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STUDY OF SAHELIAN CONVECTION FROM SATELLITE DATA FROM 1996 TO 2006

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Abstract

In the Sahel, the passage of the rain season at the dry season is caused by the circulation of the winds on our planet. In this climatic zone, the main part of the populations draws their income from the agropastorales activities. The network of in situ measurements is obsolete, to see non-existent. We tried to explain the climatic modifications starting from satellite data Météosat. From a composite analysis on the Météosat images, we showed that the convective activity of the rain season was reinforced these five last years compared to the ten years previous.

Key words : Convection, Météosat, Rains, Sahel, Radiosondage

Introduction

The years of drought when convection is less present, have pushed the rural population of the Sahel region to settle on the outskirts of cities and occupy their watersheds. In the last five years, the cities are flooded and peri-urban populations from the exodus have a lot of difficulties with their homes because of these floods. These phenomena related to the rain suggested to study the convection in this climatic zone, the passage from the dry years to the humid years starting from the data of the satellite by making a composite analysis.
In this work a study of Sahelian meteorology of convective disturbances was conducted at first. The composite analysis method is described.
We have attempted to explain climate change from Meteosat satellite data.
From a composite analysis of Meteosat imagery we have shown that the convective activity of the rainy season has increased from 2002 to 2006 compared to the period 1997-2001.
Our results are validated by the statistics on the squall lines at the Saint Louis station in Senegal and the water profiles obtained from the radiosondages of Dakar.
The rest of the work will be a long-term statistical study to see if we can detect a convection-related cyclic phenomenon in this climate zone

General information on Sahelian meteorology.

The climate system in Sahelian Africa is relatively simple. Seasonal cycles, large-scale aerosol circulation, and rainfall distributions are governed by intertropical-front movements that limit ocean and continental air masses (Domergue, 1980).

Geographical situation of the Sahel.

The geographical zone of the Sahel is between the latitudes 11 ° and 15 ° North. It represents a band about 5000 km long and 300 km wide located at the southern limit of the Sahara. Climate, agriculture and lifestyle are relatively unified from one country to another. The delineation of the Sahel is generally not examined in political or geographical terms, but in terms of the amount of rainfall. In the north, at the border separating the Sahel from the Sahara, rainfall is of the order of 200 mm per year, while in the south, their volume reaches 600 to 700 mm at the border of the Sudanese zone (Figure 2.1) . The main characteristic of the Sahelian zone is that it is subject to long and frequent periods of drought.

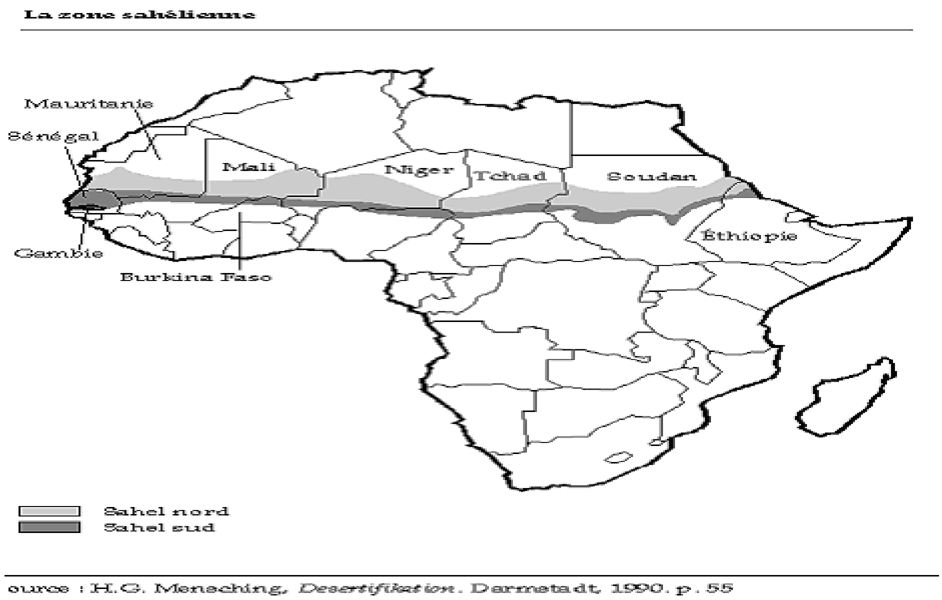

***Figure 1*: A map of Africa; the Sahel highlighted in orange.**

• http://www.isnar.cgiar.org/publications/books/sahel/english/chap1-1-2.htm#1 (last consultation on 22/05/2007)

Climate situation.

The inhabitants of temperate latitudes are accustomed to permanent climatic humidity as well as frequent and sufficient rainfall for agriculture. In the Sahel, where the climate is tropical with variable humidity, the situation is very different. There are no discernible seasonal changes in temperature. There are temperature differences between day and night, between the plain and the mountain, but not really between summer and winter. The rainy season of three to four months in a row occurs in summer (June / July until August / September). The rainfall volume varies between 200 and 600mm. The intense sunshine and high temperatures cause the evaporation of most of this water, already rare, before it can be used for agriculture. The moisture required for agricultural production is only provided for 2 to 4 months per year. The rest of the year is characterized by an arid and desert climate. Françoise de Salmand in 1975 and J-Louis Domergue in 1980 studied the few factors that lead to this climate situation. In the Sahel, the transition from the rainy season to the dry season is caused by the circulation of winds on our planet (figure 2)

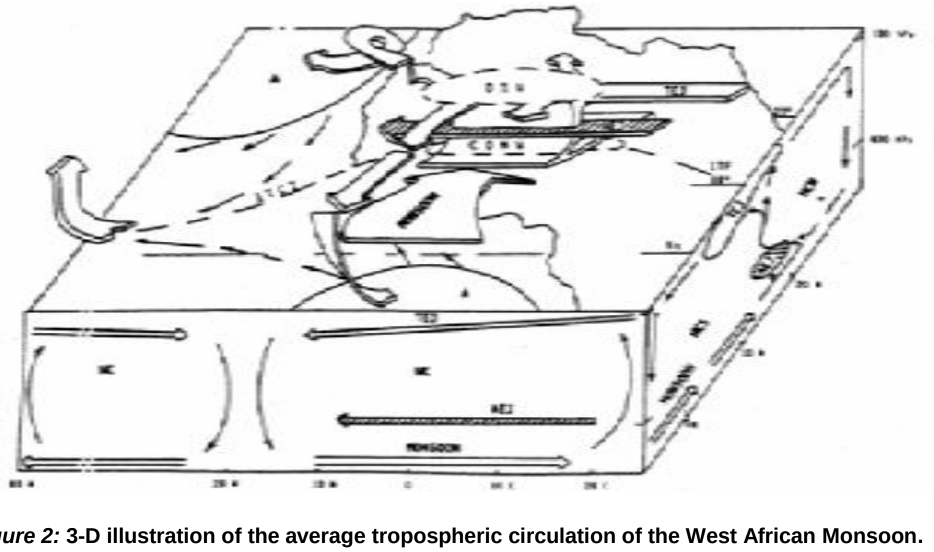

***Figure 2:* 3-D illustration of the average tropospheric circulation of the West African Monsoon.**

Figure 2: 3-D illustration of the average tropospheric circulation of the West African Monsoon.
The Intertropical Convergence Zone for Active Precipitation (known as the ITC zone of the Intertropical Convergence Zone) exerts a very strong influence on the climate in the Sahel. At the equator, masses of trade winds pour into this convergence zone that moves to the tropics, depending on the season. Precipitation from the convergence zone falls on the equator in all seasons. On the other hand, the dry regions of the desert (the tropical outer zone) experience only a period of precipitation in summer.
In winter, the Sahel is under the influence of the northeastern trade wind. Because of the long journey in the desert, this wind is hot and dry and rainfall is scarce. The further north we go to the Sahel, the longer the dry season, Figure3 a.
In summer, the sun is upright on the Tropic of Capricorn, in the middle of the Sahara. The ITC zone moves north with a slight delay on the sun to the 15th or 16th parallel, that is, to the regions north of the Sahel (Figure 3b). Southwesterly over the Sahel, these winds became wet as they passed over the tropical seas of the Gulf of Guinea, blowing to the southeast and discharging, bringing long-awaited water to the Sahel.

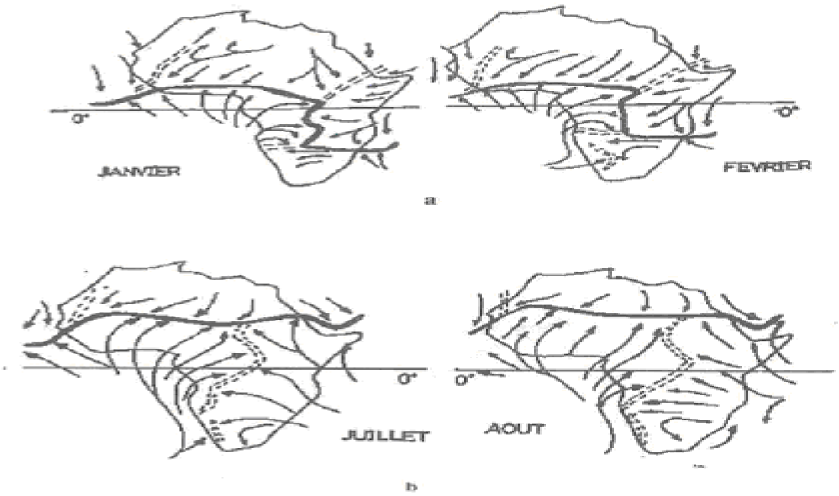

Figure 3: **Wind flow and position of the intertropical front surface a) January and February, (b) July and August (ASECNA, 1973)**

For agriculture, the variability of rainfall is much greater than the actual quantity and seasonal change. The displacement of the intertropical convergence zone and therefore of the precipitation zone is irregular. From year to year, differences of 50% or more may occur, depending on the northward advance or the delay of the air mass convergence zone. Precarious rainfall on the Sahara is increasing. In temperate latitudes, when 100 mm less fall in a year, harvests are not compromised. In the Sahel, this reduction brings the annual average below 500 mm required for crops, thus condemning all harvests.

Figure 4 shows the variability of rainfall in the Sahel since the beginning of the century. It indicates that years above or below average are increasing. If several dry years follow one another, the nutrition problems become much worse. We can make up for an unsuccessful year without major problems for the populations, if the food reserves are sufficient. However, this is not possible if no harvest is made in successive years, as was the case during the successive droughts between 1968 and 1973 (Brown and Wolf, 1985).

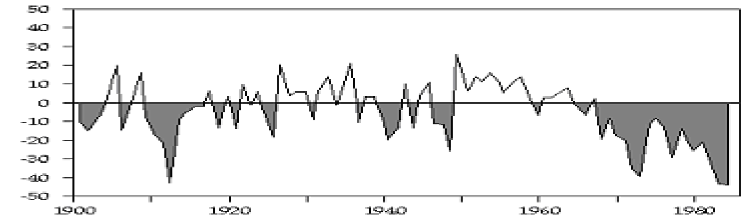

Figure 4: **Rainfall variation for all the Sahel area in% compared to the century average.**

The occurrences of the convective systems that we will describe in the following paragraph. The lack of in situ data and the shortcomings of dynamic models to simulate climate are leading to enormous difficulties in understanding and predicting climate in Sahelian Africa.

Climatology of Squall Lines in the Sahelian Zone.

In the Sahel we have a deep convection rain due to squall lines and that of local convection.

The squall lines on the ground.

Satellite aspect of squall lines.

They appear as cloud clusters of approximately circular, oval or linear shape. The satellite images give a global view of the MCS and place them in their synoptic context. They allow monitoring during their entire life cycle. The internal structure (figure cut) is described by a cert

In the Sahel, the determination of intensity thresholds is important (Maddox, 1980).

In the early 1980s Fortune (1980), Martin and Scheiner (1981) indicated that squall lines could be distinguished from other cloud systems by satellite imagery because squall lines have a more compact and oval shape. On a satellite image a squall line can be separated from other cloud clusters because it has the following characteristics (Figure 5):

- a clear border at the front, preceded by a zone of "clear sky", that is to say cloudless, while the back, which often corresponds to the eastern edge of the cloud cluster, is difficult definable.

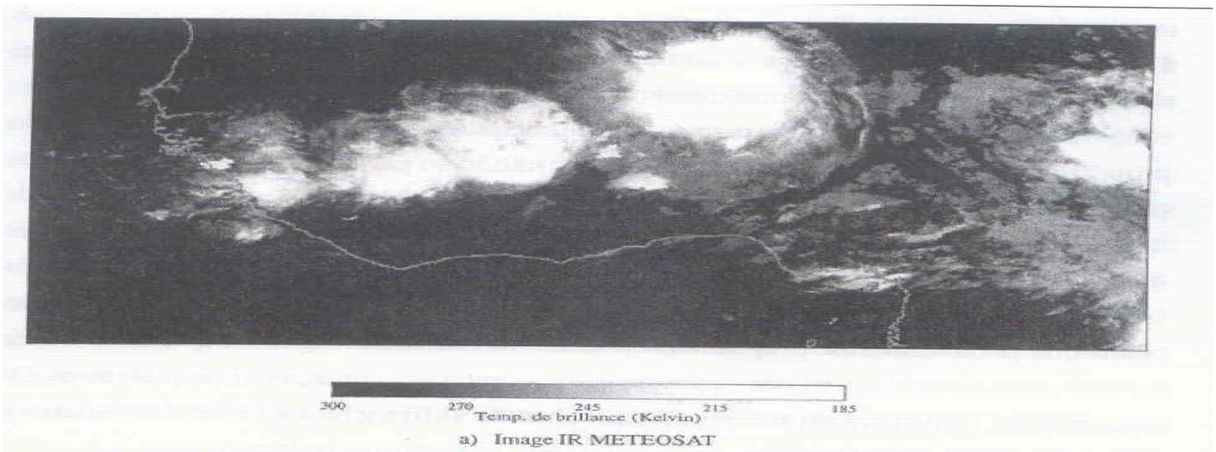

Figure 5: **Examples of images of convective systems observed on August 1, 1998 over West Africa. (Adapted from Ramage, C. M. F. Kebe, 2005).**

Appearance of squall lines seen by the radar

The mesoscale structure seen by the radar (figure 6) generally presents the following aspects:

- a variable north-south orientation;
- the appearance of a series of intense reflectivity cells connected by echoes of more moderate intensity;

a strong reflectivity gradient on the leading edge (that is, the gradient is stronger on the leading edge than on the trailing edge of the convective portion);

elongate cells oriented at 45 ° -90 ° with respect to the line;

- A stratiform part of dimension greater than 104 km2 in horizontal surface with a concavity of the rear edge that is believed to be associated with the influx of meso-scale of dry air which erodes a portion of

the stratiform echo;
- A secondary peak of reflectivity which is separated from the convective line by a narrow channel of low reflectivity.

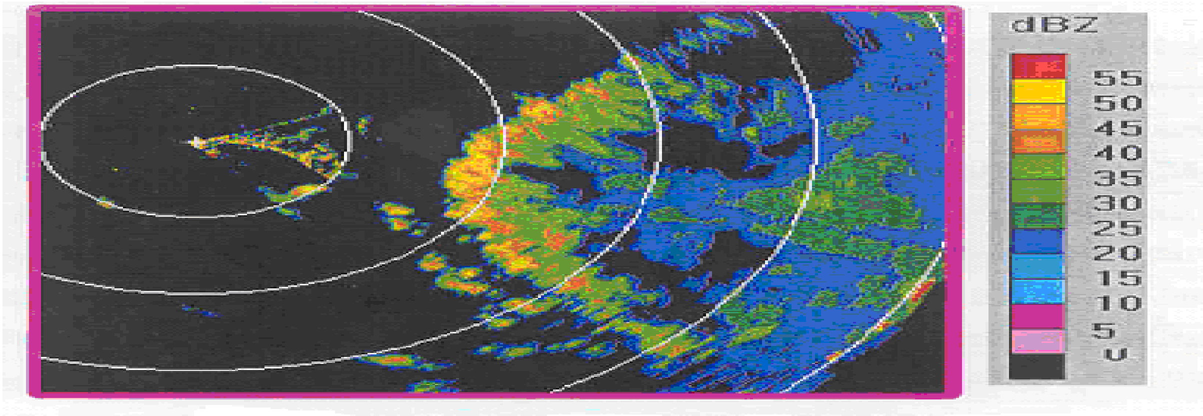

Figure 6: **Radar echoes of the squall line observed on 25/07/1996 at 12:56 UTC in Dakar. The concentric circles are 50 km apart. The + represents the position of the Radar (archive of the Laboratory of Atmospheric Physics (LPA), SANAGA digitization) (after Kebe, 2002).**

Kinematics of squall Lines

Squall lines are well-organized fast MCSs (Mathon et al., 2002). They consist of a south-to-north alignment of cumulonimbus and move from east to west. Clouds cumulos nimbus (cb) have been the subject of several studies for years Sauvageot, 1975, 1968.
B. Diop in 1996, Garba A., 1997 studied Squall lines. Their trajectories, speeds of movement and their life span have been well established in the Sahelian zone (Dhonneur 1987, SALL 2002, Desbois et al., 1988, D'Amato and Lebel, 1998). The fastest squall lines are observed on the central Sahel, that is, between eastern Niger and western Mali. Laing et al. Found that the Sahelian squall lines have an average life of 11.5 hours. In Figure 2.7 (Sall, 2005) we have MCS trajectory.

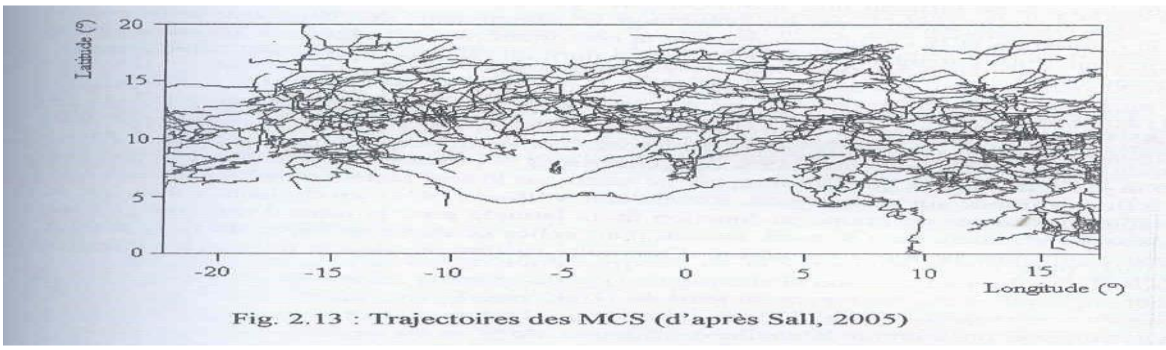

Figure 7: **Trajectories of SAMs (from Sall, 2005)**

Places of generation and dissipation.

Mathon et al. in 2001 showed that in the central Sahel, generations occur at altitudes below 400 meters. This shows that the orographic factor is not the only triggering factor for deep convection in this climate zone.
The studies of Hodges and Thorncroft 1997, Laing and Fritsch 1993 and Sall 2002
have revealed that the high reliefs also create a convective forcing (The places of dissipation are the mountains of Cameroon and the plateau of Jos, the Mont Marra, in other words the same reliefs as those of the generation.) There is also a strong dissipation near the coasts. Guinea also on the continent as above the oceans (Figure 8).

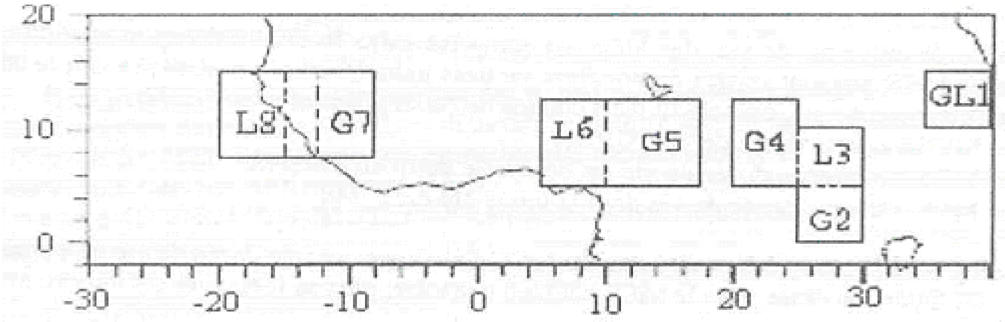

Figure 8: **Generation (G) and dissipation (L) locations of MCS observed in the Sahel. The number assigned to the location (based on Hodges and Thorncroft 1997, taken from Badiane, 2007).**

For the Sahel, studies of Yang and Slingo in 2001, those of Nesbitt and Zipser in 2003 a difference between deep convection on the tropical oceans and those over the continents Sall's work in 2002 showed that the diurnal cycle of MCS was unimodal with a maximum between 13:00 and 16:00 (local solar hours) (Figure 9). Mathon and Laurent 2001 reached the same conclusions.

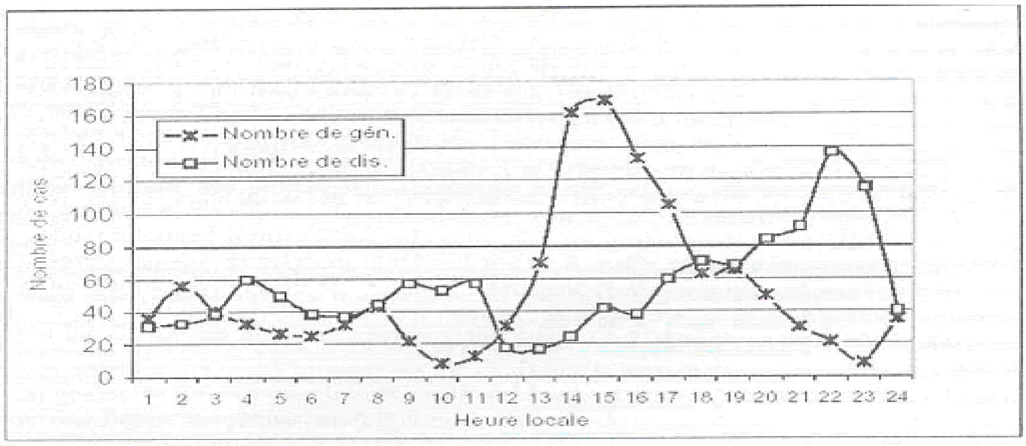

Figure 9: **Diurnal cycle of generation and dissipation of MCS on the Sahel. Sall, 2000**

Rainfall associated with convective systems.

Resuming the investigations of D. Badiane in his thesis, the work of Laurent et al. in 1998 estimated that L.G contributes 95% of annual rainfall and accounts for 80% of convective cloudiness in the Sahel. Chong and Hauser, 1989; Houze 1993, 1997; Diop et al. , 1996, estimated the contributions of the convective part and the stratiform part 65% and 35%.

The average rainfall contribution of convective systems to the Sahel given by Table 1 (Badiane 2007).

Class	Contribution to annual rainfall	Proportion of convective cover	Rainfall efficiency	Proportion to the overall population
MCS	80-95%	60-80%	5-15mm	90-99%
MCC	16-22%	10-16%	10-19mm	1-10%

Table 1: **Summary of mean pluviometric contributions of mesoscale convective systems (Adapted from D. Badiane 2007)**

The study of Mohr's (2004) relative share of convective systems with monthly rainfall in the Sahel is given in the following table with a three-part zonage of the Sahel according to latitude; one for the north latitude zone> 15 ° N, for the central zone 10-15 and for the southern zone <10 °.

	>15° N	10-15° N	< 10° N

May	34%	66%	74%
June	53%	81%	72%
july	66%	79%	62%
August	74%	77%	64%
September	73%	82%	70%

Table 2: **relative contributions of convective systems to monthly rainfall in the Sahel (adapted from Mohr, Gaye, 2002)**

In the following we began to want to understand from the convection in this climate zone, the transition from dry years to wet years from Meteosat data using a composite analysis.

Méthode

The theoretical support of the study is composite analysis. This method was used by Reed (1971), and Burpee (1976) and many others to study the structure of the East waves. If the phenomenon we are trying to describe has a physical reality, the results of all the averages carried out show a coherent structure meteorologically.
We worked on ten years of images with obviously some holes. The percentage of lost images is 3.6%. The images of the first eight years of our study are infrared images. For the years 2005 and 2006 we worked with MSG 10.8.
The images are thresholded at -40 ° C. The ICP (Deep Convection Index) is defined. In the images, the ICP is represented by a line that we called the Deep Convection Line (LCP).

$$ICP = \partial CN.n$$

$$\partial CN = \frac{CN(-40^0)}{N}.n$$

∂N is an average value of CN; N is the number of images

n is the number of times the grid point has the temperature less than or equal to - 40 ° C.

Results Obtained

Analysis of Meteosat images.

Composite images between 1997-2001

The convection line (figure 10) is a little above the latitude of Saint Louis (around 16 °)
ICP> ou = 69,66.

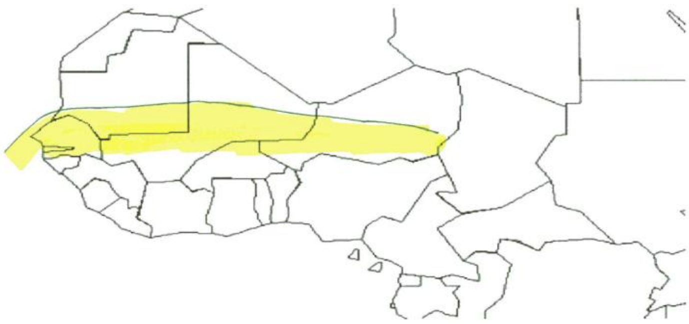

Figure **10: composite image 1997-2001, LCP in southern Mauritania.**

Composite images between 2002-2004

Figure 11 shows that convection globally covers the Sahel. The LCP encompasses all of

Mauritania.
The convection line goes a little below the 27th latitude

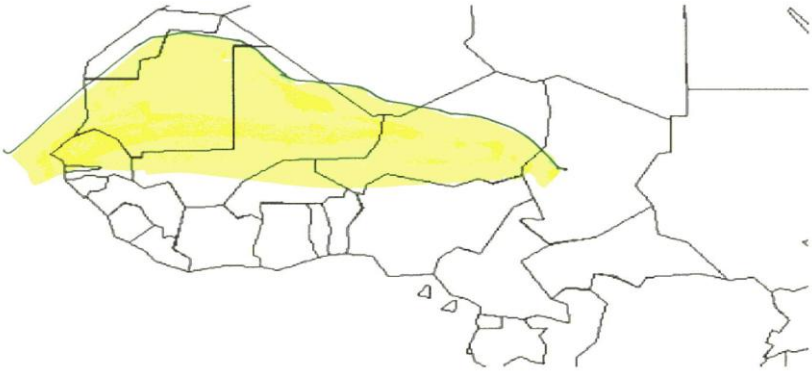

Figure 11: **2002-2004 composite image, LCP in southern Mauritania.**

Composite des images des années 2005 et 2006

Figure 12 shows an ICP from MSG images 2005 and 2006; it shows that convection is present beyond the Sahel.
The LCP shows that convection is well present in the sahel.

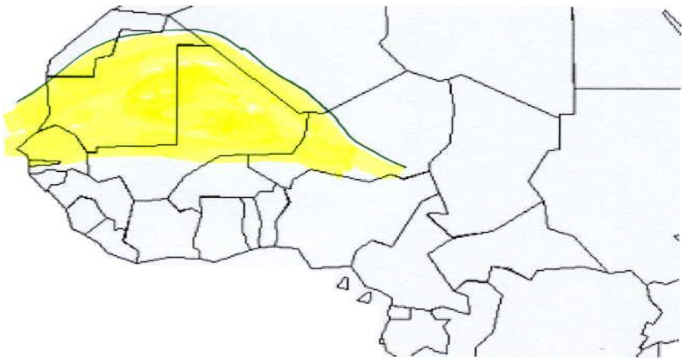

Figure **12: composite image 2006-2007, LCP in the North of Mauritania.**

Statistics of squall lines.

The number of squall lines detected at the station of Saint Louis in Senegal. Here we counted only the lines of rainy squall. Figure 13 shows that the years 2002 - 2006 are generally more convective and rainy than the years 1997-2001;

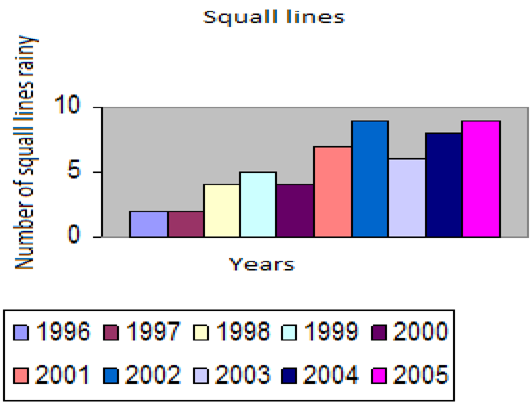

Figure 13: **Number of Squall lines on the Saint Louis Station from 1996 to 2005.**

Radiosonde analyzes.

We examined the difference between the 2002-2006 (Figure 14) Wintering Average and the 1997-2001 wintering average.

The years 2002-2006 are generally wetter in the upper layers.

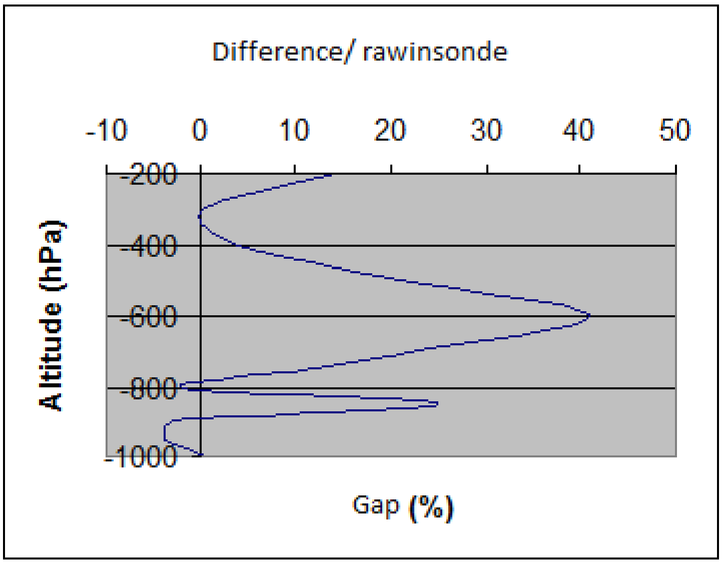

Figure 14: **Difference between the 1996-2001 mean wintering profile and the 2002-2005 mean wintering profile.**

Conclusion

In the Sahel, the transition from the rainy season to the dry season is caused by the circulation of winds on our planet. In this climatic zone most of the population derives their income from agropastoral activities. The measurement network in sut is obsolete or nonexistent.

We have attempted to explain climate change from Meteosat satellite data.

From a composite analysis of Meteosat imagery we have shown that the convective activity of the rainy season has increased from 2002 to 2006 compared to the period 1997-2001.

Our results are validated by the MNC statistic and the water profiles obtained from radiosonde surveys.

Thanks.

Our thanks to Université Gaston Berger de Saint Louis (Senegal).

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