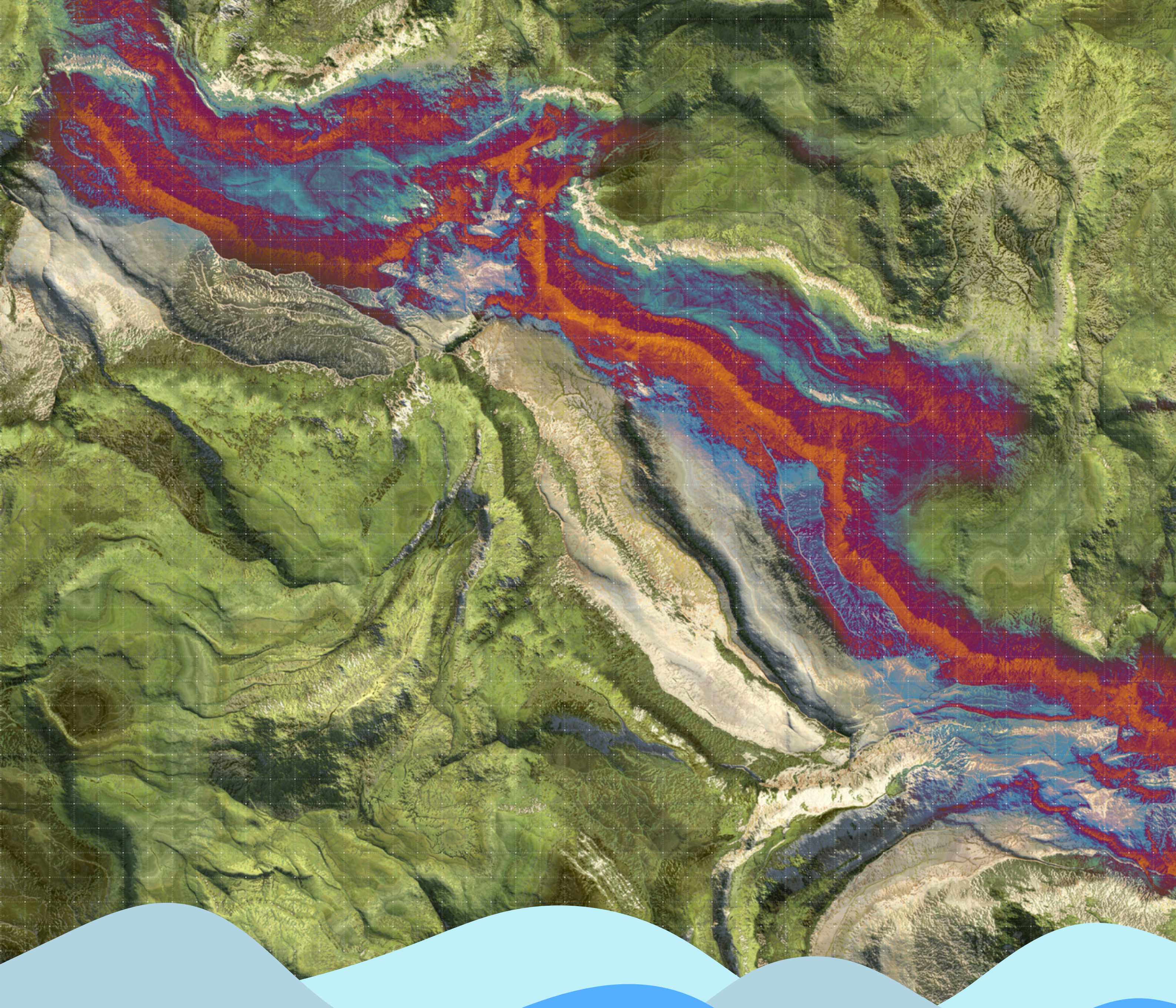

# Understanding Climate Change and Canada's Oceans

WINTER 2024

Sea Change Canada

# TABLE OF CONTENTS



*Last Updated 17/01/2024*

Earth's oceans cover close to 70% of our planet's total surface area and are an integral aspect of supporting our planet and combating the climate crisis (Wurl et al., 2017). Our oceans are important in supporting the stability of our ecosystems through weather and climate moderation, heat and moisture redistributing, and oxygen production (Hossain, 2019; Li et al., 2020; Mendler de Suarez et al., 2014). While for humanity, our oceans play a vital role in providing essential benefits like food, livelihoods, transportation, and recreation (Bari, 2017; Mendler de Suarez et al., 2014). However, all of these benefits are in jeopardy as rising temperatures threaten to fundamentally alter our ocean's function and ecosystem services (Geiser, 2021).

## WHAT IS CLIMATE CHANGE?

Climate change is an increase in global temperatures and resulting problems due to elevated anthropogenic greenhouse gas emissions. In our solar system, the sun is a major source of energy for our planet. Incoming solar radiation comes to the Earth where 30% is reflected out into space by the Earth's surface and atmosphere, 47% is absorbed by the Earth's surface and oceans, and the remaining 23% is absorbed by greenhouse gas molecules, the ozone layer, and dust (Webb, n.d.). Greenhouse gases include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), chlorofluorocarbons, and water vapour. In the context of climate change, the focus is on carbon dioxide (CO2) and methane (CH4) because they are two of the major drivers of human-induced climate change. Carbon dioxide (CO2) and methane (CH4) circulate across the Earth, transitioning through the carbon cycle between carbon sinks and sources. Carbon sinks, such as the oceans, wetlands, and soil, play a role in storing carbon- while carbon sources, including fossil fuel combustion, volcanic activity, and animal respiration, release carbon into the atmosphere. Figure 1 depicts Earth's carbon sinks and sources. Across geologic time, carbon levels in sinks and sources have gradually fluctuated, resulting in differences in global temperature, acidification levels, and ecosystem functions.

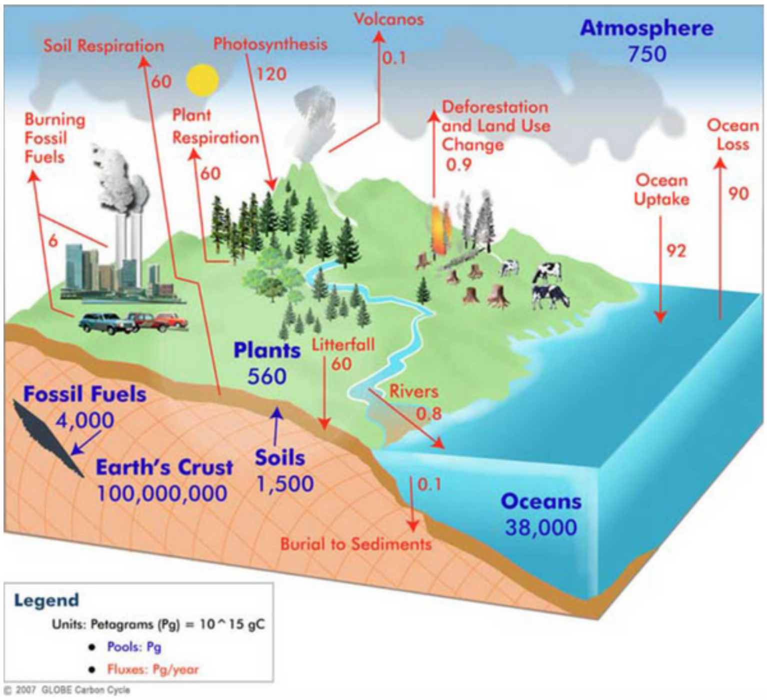


*Figure 1: Earth's carbon sinks and releases (http://globecarboncycle.unh.edu/diagram.shtml)*

Since the industrial revolution in the 1800s, humans have been releasing materials from Earth's carbon sinks through the extraction and burning of fossil fuels. Fossil fuels are thousand to million-year-old carbon sinks composed of decayed carbon-rich plant and animal matter that can be burned to produce non-renewable energy. Coal, oil, and natural gas are examples of fossil fuels used for the majority of our energy needs, including transportation, manufacturing, and electricity. As seen in Figure 2, the amount of carbon in the atmosphere is the highest it has been in the last 800,000 years.

After being burned, the carbon from the greenhouse gasses in the fossil fuels is released into the atmosphere, where it remains until eventually being transferred into a new carbon sink. While in the atmosphere, these greenhouse gasses exacerbate the greenhouse effect. The greenhouse effect is a natural process where greenhouse gasses trap outgoing energy from the sun. The greenhouse effect is important because it keeps our planet's average surface temperature at 15°C and prevents a potential decrease of Earth's average surface temperature by 33°C (NASA, 2023). While the greenhouse gas effect is vital for sustaining life, too many greenhouse gasses entering the atmosphere can be devastating. As a society, we are already experiencing the impacts of climate change through extreme weather events like heat waves, longer and hotter wildfire seasons, and heightened sea levels. However, these impacts will increase as we burn more fossil fuels and temperatures continue to rise.

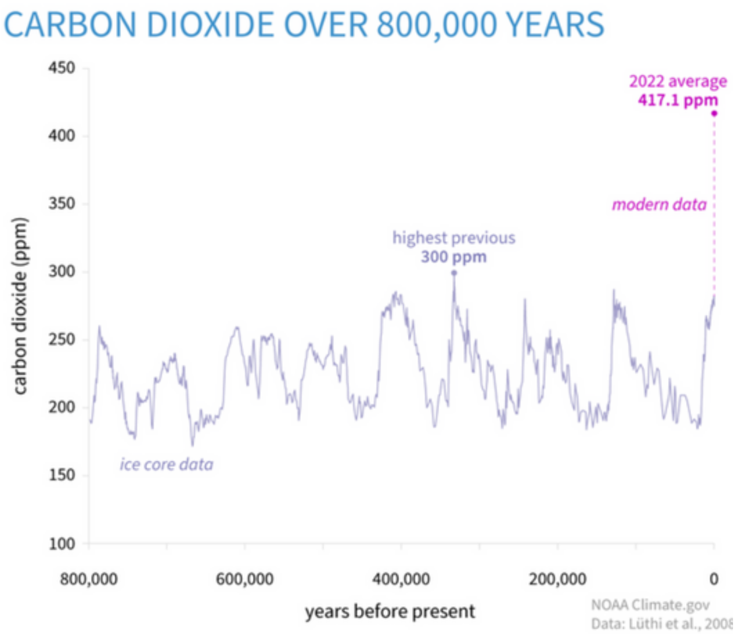


*Figure 2: Graph of atmospheric carbon dioxide over the past 800,000 years to 2022. Source (https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide)*

## HOW DOES CARBON ENTER THE OCEAN?

Carbon dioxide ($CO_2$) becomes dissolved in our oceans in two ways. The first is through gas exchange between the atmosphere and ocean through a process known as diffusion. For the ocean, the surface acts as a boundary between air and water that gases like $CO_2$ can move between. Naturally, the atmosphere and ocean have differing concentrations of $CO_2$, which creates areas of higher and lower concentrations. Diffusion is a process where molecules move from an area of high concentration (atmosphere) to an area of lower concentration (ocean) in an effort to create equilibrium (DeVries, 2022). The second way $CO_2$ becomes dissolved in seawater is through biological processes, including photosynthesis by marine organisms. This process involves marine organisms like phytoplankton taking in dissolved $CO_2$ and releasing oxygen (Marinov & Sarmiento, 2004). These processes are not equal across the globe- factors like temperature and wind speed can directly impact rates of diffusion and gas exchange. With that in mind, the ocean is not an endless carbon sink. Over time rates of carbon uptake by the ocean have been decreasing, indicating that although our ocean has been mitigating much of climate change, this may change in the coming decades (Jens Daniel Müller et al., 2023).

## HOW IS CLIMATE CHANGE SET TO IMPACT OUR OCEANS?

The ocean is one of Earth's primary carbon sinks and has helped to sequester 90% of excess heat and 25% of carbon dioxide emissions, which is equivalent to over 150 billion metric tons of carbon (DeVries, 2022; Li et al., 2023; National Oceanic and Atmospheric Administration, Fisheries, 2020).

However, storing excess carbon in the ocean can have detrimental impacts and is not a sustainable, long-term solution to climate change. There are four major ways climate change is set to impact our oceans: ocean warming, acidification, sea level rise, and changes to ocean circulation.

## Ocean warming

Over the past century, our oceans have been taking excess carbon dioxide from the atmosphere. In 2023, it was estimated that the ocean had warmed by 0.70F since 1880 (National Centers for Environmental Information, 2023). While 0.70F may seem insignificant, the trend of rising temperatures is alarming because approximately 63% of this warming has occurred in the last five decades alone (Dahlman & Lindsey, 2023). Rising ocean temperatures pose threats like coral bleaching, sea-level rise due to thermal expansion, more intense precipitation events, and ice sheet melt, alongside ecosystem degradation and biodiversity loss (Cheng et al., 2022).

## Ocean acidification

Another issue resulting from rising ocean temperatures is ocean acidification. Ocean acidification describes a decrease in ocean water pH due to increased carbon absorption. As climate change continues, our oceans intake more carbon dioxide ($CO_2$) from the atmosphere, resulting in a decrease in ocean water pH. Ocean acidification can make it difficult for species like oysters, coral, and zooplankton to gain carbonate ($CO_3^{-2}$), a compound necessary to create their shells and skeletons (National Oceanic and Atmospheric Administration, Fisheries, 2020). Over time, this can have cascading effects across marine ecosystems, leading to food web disruptions, ecosystem degradation, and biodiversity loss (Zunino et al., 2021).

## Sea level rise

Sea level rise is another major ocean issue related to climate change that is caused by two main factors- melting terrestrial ice and the thermal expansion of water. Terrestrial ice is found across the globe in the form of ice sheets and glaciers created by the freezing and compacting of freshwater and snow. Increasing temperatures cause ice sheets and glaciers to thaw, resulting in meltwater that flows into the oceans and increases sea level. Elevated ocean water temperatures also lead to the thermal expansion of the water. Thermal expansion essentially describes volume changes in matter as a result of temperature fluctuations. In the case of seawater, as our ocean temperature increases, the volume of the water grows, and consequently sea level rises. On a regional scale, sea level rise is not uniform due to ocean circulation and isostatic rebound from ice sheet loss, causing ocean water to move and pool in certain areas. In Canada specifically, sea level rise projections have estimated that British Columbia and the maritime provinces will be hit hardest with over 1m of sea level rise by 2100 (James et al., 2021). Over time, sea level rise will have implications, including coastal erosion, flooding, loss of coastal habitats, and saltwater intrusion into freshwater supplies (Cazenave & Cozannet, 2014).

## Impact on ocean circulation

Climate change is also set to impact ocean circulation. Ocean circulation is the movement of water across the ocean due to variations in temperature and salinity (also-known as density) or forces like wind (National Oceanic and Atmospheric Administration, 2019). Ocean circulation is important because it helps to control climate and move heat and nutrients across marine ecosystems (Visbeck & Keiser, 2021). Also known as the ocean conveyor belt, thermohaline circulation (THC) is one of the largest ocean circulation patterns. Figure 3 shows thermohaline circulation on a global scale. Thermohaline circulation slowdown or shutdown, specifically the portion known as Atlantic Meridional Overturning Circulation (AMOC), is a major concern. Slowing or reducing the THC and AMOC would deeply alter weather patterns, reduce agricultural output, and impact the stability of marine ecosystems.

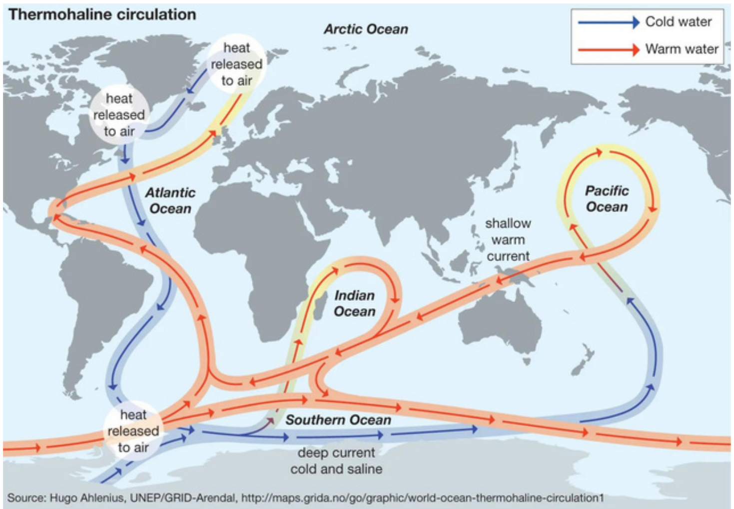


*Figure 3: Map of thermohaline circulation across the globe. Source (https://www.britannica.com/science/thermohaline-circulation#/media/1/591633/109639)*

## HOW DO WE REDUCE CLIMATE CHANGE?

Humanity is addressing climate change through two primary approaches: adaptation and mitigation. Adaptation describes the process of altering our ways of life to the consequences of climate change. Adaptation strategies for climate change include infrastructure upgrades like seawalls and dune restoration to protect against sea level rise, ecosystem restoration like dune restoration to buffer against extreme weather events, and increased disaster management (Abbass et al., 2022). Generally, adaptation strategies enhance the resilience of both communities and individuals. However, adaptation strategies do not directly reduce greenhouse gas emissions and mitigate the procession of climate change. Mitigation strategies focus on reducing greenhouse gas emissions to prevent accelerating climate change. Popular mitigation strategies include switching to renewable energy sources like solar and wind, reducing energy consumption, and carbon removal methods such as carbon capturing (Fawzy et al., 2020). A combination of adaptation and mitigation strategies are considered to be the most impactful because together they address the root cause of climate change while building resilience to the threats we are currently experiencing. At this stage, many communities are struggling to implement adaptation and mitigation strategies due to a lack of funding, policy, and implementation of effective urban planning (Aboagye & Sharifi, 2024; Grafakos et al., 2019).

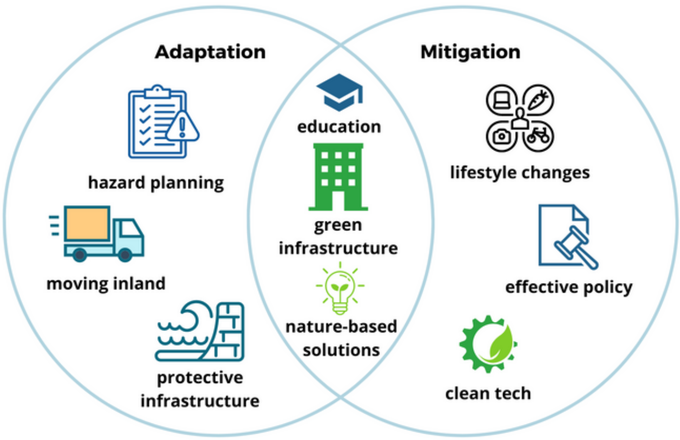


*Figure 4: Venn Diagram depicting coastal adaptation and mitigation strategies, made using Canva.*

## WHAT CAN PEOPLE DO ABOUT CLIMATE CHANGE?

Climate change can be overwhelming, and at times it can feel like our efforts are a drop in the bucket. However, there are lots of ways the average person can contribute to addressing climate change. Some of these can include:

- Reduce Energy Consumption:
  - Switching to energy-efficient appliances and bulbs.
  - Turning off lights and electronics when you're not using them.
  - Adjusting your thermostat to conserve energy.
- Consider your consumption and Reduce Waste and Support Sustainable Products:
  - Being mindful about your consumption.
  - Using reusable bags, containers, and water bottles.
  - Trying to avoid single-use plastics where possible.
- Raise Awareness and Advocate:
  - Stay informed about climate change but not overwhelmed.
  - Support local initiatives like non-profits working toward a sustainable future.

## REFERENCES


Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H., & Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environmental Science and Pollution Research*, *29*(28), 42539–42559. Springer. https://doi.org/10.1007/s11356-022-19718-6

Aboagye, P. D., & Sharifi, A. (2024). Urban climate adaptation and mitigation action plans: A critical review. *Renewable & Sustainable Energy Reviews*, *189*, 113886–113886. https://doi.org/10.1016/j.rser.2023.113886

Bari, A. (2017). Our Oceans and the Blue Economy: Opportunities and Challenges. *Procedia Engineering*, *194*, 5–11. https://doi.org/10.1016/j.proeng.2017.08.109

Cazenave, A., & Cozannet, G. L. (2014). Sea level rise and its coastal impacts. *Earth's Future*, *2*(2), 15–34. https://doi.org/10.1002/2013ef000188

Cheng, L., von Schuckmann, K., Abraham, J. P., Trenberth, K. E., Mann, M. E., Zanna, L., England, M. H., Zika, J. D., Fasullo, J. T., Yu, Y., Pan, Y., Zhu, J., Newsom, E. R., Bronselaer, B., & Lin, X. (2022). Past and future ocean warming. *Nature Reviews Earth & Environment*, 1–19. https://doi.org/10.1038/s43017-022-00345-1

Copernicus. (2023, November 10). 2023 on track to become the warmest year after record October. Climate.copernicus.eu. https://climate.copernicus.eu/2023-track-become-warmest-year-after-record-october

Dahlman, L., & Lindsey, R. (2023, September 6). Climate Change: Ocean Heat Content. Climate.gov. https://www.climate.gov/news-features/understanding-climate/climate-change-ocean-heat-content

DeVries, T. (2022). The Ocean Carbon Cycle. Annual Review of Environment and Resources, 47, 317–341. https://doi.org/10.1146/annurev-environ-120920-111307

Fawzy, S., Osman, A. I., Doran, J., & Rooney, D. W. (2020). Strategies for mitigation of climate change: a review. Environmental Chemistry Letters, 18(18), 2069–2094. Springer. https://link.springer.com/article/10.1007/s10311-020-01059-w

Geiser, L. (2021). The Importance of the World's Oceans in Climate Change Resilience. https://sites.dundee.ac.uk/energyhubplus/wp-content/uploads/sites/195/2022/07/Lauren-Geiser-COP26-Paper.pdf

Grafakos, S., Trigg, K., Landauer, M., Chelleri, L., & Dhakal, S. (2019). Analytical framework to evaluate the level of integration of climate adaptation and mitigation in cities. *Climatic Change*, *154*(1-2), 87–106. https://doi.org/10.1007/s10584-019-02394-w

## REFERENCES


Hossain, M. M. (2019). Future importance of healthy oceans: Ecosystem functions and biodiversity, marine pollution, carbon sequestration, ecosystem goods and services. *Journal of Ocean and Coastal Economics*, *6*(2). https://doi.org/10.15351/2373-8456.1103

James, T. S., Robin, C., Henton, J. A., & Craymer, M. (2021). *Relative sea-level projections for Canada based on the IPCC Fifth Assessment Report and the NAD83v70VG national crustal velocity model*. https://doi.org/10.4095/327878

Li, C., Huang, J., Ding, L., Liu, X., Yu, H., & Huang, J. (2020). Increasing Escape of Oxygen From Oceans Under Climate Change. *Geophysical Research Letters*, *47*(11). https://doi.org/10.1029/2019gl086345

Li, Z., England, M. H., & Groeskamp, S. (2023). Recent acceleration in global ocean heat accumulation by mode and intermediate waters. *Nature Communications*, *14*(1), 6888. https://doi.org/10.1038/s41467-023-42468-z

Marinov, I., & Sarmiento, J. L. (2004). The Role of the Oceans in the Global Carbon Cycle: An Overview. *The Ocean Carbon Cycle and Climate*, *40*.

Mendler de Suarez, J., Cicin-Sain, B., Wowk, K., Payet, R., & Hoegh-Guldberg, O. (2014). Ensuring survival: Oceans, climate and security. *Ocean & Coastal Management*, *90*, 27–37. https://doi.org/10.1016/j.ocecoaman.2013.08.007

Müller, Gruber, N., Carter, B. R., Feely, R. A., Ishii, M., Lange, N., Lauvset, S. K., Murata, A., Olsen, A., Pérez, F. F., Sabine, C. L., Toste Tanhua, Rik Wanninkhof, & Zhu, D. (2023). Decadal Trends in the Oceanic Storage of Anthropogenic Carbon From 1994 to 2014. *AGU Advances*, *4*(4). https://doi.org/10.1029/2023av000875

NASA. (2022, January 29). *World of Change: Global Temperatures*. Earth Observatory; NASA Earth Observatory. https://earthobservatory.nasa.gov/world-of-change/global-temperatures

NASA. (2023). *What is the greenhouse effect?* Climate Change: Vital Signs of the Planet. https://climate.nasa.gov/faq/19/what-is-the-greenhouse-effect/#:~:text=Greenhouse%20gases%20are%20part%20of

National Centers for Environmental Information. (2023). *Climate at a Glance*. Www.ncei.noaa.gov. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/global/time-series/globe/ocean/ann/4/1880-2022?trend=true&trend_base=10&begtrendyear=1880&endtrendyear=2022

National Oceanic and Atmospheric Administration. (2019). Thermohaline Circulation - Currents: NOAA's National Ocean Service Education. Noaa.gov. https://oceanservice.noaa.gov/education/tutorial_currents/05conveyor1.html

## REFERENCES


National Oceanic and Atmospheric Administration, Fisheries. (2020, December 23). *Understanding ocean acidification*. NOAA Fisheries. https://www.fisheries.noaa.gov/insight/understanding-ocean-acidification#:~:text=For%20good%20reason%2C%20ocean%20acidification

Visbeck, M., & Keiser, S. (2021). *Climate Change and Its Impact on the Ocean*. https://library.oapen.org/bitstream/handle/20.500.12657/54276/1/9783038978763.pdf#page=104

Webb, P. (n.d.). *8.1 Earth's Heat Budget*. Rwu.pressbooks.pub. https://rwu.pressbooks.pub/webboceanography/chapter/8-1-earths-heat-budget/

Wurl, O., Ekau, W., Landing, W. M., & Zappa, C. J. (2017). Sea surface microlayer in a changing ocean – A perspective. *Elem Sci Anth*, *5*(0), 31. https://doi.org/10.1525/elementa.228

Zunino, S., Libralato, S., Canu, D., Prato, G., & Solidoro, C. (2021). Impact of Ocean Acidification on Ecosystem Functioning and Services in Habitat-Forming Species and Marine Ecosystems. *Ecosystems*. https://doi.org/10.1007/s10021-021-00601-3