Journal of Sustainable Development; Vol. 7, No. 4; 2014
ISSN 1913-9063 E-ISSN 1913-9071
Published by Canadian Center of Science and Education

Prediction of the Climatologically Data

Mohammad S Islam[1] & Nahid Sultana[2]

[1] McMaster University, Hamilton, Ontario, Canada

[2] Department of Computer Science, College of Computer Sciences and Information Technology, University of Dammam, Dammam, Saudi Arabia

Correspondence: Mohammad S Islam, McMaster University, 1280 Main St W, Hamilton, ON L8S 4L8, Canada. Tel: 1-289-244-9902. E-mail: mohammis@mcmaster.ca

Received: March 25, 2014 Accepted: June 4, 2014 Online Published: July 16, 2014

doi:10.5539/jsd.v7n4p71 URL: http://dx.doi.org/10.5539/jsd.v7n4p71

Abstract

The aim of this study was to predict the three climatologically data of daily maximum temperature (Tmax), daily minimum temperature (Tmin) and daily total precipitation (Ptot) at the Hamilton airport (HA), Ontario, Canada. To serve the stated objective, the observed Tmax, Tmin and Ptot data from the years of 1960 to 2005 at the Hamilton and Toronto airport, Ontario, Canada were utilized. The dataset of Hamilton airport from 1960 to 1984 were then fitted with Time Series (TS) regression model to predict the Tmax, Tmin and Ptot for the years of 1985 to 2005 at the Hamilton airport, Ontario, Canada. Additionally, the changes in the climatologically data averaged over one- and 10-year period were also investigated. The results showed that the TS model was best suited in generating the daily maximum temperature and daily minimum temperature, whereas it was not capable of evaluating the daily total precipitation at the Hamilton airport. Finally, a detailed statistical analysis was performed to support the findings.

Keywords: climatologically data, daily maximum temperature, daily minimum temperature, daily total precipitation, time series, statistical analysis

1. Introduction

The climate of a place is the description of the long-term pattern of weather in a particular area (USGCRP, 2009). More precisely, it is the average weather of climatologically data, such as averages of temperature, precipitation, humidity, wind velocity, sunshine, and other phenomena such as frost, fog, and hail storms, for a particular region in a period of usually over 30-years (Ahrens, 2011). A day-to-day variation of any factor that is characteristic of the climate of a particular place is also considered. Although the climate assumes a long-term consistency and stability in these patterns, climate is nevertheless a changeable phenomenon (Hengeveld et al., 2005).

The historical record shows that both natural and human factors change Earth's climate (Gore, 2007; Letcher, 2009, EPA, 2014). Before the Industrial Revolution in the 1700s, changes in climate resulted slowly over a wide range of time scales, and they were primarily due to the natural causes of volcanic eruptions, and changes in solar activity and Earth's orbit (Hile, 2009; EPA, 2014). Since the Industrial Era of 1700s, the humans had influenced an increasing effect on climate, in particularly by adding billions of tons of heat-trapping greenhouse gases (mainly water vapour, carbon dioxide, methane, nitrous oxide and ozone) to the atmosphere (Moomaw, 2002; Hile, 2009; EPA, 2014). Most of the observed warming since the mid-20th century is due to human-caused greenhouse gas emissions (Gore, 2006; Hile, 2009; Ahrens, 2011; EPA, 2014). Recently, Gore (2014) added that nninety million tons of CO_2 and other gasses are pumped out every day making the planet hotter, which would equate the man-made pollution to 4,00,000 Hiroshima-scale atomic bombs.

A number of studies showed that the average temperatures have climbed 1.4 degrees Fahrenheit (0.8 degree Celsius) around the world since 1880, much of this in recent decades (Hile, 2009; Kegley & Raymond, 2012). Australian average temperatures are projected to rise by 0.6 to 1.5 ºC by 2030, and if the global greenhouse gas emissions continue to grow at rates consistent with past trends, warming is projected to be in the range of 2.2 to 5.0 ºC by 2070 (CSIRO, 2010). The 20th century's last two decades were the hottest in 400 years and possibly the warmest for several millennia, according to a number of climate studies (Khan, 2009; Marsa, 2013). The oceans absorb 85% of the excess heat trapped by the atmosphere resulting the raise in the temperature of ocean water

(Cazenave & Llovel, 2010; Levitus et al., 2009). Thus, raising sea level is one of the most visible effects of climate change, and the report found that sea levels are increasing more rapidly than in previous decades (Hansen, 2007; Gore, 2006; Ahrens, 2011; Hensen et al., 2010). Global average sea level rose roughly eight inches from 1880 - 2009 (Church & White, 2011; Church et al., 2011). If current warming patterns continue, arctic summers could be ice-free by 2040, and sea levels could rise as much as 23 inches by 2100 (NRDC, 2014). Additionally, changing climate has shifted monsoon patterns, which triggers the intense tropical cyclones along the western coast of the U.S., Atlantic Canada and Mexico (IPCC, 2013). In Canada, the ramifications have already begun across the country, and scientists have predicted that the symptoms could grow worse with each passing decade (IPCC, 2013).

The researchers use computer models to better understand the issues of the climate system and project future climate changes. A few number of previous investigations had dealt with the prediction models for the climatologically data. Though the climatologically data is typically measured at successive time intervals, the previous studies were lacked of Time Series analysis, where ordering is most important (Box et al., 2008; Young, 2011), to predict the future values based on previously observed data.

Time Series (TS) analysis is a special type of regression models to estimate the relationships among dependent and independent variables (Box et al., 2008; Cryer & Chan 2008). This tool is widely used for modeling and analyzing variables for prediction and forecasting purposes in various fields, namely economics, finance, biology, and engineering for more than 200 year (Ghafoori & Islam, 2013). In this technique, the memory effect is measured by the autocorrelation function (ACF) or serial correlation coefficient (ρk) (Cryer & Chan, 2008; Young, 2011).

2. Research Significance

This study enhances the findings of the past studies by: (a) incorporating three climatologically data of daily maximum temperature (Tmax), daily minimum temperature (Tmin) and daily total precipitation (Ptot) having a wide variation in individual values at the Hamilton airport for the years of 1960 to 2005; (b) performing time series (TS) regression analysis to predict each of the aboven mentioned climatologically data for the years of 1986 to 2005; and finally, (c) comparing the predicted Tmax, Tmin and Ptot at the Hamilton airport with the results obtained by the experimental procedures. Additionally, the variation in the Tmax, Tmin and Ptot averaged over 10-year period was also studied.

3. Methodology

A total of 16,802 sets of observations (Tmax, Tmin and Ptot) from the Hamilton and Toronto airports were utilized for this study. Some missing observations were also present in the both database. Table 1 shows the number of missing observations at the Hamilton airport and Toronto airport. It was stated that precipitation with very low amount (<0.2mm) was also treated as no rain. The missing observations of daily total precipitation for both airports are high in numbers.

Table 1. Number of missing observations

Name	Tmax	Tmin	Ptot
Hamilton airport(HA)	153	224	2233
Toronto airport(TA)	154	230	1995
Both TA and HA	13	16	604

The missing observations of climatologically data at both the Hamilton airport and Toronto airport were determined in the following procedures:

1) Observations missing at the same day at the both airports were determined using the interpolation.

2) Observations missing only at the Hamilton Airport were determined using the regression equations and the corresponding value at the Toronto airport.

3) Observations missing at the Toronto Airport were also determined using the regression equation and the corresponding value at the Hamilton Airport.

In order to determine the missing observations at the Hamilton airport or Toronto airport, the observations of Tmax, Tmin and Ptot were sorted by month, and a monthly regression equation was determined after omitting each missing record. The missing Tmax, Tmin and Ptot data were filled up with the three regression equations as shown in Equations 1, 2, and 3, respectively.

$$(Tmax)_{HAM}= a + b^* (Tmax)_{TOR} \quad (1)$$

$$(Tmin)_{HAM}= a + b^* (Tmin)_{TOR} \quad (2)$$

Where: a is the intercept of the regression line; b is the slope of the regression line; a and b are the r egression coefficients

$$(Ptot)_{HAM}= a * (Ptot)_{TOR} \quad (3)$$

Where: a is the regression coefficient (slope of the regression line)

Exploratory data analysis was conducted for the Hamilton airport. Especially, the histogram, box plot and density plot of daily maximum temperature, daily minimum temperature and daily total precipitation at the Hamilton airport was constructed. The autocorrelation function (ACF) and partial autocorrelation function (PACF) analysis were conducted to identify the autoregressive (AR) models for generating the Tmax, Tmin and Ptot data at the Hamilton airport. The analysis of the residual plots was performed for all these three cases.

The daily maximum temperature, the daily minimum temperature, and the daily total precipitation at the Hamilton airport averaged over one year were calculated, and the change in the climatologically data over the year was also observed. The variation in the yearly averaged Tmax, Tmin and Ptot over the years did not show any definite pattern. In order to overcome this phenomenon, the Tmax, Tmin and Ptot averaged over 10-year period were determined.

4. Results and Discussions

4.1 Retrieve Missing Observations

The statistical parameters (the coefficients of a and b, Prob(t) of a and b, p-value, R2 and R2adj) of the linear regression models for the Tmax, Tmin and Ptot are shown in Tables 2-4, respectively. Tables 2 and Table 3 shows that the R^2 values varied from 0.606 (June) to 0.900(February) with an average of 0.760 for the daily maximum temperature, and from 0.563 (July) to 0.877 (March) with an average of 0.769 for the daily minimum temperature, respectively. Additionally, the Prob(t) values for all regression coefficients for the Tmax and Tmin regression models were in close proximity to 0.0000, which illustrates that the parameters were significant and the less likely that the actual parameter value could be zero. Additionally, another reliable parameter for multiple regression models R^2_{adj} values for both models were shown to be very close to the R^2 values. In the case of Ptot, the proposed regression model did not show a good correlation with the dependent and independent variables, and only 60% of the data explained by the dependent variables.

Table 2. Statistical parameters of linear regression model for Tmax (Eq. 1)

Month	Regression Values		Prob(t) of		R^2	R^{2adj}	p-value
	a	b	a	b			
January	-0.69993	0.98912	2.07e-05	<2.0e-16	0.7097	0.7090	<2.2e-16
February	-0.67174	1.03465	3.78e-14	<2.0e-16	0.8999	0.8996	<2.2e-16
March	-0.49953	1.12381	9.17e-05	<2.0e-16	0.8499	0.8496	<2.2e-16
April	-0.51985	1.21440	0.16e-00	<2.0e-16	0.7299	0.7293	<2.2e-16
May	2.54295	0.99242	9.81e-16	<2.0e-16	0.6454	0.6446	<2.2e-16
June	5.63325	0.8372	8.24e-14	<2.0e-16	0.6063	0.6053	<2.2e-16
July	6.22819	0.81142	<2.0e-16	<2.0e-16	0.6515	0.6508	<2.2e-16
August	4.63820	0.8738	2.47e-10	<2.0e-16	0.6964	0.6956	<2.2e-16
September	-0.08544	1.05960	0.86e-00	<2.0e-16	0.8277	0.8273	<2.2e-16
October	-0.60642	1.12503	0.10e-00	<2.0e-16	0.8200	0.8196	<2.2e-16
November	-1.15899	1.12402	6.95e-08	<2.0e-16	0.8182	0.8178	<2.2e-16
December	-0.80432	1.09064	3.07e-16	<2.0e-16	0.8677	0.8674	<2.2e-16

Table 3. Statistical parameters of linear regression model for Tmin (Eq. 2)

Month	Regression Values		Prob(t) of		R^2	R^{2adj}	p-value
	a	b	a	b			
January	-2.40778	0.99625	<2.0e-16	<2.0e-16	0.8638	0.8634	<2.2e-16
February	-2.62498	0.97916	<2.0e-16	<2.0e-16	0.8607	0.8604	<2.2e-16
March	-1.58858	1.07790	<2.0e-16	<2.0e-16	0.8769	0.8766	<2.2e-16
April	-1.77250	1.15319	<2.0e-16	<2.0e-16	0.7521	0.7516	<2.2e-16
May	-2.38829	1.26323	2.3e-13	<2.0e-16	0.6733	0.6726	<2.2e-16
June	-0.27351	0.99109	0.62e-00	<2.0e-16	0.5710	0.5700	<2.2e-16
July	0.76781	0.87975	0.20e-00	<2.0e-16	0.5629	0.5619	<2.2e-16
August	-2.05664	1.00126	1.6e-04	<2.0e-16	0.6892	0.6884	<2.2e-16
September	-3.45112	1.09761	<2.0e-16	<2.0e-16	0.8502	0.8498	<2.2e-16
October	-2.62824	1.07248	<2.0e-16	<2.0e-16	0.8393	0.8389	<2.2e-16
November	-2.20415	1.06339	<2.0e-16	<2.0e-16	0.8338	0.8334	<2.2e-16
December	-2.28595	0.99274	<2.0e-16	<2.0e-16	0.8506	0.8503	<2.2e-16

Table 4. Statistical parameters of linear regression model for Ptot (Eq. 3)

Month	Regression Value (a)	Prob(t) of a	R^2	R^{2adj}	p-value
January	0.8943	<2.0e-16	0.5474	0.5462	<2.2e-16
February	0.90270	<2.0e-16	0.7497	0.7490	<2.2e-16
March	0.93746	<2.0e-16	0.7075	0.7068	<2.2e-16
April	0.95459	<2.0e-16	0.6799	0.6791	<2.2e-16
May	0.67739	<2.0e-16	0.5784	0.5774	<2.2e-16
June	0.61398	<2.0e-16	0.4373	0.4358	<2.2e-16
July	0.67324	<2.0e-16	0.4737	0.4725	<2.2e-16
August	0.51751	<2.0e-16	0.2812	0.2795	<2.2e-16
September	0.81218	<2.0e-16	0.6130	0.6122	<2.2e-16
October	1.00938	<2.0e-16	0.7277	0.7272	<2.2e-16
November	0.89430	<2.0e-16	0.7277	0.7270	<2.2e-16
December	0.88091	<2.0e-16	0.6380	0.6372	<2.2e-16

4.2 Exploratory Data Analysis

Figures 1-3 show the histogram, box plot and density plot of daily maximum temperature, daily minimum temperature and daily total precipitation at the Hamilton airport, respectively. Another parameter of the exploratory data analysis of qq-plots for the Tmax, Tmin and Ptot is presented in Figure 4. As can be seen from Figures 1 and 2, the daily maximum and daily minimum temperature data follow nearly normal distribution, and no outliers were shown in the database. However, in the case of daily total precipitation data, the observations were not normally distributed (nearly skewed to right). Additionally, the box plot (Figure 2(b)) and qq-plot (Figure 4(a)) of Ptot indicated that the data contained outliers.

4.3 Time Series Analysis

Figures 5-7 shows the ACF and PACF of the observed Tax, Tmin and Ptot data for the years of 1960 to 1984 at the Hamilton airport. As can be shown from Figures 5 and 6, the autocorrelation function (ACF) for the Tmax and Tmin indicated a strong serial correlation at all lags of data, and the data were auto correlated. However, in the case of Ptot, as shown in Figure 7, the ACF values for more than AR(1) lie within the 95% confidence level, which showed an indication of having no correlation after the lag 1. Results obtained from the Partial Autocorrelation Function (PACF) demonstrated that AR(1) model is the best candidate to represent the observed data for Tmax, Tmin and Ptot.

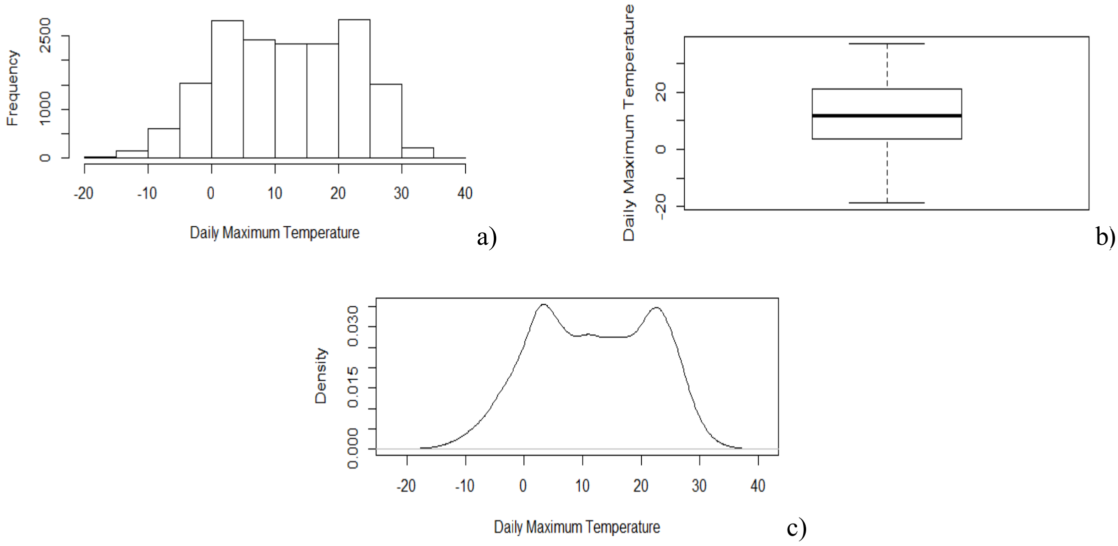

Figure 1. (a) Histogram, (b) box plot and (c) density plot of daily maximum temperature at Hamilton Airport

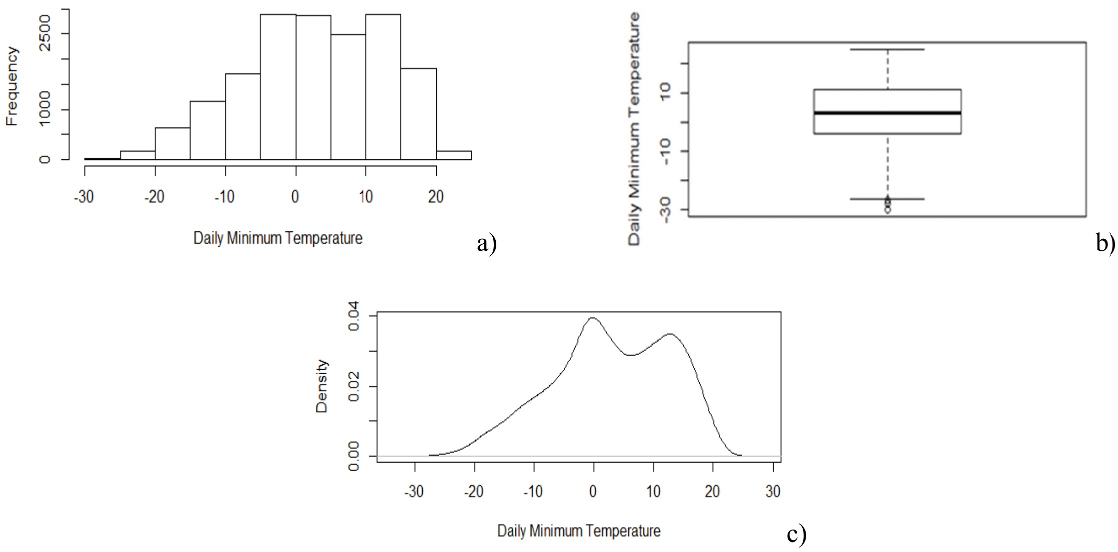

Figure 2. (a) Histogram, (b) box plot and (c) density plot of daily minimum temperature at Hamilton Airport

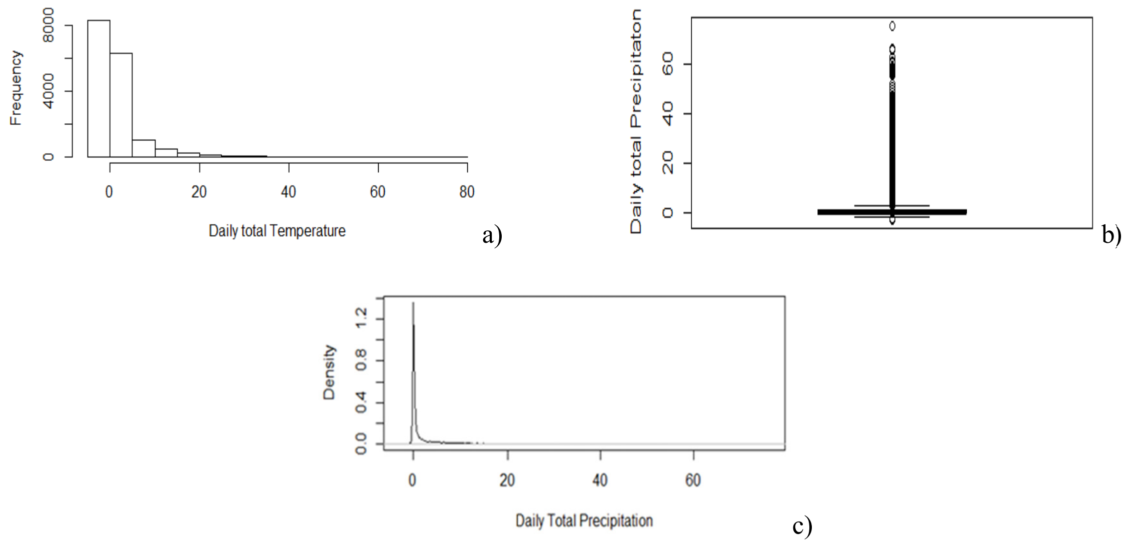

Figure 3. (a) Histogram, (b) box plot and (c) density plot of daily total precipitation at Hamilton Airport

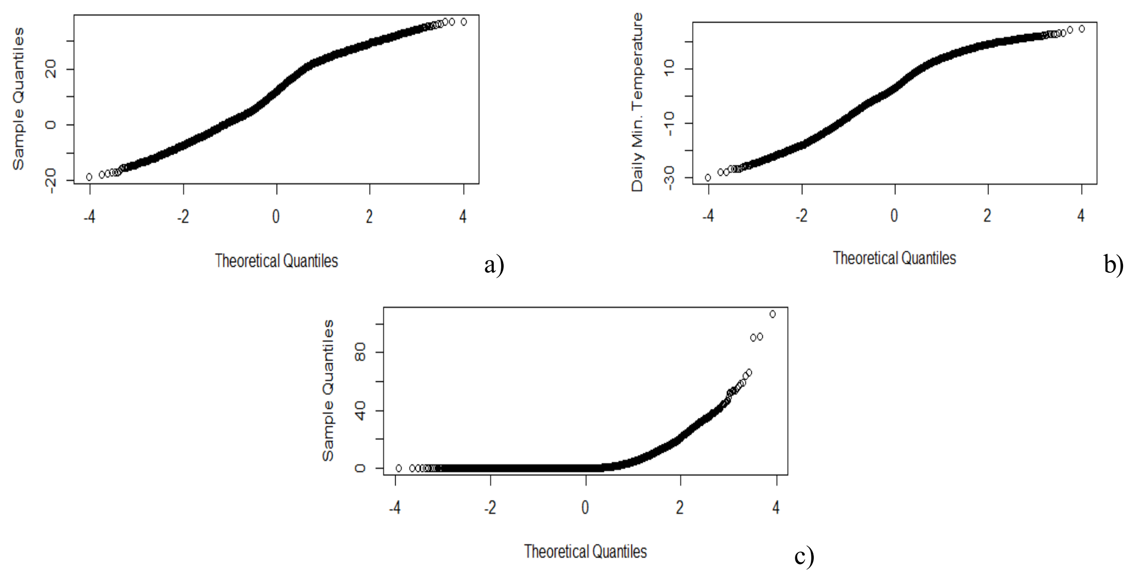

Figure 4. Qq-plot of the predicted (a) Tmax, (b) Tmin, and (c) Ptot at Hamilton airport

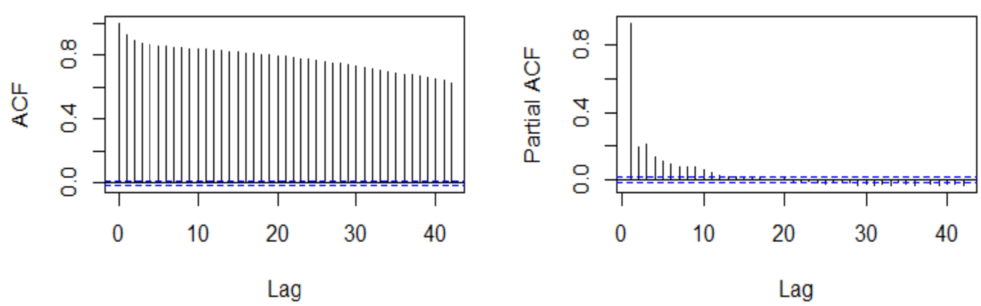

Figure 5. ACF and PACF of the observed Tmax at the Hamilton airport

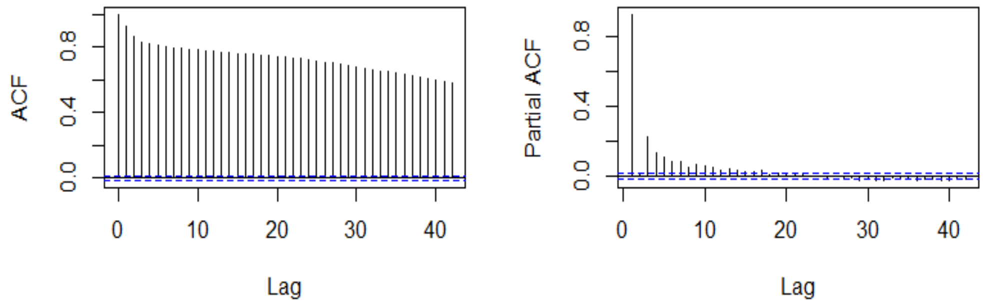

Figure 6. ACF and PACF of the observed Tmin at the Hamilton airport

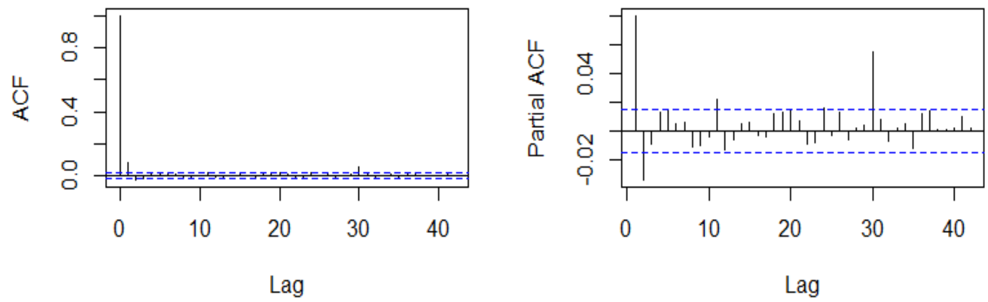

Figure 7. ACF and PACF of the observed Ptot at the Hamilton airport

The first order Markov model [AR(1) model], shown in Equation 4, would be the best model to generate the 21 years (1985-2005) of data for the Tmax, Tmin and Ptot at the Hamilton airport. Using the values of sample statistics for the Tmax, Tmin and Ptot, Equations 5-7 represent the AR(1) models for the Tmax, Tmin and Ptot at the Hamilton airport. The predicted Tmax, Tmin and Ptot at the Hamilton airport were generated for the years of 1985 to 2005. The observed vs. predicted values of Tmax, Tmin and Ptot at Hamilton airport for the years of 1985 to 2005 are shown in Figure 8.

$$X_t = \mu_x + \rho_x(1)\ (x_{t-1} - \mu_x) + t_t\ \alpha_x\ [1 - \rho^2_x(1)]^{0.5} \tag{4}$$

Where: μx, σx, ρx(1) are determined by corresponding sample statistics, and t_t is chosen randomly from a N(0,1) distribution

$$(X_t)_{Tmax} = 11.5889 + 0.929\ (x_{t-1} - 11.5889) + t_t\ 10.3456\ [1 - (0.929)^2]^{0.5} \tag{5}$$

$$(X_t)_{Tmin} = 2.78014 + 0.928\ (x_{t-1} - 2.78014) + t_t\ 10.1026\ [1 - (0.928)^2]^{0.5} \tag{6}$$

$$(X_t)_{Ptot} = 2.15827 + 0.080\ (x_{t-1} - 2.15827) + t_t\ 5.5129\ [1 - (0.929)^2]^{0.5} \tag{7}$$

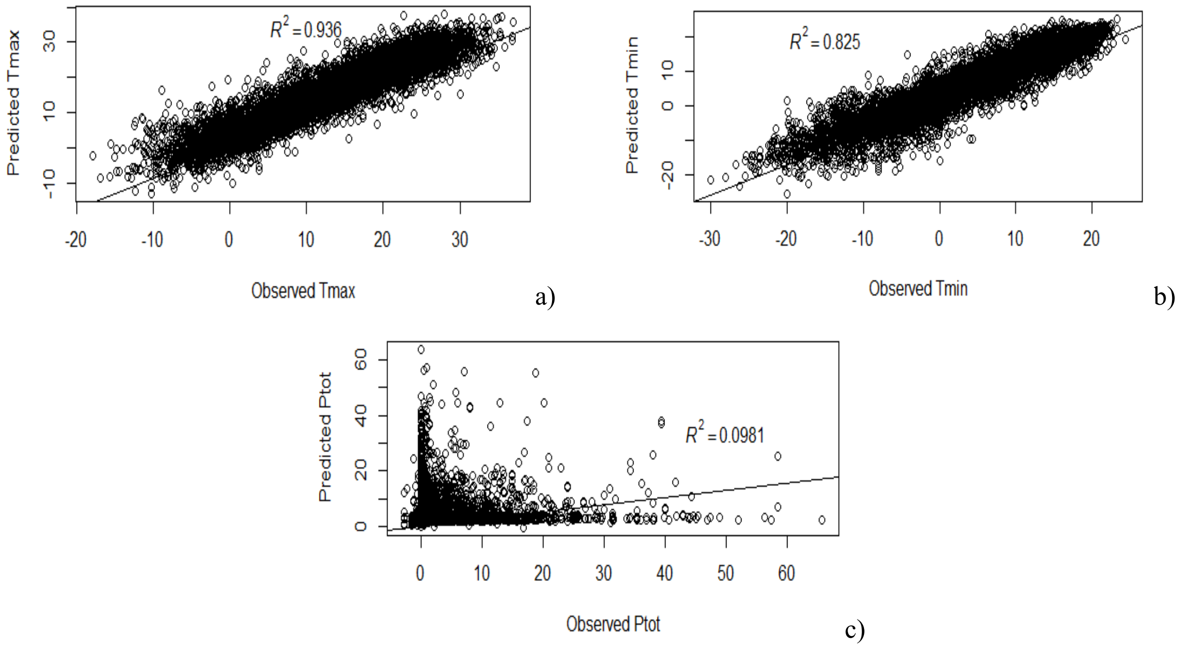

Figure 8. The observed vs. predicted Tmax, Tmin and Ptot at Hamilton airport

As can be shown from Figures 8(a) and 8(b), a good correlation with R^2 values of 0.936 and 0.825 existed between the observed and predicted Tmax and Tmin at the Hamilton airport, respectively. This implied that more than 94% and 83% of the variability of dependent variable (Y) was explained by the models. Additionally, both models produced the least amount of scattered data, which indicated less error in the analytical results. However, the model for predicting Ptot produced a huge amount of scattered data reusting in a little or no correlation with R2 of 0.0981 existed between the observed and predicted Ptot at the Hamilton airport, as shown in Figure 8(c).

Figure 9 show the residual plots of the Tmax, Tmin and Ptot at the Hamilton airport. As can be shown in Figures 9(a) and Figure 9(b), there is a lack of any trends for the Tmax and Tmin at the Hamilton airport and the data are presented around the zero line. This indicated that the models are valid for predicting the Tmax and Tmin at the Hamilton airport. Since the majority of the data lies below the zero line, it can be added that the model could overestimate the results of Tmax and Tmin. In the case of the Ptot, Figure 9(c) demonstrated that the residuals did not follow any trend, and they were not presented around the zero line, rather they stayed below the zero line. That indicated that the AR(1) model generated the overestimation of the daily total precipitation as compared to that recorded at the Hamilton airport. The residual plots of AR(1) model for the Tmax, Tmin and Ptot for the years of 1985 to 2005 at the Hamilton airport was shown in Figure 10. The findings obtained from Figure 10 were shown to identical with those illustrated by Figure 9(c).

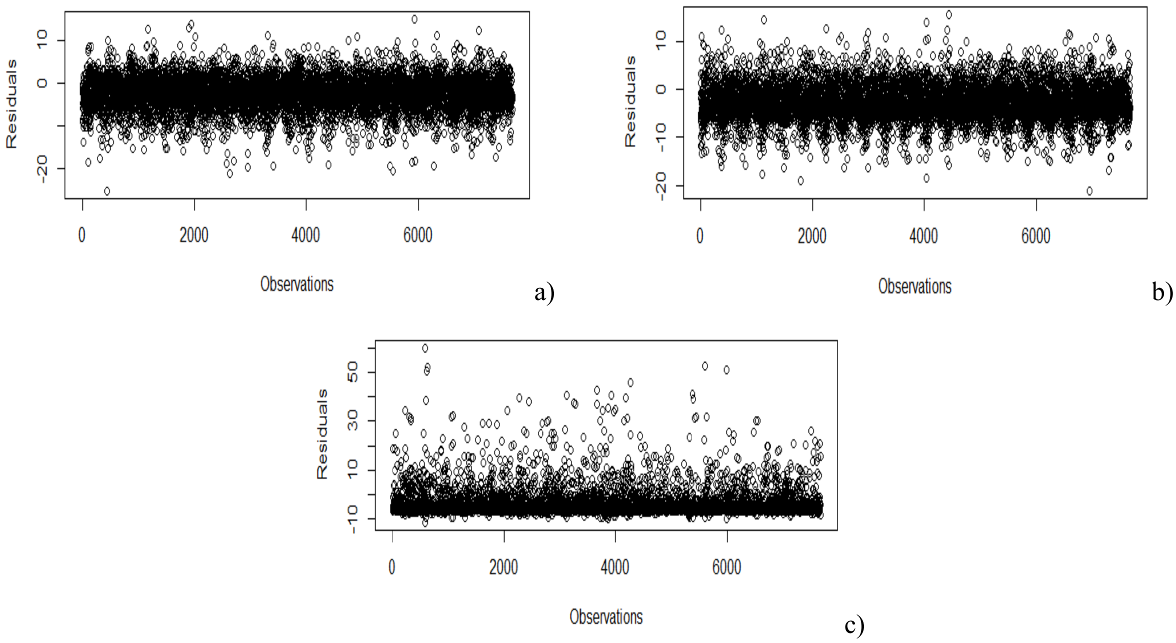

Figure 9. Residual plot of Tmax, Tmin, and Ptot (observations vs. residuals) from 1985 to 2005

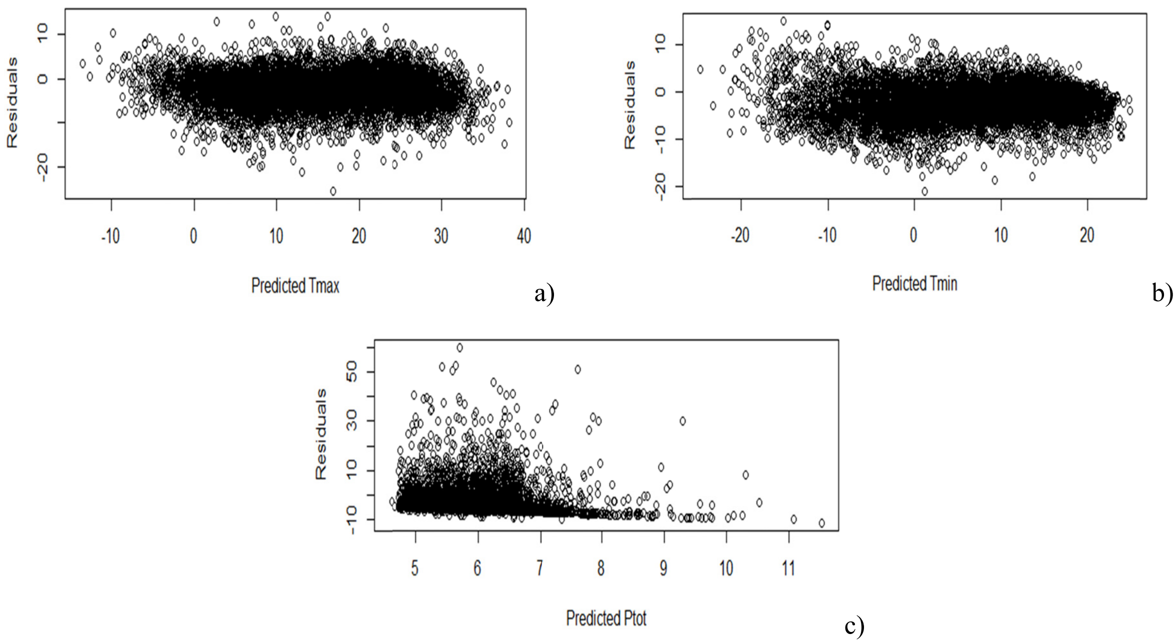

Figure 10. Residual plots of AR(1) model for (a) Tmax, (b) Tmin and (c) Ptot from 1985 to 2005

The performance statistics (correlation coefficient, RMSE and NASH model index) of AR(1) model for the Tmax, Tmin and Ptot at the Hamilton airport is documented in Table 5. As can be shown, the correlation statistics of Tmax and Tmin was greater than 92%, whereas that of for the Ptot was very low (less than 5%). Additionally, the NASH model index for the both Tmax and Tmin (= 0.80) was much greater than that of the Ptot (=0). These illustrates the findings of the AR(1) model was best suited in generating the Tmax and Tmin data at the Hamilton airport, whereas it was nearly unable to predict the Ptot. It can also be added that the model was slightly better for generating the Tmin than for predicting the Tmax at the Hamilton airport.

The graphical plots of the Tmax, Tmin and Ptot over the 1985 and those of for the years of 1985 to 2005 at the Hamilton airport are shown in Figures 11 and 12, respectively. As it can be shown from Figures 11(a) and (b), and Figures 12(a) and (b), the model performance was very good in generating the Tmax and Tmin values at theHamilton airport, respectively. Conversely, it was very poor in predicting Ptot at Hamilton airport (Figure 11(c) and Figure 12(c)). The AR(1) model slightly overestimated the Tmax and Tmin, whereas the model generated the out of range data for the Ptot at the Hamilton airport.

Table 5. Performance statistics of AR(1) mode l

Models	RMSE	Correlation Coefficient	NASH model index
Tmax	4.5808	0.927	0.8078
Tmin	4.5202	0.925	0.8022
Ptot	6.5699	0.048	-0.0033

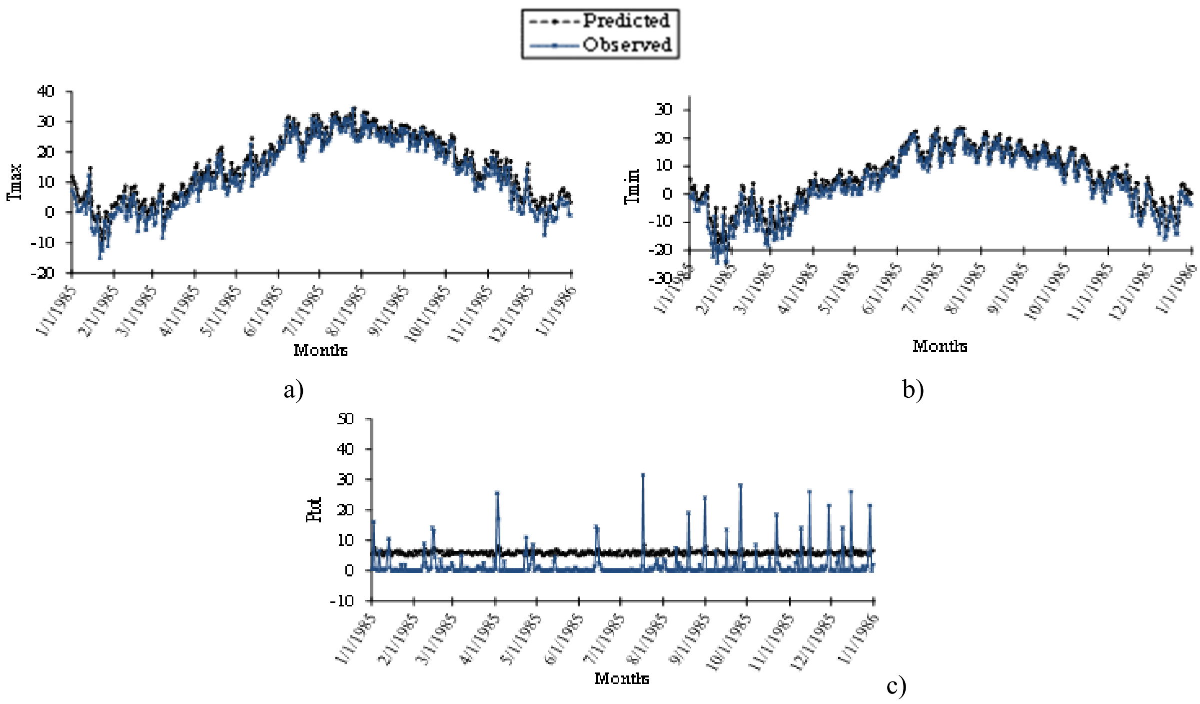

Figure 11. Graphical plot of the observed and predicted (a) Tmax, (b) Tmin and (c) Ptot for year 1985

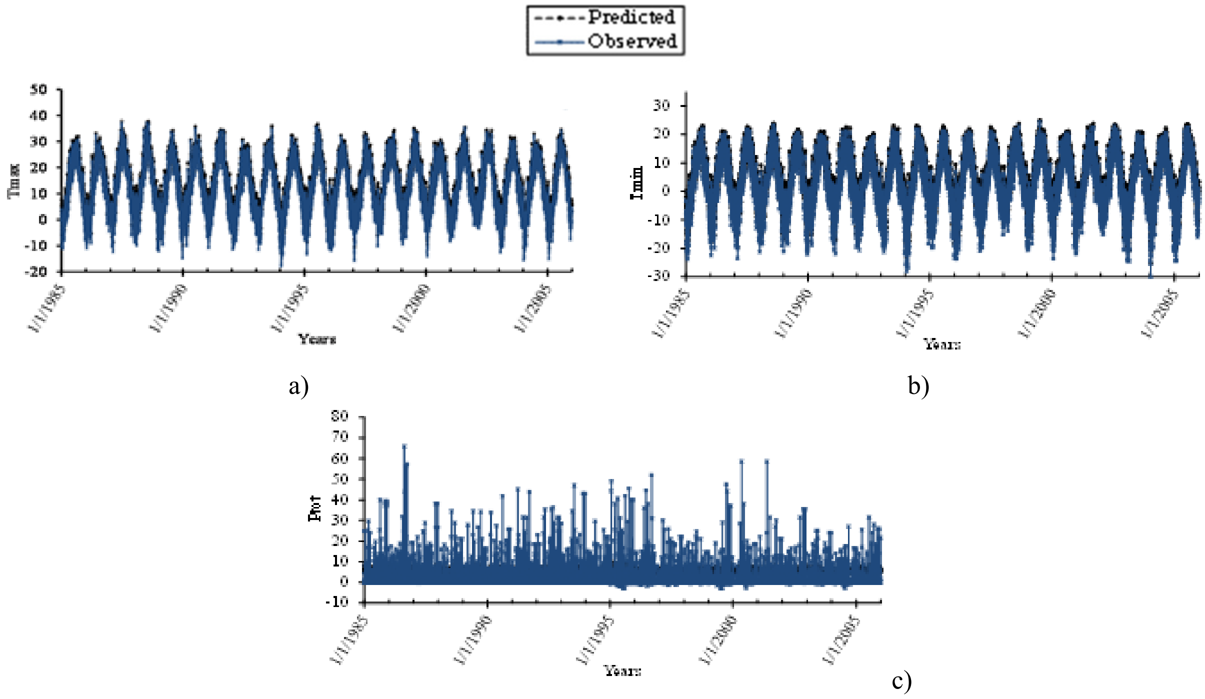

Figure 12. Graphical plot of the observed and predicted (a) Tmax, (b) Tmin and (c) Ptot versus years (1985 to 2005)

4.4 The Change in the Climatologically Data

Figure 13 presented the variation in the yearly averaged Tmax, Tmin and Ptot over 10-year period. As can be shown, the 10-year averaged of the Tmax and Tmin at the Hamilton airport increased gradually over time, and they raised by 0.80°C and 0.66°C from 1960 to 2005, respectively. On the other hand, the 10-year averaged Ptot over time did not show any pattern. The results showed that the long-term trends were more apparent when temperatures were averaged over a 10-year period instead of one year period.

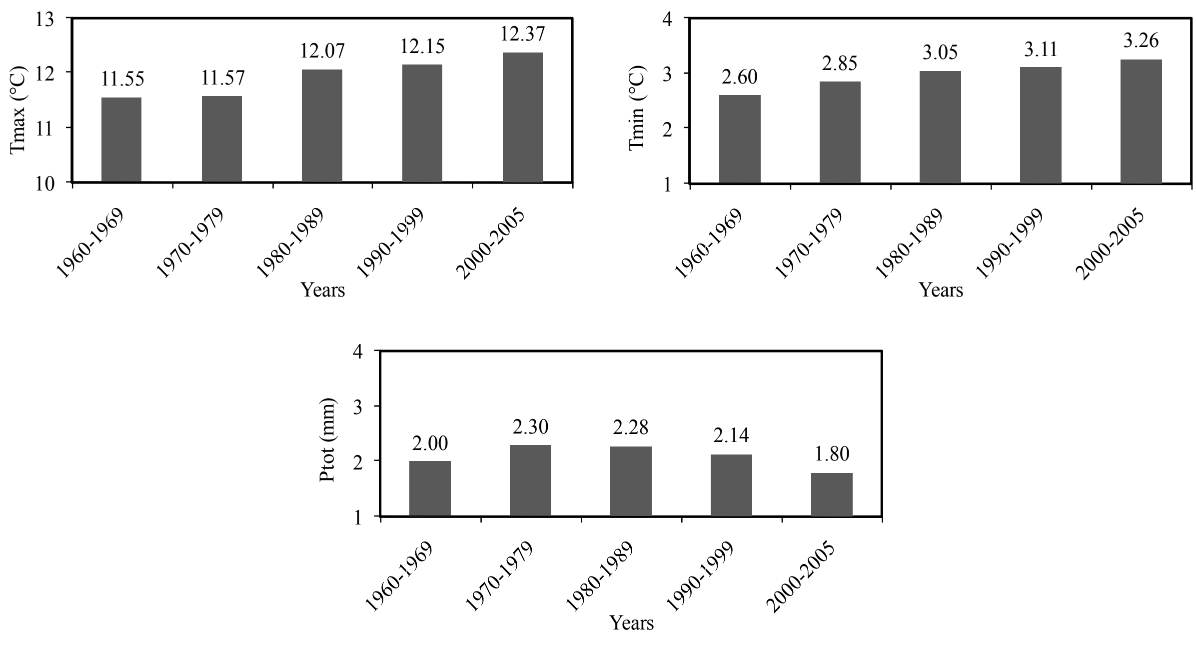

Figure 13. Tmax, Tmin and Ptot for the averaged over 10-year period

5. Conclusions

The results of the study showed that daily maximum temperature (Tmax) and daily minimum temperature (Tmin) at the Hamilton Airport can accurately be predicted from the values obtained at the nearly city (Toronto), whereas the daily precipitation at the Hamilton airport cannot accurately determined from the observed Ptot at the nearly city. Time series of auto correlation having AR(1) model is the best candidate to represent the observed data for Tmax, Tmin and Ptot at the Hamilton airport for the years of 1960 to 1985. A good correlation with R^2 values of 0.936 and 0.825 existed between the observed and predicted Tmax and Tmin at the Hamilton airport for the years of 1985 to 2005, respectively, whereas a little or no correlation with R^2 of 0.0981 existed between the observed and predicted Ptot at the Hamilton airport. The residual plots of AR(1) model for the Tmax, Tmin and Ptot from 1985 to 2005 also showed the identical findings. The correlation statistics of Tmax and Tmin was greater than 92%, whereas that of for the Ptot was very low (less than 5%). Additionally, the NASH model index for the both Tmax and Tmin (= 0.80) was much greater than that of the Ptot (=0). These illustrates the findings of the AR(1) model was best suited in generating the Tmax and Tmin data at the Hamilton airport, whereas it was nearly unable to predict the Ptot. The 10-year averaged of the Tmax and Tmin at the Hamilton airport increased gradually over time, and they raised by 0.80°C and 0.66°C from 1960 to 2005, respectively. On the other hand, the 10-year averaged Ptot over time did not show any pattern.

Acknowledgments

The author would like to thank Professor P. Coulibaly in the Department of Civil Engineering at the McMaster University for providing the data. This study was conducted with the collaboration of RIN-BD.

References

Ahrens, C. D. (2011). *Essentials of Meteorology: An invitation to the atmosphere* (6th ed.). Cengagee, USA.

Box, G. E. P., Jenkins, G. M., & Reinsel, G. C. (2008). *Time Series Analysis: Forecasting and Control* (4th ed.). Wiley, USA. http://dx.doi.org/10.1002/9781118619193

Cazenave, A., & Llovel, W. (2010). Contemporary sea level rise. *Annual Review of Marine Science, 2*, 145-173. http://dx.doi.org/10.1146/annurev-marine-120308-081105

Church, J. A., & White, N. J. (2011). Sea-level rise from the late 19th to early 21st century. *Surveys in Geophysics, 32*, 585-602. http://dx.doi.org/10.1007/s10712-011-9119-1

Cryer, J. D., & Chan, K. S. (2008). *Time Series Analysis with Applications in R* (2nd ed.). Springer, New York, USA. http://dx.doi.org/10.1007/978-0-387-75959-3

CSIRO. (2010). *State of the Climate*. Australian Government Bereau of Meteorology. Retrieved March 13, 2014, from http://www.bom.gov.au/climate

Duchon, C., & Hale, R. (2012). *Time Series Analysis in Meteorology and Climatology: An Introduction (Advancing Weather and Climate Science)*. Wiley-Blackwell, USA. http://dx.doi.org/10.1002/9781119953104

EPA (Environmental Protection Agency). (2014). *Causes of Climate Change.* Retrieved March 14, 2014, from http://www.epa.gov/climatechange/science/causes.html

Ghafoori, N., & Islam, M. S. (2013). Time series analysis for the prediction of ASR-Induced expansions. *Journal of Building and Construction Materials, 49*, 194-200. http://dx.doi.org/10.1016/j.conbuildmat.2013.08.015

Gore, A. (2007). *An Incovenient Truth: the Crisis of Global Warming* (1st ed.). Viking, New York, USA.

Gore, A. (2014). Drastic climate change, *Climate Training Conference*. Johannesburg, SA. Retrieved March 15, 2014, from http://mg.co.za/article/2014-03-13-climate-change-making-everything-more-extreme

Hansen, J. E. (2007). Scientific reticence and sea level rise. *Environmental Research Letters, 2*(2). http://dx.doi.org/10.1088/1748-9326/2/2/024002

Hansen, J., Ruedy, R., Sato, M., & Lo, K. (2010). Global surface temperature change. *Reviews of Geophysics, 48.* http://dx.doi.org/10.1029/2010RG000345

Hengeveld, H., Whitewood, B., & Fergusson, A. (2005). An Introduction to Climate Change: A Canadian Perspective, *Environment Canada*, Minister of Public Works and Government Services, Canada. Retrieved March 10, 2014, from http://www.msc.ec.gc.ca/education/scienceofclimatechange

Hile, K. (2009). *The handy Weather answer book* (2nd ed.). Visible Ink, Canton, USA.

IPCC (Inter-governmental Panel on Climate Change). (2013). *Canada at greater risk from climate change.*

Retrieved March 8, 2014, from http://www.thestar.com/news/world/2013/09/30/great_lakes_climate_expected_to_warm_more_than_global_rise_says_un_report.html

Kegley, C. W., & Raymond, G. A. (2012). *The global future: a brief introduction to world politics* (1st ed.). Wadsworth, Boston, USA.

Khan, B. H. (2009). *Non-Conventional Energy Resources* (1st ed.). Tata MaGraw-Hill, New Delhi, India.

Letcher, T. (2009). *Climate Change: Observed Impacts on Planet Earth* (1st ed.). Elsevier publishing, Netherlands.

Levitus, S., Antonov, J. I., Boyer, T. P., Locarnini, R. A., Garcia, H. E., & Mishonov, A. V. (2009). Global ocean heat content 1955–2008 in light of recently revealed instrumentation problems. *Geophysical Research Letters, 36.* http://dx.doi.org/10.1029/2008GL037155

Marsa, L. (2013). *Fevered: Why a hotter planet will hurt our health- and how can we save ourselves* (1st ed.). Rodale, Los Angeles, USA.

Moomaw, W. R. (2002). *Global Warming, Climate Change and Sustainability,* Tufts University, USA, Retrieved March 8, 2014, from http://ecoethics.net/hsev/2001-2002/200111-Nov/Moomaw-2002.pdf

NRC (National Research Council). (2010). Advancing the Science of Climate Change. *National Research Council*. The National Academies Press, Washington, DC, USA.

NRDC (Natural Resources Defense Council). (2014). *The Consequences of Global Warming on Glaciers and Sea Levels*. Retrieved March 15, 2014, from http://www.nrdc.org/globalwarming/fcons/fcons4.asp

USGCRP. (2009). *Global Climate Change Impacts in the United States.* In T. R. Karl, J. M. Melillo, & T. C. Peterson (Eds.), *United States Global Change Research Program*. Cambridge University Press, New York, NY, USA.

Young, P. C. (2011). *Recursive Estimation and Time-Series Analysis* (2nd ed.), Springer-Verlag, London, UK. http://dx.doi.org/10.1007/978-3-642-21981-8