

**Research Article**

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Mechanism of the Intertropical Convergence Zone (ITCZ) in rainfall in West Africa: The case of Guinea

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Guinea is swept by the Intertropical Convergence Zone (ITCZ) from May to January. During this period, the ITCZ, combined with the West African monsoon, brings torrential rains affecting all of Guinea's natural regions, with higher average rainfall in coastal areas and at higher altitudes, and beginning as early as May. Our study highlights this imbalance by clearly delineating the four climatic regions of Guinea.

Keywords: ITCZ; West African Monsoon; rain; climatic region**Introduction**

The rainy season in the Sudan-Sahelian belt (between 10°North and 20°North) is governed by atmospheric and oceanic dynamics controlled by the West African Monsoon (WAM) system. During the rainy season, the southeasterly maritime trade winds cross the African continent and form the monsoon flow. This flow meets the northeasterly land winds, known as the Harmattan, in the Intertropical Convergence Zone (ITCZ), a region of updrafts resulting from the meeting of two air masses [1]. The persistent presence of the ITCZ promotes advection over the area it covers, the Gulf of Guinea, and over a broad period (from July to January).

Position of the Intertropical Convergence Zone (ITCZ)

In climatology, the ITCZ corresponds to the meteorological

equator (ME). Its variations have a significant effect on rainfall for many equatorial nations, producing dry seasons and wet seasons (monsoons). Prolonged anomalies in the ITCZ can produce extreme weather events in the intertropical zones. Calm or weak winds of variable direction are found in the lower layers of the atmosphere near the ITCZ. These equatorial calms follow, with a slight delay, the annual meridional shift. Climate change will cause the Intertropical Convergence Zone to shift northward. This shift is temporary (lasting about twenty years) but will have significant consequences for agriculture. The position and structure of the ITCZ vary depending on location and season. It is often extremely clear over the Atlantic Ocean, where it takes the form of a narrow and well-defined convergence line, along which a multitude of

thunderstorms develop, whose “anvils” form an almost continuous cloud cover (Figure 1). Above the continents, it is marked by a band of intense convective activity which often remains broad and diffuse.

The Intertropical Convergence Zone in Africa (ITCZA)

In West Africa, where the Intertropical Convergence Zone (ITCZA) varies from a centered position between 5°North in winter

and 20°North in summer, which covers the Sahelian band and the equatorial band (Figure 2). During the boreal summer (June-September), the dynamics of West Africa are dominated by the northward movement of the West African monsoon, a mass of warm, humid air originating in the Atlantic. This flow encounters dry air from the Sahara (the Harmattan) at the Intertropical Convergence Zone (ITCZA), resulting in heavy rainfall.

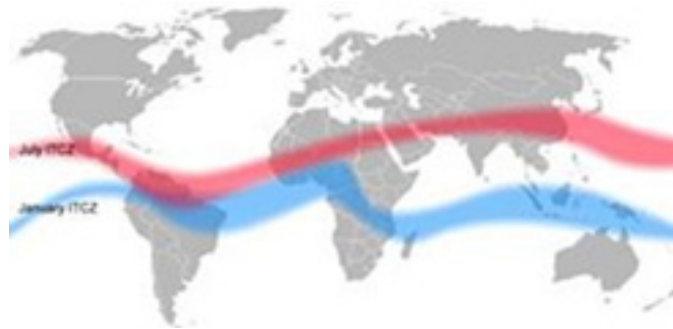


Figure 1: ZCIT position in January (Blue) and in July (Red).

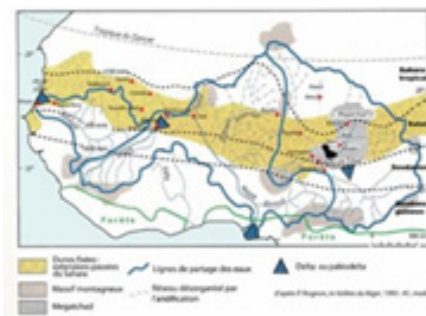


Figure 2: Sudano-Saharan Strip.

Studies show that vegetation types are distributed along bands that correspond fairly precisely to the annual movement of the Intertropical Convergence Zone (ITCZ). In summer, large quantities of water vapor from the Gulf of Guinea are advected in the lower atmosphere by the trade winds (African monsoon flow) towards the ITCZ. Numerous thunderstorms develop more than 1,000 km south of the ITCZ in regions where the moist layer is quite thick. As one approaches the ITCZ, the moist layer becomes thinner, and convection is characterized mainly by the presence of 600- or 700-km-long convection bands (squall lines), oriented north-south, which propagate westward for one to two days and provide most of the rainfall associated with sub-Saharan regions. The immediate vicinity of the Intertropical Convergence Zone (ITCZ), due to the thin layer of moist air, very rarely receives precipitation. However, the position of the ITCZ is not the only factor governing the strength and frequency of convection. Indeed, no significant difference has been observed between the positions of the ITCZ during dry years and those observed during the wettest years.

African Monsoon Continental Tropical Convective System

During the August 2010 campaign in Niamey, Niger, during the

African monsoon season, the observed systems were formed from the interaction of different air masses (Figure 3). The northward movement of the ITCZ during the boreal summer creates a northward shift of the trade winds over the African continent. This monsoon flow (southwest) brings moisture from the ocean into the lower troposphere, where it meets the warmer, drier Harmattan flow (northeast) to create a convergence zone known as the Intertropical Front (ITF) [2,3]. At high altitudes, three jet streams maintain and influence the formation of convective systems: the African East Jet (AEJ; east-west at 650 hPa), the Tropical East Jet (TEJ; east-west at 150 hPa), and the Subtropical West Jet (JOST; west-east at 200 hPa) [4,5]. Low-level humidity combined with significant vertical and horizontal wind shear promotes the formation of cumulonimbus clouds [6]. Cumulonimbus clouds cluster in circular groups or lines (squall lines). A cold subsiding flow (density current) causes air masses to rise ahead of the system. A cold front forms, maintaining convection and renewing the convective parts of the system [7,8], while the old convective cells are located behind the system, thus creating the stratiform part (Figure 4). The MCS advances from east to west; when it is no longer fueled by convection, its stratiform part can persist for several more hours.

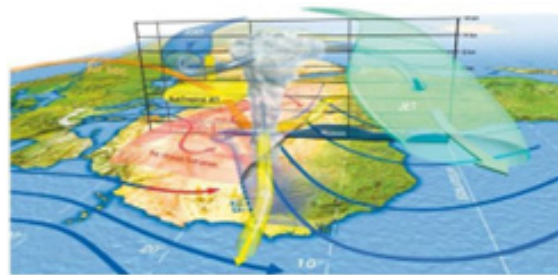


Figure 3: The African monsoon (Lafore et al. 2007).

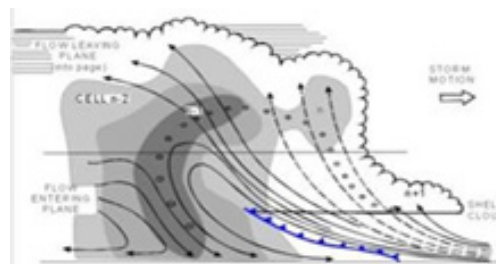


Figure 4: Convective cells of an MCS (Browning and al. 1976).

The Intertropical Convergence Zone over Guinea

In Guinea, we observe that disturbances from the Intertropical Convergence Zone (ITCZ) are very early. They begin as early as the start of May and persist until the end of October, or even November; this results in a rainfall period of up to seven months (Figure 5a).

The regions with the highest average rainfall are those located in the center of the ITCZ: Conakry with over 4000 mm; Kindia with 2500 mm; and Nzérékoré with 2000 mm. The Kankan region has an average rainfall of 1500 mm despite the presence of abundant vegetation (Figure 5b).

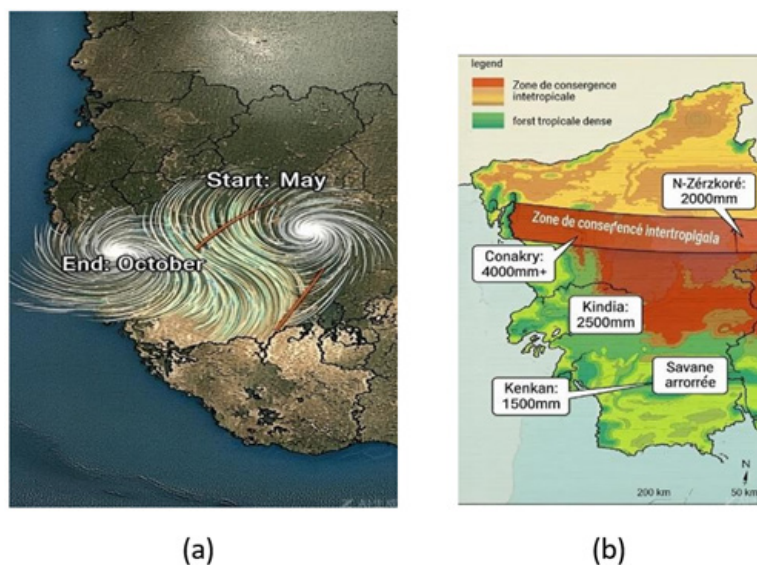


Figure 5: (a) Duration of disruptions due to the movement of the ITCZ over Guinea. (b) Average annual rainfall amounts due to the passage of the ITCZ over certain cities in Guinea.

Maximum and minimum values are estimated from the typical interannual variability of the West African monsoon (coefficient of variation of 20-35%). Exceptionally wet years (e.g., 2012 with SPI > +2 in Boké) and dry years were taken into account. The methodology used is as follows:

- a. Averages are calculated from reference climatological data (primarily for the period 1991-2020);
- b. For the period 2000-2025, the data follow observed trends, including exceptionally wet years (2008, 2012) and relatively dry years (2001, 2015);
- c. Maximum values correspond to the wettest years of the period (generally 130-150% of the average);
- d. Minimum values correspond to the driest years (generally

50-70% of the average). - Variability is greater on the coast (Conakry, Boké, Kindia) due to oceanic influence.

Based on Table 1 and the histogram (Figure 6), rainfall distribution varies significantly, reaching a peak of 1143 mm (in August) and less than 500 mm (in August) in Upper Guinea:

- a. Conakry is the rainiest city (peak of 1143 mm in August);
- b. Boké and Labé follow with peaks exceeding 500-550 mm in August;
- c. Siguiri and Kankan (Upper Guinea) receive the least rainfall.

Rainfall peaks generally occur in July-August on the coast and in August-September in Forest Guinea.

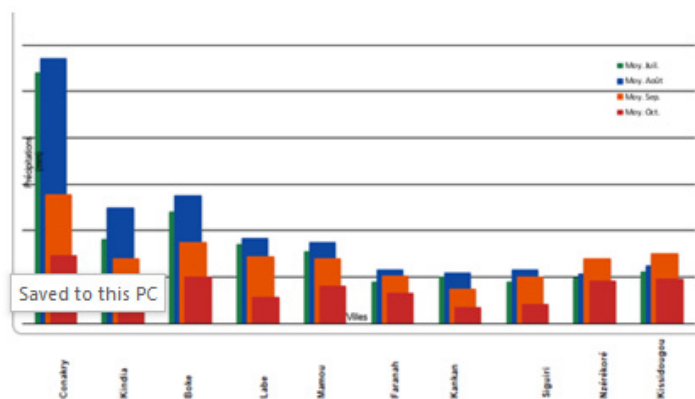


Figure 6: Average rainfall per city per month (mm).

Table 1: Average rainfall in the main cities of Guinea (July –October) referenced period 2000-2025. Average rainfall in the cities of Guinea (July-October).

Geographic informations				Jul			August				September		October		
City	Natural region	Latitude	Altitude	Average Jul.	Max Jul.	Min Jul.	Average August	Max August	Min August	Average Sep.	Mas Sep.	Min Sep.	Mos. Oct.	Mas Oct.	Min Oct.
Conakry	Guinée Maritime	9.511N,13.710	26m	1082	1450	720	143	1520	780	556	750	350	292	420	160
Kindia	Guinée Maritime	10.06°N,12,86°D	320m	360	480	230	500	680	320	280	400	170	180	270	100
Boké	Guinée Maritime	11.181N, M.28 O	70m	480	650	300	550	740	370	350	490	210	200	310	110
Labé	Moyenne Guinée	11.31N,12.28 O	1070m	340	460	210	367	500	240	288	390	180	113	180	60
Mamou	Moyenne Guinée	10.37N, 12,09 D	780m	310	430	195	350	480	225	280	380	175	160	240	85
Faranah	Haute Guinée	10.05°N,10.74:0	470m	177	250	110	229	320	145	204	290	130	132	200	70
Kankan	Haute Guinée	10.39°N,9.30°O	380m	200	290	120	219	310	140	148	220	85	67	110	30
Siguiri	Haute Guinée	11.42°N,9.17°O	310m	180	260	105	230	330	145	200	290	120	80	130	35

Nzérékoré	Guinée Forestière	7.75'N,8.83'O	480m	195	280	120	212	300	140	281	390	180	183	260	100
Kissidou-gou	Guinée Forestière	9.191N,10.10	510m	220	310	140	250	350	165	300	420	195	190	270	105

Reference period : 2000-2025| Precipitation in millimeters (mm).

Table 2: Comparative rainfall analysis by natural region. Monthly averages (mm) | from July to October | Period 2000-2025.

Natural Region	City	Aver. Jul.	Aver. August	Moy. Sep.	Moy. Oct.	Total Season (mm)	Rainfall max (mm)	Rainf all min (mm)	Variability (%)
Guinée Maritime	Conakry	1082	1143	556	292	3073	Août (1143)	Octobre (292)	110,8%
	Kindia	360	500	280	180	1320	Août (500)	Octobre (180)	97,0%
	Boké	480	550	350	200	1580	Août (550)	Octobre (200)	88,6%
Moyenne Guinée Maritime		640,7	731,0	395,3	224,0	1991,0			
Moyenne Guinée	Labé	340	367	288	113	1108	Août (367)	Octobre (113)	91,7%
	Mamou	310	350	280	160	1100	Août (350)	Octobre (160)	69,1%
Moyenne Moyenne Guinée		325,0	358,5	284,0	136,5	1104,0			
Haute Guinée	Faranah	177	229	204	132	742	Août (229)	Octobre (132)	52,3%
	Kankan	200	219	148	67	634	Août (219)	Octobre (67)	95,9%
	Siguiri	180	230	200	80	690	Août (230)	Octobre (80)	87,0%
Moyenne Haute Guinée		185,7	226,0	184,0	93,0	688,7			
Guinée Forestière	Nzérékoré	195	212	281	183	871	September (281)	Octobre (183)	45,0%
	Kissidoukou	220	250	300	190	960	September (300)	Octobre (190)	45,8%
Moyenne Guinée Forestière		207,5	231,0	290,5	186,5	915,5			

By comparing the amounts of rain with the natural region (Table 2), we find that, for the regions of Maritime Guinea (Conakry, Kindia and Boké), Middle Guinea (Labé and Mamou) and Upper Guinea (Faranah, Kankan and Siguiri), the maximum rainfall is reached in August and the minimum in October, whereas for Forest Guinea the maximums are in September.

Conclusion

The Intertropical Convergence Zone (ITCZ), or meteorological equator, is centered over Guinea for a considerable period, between six and seven months. This presence promotes favorable rainfall.

The spatial and temporal distribution of rainfall highlights four natural regions:

- Maritime Guinea: high coastal rainfall, peaking in July-August (3000-4000 mm/year);
- Middle Guinea: moderate to high rainfall, influenced by altitude (2200-2800 mm/year);
- Upper Guinea: lower rainfall, Sudanese climate (1500-2000 mm/year);
- Forest Guinea: more spread-out rainfall, later peak in August-September (2200-2300 mm/year).

The regions near the coasts or those at higher altitudes receive abundant rainfall. We propose investigations to understand their contribution to rainfall in future study.

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