EXAMINATION OF ARCHIVAL CANADIAN WIND DATA FOR INHOMOGENEITIES DURING 1953-2005

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1. INTRODUCTION

Several studies have reported significant increases in the intensity and frequency of storms. Most notable has been the controversy over whether hurricanes occur more often in the Atlantic and Caribbean than a century ago (Landsea, 2007) and if this has an anthropogenic cause (Mann and Emmanuel, 2006). One recent article predicts global warming will increase the severity of hurricanes in the 21st century but that their number may decrease (Knutson et al, 2007). There have also been reports of increasingly severe thunderstorms. A study that examined archival newspaper accounts of severe weather in Dufferin County in Ontario, Canada reported a 25% increase in wind speed over the past 20 years (MacIver, 2005). Studies based on hourly pressure measurements have found a statistically significant decrease in pressure over the Canadian Arctic over the past 50 years during winter months (van Wijngaarden, 2005).

2. METHODOLOGY

This study examined records of wind measurements archived by Environment Canada.

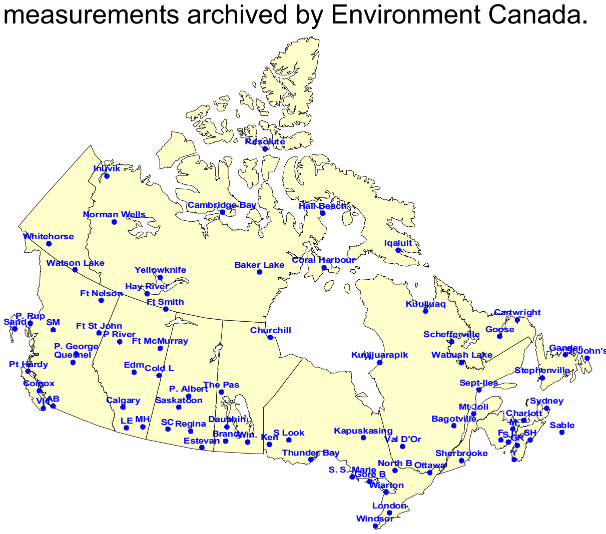

Fig. 1: Stations used in analysis.

These data were recorded every hour at 75 primarily airport stations located as shown in Fig. 1. Data is available from 64 stations beginning in 1953. Seven stations, located mostly in the Arctic began operating later in the 1950s while 3 stations opened in 1961 and 1 in 1962. The dataset consists of over 34 million measurements. Less than 1% of the data is missing for the period of this study Jan. 1953 to May, 2005.

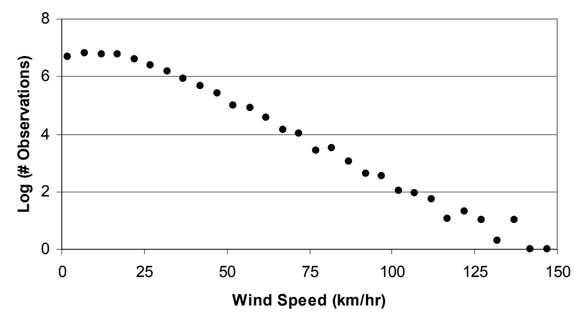

Fig. 2: Distribution of Hourly Wind Measurements

The archive records wind speed in units of 1 km/hr. The number of measurements in 5 km/hr intervals is displayed in the semilog graph in Fig. 2. Similar graphs were obtained when the distribution was plotted separately for each season. The only difference was that fewer high wind events occurred in summer than in the other seasons.

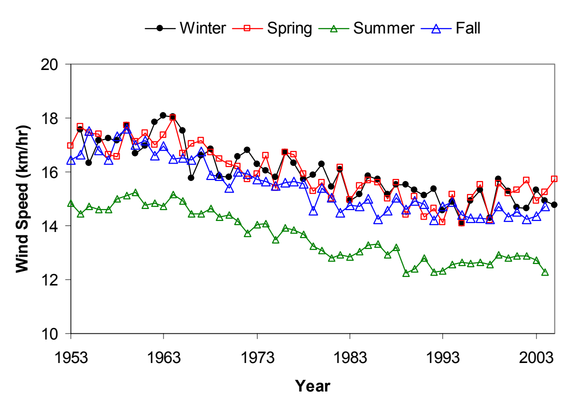

Fig. 3: Average wind speed for winter (black), spring (red), summer (green) and fall (blue) averaged over the 75 stations in this study.

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For every station, the average wind speed was found for the 4 seasons of each year. Fig. 3 shows the results averaged over all stations. A statistically significant downward trend over the period 1953-2004 is evident for all seasons. The overall decrease in wind speed occurs primarily beginning in the mid 1960s and continues only until the mid 1980s.

3. INHOMOGENEITIES

It is well known that dramatic changes in measurements of temperature, relative humidity, precipitation etc. can result from changes in instruments (van Wijngaarden and Vincent, 2005). Station records show these discontinuities occurred even though instruments were inspected regularly at least every several years. Anemometers unlike thermometers, dewcels or rain gauges, have moving parts and are more susceptible to friction affecting their performance. It is therefore critical to examine the wind data for inhomogeneities before attributing any trend as shown in Fig. 3 due to a change in climate (Vincent et al, 2007).

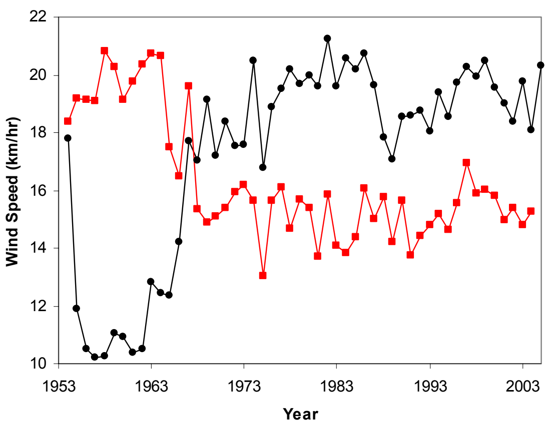

Fig. 4: The average annual wind speed is plotted for Stephenville, Newfoundland (black) and Shearwater, Nova Scotia (red).

Examples of a step discontinuity are shown in Fig. 4 for two stations located in the eastern Maritime region of Canada. The sudden change in average annual wind speed occurred in all four seasons in the same year. For Stephenville, the wind speed fell by nearly 50% two years after the station was opened and increased by 5.5 km/hr in 1967. For Shearwater, wind speed suddenly decreased by 3.5 km/hr in 1967. There is no obvious trend in wind speed after 1967 for either station.

Fig. 5 shows data having multiple discontinuities for two stations both located in northern Ontario. For Thunder Bay, the average wind speed increased by 4.5 km/hr in 1966 followed by a comparable decrease three years later. Data for Sioux Lookout exhibits a downward step of 4 km/hr in 1969 followed by a sharp increase in 1985.

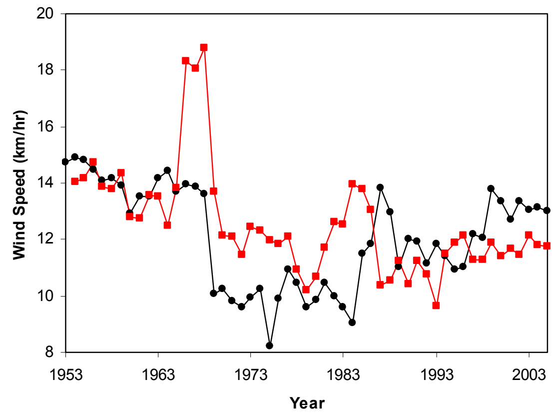

Fig. 5: The average annual wind speed is plotted for Sioux Lookout (black) and Thunder Bay (red).

A systematic examination for discontinuities was done as follows. Data was averaged over 5 year intervals and the difference between wind speeds found for adjacent 5 year periods was evaluated. The year of maximum change was then found for each station. The distribution of these maximum wind speed changes for the 75 stations is shown in Fig. 6. Wind Speed changes of less than 2 km/hr are comparable to the year to year fluctuation of the data and therefore do not constitute a step inhomogeneity. However, data from nearly 40% of the 75 stations experience steps of magnitude ≥ 3 km/hr. The maximum wind speed changes were negative for

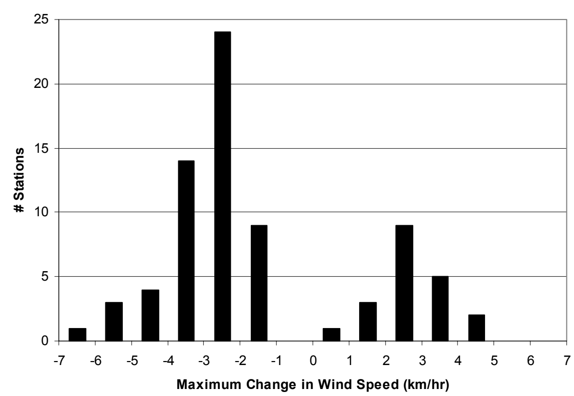

Fig. 6: Distribution of Maximum Wind Speed Changes occurring among 75 Stations.

55 of the 75 stations and the magnitudes of the negative steps were considerably larger than that of the positive steps. The temporal distribution of the maximum wind speed changes is given in Fig. 7. Most large negative wind speed changes occurred before the late 1980s and account for the decreasing trend in wind speed evident in Fig. 3.

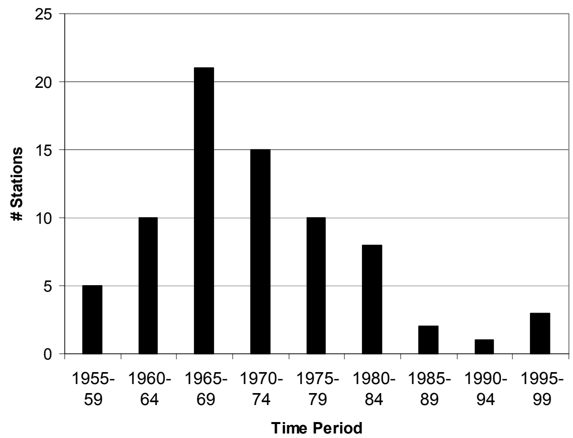

Fig. 7: Temporal Distribution of Maximum Wind Speed Changes occurring among 75 Stations.

4. HIGH WIND EVENTS

There were over 250,000 (8,000) observations of hourly wind speeds ≥ 50 (75) km/hr observed at

Station		% Hr Winds	
Name	**Province /Territory**	**≥ 50 km/hr**	**≥ 75 km/hr**
Sandspit	B.C.	5.3	13.3
Baker Lake	Nunavut	5.2	5.1
Cambridge Bay	Nunavut	4.0	2.7
Coral Harbour	Nunavut	4.4	6.2
Hall Beach	Nunavut	2.9	2.6
Iqaluit	Nunavut	3.4	5.4
Resolute	Nunavut	7.4	9.7
Lethbridge	Alberta	6.6	8.7
Churchill	Manitoba	3.9	2.5
Sable Island	Nova Scotia	8.0	7.7
Cartwright	Nfld	3.8	7.8
Gander	Nfld	2.9	2.3
St. John's	Nfld	5.7	6.9
Totals		**63.5**	**80.9**

Table I. Thirteen of the 75 stations account for most of the total number of observed hourly wind speeds ≥ 50 (75) km/hr during 1953-05.

the 75 stations during 1953-05. The seasonal distribution of winds ≥ 50 km/hr was as follows: winter (40%), spring (26%), summer (7.5%) and fall (27%) while for the 75 km/hr threshold, data were distributed in winter (48%), spring (20%), summer (4%) and fall (27%). Table I shows high winds occurred most frequently at stations predominantly located in the Arctic or near the coast. The only exception is Lethbridge situated near the Rocky Mountains.

Trends in average wind speed and in the frequency of high winds are not necessarily the same. Figs. 8 and 9, however, show a strong correlation between the average annual wind speed and the number of hourly observations of winds ≥ 50 km/hr. Indeed, the decrease of 6 km/hr in average wind speed occurring at Lethbridge in

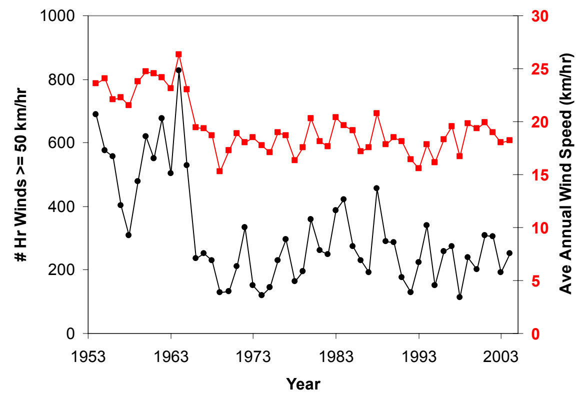

Fig. 8: Average wind speed and number of hourly winds ≥ 50 km/hr observed at Lethbridge, Alta.

1966 coincides with a reduction in the number of hourly winds ≥ 50 km/hr by nearly a factor of 4. Fig. 9 shows data taken at Iqaluit. There is a near absence of high winds during 1965-74 when the average annual wind speed also decreased.

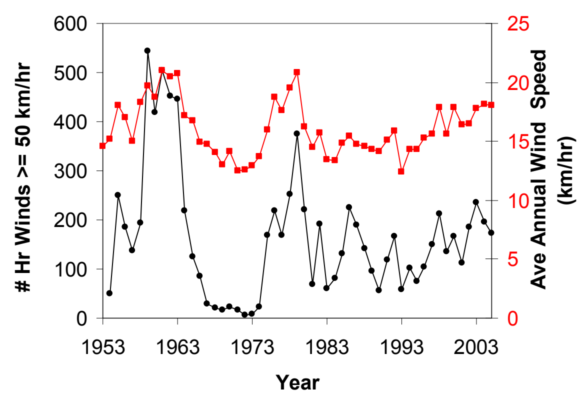

Fig. 9: Average wind speed and number of hourly winds ≥ 50 km/hr observed at Iqaluit, Nunavut.

5. RESULTS and CONCLUSIONS

The annual wind speed averaged over the 75 stations in this study and the total number of hourly winds ≥ 50 km/hr observed are shown in Fig. 10. The data show statistically significant decreasing trends for 1953-04 given in Table II.

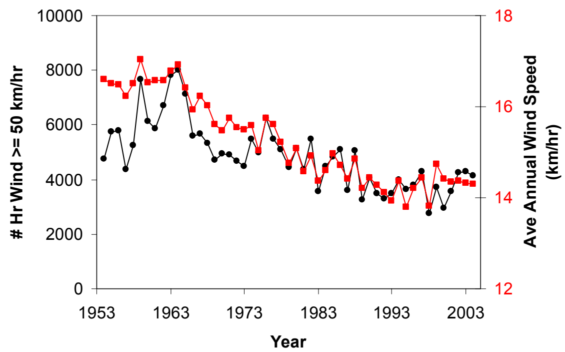

Fig. 10: Average annual wind speed and number of hourly winds ≥ 50 km/hr are plotted for 75 stations in Canada.

The wind speed primarily decreases beginning in the 1960s until the late 1980s coinciding with the large discontinuities observed in the data. The trends for the period 1988-04 are much smaller and are not statistically significant.

Interval	Trends	
	Ave. Wind Speed km/hr/yr	# Wind ≥ 50 km/hr events/yr
1953-04	-0.06	-59
1988-04	-0.001	-3

Table II: Trends for average wind speed and number of hourly winds ≥ 50 km/hr observed at all 75 stations in Canada.

A variety of discontinuities that abruptly decreased wind speed affected many stations. Some data exhibited multiple steps where a sudden increase in wind speed was followed by a dramatic decrease a few years later. Other stations, in relatively close geographical proximity, exhibited large wind speed changes of opposite sign in the same year. It is therefore reasonable to conclude these steps are due to instrumental problems and it would be interesting to examine records describing anemometer maintenance.

This study found a strong correlation between the average wind speed and the frequency of high winds. Indeed, the inhomogeneities were more pronounced in the latter. One could argue that this study, which examined primarily airport data, is less sensitive to high wind observations as airports are preferentially located away from areas prone to severe weather. Nevertheless, after taking into account the effect of discontinuities, no clear trends in either average wind speed or frequency of high wind events were evident at the most windy stations.

In conclusion, the decreasing trends in wind speed and the frequency of high winds during 1953-2005 observed at 75 stations spread across Canada result from abrupt discontinuities that are indicative of instrument/measurement errors. Hence, considerable caution is warranted before concluding that any statistically significant change in wind speed has occurred due to climate change during the last half century in Canada.

6. Acknowledgements

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7. References

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