Variations and Trends of Some Meteorological Parameters at Ibadan, Nigeria.

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ABSTRACT

Variations and trends of some meteorological parameters over a tropical-humid station, Ibadan ($07^0$26'N, 03° 54´E) in the southwestern part of Nigeria have been observed using daily mean data of each of the parameters taken at the International Institute of Tropical Agriculture (I.T.T.A.), Ibadan, between 1988 and 1997.

The monthly series of the meteorological parameters show an annual decreasing trend, which is not statistically significant except those of rainfall and relative humidity data series that show an increasing trend, which is statistically significant when the Mann-Kendall (τ) and Spearman rho statistics were applied. It has also been found that the annual variations of the parameters are in synchronism with the north-south movement of the surface Inter-tropical discontinuity (ITD). The yearly series of the parameters show that solar radiation and evaporation rate have significant decreasing trend, while other parameters show an increasing trend that is not statistically significant.

Also the yearly data series for temperature and sunshine hour appear to show similar behavior to the global warming trends.

(Keywords: warming, trend, statistically significant, Inter-tropical discontinuity, synchronism).

INTRODUCTION

Weather is generally considered as the state of the atmosphere at a given time at any given location (Barry and Chorley, 1976). It may also be referred to as the aspects of the atmospheric state which is visible and experienced and which affect human activities. The weather conditions of any given location is often described in terms of the meteorological elements which include the state of the sky, temperature, winds, pressure, precipitation, and humidity. These factors initiate and influence the atmospheric processes (Ayoade, 1993).

Over the universe, the atmosphere also responds to other phenomenon like El Nino, La-Nina, direct and indirect energy releases into the atmosphere by human activities and effects of burning of fossil fuel-cum-the industrial releases and atmospheric pollution. All these result in the spatial and time variation of weather. (Obioh, 1994; Ogolo, 2002). The profound influence of climate and weather over man's activities can be seen from his everyday life. Forces of nature have regulated to a very great extent the sort of food we eat, what we wear, how we live and our mental alertness, our physical characteristics and even our radical differences when closely examined have at least some relationship with climate.

Climate and weather are vitally important in agriculture. For instance some climatic effects such as frosts at critical times can wipe out crops, while dearth of rain will hinder pasture and crops from growing. This will in turn bring about food scarcity in the affected regions and may further have a debilitating impact on world economy. Therefore, a better understanding of climatic variability is essential in the agriculture of today.

In most studies carried out in recent years with respect to climate change, for example, on temperature, analyses as conducted by the intergovernmental panel on climate change (IPCC), have found a 0.3^oC to 0.6^oC rise in global mean temperature during the last century (IPCC, 1990; Murat et al, 1995) and a somewhat larger temperature increases have been projected in the IPCC's Third Assessment Report (IPCC, 2001) as

a result of projections that sulphur dioxide emissions are likely to be controlled. In a recent study carried out over Turkey by Murat et al., (1992) it was found out that trends in annual mean temperature for Turkey, using departure of 21-year running means from the normal for 1941-1970, rose by approximately 0.5^{o}C between 1930 and the mid-1960's.

Water vapor, which is the link between the surface and the atmosphere in the hydrological cycle, has also been found to have long-term variations in the atmosphere. The most recent global estimate, as reported in the December 1995 edition of American Geophysical Union (AGU), shows an increase in precipitable water during 1973-1990, with the largest trends in the tropics where increases as large as 13% per decade were found. Similar studies on water vapor trend carried out over North America shows increases in precipitable water over all regions except northern and eastern Canada where it fell slightly (AGU, 1995). Olaniran and Sumner (1989) in their study on long-term variability of rainfall conditions in Nigeria in terms of the onset, retreat, and length of rainy season has found that the series for retreat of rainfall showed evidence for quasi-triennial and quasi-6-year oscillations, while that of rainy season length displayed quasi-biennial and quasi-triennial oscillations.

Adeyemi and Aro (2004) in their study on trends in the variations of surface water vapor density in four Nigerian stations showed that surface water vapor density is higher at night by an average of 9.9% than during the day in the southern stations while in the midland station of Minna, the reverse is the case. Observing seasonal variations of refractivity gradient in three climatic zones in Nigeria, Willoughby et al., (2002) has found out that in each of the zones, the characteristic topographical features have greater influence on refractivity gradient behavior. In this paper, the focus is on observing the trends in the variations of six meteorological parameters at Ibadan, a station located in southwestern Nigeria.

ACQUISITION OF DATA AND ANALYSIS TECHNIQUE

Daily data of solar radiation, relative humidity, temperature, evaporation, rainfall and wind speed for the station under investigation were collected, for the period 1988 to 1997, from the International Institute of Tropical Agriculture (IITA), Ibadan. Monthly means of these parameters were then obtained from the collected daily data.

Trend refers to the monotonic increase or decrease in average value between the beginning and the end of a time series (Giles and Flocas, 1984). Although the trends in climatic data are seldom linear (Olaniran and Sumner, 1989; Mitchell et al., 1966), the linear regression method has been used to search for trends in many climatic time series (e.g. Ayoade (1993), Hutchinson (1985), and Subbaramayya and Bhanu Kumar (1987)). In testing for non-randomness against trend, Mitchell et al., (1966) suggested the use of either Mann-Kendall (τ) or Spearman rho statistics. In this study, Mann-Kendall (τ) or Spearman rho statistics shall be used to examine possible decreasing or increasing trend.

RESULTS AND DISCUSSION

Seasonal distributions of the meteorological parameters: Figure 1 (a-g) show the seasonal distributions of the meteorological variables at Ibadan. Ibadan lies in the low latitude 7^{0}26'N and longitude 3^{0}5'E and is situated near the forest-grassland boundary of southwestern Nigeria. In Ibadan we have two seasons namely the dry and the wet seasons, the occurrence of which is greatly influenced by its latitudinal location. Between March and October, that is, during the rainy season period, the city is under the influence of moist maritime south- west monsoon wind which blows inland from the Atlantic Ocean. The dry season occurs from November to February during which time, the dry dust laden winds blow from the Sahara desert. This period is characterized with low humidity and high rate of evaporation.

Figure 1a shows that solar radiation has considerable seasonal variations. It maintains two peaks with a minimum in August. The August minimum is due to the fact that August month is the core rainy month that is characteristic of incessant cloud formation thereby depleting the amount of solar radiation reaching the earth's surface. This observation is also noticeable in sunshine hour, air temperature and evaporation rate (see Figures 1b, c and f). In the case of solar radiation and sunshine hour, the first peak lasts between February and May, while the second peak is found between November and December. The months of March and November/December

are the months of first and second peaks respectively for air temperature and rate of evaporation. Humidity rises gently from January (57.00 ± 4.42) % to the peak in August (84.00 ± 0.91) % and thereafter decreases to December (67.00 ± 1.37) % (see Figure 1d).

The month of January is the month of lowest humidity. The wind speed on the other hand (see Figure 1e) peaks in March, which incidentally is the transitional month between the dry and the rainy seasons in southwestern Nigeria (Adeyemi and Aro, 2004; Ogolo 2002; Oguntoyinbo, 1978, 1985). Figure 1g shows that rainfall amount exhibit bi-modal peaks which characterizes the variational trend of rainfall in Ibadan. The first maximum occurs in July with a mean value of (195.88 ± 11.67)mm and the second maximum occurs in September with a mean value of (230.41 ± 9.11)mm. The dip in between the two peaks is synonymous with the little dry season (LDS) that commonly occurs during this period. This period is marked by low stratus cloud, high humidity and relatively low and constant temperature. This occurs when the ITD (Inter-tropical discontinuity) line is at its most northerly position (Balogun, 1981; Balogun and Adedokun, 1985; Adejokun, 1966).

The seasonal trend of the parameters was also investigated and the results of the statistical test applied are shown in Table 3. If we ignore the significance of the test statistics from the Mann-Kendall and Spearman rho tests, all the meteorological parameters except relative humidity show increasing trend (i.e. they show positive signs) in the dry season and decreasing trend (i.e. they show negative signs) in the wet season. Relative humidity on the other hand shows a decreasing trend in the dry season which is expected while both rainfall and relative humidity show increasing trend in the wet season.

Temporal Distribution of Coefficient of Variation

Figures 2(a-g) describe the temporal distribution of coefficients of variation (CV) for the meteorological parameters under study at Ibadan. The coefficients of variations are computed in order to investigate the month-to-month variability of the meteorological parameters. The coefficient of variation is defined as (Murat et al, 1995):

$$CV = \left(\frac{\sigma}{MP} \right) 100\%$$

where MP stands for monthly mean of any of the meteorological parameters and σ is the standard deviation for each of the parameters. The CV for solar radiation ranges from 9 – 13%, sunshine hour from 9-30%, air temperature 1-4%, relative humidity 2.6-24%, wind speed 8-23%, evaporation rate 4.7-17% and rainfall 22-97%. From the foregoing, rainfall is the most variable parameter, while the least variable parameter is air temperature.

Trends in Annual Mean of the Meteorological parameters: Figures 3(a-g) describe the decadal variations and trends in the annual mean of the meteorological parameters. Solar radiation shows a steep downward trend between 1989 and 1993 and thereafter increases slightly in the subsequent four years. 1993 therefore experiences low receipt of solar radiation, which may be unconnected with undue long cloud coverage due to heavy rainfall culminating into low sunshine hours experienced at the station throughout the year (see Figures 3 b & g). Sunshine hour decreases from 1989 to 1991 and then rises in the following four years (See Fig. 3b). The years 1990-1994 have sunshine hour values below the yearly average while the years 1995-1997 maintains values that are far above the yearly average.

Air temperature on the other hand, rises gently between 1989 and 1991 and then decreases until 1994. Thereafter, it increases progressively to 1997 (See Fig. 3c). The annual mean of air temperature for the years 1989 –1991 and 1994-1997 exhibit a behaviour that relates well to the global warming trend. A well-defined warming observed between 1989 and 1997 was interrupted by a short cooling period in the annual mean temperatures in 1993 and 1994. The coldest years in the series are the years 1989 and 1992.

The different trends observed between solar radiation and sunshine hour could best be explained using Table 3. The two show a decreasing trend during the rainy season. This is to be expected. During the dry season, opposite trends were observed. The opposite trends observed during the dry season may be explained using the prevailing climatic conditions of that period. During the dry season, cloud and cloud formations are absent hence the increasing trend in temperature, while the decreasing trend observed in sunshine hour may be likened to instrumentation characterization (Igbal, 1983).

Relative humidity and wind speed (see Figures 3d & e) values oscillate about the yearly means of (74.00 ± 0.82)% and (3.8 ± 0.092)m/s respectively. They also maintain a maximum in 1992 and a minimum in 1994 and 1995 respectively.

From Figure 3f, yearly means of evaporation rate indicate a decreasing trend. The first half of the period under investigation is characterized by annual means of evaporation rate that are consistently higher than the yearly average while the second half is characterized by values that are consistently below the yearly average despite the warming trend of 1994-1997. The time series plot for rainfall (see Figure 3g) exhibits a fluctuation in the annual means with a coefficient of variation 10.4%. This is the parameter with the highest coefficient of variation among all the meteorological parameters.

The downward trend of 1988-1990 was interrupted by sharp increases between 1991 and 1993 to an above yearly average. This was followed by a drought year in 1994 where annual rainfall amount dropped to the minimum. Between 1995 and 1997, rainfall amount in this station follow an increasing trend. The years 1988, 1991, 1993, and 1995-1997 have been identified as years of above yearly average rainfall, while the years 1989, 1990, 1992 and 1994 are years of near and below yearly average rainfall. The above yearly average rainfall has been associated with late retreat of rainfall in the area, while the near and below yearly average rainfall is a consequence of an early retreat of rainfall (Olaniran and Sumner, 1989).

The monthly series (as in Figure 1) and the yearly series (as in Figure 3) of the meteorological parameters were next examined for possible increasing or decreasing trend using the Mann-Kendall (τ) and Spearman rho rank statistics (Sneyers, 1990; Murat et al., 1995). The results obtained are shown in Tables 1 and 2. Table 1, showing the yearly correlation time series of all the meteorological parameters, suggests that the observed trends in the time series of all the meteorological parameters except those of solar radiation and rate of evaporation during the period of observation (i.e. 1988-1997) are statistically not significantly different from a randomly fluctuating series. Although all these parameters exhibit an increasing trend (correlation being positive for both statistics) except for rainfall amount that shows a decreasing trend, but these correlations are statistically not significant. However, for solar radiation and rate of evaporation, both parameters exhibit significant decreasing trend during this period (1988-1997) at this station.

The same statistics applied to the monthly time series (see Table 2) of all the meteorological parameters suggests that, with the exception of relative humidity and rainfall amount, Ibadan experiences a decreasing trend in all the meteorological parameters annually. This trend is significant at 0.01 alpha levels for wind speed and 0.05 alpha levels for solar radiation and evaporation, while for others it is not significant. The monthly time series for relative humidity and rainfall are of increasing trend during the period under investigation at Ibadan with it being significant only for relative humidity. The observed trend in the meteorological parameters as indicated in the monthly time series can simply be explained in terms of the mode of advance and retreat of the rain-producing mechanisms, specifically, the Inter-tropical Discontinuity (ITD).

The ITD has a migratory nature that is fundamental to the understanding of Nigeria and West Africa climates. It invades from the south at the beginning of the rainy season in a highly irregular manner, in series of surges, stagnations and retreats (Adejokun, 1966). The observed trend is therefore in synchronism with the north-south movement of the ITD.

According to the results of the statistical tests applied to the monthly (average over ten years) Ibadan data, without considering the significance of the test statistics from the Mann-Kendall and Spearman rho tests, most of the meteorological parameters show a decreasing trend (i.e. they show negative signs). On the other hand the yearly fluctuations have shown that temperature and sunshine hour among others at Ibadan exhibit a trend that is similar to the global warming trend during the period 1988-1997 (see Table 1).

Table 1: Results of Statistical Tests Applied to the Yearly Mean Series. Significance Levels are Indicated: 95% (*), 99% (**).

Meteorological Parameter	Mann-Kendall tau_b	Spearman
Solar Radiation	-0.449* (decreasing trend)	-0.602* (decreasing trend)
Sunshine hour	0.225	0.280
Temperature	0.244	0.358
Relative humidity	0.156	0.224
Windspeed	0.022	0.067
Evaporation	-0.644** (decreasing trend)	-0.709* (decreasing trend)
Rainfall	-0.067	-0.079

Table 2: Results of Statistical Tests Applied to the Monthly Mean Series. Significance Levels are Indicated: 95% (*), 99T (**).

Meteorological Parameter	Mann-Kendall tau_b	Spearman
Solar Radiation	-0.333	-0.510* (decreasing trend)
Sunshine hour	-0.061	-0.014
Temperature	-0.273	-0.399
Relative humidity	0.364* (increasing trend)	0.448
Wind speed	-0.545** (decreasing trend)	-0.699** (decreasing trend)
Evaporation	-0.394* (decreasing trend)	-0.636* (decreasing trend)
Rainfall	0.242	0.203

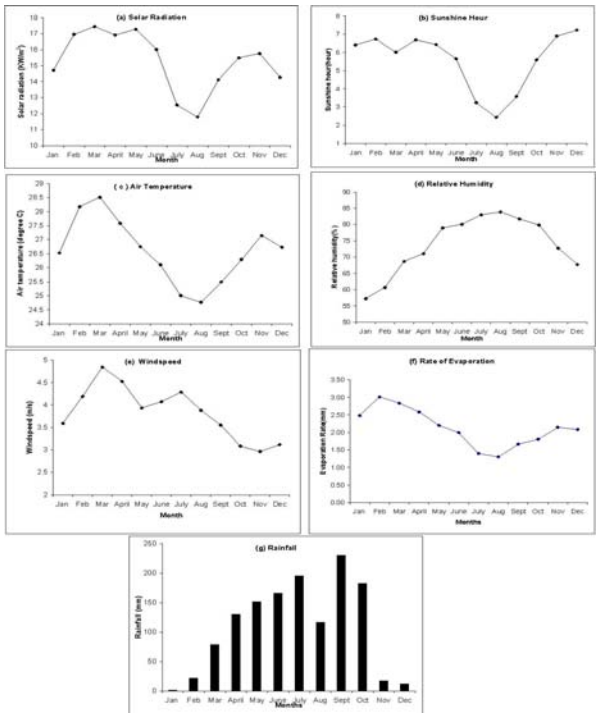

Figure 1: Mean Seasonal Patterns of the Meteorological Parameters Under Study Averaged Over Ten Years at Ibadan.

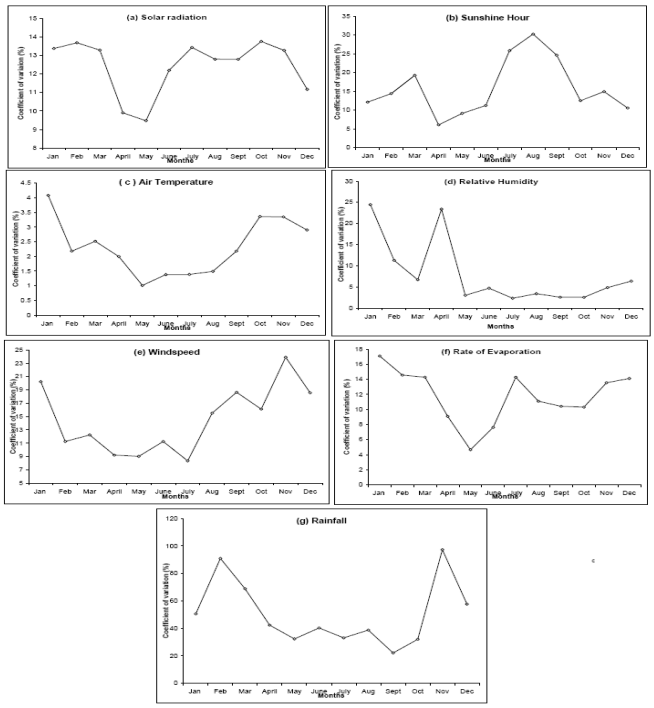

Figure 2: Annual Distribution of Coefficients of Variation for the Meteorological Parameters Under Study over Ibadan.

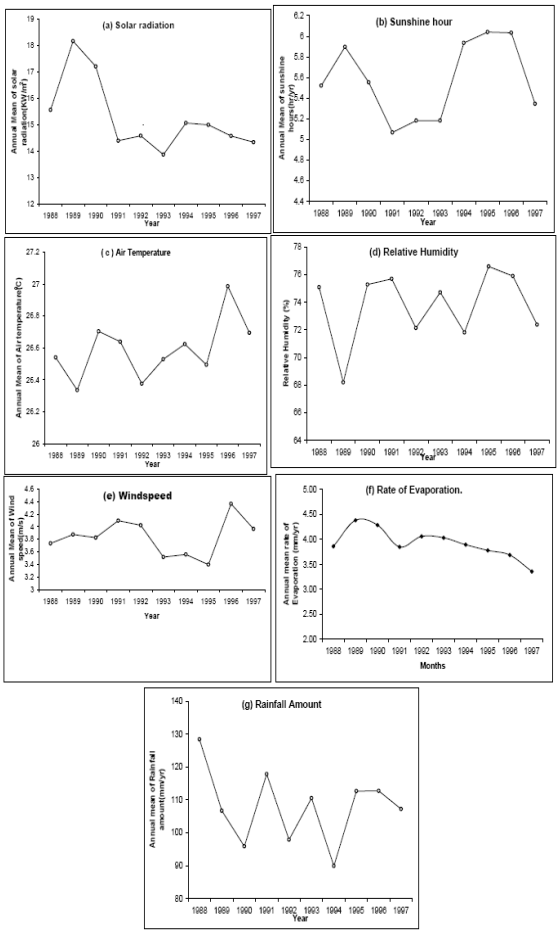

Figure 3: Annual Mean Variations of the Meteorological Parameters Under Study over Ibadan.

CONCLUSION

The evaluation of decadal yearly and monthly mean values of some meteorological parameters, which include solar radiation, sunshine hour, air temperature, relative humidity, wind speed, evaporation and rainfall amount at Ibadan demonstrates the existence of marked variations and trends in the parameters in the station. Monthly mean values for each of the parameters illustrates the progressive invasion of the station by the rain inducing southwesterlies south of the surface ITD as the surface advances northward from the coast between February and May and its retreat in the reverse direction between September and November. A notable deterioration in the values of all the parameters except relative humidity and rainfall has been identified which is statistically significant for solar radiation, evaporation rates (at 0.05 alpha level), and wind-speed (at 0.01 alpha level). For temperature and sunshine hour, the deterioration is not statistically significant.

It is, however, difficult to argue for a well-defined change in most of the meteorological parameters based on the yearly time series analysis performed in this work. Only solar radiation and evaporation rate show statistically significant decreasing trend during the period of observation. The trend shows by others are statistically not significant. However, comparing the temperature data with the global temperature trends, a warming trend is observed in the temperature and sunshine hour series in this station.

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