

Variability and climatic extremes in the Republic of Chad

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Abstract

The study of trends and extremes in the Republic of Chad yields that, reduced Center index shows large Inter-annual variability of rainfall that is organized in a wet (1960-1970) phase followed by a dry phase (1971-1993) and a climb up to (1994-2008). This rainfall deficit over a long period has caused a larger decline in annual rainfall, which is 15.3%. What is relatively high compared to similar studies carried out in the West African region and Central Africa (about 7%). The percentage of the number of rainfall events decreases so that the disc of consecutive dry days increases. The temperatures of the hot days and nights increase exponentially. These events prove to the requisite standard that, the Republic of Chad is not immune to the phenomenon of climate change. The realization of such events bears witness to their probabilistic and non-linear character.
Keywords: variability, precipitation, extreme temperatures, Chad.

I. INTRODUCTION

Chad is one of the countries of the Sahel which suffers from water shortage from one season to another, and from one year to another (Abdoulaye, 2013). To understand the problem of water shortage, it is essential to analyze the series of temperatures and rainfalls to detect trends and extremes in the context of climate change to help better planning of adaptation actions.

A study similar to that we have made, was made by Aguilar (Aguilar et al. 2009) on the variations of temperature and rainfall in West Central Africa, Guinea Conakry and Zimbabwe between 1960 and 2006. Such a study should have been of benefit for the Republic of Chad. This study brings not only complement to Aguilar et al.'s studies (2009), but also helps to understand the atmospheric events that affect particularly the region of Chad in the core of the socio-economic activities.

II. AREA OF STUDY AND DATA

The study area stretches between longitude 14 ° to 24 ° E and latitudes 7 ° to 24 ° N (Fig.1) on the climate map, this area has almost the same climate as West Africa led by the movement of the Intertropical convergence zone (ITCZ) with:

• A relatively high heat from March to June period characterized by temperatures of the order of 45 ° C;

• A rainy season from May to October where the average annual rainfall ranges from 50 mm to more than 1350 mm.

• A period relatively dry and cold from November to February.

As a result, this area is facing very serious problems of water lack. Precipitations are characterized by very inhomogeneous spatial and temporal distributions, from one station to another and the impact is virtually live on purely rain-fed agriculture. This depends on agro-pastoral activities that occupy almost 95% of the active population (Abdoulaye, 2013). These activities are mainly focused on livestock (cattle, camels, goats, sheep, poultry...) and the crops that are Arabic Gum, groundnuts, beans etc. cereals (millet, sorghum, maize, wheat...), manioc and other tubers which constitute the main subsistence crops throughout the region although it is an oil producing area.

The data used in his study are obtained from the national meteorology services of the country. They concern the rainfall and daily temperature (maximum and minimum), six stations in the main cities are distributed homogeneously in the study area. These data cover a period of 49 years from 1960 to 2008.

Figure1 represents a map of Chad study stations and table1 gives the characteristics of the stations.

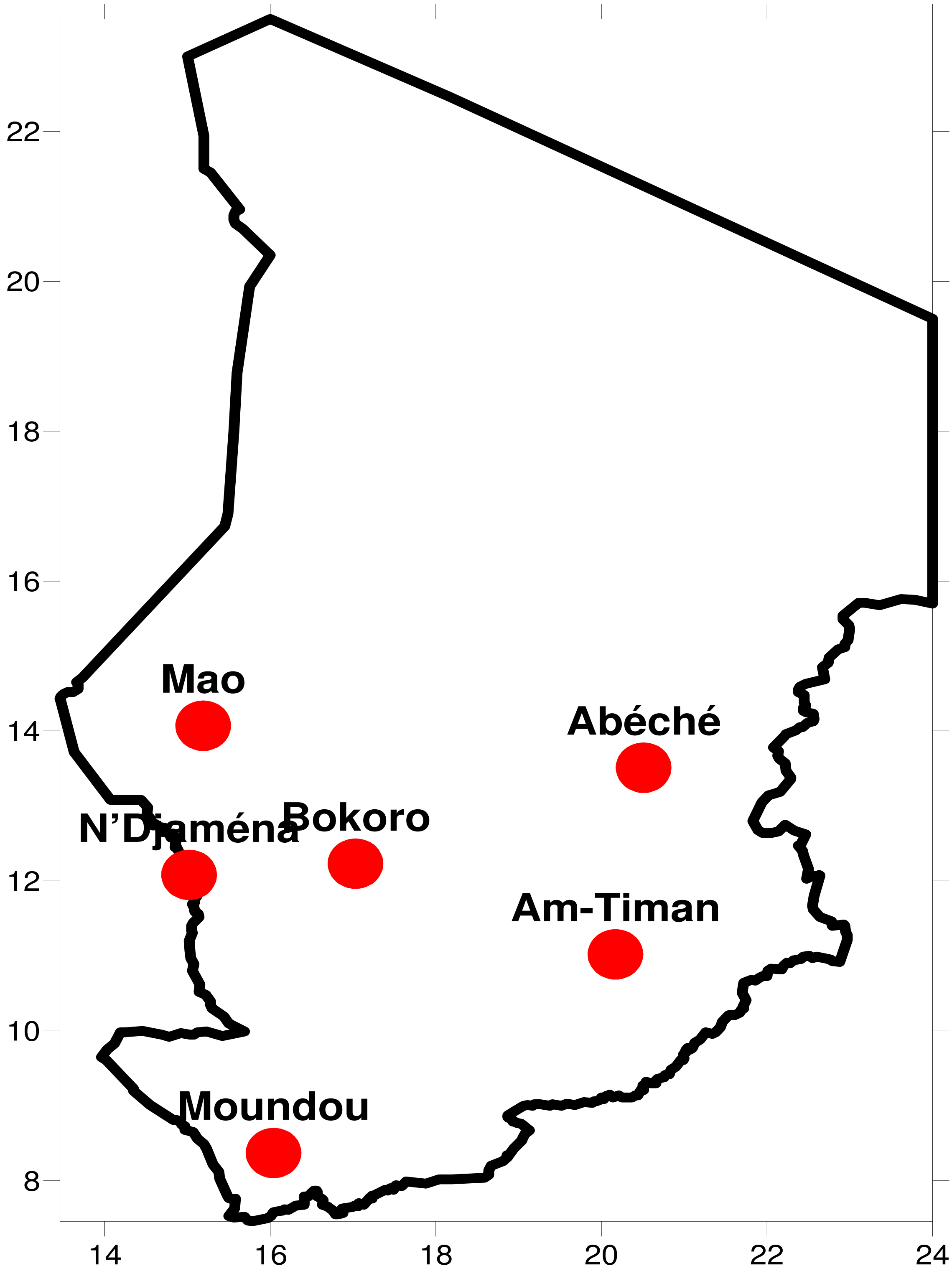


Figure 1: Map of the Republic of Chad and the study stations

Table 1: Geographical characteristics of stations in Chad.

Code OMM	Station	Logitude	Latitude	Altitude	Period of rainfall	Period of temperatures
64756	Abéché	20.51	13.51	545	1960-2001	1960-2001
64754	Am-Timan	20.17	11.02	435	1951-1989	1951-1989
64711	Bokoro	17.03	12.23	300	1951-2004	1951-2004
64701	Mao	15.19	14.07	536	1951-1993	1951-1993
64706	Moundou	16.04	8.37	420	1951-2010	1951-2010
64700	N'Djaména	15.02	12.08	300	1950-2010	1950-2010

III. METHODS

Several approaches were used for the treatment of temperature and rainfall data in order to homogenize the series of characterized stations. The first approach concerns the variability of abrupt changes characteristics of the data sets, and on the other hand it analyses trends.

1. Rainfall variability

To better visualize the periods of deficit and surplus rainfall, moving averages have been focused and reduced by the formula (Arcdoin B. S., 2004, Kay et al. 2007, Abdoulaye B.; 2013): ΔX/gt; 0 = surplus year; ΔX_i/lt; 0 = deficit year.

Where $\Delta \mathbf{X_i}$ is the total annual rainfall, for the station number **i**, **gt** the average annual precipitation for the station **i** and **lt** is the difference type of annual totals.

The extent of the drought is estimated from the deficit calculation. For precipitation variables whose time series presents a break, this method specifies the percentage change in the average around the date of breakdown (Abdoulaye, 2013). This deficit presented in table 2, is obtained by calculation.

2. Analysis of trends

In this second phase, we determined the indices of climate extremes in the series of data in order to characterize their trends. A trend is a gradual change in the properties of a random variable. It may result for example from the progressive development of a basin watershed (urbanization, climate change,).

Currently you can meet in the literature many definitions of climate index series, some are most recommended by the Organization of the World Meteorology (WMO) and the international scientific community. A set of 27 climate indicators has been calculated using available software RClimDex (http://cccma.seos.uvic.ca/ETCCDMI/software.shtml) which has been developed in different stages by (Frich et al., 2002; Zhang and Yang, 2004).

Among the rainfall indices, we focus on: the average rainfall, the maximum period of drought, the number of heavy rainfall events, the number of rainy and dry days, as well as extreme temperatures.

IV. RESULTS AND DISCUSSIONS

The calculation of the average rainfall index led to the analysis of temporal variability of precipitation in Chad. This analysis revealed two wet and dry periods: table 2 and Figure 1. There is also a severe drought from 1980-1997 and growth circa from 1994 to the present day. This observation is in agreement with studies on precipitations in West and Central Africa (Kay et al., 2007; Abbas b., 2013).

Table 2: Dry and wet sequences over the year in Chad.

Dry sequences	Wet sequences	Duration (month)	SPI Values	maximum Intensity
	1960-1970	120	2.5	Very wet
1971 - 1993		264	-3	Extremly severe
	1993-2008	60	1	Moderate wetness

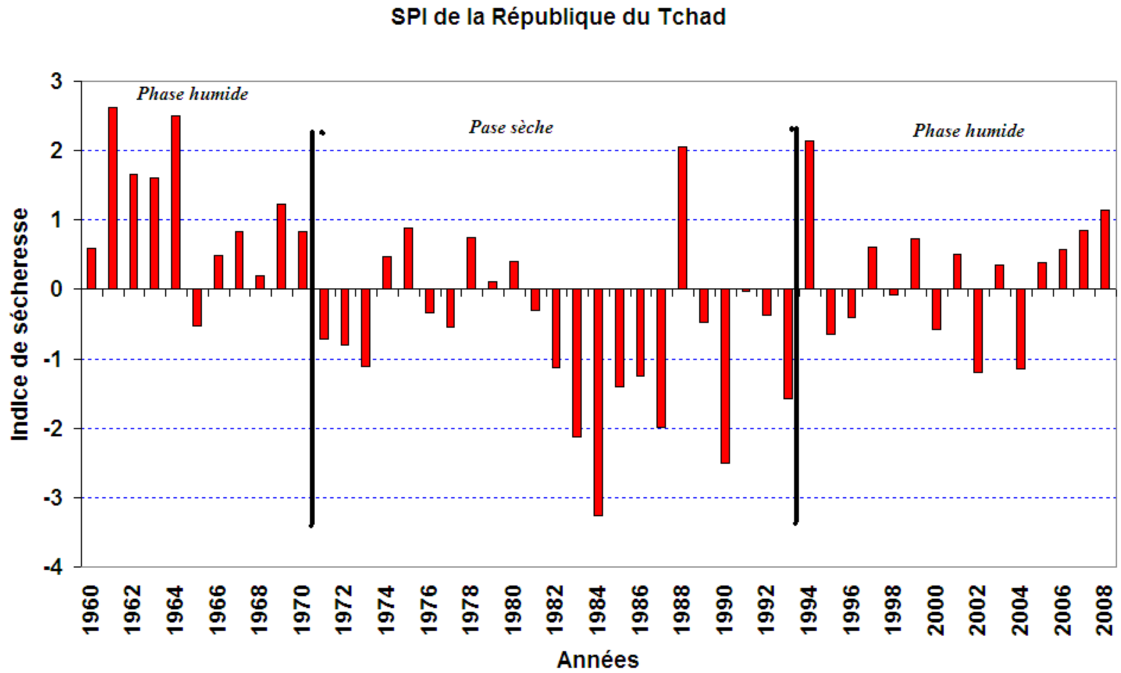


Figure 2: Rainfall fluctuations in Chad.

The intrusion of drought and its persistence sometimes throughout a decade did not only affect the appearance of the ruptures at the level of inter-annual rainfall series, it has also caused significant differences in averages. Throughout the area, the precipitation deficit and the average are 15.3% and 90.2 mm, respectively (Abdoulaye, 2013). What shows a certain severity of drought which can be seen on table 2, known by Chad compared to the countries of the Gulf of Guinea and Central Africa where it has been noted reductions in precipitation of only 7% (Aguilar, et al., 2009). But this inhomogeneity of the rainfall deficits seem to characterize nonlinear behavior of precipitation (Kay et al., 2007; Abdoulaye b. et al.; 2013).
Trends calculated from precipitation indices are presented in table 3 and compared with those of Aguilar on the globe.

First, Chad and Central Africa rainfall indices show significant decreases in precipitation, while global averages show an increase. For Chad there is a phenomenon of decline in rainfall in all the annual time series of precipitation around 1971 and 1993 linked probably to El Niño (IPCC, 1998) and the decrease of total precipitation, the length of the maximum number of consecutive dry days increases in Chad from Central Africa and the length of maximum number of consecutive wet days shows decreased significantly in Chad. This decline has been very remarkable in the 1980-1990 decade. This may be related to serious drought of 1983 and 1984 due to El Niño (IPCC, 1998). Therefore, it should be noted that Chad has seen its rainfall decreased since the beginning of the year 1970 and worst is marked by historic 1983-1984 drought which affected the entire central Africa region and the Sahel. This decrease in rainfall could also be explained by the position of the ITCZ linked to the Sun's declination (Matsuyama et al.., 1994) ; (McGregor and Nieuwolt, 1998), the anticyclones of Helena in the Azores, the African easterly Jet and the tropical East jet (Druyan and Hall, 1996), which play a determining role in tropical precipitations (Abdoulaye B. et al.., 2013). Equatorial Atlantic Africa, the role of North component of the JEA in convection and convergence of humidity during the seasons MAM and its lower layer has recently been clarified by (Patil et al. 2011). However, the review of studies on the Sahel made by (Nicholson, 2000) with weather observations stated rather than drought is associated with complex changes in the regime rainfall than in the simple shift of the ITCZ. And it also seems that this precipitation regime is strongly modulated by surface processes (Nicholson, 2000) through the growth of the albedo or the decline in the productivity of the soil, the radioactive effects of dust that might affect the climate at large scale. Although Chad has an intermediate geographic position between West Africa and Central Africa, the relationship between the vertical structure of the vertical velocity and distribution of precipitation for these two sub-regions is similar (Suzuki) 2011.

Table3: Trends in indices of extreme precipitation events in the Republic of Chad. The overall values are those of Alexander et al. (2006).

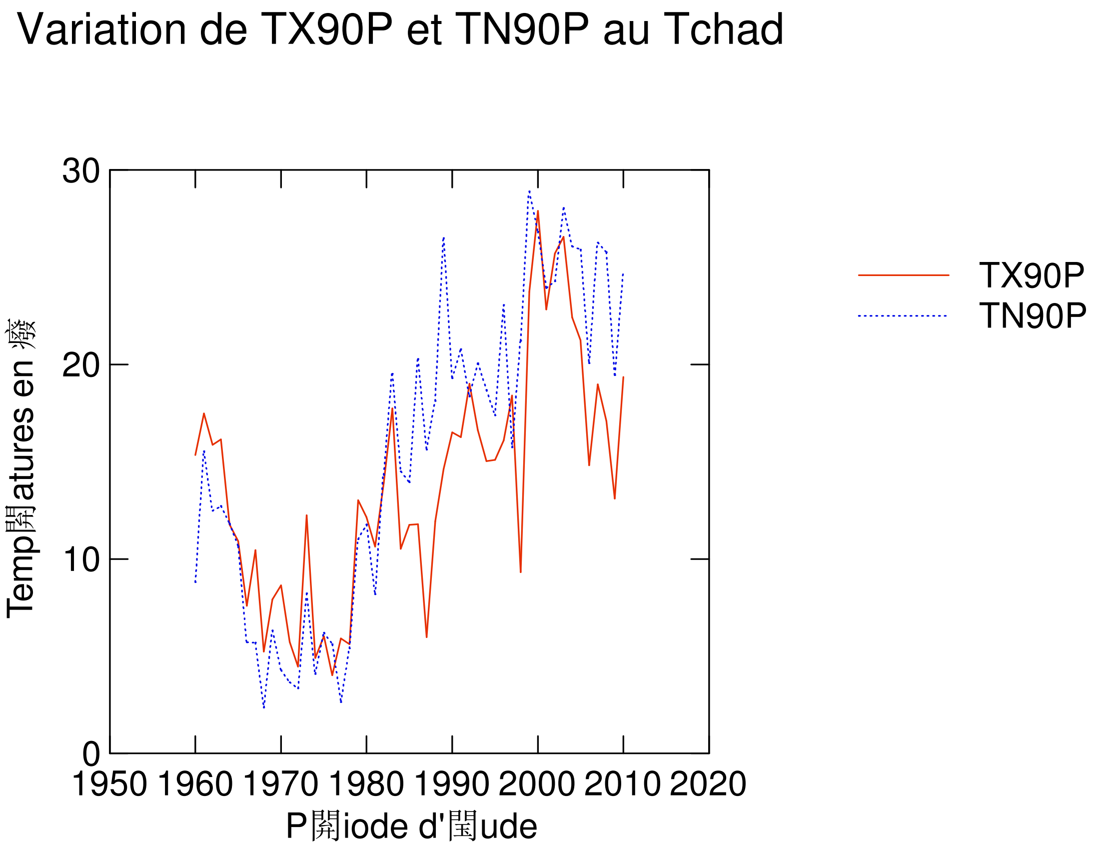
Indices	**calculed values**	**Values obtained by Aguilar(2009) in Central Africa**	**Over all values (world)**	**Unities**
Total precipitation	-4.303	-31.13	10.59	mm/Decade
Dry days consecutive CSD	0.475	-0.06	-0.55	days/Decade
Humid days consecutive CWD	-0.029	-0.35	-0.02	days/Decade
Number of days of high precipitation R10	-0.145	-0.67	0.29	days/Decade
Number of days of high precipitation R20	-0.093	-0.17	0.17	days/Decade
Very wet precipitation with R95p	-1.975	-12.19	4.07	mm/Decade
Extremely wet precipitation with R99p	-1.116	-3.66	2.52	mm/Decade
Quantité maximale d'1 jour de précipitations RX1j	-0.460	-0.87	0.85	mm/Décade
Maximum quantity of 5 days with precipitation RX5j	-1.035	-1.54	0.55	mm/Décade

Since then, Giannini and other scientists tried to understand and specifically the behavior of the oceans. It could be at the origin of precipitation and drought in a region over a decade. «http://iopscience.iop.org/1748-9326/8/2/024010» of Giannini, published in environmental research letters says: in the 20th century, while the tropical oceans global growth evenly over hot due to emissions of greenhouse gases, the North Atlantic has changed little and in some areas has even become cooler.

"Why? Since aerosols of sulfate - essentially pollution from fossil fuel burning in North America and Europe - have stopped radiation from the Sun to reach the Earth's surface here, Giannini indicates."Normally, the North Atlantic will introduce air displacement of the monsoon in the African continent, which is eventually worn through the Sahel and gives its rainfall. In 1980s, Giannini and colleagues presume that the aerosols over the North Atlantic Ocean have reduced significantly the evaporation, cutting the supply of moisture to the Sahel and throwing the region into a state of persistent drought. Trends for temperature indices are presented in table 4 and Figure 3.

With hot extremes of temperature of the days and nights that increase exponentially in Chad compared to that of Central Africa and global. Trends in temperatures of cold days diminish; these series indicate clearly that global warming is significant in Chad. The hottest of the year days and nights have roughly comparable values but is still higher than the overall average. The coldest days and nights of the year are faster than the global average increases while the planet tends toward the coldest days. The tendency of hot days and nights is the increase in temperatures as we can see from figure 3 and table 3, which shows the series of warm nights compared to the warm days. This can be explained by the phenomenon of greenhouse which occurs in the night. The daily temperature which decreases overall is increased in Chad but showing little change in the Central Africa region.

Figure 3: Interannual evolution of the temperatures of hot days and nights in Chad.



CONCLUSION

Our study corroborates with the commonly felt sentiment locally, a climate change relative to the decline in rainfall in Chad in general. This feeling is therefore well founded. This study detects trends in wet and dry years in Chad and examines the manifestations of climate variability such as droughts which have followed with a certain severity from the 1970s and 1984. This variability of climate has caused a decrease in rainfall 15.3. Observed in the early 1980s drought is most significant. It seems large-scale climate have had a significant impact on the whole of West Africa and Central Africa sub-regions. Indeed, the corresponding drying of the large rivers of the basin started in 1970 and continued in the 1980s (Laraque et al., 2001). This drought has amplified significant anthropogenic wind erosion almost throughout the region (Baohoutou L. 2010). As a result, it would be important that policymakers draw and apply the resulting lessons of adaptation measures derived from the Kanem (between 12 ° and 20 ° N) agro-sylvo-pastoral development project in arid and semi-arid regions of Chad. It therefore plans adequate institutional adaptation measures to incorporate the concept of adaptation to create a Development Fund and to launch ground projects in consultation with the area communities through improved seed and suitable, irrigation projects, protection of the soil cover, recovery of agricultural and pastoral land abandoned to the sand dunes in the villages.

Acknowledgement

This article was made with the financial support of the Centre Abdus Salam International Centre for Theoretical Physics (ICTP) Trieste in Italy through the OAS-AC-71 project and that of CEPAMOQ (University of Douala), Cameroon. The authors are grateful to professors Abdelkerim MOHAMED, KWATO NJOCK G. Moses and Bernard MPassi Mabiala for their multifaceted support and the anonymous reviewers for their contribution to the improvement of this work.

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