Historical precipitation characteristics in the Palliser’s Triangle region of the Canadian prairies

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Key Messages

- Drought is a recurrent and spatially variable feature of Palliser’s Triangle.
- Teleconnections (ENSO, PDO and PNA) affect seasonal and long-term variation in precipitation across the Canadian prairies.
- Among teleconnections, the PDO has the greatest effect on precipitation in Palliser’s Triangle.

The Palliser’s Triangle region of the Canadian prairies is a drought prone area. The region’s dry belt extending from Lethbridge, Alberta to Swift Current, Saskatchewan has variously expanded and shrunk over the course of the 20th century. Since 1980, it has been expanding east and north towards Regina and Saskatoon, Saskatchewan. Teleconnections such as the El Niño/Southern Oscillation (ENSO), the Pacific North American (PNA) pattern, and the Pacific Decadal Oscillation (PDO) are known to have effects on the precipitation received in the region. The main purpose of this research is to understand how teleconnections alter the pattern of precipitation across Palliser’s Triangle. The PDO was shown to have the greatest influence over precipitation. The study shows that winter values of a teleconnection index have a greater influence on spring and summer precipitation than the spring and summer values of the same index.

Keywords: Palliser’s Triangle region, Canadian prairies, teleconnections, ENSO, PDO, PNA

Introduction

The Canadian prairies are noted for their agricultural production, however, there are areas of the region that are known for being more prone to drought than others. One such area, known as Palliser’s Triangle, extends across southern Alberta and Saskatchewan to the southwest corner of Manitoba (Villmow 1956; Spry 1959; Gan 2000; Marchildon et al. 2009). Known for its dryness, there is, however, variability from year to year in the amount of precipitation received. Different teleconnections such as the El Niño/Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), and the Pacific North American (PNA) pattern, have been known to affect temperature and precipitation across the Canadian prairies and over the globe (Maybank et al. 1995; Bonsal and Lawford 1999; Gan 2000; Shabbar and Skinner 2004; Coulibaly 2006; St. George et al. 2009; Vicente-
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Serrano et al. 2011; Dong and Dai 2015; Vincent et al. 2015). Interannual variations in precipitation in the Canadian prairies have been associated with ENSO and PDO variations (Shabbar et al. 1997; Bonsal and Lawford 1999; Bonsal et al. 2001; Shabbar and Skinner 2004; Shabbar and Yu 2012). The objectives of this research are to: i) investigate the amount of precipitation that Palliser’s Triangle receives at different locations; ii) identify those areas within Palliser’s Triangle that are the most variable in the amount of precipitation received; and iii) examine the correlations between climate modes (teleconnections) and precipitation in regions of Palliser’s Triangle.

Background

During John Palliser’s 1857–1860 expedition into the heart of the central plains of North America, he observed that an area of the prairies was more arid than the land that bordered it to the north (Marchildon et al. 2009). This area became known as Palliser’s Triangle. Its northern boundary is set at 52°N from where it extends south to the USA-Canada border between 100°W in southwestern Manitoba and 114°W in southeastern Alberta (Villmow 1956; Spry 1959; Marchildon et al. 2009) (Figure 1). There is a drier interior within the region around the Alberta-Saskatchewan border extending west to Medicine Hat, Alberta and east to Swift Current, Saskatchewan known as the dry belt (Villmow 1956; Maybank et al. 1995; Marchildon et al. 2008, 2009: Masud et al. 2015). The dry belt lies in the rain shadow of the Rocky Mountains, which restrict the flow of moisture from the Pacific Ocean and cause it to receive much lower precipitation (<350 mm per annum) than the average precipitation of Palliser’s Triangle (Marchildon et al. 2008). Although the whole of Palliser’s Triangle is vulnerable to drought, the precipitation record and pattern show a great deal of interannual variability (Marchildon et al. 2009; St. George et al. 2009). Neither is the amount of atmospheric moisture the only variable factor. The area experiences high moisture losses due to chinook winds. Also, the soils are typically of light texture and have low water retention capacity making the area more sensitive to drought (Marchildon et al. 2008). Not least, the size of the dry belt has also fluctuated over the 20th century, growing up to seven times larger during the 1930s than its present size (Marchildon et al. 2009).

Vincent et al. (2015) showed a significant increase in the annual mean temperature (1° to 2°C) of the southern parts of the Canadian prairies over the period 1948 to 2012, with the highest warming occurring in winter and spring. In contrast, annual and seasonal total precipitation amounts have decreased in the region (Vincent et al. 2015). Also the increase in temperature has triggered a decrease in the amount of precipitation falling as snow. Millet et al. (2009) showed that the prairie pothole region (PPR) varies greatly in atmospheric moisture by presenting a precipitation gradient from east to west. The PPR is prairie grassland, which occupies approximately 750,000 km² and cov-
ers parts of three Canadian provinces (Alberta, Saskatchewan, and Manitoba) and five U.S. states (Montana, North and South Dakota, Minnesota, and Iowa). Precipitation in the east of the region was nearly triple the amount received in the west (Millet et al. 2009). The Palmer Drought Severity Index and decadal analysis for the 20th century indicate that southeastern Alberta and southwestern Saskatchewan comprise the most drought prone area in the prairies (Millet et al. 2009). Millet et al. (2009) also determined that conditions across the western prairies in the 1980s were similar to those of the Dust Bowl of the 1930s, and that the 1990s was the wettest decade of the 20th century. Similar findings on the interdecadal variation of precipitation have been found by Chipanshi et al. (2006), Bonsal et al. (2013), and Masud et al. (2015). Bonsal et al. (2017) found that the region of the South Saskatchewan River Basin has experienced many interdecadal periods of variability changing from cool/wet to warm/dry throughout the 20th century. The interdecadal changes are attributed to variation in the 500 mb pressure height above the region, with ridging associated with warm/dry periods and troughing with cool/wet periods. Bonsal and Wheaton (2005) confirm that the 2001–2002 Canadian prairie drought was caused by anomalous persistent ridges over the USA and southern Canada that continued for several seasons. Bonsal and Regier (2007) investigated the 2001–2002 drought and found that the west-central Canadian prairies experienced severe precipitation deficit due to anomalous above average pressure heights which led to warmer and drier than normal surface conditions.

Masud et al. (2015) have shown that the southern parts of the Saskatchewan River Basin including the western part of the South Saskatchewan River watershed and regions around the Alberta-Saskatchewan border experience high drought risk. In contrast, moderate drought risk is characteristic of the North Saskatchewan River watershed with the exception of its eastern parts, which are at high risk. Still lesser but more frequent drought risk is associated with areas near the Saskatchewan-Manitoba border, and particularly in those parts of the border within the Saskatchewan River watershed. Masud et al. (2015) also identified an association between drought severity and drought duration, with areas recording highest drought severity being closely associated with areas of greatest drought duration.

Climatic variability and drought

It has been known for many years that the ENSO has an effect on precipitation in many places across the globe and, in particular, western Canada (Maybank et al. 1995; Kumar and Hoerling 1997; Bonsal and Lawford 1999; Shabbar and Skinner 2004; Coulibaly 2006; St. George et al. 2009; Vicente-Serrano et al. 2011; Dong and Dai 2015). Sea surface temperatures (SSTs) in the equatorial Pacific have been shown to influence prairie precipitation (Shabbar et al. 1997; Bonsal and Lawford 1999; Shabbar and Skinner 2004). Colder than average SSTs in the equatorial Pacific in the previous winter tend to bring wetter summers to the Canadian prairies. These colder SSTs indicate the ENSO is in a cool phase, or La Niña, while warmer than average SSTs bring drier summers to the region. Shabbar and Skinner (2004) also connected the longer-term variability of moisture conditions in the Canadian prairies to the interdecadal pattern of the PDO. The PDO has been shown to be an important control on the variability of precipitation received, bringing more (or less) rain and snow during its negative (or positive) phases (Mantua and Hare 2002; Newman et al. 2003; Shabbar and Skinner 2004; Dong and Dai 2015). El Niño and the positive phase of the PDO have been related to warm winter temperatures in western and central Canada (Shabbar and Khondekar 1996; Bonsal et al. 2001; Mantua and Hare 2002; Shabbar and Yu 2012).

St. George et al. (2009) have used tree-ring records to identify long-term drought periods, and have established that a few ‘megadroughts’ occurred in the 18th century. Bonsal et al. (2013) found similar results with events dating back to the 14th century, and noted that pre-instrumental droughts typically had longer durations than modern droughts. St. George et al. (2009) attempted to connect summer tree-ring records with the ENSO and the PDO but failed to find any significant results. Instead, they suggested that winter values of the ENSO and the PDO are more strongly related to summer drought conditions, but could not demonstrate the relationship because the tree-ring records only correlate to summer growing conditions (St. George et al. 2009). Bonsal and Lawford (1999) showed that more extended dry spells were recorded during the second summer after an El Niño event occurred, while the opposite was true following La Niña events when far fewer dry spells occurred.

The PNA in upper-atmosphere circulation has been shown to be an important factor affecting temperature and precipitation across North America (Coulibaly 2006), and most influentially in winter. Bonsal and Lawford (1999) showed that the PNA follows the patterns of the ENSO, meaning that the PNA index often shows strong positive (or negative) values during El Niño (or La Niña). The PNA is also associated with drought on the Canadian prairies (Hryciw et al. 2013). Positive PNA values have also been related to drier than normal springs and summers over the prairies (Knox and Lawford 1990; Bonsal et al. 1999).

Data and methodology

Monthly precipitation totals for 12 stations were obtained from Environment and Climate Change Canada (2018). With the exception of Edmonton, all stations are located within an area bounded approximately by 49°N to 52°N, and 100°W to 114°W. Average annual precipitation was calculated for two time periods, 1950 to 1979 and 1980 to 2009. Average seasonal precipitation for spring (March to May) and summer (June to August) was calculated for both time periods. Using the long-term average precipitation, both annual and seasonal for the two time periods, the average deviation was calculated. With the aid of ArcGIS, data for each station was recorded, and several maps were created to display the average precipitation and average deviation data. Isohyets were used to show areas of equal pre-
Precipitation and to identify locations that were most vulnerable to drought.

Teleconnection data for the ENSO and the PNA were taken from the US National Oceanic and Atmospheric Administration’s Climate Prediction Center (NOAA 2018), and data for the PDO were retrieved from the University of Washington’s Joint Institute for the Study of the Atmosphere and Oceans (JISAO 2018). Average annual index values were calculated, as well as seasonal averages for spring and summer (March to August). These values were then compared with the total annual and total spring and summer precipitation for each of the 12 stations using Pearson’s correlation coefficients. The average winter (December to February) index value for the ENSO, the PDO, and the PNA were correlated with the spring and summer precipitation totals.

Results and discussion

Average precipitation

Average annual precipitation. The average precipitation from 1950 to 1979 across all 12 stations indicates that there was a dry belt (≤420 mm) extending from Medicine Hat towards Swift Current (Figure 2A). Between 1980 and 2009 the dry belt expanded from Lethbridge in the west towards Swift Current in the east, and also north towards Saskatoon (Figure 2B). Moving outwards from the core, the average annual precipitation increased. The driest station was Medicine Hat, then in decreasing order of dryness Swift Current, Saskatoon, and Lethbridge (Figure 3). Similar results were found by Maybank et al. (1995) and Marchildon et al. (2009), who found the area between Medicine Hat eastward towards Swift Current was more arid than the surrounding region. The wettest station was Cypress River, then in order of decreasing wetness Brandon, Edmonton, and Pierson (Figure 3). These wetter stations formed a band around the drier stations extending north and east of the core of dryness.

Average seasonal precipitation. Average spring precipitation had a pattern similar to the average annual precipitation from 1950 to 1979 with a dry belt (≤100 mm) from Edmonton in the northwest, Saskatoon in the east and Swift Current in the south (Figure 4A). Between 1980 and 2009, the dry area shifted westward slightly to include Medicine Hat but not Edmonton (Figure 4B). The driest spring station was Swift Current, then in order of decreasing dryness Saskatoon, Medicine Hat, and Edmonton (Figure 5). The wettest spring station was Cypress River, then in order of decreasing wetness Brandon, Pierson, and Lethbridge (Figure 5).

The Canadian prairies receive the majority of their precipitation during the summer season. Despite this, a dry belt extending from Lethbridge towards Swift Current and northwards towards Saskatoon existed between 1950 and 1979 (Figure 6A). Between 1980 and 2009 the dry belt was still evident (Figure 6B). Surrounding it, there was a band of moderate moisture, and finally a wet band was observed in the periphery. There was no significant change in summer precipitation between the two study periods. In both periods, the driest summer stations in order of decreasing dryness were Medicine Hat, Saskatoon, Lethbridge, and Swift Current (Figure 7). The wettest stations were Edmonton, Cypress River, Brandon, and Calgary (Figure 7).

Average deviation of precipitation

Average annual. The average deviation of annual precipitation was more variable between 1950 and 1979 (Figure 8A) than between 1980 and 2009 (Figure 8B). For 1950 to 1979, the east was more variable than the west with the exception of Lethbridge (Figure 8A). The least variable stations were Saskatoon, Edmonton, Calgary, and Swift Current while between 1980 and 2009 the least variable stations were Calgary, Cypress River, Saskatoon, and Edmonton (Figure 8B). The most variable stations between 1950 and 1979 were Brandon, Estevan, Kellihier, and Lethbridge while between 1980 and 2009 Pierson, Kellihier, Estevan, and Medicine Hat were the most variable (Figure 9).

Average seasonal. The average deviation of spring precipitation showed that between 1950 and 1979, Calgary was the least variable. With the exception of Lethbridge, the western stations had less deviation than stations in Manitoba (Figure 10A). Between 1980 and 2009 Manitoba stations were more variable than the western stations. The least variable station was Medicine Hat (Figure 10B). The range of deviation was larger between 1950 and 1979 than between 1980 and 2009. The least variable stations in the earlier period were Calgary, Edmonton, Swift Current, and Saskatoon, while in the later period the least variable stations were Medicine Hat, Lethbridge, Saskatoon, and Swift Current (Figure 11). Between 1950 and 1979, the most variable stations were Cypress River, Lethbridge, Estevan, and Brandon, while between 1980 and 2009 the most variable stations were Brandon, Cypress River, Pierson, and Calgary (Figure 11).

The summer average deviation for 1950 to 1979 had a pattern similar to the spring of that period. Western stations were less variable than their eastern counterparts, with Saskatoon identified as the least variable station, and Brandon and Kellihier the most variable (Figure 12A). Between 1980 and 2009, there was greater overall variability in precipitation (Figure 12B). Over the 1950 to 1979 period the least variable stations were Saskatoon, Edmonton, Swift Current, and Lethbridge while in the later period the least variable stations were Saskatoon, Calgary, Cypress River, and Swift Current (Figure 13). The most variable stations between 1950 and 1979 were Brandon, Estevan, and Medicine Hat while between 1980 and 2009 the most variable were Lethbridge, Edmonton, Brandon, and Kellihier (Figure 13).

Correlation between precipitation and teleconnections

ENSO. The Pearson correlation coefficients between average annual precipitation and average annual value of the Southern Oscillation Index (SOI) were significant at the 99% confidence level (P < 0.01) for Pierson, Brandon, Saskatoon, and Estevan (Table 1). The positive sign of the correlation coefficient suggests that these locations receive larger amounts of precipitation during the cold phase of the ENSO, La Niña. There also appears
Precipitation anomalies and climate variabilities

Figure 2
30-year average annual precipitation for 1950 to 1979 and 1980 to 2009 for Palliser’s Triangle
Cartography: Dustin Roussin

Figure 3
Average annual precipitation from 1950 to 2009 across Palliser’s Triangle
Figure 4
30-year average spring precipitation for 1950 to 1979 and 1980 to 2009 for Palliser’s Triangle
Cartography: Dustin Roussin

Figure 5
Average spring precipitation from 1950 to 2009 across Palliser’s Triangle
Figure 6
30-year average summer precipitation for 1950 to 1979 and 1980 to 2009 for Palliser’s Triangle
Cartography: Dustin Roussin

Figure 7
Average summer precipitation from 1950 to 2009 across Palliser’s Triangle
Precipitation anomalies and climate variabilities

Figure 8
Average deviation from 30-year average annual precipitation for 1950 to 1979 and 1980 to 2009 for Palliser’s Triangle
Cartography: Dustin Roussin

Figure 9
Average deviation of annual precipitation from 1950 to 2009 for Palliser’s Triangle
Figure 10
Average deviation from 30-year average spring precipitation for 1950–1979 and 1980–2009 for Palliser’s Triangle
Cartography: Dustin Rousin

Figure 11
Average deviation of spring precipitation for the Palliser’s Triangle, 1950 to 2009
Precipitation anomalies and climate variabilities

Figure 12
Average deviation from 30-year average summer precipitation for 1950 to 1979 and 1980 to 2009 for Palliser’s Triangle
Cartography: Dustin Roussin

Figure 13
Average deviation of summer precipitation for Palliser’s Triangle, 1950 to 2009
to be a relationship between precipitation at Lethbridge and El Niño, suggesting that it is wetter during this phase of the ENSO in spring and summer (Table 1). The area around Brandon had a significant result with the combined spring and summer values, suggesting that La Niña brings more precipitation to the region (Table 1). There were no significant results between the winter index value of the ENSO and the combined spring and summer precipitation totals (Table 2). These results conform with the majority of research conducted on the ENSO, where La Niña (El Niño) tends to bring with it wetter (drier) conditions across the Canadian prairies (Maybank et al. 1995; Bonsal et al. 1999; Shabbar and Skinner 2004; Coulibaly 2006; St. George et al. 2009; Vicente-Serrano et al. 2011; Dong and Dai 2015).

**PDO.** The PDO yielded a greater number of significant results than the other teleconnections (Table 1). The correlation between average annual precipitation and the average annual PDO index yielded significant results in all eastern stations bar Kelliher. The stations were in order of decreasing significance, Pierson, Brandon, Estevan, Regina, Saskatoon, and Cypress River (Table 1). The negative sign of the correlation coefficients suggests that the aforementioned stations received more precipitation during the negative or cool phase of the PDO. This relationship continues for the combined spring and summer values for Brandon and Estevan, where the coefficient is both significant and negative (Table 1). Kelliher had a coefficient that was positive and significant, suggesting that the region’s precipitation is heavier during the positive phase of the PDO (Table 1). The correlation between the winter index value and combined spring and summer precipitation totals was both negative and significant for Estevan, Regina, Brandon, Swift Current, and Pierson, implying that the amount of precipitation received at these stations increases during the negative phase of the PDO (Table 2). This suggests that the winter values have a larger control on the precipitation received on the prairies than the spring and summer index values (Tables 1 and 2). The PDO appears to be the strongest variable in the interdecadal patterns of drought and precipitation variability, as presented by Shabbar and Skinner (2004), Dong and Dai (2015), and Vincent et al. (2015).

**PNA.** Calgary recorded the only significant relationship between average annual precipitation and the average annual index of the PNA (Table 1). The positive sign of the correlation coefficient suggests that the positive phase of the PNA is an important control on the amount of precipitation received in the Calgary area. However, since the value is low and other surrounding areas were not significant, this result should be viewed with caution. The combined spring and summer values, however, yielded significant results for Estevan, Regina, and Pierson (Table 1). The negative value of the coefficient suggests that during the negative phase of the PNA the amount of precipitation received increases. There were no significant results between the winter index value of the PNA and the combined spring and summer precipitation totals (Table 2). These results corroborate other studies conducted for the region, which show that the PNA during the negative phase brings increased precipitation and fewer dry periods (Knox and Lawford 1990; Bonsal and Lawford 1999; Coulibaly 2006; Hryciw et al. 2013). Researchers have shown that the PNA is most influential during winter, but that there is also a relationship between the spring and summer values and the growing season precipitation in the more western stations.

### Table 1
Correlation between average annual and spring/summer teleconnection indices and average annual and spring/summer precipitation totals for stations within Palliser’s Triangle, 1950 to 2009

<table>
<thead>
<tr>
<th>Weather Station</th>
<th>ENSO Annual</th>
<th>PDO</th>
<th>PNA</th>
<th>ENSO Spring/Summer</th>
<th>PDO Spring/Summer</th>
<th>PNA Spring/Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edmonton</td>
<td>-0.07</td>
<td>-0.09</td>
<td>-0.03</td>
<td>0.07</td>
<td>-0.07</td>
<td>-0.05</td>
</tr>
<tr>
<td>Calgary</td>
<td>-0.13</td>
<td>-0.19</td>
<td>-0.07</td>
<td>0.02</td>
<td>0.20*</td>
<td>0.15</td>
</tr>
<tr>
<td>Lethbridge</td>
<td>-0.14</td>
<td>-0.21*</td>
<td>-0.09</td>
<td>0.08</td>
<td>0.04</td>
<td>-0.15</td>
</tr>
<tr>
<td>Medicine Hat</td>
<td>-0.12</td>
<td>-0.18</td>
<td>-0.05</td>
<td>0.07</td>
<td>0.09</td>
<td>-0.17</td>
</tr>
<tr>
<td>Swift Current</td>
<td>0.03</td>
<td>-0.14</td>
<td>-0.12</td>
<td>0.07</td>
<td>0.09</td>
<td>-0.18</td>
</tr>
<tr>
<td>Saskatoon</td>
<td>0.21*</td>
<td>0.01</td>
<td>-0.23*</td>
<td>-0.07</td>
<td>0.08</td>
<td>-0.13</td>
</tr>
<tr>
<td>Regina</td>
<td>0.11</td>
<td>-0.08</td>
<td>-0.26*</td>
<td>-0.01</td>
<td>0.00</td>
<td>-0.22</td>
</tr>
<tr>
<td>Kelliher</td>
<td>0.05</td>
<td>-0.16</td>
<td>-0.01</td>
<td>0.23*</td>
<td>0.15</td>
<td>0.07</td>
</tr>
<tr>
<td>Estevan</td>
<td>0.21*</td>
<td>0.12</td>
<td>-0.29*</td>
<td>-0.07</td>
<td>0.03</td>
<td>-0.26</td>
</tr>
<tr>
<td>Pierson</td>
<td>0.33*</td>
<td>0.05</td>
<td>-0.36*</td>
<td>-0.10</td>
<td>-0.10</td>
<td>-0.22</td>
</tr>
<tr>
<td>Brandon</td>
<td>0.32*</td>
<td>0.23*</td>
<td>-0.32*</td>
<td>-0.24*</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Cypress River</td>
<td>0.06</td>
<td>-0.04</td>
<td>-0.23*</td>
<td>-0.03</td>
<td>-0.11</td>
<td>-0.07</td>
</tr>
</tbody>
</table>

* Significant at 0.01

### Table 2
Correlation between winter average teleconnection index (December to February) and combined spring and summer precipitation totals across Palliser’s Triangle

<table>
<thead>
<tr>
<th>Weather Station</th>
<th>SOI</th>
<th>PDO</th>
<th>PNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edmonton</td>
<td>-0.04</td>
<td>-0.03</td>
<td>-0.03</td>
</tr>
<tr>
<td>Calgary</td>
<td>-0.13</td>
<td>-0.10</td>
<td>0.03</td>
</tr>
<tr>
<td>Lethbridge</td>
<td>-0.16</td>
<td>-0.07</td>
<td>-0.14</td>
</tr>
<tr>
<td>Medicine Hat</td>
<td>-0.13</td>
<td>-0.12</td>
<td>-0.12</td>
</tr>
<tr>
<td>Swift Current</td>
<td>-0.04</td>
<td>-0.22*</td>
<td>-0.09</td>
</tr>
<tr>
<td>Saskatoon</td>
<td>-0.01</td>
<td>0.10</td>
<td>-0.06</td>
</tr>
<tr>
<td>Regina</td>
<td>-0.04</td>
<td>-0.26*</td>
<td>-0.09</td>
</tr>
<tr>
<td>Kelliher</td>
<td>-0.17</td>
<td>0.06</td>
<td>0.19</td>
</tr>
<tr>
<td>Estevan</td>
<td>0.04</td>
<td>-0.27*</td>
<td>-0.06</td>
</tr>
<tr>
<td>Pierson</td>
<td>-0.02</td>
<td>-0.22*</td>
<td>-0.11</td>
</tr>
<tr>
<td>Brandon</td>
<td>0.00</td>
<td>-0.24*</td>
<td>-0.05</td>
</tr>
<tr>
<td>Cypress River</td>
<td>0.07</td>
<td>-0.19</td>
<td>-0.19</td>
</tr>
</tbody>
</table>

* Significant at 0.01

### Conclusion

The climate of the Palliser’s Triangle region of the Canadian prairies is dynamic exhibiting a large variability across the area. Precipitation varies both spatially and temporally and is affected by several teleconnections. It was shown that a core of dryness straddles the Alberta-Saskatchewan border from Leth-
bridge eastwards towards Swift Current as identified by other researchers. However, research reported here suggests that it now extends north to Saskatoon. Historically the dry region has expanded and contracted several times. The amount of precipitation varies from east to west with the east receiving up to three times as much precipitation over the year. The western region was shown to be less variable during both spring and summer than areas further east. Variation within the region was not only spatial, but also changed with time, with 1950 to 1979 showing less range but more variation between stations than the 1980 to 2009 period. The variation between 1980 and 2009 resulted from the fact the 1980s was a very dry decade while the 1990s was the wettest of the 20th century. The PDO was shown to have the most widespread influence on eastern stations during its negative phase. The eastern Saskatchewan and western Manitoba stations received more precipitation during the negative or cool phase of the PDO. The ENSO showed similar, but weaker results, in the same regions of eastern Saskatchewan and western Manitoba during La Niña (cold phase). The PNA only had significant results from the correlation between the combined spring and summer months. It has been proposed that the winter values of a teleconnection index could have a greater influence on spring and summer precipitation than the spring and summer values of the same index. This was the case with regards to the PDO, wherein most Saskatchewan and all Manitoba stations returned significant results, showing that the negative phase of the PDO in winter is related to a wetter growing season in the eastern Canadian prairies. Since drought is such a complicated phenomenon, and this research only focused on the meteorological aspect, further research is needed to examine the linkage between teleconnections, ground moisture conditions, and hydrologic runoff in these areas.

The preceding analysis has suggested that teleconnections affect the amount and pattern of precipitation across the Canadian prairies, and that recent decades have witnessed expansion of the drought prone area of Palliser’s Triangle towards the east and northeast. This said, results of the analysis should be viewed with a degree of caution. While the observed changes in precipitation patterns between the two 30-year periods can be accepted as correct, in the sense that analysis for each period is based on the same number and distribution of weather stations, the limited number of those stations and their precise locations may impart spatial biases in the cartography that do not reflect the ‘true’ patterns of precipitation. The analysis reported here is based on just 12 weather stations. Their distribution leaves large areas of Palliser’s Triangle and the wider prairie region without input into the maps showing precipitation patterns. To confirm existing findings and to minimize the risk of spatial biases in analysis, additional research is desirable based on a larger number of weather stations, which are evenly distributed across the prairies.

Acknowledgements

The authors would like to thank the University of Winnipeg for financial support of this project. Thanks are also extended to Brian McGregor for his help with cartography and ArcGIS, and to Brad Russell for his assistance in recovering corrupted ArcGIS data. The authors are also grateful to Bernard Thraves, formerly of University of Regina, and the two anonymous reviewers for their insightful comments and suggestions.

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JISAO. 2018. Joint Institute for the Study of the Atmosphere and


