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SYMPOSIUM ON VERTICAL MOTION IN THE EQUATORIAL UPPER OCEAN AND ITS EFFECTS UPON LIVING RESOURCES AND THE ATMOSPHERE

(SCOR WG 56 symposium, PARIS, 6-10 May, 1984, UNESCO)

ZONAL PRESSURE GRADIENT VARIABILITY ALONG THE EQUATORIAL ATLANTIC FROM OCTOBER 1982 TO AUGUST 1984

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Introduction.

In response to the mean westward wind stress, the thermocline along the equator slopes downward from east to west, leading to a negative zonal pressure gradient (ZPG) at the surface relative to a deep reference level. This results in much greater heat storage in the mixed layer in the western side of the ocean basin when compared with the eastern side. The relaxation of the zonal wind stress which also relaxes the ZPG plays consequently an important role in the redistribution of the zonal heat storage. This relaxation can occur on a seasonal or interannual time scale. In the Pacific Ocean, the interannual relaxation is well documented due to the dramatic contrast along the Ecuador and Peru coasts when the so-called "El Nino" phenomenon occurs. In the Atlantic Ocean, the relaxation of the wind stress is a seasonal phenomenon around March-April at the equator, which however can be intensified on an interannual basis as it was observed during the 1963 EQUALANT Experiment. When such a dramatic change develops, equatorial warm waters invasion is observed along the coasts of Angola, Namibia and this inhibits the development of the Benguela coastal upwelling (Stander and de Decker, 1969) in an Atlantic counterpart of the Pacific El Nino phenomenon.

The ZPG is thought to be important in the dynamics of the Equatorial Undercurrent (EUC). Philander (1973) has given a comprehensive summary of theories and observations describing the stationary behavior of the EUC as a response of the equatorial ocean to a constant ZPG. More recently models of an equatorial ocean initially at rest and zonally bounded have shown that a ZPG establishes sometimes after a sudden onset of the wind. The ZPG forms in the wake of zonally propagating equatorially trapped waves A substantial gradient is established within a month and an equilibrium state approximately 150 days after the onset of the wind (Cane, 1979; Philander and Pacanowsky, 1980). In the case of abrupt relaxation of a zonally uniform westward directed windstress, the ZPG is eliminated in the wake of a Kelvin and Rossby waves within the same time scales as in the case of the onset of the equatorial wind field (Philander, 1981).

The EQUALANT data set from the 1963 year was complemented during the 1974 summer by the GATE data. This new data set let us to address the question of the temporal variability of the ZPG and its relation with changes in the wind stress or EUC fluctuations. We found (Katz et al., 1977) that the ZPG has a seasonal signal in phase with the zonal wind stress which suggested an equilibrium response at low frequencies. These results were confirmed by the 1979 FGGE data set: the seasonal cycle of ZPG has in the central equatorial Atlantic a minimum in March to April, its reaches its yearly maximum value in September to October. The mean value and the yearly cycle being nearly balanced by the westward directed wind stress (Lass et al., 1983).

In the eastern equatorial Atlantic, the ZPG relaxes to zero or even reverses sign toward the African coast. This situation was first investigated by Neuman (1965) using the data from the IGY cruise of the RV "Crawford" in November 1958 just at the end of the SW African monsoon. This let him to identify a slope reversal between about 7°W and the African coast, indicated by a rise of the sea surface of 8 or 9 dyn.cm towards Africa. This rise of the seasurface toward the African coast can be explained as the result of an eastward water transport in the surface strata of the inner part of the Gulf of Guinea.

If the zonal slope downward to the east is a necessary requirement for the development of an EUC, the Atlantic EUC should be missing in the Gulf of Guinea where the slope is reversed.

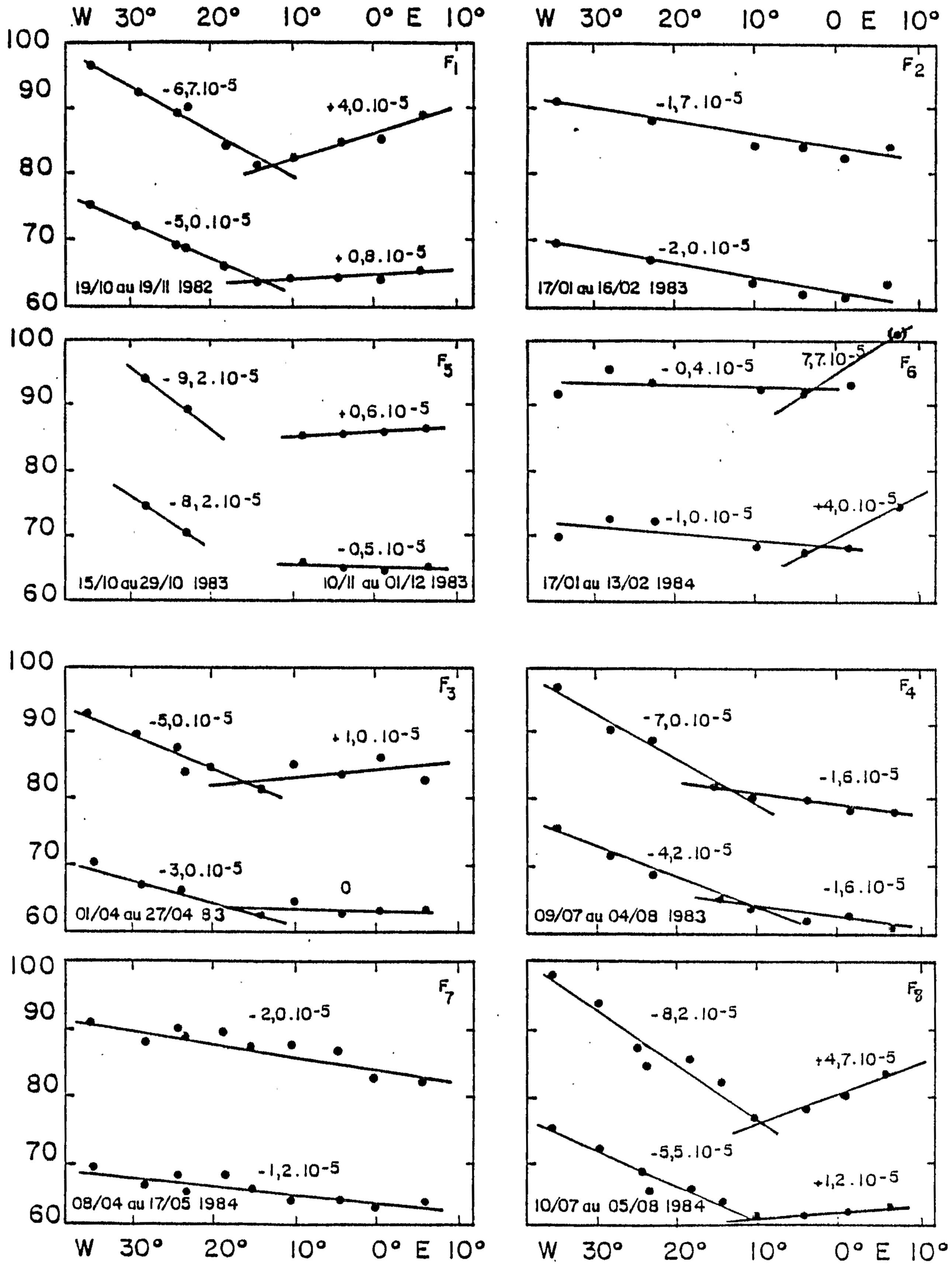
Until now it has been impossible to relate with some confidence the variations in EUC transport and ZPG variations. In the Pacific Ocean however, around 150°W, during March-April 1980, when the eastward ZPG was the strongest, Leetma and Spain (1981) evidenced the largest EUC transport per unit width. It rapidly decreased to the west and more slowly to the east. An extreme example of EUC and surface PG variations was presented by Firing et al. (1983) for the 1982-83 El Nino-Southern Oscillation event in the central Pacific. They found that the EUC disappeared when the sea surface slope, inferred from island sea-level measurements, became weak or changed sign. Knox and Halpern (1982) have shown that a sharp increase (15 dyn.cm) in dynamic height in a relatively short time (19 days) may result from the propagation of an equatorial Kelvin wave pulse. This change in dynamic height would implie a velocity fluctuation of 35 cm/s and a zonal transport per unit width change of 88 m^2/s.

Mangum and Hayes (1984) have shown that in April 1982 and in September 1982 before the onset of the ENSO event, the ZPG was anomalously negative (greater downward thermocline slope from east to west).

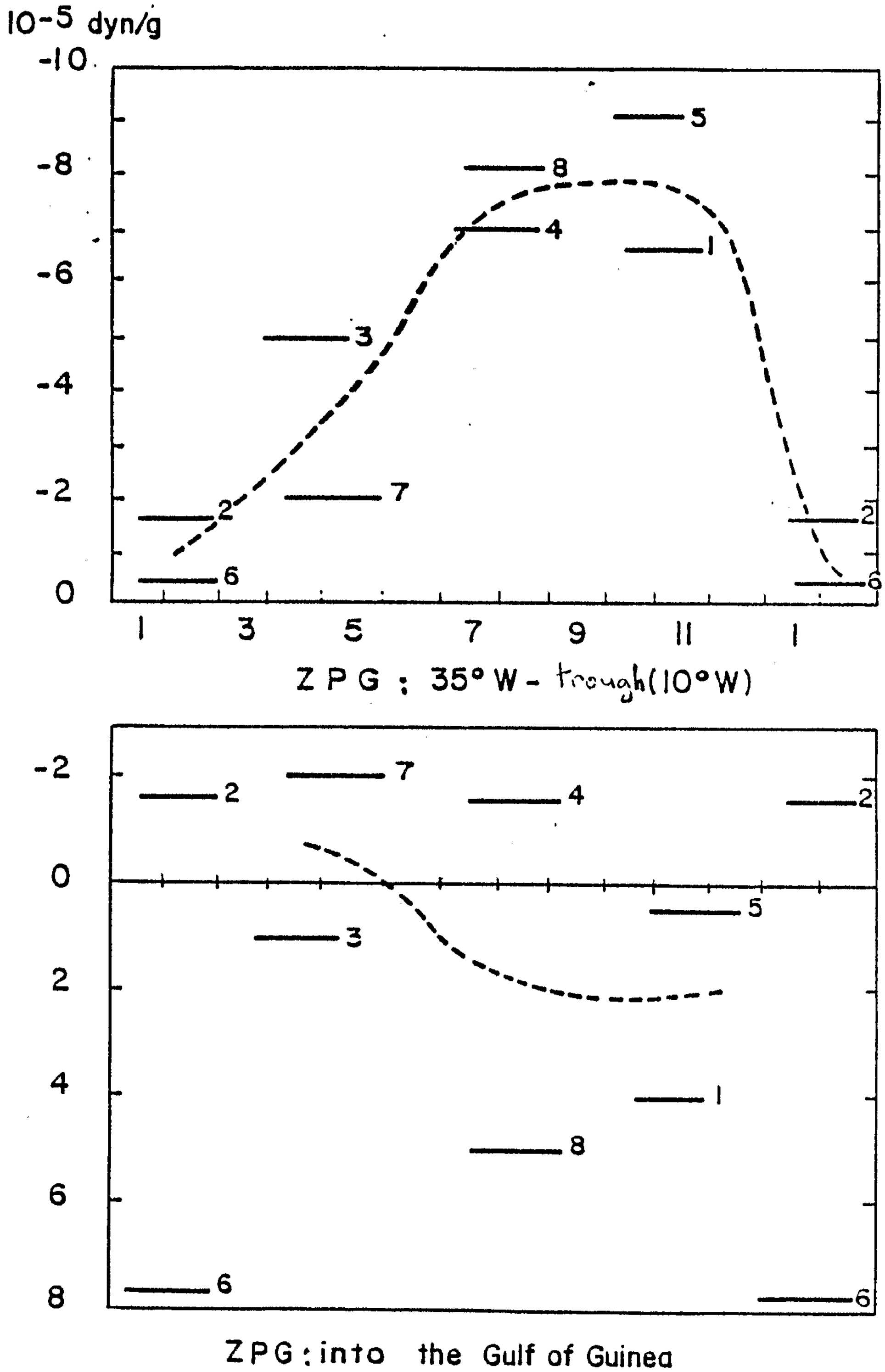
The FOCAL data set :

Because of its importance to the development of equatorial dynamics and implications in climate research, studies of ZPG and the relationship to zonal windstress along the Equator have recently drawn considerable attention during the FOCAL-SEQUAL experiment from October 1982 to August 1984.

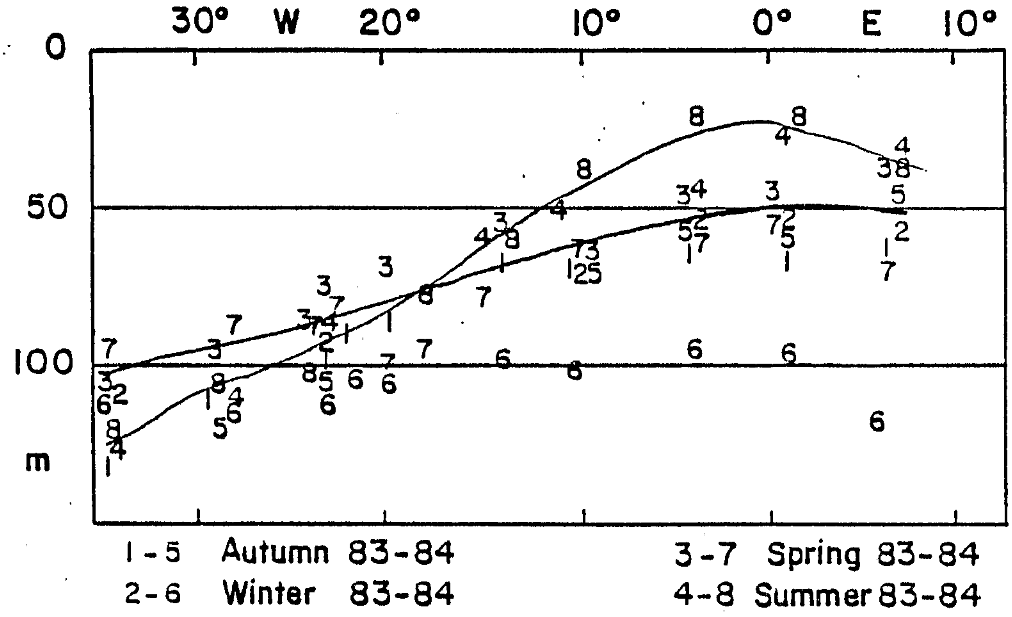
Difficulties in understanding the role of ZPG in equatorial dynamics is hampered by a lack of synoptic zonal CTD measurements along the equator and the FOCAL data set is also faced with this criticism. To smooth the data, we have estimated an averaged value of the dynamic height between 1°N and S (5 CTD stations) and the sea surface slope has been hand-smoothed in order to reach the less chaotic feature. The wind stress has been averaged between 2°N and S.



Dynamic height of the 0db and 50 db surface relative to 500 db during the eight FOCAL cruises. Data are 1°N-1°S averaged values. DPC unit is in dyn/g



Annual cycle of the Zonal Pressure Gradient along the Equator in the Central Atlantic (35°W to about 10°W) and in the eastern Atlantic, the Gulf of Guinea, from the eight FOCAL cruises data set.



1°N-1°S averaged values of the 20°C depth along the Equator during the eight FOCAL cruises. Numbers from 1 to 8 refer to FOCAL cruise numero.