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SOME EMPIRICAL EVIDENCE OF GLOBAL WARMING IN GHANA

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Summary

Analyses show that temperatures in Ghana were significantly higher during the 1961-90 era than in the 1931-60 era; this rising trend was discerned even over the last three decades 1961-70, 1971-80 and 1981-90. It involved maximum, minimum, and average temperatures throughout the year, and across virtually the whole country; just the low altitude and non-industrialized Axim, Saltpond, and Kete-Krachi regions experienced some spells of rather higher 1931-60 temperatures. Given the current worldwide 'greenhouse' global warming evolution, this rising temperature development is particularly noteworthy. Urbanization, coupled with the modest industrial development in Ghana, over the past six decades possibly also contributed to it. That notwithstanding, the temperature cycle throughout Ghana has remained quite stable all this while; consistently attaining a maximum in February or March, declining steadily to a minimum in August, and then rising to a second but lower peak in about November.

Introduction

The threat of global warming, deriving from the accumulation of carbon dioxide, methane, and other 'greenhouse' gases in the earth's lower atmosphere, has raised much concern and awareness, in both scientists and politicians alike. In fact, current atmospheric dynamics point towards an overall temperature increase of about 2-5 °C over the next century; a rate unprecedented in the past 10,000 years. The concern over the threats posed by global warming has prompted two World Climate conferences, the second of which was held in 1990, in the International Conference Centre, Place de Varembe, Switzerland. At this gathering, the effects of human activities in increasing 'greenhouse' gases, and hence global warming, was acknowledged. It was projected that this would raise sea levels by some 65 cm ± 35 cm by the end of the century, with very dire repercussions on natural, managed, and socio-economic resources. These menacing developments would derive basically from the impact of global warming on the hydrological resource systems and cycles, resulting in floods and droughts world-wide.

Underlying the litany of destructive effects envisaged from global warming is the melting of the polar snow and ice covers, with the resultant water avalanche swelling the expanses and levels of the oceans and rivers. The result would be substantive dislocations within coastal and terrestrial ecosystems; and by extension, quite a diversity of socio-economic establishments stand to be adversely affected. In general, the global rainfall profile would cause severe droughts in certain areas and excessive rains in others; and the attendant disruptions in agriculture, wild-life and game, would threaten the very existence and survival of mankind.

At present, however, there does not appear to be any developments frightful enough to make these gloomy projections imminent, with most indicators pointing only to a facade that would appear remote and could, at worst, be just unfolding. All the same, climatologists are keeping a keen eye over changes in the climatic profile, particularly as could be related to global warming; for the time being, however, some impression appears to have been created that there is not much tangible cause for alarm. For instance, in a comparative study of temperatures in Ghana in the 1931-1960 and 1961-1990 eras, Ontoyin (1993) would only describe the temperature increase he discerned within the last three decades as just ap-

parent, and hence not significant; therefore, the only inference he could draw from this was that the rising temperatures were not important enough to indicate a climate change in Ghana.

Nevertheless, the Intergovenmental Panel on Climate Change (IPCC) has been quite positive in warning that a change in the climate is imminent, as a result of increasing emissions of 'greenhouse' gases. The caution was given that the repercussions are expected to be even all the more bleak for developing countries, given the various stresses and constraints undermining them. In fact, on the Ghanaian scene, Larmie (1993) observed that the annual mean air temperatures within the Densu Basin have increased steadily from 1974 to 1990, by about 3.5 per cent; he also reported that the Densu river itself has as well experienced a temperature increase, of about 4.02 per cent. More importantly, he blamed climatic changes as the basic cause of these temperature devlopments.

Be that as it may, the threat of global warming, and its attendant impacts on all that sustains humanity, have prompted quite a flood of remedial and even panic actions. Among the resolutions taken, the second World Climate Conference (1990) prescribed sustained research towards a better understanding, modelling, and prediction of the climate system. Intensified effort towards prediction in short-term national and regional climate analyses was also recommended. Yet one other prescription was the provision and international exchange of long-term climate data with high priority.

The present work is a subscription to the valid recommendations of the World Climate Conference (1990); it is an attempt at an empirical profile analyses of the regional climatic changes in Ghana, a country so vitally perched on its hydrological resources for agriculture, forestry, and fisheries. It is, necessary to identify the extent to which the various regions and sub-continents, especially those sustaining the crucial resources of the world, are susceptible to the global warming menance; this should enable appropriate strategies to be developed in place, and in time, to counter or accommodate any crises.

Experimental

Data analyses and results

The original monthly temperature data for each year within the period 1931-90, for the various synoptic stations in Ghana, were collected from the Head office, Ghana Meteorological Services Department, Accra. These have been variously abridged in this report into mean temperatures for the months and decades (Tables 1 and 2). Unfortunately, most of the available data for the 1931-60 era covered only the latter part from about 1945 onwards; and, moreover, such data involved just 11 of the synoptic stations. Consequently, it is only these 11 stations that could be used for comparing temperatures within the 1931-60 and the 1961-90 eras just as was done by Ontoyin (1993).

In any case, these 11 stations do substantively cover all the ten regions of Ghana: from North to South, and East to West. However, for the assessment of the temperature trends between the decades within the 1961-90 era, some of these stations were changed for others (Table 2). In all cases, the data were cross-checked with records at the Architectural Engineering Services Consultancy (AESC) - Hydro Division, Accra, Ghana. Table 1 is the 30-year mean maximum and minimum temperatures for the various months; these cover the two 30-year eras of 1931-60 and 1961-90. In one set of analyses, temperatures during the 1931-60 era have been compared with those in 1961-90; this relates to the mean maximum and the mean minimum, and as well as the overall mean or average temperatures for the various months, at the 11 regional stations in Table 1. Summary results are given in Tables 3-5 respectively. The overall mean minimum, maximum, and average temperatures for the two eras are given in Table 6.

Table 7 is a summary of the mean temperatures for the three most recent decades: 1961-70, 1971-80, and 1981-90. In another analysis, the temperature development within these three decades were assessed; the results are summerized in Table 8.

TABLE 1

Monthly mean minimum and maximum temperatures (°C) in Ghana

a) 1931-60 mean maximum

Synoptic stations Months:	J	F	M	A	M	J	J	A	S	O	N	D
Wa	19.6	21.8	23.7	24.0	23.1	22.0	21.5	21.4	21.3	21.4	21.1	19.5
Nav'go	19.3	21.6	24.3	25.7	24.9	23.1	22.4	22.2	21.9	22.0	20.4	18.9
Tamale	20.3	23.0	24.5	24.6	23.5	22.4	22.0	21.9	21.8	21.9	21.7	19.9
Yendi	19.7	21.7	23.6	24.0	23.0	22.1	21.6	21.6	21.5	21.4	20.4	18.9
Kumasi	19.9	21.4	22.0	22.1	22.1	21.7	21.2	20.7	21.0	21.3	21.2	20.6
K-Krachi	20.0	22.4	23.9	23.7	23.4	22.5	22.1	21.9	22.5	22.0	21.4	19.6
Ho	21.8	22.5	22.8	22.8	22.6	21.9	21.1	20.7	21.3	21.5	22.0	22.0
Ada	24.7	25.4	25.7	25.4	24.6	24.0	23.0	22.6	22.2	24.1	25.1	24.5
Accra	22.8	23.4	23.6	23.6	23.3	22.5	21.7	21.3	21.9	22.3	22.8	23.0
S'pond	23.2	23.8	24.1	24.1	23.8	23.2	22.3	21.3	22.2	23.0	23.1	23.8
Axim	23.5	24.0	24.2	24.4	23.7	23.3	23.1	22.3	22.9	23.4	23.0	23.2

b) 1931-60 mean maximum

Wa	34.5	35.9	36.0	35.0	32.8	30.8	29.2	28.8	29.5	32.1	34.6	33.9
Nav'go	35.2	37.2	38.6	38.0	35.0	32.4	30.6	29.7	30.5	33.4	36.1	35.2
Tamale	35.6	37.0	37.4	35.8	33.5	31.0	29.7	29.3	29.8	32.3	35.0	35.0
Yendi	35.2	36.6	36.7	35.4	33.3	30.6	29.3	29.1	29.7	32.0	34.6	34.6
Kumasi	31.0	31.4	31.4	31.0	30.3	28.6	27.0	26.7	28.3	29.6	30.7	30.5
K-Krachi	34.9	36.4	35.8	34.8	33.4	31.1	29.6	29.7	29.7	32.1	33.8	34.1
Ho	33.3	35.4	33.5	33.0	32.0	30.4	28.9	28.9	30.3	31.1	32.4	32.8
Ada	30.2	30.8	31.3	31.3	30.5	29.8	27.1	26.5	27.8	29.2	30.6	30.9
Accra	31.7	31.8	31.9	31.7	30.8	28.7	27.3	27.3	28.5	29.7	31.1	31.4
S'pond	30.7	31.3	31.7	31.5	30.6	28.8	27.2	26.5	27.7	29.3	31.3	31.2
Axim	30.2	30.9	31.0	31.2	30.2	28.1	27.6	27.0	28.0	28.8	30.5	30.6

c) 1961-90 mean maximum

Wa	19.3	22.2	24.4	24.6	23.7	22.4	21.8	21.6	21.5	22.0	20.8	19.3
Nav'go	19.5	22.0	24.5	26.1	25.1	23.3	22.7	22.3	23.7	22.2	20.2	19.0
Tamale	19.5	22.9	25.0	25.2	24.1	22.7	22.4	22.2	22.0	22.2	20.9	18.9
Yendi	19.7	22.4	24.2	24.4	23.4	22.2	21.9	21.7	21.5	21.6	20.0	18.9
Kumasi	20.3	22.1	22.2	22.3	22.2	21.6	21.2	21.0	21.2	21.5	21.6	20.7
K-Krachi	19.9	23.6	24.8	24.9	24.2	23.1	22.8	22.5	22.4	22.7	22.4	20.8
Ho	22.1	23.1	23.3	23.4	2.30	22.2	21.6	21.3	21.5	21.9	22.4	20.8
Ada	24.6	26.0	26.0	25.9	25.2	24.3	23.7	22.0	23.4	24.5	25.1	24.5
Accra	23.4	24.0	24.2	24.2	23.9	23.1	22.5	22.2	22.4	22.9	23.5	23.3
S'pond	22.9	23.8	23.9	23.9	23.6	23.0	22.5	21.8	22.3	22.8	23.0	22.2
Axim	23.4	24.4	24.4	24.2	23.6	23.2	23.1	23.1	22.9	23.3	23.2	23.2

d) 1961-90 mean maximum

Wa	34.5	36.5	36.9	35.6	33.7	31.3	29.6	29.1	30.1	32.7	34.6	34.2
Nav'go	35.2	37.6	38.9	38.2	36.0	33.0	31.1	30.3	31.2	34.2	36.2	35.1
Tamale	35.6	37.6	37.7	35.9	34.0	31.4	30.1	29.8	30.5	33.0	33.4	33.1
Yendi	35.3	37.1	37.2	35.7	33.6	31.2	29.7	29.3	30.3	32.2	34.7	34.5
Kumasi	32.0	33.5	32.9	32.3	31.3	29.5	28.0	27.7	28.6	30.1	31.2	30.7
K-Krachi	33.9	35.7	35.3	34.2	32.6	30.6	29.3	29.2	30.0	31.5	33.0	32.9
Ho	33.8	34.8	31.0	33.0	31.9	30.0	28.8	28.5	29.4	30.9	32.3	32.1
Ada	31.8	32.5	32.7	32.5	31.9	30.0	28.8	28.5	29.4	30.9	32.3	32.1
Accra	32.1	32.7	32.5	32.2	31.3	29.2	28.0	27.9	29.0	30.5	31.6	31.7
S'pond	30.6	31.3	31.3	31.3	30.3	28.3	27.2	26.6	27.4	29.2	30.6	30.6
Axim	30.0	30.8	30.9	30.9	30.0	28.4	27.4	26.9	27.4	28.5	29.9	30.0

TABLE 2

Monthly mean temperatures in Ghana for the decades 1961-70, 1971-80, 1981-90

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Wa												
1961-70	26.8	29.0	30.3	29.6	28.4	26.6	25.6	25.1	23.4	27.1	27.6	26.7
1971-80	27.0	29.7	30.6	30.2	26.2	25.8	25.7	25.4	26.8	27.2	27.5	26.6
1981-90	29.7	29.6	31.2	30.8	29.4	27.4	26.1	25.9	26.2	28.0	28.3	26.8
Navorngo												
1961-70	27.1	29.5	31.6	31.5	30.4	28.1	26.9	26.0	26.3	26.1	26.1	27.0
1971-80	27.6	30.2	32.4	33.0	31.3	28.4	27.1	26.7	27.0	28.7	28.4	27.0
1981-90	27.4	30.2	32.4	33.0	31.3	28.4	27.1	26.7	27.0	28.7	28.4	27.2
Tamale												
1961-70	27.9	30.2	31.1	29.9	26.6	26.8	26.2	25.7	25.5	27.3	28.0	27.5
1971-80	27.8	30.3	31.4	30.6	28.8	27.0	26.3	28.1	26.2	27.4	27.9	26.7
1981-90	26.9	30.0	30.9	31.8	31.2	28.7	27.4	26.3	26.5	28.2	28.6	26.7
Wenchi												
1961-70	26.5	27.8	27.7	27.2	26.6	25.2	24.3	24.0	24.3	25.0	25.3	25.2
1971-80	26.1	27.9	27.9	27.2	26.6	25.3	24.4	24.3	24.7	25.5	25.7	25.0
1981-90	26.4	28.5	28.3	27.9	26.9	26.1	25.1	24.8	25.3	25.3	26.2	25.6
Kumasi												
1961-70	25.7	27.1	27.1	27.0	26.4	25.3	24.5	24.0	24.6	25.5	26.0	25.6
1971-80	26.2	27.7	27.6	27.3	28.8	25.6	24.6	24.0	24.9	25.6	26.4	25.7
1981-90	26.6	28.7	28.0	27.8	27.1	25.9	24.8	24.6	25.3	26.2	26.9	26.0
Koforidua												
1961-70	26.0	27.2	27.4	27.3	26.8	25.7	25.0	24.9	25.5	28.3	28.7	28.6
1971-80	26.6	27.6	27.6	27.3	27.1	25.8	24.9	24.0	25.7	26.4	26.6	25.9
1981-90	26.7	28.4	28.0	28.0	27.1	26.3	25.3	25.4	28.0	26.6	26.9	26.5
Ho												
1961-70	27.6	28.8	28.4	27.9	27.3	25.8	25.0	24.7	25.5	26.3	27.3	27.4
1971-80	28.0	28.9	28.8	26.2	27.1	26.1	25.5	25.2	25.8	26.7	27.7	27.2
1981-90	24.3	29.3	29.0	28.7	27.3	26.5	25.2	25.6	26.1	26.8	28.3	27.7
Accra												
1961-70	27.4	26.2	28.0	28.9	27.4	25.9	25.0	24.7	25.4	26.3	27.2	27.4
1971-80	27.9	28.3	28.3	28.1	27.5	26.2	25.2	25.0	25.0	26.7	27.6	27.4
1981-90	28.0	28.8	28.9	28.9	28.0	27.1	25.8	25.7	26.1	27.0	28.0	27.8
Saltpond												
1961-70	27.1	27.8	27.9	28.3	27.6	26.2	25.3	24.6	24.9	26.3	27.2	27.2
1971-80	26.8	27.5	27.5	27.3	26.8	25.6	24.6	24.0	24.7	25.8	26.7	26.5
1981-90	26.4	27.6	27.3	27.5	26.8	25.7	24.8	24.5	26.0	25.9	28.9	26.6
Takoradi												
1961-70	24.3	27.3	27.4	27.6	27.0	26.2	25.2	24.6	27.0	25.7	26.4	26.7
1971-80	26.7	27.3	27.5	27.4	27.0	25.9	25.0	24.5	26.1	25.8	26.6	26.6
1981-90	26.7	27.7	28.0	28.1	27.4	26.6	25.8	25.3	25.7	26.5	27.0	28.8
Axim												
1961-70	26.8	27.5	27.5	27.4	27.0	26.0	25.3	26.1	25.1	25.8	26.5	26.7
1971-80	26.7	27.4	27.5	27.2	26.6	25.7	26.1	24.8	25.0	25.9	26.3	26.3
1981-90	26.7	27.8	27.9	28.0	26.8	26.1	25.4	25.0	25.3	26.2	26.7	26.7

A more detailed development analysis of the monthly mean temperatures for these three recent decades was carried out; but for this, Wenchi, Takoradi, and Koforidua were substituted for Yendi, Kete-Krachi, and Ada. The data are presented in Table 2. Table 10 gives a summary of the analysis of variance.

Discussion and conclusions

Among the various factors that affect or contribute to climate, by far the most important ones relate to temperatures; in fact, temperature is the most significant climate indicator, and certainly along with rainfall. That there is at present a global warming evolution is an over-whelming consensus of all scientists; specifically, a temperature increase of 2-5 °C over the next century has been projected. Climate change is also influenced, but to a lesser extent, by economic development, deforestation, and urbanization or industrialization. Radiations, 'greenhouse' gases, carbon dioxide and methane, all of which are direct products of industrialization, have also been blamed as colluding culprits. Hence, the Second World Climate Conference (1990), cautioned developing countries to avoid Western model developmental pathways to industrialization; but rather, to adopt efficient, clean, and environmentally benign technologies. They were as well beckoned to follow only ecologically sustainable programmes of development; given that the stresses and constraints undermining developing countries render them the most vulnerable to all the negative impacts of global warming.

Ghana, as a developing and agricultural tropical country, has not considered herself a priviledged exception to these ominous but candid forebodings. Hence, some efforts are already under way to adjust to these developments; these include a workshop on climatic change and its impact on water resources, held in Accra in March, 1993. The truth is, the climatic change in Ghana has already affected the coastal landscapes and the rainfall pattern drastically; this has led to periods of serious droughts, such as in 1994. It is, therefore, necessary to take some empirical stock of the climate profile locally; to ascertain the significance or realities of these developments with a view to evolving timely safeguards and strategies of accommodation. It is important that in determining the trend of climatic change, the shortest possible time from within which a change becomes significant, is defined; lest, one be overtaken by a decade or a year too late or too early. Climatologists use units of 30-year periods for studying and analyzing climatic changes; however, in the present studies, shorter 10-year periods have also been compared for the significance of temperature changes in Ghana.

The ANOVA results in Tables 3, 4 and 5 show that differences between 1931-60 temperatures and

TABLE 3
ANOVA table comparing mean monthly maximum temperatures in Ghana: 1931-60 vrs 1961-90

Source of varation	*DF*	*Sum of squares*	*Mean squares*	*F-ratio*
Synotic stations	10	751.50	75.15	144.89***
Months	11	1112.60	101.15	195.01***
Eras	1	6.00	6.00	11.57***
Experimental error	241	125.00	-	
Total	263	1995.10	-	-

TABLE 4
ANOVA table comparing mean monthly minimum temperatures in Ghana: 1931-60 vrs 1961-90

Source of varation	*DF*	*Sum of squares*	*Mean squares*	*F-ratio*
Synotic stations	10	183.90	18 39	27.94***
Months	11	245.17	22.29	33.86***
Eras	1	4.80	4.80	7.29***
Experimental error	241	158.63	0.66	-
Total	263	592.50	-	-

TABLE 5
ANOVA table comparing monthly mean temperatures in Ghana: 1931-60 vrs 1961-90

Source of varation	*DF*	*Sum of squares*	*Mean squares*	*F-ratio*
Synotic stations	10	139.71	13.97	41.49 ***
Months	11	446.69	40.61	120.58 ***
Eras	1	5.05	5.05	14.99 ***
Experi-mental error	241	81.16	0.34	-
Total	263	672.61	-	-

TABLE 6
Mean temperatures in Ghana: 1931-60 and 1961-90 eras

	1931-60	*1961-90*	*Standard Error*
Mean maximum	31.55	31.85	± 0.0062
Mean minimum	22.43	22.70	± 0.0087
Mean average	26.99	27.77	± 0.0079

1961-90 temperatures were highly significant; this relates to the monthly maximum, the monthly minimum, and inevitably to the monthly mean temperatures. The differences are also quite evident in the graphs of Fig. 1 and 2; and, in Table 6 which shows the overall means for the two eras. Ontoyin (1933), however, did not attempt any statistical comparisons between temperatures for the 1931-60 and 1961-90 eras; pointing to the seemingly sizable difference between the lengths of the available records as his reason. Admittedly, longer 1931-60 records would have been preferable, furthermore, it certainly would matter if inclusion of the missing 1931-60 data would generally make a determining change or impact on mean temperatures within that era. But then, climatologists contended that the climate process could be considered practically stationary in the context of a short frame, within the order of some 30 years, which would thus cover the subsample of some 10 years used out of the 1931-60 records.

TABLE 7
Mean temperatures for 1961-70,1971-80, 1981-90 in Ghana (^{o}C)

Synoptics stations	*1961-70*	*1971-80*	*1981-90*
Navrongo	27.35	27.53	28.03
Tamale	28.37	28.56	28.98
Tamale	27.89	28.04	28.32
Wenchi	25.66	25.88	26.37
Kumasi	25.75	26.05	26.49
Koforidua	26.33	26.37	26.75
Ho	26.83	27.08	27.42
Accra	26.82	26.99	27.50
Saltpond	26.69	26.15	26.24
Takoradi	26.45	26.28	26.52
Axim	26.39	26.20	26.52

(average s.e. of means = ± 1.914)

TABLE 8
ANOVA table comparing 1961-70/1971-80/1981-90 decade mean temperatures

Source of varation	*DF*	*Sum of squares*	*Mean squares*	*F-ratio*
Decades	2	1.5384	0.7682	10.96***
Region	10	23.6420	2.3642	33.74*
Error	20	1.4014	0.0701	-
Total	32	26.5818	-	-

TABLE 9
Duncan multiple range tests

Decades	*1961-70*	*1971-80*	*1981-90*
Means	*26.77*	*26.83*	27.22 +

+ Means underscored by the same line are not significntly different.

TABLE 10
ANOVA table comparing monthly mean temperatures in Ghana: 1961-70,1971-80,1981-90

Source of varation	*DF*	*Sum of squares*	*Mean squares*	*F-ratio*
Main plots				
Regios	10	139.71	13.97	41.49 ***
Months	11	5830.13	53.01	58.25 ***
Errors	110	99.82	0.91	-
Sub-plots				
Decade/town	2	9.98	4.99	7.34 **
Interaction	20	13.67	0.68	0.02 ns
Error	243	10682.46	43.96	-
Total	395	11656.76	-	-

ably not differing significantly from the overall average temperatures for the entire 1931-60 era. Thus, the rather limited 1931-60 records used for the anlyses would appear acceptable; at least, for practical purposes.

Actually, of the 22 synoptic stations in Ghana, records are adequate for just 11 of them for the 1931-60 era; these date from just about 1945 thereon, reflecting the later end of the era. If the prevailing trend of temperature increase is anything to go by, these records would most likely reflect the warmer later periods of the era. That is, had records for the earlier part of 1931-60 been available for inclusion, mean temperatures for that era would most likely have been lower than those actually used for the analyses, and would have even boosted the significance of the differences between temperatures for the two eras.

For the data used in the present exercise, the difference between the 1931-60 and the 1961-90 temperatures would appear to be even a conservative estimate; and as such, its assessment is all the more definitive and empirical. Given that the later half of the 1931-60 reflected the warmer part of that era, the rather limited records used could be deemed as being all the more expedient; particularly, as the temperatures involved, turned out to be significantly different from those for warmer 1961-90 era. In any case, such limited records would appear to be the next best things, under constraints of missing data.

Results in Tables 8 and 10 indicate that differences between temperatures of the last three 1961-70, 1971-80, and 1981-90 decades were, highly significant. Table 9 shows that temperatures for the last decade were significantly higher that those of the previous two; and that temperatures for the 1971-80 decade were higher, albeit not significantly so, than during the 1961-70 decade. That is, as currently as the last three decades, the culminating temperature developments in Ghana were quite evident.

Furthermore, the temperature developments over the last three decades may be taken to illustrate significant temperature or climate changes within a much shorter time frame than has been presumed. As explained above, climatologists have contended that the climate process, when viewed on a short scale of about 30 years, could be considered practically stationary; within which no significant variations might be expected, unless as might derive from some major epoch developments. In any case, the Second World Climate Conference (1990) actually proposed intensified efforts towards prediction in short-term climate variability. It was even resolved that projections of regional climate and climate impacts are much less certain than those on a global scale. These would thus make the significant temperature developments in Ghana defined in the present studies, especially over the last three decades, all the more noteworthy.

One might, however, note that for the Kete-Krachi, Saltpond, and Axim regions there were some spells of, rather, 1931-60 higher temperatures (Fig 1). In the case of the Kete-Krachi region, 1931-60 had distinctly higher mean maximum temperatures, and generally higher monthly means; however, the 1961-90 mean monthly minima followed the mainstream of being higher for all the months. Within the Saltpond region, 1931-60

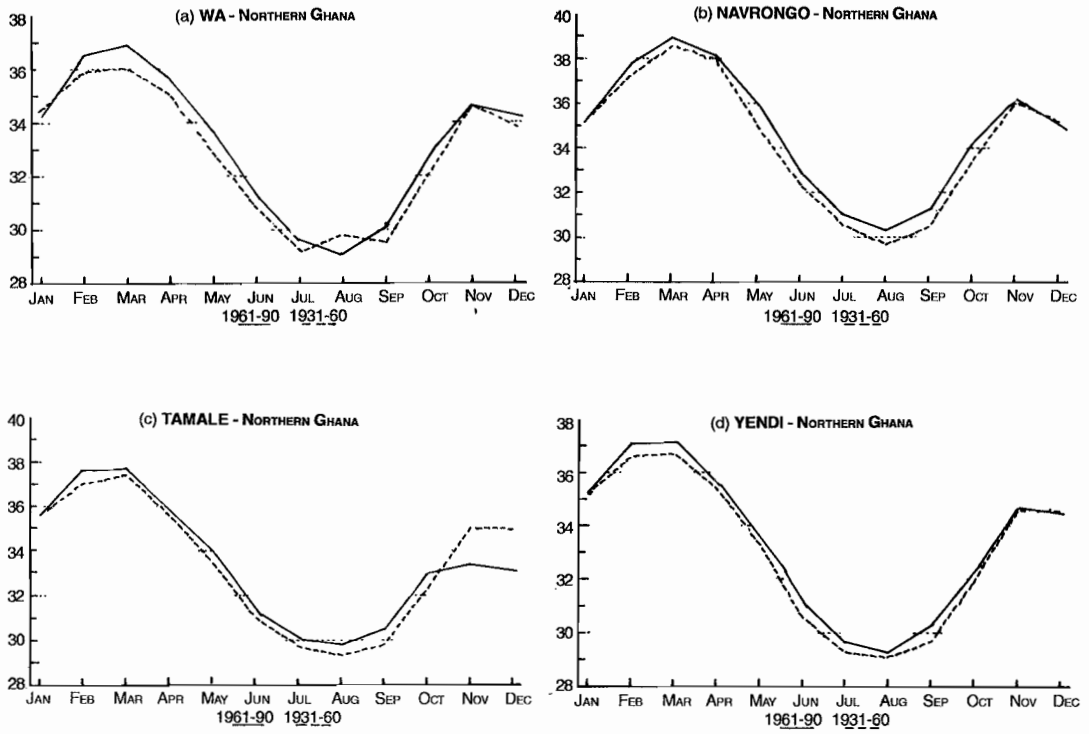

Fig.1 (a-d) Monthly mean maximum temperatures (^{o}C) in Ghana: 1931-60, 1961-90

maximum, minimum, and average temperatures were only slightly higher. It might be pertinent to note that Saltpond has experienced considerable economic and urban decline from the 1960s to the present; in case this could account for the reverse climate trend there. The temperature picture for the Axim area, however, involves the two eras outshining each other for different periods of the year.

Ontoyin (1993) suggested that within these regions which experienced some higher 1931-60 temperatures rather, conditions in the last 30 years might have been more cloudy and rainy. In any case, one thing that happens to be common about these odd regional points is their low altitude: Kete-Krachi, 67 m (MSL), Saltpond, 2 m (MSL), and Axim 9 m (MSL); this contrasts with the relatively high altitudes of over 150 meters for the other regions. However, the exception would appear to be Accra; which, with a low altitude of only 59 m, experienced distinctly high 1961-90 temperatures all round. Evidently, the cosmopolitan and industrialized profile of the Accra region could also be an important factor.

The present studies thus appear to provide some empirical evidence that there has been a general significant soaring of temperatures in Ghana, from about 1945, up to 1990; these temperature developments possibly date much further back from the 1930s. The increasing trend has been evident even over the last three decades. As Ontoyin (1993) concluded, these developments might involve the current global warming trend, deriving from the present 'greenhouse'

saga; urbanization and the modest pace of industrial development in Ghana could also be probably contributing factors, albeit, certainly meriting future investigation.

It is also evident that differences between temperatures for the various months throughout the year and temperatures for the various synoptic stations, were highly significant (Tables 3, 4, 5, 8 and 10); these were, however, as expected across the different regions throughout the country, and over the different months of the year.

peratures have attained their highest peak in all regions, invariably, around February and March; and for the Axim area, consistently in April. Thence, they decline steadily to a minimum in August, just as regularly, in virtually all regions; to be followed by a rise to a typical second but smaller peak in November, throughout the country. These trends in the temperature cycle have been that invariably steady across the entire country during the past 5-6 decades. Would that this temperature landscape in Ghana could serve as a

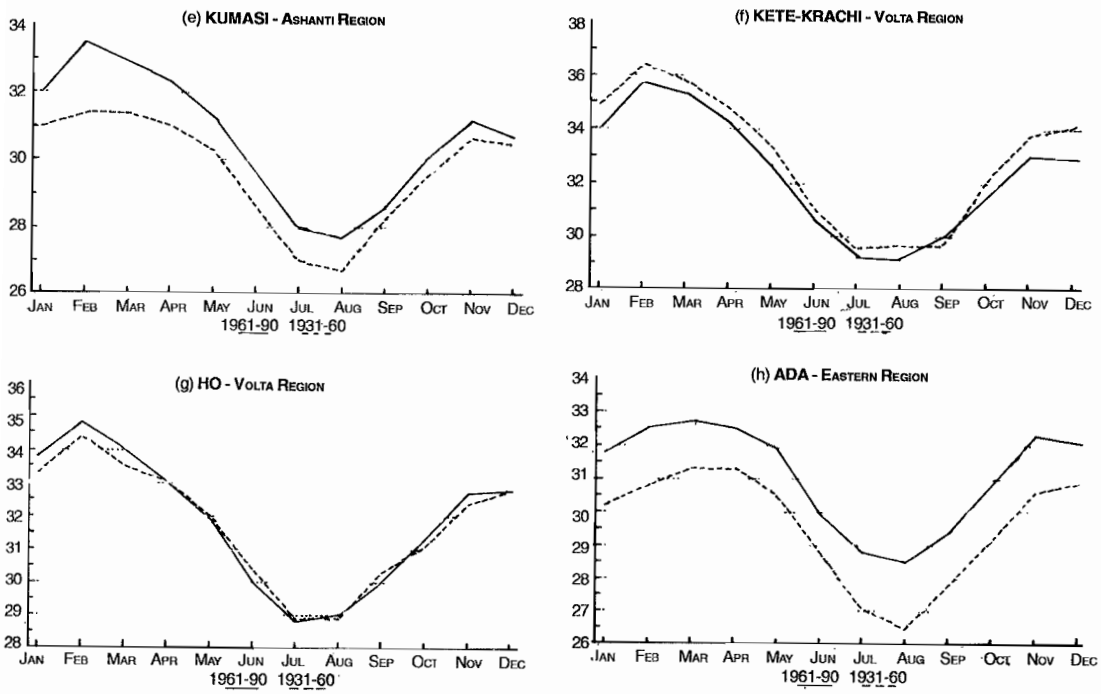

Fig.1 (e-h) Monthly mean maximum temperatures (^{o}C) in Ghana: 1931-60, 1961-90

In any case, such noteworthy developments over the two 30-year eras and the last three decades notwithstanding, the yearly temperature cycle in Ghana, as such, has remained quite steady throughout all the regions. (Fig. 1 and 2). Temreference model for the West African subregion.

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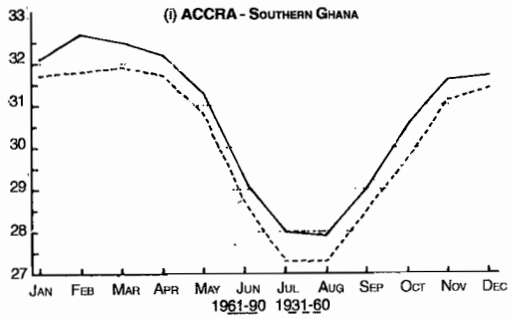
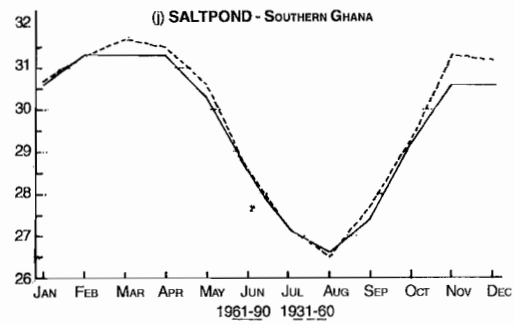
The author wishes to express his sincere gratitude to the Ghana Meteorogical Services Depart-





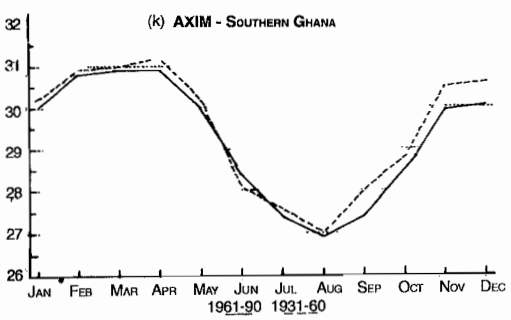
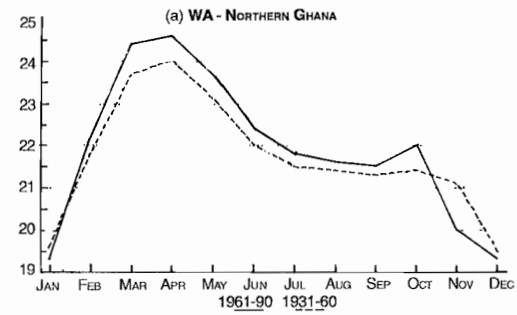
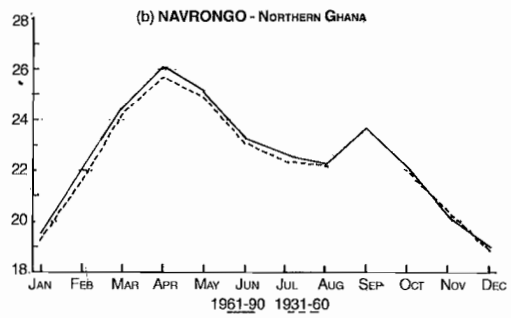


Fig.1 (i-k) Monthly mean maximum temperatures (^{o}C) in Ghana: 1931-60, 1961-90





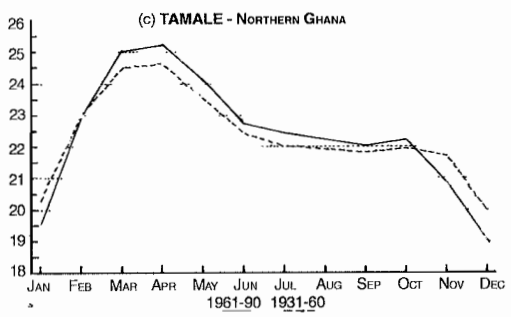


Fig.2 (a-c) Monthly mean minimum temperatures (^{o}C) in Ghana: 1931-60, 1961-90

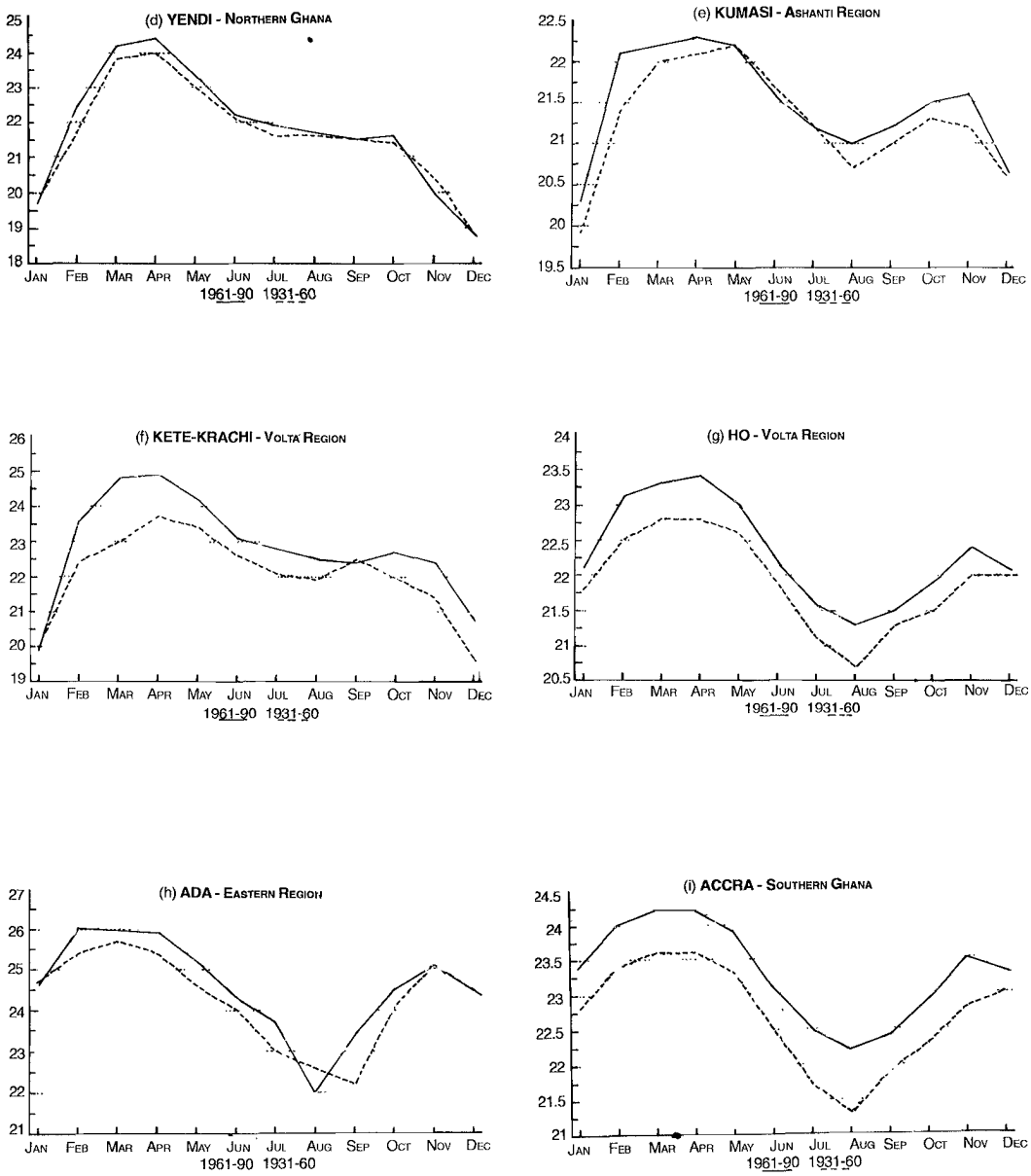


Fig.2 (d-i) Monthly mean minimum temperatures (^{o}C) in Ghana: 1931-60, 1961-90

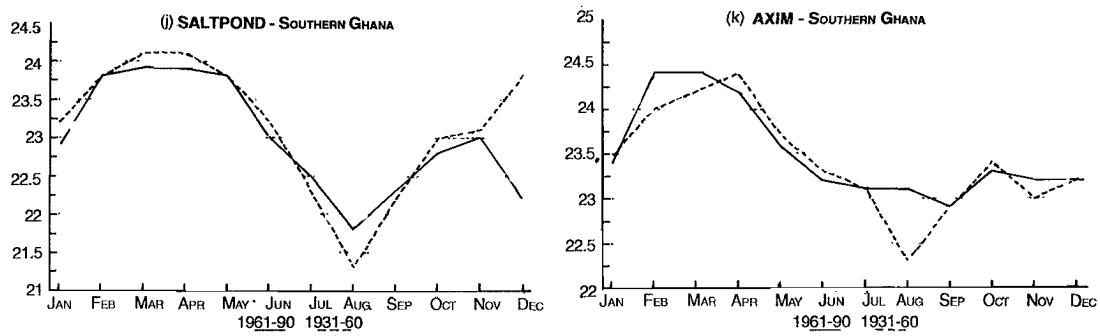


Fig.2 (j-k) Monthly mean minimum temperatures (^{o}C) in Ghana: 1931-60, 1961-90

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