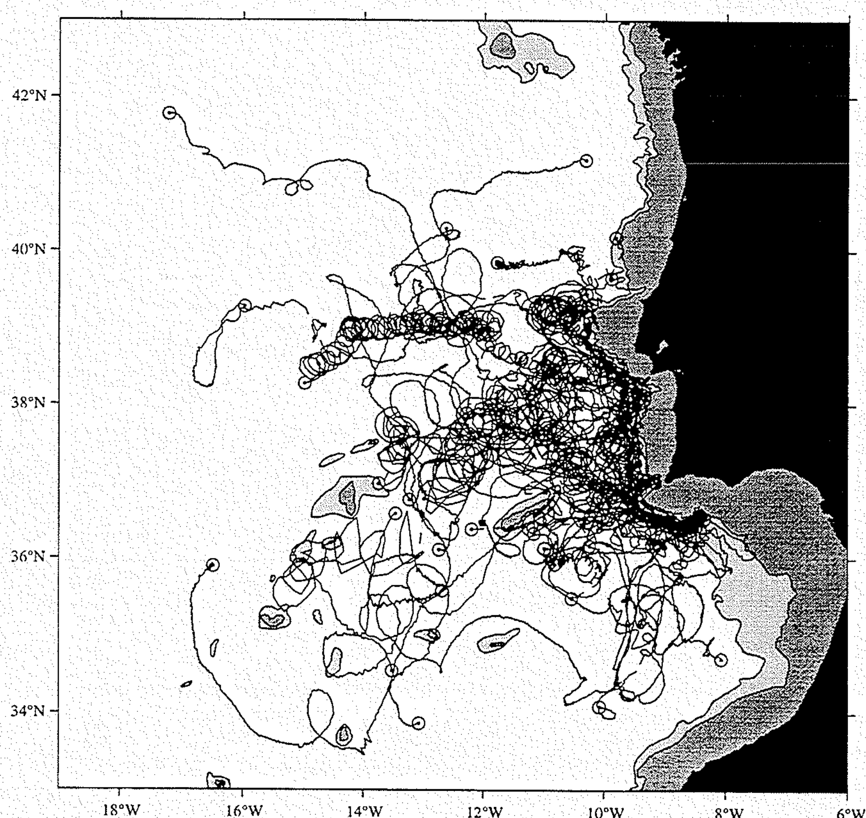
A Mediterranean Undercurrent Seeding Experiment (AMUSE):
Part II: RAFOS Float Data Report
May 1993 - March 1995

by

Heather D. Hunt, Christine M. Wooding, Cynthia L. Chandler,
and Amy S. Bower

June 1998



Woods Hole Oceanographic Institution
Technical Report
WHOI-98-14

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Approved for Distribution:

Terrence M. Joyce, Chairman
Department of Physical Oceanography

Abstract

This is the final data report of all acoustically tracked RAFOS data collected in 1993-1995 during A Mediterranean Undercurrent Seeding Experiment (AMUSE). The overall objective of the program was to observe directly the spreading pathways by which Mediterranean Water enters the North Atlantic. This includes the direct observation of Mediterranean eddies (meddies), which is one mechanism that transports Mediterranean Water to the North Atlantic. The experiment was comprised of a repeated high-resolution expendable bathythermograph (XBT) section and RAFOS float deployments across the Mediterranean Undercurrent south of Portugal near 8.5°W. A total of 49 floats were deployed at a rate of about two floats per week on 23 cruises on the chartered Portuguese-based vessel, Kialoa II, and one cruise on the R/V Endeavor. The floats were ballasted for 1100 or 1200 decibars (db) to seed the lower salinity core of the Mediterranean Undercurrent. The objectives of the Lagrangian float study were (1) to identify where meddies form, (2) to make the first direct estimate of meddy formation frequency, (3) to estimate the fraction of time meddies are being formed, and (4) to determine the pathways by which Mediterranean Water which is not trapped in meddies enters the North Atlantic.

Front Cover Figure Caption: "Spaghetti" diagram showing the AMUSE float tracks. The floats were launched south of Portugal, at about 36.6°N 8.4°W, to seed the Mediterranean Undercurrent. Untrackable float segments are represented as dashed lines; 'out of the page' symbols mark the surface positions. The 1000 and 2000 meter isobaths are shaded in gray.

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1. Introduction

This is the final data report of all acoustically tracked Ranging and Fixing of Sound (RAFOS) float data collected in 1993-1995 during A Mediterranean Undercurrent Seeding Experiment (AMUSE). Principal investigators for the project were Amy Bower of the Woods Hole Oceanographic Institution, Laurence Armi of the Scripps Institution of Oceanography, and Isabel Ambar of the University of Lisbon. The overall objective of the program, funded by the National Science Foundation and by the Luso-American Foundation for Development (FLAD), was to observe directly the spreading pathways by which Mediterranean Water enters the North Atlantic. This includes the direct observation of Mediterranean eddies (meddies), which is one mechanism that transports Mediterranean Water into the North Atlantic. The experiment was comprised of high-resolution expendable bathythermograph (XBT) and RAFOS float deployments in a

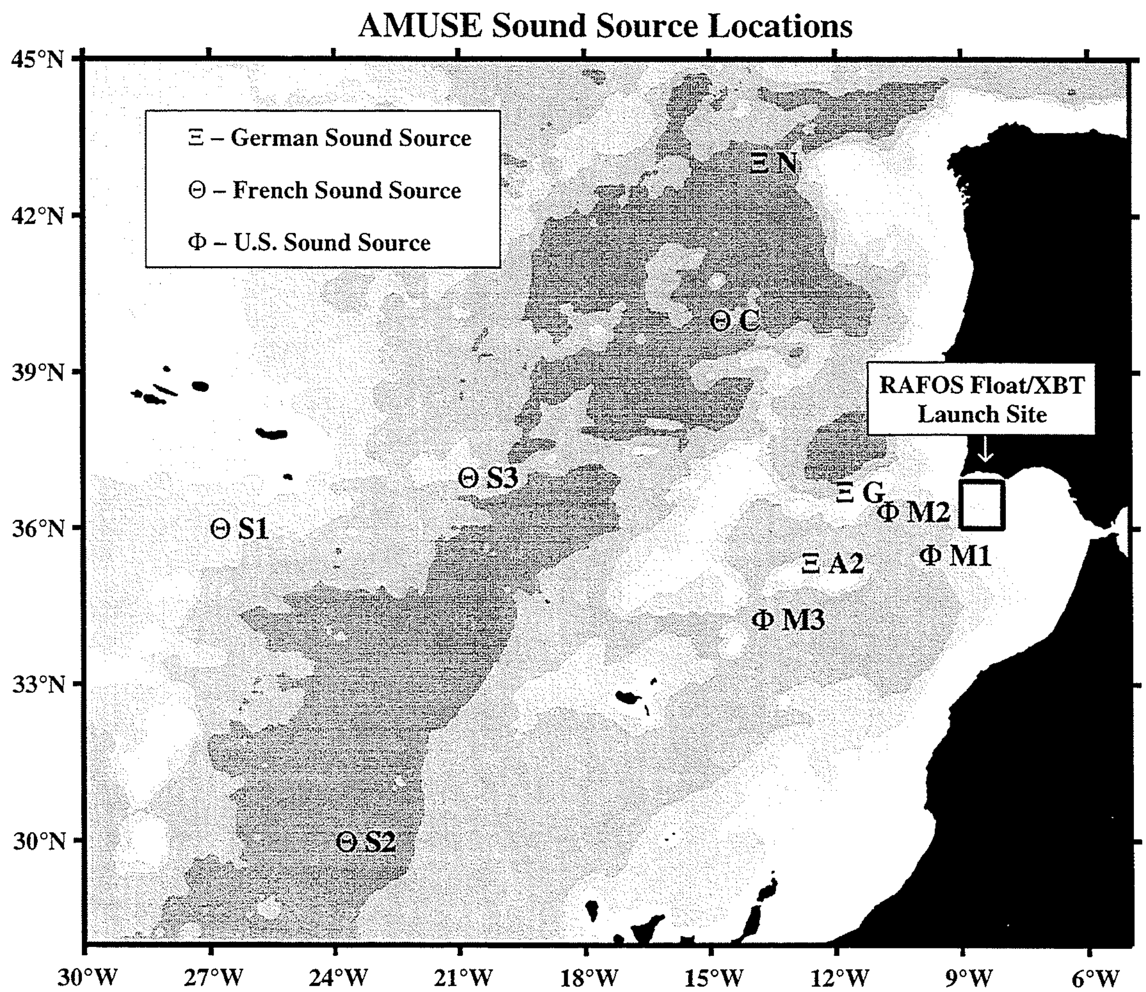

Figure 1: AMUSE float and XBT deployment and sound source locations in the eastern North Atlantic. Bathymetry intervals are every 1000 meters, shown by different shades of gray.

section across the Mediterranean Undercurrent south of Portugal (see Figure 1 and Figure 2). The objectives of the Lagrangian float study were (1) to identify where meddies form, (2) to make the first direct estimate of meddy formation frequency, (3) to estimate the fraction of time meddies are being formed, and (4) to determine the pathways by which Mediterranean Water which is not trapped in meddies enters the North Atlantic.

The Mediterranean Undercurrent is comprised of two salinity maxima. The deeper salinity core was chosen as the target for the float seeding since the water from this core is found in almost all meddies, while water from the upper core is found in only some meddies.

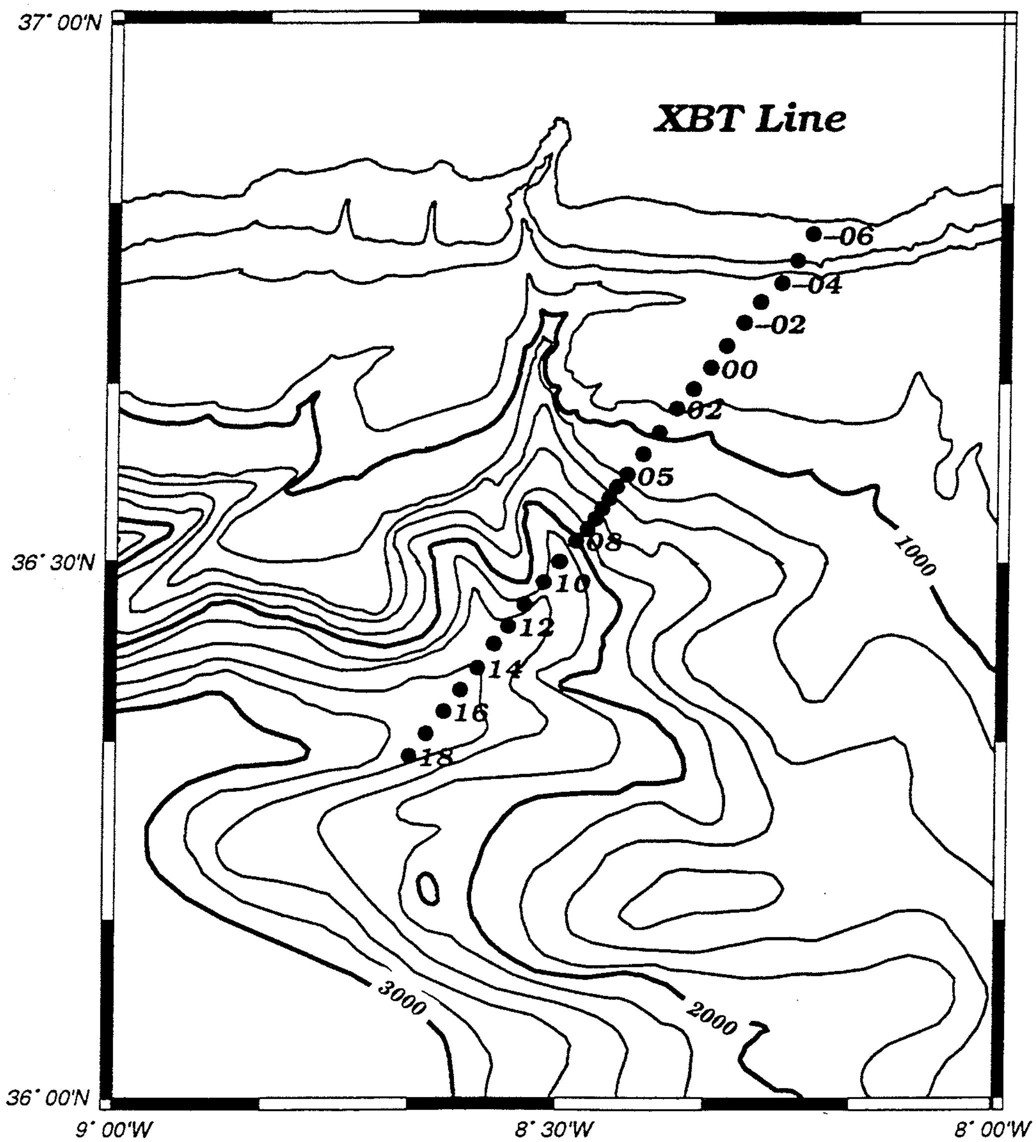

Figure 2: An expanded view of the float and XBT launch site, shown in Figure 1. The black dots mark where the XBTs were deployed. Floats were launched between XBT launch locations 05 and 08. Bathymetric contours are shown every 200 meters.

The first two floats were launched from the R/V Oceanus in May 1993 during a preliminary CTD survey of the Undercurrent south of Portugal aimed at finding the best float launch site for the repeated seeding. Forty-seven floats were subsequently deployed at a rate of about two floats per week on 22 of 24 cruises of the Portuguese-based chartered vessel Kialoa II between July 1993 and March 1994 (see Figure 3 and Table 1). The floats were ballasted for 1100 or 1200 decibars (db). They were programmed for up to 11-month missions, and tracked using seven moored sound sources. Three of the sources were deployed specifically for AMUSE from the R/V Oceanus in May 1993, and the others had been deployed by German and French scientists for other experiments.

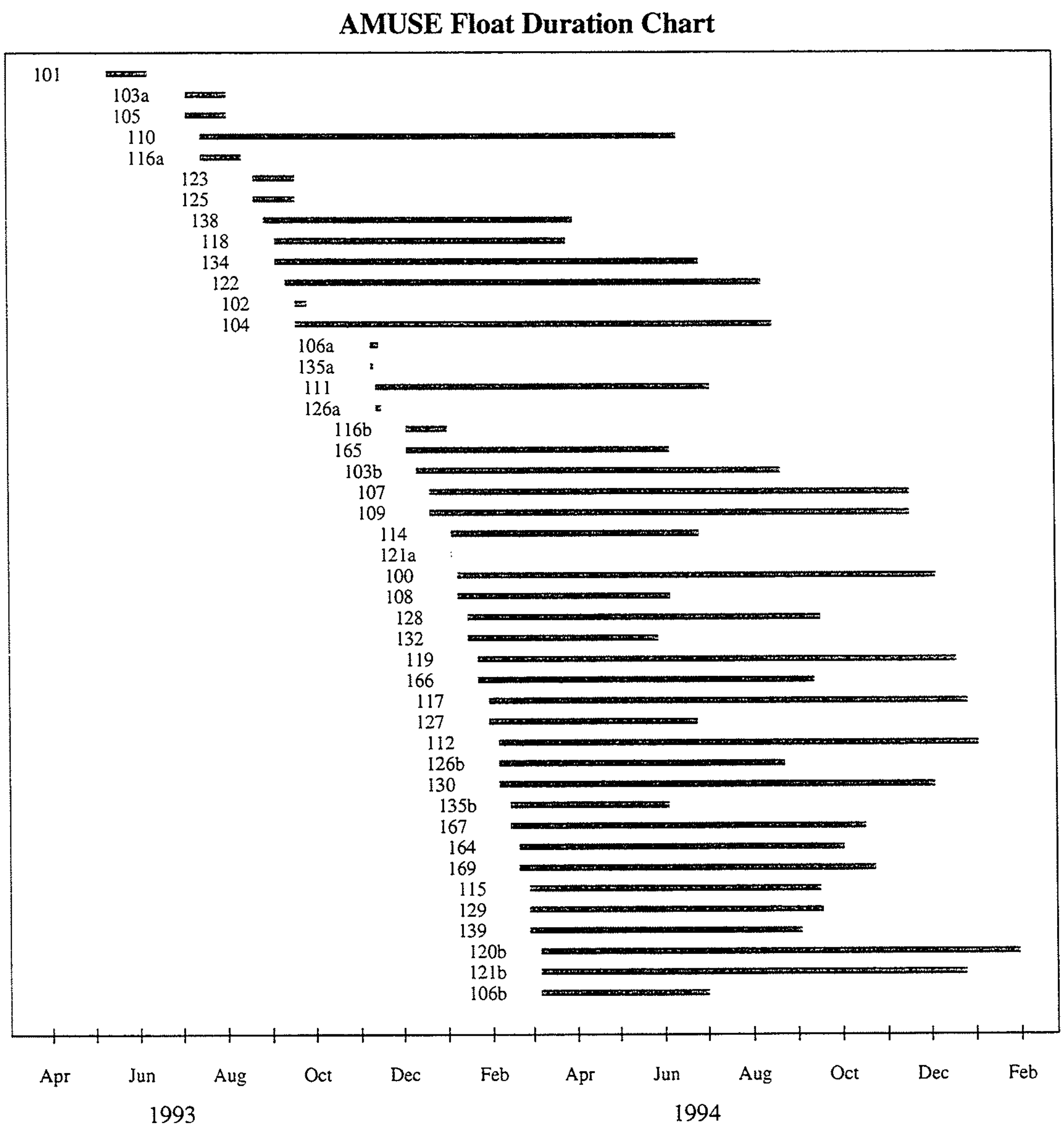

Figure 3: Float duration chart showing the periods that the floats were in the water. Float numbers are marked on the left. Floats are listed in order of launch date from top to bottom.

2. Description of the RAFOS Floats

The RAFOS float is an acoustically tracked subsurface Lagrangian drifter (see Rossby *et al.* (1986) for a complete description of the RAFOS system), which is programmed to listen for signals from moored sound sources. The RAFOS float determines the time-of-arrival (TOA) of these signals, from which, given the speed of sound in water, its position can be determined. The TOA of the acoustic signals, as well as temperature and pressure measurements are stored in the float's micro-processor memory. Also stored in the float's memory are correlation heights for each TOA, which indicate the quality of the TOA signal heard. The sound sources in this experiment were programmed to transmit an 80 second long continuous wave tone, which linearly increases its frequency from 259.375 Hz to 260.898 Hz. The individual sound sources broadcast this tone three times a day, and broadcast at different times (beginning at 0030, 0100, and 0130 UTC, and every eight hours thereafter). The floats in this experiment listened for these signals once every eight hours (beginning at 0025 UTC). The float temperature sensors were built by Yellow Springs Instrument Company and were calibrated to ±0.01°C. These thermistors were mounted on the main float board and logged manually. Float pressure sensors were built by Data Instruments and calibrated to ±1% at 2000 psi.

Table 1. RAFOS Float Summary – launch and surface data

Float ID	*Launch Site*	*LAUNCH*			*SURFACE*			*Length of Mission (days)*
		Date (yymmdd)	*Latitude (°N)*	*Longitude (°W)*	*Date (yymmdd)*	*Latitude (°N)*	*Longitude (°W)*	
101	OCctd110	930511	36.556	8.438	930610	37.692	10.064	30
113	OCctd111	930511	36.536	8.458	930512	36.533	8.447	1
103a	K0106	930705	36.561	8.442	930804	36.276	11.179	30
105	K0107	930705	36.539	8.462	930804	37.636	11.675	30
110	K0207A	930715	36.525	8.480	940613	38.014	15.150	333
116a	K0205	930715	36.577	8.429	930814	37.621	11.516	30
123	K0306	930821	36.564	8.442	930920	36.524	8.340	30
125	K0307	930821	36.542	8.460	930920	37.085	9.385	30
124	K0405A	930828	36.571	8.432	no show			
138	K0407	930828	36.540	8.465	940401	39.623	9.912	216
118	K0506	930904	36.561	8.443	940327	39.654	12.967	204
134	K0507	930904	36.542	8.460	940628	36.686	13.435	297
120a	K0606A	930911	36.549	8.453	930914	36.498	8.827	3
122	K0607A	930911	36.533	8.471	940810	37.891	12.311	333
102	K0706	930918	36.561	8.446	930928	36.965	9.850	10
104	K0707A	930918	36.531	8.471	940817	40.481	9.856	333
106a	K0906	931109	36.562	8.446	931116	36.689	9.313	6
135a	K0907A	931109	36.532	8.470	933113	36.476	8.566	5

Table 1. RAFOS Float Summary (continued)

Float ID	Launch Site	LAUNCH			SURFACE			Length of Mission (days)
		Date (yymmdd)	Latitude (°N)	Longitude (°W)	Date (yymmdd)	Latitude (°N)	Longitude (°W)	
111	K1006	931113	36.561	8.444	940705	35.209	10.266	235
126a	K1007	931113	36.542	8.463	931118	36.490	8.558	5
116b	K1205A	931204	36.572	8.437	940103	36.963	10.101	30
165	K1208	931204	36.522	8.482	940607	38.106	10.689	185
103b	K1306	931211	36.563	8.445	940822	37.663	11.103	254
170	K1307A	931211	36.531	8.470	940905	33.010	19.273	269
107	K1406	931220	36.562	8.444	941118	35.924	10.894	333
109	K1407A	931220	36.532	8.471	941118	41.803	17.204	333
114	K1505A	940104	36.572	8.434	940627	39.210	10.223	174
121a	K1506A	940104	36.551	8.453	940106	36.481	8.737	3
100	K1606	940108	36.561	8.445	941206	34.032	10.156	333
108	K1608	940108	36.521	8.480	940607	36.135	11.081	151
128	K1705A	940115	36.568	8.435	940918	40.340	12.760	246
132	K1706A	940115	36.550	8.452	940529	36.377	12.197	134
119	K1806A	940122	36.549	8.454	941220	41.272	10.487	333
166	K1807A	940122	36.531	8.470	940914	35.622	12.707	245
117	K1905A	940129	36.573	8.434	941228	39.351	15.716	333
127	K1907A	940129	36.534	8.472	940625	39.968	9.977	148
112	K2005A	940205	36.571	8.433	950104	36.007	16.478	333
126b	K2006A	940205	36.551	8.453	940824	36.666	13.236	201
130	K2007A	940205	36.530	8.471	941205	38.648	11.350	303
135b	K2105A	940213	36.570	8.434	940605	39.229	10.288	112
167	K2106A	940213	36.560	8.443	941018	39.312	11.057	247
164	K2205A	940219	36.572	8.434	941003	36.149	10.317	226
169	K2207	940219	36.541	8.460	941025	33.889	13.091	249
115	K2305A	940226	36.572	8.435	940917	34.373	13.501	203
129	K2307A	940226	36.532	8.467	940919	36.874	13.427	206
139	K2307	940226	36.542	8.460	940904	36.116	12.780	190
120b	K2406	940305	36.562	8.444	950201	37.881	12.102	333
121b	K2406A	940305	36.552	8.452	941226	35.022	7.555	297
106b	K2407	940305	36.542	8.461	940702	37.695	12.598	119

The RAFOS float electronics were built by Sea Scan, Inc. The WHOI float group (Jim Valdes, Bob Tavares, and Brian Guest) assembled the floats and ballasted them in the ballasting tank at Webb Research Corporation. A few floats were ballasted by the WHOI float group at the University of Rhode Island for comparison purposes. Isobaric floats were initially ballasted with a hollow drop weight that forces the floats to be neutrally buoyant at a desired pressure surface. More detail on the ballasting procedure can be found in the report by Anderson-Fontana *et al.*, 1996. It became apparent, after several floats sank, registered overpressure, and then surfaced early, that the hollow drop weights were susceptible to leaking and corrosion. The hollow weights were replaced early in the field program with solid drop weights, solving these problems. The floats were placed in the Mediterranean Undercurrent off Cape St. Vincent to follow the 1100 or 1200 db pressure surface.

After the float completes its mission, it is programmed to drop its external ballast, rise to the ocean surface, and telemeter its data to Service Argos receivers aboard the NOAA Polar Orbiting Environmental Satellites. Through Service Argos, the data are relayed to a ground station and transferred to a Global Processing Center. There, the data are processed and then transferred via the Internet to WHOI. The raw float data, including temperature, pressure, TOAs and respective correlations, are converted from hexadecimal to decimal, and are then ready for advanced processing, editing, and tracking.

3. Sound Source Deployment

Seven sound sources were used to track the AMUSE floats (locations shown in Figure 1). Three of these (M1-M3) were deployed specifically for AMUSE during the May 1993 CTD survey. Their placement was designed to provide maximal coverage along the south coast of Portugal and around Cape St. Vincent, a potential site of meddy formation and float dispersal. The other four sources, deployed by IFREMER (C) and IfM/Kiel (N, G, A2) for other experiments provided valuable coverage once the AMUSE floats moved away from the continental slope and into the Iberian Basin. The relatively large number of sources was needed to minimize topographic shadowing due to the rugged Horseshoe Seamounts and the Estremadura Promontory.

The vital statistics for each source are given in Table 2. All the sources were built by Webb Research Corporation and signaled every eight hours, beginning at 00:30, 01:00, 01:30, or 01:32 (pong times). Two sources, M3 and G, had clock failures within a year of activation. The clock of sound source N jumped 16 seconds 20 months after activation.

4. Float Deployment

To choose a suitable launch site for the floats, the seeding experiment was preceded by a detailed CTD survey of the Undercurrent in the western Gulf of Cadiz in May, 1993 from the R/V Oceanus OC258 (Bower *et al.*, 1997). In choosing a float deployment site, we tried to balance three basic criteria. The launch site had to be (1) downstream of the region in the eastern Gulf of Cadiz where the Mediterranean Water is being carried in a bottom-trapped gravity current; (2) upstream of all potential meddy formation sites that had been suggested in the literature; and (3) close to a suitable port for easy access. Based on the results of the CTD survey, a site was chosen south of Portugal in Portimao Canyon near 36° 30'N, 8° 00'W (Figures 1 and 2). To launch floats and XBTs on a weekly basis,