Climate change explained

Climate change is happening and is due to human activity, this includes global warming and greater risk of flooding, droughts and heat waves.

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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 0.8°C over the last century. 13 of the 14 warmest years on record have occurred in the 21st century and in the last 30 years each decade has 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[1].

The UK is already affected by rising temperatures. The average temperature in Britain is now 1˚C higher than it was 100 years ago and 0.5˚C higher than it was in the 1970s[2].

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[3].

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

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[4].

The chemistry of the oceans is also changing as they absorb much of the excess carbon dioxide being emitted into the atmosphere. This is causing the oceans to become acidic more rapidly than at any point in the last 65 million years[5].

Melting polar ice and glaciers

As the Arctic warms, sea ice is decreasing rapidly[6]. In the Antarctic, sea ice has slowly increased, driven by local changes in wind patterns and freshening sea water[7]. Over the past 20 years 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[8].

Rising sea levels

As land ice melts and the warming oceans expand, sea levels have risen. Between 1901 and 2010 the global average sea level rose by 0.19 metres, likely faster than at any point in the last 2,000 years[9].

More extreme weather events

More damaging extreme weather events are being seen around the world[10]. 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[11].

Causes of climate change

Rising levels of carbon dioxide and other 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[12].

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.[13]

Carbon dioxide levels have increased by more than 40% since before the industrial revolution.[14] 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[15]:

- 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.[16]

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. They show that levels of greenhouse gases in the atmosphere are closely linked to global temperatures. Rises in temperature are accompanied by an increase in the amount of greenhouse gases.[17]

These ice cores also show that, over the last 350 years, greenhouse gases have now rapidly increased to levels not seen for at least 800,000 years and very probably longer.[18] 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. [19]

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.[20]

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. 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).[21]

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 see.

All these climate models tell us that by the end of this century, without an extremely significant reduction in the amount of greenhouse gases we produce, the world is

likely to become more than 3 ˚C warmer than in the 19th century. Note that this is a global average and that regional changes in some places will be even higher than this. There could even be global average rises of up to 6˚C which would have catastrophic impacts.[22]

This means that our action – or inaction – on greenhouse gas emissions today will have a substantial effect on climate change in the future.

The effects of climate change

We can already see the impacts of climate change and these will become more severe as global temperatures rise.[23] How great the impacts will become depends upon our success in reducing greenhouse gas emissions.

The effects of rising temperatures on the UK

If global emissions are not reduced, average summer temperatures in the south east of England are projected to rise by[24]:

- over 2˚C by the 2040s (hotter than the 2003 heatwave which was connected to 2,000 extra deaths in the UK)
- up to nearly 4˚C by the 2080s

Rises in global temperature will have both direct and indirect effects on the UK. The UK's food supplies could be affected as crops in the UK and overseas could fail or be damaged by changes in temperature, rainfall and extreme weather events[25].

These extreme weather events in the UK are likely to increase with rising temperatures, causing[26]:

- 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 some areas and not enough in others will contribute to both flood and drought conditions. We are already seeing increasing numbers of heavy rainfall events, and expect this increase to continue[27], 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.[28]

Changes in the oceans

Increasing temperatures and acidification of the oceans are threatening sea life around the world. Coral reefs in particular will be at major risk if ocean temperatures keep increasing. [29]

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 properties at risk from coastal flooding during stormy weather. [30]

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

The impact of warming on food production

Even with low levels of warming (less than 2 ˚C above the temperature in 1800), global production of major crops such as wheat, rice and maize may be harmed. Though warming may help some crops to grow better at high latitudes, food production in low latitudes will very likely suffer. This will cause a growing gap between food demand and supply.[31]

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. [32]

The impact on ecosystems

Rapid, large changes in global temperatures (4˚C or more above the temperature in 1800 by the end of this century) could cause the extinction of entire species. Even with smaller amounts of warming species will be placed more at risk. The animals and plants most at risk will be those that:[33]

- have no new habitats to move to
- can't move quickly to new habitats
- are already under threat from other factors

Extinctions could have an enormous impact on the food chain. Most ecosystems would struggle to live with large changes in climate which happen rapidly within a century or so.[34]

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 crops are affected and warmer temperatures could increase the range of disease-carrying insects. Vulnerable people will be at risk of increased heat exposure, although there will likely be fewer health problems related to cold temperatures.[35]

Poverty

Populations 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.[36]

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.[37]

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[38]:

- 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

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.[39]

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 almost entirely melt. 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 temperature in 1800. All

indications are that, should we pass one of these tipping points, there would be a range of extremely severe impacts.[40]

Agreement among experts

Overwhelming amounts of scientific evidence show 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 potentially 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

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 that 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 undeniable 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.

DECC'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

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. 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.

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

UK government action

The UK government is:

1. working to secure global emissions reductions
2. reducing UK emissions
3. adapting to climate change in the UK

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[1] 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. More information on global temperature records can be found in the World Meteorological Organisation's Statement on the Status of the Global Climate in 2013. Recent Arctic temperature records can be found in NOAA's 2013 Arctic Report Card.

[2] The Met Office hold records of UK temperature from 1910, and also the Central England Temperature (CET) which stretches back to 1659.

[3] 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.

[4] SPM AR5 WGI, B.2, Observed Changes in the Climate System: Ocean.

[5] SPM AR5 WGI, B.5, Observed Changes in the Climate System: Carbon and Other Biogeochemical Cycles. IPCC AR5 WGII Chapter 6: Ocean systems discusses the rate of ocean acidification in a geological context in section 6.1.2.2. Paleontological Records. For the most recent official atmospheric greenhouse gas figures see the WMO's Greenhouse Gas Bulletin for 2013.
[6] see measurements from the National Snow and Ice Data Centre.
[7] 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.
[8] SPM AR5 WGI, B.3, Observed Changes in the Climate System: Cryosphere.
[9] SPM AR5 WGI, B.4, Observed Changes in the Climate System: Sea Level.
[10] 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.
[11] SPM AR5 WGI, B.1, Observed Changes in the Climate System: Atmosphere.
[12] A comprehensive and readable history of the discovery of the greenhouse effect is provided by the American Institute of Physics
[13] SPM AR5 WGI, D.3, Understanding the Climate System and its Recent Changes: Detection and Attribution of Climate Change.
[14] For the most recent official figures see the WMO's Greenhouse Gas Bulletin for 2013. Hourly measurements of atmospheric $CO_2$from the observatory at Mauna Loa (the world's longest running timeseries) can be found online.
[15] SPM AR5 WGIII, SPM.3: Trends in stocks and flows of greenhouse gases and their drivers. See Figure SPM.2 in particular.
[16] SPM AR5 WGI, B.5, Observed Changes in the Climate System: Carbon and Other Biogeochemical Cycles.
[17] The British Antarctic Survey provide a good overview of determining past climate changes from ice cores. For more information on how past climate change can tell us about the future, see the Geological Society's position statement on climate change.
[18] SPM AR5 WGI, B.5, Observed Changes in the Climate System: Carbon and Other Biogeochemical Cycles.
[19] 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.
[20] SPM AR5 WGI, D.3, Understanding the Climate System and its Recent Changes: Detection and Attribution of Climate Change.
[21] The World Meteorological Organisation has a readable introduction to the more complex climate models which are run using supercomputers. The American Institute of Physics provides an overview of how the first simple climate models were developed.
[22] SPM AR5 WGI, E.1, Future Global and Regional Climate Change: Atmosphere Temperature.
[23] SPM AR5 WGII, A-1 gives an overview of climate impacts already being observed.

[24] The UK Climate Projections 2009 (UKCP09) show an increase in average summer temperature in the 2050s under a medium emissions scenario of about 2.8°C.
[25] The UK Climate Change Risk Assessment, 2012 discusses the major risks and benefits to the UK from a changing climate.
[26] The UKCP09 website contains further information on projections of rainfall, sea level rise and increase in the warmest day of summer.
[27] 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.
[28] 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.
[29] SPM AR5 WGII, B-2, Sectoral Risks and Potential for Adaptation: Marine systems.
[30] 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.
[31] SPM AR5 WGII, A-1, Observed Impacts, Vulnerability, and Exposure discusses how food production has already been affected by climate change; while B-2, Sectoral Risks and Potential for Adaptation: Food security and food production systems discusses potential changes from local increases in temperature.
[32] 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.
[33] SPM AR5 WGII, B-1, Key Risks across Sectors and Regions and B-2, Sectoral Risks and Potential for Adaptation: Terrestrial & Freshwater Ecosystems
[34] SPM AR5 WGII, B-1, Key Risks across Sectors and Regions.
[35] SPM AR5 WGII, B-2, Sectoral Risks and Potential for Adaptation: Human health.
[36] SPM AR5 WGII, B-2, Sectoral Risks and Potential for Adaptation: Livelihoods and poverty.
[37] 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).
[38] 'The Global Climate 2001-2010: a decade of climate extremes - Summary Report', 2013. World Meteorological Organisation.
[39] 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.
[40] 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’.