Institute for Catastrophic Loss Reduction
Building resilient communities

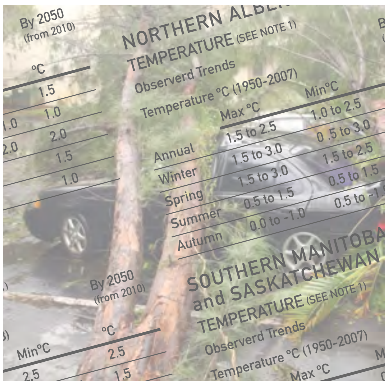
Institut de Prévention des Sinistres Catastrophiques
Construction de resilient communities

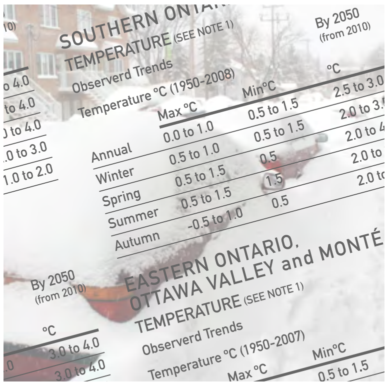
Climate change information for adaptation

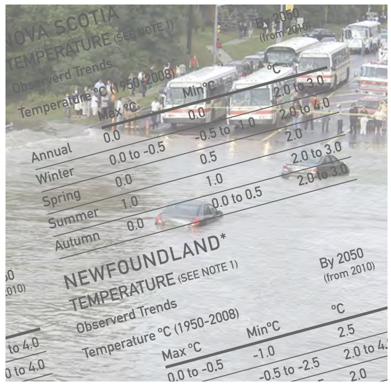
Climate trends and projected values for Canada from 2010 to 2050

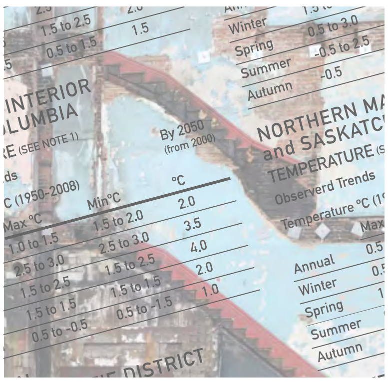
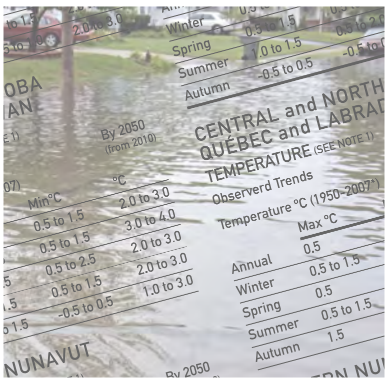
By James P. Bruce

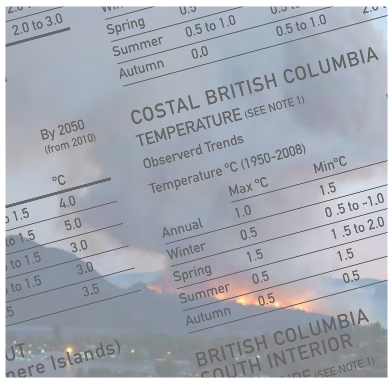
March 1, 2011

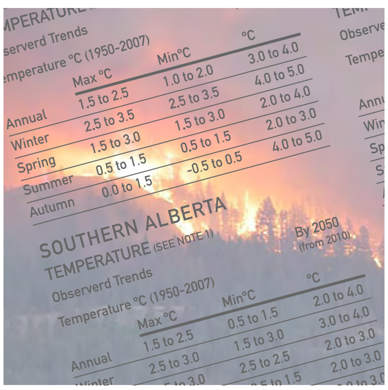


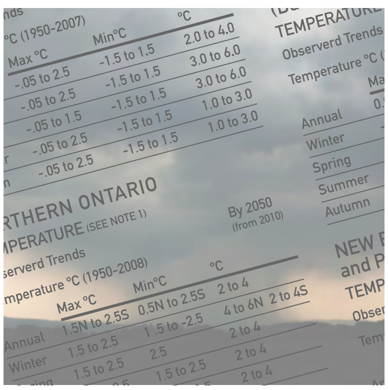
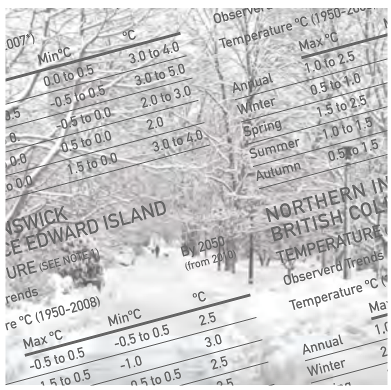








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**climatic, not political, regions*

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CLIMATE CHANGE INFORMATION FOR ADAPTATION
for the
INSTITUTE FOR CATASTROPHIC LOSS REDUCTION

J. P. Bruce 18 Feb. 2011*

I INTRODUCTION

Many people postpone action to adapt their businesses and management activities to the changing climate because of uncertainties about future climatic conditions. It is true that the range of projected futures becomes rather large by the end of the century. This is due to uncertainties about future greenhouse gas emissions and the differences in results from various global climate models.

However, for many purposes, planning horizons are less than a century and modelled results are not very divergent out to 2050. In addition, anthropogenic factors, i.e. greenhouse gas increases, have been overwhelmingly dominant in driving changes in global and large scale regional, climate since about 1970. They will continue to dominate in the coming 4 decades. Thus, trends that have been measured and observed in climate-related factors over the past 4 decades are likely to continue or possibly intensify somewhat in the next 40 years. When extension of such trends is similar to projections to 2050 by climate models, event greater confidence can be placed in the estimates of future climate. An example of comparison between extrapolated temperatures in the Athabasca River basin and projections with three Atmosphere Ocean Global Climate Models with the A_2 (high) emission scenario, is shown in Fig. 1. (next page)

The highest emission scenario is the closest to observed trends. Recent information on GHG concentrations, emissions and impacts lead to the view that climate change is advancing more rapidly than estimated earlier. Global atmospheric CO_2 concentration increases averaged 1.6 ppm/year from 1970 to 2007, but 1.9 ppm/year from 2000 to 2007 (Levinson, 2008). From 1990 to 2000, the atmosphere's CO_2 increased at a rate of 3.1 gigatonnes carbon per year but from 2000 to 2008 the rate was 4.1gt C/year (IGBP, 2009).

At the same time the International Energy Agency in late 2007 reported that global energy use and greenhouse gas emissions have been rising very rapidly. It projects a 55% increase in world energy needs between 2005 and 2030 and a 57% increase in greenhouse gas emissions. This could be tempered by aggressive global efforts to reduce emissions, not evident to date. Of course, the recent economic downturn had a short term effect on this rate of change. It is estimated that in 2009 a reduction of about 1% in global emissions occurred, but 2010 emissions are again on a path to record highs.

*Note; This is a revised and up-dated version of the draft dated 18 March 2010 by Bruce and Egener.

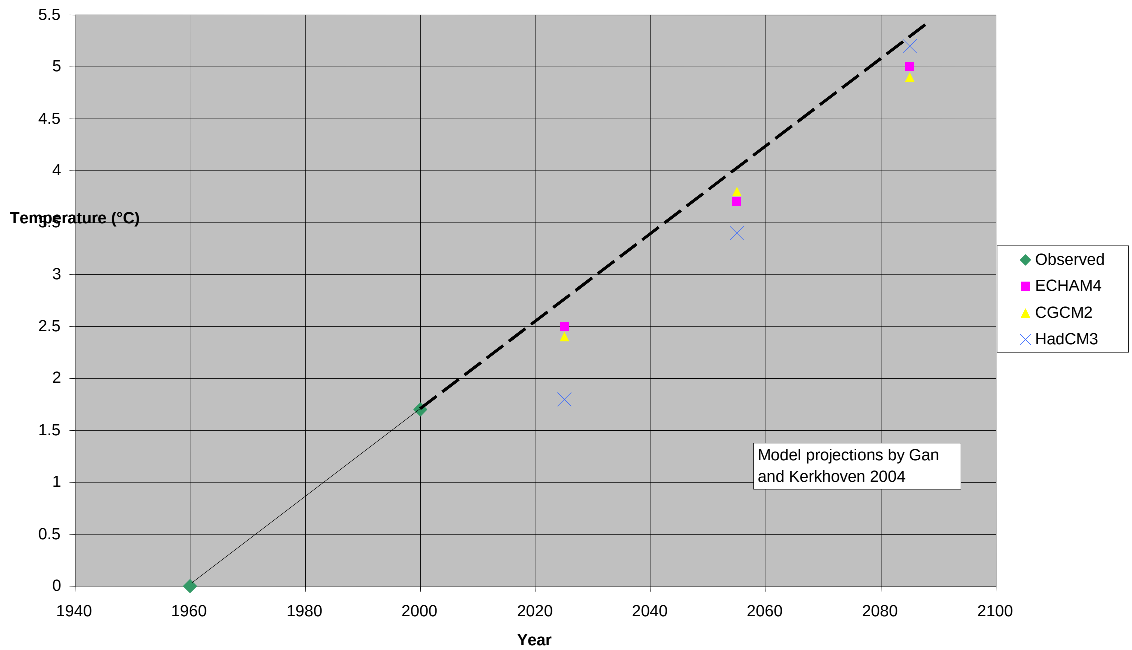
A 57% increase to 2030 is a more rapid increase than the greatest increase in SRES emission scenarios of IPCC, which have been used in previous climate projections. The evidence in the climate system of the acceleration of greenhouse gas emissions and concentrations can be seen in several manifestations. The decline in ice cover in the Arctic has been more rapid than in any of the IPCC scenario modeled results. Ice melt in Greenland, and effects in Antarctica have recently exceeded the rates of change projected by IPCC.

The extrapolation of observed trends is most useful for temperature and factors closely related to it. For precipitation, influencing factors, such as changes in ice cover of lakes and oceans, need to be taken into account in extending trends. This has been done somewhat subjectively in the tables which follow.

This approach to the changing climate has been used successfully with a number of Canadian communities in diverse regions of the country. This report summarizes for 18 regions, the observed climate trends to date and some climate related factors. Projections are then given to 2050 of these key climate and climate-related factors. These related factors emphasize events or trends which result in hardship or damages or benefits, and are often felt most strongly in communities. An emphasis has been placed on extreme events when data and projections were available, since they often cause the largest damages and human disruptions. Where very limited Canadian data are available, trends in adjacent U.S.A., where much more such data have been available and analyzed, are cited.

It is hoped that this fairly straight forward presentation of information will assist in demystifying climate change to permit initiation of pro-active adaptation measures.

Figure 1
Temperature Trends and Projections
Athabasca River Basin



II REPORT FORMAT

In each subsequent section for 17 regions of Canada the following format has been followed to the extent practical with available information and publications.

Region	Observed Trends	Projections to 2050
e.g. Coastal British Columbia:	Temperature changes (seasonal) Temperature thresholds Precipitation changes (seasonal) Ratio of snow to total precipitation Intense rain – frequency and intensity Winds Freezing Precipitation Riverflow Break-up Wildfires Sea level rise Storm surges and wave heights Permafrost thaw	

Also for each region there are some notes to augment the information in the tables and where important a short description of natural modes of the climate system affecting year to year variations from the climate change trend. The latter addresses, frequently cited phenomena such as, El Niño-Southern Oscillation, North Atlantic Oscillation and Arctic Oscillation and their likely effects on the region.

III HOW TO INTERPRET AND USE THESE TABLES

1. These Tables are intended for initial assessment of adaptation priorities. For criteria for more detailed design of adaptation measures, the appropriate comprehensive references should be consulted. A list of references is provided with this set of tables.
2. Where a range of values is indicated, this is to indicate the range recorded or projected within this region.
3. All figures are positive or rising trends unless otherwise noted.
4. A subscript indicates the return period, i.e. the recurrence interval of events greater than a specific value, e.g. $P_{20,}$ T_{20} .
5. >99% refers to an event of a magnitude that occurs in less than 1% of those events over the period of record.
6. Percentage (%) changes in precipitation are changes, over the period indicated, of % of long term averages (back to 1900 or earlier).
7. For intense winter storms (under Wind) the Canadian Climate Model (CGCM2) projects, for South of 60^oN, increases in numbers of intense events, but decreases in frequency of all storms. For regions North of 60^oN both frequency of all storms and of intense storms are projected to increase. Intense storms have central pressure <970hpa.
8. Lightning data associated with severe thunderstorms is only available since 1999 so trend analyses are not useful. However, in USA lightning related insurance losses rose sharply with temperatures greater than 20^oC. Most wildfires in northern Canada and the boreal forest are set by lightning.
9. Projections of values from 2010 to 2050 are based upon a combination of:
   i) Outputs of Atmosphere-Ocean climate models with the system forced by expected increases in greenhouse gases in the atmosphere, (A2 scenario high emissions), and
   ii) extrapolation, with physical reasoning, of observed trends since the 1960s.
10. In some cases there is a range of projections available from the various climate models and estimates of future greenhouse gas emissions. In most cases, only the most likely values are given, often from an ensemble of models compiled by IPCC, but generally assuming a high emission scenario, consistent with recent observations.
11. While data are presented on annual, maximum and minimum streamflow trends and projections, it must be recognized that a major effect of climate change is a change in seasonality of flow regimes. For most small and mid-size rivers, this is usually manifest in greater winter flows, earlier freshet in spring and lower flows May to October.

IV CLIMATE TABLES BY REGION **See following sections**

REGION: COASTAL BRITISH COLUMBIA

	OBSERVED (TRENDS)	BY 2050 (from 2010)
TEMPERATURE **See Note 1** **See Note 5**	**Temperature °C (1950-2008)**	°C

	Max. °C	Min. °C	By 2050 °C
Annual	1 °C	1.5 °C	1.5 °C
Winter	0.5	0.5 to -1	1
Spring	1.5	1.5 to 2	2
Summer	0.5	1.5	1.5
Autumn	0.5	0.5	1

Temperature Extremes (1950-2007)	Observed	By 2050
Warm Days >25°C max.	2/decade	10 days
Frost Free Days	>30 South, 0 North	20 days

PRECIPITATION

See Note 1

Precipitation (1950-2007)

	Observed %	By 2050 %
Annual	15% to 25%: Rain 20 to 30% Snow -30% to -50%	5 to 10%
Winter	-10	10
Spring	30 to 40	15
Summer	5 to 15	-20S to 0 N
Autumn	-5 to 10	5

Ratio of Snow to Total Precipitation (1950-2007)

	Observed	By 2050
Annual	-10	-15
Winter	-9	-12
Spring	-15	-20
Autumn	6	0

Intense Precipitation (1958-2007)	By 2050
Amounts of severe events +16% (>99%) (adjacent U.S.A.)	P_{20} 15%
Frequency heavy rain amounts +12% (>99%) (adjacent U.S.A.)	$P_{20} \rightarrow P_{10}$

COASTAL BRITISH COLUMBIA **Page 2**

	OBSERVED (TRENDS)	BY 2050 (from 2010)
WIND **See Note 2**	**Intense Winter Storms** (Central Pressure <970hpa) Over Northern Hemisphere (1950-2000) 1200 per year to 1300 (8%)	8-15% more frequent
	Significant Wave Heights (1950-2000) 5 cm	+7cm
RIVERFLOW	**Dates of Spring break-up (1948-2002)** 15 days earlier	30 days earlier
	Snow Pack - 1 April (1950-1997) -20%	-15%
	Streamflow (1967-1996) **%**	%
See Note 3	Annual: -20%	-20%
	Minimum Daily: -30	-30
	Maximum Daily: -20 to 20	10
SEA LEVEL **See Note 4**	**Mean (1993-2007)** 3.2cm/decade Relative Rise over Century Victoria: 8cm Vancouver: 4cm Prince Rupert: 12cm	15 to 25cm Note: Land Subsidence Fraser Delta ~2cm/decade
	El Nino Year up to 3cm more	3cm (El Nino)

Note 1: Ranges in observed and projected values indicate differences over the region.

Note 2: **Wind-disaster records of Public Safety Canada** indicate for storms >100km/h national frequency rose 16% from 1970 to 1990 with most in coastal regions, except for tornadoes.

Note 3: Major floods and landslides (from PSC data base), where intense rains, or rain on snow, apparently increased 80% nationally between the 1970s and 1990s. However, 1970s event recording may have been less thorough than in 1990s. Data base extends only to 2005.

Note 4: Sea level and storm surges: With rising relative sea level, even though isostatic rebound of the land has minimized the effect except in Fraser River Delta, and increased frequency of intense winter storms (up to 15% by 2050) increased storm surge activity and water levels expected. These events are often associated with heavy rain events on land with reduced capability of discharge to sea and increased flooding (e.g. Saanich Peninsula, Nov. 2009.)

Note 5: Annual variability above and below climate change driven trends is related to large-scale modes of the natural climate system. This region is especially affected by ENSO (El Nino-La Nina) and the Pacific Decal Oscillation (PDO). When PDO is in a warm phase and El Nino conditions develop, warmer, drier conditions with lower stream flow occur in Western Canada as departures from the global trend. Temperature trends in 1950-99 of 2.5°C were estimated in Western mountainous regions to have been 0.5°C less without a generally positive PDO. (Bonfils et al. 2008)

	OBSERVED (TRENDS)	BY 2050 (from 2010)
TEMPERATURE **See Note 1** **See Note 5**	**Temperature °C (1950-2007)**	°C

	Max. °C	Min. °C	By 2050 °C
Annual	1 to 2.5 °C	2.5 °C	2.5
Winter	0.5 to 2.5	1.5 to 2.5	1.5
Spring	1.5 to 2.5	2.5	2.5
Summer	1 to 1.5	1.5 to 2.5	2
Autumn	0.5 to 1.5	0.5 to 1.5	1.5

OBSERVED (TRENDS)	BY 2050 (from 2010)
Frost free days: 20 to 30	20 to 30 days
Growing Season: >5 °C 10 to 20 days	10 to 20 days
Severe heat wave: 1 in 20 years	1 in 4 years

PRECIPITATION

See Note 1

Precipitation (1950-2007)

	%	Amount mm/yr	By 2050 %
Annual	-10 to 25%		5%
Winter	-10 to -25		10 to 15
Spring	30 to 40		10 to 15
Summer	-10 to 30		-15 to -20
Autumn	15 to 35		10 to 15

Rates of Snow to Total Precipitation

(Trend 1950-2007)	%	By 2050 %
Annual	-10 to -20	-15
Winter	-10	-10
Spring	-10 to -20	-15
Autumn	-5	0

Intense Precipitation (1958-2007)

OBSERVED (TRENDS)	BY 2050 (from 2010)
Amounts of severe events +16% (>99 percentile) (adjacent U.S.A.)	P_{20} +10%)
Frequency heavy rain amounts +12% (>99 percentile) (adjacent U.S.A.)	$P_{20} \rightarrow P_{10}$

	OBSERVED (TRENDS)	**BY 2050 (from 2010)**
WIND **See Note 2**	**Intense Winter Storms** (Central Pressure <970hpa) Over Northern Hemisphere per year Number 1200 to 1300 8%	8 to 15% more frequent
RIVERFLOW	**Dates of Spring break-up (1948-2002)** 10 to 15 days earlier	25 days earlier
See Note 3	**Snow Pack - 1 April (1950-1997)** -40%	-20%
	Streamflow (1967-1996) **%**	%
	Annual: -10 to -40%	-20 to -40%
	Minimum Daily: 20 to -30	-25 to -30
	Maximum Daily: -40	-20
	Low Flows: (1963-2003) Summer 7 day flows Significant downward trend	Continued decrease
GLACIERS	**Glaciers (1995-2005)** **-0.65m Water equivalent loss**	Loss ½ of volume
FOREST WILDFIRES AND INSECTS **See Note 4**	**Observed Nationally** Additional 100,000 km^2 burned per 1ºC temperature increase (1970-2000)	**Projections** Continued increase in frequency and area burned
MOUNTAIN PINE BEETLE	**9.2 million ha, in B.C. Southern and Central**	

Note 1: Ranges in observed and projected values indicate differences over the region.

Note 2: **Wind-disaster records of Public Safety Canada** indicate for storms >100km/h national frequency rose 16% from 1970 to 1990 with most in coastal regions, except for tornadoes.

Note 3: Major floods and landslides (from PSC data base), where intense rains, or rain on snow, apparently increased 80% nationally between the 1970s and 1990s. However, 1970s event recording may have been less thorough than in 1990s. Data base extends only to 2005.

Note 4: Wildfires: Approximately 80% of fires set by lightning. Lightning caused fires are projected to increase globally by 44% by 2100.

Note 5: Annual variability above and below climate change driven trends is related to large-scale modes of the natural climate system. This region is especially affected by ENSO (El Nino-La Nina) and the Pacific Decal Oscillation (PDO). When PDO is in a warm phase and El Nino conditions develop, warmer, drier conditions with lower stream flow occur in Western Canada as departures from the global trend. Temperature trends in 1950-99 of 2.5°C were estimated in Western mountainous regions to have been 0.5°C less without a generally positive PDO. (Bonfils et al. 2008)

REGION: NORTHERN INTERIOR BRITISH COLUMBIA PAGE 1

	OBSERVED (TRENDS)	BY 2050 (from 2000)
TEMPERATURE **See Note 1**	**Temperature °C (1950-2007)**	°C

	Max. °C	Min. °C	By 2050 °C
Annual	1 to 1.5	1.5 to 2	2 °C
Winter	2.5 to 3	2.5 to 3	3.5
Spring	1.5 to 2.5	1.5 to 2.5	4
Summer	0.5 to 1.5	1.5 to 1.5	2
Autumn	0.5 to -0.5	0.5 to -0.5	1

Temperature Extremes (1950-2003)	Observed	By 2050
Frost free days	10 to 30	30days
Growing Season >5°	10 to 20 days	20 days

	OBSERVED (TRENDS)	BY 2050 (from 2000)
PRECIPITATION **See Note 1**	**Precipitation (1950-2007)** %	%

	%	By 2050 %
Annual	5 to 10%	10%
Winter	-5 to 10	10
Spring	0 to 10	10
Summer	0 to 10	0
Autumn	15	10

Ratio of Snow to Total Precipitation (1950-1998)

	%	By 2050 %
Annual	0 to -6	-5
Winter	0 to -3	-3
Spring	-18	-20
Autumn	6 to 0	0

	OBSERVED (TRENDS)	BY 2050 (from 2000)
	Intense Precipitation (1950-2003) Very wet days >95percentile 5 days/yr	P_{20} 0 to 10% amt. $P_{20} \rightarrow P_7$ to P_{10}
***WIND** See Note 2	**Intense Winter Storms** (Central Pressure <970hpa) Over Northern Hemisphere (1950-2000) Numbers 8%	8 to 15% more frequent

NORTHERN INTERIOR BRITISH COLUMBIA PAGE 2

	OBSERVED (TRENDS)	BY 2050 (from 2000)
RIVERFLOW	**<u>Dates of Spring break-up</u> (1948-2002)** 10 to 20 days earlier except no change NE	10 days earlier
See Note 3	**<u>Snow Pack</u> - 1 April (1950-1997** -20% to -40%	-30%
	<u>Streamflow</u> (1967-1996)	
	%	%
	Annual: -30% to 20	0%
	Minimum Daily: -10% to 20	-10
	Maximum Daily: -30% to 20	0
	Low Flows (7 day) significant downward trend	Continue
FOREST WILDFIRES AND INSECTS **See Note 4**	**<u>Observed</u>** <u>Nationally</u> additional 100,000 km^2 burned per 1^{o}C temperature increase (1970-2000) Regionally – 6% of area burned/year 1957-1997	**<u>Projections</u>** Area burned increase by 50%
MOUNTAIN PINE BEETLE	**9.2 million ha, in B.C.**	

Note 1: Ranges in observed and projected values indicate differences over the region.

Note 2: **Wind-disaster records of Public Safety Canada** indicate for storms >100km/h national frequency rose 16% from 1970 to 1990 with most in coastal regions, except for tornadoes.

Note 3: Major floods and landslides (from PSC data base), where intense rains, or rain on snow, apparently increased 80% nationally between the 1970s and 1990s. However, 1970s event recording may have been less thorough than in 1990s. Data base extends only to 2005.

Note 4: Wildfires: Approximately 80% of fires set by lightning. Lightning caused fires are projected to increase globally by 44% by 2100.

REGION: YUKON and MACKENZIE DISTRICT   PAGE 1

	OBSERVED TRENDS	BY 2050 (from 2010)

TEMPERATURE

See Note 1

Temperature °C (1950-2007)

	Max. °C	Min. °C	By 2050 (from 2010) °C
Annual	1.5 to 2.5	1 to 2	3 to 4
Winter	2.5 to 3.5	2.5 to 3.5	4 to 5
Spring	1.5 to 3	1.5 to 3	2 to 4
Summer	0.5 to 1.5	0.5 to 1.5	2 to 3
Autumn	0 to 1.5	-0.5 to 0.5	2 to 4

Temperature Extremes (1950-2007)

	Observed	By 2050 (from 2010)
Frost free season	10 to 30 days	30 days
Growing season >5-°C	10 to 20 days	25 days

PRECIPITATION

See Note 1

Precipitation (1950-2007)

	%		By 2050 (from 2010) %
Annual	0 to 35%	Largest increases in North	10 to 15%
Winter	0 to 40		15 to 20
Spring	0 to 40		10 to 15
Summer	-10 to 10		5 to 10
Autumn	10 to 20		10 to 15

Ratio of Snow to Total Precipitation (1950-2003) %

Annual	-10 to 10%
Winter	0 to 5
Spring	-15 to 0
Autumn	0 to 10

By 2050 (from 2010): %

Snowfall increase up to 40% Northern areas

Intense Precipitation (1958-2007)

P_{20} 25 to 50 mm: average (1981-2000)
Very heavy >99%: 23% amounts
Very heavy >99%: 13% frequency
(adjacent Alaska for both of the above)

By 2050 (from 2010): P_{20} 10 to 15%
$P_{20} \rightarrow P_5$ to P_{15}

Freezing precipitation (rain and drizzle) (1953-2004) 5 to 20%

By 2050 (from 2010): Increase Winter ~20%

<table>
<tr><td>WIND
See Note 2 and 4</td><td><u>Intense Winter Storms</u> <970hpa central
Northern Hemisphere pressure
(1950-2000) 8%
Coastal Storms number 75% (1980-2004)</td><td>8 to 15%</td></tr>
<tr><td rowspan="2">RIVERFLOW

See Note 3</td><td><u>Dates of Spring break-up</u> (1950-2005)
10 to 25 days earlier
e.g. Dawson City (Yukon River)
Breakup 1900-1980 in May: 1985-2005 in April</td><td>Continue earlier</td></tr>
<tr><td><u>Streamflow</u> (1967-1996)
<table><tr><td>Annual</td><td>-20%S to 7%N</td></tr><tr><td>Minimum Daily</td><td>0 to 20%</td></tr><tr><td>Maximum Daily</td><td>-10 to 10%</td></tr></table></td><td>10 to 30%
Mainly in April to July</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>SEA LEVEL
See Note 4</td><td>Mean (1993-2007) 3.2/decade</td><td>15 to 25cm</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>PERMAFROST THAW</td><td>Some thaw in discontinuous permafrost areas</td><td>30% of southern areas</td></tr>
<tr><td>WILDFIRES
See Note 5</td><td>Area burned tripled from 1960s to 1990s</td><td>~10 days longer fire season</td></tr>
</table>

Note 1: Ranges in observed and projected values indicate differences over the region.

Note 2: Wind-disaster records of Public Safety Canada indicate for storms >100km/h national frequency rose 16% from 1970 to 1990 with most in coastal regions, except for tornadoes.

Note 3: Major floods and landslides (from PSC data base), where intense rains, or rain on snow, apparently increased 80% nationally between the 1970s and 1990s. However, 1970s event recording may have been less thorough than in 1990s. Data base extends only to 2005. Southern region – heavy rain on snow, floods in spring more frequent.

Note 4: Sea level and storm surges: Sensitivity to sea level rise and storm surge is high to moderate in much of Beaufort Sea shoreline. Reduction of sea ice to protect shores from erosion and damages to continue and coastal land subsidence of 1.8 to 3 mm/yr exacerbates erosion. Annual number of open water storms on adjacent Alaskan coast averaged 15 (1950-1980) but 24 (1980-2004). Storm surges as high as 2m have been observed in areas near Tuktoyuktuk.

Note 5: Wildfires: Approximately 80% of fires set by lightning. Lightning caused fires are projected to increase globally by 44% by 2100.

REGION: SOUTHERN* ALBERTA

	OBSERVED TRENDS	BY 2050 (from 2010)
TEMPERATURE	**Temperature °C (1950-2007)**	
See note 1		

Season	Max. °C	Min. °C	By 2050 °C
Annual	1.5 to 2.5	0.5 to 1.5	2 to 4
Winter	2.5 to 3	1.5 to 3	3 to 4
Spring	2.5 to 3	2.5 to 2.5	2 to 4
Summer	0.5 to 2.5	-0.5 to 1.5	2 to 3
Autumn	-0.5 to 0.5	-1.5 to 0.5	2 to 3

Temperature Extremes (1950-2007)

	Observed	By 2050
Frost free days	-5 to 20 days	25 days
Growing Season >5 °C	15 to 30 days	30 days

PRECIPITATION

See note 1

Precipitation (1950-2007)

Season	% of long term average	By 2050 %
Annual	-20 to 0	0 to 10
Winter	-15 to -5	10 to 15
Spring	0 to 5	5 to 15
Summer	0 to -10	-5 to -10
Autumn	-5 to 0	0 to 5

Ratio of Snow to Total Precipitation

Season	(1950-2003) %	By 2050 %
Annual	-20 to -5	-15
Winter	0 to 3	-10
Spring	-20 to 0	-20
Autumn	-5 to 0	-10

Intense Precipitation (1958-2007)

See note 6

Observed	By 2050
P_{20}: 25 to 50 mm/day: average (1981-2000)	P_{20}: 10 to 15% severity
P>99%: 13% frequency (adjacent USA)	$P_{20} \rightarrow P_{10-15}$ frequency
P>99%: 15% amount (adjacent USA)	

WIND
See Note 2

Intense Winter Storms

	Observed	By 2050
<970hpa central pressure Northern Hemisphere	**8%**	8 to 15%

*Roughly south of an E-W line through Red Deer

SOUTHERN ALBERTA **PAGE 2**

	OBSERVED (TRENDS)	BY 2050 (from 2010)
RIVERFLOW	**Dates of Spring break-up (1950-2005)** Earlier date some significant (10 to 15 days)	Continue earlier By 30 days
	Snow Pack - 1 April (1950-1997) -20%	--40% ???
See Note 3	**Glaciers – (1965-2004)** **-22% of mass balance (Peyto)**	Continued loss
	Streamflow (1967-1996) %	%
	Annual: -10 to -20	-5 to -15
	Minimum Daily: -30% to 20	-10 to -20
	Maximum Daily: -20 to -10	0
LIGHTNING **Flash density** **See Note 5** **See Note 7**	**(1999-2008)** Average 0.5 to 3.5 flash/km^2/year Max 0.5 to 4 flash/km^2/year	Increase 20%
DROUGHT	**(1900-2002)** Palmer drought severity index: significant trend towards increased severity	Severe droughts twice as frequent

Note 1: Ranges in observed and projected values indicate differences over the region.

Note 2: Wind-disaster records of Public Safety Canada indicate for storms >100km/h national frequency rose 16% from 1970 to 1990 with most in coastal regions, except for tornadoes. Fifty year return period maximum winds are 100 to 140 km/hr from Calgary region to extreme southwest.

Note 3: Major floods and landslides (from PSC data base), where intense rains, or rain on snow, apparently increased 80% nationally between the 1970s and 1990s. However, 1970s event recording may have been less thorough than in 1990s. Data base extends only to 2005. Generally winter flows increasing and summer and autumn flows declining. Flash floods in small basins becoming more frequent spring and summer.

Note 4: Annual variability above and below climate change driven trends is related to large-scale modes of the natural climate system. This region is especially affected by ENSO (El Nino-La Nina) and the Pacific Decal Oscillation (PDO). When PDO is in a warm phase and El Nino conditions develop, warmer, drier conditions with lower stream flow occur in Western Canada as departures from the global trend. Temperature trends in 1950-99 of 2.5°C were estimated in Western mountainous regions to have been 0.5°C less without a generally positive PDO. (Bonfils et al. 2008)
Note 5: Most wild fires set by lightning. Global estimate lightning increase by 44% in 21st century. (Price & Rind, 1994)

Note 6: $\mathbf{P_{20}}$ signifies the precipitation likely to be equalled or exceeded only once in 20 years on average a long period.

Note 7: Hail is relatively frequent (5 to 8 days per year) east of the Rocky Mountain range in Southern and Central Alberta. However, in drought periods, such as 2001 and 2002, with drier air in lower levels of the atmosphere, hail is substantially less frequent.

REGION: CENTRAL* ALBERTA PAGE 1

	OBSERVED TRENDS	BY 2050 (from 2010)
TEMPERATURE **See Note 1**	**Temperature °C (1950-2007)**	

	Max. °C	Min. °C	By 2050 °C
Annual	1 to 2.5	1 to 2.5	2 to 4
Winter	1.5 to 3	1.5 to 3	3 to 4
Spring	2.5 to 3.5	1.5 to 2.5	3 to 4
Summer	0.5 to 1.5	0.5 to 1.5	2 to 3
Autumn	-0.5 to 0	-1.5 to -0.5	2 to 3

	Observed	By 2050
Frost free season	10 to 20 days	25 days
Growing season >5 °C	10 to 30 days	30 days

PRECIPITATION

See Note 1

Precipitation (1950-2007) %

	Observed %	By 2050 %
Annual	-10 to -20	5 to 10
Winter	-5 to 0	5 to 10
Spring	-5 to 0	10 to 15
Summer	-5 to -10	0 to -5
Autumn	-5 to 5	5 to 10

Ratio of Snow to Total Precipitation (1950-2003) %

	Observed %	By 2050 %
Annual	-5 to -10	-15
Winter	0	-10
Spring	-5 to -15	-15
Autumn	-5 to -10	-5

OBSERVED TRENDS	BY 2050 (from 2010)
Intense Precipitation (1958-2007) Spring heavy rains increased 5% per decade in frequency over past century	P_{20} 5 to 10%$_{amount}$ $P_{20} \rightarrow P_{10\ to\ 15 frequency}$
Freezing precipitation (rain and drizzle) average (1961-1990) **Precipitation: 15 to 20 hrs/year** Increase up to 20% extreme North	Increase

	OBSERVED TRENDS	BY 2050 (from 2010)
WIND **See Note 2**	**Intense Winter Storms** Northern Hemisphere **(1950-2000) 8%**	8 to 15%

*Approximately between East/West line and through Red Deer and through Fort MacMurray

	OBSERVED TRENDS	BY 2050 (from 2010)
RIVERFLOW	**Dates of Spring break-up (1973-1999)** 10 days earlier (Peace River)	20 days earlier
	Snow Pack - 1 April (1950-1997) -20%	-30%
See Note 3	**Glaciers – (1965-1997)** Average decrease 25%	Continued decrease ~5%/decade
	Streamflow (1967-1996) % Annual: -20 Minimum daily: -20 to 10 Maximum daily: -30 to -10	% -20 -20 0 to -10
PERMAFROST THAW	Declining at higher elevations in western areas	Continue decline to even higher elevations
WILDFIRES and LIGHTNING See Note 4 See Note 5	National area burned increased 100,000km^2 per ^{o}C warming (1970-2000)	Continued increase. Area burned increase 15%
DROUGHT	**Palmer Drought Severity Index:** significant increase in frequency and intensity over 20th century	Continued more intense drought: doubled frequency of severe events

Note 1: Ranges in observed and projected values indicate differences over the region.

Note 2: Wind-disaster records of Public Safety Canada indicate for storms >100km/h national frequency rose 16% from 1970 to 1990 with most in coastal regions, except for tornadoes.

Note 3: Major floods and landslides (from PSC data base), where intense rains, or rain on snow, apparently increased 80% nationally between the 1970s and 1990s. However, 1970s event recording may have been less thorough than in 1990s. Data base extends only to 2005.

Note 4: Most fires set by lightning. Global estimate lightning increase by 44% in 21st century. (Price and Rind, 1994)

Note 5: Hail is relatively frequent (5 to 8 days per year) east of the Rocky Mountain range in Southern and Central Alberta. However, in drought periods, such as 2001 and 2002, with drier air in lower levels of the atmosphere, hail is substantially less frequent.

REGION: NORTHERN* ALBERTA PAGE 1

	OBSERVED TRENDS	BY 2050 (from 2010)
TEMPERATURE **See Note 1**	**Temperature °C (1950-2007)** **Max. °C** / **Min. °C** Annual: 1 to 2.5 / 1 to 2.5 Winter: 1.5 to 3 / 1.5 to 3 Spring: 1.5 to 3 / 1.5 to 2.5 Summer: 0.5 to 1.5 / 0.5 to 1.5 Autumn: 0 to -1 / -0.5 to -1.5	°C 2 to 4 3 to 4 2 to 4 2 to 3 1 to 2
	Temperature Extremes (1981-2007) Frost free season 10 to 20 days Growing season >5 °C 10 to 30 days	25 days 30 days
PRECIPITATION **See Note 1**	**Precipitation (1950-2007) %** Annual: 0 to 10 Winter: 5 to 10 Spring: 0 to 5 Summer: -5 to 5 Autumn: -5 to 5	% 5 to 10 10 to 15 10 to 15 -5 to 5 0 to 5
	Ratio of Snow to Total Precipitation (1950-2003) % Annual: -10 to 0 Winter: 0 Spring: -5 to -10 Autumn: -5 to -10	% -10 -5 -10 0
	Intense Precipitation (1958-2007) – no trend data P_{20} 25 to 50 mm average (1981-2000)	P_{20} 10 to 15% $P_{20} \rightarrow P_{10\ to\ 15}$
	Freezing precipitation (rain and drizzle) average (1961-1990) **Precipitation: <25hrs/year** **Rain: <10hrs/year**	Little change
WIND **See Note 2**	**Intense Winter Storms** Northern Hemisphere **(1950-2000) 8%**	8 to 15%

*North of an East/West line through Fort McMurray

	OBSERVED TRENDS	**BY 2050 (from 2010)**
RIVERFLOW	**Dates of Spring break-up (1950-2005)** Earlier date non-significant statistically	Continue earlier
	Snow Pack - 1 April (1950-1997) -20%	-25%
See Note 3	**Glaciers – (1965-2004) – Central Alberta** -22 to -25% mass balance (Peyto and Athabasca)	Continued loss
	Streamflow (1967-1996) % Annual: -20 to 0% Minimum daily: -10 to 20 Maximum daily: -30 to 10	% -20 -20 -10
PERMAFROST THAW	In discontinuous permafrost areas	Continued thaw. Drying of peatland Increase active layer depth by 50%
WILDFIRES and LIGHTNING See Note 4	0.5 to 2 flashes/km^2/year (1999-2008) National area burned increases 100,000km^2 per ^{o}C warming.	Increased lightning and fire incidence ~20%
DROUGHT	**Palmer Drought Severity Index:** significant increase in frequency and intensity over 20th century	Continued more intense drought: doubled frequency

Note 1: Ranges in observed and projected values indicate differences over the region.

Note 2: Wind-disaster records of Public Safety Canada indicate for storms >100km/h national frequency rose 16% from 1970 to 1990 with most in coastal regions, except for tornadoes.

Note 3: Major floods and landslides (from PSC data base), where intense rains, or rain on snow, apparently increased 80% nationally between the 1970s and 1990s. However, 1970s event recording may have been less thorough than in 1990s. Data base extends only to 2005.

Note 4: Most fires set by lightning. Global estimate lightning increase by 44% in 21st century.

REGION: SOUTHERN SASKATCHEWAN and MANITOBA PAGE 1

	OBSERVED TRENDS	BY 2050 (from 2010)
TEMPERATURE **See Note 1**	**Temperature ^{o}C (1950-2007)** Max. ^{o}C / Min. ^{o}C Annual: 1 to 2 / 0.5 to 2 Winter: 1.5 to 3 / 1 to 3 Spring: 0.5 to 3 / 1 to 2.5 Summer: -0.5 to 2.5 / -0.5 to 1.5 Autumn: -0.5 / -0.5 to 1	^{o}C 2 to 4 3 to 4 3 to 4 2 to 4 1 to 2
	Temperature Extremes (1950-2007) Frost Free Days 10 to 30 days Growing Days >5 ^{o}C -10 to 20	T_{max20}: 2 to 4 ^{o}C $T_{max20} \rightarrow T_{max10\text{-}15}$ 25 days 20 days
PRECIPITATION **See Note 1**	**Precipitation (1950-2007)** % Annual: -10 to 20 Winter: -10 to 15 Spring: -10 to 15 Summer: -10 to 10 Autumn: 5 to 20	% -5 to 10 0 to 15 5 to 15 -10 to 10 -10 to 10
	Ratio of Snow to Total Precipitation (1950-2003) % Annual: -5 to 0 Winter: 0 Spring: -10 to 5 Autumn: -5 to 10	% -10 -10 -15 -5
	Intense Precipitation (1958-2007) Days with amounts in events >99% 15% (adjacent USA) Days with heavy rain >99% frequency 13% (adjacent USA) P_{20} 25 to 50mm (Average 1981-2000)	P_{20}: 5 to 10% $P_{20} \rightarrow P_{10}\text{-}P_{15}$
WIND **See Note 2**	**Intense Winter Storms** <970hpa central pressure Northern Hemisphere **(1950-2000)** **8%**	8 to 15%

	OBSERVED TRENDS	BY 2050 (from 2010)
RIVERFLOW	**Dates of Spring break-up (1950-2005)** Earlier date: non-significant	Continue earlier
See Note 3 and Note 4	**Streamflow (1967-1996)**	%
	Annual: -30 to -40%	-20
	Minimum Daily: -10 to 30%	-20
	Maximum Daily: -20 to -30%	-0
Permafrost Thaw	Occurring in mid province in discontinuous permafrost areas	Permafrost gone from region with drying of peatlands
Lightning	**Flash density average (1999-2008)** 1.5 to 4 flash/km$^{2/}$yr	increase

Note 1: Ranges in observed and projected values indicate differences over the region.

Note 2: Wind-disaster records of Public Safety Canada indicate for storms >100km/h national frequency rose 16% from 1970 to 1990 with most in coastal regions, except for tornadoes.

Note 3: Major floods and landslides (from PSC data base), where intense rains, or rain on snow, apparently increased 80% nationally between the 1970s and 1990s. However, 1970s event recording may have been less thorough than in 1990s. Data base extends only to 2005.

Note 4: An exception to declining flows is Red River through Winnipeg. Climate change induces greater moisture transport from Gulf of Mexico and more precipitation in the U.S. headwaters of the Red River in spring. This suggests increasing flood threats along the Red River.

REGION: NORTHERN SASKATCHEWAN and MANITOBA PAGE 1

	OBSERVED TRENDS	BY 2050 (from 2010)
TEMPERATURE **See Note 1**	**Temperature °C (1950-2007)** **Max. °C / Min. °C** Annual: 0.5 to 2.5 / 0.5 to 1.5 Winter: 0.5 to 1.5 / 0.5 to 1.5 Spring: 1.5 to 2.5 / 0.5 to 2.5 Summer: 0.5 to 1.5 / 0.5 to 1.5 Autumn: -0.5 to 1.5 / -0.5 to 0.5	**°C** 2 to 3 3 to 4 2 to 3 2 to 3 1 to 3
	Temperature Extremes (1981-2007) Frost Free days 20 Growing Season days >5 °C 10 to 20	25 days 15 days
PRECIPITATION **See Note 1**	**Precipitation (1950-2007)** **%** Annual: -5 to 15% Winter: -10 to 15 Spring: -5 to 15 E Summer: 0 to 15 Autumn: 5 to 15	% 0 to 15 5 to 20 15W to 25E -5 to 15 5 to 15
	Ratio of Snow to Total Precipitation **(1950-2003) %** Annual: 0 to 5 E Winter: 0 Spring: -10 to 10 E Autumn: 0 to 5	% -5 -5 -10 0
	Intense Precipitation (1950-2007) Number of days with rain >99% -5 to 0 P_{20} average (1981-2000): 25 to 50 mm	P_{20}: 10mm (severity) $P_{20} \rightarrow P_{10\text{-}15}$ (frequency)
WIND **See Note 2**	**Intense Winter Storms** <970hpa central pressure Northern Hemisphere **(1950-2000)** 8%	8 to 15%

	OBSERVED TRENDS	**BY 2050 (from 2010)**
RIVERFLOW **See Note 3 and footnote for southern Manitoba and Saskatchewan page 2**	**Dates of Spring break-up (1950-2005)** Earlier date non-significant	Continue earlier Ice free season on Hudson Bay increases towards late November into December
	Streamflow (1967-1996) **%** Annual: -20 to 10% Minimum Daily: -20 to 10 Maximum Daily: -30 to 10	% -10 -10 -15
SEA LEVEL	Mean (1993-2007) 3.2cm/decade	20cm
PERMAFROST THAW	In discontinuous permafrost areas	Throughout area with drying of peatlands
LIGHTNING FLASH DENSITY	0.5 to 2 flashes/sq.km/yr	Further increase
WILDFIRES	Regionally: >400,000ha average burned (1959-1997) Nationally: area burned increased by 100,000km^2 per ^{o}C increase in temperature (1970-2000)	50% increase area burned

Note 1: Ranges in observed and projected values indicate differences over the region.

Note 2: Wind-disaster records of Public Safety Canada indicate for storms >100km/h national frequency rose 16% from 1970 to 1990 with most in coastal regions, except for tornadoes.

NORTHERN SASKATCHEWAN and MANITOBA PAGE 3

Note 3: Major floods and landslides (from PSC data base), where intense rains, or rain on snow, apparently increased 80% nationally between the 1970s and 1990s. However, 1970s event recording may have been less thorough than in 1990s. Data base extends only to 2005.

Note 4: Most fires set by lightning. Global estimate lightning increase by 44% in 21st century.

REGION: WESTERN NUNAVUT PAGE 1

	OBSERVED TRENDS	BY 2050 (from 2010)
TEMPERATURE **See Note 1** **See Note 5**	**Temperature ^{o}C (1966-2003)** Annual: 0.5 to 1.5/decade Winter: -0.5 to 1.5/decade Spring: 0.5 to 1.5/decade Summer: 0 to 1.5/decade Autumn: 0.5 to 1.5/decade	**^{o}C** 2 to 4 3 to 5 0 to 3 1 to 3 3 to 6
	Temperature Extremes (1981-2007) Frost days: -20 to -10 Heating degree days: -300 to -500^{o} days	-20 -500^{o} days
PRECIPITATION **See Note 1**	**Precipitation %/decade (1966-2003)** **%** Annual: -10 to 15% Winter: -10 to 10 Spring: -5 to 15 Summer: --5 to 15 Autumn: -10 to 15	% 10 to 25 10 to 25 10 to 20 10 to 15 10 to 20
	Ratio of Snow to Total Precipitation (1950-2003) % Annual: 10 to 30 Winter: 0 to 10 Spring: 0 to 5 Autumn: -5 to 10	% -10 5 0 -15
	Intense Precipitation (1958-2007) P>10mm: 2 to 6 days per decade P_{20}: 15 to 35mm average 1981-2000	$P_{20:}$ 10 to 20% $P_{20} \rightarrow P_{10\ to\ 15}$
	Freezing precipitation (rain and drizzle) average (1961-1990) Precipitation: <25hrs Rain: <10hrs	8% increase/decade in spring
WIND **See Note 2**	**Intense Winter Storms** <970hpa central pressure Northern Hemisphere (1950-2000) 8%	8 to 15%

	OBSERVED TRENDS	BY 2050 (from 2010)
RIVERFLOW	**Dates of Spring break-up (1950-2005)** Earlier date non-significant	Continue earlier especially in western areas
	Snow Pack	As ice free season on Hudson Bay and Beaufort Sea increases, greater snow pack will develop in early winter in eastern mainland areas and western archipelago.
See Note 3	**Streamflow (1967-1996)** **%** Annual: 10 to 30% Minimum daily: -10 to 30 Maximum daily: 15 to 30 In mainland area	% 10 to 30 0 to 10 20 to 30
SEA LEVEL **See Note 4**	Mean (1993-2007) 3.2cm/decade	15 to 25cm
PERMAFROST THAW	Initial thawing in discontinuous permafrost areas.	Continuous permafrost becoming discontinuous
GLACIERS	Mass loss Arctic archipelago 25km^3/year (1995-2000)	Increase in loss of mass

Note 1: Ranges in observed and projected values indicate differences over the region.

Note 2: Wind-disaster records of Public Safety Canada indicate for storms >100km/h national frequency rose 16% from 1970 to 1990 with most in coastal regions, except for tornadoes.

Note 3: Major floods and landslides (from PSC data base), where intense rains, or rain on snow, apparently increased 80% nationally between the 1970s and 1990s. However, 1970s event recording may have been less thorough than in 1990s. Data base extends only to 2005.

Note 4: Sea level and storm surges: Sensitivity to sea level rise and storm surge is high to moderate on the Beaufort Sea coastline much of which is subsiding. Sea ice to protect shores from erosion and damages is being reduced and frequency of severe storms increasing.

Note 5: Re Arctic Archipelago: The most completely analyzed climate record in the Canadian Arctic archipelago is for Eureka on Western Ellesmere Island at 79.98°N and 85.93°W. This is near the dividing line between Western and Eastern Nunavut. Observations taken 7 times a day from 1953 to 2007 reveal a strong reversal of temperature trends in the early 1970s. Temperatures were falling from 1960 to 1972 but have shown a strong rise since then, with a trend of +0.88 degrees per decade. Winter trends since 1972 have been 0.67 degrees/decade, spring: 1.14 degrees/decade, summer: 0.42 degrees/decade and autumn: 1.25 degrees/decade. Similar annual trends were found for 11 stations globally, North of 75°N, by the Goddard Institute for Space Studies. With large scale climate change driven overwhelmingly by greenhouse gases since about 1970, it can be assumed that the observed rising trend since 1972 will continue. The falling temperature trend from 1953 to 1970 was due probably to internal variability through the Arctic and North Atlantic Oscillations. Thus for indications of future trends the warming of the past approximately 4 decades is likely to continue and accelerate as climate models suggest and as more ice disappears from the surrounding seas. Unfortunately for this analysis published trend data for elsewhere in the Canadian Arctic is for 1900 to 2007 and 1950 to 2007 (Vincent and Mekis 2009) which include the cooling phase and the greenhouse gas driven warming and so substantially underestimates current and projected warming rates for the next 4 decades.

	OBSERVED TRENDS	BY 2050 (from 2010)
TEMPERATURE **See Note 1**	**Temperature °C (1950-2007)** °C	

	Max. °C	Min. °C	By 2050 °C
Annual	1.5**N** to 2.5**S**	0.5**N** to 2.5**S**	2 to 5
Winter	1.5 to 2.5	0.5 to 2.5	4 to 6N 2 to 4S
Spring	1.5 to 3.5	1.5 to 2.5	2 to 4
Summer	1.5 to 2.5	-0.5 to 1.5	2 to 4
Autumn	0.5 to 1.5	-1.5 to 1	2 to 4

Temperature Extremes (1950-2007)		By 2050
		T_{max20} 2 to 4°C T_{min20} 4 to 6°C
Frost free season	10 to 20 days	20 days
Warm days T_{max} >25 °C:	10 to 15 days	15 days

PRECIPITATION

See Note 2

Precipitation (1950-2007)

	%	By 2050 %
Annual	-20 to 20	5 to 15
Winter	-10 to 5	20 to 30N 10 to 20S
Spring	-10 to 5	10 to 20
Summer	0 to 10	0 to 10
Autumn	0 to 15	0 to 10

Ratio of Snow to Total Precipitation (1950-2007)

	%	By 2050 %
Annual	-5 to -10	-15
Winter	0 to 3	-10
Spring	-6 to 3	-5
Autumn	-3 to 0	-15

Observed trends	By 2050 (from 2010)
Intense Precipitation (1958-2007) Amounts in severe events (>99%): 31% (adjacent USA) Frequency heavy rain amounts (>99%): 27% (adjacent USA) Number of days with amounts ≥ 95th percentile: 3 to 6	P_{20}: 5 to 10% severity $P_{20} \rightarrow P_{10\ to\ 15}$ frequency
Freezing precipitation (rain and drizzle) average (1961-1990) **Precipitation: <35hrs** **Rain: <10hrs**	60 to 85% increase in freezing rain events

NORTHERN ONTARIO **PAGE 2**

	OBSERVED TRENDS	**BY 2050 (from 2010)**
WIND **See Note 2**	**Intense Winter Storms** Northern Hemisphere <970hpa central pressure 8%	8 to 15%
RIVERFLOW	**Dates of Spring break-up (1950-2002)** Earlier, mostly significant	Earlier still
See Note 3	**Snow Pack**	As ice free season on Hudson and James Bays increases towards late November and into December, greater snow pack will develop in early winter in coastal areas.
	Streamflow (1967-1996) %	%
	Annual: -40 to 10	-20
	Minimum Daily: -30 to 10	-20
	Maximum daily: -40 to 10	-10
Forest Fires	Area burned increased 27% from 1981-1990 to 1991-2000 (But large fire year 1980)	50 to 500% increase in area
Permafrost and Peatlands	Thawing evident Southern area	Greatest impact Northern area with peatlands drying out

Note 1: Ranges in observed and projected values indicate differences over the region.

Note 2: Wind-disaster records of Public Safety Canada indicate for storms >100km/h national frequency rose 16% from 1970 to 1990 with most in coastal regions, except for tornadoes.

Note 3: Major floods and landslides (from PSC data base), where intense rains, or rain on snow, apparently increased 80% nationally between the 1970s and 1990s. However, 1970's event recording may have been less thorough than in 1990s. Data base extends only to 2005. Spring floods earlier but summer rain – induced floods more frequent.

	OBSERVED (TRENDS)	BY 2050 (from 2010)
TEMPERATURE **See Note 1**	**Temperature °C (1950-2007)** Annual: Max. °C 0 to 1; Min. °C 0.5 to 1.5 Winter: Max. 0.5 to 1; Min. 0.5 to 1.5 Spring: Max. 0.5 to 1.5; Min. 0.5 to 1.5 Summer: Max. 0.5 to 1.5; Min. 1.5 Autumn: Max. -0.5 to -1; Min. 0.5	°C 2 to 3.5 2 to 3.5 2 to 4 2. to 3 2 to 3
See Note 6	**Temperature Extremes (1950-2007)** Frost free days 0 to 30 Growing days >5°C 10 to 30 Toronto T_{max}>30 °C ~20 days average (2000-2010)	25 20 Double T_{max20} 4°C $T_{max20} \rightarrow T_{max10}$ (i.e. double frequency)
PRECIPITATION **See Note 1**	**Precipitation (1950-2007)** ***(compared to long term average)*** Annual: 10 to 20%: 1.5 to 5mm/decade Winter: 0 to 3mm/decade most in lee of Gt. Lakes Spring: 0 to 1.5mm/decade Summer: 0 Autumn: 1.5 to 3mm/decade Annual	% 5 5 to 20 10 to 15 0 to 10 0
	Ratio of Snow to Total Precipitation (1950-2007) Annual -1.5%/decade	-5 to -10%

Precipitation cont'd **See Note 5**	**Intense Precipitation (1958-2007)** P_{20} = 50 to 75 mm: average (1981-2000) Severity of precipitation events (>99%) 31% (adjacent USA) Frequency heavy rain amounts (>99%) 27% (adjacent U.S.A.) Greatest % increase observed in Spring 7 to 15% per decade (May)	P_{20} 10% Increase severity $P_{20} \rightarrow P_{10}$ (double in frequency)
Precipitation cont'd	**Freezing precipitation (rain and drizzle) average (1961-1990)** **Precipitation: 50 hours** **Rain: 10 to 25 hours**	>6 hr events: 40% over frequency of (1965-2005)
WIND **See Note 2 and 4**	**Intense Winter Storms** (Central Pressure <970hpa) Over Northern Hemisphere (1950-2000) Numbers 8%	8 to 15%
RIVERFLOW	**Dates of Spring break-up (1948-2002)** **Earlier – not significant**	15 days earlier
	Ice Cover (1973-2008) Great Lakes – average winter cover 30% to 15% Huron 33% to 10% Erie	Great Lakes Winter Ice Cover Close to zero
See Note 3 **See Note 5**	**Streamflow (1967-1996) %** Annual: 10 to -20 Minimum Daily: 10 to -20 Maximum Daily: -10 to -30	% -10 -20 -10 to 10

Note 1: Ranges in observed and projected values indicate differences over the region.

Note 2: Wind-disaster records of Public Safety Canada indicate for storms >100km/h national frequency rose 16% from 1970 to 1990 with most in coastal regions, except for tornadoes. Ontario recorded 29 tornadoes in 2006 and again in 2009 – long term average is 11.

Note 3: Major floods and landslides (from PSC data base), where intense rains, or rain on snow, apparently increased 80% nationally between the 1970s and 1990s. However, 1970s event recording may have been less thorough than in 1990s. Data base extends only to 2005. (See Note 5)

Note 4: Storm surges: Trends towards reduced ice cover and stronger winds over Great Lakes increase incidence of damaging storm surges. e.g. Average Wind Lake Superior increased 4.5 to 4.9m/sec from 1985 to 2007.

Note 5: Intense Precipitation: 7 flood-producing heavy rain events Toronto area (1987-2007) all >P_{2o} from previous records. Rain intensities greatest seasonal increase in Spring over southern Ontario. Severe flash floods - Stratford, Peterborough, Toronto, Hamilton etc. (2000-2009).

Record observed short duration rain intensities:
Tobermory Cypress Lake: 60 min 112mm, two hour 118mm (2003)
Toronto North York: 15 min 66mm, 30 min 90mm, 2 hour 132mm (2005)
Upper Grand River basin: 1 day >200mm (2004)
Peterborough (Trent University), one day 240 mm (2004)

Note 6: In some places near the Great Lakes little change or declines in number of hot days T_{mas}>30^oC are due to cooler waters of the lakes in spring and summer.

	OBSERVED TRENDS	BY 2050 (from 2010)

TEMPERATURE

See Note 1

Temperature ^{o}C (1950-2007)

	Max. ^{o}C	Min. ^{o}C	By 2050 ^{o}C
Annual	0.5 to 1.5	0.5 to 1.5	2.5 to 4
Winter	0.5 to 1.5	0 to 1.5	3 to 4
Spring	0.5 to 1.5	0.5 to 1.5	3 to 4
Summer	1 to 1.5	1.5 to 2	2 to 4
Autumn	-0.5 to 0.5	-0.5 to 0.5	2 to 3

Temperature Extremes (1950-2007)

	Observed	By 2050
Frost-free days	20 to 30	25 days
Growing season	10 to 20 days	20 days

PRECIPITATION

See Note 1

Precipitation (1950-2007)

	Observed %	By 2050 %
Annual	5 to 15%	5 to 15
Winter	-5 to 15	10 to 15
Spring	5 to 15	15 to 20
Summer	0 to 10	0 to 10
Autumn	0 to 15	0 to 10

Ratio of Snow to Total Precipitation (1950-2007) %

	Observed %	By 2050 %
Annual	0 to -10%	-10 to -20%
Winter	0 to -5	-15
Spring	0 to -10	-15
Autumn	0 to 5	-5 to -10

Intense Precipitation (1981-2000)

P_{20}: 50 to 75 mm (average)
Greatest 1 day rainfall 1950-2007 trend
15mm SE to -10mm NW
Number of days with rainfall ≥ 95th percentile 6SE, -3NW (1950 to 2007)

By 2050: P_{20}: amount 5 to 10%
$P_{20} \rightarrow P_{10\ to\ 15}$ (frequency)

Freezing precipitation (rain and drizzle) average (1961-1990)

Precipitation: 50 hours annual average
Rain: 25 hours annual average

By 2050: Events >6hr duration
Winter(DJF) 65%
Nov. & Spring 0

	OBSERVED TRENDS	**BY 2050 (from 2010)**
WIND **See Note 2**	**Intense Winter Storms** <970hpa central pressure Northern Hemisphere **(1950-2000)** 8% more frequent	8 to 15% more frequent
RIVERFLOW	**Dates of Spring break-up (1950-2005)** Earlier date non-significant	Continue earlier
	Streamflow (1967-1996)	
	%	%
	Annual: -10 to -30	-10
	Minimum Daily: 10 to -20	-10
See Note 3	Maximum Daily: -20	0

Note 1: Ranges in observed and projected values indicate differences over the region.

Note 2: Wind-disaster records of Public Safety Canada indicate for storms >100km/h national frequency rose 16% from 1970 to 1990 with most in coastal regions, except for tornadoes.

Note 3: Major floods and landslides (from PSC data base), where intense rains, or rain on snow, apparently increased 80% nationally between the 1970s and 1990s. However, 1970s event recording may have been less thorough than in 1990s. Data base extends only to 2005. Increased frequency of flash floods in small watersheds, spring and summer.

Note 4: Intense Precipitation: Recent one-day intense event Ottawa (M-C Airport) 137mm (Sept.2004).

REGION: CENTRAL and NORTHERN QUEBEC and LABRADOR PAGE 1

	OBSERVED TRENDS	BY 2050 (from 2010)
TEMPERATURE **See Note 1**	**Temperature °C (1950-2007*)**	

	Max. °C	Min. °C	°C
Annual	0.5 °C	-0.5 to 1.5 °C	4
Winter	-0.5 to -1.5	-0.5 to 1.5	5
Spring	0.5	-1.5 to 1.5	3
Summer	0.5 to 1.5	0.5 to 1.5	3
Autumn	1.5	1.5	3.5

	Temperature Extremes (1950-2007)	Days
Frost free days	10 to 30	10 to 30
Growing days (>5 °C)	20 to 30	20 to 30

PRECIPITATION — **See Note 1**

Precipitation (1950-2007)

	%	%
Annual	10 to 30% ~100mm	10 to 15
Winter	-5 to 15	5 to 20
Spring	15 to 25	10 to 20
Summer	0 to 15	0 to 10
Autumn	10 to 35	0 to 20

	OBSERVED TRENDS	BY 2050 (from 2010)
	Ratio of Snow to Total Precipitation (1950-2007) Annual 10%	-10 to 10%
	Intense Precipitation (1958-2007) P_{20} 25 to 50 mm	P_{20} 10 to 15%
	Freezing precipitation (rain and drizzle) average (1961-1990) **Precipitation: <25hrs** **Rain: <10hrs**	Increasing
WIND **See Note 2**	**Intense Winter Storms** <970hpa central pressure Northern Hemisphere **(1950-2000) 8%**	8 to 15%

* Note: North East parts of this region were cooling from 1950 to early 1990s and warming since. See Note 5 for explanation.

	OBSERVED TRENDS	BY 2050 (from 2010)
RIVERFLOW **See Note 3**	**Dates of Spring break-up (1948-2002)** Earlier date non-significant	Continue earlier especially in western areas As ice free season on Hudson Bay increases towards late November to December, greater snow pack will accumulate in early winter in western areas.
	Streamflow (1967-1996) Annual: 0 to 20% Minimum Daily: -10% Maximum Daily: -10%	increases Annual and Maximum Continued decrease minimum
SEA LEVEL **See Note 4**	Mean (1993-2007) 3.2cm/decade	15 to 25cm
PERMAFROST THAW	Occurring in discontinuous permafrost areas	13 of 14 community airports threatened with disruption. Greatest impact James Bay lowlands
WILDFIRES	National: Additional 100,000km^2 burned per ^{o}C average temperature increase - 1970-2000. Regional average 400,000ha. (1959-1997) area burned	50% increase in area burned

Note 1: Ranges in observed and projected values indicate differences over the region.

Note 2: Wind-disaster records of Public Safety Canada indicate for storms >100km/h national frequency rose 16% from 1970 to 1990 with most in coastal regions, except for tornadoes.

Note 3: Major floods and landslides (from PSC data base), where intense rains, or rain on snow, apparently increased 80% nationally between the 1970s and 1990s. However, 1970s event recording may have been less thorough than in 1990s. Data base extends only to 2005. Flash floods in small watersheds more frequent with rain on snow events spring and rain events in summer.

Note 4: Sea level and storm surges: Sensitivity to sea level rise and storm surge is high to moderate in much of Ungava Bay, and a few embayments in Northern Labrador. Sea ice to protect shores from erosion and damages gradually reduced on Hudson Bay and other coasts. While much of St. Lawrence North Shore is rising, erosion with reduced ice and storm surges is increasing problem (see N.B. and P.E.I.). Higher sea levels extend up St. Lawrence River estuary. For a 20cm increase in sea level (by 2050) a 14cm rise expected at Quebec city and Rimouski. By then damaging storm surges at Rimouski would be 3 times more frequent.

Note 5: Newfoundland and Labrador and Eastern Arctic: The North Atlantic Oscillation (NAO), linked to the Arctic Oscillation (AO), is a mode of the internal variation of the global climate system that periodically changes from positive to negative. In its positive phase it brings colder water and air to coastal regions of Labrador and Newfoundland with strong north-easterly winds. The negative phase of NAO brings warmer conditions with warmer, drier winters especially in eastern coastal regions. Temperature trends from 1950 to 1998 reflect a mainly positive NAO phase. There is a hint in climate model outputs that positive NAO may be more frequent in a greenhouse gas forced climate. Thus, general warming in inland (western) parts of Newfoundland and Labrador are likely to be faster than that felt along the east coast.

REGION: EASTERN NUNAVUT (Baffin and Ellesmere Islands) PAGE 1

	OBSERVED TRENDS	BY 2050 (from 2010)

TEMPERATURE

See Note 1

See Note 5

Temperature ^{o}C (1950-2007)*

	Max. ^{o}C	Min. ^{o}C	By 2050 (from 2010) ^{o}C
Annual	0	0 to 0.5	2 to 4
Winter	-0.5 to 0.5	-0.5 to 0.5	3 to 4
Spring	-0.5 to 0.5	-0.5 to 0	2 to 4
Summer	0.5 to 0	0.5 to 0	1 to 2
Autumn	1 to 0	1.5 to 0	3 to 4

Temperature Extremes (1981-2007)

Observed	By 2050 (from 2010)
Frost Free Season: Start -10days, End 30 days later	20 days
Heating degree days: -100 to -500	-300 degree days

Temperature Trends - Eureka (1972-2007)

	Observed	By 2050 (from 2010)
Annual	0.88°C/dec.	As above
Winter	0.67°C/dec	
Spring	1.14°C/dec	
Summer	0.42°C/dec	
Autumn	1.25°C/dec	

PRECIPITATION

See Note 1

Precipitation (1950-2007) %

	Observed %	By 2050 (from 2010) %
Annual	10S to 35N	10 to 25
Winter	-20S to 45N	10 to 25
Spring	15S to 45N	10 to 20
Summer	15S to 20N	5 to 10
Autumn	20S to 40N	15 to 35

Ratio of Snow to Total Precipitation (1950-2003)

	Observed	By 2050 (from 2010)
Annual	0 S to 5 N	0
Winter	15	5
Spring	0	-5
Autumn	10 S to 0 N	0

See Note 3

Intense Precipitation (1981-2000)

Observed	By 2050 (from 2010)
P_{20} 25 to 50 mm S 10 to 25mm N (Average values)	P_{20} 10 to 20% $P_{20} \rightarrow P_{7 \text{ to } 15}$

PRECIPITATION Cont'd	**EASTERN NUNAVUT PAGE 2** **Freezing precipitation (rain and drizzle) average (1961-1990)** Precipitation: <25hrs Rain: <10hrs Trend: 5 to 20% (1953 to 2004)	8% Increase/decade especially spring
WIND **See Note 2**	**Intense Winter Storms** Northern Hemisphere (1950-2000) 8%	8 to 15%
RIVERFLOW	**Dates of Spring break-up (1950-2005)** Earlier date non-significant	Continue earlier
See Note 3	**Streamflow (1967-1996)** Annual Minimum Daily *NO DATA* Maximum daily	Decrease autumn, Increase spring
SEA LEVEL **See Note 4**	Mean (1993-2007) 3.2cm/decade	15 to 25cm
PERMAFROST THAW	In discontinuous permafrost areas	Continuous permafrost becomes discontinuous in many areas.
GLACIERS	Mass loss Arctic archipelago $25km^3$/year (1995-2000)	Increase in loss of mass

Note 1: Ranges in observed and projected values indicate differences over the region.

Note 2: Wind-disaster records of Public Safety Canada indicate for storms >100km/h national frequency rose 16% from 1970 to 1990 with most in coastal regions, except for tornadoes.

Note 3: Major floods and landslides (from PSC data base), where intense rains, or rain on snow, apparently increased 80% nationally between the 1970s and 1990s. However, 1970s event recording may have been less thorough than in 1990s. Data base extends only to 2005. Increasing frequency heavy rain or snow, spring and summer, Baffin Island causing floods, e.g. Pangnirtung, June 2008.

Note 4: Sea level and storm surges: Sea ice to protect shores from erosion and damages being reduced.

Note 5: Re Arctic Archipelago: The most completely analyzed climate record in the Canadian Arctic archipelago is for Eureka on Western Ellesmere Island at 79.98°N and 85.93°W. This is near the dividing line between Western and Eastern Nunavut. Observations taken 7 times a day from 1953 to 2007 reveal a strong reversal of temperature trends in the early 1970s. Temperatures were falling from 1960 to 1972 but have shown a strong rise since then, with a trend of +0.88 degrees per decade. Winter trends since 1972 have been 0.67 degrees/decade, spring: 1.14 degrees/decade, summer: 0.42 degrees/decade and autumn: 1.25 degrees/decade. Similar annual trends were found for 11 stations North of 75°N by the Goddard Institute for Space Studies. With large scale climate change driven overwhelmingly by greenhouse gases since about 1970, it can be assumed that the observed rising trend since 1972 will continue. The falling temperature trend from 1953 to 1970 was due probably to internal variability through the Arctic and North Atlantic Oscillations. Thus for indications of future trends the warming of the past approximately 4 decades is likely to continue and accelerate as climate models suggest and as more ice disappears from the surrounding seas. Unfortunately for this analysis published trend data for elsewhere in the Arctic is for 1900 to 2007 and 1950 to 2007 (Vincent and Mekis 2009) which include the cooling phase and the greenhouse gas driven warming and so substantially underestimates current and projected warming rates for the next 4 decades.

Note 6: In recent years, a surface wind of 120 km/hr has been observed at Iqaluit, and 132 km/hr at Pangnirtung (Feb. 2010). Both were influenced by downslope terrain.

	OBSERVED (TRENDS)	BY 2050 (from 2010)
TEMPERATURE **See Note 1**	**Temperature °C (1950-2007)**	°C
	Annual — Max. °C: - 0.5 to 0.5; Min. °C: -0.5 to 0.5	2.5
	Winter — Max. °C: -1.5 to 0.5; Min. °C: -0.5 to 0.5	3
	Spring — Max. °C: 0 to 0.5; Min. °C: 0 to 0.5	2.5
	Summer — Max. °C: 0.5; Min. °C: 0.5 to 1.5	2 to 3
	Autumn — Max. °C: -0.5; Min. °C: 0 to 0.5	2.5
	Temperature Extremes (1950-2007) Frost free days: 10 to 30 Growing season >5°C: 10 to 20 days	20 days 20 days T_{max20}: 2 to 4 °C $T_{min\ 20}$: 4 to 6 °C
PRECIPITATION **See Note 1**	**Precipitation (1950-2007)** %	%
	Annual: -20 to 20	0 to 10
	Winter: -5 to -10	0 to 10
	Spring: 5 to 10	5 to 15
	Summer: -10 to 10	-5 to 10
	Autumn: 5 to 15	0 to 5
	Ratio of Snow to Total Precipitation (1950-2007)	
	Annual: 0 to 5	- 10
	Winter: 0 to 5	-10
	Spring: 0 to 5	- 10
	Autumn: 0 to 5	-10
	Intense Precipitation (1958-2007) For NB Amounts of Precipitation in severe Events (>99 percentile) 67% (adjacent USA Maine) Frequency heavy daily rain (>99 percentile) 58% (adjacent USA)	P_{20} 10%+ (severity) $P_{20} \rightarrow P_{10\ to\ 15}$ (frequency)

NEW BRUNSWICK and PRINCE EDWARD ISLAND PAGE 2

	OBSERVED (TRENDS)	**BY 2050 (from 2010)**
WIND **See Note 2**	**Intense Winter Storms N. Hemisphere** 1950 to 2000 (<970hpa) Numbers 8%	8 to 15%
	Significant Wave Heights (1950-2000) 2 cm	5 cm
	Hurricanes (June to Nov.)	More frequent intense events
RIVERFLOW	**Dates of Spring break-up (1948-2002)** Several times causing ice jams and floods	Continued multiple breakups Average 5 days earlier
See Note 3	**Streamflow (1967-1996)** **%** Annual: -30% Minimum daily: -20 to -30 Maximum daily: -20 to -30	-30% Lower minima
SEA LEVEL **See Note 4**	Mean (1993-2007) +3.2cm/decade (Also land subsiding)	15 to 25cm
	Storm Surge Southern Gulf >3.6M (2000) 1 in 40 years	>4m 1 in 20 yrs >3.6m 1 in 2 yrs
FREEZING PRECIPITATION	Average (1961-1990) Precipitation (rain + drizzle): 50 hours Rain: 25 hours	Little change but more in winter, less in spring.

Note 1: Ranges in observed and projected values indicate differences over the region.

Note 2: Wind-disaster records of Public Safety Canada indicate for storms >100km/h national frequency rose 16% from 1970 to 1990 with most in coastal regions, except for tornadoes.

Hurricanes or hurricane spawned storms, more frequent in Atlantic Provinces, as water temperatures in source region increases (2°C by 2050). Path of hurricanes unlikely to change but more intense storms will survive the long path from source regions in southern North Atlantic.

Note 3: Major floods and landslides (from PSC data base), where intense rains, or rain on snow, apparently increased 80% nationally between the 1970s and 1990s. However, 1970s event recording may have been less thorough than in 1990s. Data base extends only to 2005. Flash floods in small watersheds increase spring and summer, due to heavy rains, and in autumn with more frequent hurricanes.

Note 4: Sea level and storm surges: Rising relative sea level plus increase in frequency of intense winter storms and hurricanes suggest much more frequent storm surge flooding in future as indicated in tables.

	OBSERVED (TRENDS)	BY 2050 (from 2010)
TEMPERATURE **See Note 1**	**Temperature °C (1950-2007)** **Max. °C / Min. °C** Annual: -0.5 to 0.5 / -0.5 to 0.5 Winter: 0 to -0.5 / -0.5 to -1 Spring: 0 / 0.5 Summer: 1 / 1 Autumn: -0.5 to 0 / 0 to 0.5	**°C** Annual: 2 to 3 Winter: 2 to 4 Spring: 2 Summer: 2 to 3 Autumn: 2 to 3
	Temperature Extremes (1950-2007) Frost free days 10 to 20 Growing Season 10 to 20 days	days 20 15
PRECIPITATION **See Note 1**	**Precipitation (1950-2007)** **%** Annual: 5 to 30% of long term average Winter: -5 to 5 Spring: 15 to 20 Summer: -5 to 5 Autumn: 5 to 15	% Annual: 0 to 10 Winter: 0 to 10 Spring: 10 to 15 Summer: 0 to 5 Autumn: 10 to 15
	Ratio of Snow to Total Precipitation (1950-2003 % Annual: 0 to 5 Winter: 5 Spring: 5 Autumn: 5	% Annual: -8 Winter: -5 Spring: -5 Autumn: -5
	Intense Precipitation (1958-2007) P_{20} 50mm to 75mm Days with severe events - rain (>95percentile) 2 to 4 (See Hurricanes under Note 2)	P_{20}: 5 to 10% (Severity) $P_{20} \rightarrow P_{10\text{-}15}$ (frequency)
	Freezing precipitation (rain and drizzle) average (1961-1990) **Precipitation: 50 hours** **Rain: 25 hours**	Little change, more winter less in spring

	OBSERVED (TRENDS)	BY 2050 (from 2010)
WIND **See Note 2**	**Intense Winter Storms** <970hpa central Northern Hemisphere pressure 8% (1950-2000)	8 to 15%
	Significant Wave Heights (1950-2000) 2 cm	5cm
See Note 2	**Hurricanes** **(June to Nov.)**	More frequent intense events
RIVERFLOW	**Dates of Spring break-up (1967-1996)** Non significant delay	3 days earlier
See Note 3	**Streamflow (1967-1996) %** Annual: -20 to -30 Minimum daily: -30W to 30E Maximum daily: -10 to 20	% -20 -15 to 10 10
SEA LEVEL **See Note 4**	Mean (1993-2007) +3.2cm/decade	15 to 25cm

Note 1: Ranges in observed and projected values indicate differences over the region.

Note 2: Wind-disaster records of Public Safety Canada indicate for storms >100km/h national frequency rose 16% from 1970 to 1990 with most in coastal regions, except for tornadoes.

Hurricanes or hurricane spawned storms, more frequent in Atlantic Provinces, as water temperatures in source region increase (2^{o}C by 2050). Path of hurricanes unlikely to change but more intense storms will survive the long path from source regions in southern North Atlantic.

Note 3: Major floods and landslides (from PSC data base), where intense rains, or rain on snow, apparently increased 80% nationally between the 1970s and 1990s. However, 1970s event recording may have been less thorough than in 1990s. Data base extends only to 2005. More flash floods from heavy rain and hurricane events – spring, summer, autumn.

Note 4: Sea level and storm surges: Rising sea level affects all coastal regions, exacerbated by storm surges from more frequent severe winter storms and hurricanes (see under WIND above).
See: Storm surges for Gulf of St. Lawrence coast under New Brunswick and Prince Edward Island.

REGION: NEWFOUNDLAND* PAGE 1

	OBSERVED TRENDS	BY 2050 (from 2010)
TEMPERATURE **See Notes 1 and 5**	**Temperature °C (1950-2007)**	

Temperature	Max. °C	Min. °C	By 2050 °C
Annual	0 to -0.5	-1	2.5
Winter	-1.5	-0.5 to -2.5	2 to 4
Spring	0.5	-0.5 to 0.5	2
Summer	0.5 to 1	0.5 to 1.5	2 to 4
Autumn	0	0.5 to 1	2 to 4

Temperature Extremes (1950-2007)	Observed	By 2050
Frost Free Days	5 to 30	30
Growing season ≥5°C:	0 to 20W	20 central and West

PRECIPITATION

See Note 1

Precipitation (1950-2007)	%	By 2050 %
Annual	10 to 15	5
Winter	-5 to 5	10
Spring	0 to 10	5
Summer	10	0 to 5
Autumn	10	5
		5

Ratio of Snow to Total Precipitation (1950-2003)	%	By 2050 %
Annual	3	-10
Winter	6	-10
Spring	-6	- 5
Autumn	6	-5

Intense Precipitation (1950-2007)	By 2050
$P_{20:}$ 50 to 75mm: Average (1981-2000) Frequency heavy rain amounts (>99%) increase 2 to 4 days over period	P_{20}: 5 to 10% P_{20}: → P_{10}

- For Labrador, see North and Central Quebec and Labrador.
  (These are climatic, not political regions.)

	OBSERVED TRENDS		BY 2050 (from 2010)
WIND **See Note 2**	**Intense Winter Storms N. Hemisphere (1950-2000)** <970hpa central pressure **8%**		8 to 15%
	Significant Wave Heights (1950-2000) 2cm		5cm
	Hurricanes (**See Note 2)**		More frequent intense events
RIVERFLOW	**Dates of Spring break-up (1950-2005)** Earlier: non-significant trend		10 days
See Note 3	**Streamflow (1967-1996)**	**%**	%
	Annual	-10 to -30 except +10 SE	-20
	Minimum Daily	-30	-30
	Maximum daily	10 to -10	0
SEA LEVEL **See Note 4**	Mean (1993-2007) 3.2cm/decade		15 to 25cm
Freezing Precipitation (1961-1990)	Rain plus drizzle 50 hrs W to 150 hrs E Rain 25 hrs W		Increase

Note 1: Ranges in observed and projected values indicate differences over the region.

Note 2: **Wind-disaster records of Public Safety Canada** indicate for storms >100km/h national frequency rose 16% from 1970 to 1990 with most in coastal regions, except for tornadoes. **Hurricanes or hurricane spawned storms,** more frequent in Atlantic Provinces, as water temperatures in source region increase (2^{o}C by 2050). Path of hurricanes unlikely to change but more intense storms will survive the long path from source regions in southern North Atlantic.

Note 3: **Major floods and landslides** (from PSC data base), where intense rains, or rain on snow, apparently increased 80% nationally between the 1970s and 1990s. However, 1970s event recording may have been less thorough than in 1990s. Data base extends only to 2005. More flash floods in intense rain events and hurricanes – spring, summer, autumn.

Note 4: Sea level and storm surges: 40 year return period storm surge ~1m near Middle Arm. Most of coast not vulnerable but beaches impacted by hurricanes 5 times from 1990 to 2005. Severe winter storms and hurricanes becoming more frequent, reducing return period and increasing damages (see under WIND above).

Note 5: Newfoundland and Labrador and Eastern Arctic: The North Atlantic Oscillation (NAO), linked to the Arctic Oscillation (AO), is a mode of the internal variation of the global climate system that periodically changes from positive to negative. In its positive phase it brings colder water and air to coastal regions of Eastern Arctic, Labrador and Newfoundland with strong north-easterly winds. The negative phase of NAO brings warmer conditions with warmer, drier winters especially in eastern coastal regions. Temperature trends from 1950 to 1998 reflect a mainly positive NAO phase. There is a hint in climate model outputs that positive NAO may be more frequent in a greenhouse gas forced climate. Thus, general warming in inland and western parts of Newfoundland and Labrador are likely to be faster than that felt along the east coast.

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