N84 27306

THE DEPICTION OF THE ALBORAN SEA GYRE DURING DONDE VA? USING REMOTE SENSING AND CONVENTIONAL DATA

Paul E. La Violette
Naval Ocean Research and Development Activity
NSTL, MS 39529 U.S.A.

ABSTRACT

Experienced oceanographic investigators have come to realize that remote sensing techniques are most successful when applied as part of programs of integrated measurements aimed at solving specific oceanographic problems. A good example of such integration occurred during the multi-platform international experiment, "Donde Va?" in the Alboran Sea during the period June through October, 1982. The objective of "Donde Va?" was to derive the interrelationship of the Atlantic waters entering the Mediterranean Sea and the Alboran Sea Gyre. The experimental plan conceived solely with this objective in mind consisted of a variety of remote sensing and conventional platforms: three ships, three aircraft, five current moorings, two satellites and a specialized beach radar (CODAR). Integrated analyses of these multiple-data sets are still being conducted. However, the initial results show detailed structure of the incoming Atlantic jet and Alboran Sea Gyre that would not have been possible by conventional means.

1. INTRODUCTION

In the past (and to a certain extent, at this writing) most ocean studies utilizing satellite imagery have been descriptive in nature. Normally, they implied that certain ocean events were taking place, based on a general knowledge of the regional oceanography, past experience with the phenomenon under discussion, and information on the meteorological conditions occurring at the time. Such descriptive studies have and will continue to be useful. There is no question that the broad synoptic views provided by satellite imagery provide valuable insights to the physical and biological events taking place in the ocean. Many of the studies now being conducted on fronts and eddies have evolved to their present state due to information provided by satellite imagery.

Technological advances in interactive computer systems, advanced satellite sensors with improved calibrations, and the development of more accurate sensor algorithms have allowed satellite data to shift from a purely descriptive tool of ocean research to one that is equally quantitative. As a result, experienced oceanographers have come to realize that satellite data are most useful when applied as an integral part of an ocean data set whose collection is aimed at solving specific oceanographic problems.

To be successful, such an approach requires that the investigator reexamine some of the basic concepts of his study field. The statement that the physical, chemical, and biological processes taking place in the ocean are normally interrelated is not a platitude. One must force oneself to remember that, although these relationships are not linear, a thorough understanding of the various processes taking place in any one discipline, quite often requires a broad understanding of the processes occurring in others. For example, a synoptic quantitative view of the spatial and temporal events taking place in and about the region of a front would be needed for a proper study of some particular single aspect of the front. To a limited degree, satellite (and aircraft) remote sensing techniques can now provide these synoptic and quantitative views.

The limitations are imposed by the fact that remote sensors have no direct connection with the ocean. Data collection using these techniques is, thus, limited to the utilization of the electromagnetic radiation of the ocean. However, the data blended within a strong integrated data collection program (i.e., remote sensed and in situ data) can be descriptively and quantitatively used to bring about a broad understanding of ocean processes.

A good example of such integration occurred during the multi-platform, international experiment, "Donde Va?" in the Alboran Sea during the period June through October, 1982. The objective of "Donde Va?" was to derive the interrelationship of the Atlantic waters entering the Mediterranean Sea and the Alboran Sea Gyre. The experimental plan, conceived solely with this objective in mind, consisted of a variety of remote sensing and conventional platforms: three ships, three aircraft, five current moorings, two satellites, and a specialized beach radar (CODAR) (La Violette, et al., 1982; Kinder, 1983). Integrated analyses of these mutiple-data sets are still being conducted. However, the initial results show detailed structure of the inflowing Atlantic water and Alboran Sea Gyre that would not have been possible by conventional means. Portions of the results of this experiment are presented here to illustrate the philosophic remarks made above.

2. THE ALBORAN SEA

The Alboran Sea is the most western of the series of semi-enclosed, evaporative basins which form the Mediterranean Sea. As such, the Alboran Sea forms the first junction between the warm, highly saline waters of the Mediterranean and the colder, less-saline waters of the Atlantic. The circulation and physical properties of the waters in the Alboran Sea reflect this juncture. Atlantic water flows into the basin from the west through the narrow (20 km) and shallow (300 m) Strait of Gibraltar to form a 200 m surface layer (Lanoix, 1974). Mediterranean water (13.1°C and 38.4‰) entering the Alboran Sea through its broader eastern end, flows westward below the incoming Atlantic water continuing out of the Mediterranean through the Strait of Gibraltar. Mixing between the Atlantic and Mediterranean waters is continuously taking place in the Alboran Sea, and the vertical and horizontal variations of temperature and salinity that are found in the upper 300 meters are a result of this mixing.

The narrowness of the Strait of Gibraltar, the angle of the strait with respect to the Alboran Sea, and the effect of the earth's rotation control the mean positions of the two water masses in the sea (Preller and Hurlburt, 1982). Imposed on these mean conditions are the long-period changes created by year-to-year and seasonal variations in the rate of evaporation within the Mediterranean and the short-term changes caused by the tides and meteorological events (Frassetto, 1960; Peluchon and Donguy, 1962; and Crepon, 1965).

These physical controls force the Atlantic water to enter the Alboran Sea as a band less than 30 km wide and at a speed of greater than 100 cm/sec (Lacombe, 1961; Peluchon and Donguy, 1962; Lanoix, 1974; Cheney 1977; Cheney, 1978; Wannamaker, 1979; and La Violette, 1983). Once in the sea, the band of Atlantic inflow tends to bend southward to form a clockwise circulation system called the Alboran Sea Gyre which is a permanent feature occupying most of the basin west of Alboran Island. When the water of the gyre reaches the African coast west of Cape Tres Forcas, (normally around 3°30'W) it splits into two branches--one flows west along the coast toward the Strait of Gibraltar, and the other into the sea's eastern basin to form a series of less intense, smaller gyres that hug the African coast. A classic depiction of the gyre is shown by Lanoix (1974) who used ship data collected in July and August 1962 to form a chart of dynamic topography (Figure 1).

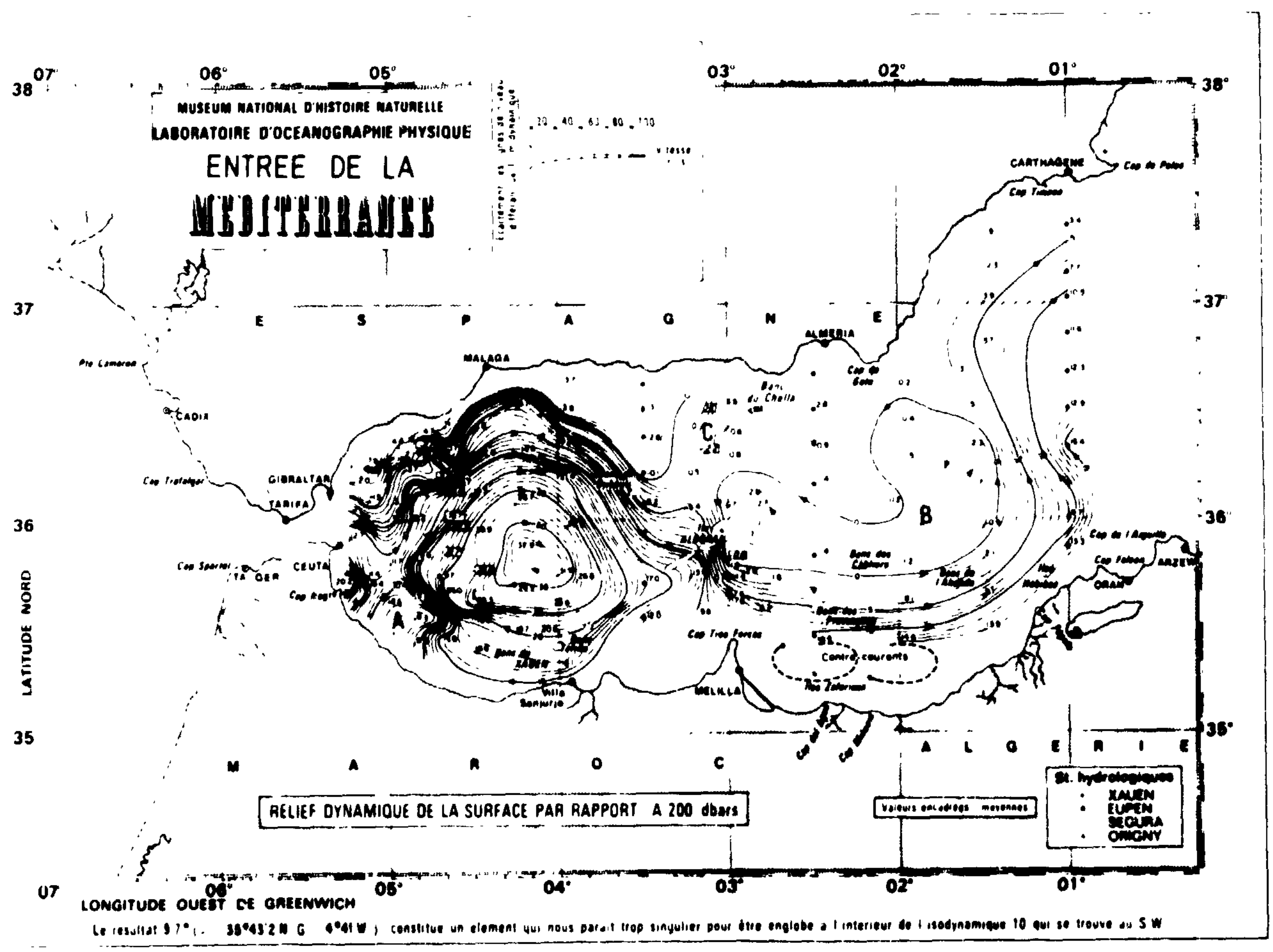


Figure 1. Dynamic topography for the surface based on 200 dbars for the period July and August 1962 (Lanoix, 1974).

For the purposes of this paper, it most be understood that the problem with studying the currents that constitute the Alboran Sea Gyre is the difficulty in quantitatively measuring the spatial changes that occur in time. An examination of satellite imagery shows that the surface thermal gradients associated with the Atlantic inflow have large spatial variations that occur over a few days. Although a number of investigators (Cheney, 1978; Cheney and Doblar, 1982; Wannamaker, 1979; Gallagher, et al., 1981a; Gallagher, et al., 1981b; Philippe and Harang, 1982) have used satellite imagery in their studies of the Alboran Sea, very little work has been done to quantitatively associate the surface radiation temperatures shown in the thermal imagery with either the subsurface temperatures or the regional flow.

If the large day-to-day horizontal temperature changes shown in the satellite infrared (IR) imagery reflect current variations, then compositing current-related measurements made over longer periods such as weeks, can mask critical movements in the current. For similar reasons, positioning long-period current moorings across the historical location of the axis of the Atlantic inflow can result in a deceptive data set. The thermal gradient changes shown by the satellite IR data indicate that the axis of the Atlantic inflow varies considerably from the historical mean. Thus, without simultaneous horizontal data to aid in the analyses, interpretation of the current mooring data by themselves could lead to erroneous conclusions. Similar remarks may be made concerning analyses of vertical sections of temperature or salinity that do not include coincident horizontal data.

In effect, to fully understand the conditions which create the Alboran Sea Gyre, data collections must be made that include horizontal, as well as vertical, data sets. With this methodology as a basis, the Donde Va? experiment was conducted in 1982, with the methodology of the data collection laying particular emphasis on measuring the Atlantic inflow.

3. THE SATELLITE AND IN SITU DATA

3.1 Satellite Data Registration:

Accurately locating the geographic position of dynamic ocean features seen in satellite imagery is a major problem. Good earth referencing is important, especially if satellite data are to be correlated with other satellite, ship, or aircraft data.

TIROS-N and post-TIROS-N satellite data (NOAA 6, 7 and 8) distributed in computer compatible tapes (CCT'S) by such satellite data distribution centers as NOAA/EDIS (U.S.) and CMS (France) have incorporated in their data geographic positions. Imagery constructed from these data have been shown to have standard deviations of 1.7 km about mean errors of 3.7 km (Clark and La Violette, 1980). This accuracy allows the registration process to be taken one step further: i.e., to allow common map projections to be made, such as mercator or equal area projections. The method often used to warp NOAA type data to various standard map projections utilizes two-dimensional, third-order polynomials derived from the latitude/longitude data on the CCT. In the Mediterranean, with its easily identifiable landmarks and comparatively short fetches, these registrations can be improved upon and made extremely accurate. Figure 2 showing the Alboran Gyre is a good example. The results of such warping can be done with sufficient accuracy to produce time-lapse sequences (movie loops) of oceanographic features with no noticeable misregistration jitter.

3.2 Atmospheric Correction of Satellite Data:

In addition to the obvious interference of clouds, the more subtle degradation of infrared and visible satellite imagery by absorption and radiation of the atmosphere moisture and aerosols plays a large role in limiting the oceanographic use of imagery in these spectral ranges. These atmospheric constituents must be compensated for in order to quantitatively compare one day's images to another or to in situ data. This problem has several possible solutions.

To arrive at the absolute temperatures of the ocean, infrared imagery may be corrected by several methods. The one showing the most promise is the multichannel single-satellite approach (McClain, et al., 1982). The principle behind the mutlichannel correction is illustrated in Figure 3. The three IR channels of the Advanced Very High Resolution Radiometer (AVHRR) aboard the NOAA-7 satellites used in this study, cover spectral ranges respectively of 3.55-3.93 microns, 10.5-11.5 micons, 11.5-12.5 microns, referred to as the 3.7 micron, 11 micron, and 12 micron channels, fall within "atmospheric windows." These spectral bands thus, have relatively high transmittances with regard to middle- and far-infrared spectral range energy emitted by the ocean surface. The most significant atmospheric absorption constituents in these regions are water vapor and aerosols. However, the amount of absorption varies for each spectral region: the 3.7 micron channel has a transmittance of approximately 90%, the 11 micron channel has a transmittance of approximately 75%, and the 12 micron channel transmittance is approximately 80%. These variations in infrared transmittance for the same ocean scene allows an atmospheric moisture correction to be made that will result in absolute ocean temperatures. An empherical algorithm can be derived by subtracting the effects of one channel from another with the remainder being a factor of the amount of moisture present in the atmosphere.

Although limited to night use, one of the preferred channels to use (because of its high transmittance rate) is the 3.7 micron channel; however, high noise levels in this channel in the NOAA-7 and NOAA-8 satellites have, until very recently, precluded any real use of multichannel algorithms.

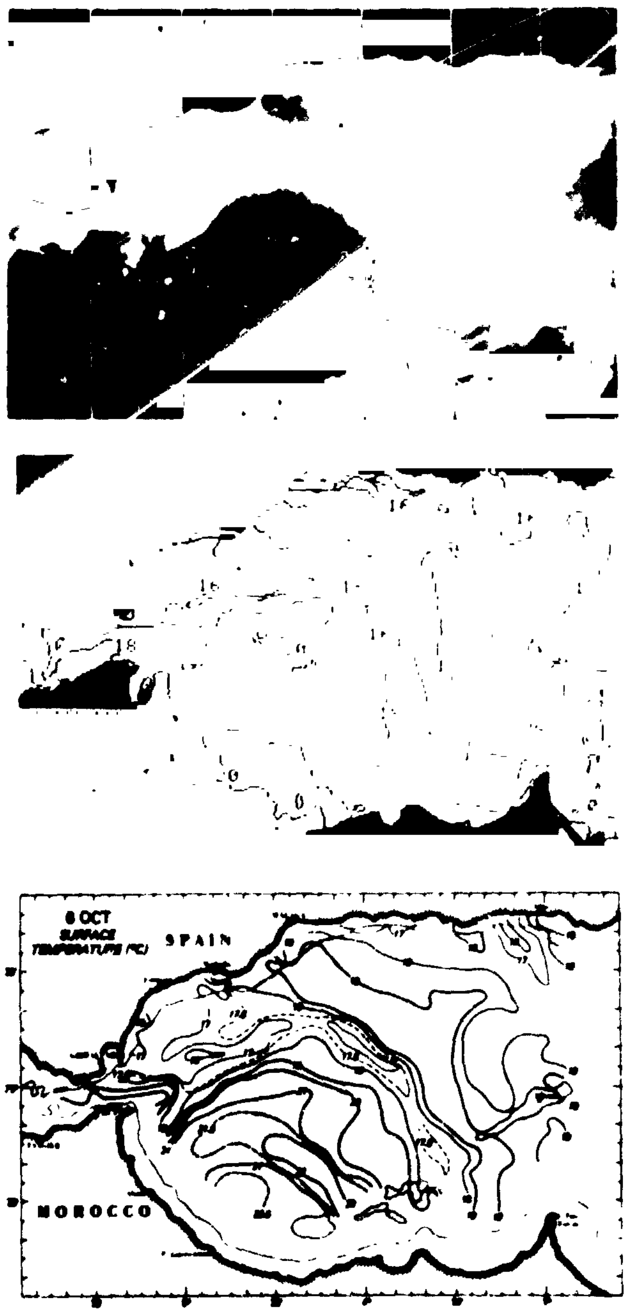


Figure 2. Satellite (a,b) and aircraft (c) sea surface temperatures for the Alboran Sea for 6 October 1982. To produce the thermal image the satellite data was registered to a mercator projection and then atmospherically corrected using an algorithm developed by McClain, et a'., 1982. The correction leaves a systematic negative bias to the data of approximately 1°C. In this instance, a study of 76 aircraft XBTs dropped within three hours of the satellite overpass showed a bias of exactly 1°C with a standard deviation of 0.6°C. The isolines in (b) are computer smoothed outlines of the equivalent temperature values of the atmospherically corrected thermal image (La Violette, 1983).

ORIGINAL PAGE IS
OF POOR QUALITY

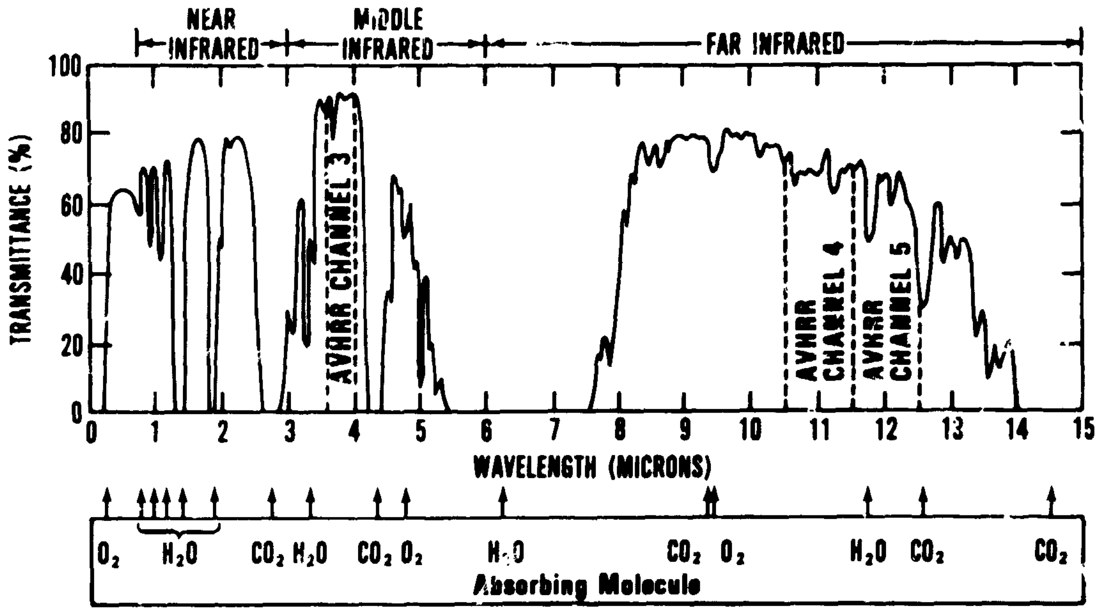


Figure 3. The wavelength of the three channels of the NOAA AVHRR as a function of transmittance for an atmospheric path containing 1.7 cm of precipitable water.

3.3 The Alboran Sea Satellite Data:

One of the primary satellite sensors used during Donde Va? is the AVHRR of NOAA-7. The 11 and 12 micron channels of this radiometer are the principal data sources. The NOAA satellite and the AVHRR are described by Schwalb (1978) and Hussy (1979).

During the period November 1981 through October 1982, NOAA-7 data of the Alboran Sea were collected and examined at the Centre de Meteorlogie Spatiale (CMS) satellite data receiving station at Lanion, France. The data were used in the field to help operationally control the survey and retained for post-survey analyses. From these, 24 AVHRR tapes were selected for the period 6 through 20 October 1982 that were sufficiently cloud-free to use in the present analysis. These tapes were calibrated, atmospherically corrected and geometrically registered (to a mercator projection) using the Naval Ocean Research and Development Activity (NORDA) interactive computer system. The atmospheric-corrections were made using the split-window technique developed by McClain, et al., (1982).

In addition to the NOAA-7 AVHRR data, NIMBUS-7 Coastal Zone Color Scanner (CZCS) data are used. A description of the NIMBUS satellite and the CZCS can be found in Hovis, et al., 1980.

3.4 The Surface Data:

Most of the nonsatellite data used in this study were obtained from a United States Naval Oceanographic research aircraft. These data include both oceanographic and meteorological information. The aircraft made four mapping flights that collected continuous precision radiometric thermometer (PRT-5), airborne expendable bathythermograph (AXBT), and sonobuoy (drift) data over the Alboran Sea west of Alboran Island (since the incoming Atlantic water is restricted to the upper 200 m, these temperature data include all of the inflowing water). A full description of this aircraft's instrumentation during Donde Va?, as well as extensive analysis of the collected data can be found in La Violette (1983) and La Violette and Kerling (1983).

The remaining ocean data were collected by Donde Va? research vessels using conventional expendable bathythermographs (XBTs) and Conductivity/Temperature/Depth (CTD) profilers. These vessels also provided meteorological information for selected days and positions. Additional weather data were obtained from Spanish coastal meteorological stations, a special Spanish weather station established on Alboran Island, and from the Royal Air Force Meteorological Office, Gibraltar.

4. ANALYSIS AND DISCUSSION

The twice-daily passes of the NOAA-7 over the study area permitted almost continuous moitoring of the surface thermal changes that occurred in the Alboran Sea Gyre during the October period when intensive air and sea measurements were being conducted as part of Donde Va?. The NOAA-7 infrared imagery show that a number of submesoscale cold-water features were being advected about the gyre during that period. Although the present study is centered about the October 1982 movement of these cold-water features, the features are also visible in almost all of the satellite infrared imagery collected during the one year Donde Va? study period (November 1981 through October 1982). An examination on satellite imagery of other years also show these mesoscale cold-water features are normally present as part of the Alboran Sea Gyre. In fact, two features similar in appearance and location to the cold water features can be seen in the dynamic topography presentation by Lanoix (1974) in Figure 1.

Figure 4 shows two sequences of five images each spaced 12 hours apart starting on the afternoon of 6 October through the afternoon of 8 October, 1982 for one sequence and for the period from early morning 11 October through the afternoon of 13 October 1982 for the other sequence (the image from the morning pass for 13 October has been omitted from the second sequence because of clouds). The arrows, dots and

---

Figure 4. Registered and atmospherically corrected NOAA-7 infrared imagery of the Alboran Sea for the periods 6 through 8 October and 1 through 13 October 1982 (La Violette, 1984).

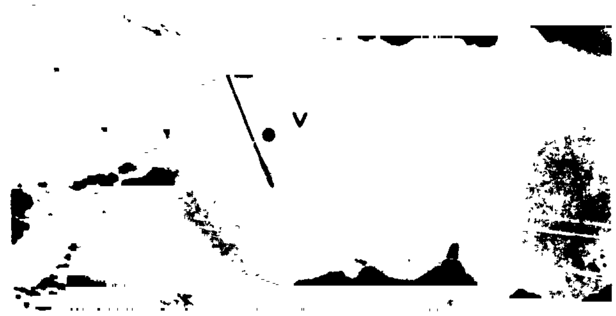
ORIGINAL PAGE IS
OF POOR QUALITY

1432 GMT 6 OCTOBER

0256 GMT 7 OCTOBER

1422 GMT 7 OCTOBER

0244 GMT 8 OCTOBER

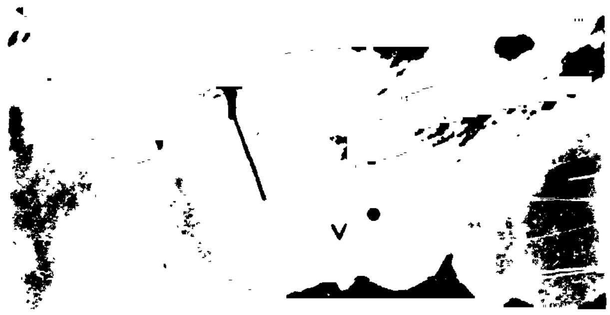


1408 GMT 8 OCTOBER

0349 GMT 11 OCTOBER 1982

1513 GMT 11 OCTOBER 1982

0337 GMT 12 OCTOBER 1982



1501 GMT 12 OCTOBER 1982

1449 GMT 13 OCTOBER 1982

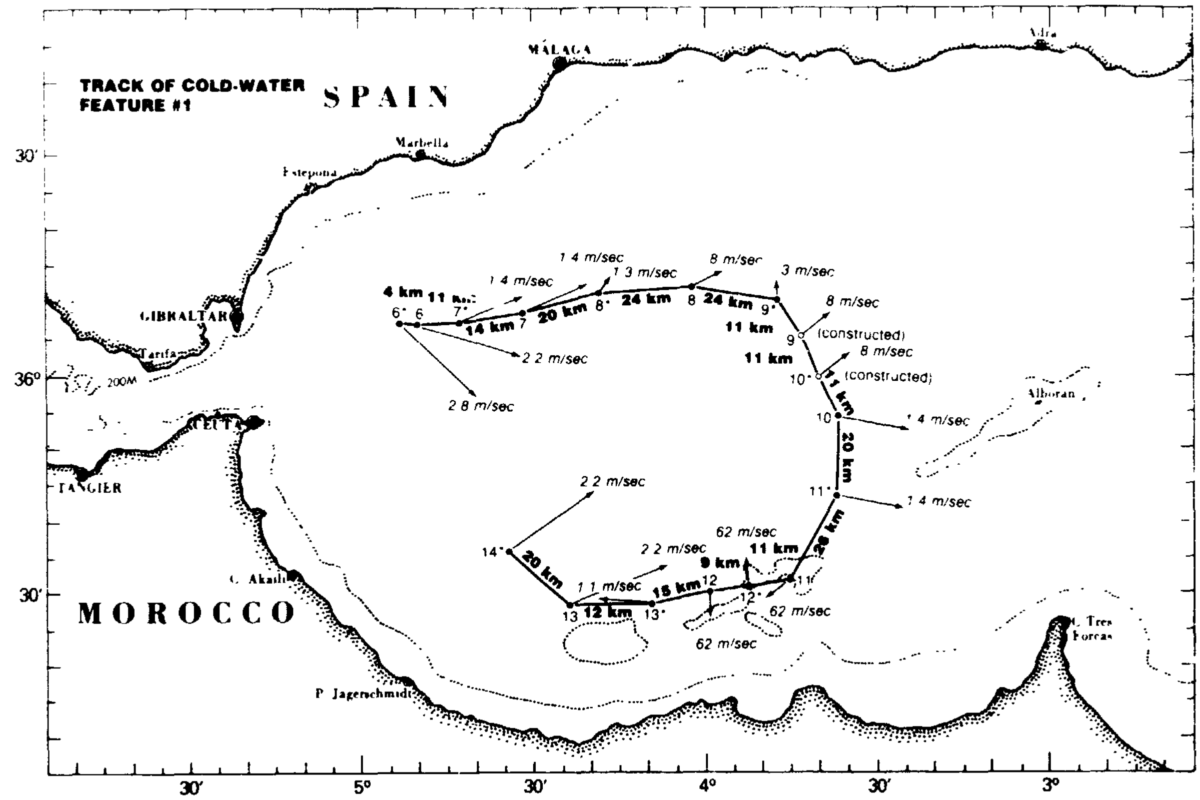


Figure 5. A plot of the complete track of the feature marked with a "bar" in Figure 4. The arrows represent the direction and speed of the wind at or near the time of the plotted position of the cold water feature (La Violette, 1984).

bars in each of the imagery trace the movement of two cold-water features from their apparent origin east of Gibraltar across the top of the gyre. The five-image sequence covers only portions of the features total movements. In Figure 5, a plot of positions taken from satellite data, shows the complete circuit of feature #6 (the bar in the second sequence) around the gyre until it became hidden by clouds on the afternoon of 14 October.

The vertical sections in Figure 6 constructed from AXBT data along 36°N latitude, shows the structure of three of the cold water features with depth. These sections show that generally the cold water in the area had upwelled from greater than 100 meters. In addition, data from the USNS BARTLETT for 7 October 1982, (CTD station 120--T. Kinder, personal communication) give salinity values of 36.73 ppt in the same area as the feature for 6 October. Comparison of these data with historical data (e.g., Lacombe and Tchernia, 1982) indicates the upwelled water is of Atlantic origin.

Note that in the second five-image sequence of Figure 4, another cold-water feature can be seen to develop on 12 October in the region east of Gibraltar. During the aircraft flights over the front, it was noted that sharp color changes were coincident with the thermal front. This effect suggested a method to derive the

ORIGINAL PAGE IS
OF POOR QUALITY

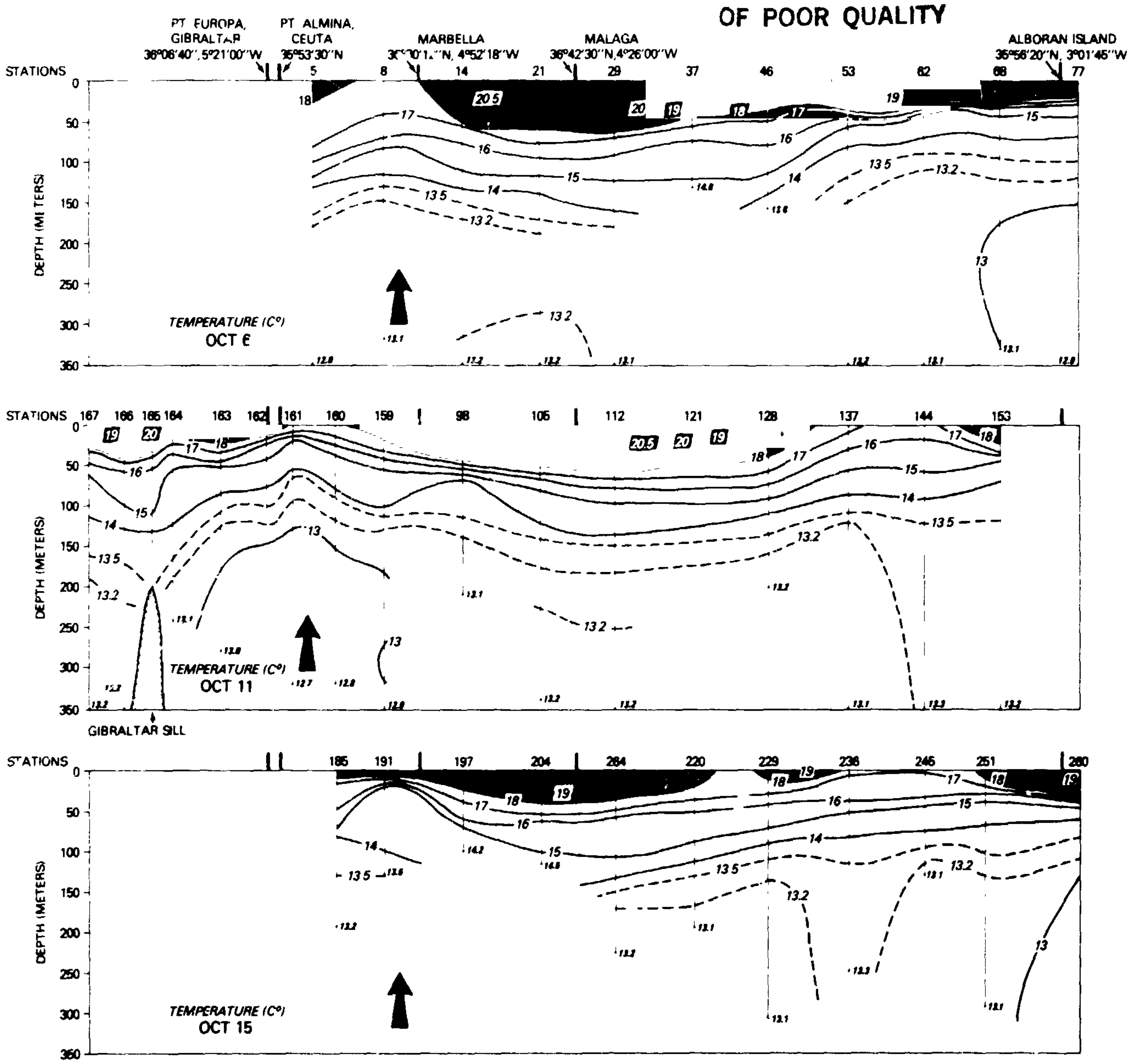


Figure 6. East-west vertical temperature sections taken along the 36° latitude (data based on aircraft XBTs). The arrows refer to cold water features found near the Strait of Gibraltar. The 6 October arrow refers to the "v's" in Figure 4, whereas the arrow on 11 October refers to the "bars" shown in the same figure (La Violette, 1984).

movement of the front for periods less than 12 hours. An enlargement of the IR image for the afternoon of 12 October (1501 hrs) is presented in Figure 7 together with NIMBUS-7 CZCS visible image of the same area for 1155 hrs of the same day. (The CZCS enhancement uses the principal component analysis method described in Holyer and La Violette, 1983. This particular enhancement is designed to show the distribution of chlorophyll). Examination of the NOAA imagery shows that the feature (called here feature #7) moved approximately 17 km in the 11 hours from the time of the morning NOAA IR image to the time of the afternoon NOAA IR image; or at an average speed of approximately 0.4 m/sec. The CZCS image indicates a movement of approximately 9 km

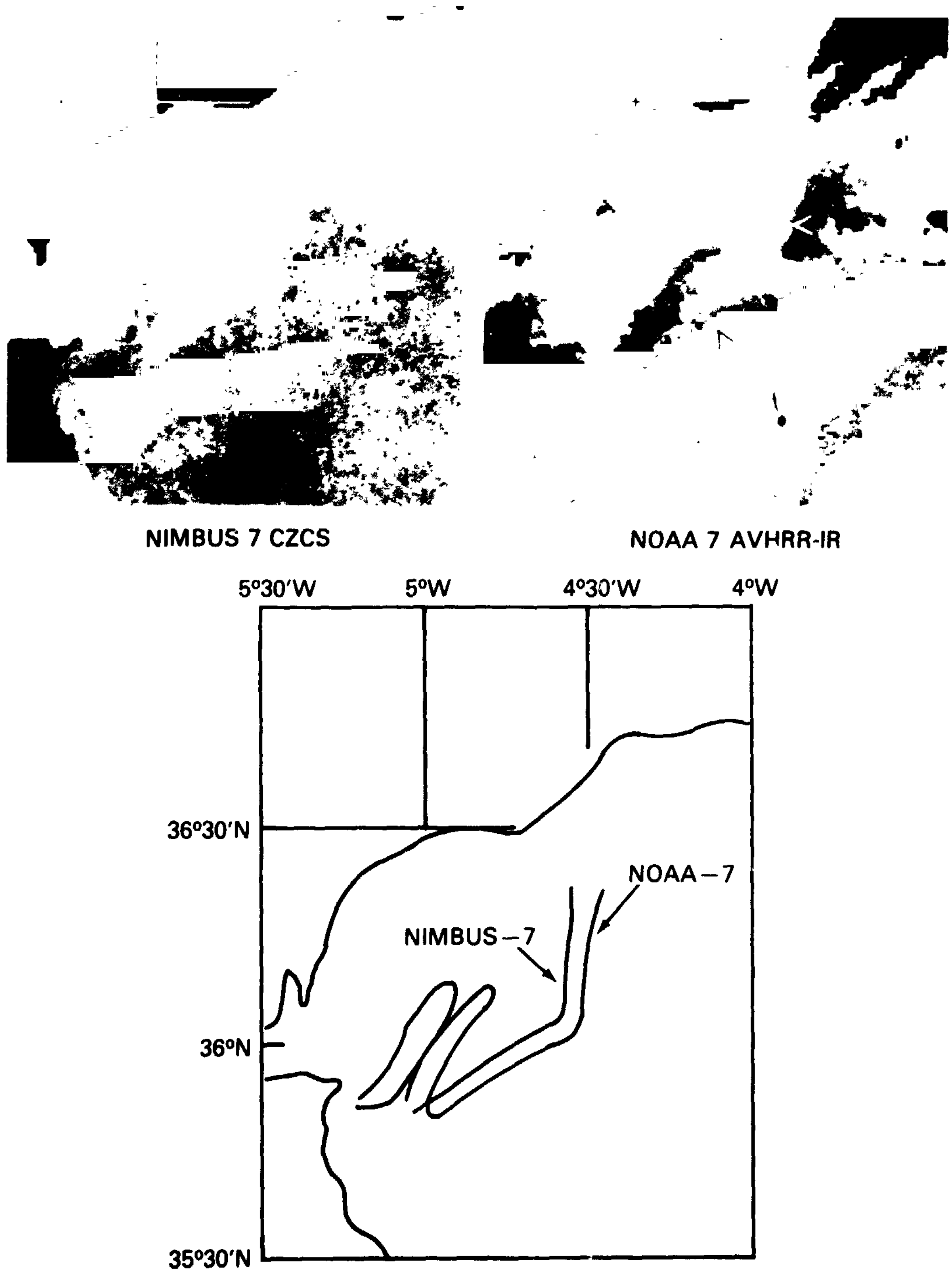


Figure 7. The short term movement of Feature #7 shown by Nimbus CZCS visible and NOAA-7 AVHRR infrared imagery. The movement amounting to approximately 9 km took place between 1155 (Nimbus) and 1501 (NOAA) hours GMT on 12 October 1982 (La Violette, 1984).

in the time between the Nimbus noon pass and NOAA afternoon pass (i.e., if one assumes that the sharpest gradient change in the CZCS image is directly associated with the sharpest thermal gradient in the NOAA imagery.). This equates to a movement of 0.8 m/sec or twice the rate of movement for the 11-hour period between the two NOAA imagery. The figure gives a graphic indication of how much movement can take place in four hours.

Figure 8 shows feature #8 as defined by the satellite and aircraft data. The aircraft PRT and AXBT data analysis shows the spatial continuity of the feature down to 350 m. However the vertical section in Figure 6 indicates the upwelling does not appear to go deeper than 75 m. Because of clouds, this feature was visible in only three of the IR imagery.

In comparing the different cold-water features, it is important to note that they are not equally distinguishable in the thermal imagery. In the fifteen-day period, only nine are distinct enough to be tracked for several days. In addition to thermal clarity, the times the features can be tracked are limited by cloud cover. The two five-image sequences presented here show that the advective movement of the features are easily followed (the author has made a loop-movie for the full fifteen days which shows this advection quite graphically). It is, however, more difficult to assign a particular point on any one feature and then precisely track that point from image-to-image as the feature moves about the gyre. Nevertheless, reasonable measurements of speeds may be made by marking the general leading edge of the feature with indicators such as the arrows in the first of the five-image sequences. Such measurements show that the advective speed of the features varied from day-to-day; ranging from 0.2 to 0.6 m/sec with the average speed being 0.4 m/sec.

In a study of the drift rate of sonobuoys dropped from the Navy aircraft during 9 through 18 October, La Violette (1983) shows that surface currents associated with the incoming Atlantic water flowed at speeds equal to or greater than 1.0 m/sec, and that on the average, the fastest speeds (i.e., speeds of $\geq$ 1.2 m/sec) were limited to a band less than 16 km wide centered approximately between the 17° and 18°C surface isotherm. Of interest is the fact that the band of fast moving surface water flowed just inside the periphery of the advected cold-water features shown in the satellite imagery. (The arrows in Figure 8 represent the sonobouy drift data analyses.)

Comparing the average drift speed of the sonobuoys ($\geq$ 1.2 m/sec) at the periphery with the average advective speed of the cold-water feature (0.4 m/sec) gives an indication of the differences between the surface currents and the translation speed of the cold features in the area of the Marbella Lines. As the features were advected around the gyre, these differences were reduced. Examination of the sonobuoy-based current data dropped in the neighborhood of Alboran Island on 18 October and the advected speeds derived from the 18 and 19 October imagery reveals that while the sonobuoy drift speeds decreased sharply from the velocities found south of Marbella, the translation speed of the features remained essentially the same.

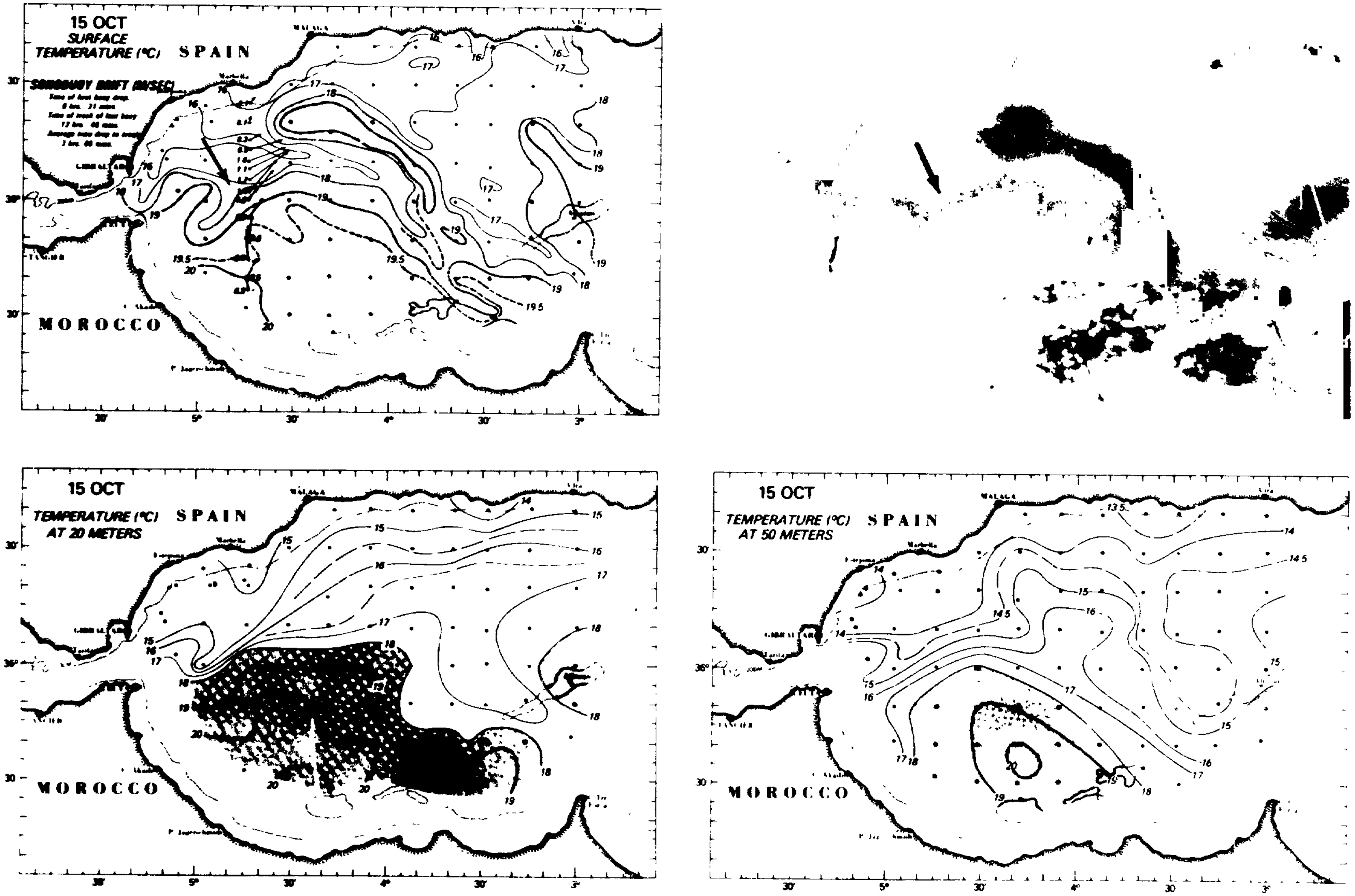


Figure 8. Aircraft data analysis for surface, 20, and 50 m and the morning NOAA-7 infrared imagery for 15 October. The surface aircraft data was derived from a precision radiation temperature sensor whereas the subsurface was derived from more widely spaced data obtained from aircraft expendable bathy thermographs. The arrows represent the initial drop position and drift rate and direction of sonobouys dropped on 15 October. The large arrow marks the position of the cold water feature seen in both the PRT analysis and the satellite image (La Violette, 1984).

5. CONCLUSIONS

The above discussion and data analyses were liberally extracted from La Violette (1983) and La Violette (1984). It is suggested that the reader refer to these studies for a more extensive analysis. From the brief discussion presented here, it is shown by the satellite data that, rather than being a simple linear flow angled into the Alboran Sea from the Strait of Gibraltar, the incoming Atlantic water and the continuously generated cold-water features east of Gibraltar are linked.

The complexity of the data together with the rapid change in conditions show why any regional current study must be accompanied by horizontal and vertical data. In this study remote sensors aboard satellite and aircraft provided this data, with the aircraft XBT also providing temperature information down to 350 m. In comparison, the satellite and aircraft data show the close relationship of the surface and subsurface waters down to 20 m and greater (Figure 8). Thus, the data indicates that the structural displays of thermal gradients shown by the satellite imagery may be reliably used as indications of conditions in the near-surface layers.

The purpose of this paper is to show that satellite data may be used as a reliable, quantitative input to an integrated ocean data set. Emphasis has been placed on understanding the oceanography of the region and knowing the limitations of the satellite data. Other basic concepts such as computer techniques are required if the data are to be quantitatively used. Certainly, atmospheric corrections provide a reliability of the thermal values presented in the imagery. This, in turn, provides a continuity that can be expanded to thermal data from other sources. Proper registration is also extremely useful in allowing several days of data to be studied as a temporal continuity.

As the study presented has attempted to show, the exploitation of satellite imagery in conjunction with other data sources can provide an imaginative investigator with a powerful analytical tool to study the ocean.

6. REFERENCES

Cheney, R. E. and R. A. Doblar, 1982. Structure and Variability of the Alboran Sea Frontal System. J. Geophys. Res. v. 87, n. C1, p. 585-594.

Cheney, R. E., 1978. Recent Observations of the Alboran Sea Frontal System. J. Geophys. Res., v. 83, n. C9, p. 4593-4597.

Cheney, R. E., 1977. Aerial Observations of Oceanic Fronts in the Western Mediterranean Sea. Technical Note 3700-69-77, U.S. Naval Oceanographic Office, Washington, D.C., July, 23 p.

Clark, R. and P. E. La Violette, 1980. The Detection of Moving Oceanic Fronts Using Successive TIROS-N Imagery. Geo. Res. Lett., v. 8, n. 3, p. 229-232.

Crepon, M., 1965. Influence de la pression atmospherique sur le niveau moyen de la Mediterrane occidentale et sur le flux a travers le detroit de Gibraltar. Presentation d'observations, Cah. Oceanogr. v. 17, n. 1, p. 14-32.

Frassetto, R., 1960. A Preliminary Survey of Thermal Microstructure in the Strait of Gibraltar. Deep Sea Res. v. 7, n. 3, December, p. 152-162.

Gallagher, J. J., M. Fecher and J. Gorman, 1981a. Project HUELVA - Oceanographic/Acoustic Investigation of the Western Alboran Sea. Naval Underwater Systems Center Technical Report 6023. 106 p.

Gallagher, J. J., M. Philippe and B. Wannamaker, 1981b. Satellite Monitoring of Ocean Temperature Variability in the Mediterranean Sea. Oceanography from Space. J.F.R. Gower (Editor), Plenum Press, NY, p. 175-182.

Holyer, R. J. and P. E. La Violette, 1983. The Use of Principal Components Analysis Techniques on Nimbus-7 Coastal Zone Color Scanner Data to Define Mesoscale Ocean Features through a Warm, Humid Atmosphere. Naval Ocean Research and Development Activity Report No. 60. (In preparation)

Hovis, W. A., D. L. Clark, F. Anderson, R. W. Austin, W. H. Wilson, E. T. Baker, D. Ball, H. R. Gordon, and J. L. Mueller, 1980. Nimbus-7 CZCS: System Description and Initial Imagery. Science v. 210, p. 60-63.

Hussey, W. J., 1979. The TIROS-N/NOAA Operational Satellite System. NOAA NESS Tech. Memo. 95, National Environmental Satellite Service/NOAA, Washington, D.C., 35 p.

Kinder, T. H., 1983. Donde Va? An Oceanographic Experiment Near the Straits of Gibraltar. Proceedings of IAPSO/ONR/NFKO Workshop on Straits Inst. Phy. Ocean., Copenhagen, Den.

Lacombe, H., 1961. Etude Hydrologique et Dynamique du Detroit de Gibraltar, Mai-Juin, 1961. Compte-Rendu Preliminaire. Cahiers v. 13, n. 7, July-August, p. 431.

Lacombe, H. and P. Tchernia, 1971: Caracteres Hydrologiques et Circulation des Eaux a Mediterranean. The Mediterranean Sea: A Natural Sedimentation Laboratory, D. V. Stanley, (Editor), p. 25-36.

Lanoix, F., 1974. Project Alboran. Etude Hydrologique et Dynamique de la Mer D'Alboran. NATO Technical Report 66, 39 p. and 32 figures.

La Violette, P. E., 1983. Short-term Measurements of Surface Currents Associated with the Alboran Sea Gyre during Donde Va?. EOS, v. 64, n. 18, p. 248.

La Violette, P. E., 1984. The Advection of Submesoscale Thermal Features in the Alboran Sea Gyre. JPO (In press)

La Violette, P. E. and J. Kerling, 1983. An Analysis of Aircraft Data Collected in the Alboran Sea during Donde Va? 6 through 18 October 1982. NORDA Tech. Note 222.

La Violette, P., T. H. Kinder, R. Preller, and H. E. Hurlburt, 1982. Donde Va?: A Mesoscale Flow Dynamics Experiment in the Straits of Gibraltar and Alboran Sea. XXVIIIth Congress and Plenary Assembly of ICSEM, Cannes, France, December 2-11, 1982. (In proceedings)

McClain, E. P., W. G. Pichel, C. C. Walton, Z. Ahmad, and J. Sutton, 1982. Multi-channel Improvements to Satellite-Derived Global Sea Surface Temperatures. XXIV COSPAR Meeting, Ottowa, Canada, May 1982. (In proceedings)

Peluchon, G. and J. R. Donguy, 1962. Travaux Oceanographiques de la 'ORIGNY' dans le Detroit de Gibraltar (Mai-Juin, 1961). Etude des Courants Superficiels dans le Detroit de Gibraltar en Relation Avec la Temperature de Surface. Cahiers Oceanographiques, v. 14, n. 9, November, p. 626-632.

Philippe, M. and L. Harang, 1982. Surface Temperature Fronts in the Mediterranean Sea from Infrared Satellite Imagery. Hydrodynamics of Semi-enclosed Sea by J.C.J. Nihoul (Editor), Elsevier, Amsterdam, p. 91-128.

Preller, R. and H. E. Hurlburt, 1982. A reduced gravity model of circulation in the Alboran Sea. In Hydrodynamics of Semi-enclosed Seas. J.C.J. Nihoul (editor), Elsevier, p. 75-90.

Schwalb, A., 1978. The TIROS-N/NOAA A-G Satellite Series. National Environmental Satellite Service. NOAA, Washington, D.C., March, NOAA Tech. Memo. NESS 95, 75 p.

Wannamaker, B., 1979. The Alboran Sea Gyre: Ship, satellite and historical data. SACLANT ASW Research Centre Report SR-30. 27 p.