Health and Climate Change - Introduction

Changes to environment and ecosystems: a climate change primer

Interested in climate change but not sure where to start? Our primer will help you understand the basics

Climate refers to the weather conditions that generally prevail in an area over a long period of time. These conditions include, but are not limited to, temperature, rainfall (precipitation) and humidity. Climate is a measure of patterns and can be thought of as the average weather in one given location over 30 years or longer.

Changes within the normal range of weather defined by a climate – for example, an unusually cold winter, a wetter than average spring, a summer drought – are referred to as climate variability.

What we call climate change is a change in global or regional climate patterns, especially change caused by increased levels carbon dioxide in the atmosphere as a result of burning fossil fuels. Climate change is being driven by the build-up of greenhouse gases in the atmosphere, mainly due to human activities. Higher greenhouse gas levels are causing an enhanced greenhouse effect, leading to a global rise in temperature.

Higher temperatures are melting the icecaps and, with the thermal expansion of oceans, raising sea levels. Significant changes to weather patterns are expected – more severe storms, more rain in wet areas, less rain in dry areas.

Other factors affect climates over differing timescales, including solar activity, ocean currents and other natural cycles. These factors are being swamped by the effects of greenhouse gases.

Climate changes are profoundly affecting the Earth's environment and ecosystems. These effects are made worse by other forms of environmental degradation.

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Dynamic influences on climate change

The factors behind climate change are complex, dynamic and interlinked

The Earth's physical, chemical, biological and social systems are interlinked. Change one thing and the results can be far-reaching – and not easy to predict.

The Earth is a dynamic system, constantly changing. It may appear static because the underlying dynamics have reached an equilibrium state or because changes are occurring over very long timeframes. The dynamics arise because different parts of the system interact with one another – chemicals react, waves erode coasts, animals eat one another. Because there are so many parts to the system, it is hugely complex. Researchers therefore tend to focus on a subset of factors that are most relevant to their area of interest.

Nevertheless, in principle it is possible to describe the behaviour of a system in terms of the nature of the interactions between its different components. The relationship between them can broadly be defined as being either:

- positive (e.g. more sunlight is associated with more plant growth), or
- negative (e.g. more sheep is associated with less grass).

Interactions are often complicated or nonlinear – e.g. how an element responds depends on the size of the change. A change may also affect itself, through feedback mechanisms:

- negative feedback (more predators means less prey; predators starve and their numbers fall; prey recovers)
- positive feedback (fish stocks run low, fishermen catch smaller fish; fewer fish reproduce, fish stocks fall further).

Negative feedback loops are stabilising forces and common in biological control systems and ecology.

Positive feedback systems, by contrast, can be powerful drivers of change. Rather than helping to rebalance the system, some environmental factors can reinforce a shift towards an extreme. A major fear in climate change is that positive feedback systems could push us further towards environmental catastrophe, by driving temperatures up on their own. An example might be the sudden release of huge quantities of methane from melting permafrost or reserves buried under the oceans.

Systems that are highly sensitive to starting conditions are described by chaos theory. Although governed by rules, they appear chaotic and unpredictable. Chaos theory is often likened to the 'butterfly effect', a term coined by mathematician and meteorologist Edward Lorenz to describe a situation whereby the flapping of a butterfly's wings in one part of the planet sets off a tornado somewhere else.

For people, the implications are far-reaching. Increased greenhouse gas emissions are not being harmlessly absorbed into the atmosphere. They are triggering profound chemical, geophysical, meteorological, biological and social changes. Butterflies' wings are flapping like mad all over the globe.

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Why is temperature change bad for people?

Organisms – including humans – are adapted to a narrow range of temperatures

In humans, internal body temperature is maintained at a remarkably constant 36–37°C, thanks to a variety of homeostatic mechanisms, coordinated by a thermostat in the hypothalamus region of the brain.

When body temperatures rise, negative feedback systems kick in – sweating, blood vessel dilation near the skin (vasodilation), behavioural responses (seeking shade, eating ice cream) and so on.

Ongoing exposure to elevated temperatures is highly dangerous, leading to heatstroke. Symptoms include headache, nausea, confusion a racing heart and convulsions. If left untreated, heat stroke can cause death.

Heat stroke occurs when the body is no longer able to cope with the environmental temperature and its ability to thermoregulate breaks down, leading to a rise in core temperature. Cell death and inflammation result, leading eventually to multiple organ failure. The detailed mechanisms of heatstroke are still being investigated but they involve molecules called heat-shock proteins and cytokines. A better understanding of the role of these molecules could suggest new ways to treat heatstroke.

Thermoregulation is important because the speed of biochemical reactions – chemical kinetics – varies with temperature. In addition, biological molecules such as proteins lose their shape (denature) and are inactivated if temperatures rise too high. Important enzymes stop working at temperatures even a few degrees either side of the optimum.

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How does climate change affect human health?

Climate change brings with it an increase in malnutrition, mental health conditions, infectious disease spread and even death

Climate change is often thought of in terms of its effects on our physical environment: melting icecaps, rising sea levels, heat-waves and storms. But increasing evidence shows that the human impact – and the impact on human health – will be a major challenge for scientists, politicians and ordinary people in years to come.

The precise extent of the impact is difficult to quantify exactly because there are so many different factors at play. But one thing is certain: climate change is having an effect, and as the planet warms up, that effect is only going to increase.

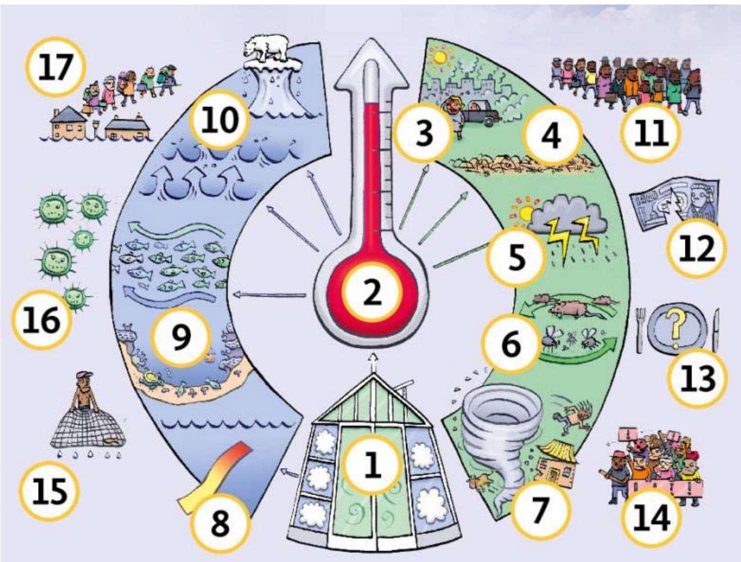


Illustration © Glen McBeth

Rising greenhouse gas levels are triggering climate and environmental changes that will affect human health in many ways.

1. Rising greenhouse gas levels

Which lead to:

2. Temperature rise

Which leads to:

3. Higher temperatures
4. Crop failure
5. Altered weather patterns
6. Injury
7. Homelessness
8. Ocean acidification
9. Marine ecosystem shift
10. Sea level rise

These changes (from 3–10) in turn lead to:

11. Mass migration
12. Economic disruption
13. Malnutrition
14. Social unrest
15. Aquaculture failure
16. Infectious disease spread
17. Displacement

Direct and indirect consequences

The first major health impact of climate change is the rise in rates of mortality and diseases caused by extreme weather events. These include floods, droughts, tsunamis, heat-waves and other disasters which kill thousands of people in both the developed and developing worlds. Over 280,000 people were killed by the Asian tsunami of 2004, for example, while in the UK, in 2018, a fortnight-long heat wave caused an extra 663 deaths when compared to average figures.

Disasters like these make the headlines, but the indirect health consequences of climate change are just as important. Higher temperatures pose major health risks to older people and raise the likelihood that those who work outside – such as farmers and builders – will suffer from heat exhaustion and heat stroke. Many killer diseases, including malaria and cholera, increase as temperature and rainfall increase. The mosquitos that carry the malaria virus, for example, thrive in hot and humid conditions – weather which climate change is likely to make more common.

Malnutrition and mental health

A third impact on human health is yet more indirect, and comes as a result of climate change's effect on human society and economic development. Experts now think that climate change is raising rates of malnutrition and mental health, for example. The connection may not be obvious, so let's take each issue in turn.

In the developing world, malnutrition is rising because crops are failing, and that's happening because of extreme weather. It's estimated that climate-related disasters in Africa affected 16 million people during the ten years prior to 2018. Cycles of drought and flood make it harder and harder for subsistence farmers to grow enough food to feed their families. And when the rain does come, it washes the topsoil away, degrading the land, so it becomes even more difficult to cultivate crops in the future. As a result, people go hungry and children in particular suffer from malnourishment.

The impact of climate change on mental health is a relatively new field of enquiry, but it should not be underestimated. People who have survived droughts, floods, tropical storms and similar extreme weather events often lose their homes and their families. As a result, they can experience post-traumatic stress disorder, severe depression and other mental health problems. In 2018, Australian researchers showed that suicide rates increase alongside rising temperatures. In developing countries, where the impacts of climate change are at their most severe, there is less access to mental health services, so symptoms go untreated and unchecked.

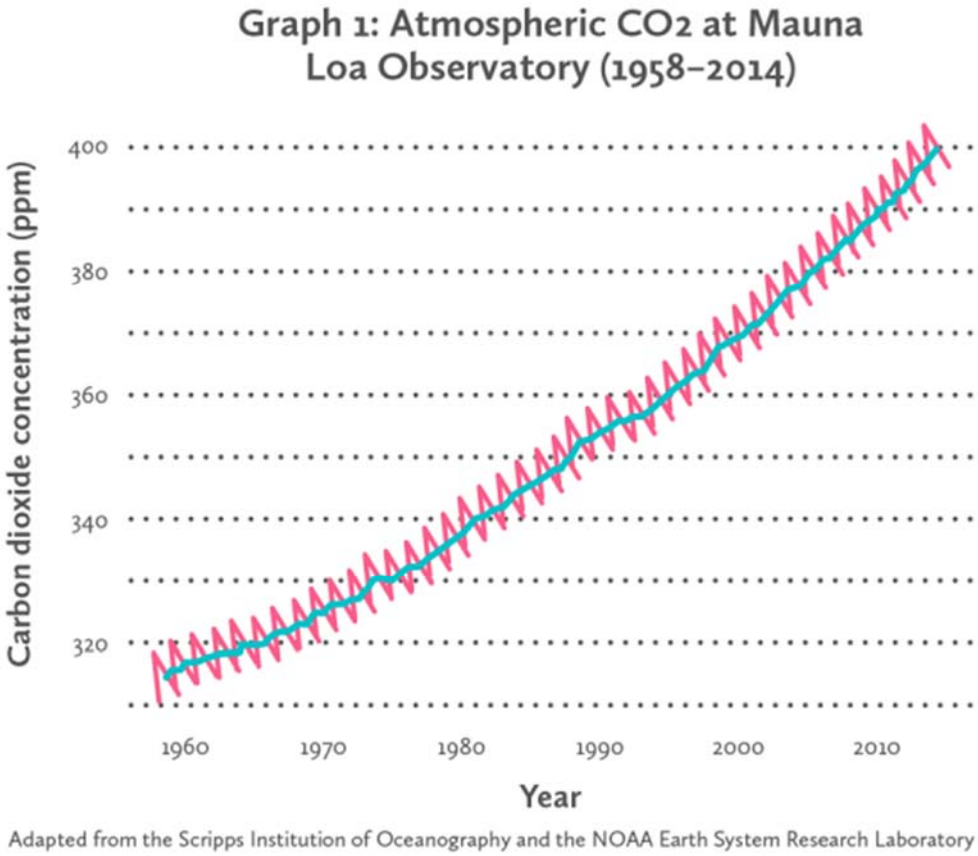
Are there benefits to climate change?

There are possible health benefits of climate change. Older people living in more temperate countries may be less at risk of dying from the cold during harsh winters, and farmers may find agricultural yields improve as a result of a longer summer.

However, the benefits are likely to accrue for small numbers of people in more affluent countries. The losers from climate change are expected to be the poor and vulnerable in the developing world.

Upwards trends in climate change

Our climate is changing; with greenhouse gas emissions still rising, the planet is poised to undergo a profound change



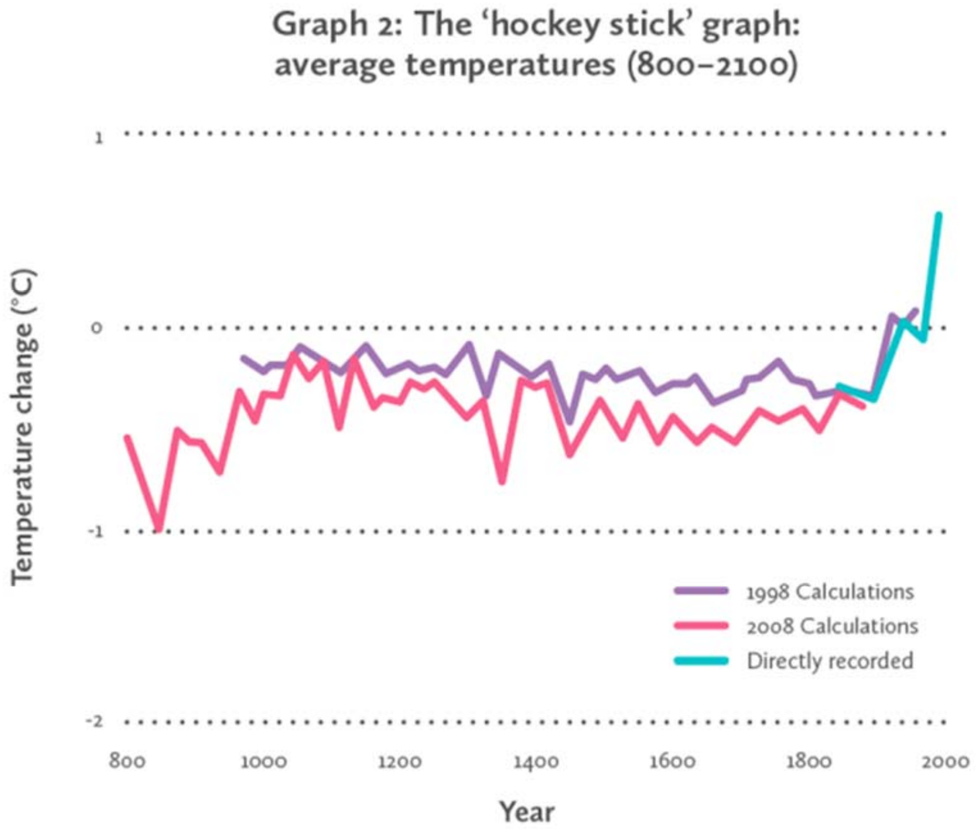
CO_2 levels

Concerned about rising carbon dioxide levels, in 1958 US scientist Charles Keeling began recording atmospheric carbon dioxide levels on the Mauna Loa volcano in Hawaii. Despite many challenges, Keeling gathered a remarkable set of data recording a steady rise in carbon dioxide levels – from his first measurement of 313 parts per million (ppm) in 1958 to over 370 ppm by 2005, the year of his death. Other researchers took over the task and the full record now tracks an upwards trend that shows CO_2 levels increasing above 410 ppm (see graph 1).

The records even show that annual cycles are linked to seasonal plant growth in the northern hemisphere, as well as the impact of volcanic eruptions and weather patterns such as El Niño.

Sea level rise

Based on satellite measurements, sea levels are rising by over 3 mm every year, up from less than 2mm in 1995. Scientists think that during the previous 3,000 years, it rose fairly consistently at a rate of around 0.1 to 0.2 mm per year. Some of the sea level rise comes from thermal expansion – water expanding as it heats up under climate change – whilst the rest comes from melting ice sheets and glaciers.



Adapted from Jones P et al. 'High-resolution palaeoclimatology of the last millennium' (2009)

Temperature rise

The 'hockey stick' graph (see Graph 2), originally published in the journal *Nature* in 1998, and then extended a year later, showed average temperatures over the past 1,000 years with a sudden spike (the upwards curve of the 'stick') in the 20th century. A version of this graph appeared in the Intergovernmental Panel on Climate Change's 2001 assessment report.

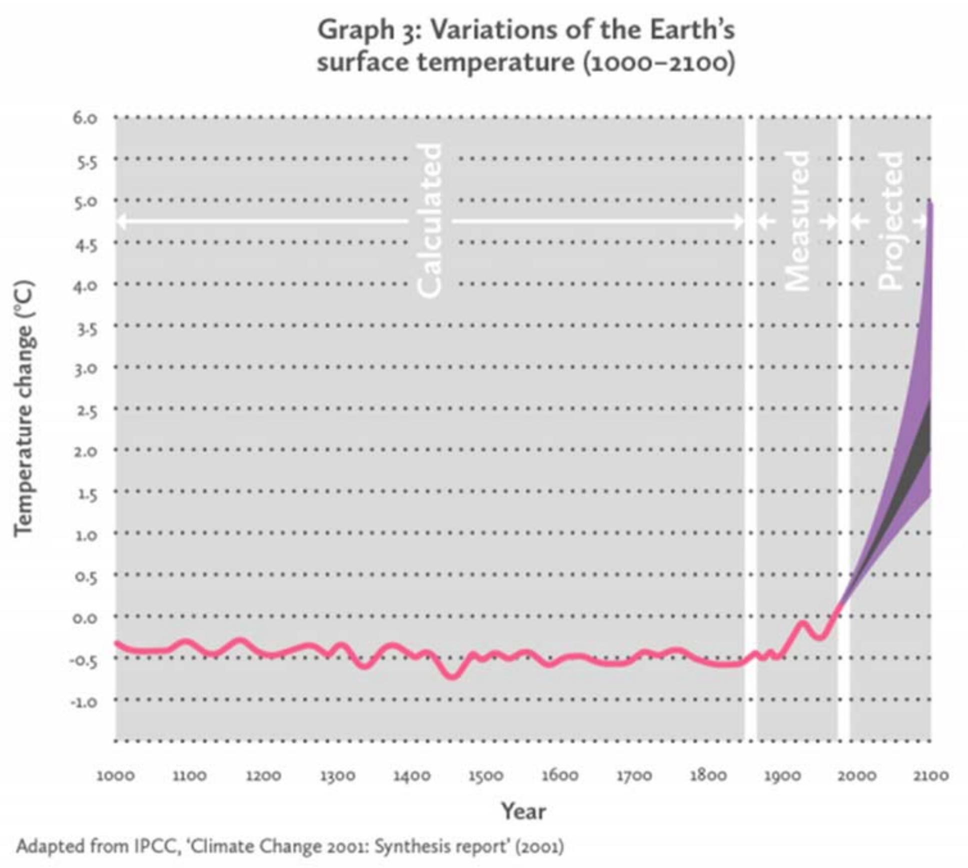
The top ten warmest years on record have all been from 1998 onwards, and 2013-2018 all made the top ten.

The hockey stick graph has proved controversial, with some commentators questioning the accuracy of historical temperature data obtained from sources such as ice cores and tree ring analysis, in which the size of the rings of a tree are measured to see how much it has grown each year (which is dependent on climate). However, over the years, the weight of evidence has piled up in favour of the hockey stick version of events, with many different scientific groups coming to the same conclusions.

Graph 3 (below) shows variations of the Earth's surface temperature (1000–2100). In 2018, the World Meterological Organization announced that the average global temperature will likely increase by between 3-5ºC this century, above the 2ºC limit that was proposed by scientists for avoiding the worst consequences of climate change.

Ocean acidity

Ocean pH is falling due to increased carbon dioxide dissolving in our seas (acidification); the average ocean pH has dropped by about 0.1 units since pre-industrial times. Because of the way the pH scale works, this equates to the oceans being about 28% more acidic today.



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The known impact of climate change

Documented evidence of the biological impact of climate change

How can we be sure that a change in the environment is actually the result of climate change?

Because the Earth's climate cannot be deliberately altered, the best evidence is generally association – when the observed impact corresponds to a period of climate change. This association can be strengthened if:

- other possible causes can be eliminated
- a plausible mechanism exists to explain the link to the climate.

Climate-linked changes have been seen in a wide range of biological systems – from the blooming of spring flowers to the nest building of birds. Some of the best-documented cases use data collected over many years, often not for climate change purposes:

Timing of bird migration

One 2016 study looked at changes in migration timing of 413 species of birds over an average of 38 years – although records from as far back as the 18th century were used for some species. The researchers found that in response to warmer spring conditions, birds from five different continents have migrated earlier by an average of two days per decade and one day per degree Celsius.

Spawning range of Atlantic mackerel

Monitoring of Atlantic mackerel between 1977-2010 suggests they may have shifted their spawning range by as much as 38 km north per degree Celsius of ocean warming. Slightly more recent research focusing on records of spawning between 1992-2013 suggests that for every degree of warming the fish are spawning around 28 km further north. Whilst there is some variability in the estimates there seems to be no doubt about the general trend. In 2015, Atlantic mackerel were found in Isfjorden, Svalbard – midway between Norway and the North Pole – for the first time.

Blooming trees

Monitoring of tree blooming times in a protected area called the Walden Pond Reservation in Concord, Massachusetts, goes as far back as the 1840s, when the writer Henry David Thoreau kept his own records. According to biologists who, in 2018, compared these records with data collected in the past decade, some tree species are now blooming two to three weeks earlier.

Arthropod declines

In the 1970s, ecologists working in the Luquillo rainforest in Puerto Rico sampled arthropods (including spiders and scorpions) in the forest as part of a long-term research program. In 2011 and 2012, a different team of researchers returned to the same spot and repeated the study, using tje same-sized sticky traps and nets that the first group had used. Over four decades, the total weight of arthropods captured using the same sampling methods had decreased by at least four times in nets and at least 30 times in sticky traps. The researchers concluded that this decrease was due to a 2ºC rise in average temperature as well as an increasing number of spikes in temperature due to extremely hot days.

In addition, a 2016 study looked for evidence of the impacts of climate change across 94 different ecological processes, from budding and flowering of plants to the productivity of fisheries – what they referred to as 'the broad footprint of climate change'. The authors found evidence for the impacts of climate change in 82% of these processes. There was widespread evidence for the expansion of the ranges of warm-adapted species as well as shrinking of the ranges of cold-adapted species. Climate change was also responsible for shifts in the distribution of disease-carrying insects and for a decrease in yields of important crops such as rice, maize and coffee.

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