FEASIBILITY OF MONITORING WEST AFRICAN OCEANIC FRONT FROM SATELLITES

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For the past several years, the fisheries off the west coast of Africa have attracted worldwide attention because of the large catches in an area of contrasting warm and cold water masses near the Equator. The several cruises of the Congo-Brazzaville oceanographic vessel OMBANGO in this area have shown that schools of tuna generally follow the seasonal movement of the boundary, or oceanic front, between these water masses (LeGuen, et al., 1965). Further, the cruises have yielded sufficient information to hypothesize that the concentrations of yellowfin tuna should be greatest in waters of 24° to 25° C.

Berrit (1962) found evidence in sea-surface temperature and salinity data for the existence of the oceanic front (designated the Gabon-Angola Front), which appeared seasonally between 16° S. latitude and the Equator along the west coast of Africa (Fig. 1). This finding followed considerable research in the area east of approximately 5° W. longitude by Berrit (1959) and others.

Advances in the use of earth-orbiting satellites for earth resources observation led to the concept of using a satellite system to monitor the position of the Gabon-Angola Front. Previously, two satellite-mounted sensors, one operating in the infrared (IR) wavelength region and the other in the visible wavelength region, have delineated well-known oceanographic features. Wilkerson (1967) has shown that certain features related to the Gulf Stream are discernible from IR data relayed to earth from experimental NIMBUS satellites. He obtained TV-pictures that clearly outlined the western edge of the Gulf Stream and indicated the presence of warm Gulf Stream water moving alongside the colder shelf water.

More recently, a TV-picture in the visible wavelength region from the Application Technology Satellite II (ATS II) has shown a region of upwelling associated with the Peru Current and its westward extension, the Pacific South Equatorial Current. This region of high thermal contrast was discernible by relating the band of low surface clouds to the surface current pattern (LaViolette and Chabot, 1967).

The major objective of the present study, therefore, was to determine the feasibility of monitoring the Gabon-Angola Front--and thereby provide to commercial fishermen real-time information on the position of the Front and the probable location of tuna.

OBSERVATIONS

The field phase of the feasibility study was conducted during cruise 6802 of the R/V UNDAUNTED (BCF Miami) in west African waters from September 19 to November 22, 1968. An Automatic Picture Transmission system, capable of receiving and photographing images from both visible and IR sensors mounted on satellites, was used on the vessel to acquire satellite data. At the time of the study only the ESSA-6 weather satellite was operational and only in the visible mode (no IR sensor was carried aboard ESSA-6), so no IR data were acquired. Surface truth data, both oceanographic and meteorological, were obtained on the UNDAUNTED for association with the satellite data.

The satellite TV-picture receiving equipment on board the UNDAUNTED, which was activated for 37 orbits, yielded 123 photographs from the ESSA-6 weather satellite during the cruise. The number of photographs received during an orbital overpass depended on the length of time the satellite was above the horizon as "seen" by the receiving antenna on the vessel. Each picture transmission required 3.4 minutes plus a 2.4-minute synchronization period between transmissions;

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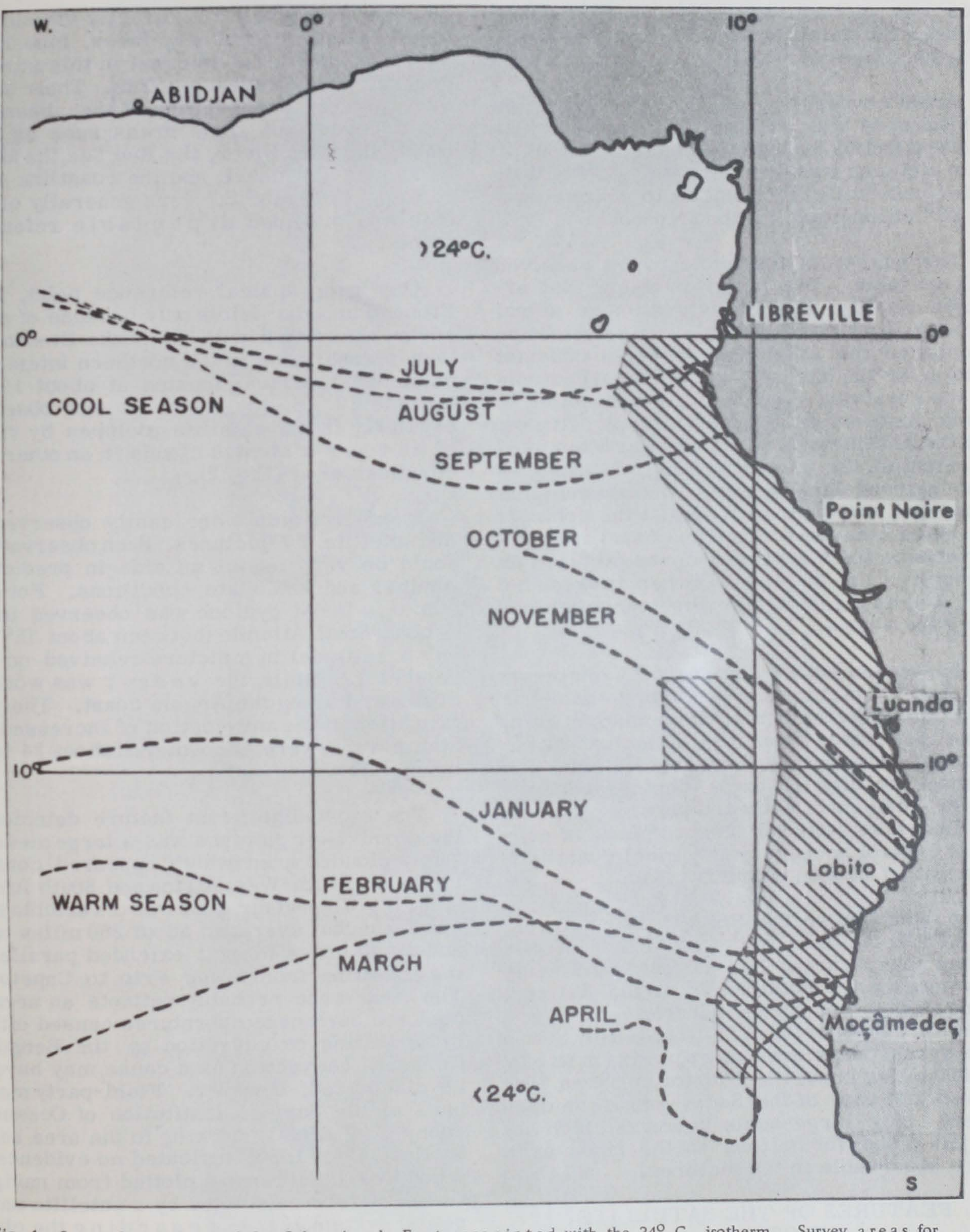

Fig. 1 - Seasonal movement of the Gabon-Angola Front associated with the 24° C. isotherm. Survey areas for R/V UNDAUNTED Cruise 6802 are hatched.

thus one picture was received for each 6 minutes the satellite was above the horizon, or a maximum of four pictures per orbit.

Areal coverage of the TV-pictures in an orbital pass was extensive. In some orbits passing nearly overhead, the area covered in four pictures was approximately 80° of latitude (from Sicily to a point south of Capetown) by 25° of longitude (at the Equator).

The quality of the photographs received was variable. The major problem that affected quality was the variation of signal strength between orbits. This fluctuation prohibited the establishment of a constant setting for the intensity and contrast controls on the receiver. Operator experience led to more frequent acceptable control settings, but the first picture of an orbit was often used to establish the proper setting. In pictures that included large areas of broken cumulus clouds, it was difficult to adjust the contrast to reveal both cloud detail and coastline. Interference lines appeared in the pictures as a result of the ship's roll (when it exceeded 15°) and as a result of radio transmissions from the vessel.

To supplement the shipboard TV-pictures, 276 ESSA-6 pictures of African coastal waters during September 15-December 1, 1968, were purchased from the Mulemba Astronomical Observatory, Luanda, Angola. The average quality of these photographs was better than that of the shipboard pictures, but they also suffered from the lack of contrast control necessary to reveal coastlines in areas of broken cumulus clouds.

In addition to the ESSA-6 TV-pictures, 15 ATS III pictures of the southeast Atlantic Ocean taken during late October and early November were obtained from the National Aeronautics and Space Administration (NASA). Because the ATS III satellite is in a geo-synchronous orbit at approximately 22,000 miles above the Equator, and was stationed just east of the South American continent, only large-scale features such as major cloud formations in the study area were observable in the pictures.

FEATURES OF THE SATELLITE PICTURES

The features revealed by the satellite TV-pictures can be separated into two groups--those directly visible, and those manifested by cloud patterns. The directly visible features include coastlines, lakes, mountains, and islands--all of interest in this study as geographical reference points. Their use in this capacity depended upon the absence of cloud cover, but some areas such as Lake Chad, the Nile River, the Red Sea, the Mediterranean Sea coast, and the coastline south of Cape Frio (18° S.) were generally cloud-free and provided dependable reference points.

One geographical reference point, Lake Etosha Pan, was visible only because of cloud cover associated with it. Lake Etosha Pan is a marsh area in the northern interior of South-West Africa, located at about 19° S. latitude 16° E. longitude. It was observed regularly in the satellite pictures by virtue of its cover of stratus clouds in an otherwise cloudless area (Fig. 2).

Storm systems were easily observed in the satellite TV-pictures. Such observations could be very useful as aids in predicting weather and sea state conditions. For example, a large cyclone was observed in the central South Atlantic (between about 35° and 50° S. latitude) in a picture received on November 12, while the vessel was working southward along the Angola coast. The picture allowed the anticipation of increased sea states which were encountered about 24 to 48 hours later.

The most significant feature detected in the cloud cover pictures was a large clear or thinly clouded area which appeared consistently off South-West Africa and South Africa (Fig. 3). This clear zone was of variable size and shape, but averaged about 250 miles wide and 1,200 miles long; it extended parallel to the coastline from Cape Frio to Capetown. The clear zone probably reflects an area of cool sea surface temperatures caused either by upwelling or advection by the Benguela Current. (Advection as a cause may have to be discounted, however. Field-party members of the Scripps Institution of Oceanography R/V ARGO, working in the area early in November 1968, indicated no evidence of a northward current as plotted from navigational offsets calculated by a satellite navigation system.) Data regarding the clear zone were not acquired by the UNDAUNTED because the vessel did not work that far south.

No cloud features were detected in the satellite pictures which could be associated

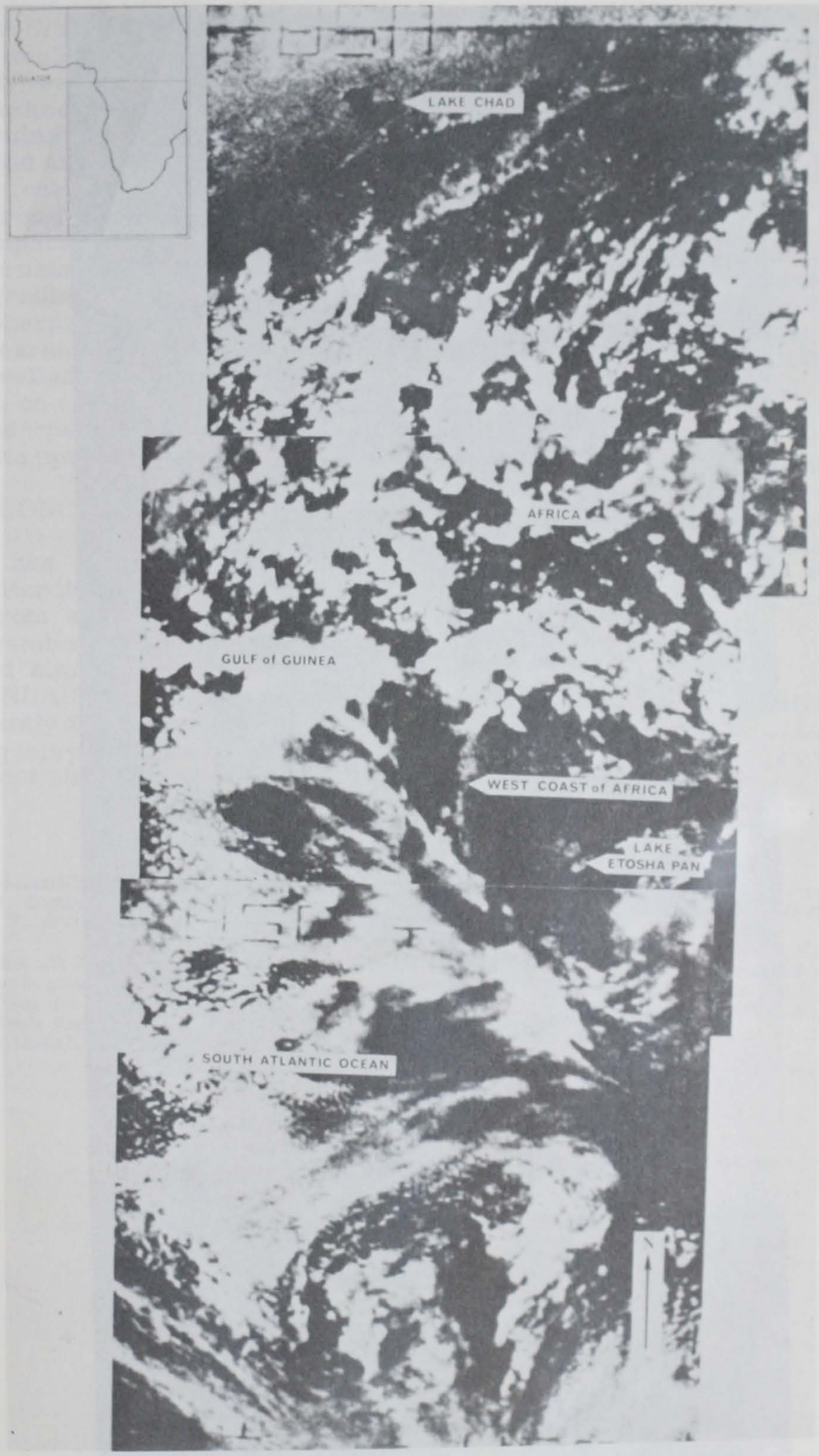

Fig. 2 - Mosaic of typical ESSA-6 weather satellite TV-pictures received during UNDAUNTED Cruise 6802 showing important geographical features. Dark swath on outline map shows surface area covered by mosaic.

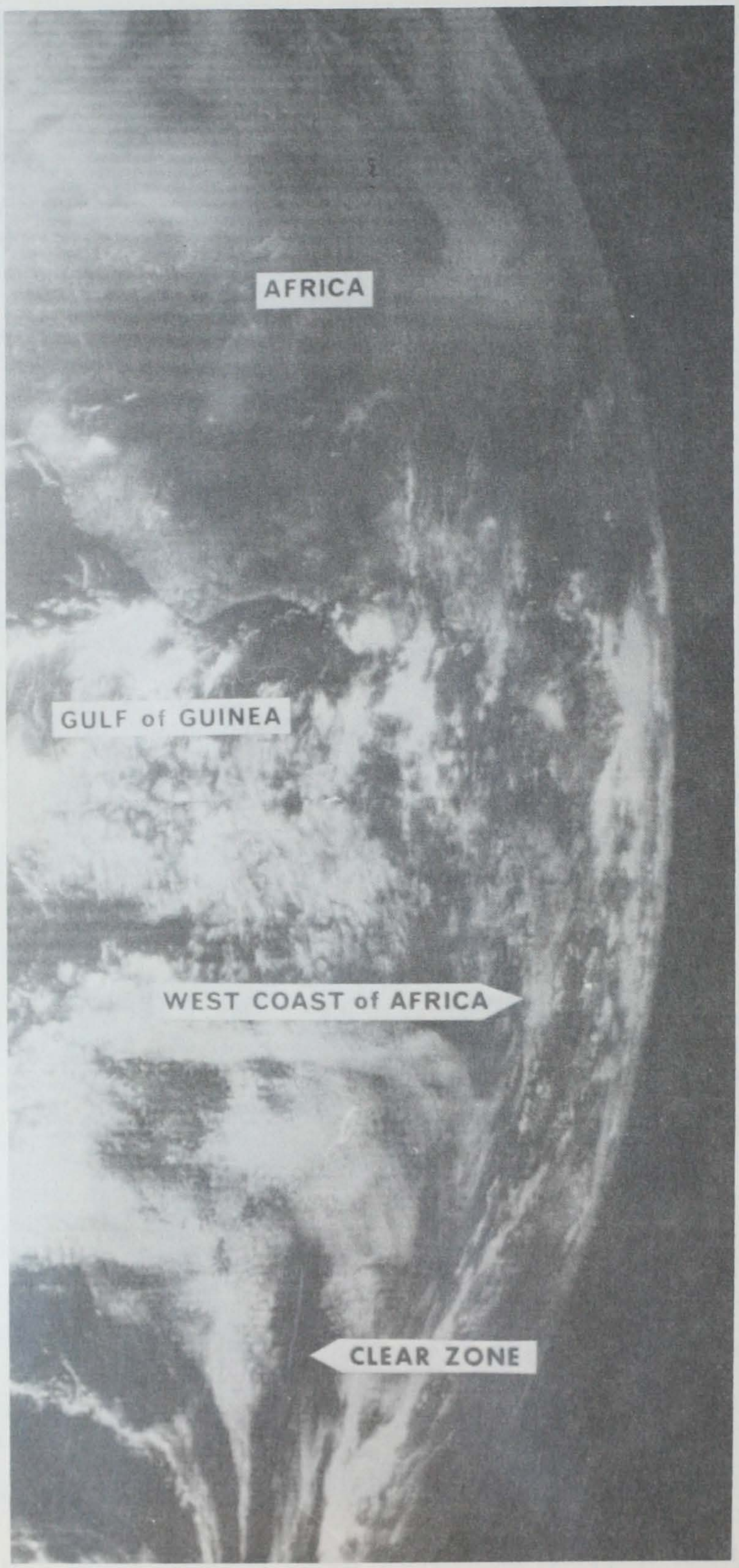

Fig. 3 - ATS III TV-picture showing clear zone extending along the west African coastline from Cape Frio to Capetown.

with the position of the Gabon-Angola Front. The area of the Front was generally covered with broken cumulus clouds, but no pattern or discontinuity was discernible that could be related to the known position of the Front. During the cruise period, the Front was weakly developed and involved gradients that never actually constituted a frontal configuration. The strongest horizontal gradient of sea surface temperature for the 23° to 25° C. range (the range usually involved in the center of the frontal gradient) was 2° C. in 30 nautical miles. Sharper gradients were found around small nearshore patches of cool (less than 21° C.) upwelled water, but these had an apparent effect on cloud formation in only a few photographs--perhaps because of the small size of the upwelling areas.

CONCLUSIONS

This study has revealed that it is not feasible to monitor the position of the Gabon-Angola Front from satellite data during the September-December period, assuming that the oceanic and atmospheric conditions encountered on UNDAUNTED cruise 6802 were typical. Apparently the gradients involved in the Front during this period were too weak to produce an abrupt change in cloud cover.

A distinct pattern in the cloud cover was observed consistently off South-West Africa and South Africa, which is apparently related to cool sea surface temperatures from upwelling or advection of the Benguela Current. The large clear zone associated with the cloud pattern should provide a useful environment for air-sea interaction and satellite monitoring feasibility studies for the following reasons: (1) The presence of the clear zone is predictable. (2) Its boundaries are sharply delimited and probably reflect sharp sea surface temperature gradients. (3) It changes shape, mainly along the northern limit of the zone in a period of less than 24 hours. (4) Cumulus, stratus, and clear areas could be studied within a radius of about 50 miles in the vicinity of the northern boundary. (5) Frequently, a bifurcation appears in the northern boundary of the clear zone, probably reflecting advective patterns of surface waters. (6) The clear zone is associated with either a major upwelling area or a major surface current, or both.

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