April 4, 2019

Supplemental Climate Information for Grasslands National Park

Prepared by:

Scott Parker, Ph.D.
Office of the Chief Ecosystem Scientist

Parks Canada Parcs Canada

Contents

Preface

This is a supplement to the "Let's Talks about Climate Change: Prairie and Boreal Plains Region" (Parker, 2017) report and is intended to support climate change discussions at Grasslands National Park.

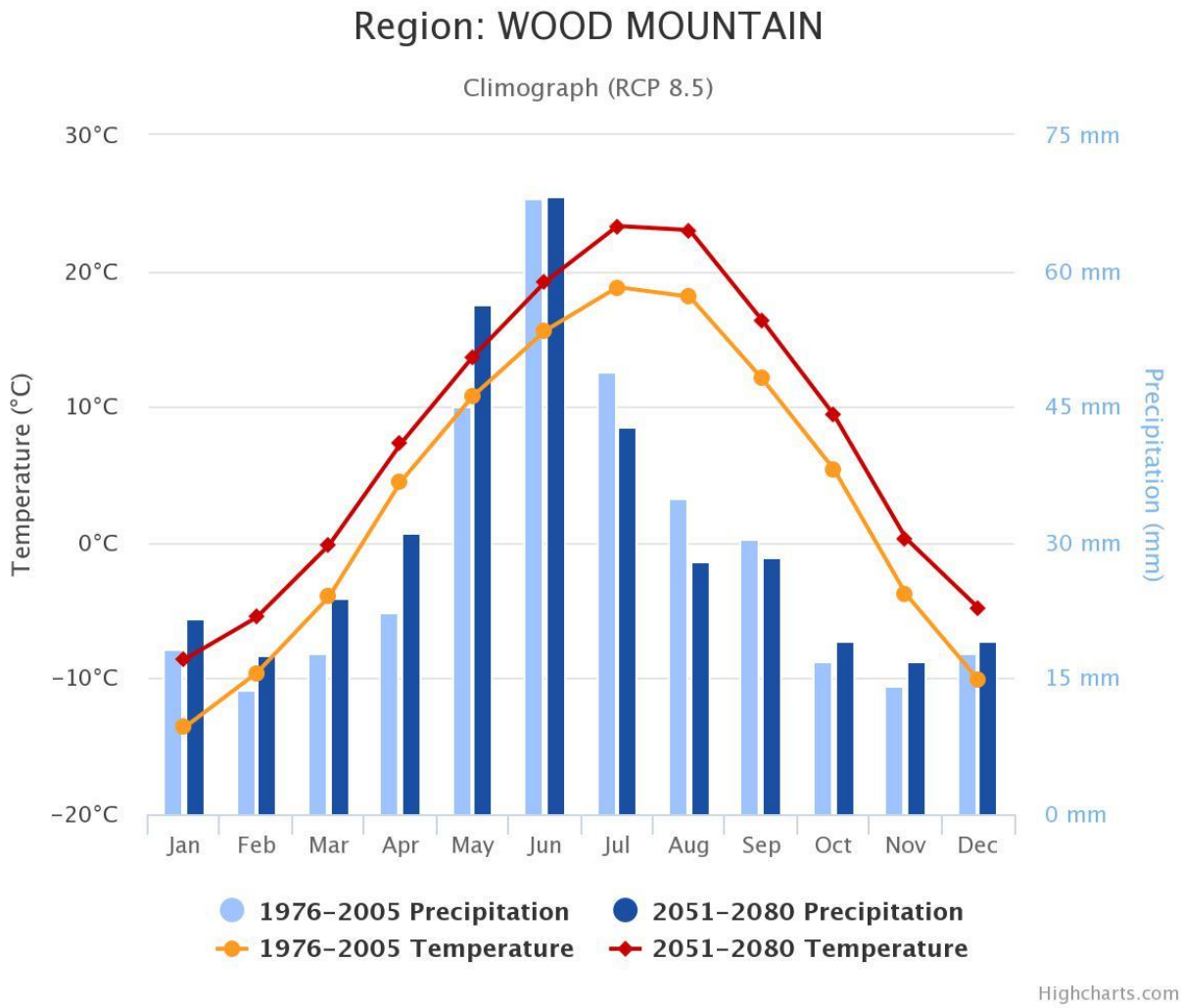
Future climate projections are modelled with several different greenhouse gas concentration trajectories called **Representative Concentration Pathways (RCP)** (Vuuren *et al.*, 2011). They describe possible climate futures and are named after respective radiative forcing values in the year 2100 relative to pre-industrial values (i.e., +2.6, +4.5 and +8.5 watts/m^2). **RCP 2.6** assumes we take action and greenhouse gas emissions peak in 2010-2020 and decline thereafter. **RCP 4.5** assumes emissions peak around 2040 and then decline. **RCP 8.5** assumes we take no action and emissions continue to rise "status quo" throughout the 21st century. We are currently tracking RCP 8.5.

This is a site focussed document and to understand the larger climate change context please consult Canada's changing climate assessment reports (e.g., Bush and Lemmen, 2019; Warren and Lemmen, 2014) and the Intergovernmental Panel on Climate Change assessment reports (e.g., IPCC, 2014). With respect to adaptation and mitigation options, please review Gross *et al.* (2016), Parker *et al.* (2018) or Rockman *et al.* (2016).

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 verify with original sources.

Summary Climograph



Climograph for the Wood Mountain region. Monthly mean temperature and total precipitation for 1976-2005 baseline and 2051-2080 future projection (RCP 8.5). Figure source: Climate Atlas of Canada (https://climateatlas.ca/).

1. Observed Climate Trends

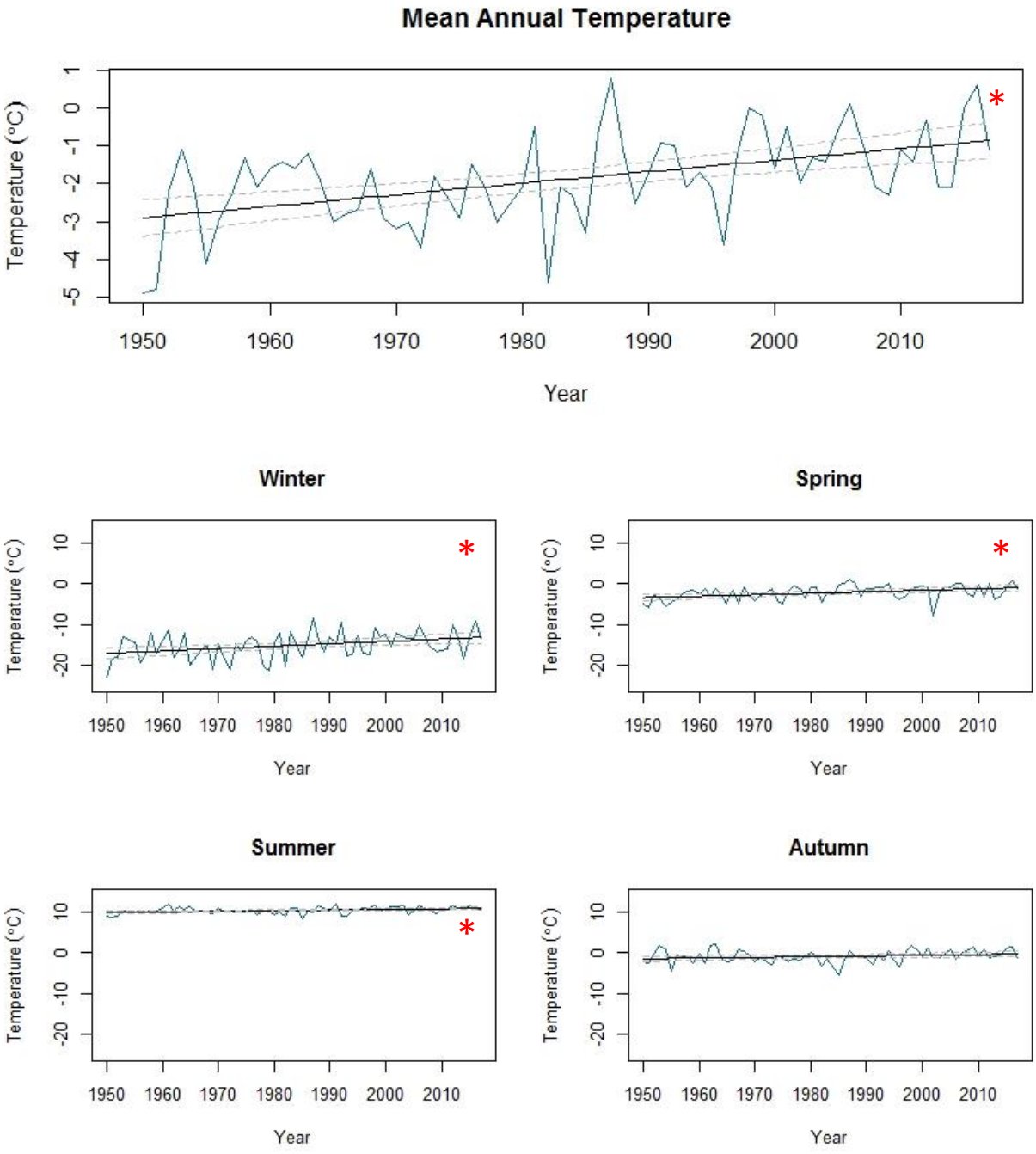
There are several meteorological stations in the Grasslands NP region with current (see: https://weather.gc.ca/) and historical data (see: http://climate.weather.gc.ca/). These databases contain hourly, daily and monthly weather data and may be suitable for specific analysis or information needs.

For the purpose of longer term trend analysis, the Adjusted and Homogenized Canadian Climate Data (AHCCD) (ECCC, 2017) is presented here. The AHCCD incorporates adjustments to data to account for discontinuities from non-climatic factors such as instrumentation changes or station relocation. The following table highlights AHCCD stations with temperature data in the Grasslands region. Since Swift Current has the most up to date and longest time series it was selected for temperature, precipitation and wind trend analysis. Data from 1950 onwards is used to present contemporary trends in climate change.

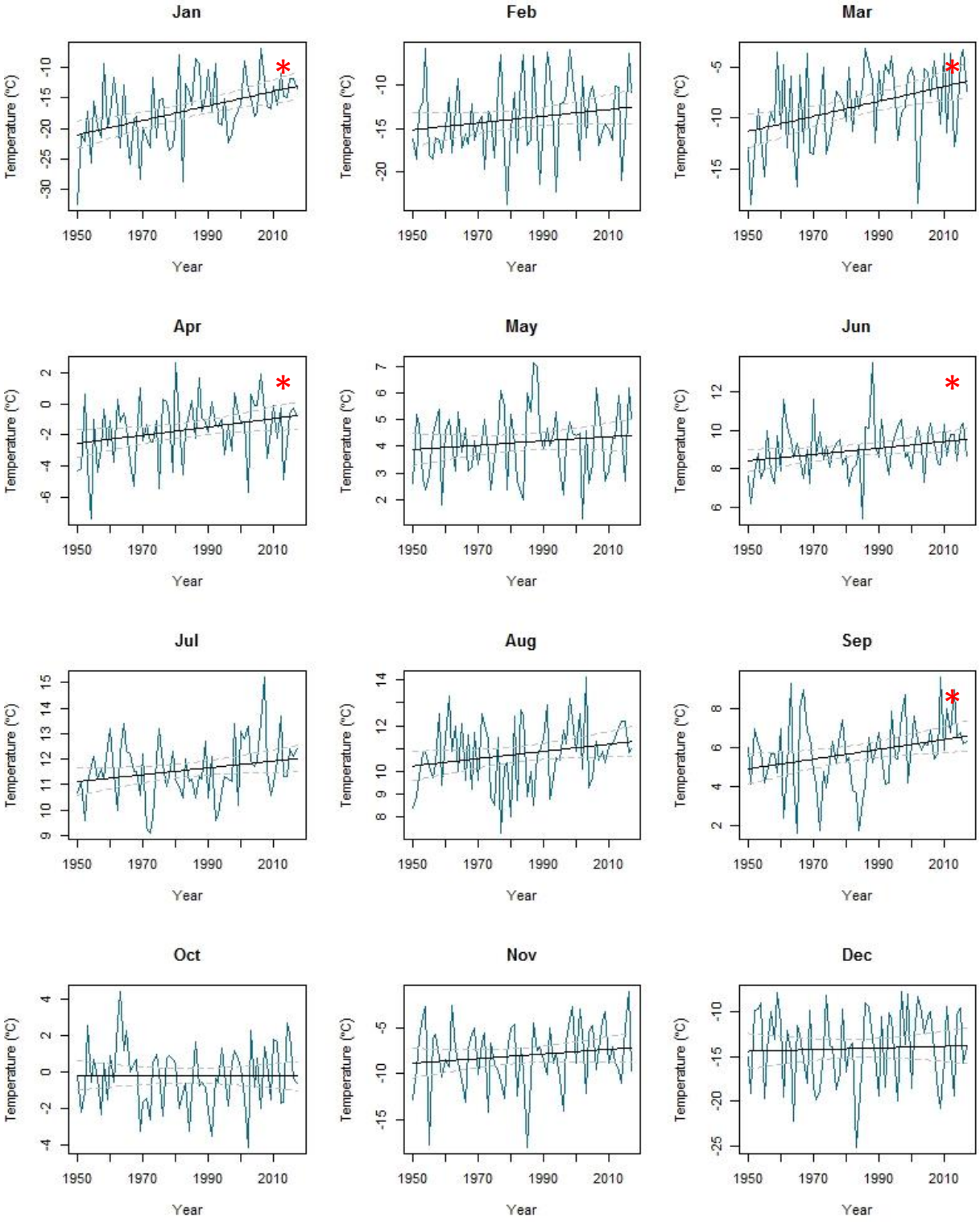
Available temperature Adjusted and Homogenized Canadian Climate Data for the Grasslands NP region.

Province	Station Name	Station ID	Begin Year	End Year
SK	Aneroid	4020160	1922	2005
SK	Poplar River	4038740	1956	2002
SK	**Swift Current**	**4028038**	**1885**	**2017**
SK	Val Marie	4038400	1937	2010

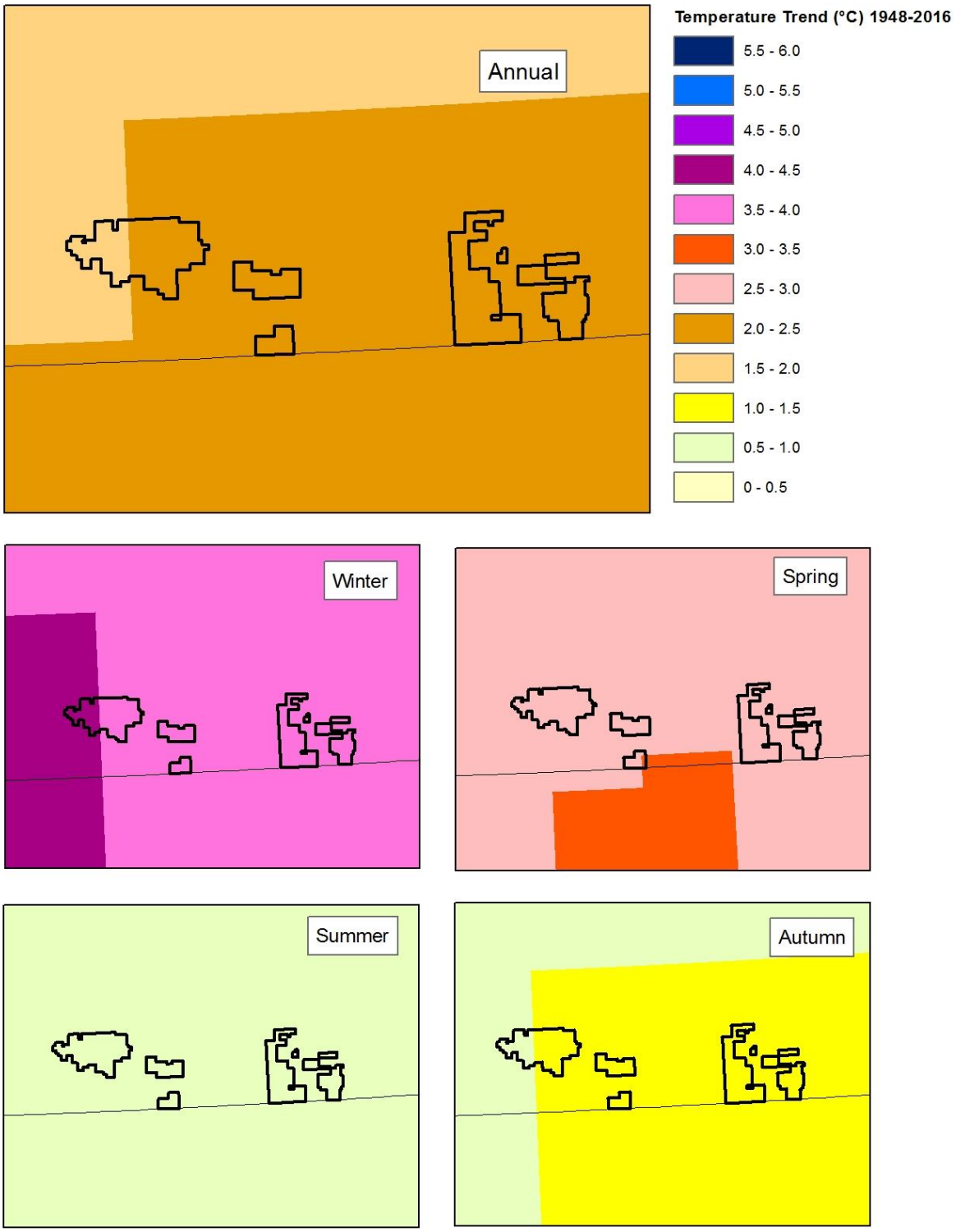
1.1 Temperature



Swift Current mean annual and seasonal temperature 1950 to 2017. A statistically significant (P<0.05) increase observed in mean annual and all seasonal temperatures, except autumn (Sep, Oct, Nov). Mean annual temperature increased +2.0°C and winter (Dec, Jan, Feb) increased the most of all the seasons, +3.9°C. Trend determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend (P<0.05).

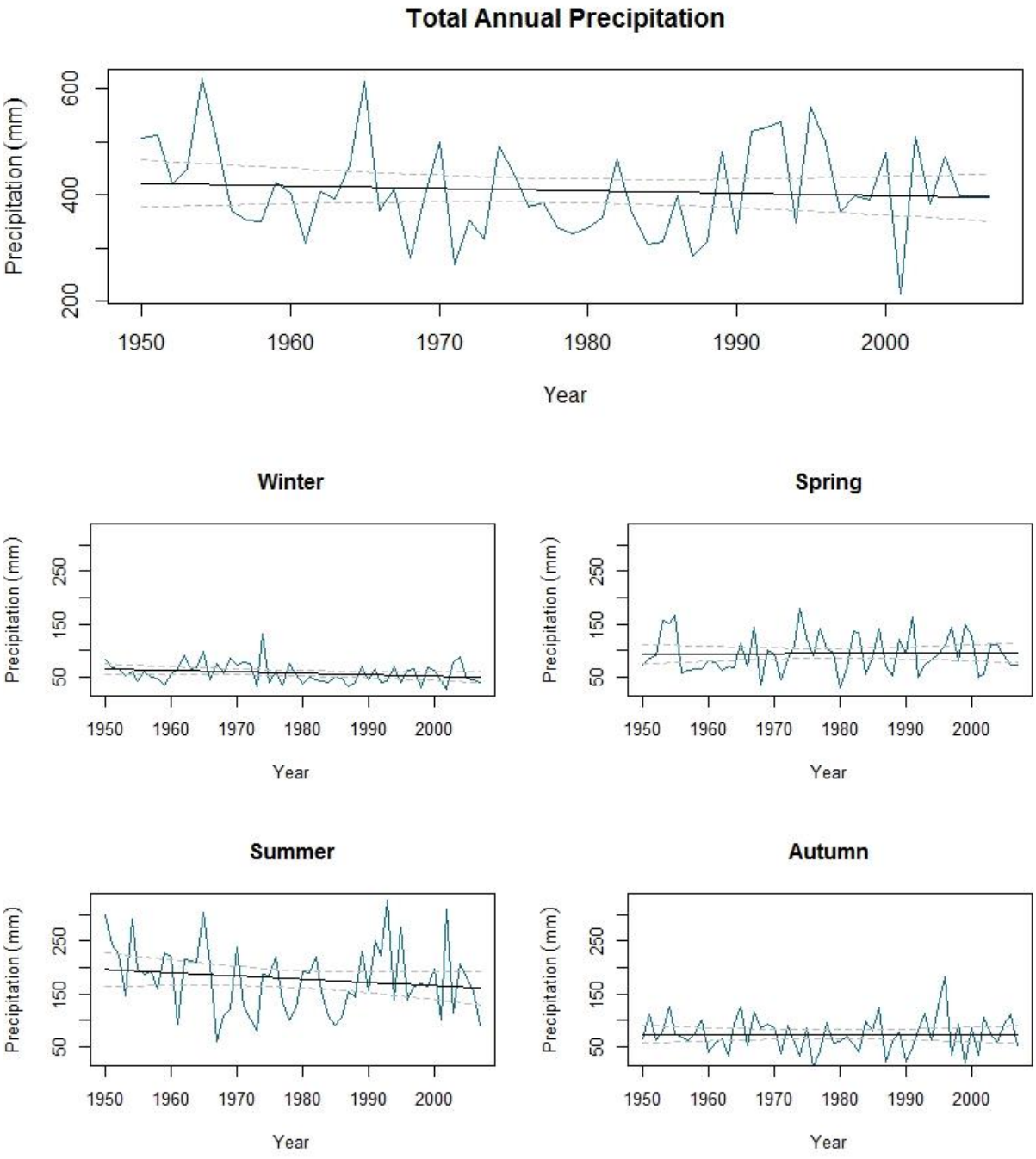


Swift Current mean monthly temperature 1950 to 2017. Jan, Mar, Apr, Jun, and Sep demonstrated a statistically significant (P<0.05) increase. Jan demonstrated the greatest increase, +7.9°C. Trend determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend (P<0.05).

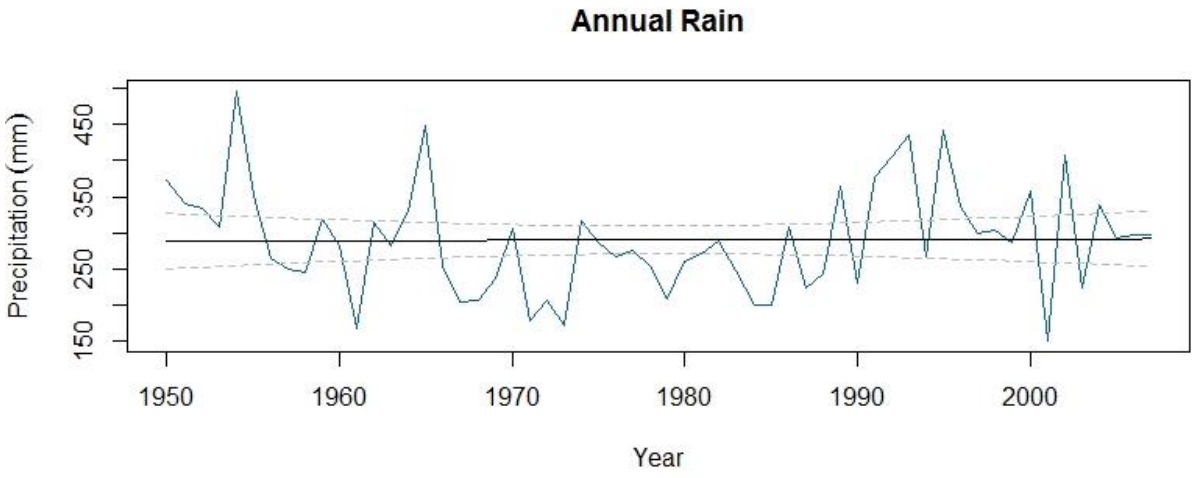


Mean annual and seasonal temperature trends (˚C) for Grasslands from 1948 to 2016. Based on Canadian gridded data (CANGRD) it represents the change in temperature over the period of record (1950-2016). Data source: https://climate-change.canada.ca/climate-data/#/historical-gridded-data.

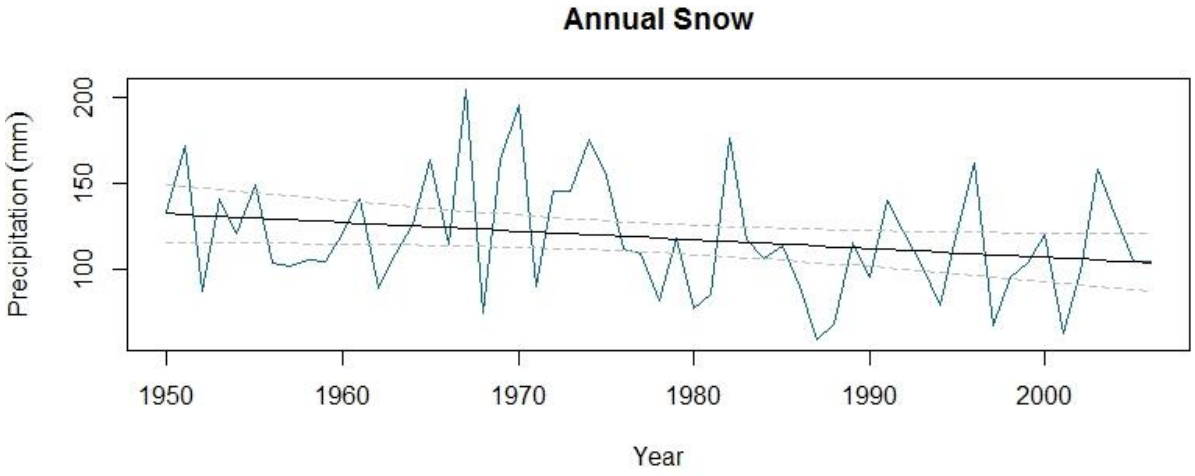
1.2 Precipitation



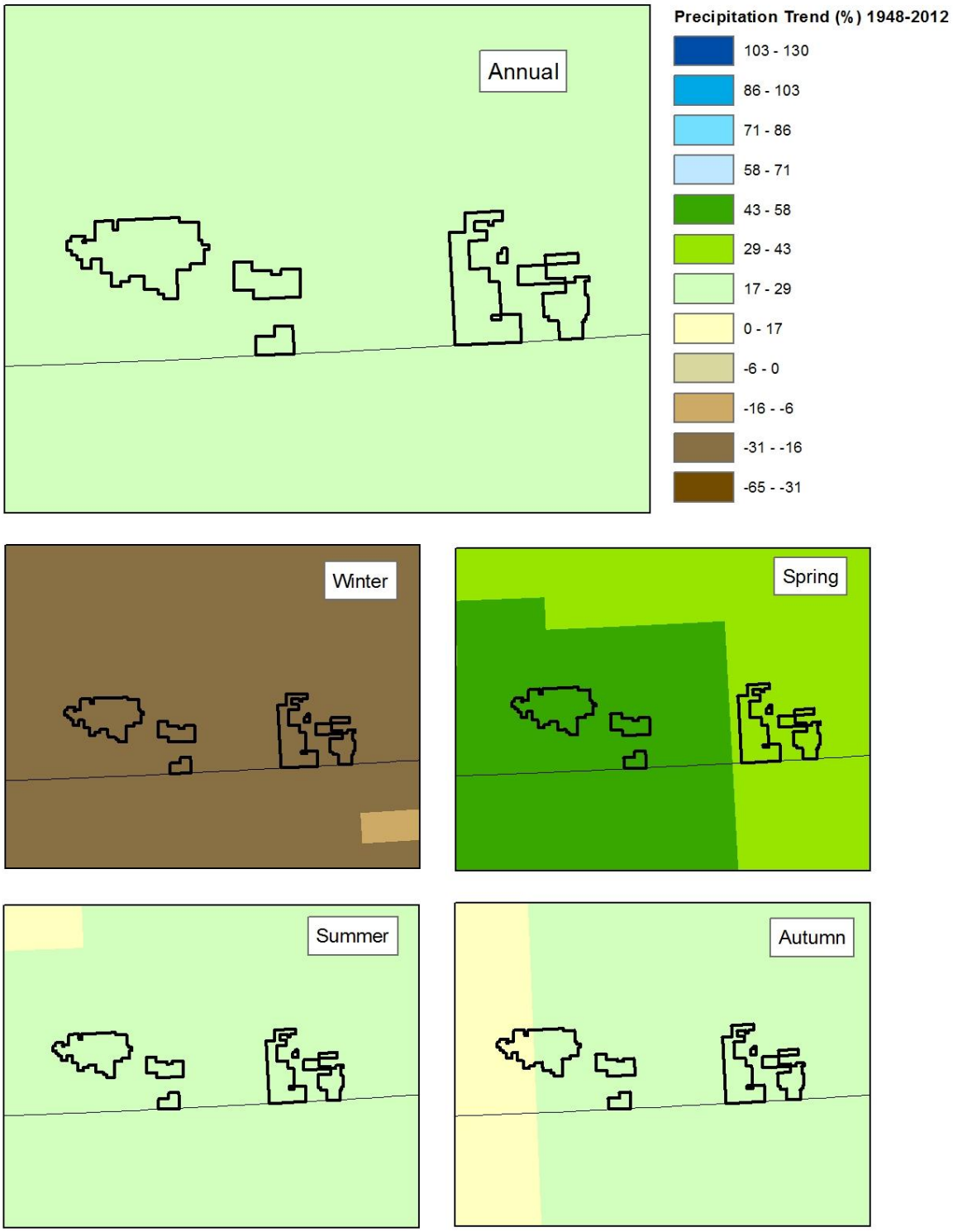
Swift Current total annual and seasonal precipitation 1950 to 2007. Except for the spring (Mar, Apr, May), precipitation demonstrated a slight declining trend for the annual and other seasonal periods, this however was not statistically significant (P<0.05). Trend determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend (P<0.05).



Swift Current total annual rain demonstrated a slight, but not statistically significant (P<0.05) decline between 1950 and 2007.

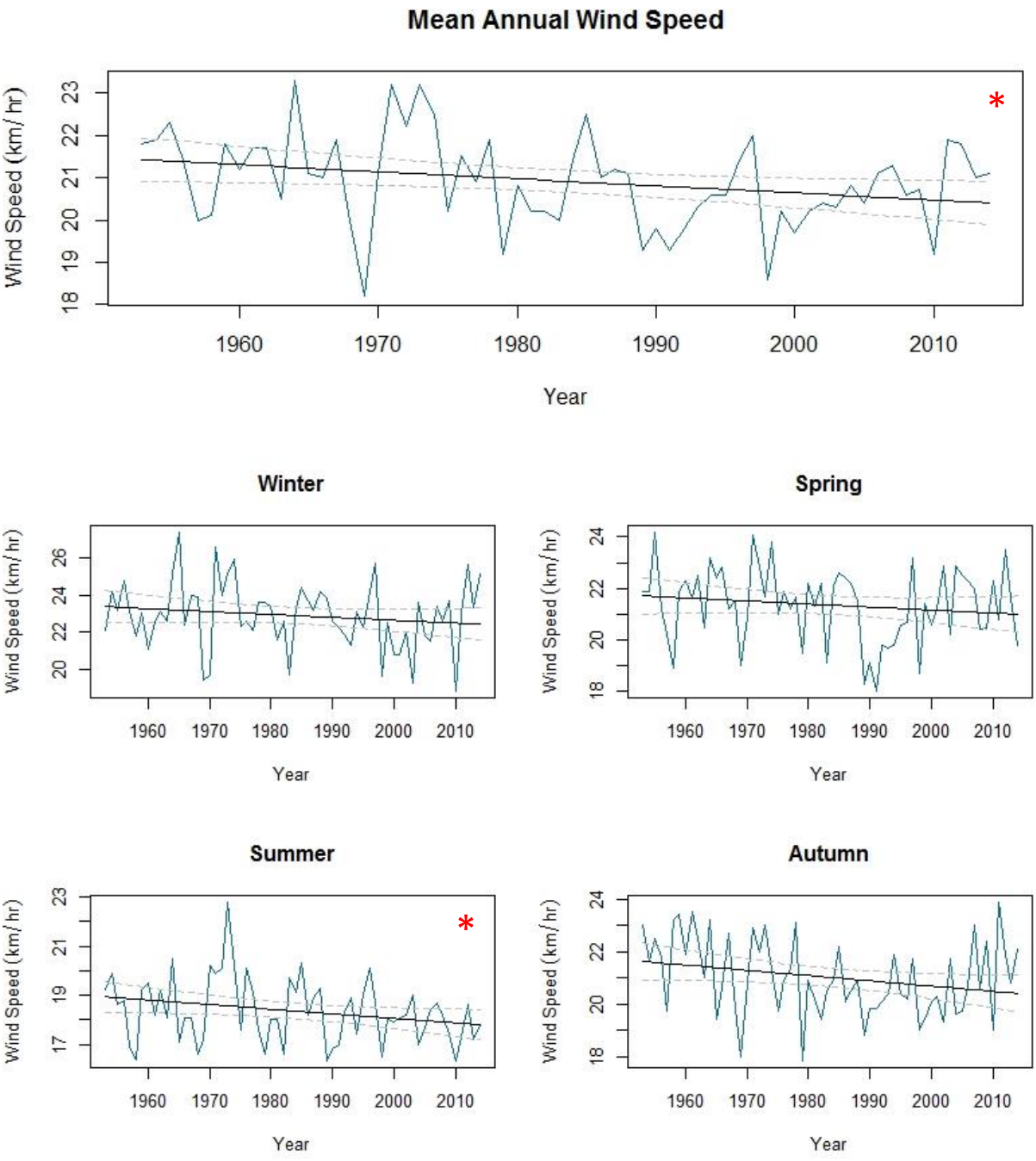


Swift Current total annual snow demonstrated a slight, but not statistically significant (P<0.05) decline between 1950 and 2007.



Total annual and seasonal precipitation trends (%) for Grasslands NP from 1948 to 2012. Based on Canadian gridded data (CANGRD) the relative trends reflect the percent change in total precipitation over the period of record (1948-2012). Data source: https://climate-change.canada.ca/climate-data/#/historical-gridded-data.

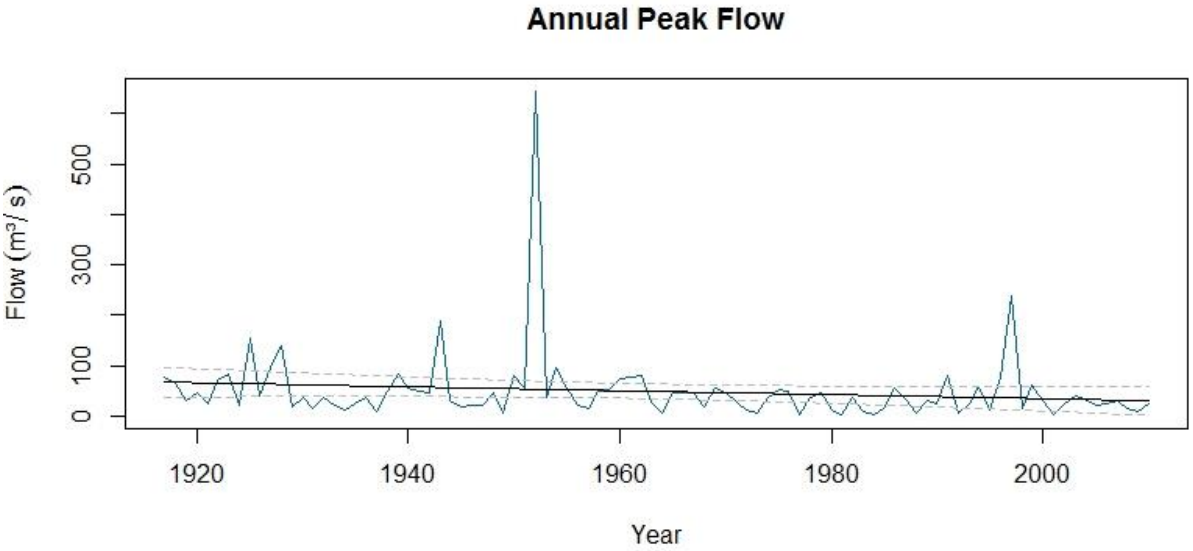
1.3 Surface Wind Speed



Swift Current mean annual and seasonal wind speeds 1953 to 2014. Mean annual wind speed demonstrated a statistically significant (P<0.05) decrease, -1.1 km/hr (5%). While all seasons demonstrated a declining trend, only summer (Jun, Jul, Aug) was statistically significant (P<0.05), -1.1 km/hr (6%).

1.4 Hydrological Regimes

Changes to temperature (e.g., snowmelt) and precipitation (e.g., intensity, duration, frequency, rain vs snow) affects stream hydrology.

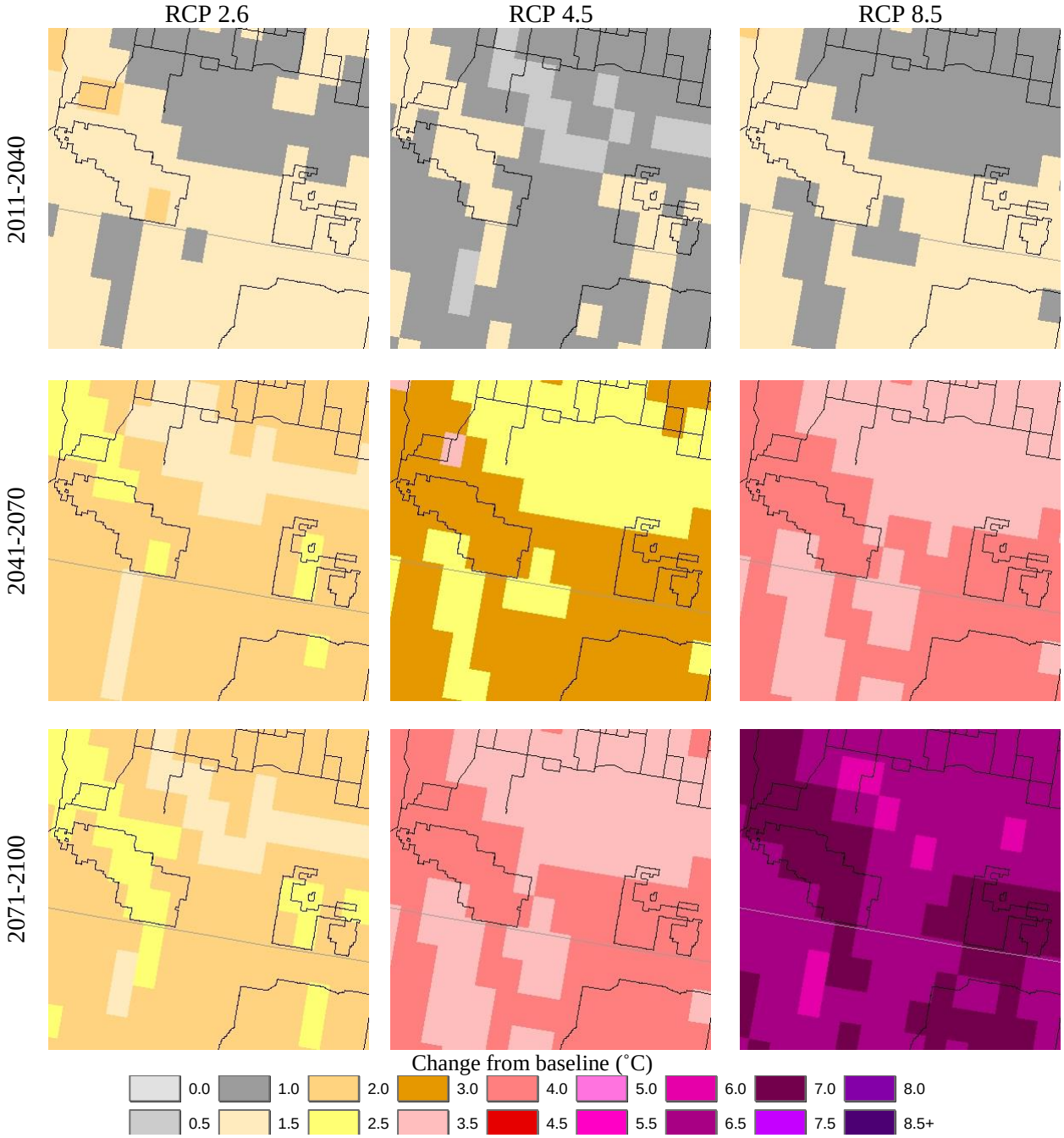


Frenchman River near the International Border peak flow data (Station 11AC041). A statistically significant ($P<0.05$) trend was not observed for peak flow. Note the April 15, 1952 flood event with a maximum peak flow of 643 m^3/s. Trend determined using a generalized linear model (R Core Team, 2017) and data from EC Data Explorer, HYDAT (July 16, 2018) (https://ec.gc.ca/rhc-wsc/). Since seasonal daily flow data is available from 1917 additional analysis is possible and could reveal patterns in timing and volume of flows.

The White Mud (Frenchman) valley, including the town of Eastend (shown), flooded on April 15-16, 1952. Above-normal snowpack in the Cypress Hills and below-normal spring temperatures are the reported cause. Photo source: http://saskhistoryonline.ca/islandora/object/eastend%3A18.

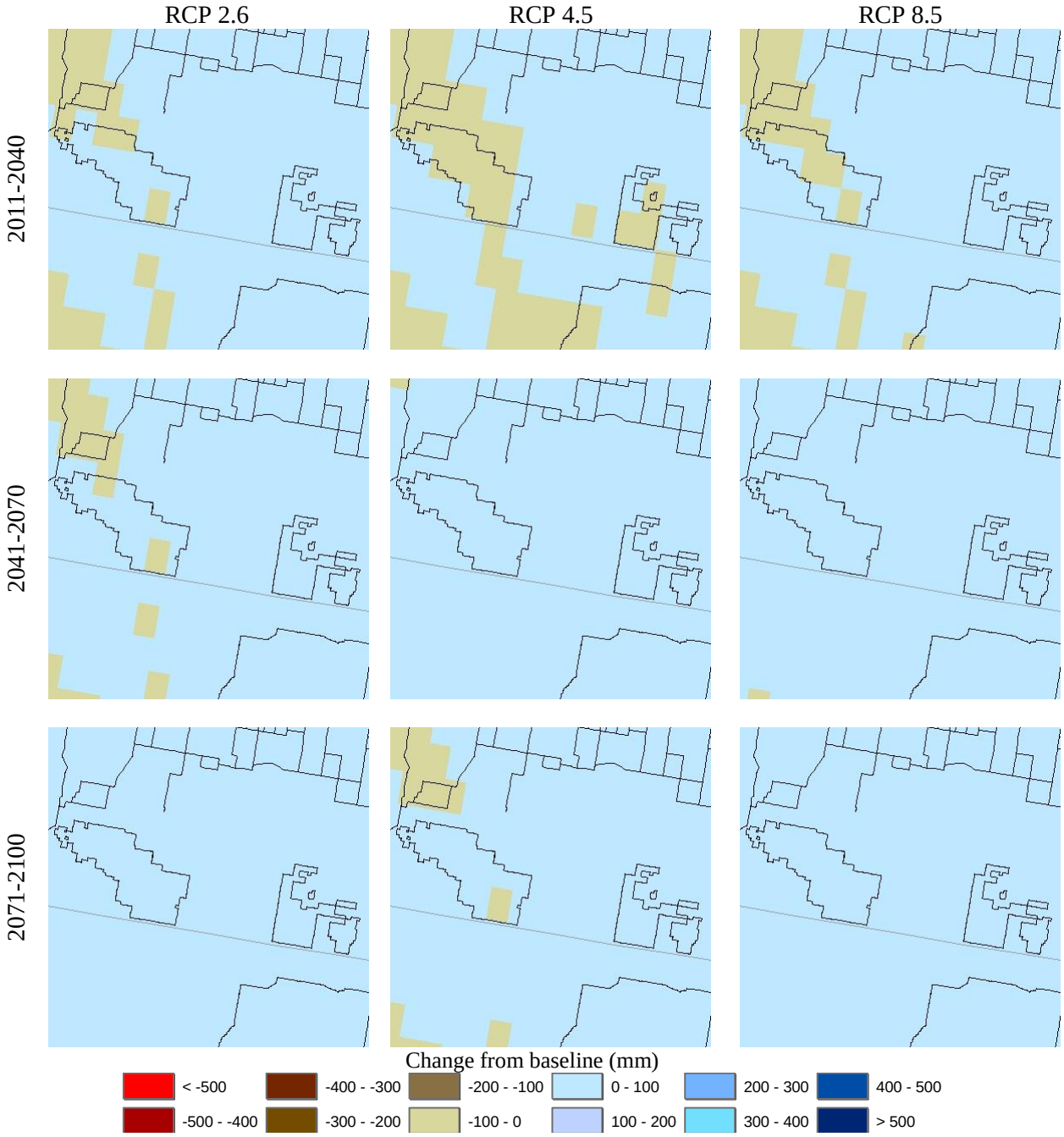
2. Projected Climate Trends

2.1 Temperature



Projected mean annual temperature increase for Grasslands NP from a 1980-2010 baseline. Composite projection of CanESM2, CESM1CAM5, HADGEM2ES and MIROCESM. Data source: Natural Resources Canada, Canadian Forest Service, http://cfs.nrcan.gc.ca/projects/3 (Price *et al.*, 2011). Depending on the RCP scenario and location, mean annual temperatures are projected to increase 3.0 to 6.5 °C by 2071-2100.

2.2 Precipitation



Projected total annual precipitation change for Grasslands NP from a 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). Depending on the RCP scenario and location, total annual precipitation is projected to increase 0 to 40 mm by 2071-2100.

Rainfall Intensity, Duration and Frequency (IDF)

These rainfall IDF values are calculated with IDF_CC Tool 3.0 (http://www.idf-cc-uwo.ca) using Generalized Extreme Values (Simonovic *et al.*, 2017).

Historic Baseline total precipitation amounts (mm) for Grasslands NP.

T (years)	2	5	10	25	50	100
5 min	5.18	7.87	10.20	13.99	17.59	22.02
10 min	7.61	11.82	15.21	20.37	24.95	30.25
15 min	8.36	13.21	17.19	23.35	28.92	35.47
30 min	9.34	14.72	19.49	27.38	34.98	44.43
1 h	12.45	18.83	24.60	34.39	44.05	56.32
2 h	14.48	20.35	25.85	35.41	45.05	57.50
6 h	20.66	28.84	36.18	48.40	60.20	74.87
12 h	25.56	36.08	45.67	61.90	77.87	98.11
24 h	31.81	46.63	59.21	79.39	98.37	121.58

Projected (2050-2100) precipitation (mm) for Swift Current using an ensemble of models and **RCP 4.5**.

T (years)	2	5	10	25	50	100
5 min	5.77	8.74	11.52	16.22	20.52	25.98
10 min	8.47	13.12	17.18	23.62	29.11	35.70
15 min	9.31	14.66	19.41	27.07	33.74	41.86
30 min	10.40	16.35	22.01	31.74	40.81	52.43
1 h	13.87	20.91	27.78	39.87	51.40	66.46
2 h	16.12	22.60	29.19	41.05	52.56	67.85
6 h	23.01	32.02	40.85	56.10	70.24	88.35
12 h	28.47	40.07	51.57	71.76	90.86	115.77
24 h	35.43	51.78	66.86	92.03	114.77	143.47

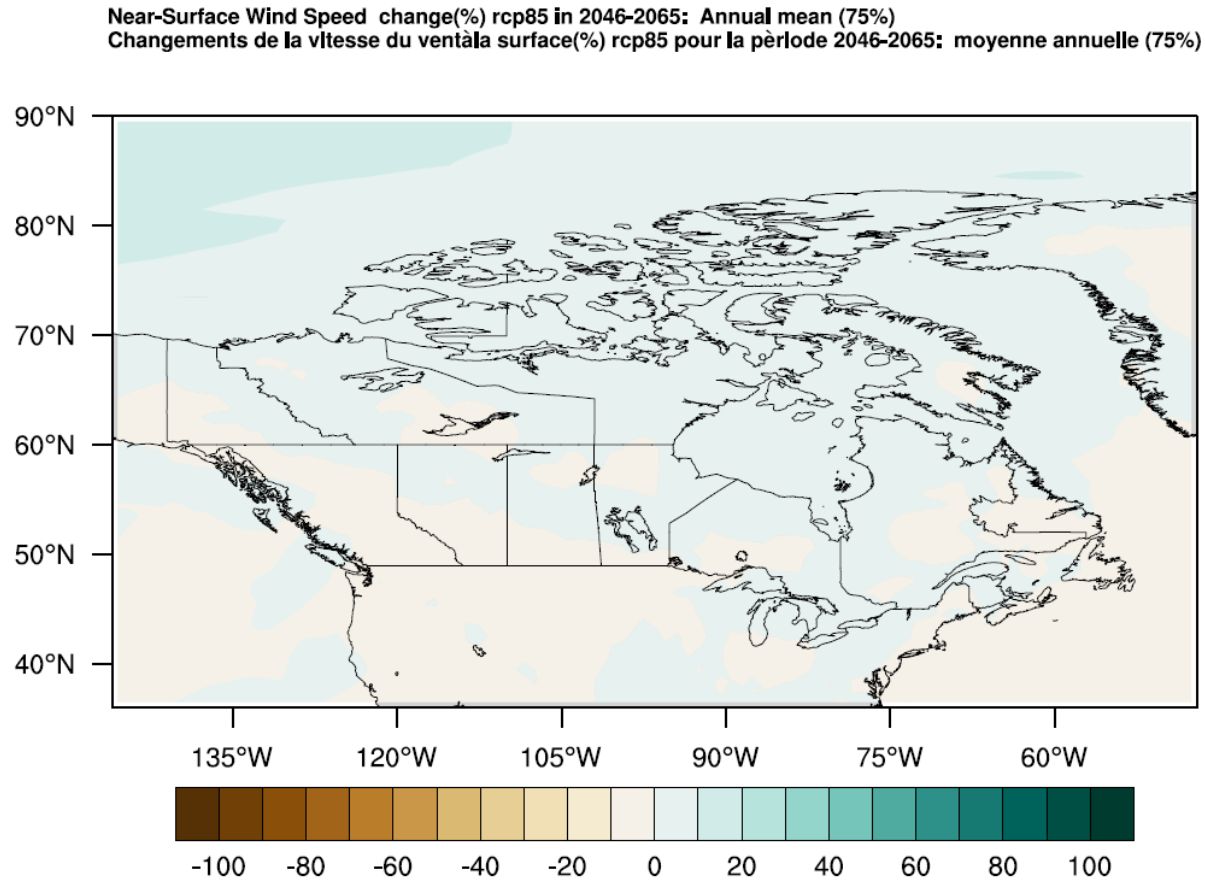
Projected (2050-2100) precipitation (mm) for Swift Current using an ensemble of models and **RCP 8.5**.

T (years)	2	5	10	25	50	100
5 min	5.70	8.93	11.85	15.94	19.74	24.34
10 min	8.37	13.40	17.66	23.21	28.00	33.44
15 min	9.20	14.98	19.96	26.61	32.46	39.21
30 min	10.28	16.69	22.63	31.19	39.26	49.11
1 h	13.71	21.35	28.57	39.18	49.44	62.25
2 h	15.94	23.08	30.01	40.34	50.56	63.56
6 h	22.74	32.70	42.01	55.14	67.57	82.76
12 h	28.14	40.92	53.03	70.52	87.40	108.45
24 h	35.03	52.88	68.74	90.45	110.41	134.40

IDF observations and projections park centroid (Lat: 49.16015 º, Lon: -107.53555 º). Observe that today's "one in 100 year" rainfall event (i.e., 56.32 mm/hr) is projected to be closer to a "one in 50 year" event by 2050-2100 for both RCP scenarios and the future "one in 100 year" rainfall event is projected to increase slightly in intensity (i.e., 62.25 - 66.46 mm/hr).

2.3 Wind

Mean wind speeds are generally projected to decrease (see figure below).

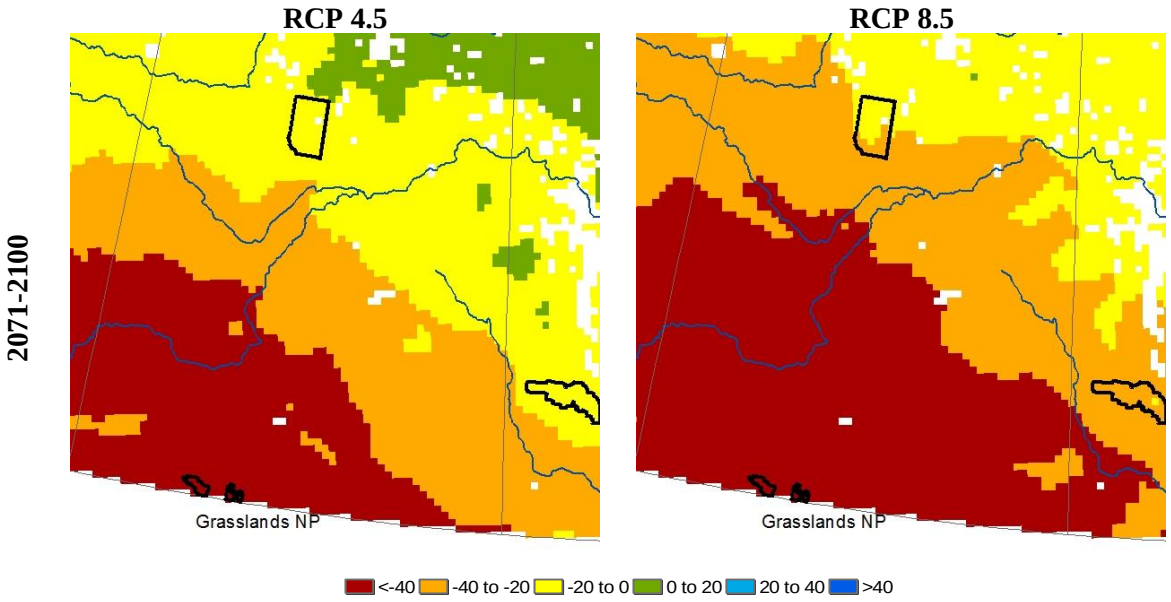


The CMIP5 climate model (http://climate-scenarios.canada.ca/?page=download-cmip5) projects a decrease in wind speed in 2046-2065 from 1986-2005 reference period (RCP 8.5) for the Grasslands NP region.

2.4 Other Variables

Climate Moisture Index

Climate Moisture Index (CMI) is calculated as the difference between annual precipitation and potential evapotranspiration (PET) - the potential loss of water vapour from a landscape covered by vegetation. Positive CMI values indicate wet or moist conditions while negative CMI values indicate dry conditions.

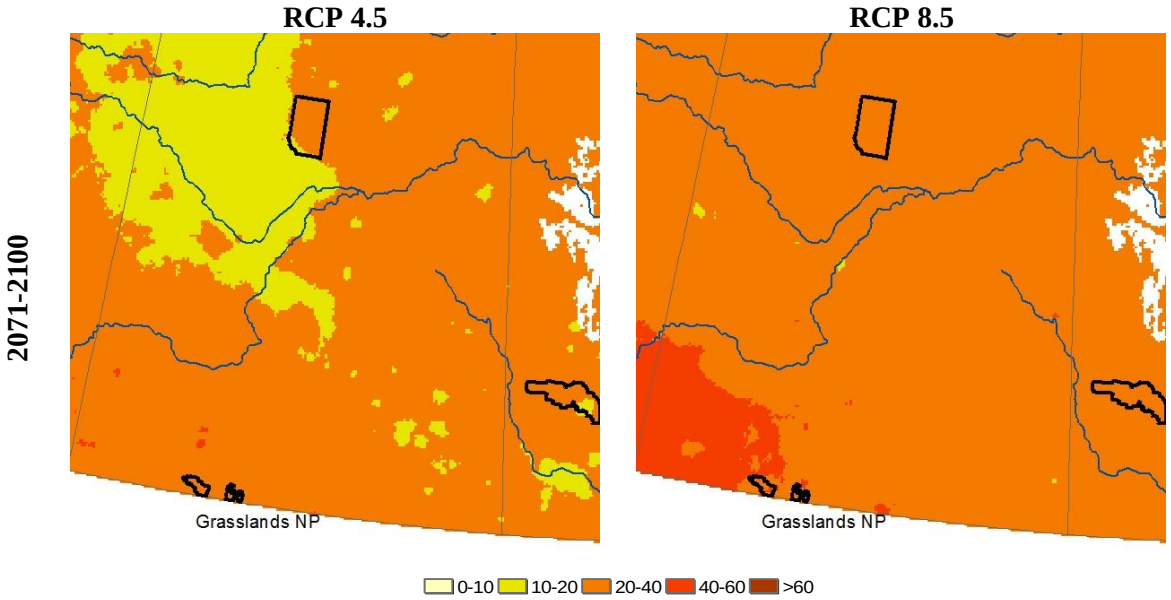


Projected change in Climate Moisture Index for southern Saskatchewan from baseline (1981-2010). A positive value = wetter conditions, while a negative value = drier conditions. Grasslands NP is projected to experience a decreased CMI value of -60 to -80 by 2071-2100 (much drier). Data source: Natural Resources Canada, http://www.nrcan.gc.ca/forests/climate-change/forest-change/17772.

Some studies suggest that drought conditions will become increasingly more common and severe (e.g., Masud *et al.*, 2017).

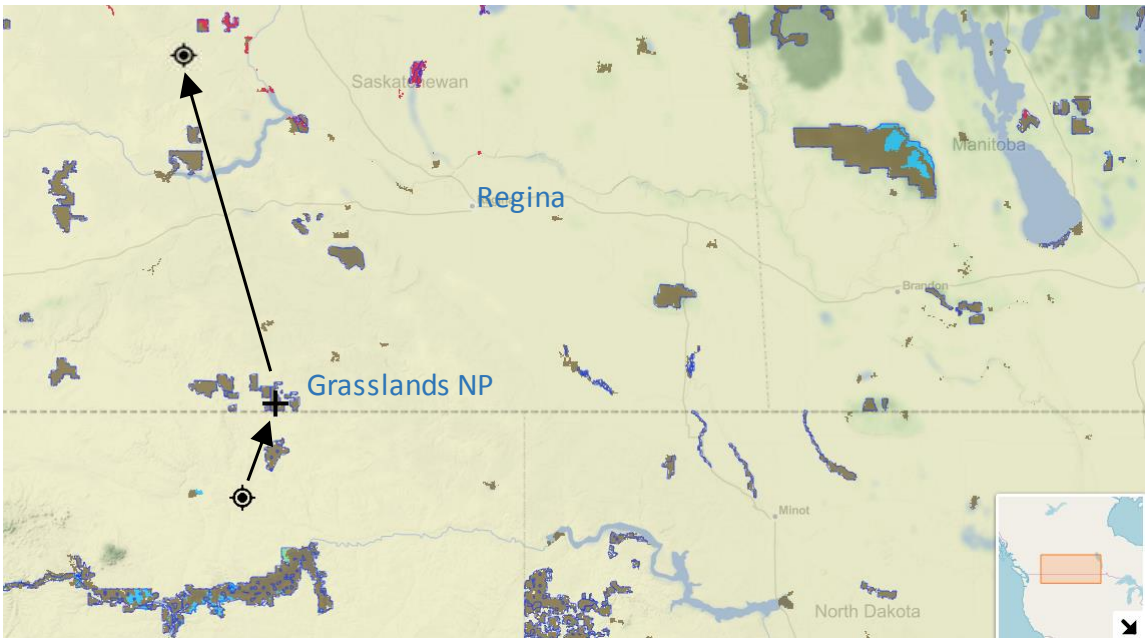
Of note, Agriculture and Agri-Food Canada maintains the "Canadian Drought Monitor" (access CDM here) which provides timely information on drought conditions in the region. Historic data of drougt conditions is available.

Wildfire Season



Projected increase in wildfire season for southern Saskatchewan from baseline (1981-2010). Increased length in days from baseline (1981-2010) under RCP 4.5 and RCP 8.5 scenarios. Grasslands NP is projected to experience a 30 to 40 day longer wildfire season by 2071-2010. Data source: Natural Resources Canada, http://cfs.nrcan.gc.ca/fc-data-catalogue.

Climate Displacement



Origin of the future climate type and future destination of the current climate type for Grasslands (2080's, RCP 8.5) determined using AdaptWest's Climate Displacement Tool (https://adaptwest.databasin.org/pages/climate-displacement-protected-areas).

Biodiversity

- Stephens *et al.* (2018) discuss the climate change variables (e.g., growing degree days, winter severity, drought, etc...) and their impacts to black-tailed prairie dogs in the Grasslands region.
- Li and Guo (2012) discuss how vegetation phenology and condition has changed slightly in Grasslands NP due to climate change.
- Henderson (2010) studied vegetation in Grasslands NP and includes some discuss on the impact of future climatic conditions.

3. References

ECCC. (2017). *Adjusted and Homogenized Canadian Climate Data (AHCCD)*. Environment and Climate Change Canada. https://www.ec.gc.ca/dccha-ahccd/

Gross, J. E., Woodley, S., Welling, L. A., and Watson, J. E. M. (Eds.). (2016). *Adapting to Climate Change. Guidance for Protected Area Managers and Planners* (Vol. No. 24). Gland, Switzerland: IUCN.

Henderson, J. A. (2010). *A study of the response of the northern mixed-grass prairie in Grasslands National Park, Saskatchewan to a changing climate.* (M.Sc.), University of Reginahttps://central.bac-lac.gc.ca/.item?id=MR79909&op=pdf&app=Library

IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Intergovernmental Panel on Climate Change (IPCC). Geneva, Switzerland. http://www.ipcc.ch/report/ar5/

Li, Z. Q. and Guo, X. L. (2012). Detecting Climate Effects on Vegetation in Northern Mixed Prairie Using NOAA AVHRR 1-km Time-Series NDVI Data. *Remote Sensing, 4*(1), 120-134. doi:10.3390/rs4010120.

Masud, M. B., Khaliq, M. N., and Wheater, H. S. (2017). Future changes to drought characteristics over the Canadian Prairie Provinces based on NARCCAP multi-RCM ensemble. *Climate Dynamics, 48*(7-8), 2685-2705. doi:10.1007/s00382-016-3232-2.

Parker, S. (2017). *Let's Talk about Climate Change: Prairie and Boreal Plains Region*. Parks Canada, Office of the Chief Ecosystem Scientist.

Parker, S., Barr, S., and Harrop Archibald, H. (2018). *Climate Change Adaptation Options for Biodiversity: Part 1. Context and Guidance Report*. Office of the Chief Ecosystem Scientist, Parks Canada Agency, Gatineau, QC. doi:10.13140/RG.2.2.31409.02403/1.

PCIC. (2014). *Statistically Downscaled Climate Scenarios*. Pacific Climate Impacts Consortium, University of Victoria. https://www.pacificclimate.org/data/statistically-downscaled-climate-scenarios

Price, D. T., McKenney, D. W., Joyce, L. A., Siltanen, R. M., Papadopol, P., and Lawrence, K. (2011). *High-Resolution Interpolation of Climate Scenarios for Canada Derived from General Circulation Model Simulations*. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta. http://cfs.nrcan.gc.ca/publications?id=32971

R Core Team. (2017). *R: A Language and Environment for Statistical Computing (ver. 3.4.3)*. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org

Rockman, M., Morgan, M., Ziaja, S., Hambrecht, G., and Meadow, A. (2016). *Cultural Resources Climate Change Strategy*. Cultural Resources, Partnerships, and Science and Climate Change Response Program, National Park Service (NPS). Washington, DC. https://www.nps.gov/subjects/climatechange/culturalresourcesstrategy.htm

Simonovic, S. P., Schardong, A., and Sandink, D. (2017). Mapping Extreme Rainfall Statistics for Canada under Climate Change Using Updated Intensity-Duration-Frequency Curves. *Journal of Water Resources Planning and Management, 143*(3), 12. doi:10.1061/(asce)wr.1943-5452.0000725.

Stephens, T., Wilson, S. C., Cassidy, F., Bender, D., Gummer, D., Smith, D. H. V., *et al.* (2018). Climate change impacts on the conservation outlook of populations on the poleward periphery of species ranges: A case study of Canadian black-tailed prairie dogs (Cynomys ludovicianus). *Global Change Biology, 24*(2), 836-847. doi:10.1111/gcb.13922.

Vuuren, D., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., *et al.* (2011). The representative concentration pathways: an overview. *Climatic Change, 109*(1-2), 5-31. doi:10.1007/s10584-011-0148-z.

Warren, F. J. and Lemmen, D. S. (Eds.). (2014). *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation*. Ottawa, ON: Government of Canada.

Appendix 1. Climate Atlas of Canada data for Wood Mountain

The Wood Mountain (brown) regional grid cell in the Atlas of Canada (https://climateatlas.ca/).

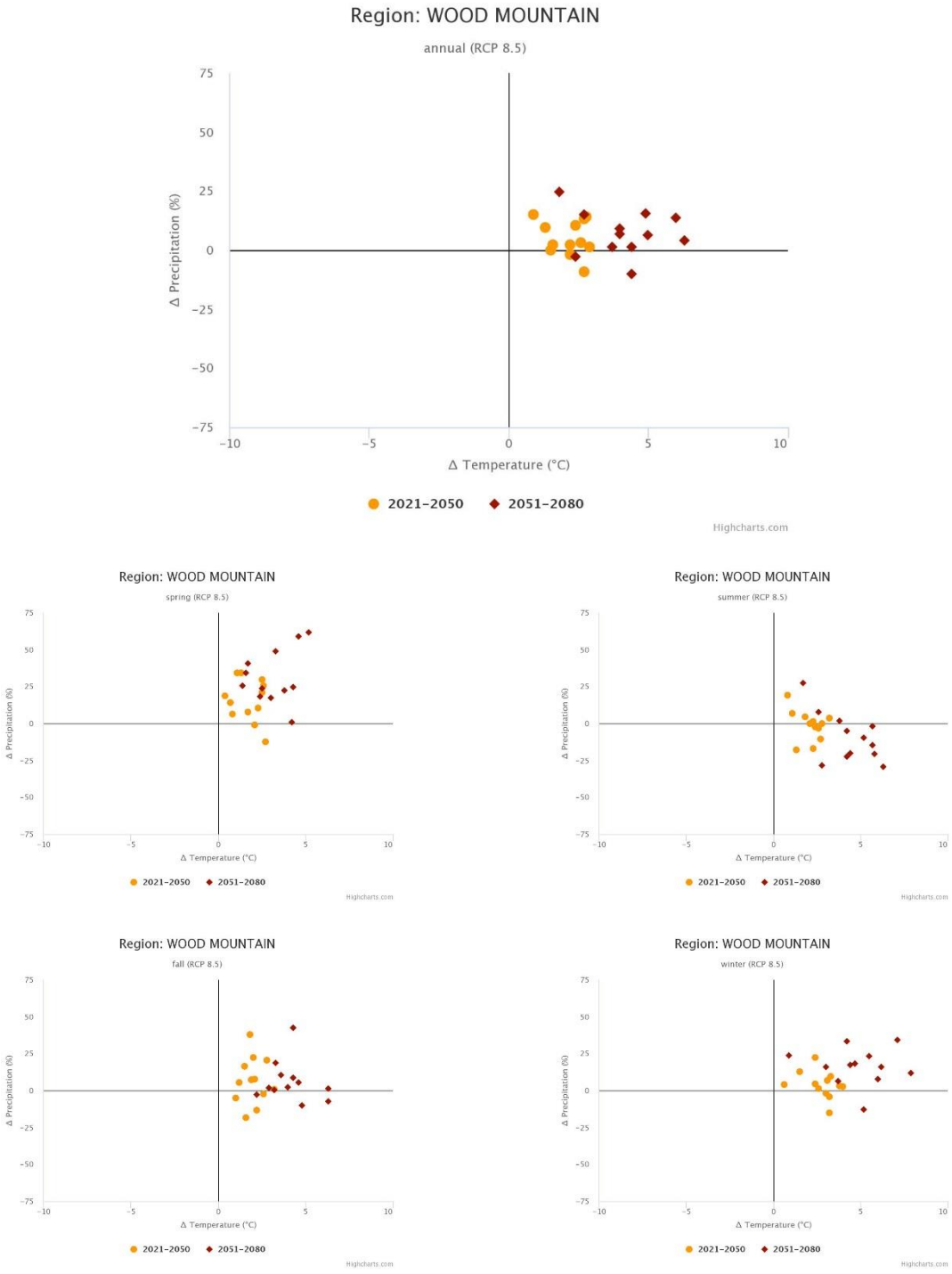
RCP 8.5: High Carbon climate future

GHG emissions continue to increase at current rates

Variable	Period	1976-2005	2021-2050			2051-2080		
		Mean	Low	Mean	High	Low	Mean	High
Precipitation (mm)	Annual	349	244	366	514	244	373	525
Precipitation (mm)	Spring	85	48	100	169	52	111	196
Precipitation (mm)	Summer	152	73	148	261	56	139	250
Precipitation (mm)	Fall	61	25	66	127	27	65	120
Precipitation (mm)	Winter	50	24	52	84	28	58	95
Mean Temperature (°C)	Annual	3.7	3.7	5.9	8	5.2	7.9	10.6
Mean Temperature (°C)	Spring	3.8	1.7	5.5	8.9	3.4	6.9	10.3
Mean Temperature (°C)	Summer	17.5	17.3	19.6	22	18.9	21.9	24.9
Mean Temperature (°C)	Fall	4.6	3.7	6.5	9	5.9	8.7	11.7
Mean Temperature (°C)	Winter	-11.1	-13.3	-8.4	-3.4	-11.3	-6.2	-1
Tropical Nights	Annual	0	0	1	3	0	3	15
Very hot days (+30°C)	Annual	19	16	34	62	27	55	84
Very cold days (-30°C)	Annual	6	0	2	11	0	1	6
Date of Last Spring Frost	Annual	May 22	May 3	May 13	May 26	April 26	May 7	May 16
Date of First Fall Frost	Annual	Sep. 15	Sep. 13	Sep. 24	Oct. 3	Sep. 21	Oct. 1	Oct. 11
Frost-Free Season (days)	Annual	115	114	133	150	130	148	166

Climate projection summary for Wood Mountain, RCP 8.5

Scatterplot for Temperature and Precipitation Models

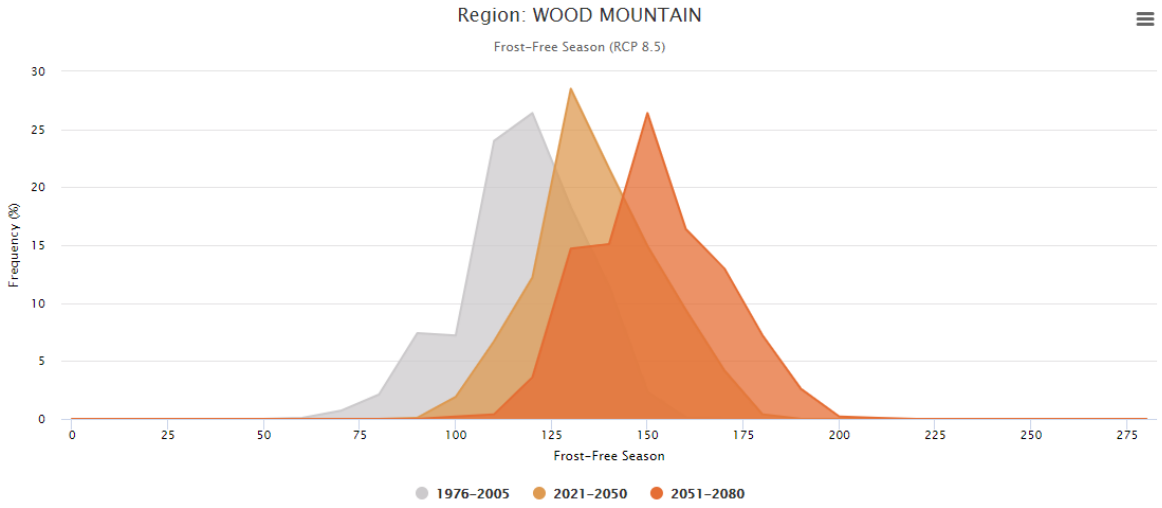


Climate models for the Grasslands NP region. Each point represents a single model-simulated temperature/precipitation response to the RCP 8.5 scenario. Statistically downscaled data (Bias Corrected Spatial Disaggregation; BCSD) derived from 12 CMIP5 global climate models (PCIC, 2014). Most models project warmer and wetter conditions for spring and winter. While projections for summer and fall are warmer, precipitation is less certain.

Frost-Free Season (RCP 8.5)

Mean value

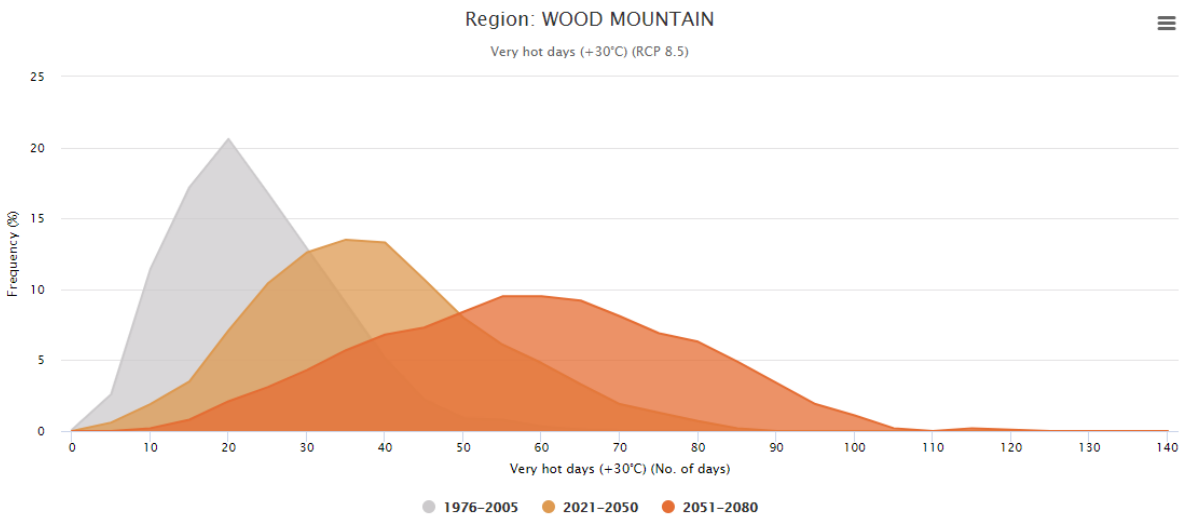
Recent past 1976-2005		Immediate future 2021-2050		Near future 2051-2080
115.3	→	133.2	→	147.8

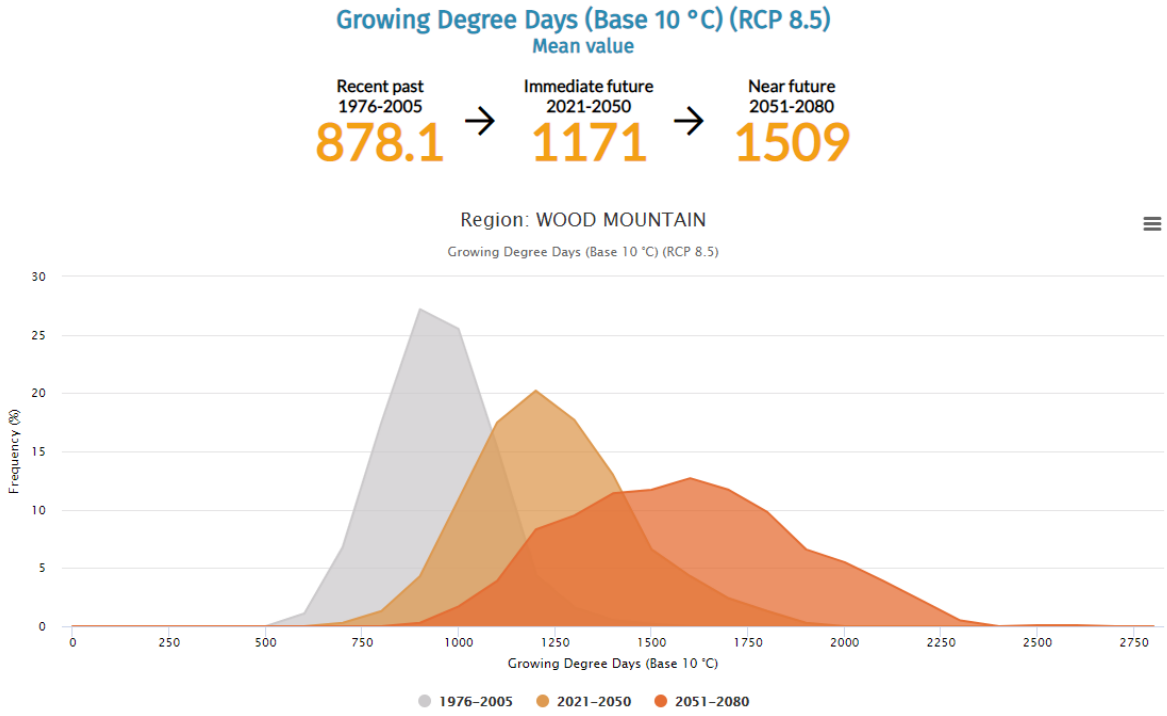


Very hot days (+30°C) (RCP 8.5)

Mean value

Recent past 1976-2005		Immediate future 2021-2050		Near future 2051-2080
18.7	→	34.0	→	55.2




Growing Degree Days (Base 10 °C) (RCP 8.5)
Mean value
Recent past
1976-2005
878.1
Immediate future
2021-2050
1171
Near future
2051-2080
1509
Region: WOOD MOUNTAIN
Growing Degree Days (Base 10 °C) (RCP 8.5)
Frequency (%)
30
25
20
15
10
5
0
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
Growing Degree Days (Base 10 °C)
1976–2005
2021–2050
2051–2080