Climate change explained

Contents

Climate change now

There is clear evidence to show that climate change is happening. Measurements show that the average temperature at the Earth's surface has risen by about 1°C since the pre-industrial period. 17 of the 18 warmest years on record have occurred in the 21st century[1] and each of the last 3 decades have been hotter than the previous one. This change in temperature hasn't been the same everywhere; the increase has been greater over land than over the oceans and has been particularly fast in the Arctic[2].

The UK is already affected by rising temperatures. The average temperature in the UK is now about 1°C higher than in the 1960s. All ten of the warmest years in the UK have occurred since 1990 with the eight warmest occurring since 2002[3].

Although it is clear that the climate is warming in the long-term, note that temperatures aren't expected to rise every single year. Natural fluctuations will still cause unusually cold years and seasons but these events will become less likely[4].

Along with warming at the Earth's surface, many other changes in the climate are occurring:

- warming oceans
- melting polar ice and glaciers
- rising sea levels
- more extreme weather events

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[1] https://www.metoffice.gov.uk/news/releases/2018/2017-temperature-announcement

[2] Summary for Policymakers of the Working Group I contribution to the IPCC's 5th Assessment Report (SPM AR5 WGI), B.1, Observed Changes in the Climate System: Atmosphere.

[3] Kendon et al. 2017. State of the UK Climate 2016, Met Office, Exeter, UK.

[4] The Met Office report 'Too hot, too cold, too wet, too dry: Drivers and impacts of seasonal weather in the UK' explains from a UK perspective how seasonal and annual variability in our weather might be affected by changes to the climate.

Warming oceans

While the temperature rise at the Earth's surface may get the most headlines, the temperature of the oceans has been increasing too. This warming has been measured all the way down to 2 km deep[5].

The chemistry of the oceans is also changing as they absorb approximately a third of the excess carbon dioxide being emitted into the atmosphere. This is causing the oceans to become acidic more rapidly than perhaps any point in the last 300 million years[6].

Melting polar ice and glaciers

As the Arctic warms, sea ice is decreasing rapidly. [7] In the Antarctic, sea ice has slowly increased, driven by local changes in wind patterns and freshening sea water. [8] However, in recent years Antarctic sea ice has stopped growing. [9] Over the past few decades the ice sheets (the great masses of land ice at the poles) in Greenland and the Antarctic have shrunk, as have most glaciers around the world. [10]

Rising sea levels

As land ice melts and the warming oceans expand, sea levels have risen. Global sea level has risen by around 20cm over the past century, likely faster than at any point in the last 2,000 years. The rate of sea level rise has increased substantially over the 20th Century and further rise this century is inevitable – how much depends on the amount of human greenhouse gas emissions. [11]

More extreme weather events

More damaging extreme weather events are being seen around the world. [12] Heat waves have become more frequent and are lasting longer. The height of extreme sea levels caused by storms has increased. Warming is expected to cause more intense, heavy rainfall events. In North America and Europe, where long-term rainfall measurements exist, this change has already been observed. [13]

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[5] SPM AR5 WGI, B.2, Observed Changes in the Climate System: Ocean.
[6] IPCC AR5, WG2, 2014. Chapter 30: The Oceans.
[7] see measurements from the National Snow and Ice Data Centre.
[8] This webpage from the National Snow and Ice Data Centre in the US provides a good review of the reasons why Antarctic sea ice is increasing in area.
[9] See 'Arctic sea ice melt season and Antarctic sea ice state 2017' https://www.metoffice.gov.uk/research/monitoring/sea-ice
[10] SPM AR5 WGI, B.3, Observed Changes in the Climate System: Cryosphere.
[11] SPM AR5 WGI, B.4, Observed Changes in the Climate System: Sea Level.
[12] see the Summary for Policymakers of the IPCC's Special Report on Extreme Events and the WMO's Statement on the Status of the Global Climate in 2013.
[13] SPM AR5 WGI, B.1, Observed Changes in the Climate System: Atmosphere.

Causes of climate change

Rising levels of carbon dioxide and other greenhouse gases, such as methane, in the atmosphere create a ‘greenhouse effect’, trapping the Sun’s energy and causing the Earth, and in particular the oceans, to warm. Heating of the oceans accounts for over nine tenths of the trapped energy. Scientists have known about this greenhouse effect since the 19th Century. [14]

The higher the amounts of greenhouse gases in the atmosphere, the warmer the Earth becomes. Recent climate change is happening largely as a result of this warming, with smaller contributions from natural influences like variations in the Sun’s output. [15]

Carbon dioxide levels have increased by about 45% since before the industrial revolution. [16] Other greenhouse gases have increased by similarly large amounts. All the evidence shows that this increase in greenhouse gases is almost entirely due to human activity. The increase is mainly caused by: [17]

- burning of fossil fuels for energy
- agriculture and deforestation
- the manufacture of cement, chemicals and metals

About 43% of the carbon dioxide produced goes into the atmosphere, and the rest is absorbed by plants and the oceans. Deforestation reduces the number of trees absorbing carbon dioxide and releases the carbon contained in those trees back into the atmosphere. [18]

Evidence and analysis

Evidence from past climate change

Ancient ice from the polar ice sheets reveal natural temperature changes over tens to hundreds of thousands of years. Air bubbles trapped in the ice show that levels of greenhouse gases in the atmosphere are closely linked to global temperatures. Rises in temperature match closely with an increase in the amount of greenhouse gases. [19]

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[14] A comprehensive and readable history of the discovery of the greenhouse effect is provided by the American Institute of Physics

[15] SPM AR5 WGI, D.3, Understanding the Climate System and its Recent Changes: Detection and Attribution of Climate Change.

[16] For the most recent official figures see the WMO’s Greenhouse Gas Bulletin for 2016. Hourly measurements of atmospheric CO2 from the observatory at Mauna Loa (the world’s longest running timeseries) can be found online.

[17] SPM AR5 WGIII, SPM.3: Trends in stocks and flows of greenhouse gases and their drivers. See Figure SPM.2 in particular.

[18] SPM AR5 WGI, B.5, Observed Changes in the Climate System: Carbon and Other Biogeochemical Cycles.

[19] The British Antarctic Survey provide a good overview of determining past climate changes from ice cores. For more information on how past climate

These ice cores also show that, over the last 350 years, greenhouse gases have rapidly increased to levels not seen for at least 800,000 years and very probably longer. [20] Modern humans, who evolved about 200,000 years ago, have never previously experienced such high levels of greenhouse gases.

Natural fluctuations in climate

Over the last million years or so the Earth's climate has had a natural cycle of cold glacial and warm interglacial periods. This cycle is mainly driven by gradual changes in the Earth's orbit over many thousands of years, but is amplified by changes in greenhouse gases and other influences. Climate change is always happening naturally, but greenhouse gases produced by human activity are altering this cycle.

Volcanic eruptions and changes in solar activity also affect our climate, but they alone can't explain the changes in temperature seen over the last century. [21]

Scientists have used sophisticated computer models to calculate how much human activity – as opposed to natural factors – is responsible for climate change. These models show a clear human 'fingerprint' on recent global warming.[22] The latest Assessment Report from the IPCC said it was extremely likely that most of the observed increase in global temperature since the 1950s is due to human activity.

Climate models and future global warming

We can understand a lot about the possible future effects of a warming climate by looking at changes that have already happened on Earth. But we can get much more insight by using mathematical models of the climate.

Climate models can range from a very simple set of mathematical equations (which could be solved using pen and paper) to the very complex, sophisticated models run on supercomputers (such as those at the Met Office).[23]

While these models cannot provide very specific forecasts of what the weather will be like on a Tuesday in 100 years time, they can forecast the big changes in global climate which we could expect to see in the future.

All these climate models tell us that under a scenario of ever-increasing greenhouse gas emissions the world could become up to 4.8°C warmer than the pre-industrial

change can tell us about the future, see the Geological Society's position statement on climate change.

[20] SPM AR5 WGI, B.5, Observed Changes in the Climate System: Carbon and Other Biogeochemical Cycles.

[21] A useful figure showing scientists' best judgement for the contribution to global temperature rise from man-made influences (e.g. greenhouse gases and other pollutants), natural factors (e.g. the sun and volcanoes) and other factors is Figure TS.10 on page 66 in the AR5 Technical Summary report.

[22] SPM AR5 WGI, D.3, Understanding the Climate System and its Recent Changes: Detection and Attribution of Climate Change.

[23] The Met Office has a blog article and video introduction to climate models. The American Institute of Physics provides an overview of how the first simple climate models were developed.

period by the end of this century[24]. Note these are global averages and that temperatures in certain regions, such as the Arctic, would be even higher than this. [25]

At the Paris climate conference (COP21) in December 2015, 195 countries adopted the first-ever universal global climate deal that is due to come into force in 2020. The agreement sets out a global action plan to put the world on track to avoid dangerous climate change by limiting global warming to well below 2°C above pre-industrial levels and pursue efforts towards limiting to 1.5°C.[26] The country commitments we have seen so far represent a dramatic improvement on 'business as usual' emissions projections. But these commitments are predicted to give rise to global temperature increases of around 3°C. Further urgent action is needed therefore to put us on track to well below 2°C[27] .

The impacts of climate change

We can already see the impacts of climate change and these will become more severe and widespread as global temperatures rise.[28] How great the impacts will become depends upon our success in reducing greenhouse gas emissions.

The effects of rising temperatures on the UK

Even if global temperature increases are limited to 2°C or less, there are projected to be impacts for the UK. Temperatures over land would be expected to increase by more than the 2°C global average. In a 2°C world in the UK there could be a 30% decrease in river flows during 'dry' periods, a 5-20% increase in river flows during 'wet' periods, and between 700 and 1,000 more heat-related deaths per year in South-East England compared to today.

In a 4°C world in the UK impacts become increasingly severe and may not be avoidable through adaptation. For example, damages caused by river, coastal and surface water flooding all increase markedly with 4°C of warming. Residual flood risks remain high under all adaptation scenarios considered, suggesting limits in the amount of risk that can be avoided through investment in flood defences and other responses. Potentially irreversible impacts to the natural environment are projected with 4°C of warming, including risks to species in protected areas and internationally important UK bird populations.[29] Extreme weather events in the UK are also likely to increase with rising temperatures, causing: [30]

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[24] SPM AR5 WG1,. Table SPM.2.
[25] AR5 Technical Summary Fig.2.
[26] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[27] Emissions Gap Report 2017, Executive Summary – 1.Overarching conclusions. United Nations Environment Programme.
[28] SPM AR5 WGII, A-1 gives an overview of climate impacts already being observed.
[29] CCRA3 Evidence Report 2017.
[30] The UKCP09 website contains further information on projections of rainfall, sea level rise and increase in the warmest day of summer.

- heavier rainfall events – with increased risk of flooding
- higher sea levels – with larger storm waves putting a strain on the UK's coastal defences
- more and longer-lasting heat waves

The effect of warming on rainfall patterns and water supplies

Changing rainfall patterns will affect water supplies. Too much rainfall in a short amount of time in some areas and not enough in other areas will contribute to both flood and drought conditions. We are already seeing increasing numbers of heavy rainfall events, and expect this increase to continue[31], with greater risk of river and flash flooding.

Mountain glaciers are expected to continue melting which, along with reduced snow cover, will put stress on communities that rely on these as sources of water.[32]

Changes in the oceans

Increasing temperatures and acidification of the oceans are threatening marine ecosystems around the world. Coral reefs in particular will be at major risk if ocean temperatures keep increasing.[33]

Sea levels will keep rising as the polar ice sheets and glaciers melt and the warming oceans expand. Even small increases of tens of centimetres could put thousands of lives and settlements at risk from coastal flooding during stormy weather.[34]

Coastal cities with dense populations are particularly vulnerable, especially those that can't afford flood protection.

The impact of warming on food production

Increased temperatures, changes to rainfall patterns, and an increased risk of extreme weather events will all negatively affect the production of major food crops such as wheat, rice and maize. In tropical and temperate regions, climate change without adaptation will have a negative impact on these crops for local temperature increases of 2°C or more, although some individual locations may benefit. Overall, we expect that warming will cause more negative effects than positive ones on crop

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[31] SPM AR5 WGI, B.1, Observed Changes in the Climate System: Atmosphere and Table SPM.1 discuss observed changes in rainfall; E.2, Future Global and Regional Climate Change: Atmosphere Water Cycle discusses projected future changes in rainfall.
[32] SPM AR5 WGII, B-2, Sectoral Risks and Potential for Adaptation: Freshwater Resources. Also see the section on risks in Central and South America in Assessment Box SPM.2 Table 1.
[33] SPM AR5 WGII, B-2, Sectoral Risks and Potential for Adaptation: Marine systems.
[34] SPM AR5 WGII, B-1, Key Risks across Sectors and Regions and B-2, Sectoral Risks and Potential for Adaptation: Coastal systems and low-lying areas.

production[35]. At higher levels of warming this will cause a growing gap between food demand and supply.

Because trade networks are increasingly global, the effects of extreme weather events in one part of the world will affect food supply in another. For example, floods or droughts that damage crops in Eastern Europe or the US can directly affect the cost and availability of food in the UK.[36]

The impact on ecosystems

Rapid, large changes in global temperatures (4˚C or more above the pre-industrial temperature by the end of this century) and changes in rainfall patterns will increase the vulnerability of many species to climate change and may lead to the extinction of entire species. Even with smaller amounts of warming many species will be placed at greater risk. The animals and plants most at risk will be those that:[37]

- have no new habitats to move to
- can't move quickly to new habitats
- are already under threat from other factors, such as overharvesting or habitat loss and degradation because of human activity

Extinctions and changes in the number of species in a population will have an enormous impact on food chains. Most ecosystems would struggle to function as they currently do under large changes in climate that happen rapidly within a century or so.[38]

The impact on human health

Climate change is expected to make some existing health problems worse as temperatures increase. Malnutrition could become more widespread as crop yields are affected by increased drought conditions in some regions, leading to reduced food production. Warmer temperatures could increase the range over which disease-carrying insects are able to survive and thrive. Vulnerable people will be at risk of increased heat exposure and the number of deaths due to temperature extremes is expected to increase in the future, although in the long term there will likely be fewer health problems related to cold temperatures.[39] The amount of people at significant risk from flooding is expected to increase in the future [40] and some studies have shown that there is likely to be an increase in disease relating to worsening air

[35] IPCC, 2014: Box 7.1, Chapter 7, Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the 5th Assessment Report of the IPCC

[36] More details on the impact of global warming in food production can be found in IPCC AR5 WGII Chapter 7: Food Security and Food Production Systems.

[37] SPM AR5 WGII, B-1, Key Risks across Sectors and Regions and B-2, Sectoral Risks and Potential for Adaptation: Terrestrial & Freshwater Ecosystems

[38] SPM AR5 WGII, B-1, Key Risks across Sectors and Regions.

[39] SPM AR5 WGII, B-2, Sectoral Risks and Potential for Adaptation: Human health.

[40] Global Facility for Disaster Reduction and Recovery, 2016. The making of a riskier future: how our decisions are shaping future disaster risk. Available at http://www.worldbank.org/en/news/press-release/2016/05/16/unprepared-for-a-risky-future

pollution[41] The populations likely to be most affected by the health impacts of climate change are those that are already hardest hit by climate change, particularly in developing countries. [42]

Poverty

People with low income in both developed and developing countries will be most vulnerable to the impacts of climate change. Decreasing food production, an increase in health issues associated with climate change, and more extreme weather will slow economic growth, making it increasingly difficult to reduce poverty.[43]

The impact of extreme weather events globally

Growing populations and increasingly expensive infrastructure are making our societies more vulnerable to extreme weather events. Heat waves and droughts are expected to become more common and more intense over the coming century, and more frequent heavy rainfall events and rising sea levels will increase the risk of floods.[44]

While not all extreme weather events can be directly linked to human influences, we are already seeing the huge impacts on society that extreme weather events can have. The World Meteorological Organization (WMO) reported that between 2001 and 2010 extreme weather events caused:[45]

- more than 370,000 deaths worldwide (including a large increase in heatwave deaths from 6,000 to 136,000) – 20% higher than the previous decade
- an estimated US$660 billion of economic damage – 54% higher than in the previous decade

Research has shown that the record global average temperature and the extreme heatwave in Asia during 2016 would not have happened without warming due to human activity. Human-caused climate change also influenced other events in 2016, including extreme heat in the Arctic, the duration of coral bleaching in the Great Barrier Reef, the increased the risk of wildfires in the western US, extreme rainfall in China and drought conditions in South Africa that led to food shortages[46].

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[41] https://www.metoffice.gov.uk/research/news/2017/climate-change-to-increase-number-of-deaths-related-to-poor-quality
[42] http://www.who.int/news-room/fact-sheets/detail/climate-change-and-health
[43] SPM AR5 WGII, B-2, Sectoral Risks and Potential for Adaptation: Livelihoods and poverty.
[44] SPM AR5 WGI, Table SPM1 (page 7) and E.1, Future Global and Regional Climate Change: Temperature and E.2 Future Global and Regional Climate Change: Water Cycle. See also SPM AR5 WGII, A-1, Observed Impacts, Vulnerability, and Exposure and B-2, Sectoral Risks and Potential for Adaptation (in particular the sections on Freshwater Resources, Urban Areas, Key economic sectors and services, Human health and Human security).
[45] 'The Global Climate 2001-2010: a decade of climate extremes – Summary Report', 2013. World Meteorological Organisation.
[46] Explaining Extreme Events of 2016 from a Climate Perspective. Bulletin of the American Meteorological Society.

Possible abrupt changes in our climate

Most discussions of climate change look at what is most likely to happen, such as the likely temperature changes if we do, or don't, take action to reduce greenhouse gas emissions.

But scientists have identified the possibility that with sustained high temperatures major elements of the Earth's climate could be drastically altered. These 'tipping points' in our climate are less likely, but potentially much more dangerous.[47]

While known impacts from small temperature rises could be managed (although this will become increasingly expensive as temperatures increase), passing a tipping point could cause large or abrupt changes, some of which may be effectively irreversible.

For example:

- Arctic permafrost could thaw rapidly, releasing greenhouse gases that are currently 'locked away' and causing further rapid warming
- the great sheet of ice covering Greenland, which contains enough ice to cause up to 7 metres of sea level rise, could melt almost entirely. While this would take a long time to happen, it is possible that the ice sheet would not be able to regrow after a certain amount of melting occurs.

While such events are considered unlikely, they can't be ruled out, even under relatively low temperature rises of less than 2 ˚C above the pre-industrial temperature. All indications are that, should we pass one of these tipping points, there would be a range of extremely severe and potentially irreversible impacts.[48]

Agreement among experts

The great majority of scientific evidence, built up over many years, shows that the planet is warming and that human activity is the main contributor to this warming.

Many leading national scientific organisations have published statements confirming the need to take action to prevent dangerous climate change. These include:

- the G8+5 National Science Academies' Joint National Statement which represents the UK, along with Brazil, Canada, China, France, Germany, India, Italy, Japan, Russia and the United States
- the American Association for the Advancement of Science (AAAS) statement

[47] See SPM AR5 WGII, Assessment Box SPM.1, Human Interference with the Climate System, and also the Technical Summary of AR5 WGI, TFE.5 | Irreversibility and Abrupt Change.
[48] SPM AR5 WGI, E.8, Future Global and Regional Climate Change: Climate Stabilization, Climate Change Commitment and Irreversibility. SPM AR5 WGII, B-1, Key Risks across Sectors and Regions. The Technical Summary of WGI contains a useful box (TFE.5 page 70) on projected 'Irreversibility and Abrupt Change'.

The Royal Society and US National Academy of Sciences have produced an authoritative and accessible report on Climate Change Evidence and Causes which provides answers to many common questions

You can find out more about the scientific evidence on climate change from:

- The Met Office Hadley Centre
- Frequently Asked Questions from the Intergovernmental Panel on Climate Change
- The UK Geological Society

The role of the IPCC

The Intergovernmental Panel on Climate Change (IPCC) is an independent body composed of scientists from around the world. It has been tasked by the United Nations to assess and review the most recent scientific, technical and socio-economic evidence related to climate change.

The IPCC's Fifth Assessment science report concluded that the scientific evidence for a warming climate is indisputable and that 'human influence on the climate system is clear'.

The UK Government has always fully supported the work of the IPCC and regards its assessments as the most authoritative view on the science of climate change available.

BEIS's summaries of the IPCC 5th Assessment reports 2013/14:

- The Physical Science Basis of Climate Change report, 27 September 2013
- Impacts, Adaptation and Vulnerability report, 31 March 2014
- Mitigation of Climate Change report, 12 April 2014

The IPCC are preparing a Special Report on Global Warming of 1.5 °C and aim to publish it in October 2018. The report will present scientific evidence on the impacts of warming of 1.5 °C above pre-industrial levels, and pathways to stay below 1.5 °C.

The IPCC are also preparing two additional Special Reports: Ocean and Cryosphere in a Changing Climate; and Climate Change and Land. These reports will be finalised in September 2019.

Tackling climate change

If we take action to radically reduce greenhouse gas emissions now, there's a good chance that we can limit average global temperature rises to 2˚C above pre-industrial levels. This doesn't mean that there will be no more changes in the climate – warming is already happening – but we could limit, adapt to and manage these changes.

If we take action now:

- we will avoid burdening future generations with greater impacts and costs of climate change
- economies will be able to cope better by mitigating environmental risks and improving energy efficiency
- there will be wider benefits to health, energy security and biodiversity

The economic benefit of taking action now

It makes good economic sense to take action now to drastically cut greenhouse gas emissions. If we delay acting on emissions, it will only mean more radical intervention in the future at greater cost[49], and larger impacts on society.

Taking action now can also help to achieve long-term, sustainable economic growth[50] from a low-carbon economy.

UK government action

The UK played a key role in securing the 2015 Paris Agreement, where for the first time, 195 countries adopted the first-ever universal, legally binding global climate deal.

The Agreement sets out a global action plan to put the world on track to avoid dangerous climate change. Governments agreed to a long-term goal of keeping the increase in global average temperature to well below 2°C above pre-industrial levels and to aim to limit the increase to 1.5°C. To achieve this, they also agreed to reaching a global balance of sources and sinks of greenhouse gases in the second half of the century. This would significantly reduce risks and the impacts of climate change.

In 2008 the UK introduced the Climate Change Act. As a result the UK is committed by 2050 to reduce our emissions by 80% compared to 1990 levels, and to a series of five-year carbon budgets to get there. Between 1990 and 2016 we have reduced our emissions by over 40%.

49 http://www.avoid.uk.net/feasibility/
50 AR5 WG3 SPM.