6.10 TRENDS AND VARIABILITY IN WINTER COLD AND WARM SPELLS OVER CANADA

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1. Introduction

With increasing greenhouse gas concentrations, a number of Global Climate Models are predicting an increased frequency of extreme high temperature events, and decreases in extreme low temperature events. To a large extent, the observational record validates this forecast over many parts of the globe (Karl et al. 1999). Canada's climate is known for its high degree of variability. On occasion, extreme cold events during winter can persist for prolonged periods creating great inconveniences and disruptions in economic activities. Although perceived as beneficial, extreme winter warm events can also adversely affect environmental and economic activities including winter transportation, flooding, and the skiing industry. This study examines characteristics of winter cold and warm spells over Canada for the period 1950-98. This includes trends in the frequency, duration and intensity of spells for a network of stations across the country.

2. Data and Methodology

Temperature data consist of daily minimum and maximum values for 210 relatively evenly distributed stations across Canada. The data have been adjusted for inhomogeneities caused by station relocation and changes to instruments and observing practices (Vincent et al. 2000). Climatological observations prior to the 1950s are sparse in the northern regions (north of 60^{o}N) of Canada. Therefore, the analyses are confined to the 1950-98 period. Furthermore, stations having more than 20% of their observations missing are excluded from the computations.

To define cold spells, the 20th percentiles of the daily winter (JFM) minimum temperature distributions are determined for each station during the 1961-90 climatological base period. Individual spells are then defined as those events in which the minimum temperatures remained below this threshold for at least three consecutive days. Similarly, warm spells are defined as those events in which the winter maximum temperatures remained above the top 20th percentile for at least three consecutive days.

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The majority of this investigation focuses on trends in the number, duration and intensity of cold and warm spells during the second half of the 20th century. The trend calculation involves a statistical model that takes the spurious effects of the serial correlation into account (e.g. Zhang et al. 2000). For this model, lag-one correlation is firstly removed from the time series. The non-parametric Kendall's tau (Sen 1968) procedure is then used to determine both the magnitude and the statistical significance of the trend. This procedure guards against the effects of outliers while fitting a trend line to the data. All trends are assessed for statistical significance at the 5% level.

3. Results

a) Climatology of Cold Spells

Figure 1 shows distributions in the number of cold spells at Prince George, B.C. and St. Anthony, Nfld. These two stations are representative of western and eastern Canada, respectively. The Kolmogorov-Smirnov test reveals that the empirical distribution at both locations follows the Poisson distribution at the 1% level of significance (shown by the solid lines). Most stations in western Canada experience about three cold spells per year. Due to frequent incursions of warmer, maritime air masses, the number of cold spells is somewhat lower over the Great Lakes (~ 2 per year). Further analyses indicate that there is a 75% probability of getting two or more cold spells over the Prairies. This number drops to 55% over the Great Lakes region, but rises to around 70% over eastern Canada.

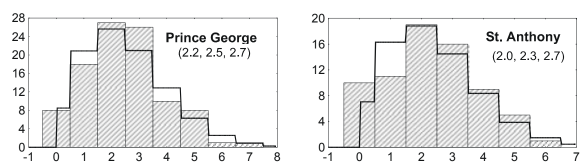

Fig. 1. *Distribution of the number of cold spells. The solid line shows the fitted Poisson distribution. The mean number of spells and the corresponding 95% confidence limits are shown in brackets.*

Distributions of cold spell durations for the same two stations are shown in Fig. 2. The data are fitted to an exponential distribution. Coincident with longer average durations, variability in the length of cold spells is also higher over western Canada. This is likely attributable to frequent outbreaks of Arctic air into the region which often results in prolonged periods of very cold temperatures. This is also the region where variability in winter temperature is highest (Bonsal et al. 2001a). The average duration of spells decreases toward central and eastern regions of the country.

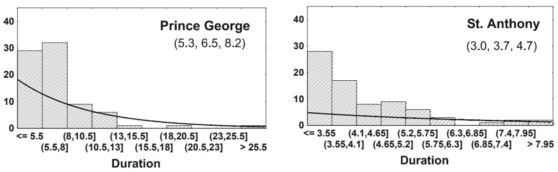

Fig. 2. *Distribution of the duration of cold spells. The solid line shows the fitted exponential distribution. The mean duration of spells and the corresponding 95% confidence limits are shown in brackets.*

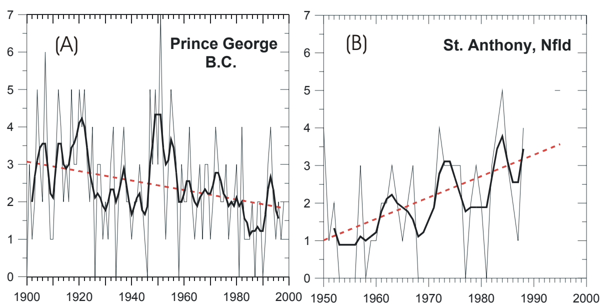

Fig. 3. *Time series of winter cold spells from 1900-98. A five-point filter and linear trend are shown by a heavy line and dotted line, respectively.*

Time series of winter cold spells for the two stations are displayed in Fig. 3. A five-point Gaussian filter and linear trends are also shown. At Prince George (Fig. 3a), a strong component of interannual variability is noticeable from the mid 1940s to the mid 1950s. The mean number of cold spells is also considerably higher during this period. There is a significant downward trend in the number of cold spells throughout the record. Concomitant with this decrease, the number of warm spells shows a steady rise (not shown). St. Anthony (Fig 3b) also displays wide year-to-year fluctuations. A striking feature of the graph involves a sharp increase in the number of cold spells. During this period, there has been a gradual decrease in the number of warm spells (not shown).

b) Trends in cold and warm spells

Figure 4(a) shows that from 1950-98, the number of winter cold spells has decreased over western Canada. Most of the decreases have occurred in British Columbia and Alberta. Consistent with these results, Bonsal et al. (2001b) found an upward trend in the 5^{th} percentile of daily minimum temperatures in western Canada for the same season. Eastern Canada on the other hand shows several statistically significant increases during this period, particularly along the east coast. These increases are likely attributable to variability in large scale oscillations including the NAO.

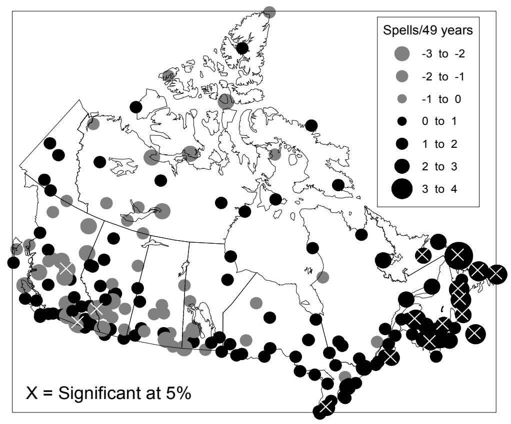

Fig. 4a. *Trends in the number of winter cold spells during the 1950-98 period.*

The number of winter warm spells (Fig. 4b) shows increases throughout most of southern Canada. The increases are statistically significant from the Great Lakes to the Yukon. In eastern Canada, the increases are generally small and not significant.

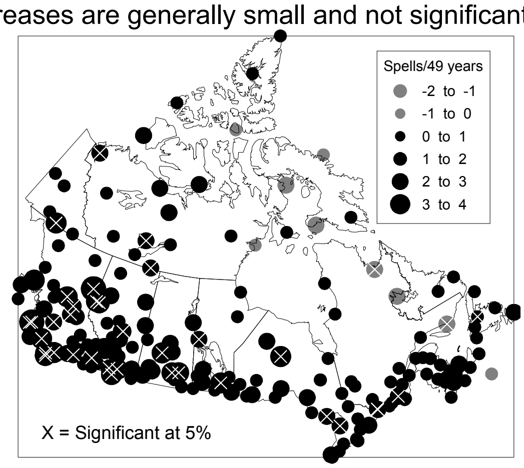

Fig. 4b. *Trends in the number of winter warm spells during the 1950-98 period.*

Figure 5a shows that the cold spells are generally getting shorter in western Canada and the western Arctic; however, in eastern Canada, there is a tendency towards longer cold spells. Substantial increases are noted along the eastern shores.

Winter warm spells are getting longer over the majority of the country with the largest changes over British Columbia (Fig. 5b). One exception is over Newfoundland and Labrador where the duration of warm spells has decreased.

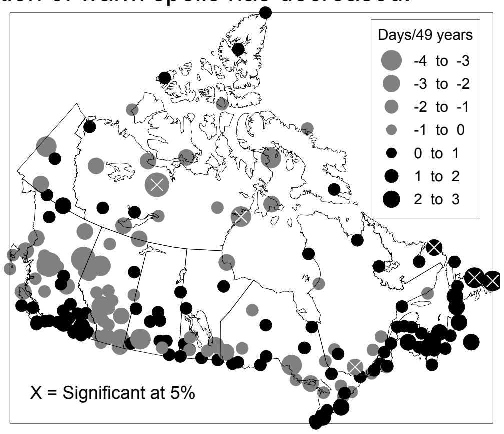

Fig. 5a. *Trend in the duration of winter cold spells during the 1950-98 period.*

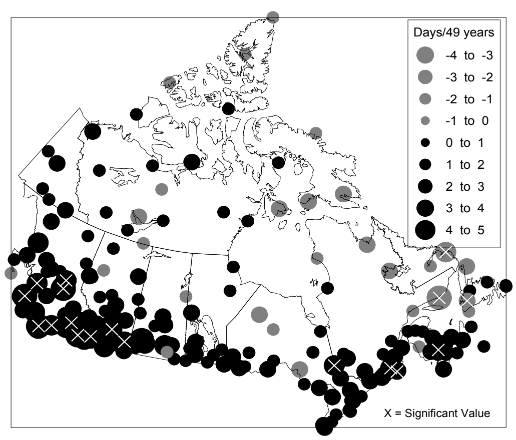

Fig. 5b. *Trend in the duration of winter warm spells during the 1950-98 period.*

Lastly, trends in the intensity of cold and warm spells are examined. Intensity is defined as the magnitude of the average daily minimum and maximum temperature during all days contained within a spell. The spatial distribution of intensity of cold spells shows increases of 5 to 7^{o}C over the Northwest Territories, Alberta and British Columbia (not shown). In the east, mixed and generally insignificant trends are observed. The temperatures for winter warm spells are on the rise in British Columbia with significant increases of 2 to 3^{o}C in the southern portions of the province (not shown).

4. Conclusions

Trends and variations in the number, duration and intensity of winter cold and warm spells over Canada are examined. Results show that on average, most regions experience 2 to 3 cold spells per year, however, there is considerable year-to-year variability throughout the country. From 1950-98, western Canada experienced a downward trend in the frequency of cold spells while the east had a discernible upward trend. This period was also associated with an increase in the number of winter warm spells over a region extending from the west coast to the Great Lakes. In concert with fewer cold spells, the duration of cold spells has decreased in the west but increased over the east. The duration of winter warm spells have also increased in western Canada. In regions associated with fewer cold spells, there is evidence that the intensity of these spells has been decreasing. Moreover, the intensity of warm spells shows an increasing trend, especially over British Columbia.

Reasons for these trends require further investigation but may be influenced by changes in large scale oscillations such as ENSO and the NAO. For example, the increase in the number of cold spells over eastern Canada appears to be related to the decadal-scale shift in the NAO-like pattern in western Atlantic circa 1970. This study improves our knowledge regarding extreme winter temperature events over Canada during the second half of the 20th century. It also provides insight into potential future changes to these events given the possibility of climate change.

5. References

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