2 Climate Change – Living in a Warmer World

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Planet Earth has experienced large shifts in climate over time. In the depths of the last Ice Age, around 20,000 years ago, average temperatures were about 5°C lower than they are today. It looks now as though global warming is likely to heat up the world between 2 and 6°C by the year 2100. Past climate shifts have had dramatic impacts on the land and its inhabitants, particularly with changes in the incidence of floods, droughts, snow and windstorms, and other climate extremes. Those differences in average temperature may seem small, but they have a huge effect on the environment and the lives of plants and animals.

In the 19th century, the globe was much colder than it is now. The world was experiencing the end of the Little Ice Age, a time of cooler climate over much of the planet which lasted about 250 years. The first reliable thermometer measurements, taken in the 1850s and 1860s, show temperatures that were close to 1°C below average temperatures today.
Our environment has changed already and our everyday lives will be affected — from access to food, water and even land, to health and biodiversity — as the world continues to warm over the next 100 years and beyond.

Climate warming really got seriously under way in the 1970s. Recorded temperatures over the planet have now warmed by 1.0°C from the 1880s to 2015. Fifteen of the sixteen warmest years have all been recorded since 2000. The warmer temperatures have had effects on our environment, perhaps the most noticeable of which is the marked loss of ice in most of the mountain glaciers of the world. Since 1950, there has been a massive retreat of mountain glaciers. From 1980 to 2011 these glaciers lost, on average, 1.4 metres of water equivalent (the depth of water that results if the whole snow pack melts) from their surfaces to the oceans. This contributes to sea-level rise. Another impact of glacier melt is that the extra snow melting under warmer temperatures will provide more fresh water in winter and spring where river flows are low. The melting glaciers are also expected to bring a reduction to winter electricity requirements.

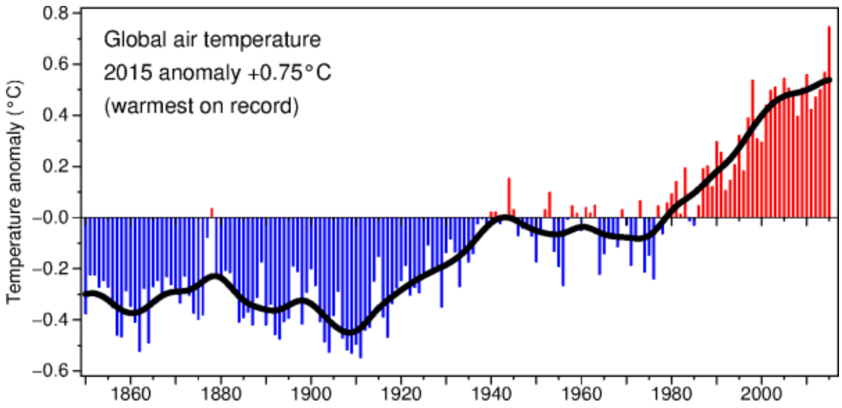
A change in the world's late 20th century climate occurred in the mid-1970s with accelerated warming, coupled with an increase in El Niño events in the Pacific Ocean. There was an immediate impact over areas especially affected by this climate phenomenon, such as in Australia, the Pacific and the Americas. El Niño events magnify the effects of global warming. The more frequent El Niños have caused more droughts in Australia and southern Africa and more floods in parts of South America and western areas of North America.

Just before the commencement of the 21st century, the Pacific Basin entered a climate phase characterised by more frequent La Niña events. This was heralded by a more energetic North Atlantic hurricane season, flooding events in Australia, and other climate extremes. Temperatures continued to increase, but more slowly than in the late 20th century, while the oceans absorbed heat at a rapid rate. The climate switched again in late 2014 to the phase characterised by more frequent El Niño events, which warm the atmosphere. The severe 2015/16 El Niño episode has been ranked as one of the three strongest in records back to the late 19th century. Dramatic impacts occurred, including especially severe coral bleaching on the Great Barrier Reef. This pushed up tropical cyclone activity over the western South

Pacific, especially near Vanuatu, Fiji and Tonga, and produced severe drought in parts of Africa and Australia.

The change in climate forces created by warming will alter the pattern of climate extremes. Warmer air holds more moisture, which means that heavy rainfall and floods are more likely.

Global surface temperature record (land and marine) 1850-2015, relative to the 1961-1990 mean

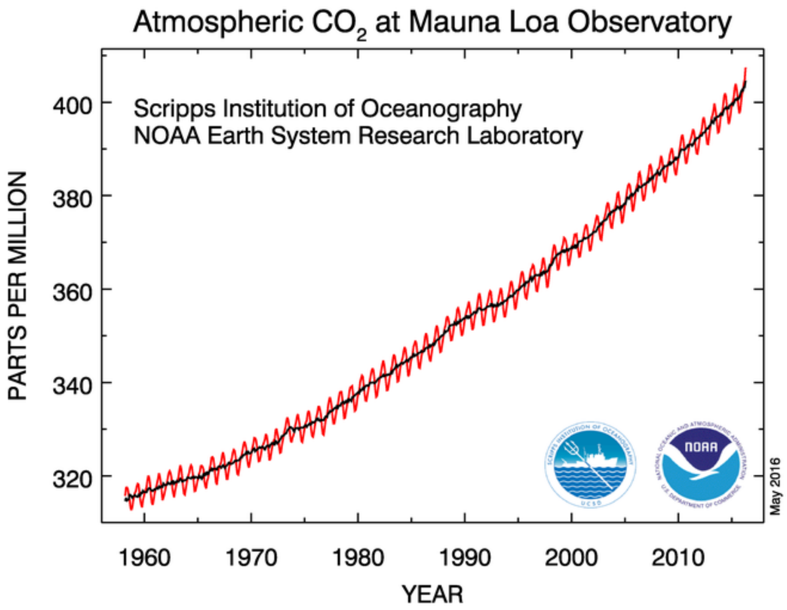


This time series, from the Climatic Research Unit (CRU), shows the combined global land and marine surface temperature record from 1850 to 2015.1850 marks the commencement of reliable instrumental observations.

At the same time higher average temperatures mean dramatically fewer frosts and more heatwaves and droughts. Climate scientists are quite clear that greenhouse gases in the atmosphere are increasing, and that these must have an impact on climate. There is incontrovertible evidence that the amounts of greenhouse gases in the atmosphere started rising at the start of the Industrial Revolution, and are continuing to do so at an accelerating rate.

The greenhouse gases — carbon dioxide, methane and chlorofluoro-carbons (CFCs) — trap heat in the atmosphere. The basic laws of physics require that an increase in these gases will change climate. It is the considered opinion of the world's most respected climate scientists, who were asked by the United Nations in 1988 to report on how rising amounts in greenhouse gases might change global climate. The latest 2013 conclusions from the International Panel on Climate Change is that "*continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system*. *Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions."*

As the numbers of impacts grow with increasing global mean temperature, interactions between them might increasingly occur, compounding the overall impact. For example, significant pressure on water resources and changes in the hydrological cycle, combined with a large shock to agricultural production due to extreme temperatures across many regions, will most probably affect both human health and livelihoods. This might flow into effects on economic development, hindering growth in GDP by reducing a population's work capacity. As warming progresses toward 4°C, combined with nonclimate-related social, economic and population stresses, the risk of crossing critical social system thresholds will grow. Those existing institutions that would have supported adaptation actions very likely become much less operative and even fail. One example is a risk that sea-level rise in atoll countries exceeds the capacity of controlled, adaptive migration, resulting in the need for complete relocation of a sovereign nation. Stresses on human health, such as heatwaves, malnutrition, and decreasing quality of drinking water due to seawater intrusion, have the potential to overburden health-care systems to a point where adaptation is no longer possible, and dislocation is forced.



The Mauna Loa carbon dioxide (CO_2) record — 1958 to 2016

Since the Industrial Revolution, about 360 billion tonnes of carbon have been emitted by humans into the atmosphere as carbon dioxide (CO_2) from burning of fossil fuels, deforestation and land use. Atmospheric measurements show that about half of this CO_2 remains in the atmosphere and that, so far, the ocean and terrestrial sinks have steadily increased. If the pace of the last decade continues, CO_2 will reach 450 ppm by the year 2040. CO_2 is the most important manmade greenhouse gas, produced mainly by the burning of fossil fuels such as coal, oil and natural gas. The pace of the rise depends strongly on how much fossil fuel is used globally. If atmospheric CO_2 concentrations double, global average surface temperatures would eventually warm between 2 and 5°C above pre-industrial levels.

In December 2015 the 195 nations of the world negotiated the Paris Agreement within the United Nations Framework Convention on Climate Change. The principal aim was to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and aim to reach "global peaking of greenhouse gas emissions as soon as possible". As at the end of April 2016, 177 countries had signed the agreement. It will enter into force only if 55 countries that produce at least 55% of the world's greenhouse gas emissions ratify it. Current pledges of Intended Nationally Determined Contributions (INDCs) emissions reductions give 3 to 4°C of warming. However, the contributions should be reported every five years and are to be registered by the UNFCCC Secretariat. Each new reduction target should be more ambitious than the previous one. Although further warming will occur, the Paris Agreement provides the mechanism where countries ratchet up their "Nationally Determined Contributions" (NDCs) over time. This represents the opportunity and hope for global greenhouse gas mitigation. Only time will tell if the political commitment is there – but virtually all countries have accepted the negotiated agreement, which is a bottom up approach. To really work, it still requires ratification and then some measure of enforcement! While past climate changes have had huge effects on life and land in the world, it is impossible to say with any certainty what any specific effects will be in every region, particularly because the change will happen much more quickly than ever before. The approach scientists use to deal with these uncertainties is to develop 'scenarios' that describe a plausible range of future climates consistent with the latest climate modelling results. Uncertainty bedevils components of the science of climate change. It will not be eliminated any time soon, so the best way to help policy makers is to try to forge a consensus about the degree of confidence that can be assessed and provide climate scenarios for guidance.

Wildlife, native forests and coral reefs are expected to be hit hard by the changing climate. The current climate scenarios show that temperatures will rise too fast for many species and they will be unable to adjust quickly enough to establish themselves in more suitable climates several hundred kilometres away. Without human intervention there is a high chance they will become extinct. The speed at which the changing climate is driving both animals and plants by creating new barriers and boundaries is faster today as compared to the prehistoric change in the last 20,000 years. There are risks to coral reefs where sea temperatures in many tropical regions have increased by almost 1°C over the past 100 years, and are currently increasing at 1.2°C per century. Mass coral bleaching has occurred in association with episodes of elevated sea temperatures over the past 20 years and this mass bleaching has resulted in significant losses of live coral in many parts of the world. The rapidity of the changes that are predicted indicates a major problem for tropical marine ecosystems.

Insect species play fundamental roles in providing services for animals and plants, such as pollination of native plants and crops, the turnover of nutrients, and reducing pest species via natural enemies. Many other species are pests of crops and forests, carriers of disease, invasive and nuisance insects to humans.

From climate scenarios, environmental effects on other climate-related features such as water resources can be evaluated. This evaluation is vital if we are to plan for activities such as utilizing the water assets of Australia's Murray-Darling Basin. We live on a water planet and it is essential for life on Earth. Water is needed to grow food, to support our industries and to maintain our quality of life. Seventy per cent of the surface of the Earth is made up of ocean.

Changes to the availability and quality of freshwater resources are expected to be one of the major ways in which people, and the environment, experience climate change impacts over the coming century. With demand for fresh water increasing and a warmer climate changing the availability and quality of fresh water, how we manage to supply all our water needs will need to change.

Predictions of a rising sea level, and debate over how much land will be lost, is perhaps the most widely reported physical impact we can expect as our world gets warmer. Many regions will find that their current crops and pasture species are no longer suitable under a changed climate. Climate warming has already caused some changes in crops grown in parts of the world, and it is now possible to grow some crops in more poleward latitudes and higher elevations than before. Whether you're a corn grower in the United States or a wheat grower in Australia, climate change is likely to play an increasingly large part in planning decisions over the next several decades and beyond for those involved in food production and security. Key adaptations through farm level management and via effective crop breeding systems are required for ensuring sustainable and productive wheat systems that augment global food security.

Of the approximately 14 billion hectares of ice-free land on Earth, around 10% is used for crop cultivation, while an additional 25% of land is used for pastures. Moderate warming may benefit pasture yields in temperate regions, while it would decrease yields in semi-arid and tropical regions where countries are also likely to face water resource and land degradation issues. Direct climate change impacts (e.g. temperature and rainfall), and also livestock emissions (mainly how mitigation imperatives will affect livestock production) and observed consumer patterns (rising vegetarianism in the affluent versus rising demand for animal protein with rising affluence) are important issues.

In the oceans, changes in primary and secondary production, which is production of plankton, krill and crustaceans — the foundation of the marine food web — will obviously have a major effect on fisheries production. On a brighter note, warmer temperatures are likely to mean some warmer water fish species will move towards the poles.

Even human health will be affected by rising temperatures. The necessity to plan for increasing frequency and severity of heatwaves, especially in our urban areas, and various temperature-sensitive infectious diseases, or their vectors, indicate that global warming is also influencing patterns of distribution and occurrence.

We must think of climate change in terms of risk, not certainty. The climate problem, like the ozone problem, is filled with 'deep uncertainties': uncertainties in both probabilities and consequences that are not resolved today and may not be resolved to a high degree of confidence before we have to make decisions about how to deal with their implications. Human-induced climate change is widely regarded as one of the greatest — if not *the* greatest — moral challenges of the 21st century. Not merely does it raise numerous ethical issues, but many of these are profoundly difficult and take us to the limits of our moral imagination. The lack of major climate policy in many countries raises ethical and intergenerational issues. There is hope with the Paris Agreement, but action has to occur now, with strong pressure from civil society.

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While the reviewer has provided comment on drafts of this article, he does not necessarily endorse it in its final form. The author is solely responsible for any errors and judgements that may exist in the published article.

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