CCCR2019 | REPORT

Chapter Key Messages

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Canada

Canada's Changing Climate Report – Chapter Key Messages

The Key Messages from *Canada's Changing Climate Report* are chapter-based findings considered most relevant to audiences of this report and of the National Assessment as a whole. Assessed levels of confidence in findings, and likelihood of results are indicated with italicized terms.[1] Chapters 1 and 8 of *Canada's Changing Climate Report* do not have chapter Key Messages. To see the full report, go to www.ChangingClimate.ca/CCCR2019.

1 This report uses the same calibrated uncertainty language as in the IPCC's Fifth Assessment Report. The following five terms are used to express assessed levels of confidence in findings based on the availability, quality and level of agreement of the evidence: very low, low, medium, high, very high. The following terms are used to express assessed likelihoods of results: virtually certain (99%–100% probability), extremely likely (95%–100% probability), very likely (90%–100% probability), likely (66%–100% probability), about as likely as not (33%–66% probability), unlikely (0%–33% probability), very unlikely (0%–10% probability), extremely unlikely (0%–5% probability), exceptionally unlikely (0%–1% probability). These terms are typeset in italics in the text. See chapter 1 for additional explanation.

CHAPTER AND SECTION	KEY MESSAGE
CHAPTER 2 – UNDERSTANDING OBSERVED GLOBAL CLIMATE CHANGE	
Observed changes in the global climate system	Warming of the climate system during the Industrial Era is unequivocal, based on robust evidence from a suite of indicators. Global average temperature has increased, as have atmospheric water vapour and ocean heat content. Land ice has melted and thinned, contributing to sea level rise, and Arctic sea ice has been much reduced.
Understanding the causes of observed global change	Warming has not been steady over time, as natural climate variability has either added to or subtracted from human-induced warming. Periods of enhanced or reduced warming on decadal timescales are expected, and the factors causing the early 21st century warming slowdown are now better understood. In the last several years, global average temperature has warmed substantially, suggesting that the warming slowdown is now over. The heat-trapping effect of atmospheric greenhouse gases is well-established. It is *extremely likely* that human activities, especially emissions of greenhouse gases, are the main cause of observed warming since the mid-20th century. Natural factors cannot explain this observed warming. Evidence is widespread of a human influence on many other changes in climate as well.
CHAPTER 3 – MODELLING FUTURE CLIMATE CHANGE	
Future change and climate forcing	Emissions of greenhouse gases from human activity, particularly carbon dioxide, will largely determine the magnitude of climate change over the next century. As a result, reducing human emissions will reduce future climate change.

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Modelling the response of the climate system to external forcing	In the near term (to approximately 2040), projected warming will be similar under all emission pathways. However, by the late 21st century, the differences between possible emission pathways will have a considerable effect. Available estimates indicate that the global climate will warm by an additional 1°C (for a low emission scenario) to 3.7°C (for a high emission scenario). Scenarios that would limit warming to an additional 1°C or less require rapid and deep emission reductions.
Cumulative carbon dioxide and global temperature change	Global temperature change is effectively irreversible on multi-century timescales. This is because the total amount of carbon dioxide emitted over time is the main determinant of global temperature change and because carbon dioxide has a long (century-scale) lifetime in the atmosphere.
Regional downscaling	Climate projections are based on computer models that represent the global climate system at coarse resolution. Understanding the effects of climate change for specific regions benefits from methods to downscale these projections. However, uncertainty in climate projections is larger as one goes from global to regional to local scale.
CHAPTER 4 – CHANGES IN TEMPERATURE AND PRECIPITATION ACROSS CANADA	
Temperature	It is *virtually certain* that Canada's climate has warmed and that it will warm further in the future. Both the observed and projected increases in mean temperature in Canada are about twice the corresponding increases in the global mean temperature, regardless of emission scenario. Annual and seasonal mean temperatures across Canada have increased, with the greatest warming occurring in winter. Between 1948 and 2016, the best estimate of mean annual temperature increase is 1.7°C for Canada as a whole and 2.3°C for northern Canada.

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	While both human activities and natural variations in the climate have contributed to the observed warming in Canada, the human factor is dominant. It is *likely* that more than half of the observed warming in Canada is due to the influence of human activities.
	Annual and seasonal mean temperature is projected to increase everywhere, with much larger changes in northern Canada in winter. Averaged over the country, warming projected in a low emission scenario is about 2°C higher than the 1986–2005 reference period, remaining relatively steady after 2050, whereas in a high emission scenario, temperature increases will continue, reaching more than 6°C by the late 21st century.
	Future warming will be accompanied by a longer growing season, fewer heating degree days, and more cooling degree days.
	Extreme temperature changes, both in observations and future projections, are consistent with warming. Extreme warm temperatures have become hotter, while extreme cold temperatures have become less cold. Such changes are projected to continue in the future, with the magnitude of change proportional to the magnitude of mean temperature change.
Precipitation	There is ***medium confidence*** that annual mean precipitation has increased, on average, in Canada, with larger percentage increases in northern Canada. Such increases are consistent with model simulations of anthropogenic climate change.
	Annual and winter precipitation is projected to increase everywhere in Canada over the 21st century, with larger percentage changes in northern Canada. Summer precipitation is projected to decrease over southern Canada under a high emission scenario toward the end of the 21st century, but only small changes are projected under a low emission scenario.

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	For Canada as a whole, observational evidence of changes in extreme precipitation amounts, accumulated over periods of a day or less, is lacking. However, in the future, daily extreme precipitation is projected to increase (*high confidence*).
Attribution of extreme events	Anthropogenic climate change has increased the likelihood of some types of extreme events, such as the 2016 Fort McMurray wildfire (*medium confidence*) and the extreme precipitation that produced the 2013 southern Alberta flood (*low confidence*).
CHAPTER 5 – CHANGES IN SNOW, ICE AND PERMAFROST ACROSS CANADA	
Snow cover	The portion of the year with snow cover decreased across most of Canada (*very high confidence*) as did the seasonal snow accumulation (*medium confidence*). Snow cover fraction decreased between 5% and 10% per decade since 1981 due to later snow onset and earlier spring melt. Seasonal snow accumulation decreased by 5% to 10% per decade since 1981 with the exception of southern Saskatchewan, and parts of Alberta and British Columbia (increases of 2% to 5% per decade).
	It is *very likely* that snow cover duration will decline to mid-century across Canada due to increases in surface air temperature under all emissions scenarios. Scenario-based differences in projected spring snow cover emerge by the end of the century, with stabilized snow loss for a medium emission scenario but continued snow loss under a high emission scenario (*high confidence*). A reduction of 5% to 10% per decade in seasonal snow accumulation is projected through to mid-century for much of southern Canada; only small changes in snow accumulation are projected for northern regions of Canada (*medium confidence*).
Sea ice	Perennial sea ice in the Canadian Arctic is being replaced by thinner seasonal sea ice (*very high confidence*). Summer sea ice area (particularly multi-year ice area) declined across the Canadian Arctic at a rate of 5% per decade to 20% per decade since 1968 (depending on region); winter sea ice area decreased in eastern Canada by 8% per decade.

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	It is *very likely* that increased temperatures under all emissions scenarios will result in continued reduction in sea ice area across the Canadian Arctic in summer and the east coast in winter. Most Canadian Arctic marine regions will be sea ice-free for part of the summer by 2050 (*medium confidence*), although the region to the north of the Canadian Arctic Archipelago and Greenland will be the last area in the Arctic with multi-year ice present during the summer (*very high confidence*). Multi-year ice will, therefore, still drift into the Northwest Passage (and present a navigation hazard for shipping) even when the Arctic Ocean is sea ice-free during the summer.
Glaciers and ice caps	Canada's Arctic and alpine glaciers have thinned over the past five decades due to increasing surface temperatures; recent mass loss rates are unprecedented over several millennia (*very high confidence*). Mass loss from glaciers and ice caps in the Canadian Arctic represent the third largest cryosphere contributor to global sea level rise (after the Greenland and Antarctic ice sheets) (*very high confidence*).
	Under a medium emission scenario, it is projected that glaciers across the Western Cordillera will lose 74 to 96% of their volume by late century (*high confidence*). An associated decline in glacial meltwater supply to rivers and streams (with impacts on freshwater availability) will emerge by mid-century (*medium confidence*). Most small ice caps and ice shelves in the Canadian Arctic will disappear by 2100 (*very high confidence*).
Lake and river ice	The duration of seasonal lake ice cover has declined across Canada over the past five decades due to later ice formation in fall and earlier spring breakup (*high confidence*). Seasonal maximum lake ice cover for the Great Lakes is highly variable since 1971 (*very high confidence*), with no significant trend.
	Spring lake ice breakup will be 10 to 25 days earlier by mid-century, and fall freeze-up 5 to 15 days later, depending on the emissions scenario and lake-specific characteristics such as depth (*medium confidence*).

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Permafrost	Permafrost temperature has increased over the past 3–4 decades (*very high confidence*). Regional observations identify warming rates of about 0.1°C per decade in the central Mackenzie Valley and 0.3 to 0.5°C per decade in the high Arctic. Active layer thickness has increased by approximately 10% since 2000 in the Mackenzie Valley. Widespread formation of themokarst landforms have been observed across northern Canada. Increases in mean air temperature over land underlain with permafrost are projected under all emissions scenarios, resulting in continued permafrost warming and thawing over large areas by mid-century (*high confidence*) with impacts on northern infrastructure and the carbon cycle.
CHAPTER 6 – CHANGES IN FRESHWATER AVAILABILITY ACROSS CANADA	
Surface runoff: streamflow	The seasonal timing of peak streamflow has shifted, driven by warming temperatures. Over the last several decades in Canada, spring peak streamflow following snowmelt has occurred earlier, with higher winter and early spring flows (*high confidence*). In some areas, reduced summer flows have been observed (*medium confidence*). These seasonal changes are projected to continue, with corresponding shifts from more snowmelt-dominated regimes toward rainfall-dominated regimes (*high confidence*). There have been no consistent trends in annual streamflow amounts across Canada as a whole. In the future, annual flows are projected to increase in most northern basins but decrease in southern interior continental regions (*medium confidence*).

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	Streamflow-related floods result from many factors, and in Canada these mainly include excess precipitation, snowmelt, ice jams, rain-on-snow, or a combination of these factors. There have been no spatially consistent trends in these flood-causing factors or in flooding events across the country as a whole. Projected increases in extreme precipitation are expected to increase the potential for future urban flooding (*high confidence*). Projected higher temperatures will result in a shift toward earlier floods associated with spring snowmelt, ice jams, and rain-on-snow events (*medium confidence*). It is uncertain how projected higher temperatures and reductions in snow cover will combine to affect the frequency and magnitude of future snowmelt-related flooding.
Surface water levels: lakes and wetlands	In regions of Canada where there are sufficient data, there is no indication of long-term changes to lake and wetland levels. Future levels may decline in southern Canada, where increased evaporation may exceed increased precipitation (*low confidence*). Projected warming and thawing permafrost has the potential to cause future changes in many northern Canadian lakes, including rapid drainage (*medium confidence*).
Soil moisture and drought	Periodic droughts have occurred across much of Canada, but no long-term changes are evident. Future droughts and soil moisture deficits are projected to be more frequent and intense across the southern Canadian Prairies and interior British Columbia during summer, and to be more prominent at the end of the century under a high emission scenario (*medium confidence*).
Groundwater	The complexity of groundwater systems and a lack of information make it difficult to assess whether groundwater levels have changed since records began. It is expected that projected changes to temperature and precipitation will influence future groundwater levels; however, the magnitude and even direction of change is not clear. Spring recharge of groundwater aquifers over most of the country is anticipated to occur earlier in the future, as a result of earlier snowmelt (*medium confidence*).

CHAPTER AND SECTION	KEY MESSAGE
CHAPTER 7 – CHANGES IN OCEANS SURROUNDING CANADA	
Ocean temperature	Upper-ocean temperature has increased in the Northeast Pacific and most areas of the Northwest Atlantic over the last century, consistent with anthropogenic climate change (*high confidence*). The upper-ocean has warmed in the Canadian Arctic in summer and fall as a result of increases in air temperature and declines in sea ice (*medium confidence*).
	Oceans surrounding Canada are projected to continue to warm over the 21st century in response to past and future emissions of greenhouse gases. The warming in summer will be greatest in the ice-free areas of the Arctic and off southern Atlantic Canada where subtropical water is projected to shift further north (*medium confidence*). During winter in the next few decades, the upper ocean surrounding Atlantic Canada will warm the most, the Northeast Pacific will experience intermediate warming rates and the Arctic and eastern sub-Arctic ocean areas (including Hudson Bay and Labrador Sea) will warm the least (*medium confidence*).
Ocean salinity and density stratification	There has been a slight long-term freshening of upper-ocean waters in most areas off Canada as a result of various factors related to anthropogenic climate change, in addition to natural decadal-scale variability (*medium confidence*). Salinity has increased below the surface in some mid-latitude areas, indicating a northward shift of saltier subtropical water (*medium confidence*).
	Freshening of the ocean surface is projected to continue in most areas off Canada over the rest of this century under a range of emission scenarios, due to increases in precipitation and melting of land and sea ice (*medium confidence*). However, increases in salinity are expected in off-shelf waters south of Atlantic Canada due to the northward shift of subtropical water (*medium confidence*). The upper-ocean freshening and warming is expected to increase the vertical stratification of water density, which will affect ocean sequestration of greenhouse gases, dissolved oxygen levels, and marine ecosystems.

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Marine winds, storms and waves	Surface wave heights and the duration of the wave season in the Canadian Arctic have increased since 1970, and are projected to continue to increase over this century as sea ice declines (*high confidence*). Off Canada's east coast, areas that currently have seasonal sea ice are also anticipated to experience increased wave activity in the future as seasonal ice duration decreases (*medium confidence*). A slight northward shift of storm tracks, with decreased wind speed and lower wave heights off Atlantic Canada, has been observed and is projected to continue in future (*low confidence*). Off the Pacific coast of Canada, wave heights have been observed to increase in winter and decrease in summer, and these trends are projected to continue in future (*low confidence*).
Sea level	Globally, sea level has risen, and is projected to continue to rise. The projected amount of global sea-level rise in the 21st century is many tens of centimetres and it may exceed one metre. However, relative sea level in different parts of Canada is projected to rise or fall, depending on local vertical land motion. Due to land subsidence, parts of Atlantic Canada are projected to experience relative sea-level change higher than the global average during the coming century (*high confidence*). Where relative sea level is projected to rise (most of the Atlantic and Pacific coasts and the Beaufort coast in the Arctic), the frequency and magnitude of extreme high water-level events will increase (*high confidence*). This will result in increased flooding, which is expected to lead to infrastructure and ecosystem damage as well as coastline erosion, putting communities at risk. Adaptation actions need to be tailored to local projections of relative sea-level change. Extreme high water-level events are expected to become larger and occur more often in areas where, and in seasons when, there is increased open water along Canada's Arctic and Atlantic coasts, as a result of declining sea ice cover, leading to increased wave action and larger storm surges (*high confidence*).

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Ocean chemistry	Increasing acidity (decreasing pH) of the upper-ocean waters surrounding Canada has been observed, consistent with increased carbon dioxide uptake from the atmosphere (*high confidence*). This trend is expected to continue, with acidification occurring most rapidly in the Arctic Ocean (*high confidence*). Subsurface oxygen concentrations have decreased in the Northeast Pacific and Northwest Atlantic oceans off Canada (*high confidence*). Increased upper-ocean temperature and density stratification associated with anthropogenic climate change have contributed to this decrease (*medium confidence*). Low subsurface oxygen conditions will become more widespread and detrimental to marine life in future, as a result of continuing climate change (*medium confidence*). Nutrient supply to the ocean-surface layer has generally decreased in the North Pacific Ocean, consistent with increasing upper-ocean stratification (*medium confidence*). No consistent pattern of nutrient change has been observed for the Northwest Atlantic Ocean off Canada. There are no long-term nutrient data available for the Canadian Arctic.