National Defence Défense nationale

Canadian Forces College

Collège des Forces Canadiennes

# CLIMATE CHANGE IMPACT ON THE DEMAND FOR CANADIAN ARMED FORCES OPERATIONS

Lieutenant-Commander Tyler Smith

## JCSP 46

## Master of Defence Studies

**Disclaimer**

Opinions expressed remain those of the author and do not represent Department of National Defence or Canadian Forces policy. This paper may not be used without written permission.



## PCEMI 46

## Maîtrise en études de la défense

**Avertissement**

Les opinons exprimées n'engagent que leurs auteurs et ne reflètent aucunement des politiques du Ministère de la Défense nationale ou des Forces canadiennes. Ce papier ne peut être reproduit sans autorisation écrite.



Canada

CANADIAN FORCES COLLEGE/COLLÈGE DES FORCES CANADIENNES

JCSP 46 – PCEMI 46
2019 - 2020

MASTER OF DEFENCE STUDIES / MAÎTRISE EN ÉTUDES DE LA DÉFENSE

# CLIMATE CHANGE IMPACT ON THE DEMAND FOR CANADIAN ARMED FORCES OPERATIONS

By Lieutenant-Commander T.A.D. Smith



**Word Count**: 15,115

**Nombre de mots**: 15,115

# TABLE OF CONTENTS

## TABLES



## FIGURES

## ABSTRACT

Climate change will impact the demand for Canadian Armed Forces (CAF) operations at home and abroad. It will also change the capabilities required to conduct operations in regions where climate related disasters will become more prevalent. Nevertheless, strategic policy and operational planning for climate change have not evolved sufficiently to provide a clear picture of risk to the CAF's mandate to be strong at home, secure in North America, and engaged in the world.

This paper will show that climate change is inevitable, and mitigation measures taken by Canada and likeminded nations will not be sufficient to stop the current warming trend. Adaptation to the inevitable risks of climate change should therefore be the primary focus of CAF planning for readiness and operations in the future. This paper will also demonstrate that climate change risks to Canada's domestic security will be less severe than other areas of the world. The relatively moderate and predictable nature of climate change impacts to Canada will require all levels of government to adopt climate adaptation strategies to protect key infrastructure, but the CAF should not see an appreciable increase in demand for domestic Humanitarian Assistance Disaster Relief (HADR) over the coming decades. Conversely, Climate change may have severe impacts to other regions of the world that lack the resilience of industrialized western nations. It will be in Canada's national interest to maintain the ability to respond to HADR, peace support, and warfighting operations in regions affected by climate related disasters. Therefore, the CAF will likely see an increase in demand for expeditionary operations, and may require new capabilities to maintain operational relevance.

## CHAPTER 1 – INTRODUCTION & LITERATURE REVIEW

Climate has changed throughout the history of our planet, drastically altering the evolution of life on earth. Human civilizations have risen and fallen with changes in geography and climate over the course of history, and current civilizations will not be spared this fate if humanity fails to recognize and adapt to these changes. Climate change will disproportionately and unjustly affect developing regions of the world, and Canada will have both a moral and practical interest in responding to climate induced crises abroad. This study will show that the CAF must be prepared to support an increase in expeditionary operations, and reconsider the capabilities required to operate in regions with reduced civil resilience in the face of climate change. Climate challenges faced by Canada in terms of domestic security are not predicted to exceed the capability of provincial and municipal governments as long as adaptive measures are taken. Therefore, CAF intervention is not likely to be the most suitable or cost effective response to domestic climate risks in the future.

Political and military leadership broadly recognize that climate change is a pressing issue, but public policy often falls short of the scientific rigour necessary to initiate substantive action. Media sources and activists frequently present climate change in terms like “Existential Threat,” perpetuating the idea that it will result in the end of humanity, but hyperbole is not helpful in defining realistic climate change impacts on Canada and Canadian interests. Unfortunately, few CAF officers possess the expertise required to build a realistic picture of the impacts of climate change on defence. Without a detailed understanding of climate risks, including timelines and probabilities of these risks, it is impossible to develop a strategy to mitigate the effects of climate change on the CAF mandate to protect Canadians.

This research project will provide a summary of current and historical climate data analysis, as well as future modeling to describe specific climate change threats as they relate to Canada and regions of Canadian interest. The evidence presented will be a collation of regional climate model predictions (RCMs), applying the most likely scenarios to determine concrete risks from severe weather, sea level rise, wild fires, and floods. A cross section of RCMs will also be examined for vulnerable regions that may be of interest to Canada such as Southeast Asia. Climate change defence policies of other nations will be analyzed, and compared with current Government of Canada (GOC) and Department of National Defence (DND) policy and strategy. This project will also endeavour to outline recommendations for CAF leadership to consider when planning operations now and into the future.

Climate change is an ever present topic of media and political interest in Canada and around the world. According to Bell Media, Climate change was the 3rd most reported news story in Canada in 2019, often linked to political messages in the federal election campaign.[1] Canadian News media often cites climate change as an existential threat that demands urgent action to address, before causing irreparable damage to the planet, and humanity's chances for survival.[2] Politicians also use messages about climate change to gain support for a variety of initiatives from economic reform to social justice issues like gender equality.[3] Government policies extensively, though often imprecisely, describe climate change risk factors in a broad spectrum of issues, including infrastructure and development considerations, but also in less likely policies

[1] Rob Duffy. *CTV NATIONAL NEWS Recaps the Top 10 Stories of 2019, Beginning Dec. 23.* December 20, 2019. https://www.bellmedia.ca/the-lede/press/ctv-national-news-recaps-the-top-10-stories-of-2019-beginning-dec-23/ (accessed January 20, 2020).

[2] David Crane. *Climate change, existential risk should be at the center of political debate in Canada.* August 12, 2019. https://www.hilltimes.com/2019/08/12/biotechnology-291/211025 (accessed January 20, 2020).

[3] Hon. Catherine Mckenna, MP, interview by https://www.facebook.com/citizensforpublicjustice/videos/10155270629980889/. (November 14, 2017).

relating to mental health and women's issues.[4] Think tanks often contribute to the rhetoric on climate change, but such reports are usually oversimplified for an uninformed audience, are scarce on climate modelling details, and therefore offer little practical value to solving an extremely complex problem. One example of an often cited think tank study on climate security was led by retired US Admiral Frank Bowman under The Center for Climate and Security. The report recommends three lines of effort "Assess, Prepare, Support" but fails to introduce a detailed assessment of climate change risks to security, or articulate any specific insight into addressing these risks other than broad recommendations for government action.[5]

Climate research has progressed substantially in recent years, offering new insights into historical climate conditions and facilitating more accurate predictions of future climate trends through advanced statistical modeling. A diverse group of experts within the UN International Panel on Climate Change (IPCC) have generated a battery of global and regional climate modeling that can be applied to regional climate problems in Canada and around the world.[6] The US National Oceanic and Atmospheric Administration (NOAA) has also produced medium to high certainty models that are publically available and can be used to help inform thoughtful strategies for climate change.[7] Both of these resources will form the basis of this research project, but a much more in depth analysis of specific climate modeling is required to understand the practical challenges faced by the CAF. There remains a significant gap between publically digestible reports by organizations like the IPCC, and detailed climate research intended for a

[4] Environment and Climate Change Canada. n.d. https://climate-change.canada.ca/climate-action-map/App/index?GOCTemplateCulture=en-CA (accessed January 20, 2020).

[5] Climate and Security Advisory Group. *Responsibility to Prepare.* Washington: The Centre for Climate and Security, 2018.

[6] United Nations International Panel on Climate Change. *Assessment Report 5 - Working Group 1 - The Physical Science Basis.* New York: Cambridge University Press, 2013

[7] National Oceanic and Atmospheric Administration. *Climate Monitoring.* n.d. https://www.ncdc.noaa.gov/climate-monitoring/global/globe/1/201912 (accessed January 20, 2020).

scientific audience. The literature has not adequately bridged this gap with reports that are regionally specific enough to inform practical action for the CAF, but are also general enough to resonate with a lay audience.

This paper will not expend effort on highlighting the importance of contemporary climate change as a problem, as this has been done ad nauseam for several decades. Instead, this study will attempt to advance understanding of what should be done to address these inevitable changes, beginning with a brief summary of how earth's climate has changed over the past 2.5 million years. A baseline understanding of historical climate trends will provide insight into some of the factors that contribute to climate change. One example of such a misconception extant in policy is the Pan Canadian Framework on climate change, which states "Taking strong action to address climate change is critical and urgent. The cost of inaction is greater than the cost of action: climate change could cost Canada $21-$43 billion per year by 2050."[8] This statement contradicts other, more recent analysis that found climate change may have a net benefit for the Canadian economy, despite some regional challenges.[9] Many such contradictions exist because of the complexity and uncertainty that still remains in the analysis and prediction of earth's climate, especially given the high probability that atmospheric CO2 concentration is higher than at any other time since the start of the Pleistocene epoch.[10] A lack of precision and clarity within policy increases the disconnect between decision makers and the scientific data,

[8] Canada, Government of. *Pan Canadian Framework on Clean Growth and Climate Change: Canada's Plan to Address Climate Change and Grow the Economy.* Ottawa: Government of Canada, 2016, 1.

[9] Marshall Burke, Solomon M. Hsiang & Edward Miguel. "Global non-linear effect of temperature on economic production." *Nature, vol. 527*, 2015: 235-239.; Simon Dalby, Daniel Scott, Clay Dasilva, Alex Suen. "Canada in a Climate Disrupted World." *Wilfred Laurier University Geography and Environmental Science Publications*, 2017.

[10] United Nations International Panel on Climate Change. *Assessment Report 5 - Working Group 1 - The Physical Science Basis.* New York: Cambridge University Press, 2013. 400.

often exemplified when short term weather events are confused with long term climate trends or future statistical modelling.

The imprecision in generalist climate reports often misrepresent climate change as a globally and temporally uniform phenomenon, and this misinterpretation can lead decision makers to misdirect efforts toward low priority risks for climate change adaptation in their respective region. A Canadian example of this was the misattribution of the collapse of a PEI road to climate change, when in fact it was due to predictable and natural coastal erosion.[11] There is a tendency for Government of Canada policy to focus on climate change mitigation rather than adaptation, even though many scientists posit that adaptation is necessary to address changes that are already inevitable.[12] Given the extremely low contribution of Canada to global greenhouse gas emissions, and the persistent ineffectiveness of international climate agreements, it is important to recognize what Canadians need to do in order to adapt to climate change, rather than attempt to mitigate it. Despite the large amount of useful data, there remains substantial uncertainty on some key aspects of climate change. Fortunately, it is possible to filter some of this uncertainty as irrelevant to the topic of defence, or at least bound uncertain predictions according to likelihood and risk.

A review of literature exposes the fact that climate change will yield diverse effects across different regions, and there may not be a uniform increase in the frequency of climate related disasters. An example of this can be found in a 2007 MIT model by Emanuel et al. that used downscaling of IPCC AR4 climate models to show that tropical cyclone generation is a function of ocean/atmosphere temperature differential, rather than absolute atmospheric or sea

[11] Natural Resources Canada. 2016. *Canada's Marine Coasts in a Changing Climate.* Ottawa: Government of Canada.

[12] S. Fred Singer, Dennis T. Avery. 2007. *Unstoppable Global Warming: Every 1500 Years.* Plymouth, UK: Rowman and Littlefield Publishers Inc.

surface temperature.[13] They predict that a warming climate will not result in an increase in tropical cyclone generation in all regions, and may actually lead to fewer hurricanes in the Atlantic.[14] The lack of significant increase in tropical cyclone landfall in the past century in the eastern US as tracked by NOAA[15] supports the Emanual et al. simulation, but it will still be decades before an acceptable amount of measurement is available to prove the model correct. The point of this example is to highlight that climate is not simple or uniform, and valuable research such as this should not be discarded from climate risk considerations, even of this information occasionally runs counter to political/strategic narratives. It will require a longer time period and better measurement to pinpoint the changes to climate systems globally, and it is therefore counterproductive to make sweeping generalizations that minimize the complexity of predicting climate across diverse regions over time. It is the aim of this project to explore sound observational data, and the best modeling available to make specific predictions of climate change risks within Canada and abroad. This study will argue that detailed and nuanced understanding of climate change threats, informed by robust scientific evidence and modeling, is urgently needed to shape CAF strategy and operational planning, so as to enable effective adaptation to these inevitable threats and to minimize effort wasted on untenable solutions.

The first chapter of this project will highlight the daunting, but realistic view that Canada will not be able to prevent or reduce climate change, no matter how strongly Canadians may wish to do so. The first chapter will also attempt to resolve some of the misconceptions that exist in policy and think tank reports, but are no longer supported by scientific evidence. The second

[13] Kerry Emanuel, Ragoth Sundararajan, John Williams. 2007. "Hurricanes and Global Warming: Results from Downscaling IPCC AR4 Simulations." American Meteorlogical Society 347-367.

[14] Ibid.

[15] National Oceanic and Atmospheric Administration. kein Datum. *Climate Monitoring.* Zugriff am 20. January 2020. https://www.ncdc.noaa.gov/climate-monitoring/global/globe/1/201912.

chapter of this paper will examine specific risks to Canada from climate change, including sea level rise, severe storms, wildfires, and floods.[16] Extreme weather events will likely increase in some areas due to climate change, but weather may also become milder and less prone to disaster in some regions. The third chapter of this study will identify some of the climate change threats affecting other regions of the world, and how they relate to CAF operations. It is highly probable that other regions such as Asia will experience significantly more hardship from climate change than Canada, and this could substantially increase the demand for CAF intervention abroad, not only for humanitarian disaster relief (HADR), but also peace support and warfighting operations. Canada may also lack critical capabilities required to meaningfully respond to the effects of climate change abroad, such as naval supply ships, amphibious capability, and robust logistics support for land forces.

The notion that climate change will cause problems around the world has been known for decades, but lack of precision and clarity in public discourse has hampered meaningful action. This paper will endeavour to resolve commonly held misconceptions about climate change including our limited ability to prevent it. This paper will highlight realistic impacts to Canada in an effort to frame the demand for domestic HADR operations, and highlight future capabilities that may be required to conduct increased expeditionary operations in a changing climate.

[16] The impact of climate change on CAF operations in the Canadian Arctic was explored in detail in a separate paper by the author. For more information on climate change and arctic operations see: T.A.D. Smith, "Climate Change and Force Mobility in the Canadian Arctic: Implications for Operational Planners." Joint Command and Staff Program Course Paper, Canadian Forces College. 2019.

## CHAPTER 2 – THE HISTORY AND INEVITABILITY OF CLIMATE CHANGE

*"All Models are wrong, but some are useful" – George Box*

### Introduction

The above quote represents a very old idea in statistics, and the lesson is central to understanding the foundation for climate science. Current understanding of climate change is informed by a brief 100 years or so of systematic observation, an extremely short period of measurement when considering the vast timelines involved in geologic processes. Direct measurements of weather and climate patterns have also suffered from disparate technology as the precision of instruments and density of measurements have significantly increased over the history of climate science. Knowledge of climate change must therefore depend upon indirect measurements and limited contemporary observations, which are informed by mathematical models. Fortunately for those interested in climate change impacts to defence policy, climate scientists have been working diligently to solve not only the formidable challenges of modeling climate, but have become increasingly diligent in describing the level of certainty in their data.

This chapter will apply a multidisciplinary approach to describing the scientific basis of climate observation and modelling, specifically illuminating where uncertainty in the data should be considered by defence planners. A survey of data will be used to highlight the fact that there are regional differences in the manifestation of climate change effects, countering the limitations inherent in generalized reports that are not useful for informing defence policy or planning. Economic considerations will also be examined to provide context for climate models, and demonstrate the competing problems of human security from an economic versus environmental perspective. Finally, this section will highlight the challenge of attempts to prevent climate

change, and argue that there is little that can be done at this point to stop climate change from impacting human civilization. Humanity has no choice but to adapt to the changing environment.

**The Pleistocene epoch: 2.5 Million Years of Rapid Climate Change**

In order to analyze the science behind climate change, it is first important to provide a brief description of the scientific basis for analysis of climate change over time, beginning with the start of the Pleistocene epoch 2.5 million years (mya) before present (BP). The reason why this time period is of significance to the discussion of climate change is because it is defined by the colder climate pattern that persists in characterizing the environment to present day.[17] Figure 1.1 shows the transition from a much warmer and less volatile climate during the Paleocene and Eocene epochs (65mya BP), to the much colder and more variable climate of today. The Pleistocene and Holocene epochs are unique from earlier time periods due to naturally recurring cycles of glacial maxima (commonly known as ice ages) and deglaciations.[18] The cycles of warming and cooling that define the Pleistocene and Holocene epochs occur rapidly, relative to geologic time, on the order of 20kya to 40kya in duration.

[17] James, Zachos, Mark Pagani, Lisa Sloan, Ellen Thomas, Katharina Bilups. "Trends, Rhythms, and Aberations in Global Climate 65ma to Present." *Science*, 2001: 686-93.

[18] Tjeerd Van Andel. *New News on an Old Planet: A Hostory of Global Change.* New York: Cambridge University Press, 2000.

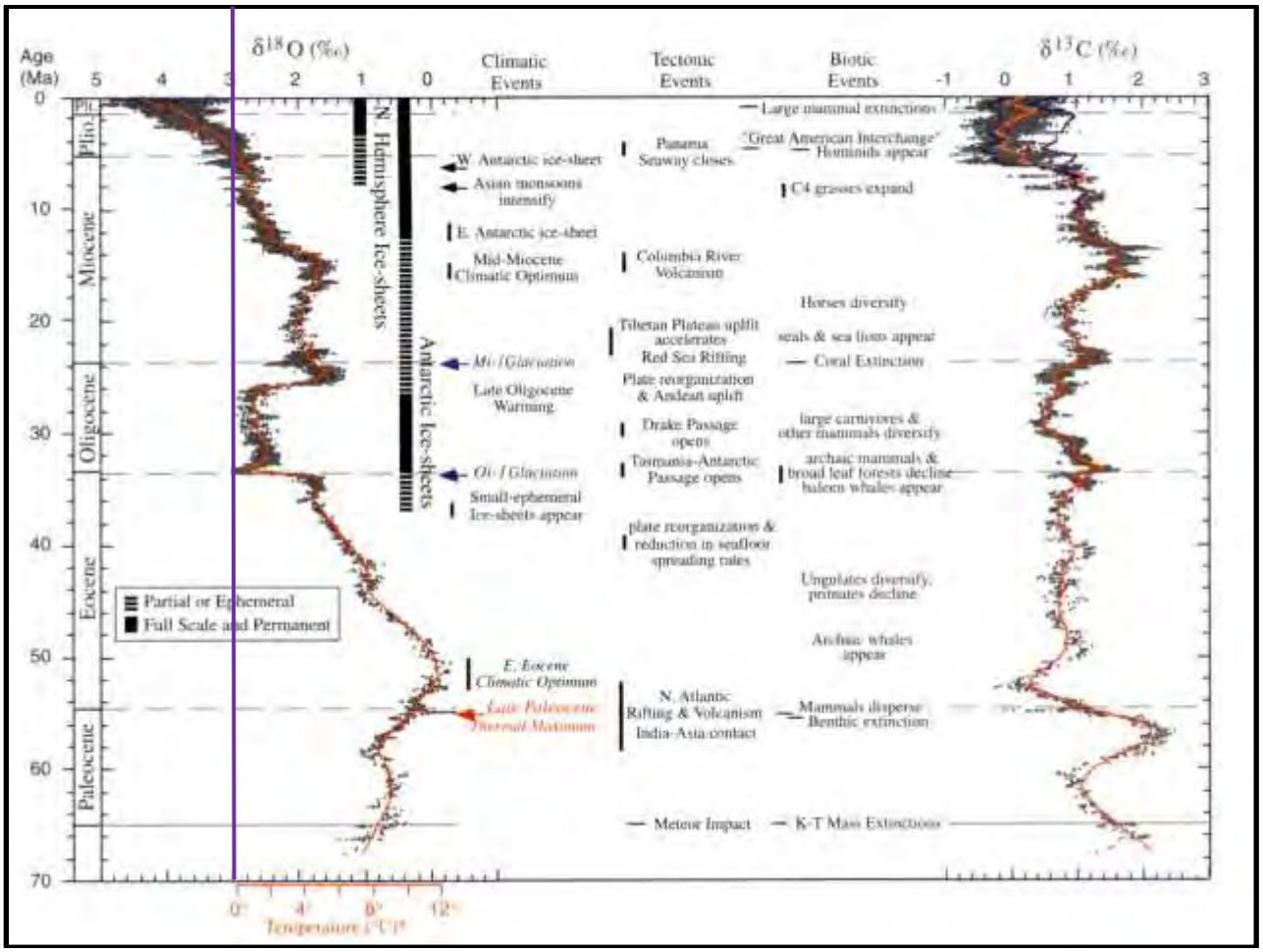


**Figure 2.1 -- 65mya of Global Temperature Variation Relative to Present Day (Purple Line)**
Source: Zachos et al. Trends, Rhythms, and Aberrations in Global Climate 65ma to Present, 2001.

Figure 2.2 shows how earth's climate since the start of the Pleistocene epoch, approximately 2.5mya BP, has cycled between warm interglacial periods and periods of re-glaciation where average global temperatures dropped rapidly.[19]

[19] Jeremy Shakun, David Lea, Lorraine Lisiecki, Maureen Raymo. "An 800Kyr Record of Global Surface Ocean δ18O and implications for Ice Volume-Temperature Coupling." *Elsvier: Earth and Planetary Science Letters*, 2015: 58-68.

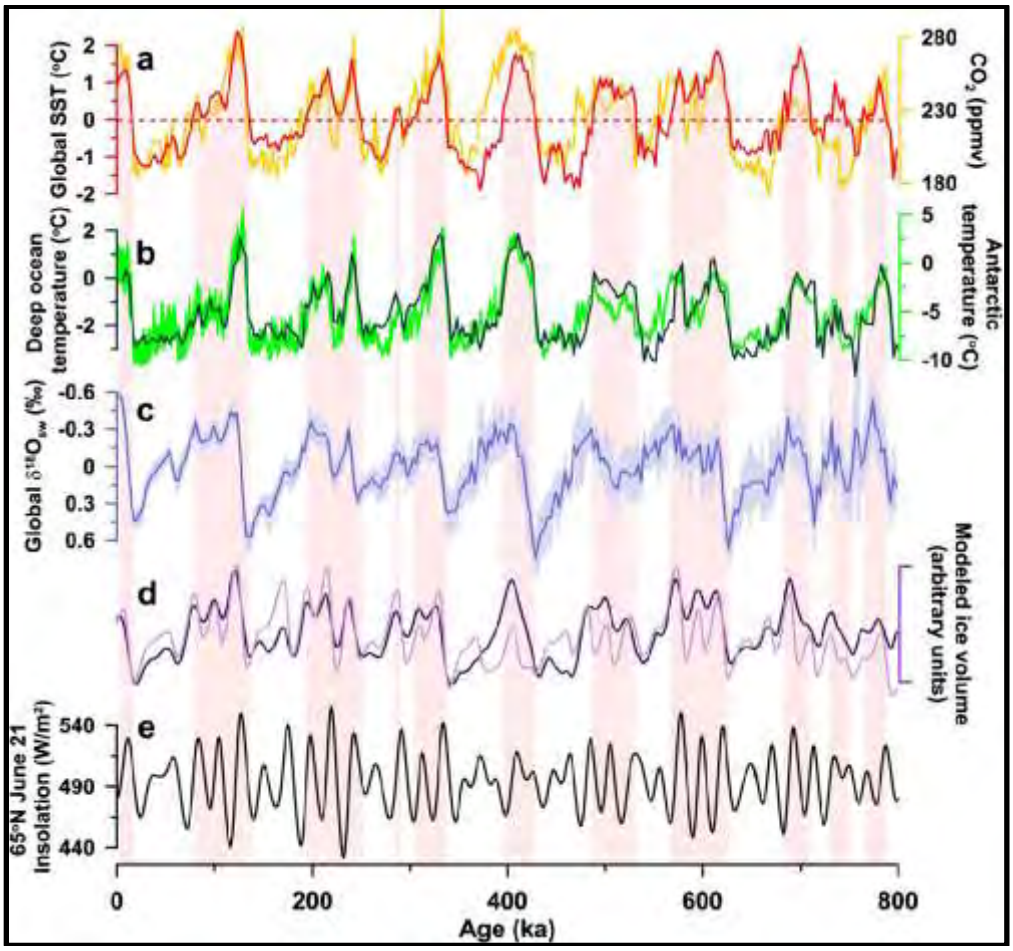


**Figure 2.2-- Global Temperature Variations 800kya to present**
Source: Shakun et al. An 800Kyr Record of Global Surface Ocean δ18O and implications for Ice Volume-Temperature Coupling. 2015.

There are natural factors involved in the global climate cycle including volcanic activity, changes in solar output, changes in earth's orbit and axial tilt, changes in oceanic and atmospheric chemistry, and the rate of carbonate weathering from sedimentary rocks.[20] Serbian physicist Milutin Milankovitch was one of the founding contributors to planetary climate science, pioneering methods to model climate change that laid the foundations for modern understanding of the natural variability of earth's climate. His most famous contribution to understanding the variability of global climate was through modeling of variations in the amount

[20] United Nations International Panel on Climate Change. *Fifth Assessment Report, Working Group 1: The Physical Science Basis.* New York: Cambridge University Press, 2013

of solar energy reaching the earth's surface (insolation). His observations and analysis were based on variations in earth's orbit (precession, obliquity, eccentricity) and cyclical variations in solar output.[21]

Milankovitch's theory remained controversial until 1976 when Hayes, Imbrie, and Shackleton were able to test the "Milankovitch Cycle" theory based on paleoclimate evidence from ocean sediment and ice core data, solidifying the link between insolation and the initiation of warming or cooling periods in the climate cycle.[22] Various complementary methods have been used to interpolate climatic conditions of the past, and there is sufficient confirmation between methods to demonstrate a high degree of certainty in the understanding of past climatic conditions. The method used by Hayes et al. analyzed the concentration of a rare isotope of Oxygen, $\delta O^{18}$ relative to its more common cousin $\delta O^{16}$. The presence of $\delta O^{18}$ within a water molecule makes it slightly more resistant to evaporation than one containing $\delta O^{16}$. Hayes et al. determined that higher quantities of $\delta O^{16}$ present in contemporary ice and benthic sediments are due to this process, and can be used to estimate the amount of ice locked up in glaciers when the ice or sediment was deposited. From this estimate they were able to determine probable global temperature at each layer in the column of ice or sediment. Ice and sediment can then be dated with a high degree of accuracy by measuring the progress of decay of another rare isotope, carbon $\Delta 14$, by a method well known as radiocarbon dating. A second method of dating sediment can be conducted by analyzing the properties of electrons within crystalline minerals through a process called thermo-luminescence (TL) dating.[23] Another important step in the study of ice cores is the analysis of air bubbles trapped in the ice to measure the atmospheric

[21] Mark Maslin. "Forty Years of Linking Orbits to Ice Ages." *Nature, Vol 540*, 2016: 208-210.

[22] J.D. Hayes, John Imbrie, N.J. Shackleton. "Variations in the Earth's Orbit: Peacemaker of the Ice Ages." *Science Vol 194*, 1976: 1121-1132.

[23] Christopher Ian Burbidge. 2012. "Facets of Luminescence for Dating." *Spectroscopy Letters* 118-126.

concentration of gases, including greenhouse gasses (GHG) like $CO_2$ and methane, at the time the ice core was formed.

Climate scientists had assumed that GHGs were responsible for driving climate variation prior to the 1970s, but the link between Milankovitch Cycles and temperature trends showed that the climate system is far more complex than originally thought, with chaotic interactions between many variables.[24] Greenhouse gases are the prime determinant for the habitable temperature regime of the earth, but Milankovitch's work showed that climate is not static, and a multitude of factors are involved in triggering periods of warming and cooling. Water vapour is the most important greenhouse gas in terms of warming earth's climate, providing 2-3 times the warming effect of CO2.[25] Naturally occurring greenhouse gasses are responsible for maintaining earth's warm climate, but several studies have found with that past periods of warming were likely not caused by an increase in greenhouse gasses. Nicolas Cailon et al. investigated Vostok ice core samples in an attempt to determine a causal relationship between naturally occurring CO2 and global temperature. They found that atmospheric CO2 concentration showed an 800+/-200ya lag between global temperature increase, and rise in global CO2 concentrations.[26] This data is a strong indication that atmospheric CO2 was likely not a cause of previous episodes of global warming, but rather was a symptom of a warming planet that was initiated by other factors such as Milankovitch Cycles.[27] Atmospheric CO2 increases as the earth warms, primarily

[24] Michel Crucifix. *Why Could Ice Ages be Unpredictable.* Louvain-La-Neuve: Climate of the Past, 9. October 2013.

[25] United Nations International Panel on Climate Change. *Fifth Assessment Report, Working Group 1: The Physical Science Basis.* New York: Cambridge University Press, 2013.

[26] Nicolas Cailon, Jeffrey Severinghaus, Jean Jouzel, Jean-Marc Barnola, Jiancheng Kang, Volodya lipenkov. "Timing of Atmospheric CO2 and Anarctic Temperature Changes Across Termination III." *Science*, 2003. 299.

[27] Ibid.

because CO2 is less soluble in warm sea water than it is in cooler sea water.[28] Cailon et al. concluded that if anthropogenic CO2 is initiating an artificial warming of the climate, then the effects of global warming will be enhanced by the positive feedback of $CO_2$ dissolution from the oceans into the atmosphere.[29]

Many climate scientists believe that carbon dioxide generated by human activity is likely increasing the rate of warming, especially given observations since the start of the Industrial Revolution. The scientific consensus for human influence on global warming is rooted in direct comparison of atmospheric CO2 concentrations over the last 50 years, with reasonably certain atmospheric CO2 measurements from ice cores and benthic sediment formed throughout the Pleistocene epoch. Current measurements show more than of 400 parts per million (ppm) of CO2 in the atmosphere, compared to model estimates of less than 300ppm from natural sources. It is indisputable that CO2 is a greenhouse gas, and it is highly likely that humans have added significantly to the rise in atmospheric CO2 that has been observed.[30] There remains some uncertainty in quantifying the impact of human generated GHGs on global warming vice natural processes alone, but the IPCC estimates that just over half of the warming observed since 1950 is linked in some way to human activity.[31] There is broad agreement in the certainty of global

[28] N. Precious Mongwe, Marcello Vichi, and Pedro M. S. Monteiro. "The seasonal cycle of pCO2 and CO2 fluxes in the Southern Ocean: diagnosing anomalies in CMIP5 Earth system models." *Biogeosciences*, 2017.

[29] Nicolas Cailon, Jeffrey Severinghaus, Jean Jouzel, Jean-Marc Barnola, Jiancheng Kang, Volodya lipenkov. "Timing of Atmospheric CO2 and Antarctic Temperature Changes Across Termination" *Science*, 2003. 299.

[30] Environment and Climate Change Canada. *Canada's Changing Climate Report.* Gatineau: Government of Canada, 2019.

[31] United Nations International Panel on Climate Change. *Fifth Assessment Report, Working Group 1: The Physical Science Basis.* New York: Cambridge University Press, 2013.

temperature increase, both from remote space based sensors and direct measurements at locations throughout the world.[32]

Various ecosystems are also showing adaptation to a warmer temperature regime, further confirming the scientific consensus that the planet is getting warmer. One such process is termed "coral bleaching," which can be described as the ejection of symbiotic algae from coral organisms, and is attributable to environmental stress such as change in ocean temperature.[33] Extensive studies have been done on coral bleaching as an adaptive process, and some studies have proposed that the current rate of warming is such that coral will not be able to adapt quickly enough to survive changing temperatures.[34] However, more recent research such as a study done by Guest et al. found that genetic variability within coral colonies coincided with uneven bleaching, and that studies concerned with mass coral extinction have underestimated the adaptability of coral reefs to environmental changes.[35] Further observation will be needed to determine if coral ecosystems are able to adapt to the current rate of warming, but in any case the changes in these ecosystems are a compelling confirmation of what has been observed in terms of global temperature change.

Another significant ecosystem change that has been observed and attributed to warming is the increased production of Boreal forests. A 2014 study of Boreal forests in Finland found that there has been an increase in annual growth of tress from 49.5 million $M^3$ / Year in 1960 to

---

[32] United Nations International Panel on Climate Change. *Summary for Policymakers, In: Global Warming of 1.5c An IPCC Special Report on the Impacts of Global Warming of 1.5c Above Pre-Industrial Levels.* New York: UN IPCC, 2018.

[33] Rob Rowan. "Thermal Adaptation in Reef Coral Symbionts. "*Nature Vol 430*, 2004: 742.

[34] Ove Hoegh-Guldberg, Ross J. Jones,Selina Ward, William K. Loh. "Is Coral Bleaching Really Adaptive?" *Nature 415*, 2002: 601-602.

[35] James R. Guest, Andrew H. Baird, Jeffrey A. Maynard, Efin Muttaqin, Alasdair J. Edwards, Stuart J.Campbell, Katie Yewdall, Yang Amri Affendi, Loke Ming Chou. "Contrasting Patterns of Coral Bleaching Susceptibility in 2010 Suggests an Adaptive Response to Thermal Stress." *PLOS One Vol 7 Iss 3,*2012:1-8.

103.9 million $M^3$ / year in 2008.[36] Kauppi et al. attributed over half of this increase to the direct effects of warming, namely a near doubling of the number of "growing degree days", and improved mobility of nutrients in the soil.[37] The remainder of growth increase could have been linked to other human influenced factors, like the increased availability of CO2 in the atmosphere, which has been found to accelerate the growth of plants under a wide range of conditions.[38] Regardless of the potential benefits to the natural health of Boreal forests, and increased forestry production , the increase in growth offers further confirmation that global temperatures have indeed been increasing over the past century.

The climate is changing due to a complex set of anthropogenic and natural factors. The problem of climate change has been brought into focus and there remains little credible challenge to these observations given confirmation by new research and technologies.[39] Common disagreements to the observed warming trend is usually rooted in misinterpretation of singular weather events, or naturally induced decadal scale cooling events as indicative that the climate is not warming.[40] Both of these misinterpretations are ignorant geologically significant time scales, namely the 10,000 year warming trend that has been characterized by the disappearance of massive ice sheets that covered most of north America and Eurasia.[41] Uncertainty does however remain regarding how different aspects of the climate system (insolation, greenhouse gasses,

---

[36] Pekka E. Kauppi, Maximilian Posch, Pentti Pirinen. „Large Impacts of Climatic Warming on Growth of Boreal Forests since 1960." *PLOS One Vol 9 Iss 11*, 2014: 1-6.

[37] Ibid.

[38] Joseph R. Stinziano, Danielle A. Way. „Combined effects of rising [CO2] and temperature on boreal forests: Growth, Physiology, and limitations. "*Botany. Vol. 92 Issue 6*, 2014: 425-436.

[39] United Nations International Panel on Climate Change. *Summary for Policymakers, In: Global Warming of 1.5c An IPCC Special Report on the Impacts of Global Warming of 1.5c Above Pre-Industrial Levels.* New York: UN IPCC, 2018.

[40] Lei Zhang. 2016. "The roles of external forcing and natural variability in global warming hiatuses." *Springer-Verlag Berlin Heidelberg.*

[41] Tjeerd Van Andel. 2000. *New News on an Old Planet: A History of Global Change.* New York: Cambridge University Press. 71.

clouds, particulate, land cover, etc.) interact to produce the changes that have been directly and indirectly observed. As explored in the previous section, significant effort has been expended in framing the problem of climate change, but there has been very little progress made toward understanding what can be done to stop or reverse the current warming trend. Unfortunately, few options exist to reduce the rate of warming over the next several centuries. According to Environment and Climate Change Canada, "Global temperature change is effectively irreversible on multi-century timescales."[42] It should also be emphasized that the climate is changing significantly due to natural variability, even when human impact is removed from the analysis. Many reports have detailed the "global warming hiatus" that has likely reduced the rate of warming over the last 20 year due to changes in the natural variability of the climate,[43] and warming will likely accelerate once these natural forcings once again become positive. Since there is currently no way to avoid the changes that have been confirmed through extensive observation and modeling, it is therefore imperative that adaptation measures are planned and implemented, and that the defence community is aware of what these mitigation measures mean for national security.

**Climate Change is Unavoidable, Humanity Must Adapt**

The IPCC has recommended urgent and radical measures to reduce greenhouse gas emissions since the first assessment report published in 1990.[44] Despite the extreme and widespread warnings from the IPCC, and other organizations, populations and governments have

[42] Environment and Climate Change Canada. *Canada's Changing Climate Report.* Gatinueau: Government of Canada, 2019.

[43] Lei Zhang. "The roles of external forcing and natural variability in global warming hiatuses." *Springer-Verlag Berlin Heidelberg*, 2016.

[44] United Nations International Panel on Climate Change. *Climate Change: The IPCC Scientific Assessment.* New York: Cambridge University Press, 1990.

been unable to find achievable solutions to reduce greenhouse gas emissions. The European Union has demonstrated an extremely high level of public will and government action to curb greenhouse gas emissions, pledging to collectively spend 100 billion dollars on alternative energy and carbon dioxide reduction by 2020.[45] Europe's closely spaced population, fully developed economies, and relatively mild climate place the EU in an ideal position to implement sustainable energy initiatives. Despite Europe's advantages toward curbing emissions, the European Environment Agency (EEA) has assessed a reversal of the emissions reductions that were achieved in the 2010's, and the EU will most likely fall short of their planned 2030 GHG reduction targets.[46] Figure 2.3 shows the EEA's low confidence in meeting emission targets


**Figure 2.3—Likelihood of meeting EU emissions targets**
Source: European Environment Agency *Environmental State and Outlook. 2019.*

Other developed nations like Canada, the US, and Australia will face substantially greater challenges over their European counterparts. This is due to larger distribution of population and greater reliance on natural resources and agriculture, which are inherently more GHG intensive. The political will to reduce or eliminate human impact on the climate has not manifested beyond Europe and North America, and the fastest growing emitters of GHGs (such as China, India, and

[45] United Nations. *United Nations Climate Change: The Paris Agreement.* 2015. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement (Zugriff am 22. February 2020).

[46] European Environment Agency. *Environmental State and Outlook 2020.* European Environment Agency, 2019.

other rapidly industrializing nations) are not likely to reduce emissions anytime in the near future.[47]

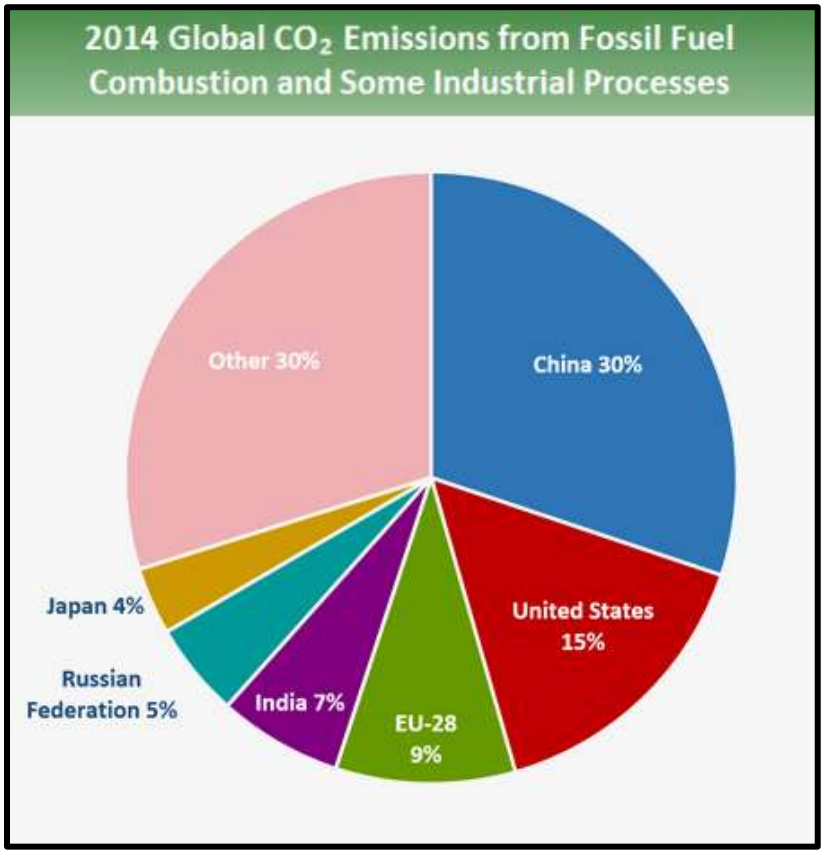


**Figure 2.4 -- GHG Emissions by Country**
Source: EPA *Global Greenhouse Gas Emissions Data.* 2014

Canada accounts for just 1.6% of global GHG emissions by CO2 Global warming potential (GWP) equivalent.[48] Most of Canada's GHG emissions are from electrical power generation, industry, agriculture, and transportation of food and economic goods.[49]

[47] David Campbell. "What is Climate Change Policy Now Trying to Achieve?" *Economic Affairs Vol 35, No. 3*, 2015: 428-442.

[48] Government of Canada. *Global Greenhouse Gas Emissions.* 5. May 2019. https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/global-greenhouse-gas-emissions.html (Zugriff am 23. February 2020).

[49] Ibid.

**Table 2.1 – Global CO2 Emissions from Personal Motor Vehicle Use**

| Canada (2007) | US (2018) | EU (2017) | Total estimate for Canada, US, Europe | Global Total (All Sources) |
|---|---|---|---|---|
| 77.00 MMT | 1054.1 MMT | 389.2 MMT | 1520.4 MMT | 36 000 MMT |
| | | | | **4.223%** |

When asked about the causes of climate change, most people state that driving personal vehicles is the leading cause of global warming, and using electric cars or public transportation are effective ways to curb GHG emissions.[50] However, the reality of human generated sources of GHG emissions is skewed decidedly away from personal vehicle use. In order to calculate the total GWP of personal vehicle use in developed western countries, statistics were taken from a 2018 Environmental Protection Agency report,[51] Statistics Canada Inventory of Greenhouse Gasses,[52] and a figure derived from EU total emissions for 2017 applied to an EU parliamentary report claim that 12% of GHG emissions are from private vehicles.[53] Table 2.1 shows the summary calculation of personal motor vehicle emissions for Canada, the US, and the EU, as generating just over 4% of all GHG emissions worldwide. This highlights a substantial disconnect between public and policy understanding of the climate change problem, and exposes a gross overestimation of the effectiveness of consumer choices in reducing GHG emissions. If every person in Canada, the US, and Europe were to stop driving gasoline and diesel powered

[50] Travis William Reynolds, Ann Bostrom, Daniel Read, M. Granger Morgan. "Now what do people know about global climate change? Survey studies of educated laypeople." *Risk analysis : an official publication of the Society for Risk Analysis vol. 30,10.* , 2010: 1520-38.

[51] Environmental Protection Agency. "Inventory of US Greenhouse Gas Emissions and Sinks 1990-2018." *Environmental Protection Agency.* 2018.

[52] Government of Canada. *Global Greenhouse Gas Emissions.* 5. May 2019. https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/global-greenhouse-gas-emissions.htm (23February2020).

[53] EU Parliament. "CO2 Emissions from cars: Facts and Figures." 2019. https://www.europarl.europa.eu/news/en/headlines/society/20190313STO31218/co2-emissions-from-cars-facts-and-figures-infographics (Zugriff am 23. February 2020).

cars tomorrow, it would prevent just 0.08 degrees of the 2 degrees of warming target over the next 100 years. According to the EPA, household energy use for heating, cooling and domestic services are responsible for even fewer GHG emissions than personal vehicle use.[54] Considering the relatively small global impact that personal vehicles and household energy in North America and Europe can have on total GHG emissions, other sectors must be considered for reduction of emissions including industry and agriculture.

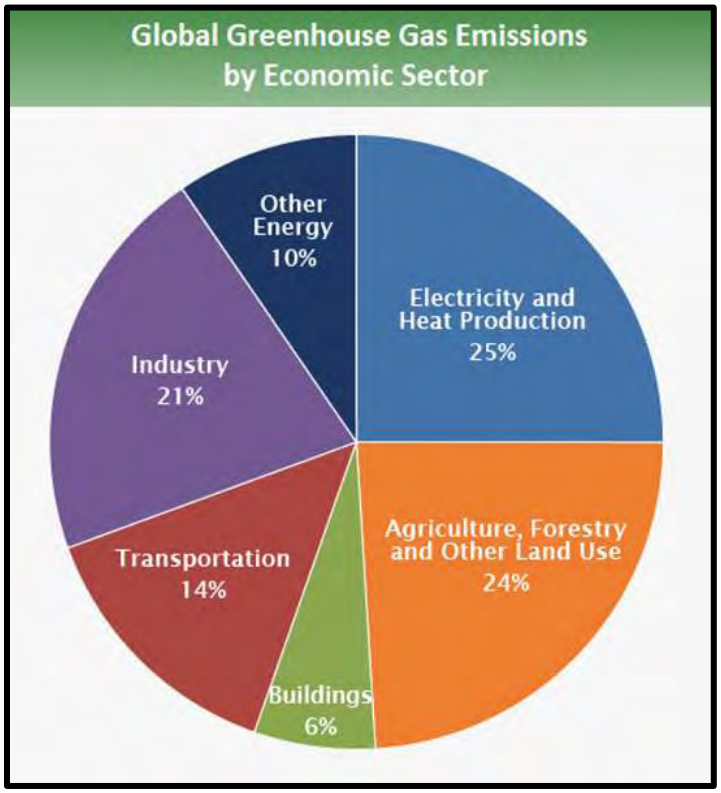


**Figure 2.5 -- GHG Emissions by Sector (US)**
Source: EPA *Global Greenhouse Gas Emissions Data.* 2014.

Figure 2.5 outlines the EPA estimates for GHG emissions by sector in the US in 2017. Canada's greenhouse gas profile is similar to the US, with the caveat that the Canadian oil and

[54] Environmental Protection Agency (EPA). *Global Greenhouse Gas Emissions Data.* 2014. https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data (Zugriff am 23. February 2020).

gas sector is treated as separate from other Canadian industries by the Government of Canada.[55] When all sources of GHGs are considered from a holistic perspective, it presents a much more challenging problem than alluded to in many of the policy documents mentioned in the previous section. Consumers are increasingly willing to adopt energy efficient practices when it comes to their personal transportation and home energy use, as these choices yield an economic as well as moral benefit.[56] However, consumers will likely not be willing to accept GHG mitigation strategies that impact human security concerns such as the price and availability of necessities like food and clothing, or other consumer goods that are necessary for the care of children, education, health, or self actualization.[57]

The aggressive targets of mitigating warming to 2 degrees Celsius over the next 100 years would have an unpalatably high impact on humanity's ability to provide the basic necessities of life, and would destroy the means to raise most of the world's 8 billion people out of poverty. Bjorn Lomborg is one of many economists who acknowledge the impact that climate change will have on security and prosperity, but argues that efforts to mitigate warming by limiting GHG emissions in the developing world will be more costly and harmful than adapting to the effects of climate change.[58] He is in agreement with other economists and foreign policy experts, such as David Victor and Charles Kennel who agree that the goals currently set by climate policy are unachievable, are not solely representative of the health of the environment, and have not been made in due regard to the costs of *mitigation*, versus the costs of *adaptation*.[59] Lomborg recently

[55] Government of Canada. *Global Greenhouse Gas Emissions.* 5. May 2019. https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/global-greenhouse-gas-emissions.htm (23 February 2020).

[56] Victoria K. Wells, Cerys A. Ponting & Ken Peattie. "Behavior and Climate Change: Consumer Perceptions of Responsibility." *Journal of Marketing Management Vol. 27, Nos. 7–8*, 2011: 808–833.

[57] Ibid.

[58] Bjorn Lomborg. "Impact of Current Climate Proposals." *Global Policy Volume 7. Issue 1*, 2016.

[59] David G. Victor, Charles F. Kennel. "Ditch the 2 °C warming goal." *Nature Vol 514*, 2014: 30-31.

published a peer reviewed article showing that even if the Paris targets are met over the next 100 years, there will be very little change to the rate of warming.[60] Figure 2.6 shows the global temperature rise modeled by RCP 8.5, compared to meeting optimistic and pessimistic Paris GHG emission targets.

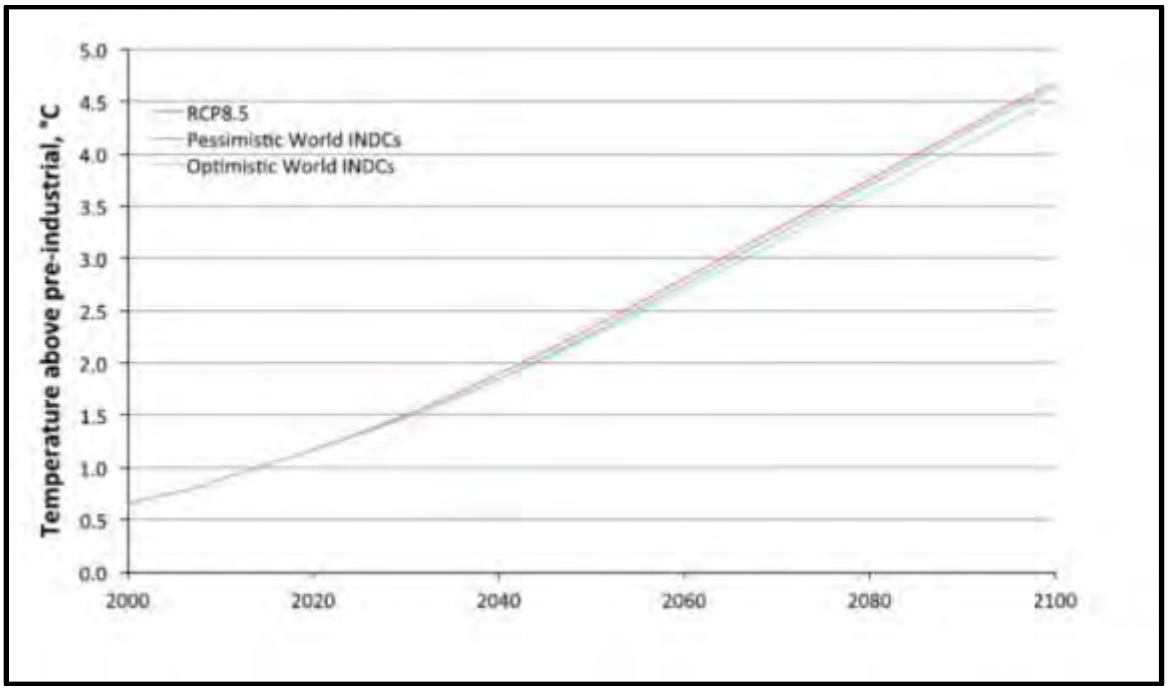


**Figure 2.6 -- Global Warming Mitigation Based on Paris Agreement Reduction Targets**
Source: Lomborg, *Impact of Current Climate Proposals*, 2016

Even if industrial processes were completely halted in favour of eliminating GHG emissions, the earth will continue to warm through existing anthropogenic GHGs and natural processes for several centuries.[61] Development will not be halted, because the destabilization of human security from the scarcity of necessities and economic development would be far worse than security threats posed by climate change. Efforts to deal with climate change as a national security threat must therefore be focused on adaptation, rather than mitigation. The Government

[60] Bjorn Lomborg. "Impact of Current Climate Proposals." *Global Policy Volume 7. Issue 1*, 2016.
[61] Environment and Climate Change Canada. *Canada's Changing Climate Report.* Gatineau: Government of Canada, 2019.

of Canada will not be able to make any measurable progress against climate change through domestic reductions alone, and it is very unlikely that Canada can muster the diplomatic credibility required to influence reduction by the world's largest GHG emitters. Figure 2.7 Shows how GHG emissions have continued to increase by most large emitters, despite promises made at global summits such as Kyoto and Paris.[62]

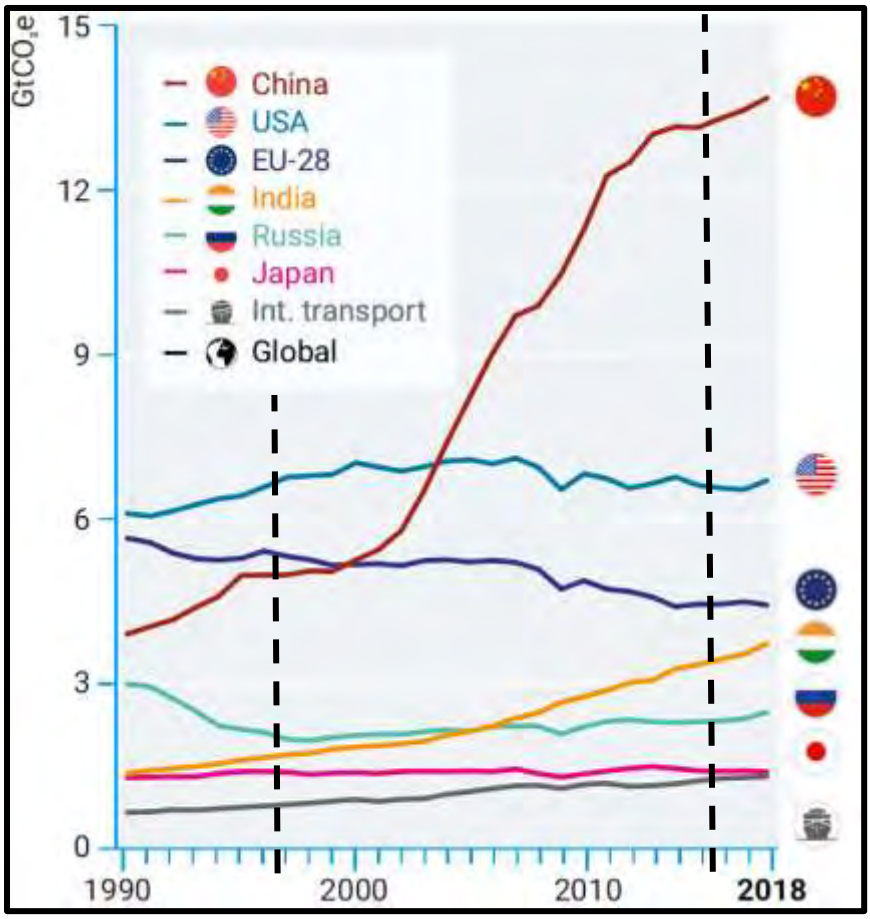


**Figure 2.7 - Greenhouse Gas Emissions Following Kyoto (1997) and Paris (2015)**
Source: UN Environment Program, *Emissions Gap Report, 2019.*

Sentiments of this nature are unpopular and policy rarely reflects so bleak a picture of climate change. On the contrary, politicians often capitalize on climate action plans for political gain, as was the case with the 2019 Liberal election campaign, but these promises have so far proven

[62] United Nations Environment Program. 2019. *Emissions Gap Report.* New York, NY: United Nations.

ineffective in addressing the reality of climate change.[63] Even though there is nothing Canada can do to mitigate climate change, national security and defence professionals can be educated about the specific risks to Canada and Canadian interests, and subsequently explore solutions to adapt to inevitable impacts of climate change. The CAF is not isolated from this reality, and changes to operational demand in the future must be considered so that CAF capabilities and capacities can be shaped accordingly. This is the challenge that will be explored in subsequent chapters.

**Conclusion**

The complexity of climate systems makes it difficult to accurately predict the effects of climate change on specific regions with sufficient fidelity to be useful for adaptation. However, observational and modeling data is becoming increasingly available and reliable, and some predictions can be made as to which regions will experience the most impactful changes over a fast enough timeline to require federal government and CAF intervention. It is possible to examine how demand for CAF operations will likely change over the long term. Fortunately for Canadians and the CAF, it is unlikely that Canada will experience challenges that are insurmountable or present an "existential threat," despite the inevitability of a warming climate trend over the next 100 years. The specific threats that climate change poses to Canadian domestic security will be explored in detail in the next chapter.

[63] Lucas Powers. 2019. "Trudeau's claim that Canada is 'on track' to meet 2030 climate target is misleading." *CBC News Politics: Fact Check*, September 25.

## CHAPTER 2 – CLIMATE THREATS TO CANADIAN DOMESTIC SECURITY

### Introduction

A 2019 Environment and Climate Change Canada (ECCC) report highlights the full spectrum of risks that Canada may face in the future based on a very broad survey of theoretical models.[64] The ECCC report expresses the gravity of risks faced by climate change, and succeeds in creating an emotional investment in climate change as a subject of importance. The unfortunate side effect of this approach is one shared by many policy documents of this nature: an erosion of practical utility for informing decision makers of realistic threats for different regions of Canada. The problem with favouring emotional arguments over scientifically sound climate science is that policy makers may be led to misinterpret risks, and apply mitigations that are not relevant for their region or time scale of responsibility. Relying on broad scope policy documents such as this could similarly lead the defence community to make assumptions that are not supported by a more detailed analysis of observations and modeling.

The 4th assessment report of the United Nations International Panel on Climate Change (IPCC AR 4) introduced new and valuable features to the conclusions and recommendations contained therein. They included a qualitative assessment of the certainty of evidence for each statement; and an easily accessible database for all source data used in the production of the report. These changes have significantly improved the ability of the broader community to analyze and apply climate change data to practical prediction and mitigation measures. The result since 2007 has been a small, but significant increase in multifactor and multidisciplinary analysis of the effects of climate change, which will continue to improve the data available for policy makers to assess risk, and plan mitigation strategies to deal with climate change.

[64] Environment and Climate Change Canada. 2019. *Canada's Changing Climate.* Gatineau: Government of Canada

There has been increased effort in downscaling global climate models (GCMs) to find more reliable, region-specific predictions about how our changing climate will affect areas of interest for defence and security. Relying on the ECCC report and similar documents alone would inculcate an opinion among defence planers that Canada will face an increase in all forms of domestic natural disasters, requiring a shift of focus toward domestic demand, and away from expeditionary operations. However, a deeper study of decadal observations and future models does not support the hypothesis that the CAF will be required to respond more often domestically. On the contrary, the specific risks faced by Canada such as sea level rise and floods, are more likely to be of concern for municipal planners, based on the mitigation measures required and time scale involved. Disasters that are more difficult to mitigate such as wildfires and severe storms, are likely to become less common in most regions of Canada, and therefore the CAF may counterintuitively see a reduced role domestically over time. Political will is always a consideration for the demand for CAF support to domestic disasters, and public perception may increase demand for the CAF domestically in the short term, regardless of the measurable prevalence and severity of natural disasters.

This chapter will examine specific climate change risks to Canada, through directly measured trends that have manifested over the past century. A broad survey of current regional and global climate models will also be used to illustrate the probability of future climate trends, based on a range of warming profiles from 2.5 to 8.5 degrees. Four specific climate threats will be explored in detail, namely sea level rise, severe storms, wildfires, and floods, in order to address the most often cited dangers of a changing climate.

**Sea Level Rise Will Slowly Impact Coastlines Over Centuries**

Sea level change is not an absolute value when considering the impact to Canada's coastlines. An important factor in determining how increases in global mean sea level (MSL), balance against vertical rebound of the land, which is still occurring due to the weight of ice over north America during the last glacial maximum.[65] This means that the east coast of Canada will experience a moderate rise of sea level over the next century, the west coast and arctic will experience a relative fall in sea level over the next century. Figure 3.1 demonstrates how these differences will likely manifest across Canada, based on a predicted MSL rise of 0.6cm per year averaged over the next 100 years, while accounting for varying levels of isostatic rebound or subsidence.[66] Based on both observed and modeled MSL increase over time, it is unlikely that sea level rise will present an urgent threat to any of Canada's coastal communities. However, it will be a consideration for future infrastructure projects, to ensure the gradual rise of sea level is factored into height above Higher High Water Large Tide (HHWLT) requirements for jetties, sea walls, road embankments, and other infrastructure. The connection between 0.6cm of sea level rise per year is often cited as further exasperating increases in storm surge risk for coastal areas.[67] However, as will be discussed in the next section, these outcomes may not manifest in Canada to the same extent as other regions around the world.

[65] Environment and Climate Change Canada. 2019. *Canada's Changing Climate.* Gatineau: Government of Canada. 349.

[66] Natural Resources Canada. 2016. *Canada's Marine Coasts in a Changing Climate.* Ottawa: Government of Canada. 47.

[67] Environment and Climate Change Canada. 2019. *Canada's Changing Climate.* Gatineau: Government of Canada. 349.

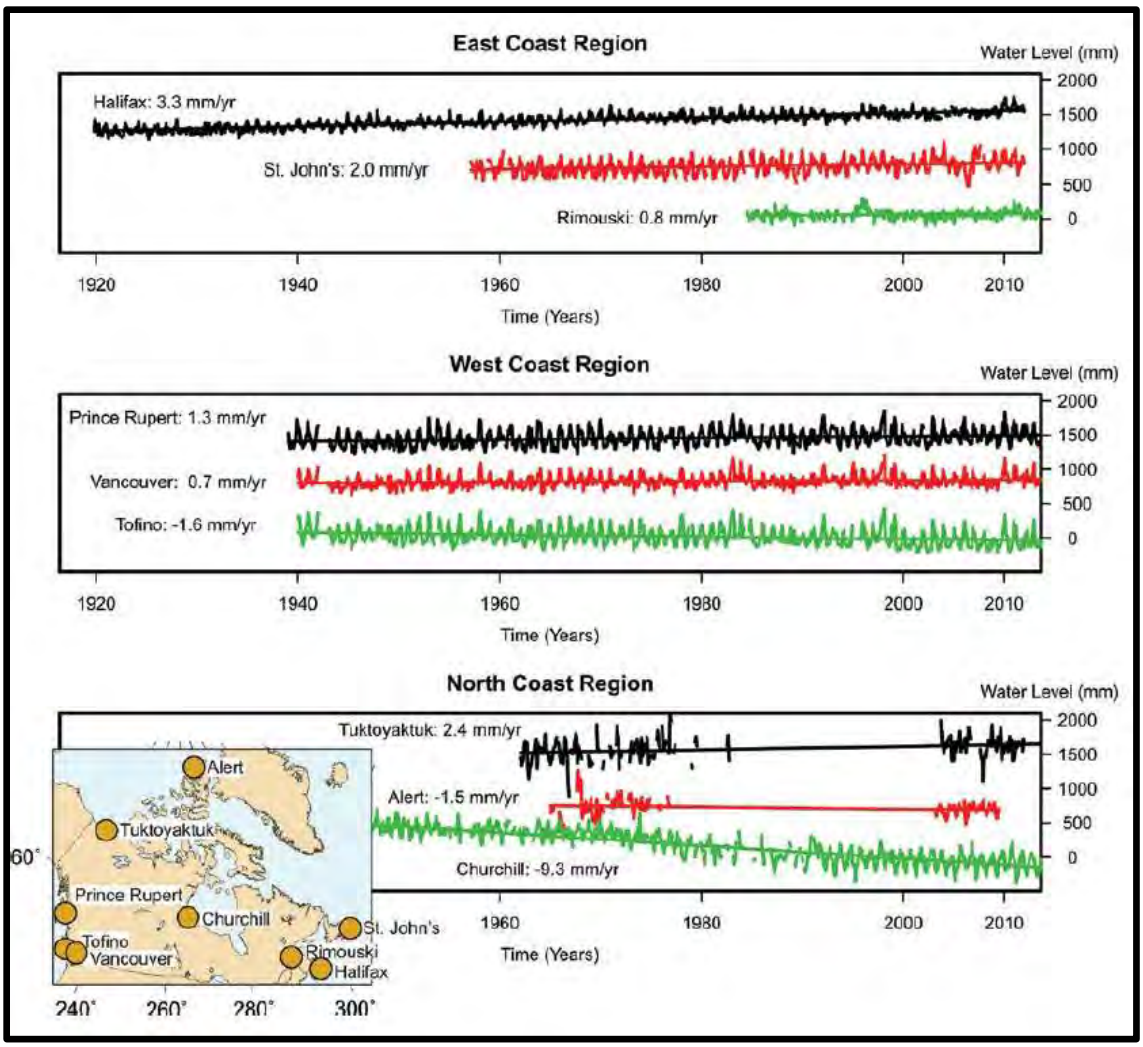


**Figure 3.1- Relative Sea Level Change Due to Vertical Land Movement and Global MSL**
Source: Natural Resources Canada, *Canada's Marine Coasts in a Changing Climate, 2016.*

Halifax presents a particular case study of interest for national defence considerations. Halifax will experience the largest increase in relative sea level of any major urban centre, based on estimates modeled by Natural Resources Canada.[68] Halifax is also home to Canada's naval forces on the Atlantic coast, and therefore any impact to local infrastructure of sea level rise will also impact a significant portion of the Government of Canada's ability to respond to natural

[68] From Natural Resources Canada. 2016. Canada's Marine Coasts in a Changing Climate. Ottawa: Government of Canada Long-term trends of relative sea-level change in Canada observed at representative tide gauges. Tide gauge data *obtained from the* Permanent Service for Mean Sea Level at http://www.psmsl.org/data/obtaining *and accessed* 19 September 2014.

disasters and other national security threats. Sea level is predicted to increase by 3.3mm per year, or 33cm over the course of the next century.[69] This increase will not generate an urgent or catastrophic impact to the City of Halifax, or to the CAF/DND units or infrastructure housed there, but it may impact the resilience of infrastructure to storm damage over the coming decades. The municipality of Halifax and Natural Resources Canada have already started to incorporate the effects of sea level rise in building standards to mitigate climate change impacts over the 100 years.[70]

The current jetty replacement project in Esquimalt is also a good example. It is replacing infrastructure that was built 70 years ago, and has been designed to withstand the contemporary impacts of climate change, and more critically earthquakes and tsunami.[71] The infrastructure at Canadian Forces Base (CFB) Halifax will similarly require built in resilience, but due to increased awareness of climate change, will undoubtedly have similar measures incorporated into deigns for future jetties. Though sea level is not a consideration for military planners in the short term, construction and real property decision makers will be compelled to consider climate change as a risk factor to aging infrastructure.

Addressing the problem of sea level rise on aging infrastructure is not a simple undertaking. Coastal systems are inherently dynamic, and artificial protection methods can have unintended consequences for the natural resilience of coastal systems, which in turn will impact the stability of infrastructure built on or near shorelines.[72] For example, if a retaining wall is

---

[69] Natural Resources Canada. 2016. *Canada's Marine Coasts in a Changing Climate.* Ottawa:Government of Canada.

[70] —. 2015. "Planning for Sea Level Rise in Halifax Harbour." *NRCAN Climate Change: Impacts and Adaptations.* November 16. Accessed April 12, 2020. https://www.nrcan.gc.ca/environment/resources/publications/impacts-adaptation/tools-guides/16301.

[71] Stantec. n.d. *B Jetty Replacement Project.* Accessed March 16, 2020. https://www.stantec.com/en/projects/canada-projects/b/b-jetty-replacement.

[72] Natural Resources Canada. 2016. *Canada's Marine Coasts in a Changing Climate.* Ottawa: Government of Canada. 127.

constructed to protect a roadway that is being threatened by a combination of sea level rise, and increased amplitude of wave action from storms, it could unintentionally block the flow of sediment via longshore current. Figure 3.2 shows how shoreline erosion can be accelerated near the protective measure, causing unintended destruction to infrastructure further "downstream" of the longshore current.[73]


**Figure 3.2 -- Coastal Erosion Accelerated by Human Mitigation Measures**
Source: Bernatchez, Fraser, *Evolution of Coastal Defence Structures and Consequences for beach width trends, Quebec, Canada,* 2012.

Much of the waterfront infrastructure in Halifax is comprised of the naval dockyard, which engenders a particular responsibility in the Department of National Defence to ensure sustainable

[73] Pascal Bernatchez, Christian Fraser. 2012. "Evolution of Coastal Defence Structures and Consequences for beach width trends, Quebec, Canada." *Journal of Coastal Research 28:6* 1550-1566.

solutions are put in place to protect critical infrastructure and minimize risk to CAF operations. Fortunately, the risks associated with sea level rise will manifest slowly enough over many decades so as to not directly impact the CAF's ability to respond to domestic or expeditionary operations.

**Lower Risk of Wildfires Across Canada, Except for Southern BC**

Wildfires occur every year throughout many regions of the planet, and often receive extensive media coverage. Wildfires in Canada for example were voted the top news story of 2016 by senior editors of the Canadian Press.[74] Wildfires are influenced by weather, which can be linked to climate change when observed over decades, and other factors such as forestry management and human caused fires are filtered from statistical observations. High temperatures, low precipitation and high winds create the conditions for greater wildfire risk to natural and human environments, and as these factors change over time and across geography, so does the risks associated with wildfires. Human encroachment into natural areas also increases the risk both of triggering wildfires, and increases the likelihood of losses due to wildfires. [75] Statistics that examine human impact alone, such as insurance losses, are useful for civic planning and risk management, but such methods based on human decision making are not useful for assessing how climate change is directly increasing risk over time. Therefore, studies that assess human factors in the absence of climatological data, including the frequency of OP LENTUS activation, will not be used to demonstrate causation in this analysis.

[74] Lauren Krugel. 2016. "Fort Mcmurray Wildfire Voted Top Canadian News Story of 2016." *Globe and Mail.* December 20. Accessed February 29, 2020. https://www.theglobeandmail.com/news/national/fort-mcmurray-wildfire-voted-canadas-news-story-of-the-year-for-2016/article33386700/.

[75] B.J. Stocks Wildfire Investigations Ltd. 2013. *Evaluating Past, Current and Future Forest Fire Load Trends in Canada.* Sault St. Marie: B.J. Stocks Wildfire Investigations Ltd.

Environment and Climate Change Canada have made statements alluding to an increase in wildfires because of the Industrial Revolution. The 2019 report on climate change claims "The changing frequency of temperature and precipitation extremes can be expected to lead to a change in the likelihood of events such as wildfires."[76] The Environment and Climate Change Canada report does not include any data to support this statement, which makes it difficult to assess the risk posed by an increase in wildfires due to climate change, especially as there will be different trends and impacts in different climatic regions of Canada. In contrast to the claims made in the 2019 ECCC report, Prime Minister Justin Trudeau made this statement following the Fort McMurray Fires in 2016 "There have always been fires. There have always been floods. Pointing at any one incident and saying: 'This is because of that,' is neither helpful, nor entirely accurate. We need to separate a pattern over time from any one event."[77] Prime Minister Trudeau's comments are much more in line with the stance taken by many climate scientists who are careful about attributing specific weather events to climate change.[78]

Weather events from year to year are often mistaken as markers for climate change, especially in the media, and amongst those who lack an understanding of the difference between weather and climate. Even credible media outlets like *McLean's Magazine* in Canada are not immune from misinformation, such as one 2018 article that claimed that wildfires have doubled since the 1970s, despite statistical data (represented in figure 3.3) that shown no such trend.[79] US President Donald Trump tweeted a comment in 2019 that a blizzard on the eastern seaboard of

---

[76] Environment and Climate Change Canada. 2019. *Canada's Changing Climate.* Gatineau: Government of Canada.

[77]Mike Desouza. 2017. "Did Catherine McKenna just contradict Trudeau on climate change?" September 12. Accessed February 29, 2020. https://www.nationalobserver.com/2017/09/12/analysis/did-catherine-mckenna-just-contradict-trudeau-climate-change.

[78] National Oceanic and Atmospheric Administration. 2018. *What's the Difference Between Weather and Climate?* March 23. Accessed February 29, 2020. https://www.ncei.noaa.gov/news/weather-vs-climate.

[79] Edward Struzik. 2018. "Is Canada Ready for the Next Big Wildfire." *Macleans.* December 21. Accessed February 29, 2020. https://www.macleans.ca/opinion/is-canada-ready-for-the-next-big-wildfire/.

the US was evidence that climate change is not happening.[80] This claim was quickly disputed by a broad range of media sources including CNN, despite their own misrepresentation of wildfires in California being proof of global warming.[81] Both President Trump and CNN could be described as misinterpreting weather events for climate change, and policy makers within DND should be wary of basing decisions on interpretations in the media, without advice on specific climate change effects on security and defence. Environment and Climate Change Canada has already demonstrated this mistake in their 2019 policy document, stating "…the 2013 flood in southern Alberta or the 2016 Fort McMurray wildfire. In both cases, human-caused greenhouse gas emissions may have increased the risk of such extreme events."[82] However, when the wildfire data is analyzed from 1980, there is very little to indicate a clear trend, and cursory analysis may even point to a slight decline in both the number of fires observed, as well as the total area burned year over year. Figure 3.3 graphically displays an aggregate of wildfire data from the Canadian National Fire Database, and the National Forestry Database.[83]

[80] Lybrand Holmes. 2019. *Cable News Network (CNN): Politics.* February 11. Accessed February 29, 2020. https://www.cnn.com/2019/02/11/politics/fact-checking-trump-snowstorm-tweet/index.html.

[81] Stephen Collinson, Maeve Reston, and Caitlin Hu. 2019. "Cable News Network." *Can California's wildfires teach America a lesson?* October 30. Accessed February 29, 2020. https://www.cnn.com/2019/10/30/world/meanwhile-in-america-october-31/index.html.

[82] Canada, Environment and Climate Change. 2019. *Canada's Changing Climate.* Gatineau: Government of Canada.

[83] Natural Resources Canada. 2019. "Natural Resources Canada." *Statistics from the Canadian National Fire Database.* Accessed April 19, 2020. https://cwfis.cfs.nrcan.gc.ca/ha/nfdb.

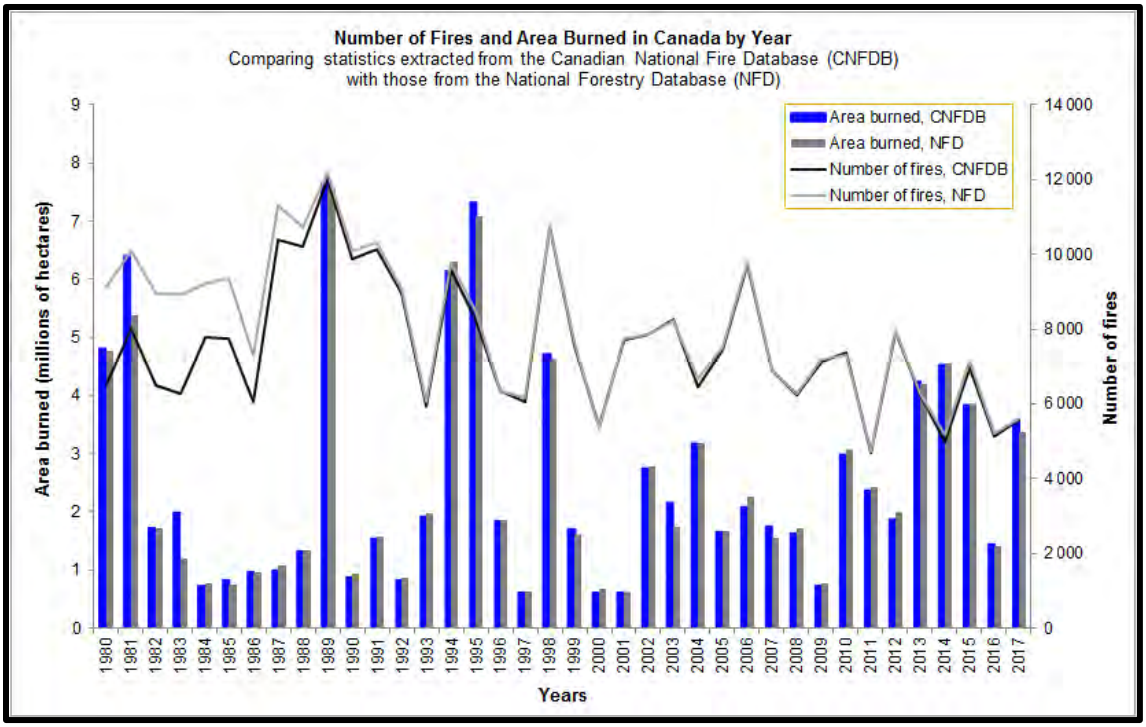


**Figure 3.3 -- Wildfire Statistics 1980 – Present**
Source: Natural Resources Canada *Statistics from the Canadian National Fire Database. 2019.*

The data for wildfires in Canada does not seem to point to a trend, and has the limitation of not accounting for improved surveillance methods, and increased human activity in the wilderness over the last 30 years. Wildfire spotting has undergone significant modernization since 1980, transitioning from local observation outposts to predominantly aerial and space surveillance.[84] When observation factors are considered, it is more likely that there has been a slight decline in wildfires in Canada since 1980.[85] The US forester society has observed a likewise downward trend in the number of forest fires in the US. A letter published in the *Journal of Forestry* in 2018 specifically highlights how media reports and political statements

[84] Canadian Space Agency. 2018. "Canadian Space Agency." *Wildfire burn scars mapped by satellites.* September 4. Accessed February 29, 2020. https://www.asc-csa.gc.ca/eng/blog/2018/09/13/wildfire-burn-scars-mapped-by-satellites.asp.

[85] B.J. Stocks Wildfire Investigations Ltd. 2013. *Evaluating Past, Current and Future Forest Fire Load Trends in Canada.* Sault St. Marie: B.J. Stocks Wildfire Investigations Ltd.

are increasingly claiming that wildfires have become more frequent, which directly contradicts an observed reduction of wildfires nationwide.[86]

Figure 3.4 shows the national trend of area burned by lightening vs human caused fires, and though there is a decline in both, human caused fires show a steeper decline than lightening sparked fires, suggesting some of the decline is due to better education and forestry management practices.

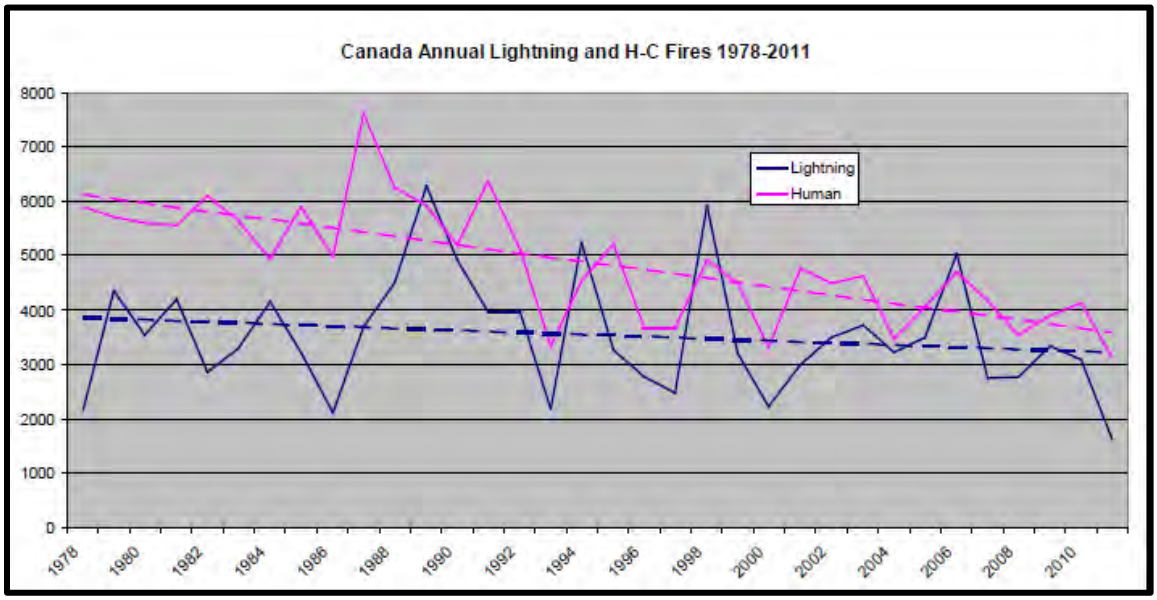


**Figure 3.4- Number of Human vs. Lightening Caused Fires 1978-Present**
Source: B.J. Stocks, *Evaluating Past, Current and Future Forest Fire Load Trends in Canada, 2013*

It should be noted that both the B.J. Stocks report and the Natural resources Canada report highlight the decline in forest fires nationwide, but point to future models that predict a possible increase in wildfires due to climate change. The contributing factors to be accounted include earlier and longer fire seasons, and slightly higher temperatures.[87] However, these models are not supportable by observed trends over several decades, and can be further challenged by applying

[86] David B South. 2018. "Facts About Wildfires." *Journal of Forestry* 90-91.
[87] B.J. Stocks Wildfire Investigations Ltd. 2013. *Evaluating Past, Current and Future Forest Fire Load Trends in Canada.* Sault St. Marie: B.J. Stocks Wildfire Investigations Ltd.

precipitation observations and models, which are better supported by the observed effects of climate change.

Statistical analysis can not be the sole source of information in a robust scientific investigation; a firm causal relationship must be established through persistent observation and testing of a statistically informed hypothesis. It is therefore necessary to attempt to infer an underlying mechanism to explain observations, and over time refine the hypothesis so as to provide the best possible policy and operational planning advice. When it comes to the decline of frequency of wildfires in Canada, climate change should indeed be seen as a contributing factor. Precipitation amounts across Canada have been substantially increasing in most areas, across most seasons, with the only exception being a slight modeled decline in southern BC during a few summer seasons within the 1948-2009 sample. The years with lower than expected rainfall have coincided with less frequent, but intense wildfire seasons, especially 2017 and 2018.[88] Figure 3.5 shows the results of a Statistics Canada study that found an increase in total annual precipitation trends across all climatic regions in Canada.

[88] Statistics Canada. 2015. "Annual mean precipitation percentage departure from 1961 to 1990 normal and linear trend for Canada and climatic regions,1 1948 to 2009." *Statistics Canada.* November 27. Accessed March 4, 2020. https://www150.statcan.gc.ca/n1/pub/16-002-x/2011003/ct016-eng.htm.

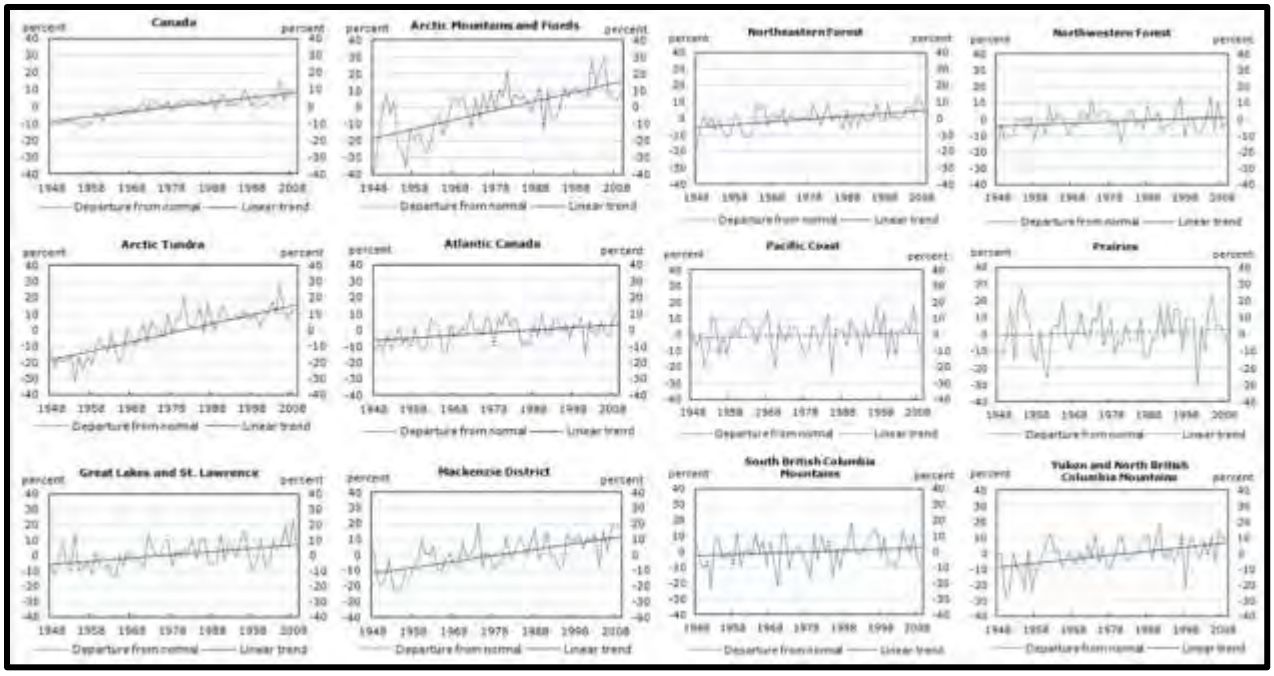


**Figure 3.5 -- Monthly Precipitation Trends in Canada: % Departure from Normal**
Source: Statistics Canada *Annual mean precipitation percentage departure from 1961 to 1990 normal and linear trend for Canada and climatic regions, 2015.*

The demand for future CAF intervention in major wildfire events is just as unclear as the trend of wildfires over the past several decades. Wildfires may not become more prevalent over time, but they are inherently episodic with years to decades of separation between major events.[89] This makes emergency planning, which is the responsibility of the provinces, expensive and difficult in the face of growing development near fire prone wilderness areas. The unpredictable nature of forest fires will mean that there will likely always be a role for the CAF to play in assisting provinces battling wildfires, as it would prohibitive to maintain constant resources to deal with disaster events with a 5-10 year or greater recurrence interval.[90] Ironically, if wildfires were to become more frequent, then provincial authorities may be better enabled to

[89] B.J. Stocks Wildfire Investigations Ltd. 2013. *Evaluating Past, Current and Future Forest Fire Load Trends in Canada.* Sault St. Marie: B.J. Stocks Wildfire Investigations Ltd

[90] Government Of Ontario. 2019. "Government Of Ontario Emergency Preparedness." *Wildland Fire Management Strategy.* December 10. Accessed April 13, 2020. https://www.ontario.ca/page/wildland-fire-management-strategy.

prioritize their own emergency resources and rely less on the CAF for assistance. However, an increase of wildfires over time is not currently supported by the evidence as previously discussed. A solution to the high cost of maintaining the large capability that is required to respond to the largest fire events, could be to improve sharing agreements for international firefighting resources. Canada, the U.S. and Australia already routinely share firefighting resources, because offset fire seasons make it practical to do so.[91] An improvement and formalization of firefighting resource sharing is something that could be established between the minister of public safety, and their counterparts in partner nations. The CAF will continue to be an option for the Government of Canada to assist in the event of climate related disasters abroad, as was the case with hurricane Katrina in 2005.

The other problem to be addressed is to question what effects the CAF can bring to the table when it comes to battling wildfires. The OP LENTUS 17-4 post operation report highlighted the fact that CAF personnel lacked the required training to deal with wildfires, and required a significant period of training and orientation both within Joint Task Force Pacific Headquarters (JTFPHQ), and in forward deployed field units. The report also highlighted that there was insufficient consultation with emergency management authorities when defining the capabilities required from the CAF, which may be a symptom of a political shift from the CAF being a tool of last resort, to a first in-last out type agency.[92] Considering that wildfires are likely to only increase episodically in southern British Columbia, and in no other region, it might make sense for the JTFW IRU, JTFPHQ, and western reserve units to incorporate some level of

[91] Mia Rabson. 2020. "Canada Offers More Aid for Australia as Bushfires Burn." *CBC News*, January 9.

[92] Commander Joint Task Force Pacific. 2018. "POST OPERATION REPORT JOINT TASK FORCE PACIFIC OPERATION LENTUS 17-04." *Global News.* December 18. Accessed March 7, 2020. https://globalnews.ca/news/4364688/bc-wildfire-2017-radios-military/

wildfire preparedness training into their readiness  model, but the CAF should not expect a sustained increase in demand.

**More Floods in Eastern Canada**

As discussed in the previous section, wildfires in Canada have been declining steadily in most regions since the 1970s due in part to increased precipitation amounts across all regions and during most seasons of the year.[93] The increase in precipitation has been observed with sufficient fidelity, and over a long enough time period to be statistically attributable to climate change.[94] Increasing precipitation can yield economic benefits from improved crop production, longer growing seasons, and the expansion of new arable land regions that were previously unsuitable for farming.[95] Unfortunately, increasing precipitation may also present increased risk of flooding in some areas, and a national level observation of flood frequency in Canada supports this assessment.[96] Flood risk is a complicated science, and requires an examination of many interdependent human and physical geographic factors prior to assessing the specific contribution of climate change to any event or series of events. Natural factors for flood risk include climate driven events such as accumulation of snow pack, especially in mountainous regions, the timing and rate of temperature increase in the spring, as well as cumulative and episodic precipitation amounts. The natural migration and change in the river through erosion and sedimentation processes are also important natural factors to consider.

---

[93] Statistics Canada. 2015. "Annual mean precipitation percentage departure from 1961 to 1990 normal and linear trend for Canada and climatic regions,1 1948 to 2009." *Statistics Canada.* November 27. Accessed March 4, 2020. https://www150.statcan.gc.ca/n1/pub/16-002-x/2011003/ct016-eng.htm.

[94] Environment and Climate Change Canada. 2019. *Canada's Changing Climate.* Gatineau: Government of Canada.

[95] Simon Dalby, Daniel Scott, Clay Dasilva, Alex Suen. 2017. "Canada in a Climate Disrupted World." *Wilfred Laurier University Geography and Environmental Science Publications.*

[96] Environment and Climate Change Canada. 2019. *Canada's Changing Climate.* Gatineau: Government of Canada.

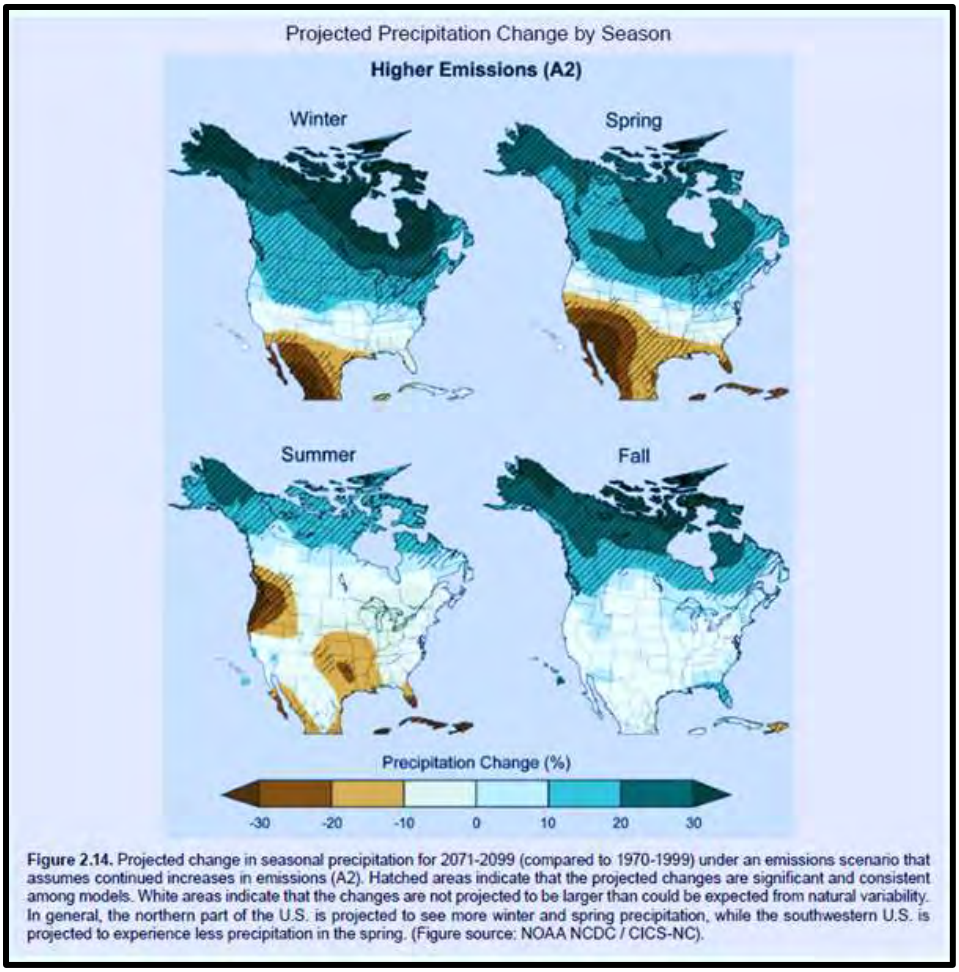


**Figure 2.14.** Projected change in seasonal precipitation for 2071-2099 (compared to 1970-1999) under an emissions scenario that assumes continued increases in emissions (A2). Hatched areas indicate that the projected changes are significant and consistent among models. White areas indicate that the changes are not projected to be larger than could be expected from natural variability. In general, the northern part of the U.S. is projected to see more winter and spring precipitation, while the southwestern U.S. is projected to experience less precipitation in the spring. (Figure source: NOAA NCDC / CICS-NC).

**Figure 3.6 – Increased Precipitation Across Most of Canada Over Most Seasons**
Source: NOAA NCDC / CICS-NC. *Our Changing Climate in Climate Change Impacts in the United States: The Third National Climate Assessment. 2015.*

Human development poses several problems when it comes to initiating floods, or increasing their devastation. These factors include increased rates of runoff from highly efficient storm drain and road systems, channelling a far greater than the runoff rate than natural ground. Infrastructure protection measures such as canalization and riprap (fortification of banks, dykes and bridge foundations) also prevent the natural evolution of a river system, and lead to increased energy and erosion at other locations upstream and downstream.[97] Large population centres, which are usually found along rivers, are at amplified risk commensurate with the larger

[97] United States Geological Survey. 2000. *Dams and Rivers: A Primer on the Downstream Effects of Dams.* Denver, CO: US Geological Survey Branch of Administrative Services.

scale of infrastructure funnelled flood waters. Ice jam flooding occurs when ice becomes jammed in melting river channels during spring thaw, and is estimated to account for US $300 million of damage annually.[98] Ice jam events have been observed to be increasing due to premature winter breakup events over the last several years, which may be linked to climate change.[99] The unpredictable nature and high severity potential of ice jam floods may create increased demand for CAF assistance, though these events tend to occur outside of major urban areas.

Human management of water levels through dams and reservoir systems have also been implicated as a contributing factor in major floods, including the Ottawa River flooding in 2019. The Ottawa River watershed is home to several hydroelectric dams that have authority for controlling the flow of the Ottawa River for hydroelectric purposes. The independent report commissioned by the Ontario government in 2019 found that there was no human error, and that local dam operators likely did all they could to mitigate the impacts of flooding.[100] However, the reservoir system was not designed to handle water for flood mitigation purposes, only for hydroelectric power generation, and therefore their ability to mitigate floods in 2017 and 2019 was negligible.[101] The 1943 *Act Respecting the Water Powers of the River Ottawa* states that dam operators must manage water levels to at least a standard that would do no more harm than natural river flows.[102] However, this aspiration is functionally impossible, as the mere existence of the dams changes the nature of river flow rates, and prevents the natural channel migration and erosion/deposition characteristics of the river.[103] The fact that dams in the Ottawa watershed

[98] Prabin Rokaya, Sujata Budhathoki, & Karl-Erich Lindenschmidt. 2018. "Trends in the timing and magnitude of ice jam floods in Canada." *Scientific Reports.*

[99] Ibid.

[100] Douglas McNeil, P.Eng. 2019. *An Independent Review of the 2019 Flood Events in Ontario.* Ontario's Special Advisor on Flooding Report to Government, Winnipeg: McNeil Consulting Inc.

[101] Ibid.

[102] Government of Ontario. 1943. "Statutes of the Province of Ontario 1943." *Legislative Assembly of Ontario.* Accessed March 9, 2020. http://www.ontla.on.ca/library/repository/ser/23347/v077pt1-1943-208.pdf.

[103] United States Geological Survey. 2000. *Dams and Rivers: A Primer on the Downstream Effects of*

were not built with any deliberate flood mitigation capacity means that it is impossible for the river channel to naturally evolve to accommodate changes in precipitation over time, and watershed regulators have limited ability to change management practices. The 2019 flood may not have been due to human error, but it was found that the second peak of the river, which was responsible for most of the damage, was due primarily to the release of upstream water from reservoirs that were not engineered to allow for this level of flood risk, and therefore had no other options.[104]

In spite of the complexity of human watershed management factors, the 2017 and 2019 floods can be attributed to two unusual and very different meteorological situations. The 2019 event was one of particular interest to assessing increased flood risk due to climate change in Canada, because it began with a record setting snow pack contributing a measurable, but coincidentally unpredictable quantity of water to the Ottawa River.[105] Figure 3.7 Shows the unusually late accumulation of snow (maximum and minimum values) that when combined with late and rapid warming in April, contributed to the 100-year flood event in 2019. Snow depth at the Ottawa International Airport at the beginning of March 2019 was 51cm, compared to a normal value of 17cm, due to the abnormally cold temperatures for that time of year. Average daily highs in March 2019 were just 2.4C, with low temperatures between -20C and -30C until mid-month.[106] Most of the unusually high quantity of snow was melted by a return to normal conditions toward the end of March as shown in Figure 3.7. This example illustrates how natural fluctuations in weather events can be amplified by climate change, in this case returning to

*Dams.* Denver, CO: US Geological Survey Branch of Administrative Services.

[104] Douglas McNeil, P. Eng. 2019. *An Independent Review of the 2019 Flood Events in Ontario.* Ontario's Special Advisor on Flooding Report to Government, Winnipeg: McNeil Consulting Inc.

[105] Ibid.

[106] Environment and Climate Change Canada. 2020. *Canadian Climate Normals 1981-2010.* March 10. https://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?stnID=4333&autofwd=1.

normal temperatures that are a few degrees higher than they would have been several decades ago.

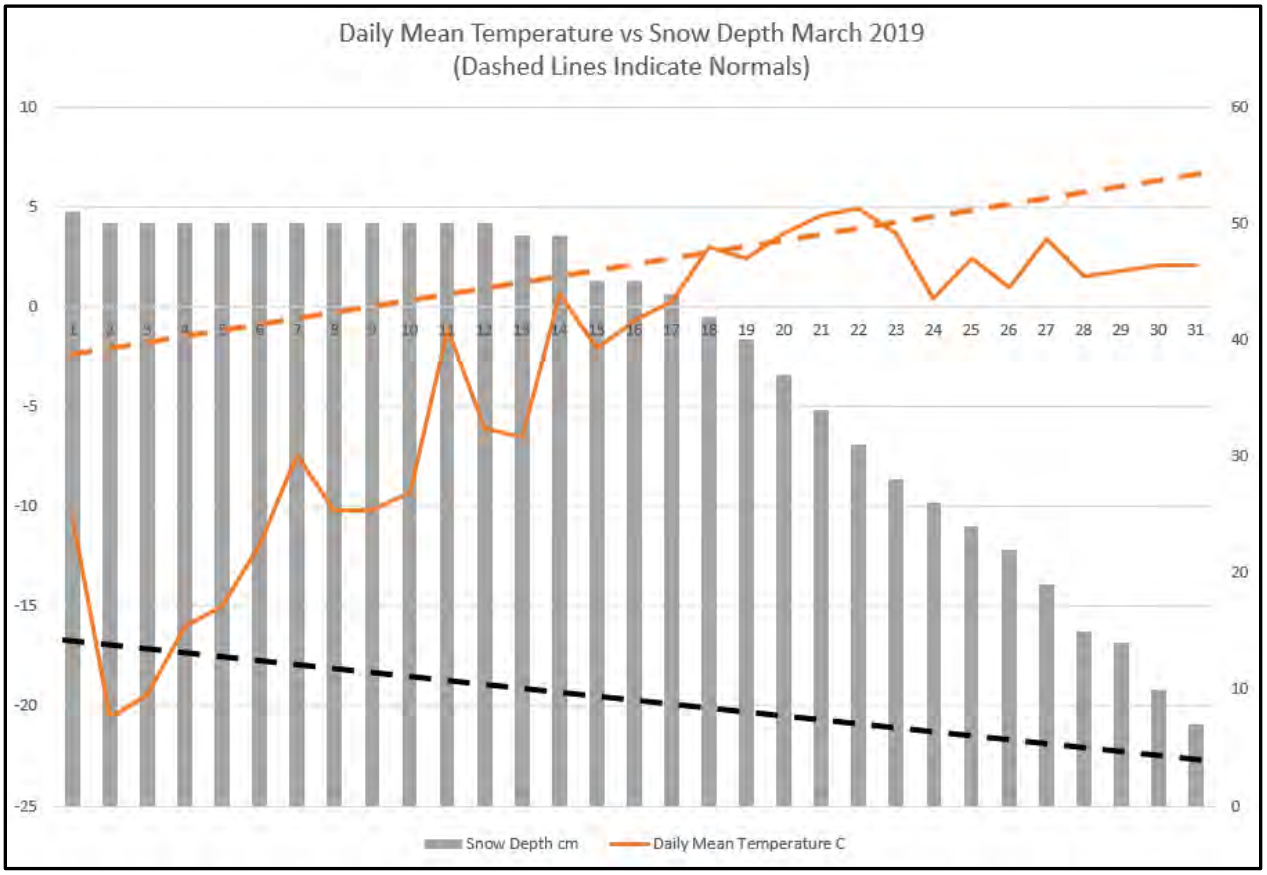


**Figure 3.7 -- Unusually large 2019 Snow Pack Melt**
Source: Author (Source data accessed through ECC Canada). 2020.

Climate change will continue to generate changes in precipitation patterns, and temperature, which for Canada will have an amplified effect in the form of increased flood risk, especially in Eastern Canada due to higher annual snow pack. Canadian infrastructure was designed under a static climate and geomorphological paradigm, which is problematic with or without the impacts of climate change. Many cities are experiencing river management problems that were inherited from earlier years of development that lacked modern insight into fluvial

considerations for civil engineering.[107] It is a common fault of civic planners and developers; making the assumption that rivers are static entities, when in fact rivers are highly dynamic over relatively short geologic time periods. The Ottawa reservoir management issue highlights potential risks for climate change that may require expensive and inefficient CAF intervention until provincial authorities dedicate resources to address the underlying causes of flooding and build resilience into civil infrastructure. Climate change will have disparate effects regionally for Canada, meaning that the CAF is not likely going to be called upon for flooding in every area over time. It is likely that Eastern Canada will require more CAF assistance for flooding in the future, and it may be necessary to train and structure units to work with local authorities in the face of increased flooding frequency.

**Fewer Severe Storms in the Atlantic**

The dominant narrative in climate policy documents is the assumption that hurricanes have increased in severity and frequency in the Atlantic Ocean, causing increased damage and threats to Coastal Cities in Canada and the US.[108] This narrative has been supported by numerous media reports, and is often quoted by politicians when addressing the threats of climate change.[109] However, the observations over the last 200 years are less conclusive than is often described by politicians and public policy papers regarding climate change. The Geophysical Fluid Dynamics Laboratory at Princeton University conducted an extensive analysis of tropical cyclones (Hurricanes in the Atlantic) and found that there was no measurable increase in the

[107] Dan Shrubsole. 2011. "Flood management in Canada at the crossroads." *Global Environmental Change Part B: Environmental.* June 15. Accessed March 10, 2020. https://www.tandfonline.com/loi/tenh19.

[108] Environment and Climate Change Canada. 2019. *Canada's Changing Climate.* Gatineau: Government of Canada. 377.

[109] National Observer. 2017. *Did Catherine McKenna Just Contradict Trudeau on Climate Change?* September 12. Accessed February 12, 2020. https://www.nationalobserver.com/2017/09/12/analysis/did-catherine-mckenna-just-contradict-trudeau-climate-change.

frequency of storms since the 1800s, and when accounting for improved observation methods of storms that make landfall on the US east coast, there may even be a slight decline in the frequency of storms.[110]

The potential decline in the frequency of storms is acknowledged by a study conducted by scientists at the Massachusetts Institute of Technology (MIT). They used downscaling of IPCC AR4 models to demonstrate that warming temperatures may reduce the frequency and severity of Atlantic Storms.[111] Another model by Li et al. used high horizontal resolution modeling as opposed to downscaling of GCMs to study the behaviour of hurricane statistics in a warming climate model, and found a similar reduction in frequency and intensity, but an increase in modeled extreme precipitation.[112] Emmanuel et al. persisted in this analysis by proposing a causal mechanism to describe the statistical observations and model projections; the sea surface and air temperature differential will decrease, despite higher temperatures within the ocean atmosphere system. This hypothesis requires further observation and modelling, but the resulting conclusion would be that the ocean-atmosphere energy transfer required to generate and sustain severe storms may become less over time in the North Atlantic, reducing the frequency and severity of storms.[113]

An interesting archeological analogue may also lend support for the hypothesis of not only fewer hurricanes, but also less intense mid latitude cyclonic storms in the North Atlantic

---

[110] Geophysical Fluid Dynamics Laboratory, Princeton University. 2011. *Historical Atlantic Hurricane and Tropical Storm Records.* Accessed February 12, 2020. https://www.gfdl.noaa.gov/historical-atlantic-hurricane-and-tropical-storm-records/.

[111] Kerry Emanuel, Ragoth Sundararajan, John Williams. 2007. "Hurricanes and Global Warming: Results from Downscaling IPCC AR4 Simulations." American Meteorlogical Society 347-367.

[112] Fuyu Li, William D. Collins, Michael F. Wehner, and L. Ruby Leung. 2013. "Hurricanes in an aquaplanet world: Implications of the impacts of external forcing and model horizontal resolution." *JOURNAL OF ADVANCES IN MODELING EARTH SYSTEMS, VOL. 5,* 134-145.

[113] Kerry Emanuel, Ragoth Sundararajan, John Williams. 2007. "Hurricanes and Global Warming: Results from Downscaling IPCC AR4 Simulations." American Meteorlogical Society 347-367.

near Greenland. There is a high probability that earth underwent a warming period from 800 A.D. to 1200 A.D. with robust archeological evidence for thriving civilizations around the world, especially those in Europe. Based on sediment analysis, Blas et al. found a link between human activity and agricultural surpluses due to better agricultural conditions in Spain. The warmer climate during this period proved beneficial for northern Europe, by providing longer growing seasons, increased precipitation, melting permafrost and receding glaciers.[114]

More archeological evidence for a surge in European prosperity comes from the expansion of Viking settlements in Greenland, Iceland, and North America, which have been directly linked to warmer temperatures than present day.[115] It is more difficult to determine predominant weather patterns from archeological evidence, but it is possible that both mild temperatures, and calmer wind patterns contributed to Viking success in Greenland, especially considering their reliance on maritime travel. A multidisciplinary approach was employed by Kuijpers and Mikkelsen in a 2008 study of alluvial sedimentation relative to Viking artifacts in Greenland. They found that wind patterns steadily increased over the period of settlement, reaching maximum force around 1300 AD at the commencement of a significant cooling of the Greenland climate.[116] The cooling trend and increasingly violent wind pattern coincided with the disappearance of Viking settlements at the start of the "little ice age."[117] A perfect comparison cannot be made between the Medieval warm period and climate change of today, but

[114] Mario Morello´n Blas, Valero-Garce´s, Pene´lope Gonza´lez-Sampe´riz. 2009. "Climate changes and human activities recorded in teh sediments of Lake Estanya (NE Spain) during the Medieval Warm Period and Little Ice Age." *J Paleolimnol (2011) 46* 423–452..

[115] G. Everett Lasher, Yarrow Axford. 2019. "Medieval warmth confirmed at the Norse Eastern Settelment in Greenland." *Geology Society of America Vol 47 n. 3* 267-270.

[116] Antoon Kuijpers, Naja Mikkelsen. 2008. "Geological records of changes in wind regime over south Greenland since the Medieval Warm Period: A tentative reconstruction." *Polar Record 45 (232)* 1-8.

[117] G. Everett Lasher and Yarrow Axford. 2019. "Medieval warmth confirmed at the Norse Eastern Settelment in Greenland." *Geology Society of America Vol 47 n. 3* 267-270.

consideration of weather pattern changes during the warming and cooling in the Medieval period is nevertheless valuable for validating climate models against climate change effects of the past.

Severe storms may still present a significant problem to consider as the climate changes. Both GFDL and Emanuel et al. acknowledge that different dynamics outside of the Atlantic Basin may indeed produce much more severe storms, especially for regions in the Pacific Ocean.[118] The GDFL report also highlights the possibility that though storms are less frequent, they may produce more precipitation due to the higher water content available in warmer air.[119] Specific examples that are indicative of this increase in precipitation trend is the recent landfall of hurricanes such as Harvey in 2017. Harvey caused extensive flooding in Texas, registering precipitation values that were modeled to be a 9000 year return event under current understanding of climate normals.[120] Flood mitigation infrastructure was overwhelmed and millions of dollars of damage resulted.[121] Severe tropical cyclones have impacted Canada in the past, though less frequently than in the US. The increase in precipitation observed in US storms could be inferred to apply to storms that also make landfall in Canada. Increased flood resilience of infrastructure will be similarly necessary to deal with the increased precipitation from tropical cyclones over the coming decades, but storm surge and severe winds are less likely to be a factor in planning for domestic disaster relief. The CAF may have a role in the short term assisting local authorities with the impacts of flooding on inadequate infrastructure following severe storms, but this role should become less important as municipalities progress their own climate change mitigation measures.

---

[118] Geophysical Fluid Dynamics Laboratory, Princeton University. 2011. *Historical Atlantic Hurricane and Tropical Storm Records.* Accessed February 12, 2020. https://www.gfdl.noaa.gov/historical-atlantic-hurricane-and-tropical-storm-records/.

[119] Ibid

[120] Geert Jan van Oldenborgh, Karin van der Wiel , Antonia Sebastian , Roop Singh, Julie Arrighi. 2017. "Attribution of extreme rainfall from Hurricane Harvey August 2017." *Environmental Research Letters Vol 12.*

[121] Ibid.

The CAF still has room to improve the robustness of defence resources available to respond to domestic natural disasters. Different regions will continue to face different threats, and these differences may become more pronounced over time. CAF response is limited by the location of major regular force bases relative to the highest risk locations for disasters. For example, the highest risk of flooding applies to major urban centres like Calgary and Montreal, which do not have a large military presence.[122] The reserves have been, and will continue to be heavily relied upon for disaster response, especially in areas without large CAF bases. Trends in the risk of climate related disasters could be used to tailor the training and resources allocated to reserve units, and it could become part of their normal readiness cycle. Additionally, JTFP and JTFW could be resourced specifically to address forest fires in BC, while FOIE and JTFA could be resourced and structured to better prepare for flooding events in eastern Canada. The relative increase in major disasters abroad that is explored in the next chapter suggests that regular force units must be ready to conduct more expeditionary HADR in the future. This further supports the idea that the reserves must take on a larger portion of the burden for responding to disaster relief operations in Canada.

**Conclusion**

CAF Leadership often highlight Climate Change as a threat to Canadian domestic security. Senior staff at Canadian Joint Operations Command (CJOC) often point to a significant increase in OP LENTUS (domestic disaster relief) operations since 2015 as an indication of increased climate change effects.[123] In the absence of an empirical increase in the frequency of

[122] Dan Shrubsole. 2011. "Flood management in Canada at the crossroads." *Global Environmental Change Part B: Environmental.* June 15. Accessed March 10, 2020. https://www.tandfonline.com/loi/tenh19. 64.

[123] Canadian Joint Operations Command. "Environmental Impacts on Security." *(Lecture Canadian Forces College Climate Symposium, Toronto, ON, February 12 2020).*

climate related disasters, the increase in CAF domestic responses must be attributable to a different set of factors. Public Safety Canada and CAF operations planners have already highlighted a shift in philosophy from the CAF as a force of last resort, to a first-in last-out responder to these extreme events at home.[124] While there is considerable political and public will to see the CAF responding to disasters in Canada, it remains to be seen if this will remain palatable given the cost of such operations, both financially and in terms of force readiness. If observed trends continue to show a decline in disasters in many areas across Canada, there may very well be a reduction in domestic demand for CAF operations. This conclusion does not minimize the fact that climate change will present significant challenges to Canadian prosperity if mitigation measures are not adopted by civil authorities. Other regions of the world will almost certainly face increased challenges due to climate change that will have implications for Canadian security.

[124] Commander Joint Task Force Pacific. 2018. "POST OPERATION REPORT JOINT TASK FORCE PACIFIC OPERATION LENTUS 17-04. Annex B Line 23." *Global News.* December 18. Accessed March 7, 2020. https://globalnews.ca/news/4364688/bc-wildfire-2017-radios-military/.

## CHAPTER 3 – CLIMATE IMPACTS TO CAF EXPEDITIONARY OPERATIONS

### Introduction

The United Nations (UN) International Panel on Climate Change (IPCC) has clearly documented that many nations around the world are facing serious security threats due to climate change, both in terms of economic prosperity, resilience of critical infrastructure, and conflict with neighboring states that are facing their own climate related challenges. This chapter will explore two facets of climate change that may impact the way the CAF conducts operations; namely that the demand for expeditionary operations will increase, and the capabilities required to conduct expeditionary operations will change.

The impacts of climate change on US and Australian interests offer a particular contrast to Canada in terms of climate threats. Australia offers an excellent comparison because it is similar to Canada in terms of history, culture, economy, and demography, but Australia is vastly different in terms of geography, climate, and geopolitical situation. Australia is located close to the heart of southeast Asia, a region in stark contrast in terms of cultural and economic characteristics. It is also a region that is highly susceptible to the effects of climate change, most notably sea level rise and severe storms. Impacts to Australia's security have been, and will continue to be of consequence to Canada due to our diplomatic and military relationships. Australia also offers an important a case study for understanding that domestic climate change impacts to Canada are small, when compared to other regions of the world.

The USA's position as the world's superpower means that climate change will impact US interests in many other regions outside of North America.[125] The US has extensive interest in Southeast Asia in particular, and it is also one of the most challenging regions for the US to

[125] Direct climate change impacts to the continental United States were alluded to in chapter one, and therefore do not require further elaboration.

project power in the face of increased Chinese influence in the region. The difficulty in power projection will likely be amplified by the effects of climate change, and the US is taking substantial measures to mitigate any erosion of their power projection capability. The US is Canada's closest defence partner, as well as the most influential military force in the world. Any impact to the US ability to project power in Southeast Asia will similarly affect the CAF's ability to operate in that region.

**Climate Change Will Increase Demand for CAF Operations Abroad**

The US strategic pivot to the Pacific theatre has been well documented in policy since the early 2010s, and recent analysis of this shift has progressively highlighted climate change as a major consideration for operational and strategic planners. Southeast Asia is the region of the world most affected by meteorological disasters and future models predict this trend will get much worse over time due to climate change.[126] Tropical cyclones in the north Atlantic were discussed in the previous chapter citing several studies that predict a negligible change to the frequency of storms on the US east coast, but the same authors found broad and compelling evidence that the severity of cyclones in the Pacific may substantially increase with as little as 2.5 degrees of warming.[127] Figure 4.1 shows a summary of Emanuel's results for the change in cyclone track density projected forward from 2006, relative to historical data prior to 2005.

[126] Centre for Climate Security. 2015. *The US Asia Pacific Rebalance, National Security and Climate Change.* Washington, D.C.: Centre for Climate and Security.14.

[127] Kerry Emanuel. 2013. "Downscaling CMIP5 climate models shows increased tropical cyclone activity over the 21st century." *Program in Atmospheres, Oceans, and Climate, Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology.* July 23. www.pnas.org/cgi/doi/10.1073/pnas.1301293110

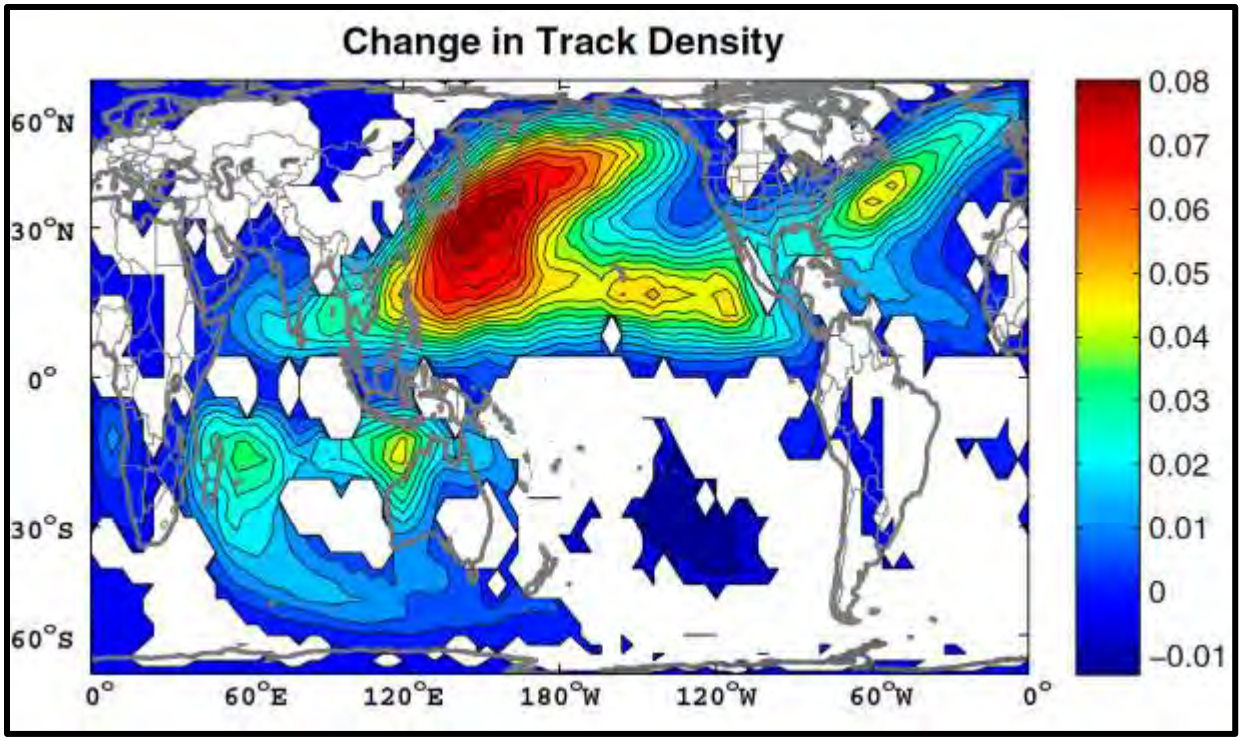


**Figure 4.1- Increased Tropical Cyclone Tracks in the NW Pacific**
Source: Emanuel, Downscaling CMIP5 climate models shows increased tropical cyclone activity over the 21st century. 2013.

Emanuel's article is particularly useful, because it compares a broad spectrum of models, representative of the range of uncertainty and confidence level among cyclogenesis models. Emanuel emphasizes that a significant amount of analysis has been done on Atlantic cyclogenesis, with results showing either a small increase or no increase at all.[128] Though Emanuel concluded that the Western Pacific may see a substantial increase in Cyclone tracks, a report by Wildlansky et al. found that the frequency of cyclones may remain the same or see a small decrease when considering the islands of greatest concern for the US military operations, namely Guam and Oahu.[129] Widlansky et al. also found from their analysis of multiple models

[128] Kerry Emanuel. 2013. "Downscaling CMIP5 climate models shows increased tropical cyclone activity over the 21st century." *Program in Atmospheres, Oceans, and Climate, Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology.* July 23. www.pnas.org/cgi/doi/10.1073/pnas.1301293110

[129] Matthew J. Widlansky, H. Annamalai, H. Stephen B. Gingerich, Curt D. Storlazzi, John J. Marra, Kevin I. Hodges, Bary Choy.2019. "Tropical Cyclone Projections: Changing Climate Threats for Pacific Island Defence Installations." Weather, Climate, and Society Vol. 11. 3-15.

that tropical cyclone tracks approaching within 5 degrees latitude (300 nautical miles) of Guam and Oahu may see an increase in average intensity, along with the predicted reduction in frequency, which may be of more concern to US and Canadian operations.[130] Less frequent, but more intense storms mean that there will be fewer interruptions to operations over the long term, but interruptions in operations may be prolonged due to greater potential damage to shore facilities. The strength of any particular storm may also mean the difference between naval and ground forces "riding it out" in the area, or leaving the path of the storm altogether, which would increase the amount of time required to respond to a security threat or humanitarian crisis in the wake of a storm.[131] This factor amplifies the difficulty of power projection in the Pacific theatre, and could provide an advantage to regional powers such as China, whose deployment of forces would be more expedient due to simple proximity to the affected region. The threshold for which ships are able to operate in a high sea state is also an important factor, which will be considered in the next section.

Water scarcity is forecast to become a major problem in areas that already face stability challenges in the Indo-Asia Pacific, including the Indian sub-continent and Southeast Asia.[132] Asia is a region of growing importance to both Canada and the US, and is close enough to Australia to present particular consideration as a threat in the event of further erosion of stability.[133] A significant problem exists due to the transnational supplies of water flowing through multiple nations, and whose resources are of critical importance for both economic

[130] Matthew J. Widlansky, H. Annamalai, H. Stephen B. Gingerich, Curt D. Storlazzi, John J. Marra, Kevin I. Hodges, Bary Choy.2019. "Tropical Cyclone Projections: Changing Climate Threats for Pacific Island Defence Installations." Weather, Climate, and Society Vol. 11. 3-15.

[131] Jennifer Hlad. 2018. "Life in Typhoon Alley." *Air Force Magazine*, August 29.

[132] Ester Babson. 2018. *Strained Stability: Climate Change and Security in South East Asia.* American Security Project

[133] US Department of Defence. 2019. *Indo-Pacific Strategy Report.* Washington D.C.: US Department of Defence.

prosperity, as well as for human security, given that subsistence farming is still the means of survival for millions of people in the region.[134]

Several nations in the Indo-Pacific have implemented International water treaties, capitalizing on water security as an opportunity for regional cooperation, but tension arises when water quality or quantities shift to an extent that threatens any one nation's internal stability.[135] When this occurs, history shows that water treaties can be unilaterally discarded as is the case with the ongoing disagreement between Turkey and neighboring countries over the waters of the Euphrates, and between Laos and its neighbours since 2016.[136] In cases such as these, the nature of water as a basic need for survival emerges and trumps all other international considerations. Fortunately, disagreements over water have rarely resulted in war, and historical disagreements in other regions have eventually resolved through diplomacy. Water resources will become more stressed in the aforementioned regions as the climate changes, and when coupled with population growth, and in some areas population may start to exceed resource capacity. This has already been observed in some areas, which has increased the displacement of people, and the potential for existentially motivated conflict.[137]

India and Pakistan present another facet of water as a source of historical cooperation, but one that can easily shift to a resource of contention or a tool used as leverage in other unrelated disputes. For example, in 2016 India responded to a Kashmiri separatist attack by threatening to withhold water on the Indus River, violating treaty obligations with Pakistan.[138] The move by India threatened both Pakistan and the Kashmir region, and could have had a severe impact on

---

[134] Joshua Busby. 2017. *Water and US National Security.* New York, NY: Council on Foreign Relations.
[135] Jaroslav TIr, Douglas M. Stinnett. 2012. "Weathering climate change: Can Institutions Mitigate International Water Conflict?" *Journal of Peace Research 49:1* 211-225.
[136] Joshua Busby. 2017. *Water and US National Security.* New York, NY: Council on Foreign Relations.
[137] Jaroslav TIr, Douglas M. Stinnett. 2012. "Weathering climate change: Can Institutions Mitigate International Water Conflict?" *Journal of Peace Research 49:1* 211-225.
[138] Joshua Busby. 2017. *Water and US National Security.* New York, NY: Council on Foreign Relations.

both the economy, and the health and safety of Pakistanis.[139] Given the history of war between India and Pakistan, and the fact that both nations possess nuclear weapons, water could very easily become the motivating factor for a disastrous conflict. Disputes such as these serve to threaten US interests for peace and international cooperation in strategically important regions, and the US has an interest in supporting and preserving water security and supporting international agreements to that effect.[140] Figure 4.2 (below) shows a composite of water security risk globally. This risk was assessed using a hybrid of water scarcity probability under RCP 8.5 Models, combined with a human security risk factor based on social and environmental resilience.[141] Based on this analysis it is clear that water scarcity poses high risk for areas that already face instability from other factors, which will be exacerbated by climate change.

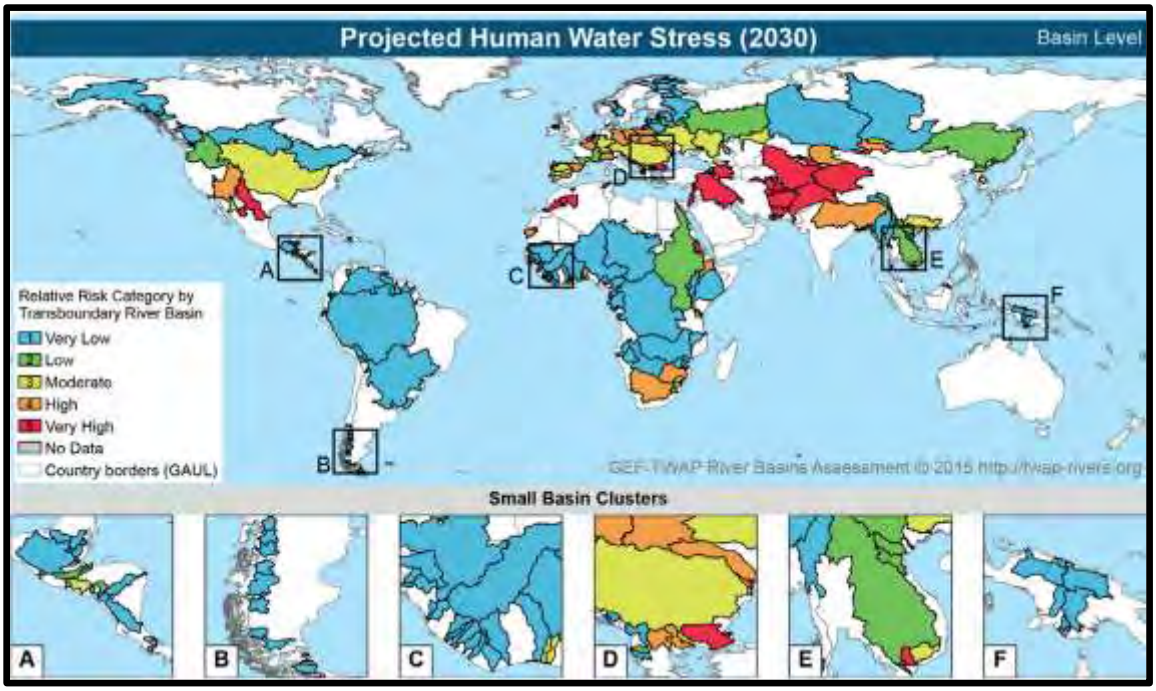


**Figure 4.2 – Projected Human Water Stress Related to River Basins.**
Source: Transboundary Waters Assessment Programme, *Transboundary River Basins: Status and Trends, 2020*

[139] Joshua Busby. 2017. *Water and US National Security.* New York, NY: Council on Foreign Relations.
[140] Ester Babson. 2018. *Strained Stability: Climate Change and Security in South East Asia.* American Security Project.
[141] Transboundary Waters Assessment Programme. 2016. "Transboundary Waters Assessment Programme." *Transboundary River Basins: Status and Trends.* Accessed April 1, 2020. http://geftwap.org/publications.

According to the DND Future Security Environment study, Canadian defence priorities are likely to align with US interests for the foreseeable future, and the degradation of stability in areas of interest to the US, will similarly impact Canadian interests abroad.[142] Water motivated conflict will have human security dimensions that can not be solved by military force alone, and therefore aligns with the type of middle power peacebuilding and stability operation that is achievable as a whole of government solution, and is more in line with Canada's preferred contribution to global security.[143] The solution to water motivated conflict will require strengthening of trans border water agreements, which have similar characteristics to international trade agreements. Canada has historically demonstrated success in negotiating favorable trade agreements, despite vast economic power differences with partners such as the US and EU.[144] Canada could therefore be an effective third party broker as has been demonstrated in past human security initiatives, providing full spectrum support to the prevention or resolution of conflicts.[145] The CAF will be critical in providing security and peace support as part of a whole of government effort.

**Climate Change Will Affect the Capabilities Required for CAF Operations**

The CAF strategy on dealing with the effects of climate change is far from comprehensive, due in part to a lack of clarity regarding the diverse range of climate change impacts. It is important to separate the impact of climate change on expeditionary operations from domestic or force generation considerations: the effects of climate change are different

[142] Chief of Force Development, Canadian Armed Forces. 2014. *Future Security Environment 2013-2040.* Winnipeg, MB: 17 Wing Winnipeg Publishing Office. 5.

[143] Peter Jones. 2017. "Canadian Global Affairs Institute." *Canada and Mediation: Issues and Considerations.* Accessed April 1, 2020. https://www.cgai.ca/canada_and_mediation_issues_and_considerations.

[144] Erick Duchesne. 2013. "Regional Trade and Economic Negotiations." *International Negotiation 18:1-3.*

[145] Norman Hillmer, J. L. Granatstein, 2007. *Empire to umpire: Canada and the world into the 21st century.* Toronto: Nelson Education. 318.

across the regions that the CAF must operate, and are dependant on the tasks that the CAF may be required to perform. The Department of National Defence released an energy and environment strategy in 2017, that discussed the topic of sustainability, but did not include any plan for adapting to the effects of climate change for operations at home or abroad. The report highlighted the need for sustainable infrastructure, but all discussion was focussed on energy efficiency, with no guidance whatsoever on adopting climate-resilient building standards, or dealing with resilience of force sustainment on expeditionary operations. The report acknowledged the importance of climate adaptation by stating: "Climate change is already affecting DND's real property portfolio across Canada, but more so in the North. DND is planning and adapting its operations for the current and future impacts of climate change".[146] However, this was added only as a caption to an image near the end of the document, and no climate adaptation was mentioned whatsoever in the body text. Annex 1 assigned tasks and OPIs, and included just one mention of climate adaptability; an assessment of source water vulnerability for real property.[147] As discussed in the previous chapter, there are several potential climate threats to real property in Canada, most can be mitigated with foresight such as gradual sea level rise and increased risk of flooding. Source water vulnerability is not the most pressing area of concern, considering the expected increase in precipitation over most regions of Canada.[148] However, as will be discussed later in this chapter, source water vulnerability for expeditionary operations is a very high risk in some regions, and may be a risk in some domestic HADR situations, but these considerations are not mentioned in this report.

[146] Department of National Defence. 2017. *Defence Energy & Environment Strategy, Harnessing energy efficiency and sustainability: Defence and the Road to the Future.* Ottawa, ON: Government of Canada. 26.

[147] Ibid. 31.

[148] Refer to the explanation of domestic climate change threats in Canada in chapter 2.

The CAF is not the only organization that is struggling with the application of high level strategy to practical measures, however. Palmer-Maloney insightfully found that environmental assessment in US joint operations planning is focused on reducing harm to the local ecology, but that "the significance of the natural environment and the need for environmental resource management during security and stability operations in a time of military intervention are missing."[149] Similarly, a US DOD report found that US base commanders and operational commanders were unable to execute climate mitigation strategies due to a lack of regional specificity regarding infrastructure and operational guidelines.[150] The CAF faces similar challenges.

Part of the problem with the CAF approach to climate change, is the tendency to treat climate mitigation as a separate line of effort, rather than an intrinsic part of the culture and thought processes of operations planners and project managers. According to a 2017 auditor general report, National Defence was identified as one of nine departments that "…did not fully assess climate change risks in their areas of responsibility. None provided specific information on the possible consequences, likelihood, or magnitude of climate change impacts."[151] The auditor general report shows how the CAF, as part of DND has not yet adopted climate change risks into plans and strategy. One example of how climate factors should be introduced into the cognitive capability of defence professionals is a simple understanding of recurrent climate variability events such as El Nino. Ariel et al. describes how improved forecasting of recurrent

[149] Laura Jean Palmer-Moloney,. 2012. *Human-Environment Interaction and Water Complexities: Mustering Science and Policy for a Coastal Resources Management Approach to Counter Insurgency(COIN) Operations.* Dissertation, Ann Arbour MI: East Carolina University, Pro Quest UMI.

[150] Michael Durant Thomas. 2017. *The securitization of climate change: Australian and United States' military responses 2003-2013.* Canberra, Australia: Springer International Publishing.

[151] Office of the Auditor General of Canada. 2017. *2017 Fall Reports of the Commissioner of the Environment and Sustainable Development to the Parliament of Canada: Report 2—Adapting to the Impacts of Climate Change.* Ottawa: Government of Canada.

events like El Nino has increased the preparedness of NGOs for planning relief operations in zones prone to drought and floods.[152] Figure 4.3 shows how El Nino events have become stronger over the last few decades, organized by central Pacific versus eastern Pacific events. A very basic understanding of this phenomenon is all that is required to alert planning staffs to the potential for unusual weather over the course of an operation. El Nino events cannot be predicted with absolute certainty, as the recurrence interval varies between 4 and 7 years.[153]

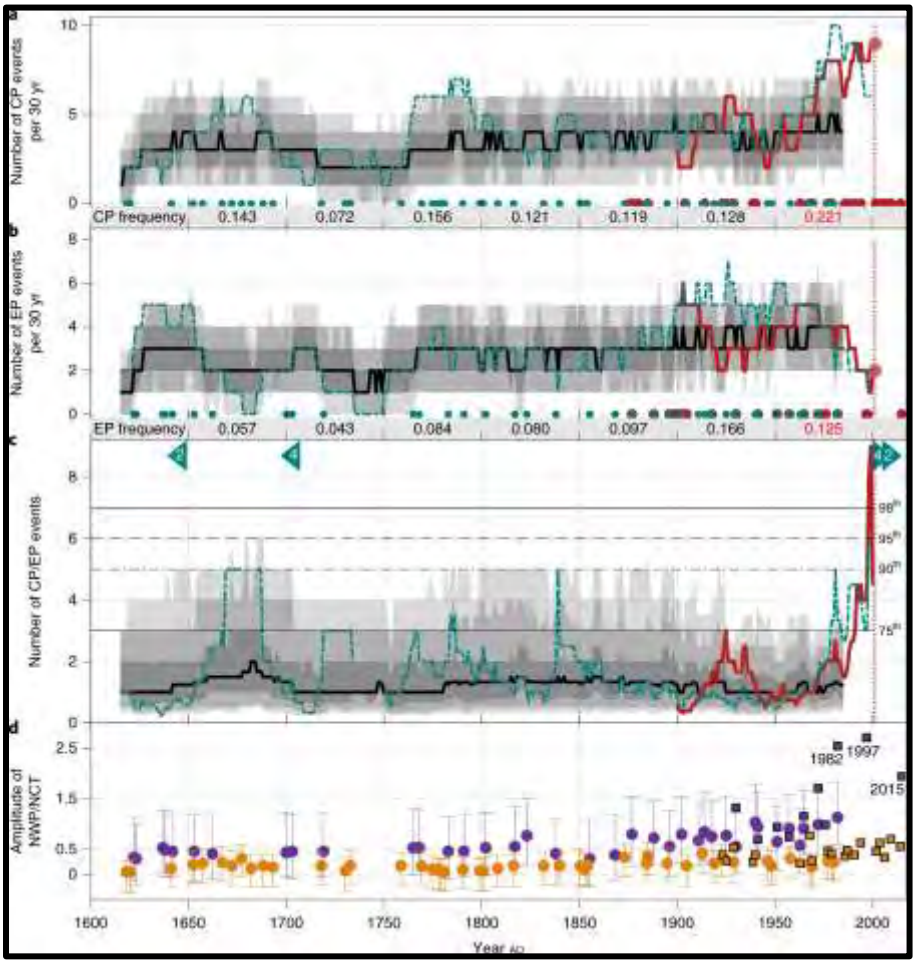


**Figure 4.3-- Frequency and Amplitude Eastern Pacific/Central Pacific El-Nino Events**
Source: Freund. Higher frequency of Central Pacific El Niño events in recent decades relative to past centuries. 2019.

[152] Arielle S. Tozier de la Poterie, Wasswa Eddie Jjemba, Roop Singh, Erin Coughlan de Perez, Cecilia V. Costella, Julie Arrighi. 2018. "Understanding the use of 2015–2016 El Niño forecasts in shaping early humanitarian action in Eastern and Southern Africa." *International Journal of Disaster Risk Reduction* 81-94.

[153] Michael McPhaden. 2015. "Predicting El Niño Then and Now." Climate.gov. April 3. Accessed April 5, 2020. https://www.climate.gov/news-features/blogs/enso/predicting-el-ni%C3%B1o-then-and-now.

However, the El Nino Southern Oscillation can still be accounted for by planners, who should understand that at some stage of a campaign, in addition to a myriad of other considerations, forces may have to deal with unusual flood or drought conditions in their area of operations.[154] Despite the unpredictability of El Nino, improved intelligence could identify an increased prevalence of certain weather patterns, and give at least a qualitative risk assessment for an approaching El Nino event.[155] Basic climate awareness is a simple cognitive tool, which should be incorporated into CAF operations planning to mitigate risk, regardless of the diverse climate change effects across different regions. Climate change will mean that conventional knowledge and past experiences will not be sufficient to prepare for future operating environments.

Canada has had an intermittent presence in the Indo Pacific over the past century, but has been increasingly asked to respond to natural disasters, contribute to UN peace support operations, intercept illegal migrants and illicit cargo, and plan for security threats approaching Canada from the Indo Pacific region.[156] These activities are not only important to demonstrate Canada's diplomatic and economic interest in the region, but to ensure that Royal Canadian Navy (RCN) ships and other CAF force elements are able to interoperate with partners in the region, and sustain operations at short notice.[157] Successive Liberal and Conservative governments have both made statements expecting the CAF to be called upon more often to conduct operations in Southeast Asia, ranging from peace support to Humanitarian Assistance

---

[154] The CAF employs meteorological technicians to brief commanders on short term weather, but the joint publications on operational planning fail to mention short or long term climate variability as a matter of importance to planners. Joint Doctrine Branch, Canadian Forces Warfare Centre. 2011. *CFJP 3.0 Operations.* Ottawa, ON: Department of National Defence.

[155] Michael McPhaden. 2015. "Predicting El Niño Then and Now." *Climate.gov.* April 3. Accessed April 5, 2020. https://www.climate.gov/news-features/blogs/enso/predicting-el-ni%C3%B1o-then-and-now.

[156] Lombardi, Ben. 2016. *The Future Maritime Operating Environment and the Role of Naval Power.* Ottawa, ON: Defence Research and Development Canada.

[157] Royal Canadian Navy. 2019. *HMCS Ottawa departs on deployment to the Asia-Pacific region.* August 6. Accessed March 30, 2020. https://www.canada.ca/en/department-national-defence/news/2019/08/hmcs-ottawa departs-on-deployment-to-the-asia-pacific-region.html.

Disaster Relief (HADR), and possibly warfighting.[158]According to the IPCC, climate change will almost certainly increase the impact of natural disasters in the Indo Pacific region,[159] which may increase the frequency that a Canadian military response will a desirable option for the Government of Canada. Tropical cyclones may increase in frequency and intensity in the western Pacific According to multiple models across RCP 2.5 – RCP 8.5 emission scenarios as analyzed by Emanuel at al.[160]

The effects of climate change can have several major impacts for the CAF, in terms of supporting force generation and force projection to the Asia Pacific region. The RCN has been able to continue expeditionary or "blue water" operations over the past five years, despite the decommissioning of both supply ships without replacement. Mitigation measures for the lack of afloat logistic support have included reliance on partners such as Spain and Chile for "borrowed" replenishment ship capability, the lease contract of the Naval Replenishment Unit (NRU) *Asterix,* and of course heavy reliance on the US Navy's extensive logistics ships and installations around the world.[161] The RCN often relies upon safe havens and resupply available through US or other partners, and any impact to the availability of these facilities will severely restrict operations. It should be considered that if there is reduced availability of resources for fleet support such as jetties, fuel, provisions, and ammunition, then it is far more likely that a

[158] Simon Palamar. 2015. "Will Canada be a Constructive Power in East Asia." In *Mutual Security in the Asia-Pacific: Roles for Australia, Canada and South Korea*, by Kang, Manicom, James, Palamar, Simon Choi, 111-131. Seoul http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=1409636&site=ehost-live&scope=site.

[159] United Nations International Panel on Climate Change. 2018. *Summary for Policymakers, In: Global Warming of 1.5c An IPCC Special Report on the Impacts of Global Warming of 1.5c Above Pre-Industrial Levels.* New York: UN IPCC.

[160] Kerry Emanuel, Ragoth Sundararajan, John Williams. 2007. "Hurricanes and Global Warming: Results From Downscaling IPCC AR4 Simulations." *American Meteorlogical Society* 347-367.

[161] Jeffrey F. Collins, Andrea Lane. 2018. "Why Canada Needs a New Supply Ship for Relief Missions." *Policy Options.* June 21. Accessed February 27, 2020. https://policyoptions.irpp.org/magazines/june-2018/why-canada-needs-a-new-supply-ship-for-relief-missions/.

Canadian ship will face denial of these services than a US Navy ship. Even a small reduction in port infrastructure availability from direct storm damage, or delayed fuel or provision delivery would mean that US ships will be served first, thus amplifying the risk of disruption to Canadian ships in allied ports.[162]

The increased risk to water and food security due to the impact of climate change is a potential threat to the CAF's ability to conduct operations abroad.[163] The RCN is not susceptible to risks from local water security, as ships can desalinize more than enough water to sustain the crew indefinitely, but local acquisition of food remains an important enabler for the RCN, especially given the limited number of Canadian support ships available. Ground and air forces have some capacity to purify their own water, but unless situated on a coast with desalinizing equipment, they would still have to draw water resources from bodies that are likely to be stressed with the requirements of the local population.[164] In the event of any of the aforementioned operations, the CAF will not have the luxury of utilizing local food or water resources, as scarcity of these resources may be the very source of instability that warrant a CAF response. The CAF can not add to this instability by placing additional strain on these resources, or even be perceived to be taking resources away from the local population. Any operation will

[162] Based on the experience of the author from naval operations in the pacific. Canadian ships normally have excellent access to USNS supply ships, and USN port facilities, but depending on operational tempo in a given region, preference must be given to USN vessels. RCN ships will normally have to make deviations to routes/mission planning based on USNS oiler availability, which could be exacerbated by a disruption in service due to unforeseen extreme weather events.

[163] Office of the Director of National Intelligence. 2012. *Global Water Security.* Washington: US State Department.

[164] Defence Research and Development Canada. 2006. *Water collection purification system: Identifying CF capabilities and requirements and assessing off the shelf purification systems.* Technical Report, Toronto: Defence R&D Canada. 13.

therefore have to include some provision of emergency resources to local populations to avoid this perception, which to lead to a strategic/legitimacy failure of mission.[165]

The importance of amphibious capability cannot be overstated when discussing operations in the face of a changing climate. The lack of infrastructure resilience, especially in regions susceptible to climate change like SE Asia, means that airfields and sea ports have a lower probability of survival over time, especially in a HADR situation.[166] Australia has also recognized this, which is why they have invested $3.1 billion into two amphibious landing helicopter dock (LHD) ships to enable the movement of troops, vehicles, and equipment to where they are needed anywhere in the world.[167] The Australian Defence Force has included climate change in defence policy for the last 12 years, despite the heavily politicized nature climate change as a factor in policy planning. The politicized nature of climate change makes it inherently difficult for an apolitical institution such as the Australian Defence Force to take a neutral stance in the face of ambiguous predictions on the effects of climate change over time.[168] The ambiguity due to lack of regional granularity faced by Canadian and US defence officials, similarly affects Australia, as domestic impacts will be substantially different than the effects on closely neighboring Asian states.[169]

Despite representing a government that was usually conservative in its response to climate change, the Australian Deputy Secretary of Defence Peter Jennings testified before a

---

[165] United Nations. 2008. *United Nations Peacekeeping Operations: Principles and Guidelines.* New York, NY: United Nations Department of Peacekeeping. 82.

[166] Matthew J. Widlansky, H. Annamalai, H. Stephen B. Gingerich, Curt D. Storlazzi, John J. Marra, Kevin I. Hodges, Bary Choy.2019. "Tropical Cyclone Projections: Changing Climate Threats for Pacific Island Defence Installations." Weather, Climate, and Society Vol. 11. 3-15.

[167] Royal Australian Navy. 2018. *HMAS Canberra.* Accessed March 30, 2020. https://www.hmascanberra.com/history/nushipcanberra.html.

[168] Michael Durant Thomas. 2017. *The securitization of climate change: Australian and United States' military responses 2003-2013.* Canberra, Australia: Springer International Publishing. 122..

[169] Robert Lawson. 2007. "Climate Change in the Asia-Pacific Region: Security Implications for Australia." *Centre for Defence and Strategic Studies.* Canberra: Australian Defence College. 10.

senate committee that climate change is a risk that will have to be accounted for over the next 30-50 year timeline, especially when considering long term equipment and infrastructure investments.[170] Jennings emphasized that Australian security threats due to climate change will most predominantly come from the destabilization of island states in the south Pacific, which have little resilience to the effects of sea level rise, extreme weather, and changes in agricultural and industrial viability due to changing weather patterns.[171] Australia has invested significantly in new assets to address the potential increase in security and humanitarian crises in the south Pacific, events that are likely to increase as the climate changes. In addition to the two amphibious landing ships already mentioned, a strategic airlift ship, and two additional infantry battalions will be established to be specifically employed for humanitarian and stability operations.[172]


**Figure 4.4 -- HMAS Canberra Loads Australian Light Armoured Vehicles**
Source: Royal Australian Navy

[170] Michael Durant Thomas. 2017. *The securitization of climate change: Australian and United States' military responses 2003-2013.* Canberra, Australia: Springer International Publishing. 120-122.
[171] Ibid.
[172] Natalie Alexander. 2011. "Climate Change on the Radar." *Defence Magazine, 3:11*, 30.

The US Navy is currently addressing questions about sea keeping characteristics of their surface ships and amphibious capabilities, which was first discussed as a problem for a changing threat environment, but is also becoming an issue because of climate change. An article by Dr. Craig Hooper in *Next Navy* highlights the fact that the US Navy's current design philosophy for surface ships has been primarily influenced by counter-insurgency (COIN) operations in regions with benign sea states (less than sea state 3), such as the Arabian Gulf and Indian Ocean. USN ship design over the past several decades has not adequately accounted for a potential resurgence of peer conflict, which will likely occur in northern seas where wave heights are frequently more extreme.[173] The US Navy has faced this problem in the past according to a 1982 report on the disparity between Russian and USN ship sea keeping qualities.[174] Hooper specifically mentions amphibious ships, as there is a architectural conflict between the maximum weight of United States Marine Corps (USMC) vehicles that can be operated, and the stability characteristics of the ship used to deliver them.[175] Considering the importance of amphibious ships for HADR operations, climate change will make ship design a key area of concern for future planning in the face of climate change. The US military may face challenges with amphibious capabilities in a changing climate, but the CAF has failed to develop any substantial amphibious capability, despite being identified as a critical capability for HADR missions.[176] The ability to provide force mobility from the sea, weather amphibious or not, may very well be a deciding factor in the CAF's ability to respond to disasters, or conduct operations in a changing climate.

---

[173] Craig Hooper. 2018. "Sea State 3 Limitations Mean Failed Operations." *Next Navy.* May 4. Accessed March 30, 2020. http://nextnavy.com/sea-state-3-limitations-means-failed-operations/.

[174] Susan L Bales. 1982. *Designing ships for the Natural Environment.* Washington, D.C: United States Navy Association of Scientists and Engineers.

[175] Craig Hooper. 2018. "Sea State 3 Limitations Mean Failed Operations." *Next Navy.* May 4. Accessed March 30, 2020. http://nextnavy.com/sea-state-3-limitations-means-failed-operations/.

[176] Royal Canadian Navy. 2015. *Leadmark 2050: Canada in a new Maritime World.* Gatineau, QC. Department of National Defence.

**Conclusion**

The CAF is likely to see an increase in demand for expeditionary operations due to the disproportionate impacts of climate change on other regions of the world. This need for CAF intervention will be amplified by human development factors, such as lower climate change resilience in the areas most affected by climate change, and increasing globalization of world markets. Climate awareness must be adopted as a critical cognitive tool in operational and strategic planning, as past experience and status quo will not be sufficient to inform commanders on the impact of the environment on the CAF. The CAF must also be prepared to adapt to the direct impacts of climate change on mobility infrastructure and logistic support abroad, in order to remain capable of operating in regions of strategic importance to Canada. The CAF should look to measures being taken by allies like the United States and Australia, who are increasingly strengthening mobility and sustainment capabilities, in anticipation of more challenging expeditionary operations due to climate change.

## CHAPTER 4 – CONCLUSION

The Canadian Armed Forces must be prepared to increase capability and capacity to conduct expeditionary operations in response to threats posed by climate change. The scientific evidence for both contemporary and historical climate change patterns was presented in order to demonstrate the unavoidable reality that climate change will continue to impact humanity, and the CAF may be called upon to act in increasingly difficult circumstances. There is little chance that efforts to reduce GHG emissions will be successful in mitigating climate change over the next one hundred years, and therefore adaptation to the effects of climate change is necessary to ensure the viability of Canadian infrastructure and government departments, including the CAF. Climate change will have a diverse range of impacts across different regions of Canada and across the globe, which is why generalized statements and oversimplification of climate change effects are not sufficient to guide useful climate change action plans. Operational and strategic planners within the CAF still lack a proper action plan to address climate change, and more detailed awareness of specific climate impacts is required to prepare for climate related challenges. The CAF should remedy the lack of direction on climate change by appointing a lead agency to provide a detailed analysis of the impacts of climate change on operations, a role that would be well suited to Canadian Forces Intelligence Command (CFINTCOM) due to existent earth sciences expertise.

Climate change threats to Canadian domestic security are likely to be less problematic than security in other regions of the world, therefore capacity to deal with domestic disasters should not necessarily shift resources away from expeditionary readiness. Due to the predictable and relatively moderate nature of climate change impacts in Canada, all levels of government should be capable of establishing climate-resilient infrastructure and emergency management

plans to deal with domestic climate risks. There is little evidence to indicate that the increase in OP LENTUS activations observed by CJOC over the past five years is directly attributable to climate change. The hypothesis that OP LENTUS has increased in frequency due to climate change is even less defensible when considering the extremely short five-year timeline examined by CJOC, which is insignificant when attempting to examine long term climate trends. The observed increase in OP LENTUS activations does however coincide with a change of government, and is also associated with the end of major CAF operations in Afghanistan, both of which contribute to the perceived supply and demand for CAF resources. There are numerous other reasons that could have contributed to the increase in OP LENTUS activations, including changing public perception about the role of the CAF, increased apprehension of climate related disasters, and the dynamic relationships between provincial authorities and their federal counterparts. Based on detailed analysis of climate models alone, the CAF should not see an drastic increase in domestic HADR operations, as long as proper climate change mitigation measures are implemented by government and industry. Despite the lack of evidence for an increase in domestic disasters, the CAF could be better structured to respond to HADR missions in Canada. Measures that could be adopted include developing greater cooperation with nations that have offset disaster seasons like Australia, strengthening the emergency management expertise within regional JTFs, and reducing strain on the regular force by increasing the Reserves' capacity to respond.

There is a high probability that climate related disasters will become much more severe in developing regions of the world including areas of strategic interest to Canada such as the Indo-Asia Pacific. This will have a disproportionate effect on peace and security, not only because of the greater frequency and intensity of disasters, but also because developing nations have less

civil resilience to mitigate disasters or degraded economic productivity. Water security in particular could result in increased tension between rival states, and therefore raise the possibility that international intervention will be required to support a peaceful resolution. Threats to human security will be at the forefront of any climate related conflict, and therefore the CAF would be well positioned to assist, based on Canada's traditional role in peace support operations.

The CAF must be prepared to operate in areas that have been devastated by climate related disasters or economic collapse, which means that CAF operations can no longer rely on local commercial services, infrastructure, airports, or seaports for sustainment. The CAF must re-evaluate the capabilities required to execute not only HADR, but the full spectrum of operations in climate affected regions. Australia and the United States have recognized capabilities that are critical to operating in regions destabilized by climate change, most notably sealift, airlift, and amphibious capabilities, and the CAF should likewise be considering these capabilities in future force structures.

The CAF assumes significant risk by continuing to operate with a superficial understanding of the impact of environmental threats to operations. Climate change will be an important factor for strategic and operational planning, which will require nuanced and detailed awareness of apolitical scientific evidence. Climate Change is a daunting problem fraught with uncertainty, but if given sufficient attention, the CAF will be able to adapt and preserve operational effectiveness in the future.

## BIBLIOGRAPHY


Alexander, Natalie. 2011. "Climate Change on the Radar." *Defence Magazine, 3:11*, 30.

Antoon Kuijpers, Naja Mikkelsen. 2008. "Geological records of changes in wind regime over south Greenland since the Medieval Warm Period: A tentative reconstruction." *Polar Record 45 (232)* 1-8.

Arielle S. Tozier de la Poterie, Wasswa Eddie Jjemba, Roop Singh, Erin Coughlan de Perez, Cecilia V. Costella, Julie Arrighi. 2018. "Understanding the use of 2015–2016 El Niño forecasts in shaping earlyhumanitarian action in Eastern and Southern Africa." *International Journal of Disaster Risk Reduction* 81-94.

Babson, Ester. 2018. *Strained Stability: Climate Change and Security in South East Asia.* American Security Project.

Bales, Susan L. 1982. *Designing ships for the Natural Environment.* Washnigton, D.C.: United States Navy Association of Scientists and Engineers.

Bernatchez, Pascal, Christian Fraser. 2012. "Evolution of Coastal Defence Structures and Consequences for beach width trends, Quebec, Canada." *Journal of Coastal Research 28:6* 1550-1566.

Burbidge, Christopher Ian. 2012. "Facets of Luminescence for Dating." *Spectroscopy Letters* 118-126.

Busby, Joshua. 2017. *Water and US National Security.* New York, NY: Council on Foreign Relations.

Canadian Joint Operations Command. n.d. "Environmental Impacts on Security." *(Lecture Candian Forces College Climate Symposium, Toronto, ON, February 12 2020).*

Centre for Climate Security. 2015. *The US Asia Pacific Rebalance, National Security and Climate Change.* Washington, D.C.: Centre for Climate and Security.

Chief of Force Development, Canadian Armed Forces. 2014. *Future Security Environment 2013-2040.* Winnipeg, MB: 17 Wing Winnipeg Publishing Office.

Council of Canadian Academics. 2019. *Canada's Top Climate Change Risks: The Expert Panel on Climate Change Risks and Adaptation Potential.* Ottawa: Council of Canadian Academics.

Crucifix, Michel. 2013. *Why Could Ice Ages be Unpredictable.* Louvain-La-Neuve: Climate of the Past, October 9.

Defence Research and Development Canada. 2006. *Water collection purification system: Identifying CF capabilities and requirements and assessing off the shelf purification*

*systems.* Technical Report, Toronto: Defence R&D Canada.

Department of Naitonal Defence. 2017. *Defence Energy & Environment Strategy, Harnessing energy efficiency and sustainability: Defence and the Road to the Future.* Ottawa, ON: Government of Canada.

Department of National Defence. 1997. *A Commitment to Change: Report on the Recommendations of the Somalia Comission Inquiry.* Ottawa: DND.

Department of National Defence. 2017. *Strong Secure Engaged.* Canada's Defence Policy, Ottawa: Government of Canada.

Duchesne, Erick. 2013. "Regional Trade and Economic Negotiations." *International Negotiation 18:1-3.*

Emanuel, Kerry. 2013. "Downscaling CMIP5 climate models shows increased tropical cyclone activity over the 21st century." *Program in Atmospheres, Oceans, and Climate, Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology.* July 23. www.pnas.org/cgi/doi/10.1073/pnas.1301293110.

Emanuel, Kerry, Ragoth Sundararajan, John Williams. 2007. "Hurricanes and Global Warming: Results From Downscaling IPCC AR4 Simulations." *American Meteorlogical Society* 347-367.

Environment and Climate Change Canada. 2019. *Canada's Changing Climate.* Gatineau: Government of Canada.

—. 2020. *Canadian CLimate Normals 1981-2010.* March 10. https://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?stnID=4333&autofwd=1.

Fisheries and Oceans Canada. 2012. *State of the Oceans report 2012.* Ottawa: Communications Branch - Fisheries and Oceans.

Fred Singer, Dennis Avery. 2007. *Unstoppable Global Warming: Every 1500 Years.* Lanham: Rowman and Littlefield Publishers.

Freund, Mandy B. Benjamin J. Henley, David J. Karoly, Helen V. McGregor, Nerilie J. Abram & Dietmar Dommenget. 2019. "Higher frequency of Central Pacific El Niño events in recent decades relative to past centuries." *Nature Geoscience 12* 450-455.

Fuyu Li, William D. Collins, Michael F. Wehner, and L. Ruby Leung. 2013. "Hurricanes in an aquaplanet world: Implications of the impacts of external forcing and model horizontal resolution." *JOURNAL OF ADVANCES IN MODELING EARTH SYSTEMS, VOL. 5,* 134-145.

G. Everett Lasher, Yarrow Axford. 2019. "Medieval warmth confirmed at the Norse Eastern Settelment in Greenland." *Geology Society of America Vol 47 n. 3* 267-270.

Geert Jan van Oldenborgh, Karin van der Wiel , Antonia Sebastian , Roop Singh, Julie Arrighi. 2017. "Attribution of extreme rainfall from Hurricane Harvey August 2017." *Environmental Research Letters Vol 12.*

Geophysical Fluid Dynamics Labratory, Princeton University. 2011. *Historical Atlantic Hurricane and Tropical Storm Records.* Accessed February 12, 2020. https://www.gfdl.noaa.gov/historical-atlantic-hurricane-and-tropical-storm-records/.

Government of Canada. 2019. "Government of Canada." *National Defence to contribute funding for upgrades at Inuvik Airport.* September 4. Accessed October 25, 2019. https://www.canada.ca/en/department-national-defence/news/2019/09/national-defence-to-contribute-funding-for-upgrades-at-inuvik-airport.html.

Government Of Ontario. 2019. "Government Of Ontario Emergency Preparedness." *Wildland Fire Management Strategy.* December 10. Accessed April 13, 2020. https://www.ontario.ca/page/wildland-fire-management-strategy.

Government of Ontario. 1943. "Statutes of the Province of Ontario 1943." *Legislative Assembly of Ontario.* Accessed March 9, 2020. http://www.ontla.on.ca/library/repository/ser/23347/v077pt1-1943-208.pdf.

Hayes, J.D. Imbrie, John, N.J. Shackleton. 1976. "Variations in the Earth's Orbit: Peacemaker of the Ice Ages." *Science Vol 194* 1121-1132.

Hillmer, Norman, Granatstein, J. L. 2007. *Empire to umpire : Canada and the world into the 21st century.* Toronto: Nelson Education.

Hlad, Jennifer. 2018. "Life in Typhoon Alley." *Air Force Magazine*, August 29.

Hooper, Craig. 2018. "Sea State 3 Limitations Mean Failed Operations." *Next Navy.* May 4. Accessed March 30, 2020. http://nextnavy.com/sea-state-3-limitations-means-failed-operations/.

Jaroslav TIr, Douglas M. Stinnett. 2012. "Weathering climate change: Can Institutions Mitigate International Water Conflict?" *Journal of Peace Research 49:1* 211-225.

Joint Doctrine Branch, Canadian Forces Warfare Centre. 2011. *CFJP 3.0 Operations.* Ottawa, ON: Department of National Defence.

Jones, Peter. 2017. "Canadian Global Affairs Institute." *Canada and Mediation: Issues and Considerations.* Accessed April 1, 2020. https://www.cgai.ca/canada_and_mediation_issues_and_considerations.

Lawson, Robert. 2007. "Climate Change in the Asia-Pacifi Region: Security Implications for Australia." *Centre for Defence and Strategic Studies.* Canberra: Australian Defence College.

Lombardi, Ben. 2016. *The Future Maritime Operating Environment and the Role of Naval*

*Power.* Ottawa, ON: Defence Research and Development Canada.

Mario Morello´n Blas, Valero-Garce´s, Pene´lope Gonza´lez-Sampe´riz. 2009. "Climate changes and human activities recorded in teh sediments of Lake Estanya (NE Spain) during the Medieval Warm Period and Little Ice Age." *J Paleolimnol (2011) 46* 423–452.

Maslin, Mark. 2016. "Forty Years of Linking Orbits to Ice Ages." *Nature, Vol 540* 208-210.

McNeil, Douglas P.Eng. 2019. *An Independent Review of the 2019 Flood Events in Ontario.* Ontario's Special Advisor on Flooding Report to Government, Winnipeg: McNeil Consulting Inc.

McPhaden, Michael. 2015. "Predicting El Niño Then and Now." *Climate.gov.* April 3. Accessed April 5, 2020. https://www.climate.gov/news-features/blogs/enso/predicting-el-ni%C3%B1o-then-and-now.

National Observer. 2017. *Did Catherine McKenna Just Contradict Trudeau on Climate Change?* September 12. Accessed February 12, 2020. https://www.nationalobserver.com/2017/09/12/analysis/did-catherine-mckenna-just-contradict-trudeau-climate-change.

Natural Resources Canada. 2016. *Canada's Marine Coasts in a Changing Climate.* Ottawa: Government of Canada.

—. 2019. "Natural Resources Canada." *Canada Permafrost.* Accessed October 21, 2019. https://open.canada.ca/data/en/dataset/d1e2048b-ccff-5852-aaa5-b861bd55c367.

—. 2019. "Natural Resources Canada." *Statistics from the Canadian National Fire Database.* Accessed April 19, 2020. https://cwfis.cfs.nrcan.gc.ca/ha/nfdb.

—. 2015. "Planning for Sea Level Rise in Halifax Harbour." *NRCAN Climate Change: Impacts and Adaptations.* November 16. Accessed April 12, 2020. https://www.nrcan.gc.ca/environment/resources/publications/impacts-adaptation/tools-guides/16301.

Nicolas Cailon, Jeffrey Severinghaus, Jean Jouzel, Jean-Marc Barnola, Jiancheng Kang, Volodya Lipenkov. 2003. "Timing of Atmospheric CO2 and Anarctic Temperature Changes Across Termination III." *Science* 299.

Office of the Auditor General of Canada. 2017. *2017 Fall Reports of the Commissioner of the Environment and Sustainable Development to the Parliament of Canada: Report 2—Adapting to the Impacts of Climate Change.* Ottawa: Government of Canada.

Office of the Director of National Intelligence. 2012. *Global Water Security.* Washington: US State Department.

Palamar, Simon. 2015. "Will Canada be a Consctructive Power in East Asia." In *Mutual Security in the Asia-Pacific : Roles for Australia, Canada and South Korea*, by Kang, Manicom,

James, Palamar, Simon Choi, 111-131. Seoul, Korea : http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=1409636&site=ehost-live&scope=site.

Palmer-Moloney, Laura Jean. 2012. *Human-Environment Interaction and Water Complexities:Mustering Science and Policy for a Coastal Resources Management Approach to Counter Insurgency(COIN) Operations.* Dissertation, Ann Arbour MI: East Carolina University, Pro Quest UMI.

Powers, Lucas. 2019. "Trudeau's claim that Canada is 'on track' to meet 2030 climate target is misleading." *CBC News Politics: Fact Check*, September 25.

Prabin Rokaya, Sujata Budhathoki, & Karl-Erich Lindenschmidt. 2018. "Trends in the timing and magnitude of ice jam floods in Canada." *Scientific Reports.*

Rabson, Mia. 2020. "Canada Offers More Aid for Australia as Bushfires Burn." *CBC News*, January 9.

Royal Australian Navy. 2018. *HMAS Canberra.* Accessed March 30, 2020. https://www.hmascanberra.com/history/nushipcanberra.html.

Royal Canadian Navy. 2019. *HMCS Ottawa departs on deployment to the Asia-Pacific region.* August 6. Accessed March 30, 2020. https://www.canada.ca/en/department-national-defence/news/2019/08/hmcs-ottawa-departs-on-deployment-to-the-asia-pacific-region.html.

Royal Canadian Navy. 2015. *Leadmark 2050: Canada ina new Maritime World.* Gatineau, QC.: Department of National Defence.

Shakun, Jeremy, David Lea, Lorraine Lisiecki, Maureen Raymo. 2015. "An 800Kyr Record of Global Surface Ocean δ18O and implications for Ice Volume-Temperature Coupling." *Elsvier: Earth and Planetary Science Letters* 58-68.

Shrubsole, Dan. 2011. "Flood management in Canada at the crossroads." *Global Environmental Change Part B: Environmental.* June 15. Accessed March 10, 2020. https://www.tandfonline.com/loi/tenh19.

Singer, S. Fred, Dennis T. Avery. 2007. *Unstoppable Global Warming: Every 1500 Years.* Plymouth, UK: Rowman and Littlefield Publishers Inc.

n.d. "Snow on the Ground Monthly - Ottawa Kanata." *WeatherStats.ca.* Accessed March 10, 2020. https://ottawa.weatherstats.ca/charts/snow_on_ground-monthly.html.

Stantec. n.d. *B Jetty Replacement Project.* Accessed March 16, 2020. https://www.stantec.com/en/projects/canada-projects/b/b-jetty-replacement.

Statistics Canada. 2015. "Annual mean precipitation percentage departure from 1961 to 1990 normal and linear trend for Canada and climatic regions,1 1948 to 2009." *Statistics*

*Canada.* November 27. Accessed March 4, 2020. https://www150.statcan.gc.ca/n1/pub/16-002-x/2011003/ct016-eng.htm.

Thomas, Michael Durant. 2017. *The securitization of climate change: Australian and United States' military responses 2003-2013.* Canberra, Australia: Springer International Publishing.

Transboundary Waters Assessment Programme. 2016. "Transboundary Waters Assessment Programme." *Transboundary River Basins: Status and Trends.* Accessed April 1, 2020. http://geftwap.org/publications.

United Nations Environment Program. 2019. *Emissions Gap Report.* New York, NY: United Nations.

United Nations International Panel on Climate Change. 2013. *Fifth Assessment Report, Working Group 1 : The Physical Science Basis.* New York: Cambridge University Press.

United Nations International Panel on Climate Change. 2018. *Summary for Policymakers, In: Global Warming of 1.5c An IPCC Special Report on the Impacts of Global Warming of 1.5c Above Pre-Industiral Levels.* New York: UN IPCC.

United Nations. 2008. *United Nations Peacekeeping Operations: Principles and Guidelines.* New York, NY: United Nations Department of Peacekeeping.

United States Geological Survey. 2000. *Dams and Rivers: A Primer on the Downstrem Effects of Dams.* Denver, CO: US Geological Survey Branch of Administrative Services.

US Department of Defence. 2019. *Indo-Pacific Strategy Report.* Washington D.C.: US Department of Defence.

Van Andel, Tjeerd. 2000. *New News on an Old Planet: A Hostory of Global Change.* New York: Cambridge University Press.

Walsh, J., D. Wuebbles, K. Hayhoe, J. Kossin, K. Kunkel, G. Stephens, P. Thorne, R. Vose, M. Wehner, J. Willis, D. Anderson,. 2014. *Our Changing Climate in Climate Change Impacts in the United States: The Third National Climate Assessment.* Washington, D.C: U.S. Government Printing Office.

Widlansky, Matthew J. Annamalai, H. Gingerich, Stephen B. Storlazzi, Curt D. Marra, John J. Hodges, Kevin I. Choy, Bary. 2019. "Tropical Cyclone Projections: Changing Climate Threats for Pacific Island Defence Instalations." *Weather, Climate, and Society Vol. 11.* 3-15.

Zachos, James, Mark Pagani, Lisa Sloan, Ellen Thomas, Katharina Bilups. 2001. "Trends, Rhythms, and Aberations in Global Climate 65ma to Present." *Science* 686-93.