



CANADA'S CHANGING CLIMATE REPORT: CHANGES IN SNOW, ICE, & PERMAFROST, & FRESHWATER AVAILABILITY ACROSS CANADA



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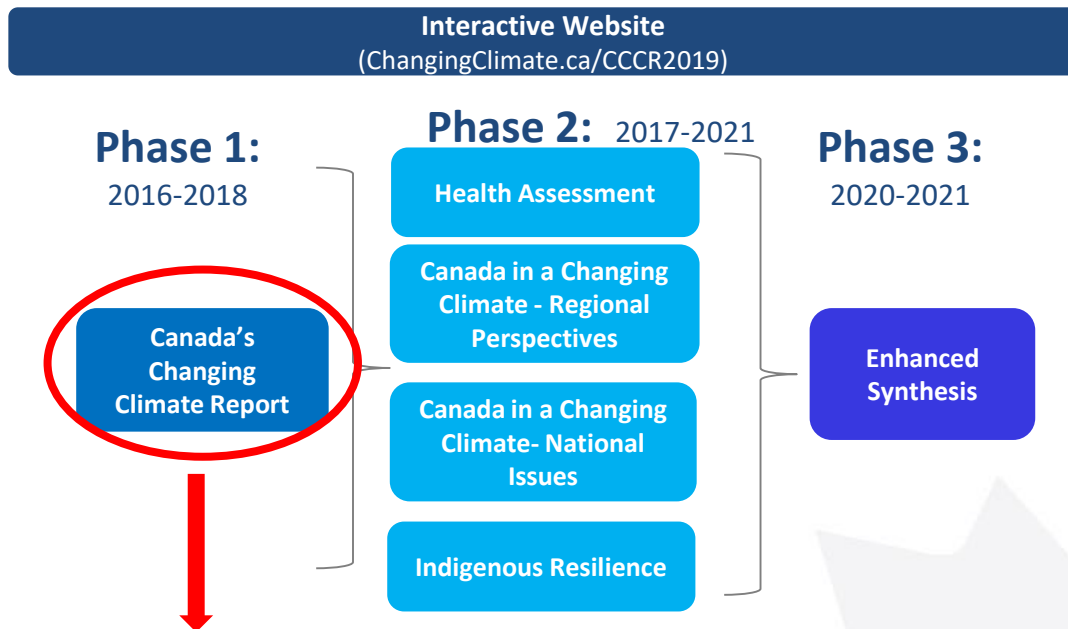
CANADA'S CHANGING CLIMATE REPORT

- A collaborative effort: Environment and Climate Change Canada; Fisheries and Oceans Canada; Natural Resources Canada; University experts
- Initiated 4 years ago, as input to the next national assessment
- Contributions from 43 government and academic authors
- Peer-reviewed science assessment report similar to Intergovernmental Panel on Climate Change and based on published scientific literature
- <https://changingclimate.ca/>



Canada's National Assessment on Climate Change

Canada in a Changing Climate: Advancing our Knowledge for Action



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

Canada's Changing Climate Report

10 HEADLINE STATEMENTS FOR THE WHOLE REPORT

KEY MESSAGES FOR EACH MAJOR CHAPTER
Assessed confidence in findings and likelihood of results

Chapter 1
About this Report

Chapter 2
Observed Global
Climate Change

Chapter 3
Modelling Future
Climate Change

Chapter 4
Changes in
Temperature and
Precipitation

Chapter 5
Changes in
Snow, Ice and
Permafrost

Chapter 6
Changes in
Freshwater
Availability

Chapter 7
Changes in
Oceans
Surrounding
Canada

Chapter 8
Changes in Canada's Regions in a
National and Global Context

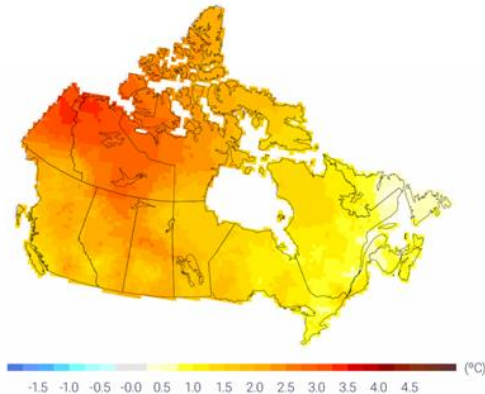


Both past and future warming in Canada is, on average, about double the magnitude of global warming.

— Canada's Changing Climate Report

ChangingClimate.ca/CCCR2019

Canada



Mean annual temperature increase
1948-2016

- Canada has warmed by 1.7°C between 1948 and 2016, about two times global warming.
- Northern Canada has warmed by 2.3 °C, about three times global warming.
- The observed warming is primarily due to human activities and is effectively irreversible.



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

Canada



- 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.



Chapter 5: CHANGES IN SNOW, ICE AND PERMAFROST ACROSS CANADA

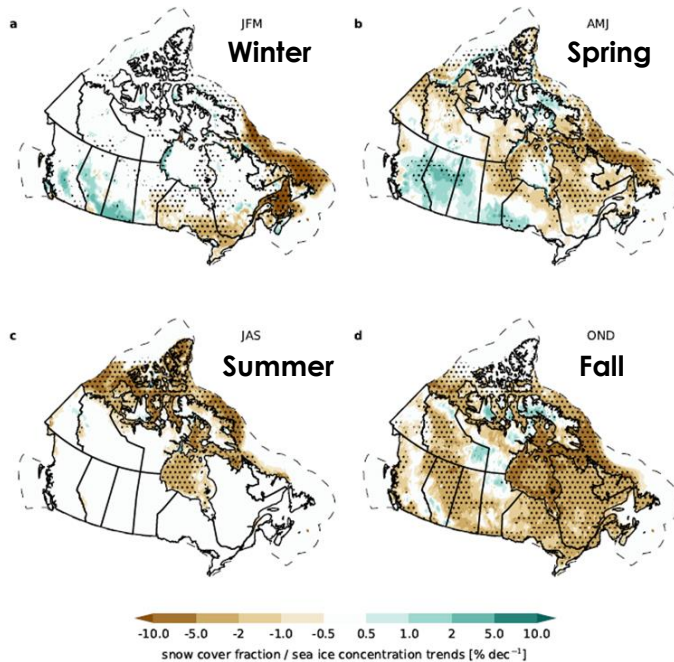
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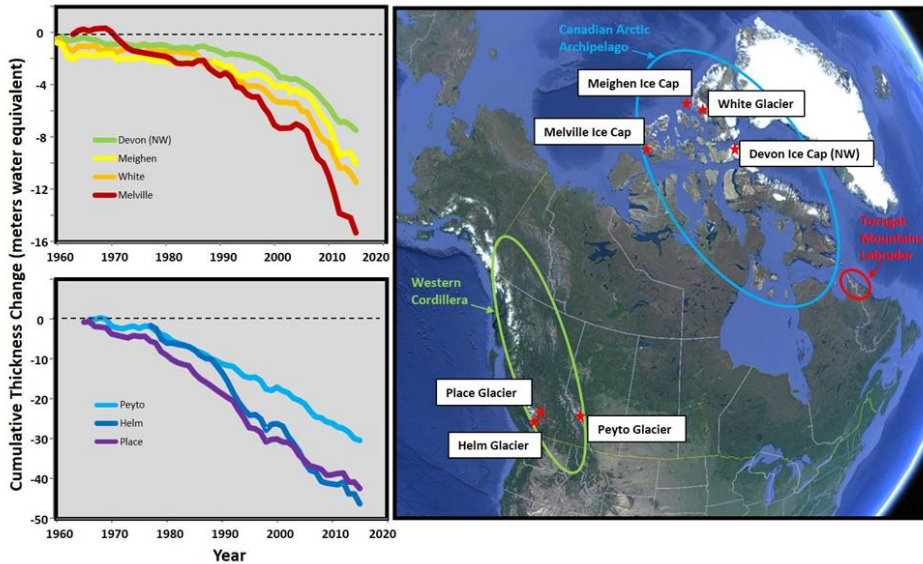
Historical snow cover fraction and sea ice concentration trends



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

- The portion of the year with snow cover decreased across most of Canada by 5% to 10% per decade (*very high confidence*)
- Summer sea ice area declined across the Canadian Arctic by 5% to 20% per decade since 1968 (depending on region); winter sea ice area decreased in eastern Canada by 8% per decade (*very high confidence*)
- Perennial sea ice in the Canadian Arctic is being replaced by thinner seasonal sea ice (*very high confidence*).

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

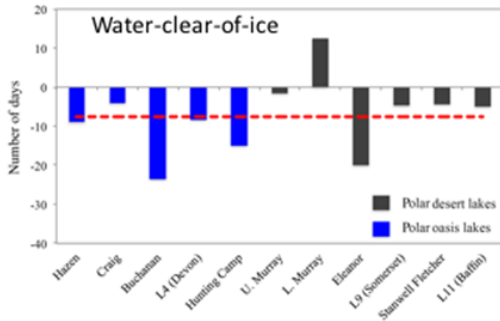


- Canada's Arctic and alpine glaciers have thinned over the past five decades due to increasing surface temperatures (*very high confidence*)
- Recent mass loss rates are unprecedented over several millennia (*very high confidence*)

Locations of monitoring sites in the Canadian Arctic Archipelago and the Western Cordillera.

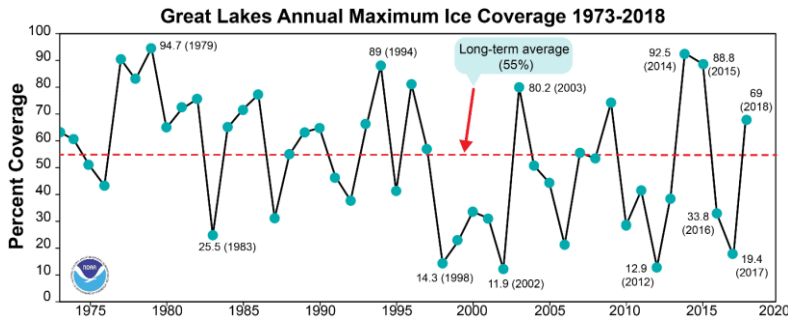
Time series of cumulative thickness of reference glaciers in the Canadian high Arctic (top left) and Western Cordillera (bottom left) since the early 1960s

Observed changes in lake ice cover



Changes in ice cover for selected lakes in the Canadian high Arctic, 1997–2011

- 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*)

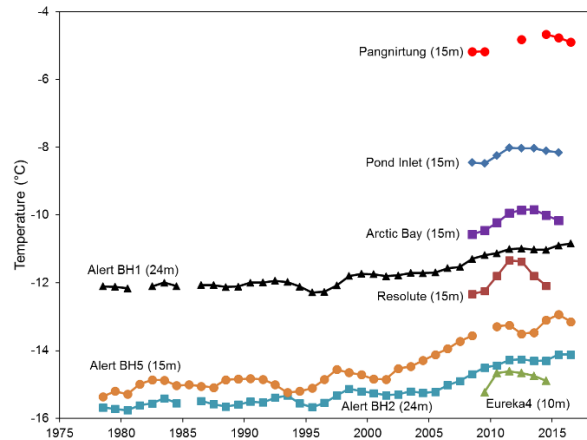
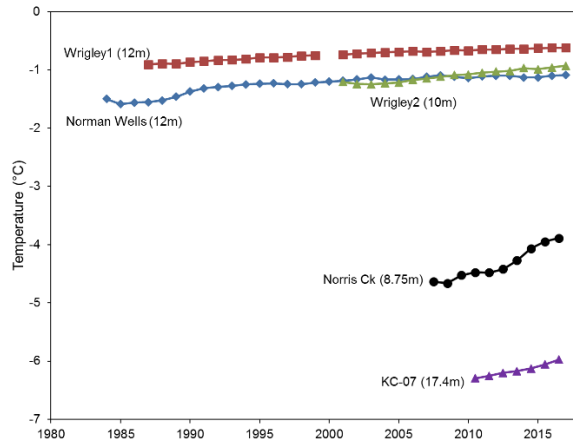


- Seasonal maximum lake ice cover for the Great Lakes is highly variable since 1971 (*very high confidence*), with no significant trend

Laurentian Great Lakes annual maximum ice cover, 1973–2018

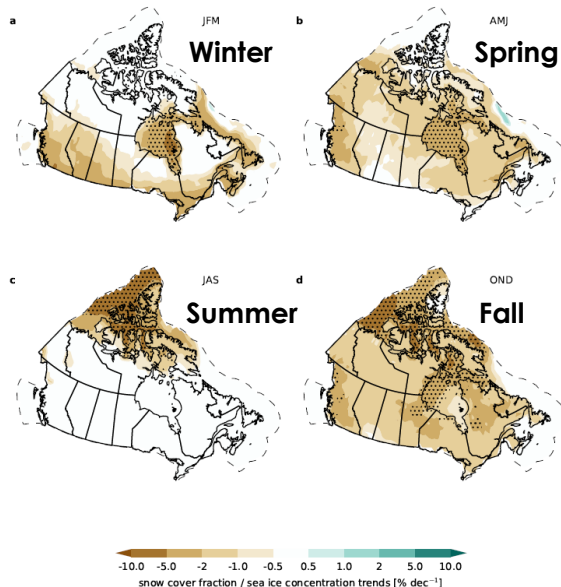
Observed trends in permafrost temperature

- Permafrost temperature has increased over the past 3-4 decades (*very high confidence*)
- Regional observations identify warming rates of 0.3 to 0.5°C per decade in the high Arctic. The rate of increase is lower in the Mackenzie Valley, but permafrost temperatures are already close to 0°C in this region, so energy melts ground ice rather than raising the temperature further



Observed trends in permafrost temperatures for locations in the northwestern Arctic and Mackenzie Valley region (left) and eastern and high Arctic (right)

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

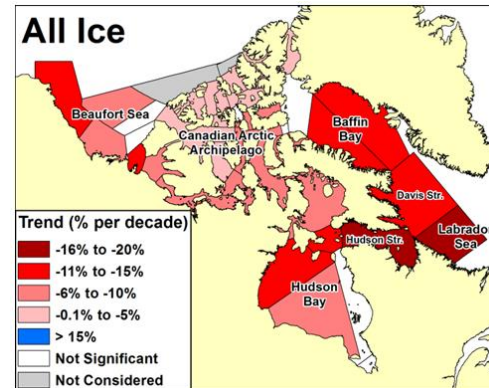
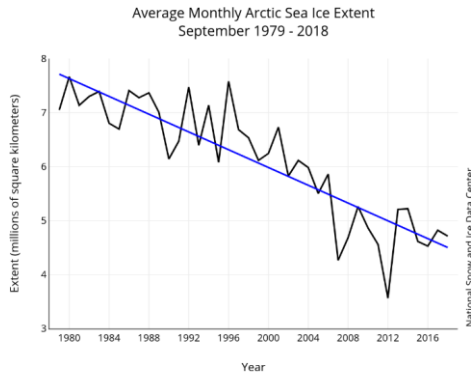


Projected terrestrial snow cover fraction and sea ice concentration seasonal trends (% per decade) for the 2020–2050 period under a high emissions scenario (RCP8.5)

- Increases in mean air temperature under all emissions scenarios result in projected reductions in (*high confidence*):
 - snow cover duration across Canada
 - sea ice area in the Canadian Arctic in summer and the east coast in winter
 - permafrost warming and thawing across northern Canada
- Under a medium emissions scenario, it is projected that glaciers across the Western Cordillera will lose 74 to 96% of their volume by late century (*high confidence*).
- Spring lake ice breakup will be 10 to 25 days earlier and fall freeze-up 5 to 15 days later by mid-century, depending on the emissions scenario and lake-specific characteristics such as depth (*medium confidence*)

The Last Ice Area

- Summer sea ice reductions are occurring across the pan-Arctic and in the Canadian Arctic
- The northern 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 still drift into the Northwest Passage (and present a navigation hazard for shipping) when the Arctic Ocean is sea ice-free during the summer



Left: Pan-Arctic September ice extent, 1979 to 2018 (decline of 12.8 percent per decade).
Right: Trends in summer total ice cover for Canadian Arctic regions, 1968–2016

Changes in snow, ice and permafrost paint a coherent picture of a warming world

1. Over the past three decades, the proportion of Canadian land and marine areas covered by snow and ice have decreased, glaciers have lost mass, and permafrost temperatures have risen
2. These changes to the Canadian cryosphere are consistent those observed in other northern regions (Alaska, northern Europe, and Russia)
3. Observed changes are in large part a response to increasing surface temperature
4. Further changes to the cryosphere over the coming decades are virtually certain, as temperatures are projected to increase under all future emission scenarios



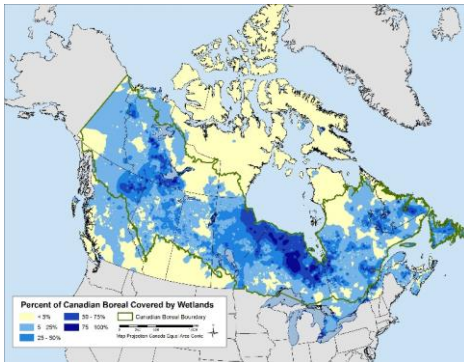
Chapter 6: CHANGES IN FRESHWATER AVAILABILITY ACROSS CANADA

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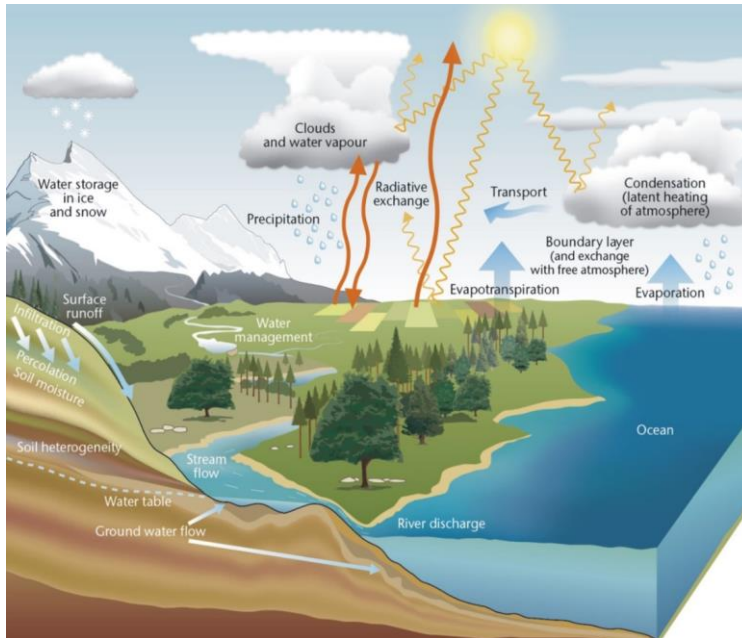
Canada's Freshwater



Top: Canada's major lakes and rivers.
Bottom: Percent of Canadian boreal area covered by wetlands

- Vast amounts of freshwater: Lakes, rivers, wetlands, groundwater, snowpacks, glaciers, & the soil
- Over 8500 rivers and > 2 million lakes - ~9% of Canada
- Wetlands: ~16% of the Canada's landmass
- Fundamental to the environment, social & economic activities: Aquatic ecosystems, agriculture, industry, hydro-electricity, drinking water, recreation

Water Cycle



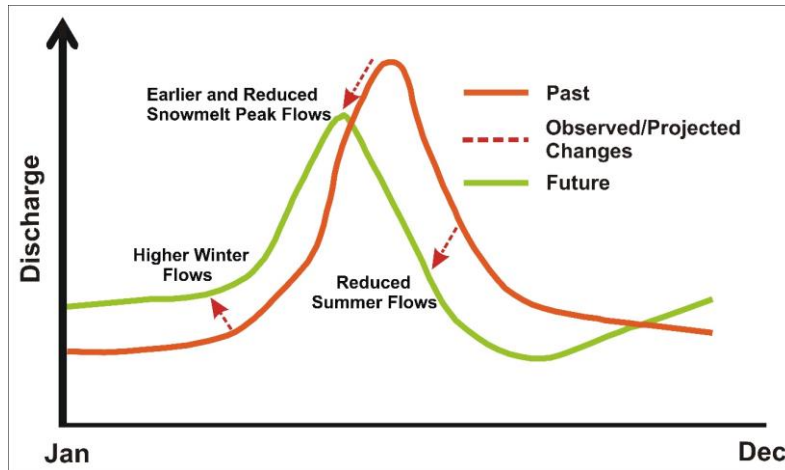
- Freshwater availability: Processes & interactions within the water cycle
- Closely linked with changes in temperature, precipitation, snow & ice, oceans
- Human management: Dams, reservoirs, withdrawals - an important component of the water cycle

The water cycle, its components, relevant processes, and interactions

Changes in Streamflow Timing

The seasonal timing of peak streamflow has shifted, driven by **warming temperatures**. Over the last several decades, 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*).

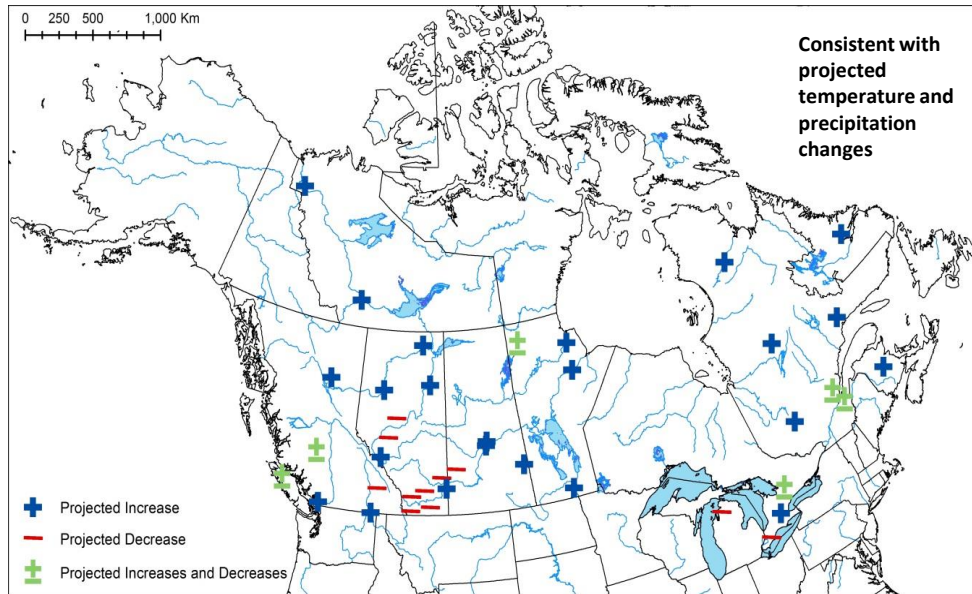
Seasonal changes projected to **continue**, with shifts from more snowmelt-dominated regimes **toward rainfall-dominated regimes** (*high confidence*).



Schematic showing past and projected future changes to streamflow timing

Changes in Streamflow Magnitude

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*).



Projected future changes to annual streamflow in Canada

Changes in Streamflow Related Flooding

There have been no spatially consistent trends in many flood-causing factors or in flooding events across the country.

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.

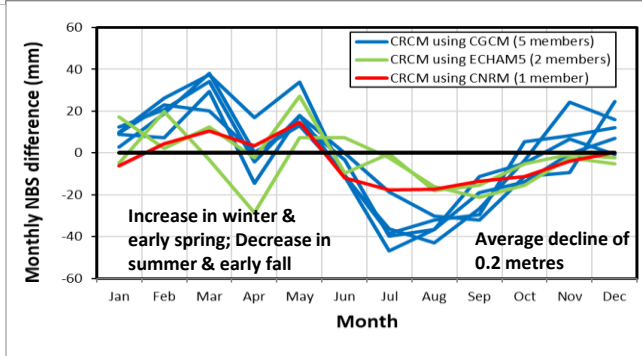
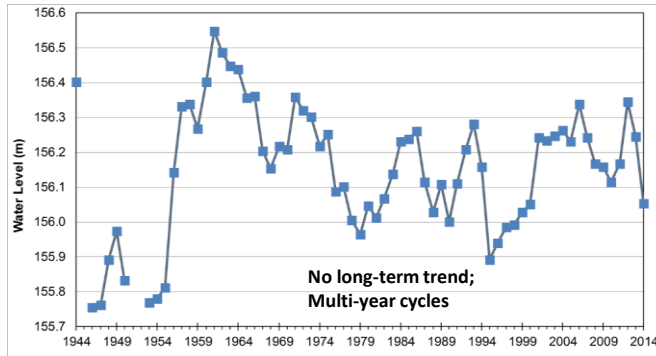


Changes in Surface Water Levels

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*).



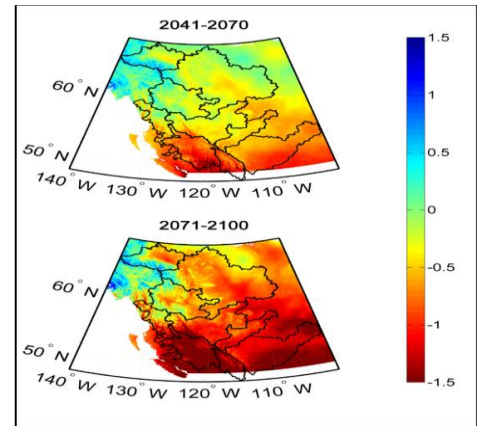
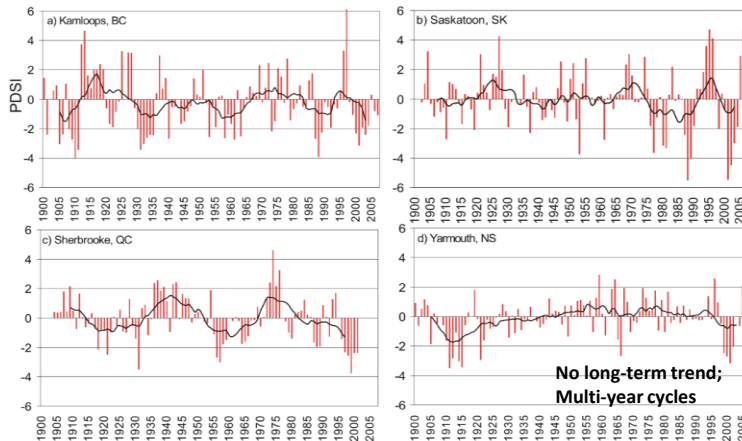
Left: Water levels for Great Bear Lake, 1944–2014

Right: Difference in monthly Lake Michigan/Huron net basin supply 2041–70 minus 1961–2000

Changes in 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*).

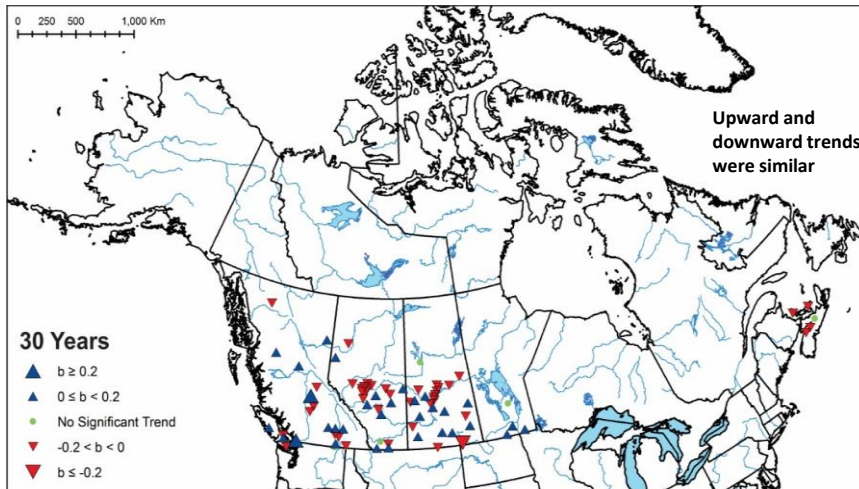


Left: Annual Palmer Drought Severity Index for four selected Canadian locations, 1900–2007
Right: Changes in annual Standardized Precipitation Evapotranspiration Index for western Canada

Changes in Groundwater

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).

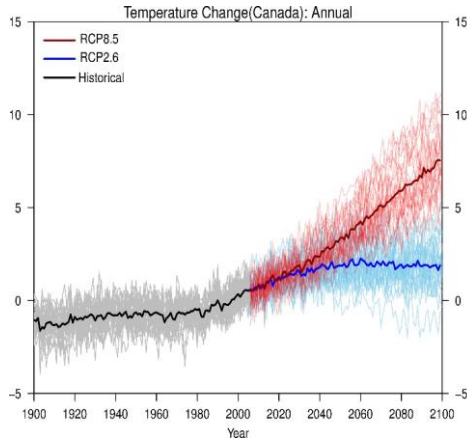


Annual mean groundwater level trends for selected areas of Canada; 1976-2005

Take Away Messages

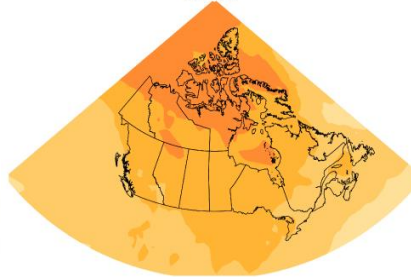
- Anticipated changes from anthropogenic climate warming will directly affect the timing and amount of future freshwater supplies, and these may be exacerbated by human management alterations to freshwater systems.
- The impacts are expected to be more prominent toward the end of this century under higher emission scenarios, given the larger associated climate changes.
- Of particular concern are impacts in regions that currently rely on snow and ice melt as freshwater sources, as well as continental interior areas, where increased evapotranspiration from warmer temperatures could reduce future water supplies.
- However, freshwater supplies in all regions of Canada are expected to be affected in one way or another. It is also anticipated that water-related extremes, such as droughts and floods, will intensify these impacts.

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



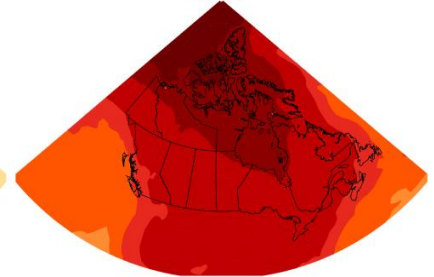
Low global emissions
limited warming

Temperature change RCP2.6 in 2081-2100
Annual



High global emissions
large warming

Temperature change RCP8.5 in 2081-2100
Annual



- Scenarios with large and rapid warming illustrate the profound effects on Canadian climate of continued growth in greenhouse gas emissions.
- Scenarios with limited warming require Canada and the rest of the world to reduce carbon emissions to near zero early in the second half of the century.

Thank You

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