SOFAR Float Mediterranean Outflow Experiment
Data from the Second Year, 1985-1986

by
Marguerite E. Zemanovic
Philip L. Richardson
James R. Valdes
James F. Price
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September 1988

Technical Report

Support was provided by the National Science Foundation under grant Numbers OCE 82-14066 and OCE 86-00055.

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Woods Hole, Massachusetts 02543  
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Robert C. Beardsley, Chairman  
Physical Oceanography
SOFAR Float Mediterranean Outflow Experiment — Data from the Second Year, 1985–1986

Marguerite E. Zemanovic
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August 18, 1988
Abstract

In October, 1984, the Woods Hole Oceanographic Institution SOFAR float group began a three-year-long field program to observe the low frequency currents in the Canary Basin. The principal scientific goal was to learn how advection and diffusion by these currents determine the shape and amplitude of the Mediterranean salt tongue. Fourteen floats were launched at a depth of 1100 m in a cluster centered on 32°N, 24°W, and seven other floats were launched incoherently along a north/south line from 24°N to 37°N. At the same time investigators from Scripps Institution of Oceanography and the University of Rhode Island used four other SOFAR floats to tag a Meddy, a submesoscale lens of Mediterranean water.

In October, 1985, seven additional floats were launched, four in three different Meddies, one of which was tracked during year 1. This report describes the second year of the floats launched in 1984 and the first year of the ones launched in 1985. Approximately 41 years of float trajectories were produced during the first two years of the experiment. One of the striking accomplishments is the successful tracking of one Meddy over two full years plus the tracking of two other Meddies during the second year.
1 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-depth mean 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 intended to answer these questions was made up of two elements: (i) deployment of a coherent float cluster and additional floats over a wider geographical area (Figure 1), and (ii) deployment of a mooring with four current meters at nominal depths of 500, 1000, 1100 and 3000 meters (Figure 2).

1.1 Float Deployments

A cluster of 14 floats was launched in 1984 near 32°N, 24°W with nearest neighbors at about 20 km initial spacing. 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 wider region and data will be used to estimate regional variations of the first order properties (mean velocity, eddy kinetic energy, spectra, etc.).
Figure 1: Float launch positions.
Figure 2: Location of autonomous listening station (ALS) moorings, current meter moorings, and bathymetry in the experimental area.
Seven floats were deployed in 1984 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 were launched by L. Armi and T. Rossby within a Meddy, a submesoscale eddy of the Mediterranean water (Armi and Zenk, 1984). These eddies are approximately 100 km in diameter, 800 m thick, and are centered at a depth of 1100 m. The data from 1984–1985 have been described in a data report by Price et al. (1986). In 1985 four floats were launched in three different Meddies, one of which was being tracked by 1984 floats, and three additional floats were launched outside of Meddies. This report discusses the second year of the floats launched in 1984 and the first year of the floats launched in 1985.

1.2 Current Meter Mooring

A mooring with four current meters was set in the center of the SOFAR float cluster near 32°N, 24°W (Figures 1 and 2). 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. These data have been described by Tarbell et al. (1987) and by Schmitz et al. (1988).

2 1985 and 1986 Cruises

In the Fall of 1985 we returned to the Canary Basin to retrieve and reset the ALS moorings and to launch additional floats (Tables I and II). We launched four floats (144, 145, 146 and 147) along a line between 21°N, 18°W and 24°N, 24°W, one by chance in a Meddy. On a subsequent cruise, three additional floats were
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ALS MOORINGS

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Note:
A-D are WHOI moorings, F1-F3 are moorings maintained by COB, France (Colin de Verdière, personal communication).
### TABLE II

**FLOAT FILE STATISTICS FOR 1985 - 1986 TRACKING**

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**MEDDY FLOATS**

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<th>START LONG. deg W</th>
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* Retracked from 1984 with available French ALS's.
launched by L. Armi in two Meddies – one float (150) in the Meddy tracked by floats during the first year and two floats (148, 149) in a third, newly discovered Meddy.

In the Fall of 1986 we retrieved and reset the ALS moorings and searched for two of the Meddies using a shipboard hydrophone. We found and measured, with CTD profiles, the Meddy tracked since the Fall 1984. These data were combined with data from three earlier cruises to the Meddy; a detailed description of its movement and changes in physical structure is given by Armi et al. (1988a,b). We were unsuccessful in our search for the second Meddy expected to be in the vicinity of floats 148 and 149. We conclude that this Meddy collided with Hyères seamount in July 1986 and the normal Meddy circulation was severely disrupted or destroyed. Floats 148 and 149 which had been looping in the Meddy stopped looping, their depth suddenly increased and their temperature decreased. Our search near these two floats in October 1986 failed to find any salty water indicative of a Meddy. A possibility exists that the Meddy shed the floats during its collision with Hyères seamount but kept moving afterward away from the floats. A more complete discussion of the three tracked Meddies is given by Richardson et al. (submitted).

3 Float Data

All floats (except 149 and 150) were ballasted for 1100 m, which is near the salinity maximum and within the sound channel (see Table II). Most of the floats settled slightly deeper than this — typically about 1200 m (Table III) — which is well within the Mediterranean layer. In addition to float position, we obtained temperature and pressure at two-day intervals. From these data we can determine the statistics of isotherm fluctuation, and for the coherent cluster, the horizontal scales of the fluctuations.
### TABLE III

**1984 - 1986 FLOAT FILE STATISTICS**

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* Last four digits of Julian day counter.  TOTAL 40.6 yrs.
The floats were tracked acoustically by signals received at a net of four Autonomous Listening Stations (ALS's) supplemented by three French ALS's which were useful for floats that drifted west of the Meteor seamounts (Figure 2). The ALS's worked normally and the tracking of these floats proceeded smoothly.

4 Data Processing and Float Tracking

A report in preparation by W. B. Owens and T. K. McKee will describe the float tracking process in detail. Some elements of the final processing phase are described briefly here.

The ALS cassette tapes containing times of arrivals and telemetry for each float were processed at Woods Hole Oceanographic Institution in three phases. The first phase converts the raw data into a time series of possible times of arrival and amplitudes of their correlations for each ten minute interval that the ALS's were in the water. The second phase, float tracking, has three steps: (1) identify and extract the float signals for each ALS; (2) track the floats and estimate the drift of the SOFAR float clock; and (3) create a FLOATER format (McKee, 1986) file for each float containing raw positions and pressure and temperature telemetry. The tracking used a constant sound speed. The third phase consists of editing, interpolating, and smoothing the data to produce final float trajectories and velocity, temperature, and pressure time series.

Trajectory and time series plots were inspected for outliers, and the preliminary FLOATER format files were edited where necessary to eliminate obviously bad positions, temperature, and pressure values. Listings of direction and speed derived from consecutive positions were used to detect unusually high speeds indicative of erroneous positions. First differences between consecutive temperatures and pressures were calculated and inspected for unrealistic values. Radical changes in temperature that were not accompanied by a similar change in
pressure (or vice versa) were presumed to indicate an erroneous value. Temperature and pressure that drifted outside the range of the sensors was listed as being offscale. Temperature and pressure values that were not associated with a position were deleted.

Trajectories having gaps of greater than ten days were broken into subfiles and labeled A, B, C, etc. Gaps of less than ten days duration in position, temperature, and pressure were linearly interpolated, producing daily values of temperature and pressure from the bi-daily values recorded.

These interpolated series were then smoothed using a five point one-day half-width Gaussian filter. Finally, a cubic spline was fitted to the smoothed positions and east and north components of velocity were calculated to coincide with the positions at 24-hour intervals. Float data from 1984–1985 were merged with those from 1985–1986.

A float file name is up to six characters long and is made up of three parts:

1. A two letter code to indicate the experiment, in this case, EB (for "Eastern Basin").

2. A one to three digit identifier assigned to the float before its launch.

3. A single letter suffix (A, B, C, ...Z) that was added to the file name if the float record was broken into sections due to gaps in the data. An example is float name EB124B — Experiment Code EB, Float 124, Section B.

The accuracy of the tracking may be judged by comparing the known launch position with the first position calculated by tracking. The differences between these two positions as well as the time difference between launch and the first position have been given by Price et al. (1986). The position difference is 5.6 km with an average time delay of nine hours, which is more than adequate accuracy for most purposes. A measure of the precision of the tracks can be obtained from
(a) the variability in the ranges between a float and the ALS's for each position and (b) the point to point variations in the estimates of the float clock drift. Both of these suggest that the precision of the float positions is approximately 2 km.

The floats used in this experiment were very similar in design to the floats deployed in the Gulf Stream Recirculation Experiment (GUSREX) program where they functioned fairly reliably. A defective component in the telemetry circuit discovered after launch caused some failures in temperature and pressure and a shorter than normal life of some floats. At the end of year two there were 15 floats still being tracked (Figure 3, Table II). The final recovery of ALS’s is scheduled for June 1988, which will give another 1.5 years of tracking for these floats.

5 Summary Plots

Displacement vectors of the floats from 1984 to 1986 and for the first and second year of the experiment are given in Figures 4a to 4c. Composites of trajectories are shown in Figures 5a to 5c. Similar plots for Meddy floats are given in Figures 6a to 6c and Figures 7a to 7c. The detailed movement of the three Meddies is shown by float 128 in Meddy 1, float 149 in Meddy 2, and float 145 in Meddy 3 (Figure 8). Telemetry from these three floats is given in Figure 9.

Summary plots of float trajectories and progressive vector plots from two current meters for each two-month period during the two years are shown in Appendix A. Individual trajectories and time series plots of T, P and velocity for 19 floats are given in Appendix B, and for seven Meddy floats in Appendix C (see Table II).

The floats and current meters launched in the vicinity of 32°N, 24°W show a relatively swift mean westward flow (see Price et al., 1986). One float went 1320 km westward over the two years. We conclude the float cluster was launched in a rather narrow westward flowing jet ~100 km in width. Current meters show
Figure 3: Bar graph showing the time that each float was tracked.
Figure 4a: Displacement vectors from the first to last position of each float (1984–1986).
Figure 4b: Displacement vectors from the first to last position of each float (1984–1985).
Figure 4c: Displacement vectors from the first to last position of each float (1985–1986).
Figure 5a: A composite of 24 float trajectories between 1984–1986. Arrowheads are located at 30-day intervals along the trajectories.
Figure 5b: A composite of 21 float trajectories between 1984-1985. Arrowheads are located at 30-day intervals along the trajectories.
Figure 5c: A composite of 19 float trajectories between 1985–1986. Arrowheads are located at 30-day intervals along the trajectories.
Figure 6a: Displacement vectors for floats launched in Meddies (1984–1986).
Figure 6b: Displacement vectors for floats launched in Meddies (1984–1985).
Figure 6c: Displacement vectors for floats launched in Meddies (1985–1986).
Figure 7a: A composite of eight float trajectories launched in Meddies (1984–1986).
Figure 7b: A composite of four float trajectories launched in Meddies (1984–1985).
Figure 7c: A composite of seven float trajectories launched in Meddies (1985-1986).
Figure 8: The translation of three Meddies as given by the trajectories of SOFAR floats — float 128 in Meddy 1, float 149 in Meddy 2, and float 145 in Meddy 3. The floats in Meddies 1 and 2 continued to loop up to the end of the tracking in October 1986. Meddy 2 collided with a seamount in July–August 1986 and the two floats (148, 149) stopped looping.
Figure 9: Temperature and pressure series from a float in each Meddy. All three floats initially settled deep and gradually rose toward the target pressure shown by dark arrows. The large drop in temperature measured by float 149 coincides with Meddy 2’s collision with Hyères seamount and the float encountering cooler fresher water. The downward spikes in temperature and pressure of float 128 in July 1985 and spring 1986 are inferred to be a result of the float encountering patches or layers of fresher cooler water.
that it was not confined to just the Mediterranean water, and that it was surface intensified (Tarbell et al., 1987). A few floats drifted westward in this region during the two years suggesting the jet was a relatively long-lived feature. Evidence from our current meters located near 32°N and others near 33°N (Zenk and Muller, 1988) suggests the jet may have migrated from 32°N to 33°N during the two years. Away from the jet the mean flow is weak and generally eastward.

The three Meddies moved on average southwestward with a mean velocity of 1.6 cm/sec toward 202° (Figure 8). Meddy 1, tracked for two years, moved 1090 km southward with a mean velocity of 1.8 cm/sec. By October 1986 this Meddy was found to be almost totally decayed as compared to its original structure (see Armi et al., 1988a,b). Meddy 2 drifted 530 km southwestward for 8.5 months with a mean velocity of 2.2 cm/sec and collided with Hyères seamount near 31°N, 29°W. At this time the two floats trapped in this Meddy stopped looping implying a major disruption of this Meddy. Meddy 3 drifted 380 km southwestward for a year with a mean velocity of 1.2 cm/sec. Further tracking in 1986–1988 may give longer trajectories for Meddies 1 and 3.

6 Acknowledgements

This research was made possible with funds provided by the National Science Foundation (OCE82-14066 and OCE86-00055). Principal investigators were J. F. Price and P. L. Richardson.

Floats were purchased from Webb Research Corporation. They were ballasted, prepared for sea and launched by the WHOI float operations group consisting of J. R. Valdes, R. D. Tavares and B. J. Guest. The operations group also maintained, moored and retrieved the ALS’s. The floats were tracked by M. E. Zemanovic at Woods Hole Oceanographic Institution using a system developed by W. B. Owens. M. A. Lucas typed the manuscript.
7 References


Appendix A — Two Month Composites of Trajectories from October 1984 to September 1986

Twelve plots are presented showing a summary of all float trajectories for each two-month period from October 1984 to September 1986, and two progressive vector plots (dashed arrows) from current meters, one at 33°N, 24°W (Zenk and Muller, 1988), and the other at 32°N, 24°W (Tarbell et al., 1987).
Appendix B — Plots of Individual Floats

A trajectory plot and time series plots are presented for each float. The order of the time series plots is velocity stick diagram, $u$ and $v$ velocity component overplot, and temperature and pressure overplot. A common scale is used for the time axis, but the $y$ axis varies for each float according to the minima and maxima of the variable plotted. Two hundred days of data are plotted on each page. Float files of lengths greater than 200 days are continued on subsequent pages. The time axis is annotated with the last four digits of the Julian day and with the calendar months. Refer to the conversion chart (Appendix D) to convert Julian day to calendar day. Data points are marked daily.

A trajectory for each float is plotted on a mercator projection. For the longitude axis, negative numbers indicate longitudes west of the Greenwich Meridian. Along the trajectories, open circles denote the first float position, small dots mark the daily positions, large dots the tenth day, and every twentieth day is annotated with the last four digits of the Julian date.

Stick plots show velocity every day. The stick length indicates the speed in cm s$^{-1}$, and the angle the stick makes with the horizontal axis represents the direction. North is toward the top of the page. The east and north components of velocity can be seen separately in overplots plotted to the same scale as the stick plots.

Temperature and pressure are overplotted, temperature on a centigrade scale marked on the left $y$ axis, pressure in decibars marked on the right $y$ axis with deeper values at the bottom of the scale.
EASTERN BASIN 121

U \& V \text{ cm/s}

20 10 0 10 20

-20 -10 0 10 20

JULIAN DAY

APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER

1986

47
EASTERN BASIN 121

NORTH [x] cm/s

EAST [●] cm/s

JULIAN DAY

OCTOBER 1985

JANUARY 1986

FEBRUARY

MARCH

NOVEMBER

1985

1986

1 JAN-88 14:31:52

PLOT 1 OF 2

6320 6340 6360 6380 6400 6420 6440 6460 6480 6500 6520

6320 6340 6360 6380 6400 6420 6440 6460 6480 6500 6520
EASTERN BASIN 126
EASTERN BASIN

Plot of 2 SPL.

U & V cm/s

JULIAN DAY

1-JAN-86 14:38:41

OCTOBER NOVEMBER DECEMBER JANUARY FEBRUARY MARCH APRIL

1985 1986

U & V cm/s

JANUARY-FEBRUARY 1986

68
EASTERN BASIN 127A

PRESSURE [hPa]

TEMPERATURE [°C]

JULIAN DAY

JUNE 1985

PLOT 2 OF 4
EASTERN BASIN 130

LATITUDE N

LONGITUDE ° W

33 32 31 30 29 28 27 26 25

66 65 64 63 62 61 60

PLOT 1 OF 1
EASTERN BASIN 130

TEMPERATURE [°C]

PRESSURE [db]

JULIAN DAY

OCTOBER 1985  NOVEMBER  DECEMBER  JANUARY  FEBRUARY  MARCH  APRIL

1-JAN-86  14:45:21
EASTERN BASIN 133

Plot 2 of 4

1-JAN-88 14:49:25
EASTERN BASIN 137

A graph showing the changes in east and north components over Julian days from April 1986 to October 1986. The graph indicates fluctuations in the components with time.
EASTERN BASIN 138

LATITUDE

LONGITUDE W

42 41 40 39 38 37

-22 -21 -20 -19 -18 -17

PLOT 1 OF 1

1-20K-98 14:50:32
10 Appendix C — Meddy Floats

Individual float trajectory plots and a group of time series plots are presented for seven Meddy floats tracked in 1985 and 1986. These data were processed in parallel with our own data, but smoothing was omitted. Speeds were calculated from consecutive positions and subsampled to one per day before plotting. In addition, displacement vectors of the Meddy floats from 1984 to 1986 and for the first and second years of the experiment are given in Figures 6a to 6c. Composites of trajectories from Meddy floats are given in Figures 7a to 7c.
EASTERN BASIN 145

TEMPERATURE [°C]

PRESSURE [db]

JULIAN DAY

OCTOBER 1985
NOVEMBER
DECEMBER
JANUARY 1986
FEBRUARY
MARCH

30-DEC-87 13:34:49

PLOT 1 OF 2
EASTERN BASIN 148

\[ \text{x [cm/s]} \]

\[ \text{NORTH} \]

\[ \text{EAST} \]

JULIAN DAY

JUNE 1986

JULY

AUGUST

SEPTEMBER

OCTOBER

NOVEMBER

DECEMBER

PLOT 2 OF 2

23-DEC-87 09:35:15
EASTERN BASIN 148

TEMPERATURE [°C]

PRESSURE [db]

off scale

JULIAN DAY

DECEMBER 1985 JANUARY 1986 FEBRUARY MARCH APRIL MAY

23-DEC-87 09:35:05

PLOT 1 OF 2
EASTERN BASIN 148

PRESSURE [A] db

6580 6600 6620 6640 6660 6680 6700 6720 6740 6760 6780

JULIAN DAY

JUNE 1986

TEMPERATURE [°C]

off scale

209
EASTERN BASIN 149

U & V cm/s

JULIAN DAY

DECEMBER 1985  JANUARY 1986  FEBRUARY  MARCH  APRIL  MAY

23-DEC-87  09:36:35
11 Appendix D — Calendar Conversion Tables

These tables give the year day and truncated Julian day for each calendar
date for the years 1984 through 1986. The truncated Julian days range from
5701–6796. To convert to true Julian date, add 2440000.5 to these numbers.
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### Title and Subtitle

SOFAR Float Mediterranean Outflow Experiment  
Data from the Second Year, 1985-1986

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### Abstract (Limit: 200 words)

In October, 1984, the Woods Hole Oceanographic Institution SOFAR float group began a three-year-long field program to observe the low frequency currents in the Canary Basin. The principal scientific goal was to learn how advection and diffusion by these currents determine the shape and amplitude of the Mediterranean salt tongue. Fourteen floats were launched at a depth of 1100 m in a cluster centered on 32°N, 24°W, and seven other floats were launched incoherently along a north/south line from 24°N to 37°N. At the same time investigators from Scripps Institution of Oceanography and the University of Rhode Island used four other SOFAR floats to tag a Meddy, a submesoscale lens of Mediterranean water.

In October, 1985, seven additional floats were launched, four in three different Meddies, one of which was tracked during year one. This report describes the second year of the floats launched in 1984 and the first year of the ones launched in 1985. Approximately 41 years of float trajectories were produced during the first two years of the experiment. One of the striking accomplishments is the successful tracking of one Meddy over two full years plus the tracking of two other Meddies during the second year.

### Document Analysis

**a. Descriptors**

1. SOFAR floats
2. Canary Basin
3. Mediterranean Outflow

**b. Identifiers/Open-Ended Terms**

**c. COSATI Field/Group**

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