November 1-2, 2017

Supplemental Climate Information: York Factory National Historic Site and Wapusk National Park

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Parks Canada Parcs Canada

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Preface

This is a supplement to the "Let's Talks about Climate Change: Arctic and Hudson Plains Region" report (Parker, 2017) and is intended to support discussion at a climate change adaptation workshop for York Factory National Historic Site on November 1-2, 2017.

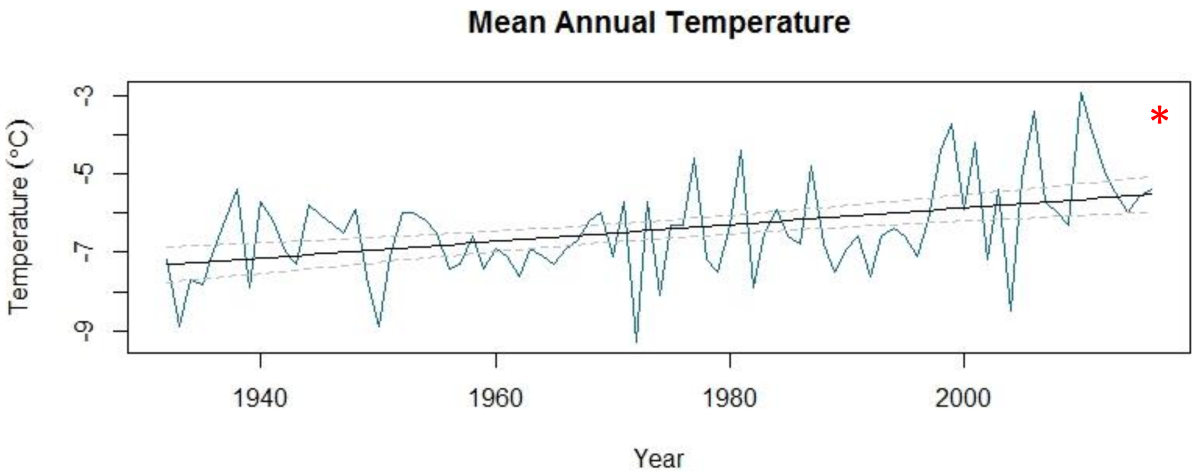
Disclaimer

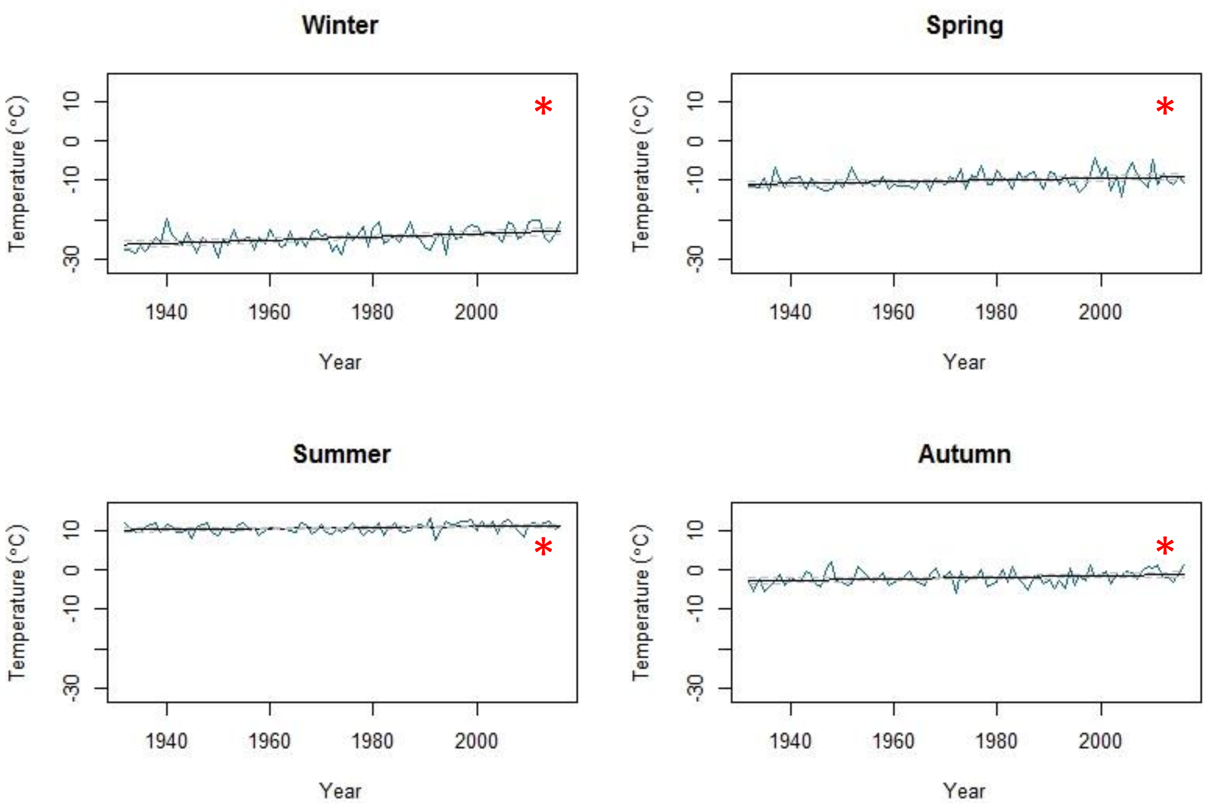
Views, statements, findings and conclusions are solely those of the author and do not necessarily reflect the views and policies of Parks Canada. Although the author has made every effort to ensure that the information is accurate, complete and correct, neither Parks Canada nor the author can guarantee its integrity. Readers are encouraged to review original sources.

1. Observed Climate Trends

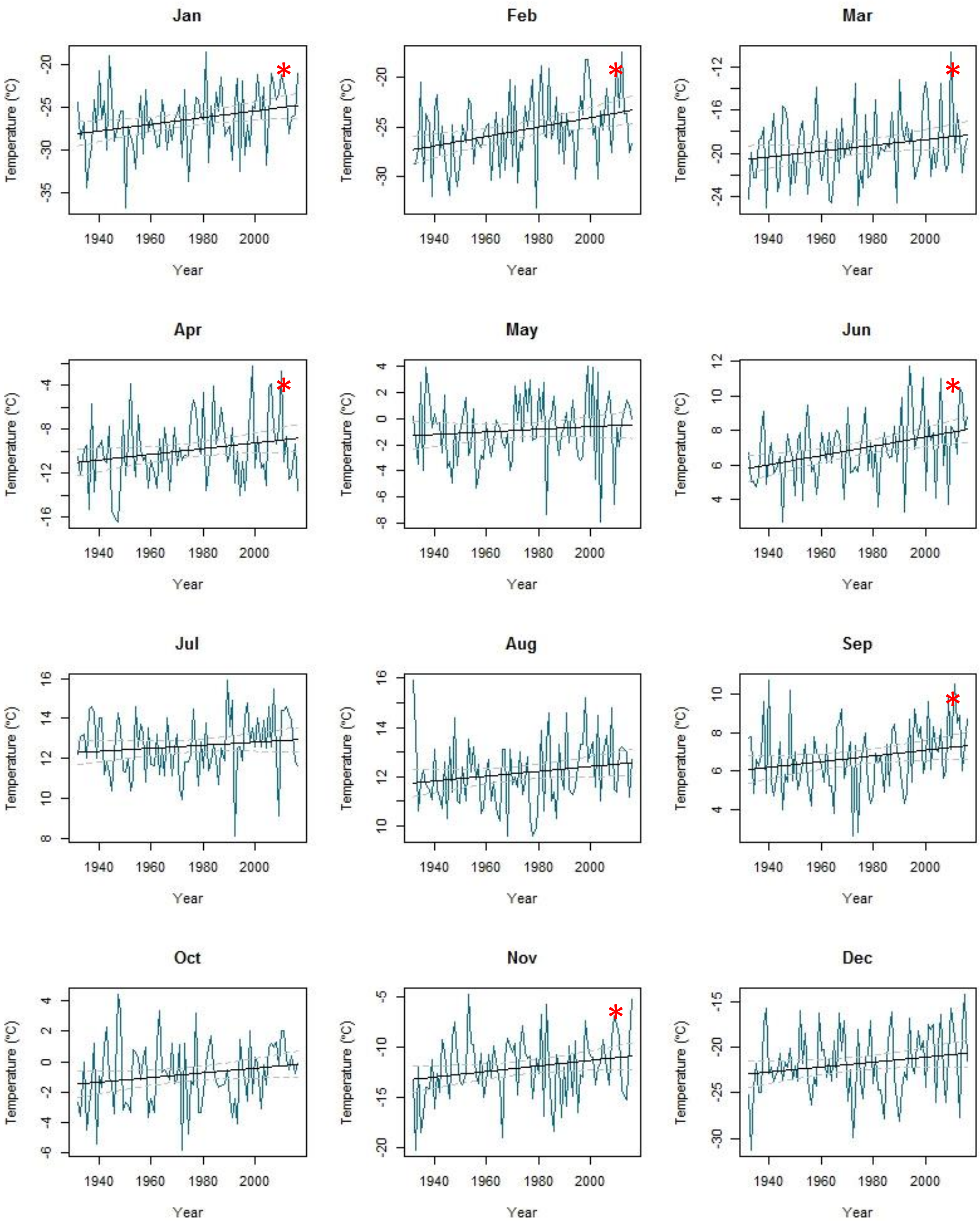
1.1 Temperature

Mean monthly temperature at Churchill climatological station (5060595) from 1932 to 2016 (ECCC, 2017). Trend determined using a generalized linear model (R Core Team, 2014) including 95% confidence intervals. "*" = statistically significant trend ($P<0.05$).



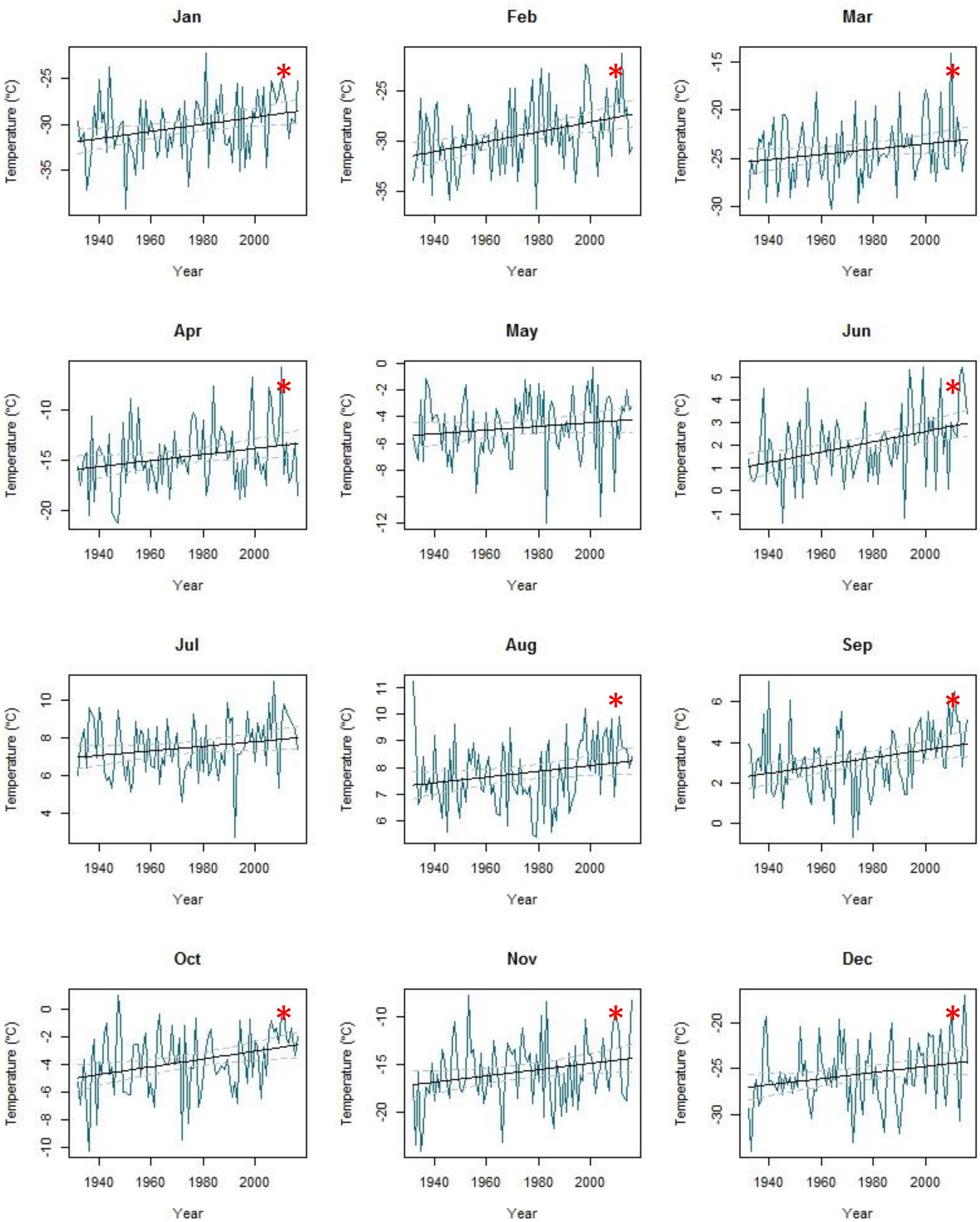


Mean annual temperature has increased by ~1.8°C since 1932. All seasons have demonstrated a statistically significant increases, the greatest being observed for winter (Dec, Jan, Feb), ~3.4°C since 1932. Summer (Jun, Jul, Aug) has increased by ~1.1°C.

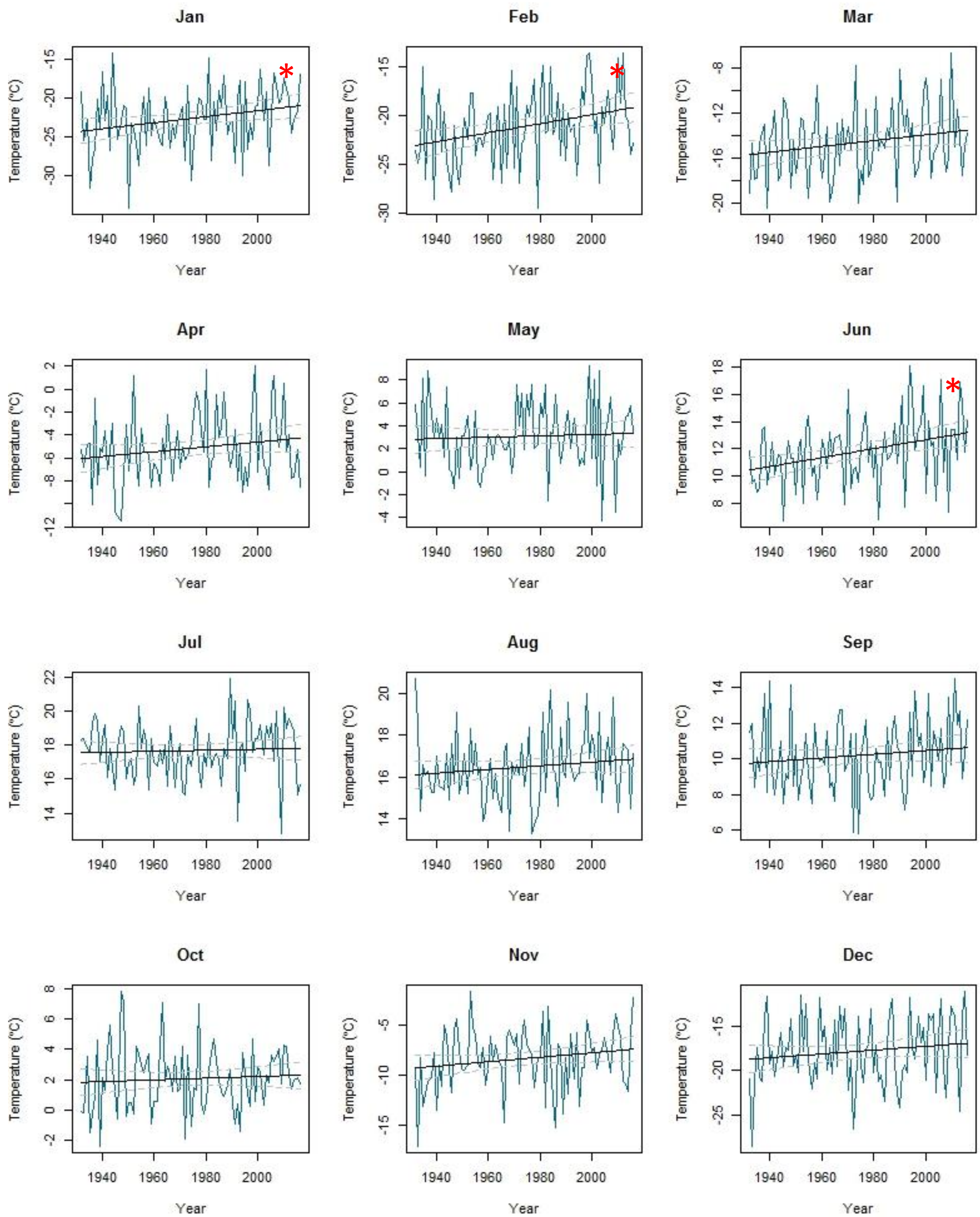


Greatest increase observed for Feb, ~4°C since 1932.

Mean Monthly Minimum Temperature

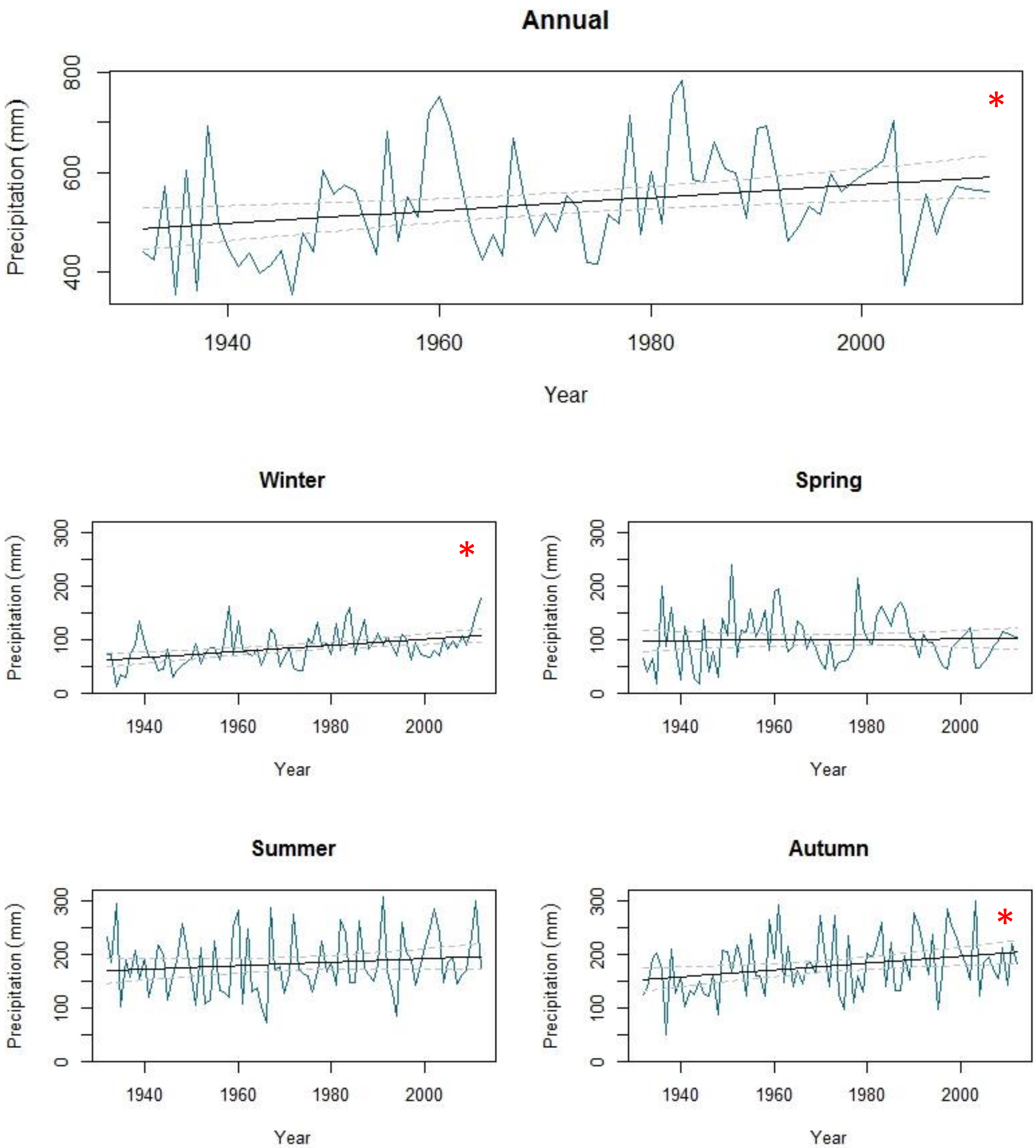


Mean Monthly Maximum Temperature

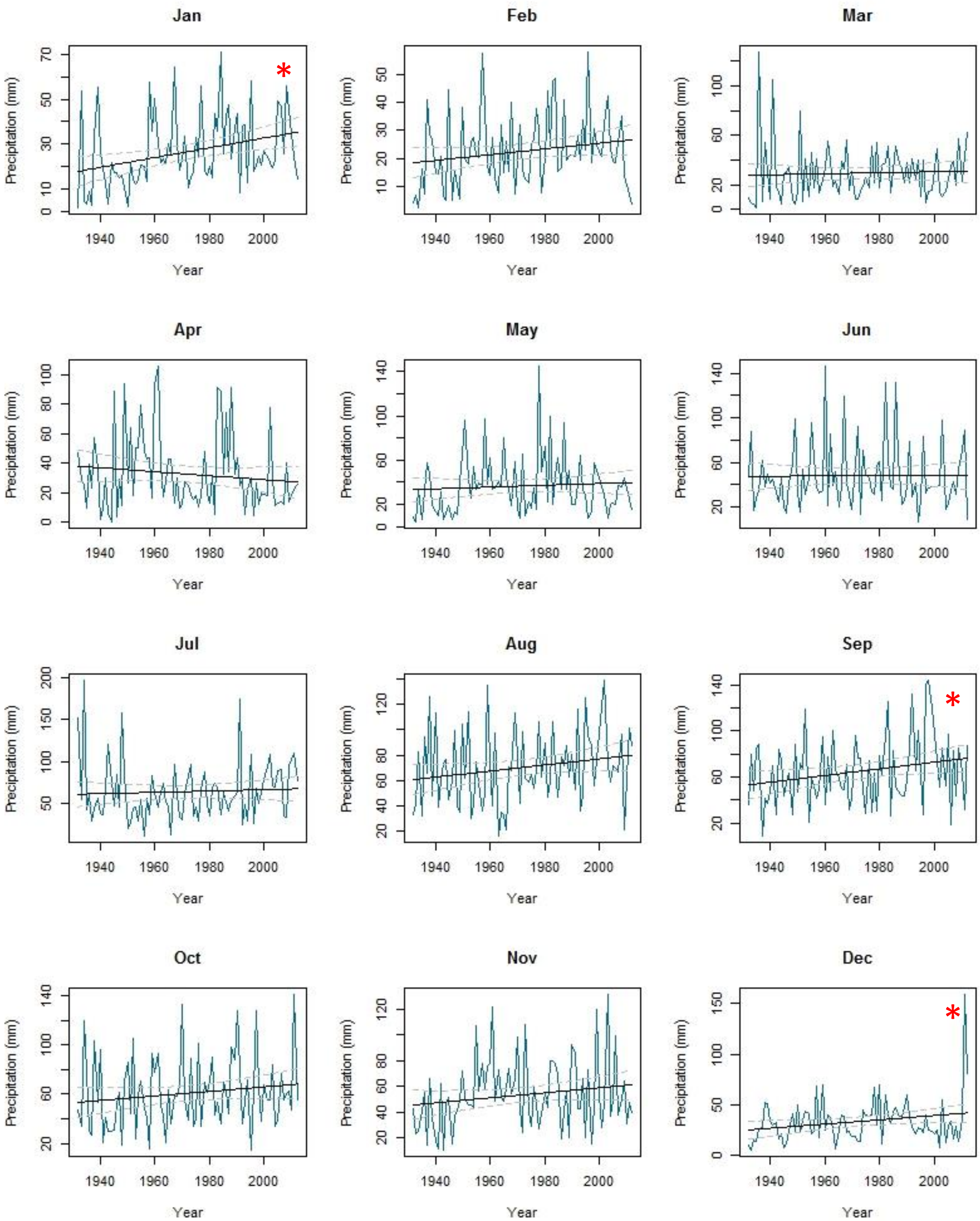


1.2 Precipitation

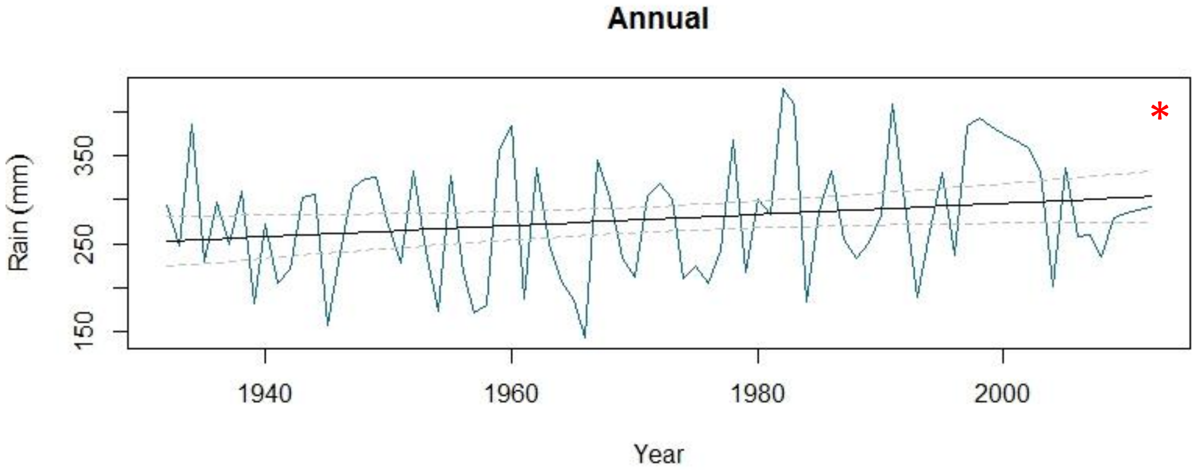
Total precipitation at Churchill climatological station (5060606) from 1932 to 2012 (ECCC, 2017). Trend determined using a generalized linear model (R Core Team, 2014) including 95% confidence intervals. "*" = statistically significant trend (P<0.05).



Total annual precipitation has increased by ~108 mm (22%) since 1932. Winter and autumn have shown statistically significant increases, the greatest being observed for autumn (Sep, Oct, Nov), ~54 mm (36%).

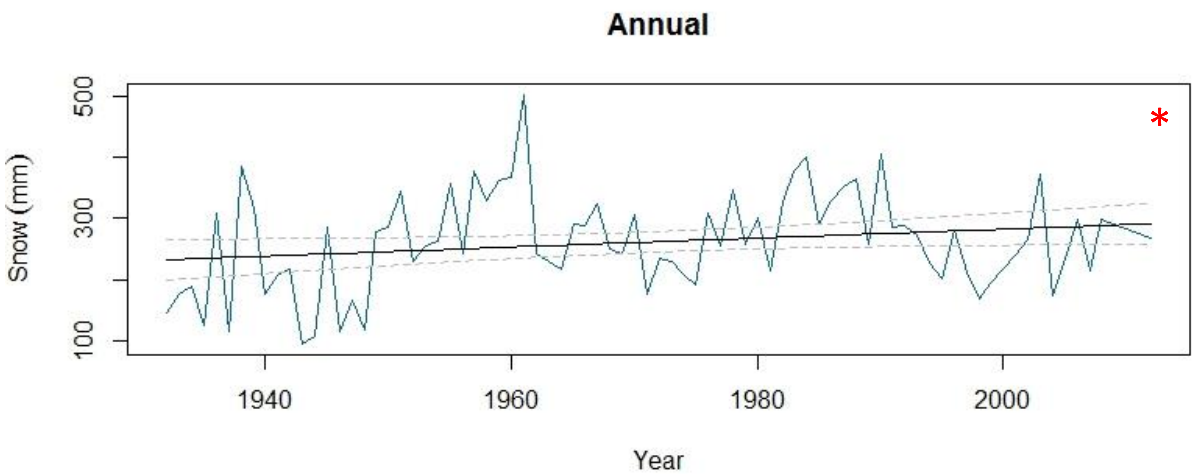

Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Precipitation (mm)
Year
1940
1960
1980
2000
*

Total Annual Rain



Total annual rain has demonstrated a statistically significant increase, ~53 mm (21%) since 1932.

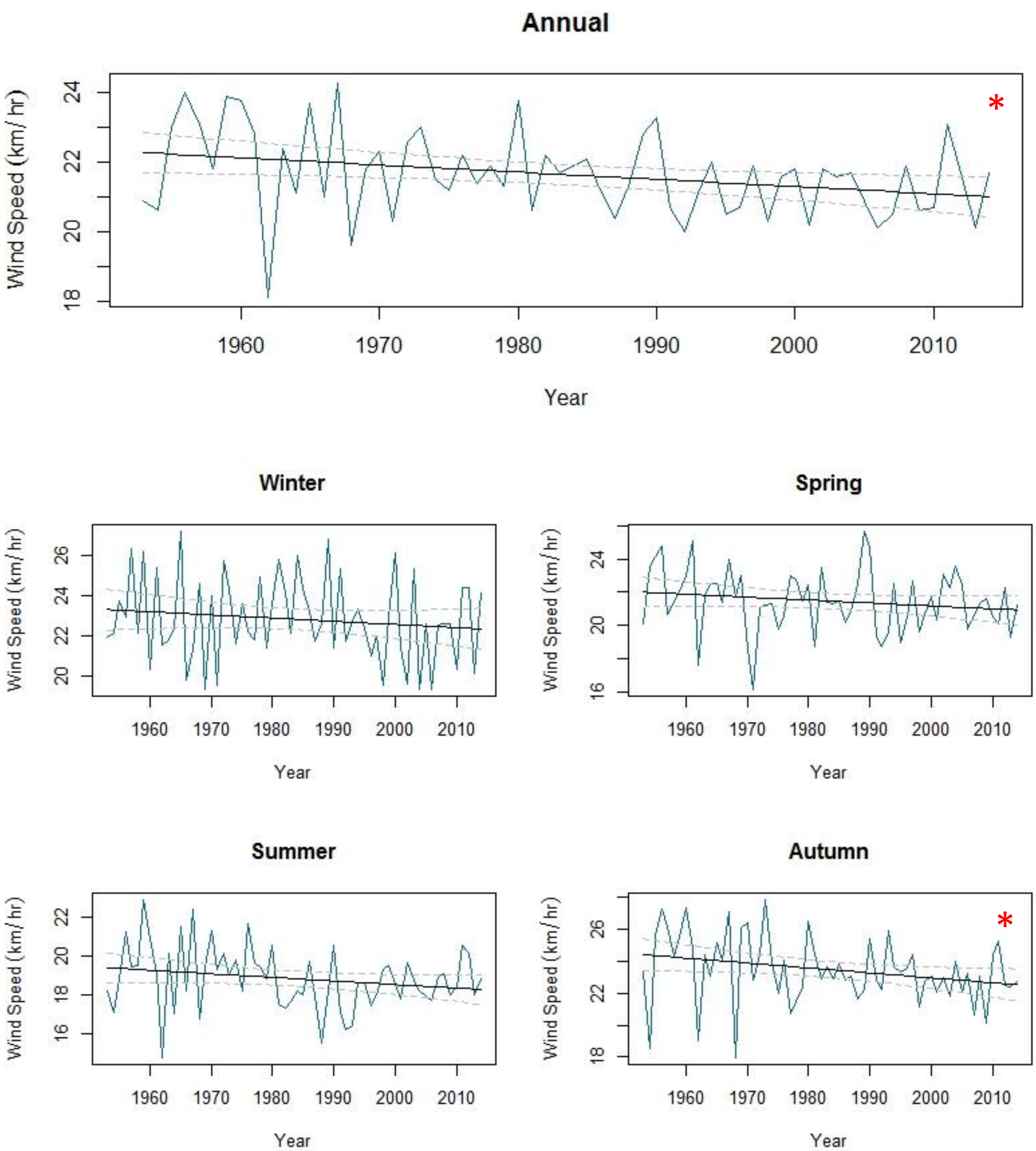
Total Annual Snow



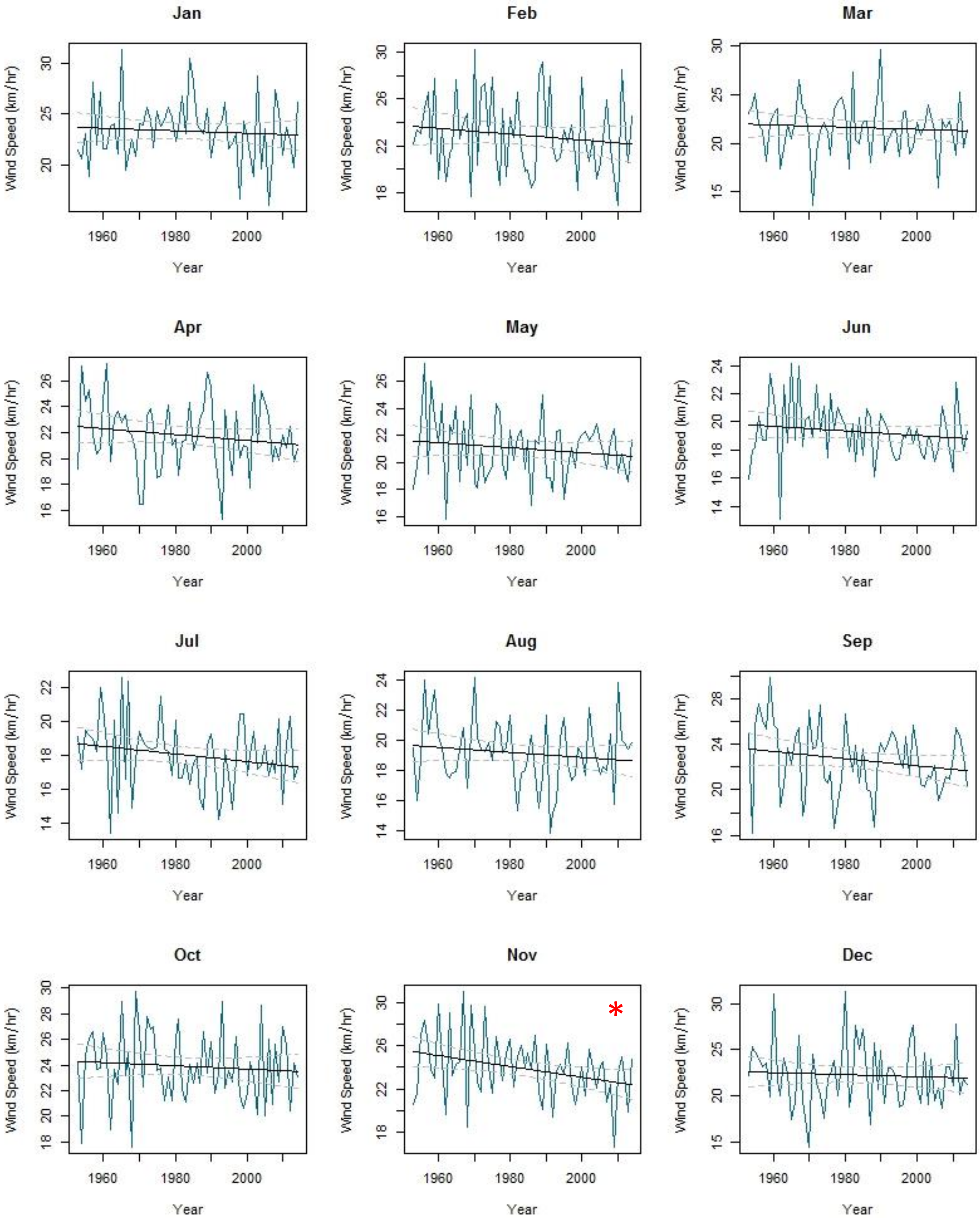
Total annual snow has demonstrated a statistically significant increase, ~62 mm (27%) since 1932.

1.3 Surface Wind Speed

Mean wind speeds at Churchill climatological station (5060600) from 1953 to 2014 (ECCC, 2017). Trend determined using a generalized linear model (R Core Team, 2014) including 95% confidence intervals. "*" = statistically significant trend (P<0.05).

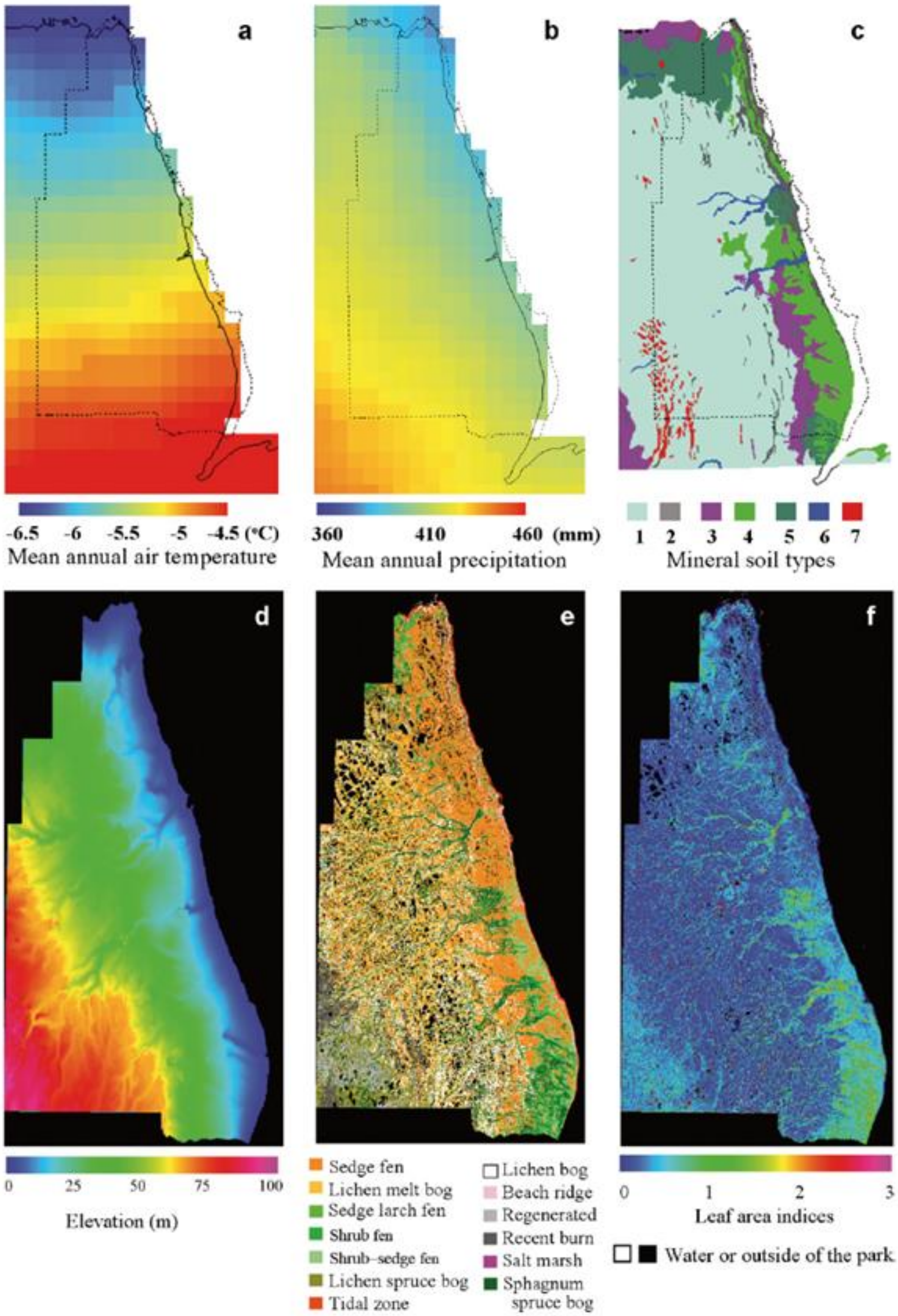


Mean annual wind speeds have demonstrated a statistically significant decrease by ~1.3 km/hr (6%) since 1953. Seasonally, autumn (Sep, Oct, Nov) has demonstrated the greatest decrease ~2 km/hr (8%) since 1953.



Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Wind Speed (km/hr)
Year
1960
1980
2000
*

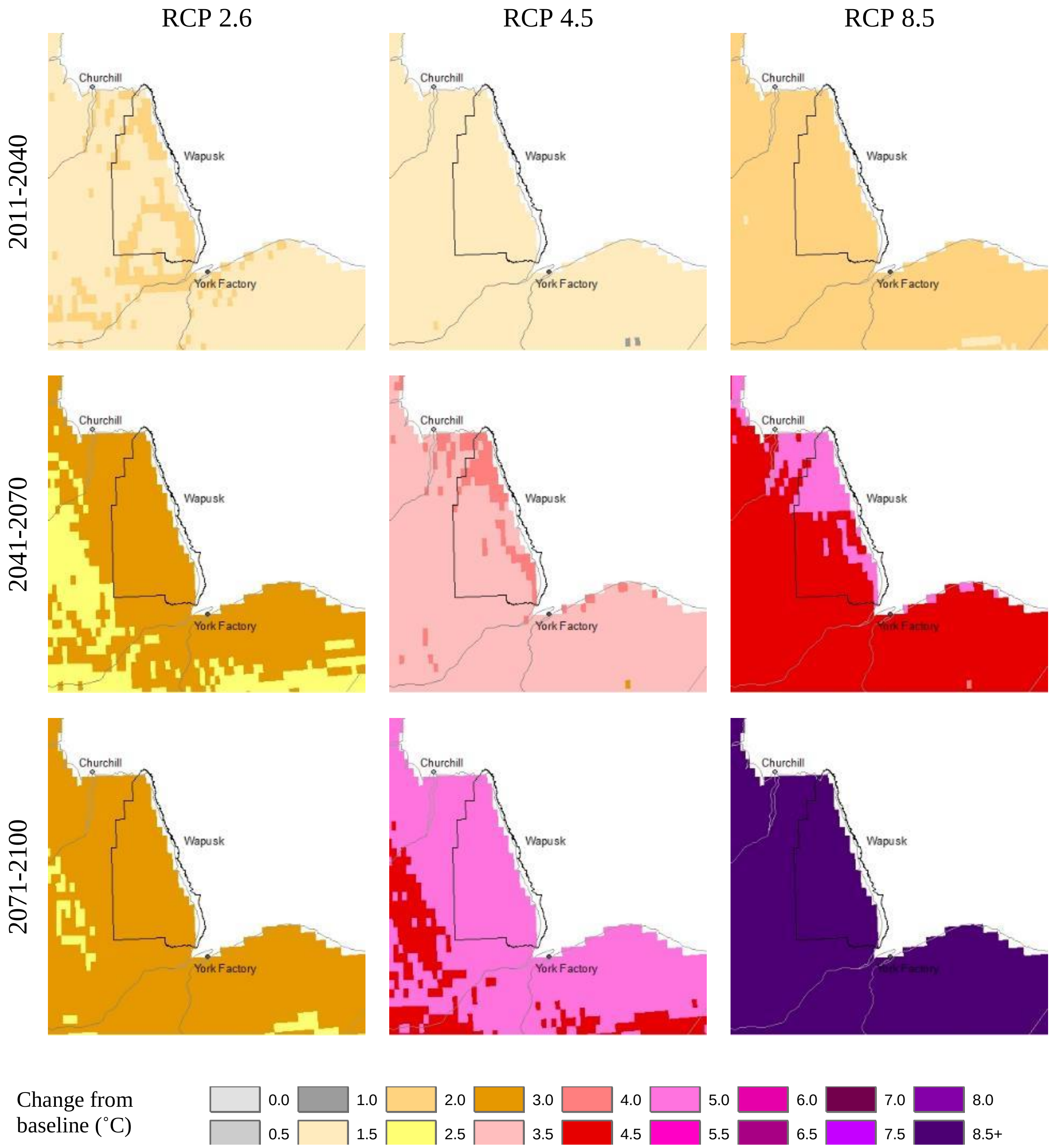
1.4 Regional Differences



Distribution of (a) mean annual temperature, (b) mean annual precipitation, (c) mineral soil conditions, (d) elevation, (e) land cover types, and (f) leaf area indices for Wapusk NP. Images from Zhang *et al*. (2012). Mean annual temperature in York Factory is ~1.5 ˚C warmer than Churchill, similarly total annual precipitation is ~50 mm greater in York Factory than Churchill.

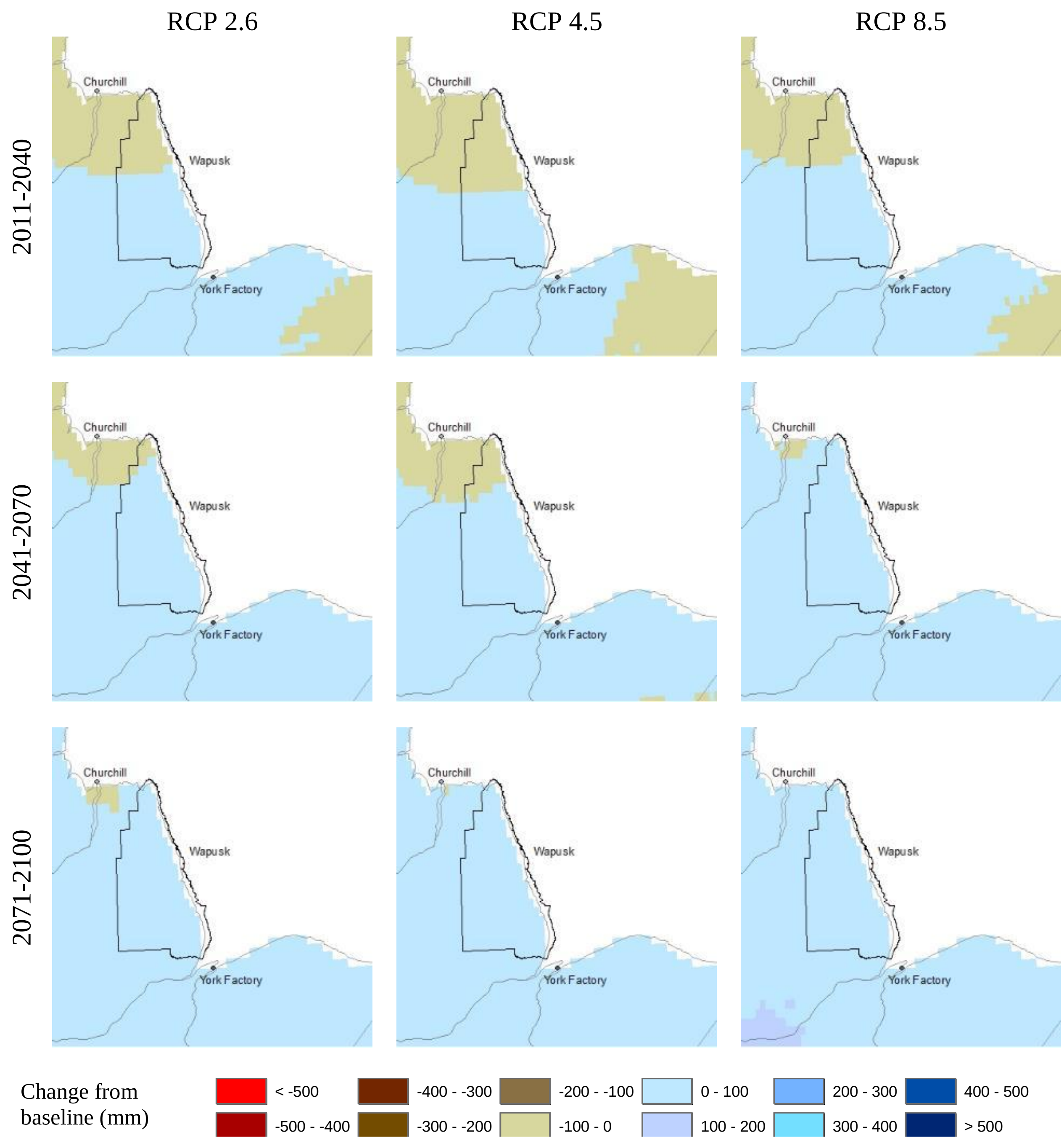
2. Projected Climate Trends

2.1 Temperature



Mean annual temperature increase for Churchill - York Factory area from 1980-2010 baseline. Composite projection of CanESM2, CESM1CAM5, HADGEM2ES and MIROCESM. Natural Resources Canada, Canadian Forest Service, http://cfs.nrcan.gc.ca/projects/3 (Price *et al.*, 2011).

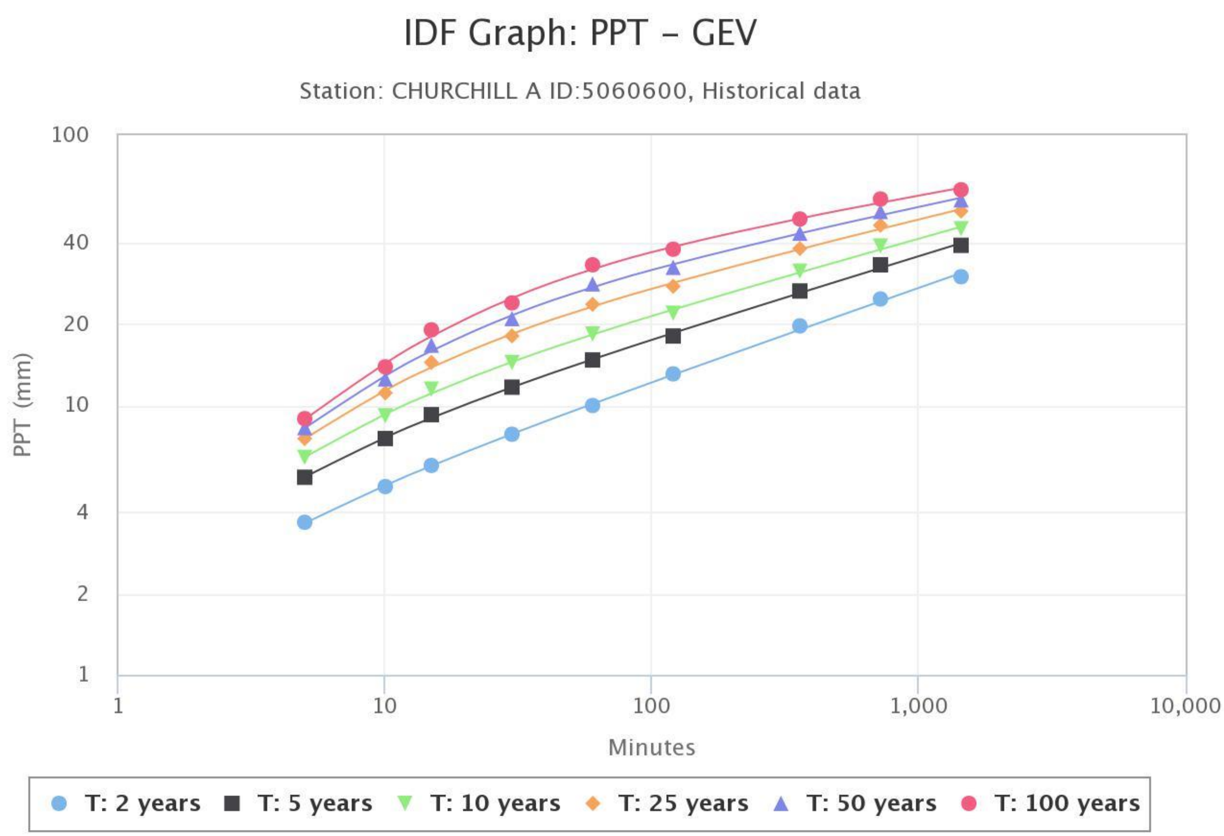
2.2 Precipitation



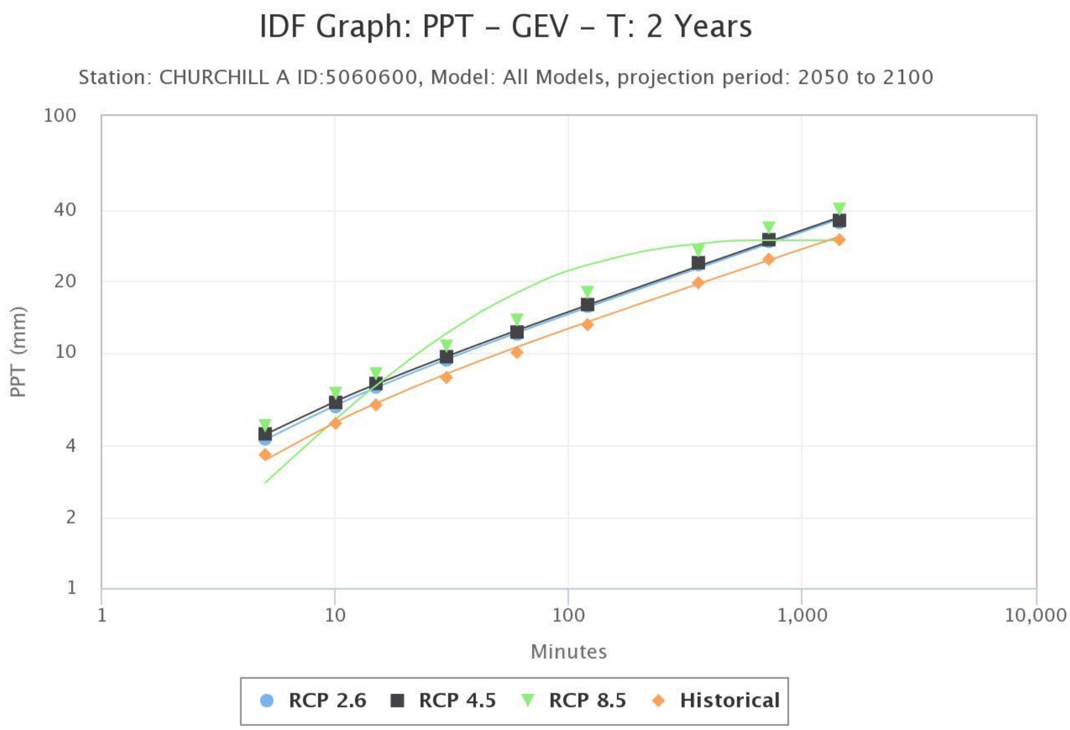
Total annual precipitation change for Churchill – York Factory area from 1980-2010 baseline. Composite projection of four spatially interpolated downscaled Global Circulation Models: CanESM2, CESM1CAM5, HADGEM2ES and MIROCESM. Data source Natural Resources Canada, Canadian Forest Service, http://cfs.nrcan.gc.ca/projects/3 (Price *et al.*, 2011).

2.3 Rainfall Intensity, Duration and Frequency (IDF)

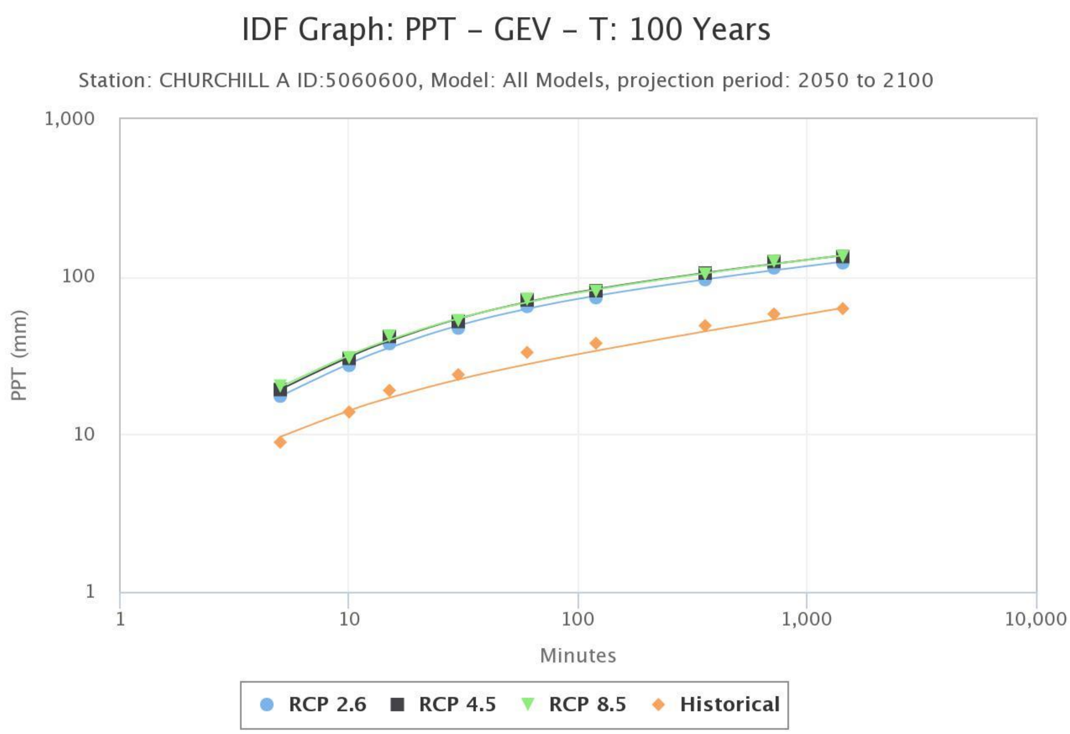
Extreme rainfalls calculated in IDF_CC Tool 2.0 (http://beta.idf-cc-uwo.ca/). The tool uses a Generalized Extreme Values (GEV) distribution. For more details on extreme rainfall events, see Simonovic *et al.* (2017).



Baseline total precipitation amounts for Churchill climatological station (5060600) from 1963-2002 for different return periods (T).



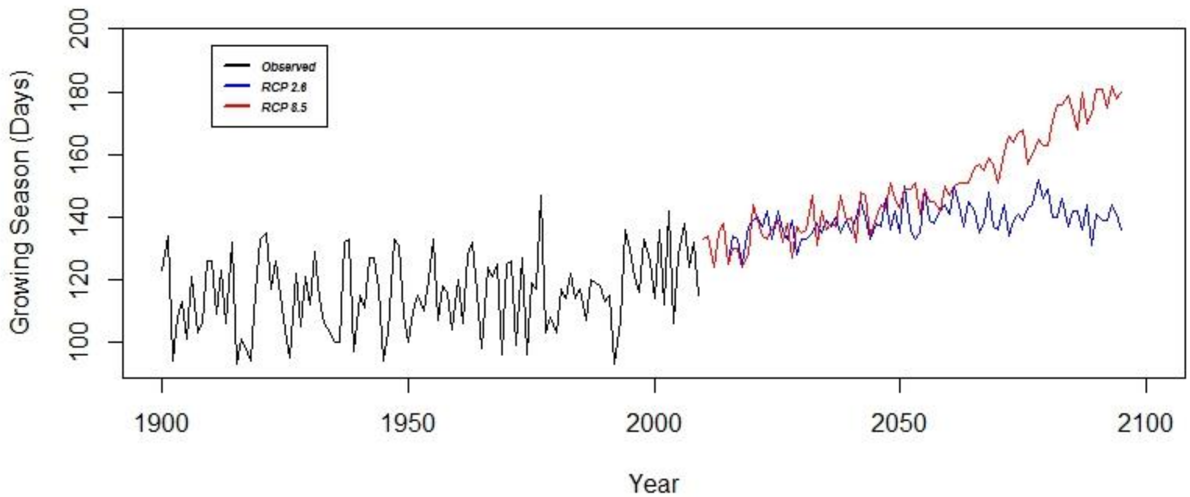
Projected total precipitation for **one in 5-year** events for the period 2050-2100 using ensemble of models.

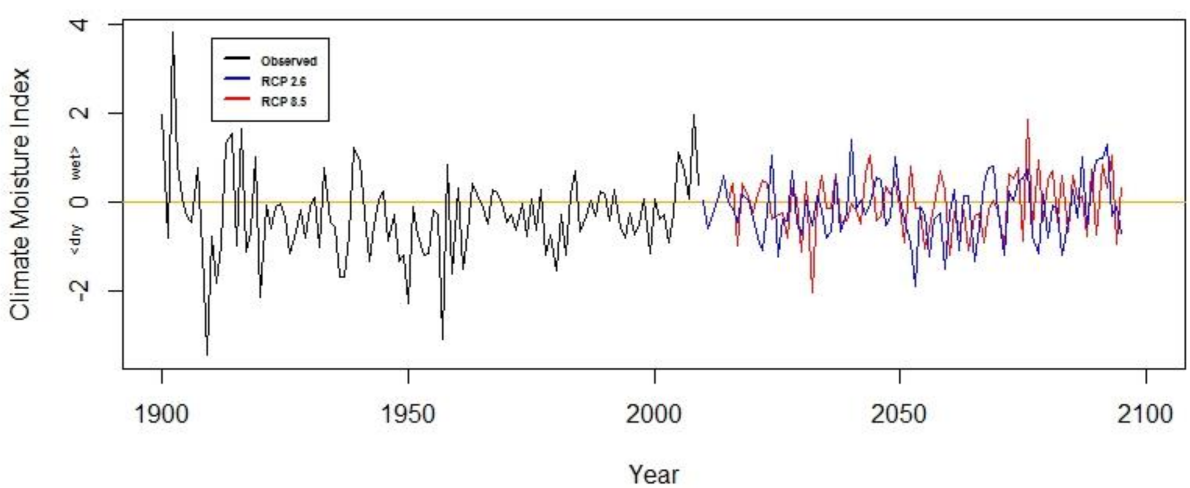


Projected total precipitation for **one in 100-year** events for the period 2050-2100 using an ensemble of climate models. One way to consider this, is that today's "one in 100 year" event (i.e., 62 mm/day) is projected to become a "one in 10 year" event (i.e., increase from a 1% to 10% probability/year event) and the future "one in 100 year" event is projected to increase 134 mm/day.

2.4 Growing Season and Climate Moisture Index

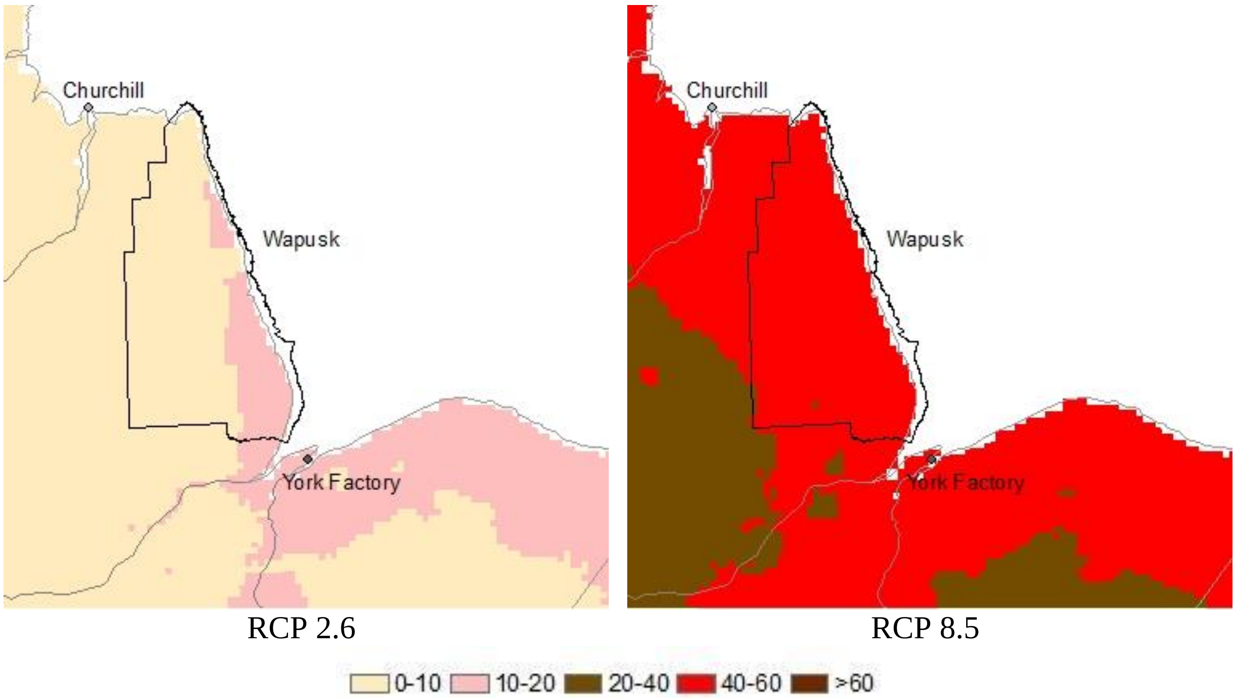
The Climate Moisture Index (CMI) is calculated as the difference between annual precipitation and potential evapotranspiration – the potential loss of water vapour from a landscape covered by vegetation (http://www.nrcan.gc.ca/forests/climate-change/forest-change/17772). A positive CMI value indicates wet or moist conditions and a negative indicates dry conditions.





3. Climate Change Impacts

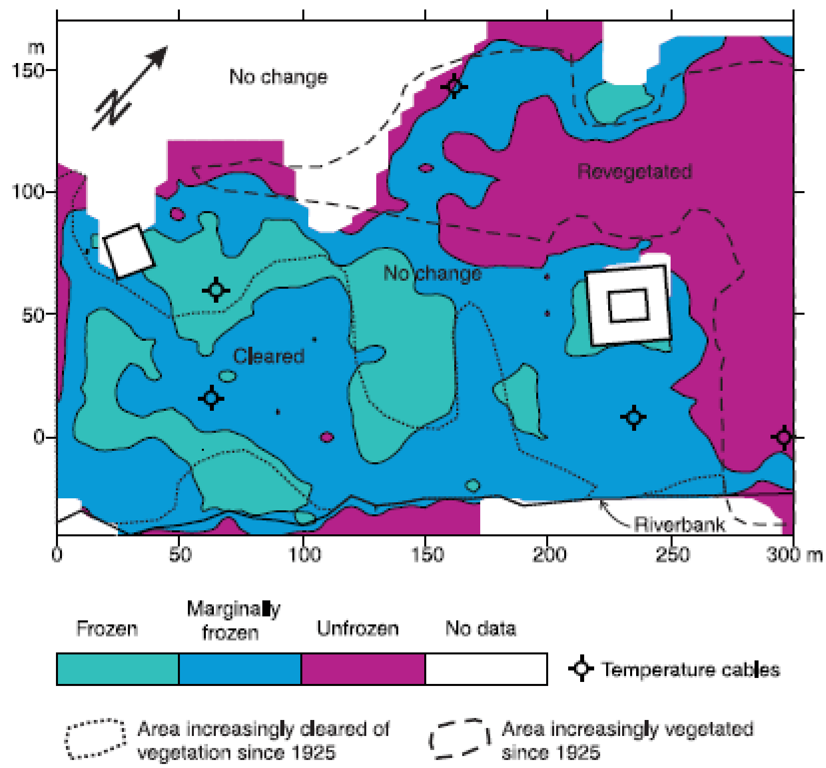
3.1 Wildfire



Projected increase in wildfire season for Churchill – York Factory area. Length in days from baseline (1981-2010) by 2071-2100 under RCP 2.6 and 8.5 scenarios. Data source Natural Resources Canada, http://cfs.nrcan.gc.ca/fc-data-catalogue.

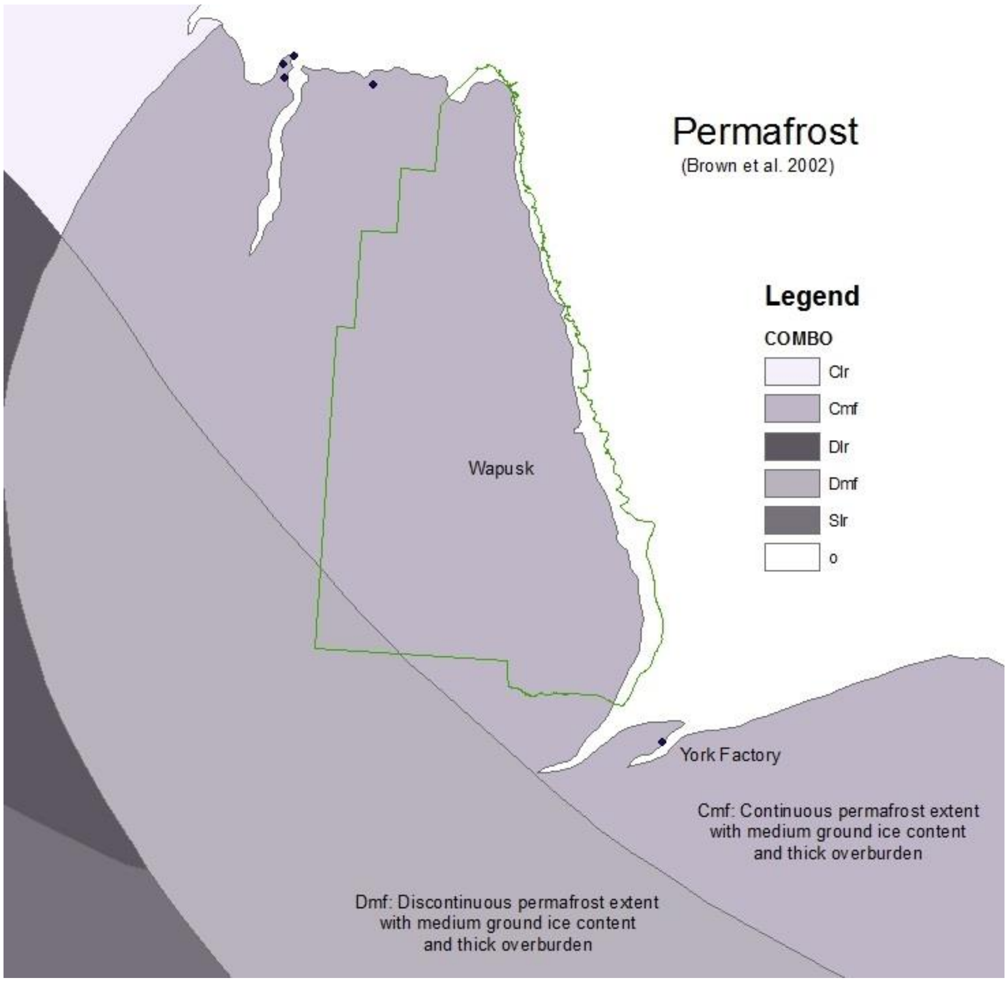
3.2 Permafrost

Initially classified as continuous permafrost by Brown *et al.* (2002), a site specific assessment by Sladen *et al.* (2009) confirmed the permafrost at York Factory to be discontinuous. Furthermore, they interpreted the current distribution of permafrost to be related to vegetation cover, i.e., cleared areas have maintained permafrost while re-vegetated areas have promoted snow accumulation (insulating blanket) and higher mean ground temperatures resulting in a loss of permafrost. Where present, permafrost is generally less than 15 m thick and warmer than -1 ˚C.

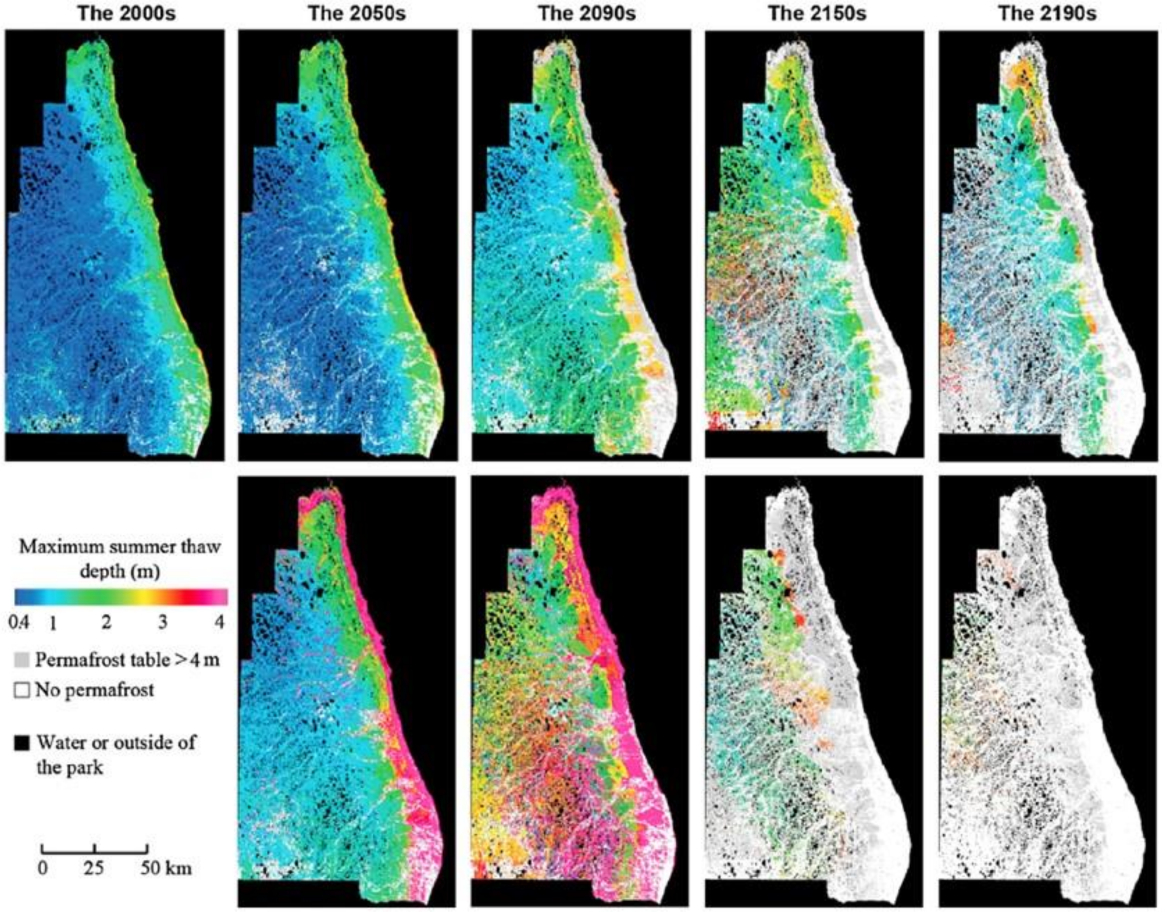


Permafrost map of York Factory with main vegetation changes since 1925 (Sladen *et al.*, 2009).

Modelling and mapping of permafrost in Wapusk NP appear to indicate that the average active layer thickness (~0.5-2 m) has increased by 37% from the 1900s to 2000s due to climate change, and permafrost has disappeared in some southern areas (Zhang *et al.*, 2012). Continued permafrost thaw and loss is projected, and in one estimate only 20 to 65% of region is projected to be underlain by permafrost by end of twenty-second century (Dyke and Sladen, 2010; Zhang, 2013).

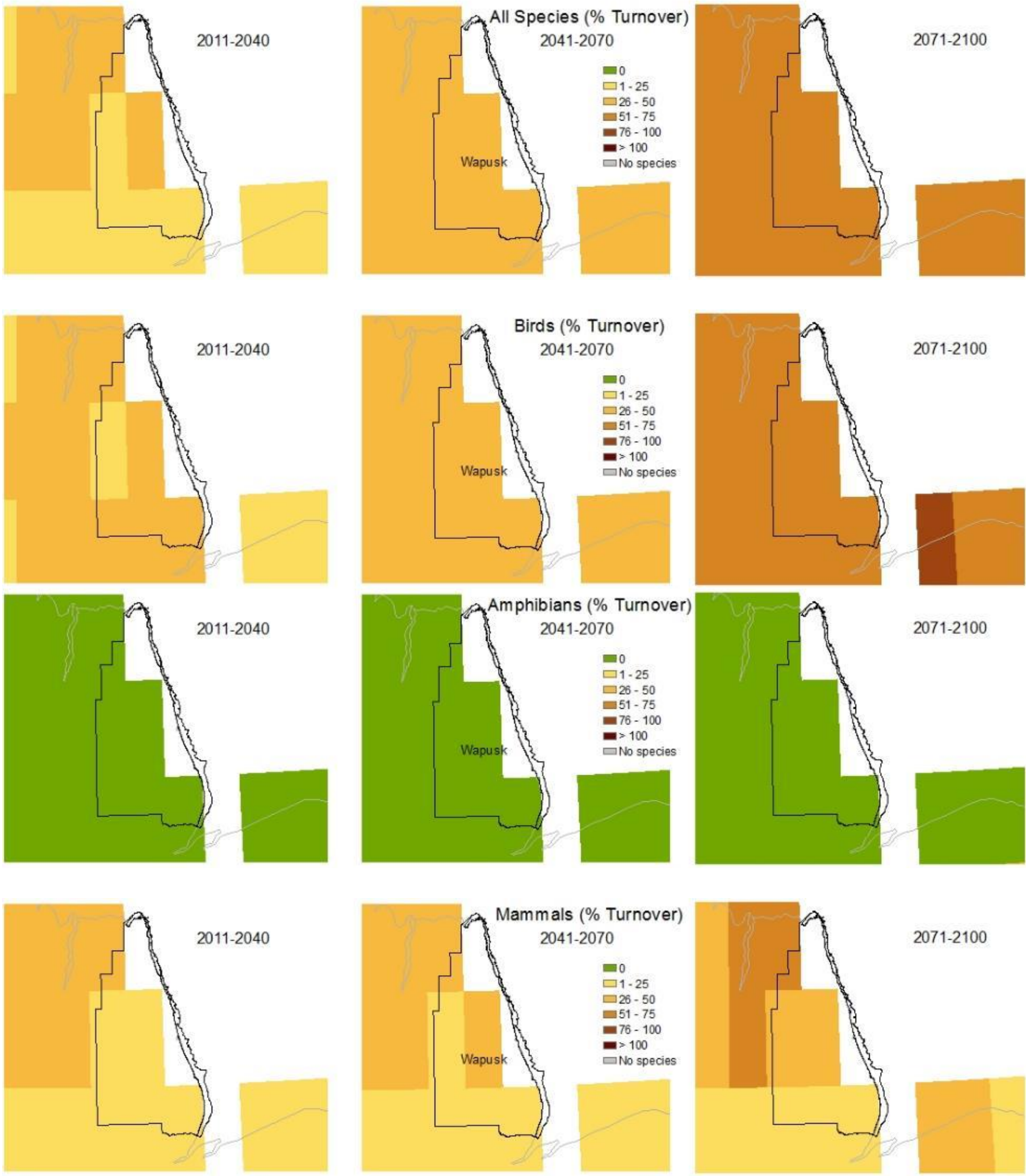


Permafrost and ground ice map clipped from the work of Brown *et al.* (2002). **Note:** Sladen *et al.* (2009) provides a more accurate description of conditions for York Factory.



Maximum summer thaw at depth from 2000 to 2200 for Wapusk NP. Top panels are under the CCCma scenario and the bottom panels are under the ECHAM scenario. By 2200 only 20% to 65% of land is projected to be underlain by permafrost (Zhang, 2013).

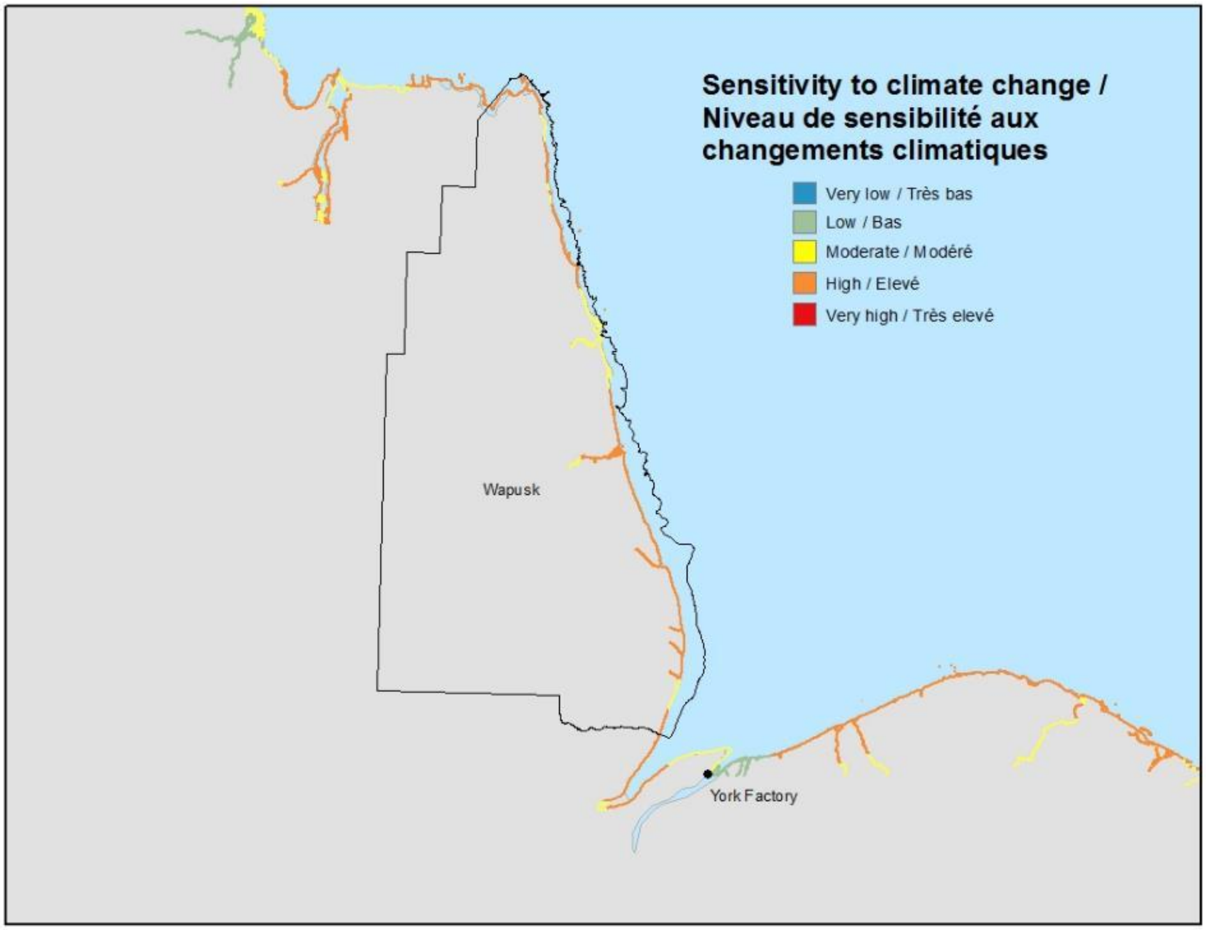
3.3 Biodiversity



Percentage of projected species turnover (50 km x 50 km grid) relative to current species occurrence, assuming full dispersal (i.e., species can move into new areas) using ten coupled atmosphere-ocean general circulations models (AOGCMS) as in Lawler et al. (2009) and the A2 emission scenario. **Species turnover** is calculated as a composite measure of **species loss** (i.e., % of species currently in a cell whose projected future range does not include the cell) and **species gain** (i.e., % increase in species due to range expansion). Data and analysis discussed further in Lindsay et al. (2016).

3.4 Shoreline Erosion

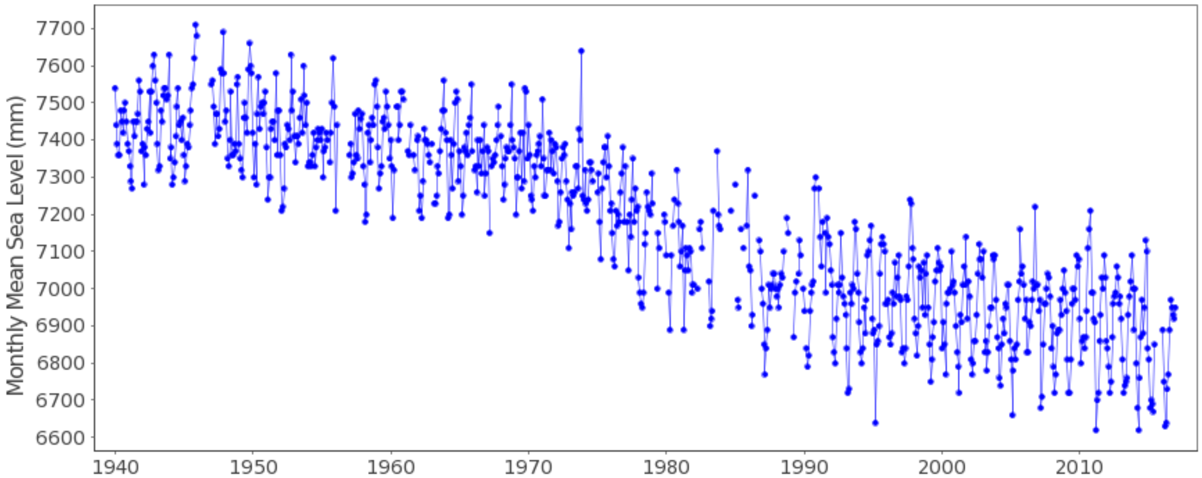
Due to riverbank erosion along the Hayes River, the remains of two earlier York Factories have already disappeared. It is estimated the current site will be lost within 100 to 150 years (Petzet and Ziesemer, 2008). The 10 m high banks at York Factory have been reported to be eroding at 0.5 – 0.6 m/yr (Petzet and Ziesemer, 2008; Skaftfeld *et al.*, 2005). The shoreline will become increasingly more vulnerable to erosion as the permafrost thaws.



Preliminary map of coastal sensitivity to climate change. Sensitivity is based on coastal materials, landforms, relief, ground ice, wave height, tidal range, recent trends in sea ice concentration, and projected sea level rise to 2050. Data provided by Natural Resources Canada (Couture and Manson, 2016).

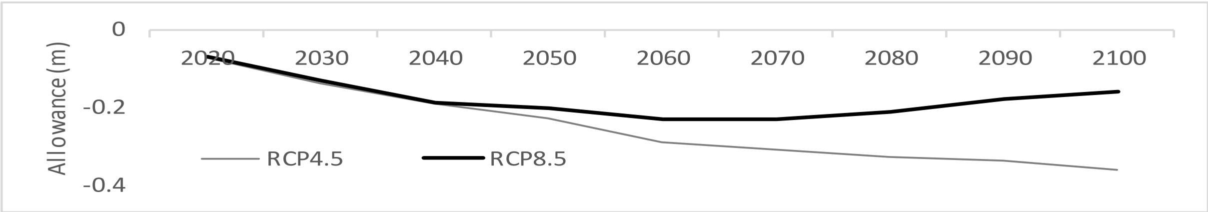
Sea Level Rise

A. Observed



Tide gauge record from Churchill, MB. Data from [Permanent Service for Mean Sea Level](). While the area experiences macro-tides, the downward trend is reflects post-glacial isostatic rebound of the earth's crust, so the sea level appears to be falling.

B. Projected



Vertical allowances for Churchill acquired from the Canadian Extreme Water Level Adaptation Tool (CAN-EWLAT). The vertical allowance is a "recommended change in the elevation of coastal infrastructure required to maintain the current level of flooding risk in a future scenario of sea level rise". These estimates are based on a future projection of regional sea level rise using the RCP 4.5 and RCP 8.5 scenarios and the historical water level records, including both tides and storm surge

4. Additional Reading

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Secretariat, Ottawa, Ontario. http://www.ccea.org/wp-content/uploads/2015/10/CCEA_WildlifeConservationProtectedAreasandClimateChangeinCanada_Digital.pdf.

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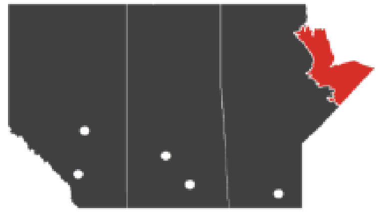
Appendix 1. Manitoba Hudson Plains Climate Report Card

Prepared by the Prairie Climate Centre (http://prairieclimatecentre.ca/)

Prairie Climate Centre
From Risk to Resilience



Manitoba Hudson Plains

Low Carbon Emissions (RCP4.5)

Climate Variable	Season	1981–2010 (Baseline)	2021–2050 Projections L	2021–2050 Projections M	2021–2050 Projections H	2051–2080 Projections L	2051–2080 Projections M	2051–2080 Projections H
Mean Temperature	Annual	-4.6 °C	-3.3 °C	-2.7 °C	-1.9 °C	-1.9 °C	-1.4 °C	-1.0 °C
	Summer	12.5 °C	13.2 °C	13.8 °C	14.3 °C	14.2 °C	14.7 °C	15.1 °C
	Winter	-23.1 °C	-21.1 °C	-20.1 °C	-19.0 °C	-19.0 °C	-18.0 °C	-17.0 °C
Precipitation	Annual	439.5 mm	446.8 mm	468.9 mm	492.3 mm	462.9 mm	482.2 mm	504.5 mm
	Summer	164.4 mm	152.3 mm	167.2 mm	181.1 mm	157.8 mm	168.3 mm	178.8 mm
	Winter	67.1 mm	68.9 mm	73.9 mm	79.1 mm	73.1 mm	79.0 mm	85.6 mm
Days ≥ 30 °C	Annual	0.5 days	0.1 days	1.5 days	3.3 days	0.8 days	2.4 days	4.5 days
Nights ≥ 20 °C	Annual	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days	0.1 days
Days ≤ -30 °C	Annual	40.8 days	14.8 days	22.0 days	29.2 days	5.0 days	11.2 days	17.5 days
Frost-Free Period	Annual	99.6 days	98.9 days	112.7 days	127.0 days	111.6 days	123.7 days	136.1 days
5 °C Degree Days	Annual	822.4	917.1	984.9	1046.3	1059.6	1114.8	1174.4
10 °C Degree Days	Annual	327.9	381.6	432.4	481.2	470.5	513.2	554.0
Freeze-Thaw Cycles	Annual	49.0 cycles	41.3 cycles	50.5 cycles	59.9 cycles	39.3 cycles	47.6 cycles	56.2 cycles
Max 1-day Precip Total	Annual	38.2 mm	26.4 mm	46.8 mm	72.8 mm	25.9 mm	45.2 mm	68.7 mm
Max 3-day Precip Total	Annual	83.3 mm	60.0 mm	103.5 mm	158.0 mm	59.3 mm	101.2 mm	149.8 mm

High Carbon Emissions (RCP8.5)

Climate Variable	Season	1981–2010 (Baseline)	2021–2050 Projections L	2021–2050 Projections M	2021–2050 Projections H	2051–2080 Projections L	2051–2080 Projections M	2051–2080 Projections H
Mean Temperature	Annual	-4.6 °C	-3.1 °C	-2.4 °C	-1.5 °C	-0.9 °C	0.3 °C	1.8 °C
	Summer	12.4 °C	13.5 °C	14.0 °C	14.7 °C	15.2 °C	16.1 °C	17.2 °C
	Winter	-23.0 °C	-20.8 °C	-19.3 °C	-17.9 °C	-17.1 °C	-15.4 °C	-13.4 °C
Precipitation	Annual	438.6 mm	451.0 mm	474.9 mm	499.0 mm	464.7 mm	500.1 mm	540.3 mm
	Summer	164.4 mm	155.9 mm	167.1 mm	180.4 mm	154.7 mm	170.1 mm	193.1 mm
	Winter	66.3 mm	66.6 mm	74.6 mm	81.6 mm	76.1 mm	84.9 mm	96.1 mm
Days ≥ 30 °C	Annual	0.5 days	0.2 days	1.8 days	3.8 days	2.6 days	5.1 days	8.2 days
Nights ≥ 20 °C	Annual	0.0 days	0.0 days	0.0 days	0.0 days	0.0 days	0.5 days	1.6 days
Days ≤ -30 °C	Annual	40.2 days	10.4 days	19.0 days	27.7 days	0.2 days	4.6 days	9.0 days
Frost-Free Period	Annual	100.1 days	101.7 days	117.4 days	131.6 days	123.2 days	136.6 days	149.4 days
5 °C Degree Days	Annual	817.4	956.1	1022.8	1095.6	1188.5	1322.5	1501.0
10 °C Degree Days	Annual	323.1	404.7	456.1	507.7	562.6	662.0	779.0
Freeze-Thaw Cycles	Annual	48.6 cycles	39.9 cycles	49.5 cycles	58.4 cycles	36.9 cycles	45.4 cycles	53.8 cycles
Max 1-day Precip Total	Annual	37.3 mm	26.5 mm	50.2 mm	77.0 mm	27.1 mm	49.0 mm	77.0 mm
Max 3-day Precip Total	Annual	80.8 mm	60.6 mm	108.8 mm	168.1 mm	62.1 mm	109.3 mm	174.1 mm

L = Low Projection (10th Percentile) M = Mean Projection H = High Projection (90th Percentile)

Where did this data come from?

Global Climate Models (GCMs) are used to depict how the climate is likely to change in the future. Since no one climate model can be considered 'correct', it is important to use many GCMs to capture a range of possible conditions. The GCM data we used were obtained from the Pacific Climate Impacts Consortium (PCIC). PCIC collected temperature and precipitation data produced by 12 different models and used advanced statistical techniques to create high-resolution (daily, 10km) versions of the data for all of Canada (for more information visit pacificclimate.org).

What is the difference between the 'Low' and 'High' Carbon emission scenarios?

One of the most important inputs into GCM simulations of the future climate is the expected concentration of greenhouse gases (GHGs; especially carbon dioxide) in the atmosphere as a result of human activity. In the scientific literature these future GHG concentrations are used to calculate Representative Concentration Pathways (RCPs). The High Carbon scenario (RCP8.5) assumes that we continue to emit very large amounts of carbon dioxide from the burning of fossil fuels; the Low Carbon scenario (RCP4.5) assumes that drastic reductions of emissions in the coming decades will stabilize the concentration of GHGs in the atmosphere by the end of this century. We did not use RCP2.6, an even lower emissions scenario.

How were the Low, Mean, and High values calculated?

For a variety of climate variables, we used the projected values from the 12 models to calculate an *ensemble* (average) value for each year. The ensemble values for the 2021-2050 and 2051-2080 periods were used to calculate the **'M'**, or mean, values. To portray the range of values within the 30-year periods, we calculated the 10th and 90th percentiles; 10% of the annual values are lower than the **'L'** values and 10% of the annual values are higher than the **'H'** values. For comparative purposes, we also calculated ensembles for the baseline period of 1981-2010 (as simulated by the models).

Some definitions

Frost-Free Period: number of consecutive days without freezing temperatures

5 °C Degree Days: cumulative number of degrees greater than 5 °C (using daily mean temperatures)

Freeze-Thaw Cycles: number of days with maximum temperature > 0 °C and minimum temperature < -1 °C

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