Unpacking the Science in Climate Change Teaching

GZ Science Resources

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Content Knowledge of Climate Change: Preparation for Junior Secondary School Science teaching

Climate Change – PCK (GZ)

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Introduction

Climate change (CC), understood to be a long-term measurable change in climate, is accelerating due to anthropogenic (human-caused) activities (IPCC, 2013, p. 121). CC repercussions will vary across New Zealand (NZ), but they can now be predicted with a good level of confidence (Ministry of the Environment, 2018). Past and present human industry, including the combustion of fossil fuels, transport, and agriculture (NASA, 2018), have increased the concentration of greenhouse gases (GHG) in the atmosphere. This has shifted the net balance of radiant energy from the Sun (IPCC, 2013, p. 121, 126), causing the average Earth temperature to rise. CC will shift rainfall patterns; some regions in NZ are projected to get drier, while others will get wetter (Ministry of the Environment, 2018). Extreme weather events will increase in frequency (IPCC, 2014, p. 1374), oceans will undergo further acidification (DeWeerdt, 2017), and the rate of cryosphere melting will accelerate (Wong, 2016). CC is an important issue that should form an integral part of science education, and students must be able to draw from a solid scientific knowledge. This will enable them to be informed 21st century citizens, preparing them to adapt to the challenges of CC, and contribute to the adaptation and mitigation solutions reducing its impact (National Research Council, 2012).

Understanding the causation of CC is the first step to scientific verification (Wong, 2016), and required when planning an effective unit of learning. Shulman (1986) claimed "those who understand, teach" (p. 14), and he emphasised the need for teachers to develop a clear understanding about what they are to teach, as part of their Pedagogical Content Knowledge (PCK). Gess-Newsome (2015), expanding on the idea of PCK, explained that effective teaching requires a topic-specific professional knowledge (TSPK), where the focus on content knowledge is at a more detailed level, rather than just at a broader disciplinary level. Achievement Objectives from across all four strands of the Science curriculum, from the NZ Curriculum L3-6, can contribute into a robust contextualised CC teaching programme (Ministry of Education, 2014), and be based on the mechanics of causation and CC consequences. Content knowledge of CC encompasses why carbon dioxide gas (CO_2), in particular, is responsible for the greenhouse effect, therefore, speeding up the transfer of thermal energy (Tasquier, Pongiglione & Levrini, 2014). The carbon cycle, and components in the climate system will help students understand the difference between natural fluctuations and those acerbated by human activity. The consequences of CC, and specifically those that directly affect NZ, can be linked to adaptation and mitigation options (IPCC, 2014, p. 1374), to provide pathways for the involvement and empowerment of the learners.

The Development of Climate Change Science

Aspects of science, forming the keystone of current CC understanding, such as the greenhouse effect, have been common knowledge within the scientific community since the late 19th Century (Cohen & Waddell, 2009), when scientists began to link the increase of CO_2 in the atmosphere to a global temperature rise. In 1896, a Swedish physicist, Svante Arrhenius, predicted the global temperature could rise as much as 6°c if CO_2 levels doubled in the atmosphere (Cohen & Waddell, 2009). Records for global average temperature have been reliably collected since 1850 (Reisinger, 2009), once measuring stations were established around the world.

Public awareness about the looming global crisis of CC started to creep into the mainstream by the late 1970's. Observations, collected from established branches of science dealing with climate, atmosphere, oceanography, carbon cycling, and the greenhouse effect, were used to make much more accurate future predictions with the availability of effective modelling computers (Rich, 2018). Worldwide cooperation of scientists culminated in the formation of the Intergovernmental Panel on Climate Change (IPCC) in 1988, which release periodic Assessment Reports (Cohen & Waddell, 2009), used by Governments, policy groups, and industry, to justify and plan CC initiatives (Colaianne, 2015).

The Carbon cycle

There is a fixed amount of carbon on Earth, much of it combined with other elements forming compounds, that moves through a carbon cycle, from one reservoir to another, with varying processes and timescales (Cohen & Waddell, 2009). Atmospheric CO_2 is the key driver of CC, but makes up one the smallest carbon reservoirs (Dlugokencky & Tans, 2015). The largest reservoir of carbon is in ocean water, acting as a *carbon sink*, with a net movement of carbon into the ocean from the atmosphere (Lal, 2008). Once in the ocean, carbon enters the marine food chain via photosynthesis, as well as being utilised for invertebrate shells and skeletons made by calcifiers, such as marine molluscs and microorganisms (DeWeerdt, 2017). This sequestration mechanism acts as a *biological pump,* with carbon moving in one direction through the ocean's organisms (Science Learning Hub, 2010). Carbon from the sedimentary remains of marine organisms becomes locked up, often for millions of years, once it is processed into rocks, such as limestone, and fossil fuel carbon reservoirs (Science Learning Hub, 2010), with coal forming from ancient plant remains, and natural gas and oil from marine organisms (Lal, 2008). Methane (CH_4), mostly formed through biological processes, is a potent GHG found in the atmosphere, in permafrost near the poles, and also stored under the sea floor in the form of hydrates, stabilised by pressure and stable cool temperatures (Schuur et al., 2008).

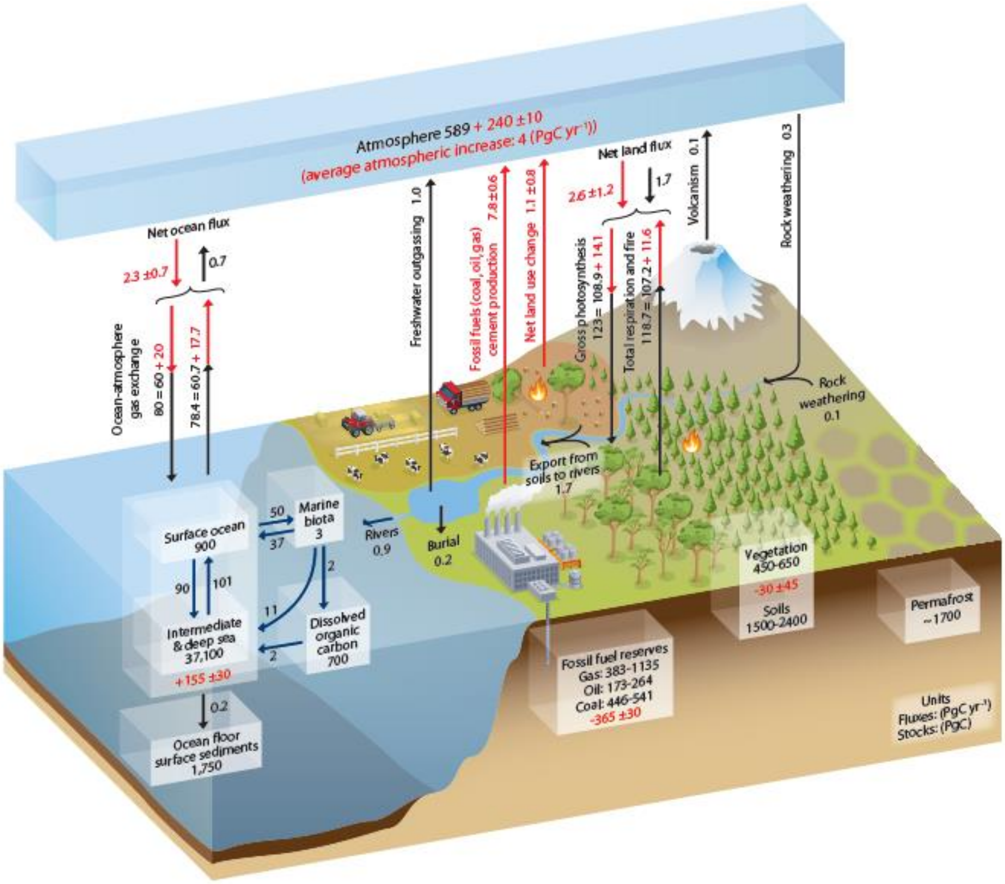

Figure 1. Global carbon cycle model. Black numbers represent reservoir mass in PgC (1 PgC = 10^{15} gC). Black arrows (in PgC yr^{-1}) indicate exchange fluxes (movement) prior to the Industrial Era (1750). Red arrows indicate annual average 'anthropogenic' (caused by human activity) movement over the 2000–2009 period. Red numbers show the total change of anthropogenic carbon from 1750–2011 (IPCC, 2013, p. 471)

Human activity is increasing the net flow of carbon from other reservoirs into atmospheric CO_2 (Millar, Allen, Rogelj, & Friedlingstein, Pierre, 2016). Anthropogenic combustion of fossil fuels accounts for the greatest change to the carbon cycle in the post-industrial age, which converts most of the carbon locked up in oil, gas, or coal, into CO_2 released into the atmosphere (Millar et al., 2016). Past records from ice cores show that the level of CO_2 in the atmosphere is higher than at any time since humans have been on Earth (Reisinger, 2009). "Carbon dioxide concentrations [in the atmosphere] have increased by 40 per cent since pre-industrial times" (Ministry of the Environment, 2016, p. 17), and currently sits at around 406ppm (CO2.Earth., 2018). As the atmospheric CO_2 increases, so too does the amount dissolved in the oceans, with currently over 30% of anthropogenic emissions transferred to the ocean's waters (DeWeerdt, 2017; Ministry of the Environment, 2016). Recent data indicate that carbon sequestration in the land and ocean sinks may have reached capacity (Lal, 2008).

The Greenhouse Effect and thermal transfer

The Earth's atmosphere is comprised of a mixture of mostly N_2 (78%) and O_2 (21%), with only trace amounts of CO_2 (0.03%) (Boorstein, & Renneboog, 2012, p. 62). The Sun, from which the Earth receives virtually all of its energy, is a hot radiating body and, therefore, sends out the radiation in the form of short wavelengths (around 0.5 microns), mostly as visible light. The short wavelength radiant energy travels with little resistance through the Earth's atmosphere until it reaches the surface, where it is absorbed, and then most of the energy re-radiated. The Earth is much cooler than the Sun, so energy travels in longer wavelengths (from 8 to 13 microns), mostly as infrared radiation (heat) (Wong, 2016). Atmospheric CO_2, H_2O, and methane (CH_4) are able to absorb and emit this longer wavelength energy, causing the atmosphere to heat up, as more energy is retained than released back out into space (Ministry for the Environment, 2016). The change in the radiation balance of the Earth is known as *radiative forcing* (Park & Allaby, 2017). This is the principle of the *greenhouse effect* (Park & Allaby, 2017), and gases that absorb the infrared radiation are known as greenhouse gases (GHG). Some gases, such as O_2 and N_2 are insignificant in regards to the greenhouse effect, resulting from their particular molecular structure. CH_4 and H_2O are 'stronger' GHG than CO_2, but due to their 'half-life', they have less influence (Cohen & Waddell, 2009). H_2O cycles rapidly through the atmosphere and CH_4 only persists for around 12 years, compared to CO_2, which remains for hundreds of years (Wong, 2016). Shifts in the past atmospheric concentrations of CO_2 are linked to natural fluctuations in the climate, but it is now apparent that the predominant factor in current CC is anthropogenic emissions of GHG (IPCC, 2013, p.121).

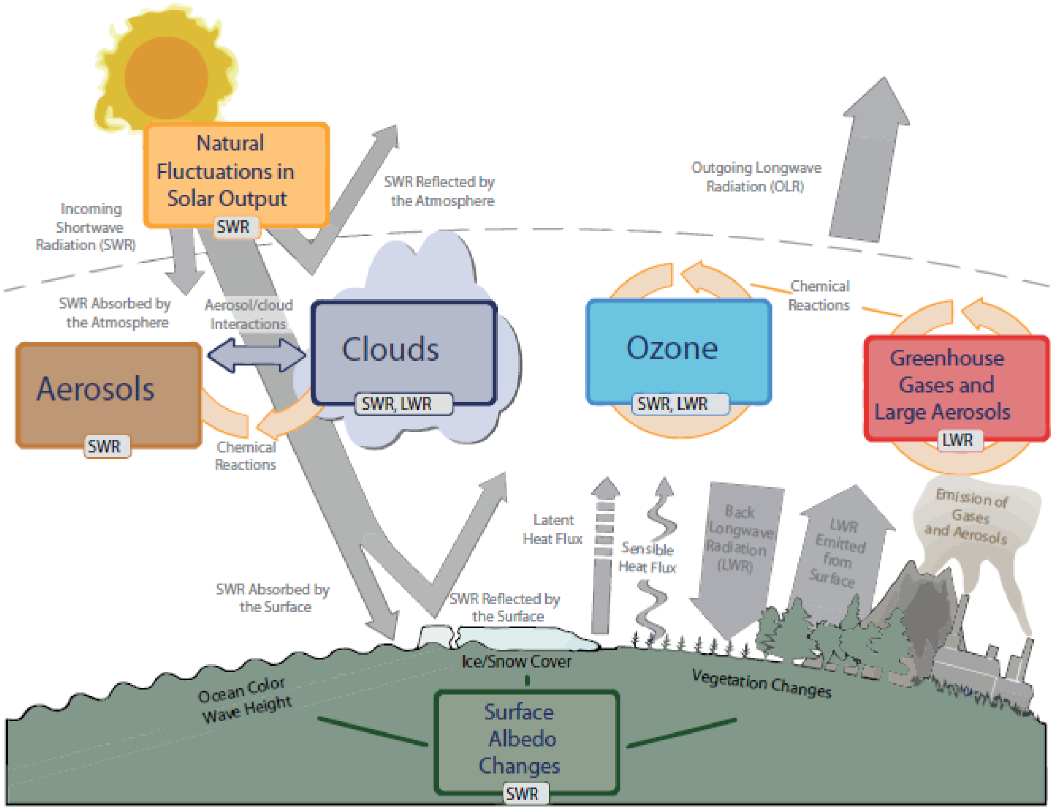

Figure 2. The greenhouse effect and radiative forcing. (IPCC, 2013, p. 126)

Climate change, extreme weather events and increasing global temperature

Climate, the average weather occurring over a long-term in a particular region (Park & Allaby, 2017), is influenced by temperature, precipitation, and amounts of solar radiation. Climate is also determined by altitude, longitude, and the distance to large bodies of water, and in contrast to weather, which is normally limited to a smaller area, changes are much more gradual. Powered by the solar radiation, the Earth experiences natural fluctuations and cycles in its climate (IPCC, 2013, p. 129). Scientists use evidence, in the form of observations and models, to establish that human activity contributes to climate change. Reliable temperature and rainfall observations have been recorded since the end of the 19th century. The *Keeling curve* represents readings of atmospheric CO_2 from the Mauna Loa Observatory in Hawaii, collected since 1958 (Park & Allaby, 2017). Climate Signals are long-term trends, including temperature, sea level, glaciation, and rainfall patterns (www.climatesignals.org, 2018), and allow us to detect if there has been any significant departure from naturally expected climate trends (Cohen & Waddell, 2009). Evidence can also be collected from "vegetation, soil, [and] historical ice-cores" (Cohen & Waddell, 2009, p. 44), enabling us to see trends over much longer time spans. Naturally fluctuating temperature and carbon dioxide signals, prior to human activity, can be compared to post-industrial signals. Using observations and projections, scientists can now state that it is "extremely likely" (Ministry of the Environment, 2016, p. 25), with a confidence of 95-100%, that CC is due to anthropogenic influence (Ministry of the Environment, 2016).

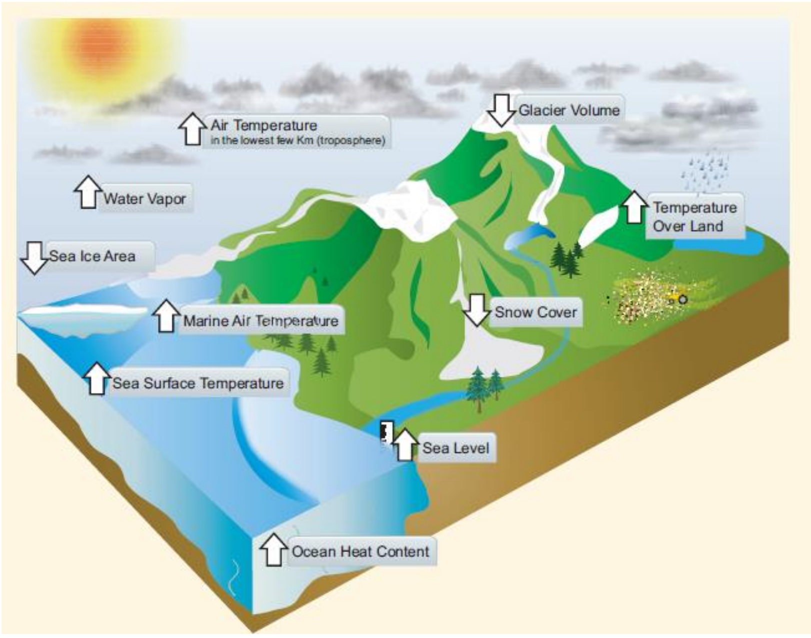

Figure 3. Features of the climate system (climate signals) affected by climate change. The arrows show the direction of change. (IPCC, 2013, p. 198)

The past three decades have been hotter than all decades since temperature observations were recorded in the 19th Century, and the warmest has been the most recent decade (IPCC, 2013, p. 161). Using climate models generated from the NIWA supercomputer, the Ministry for the Environment (2016) predicts that, for a medium emissions scenario, NZ may experience a temperature increase of "0.8°C by 2040, 1.4°C by 2090, and 1.6°C by 2110, relative to the 1986–2005 period" (p. 11), with a maximum of 5.0°C in 2110, using the highest emission scenario. Changing rainfall patterns can also be predicted using CC models, and in NZ it is projected that the west of both Islands will become gradually wetter and the north and east will become drier in climate (Ministry of the Environment, 2016). In future, it is also predicted that NZ will have "more "hot days" and fewer frosts" (NIWA, 2016). Temperature and precipitation extremes have increased and become more frequent around the world (Stott, 2016). Extreme weather events (EWE) are stronger, and occur less often than typical weather. EWE are induced by both natural and anthropogenic forcings (IPCC, 2013, p. 1374), which cause a shift in the radiative energy balance powering the Earth's climate system. EWE include droughts, storms, deluges, heat waves, and tornados (Hansen, Sato, & Ruedy, 2012), and have increased in frequency since the 1950's (NASA, 2013). EWE in NZ are predicted to increase in frequency, and include both extreme rainfall events and drought across the country (Ministry for the Environment, 2016.).

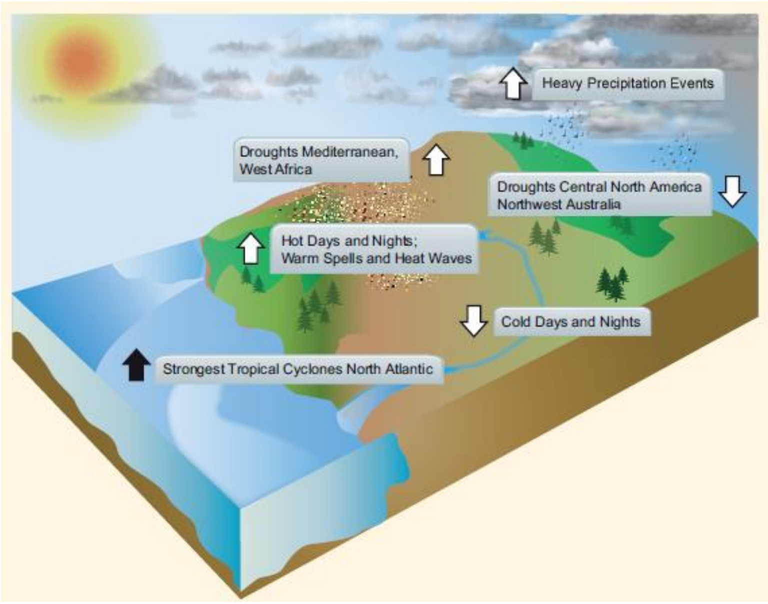

Figure 4. Frequency trends for Extreme Weather Events in the past 50+ years. (IPCC, 2013, p. 219)

Melting of the Cryosphere and sea level rise, and ocean acidification.

Multiple lines of evidence show that global warming, as a consequence of CC, has caused the reduction of the *cryosphere*, consisting of sea and land ice, glaciers, and permafrost (IPCC, 2013, p. 319; Park & Allaby, 2017), in the past 30 years (Wong, 2016). Paleo records show that previous episodes of naturally induced global warming, around 2°C warmer than current temperatures, had produced a sea level rise (SLR) of more than 5m above present levels (IPCC, 2013, p. 1139). Observations now show that the Arctic sea ice is becoming thinner and smaller with each passing year (IPCC, 2013, p. 319). Continued warming of the planet could cause some large ice sheets, such as Greenland, to totally disappear, adding nearly 7m to long-term SLR (IPCC, 2013, p. 1140). The main contributors (75%) to SLR have been the melting of glaciers, predicted to continue shrinking even if the temperature stabilises (IPCC, 2013, p. 319), and more recently the Antarctic and Greenland ice sheets. Calving glaciers make up 90% of the continental ice loss (Hattermann, Nøst, Lilly, &. Smedsrud, 2012). The disappearance of surface ice and snow is reducing the albedo, revealing dark rock or water, therefore, a significantly higher amount of energy is absorbed rather than reflected. This increases the average temperature near the polar areas, and induces even further melting (Cohen & Waddell, 2009). Thermal expansion from heating oceans also contributes to SLR (IPCC, 2013, p. 1139), as the average temperature of the ocean risen 0.17°C in the past 40 years (Wong, 2016). The ocean water has a high capacity to absorb energy and, therefore, shows a slower increase in temperature than on land. Increasing sea temperatures, and melting permafrost can also release stored CH_4, a strong GHG, into the atmosphere. (Schuur et al., 2008).

Predicted ranges for SLR by 2100 are from 0.26 to 0.98 m, depending upon future emission levels (IPCC, 2013, p. 1140). In the last decade the rate of SLR is double that compared to the previous century (Wong, 2016), with small islands most exposed to risk (IPCC, 2014, p. 1616). NZ is particularly susceptible to SLR, due to the long coastline, and the position of many communities, and major cities, in low-lying areas near to the coast (Lawrence, Bell, Blackett, Stephens, & Allan, 2018). The rising sea levels will cause coastal land erosion and flooding, and result in reduced land area (Ministry of the Environment, 2018). Additionally, the reduced cryosphere will cause loss of habitat for polar and alpine communities, and reduced meltwater from glaciers, such as those in the Himalayas glaciers, increasing water scarcity for large human populations (Wong, 2016).

$CO_{2,}$ from anthropogenic activity, is being dissolved into the ocean carbon sinks, causing ocean acidification (IPCC, 2013, p. 259). Since the Industrial Revolution, the pH of the water has decreased from an average of 8.2 down to 8.1, resulting in a 26% increase in hydrogen ions released from the acid (DeWeerdt, 2017). Acidification is detrimental to many marine organisms, as most function optimally within a narrow range of pH. Outside of this range an organism requires more energy to complete physiological functions, which results in less energy being available for food procurement and reproduction (IPCC, 2013, p. 295). Lack of carbonate, neutralised by acid, creates weak or deteriorating shells and skeletons in marine organisms (Young & Gobler, 2016), and some corals (DeWeerdt, 2017). Corals are also very vulnerable to a temperature increase in the oceans, with significant portions of the Australian coral reef system being bleached (IPCC, 2014, p. 1375). Additionally, warmer oceans are able to dissolve less oxygen, causing levels to O_2 drop (IPCC, 2013, p. 296), and placing more stress on marine communities.

Climate Change Impacts and Adaptation

CC is causing global temperatures to rise, changing rainfall patterns, increasing the frequency and strength of EWE, increasing ocean acidification and SLR; all of which is producing a multitude of consequences around the world (Reisinger, 2009). NZ is also likely to experience climate shifts, and many endemic species, already under threat, may face extinction (Climate Change Adaptation Technical Working Group, 2018), as they are unable to adapt to the rapid changes in their habitats. In NZ, we are likely to see ecosystem damage (IPCC, 2014, p. 1375), habitat shifts for plant and animal species, and an earlier start of spring plant growth, migration, and mating events (Ministry of the Environment, 2018). CC will affect the way we produce our food, manage our land and water resources, as well as have an impact on the infrastructure that we rely on in our rural and urban communities (Climate Change Adaptation Technical Working Group, 2018).

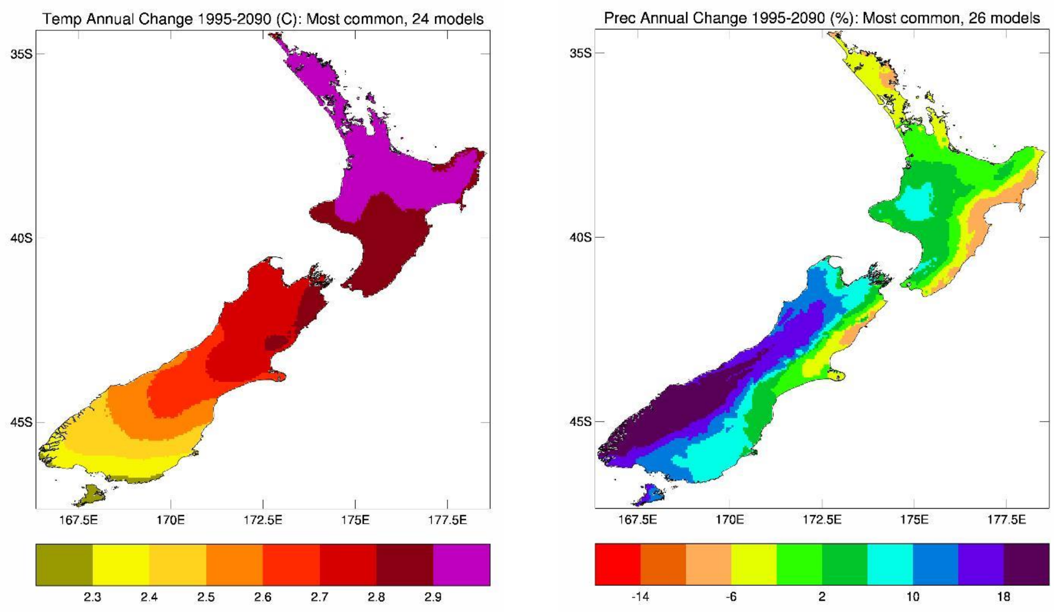

Figure 5. Projected annual temperature (left) and precipitation (right) change between 1995 and 2090 from highest range (RCP8.5) emission models. (Ministry of the Environment, 2016, pg. 31)

Climate Change – PCK (GZ)

In responding to the impacts of CC, we must consider adaption, utilising both immediate remedial projects and planned responses to future predicted impacts (Cohen & Waddell, 2009), and anticipating issues before they arise (Climate Change Adaptation Technical Working Group, 2018). Adaptation to CC must take into account a range of scenarios, recognising regional variations, in temperature, rainfall, and other factors (Cohen & Waddell, 2009). In NZ, planning for adaptation has already begun, moving from conceptual into implementation (IPCC, 2014, p. 1374), with strategies for avoiding, accommodating, retreating, and defending against CC impact (Climate Change Adaptation Technical Working Group, 2018). Examples of adaptation strategies include habitat protection, migration corridors between alternative habitats, and coastal planting. Preparation for more frequent EWE could include relocating vital municipal resources such as power and water supplies to safer sites, building flood barriers, and running drills in response to possible future scenarios (US EPA, 2017). Implementing adaptation strategies in NZ will involve working in partnership with iwi / hapū (Nottage, 2010), and making the best use of local knowledge and Mātauranga Māori, to create feasible projects (Climate Change Adaptation Technical Working Group, 2018).

Mitigation responses to climate change

Whereas adaptation strategies deal with reducing the impact felt by a range of observed current and projected future CC challenges, mitigation focuses on limiting or controlling the factors contributing to CC (IPCC, 2014, p. 114). Mitigation comprises of actions untaken by countries, businesses, and individuals to reduce or avoid the negative effects due to CC, and this can include limiting energy use, developing alternative low carbon fuel, or sequestering CO_2, either naturally or with technological innovations (Lal, 2008). Even with comprehensive mitigation remedies to drastically curtail current CO_2 emission rates, the inertia of the CC system will allow only slow stabilisation of temperature, with a projected rise of 2°c. However, the consequences of doing nothing far outweigh the efforts and costs of mitigation (Reisinger, 2009). Mitigation must consider a range of projected CO_2 emissions in the planning stage, called Representative Concentration Pathways (RCPs) (Millar et al., 2016; NIWA, 2016).

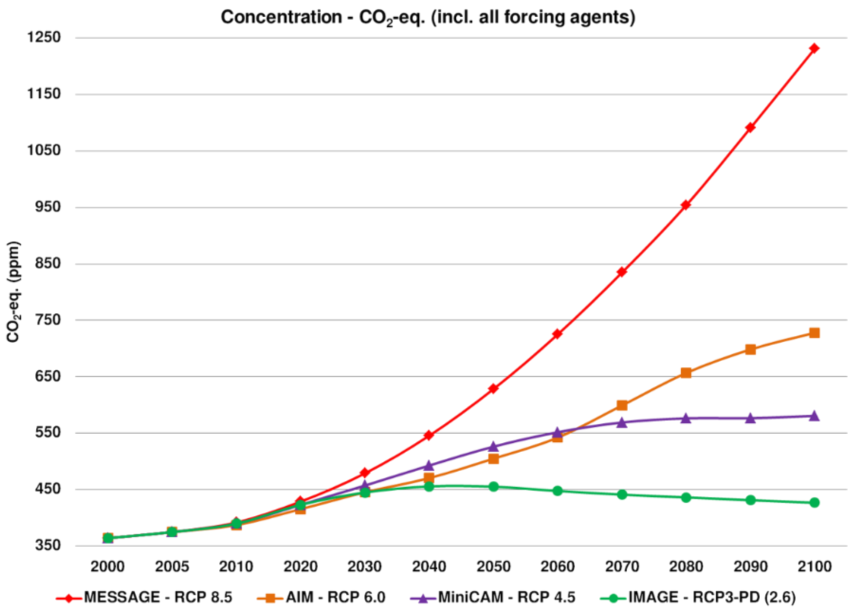

Figure 6. Projected possible atmospheric CO_2 levels (ppm) from four RCP models. Retrieved from: https://commons.wikimedia.org/wiki/File:All_forcing_agents_CO2_equivalent_concentration.png

Worldwide emission reduction targets were set by the *Kyoto Protocol* in 1997 (Park & Allaby, 2017), when most developed countries agreed to reduce their emissions of GHG by at least 5% by 2012 (Hodson, 2017). The 2015 Paris Climate Agreement, signed by 194 countries, focussed on self-imposed emissions targets that would limit the global temperature to below 2°c above pre-industrial levels in the 21st Century (UNFCCC, 2018). Carbon credits, which have monetary value, were issued to developed countries, and are based on agreed emission reduction targets. Carbon credits can be traded (emissions trading) to offset excess emissions, or used as an incentive to reduce the emissions target further. Numerous other international groups, such as the IPCC, are also contributing to the scientific knowledge base and policy to help with adaptation and mitigation responses (Cohen & Waddell, 2009).

CC mitigation actions can involve the creation of natural carbon sinks such as forestation, where the planting of trees utilises photosynthesis to draw CO_2 out of the atmosphere and store the carbon for longer periods as organic material (Cohen & Waddell, 2009). Other sinks are location dependent, such as utilising the oceans' capacity as a carbon sink, or geological storage, where CO_2 is pumped, then sequestered into porous rocks (Cohen, & Waddell, 2009). Carbon offsetting projects can target alternative fuels and renewable energy, or landfill and fuel production gas capture (Cohen, & Waddell, 2009). The global energy industry alone emits over

30 billion tonnes of CO_2 each year, and in order to comply with the Paris agreement, 4 billion tonnes of carbon must be sequestered annually by 2014, rising to over 11 tonnes by 2060 (Bourzac, 2017). Industry in NZ is currently removing around 30% of its GHG emissions yearly, as part of its mitigation response (archive.stats.govt.nz, 2016). Industry and individuals have a role to play in mitigation by reducing their *carbon footprint*, the amount of CO_2 emitted each year in the course of production or daily life (Park & Allaby, 2017). Businesses and industry can invest in carbon-offset programmes in developing countries, such as clean water or forestation (www.carbonfootprint.com, 2018). Individuals can contribute by reducing their own carbon footprint, in small but cumulative ways, such as tree planting, reduced energy consumption in their homes, switching to alternative fuels in their transportation, or becoming involved in community adaptation and mitigation projects.

Teaching implications of Climate change

Climate change is a very broad, complex, and challenging subject (Oversby, 2014), with many interacting systems that can confuse both students and teachers (National Research Council, 2012). Science teachers can experience a disconnection between CC content knowledge and the curriculum their schools require them to follow, and they can be disadvantaged by their own lack of content knowledge on the subject, that encompasses many disciplines (Tasquier et al., 2014). Misconceptions held by students (Bangay & Blum, 2010) may include confusing ozone depletion and pollution as causes of temperature rise and CC (National Research Council, 2012, p. 39). Unconnected concepts can have less significance if not taught together as one unit (National Research Council, 2012, p. 11), so it is important to create an integrated CC teaching programme based on solid science knowledge that logically connects one idea to another. Key concepts must be drawn from scientifically valid sources, such as the IPCC framework, when developing a unit on CC (Colaianne, 2015).

Understanding the causes of CC is the first step to scientific verification (Wong, 2016), and required when planning an effective unit of learning, where teachers need to ensure that they have comprehensive and up-to-date knowledge of the key concepts taught. While pioneering the concept of Pedagogical Content Knowledge (PCK), Shulman (1986) stated that "those who understand, teach" (p. 14), and he emphasised the need for teachers to develop a clear understanding what they are to teach (Kind, 2009), before combining it with pedagogical, assessment and curricular knowledge (Hestness, McGinnis, Breslyn, McDonald, & Mouza, 2017). Gess-Newsome (2015), expanding on the idea of PCK, explained that effective teaching requires a topic-specific professional knowledge (TSPK), where the focus on content knowledge is at a more detailed level, rather than just at the broader disciplinary level it is found within.

CC impacts can seem insurmountable, and even fear-inducing to students, with several of my colleagues sharing past experiences of students being upset after watching documentaries on the topic. From my own perspective, focusing on the tragedy of CC can create helplessness in the students. Imagery, such as dying polar bears on shrinking ice flows, the CC 'poster child', although effective for public attention to the cause, can be alarming for children. While basing a CC learning programme on solid scientific evidence and modelling, teachers also have a responsibility to include adaptation and mitigation solutions, allowing students the opportunity to contribute NZ based solutions, tailored to their own capabilities. A climate-literate student (Hestness, et al., 2017) will be able to understand the scientific concepts of the climate system, greenhouse effect and the role that CO_2 and other GHG plays in retaining energy on Earth. The student must also be able to access and evaluate credible information sources, as well as communicating and sharing ideas with others (National Research Council, 2012). The challenge to teachers and the education system is to prepare our students with the knowledge that enables them to understand the current and future challenges of climate change (Bangay & Blum, 2009).

Summary

There is now almost universal consensus from the scientific community that human activity, producing CO_2 and other GHG, have changed the energy balance from solar radiation, increasing the average temperature of the Earth, and this is permanently altering the climate around the globe (IPCC, 2013, p. 121, 126). With powerful computers becoming available, models are becoming a more accurate predictor to enable attribution of temperature rise, SLR, and EWE, to CC (Stott, 2016). There is a positive net flow of carbon moving from other reservoirs of the carbon cycle into the atmosphere (Cohen & Waddell, 2009), increasing the CO_2 concentration. The main driver of this change is the combustion of fossil fuels for industry, transportation, and energy generation (Reisinger, 2009). The greenhouse effect, created by radiative forcing from CO_2 and other GHG (Park & Allaby, 2017), transforms radiant energy from the Sun into heat energy, leading to a temperature increase on the Earth's surface. Increasing temperature is accelerating the melting of the cryosphere (IPCC, 2013, p. 319), causing the global sea level to rise. Oceans are also gradually increasing in temperature, leading to thermal expansion (IPCC, 2013, p. 1139), and further adding to SLR. The average temperature in the polar regions is rising quicker than the rest of the planet, partly due to albedo reduction, as darker ground under the ice becomes exposed by the melting snow and ice (Cohen & Waddell, 2009). In addition, oceans are acting as a major sink of anthropogenic CO_2, and becoming acidified (IPCC, 2013, p. 297).

Governments, industry, and individuals are planning and initiating CC adaptation initiatives to reduce projected harm to humans and ecosystems (Climate Change Adaptation Technical Working Group, 2018). Like many countries, NZ is susceptible to a multitude of consequences, and we must work with our communities to find the most appropriate solutions (Climate Change Adaptation Technical Working Group, 2018). Because current levels of anthropogenic CO_2 will continue to cause a rise in global temperature (Reisinger, 2009), mitigation effects are required to reduce emissions (Millar et al., 2016), in accordance with agreed guidelines (UNFCCC, 2018).

CC is a complex science to teach, with many students and teachers having pre-existing misconceptions (National Research Council, 2012). Teachers must be mindful of the imagery they use with their students, to prevent fearful reactions, and instead build on a firm foundation of science. Opportunities for students to contribute to both NZ adaptation and mitigation responses should be offered within the CC programme (Bangay & Blum, 2009). We must provide students with the tools to become active and informed decision makers, so they are able to contribute to, and create solutions, for an issue that in some way will affect all life on the planet.

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