 1720-1800 is a good reference for pre-industrial conditions, as it is relatively free of large volcanic eruptions which can cool the Earth's climate. By studying long instrumental records, proxies such as tree rings, and climate models they concluded that "pre-industrial" conditions were likely between 0.55°C and 0.80°C cooler than the 1986-2005 average which was used by IPCC as a reference period for computing model projections, and which is virtually identical to the 1981-2010 average used in this statement. The range reflects the difficulty in estimating a baseline for a period when temperature measurements were being made in only a very limited number of places.

The instrumental observations show that the 1981-2010 period is around 0.63°C warmer than 1880-1900, indicating that temperatures in the 1880-1900 period were broadly similar to those of 1720-1800 mentioned above, as well as to those of 1850-1900, which is used as a "pre-industrial" reference period in some sources. Therefore, the reference period 1880-1900 which is used here provides an estimate of pre-industrial temperatures that is consistent with the range reported by Hawkins et al. In addition, it has the benefit of being a common period for the start of instrumental records across the three conventional global datasets.

44 http://unfccc.int/paris_agreement/items/9485.php

45 Hawkins, E., P. Ortega, E. Suckling, A. Schurer, G. Hegerl, P. Jones, M. Joshi, T.J. Osborn, V. Masson-Delmotte, J. Mignot, P. Thorne, and G.J. van Oldenborgh, Estimating changes in global temperature since the pre-industrial period. Bull. Amer. Meteor. Soc., https://doi.org/10.1175/BAMS-D-16-0007.1