JP2.4 VARIATIONS AND TRENDS IN CLIMATE INDICES FOR CANADA

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1. INTRODUCTION

The prospect of climate change caused by anthropogenic activities has generated a variety of research focusing on investigating the past climate and predicting the climate of the future. In Canada, several studies have already presented detailed analysis of the temperature and precipitation variability and trends over the past century (Zhang et al. 2000, Bonsal et al. 2001, Zhang et al. 2001). Meanwhile, variables of social and economic interest, based on daily temperature and precipitation observations, have not yet received much attention with the exception of few preliminary analyses (Vincent and Mekis 2001, Shabbar and Bonsal 2003, Groisman et al. 2003). Climate indices are valuable to evaluate the potential impact of climate change on our activities, agriculture and economy and they are also useful to monitor the climate change on a global basis (Peterson et al. 2001). The objective of this work is to present a study of the variations and trends in selected climate change indices for Canada over 1950-2001 and 1900-2001.

2. DATA

2.1 Temperature indices

The indices are based on daily maximum, minimum and mean temperatures for 210 stations across the country. Homogeneity problems caused by station relocation and change in observing procedures were addressed using a technique based on regression model with surrounding stations (Vincent et al. 2002). Table 1 presents a list of the indices assembled into categories to provide different and independent information. The frost-free season is the maximum number of days with daily minimum temperature above 0°C, whereas the growing season length is the number of days starting with mean temperature above 5°C for 5 consecutive days and ending with mean temperature below 5°C for again 5 consecutive days . To examine the temperature variability, the extreme temperature range (difference between the highest daily maximum and the lowest daily minimum temperature during the year) and the standard deviation of the daily mean (computed from the daily 1961-1990 averages) were analyzed. The cold extremes are given by the frost days (with minimum below 0°C), cold nights, cold days and cold wave duration index while the warm extremes are set by the summer days (with maximum above 25°C), warm nights, warm days and heat wave duration index. The percentile used for the above variables is obtained from 150 values: five equally space day's window centered at the calendar day over 1961-1990. The cold (heat) wave duration index is the maximum number of consecutive days during the year with the minimum temperature 5°C below the daily normal (maximum temperature 5°C above the daily normal): the daily normal is also calculated from 150 values as for the percentiles.

2.2 Precipitation indices

In this study, the Canadian Historical Rehabilitated Precipitation dataset (Mekis and Hogg, 1999) was used. The dataset contains 495 long-term and homogeneous daily rain and snow series that are specifically designed for climate change analyses in Canada. Adjustments were applied on the daily level for rain and snow separately. For each rain gauge type, corrections to account for wind undercatch and evaporation, gauge specific wetting loss corrections were implemented. For snowfall, density corrections based upon coincident ruler and Nipher measurements were applied to all ruler measurements. Great care was taken to properly account for the trace measurement as well. A list of the precipitation indices is presented in Table 2: the indices are also classified into categories to provide different and independent information. The indicator computation was applied only for greater then trace events (except the snow to total ratio). To determine the frequency of precipitation events, trends are computed on the annual number of days with total precipitation, rain, and snow. The number of maximum consecutive dry days in every year is used to characterize long dry spells at each location. To measure the intensity of the events, the simple day intensity index for total precipitation and rain is examined. The simple day intensity index for rain is the ratio between annual total rain amount and the number of days with rain (same calculation is applied for total precipitation). The ratio of snowfall to total precipitation describes the change in the form of precipitation. To represent extreme wet conditions, the time series of the highest 5-day total precipitation, rain and snow were analyzed. The very wet days (number of days with total precipitation above 10 mm) and the number of days with total precipitation above the 95th percentile (calculated from the 1961-1990 average) are also included in the study.

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Table 1. Number of stations with significant negative, not significant and significant positive trends for the temperature indices over 1900-2001 and 1950-2001 respectively (significant at 5% level). The number in bold indicates that more than 25% of the stations have significant trend. Shaded results are presented in Figure 1.

		1900-2001			1950-2001		
Categories	Indices	negative	not sign.	positive	negative	not sign.	positive
Season length	Frost-free season	1	29	**36**	0	133	30
	Growing season length	0	53	10	0	138	19
Variability	Extreme temperature range	**24**	40	0	9	147	2
	Standard deviation of Tmean	17	54	1	10	140	17
Cold extremes	Frost days	**44**	22	0	**48**	113	2
	Cold nights: days with Tmin < 10th perc.	**60**	12	1	**69**	102	0
	Cold days: days with Tmax < 10th perc.	**32**	42	0	37	129	3
	Cold wave duration index	**24**	47	2	13	158	0
Warm extremes	Summer days: days with Tmax > 25°C	5	53	8	0	123	28
	Warm nights: days with Tmin > 90th perc.	0	34	**39**	1	127	**43**
	Warm days: days with Tmax > 90th perc.	2	57	15	1	139	29
	Heat wave duration index	3	67	4	3	156	10

Table 2. Number of stations with significant negative, not significant and significant positive trends for the precipitation indices over 1900-2001 and 1950-2001 respectively (significant at 5% level). The number in bold indicates that more than 25 % of the stations have significant trend. Shaded results are presented in Figure 2.

		1900-2001			1950-2001		
Categories	Indices	negative	not sign.	positive	negative	not sign.	positive
Frequency	Days with total precipitation	1	18	**55**	6	121	**110**
	Days with rain	1	15	**60**	3	90	**151**
	Days with snow	2	41	**36**	31	187	28
	Maximum number of consecutive dry days	**51**	23	0	35	198	4
Intensity	Simple day intensity index for total prec.	**42**	29	3	**60**	169	8
	Simple day intensity index for rain	**40**	33	3	**76**	162	6
	Ratio of snowfall to total precipitation	17	49	9	56	176	6
Extremes	Highest 5-day precipitation	1	65	9	5	222	11
	Highest 5-day rain	0	68	9	3	230	12
	Highest 5-day snow	7	64	9	33	203	11
	Very wet days (prec. > 10 mm)	4	54	18	9	214	21
	Days with total prec. > 95th percentile	3	64	9	2	229	13

3. METHODOLOGY

The non-parametric Kendall's test was used to estimate the slope of the trend at any individual station. This method is less sensitive to the non-normality of a distribution and it is less affected by extreme values and outliers, as compared to the least squares method. Since serial correlation is often present in many climatological time series, the procedure also takes into account the first lag autocorrelation: a detailed description of the trend computation can be found in Zhang et al. 2000. The 3/5 rule was applied for both temperature and precipitation indices (in any month if more than 3 consecutive days or more than 5 random days are missing, then the month is missing for the year). For each station trends are computed only if less than 20% of the years are missing. A single time series is also produced for the entire country by averaging the stations anomalies (departures from the 1961-1990 average). Since very few stations have climate observations prior 1945 in the northern regions of the country (north of 60°N), trends are analysed for two separate time periods: 1950-2001 and 1900-2001.

4. RESULTS

4.1 Trends in temperature indices

Table 1 summarizes the findings by presenting the number of stations with significant decreasing trends, no significant trends and significant increasing trends for each temperature indices. For 1950-2001, the frost-free season has increased by 15 to 20 days at many stations across the country (Fig. 1a) whereas the growing season length has significantly increased only at a few stations. The variability defined by the extreme temperature range (Fig. 1b) and the standard deviation of the daily mean has not changed much at most stations over the same period. The results also show that more stations have changed in their cold extremes than in their warm extremes. For example, the number of frost-days and cold nights (Fig. 1c) has significantly decreased by 15 to 30 days at many stations whereas the number of cold days and the cold wave duration have decreased mostly in the west. Conversely, the summer days and heat wave duration have not greatly changed while several stations have experienced significant increasing trends in the number of warm nights and warm days (Fig. 1d) over the past 50 years. These positive trends occur mostly in the west.

Over 1900-2001, similar trends were found with a few exceptions . The frost-free season has increased by 20 to 30 days while the growing season has not significantly changed. The extreme temperature range has decreased by 4 to 6°C at more than half of the stations. The results also show many stations with significant decreasing trends in the cold extremes. The average anomaly series of the whole country for the number of cold nights has also been decreased by 30 days throughout the century (Fig. 3a). The warm extremes have not greatly changed (Fig. 3b) with the exception of the warm nights where the time series for the whole country shows an increase of 18 days over the past century.

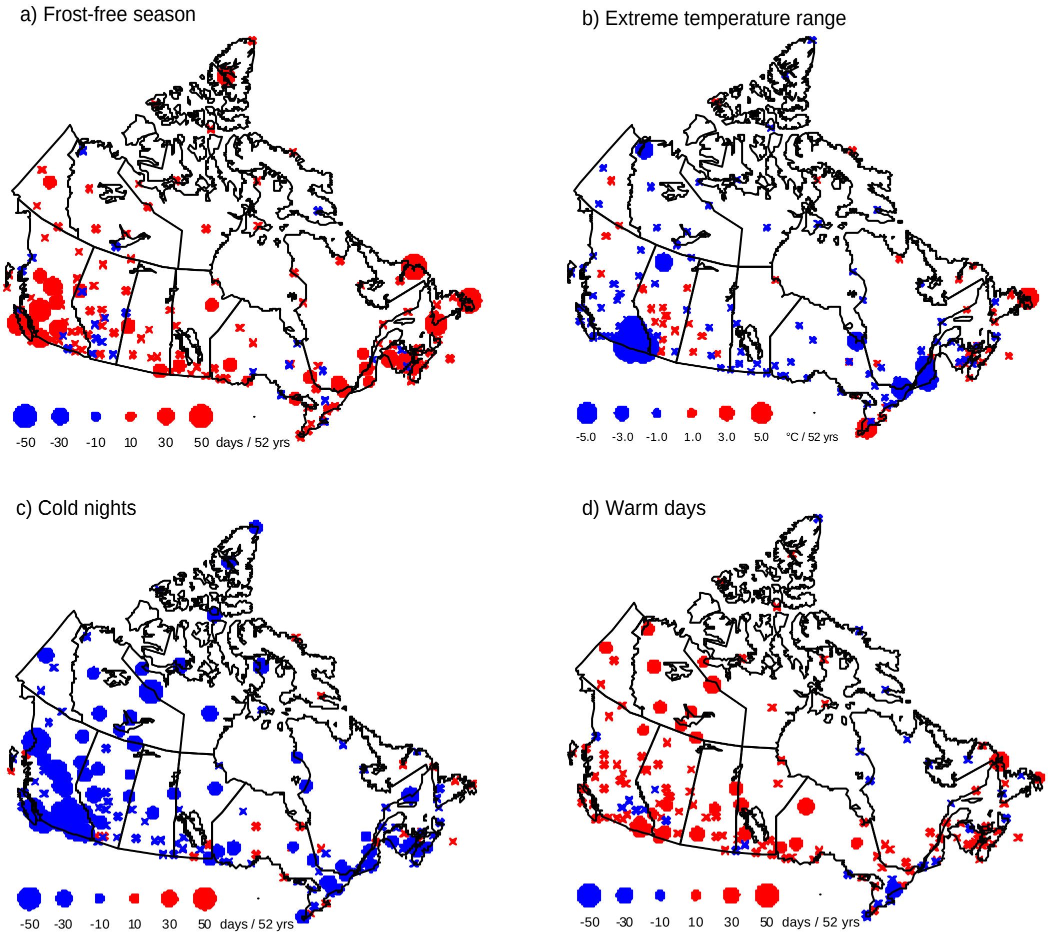

Figure 1. Trends in four temperature indices over 1950-2001.

4.2 Trends in precipitation indices

The results are summarized in Table 2. For the 1950-2001 period, the number of days with total precipitation has increased by 20 to 40 days: this increasing is mostly due to the increasing number of days with rain almost everywhere (Fig. 2a). The number of days with snow has decreased in the southern regions of the country (south of 60°N) whereas it has substantially increased on the north and northeast. The negative trends observed at many stations in the number of maximum consecutive dry days are in agreement with the positive trends in days with precipitation. Over the same period, the intensity of the precipitation events has significantly decreased at most stations while the ratio of snowfall to total precipitation has decreased in the south and increased at a few stations in the north (Fig. 2b). The findings also show that there are no consistent changes in the extremes precipitation. Only a few stations displayed significant change in the highest 5-day precipitation (Fig. 2c), rain and snow. The number of very wet days and days with total precipitation above the 95th percentile (Fig. 2d) has not greatly changed at most locations.

The pattern of increasing frequency, decreasing intensity and no changes in extremes remains the same over 1900-2001. The number of days with rain anomalies for the entire country (Figure 3c) shows that there are over 30 more days with rain in Canada since the beginning of the century. The increase in the number of days with rain and snow is consistent across the country. Most stations show decreasing trends in the simple day intensity index for total precipitation and for rain whereas the ratio of snowfall to total precipitation does not show as consistent trends as it displayed for the last half of the century (it could be analyzed only for the southern stations). Only a few stations show any significant trend in the form of extreme precipitation, and the time series for the country does not display any considerable change either (Fig. 3d).

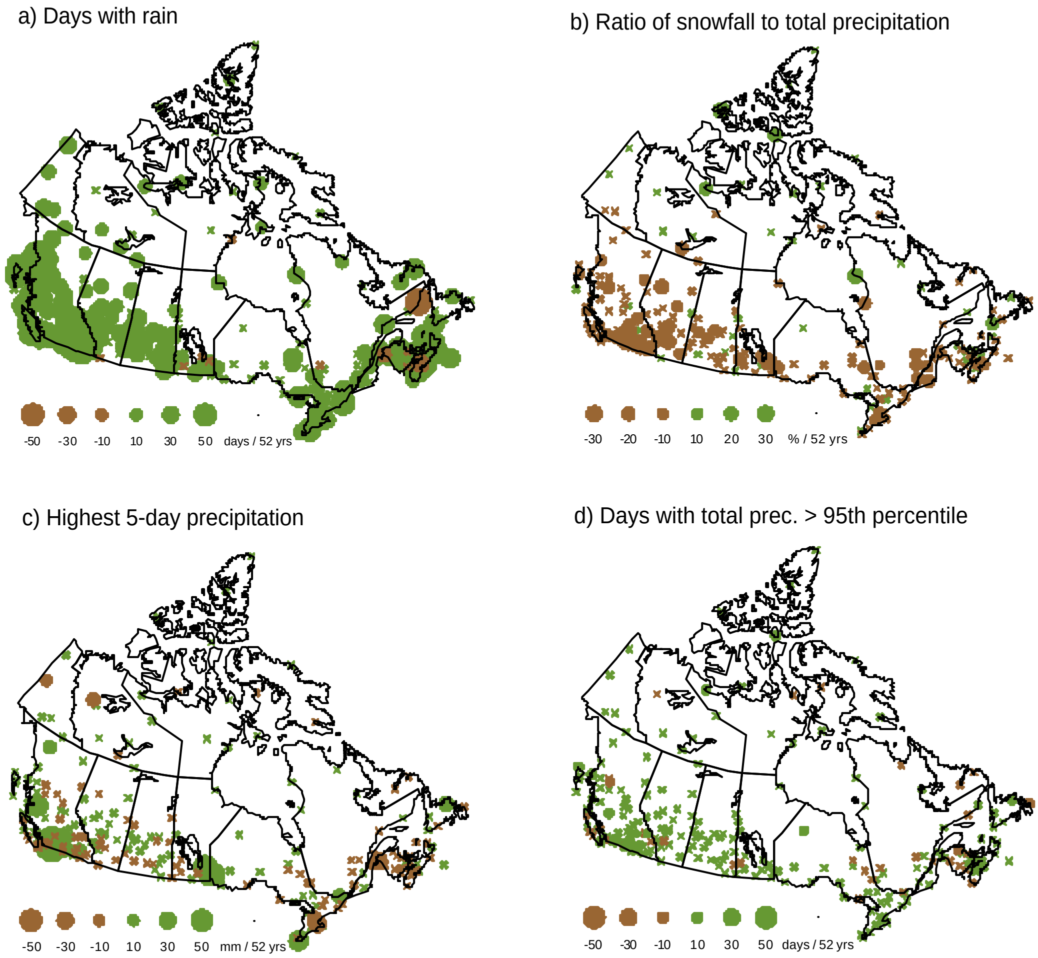

Figure 2. Trends in four precipitation indices over 1950-2001.

5. CONCLUSION

The analysis of variations and trends in climate indices highlighted important features of our changing climate. Overall, the extreme cold temperatures have changed more than the extreme warm temperatures, and the frost-free season became longer. The changes in precipitation events are mainly due to more frequent rain and not to a change in the form of extremes. A paper presenting a more detailed analysis of the trends and variations in the climate indices is under preparation. Additional indices and seasonal distribution will also be examined on local and regional scale.

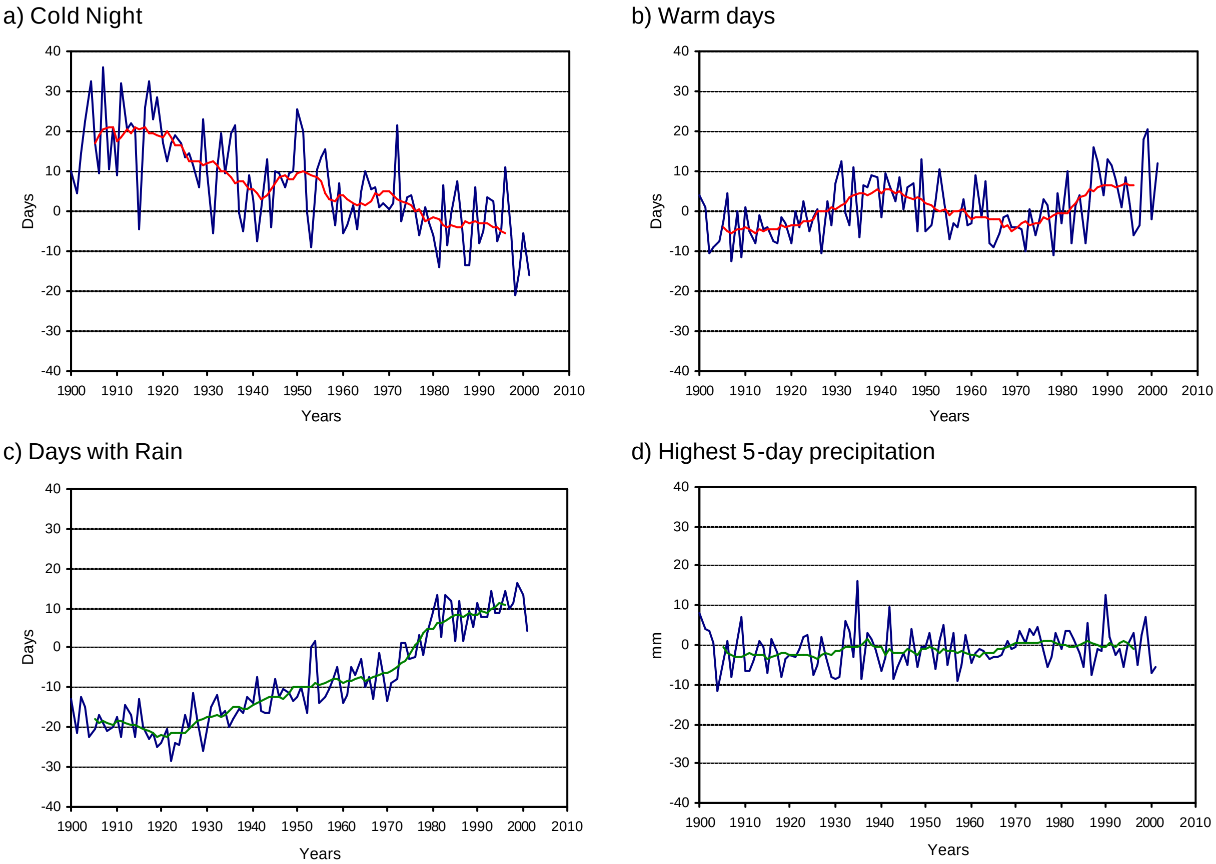

Figure 3. Temperature and precipitation indices anomalies over 1900-2001 for Canada. The red (green) line is the 11-year running mean for the given temperature (precipitation) index.

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