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Provisional Statement on the Status of Global Climate in 2011-2015

Introduction and executive summary

The five-year period from 2011 to 2015 has been the world's warmest five-year period on record. It is likely that 2015 will be the world's warmest year on record, with data to the end of October showing temperatures well above those of any previous year. The 2011-15 period was also the warmest on record for every continent except Africa.

The record high temperatures in the five-year period 2011-2015, along with the annual record set in 2014 and likely to be broken in 2015, are consistent with established long-term warming trends, the dominant cause of which is the emission of anthropogenic greenhouse gases. Year to year temperature changes occur in conjunction with the long term warming trend, in particular as a result of El Niño and La Niña events.

The single most significant event of the period in humanitarian terms was the 2011-12 famine in the Horn of Africa, to which drought in late 2010 and 2011 was a major contributor. More than 250,000 excess deaths in the Horn of Africa were attributed to this event. On shorter timescales, no single climate-related disaster in the 2011-15 period caused short-term casualties on the scale of some of the worst events of the first decade of the 21st century, such as the 2003 European heatwave and Cyclone *Nargis* in Myanmar in 2008, but many of the worst disasters of the period were still the result of extreme weather and climate events. Three tropical cyclones – including the period's worst single disaster, Typhoon *Haiyan* – each killed more than 1,000 people in the Philippines, whilst India and Pakistan suffered casualties on a comparable scale from flooding in 2013, and heatwaves in 2015. The southeast Asian floods of 2011 and Hurricane *Sandy* in the Caribbean, especially Haiti, and the United States in 2012 both caused economic losses in excess of US\$40 billion.

Scientific assessments have found that many extreme events in the 2011-15 period, especially those relating to extreme high temperatures, have had their probabilities substantially increased as a result of anthropogenic climate change – by a factor of 10 or more in some cases – with more than half the events scientifically assessed showing an anthropogenic climate change signal of some description in their risk. In addition to this, there have been longer-term events which have not yet been the subject of formal attribution studies but are consistent with projections of near- and long-term climate change, such as increased incidence of multi-year drought in the subtropics, as manifested in the 2011-15 period in the southern United States, parts of southern Australia and, towards the end of the period, southern Africa. There have also been events, such as the unusually prolonged, intense and hot dry seasons in the Amazon basin of Brazil in both 2014 and 2015 (especially the latter), which, while they cannot yet be stated with confidence to be part of a long-term trend, are of considerable concern in the context of potential “tipping points” in the climate system as identified by AR5.

This provisional assessment describes the state of the key components of the climate system in the 2011-15 period, with a focus on those events, such as multi-year droughts, which require a longer-term perspective than is possible in an annual report. A final assessment, which will contain finalised information for components of the climate system for which 2015 information is incomplete or not yet available, will be issued in the second half of 2016.

The world's warmest five-year period on record

According to preliminary figures as of the end of October 2015, 2011-15 was the world's warmest five-year period¹ on record. Using the mean of three major global data sets², temperatures for the 2011-15 period were 0.57°C (1.03°F) above the average for the standard 1961-90 reference period. This compares with the 2006-10 period, in which temperatures were 0.51°C above average, and is consistent with a continued sustained warming trend which has been apparent in global data since the mid-1970s.

The 2011-15 period contained what is currently the world's warmest year on record, 2014, which had temperatures 0.61°C (1.10°F) above the 1961-90 average, whilst 2013 currently ranks as the equal fourth warmest year. 2015 is on track to surpass the 2014 record, with temperatures to the end of October 0.73°C (1.31°F) above the 1961-90 average. 2011 and 2012, both of which (especially the former) were substantially influenced by La Niña events, were somewhat less warm but were still warmer than any year which occurred prior to 1998, and warmer than any previous La Niña year. The world's ten warmest years have all occurred since 1998, with eight of them being since 2005. Whilst a strong El Niño event is currently in progress, the impact of El Niño (and La Niña) on global annual mean temperatures is typically strongest in the second calendar year of the event, and hence the year whose annual mean temperature is likely to be most strongly influenced by the current El Niño is 2016 rather than 2015.

Warmth was widespread around the world throughout the period, both on land and in the ocean. Temperatures for the 2011-15 period were more than 1°C above the 1961-90 average over most of Europe, the Asian part of the Russian Federation, and most remaining areas north of 60°N, reaching 3°C above average locally on the Russian Arctic coast. They were also more than 1°C above average over much of the Saharan and Arabian region, the southwest United States and northwest Mexico, and in interior Brazil. No large land areas were consistently cool through the five-year period, although some had individual cool years (for example, northern Australia in 2011 and 2012, central North America in 2013 and 2014, and central Asia and Alaska in 2012).

It was the warmest five-year period on record for Europe, South America, Asia, Oceania, and North America (where record warm conditions in the west offset near-average temperatures in parts of the east), and ranked second for Africa. Europe's temperatures for 2011-15 were 1.26°C above the 1961-90 average, 0.23°C warmer than any previous five-year period. Europe had its warmest year on record in 2014, Oceania in 2013 and South America in 2012, while both South America and Asia are on course to set new annual records in 2015. Notable seasonal anomalies included the warmest springs on record for North and South America (both 2012) and Europe and Oceania (both 2014); the hottest summer on record for North America (2012), the warmest autumn and winter on record for South America (both 2015), and the warmest June-August on record for Africa (2015).

A particularly noteworthy feature of the 2011-15 period was the occurrence of individual years in which substantial land areas set records by large margins. The (continental) United States in 2012, Australia in 2013 and Europe in 2014 broke previously existing records for annual mean temperatures by between 0.17 and 0.40°C, whilst at the time of writing, the South American mean temperature anomaly for 2015 to date is 0.30°C above its previous annual record, and the Russian Federation 0.2°C above its previous annual record.

Global ocean temperatures were also at unprecedented levels. Globally averaged sea surface temperatures for 2014 were the highest on record for a calendar year, and data for January-October 2015 indicate that 2015 temperatures are on track to exceed 2014's annual record. Sea surface temperatures for 2011-15 were above average in most of the world, although they were below average in parts of the Southern Ocean and the eastern South Pacific; areas where 2011-15 was the

warmest five-year period on record include most of the South Indian Ocean, the Southern Ocean south of Australia, the central and eastern North Pacific, the western equatorial Pacific, most of the western half of the North Atlantic north of the tropics, parts of the subtropical western South Atlantic, and the Mediterranean Sea. Warm temperatures also occurred in the subsurface, with globally integrated ocean heat content in the 0-700 metre layer in 2013 and 2014 higher than that in any previous year according to five different data sets.

Two notable ocean temperature anomalies which developed in the later part of the period, from late 2013 onwards, were a large area of very warm water in the eastern North Pacific, with sea surface temperatures more than 2°C above average in places, and a persistent pool of below-normal sea surface temperatures in the eastern North Atlantic between the British Isles and the southern tip of Greenland.

Precipitation

Global precipitation over land areas was strongly influenced early and late in the 2011-15 period by the El Niño-Southern Oscillation (ENSO), with La Niña conditions for much of 2011 and early 2012, and El Niño conditions in the later part of 2015. 2011 was assessed by NOAA as being the world's second-wettest year on record averaged over global land areas, with 2012, 2013 and 2014 all very close to the long-term average.

A major feature of the 2011-15 period was the existence of persistent multi-year rainfall anomalies in several parts of the world, most of which began after the end of the 2011-12 La Niña. Three regions contained large areas in which rainfall for the three years from October 2012 to September 2015 was below the 10th percentile over large areas – much of the eastern half of Brazil, the western United States (especially California), and parts of eastern Australia (especially inland Queensland and western Victoria), along with the North Island of New Zealand. (Droughts in these regions are discussed in more detail in a later section). Regions where precipitation over the same period exceeded the 90th percentile included much of southeast Europe (along with the Asian part of Turkey), the Russian Far East, and an area of subtropical eastern South America incorporating northern Argentina, Uruguay, southern Paraguay and the far south of Brazil.

2011 was a very wet year in many areas which typically see high rainfall during La Niña years, including much of Australia, Indonesia, the Philippines and mainland southeast Asia, Pakistan, parts of southern Africa and northwest South America, while it was very dry in the southern United States (especially Texas) and northern Mexico. In areas not so strongly influenced by ENSO, there was a marked north/south split in Europe, with very wet conditions in Scandinavia and very dry conditions in much of central and southeast Europe.

Major precipitation anomalies at the annual timescale were less common in the years from 2012 to 2014. Outside those regions with major multi-year anomalies as described above, significant annual wet anomalies occurred in northeast Europe in 2012 (when Estonia had its wettest year on record), much of China in 2012, and Argentina (wettest year on record) and southeast Europe in 2014, while regions which were very dry included much of the central United States and central Russia in 2012, parts of the southern half of Africa in 2013, and central Africa and western Russia in 2014.

Whilst precipitation anomalies associated with the 2015 El Niño are still emerging at the time of writing, 2015 has been a very dry year in many regions with typical dry signals during El Niño, including most of Brazil (except the southeast), Central America and the Caribbean, southeast Asia, Indonesia and many Pacific island countries, and southern Africa, although the impact has been less consistent in Australia and the Indian subcontinent. It has been wet in many subtropical parts of

South America, and in parts of the southern United States and northern Mexico. In Europe, 2015 has been dry in central and eastern parts of the continent, but wet in Turkey.

Large-scale modes of climate variability

The 2011-15 period began with a strong La Niña event and finished with a strong El Niño. The 2010-11 La Niña event was a significant event which had major impacts in numerous parts of the world. It ranked as one of the strongest La Niña events of the post-1950 period. The six-month mean of the Southern Oscillation Index (SOI) for November 2010 – April 2011 was +22, the highest since 1917, although ocean temperatures were less extreme; the lowest value of the NOAA Oceanic Niño Index³ was -1.4°C , similar to that of the 2007-08 event and slightly higher than 2000.

The 2010-11 La Niña broke down in the first half of 2011, but weak to moderate La Niña conditions redeveloped in late 2011 and early 2012. El Niño-Southern Oscillation (ENSO) conditions then remained generally neutral for the next three years before an El Niño event developed rapidly during the Northern Hemisphere spring of 2015. This event strengthened further through mid-2015 and, as of November 2015, is one of the three most intense El Niño events of the post-1950 period (alongside 1982-83 and 1997-98), with sea surface temperatures more than 2°C above average over most of the central and eastern equatorial Pacific.

Markedly negative phases of the Arctic Oscillation (AO) and North Atlantic Oscillation (NAO) through the Northern Hemisphere winter of 2010-11 led to very cold mean winter temperatures in much of Europe, although the most extreme temperature anomalies were in December 2010 with January and February 2011 having near-normal temperatures. The NAO and AO were then mostly positive through the remaining Northern Hemisphere winters of the 2011-15 period, although there was a notable negative phase during March 2013, which contributed to very cold conditions during that month in Europe. Short-term extreme phases of the Southern Annular Mode (SAM) also contributed to significant climate anomalies in various parts of the Southern Hemisphere, notably when a sharp negative phase in September 2013 contributed to what was then Australia's largest positive monthly temperature anomaly on record.

After being in a positive mode (that is, relatively warm waters in the western tropical Indian Ocean and cool waters in the east) for much of the 2006-10 period, the Indian Ocean Dipole (IOD) was more variable in the 2011-15 period. There were positive phases for parts of the Southern Hemisphere winter and spring in 2011, 2012 and 2015, and negative phases in 2013 and 2014, but the 2011-14 events were all relatively short-lived with significant anomalies (more than 0.5°C) not persisting for more than two to three months.

Major extreme events of the 2011-15 period

The 2011-15 period featured large numbers of extreme weather and climate events, including heat and cold waves, tropical cyclones, floods, droughts and severe storms.

In terms of casualties, the worst single short-period event of the period was Typhoon *Haiyan (Yolanda)*⁴ in the Philippines in November 2013. *Haiyan (Yolanda)* is estimated to have caused over 7,800 deaths. Floods and associated landslides in northern India in June 2013 left more than 5,800 people dead or missing. A flash flood in southern Brazil in January 2011 claimed more than 900 lives, and floods in southeast Asia between July and October 2011 were responsible for more than 800 deaths. More than 3,700 deaths were attributed to heatwaves in India and Pakistan in May and June 2015. At longer timescales, the famine in Somalia between late 2010 and early 2012, to which the

2010-11 drought was a major contributing factor, was estimated by the Famine Early Warning Systems Network to have been responsible for approximately 258,000 excess deaths.

There were also a number of events during the 2011-15 period which caused very large economic losses. Amongst those events which were assessed by various sources⁵ as having economic losses in excess of US\$20 billion were Hurricane *Sandy* in the Caribbean, especially Haiti, eastern United States and eastern Canada in October 2012 (assessed by NCEI at US\$67 billion), the 2011 southeast Asian floods, drought in the southern and central United States in 2012 and 2013, and floods in central Europe in May and June 2013.

Heatwaves a regular occurrence

While no individual heatwave of the 2011-15 period had the extreme impacts of the heatwaves of 2003 in central Europe or 2010 in Russia, major heatwaves were a regular feature of the 2011-15 period.

As noted above, the most significant heatwaves of the period in terms of documented casualties occurred in May and June 2015 during the pre-monsoon periods in India and Pakistan. While temperatures near or above 45°C are not uncommon at that time of year in many parts of interior India and Pakistan, the 2015 pre-monsoon period saw such temperatures extend to near-coastal regions which do not normally experience such extreme heat, including the Karachi region in Pakistan and Andhra Pradesh in eastern India, where the heat was also accompanied by very high humidity.

Western and central Europe saw their most significant heatwave since 2003 in the first half of July 2015. A national record of 40.3°C (which was equalled a few weeks later) was set in Germany, whilst all-time records for specific locations were set in countries including Spain, France and Switzerland. It was the longest heatwave on record for Spain, which had its hottest July on record, as did Switzerland and Austria. There were also significant heatwaves in parts of Europe in the summers of 2012, 2013 and 2014. All three of these set national records in one or more countries, including the first recorded temperatures of 40°C or above in Austria (2013).

A prolonged heatwave affected many parts of eastern Asia in July and August 2013. Both Japan and the Republic of Korea had their hottest summer on record, with Japan also experiencing a national record of 41.0°C in August 2013. Parts of eastern China, especially in the vicinity of Shanghai, were also badly affected. Hangzhou, with a previous record high temperature of 40.3°C, exceeded that value on 10 separate days in late July and early August, with a peak of 41.6°C..

Australia experienced extreme heat in the summers of 2012-13 and 2013-14. January 2013 was Australia's hottest month on record, with records being set at many locations, including Sydney (45.8°C) and Hobart (41.8°C). In January 2014 records were set for persistent heat in places, including four consecutive days above 41°C in Melbourne. A major heatwave affected large parts of South America, including northern Argentina, Uruguay, Paraguay and southern and central Brazil, in October 2014, with all-time record high temperatures at São Paulo and Brasilia, and readings as high as 46°C in northern Argentina. Extreme heat also affected northern and central Argentina in December 2013, when Buenos Aires experienced its longest recorded heatwave.

Despite overall warmth, some periods of significant cold and snow

Despite the overall warmth of the 2011-15 period, there were still some episodes of abnormal cold and snow in the major Northern Hemisphere continents.

A prolonged period of extreme cold affected large parts of Europe in February 2012. It was the most significant cold spell since either 1985 or 1987 in many parts of central and western Europe, with temperatures remaining below 0°C continuously for two weeks or more in most of central Europe, although no significant low temperature records were set. This event also brought extremely heavy snow in some places, especially in parts of eastern Italy downwind of the Adriatic Sea. March 2013 was also notably cold in much of Europe with significant blizzards in places.

The winters of 2013-14 and 2014-15 were both significantly colder than normal in many central and eastern parts of the United States and southern Canada, with low temperatures persisting through the region for extended periods, although the lowest temperatures reached were mostly several degrees above record levels. (In contrast, winter temperatures during these winters were at record highs on the west coast). The cold was especially persistent in February 2015, when locations such as Montreal, Toronto and Syracuse did not rise above 0°C at any time during the month. In coastal regions the cold conditions in the 2014-15 winter was accompanied by frequent snowfalls, resulting in Boston experiencing its greatest seasonal snowfall on record.

Destructive floods in many parts of the world

Destructive flooding occurred in many parts of the world, causing major casualties and humanitarian impacts, heavy economic losses or both.

India and Pakistan were a primary focus of flooding, with destructive events occurring in one or both countries in each monsoon season from 2011 to 2014. The most destructive single event occurred in June 2013, when very heavy rain in the far north of India, particularly in Uttarakhand state, was a major contributor to a series of events which resulted in more than 5,800 deaths. Four-day rainfalls over the most severely-affected region were unprecedented, and the wettest day (16 June) had one-day rainfall 105% higher than that of any previous June day. Many of the deaths occurred in landslides, whilst the flooding was exacerbated by snowmelt at higher elevations (due to an above-average seasonal snowpack and the unusually early timing of the storm during the monsoon season) and glacial lake outbursts. Destructive flooding also occurred in Kashmir, and downstream areas in both India and Pakistan, in September 2014, while Pakistan also experienced significant flooding in both 2011 and 2012, although in both years the flooding was more localised than it had been in the historic floods of 2010.

Further east in Asia, persistently above-average rainfall during the peak rainy season of June-September 2011 was responsible for major and long-lived flooding in southeast Asia, with seasonal rainfall totals about 35% above normal over an area centred on the upper Chao Phraya catchment in northern Thailand. Thailand was the worst-affected country, with flooding initially in rural areas and then moving downstream to inundate large areas of Bangkok by late October. Neighbouring countries, especially Laos and Cambodia, were also badly affected. More than 800 deaths occurred in the floods and economic losses were estimated at US\$40 billion or more, much of it through lost industrial production as flooding caused factory closures and interrupted supply chains.

Flash floods caused significant casualties in many parts of the world during the 2011-15 period. The worst single event occurred in January 2011, when more than 900 lives were lost in a flash flood north of Rio de Janeiro, Brazil.

Along with the southeast Asian floods of 2011, a number of other events affected large areas. Flooding in the Danube and Elbe basins of central Europe in May-June 2013, and in eastern Australia (especially Queensland) in early 2011, caused economic losses estimated in the tens of billions of

dollars in both cases, although casualties were relatively modest compared with events in Asia. Extensive flooding in the Paraná river basin in central South America in June and July 2014 also caused limited direct casualties but affected more than 700,000 people in Paraguay, western Brazil and northern Argentina, with some displaced people in Paraguay still unable to return to their homes in late 2014.

Prolonged droughts affect several continents

Brazil was badly affected by drought for much of the 2011-15 period. The northeast of the country suffered significant drought in 2012 and 2013. A relatively localised drought also developed in the São Paulo region during 2013, which spread to many other parts of eastern Brazil during the second half of 2014 and early 2015. Conditions improved slightly in some parts of eastern Brazil from February 2015, although the northeast remained dry. Meanwhile, large parts of the Amazon basin were extremely dry in the Southern Hemisphere winter and spring in both 2014 and 2015, especially the latter- for example, rainfall at Manaus for June-October 2015 was 58% below normal. (Whilst this is normally the drier part of the year, rainfall still averages 50 to 100 millimetres per month; the 2015 rainfall totals were more typical of the dry season of a savanna climate than a rainforest one). The dry conditions, which were accompanied by temperatures generally 2 to 3°C above normal, contributed to very high fire activity, with the number of fires in Amazonas state in 2015 at record levels. The drought in the São Paulo region placed great stress on local water resources, with levels in local water storages falling to below 10% during the 2014-15 summer, and resultant severe restrictions on water supply.

The United States and adjacent areas of northern Mexico also experienced significant drought over large areas in the 2011-15 period. 2011 was a severe drought year focused on Texas and northern Mexico, with drought conditions spreading to cover much of the central United States during 2012 and 2013. In July 2012, 64.5% of the continental United States was classified as being in drought, the largest extent since the Dust Bowl years of the 1930s. From 2013 onwards, conditions improved east of the Rockies but worsened in the west, where California experienced one of its most severe droughts on record. Californian rainfall was at least 20% below normal in each of the four rainfall years⁶ from 2011-12 to 2014-15, an unprecedented event, and the total rainfall for the four years from October 2011 to September 2015 was 30% below normal, well below the previous record for an equivalent period (26% below normal in 1986-90). Total economic losses due to drought in the United States between 2011 and 2014 were estimated at approximately US\$60 billion.

Significant long-term droughts also occurred in Australia and southern Africa. In Australia, much of inland Queensland and adjacent areas of northern inland New South Wales have had rainfall well below normal since mid-2012, with multi-year rainfall deficits over many parts of the region reaching levels not seen since the 1930s. Sustained below-normal rainfalls have also occurred since mid-2012 over an area focused on western Victoria, spreading to cover most remaining parts of Victoria and southern South Australia from mid-2014 onwards. Parts of southern Africa were also affected by drought from late 2013, particularly Namibia, Angola and the Northwest Province of South Africa in the 2013-14 wet season, and much of South Africa from mid-2014 onwards; the period from July 2014 to June 2015 was the driest on record for the province of KwaZulu-Natal, and the fifth-driest for South Africa as a whole. Indian monsoon season (June-September) rainfall was more than 10% below normal in both 2014 and 2015, the first time this had occurred in two consecutive years since 1986-87, but the impact of this was moderated by improvements in agricultural productivity in recent decades, as well as above-normal rainfall outside the core monsoon season.

Shorter-term droughts had major impacts in some parts of the world. The 2010-11 drought in the Horn of Africa, resulting from the successive failure of the October-November 2010 and March-May

2011 rainy seasons, had major humanitarian impacts (including stock and crop losses, food shortages and large-scale displacement of the population), especially in Somalia, which was already badly affected by conflict, and adjacent areas of northern Kenya. The UN Office for the Coordination of Humanitarian Affairs (OCHA) estimated that 13 million people required humanitarian aid, while the Famine Early Warning Service Network estimated excess mortality of 258,000 in Somalia during the period from October 2010 to April 2012. Further drought redeveloped in parts of east Africa, particularly northern Ethiopia and Eritrea, during 2015.

From mid-2015 onwards, significant drought, associated with El Niño, affected many parts of Indonesia, as well as parts of nearby countries in south-east Asia and the western Pacific (such as Papua New Guinea, Vanuatu and Fiji). The drought conditions contributed to exceptionally severe levels of fire activity on the islands of Sumatra and Borneo, causing severe smoke pollution over large parts of the region. The smoke haze caused widespread disruption in Indonesia, Singapore and Malaysia, and is expected to have significant health impacts although the extent of these has not yet been quantified at the time of writing.

Tropical cyclones

Tropical cyclones are typically amongst the most destructive of meteorological phenomena, and the 2011-15 period was no exception to this. Whilst no cyclone during the period caused casualties on the scale of some of the most notable historic events, there were still three cyclones in the 2011-15 period, all in the Philippines, which were responsible for 1,000 or more deaths, whilst the single largest economic loss from a meteorological event in the 2011-15 period was also from a tropical cyclone, Hurricane *Sandy* in 2012.

Typhoon *Haiyan (Yolanda)* made landfall on the east coast of the Philippines in November 2013. It was one of the strongest storms ever to make landfall anywhere in the world, with maximum sustained 10-minute winds of 230 km/h. More than 7,800 deaths were attributed to *Haiyan (Yolanda)*, mostly due to storm surge in and around the city of Tacloban, making it the worst single short-term event of the 2011-15 period in terms of casualties. The other two most destructive cyclones, *Washi (Sendong)* in December 2011 and *Bopha (Pablo)* in November-December 2012, both principally affected the southern island of Mindanao – a region historically south of the main tropical cyclone impact areas. *Washi (Sendong)* only reached tropical storm intensity but caused catastrophic flooding on the north coast of Mindanao, while *Bopha (Pablo)*, which was assessed as a typhoon (one of only two typhoons ever to do so so far south), made landfall on the island's east coast, having first caused significant damage in Palau. Both *Washi (Sendong)* and *Bopha (Pablo)* were responsible for more than 1,000 deaths, with hundreds more missing.

Hurricane *Sandy* affected the Caribbean and the east coast of the United States in October 2012. Having first caused major damage and significant casualties in the Caribbean, *Sandy* approached the east coast of the United States, taking a westward turn and making landfall in New Jersey as a transitioning extratropical storm. *Sandy's* large size contributed towards major coastal flooding from storm surge, with record water levels reached in numerous locations. Substantial areas of Lower Manhattan were inundated, as were many other coastal areas in New York City, on Long Island, in New Jersey and in surrounding states, whilst there was also significant flooding on land from heavy rainfall, and heavy snow at higher elevations. In total 233 deaths in the United States and the Caribbean were directly or indirectly attributed to *Sandy*, and total economic losses were estimated at US\$67 billion.

Amongst the world's most intense tropical cyclones of 2011-2015, along with *Haiyan* and *Bopha*, a notable cyclone was *Patricia* which made landfall in Jalisco state on the west coast of Mexico in

October 2015. *Patricia* was the most intense cyclone ever recorded in the Western Hemisphere, with measured 1-minute sustained winds of 322 km/h and a minimum central pressure of 879 hPa, although its small size and the relatively sparse population of its landfall point limited casualties and damage. Also noteworthy in this category were *Phailin*, which made landfall on the coast of Odisha in eastern India in October 2013, and *Pam*, which passed through the islands of Vanuatu in March 2015 and was responsible for the most significant natural disaster in that country's history. Effective warnings and evacuations, affecting more than a million people, vastly reduced the casualties from *Phailin* compared with similar cyclones in the past, with only 44 deaths reported (compared with about 10,000 in the 1999 "Odisha Cyclone" in the same region).

Overall global tropical cyclone activity was above normal in 2013, with 94 cyclones reported (compared with the 1981-2010 average of 85), and is on course to be above normal again in 2015, particularly for the number of high-intensity cyclones. The 2012 season was close to normal, while 2011 (74) and 2014 (78) were somewhat below normal. The Northwest Pacific was particularly active in 2013 and 2015, and the North Atlantic in 2011.

Damaging tornadoes and windstorms

The United States had one of its most active tornado seasons on record in 2011. The total number of tornadoes ranked as the third-highest on record, whilst six tornadoes assessed as category 5 on the Enhanced Fujita (EF) scale, ranking second behind 1974. There were 157 deaths in a tornado in Joplin, Missouri in May 2011, the largest number of deaths from a single tornado in the United States since 1947. However, tornado activity was below the 1991-2010 average in the remaining four years of the 2011-15 period, with 2014 having the lowest number of recorded tornadoes since modern radar observing capabilities were introduced around 1990, and 2012 and 2013 also ranking in the four lowest years since 1990⁷. 551 deaths were reported as a result of tornadoes in the United States in 2011, but fewer than 100 in each of the four succeeding years. Notable non-tornadic severe thunderstorms in the United States during the period included the event of late June 2012, which caused severe wind damage across a wide area of the central and eastern states and left 3.4 million people without power.

Windstorms associated with extratropical cyclones occurred numerous times in Europe during the period. Two of the most notable events were in late 2013. The first, in late October, resulted in the highest recorded wind gust in Denmark (53.5 m/s) and caused significant damage in northwest Europe, particularly in the United Kingdom, Denmark, France, Germany, the Netherlands and Sweden. The second, in early December, caused the highest storm surge levels in the North Sea since 1953 on the coasts of the Netherlands and parts of the eastern United Kingdom, although damage from coastal flooding was limited. This began a sequence of storms during the 2013-14 winter which ultimately led to the United Kingdom having its wettest winter on record, and also caused significant wind damage and coastal erosion in places. However, no individual European windstorm in the 2011-15 period was as significant, either in terms of casualties or property losses, as events such as *Lothar* (1999), *Kyrill* (2007) or *Xynthia* (2010).

Anthropogenic climate change contributed to some extreme events

An increasingly active area of research in the last few years has been the assessment of the extent, if any, to which anthropogenic climate change has influenced the probability of individual extreme events. The bulk of these studies are published in an annual supplement to the Bulletin of the American Meteorological Society (BAMS), although some have been published elsewhere in the scientific literature.

Of 79 such studies published by BAMS between 2011 and 2014, more than half found that anthropogenic climate change contributed to the extreme event under consideration, either directly or through its influence on large-scale climate drivers (e.g. changes in atmospheric circulation influenced by abnormally warm sea-surface temperatures in key areas).

The most consistent influence of anthropogenic climate change has been on the probability of extreme heat, at various timescales from a few days through to a full year, with some studies finding that the probability of the observed event has increased by 10 times or more as a result of anthropogenic climate change. Amongst events for which such conclusions have been drawn have been the record high seasonal and annual temperatures in the United States in 2012 and in Australia in 2013, hot summers in eastern Asia and western Europe in 2013, heatwaves in spring and autumn 2014 in Australia, record annual warmth in Europe in 2014, and the Argentine heatwave of December 2013. It was also found that anthropogenic climate change has made some of the cold extremes which did occur (such as the cold winters which occurred in Europe in 2010-11 and in the U.S. Midwest in 2013-14) less probable.

The contribution of anthropogenic climate change to precipitation extremes (both high and low) was found to be less consistent. Few strong direct signals were found, although in some cases, warm sea surface temperature anomalies were found to play a role in forcing circulation shifts which contributed to precipitation extremes (for example, persistent warmth in the tropical western Pacific-Indian Ocean warm pool was found to contribute to increased drought risk in east Africa). In numerous cases, including the 2011 southeast Asian floods, the 2013-15 southern Brazil drought, and the very wet United Kingdom winter of 2013-14, no clear evidence was found of an influence from anthropogenic climate change, whilst in some other cases (e.g. extreme high rainfall in southeast Australia in March 2012), some indication was found of an anthropogenic influence, but well short of the level at which it could be confidently separated from background natural variability.

Concentration of long-lived greenhouse gases continues to increase

The concentration of major long-lived greenhouse gases in the atmosphere continued to increase during the 2011-15 period.

In 2014, the annual mean⁸ concentrations in the atmosphere of carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O) were, respectively, 397.7 parts per million (ppm), 1833 parts per billion (ppb), and 327.1 ppb. (CO₂ is responsible for about 65% of the total radiative forcing from long-lived greenhouse gases, with CH₄ responsible for about 17% and N₂O for 6%).

These concentrations have increased consistently throughout the period from 2011 onwards, with annual rates of increase ranging between 1.7 and 2.8 ppm per year between 2011 and 2014 for CO₂, 5 to 9 ppb per year for CH₄, and about 1 ppb for N₂O. Preliminary 2015 data to October from NOAA marine surface layer observations indicate that CO₂ is showing a similar rate of increase in 2015 to that observed in the previous four years. In the cases of CO₂ and N₂O, the growth rates observed from 2011-14 are slightly higher than the 1995-2014 average, while those for CH₄ reflect a renewed period of growth following a period of little change in CH₄ concentrations from 1999 to 2006.

In its 2014 Greenhouse Gas Bulletin, WMO's assessment was that approximately 44% of the total CO₂ emitted by human activities from 2004 to 2013 remained in the atmosphere, with the remaining 56% removed by oceans and the terrestrial biosphere.

Antarctic ozone hole stabilises, but not yet strong evidence of recovery

The Antarctic ozone hole showed no clear trend in the 2011-15 period. Following rapid deterioration between 1980 and the mid-1990s, most measures of the Antarctic ozone hole have shown no clear trend over the last 20 years, with substantial interannual variability depending on seasonal atmospheric conditions. This is consistent with expectations that reduced emissions of ozone-depleting substances, following the adoption of the Montreal Protocol, would prevent further significant deterioration, but that it would take until the mid-21st century for substantial recovery to occur.

The 2015 Antarctic ozone hole was substantially larger⁹ than the average of recent years, due to favourable atmospheric conditions (with a large, stable polar Antarctic vortex and low stratospheric temperatures). NASA assessed it as being the third-largest hole on record (26.9 million square kilometres), behind only 2000 and 2006, while KNMI also ranked it as the largest since 2006, and fifth-largest overall. The ozone holes from 2012 to 2014 inclusive were substantially smaller, with 2012 being the second-smallest of the last 20 years in both data sets. The overall average size for the 2011-15 period was very close to that of the last 20 years.

Whilst the Arctic does not have a regular ozone hole, due to atmospheric conditions generally being less favourable than they are in the Arctic, significant ozone depletion occurred there in the northern hemisphere spring of 2011, following a period of unusually prolonged low stratospheric temperatures. Arctic ozone depletion in March and April 2011 was the highest ever observed, with total ozone loss during these months comparable to that observed in the Arctic in below-average years. No comparable Arctic depletion has occurred in the years since 2011.

Widespread melting of ice except in the Southern Ocean

Arctic sea ice continued its decline in the 2011-15 period. The minimum summer sea ice extent¹⁰ in 2012, 3.39 million square kilometres, was the lowest on record, with the summer sea-ice extent for 2011 being the third lowest and 2015 being fourth lowest for the post-1979 satellite record. The mean Arctic sea extent in September, normally the month with the smallest sea ice extent, in 2011-15 was 4.70 million square kilometres, 28% below the 1981-2010 average and lower than the previous lowest five-year average of 5.04 million square kilometres in 2006-10. Arctic sea ice has not been declining as rapidly in winter as it has in summer, but 2015 still saw the lowest winter maximum on record, 14.39 million square kilometres, and all five years from 2011 to 2015 had winter maximum extents below the 1981-2010 mean.

In contrast, for much of the 2011-15 period, the Antarctic sea ice extent was above the 1981-2010 mean value, particularly for the winter maximum. In September 2014, the sea ice extent in the Southern Ocean reached 20.16 million square kilometres, 1.45 million square kilometres above the 1981-2010 average and the highest value in the satellite record. The 2013 and 2012 maxima ranked second and third, respectively. However, an abnormally slow winter freeze-up in 2015 saw sea ice extent return to near-average levels by spring 2015, with the 2015 maximum (in early October) of 18.83 million square kilometres, only 0.7% above the 1981-2010 average. The observed long-term increase in Antarctic sea ice since 1979 is the subject of continuing research, with stratospheric ozone depletion and resultant changes in the atmospheric circulation around the Antarctic considered among possible contributing factors.

Summer surface melting of the Greenland ice sheet continues at above-average levels, with the summer melt extent exceeding the 1981-2010 average in all five years from 2011 to 2015. 2012, in addition to its record low sea ice extent, had clearly the most extensive Greenland surface melting of any year in the satellite record, with ice core records from the Summit station suggesting that 2012 was the first significant melting event at that location since 1889. The other years in the period were

less extreme, with melting focused on the edges of the ice sheet. Uncertainties are large in the assessments of the state of the Antarctic ice sheet. A number of different studies, using different instruments and methodologies, have all concluded that net ice loss is continuing to occur in West Antarctica, but results are less consistent for East Antarctica.

Mountain glaciers also continued their decline in the 2011-15 period. Preliminary mass balance data indicate mean losses from the reference glaciers of between 600 and 1100 millimetres of water equivalent in each of the years from 2011 to 2015, a rate of loss which is typical for the post-2000 period. There was also a warming of temperatures at 20 metres depth in Arctic regions with permafrost, with the strongest warming generally in the coldest regions, whilst most regions with observations saw an increase in the thickness of the permafrost active layer.

Northern Hemisphere snow cover extent anomalies showed strong seasonal differences but overall mean extent in the 2011-15 period was close to the 1981-2010 average. Snow cover extent was well below average in all five years of the period in all months from May to August, continuing a strong downward trend in those months, with 2012 (also notable for extensive melting of sea and land ice in the Arctic as noted above) setting new record lows for June and July. In contrast, snow cover in the Northern Hemisphere autumn was generally well above normal, including a record high November extent in 2014. Winter and early spring snow cover extent showed large interannual variability but five-year averages were close to normal. The largest seasonal anomaly occurred in the 2012-13 winter, when snow cover extent was well above normal through the winter, including a record high extent for December.

Sea levels continue to rise

Global sea levels continued to rise over the 2011-15 period. The level of inter-annual variability in global sea level over the 2011-15 period was high by the standards of the satellite era. The period began with global sea level about 10 millimetres below the long-term trend value in early 2011, due to the strong La Niña of that time, and resultant high rainfall over some land areas resulting in above-normal water storage on land (especially in Australia). Sea levels quickly rebounded as the La Niña ended and had returned to trend or above by mid-2012. There was a further marked rise in early 2015 as an El Niño developed, with sea levels about 10 millimetres above trend by August 2015. Both the 2010-11 and 2015 departures from trend were larger than anything observed between 1993 and 2009, including during the very strong 1997-98 El Niño. The trend over the full satellite record from 1993 to present of approximately 3 mm per year is larger than the average 1900-2010 trend (based on tide gauges) of 1.7 mm per year.

A number of studies have concluded that the contribution of continental ice sheets, particularly Greenland and west Antarctica, to sea level rise is accelerating. Cryosat-2 data show that the contribution of Greenland ice sheet melting to global sea level rise in the 2011-13 period (which includes the extreme melt year of 2012) was approximately 1.0 mm per year, well in excess of the 0.6 mm per year reported in the IPCC Fifth Assessment report for the 2002-11 period.

There have been strong regional differences in rates of sea level rise in the Pacific Ocean over the 1993-2014 period, largely associated with the El Niño-Southern Oscillation¹¹, and the predominance of El Niño events in the 1990s and La Niña events between 2007 and 2012. The western Pacific has seen the world's fastest rates of sea level rise over this period, more than 10 millimetres per year in places, whereas parts of the eastern Pacific have seen little change in sea level over the 1993-2014 period. Sea level rise has been more consistent in the Atlantic and Indian Oceans with most parts of both oceans showing rates similar to the global average.

Data sources

Sources for data used in this statement include:

- WMO Statements on the Status of the Global Climate for the years from 2011 to 2014.
- Various National Meteorological and Hydrological Services (NMHSs), through material published directly or supplied to WMO, and through data shared through standard WMO channels. A full list of contributing NMHSs will be included in the final version of this Statement, to be published in 2016.
- The annual State of the Climate Reports published in the Bulletin of the American Meteorological Society, and the supplements to these which include assessments of the contribution of anthropogenic climate change to a range of extreme events.
- The EM-DAT emergency events database maintained by the Centre for Research on the Epidemiology of Disasters at the Université catholique de Louvain, Belgium.
- The Global Precipitation Climatology Centre (GPCC) at Deutscher Wetterdienst, Germany.
- The WMO's Global Atmosphere Watch and Global Cryosphere Watch programmes.
- The World Glacier Monitoring Service at the University of Zürich, Switzerland.
- National Snow and Ice Data Centre, Boulder, USA.
- CSIRO Marine and Atmospheric Research, Australia.
- Joint Typhoon Warning Center, Honolulu, USA.
- NASA Goddard Institute of Space Studies, New York, USA.
- Instituto Nacional de Pesquisas Espaciais (National Institute for Space Research), Brazil.
- African Centre for Meteorological Applications for Development (ACMAD), Niamey, Niger.
- IGAD Climate Prediction and Applications Centre (ICPAC), Nairobi, Kenya.