# Seasonal and Spatial Patterns of Rainfall Trends on the Canadian Prairie

H.W. Cutforth[1], O.O. Akinremi[2] and S.M. McGinn[3]

[1]SPARC, Box 1030, Swift Current, SK S9H 3X2
[2]Department of Soil Science, University of Manitoba, Winnipeg, MB R3T 2N2
[3]Lethbridge Research Centre, Lethbridge, AB T1J 4B1

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## Abstract

We used regression analysis to establish linear trends of annual and seasonal rainfall amounts and number of events at 140 stations with 40 years of record from 1956 to 1995 across the Canadian Prairie. There has been a significant increase in the rainfall amounts and number of events. Increase in annual rainfall was 51 mm or about 16% of the 40 yr mean while the number of rainfall events increased by 17 or about 29%. Spring (January to April) experienced proportionately the largest increase, with amount and number increasing by 46% and 64%, respectively. This may be related to the conversion of snow to rain as a result of climatic warming during this period. The increase in rainfall amount and number of events during summer (May to August) were similar to the annual patterns. There was no significant increase in rainfall amount and number of events during the fall season (September to December). The increases in rainfall amount and number of events were not uniform across the prairies, with the least increase in rainfall amount and number of events in southern Manitoba, and the largest increase in Alberta and Saskatchewan. Little or no change in amounts occurred in the northern portion of the prairie provinces. The results confirmed that the prairies are not getting drier, however, there are seasonal and spatial differences in rainfall trends.

## Introduction

The consensus of opinion among climatologists is that, on average, global temperature will rise with increases in atmospheric concentration of greenhouse gases (Vinnikov et al. 1990; Karl et al. 1997). For precipitation on a global scale, it is believed that as temperature increases, more evaporation takes place, leading to more precipitation (Karl et al. 1997). However, spatial and temporal nonuniformity is expected to accompany both temperature and precipitation changes around the globe. For the Canadian Prairie, Akinremi et al. (1999) reported that precipitation increased by 0.62 mm $yr^{-1}$ or about 10% between 1921 and 1995. On the other hand, Ripley (1986) examined the annual and seasonal trends of precipitation at three stations in Saskatchewan and noted recent decreases in annual and summer precipitation and increases in winter and spring precipitation. Raddatz (1998) suggests that the frequency of thunderstorms during the early and late portions of the growing season has declined due to a change from perennial grasses to annual cereals. Conversely, the potential for deep convection has been enhanced during periods of rapid foliage expansion and seed production for annual crops.

## Objective

The objective of our study was to determine the trend in rainfall during the recent 40 yr period from 1956 to 1995 and assess the spatial and seasonal pattern of these trends.

## Methods

The weather data used in this study were obtained from the Environment Canada archive for the three prairie provinces (Alberta, Saskatchewan and Manitoba). A total of 140 stations from across the Prairie Provinces which had complete daily precipitation records within the 40 years from 1956 to 1995 were used. We defined a rainfall event as any day with measurable amount of rain. We corrected the historical rainfall data for inhomogeneities such as differences in gauge type and wetting losses by increasing the daily rainfall prior to 1975 by a factor of 1.05 in accordance with the results of Metcalfe et al. (1997). Beginning in 1956, the daily rainfall amount and number of events at each station were accumulated annually and seasonally: January through April (JFMA-late winter and spring), May through August (MJJA-summer growing season), and September to December (SOND-fall and early winter). Mean annual and seasonal rainfall amount and number of events were calculated for the entire prairie using the 140 stations. Regression analysis was used to establish linear trends of rainfall amounts and number of rainfall events at each station. We used the t-test to determine if the linear trends were significantly different from zero at the 5% probability level.

## Results

a) Rainfall characteristics

On the Canadian prairie, the annual mean rainfall was 318.4 mm from annual total of 60 rainfall events during the last 40 years (Table 1). Six percent of the annual rainfall amount falls in JFMA, 75% in MJJA, and 19% in SOND. Of the 60 rainfall events recorded in a year, 9% occurred in JFMA, 67% (40) in MJJA, and 24% in SOND. Hence, MJJA had the most amount of rainfall, the highest number of rainfall events and the highest relative rainfall intensity compared to JFMA and SOND (6 mm per event in MJJA compared to 3.4 mm per event in JFMA and 4.2 mm per event in SOND).

b) Linear trends in rainfall amount and number of events

Annual prairie rainfall increased by 1.28 mm $yr^{-1}$ between 1956 and 1995 (Table 1). Thus, average annual rainfall across the prairie had increased by 51.2 mm or about 16% during the 40 yr study period. Rainfall in JFMA increased by 0.22 mm $yr^{-1}$. This increase represents about 46% of the 40 yr mean rainfall. Although the amount of rainfall during JFMA was small, 19 mm on average, it has experienced proportionately the largest increase. The increase in rainfall may be due to the conversion of snow to rain with the warming trend on the prairie (Saunders and Byrne 1994). The trend of rainfall during the summer months parallels the annual trend. Rainfall in MJJA increased by 0.98 mm $yr^{-1}$, or about 16% of the 40 yr mean. The increase in summer rainfall may be due to an increase in convective activities associated with increased soil surface

evaporation and evapotranspiration from plants (Raddatz 1998). Unlike the first eight months of the year, the increase in rainfall during SOND was small (0.08 mm $yr^{-1}$) and was not significant.

The annual number of rainfall events averaged across the prairies had increased by 0.43 events $yr^{-1}$. Thus, rain is falling more frequently on the prairie now compared to the mid-1950's. The number of rainfall events in JFMA and in MJJA increased (0.09 and 0.28 events $yr^{-1}$, respectively). The increase in the number rainfall events in SOND was small (0.06 events $yr^{-1}$) and was not significant.

Table 1. Annual and seasonal rainfall amounts and events (40 yr mean from 1956 to 1995) and linear trends of rainfall amounts and number of events averaged across the 140 stations. Numbers in bold-face type are significant ($P<0.05$).

| Season | Average Prairie Rainfall | | Rainfall Amount | | Number of Rainfall Events | |
|---|---|---|---|---|---|---|
| | Amount (mm) | Number of events | Linear trend (mm $yr^{-1}$) | Linear trend (% per 40 yr) | Linear trend (# $yr^{-1}$) | Linear trend (% per 40 yr) |
| Annual | 318.4 | 59.8 | 1.28 | 16 | 0.43 | 29 |
| JFMA | 19.1 | 5.6 | 0.22 | 46 | 0.09 | 64 |
| MJJA | 239.5 | 40.1 | 0.98 | 16 | 0.28 | 28 |
| SOND | 59.8 | 14.1 | 0.08 | 5 | 0.06 | 17 |

c) Spatial pattern of trends in rainfall amount and number of events

The spatial pattern of the trends in annual rainfall amount and number of events on the prairies is shown as contoured maps prepared from the trend at each of the 140 stations and expressed as a percentage of the 40 yr mean from 1956 to 1995 at each station (Fig. 1 top). A large area of southern Saskatchewan and Alberta showed increases in excess of 22% whereas the least increase (less the 7%) was found in southern Manitoba and in the northern prairie region. The Lake Winnipegosis-southeast Saskatchewan corridor had an increase of more than 35% in rainfall events (Fig. 1 bottom) and coincides roughly with the same region with more than 22% increase in rainfall amount (Fig. 1 top). Also, northern Saskatchewan and Alberta experienced the least increase in the number of rainfall events - less than 5%; these regions also had the least increase in rainfall amount - less than 7%. Two regions with the largest increase in the number of rainfall events were in southern Alberta-Saskatchewan and central to northwestern Saskatchewan, extending slightly into portions of northeast Alberta. In these regions, rainfall events have increased by more than 35% between 1956 to 1995.

Rainfall during JFMA increased by more than 50% along a northwest-southeast corridor through Alberta and Saskatchewan, and a southwest-northeast corridor through Saskatchewan and Manitoba (Fig. 2 top). The number of rainfall events during JFMA increased considerably over a large portion of the prairies with increases in excess of 60% in most of Saskatchewan, central and northern Alberta, and southwestern Manitoba. Only small portions of northern and

southwestern Saskatchewan and of southern Alberta had increases in rainfall events that were less than 20% during JFMA.

The spatial pattern of the trends in MJJA rainfall amounts and number of events (Fig. 3) was similar to the annual trends (Fig. 1). Rainfall amount increased by more than 22% over a large portion of Saskatchewan and southern Alberta (Fig. 3 top). Southern Manitoba and the northern portion of the prairie provinces experienced the least increase (less than 7%). Regions with the largest increase in number of summer rainfall events include southern Alberta and the southern and central portions of Saskatchewan (Fig. 3 bottom) with increases of more than 35%. The northern portions of Alberta and Saskatchewan had increases of less than 5%.

## Conclusions

There has been a significant increase in rainfall amount and number of events on the Canadian Prairie during 40 yrs from 1956 to 1995. Annual rainfall has increased by 51 mm or about 16% while number of rainfall events increased by 17 or about 29%. These increases were limited to the first eight months of the year. The increases in rainfall amount and number of events were not uniform across the prairies, with the largest increases occurring in Alberta and Saskatchewan and the least increases occurring in southern Manitoba. Little or no change in amounts were obtained in the northern portion of the prairie provinces. In general, the results confirm that the Canadian Prairie has not been getting drier. However, there are seasonal and spatial differences in rainfall trends across the prairies.

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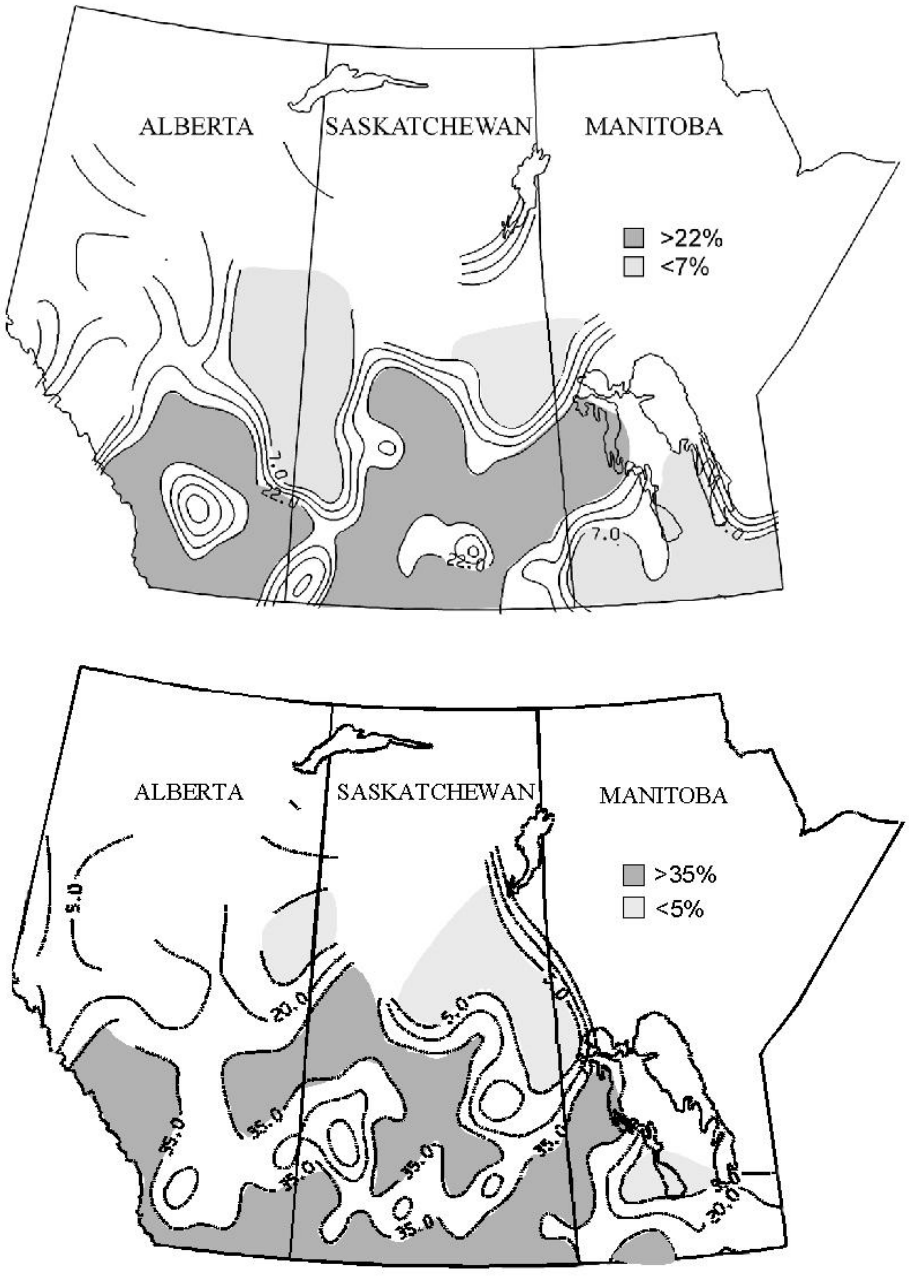


Figure 1. Spatial distribution of linear trends in annual amount of rainfall at contour intervals of 5% (top) and annual number of rainfall events (bottom) at contour intervals of 15% across the prairie from 1956 to 1995.

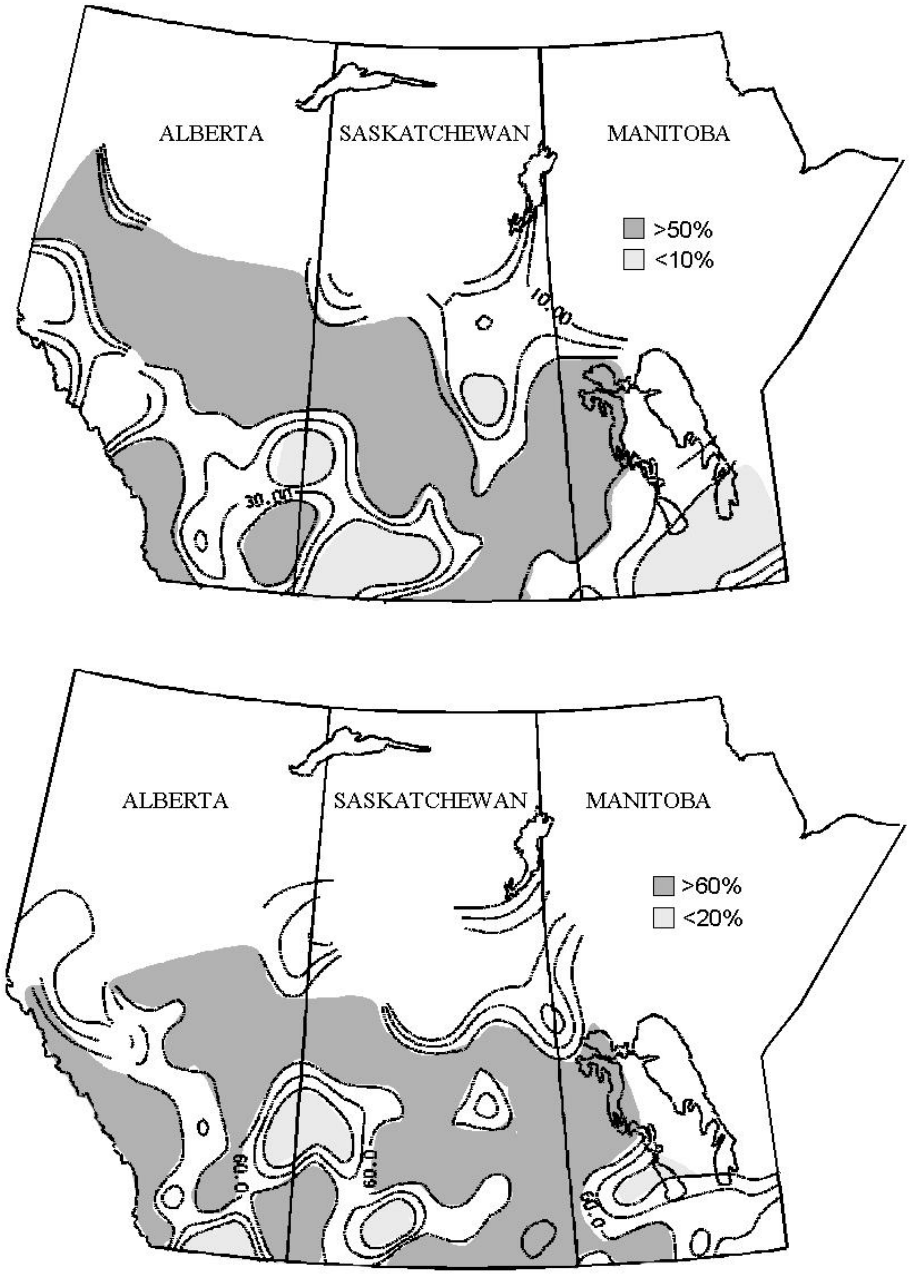


Figure 2. Spatial distribution of linear trends in amount of rainfall at contour intervals of 20% (top) and number of rainfall events at contour intervals of 20% (bottom) during JFMA across the prairie from 1956 to 1995.

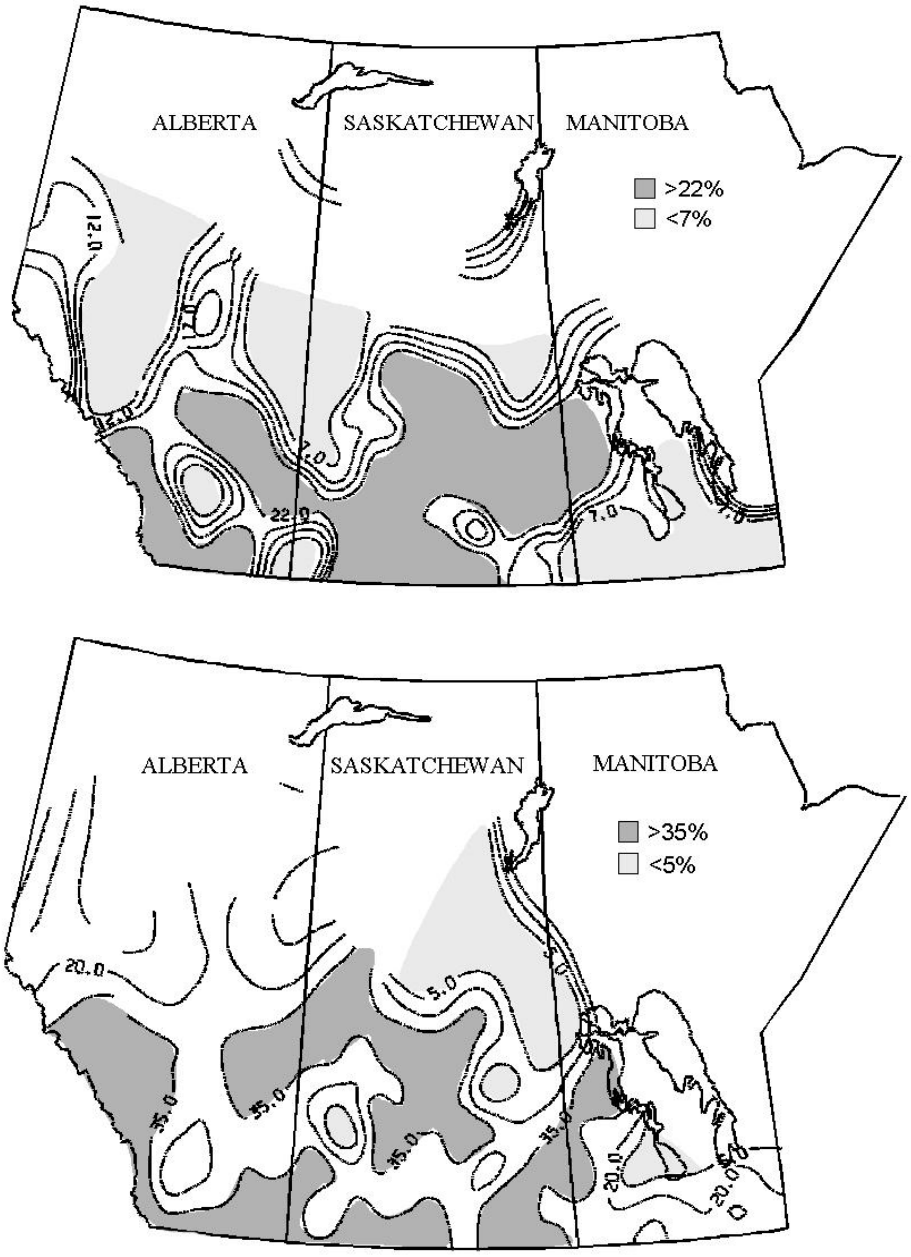


Figure 3. Spatial distribution of linear trends in amount of rainfall at contour intervals of 5% (top) and number of rainfall events at contour intervals of 15% (bottom) during MJJA across the prairie from 1956 to 1995.