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

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

- 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
Canada has warmed, faster than the global average

- 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.
The effects of widespread warming are evident across many indicators.

Changes in annual precipitation 1948-2012

- Annual precipitation has increased in many regions since 1948.
- Averaged over the country, normalized precipitation has increased by about 20% from 1948 to 2012.
- An increase in growing season length of about 15 days between 1948 and 2016 has been observed.

Length of growing season (days)
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
A warmer world - declines in snow, ice and permafrost

- Over the past three decades, the proportion of Canadian land and marine areas covered by snow and ice have decreased, permafrost temperatures have risen, and Arctic and alpine glaciers have thinned at rates unprecedented for several millennia.
Canadian areas of the Arctic and Atlantic Oceans will experience longer and more widespread sea ice-free conditions.

- Canadian Arctic marine areas are projected to have extensive ice-free periods during summer by mid-century.
- The last area with summer sea ice is projected to be within and north of the Canadian Arctic Archipelago.
- This area will be an important refuge for ice-dependent species and an ongoing source of potentially hazardous ice which will drift into Canadian waters.
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 streamflows.

• Smaller snowpacks and loss of glacier ice this century will combine to produce lower summer streamflows.

• Warmer summers will increase evaporation of surface water and contribute to reduced summer water availability in the future despite more precipitation in some places.
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. In some areas, reduced summer flows have been observed.

- Seasonal changes projected to continue, with shifts from more snowmelt-dominated regimes toward rainfall-dominated regimes.
Most of the observed temperature increase can be attributed to human influence

• Anthropogenic (human) activities explain most of the historical warming trend in annual average temperature, as well as for the hottest and coldest temperatures of the year

• Natural external factors (solar and volcanic activity) play a very minor role
Anthropogenic climate change has increased the likelihood of some types of extreme events.

- Canada is already seeing the impacts of human-caused climate change in extreme events
- The 2013 Alberta floods: increased likelihood of extreme rainfall
- The 2016 Alberta wildfire: increased likelihood of extreme wildfire risk and length of the fire season

Schematic illustration of event attribution
Future warming in Canada depends directly on global emissions

- Low emission scenario: an additional annual warming of about $2\degree$C is projected by mid-century, with temperatures steady after that.
- High emission scenario: temperature increases will continue, reaching more than $6\degree$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.
Regional climate changes, such as for Canada, are closely related to change in the global mean.

- Canada is projected to warm at twice the global rate, regardless of the emissions scenario
- Many impacts-relevant metrics, such as growing season length, scale with temperature
Annual and winter precipitation is projected to increase everywhere in Canada over the 21st century, with larger changes under a high emission scenario.

Larger percent changes are projected for northern Canada.

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.
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.

- 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.
More intense rainfalls will increase urban flood risks

- Projected increases in extreme precipitation are expected to increase the potential for future urban flooding.

- Projected higher temperatures will result in a shift toward earlier floods associated with spring snowmelt, ice jams, and rain-on-snow events.

- 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.
Future increases in the frequency and intensity of extreme temperature and precipitation 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)
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 coast in the Arctic where the land is subsiding or slowly uplifting.
- 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.
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.
Take home messages on extremes…..

• The magnitude of future warming will be determined by the extent of future GHG (principally, CO₂) emissions or mitigation

• Across Canada, we have already observed increases in the hottest temperatures and larger increases in the coldest temperatures.

• Substantial future changes are projected in temperature extremes. There will be more hot and fewer cold temperature extremes.

• Warmer temperatures are accompanied by an increase in atmospheric moisture, which increases extreme precipitation.

• Although we cannot focus on individual locations, we can use robust large-scale projections and theoretical understanding to understand future changes in locally-relevant climate extremes.