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Circulation in the Algerian Basin During June 1986

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Hydrographic measurements, made in the Algerian Basin during June 1986 as part of the Western Mediterranean Circulation Experiment, together with satellite infrared images, are used to describe the flow of major water types in the region. Modified Atlantic Water flows eastward along the Algerian coast as the Algerian Current to 4°E, where it breaks into a series of eddies and spreads far offshore. It then flows partly northward into the Ligurian-Provencal Basin and partly eastward through the Strait of Sardinia. The subsurface Levantine Intermediate Water turns sharply northward after flowing westward through the Strait of Sardinia and forms a narrow vein along the Sardinian Coast. Winter Intermediate Water flows southward around the Balearic Islands. Its eastern branch recirculates back to the north, whereas part of the western branch contributes to the Algerian Current by flowing eastward beneath the Modified Atlantic Water. Two large, long-lived eddies are confirmed in the area. The easternmost of these, and other features with unresolved horizontal structure between Sardinia and Menorca, extend from the surface through the pycnocline.

Introduction

The Algerian Basin is that portion of the western Mediterranean lying between the Algerian coast and the Balearic Islands, bounded in the west by the Alboran Sea and in the east by the Strait of Sardinia. The measurements reported here are a component of the Western Mediterranean Circulation Experiment (WMCE) and were planned to depict the general circulation of the Algerian Basin (Figure 1). Emphasis was placed on the natural passages into and out of the basin, and on the Algerian Current (AC), which dominates the surface flow. The western portion of section 10 was made beneath a track of the GEOSAT altimetric satellite, although the comparison is not reported here. Because of constraints imposed by time and weather, depths of casts were limited to 1000 m, and some of the planned sections (e.g., section 8) were shortened.

Prior to the WMCE, oceanographic measurements in the Algerian Basin consisted of studies of subregions, or of isolated stations or sections. A comprehensive review of the mean conditions has been given by *Hopkins* [1985], and the composite of historical data used to define a seasonal climatology by *Guibout* [1987]. By contrast, the present work provides, as nearly as possible by a single-ship survey, a synoptic picture, one of many possible realizations of the region. In this description, we will follow, like the circulation itself, a predominantly cyclonic course around the basin. Results will be presented from several conductivity, temperature, and depth (CTD) sections (Figure 1) and from coincident satellite infrared (IR) images. The discussion section will place these results in historical and climatological perspective.

Several components of the WMCE partially overlap the work presented here. Most closely related are the measurements of the front between Almeria and Oran [*Arnone et al.*, this issue] and of the Algerian Current, which flows along the Algerian coast from approximately 1°W to 4°E [*Millot*, 1985]. East of 4°E, the AC has been shown to undergo an apparent instability, which leads to the growth of both cyclonic and anticyclonic eddies. Those with anticyclonic rotation become dominant and are responsible for intense lateral mixing between the inflowing Modified Atlantic Water (MAW) and the Mediterranean Surface Water (MSW) [*Millot*, 1985].

The surface flow pattern revealed by satellite IR images over a succession of summers indicates eastward moving eddies along the Algerian coast. The surface circulation during 1986 may have been unusual due to two large, slowly moving, anticyclonic eddies that dominated the interior of the basin [*Millot*, 1987*a*; *Taupier-Letage and Millot*, 1988]. However, it is possible that the eddies are common in the area, and only the conditions that make them visible in IR images are unusual. Properties of the eddies will be further described in this paper.

The waters of the Algerian Basin are characterized here by their temperature-salinity (TS) properties, which can be readily identified in TS diagrams (Figure 2). MAW is defined as having salinity less than 37.5, independent of temperature. It is derived from Atlantic water of salinity near 36 which has recently flowed eastward through the Strait of Gibraltar and has been subjected to surface fluxes, especially heating, and to mixing with Mediterranean surface water. Levantine Intermediate Water (LIW) is formed in the eastern Mediterranean and flows westward through the straits of Sicily and Sardinia. It is characterized by a salinity maximum, reaching, in station 64, the extreme values $S = 38.65$, $T = 13.85$. Adopting the terminology of *Salat and Font* [1987], Winter Intermediate Water (WIW) is the result of winter convection in the northern Catalan Sea and the Gulf of Lions, and is recognized by a temperature minimum with $T < 13.0$°C located above the LIW. Western Mediterranean Deep Water (WMDW), created by deep winter convection near the Gulf of Lions and filling the Western Mediterranean below the water types just described, lies below the depth range of the present measurements.

Instruments and Methods

Data were collected with a MK III CTD made by Neil Brown Instrument Systems, calibrated before the cruise and checked on several occasions during the cruise by bottle

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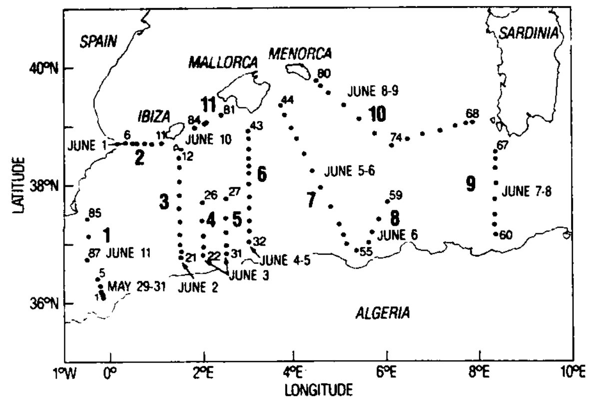

Fig. 1. Identification of CTD stations, section numbers, and dates.

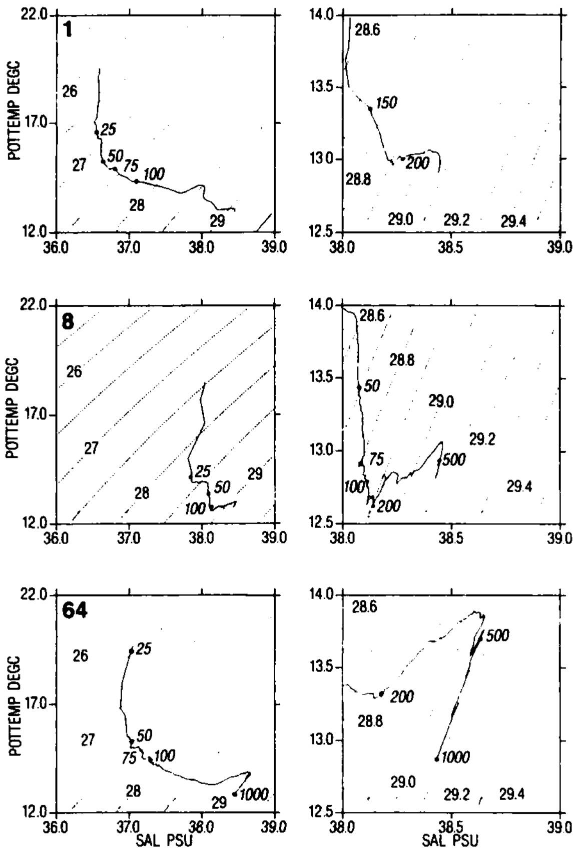

Fig. 2. TS plots for three stations showing characteristics of representative water masses. For each station, a full-depth plot is on the left, and an expanded plot of the deeper layers is on the right. Contours of sigma-theta are superimposed, and depths in meters are given at several points along each trace. Station 1 indicates MAW ($S < 37.5$) in the upper 100 m near the Algerian coast. Station 8 has a layer of WIW ($T < 13.0$) between 75 and 400 m. Station 64 illustrates the salinity maximum typical of LIW.

samples, which were analyzed on board using a Guildline model 8400A Autosal. Measurement accuracies during the cruise were within the manufacturer's specifications: pressure 6 m (dominated by hysteresis), temperature 0.005°C, and conductivity equivalent to 0.005 salinity. Casts were made to 1000 m or to within a few meters of the bottom in shallow water, as determined by an acoustic pinger attached to the wire near the CTD.

Although some preliminary data were available during the cruise, all results shown here were prepared from frequency shift keying (FSK) coded audio tapes after the cruise. Data were edited at their original resolution (30-Hz sampling), and finally reduced to 1-m resolution for final analysis. Derived quantities were obtained using the practical salinity standard and the 1980 equation of state [*Fofonoff and Millard*, 1983].

Geostrophic currents were computed relative to 1000 dbar except in section 2, where 700 m was used. The low currents typical of the deep Mediterranean make the calculated surface currents and their transports insensitive to the choice of reference depth. Shallow stations were extended downward by appending below them the profile of dynamic height of the nearest deep station. This practice yields artificial zero velocities for depths below the shallow station, but suffices to resolve the relatively vigorous near-surface currents. Diplomatic difficulties prevented stations being taken within 12 mi (~19 km) of the Algerian coast. This was especially unfortunate for sections 1 and 3–6, since, as will be seen, some of the strongest currents in the basin were found near this limit.

Satellite images, received and processed at the Naval Ocean Research and Development Activity, Mississippi, were examined for the periods May–June, whenever available during this largely cloudy period.

Observations

Atlantic Water and the Algerian Current

The AC is a prominent feature in sections 1 and 3–6. It consists largely of MAW, defined as customary by salinity less than 37.5. During these late spring sections, the MAW is also characterized by temperature 2° or 3°C lower than Mediterranean surface water, making it evident in satellite IR images. The kinematic boundary of the AC, taken here to be the 3 cm/s isotach, places the AC within 60 km of the Algerian coast in all five sections, and between the surface and 200-m maximum depth. The currents in section 1 reach their maximum at the southern limit of the section. Section 3 (Figure 3) provides the narrowest example of the AC, where it is confined between stations 19 and 20. Between these stations, maximum speeds of over 100 cm/s occur at the surface. Deeper portions of the current include the cold WIW, discussed at the end of this part of the paper.

The average geostrophic transport of MAW in these sections (Table 1) is approximately 0.4 Sv. The low transport for section 6 is somewhat artificial: much of the water is only slightly saltier than 37.5. In section 3 the surface water north of station 15, which marginally qualifies as MAW, appears to wrap around a large anticyclonic eddy (discussed later).

There is no evidence for the AC east of section 6. However, MAW is still present as a broad layer everywhere in sections 7–10 except at stations 44–48 and 75. The layer is typically 20–60 m deep but deeper in the center of the Strait of Sardinia. Surface currents associated with the MAW are too complex to be resolved by the station grid. The overall pattern supports the impression derived from satellite images; the AC evolves entirely into a series of eddies and

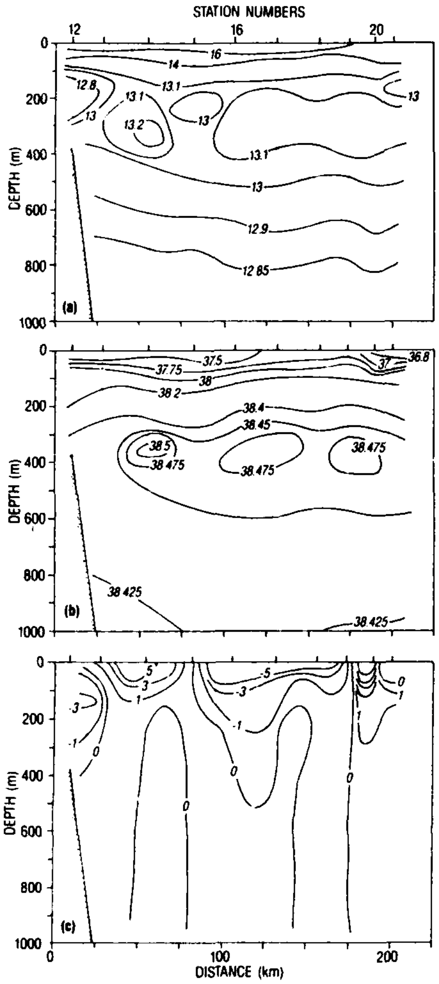

Fig. 3. CTD data along section 3 from Ibiza (station 12) southward to the Algerian coast along longitude 1°30′E. (*a*) Potential temperature, in degrees Celsius, (*b*) salinity, and (*c*) geostrophic current, cm/s, positive eastward. The isotachs near station 20, too crowded to be labeled, show the AC confined to a jet with surface speeds of over 100 cm/s.

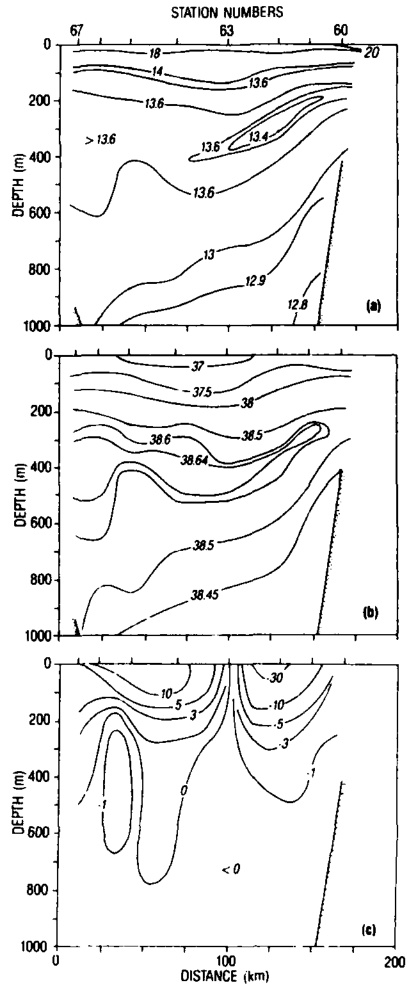

Fig. 4. Section 9, from the Algerian coast (station 60) across the Strait of Sardinia along longitude 8°20′E. Otherwise as in Figure 3.

meanders near 4°E and does not exist as a coherent entity east of there.

In the Strait of Sardinia (Figure 4) the layer of MAW varies in depth from 60 to 80 m on each side to 130 m in midchannel (station 63). Eastward flow is found only north of station 63, where maximum speeds up to 21 cm/s are found at the surface. To the south, the flow is westward with a surface maximum of 33 cm/s. The CTD data agree with the IR image taken 1–2 days after the section (Figure 5). A filament of cool water ($T < 19$°C) bulges eastward, intercepting the section near station 62 and again north of station 66. The plume, despite its low temperature, does not have the low salinity of MAW. It may be the result of upwelling along the southern coast of Sardinia. It appears that the flow runs nearly parallel to this feature and so accounts for the westward flow of MAW in the southern strait.

TABLE 1. Volume Fluxes in Sverdrups for the Five Sections across the AC

Section	MAW	AC	Net
1	0.34	0.42	0.22
3	0.27	0.34	0.11
4	0.45	0.79	—
5	0.40	0.60	—
6	0.08	0.38	0.14

The figure for MAW corresponds to $S < 37.5$ and that for the AC to speeds >3 cm/s. Net values are for the entire section above 1000 m. All fluxes are eastward.

Levantine Intermediate Water

The LIW of the western Mediterranean is found in its most concentrated form in the Strait of Sardinia ($S > 38.64$), where it occupies a layer from station 61 northward. The layer lies between 250 and 650 m, with the deeper and thicker portions on the north side of the strait (Figure 4). The flow is westward everywhere in this layer except for a small region of weak counterflow in midchannel, with the strongest currents, nearly 3 cm/s, north of station 65.

West of the strait, the LIW turns sharply northward. A striking feature of section 10 (Figure 6) is the nearly pure

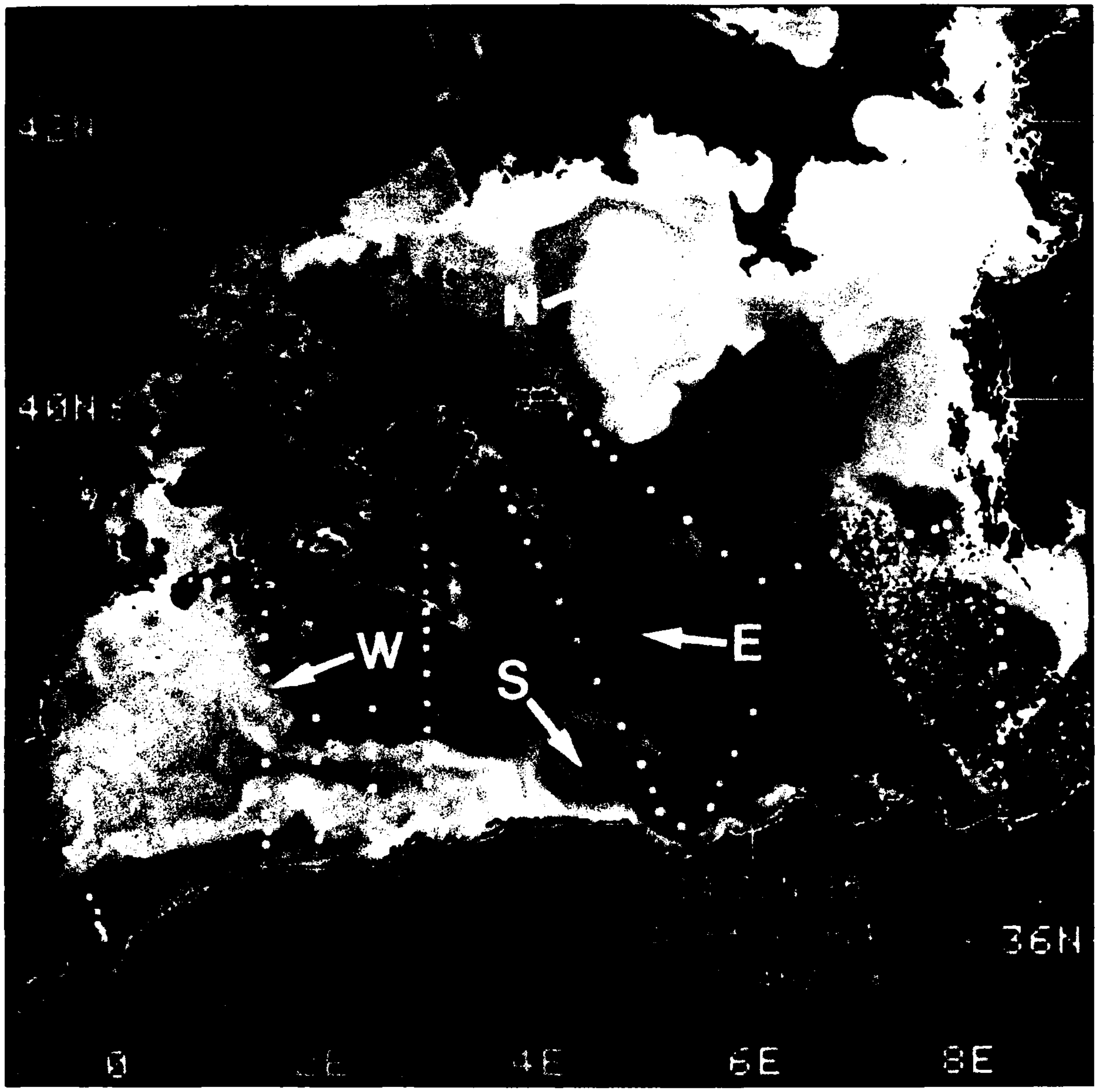

Fig. 5. Satellite IR image of June 9, 0248 UT. The picture was taken about one day after the end of section 9 and is nearly coincident with station 74. The arc of cool (light colored) water in the Strait of Sardinia is partly obscured by clouds, which appear as dark speckles.

LIW ($S > 38.64$) flowing northward at up to 3 cm/s along the Sardinian coast between 250 and 600 m. Since this water is found only in stations 68 and 69, and since station 68 is barely seaward of the 200-m isobath, the width of the vein of LIW must be between 20 and 40 km.

A lens of modified LIW extends throughout the Algerian Basin. Its salinity maximum decreases westward and away from the center of the basin (Figure 7). The depth of this maximum is generally between 300 and 500 m. No large-scale pattern in the depth of the salinity maximum can be identified, since many stations exhibit multiple salinity maxima characterized by small differences in salinity but large differences in depth. The region where the salinity maximum has its lowest values (<38.45), that is, the region where the LIW appears in its most highly modified form, is south of the Balearic Islands and, to a lesser extent, the extreme southern portion of section 1.

Winter Intermediate Water

The WIW finds its equilibrium depth in the Algerian Basin at depths of 100–300 m, where it is identifiable by a temperature minimum above the ubiquitous LIW (Figure 8). Taking the defining attribute to be $T < 13.0°C$, WIW is found in the northern and eastern Algerian Basin and unevenly along the western Algerian coast, although its influence is evident

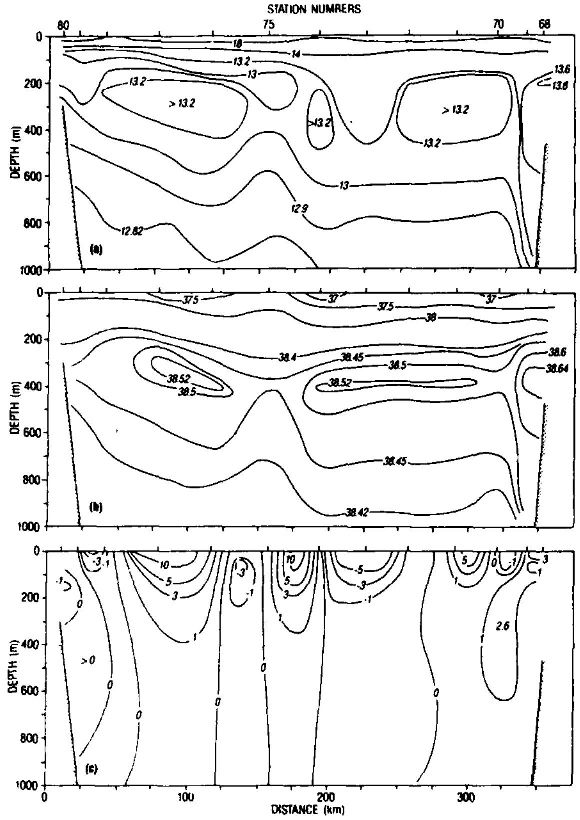

Fig. 6. Section 10, Sardinia (station 68) to Menorca. (*a*) Potential temperature, in degrees Celsius, (*b*) salinity, and (*c*) geostrophic current, cm/s, positive northward.

throughout the region by the appearance of a temperature minimum.

Between 100- and 450-m depth, WIW fills much of the channels between Spain and Ibiza and Ibiza and Mallorca (sections 2 and 11). Minimum temperatures there are below 12.7°C, the coldest encountered during this survey. Concentration of this water along the western sides of the channels confirms that it is flowing southward from its formation region to the north. The 700-dbar reference depth used for geostrophic currents in section 2 yields southward currents everywhere, with speeds up to 18 cm/s at the surface and 12 cm/s in the temperature minimum at 150- to 200-m depth. The net southward transport in section 2 is 0.75 Sv. These channels thus appear to be a significant route for WIW into the Algerian Basin. The westward flow of WIW south of Ibiza is clear at the northern end of section 3 (Figure 3).

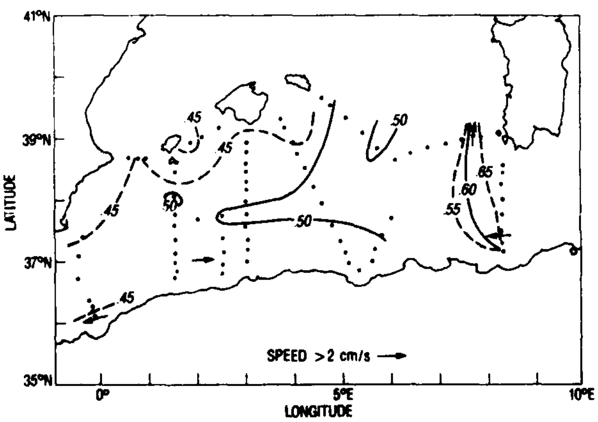

Fig. 7. Contours of maximum salinity, indicating the concentration of LIW. Contours are labeled with salinity in excess of 38 practical salinity units. Currents greater than 2 cm/s are indicated by arrows.

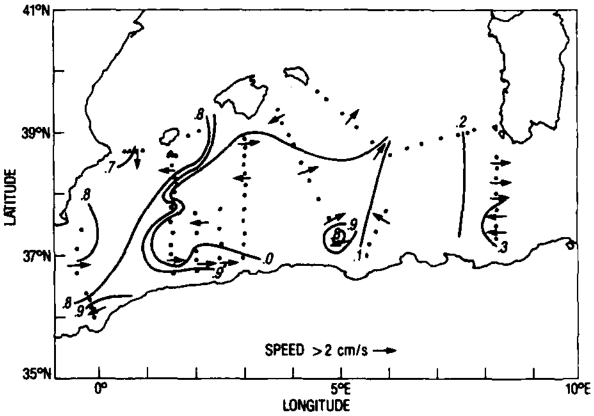

Fig. 8. Contours of minimum potential temperature above 350 m, indicating the concentration of WIW. In labeling the contours, the two leading digits, either 12 or 13, have been suppressed. Currents greater than 2 cm/s are indicated by arrows.

In section 10 (Figure 6), WIW forms a thin layer extending from the Menorcan shelf as far east as station 75. The flow is southward (1 cm/s) close to the coast west of station 78 at 100- to 200-m depth. East of there, the flow is northward. A similar WIW flow reversal is found at the northern limit of section 7. Directly south of Mallorca in section 6, no WIW is found. Since section 6 ends within a few kilometers of the 200-m isobath of the Balearic shelf, it seems unlikely that any WIW could have been present when the section was made. We conclude that WIW flows southward around the eastern coast of Menorca but that it turns northeastward somewhere southeast of Mallorca and is recirculated into the Provencal Basin.

The current of WIW turns southward between sections 1 and 3 and splits into eastward and westward flowing branches. In section 1 the WIW has minimum temperature in midchannel and peak current flowing westward at 5 cm/s between stations 4 and 5 at 200-m depth. A second region of westward flow exists north of station 86. In contrast, sections 3–6 show WIW flowing eastward near the Algerian coast at 150- to 200-m depth at 1 cm/s. Along this route, the minimum temperature becomes steadily warmer toward the east, as though from mixing.

An isolated patch of WIW exists near, but detached from, the Algerian coast in section 7 (station 52) between 120 and 220 m. The small velocity in this patch and the weak flows in opposite directions on either side associate it with eddy "S" in Figure 5. A similar patch at station 15 (Figures 3 and 8) also exists in the center of another anticyclonic eddy, described further in the next section. The WIW and the

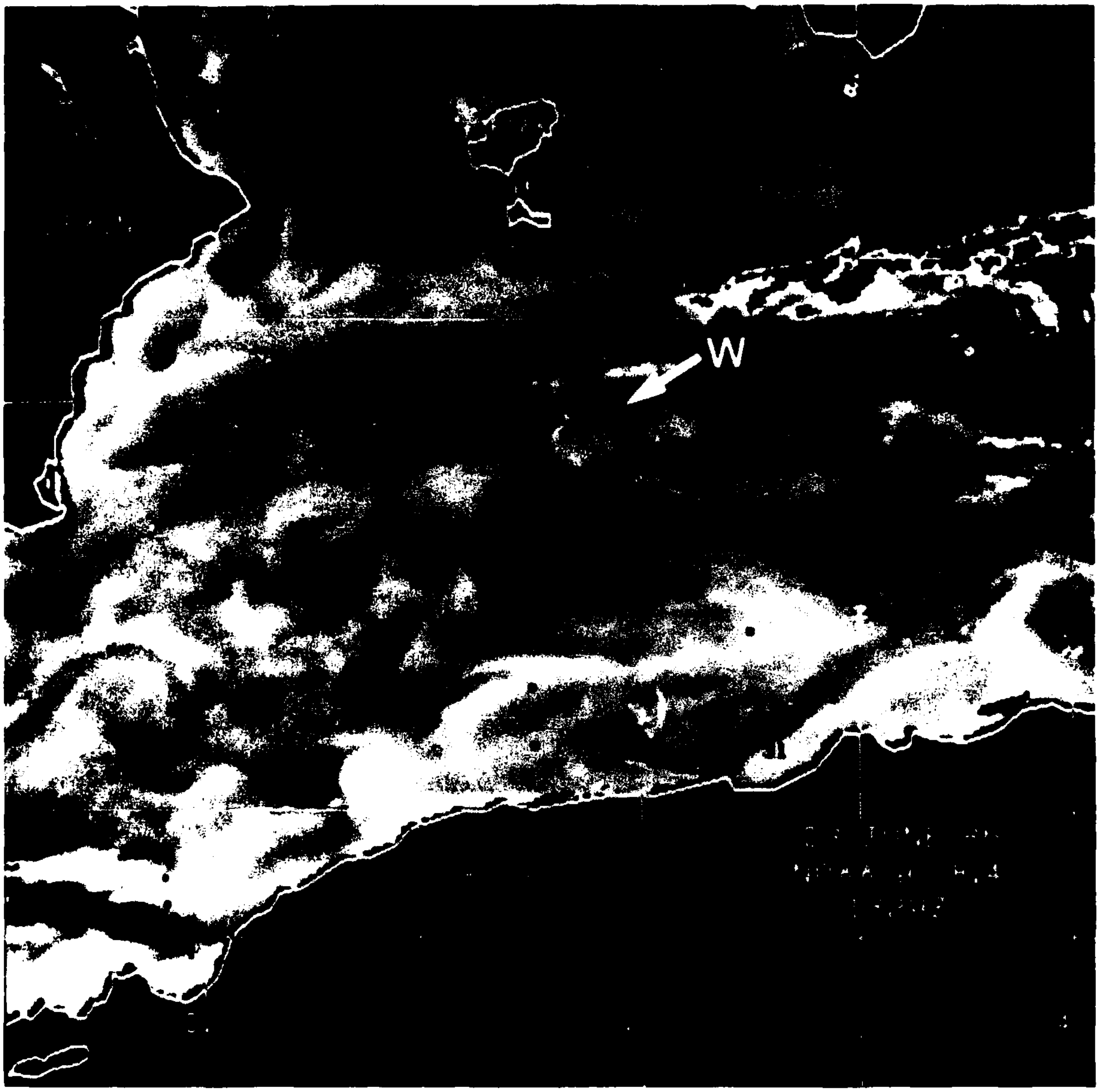

Fig. 9. Satellite IR image of June 3, 1329 UT, coincident with station 26. The eddy just north of station 26 is eddy W, a long-lived feature.

MAW above it evidently act together during the formation of eddies by the AC.

Long-Lived Eddies

Among the many transient thermal features of the IR images we examined were the ghostly traces of two anticyclonic eddies which persisted over a period of several weeks. They are the same eddies reported by *Taupier-Letage and Millot* [1988], who denoted them as W for the western eddy and E for the eastern. Our IR data are in fact part of the same sequence of satellite images, although the image processing was done independently. The eddies identified in these images are used here to interpret the CTD data.

The alternating eastward and westward flows between stations 13 and 18 (Figure 3) are due to eddy W. This eddy can be seen clearly in a series of IR images during May and June as it drifted slowly westward with an average translation speed of 5 cm/s. The image of June 3 (Figure 9), made during the same section, shows the eddy center some 40 km east of the point between stations 14 and 15. It appears limited to the upper 200 m of the water column, although might have been found deeper if the section had cut through the center of the dish-shaped eddy.

Entrainment and circulation of MAW around the eddy are indicated by the lens of fresh water near 30-m depth between stations 13 and 15. It is further indicated by the deepening of the MAW in the northern portion of section 4, where the depth of 37.5 isohaline increases from 25 m at station 25 to 80 m at station 26. A bolus of WIW (min $T < 12.9°C$, 150–250 m) is also part of the eddy. The presence of both water types in the eddy is evidence that it once had an intimate connection with the AC.

Eddy E dominates the central portion of section 7, where it is centered between stations 49 and 50. Peak eddy speeds are of the order of 10 cm/s at the surface. It is also evident in a long series of satellite images (e.g., Figure 5). A CTD section across its southern radius has been reported by *Millot* [1987*a*], who has reported the eddy to have a filament of LIW around its perimeter but none at its center. The presence of LIW in section 7 at the apparent center of the eddy reflects the section having cut across its rim.

Eddy N, a fourth anticyclonic eddy, seen in Figure 5 some 100 km north of Menorca, is noteworthy. The feature cannot be tracked by IR imagery because of persistent cloud cover, but it has been detected by the Geosat satellite altimeter. The altimetric signal shows a dome with height more than twice that of eddy E, implying a feature with deep vertical structure. We conclude that it too is long lived.

Along section 10 (Figure 6), away from the channel sides, the pattern of alternating currents found at the surface persists with decreasing speed deep into the water column. Indeed, vestiges of the pattern may be seen all the way to the 1000-m reference level. However, there is no evidence that the currents are organized as eddies. No persistent eddy pattern can be found in the satellite images. The only possible anticyclonic eddy (to match those already described) would have to be centered near station 74. Such an eddy would have a symmetric velocity field, but an unlikely asymmetry in its hydrographic properties: a lens of LIW on the east but not on the west.

Discussion

Atlantic water flowing into the Mediterranean undergoes significant mixing in the Strait of Gibraltar and the Alboran Sea. It forms the AC after passing south of the Almeria-Oran front [*Tintoré et al.*, 1988] with the characteristics of MAW. The volume flux of this current is difficult to measure because it flows partly over the shallow water near the Algerian coast, where geostrophic methods cannot be applied. Our value of 0.5 Sv (Table 1) for flow faster than 3 cm/s seems approximately correct, since the contribution from slower currents appears small.

The inflow past Gibraltar is variously estimated as 1.2–1.6 Sv [*Bethoux*, 1980; *Perkins et al.*, 1990]. The unknown extent of recirculation between Atlantic and Mediterranean waters in the Alboran Sea prevents application of these values to the AC. Nevertheless, the eastward and westward volume fluxes across section 1 should be comparable when averaged over several days, since the limited capacity of the Mediterranean reservoir would otherwise lead to unrealistic variations in sea surface elevation [*Bormans et al.*, 1986]. The consistent net eastward flux found in sections 1, 3, and 6 (Table 1) indicates that some of the westward flow is deeper than the 1000 m used here as a geostrophic reference level.

The disappearance in our sections of the AC east of section 6 (at 3°30′E) confirms the breakup of the AC at about that longitude into a complex pattern of eddies that is shown by other WMCE data [*Millot*, 1985] and by numerous satellite images. The distribution of MAW throughout the surface layers of the eastern Algerian Basin is apparently the result of this instability. We cannot improve upon the graphic description that MAW passes among eddies of this region "as through a set of paddle-wheels" [*Taupier-Letage and Millot*, 1988]. We note, however, the difficulty in identifying MAW from surface temperature alone. In the eastern Algerian Basin, the layer of MAW is relatively thin (20–60 m), moves slowly (<10 cm/s), and has been separated from its source in the Strait of Gibraltar for a long time (3 months). Its absolute temperature is therefore largely controlled by its history of surface heating, although the straining of local surface temperature anomalies continues to be an indicator of eddy activity. Salinity is the more effective tracer in the present data.

The exchange of surface water between the Algerian and Liguro-Provincal basins is substantial. Along section 10 (Figure 6), the transport of MAW ($S < 37.5$) is 0.52 Sv northward and 0.24 Sv southward, both in layers 30–60 m deep. In the smaller passages around the Balearic Islands, minimum surface salinities are barely below 37.5, indicating no significant passage of MAW. Net flux through section 10 is 1.44 Sv northward, and through section 2 is 0.75 Sv southward. These large values are best considered as particular realizations of a highly variable flow. Since the estimates are only for the upper layer, any flux imbalance they imply can be sustained for many days through change in thermocline depth and compensating flow in the deep water; the problem of changes in sea surface height does not arise, as it would if net fluxes were involved.

The Strait of Sardinia is climatologically characterized by a mean eastward flow of MAW at the surface overlying a mean westward flow of LIW. The volume flux in each direction has been estimated at approximately 1 Sv [*Bethoux*, 1980; *Manzella et al.*, 1988], i.e., rather more than half the flow in the Strait of Gibraltar. The distribution of tritium indicates that the westward flow may be found at depths as shallow as 100 m and that the eastward surface flow is not deeper than that value [*Andrie and Merlivat*, 1988]. Total exchange between the eastern and western Mediterranean basins must also include the significant contribution of the Strait of Corsica [*Astraldi et al.*, this issue]. A seasonal pattern in the flow has not been demonstrated, although some variability is expected in response to the abrupt wintertime renewal of the deep water and its gradual depletion during the rest of the year, as has been suggested for the Strait of Gibraltar [*Bormans et al.*, 1986].

Section 9 (Figure 4) shows MAW flowing in both directions in the strait and has been interpreted through an IR image (Figure 5) as the result of a cut across a plume of surface water that formed an arc in the strait. Other images show a wide variety of patterns. Images from early May show a pair of eddies near the western end of the strait, one in the northern half, one in the southern, both apparently cyclonic. The images of June 2 and 3 show two similarly placed eddies but with the southern eddy anticyclonic, similar to the pair reported by *Garzoli and Maillard* [1979] in both the MAW and LIW. Many other images can only be characterized as complex.

The deep westward flow in the Strait of Sardinia is the source of LIW in the western Mediterranean. It is typified in the present data by a maximum salinity of 38.64, which decreases rapidly toward the west, and a maximum temperature of 14.0°C. Historically, this water has been described as forming two branches, one on each side of the strait, with nearly identical TS properties and little seasonal variability [*Garzoli and Maillard*, 1979; *Guibout*, 1987, plates 19–20]. The cause of the splitting has been described and modeled by two stationary eddies, a cyclonic one at the northern side of the strait and an anticyclonic one on the southern side, both lying between 8° and 8°30'E [*Garzoli et al.*, 1982]. Here (Figure 4) the two branches are not distinct; LIW extends all across the strait but is thicker and deeper in the north.

After leaving the strait, the LIW turns abruptly northward (Figure 6) [*Katz*, 1972; *Guibout*, 1987, plates 23–26; *Millot*, 1987*b*] and follows northward along the coasts of Sardinia and Corsica. The measurements presented here show this flow to be between 20 and 40 km wide with maximum speed of 2.6 cm/s. Earlier reports of a branch of LIW flowing westward along the Algerian coast, beneath the eastward flowing AC, are not supported by the present data.

The northward flowing LIW travels around the northern rim of the Liguro-Provencal Basin [*Millot*, 1987*b*], where it enters the Catalan Sea, north of the Balearic Islands. Its transit through that region is reportedly much more rapid in winter than in summer, which results in the passage of seasonal pulses of relatively less modified LIW. Taking into account the estimated transit time of 2 months through the Catalan Sea, this water enters the Algerian Basin through the passages on both sides of Ibiza from January to May or June [*Font*, 1987]. The salinity maximum of LIW near the Balearic Islands in the present data (38.43–38.46) is somewhat lower than historical peak values (38.5; *Font* [1987]) but is within the range of values reported in the Alboran Sea (38.43–38.48E [*Parrilla et al.*, 1986]). The differences are small enough to attribute to interseasonal or interannual variability. The smallest values for the LIW salinity maximum we observed (Figure 7) were in and near the Balearic Islands.

Eddies in the Algerian Basin also contain LIW with nearly the same properties as found in the Strait of Sardinia [*Millot*, 1987*a*; present study]. The hypothesis of *Millot* [1985, 1987*a*], that these eddies represent a second route for the transport of LIW toward the west, is strongly supported by the present study and accounts for several features of the distribution of the salinity maximum (Figure 7). After entrainment by eddies near Sardinia, patches of LIW drift slowly westward with the eddy, which is constrained by its size to lie toward the center of the basin. During this passage, mixing accounts for the westward decrease of peak LIW salinity in the Algerian Basin and for its concentration toward midbasin. The decrease in peak salinity along this route is less than that associated with the longer northern route, thereby giving rise to the salinity gradient south of the Balearic Islands, where the two routes meet.

The only long-term measurements from the center of the basin of which we are aware consist of a single current meter mooring at 38°N, 5°E deployed for 2 months during midwinter [*Perkins*, 1972]. Interpretation of those data in terms of eddies is necessarily ambiguous, but if it is so interpreted, it places some constraint on the eddy structure. The overall character of this flow indicates that eddies may have been present in either the surface or deep water, but that they were not common to the 200-m level and to the 700-m and deeper levels.

Currents associated with eddy E and those found along section 10 (Figure 6) are remarkable in extending from the surface to at least 300-m depth, with some weak structure extending much deeper. This is deeper than any major current system of the region. The only process in the western Mediterranean with such an inherently deep structure is the wintertime formation of bottom water near the Gulf of Lions, but the formation of deep convective chimneys must lead to cyclonic circulation, opposite that of all the observed eddies. Creation of such structures by winds remains to be demonstrated. We conjecture that the deep structure arises after the formation of the eddy as part of the adjustment dynamics. Finally, we note that the only confirmed deep structures are in the eastern half of our study area, possibly indicating a different mechanism operating there than in the west.

The WIW passes southward on both sides of Ibiza and around the eastern end of Menorca. It is easily recognized south of the Balearic Islands in winter and in early summer by a temperature minimum of less than 13°C positioned above the warmer LIW [*Guibout*, 1987, plates 1 and 5; present study]. The branch of WIW that flows southward east of Menorca is recirculated northward again farther offshore (Figure 8).

The western branches of WIW flow partly westward into the Alboran Sea. The remainder flows eastward along the Algerian coast below the MAW in sections 3–6 and appears to be kinematically merged with the MAW to form the AC in those sections. The route of this water from the northern side of the basin to the southern must lie between sections 1 and 3, since the flow along the Algerian coast diverges from that region (Figure 8). East of section 6, the isolated patch of WIW at station 52 suggests that it, like the MAW evident in IR images, forms eddies which are detached from the coast.

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Hydrographic measurements, made in the Algerian Basin during June 1986 as part of the Western Mediterranean Circulation Experiment, together with satellite infrared images, are used to describe the flow of major water types in the region. Modified Atlantic Water flows eastward along the Algerian coast as the Algerian Current to 40E, where it breaks into a series of eddies and spreads far Ligurian-Provencal Basin and partly eastward through the Strait of Sardinia. The subsurface Levantine Intermediate Water turns sharply northward after flowing westward through the Strait of Sardinia and forms a narrow vein along the Sardinian Coast. Winter Intermediate Water flows southward around the Balearic Islands. Its eastern branch recirculates back to the north, whereas part of the western branch contributes to the Algerian Current by flowing eastward beneath the Modified Atlantic Water. Two large, long-lived eddies are confirmed in the area. The easternmost of these, and other features with unresolved horizontal structure between Sardinia and Menorca, extend from the surface through the pycnocline.

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