# The Origin and Characteristics of the Algerian Current

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13. Abstract *(Maximum 200 words).* Satellite and ship data collected between May 1 and 22, 1986, show that the Algerian Current originates in the Almeria-Oran Front and remains within 30 km of the Algerian coast for over 300 km, between Oran and Algiers. The differences between the water masses of the current and the resident regional waters are clearly observed in the chlorophyll concentrations and optical characteristics, thus permitting the resulting patterns to be used as tracers of the circulation. During this field period, the Algerian Current begins as an extension of the Almeria-Oran Front, which is found at the western periphery of the Eastern Alboran Gyre. This major oceanographic salinity front ($\Delta S > 1$/km) delineates the boundary of the Algerian Current, which has average surface velocities of 40cm/s and maximum speeds reaching 80 cm/s. The current, which has a volume transport between 0.4 and 0.5 Sv, is confined to the upper 150 m and is in geostrophic balance. A sequence of coastal zone color scanner (CZCS) and advanced very high resolution radiometer (AVHRR) satellite imagery showing the rapidly evolving surface circulation features is augmented with in situ ship data of current and water mass characteristics. Rapid undulations and frontal movements of the current were observed during the study period; however, the flow remained unbroken

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# The Origin and Characteristics of the Algerian Current

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Satellite and ship data collected between May 1 and 22, 1986, show that the Algerian Current originates in the Almeria-Oran Front and remains within 30 km of the Algerian coast for over 300 km, between Oran and Algiers. The differences between the water masses of the current and the resident regional waters are clearly observed in the chlorophyll concentrations and optical characteristics, thus permitting the resulting patterns to be used as tracers of the circulation. During this field period, the Algerian Current begins as an extension of the Almeria-Oran Front, which is found at the western periphery of the Eastern Alboran Gyre. This major oceanographic salinity front ($\Delta S > 1$/km) delineates the boundary of the Algerian Current, which has average surface velocities of 40 cm/s and maximum speeds reaching 80 cm/s. The current, which has a volume transport between 0.4 and 0.5 Sv, is confined to the upper 150 m and is in geostrophic balance. A sequence of coastal zone color scanner (CZCS) and advanced very high resolution radiometer (AVHRR) satellite imagery showing the rapidly evolving surface circulation features is augmented with in situ ship data of current and water mass characteristics. Rapid undulations and frontal movements of the current were observed during the study period; however, the flow remained unbroken between 1° and 3°E. Current instability increased eastward as the undulations were sharper and the current appeared to depart from the coast near Algiers.

## INTRODUCTION

Satellite imagery of the western Mediterranean Sea collected over the last decade indicates a much more complex surface circulation than suggested by *Ovchinnikov* [1966]. *Arnone and La Violette* [1986] and *Millot* [1985, 1987*a*] observed that the surface circulation in the western Mediterranean is composed of an interconnecting series of anticyclonic gyres that propagate eastward along the northern coast of Africa. The Atlantic Water (AW) entering the Alboran Sea forms two anticyclonic gyres: the Western and Eastern Alboran Gyres (Figure 1) [*Lanoix*, 1982; *Parrilla et al.*, 1986; *Wiesenburg and Arnone*, 1986; *Tintore et al.*, 1988]. As the AW moves eastward, it mixes with the deeper Levantine Intermediate Water (LIW), forming Modified Atlantic Water (MAW), which typically has salinities of 36.5 and temperatures of 16°C during March [*La Violette*, 1986]. The temporally changing size and shape of the Western Alboran Gyre can occupy the entire western Alboran Basin of 200 km across to less than one-half that size [*Lanoix*, 1982; *Arnone and Oriol*, 1986; *Perkins and Pistek*, this issue; *Heburn and La Violette*, 1987; *Perkins et al.*, 1990]. In the area of Cape Tres Forcas the second anticyclonic Eastern Alboran Gyre is formed (Figure 1). Little has been reported about this second gyre. Previous results of *Lanoix* [1982] showed the absence of this gyre and that the flow was continuous along the southern region between Cap Tres Forcas and Oran. However, repeated observations of satellite imagery show that the Eastern Alboran Gyre "typically" extends across the entire basin (250 km in diameter). Time-sequential thermal infrared (IR) satellite imagery for October 1982 and May 1986 used in the present study indicates rotational speeds of approximately 40 cm/s.

The boundary of the Eastern Alboran Gyre that extends between Almeria and Oran, named the Almeria-Oran Front [*Wiesenburg and Arnone*, 1986; *Tintore et al.*, 1988], separates MAW from the denser, more saline surface waters ($S >$ 37.6 psu) of the interior Western Mediterranean Basin. In the vicinity of Oran, the current splits into a westerly component, which completes the gyre, and into an easterly component, which forms a strong easterly current along the Algerian coast (Algerian Current).

The eastward flowing Algerian Current boundary appears in the imagery as a continuous undulating ocean feature lying within 30 km of the Algerian coast. At approximately 3°E, offshore of Algiers, the regular undulations transition to irregular anticyclonic eddies. Farther east, the Algerian Current is not clearly defined as a continuous flow, but rather as a series of eddies that detach from the African coast and migrate several hundred kilometers offshore into the center of the western Mediterranean [*Perkins and Pistek*, this issue; *Millot*, 1987*a*, *b*]. These eddies increase in diameter as they propagate eastward, evolving from diameters of approximately 30 km to 100 km [e.g., *Millot*, 1985; *Arnone and La Violette*, 1986]. Satellite imagery also indicates that cold, chlorophyll-rich waters characteristic of upwelling regions are present in this current/eddy system [*Arnone and La Violette*, 1986].

In this paper we examine the Algerian Current from its beginning as an extension of the Almeria-Oran Front to its conclusion in unstable eddy shedding near Algiers. Our objective is to characterize the temporal and spatial structure of the Algerian current and the mechanisms that control it by integrating ship measurements with concurrent satellite imagery. We will show that the distribution of bio-optical properties found on the surface layers is closely coupled to the physical processes related to the current and may be used as tracers of the circulation.

## CRUISE OPERATION AND DATA ANALYSES

### *Shipboard Data Collection*

An oceanographic cruise was conducted aboard the USNS *Lynch* from May 1 to 21, 1986, to investigate the Almeria-

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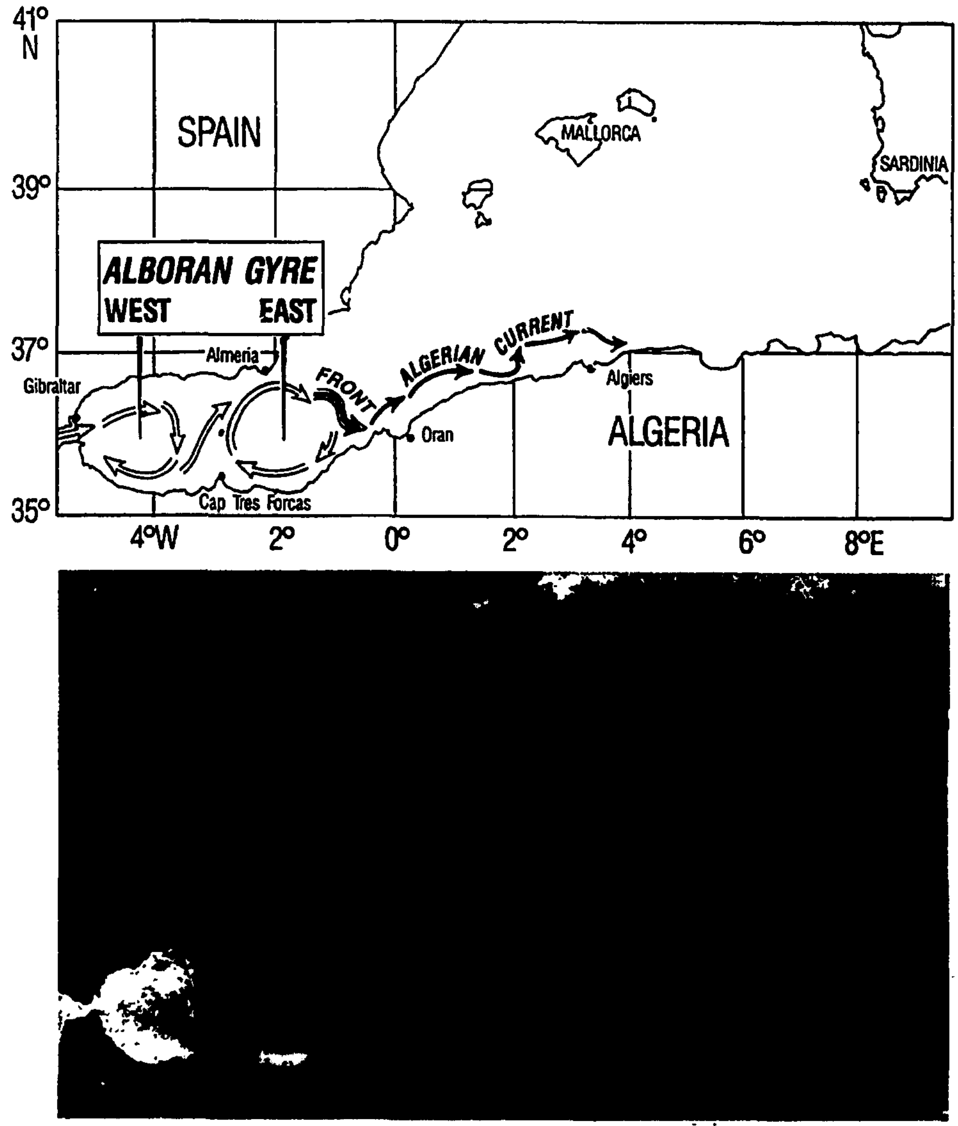


Fig. 1. (Top) Schematic diagram of the surface flow field in the Alboran Sea and along the coast of Algeria. (Bottom) NOAA 9 thermal IR image of the western Mediterranean from the Strait of Gibraltar to the Strait of Sicily collected May 12, 1986. The data are from channel 4 (10.5 μm); the dark tones are warmer temperatures, and white tones are colder temperatures.

Oran Front and associated flow of the Algerian Current. The Almeria-Oran Front was surveyed at both the beginning and the end of the field study to observe temporal changes that occurred during the 3-week period. Along the African coast, nine meridional transects at 30-min increments were made beginning at 1°W and ending at 3°E (Figure 2). Each transect began 25 km from the Algerian coast and ended in the regional resident waters located 80 km to the north.

Vertical profiles of conductivity, temperature, and chlorophyll fluorescence were collected at 43 stations (Table 1). These measurements were made with a Neil Brown Instruments, Inc., Mark IIIB conductivity-temperature-depth (CTD) unit interfaced to a SeaMarTech model 6000 in situ fluorometer. Although vertical profiles were made to 1000 m, only the upper 100 m will be discussed here, since we are concerned with characterizing the regional surface properties. Water samples were obtained at 17 discrete depths at each station, and the chlorophyll concentrations were determined by the method of *Smith et al.* [1981].

Surface measurements (upper 2 m) of conductivity, temperature, and light transmission were also made continuously along several transects using a towed instrument package [*Rein et al.*, 1985; *Arnone and Wiesenburg*, 1988]. This towed system includes Sea Bird, Inc., temperature and conductivity sensors and a SeaTech, Inc., beam transmissometer. The sensor package was towed at 8 kn (about 4.2 m/s), and data were collected every 12 s, which equates to one measurement every 50 m. The beam transmissometer measured the percent light transmission at 670 nm across a 25-cm path length.

Current velocity measurements were made continuously using an RD Instruments, acoustic Doppler current profiler (ADCP). The ADCP recorded 14-min averages of 75 depth increments from the surface to approximately 150 m. The

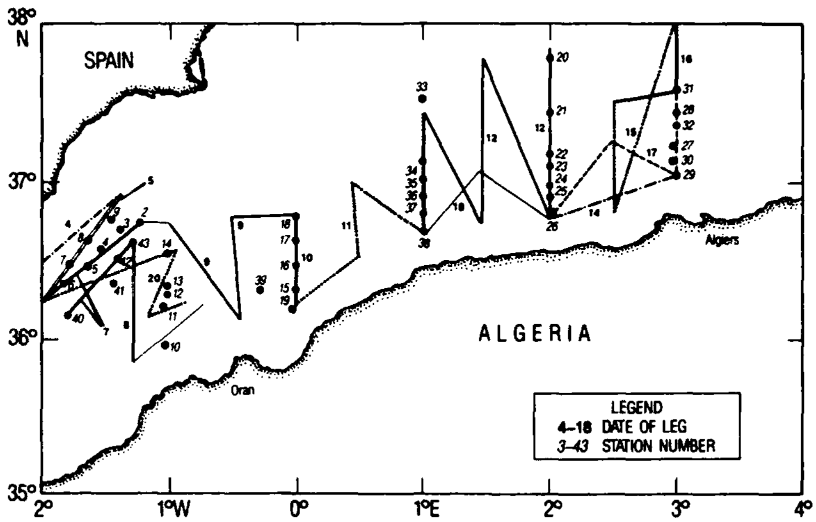


Fig. 2. Chart illustrating the station location (numbers in italics) and surface transect legs in the western Mediterranean. The numbers of the transect legs correspond to the date in May 1986 that the transect was surveyed (i.e., May 9, 1986, is labeled 9).

system interfaces with ship navigation and computes $u$ and $v$ components of velocity to a resolution better than 5 cm/s. These data were available in near real time to aid in station selection.

### *Satellite Data Processing*

During the field study, NOAA 8 and NOAA 9 advanced very high resolution radiometer (AVHRR) IR satellite data were received at a ground station located at the Naval Ocean Research and Development Activity (NORDA) (now Naval Oceanographic and Atmospheric Research Laboratory) in Mississippi. These images were calibrated, enhanced, and transmitted via INMARISAT to the USNS *Lynch* at sea. The registered IR imagery provided the location of ocean features to the shipboard scientists in near real time, allowing them to optimally select the ocean sampling strategy.

For the postsurvey analysis of the field data, a total of 40 daily AVHRR images was remapped to a standard Mercator projection with particular concern given to proper registration. The AVHRR images in this study were taken from channel 4, since the small temperature gradients in the Mediterranean are not clearly defined by the multichannel sea surface temperature (SST) algorithm [*La Violette and Holyer* [1988]. All thermal imagery has been processed such that warmer waters are dark, and the colder waters are white.

Complementing AVHRR, ocean color images were collected for this experiment during the final weeks of operation of the Nimbus 7 coastal zone color scanner (CZCS). (The CZCS stopped operation June 14, 1986.) Approximately 40 CZCS images were collected from April, May, and June 1986 and processed using the atmospheric correction algorithms by *Gordon* [1978] and *Gordon et al.* [1983]. The images were processed to represent distributions of phytoplankton pigment concentration (chlorophyll *a* and phaeophytin) [*Gordon and Clark*, 1980]. The resulting satellite-derived chlorophyll concentration was shown to be very closely correlated with ship measurements [*Lohrenz et al.*, 1988*a*, *b*].

Ocean color imagery is responsive to biological processes in the surface ocean. The color signature results from the absorption and scattering of radiation in the first attenuation length [*Gordon and McCluney*, 1975]. For MAW and surface Mediterranean waters, the depth of one attenuation length is approximately 10 and 20 m, respectively. Thus the resulting water-leaving radiance sensed by CZCS is related to the first 10–20 m of the water column and is not influenced by the afternoon solar heating problems of the first centimeters that occur in the thermal IR imagery.

The ocean color signature represents biological differences in the upper water column and provides a method of differentiating water masses with differing biohistories. This is advantageous in Mediterranean waters, since the major

TABLE 1. Summary of Data Collected During USNS *Lynch* Cruise 705–86

| Date | Station* | Towed Transit Number | Area Covered |
|---|---|---|---|
| May 1–8 | 2–9 | 4, 5, 7 | Almeria-Oran Front |
| May 8–9 | 10–14 | 8 | 1°W, section (N/S) |
| May 10–12 | 15–19 | 10 | 0°, section (N/S) |
| May 12–15 | 20–26 | 12 | 2°E, section (N/S) |
| May 16–18 | 27–32 | 16, 17 | 3°E, section (N/S) |
| May 18–20 | 33–38 | 11, 12, 18 | 1°E, section (N/S) |
| May 21 | 41–43 | 20 | Almeria-Oran Front |

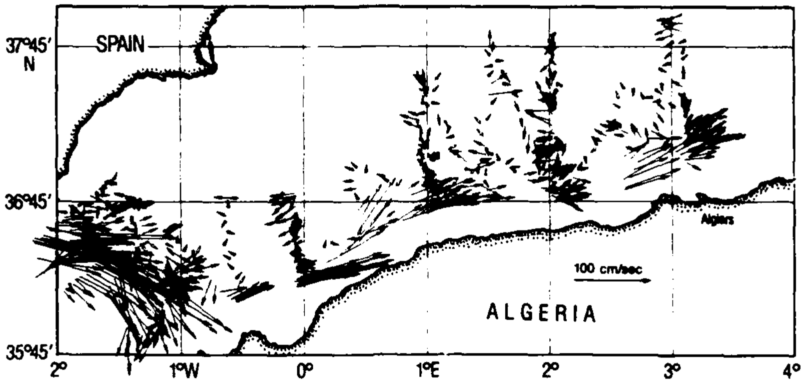


Fig. 3. Vector representation of ADCP data from a depth of 10 m is illustrated for the entire 3-week experiment. The arrows are averages of data collected every second for 14 min. The Algerian Current reached speeds of 80 cm/s at 0°E longitude.

changes in the current field are a result of salinity, not temperature variations. Thus by coupling the bio-optical water properties with salinity and velocity measurements, we can describe the circulation in this region using ocean color distribution to complement the more subtle temperature distributions.

## RESULTS AND DATA INTERPRETATION

### *Surface Currents (Acoustic Doppler)*

The regional surface circulation for May 1–22 is defined with 10-m current vectors (Figure 3) derived from instantaneous Doppler profiler measurements. These measurements graphically demonstrate the existence of strong southeastward flow along the Almeria-Oran Front (average speeds of 40 cm/s and maximum speeds of 60 cm/s), with further amplification along the Algerian coast (maximum speeds of 80 cm/s). In the vicinity of Oran, a partial separation in the flow is observed with a portion moving westward to complete the Eastern Alboran Gyre. Most of the flow, however, continues eastward, staying within 30 km of the coast. A continuous current front, defining the separation of MAW and Mediterranean surface water, extends along the Almeria-Oran Front and along the African coast for 300 km.

For comparison with the ADCP current vectors, dynamic heights at the surface were calculated for all 43 stations using a 500-m reference depth. The contoured dynamic topography (Figure 4) indicates substantial agreement with measured surface currents. ADCP current measurements provide the basis for interpreting satellite imagery. Direct comparison of Figure 3 with individual satellite images requires near-synoptic satellite and velocity measurements, since frontal features in this region were changing from day to day. The 3-week composite of the velocity vectors is best compared with the satellite sequence (Plates 1 and 2). To facilitate direct satellite comparison, however, a subset of ADCP vectors have been overlaid on the May 11 satellite image.

### *Satellite Imagery*

Several-day sequences of thermal IR and CZCS ocean color images are presented in Plates 1 and 2.

The thermal character of the Algerian Current, especially at the Almeria-Oran Front, changes in the sequence of IR images. MAW of the Eastern Alboran Gyre and the Algerian Current are warmer than the Mediterranean surface waters to the northeast in the April 30 and May 1 images. This temperature distribution begins to change on May 2. By May 10 the cooler Mediterranean surface waters have warmed to

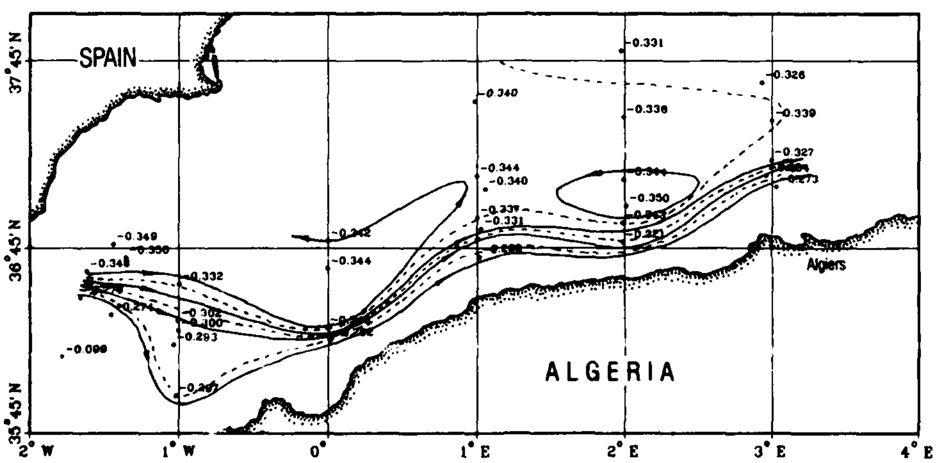


Fig. 4. Surface dynamic height field calculated from the 43 stations using the 500-m surface as the reference surface. These contoured results indicate a geostrophic approximation that closely resembles the ADCP velocity field.

a temperature similar to that of the Eastern Alboran Gyre and the Algerian Current. Note that the thermal gradients across the Algerian Current are not well defined.

The ocean color patterns clearly define the boundaries of the Algerian Current (Plate 2) and imply flow direction. The distribution of high pigment concentration areas agrees well with the ADCP current velocity distribution.

The changes in pigment concentration shown in this sequence indicate that April 27 and 30 had higher phytoplankton concentrations than the days in May that followed. It can be postulated that strong wind events occurring in the last days of April (not shown) are responsible for mixing the surface waters. Such mixing entrains nutrients into the surface waters and results in increased primary production [*Lohrenz et al.*, 1988*a*] and elevated levels of chlorophyll as detected in CZCS imagery. As calm sea conditions developed during the first week in May, the surface water column stabilized, and mixing decreased.

### *Almeria-Oran Front*

Some characteristics of the Almeria-Oran Front are best observed in thermal and ocean color satellite imagery sequences. Sequences of these images show rapid local variations and evolution of anticyclonic eddies, which suggest flow instabilities at the frontal boundary. The near-symmetrical 72-km-diameter anticyclonic eddy seen in early May is defined in the imagery by cooler, chlorophyll-rich water encircling a warmer MAW core. By May 10 the eddy boundary is advected into the main core of the Algerian Current, and a perturbation of the frontal boundary is observed downstream in the image. The position of the Almeria-Oran Front, as defined by both ocean color and temperature, progresses eastward (25 km) in early May, and then retreats westward in late May.

CTD stations were occupied across the Almeria-Oran Front to assess the vertical extent of the front. Stations 40–43 (Figure 2) show distinctive water mass separation characterized by the temperature salinity (TS) relationship (Figure 5*a*). Stations 40 and 41 are representative of MAW waters ($\sigma_t$ = 27), while stations 42 and 43 are characteristic of Mediterranean surface water ($\sigma_t$ = 28). The vertical TS profiles merge at a $\sigma_t$ of 28.75 at 200 m; below this depth, similar water mass characteristics occur at both sets of stations. The MAW at station 40 extends to 200 m. Similar results were observed for other stations at the Almeria-Oran Front.

Cross sections of temperature, salinity, and chlorophyll concentrations (to a depth of 100 m) across the Almeria-Oran Front were collected on May 1 and 2 (Figure 6) and on May 19 and 20 (Figure 7). In both sections, salinity clearly characterizes the abruptness of the front. The surface salinity gradient is shown as approximately 2 psu within a 2-km distance.

The early May section (Figure 6) does not reveal as strong a salinity gradient near the surface as in late May (Figure 7), although the subsurface structure (>60 m) is similar. This difference suggests that the subsurface structure is more persistent than the variable surface frontal boundary.

From data collected in early and late May, the salinity structure across the Almeria-Oran Front remained the same, but surface waters showed a net increase in temperature. MAW increased from 16° to 19° during this period, while

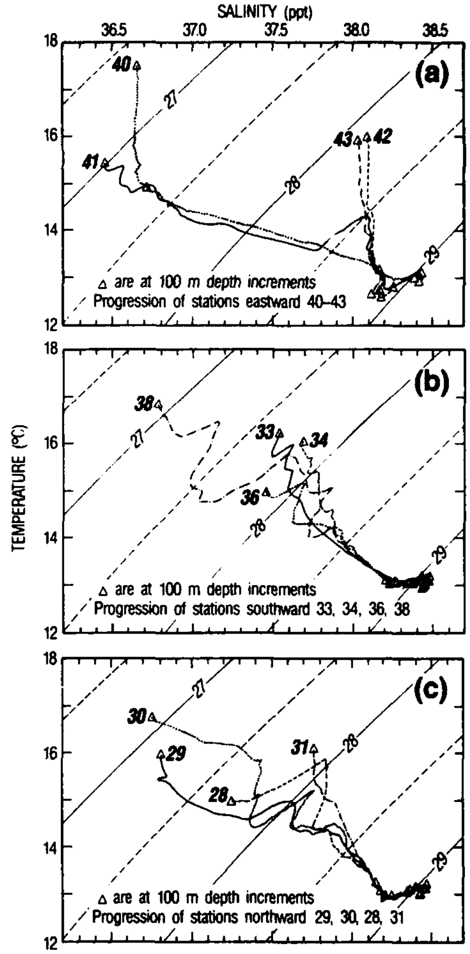


Fig. 5. Plots of temperature versus salinity at stations (*a*) across the Almeria-Oran Front, (*b*) at 1°E, and (*c*) at 3°E. Data are plotted from the surface to 1000-m depth with a triangular marker every 100 m.

surface Mediterranean waters increased from 15° to 18°. The temperature increase in mid-May not only is observed at the surface but is also observed throughout the upper 100 m. A similar increase in the surface temperature was observed in the thermal satellite sequence shown in Plate 1.

The changes in chlorophyll cross sections collected in early and mid-May (Figures 6*c* and 7*c*) are apparently due to the presence of an anticyclonic eddy, which is observed in the surface waters in early May. The early May section shows surface chlorophyll concentrations of 0.40 mg/m$^3$ in MAW waters, increase to 0.85 mg/m$^3$ at the eddy interior (stations 3 and 4). Continued increase in chlorophyll to 1.3 mg/m$^3$ is observed at the eastern boundary (station 2) of the eddy. Similar high chlorophyll distributions associated with frontal eddies are shown in the April 30 CZCS imagery (Plate 2). A chlorophyll maximum occurs at 40 m within the eddy center (station 3). The chlorophyll maximum slopes down the vertical density gradient between stations 4 and 5.

The chlorophyll cross section for mid-May (Figure 7*d*) shows a reduced surface chlorophyll gradient (0.2–0.3 mg/m$^3$) and a complex subsurface maximum at the frontal location. Within the frontal zone (station 41), the chlorophyll maximum occurred at 30 m. The downward extension of the isopleths between stations 41 and 42 is suggestive of downwelling along the isopycnal surface. Downwelling in this

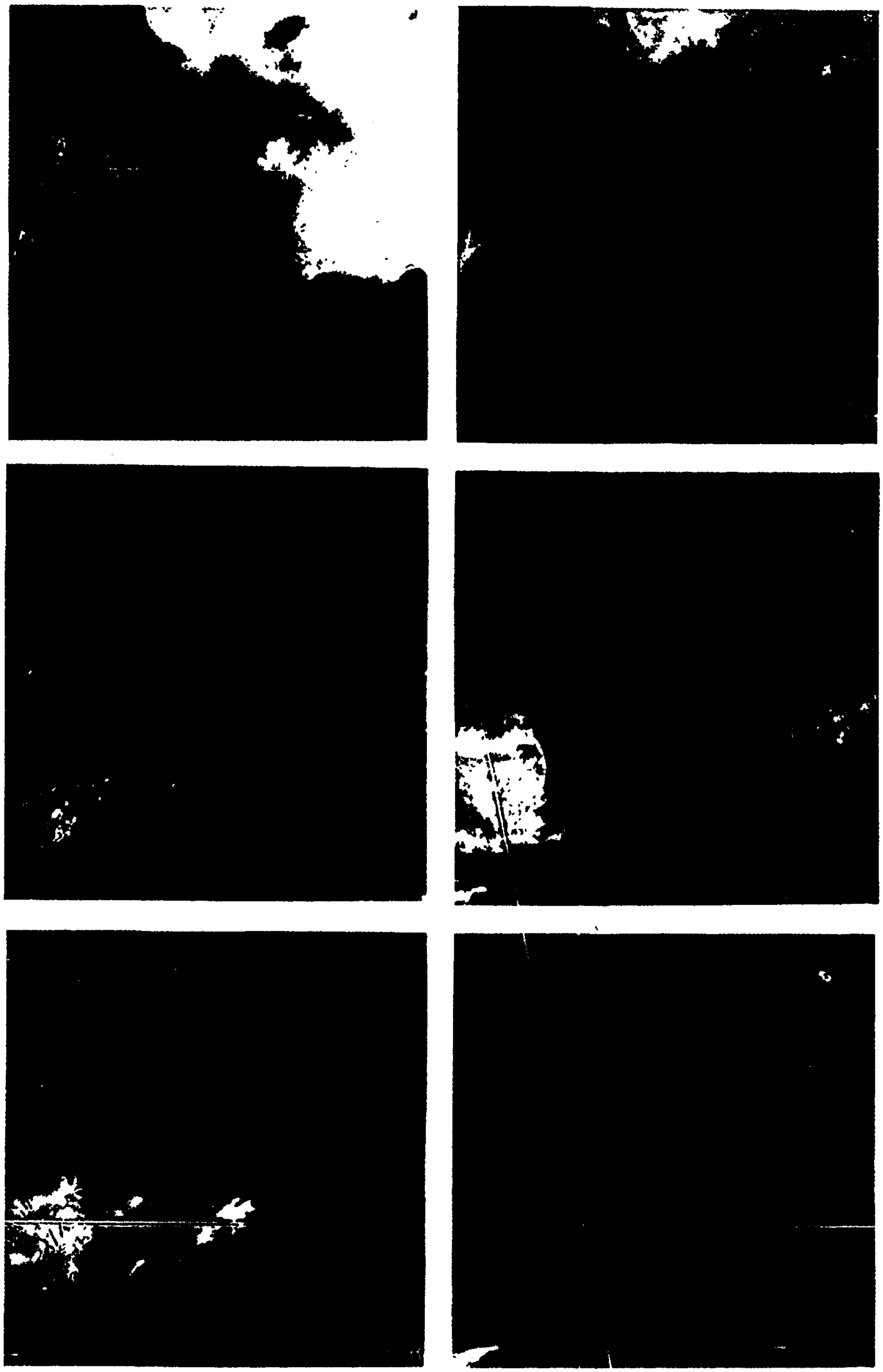

Plate 1. Sequence of AVHRR thermal IR images of the temporal origins of the Algerian Current. The May 11 image has the ADCP current vectors superimposed, and the May 12 image shows station locations.

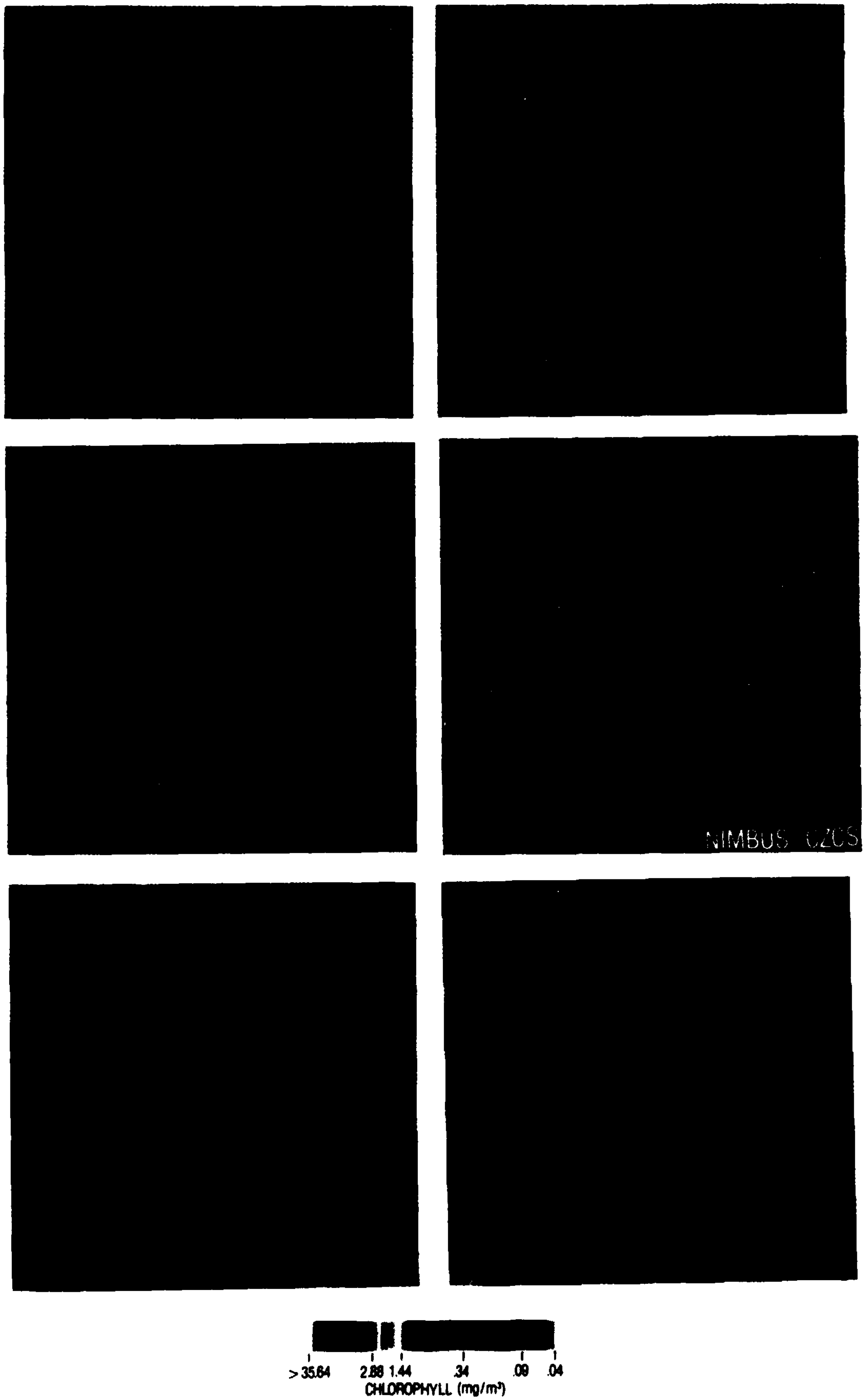


Plate 2. A sequence of CZCS imagery representing phytoplankton pigment concentration for a time period similar to Plate 1 shows a strong biological coupling with the circulation at the origins of the Algerian Current. A nonlinear calibration wedge of the chlorophyll concentration is displayed at the bottom of the plate. ADCP current vectors and station locations are superimposed on May 11 and May 12 images, respectively.

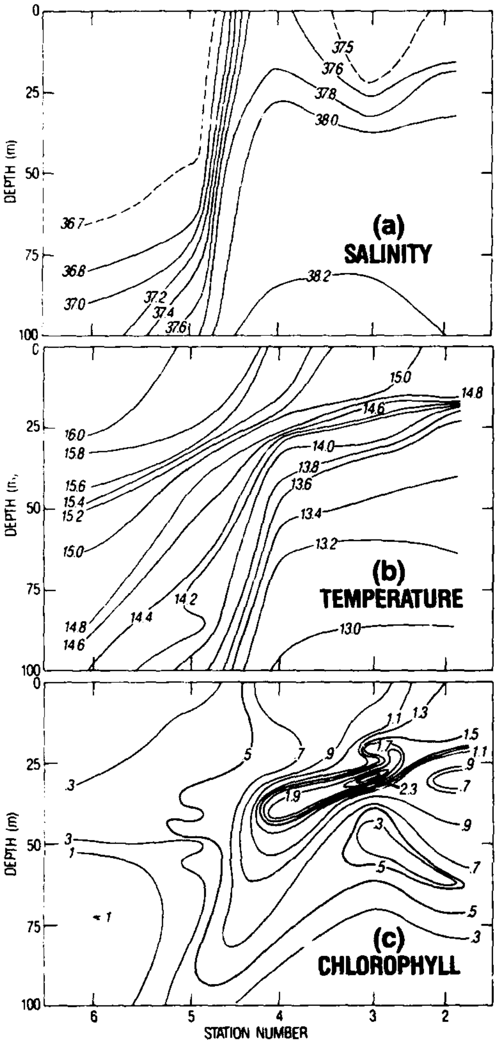


Fig. 6. Contour of station data of the upper 100-m depth across the Almeria-Oran Front for (*a*) salinity, (*b*) temperature, and (*c*) chlorophyll collected in early May.

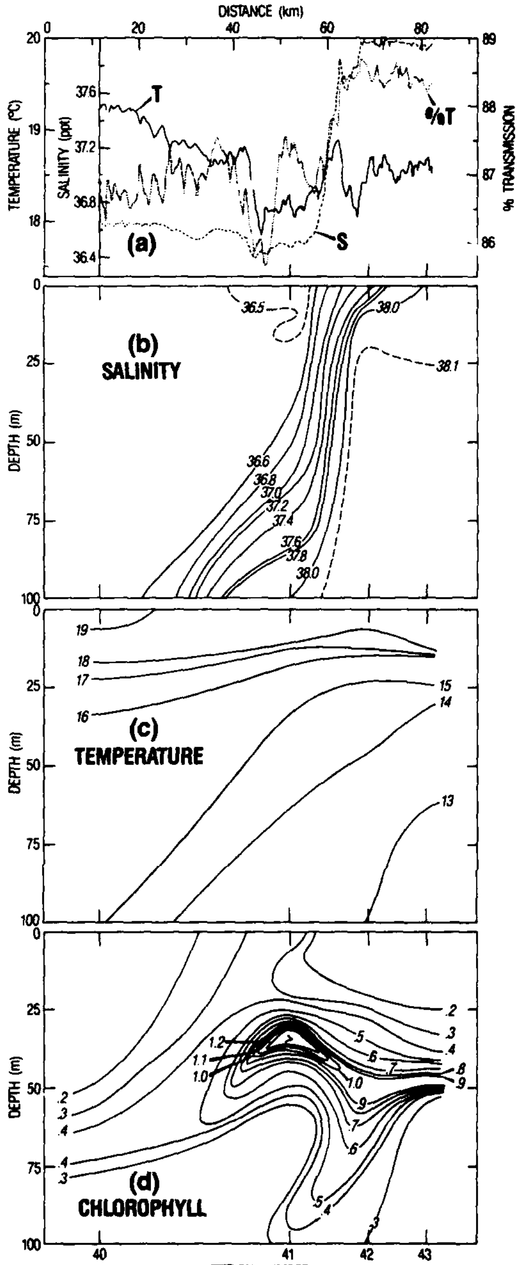


Fig. 7. (*a*) Surface transect of temperature, salinity, and percent transmission across the Almeria-Oran Front made with a towed instrument system, and contour of station data (40–43) for (*b*) salinity, (*c*) temperature, and (*d*) chlorophyll, which were collected along the same transect in mid-May.

transect has been confirmed based on the high levels of photochemically produced hydrogen peroxide that were observed at depth [*Johnson et al.*, 1988].

Surface salinity, temperature, and percent transmission from the towed instrument package show marked differences across the frontal system. Similar characteristics are observed between the optical properties (percent transmission) and the chlorophyll concentrations in MAW and Mediterranean waters. Similar distributions of surface bio-optical properties and salinity are observed at other frontal regions and are believed to be associated with frontal circulation (convergence, divergence) and internal cross-frontal motion [*Prieur et al.*, 1981; *Lohrenz et al.*, 1988*b*].

### *Algerian Current East of the Almeria-Oran Front*

*Satellite imagery.* In the April and early May imagery (Plates 1 and 2), the Algerian Current transports an elongated, horizontal, warmer water mass with high chlorophyll content adjacent to the Algerian coast. The front between the MAW and Mediterranean surface water is well defined by the chlorophyll concentration; however, the surface temperature gradient is weak. The sequence of imagery shows further (2-week period) development of undulations in the horizontal flow along the coast. Additionally, by May 12 the satellite sequence shows that the temperature character of the Algerian Current system in comparison with the resident water has reversed: the MAW is represented by cooler temperatures compared with the Mediterranean surface waters. The chlorophyll character, however, remains relatively unchanged through the sequence, i.e., MAW was higher in concentration.

Along the Algerian coast, CZCS imagery indicates that small localized areas of elevated chlorophyll levels occur at the coast and extend directly northward for 10 to 30 km before being advected eastward into the main flow field of the current. These nearshore, chlorophyll-rich areas can also be seen in the thermal images as colder waters and are probably an indication of upwelling. Two of these areas are located at the coast at 0°40′E and at 2°E. Comparison of the position of these rich coastal chlorophyll areas in the CZCS and AVHRR imagery sequences indicates eastward migration of these regions down the Algerian coast at a speed of 2 km/d. Similar features have been observed in other CZCS and AVHRR imagery [*Arnone and La Violette*, 1986; *Millot*, 1987*a*].

The May 12 thermal image (Plate 1) reveals a 32-km region of slightly warmer water that undulates parallel to the cooler MAW. This warmer region is located north of the current and major salinity front as defined by cross-section data (Figures 8 and 9). These surface waters, which characterize a transition region between the two water masses, have significant subsurface structure. A gentle anticyclonic undulation is observed centered at 1°E, and a sharp cyclonic meander at 2°E. The anticyclonic feature contains colder water with elevated chlorophyll concentrations adjacent to the coast. These features are strong indicators of upwelling. In the cyclonic meander, warmer water with low chlorophyll concentrations is observed and suggests a converging downwelling water mass.

*The 1°E ship data.* The cross sections of temperature, salinity, and chlorophyll at 1°E (stations 33–38) show the MAW close to the coast (Figure 8). Steeply sloping isohalines have their strongest gradient between stations 37 and 38, where greatest current velocities are observed. The TS relationship (Figure 5*b*) shows that stations 38 and 30 are representative of MAW and have characteristics similar to those found in the Almeria-Oran Front section ($\sigma_t$ = 27). Figure 8 shows the salinity changes from 36.8 to 37.2 within 16 km across the front. The influence of the Algerian Current also extends offshore, as illustrated in the subsurface salinity signature. A 44-km transition region occurs adjacent to the major salinity front, which is north of station 37 and extends to station 35 (latitudes 36°45′N to 37°10′N). The transition region extends vertically to 100 m and is characterized by highly varying salinity differences in the upper 40 m. A doming of isohalines at station 35 extends to the surface, where a secondary salinity front is observed, with salinities increasing to 37.6. Surface salinity data from the towed system show that the two distinct fronts correspond to subsurface salinity features.

The cross section of the eastward component of velocity from the ADCP is shown in Figure 8*e*. Velocities of 40 cm/s are observed in the upper 30 m near the coast at station 38. The eastward velocities do not extend deeper than 75 m, and the eastward component of the Algerian Current is not observed north of station 35, 62 km from the coast.

The chlorophyll cross section (Figure 8*d*) shows the chlorophyll maximum (1.6 mg/m$^3$) is shallow (25 m) near the peak of the salinity dome at station 36. Farther offshore in the Mediterranean surface waters, a deep chlorophyll maximum (1 mg/m$^3$) occurs at 65 m (station 34). The chlorophyll distribution in the frontal region is indicative of upwelling, as shown in previous cross sections along the Almeria-Oran Frontal boundary. Analysis of the relationship between chlorophyll and nitrate by *Lohrenz et al.* [1988*a*] showed that the depth of the chlorophyll maximum was controlled by the nitracline depth, a confirmation of the importance of upwelling in this region.

*The 3°E ship data.* Thermal and color satellite imagery collected during May and June 1988 suggests that the Algerian Current appears to detach from the coast and become unstable at approximately 3°E. Figure 9 shows surface transect data and cross sections of salinity, temperature, chlorophyll, and current velocity from stations 28 to 32, which were collected between May 16 and 17.

The major salinity front between MAW (36.8) and Mediterranean surface water (37.4) occurs between stations 28 and 27 (37°18′N) and defines the current boundary approximately 62 km off the coast. This frontal position agrees with the offshore movement of the flow as seen in the satellite imagery.

The observed subsurface doming of isohalines at the front is similar to that shown in Figure 8. The sharply defined salinity front is also seen in the transect made with the towed instrumentation. Between stations 27 and 31 the surface salinity transect is variable compared with the Mediterranean waters to be the north and the MAW to the south. This area comprises a 20-km transition region similar to that shown for 1°E, which is bounded by sharp salinity gradients to the south and overlying the subsurface doming of isohalines. Transition regions having similar subsurface features are observed across the frontal boundaries in other cross sections, which are not presented in this study.

The ADCP current velocity cross section (eastward velocity Figure 9*e*) reveals a core of eastward flowing water that extends to 90 m between stations 29 and 28 (velocities north of station 28 are not available). The velocities were greatest at the surface, where average speeds of >30 cm/s were observed. Comparison with the 1°E cross section indicates that the current had moved offshore, had decreased in velocity, and had increased in depth. The integrated eastward transport through this section was 0.35 Sv, which is similar to that computed for geostrophic transport by *Perkins and Pistek* [this issue]. The major flow was firmly aligned with the isopycnal gradients.

Figure 9*c* shows a similar chlorophyll structure to the 1°E section with a maximum of 0.8 mg/m$^3$ located near the surface (35 m) at station 29 in MAW. A deeper chlorophyll maximum of 1.7 mg/m$^3$ is located at 75 m in Mediterranean waters. Similarly, a depression of the chlorophyll maximum is observed in the frontal zone (station 28). A dome of the chlorophyll concentrations is observed at depth between stations 29 and 30, again indicative of upwelling near the coast.

*Algerian Current transport.* The transports associated with the Algerian Current were computed from across sections of the ADCP along longitudinal section 1°W, and 0°, 1°, 2°, and 3°E (Table 2). Unfortunately, we did not approach the coast closely enough to resolve the complete eastward transport. In the two completely resolved cross sections, the current is concentrated in a near-surface core, and the 0.1 m/s isotach extends to about a 50-m depth in the west and to about a 90-m depth in the easternmost section. The estimated transports are not complete due to the limitations of the sampling but are consistent with the assumption of constant (or nearly so) transport of about 0.4–0.5 Sv in the Algerian Current to about 3°E.

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