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Evidence of mesoscale eddies in the Northeast Atlantic from a drifting buoy experiment

Northeast Atlantic
Drifting buoy
Atlantic eddy
Satellites
Marine currents

Atlantique Nord-Est
Bouée dérivante
Tourbillon anticyclonique
Satellites
Courants marins

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ABSTRACT

— A drifting buoy experiment was conducted in the Northeast Atlantic from February to September of 1976. A large anticyclonic eddy was observed in the experiment area as the buoys were tracked by the "Nimbus F" satellite. The diameter of the eddy ranged from 100 to 150 km and buoys circled around its center at a mean speed of 10 to 15 cm/sec., completing the cycle in 20 to 30 days. Direct current measurements taken under two drifting buoys in the experiment area in May of 1976 showed the eddy currents extending to a depth of at least 600 m and probably deeper.—

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RÉSUMÉ

Mise en évidence d'un tourbillon anticyclonique dans l'Atlantique Nord-Est à partir d'une expérience de bouées dérivantes

— Une expérience conduite à l'aide de bouées dérivantes, ancrées à 100 m de profondeur, suivies par le satellite américain « Nimbus F », a permis de mettre en évidence un vaste tourbillon anticyclonique dans l'Atlantique Nord-Est. Celui-ci a été observé entre février et septembre 1976. Son diamètre est de 100 à 150 km, il est parcouru en un temps de 20 à 30 jours à une vitesse moyenne de 10 à 15 cm/s. Une courte campagne effectuée en 1976 permet de dire qu'il se propage jusqu'à 600 m de profondeur et très vraisemblablement au-delà. —

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INTRODUCTION

During the past 10 years, oceanic eddies have been observed in all the oceans with more frequent observations in the Atlantic. The increased frequency of these eddies observations is due to the development of new methods of observation and the intensification of measurements at sea during research programs such as Mode, Polygon and Polymode. A tentative inventory of these eddies has been recently drawn up by

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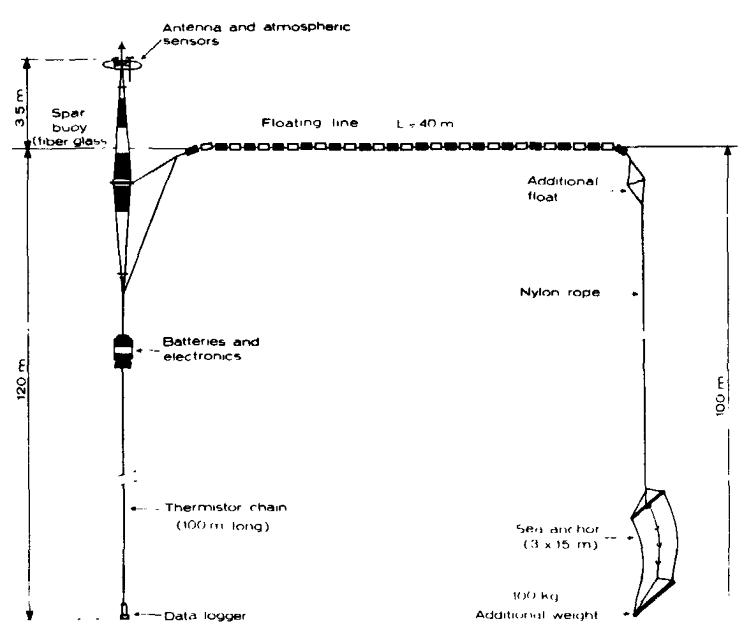
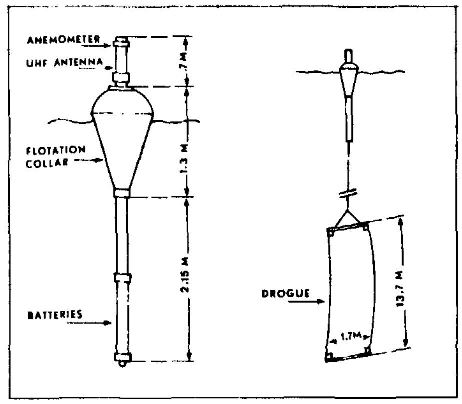




NOVA BUOY

Figure 1
Left: "L 55" French buoy; right: "Nova" buoy from Noaa (National Data Buoy Office).

J. C. Swallow (1976). The eddies are more frequently observed near the edge of the large oceanic currents but are also found in areas of weak mean currents. Some have been observed at the surface of the oceans, others at greater depths with diameters ranging from a few kilometers up to 150 or 200 km.

A recent experiment with drifting buoys tracked by the US satellite "Nimbus F" has shown the existence of such an eddy in the Northeast Atlantic, west of the French coast. The first results of these observations are presented in this article.

The area of investigation was chosen from results collected during hydrological cruises regularly conducted from 1972 to 1974 (Fruchaud B., 1975; Fruchaud-Laparra *et al.*, 1976, *a* and *b*). It is characterized by a weakness of horizontal gradients of temperature and salinity. Its computed currents are less than 5 cm/sec. and it is located outside of the heavily trafficked shipping routes.

Two different models of drifting buoys were deployed for this experiment (Fig. 1): French "L 55" buoys and "Noaa Nova" buoys.

The French "L 55" buoys are fiber glass spar buoys, 10 m long extending 3.5 m above the sea surface. They contain a battery and electronic circuit package located 12 m beneath the surface. In order to minimize the drift of the buoy due to the effect of the wind and the surface currents, it is equipped with a sea anchor at the 100 m depth. The anchor consists of a rectangular plastic sheet (3 x 15 m) weighted with a 100 kg iron rod. These different elements are described in several internal reports (Bervas J. Y., 1974; Juhel P., 1976). The data collected by these buoys (wind speed and direction, air temperature, sea water temperature at − 1 and − 12 m and technological parameters) are transmitted by the "Nimbus 6" satellite which determines the buoy position. The wind measurement is transmitted as two components averaged over 10 minutes (NS and EW) computed from elementary vectors obtained at each revolution of the anemometer. These buoys are also equipped with a 100 m long thermistor chain hanging under the container. The chain consists of ten temperature sensors, 11 m apart and a pressure sensor at the lower part of the line. These data are available only upon recovery of the buoy.

The "Nova" buoys were developed by the Noaa Data Buoy Office (Ndbo) and were deployed by E. G. Kerut from the "Jean Charcot". They were equipped with an anemometer, a sea water temperature sensor and a sea anchor located at a depth of 100 m. The "Nova" buoy is a small fiber glass spar buoy, 4.2 m long with a conical floatation collar for buoyancy. The sea anchor used with this buoy is 1.7 m wide and 13.7 m long.

These two different buoy models were not equipped with a drogue sensor. Consequently, evidence of the presence of the drogue during any experiment is certain only for the buoys which were recovered with their sea anchor.

This paper presents the trajectories of the buoys which were deployed during three consecutive experiments from February to November, 1976. The experimental program is scheduled to end in September, 1977. At the beginning of each experiment, the "L 55" buoys were deployed from the same location and the "Nova" buoys were also deployed in close proximity to the "L 55" deployments. The trajectories are presented in Figures 2-6. One daily buoy position was obtained at approximately 12 noon. The positioning accuracy of the buoys has been estimated at ± 2 nautical miles for the "L 55" buoys and ± 3 nautical miles for the "Nova" buoys. These estimates were the result of experiments conducted from a moored buoy.

PRESENTATION OF THE RESULTS

The first experiment was conducted from February 7th to April 21st (Fig. 2). The outstanding phenomenon

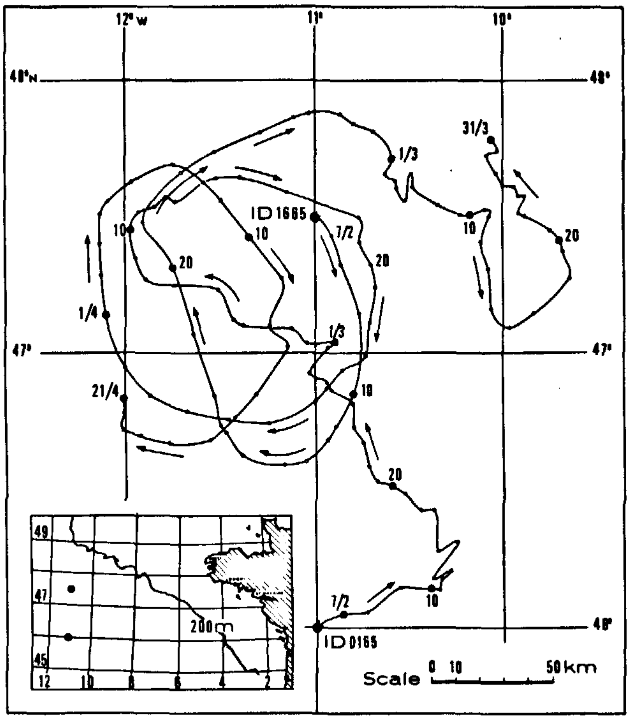


Figure 2

Drift of two "L 55" buoys (ID 1665 and ID 0165) during the first experiment (February 7th to April 21st). Only one daily position is reported.

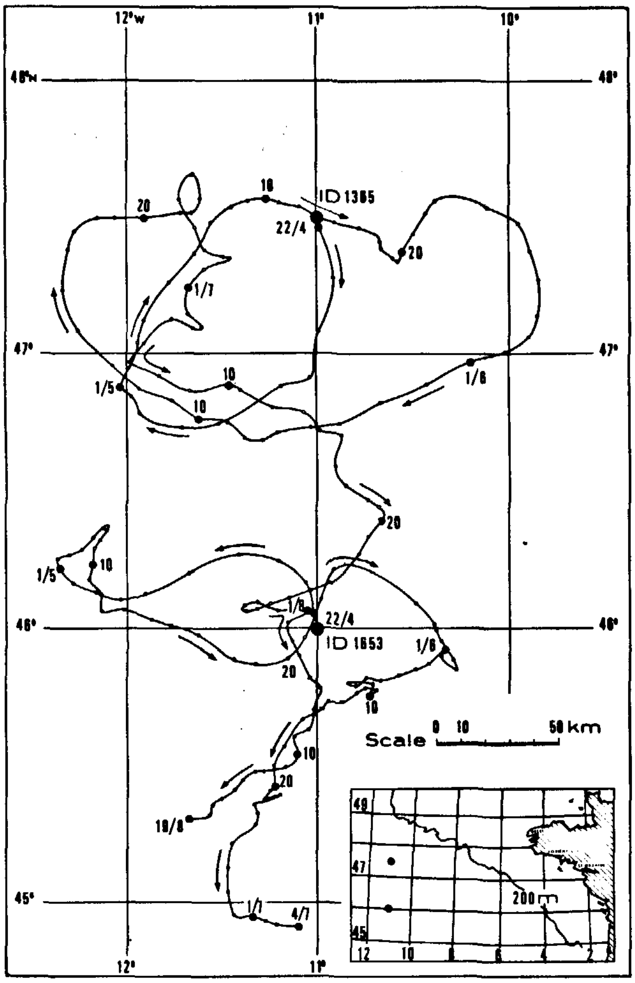


Figure 3

Drift of two "L 55" buoys (ID 1365 and ID 1653) during the second experiment (April 22nd to August 19th).

is the drift of the buoys along an anticyclonic, quasi circular, trajectory whose center was located at approximately 47.10°N and 11.20°W. This drift suggests the existence of a large eddy with a diameter of 110 km. The northern buoy (ID 1665) drifted along that eddy until March 15th and, then, left it to follow a cyclonic trajectory of a smaller diameter (approximately 50 km) before being recovered by a spanish trawler. The second buoy (ID 0165) entered the anticyclonic eddy on March 1st and remained in it until its recovery on April 21st, 1976. Each of these two buoys (still drogued when recovered) drifted at a mean daily speed of 10 cm/sec., reaching maximum speeds of 35 cm/sec. A complete revolution was accomplished in 24 days. From February 25th to March 11th, the two buoys followed "opposite trajectories" and it seems that the eddy itself drifted NE approximatively 20 nautical miles since the beginning of the experiment. Conversely, during the last revolution, the center of the eddy can be estimate near $\varphi = 47.12$°N, G = 11.40°W which would give a 30 miles W-SW drift from its preceeding location.

During this experiment, the vertical structure (from buoy ID 0165) was quite homogeneous until March 23rd ($dT/dZ \leq 10^{-3}$ °C/m); then a small seasonal heating appeared and a value of 3×10^{-3} °C/m was reached at the end of the experiment.

The second experiment lasted from April 22nd to August 19th. Six buoys (two "L 55" and four "Nova" buoys) were launched in the same area from April 22nd to 25th. As for the first experiment, these two "L 55" buoys were recovered with their "sea anchors". Only one "Nova" buoy was recovered (ID 1363); its sea anchor was not present. Figure 3 shows the trajectories which were followed by the two "L 55" buoys.

The northern buoy (ID 1365) drifted first along an anticyclonic trajectory, quite similar to that observed previously, at a mean daily speed of 15 cm/sec. It then followed an elliptical trajectory (200 × 90 km) at a mean speed of 12 cm/sec. before it changed its course to 220° on June 29th until July 7th. It then drifted at a heading of 120° until July 20th and 210° until August 19th, at which time it was recovered.

The drift from April 22nd to June 29th is very similar to the trajectory of a "Nova" buoy (ID 1371) which is shown in Figure 4. On May 14th, the two buoys were 33 km apart and on June 29th had drifted to within 15 km of each other after a drift of 500 km at a mean daily speed of 12.5 cm/sec. Their maximum separation reached 50 km on June 17th after the "Nova" buoy had completed a small anticyclonic loop. On June 30th, the "L 55" buoy (ID 1365) changed its course to the south and then to E-NE.

The second "L 55" buoy (ID 1653) did not join the anticyclonic eddy as in the first experiment. It was located only a few kilometers from its deployment location one month after its launching and then drifted to the South-West from June 1st to 30th and then to the east until it was recovered on July 4th.

The trajectories which were followed by the two "L 55" buoys (Fig. 3) show a significant change in their orien-

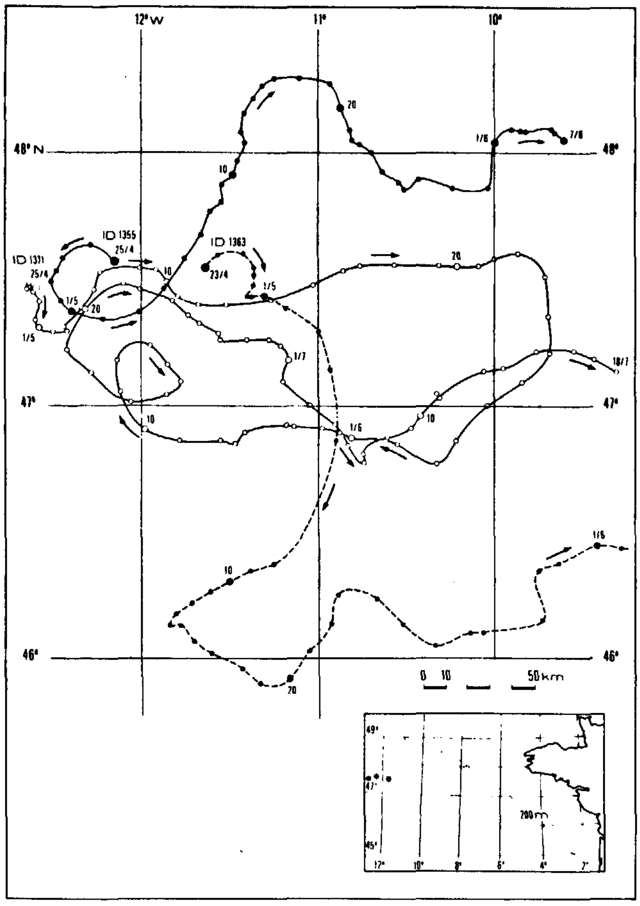


Figure 4

Drift of three "Nova" buoys (ID 1365, ID 1371 and ID 1363) deployed on April 23rd and 25th. Buoy "ID 1363" was recovered on June 30th without its sea anchor.

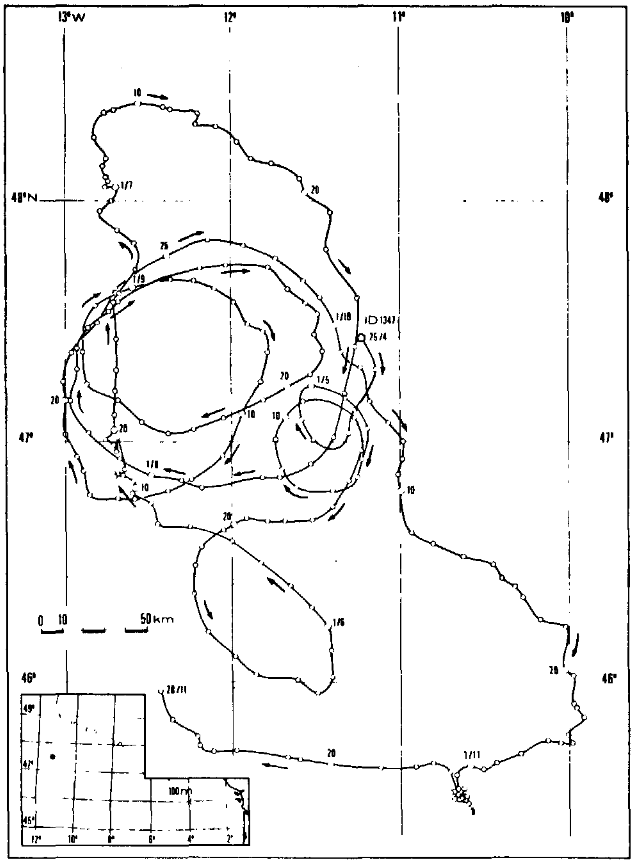


Figure 5

Drift of a fourth "Nova" buoy (ID 1347) deployed on April 25th. It was located until January 25th, 1977.

tation between May 19th and 20th. This change in orientation does not appear on the trajectory of the "Nova" buoy (Fig. 4). This phenomemon and also the general features of the trajectory of the southern buoy (ID 1653) seem to be related to the effect of the wind on the buoy which is a topic for further discussion.

In Figure 5, only a portion of the drift of a "Nova" buoy (ID 1347) is presented. It was deployed on April 25th and tracked until January 25th, 1977. It first drifted along two anticyclonic loops approximately 50 km in diameter. It then drifted along a cyclonic loop and into a large anticyclonic eddy in which it drifted for three consecutive cycles at a mean speed of 11.2 cm/sec. until October 1st. This eddy had a diameter of 130 km and its center was located by $\varphi = 47.18$°N and G = 12.08°W, 60 km W-NW from the center of the eddy observed during the first experiment. The three revolutions which were run by that "Nova" buoy from July 15th to October 1st are located inside the trajectory of two and later only one "L 55" buoys which were deployed on August 19th and 20th (Fig. 6). The northern buoy (ID 1653) drifted along an elliptical trajectory, left it on September 30th and successively went over two smaller cyclonic loops before it failed. The second buoy, which was deployed 30 nautical miles south of the first, followed a quasi-parallel path to that of the northern buoy from August 24th to September 23rd but at a slower speed. It was observed that for seven days (September 9th to 16th), it stopped drifting while the other buoy (ID 1653) drifted to the north at a speed of 10 to 15 cm/sec. These two buoys (ID 1653 and 0165) were not recovered.

Two other trajectories of "Nova" buoys (ID 1355 and ID 1363) are also presented in Figure 4.

The buoy "ID 1355" had a similar drift to that of the "Nova" buoy (ID 1371) until May 5th. It then drifted to the North-East until May 16th and to the South-West and West before it failed on June 7th. It did not enter the large eddy observed at that time from buoys "ID 1371 and 1365".

The last "Nova" buoy (ID 1363) was recovered on June 30th without its sea anchor by a French trawler. For that reason, its trajectory cannot be compared with the others. Moreover, it is noted that from April 23rd to May 5th, its drift was similar to that of the "L 55" buoy "ID 1365" (Fig. 2).

DIRECT CURRENT MEASUREMENTS

During two short periods from April 23rd to May 5th, and from May 1st to 5th, Anderaa currentmeters at 100, 600, 1 870 and 3 250 m were installed under two drifting buoys which were launched at locations M 1 ($\varphi = 47.26$°N,

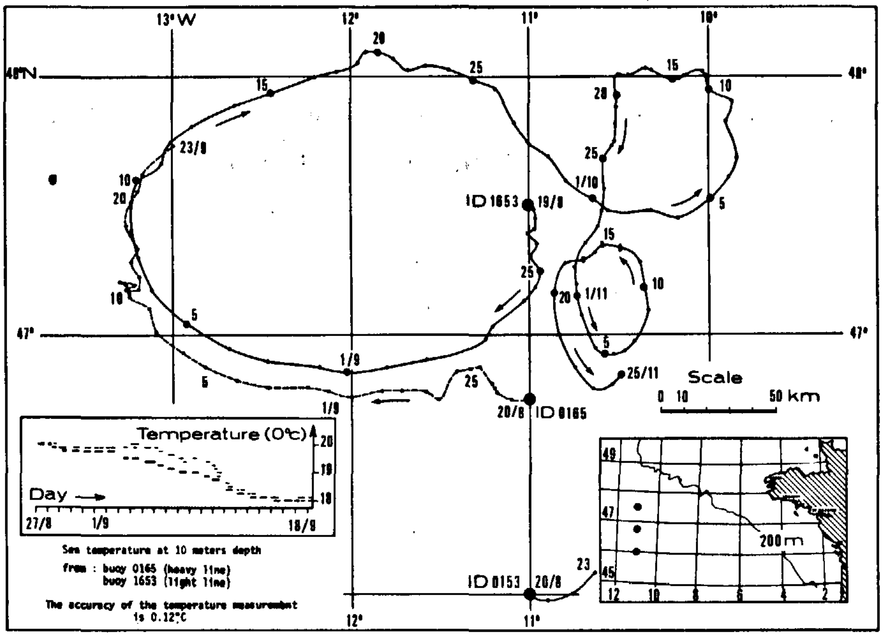


Figure 6

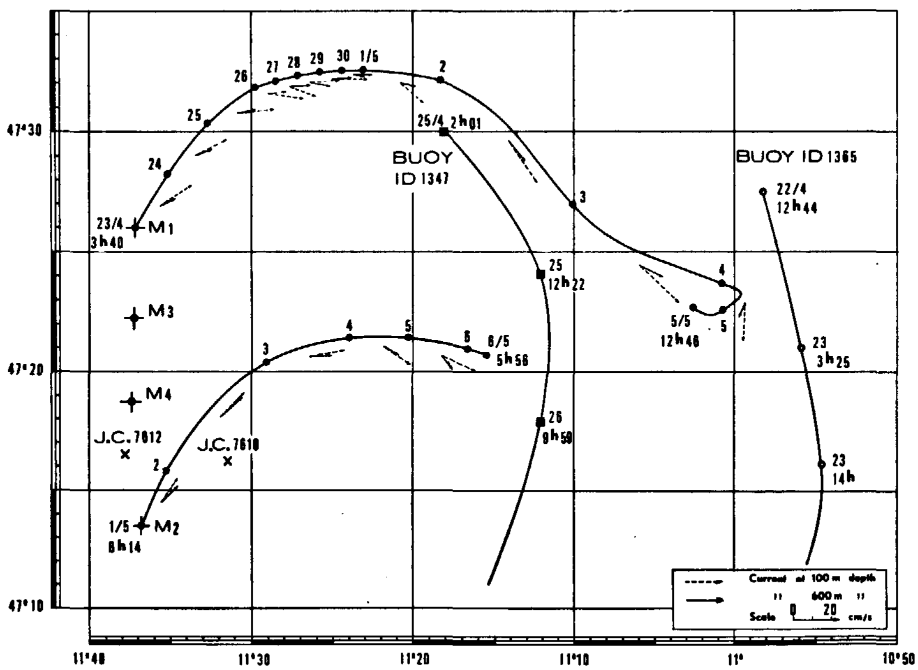
Drift of three "L 55" buoys (ID 1653, ID 0165 and ID 0153) during the third experiment from August 19th to November 25th. Buoy "ID 0153" was destroyed by a ship after three days at sea.

G = 11.37°W) and M 2 (φ = 47.13°N, G = 11.37°W) (Fig. 7). It is well known (Gould, 1975) that in such moorings the vertical movements of the buoy due to wave action can pump up the measured velocities. In order to reduce these vertical movements, spar buoys were used, and the mooring line down to 600 m was nylon rope offering a certain elasticity. During these measurements, weather conditions remained good; sea states only between 2 and 4 (Ices scale) were encountered.

In view of this, it seems reasonable to suppose that these measurements are significant. Moreover, the main conclusion of this chapter will not be changed in case of an error on currents speeds up to 30% at 100 and 600 m.

Times series from the pressure sensors on the currentmeters indicate that the tilt of the lines remained generally very small (less than 3°) but on two occasions under the "M 1" buoy, it reached, for a few hours only, 8° (May 2nd and 4th).

These two buoys were located from the "Jean Charcot" on the average once each day in order to determine their trajectories. Measurements from the currentmeters were calibrated in order to obtain the real daily mean current at each level. These results are reported in Tables 1 and 2 and in Figure 7 for currentmeters at 100 and 600 m. Points M 3 and M 4 in Figure 7 represent two subsurface moorings with currentmeters at 2 690 and 4 660 m (10 m above the sea bed).



Mean current at 100 m and 600 m from currentmeters under two drifting buoys

Figure 7

Drift of two buoys (M 1 and M 2) with currentmeters at 100, 600, 1 870 and 3 250 m. The arrows on the tracks give the mean daily value of currents at 100 and 600 m. M 3 and M 4 are subsurface moorings at 4 660 and 2 690 m. JC 7612 and 7610 represent two CTD stations.

Table 1
Buoy "M 1"; mean daily currents.

Date	Depth 100 m		Depth 600 m		Depth 1 870 m		Depth 3 250 m		"M 1" buoy		Tidal coeff.	
	Speed (*)	Dir.	Speed (*)	Dir.	Speed (*)	Dir.	Speed (*)	Dir.	Speed (*)	Dir.	Morn.	Evg.
23/4/76	20	57	9	62	1.5	175	3	220	7	32	43	45
24/4/76	19	64	9	68	3.6	202	1	180	6	37	48	52
25/4/76	19	83	10	78	3.1	31	2	170	5	53	56	60
26/4/76	19	97	10	83	2	92	2	180	2	72	64	68
27/4/76	15	110	12	86	6	74	2.5	107	2	78	71	75
28/4/76	16	85	11	100	5	85	2	159	2	81	77	79
29/4/76	19	90	11	85	4	186	6	198	2	85	81	82
30/4/76	6	97	10	90	4	92	5	279	2	90	83	83
1/5/76	16	130	8	104	4	89	2	345	7	98	82	81
2/5/76	27	145	14	140	7.5	146	4	142	16	133	79	77
3/5/76	29	133	4	116	11	78	9	77	15	118	74	71
4/5/76	20	183	8	204	9	291	9	288	2.5	180	67	64

(*) Centimeters per second.

Table 2
Buoy "M 2": mean daily currents.

Date	Depth 100 m		Depth 630 m		"M 2" buoy		Tidal coeff.	
	Speed (*)	Dir.	Speed (*)	Dir.	Speed (*)	Dir.	Morn.	Evg.
1/5/76	15 (**)	33 (**)	12.5 (**)	45 (**)	7.3	25	82	81
2/5/76	18	44	16.5	48	13.3	42	79	77
3/5/76	19	80	12	85	7.8	74	74	71
4/5/76	18	124	9.5	122	5.3	90	67	64
5/5/76	20	144	10 (**)	141 (**)	5.3	102	60	56

(*) Centimeters per second.
(**) Mean value for 12 hours only.

Corrected values obtained under the "M 1" buoy confirm the existence of an anticyclonic eddy at a 100 m depth. The speed of the current was generally constant between 15 and 25 cm/sec. At 600 m, measured speeds were slower ($V = 10 \pm 2$ cm/sec.) but the successive orientations of the current showed that the observed eddy is still present at a depth of 600 m. At greater depths (1 870 and 3 250 m), currents are weak and variable both in speed and direction.

The increase of the drift speed of the "M 1" buoy on May 2nd and 3rd is related to the increase of the speeds at the four levels and also to the similar directions of the currents.

Data were obtained only at 110 and 630 m from the "M 2" buoy. At these two levels, a clockwise rotation was observed similar to that observed under "M 1". The higher speeds were measured at 110 m under "M 1", and at 630 m under "M 2".

Data from subsurface moorings "M 3" and "M 4" which were collected at the same moment are presented in Figure 8.

At 2 690 m, currents are weak and because of a modulation by tidal currents, the resulting speed is very often (40% of the time) less than the threshold of the rotor of the currentmeter which is of the order of 2 to 3 cm/sec. These data can nevertheless serve to show that currents are quite slow at this depth.

At 10 m above the seafloor, higher speeds were measured except at the beginning of the recording where the current speed is sometimes also less than the threshold of the rotor.

During the 12 days of measurement, a slow anticlockwise rotation of the current was observed. From the beginning of May, as observed under the "M 1" buoy at 1 870 and 3 250 m, an increase of the current speed was observed. A mean daily value of 6 cm/sec. was reached at 4 660 m.

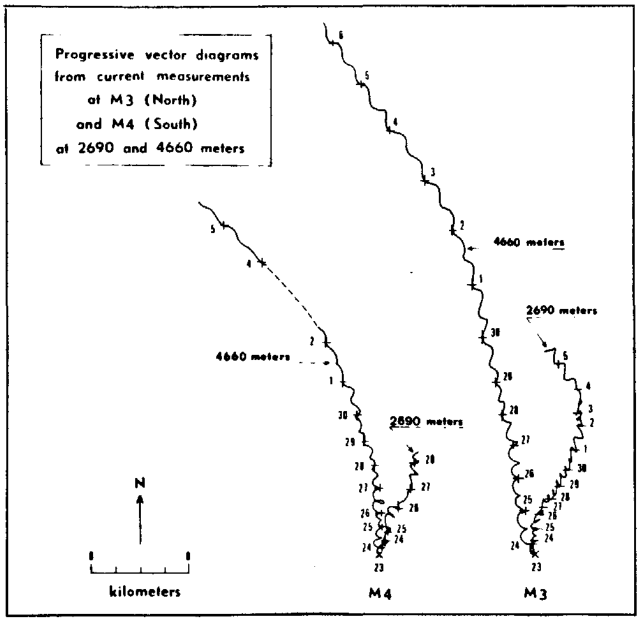


Figure 8
Progressive vector diagrams at 4 660 and 2 690 m at M 3 and M 4.

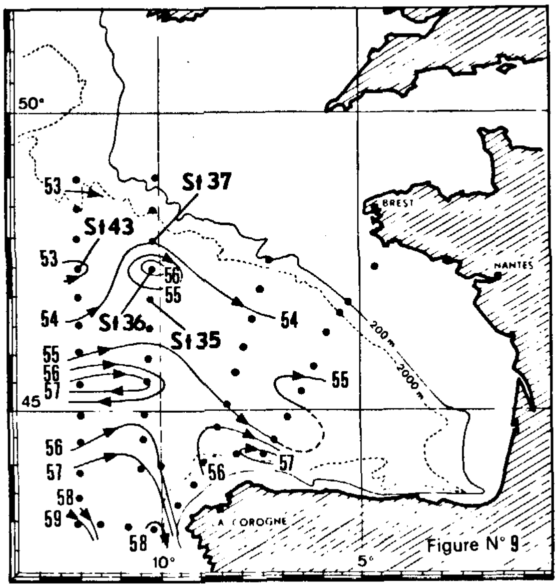


Figure 9
Computed surface currents with a level of no motion at 550 dbars. Phygas 33 *cruise* (4*th to* 23*th of July*, 1973).

HYDROLOGICAL DATA

The influence of mediterranean water which appears below 600 m is the most typical feature of TS diagrams from that area. It is characterized by a spike on the $\sigma\ t = 27.50$ curve at a depth near 950 m and a decrease of T and S down to 1 800 m with a slow increase of $\sigma\ t$ ($27.7 \leqq \sigma\ t \leqq 27.8$).

Figure 9 shows a map of surface computed currents from data collected in April and May, 1973, 3 years before the beginning of this drifting buoy experiment (Fruchaud-Laparra *et al.*, 1976, *a*). The level of "no motion" was chosen at 550 m on the theory that the minimum of salinity which is observed for the whole area at that depth, represents the upper limit of the influence of mediterranean waters. This map shows clearly that in the whole area currents are weak and that mesoscale eddies are present in several locations.

An anticyclonic eddy appears clearly near 47.30°N and 10.15°W. The shape of the Δ D curves between pairs of stations 36-35, 37-36 and 43-36, shows that this result should not be modified by taking a deeper level of reference, for example 1 800 m (Fig. 10). In that case, the eddy would reach a depth of 1 300 m and speeds up to 8 cm/sec. would be observed at the surface. It would include partly the mediterranean layer.

Table 3 gives the values of the heat and salt content for the first 550 m at these four stations.

QT and QS values at station No. 36, which is in the center of the eddy, indicate that it was composed of warmer and saltier waters than those found outside of the eddy. This is particularly clear for the distribution of heat down to 550 m and indicates that it is not the result of a seasonal heating. In the similar anticyclonic eddy which has been observed in 1976, evidence of a horizontal gradient of temperature can also be seen from data obtained during the third experiment (Fig. 6). From September 3rd to 5th, the two "L 55" buoys were drifting 15 km apart on parallel trajectories. The northern buoy was recording 0.5°C higher temperatures at 10 m under the surface. This temperature difference

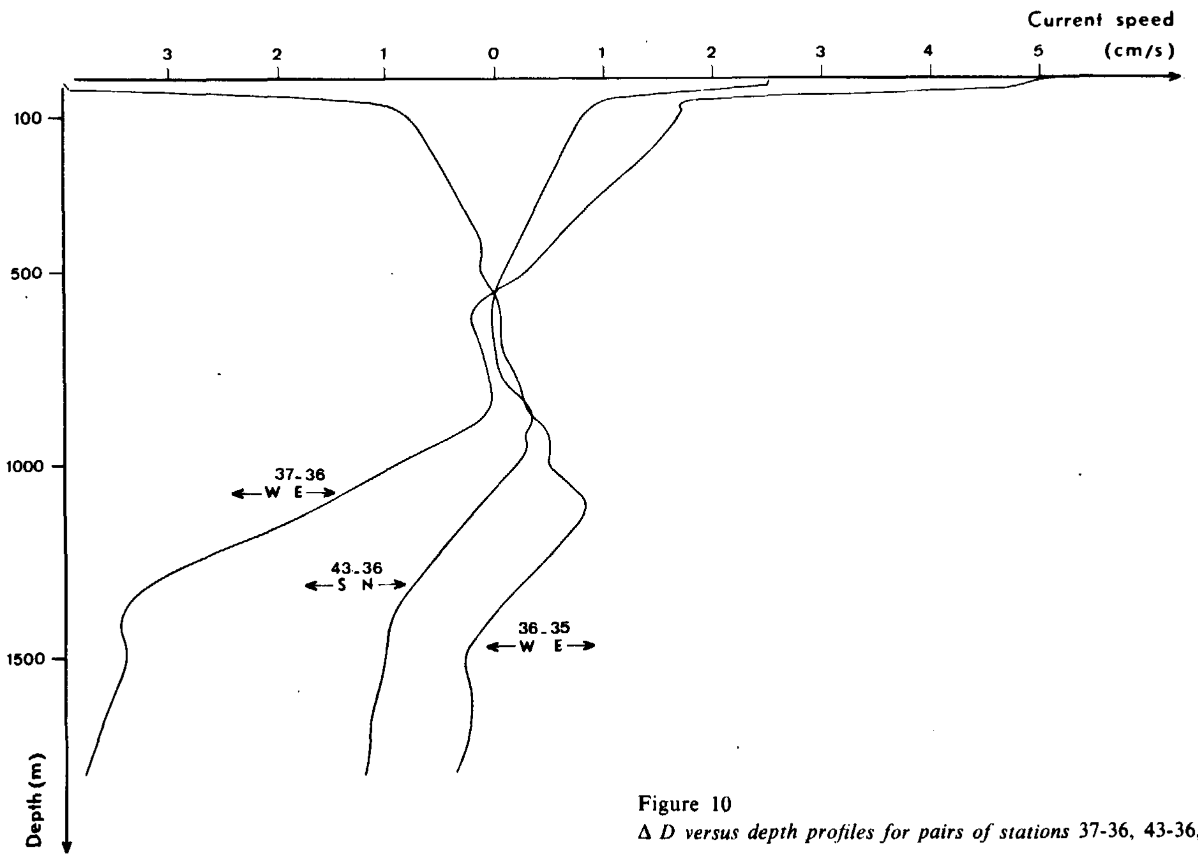


Figure 10
Δ D versus depth profiles for pairs of stations 37-36, 43-36, 36-35.

Table 3
Values of the heat and salt content for the first 550 m at stations 35, 36, 37 and 43.

Depth (meters)	Station 35 QT (kcal/cm²)	Station 35 QS (g/cm²)	Station 36 QT (kcal/cm²)	Station 36 QS (g/cm²)	Station 37 QT (kcal/cm²)	Station 37 QS (g/cm²)	Station 43 QT (kcal/cm²)	Station 43 QS (g/cm²)
0	0	0	0	0	0	0	0	0
50	82.1	182.2	88.7	184.7	81.5	183.9	78.4	183.7
100	58.9	177.2	61.9	174.6	58.5	176.1	56.0	173.1
150	58.7	181.2	59.9	181.9	55.8	176.0	56.1	180.9
200	55.5	173	57.9	178.6	56.4	180.8	57.4	185.2
250	56.6	178.8	56.0	174.5	55.0	178.2	54.4	174.8
300	57.0	180.5	59.4	187.3	54.4	176.8	55.2	178.2
350	55.3	176	52.6	166.6	58.3	189.2	56.2	178.8
400	56.9	181.7	58.2	185.6	50.6	164.0	53.1	172.1
450	55.2	177.1	55.6	178.9	54.9	180.4	55.9	183.7
500	53.9	174.1	55.3	178.0	53.0	176.8	51.0	170.8
550	54.5	178.0	54.7	178.0	53.1	176.8	53.2	177.7
QT or QS	644.6	1 959.8	660.2	1 968.7	631.5	1 959.9	626.7	1 959.0

disappears after November 13th when these two buoys begin to follow (but not simultaneously the same trajectory).

Such an eddy has not been observed systematically during all the cruises which were carried out in that area. Moreover, anticyclonic eddies were observed in 1972 (Fruchaud, 1975, p. 19) near 47°N and 8.30°W and in 1973 (Fruchaud-Laparra *et al.*, 1976, *a*, p. 71) near 48°N and 10°W. Maps of subsurface computed currents at 200 and 400 decibars by Helland Hansen (1930) show clearly the existence of such an anticyclonic eddy (Fig. 11) in the same area. Currents are computed with a level of no motion at 2 000 dbars; speeds up to 15 cm/sec. are obtained at 200 and 400 m.

DISCUSSION AND CONCLUSION

A fundamental question linked to the method of measurement, mainly for "L 55" buoys, is to evaluate the extent to which the trajectories of the buoys are representative of subsurface currents. Kirwan *et al.* (1975) have shown that large errors can accumulate in the interpretation of such trajectories, relative to the wind speeds and directions versus surface and subsurface currents. Because of a lack of data on surface currents and on the drag coefficient of wind on the upper part of the buoy, it does not seem possible to use their method or a similar one to try to correct the trajectories of the buoys in order to obtain a better description of the currents at the level of the sea anchor. For these reasons, only comparisons between buoys of the same type or of different types should be studied. These experiments show clearly that exactly the same buoys (Nova buoys) deployed in a same area (at distances of 20 to 30 nautical miles apart) can follow very different trajectories (Fig. 4 and 5). On the other hand, buoys of different shapes can follow very similar trajectories for at least 45 days (Fig. 3 and 4).

A comparison of "wind" and buoy trajectories during a given period allows the formulation of the following hypothesis. If currents at the level of the sea anchor are weak (less than 10 cm/s), the buoy drift is quite similar to the wind trajectory; however, if current speeds are significant (15 to 30 cm/s), the large scale features of the buoy drift are representative of the motion of water particles at the level of the sea anchor. It must be noted that the measurements which have been made in the eddy give values of that order which correspond quite well to observed drift speeds of the buoys.

The first verification of this hypothesis is given by the comparison of the trajectories of buoys "ID 1653" (L 55), "ID 1365" (L 55), "ID 1371" (Nova buoy) and the wind trajectory from buoy "ID 1653" (Fig. 12 *a*). From April 22nd to May 19th, the general orientations of

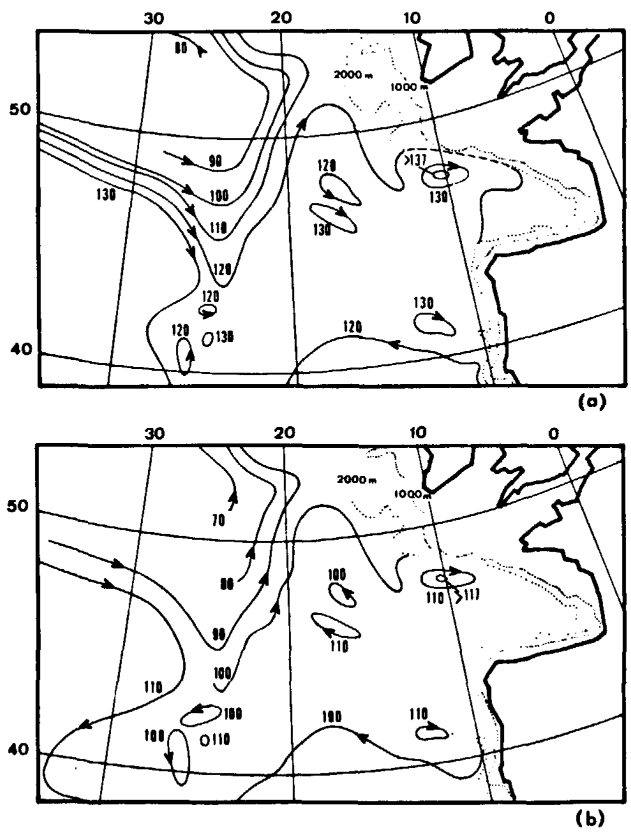


Figure 11
The topography of the 200 dbars (a) and 400 dbars (b) surface relative to the 2 000 dbars surface from Helland Hansen, 1930.

the drift of the buoy "ID 1653" and the wind trajectory look very similar and, typically, all the changes of orientation occur at the same time: 1st, 6th and 13th of May. For the four corresponding periods, April 22nd to May 1st, May 1st to 7th, 7th to 13th, 13th to 19th, values of the ratio between the buoy speed and the wind speed, respectively equal to 0.018, 0.011, 0.010, 0.015, can be computed. Larger values are obtained for corresponding higher values of the wind speed.

Later on, it also appears that all the "backward" movements of the buoy are linked with reversed winds with speeds greater than 6 m/sec., for exemple, between May 30th and June 1st, June 8th to 11th and on June 22nd.

Conversely, the drift of buoys "ID 1365" (L 55) and "ID 1371" (Nova buoy) are very similar and opposite from the wind trajectory which would seem to conclude that they are representative of water movements at 100 m. The sudden change of the drift orientation on June 29th or 30th observed for these two buoys is also visible on the trajectory of buoy "ID 1347" (Fig. 5) and cannot be due to the wind which was at that time less than 6 m/sec. and of unstable direction.

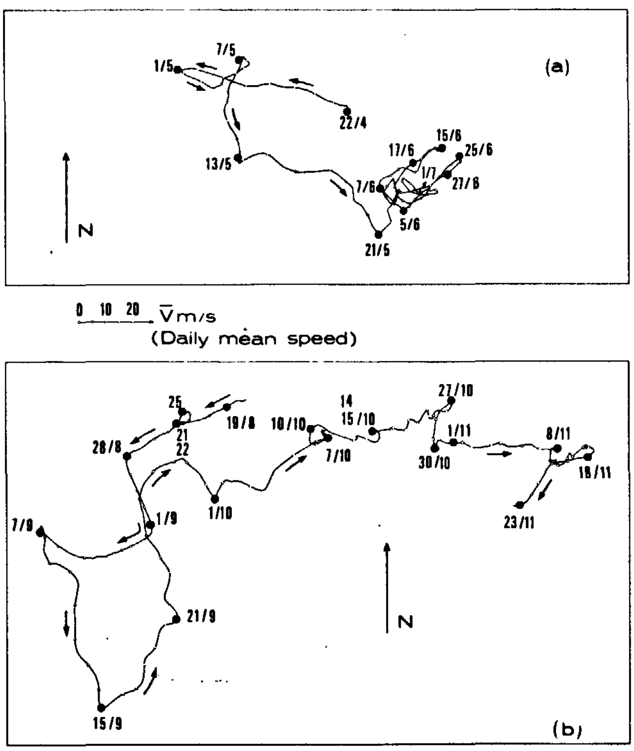


Figure 12

Progressive vectors diagrams from wind measurements for buoy "ID 1653": (a) second experiment and (b) third experiment.

A same type of phenomenon was observed during the third experiment (Fig. 6). Buoy "ID 0165" remained practically stationary for 6 days (August 8th to 15th) when it encountered northern winds (Fig. 12 *b*). The other buoy (ID 1653) which was drifting at a higher speed proceeded on its way to the North and North-East.

Another question is to determine the maximum depth to which this sort of eddy extends. If hydrological considerations argue to its limitation at 600 m which represents the boundary layer between NACW (North Atlantic Central Water) and MW (Mediterranean Water), current measurements at that level and the shape of the $\Delta D = f(p)$ profiles indicate that such eddies probably reach greater depths. Because of the variability of measured currents at 1 870 m, it may be concluded that their lower limit is between these two depths. As a comparison, it can be reported that Howe and Tait (1967) have suggested a lower limit depth of 1 200 m for a cyclonic eddy observed by $\varphi = 53.30°N$ and $G = 19°W$.

The anticyclonic eddy was observed quasi continuously from February to October, 1976. Although that experiment is still going on (July 1977), it has not been reobserved since October, 1976. It is not possible to decide whether it has vanished or simply drifted. Nevertheless, because of preceeding observations (Helland Hansen, Fruchaud-Laparra *et al.*, *a* and *b*), it can be said that this area is favorable to the existence of such eddies. Computed maps of current suggest that they should be included in a large anticyclonic system linked to the division of the Gulf Stream in several branches east of 25°W (Helland Hansen, 1930). Although the hypothesis of a seasonal phenomenon does not seem probable, the few data available are not sufficient to determine the origin of such eddies. Other fundamental questions concerning these eddies are still unanswered:

– how are they coupled to the mean circulation and what is their contribution to that circulation?

– from what source do they drain energy? Is it the current field, is it the density field?

– what is their mean life?

– what is the associated hydrological structure and its time dependence?

Answers to these questions or to some of them will be sought through further investigations at sea involving simultaneously more sophisticated drifting buoys, subsurface floats, hydrological and current measurements.

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