P3.5 INFLUENCE OF LOCAL SSTAs AND SURFACE PROCESSES ON THE SAHEL RAINFALL

Marco Gaetani *
Giovanni A. Dalu
Valerio Capecchi
Marina Baldi
IBIMET – CNR, Roma, Italia

1. INTRODUCTION

The monsoonal dynamics in the Sahel is sensitive to the interannual fluctuations in the meridional gradient of the moist static energy (MSE = CpT + Lq + gz), in the planetary boundary layer (PBL). Wet conditions are related to large gradients of MSE and dry conditions are related to weak gradients (Eltahir and Gong, 1996; Fontaine and Philippon, 2000).

Over sea the MSE in the PBL is mainly regulated by SST. From April to August an intense cooling (about 4 C) of the equatorial Atlantic waters in the Gulf of Guinea intensifies the sea-land temperature contrast which leads the onset of the West Africa monsoon (WAM) (Fig.1). This sea-land thermal contrast brings a substantial change of the wind, which, between April and July, changes into an intense southwesterly flow, pushing the ITCZ and its rain belt inland (Okumura and Xie, 2004).

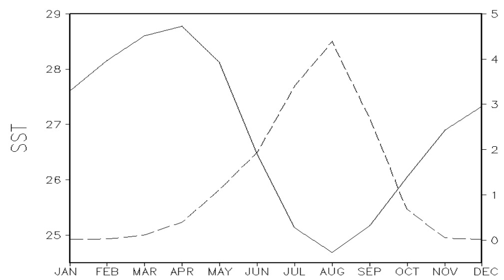

Figure 1: Climatological monthly means of SST in the Gulf of Guinea (solid line, [C], NOAA) and rainfall in the Sahel (dashed line, [mm / day], GPCP).

In the PBL over land, the MSE is modified by the re-evaporation process from the rain forest in the Guinea region (Philippon and Fontaine, 2001).

In this scenario, the purpose of this work is to analyze the statistical correlation between the rainfall in the Sahel and the rainfall in the Guinea region and the SSTAs in the Gulf of Guinea in the months preceding the WAM, in order to find a set of predictors for the interannual variability of the rainfall in Sahel, applying a linear regression method with cross validation.

2. DATA AND METHOD

Using rainfall data from GPCP dataset (Huffman et al., 1997) and SST data from NOAA Optimum Interpolation SST V2 dataset (Reynolds et al., 2002) in the period 1983-2002, we correlate the rainfall in the Sahel, cumulated in July-September (JAS), with the SSTAs in the Gulf of Guinea, averaged in a 3-months sliding window.

The NOAA SST data are available from December 1982 to present, from 89.5°S to 89.5°N and 0.5°E to 359.5°E, with a horizontal resolution of 1.0°. The GPCP data cover the period 1979-present, and have 2.5° horizontal resolution from 88.75°S to 88.75°N and from 1.25°E to 358.75°E.

The JAS amount of the rainfall and the SSTAs are computed averaging over the regions in Tab.1 and Fig.2.

	Longitude	Latitude
Guinea Gulf	15° W - 10° E	5° S - 7° N
Guinea Coast	10° W - 10° E	5° N – 10° N
Sahel	10° W - 10° E	10° N - 20° N

Table 1: Boundaries of the region used in the analysis.

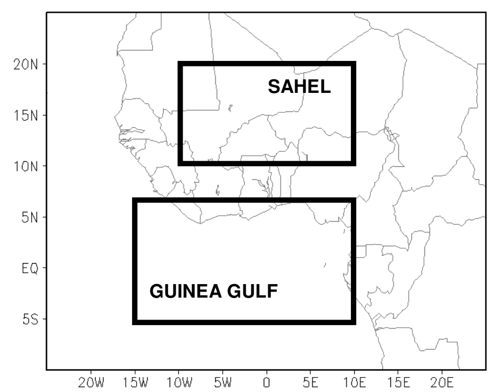

Figure 2: Gulf of Guinea and Sahel boxes.

We find that the correlation between the monsoonal rainfall and the previous fall SSTAs is very high. The correlation coefficient between the rainfall in the year 0 and the October-

* Corresponding author address: Marco Gaetani, Institute of Biometeorology, 00185 Roma, Italia, +39649937680; email: m.gaetani@ibimet.cnr.it.

December (OND) SSTA in the year -1 is R = 0.73, a value that exceeds the 99% level of significance for a series with 19 degrees of freedom (dof).

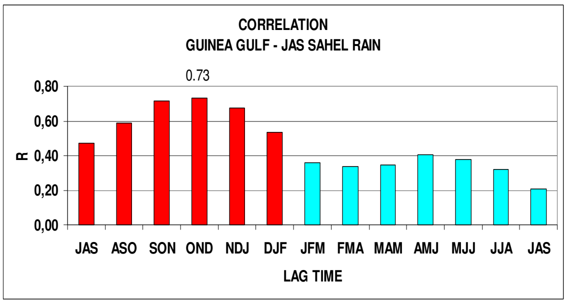

Figure 3: Correlation coefficient between the JAS Sahel rainfall amount and the previous Guinea Gulf SSTA averaged on a 3-months sliding window (Blue, year 0; red, year -1).

Applying the same method to the 1979-2002 GPCP rainfall in the Guinea Coast region (Tab.1 and Fig.4), we find a sizable correlation between the JAS Sahel rainfall in the year 0 and the OND Guinea Coast rainfall in the year -1 (Fig.5). The coefficient R = 0.39 is a value that exceeds the 95% level of significance for a series with 19 dof.

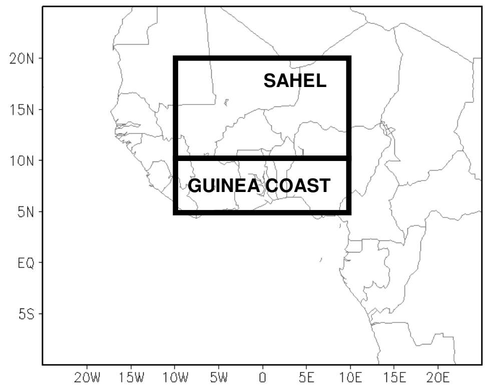

Figure 4: Coast of Guinea and Sahel boxes.

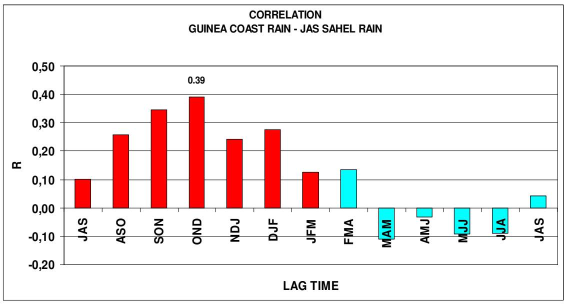

Figure 5: Correlation coefficient between the JAS Sahel rainfall amount and the previous Guinea Coast rainfall amount averaged on a 3-months sliding window (Blue, year 0; red, year -1).

A multi-linear regression (MLR) method with cross validation is used to equate the JAS rainfall in the Sahel with the combination of the OND SSTA in the Gulf of Guinea and the OND rainfall in the Guinea region.

$$R^{Sahel}_{JAS(0)} = a\, SSTA^{Gulf}_{OND(-1)} + b\, R^{Coast}_{OND(-1)} + c \quad (1)$$

For each year, the forecast for the JAS Sahel rainfall is performed computing the a, b and c coefficients in Eq.1 applying the MLR over all the years from 1983 to 2002, less the year of the forecast.

3. RESULTS

The 1983-2002 interannual variability of the observed and forecasted JAS rainfall amounts in the Sahel region is shown in Fig.6. The correlation coefficient between observed and forecasted rainfall is R = 0.65, a value that exceeds the 99% level of significance for a series with 19 dof.

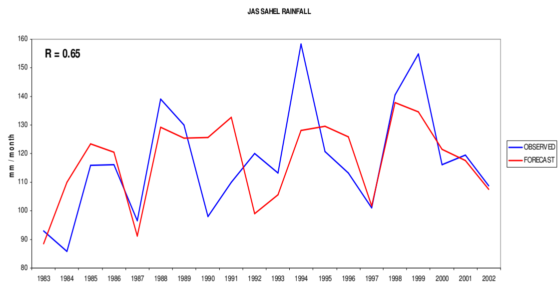

Figure 6: Sahel JAS rainfall amount, observed (blue) and forecasted (red).

In order to evaluate the skills of the MLR analysis, we use the following contingency table (Tab.2): an observed forecasted event is a hit (h); a forecast of a not observed event is a false alarm (fa); an observed a not forecasted event is a miss (m); and a not forecasted not observed event is a correct negative (cn).

		Event observed	
		yes	no
Event forecasted	yes	h	fa
	no	m	cn

Table 2: Contingency table.

The hit rate is the percentage of detection for an observed event:

$$H = \frac{h}{h+m} \quad (2)$$

Defining a wet event a year with the rainfall amount greater than the mean climatological value and a dry event when the rainfall is less

than the average, it results H = 0.88 for wet events and H = 0.50 for dry events.
In order to determine the role of each predictor, we perform the forecast using in Eq.1 Guinea Coast rainfall and Guinea Gulf SSTA separately. The linear regression with cross validation applied on SSTAs and Sahel rainfall gives a correlation coefficient R = 0.67 (99% level of significance) between observed and forecast precipitation (Fig.7), a hit rate H = 0.75 for wet events, and H = 0.50 for dry events.

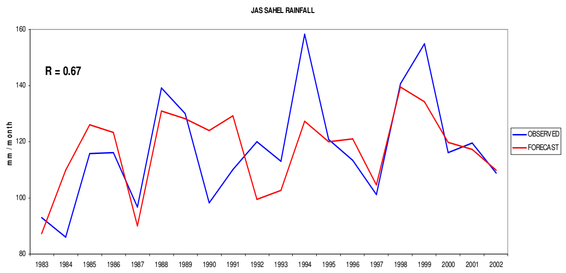

Figure 7: Sahel JAS rainfall amount, observed (blue) and forecasted (red). The forecast is performed using only the SSTA in the Gulf of Guinea in OND(-1).

Because its lower correlation with Sahel rainfall, the Guinea Coast precipitation is not a good predictor, when used alone: the correlation coefficient between forecast and observed rainfall is R = 0.20 (75% level of significance), and the hit rates are H = 0.63, for wet events, and H = 0.58, for dry events.

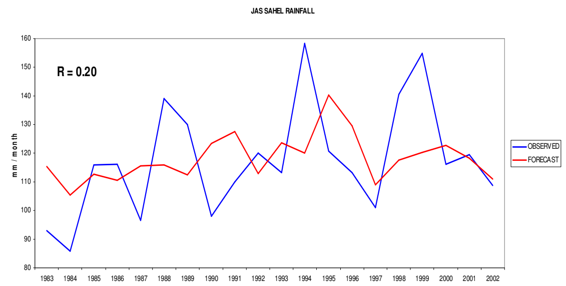

Figure 8: Sahel JAS rainfall amount, observed (blue) and forecasted (red). The forecast is performed using only the rainfall amount in the Coast of Guinea in OND(-1).

A summary of these results is shown in Tab. 3: the MLR analysis, applied to SSTAs and rain, results a good method for detection of wet events in the Sahel region. The SSTA appear as the main predictor, but inclusion of the rainfall in the Coast of Guinea improves the hit rate, despite its lower statistical results. Detecting a dry event with this method is more difficult, the rainfall in the Coast of Guinea appears as the main predictor, but it is not able to increase the hit rate obtained using SSTA.

	SSTA + RAIN	SSTA	RAIN
WET	0.88	0.75	0.63
DRY	0.50	0.50	0.58

Table 3: Hit rates for wet and dry events in Sahel, computed applying MLR analysis to SSTAs and rainfall, and to SSTAs and rainfall separately.

AKNOWLWDGMENTS

The GPCP data are the NASA (Goddard Space Flight Center's Laboratory for Atmospheres) contribution to the GEWEX Global Precipitation Climatology Project.
NOAA OI SST V2 data provided by the NOAA-CIRES ESRL/PSD Climate Diagnostics branch, Boulder, Colorado, USA, from their Web site at http://www.cdc.noaa.gov/.

REFERENCES

Eltahir, E.A.B., and C. Gong, 1996: Dynamics of wet and dry years in West Africa. *J. Climate*, **9**, 1030-1042.

Fontaine, B., and N. Philippon, 2000: Seasonal evolution of boundary layer heat content in the West African monsoon from the NCEP/NCAR reanalysis (1968-1998). *Int. J. Climatol.*, **20**, 1777-1790.

Huffman G.J., and coauthors, 1997: The Global Precipitation Climatology Project (GPCP) combined precipitation dataset. *Bull. Amer. Meteor. Soc.*, **78**, 5-20.

Okumura, Y., and S.P. Xie, 2004: Interaction of the Atlantic equatorial cold tongue and the African monsoon. *J. Climate*, **17**, 3589-3602.

Philippon, N., and B. Fontaine, 2002: The relationship between the Sahelian and previous 2nd Guinean rainy season: a monsoon regulation by soil wetness? *Ann. Geophys.*, **20**, 575-582.

Reynolds, R.W., and coahutors, 2002: An improved in situ and satellite SST analysis for climate. *J. Climate*, **15**, 1609-1625.