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DRIFTER AND FLOAT OBSERVATIONS IN THE ADRIATIC SEA (1994-1996): DATA REPORT

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Jan L. Spoelstra
Director

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Drifter and Float Observations in the Adriatic Sea (1994-1996): Data Report

P.-M. Poulain, P. Zanasca

Executive Summary: This memorandum describes the current, temperature and other data, acquired during the Adriatic Sea drifter and float programme, of the Otranto Gap Experiment (OGEX), the aim of which was to develop an understanding of the complex physical processes which contribute to large and meso-scale oceanographic variability in support of military operations in the Adriatic Sea.

Prevailing surface and intermediate currents dispersed the drifters and floats from the point of deployment, to sample most of the Adriatic Sea and some of the Ionian Sea, providing the first large-scale, accurate, near surface current data set of this sea area, from which important circulation characteristics were identified, quantified and interpreted. The trajectories of surface drifters and sub-surface floats in the coastal environment of the Adriatic Sea can be used for military mission planning and on-scene decisions for Mine Counter Measures (MCM) operations. In addition, the temperature data collected by Lagrangian instruments can be used to improve sound propagation models for underwater acoustic detection in the context of Anti Submarine Warfare (ASW).

The results demonstrate that drifter and float measurements can be a practical and cost effective alternative to the use of stationary current meters.

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Drifter and Float Observations in the Adriatic Sea (1994-1996): Data Report

P.-M. Poulain, P. Zanasca

Abstract: During the period December 1994 to November 1995, 62 Argos tracked surface drifters, one Argos tracked drifter drogued to 300 m and 3 Argos tracked sub-surface floats were released in the Adriatic Sea to describe the characteristics of the sub-tidal surface and intermediate level (300 m) circulation and temperature fields at scales ranging from a few kilometres (mesoscale) to hundreds of kilometres (large scale).

These Lagrangian data sets, extending to December 1996, are described in this report. Full details of the data acquisition systems and data processing are provided to serve as a reference for the analyses published in the scientific literature. Graphics are included in the Annexes to illustrate drifter and float performance, position and temperature data, and Eulerian statistics.

The drifter and float measurements comprise the first basin scale, accurate velocity and temperature *in situ* data over the Adriatic Sea. They describe quantitatively the major circulation features over the entire semi-enclosed basin in which issues such as defence, pollution and fisheries are paramount.

At smaller scales, the Lagrangian data were used, in conjunction with hydrographic and satellite measurements, to study the mesoscale structure and dynamics of the complex circulation patterns in the Strait of Otranto and Southern Adriatic.

Contents

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Introduction

Several years ago, low cost, Argos tracked, Lagrangian mixed-layer drifters which could easily be deployed from ships of opportunity were developed by the World Climate Research Programme for long term sampling of the upper ocean environment (WCRP-26, 1988). This development afforded an opportunity for SACLANTCEN to begin a comprehensive measurement program of surface currents and sea surface temperature (SST) in support of Mine Counter Measure (MCM) operations in the Adriatic Sea. Lagrangian drifters provide a broad, basin-scale, coverage of mesoscale surface circulation and SST structures that can be used to complement ocean acoustic measurements and predictions of operational ocean acoustic environmental models and to study the movement characteristics of water masses. Drifter data are also used to validate satellite sensed oceanic parameters.

In the early 1990's, subsurface floats that cycle vertically from a depth where they are neutrally buoyant to the surface, were developed to explore deep ocean currents and water mass properties in the world ocean basins. These devices are tracked by, and relay data to, the Argos system when they are at the surface. At depth, some designs are tracked acoustically. SACLANTCEN pioneered the use of such instruments in the relatively shallow and constrained geography of the Adriatic Sea with the objective to autonomously track intermediate currents near 300 m depth and to monitor the temperature in the water column for long time periods (i.e., up to a year). Such data are useful for MCM and ASW operations in the Adriatic Sea.

Drifter and float deployments began in December 1994 and by November 1995, 63 drifters and 3 floats had been released from various research vessels. By December 1996, approximately 6,300 days of drifter data had been acquired through Service Argos. This memorandum describes the drifter and float data obtained from December 1994 to December 1996. The drifter and float position data were used to construct a velocity data set, from which maps and statistics of the circulation were made. A detailed description of the Adriatic Sea circulation as measured by the surface drifters can be found in Poulain (1998).

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Data acquisition systems

2.1 DRIFTER HARDWARE AND SOFTWARE

2.1.1 Surface drifter

The surface drifter used in this study is similar to the one used in the Coastal Dynamics Experiment (CODE) in the early 1980's (Davis, 1985). It consists of a slender, vertical, 1 m-long negatively buoyant tube with four drag-producing vanes extending radially from the tube over its entire length (Fig. 1a). The total lateral extent of the system is about 1 m. The buoyancy is provided by four small spherical floats attached on the upper extremities of the vanes with a short (about 27 cm) flexible line. A small antenna for satellite tracking and data transmission is attached on the top of the tube and extends about 37 cm above the sea level (Fig. 1b). A thermistor is embedded in the main tubular hull at about 40 cm under the sea level for measuring sea surface temperature (SST). The drifters used in this study were manufactured by Technocean, Cape Coral, Florida, USA.

The drifter can be easily deployed in a cardboard box by any able-bodied person as its weight is only about 8.4 kg (Figs. 1c and 1d). Since the deployment box is sealed with sea-water soluble tape, it breaks open within an hour of immersion and allows the drifter to extend its four drag-producing vanes. The transmitter is switched on by removing (manually before release or automatically in the water) a magnet that is originally attached to the hull with water soluble tape.

Comparison with current meter measurements (Davis, 1985) and studies using dye to measure relative water movements (D. Olson, Personal Communication) showed that the CODE drifter-inferred velocities are accurate to about 3 cm/s, even under strong wind conditions.

The transmission period of the ST-5 transmitter is 90 ± 6 s. The controller samples the thermistor once a minute and calculates an average temperature every 15 minutes. At the time of drifter manufacture, the SST sensor was calibrated to ±0.1°C in the range of -5 to 39°C. The temperature data is transmitted by the ST-5 with 0.05°C resolution.

In order to take advantage of a special scientific tariff for Argos tracking and data telemetry, the ST-5 was programmed to transmit with an intermittent duty cycle after 30 days of continuous operation. A repetitive duty cycle with transmission enabled for 24 hours and disabled for the consecutive 48 hours was adopted.

2.1.2. Drogued drifter

One drifter drogued to 300 m depth was used to track the intermediate currents. It is similar to the WOCE/TOGA Lagrangian Drifter (Sybrandy and Niiler, 1991) but the tether between the subsurface sphere and the holey-sock was extended in order to have the drogue centered at 300 m nominal depth. Sea surface temperature and drogue presence data (from a sea water switch and a strain gauge) are telemetered with, and the positioning are done by, the Argos system. Transmissions are continuous (i.e., every 90 seconds) for 90 days after which they are enabled for one day out of three, during another 90 days. Details about the WOCE/TOGA Lagrangian drifter can be found in Poulain et al. (1996). The drifter used was manufactured by Clearwater Instrumentation, Watertown, Massachusetts, USA.

2.2 FLOAT HARDWARE AND SOFTWARE

The ALACE and MARVOR floats (Fig. 2) are systems that cycle vertically from a pre-determined depth where they are neutrally buoyant to the surface where they are located by, and relay data to, the Argos system onboard the NOAA polar-orbiting satellites. They change their buoyancy by pumping hydraulic fluid from an internal reservoir to an external bladder, thereby increasing float volume and buoyancy. For our study in the Adriatic Sea, both systems were programmed according to the following repetitive cycle: drift at 300 dbar nominal depth for about 2 days followed by about one day at surface (Fig. 3).

2.2.1 ALACE float

The Autonomous Lagrangian Circulation Explorer (ALACE) is a neutrally buoyant subsurface float originally developed to provide general circulation velocity observations and repeated vertical profiles for the World Ocean Circulation Experiment (WOCE).

The ALACE is an aluminum cylinder about 1 m long and with 17 cm diameter (Davis et al., 1992). A complete float has a mass of about 23 kg. A 70 cm-long antenna is mounted on the top. A 35-cm diameter plastic disk surrounds the pressure case, perpendicular to the float axis, and about 25 cm from the top cap. It provides resistance to relative flow past the float and damps heaving oscillations when the float is at the sea surface. The major components of the ALACE are shown in Fig. 4. There are three major subsystems: a hydraulic system to adjust buoyancy, a microprocessor to schedule and control various functions, and the Argos transmitter and antenna. The external bladder that receives hydraulic fluid is located at the bottom of the float. It has the form of a hemisphere. When the float has the minimum volume, the bladder retracts into a hemispheric cavity of approximately the same radius than the lower end cap. A small oil-filled flexible tube mounted outside of the end cap is ported to an internally mounted strain-gauge pressure transducer in order to measure the external pressure. An internal thermistor is cemented to the lower end cap to report at-depth temperature. The power provided by a lithium battery pack corresponds to a typical autonomy of 128 dives down to 400 dbar.

The profiling temperature ALACE has an additional temperature probe in the top end cap. It is manufactured from a stainless steel tube, 10 cm long and with 0.5 cm outer diameter. It contains a thermistor packed in a thermally-conductive grease (Sherman, 1993). Temperature and pressure are sampled every 2.5 seconds while the float is ascending. The temperature is averaged in 108 bins of 3 dbar.

The oceanographic data telemetered to Argos includes (1) the pressure and temperature (internal) averaged during the first half and second half of the time spent at depth and (2) the 3-dbar averaged temperature profile.

The ALACE floats used in this experiment were ballasted in laboratory to become neutrally buoyant at a nominal depth of 300 dbar for the typical values of temperature (14 °C) and salinity (38.7 PSU) encountered in the release area (Gacic et al., 1996). They were programmed to stay at the surface for 21.02 hours and to perform a complete dive cycle in 72.05 hours.

The ALACE basic hardware was manufactured by Webb Research Corporation, East Falmouth, Massachusetts, USA. The float was equipped with a temperature sensor, was ballasted and was programmed at Scripps Institution of Oceanography, La Jolla, California, USA.

2.2.2. MARVOR float

Also designed within the framework of WOCE, the MARVOR (which means sea horse in the old Celtic language) is a multicycle subsurface float that drifts freely at a prescribed pressure and provides direct measurements of the deep oceanic circulation (Ollitrault et al., 1994). It is a RAFOS[1] type float that can be located at depth by recording times of arrival of SOFAR[2] signals emitted by moored acoustic sources. It ascends to the surface at regular intervals to transmit data via the Argos satellite system.

The housing of the MARVOR is made up of an aluminum cylinder 17 cm in diameter, 1.8 m long (2.4 m with antenna) and 38 kg in weight (Fig. 5). It is sealed at the top by a hemispherical cap fitted with a hydrophone, an Argos antenna, a damping disk and a SAIL connector. The bottom end comprises all electro-hydraulic parts inside the tube and a neoprene bladder, outside, protected by a fiber glass housing. A pressure sensor is connected through the cap with bladder oil, and a temperature probe is stuck on the internal face of the cap. The hydraulic system permits the float to go either up or down by transferring oil from an internal reservoir to the bladder. Two valves, with different rates, are used to let oil flow from the bladder to the reservoir, under the effect of hydrostatic pressure. A motor driven micro-pump transfers oil from the reservoir to the bladder. Contrary to the ALACE, the MARVOR does not require ballasting to a prescribed depth prior to its operational use. The pressure level is simply programmed and, from the information provided by the pressure sensor, the volume of the bladder is modified to reach and maintain the desired pressure. Hence, the MARVOR is an isobaric float. At neutral depth, pressure and temperature are measured at 1-hour intervals with an accuracy of ±0.03°C and ±10 dbar, respectively. Automatic buoyancy adjustments are made to keep the float at the selected operating depth.

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[1] RAFOS means SOFAR spelled backward and corresponds to a float that listen to sound signals emitted by fixed moored sources.
[2] SOFAR stands for Sound Fixing and Ranging.

Due to the unavailability of moored sound sources, the RAFOS acoustic tracking was not performed and locations were only calculated when the float came to the surface using the Argos system. In other words, we used the MARVOR as an autonomous system like the ALACE.

Given the prescribed target depth of 300 dbar and the desired short dive cycle of less than three days imposed by experiment objectives, the MARVOR software was updated and the float was tested at sea in March 1995 (TEKELEC, 1995). The objective of the test at sea was to program the MARVOR in such a way as to minimize the descent time down to the shallow depth of 300 dbar keeping a limited depth overshooting. One short dive cycle of about 4 hours was performed. After setting various parameters controlling the actions of the two valves and the pump, the test revealed that the total time spent for buoyancy loss and diving to about 300 dbar was about 2.75 hours and that the time spent for rising up to the surface and buoyancy retrieving was about 1.5 hours. Fig. 6 depicts the pressure in dbar and the hydraulic actions (valve opening or pump activation times in tens of seconds) versus local time during the diving cycle. The pressure overshooting at the end of the dive was about 34 dbar. Only one pump action during 5 seconds stopped the diving and forced the float to rise to the equilibrium depth near 300 dbar. Based on these experimental results, the parameters were set for the Adriatic mission with a diving phase of approximately 3 hours, 48 hours of free drift at 300 dbar, an ascent period with buoyancy recovery of about 1.5 hours and Argos transmissions at the surface for 19.5 hours.

The pressure and temperature measured at hourly intervals both at depth and at the surface are telemetered to the Argos system while the float is at the surface, along with ancillary technical data.

The MARVOR float was manufactured by TEKELEC-Systemes, Les Ulis, France. It was tested and calibrated by IFREMER, Brest, France.

2.3. ARGOS TRACKING AND DATA TELEMETRY

The Argos Data Collection and Location System (DCLS) installed on the National Oceanographic and Atmospheric Administration (NOAA) polar-orbiting Tiros-N satellites, receives and processes all transmissions of the Argos transmitters visible by the satellites. The satellite orbit is sun-synchronous and has a duration of approximately 101 minutes (14 orbits per day). With the DCLS on two NOAA satellites (with an offset of 75° between orbital planes) the mean number of passes per 24 hours over a site near latitudes 40°N and 46°N is 12. Each time a satellite passes over a telemetry ground station of the Argos ground system, the DCLS downlinks the recorded data.

Platform location is determined by calculation of the Doppler effect on received frequencies. A given Doppler frequency shift corresponds to a field in the form of a half-cone with the satellite at its apex. The intersection of the various location cones obtained during the satellite overpass with the sea surface gives two possible positions for the transmitter. This ambiguity is removed using additional information, such as previous location and range of possible speeds. Prior to position calculation geometric tests are carried out to eliminate platforms for which an acceptable degree of accuracy cannot be guaranteed. The main causes of rejection are: (1) excessive erroneous frequency shift, (2) unsatisfactory convergence due to noisy platform oscillator and (3) unacceptable distance from ground track (platforms too close and too far from the ground track cannot be located accurately). We have calculated the distribution of the number of locations per day from all the CODE surface drifters (Fig. 7a) and the WOCE/TOGA drifter (Fig. 7b). For the surface drifters, only the first 30 days of continuous transmissions were considered. The distribution of the number of all transmissions with good data collection (including those without location) per day is also depicted in Fig. 7. For the surface drifters, the most frequent numbers are 12 data links and 8 positions per day. These statistics are good given that the mean number of passes per 24 hours over a site near latitudes 40°N and 46°N is 12. In contrast, the most frequent numbers for the WOCE/TOGA drifter drogued to 300 m are 11 data links and only 3 positions per day. This indicate that the surface buoy of the WOCE/TOGA system remained often submerged hampering effective transmissions to the satellites, as confirmed by the sea water switch data (see Fig. 12). The location accuracy is provided by Service Argos by means of location classes: Classes 3, 2 and 1 correspond to an accuracy better than 150 m, 350 m and 1000 m, respectively.

Drifter data can be obtained via the Argos on-line consultation service using, for example, the normal telephone network. In this way the data is available within a few hours from the time of measurement. With our approval, the position and SST drifter data were disseminated in quasi real time on the Global Telecommunications System (GTS) to be readily available for injection into weather forecast models of various national meteorological centers. At the end of each month, Service Argos copies the month-long data set onto floppy disks which are mailed to the user.

2.4 DEPLOYMENTS

Most surface drifters were deployed in their deployment cartons (Figs. 1c and 1d). Because the deployment box is sealed with tape that readily dissolves in water and the on/off magnet is secured with the same paper tape, the box rapidly disintegrates in water releasing the drifter and turning on the Argos transmitter, within an hour from deployment. Drifters were generally thrown over the side away from ship-generated turbulence while proceeding at normal ship speed (Fig. 1d). All of the drifters deployed from NRV *Alliance* were checked for good transmission prior to deployment using a portable Telonics receiver by partially opening the deployment box and removing the magnet.

The deployment sites of the 62 surface drifters that were released in the Adriatic are shown with star symbols in Fig. 8a. The majority of them (52) were deployed in the eastern side of the Strait of Otranto as part of the NATO SACLANT Otranto Gap project whose major goal was to assess the regional oceanography and the marine geology of the Albanian continental shelf and the Strait of Otranto. Clusters of drifters were deployed at fixed locations in the strait from December 1994 to October 1995. Deployments in December 1994, May and August 1995 were conducted during hydrographic and mooring operations onboard the NRV *Alliance* (OGEX0, OGEX1 and OGEX2 cruises). Additional releases in May, July and October 1995 were performed by the Hellenic Navy Hydrographic Office. The repetitive seeding was planned to maintain a continuous minimal population of drifters in the Strait of Otranto area in order to study the mesoscale and seasonal variabilities of its surface currents. An attempt was made to extend the Lagrangian measurements to the entire Adriatic basin by releasing 10 drifters in the northern and central Adriatic in May

1995 during a "Programma di Ricerca e Sperimentazione per il Mare Adriatico" (PRISMA) hydrographic cruise.

The WOCE/TOGA drifter drogued to 300 m and the MARVOR and ALACE floats were deployed from NRV *Alliance* during the OGEX1 cruise (May 1995) in the Strait of Otranto area (Fig. 8b). The ALACE was recovered in the northern Ionian Sea on 26 August 1995 during OGEX2. After maintenance and battery change, the same ALACE (with ID number 23590) was re-deployed at the same location in the Strait of Otranto in November 1995. A list with the drifter and float life statistics is shown in Table 1.

TABLE 1: ADRIATIC SEA DRIFTER AND FLOAT LIFE STATISTICS (1)

DRIFTER ID	DEPLOYMENT TIME	LAT	LON	TEMP	LAST FIX TIME	LAT	LON	MIN LAT	MAX LAT	MIN LON	MAX LON	TRANS CYCLE	LAST TEMP	LIFE TIME	TRANS CONT	LIFE TEMP	TYPE DEATH	COMMENTS
23123	337.525	39.749	19.249	16.07	557.201	31.100	28.210	30	41	16	29	365.791		219.676	28.266	219.676	1	CODE
23124	337.556	39.749	19.080	15.76	337.668	39.732	19.074	38	40	18	20			0.113	0.113	0.113	4	CODE
23125	337.597	39.918	19.084	15.98	436.762	42.109	17.994	38	43	16	20	365.789		99.164	28.192	99.164	4	CODE
23129	337.629	39.917	19.251	16.92	337.629	39.917	19.251										4	CODE
23131	337.688	39.833	19.334	17.41	443.581	42.015	17.725	38	43	15	20	365.790		105.893	28.102	105.893	4	CODE
23134	337.767	39.833	19.159	15.96	449.231	42.763	14.588	37	44	13	20	365.789		111.464	28.021	111.464	4	CODE
23135	337.879	39.833	18.997	15.91	449.774	43.559	14.176	38	44	13	20	365.787		111.895	27.908	111.895	4	CODE
23321	491.685	44.824	12.660	15.40	570.537	43.246	14.157	42	46	11	15	522.646		78.852	30.962	78.852	4	CODE
23324	492.733	44.541	13.775	16.20	529.567	45.405	13.260	43	46	11	14	523.701		36.834	30.968	36.834	4	CODE
23323	492.861	44.319	13.450	14.90	523.771	45.575	13.375	43	46	12	14			30.910	30.910	30.910	2	CODE
23322	493.013	44.074	13.110	15.80	497.816	44.021	13.462	42	45	12	14	494.995		4.803	1.982	4.803	4	CODE
23325	494.273	42.904	14.205	16.70	576.260	39.434	17.134	38	44	13	19	525.263		81.987	30.990	81.987	1	CODE
23326	494.395	43.151	14.523	16.20	588.289	41.949	15.563	40	44	12	16	525.334		93.894	30.939	93.894	1	CODE
23327	494.544	43.387	14.834	16.20	663.536	33.929	19.313	32	45	12	20	525.525		168.992	30.981	168.992	3	CODE
23328	496.178	43.602	15.108	15.80	520.816	44.542	14.289	42	45	13	16		520.750	24.638	24.638	24.572	2	CODE
23330	501.612	42.499	16.665	15.85	573.710	40.163	18.482	39	44	13	19	532.543		72.097	30.931	72.097	1	CODE
23329	501.738	42.169	16.164	15.45	561.753	40.309	18.399	39	43	15	19	532.705		60.016	30.967	60.016	1	CODE
23339	502.372	39.917	19.250	17.37	631.735	31.679	19.325	30	43	17	21	533.533		129.362	31.161	129.362	4	CODE
23337	502.879	39.833	19.155	17.16	680.548	32.782	16.828	31	41	15	21	533.534		177.669	30.655	177.669	3	CODE
23331	502.879	39.833	19.317	17.53	515.682	40.087	18.883	38	41	17	20			12.803	12.803	12.803	4	CODE
23332	502.901	39.927	19.418	17.13	527.579	39.693	19.655	38	41	18	20			24.679	24.679	24.679	1	CODE
23338	502.903	39.917	19.083	16.19	680.548	39.813	17.307	38	44	13	20	533.536		177.645	30.633	177.645	3	CODE
23333	502.923	40.001	19.501	17.04	505.762	39.975	19.473	38	41	18	20			2.839	2.839	2.839	4	CODE
23334	502.945	40.084	19.413	16.85	647.303	31.873	17.676	30	41	16	20	533.535		144.358	30.589	144.358	3	CODE
23340	502.951	40.000	19.333	17.30	650.021	36.144	18.497	34	42	16	20	533.537		147.070	30.585	147.070	3	CODE
23335	502.971	40.082	19.248	17.15	542.535	38.465	20.547	37	41	18	21	533.535		39.564	30.565	39.564	1	CODE
23341	502.979	40.000	19.167	16.94	623.486	34.441	23.020	33	43	16	24	533.535		120.506	30.556	120.506	4	CODE
23336	502.996	40.083	19.081	16.87	598.679	38.903	17.104	37	43	16	20	533.535		95.683	30.539	95.683	1	CODE
23342	503.010	40.000	19.000	16.05	628.784	44.797	13.899	39	45	12	20	533.537		125.773	30.527	125.773	1	CODE
24518	503.617	39.999	19.167	20.03	590.526	42.518	17.203	38	43	16	20			86.909	86.909	86.909	2	WOCE/TOGA
23588	503.967	40.000	19.084		524.756	40.017	18.759	38	41	17	20			20.793	20.793	20.793	4	MARVOR
23589	503.997	40.001	19.251		603.201	39.333	17.342	38	41	16	20			99.203	99.203	99.203	2	ALACE
23343	505.474	40.000	19.707	18.94	511.200	39.749	19.524	38	41	18	20			5.727	5.727	5.727	2	CODE
23344	506.090	40.167	19.454	17.54	668.662	32.155	19.001	31	41	17	24	537.029		162.573	30.939	162.573	3	CODE
23345	507.458	40.667	19.185	17.02	546.701	42.163	19.001	39	43	17	20	538.429		39.242	30.971	39.242	1	CODE
23346	571.360	39.833	19.333	22.60	579.538	40.100	19.747	38	41	18	20			8.178	8.178	8.178	1	CODE

PRESUMED TYPES OF DEATH: 1=GROUNDED, 2=PICKED-UP, 3=BATTERY, 4=UNKNOWN

Table 1 *Drifter and float life statistics, including identification number; time, latitude and longitude of deployment and of last good fix; bucket water temperature at deployment; the geographical area covered given by the latitude and longitude extrema; times of last continuous transmission and last good temperature; life times of drifter, of continuous transmission and of temperature sensor; type of death and comments. All times are Universal Time (UT) and are expressed in modified Julian days referred to 1994 (see conversion tables in Annex A)*

TABLE 1: ADRIATIC SEA DRIFTER AND FLOAT LIFE STATISTICS (2)

DRIFTER	DEPLOYMENT				LAST FIX			MIN	MAX	MIN	MAX	TRANS	LAST	LIFE	TRANS	LIFE	TYPE	COMMENTS
ID	TIME	LAT	LON	TEMP	TIME	LAT	LON	LAT	LAT	LON	LON	CYCLE	TEMP	TIME	CONT	TEMP	DEATH	
23347	571.384	39.917	19.250	24.00	698.293	37.393	20.270	35	43	15	21	602.353		126.909	30.969	126.909	3	CODE
23348	571.408	39.833	19.167	23.00	664.654	36.569	21.218	34	40	18	22	577.245		93.245	5.837	93.245	4	CODE
23349	571.433	39.917	19.083	23.80	677.334	34.372	20.072	32	40	17	22	602.432		105.901	31.000	105.901	3	CODE
23350	571.458	40.000	19.000	25.80	596.642	38.912	19.770	37	41	17	20			25.183	25.183	25.183	4	CODE
23351	571.485	40.083	19.083	24.40	731.444	36.960	21.437	34	41	17	23	602.437		159.959	30.953	159.959	3	CODE
23352	571.507	40.000	19.167	25.60	674.451	35.110	20.911	33	41	17	22	602.505		102.944	30.998	102.944	3	CODE
23353	571.529	40.083	19.250	26.40	736.992	42.812	16.708	35	43	15	23	602.503		165.463	30.974	165.463	3	CODE
23354	571.550	40.000	19.333	23.50	689.479	41.281	16.536	38	44	14	20	602.506		117.930	30.956	117.930	2	CODE
23355	571.576	39.917	19.417	24.60	580.979	39.861	19.423	38	40	18	20			9.403	9.403	9.403	4	CODE
23356	603.819	39.833	19.171	25.76	673.729	41.652	16.509	38	44	13	20	634.760		69.910	30.941	69.910	2	CODE
24098	603.849	39.834	19.332	25.36	625.285	43.023	16.229	38	44	15	20			21.436	21.436	21.436	1	CODE
24099	603.861	39.916	19.416	25.44	661.770	40.425	18.314	38	45	12	20	634.762		57.909	30.901	57.909	2	CODE
24100	603.883	39.918	19.250	25.67	718.741	42.254	15.455	38	45	12	20	634.763		114.858	30.880	114.858	4	CODE
24101	603.905	39.917	19.083	25.48	652.767	44.144	14.875	38	45	13	20	634.763		48.862	30.859	48.862	1	CODE
24102	603.922	40.000	19.000	25.44	778.735	34.432	21.450	33	44	13	22	634.760		174.813	30.838	174.813	3	CODE
24103	603.945	40.000	19.167	25.72	781.690	38.870	17.332	37	44	13	20	634.761		177.745	30.816	177.745	3	CODE
24104	603.966	40.000	19.333	25.48	620.508	42.602	17.516	38	43	16	20			16.542	16.542	16.542	2	CODE
24105	603.985	40.083	19.250	25.40	610.587	40.523	19.198	39	41	18	20			6.602	6.602	6.602	2	CODE
24106	604.010	40.083	19.083	25.19	633.552	43.692	15.434	39	44	14	20			29.542	29.542	29.542	2	CODE
24120	651.269	39.833	19.333	22.40	813.526	41.849	17.803	38	43	16	20	682.257		162.257	162.257	162.257	3	CODE
24121	651.297	39.833	19.167	22.90	778.262	42.531	15.075	38	44	13	20	682.261		126.966	126.966	126.966	2	CODE
24122	651.320	39.917	19.083	23.40	829.255	36.672	21.553	35	40	17	22	682.327		177.935	177.935	177.935	3	CODE
24123	651.349	39.917	19.250	23.10	795.043	42.085	15.615	38	45	12	20	705.093		143.695	143.695	143.695	2	CODE
24124	651.376	39.917	19.417	23.10	739.299	44.458	14.389	38	45	13	20	682.326		87.923	87.923	87.923	2	CODE
24125	651.400	40.000	19.333	23.60	781.082	41.784	18.274	39	43	15	20	682.325		129.682	129.682	129.682	4	CODE
24126	651.428	40.000	19.167	23.30	724.021	39.416	19.974	36	41	17	21	682.325		72.594	72.594	72.594	1	CODE
24127	651.456	40.000	19.000	23.40	820.321	38.637	19.580	36	44	13	20	682.396	816.720	168.865	168.865	165.264	4	CODE
24128	651.482	40.083	19.083	23.80	784.311	42.089	16.091	38	45	12	20	682.465		132.829	132.829	132.829	4	CODE
24129	651.508	40.083	19.250	23.40	782.745	39.960	18.949	38	43	15	20	681.542		131.237	131.237	131.237	4	CODE
23590	689.415	40.001	19.248	17.29	1095.012	43.764	13.813	38	45	12	20			405.597	405.597	405.597	3	ALACE

PRESUMED TYPES OF DEATH: 1=GROUNDED, 2=PICKED-UP, 3=BATTERY, 4=UNKNOWN

Table 1 *Drifter and float life statistics, including identification number; time, latitude and longitude of deployment and of last good fix; bucket water temperature at deployment; the geographical area covered given by the latitude and longitude extrema; times of last continuous transmission and last good temperature; life times of drifter, of continuous transmission and of temperature sensor; type of death and comments. All times are Universal Time (UT) and are expressed in modified Julian days referred to 1994 (see conversion tables in Annex A)*

3
Data processing

3.1. ROUTINE PROCESSING

The Argos data base in Toulouse, France was interrogated on an ad hoc basis via the telephone network and Enhanced Location Software for Argos (ELSA) to obtain recent drifter positions and SST data. They were used to monitor drifter movements (especially during sea trials) and to optimize additional seeding of drifters based on existing drifter numbers and positions. Complete position and sensor data were obtained from Service Argos once a month on floppy disks.

3.2. REDUCTION AND EDITING

3.2.1 Drifter data reduction

The data for each drifter (CODE and WOCE/TOGA) were read, reduced and written into individual files (B-files) which were updated monthly as long as the instrument provided good data. The sensor data were processed and reduced in the following way. The sensor data (i.e., time, voltage and temperature) records telemetered during a single satellite overpass were decompressed, that is, each record was repeated by a number of times equal to a given compression index and the repeated records were shifted back in time by successive 90 s increments. The data were then sorted in increasing sequential order and the median values were estimated. These median statistics were assigned to the drifter location and were written into the output raw file. Note that the median sensor and the position times vary according to the time distribution of sensor data transmissions during the satellite pass. For the passes with good sensor data but for which no drifter location was provided by Service Argos, the output raw latitude and longitude were assigned with the 999.999 default value.

During the reading and reduction process, the data were converted into modified Julian days referred to the year 1994 (Annex A) and longitudes west of the Greenwich meridian were converted into negative east longitudes. The deployment coordinates (time, latitude, longitude and bucket SST) were added to the drifter time series as the initial record. A location class 4 (accuracy better than 100 m determined by ship GPS navigation system) was assigned to this record. The raw data time series for drifter 23326 are presented in Fig. 9a. Data spikes are evident in the position and temperature time series, especially in May 1995. The location classes and the distribution of position fixes during the day are also displayed in Fig. 9b. Edited time series are shown in Fig. 9c.

3.2.2 ALACE and MARVOR Data reduction

The ALACE data (i.e., position, time, sea surface and deep temperatures, temperature profile) telemetered during each individual satellite overpass were processed using software developed by Scripps Institution of Oceanography, La Jolla, California, USA. Hexadecimal records were transformed into physical units using coefficients obtained from laboratory pressure and temperature calibrations. Converted data were written into the B-files. The MARVOR hourly temperature and pressure data were read directly from the raw Argos messages and written into the B-files without any processing. For the passes with good sensor data but for which no drifter location was provided by Service Argos, the output raw latitude and longitude were assigned with the 999.999 default value. The raw position data (latitude and longitude) are plotted versus time in Figs. 10a, 10b and 10c for the two ALACEs and the MARVOR, respectively. Also shown for each float, are the times of surface fixes in a three day window. The 24 hour transmission period (at the surface) and the 48 hour diving period are striking for the two ALACE floats.

The raw temperature and pressure (depth) data for the first ten dives of ALACE 23589 are depicted in Fig. 11.

3.2.3 Determination of time of last good fix and type of death

The type of malfunction or the circumstances of the termination receipt of good quality oceanographic data have been carefully investigated by examining the suspect records in the context of their proximity to the coast line, their lack of motion and the probability that they were picked up by seafarers. The large temperature variations corresponding to diurnal heating of the air are also a good indicator of grounding. Thus, the time for the last good fix was determined and the type of "*death*" was classified into one of four categories: Grounded; Picked-up; Battery failure; Unknown (Table 1). As a example, drifter 23326 (Fig. 9a) ended up on the Italian shore and the time of last good fix was taken as 11 August 1995 at 06:56 UT.

3.2.4 Determination of time of drogue loss (WOCE/TOGA drifter)

The sea-water switch on the surface floatation sphere of the WOCE/TOGA drifter provides submergence data which are used to determine whether or not the holey-sock drogue is attached. Submergence counts, i.e., the number of seconds the sphere is submerged per half hour time periods, are displayed in Fig. 12. Values as large as 300 seconds (5 minutes) were obtained during the first 30 days of drift. After that time, except for occasional spikes, the nil submergence count indicates that the drifter had probably lost its drogue.

3.2.5 Location data editing

As discussed above, Service Argos provides quality indices, designated location classes, for all locations determined. Being probabilistic, these indices do not preclude the occurrence of occasional large errors. An editing procedure derived from statistical tests for the full sequence of data values was applied, based upon speed between consecutive locations.

The raw data in the period between deployment and last good fix times were processed as follows:

1) For each drifter or float, a range of physically possible values of latitude and longitude are defined. Data points outside this range are flagged with a time equal to 999.999.

2) The records are arranged in ascending temporal sequence. Velocity components are estimated for each satellite separately by finite differencing successive positions.

3) Only velocities computed from the data points inside the same 24-hour transmission window are considered. Velocities corresponding to a time difference in excess of 48 hours are excluded. Suspected outlier velocity points are searched using Chauvenet's criterion. Assuming that the underlying basic velocity distribution is Gaussian, this statistical test rejects observations that are more than c times the standard deviation from the mean. The value of c satisfies $N\,P(-c) = 0.5$ where N is the total number of observations and P is the cumulative distribution function of the Gaussian distribution (Hawkins, 1980). Thus, on average, half an observation is rejected, regardless of N. The Chauvenet limits obtained for the two components of velocity are then averaged. The velocity observations exceeding these averaged limits are considered to be unreliable.

4) Since an unreliable velocity observation corresponds to two position points, deciding which point of the pair is the flawed location is not trivial. This choice is usually made by considering the location classes. The point with the lowest location quality index is chosen as the flawed observation. In the case of a pair of points with identical classes, the previous and successive velocity magnitudes are used. If the previous (successive) velocity magnitude is larger than the successive (previous) one, the first (second) point is considered flawed.

5) When a latitude or longitude point is considered flawed, the corresponding time is assigned the 999.999 value. The statistical editing process is then iterated (operations 2 to 5) excluding the records flagged by a 999.999 time value.

The iteration procedure stops when one of the following conditions is fulfilled: (a) Three consecutive iteration loops result in no reduction of the number of edited points. (b) The difference between the mean speed (i.e., the magnitude of the mean velocity vector) computed from the present and previous edited velocity distributions, is inferior to 0.05 cm s^{-1} (value determined experimentally).

It is important to note that if one of the Chauvenet limits happens to be (or comes) within the drifter or float velocity resolution, then the rejection limit is substituted by the constant resolution value for the rest of the iterative procedure. This is necessary to stop the loop process for some velocity distributions (usually with a relatively small number of points) which would have removed the entire set of observations. The velocity resolution was estimated by taking into account the position resolution provided by Argos (one thousandth of a degree) and the minimum time separation between fixes by the same satellite (about 100 minutes). It is about 1.85 cm s^{-1}.

At the end of the statistical editing process, the data of the different satellites are recombined into a single sequence series. Records with identical times are edited, retaining only the data stream corresponding to the highest location class, or to the location more similar to the adjacent data points. Those records with time not substituted by the 999.999 value are written in a position edited file (named P-file) containing the position time, latitude, longitude and location class.

When the position time series are scrutinized, remaining spikes are removed using a manual interactive program which flags the corresponding records with a time equal to 999.999 in the P-file.

3.2.6 Determination of time of last good sea surface temperature (CODE drifters)

The time of last good sea surface temperature was estimated by examining the temperature records and comparing them to typical climatological values in the sea area. Continuous unacceptable range temperatures were edited out by assigning the temperature cut-off time before the anomalous values start.

3.2.7 Sea surface temperature editing (CODE drifters)

For each satellite, the temporal temperature variations are computed from successive overpasses within the same 24-hour transmission time period. Using Chauvenet's criterion and the comparison with the neighboring variations, temperature points are edited iteratively in a way similar to the location data (see section 3.2.5). When only one temperature record is available in the 24-hour window, this value is compared to the mean temperature during the preceding and subsequent 24-hour time periods, and rejected if both differences exceed 0.15°C (threshold value obtained experimentally and equal to three times the temperature resolution).

At the end of the temperature editing process, the data corresponding to the different satellites are combined and records with identical times are edited. The temperature time series are edited manually and all sensor data records (time, temperature and battery voltage) are written in a sensor edited file (called S-file) where the flawed temperature values are substituted by 999.999.

3.3. INTERPOLATION AND FILTERING

The despiked data were interpolated onto regular intervals using an optimum analysis technique known as Kriging (Hansen and Herman, 1989; Hansen and Poulain, 1995). The Kriging used here employed an analytic function fit to a structure function computed from the entire despiked data set. The structure function is defined as

$$S_{ij} = 0.5\langle(x_i - x_j)^2\rangle, \qquad (1)$$

where x_i and x_j are the observations (latitude, longitude or temperature) of the same instrument at times t_i and *tj*, and ⟨⟩ represents an ensemble mean. Assuming stationary statistics, the ensemble mean was substituted by a time average procedure in which the squared differences of the observations were sorted into one hour lag intervals and averaged. The results are presented in Figs. 13a and 13b for time lags up to 10 days. The number of pairs of observations considered is also depicted. Due to the 24-hour-on/48-hour-off transmitter duty cycle, few data pairs exist for lags included between 1 and 2 days, 4 and 5 days, etc.

To provide structure function values at all possible lags needed for the interpolations, the empirical values must be modelled by a conditionally negative definite function.

We used a fractional Brownian motion model (Hansen and Poulain, 1995)

$$\hat{S} = \alpha\tau^{\beta} \tag{2}$$

in which τ denotes time lag (in days) and the parameters α and β are determined from the empirical data. The fitting of the above model was only applied for those time lags with many observation pairs to avoid data gaps created by the intermittent transmission mode. The parameter β was varied from 1 to 2 by increments of 0.01 and for each value, α was obtained by least squares fitting. The pair of parameters corresponding to the maximum explained variance was selected. These parameter values are listed in Table 2. The corresponding model analytical functions are depicted in Fig. 13 (dotted curve).

The edited position and temperature from the drifters and floats were interpolated at regular 2-hour intervals using the Kriging technique with the above structure function model. Following experimentation, 20 observations were selected, 10 preceding and 10 following each interpolation point, to carry out the Kriging interpolation technique (files called K-files). When data are few, as at the beginning or end of a drifter life, or where data intermittent, interpolations were done with as few as a single observation on either side of the interpolation time. Both the interpolated value and an estimate of its accuracy were computed.

The interpolated positions and temperature were then low-pass filtered with a designed filter cut-off period at 36 hours (-3 dB at 36 hours and -49 dB at 27 hours) in order to remove high frequency fluctuations such as diurnal temperature variations and tidal/inertial currents. The low-pass time series were finally subsampled every 6 hours and the velocity was computed by finite centered differencing the 6-hourly interpolated/filtered position data. The processed data files (called F-files) contain 6-hourly values of position, velocity and temperature. The velocity for the first and last records of each drifter, the temperature after failure of the SST sensor, and all the variables during temporary grounding, were assigned the 999.999 default value. If the time difference between the interpolated point and the closest edited observation is larger than 3 days, the corresponding velocity was assigned 999.999 in order to avoid meaningless interpolated velocity estimates in large data gaps. As an example, the smoothed and interpolated time series for drifter 23326 are depicted in Fig. 14. The raw position fixes are also shown. Note how the Kriging and low-pass filtering processes fill the 2-day gaps of the intermittent duty cycle after 30 days of continuous transmissions.

Table 2 *Values of the model structure function parameters determined from the empirical latitude, longitude and temperature structure functions.*

$$\hat{S} = \alpha\tau^{\beta}$$

	α	β
Latitude	0.007198	1.52
Longitude	0.004764	1.57
Temperature	0.1786	1.00

4
Data presentation

Selected drifter and float data are presented in the figures of Annexes B to D. Information on instrument performance, survivability and time distribution of data is given in Annex B. Annex C includes various graphical representations of the drifter and float data, e.g., graphics showing the ensemble of total displacements and trajectories of all the drifters and floats, float temperature profiles and contour plots, etc. Annex D focuses on the Adriatic Sea. Trajectory plots for the individual seasons are presented. The loci of fast surface flows are shown. Some Eulerian statistics of velocity and temperature are displayed in 15′ latitude by 15′ latitude boxes.

5
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References

Davis, R.E. (1985). Drifter observations of coastal currents during CODE. The method and descriptive view. *Journal of Geophysical Research*, **90**: 4741-4755.

Davis, R.E., D.C. Webb, L.A. Regier and J. Dufour (1992). The Autonomous Lagrangian Circulation Explorer (ALACE), *Journal of Atmospheric and Oceanic Technology*, **9**: 264-285.

Hansen, D.V. and Herman, A. (1989). Temporal sampling requirements for surface drifting buoys in the tropical Pacific. *Journal of Atmospheric and Oceanic Technology*, **6**: 599-607.

Hansen, D.V., and Poulain, P.-M. (1996). Processing of WOCE/TOGA drifter data. *Journal of Atmospheric and Oceanic Technology*, **13**: 900-909.

Hawkins, D.M. (1980). Identification of outliers. London Chapman and Hall.

Gacic, M., V. Kovacevic, B. Manca, E. Papageorgiou, P.-M. Poulain, P. Scarazzato and A. Vetrano (1996) Thermohaline properties and circulation in the Otranto Strait, Bulletin de l'Institut oceanographique, Monaco, CIESM Sciences Series 2, special volume 17, 117-145.

Ollitrault, M., G. Loaec and C. Dumortier (1994). MARVOR : A multi-cycle RAFOS float, Sea Technology, February 1994.

Poulain, P.-M., P. Zanasca and A. Warn-Varnas (1996). Drifter observations in the Nordic Seas (1991-1995) - Data report, SACLANTCEN Memorandum, SM-299, La Spezia, Italy SACLANT Undersea Research Centre.

Poulain, P.-M. (1998). Drifter Observation of Surface Circulation in the Adriatic Sea between December 1994 and March 1996. *Journal of Marine Systems* : In press.

Sherman, J. (1993). Profiling ALACE instruments, NRL report.

Sybrandy, A.L. and Niiler, P.P. (1991) WOCE/TOGA Lagrangian drifter construction manual. SIO REF 91/6, WOCE Report 63, San Diego, California, Scripps Institution of Oceanography.

TEKELEC (1995). MARVOR float for SACLANT - Visit Report. Internal report 3144-A, Les Ulis, France, Tekelec Systemes.

WCRP-26 (1988). Report of the First Meeting of the Surface Velocity Programme Planning Committee, SVP-1, and TOGA Pan-Pacific Surface Current Study. WMO/TD 323, WOCE Report 24/88, Wormley, United Kingdom, WOCE International Project Office.

Figures

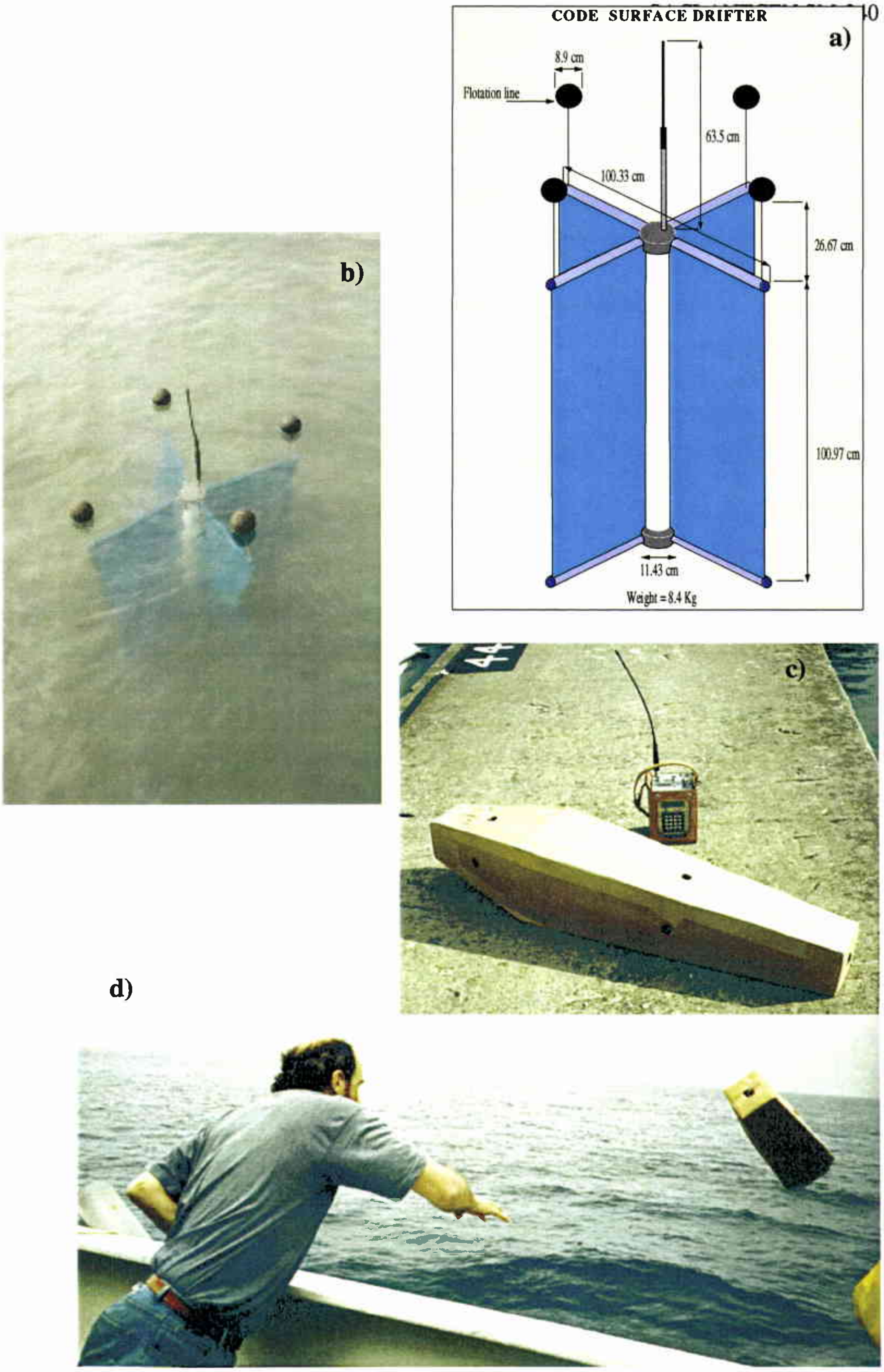


Figure 1 *Schematic diagram of the CODE surface drifter (a). Photograph of a deployed CODE drifter (b). Photograph of the CODE drifter packed in its deployment cardboard box. The portable receiver used to test the Argos transmission before deployments is also shown (c). Launch of a CODE drifter from NRV* Alliance *(d)*

Figure 2 *Photograph of the ALACE (left) and MARVOR (right) floats.*

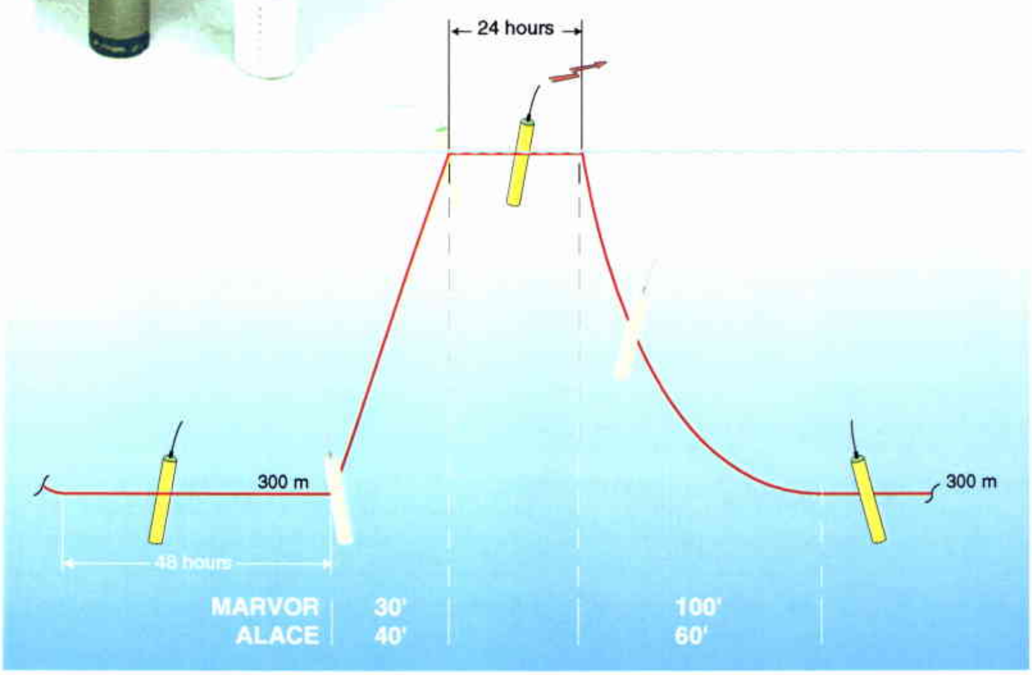


Figure 3 *Dive cycle of the ALACE and MARVOR floats. Typical durations for descent and ascent are indicated in minutes for each instrument.*

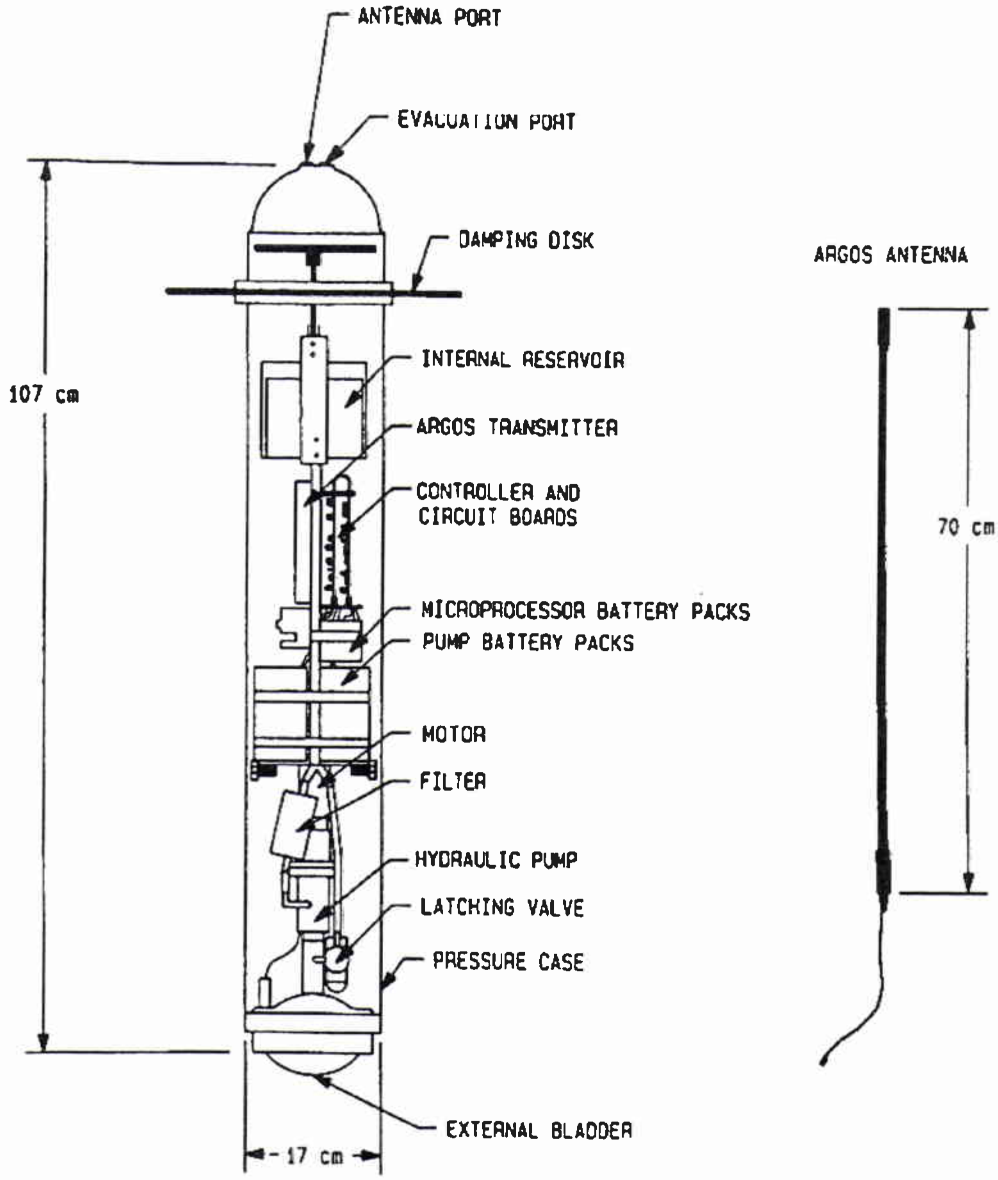


Figure 4 *Schematic of the ALACE float, without temperature probe.*

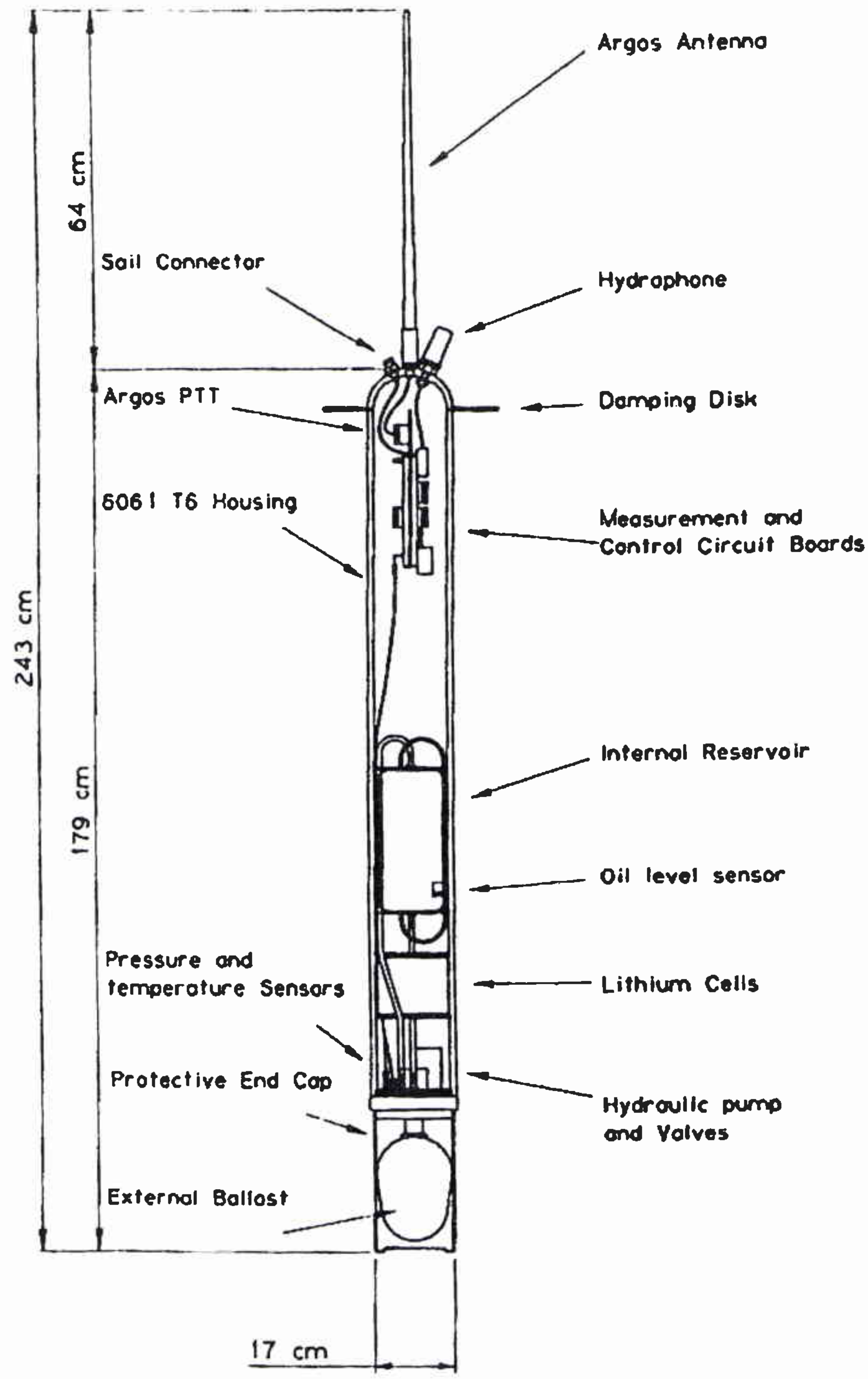


Figure 5 *Schematic of the MARVOR float*

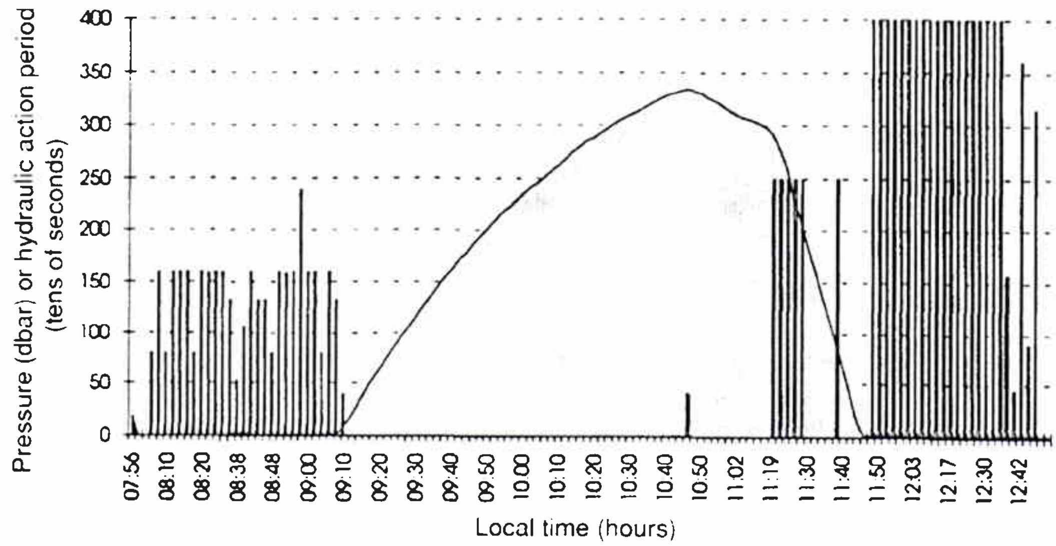
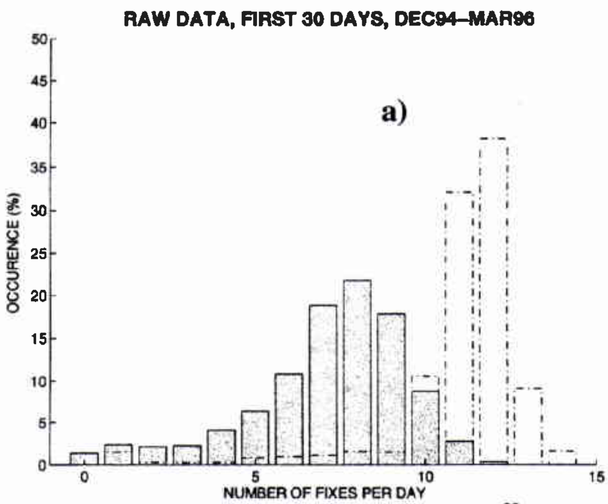


Figure 6 *Pressure (dbar) and hydraulic actions (valve opening or pump activation times in tens of seconds) versus local time during a test diving cycle of the MARVOR.*



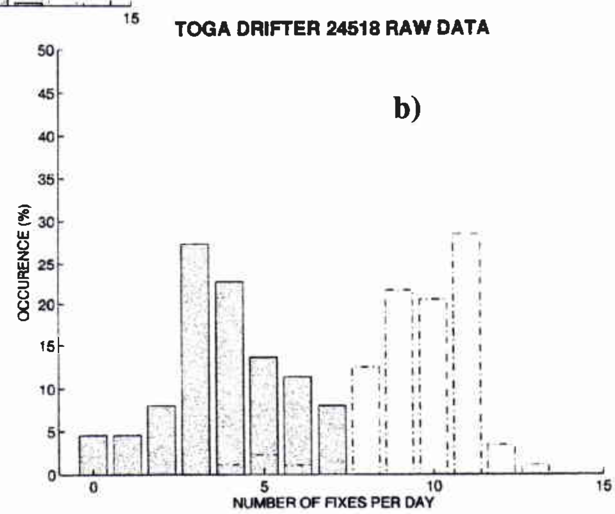
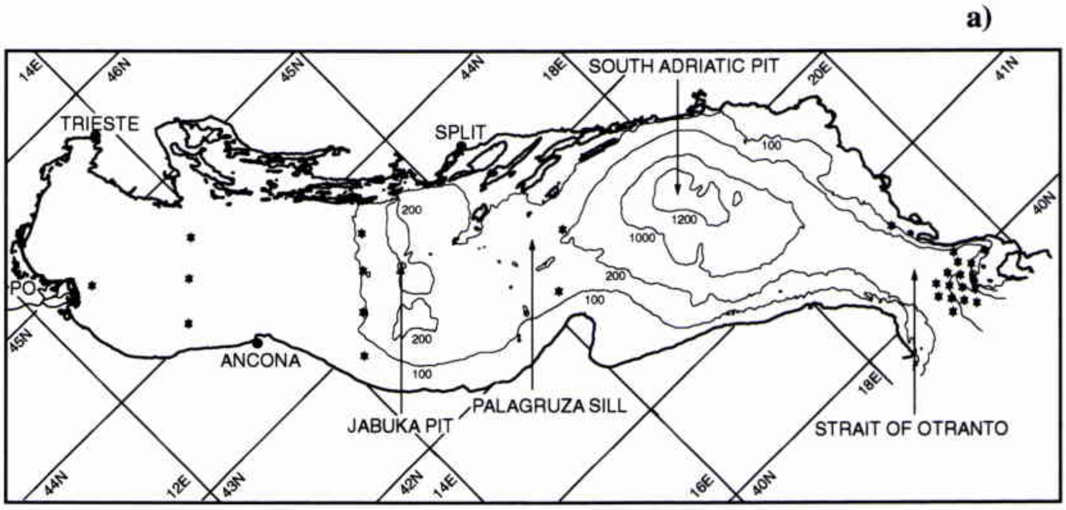


Figure 7 *Histogram of the number of position (solid columns) and data (dot-dashed columns) for all the CODE drifters during their first 30 days of operation (a) and for the WOCE/TOGA drifter (b).*



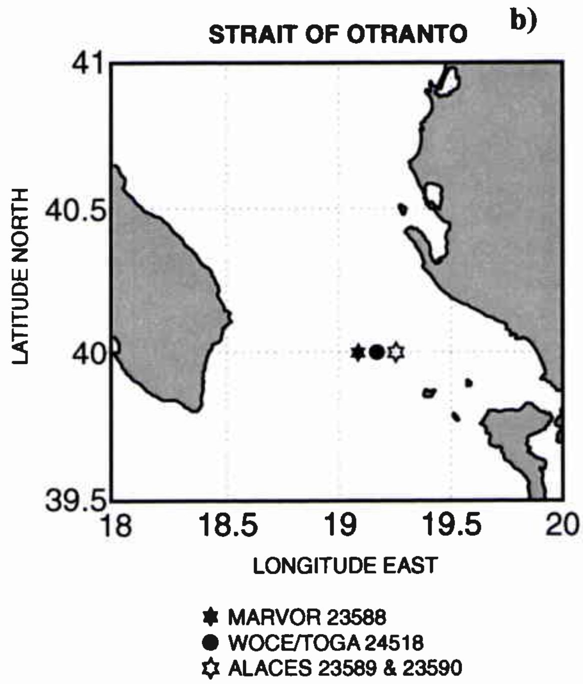


Figure 8 *Bathymetry of the Adriatic sea with sites (star symbols) of surface drifter deployments (a). Strait of Otranto and deployment locations of the TOGA/WOCE drifter and the ALACE and MARVOR floats (b)*

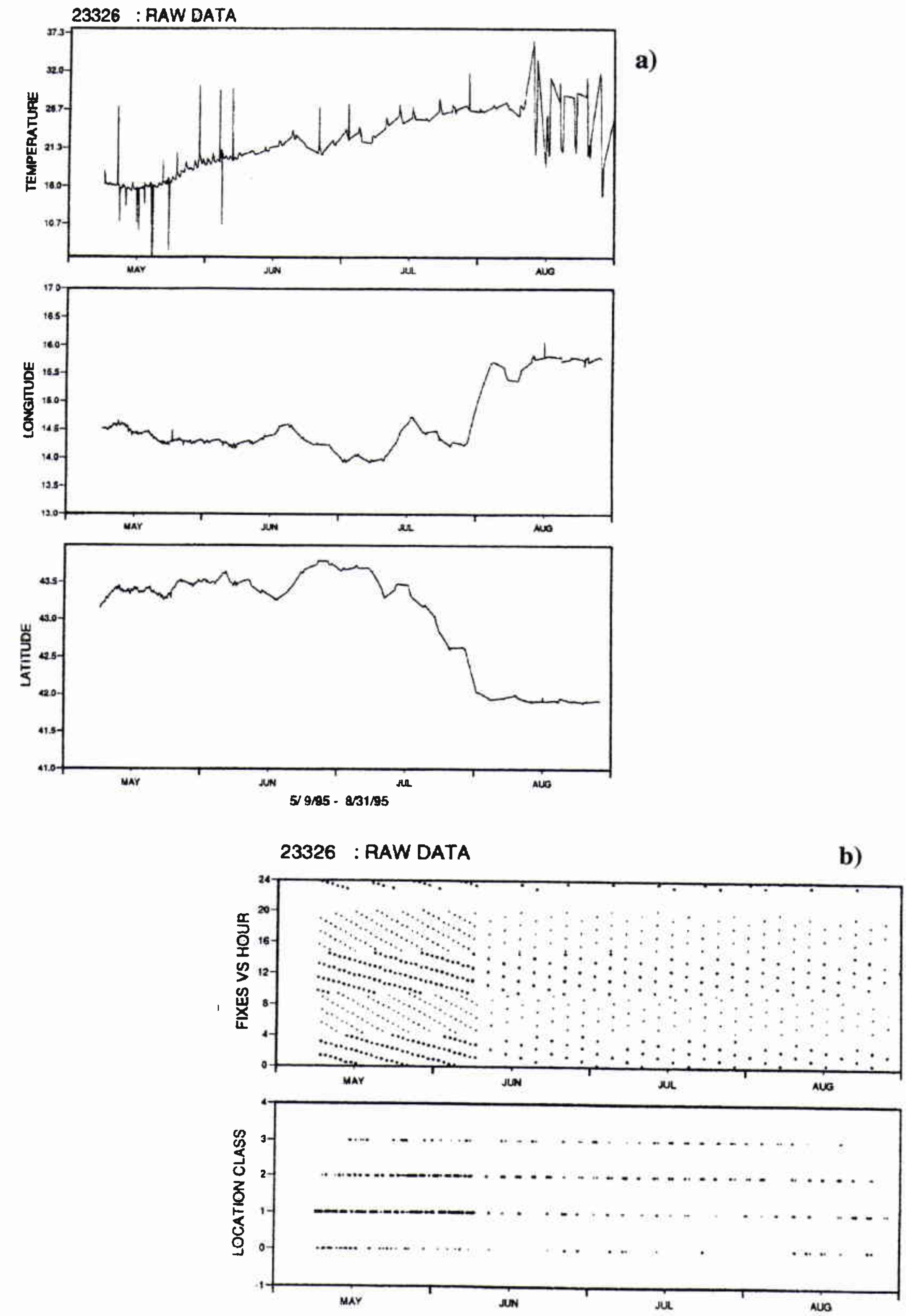


Figure 9 *Raw data time series for drifter 23326. (a) Latitude, longitude and temperature. (b) Location class and distribution of data received during an 24 hour period (dot and star symbols for NOAA12 and NOAA14 satellites, respectively).*

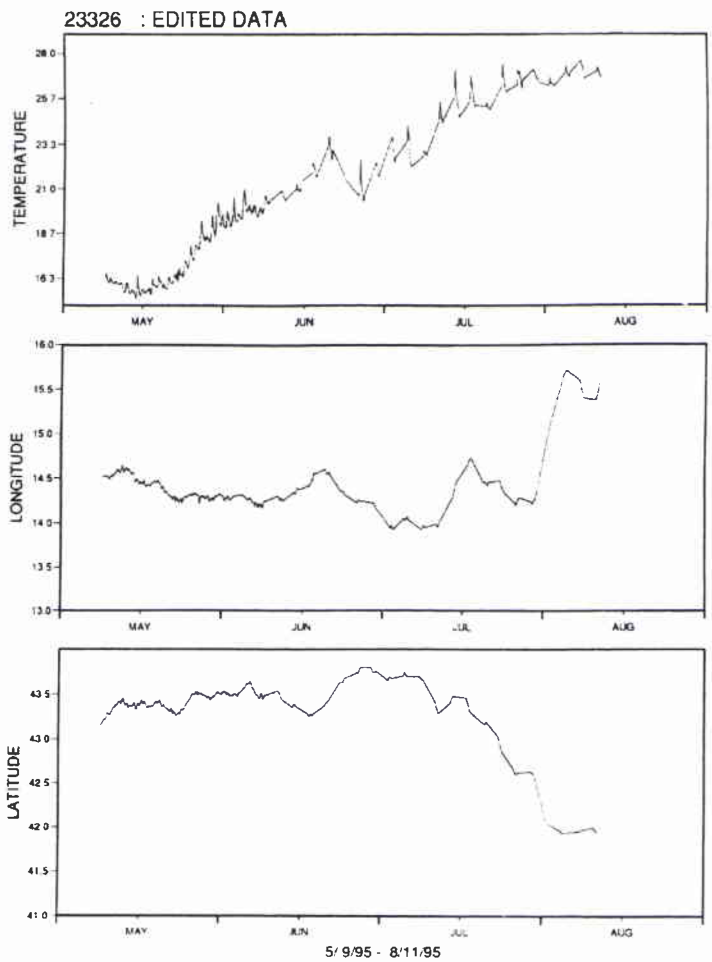
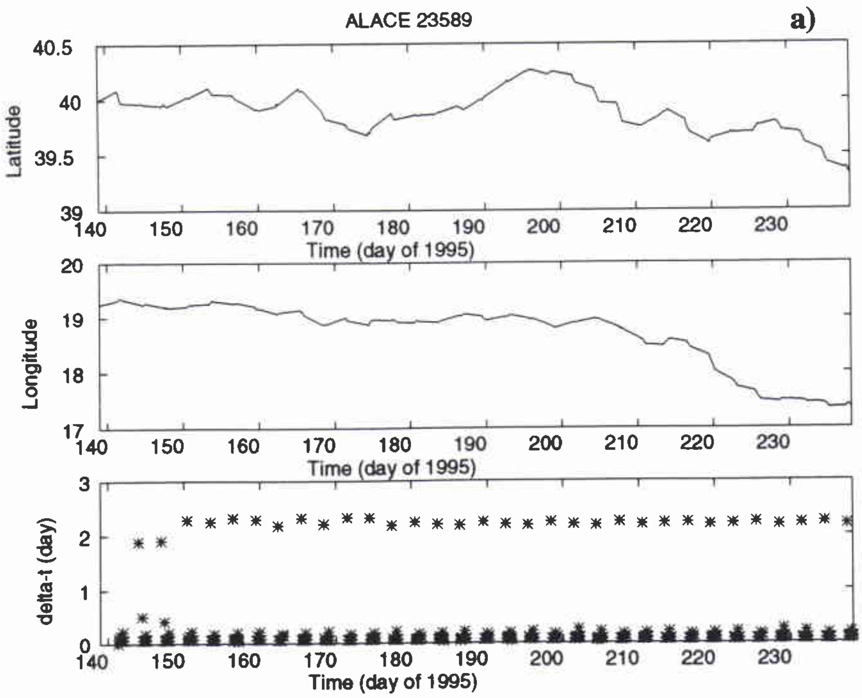


Figure 9c *Edited time series of temperature, latitude, longitude for drifter 23326.*



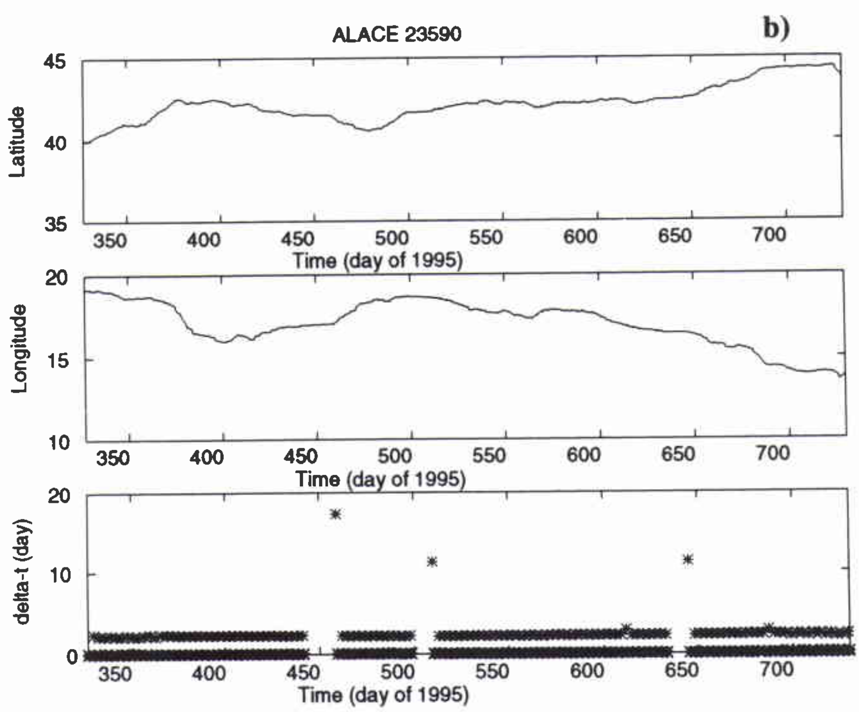


Figure 10 *Raw position data (latitude and longitude) and times of surface fixes in a three day window for ALACE 23589 (a), ALACE 23590 (b).*

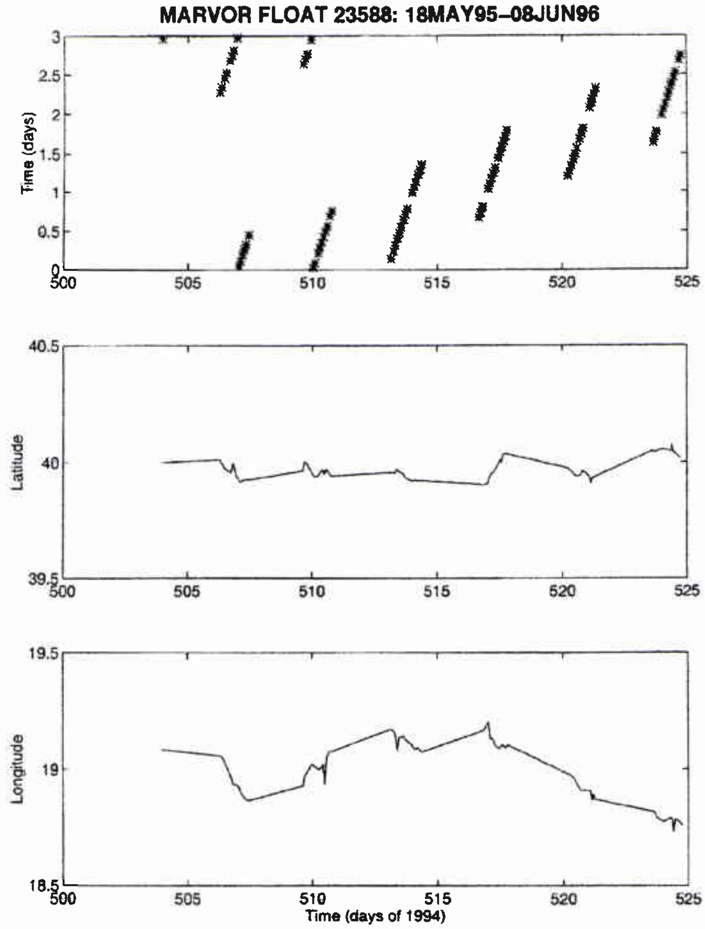


Figure 10c *Raw position data (latitude and longitude) and times of surface fixes in a three day window for MARVOR.*

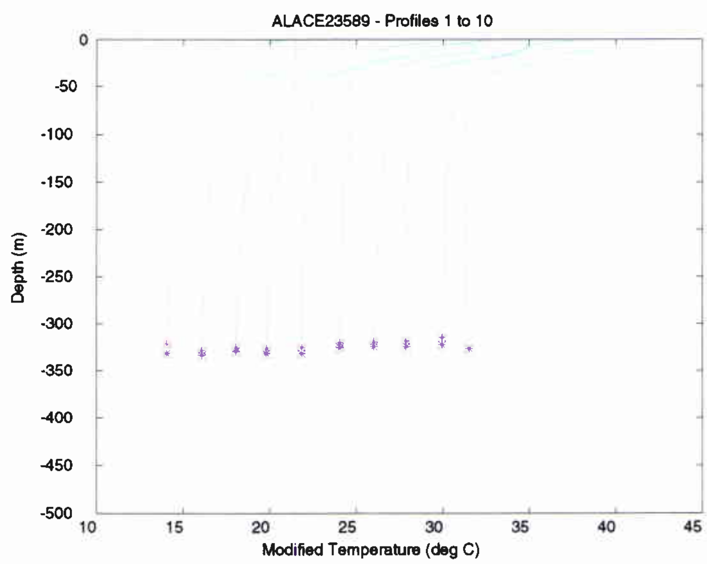


Figure 11 *Raw temperature and pressure (depth) data versus time for ALACE 23589. For each of the first 10 cycles, the two deep pressures are plotted with star symbols (in red for the first half period of immersion and in blue for the second) along with the vertical temperature profile measured during ascent . The successive profiles are shifted to the right of each other by 2 °C*

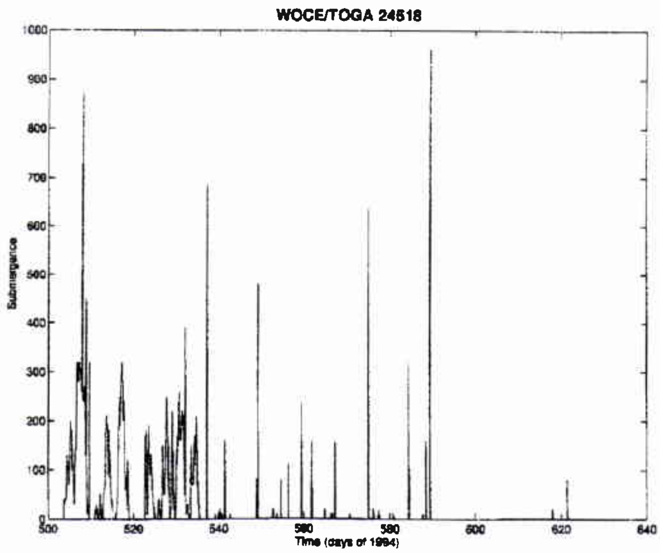


Figure 12 *Submergence counts for WOCE/TOGA drifter 24518.*

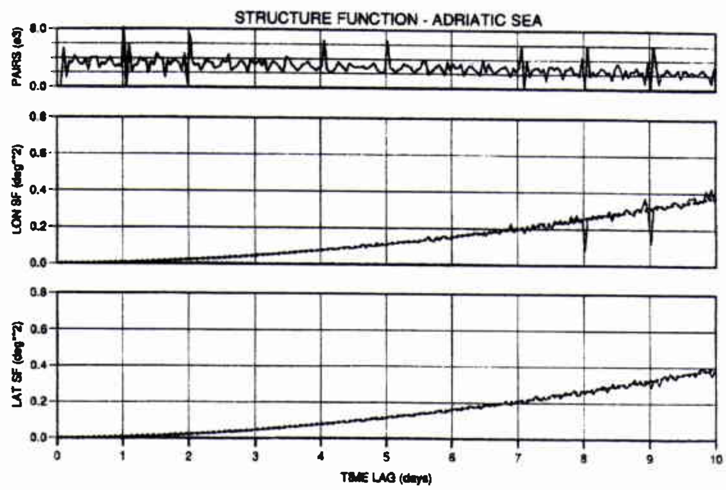


Figure 13a *Structure functions for position data with analytical function fit.*

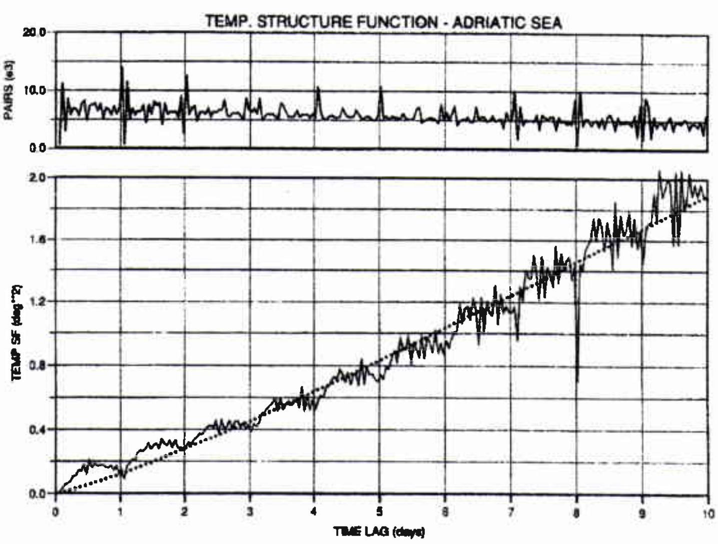


Figure 13b *Structure functions for temperature data with analytical function fit.*

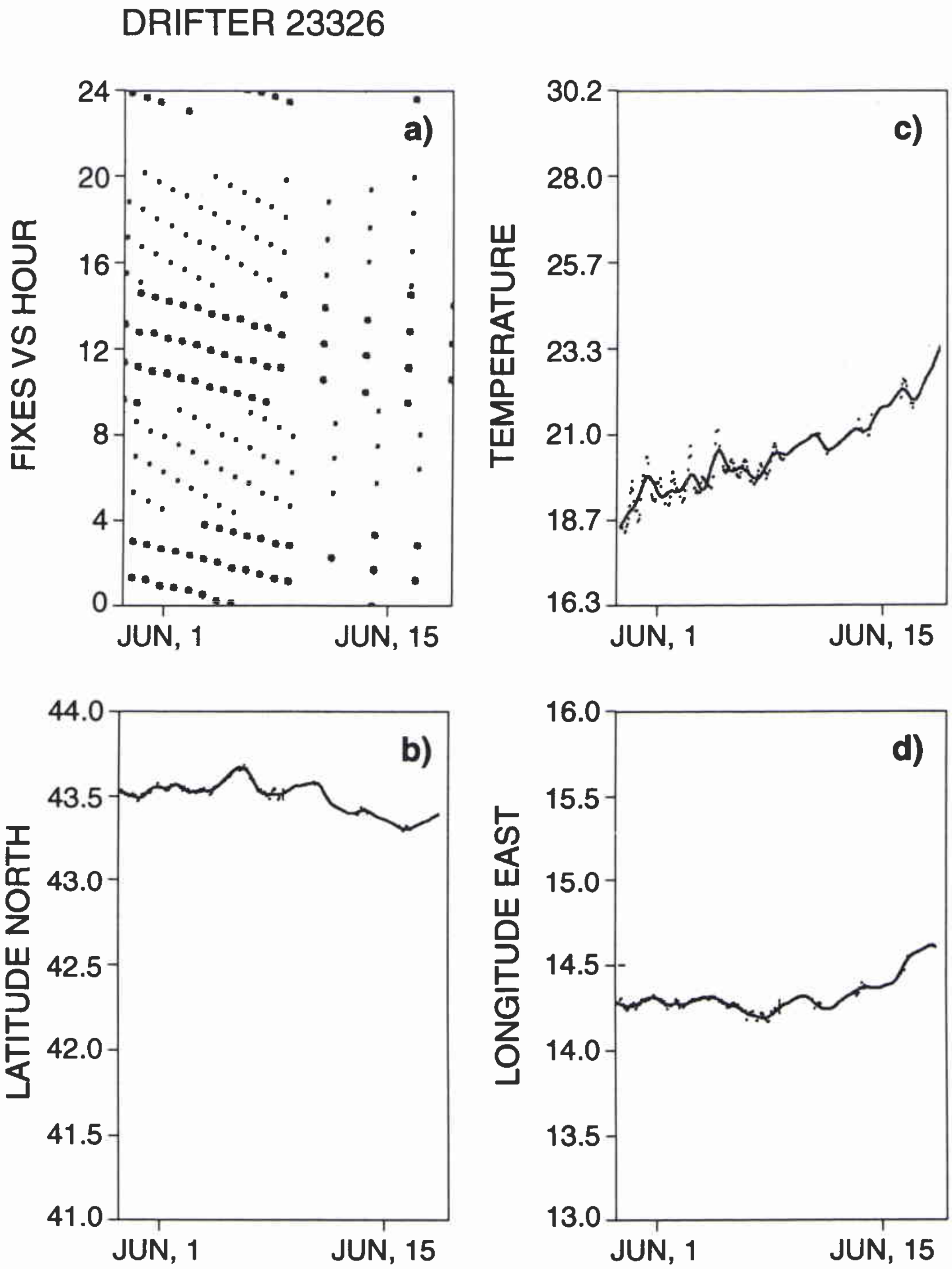


Figure 14 *Raw data points (dots) and low-pass filtered and kriged time series (solid lines) for drifter 23326 versus time: (a) Time of the day in hours of the location fixes, (b) Latitude, (c) Temperature and (d) longitude . Note the intermittency of the raw data after 30 days of continuous transmissions.*

Annex A
1994 day conversion tables

All times in the Adriatic sea drifter data set are Universal Time (UT) and are expressed in modified Julian days referred to year 1994 (first year of the program). This annex contains the date conversion tables for years 1994 to 1996.

Table A1 *Modified Julian Day – Year 1994 (referred to 1994)*

Month Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1	32	60	91	121	152	182	213	244	274	305	335
2	2	33	61	92	122	153	183	214	245	275	306	336
3	3	34	62	93	123	154	184	215	246	276	307	337
4	4	35	63	94	124	155	185	216	247	277	308	338
5	5	36	64	95	125	156	186	217	248	278	309	339
6	6	37	65	96	126	157	187	218	249	279	310	340
7	7	38	66	97	127	158	188	219	250	280	311	341
8	8	39	67	98	128	159	189	220	251	281	312	342
9	9	40	68	99	129	160	190	221	252	282	313	343
10	10	41	69	100	130	161	191	222	253	283	314	344
11	11	42	70	101	131	162	192	223	254	284	315	345
12	12	43	71	102	132	163	193	224	255	285	316	346
13	13	44	72	103	133	164	194	225	256	286	317	347
14	14	45	73	104	134	165	195	226	257	287	318	348
15	15	46	74	105	135	166	196	227	258	288	319	349
16	16	47	75	106	136	167	197	228	259	289	320	350
17	17	48	76	107	137	168	198	229	260	290	321	351
18	18	49	77	108	138	169	199	230	261	291	322	352
19	19	50	78	109	139	170	200	231	262	292	323	353
20	20	51	79	110	140	171	201	232	263	293	324	354
21	21	52	80	111	141	172	202	233	264	294	325	355
22	22	53	81	112	142	173	203	234	265	295	326	356
23	23	54	82	113	143	174	204	235	266	296	327	357
24	24	55	83	114	144	175	205	236	267	297	328	358
25	25	56	84	115	145	176	206	237	268	298	329	359
26	26	57	85	116	146	177	207	238	269	299	330	360
27	27	58	86	117	147	178	208	239	270	300	331	361
28	28	59	87	118	148	179	209	240	271	301	332	362
29	29		88	119	149	180	210	241	272	302	333	363
30	30		89	120	150	181	211	242	273	303	334	364
31	31		90		151		212	243		304		365

Table A2 *Modified Julian Day – Year 1995 (referred to 1994)*

Month Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	366	397	425	456	486	517	547	578	609	639	670	700
2	367	398	426	457	487	518	548	579	610	640	671	701
3	368	399	427	458	488	519	549	580	611	641	672	702
4	369	400	428	459	489	520	550	581	612	642	673	703
5	370	401	429	460	490	521	551	582	613	643	674	704
6	371	402	430	461	491	522	552	583	614	644	675	705
7	372	403	431	462	492	523	553	584	615	645	676	706
8	373	404	432	463	493	524	554	585	616	646	677	707
9	374	405	433	464	494	525	555	586	617	647	678	708
10	375	406	434	465	495	526	556	587	618	648	679	709
11	376	407	435	466	496	527	557	588	619	649	680	710
12	377	408	436	467	497	528	558	589	620	650	681	711
13	378	409	437	468	498	529	559	590	621	651	682	712
14	379	410	438	469	499	530	560	591	622	652	683	713
15	380	411	439	470	500	531	561	592	623	653	684	714
16	381	412	440	471	501	532	562	593	624	654	685	715
17	382	413	441	472	502	533	563	594	625	655	686	716
18	383	414	442	473	503	534	564	595	626	656	687	717
19	384	415	443	474	504	535	565	596	627	657	688	718
20	385	416	444	475	505	536	566	597	628	658	689	719
21	386	417	445	476	506	537	567	598	629	659	690	720
22	387	418	446	477	507	538	568	599	630	660	691	721
23	388	419	447	478	508	539	569	600	631	661	692	722
24	389	420	448	479	509	540	570	601	632	662	693	723
25	390	421	449	480	510	541	571	602	633	663	694	724
26	391	422	450	481	511	542	572	603	634	664	695	725
27	392	423	451	482	512	543	573	604	635	665	696	726
28	393	424	452	483	513	544	574	605	636	666	697	727
29	394		453	484	514	545	575	606	637	667	698	728
30	395		454	485	515	546	576	607	638	668	699	729
31	396		455		516		577	608		669		730

Table A3 *Modified Julian Day – Year 1996 (referred to 1994)*

Mont h Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	731	762	791	822	852	883	913	944	975	1005	1036	1066
2	732	763	792	823	853	884	914	945	976	1006	1037	1067
3	733	764	793	824	854	885	915	946	977	1007	1038	1068
4	734	765	794	825	855	886	916	947	978	1008	1039	1069
5	735	766	795	826	856	887	917	948	979	1009	1040	1070
6	736	767	796	827	857	888	918	949	980	1010	1041	1071
7	737	768	797	828	858	889	919	950	981	1011	1042	1072
8	738	769	798	829	859	890	920	951	982	1012	1043	1073
9	739	770	799	830	860	891	921	952	983	1013	1044	1074
10	740	771	800	831	861	892	922	953	984	1014	1045	1075
11	741	772	801	832	862	893	923	954	985	1015	1046	1076
12	742	773	802	833	863	894	924	955	986	1016	1047	1077
13	743	774	803	834	864	895	925	956	987	1017	1048	1078
14	744	775	804	835	865	896	926	957	988	1018	1049	1079
15	745	776	805	836	866	897	927	958	989	1019	1050	1080
16	746	777	806	837	867	898	928	959	990	1020	1051	1081
17	747	778	807	838	868	899	929	960	991	1021	1052	1082
18	748	779	808	839	869	900	930	961	992	1022	1053	1083
19	749	780	809	840	870	901	931	962	993	1023	1054	1084
20	750	781	810	841	871	902	932	963	994	1024	1055	1085
21	751	782	811	842	872	903	933	964	995	1025	1056	1086
22	752	783	812	843	873	904	934	965	996	1026	1057	1087
23	753	784	813	844	874	905	935	966	997	1027	1058	1088
24	754	785	814	845	875	906	936	967	998	1028	1059	1089
25	755	786	815	846	876	907	937	968	999	1029	1060	1090
26	756	787	816	847	877	908	938	969	1000	1030	1061	1091
27	757	788	817	848	878	909	939	970	1001	1031	1062	1092
28	758	789	818	849	879	910	940	971	1002	1032	1063	1093
29	759	790	819	850	880	911	941	972	1003	1033	1064	1094
30	760		820	851	881	912	942	973	1004	1034	1065	1095
31	761		821		882		943	974		1035		1096

Annex B
Drifter performance statistics

The statistics of the drifter and float system performances are presented in the tables and figures included in this Annex. The time distribution of the drifter data is represented in two ways: (1) Bar diagram showing the life times of all drifters and (2) the distribution of the number of active drifters as a function of time. Longevity characteristics are displayed in a survivability plot.

Table B1 *Surface drifter performance statistics: Maximum life time, half-life and number of drifter-days.*

	days	*years*
Maximum Life Time	220	
Half Life	102	
Number of Drifter-days and Drifter years	6276	17.2

Table B2 *Days, years and percentage of drifter presence in the Adriatic and Ionian Seas.*

	days	*years*	*percentage*
Number of Drifter-days and Drifter years			
in the Adriatic Sea (North of 40N)	3868	10.6	62
in the Ionian Sea (South of 40N)	2408	6.6	38

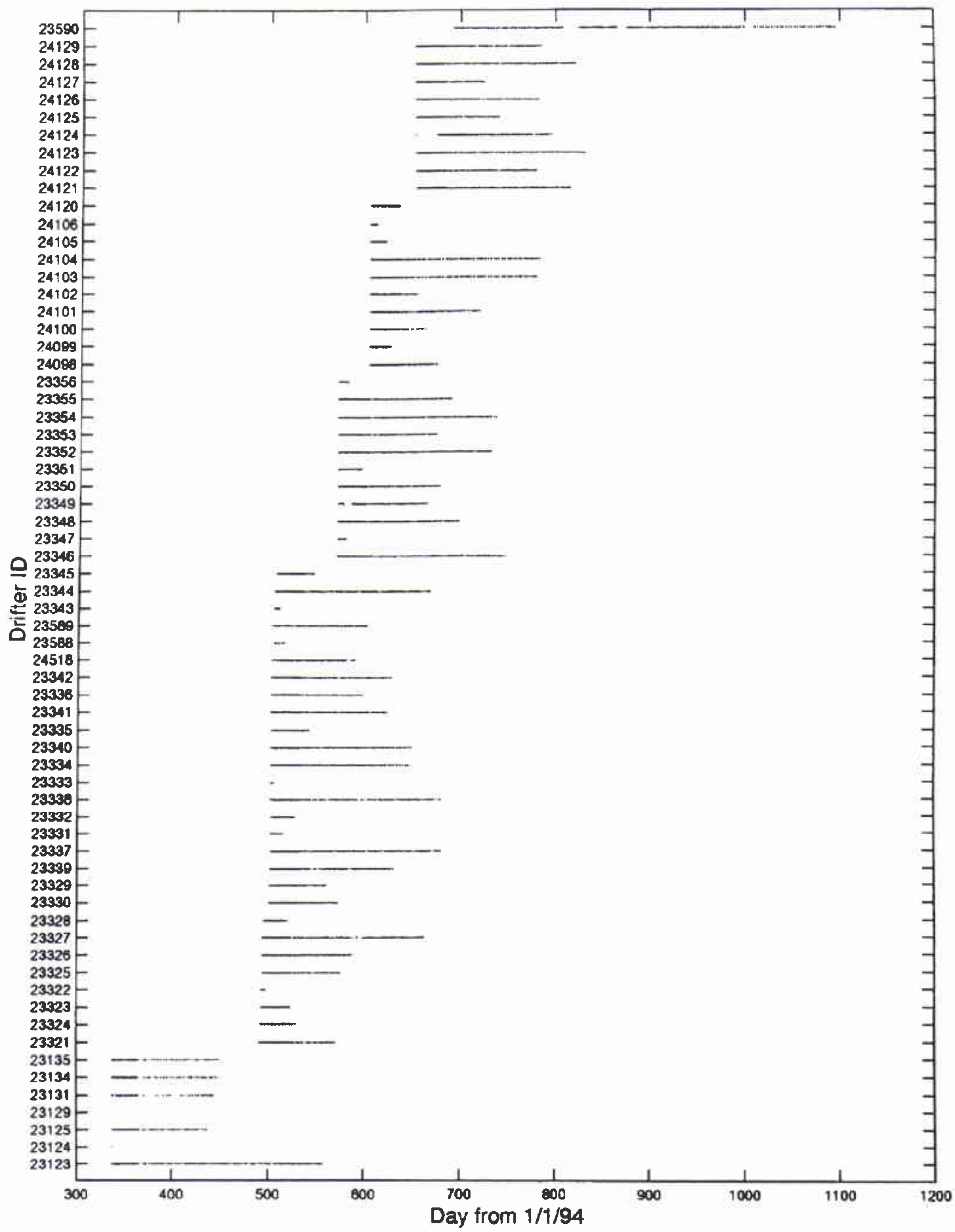


Figure B1 *Horizontal bar diagram showing the life times of all the drifters and floats between December 1994 and December 1996.*

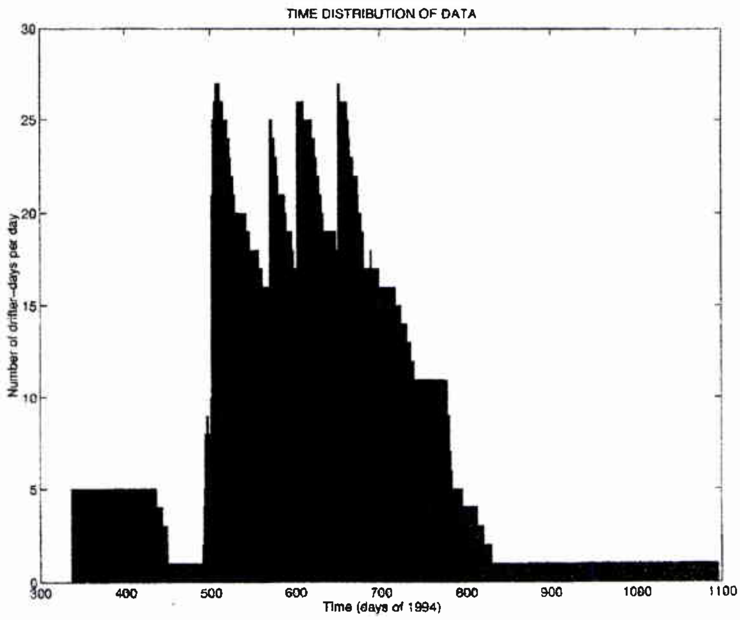


Figure B2 *Total number of simultaneous drifters and floats alive as a function of time.*

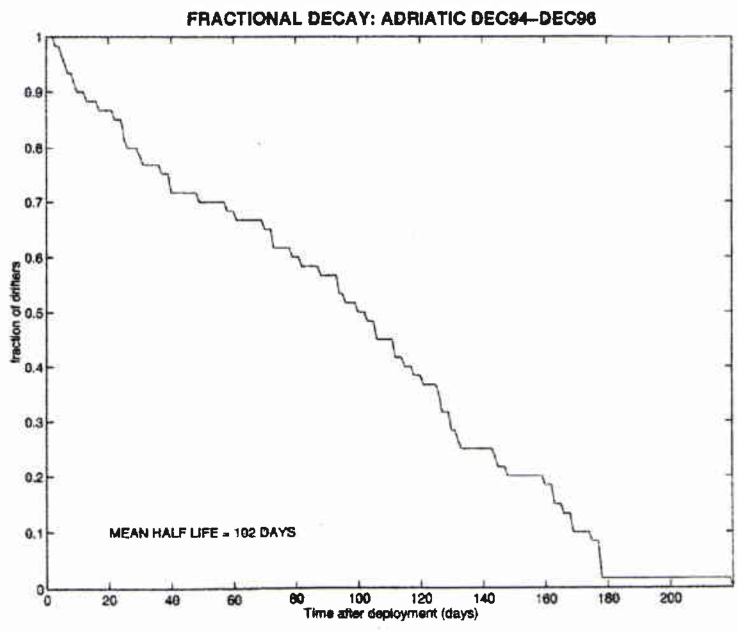


Figure B3 *Drifter survivability plot showing the fraction of deployed drifters still transmitting (and freely drifting with the currents) as a function of time after deployment. The time corresponding to a fraction of 0.5 is the mean half life, i.e., 102 days.*

Annex C
Composite trajectory maps and temperature contour plots

This section includes geographical maps and vertical cross-sections with various representations of the global data set. Composite "spaghetti" diagrams (total displacements, trajectories of drifters and floats) and contour plots of the temperature profiles obtained from the floats are presented.

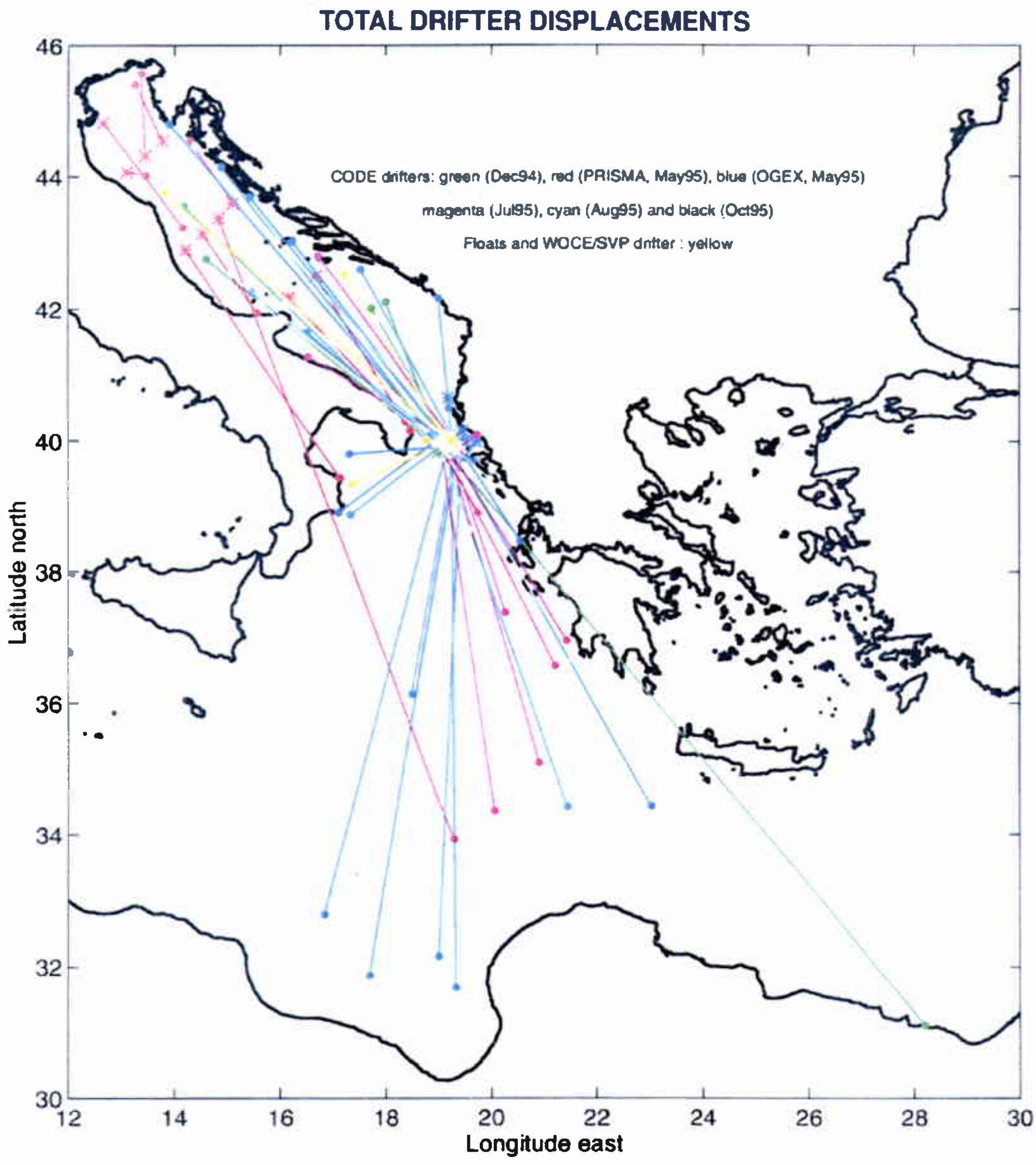


Figure C1 *Total displacements for all the drifters and floats. Star and solid circle symbols indicate the deployment and last fix locations, respectively. The lines are color coded with respect to the different deployment episodes.*

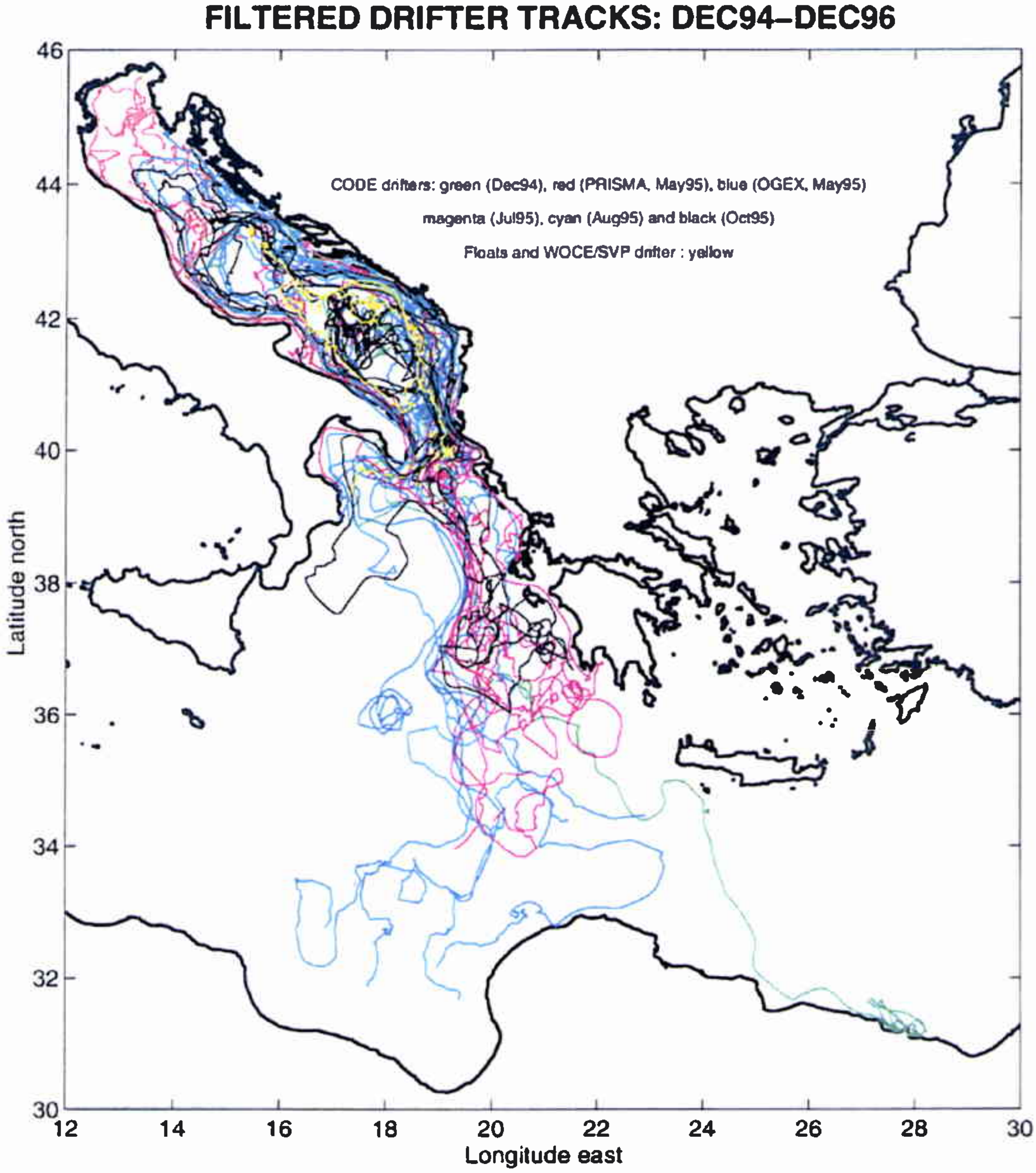


Figure C2 *Filtered trajectories for all the drifters and floats color coded with respect to the different deployment episodes.*

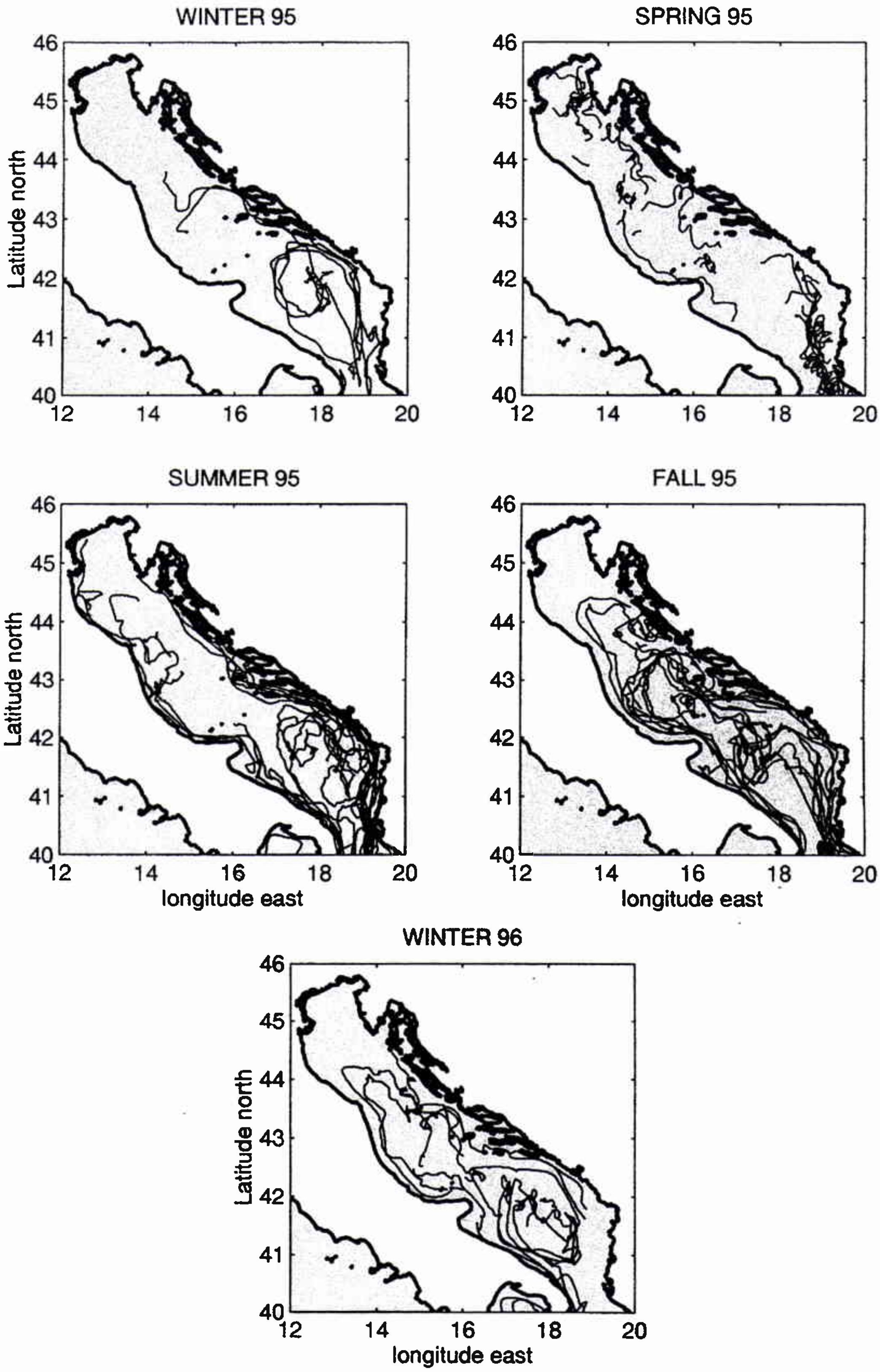


Figure C3 *Filtered trajectories of the surface drifters for the different seasons.*

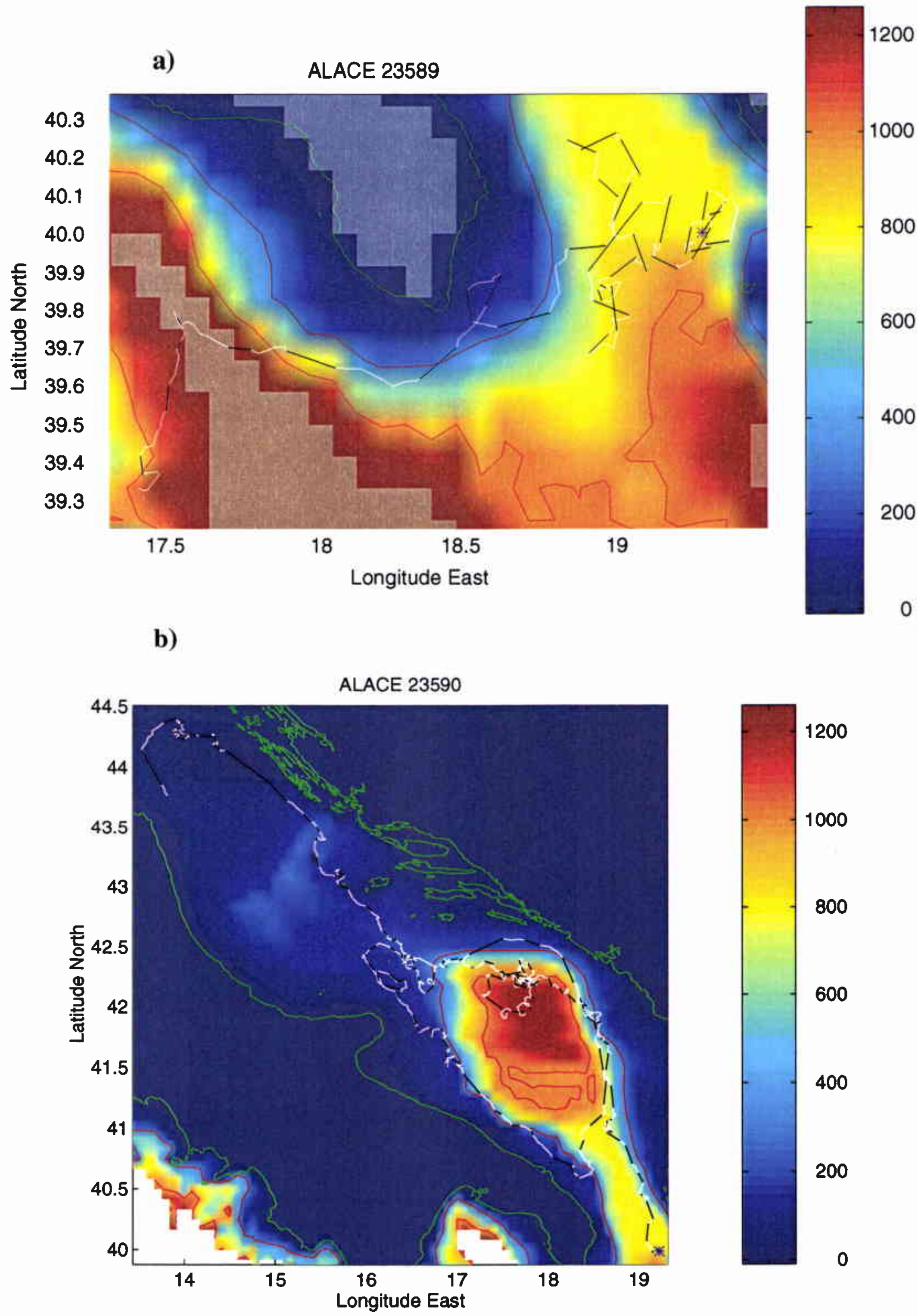


Figure C4 *Edited trajectories of the ALACE floats with surface (deep) segments in white (black) superimposed on the bathymetry. The bathymetry (1/12° resolution) is color-coded and is also contoured (isobaths of 300 and 1000 m in red. A star symbol is shown at the deployment location : (a) float 23589 and (b) float 23590.*

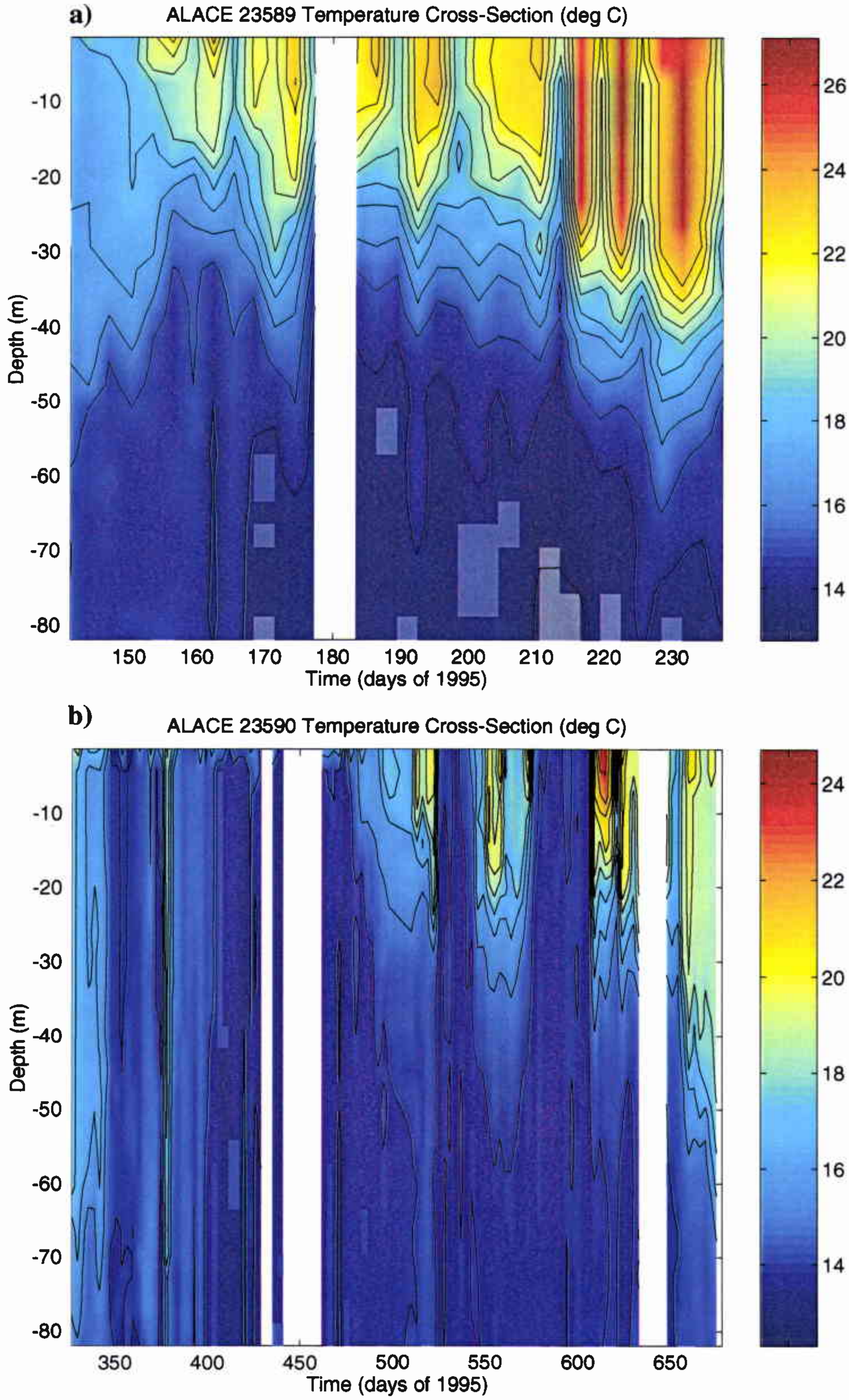


Figure C5 *Contour sections of the temperature in the water column above 80 m as a function of time following the Alace floats: (a) 23589 and (b) 23590. The development of the seasonal mixed-layer and thermocline in spring and summer is evident, along with strong localized mesoscale temperature features.*

Annex D
Drifter data in the Adriatic Sea: Velocity and temperature statistics

A composite "spaghetti" diagram and a plot showing the loci of the fast surface currents (speed in excess to 40 cm/s) are showed for the Adriatic Sea. Eulerian statistics calculated by averaging the drifter low-pass filtered velocity observations in bins of 15′ latitude by 15′ latitude are reported. The number of observations, the mean value and the variance are displayed. The statistics are represented as mean velocity vectors and principal axes of variance. The principal axes of velocity variance have been computed as follows: Their length is equal to twice the roots λ_1 and λ_2 of

$$(\langle u'^2\rangle-\lambda(\langle v'^2\rangle-\lambda) - \langle u'v'\rangle^2 = 0, \qquad \text{(D1)}$$

where u′ and v′ are the residual velocity components. The direction of the major axis, θ, is related to $\langle u'v'\rangle$ by

$$0.5\, tan(2\theta) = \frac{\langle u'v'\rangle}{(\langle v'^2\rangle - \langle u'^2\rangle)} \qquad \text{(D2)}$$

The seasonal cycle of the sea surface temperature is also depicted.

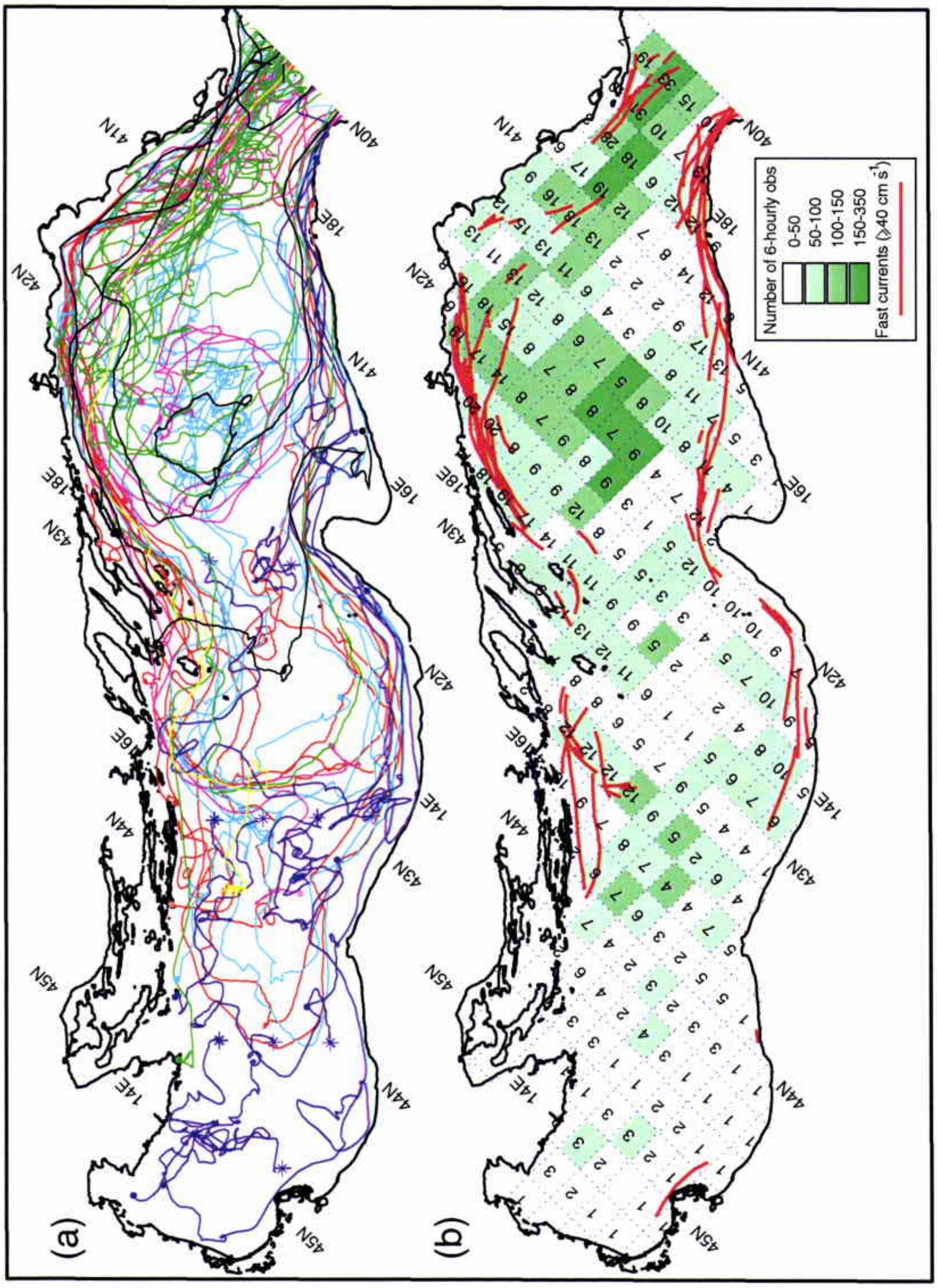


Figure D1 *Low-pass filtered drifter trajectories in the Adriatic Sea color-coded according to the deployment events: 3 December 1994, OGEX0 (magenta), 6-16 May 1995, PRISMA (blue), 17-22 May 1995, OGEX1 (green), 25 July 1995 (black), 26 August 1995, OGEX2 (red) and 13 October 1995 (cyan). Star and solid circle symbols are depicted at the deployment and last "good" transmission sites, respectively (a). Drifter trajectory segments corresponding to speeds in excess to 40 cm/s. The number of individual drifters (posted numbers) and the number of 6-hourly velocity observations (green tints) in 15' by 15' bins illustrate the non-uniform spatial distribution of the drifter data set (b).*

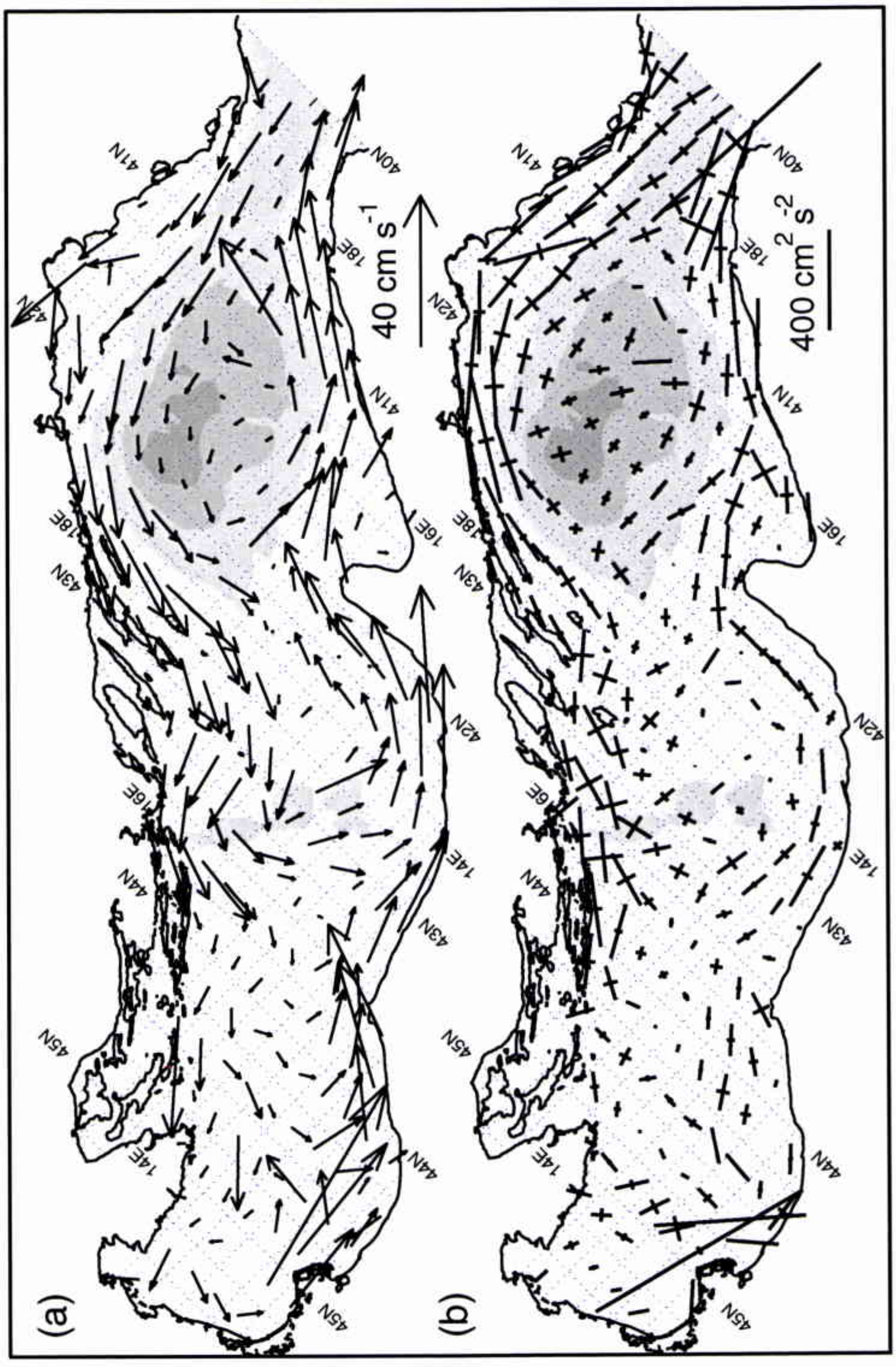


Figure D2 *Maps of mean currents (a) and principal axes of sub-tidal velocity variance (b) as estimated in 15' by 15' bins from the entire surface drifter data set. Gray shades indicate regions deeper than 200, 1000 and 1200 meters.*

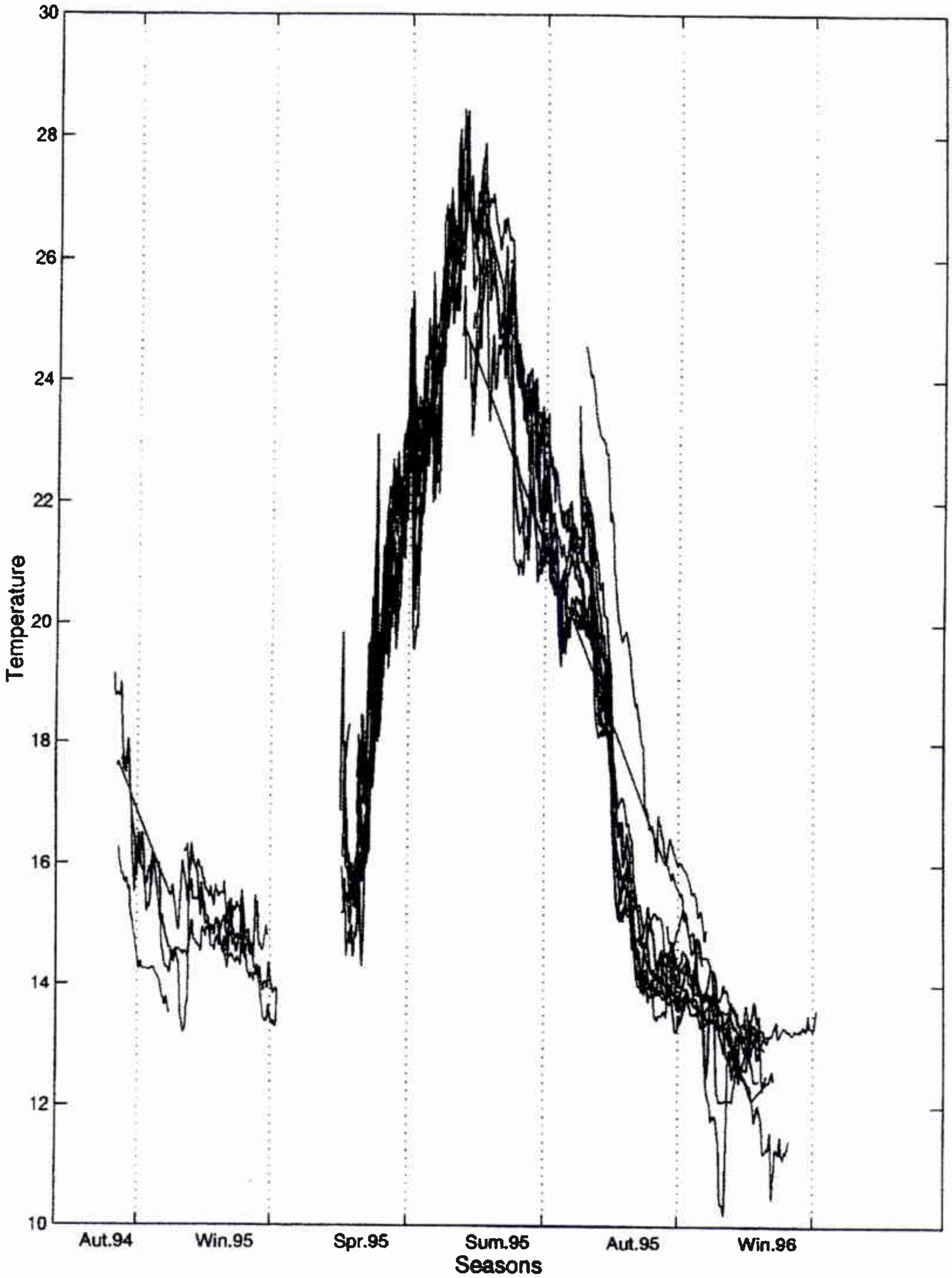


Figure D3 *Low-pass filtered sea surface temperature for all the drifters plotted versus time. The seasonal variations between 10°C and 28°C are evident.*

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Title

Drifter and float observations in the Adriatic Sea (1994-1996): data report

Abstract

During the period December 1994 to November 1995, 62 Argos tracked surface drifters, one Argos tracked drifter drogued to 300 m and 3 Argos tracked sub-surface floats were released in the Adriatic Sea to describe the characteristics of the sub-tidal surface and intermediate level (300 m) circulation and temperature fields at scales ranging from a few kilometres (mesoscale) to hundreds of kilometres (large scale).

These Lagrangian data sets, extending to December 1996, are described in this report. Full details of the data acquisition systems and data processing are provided to serve as a reference for the analyses published in the scientific literature. Graphics are included in the Annexes to illustrate drifter and float performance, position and temperature data, and Eulerian statistics.

The drifter and float measurements comprise the first basin scale, accurate velocity and temperature in situ data over the Adriatic Sea. They describe quantitatively the major circulation features over the entire semi-enclosed basin in which issues such as defence, pollution and fisheries are paramount.

At smaller scales, the Lagrangian data were used, in conjunction with hydrographic and satellite measurements, to study the mesoscale structure and dynamics of the complex circulation patterns in the Strait of Otranto and Southern Adriatic.

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