



Government
of Canada

Gouvernement
du Canada

Canada's Changing Climate Report

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

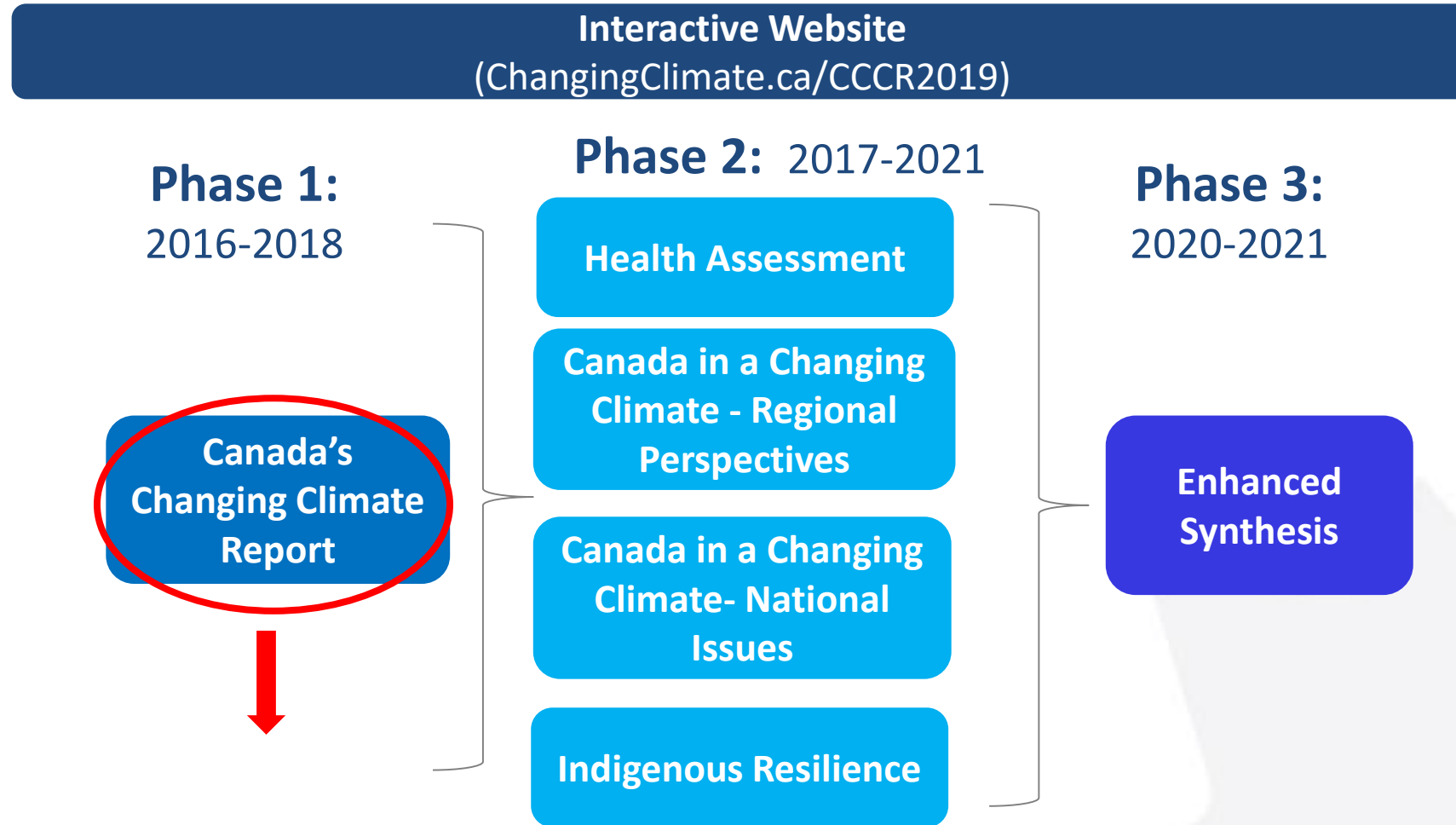
Chapter 7: Changes in Oceans Surrounding Canada

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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 – scope and structure

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

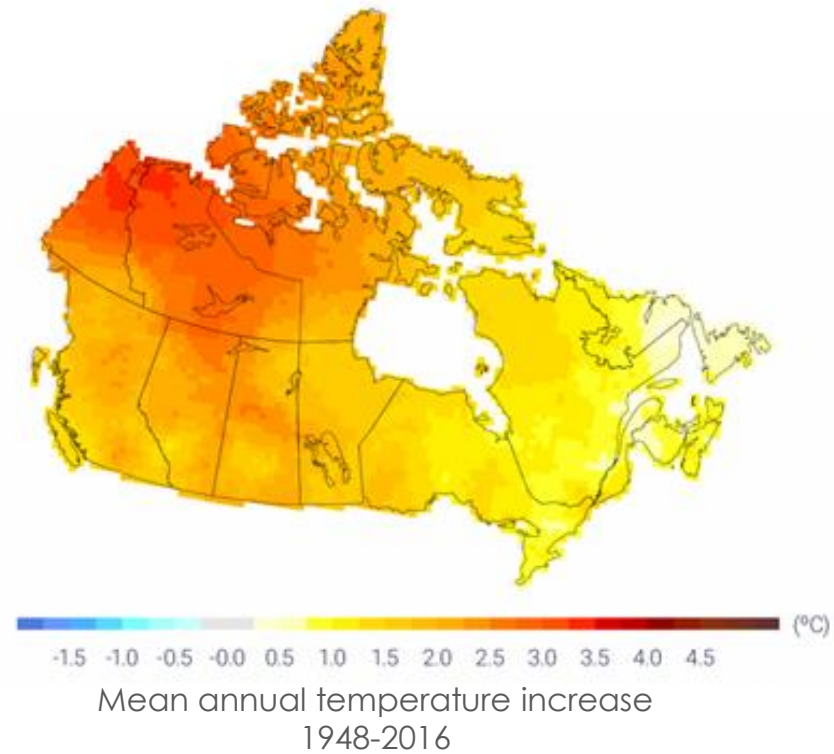


Both past and future warming in Canada is, on average, about double the magnitude of global warming.

– Canada's Changing Climate Report

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Canada



- 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.

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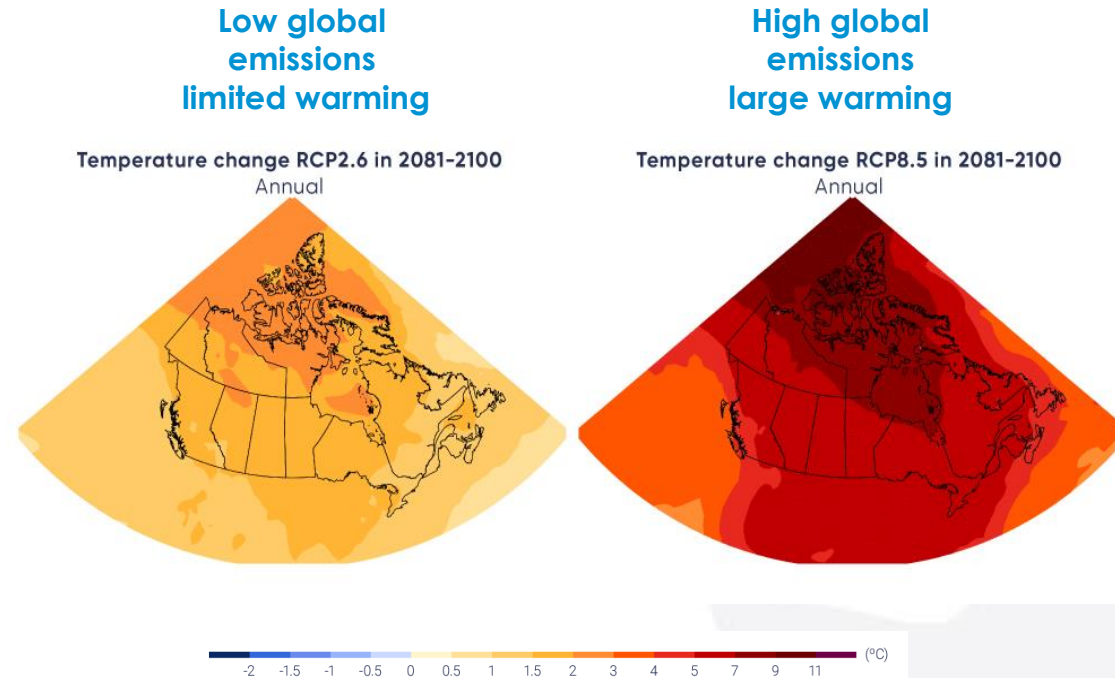
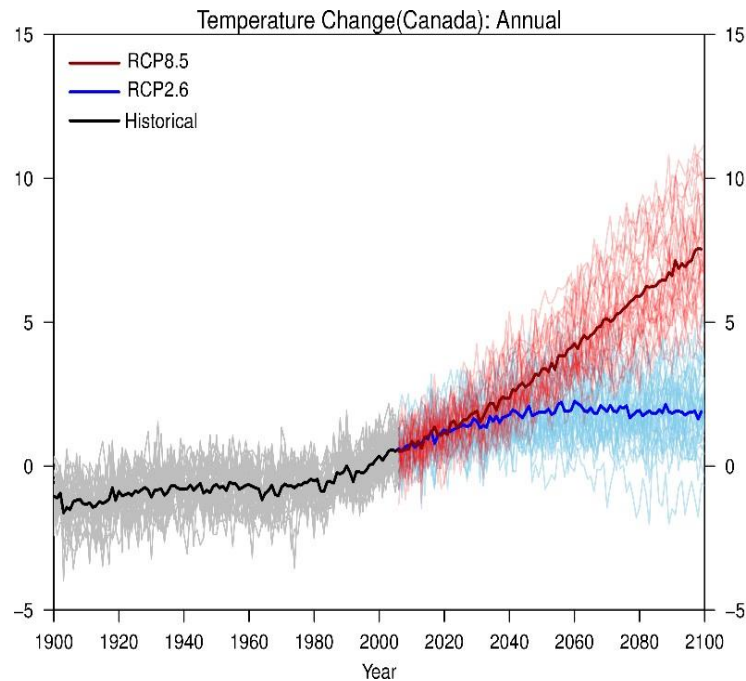
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Canada



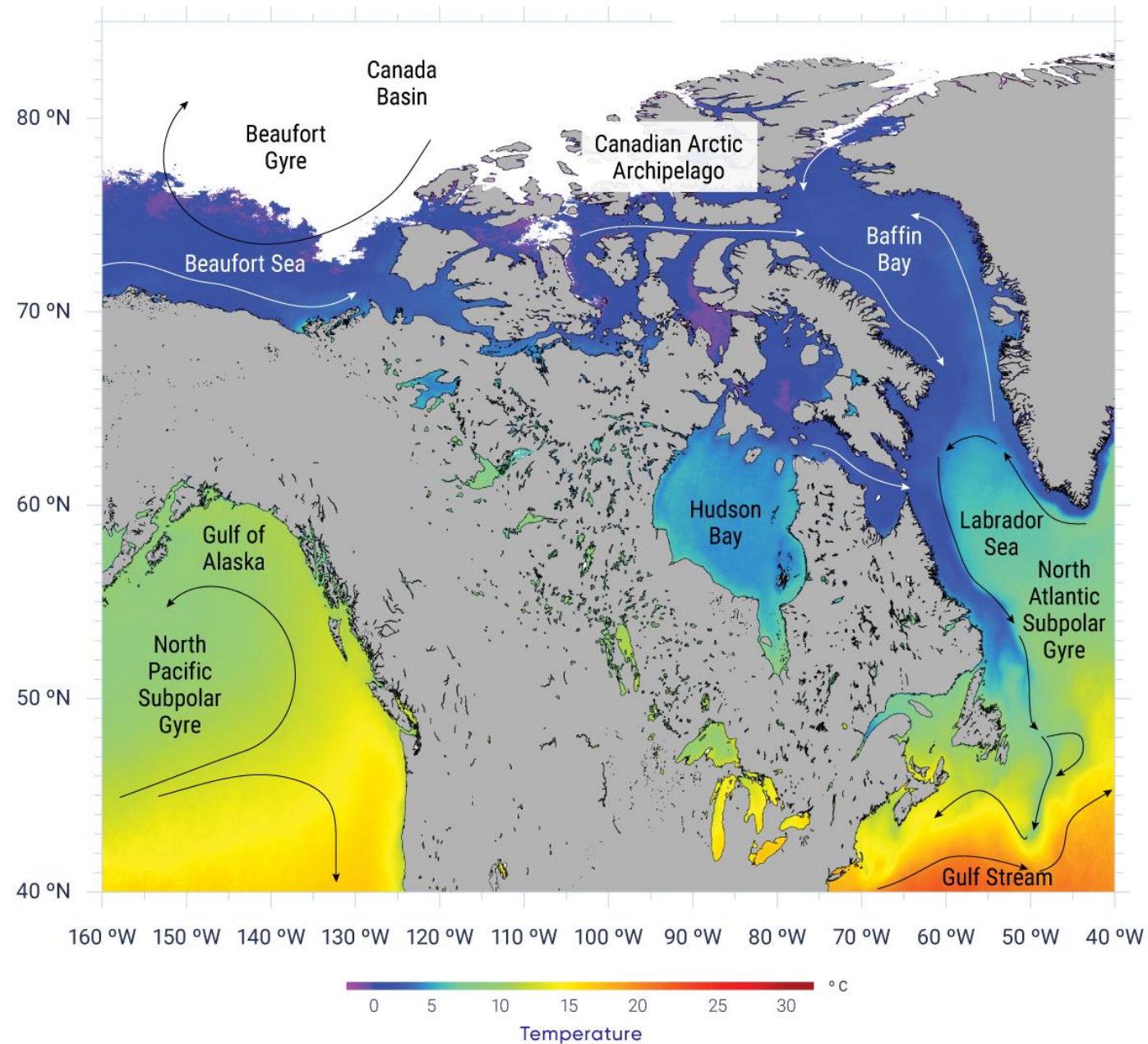
- Across Canada, we are experiencing:
 - more extreme heat/less extreme cold
 - less snow and ice cover
 - thinning glaciers
 - warmer and more acidic oceans
 - increased precipitation
 - earlier spring peak streamflow
 - thawing permafrost
 - rising sea level
- Because some further warming is unavoidable,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

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 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.

Oceans Surrounding Canada



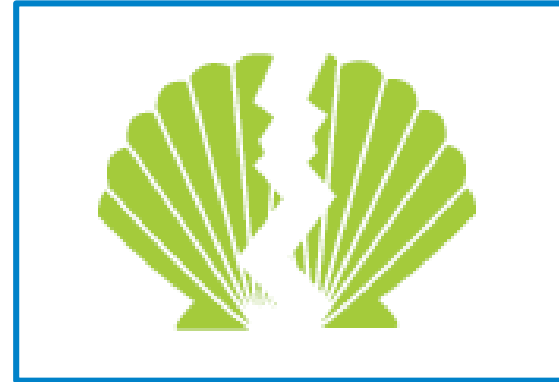
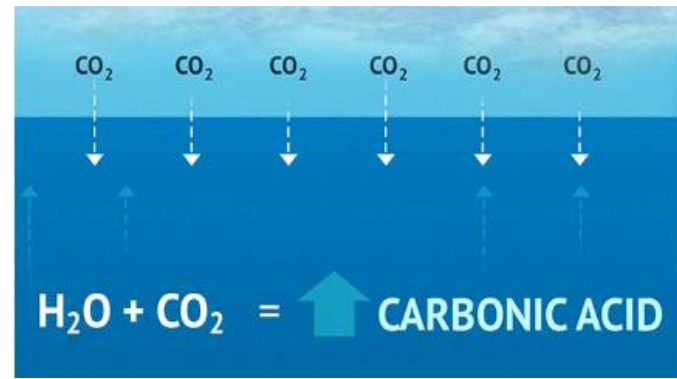


Oceans surrounding Canada have warmed, become more acidic, and less oxygenated, consistent with observed global ocean changes over the past century.

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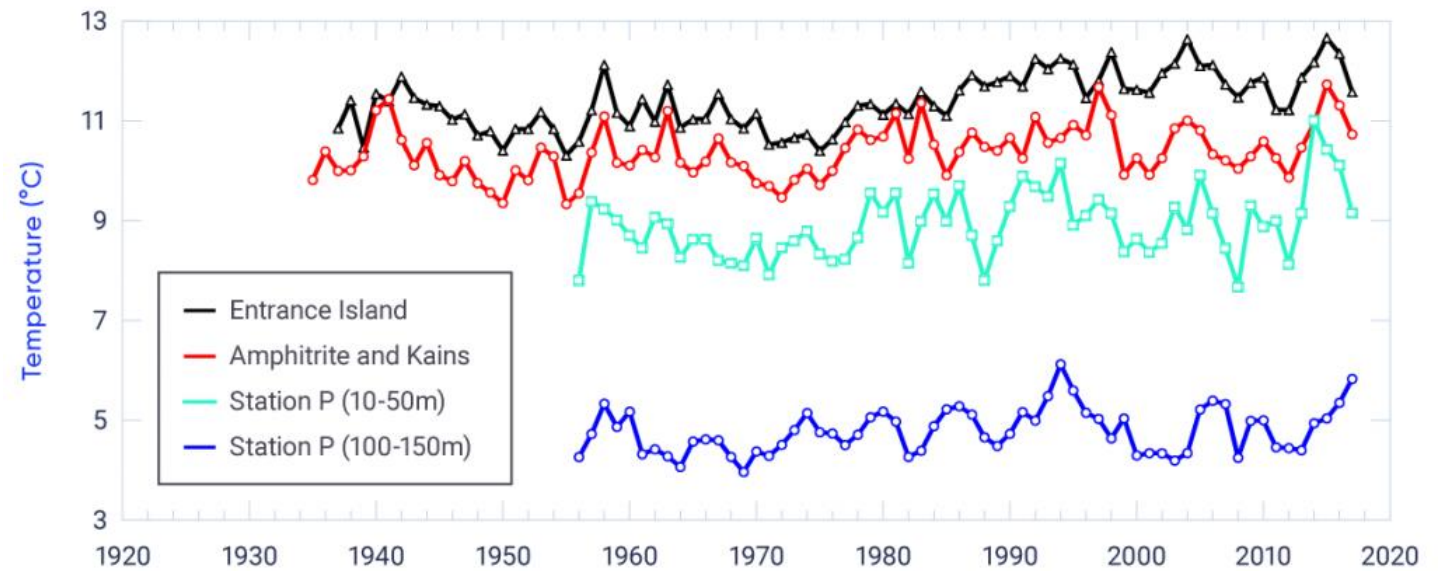
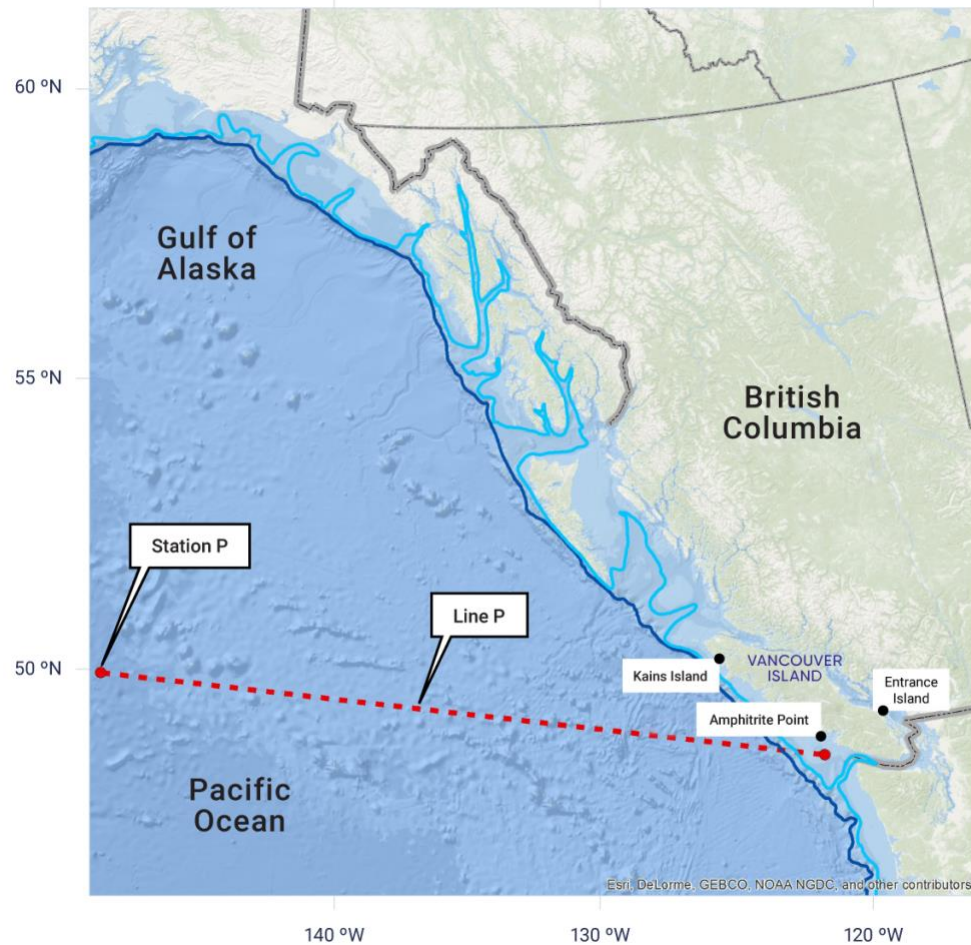
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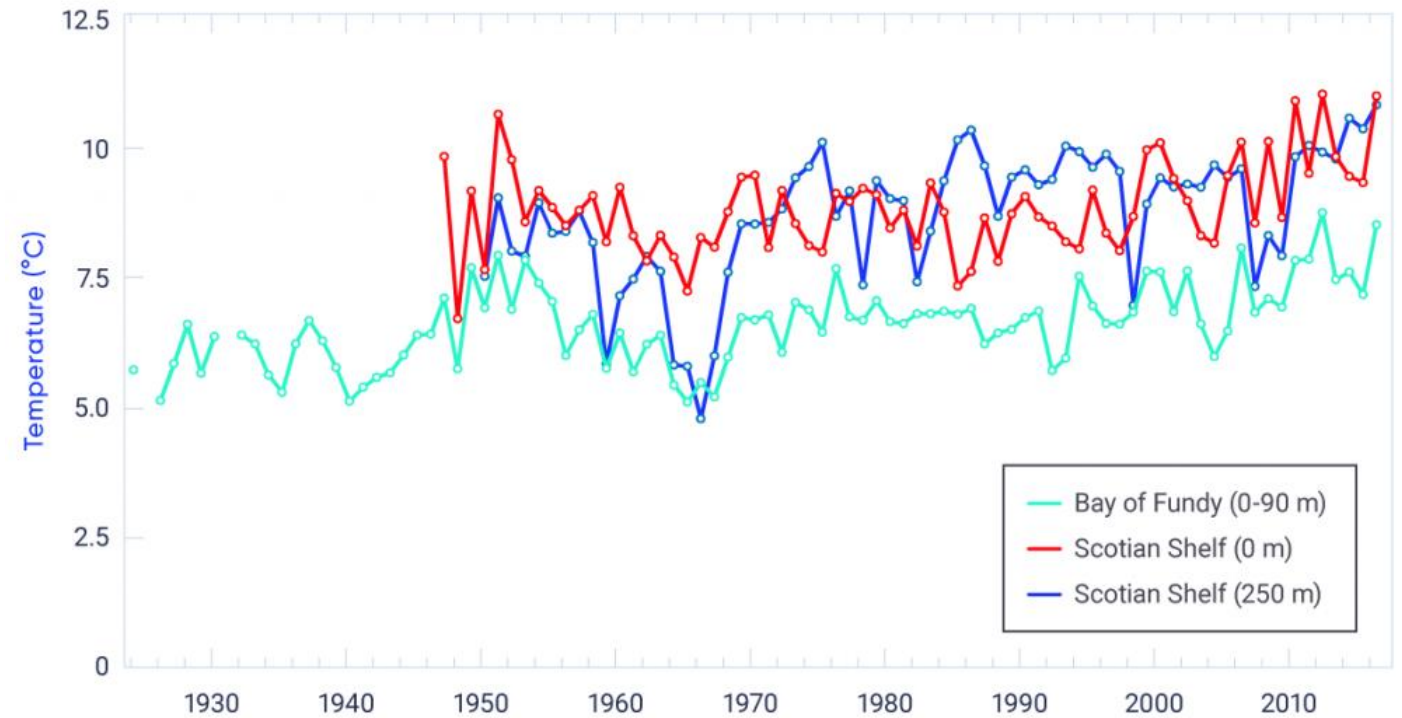
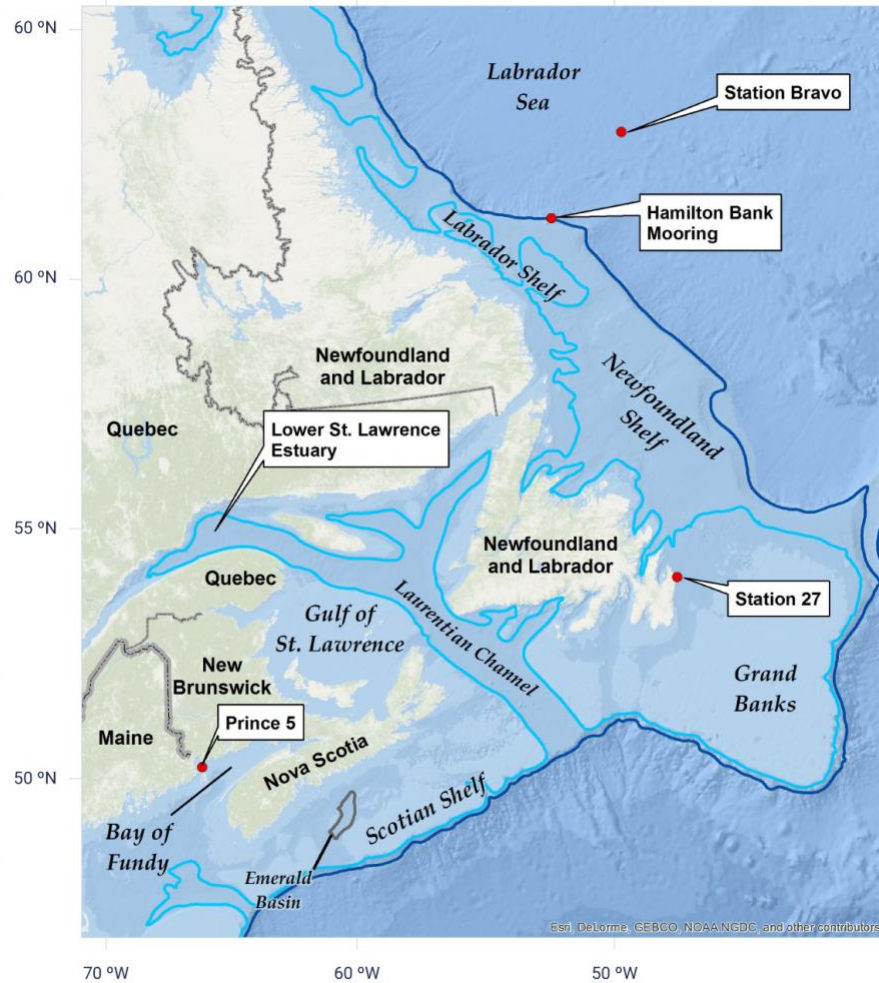


- Ocean warming and loss of oxygen will intensify with further emissions of all greenhouse gases.
- Ocean acidification will increase in response to additional carbon dioxide emissions.
- These changes threaten the health of marine ecosystems.

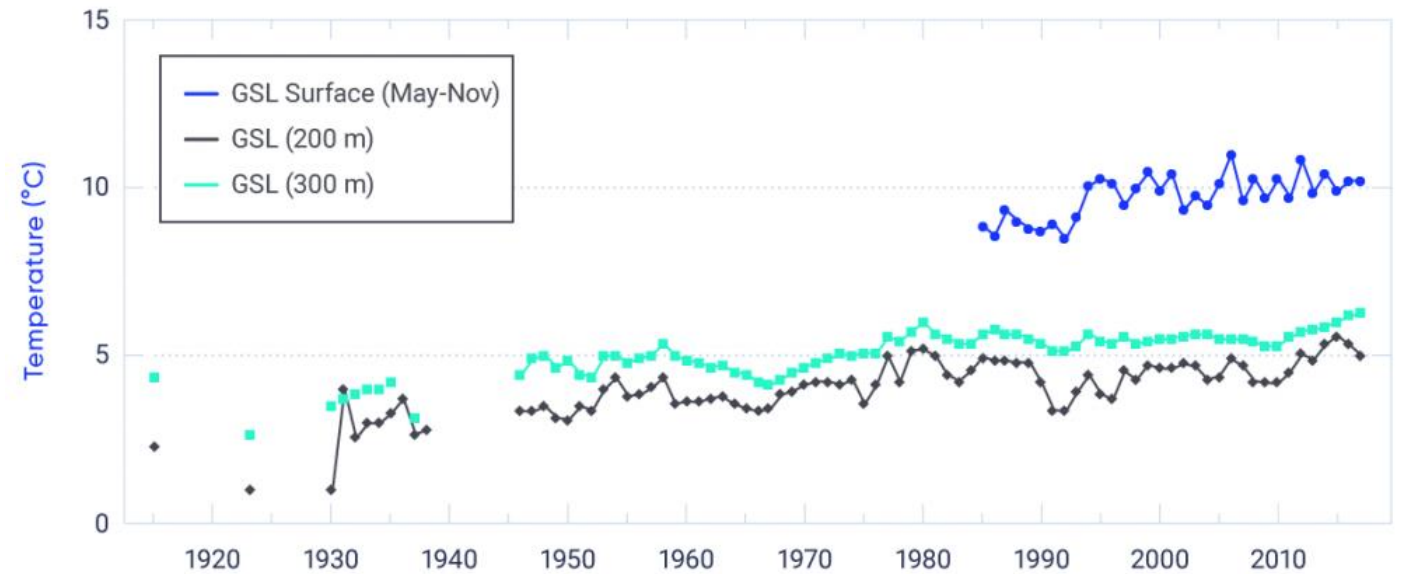
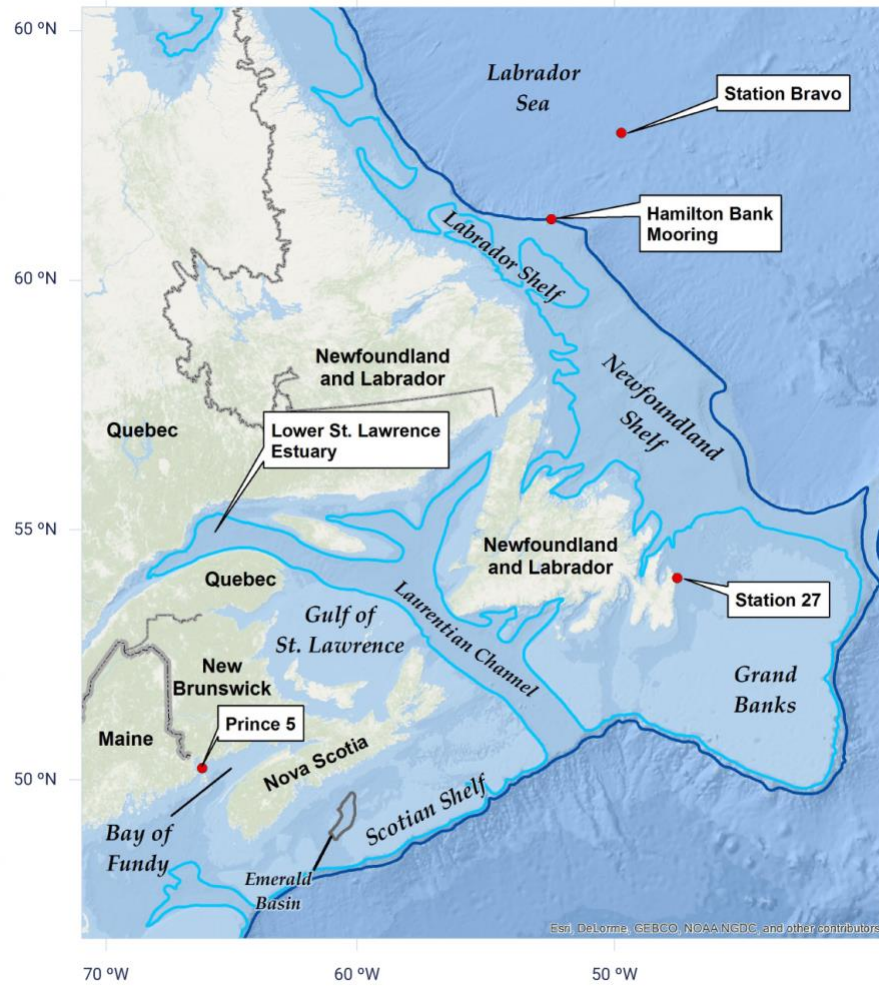
Ocean Temperature Trends



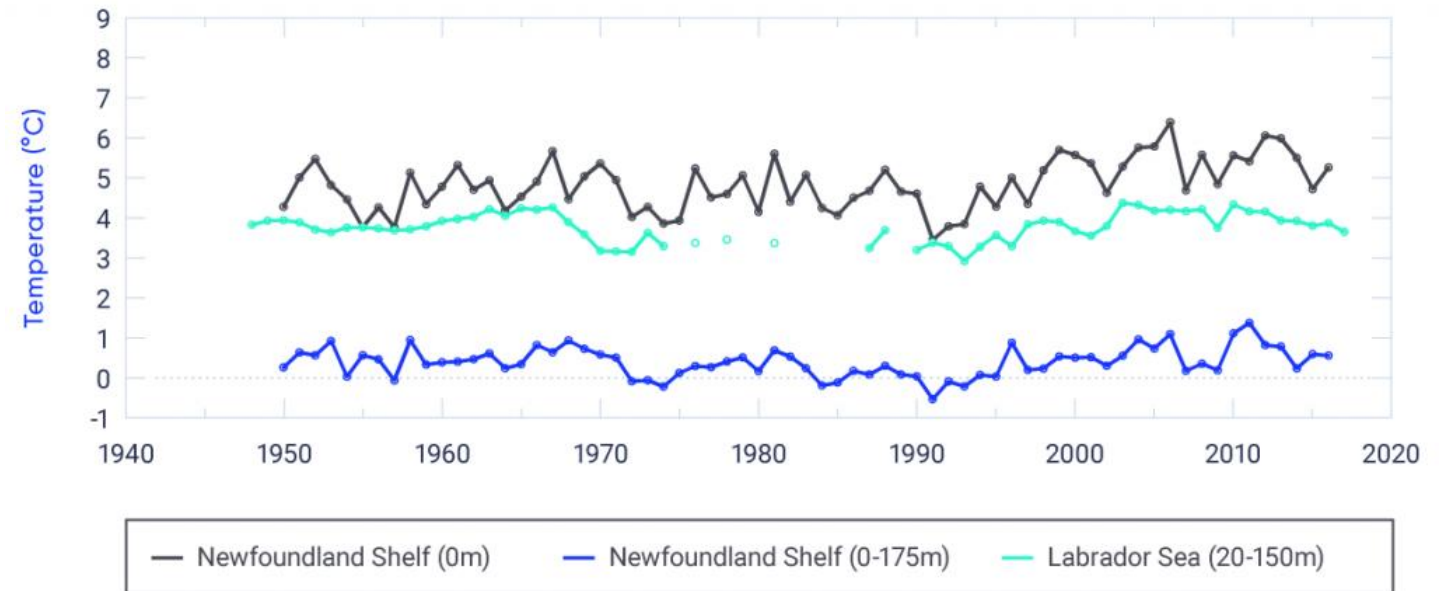
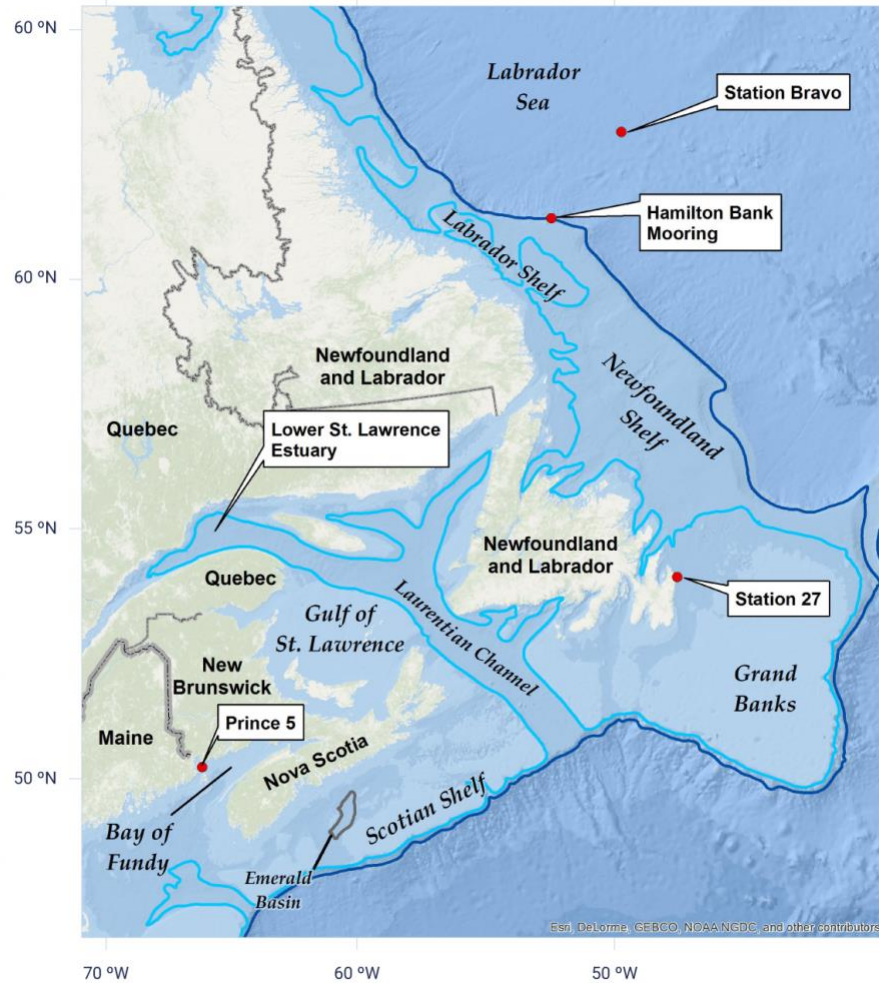
Ocean Temperature Trends



Ocean Temperature Trends



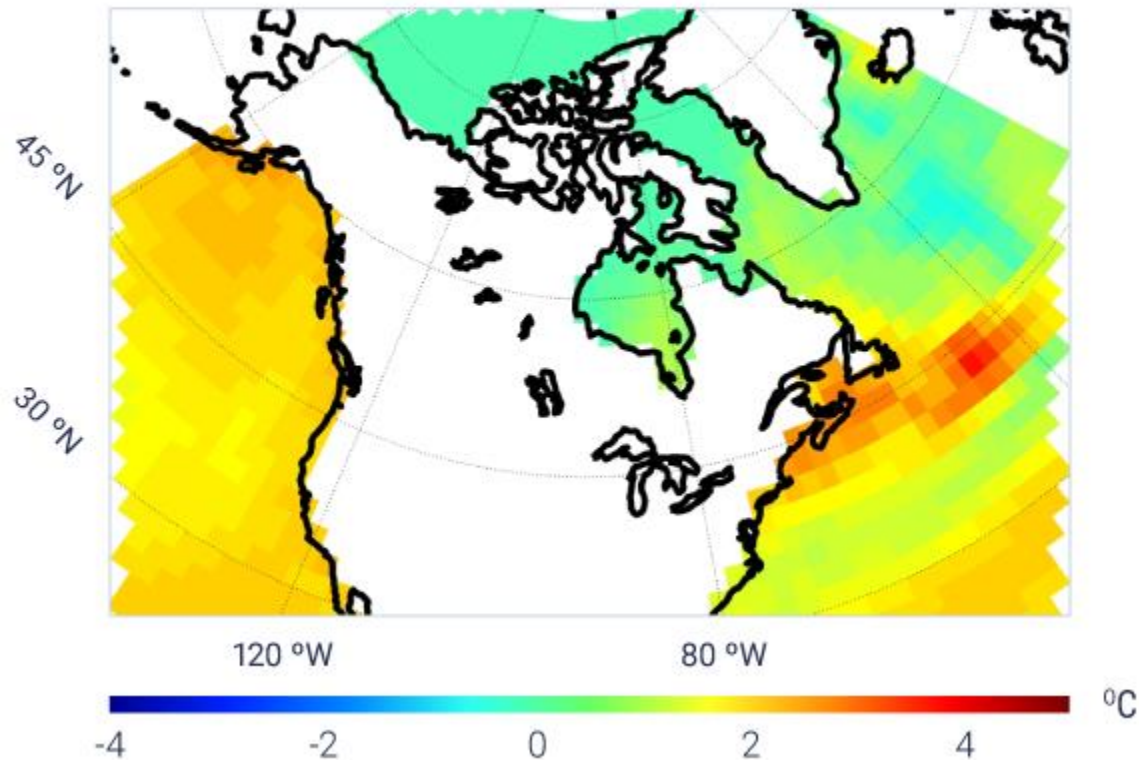
Ocean Temperature Trends



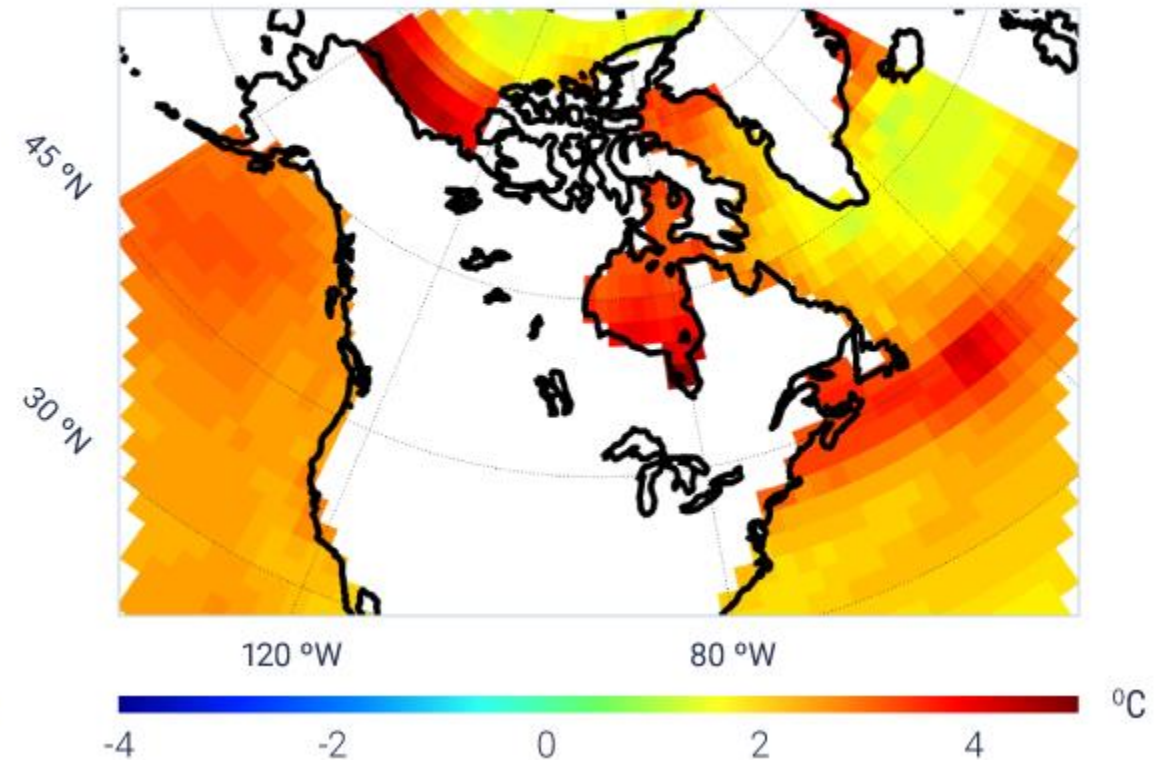
Ocean Temperature Projections

Mean SST Change: (2046-2065) - (1986-2005)

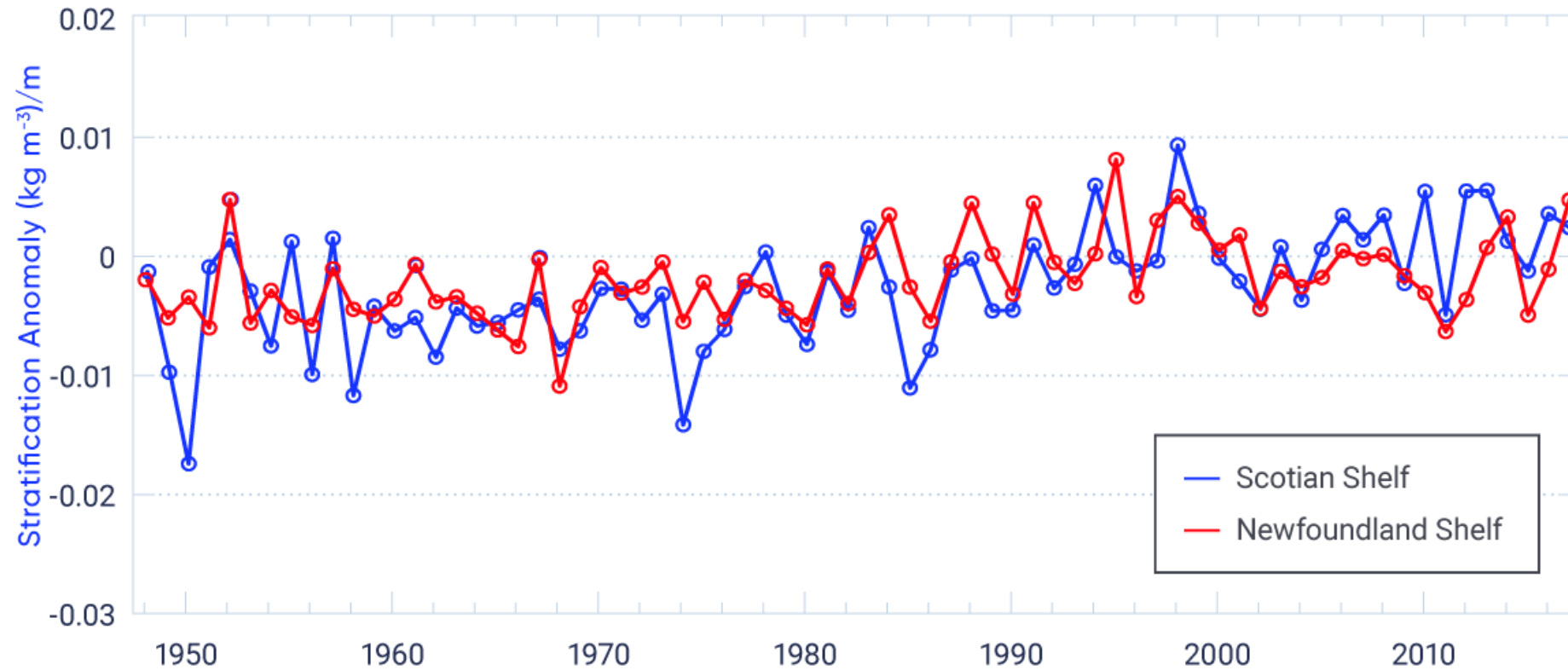
c) February



d) August



Ocean Salinity and Density Stratification

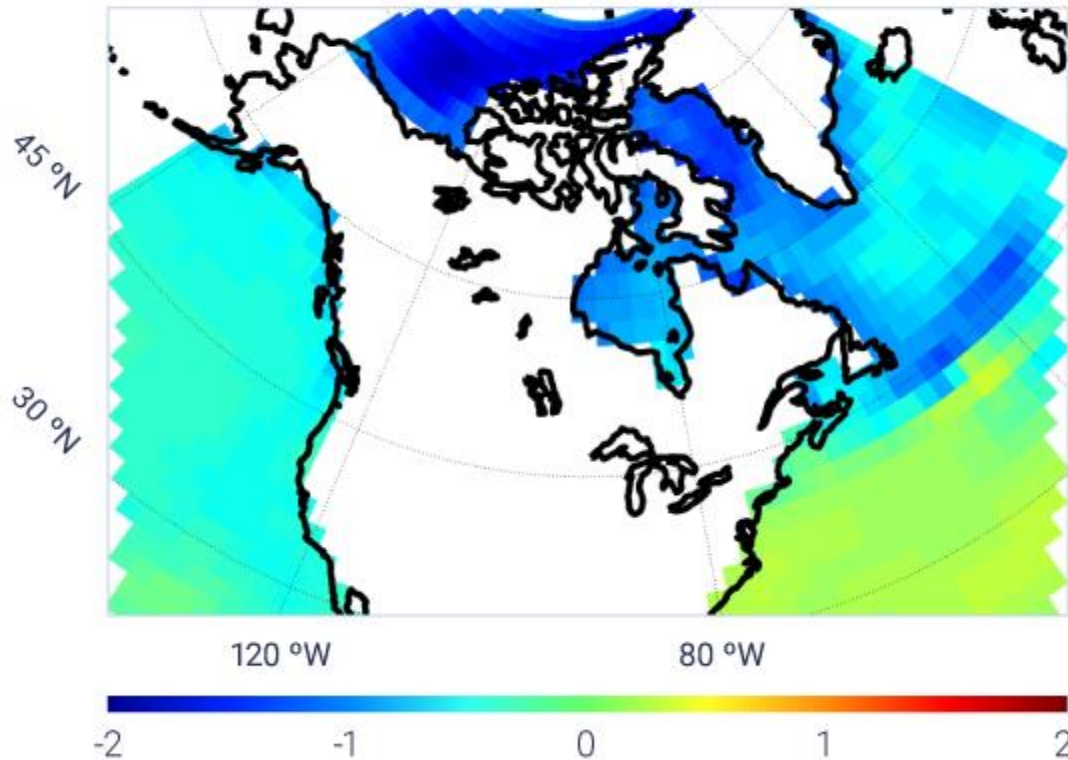


- Reference period for anomaly: 1981-2010

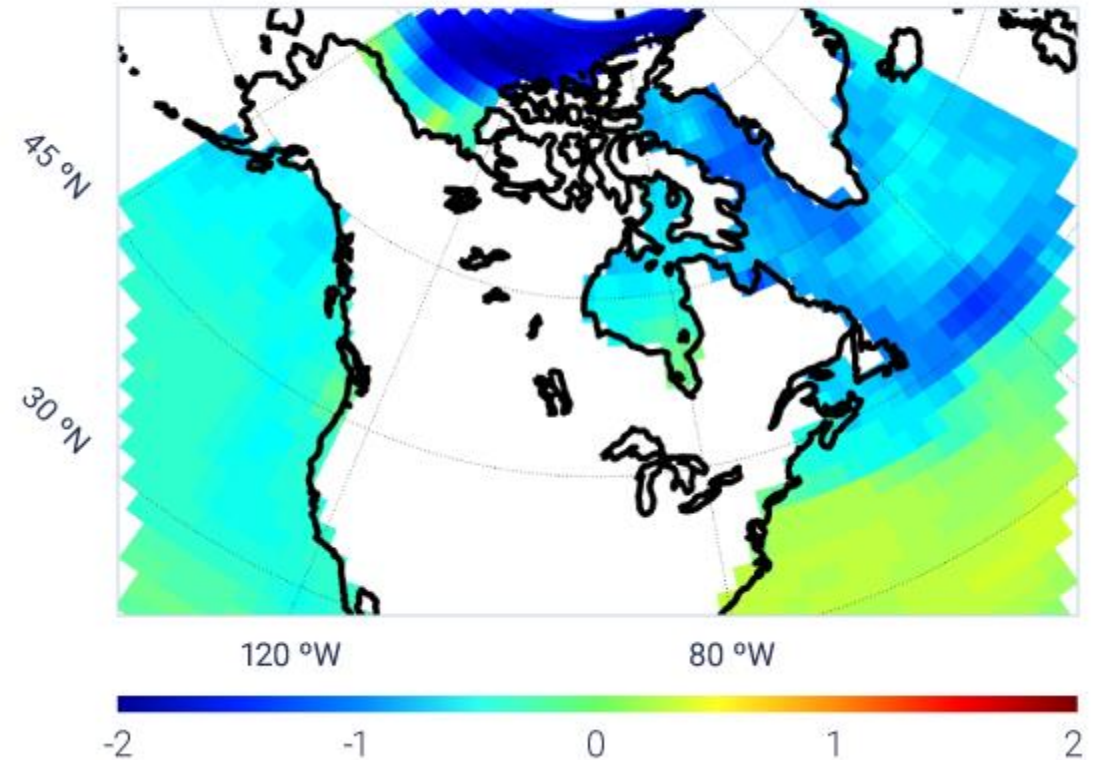
Ocean Salinity and Density Stratification

Mean SSS change: (2046–2065) – (1986–2005)

c) February



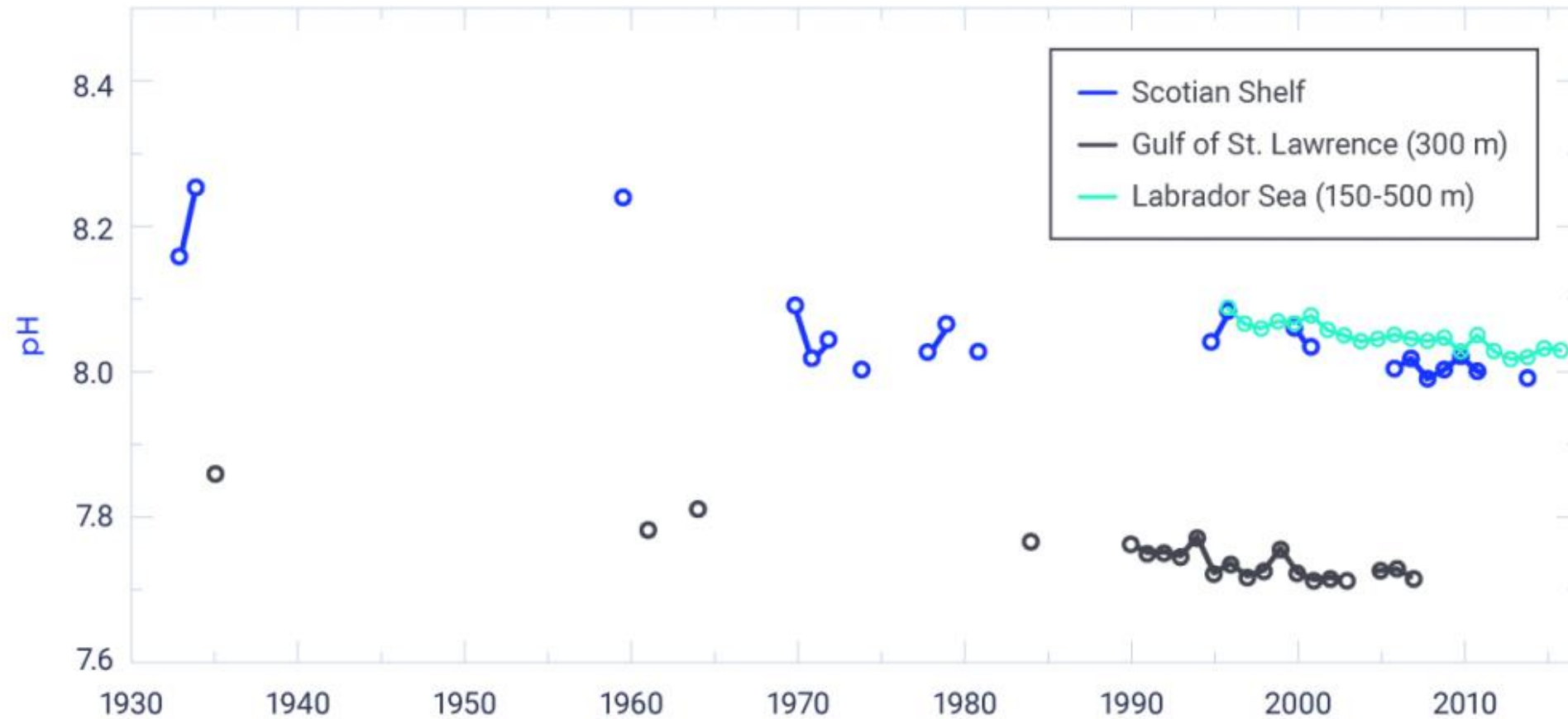
d) August



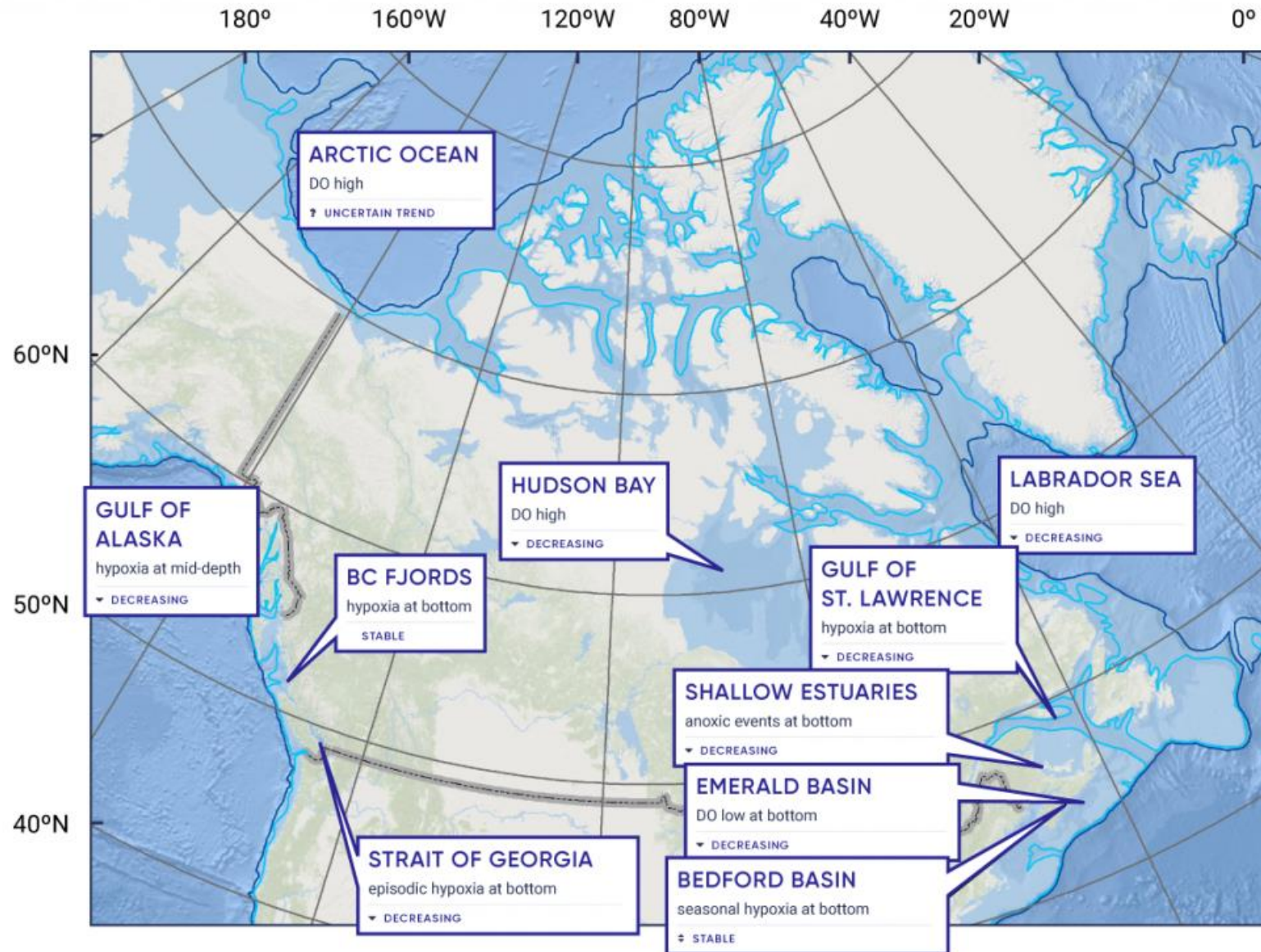
Marine Winds, Storms and Waves

- 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*).

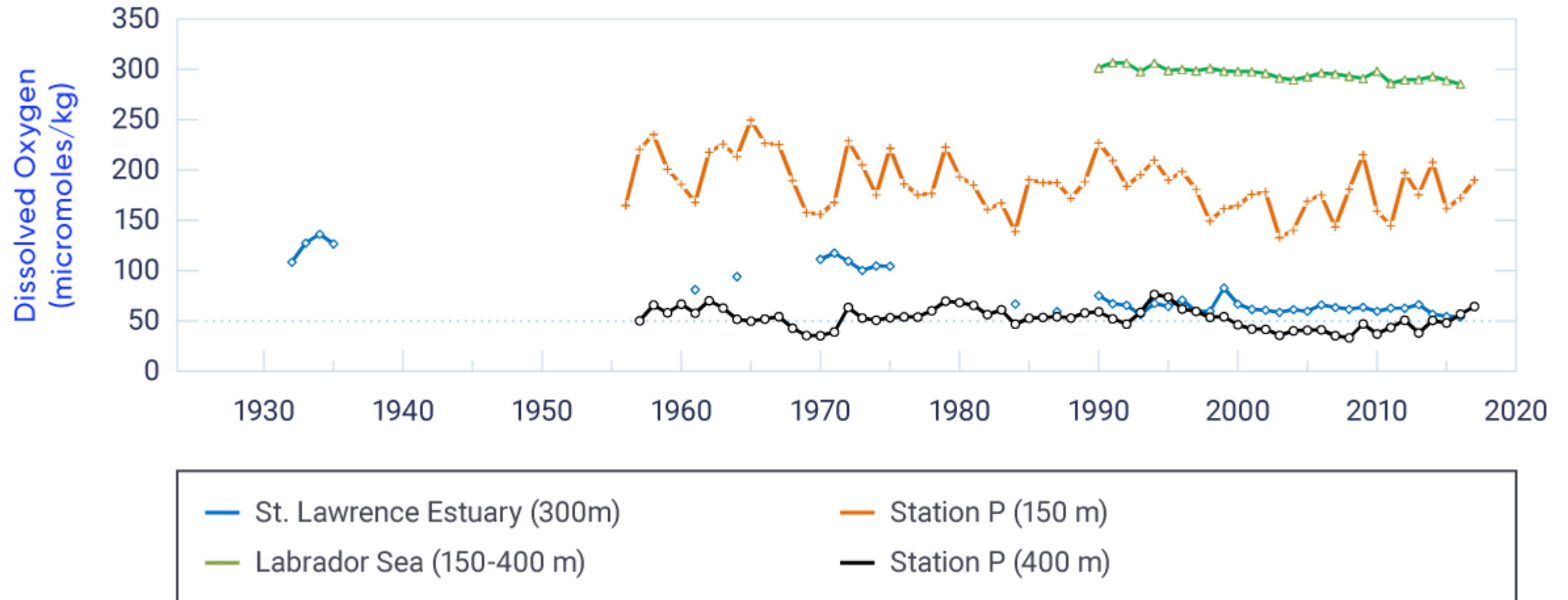
Ocean Acidification



Ocean Deoxygenation



Ocean Deoxygenation





Local sea level changes are from global sea level rise and land uplift and sinking. The vertical land motion is a response to the retreat of the last great ice sheet.



- Local sea level is projected to rise and increase flooding, along most of the Atlantic and Pacific coasts of Canada and the Beaufort coast in the Arctic.
- The loss of sea ice in Arctic and Atlantic Canada further increases the risk of damage to coastal infrastructure and ecosystem due to larger storm surges and waves.

Examples of Coastal Flooding and Damage

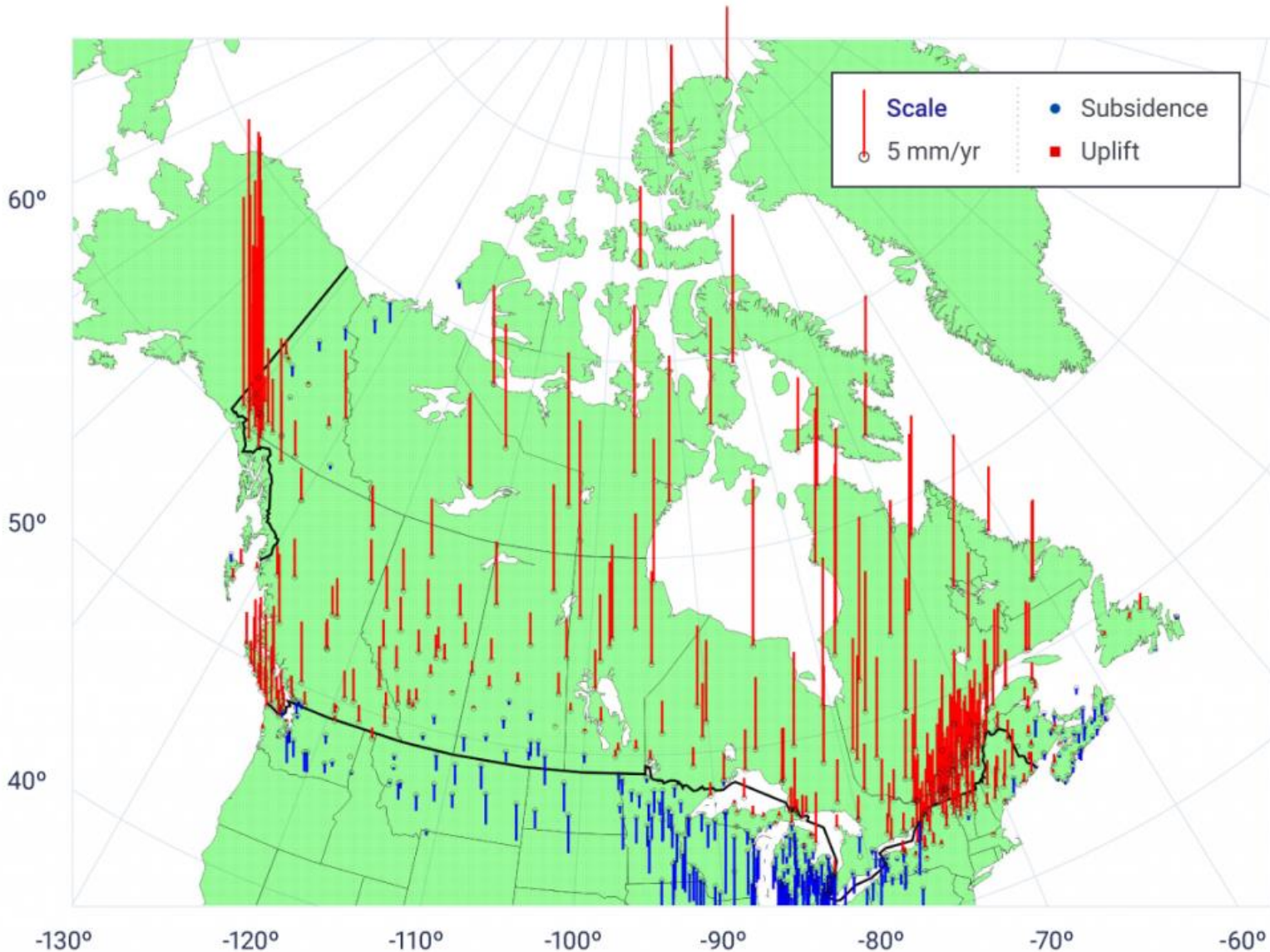


LEFT — Storm surge on the Sunshine Coast Highway (Highway 101) at Davis Bay, British Columbia, located on the mainland coast north of Vancouver, British Columbia, on February 6, 2006. Photo courtesy of B. Oakford.



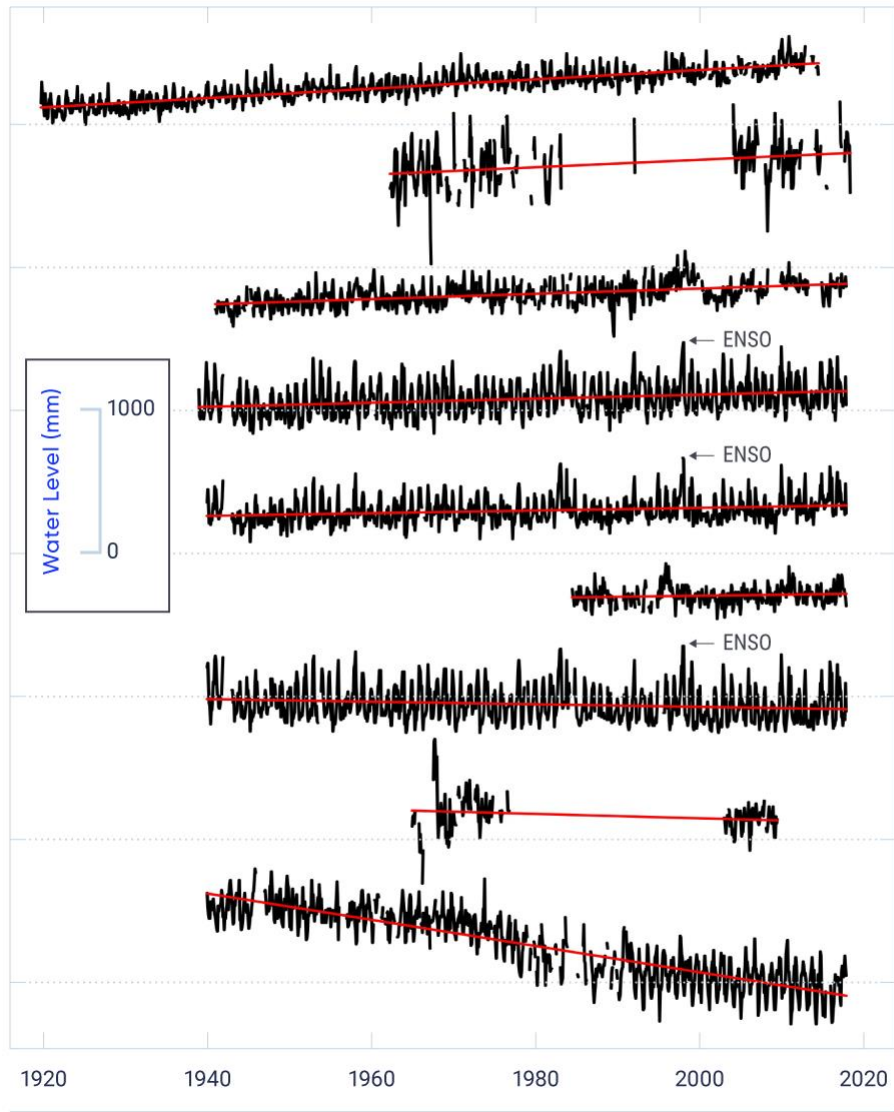
RIGHT — Example of coastal erosion and roadway damage at Conrads Road on Queensland Beach, Nova Scotia, following the January 4, 2018, blizzard. Photo credit: Colleen Jones, CBC, January 5, 2018.

Crustal Uplift and Subsidence



- A major determinant of sea-level change in Canada is vertical land motion.
- Oceanographic factors also affect the absolute elevation of the sea surface.
- Land subsidence (sinking) increases relative (local) sea-level, while land uplift does the opposite.
- Across much of Canada, land uplift or subsidence is mainly due to the delayed effects of the last continental glaciation (ice age), called glacial isostatic adjustment (GIA).

Long-Term Trends of Relative Sea-Level Change



Halifax
3.3 mm/yr

Tuktoyaktuk
2.5 mm/yr

St. John's
1.9 mm/yr

Prince Rupert
1.4 mm/yr

Vancouver
0.9 mm/yr

Rimouski
0.6 mm/yr

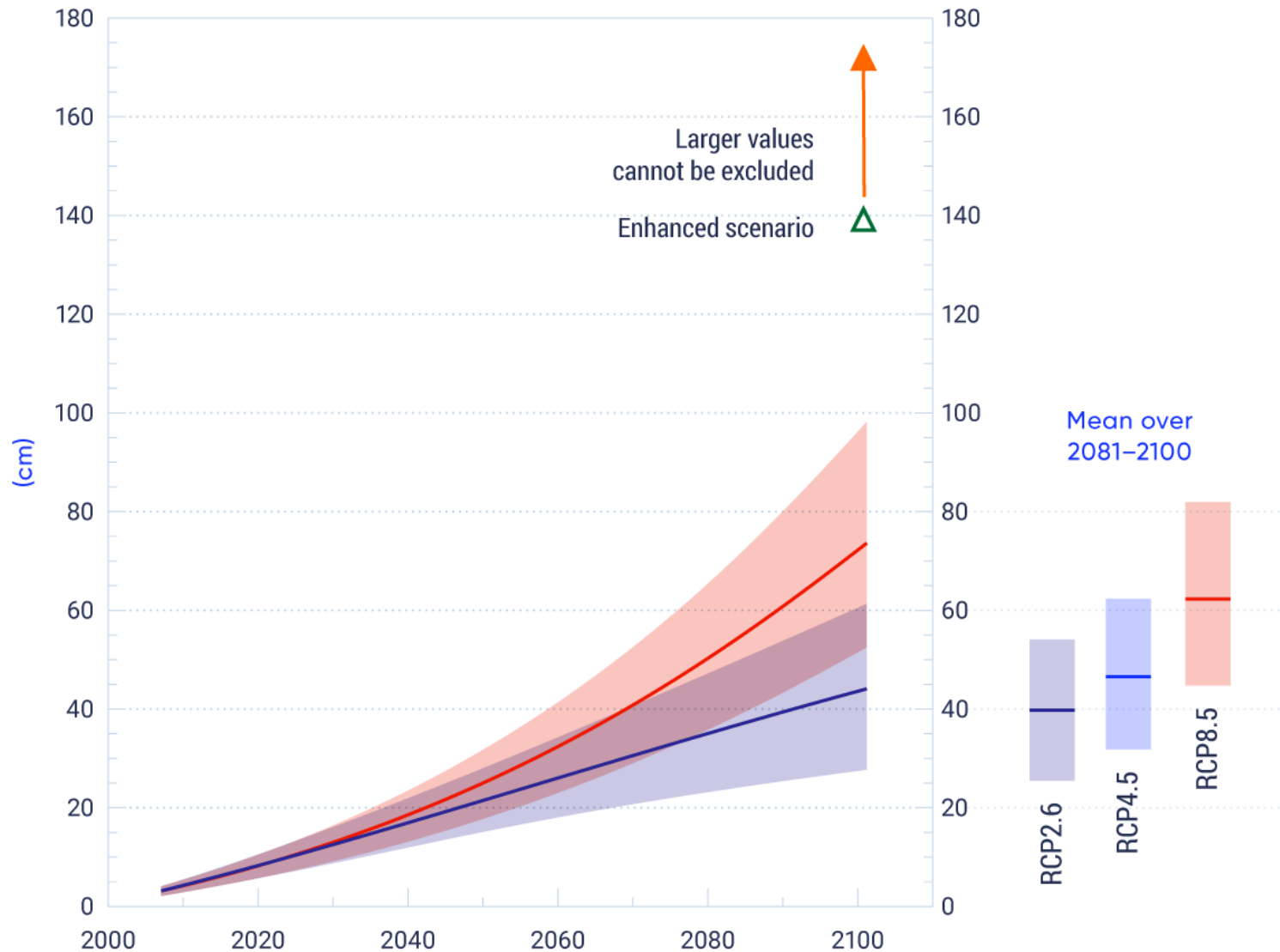
Tofino
-0.9 mm/yr

Alert
-1.5 mm/yr

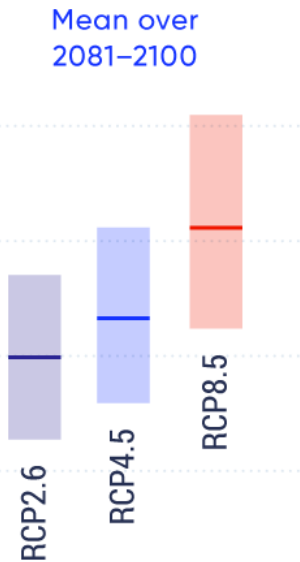
Churchill
-9.3 mm/yr



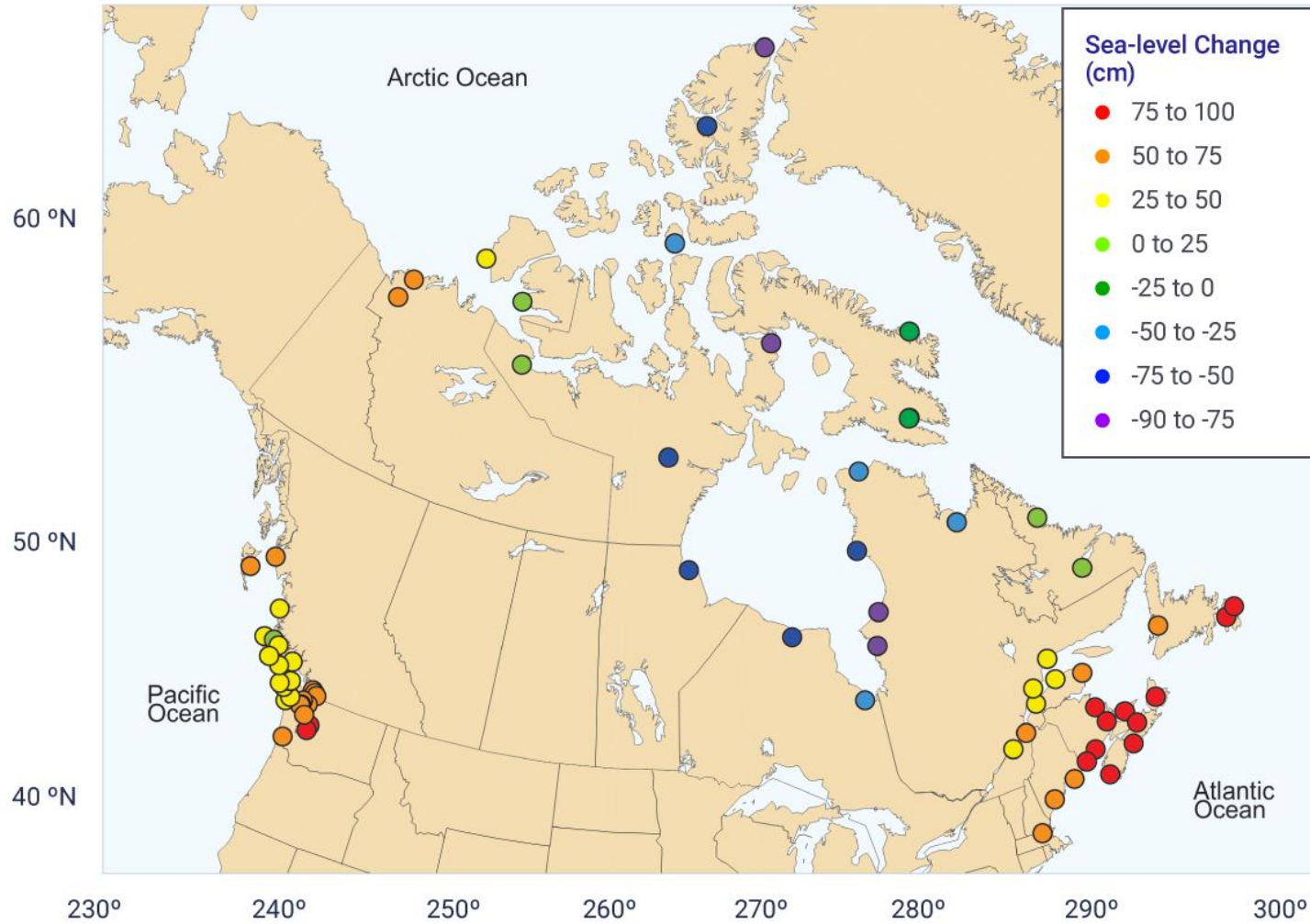
Projected Global Sea-Level Rise During the 21st Century



- Global (absolute) mean sea level is projected, in IPCC AR5, to rise by 28 to 98 cm by 2100, relative to 1986–2005
- But global mean sea-level rise could exceed 1 m by 2100 if additional contributions of water come from the marine-based sectors of the Antarctic Ice Sheet

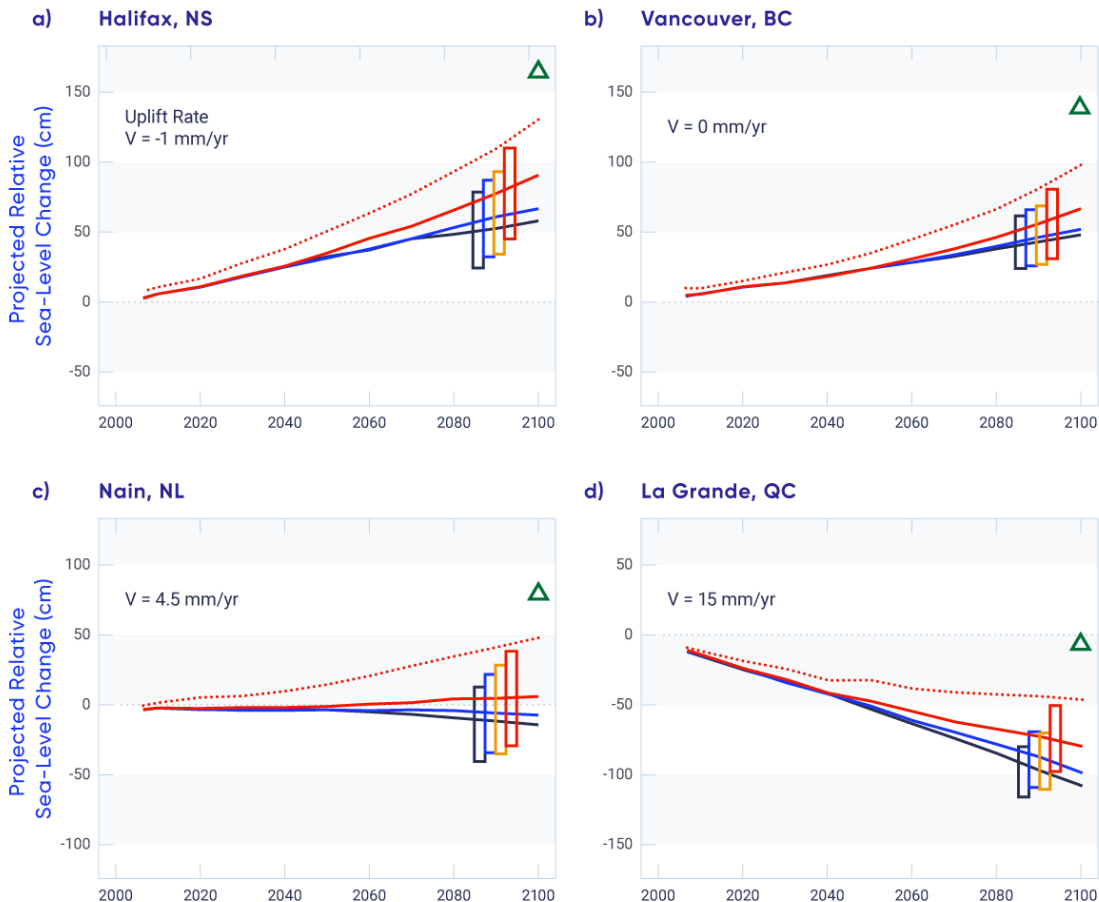


Relative Sea-Level Change in Canada

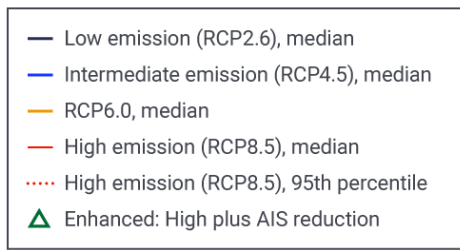


- End-of-century projected relative (local) sea-level change under a high emission scenario, relative to 1986-2005 reference period
- Global mean sea level is projected to rise, but along Canada's coastlines, sea level will rise in some places, fall elsewhere.
- Much of Hudson Bay and the Canadian Arctic Archipelago are projected to experience continuing sea-level fall, while the rest of Canada is projected to experience sea-level rise.

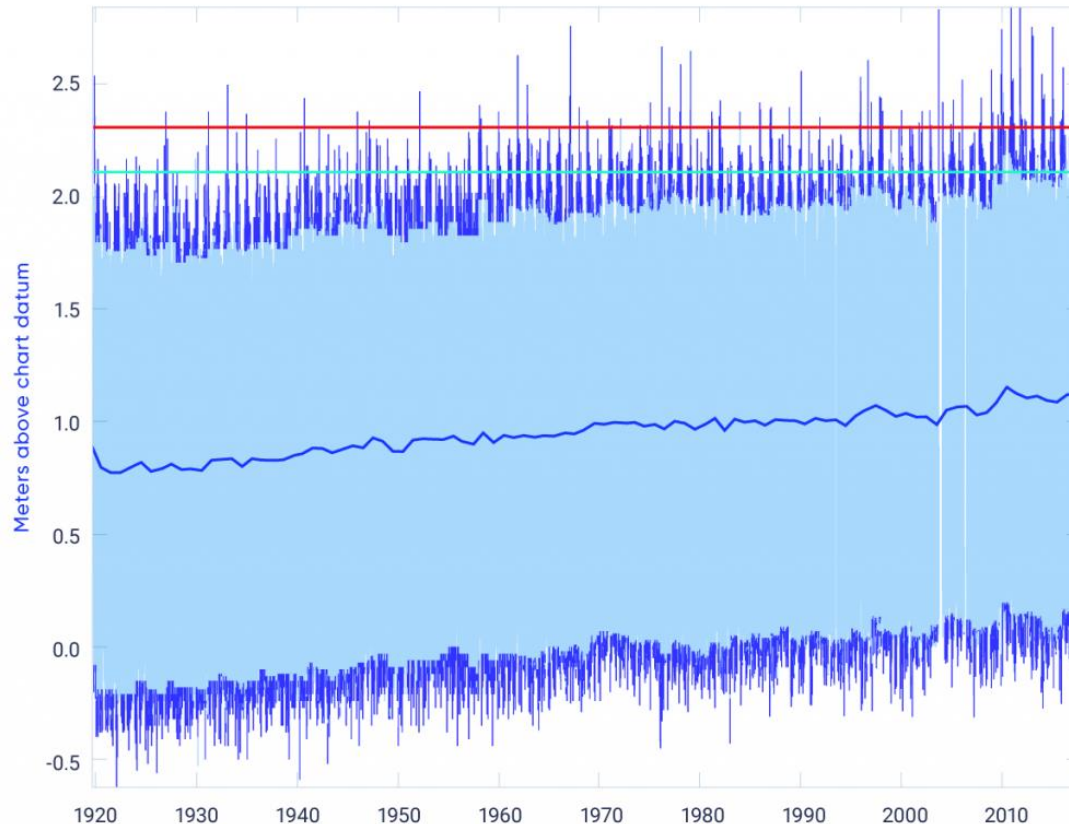
Relative Sea-Level Change in Canada



- Projected relative (local) sea-level change through the century, relative to 1986-2005 reference period, for four different locations with different amounts of vertical land motion.
- Relative sea level will rise in some places, fall elsewhere.
- Green triangle shows the projection for the enhanced scenario with additional sea-level rise from Antarctica
- Sea-level projections are similar through to about 2050 or 2060.



Extreme Water Levels



- Hourly water levels recorded at Halifax Harbour for 1920 to 2018, with 5% extremes shown in dark blue and the 90% mid-range in light blue.
- Mean sea level (thick blue line) exhibits short-term variability superposed on a long-term increase throughout the record duration.
- The table shows that the frequency of high-water level events has increased with the rise in sea level over the decades.

Decade	1920-1929	1930-1939	1940-1949	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2009	2010-2017	sum
Number of events (>2.3m)	1	3	4	5	10	15	11	12	24	46	131
Number of events (>2.2m)	3	8	16	15	32	33	31	31	46	76	291
Number of events (>2.1m)	14	16	32	39	64	72	73	70	86	130	596
Number of events (>2.0m)	39	44	78	80	121	126	134	149	154	186	1111

Summary

- There is strong evidence of human-induced changes during the past century in key ocean-climate properties — such as temperature, sea ice, sea level, acidity, and dissolved oxygen — off Canada.
- Warmer ocean temperature has contributed to declining sea ice and increasing sea level. However, there is an area south of Greenland where there has been little ocean warming, so regional trends do differ.
- In general, warming and freshening at the ocean surface is projected during this century, which will continue to increase stratification and reduced sea ice.
- Ocean acidification and decreasing subsurface oxygen levels will continue, with increasingly adverse implications for marine ecosystems.
- 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, leading to increased flooding.
- Declining sea-ice cover is projected to lead to increased wave action and larger storm surges, causing larger and more frequent extreme high water-level events along Canada's Arctic and Atlantic coasts.
- The impacts of climate change (warming waters, ocean acidification, sea-level rise) depend on the pathway of carbon emissions. Strong mitigation of carbon emissions will minimize future effects of climate change.

Thank you!

Questions?



<http://www.changingclimate.ca/CCCR2019>

<https://www.nrcan.gc.ca/environment/impacts-adaptation/21177>

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