Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi
Iğdır University Journal of the Institute of Science and Technology

Trend and Frequency Analyses of Rainfall in North West Geopolitical Zone of Nigeria

Abubakar Ismail[2], Isaiah Adesola OKE[1]

ABSTRACT: The major occupation of people in the North-west geopolitical zone of Nigeria is farming, which depends on rainfall and other factors. It is well known that climate change has been contributing to change in amount of rainfall worldwide. In this paper the existence of trend and rainfall frequency analyses were conducted on rainfall data in North-west geopolitical zone of Nigeria with a particular attention to yearly total rainfalls using Mann- Kendall and Sen's slope techniques as well as Pearson log type III distribution. Rainfall data from 1905 – 2008 were collected from five locations in the region and the test were conducted using standard methods stated in literature. The study revealed that there are trends in the rainfall in the region and Sen's test revealed that the trends are significant at 99 % confidence level. Sen's slopes revealed that there are downward trends in the rainfall for the last 30 years in all the five locations. The slopes are -0.94, -6.91; -0.94; -0.84 and -5.66 mm/year for Sokoto, Kano, Kebbi, Kaduna and Katsina respectively. Rainfall frequency analyses for 2 years return period for these locations (Sokoto, Kano, Kebbi, Kaduna and Katsina) are 651.08 mm; 844.42 mm 735.68 mm, 1168.47 mm and 669.52 mm respectively. It was concluded that there are downward trends in the rainfall in last 3 decades for all the locations.

Keywords: Hydrological data, Rainfall, Sen's estimator, Trend analysis, Non-parametric tests

Nijerya'nın Kuzeybatı Jeopolitik Bölgesine Düşen Yağış Miktarlarının Eğilim ve Frekans Analizi

ÖZET: Nijerya'nın kuzeybatı jeopolitik bölgesinde yaşayan insanların büyük çoğunluğu yağış miktarı ve diğer faktörlere bağlı olarak tarımla iştigal ederler. İklim değişikliğinin dünya çapında yağıştaki miktar değişimine katkı sağladığı bilinmektedir. Bu çalışmada mevcut olan yağış frekans ve eğilim analizlerinde Pearson log tip III dağılımı hem de Mann-Kendall ve Sen'in eğim teknikleri kullanılarak yıllık yağış miktarlarının toplamlarına dikkatle Nilerya'nın kuzeybatı jeopolitik bölgesindeki yağışlar üzerine odaklanılmıştır. 1905-2008 yılları arasındaki yağış bilgileri bölgedeki beş yerden toplanmış ve literatürde verilen standart metotlarla test edilmiştir. Çalışma, bölgedeki yağışlarda eğilimler olduğu, bu eğilimlerin Sen'in testlerine göre % 99 oranında önemli seviyeye sahip olduğunu ortaya çıkarmıştır. Sen'in eğimleri tüm yerleşim yerlerinde son 30 yılda aşağı doğru eğilimlerin var olduğunu açığa çıkarmıştır. Eğimler Sokoto, Kano, Kebbi, Kaduna ve Katsina için sırasıyla -0.94, -6.91; -0.94; -0.84 ve -5.66 mm/yıl şeklindedir. Yağış frekans analizi bu yerleşim yerlerinde 2 yıllık geriye dönük periyotlar için 651.08 mm; 844.42 mm 735.68 mm, 1168.47 mm ve 669.52 mm (Sokoto, Kano, Kebbi, Kaduna ve Katsina) sırasıyla ölçülmüştür. Tüm yerleşim birimlerinde son 30 yılda yağışta azalma eğilimi olduğu tespit edilmiştir.

Anahtar kelimeler: Hydrolik veriler, yağış, trend analizi, parametrik olmayan testler

Cilt: 4, Sayı: 2, Sayfa: 65-77, 2014
Volume: 4, Issue: 2, pp: 65-77, 2014

1 Obafemi Awolowo University, Ile-Ife, Engineering, Civil Engineering, Ile-Ife, Nijerya
2 Ahmadu Bello University, Zaria, Engineering, Water Resources and Environmental Engineering, Zaria, Nijerya
Sorumlu yazar/Corresponding Author: Isaiah Adesola OKE, okeia@oauife.edu.ng

Geliş tarihi / *Received:* 10.04.2013
Kabul tarihi / *Accepted:* 17.09.2013

INTRODUCTION

Part of Nigeria is located in African Sahel. The Sahel is characterized by strong climatic variations and an irregular rainfall (Nwafor 2007; Umoh 2007). It was reported that rainfall decrease of 29-49% has been observed in the 1968-1997 period compared to the 1931-1960 baseline period within the Sahel region (Odjugo, 2005). The West Africa region has experienced a marked decline in rainfall from 15 to 30% depending on the area (Nkomo et al., 2006). The pattern of rainfall in northern Nigeria (North West geopolitical zone inclusive, Figure 1) is highly variable in spatial and temporal dimensions with inter-annual variability of between 15 % and 20% (Abaje et al., 2010). As a result of the large inter-annual variability of rainfall, it often results in climate hazards, especially floods and severe and widespread droughts with their devastating effects on food production and associated calamities and sufferings.

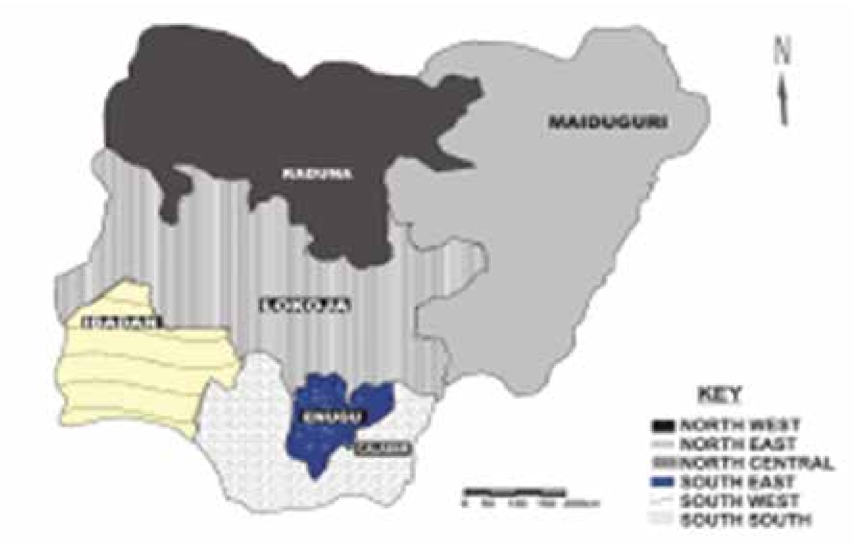

Figure 1(a). Map of Nigeria showing the six geopolitical zones

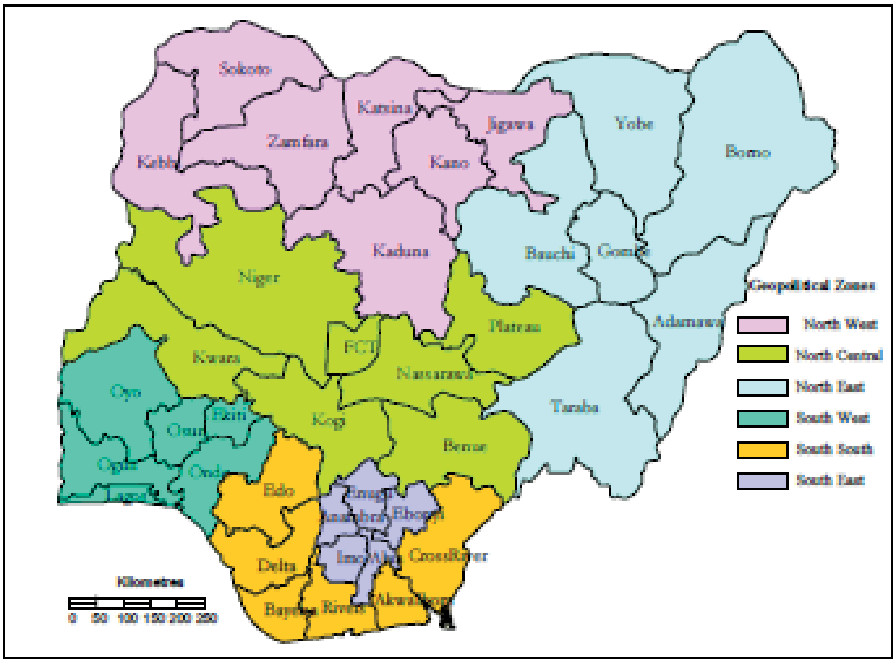

Figure 1(b). Map of Nigeria showing all the states and six geopolitical zones

Crops and animals derived their water resources largely from rainfall. It is considered as the main determinant of the types of crops that can be grown in the area and also the period of cultivation of such crops and the farming systems that can be practiced. The climate is semiarid with a zone of savannah-type vegetation as part of the sub-Saharan Sudan belt of West Africa. These show that a detailed knowledge of rainfall regime is an important prerequisite for agricultural planning. The effects of climatic change and variability have been analysed by many researchers in a variety of geophysical fields. Most previous studies concerning climatologic trends using non-parametric test are Hirsch et al.,(1982), Van Belle and Hughes (1984); Kahya et al. (1998) for water quality variables; Kalayci and Kahya (2004) for streamflow; Zhang et al. (2000) for precipitation; and Cengiz et al. (2003) for lake levels. From these and other studies, a range of potential climatic impacts on the hydrologic regime for various geographic areas can be hypothesized. Correlations between hydrologic variables and meteorological variables were evaluated by Burn and Hag Elnur (2002), which documented similarities in trends and hydrologic patterns in two different variables at selected locations. The study utilized only the Mann–Kendall test to detect trends for 18 hydrologic variables that reflect different parts of the hydrologic cycle from a network of 248 Canadian streamflow catchments.

Previous studies that used Kendall's test to identify hydroclimatologic trends and possible climatic variations include: Van Belle and Hughes (1984) described two classes of procedures in detail; intrablock methods (procedures that compute a statistic, such as Kendall's τ, for each block or season and then sum these to produce a single overall statistic) and aligned ranks method (procedures that first remove the block effect from each datum, second sum the data over blocks, and finally produce a statistic from these sums (Partal and Kahya, 2006). Van Belle and Hughes (1984) found that aligned rank methods are asymptotically more powerful than intrablock methods; however, intrablock methods are more adaptable. Lettenmaier et al. (1994) looked for evidences of long-term trends in precipitation, mean temperature, temperature range, and streamflow over the continental USA by adopting the Mann–Kendall test. Lettenmaier et al. (1994) tried to investigate seasonal and spatial characteristics of climatic variables using large data sets of 1009 streamflow stations and 1036 stations, a subset of the Historical Climatologic Network throughout the continental USA. In the study, increase in precipitation during autumn was found in a quarter of the entire stations, mostly located in the central part of the USA. Yue and Hashino (2003) studied long term trends in Japanese annual and monthly precipitation and generally found significant negative trends. Zhang et al. (2000) analysed precipitation totals and ratios of snowfall to total precipitation in Canada during the 20th century and pointed out a prevailing wetter pattern in Canadian climate. The study emphasised significant increasing trends in annual precipitation totals and decreasing trends in winter precipitation. As a follow-up study, Zhang et al. (2001) searched trends in 11 hydrometric variables in Canadian catchments by applying a method proposed by Von Storch and Navarra (1995) to eliminate the effects of serial correlation prior to performing the Mann–Kendall test. It was noted, in general, decreasing streamflow trend characteristics. Hirsch and Slack (1984) propose an extension of the Mann–Kendall test for trend (especially robust against serial correlation effects). It was highlighted that when there is no serial correlation, this test is less powerful than a related simpler test that is not robust against serial correlation.

Lins and Slack (1999) evaluated 395 streamflow records in the USA for the presence of trends in selected quantiles of discharge. The study made a general statement to the effect that the USA streamflow climatology is getting wetter but having less extreme events. When it comes to reviewing germane studies in Turkey, a limited number appear to be available. For streamflow variables, Kahya and Kalayci (2004) identified the regions of western and southeastern Turkey as an area of significant decreasing trends. These streamflow trends were said to be all season-wise homogeneous; at the same time, some of those were noted to be homogeneous station-wise as well. Cıgızoglu et al. (2003) investigated trend existences in maximum, mean and low flows in Turkish rivers using daily mean values for nearly 100 stations. The study detected trends in the majority of rivers located in western and southern Turkey, as well as in some parts of central and eastern Turkey. The number of trends in the mean and low flow data was larger than that of maximum flow data. Türkeş et al. (1995) applied four statistical tests to the annual mean temperature series over Turkey and concluded that these series were generally dominated by a cooling tendency in the last two decades. Kadıŏglu (1997) used the seasonal Kendall test to detect temperature trends across Turkey and observed that there was a tendency for a warming trend over the period 1939–89, in contrast to a tendency for a cooling trend lasting from 1955 to 1989 (Partal and Kahya, 2006). Karaca et al.

(1995) applied the Mann–Kendall test and the method of linear regression to the monthly mean temperatures to detect the urban heat-island effects in Istanbul. The study found positive trends for southern stations and negative trends for northern stations in Istanbul. Toros (1993) examined seasonal and annual rainfall data of the western part of Anatolia using 68 stations for the period 1930–92, finding a decrease in rainfall after 1982 and concluding that this decrease did not result from climatic change, but rather was only due to rainfall fluctuations. Türkeş (1996) analysed the spatial and temporal characteristics of Turkish annual mean rainfall data for long-term trends, for fluctuations and changes in runs of dry and wet years, and rainfall-regime regions at 91 stations with a recording length ranging from 54 to 64 years. Annual rainfall series of 17 stations exhibited a significant trend in the mean, and the majority of trends had a downward direction (Partal and Kahya, 2006). Previous studies in Nigeria involves karfanchan (Abaje et al., 2010), Port Harcourt , Sokoto and other locations across Nigeria. The trend-related studies concerning Nigeria have not show trend in Kano and other parts of Northwest of Nigeria. The purpose of this study is to characterize trend of total amount of rainfall in North West geopolitical zone of Nigeria (Figure 1) with a particular attention to rainfall trend and rainfall frequency analyses.

MATERIALS AND METHOD

Information on rainfall (1905 to 2008) in selected locations (Kano, Sokoto, Birnin Kebbi, Katsina and Kaduna) in North West geopolitical zone of Nigeria were collected from literature such as Akintola (1986), institutions, local government headquarters, state and Federal government archives (Ministry of Water Resources; Nigerian Meteorological Agency (NIMET) Abuja; etc). The data were analysed using standard methods with a particular attention to yearly total, mean and maximum rainfalls. Non- parametric tests were conducted using Mann- Kendall and Sen's slope techniques and rainfall frequency analyses were conducted using log-Pearson type III method. Figure 2 presents the procedure and steps of the methodology used. Estimates of the recurrence interval (T) were obtained using the Cunane plotting position formula for Log Pearson Type III distribution as follows:

$$T = \frac{N + 0.2}{R_i - 0.4} \quad (1)$$

Where; N is the number of years of record and R_i is the rank obtained by arranging the annual flood series in descending order of magnitude with the maximum being assigned the rank of 1.

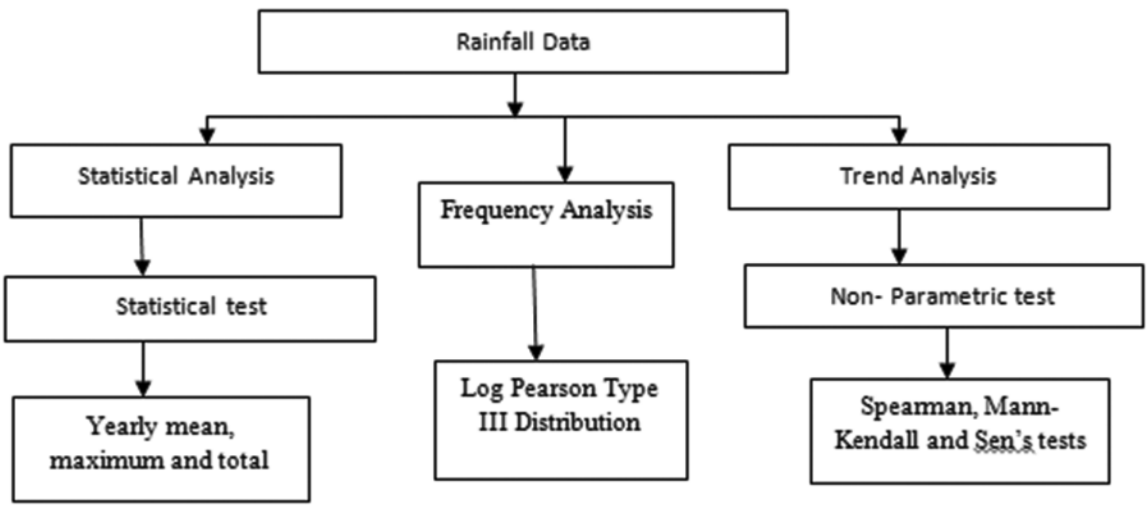

Figure 2. Procedures of analysis methodology used in this study

RESULT AND DISCUSSION

Result of this study is discussed in the following categories: statistical parameters for the rainfall from the five locations, trend analysis of the rainfall from these locations and log-Pearson type III method.

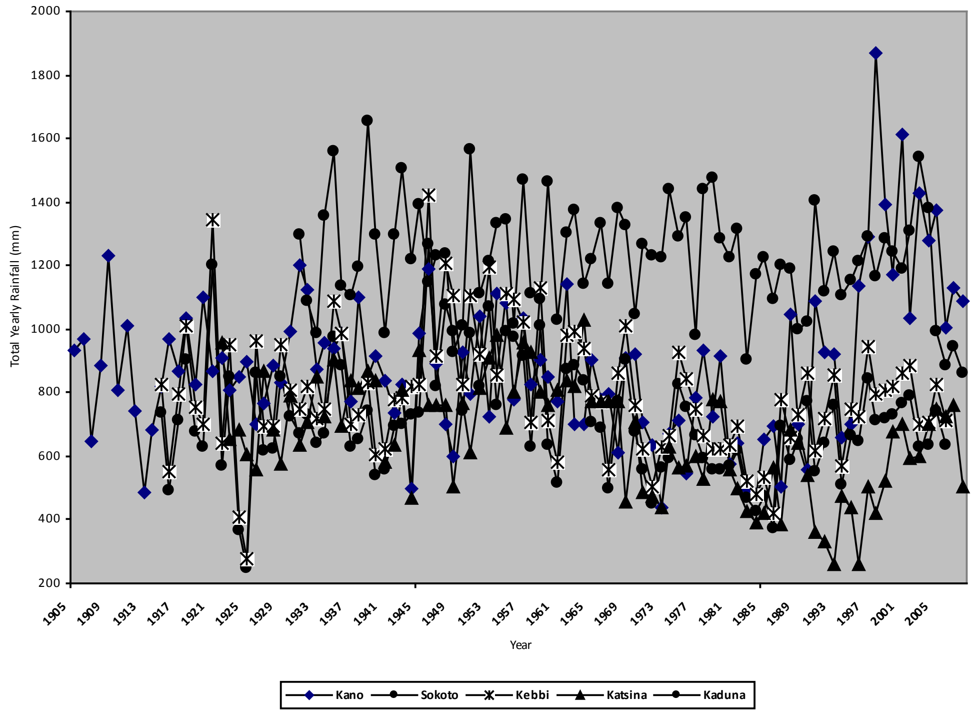

Figure 3(a). Annual rainfall of the selected locations.

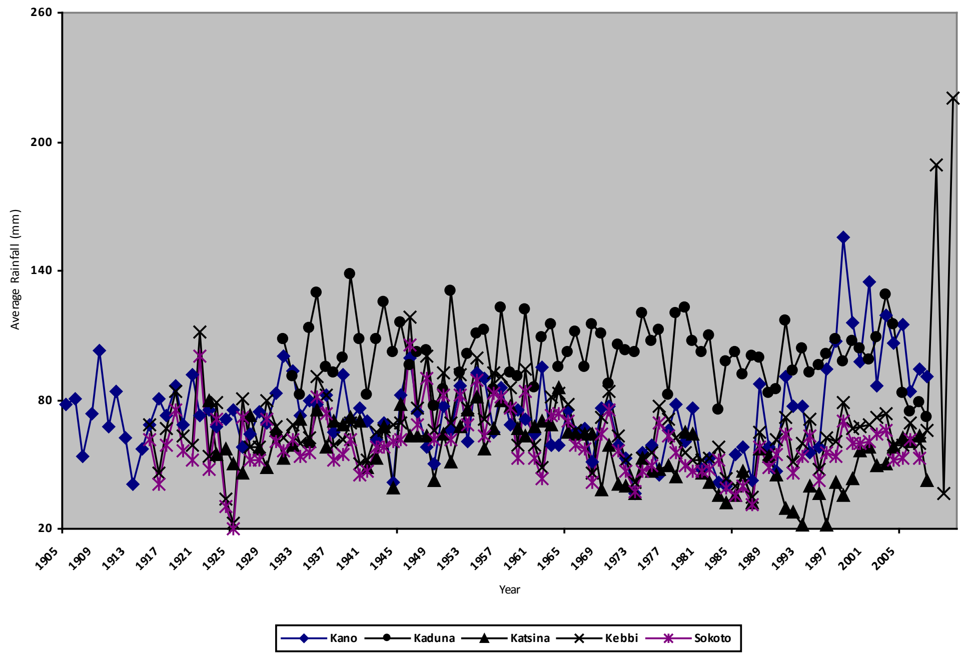

Figure 3(b). Average rainfall of the selected locations.

Statistical parameters for the rainfall from the five locations: Figure 3 shows yearly total and mean rainfall from these locations. Table 1 presents monthly mean, total and maximum rainfall from these selected locations. Figure 3(a and b) presents time series of the rainfall in the five locations. Table 1 shows statistical data on the rainfall from these selected locations. These data presented in these figure and table are useful in the water resource and water management. The data provide variation in the rainfall and specific parameters of the rainfall. In addition, these information are useful for planning and budgeting in agriculture sector (beginning and end of rainfall in the region, range of rainfall, monthly rainfall expected and well as average yearly rainfall). It can be seen clearly from the figure and the table that rainfall is a function of many factors such as location, longitude, latitude, elevation etc.

Figure 1 provides location of these locations on the map of Nigeria. From this figure Sokoto (latitude 12.68^0N; longitude 5.31^0E and 272 m above sea level) is above Kebbi (latitude 12.69^0N; longitude 4.26^0E and 261 m above sea level) and the average annual rainfall increased from 556 mm per year to 582 mm per year, which indicates that rainfall drops with increasing latitude toward the North of equator. Also, Katsina (latitude 13.03^0N; longitude 8.13^0E and 461 m above sea level) and Kano (latitude 11.66^0N; longitude 9.18^0E and 449 m above sea level) are very close to each other, but rainfall dropped from 642 mm per year in Kano to 619 mm per year in Katsina, which indicates that rainfall drops with longitude towards the eastern part of Greenwich Meridian. Kaduna (latitude 10.62^0N; longitude 8.48^0E and 755 m above sea level) is below other locations but has the highest average annual rainfall, which indicates that rainfall increases with reduction in latitude toward equator from the North. These agree with literature such as Ismail and Oke (2012) which provides a statistical model that relates average annual rainfall to these three factors (longitude, latitude and elevation).

Trend analysis of the rainfall from these locations: The Spearman rank-correlation coefficient is described as follows (Loveday, 1980; Antonopoulos et al., 2001):

$$R_{sp} = 1 - \frac{6\sum_{i=1}^{n} D_i^2}{n_c\left(n_c^2 - 1\right)} \tag{2}$$

Where; n_c is the total number of values in each time series, D is the difference in the rank and i is the chronological order number. The difference between rankings is computed as $D_i = R_{xi} - R_{yi}$, where: R_{xi} is the rank of a measured variable in chronological order and R_{yi} is the series of measurements transformed to its rank equivalent, by assigning the chronological order number of a measurement in the original series to the corresponding order number in the ranked series, y. The null hypothesis, $H_0:R_{sp} = 0$ (there is no trend), against the alternate hypothesis, $H_1:R_{sp} < \text{or} > 0$ (there is a trend), is checked with the test statistic(Antonopoulos et al., 2001):

$$t_t = R_{sp}\left[\frac{n-2}{1-R_{sp}^2}\right]^{0.5} \tag{3}$$

Where; t_t has Student's t-distribution, with ν = n-2 degrees of freedom. The study revealed that there are trends in the rainfall in the region (Table 2). The values of Spearman rank correlation coefficient range from 0.76 to 0.99. The values t_t range from 49.36 to 2656.03 with a critical value of 2.75. These show that there are trends in the rainfall in these selected locations. The trends are also significant (t_c. 2.75) at 99 % confidence level.

Table 2. Trend analysis of the rainfall data at various location

Location	R_{sp}			t_t			Degree of freedom (n_c)	Critical value of t-distribution at 99% confidence level
	Group A	Group B	Group C	Group A	Group B	Group C		
Sokoto	0.89	0.91	0.82	128.30	151.70	71.23	30	2.75
Kebbi	0.89	0.91	0.82	128.30	151.70	71.23	30	2.75
Kano	0.76	0.75	0.83	2656.43	2656.43	2656.43	34	2.72
Kaduna	0.99	0.99	0.98	52.83	49.36	78.01	25	2.79
Katsina	0.92	0.89	0.88	164.08	112.35	110.37	28	2.74

Table 1. Statistical Summary of the rainfall data from all the locations

Location	Statistical parameters/Month	January	February	March	April	May	June	July	August	September	October	November	December
Kano	Mean	0.03	0.23	1.69	13.60	60.79	123.77	224.85	314.90	140.41	13.49	0.05	0.00
	Maximum	1.52	8.10	69.08	187.32	225.80	329.30	604.10	571.80	444.10	117.02	4.31	0.00
	Minimum	0.00	0.00	0.00	0.00	0.50	6.50	32.50	50.50	26.90	0.00	0.00	0.00
	Median	0.00	0.00	0.00	2.03	48.20	112.52	207.15	308.61	120.70	4.57	0.00	0.00
	SD	0.18	1.14	7.90	26.38	46.42	61.77	104.88	101.51	74.34	19.49	0.45	0.00
Sokoto	Mean	0.03	0.06	1.65	13.07	47.80	126.81	174.94	224.04	127.41	25.11	0.09	0.00
	Maximum	3.00	3.00	33.30	105.10	154.43	355.10	361.60	509.50	374.90	114.30	8.90	0.00
	Minimum	0.03	0.06	1.65	0.25	0.50	9.91	56.80	67.20	20.30	0.50	0.09	0.00
	Median	0.00	0.00	0.00	7.30	40.15	122.05	162.35	207.13	115.78	17.54	0.00	0.00
	SD	0.31	0.42	5.85	17.17	37.48	71.40	71.87	91.18	72.17	22.15	0.92	0.00
Kebbi	Mean	0.04	0.07	1.86	9.06	49.97	138.18	194.33	242.24	135.01	16.68	0.11	0.00
	Maximum	3.36	3.36	37.30	117.71	172.96	397.71	404.99	570.64	419.89	128.02	9.97	0.00
	Minimum	0.00	0.00	0.00	0.00	0.00	11.10	63.62	75.26	0.00	0.00	0.00	0.00
	Median	0.00	0.00	0.00	5.15	43.57	135.18	182.45	222.88	128.30	9.07	0.00	0.00
	SD	0.35	0.47	6.56	19.23	41.98	79.97	80.49	102.12	80.83	24.80	1.03	0.00
Kaduna	Mean	0.19	2.24	12.01	53.41	128.28	170.98	221.30	295.05	260.56	74.31	3.00	0.52
	Maximum	14.50	50.80	84.84	232.66	309.88	296.50	406.60	548.80	466.60	255.81	42.10	33.78
	Minimum	0.00	0.00	0.00	0.00	14.51	45.30	67.56	123.44	22.85	2.80	0.00	0.00
	Median	0.00	0.00	2.72	43.81	121.40	175.39	217.55	301.50	265.75	58.34	0.00	0.00
	SD	1.64	8.72	19.44	45.56	58.09	47.27	69.60	83.28	82.28	60.71	8.60	3.90
Katsina	Mean	0.03	0.01	0.46	4.07	43.09	82.01	140.76	214.03	147.20	30.17	1.85	0.13
	Maximum	1.78	0.51	11.20	32.00	158.50	209.30	341.00	425.45	419.10	198.88	59.20	11.70
	Minimum	0.00	0.00	0.00	0.00	0.00	3.40	35.05	66.80	14.73	0.00	0.00	0.00
	Median	0.00	0.00	0.00	0.00	33.60	67.82	136.40	208.03	113.10	10.41	0.00	0.00
	SD	0.21	0.06	1.94	6.86	36.14	44.14	75.87	80.80	98.82	44.23	7.80	1.25

Sen's estimator: It is well known that if a linear trend is present in a time series, then the true slope (change per unit time) can be estimated by using a simple non-parametric procedure developed by Sen (1968). The slope estimates of N pairs of data are first computed as follows (Partal and Kahya, 2006; Drapela and Drapelova, 2011):

$$f(t) = Q(t) + b \tag{4}$$

$$Q_I = \frac{X_j - X_k}{j - k} \tag{5}$$

For

$$Q \begin{cases} \frac{1}{2}\left(Q_{\frac{N}{2}} + Q_{\frac{N+2}{2}}\right) & \text{if } N \text{ is even} \\ Q_{\frac{N+1}{2}} & \text{if } N \text{ is odd} \end{cases} \tag{6}$$

Sen's estimators revealed that there are changes in yearly total rainfalls (Table 3) for the year 1905 - 1939; increased by 5.37 mm/year for the year 1940 - 1974; dropped by 6.91 mm/year for the year 1975 - 2008 with overall drop of 1.76 mm/year for the year 1905 - 2008.

Table 3. Trend analysis of the rainfall data at various location

Location	Sen's slope (mm/year)			S			Variance	Z Values		
	Group A	Group B	Group C	Group A	Group B	Group C				
Sokoto	0.64	10.08	-0.94	-2	-6	-6	5.33	-1.30	-3.03	-3.03
Kebbi	0.64	10.08	-0.94	-2	-6	-6	5.33	-1.30	-3.03	-3.03
Kano	-1.60	5.37	-6.91	-6	2	-17	91.00	-0.73	0.10	-1.89
Kaduna	0.54	1.09	-0.84	-2	-2	-7	8.33	-1.04	-1.04	-2.77
Katsina	-1.38	11.29	-5.66	-6	-4	-6	1.33	-6.06	-4.33	-6.06

Mann-Kendall test (M-K): M-K test is to test the null hypothesis H_0 of no trend (the observations x_i are randomly ordered in time, against the alternative hypothesis), H_1 (where there is an increasing or decreasing monotonic trend. The data values are evaluated as an ordered time series). Each data value is compared with all subsequent data values. If a data value from a later time period is higher than a data value from an earlier time period, the statistic *S* is incremented by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, *S* is decremented by 1. The net result of all such increments and decrements yields the final value of *S*. The M-K test statistic *S* is calculated using the formula (Partal and Kahya, 2006; Drapela and Drapelova, 2011):

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}\left(x_j - x_k\right) \tag{7}$$

$$\operatorname{sgn}\left(x_j - x_k\right) = \begin{cases} +1 \text{ if } & x_j - x_k > 0 \\ 0 \text{ if } & x_j - x_k = 0 \\ -1 \text{ if } & x_j - x_k < 0 \end{cases} \tag{8}$$

Where x_j and x_k are the annual values in years j and k, j > k, respectively.

If n < 10, the value of |S| is compared directly to the theoretical distribution of S derived by Mann and Kendall. The two tailed test is used. At certain probability level H_0 is rejected in favour of H_1 if the absolute value of S equals or exceeds a specified value $S_{\alpha/2}$, where $S_{\alpha/2}$ is the smallest S which has the probability less than α/2 to appear in case of no trend. A positive (negative) value of S indicates an upward (downward) trend. The values of S revealed that there are downward trend in the rainfall in all the groups and in all the locations (S<0). The downward trends are well pronounced in 1975 -2008 (Group C) than any other group as the values are higher than the values of S in other groups. For n ≥ 10, the statistic S is approximately normally distributed with the mean and variance as follows (Partal and Kahya, 2006; Drapela and Drapelova, 2011):

$$E(S) = 0 \tag{9}$$

$$VAR(\Sigma) = \frac{1}{18}\left[\nu_\chi(\nu_\chi - 1)(2\nu_\chi + 5) - \sum_{p=1}^{\theta}\tau_\pi(\tau_\pi - 1)(2\tau_\pi + 5)\right] \tag{10}$$

Where, q is the number of tied groups; t_p is the number of data values in the pth group. The standard test statistic Z is computed as follows (Partal and Kahya, 2006; Drapela and Drapelova, 2011):

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} & if \quad S > 0 \\ 0 & if \quad S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} & if \quad S < 0 \end{cases} \tag{11}$$

The presence of a statistically significant trend is evaluated using the *Z* value. A positive (negative) value of *Z* indicates an upward (downward) trend. To test for either an upward or downward monotone trend (a two-tailed test) at *α* level of significance, H_0 is rejected if the $|Z| > Z_1\text{-}\alpha/2$, where $Z_1\text{-}\alpha/2$ is obtained from the standard normal cumulative distribution tables. Table 2 presents the values Sen's estimate (slope) , Mann- Kendall test (S , variance and Z). These values of S and Z revealed that there are downward trends in the yearly total rainfall in the region (in all the locations). The downward trends are well spread in the last 30 years (3 decades, between 1975 and 2008). The downward trends are in order of -0.64; 5.66; -0.94 and -0.86 mm/ year..

Rainfall Frequency Analysis: Rainfall frequency analysis is a viable method of flood flow estimation in most situations and provides reliable prediction in regions of relatively uniform climatic condition from year to year and it is now an established method of determining critical design discharge for small to moderately sized hydraulic structures (Izinyon et al., 2011). A random variable is a quantity that depends on chance the values or range of values can be predicted only with probability not with certainty. Literature presents examples of hydrologic random variables as mean monthly or annual stream discharge, precipitation etc. and a frequency relationship represents the likelihood of occurrence of values of a random variable. A distribution function provides a probabilistic model of phenomenon represented by a particular random variable. Standard probability distribution functions commonly used in water resources engineering have been identified in the literature such as Oke (2007) to include Normal, log Normal, Pearson, Log Pearson Type III and Extreme value Type 1 (EVI) and each distribution can be used to predict design floods.

The Theory of Log-Pearson Type III Probability Distribution: The log-Pearson Type III distribution is a statistical technique for fitting frequency distribution data to predict the design flood for a river at some site. Once the statistical information is calculated for the river site, a frequency distribution can be constructed. The probabilities of floods of various sizes can be extracted from the curve. The probability density function (PDF) for the distribution is given as (Oke, 2007);

$$f(x) = \frac{\lambda_3^{\beta_3}(x-\varepsilon)^{\beta_3-1}\varepsilon^{-\lambda_3(x-\varepsilon)}}{\Gamma(\beta_3)} \tag{12}$$

Because the problem with most hydrologic data is that an equal spread does not occur above and below the mean as the lower side is limited to the range from the mean to zero (although in many cases the minimum may be well above zero) while there is theoretically no limitation on the upper range, it contributes to what is called a skewed distribution. The coefficient of skew (G) being mathematically defined by (Izinyon et al., 2011):

$$G = \frac{N\sum_{i=1}^{N}\left(X_i - \overline{X}\right)^2}{\left(N-1\right)\left(N-2\right)\sigma^3} \quad (13)$$

Where; σ is the standard deviation. Pearson (1930) proposed a general formulation that fits many probability distribution including the normal, beta and gamma distribution. A form of the Pearson probability distribution called the Pearson type III has 3 parameters that include the skew coefficient as well as the mean and standard deviation. The Pearson Type III distribution is represented as follows:

$$X = \overline{X} + K\sigma \quad (14)$$

Where K = frequency factor determined from Tables (Izinyon et al., 2011). The model parameters X, standard deviation and the skew coefficient (g) are computed from n observations X, with the following formular:

$$\overline{X} = \frac{\sum_{i=1}^{N} X_i}{N} \quad (15)$$

$$\sigma = \sqrt{\frac{\left(\sum_{i=1}^{N}\left(X_i\right)\right)^2}{\left(N-1\right)}} \quad (16)$$

$$G = \frac{N\sum_{i=1}^{N}\left(X_i - \overline{X}\right)^3}{\left(N-1\right)\left(N-2\right)\sigma^3} \quad (17)$$

However, the Log Pearson Type III distribution of X which has been widely adopted to reduce skewness is equivalent to applying Pearson Type III to the transformed variable log X and it is represented in the literature (Izinyon et al., 2011) as:

$$\log_{10} X = \log_{10} \overline{X} + K\sigma_{\log} \quad (18)$$

Where; X is the discharge value of some specified probability, logX is the average of the log X discharge values, K is frequency factor. $\sigma_{\log x}$ is the standard deviation of log x values. The frequency factor K is a function of skewness coefficient and return period and can be read from published tables (Izinyon et al., 2011) developed by integrating the appropriate probability density function.

The discharge magnitude for various return periods are found by solving the general equation. The mean, standard deviation of the data and skewness coefficient can be calculated using the following formulae:

$$\log_{10} \overline{X} = \frac{\sum_{i=1}^{N} \log_{10} X_i}{N} \quad (19)$$

$$\sigma_{\log} = \sqrt{\frac{\left(\sum_{i=1}^{N}\left(\log_{10} X_i\right)\right)^2}{\left(N-1\right)}} \quad (20)$$

$$G = \frac{N\sum_{i=1}^{N}\left(\log_{10} X_i - \log_{10}\overline{X}\right)^3}{\left(N-1\right)\left(N-2\right)\sigma_{\log}^3} \quad (21)$$

Where; N is the number of entries of X the flood of some specified probability $\log X_i$ is the average of the log x discharge values, Tables 4 and 5 present information on results of rainfall frequency analyses and applications respectively. Figure 4 shows relationship between rainfall and return period (application of log-Pearson type II distribution).

From the figure the correlation coefficient the relationship ranges from 0.86 to 0.99 which indicates a good relationship (Loveday, 1980).

Table 4. Results of rainfall frequency analyses

Location	Basic statistical information							
	Mean Rainfall (X, mm)	Standard deviation of the rainfall (σ)	Skewness (G)	Mean Rainfall (Log X, mm)	Standard deviation of the rainfall (σ_{log})	Skewness (G_{log})	Regression equation	Correlation coefficient (R^2)
Sokoto	713.64	178.99	0.45	2.84	0.11	-0.64	$Y = 139.16\, Log_e(X) + 557.01$	0.940
Kebbi	798.24	199.18	0.44	2.89	0.10	-0.68	$Y = 139.16\, Log_e(X) + 641.61$	0.940
Kano	887.96	242.54	0.96	2.93	0.12	-0.04	$Y = 215.07\, Log_e(X) + 665.61$	0.981
Kaduna	1221.84	172.15	2.26	3.08	0.06	2.48	$Y = 168.68\, Log_e(X) + 1056.5$	0.990
Katsina	663.80	173.24	-0.22	2.81	0.13	-0.89	$Y = 116.30\, Log_e(X) + 536.14$	0.864

Table 5. Application of rainfall frequency analyses

Location	Rainfall (mm) in specific returned Period							
	1 Year	2 years	5 years	10 years	25 years	50 years	100 years	200 year
Sokoto	447.30	651.08	858.26	949.91	1047.99	1116.37	1168.90	1227.69
Kebbi	531.91	735.68	942.86	1034.51	1132.59	1200.97	1253.51	1312.29
Kano	559.91	844.42	1067.44	1212.96	1387.59	1514.68	1640.32	1751.64
Kaduna	1064.24	1168.47	1321.69	1443.91	1617.79	1729.68	1764.11	1992.50
Katsina	369.29	669.50	811.05	881.74	954.84	1000.75	1041.12	1077.50

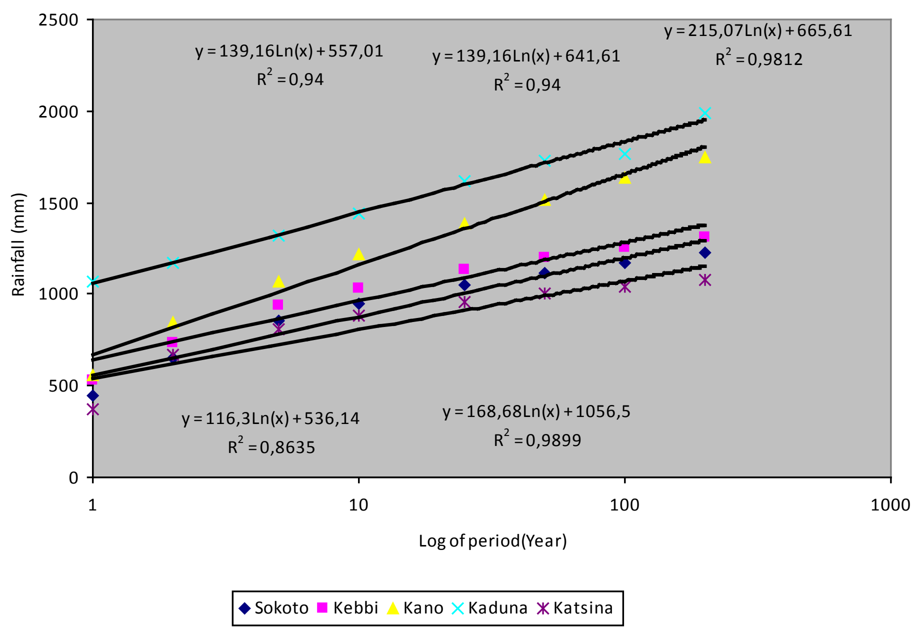

Figure 6. Application of rainfall frequency analysis

CONCLUSION

In this study rainfall trend and rainfall frequency analysis of selected region in Nigeria was presented. It can be concluded based on the study that there are trends in the rainfall in the region. The trends are downward trend in the last 30 years in all the locations. The trends are significant at 99 % confidence levels. The probability distribution function applied to return periods are useful for engineering design of hydraulic structure, flood routing and prediction, storm water management and water resources and management.

SYMBOLS and ABBREVIATIONS

f(x)	probability density as a function of x
Γ	gamma function
$\beta = \frac{1}{x}$	shape parameter for 1 parameter distribution
$\lambda_2 = \frac{\bar{x}}{(S_x^2)}$	scale parameter for 2 parameter distribution
$\beta_2 = \frac{\bar{x}^2}{(S_x^2)} = \frac{1}{(CV^2)}$	shape parameter for 2 parameter distribution
λ_3	$\frac{S_x}{\sqrt{\beta_3}}$ scale parameter for 3 parameter distribution
β_3	$\left(\frac{2}{(C_2)}\right)^2$ shape parameter for 3 parameter distribution
ε	$\bar{x} - \Sigma_x \sqrt{\beta_3}$ location parameter
S_x	standard deviation
CV	coefficient of variation
$\bar{x}$	mean of the sample
R_i	Reliability of the system based on the selected design parameter (dimensionless)

REFERENCES

Abaje, I.B.; Ishaya, S. and Usman S.U. 2010 , An Analysis of Rainfall Trends in Kafanchan, Kaduna State, Nigeria. Research Journal of Environmental and Earth Sciences 2(2): 89-96.

Adebayo A.A, and Umar A.S 2005. “Climate”, in Tukur A. L, Adebayo A. A and Galtima M. Eds, The land and people of the Mambilla Plateau, Heinemann, Ibadan. pp. 25-32.

Adefolalu D.O, Pam, J.L, and Habbi H.M 2007. “Climate change and safety of air transportation – A Nigerian perspective”. Proceedings of the International Conference on the impacts of extreme weather and climate on socio-economic development in Africa held at the Federal University of Technology, Akure, Nigeria, 11-15 Nov. 2007. pp. 1-15.

Afiesimama E.A, Ojo S.O, and Gbuyiuro S.O 1999. “The diagnosis of climatic trends over Nigeria in the last half century of this millennium”, A paper presented at the Annual Conf. Meteorol. Organization, Lagos.

Akintola, J.O 1986 .: Rainfall Distribution in Nigeria 1892–1983, 1st edn. Impact Publishers Nigeria Ltd, Ibadan.

Antonopoulos, V. Z.; D. M. Papamichail and K. A. Mitsiou 2001. Statistical and trend analysis of water quality and quantity data for the Strymon River in Greece. Hydrology and Earth System Sciences, 5(4), 679–691

Ayuba H.K, Maryah U.M, and Gwary D.M 2007. “Climate change impact on plant species composition in six semi-arid rangelands of Northern Nigeria”, Nig. Geogr. J., 5(1):35-42.

Burn D.H, and Hag Elnur M.A. 2002. Detection of hydrological trends and variability. Journal of Hydrology 255: 107–122.

Cengiz T, Kahya E, Karaca M. 2003. Trends and annual cycles in Turkish lake levels. International Association of Hydraulic Engineering

Drápela , K and I. Drápelová 2011. Application of Mann-Kendall test and the Sen’s slope estimates for trend detection in deposition data from Bílý Kříž (Beskydy Mts., the Czech Republic) 1997–2010. Beskydy, 4 (2): 133–146

Hirsch R.M, and Slack J.R. 1984. A non-parametric trend test for seasonal data with serial dependence. Water Resources Research 20: 727–732.

Hirsch R.M, Slack J.R, and Smith R.A. 1982. Techniques of trend analysing for monthly water quality data. Water Resources Research 18:107–121.

Izinyon, O.C;. Ihimekpen, M.D and G.E. Igbinoba 2011 Flood Frequency Analysis of Ikpoba River Catchment at Benin City Using Log Pearson Type III Distribution Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 2 (1): 50-55

Kadıöglu M. 1997. Trends surface air temperature data over Turkey. International Journal of Climatology 17: 511-520.

Kahya E, and Kalayci S. 2004. Trend analysis of streamflow in Turkey. Journal of Hydrology 289: 128–144.

Kahya E, Kalayci S, and Burdurlu Y. 1998. Analysis of trends in the water quality parameters of Gediz basin. In Proceedings of 1st International

Karaca M, Antepliogˇlu U¨ , Karsan H. 1995. Detection of urban heat island in PIstanbul, Turkey. Il Nuovo Cimento 18: 49–56.

Lettenmaier D.P, Wood E.F, and Wallis J.R. 1994. Hydro-climatological trends in the continental United States, (1948–88). Journal of Climate 7: 586–607.

Lins H, and Slack J.R. 1999. Streamflow trends in United States. Geophysicsal Research Letters 26: 227–230.

Loveday, R. 1980. Statistics, A second course in statistics, 2nd edn, University Press Cambridge

Nkomo J.C, Nyong A.O, and Kulindwa K 2006. The Impacts of Climate Change in Africa. Final Draft submitted to the Stern Review on The Economics of Climate Change.

Nwafor J.C 2007. Global climate change: The driver of multiple causes of flood intensity in sub-Saharan Africa. Paper presented at the International Conference on Climate Change and Economic Sustainability held at Nnamdi Azikiwe University, Awka, Nigeria. 12-14 June 2007.

Obot; N.I.M; Chendo; A.C; Udo,S.O and Ewona. I.O 2010. Evaluation of rainfall trends in Nigeria for 30 years (1978-2007). International Journal of the Physical Sciences. 5(14), 2217-2222.

Odjugo P.A.O 2005. “An analysis of rainfall pattern in Nigeria”, Global J. Environ. Sci., 4(2): 139-145.

Oke, I. A 2008 Utilization of Weibull Techniques For Short Term Data In Environmental Engineering. Environmental Engineering and Sciences. 25 (7),1099- 1107

Partal, T and Kahya,E 2006. Trend analysis in Turkish precipitation data. Hydrol. Process. 20, 2011–2026.

Sen P.K. 1968. Estimates of the regression coefficient based on Kendall’s tau. Journal of the American Statistical Association 39: 1379–1389.

Toros H. 1993. Trend analysis of climatologic series in Turkey. MSc thesis, Institute of Science Technology, Istanbul Technical University.

Türkeş, M. 1996. Spatial and temporal analysis of annual rainfall variations in Turkey. International Journal of Climatology 16: 1057–1076.

Türkeş, M, Ŝumer U.M, and Kılı¸c G. 1995. Variations and trends in annual mean air temperatures in Turkey with respect to climatic variability.

Umoh E 2007 , “Flooding problems in Rivers state”, J. Environ. Sci. 4(2): 44-60.

Van Belle G, and Hughes J.P. 1984. Nonparametric tests for trend in water quality. Water Resources Research 20: 127–136.

Von Storch H, and Navarra A. 1995. Analysis of Climate Variability—Applications of Statistical Techniques. Springer-Verlag: New York.

Yue S, and Hashino M. 2003. Long term trends of annual and monthly precipitation in Japan. Journal of the AmericanWater Resources Association39: 587–596.

Zhang X, Harvey K.D, Hogg W.D, and Yuzyk T.R. 2001. Trends in Canada streamflow. Water Resources Research 37: 987–998.

Zhang X, Vincent L.A, Hogg W.D, and Niitsoo A. 2000. Temperature and precipitation trends in Canada during the 20th century. Atmospheric Ocean 38: 395–429.