Variability and Trends in some Environmental Time Series along the Ivoirian and the Ghanaian Coasts

Kwame A. Koranteng*
Olivier Pezennec**

* Fisheries Research & Utilization Branch
(FRUB)
P.O. Box B-62
Tema
Ghana

** Centre National des Sciences
Halieutiques de Boussoura
(ORSTOM/CNSHB)
BP 1984
Conakry
Guinea

Abstract

Changes observed since 1966 in the Côte-d'Ivoire-Ghana coastal ecosystem are described. The specific characteristics of this ecosystem appear to be unique in the Guinea Current large marine ecosystem of which it is part. An analysis of several temperature data set is performed; this shows that the two upwelling seasons which occur in this ecosystem, have both changed in intensity, resulting in a weaker contrast between them. Also observed is a decrease in rainfall and an increase in wind speed. Some of these local environmental changes are in consonance with global changes.

Résumé

Depuis 1966, les changements observés dans l'écosystème de Côte-d'Ivoire-Ghana sont décrits. Cet écosystème, aux caractéristiques spécifiques, apparaît comme unique dans l'ensemble plus vaste que représente l'écosystème du courant de Guinée auquel il appartient. L'analyse de différents jeux de données de température montrent que les deux upwellings sai-

sonniers qui se produisent dans cet écosystème ont vu leur intensité changer, d'où résulte un moindre contraste entre leurs intensités respectives. L'intensité des pluies a décru tandis que celle des vents s'est accrue. Certains de ces changements environnementaux sont à mettre en parrallèle avec des changements plus globaux.

1. SPECIFICITY OF THE CÔTE-D'IVOIRE-GHANA ECOSYSTEM

The Western Gulf of Guinea is part of the Guinea Current large marine ecosystem (Sherman *et al.*, 1991). The upwellings which occur in this area, especially off Côte-d'Ivoire and Ghana, (Fig. 1) have been actively studied since the early 1960s. Two upwelling seasons occur: a major one (in French the 'grande saison froide') and a minor one ('petite saison froide') have been identified (Morlière, 1970; Arfi *et al.*, 1991). Each of these two upwelling events has a main center and creates an important spatial and temporal heterogeneity in the Ivoiro-Ghanaian coastal marine ecosystem. Furthermore, the upwellings observed off Côte-d'Ivoire and Ghana are rather peculiar in that they cannot be said to be of the Ekman-type (Houghton, 1976; Bakun, 1978). The mechanisms causing the upwelling are not well understood, thus complex interactions among several processes are thought to contribute to the observed coolings and the related upwelling (Ingham, 1970; Marchal and Picaut, 1977; Picaut, 1983; Colin, 1988; Bard and Koranteng, 1995). As the observed cooling cannot be only related to wind intensity, analysis of sea temperatures has been the main approach to quantitatively assess the upwelling. In this paper, therefore, results are presented which are based on the analysis of available series of sea temperatures.

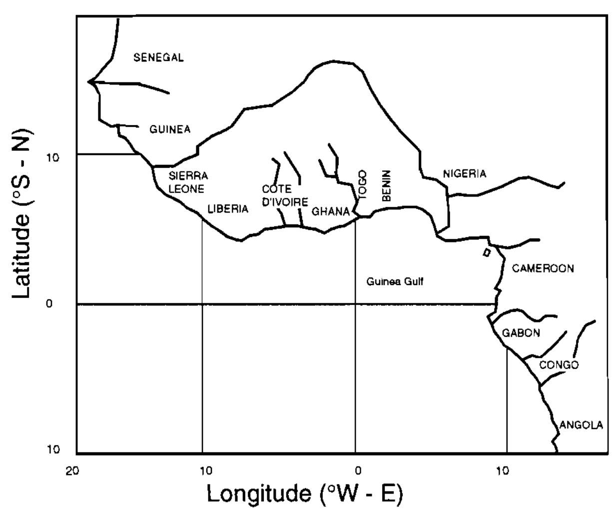

Fig. 1a: West Africa from Senegal to Angola, also showing the course of major rivers.

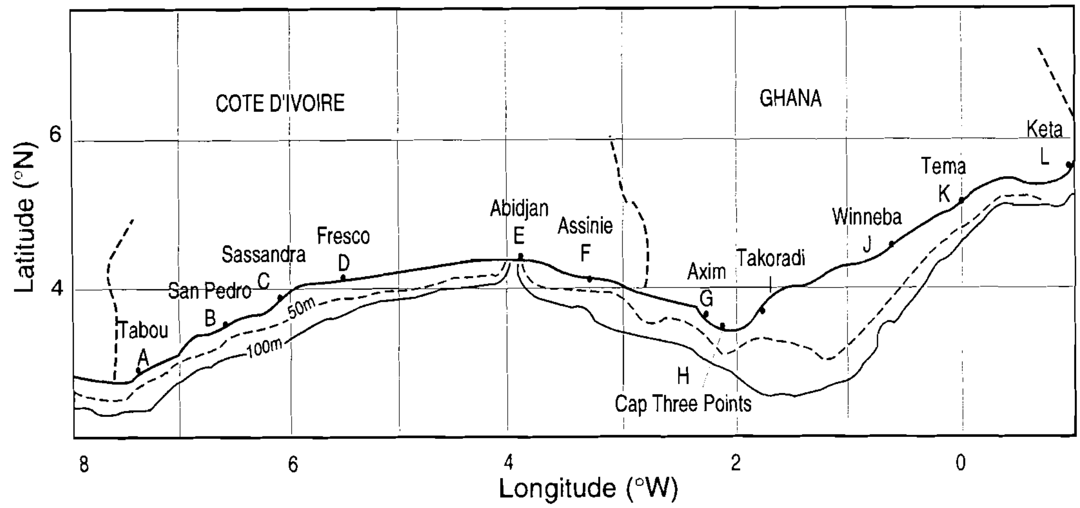

Fig. 1b: Continental shelves off Côte-d'Ivoire and Ghana and coastal stations mentioned in the text.

2. Importance of the environment to the Ivoirian and Ghanaian small pelagic fisheries

Numerous scientific contributions on the fisheries for small pelagics of this area have acknowledged the importance of the marine environment to the abundance and availability of these fishes. The key factors in this ecosystem that have been considered to affect the pelagic fishery were the occurrence of two upwellings (ORSTOM/FRU, 1976; Cury and Roy, 1987; Mendelssohn and Cury, 1987; Le Loeuff *et al.*, 1993; Bard and Koranteng, 1995) freshwater discharge from major rivers (Binet, 1982; Mahé, this vol.) and water currents (Binet *et al.*, 1991). Consequently, observed patterns and trends of rainfall and river discharge in the area are included in this paper. No consistent time series exist on currents. Key results of the analysis of time series of wind data are also presented, because of the known influence of wind on physical processes such as upwelling intensity, turbulence, and surface mixing in the upper layer of the ocean.

3. Available data: rainfall and river discharge, sea temperatures and wind

The pattern and trends of rainfall observed at some coastal Ivoirian (Tabou, Grand-Lahou and Abidjan) stations (Pezennec, 1994) and Ghanaian (Axim, Saltpond, Takoradi, Tema) stations (Mensah, 1991) are presented. The data are available as monthly means of rainfall. Monthly volume of the river discharge for the four major Ivoirian rivers recorded in the last four decades were used; similar data could not be obtained in Ghana (see Mahé, this vol.).

Several sea temperature data set are used in order to explore changes that may have occurred in the ecosystem. Beach sea surface temperatures have been recorded daily at twelve coastal stations in Côte-d'Ivoire and Ghana since the 1970s and 1960s respectively (Arfi *et al.*, 1991). Offshore sea surface temperature for the area were obtained from the Comprehensive Oceanic and Atmospheric Data Sets (COADS) database (Roy and Mendelssohn, this vol.). Monthly means for two by two degree squares (longitude and latitude) for the area between 4 - 6°N and 2 - 8°W (off Côte-d'Ivoire), and 2°W - 2°E (off Ghana) are used in the analysis. SST and the cooling events which affect these coastal waters were also followed using METEOSAT infrared satellite imagery received and processed at the 'Unité de Traitement des Images Satellitales' (UTIS; ISRA/ORSTOM) in Dakar, Senegal. Available data from vertical profiles of sea temperatures recorded off Abidjan (Côte-d'Ivoire) and Tema (Ghana) were also examined, as well as the depth of the 21°C isotherm, which corresponds to the depth of the top of the thermocline in the Gulf of Guinea (Merle, 1978).

Values of the two components (zonal and meridian) of the wind were obtained from the COADS database; the resultant intensity and direction of the wind were computed using these values.

All analyses start from 1966, the year from which reliable fisheries data in the two countries begin.

4. Observed general patterns

4.1. Rainfall and river discharge

The seasons observed in the Ivoirian and Ghanaian coastal area could be classified as follows:

i) main dry season (December -May);
ii) main raining season (May-July);
iii) a second dry season (July-September);
iv) a second raining season (September-November).

The rainfall patterns observed at the selected Ivoirian and Ghanaian stations are in agreement with this classification (Fig. 2). It rains less in coastal Ghana than in coastal Côte-d'Ivoire. The volume of river discharge recorded in the western part of Côte-d'Ivoire is much more important than in the central or eastern parts. A first, minor period of flood is observed in June, the major flood occurs from August to November.

4.2. Wind intensity and direction

The major winds in this area are southerly to south-westerly. This direction is the same in both countries from January to April but for the rest of the year the south-westerly direction is more pronounced in Ghana. During the period 1966-1990,

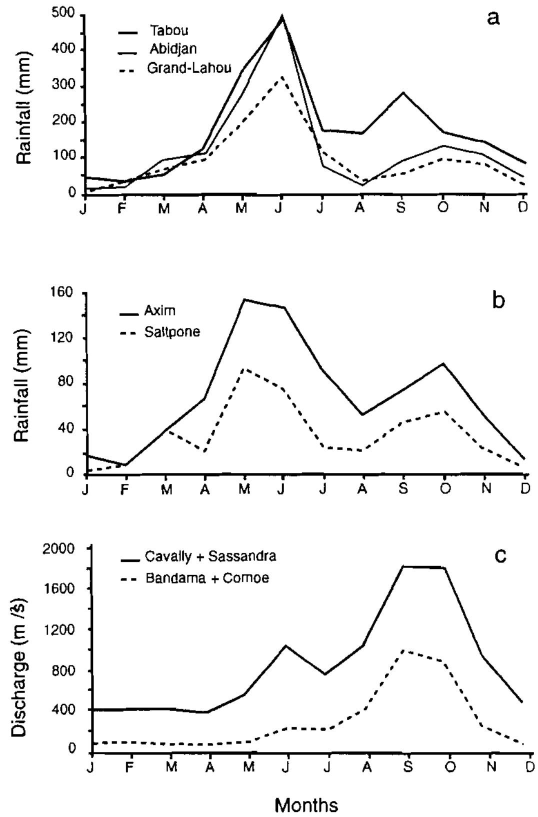

Fig. 2: Monthly means of rainfall in Côte-d'Ivoire (a), in Ghana (b) and river discharge in Côte-d'Ivoire (c).

the following were observed (Fig. 3):

- the meridian component of the wind increases between April and June, peaks in June-July and declines steadily untill January;
- the zonal component has two maxima, one in February-March and the other in August-October.

The resultant wind follows a pattern similar to that of the meridian component, with a maximum in June-July.

4.3. Intensity and extent of the two upwellings

Figure 4 shows fortnightly average temperatures recorded at coastal stations in Ghana and Côte-d'Ivoire in the period 1978-1991. The means for each station clearly show the two upwelling seasons occuring in this ecosystem. The minor upwelling season is observed between January and March, is more intense in Côte-d'Ivoire, especially in the western part, obviously than in Ghana (Fig. 5). The major upwelling is observed between July and September along the entire coastline. However, the configuration of the continental shelf in western Ghana favours a stronger development of this upwelling in that area. From the remote sensing pictures (Fig. 6), the surface isotherms recorded during the minor upwelling season are typical of an upwelling event which affects western Côte-d' Ivoire (East of Cape Palmas) and extends to the eastern part of Côte-d'Ivoire but which is not very visible off Ghana. During the major upwelling season, the upwelling is well

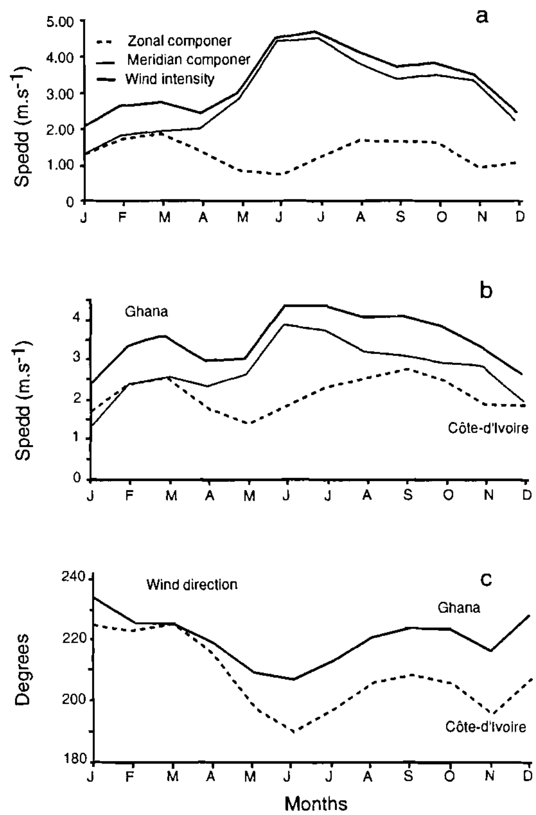

Fig. 3: Monthly means of the zonal and meridian components of the wind (a), of wind intensity (resultant) (b) and of wind direction (in degrees from the South-North direction) (c) along the Côte-d'Ivoire and Ghana coasts.

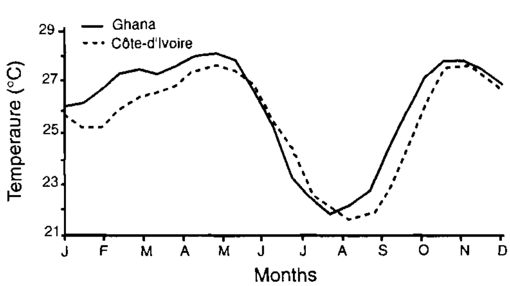

Fig. 4: Fortnightly means of the sea surface temperature from the coastal stations of the Côte-d'Ivoire and of Ghana (1978-1991 average).

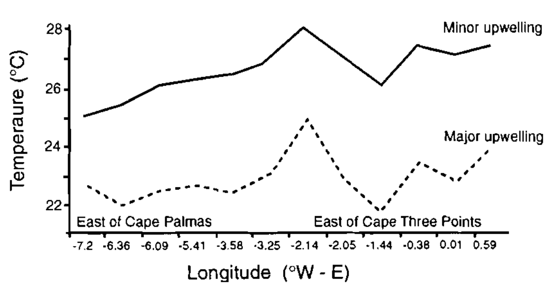

Fig. 5: Means of the sea surface temperature during the two upwelling seasons from western Côte-d'Ivoire to eastern Ghana. (1978-1991 average for each station).

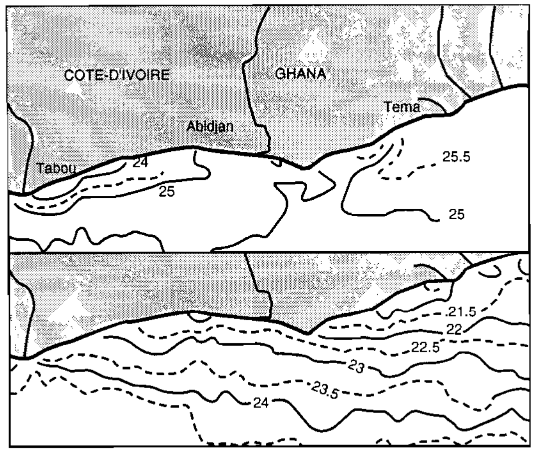

Fig. 6: Surface isotherms (in °C) in the Ivoirian and Ghanaian coastal regions (from Meteosat remote sensing picture, UTIS):
-upper panel, minor upwelling season (January 26-31, 1990);
-lower panel, major upwelling season (September 01-05, 1986). From Pezennec and Bard (1992).

developed over the Ghanaian continental shelf and extends to Côte-d'Ivoire. Even though the difference between the two upwelling seasons seems quite important, it has been observed that the minor upwelling off Côte-d'Ivoire may occasionally be as strong as the major upwelling. For example, the 1986, 1987 and 1990 minor upwelling seasons were very intense off Côte-d'Ivoire and as, indicated in Figure 7, the rise of the thermocline during these seasons was quite similar to the situation observed during the major upwelling season.

4.4. Trends in environmental time series

The mean annual rainfall recorded at stations in Côte-d'Ivoire and Ghana showed a significantly decreasing trend from 1968 to 1990 (Fig. 8). According to Lamb *et al.* (1986), this decrease of rainfall was a general observation in sub-saharan Africa during the 1970s and 1980s (see also Mahé, this vol.). A decrease of river discharge was also observed during the 1980's for tropical rivers in the Gulf of Guinea (Mahé, 1991). In Côte-d'Ivoire, a drastic decrease of river discharge was observed in the early 1970s (Fig. 8) but no trend was evident after the building of dams on the rivers Bandama (1972) and Sassandra (1978). The annual means of the two components of the wind show a significantly increasing trend from 1966 to 1990 in both countries (Fig. 9). For the minor upwelling season, there is no significant trend for both components in both countries (Pezennec, 1994). In the major upwelling season, the two components show different trends: the zonal component shows a significantly increasing trend in both countries, but no trend could be observed for the meridian component. This difference would imply that the direction of the wind becomes closer to that of the equator.

As depicted in Figure 9, the annual means of the wind speed (resultant) show a significantly increasing trend in both countries (1966-1990). A similar trend is observed during the major upwelling season in both countries but no trend could be observed for the minor upwelling season (Pezennec, 1994). Bakun (1990) reported increasing wind speed in other upwelling areas and attributed this trend to the greenhouse effect.

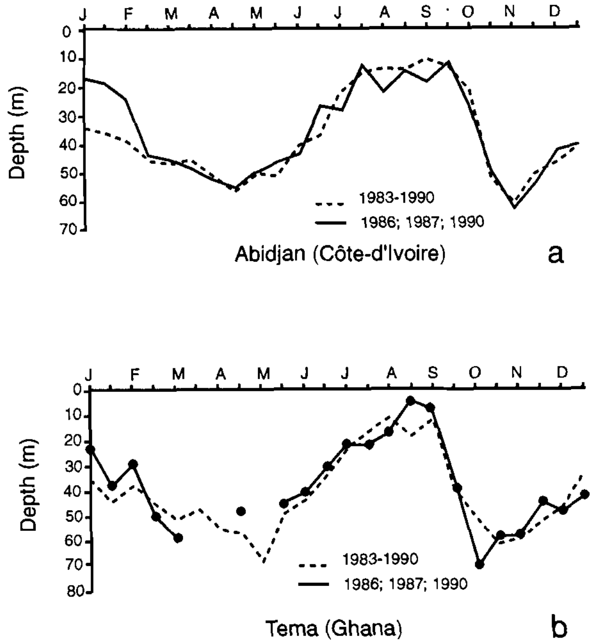

Fig. 7: Fortnightly depth of the 21°C isotherm off Abidjan (Côte-d'Ivoire) (a) and Tema (Ghana) (b).

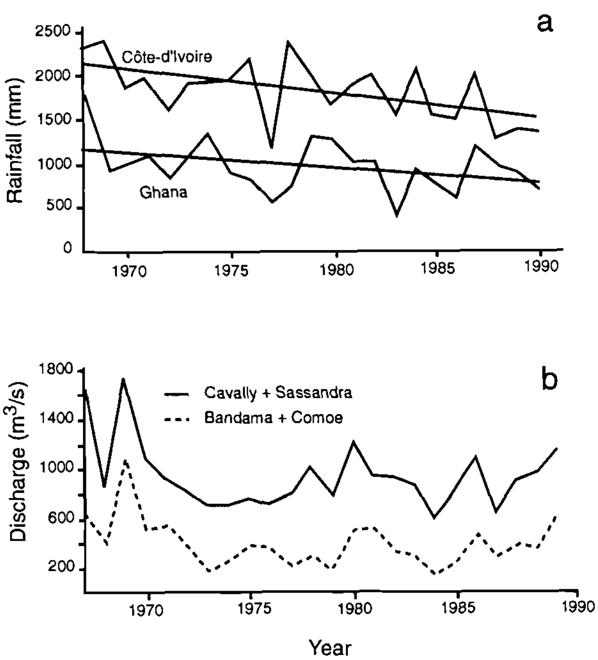

Fig. 8: a) Annual mean rainfall in the coastal areas of Côte-d'Ivoire (average for Tabou, Grand-Lahou and Abidjan) and Ghana (average for Takoradi and Tema); b) Annual means of river discharges in the Côte-d'Ivoire (sum of Bandama-Comoe and Cavally-Sassandra). The linear trends are least-squares estimates (Côte-d'Ivoire: $p=0.002$; Ghana: $p=0.03$)

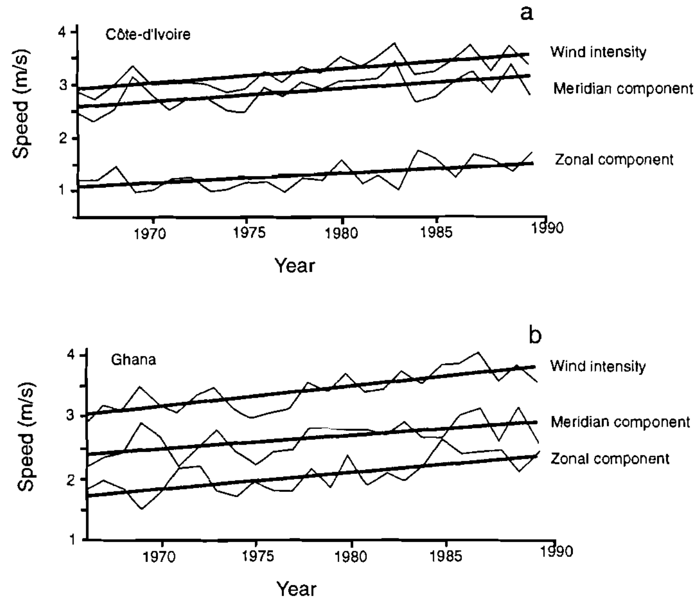

Fig. 9: Annual means of the wind components and wind intensity (resultant) off Côte-d'Ivoire and off Ghana and linear trends observed from 1966 to 1990 (Côte-d'Ivoire: Wind intensity $p=0.0004$; Meridian component $p=0.018$; Zonal component $p=0.02$. Ghana: Wind intensity $p=0.00006$; Meridian component $p=0.011$; Zonal component $p=0.001$).

4.5. Changes in relative upwellings intensities

The annual means of offshore sea surface temperatures sharply decreased between 1973 and 1976 in both countries, increased till the mid 1980s and decreased again, especially after 1987. The main point, however, is that the two upwelling seasons did not exhibit the same trends. Offshore temperatures recorded during the major upwelling season appear to have increased during the period under consideration, whereas those recorded during the minor upwelling season show an

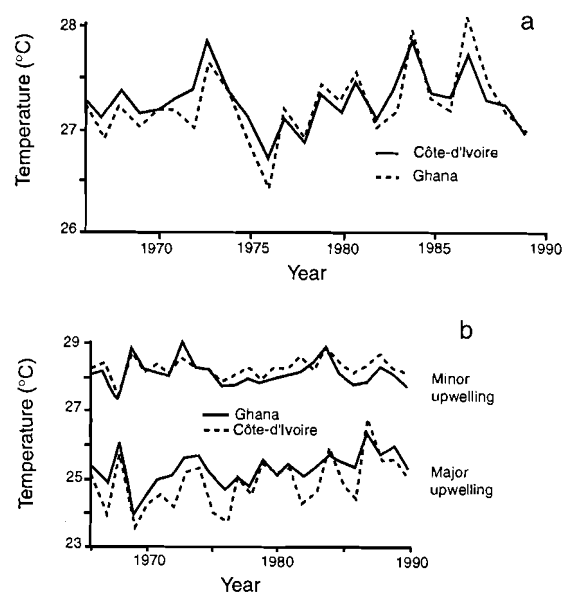

Fig. 10: a) Annual means of the offshore sea surface temperature off Côte-d'Ivoire and Ghana; b) annual means of the SST for the minor and major upwelling seasons (from COADS data).

opposite trend (Fig. 10). The result is that the difference between the intensity of the two upwelling seasons is decreasing with a significant trend since the early 1970s (Fig. 11). In both countries, the difference between the average temperature of the two upwelling seasons reduced on the average, by one degree between 1970 and 1990 (Pezennec and Bard, 1992).

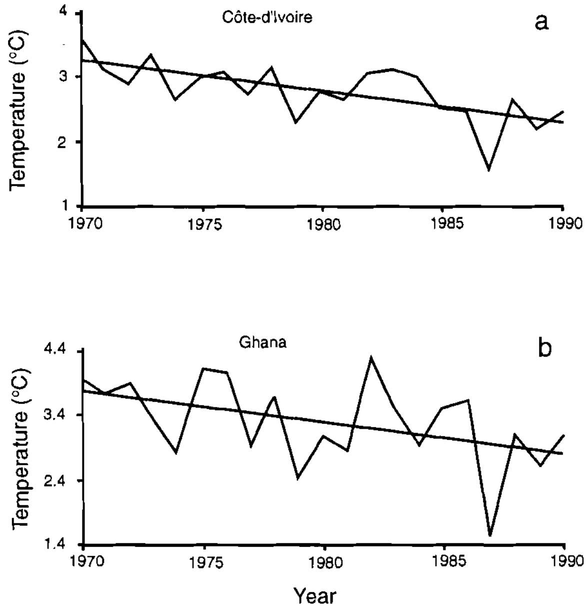

Fig. 11: Differences between the mean temperatures of the minor upwelling season (PSF) and the major upwelling season (GSF) from 1970 to 1990 (from COADS data), Côte-d'Ivoire (a), Ghana (b). The linear trends are least-squares method estimates (Côte-d'Ivoire p=0.0013; Ghana p=0.039).

Discussion

The coastal region off Côte-d'Ivoire and Ghana is unique in the Guinea Current large marine ecosystem. The intensity of some of the large upwelling areas of the world have increased; this change may be related to global climatic change. Although some global climatic changes, such as an increase of wind speed and a decrease of rainfall have also been noticed in this region, these have apparently not affected the intensity of the upwelling. Rather, the observed local change is that the relative intensity of the two upwellings (major vs minor) of this region has changed.

Acknowledgments

The DUSRU (Dynamics and Uses of Sardinella Resources from Upwelling off Ghana and Côte-d'Ivoire) program provided the means to have this work done. We thank the CEOS (Climate and Eastern Ocean Systems) project for sponsoring our participation in the Monterey meeting.

REFERENCES CITED

Arfi R., O. Pezennec, S. Cissoko and M. Mensah. 1991. Variations spatiale et temporelle de la résurgence ivoiro-ghanéenne. *In*: P. Cury and C. Roy (eds.). *Pêcheries ouest-africaines: variabilité, instabilité et changement*. ORSTOM, Paris: 162-172.

Bakun A. 1978. Guinea Current upwelling. *Nature*, 271:147-150.

Bakun A. 1990. Global climate change and intensification of coastal ocean upwelling. *Science*, 247: 198-201.

Bard F. X. and K. A. Koranteng (eds.). 1995. *Dynamics and Uses of Sardinella Resources from Upwelling off Ghana and Côte-d'Ivoire (DUSRU), Accra, 5-8 October, 1993*, ORSTOM, Paris 438p.

Binet D. 1982. Influence des variations climatiques sur la pêcherie des *S. aurita* ivoiro-ghanéennes: relation sécheresse-surpêche. *Oceanol. Acta*, 5: 443-452.

Binet D., E. Marchal and O. Pezennec. 1991. *Sardinella aurita* de Côte-d'Ivoire et du Ghana. Fluctuations halieutiques et changements climatiques. *In*: P. Cury and C. Roy (eds.). *Pêcheries ouest-africaines: variabilité, instabilité et changement*. ORSTOM, Paris, 320-342.

Colin C. 1988. Coastal upwelling events in front of the Ivory Coast during the FOCAL program. *Oceanol. Acta*, 11: 125-138.

Cury P. and C. Roy. 1987. Upwelling et pêche des espèces pélagiques côtières de Côte-d'Ivoire: une approche globale. *Oceanol. Acta*, 10: 347-357.

Houghton R.W. 1976. Circulation and hydrographic structure over the Ghana continental shelf during the 1974 upwelling. *J. Geophys. Res.*, 94 (4): 4816-4828.

Ingham M.C. 1970. Coastal upwelling in the northwestern Gulf of Guinea. *Bull. Mar. Sci.*, 20: 1-34.

Lamb P.J., R.A. Peppler, S. Hastenrath. 1986. *Nature*, 322: 238-240.

Le Loeuff P., E. Marchal and J.B. Amon Kothias. 1993. Environnement et ressources aquatiques de Côte-d'Ivoire. ORSTOM, Paris, T1: Le Milieu marin, 586p.

Mahé G. 1991. La variabilité des apports fluviaux au golfe de Guinée utilisée comme indice climatique. *In*: P. Cury and C. Roy (eds.) *Pêcheries ouest-africaines: variabilité, instabilité et changement*. ORSTOM, Paris: 147-161.

Marchal E. and J. Picaut. 1977. Répartition et abondance évaluées par échointégration des poissons du plateau continental ivoiro-ghanéen en relation avec les upwellings locaux. *J. Rech. Océanogr.*, 2: 39-57.

Mendelssohn R. and P. Cury. 1987. Fluctuations of a fortnightly abundance index of the Ivorian coastal pelagic species and associated environmental conditions. *Can. J. Fish. Aquat. Sci.*, 44: 408-428.

Mensah M.A. 1991. The influence of climatic changes on the coastal oceanography of Ghana. *In*: P. Cury and C. Roy (eds.) *Pêcheries ouest-africaines: variabilité, instabilité et changement*. ORSTOM, Paris: 67-79.

Merle J. 1978. *Atlas hydrologique saisonnier de l'océan Atlantique intertropical*. Travaux et Documents, ORSTOM, 82, 184 p.

Morlière A. 1970. Les saisons marines devant Abidjan. *Doc. Scient. Cent. Rech. Océanogr. Abidjan*, 2: 1-15.

ORSTOM/FRU. 1976. *Rapport du groupe de travail sur la sardinelle (S. aurita) des côtes ivoiro-ghanéennes, Abidjan, 28 juin-3 juillet 1976*, ORSTOM, 62 p.

Pezennec O. 1994. *Instabilité et changements de l'écosystème pélagique côtier ivoiro-ghanéen. Variabilité de la ressource en sardinelles : faits, hypothèses et théories*. Thèse de Doctorat. Océanologie biologique. Université de Bretagne Occidentale, Brest.

Pezennec O. and F.X. Bard. 1992. Importance écologique de la petite saison d'upwelling ivoiro-ghanéenne et changements dans la pêcherie de *Sardinella aurita*. *Aquat. Living Resour.*, 5: 249-259.

Picaut J. 1983. Propagation of the seasonal upwelling in the eastern equatorial Atlantic. *J. Phys. Oceanogr.*, 13: 18-37.

Sherman K., L. M. Alexander and B. D. Gold (eds.). 1991. *Food chains, yields, models, and management of large marine ecosystems*. Westview Press, 310 p.