Precipitation Trends on the Canadian Prairie

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Abstract

The amount and timing of precipitation on the Canadian Prairie is critical to grain production. Information on the precipitation trend is therefore vital to this region. Regression analysis was used to establish linear trends of precipitation amounts and number of precipitation events at 37 stations with 75 years of record (prior to and including 1995) across the Canadian Prairie. There has been a significant increase in the number of precipitation events mainly due to an increase in the number of low-intensity events. As such precipitation events are not getting more intense. From 1921 to 1995 on the Canadian Prairie, the number of precipitation events (excluding events that are 0.5 mm or less) has increased by 16 events, and precipitation and rainfall amounts have increased by 0.62 mm and 0.60 mm per annum, respectively. During the period from 1921 to 1960 the trends in precipitation, rainfall and snowfall were not statistically different from zero. However, from 1961 to 1995, snowfall has declined by 0.95 mm per year. The trends in the most recent period (1961 to 1995) were also significantly different from those in the 1921 to 1960 period for snowfall. The difference in trends between the two periods for snowfall, combined with the inverse relationship in the rainfall-snowfall trends suggest that these trends may be related to climate change.

Introduction

An analysis of 100 years of historical air temperature records in Canada revealed a warming trend of 1.1 °C per century (Skinner and Gullet 1993). The trend in minimum (mostly nighttime) temperature was 1.5 °C per century, which was twice that of maximum (mostly daytime) temperature. They concluded that significant decreases in mean temperature range (an important measure of climate variability) occurred in most regions during all seasons. This reduced temperature range has been attributed to increasing cloud cover which is relevant to the precipitation trend. As cloud formation is a precursor of precipitation, increasing cloud cover may be associated with precipitation events.

Objective

The objective of this study is to examine trends in the precipitation amounts and number of precipitation events at climatological stations with at least 75 years of precipitation records prior to 1996.

Methods

We searched the Environment Canada Archive for the three prairie provinces (Alberta, Saskatchewan and Manitoba) for stations across the prairies with 75 years of complete precipitation record prior to 1996 and found 49 stations. A challenging problem in the study of precipitation trend is inhomogeneity of historical precipitation data. The historical precipitation data across Canada are inhomogeneous due to several changes in the measurement techniques (Groisman and Easterling, 1994; Metcalfe et al. 1997). The implication of the changes in the measurement techniques is that historical precipitation data can not be used for rigorous trend analysis until the inhomogeneities are identified and adjustments are made to the data to remove them. Of the 49 stations used in our preliminary analysis, 37 stations across the prairies used the ruler method to measure snowfall amounts. The time series of snow at these 37 stations remain homogeneous as the measurement technique was unchanged. For these same 37 stations we corrected the historical rainfall data for 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).

The annual precipitation was divided into five classes. Class 1 contained the number of precipitation events in the range of 0 to 0.5 mm, which was expected to isolate small events and trace amounts. Although trace amount is defined as precipitation events that are less than 0.2 mm, we increased the limit of precipitation in Class 1 to 0.5 mm to ensure that this class captured all small events. As a result of possible inhomogeneity in the definition of trace and our lack of correction of trace amounts, we did not include Class 1 in our trend analysis. Class 2 ranged from 0.5 to 5 mm, Class 3 ranged from 5 to 10 mm, Class 4 ranged from 10 to 25 mm, while Class 5 contained the number of precipitation events that were greater than 25 mm. While Classes 2 and 3 represented “small” events, Classes 4 and 5 contained the “big” precipitation events. Class 6 was the sum of Classes 2 to 5 and represented the total number of precipitation events larger than “trace” amounts in a year. We examined each of the 5 classes (2-6) for trends and whether the pattern of the trends agree with the intensification hypothesis, i.e., a reduction in the number of events in the lower classes (Classes 2 and 3) with a corresponding increase in the number of events in the higher classes (Classes 4 and 5) with time. We defined a precipitation event as any day with measurable amount of precipitation. We used the t-test to determine if the linear trends were significantly different from zero at the 5% probability level.

Results

On the Canadian prairie from 1921 to 1995, the annual mean precipitation was 475.7 mm from a total of 94 precipitation events (Table 1). Of this amount, rainfall accounts for 70% and snowfall for the remaining 30%. More than 50% of annual precipitation events were in Class 2. However, Class 2 constituted only 23% of the amount of precipitation. On the other hand, only 2.5% of annual events were in Class 5 but the amount of precipitation in this class was 19% of the total. Class 4 provided the highest amount of precipitation (33% of total). The rainfall pattern was similar to that of total precipitation. Compared to rainfall, a larger proportion of snowfall events were low intensity events. For example, Class 2 contributed 20% of total amount of rainfall, while it accounted for 33% of total snowfall. The characteristics of precipitation on the prairie suggest that a change in the frequency of Class 2 would have a small impact on the total precipitation compared to changes in other higher classes.

Table 1. Distribution of precipitation events and amounts in five classes, mean of a 75 year time series (1921-95) on the Canadian Prairie.

	Range (mm)	Precipitation		Rainfall[y]		Snowfall	
		Number of events	Amounts (mm)	Number of events	Amounts (mm)	Number of events	Amounts (mm)
Class 1	0-0.5	11.6	3.7	5.2	1.6	6.9	2.2
Class 2	0.5-5	52.6	109.8	30.6	64.6	23.4	47.8
Class 3	5-10	16.3	111.9	9.7	68.9	6.8	43.8
Class 4	10-25	10.7	159.8	7.6	116.6	3.0	41.5
Class 5	>25	2.4	90.5	2.1	78.6	0.3	10.1
Total		93.6	475.7	55.2	330.3	40.3	145.4

[y]Note that the sum of rainfall and snowfall amounts and number in each class may not add to that of precipitation due to days with both rainfall and snowfall.

Across the Canadian Prairie, precipitation amount has increased by 0.62 mm yr^{-1} from 1921 to 1995 and events have increased by 0.21 events yr^{-1} (Table 2). Events in the low-intensity class (Class 2) increased (significant positive trend) whereas events in the high-intensity class (Class 5) decreased (significant negative trend). Most of the increase in the total number of precipitation events is accounted for by the increase in the number of small events (Class 2).

Table 2. From 1921 to 1995, linear trends of precipitation, rainfall and snowfall amounts (mm) and events across the prairies. Numbers in bold-face type are significant (P<0.05).

Parameters	Precipitation	Rainfall	Snowfall
Amount	0.62	0.60	0.01
Class 2	0.203	0.158	0.034
Class 3	0.010	0.024	0.039
Class 4	0.009	0.015	-0.011
Class 5	-0.008	-0.005	-0.003
Class 6	0.214	0.193	0.059

Rainfall amount has increased by 0.60 mm yr^{-1} from 1921 to 1995 and events have increased by 0.19 events yr^{-1} (Table 2). Snowfall amount and events had not changed from 1921 to 1995.

However, the number of snowfall events in the higher intensity classes (Classes 4 and 5) had decreased. Therefore, most of the increase in precipitation amount and events was due to the increase in rainfall amount and events.

The 75 years of record were split into two periods; period 1 was from 1921 to 1960 and period 2 was from 1961 to 1995. Our hypothesis for this analysis was: if there is a trend in a climatic parameter resulting from the intensification of industrialization and fossil fuel emissions, the trend should be larger in the more recent of the two periods as the effect of industrialization and fossil fuel consumption will be additive in time. From 1921 to 1960 (period 1) the trends in precipitation, rainfall and snowfall amount were not statistically different from zero (Table 3). From 1961 to 1995 (period 2), rainfall increased by 1.32 mm yr^{-1} which was double the trend in the previous 40 years but neither of these trends were significantly different from zero and hence not statistically different from each other. For snow on the other hand a significant decrease of 0.95 mm yr^{-1} was obtained during the most recent 35 years. The trend in period 2 was also significantly different from that in period 1 for the snowfall amount. The opposite sign of the trends in rainfall and snowfall resulted in a reduced and non-significant trend in precipitation during the most recent period. The results demonstrated that there has been a significant decrease in snowfall amount within the last 35 years across the prairies, while rainfall has increased during this period this was not significant. It is difficult to attribute these trends directly to climate change, the pattern however coincides with model predictions made from global warming simulations. The trend in the number of events was significantly different from zero during both periods for rainfall and total precipitation but not for snow. While the trend in the number of rainfall events was higher in period 2 it was not statistically different from the value obtained in period 1. For snowfall, the trend in the number of events during period 2 was negative, however, this was not significantly different from the value obtained in period 1.

Table 3. Precipitation, rainfall and snowfall (mm) trends across the prairies for the two periods of 1921-1960 and 1961-1995.

	Precipitation		Rainfall		Snowfall	
Parameter	1921-60	1961-95	1921-60	1961-95	1921-60	1961-95
Amount (mm yr^{-1})	1.19	0.37	0.61	1.32	0.58	**-0.95**
Number (yr^{-1})	0.31	0.32	0.21	0.37	0.23	-0.14

[y]Slopes in bold-face type are significantly different from zero at $P<0.05$.

Conclusions

There has been a significant increase in the number of precipitation events on the Canadian Prairie. This increase in the number of precipitation events is mainly due to an increase in the number of low-intensity events. Thus, precipitation events do not appear to be getting more intense on the Canadian Prairie. There has been a significant increase in the amount of precipitation on the Canadian prairies during the 75 years prior to and including 1995. This increase in precipitation is mainly due to an increase in the amounts of rainfall. The difference in trends between 1921 to 1960 and 1961 to 1995 for snowfall, combined with the inverse relationship in the rainfall-snowfall trends, suggest that these may be climate change related.

References

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