Abstract Nº P-A2-04 : The predictability of malaria: Case of Senegal, West Africa

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ABSTRACT

This study is a contribution to the Climate and Health Project in development at the CPC/NOAA. Experimental risk maps and time series of malaria parameters for West Africa and Senegal in particular are generated and validated with observational clinical data recorded by the National Program for Malaria Control (NPMC) of Senegal. Some collected data from different malaria locations across African countries via the Malaria Atlas Project (MAP) are used to partially validate the model outputs. The main meteorological variables known to influence malaria include precipitations, temperature. In Senegal and over the Sahelian band in general, our previous study showed that while the rainfall season is at its peak in July-August-September (JAS), the peak of the malaria outbreak season occurs in September-October-November (SON). Furthermore, some studies have shown that Atlantic and Pacific SST modulate West Africa rainfall and indirectly malaria incidence. This work is being conducted in several stages. Firstly, we employ the Liverpool Malaria Model (LMM) and the VECTRI model (VECtor borne disease community model of ICTP, TRIeste). With these 2 malaria models, we simulate hindcasts of malaria incidence, using as inputs: daily rainfall, daily 2m maximum and minimum temperature of available datasets at the CPC/NOAA. Secondly, we employ the Canonical Correlation Analysis (CCA),where the predictand is malaria models' outputs; and the predictor is the observed SST (ERSSTv4).

DATA AND METHODS

Description of the Malaria Model

Mathematical-biological model for malaria transmission for the impact of temperature and rainfall variability on the development cycles of the malaria vector in its larval and adult stage, and also of the parasite and human host. Various components of the malaria transmission model and the parameter settings are described by Hoshen et al. 2004 and Ermert et al. (2011).

The number of emerging adult mosquitoes at the beginning of each month is taken to be proportional to the rain falling during the previous month.

The mosquito population is then combined with the biting rate, sporogonic cycle length and survival probability calculated from temperatures, together with the other parameters provided as input to the model.

The full LMM model using daily rainfall and temperature data as inputs has been successfully validated against a clinical records for example in Botswana (Jones and Morse, 2010) and Senegal Diouf et al. (2013; 2017). In this study, the standard parameter settings for malaria transmission is used.

Input climate data

Dataset	Sources	Variables (units)	Period	Resolution
CPC global data	http:// ftp.cdc.noaa.gov/ Datasets/	Daily temperature (ºC) and daily rainfall (mm)	1979-2017	0.5ºx0.5º
Africa Rainfall Climatology version2 (ARC2)	http:// ftp.cpc.ncep.noaa.gov/fews/fewsdata/ africa/arc2/	Daily rainfall (mm)	1981-2017	0.1ºx0.1º
Rainfall Estimate (RFE)	http:// ftp.cpc.ncep.noaa.gov/fews/fewsdata/ africa/rfe2/	Daily rainfall (mm)	2001-2017	0.1ºx0.1º

LMM model outputs

name	Definition / units
ActiveMo	total number of mosquitoes biting at this time step
Gdays	length of the gonotrophic cycle in days
Immcount	total number of larval mosquitoes
Incidence*	**cases per 100 people**
InfectiveMosquitoCount	Total number of infectious mosquitoes biting at this time step
nMatureMosquitoes	Total number of adult mosquitoes
Prevalence	proportion of the human population infectious
Sdays	length of the sporogonic cycle in days

*** Variable under study in the following**

Target Season: September-October-November **(SON)**
Used lead Time: March initial conditions

- **Predictors are SST indices (ºC):**
  - **SST (ERSSTv4) in March over the following ocean basins :**
  - ✓ Tropical Pacific (TROP-PAC): 15N-15S & 70W-120E
  - ✓ Golf of Guinea (GG): 5N-5S & 10E-10W
  - ✓ Global Tropic (GBL_TROP): 30N-30S & 0E-360W
  - ✓ Tropical Atlantic (TROP-ATL): 30N-30S & 15E-45W
  - ✓ Tropical North Atlantic (TROP-NTH-ATL): 30N-10S & 15E-45W
  - ✓ Tropical South Atlantic (TROP-STH-ATL): 15N-30S & 15E-45W
  - **NMME´s Models for MARic: cfsv2, cmc1, cmc2, gfdl-flor, gfdl, nasa, ncar-ccsm4 and nmme in March over the same ocean basins**
- **Predictand: Malaria incidence (%) over Senegal :**
  - ✓ Simulated malaria incidence (LMM) over Senegal based on CPC Global daily temperature, and daily ARC2 rainfall data

RESULTS

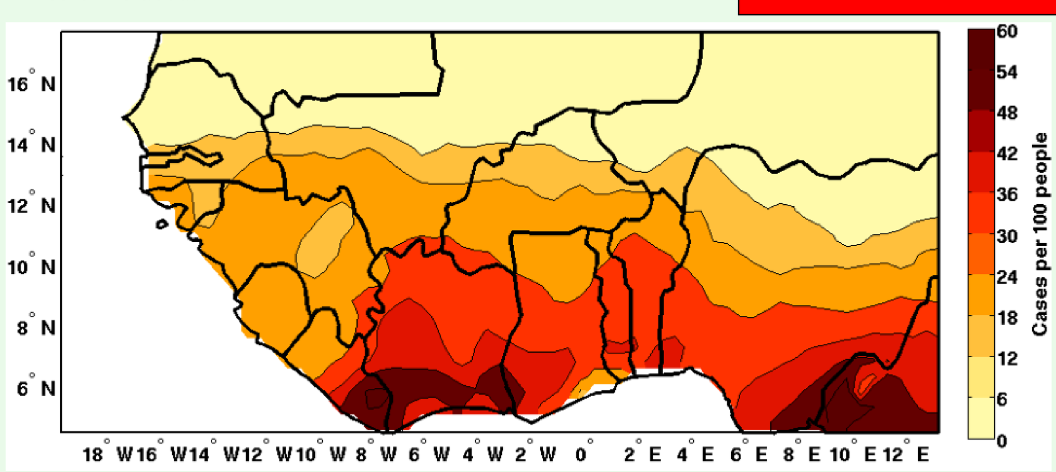


Fig. 1: Simulated spatial distribution of malaria incidence by the LMM in WA from CPC Global daily rainfall and temperature (1979-2017). Maximum occurrence area is found in the South and South-eastern of West Africa.

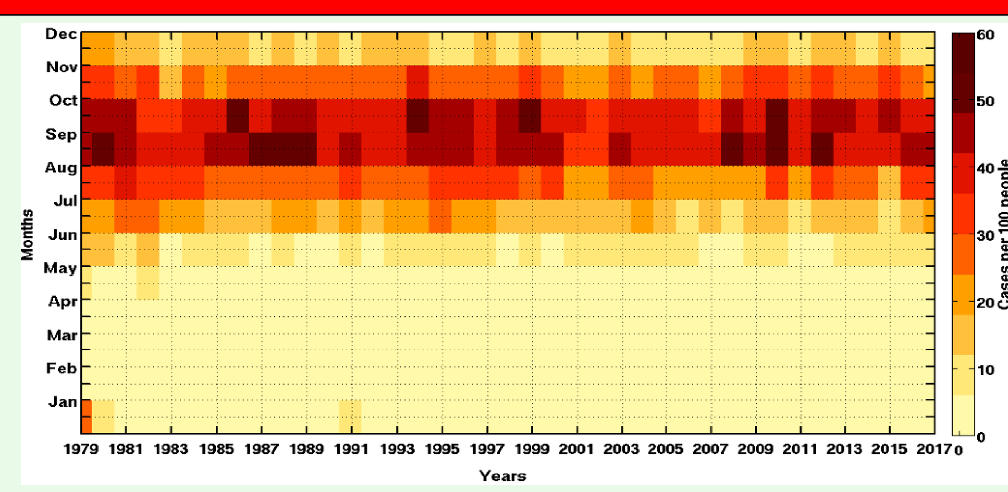


Fig. 2: Simulated intra and interannual variability of malaria incidence by the LMM in WA from CPC Global daily rainfall and temperature (1979-2017). Maximum occurrence area is found in the South and South-eastern of West Africa.

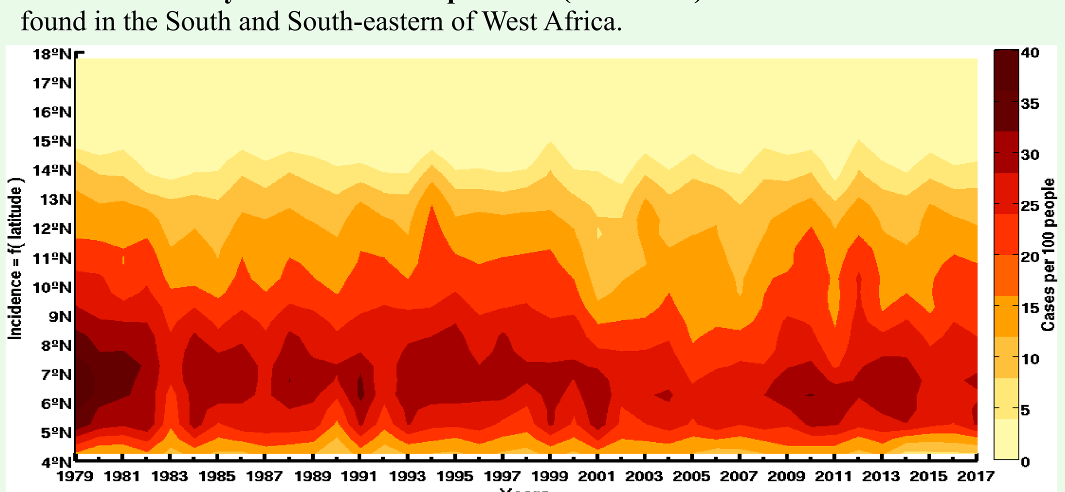


Fig. 3: Hövmuller diagram of the simulated seasonal inter-annual cycle of the malaria incidence in WA from CPC Global daily rainfall and temperature (1979-2017). Decrease in interannual variability and strong signal of malaria incidence over the Sourthern latitudes.

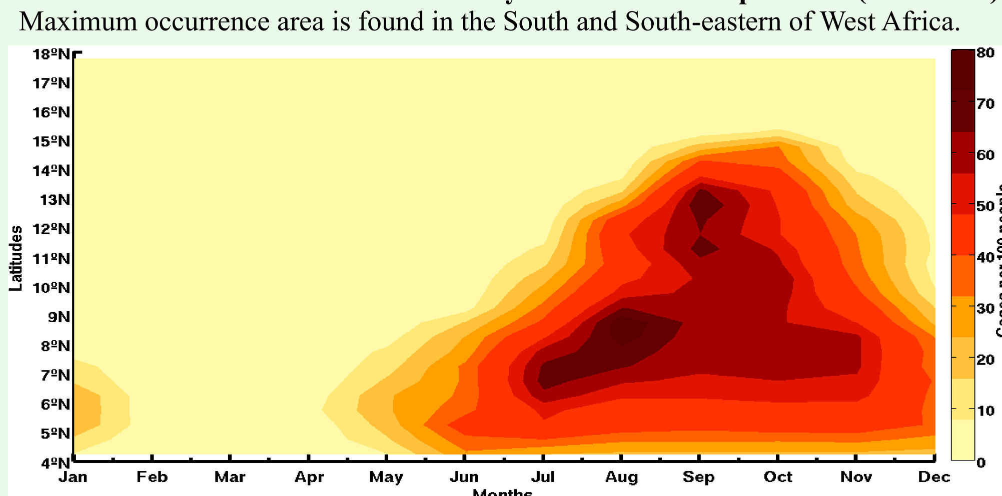


Fig. 4: Hövmuller diagram of the simulated seasonal cycle of the malaria incidence in West Africa (1979-2015). Maximum occurrence period: Sept-Oct-Nov with a peak around Sept.

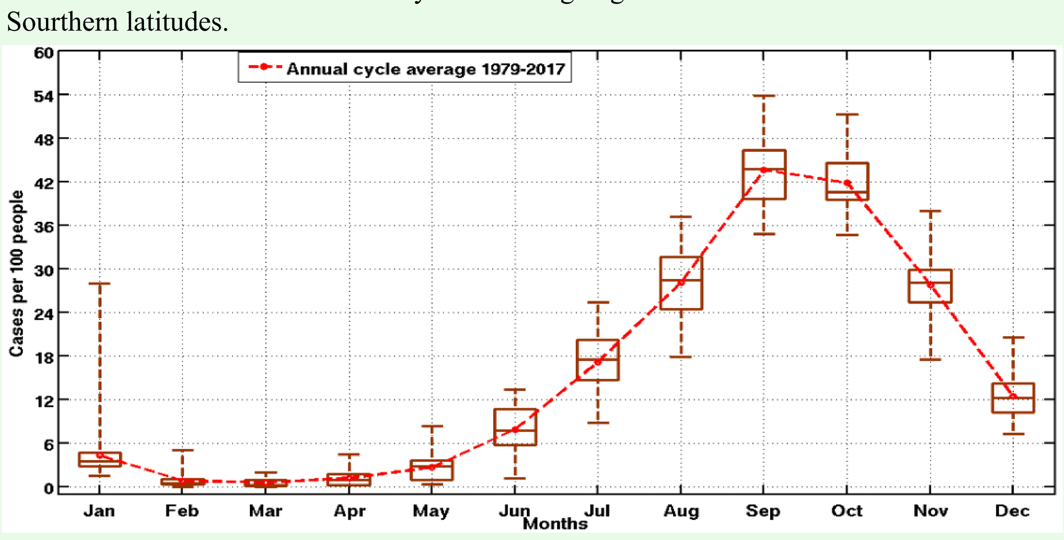


Fig. 5: Seaonal cycle of the simulated seasonal cycle of the malaria incidence in West Africa (1979-2015).
The whiskers and the maximum/minimum outliers are shown. The boxes mark the 25th and 75th percentile ranks while the whiskers give the minimum and maximum values. The red line shows the mean annual cycle. The position of the first quartile, third quartile and the median is highlighted. The peak is observed in September in West Africa.

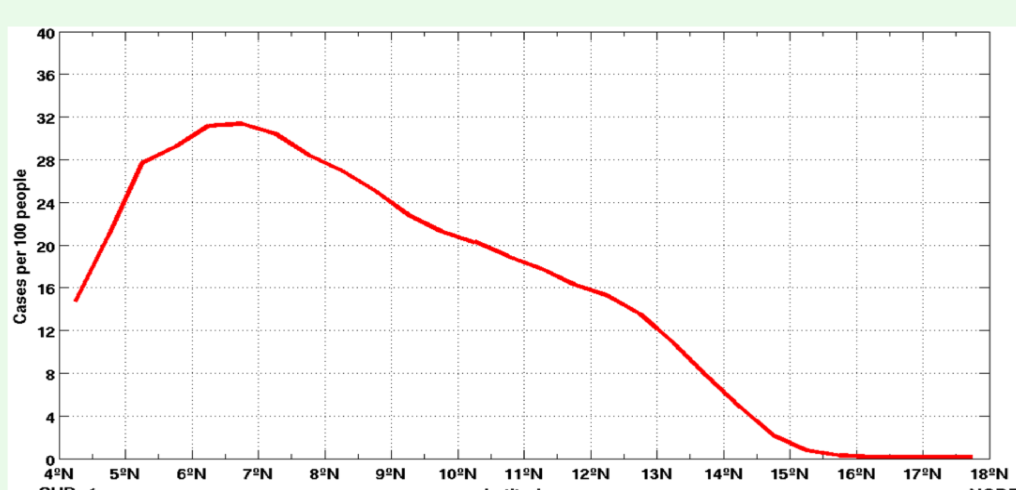
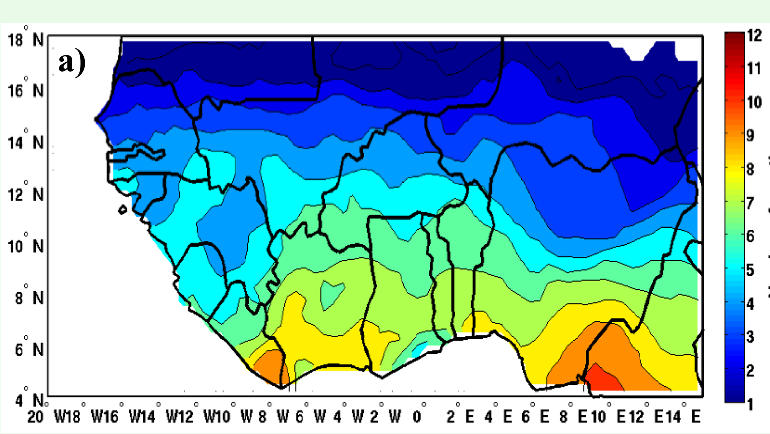
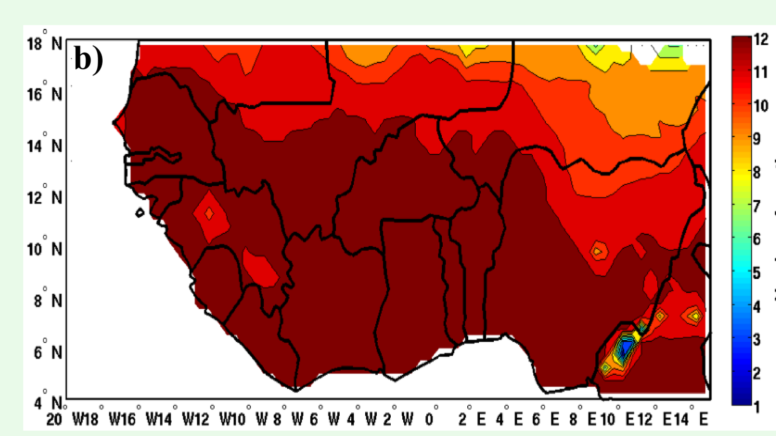


Fig. 6: Simulated latitudinal gradient of the malaria incidence by the LMM in WA from CPC Global daily rainfall and temperature (1979-2017). The latitudinal gradient in incidence is better simulated here with representation of the averaged (along the longitude) malaria incidence in West Africa. A net decrease in malaria incidence from the southern to northern latitudes is highlighted. The maximum incidence is simulated between 6 ºN-7 ºN, and then, it decreases and drops down to 0 round 16 ºN.





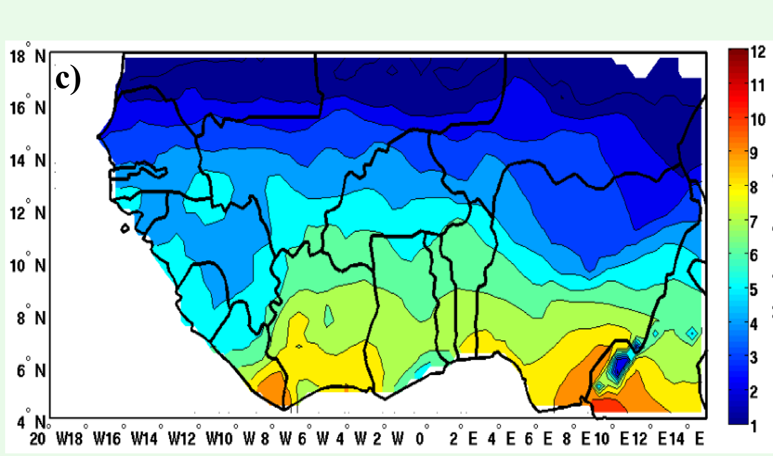


Fig. 7: Simulated length of the season (number of months) suitable for malaria transmission over West Africa. a) Length of season with suitable rainfall conditions, b) Length of season with suitable temperature conditions and c) Lenght of the malaria transmission season (month).

For rainfall, favorable conditions are met during few months over North and those conditions of favorable rainfall can last up to several months over the South (Fig. 7a), but through almost all the year, temperature conditions are favorable for malaria transmission (Fig. 7b).

For the Fig. 7c), in the extreme Nord, the LTS is around 1 to 2 months, and in the Central part of Sahel, it ranges about 3 to 4 months like as the rainfall season. For the sourthern part, the malaria transmission is around 8 months or greater.

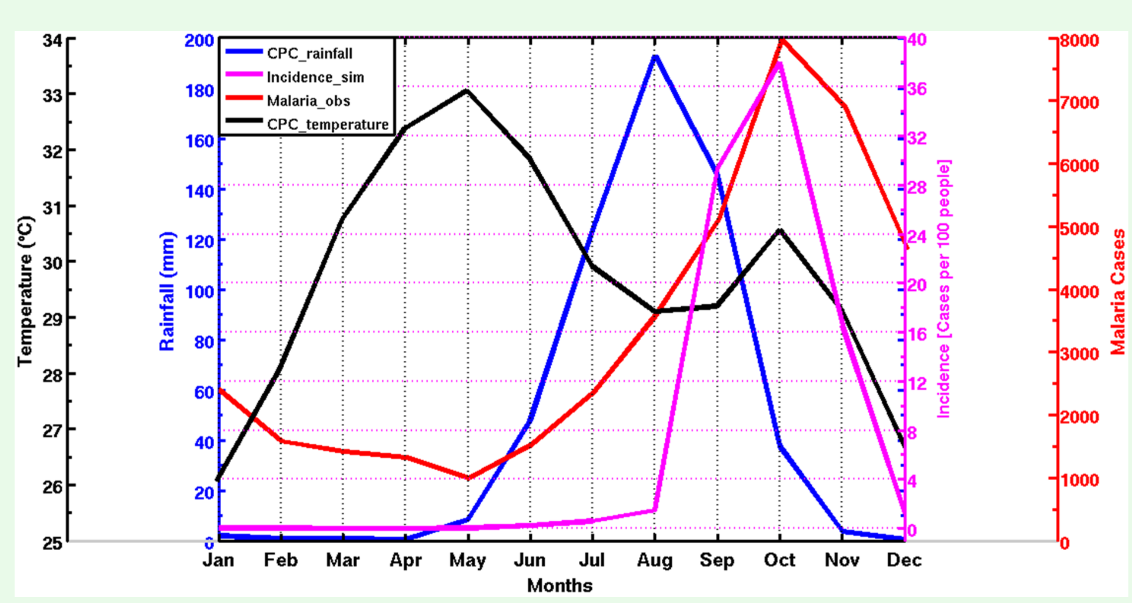


Fig. 8: Observed malaria cases (period 2001-2016) by NPMC, and simulated malaria incidence by the LMM using CPC unified data in Senegal for the common period.

- Both Observation and model agree on the high malaria transmission in September-October-November, corresponding to 2 months after the peak of rains (in August), and to second peak for temperature (October).

-The LMM does not find the malaria incidence during the dry season.
-Qualitative but not quantitative comparison between the the simulated and the actual observed data.

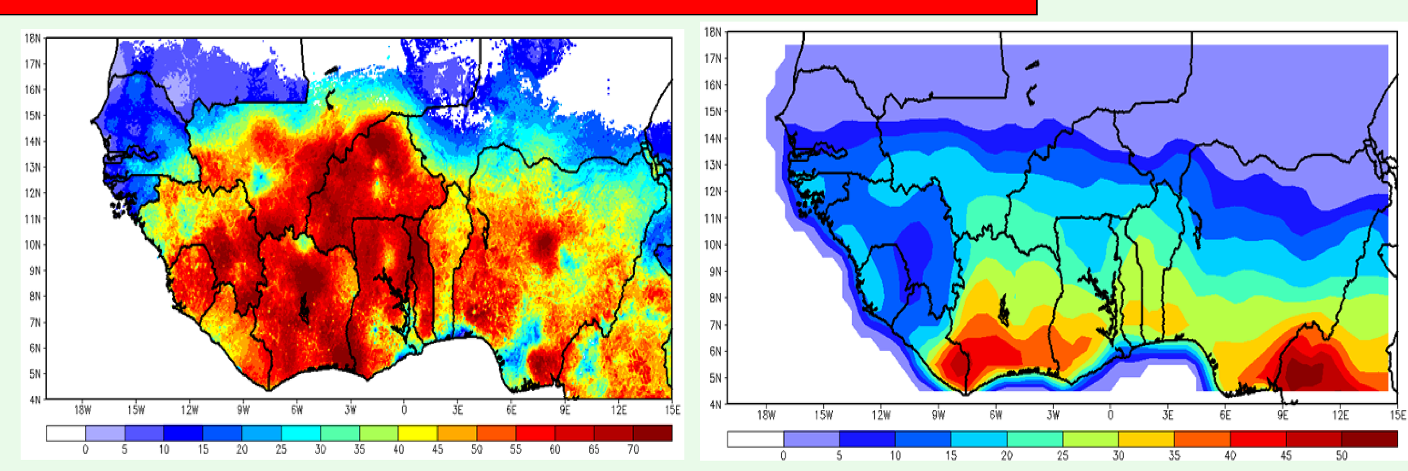


Fig. 8: Spatial distribution of malaria prevalence, MAP observations vers LMM simulations. in WA based on CPC daily precipitation and temperature data (2000-2015). 10a) Prevalence rate of P. falciparum malaria in 2-10 year olds in WA, 2000-2015 (MAP), 10b) Simulated prevalence (LMM) in WA based on CPC daily precipitation and temperature data (2000-2015).

* Malaria prevalence rate is very low in Senegal, this is related to malaria control parameters such as interventions with insecticide-treated bed nets, but also the Artemisinin-based combination therapy (ACT) for treatment.

* Unsuitable climate conditions imply limited malaria transmission in the Northern part

* The wetter area (south of West Africa) experiences endemic malaria prevalence. This is related to suitable climate and environmental conditions but also increased in insecticide resistance.

* The LMM model under-estimates the magnitude of malaria prevalence over the Southern part of WA.

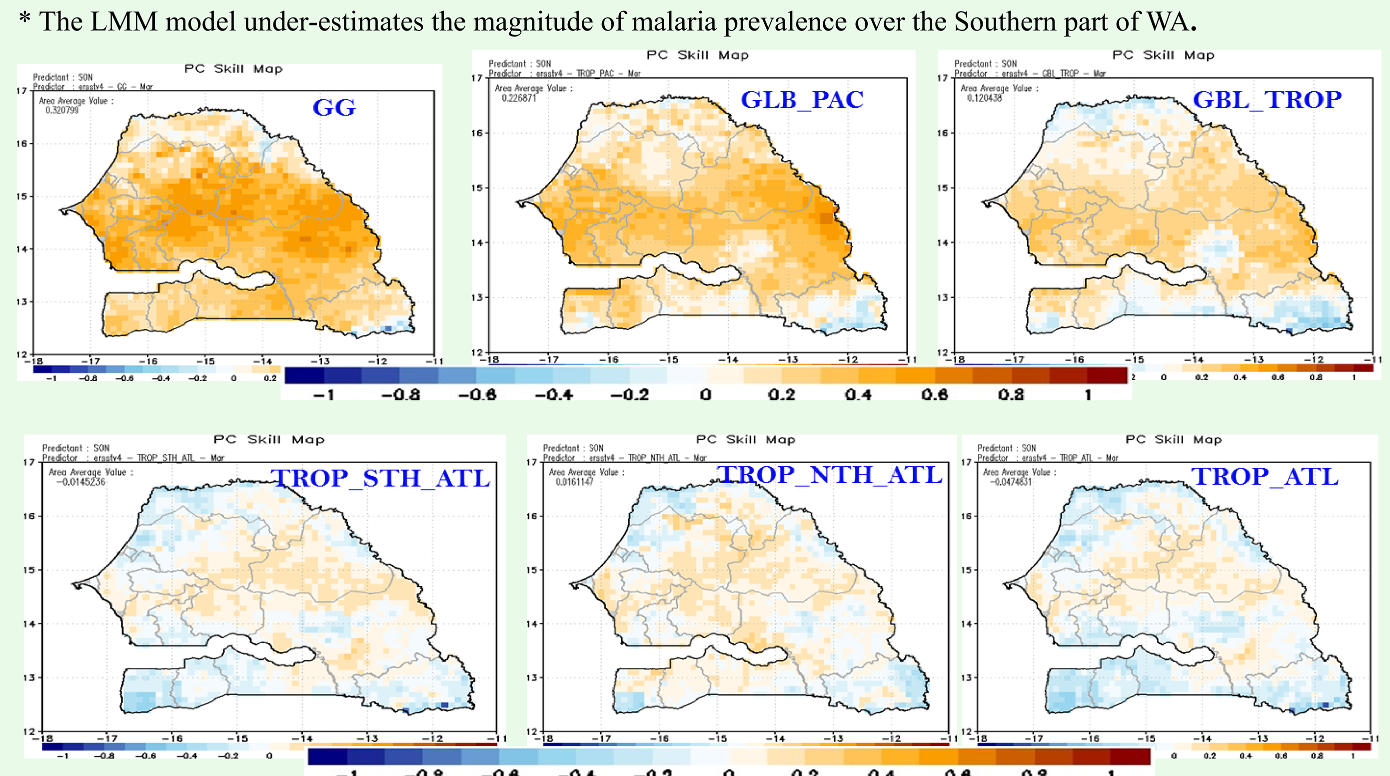
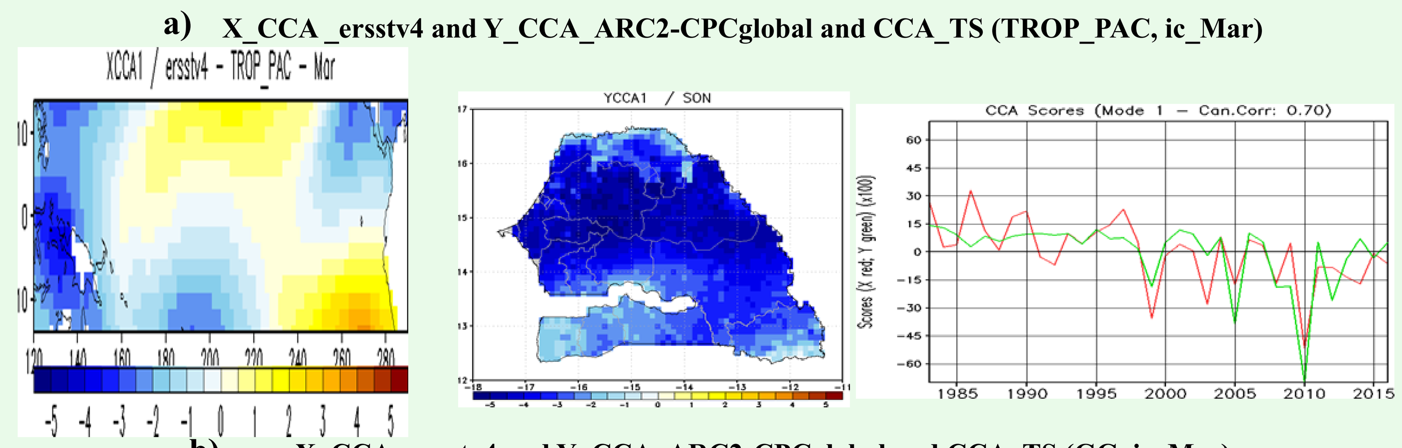
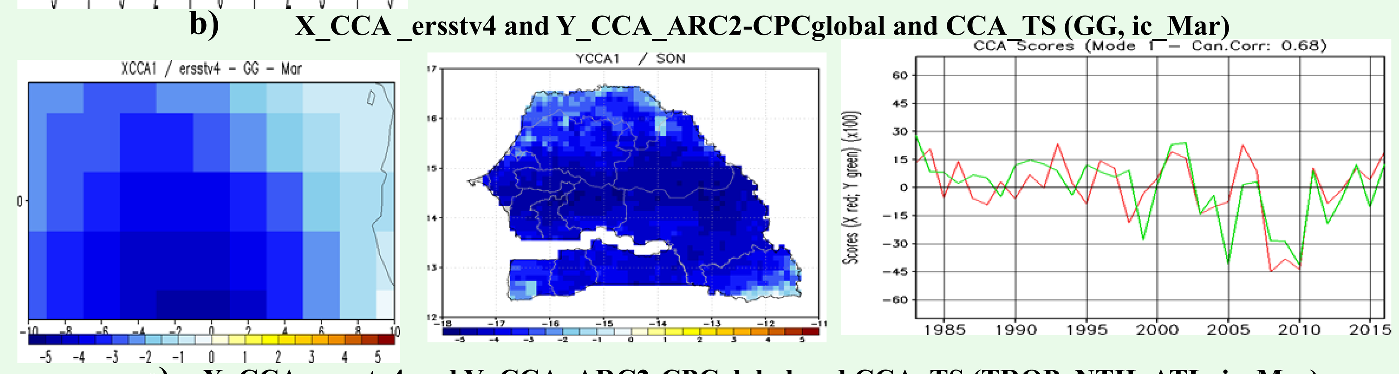


Fig. 9: Diagnostically Study : Malaria over Senegal, Prediction Performance (sensitivity test to the different parts of the tropical oceans). Best skills are shown for the Golf of Guinea, the Tropical Pacific and the Global Tropic to a lesser extent.

a) X_CCA _ersstv4 and Y_CCA_ARC2-CPCglobal and CCA_TS (TROP_PAC, ic_Mar)



b) X_CCA _ersstv4 and Y_CCA_ARC2-CPCglobal and CCA_TS (GG, ic_Mar)



c) X_CCA _ersstv4 and Y_CCA_ARC2-CPCglobal and CCA_TS (TROP_NTH_ATL, ic_Mar)

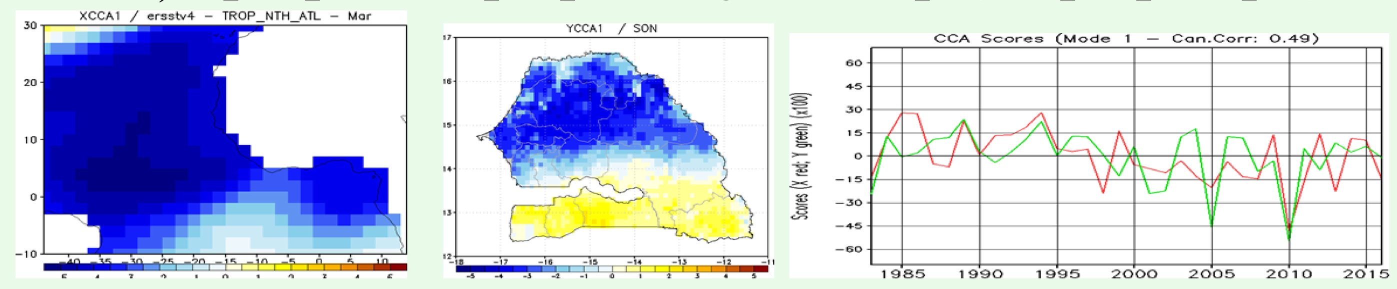


Fig. 10: In the Tropical Pacific ocean, for mode 1, a positive anomalous SST signal (warming) is associated with a negative anomalous malaria incidence signal (less malaria transmission). Very high relationship is found (r=0.70 for mode). High correlation coefficients between GG SSTs and malaria incidence (0.68) for mode. Cold SSTs imply less rainfall, so less malaria incidence. Mode 1 exhibits acceptable correlation coefficients between TROP_NTH_ATL SSTs and malaria incidence (0.49). Negative anomalous SSTs is related with less malaria transmission over the northern regions of Senegal and slight positive signal in the south.

CONCLUSIONS AND PERSPECTIVES

- This study shows that seasonal peaking behavior of malaria was predominantly unimodal. However, transmission peaks in the models tend to be delayed by one to two months in the study area. The focus of Senegal shows that both Observation and model agree on the high malaria transmission in Sept-Oct-Nov, corresponding to 2 months after the peak of rains (in Aug), and to second peak for temperature (Oct).

- Seasonal malaria transmission contrast is closely linked with the latitudinal variation of climatic covariates such as rainfall in West Africa.
- Best skills with Golf of Guinea, the Tropical Pacific and the Global Tropic to a lesser exetent.
- Positive anomalous SST signal (warming) over Pacifici associated with a negative anomalous of malaria incidence signal (less malaria transmission), while a negative anomalous SSTs is related with less malaria transmission over the northern regions of Senegal and slight positive signal in the south.

- Subseasonal and seasonal forecast: Plan to run Week 3/4 forecast on malaria with LMM and VECTRI based on NCEP CFSv2 Model products. NMME predicted SST will used late for futher diagnostic of the seasonal malaria predictability

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