No Evidence for Increasing Monthly or Annual Temperature and Precipitation Variability Across the Southern Canadian Prairies

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Abstract

Historical monthly and annual temperature (1955-2011) and precipitation (1961-2011) datasets at three representative climate stations (Calgary, Alberta; Swift Current, Saskatchewan; and Estevan, Saskatchewan) in the southern Canadian prairies were examined to determine whether the region is trending toward a more variable climate. Few significant absolute year-to-year or five-year 75-25 interquartile range temperature and precipitation temporal trends in the study area were identified. No clear and consistent signature was found for increasing temperature or precipitation variability on monthly or annual timescales.

Keywords:
Climate variability, Climate change, Southern Canadian prairies, Temperature, Precipitation

The prairie region of western Canada covers the southernmost area of the province of Manitoba (MB), south and central Saskatchewan (SK), and much of Alberta (AB). This dryland region contains over 80% of the country's arable farmland and is characterized by short, dry summers and long, cold winters with low precipitation and high evapotranspiration that leaves the area subject to seasonal and periodic water deficits [1,2]. As such, the effects of climate change, whether due to anthropogenic influences or natural cycles, have the potential to dramatically impact the security of the country's food supply and the economies of the affected provinces.

Climate models have predicted general warming as well as decreased summer precipitation in the grain belt region of the Canadian prairies [1-5]. However, few studies [6-9] have examined trends in historic climate data to determine whether changes in climate variability are occurring. In the current work, we investigate whether there is any evidence at the monthly or annual timescales for changes in temperature or precipitation variability at three representative climate stations situated across the southern Canadian prairies.

Climate data was obtained from Environment Canada's Adjusted and Homogenized Canadian Climate Data (AHCCD) database [10-12]. One climate station from southern Alberta and two stations from southern Saskatchewan (Table 1, Figure 1) were chosen for study. These stations collectively contain as complete a dataset as possible from 1955 (the earliest year for which full temperature records are available for all three stations) through 2011 (the latest year on record). A complete precipitation record for all three stations was only available from 1961 onwards. The climate parameters considered include mean temperature (T_{mean}), mean maximum ($T_{mean,max}$) and mean minimum ($T_{mean,min}$) temperature, extreme maximum ($T_{x,max}$) and extreme minimum ($T_{x,min}$) temperature, and total precipitation. Data were analysed

Table 1. Summary details of the climate monitoring stations under study.

Station	Calgary, AB	Swift Current, SK	Estevan, SK
ID	3031093	4028040/60	4012400
Latitude (°N)	51.12	50.27	49.22
Longitude (°W)	114.02	108.48	102.97
Elevation (m)	1084	318	581
Stations joined?	no	yes	yes

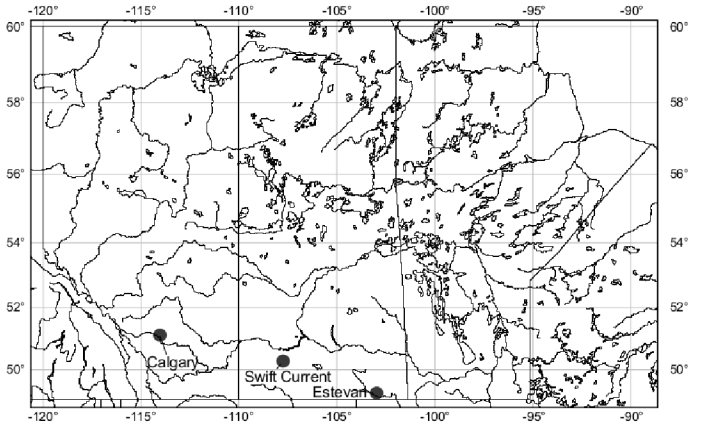

Figure 1. Locations of the climate monitoring stations in the southern prairie region of Canada (scale = 1:20,000,000).

using the parametric and non-parametric (Spearman/Kendall rank correlation [13,14]) methods within KyPlot (v.2.0b15) [15].

We have previously found substantial inter- and intrastation heterogeneity in temperature and precipitation trends on monthly and annual bases in this region [16,17]. In our prior work, the presence/absence and magnitude of any temporal trends were found to be highly dependent on the time frame investigated. To determine whether climate variability was changing at the

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monthly or annual intervals, we investigated potential temporal trends in the absolute values of the year-on-year changes in each parameter as well as possible trends in the five-year 75-25 interquartile range (5-yr IQR) for each variable (Tables 2 through 4).

There are few significant ($p<0.05$) year-to-year and 5-yr IQR temperature or precipitation variability trends between 1955 and 2011. Overall, we find no clear and consistent signature for increasing temperature or precipitation variability on monthly or annual timescales for these three representative climate stations on the southern Canadian prairies.

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Table 2. Trends in the absolute year-to-year change and the five-year 75-25 interquartile range (5-yr IQR) for annual and monthly mean (T_{mean}), mean maximum ($T_{mean,max}$), and mean minimum ($T_{mean,min}$) temperatures from 1955 through 2011 at each of the three climate stations under consideration. Values are presented as parametric linear regression/non-parametric Spearman rank correlation/non-parametric Kendall rank correlation for significance with the magnitude (parametric linear regression) or sign (non-parametric Spearman and Kendall) of the slope (°C/year) in brackets (ns=p>0.05, *=p≤0.05, **= p≤0.01, ***= p≤0.001).

	Calgary		Swift Current		Estevan	
	Year-to-Year	5-yr IQR	Year-to-Year	5-yr IQR	Year-to-Year	5-yr IQR
			T_{mean}			
Annual	ns/*/*[-]	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Jan	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Feb	ns/ns/ns	ns/ns/ns	*[0.065]/*/*	**[0.096]/**/**	ns/ns/ns	ns/ns/ns
Mar	ns/ns/ns	ns/ns/ns	ns/ns/ns	***[-0.100]/***/***	ns/ns/ns	***[-0.071]/**/***
Apr	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
May	ns/ns/ns	ns/*/*[-]	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Jun	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Jul	ns/ns/ns	**[0.015]/**/*	ns/ns/ns	**[0.030]/**/**	ns/ns/ns	ns/ns/ns
Aug	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Sep	ns/ns/ns	ns/ns/ns	*[-0.045]/*/*	ns/ns/ns	ns/ns/ns	**[-0.027]/**/*
Oct	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/*/*[-]	ns/ns/ns	ns/ns/ns
Nov	ns/ns/ns	*[0.039]/*/*	ns/ns/ns	ns/ns/ns	ns/ns/ns	*[0.039]/ns/*
Dec	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
			$T_{mean,max}$			
Annual	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Jan	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Feb	ns/ns/ns	ns/ns/ns	ns/*/*[+]	**[0.101]/***/***	ns/ns/ns	ns/ns/ns
Mar	ns/ns/ns	ns/ns/ns	ns/ns/ns	***[-0.092]/**/**	ns/ns/ns	***[-0.082]/***/***
Apr	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	*[-0.037]/*/*
May	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	*[-0.015]/*/*
Jun	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Jul	ns/ns/ns	ns/ns/ns	ns/ns/ns	**[0.045]/**/*	ns/ns/ns	ns/ns/ns
Aug	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Sep	ns/ns/ns	*[-0.036]/*/*	*[-0.053]/*/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Oct	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/*/**[-]	ns/ns/ns	ns/ns/ns
Nov	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	*[0.057]/ns/ns	ns/ns/ns
Dec	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/*/*[+]	ns/ns/ns	ns/ns/ns
			$T_{mean,min}$			
Annual	ns/*/*[+]	*[-0.007]/*/*	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Jan	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Feb	ns/ns/ns	*[-0.045]/ns/*	ns/*/*[+]	**[0.089]/**/**	ns/ns/ns	ns/ns/ns
Mar	ns/ns/ns	ns/ns/ns	*[-0.062]/ns/ns	***[-0.095]/**/**	ns/ns/ns	**[-0.046]/*/*
Apr	ns/ns/ns	*[-0.016]/ns/ns	ns/ns/ns	ns/*/*[-]	ns/ns/ns	*[0.021]/**/*
May	ns/ns/ns	*[-0.010]/*/*	ns/ns/ns	*[0.021]/*/*	ns/ns/ns	**[-0.020]/*/*
Jun	ns/ns/ns	ns/ns/ns	ns/ns/ns	*[-0.014]/ns/ns	ns/ns/ns	ns/ns/ns
Jul	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	***[-0.026]/***/***
Aug	*[-0.015]/*/*	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Sep	ns/ns/ns	ns/ns/ns	*[-0.033]/ns/ns	*[-0.027]/ns/ns	ns/ns/ns	ns/ns/ns
Oct	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Nov	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	**[0.042]/**/**
Dec	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns

Table 3. Trends in the absolute year-to-year change and the five-year 75-25 interquartile range (5-yr IQR) for annual and monthly extreme maximum ($T_{x,max}$) and extreme minimum ($T_{x,min}$) temperature from 1955 through 2011 at each of the three climate stations under consideration. Values are presented as parametric linear regression/non-parametric Spearman rank correlation/non-parametric Kendall rank correlation for significance with the magnitude (parametric linear regression) or sign (non-parametric Spearman and Kendall) of the slope (°C/year) in brackets (ns=p>0.05, *=p≤0.05, **= p≤0.01, ***= p≤0.001).

	Calgary		Swift Current		Estevan	
	Year-to-Year	5-yr IQR	Year-to-Year	5-yr IQR	Year-to-Year	5-yr IQR
			$T_{x,max}$			
Annual	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	*[-0.018]/*/*	*[-0.014]/*/*
Jan	ns/ns/ns	***[-0.069]/***/***	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Feb	ns/ns/ns	ns/ns/ns	ns/ns/ns	*[0.404]/*/*	ns/ns/ns	ns/ns/ns
Mar	ns/ns/ns	ns/ns/ns	ns/ns/ns	**[-0.074]/*/**	ns/ns/ns	ns/ns/ns
Apr	ns/ns/ns	ns/ns/ns	ns/ns/ns	**[-0.083]/**/**	*[-0.065]/**/**	***[-0.078]/***/**
May	ns/ns/ns	***[0.049]/***/**	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Jun	ns/ns/ns	**[-0.028]/**/**	ns/ns/ns	ns/ns/ns	***[-0.053]/**/**	*[-0.021]/ns/ns
Jul	ns/ns/ns	***[-0.377]/***/***	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Aug	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Sep	ns/ns/ns	*[0.034]/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Oct	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	*[-0.032]/*/*
Nov	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Dec	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
			$T_{x,min}$			
Annual	ns/ns/ns	*[0.021]/*/*	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Jan	ns/ns/ns	*[0.057]/ns/ns	ns/ns/ns	ns/ns/ns	**[0.073]/*/*	***[0.071]/***/***
Feb	ns/ns/ns	*[0.080]/*/*	*[0.151]/ns/ns	*[0.109]/*/*	ns/*/*[+]	**[0.086]/**/*
Mar	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	*[-0.012]/*/*	ns/ns/ns
Apr	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
May	ns/ns/ns	*[-0.027]/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Jun	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	*[0.032]/*/ns
Jul	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	*[-0.023]/*/*
Aug	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Sep	ns/*[-]/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Oct	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/*/*[+]	ns/ns/ns	ns/ns/*[+]
Nov	ns/ns/ns	***[0.098]/**/**	ns/ns/ns	ns/*/*[+]	*[0.080]/*/*	*[0.056]/*/*
Dec	ns/ns/ns	ns/ns/ns	ns/ns/ns	**[0.073]/**/**	ns/ns/ns	ns/ns/ns

Table 4. Trends in the absolute year-to-year change and the five-year 75-25 interquartile range (5-yr IQR) for annual and monthly total precipitation from 1961 through 2011 at each of the three climate stations under consideration. Values are presented as parametric linear regression/non-parametric Spearman rank correlation/non-parametric Kendall rank correlation for significance with the magnitude (parametric linear regression) or sign (non-parametric Spearman and Kendall) of the slope (mm/year) in brackets (ns=p>0.05, *=p≤0.05, **= p≤0.01, ***= p≤0.001).

	Calgary		Swift Current		Estevan	
	Year-to-Year	5-yr IQR	Year-to-Year	5-yr IQR	Year-to-Year	5-yr IQR
Annual	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Jan	*[-0.131]/ns/ns	*[-0.117]/ns/*	ns/ns/ns	ns/ns/ns	ns/ns/ns	**[0.164]/*/*
Feb	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	***[-0.294]/***/***
Mar	**[0.284]/*/*	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Apr	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/*/*[-]	ns/ns/ns	ns/ns/ns
May	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	*[0.436]/ns/*
Jun	ns/ns/ns	*[-0.498]/ns/ns	ns/ns/ns	***[-1.291]/***/***	ns/ns/ns	ns/ns/*
Jul	ns/ns/ns	ns/ns/ns	ns/ns/ns	***[1.122]/***/***	ns/ns/ns	ns/ns/ns
Aug	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Sep	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/*	ns/ns/ns	ns/ns/ns
Oct	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	*[-0.185]/ns/ns
Nov	ns/ns/ns	*[0.154]/*/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/ns/ns
Dec	ns/ns/ns	ns/ns/ns	ns/ns/ns	ns/*/*[+]	*[0.177]/*/*	*[0.129]/*/*