A DISCUSSION ABOUT CLIMATE CHANGE

By Harry Keys, Earth scientist and ex DOC volcanic risk manager. July 2019

Background

Following some interesting discussions at a friend's 60th birthday party earlier this year, which prompted a series of letters about climate change in the Wellington Section of NZAC's monthly bulletin Vertigo, I have spent some time looking further into some of the more controversial aspects of the climate change debate. I wanted to upgrade my own understanding about this crucial of issue for human-kind. This paper summarises the result.

Climate change is important, so it provokes debate

Earth climate and sea level have always changed between warmer and cooler intervals. What is important to us today is how much the climate suited to us humans will change over time. Climate affects land and ocean environments and fundamentals like water distribution, food production and energy use. People, communities, agencies and governments need to know the extent of possible changes and their likely impacts. Debate has ensued because of the importance of climate, projected changes, and underlying interests. Well-funded bodies promoting opposition to climate science have been around since the 1990s. It is often difficult to separate the facts from the assumptions, misinterpretations and misinformation. Even the fundamental difference between weather and climate (average weather over years to millennia) can be misunderstood. In New Zealand ideological distinctions perhaps are starting to fade, at least in the main political parties.

Building an understanding about climate change is a global effort

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988, dedicated to providing the world with an objective, scientific view of climate change, its potential impacts and risks and realistic response options. The IPCC, currently in a sixth cycle of assessment, is now a 195 member-strong organisation of governments. Prior to the IPCC an ad hoc group under the US National Academy of Sciences prepared an assessment of carbon dioxide and climate in the late 1970s, followed by other international conferences and workshops. These initiatives, in turn, were built on centuries of thinking before.

Understanding controls on climate, including the causes of the 'ice ages', have gradually developed since the 17th century. Early pioneering work included Newton's law of universal gravitation (1687), Fournier, Tyndall, Arrhenius and then Milutin Milanković's hypothesis (drawing on Newton's law) of the effect of Earth's orbital parameters (1920s) on Earth's glacial cycles. Just as with modern science, their thinking was subsequently recognised but also criticised for various reasons including the simplicity and/or incompleteness of their theories, their failure to explain precisely some observations or incorporate some other relevant aspects of climate.

Now, hundreds, maybe thousands of scientists and others from all over the world, in many specialities, volunteer their time to the IPCC. They assess the thousands of scientific papers published each year, fact checking data sets and conclusions to summarise what is known about past climate and drivers of climate. They identify the strength of scientific agreement and advise governments who develop climate policies. This gives the IPCC credibility. IPCC represents a huge body of climate science and a significant proportion of the scientific community are engaged in such work – far more than simply a small clique of activist climate scientists.

Limitations do not invalidate scientific models about climate change

Climate scientists, like earth scientists generally, are unable to perform controlled experiments on the planet as a whole and then observe results. Instead, countless empirical tests of numerous different hypotheses have built up a massive body of Earth science knowledge. Sometimes a combination of observations, comparisons and mathematical models of interactions in the climate system can be used to test hypotheses.

Climate models are mathematical representations of the complex and varied interactions between the atmosphere, oceans, land surface, ice and the sun. They estimate trends rather than events. For example, a climate model can't tell what the temperature will be on a specific day – that's weather forecasting, which also uses models (different ones). Climate models have to be tested against what we know happened in recent past decades of the instrumental era and know reasonably well, within uncertainties, of earlier times.

Repeated examination of uncertainty, testing, model development, and inter-model comparisons have refined our understanding, with underlying theories either rejected or improved and unsuccessful hypotheses abandoned. This is an illustration of the inherent self-correcting nature of science, of which the IPCC assessment process is a classic example. This is a constant seeking of the 'scientific truth', whatever that might be. On the contrary, social media and the internet do not necessarily distinguish facts from unproven statements. Arbitrators on social media are absent or weak relative to the science process.

CO_2 does cause global warming

Testing models against the existing instrumental record indicates that carbon dioxide (CO_2) in the atmosphere must cause global warming, because the models could not simulate what had already happened unless the extra CO_2 was incorporated in them. In this sense CO_2 is a 'forcing'. All other known forcings like large volcanic eruptions, solar variations, atmospheric and oceanic circulation, and albedo (related to sea ice extent and land use/cover) are adequate in explaining temperature variations prior to the rise in temperature over the last 30-50 years. But none of these other forcings are capable of explaining the rise since then.

It is crucially important to understand CO_2 impact lag

Snow and ice conditions and changes have long been of interest to many climbers, trampers and skiers. For decades we have seen major glacial retreat throughout NZ. But following the persistent El Nino – Pinatubo eruption aftermath of 1990-1995, we also saw spectacular advances of the Fox and Franz Josef glaciers into 30 year-old vegetation. Now those glaciers have again retreated dramatically. Such responses to climate change are now widespread as glaciers have become out of equilibrium with climate as the freezing point of water is exceeded more often in time and space. With a continuation of the current climate they will continue melting away for decades to centuries or more. This lag is a characteristic glacier response to changing climate, whether naturally occurring or forced by human activities.

Like the time lag in glacier change, global climate change (and science and policy) lags behind increased emissions of greenhouse gases (including CO_2, methane, nitrous oxide and fluorinated carbons). The greenhouse effect, a natural process, takes its name from the glass greenhouses which have been used for centuries to trap heat. Some have known for 150 years (Tyndall) that CO_2 absorbs infrared radiation and for 100 years (Arrhenius) that this causes the atmosphere to trap heat radiated from the Earth's surface and re-radiate it back to the surface. Whether we view the most important greenhouse gas, CO_2, as a pollutant or not is just semantics.

Humans are influencing climate change

We have known for 60 years (Keeling) that the measured concentration of CO_2 in the atmosphere has been rising above preindustrial levels and, from the mid-1950s (Suess, Revelle, Suess, Keeling, Broecker, Stuiver and Quay) it became clear this is due to fossil fuel combustion. Given the long legacy of our emissions of CO_2 in the atmosphere and the thermal inertia of the oceans, we are currently experiencing the climate effects of our fossil fuel use decades ago. It will take decades more (perhaps 40 years) for the impact of our current emissions to be reflected by sea level.

Even with uncertainties like climate sensitivity and the role of clouds discussed since the 1930s (Hulburt, Caendar, Plass), human influence on the climate system is now clear. Evidence includes the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing (aka enhanced greenhouse effect) driven by that extra gas, observed warming, and understanding of the climate system with recent advances in model-based climate studies supported by proxy studies of past climate. Anthropogenic (human-induced) global warming, estimated using models, matches the level of observed warming currently, increasing at about 0.2°C per decade, to within ±20%.

Though imperfect, climate change projections are valid

Projections have been a basic thrust of climate change science and models. (Projections are not hypotheses or predictions (though many people will see the difference as semantic). The easiest projections to understand are those to do with the melting/freezing point of ice/water and many other aspects of the cryosphere. Early projections of fewer or less intense frosts, rising snowlines and accelerated thinning/retreating of glaciers as temperatures warm, have generally been matched by recent observations. While the response of glaciers to warming conditions in the decades following the Little Ice Age (c 1450-1850 CE) has obscured their response to human-induced change, evidence is starting to emerge that some glaciers may be approaching their previous minima during sustained warmer periods of the Holocene. IPCC (2013) consider that if glaciers continue to reduce at current rates, most glaciers in the extratropical Northern Hemisphere will shrink to their minimum extent, some 8000 to 6000 years ago, within this century. Snow cover extent and duration of the snow season has decreased in the Northern Hemisphere, especially in spring. In the Southern Hemisphere, evidence is too limited to draw such general conclusions, but rising snowlines are apparent in Tongariro National Park. While these trends are expected to continue, this is not to say that these changes have been universal. Changes in synoptic weather events can affect freezing and melting. Increased moisture content of warmer air or natural variability such as ENSO obscure some trends.

Escalating sea level rise was also an early projection of climate change science. Sea level has the potential to affect many coastal cities and other people living near vulnerable coasts. IPCC (2013) conclude that the rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia and, by the early 20th century, transitioned from relatively low mean rates of rise to higher rates, reaching 3.2 [±0.4] mm/yr between 1993 and 2010. This is mainly due to glacier mass loss and ocean thermal expansion from warming.

Some climate variations do matter

Statistically significant changes in some kinds of extreme weather and climate events have been observed since about 1950. These include the number of cold days and nights (decreased) and the number of warm days and nights (increased) on the global scale. It is likely that the frequency of heat waves has increased in many areas. There are likely more land regions on Earth where the number of heavy precipitation events has increased than where it has decreased. By the late 21st century IPCC state that the frequency, intensity, and/or amount of heavy precipitation will probably increase over most of the mid-latitude land masses and over wet tropical regions, and some floods may surpass historical floods in magnitude and/or frequency in some regions. But for other regions and events like droughts, that relationship and any change in frequency or intensity are not often clear, sometimes because natural variability (e.g. due to ENSO) in weather is high anyway. Very recently some studies are starting to suggest that increased greenhouse gas concentrations <u>partially</u> drive some extreme weather events such as tropical cyclones.

Some extreme events and projections are overemphasised by both sides of the debate

Extreme events are frequently cited as examples of climate change, despite cautionary notes sounded. Individual storms, fires and pest or disease outbreaks cannot be attributed to climate change. Even if some trends and extremes in temperatures, rainfall, etc can no longer be discounted as natural variability, this does not prove that individual events are caused by human-induced global warming. But equally, arguments that weather-related disasters or increases in predators and fires are completely unrelated to climate change often misrepresent the situation too. Land use decisions sometimes have much to answer for, such as development of floodplains and large scale depletion of forests.

Climate anomalies and extreme events may contribute to increased variability. Some people cite extreme or unusual cold or snowfall events as evidence that climate is not warming or that the models don't work. Synoptic events cause many weather parameters to vary over time and so large variances can be expected with or without climate trends. A projection of increased temperature or reduced snowfall does not mean snow will never fall, or that there will be no extreme snowfalls or periods of extreme cold.

The pace of recent warming is significant

A huge body of climate science has shown that the warming trend over the last 150 years is particularly significant because it is relatively large. It is also proceeding to an extent and at a rate that appears unprecedented over decades to many millennia. Global temperature has risen from near the coldest to almost the warmest levels of the Holocene in little more than the past century, reversing a long-term cooling trend that began about 5000 years ago. Human activities are estimated by IPCC (2018) to have caused approximately 1.0°C of global warming above pre-industrial levels. Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate. Does this matter? In fact some see global temperature change as trivial compared to impacts on sea level and the hydrological cycle.

Climate warming increases sea level

Depending on emission pathways, sea levels are projected to rise between 0.55 and 1.25 metres above pre-industrial levels by 2100. The 1986–2005 average IPCC (2018) model-based projections of global mean sea level rise suggest an indicative range of 0.26 to 0.77 m by 2100 for 1.5°C of global warming, 0.1 m less than for a global warming of 2°C. The implication of a reduction of 0.1 m in global sea level rise is that up to 10 million fewer people would be exposed to related risks, assuming no migration or adaptation. Sea level rise is projected to most likely continue beyond 2100, even if global warming is limited to 1.5°C in the 21st century.

Current atmospheric CO_2 levels suggest the Pliocene Warm Period 3.3-3.0 million years ago may provide an analogy for future conditions. The global mean surface temperature then is estimated to have been 2 - 4 °C above pre-industrial levels and sea level was up to 20 metres higher, due to smaller or ephemeral ice sheets. Atmospheric CO_2 is thought to have been in the range 350-450 ppm, similar to the present-day concentration of CO_2 in the atmosphere, currently increasing through 415 ppm. During the last 800,000 years and probably for the whole of the Pleistocene, the highest CO_2 concentrations were up to up to 300 ppm during the interglacials, with minima down to 175 ppm during the glacial maxima. The claim by blogger D Avery that low concentrations during the Last Glacial Maximum threatened life has been debunked by numerous studies of pollen and human evidence.

Climate change impacts can be good and bad

Climate change will have different impacts on people and regions. Benefits include improved agriculture at higher latitudes and increased vegetation growth in some circumstances. However, sea level rise, extreme events and threats to water will be expensive to adapt to. The Thames barrier cost £1.6 billion (2016 price) to build and, while it is claimed to have paid for itself many times over, some claim it will cease to be useful before 2070. Major storm events like Hurricane Katrina caused an estimated US$80 billion dollars in damage. Reinsurance companies have long been concerned about this.

Species are becoming extinct at the fastest rate in history, partly due to climate change.

Poorer countries affected will struggle most. Developed economies will be able to afford the costs but there will be opportunity costs in doing so.

Incentivised action

Mitigation of and adaption to climate change are the subject of much debate internationally and locally. Climate stabilisation targets linked to the UN Framework Convention on Climate Change and intergovernmental meetings have driven some policy debate. Climatic 'tipping points' have been invoked in these fora but seem to have little scientific justification except possible marine ice sheet collapse in Antarctic and methane feedbacks in the Arctic. Reduction in emissions is much discussed, and some European countries appear to have made some, but so far there has been no sustained reduction in the growth rate of CO_2 in the atmosphere (as measured at Moana Loa).

There is no doubt we need to make faster progress in mitigation. For most there is no doubt about the looming impacts of anthropogenic climate change, including a rise in sea level we are bequeathing to coming generations. Sea level rise, retreat of glaciers relied on for water especially, but also temperature rise and hydrological changes, make it clear that the sooner we reduce fossil fuel emissions the better.

Developed countries would like better access to energy. Penalising developing countries, or countries like NZ where pastoral food production is said to be more carbon efficient than others, is not the answer.

In New Zealand part of the solution has to involve stronger incentives of various kinds to reduce carbon emissions. Planting trees is not enough but may help. Incentives to increase the use of renewable energy and lower fossil fuel use, especially in the transport sector, have to be part of the solution. Similarly, incentives are needed to reduce methane and nitrous oxide emissions from the farming sector. Advances in vanadium redox batteries may help overcome problems of storing renewable energy on land, as recently installed in Adelaide and Dalian, China. New Zealand has significant geothermal energy generation already consented to help the transition. Other technological advances are likely to help but we can't rely on them to solve the problem. Decoupling GDP from emissions will help and appears to be possible, if evidence is to be believed from countries like Sweden (which apparently has the highest carbon tax), and California.

Climate change is a huge issue and I have blatantly plagiarised while preparing this summary - especially reports from IPCC and articles from skepticalscience.com. Papers by Marcott et al 2013 (Reconstruction of regional and global climate for the past 11,300 years) in Science Vol 339, (6124) and Mortlock et al 2019 (The need for transparency in climate services). Risk Frontiers Newsletter No 18 (3) provide useful detail and consensus. I benefitted from a discussion with Prof James Renwick, VUW.