Moored Current Meter Data from the
Canary Basin Near 32°N, 24°W
(1984-1986)
Volume XL

by

Susan A. Tarbell, Philip L. Richardson and James F. Price

Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

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Robert C. Beardsley

Robert C. Beardsley, Chairman
Department of Physical Oceanography

Abstract

Data are shown from a two-year current meter mooring in the Canary Basin near 32°N, 24°W. Current meters were located at depths of 470 m, 970 m, 1070 m and 2970 m during the period October 19, 1984 to October 4, 1986. The mooring deployment is part of an 1984-1988 experiment to measure features of advection and diffusion of Mediterranean outflow water with neutrally buoyant SOFAR floats.

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Preface

This volume is the 40th in a series of technical reports presenting moored current meter and associated data collected by the W.H.O.I. Buoy Group.

The data in this report are from a single mooring near 32°N, 24°W and were gathered in association with a SOFAR float experiment. The SOFAR float data is presented in W.H.O.I. technical report 86-31.

Only the volumes covering data gathered since 1978 are listed here.

A data directory and bibliography for the years 1963-1978 has been published as W.H.O.I. technical report 79-88.

Volume No.	W.H.O.I. Ref. No.	Author	Experiment
XVIII	79-65	Tarbell, S., M. G. Briscoe and R. A. Weller	1978 JASIN
XXI	79-85	Mills, C. and P. Rhines	1978 W.B.U.C.
XXIII	80-40	Tarbell, S. and R. Payne	1978 POLYMODE
XXVIII	81-73	Mills, C., S. Tarbell and R. Payne	1978 L.D.E.
XXIX	82-16	Levy, E., A. Spencer, G. Needell, G. Hund and J. Luyten	1979 INDEX
XXX	82-43	Levy, E., S. Tarbell and N. P. Fofonoff	1979 GSE/NSOI
XXXI	83-30	Levy, E. and S. Tarbell	1981 WESPAC
XXXII	83-46	Levy, E.	1979 Vema Channel
XXXIII	84-6	Spencer, A., D. Chausse and W. B. Owens	1981 NPBC
XXXIV	84-16	Levy, E. and P. L. Richardson	1983 SEQUAL I
XXXV	84-36	Tarbell, S., N. J. Pennington and M. G. Briscoe	1982-84 LOTUS
XXXVI	84-37	Levy, E. and P. L. Richardson	1983-84 SEQUAL II
XXXVII	85-7	Levy, E. and P. L. Richardson	1984 SEQUAL III
XXXVIII	85-39	Tarbell, S., E. T. Montgomery and M. G. Briscoe	1983-84 LOTUS
XXXIX	86-14	Levy, E. and S. Tarbell	1983-84 HEBBLE

Introduction to the Experiment

In 1984 we began an experiment to measure features of the general circulation and eddy mixing in the vicinity of the Mediterranean Water in the eastern North Atlantic. The purpose of the program is to answer the following specific questions:

- A) What is the thermocline mean depth flow in the vicinity of the Mediterranean salt tongue? How does this observed mean flow fit with contemporary circulation schemes?
- B) What is the magnitude and isotropy of horizontal eddy diffusion in the eastern basin? What is the advective/diffusive balance of the salt tongue?
- C) What are the horizontal and temporal scales of the mesoscale eddy field? Is there a regional (1000 km scale) variation of first order eddy properties?

The field program which is intended to answer these questions was made up of three elements: (i) deployment of a coherent float cluster and additional floats over a wider geographical area, (ii) hydrographic stations, and (iii) deployment of a mooring with 4 current meters at nominal depths of 500, 1000, 1100 and 3000 meters.

(i) Float Deployments

A cluster of 14 floats was launched near 32°N, 24°W with nearest neighbors at about 20 km initial spacing (Figures 1 and 2). While this cluster remains partially intact, it will provide estimates of horizontal eddy scales and dynamic balances. The rate of breakup of this coherent cluster will provide two particle diffusion estimates. During the second and third years, this cluster will be spread over a region of the order of 300 km in diameter, and its data used to estimate regional variations of the first order properties (mean velocity, eddy kinetic energy spectra, etc.)

Seven floats were deployed along a line extending from 37°N, 21°W to 24°N, 27°W in order to explore some circulation features in the eastern basin such as the Azores front and the North Equatorial Current. An additional four floats (not shown) were launched by L. Armi and T. Rossby (Armi and Zenk, 1984) within a "meddy" (submesoscale eddy of the Mediterranean water).

All floats were ballasted for 1100 m, which is near the salinity maximum and within the sound channel. Most of the floats settled slightly deeper than this, typically about 1200 m, which is well within the Mediterranean layer.

MEDITERRANEAN OUTFLOW EXPERIMENT 1984 - 1985

Figure 1: Location of current meter mooring, float launch locations, hydrographic stations and moored autonomous listening stations (ALS).

Figure 2: Location of current meter mooring and composite of the trajectories of the SOFAR floats launched to examine the large scale circulation and eddy field. Arrow heads appear at ten-day intervals along the trajectories. Note the near zonal, low frequency sloshing suggestive of a wavelike eddy motion and especially the westward displacement of floats launched near 32°N.

The floats were tracked acoustically by signals received at an array of four Autonomous Listening Stations (ALS). Details of the first year of the SOFAR float program are given by Price et al. (1986).

(ii) Hydrography

Nansen bottle casts with twelve bottles per cast were made along the north/south line where the floats and the mooring were launched. Parameters measured were temperature, salinity, dissolved oxygen and silica concentration (Figure 3). These data have been described by Käse et al. (1986).

(iii) Current meter mooring

A mooring with four current meters was set in the center of the SOFAR float cluster near 32°N, 24°W (Figure 1). The current meters were at depths of 470 m, 970 m, 1070 m, (for some redundancy) and at 2970 m. The current meter data provide the only long term measure of vertical structure in the experiment and are an important complement to the float measurements which show only the horizontal structure.

Figure 3: Vertical sections of Nansen bottle data with location of current meters shown as X.

Discussion

The current meter progressive vector plots show predominantly westward flow at all depths from October 1984 to August 1985. Thereafter the mean flow was nearly zero as compared to the accompanying time dependent fluctuations. At 470 m the mean flow was -6.3 cm/sec, at 1070 m -3.0 cm/sec, and at 2970 m -1.2 cm/sec (Figure 4). The time series plots of velocity reveal that this westward flow, which peaked during March-April 1985, is larger in amplitude and of longer duration than others which appear throughout the record (with periods of a few months and amplitudes of a few cm/sec).

We mention this westward flow or 'jet' because it also appeared prominently in the SOFAR float trajectories from the first year. The SOFAR floats showed that the westward mean flow within the Mediterranean Water was confined to a rather narrow jet centered on 32°N which coincided with the cluster of floats (Figures 5 and 6). A few of the cluster floats moved westward 500 km over the first year. At the other float locations outside the cluster, the mean flow was eastward and very weak, typically 0.5 cm/sec, if distinguishable from zero. These first year data suggest a narrow, roughly 100 km wide, westward flowing jet of Mediterranean Water with a broad and weak return flow to the north and south.

The mean westward volume transport of the jet was estimated to be approximately $10 \times 10^6 \text{ m}^3/\text{s}$ from the mean velocity at the current meter mooring (October 1984 to August 1985) and from the float trajectories. Transport per unit width was obtained by assuming a linear relationship between the following mean velocity values and depths: 6.4 cm/sec (assumed) at the surface, 6.4 cm/sec at 470 m, 3.6 cm/sec at 970 m, 3.1 cm/sec at 1070 m, 1.2 cm/sec at 2970 m, and 0 cm/sec (assumed) at 5400 m, the depth of the sea floor. The transport per unit width was multiplied by 100 km, the approximate width of the jet inferred from SOFAR floats.

During the time of the westward flow in early May 1985 a rapid and large amplitude variation in temperature and velocity was observed centered near 1000 m. An expanded scale plot of these data is shown in Figure 7. If we assume that a circular eddy was being advected by the mean flow which at 970 m was westward at about 8 cm/sec, then we conclude from the velocity series that the eddy was cyclonic and warm, that its center passed to the north of the mooring, and that it was approximately 50 km in diameter. Alternatively, if we assume that the eddy was moving eastward, then we conclude it was anticyclonic and its center passed to the south of the mooring. This alternative explanation is attractive because warm core anticyclonic meddies have been observed in the Canary Basin. However, it is difficult to imagine how an eddy could drift eastward against such a swift mean westward velocity, and thus our tentative conclusion is that the eddy was cyclonic.

Figure 4: Mean westward velocity from October 4, 1984 to August 1, 1985 recorded at the mooring site.

Figure 5: Mean displacement vector of the SOFAR floats and mean velocity from the 1070 current meter over the interval from October 1984 to October 1985.

Figure 6: Mean zonal velocity from October 1984 to October 1985 from SOFAR floats and current meter near 1100 m depth.

Figure 7: Plot of warm event at 970 m and associated velocity for the period May 2-16, 1985. The mean velocity during this period, which was westward, was subtracted from each series in this plot. The velocity series was smoothed with a 2-day Gaussian shaped filter and subsampled at 6 hours.

Mooring

The mooring was a normal W.H.O.I. subsurface mooring (Heinmiller, 1976). It was set in October 1984 and recovered in October 1986, and was the third two-year mooring set by the W.H.O.I. Buoy Group. Table 1 lists the configuration of the mooring and various mooring statistics. Figure 2 is a chart showing the mooring position in relation to the SOFAR float tracks. The depths of the instruments were computed using program NOYFB (Moller, 1976).

Current Meters

The four instruments used on the mooring were vector averaging current meters (VACMs) built at EG&G Sea-Link. The velocities are derived using a Savonius rotor, an external vane, and an internal compass. The compass and vane values are sampled each eighth of a rotor turn and the results accumulated in registers for the length of the recording cycle, in this experiment 1800 seconds (1/2 hour). The temperature is accumulated over the length of the recording cycle and has an accuracy of about 10 millidegrees (Payne et al., 1976). The clock is a crystal oscillator that has an accuracy within one second per day.

One of the current meters had a conductivity cell attached to the instrument. No conductivity data were recovered because the shift register failed.

Table 1

Configuration of Mooring 831

Set Oct 19 1984 Cruise Oceanus 158
Recovered Oct 4 1986 Cruise Endeavor 149

Lat 32 03.4 N Water depth 5371 m
Long 24 04.0 W Magnetic variation 14 W

Item Length (meters)	Item	Depth (meters)	Data Identifier
	3 ball float	430	
2	1/2" chain		
37	37 17" glass balls on 1/2" chain		
2	3/8" chain		
2	VACM V-0431	471	8311
495	3/16" wire		
2	VACM V-0433	971	8312
89	3/16" wire		
5	5 17" glass balls on 1/2" chain		
2	3/8" chain		
2	VACM V-5106	1071	8313
1000	3/16" wire		
868	3/16" wire		
16	16 17" glass balls on 1/2" chain		
2	3/8" chain		
2	VACM V-5116	2971	8314
2	3/8" chain		
2	Release	2973	
2	1/2" chain		
500	1/4" wire		
500	1/4" wire		
500	1/4" wire		
468	1/4" wire		
200	1/4" wire		
200	1/4" wire		
10	3/4" nylon rope		
3	1/2" chain		
	3000# Anchor with Danforth	5371	

Data Processing

Data from VACM cassettes were read through an LSI interface onto a VAX disc. The data were then reformatted into the Maltais format, the time base checked, and the data converted to scientific units. Then the data quality (Table 2) was determined, bad data points edited out, and the data truncated to remove launch and retrieval transients. Gaps in the data have been linearly interpolated to create an evenly spaced time series. This series is known as the Best Basic Version (BBV) and is the basis for all further processing. A low-passed version of the data was created by applying a Gaussian filter with a half-width of 24 hours, then subsampling the filtered series once a day.

W.H.O.I. Buoy Group data are identified by a mooring number, a sequential instrument position number, a letter to indicate the data version and numbers to indicate the sampling rate. Therefore, 8314B1800, identifies data from the fourth instrument on mooring 831. The version number is B and the sampling rate is a record every half hour (1800 seconds). 8311B1DG24 is a time series that has had a Gaussian filter applied to the first instrument on mooring 831. The filter has a half width of 24 hours and is subsampled once a day.

Table 2

Data Quality

depth (meters)	data cycles	# of days	Start / Stop	Comments
471	34226	712	841020 / 861003	
971	15872	329	841020 / 850916	instrument failed
1071	34226	712	841020 / 861003	no conductivity
2971	34226	712	841020 / 861003	

Data Presentation

Composite plots of progressive vectors, 'stick' plots, and temperature plots are shown. Variables versus time plots, histograms, spectral diagrams statistics and scatterplots are also presented.

HISTOGRAMS

The histograms of 5 variables are plotted as percentage of occurrences. There are 50 cells in the x-axis of east component, north component, speed and direction. The x-axis of temperature has 100 cells.

PROGRESSIVE VECTOR PLOTS

Current vectors from one hour averages are placed head to tail to show the path a particle would have traveled in a perfectly homogeneous flow. The plot begins with an asterisk followed by annotated triangles at the first of each month.

SCATTER PLOTS

East and north components from the Gaussian filtered time series are plotted against each other. The line drawn is the principal axis, the major axis of the ellipse of variance. The values describing the principal axes in the statistical table do not quite describe the principal axes drawn on the plot as the table used the basic sampled data and the plot used the Gaussian filtered data.

SPECTRA

Plots of auto-spectra for the east component of velocity, the north component of velocity and the temperature are shown. Rotary spectra are also plotted for the velocity data. These show the decomposition of the vector series into the clockwise (solid line) and anti-clockwise (dashed line) harmonic components. Further information about the program used to create these plots may be found in the W.H.O.I. program report PROSPECT (Hunt, 1982).

The data is prewhitened and recolored. Program PROSPECT allows averaging in increasingly large groups. The 95% confidence limits are shown on the plots. The frequency-averaging sequence for this data is:

Number of freq.	Number of groups	Number of freq.	Number of groups
1	40	100	30
2	15	200	15
5	6	500	6
10	30	1000	7
20	15	100	1
100	1		

Other parameters are shown below:

data name	number points	number pieces	degrees freedom
8311	34200	1	2
8312	15870	1	2
8313	34200	1	2
8314	34200	1	2

STATISTICS

The statistics for each variable from the basic time series are presented. The equations used to derive the statistical parameters are described in 'The Buoy Group data processing system' which is in preparation.

VARIABLES VS. TIME

All plots of variables versus time are from the Gaussian filtered series. The 'stick' plots, which show individual current vectors along the time scale, are plotted two ways, with north up and rotated so that east is up.

Mooring 831

DEC 1984 MAR 1985 MAY JUL OCT DEC MAR 1986 MAY JUL

North comp

10 cm/s

East comp

DEC 1984 MAR 1985 MAY JUL OCT DEC MAR 1986 MAY JUL

Mooring 831 Temperature

```

*****
** 8311B1800 * 34226 POINTS FROM 84- X -20 TO 86- X -03
  INST. V-431      DEPTH 471 M.      BOTTOM DEPTH 5371 M.
  UNITS   =        CM/S          CM/S          CM/S          DEG C
VARIABLE  ----- EAST ----- NORTH ----- SPEED ----- TEMP
MEAN      -2.353          .440E-1      7.962          12.108
STD.ERR.  = .364E-1      .309E-1      .243E-1      .116E
VARIANCE  = 45.406      32.722      20.268      .460E
KURTOSIS  = 2.959      3.192      3.564      2.809
SKEWNESS  = -0.273      - .862E-1      0.911      -0.134
MINIMUM   = -28.028      -22.830      0.216      11.119
MAXIMUM   = 21.167      20.827      28.972      12.900
* * * * *
COVARIANCE = 3.590      ***      MAJAX = 6.808
CORR.COEFF. = .931E-1      ***      MINAX = 5.637
ORIENTATION = 75.244      ***      ELLIPSE = 0.172
*****

** 8312B1800 * 15872 POINTS FROM 84- X -20 TO 85- IX -16
  INST. V-433      DEPTH 971 M.      BOTTOM DEPTH 5371 M.
  UNITS   =        CM/S          CM/S          CM/S          DEG C
VARIABLE  ----- EAST ----- NORTH ----- SPEED ----- TEMP
MEAN      -2.866          -0.248      6.913          8.699
STD.ERR.  = .412E-1      .399E-1      .283E-1      .146E
VARIANCE  = 26.927      25.312      12.722      .340E
KURTOSIS  = 2.910      3.050      3.781      7.283
SKEWNESS  = -0.202      - .635E-1      0.948      1.194
MINIMUM   = -23.626      -21.420      0.195      8.164
MAXIMUM   = 12.358      15.998      23.692      9.801
* * * * *
COVARIANCE = -0.443      ***      MAJAX = 5.200
CORR.COEFF. = - .170E-1      ***      MINAX = 5.020
ORIENTATION = 104.376      ***      ELLIPSE = .346E
*****

** 8313B1800 * 34226 POINTS FROM 84- X -20 TO 86- X -03
  INST. V-5106     DEPTH 1071 M.     BOTTOM DEPTH 5371 M.
  UNITS   =        CM/S          CM/S          CM/S          DEG C
VARIABLE  ----- EAST ----- NORTH ----- SPEED ----- TEMP
MEAN      -1.182          0.168      5.571          8.288
STD.ERR.  = .246E-1      .224E-1      .156E-1      .116E
VARIANCE  = 20.784      17.139      8.318      .458E
KURTOSIS  = 3.068      3.215      4.733      3.785
SKEWNESS  = -0.242      .854E-1      1.159      0.183
MINIMUM   = -21.473      -17.842      0.123      7.471
MAXIMUM   = 12.776      19.057      23.003      9.488
* * * * *
COVARIANCE = 1.849      ***      MAJAX = 4.643
CORR.COEFF. = .980E-1      ***      MINAX = 4.045
ORIENTATION = 67.293      ***      ELLIPSE = 0.129
*****

** 8314B1800 * 34226 POINTS FROM 84- X -20 TO 86- X -03
  INST. V-5116     DEPTH 2971 M.     BOTTOM DEPTH 5371 M.
  UNITS   =        CM/S          CM/S          CM/S          DEG C
VARIABLE  ----- EAST ----- NORTH ----- SPEED ----- TEMP
MEAN      -0.503          -0.108      3.500          2.771
STD.ERR.  = .129E-1      .153E-1      .716E-2      .131E
VARIANCE  = 5.711      8.030      1.755      .586E
KURTOSIS  = 2.596      2.401      4.599      12.603
SKEWNESS  = - .466E-1      .951E-1      1.222      2.133
MINIMUM   = -10.448      -10.243      0.380      2.709
MAXIMUM   = 7.361      11.489      11.498      2.973
* * * * *
COVARIANCE = 1.167      ***      MAJAX = 2.918
CORR.COEFF. = 0.172      ***      MINAX = 2.286
ORIENTATION = 22.589      ***      ELLIPSE = 0.217

```

Data File 8311B1800 : Depth = 471m

Data File 8312B1800 : Depth = 971m

Data File 8313B1800 : Depth = 1071m

Data File 8314B1800 : Depth = 2971m

AUTO-SPECTRUM
8311B1800

AUTO-SPECTRUM
8312B1800

AUTO-SPECTRUM
8313B1800

AUTO-SPECTRUM
8314B1800

AUTO-SPECTRUM
8311B1800

AUTO-SPECTRUM
8312B1800

AUTO-SPECTRUM
8313B1800

AUTO-SPECTRUM
8314B1800

ROTARY SPECTRUM
CLOCKWISE IS SOLID LINE
8311B1800

ROTARY SPECTRUM
CLOCKWISE IS SOLID LINE
8313B1800

ROTARY SPECTRUM
CLOCKWISE IS SOLID LINE
8312B1800

ROTARY SPECTRUM
CLOCKWISE IS SOLID LINE
8314B1800

TOTAL SPECTRUM
8311B1800

TOTAL SPECTRUM
8313B1800

TAL SPECTRUM
8312B1800

TOTAL SPECTRUM
8314B1800

AUTO-SPECTRUM
8312B1800

AUTO-SPECTRUM
8313B1800

AUTO-SPECTRUM
8314B1800

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