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ON RELATIONSHIPS BETWEEN TROPICAL ATLANTIC SEA SURFACE TEMPERATURE, WIND STRESS AND REGIONAL PRECIPITATION INDICES: 1964–1984

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A monthly wind stress and sea surface temperature field set over the tropical Atlantic domain is used in order to recognize the main abnormal climatic phenomena which occurred during the 1964–1984 period. The most dramatic event which affected both Atlantic variables occurred during 1983–1984, a few months after the exceptionally powerful 1982–1983 El Niño. A statistical analysis, associating these fields with time series of precipitation regimes in Africa and Brazil, enlarges on some earlier studies performed from restricted occurrences.

KEY WORDS: Sea surface temperature, wind stress, precipitation

INTRODUCTION

In the preceding paper (Servain *et al.*, 1987) we presented a monthly data set of wind stress and sea surface temperature (SST) for the equatorial Atlantic for the period 1980–1984. This updates a previous atlas of these parameters (Picaut *et al.*, 1985) which henceforth results in a 21-year climatology for the equatorial Atlantic covering the period 1964–1984. In this paper we highlight some abnormal climatic events in the tropical regions observed during this time period. We also discuss the possible relationship between the wind field anomalies over the equatorial Atlantic and North-East of Brazil (Nordeste) and western subtropical Africa (Sahel).

I. MAJOR ABNORMAL EVENTS CONCERNING THE SST AND WIND STRESS OVER THE TROPICAL ATLANTIC DURING 1964–1984

The dynamics of the upper layers of the ocean in low latitudes is largely governed by the variability of the wind stress along the equator. For the Atlantic, the wind stress differs considerably depending on whether it is in the eastern part of the basin, where the wind is relatively weak and is most meridional, or whether it is in the western part where the wind is strong and most often zonal (Figure 1a). According to certain theoretical conceptions (for example Moore *et al.*, 1978) one expects that an intensification of zonal wind stress along the equator off the coast of Brazil would

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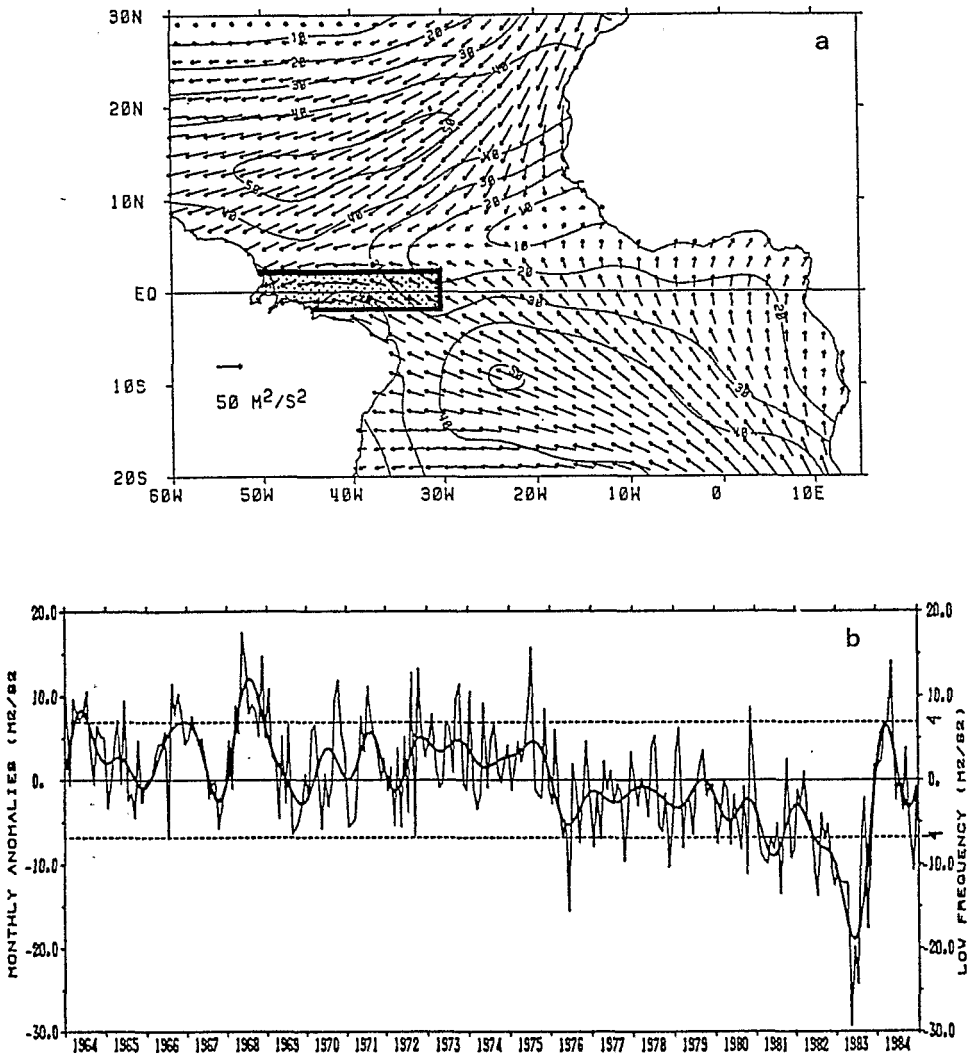

FIGURE 1 (a) Total monthly mean of wind stesss (1964–1984); (b) The time series of monthly zonal wind stress anomalies corresponding to the dotted equatorial zone in the west of the basin. One negative/positive anomaly indicates an intensification/relaxation of zonal wind in relation to the climatology.

provoke a rise in the thermocline in the eastern Atlantic. On a seasonal time scale, the modeling results of Busalacchi and Picaut (1983) show just such a response.

In order to test these hypotheses, we analysed the chronological series of monthly anomalies of zonal wind stress for the period 1964–1984 integrated along the equatorial axis for the Western Atlantic ocean (Figure 1b). It is noteworthy that the intensification of the trade winds in the region during the 1970's discussed earlier by Servain *et al.* (1985) continued beyond 1979, culminating in 1983 with the most energetic event observed during the entire 20-year period. Also outstanding is the remarkable relaxation which followed this episode from mid-1983 to mid-1984. There

was even a reversal of the trades near the mouth of the Amazon in May 1984 (Servain *et al.*, 1987). This dramatic relaxation of the wind stress along the equator is in all likelihood associated with the inverse tilting of the dynamic equatorial ocean slope observed during the FOCAL oceanographic experiment in January 1984 (Katz *et al.*, 1985).

In Figure 2 we present the analysis of SST for the eastern Atlantic. The warming of SST in the interior of the Gulf of Guinea during 1984 could be the superficial signature of an 'El Niño-type' event in the Atlantic. However, the equatorial character of this warm episode seems less marked than was that of 1968 (Lamb 1978b; Picaut *et al.*, 1985) which also followed a reversal of tradewinds at the west of the basin (Servain, 1984). In fact in 1984 the strongest positive SST anomalies were more definite south of the equator.

It is interesting to note that the climatic event from 1983 to 1984 took place after the largest El Niño phenomenon ever recorded in the equatorial Pacific (Leetmaa *et al.*, 1983). Numerous diagnostic and theoretical studies are being carried out in order to try to understand the dynamic links between these major events.

II. SOME STATISTICAL RELATIONSHIPS BETWEEN THE INTERTROPICAL ATLANTIC AND THE PRECIPITATION REGIME IN AFRICA AND BRAZIL

We wished to clarify statistically certain features of a possible teleconnection between the climatic anomalies of the intertropical Atlantic and the abnormal precipitation regimes over the African Sahel and the Brazilian Nordeste. In order to achieve this objective, we used for the subsaharan zone the precipitation anomaly time series calculated by Lamb (1985) relative to the April–October period of each year. At lower latitudes, the rainy season is linked to the passage of the Intertropical Convergence Zone (ITCZ). Consequently over Sahelian Africa, the months July, August and September are the wettest. At this time of the year, the ITCZ is furthest North. Figure 3a represents the Lamb's index for the period 1941–1985.

On the Brazilian Nordeste, the appearance, scope and average duration of the rainy season is less temporally precise. Some rather large differences between the littoral zone and the inland regions are noted. However, the months February–May are generally the most humid, especially to the North of the study region. During this period, the ITCZ is located close to the geographic equator. For the time series of precipitation anomalies over the Northern Nordeste we used the values (S. Hastenrath, personal communication) of an index initially calculated by Chu (1983) and relative to the March–April months for each year. Figure 3b gives this index for the period 1941–1985.

We estimated the part of the rainfall variance which might be explained by an Atlantic influence while analysing the correlation fields between the climatic anomalies in the entire tropical ocean domain and the anomalies of rainfall. The calculation is done for the whole 21-year period 1964–1984. Only the results which underline the connection during the rainy season between the deviations of the meridional component of the wind stress and the precipitation indices over the Sahel and the Nordeste are represented graphically (Figure 4a, b). A positive anomaly of the meridional stress is associated with a large northward wind stress. For both the Sahel (Figure 4a) and the Nordeste (Figure 4b), we find a spatial structure with significant

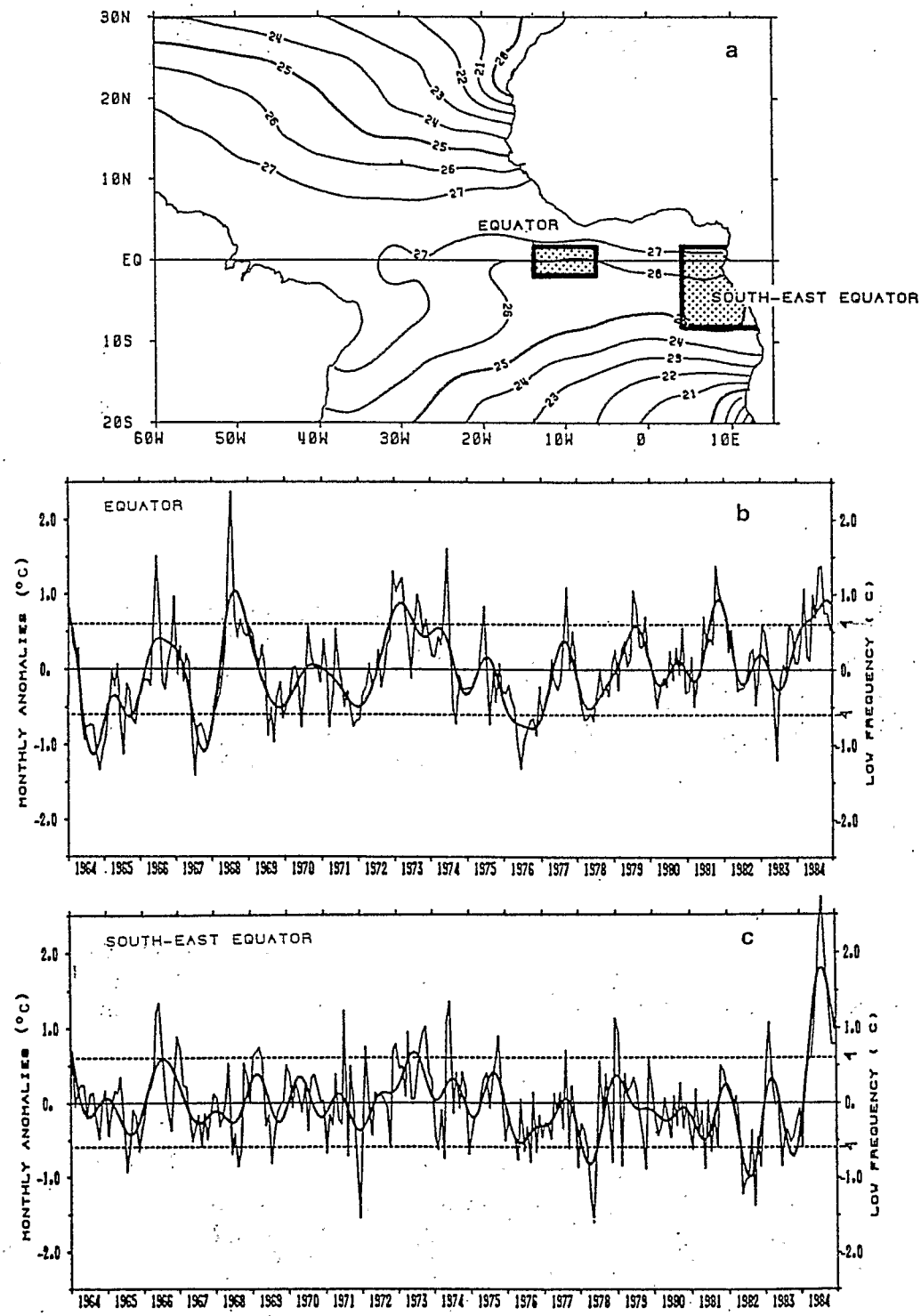

FIGURE 2 (a) Total monthly mean of SST (1964–1984). The time series of monthly SST anomalies corresponding to the dotted zones; one (b) is centered on the equator towards 10°W, the other (c) is situated along the southeastern coast of the Gulf of Guinea.

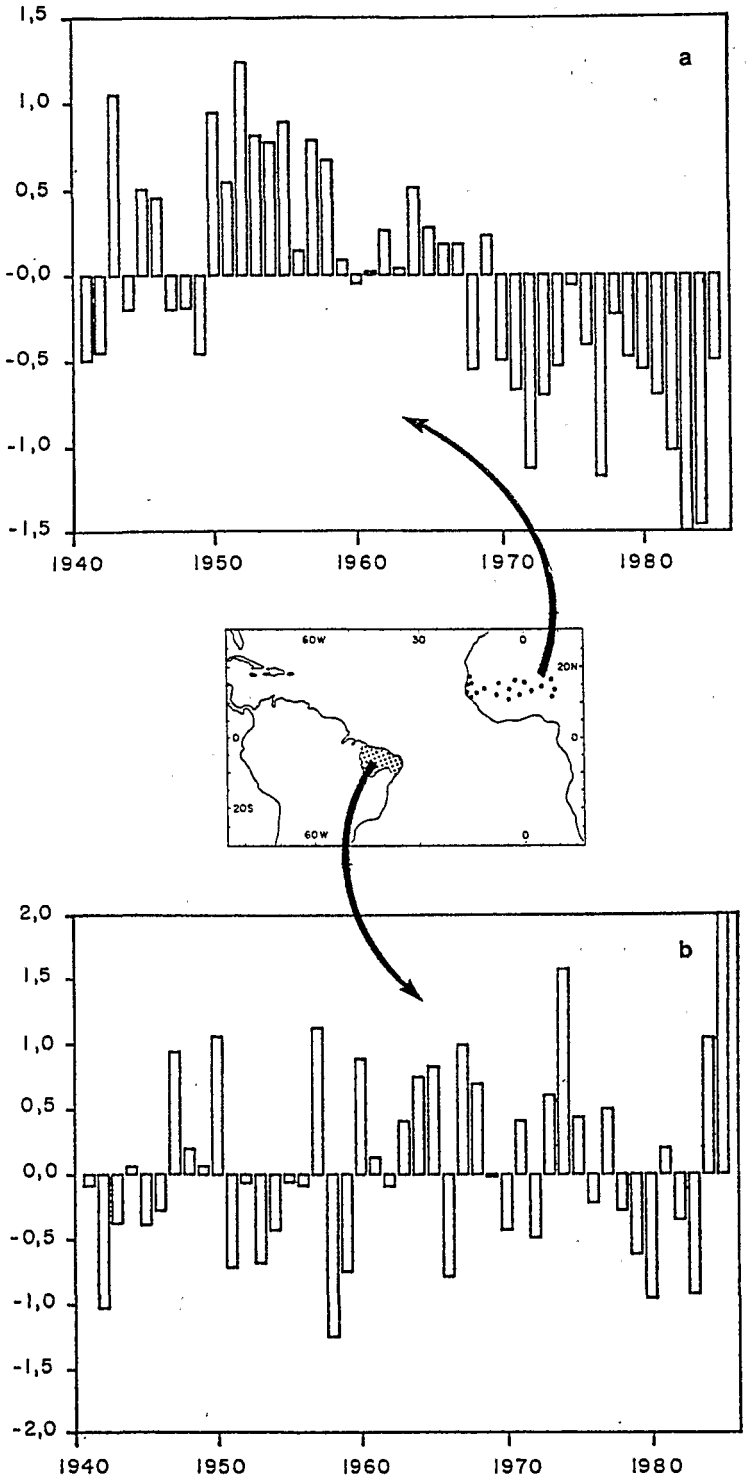

FIGURE 3 (a) Temporal series (1941–1985) of the precipitation index over subtropical west Africa according to Lamb (1985); (b) Temporal series (1941–1985) of the precipitation index over the Brazilian Nordeste according to S. Hastenrath (personal communication). Values of indexes are normalized.

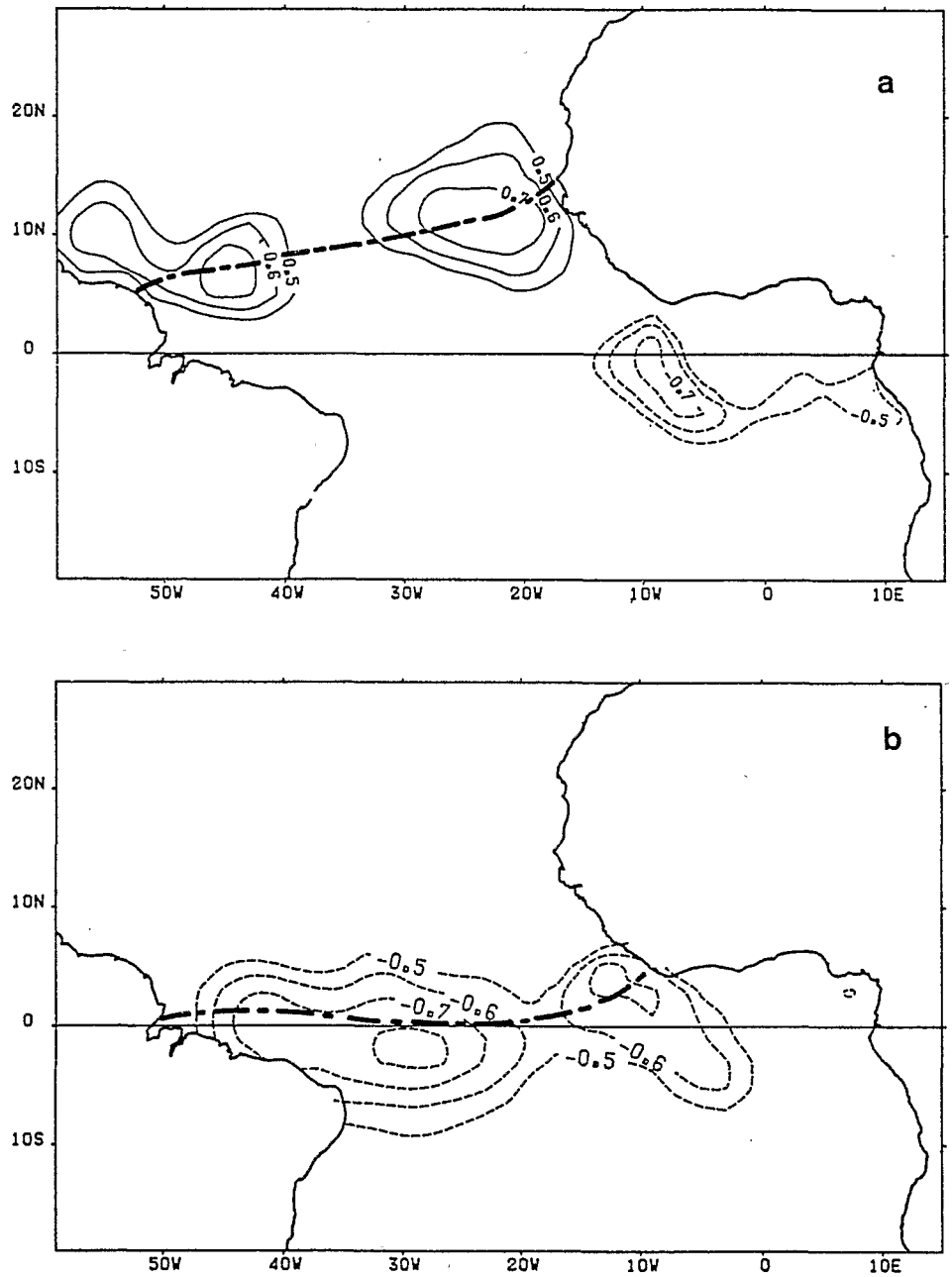

FIGURE 4 (a) Patterns of the correlation coefficient (significance >95%) between the field of monthly meridional wind stress anomalies over the tropical Atlantic (averages during July–August–September) and the Lamb index (African Sahel) for the period 1964–1984; (b) Patterns of the correlation coefficient (significance >95%) between the field of monthly meridional wind stress anomalies over the tropical Atlantic (averages during February–March–April) and the Hastenrath index (Brazilian Nordeste) for the period 1964–1984. In each case, the average position of the ITCZ is represented by a dashed line.

correlation coefficients ($P > 95\%$) which is located approximately along the axis of ITCZ. However, the Sahel is positively correlated while the Nordeste is negatively correlated.

Since in the vicinity of the ITCZ abnormal values of meridional wind stress may be interpreted as a latitudinal deviation of the meteorological equator, the preceding results may be summed up as follows. An abnormal northward displacement of the ITCZ associated with a reinforcement of the southeast trades and/or a relaxation of the northeast trades is correlated with a rise in rains over the Sahel region and with a diminution in rains over the Nordeste. The reciprocal is true for an abnormal southward displacement of the ITCZ. Furthermore, the negative structure of Figure 4a located in the Gulf of Guinea indicates that a reinforcement of the wind in this region is statistically related to a dry activity over the Sahel. All these correlations and others (Servain, 1985) are consistent with previous diagnostic studies based on dry/wet composite years (Hastenrath, 1976, 1984; Hastenrath and Heller, 1977; Lamb, 1978; Chu, 1983). Thus, using our carefully completed wind stress and SST data we assert that these relationships were continued during the entire 1964–1984 period, including the dramatic climatic events which occurred over the last few years around the tropical Atlantic region: the Sahel and Nordeste droughts.

III. CONCLUDING REMARKS

Simple analyses of the monthly fields of SST and wind stress show that climatology during the 1983–1984 period was very different from the 1964–1984 mean. An important relaxation of the wind stress from mid-1983 to mid-1984 over the west equatorial basin preceeded large positive anomalies inside the Gulf of Guinea during summer 1984. This dramatic Atlantic event occurred some months after the 1982–1983 El Niño phenomenon. Moreover from statistics for the entire 1964–1984 period on a year-to-year basis, a relationship between the intertropical Atlantic wind departures and precipitation anomalies over African Sahel and Brazilian Nordeste supports some previous results obtained from restricted time periods.

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