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STUDYING THE MOVEMENT OF THE INTER TROPICAL CONVERGENCE ZONE (ITCZ) OVER AFRICA INVERNAL EQUINOX

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ABSTRACT

In this study, we have tried to study the movement of the Inter Tropical Convergence Zone (ITCZ) over Africa in April by analyzing Temperature, (U, V) Wind and rainfall, studying oscillation of the ITCZ and its relationship with temperature in the different seasons, within the range of Africa in a long period of time (statistical period of 60 years). This is the first long term (monthly, annually, and decadal) study of the ITCZ over Africa, In this study, not only the exact position of ITCZ over Africa is determined but also its position change in the period of 60 years, These results could be used in studying the impacts of ITCZ on climate variations due to changes of position and movement of ITCZ, over Africa also the direct impacts of this movement on sudden changes of seasons start and end of untimely rains. Through the study of the ITCZ movement over Africa in vernal equinox, we find that it is limited between latitudes 2^o N to 18^o N, and the speed and direction of wind coming from the Tropical Continental air mass (cT) masses in addition to temperature, as well speed and direction of wind coming from the Tropical Maritime air mass (mT) air masses, all of them effect on the movement of ITCZ to the north and south, in different decades, which led to displacement of rain belt over Africa from north to south and vice versa , in addition to change in the amount of Total rainfall over the Abyssinian Plateau during the different decades .

1- INTRODUCTION

The ITCZ is a zone of low-pressure near the equator where two easterly trade winds originating from the Northern and Southern hemispheres converge (Roswintiarti, 1999). The thermal equator receives more incoming solar radiation than the poles because Earth is Spherical (F. Stuart Chapin et al. 2002). The Sun is overhead at midday on the tropic of cancer (23.5°N) around 21June, above the Tropic of Capricorn (23.5°S) near to 21 December, and Directly above the equator at midday during the equinoxes (Dorling Kindersley Ltd. 2012). The movement of the thermal equator shifts the belts of planetary winds and pressure systems to the north and to the south annually, as the Figure below shows.

To understand the cause and impact of the ITCZ we must first look at the trade winds and air masses over Africa.

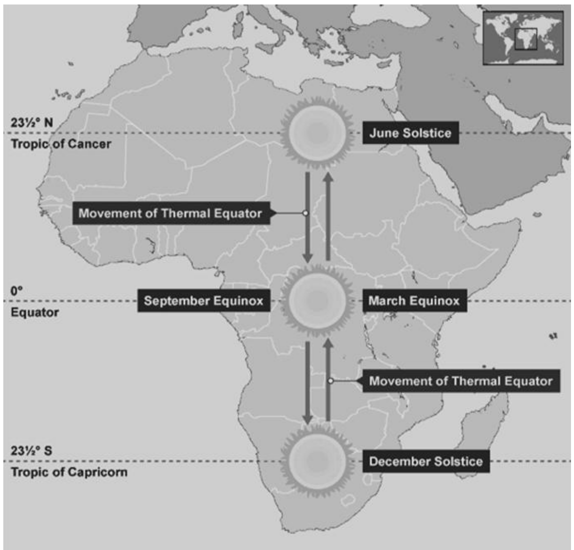

Fig. 1: Thermal Equator movement over Africa, During the year, for different seasons

2. AIR MASSES

Air masses are large bodies of air that assume particular moisture and temperature characteristics in their regions of origin. Most of Africa south of the Sahara gets its rainfall from air originating over the Atlantic Ocean and moving inland toward an equatorial zone of low pressure. The main Exception is eastern Africa, from Somalia to South Africa, which is affected by moisture-bearing air masses from the Indian Ocean (Robert Stocket al. 2012).

In meteorology, an air mass is a volume of air defined by its temperature and water vapor content. Air masses cover many hundreds or thousands of square miles and adapt to the characteristics of the surface below them. They are classified according to latitude and their continental or maritime source regions (Frederick K. Lutgens et al. 2013).

In Africa, the dry air mass is the tropical continental (cT) (north-east trade winds) air mass and the moist one is the tropical maritime (mT) air mass (south-west trade winds) (Joseph R. Oppong 2005). Each of these air masses has its own characteristic features.

2.1 Tropical Maritime air mass (mT)

This air mass originates in the Atlantic Ocean/Gulf of Guinea. The effects of the mT air mass decrease Northwards (Stephen Edem 2004). Bring warm and wet weather in summer, bring mild and wet weather in winter, usually south-west winds, quite strong winds and found in warm sector of depressions (Calvin Clarke et al. 2015).

2.2 Tropical Continental air mass (cT)

The cT air mass originates from the heart of the hot Sahara-Arabian desert and blows towards the sea (from North to South) across the whole of northern Ghana in the Dry Season (Stephen Edem 2004). It is most common during the summer months June, July and August, although it can occur at other times of the year, in tropical latitudes this air mass is hot to very hot, with low relative humidity, bringing stable weather.

When these two air masses meet, moist air is forced upward this causes water vapor to condense as the air cools and rises, resulting in a band of heavy precipitation around the globe (Danielle, et al. 2009). As the ITCZ moves north it carries the mT winds over the land. This will bring wet weather. At the same time places to the north of the ITCZ will be experiencing hot dry weather, under the influence of the cT winds.

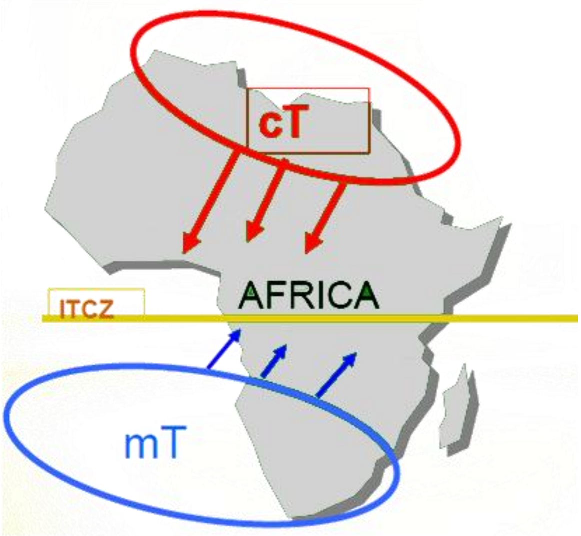

Fig. 2: Tropical Continental air mass (cT) meet with Tropical Maritime air mass (mT) over Africa, to form ITCZ.

Variation in the location of the ITCZ dramatically affects rainfall in many equatorial nations, resulting in the wet and dry seasons of the tropics rather than the cold and warm seasons of higher latitudes (Pijushkanti Saha, 2012)

3. DATA

The National Centers for Environmental Prediction and National Center for Atmospheric Research (NCEP/NCAR) reanalysis data are used in this study, the observational record is scarce over Africa. Modern satellite products like the Tropical Rainfall Measuring Mission (TRMM) dataset have only two decades of coverage. For less historically conventional variables like convergence and wind, even the very recent modern record is unavailable. For the purposes of measuring the location of the ITCZ, regular spaced information is imperative, or is at least more than a few data points, so this necessitates the use of reanalysis data.

Reanalysis uses a mix of forecast models, data assimilation methods and observation inputs to generate a dataset that coheres with both atmospheric dynamics and physical observations.

Essentially, reanalysis uses weather observations to correct the model output and interpolate this information at locations where there are no observation stations, for areas like Africa where observation stations are sparsely sampled, it is the closest available product to observation data.

3.1 Reanalysis Data

3.1.1 The NCEP/NCAR Reanalysis 1 project is using a state-of-the-art analysis/forecast system to perform data assimilation using past data from 1948 to the present. A large subset of this data is available from the Physical Sciences Division (PSD) in its original 4 times daily format and as daily averages. However, the data from 1948-1957 is a little different, in the regular (non-Gaussian) gridded data. That data was done at 8 times daily in the model, because the inputs available in that era were available at 3Z, 9Z, 15Z, and 21Z, whereas the 4x daily data has been available at 0Z, 6Z, 12Z, and 18Z. These latter times were forecasted and the combined result for this early era is 8x daily. The local ingestion process took only the 0Z, 6Z, 12Z, and 18Z forecasted values, and thus only those were used to make the daily time series and monthly means here.

3.1.2 The Global Precipitation Climatology Centre (GPCC) Precipitation 0.5degree V7 Full Reanalysis Datasets, is monthly precipitation dataset from 1901-present is calculated from global station data.

3.2 (u, v) Wind, Air Temperature, Precipitation rate & Total rainfall.

The meteorological convention for winds is that U component is positive for a west to east flow (eastward wind) and the V component is positive for south to north flow (northward wind). We have data of (u ,v) of wind, air (Air Temperature) and Precipitation rate, from 1/1957 to 1/2016 over the world , the units of (u ,v) are (m/s), the unit of Air Temperature is (degC) and the unit of Total rainfall (surface level) (mm/month) and the Statistic of variables is monthly mean at Multi levels of pressure over the world, our study will be on the continent of Africa it's located between Longitude 20° west to 55° east and Latitude 40° South to 40° North.

4. RESULTS

The study period is from 1957 to 2016 and has been divided into six periods (decades). Every period includes ten years (decade) to study the change in the ITCZ movement over Africa during different decades. April has been selected to represent the Spring, Monthly mean of wind (u, v) and temperature has been calculated for every decade.

4.1.1 ITCZ and Temperature

At the vernal equinox, the ITCZ begins to move north, and by the time of Northern Hemisphere it is generally north of the equator at all locations (C. Reid Nichol set al. 2009).

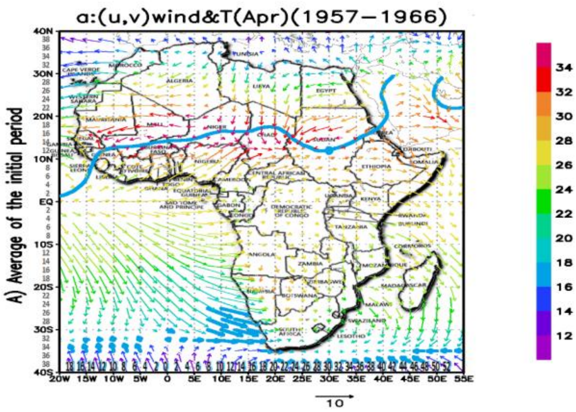

Fig. 3: Wind vector of monthly mean of April (represent Spring) colored by temperature for the first decade of study (1957 - 1966).

In West Africa at the 1st decade, the ITCZ moved over southwestern Guinea to northern Guinea between (longitude 14° W to 11° W and latitude 9.5° N to 12.5° N), crossing the border with Mali (longitude 11° W to 3.5° W and latitude 12.5° N to 13.5° N), passing through northern Burkina Faso (longitude 3.5° W to 0° and latitude 13.5° N to 14.5° N), then passing over Niger between (longitude 0° to 15° E and latitude 14.5° N to 17° N), similarly over Chad between (longitude 15° E to 23° E and latitude 15° N to 18° N), then in the eastern African continent moving over Sudan (longitude 23°E to 37° E and latitude 12° N to 16° N), and finally over northern Eritrea (longitude 37°E to 39° E and latitude 16°N to 17° N).

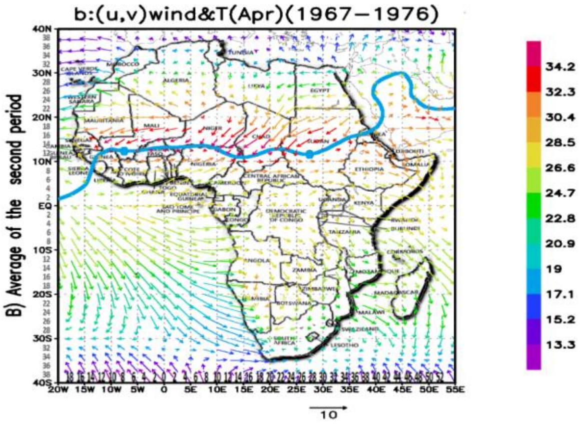

Fig. 4: Wind vector of monthly mean of April (represent Spring) colored by temperature for the 2nd decade of study (1967 - 1976).

In the 2nd decade of spring equinox, the position of the ITCZ over Africa changed from that of the first decade, the ITCZ moved slightly to the south in some areas and in others it was largely displaced.

In West Africa, the ITCZ moved to cross over the western border of the State of Sierra Leone with Guinea, moved over northern Guinea heading to southern Mali, it was noticeable that the ITCZ moved over Burkina Faso from the north in the first decade to be almost over the middle of the country in the 2nd decade.

Clearly, the big change in the ITCZ movement and position over Central Africa, specifically over Niger, the ITCZ moved between 2-5 degrees south in the 2nd decade, it moved southward to its southern border with Nigeria (longitude 1° E to 10° E and latitude 13° N to 14° N) , Heading to the north-east Nigeria (longitude 9.5° E to 13° E and latitude 11° N to 13.5° N) and northern Cameroon, Similarly, the ITCZ movement changed over Chad from (longitude 15° E to 23° E and latitude 15° N to 18° N) at the first decade to (longitude 15° E to 23° E and latitude 10° N to 13° N) at the 2nd decade.

In East Africa there was no significant change in the ITCZ movement over Sudan and Eritrea, except for its movement above the western Sudanese border with Chad from latitude (15° N) in the 1st decade to latitude (13° N) in the 2nd decade.

In comparison between the first and 2nd decades, it was clear that there was changed in the direction of the northeasterly winds movement and Southwesterly winds over Mali and Burkina Faso, with a decrease in the temperature of the wind on both sides of ITCZ and a decrease in the speed of the southwestern wind, over Niger, north-eastern Nigeria, Chad and western Sudan there was a marked increase in the speed of the northeastern wind with a change in direction of movement , on the other side south of the ITCZ decrease in the speed of southwestern wind and change in direction, with low wind temperatures on both sides of ITCZ in some areas .

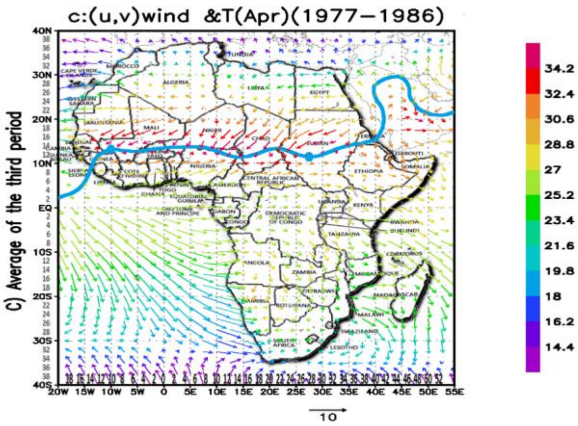

Fig. 5: Wind vector of monthly mean of April (represent Spring) colored by temperature for the 3rd decade of study (1977 - 1986).

There is no significant changes between the 3rd and 2nd decades, in terms of location ITCZ and its movement over Africa, except for minor changes, ITCZ moved from over the borders between north of Guinea and western Mali to the north to enter the Mali border from latitude 12.5° N in the 2nd decade to latitude 13° N in the 3rd decade, over Burkina Faso, Niger, northeastern Nigeria, northern Cameroon, Chad and western Sudan, the ITCZ moved 0.5 – 1^{o} degrees to the northward.

It was noticeable in the 3rd decade, the high degree of North Eastern wind temperatures and low wind speed also over Mali, and over Burkina Faso and western Niger there was a change in the direction of the northeastern wind, and over northern Cameroon and Chad, there was a decline in the speed of the northeastern winds.

But the obvious difference between the two decades, was the transition of ITCZ movement in East Africa, specifically over Eritrea, the ITCZ displaced from northern Eritrea at latitude (17 ° N) in the 2nd decade to the south of Eritrea at latitude (15 ° N) in the 3rd decade, there has been a change in the movement and direction of the northeastern winds as shown in Fig. 5 As compared to Fig. 4 .

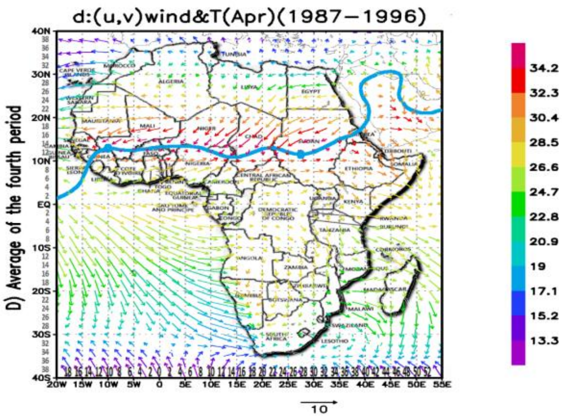

Fig. 6: Wind vector of monthly mean of April (represent Spring) colored by temperature for the Fourth decade of study (1987 - 1996).

The ITCZ movement in the fourth decade above Africa is very similar to its movement in the 3rd decade, , except the movement of the ITCZ from over the Southern Eretria at 3rd decade to Northern Eretria in the 4th decade and over the Sierra Leone border with southwestern Guinea, It moved about 0.5 degrees north to move over southwestern Guinea, To resemble its position in the 3rd decade Fig.5 .

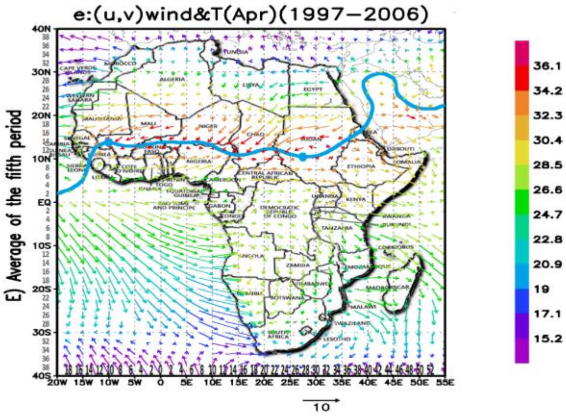

Fig. 7: Wind vector of monthly mean of April (represent Spring) colored by temperature for the Fifth decade of study (1997 - 2006).

In West and Central of Africa the ITCZ moved between 0.5 to 1 degree to the north, but in the east Africa the ITCZ moved Slightly southward , compared to the fourth decade in Fig. 6, it's shown in west Africa , the ITCZ moved to northward to move over the south-eastern border of Guinea, to the south of Mali and over northern Burkina Faso, and change its position in Central Africa, moving over the northern border of Nigeria to pass over to the southern border of Niger .

When compared between the fifth and fourth decades in terms of wind temperature, velocity and direction in west and central Africa, In the fifth decade there was a significant decrease in air temperature and wind speed (Northeasterly Winds), with a slight increase in speed Southwesterly Winds Compared to the fourth decade, by contrast completely in the east Africa specifically over eastern Chad and western Sudan and northern Eritrea, there has been a drop in wind temperature and an increase in wind speed (Northeasterly Winds), with a slight decrease in speed Southwesterly Winds, which led to the ITCZ shift southward over the border between western Sudan and eastern Chad from latitude (13° N) in the fourth decade to latitude (12.5° N) in the fifth decade, Similarly, it moved to southern Eritrea from latitude (16° N) in the fourth decade to latitude (14.5° N) in the fifth decade .

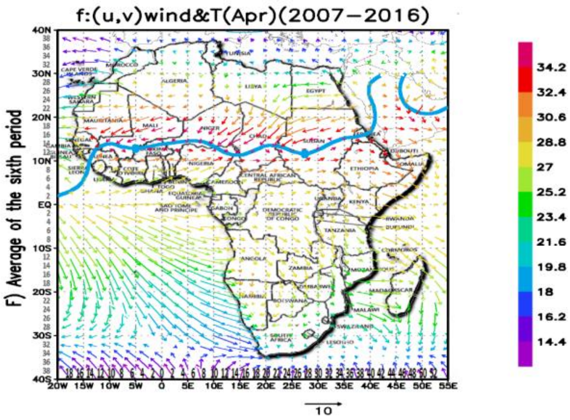

Fig. 8: Wind vector of monthly mean of April (represent Spring) colored by temperature for the Fifth decade of study (2007 - 2016).

In the sixth decade there was no significant difference in the ITCZ movement in West Africa over Guinea, southeastern Senegal, southern Mali and northern Burkina Faso compared to the fifth decade, but there was a change in its movement from 0.5-1 degree northward, in central Africa over Niger from latitude (14° N) in the 5th decade to latitude (14.5° N) in the 6th decade and northern Cameroon, from northern Cameroon (10.5° N) in the fifth decade to the northern borders of Cameroon (11° N) in the sixth decade and over Chad from (15° E to 22° E and latitude 11° N to 12.5° N) in the fifth decade to (longitude 15° E to 22° E and latitude 11.5° N to 13.5° N) in the Sixth decade, similarly in the eastern continent over Sudan, ITCZ moved north from latitude from (22° E to 36° E and latitude 10.5° N to 14.5° N) in the fifth decade to (22° E to 36° E and latitude 12° N to 15° N)in the Sixth decade and over western Eritrea, In contrast, over the eastern Eritrea, ITCZ moves south between latitudes (16.5° N) in the fifth decade to (16°N) in the Sixth .

The simple differences between the fifth and sixth decades in the speed and direction of the winds led to the migration of ITCZ to between 0.5 to 1 degree north over Central and East Africa in the sixth decade. In the south of Niger there was a slight change in the direction of the northeastern wind, While in Northern Cameroon, Chad and Sudan there was a decrease in the speed of the northeastern winds, with a slight increase in the speed of the south-west wind compared to the fifth decade.

4.1.2. ITCZ and Precipitation

Equatorial regions have two rainfall peaks a year, centered on the March and September equinoxes as the sun passes overhead. Africa, bisected by the equator, has comparable areas of freshwater to the north and south of it (Ro-McConnell et al.1987).

as shown in Fig.9 Displacement in the ITCZ movement to the South in the 2nddecade than in the first decade, it’s led to the movement of the rain belt to the south compared to the first decade, especially over the Central of Africa.

In the 3rd decade there were no significant changes in the ITCZ movement compared with the 2nddecadeexcept moving from over northern Eritrea in the 2nd decade to southern Eritrea with the northern border of Ethiopia in the 3rd decade, which led to a change in the amount of Total rainfall between the two decades over the Abyssinian Plateau , The Total rainfall over the Abyssinian Plateau was *69.5 mm/month* in the 2nd decade but it was becoming *86 mm/month* at the 3rd decade.

The change in the movement of ITCZ from over southern Eritrea in the 3rd decade to the northern Eritrea in the Fourth decade (as shown in Fig.9), which led to a slight change in the amount of Total rainfall over the Abyssinian Plateau, Total rainfall in the Fourth decade was 81.5 mm/month.

Due to the change in the ITCZ movement between the fourth and fifth decades, it is noticeable that the rain belt moved at East Africa to the south, it is also noticeable in the fifth decade that the amount of rain decreased compared to the 4th decade as shown in Fig.9 that’s mean the presence of rain indicates the presence of ITCZ and vice versa is not true.

In the sixth decade ITCZ moved between 0.5 degrees to 1 degrees north over West and Central Africa and over Sudan, it's led to the movement of the rain belt to the North compared to the 5th decade, but the ITCZ moved to North over Eretria with northern border of Ethiopia, which led to slightly increase the amount of Total rainfall over the Abyssinian Plateau compared to the 5th decade,The Total rainfall over the Abyssinian Plateau was *71.5 mm/month* in the 5th decade but it was becoming *79.5 mm/month* at the 6th decade.

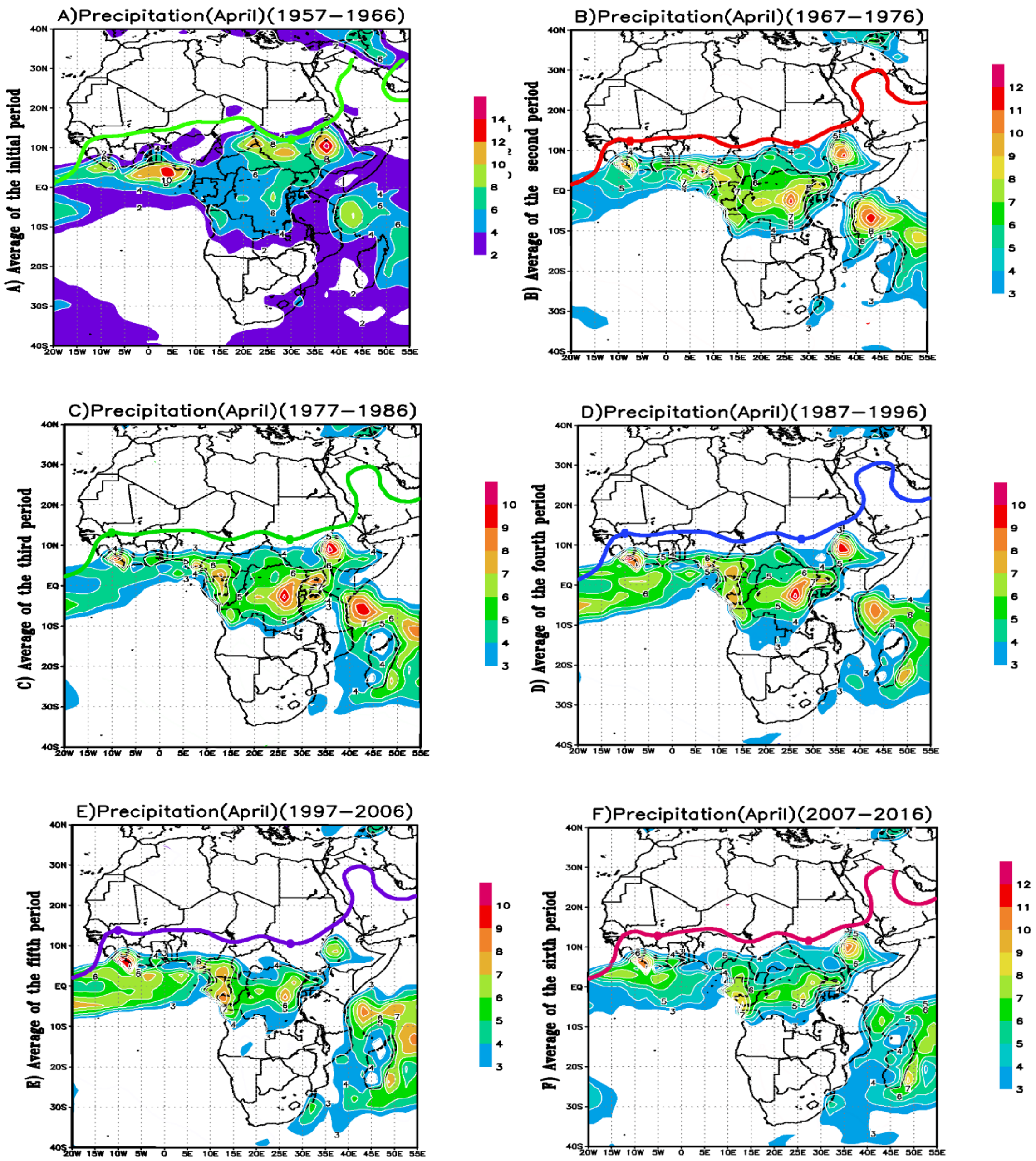

Fig.9: Movement of The ITCZ over Africa in different decades in April and it's relation with the rainfall.

5. CONCLUSION

The ITCZ is a belt of low pressure which circles the Earth generally near the equator where the trade winds of the Northern and Southern Hemispheres come together. The position of the ITCZ varies with the seasons, correlates generally to the thermal equator. Since water has a higher heat capacity than land, the ITCZ propagates poleward more prominently over land than over water, and over the Northern Hemisphere than over the Southern Hemisphere. In July and August, over the Atlantic and Pacific, the ITCZ is between 5 and 15 degrees north of the Equator, but further north over the land masses of Africa and Asia, Variation in the location of the intertropical convergence zone drastically affects rainfall in many equatorial nations, resulting in the wet and dry seasons of the tropics rather than the cold and warm seasons of higher latitudes. Longer term changes in the intertropical convergence zone can result in severe droughts or flooding in nearby areas.

So in this paper we analyzed some of the variables to explore and locate the movement of the ITCZ over Africa in the month of April, these variables are (u, v) wind in addition to the temperature, the units of (u ,v) are (m/s), the unit of Air Temperature is (degC) and the Statistic of variables is monthly mean at multi levels of pressure over the world but the study area extends from latitude 40^o South to 40^o North and from longitude 20^o West to 55^o East to include all Africa. The study period is from 1957 to 2016 and has been divided into six periods (decades). Every period includes ten years (decade).

In West Africa at the 1st decade, the ITCZ moved over southwestern Guinea to northern Guinea, crossing the border with Mali, passing through northern Burkina Faso, then passing over Niger, which divides it into about two halves between, similarly over Chad, finally in the east of Africa the ITCZ moved over Sudan, and then over northern Eritrea, the ITCZ moved to the southward in the 2nd decade specially over the Central Africa, , The change of the movement and position of ITCZ is due to changes in temperature, speed and direction of wind (Northeast trade winds and southeast trade winds). there was a change in the direction of the northeasterly winds movement and Southwesterly winds over Mali and Burkina Faso, with a decrease in the temperature of the wind on both sides of ITCZ and a decrease in the speed of the southwestern wind, over Niger, north-eastern Nigeria, Chad and western Sudan there is a marked increase in the speed of the northeastern wind with a change in direction of movement , on the other side south of the ITCZ there was decrease in the speed of southwestern wind and change in direction, which led to the displacement of the rain belt to the south compared with the 1st Decade as shown in Fig.9. In the 3rd decade, obvious difference between the two decades, was the transition of ITCZ movement in East Africa, specifically over Eritrea, the ITCZ displaced from northern Eritrea at latitude (17° N) in the 2nd decade to the south of Eritrea at latitude (15° N) in the 3rd decade , which led to a change in the amount of Total rainfall between the two decades over the Abyssinian Plateau, the Total rainfall over the Abyssinian Plateau was *69.5 mm/month* in the 2nd decade but it was becoming *86 mm/month* at the 3rd decade. There was no big difference at the 4th decade in the movement of the ITCZ over Africa, except the movement of the ITCZ from over the Southern Eretria at 3rd decade to Northern Eretria in the 4th decade. Which led to slightly changed in total amount of rainfall over the Abyssinian Plateau, the Total rainfall in the 4th decade was 81.5mm/month. At the 5th decade specially at the east of the Africa over the Sudan, the ITCZ moved southward but it was noticeable in the 5th decade that the amount of rain decreased compared to the 4th decade as shown in Fig.9 that's mean the presence of rain indicates the presence of ITCZ and vice versa is not true. The ITCZ moved between 0.5 – 1^o to the north over west and central Africa and over Sudan, which led to the movement of the rain belt to the Northward, but the ITCZ moved to North over Eretria with northern border of

Ethiopia, which led to slightly increase the amount of Total rainfall over the Abyssinian Plateau compared to the 5th decade.

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