Adv. Space Res. Vol. 9, No. 7, pp. (7)383–(7)386, 1989
Printed in Great Britain. All rights reserved.

0273–1177/89 $0.00 +.50

VARIABILITY OF THE TROPICAL ATLANTIC IN 1986–1987 AS OBSERVED BY GEOSAT AND *IN SITU* DATA

S. Arnault,* Y. Ménard** and M. S. Rouquet**

**Laboratoire d'Océanographie Dynamique et de Climatologie, Université Pierre et Marie Curie, 4 place Jussieu, Tour 14 2ème, 75252 Paris Cedex 05, France*

***Groupe de Recherche en Géodésie Spatiale, Centre National d'Etudes Spatiales, 18 ave Edouard Belin, 31055 Toulouse Cedex, France*

ABSTRACT

Launched in March 1985, the US Navy altimetric satellite GEOSAT gives the opportunity to the oceanographers to study the sea level variations with a high spatial and temporal resolution. We used 18 cycles of GEOSAT data from November 1986 until August 1987 to obtain the sea level variability in the tropical Atlantic. These first results are in good agreement with those obtained through historical hydrographic data and evidence an interannual event concerning the equatorial upwelling which seems to be also present in simultaneous in situ data.

INTRODUCTION

The Tropical Atlantic Ocean has a large spectrum of climate variability which covers timescales from weeks to decades. This variability has been analysed in the past through historical data /2,11,16/ and through specific experiments such as the Garp Atlantic Tropical Experiment (GATE, 1974), the First Garp Global Experiment (FGGE, 1979), and more recently the FOCAL (programme Français Océan Climat en Atlantique Equatorial, 1982-1984) and SEQUAL (Seasonal Equatorial Atlantic, 1982-1984) programs. These new data set evidenced phenomena such as the possible occurence of an "El Nino" phenomena in the Atlantic /7/.

During the last decade, models have been developed which describe fairly well the tropical circulation. Tropical oceans are characterized by a well marked thermocline which separates warm upper waters from deeper and colder layers. Two kinds of models are generally used: simple models such as shallow water models which isolate one dynamical process /1,6/, or three dimensional models which give a more realistic but complex view of the oceans /13,14/.

Next years will be marked by new satellite data arrival. For the first time, oceanographic satellites will provide a high spatial and temporal resolution view of oceans.

For future experiments it is important to know how to mix these three ways of studying the dynamics of the ocean (conventional in situ data, satellite data and models simulations) in order to produce the most complete information. Altimeter satellites present special interest for oceanographers because they accurately measure sea level variations and give access to geostrophic circulation. Successful attempts using altimetric data have been made in the tropical regions: Malardé et al /8/ used the three months of SEASAT data to study equatorial waves in the Pacific Ocean. More recently, Ménard /10/ combined both GEOS3 and SEASAT data to obtain the seasonal variability of the tropical Atlantic. He presented sea level anomalies maps in rather good agreement with historical data. The Exact Repeat Mission in 1986 of the US Navy altimetric satellite GEOSAT gives the opportunity to go further than this study using a continual quasi annual coverage of repetitive tracks.

Data are presented in section 2. Section 3 gives the description of the results and section 4 the analysis and conclusions.

DATA PROCESSING

The historical data set has been described in Merle and Arnault /11/. It consists of approximately 140,000 temperature and salinity profiles from 1900 until 1978, between 30N-16S 80W-20E. We derived the surface dynamic heights relative to 500 dbar using a mean T-S relationship which provides an interpolated salinity for each temperature value.

Launched in March 1985, GEOSAT performed a geodetic mission during its first 18 months of operation using a non repeat orbit. In November 1986, it was shifted onto a 17,05 day exact repeat orbit. The orbit tracks are separated by about 150 km at the Equator. Along one track, the distance between two measurements is 7 km. The tropical Atlantic 70W-14E 20N-20S is covered by about 100 tracks (Fig.1).

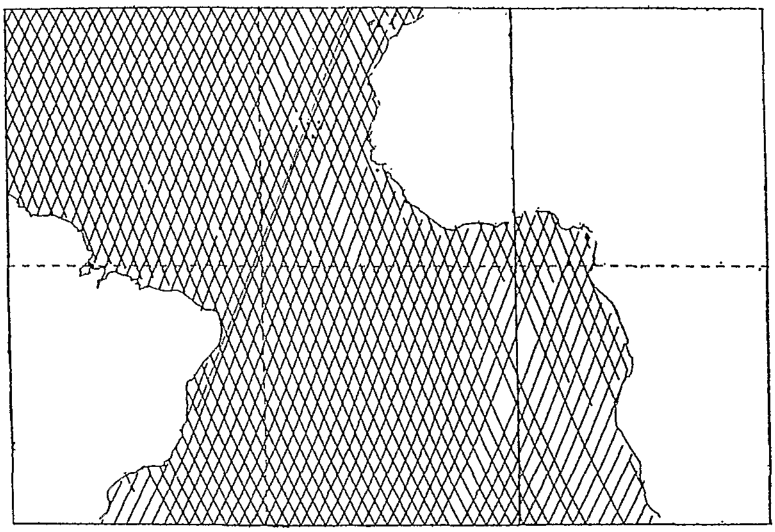

Fig. 1: GEOSAT tracks over the Tropical Atlantic Ocean between 27 April 1987 and 15 May 1987.

We used 18 repeat cycles from November 1986 to September 1987. Several corrections are applied to derive sea level heights from the raw measurements /3/. Essential corrections concern ocean tides, tropospheric and ionospheric delay. A serious problem in the tropical regions is caused by the large water vapor content which implies a tropospheric correction as large as 30 cm in regions like the InterTropical Convergence Zone (ITCZ). However, a year to year variation of the monthly average signal reveals a large scale of 1-2 cm tropospheric delay variability /12/. The FNOC model tropospheric correction, available with the GEOSAT data, was presently used. Along each track, data are subsampled at 60 km, adjusted with a second degree polynom to eliminate large scale orbit errors. The geoid influence was substracted using the collinear technique described in Ménard /9/. Then, these sea level anomalies were filtered with a median filter over 180 km. Maps of sea level anomalies were produced using an objective analysis /5/ onto a one degree latitude by two degrees longitude grid. Decorrelation scales for this analysis were 500 km and 140 days.

RESULTS

Dynamic heights anomalies obtained with historical data (Fig.2) show large zonal bands of alternatively positive and negative values. During the boreal winter-spring season, when the equatorial upwelling disappears, the equatorial zone is affected by positive values reaching 6 cm along the African coast in March. In May, the upwelling begins, starting from the coast and giving a negative anomaly maximal in July with 8 cm. In September, the northern ridge extends from 1-2N in the West to 8N in the East and borders South upon the North Equatorial CounterCurrent. This ridge is strongly developped in summer-fall season (6 cm in November) and disappears during the spring.

Sea level anomalies maps given by GEOSAT data show the Northern ridge vanishing in late December 1986. Positive values along the Equator appear only by the end of January 1987. In late February 1987 (Fig.3a), positive anomalies occur along the Equator (4 cm) and negative values (reaching 8 cm) extend around 5N from the American to the African coasts. In late April 1987, the equatorial upwelling starts near the African coast earlier than in the climatology and is the most intense by the 15 of May 1987 (Fig.3b) when the northern ridge also begins to develop. An unusual characteristic regarding the climatology, is that the upwelling seems to weaken from June to August and even more to disappear in August except for the coastal upwelling South of Abidjan (Fig.3c). The same month, the northern ridge is well developped with about 8 cm amplitude south of a strong (10 cm) negative zonal band.

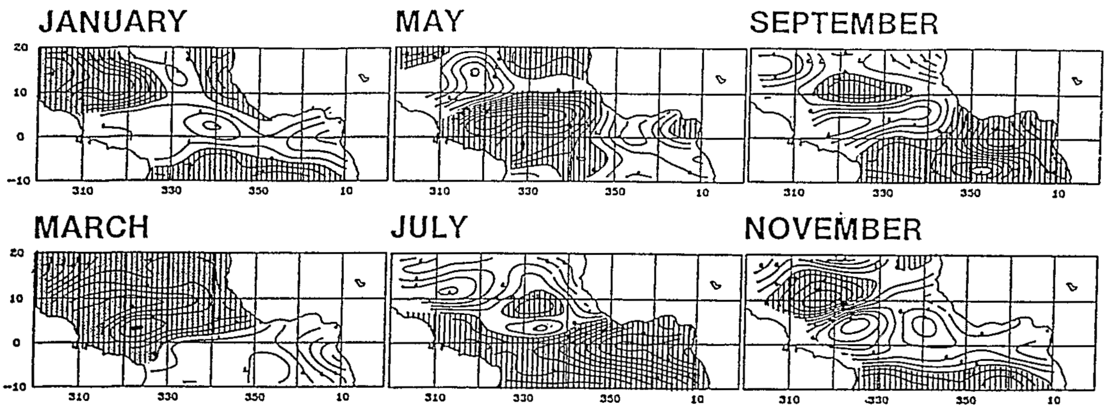

Fig. 2: Hydrographic maps of surface dynamic topography anomaly based on an historical data set. The contour interval is 1 dyn cm. The shaded area are for the negative values.

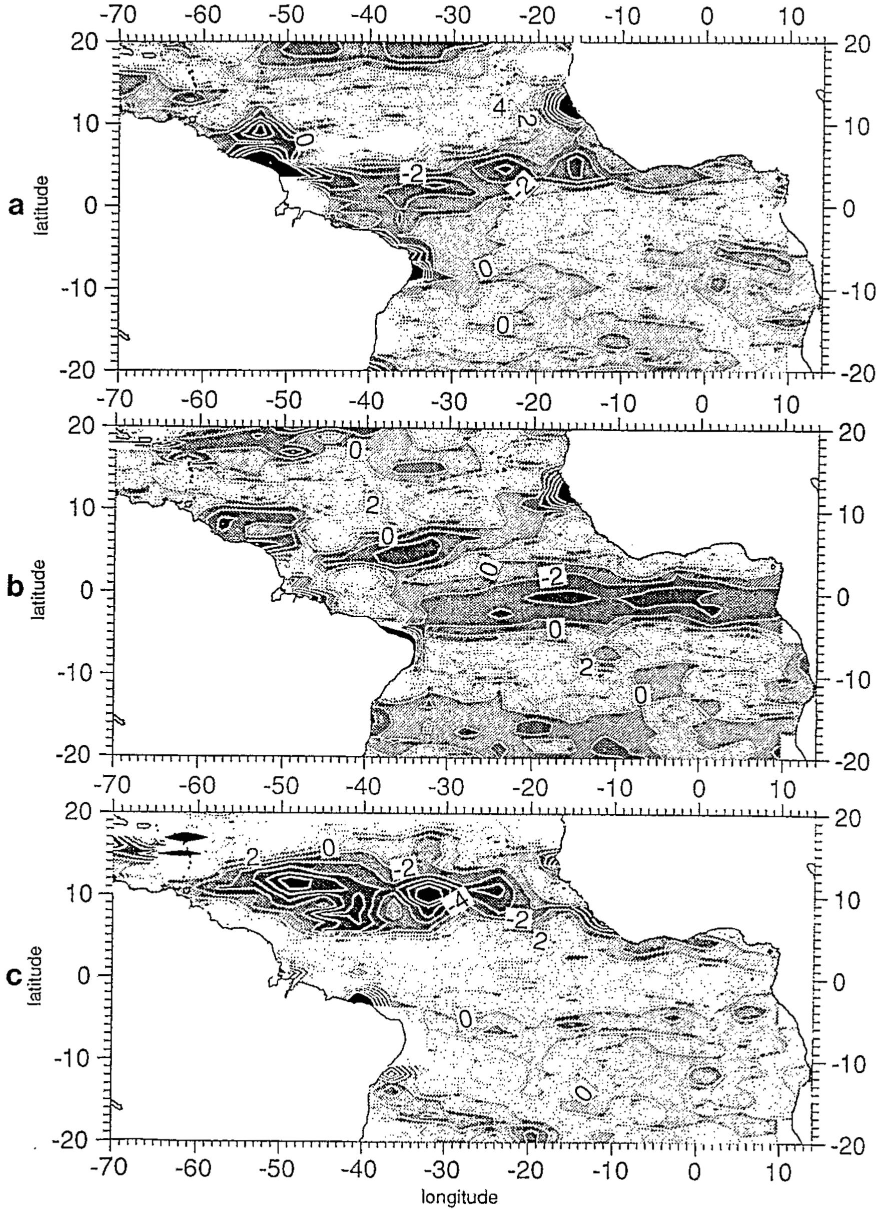

Fig. 3: Altimetric monthly objective analysis maps of the sea level anomaly for February 1987 (a), May 1987 (b) and August 1987 (c). The contour interval is 2 cm.

CONCLUSIONS

GEOSAT and hydrographic data present a rather good agreement except that the equatorial upwelling occurs one month earlier in 1987, is weaker (4-6 cm instead of 8) and disappears in August. Such differences are not easy to interpret because of the lack of simultaneous in-situ data in the tropical Atlantic. Time series of Sea Surface Temperature South of Abidjan reveal that the coastal upwelling began in May 1987 and was less stronger than those of the five years before (C.Roy, personal communication). Another way to procure the confirmation of this event in 1987 is to look at the wind. Philander /15/ has discussed the relationship which exists between the oceanic conditions and the migration of the ITCZ. In 1987, the ITCZ rapidly moved northward as earlier as mid March to reach 9N at 28W in mid June, and then, stayed at this latitude instead of gradually progressing to the North from April up to July-August /4/. So it is reasonable to think that the unusual details concerning the equatorial upwelling in 1987 evidenced by GEOSAT data really reflect an interannual anomaly rather than altimetric data artefact.

These preliminary results in the tropical Atlantic Ocean show that even if the seasonal variability is relatively weak, it can be described in details through altimetric data. As an example, an abnormal event seems present in 1987 GEOSAT data. The analysis of a complete year of altimetric data, presently in progress, will be useful to confirm these first indications. Also a comparison with simultaneous XBT's data available along a GEOSAT satellite track (20N-22W, 20S-37W) should help the interpretation of altimetric results.

REFERENCES

1. S. Arnault, Variation saisonnière de la topographie dynamique et de la circulation superficielle de l'océan Atlantique tropical, Thèse d'université Pierre et Marie Curie, Paris VI (1984)

2. S. Arnault, Tropical Atlantic Geostrophic Currents and Ship Drifts, J. Geophys. Res. 92, # C6, 5076-5088 (1987)

3. R.E. Cheney, B.C. Douglas, R.W. Agreen, L. Miller, D.L. Porter and N.S. Doyle, GEOSAT altimeter geophysical data record user hand book, NOAA technical memorandum NOS NGS 46, 29pp (1987)

4. J. Citeau, J.C. Berges and H. Demarcq, Position de la zone intertropicale de convergence le long de 28W et température de surface, Veille Climatique Satellitaire 18, 3-5 (1987)

5. P. De Mey and A.R. Robinson, Assimilation of Altimeter Eddy Fields in a Limited Area Quasi Geostrophic Model, J. Phys. Oceanogr. 17, #12, 2280-2293 (1987).

6. Y. Du Penhoat and A.M. Treguier, The seasonal linear response of the tropical Atlantic Ocean, J. Phys. Oceanogr. 15, 316-329 (1985)

7. P. Hisard and C. Hénin, Response of the Equatorial Atlantic Ocean to the 1983-1984 Wind From the Programme Français Océan et Climat Dans l'Atlantique Equatorial, J. Geophys. Res. 92, # C4, 3759-3768 (1987)

8. J.P. Malardé, P. De Mey, C. Périgaud and J.F. Minster, Observation of Long Equatorial Waves in the Pacific Ocean by SEASAT Altimetry, J. Phys. Oceanogr. 17, # 12, 2273-2279 (1987)

9. Y. Ménard, Observation of eddy fields in the Northwest Atlantic and Northwest Pacific by Seasat altimeter data, J. Geophys. Res. 88, 1853-1866 (1983)

10. Y. Ménard, Observing the Seasonal Variability in the Tropical Atlantic from Altimetry, J. Geophys. Res., in press.

11. J. Merle and S. Arnault, Seasonal variability of the surface dynamic topography in the tropical Atlantic Ocean, J. Mar. Res. 43, 267-288 (1985)

12. I. Prabhakara, I. Wuang, A.T.C. Chang and P. Gloerson, A statistical examination of Nimbus 7 SMMR data and remote sensing of sea surface temperature, liquid water content in the atmosphere and surface wind speed, J. Climate and Applied Meteo. 22, 2023-2037 (1983)

13. S.G.H. Philander and R.C. Pacanowski, A Model of the Seasonal Cycle in the Tropical Atlantic Ocean, J. Geophys. Res. 91, # C12, 192-206 (1986)

14. S.G.H. Philander, W.J. Hurlin and R.C. Pacanowski, Properties of Long Equatorial Waves in Models of the Seasonal Cycle in the Tropical Atlantic and Pacific Oceans, J. Geophys. Res. 91, # C12, 207-211 (1986)

15. S.G.H. Philander, Unusual Conditions in the Tropical Atlantic Ocean in 1984, Nature 322, 236-238 (1986).

16. P.R. Richardson and T. Mc Kee, Average seasonal variation of the Atlantic equatorial currents from historical shipdrifts, J. Phys. Oceanogr. 14, 1226-1238 (1984)