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**Session 9A: Climate and health**
**Po.9A.5**

# Climate and health: observation and modelling malaria in Ferlo (Senegal)

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## Introduction

The aims of this work by the framework of QWeCI project is to study how climate variability influences the incidence of malaria. It will also assess mitigation measures to be taken according to various climate scenarios in next years. Climate variability seems to be an important determinant for the incidence of malaria(Freeman et al., 1996; Lindsay, 1996; Kuhn, 2005). Climate has an impact on epidemiology of malaria; directly via the development rates and survival of both the pathogen and the vectors, and indirectly through changes in vegetation and land surface characteristics such as the avaibality of breeding sites.

## Objectives

- describe spatial and temporal characteristics of climate in Ferlo;
- assess and improve present understanding of climate-driver malaria inter-relationship
- evaluate LMM using observational and reanalysis database to drive model in Senegal, particularly in Ferlo;
- tailor integrated climate-disease model outputs to answer questions relevant to regional scientists and decision makers.

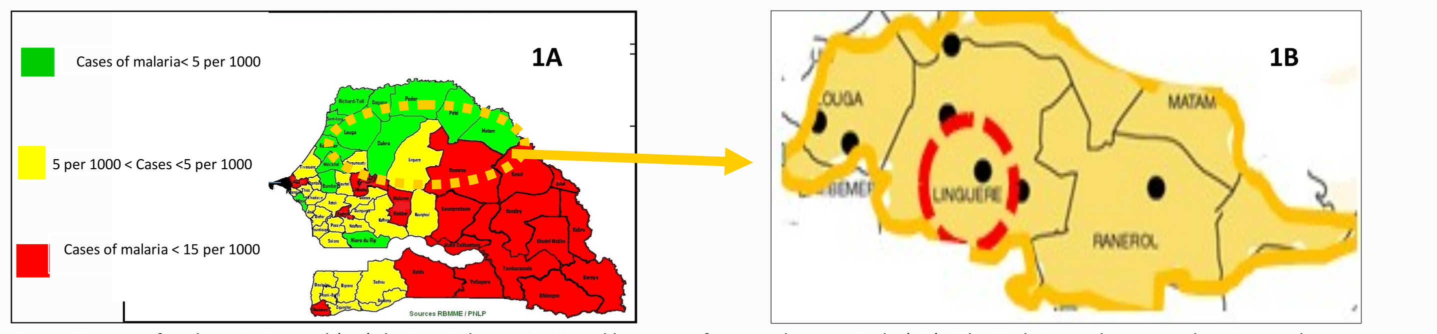


Fig 1: Zonage of malaria in Senegal (1A), by PNLP during 2009 and location of our study area, Ferlo (1B). The Ferlo is a sylvopastoral region, with a sahelian climate delimited between 16°15-14°30N and 2°50-16°O (Sarr, 2008). Malaria is further in the south of the country(1A) which is the wettest part therefore most favorable for the development of malaria. But the choice of our study area is explained by the existence of many stations for the measurement of climatic parameters that must be considered together with the factors of malaria. It is also the sentinel site observatory of QWeCI.

## Data and Methods

- ✓climate data : (daily and monthly) : rainfall, temperature (maximum and minimum), relative humidity (maximum et minimum), wind speed and direction ;
- ✓reanalysis data : NCEP, Era-interim ;
- ✓ others observations data : CRU, TRMM (satellite data), GPCP;
- ✓clinical : malaria incidence, specific morbidity.

The databases of TRMM and ERA-INTERIM are highly reliable, very close to reality (observation data). The ability to easily access to their data in temporal and spatial scale is the reason why they are privilege for validation of climate models. It is within this context that the LMM model is based on their databases as input to obtain informations about malaria as ouput.

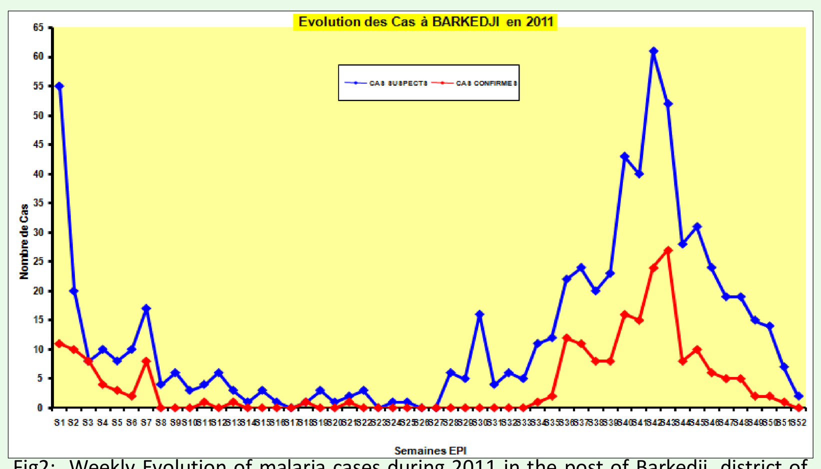


Fig2: Weekly Evolution of malaria cases during 2011 in the post of Barkedji, district of Linguere. The blue curve is the suspected cases and the red one is the confirmed cases. The peaks is observed in the 4th quarter i.e. around the 40th week, coinciding with the end of the rainy season. Preliminary malaria fever somewhat similar to those of other diseases make populations often overestimate malaria. According to PNLP, checking with TDR (Test de Diagnostic Rapide) is the only method able to confirm malaria. confirmed cases are lower than originally suspected cases(halp of confirmed case in figure 2).

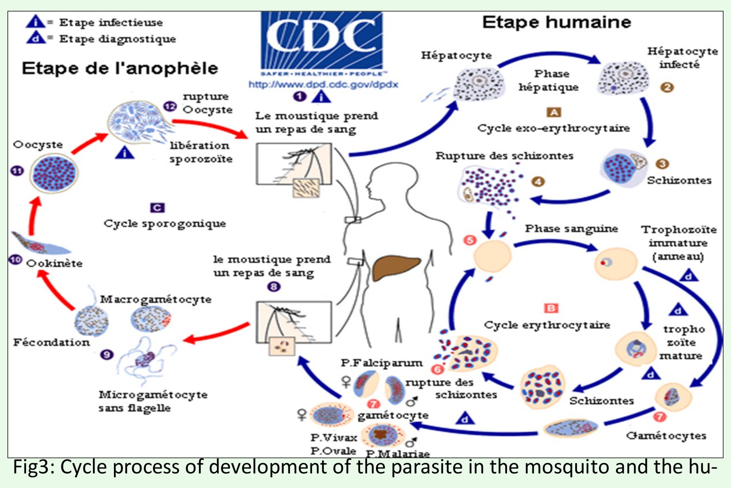


Fig3: Cycle process of development of the parasite in the mosquito and the human's body. source: http://www.pdp.cdc.gov/dpdx. The common characteristic of various plasmodium is the existence of an evolutionary cycle formed by the succession mandatory two distinct phases: an asexual cycle (called chizogonie), which take place human, and a cycle sexed (callend sporogonique) which can only take place in the mosquito vector.

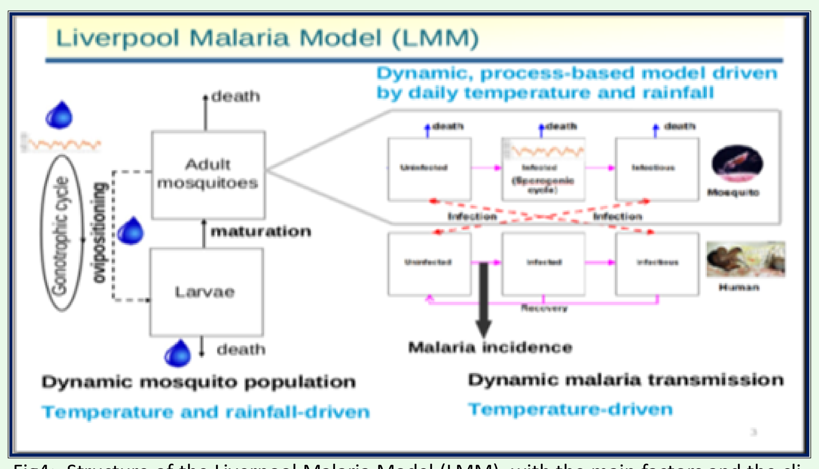


Fig4: Structure of the Liverpool Malaria Model (LMM), with the main factors and the climatic parameters influencing on malaria (Hoshen and Morse, 2004).
The Liverpool Malaria Model (LMM) is developed at the University of Liverpool, it simulates the frequency of malaria in West Africa in general and Senegal in pariculier (Hoshen and Morse, 2004). It takes into account key factors of malaria such as the anopheles, mosquitos and human host infected/infecteous, but also rainfall data (cumul of 10 days) of TRMM and the dalily data temperature of Erainterim.

## Observations results

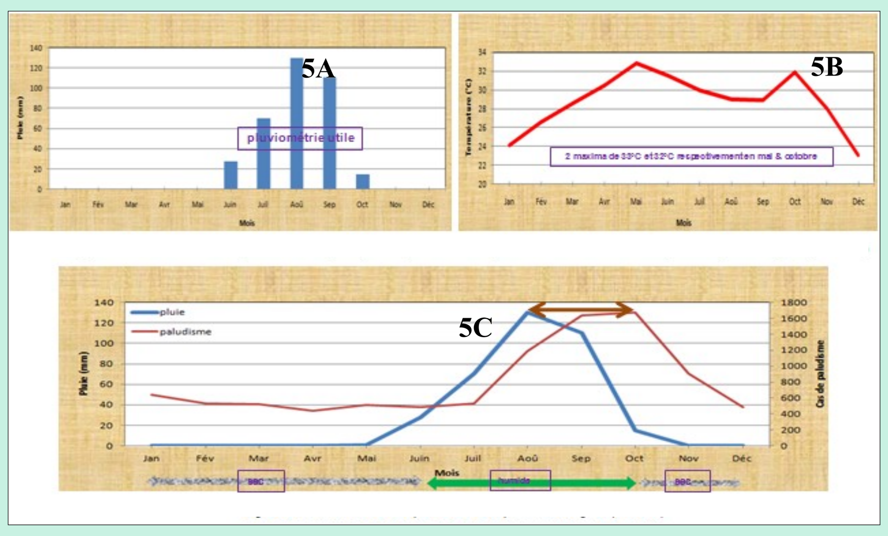


Fig5: Seasonal mean variability 1950-2010 of rainfall (5A), mean 1951-1998 of temperature(5B) and simultaneous evolution mean monthly 2001-2009 of malaria with rainfall (5C), in Linguere.

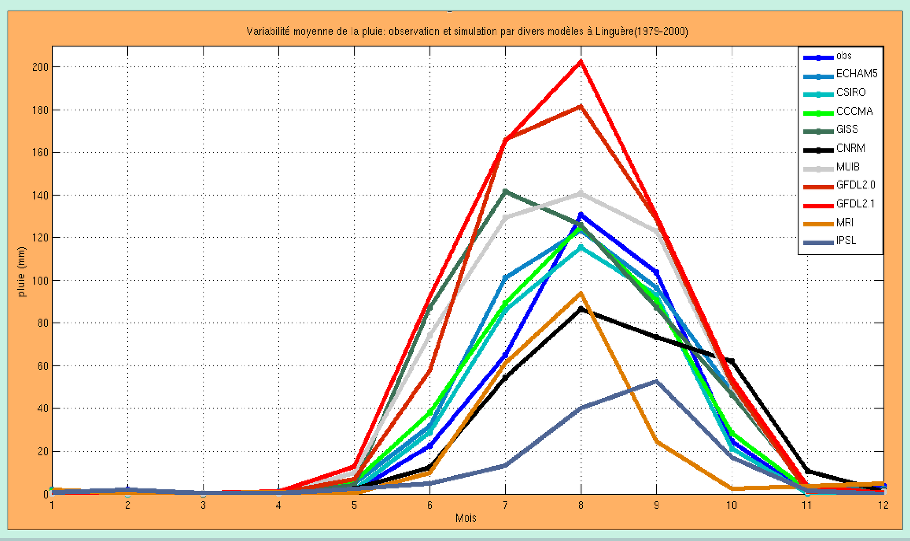


Fig6: Evolution of mean monthly rainfall with data observed versus data simulated by different models in the period 1979-2000.

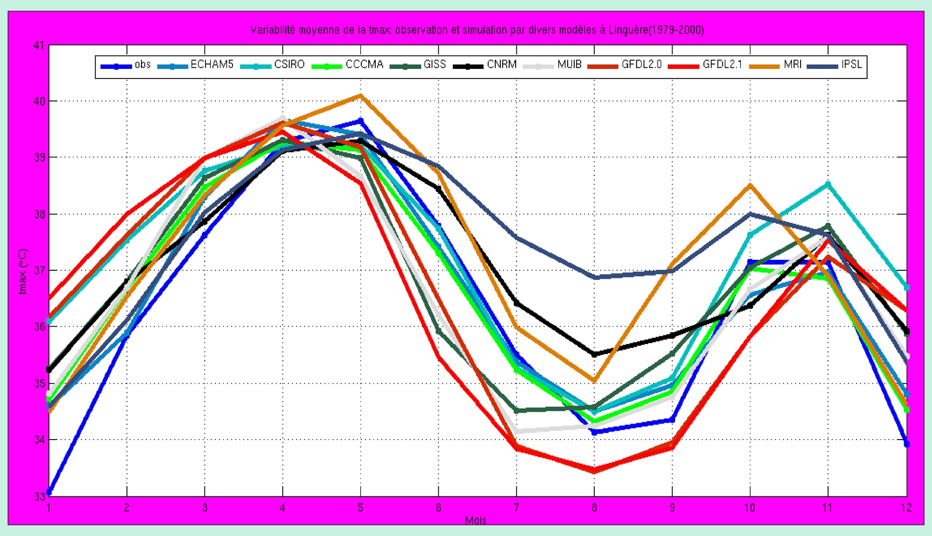


Fig7: Evolution of mean monthly temperature with data simulated by different models compared to data observed during 1979-2000.

∗ In Ferlo, the rainy season starts usually on june-july and finishes around october (Fig 5A). A gap between rainfall and malaria epidemic is observed on Fig 5C. Concerning temperature seasonal evolution, two peaks are observed on may and october coinciding respectively with installation and the withdrawal of the monsoon.

∗ Fig 6 allows to see that the models GFDL2.0, GFDL2.1, GISS and MUIB overestimate the rainfall peak with respect to the observations, and IPSL, CNRM and MRI underestimate it. The ECHAM5, CSIRO and CCCMA data have approximate better the observations (blue curve). Identifying the best climate model will allow us to choose it and couply with the LMM.

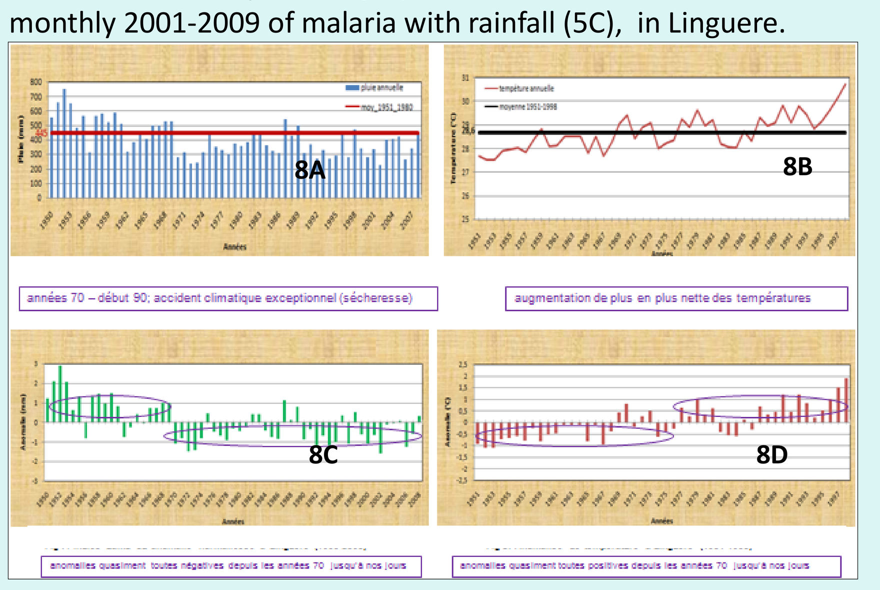


Fig8: Observation at Linguere on inter-annual variability of rainfall 1950-2008 (8A), inter-annual variability of temperature 1951-1998 (8B), Lamb index of rainfall 1950-2008 (8C) and anomalies of temperature 1951-1998 (8D).

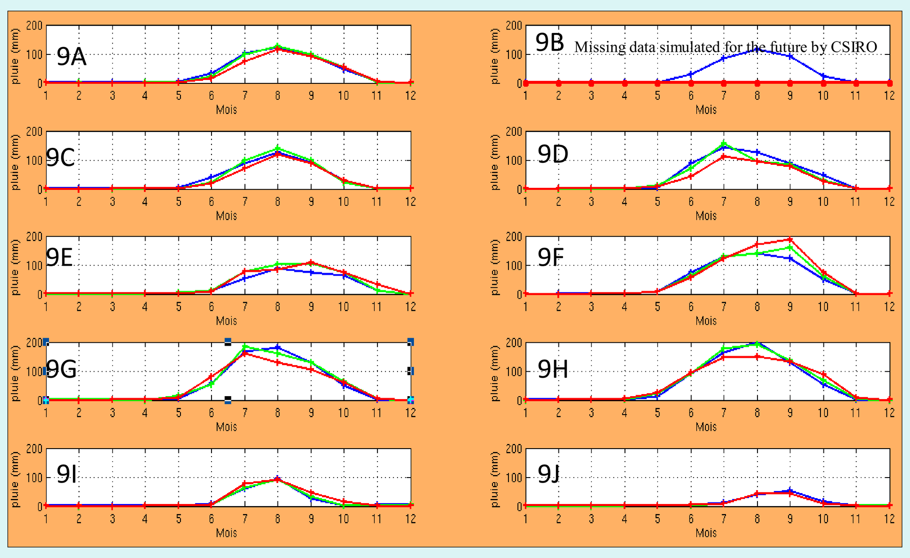


Fig9: Evolution of mean monthly rainfall simulated for the past period (1961-2000, blue curve), the near future period (2046-2065, yellow curve) and the far future period (2081-2100, red curve) with respectively the ECHAM5(9A), CSIRO(9B), CCCMA(9C), CNRM(9D), MIUB(9F), GFDL2.0 (9G), GFDL2.1(9H), MRI(9I) and IPSL(9AJ), models.

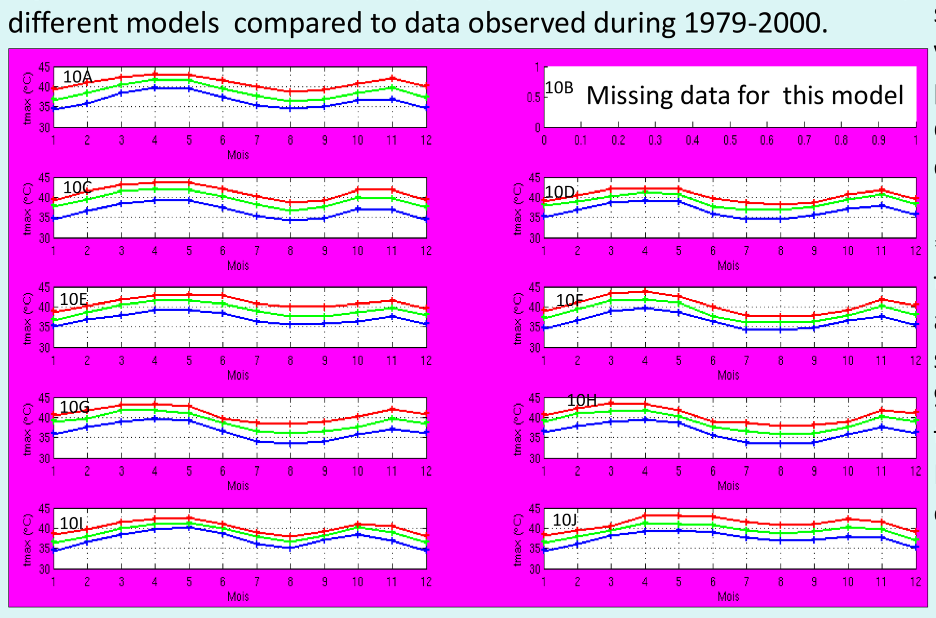


Fig10: Evolution of mean monthly maximum temperature simulated for the recent past period (1961-2000, blue curve), the near future (2046-2065, yellow curve) and the far future (2081-2100, red curve) by respectively the ECHAM5(10A), CSIRO(10B), CCCMA(10C), CNRM (10D), MIUB(10F), GFDL2.0 (10G), GFDL2.1(10H), MRI(10I) and IPSL (10J), models.

∗ Mean seasonal trend of rainfall and temperature is same through the different models compared to observation (Fig 6 $ 7) but some models underestimate the peack while others ones over-estimate it. Simulation data of ECHAM5, CSIRO and CCCMA are again much closer to the observed reality.

∗ A strong inter-annual variability of rainfall is observed through Fig 8A & 8C). The inter-annual variability is characterized mainly by decreasing of rainfall particulary since the beginning of the years from 70s to the years 90s. Since 1969, rainfall anomalies are negative, on contrary, temperature anomalies remain positive (Fig 8 D ). It is an illustration of the global warming showed in several others studies.

∗ Fig 9 shows decreasing of rainfall for the near future and particulary for the far future. August will remain the wetter months but the maximum of rainfall for the future will be below the maximum of rainfall during mean climatology 1961-2000 period.

## Simulation results

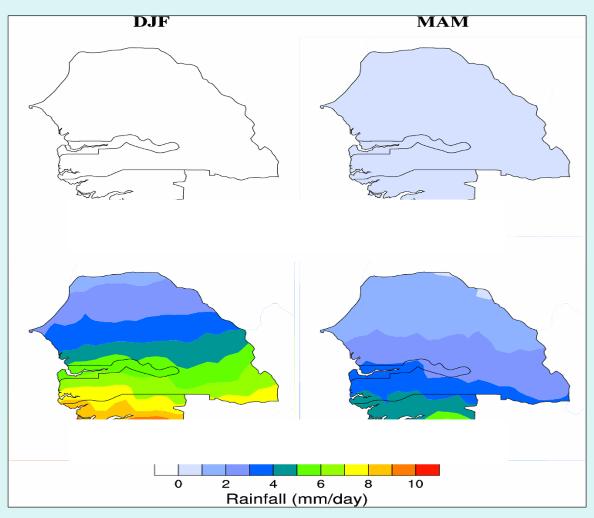


Fig11: Seasonal mean of rainfall in Senegal 1998-2008 simulated by TRMM. (Caminade et al., 2010, personal communication)

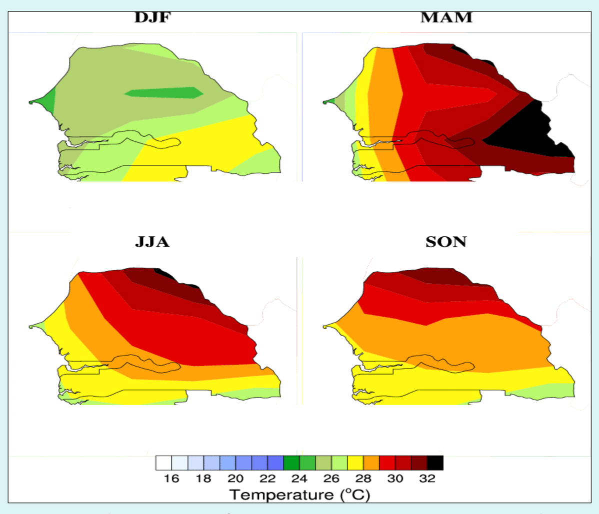


Fig12: Seasonal mean of temperature in Senegal 1998-2008 simulated by ERAINTERIM. (Caminade et al., 2010, personal communication)

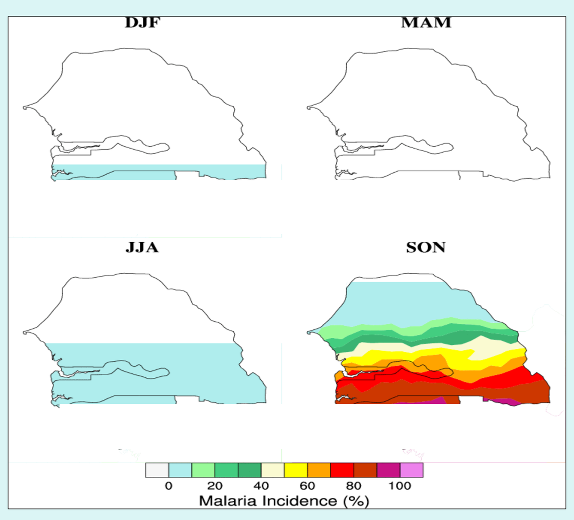


Fig13: Seasonal mean of malaria incidence during 1999-2008 associated with the TRMM rainfall and ERAINTERI temperature. (Caminade et al., 2010, personal communication)

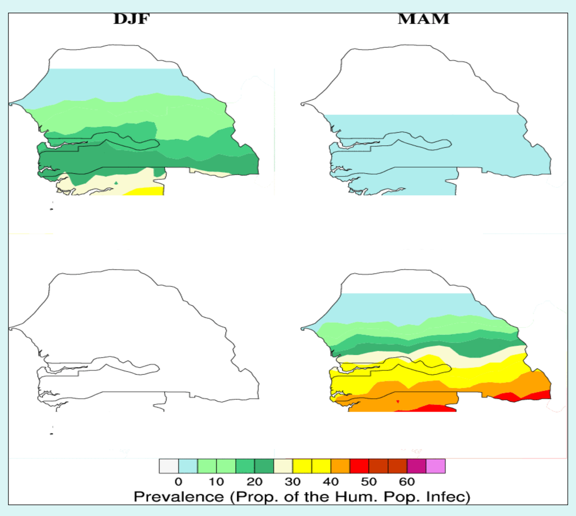


Fig14: Seasonal mean of malaria prevalence during 1999-2008 associated with the TRMM rainfall and ERAINTERIM temperatre. (Caminade et al., 2010, personal communication)

∗ southern area wetter than the rest of the country (Senegal), along the north marked by a relatively low rainfall, most of the rainfall is recorded between June and August (Fig 11).

∗ warming during march-april-may in Senegal, which approves the experts estimating that the month of may is the hottest of the year in Senegal followed by the month of october corresponding respectively to starting and stopping of rainfall and agricultural activities. The lower temperatures in december-january-february and higher temperatures in the north is observed in Fig 12.

∗LMM shows an increase of malaria incidence for the duration of the season of the disease transmission from north to south of Senegal. Concerning prevalence also, Fig 14 shows a seasonal transmission of malaria in september-october-november with increasing also from north to south (wetter area).

∗ Distribution of the rainfall and how the climate data must be formatted before being imported to the DMC is shown in Fig 16, it allows to see that malaria parameters achieve their sigificant evolution from the midle to the end of the rainy season.

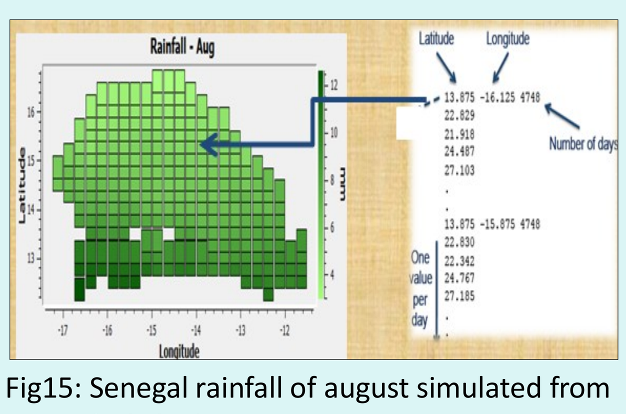


Fig15: Senegal rainfall of august simulated from TRMM's daily data 1998-20010.

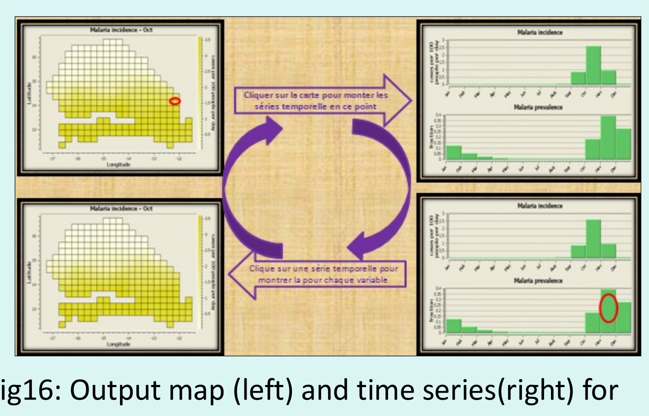

Fig16: Output map (left) and time series(right) for differents parameters included in the the DMC.

### Conclusion et perspectives

The data set considered illustrates that the Ferlo is characterized by a rainy season from June to September and the rest of the year is dominated by the dry season. Rainfall station of Linguere shows that the rainy season begins in june-july, rainfall peaked in august and decreases slowly from September. Rainfall varies from a year to another. The beginning of years 70s until the 90s is the driest period like all the Sahel.

The analysis of thermal regimes monthly average is a bimodal evolution. So the year we be devised into four period: the first period is cool and dry including december and January, with temperatures recorded a substantial decline, a consequence of the general circulation (winter period). the second period is hot and dry interesting from February to June. The third period is july to septembre, it is cool and wet. The fourth and last period is hot and wet. It is the only period favorable for malaria transmission.

In summary, it is noticed a very seasonal dynamic of malaria,.
There is often a correlation between the variability of rainfall in august , and the incidence of malaria over the coming months, a lag of one to two months of peak malaria compared to peak rainfall.
The comparison of ours observations and the preliminary results of the LMM and its interface DMC encourage the idea of modeling malaria, hence using climatic parameters however with a need for improvement.

**References:**

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**Hoshen, M. B. et A. P. Morse** (2004). A weather-driven model of malaria transmission. *Malaria Journal*, 3 (1), 32. [http ://www.malariajournal.com/ content/3/1/32].

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