Climate variations study in Atlantic Intertropical Area

Jarrige F., Citeau J.,
Rual P., Verstraete J.M.

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R. Fantechi, A. Ghazi

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CLIMATE VARIATIONS STUDY IN ATLANTIC INTERTROPICAL AREA.

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1. Objectives

The objectives of this program are to test the feasability and interest of a long term monitoring of the tropical Atlantic.

Ocean and atmosphere are coupled in a thermal engine, the energy source being in the tropics. Climate variations are directly affected by fluctuation in air/sea heat transfers and by the response of the ocean to atmospheric solicitations. Previous studies and on-going FOCAL/SEQUAL (French/US) programs have identified several major features, in the tropical Atlantic, that may be of importance to global climatic variations.

Ship of opportunity, satellites, and tide gage network are inexpensive means used to monitor meteorological conditions, heat content and mean sea level of the ocean. Their relation with these major features and the climate fluctuations are being tested during these three years of simultaneous programs. Then the long term monitoring alone may be able to follow the time variability of theses features and perhaps one day, could predict the climate fluctuations!

2. Materials and Methods

Three field operations are on-going to collect data necessary to a continuous survey of heat content, waters motions and exchange between air and sea (fig. 1). This survey will last three years from 1982 in order to describe seasonnal signals with sufficient statistical stability

a) The sea surface temperature field is observed by remote sensing : mainly METEOSAT data to which atmospheric correction will be added either with TOVS (NOAA) data, or following MIEC (ESOC) procedures. Since JUNE 1982, on weekly basis, composite pictures have been made and ground thruth from merchant ships are used for calibrations and gap filling.

b) XBTs dropped by ships of opportunity along tracks from Le Havre to South America provide 30 transequatorial temperature sections every year. This will be used to estimate heat content, thermocline depth, dynamic heights and fluxes : the slope of the thermocline in a meridional plane is associated with the intensity of the current across it. Meteorological data such as wind, moisture, air temperature, atmospheric pressure and water sample for salinity measurements are also collected in the same way.

c) Ten new instruments extend the existing tide gage network to the whole Tropical Atlantic . Mean sea level fluctuations highly correlate with variations of the heat content of the superficial layers in tropical zones (20° N - 20° S). Observed deviations from the long term averaged sea levels can then be used to monitor in turn variations of oceanic circulation. In the future, sea levels measured at islands and coastal stations will also be of great value for the calibration of satellite altimeters mapping the ocean surface.

By combining the sea level observations and XBT data, the variations of the main oceanic flows will be followed on a monthly basis. From these, momentum exchanges will be obtained within the superficial layer of the ocean. Advection of heat in the surface layer will be evaluated through variations of the spatial distribution of the sea surface temperature from satellite data and of the heat content. The air sea exchange of heat fluxes can be deduced from the variations of the distribution of sea surface temperature and air temperature. Meteorological data and sea surface temperature distribution will also be used to indicate zones where strong evaporation occasionnally occur and in some case to evaluate the evaporation rate.

3. Results

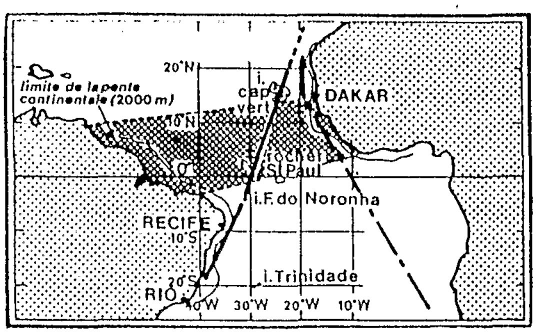

Figure 1 : Tropical Atlantic Ocean
Europe-South America ship of opportunity line
Europe-Cap Town " " "
ITCZ seasonal variation zone

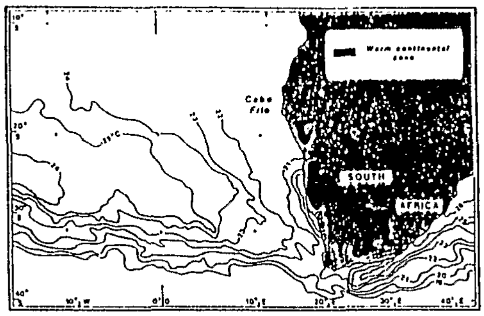

Figure 2 : Thermal mapping in the South Atlantic ocean from 13 to 19 January 1983 (Meteosat data)

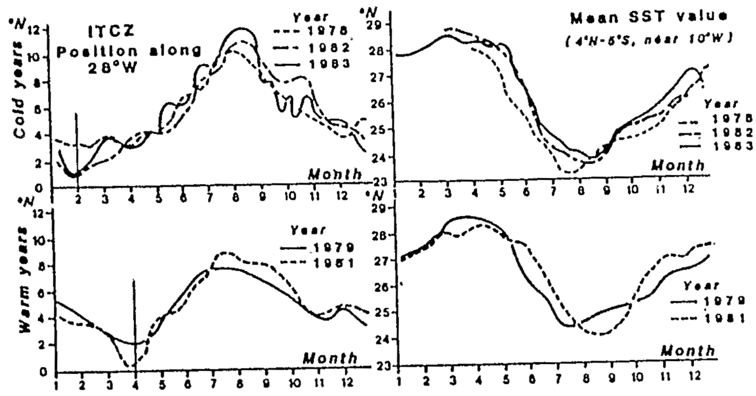

Figure 3 : Intertropical convergence zone (maximum convective cloudiness by METEOSAT/GOES-E data) and Mean Sea Surface Temperature between 4° N - 5° S around 10° W, for two years with a weak equatorial upwelling (1979-81) and three years of strong equatorial upwelling (1978-82-83).

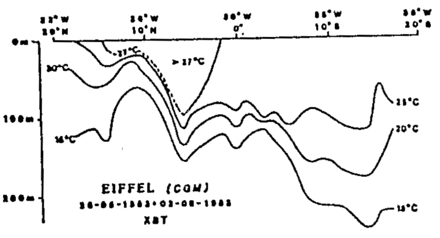

Figure 4 : Transequatorial section of temperature, along the "LE HAVRE-RIO" navigation line, from expandable Bathythermographes (XBT) launched by the S.S. EIFFEL (compagnie Générale Maritime), 26-8-83/2.9.83.

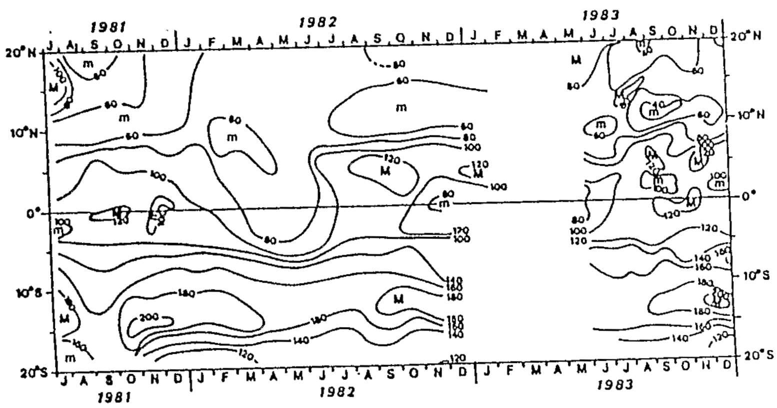

Figure 5 : Time-Space diagram of the depth(metres)of the 20° C isotherm on the navigation line, Europe-South America. XBTs launched from CGM ships of opportunity.

As a matter of fact , the beginning of our global watch of the tropical Atlantic, has been also the beginning of a serie of anomalous warm and cold events, summarized as follows :

In terms of equatorial cooling, 1981 recalls a classical year, in contrast with 1982 and 1983 which have been "cold years". Furthermore, weekly composite infrared satellite images have also revealed :

a) the weakness or the delay of the senegalese upwelling (winter 81/82 and 82/83).

b) the earliness of the gabonese upwelling and the strengthof the equatorial cooling in summers 82 and 83

c)the anomalous extent of warm central Atlantic waters towards South African coast in January 83 (fig. 2) and January 84, suggesting a "South Atlantic El Nino".

In order to relate some of these events to wind field or at least to wind limits, one of these, the Intertropical Convergence Zone has been followed along 28° W for five years and compared to the mean value of the sea surface temperature (4°N - 5°S near 10° W) - this area well described by vessel line gives also a good indication for equatorial cooling. As displayed on figure 3, the northernmost position of ITCZ (10°N - 12°N) is reached in "cold years" with mean SST near 23° C, in contrast with "warm years" where the northernmost ITCZ position lies between 7° and 9° N and lowest mean SST near 24° C. Furthermore it is suggested that at the beginning of each cold year, the ITCZ is yet to its southernmost position and moves northwards as soon as end of January or mid February. On the other hand, the first months of "warms years" display southwards movement till end of March where moving direction change (close to the typical movement that can be extracted from HASTENRATH & LAMB Atlas not described here).

This time delay, about two months, need of course to be confirmed (on-going work) in order to suggest an attractive prediction scheme, and improve the connection between equatorial cooling and the Ste Helene Anticyclone activity.

In subsurface, some of the anomalies and cold/warm year contrasts described above, have been evidenced by XBT data.

Along the Europa-South America sea route, three thermal zones can be defined, the Guinea dome, off the African coast (10° N), the equatorial area, the Brasil deep warm layer (10° S - 15° S) (fig. 4). The heat content of these three areas is very different mainly due to the different thickness of the warm upper mixed layer and thermocline. Their time variations are also very different (fig. 5). The Guinea dome and the Brasilian warm waters seem to have an annual cycle, when the first rises the other deepens, while the equatorial area has a much more chaotic behaviour. Until mid-82 it seems to behave as previously thought : an annual cycle with a rise when the wind is weak and the ITCZ at the equator, and a deepenning when the SE Trades are strong and the Gulf of Guinea upwellings are active. But from mid-82 until now there seems to be a more complex structure with a maximum around 5° N several minima at the equator and often a second maximum south of the equator, altogether with abrupt changes from one section to the other as if wave fronts were propagating.

Horizontal temperature gradients are the major component of dynamic height gradients and the isotherms slopes around 7° N and 7° S are an indication of the North Equatorial Counter Current (NECC) and of the South Equatorial Current (SEC). The first one is stronger in 82-83 than in 81. It must be very weak, if present, in the first half of 82. For the first five months of 83 a bad XBT batch produced a gap in the data which is specialy unfortunate as 82/83 is a very abnormal climatic period in many senses. The Equatorial Current (ES) and the Equatorial Undercurrent (EUC) do not show up very well on thermal sections. The spreading of the isotherms in the thermocline at the equator is an indication of the EUC but not of its strength.

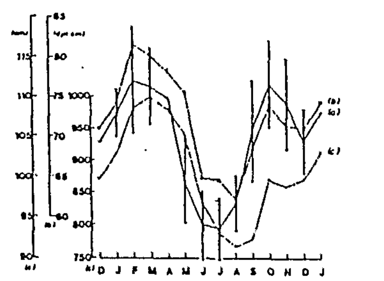

Figure 6 : Mean Sea Level (MSL), Dynamic Height (DH), Heat Content (HC) at Pointe Noire (Congo) from historical data.

(a) MSL (cm) with 95 % confidence interval

(b) D.H. (dyn.cm) 0/500 db

(c) Thermal contents $\int_0^{100} T dz$ (a.u.)

Using historical data, we have shown that the annual cycles of Mean Sea Level (MSL), Dynamic Height (DH) and Heat Content (HC) are significantly correlated in the tropical eastern Atlantic. The main upwelling events in the Dakar, Abidjan and Pointe Noire coastal areas are detected by a drop of MSL simultaneous with a decrease of DH and HC. Annual variations of MSL, DH and HC are presented for Pointe Noire in Fig. 6. It should be noticed that MSL decrease in april leads HC decrease by about one month. These results clearly show that Sea Surface Temperature (SST) is not a good indicator of the vertical thermal structure whereas MSL is sensitive to subsurface thermal structure changes.

Records from five stations have been already retrieved. The results obtained at the Dakar station are presented here (Fig.7). The tide gauge was deployed on december 23th 1982, in about 8 meters of water. During the first month, "in situ" temperature increases from 18.5°C to 19.5°C, during the same period MSL increases from 8.35m. to 8.45m., then occurs an upwelling event : from february 3rd to 17th, the temperature decreases from nearly 21°C to 15°C, and MSL from 8.50m. to nearly 8.30m.. In 1983, the upwelling onset in Dakar area was late by about one month (no upwelling in january1983). From february 17th to may 17th, the upwelling is active with temperature less than 19°C and MSL less than 8.40m.. After may 17th temperature increases regularly to reach 28°C whereas MSL slowly oscillates between 8.40m. and 8.50m.. This divergence between the two parameters may be an indication that, while the surface layer is warmed up by the sun, the thermocline stays very close to the surface and the DH or MSL are those of a dome. A closer look at Fig.7 shows that in february, MSL drops before the sea surface temperature indicating a subsurface forcing of the upwelling whereas, in march-april, the rise in sea surface temperature occurs before the rise of MSL, indicating an event originated from the surface (warming by the sun).

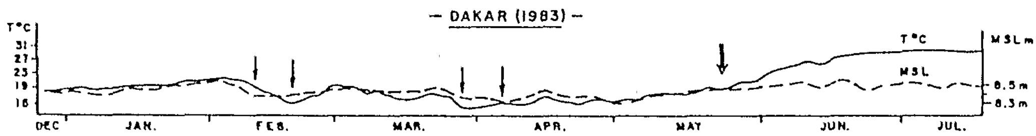

Figure 7 : Mean Sea Level and sea temperature at 8 m. at Dakar (Senegal) from december 1982 to july 1983. Both parameters are filtered for the tide up to the 3 days periods (DEMERLIAC filter).

4. Conclusions

The program is in its second year only and most of the data acquisition is going smoothly. Its processing and interpretation is only at a preliminary stage. Data from the FOCAL/SEQUAL simultaneous programs have not yet been compared to our results. But the first results are encouraging. Satellite thermography and cloud interpretation compare very well with surface and XBT data, scaling the horizontal validity of theses punctual measurements. Mean sea level and dynamic height fluctuations compare also very well and oceanic circulation changes can be monitored. The highly abnormal ocean-atmosphere conditions in 1982/83 can be traced throught with - the monitored parameters.Historical data analysis is helpful in determining the mean situation or the different situation types: for instance, the strong equatorial upwelling years and the weak ones, and their relation with the ITCZ position, the nebulosity maximum or the confluence of the trade-winds.

5. Additionnal comments and suggestions for further research

By the end of 1984, end of this contract, the field studies of the FOCAL/SEQUAL programs will be also terminated. No more intensive fields programs will be sponsored at least for several years. If it is desirable to continue to follow the interannual variation of the. decisive climate parameters, the only mean will be to continue and expend monitoring programs as this one, which is relatively inexpensive in comparison with traditional oceanic data acquisition programs. This is already done for the Pacific ocean on an international basis. In fact interannual climatic anomalies have very often a worldwide influence so the monitoring of the world ocean is the final goal in order to understand and, may be predict, the dramatic climate anomamies as the 1982/83 climate distorsion !

6. Publications and Oral Communications :

CITEAU J., GUILLOT B., LAE R., THEPENIER R.M. 1984 .- Warm and cold oceanic events in the tropical Atlantic and their relationship with the Intertropical Convergence Zone. Tropical Ocean Atmosphere Newsletter n° 23 January 1984, p 19-20.

CITEAU J., GUILLOT B., LAE R., THEPENIER R.M. 1984 .- Warm and cold oceanic events in the tropical Atlantic and their relationship with the Intertropical Convergence Zone. 4ième Congrès des Utilisateurs METEOSAT. Clermont-Ferrand (France) 30 Nov. - 2 Dec. 1983.

CITEAU J., GUILLOT B., LAE R., SLEPOUKA M., STRETTA J.M. 1984 .- Opération LISTAO et Télédétection. Bilan d'une opération (Submitted to ICCAT for publication).

LE GALL J.Y., CHAMPAGNE M., CITEAU J., GUILLOT B. 1983 .- Comparaison des données satellitaires, METEOSAT 2 et NOAA 7, utilisées pour la prévision des zones de pêche du thon blanc dans l'Atlantique Nord-Est. 8ieme Symposium Canadien de Télédétection. Montreal, 3-6 May 1983.

JARRIGE F. 1982 .- "LE HAVRE-RIO" XBT sections.Preliminary results. 2nd FOCAL-SEQUAL meeting. New-York July 1982.

RUAL P., JARRIGE F., 1984 .- Thermal structure (20° N - 20° S) along the "Europe-South America" sea route.Submitted to publication in Geophysical Research Letter, special issue "First FOCAL-SEQUAL results".

RUAL P., JARRIGE F., 1984 .- "LE HAVRE-RIO" transequatorial sections. Wind and sea temperatures. 3rd FOCAL-SEQUAL meeting. Paris, Feb. 1984.

CITEAU J., JARRIGE F., VERSTRAETE J.M., 1981.- Climate Variations Study in Atlantic Intertropical Area. 1ère Réunion du Groupe de Travail "Modélisation du Climat" de la Direction de la Recherche de la Commission des Communautés Européennes. Bruxelles, Mai 1981.