Canada's Changing Climate Report

A collaborative effort:
Environment and Climate Change Canada
Fisheries and Oceans Canada
Natural Resources Canada
University experts

CMOS Tour - 2020

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Outline:

1. Role of science assessments
2. Key messages from CCCR and IPCC SROCC (with updates)

Science assessments are a critical means of informing decision-makers

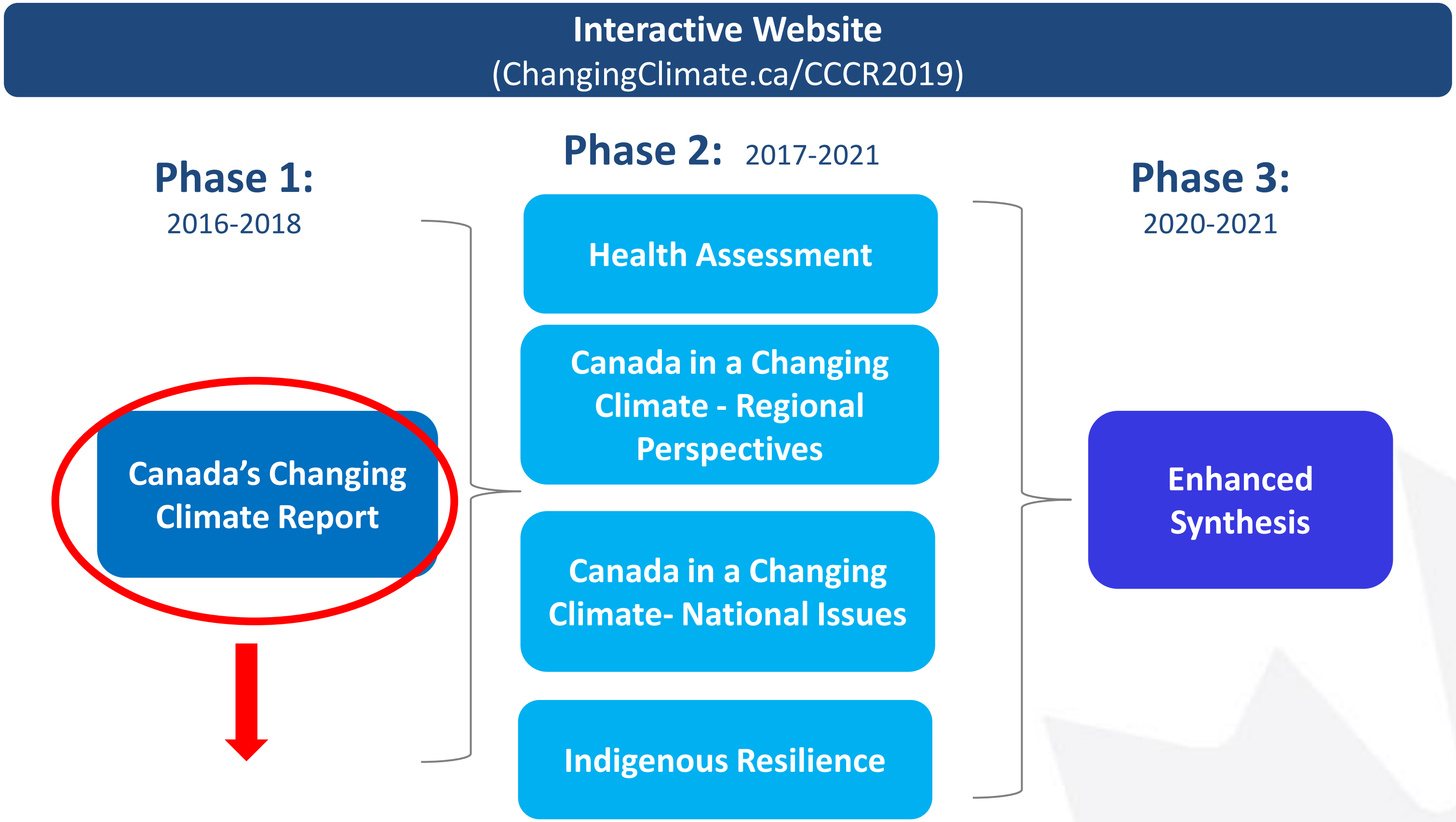
- Recognized experts as lead authors
- Identify topics relevant to decision-makers
- Critically analyze and synthesize recent developments in the published, peer reviewed scientific literature
- Provide an **assessment** of the state of scientific understanding on these topics
- Expert review of report drafts: open process
- Communicate key results to decision-makers

International assessments of climate change

National assessments of climate change

Canada’s National Assessment on Climate Change

Canada in a Changing Climate: Advancing our Knowledge for Action



Interactive Website
(ChangingClimate.ca/CCCR2019)

Phase 1:
2016-2018

Canada’s Changing Climate Report

Phase 2: 2017-2021

Health Assessment

Canada in a Changing Climate - Regional Perspectives

Canada in a Changing Climate- National Issues

Indigenous Resilience

Phase 3:
2020-2021

Enhanced Synthesis

Laying a climate science foundation for the forthcoming reports of the national assessment.

Canada's Changing Climate Report

This report is about how and why Canada's climate has changed and what changes are projected for the future. Led by Environment and Climate Change Canada, it is the first report to be released as part of *Canada in a Changing Climate: Advancing our Knowledge for Action.*

changingclimate.ca/CCCR2019/

10 HEADLINE STATEMENTS FOR THE WHOLE REPORT

Statements all associated with high confidence or more

KEY MESSAGES FOR EACH MAJOR CHAPTER

Assessed confidence in findings and likelihood of results

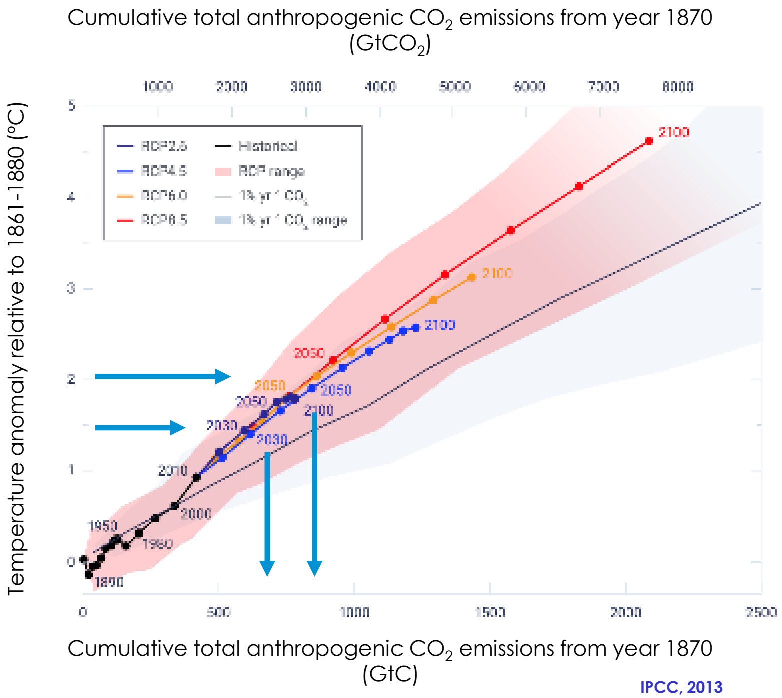
Canada's Changing Climate Report
Headline statement #1

Canada's climate has warmed and will warm further in the future, driven by human influence.

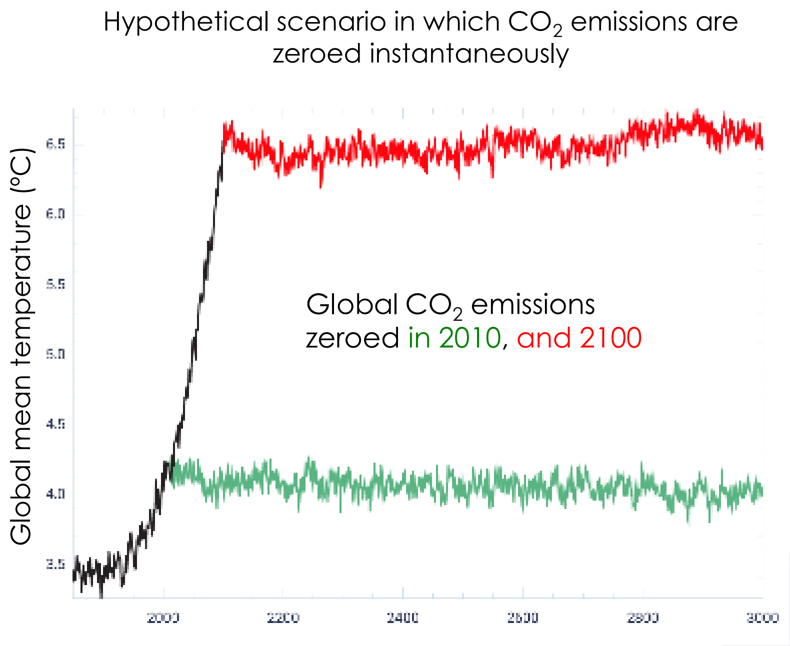
Global emissions of carbon dioxide from human activity will largely determine how much warming Canada and the world will experience in the future.

This warming is effectively irreversible.

Human Influence on Global Climate



IPCC, 2013



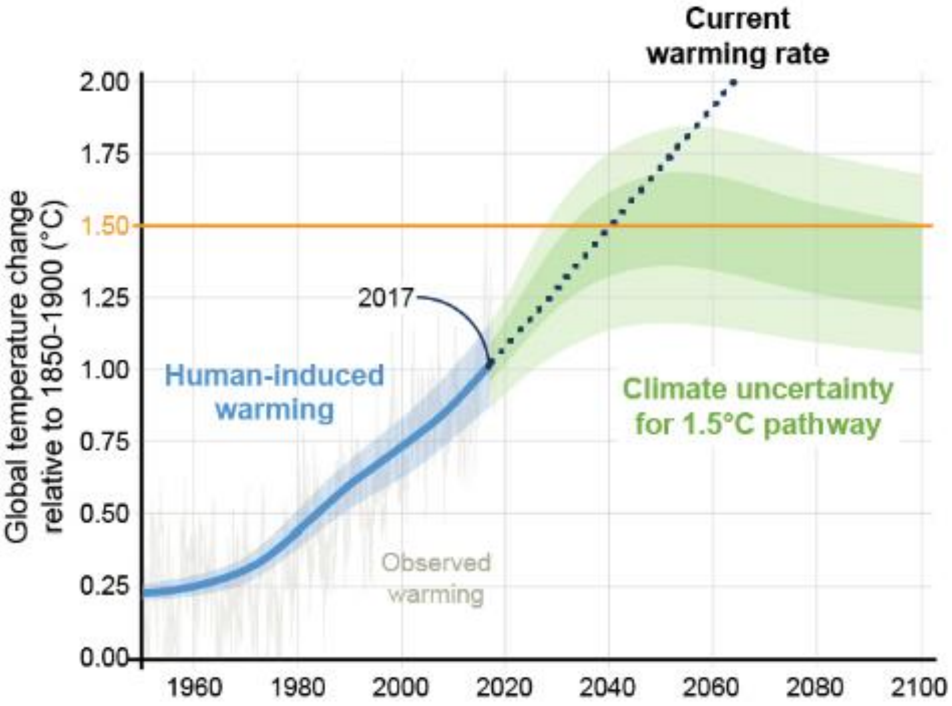
- Human emissions of CO_2 are the main determinant of future warming
- Different temperature limits have different 'carbon budgets' – total remaining cumulative CO_2 emissions

- A finite carbon budget implies CO_2 emissions must achieve 'net zero'
- Global warming will persist for centuries to millennia after emissions are zeroed

The Paris Agreement goal is to limit global warming to well below 2°C, and aim for 1.5°C

How close are we to 1.5°C?

- In 2017, human activities are estimated to have caused global warming of approximately 1°C above preindustrial. At the current warming rate, global warming is likely to reach 1.5°C by around 2040.



Impacts of Covid-19?

nature climate change

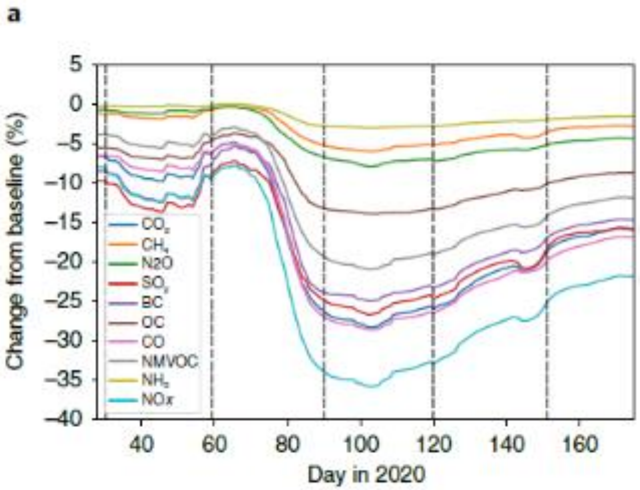
Explore our content ⌄ Journal information ⌄

nature > nature climate change > articles > article

Article | Published: 07 August 2020

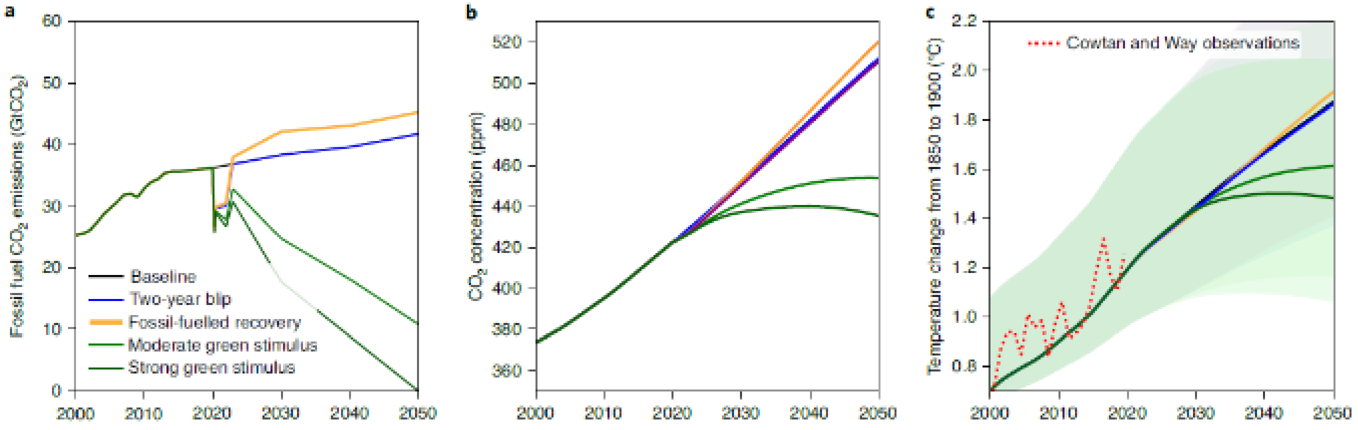
Current and future global climate impacts resulting from COVID-19

Piers M. Forster, Harriet I. Forster, Mat J. Evans, Matthew J. Gidden, Chris D. Jones, Christoph A. Keller, Robin D. Lamboll, Corinne Le Quéré, Joeri Rogelj, Deborah Rosen, Carl-Friedrich Schleussner, Thomas B. Richardson, Christopher J. Smith & Steven T. Turnock



20% reduction in global SO_2 emissions (primarily from industrial activity) weakens the aerosol cooling effect = short-term warming

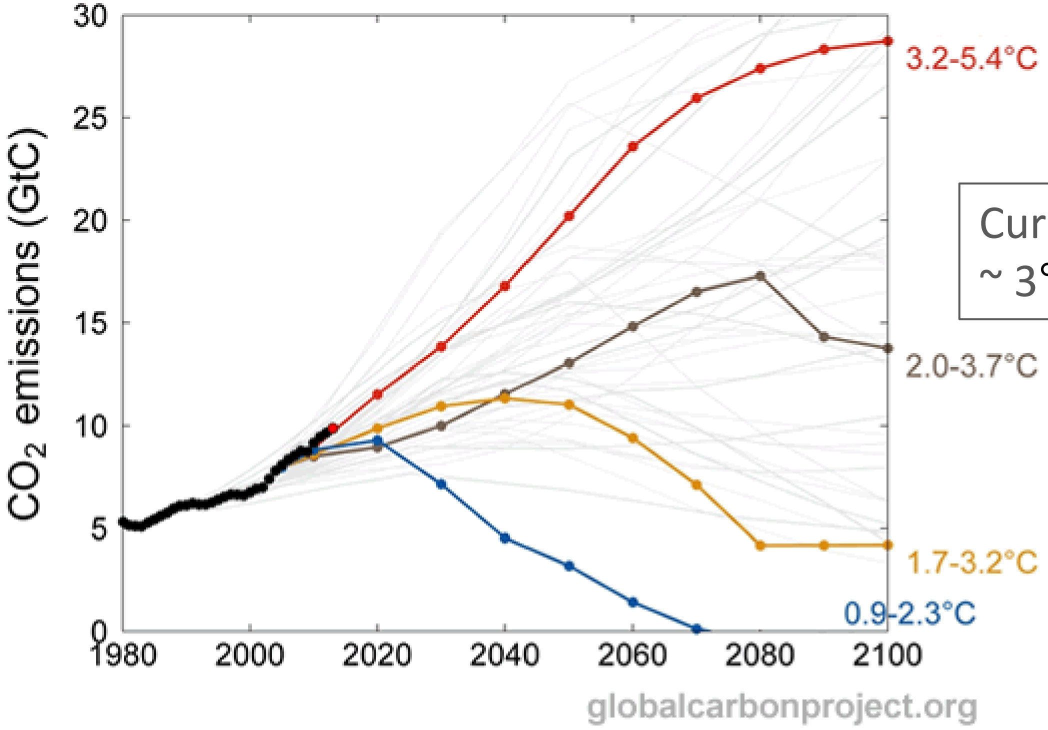
global NO_x emissions (primarily from surface transport) declined by as much as 30% in April = short-term cooling



"…the climate effect of the immediate COVID-19-related restrictions is close to negligible and lasting effects, if any, will only arise from the recovery strategy adopted in the medium term."

Keeping warming well below 2°C will require rapid global emissions reductions

Observed Emissions and Future Scenarios



globalcarbonproject.org

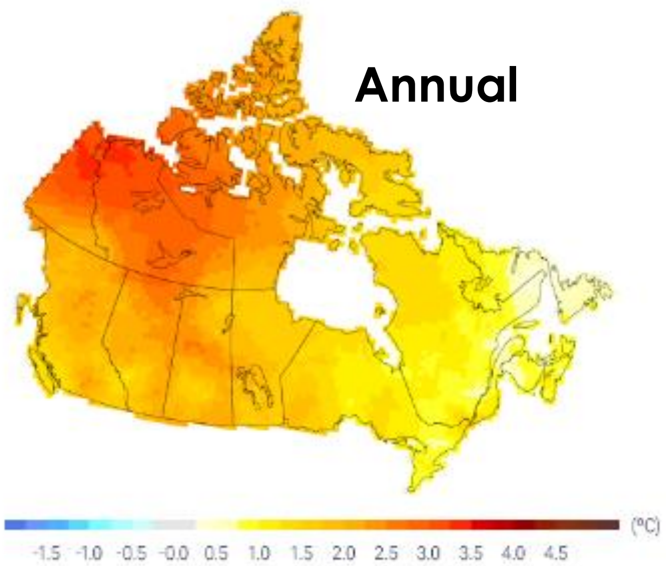
High emissions
No climate policy
Mean warming of ~4.3°C

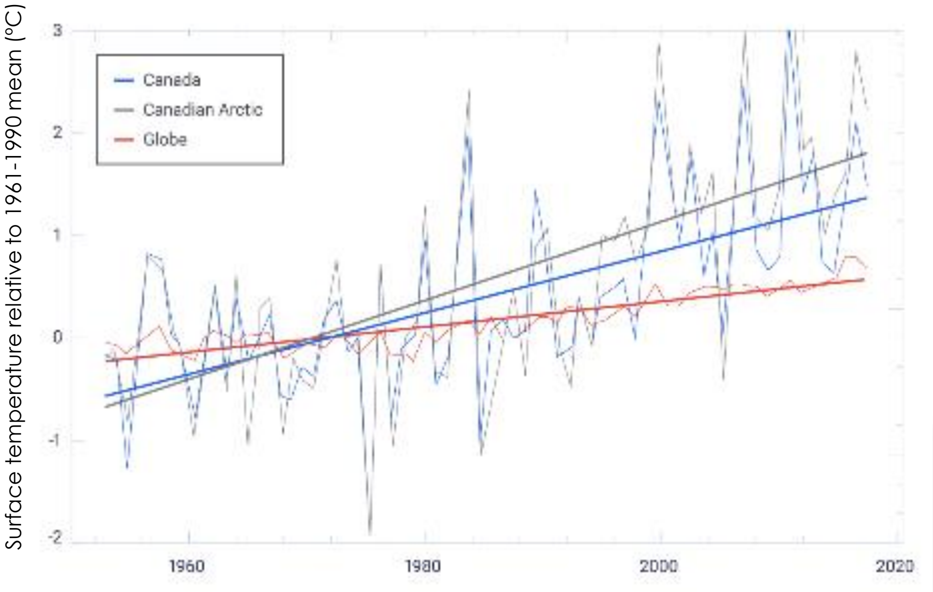
Current commitments lead to ~ 3°C by 2100 (IPCC, 2018)

Low emissions
Ambitious policy
Mean warming of ~1.6°C

- The low emission scenario will *likely* keep global temperature change < 2°C. Net zero CO_2 emissions occur around 2070. (IPCC, 2013)
- 1.5°C emission pathways reach net zero CO_2 emissions around 2050. (IPCC, 2018)

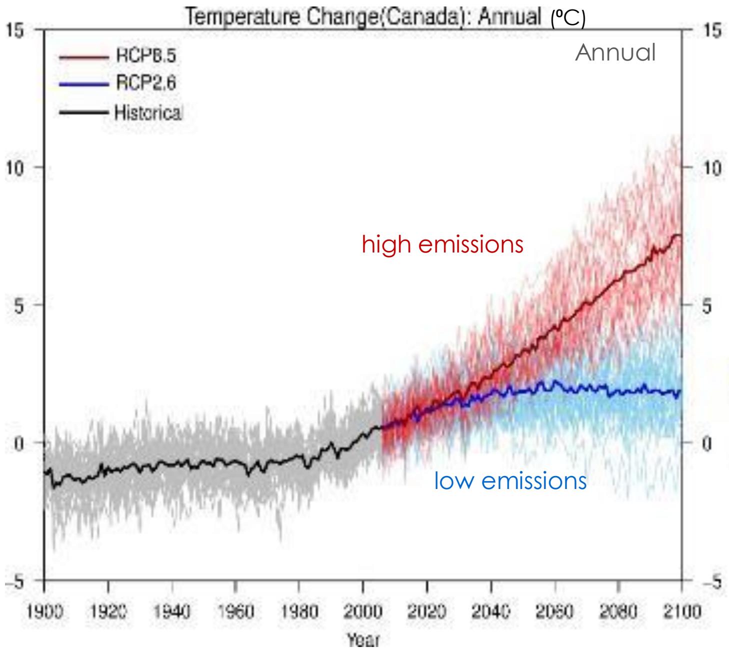
Both past and future warming in Canada is, on average, about double the magnitude of global warming

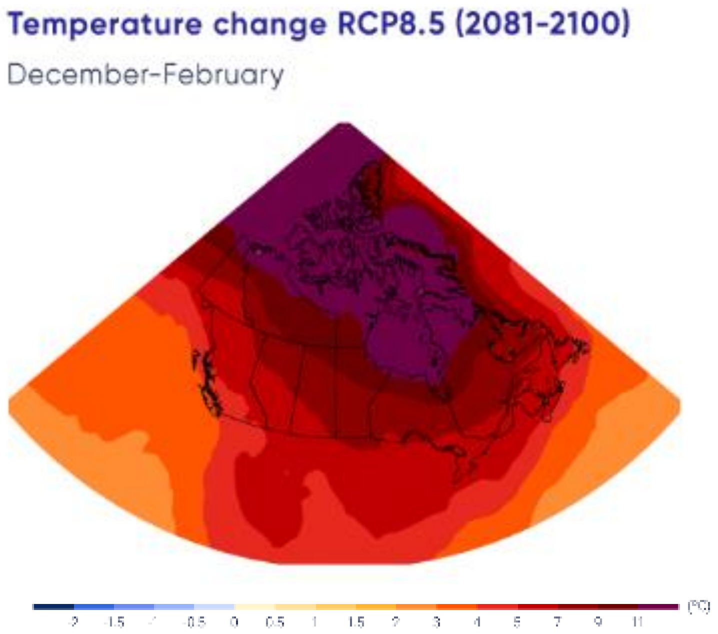




- Annual average temperature in Canada has increased by 1.7°C between 1948 and 2016.
- Canada has warmed about two times the global rate.
- Warming is not uniform across Canada. Northern Canada has warmed by 2.3°C, about three times global warming.
- Most of the observed increase in annual average temperature in Canada can be attributed to human influence.

Future warming in Canada depends directly on global emissions


Temperature Change(Canada): Annual (ºC)


Temperature change RCP8.5 (2081-2100)

December-February

- Low emission scenario: an <u>additional</u> annual warming of about 2°C is projected by mid-century, with temperatures steady after that
- High emission scenario: temperature increases will continue, reaching more than 6°C by late century

- Consistent with observed warming, future warming will be strongest in winter and in northern Canada
- Changes shown are for the late 21st century, under a high emission scenario, relative to the 1986-2005 reference period

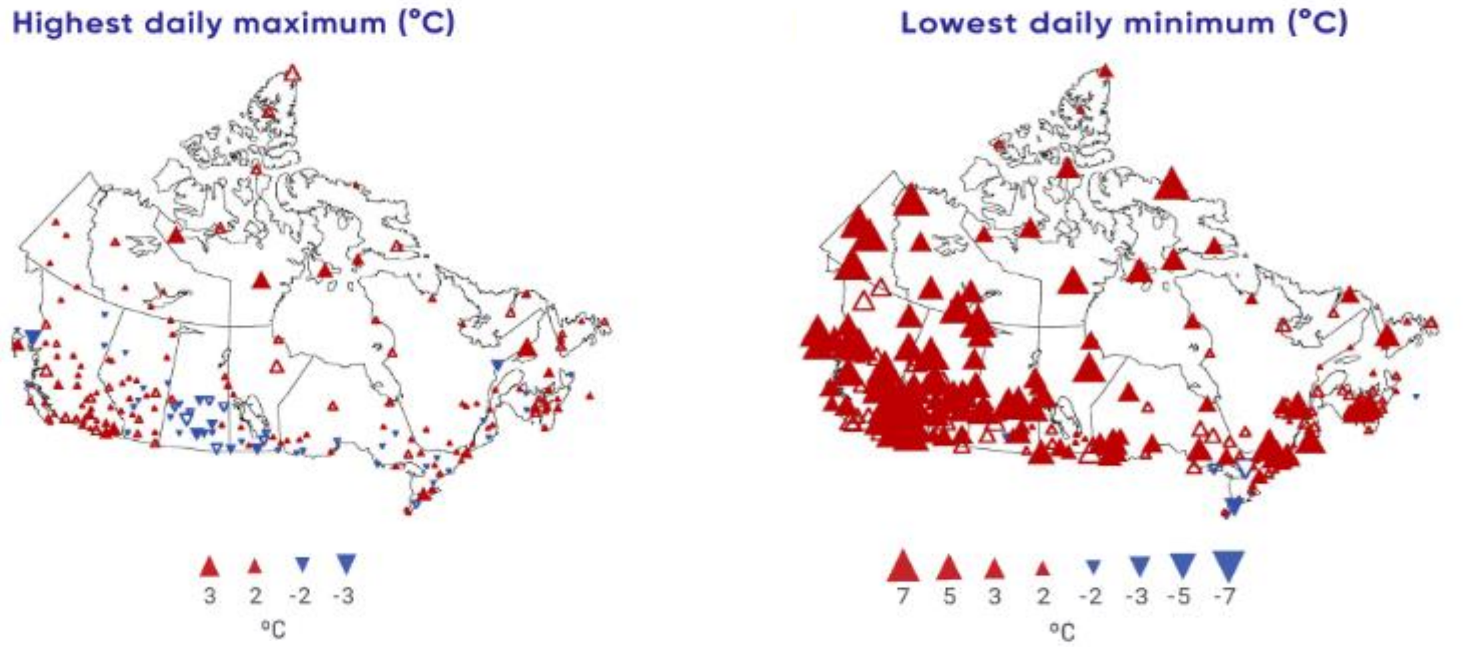
The effects of widespread warming are evident in many parts of Canada and are projected to intensify in the future.

– Canada's Changing Climate Report

ChangingClimate.ca/CCCR2019

- Across Canada, we are experiencing:
  -more extreme heat/less extreme cold
  -less snow and ice cover
  -thinning glaciers
  -warmer and more acidic oceans
  -increased precipitation
  -earlier spring peak streamflow
  -thawing permafrost
  -rising sea level
- Because some further warming is unavoidable, these observed trends will continue.

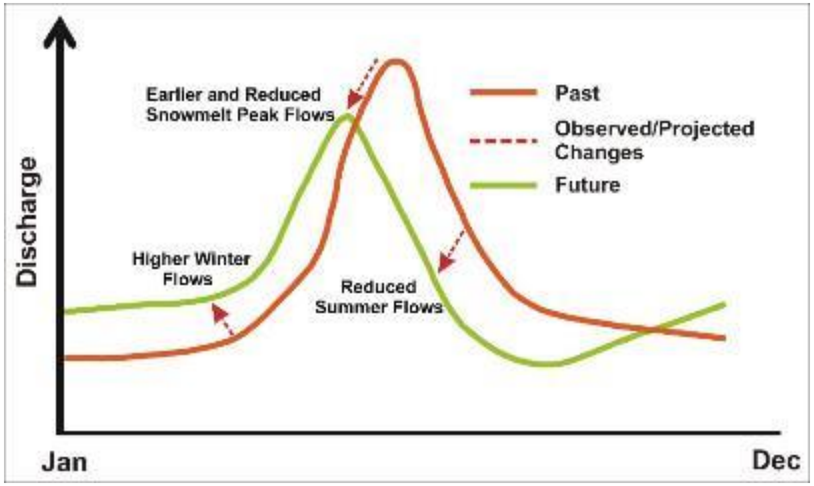
More extreme heat and less extreme cold have been observed in Canada



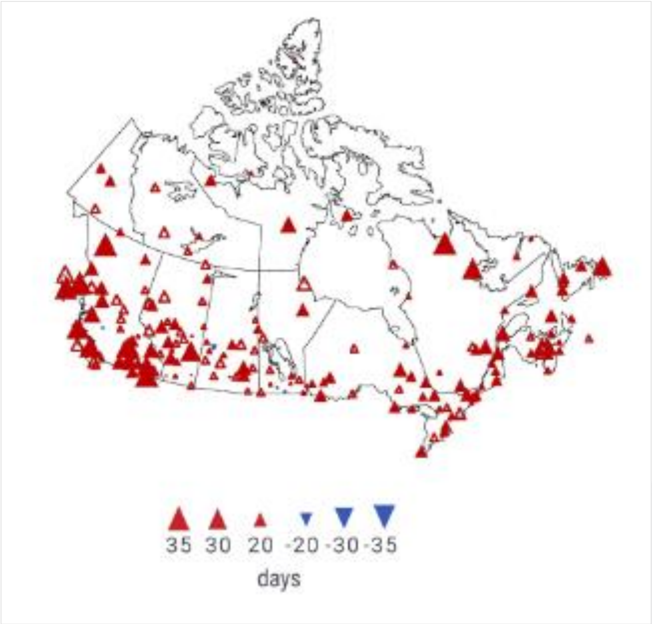
- The annual highest daily maximum temperature, averaged over Canada, increased by 0.61°C between 1948 and 2016
- The annual lowest daily minimum temperature, averaged over Canada, increased by 3.3 °C between 1948 and 2016
- Most of the observed increase in the coldest and warmest daily temperatures in Canada can be attributed to human influence

The effects of widespread warming are evident across many indicators

Changes in annual streamflow schematic

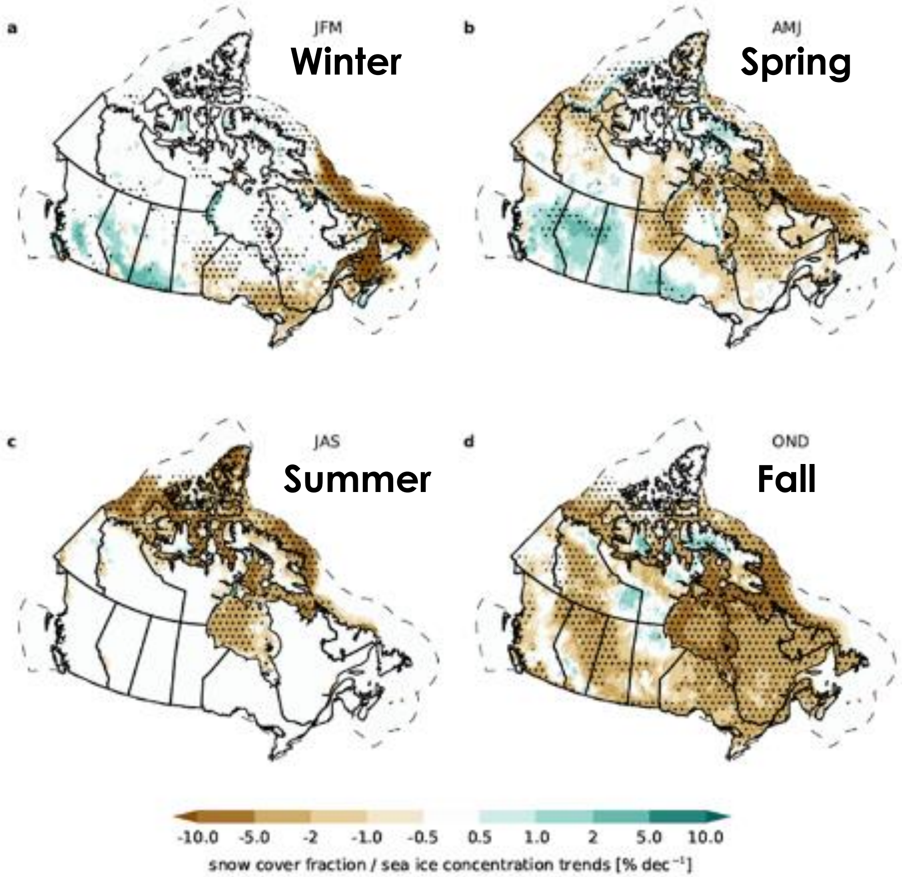


Length of growing season (days)



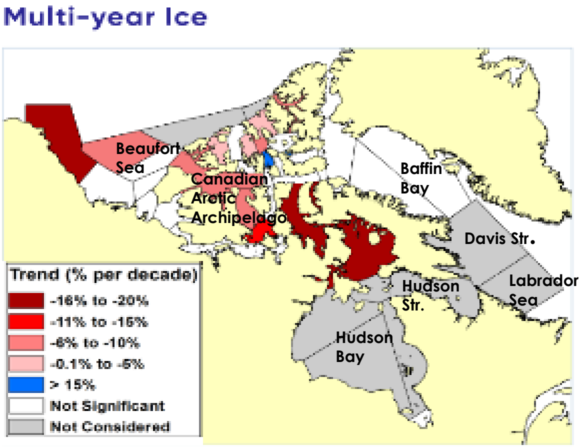
- Over the last several decades, spring peak streamflow has been earlier, with higher winter and early spring flows. In some areas, reduced summer flows have been observed.
- An increase in growing season length of about 15 days between 1948 and 2016 has been observed.

Historical snow cover and sea ice trends



Seasonal snow cover fraction and sea ice concentration trends by season, 1981–2015

- Since 1981, snow cover has decreased across most of Canada by 5% to 10% per decade.
- Since 1968, summer sea ice area declined across the Canadian Arctic by 5% to 20% per decade; fall and winter sea ice area decreased in eastern Canada by 8% per decade
- Perennial sea ice in the Canadian Arctic is being replaced by thinner seasonal sea ice



Trends in multi-year ice cover for Canadian Arctic regions, 1968–2016

Updated northern hemisphere snow trends

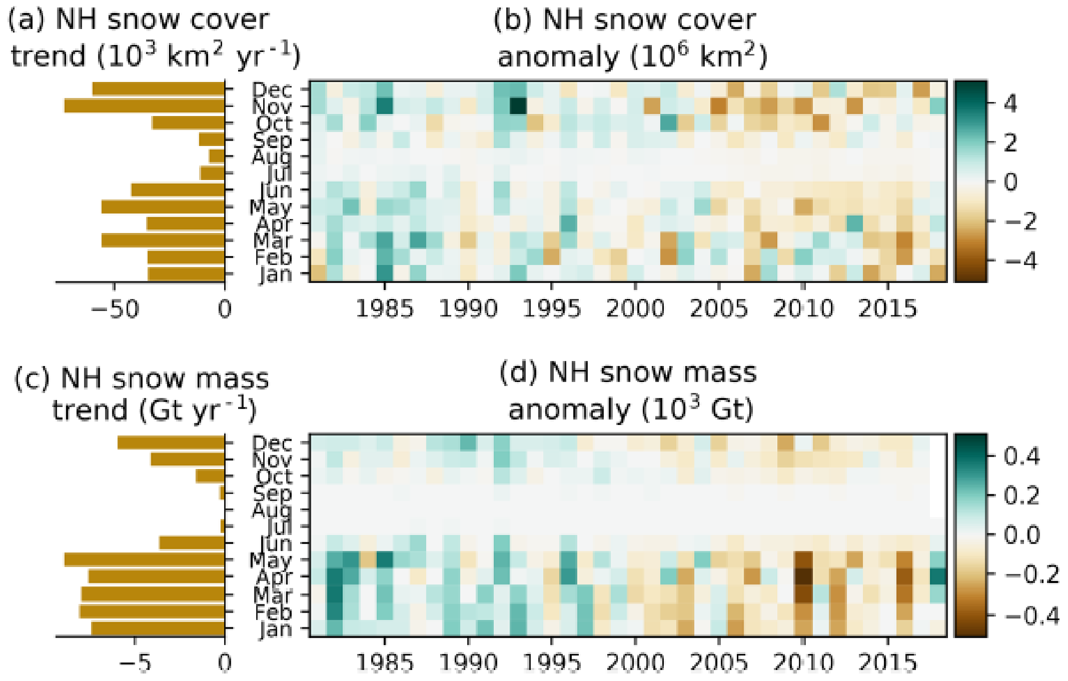
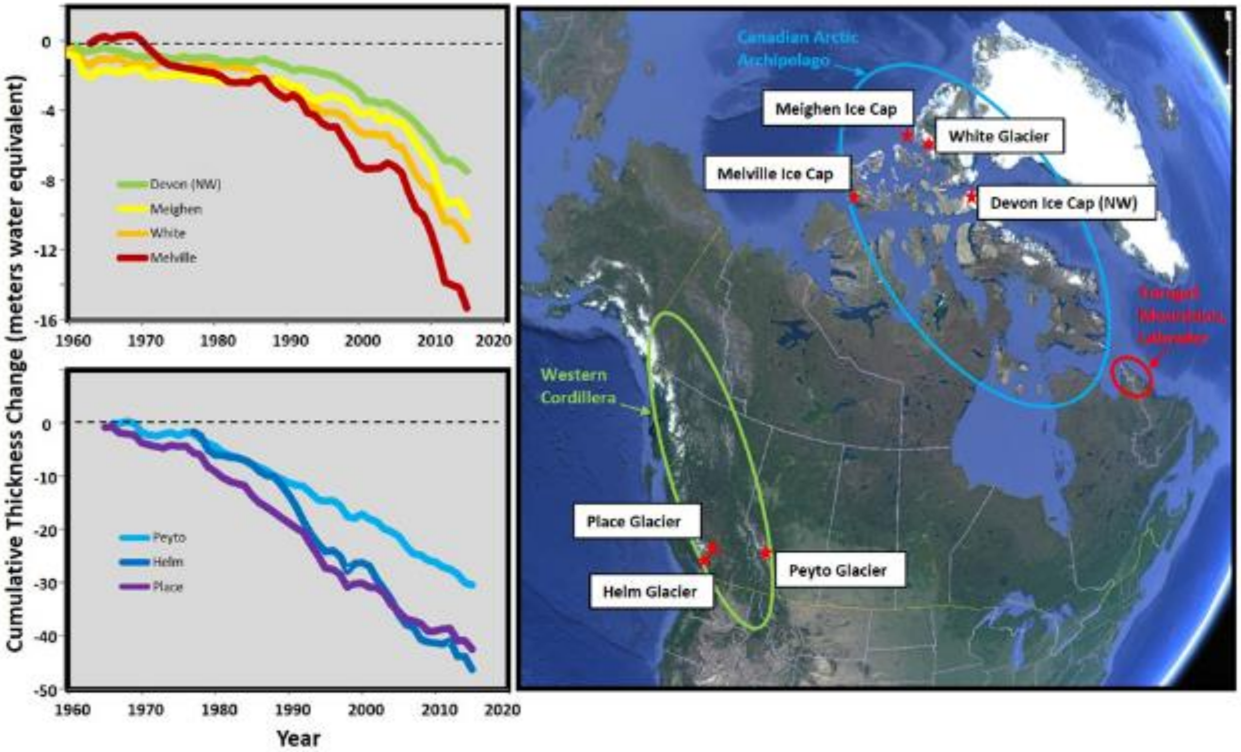


Figure 1. Observation-based NH snow extent (**a, b**) and snow mass (**c, d**) trends (**a, c**) and anomalies (**b, d**) for January 1981 through December 2018 relative to 1981–2014.

Mudryk et al., 2020

Cumulative thickness change at long-term glacier monitoring sites in Canada

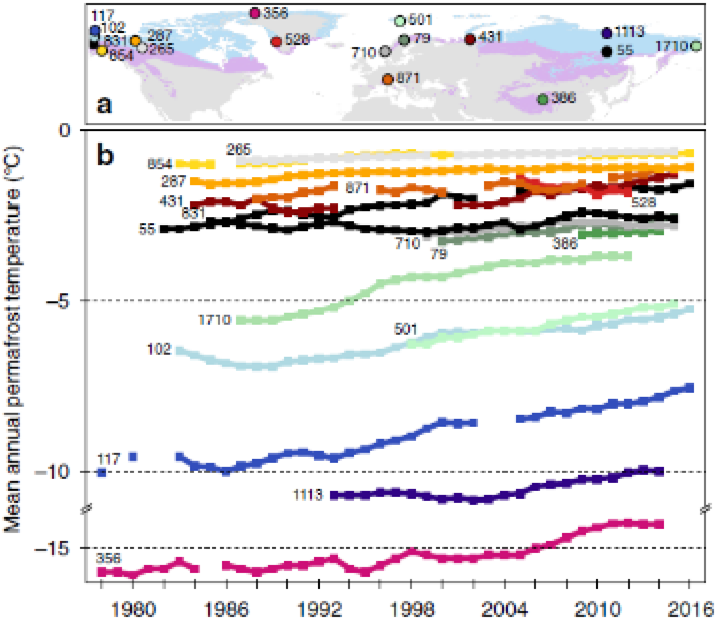


- Canada's Arctic and alpine glaciers have thinned over the past five decades due to increasing surface temperatures
- Recent mass loss rates are unprecedented over several millennia

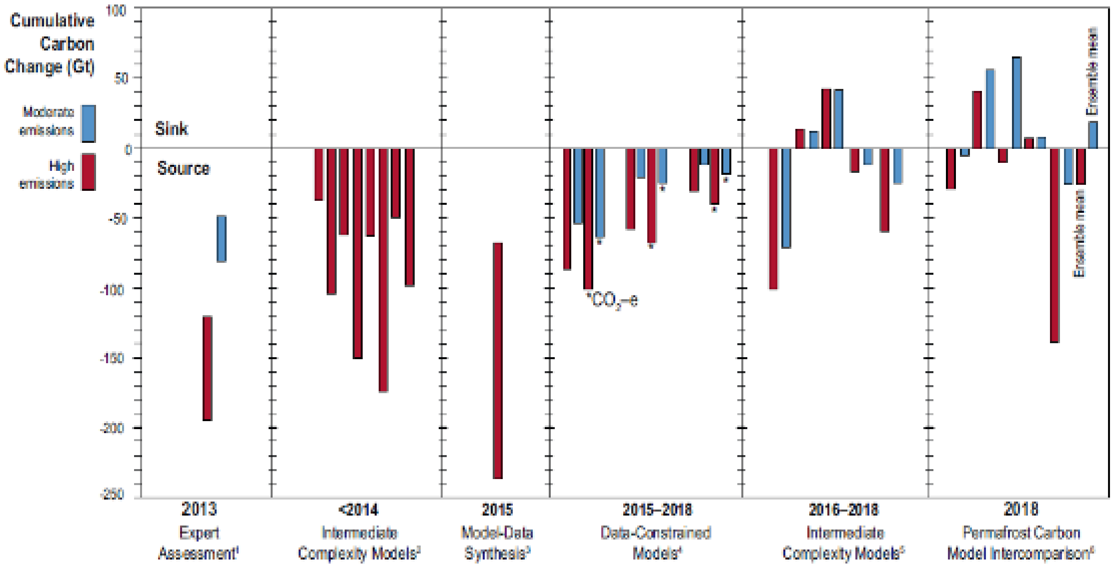
Locations of monitoring sites in the Canadian Arctic Archipelago and the Western Cordillera.
Time series of cumulative thickness of reference glaciers in the Canadian high Arctic (top left) and Western Cordillera (bottom left) since the early 1960s

Observed trends in permafrost temperature

- Permafrost temperature has increased over the past 3-4 decades.
- Permafrost is warming across Arctic and subarctic Canada, with associated landscape changes (thermokarst). Permafrost thaw has major implications for tundra regions serving as a carbon source versus sink.

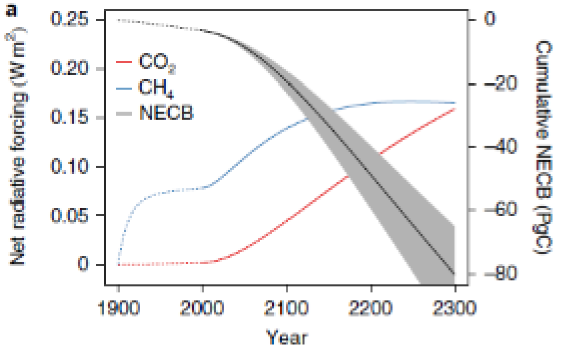


Biskaborn et al., 2019

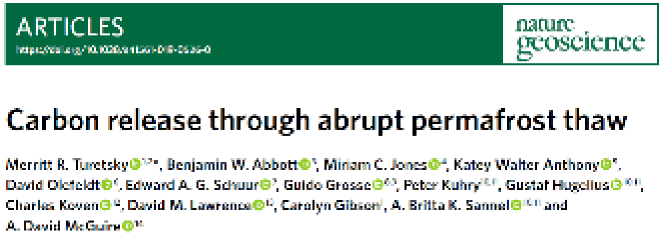


IPCC SROCC Chapter 3

Permafrost – carbon budget uncertainties

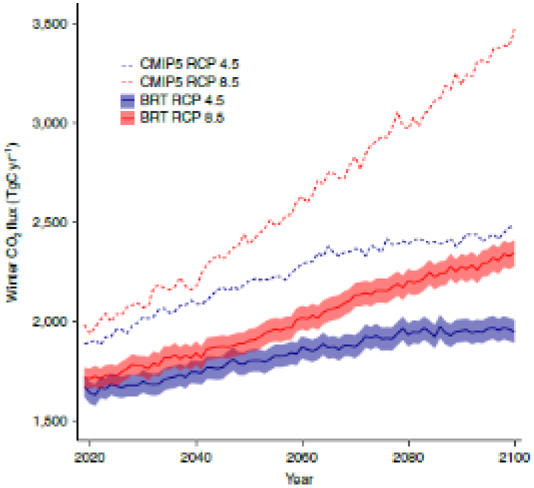


"Increases in abrupt thaw due to climate warming triggered a change in carbon behaviour from net uptake to net release."

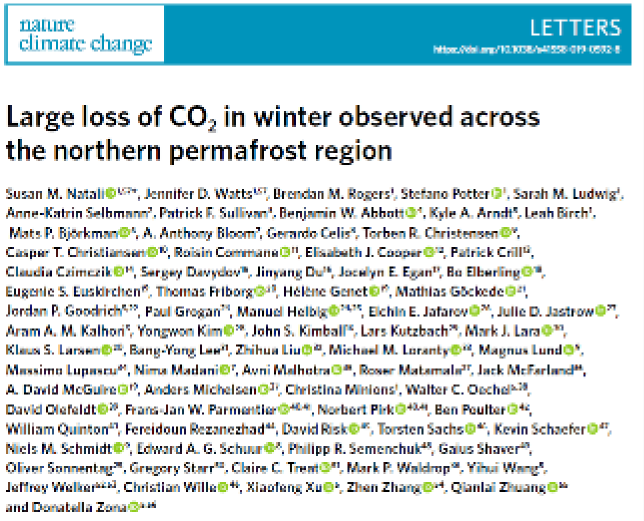


Carbon release through abrupt permafrost thaw

Merritt R. Turetsky, Benjamin W. Abbott, Miriam C. Jones, Katey Walter Anthony, David Olefeldt, Edward A. G. Schuur, Guido Grosse, Peter Kuhry, Gustaf Hugelius, Charles Koven, David M. Lawrence, Carolyn Gibson, A. Britta K. Sannel and A. David McGuire



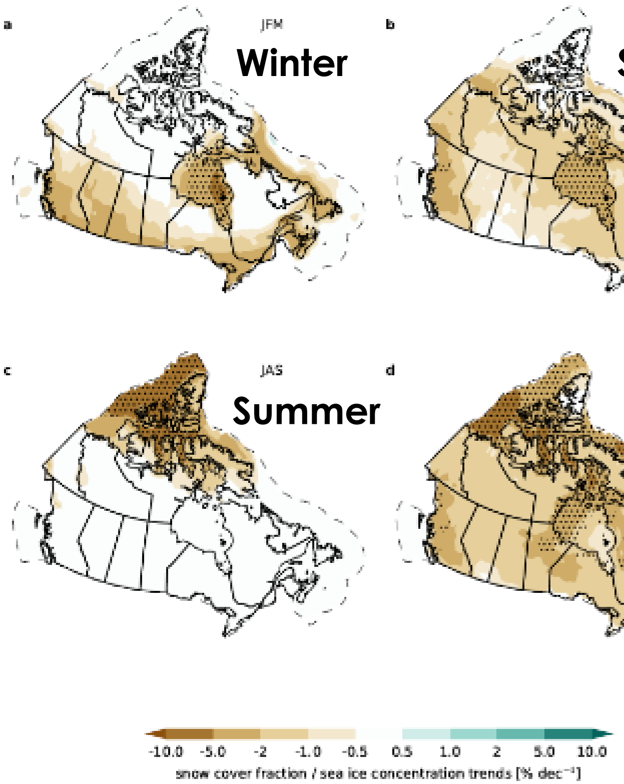
"We estimate a contemporary loss of 1,662 TgC per year from the permafrost region during the winter season. This loss is greater than the average growing season carbon uptake for this region estimated from process models (−1,032 TgC per year)."



Large loss of CO$_2$ in winter observed across the northern permafrost region

Susan M. Natali, Jennifer D. Watts, Brendan M. Rogers, Stefano Potter, Sarah M. Ludwig, Anne-Katrin Selbmann, Patrick F. Sullivan, Benjamin W. Abbott, Kyle A. Arndt, Leah Birch, Mats P. Björkman, A. Anthony Bloom, Gerardo Celis, Torben R. Christensen, Casper T. Christiansen, Roisin Commane, Elisabeth J. Cooper, Patrick Crill, Claudia Czimczik, Sergey Davydov, Jinyang Du, Jocelyn E. Egan, Bo Elberling, Eugenie S. Euskirchen, Thomas Friborg, Hélène Genet, Mathias Göckede, Jordan P. Goodrich, Paul Grogan, Manuel Helbig, Elchin E. Jafarov, Julie D. Jastrow, Aram A. M. Kalhori, Yongwon Kim, John S. Kimball, Lars Kutzbach, Mark J. Lara, Klaus S. Larsen, Bang-Yong Lee, Zhihua Liu, Michael M. Loranty, Magnus Lund, Massimo Lupascu, Nima Madani, Avni Malhotra, Roser Matamala, Jack McFarland, A. David McGuire, Anders Michelsen, Christina Minions, Walter C. Oechel, David Olefeldt, Frans-Jan W. Parmentier, Norbert Pirk, Ben Poulter, William Quinton, Fereidoun Rezanezhad, David Risk, Torsten Sachs, Kevin Schaefer, Niels M. Schmidt, Edward A. G. Schuur, Philipp R. Semenchuk, Gaius Shaver, Oliver Sonnentag, Gregory Starr, Claire C. Treat, Mark P. Waldrop, Yihui Wang, Jeffrey Welker, Christian Wille, Xiaofeng Xu, Zhen Zhang, Qianlai Zhuang and Donatella Zona

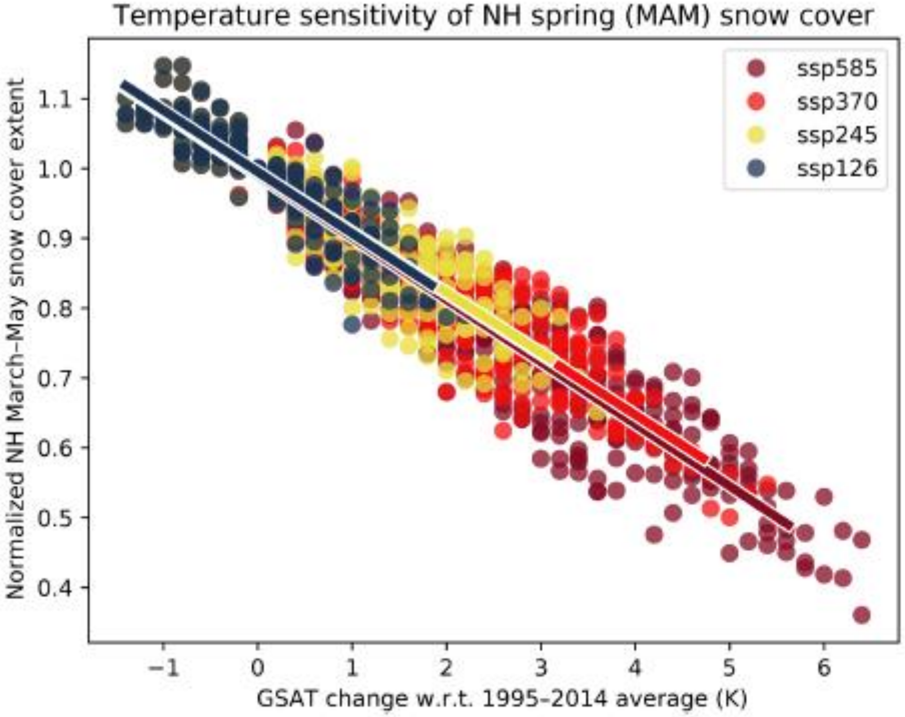
Projected changes to the snow, ice, and permafrost across Canada



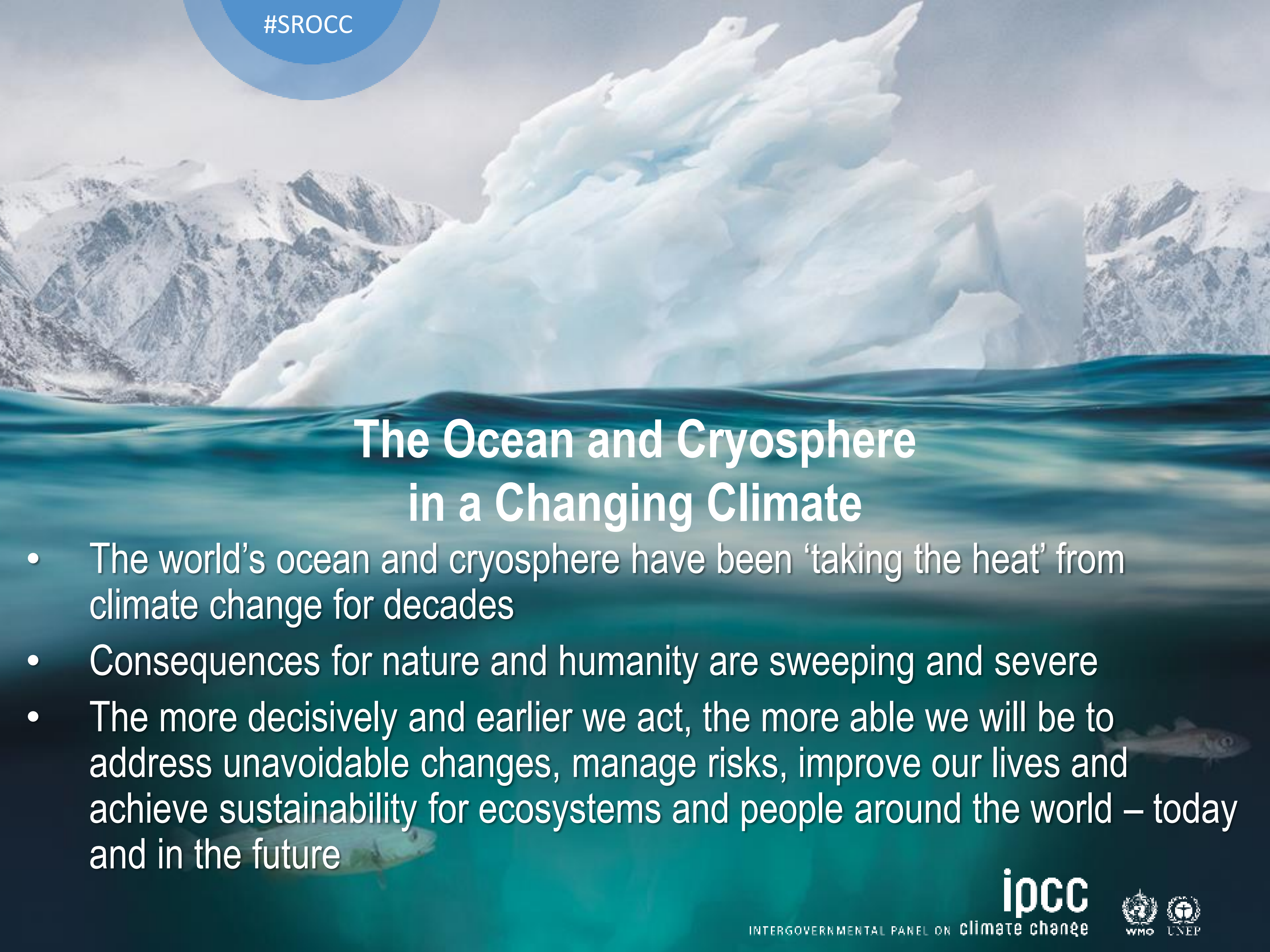
Projected terrestrial snow cover fraction and sea ice concentration seasonal trends (% per decade) for the 2020–2050 period under a high emissions scenario (RCP8.5)

- Increases in mean air temperature under all emissions scenarios result in projected reductions in snow cover duration and sea ice area, and permafrost warming and thawing across northern Canada
- The northern Canadian Arctic Archipelago and Greenland will be the last area in the Arctic with multi-year ice present during the summer.
- Multi-year ice will still drift into the Northwest Passage (and present a navigation hazard for shipping) when the Arctic Ocean is sea ice-free during the summer.

Further insights on snow cover projections



- At the hemispheric scale, future snow extent changes can be unambiguously related to global surface air temperature changes.
- Similar for other fast-response components of the cryosphere, such as sea ice and near-surface permafrost extent.



#SROCC

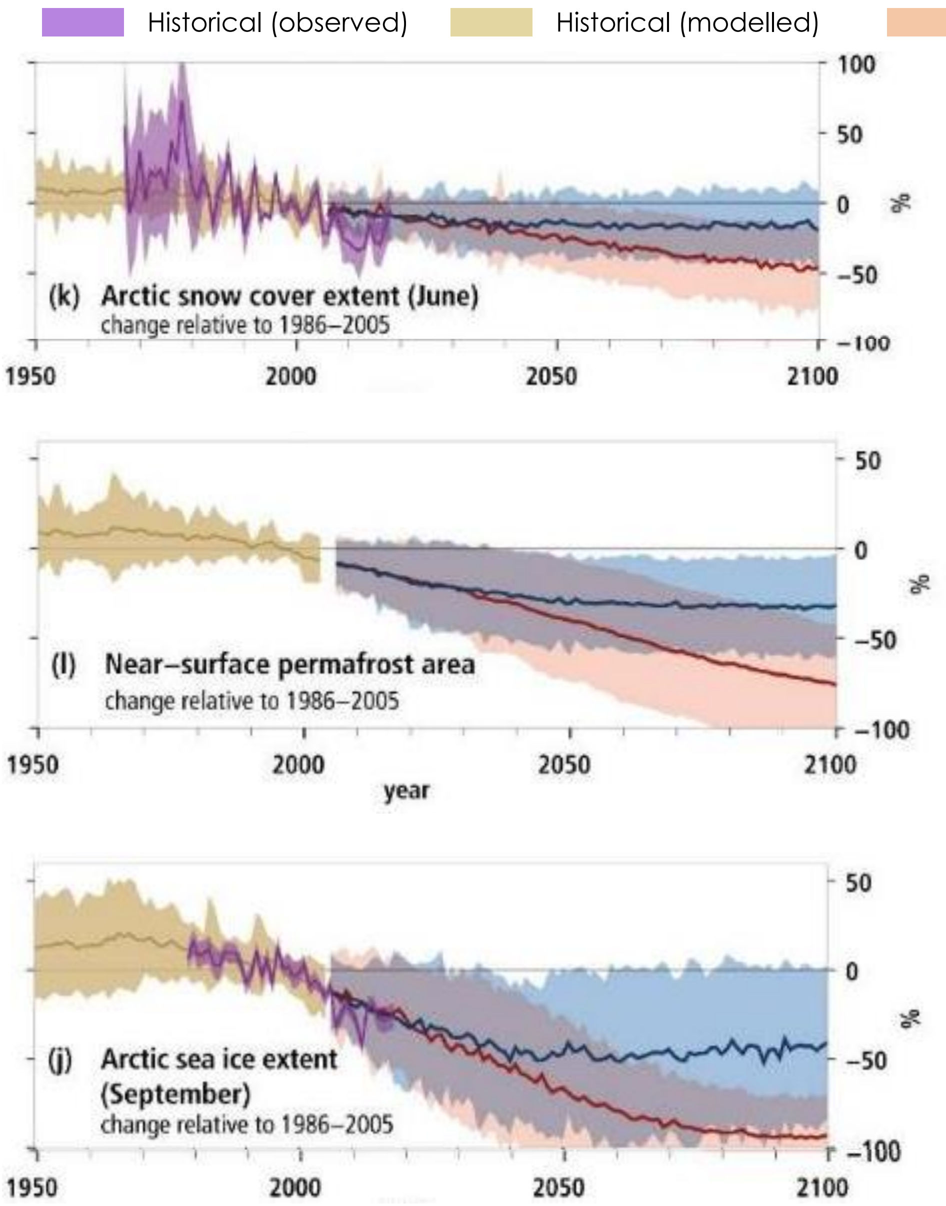
The Ocean and Cryosphere in a Changing Climate

- The world’s ocean and cryosphere have been ‘taking the heat’ from climate change for decades
- Consequences for nature and humanity are sweeping and severe
- The more decisively and earlier we act, the more able we will be to address unavoidable changes, manage risks, improve our lives and achieve sustainability for ecosystems and people around the world – today and in the future

ipcc
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

Strong mitigation is projected to stabilize snow cover and sea ice loss and permafrost extent after mid-century



(k) Arctic snow cover extent (June)
change relative to 1986–2005

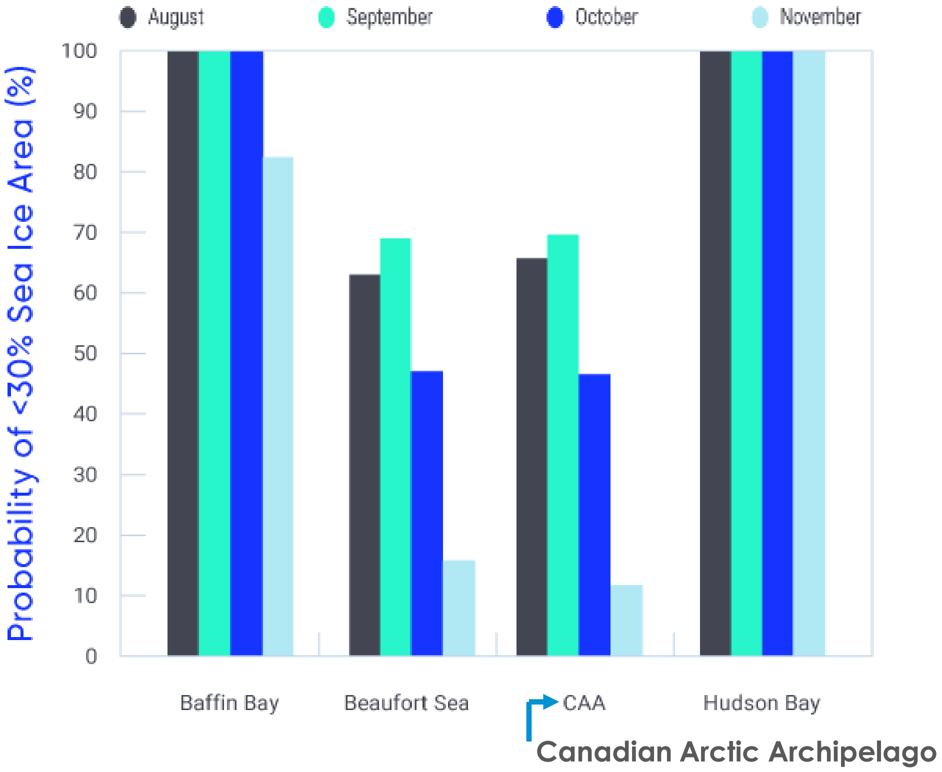
(l) Near–surface permafrost area
change relative to 1986–2005

(j) Arctic sea ice extent (September)
change relative to 1986–2005

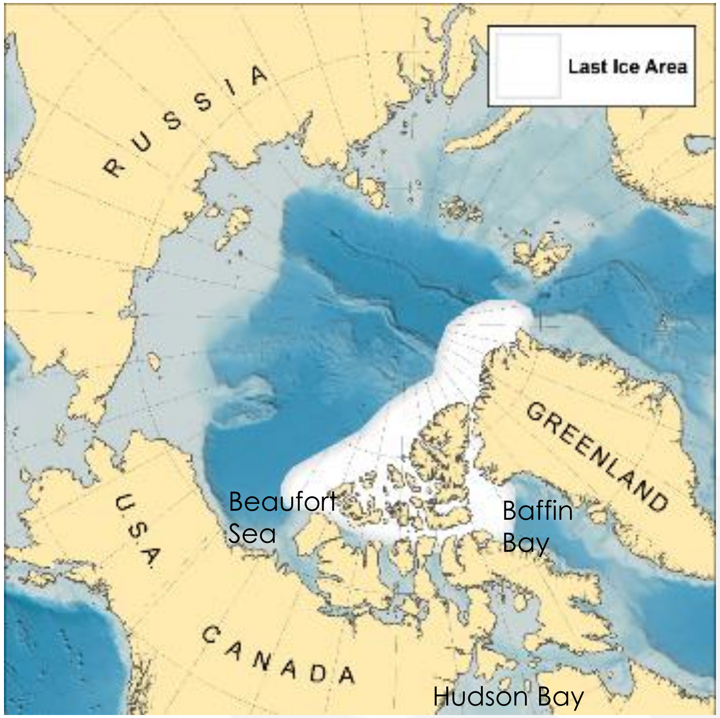
- Arctic spring snow cover decreases by additional 5-10% in the near-term, followed by no further losses under RCP2.6; additional 15-25% loss by 2100 under RCP8.5.
- Widespread permafrost thaw is projected for this century. Under a high emission scenario, cumulative release of tens to hundreds of billions of tons of permafrost carbon as CO_2 and CH_4 is projected by 2100.
- At global warming of 1.5C, the Arctic Ocean will rarely be free of sea ice in September. At 2C warming, this will occur up to one year in three.

Extensive ice-free periods are also projected for the Canadian Arctic Ocean

Probability of sea ice–free conditions by 2050



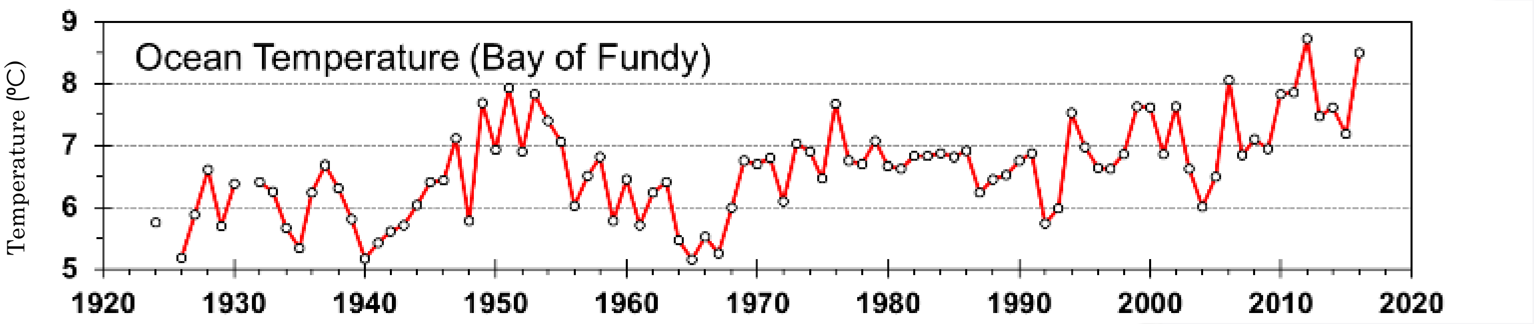
Schematic: last ice area of the Arctic Ocean



- Probability of ice-free conditions in different regions of the Canadian arctic under a high emission scenario
- The likelihood of summer ice-free conditions in the central Arctic rises with the magnitude of global temperature increases

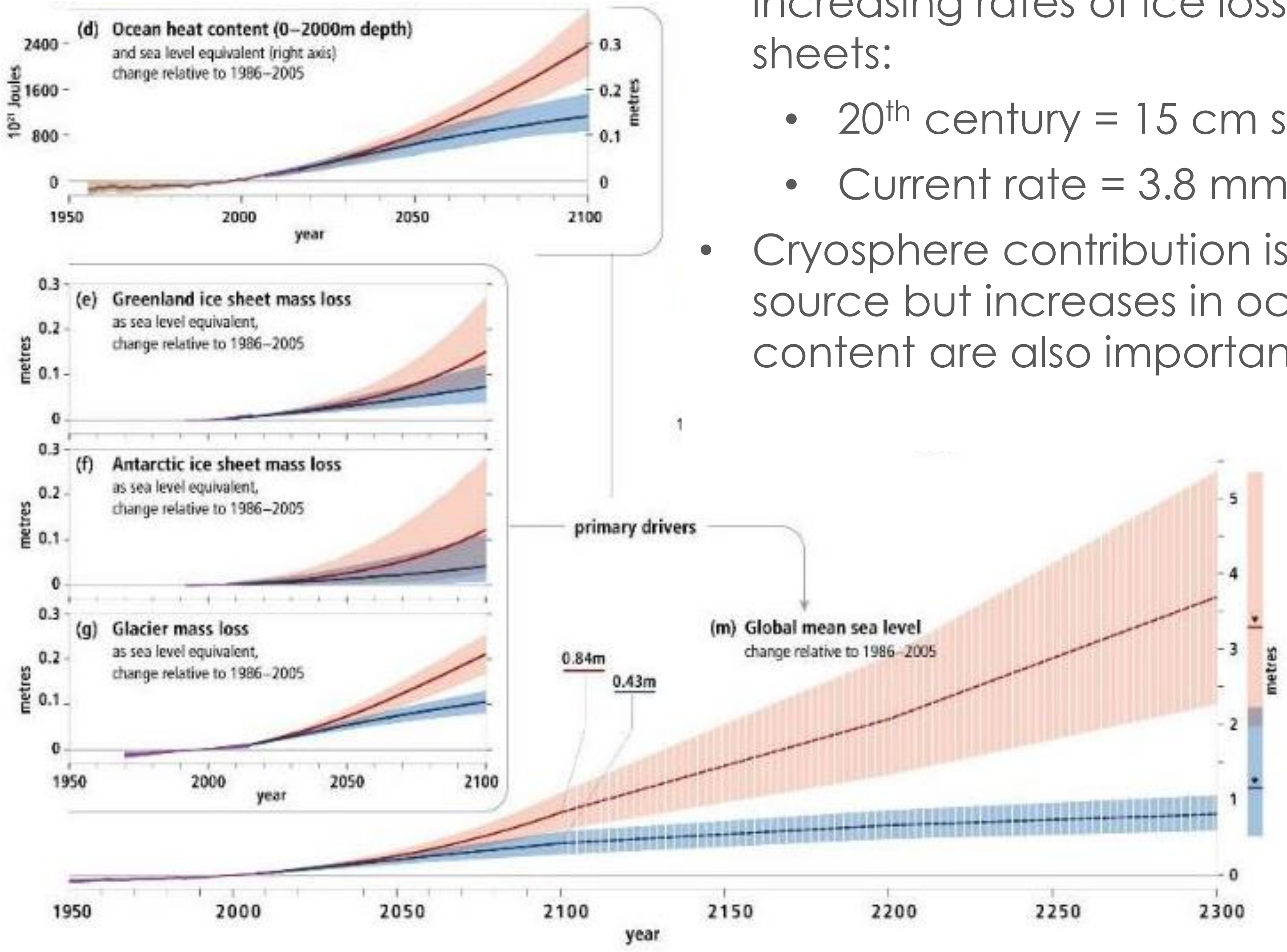
Oceans surrounding Canada have warmed, become more acidic, and less oxygenated, consistent with observed global ocean changes over the past century

- Ocean warming and loss of oxygen will intensify with further emissions of all greenhouse gases.
- Ocean acidification will increase in response to additional carbon dioxide emissions.
- These changes threaten the health of marine ecosystems.



IPCC Special Report on the ocean and cryosphere in a changing climate

- Global mean sea level is rising with acceleration in recent decades due to increasing rates of ice loss from the ice sheets:
  - 20th century = 15 cm sea level rise
  - Current rate = 3.8 mm per year
- Cryosphere contribution is the dominant source but increases in ocean heat content are also important



- Sea level rise projections to 2300 are subject to ‘deep uncertainty’

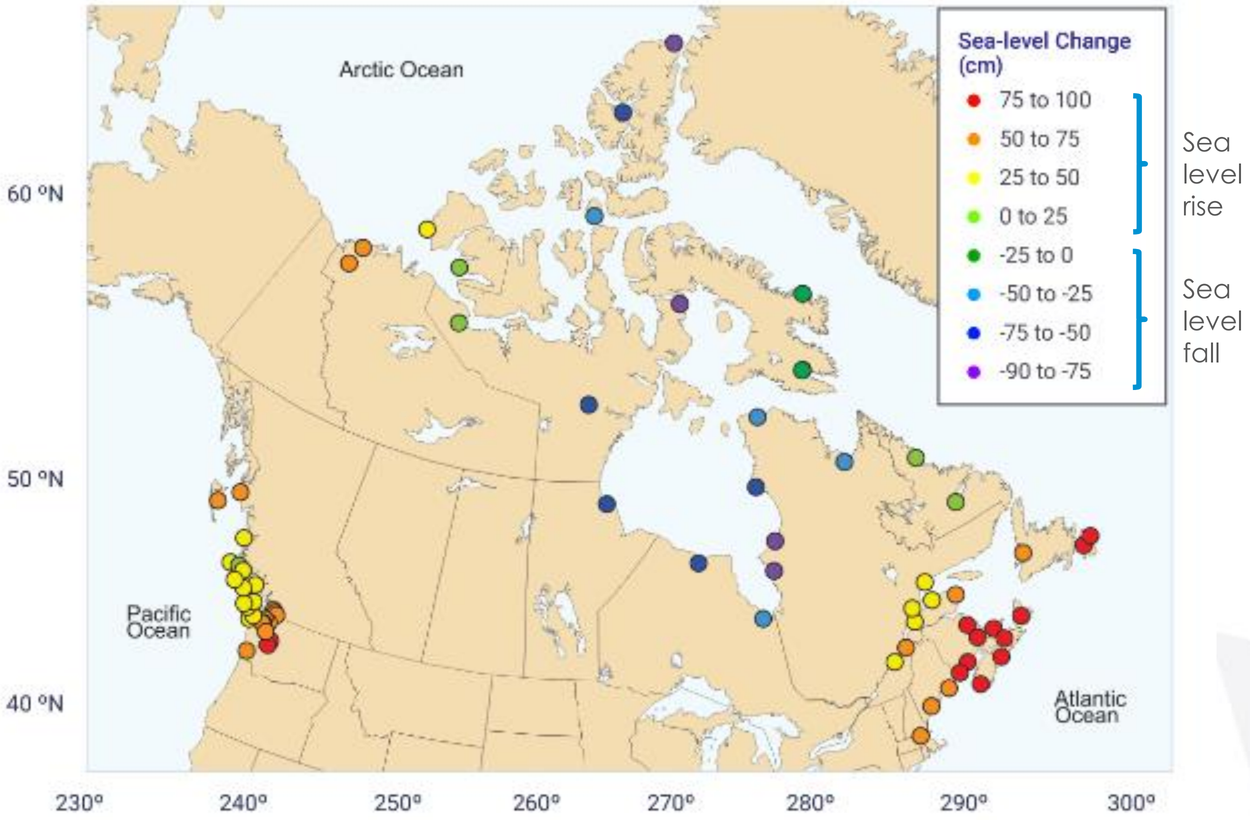
Coastal flooding is expected to increase in many areas of Canada due to local sea level rise

- Changes in local sea-level are a combination of global sea level rise and local land subsidence or uplift.
- Local sea level is projected to rise, and increase flooding, along most of the Atlantic and Pacific coasts of Canada and the Beaufort Sea coast in the Arctic.

Davis Bay, B.C. Photo courtesy of B. Oakford.

- The loss of sea ice in Arctic and Atlantic Canada further increases the risk of damage to coastal infrastructure and ecosystems due to larger storm surges and waves.

Global mean sea level is projected to rise, but along Canada's coastlines, sea level will rise in some places, fall elsewhere

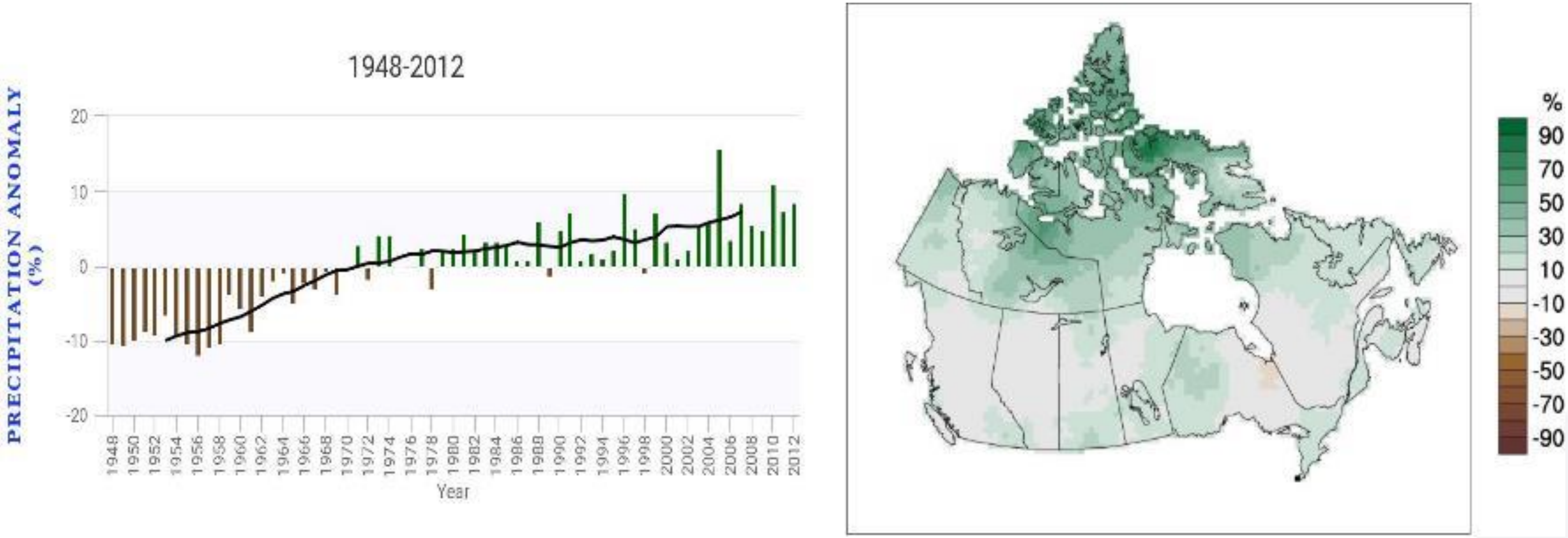


End-of-century projected relative (local) sea-level change under a high emission scenario, relative to 1986-2005 reference period

In southern Atlantic Canada, relative sea level rise is expected to be close to 1 m

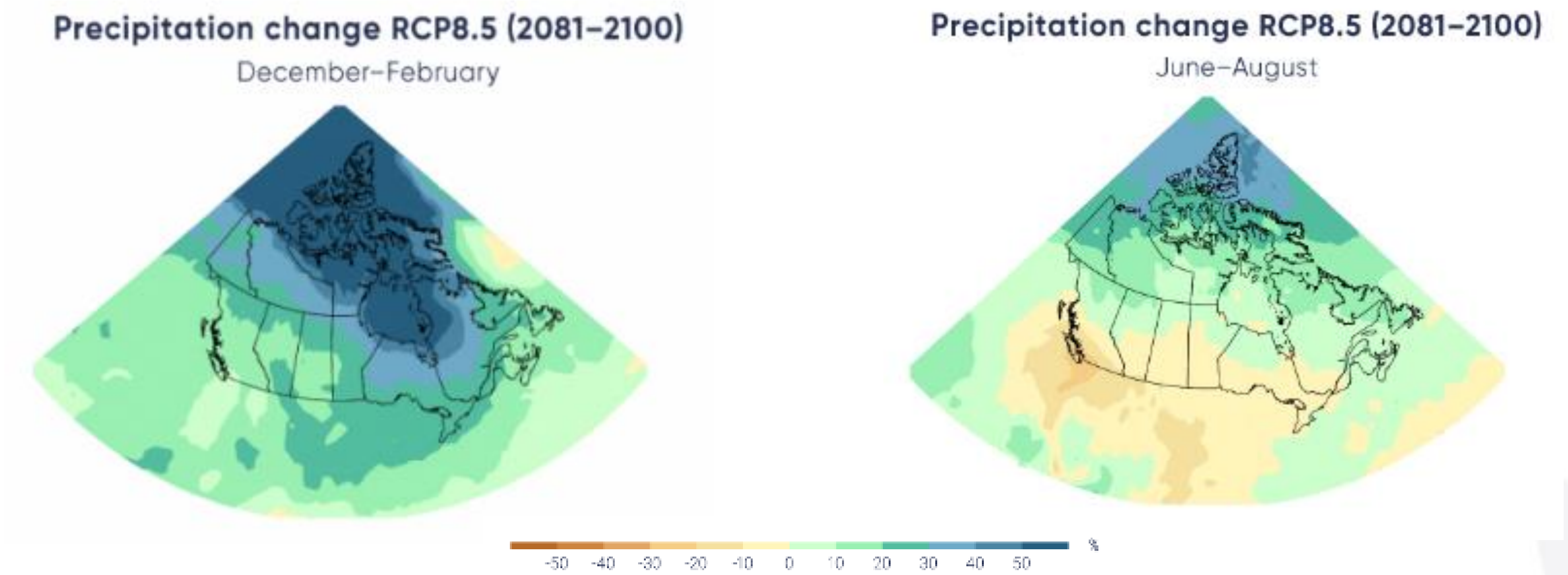
A warming climate has been associated with more precipitation on average

Changes in annual precipitation, 1948–2012



- Annual precipitation has increased in many regions since 1948, with larger percentage increases in northern Canada.
- Averaged over the country, normalized precipitation has increased by about 20% from 1948 to 2012.
- There is less confidence in observed changes in precipitation than temperature but observed increases are consistent with physical expectations.

Important seasonal differences in precipitation projections



Precipitation change RCP8.5 (2081–2100)

December–February

Precipitation change RCP8.5 (2081–2100)

June–August

- Temperatures remain sufficiently cold at high latitudes that projected increases in winter precipitation will fall as snow
- Increased rain/decreased snow during fall/spring due to warming
- Unlike for temperature, which is projected to increase everywhere in every season, precipitation has patterns of increase and decrease
- Summer precipitation is projected to decrease in southern Canada under a high emission scenario toward the end of the century

The seasonal availability of freshwater is changing with an increased risk of water supply shortages in summer

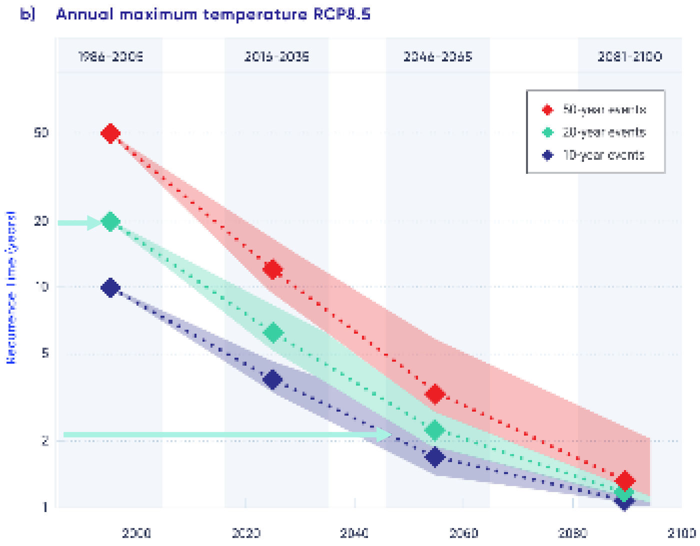
- Warmer winters and earlier snowmelt will combine to produce higher winter streamflow.
- Shallower snowpack and loss of glacier ice this century will combine to produce lower summer streamflow.

Spring freshet at Eakin Creek in BC

- Warmer summers will increase evaporation of surface water and contribute to reduced summer water availability in the future despite more precipitation in some places.

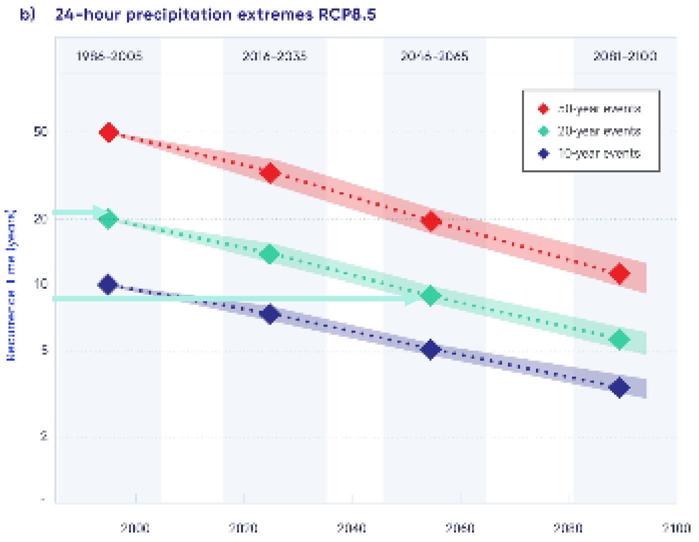
Future increases in the frequency and intensity of extreme events

Change in temperature extremes
High emission scenario



- A current 1 in 20-yr hot extreme will become a once in 2-year event by mid-century under a high emission scenario (a ten-fold increase in frequency).

Change in precipitation extremes
High emission scenario



- A current 1 in 20-yr rainfall extreme will become a once in 10-yr event by mid-century under the high emission scenario (a two-fold increase in frequency).

A warmer climate will intensify some weather extremes in the future

- Extreme hot temperatures will become more frequent and more intense. This will increase the severity of heatwaves, and contribute to increased drought and wildfire risks.
- While inland flooding results from multiple factors, more intense rainfalls will increase urban flood risks.
- It is uncertain how warmer temperatures and smaller snowpacks will combine to affect the frequency and magnitude of snowmelt-related flooding.

HEAT WAVES

WILDLAND FIRES

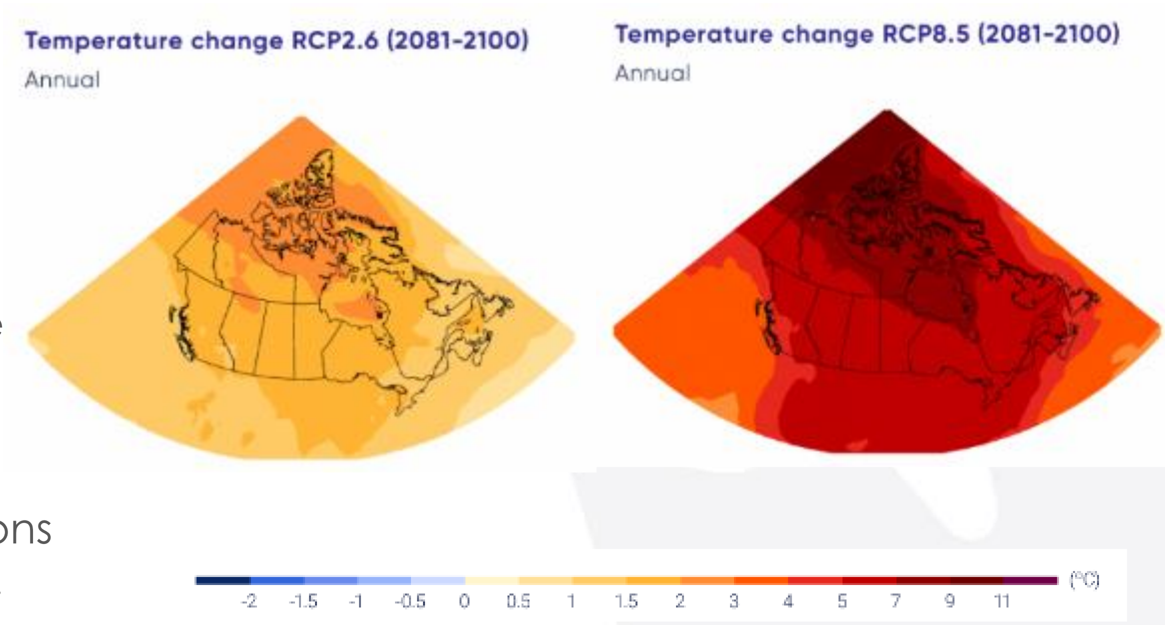
URBAN FLOODS

The rate and magnitude of climate change under high versus low emission scenarios project two very different futures for Canada

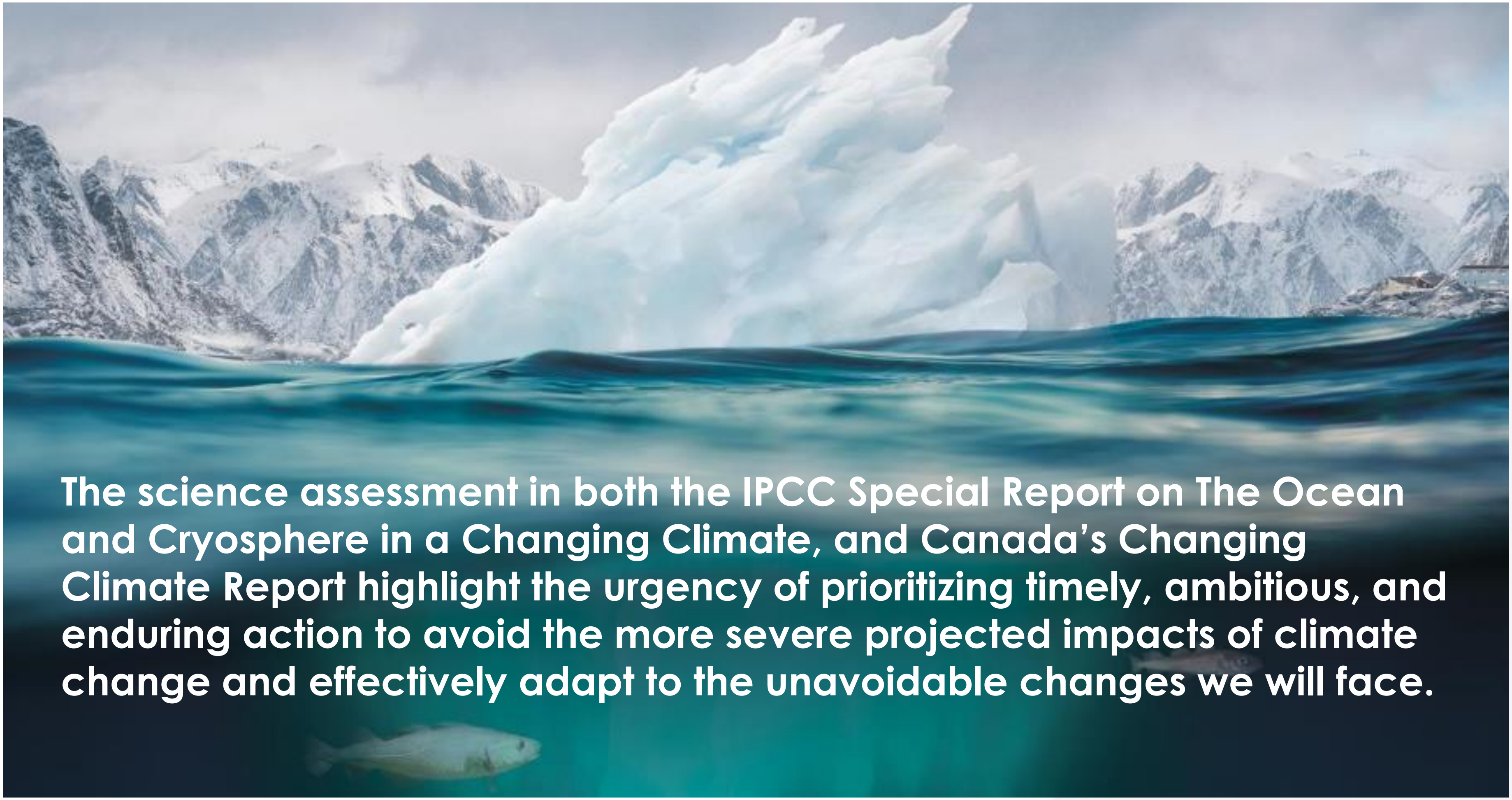
- Scenarios with large and rapid warming illustrate the profound effects on Canadian climate of continued growth in GHG emissions.
- Scenarios with limited warming will only occur if Canada and the rest of the world reduce carbon emissions to near zero early the second half of the century and reduce emissions of other GHGs substantially.

Low global emissions limited warming

High global emissions large warming



Climate change is real, and we are seeing clear evidence of it across Canada. Additional warming and further changes in climate are unavoidable.



The science assessment in both the IPCC Special Report on The Ocean and Cryosphere in a Changing Climate, and Canada's Changing Climate Report highlight the urgency of prioritizing timely, ambitious, and enduring action to avoid the more severe projected impacts of climate change and effectively adapt to the unavoidable changes we will face.

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