
THE INFLUENCE OF GULF OF GUINEA SEA SURFACE TEMPERATURE TO WEST AFRICA AND SAHEL DROUGHT OF 2005

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Abstract

The impact of sea surface temperature (SST) in the Gulf Guinea to the West Africa and Sahel drought of 2005 has been examined using Satellite data. Daily TRMM 3B42 precipitation estimates and TMI SST data sets show concurrent variability during the summer of 2005, indicating the influence of Gulf of Guinea SST over rainfall in these regions. The SSTs that contribute to the drought are no-seasonal fluctuations that occurred during this period and are caused by stronger than normal southeasterly winds that inhibit moisture convergence over the two regions. However, Sahel region was influenced in addition by westerly winds akin to the tropical intraseasonal variability of the Madden Julian Oscillation.

KEYWORDS: *Rainfall, SST, West Africa, Sahel, MJO*

Introduction

The region of West Africa (WA) and the Sahel experiences fluctuations of rainfall that vary from year to year. This variability affects the livelihoods of the people who depend on rain-fed agriculture. Although, effect of drought could influence health, economies and agriculture, the latter is worst to be affected. Many crops in these regions are sensitive to even tiny shifts in rainfall and temperatures. Some experts have already observed a linkage between crop failures and declining yields due to drought and high temperatures (Sayne, A., 2011).

Many authors have investigated the causes of drought in these regions, especially the semi-arid Sahel since 1970s. Charney (1975) attributed drought to local factors such as land degradation, desertification, atmospheric radiation and circulation and precipitation. Others attribute this to forcings outside the region, in particular the impact of global ocean SST changes (e.g. Folland et al., 1986; Palmer, 1986). Fontaine and Janicot (1996) investigated the relationship between WA rainfall and sea surface temperatures from in situ data archives that spans a period of 40 years (1950-1990). Their result showed that drought over WA is associated with warmer SSTs in the eastern Pacific and Indian Oceans, and negative SST anomalies in the north Atlantic and at the Gulf of Guinea. Quite recently, Gianinni et al. (2003) successfully simulated interannual to interdecadal variability of the Sahel rainfall with Atmospheric General Circulation Model (NSIPPI developed by NASA's Goddard Space Flight Centre). Their results showed an importance of oceanic condition surrounding Africa on influencing rainfall. This was based on the analysis of global SSTs in forcing the Sahel rainfall. Here, I investigate the impact of Gulf of Guinea SSTs on WA and the Sahel rainfall anomalies that lead to the 2005 drought using contemporaneous rainfall and SST data sets.

Data

This study employs the use of satellite data products of rainfall and sea surface temperature (SST). The Tropical Rainfall Measuring Mission (TRMM) is a joint mission between National Aeronautics and Space Administration (NASA) of US and the National Space Development Agency (NASDA-Japan space agency, now known as JAXA) aimed at sampling the tropics. The precipitation radar has a footprint of 0.25 x 0.25 horizontal resolution, with a span of (40°S-40°N, 180°W-180°E) before February 2000 and (50°S-50°N, 180°W-180°E) after. The daily 3B42 version 6 products are used in this study, covering six years (2004-2009) to allow for the study of seasonal variability at year-to-year level.

The SST data is the daily TRMM Microwave Imager (TMI), a product of the TRMM satellite (see Chelton et al., 2000). The TRMM radiometer provides an uninterrupted record of SST signatures on a global coverage of (40°S-40°N, 180°W-180°E) before February 2000 and (50°S-50°N, 180°W-180°E) after. The choice of this product over the Infrared sensors such as the Advanced Very High Resolution Radiometer (AVHRR) or Advanced Along-Track Scanning Radiometer (AATSR) is because it can view the ocean surface at all weather conditions except through raining clouds. Details of inherent advantages of using microwave instruments for measuring the oceans and sea ice are found in Mitchelson-Jacob (1996) and Robinson (2010). In this analysis, small gaps created by the sensors' inability to view through rainy clouds have been optimally interpolated using the method described by Alvera-Azcárate et al., (2005). Both rainfall and SST data sets were averaged to 3-daily composites. This is to reduce spurious signals in rainfall, and to eliminate gaps between satellite swaths for the SST.

Method

To understand the enigmatic influence of SSTs on rainfall over these regions, it is pertinent to investigate the seasonal cycles of the Gulf of Guinea, West Africa (WA) and the Sahel regions. Long-term means with respect to 12-years of data (1998-2009) were removed from both rainfall and the SST data sets. Anomalies are calculated as A in equation 1. Six years of rainfall anomaly data (2004-2009) were extracted, from which spatially averaged timeseries were formed (figure 1). A corresponding six years of spatially averaged SST anomalies were also plotted (Figure 2a).

$$A = x_i - \sum_{i=1}^n x_i \quad 1$$

$$S_c = A_{ij} - \sum_{ij} A_{ij} \quad 2$$

Since rainfall is sensitive to small variations of temperature, seasonal cycle of SST were further removed. Residuals to be used are obtained after removing the seasonal cycle S_c as shown in equation 2. This is by subtracting the means of all pixels of the three-day timeseries from the mean anomaly of pixels of consecutive three-daily data for all years. This would provide the opportunity to observe the impact of small-scale variations of SST to rainfall, particularly for the summer season. Hence, non-seasonal variability of SST for the

June-July-August (JJA) months are constructed and plotted (see figure 2b). This allows ease of comparison of year-to-year variability.

Seasonal Cycle of Rainfall

The spatially averaged timeseries of rainfall for both WA (defined in this study as 3°N-12°N, 10°W-16°E) and Sahel (12°N-25°N, 10°W-16°E) are produced (figure 1). These show seasonal fluctuations on spatially averaged rainfall anomalies for all seasons. The pattern of rainfall anomalies in WA is dissimilar to that of the Sahel because the former demonstrates two peaks in a year, one toward end of May and another toward end of August (figure 1a). For the Sahel, rain rates only peak in August (figure 1b).

It is observed that in WA, rain breaks do occur in July. In the year 2005, there was a significant drop in rain magnitude between early June and end of August. Between early July and mid-August (6 weeks), where values in other years remain positive (~2mm/day), the year 2005 exhibits negative anomaly (-1mm/day). Also evident is low values of rainfall in the Sahel between second week of July and first week of September (8 weeks - figure 1b). However, the Sahel values remain positive (less with ~1mm/day), indicating that the Sahel rainfall anomalies might be controlled in addition to other factors affecting WA. For example, in 2005, the timeseries showed May-June demonstrating significant positive rainfall anomalies compared to other years.

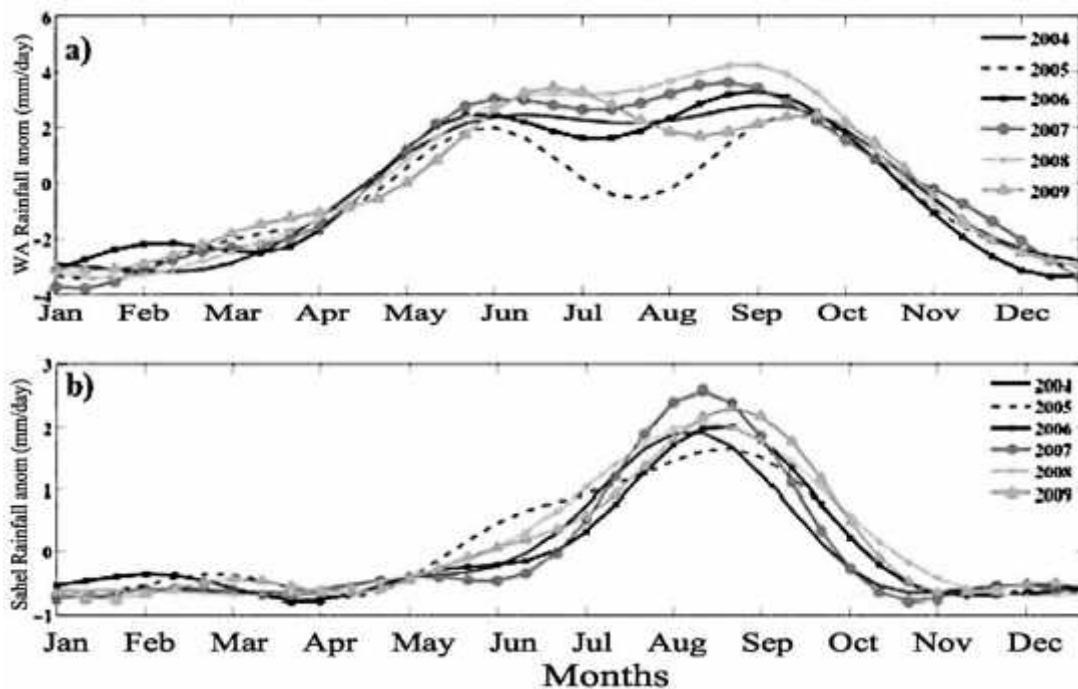


Figure 1. Seasonal cycle of rainfall based on area averages over a) West Africa [3°N-12°N, 10°W-16°E] and b) the Sahel [12°N-25°N, 10°W-16°E]. These are 3-daily TRMM 3B42 Version 6 data products covering the period 2004-2009.

It is imperative to mention that rainfall occurrence between November and March is limited to the Guinea coast while north of the region remains dry

throughout this same period. However, since the data are spatially averaged, the timeseries embodies the whole region of WA or the Sahel.

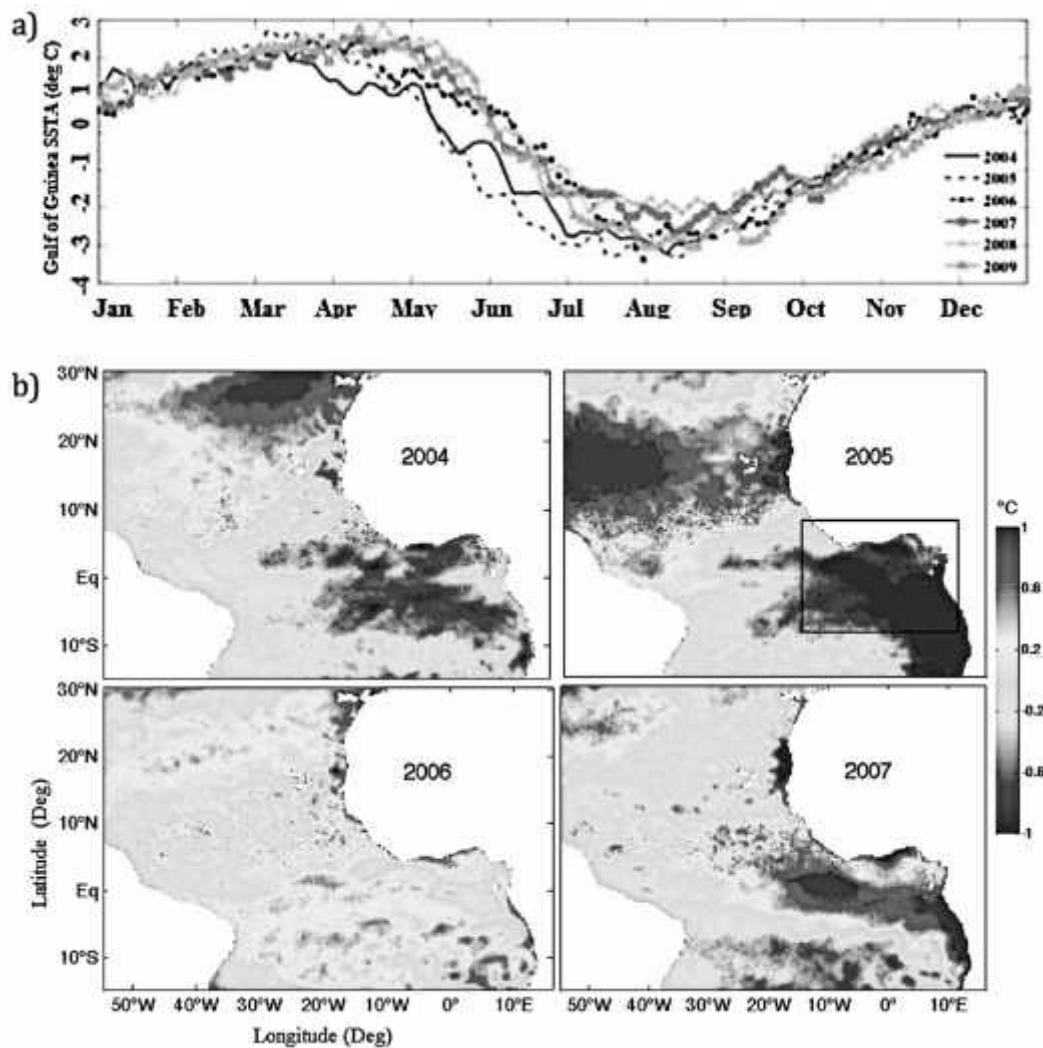


Figure 2: Sea Surface Temperature anomalies for a) area averaged timeseries at the Gulf of Guinea, and b) spatial patterns averaged for the JJA months in the equatorial Atlantic. Climatological mean and seasonal cycle has been removed based on 1998-2009.

Seasonal Cycle of SST

The spatially averaged SST timeseries in the Gulf of Guinea are shown in figure 2a. The SST of 2005 concurrently show weaker values between early May and end of July (12 weeks) compared to other years. This is particular different compared with SST of 2006. The seasonal cycle of the Gulf of Guinea clearly manifest itself throughout the year, with high positive SST anomalies in boreal spring and very low signatures from mid-May to October.

In the year 2005 (figure 2b), the JJA plot shows lower than normal SSTs during the boreal summer compared to other years. This associated cooling is connected to the southeasterly winds. These winds drive the cold tongue, leading to significant cooling to persist during the summer period by enhancing upwelling of cold subsurface waters. The strength of upwelling is solely dependent on the magnitude

of intensification of the southeasterly winds, and these have significant effect on coupled ocean-atmosphere interaction in the tropical Atlantic Ocean and particularly the Gulf of Guinea. The southeasterly winds were stronger during JJA months of 2005 due to associated large-scale atmospheric circulation south of the Atlantic.

Discussion and Conclusion

The summer of 2005 (figure 2a,b) shows substantially strong negative SST anomalies than the other years. Previous studies based on Reynolds SST anomalies indicated that such a strong negative anomaly was only recorded in 1983 and 1997 during the last two decades, which occurred during the Pacific El Niño years. Some authors indicated the link between extreme SST variability in the Atlantic to Pacific El Niño Southern

Oscillation (ENSO). Marin et al. (2009) and Polo et al. (2008) pointed out that the Atlantic Niño leads the Pacific La Niña and the later is connected only to WA rainfall anomalies rather than the Sahel. In 2005, the Pacific ENSO did not occur, so this might not have influenced the Atlantic SSTs.

Near surface processes that affect the development and maintenance of the cold tongue are essentially important factors in determining this kind of variability in SST. These processes and local wind effect are thought to be the major causes of this strong cooling in 2005 (Marin et al., 2009), while surface heat fluxes only act as negative feedback to the SST (Foltz et al., 2003; Foltz and McPhaden, 2006). The implication of this is that rainfall magnitudes are drastically reduced at times when SST can have an influence, such as the period between late-May and early-August (figure 1a, 2a).

Another important scenario in this analysis is the sensitivity of rainfall to SST changes on seasonal basis. The cooling effect in 2005 is attributable to the basin-wide strengthening of winds, which induced a shallow thermocline consistent with the tropical Atlantic mode of variability (Houghton, 1989; Marin et al., 2009). The strengthening of winds north of the equator significantly weakens rain-bearing southeasterly monsoon winds, thereby inhibiting moisture convergence over WA and the Sahel regions.

Using NCEP/NCAR reanalysis data, Hastenrath et al. (2007) attributed the cause of the 2005 drought in east Africa to pressure changes associated with strong westerlies. The strengthening of the westerlies north of the equator could be a factor, but the strengthening of southeasterlies in the Gulf of Guinea can dominate the influence of ocean forcing over WA since the monsoon winds are driven by the southeasterlies. This can be understood in this way: when the southeasterlies blow normally, they will aid the transport of moisture over land. However, on the account that they become extreme strong, they will intensify upwelling in the Gulf of Guinea thereby cooling the ocean surface. This will affect the thermodynamic processes by inhibiting heat and moisture fluxes that cause rain.

Studies from a model gave evidence that the

increase in Sahel precipitation is not coming from the Guinea coast, but from the west (Cook and Vizy, 2006). A similar study (Grist and Nicholson, 2001) indicated that in the years when the Sahel gains more rain, the low-level westerly winds are also stronger. This suggests that the forcing mechanism responsible for a wetter Sahel is not connected to warming in the Gulf of Guinea (Cook and Vizy, 2006). In the analysis of Sahel rainfall (figure 1b), May and June showed characteristics of rainfall that is not coming from the Guinea coast. It might be due to the Westerly winds carrying rainfall over the Sahel. In this case, there could be a possibility of intraseasonal oscillations of the tropics, the Madden-Julian-Oscillation (MJO) that conveys rainfall from West to east that modulated the rains. Although, the MJO is very weak in the Atlantic, this may prove so being that the May-June rainfall is not of great significance. However, the rainfall anomalies from July-September concur well with SST anomalies of the Gulf of Guinea. Therefore, it is reasonable to conclude that the Gulf of Guinea controls moisture convergence over the Sahel, and to a lesser degree by westerly winds akin to the MJO. This demonstrates that the Gulf of Guinea SST has significant effect on the 2005 drought that affected both West Africa and the Sahel regions.

Summary

The influence of Gulf of Guinea sea surface temperature on 2005 drought over West Africa and the Sahel has been investigated. Satellite SST and rainfall data sets have been used to highlight space-time variability in these regions. Seasonal variability of Gulf of Guinea SST spatial timeseries concur well with rainfall, were negative SST anomalies corresponds to negative rainfall anomalies during the boreal summer. However, rainfall anomalies in the Sahel were, in addition influenced by westerly winds that are connected with the negative phase of the MJO.

Acknowledgement

I would like to acknowledge Remote Sensing Systems for providing TMI SST dataset. The data are sponsored by the NASA Earth Science MEaSUREs DISCOVER Project. I'm grateful to NASA's Goddard Earth Sciences Data and Information Services Centre for providing TRMM precipitation data. I thank the anonymous reviewers for their useful comments.

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