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DEMONSTRATING CLIMATE CHANGE IN PRINCE EDWARD ISLAND – A PROCEDURE USING CLIMATE NORMALS AND WEATHER DATA SUITABLE FOR CLASSROOM USE

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ABSTRACT

A simple method to assess climate warming is described, which is suitable for post-secondary classes in environmental sciences. This method is based on climate normals and subsequent weather data, and is demonstrated using Government of Canada archived climate/weather data from sites in Prince Edward Island including Charlottetown Airport, Alliston and New Glasgow. The method uses a simple statistical analysis based on one or two sample Student's t-tests as well as scatter plots and linear regression to highlight the direction and magnitude of changes. Statistically significant increases of annual average temperature of 0.7°C to 1.3°C were calculated for the period after the end of the 1961-1990 climate normals for Alliston and Charlottetown, and a 0.9°C change was demonstrated for New Glasgow after the 1971-2000 climate normals. These values suggest a recent rate of change three times greater than a previous estimate of up to 0.9°C per century for the Gulf of St. Lawrence region, with a major temperature increase occurring in the late 1990s. Changes were most pronounced during September and December, and two sites showed a significant increase in continuous frost-free days during the growing season, as well as a decline in the number of days with frost during spring and fall.

Keywords: Climate change, climate normals, Prince Edward Island, weather

INTRODUCTION

That the Earth is in a period of global climate change associated primarily with an anthropogenically induced warming trend caused by greenhouse gas emissions is well established (IPCC 2014). Different parts of the world are experiencing changes at different

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rates, and major changes in temperature for high latitudes in the Northern Hemisphere, including the Canadian Arctic, have already occurred (e.g. Gauthier *et al*. 2013). These changes have resulted in major declines in extent and duration of sea ice in the Arctic Ocean, major reduction in volume of the Greenland ice sheet and a decline of permafrost (e.g. Chasmer and Hopkinson 2016, Mikkersen *et al*. 2016, Ding *et al*. 2017; and references therein).

Less extreme temperature changes have been predicted for the coastal regions of eastern Canada including Nova Scotia and Prince Edward Island. Galbraith *et al*. (2010, 2012) analyzed both air and sea-surface temperatures in the Gulf of St. Lawrence back to 1873 (for air temperature), and estimated an air temperature increase of up to 0.9°C regionally. The air temperature analysis was based primarily on data from the Charlottetown Airport weather station. Here we use these data, along with temperature data from many other sites in Prince Edward Island, to focus on changes since 1961 and climate normals for the period 1961-1990.

Many of the climate changes predicted by computer modeling (e.g. IPCC 2014) refer to global warming and provide a basis for predicting future changes. Such climate change models, however, are based on computer-intensive technologies such as satellites (e.g. Garcia-Soto *et al*. 2012) and boreholes (e.g. Beltrami *et al*. 2015) that are typically not accessible to teachers or students outside of government and university research laboratories. In addition, many operate on smoothing scales of 250 to 1200 km (e.g. Garcia-Soto *et al*. 2012) that may not inform a geographic scale that might be of greater interest to students, e.g. 'my home town'. Here I provide a simple method that facilitates a clear description of the direction and extent of temperature warming using data from Prince Edward Island.

The analysis proceeded as follows. First, the average annual temperatures for 15 sites in Prince Edward Island from 1961 to the present were used to address the question: has there been a significant change in average temperatures over that period for the island as whole? Given a positive answer, the climate normals for three sites and the associated weather data were then used to address more specific questions on climate change dealing with changes in average monthly temperatures. Because of a strong seasonal pattern to temperature increase, the analysis then addressed the issue of whether the seasonal temperature changes increased the potential growing season by way of an elongation of the frost-free period. All analyses were carried out using simple statistical tests based on archived data available from Government of Canada websites.

MATERIALS AND METHODS

Data was used from the Government of Canada website "Historical Climate Data" (climate.weather.gc.ca). Two parts of this website were used: "Canadian Climate Normals" (http://climate.weather.gc.ca/climate_normals/index_e.html) and "Historical Data" (http://climate.weather.gc.ca/historical_data/search_historic_data_e.html). In both cases Prince Edward Island was selected and the data from the relevant sites were then manually transferred to Excel (Microsoft) spreadsheets for analysis. First, I used average annual temperature values from sites across Prince Edward Island (Table 1, Fig 1) to establish the fact of temperature increase across the island over the period 1961-2016. Data from three sites (Alliston, Charlottetown

Table 1 Sites in Prince Edward Island used for climate change analysis and the years for the climate normal and subsequent data from Environment Canada.

Site	Latitude/ longitude	Years for average annual temperature	Years for climage normal	Years of weather data
Alberton[1]	46°48'N, 64°4'W	1970-2005		
Alliston[2]	46°4'N. 62°36'W	1961-2015	1961-1990	1995-2016
Bangor	46°22'N, 62°41'W	1972-2003		
Charlottetown Airport	46°17'N, 63°7'W	1961-2016	1961-1990	1991-2016
East Baltic	46°26'N, 62°10'W	1972-1999		
Ellerslie	46°36'N, 63°57'W	1966-1986		
Hunter River	46°21'N, 63°21'W	1971-1983		
Kingsboro	46°23'N, 62°7'W	2001-2005		
Long River	43°30'N, 63°33'W	1971-2002		
Monticello	46°28'N, 62°27'W	1961-2001		
New Glasgow	46°24'N, 63°2'W	1972-2016	1971-2000	2001-2016
O'Leary	46°42'N, 64°14'W	1961-2003		
St. Peters	46°25'N, 62°35'W	2004-2006		
Stanhope	46°24'N, 63°6'W	1971-2005		
Summerside Airport	46°26'N, 63°50'W	1961-2006		
Tignish	46°57'N, 64°2'W	1972-1991		
Tyne Valley	46°35'N, 63°55'W	1991-2003		
Victoria	46°13'N, 63°29'W	1994-2003		

[1] 1988 – missing data
[2] 1979, 1981-1994 – missing data

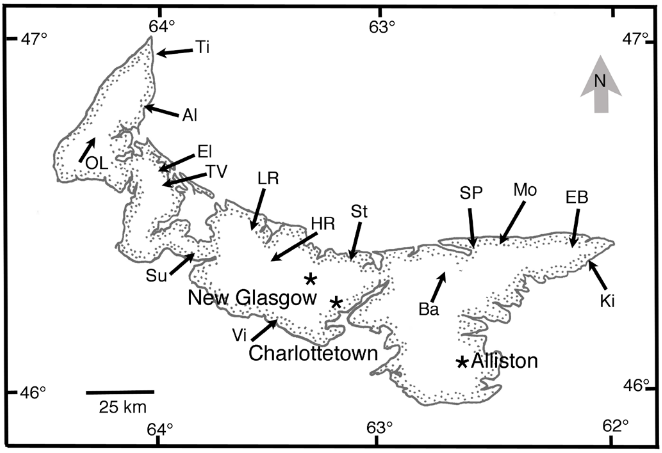


Fig 1 **Map of Prince Edward Island indicating sites used for changes in annual average temperature. Asterisks (*) indicate sites used for analyses of monthly changes in temperature and frost occurrences in spring and autumn. Arrows indicate sites used for determination of annual temperature variation 1960-present. Abbreviations: Al- Alberton; EB- East Baltic; El- Ellerslie; HR- Hunter River; Ki- Kingsboro; LR- Long River; Mo- Monticello; OL- O'Leary; SP- St. Peters; St- Stanhope; Su- Summerside; Ti- Tignish; TV- Tyne Valley; Vi- Victoria.**

Airport, New Glasgow) were then used in a more detailed evaluation (Table 1). These locations were selected because of the relative completeness of the data set relative to other sites.

Using Charlottetown Airport as the model for the procedure, the mean monthly temperatures from climate normals (in this case 1961-1990; Appendix 1) were copied into a spreadsheet with each month in a separate column. For the years 1991-2012 the monthly means were already tabulated on the website and these were copied into the appropriate column. For 2012-2016, monthly means were available only as part of 'daily' records, and the page for each month had to be inspected separately for the relevant mean value. Occasional missing monthly means were inserted by taking the mean of the previous two years.

The means and standard deviations (SD) of the monthly averages for 1991-2016 were then calculated along with the differences between the new means and the means of the climate normal. These values are shown in Table 2. The mean of the monthly differences between the climate normal and the weather data was

Table 2 **Climate normals for average monthly temperature (°C) for three sites in Prince Edward Island from 1961-1990 (Alliston, Charlottetown Airport) and New Glasgow (1971-2000) and summaries of changes in average monthly temperature from weather data from 1991-2016. Comparison of annual mean temperature based on two-tailed Student's t tests; comparison of monthly means based on one-tailed t-tests. NS = p > 0.1.**

Site		Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Mean
Alliston														
Climate normal		-7.0	-7.4	-2.5	2.4	8.7	14.7	18.6	18.2	13.8	8.6	3.2	-3.0	5.7
1991-2014	Mean	-5.9	-5.3	-1.8	3.7	9.6	15.4	19.8	19.6	15.8	9.8	4.2	-1.3	6.9
	SD	± 2.1	± 3.1	± 1.9	± 1.7	± 2.0	± 1.7	± 1.1	± 1.1	± 1.3	± 1.3	± 1.1	± 2.0	
Change		1.1	2.1	0.7	1.3	0.9	0.7	1.1	1.4	2.0	1.2	1.0	1.6	1.3 ± 0.4
Significance		0.01	< 0.01	<0.01	<0.01	<0.05	<0.05	<0.01	<0.01	< 0.01	<0.01	<0.01	<0.01	< 0.001
Charlottetown														
Climate normal		-7.7	-8.0	-3.4	2.3	8.8	14.4	18.4	18.0	13.4	8.0	2.5	-4.1	5.2
1991-2014	Mean	-7.4	-7.3	-3.0	3.0	9.2	14.6	18.9	18.6	14.7	8.7	3.3	-2.5	5.9
	SD	± 2.4	± 2.3	± 2.0	± 1.5	± 1.4	± 1.0	± 1.3	± 1.0	± 1.3	± 1.4	± 1.2	± 2.1	
Change		0.3	0.7	0.4	0.7	0.4	0.2	0.5	0.6	1.3	0.7	0.8	1.6	0.7 ± 0.4
Significance		NS	0.06	NS	<0.05	<0.05	NS	< 0.01	< 0.01	< 0.01	<0.01	<0.01	< 0.01	< 0.001
New Glasgow														
Climate normal		-7.6	-7.7	-2.9	2.9	9.1	14.8	18.8	18.3	13.8	8.1	2.7	-3.8	5.6
1991-2014	Mean	-6.6	-6.8	-2.6	3.6	9.6	14.6	19.5	19.2	15.2	9.4	3.9	-1.9	6.4
	SD	± 2.4	± 2.4	± 1.9	± 1.6	± 1.2	± 1.0	± 1.1	± 0.8	± 1.2	± 1.0	± 2.0	± 0.6	
Change		1.0	0.9	0.3	0.7	0.5	-0.2	0.7	0.9	1.4	1.3	1.2	1.9	0.8±0.30
Significance		0.07	0.08	NS	< 0.01	<0.05	NS	<0.01	< 0.01	< 0.01	<0.01	<0.01	< 0.01	< 0.001

calculated, and two-tailed, single-sample Student's t-tests (GraphPad: https://graphpad.com/quickcalcs/oneSampleT1/?Format=SD) were used to determine significance. This mean was always significantly greater than the annual mean of the climate normal ($P < 0.001$).

Changes on a monthly basis were then evaluated. Based on the initial observation that an overall annual temperature increase had occurred, the monthly data were then evaluated with a question that changed from the initial: 'are the monthly means different?' (requiring a two-tailed analysis) to 'are the monthly means greater than those of the climate normal?' (requiring only a one-tailed analysis). Next, to evaluate the magnitude of the differences in the monthly means, rather than just their absolute values, a second table was constructed in which the value for each month/year for the weather data was subtracted from the mean of the climate normal for that month. This effectively normalized the differences from each month, making the size of the monthly change easier to visualize (Appendix 1, Part B). Finally, the means from the individual months were evaluated using one-tailed, single sample Student's t-tests with the GraphPad software indicated above. Annual changes in means for days of frost and frost-free days for the three primary sites were evaluated using linear regression implemented in online software from GraphPad (www.graphpad.com/quickcalcs/linear1/).

Having demonstrated an overall temperature increase and having addressed which months showed significant increases, analyses proceeded to address if there were critical times in the year where changes in temperature would impact the length of the growing season. Accordingly, the dates of the last frost in the spring and first frost in the autumn were determined, and the number of days with frost (i.e. temperatures below 0.0°C) in each month during spring (March to June) and autumn (September to December) were tabulated. Given overall temperature increases, these values provide insight into potential changes in the length of the growing season and the general amelioration of the climate. Comparisons were made between years that comprised the climate normals and the subsequent periods.

RESULTS

Spatial and temporal variation – annual variation

During the 1961-2016 period studied here, average temperature varied considerably both temporally and spatially. The warmest sites were Alliston and Stanhope and the coldest were Alberton, O'Leary and Tignish. A lack of continuous temperature records for all sites made more precise spatial comparisons difficult. Annual variation among sites was about 1°C and the SD across all sites varied from about 0.2 to 0.4. The coldest year was 1972 with a mean temperature of 4.1 ± 0.3°C (mean ± SD), and the warmest year was 2010 with a mean of 7.9 ± 0.4°C (Fig 2). The overall correlation between mean annual temperature and year between 1961 and 2016 was $r = 0.623$ (significant at $P < 0.01$).

The years 1961-2016 showed a distinct pattern in which a relatively stable temperature regime existed between 1961 and 1997 compared to the post 1997 period. The overall means for data from all sites are shown in Fig 2, and the values for the two periods were 5.3 ± 0.7°C and 6.5 ± 0.7°C. These two values with a difference of 1.2°C were highly significant (two-tailed Student's t-test, $P < 0.001$), and confirmed a major temperature increase in the last 18 years relative to the preceding period. The difference was such that the highest annual overall mean for the province for the early period (6.4°C) was always less than the mean for the subsequent period (6.4°C vs 6.5°C), and the lowest mean for the post 1997 period was always greater than the mean for the earlier period (5.7°C vs 5.3°C; Fig 2).

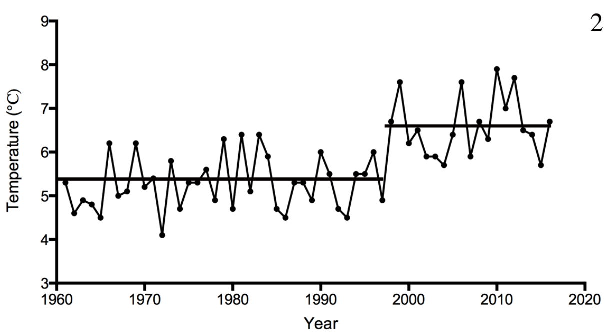


Fig 2 **Changes in average annual temperature from sites in Prince Edward Island based on all sites in Fig. 1. Note: the two lines indicate average temperature between periods 1961-1997 and 1998-2016. See Fig 1 for site locations.**

Monthly changes in temperature

A more refined analysis of temperature changes by month was done using the climate normals. The overall temperature increases were 0.7°, 0.8° and 1.3°C for Charlottetown, New Glasgow and Alliston, respectively; all were highly significant statistically (i.e. $P < 0.001$; Table 2). These increases were consistent with the changes in mean temperature for the Island shown in the previous section.

Every site/month combination had a temperature change that was in a positive direction. Of the 36 possible comparisons, 28 were significant ($P < 0.05$). All non-significant changes occurred in the first half of the year and were limited to Charlottetown and New Glasgow. Most of the non-significant changes were in the order of 0.2-0.5°C relative to climate normals. The temperature changes in the second half of the year had greater magnitude (mostly 0.7-1.6°C). At all three sites the largest increases were during September and December when increases ranged from 1.3°C to 2.0°C.

Changes in number of frost days

The increase in temperature in every month allows for the possibility of a decrease in frosts and this was evaluated for both spring and autumn months. The three sites had different patterns with respect to climate normals, with the last frost occurring 42 (Charlottetown) to 52 (New Glasgow) days after April 1 (Table 3). Allison and New Glasgow had a reduction in frost days in the period following climate normals, although only the ten-day reduction at Alliston was significant, and the six-day increase (i.e. later frosts) at Charlottetown was significant. While Alliston and New Glasgow had fewer frost days

Table 3 Climate normal and summaries of changes from weather data from 1991-2013 for days to last frost starting April 1 and number of frost days in months from March to June for three sites in Prince Edward Island. Significant differences from climate normal based on 1-tail Student's t tests: * = P < 0.05, ** = P < 0.01.

Site		Days to last frost	Number of frost days Mar	Apr	May	June
Alliston	Normal	46.0±9.9	28.2±2.5	21.6±5.4	4.4±2.8	0.05
	1991-2013	36.0±10.8**	27.1±2.7	14.9±4.8**	1.1±1.2**	0
Charlottetown	Normal	41.8±9.7	28.7±2.0	21.5±5.1	3.7±3.6	0
	1991-2016	48.1±14.2*	29.1±1.9	20.0±4.6	4.2±3.0	0.3±0.6
New Glasgow	Normal[1]	52.1±12.0	27.1±1.9	17.8±4.7	4.6±3.4	0.2±0.4
	1991-2016	48.3±11.4	26.8±5.5	16.7±4.7	3.0±1.9	0.2±0.5

[1] years 1972-1990 only

during individual months, these were significant only at Alliston with reductions during April and May of seven and three days, respectively.

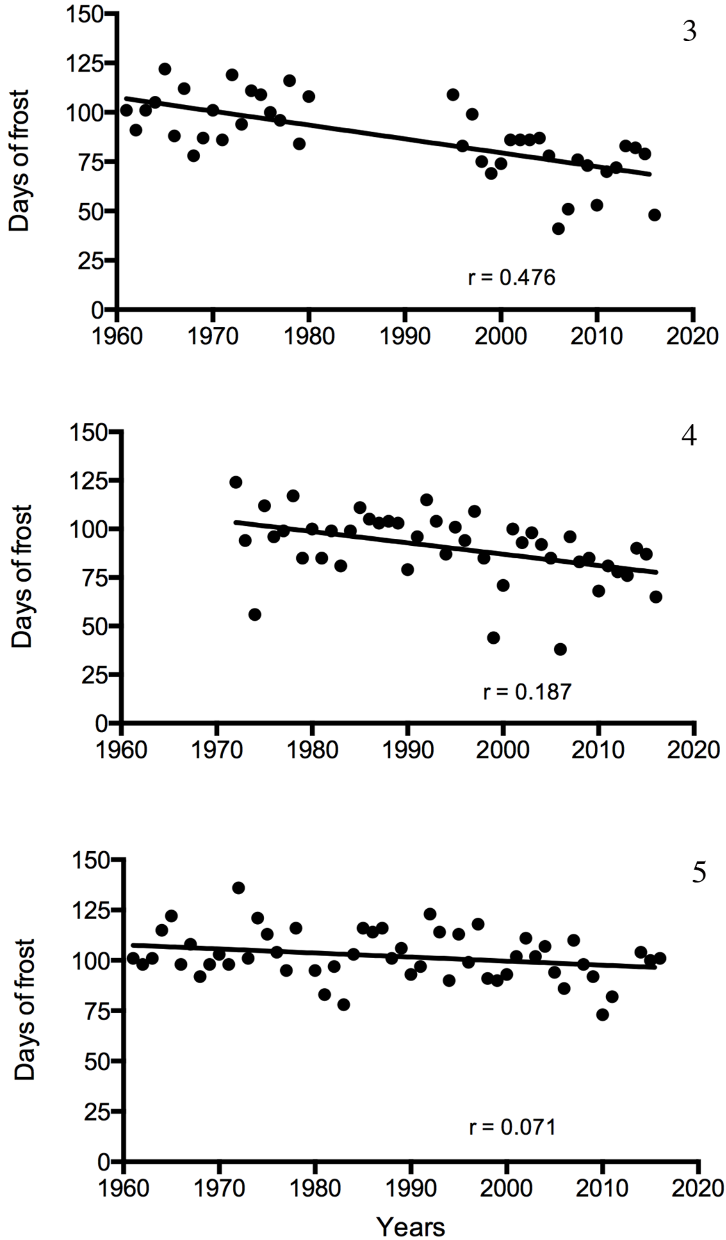
Changes in the timing and number of frosts during autumn were more apparent than in spring. Frosts during September from 1961 to present were rare, and the climate normals had the first frost occurring an average of 37 to 49 days after September 1 (i.e. early to mid-October). In the post climate normals period, there was a clear trend to a later occurrence of the first frost with later occurrences of two, six and 14 days, although this was significant only for Alliston (Table 4). Between October and December all months and sites showed fewer frost days although this was significant only for Alliston (all three months) and for New Glasgow in October.

The combination of earlier last frost in spring and later last frost in the fall led to a general trend of declining number of frost days in spring and autumn for Alliston and New Glasgow (Figs 3, 4) but not for Charlottetown (Fig 5, Table 5). This decline corresponded to an increase in continuous frost-free days for Alliston and New Glasgow (Figs 6, 7) but not Charlottetown Airport (Fig 8). The increase in the frost-free period showed a trend of about 35 days for Alliston since 1960 and about 25 for New Glasgow since 1970. The increase in the frost-free period was apparent starting in 1961 even though there was little change in average temperature over the first 35 years. For Alliston, the relationship between year and increase in continuous frost-free days was significant ($r^2 = 0.296$, $P <0.001$). The equivalent relationship for New Glasgow was also significant ($r^2 = 0.295$, $P < 0.01$)

Table 4 Climate normal and summaries of changes from weather data from 1991-2013 for days to first frost starting September 1 and number of frost days in months from September to December for three sites in Prince Edward Island. Significant differences from climate normal: * = P < 0.05, ** = P < 0.01.

Site		Days to first frost	Number of frost days Sept	Oct	Nov	Dec
Alliston	Normal[1]	49.4±9.9	0	3.0±2.7	15.8±5.6	27.3±3.3
	1994-2015	64.0±9.4**	0	0.9±1.2**	11.9±3.9**	25.2±4.6*
Charlottetown	Normal	47.3±10.9	0	4.1±3.0	17.8±5.2	28.1±2.8
	1991-2016	49.6±10.3	0	3.6±3.3	15.3±4.2	26.9±3.5
New Glasgow	Normal[2]	37.2±11.1	0.4±0.8	6.2±2.6	16.5±4.3	27.3±3.0
	1991-2016	43.2±8.7	0.0±0.0	2.9±1.6*	13.8±3.8	25.1±3.8

[1] 1961-1981 only
[2] 1971-1990 only



Figs 3-5 Total number of days of frost for months March to June and September to December for Alliston (Fig 3), New Glasgow (Fig 4) and Charlottetown Airport (Fig 5) with lines of best fit and Pearson correlation coefficients (r).

Table 5 Changes in frost-free days in spring and autumn months. See Tables 3-4 for significances of changes in spring and fall months. Note '+' indicates increase in days with frost.

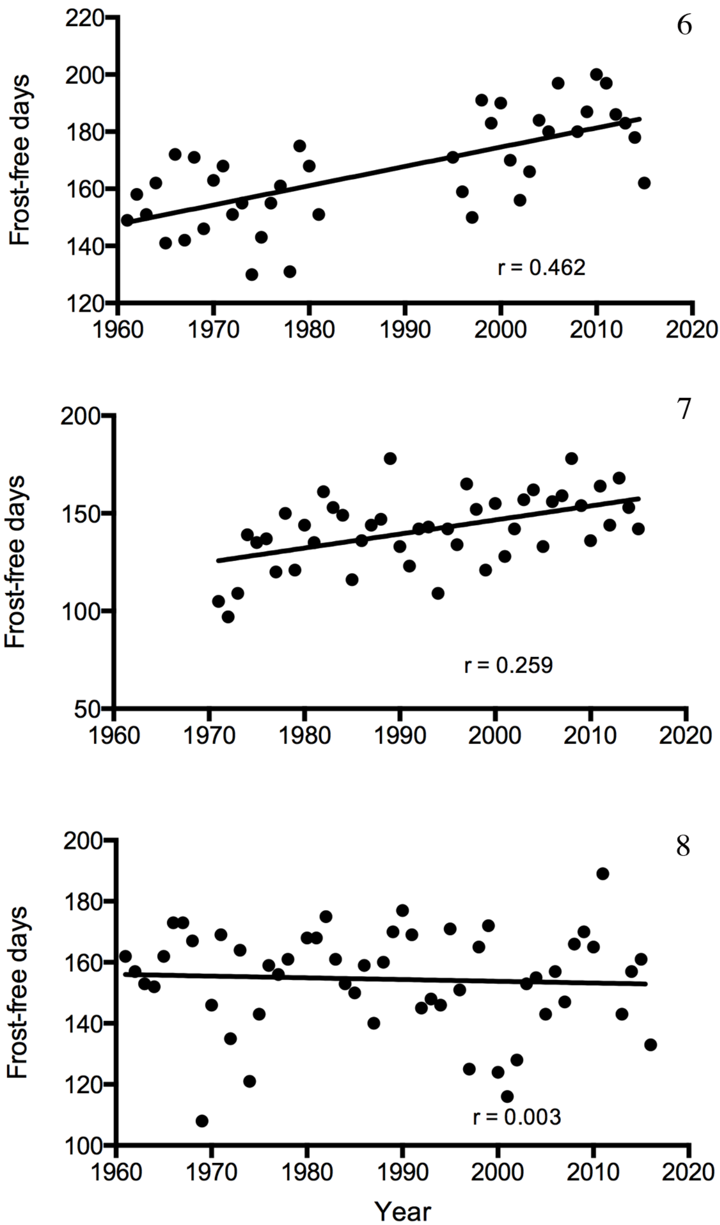
Season Spring	Reduction in days to last frost (from April 1)	March	April	Months May	June
Alliston	10.0	-1.1	-6.7	-3.3	0
Charlottetown	+3.3	+0.4	+1.5	0.5	0.3
New Glasgow	3.8	-0.3	-1.1	-1.6	0

Season Autumn	Additional days to first frost (from Sept 1)	September	October	November	December
Alliston	14.6	0	-2.1	-3.9	-1.9
Charlottetown	2.3	0	-0.5	-2.5	-1.2
New Glasgow	6.0	-0.4	-3.3	-1.7	-2.2

DISCUSSION

For purposes of this paper, the climate of an area can be defined as the 'climate normals'; these are based on weather patterns over a 30-year period and are officially updated every ten years. Here the climate normals from 1961-1990 are used because it allowed a large enough subsequent time over which changes could be generalized for statistical analysis for comparison with the climate normals. The general pattern, that the rate of change increased substantially in the late 1990s, is confirmed by the overall increase in annual temperature between the climate normals for 1961-1990 and 1971-2000, where only a 0.1°C increase for Charlottetown and a 0.4°C change for Alliston occurred in that interval. This contrasts with the more than 1°C increase for the island as a whole after the late 1990s (Fig 2).

Only one aspect of climate change was examined, i.e. temperature, and how it has changed both on an annual and monthly basis, and with respect to the occurrences of frost during spring and fall months. The latter is important because an increase in the frost-free period suggests increases in the growing season, and points to a general moderation of the cold-temperate climate of Prince Edward Island. By showing statistically significant changes from those 'normals' over a period approaching 30 years (i.e. 21 years for Alliston and 26 years for Charlottetown) climate change has been demonstrated. While the



Figs 6-8 **Maximum period of frost-free days from spring to autumn for Allison (Fig 6), New Glasgow (Fig 7) and Charlottetown Airport (Fig 8) with lines of best fit and Pearson correlation coefficients (r).**

primary period for New Glasgow was only 16 years, the direction and magnitude of the changes were consistent with the first two sites.

The overall pattern for Prince Edward Island was a gradual increase that suggested a temperature increase of over 1°C since the late 1990s. This pattern of a very slight increase between 1961 and the mid 1990s followed by an upward shift and subsequent stabilization, was also apparent in a similar analysis from Nova Scotia (Garbary and Hill, unpublished data). The Alliston increase of 1.3°C is larger than would be expected, and is likely an artifact of the limited data set, i.e. only 21 complete years (ca. 1995-2015). This period magnified the changes by omitting several years with lower temperatures, and concentrated the values into more recent years when the higher temperatures occurred.

Of the three primary sites, the smallest change during the 1960-2016 period was observed Charlottetown where the temperature increase was only 0.7°C relative to climate normals. Using mean annual temperatures from 1946 to 2016 gave an extremely weak correlation ($r^2 = 0.05$, $P > 0.05$). The relationship was substantially improved by using a five-year running average ($r^2 = 0.191$, $P < 0.01$) which showed the annual average after 2008 always above 6.0°C. Similarly, there was no positive trend in the increase in the number of continuous frost-free days in Charlottetown as was observed at the other sites.

The sudden rise in temperature at the end of the 1990s leading to a relatively stable subsequent regime requires explanation. While global temperatures have been rising (IPCC 2014), there was no sudden change in the late 1990s that would explain the result from P.E.I. Indeed, the average global temperature records for 2014 through 2016 do not seem to be reflected in the results for P.E.I., where the highest annual temperature occurred in 2010 (7.9 ± 0.4), with the warmest year since 2013 being only 6.7 ± 0.2. While this apparent decline is statistically significant ($P < 0.05$), it is based on limited observations and it would be premature to suggest a trend.

The sudden rise in annual temperature in the late 1990s is correlated with a decline in winter sea-ice area in the Gulf of St. Lawrence (Benoit *et al*. 2012, fig. 5.3-1); however, the dramatic increase in sea-ice in the early 1970s is not correlated with changes in the annual air temperatures for P.E.I. (Fig 3) that were relatively stable from 1961 to the mid 1990s. The onset of warmer temperatures in the late 1990s is correlated with the extreme El Nino-Southern

Oscillation event in 1998 (Trenberth *et al*. 2002). In addition to the long-term pattern of global warming (IPCC 2014), other phenomena may be acting on shorter time scales, e.g. the 20-year cycle of the Atlantic Multidecadal Oscillation (AMO- Chylek *et al*. 2011, 2016). On the one hand, a reversal of the trend of rising temperatures from the 1990s might be consistent with the AMO. On the other hand, it is reasonable to suggest that the successive global record setting years since 2014 (NOAA 2017, Gillis 2017, Su *et al*. 2017, Thompson 2017) will be reflected over the next few years in the average annual and monthly changes for Prince Edward Island.

Warmer temperatures in the spring and autumn in Nova Scotia in specific years have already been documented to cause changes in flowering phenology. This has occurred at least twice during the autumn/early winter in 2001 and 2006 when 95 and 136 species respectively were in flower after November 1, and flowering was still occurring in December in 2001 and even into January in 2007 for many species (Taylor and Garbary 2003, Garbary and Taylor 2007, Garbary *et al*. 2012). Similarly, advanced spring flowering in March-April was documented in 2012 that set early flowering records for Nova Scotia (Hill and Garbary 2013). The warming trends shown here for P.E.I. would suggest that the wild flora would have behaved as they did in Nova Scotia. As autumn temperatures continue to increase and result in longer frost-free periods, flowering periods for many species will almost certainly continue to be extended into the autumn on a regular basis.

In summary, the methodology presented here show that rising temperatures in P.E.I. have been increasing since the early 1960s with the rate of change increasing dramatically over the last 20 years (see Appendix 2 for Provincial Government websites on climate change). The temperature increase is more apparent at inland sites than at the more coastal Charlottetown. The increases at Alliston and New Glasgow are associated with increases in the frost-free period. This change was also observed in a similar analysis of climate change in Nova Scotia (Garbary and Hill, unpublished). It is beyond the scope of this work to determine the causal factors behind this more intense and rapid local change. However, more extreme changes can occur on smaller geographic and temporal scales than might be predicted for an entire region by global models. It is these local changes in mean temperature and frost-free periods that will affect human activities and the biological and physical responses of the natural world. Using this procedure in classrooms can introduce students to basic statistical concepts, and also provide clear demonstrations of climate change at a local level.

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Appendix 1 Portion of table for Charlottetown Airport (omitting 1996-2011) as an example of procedure. Part A indicates monthly mean and annual temperature in the climate normal and the monthly means from years 1991-2016. Part B indicates the normalized temperature differences between climate normal and the means in Part A. Note: the negative numbers in Part B indicate a temperature increase relative to the climate normal. Abbreviations: CN, climate normal; Diff, difference between climate normal and average of the monthly means; NS, not significant; SD, standard deviation.

Part A	J	F	M	A	M	J	J	A	S	O	N	D	Mean
CN	-7.7	-8.0	-3.4	2.3	8.8	14.4	18.4	18.0	13.4	8.0	2.5	-4.1	5.2
1991	-10.8	-7.2	-5.0	2.3	9.2	14.2	18.7	18.1	13.1	9.7	4.2	-5.1	5.1
1992	-8.5	-8.5	-6.0	1.2	8.9	14.2	15.9	18.5	15.0	7.5	1.0	-3.7	4.6
1993	-9.4	-12.4	-5.0	2.8	8.0	13.7	16.2	18.3	13.7	6.0	2.0	-3.0	4.2
1994	-12.1	-10.5	-2.6	4.2	8.1	15.5	20.3	17.9	13.0	8.6	3.7	-3.7	5.2
1995	-5.6	-9.2	-3.4	1.4	7.3	14.9	19.7	17.4	12.4	10.5	2.6	-4.9	5.3
. . .													
2012	-5.1	-6.1	-0.5	5.4	10.8	14.3	19.5	20.9	16.3	10.1	3.3	0.4	7.4
2013	-7.6	-5.4	-1.7	3.7	10.6	15.0	19.8	18.8	14.8	8.1	2.2	-6.0	6.0
2014	-7.1	-7.6	-6.5	2.9	8.1	14.3	21.3	18.2	14.5	10.7	2.6	-0.8	5.9
2015	-8.7	-12.6	-6.0	0.1	10.6	12.6	18.1	21.3	16.3	7.8	4.0	0.4	5.3
2016	-5.0	-3.7	-3.1	2.2	9.7	14.6	18.9	18.6	15.3	9.8	4.6	-3.3	6.6
Mean	-7.4	-7.3	-3.0	3.0	9.3	14.6	18.9	18.6	14.7	8.7	3.3	-2.5	5.9
SD	2.4	2.3	2.0	1.5	1.4	1.2	1.3	1.0	1.3	1.4	1.2	2.0	0.9
Diff	-0.3	-0.7	-0.4	-0.7	-0.5	-0.2	-0.5	-0.6	-1.3	-0.7	-0.8	-1.6	-0.7

Appendx 1 Cont'd

Appendx 1 Cont'd

Part B	J	F	M	A	M	J	J	A	S	O	N	D	Mean
1991	3.1	-0.8	1.6	0.0	-0.4	0.2	-0.3	-0.1	0.3	-1.7	-1.7	1.0	0.1
1992	0.8	0.5	2.6	1.1	-0.1	0.2	2.5	-0.5	-1.6	0.5	1.5	-0.4	0.6
1993	1.7	4.4	1.6	-0.5	0.8	0.7	2.2	-0.3	-0.3	2.0	0.5	-1.1	1.0
1994	4.4	2.5	-0.8	-1.9	0.7	-1.1	-1.9	0.1	0.4	-0.6	-1.2	-0.4	0.0
1995	-2.1	1.2	0.0	0.9	1.5	-0.5	-1.3	0.6	1.0	-2.5	-0.1	0.8	-0.1
. . .													
2012	-2.6	-1.9	-2.9	-3.1	-2.0	0.1	-1.1	-2.9	-2.9	-2.1	-0.8	-4.5	-2.2
2013	-0.1	-2.6	-1.7	-1.4	-1.8	-0.6	-1.4	-0.8	-1.4	-0.1	0.3	1.9	-0.8
2014	-0.6	-0.4	3.1	-0.6	0.7	0.1	-2.9	-0.2	-1.1	-2.7	-0.1	-3.3	-0.7
2015	1.0	4.6	2.6	2.2	-1.8	1.8	0.3	-3.3	-2.9	0.2	-1.5	-4.5	-0.1
2016	-2.7	-4.3	-0.3	0.1	-0.9	-0.2	-0.5	-0.6	-1.9	-1.8	-2.1	-0.8	-1.4
Mean	-0.4	-0.8	-0.4	-0.7	-0.5	-0.2	-0.5	-0.6	-1.3	-0.7	-0.8	-1.6	-0.7
SD	2.3	2.2	2.0	1.4	1.4	1.1	1.3	1.0	1.3	1.4	1.2	2.0	0.4
P value	NS	0.1	NS	0.0	0.1	NS	0.0	0.0	0.0	0.0	0.0	0.0	<0.001

Appenidix 2 Provincial Government websites relevant to climate change in the Maritime Provinces.

New Brunswick
http://www2.gnb.ca/content/gnb/en/departments/elg/environment/content/climate_change.html
This is the best regional website on climate change. It gives actual data on climate normals and predictions based on various climate change models. It also contains data on some sites in Prince Edward Island and Nova Scotia by providing a link "New Brunswick's Future Climate Projections: AR5 Data and Maps" — http://acasav2.azurewebsites.net/)

Nova Scotia
https://climatechange.novascotia.ca/
Brief summary of policy and general information on climate change and adaptation. Provides actual data on climate variables from around the province based on seasons (https://climatechange.novascotia.ca/adapting-to-climate-change)

Prince Edward Island
https://www.princeedwardisland.ca/en/topic/climate-change-0
A useful guide to general policy and potential impacts of climate change on various industries including agriculture, fisheries, forestry, and tourism. There is a link to an excellent manuscript on forest trees in relation to climate change (https://www.princeedwardisland.ca/sites/default/files/publications/climate_change_2010._pei_full_report.pdf)