



RESEARCH ARTICLE

OPEN ACCESS

TEMPERATURE TRENDS IN THE LOWER LATITUDES COUNTRIES OF THE CONTINENT OF AFRICA (1901 – 2015)

***Rafael Infante**

Caribbean University, Puerto Rico

ARTICLE INFO

Article History:

Received 28th May, 2019
Received in revised form
20th June, 2019
Accepted 24th July, 2019
Published online 28th August, 2019

Key Words:

Global warming; Climate change;
Temperature trends;
Lower latitudes; Africa.

ABSTRACT

The temperature trends from 1901 to 2015 for the African countries located between the latitudes 15° North to 15° South are presented. The area of study has different climate and topographic characteristics. The world's second largest tropical forest is located in this area, is also an area of unique biodiversity, and a significant carbon sink. The data shows a temperature increase with time and a variable temperature increase rate. Average temperature differences of up to 2.1°C are observed between the years 2000 to 2015 compared to the years 1901 to 1999. The temperature increase rates with time are mostly positive and the increase rates are higher for the years 2000 to 2015 compared to the years 1901 to 1999. Comparison of the increase in temperature between inland countries and coastal countries showed no significant differences. Average temperature increase rates were positive for the area studied with a much sharper rate observed since 1970. The warming trend observed agrees with projection and global models.

Copyright © 2019, Rafael Infante. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Citation: Rafael Infante. 2019. "Temperature trends in the lower latitudes countries of the continent of Africa (1901 – 2015)", *International Journal of Development Research*, 09, (08), 29139-29147.

INTRODUCTION

Over the past 50 years, the average global temperature has increased at the fastest rate in recorded history. Experts see the trend is accelerating: All but one of the 16 hottest years in NASA's 134-year record have occurred since 2000. The potential effects of global warming have increased the interest within the scientific community to study temperature and precipitation trends for different parts of the world. The impacts of global warming are being felt across the globe. Extreme heat waves have caused tens of thousands of deaths around the world in recent years. And in an alarming sign of events to come, Antarctica has been losing about 134 billion metric tons of ice per year since 2002. This rate could speed up if we keep burning fossil fuels at our current pace, some experts say, and causing sea levels to rise several meters over the next 50 to 150 years. In order to predict future effects of global warming, especially in the most vulnerable places, temperature trends are required. Presented here are temperature trends for the lower latitudes countries in Africa. The repercussions of climate change will be felt in various ways throughout both natural and human systems in the

African countries located between the latitudes 15° North to 15° South. Africa has been identified as one of the parts of the world most vulnerable to the impacts of climate change (IPCC, 2014; Niang, 2014 and Serdeczny, 2015). This African region is particularly threatened by climate change due to high climate variability and the economic and institutional resources to respond to climate changes. The most recent IPCC report (IPCC, 2013) reviewed commitments made by countries following the Paris Agreement, which established the collective goal to limit global warming to well below 2° C above pre-industrial levels and to further pursue efforts to limit the temperature increase to 1.5° C. The countries located between the latitudes 15° North to 15° South of the African continent has mainly a wet tropical climate, with moderate to extremely heavy rainfall. To the north and south of this tropical climate are belts with a dry season. Other environmental factors, such as winds, ocean currents, and the surface features of the land, create variations within these climate belts, giving different regions of Africa their particular local climates. One of the chief climate shapers in this region is the Intertropical Convergence Zone, or ITCZ, which is the point where warm, moist tropical air masses meet. The regular cycle of movements of the ITCZ carry it north of the equator between March and June and south of the equator between September and December. These movements

***Corresponding author: Rafael Infante,**
Caribbean University, Puerto Rico

Table 1. Area of study – Africa Continental Countries between the Latitudes 15°N to 15°S

Country	Location	Distance from the Equator	Population/Area	Climate
Angola	-14.61 18.48	1,390.37 Km	25,789,024/ 1,246,700 Km ²	Angola's climate is characterized by two seasons: rainfall from October to April and drought from May to August
Benin	11.13 2.937	1,056.68 Km	10,872,298/ 114,763 Km ²	Benin's climate is hot and humid. Benin has two rainy and two dry seasons. The principal rainy season is from April to late July, with a shorter less intense rainy period from late September to November.
Burkina Faso	14.93	1,390.37 Km	20,000,000/ 274,000 Km ²	The climate is generally sunny, hot, and dry. Two principal climate zones can be distinguished. The north is semiarid steppe. To the south the climate becomes increasingly of the tropical wet-dry type.
Burundi	-0.233 -3.215 30.55	389.30 Km	10,524,117/ 27,834 Km ²	Burundi in general has a <u>tropical</u> highland climate. Temperature varies considerably from one region to another, chiefly as a result of differences in altitude. Rain is irregular, falling most heavily in the northwest. Dry seasons vary in length, and there are sometimes long periods of drought. However, four seasons can be distinguished: the long dry season (June–August), the short wet season (September–November), the short dry season (December–January), and the long wet season (February–May).
Cameroon	7.367 12.65	667.38 Km	23,439,189/ 475,442 Km ²	The climate is tropical, semi-arid in the north, and humid and rainy in the rest of the country. Almost everywhere, there is a dry season in winter and a rainy season in summer due to the African monsoon.
Central African Republic	5.527 23.19	735.35 Km	4,594,621/ 622,984 Km ²	The climate is tropical, with abundant rainfall. There is one rainy season (December– March) and one long, hot, dry season (April–November).
Chad	11.40 16.17	1,668.45 Km	13,670,084/ 1,284,000 Km ²	Chad has a hot and tropical climate. The rainy season runs May–October. The dry season is often windy and cooler during the evenings.
Cote d'Ivoire	7.540 5.547	838.67 Km	24,905,843/ 322,463 Km ²	The climate of Ivory Coast is generally warm and humid, ranging from equatorial in the southern coasts to tropical in the middle and semiarid in the far north. There are three seasons: warm and dry (November to March), hot and dry (March to May), and hot and wet (June to October).
Democratic Republic of the Congo	-0.997 22.0	278.07 Km	78,736,153/ 2,345,409 Km ²	Two kinds of climate: - equatorial, hot and humid all year round with no dry season, in the central area crossed by the; - tropical, hot all year round but with a dry season, usually of short duration, in both the areas north and south of the equator. The dry season occurs in opposite periods, from December to February north of the equator, and from June to September south of the equator.
Djibouti	11.97 43.29	1,316.22 Km	884,017/ 23,200 Km ²	Djibouti is entirely within the tropical zone. Fair weather dominates the area; however, certain seasons, particularly summer, have a dust haze. Djibouti's desert climate has two seasons. During the May through September summer season, temperatures range from 32°C to 49°C The winter season lasts from October through April and has sparse rainfall, cool breezes, and temperatures near 20°C.
Equatorial Guinea	1.884 9.967	183.62 Km	1,222,442/ 28,050 km ²	The climate is typically equatorial, with high temperatures, heavy rainfall, and much cloud cover most of the year. Local variations are due to differences in elevation and proximity to the sea.
Eritrea	15.11 36.66	1,668.45 Km	4,954,645/ 117,600 Km ²	The wet seasons are from February to June and from September to December. Rainfall is higher on the coast than inland. The climate of Eritrea is tropical desert on the coast and the eastern plain, mild and semiarid in the mountainous belt, and tropical and semi-arid in the south-west. From June to September, is the rainy season, especially in the central and southern inland part.
Ethiopia	7.362 46.61	1,001.07 Km	102,403,196/ 1,104,300 Km ²	Ethiopia is in the tropical zone. It has three different climate zones according to elevation. Kolla (Tropical zone) - is below 1830 meters in elevation and has an average annual temperature of about 27°C The Danakil Depression (Danakil Desert) is about 125 meters below sea level and the hottest region in Ethiopia where the temperature climbs up to 50°C. WoinaDega (Subtropical zone) - includes the highlands areas of 1830 - 2440 meters in elevation has an average annual temperature of about 22°C. Dega (Cool zone) - is above 2440 meters in elevation with an average annual temperature of about 16°C.
Gabon	-0.844 14.18	981.56 Km	1,979,786/ 267,667 Km ²	The climate is hot and humid all year round in the north and in inland areas while in the central and southern part of the coast, the temperature becomes cooler during the dry season. The dry season is from May to September.
Gambia	13.67 -14.89	1,501.60 Km	1,857,181/ 10,689 Km ²	Tropical climate. A hot and rainy season normally lasts from June until November, but from then until May, cooler temperatures predominate, with less precipitation.
Ghana	7.383 -1.367	900.96 Km	28,308,301/ 239,567 Km ²	The <u>climate</u> of Ghana is <u>tropical</u> and there are two main <u>seasons</u> : the wet and the dry seasons, Rainy season from March to November.
Guinea	11.30 -10.72	1,204.99 Km	11,628,972/ 245,836 Km ²	The climate is tropical and humid with a wet and a dry season. Guinea is one of the wettest countries in West Africa. The monsoon season with a southwesterly wind lasts from June to November; The dry season lasts from December to May.

.....Continue

Kenya	-2.632 40.20	128 Km	49,125,325/ 580,367 Km ²	Climate varies from tropical along the coast to temperate inland to arid in the north and northeast parts of the country. The rainy season occurs from March/ April to May/June. The dry season occurs from October to November/ December.
Liberia	4.635 -8.117	722.99 Km	4,503,000/ 111,369 Km ²	The climate is tropical, hot and humid all year round, with a rainy season from May to October due to the African monsoon, and pretty frequent rains in the other months, except in the short dry season that runs from December to February, which is more marked in the north.
Malawi	-13.65 33.94	1,501.60 Km	18,091,575/ 118,484 Km ²	Malawi has a sub-tropical climate, which is relatively dry and strongly seasonal. The warm-wet season stretches from November to April. The hot, dry season lasts from September to October.
Mozambique	-11.06 39.67	2,029.94 Km	28,829,476/ 801,590 Km ²	Mozambique has a tropical climate with two seasons, a wet season from October to March and a dry season from April to September. Climatic conditions, however, vary depending on altitude. Rainfall is heavy along the coast and decreases in the north and south.
Nigeria	11.37 5.810	2,002.14 Km	20,672,987/ 1,267,000 Km ²	The climate is desert in the north, semi-desert in the center, and semi-arid of the savanna in the south. The rainy season is in the period June-September.
Republic of the Congo	3.471 17.76	508.39 Km	5,125,821/ 342,000 Km ²	The climate is hot and humid in the river basin and cool and dry in the southern highlands, with a cold, alpine climate in the Rwenzori Mountains. South of the Equator, the rainy season lasts from October to May and north of the Equator, from April to November.
Rwanda	-2.470 29.58	222.46 Km	11,262,564/ 26,338 Km ²	In Rwanda, the climate is pleasantly warm all year round, with cool nights, because of the altitude. In fact, most of the country is located on a plateau, around 1,500 meters above sea level. Precipitation ranges from 100 to 140 cm per year depending on area. There's a dry season from June to August and a rainy season from September to May.
Senegal	13.91 -15.93	1,612.83 km	14,668,522/ 196,712 Km ²	Senegal has a tropical climate. The dry season (December to April). Dakar's annual rainfall of about 600 mm (24 in) occurs between June and October
Sierra Leone	8.616 -11.04	941.07 Km	7,075,641/ 71,740 Km ²	The climate is tropical, with two seasons determining the agricultural cycle: the rainy season from May to November, and a dry season from December to May. The average temperature is 26°C and varies from around 26° to 36°C during the year.
Somalia	5.152 46.20	667.38 km	11,031,386/ 637,657 Km ²	Due to Somalia's proximity to the equator, there is not much seasonal variation in its climate. Hot conditions prevail year-round along with periodic monsoon winds and irregular rainfall. The rains occur in two periods, which are caused by the zenith passages of the sun, from March to late May and from October to early December
Tanzania	-11.34 38.41	667.38 Km	55,572,201/ 947,303 Km ²	Climate varies greatly within Tanzania. In the highlands, temperatures range between 10 and 20°C during cold and hot seasons respectively. The rest of the country has temperatures rarely falling lower than 20°C. The hottest period extends between November and February (25–31 °C) while the coldest period occurs between May and August (15–20 °C). Annual temperature is 20 °C. The climate is cool in mountainous regions. Tanzania has two major rainfall regimes: one is unimodal (October–April) and the other is bi-modal (October–December and March–May).
Togo	9.950 1.050	963.99 Km	7,965,055/ 56,785 Km ²	The climate is generally tropical with average temperatures ranging from 23 °C on the coast to about 30 °C in the northernmost regions, with a dry climate and characteristics of a tropical savanna. To the south, there are two seasons of rain (the first between April and July and the second between September and November), even though the average rainfall is not very high.
Uganda	2.533 34.67	110.4 Km	41,487,965/ 241,038 Km ²	For the most of the year, Uganda is sunny with temperatures rarely rising above 29°C. The average temperature is about 26°C, with a maximum of 18-31oC and minimum of 15-23°C. Wet seasons are March–May and October-November; dry seasons are December to February and June to August.
Zambia	13.13 27.85	1,594.29 Km	16,591,390/ 752,618 Km ²	The climate of Zambia is tropical, modified by elevation. Most of the country is classified as humid subtropical or tropical wet and dry. There are two main seasons, the rainy season (November to April) corresponding to summer, and the dry season (May to October), corresponding to winter.

Table 2. Average Temperature Table for the Study Area (1901 – 1999)

Country	Avg. Temp. °C	Avg. Max. Temp. °C	Avg. Min. Temp. °C	Standard Deviation	% RSD	Temp. Increase Rate °C/yr (r ²) [^]
Angola	21.5	22.7	20.8	0.343	1.60	0.005980 (0.251)
Benin	27.4	28.9	25.6	0.555	2.03	0.005416 (0.055)
Burkina Faso	28.2	29.7	27.0	0.461	1.63	0.004293 (0.072)
Burundi	19.9	20.9	17.5	0.717	3.60	0.015566 (0.389)
Cameroon	24.7	25.8	23.9	0.347	1.40	-0.000330 (0.001)

.....Continue

Central African Republic	25.0	25.8	24.0	0.375	1.50	0.001717 (0.017)
Chad	26.6	27.7	25.6	0.376	1.41	0.001824 (0.019)
Cote d'Ivoire	26.4	27.2	25.4	0.326	1.23	0.000696 (0.004)
Democratic Republic of the Congo	24.0	24.8	23.4	0.263	1.10	0.005105 (0.310)
Djibouti	27.7	28.8	26.7	0.407	1.47	0.000555 (0.002)
Equatorial Guinea	24.6	25.2	24.0	0.244	0.992	0.001722 (0.041)
Eritrea	26.1	27.2	24.8	0.492	1.89	0.004105 (0.058)
Ethiopia	22.5	23.5	21.2	0.435	1.93	0.004268 (0.080)
Gabon	25.0	25.6	24.1	0.241	0.96	0.000283 (0.001)
Gambia	27.3	28.5	26.6	0.357	1.31	0.002387 (0.037)
Ghana	27.2	28.8	25.6	0.493	1.81	0.0004738 (0.076)
Guinea	25.7	26.6	25.0	0.291	1.13	-0.00014 (0.0002)
Kenya	24.1	25.8	22.2	0.703	2.92	0.014105 (0.332)
Liberia	25.4	26.1	24.6	0.301	1.19	-0.00255 (0.059)
Malawi	21.9	22.8	21.1	0.378	1.73	0.004146 (0.099)
Mozambique	23.7	24.5	22.9	0.352	1.49	0.004001 (0.106)
Nigeria	27.3	28.4	26.1	0.441	1.62	0.001316 (0.007)
Republic of the Congo	24.6	25.4	23.9	0.249	0.280	0.002379 (0.075)
Rwanda	18.9	19.9	16.6	0.724	3.83	0.015853 (0.395)
Country	Avg. Temp. °C	Avg. Max. Temp. °C	Avg. Min. Temp. °C	Standard Deviation	% RSD	Temp. Increase Rate °C/yr (r ²) [^]
Senegal	27.9	29.2	26.9	0.424	1.52	0.005458 (0.137)
Sierra Leone	26.0	26.8	25.4	0.297	1.14	-0.00216 (0.044)
Somalia	26.8	27.5	26.1	0.242	0.903	0.000327 (0.002)
Tanzania	22.0	23.0	20.0	0.619	2.81	0.01359 (0.398)
Togo	27.0	28.6	25.2	0.553	2.05	0.004496 (0.054)
Uganda	22.2	23.4	20.0	0.731	3.29	0.016144 (0.403)
Zambia	21.7	22.8	20.7	0.430	1.98	0.004676 (0.098)

[^]r² – square of the correlation coefficient

determine the number and timing of rainy seasons throughout Africa. Areas within the path of the ITCZ have two rainy seasons; those at the northern and southern reaches of the ITCZ's path have only one rainy season. A significant rise in African temperatures occurred between 1979 and 2010. This finding was described based on natural variability of the climate and/or as a result of human activity and not a result of variations in the El Niño-Southern Oscillations that has previously shown to affect climate in some parts of Africa (Collins, 2011). Additional studies conducted on the African continent regarding temperatures changes focus on individual countries or a small area. African climate varies considerable across the continent. Increasing temperature trends in coastal weather stations were observed in South Africa when compared to inland stations during the time period of 1940 to 1989 (Muhlenbruch-Tegen, 1992). This was attributed to an increase in sea surface temperature (SST), but the inland stations had no significant increasing temperatures. Located within the study area is The Congo Basin. This area is comprised by the Democratic Republic of the Congo, Republic of the Congo, and Central African Republic.

It holds the world's second largest tropical rainforest, home to rare biodiversity, and acts a carbon sink, mitigating greenhouse gases emission. Meteorological data are scarce for the region posing limits to climate model projections, which are highly uncertain for the region. Nevertheless, all models consistently indicate that temperatures will rise between 1.4-2.7°C by the 2050s (USAID, 2018). Other recent studies (CSC, 2013), indicates that for the near surface air temperature, all assessed models agree on a substantial warming towards the end of the century in all seasons of the year regardless of the underlying scenario. On an annual basis a warming in the range of +1.5 and +3°C for the low and in the range between +3.5 and +6°C for the high emission scenario can be likely towards the end of the 21st century. In projected temperature increase is slightly above average in the northern parts of the region and slightly below average in the central parts. For temperature extremes (frequency of cold/hot days and nights) all models agree on a decrease/increase in the future. The countries included in this study, their locations, demographics, and local climate summary are included in Table 1. Seven of the ten most climate change-threatened countries are located within the study area. In this study we have compared average temperature data for the counties in the study area from the years 1901 to 1999 to the years 2000 to 2015. We have calculated temperature increase rates. Differences in average temperatures between inland countries and countries bordering a water body are discussed. The results are also compared to the Paris Agreement goal for global warming. The data also will aid to validate models and temperature projections for the area. For this area, models tend to disagree with one another in their representation of historical climate, leading to large amounts of uncertainty about the current and future climate system (Washington, 2013 and Creese, 2016).

MATERIALS AND METHODS

Average temperatures were obtained from The World Bank Group – Climate Change Knowledge Portal¹². All calculations: averages, maximum and minimum temperatures; standard deviations; slopes and correlation coefficients were performed using an Excel spreadsheet. Graphs were done also using the graphic capabilities of the Excel spreadsheet.

RESULTS

A summary of the average temperature, average maximum temperature, average minimum temperature, and temperature increase rate from 1901 to 1999 for the study area is shown in Table 2. A summary of the average monthly temperature, average maximum temperature, average minimum temperature, and temperature increase rate from 2000 to 2015 for the study area is shown in Table 3. A summary of the average temperature and temperature increase rates differences between 1901 to 1999 and 2000 to 2015 is shown in Table 4. In order to determine the influence of the sea surface temperature on the country average temperature we divided the countries studied into two groups: countries that have a coast and inland countries. We further divided the countries that have coast into those to the West that are bordered by the Atlantic Ocean and those to the East that are bordered by the Indian Ocean or the Red Sea. Results are shown in Tables 5, 6, 7 and 8. The average annual temperatures for all countries within the study area were summarized in periods of ten years starting from 1901 to 2010. This is done to further visualize the temperature increase rates in the area. The first group covered the years of 1901 to 1909, 9 years period; all other groups up to 2010 were 10 years periods. Results are shown in Tables 9 and 10 and are summarized in Figures 1 and 2 to further highlight the changes.

DISCUSSION

The average temperature increase among the study area between the periods of 2000 to 2015 compared to 1901 to 1999 was 1.17°C. The maximum increase was observed for Uganda, 2.1°C and the minimum increase was 0.5°C for Gabon, an indication of the gradual temperature increase that has occurred in the last one hundred and fifteen years. Seven out of the thirty countries studied were not in compliance with the Paris Agreement (average temperature raise of over 1.5°C), eleven had averages temperature rise between 1.0° and 1.4°C, and twelve had an average temperature raise of less than 1°C. The temperature increase rates for the period 1901 to 1999 for most of the countries were positive, only four had negative temperature increase rate. The temperature increase rates for the period 2000 to 2015 for most of the countries were positive, only six countries had negative temperature increase rate. A negative increase rate indicates that the average annual temperatures are not increasing. The temperature increase rates were significantly higher for the time period 2000 to 2015. However, the correlation coefficients obtained were not significant to determine the increase in temperature with time. The average temperature increase for all countries bordered by an ocean was 1.2°C compared to 1.3°C for average temperature increase for inland countries. The average temperature for the eastern countries bordering the Indian Ocean and the Red Sea is 1.3°C and for the western countries bordering the Atlantic Ocean is 0.9°C. There is a significant difference between these two averages indicating a difference in sea surface temperatures between the bodies of water and a bigger influence is eastern countries climate. Eritrea, borderer by the Red Sea, had the higher temperature increase between the periods 1901 to 1999 and 2000 to 2015. The sea surface temperature of the Red Sea is usually higher than in the Atlantic and Indian Ocean thus this body of water had a bigger influence in the country climate. In the study area there is only a slight increase in the average temperature

Table 3. Average Temperature Table for the Study Area (2000 – 2015)

Country	Avg. Temp. °C	Avg. Max. Temp. °C	Avg. Min. Temp. °C	Standard Deviation	% RSD	Temp. Increase Rate °C/yr (r ²) [^]
Angola	22.2	22.7	21.7	0.276	1.24	-0.04577 (0.443)
Benin	28.0	28.3	27.7	0.170	0.607	0.019463 (0.298)
Burkina Faso	28.8	29.2	28.3	0.234	0.813	0.014462 (0.087)
Burundi	21.0	21.6	20.6	0.297	1.41	-0.02988 (0.229)
Cameroon	25.0	25.3	24.7	0.164	1.40	0.012246 (0.126)
Central African Republic	25.5	25.9	25.2	0.222	0.871	0.014445 (0.096)
Chad	27.6	28.5	26.6	0.528	1.91	0.001369 (0.0004)
Cote d'Ivoire	26.8	27.2	26.4	0.192	0.716	0.009867 (0.059)
Democratic Republic of the Congo	24.6	25.1	24.4	0.204	0.829	-0.01113 (0.067)
Djibouti	28.4	29.1	27.9	0.322	1.34	0.004142 (0.376)
Equatorial Guinea	25.0	25.2	24.8	0.103	0.412	0.001386 (0.00007)
Eritrea	27.1	27.7	26.7	0.300	1.10	0.038198 (0.367)
Ethiopia	23.3	23.8	22.9	0.262	1.12	0.033925 (0.367)
Gabon	25.4	25.5	25.2	0.0872	0.003	0.000565 (0.001)
Gambia	28.1	28.5	27.7	0.199	0.078	0.001729 (0.002)
Ghana	27.7	28.1	27.4	0.173	0.625	0.015715 (0.187)
Guinea	26.3	26.6	25.9	0.195	0.741	0.007331 (0.032)
Kenya	25.3	25.6	24.9	0.205	0.810	0.014863 (0.119)
Liberia	25.7	26.2	25.5	0.181	0.704	0.004887 (0.059)
Malawi	22.5	23.1	22.1	0.273	1.21	0.00344 (0.004)
Mozambique	24.3	24.9	23.8	0.265	1.09	0.008525 (0.023)
Nigeria	28.0	28.7	27.4	0.353	1.26	0.034063 (0.212)
Republic of the Congo	24.9	25.3	24.6	0.149	0.590	0.010074 (0.104)
Rwanda	20.2	20.8	19.8	0.322	1.59	-0.03834 (0.322)
Senegal	28.7	29.2	28.4	0.188	0.655	0.00634 (0.026)
Sierra Leone	26.5	26.9	26.1	0.185	0.698	0.006575 (0.029)
Somalia	27.1	27.6	26.7	0.202	0.745	0.019452 (0.210)
Tanzania	23.0	23.4	22.5	0.218	0.948	-0.00529 (0.013)
Togo	27.5	27.8	27.3	0.168	0.611	0.017726 (0.252)
Uganda	23.8	24.3	23.4	0.294	1.24	-0.02721 (0.194)
Zambia	22.4	23.4	22.0	0.345	1.54	-0.01889 (0.068)

[^]r² – square of the correlation coefficient

increase for inland country compared to coastal countries. Thus the influence in the country climate caused by the adjacent body of water is not significant when compared to inland countries. Four out of eleven inland countries had negative temperature increase rates ratio from the periods between 1901 to 1999 and 2000 to 2015. Only two out of nineteen ocean bordered countries had negative temperature increase rates ratio from the periods between 1901 to 1999 and 2000 to 2015.

These countries were Angola bordered by the Atlantic and Tanzania bordered by the Indian Ocean. It is well know that the sea affects the climate of a place. Coastal areas are cooler and wetter than inland areas. Clouds form when warm air from inland areas meets cool air from the sea. The center of continents is subject to a large range of temperatures. There was an overall positive trend in temperature with time during the years 1901 to 2009. The overall temperature increase rate from 1901 to 2009 was 0.06 °C/Decade and the correlation

Table 4. Average temperature differences from the periods between 1901 to 1999^a and 2000 to 2015^b. Temperature increase rates ratio from the periods between 1901 to 1999^a and 2000 to 2015^b

Country	Avg. Temp. °C ^a	Avg. Temp. °C ^b	ΔT °C	Temp. Increase Rate °C/yr ^a	Temp. Increase Rate °C/yr ^b
Angola	21.5	22.7	1.2	0.005980	-0.04577
Benin	27.4	28.3	0.9	0.005416	0.019463
Burkina Faso	28.2	29.2	1.0	0.004293	0.014462
Burundi	19.9	21.6	1.7	0.015566	-0.02988
Cameroon	24.7	25.3	0.6	-0.000330	0.012246
Central African Republic	25.0	25.9	0.9	0.001717	0.014445
Chad	26.6	28.5	1.9	0.001824	0.001369
Cote d'Ivoire	26.4	27.2	0.8	0.000696	0.009867
Democratic Republic of the Congo	24.0	25.1	1.1	0.005105	-0.01113
Djibouti	27.7	29.1	1.4	0.000555	0.04142
Equatorial Guinea	24.6	25.2	0.6	0.001722	0.001386
Eritrea	26.1	27.7	1.6	0.004105	0.038198
Ethiopia	22.5	23.8	1.3	0.004268	0.033925
Gabon	25.0	25.5	0.5	0.000283	0.000565
Gambia	27.3	28.5	1.2	0.002387	0.001729
Ghana	27.2	28.1	0.9	0.0004738	0.015715
Guinea	25.7	26.6	0.9	-0.00014	0.007331
Kenya	24.1	25.6	1.5	0.014105	0.014863
Liberia	25.4	26.2	0.8	-0.00255	0.004887
Malawi	21.9	23.1	1.2	0.004146	0.00344
Mozambique	23.7	24.9	1.2	0.004001	0.008525
Nigeria	27.3	28.7	1.4	0.001316	0.034063
Republic of the Congo	24.6	25.3	0.7	0.002379	0.010074
Rwanda	18.9	20.8	1.9	0.015853	-0.03834
Senegal	27.9	29.2	1.3	0.005458	0.00634
Sierra Leone	26.0	26.9	0.9	-0.00216	0.006575
Somalia	26.8	27.6	0.8	0.000327	0.019452
Tanzania	22.0	23.4	1.4	0.01359	-0.00529
Togo	27.0	27.8	0.8	0.004496	0.017726
Uganda	22.2	24.3	2.1	0.016144	-0.02721
Zambia	21.7	23.4	1.7	0.004676	-0.01889

Table 5. Average temperature differences from the periods between 1901 to 1999^a and 2000 to 2015^b. Temperature increase rates ratio from the periods between 1901 to 1999^a and 2000 to 2015^b. Inland countries

Country	Avg. Temp. °C ^a	Avg. Temp. °C ^b	ΔT °C	Temp. Increase Rate °C/yr ^a	Temp. Increase Rate °C/yr ^b
Benin	27.4	28.3	0.9	0.005416	0.019463
Burkina Faso	28.2	29.2	1.0	0.004293	0.014462
Central African Republic	25.0	25.9	0.9	0.001717	0.014445
Chad	26.6	28.5	1.9	0.001824	0.001369
Democratic Republic of the Congo	24.0	25.1	1.1	0.005105	-0.01113
Ethiopia	22.5	23.8	1.3	0.004268	0.033925
Malawi	21.9	23.1	1.2	0.004146	0.00344
Republic of the Congo	24.6	25.3	0.7	0.002379	0.010074
Rwanda	18.9	20.8	1.9	0.015853	-0.03834
Uganda	22.2	24.3	2.1	0.016144	-0.02721
Zambia	21.7	23.4	1.7	0.004676	-0.01889
Averages	23.9	25.2	1.3	0.0059837	0.0001462

Table 6. Average temperature differences from the periods between 1901 to 1999^a and 2000 to 2015^b. Temperature increase rates ratio from the periods between 1901 to 1999^a and 2000 to 2015^b. Countries with a coastline

Country	Avg. Temp. °C ^a	Avg. Temp. °C ^b	ΔT °C	Temp. Increase Rate °C/yr ^a	Temp. Increase Rate °C/yr ^b
Angola	21.5	22.7	1.2	0.00598	-0.045770
Cameroon	24.7	25.3	0.6	-0.00033	0.012246
Cote d'Ivoire	26.4	27.2	0.8	0.000696	0.009867
Djibouti	27.7	29.1	1.4	0.000555	0.041420
Equatorial Guinea	24.6	25.2	0.6	0.001722	0.001386
Eritrea	26.1	27.7	1.6	0.004105	0.038198
Gabon	25.0	25.5	0.5	0.000283	0.000565
Gambia	27.3	28.5	1.2	0.002387	0.001729
Ghana	27.2	28.1	0.9	0.0004738	0.015715
Guinea	25.7	26.6	0.9	-0.00014	0.007331
Kenya	24.1	25.6	1.5	0.014105	0.014863
Liberia	25.4	26.2	0.8	-0.00255	0.004887
Mozambique	23.7	24.9	1.2	0.004001	0.008525
Nigeria	27.3	28.7	1.4	0.001316	0.034063
Senegal	27.9	29.2	1.3	0.005458	0.006340
Sierra Leone	26.0	26.9	0.9	-0.00216	0.006575
Somalia	26.8	27.6	0.8	0.000327	0.019452
Tanzania	22.0	23.4	1.4	0.01359	-0.005290
Togo	27.0	27.8	0.8	0.004496	0.017726
Averages	25.6	26.6	1.2	0.002859	0.009991

Table 7. Average temperature differences from the periods between 1901 to 1999^a and 2000 to 2015^b. Temperature increase rates ratio from the periods between 1901 to 1999^a and 2000 to 2015^b. Countries bordering by the Atlantic Ocean

Country	Avg. Temp. °C ^a	Avg. Temp. °C ^b	ΔT °C	Temp. Increase Rate °C/yr ^a	Temp. Increase Rate °C/yr ^b
Angola	21.5	22.7	1.2	0.00598	-0.04577
Cameroon	24.7	25.3	0.6	-0.00033	0.012246
Cote d'Ivoire	26.4	27.2	0.8	0.000696	0.009867
Equatorial Guinea	24.6	25.2	0.6	0.001722	0.001386
Gabon	25.0	25.5	0.5	0.000283	0.000565
Gambia	27.3	28.5	1.2	0.002387	0.001729
Ghana	27.2	28.1	0.9	0.0004738	0.015715
Guinea	25.7	26.6	0.9	-0.00014	0.007331
Liberia	25.4	26.2	0.8	-0.00255	0.004887
Nigeria	27.3	28.7	1.4	0.001316	0.034063
Senegal	27.9	29.2	1.3	0.005458	0.00634
Sierra Leone	26.0	26.9	0.9	-0.00216	0.006575
Togo	27.0	27.8	0.8	0.004496	0.017726
Averages	25.8	26.8	0.9	0.001356	0.005589

Table 8. Average temperature differences from the periods between 1901 to 1999^a and 2000 to 2015^b. Temperature increase rates ratio from the periods between 1901 to 1999^a and 2000 to 2015^b. Countries bordering by the Indian Ocean and the Red Sea

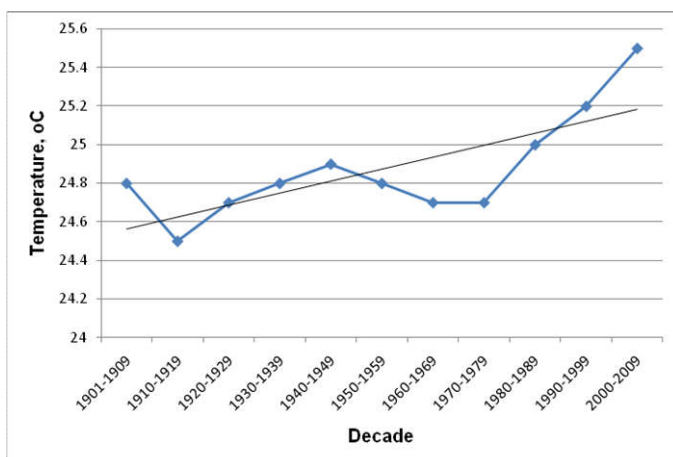
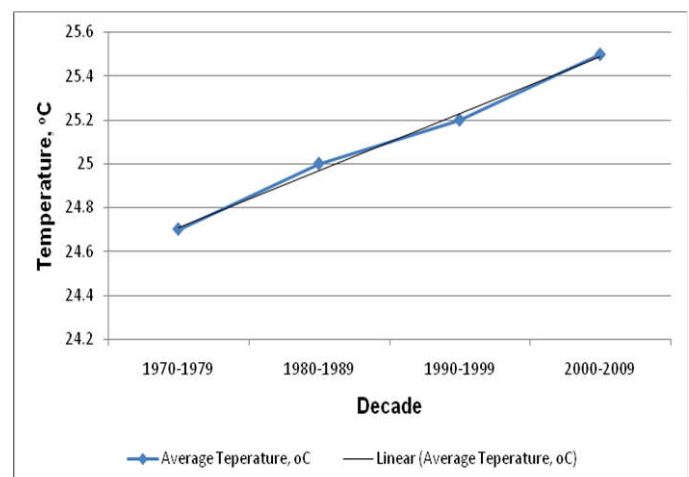
Country	Avg. Temp. °C ^a	Avg. Temp. °C ^b	ΔT °C	Temp. Increase Rate °C/yr ^a	Temp. Increase Rate °C/yr ^b
Djibouti	27.7	29.1	1.4	0.000555	0.04142
Eritrea	26.1	27.7	1.6	0.004105	0.038198
Kenya	24.1	25.6	1.5	0.014105	0.014863
Mozambique	23.7	24.9	1.2	0.004001	0.008525
Somalia	26.8	27.6	0.8	0.000327	0.019452
Tanzania	22.0	23.4	1.4	0.01359	-0.00529
Averages	25.1	26.4	1.3	0.006114	0.01953

Table 9. Average Temperatures and Standard Deviation from all Countries within the Study Area per Decade (1901 -2010)

Decade	Average Temperature, °C	Standard Deviation	% RSD
1901-1909	24.8	3.15	12.7
1910-1919	24.5	3.35	13.7
1920-1929	24.7	3.09	12.5
1930-1939	24.8	3.28	13.2
1940-1949	24.9	3.05	12.2
1950-1959	24.8	2.94	11.9
1960-1969	24.7	3.00	12.1
1970-1979	24.7	2.99	12.1
1980-1989	25.0	3.08	12.3
1990-1999	25.2	3.00	11.9
2000-2009	25.5	2.97	11.6

Table 10. Average Temperatures and Standard Deviation from all Countries within the Study Area per Decade (1901 -2010)

Decade	Average Temperature, °C	Standard Deviation	% RSD
1970-1979	24.7	2.99	12.1
1980-1989	25.0	3.08	12.3
1990-1999	25.2	3.00	11.9
2000-2009	25.5	2.97	11.6

**Figure 1. Average Temperature, °C per Decade 1901 to 2009****Figure 2. Average Temperature, °C per Decade 1970 to 2009**

coefficient was 0.743. In this time period in two occasions there was a positive temperature increase rate with a strong correlation with time. In between these two periods there was a negative temperature rate also with a strong correlation. From 1910 to 1949 the temperature increase rate was 0.13 °C/Decade the correlation coefficient was 0.983. From 1950 to 1979 there was a decrease in temperature with time, temperature rate was -0.07°C/Decade the correlation coefficient was 0.944. The temperature increase rate was 0.26°C/Decade from 1970 to 2009 with a 0.997 correlation coefficient.

Conclusions

The temperature trends from 1901 to 2015 for African countries located within the latitudes 15°North to 15° South were studied. The study area has different climate and topographic characteristics. The temperature difference between the years 1901 to 199 compared to the years 2000 to 2015 was 1.17°C on the average. There were no significant differences in the average temperature increase for inland countries compared to coastal countries. Seven out of the thirty countries studied were not in compliance with the Paris Agreement (average temperature raise of over 1.5°C), eleven had averages temperature rise between 1.0° and 1.4°C, and twelve had an average temperature raise of less than 1°C. The overall temperature increase rate was positive for the study area during the years 1901 to 2015 and this rate is significant sharper since 1970.

REFERENCES

- A. Creese, W. Pokam 2016. AFRICA'S CLIMATEHELPING DECISION-MAKERS MAKE SENSE OF CLIMATEINFORMATION. Downloaded from <https://2016report.futureclimateafrica.org/reader/central-and-southern-africa/regional-overview-central-african-climate-system/>
- Collins, J. 2011. Temperature Variability over Africa. *Journal of Climate Change*. Volume 24 pp 3349-3666.
- CSC (2013): Climate Change Scenarios for the Congo Basin. [Haensler A., Jacob D., Kabat P., Ludwig F. (eds.)]. Climate Service Centre Report No. 11, Hamburg, Germany, ISSN: 2192-4058.
- IPCC 2014. Summary for policymakers. In: Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi YL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds)]. Cambridge University Press, Cambridge, UK and New York, USA. pp 1–32.
- IPCC, Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, T. F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, P.M. Midgley, Eds. (Cambridge Univ. Press, Cambridge, 2013).
- Mark Giordano, Elisabeth Bassini(2019) Climate Change and Africa's Future. Published by the Hoover Institution. <https://www.hoover.org/research/climate-change-and-africas-future>
- Muhlenbruch-Tegen, A. 1992. Long-term surface temperature variation in South Africa. *S. Afr. J. Sci.* 88, 197-205.
- Niang I, Ruppel OC, Abdrabo MA, Essel A, Lennard C, Padgham J, Urquhart P (2014) Africa. In: Climate change 2014: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge Patz JA, Olson SH, Uejo CK, Gibbs HK. 2008. Disease emergence from global climate and land use change. *Med Clin North Am* 92:1473–1491. doi:10.1016/j.mcna.2008.07.007
- Serdeczny O, Adams S, Baarsch F, Coumou D, Robenson A, Hare W, Schaeffer M, Perrette M, Reinhardt J (2015) Climate change impacts in Sub-Saharan Africa: from physical changes to their social repercussions. *Regional Environmental Change*. Volume 15, Number 6, December 2015.
- The Climate Change Knowledge Portal. Downloaded from <https://climateknowledgeportal.worldbank.org/download-data>
- USAID 2018. Climate Risks in the Central Africa Regional Program for the Environment (CARPE) and Congo Basin (7 pages). Washington, R., R. James, W. Pokam, and W. Moufouma-Okia, 2013. Congo Basin rainfall climatology: can we believe the climate models. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 368:1–7.
