Critical Global Climate Issues Explained by Climate Science

Assignment 5: Climate Paper – Public-Facing Report (Individual)
CALS 500 Climate Science, Impacts and Services
Master of Arts in Climate Action Leadership Program, Royal Roads University
Kerra Chomlak
August 29, 2021

Purpose of Report

The purpose of this practitioner report is to outline the recent scientific conclusions on the climate and critical issues in a concise, understandable manner. It is hoped that this report will create understanding of climate science and ultimately assist local policy makers in Canada to make the case for climate adaptation action. **Critical issues are summarized and bolded, with the intent of highlighting the magnitude of climate concerns and urgency of adaptation action.** Critical issue statements are authored by Kerra Chomlak, CALS500 student. Comments on these summary statements are welcome at: https://webspace.royalroads.ca/kchomlak/.

Table of Contents

1. Introduction

The science is clear. The rate at which humans have warmed the climate is unprecedented. Impacts are intensifying and are felt across the globe. Current climate conditions are, and future conditions will continue to be, unlike anything humanity has experienced.

In all plausible future scenarios, Earth's global temperature is projected to increase. This will result in more extreme weather, melting ice, sea level rise and associated social, economic and health effects. It is imperative that planning and preparation for climate changes, or climate *adaptation*, is undertaken by a wide range of decision makers, especially at the local level.

2. A Note on the IPCC

The International Panel on Climate Change (IPCC) is the United Nations body for assessing climate science. Every five to eight years since 1990, they issue assessment reports, which are vetted by thousands of scientists and are "widely recognized as the most authoritative reference documents on the state of knowledge on climate change, its potential consequences, and response options" (Bush, 2019, p. 13). The recent *Sixth Assessment Report* (AR6) was released in August 2021 and provides the most clarity to date on the causes of climate change, observed impacts, and possible climate futures. It is entitled, "Climate Change 2021 The Physical Science Basis" (IPCC, 2021) and is a key reference in this practitioner report.

3. The Cause of Global Warming

Humans are responsible for global warming, unequivocally. This most recent conclusion of the IPCC, and is the clearest ever stated by this organization.

> "It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred" (IPCC, 2021, p. 6).

Past IPCC assessments were written less emphatically and included a percentage probability. For example, the last assessment report in 2013, concluded, "It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century" (IPCC, 2013, p. 17), with "extremely likely" assigned a likelihood value of 95–100%. Eight years later, the 2021 assessment report now uses stronger language on the cause of climate change, how it has affected all major earth systems, including our atmosphere, oceans, cryosphere (ice, glaciers, snow and permafrost), and the biosphere (living systems and ecosystems).

The IPCC can state the cause of global warming with certainty because data has improved and trends have become clear. Climate observations including Earth's surface and ocean temperatures, emissions levels, frequency of extreme weather events, amount of melting ice and permafrost have been studied in great detail and advances in technology have improved the data. For example, emissions monitors can assess various types of gases in the air to enable reporting on changes over time. In addition to measured climate conditions, prehistoric climate data is also available from thousands and hundreds of thousands of years ago. These are referred to as the paleoclimatic archives. “Proxies” of climate conditions, such as tree rings and ocean sediments, are good indicators of temperatures and other climate conditions of the distant past. The air bubbles in arctic ice cores, for example, can be chemically analyzed to determine prehistoric carbon dioxide levels and temperature with very high confidence (Masson-Delmotte et al., 2013).

Many governments, businesses and other organizations have also reviewed these data sources and supported the conclusion that humans are the cause of global warming. Environment and Climate Change Canada made a similar conclusion in *Canada’s Changing Climate Report 2019*, which is the first major report of the current national climate change assessment process. It states: “It is extremely likely that human activities, especially emissions of greenhouse gases, are the main cause of observed warming since the mid-20th century. Natural factors cannot explain this observed warming” (Bush et al., 2019, p. 38).

Why is it important to understand that humans have caused climate change? Generally, people are used to experiencing variability in the weather, so it is expected that they would ask the question, “Are these changes natural or human caused?” Climate science can now explain with certainty that the changes experienced today are not due to natural forces. This makes the argument that humans have the power and the responsibility to address global warming; it is not an issue that is beyond human control.

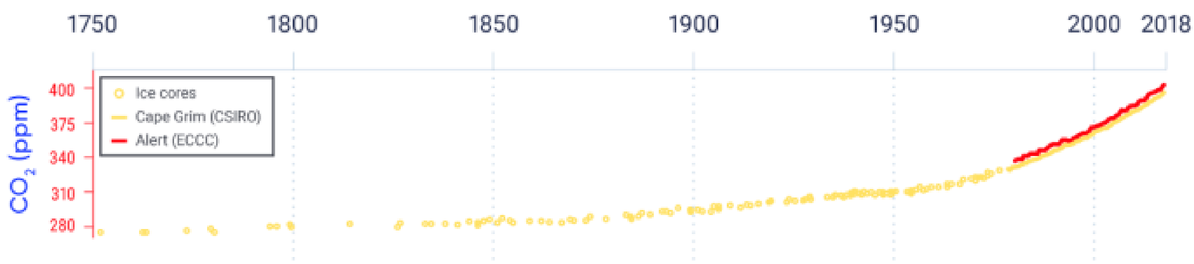
Critical Issue 1: Humans have caused global warming and therefore have the responsibility to address it.

4. Carbon Dioxide (CO_2) Levels

Carbon dioxide (CO_2) and other gases are called “greenhouse gases" because they create a layer around the earth that traps heat, similar to how a greenhouse traps heat from the sun. Without the atmosphere, the sun’s rays would be reflected back to space leaving the Earth’s surface very cold. However, when excessive amounts of greenhouse gases are emitted into the atmosphere, more heat is trapped, creating more energy in the climate system. This excess warming has increased in intensity since the 1950’s and has resulted in more extreme weather, including heat waves, droughts, fires, hurricanes and flooding, as well as reductions in snow, ice and permafrost, and sea level rise.

CO_2 is one of the most important greenhouse gases because it is emitted in large amounts from fossil fuel burning and because it lives in the atmosphere for hundreds to thousands of years (Emmanuel, 2020). There was a noticeable increase in CO_2 emissions during the industrial revolution, when new factories, machines and vehicles began emitting CO_2 into the atmosphere. Figure 1 illustrates how CO_2 emissions increased substantially after 1950. The yellow dots are paleoclimate records from arctic ice cores, indicating that CO_2 levels were at about 280 parts per million (ppm) in 1750, increasing to approximately 400 ppm in 2018. The red line is the observed CO_2 emissions levels starting in the 1970's as measured by the Canadian Greenhouse Gas Measurement Program operating at Alert, Nunavut. These data sources align closely and both show that the rate of CO_2 is increasing faster after about 1950.

Figure 1: Carbon Dioxide (CO_2) increases in the industrial era



Source: Bush et al, 2019, p. 51.

Current CO_2 levels are unprecedented, both in the amount of CO_2 in the atmosphere and also in the speed at which it has increased. Prehistoric CO_2 levels were in the 180 to 280 ppm range. Today, in mid-2021, CO_2 has been recorded as high as 420 parts per million (ppm) (NOAA, n.d.) and this is the highest level in the past 800,000 years (IPCC, 2013).

The rate at which CO_2 is increasing is also extraordinary. In prehistoric times, CO_2 fluctuated, but on a much longer timescale of about 100,000 years. In current times, CO_2 has increased by more than 40% over approximately 70 years. This fast pace of emissions release is an issue because CO_2 remains in the atmosphere for thousands of years and as humans continue to emit, concentrations will increase faster, and impacts will worsen.

Critical Issue 2: CO_2 levels are higher today than in the past 800,000 years and continue to increase at an unprecedented rate.

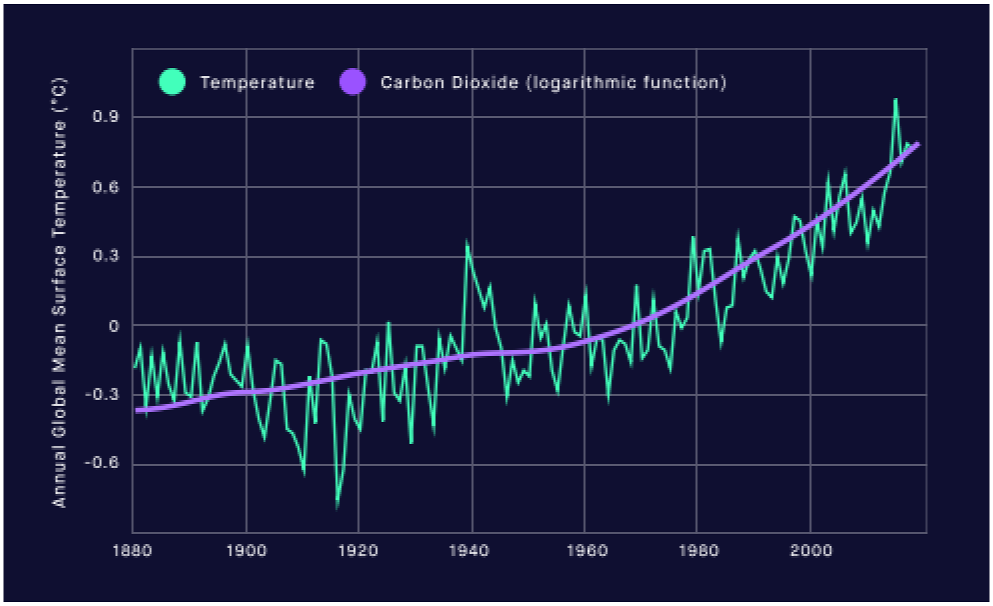
5. Increasing Temperature

Because CO_2 levels are increasing, the temperature on Earth continues to rise. Figure 2 below shows the correlation between CO_2 and temperature. The purple line shows increasing CO_2 levels (similar to Figure 1 above, but over a shorter time frame). The jagged green line is the observed temperature at Earth's surface, with the peaks and valleys illustrating variation in average temperature each year. This annual variation is expected and is due to naturally-occurring changes in temperature. For example, El Niño and La Niña phenomena affect ocean currents and temperature in the Pacific, cooling and warming the earth's temperature at regular intervals.

The overall trend upwards shows that as CO_2 increases, so does Earth's temperature. The concern is that with CO_2 levels continuing to rise at an unprecedented rate, temperature will also continue increase at an unprecedented rate into the future.

Critical Issue 3: Temperature will continue to increase at an unprecedented rate unless CO_2 levels are reduced.

Figure 2: Earth's global temperature aligns with atmospheric Carbon Dioxide (CO_2)



Source: Emmanuel, 2019, p. 10.

The y-axis on the left side of Figure 2 shows the change in annual temperature compared to a 1951 to 1980 baseline. This means the average temperature over that timeframe is shown at the zero mark to illustrate the increases in temperature, since the actual value of Earth's average temperature was about 14 degrees Celsius during that period. At present day on the right side of the graph, the temperature increase is approximately 0.8 degrees Celsius from the baseline. This may not seem like a large amount, but consider this is the change in surface temperature averaged across the whole globe, including different temperatures at different latitudes.

Similar graphs of observed temperature trends are also available at a regional level. In those regional graphs, any unusually high peaks and valleys can be attributed to specific weather events such as record high heat waves (Murdock, 2019). Those observations and trends, in combination with future projections for the region, can help local decision makers plan ahead for future climate impacts. Regional data of that type are available from a variety of climate service organizations, some of which are listed in Appendix 1.

6. Future Projections

Climate models have become very sophisticated and can accurately project future climate conditions including temperature, humidity, changes to sea level, ice cover, and much more. The models require large supercomputers and can take months to calculate the physics equations required to produce simulations of future climate conditions. Although these computer models cannot forecast every molecule of air and water with 100% certainty, different organizations around the world collaborate to confirm model inputs and outputs, which improves confidence in results. The accuracy of these models is further confirmed by running the climate projections back in time and comparing the results with measured observations. In fact, models have become so accurate, scientists have had to correct the historical record of observations based on model results. For example, when sea surface temperatures measured from ships did not match model results, scientists concluded the measurements were taken incorrectly because the model was very accurately recreating all other variables (Murdock, 2021a).

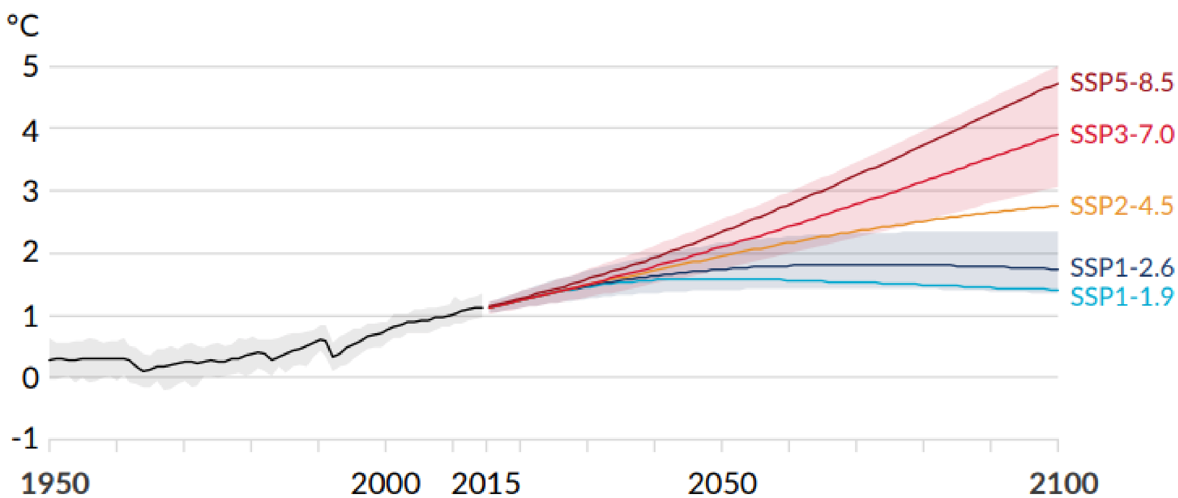
In order for climate models to make future projections, a range of possible scenarios must first be defined. One set of scenarios are referred to as the Representative Concentration Pathways (RCPs). RCPs are explained as “radiative forcing” or the amount of heating due to various concentrations of CO_2 in the atmosphere, measured in Watts per square metre (W/m^2) of energy. These pathways are intended to consider a range of heating scenarios in the future, including an optimistic or “best-case” scenario indicated by lower radiative forcing (1.9 W/m^2) and other, higher radiative forcing scenarios. The highest RCP scenario recently evaluated by the IPCC uses a forcing level of 8.5 W/m^2. Some consider this the “worst-case” scenario, while others consider it to be “business-as-usual” with a pessimistic lens on the future that assumes CO_2 emissions will not be reduced.

Modelling projects have evolved over time. The most recent Coupled Model Intercomparison Project Version 6, or CMIP6, is a collaboration of over 30 modelling centres around the world to prepare for AR6 (McSweeney & Hausfather, 2018). In addition to radiative forcing scenarios, CMIP6 gives more consideration to socio-economic factors, by integrating another set of scenarios referred to as Shared Socio-economic Pathways (SSPs). SSPs describe a range of plausible futures, considering alternative evolutions of global population, GDP, education, urbanization, technological and economic growth. They include:

- an optimistic world of sustainability-focused growth and equality (SSP1);
- a “middle of the road” world where trends broadly follow their historical patterns (SSP2);
- a fragmented world of “resurgent nationalism” (SSP3); and
- a pessimistic world of rapid and unconstrained growth in economic output and energy use (SSP5) (Hausfather, 2018).

The SSP narratives help assess what type of climate policies may be required in the future. For example, in the fossil-fueled development SSP5 pathway, energy intensive lifestyles are adopted around the world (Riahi et al., 2017), leading to increased GHG emissions, and combined with RCP8.5, result in the highest projected global temperature (the dark red line in Figure 3, below). Alternatively, the more optimistic SSP1 includes investments in education and healthcare reducing inequality and consumption is focused on low material growth, lower resource intensity and lower energy intensity, thereby reducing emissions (Hausfather, 2018). From this type of scenario modelling, decision-makers can assess the impacts of unconstrained fossil fuel burning versus more renewable energy sources for example, and the type of policies that might minimize future climate impacts. Figure 3 below is taken from the AR6; it illustrates the IPCC's most recent future projections using CMIP6 scenarios.

Figure 3: Future projections of global temperature for a range of plausible scenarios



Source: IPCC, 2021, p. 29.

This y-axis on the left side of Figure 3 shows the global surface temperature change relative to the 1850 to 1900 or the "pre-industrial" average temperature. Note this is a different baseline than in Figure 2, which shows a smaller global temperature increase because that baseline is more recent. The coloured scenarios on the right indicate the SSP scenario combined with an associated RCP radiative forcing level. The shading around the lines indicates the range of model results, with the finer lines representing the mean value of each range. The break between the black line and the coloured lines indicates "present day" and the shift from measured temperature data to modelled temperature projections.

Figure 3 illustrates that global average temperature is projected to increase by approximately 1.4 to 4.4 degrees in 2100 depending on the scenario. Note that in all scenarios, the temperature is higher than it is at present day. Even in the "best-case" SSP1-1.9 scenario, the temperature continues to rise to 2050 and remains higher in 2100 than it is today.

Critical Issue 4: In all plausible future scenarios, the global temperature is projected to be higher than it is today.

Even if carbon dioxide emissions can be held steady (“net-zero” emissions), global average temperature will remain approximately constant for centuries at the peak temperature reached. Therefore, the climate system will continue to change and adaptive measures will be required; for example, sea level will continue to rise (Bush et al., 2019).

Critical Issue 5: Even if CO_2 emissions are held steady, the global temperature will remain at its peak temperature for centuries.

7. The Paris Targets

The *Paris Agreement* under the United Nations Framework Convention on Climate Change (United Nations, 2015) aims to keep the global temperature below 1.5 degrees Celsius of warming, with a goal of limiting global warming to well below 2.0 degrees above pre-industrial levels. “Many countries considered that a level of global warming close to 2 degrees Celsius would not be safe and, at that time, there was only limited knowledge about the implications of a level of 1.5 degrees Celsius of warming for climate-related risks” (IPCC, 2018, p. v).

In the AR6, the 1.5-degree Paris target corresponds with the lowest scenario, SSP1-1.9 (Murdock, 2021b) as illustrated by the light blue line in Figure 3. In order to achieve this target, deep reductions of greenhouse gas emissions would have to happen almost immediately and the goal becomes more difficult to achieve as time goes on. An IPCC Special Report on the 1.5 target issued in 2018 states, “This Special Report confirms that climate change is already affecting people, ecosystems and livelihoods all around the world. It shows that limiting warming to 1.5ºC is possible within the laws of chemistry and physics but would require unprecedented transitions in all aspects of society” (IPCC, 2018, p. v).

In fact, in all scenarios considered in the AR6, 1.5℃ warming is projected to be reached or exceeded in the early or mid-2030s. In the highest scenario, crossing this limit would occur even earlier (Rogelj, 2021).

Critical Issue 6: The 1.5-degree target is exceeded in all scenarios within 10 to 15 years.

8. Climate Change Impacts in Canada

In Canada, temperature is expected to increase by about twice the global amount (Bush, 2019). This warming is even more pronounced in the Canadian Arctic, where the rate of warming is about three times the global rate. Canada’s more intense warming is due to altitude, latitude, and the snow/ice albedo effect, which means less sunlight is reflected back to space by white ice and snow and more heat is absorbed into darker-coloured water and land.

Critical issue 7: Canada's climate is warming at twice the global amount.

As Canada's temperature increases, the expected climate impacts include:
- increase in extreme precipitation, leading to potential flooding events;
- change in availability of freshwater throughout the year, including a risk of summer season shortages;
- increase in coastal flooding due to sea-level rise; and
- increase in wildfire and drought risks (Bush et al., 2019).

Note that more specific climate impact information is also available at a regional level from various climate service organizations, some of which are listed in Appendix A.

Another important climate impact to Canada and the world is the loss of biodiversity and impacts to ecosystems. As stated by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019), "Human actions threaten more species with global extinction now than ever before" (p. 14) and "scenarios project mostly adverse climate change effects on biodiversity and ecosystem functioning, which worsen, in some cases exponentially, with incremental global warming. Even for global warming of 1.5°C to 2°C, the majority of terrestrial species ranges are projected to shrink dramatically" (p. 18).

For many people, information on the loss of biodiversity brings up emotions of loss, fear, confusion and other feelings, which can be compounded by the wide range of other social, cultural and health impacts of global warming. These emotions must be considered when adaptation planning. Climate grief management is an emerging field with leaders in climate services now openly sharing their feelings of grief, recognizing that future planning must address the emotional side of climate impacts.

9. Conclusion and Recommendations

Earth's global temperature is projected to increase in all plausible future scenarios, which will create more extreme weather, melting ice, sea level rise and a broad range of social, economic and health effects.

Given the unprecedented societal transitions required to achieve the 1.5-degree target, it stands to reason that global warming is more likely to follow a medium or high future scenario. This will cause more climate impacts and create more difficult social, economic, cultural and health challenges at the global and local levels.

It is imperative that governments, businesses, and other organizations prepare for these impacts. Decision-makers should:

1. Access climate information on the impacts in their region, and in particular, understand the impacts under a worst-case scenario; and
2. Develop an adaptation plan and ensure resources are allocated to preparing for a range of plausible scenarios.

It makes sense to be aware of impacts related to a worst-case scenario because in all plausible scenarios, temperatures continue to increase unless emissions are reduced significantly. Putting measures in place to adapt to a higher scenario will simply result in being prepared sooner. For example, when designing buildings for 2050, architects should be aware of their local climate conditions under the worst-case scenario and could design the building to withstand those conditions. If a more optimistic scenario is achieved, the building will simply be ready for worst-case conditions earlier than required.

Appendix 1 – Climate Services Organizations and Sources of Regional Climate Data

Note this list is not inclusive, but intended to give examples of climate service organizations. Source: Murdock, 2021c.

Climate West (Prairies) - https://climatewest.ca/

Climate Data Canada - https://climatedata.ca/

Copernicus (Europe) - https://climate.copernicus.eu/

ICLEI (Canada) - https://icleicanada.org/our-work/adaptation/

Intact Centre (Ontario) - https://www.intactcentreclimateadaptation.ca/

Pacific Climate Impacts Consortium (BC) - https://www.pacificclimate.org/

Prairie Adaptation Climate Research Collaborative - https://www.parc.ca/

Local governments:

Capital Region District (BC) - https://www.crd.bc.ca/project/climate-action

City of Calgary (AB) - https://www.calgary.ca/uep/esm/climate-change/climate-actions.html

City of Edmonton (AB) - https://www.edmonton.ca/city_government/environmental_stewardship/climate-change-adaptation

Metro Vancouver (BC) - http://www.metrovancouver.org/services/air-quality/climate-action/regional-program/Pages/default.aspx

Vancouver Coastal Health (BC) - http://www.vch.ca/public-health/environmental-health-inspections/healthy-built-environment/climate-change

References

Bush, E. and Lemmen, D.S., editors. (2019). Canada's changing climate report. Government of Canada, Ottawa, ON. https://changingclimate.ca/site/assets/uploads/sites/2/2020/06/CCCR_FULLREPORT-EN-FINAL.pdf

Emanuel, K. A. (2020). Climate science, risk & solutions: climate knowledge for everyone. Massachusetts Institute of Technology. 15 May 2020. https://climateprimer.mit.edu/climate-science-risk-solutions-1220.pdf

Hausfather, Z. (2018). Explainer: How 'Shared Socioeconomic Pathways' explore future climate change. CarbonBrief. 19 April 2018. https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change

IPBES (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. S. Díaz, J. Settele, E. S. Brondízio E.S., H. T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. J. Shin, I. J. Visseren-Hamakers, K. J. Willis, and C. N. Zayas (eds.). IPBES secretariat, Bonn, Germany. https://ipbes.net/sites/default/files/2020-02/ipbes_global_assessment_report_summary_for_policymakers_en.pdf

IPCC (2021). Summary for policymakers. In: Climate change 2021: The physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

IPCC (2018). Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, … T. Waterfield (eds.)]. In Press. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf

IPCC (2013). Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the

Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/report/ar5/wg1/summary-for-policymakers/

Masson-Delmotte, V., M. Schulz, A. Abe-Ouchi, J. Beer, A. Ganopolski, J.F. González Rouco … A. Timmermann (2013). Information from Paleoclimate Archives. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter05_FINAL.pdf

McSweeney, R. & Hausfather, Z. (2018). How do climate models work? CarbonBrief. 15 January 2018. https://www.carbonbrief.org/qa-how-do-climate-models-work.

Murdock, T. (2019). Module 1, Pt 2 - Using future climate projections [Recorded Presentation]. Pacific Climate Impacts Consortium; Agricultural Climate Adaptation Research Network. https://www.youtube.com/watch?v=0eXyhJ0HiyI

Murdock, T. (2021a). Climate models: estimating future climate. Unit 4, Week 5 – Live Session. Moodle CALS500.

Murdock, T. (2021b). Course Q and A (Class) New IPCC report question. 9 August 2021. Moodle CALS500.

Murdock, T. (2021c). Course Live Session. 26 August 2021. Moodle CALS501.

National Oceanic and Atmospheric Administration (NOAA) (n.d.). Trends in atmospheric carbon dioxide. https://gml.noaa.gov/ccgg/trends/

Riahi, K., van Vuuren, D. P., Kriegler, E., Edmonds, J., O'neill, B. C., Fujimori, … Tavoni, M. (2017). The shared socioeconomic pathways and their energy, land use, and greenhouse gas emissions implications: An overview. *Global Environmental Change, 42,* 153-168. https://doi.org/10.1016/j.gloenvcha.2016.05.009

Rogelj, J. (2021). A deep dive into the IPCC's updated carbon budget numbers. RealClimate.12 August 2021. https://www.realclimate.org/index.php/archives/author/group/

United Nations (2015). Paris Agreement. https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf