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Dynamics of the Inter Tropical Front and Rainy Season Onset in Benin

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Authors' contributions

This work was carried out in collaboration between all authors. Author ABA designed the study and wrote the protocol. Authors JD and JDA performed the statistical analysis and wrote the first draft of the manuscript. Authors CL, JFL and CNA managed the analyses of the study. Authors VHED and FGN managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Rainfall onset in Benin is one of the major problems that the farmers face. This climatic factor is of a great importance for the productivity in Benin.

In this work, based on two criteria, we elaborated a new criterion, that allows us to determine with more precision, the rainy season onset in five synoptic stations in Benin: Cotonou, Bohicon, Savè, Parakou and Kandi. Then, we studied the InterTropical Front (ITF) position compared to each station at the onset date.

We used in this study, the daily rainfall data provided by the Agency for the Safety of air Navigation

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in Africa and Madagascar (ASECNA) for (1987-2016) years and the dekadal (10-day) ITF position data produced by the National Oceanic and Atmospheric Administration (NOAA) for (1989-2016) years.
Using these daily rain of the five stations and the ITF data, we calculated, the dekadal, monthly and annual rain amount, then we established a relation between the ITF position and the precipitation for each station.
Results obtained show that Cotonou have two rainy seasons. The long rainy season begins on April 7th and short season on September 11th. Bohicon, Savè, Parakou and Kandi know one rainy season that starts on April 8th, April 14th, April 29th and May 17th, respectively. Compared to these dates, the ITF islocated 679.04 km north to Cotonou, 604.46 km north to Bohicon, 597.78 km north to Savè, 573.29 km north to Parakou, and 475.33 km north to Kandi. The good correlation is obtained between the ITF position and the monthly precipitations for Parakou and Kandi regions. The correlation are good enough in Bohicon, Savè and Cotonou regions during the monsoon period.

Keywords: Rainfallonset; intertropical front; precipitation; ITF position.

1. INTRODUCTION

The drought of the years 1970 - 1990 has been accentuated more especially in the Sahel, with dramatic consequences on the economy and the life of the populations of all the West African countries [1,2]; this has attracted the attention of many researchers.

Indeed, it has been observed that rainfall in this region has reduced as well as an irregularity of seasons in some locations. Moreover, the farming which feeds the majority of the populations in Africa, depends on the regularity of the rainfallduring a season of the year, in the most of the regions situated above of 7°N. The whole rain of a year sometimes falls during three to four months only. Several authors worked on the survey of the physics of the atmospheric phenomena occurring in this part of the African continent [1,3,4]. A particular atmospheric circulation, linked to the migration of the inter-tropical front is known there [5]. These last years the satellites photos of the Earth also reveal a particular and well organized vegetation, active from the forest to the desert while passing by the savanna [6]. These investigations on the climate in West Africa have brought the researchers to grant or have more interest in the collection of scientific information (data) in all domains related to the physics of the atmosphere in this region during these last three decades around of several program.

The first of the land campaigns is the Global Atmospheric Research Program (GARP) and the Atlantic Tropical Experiment (ATE) [7-9]. The objective of this project was to investigate the tropical atmosphere and its role in the global circulation of the atmosphere. Afterwards, the West African Monsoon Experiment (WAMEX) campaign, the Tropical Deep Convection (COPT81) [10], experiment permitted to improve the knowledge of the dynamics of the grains of African lines, and showed that the numeric simulation permitted to discover or find the main features of it [11,12].

In 1992, the project Hydrological and Atmospheric Pilot Experiment in the Sahel (Hapex-Sahel) [4,13] particularly, was developed for the survey of the properties of the continental surfaces, the previous research having rather been about the atmosphere and the role played by the oceans. ThisHapex-Sahel program permitted to explain, the retroaction climate-vegetation. Some years later (1997), the West African Monsoon Project (WAMP) [14] consisted in the pluviometric variability at several temporal scales, whereas the project Coupling Atmosphere Tropical and Cycle Hydrologic (CATCH) took the relay of HAPEX-Sahel in searching for the collection of data or information concerning the interactions between continental surfaces and West-African monsoon, while implanting a vast network of measures centered on Benin in complement to the site of Niger to have a window North-South opened on the ocean. These programs have brought much progresson understanding of the African Monsoon according to different scales of time and space. The data obtained by direct measurements have been thick by these programs. In spite of it, abundant hiatuses (problems) remain: persistent lack of data in situ, weak understanding of the intra-seasonal variability, deficiencies of the dynamics models to simulate the lively climate of big difficulties in the forecasting of climate in West Africa. It is therefore appeared to concentrate more again on the processphysical and dynamic implied, for better encircle the interactions mechanisms within the system Terre-Ocean-Atmosphere (TOA) [15].

The last campaign made in this framework is the Analysis Multidisciplinary Monsoon of the African (AMMA) campaign between 2005 and 2009 that gathered the researchers from several countries such as France, Germany, the United Kingdom , the USA and several African countries such as: Benin, Niger, Mali, Ivory Coast, Senegal and Nigeria, etc. The originality of this large project holds, on the one hand, to the copiousness of these measurements campaigns and on the other hand, to its multidisciplinary character (large number of scientific disciplines and concerned group).

Moreover, the defective problems of water for the farming are not only due to the rain amount but also to its spatio-temporal distribution. The rainfall in Benin are constrained by the organization of the atmospheric circulation West African in its whole, both the one of the lower layers (monsoon and harmattan flows) and those of middle and upper atmosphere (East African Jet and East Tropical Jet) [16].

Moreover, one of the recurrent problems of the farmers is the non-mastery of the rainfall onset which is very important for the productivity.

According to [17] the non-respect of the rainfall onsetcan lower the harvests or to the best of the cases drive to the leakages of seed totaling 25%. Several researchers have also focused on the question of the rainfall onset and several methods of its determination have been proposed [18-20]. Some criteria have been developed by several researchers:

- some authorsuse the rainfall data in situ and propose the following definition: «… the three or four first precipitations registered of at least 10 mm no separated of more than 7 days » [20].
- from agronomic criteria, [21] considers the rainfall onset in the Saharian and Sudanian regions as date from May 1st collecting a water height of at least 20 mm on 3 consecutive days, without any dry sequences of more than 7 days in the 30 days that follow.
- in agro-climatic study context, [22] define the rainfall onset on different regions of Ghana and Burkina Faso, while taking into account the physiological aspects of plants.
- [23] associates the rainfall onset of the saharian to the jump in latitude of ITCZ between 5° North and 10°North, using conjointly of OLR (Outgoing Longwave Radiations) and precipitations data.
- from climatic criteria, other authors define the beginning of the rainfall onset from the first rainy event indicating the apparition of an organized conversion. The rainfall onset is based on a frequently criteria and corresponds to the date or 80% of the stations in a location of 300 km register a significant rain (>1 mm) on 2 consecutive days [24].

The ITF is a fundamental characteristic of the atmospheric circulation on West Africa [25]. It is known that the ITF, during the year migrates from the Atlantic Ocean in January and reaches its most northerly position which is around of the latitude 20°N towards August. This period also corresponds to the period of maximal rainfall in Northern Benin and Niger. The convergence zone between the Harmattan and monsoon flows on the continent constitutes a frontal zone called InterTropical Convergence Zone (ITCZ) or ITF. The contact surface between the monsoon and the trade winds of South-East (humid and unstable Indian air) determines the InterTropical Oceanic Confluence (IOC). In West Africa, the ITCZ position allows to define the climate type observed. From January to July, the convergence front progresses slowly towards the north until reaching his maximum southern extension (18 to 20 ° North), then it returns again towards the South where its progression stops towards 5 to 7 ° North [23,26]. At the annual level, the most extreme positions of these two zone are attained in January and in July. The movement of the ITCZ conducted of along with that of the different air masses (harmattan and monsoon flows), implies strong seasonal climatic variations, inducing the dry season and the wet season.

The ITF is a quasi-stationary front that is to say that its movements are slow. It is, however, animated of a movement having for period a year with the periodic oscillation to the daily scale. The precipitation in the Sudano-Sahelian zones are positively related to the latitude of ITF, during the progression and retirement of ITF [25]. Moreover, the joining between the ITF seasonal movement and the implementation of African Easterly Jet (AEJ) has been well documented in the context of rainfall onset in West Africa [27,28].

In this paper, it is a query to study the relationship between the ITF Dynamics and the rainfall onset in Benin. For this purpose, we propose to base our research work on the rainfall data of the five synoptic stations of Benin of the years (1987-2016) and the IFT position data (1989-2016) produced by NOAA to:

1. study the variability of rainfall from South to North - Benin from the monthly and decadal scales;
2. elaborate a new criterion defined from the criteria of [20,21];
3. study the average decadal latitudinal position of ITF;
4. determine the average distance of ITF at the rainfall onset for the different synoptic stations;
5. find the correlation between precipitation and the ITF position.

This information will serve a guide to the farmers and other people in different sectors of the national economy.

2. DATA AND METHODOLOGY

2.1 Site Descriptions

Benin is located between latitudes 6°30 and 12°30 N and longitudes 1◦ and 4°E. It is limited in the North by the Niger river, in the North-West by Burkina Faso, in the West by Togo, in the East by Nigeria and South by Atlantic Ocean (Fig. 1). From North to South, it is extended on 700 km. Its width varies from 125 km (along the coast) to 325 km (latitude Tanguiéta-Ségbana). The five synoptic stations stand as follow: Cotonou (latitude : 6.3°N ; longitude : 2.41°E and 5 m altitude); Bohicon (latitudes : 6°55N and 7°08 N, and longitude : 1°58E and 2°24 E), and Savè(latitude : 8°01N; longitude : 2°29 E; 177m altitude) ; Parakou (latitude : 9°21N; longitude : 2°36E; 369 m altitude) and Kandi (latitude : 11°7N; longitude : 2°56E; 288m altitude) (Fig. 1). The observations of these stations are representative of the climate of these zones. The climate typein Cotonou, Bohiconand Savèissub-equatorial, and soudanese in Parakou and Kandi [29,30,31].

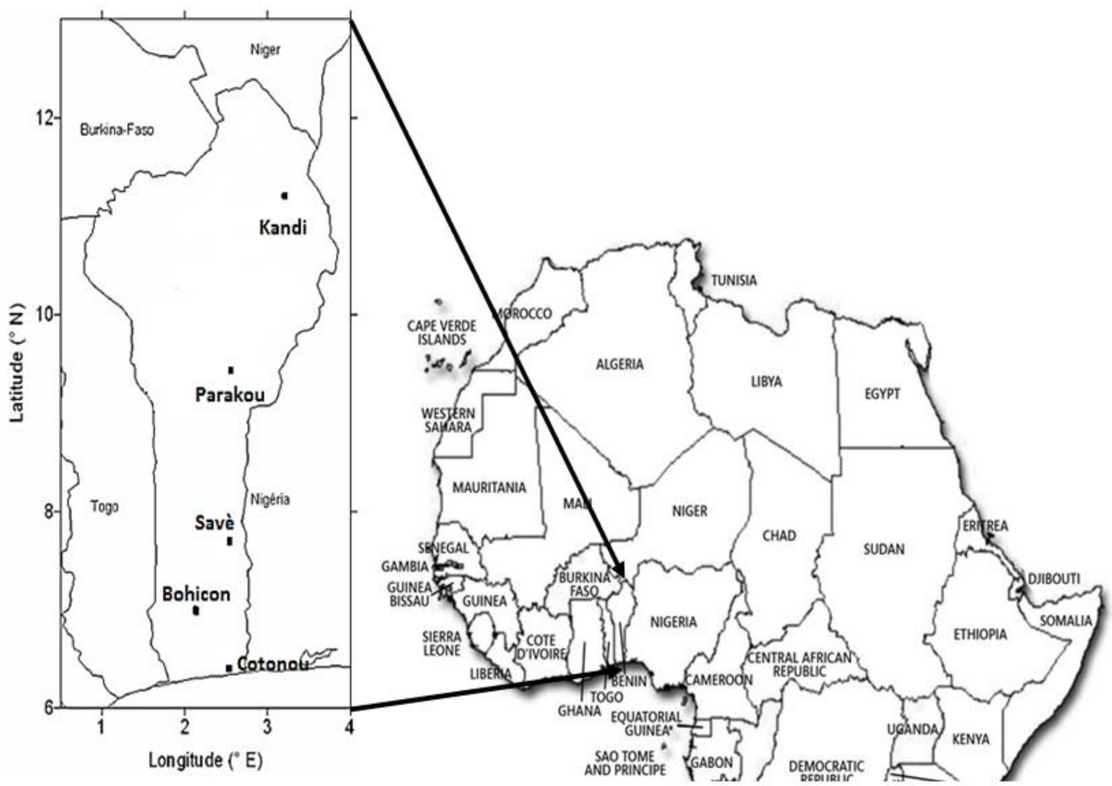

Fig. 1. Location of the stations of Cotonou, Bohicon, Savè, Parakou and Kandi

2. 2 Data

Two types of data have been used in thisstudy:

- the dailyrain data for each station have been collected on 30 years (1987-2016). These data have been supplied by ASECNA;
- the ITF data are those produced by NOAA, and are available on the site www.cpc.ncep.noaa.gov (ftp.cpc.ncep.noaa.gov/fews/itcz) from1989 to 2016. These data are dekadal (10-day) from Avril to October. The data from November to March are notavailable on the site, but they have been obtained by extrapolation to themeridians of interval 5°E. Since Benin is situated between 1° and 3°40E, we calculated the average of longitudes 0° and 5° E from 1989 to 2016.

2.3 Methods of Data Analysis

In thisstudy, the dekadal (10-day), monthly and annual cumulative have been calculated as well as theirsaverage, using the dailyrain data for five stations in Benin.

- The cumulative X isobtained by the arthimeticalsumof X_i.

$$X = X = \sum_1^n X_i \text{ , n whole, n} \geq 1 \quad (1)$$

- The average$\bar{X}$

$$\bar{X} = \frac{1}{N}\sum_1^n X \quad (2)$$

$\boldsymbol{\sigma}$ $(\mathbf{x})$Standard deviation

The standard deviation reveals the dispersion of the values around of the average. It is equivalent to the square root of the variance

$$\boldsymbol{\sigma}\,(\mathbf{x}) = \sqrt{\mathbf{V}} = \sqrt{\frac{\sum_1^n (X_i - \bar{X})^2}{N}} \quad (3)$$

The ITF distance **D** is determined by:

$$\mathbf{D} = L.\alpha \quad (4)$$

where L is the latitude and $\alpha = 1° = 111.319\ km$

2.4 Rainfall Onset Criteria

The detection method should bebased on the mechanisms of general circulation of the atmosphere in West African region. We worked here specifically on the displacement in latitude of monsoon system, not on the modulation of its precipitating intensity. For this, we used databases from different stations. Some characteristic variables beyond rainfall within the study regions are identified, namely the rainfall onset in different stations as well as the averages of pluviometric cumulative (annual, monthly, dekadal) from South to North-Benin on the period 1987-2016. The new criterion elaborated on the basis of the pooling of the criteria of [20,21]: «the date from April 1st with collected at least 20 mm rain amount on 7 consecutives days, without more than 7 days dry sequences in the 30 days that follow». Then, we compared this criterion with the one developed in [20]. The results obtained are presented in section 3.3.

3. RESULTS AND DISCUSSION

3.1 Variability of the Rainfall from Different Stations of Benin

Rainfall variability in Benin was analyzed using daily rainfall data on the period 1987-2016. Fig. 2 shows the average monthly precipitation cycles of the five stations (Cotonou, Bohicon, Savè, Parakou and Kandi) from 1987 to 2016. Monthly cumulative averages vary from 13.44 to 342.75 mm in Cotonou, 6.36 to 170.02 mm in Bohicon, 3.67 to 173.20 mm in Savè, 2.38 to 225.10 mm in Parakou, and 0 to 244.78 mm inKandi.

The peak rainfall month over Cotonou, Bohicon, Savè, Parakou and Kandi stations are June, July, September, August and August months, respectively. In Cotonou region, the precipitation curve shows two seasons. The first rainy season starts from April to July and ends in July with a peak of precipitation in June. The second season starts at early September and ends in October with a peak of precipitation in October. These two rainy seasons are interrupted by two dry periods that expand from November to March and August. These results are in concordance with those obtained in the literature [1,32,33]. In Bohicon, the precipitation curve presents a unimodal shape with a brief fall and two peaks. The first peak is observed in July where the rain amount is at 173 mm and the other in September is164 mm. In August, the monthly average rain amount at this site falls to 118 mm. Moreover, the curve of Bohicon shows that the highest rain amount is recorded between April and October and the lowest rainfall level is between November and March. These different analyses allow us to say that Bohicon knows along rainy season and along dry season. These results confirm the fact that both rainy seasons, observed formerly in this region, tend to merge because of the progressive disappearance of the small dry season in the month of August [34]. In the Savè, Parakou and Kandi stations, the monthly precipitation curves show the same unimodal shape with the peaks of precipitation in September at Savè and in August at Parakou and Kandi. These different analyses allow us to say that Savè knows a long rainy season from April to October and a long dry season from November to March. As for the regions of Parakouand Kandi, according to the different analyses of the curves, they know a long rainy season from May to September and a long dry season from October to April. The results obtained in Parakou and Kandi regions confirm what has been highlighting further north on the Sahelian rains by [1].

Moreover, we notice in the southern regions, namely Cotonou and Bohicon, the decrease of the rain amount in August. This fact is due to the particular atmospheric circulation observed in August when the sea surface temperature (SST) in the Gulf of Guinea is low [35]. August is a period when the Intertropical Discontinuity (ITD) or ITF moves Northwards and the regions associated with intense rainfall move over the Northern regions (Kandi and Parakou).

Fig. 3 shows the evolution of the annual cumulative of pluviometric on the different stations. This figure shows well the existence of North-South gradient of the precipitation to the exception of Parakou. Cotonou and Parakou have the highest rain amount (1357 mm and 1164 mm, respectively) and Kandi the lowest (1008 mm). At Bohicon and Savè, one records 1149 mm and 1079 mm respectively. The average annual cumulative found by [30,31] in the Sudanian zone is 1200 mm over the period 1954 to 2005 and near to the one found in the Parakou region. The annual rainfall in the Sudanian zone is included 800 and 1200 mm [36]. In the Kandi region, the annual rainfall is 1008 mm and near to the one which has been found by [36] in Kandi over the period 1965-2010. We can say that the annual rainfall obtained in the Parakou and Kandiregions is in this interval (800 and 1200 mm).

3.2 Dekadal Rain Analysis

Using daily rain data, we calculated the dekadal (10 days) rain depth. Fig. 4, 5, 6, 7 and 8 present the average cycles of the dekadal precipitation in the five stations.

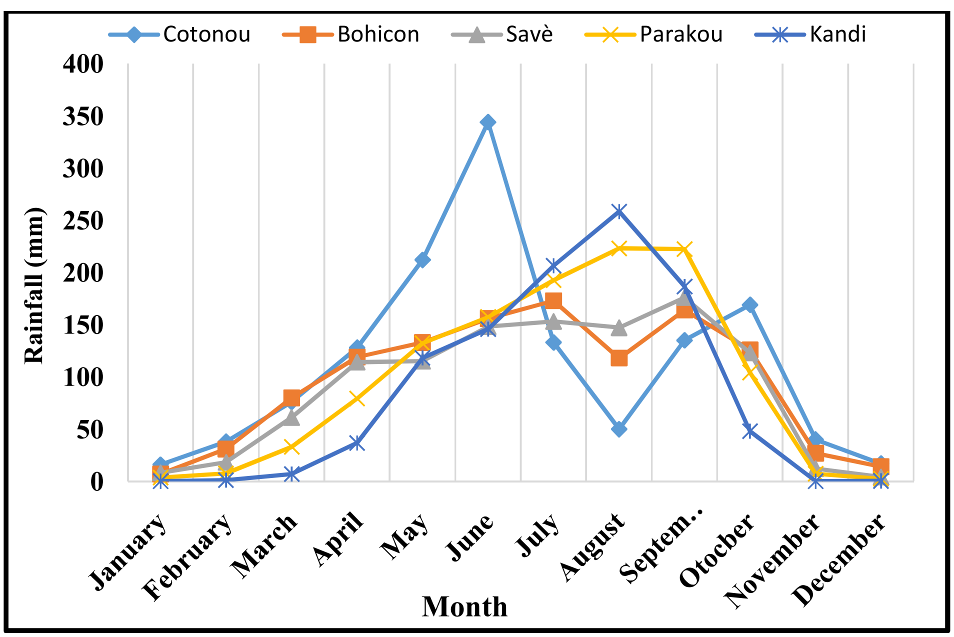

Fig. 2. Average cycle of the monthly precipitation in Cotonou, Bohicon, Savè, Parakou and Kandi regions on the period 1987-2016

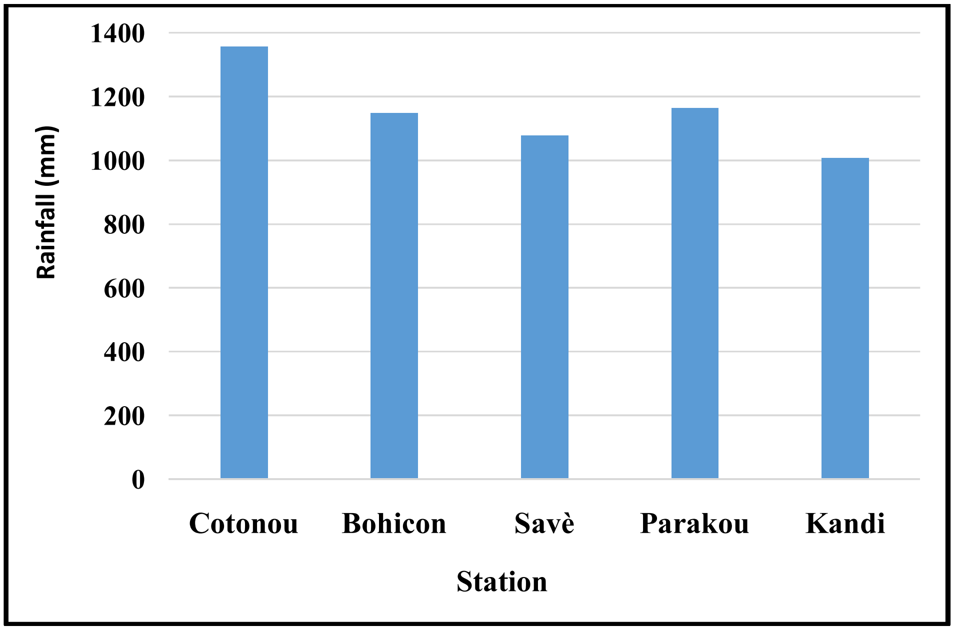

Fig. 3. Annual rainfall in the Cotonou, Bohicon, Savè, Parakou and Kandi stations from 1987 to 2016

In Cotonou, the dekadal rainfall curve presents two parts. The first part starts from the 1st to the 22nd dekad with a maximal rainfall of 134 mm reached the 17th dekad. The second part starts from 23rd to 36th dekad with a maximal rainfall of 69 mm obtained to the 28th dekad. Which confirms the presence of two rainy seasons and two dry seasons obtained previously in Cotonou region. The dekadalrain maximal are registered on June 20th and October 10th (Fig. 4).

InBohicon region, the rainfall curve is unimodal with two rainfall peaks. The first peak is observed on July 20th with a rain height equal to 69 mm, and the second is on September 30th with a rain height of 70 mm. We also observed a decrease of rain amount on August 10th with a rain height equal to 34 mm. The average dekadal precipitation cycle confirms that Bohicon knows a long rainy season and a long dry season. The lowestrainy amount are registered in January and December.

The rainfall curve of Savè has a unimodal shape. The maximal rainfall are obtained on September 10th and October 10th. Which confirms the presence of two long seasons in Savèregion: a rainy season anda dry season. The lowestheight of precipitation are registered in November and February.

InParakou and Kandi regions, the rainfall curves are unimodal. The dekadal rainfall peaks are observed on September 10th in Parakou and on August 30th in Kandi (Figs. 7 & 8). We registered on these dates, 84 mm of precipitation in Parakou and 97 mm in Kandi, respectively. Thus, Parakou and Kandi regions know a longrainy season and a long dry season. The lowest rain amount are measured from November to February in Parakou and from December to February in Kandi.

3.3 Determination of Rainfall Onset

Using the onset of rainy season criterion as definite in section 2.4, we obtained the starting dates for each year on the five stations. This allowed us to determine the average rainfall onset on the study period. The Table 1. presents the results obtained for each station.

The comparative analysis of this table reveals that the standards deviations of the new definite criterion are lower than those obtained with criterion [20]. This great uncertainty between the both criteria, shows that the method of [1] doesnot suit to the regions studied. However, the new criterion allow to the farmers to know with precision the rainfall onset of each region. This new definite criterion will therefore be retained in our study zone.

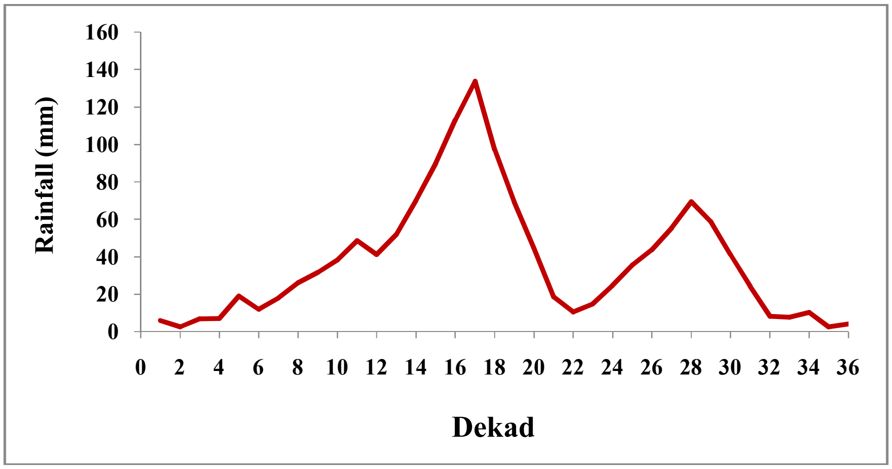

Fig. 4. Average dekadal precipitation cycle in Cotonou regionfrom 1987 to 2016

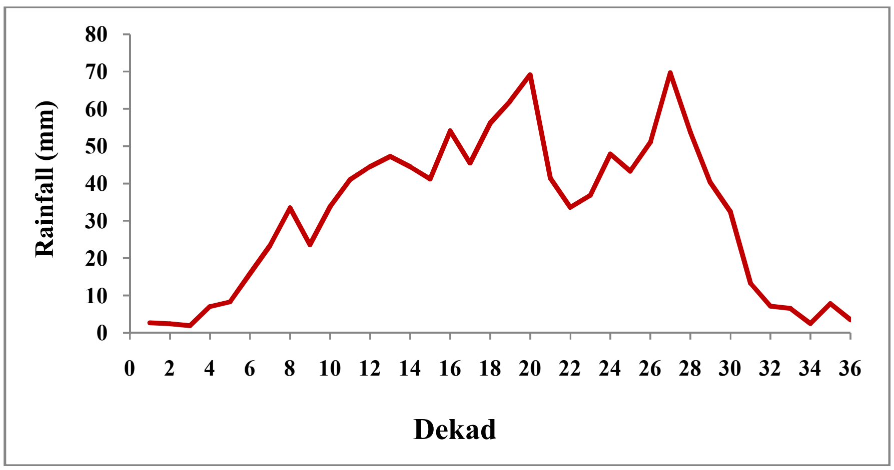

Fig. 5. Average dekadal precipitation cycle in Bohicon region from 1987 to 2016

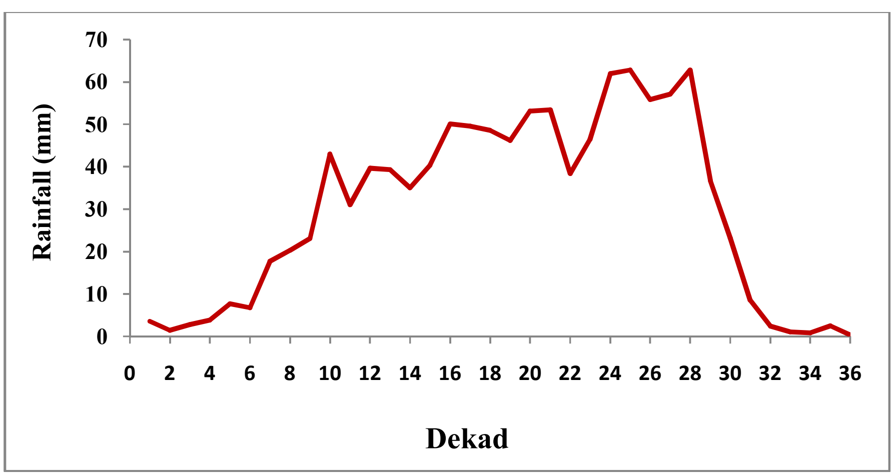

Fig. 6. Average dekadal precipitation cycle in Savè region from 1987 to 2016

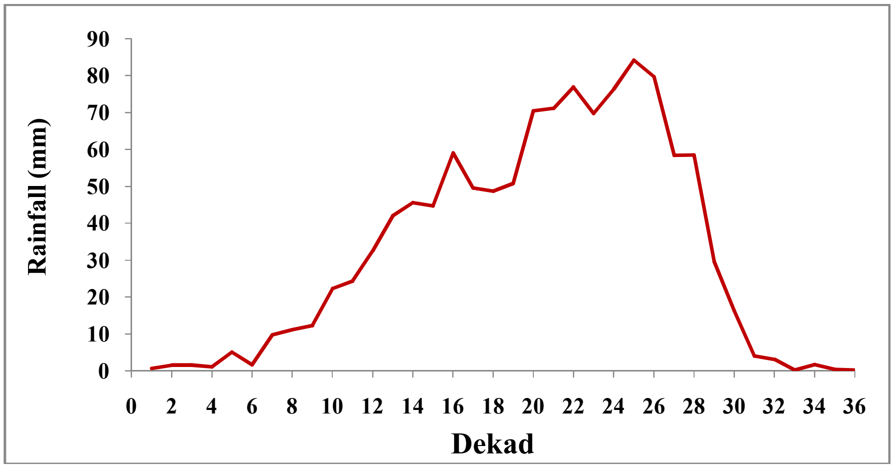

Fig. 7. Average dekadal precipitation cycle in Parakou region from 1987 to 2016

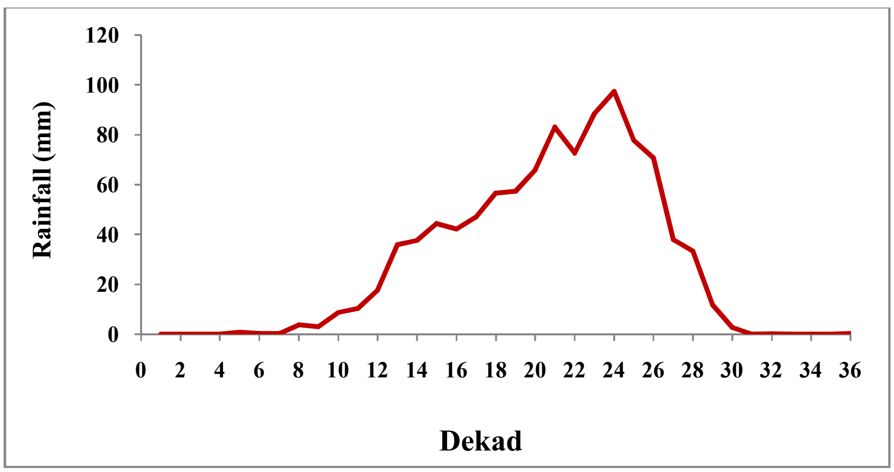

Fig. 8. Average dekadal precipitation cycle in Kandi region from 1987 to 2016

Table 1. Onset of rainy season

Stations		Cotonou (first season)	Cotonou (second season)	Bohicon	Savè	Parakou	Kandi
[20]	Date	April 4th	September 11th	April 22th	April 8th	May 8th	May 18th
	Standard deviation (day)	24	15	29	24	28	27
New criterion	Date	April 7th	September 10th	April 8th	April 14th	April 28th	May 16th
	Standard deviation(day)	10	15	9	10	15	15

3.4 Variability of the ITF Position

3.4.1 Variability of the ITF position to the dekadalscale on 1°30 E

Using the ITF dekadal data, we analyzed the monthly variability of the ITF position. The Fig. 9 shows the dekadal latitudinal position of ITF on the period 1989-2016. From January to second dekad of July, the graph illustrating the average position of ITF presents a slight growth of ITF from latitude 6.4°N to 19.3°N. From the late July to the late August, we observe a slight increase of ITF. From late August to December, we observe a rapid decline of ITF from 19.7°N to 6.4°N.

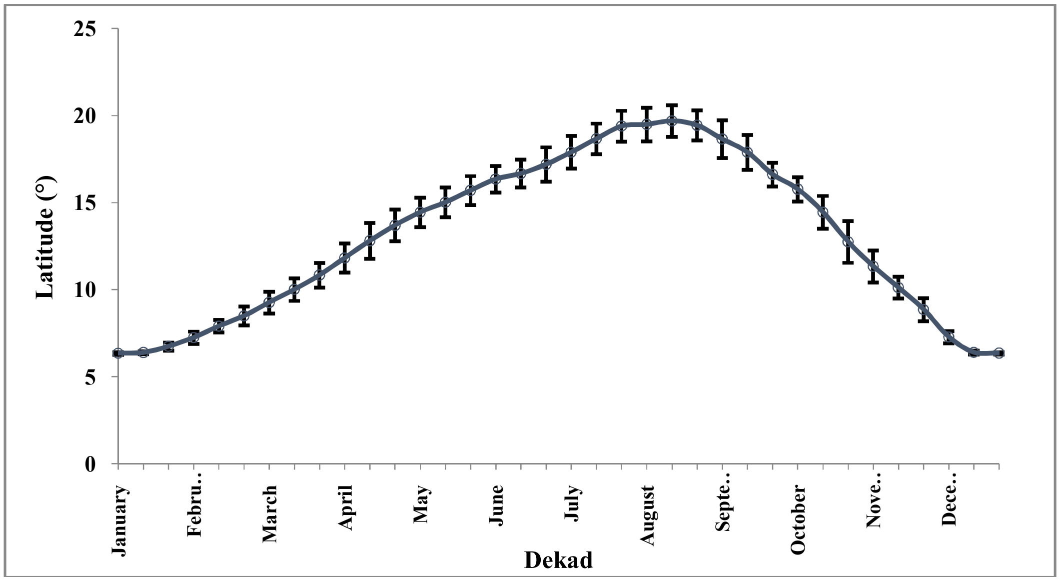

Fig. 9. Average dekadal latitudinal position of ITF on longitude 1°3 E (1989-2016).

3.4.2. ITF distance of the different sites to the rainfall onset (Monsoon period)

We determined the IFT position in relation to the rainfall onset for each station over the period 1989-2016. It consists to determine the latitudinal position of ITF to these dates, after wards to determine its position in relation to the different stations and finally to calculate the distance which separates the ITF of these sites taking into account the fact that 1 ° = 111.319 km to the equator (http://www.sunearthtools.com/dp/tools/conversion.php?lang=fr). These positions are summarized in the Table 2.

From the analysis of this table, we notice that the rain starts when the ITF is situated between 475 and 680 km at North of the station.

3.4.3. ITF distance to the different sites for eachdekad and the Correlation between precipitation and ITF position

Using the data produced by NOAA and the latitudes of the stations allowed us to determine the ITF distance in relation to each station for all dekad. The maximal height of dekadal rain amount, for both rainy seasons are measured during the dekad on June 20th and October 10th in Cotonou, and on July 20th and September 30th in Bohicon. During these dekad, the ITF is at 1914.69 km and at 1614.12 km from Cotonou and at 2159.59 km and at 1758.84 km from Bohicon, respectively. On the other stations, the maximal height of dekadal rain amount for the rainy seasons are measured during the dekadon September 10th and October 10th in Savè, September 10th in Parakou and August 30th in Kandi, respectively. During these dates, the ITF situates at 1992.61 km and at 1614.12 km from Savè, at 1992.61 km from Parakou and at 2081.66 km from Kandi. The ITF position is counted positively when the ITF is in the North of site and negatively when it is located in the South of site.

We established a relation between the ITF position and the precipitation for each station. For it, we associated to the monthly position of ITF compared to each station, to the monthly cumulatives of precipitation, in order to seek a correlation between the ITF position and the precipitations registered (Figs. 10, 11, 12, 13, 14, 15).In Cotonou, the correlation is 0.57 for the first season (Fig. 10). This correlation between the ITF position and the monthly precipitation obtained is good enough. For the second season, this correlation is 0.25 (Fig. 11). We notice that the correlation between the ITF position and the monthly precipitation during the short season is bad. We observed during the short season a particular atmospheric circulation that is established one self with the rise of the cold waters in Atlantic Oceanic. Which marks the presence of the rain fines, due to the fall of the temperature of air and the decreasing of the precipitation in the lowlayers. The precipitation to this period are due to the convection. These results confirm the work of [35] which taken into account, the influence of the ocean surface temperature front (SST) on coastal precipitation.

AtBohicon, Savè, Parakou and Kandi sites, the correlations obtained are 0.52 ; 0.61 ; 0.66 and 0.79, respectively (Figs. 12, 13, 14, 15). These value observed show a good correlation between these two greatness. For the Parakou and Kandi sites, the correlations are raised. Which reveals that the pluviometric regime in Benin is due to the ITF position. These results are near of those that have been obtained by [25] on the ITF variability and the rain amount of precipitation in Sudano-Sahelian zones in West Africa.

Table 1. ITF Position compared to the rainfall onset

Station	Latutide of station (°N)	Latutide of FIT (°N)	Postion of FIT (km)
Cotonou (First season)	6.3	12.4	679.04
Bohicon	7.17	12.6	604.46
Savè	8.03	13.4	597.78
Parakou	9.35	14.5	573.29
Kandi	11.13	15.4	475.33

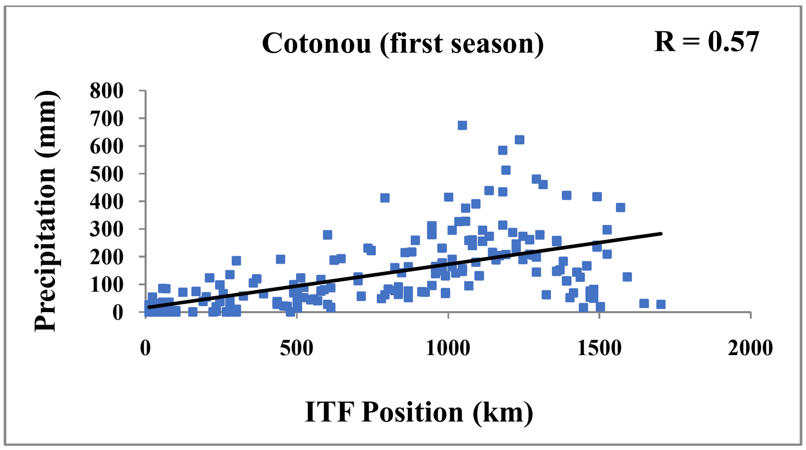

Fig. 10. Monthly precipitations in relation with the position of the ITF in accordance with the station of Cotonou (First season)

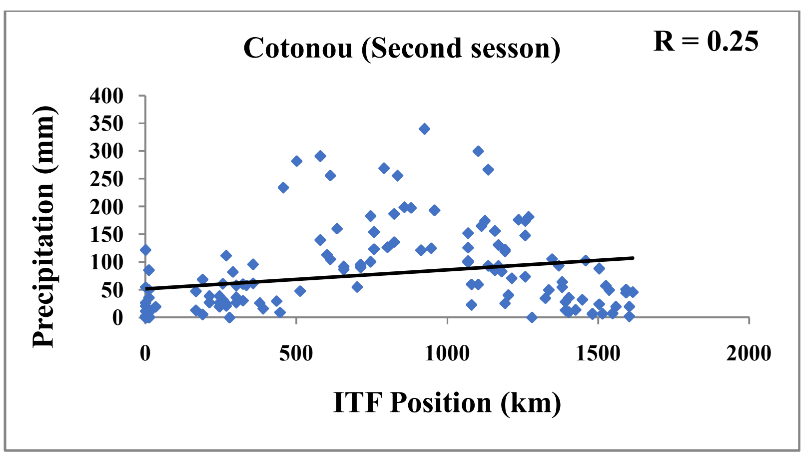

Fig. 11. Monthly precipitations in relation with the position of the ITF in accordance with the station of Cotonou (Second season)

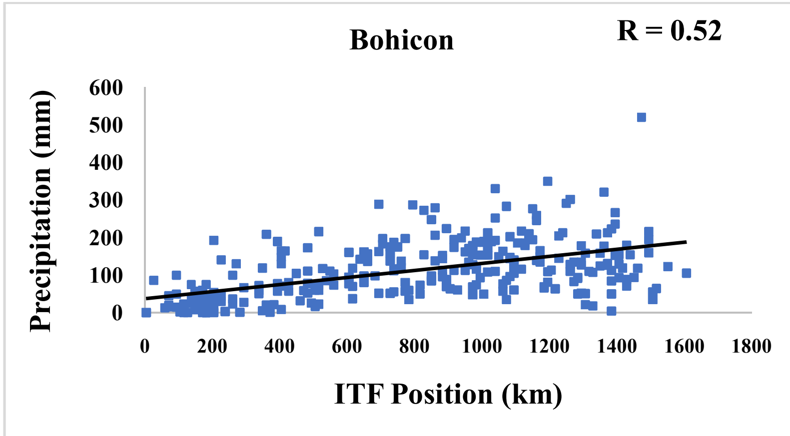

Fig. 12. Monthly precipitations in relation with the position of the ITF in accordance with the station of Bohicon

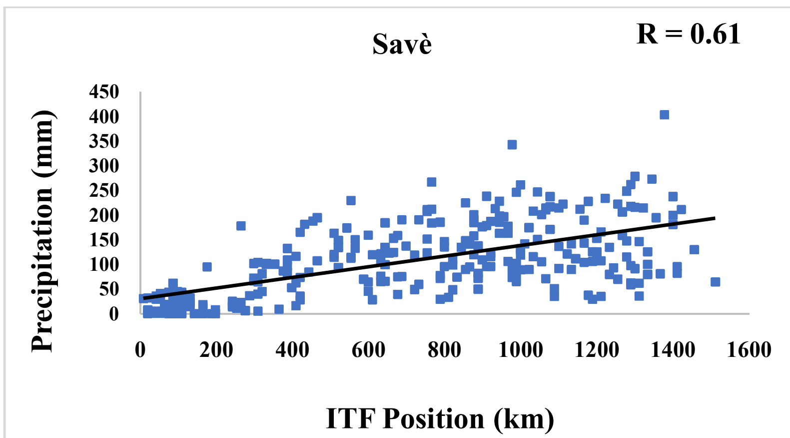

Fig. 13. Monthly precipitations in relation with the position of the ITF in accordance with the station of Savè

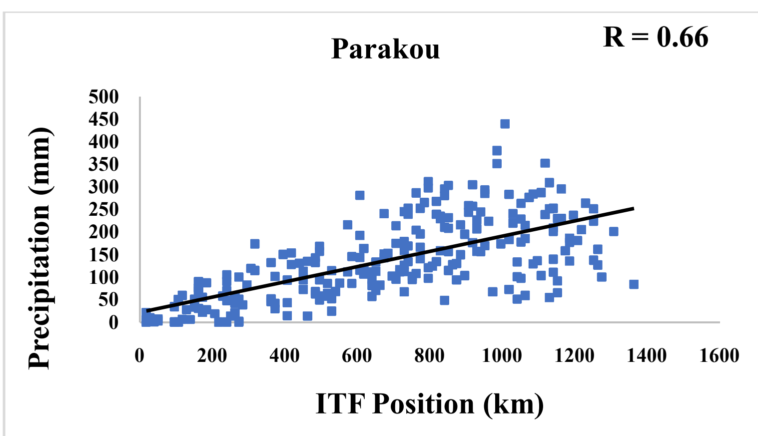

Fig. 14. Monthly precipitations in relation with the position of the ITF in accordance with the station of Parakou

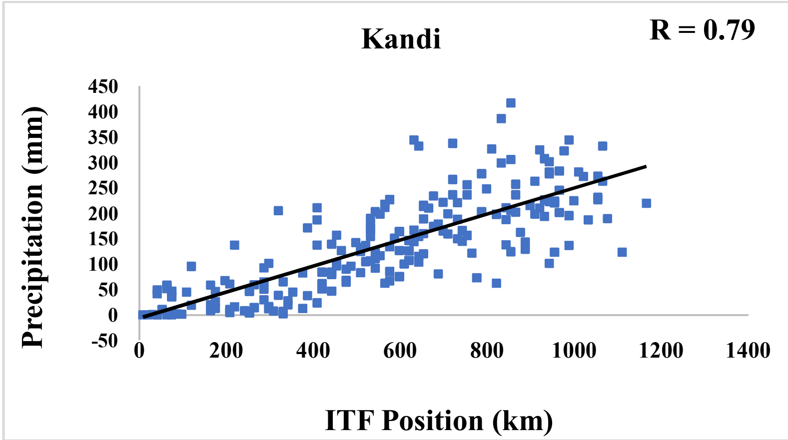

Fig. 15. Monthly precipitations in relation with the position of the ITF in accordance with the station of Kandi

4. CONCLUSION

In this study, we elaborated a new criterion to determine the rainfall onset of five synoptic stations in Benin: Cotonou, Bohicon, Savè, Parakou and Kandi. Then, we found a correlation between the monthly position of ITF and monthly precipitation foreach station. Finally, we studied the rainfall variability of each station on the period1987-2016.

The results from this work show that:

- The rainy season starts on April 7th, April 8th, April 14th, April 29th and May 17th in Cotonou, Bohicon, Savè, Parakou and Kandi regions, respectively.
- On these dates the ITF islocated 679.04 km north of Cotonou, 604.46 km north of Bohicon, 597.78 km north of Savè, 573.29 km north of Parakou and 475.33 km north of Kandi, respectively;
- There is a good correlation between the ITF position and the monthly precipitation in Parakou (0.66) and Kandi (0.79) regions. The correlations are good enough in Bohicon (0.52), Savè (0.61) and Cotonou (0.57) regions during the monsoon period;
- The annual average rainfall calculated during the study period (1987-2016) is 1357 mm for Cotonou, 1149 mm for Bohicon, 1079 mm for Savè, 1164 mm for Parakou and 1008 mm for Kandi.
- The existence of North-South precipitation gradient except Parakou is noticed.

This new criterion will allow farmers to know with more precision the rainfall onset.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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