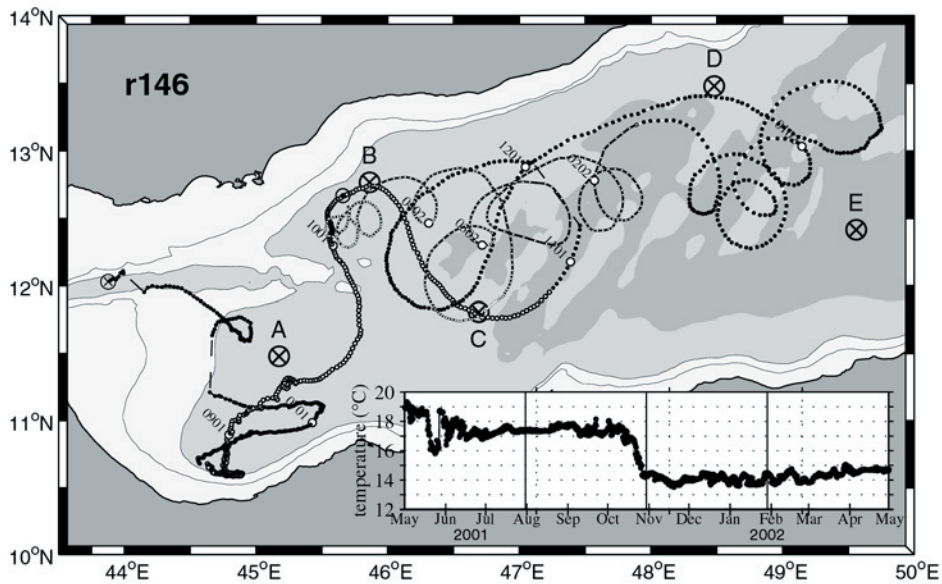
WHOI-2005-01

Woods Hole Oceanographic Institution

Red Sea Outflow Experiment (REDSOX): DLD2 RAFOS Float Data Report February 2001 - March 2003



by

Heather H. Furey, Amy S. Bower, and David M. Fratantoni

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Technical Report

Funding was provided by the National Science Foundation under Grant Number OCE-9818464.

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Approved for Distribution:

Nelson G. Hogg, Chair

Department of Physical Oceanography

Abstract

This is the final data report of all acoustically tracked second-generation Deep Lagrangian Drifter (DLD2) RAFOS float data collected by the Woods Hole Oceanographic Institution in 2001-2003 during the Red Sea Outflow Experiment (REDSOX). The float component of REDSOX was comprised of two deployments on the *R/V Knorr* and *R/V Ewing*: the first in February-March 2001, with 26 floats, and the second in August-September 2001, with 27 floats. The isobaric floats were ballasted for 650 decibars to target the intermediate-depth, high-salinity outflow waters from the Red Sea. The objectives of the Lagrangian float study were (1) to identify the spreading pathways of the equilibrated Red Sea outflow, and to quantify the velocities and eddy variability typical of this outflow and of the background oceanic environment in the Gulf of Aden, and (2) to identify and describe the mesoscale processes which contribute to the seaward transport of Red Sea Overflow Water properties through the Gulf of Aden and into the western Indian Ocean. In addition to floats activated and launched during the two cruises, four time-series sites were chosen for dual-release float moorings. The dual-release floats were released every two months between cruises and every two months after the second cruise, with the final release in March 2002. A pirate attack on the *R/V Ewing* forced some modification of the float deployment plan during the second cruise.

Front Cover Figure Caption:

Float r146, a dual-release float, plotted so that each three-month segment alternates in line style. Six-hourly positions are marked as dots, every first day of the month is marked with a large white dot outlined in black, and labeled 'MMYY'. Bathymetry is drawn at 600 and 1000 meters, and shaded in 1000-meter intervals. Sound sources are marked with a circle-X and labeled 'A'-'E'. The inset shows temperature for the same float. r146 was moored in winter 2001, and released itself from the mooring and rose up to its neutral buoyancy level of 650 dbars about two months later, in early May 2001. This float illustrates the complexity of currents in the Gulf of Aden at 650 decibars, and the prevalence of mesoscale eddies at this depth. This float also illustrates the complexity in tracking in this region, where floats continually crossed baselines between source pairs. It was typical for a float to experience temperature changes greater than 6°C from release in the western Gulf, where water was sometimes up to 20°C in winter, to about 12°C by the time it reached the central Gulf of Aden. This made accurate determination of the temperature properties, where the float temperatures were limited by hardware to modulo 4.096°C, another challenge unique to this data set.

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1. Introduction

The Red Sea Outflow Experiment (REDSOX) included two cruises in the Gulf of Aden (northwestern Indian Ocean) on the *R/V Knorr* (February 5 – March 15, 2001) and *R/V Ewing* (August 21 – September 12, 2001). The cruise reports, *Red Sea Outflow Experiment – REDSOX 1* and *Red Sea Outflow Experiment – REDSOX 2*, summarize the scientific activities completed during the two cruises. REDSOX was a joint effort between Drs. Amy Bower and David Fratantoni at the Woods Hole Oceanographic Institution and Drs. William Johns and Hartmut Peters at the Rosenstiel School of Marine and Atmospheric Science, University of Miami. The experiment was designed to study the outflow from the Red Sea and its downstream evolution through the Gulf of Aden and into the open Indian Ocean. The

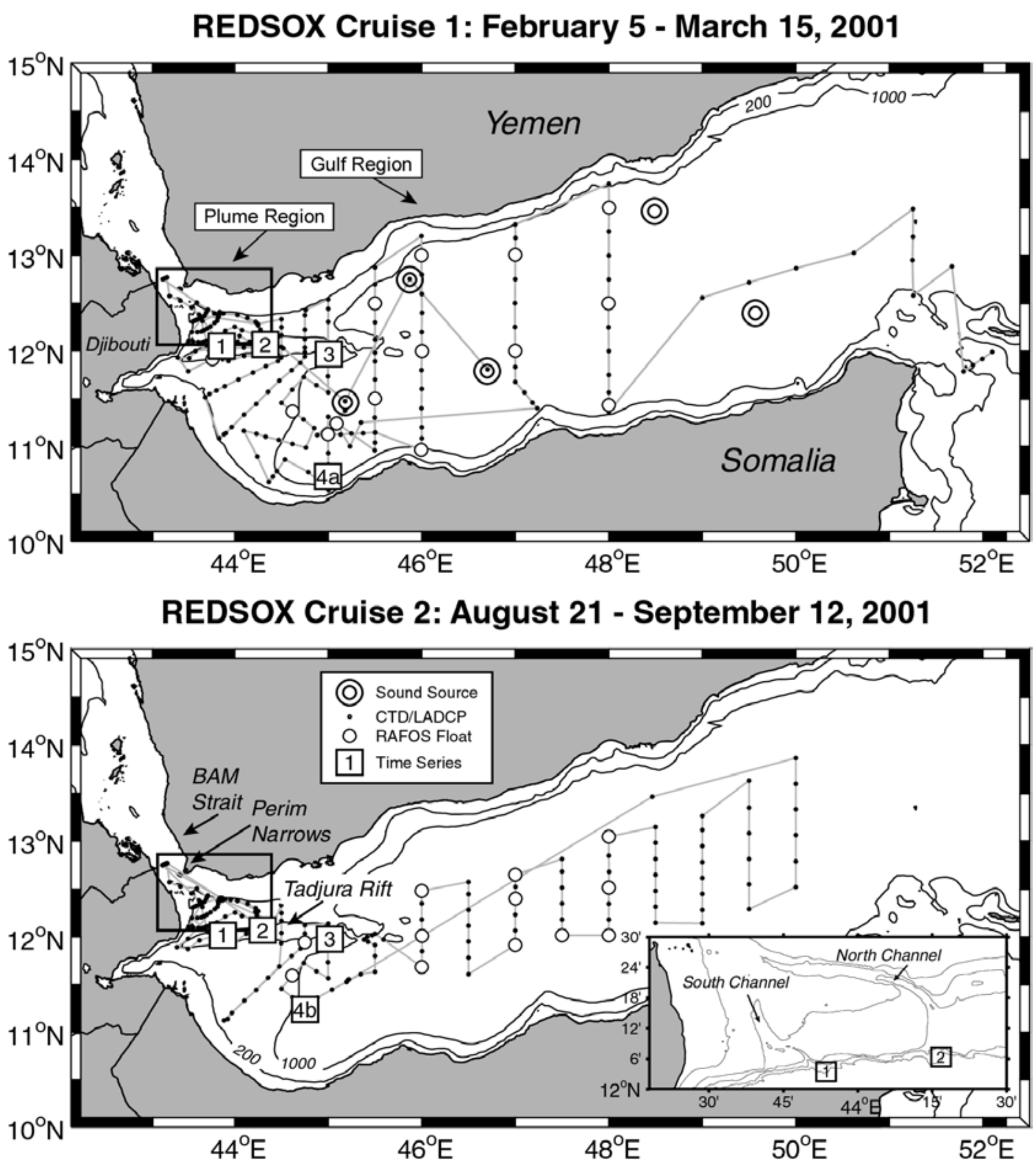

Figure 1. REDSOX-1 and -2 cruise tracks, showing sound source, float deployment and CTD locations.

timing of the two cruises was chosen to target the periods of maximum (winter; northeast monsoon) and minimum (summer; southwest monsoon) outflow transport from the Red Sea. To this end, a high-resolution CTD and LADCP survey, and four bottom-moored day-long ADCP/CTD ("Bottom Lander") stations were taken of the Plume Region, and a lower resolution CTD survey was taken and RAFOS floats were deployed in the Gulf Region (Figure 1). Drs. Johns and Peters led the Plume Region component of REDSOX, while Drs. Bower and Fratantoni were responsible for the Lagrangian and large-scale water property study of the Gulf of Aden. The objectives of the Lagrangian float study were (1) to identify the spreading pathways of the equilibrated Red Sea outflow, and to quantify the velocities and eddy variability typical of this outflow and of the background oceanic environment in the Gulf of Aden, and (2) to identify and describe the mesoscale processes which contribute to the seaward transport of Red Sea Overflow Water properties through the Gulf of Aden and into the western Indian Ocean. The isobaric floats were ballasted for 650 decibars to target the intermediate-depth high salinity and high temperature outflow waters from the Red Sea. The sampling plan of REDSOX(RSX)-2 (Figure 1), originally identical to that of RSX-1, was severely compromised by a pirate attack on the ship early in the cruise, after the Plume Region had been sampled. RSX-2 station locations, after the attack, were limited to regions greater than 50 miles from the coasts of Yemen and Somalia. In this data report, the DLD2 float component of the cruise and data processing are described in detail.

2. Description of the DLD2 Float and Dual-Release System

The DLD2 is a second-generation RAFOS (Ranging And Fixing Of Sound) float with several improvements over the traditional RAFOS float (see Rossby *et al.*, 1986, for a complete description of the RAFOS system). A detailed write-up of the improvements and workings of the DLD2 is given in Wooding *et al.*, 2002. The improvements in regards to data processing are as follows: Pressure and temperature sensors and clocks are more accurate. The status message transmitted every one-tenth of message total contains release depth and real-time surface parameters of temperature and pressure, battery voltage, and vacuum. The temperature and pressure at release, which can be considered an endpoint to the float's temperature and pressure data, are invaluable for treating rollover in these properties. Temperature and pressure along the float track are recorded as modulo 4.096°C and 409.6 dBars, respectively, and in the Gulf of Aden, where some floats experienced temperatures from ~20°C to ~12°C, the full-range temperature and pressure measurements at mission's end were critical in determining that rollovers were being treated correctly. Surface status data was analyzed and will be presented in Section 5, Float Performance. One property of these DLD2 floats that is different than the RAFOS floats is that a float is active at the moment of initialization, and not at the beginning of the cycle following activation, usually at midnight.

Fifty-three DLD2 floats were purchased from Seascan Corporation of Falmouth, MA, and assembled, calibrated (temperature and pressure), and ballasted at WHOI. The floats recorded temperature,

Table 1. REDSOX-1 & -2 Launch and Surface

Float ID	Dual Re-lease	Reset Date	Launch			Surface			Status Code
			Date	Lat	Lon	Date	Lat	Lon	
REDSOX-1									
r010	N	010309	010309	11.435	48.000	020308	12.766	51.785	00
r023	N	010228	010228	11.980	44.999	020225	8.041	53.582	00
r134	Y	010301	010701	10.699	45.002	020630	13.465	48.521	00
r136	Y	010225	010701	12.087	44.300	020630	11.672	45.189	00
r144	Y	010228	010630	11.980	44.999	020629	11.867	46.133	00
r145	Y	010301	010501	10.699	45.002	020430	15.498	54.982	00
r146	Y	010224	010501	12.034	43.874	020430	12.668	45.660	00
r147	Y	010228	010501	11.980	44.999	020430	17.131	58.286	00
r159	N	010308	010308	12.218	47.998	020308	11.844	45.666	00
r160	N	010305	010308	13.502	48.004	020304	13.025	49.810	00
r161	N	010302	010302	11.132	45.000	020302	12.929	50.966	00
r162	N	010303	010305	10.968	45.993	020302	10.705	44.634	00
r163	N	010303	010304	13.000	46.000	020302	12.787	45.390	LMR/00
r164	N	010302	010303	12.499	45.499	020302	14.649	49.921	00
r165	N	010305	010306	11.238	45.090	010730	11.462	45.321	SM/00
r166	N	010301	010302	10.699	45.002	020301	12.195	46.239	00
r167	N	010303	010304	11.999	46.009	020302	7.276	53.899	INT/00
r168	N	010226	010301	11.367	44.616	020225	13.106	48.532	00
r169	N	010307	010307	12.011	46.999	010730	12.134	50.659	SM/00
r170	N	010302	010303	11.498	45.500	020302	12.883	50.593	00
r171	N	010224	010225	12.033	43.873	020224	11.547	46.154	00
r172	N	010305	010307	13.000	47.000	020304	12.961	48.027	00
r173	N	010224	010225	11.917	43.763	020224	11.905	43.678	00
r174	N	010224	010225	12.087	44.300	020224	12.972	46.373	00
r208	Y	010224	010701	12.034	43.875	020630	12.065	43.893	00
r209	Y	010224	010501	12.087	44.300	no show			

REDSOX-2

r210	N	010903	010903	12.400	47.003	020903	12.620	48.216	00
r211	N	010905	010906	13.051	48.001	020906	13.975	48.880	00
r212	N	010831	010901	11.594	44.614	020831	12.888	54.374	00
r213	N	010901	010901	11.283	44.737	020901	11.750	48.559	00
r214	N	010905	010906	12.513	48.007	020905	14.643	51.535	00
r215	N	010905	010905	12.017	48.001	020905	13.530	53.921	00
r216	N	010831	010831	11.945	44.749	020831	16.919	55.374	00
r217	N	010831	010901	11.980	45.000	020831	12.019	49.797	00
r218	N	010826	010827	12.087	44.302	020826	12.004	44.946	00
r219	N	010827	010829	12.033	43.873	020907	11.503	45.421	00
r220	N	010903	010904	11.916	47.001	020903	11.437	44.271	00
r221	N	010904	010906	12.649	47.003	020904	11.819	44.880	00
r222	N	010904	010905	12.018	47.499	020904	15.222	54.418	00
r223	N	010902	010903	12.483	46.000	020902	14.113	49.189	00
r224	N	010902	010903	11.683	46.001	020902	11.584	47.152	00
r225	N	010902	010903	12.009	46.005	020902	12.668	49.574	LMR/00
r226	Y	010901	011101	11.283	44.736	021031	12.099	46.268	00
r227	Y	010901	020101	11.283	44.736	021231	14.194	50.466	00
r228	Y	010827	011101	12.033	43.872	021031	13.054	49.588	00
r229	Y	010827	020101	12.033	43.872	no show			
r230	Y	010827	020301	12.033	43.871	no show			
r231	Y	010831	011101	11.982	45.003	no show			
r232	Y	010826	020101	12.087	44.303	021231	13.713	48.242	00
r233	Y	010826	020301	12.086	44.304	030228	10.920	44.193	00
r234	Y	010831	020101	11.982	45.000	021231	12.511	45.965	00
r235	Y	010831	020301	11.980	45.000	030228	10.946	45.789	00
r326	Y	010826	011101	12.087	44.303	021031	11.423	44.562	00

1. **Status codes at end of float mission. 00: normal mission, 66: low battery, 80: over pressure, 83: lost weight. SM: purposefully short mission, LMR: low message return, daily messages received low compared to other floats, INT: intermittent transmissions.**

pressure and times of arrival (TOAs) of sound signals transmitted by moored sound sources. At the end of their missions, the floats dropped ballast weights, rose to the ocean surface and transmitted data to WHOI via the Service Argos Inc. satellite system. Because this experiment was at low latitudes, we chose multi-satellite coverage, where data was returned from every satellite available. The DLD2 floats were set to repeat their listening schedule every 12 hours and remain open for 8 hours 20 minutes length each cycle, so that two sound signals from each source (on a 6-hourly schedule) were heard per cycle. Two temperature and pressure measurements were taken in each listening cycle, at 2:18 and 8:18 into a cycle. This resulted in a pseudo-6-hourly schedule for the floats, with four windows of two TOA/correlation pairs each, and one T/P per 6-hours. A sampling interval of four data points per day was chosen to accurately resolve eddy scale motions and currents around sharp bathymetry. The pressure and temperature were derived from a module manufactured and calibrated by SeaScan, Inc., which utilized a thermistor as the temperature sensor and a Druck pressure sensor. Temperature accuracy is +/- 0.005°C and pressure, +/- 5 dB.

Nineteen out of 53 floats in the experiment were deployed as dual-release floats (Table 1). These floats were equipped with two releases: one connected to the ballast weight, as in a traditional RAFOS float, and the second release connected to a mooring anchor. See Zenk et al. (2000) for a complete description of a dual-release system similar (not identical) to ours. Floats were moored at four time series sights, and released in two-month intervals after each cruise, to create two-month time series at each location from February 2001 through March 2002 (seven deployments). This technique allowed for repeat sampling of specific points in the Gulf of Aden without repeat cruises.

3. Sound Sources

Five sound sources were moored in the Gulf of Aden for this experiment, and comprised all sources used for tracking (no other sources exist in this region). Four sources were deployed in the first cruise (A, B, C, E) and the last source, which was damaged in shipment to the first cruise, was repaired and deployed on the second cruise (D; see Figure 2). The sound sources used were of higher frequency (780 Hz) compared with sources more commonly used in open-ocean RAFOS applications. The extended range of the standard 260 Hz source (typically greater than 1500 km) was not required to track floats in the Gulf of Aden. The high-frequency sources were considerably less expensive, smaller, and lighter than the

Table 2. Sound Sources

	Lat (°N)	Lon (°E)	Activation Date (yyyy-mm-dd)	Pong Time (hh:mm)	Drift (sec/day)
A	11.480	45.175	2001-02-18	01:01	0.000
B	12.767	45.862	2001-02-17	01:32	0.000
C	11.808	46.691	2001-02-17	02:01	0.000
D	13.474	48.469	2001-09-09	01:02	0.015[1]
E	12.416	49.558	2001-03-10	01:31	0.000

1. Drift most likely due to a failure in the clock temperature compensation circuitry (J. Valdes, personal communication).

standard source. The sources were moored in water 1200 to 2300 meters deep, and placed at 600 meters depth. Repetition rate for the sources was 6-hourly; signal length was 40 seconds. All sources were purchased from Seascan Incorporated of Falmouth, Massachusetts. Table 2 lists sound source mooring details.

4. Float Deployment

A total of 53 floats were deployed on two cruises, the first in February-March 2001 and the second in August-September 2001, in the western Gulf of Aden west of 48°E at the level of the intermediate-depth salinity maximum associated with Red Sea Outflow Water. All floats were isobaric and ballasted for the

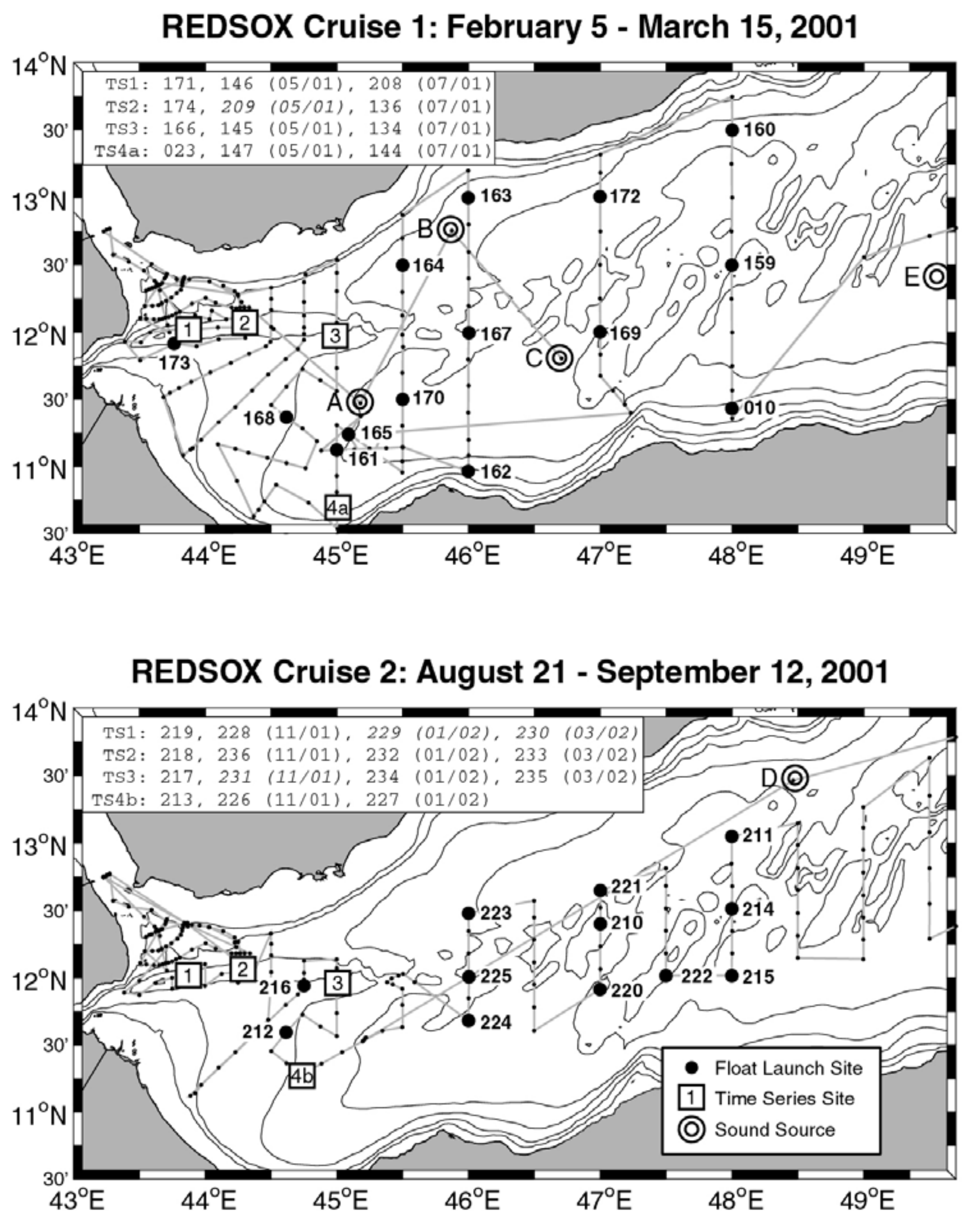

Figure 2. REDSOX-1 and -2 float deployment locations, detailing float numbers deployed. Insets to each panel list floats at time-series release sites, and give dates of release (MM/YY). Float numbers and dates in italics are floats that failed to transmit to Service Argos (no-shows).

650 dbar-pressure surface. On the first cruise, 18 single release and eight dual release floats were deployed. On the second cruise, 16 single release and 11 dual release floats were deployed (Table 1). Two floats deployed on the first cruise were short mission (90-day) floats, designed to test the performance of the sound source array and report results before the second cruise. Table 1 provides launch and surface information for all floats.

Dual-release floats were used to repeatedly release floats from four locations every two months for one year. These four sites were at the exits of the south and north channels from the Bab el Mandeb Strait (TS1 and TS2, respectively; Figure 2), which are the primary channels through which Red Sea Water is transported to the Gulf of Aden, the eastern end of the Tadjura Rift (TS3, Figure 2), where Red Sea Outflow Water was hypothesized to possibly escape the rift (Bower *et al*., 2000), and finally the southern boundary of the Gulf (TS4a, TS4b; Figure 2), where high salinity and temperature waters have been found in historical data suggestive of a boundary current (Bower *et al.*, 2000). The time-series site TS4 had to be moved on the second cruise away from the coast due to the pirate attack that had occurred earlier in the cruise. The location of TS4b was chosen at the same isobath as TS4a, and 50 miles from any land. Figure 2 shows detailed float deployment and time-series release sites, as well as sound source locations. Insets to both panels detail the floats released from the time series sites.

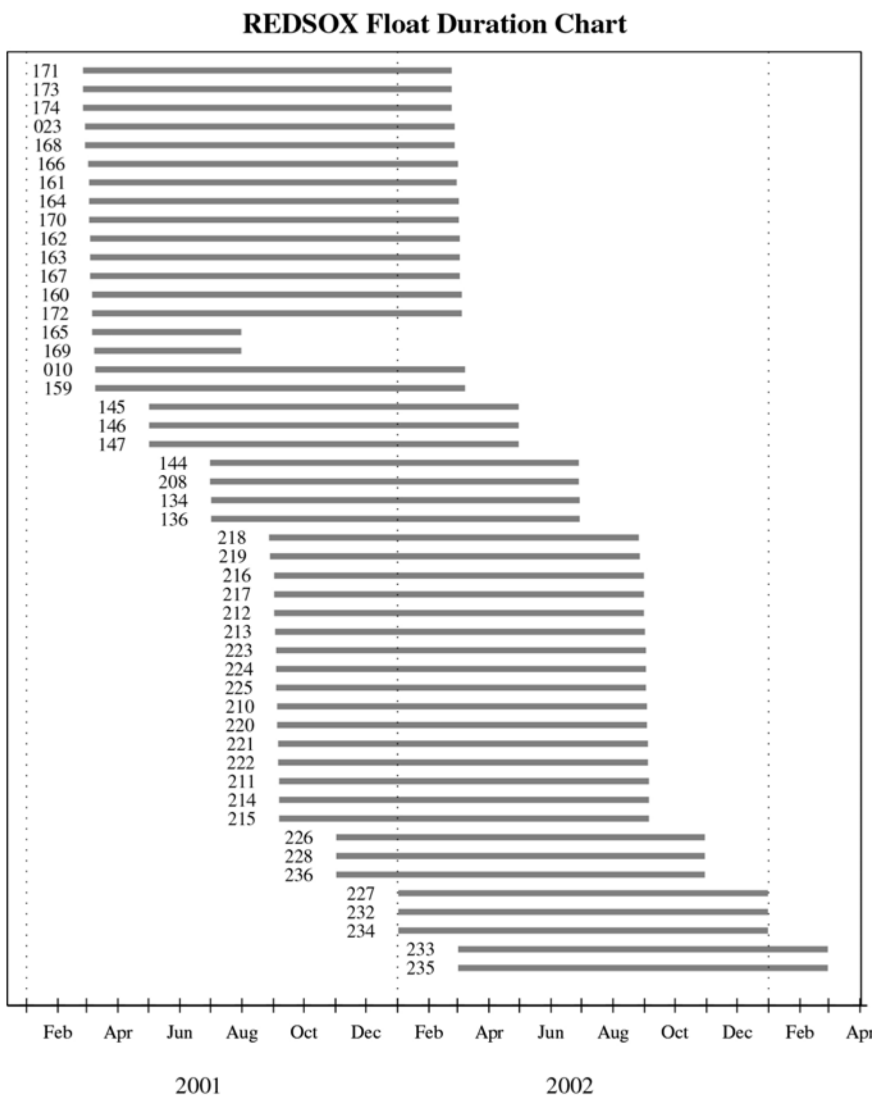

Figure 3. Chart depicts the duration of each float mission, ordered from first release at top, to last release at the bottom. Floats deployed that did not transmit are not plotted (in chronological order: May 1st 2001 (r209), November 1st 2001 (r231), January 1st 2002 (r229), and March 1st 2002 (r230)).

Float mission length was one year; so the complete sampling duration of the floats was from February 2001 through March 2003, when the last of the time-series floats surfaced. The duration chart in Figure 3 illustrates visually the RAFOS float missions in time (no-shows not plotted), highlighting the staggered release times of the dual release floats. The remaining single release floats, if not deployed at time series sites, were deployed in an evenly spaced sampling plan along the cruise track, to 48°E (see Figure 2). All single-release floats were launched using the 'Ross Perot' launching clip over the side of the ship. All dual-release floats were launched similarly, but with an additional line used to keep tension off the lanyard connecting the mooring weight to the float release.

5. Float Performance

Fifty-one of the 53 DLD2 floats were deployed for 365-day missions. The remaining two DLD2 floats were deployed as tests with 90-day missions, and completed their missions successfully. Out of the 53 floats deployed, all but four surfaced on time, with normal mission status (see Table 1). The remaining four failed to transmit entirely ('no-shows'), and were dual-release floats. Three of these no-show floats were moored on the steep sides of the tectonically-active Tadjura Rift, and it is hypothesized that these dual release floats may have been damaged on impact by the rugged bathymetry, or by slides and slumps. One float (r134, Appendix B) returned bad pressure data; one other float (r136, Appendix B) had a possible bad pressure sensor, returning a suspect cusping pressure record.

In general, ballasting of the floats was good, although almost all floats were slightly deeper than intended. Table 3 shows the ballasting performance for each float. All floats were ballasted for the 650-dbar pressure surface, and overall ballasting in the first 24 hours after launch was 63.1 dbars heavy. Ballasting was generally heavier in the dual-release floats, for unknown reasons. For RSX-1, single-release floats were 71.0 dbars heavy, while dual-release were 84.3 dbars heavy, with all RSX-1 floats averaging 73.7 dbars deep. In RSX-2, single-release floats were 22.0 dbars heavy, while dual-release were 109.0 dbars heavy, with all RSX-1 floats averaging 52.5 dbars deep. Overall, dual release ballasting was twice as deep (100.0 dbars) as single release floats (49.1 dbars). This is equivalent to about 2 grams heavy, where 1 gram is approximately equivalent to 25 dbars depth (B. Guest, personal communication). All floats for a cruise (whether single- or dual-release) were ballasted at the same time.

Table 4 describes the performance of the individual RAFOS floats that surfaced and transmitted data via ARGOS, including the number of days on surface, and the initial and final float clock offsets. Two floats, r227 and r233, had to have large initial and final float clock offsets applied during the tracking stage to get trajectory to converge in the Gulf, for unknown reasons. A summary of the transmission data listed in Table 4 is given in Table 5. Although the floats were all programmed to transmit data until the battery was dead, 5 floats stopped transmitting less than 15 days after surfacing for unknown reasons, two floats had weak transmitters, and one float transmitted intermittently, all of which reduced the percentage of messages received. This problem was especially acute in the floats launched on the first cruise. In total (not including no-shows), 77% messages were received from RSX-1 and 91% for RSX-2 (84% for both).

Table 3. REDSOX-1 & -2 Float Ballasting, Status Message Results

Float ID	*First Point*		*Target P (dbars)*	*ΔP*	*Release*[1]		*Vacuum (1-100)*		*PTT / Controller Battery (dV)*	
	T init	*P init*			*P*	*T*	*Init*	*Final*	*Initial*	*Final*
REDSOX-1										
r010	12.090	744.1	650	94.1	752.6	12.359	90	91	100	85
r023	13.610	702.4	650	52.4	710.7	9.933	92	92	101	98
r134[2]	**15.030**	**749.7**	**650**	**99.7**	**2,137.3**[3]	**12.627**	**86**	**87**	**101**	**68**
r136	**--**[4]	**--**	**650**	**--**	**877.2**	**15.173**	**87**	**88**	**100**	**89**
r144	**15.176**	**781.3**	**650**	**131.3**	**712.9**	**13.617**	**89**	**105**	**100**	**93**
r145	**14.936**	**716.7**	**650**	**66.7**	**727.3**	**10.790**	**89**	**100**	**103**	**54**
r146	**18.966**	**689.5**	**650**	**39.5**	**687.8**	**14.633**	**90**	**98**	**100**	**86**
r147	**--**	**--**	**650**	**--**	**759.7**	**10.881**	**89**	**90**	**101**	**102**
r159	--	--	650	--	726.7	14.165	89	89	103	103
r160	12.690	725.2	650	75.2	748.2	12.256	89	98	101	86
r161	15.585	725.8	650	75.8	756.4	12.988	90	108	101	84
r162	13.600	725.5	650	75.5	949.7	12.441	89	92	103	97
r163	17.246	706.4	650	56.4	699.8	14.781	89	98	105	78
r164	13.620	720.6	650	70.6	730.0	12.883	89	99	102	51
r165	16.023	701.8	650	51.8	697.3	15.092	87	89	105	70
r166	13.490	733.5	650	83.5	723.6	12.864	86	89	104	98
r167	13.197	691.4	650	41.4	708.7	10.612	86	111	101	60
r168	19.331	702.4	650	52.4	740.1	12.498	89	92	105	101
r169	13.370	737.0	650	87.0	718.7	12.052	90	91	104	104
r170	13.640	743.6	650	93.6	766.2	13.299	87	98	103	87
r171	18.278	716.6	650	66.6	747.0	13.811	89	90	102	99
r172	13.450	743.9	650	93.9	745.3	12.343	90	91	102	99
r173	--	--	650	--	739.2	18.368	89	89	103	101
r174	15.784	716.4	650	66.4	740.6	13.083	85	86	101	96
r208	**15.880**	**1178.5**	**650**	**stuck**[5]	**1,178.7**	**16.348**	**91**	**93**	**104**	**70**
r209	**no show**		**650**							

RSX-1: SR 71.0 dbars heavy, DR 84.3 dbars heavy, all 73.7 dbars heavy.

REDSOX-2										
r210	--	--	650	--	779.0	12.665	89	92	102	93
r211	11.450	673.6	650	23.6	506.9	12.264	88	90	102	91
r212	14.053	680.5	650	30.5	730.6	11.545	88	89	101	90
r213	15.870	658.3	650	8.3	672.9	13.295	88	89	103	91
r214	11.608	675.4	650	25.4	719.2	11.919	89	91	103	93
r215	12.150	645.1	650	-4.9	655.7	11.893	88	89	101	92
r216	--	--	650	--	651.6	10.757	87	88	102	99
r217	13.945	681.5	650	31.5	687.9	13.835	89	100	104	57
r218	15.160	671.7	650	21.7	687.0	12.790	89	91	103	98
r219	17.590	664.8	650	14.8	685.8	14.786	88	89	106	96
r220	13.780	669.3	650	19.3	674.1	13.512	87	89	102	92
r221	11.977	678.6	650	28.6	679.8	14.708	89	99	103	83
r222	13.483	715.0	650	65.0	757.8	10.888	89	90	101	90
r223	13.250	647.4	650	-2.6	693.8	11.739	86	88	103	93
r224	12.518	675.0	650	25.0	682.8	14.668	89	89	103	90
r225	--	--	650	--	687.3	12.181	87	89	101	90
r226	**12.010**	**693.4**	**650**	**43.4**	**701.0**	**12.556**	**88**	**100**	**102**	**94**
r227	**15.526**	**808.8**	**650**	**158.8**	**854.6**	**13.188**	**90**	**97**	**101**	**76**
r228	**15.806**	**769.6**	**650**	**119.6**	**709.1**	**14.216**	**89**	**91**	**101**	**98**
r229	**no show**	**--**	**650**	--						
r230	**no show**	**--**	**650**	--						
r231	**no show**	**--**	**650**	--						
r232	**--**	**--**	**650**	**--**	**749.6**	**12.922**	**89**	**90**	**101**	**101**
r233	**17.926**	**764.4**	**650**	**114.4**	**856.8**	**14.970**	**88**	**95**	**101**	**97**
r234	**14.550**	**780.2**	**650**	**130.2**	**740.7**	**13.510**	**89**	**96**	**103**	**93**
r235	**15.126**	**779.6**	**650**	**129.6**	**723.5**	**13.460**	**89**	**91**	**101**	**91**
r326	**14.106**	**717.3**	**650**	**67.3**	**734.5**	**12.124**	**90**	**100**	**102**	**89**

RSX-2: SR 22.0 dbars heavy, DR 109.0 dbars heavy, all 52.5 dbars heavy.

All RSX: SR 49.1 dbars heavy, DR 100.0 dbars heavy, all 63.1 dbars heavy.

1. **In DLD2 floats, one T/P returned in status message, taken just after wire is burned for release.**
2. **Bold entries indicate dual-release floats.**
3. **Float r134 had a bad pressure sensor.**
4. **Floats with first pressure records more than 4 records after launch/release were not included.**
5. **Float r208 was stuck on mooring after release.**

Table 4. REDSOX-1 & -2 Float Clock and ARGOS Information

Float ID	*ResetDate (yymmdd)*	*Initial Float Clock Offset (sec)*	*Mission Start Date (yymmdd)*	*Surface Due Date (yymmdd)*	*First Trans-mission Date (yymmdd)*	*Final Float Clock Offset (sec)*	*Days on Surface*	*Msgs Received (%)*
REDSOX-1								
r010	010309	0	010309	020308	020308	0.7	194	94
r023	010228	0	010228	020225	020225	1.8	22	83
r134[1]	**010301**	**0**	**010701**	**020630**	**020630**	**-0.2**	**150**	**100**
r136	**010225**	**0**	**010701**	**020630**	**020630**	**3.8**	**86**	**100**
r144	**010228**	**0**	**010630**	**020629**	**020629**	**0.4**	**22**	**90**
r145	**010301**	**0**	**010501**	**020430**	**020430**	**-0.7**	**126**	**100**
r146	**010224**	**?**[2]	**010501**	**020430**	**020430**	**-1.3**	**84**	**98**
r147	**010228**	**0**	**010501**	**020430**	**020430**	**-1.3**	**3**	**20**
r159	010308	0	010308	020308	020308	-1.4	3	21
r160	010305	0	010308	020304	020304	-0.1	208	96
r161	010302	0	010302	020302	020302	3.7	26	79
r162	010303	0	010305	020302	020302	-1.6	38	83
r163	010303	0	010304	020302	020302	-5.4	186	76
r164	010302	0	010303	020302	020303	-0.7	203	100
r165	010305	0	010306	010730	010730	-0.7	170	100
r166	010301	0	010302	020301	020301	-1.0	42	86
r167	010303	0	010304	020302	020302	-3.1	157	12
r168	010226	0	010301	020225	020225	-1.1	22	75
r169	010307	0	010307	010730	010730	-0.6	3	37
r170	010302	0	010303	020302	020302	-1.7	116	100
r171	010224	0	010225	020224	020224	-0.7	20	69
r172	010305	0	010307	020304	020304	-0.6	20	77
r173	010224	0	010225	020224	020224	-0.6	6	34
r174	010224	0	010225	020224	020224	-0.2	36	92
r208	**010224**	**0**	**010701**	**020630**	**020703**	**1.1**	**68**	**100**
r209	**010224**	**0**	**010501**	**no show**				

REDSOX-2								
r210	010903	0	010903	020903	020903	0.1	188	100
r211	010905	0	010906	020906	020906	-1.9	168	100
r212	010831	0	010901	020831	020831	-1.5	195	100
r213	010901	0	010901	020901	020901	-1.1	190	100
r214	010905	0	010906	020905	020905	-2.1	200	100
r215	010905	0	010905	020905	020905	-1.3	194	100
r216	010831	0	010831	020831	020831	-1.6	19	89
r217	010831	0	010901	020831	020831	0.5	181	91
r218	010826	1	010827	020826	020826	-0.3	32	98
r219	010827	0	010829	020907	020907	-1.7	52	100
r220	010903	0	010904	020903	020903	-1.3	159	100
r221	010904	0	010906	020904	020904	-0.7	184	100
r222	010904	0	010905	020904	020904	-2.2	203	100
r223	010902	0	010903	020902	020902	-1.1	177	100
r224	010902	0	010903	020902	020902	-1.2	115	100
r225	010902	0	010903	020902	020902	-1.3	89	13
r226	**010901**	**0**	**011101**	**021031**	**021031**	**-1.7**	**23**	**92**
r227	**010901**	**-150/0**[3]	**020101**	**021231**	**021231**	**-150/-2.8**	**131**	**99**
r228	**010827**	**1**	**011101**	**021031**	**021031**	**-1.6**	**22**	**92**
r229	**010827**	**1**	**020101**	**no show**				
r230	**010827**	**0**	**020301**	**no show**				
r231	**010831**	**1**	**011101**	**no show**				
r232	**010826**	**1**	**020101**	**021231**	**021231**	**-1.3**	**2**	**19**
r233	**010826**	**-117/1**	**020301**	**030228**	**030228**	**-200/-1.7**	**23**	**94**
r234	**010831**	**0**	**020101**	**021231**	**021231**	**-1.5**	**51**	**97**
r235	**010831**	**0**	**020301**	**030228**	**030228**	**-1.9**	**118**	**100**
r326	**010826**	**1**	**011101**	**021031**	**021031**	**-2.3**	**188**	**96**

1. **Bold type face indicates dual-release float.**
2. **Initial float clock offset is unknown.**
3. **For floats 227 and 233, additional float clock offsets had to be added during tracking. The value used in tracking is first, the value calculated from the original data is second.**

The RSX-1 floats transmitted for 80 days on average and RSX-2 floats for 121 days. Figure 4 displays percent message return versus number of days transmitted. No distinct difference can be seen between RSX-1 and -2, and the data falls along an exponential-shaped curve. Generally, >80% data return is achieved within about 25 days of transmission, and >95% within 50 days transmission.

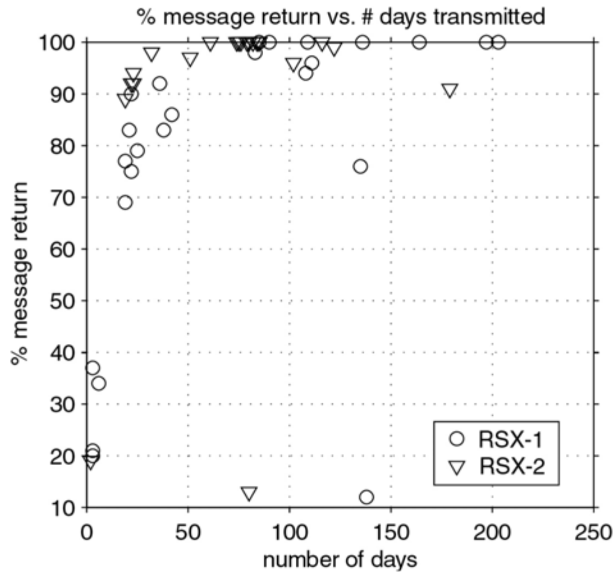

Figure 4. Float transmission performance, number of days versus percent message return of each float that transmitted.

The DLD2 status message also returns on-surface battery and vacuum readings while transmitting the data. These data are also included in Table 3, and a scatter plot of initial vs. final battery and vacuum status is presented in Figure 5. Floats generally stop transmitting when vacuum goes over 100 (indicating loss of vacuum and possible leak of seawater into the float), or when the battery power is reduced to less than about 70 dV (J. Valdes, personal communication). Float transmission performance was complicated, but not necessarily compromised, by float 'abduction', where floats were picked upon the surface while transmitting and taken to land on (presumably) small vessels. The Surface Track Gallery in Appendix A illustrates these events. Using floats r146 and r217 as examples, these floats transmitted for 84/181 days, and 98/100% data return was recovered, even though the floats had been on land after only 10/40 days adrift. There were no obvious differences between the floats taken to land and those left at sea in terms of transmission length, or final battery or vacuum status. No reason for early termination of transmissions was found from status data. Some of the early quitters may have been hit by ships in this relatively high traffic region. Table 6 summarizes the outcomes of all floats with low data return.

Table 5. Performance Summary

	RSX-1	RSX-2	RSX-1&2
# days transmitted	80	121	100
% msg return (without no-shows)	77	91	84
% msg return (with no-shows)	74	81	77
No-shows	1	3	4
Quit transmitting early (<15 days)	4	1	5
Weak transmissions	1	1	2
Intermittent transmissions	1	0	1

Table 6. REDSOX Floats with Low Data Return

OVERALL RESULTS

REDSOX-1: (25 floats)

13 floats had < 90% data return
Of those, 5 floats had < 50% data return

Of the 13 floats with < 90% data return
11 transmitted for less than 45 days
Of those, 4 transmitted for less than 10 days
Of the 13 floats with < 90% data return
1 picked up by boat:
Float 163, 76% data return; transmitted 186 days!; vacuum lost on pick up; pick-up not fatal.
2 washed ashore:
Float 171, 69% data return, transmitted 20 days, beaching fatal
Float 173, 34% data return, transmitted 6 days, beaching fatal
10 quit at sea (see below)

REDSOX-2: (24 floats)

3 floats have < 90% data return
Of those, 2 floats have < 50% data return

Of the 3 floats with < 90% data return:
2 transmitted for less than 45 days
Of those, 1 transmitted for less than 10 days

Of the 3 floats with < 90% data return:
1 washed ashore:
Float 216, 89% data, transmitted 19 days, beaching fatal
2 quit at sea (see below)

Conclusions:

1. BIG difference in data return between REDSOX 1 and 2: 13 versus 3 floats with < 90% data return.
2. Low data return NOT generally due to washing ashore or boat pick-ups. Of the 16 total floats with < 90% data return, 12 remained at sea, 10 during REDSOX-1 (winter = cooler), 2 during REDSOX-2 (summer = hotter). Of the 4 others, there were 3 fatal beachings, 1 (injury) boat pick-up.
3. REDSOX 1: 4 beachings, 5 boat pick-ups
   REDSOX-2: 12 beachings, 5 boat pick-ups
   Beachings and boat pick-ups were usually NOT fatal. Vacuum often lost on boat pick-ups.

AT-SEA FAILURES:

Focus in on floats with low data return that remained at sea: (12 floats)

REDSOX-1:

023: 83%, 22 days, started to lose vacuum, P/T go bad
147: 20%, 3 days, status variables look normal; dual-release
159: 21%, 3 days, status variables look normal
161: 79%, 26 days; loses vacuum, P/T go bad after ~12 days
162: 83%, 38 days; vacuum/battery look OK, but P (and T?) bad right away; leaker/sinker at depth.
166: 86%, 42 days; battery/vacuum look OK, bad P/T after ~5 days
167: 12%, 157 days, intermittent transmitter
168: 75%, 22 days; slight vacuum loss and bad P at end
169: 37%, 3 days, status variables look normal.
172: 77%, 20 days; status variables look normal

REDSOX-2:

225: 13%, 89 days; status variables look normal, but sparse; intermittent transmitter?
232: 19%, 2 days; status variables look normal; dual-release

Summary stats on at-sea failures:
5 floats show perfectly normal status variables (147, 159, 169, 172, 232)
2 look like intermittent transmitters or poor message-deliverers (167, 225). Both transmitted longer than 89 days.
5 lose vacuum and/or show bad P/T, possibly indicating surface or subsurface leak?

Conclusions:

1. About half of at-sea failures appear to be due to leaks and/or vacuum loss. All from REDSOX-1. None were dual-release floats. About 15-25% data lost.
2. About 20% might be due to poor transmitters.
3. About half are unexplained.

GRAND CONCLUSIONS:

Of 16 floats with < 90% data return, the following reasons can be given:
Vacuum loss and/or leaks (5) – 15-25% data lost
Fatal beachings (3) – 11-66% data lost
Intermittent transmitter or poor data recovery (2) – 88% data lost
Non-fatal but injurious boat pick-up (1) – 24% data lost
Unexplained (5) – 23-81% data lost

6. Sound Source Performance, Drift Calculations

Sound source ranges were given as 300-400 kilometers. In practice, reliable TOA signals (lower correlation, but still a usable record for tracking) were found to about 400 km. No tracking was achieved east of the 380 km barrier of sound source D (about 52°E; the second most eastward source, see Figure 2). Sources were sometimes obscured by seamounts, which affected tracking; this seemed to especially affect source B, so that tracking in the far western Gulf was worse than in the middle or eastern Gulf. Because source D was moored 6 months after the first floats were deployed, tracking was lost when floats moved quickly out of the Gulf within the first six months after the first cruise.

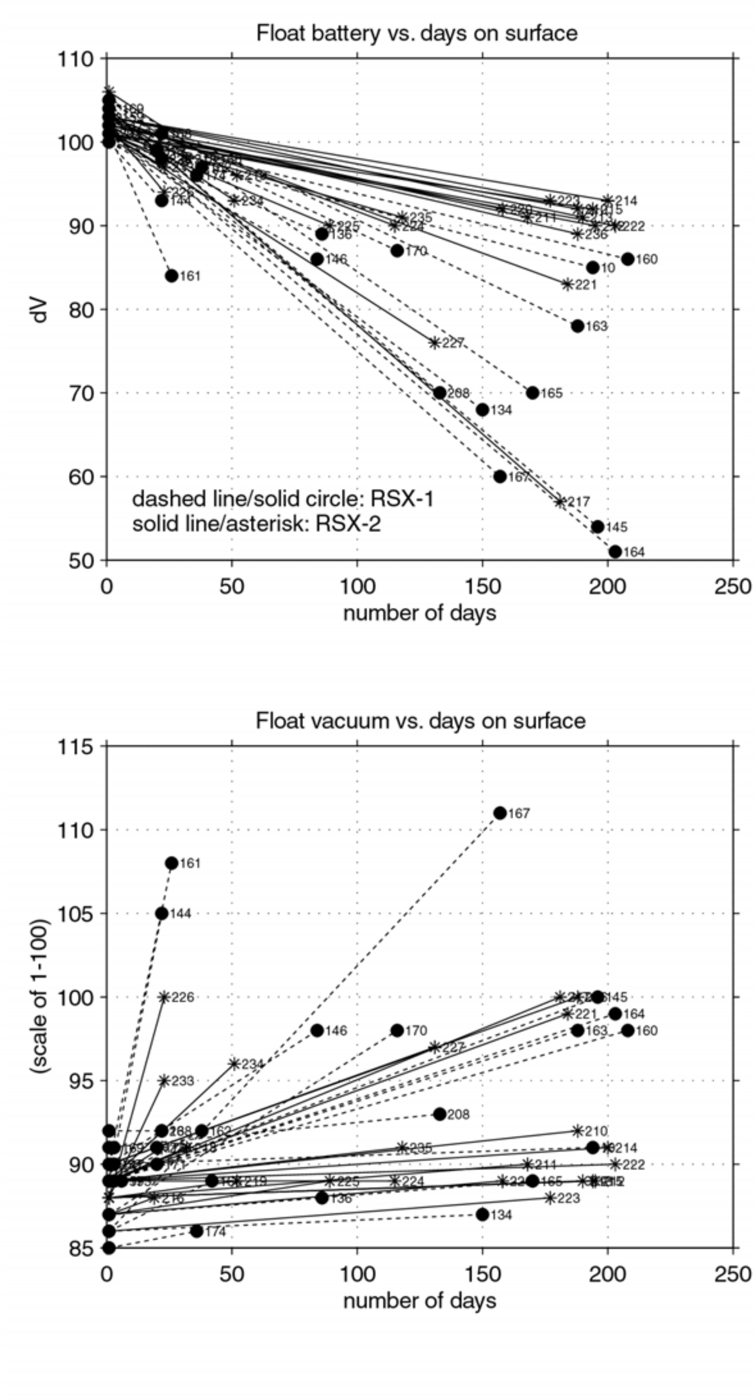

Figure 5. Status message results from DLD2 floats. Top panel shows battery voltage for each float at time of surfacing (day 0) and at time of final status message transmission, and bottom panel presents the same information for vacuum.

There were no directly observed drift estimates because none of the sources were recovered. In calculating source clock drifts for the five sources, we tried to use all available floats (49), regardless of distance between float and sound source at the time the travel time was recorded, and regardless of time between float surface and the first ARGOS fix. The only criterion was that a TOA existed within 12 hours (two records) after launch or before surface. In the end, 43 floats were used, with some floats yielding drift estimates both at launch and surface. The float position at surface was extrapolated back to the time of surface from the first two ARGOS positions after surface. A sound velocity of 1.500 km/sec was used for these calculations, this being the value used in tracking the floats. Four (A, B, C, E) of the five sources were estimated to have clock drifts that were indistinguishable from zero (Table 2). Source D had an estimated drift of 0.015 seconds/day, or 5.475 seconds/year.

7. Float Data Processing and Tracking

The floats were tracked using ARTOA2 software (Boebel et al. 2000) which originated at the University of Rhode Island with Martin Menzel and has been significantly revised by Olaf Boebel, currently at Alfred Wegener Institute Foundation for Polar and Marine Research in Bremerhaven. This software is now (Fall 2004) being upgraded and maintained at WHOI. ARTOA2, which was used to edit the temperature, pressure and TOA data, and to track the floats, is run on MATLAB. The TOAs were corrected for the Doppler shift and difference in transmission time, then interpolated using variable width (usually 20-day) cubic spline filter, before tracking. Tracking used a least-squares method if more than two TOAs were available.

The final sound velocity chosen for float tracking was 1.500 km/sec. We tested several velocity estimates (del Grosso, linear, and several estimates different than 1.500 km/sec) to ensure that this (1.500 km/sec) was the best value to use by checking the first and last track positions against the recorded launch and surface positions.

Tracking was challenging in this experiment due to the many baselines involved in such a small basin and basin-scale eddy motions of floats (see front cover figure for an example). This meant that floats were often moving in circles around and between the sources, crossing baselines. Different target locations were needed to get float tracks to cross a baseline, and this technique was used several times within each float track. Floats in the western Gulf had problems receiving signals from certain sources (usually B) due to obstruction from seamounts. The deployment of sound source D six months after the first cruise meant that a large portion of track was unavailable due to lack of sources, especially to those floats deployed on the first cruise that moved quickly eastward out of the gulf. Also, track was lost east of about 52°E, where the source transmissions from D were out of range.

Appendix A contains composite displacement vector and trajectory diagrams, as well as trajectory segments plotted in 30-day time intervals (‘movie frames’), a plot of trajectory segments plotted by speed, and both Track and Surface Track Galleries. Appendix B contains each float’s track and property plots, including temperature, pressure, u-velocity, v-velocity, and stick plot showing the direction and magnitude of the float’s velocity.

8. Acknowledgements

The authors thank the captains and crews of the *R/V Knorr* and *R/V Maurice Ewing* for their able assistance in carrying out this sea-going experiment. The second REDSOX cruise, which suffered a pirate attack and was on-going at the time of the World Trade Towers attack, had its own unique challenges. The calm and able assistance of the captain, crew, and hired safety officers were invaluable.

Jim Valdes, Brian Guest, and Bob Tavares of the WHOI Float Operations Group are gratefully acknowledged for the preparation and ballasting of the floats. The DLD component of Red Sea Outflow Experiment was funded by the National Science Foundation under Grant No. OCE-9818464 to the Woods Hole Oceanographic Institution.

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Appendix A

The following figures show the REDSOX DLD2 float data in various formats: composite displacement vector diagrams (Figure A1), composite float trajectory diagrams (Figure A2), movie frames: float trajectories plotted in 30-day segments (Figure A3), diagrams showing float track segments of speeds greater than 20 cm/sec and slower than 10 cm/sec (Figure A4), a float track gallery (Figure A5), and surface track gallery (Figure A6).

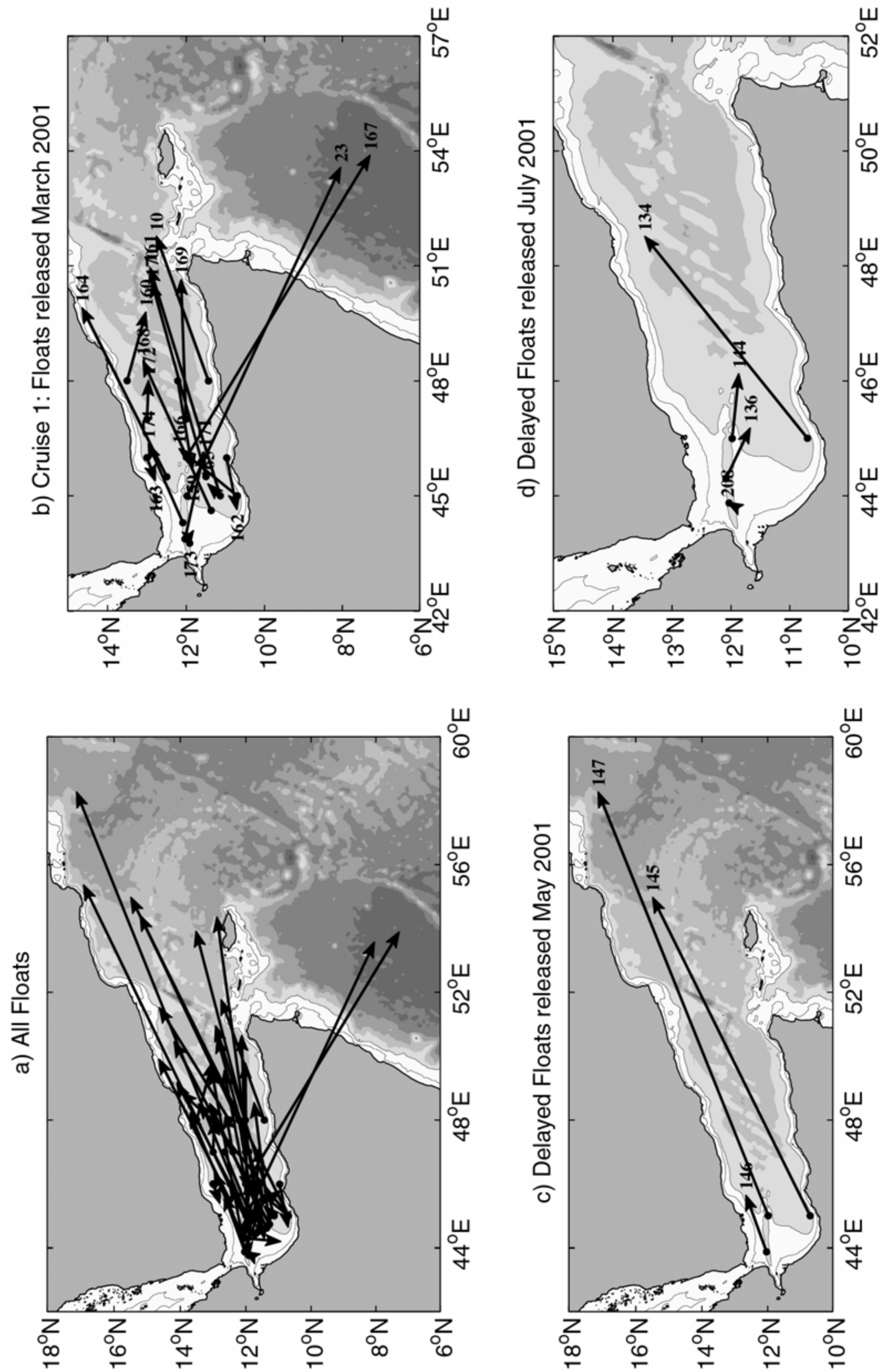


Figure A1. DLD2 float displacement vectors, separated by cruise and time series release. (a) All floats, (b) REDSOX-1 March 2001, (c) May 2001 time series release, (d) July 2001 time series release, (e) REDSOX 2 September 2001, (f) November 2001 time series release, (g) January 2002 time series release, and h) March 2002 time series release. Dots mark the launch positions, and arrowheads the surface positions. Vectors are labeled with float number at the arrowhead in all plots except for (a). The 200- and 1000-meter isobaths are drawn; bathymetry is shaded in 1000-meter intervals.

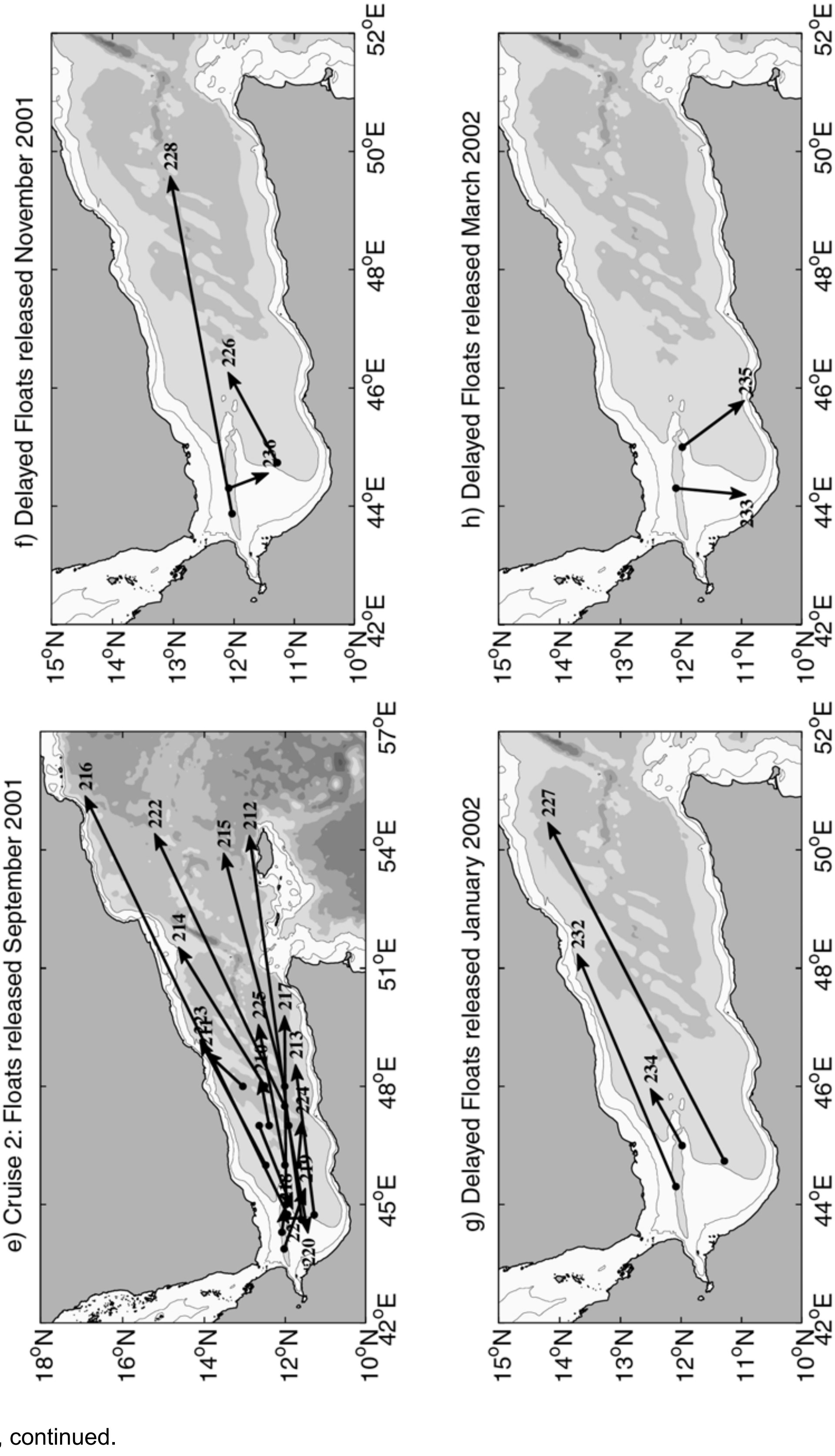


Figure A1, continued.

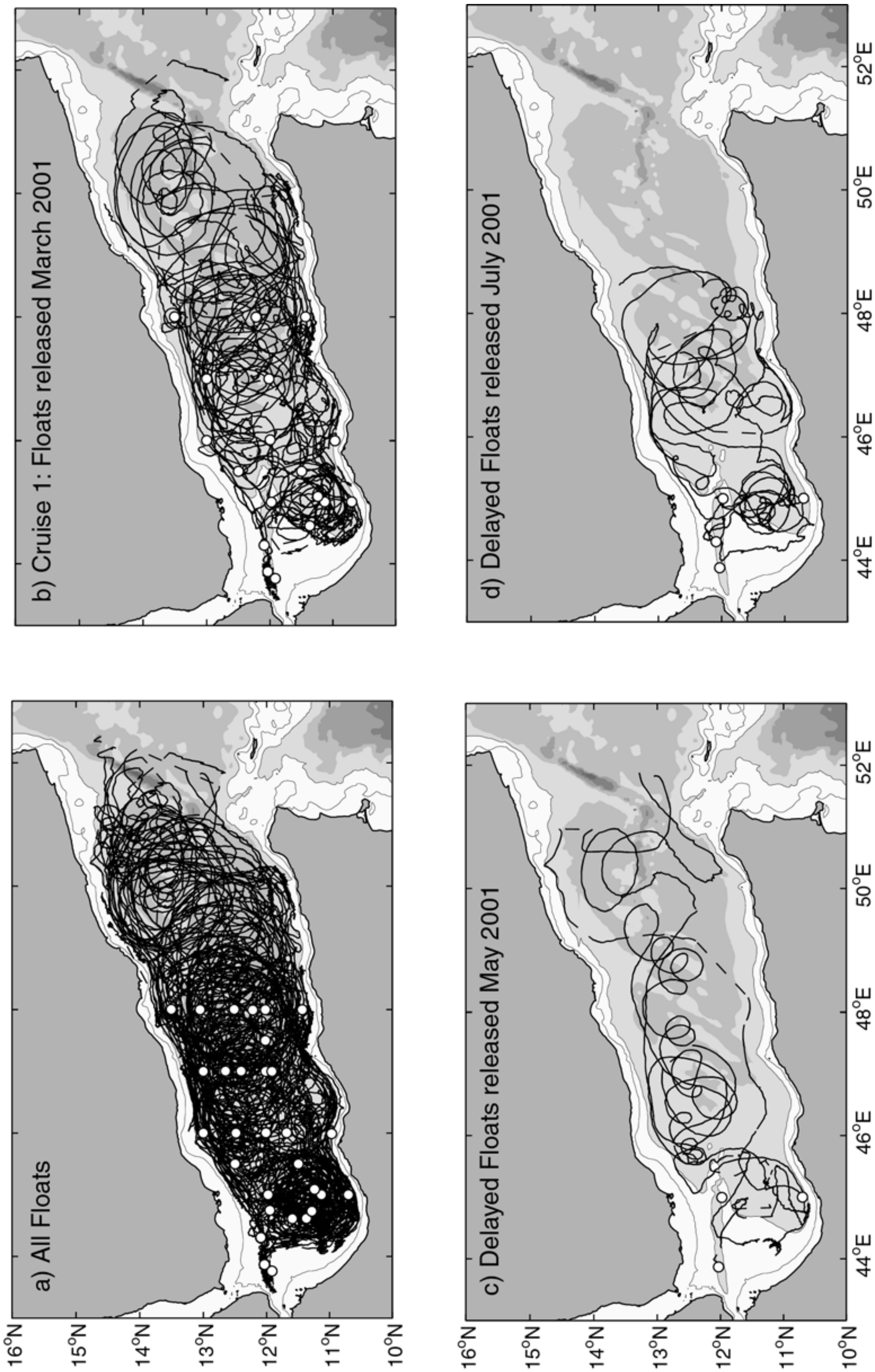


Figure A2. DLD2 float trajectory diagrams, separated by cruise and time series release. (a) All floats, (b) REDSOX-1 March 2001, (c) May 2001 time series release, (d) July 2001 time series release, (e) REDSOX 2 September 2001, (f) November 2001 time series release, (g) January 2002 time series release, and (h) March 2002 time series release. Launch positions are marked with a white dot; trajectories are represented as solid black lines; and untrackable segments are represented as dashed lines. Bathymetry is as in Figure A1.

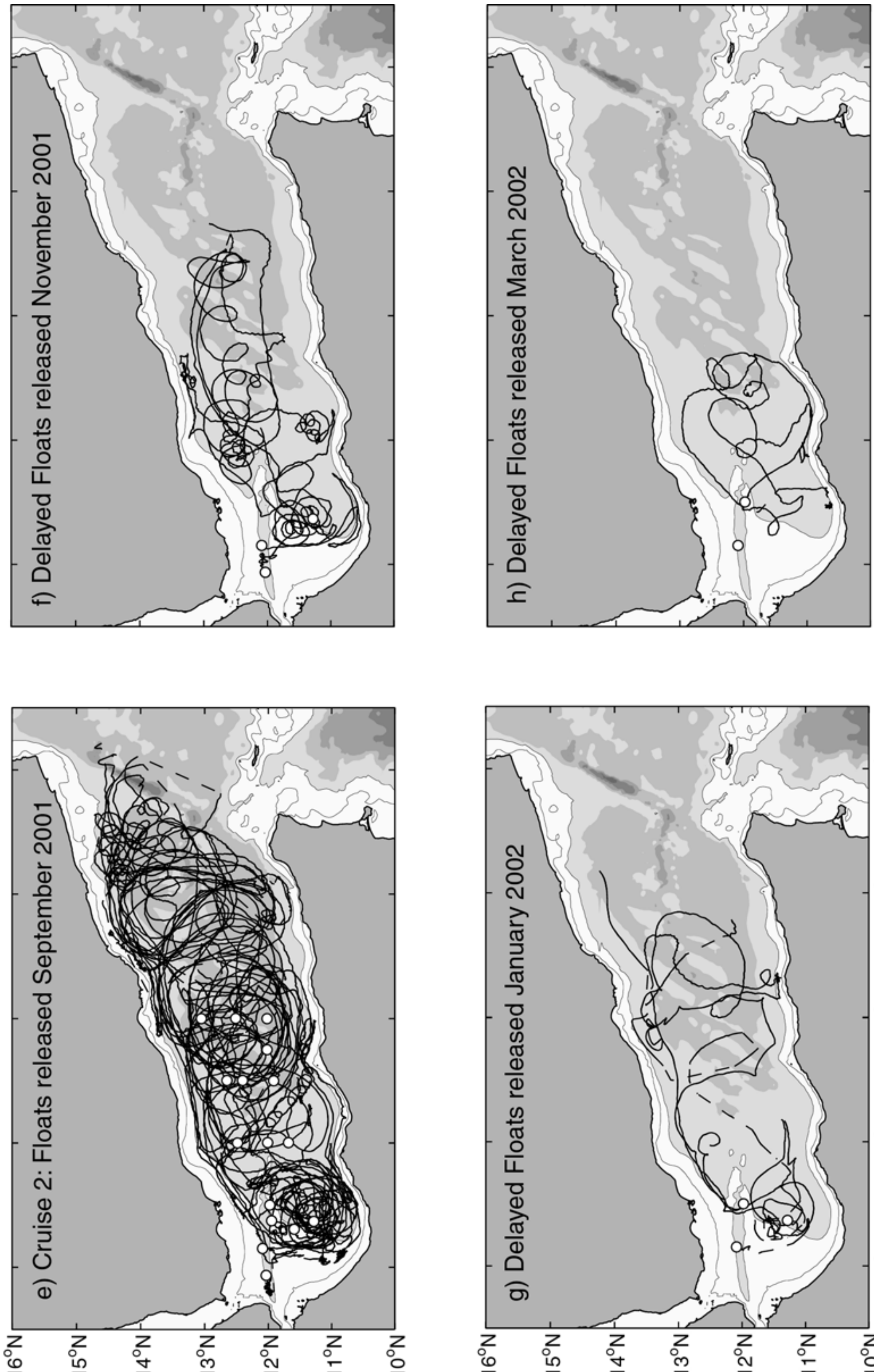


Figure A2, continued.

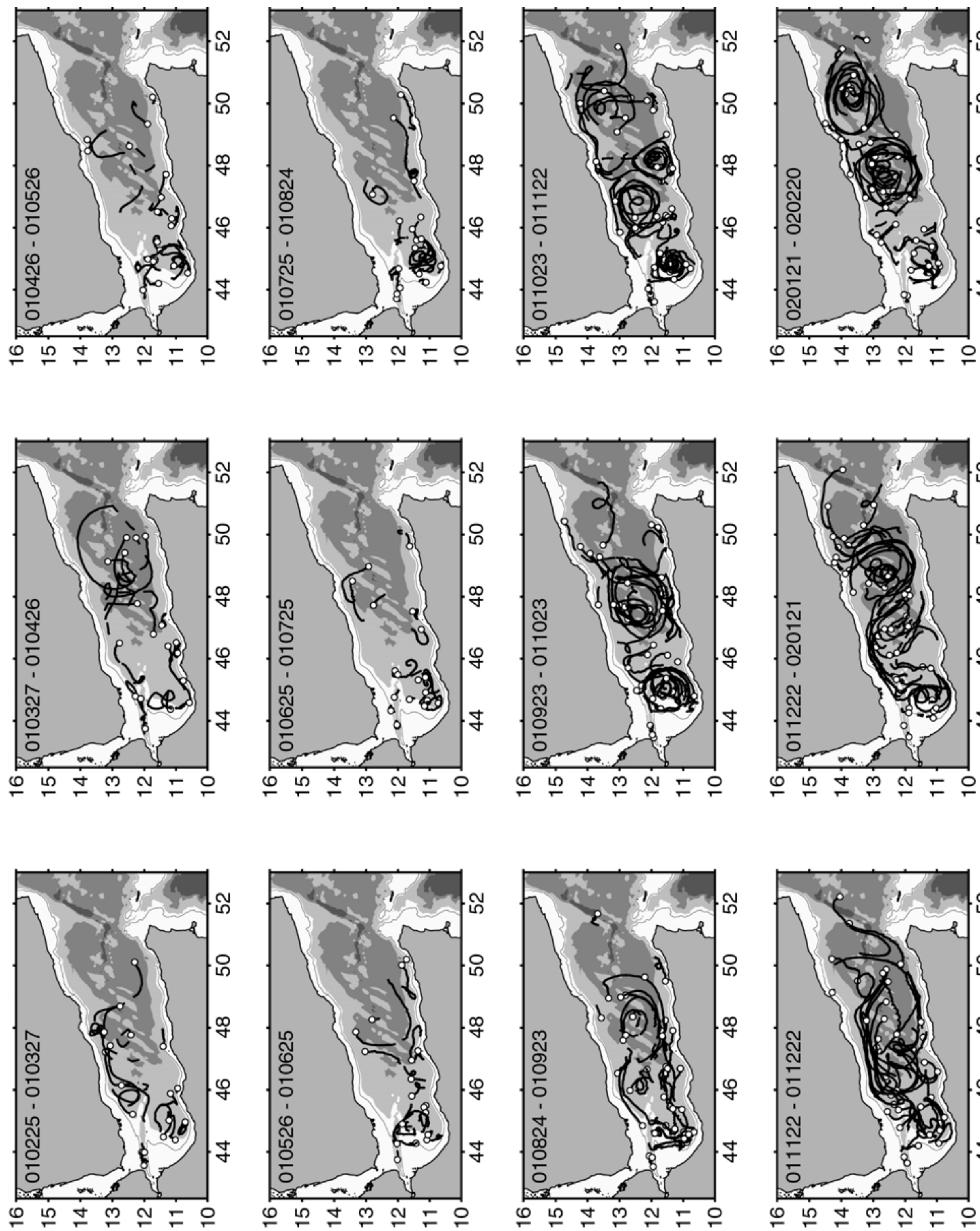


Figure A3. Float trajectories plotted in 30-day segments (120 points). Endpoints of each 30-day segment are marked with black-outlined white dots. Bathymetry is rendered as in Figure A1, except only the 600-meter isobath is drawn. Untrackable segments are drawn with a dashed line, trackable segments with a solid line. The ‘movie stills’ are all presented within the same latitude/longitude limits.

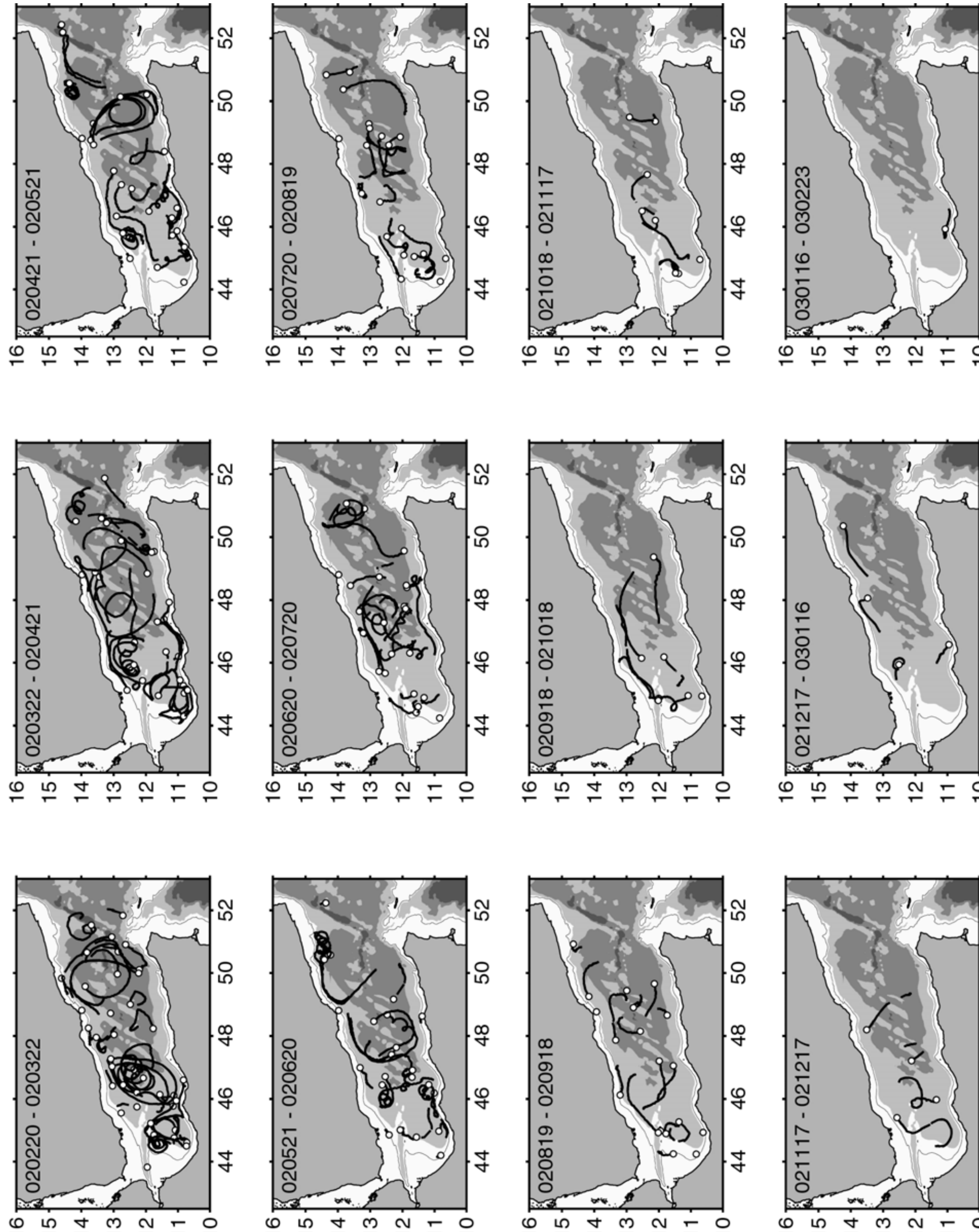


Figure A3, continued.

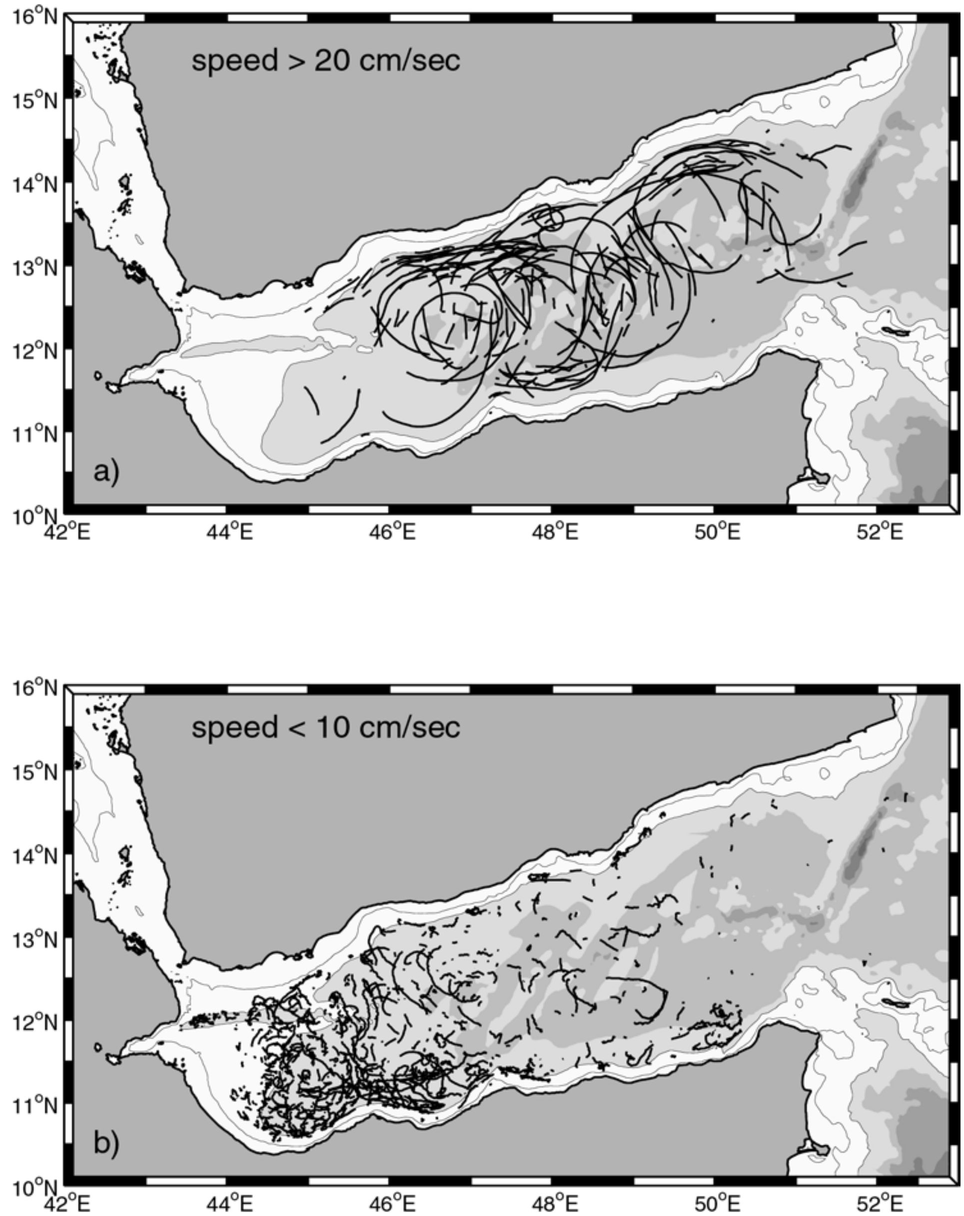


Figure A4. Float track segments with speeds (a) greater than 20 cm/sec, and (b) slower than 10 cm/sec. Tracks segments have been limited to having speeds above 20 cm/sec or below 10 cm/sec for more than two days (or >7 points at a 6-hourly sample rate). Bathymetry as in Figure A1.

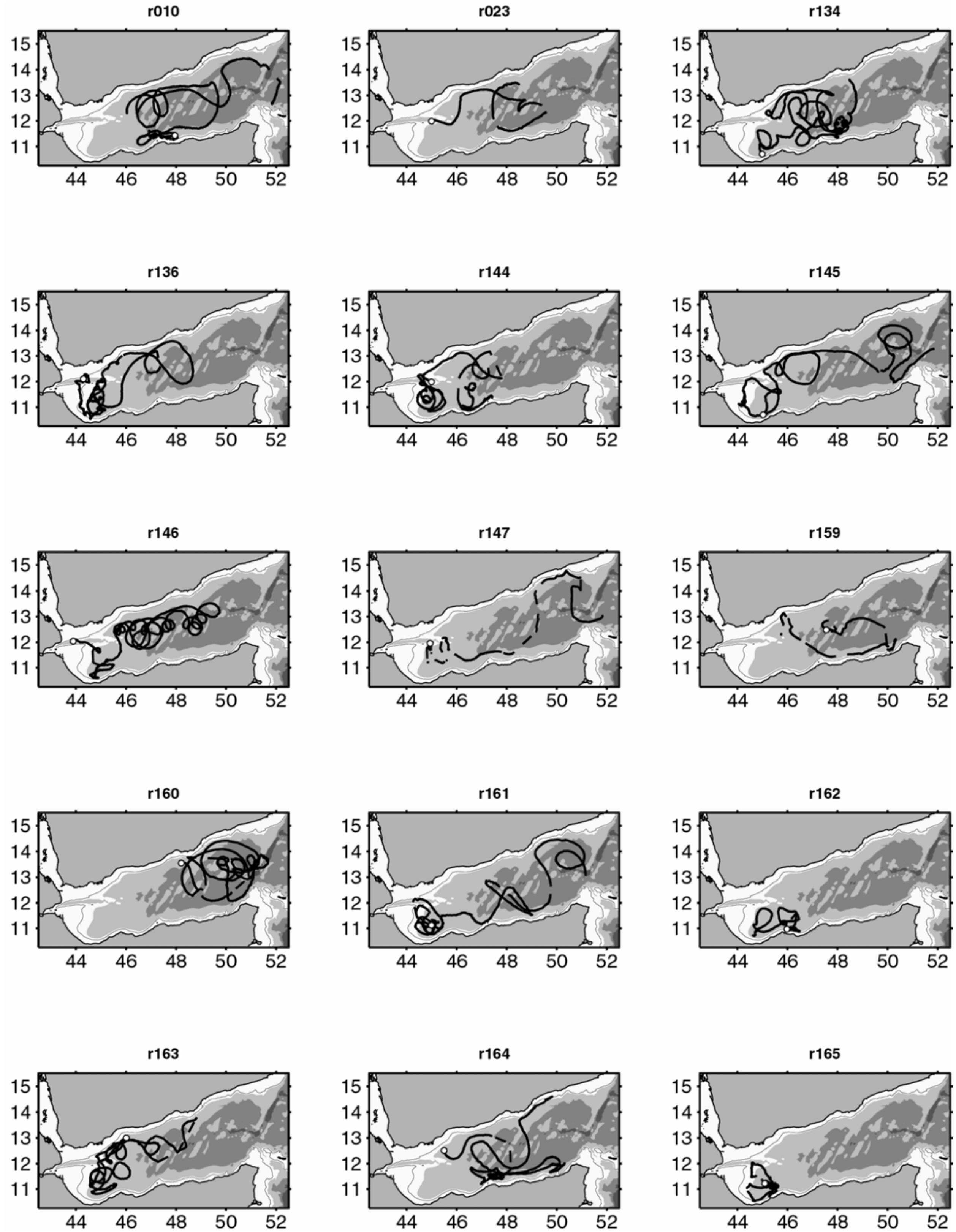


Figure A5. DLD2 float track gallery. Each tracked float is presented with bathymetry as in Figure A1, except only the 600-meter isobath is drawn. The launch position of each float is marked with a black-outlined white dot. Untrackable segments are drawn with a dashed line, trackable segments with a solid line. The float tracks are all presented within the same latitude/longitude limits.

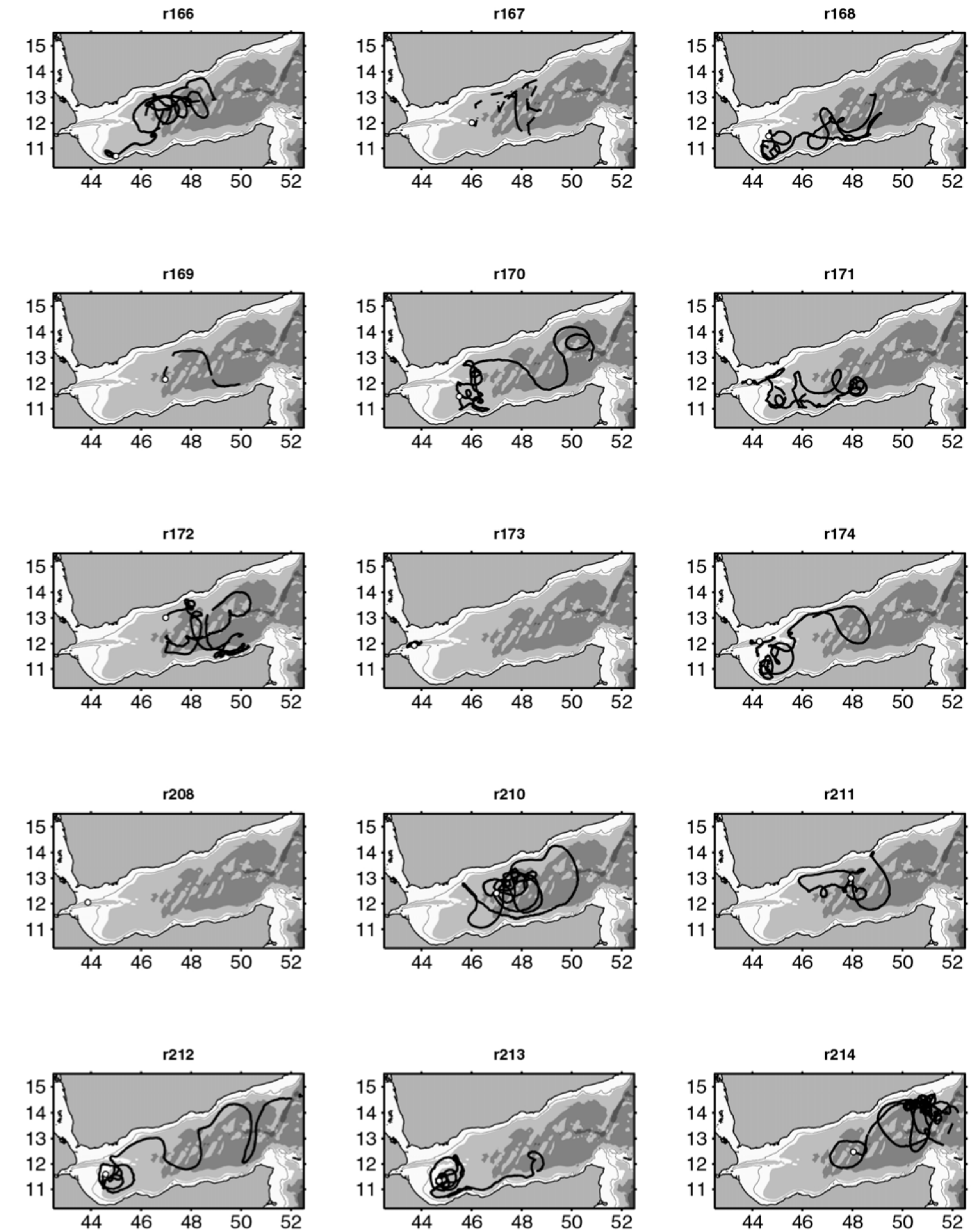


Figure A5, continued.

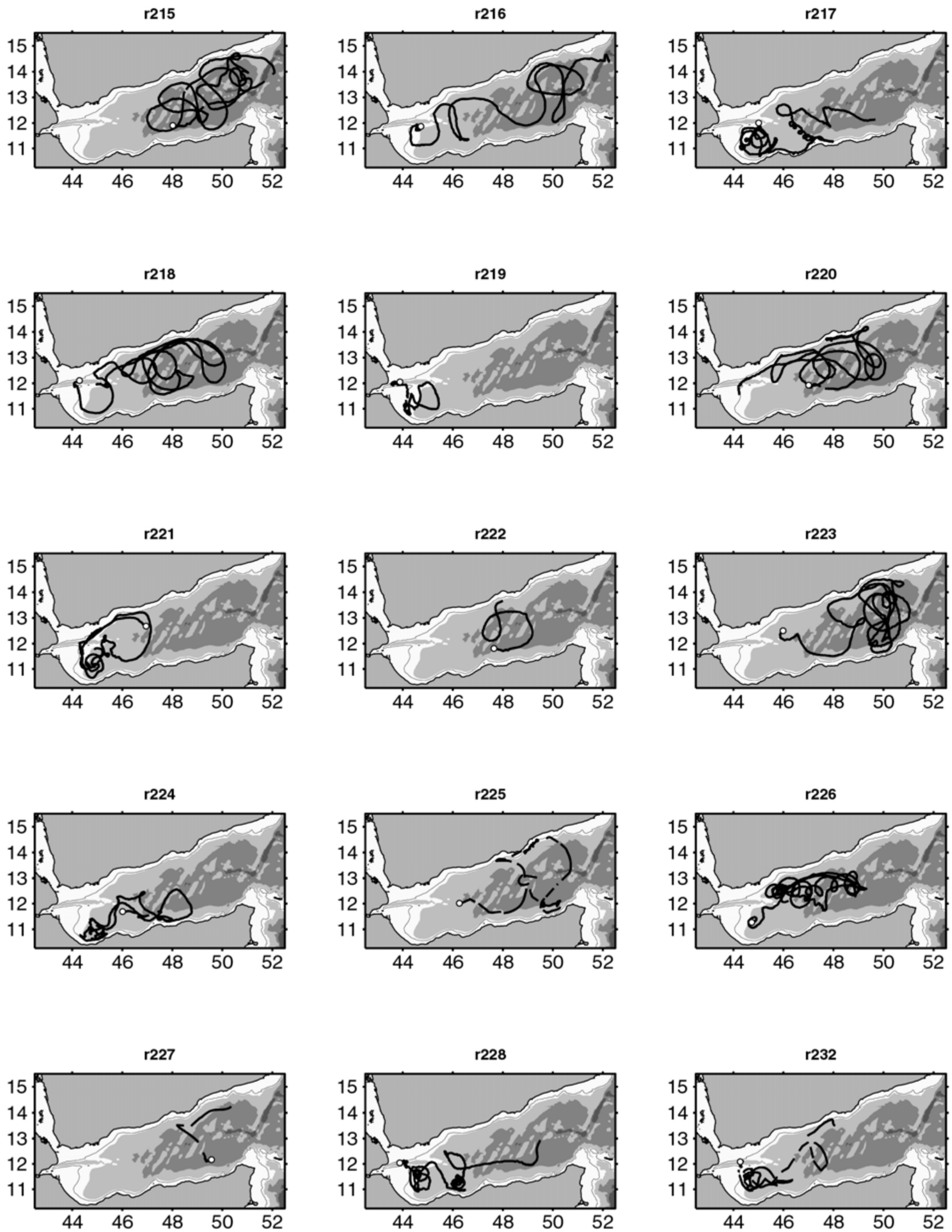


Figure A5, continued.

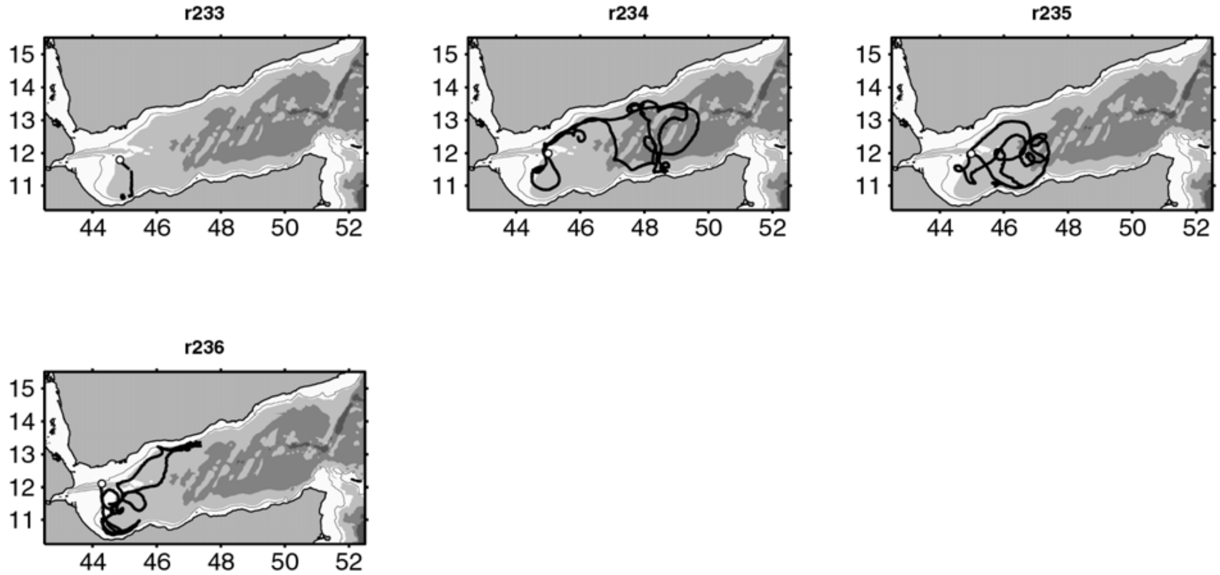


Figure A5, continued.

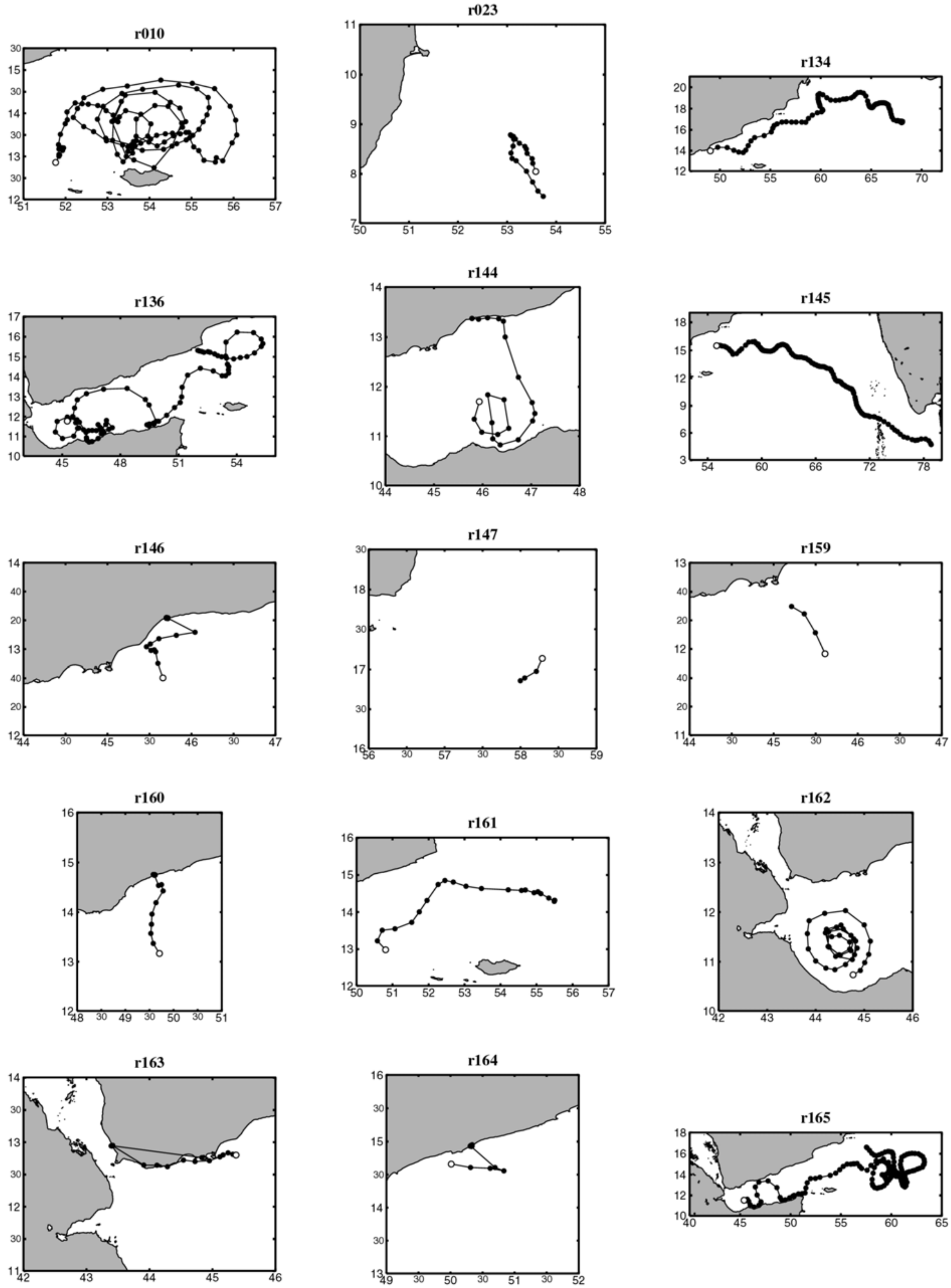


Figure A6. Surface track gallery. Surface tracks for each float are sampled daily. White dot indicates first ARGOS fix position, black dots are daily positions thereafter until float stops transmitting. Land is shaded gray; no bathymetry is shown. Many floats were picked up by vessels and taken ashore (e.g. r146), but overall, this did not affect data return as floats continued to transmit on shore.

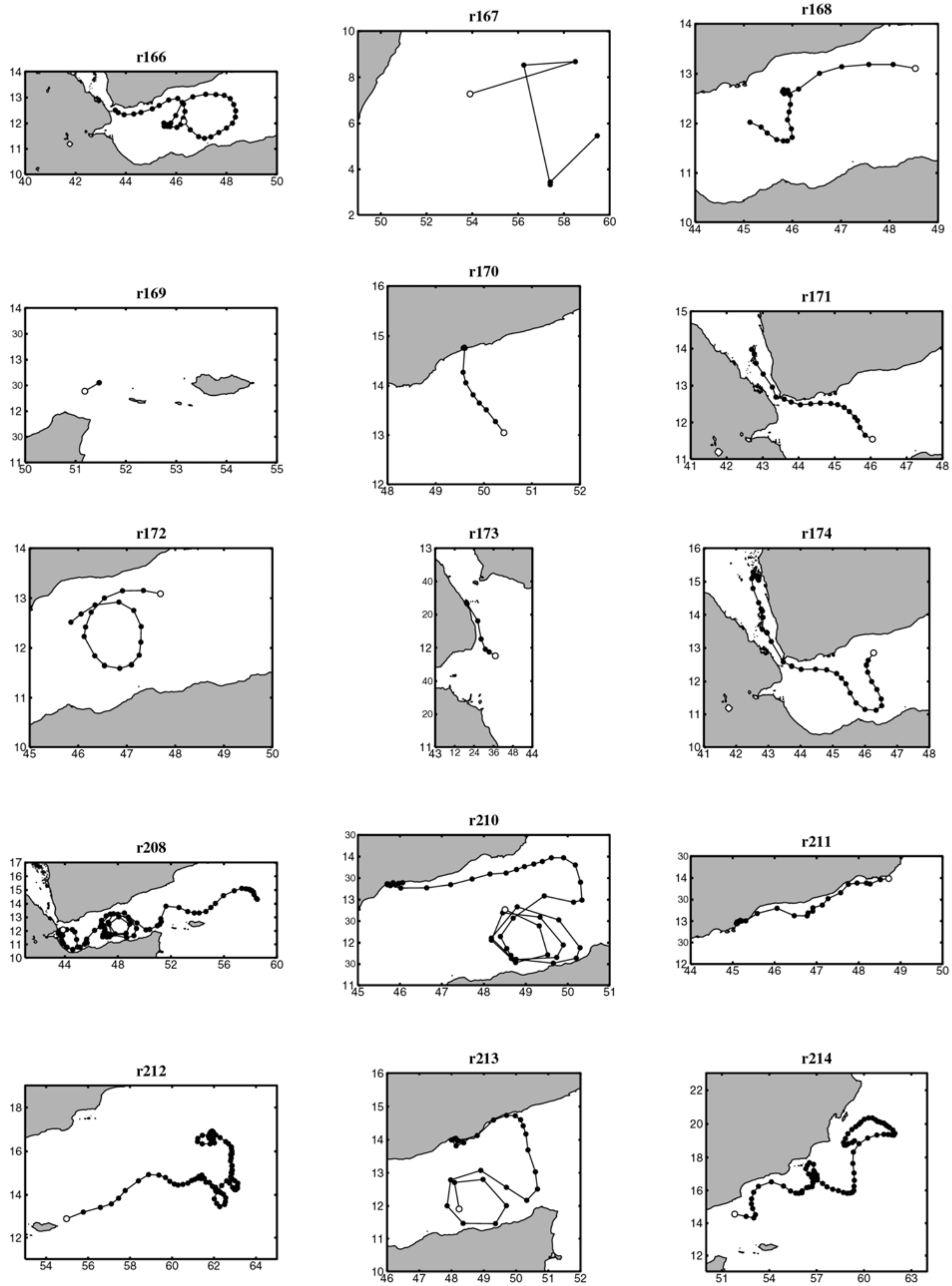


Figure A6, continued.

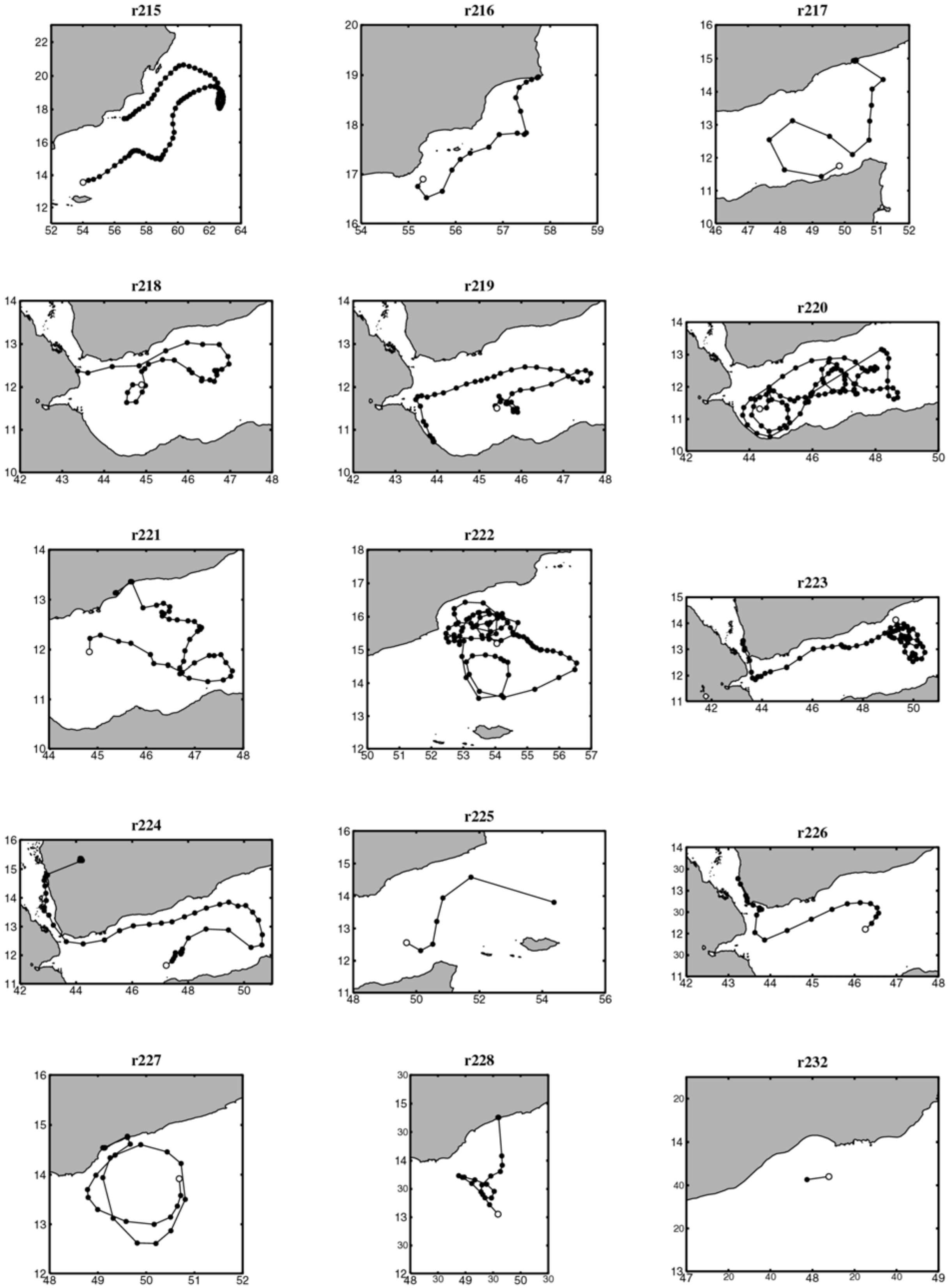


Figure A6, continued.

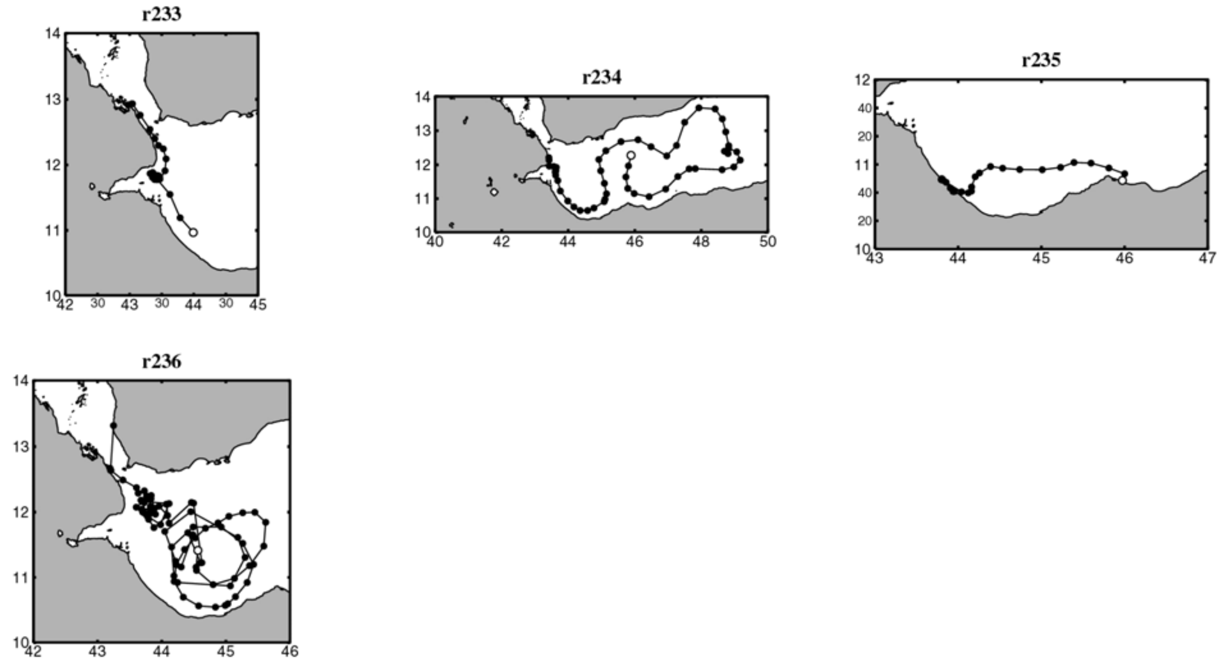


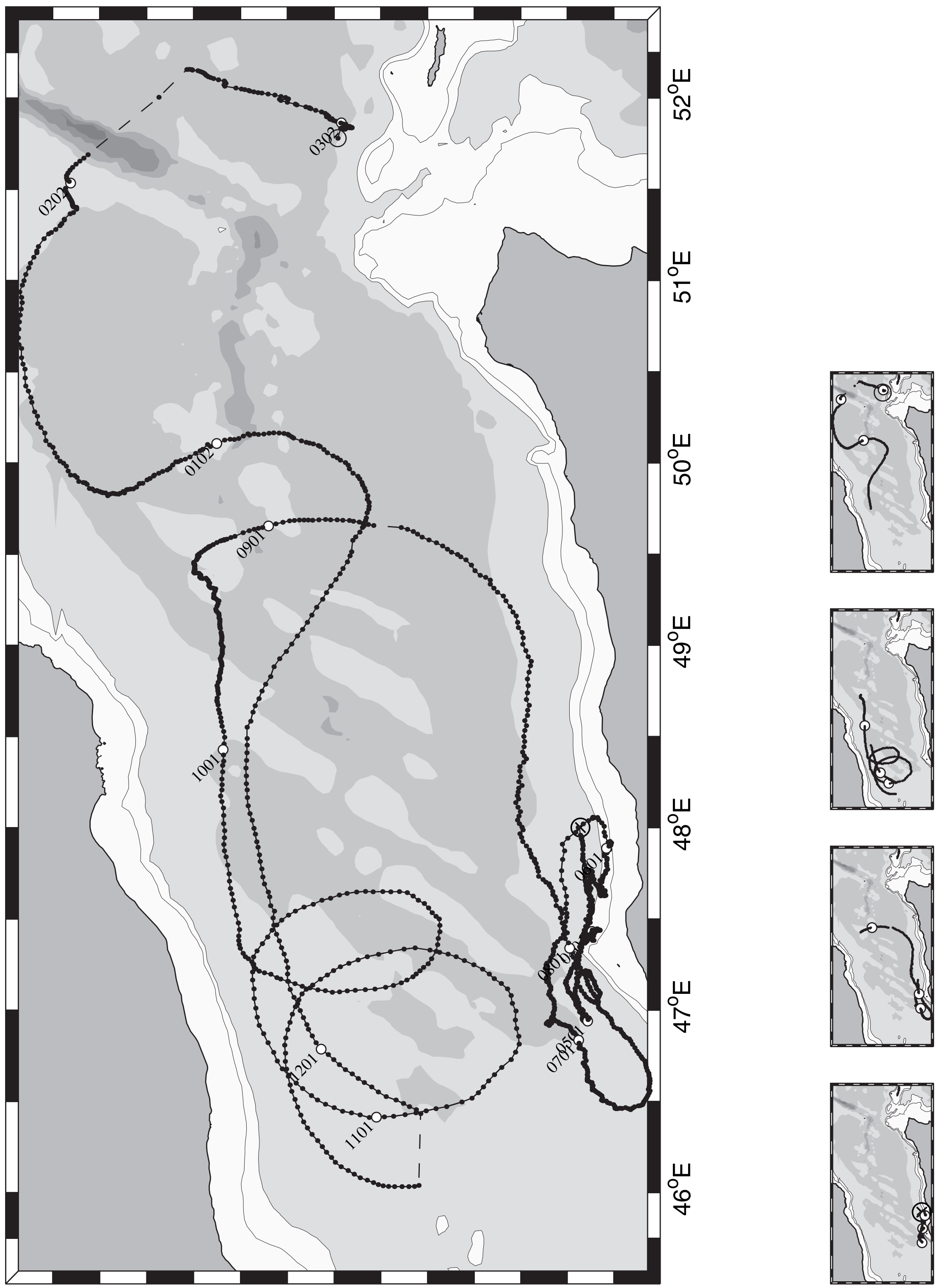
Figure A6, continued.

Appendix B

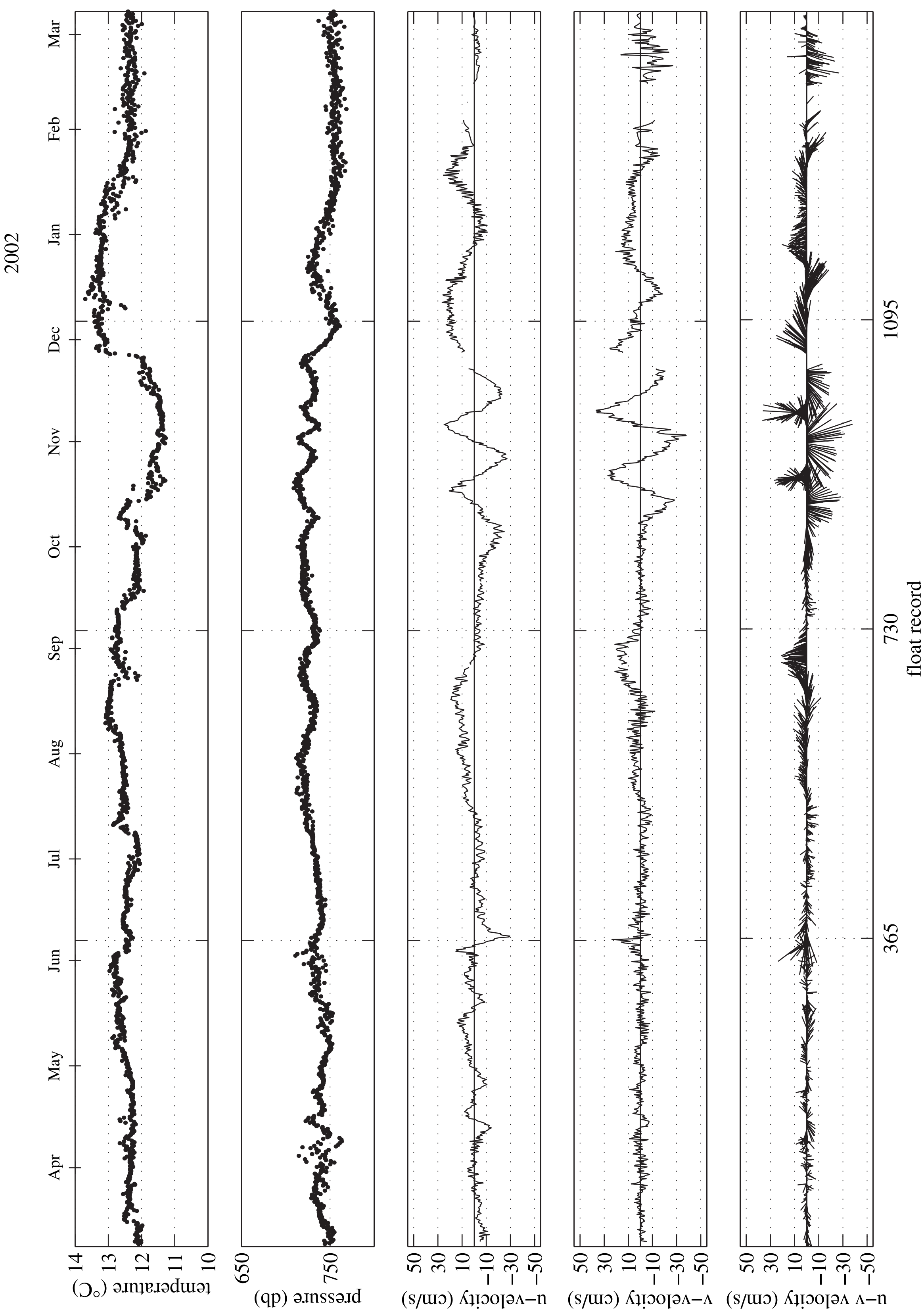
Individual float trajectories and property plots. For each float, the track is shown in one figure and property plots in a companion figure. Track plot bathymetry is shaded in 1000-meter intervals, and the 600- and 1000-meter isobath is also drawn. Daily positions are marked with dots, and monthly positions are marked as open white dots, with 'mmyy', marking the first of each month, adjacent to the white markers. Untrackable segments are drawn with a dashed line. Launch position is marked with a circle-x; surface with a circle-dot. Four small frames are included, dividing the tracks into 3-month segments. Floats r165 and r169 were set to 90-day mission lengths, and have no small track frames.

Property plots contain panels depicting temperature, pressure, u-velocity, v-velocity, and stick plots representing velocity magnitude and direction. The lower x-axis marks the float record number, which is four times per day, and is as long as the intended mission length of the float (in most cases, 365 days).

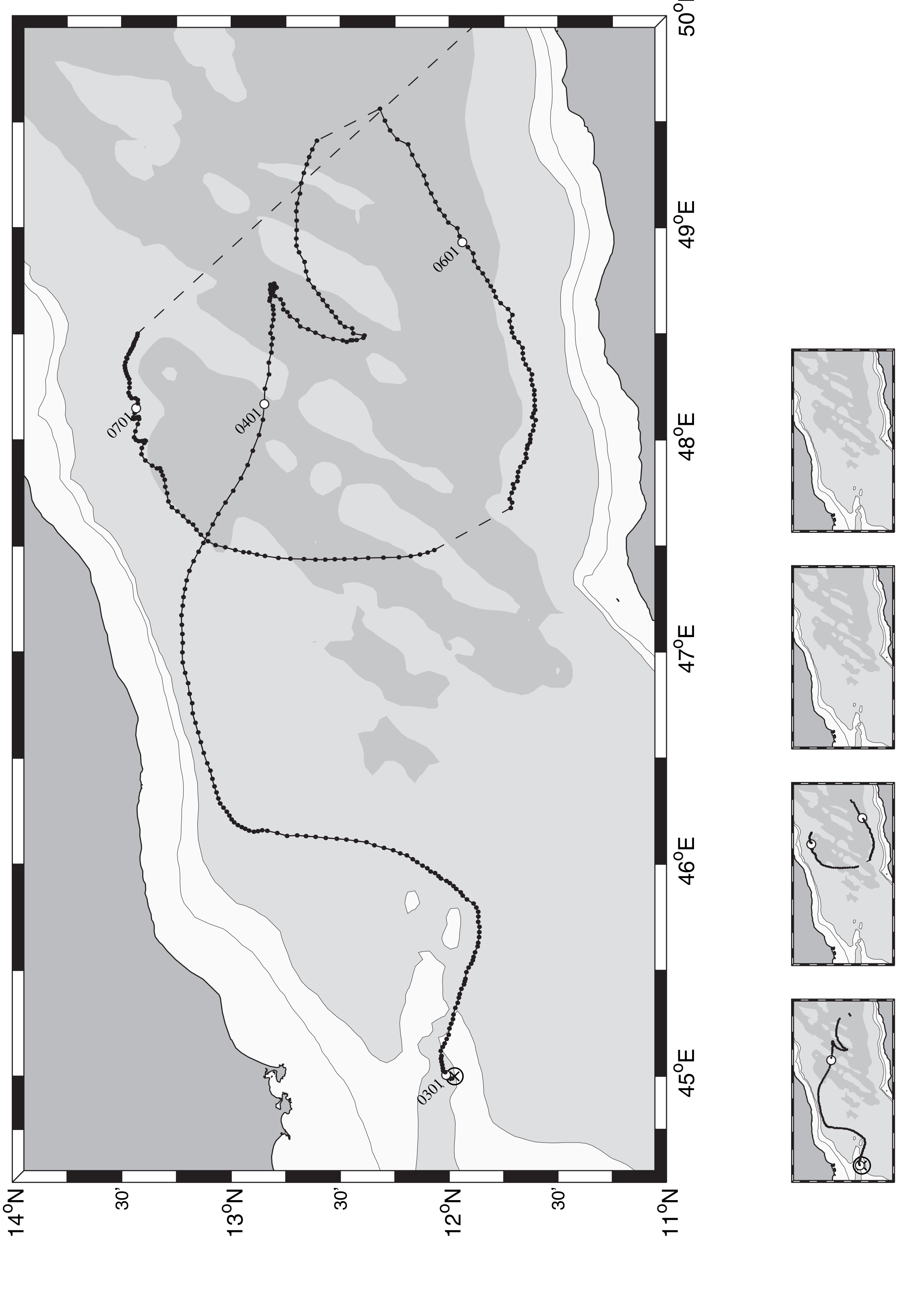
r010: 94% msg return



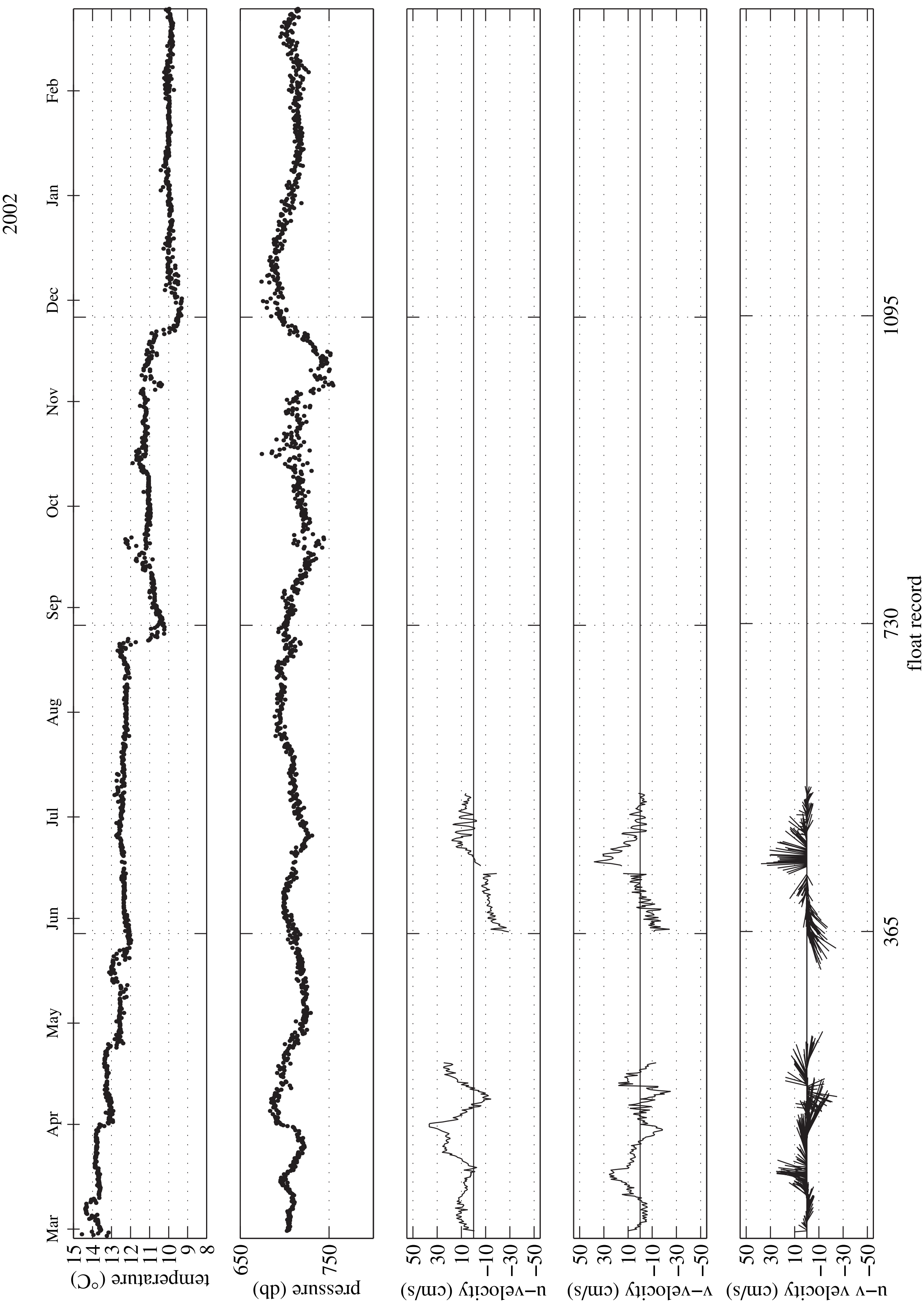
r010


2002
Mar
Feb
Jan
Dec
Nov
Oct
Sep
Aug
Jul
Jun
May
Apr
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
365
730
1095
float record

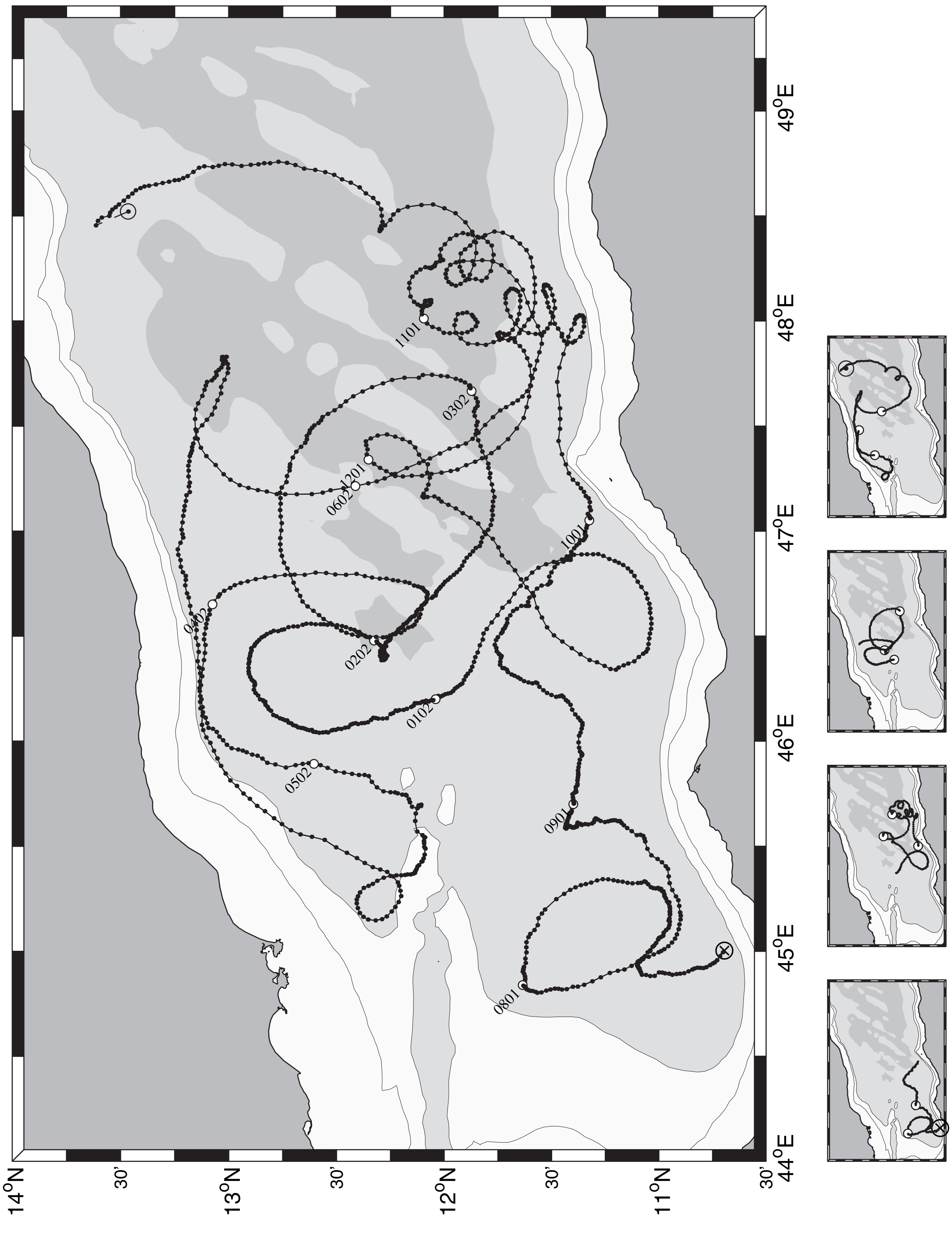
r023: 83% msg return

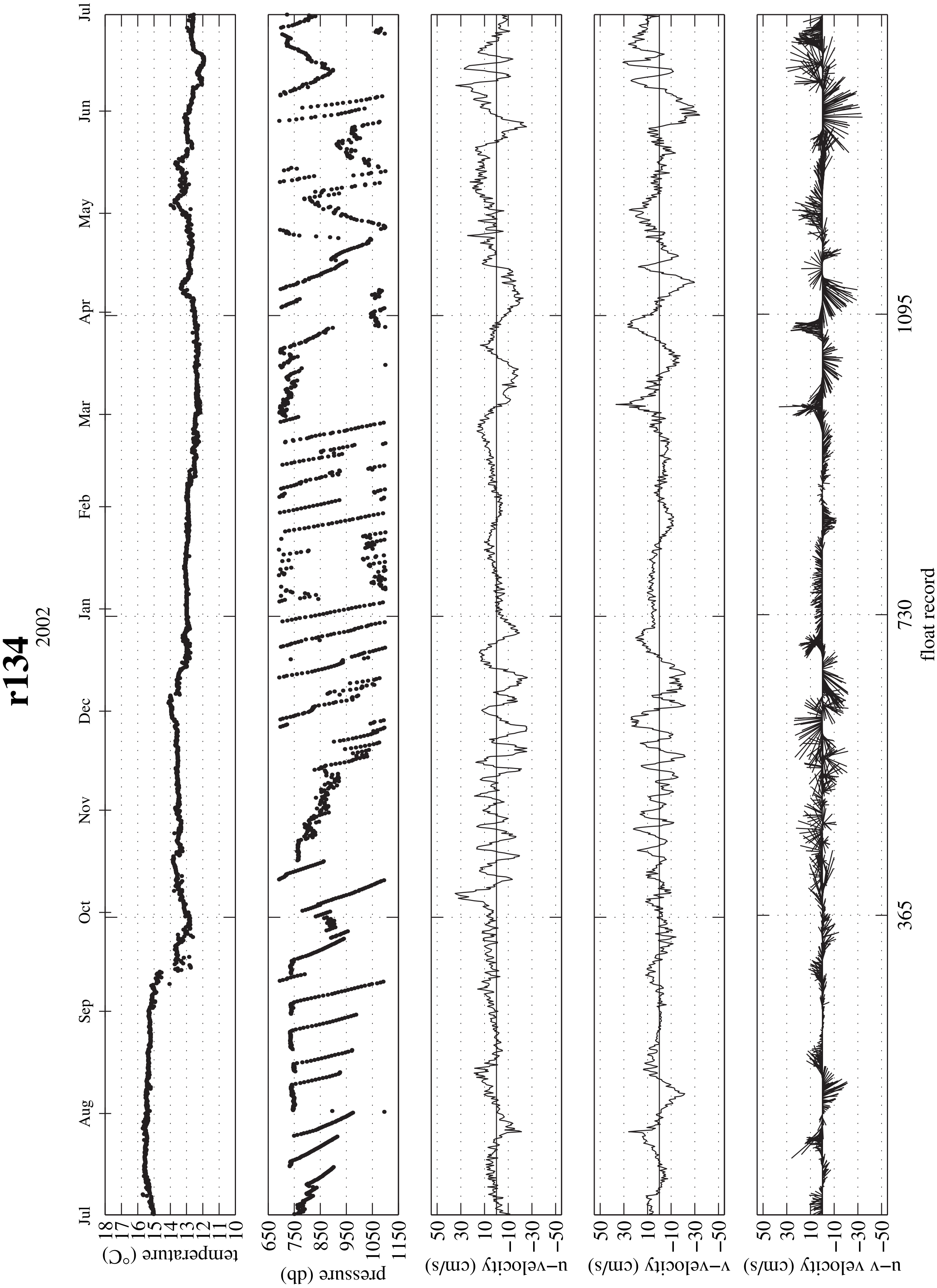


r023


2002
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
temperature (°C)
15 14 13 12 11 10 9 8
pressure (db)
650
750
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
50 30 10 −10 −30 −50
365
730
1095
float record

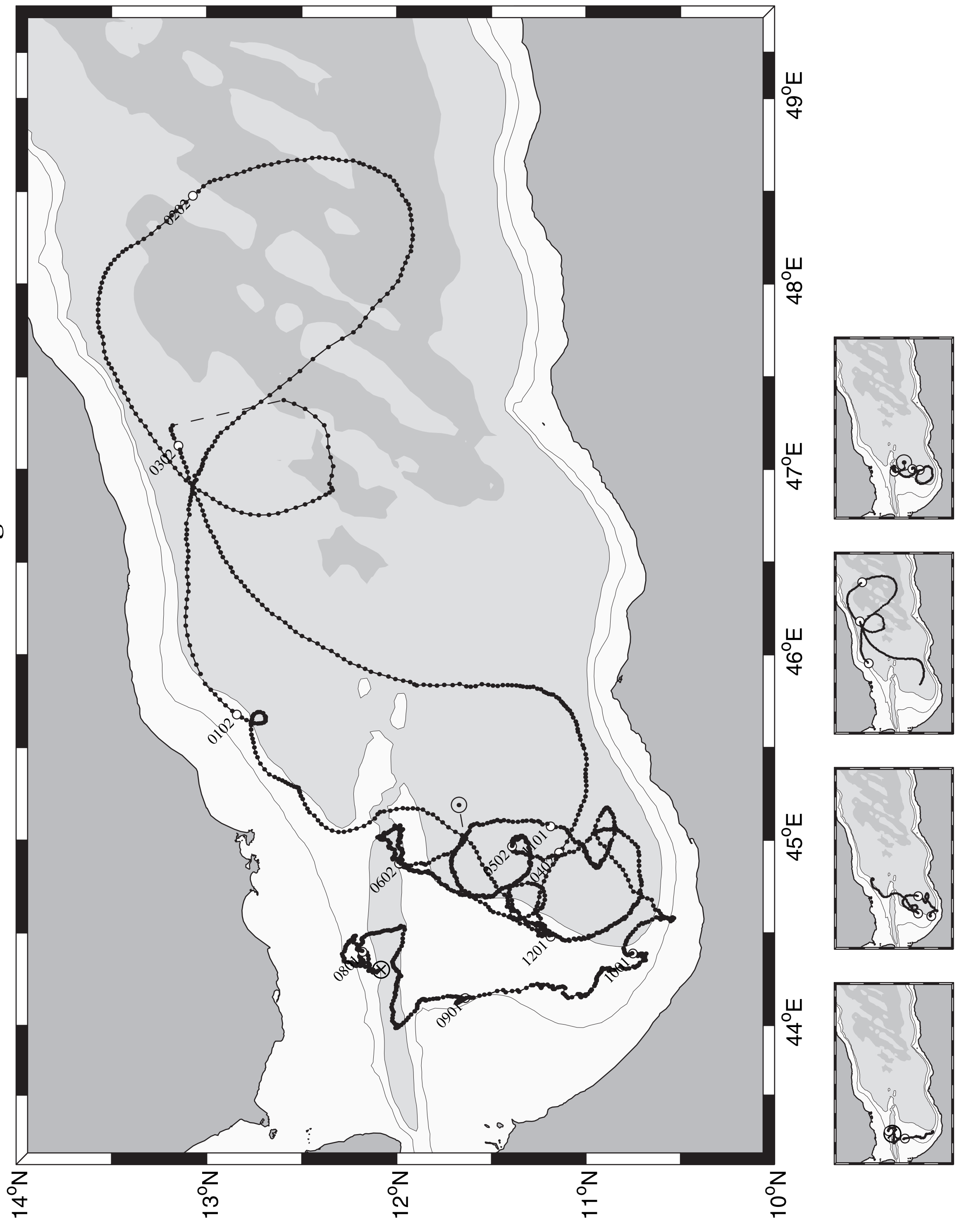
r134: 100% msg return

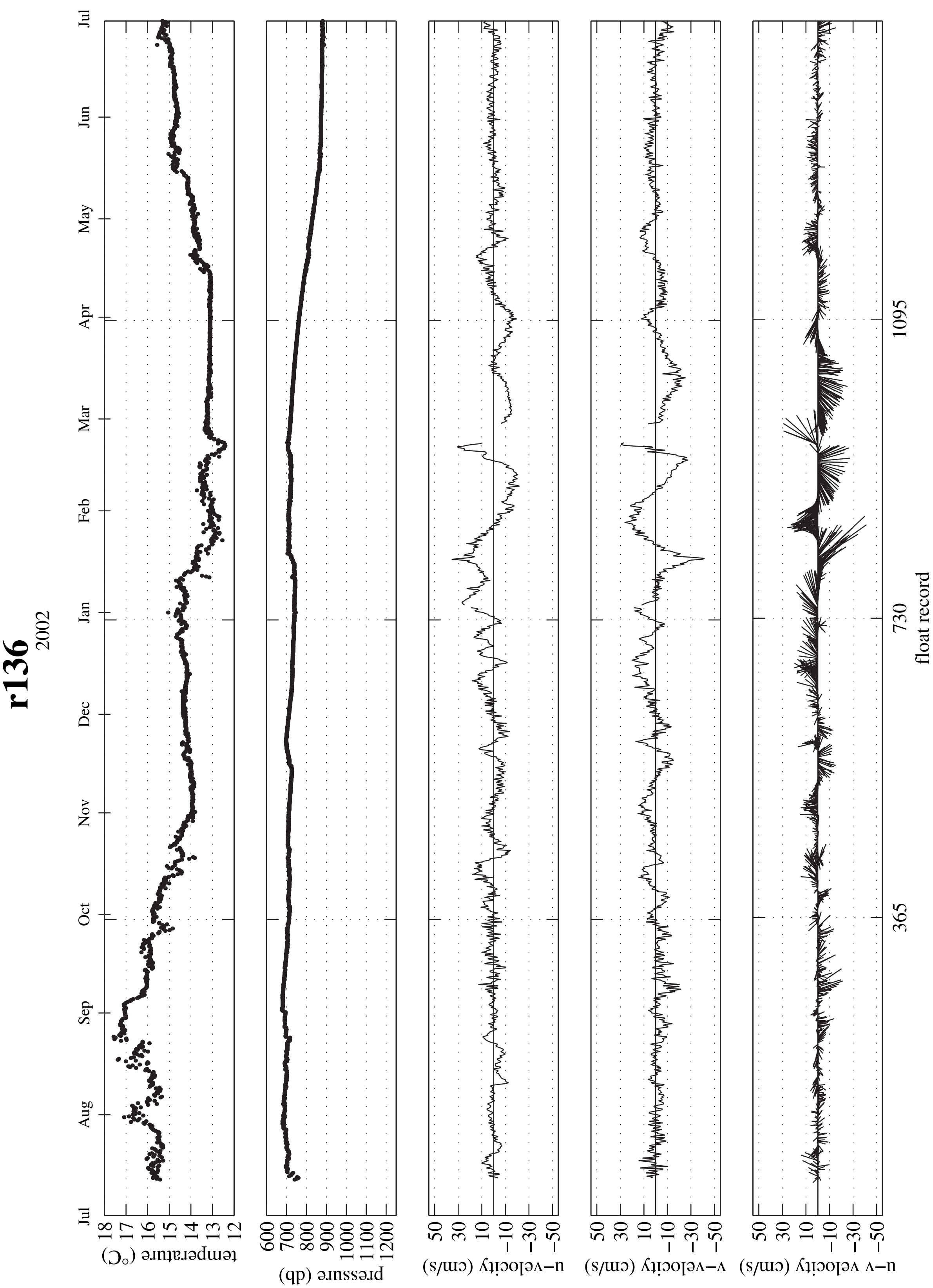




r134
2002
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
temperature (°C)
18 17 16 15 14 13 12 11 10
pressure (db)
650 750 850 950 1050 1150
u−velocity (cm/s)
50 30 10 −10 −30 −50
v−velocity (cm/s)
50 30 10 −10 −30 −50
u− v velocity (cm/s)
50 30 10 −10 −30 −50
365
730
1095
float record

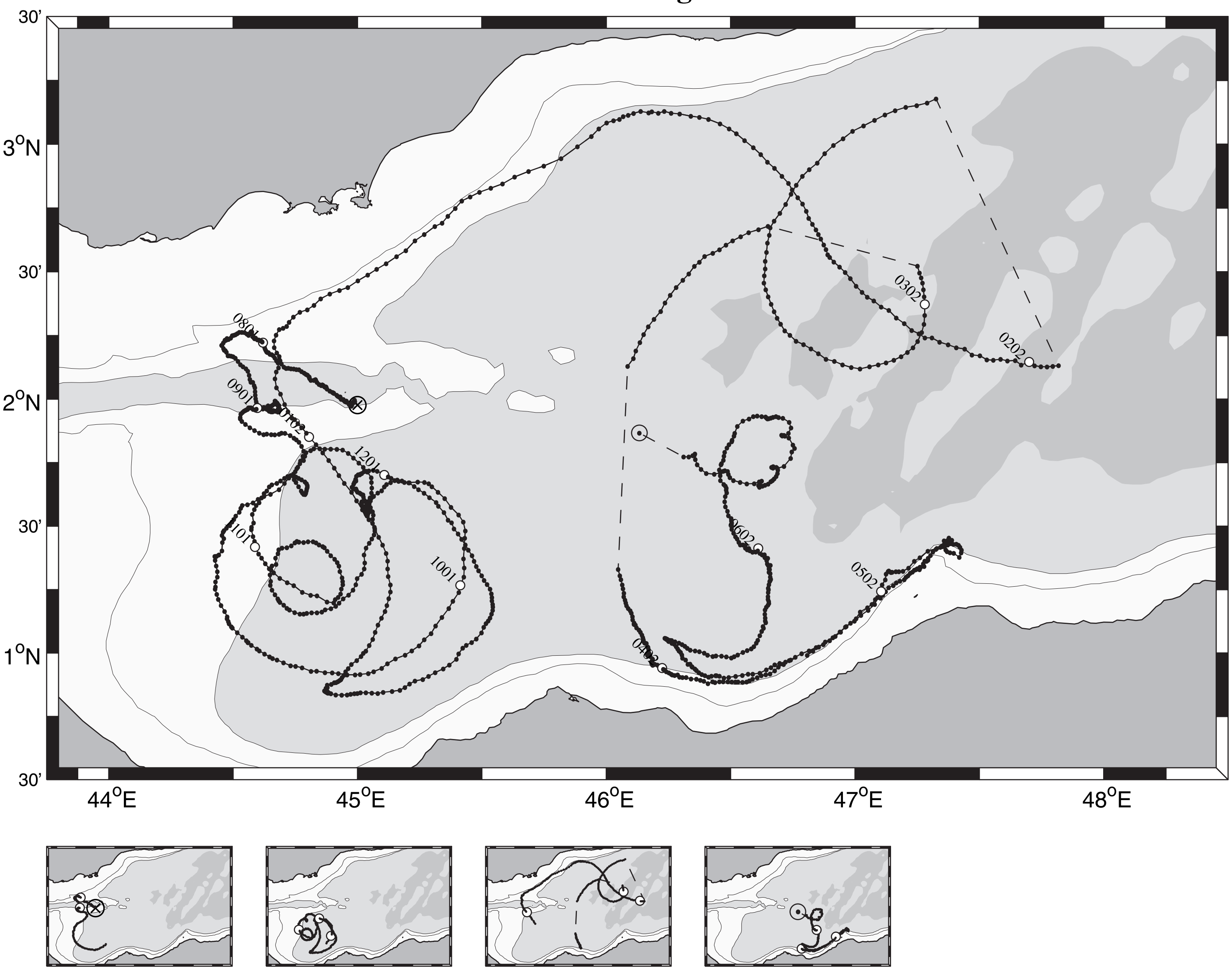
r136: 100% msg return



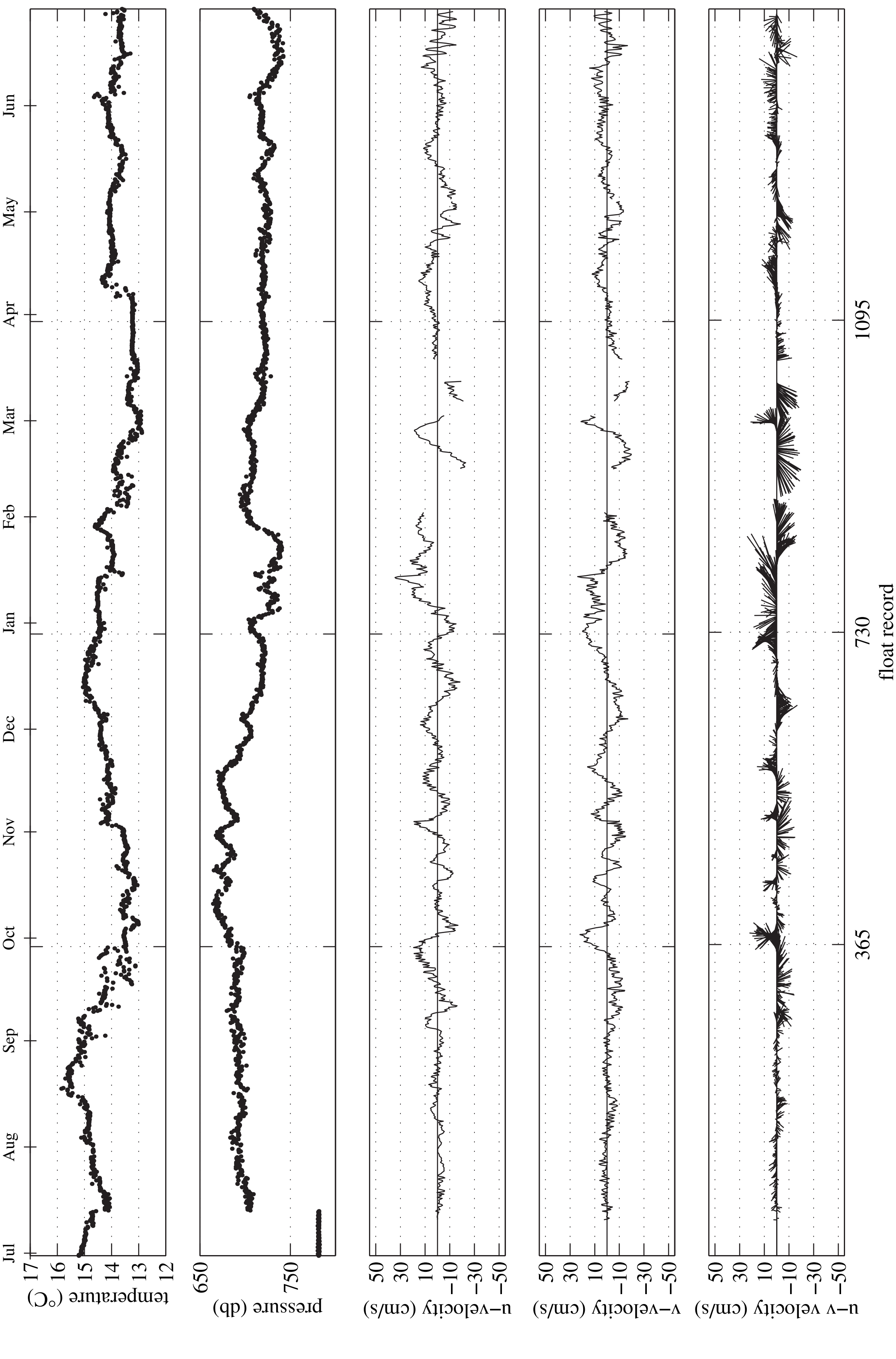


r136
2002
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
365
730
1095
float record

r144: 90% msg return

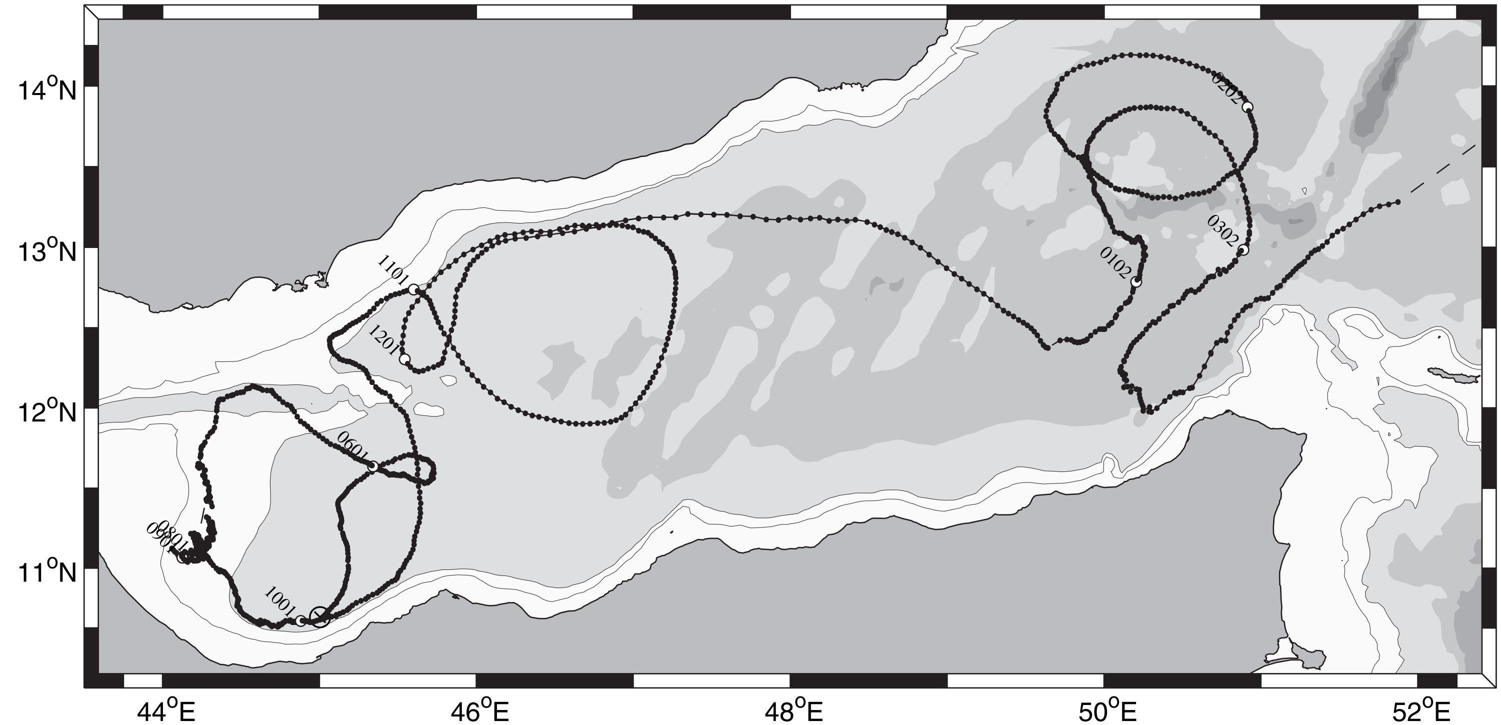


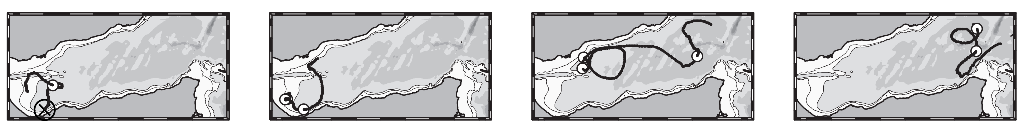
r144
2002

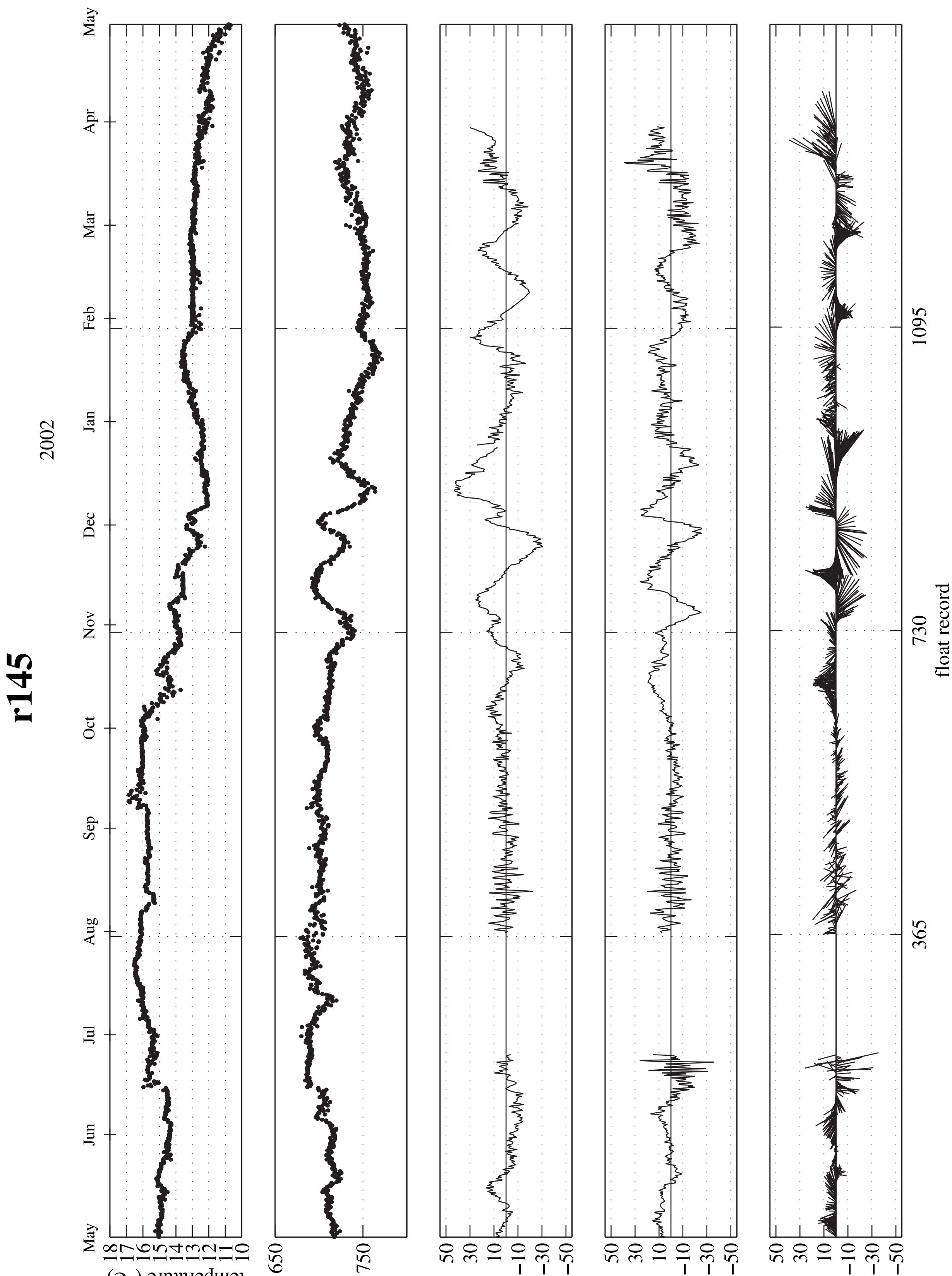


temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
365
730
1095
float record

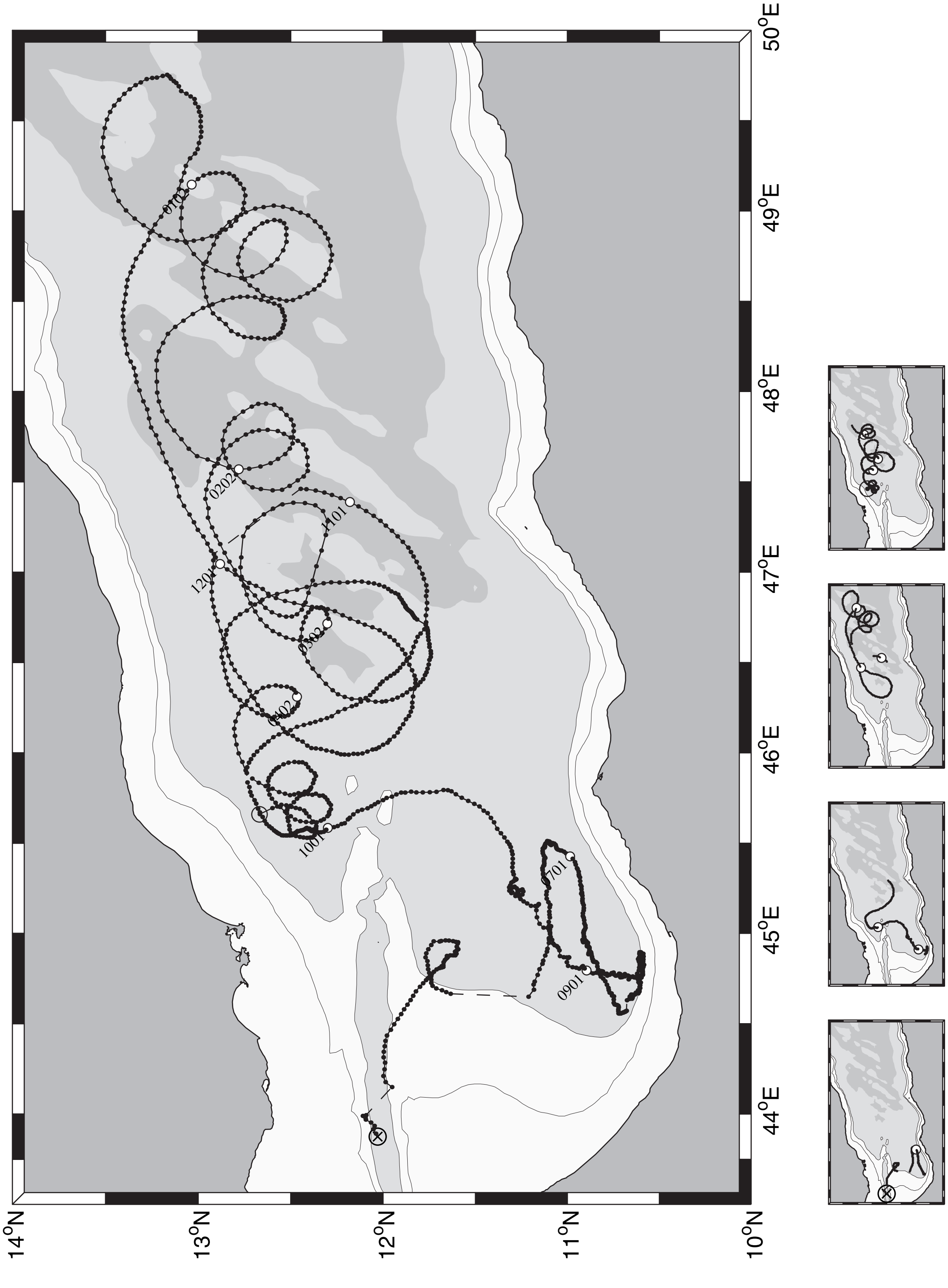
r145: 100% msg return



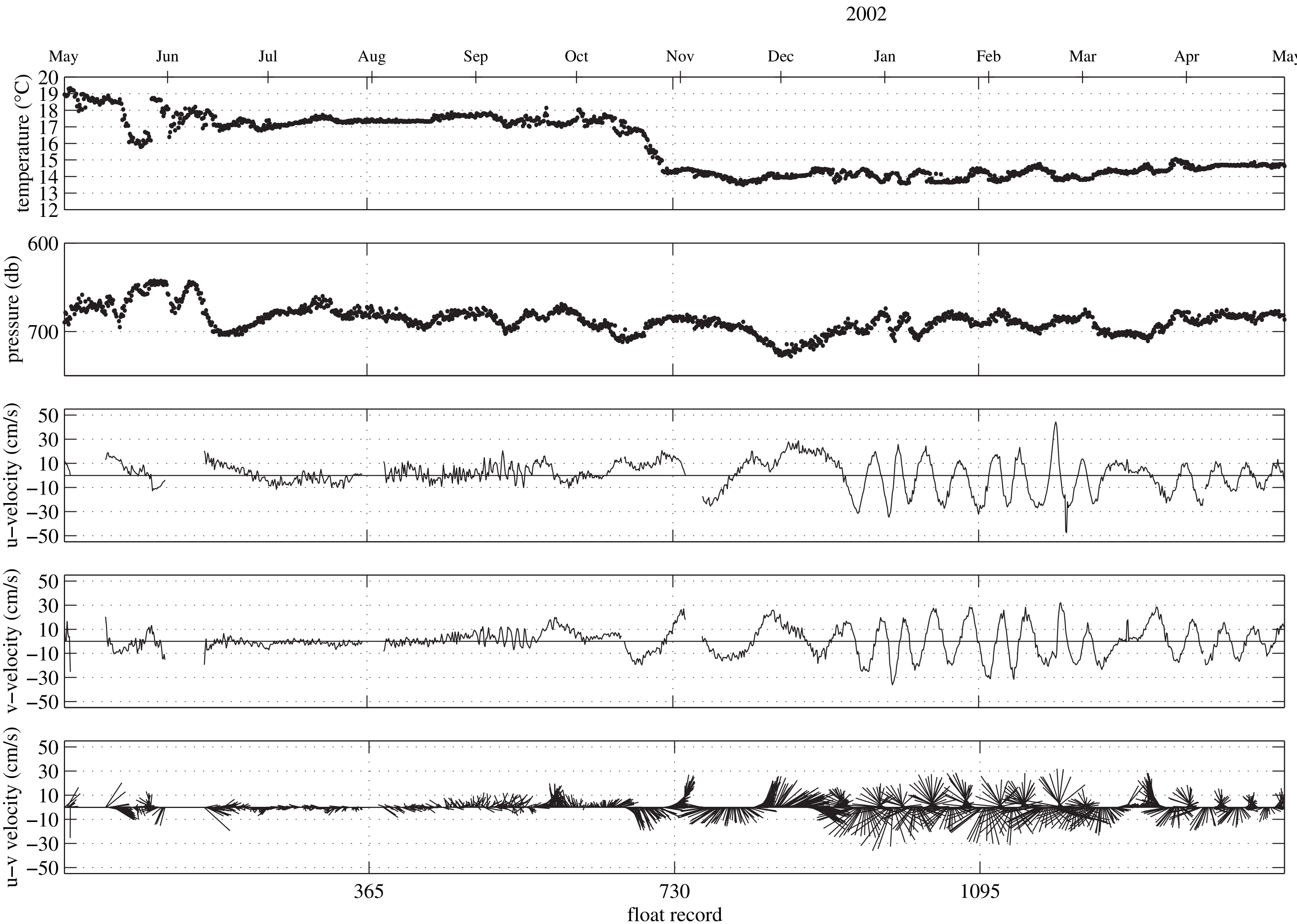



r145
2002
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
365
730
1095
float record

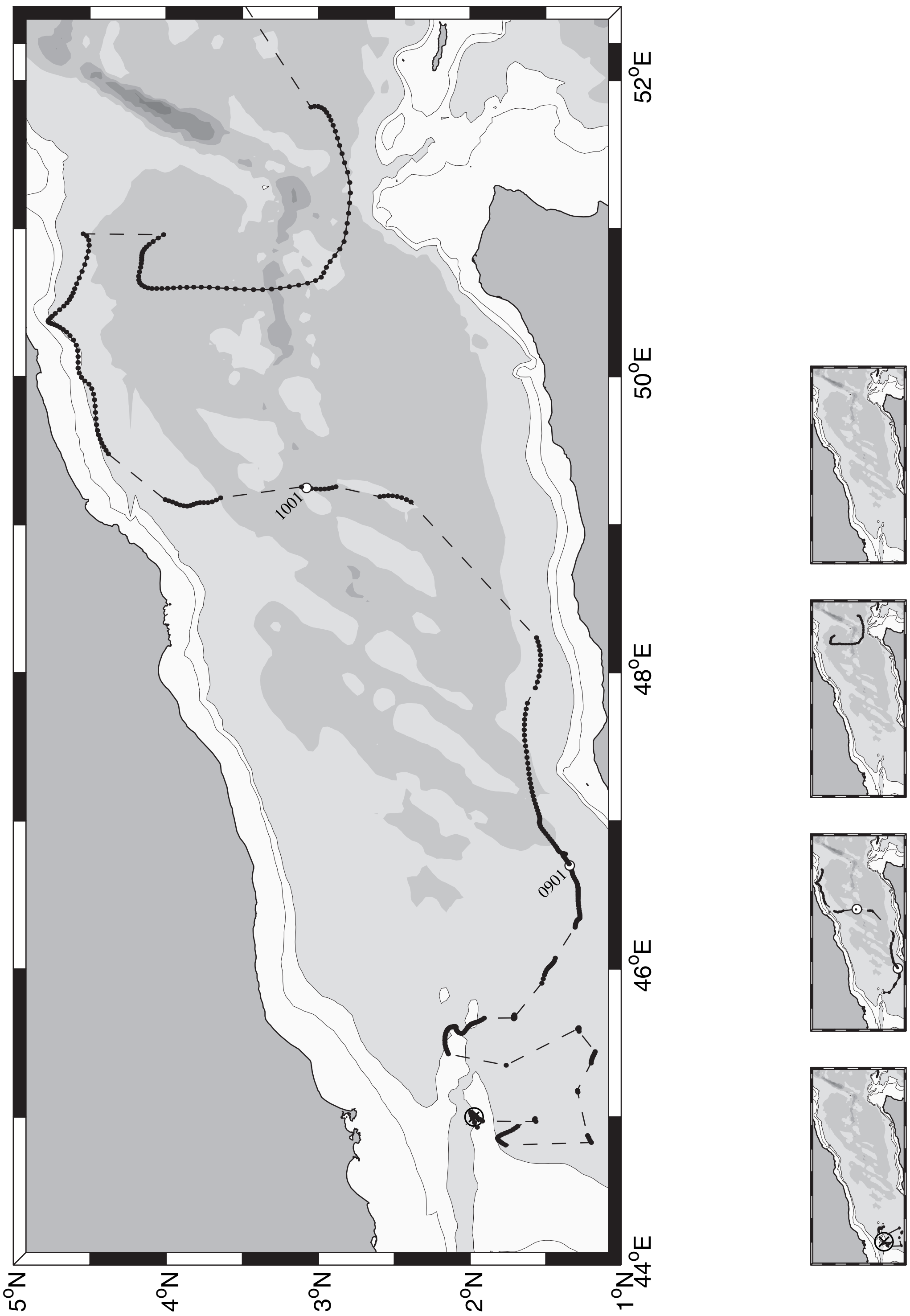
r146: 42% msg return



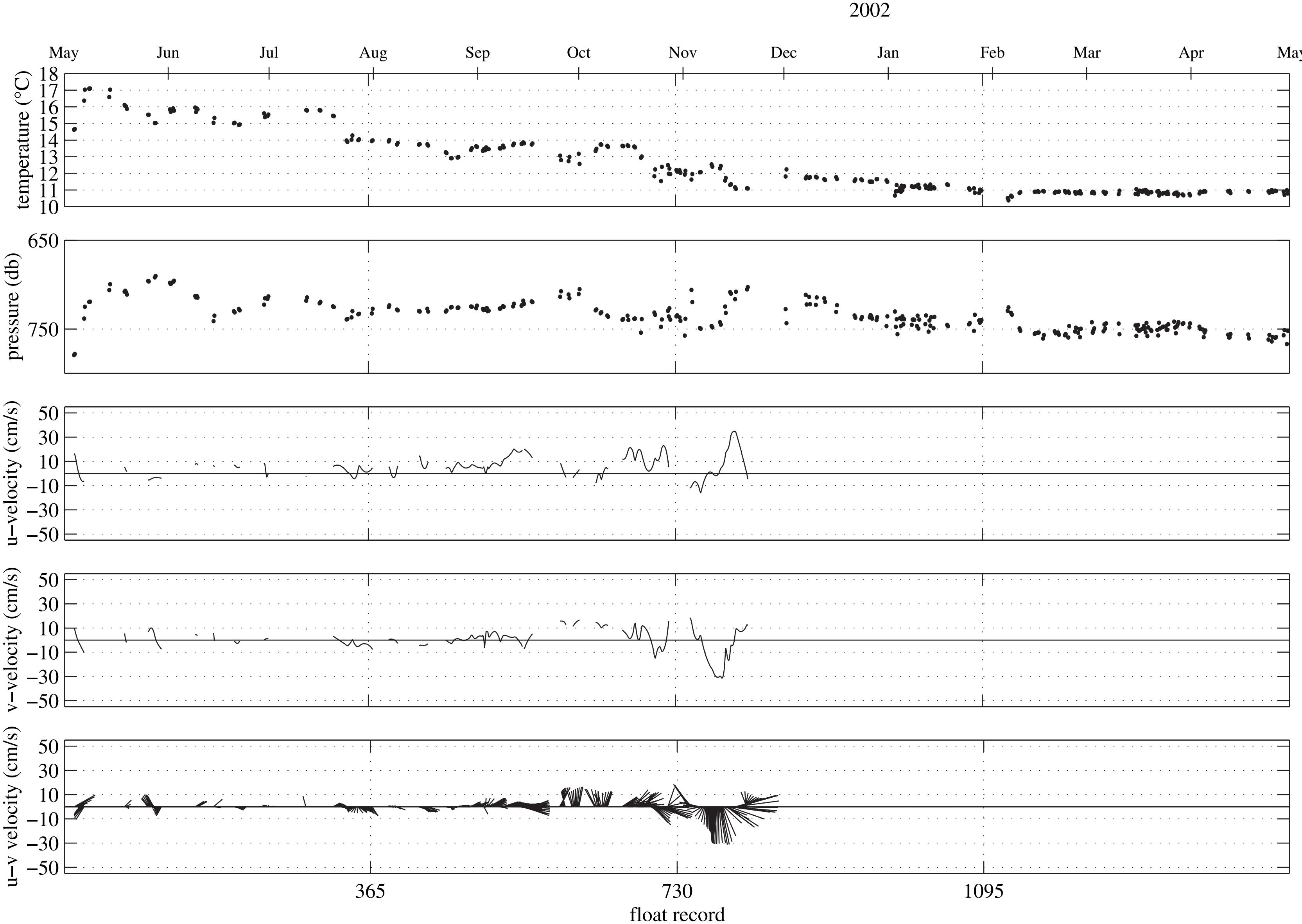
r146


2002
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
temperature (°C)
20
19
18
17
16
15
14
13
12
pressure (db)
600
700
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
50
30
10
−10
−30
−50
365
730
1095
float record

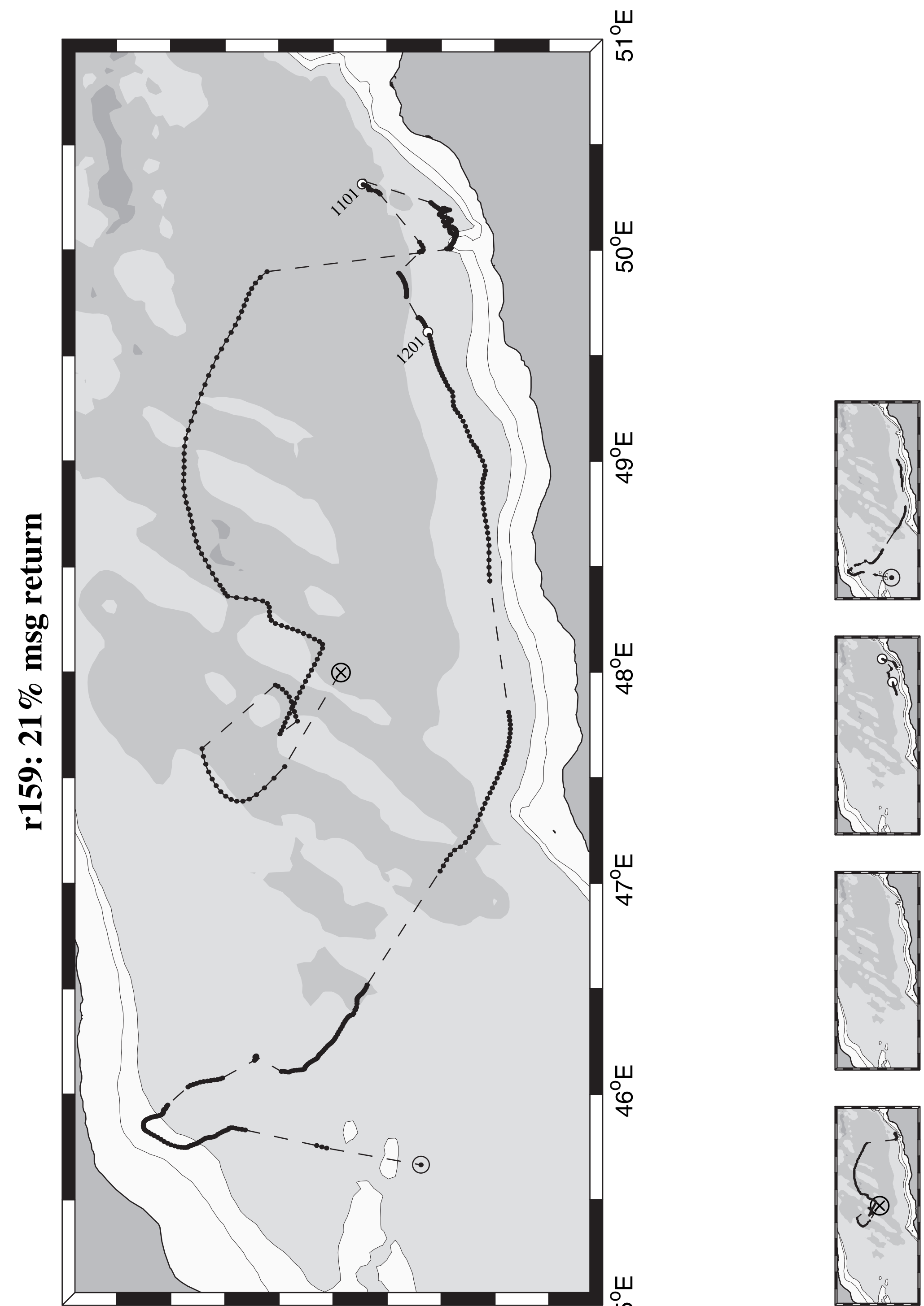
r147: 20% msg return

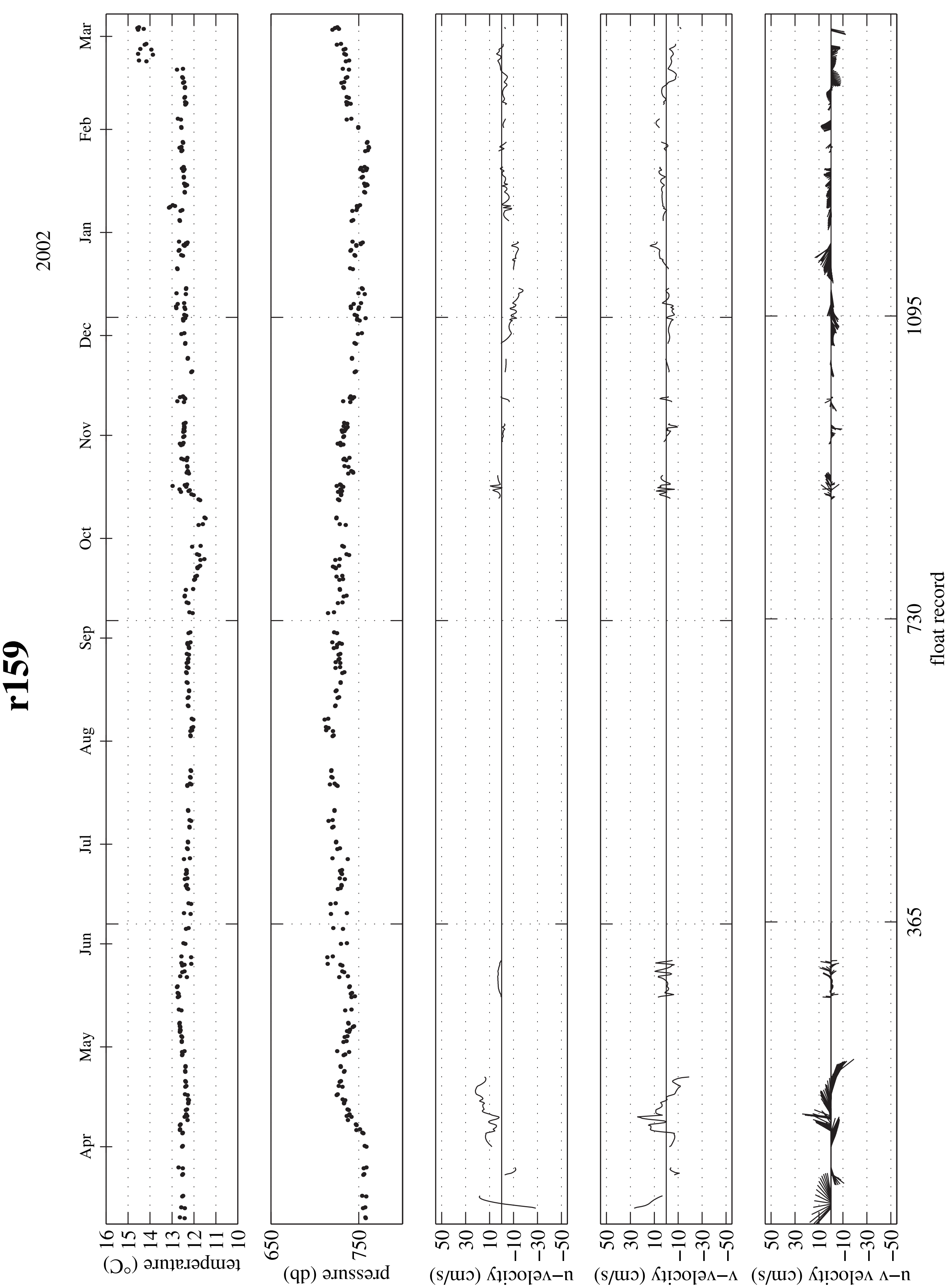


r147

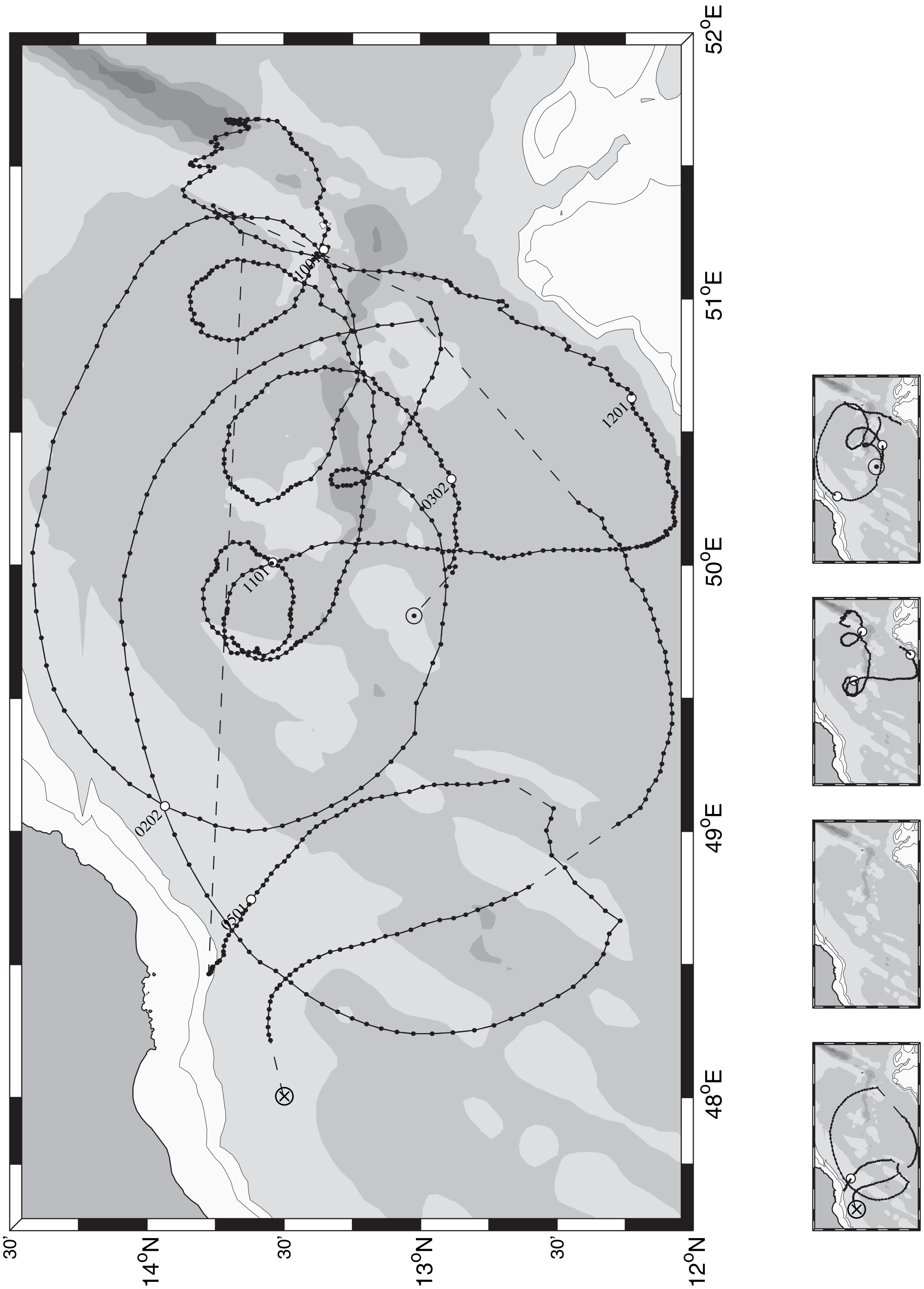


2002
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
temperature (°C)
18
17
16
15
14
13
12
11
10
pressure (db)
650
750
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
50
30
10
−10
−30
−50
365
730
1095
float record

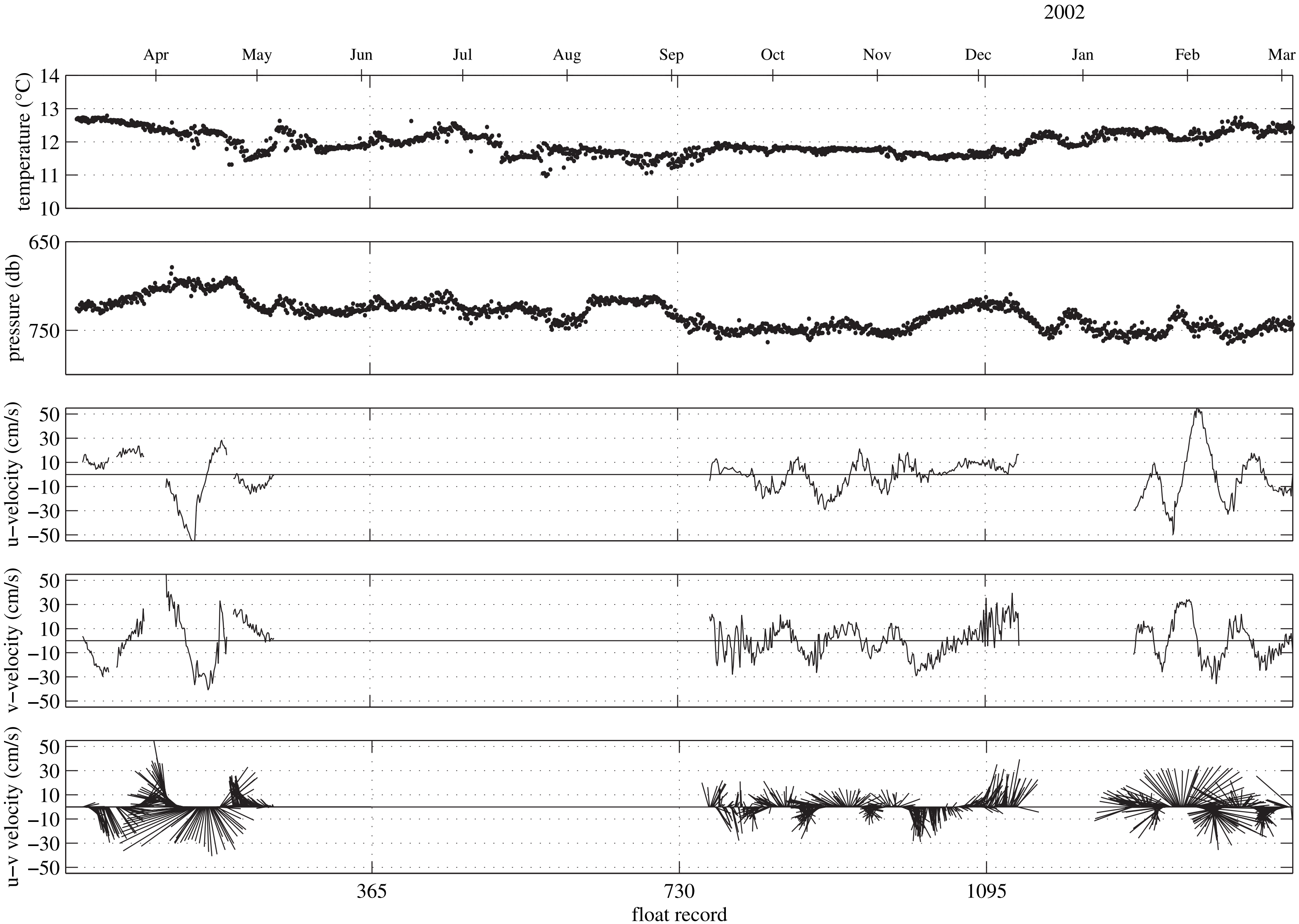

r159: 21% msg return
30'
13°N
30'
12°N
30'
11°N
45°E
46°E
47°E
48°E
49°E
50°E
51°E
1101
1201


r159
2002
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
365
730
1095
float record

r160: 96% msg return

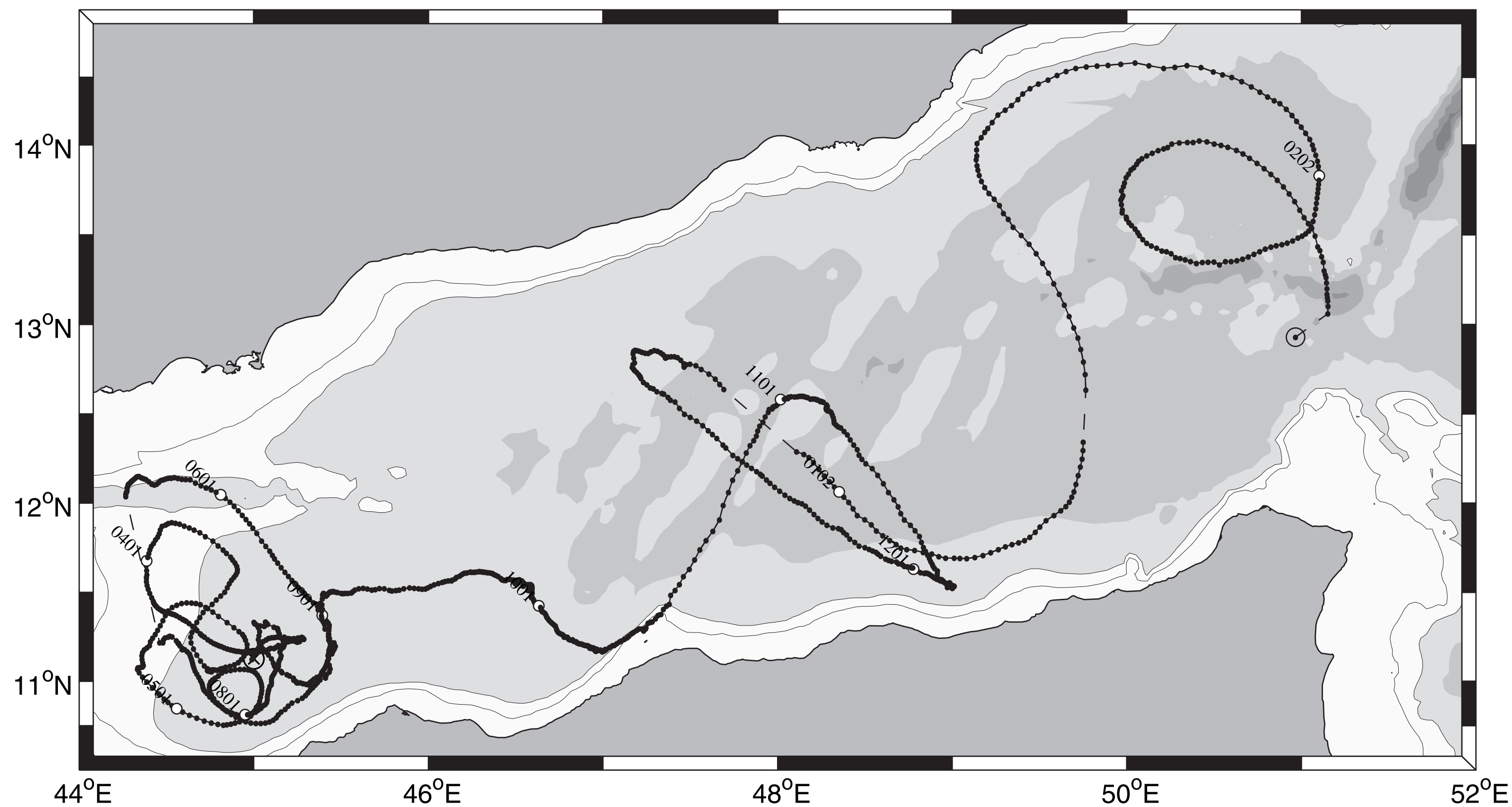


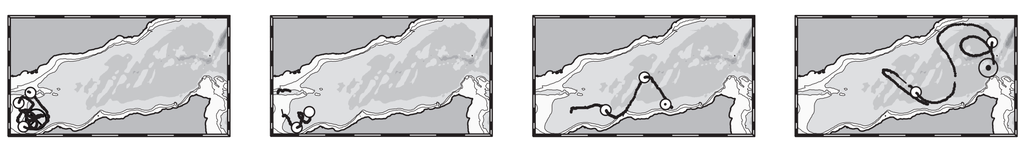
r160

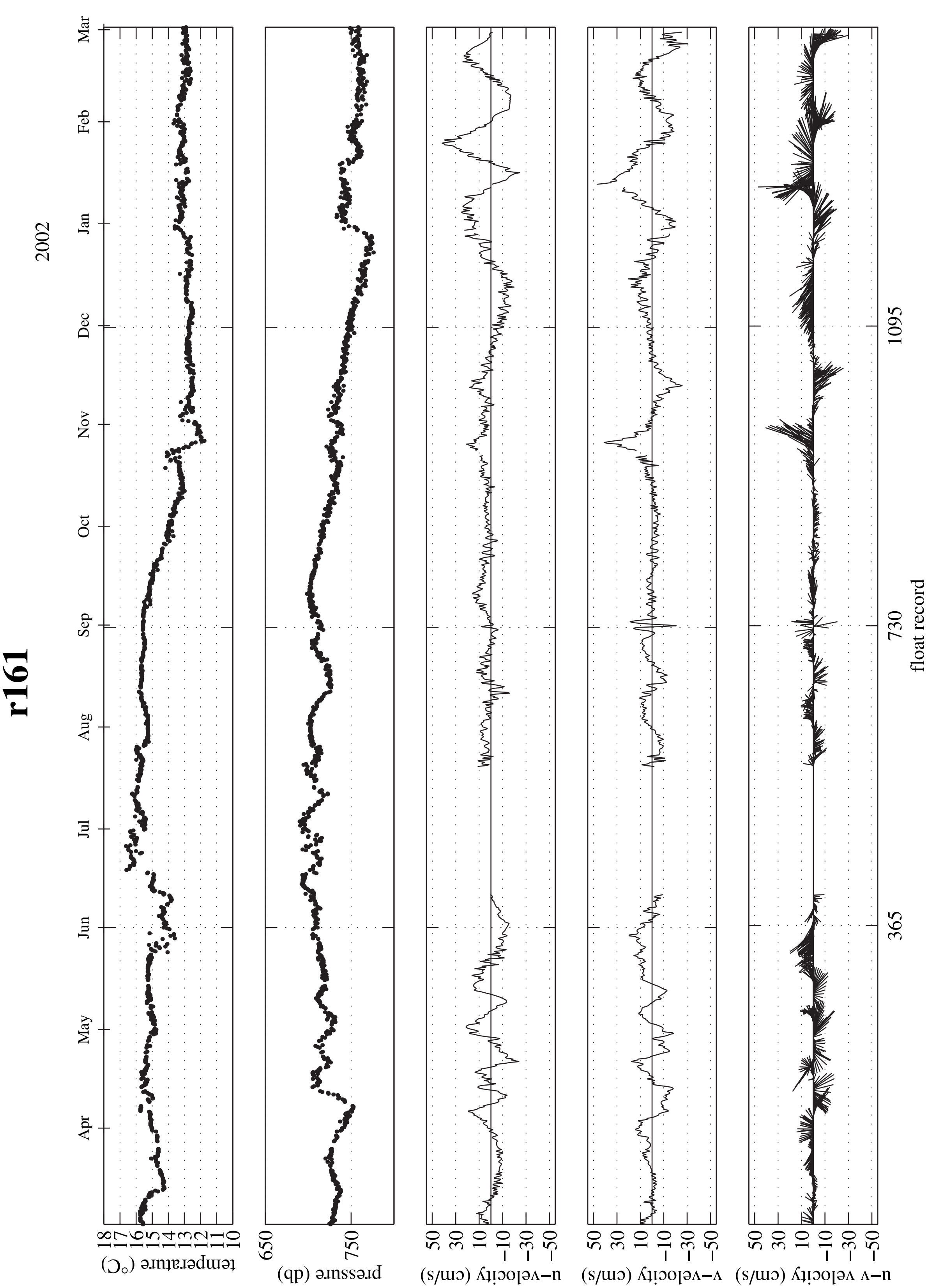


2002
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
temperature (°C)
14
13
12
11
10
pressure (db)
650
750
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
50
30
10
−10
−30
−50
365
730
1095
float record

r161: 79% msg return

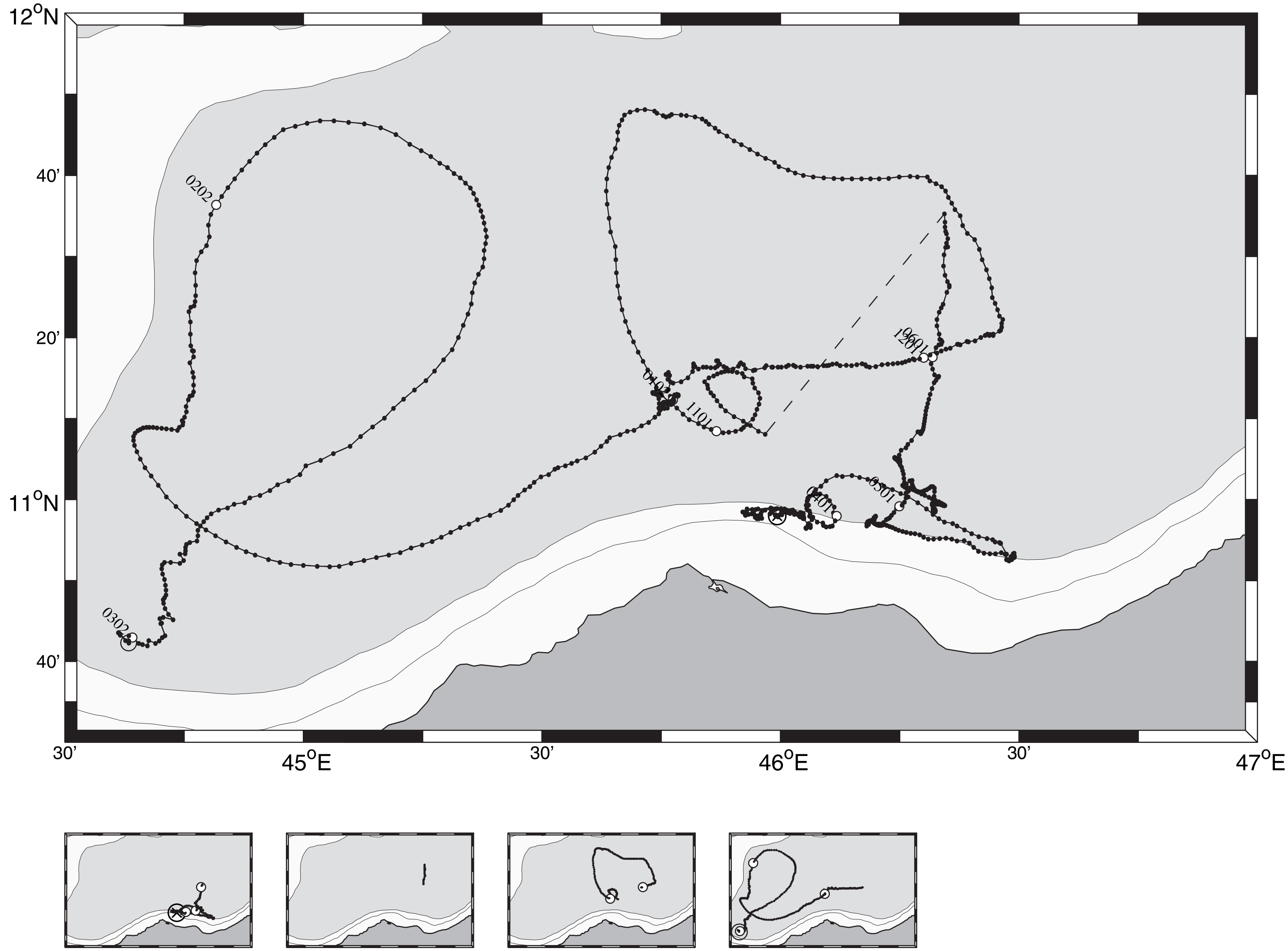




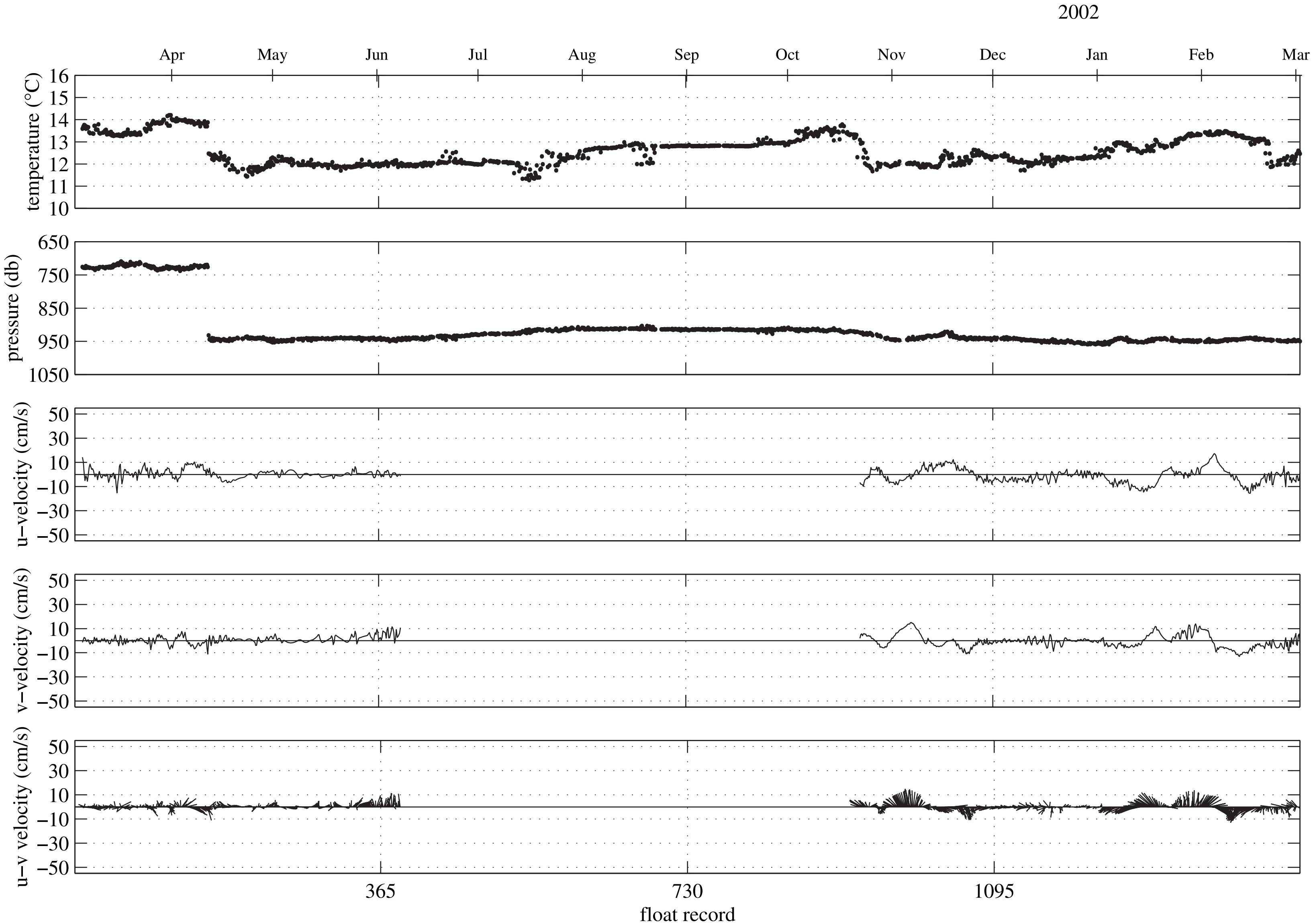


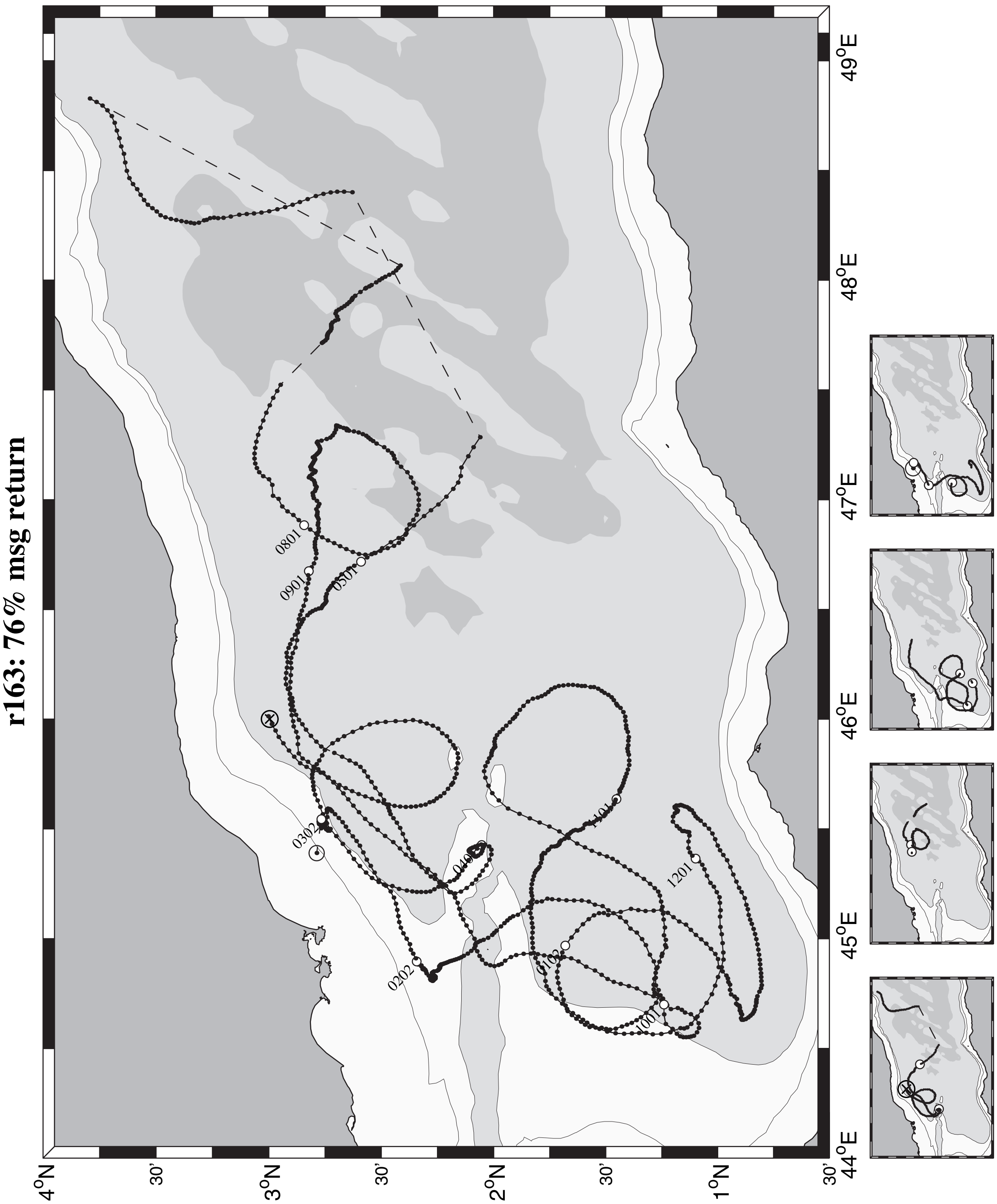
r161
2002
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
365
730
1095
float record

r162: 83% msg return

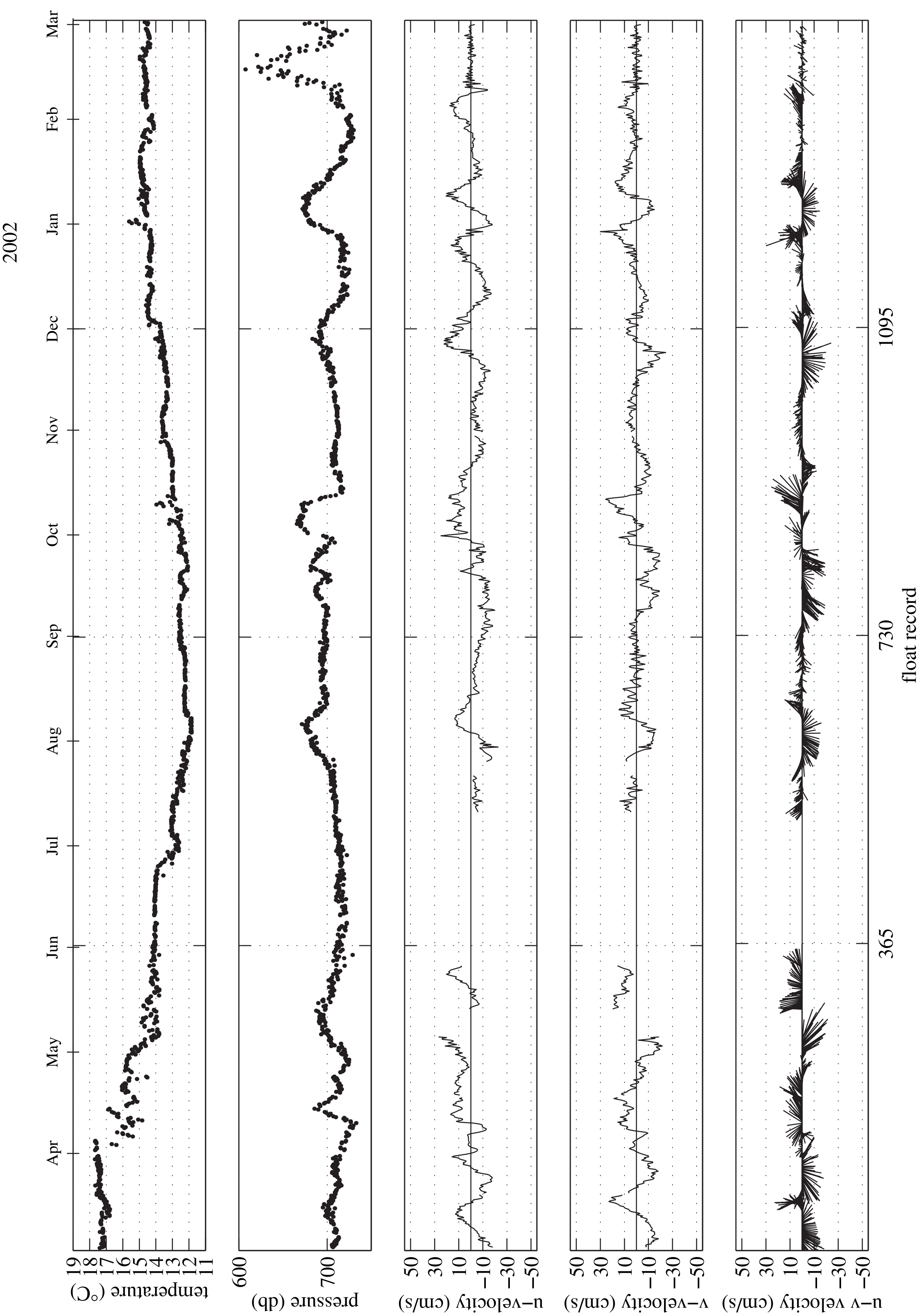


r162

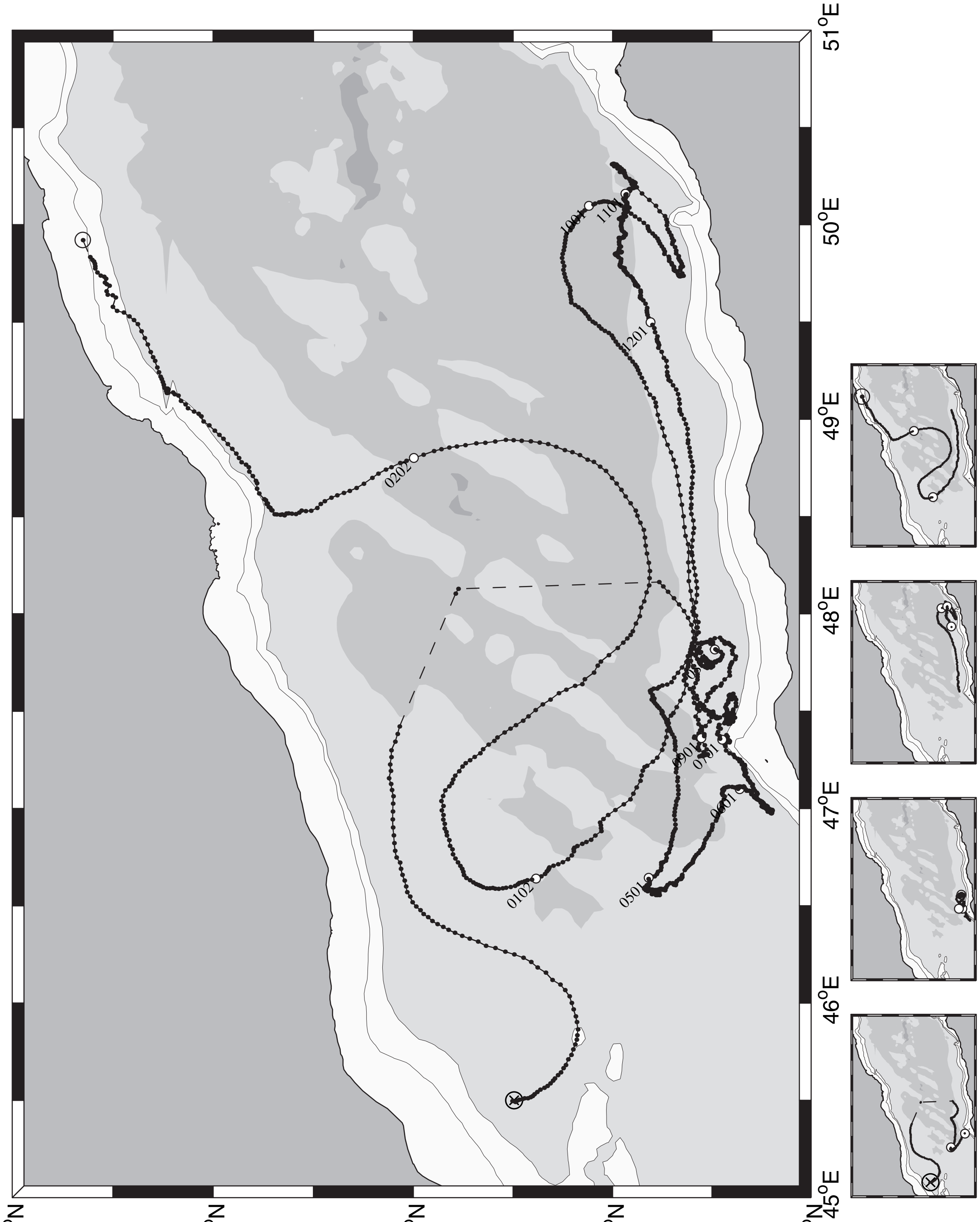

2002
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
temperature (°C)
16
15
14
13
12
11
10
pressure (db)
650
750
850
950
1050
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
50
30
10
−10
−30
−50
365
730
1095
float record


r163: 76% msg return
14°N
30'
13°N
30'
12°N
30'
11°N
30'
44°E
45°E
46°E
47°E
48°E
49°E
0801
0901
0501
0302
0401
0202
0101
1001
1101
1201

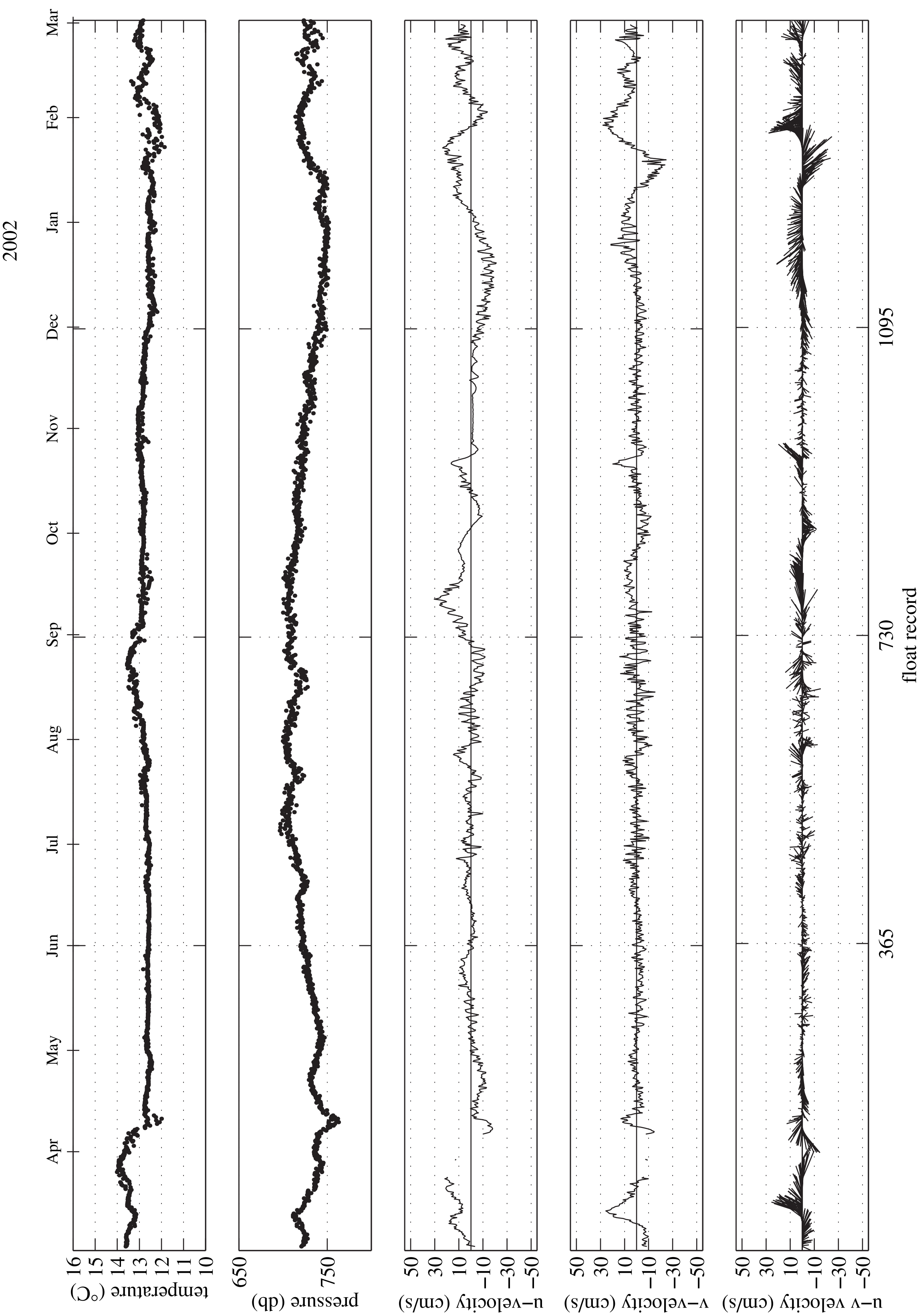
r163


2002
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
365
730
1095
float record

r164: 100% msg return

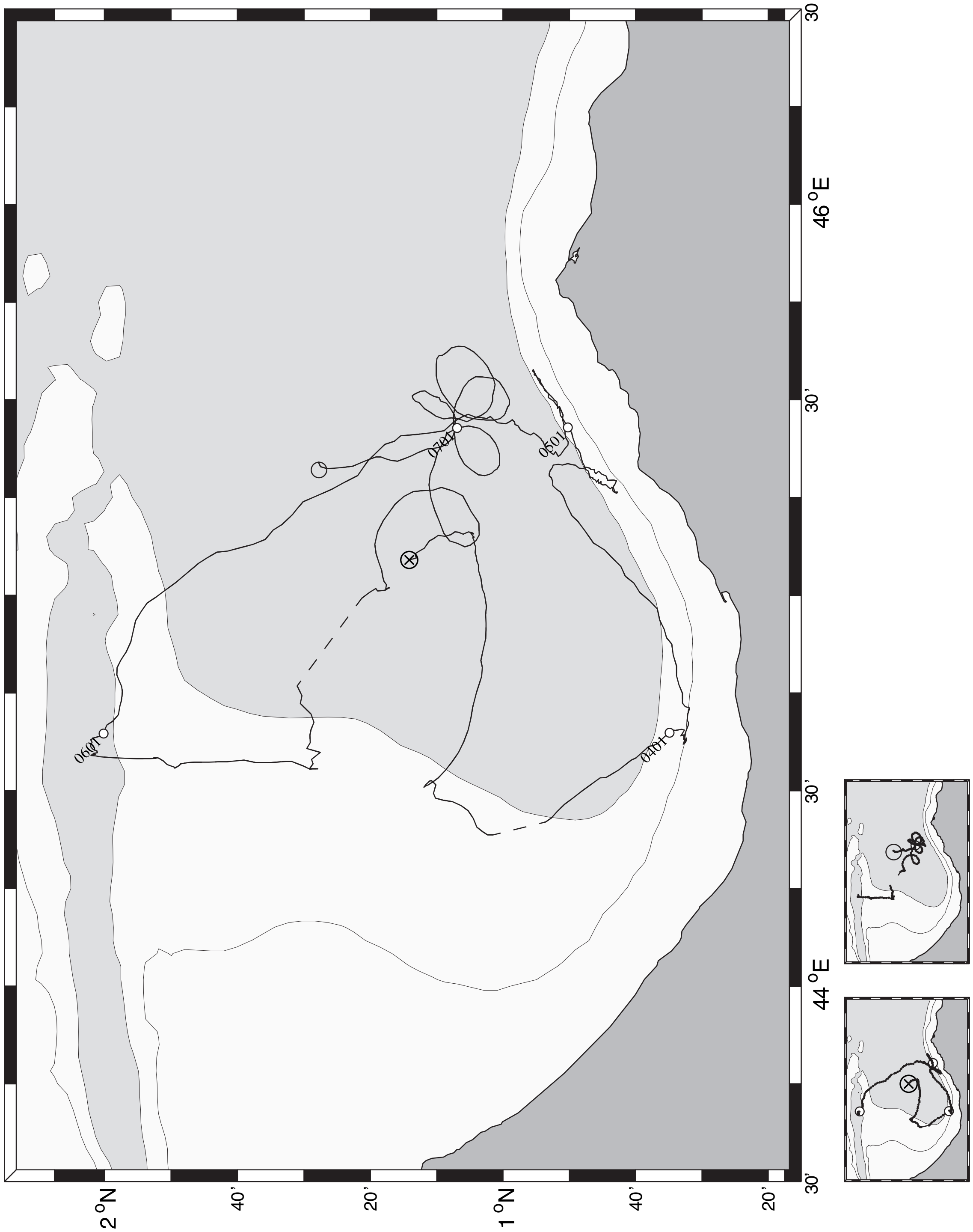


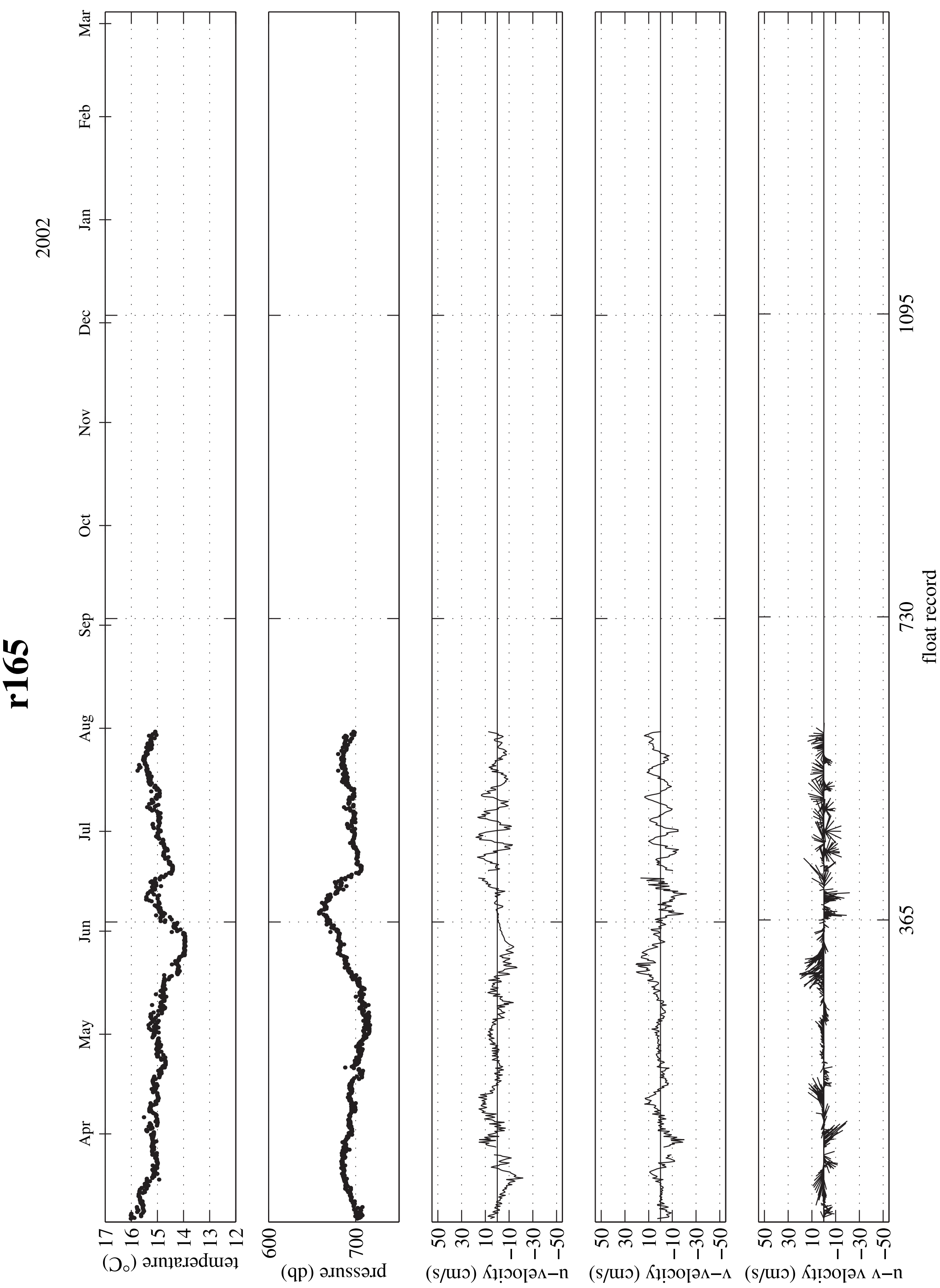
r164



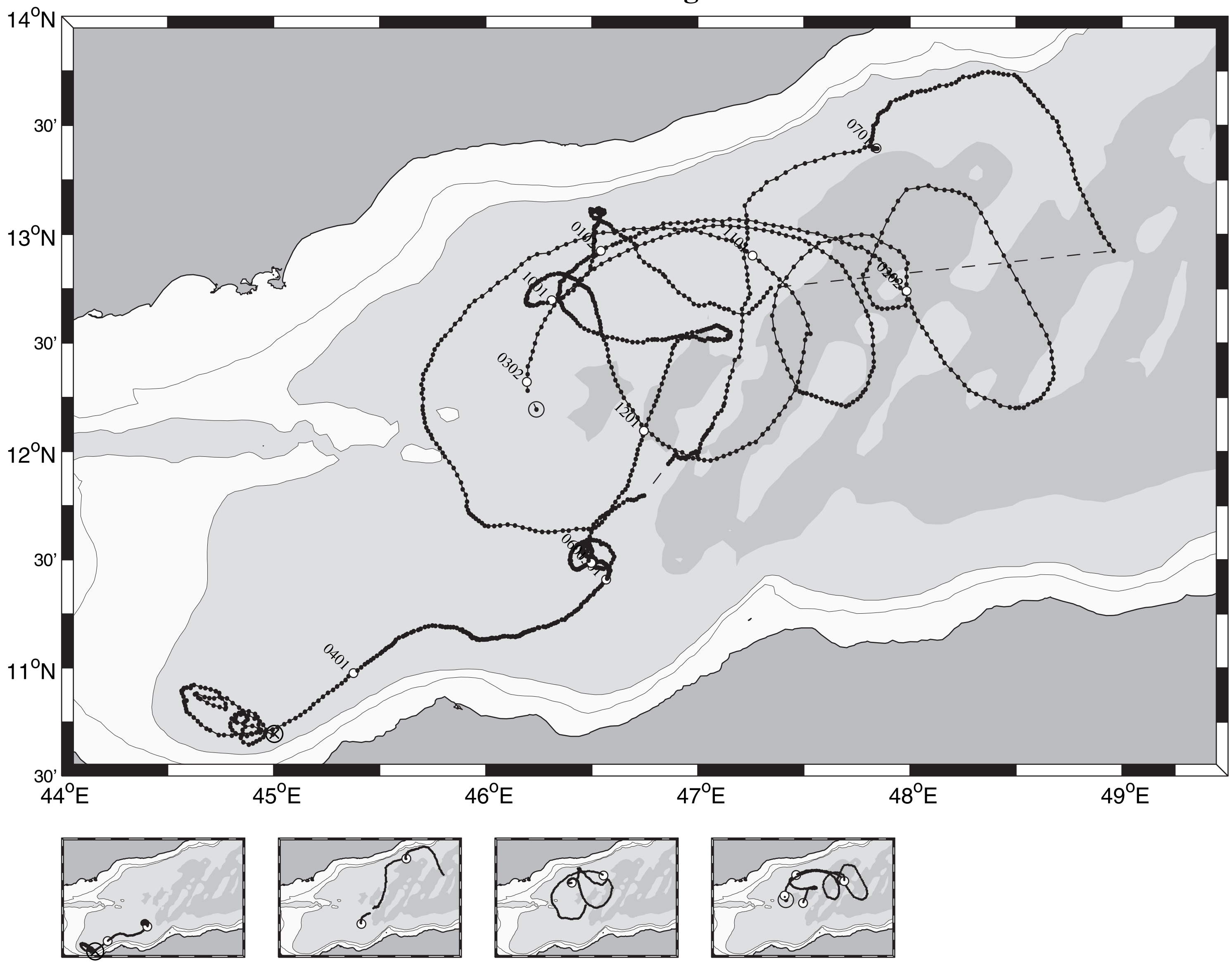
2002
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
temperature (°C)
16
15
14
13
12
11
10
pressure (db)
650
750
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
50
30
10
−10
−30
−50
365
730
1095
float record

r165: 100% msg return

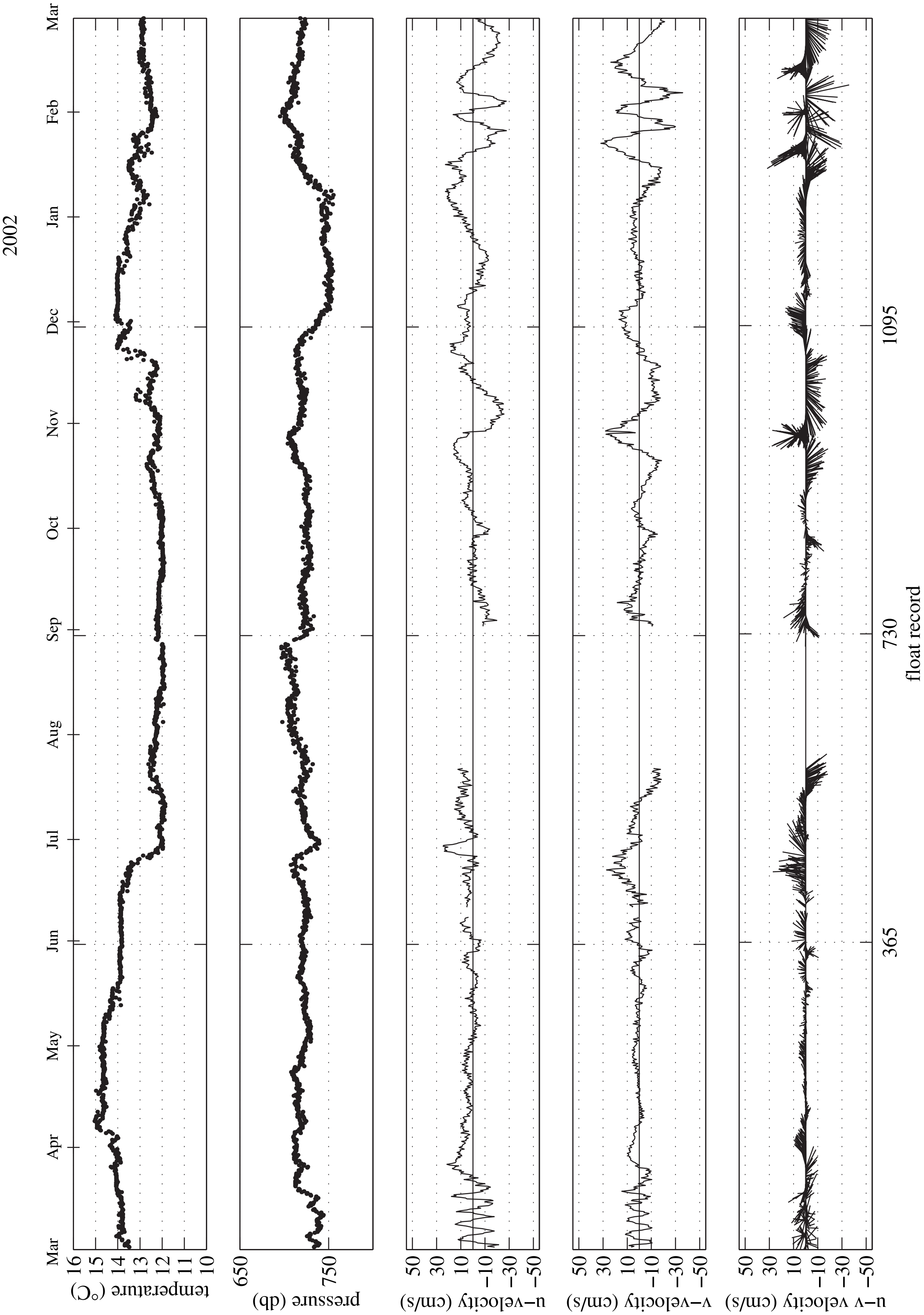



r165
2002
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
365
730
1095
float record

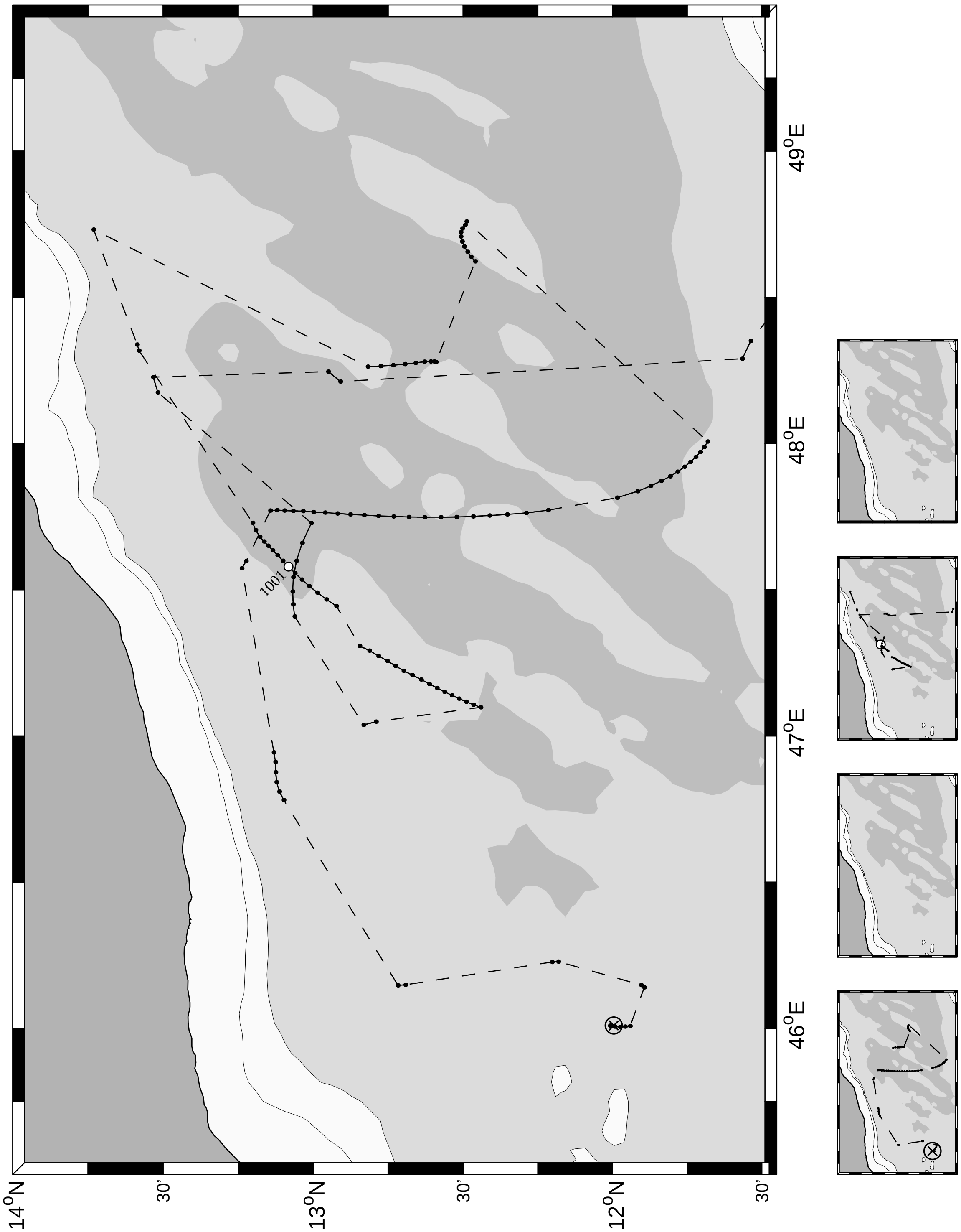
r166: 86% msg return



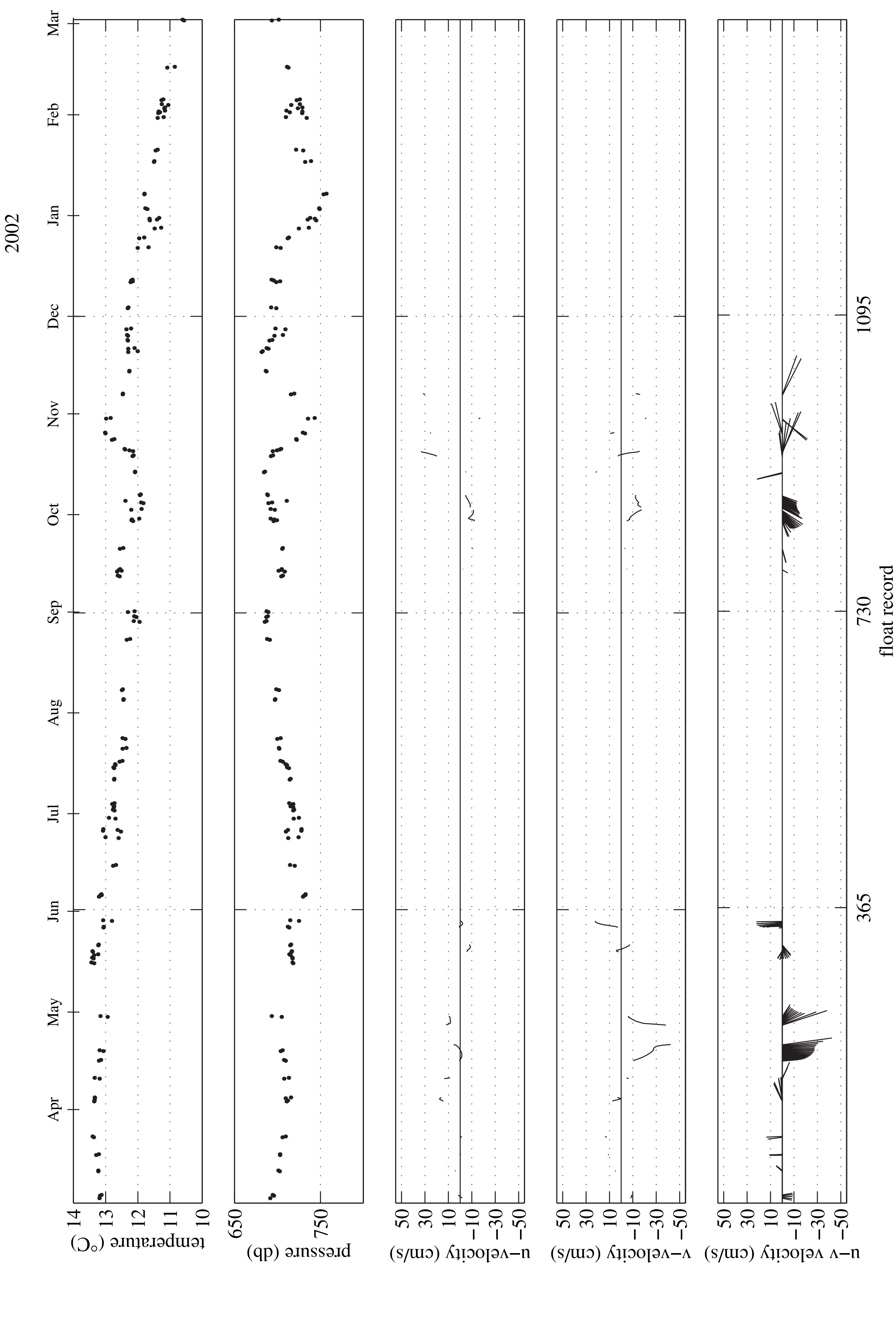
r166


2002
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
temperature (°C)
16 15 14 13 12 11 10
pressure (db)
650 750
u−velocity (cm/s)
50 30 10 −10 −30 −50
v−velocity (cm/s)
50 30 10 −10 −30 −50
u−v velocity (cm/s)
50 30 10 −10 −30 −50
365
730
1095
float record

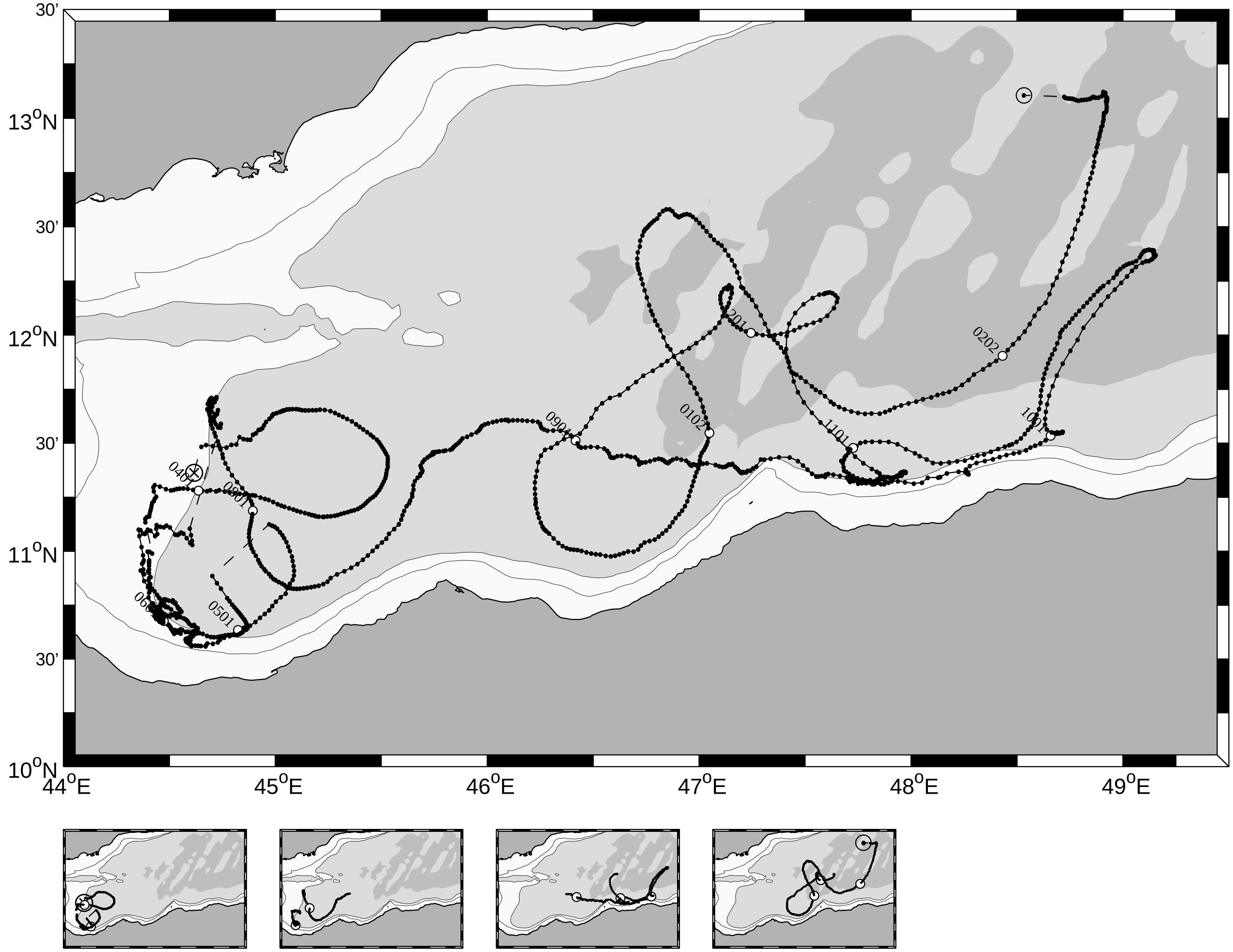
r167: 12% msg return

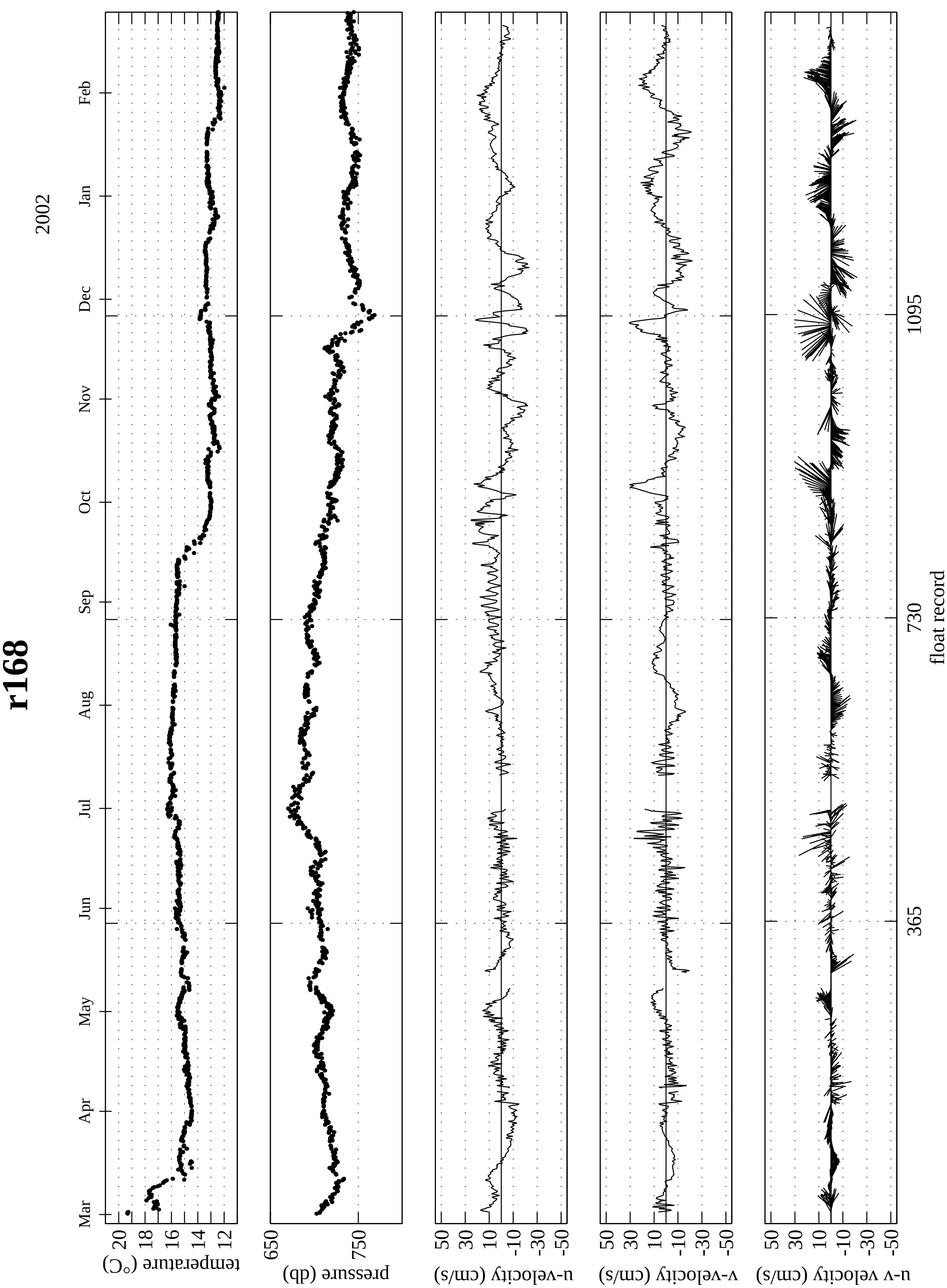


r167


2002
Mar
Feb
Jan
Dec
Nov
Oct
Sep
Aug
Jul
Jun
May
Apr
temperature (°C)
14
13
12
11
10
pressure (db)
650
750
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
50
30
10
−10
−30
−50
365
730
1095
float record

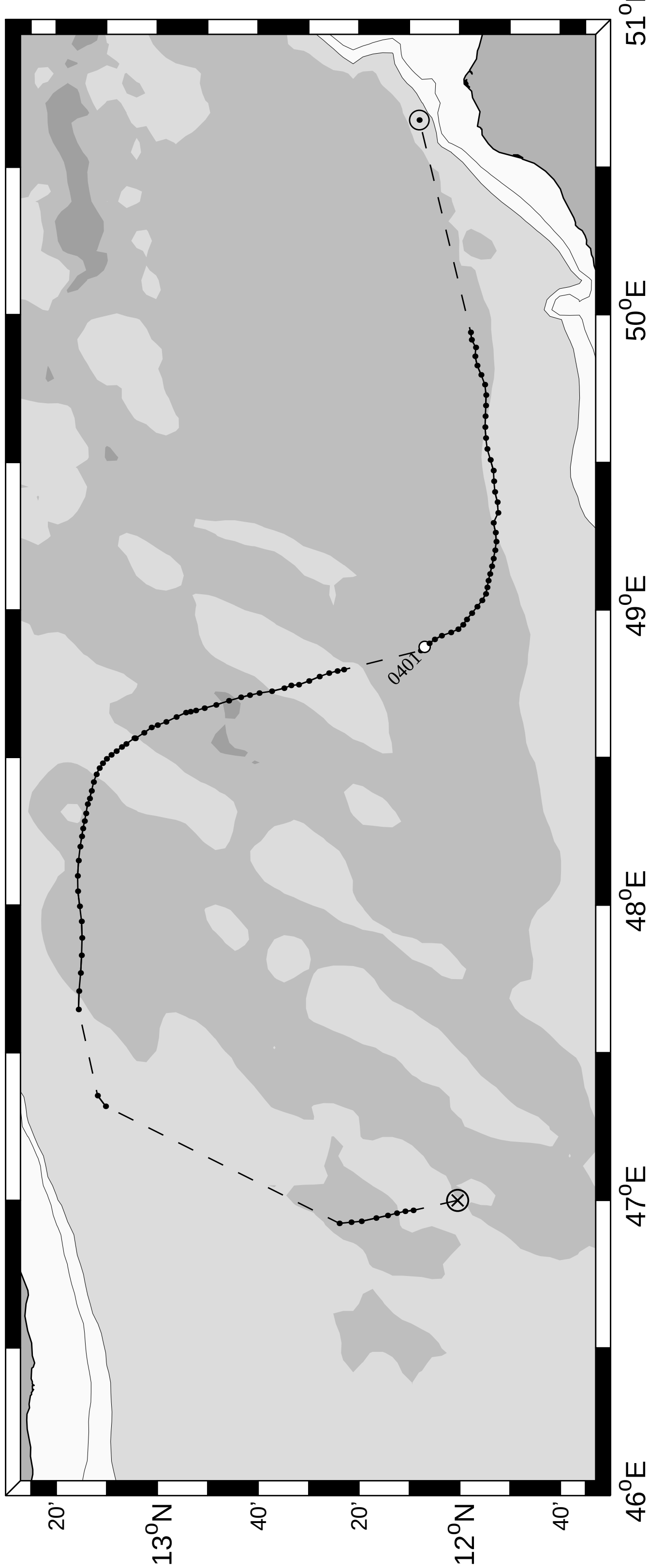
r168: 75% msg return

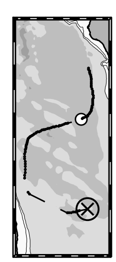


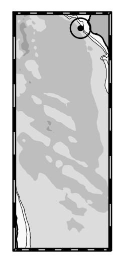


r168
2002
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
temperature (°C)
pressure (db)
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
365
730
1095
float record

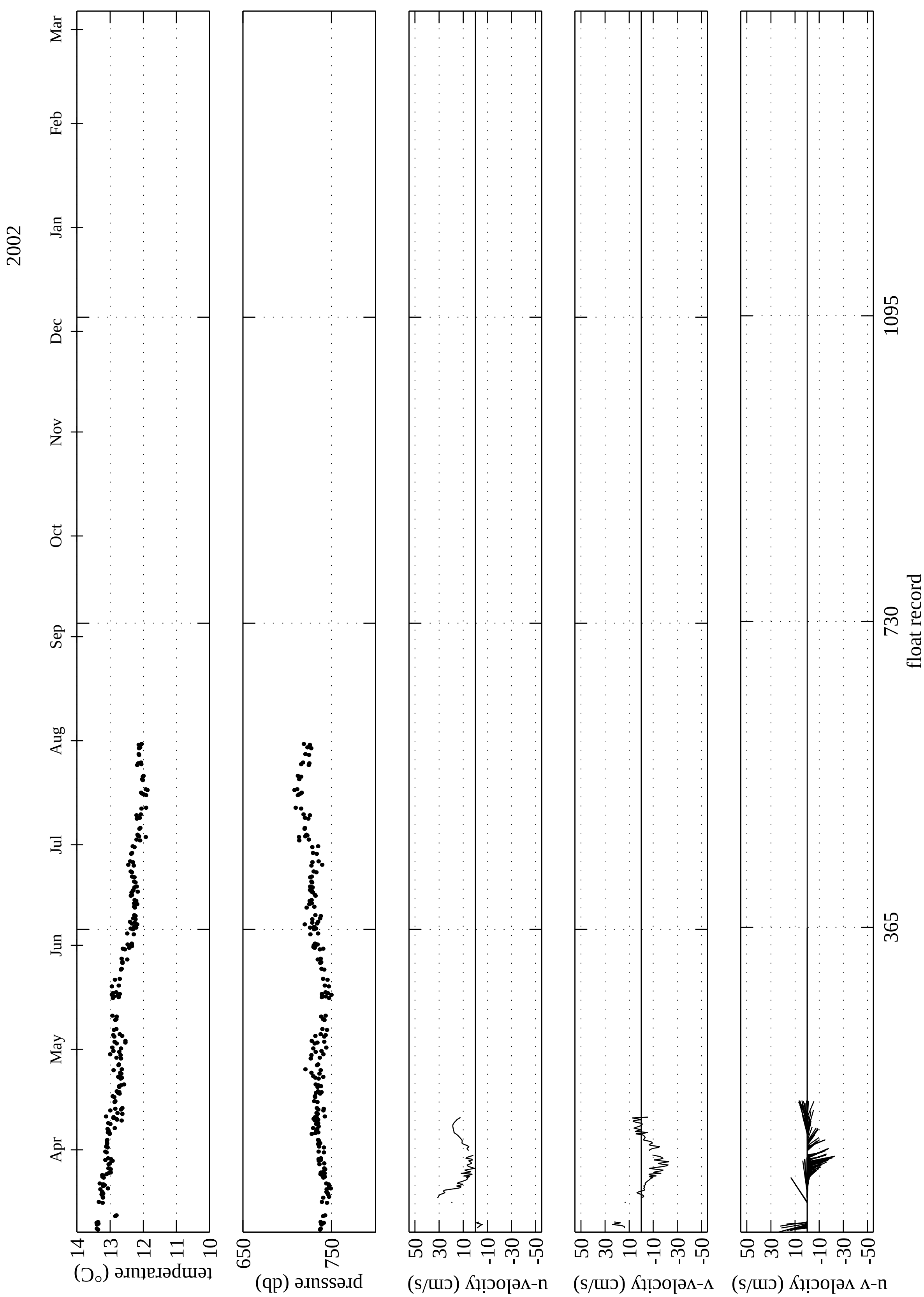
r169: 37% msg return



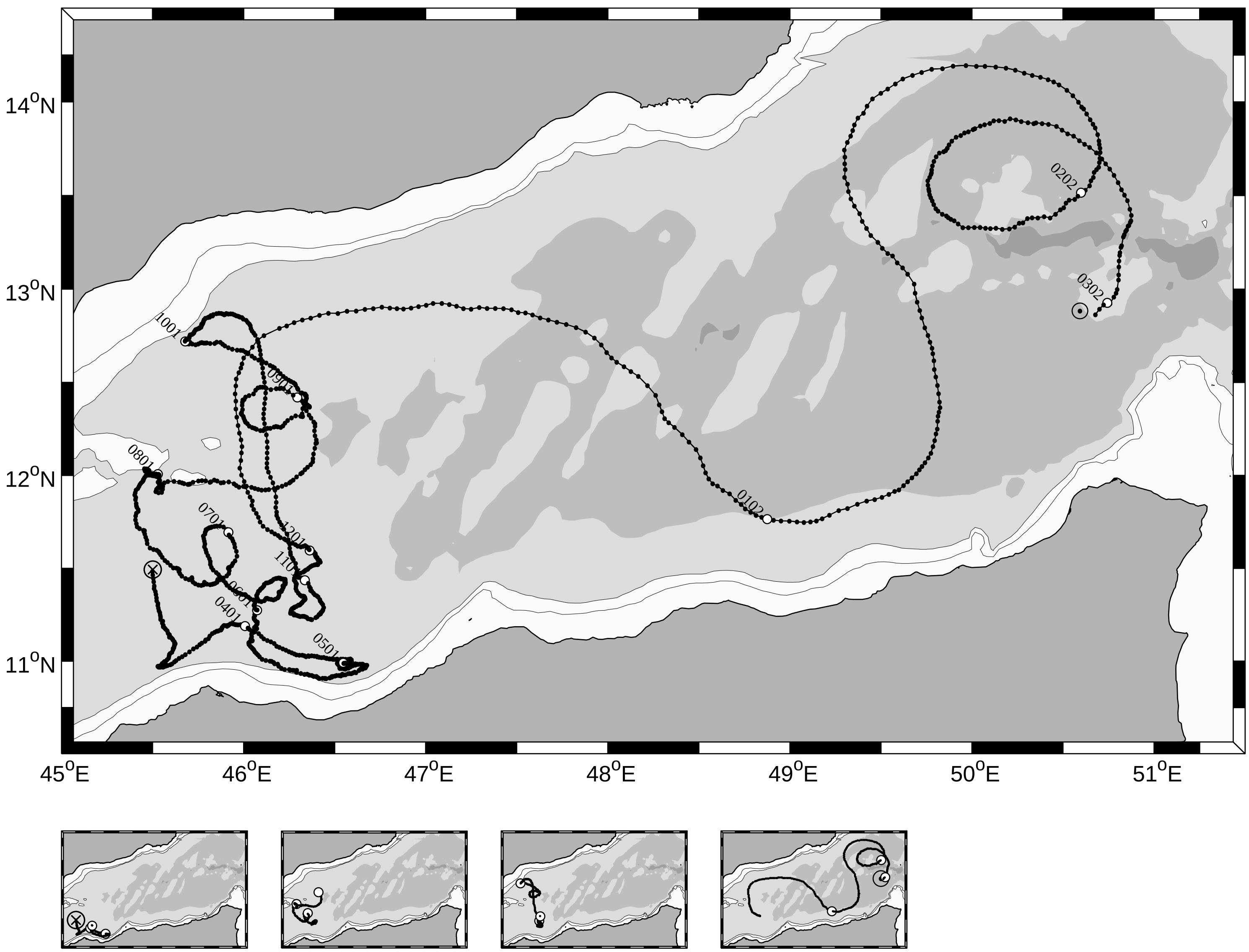


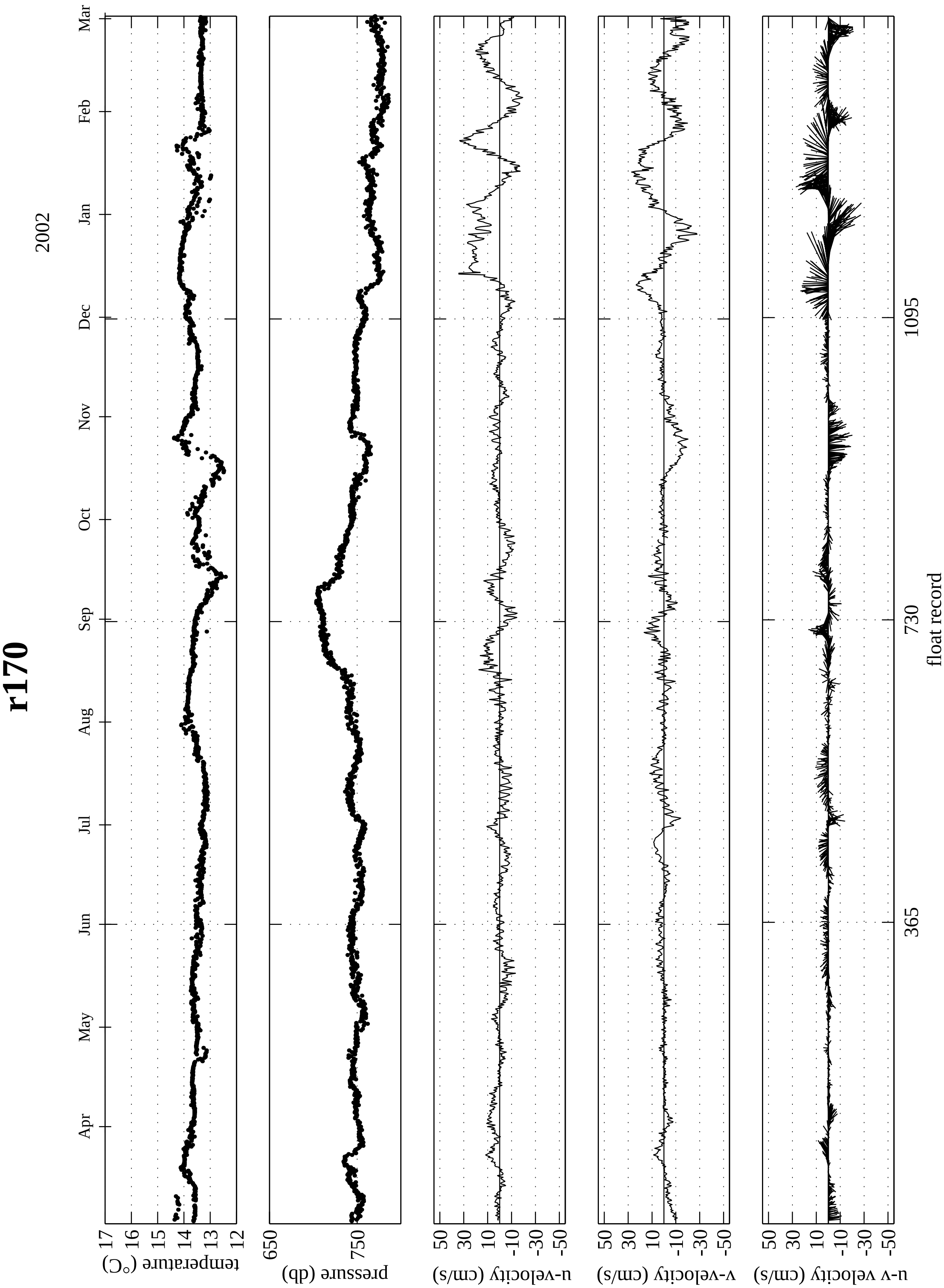


r169

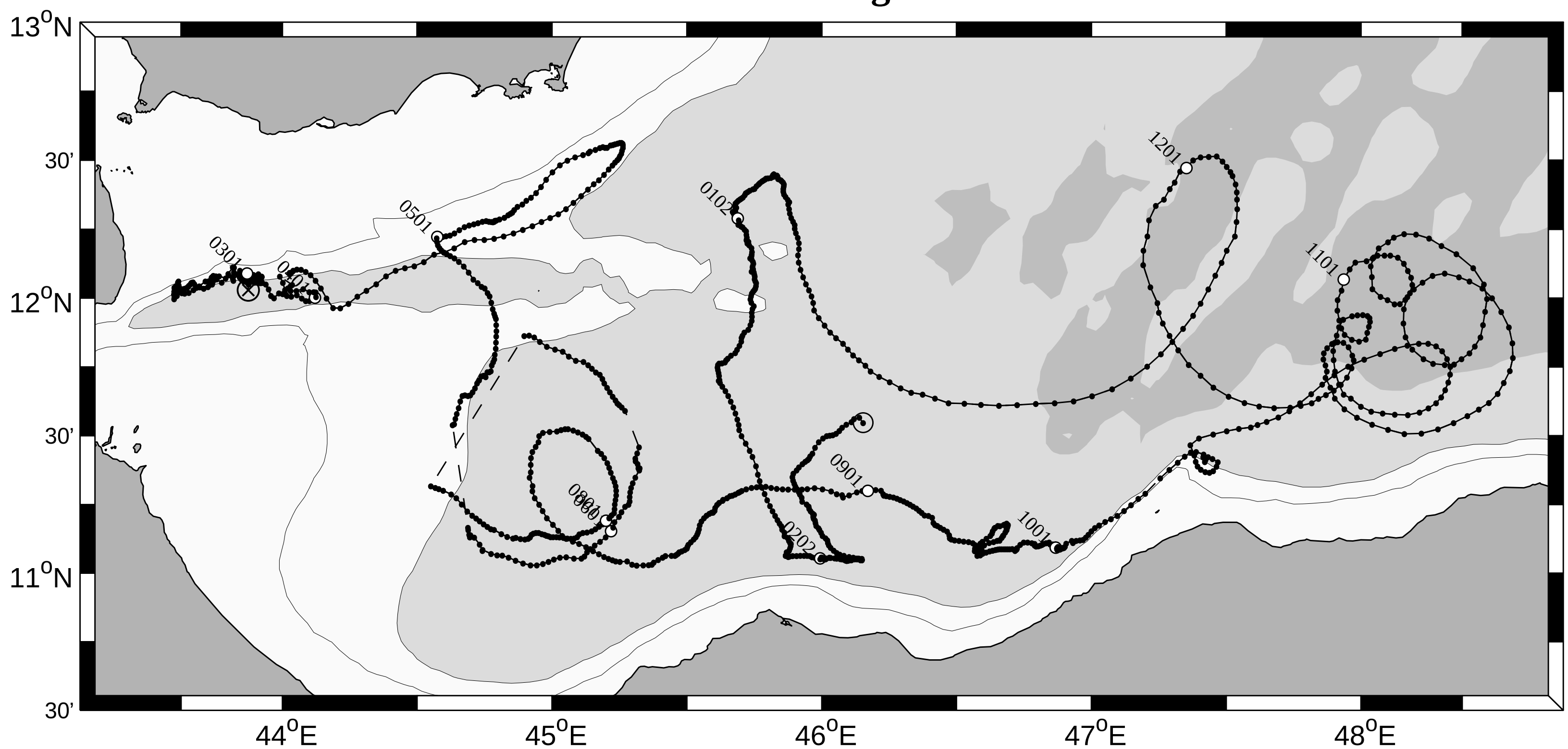

2002
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
temperature (°C)
pressure (db)
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
365
730
1095
float record

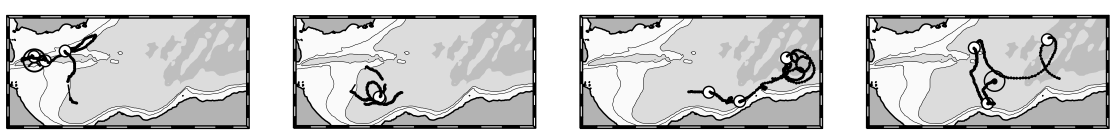
r170: 100% msg return

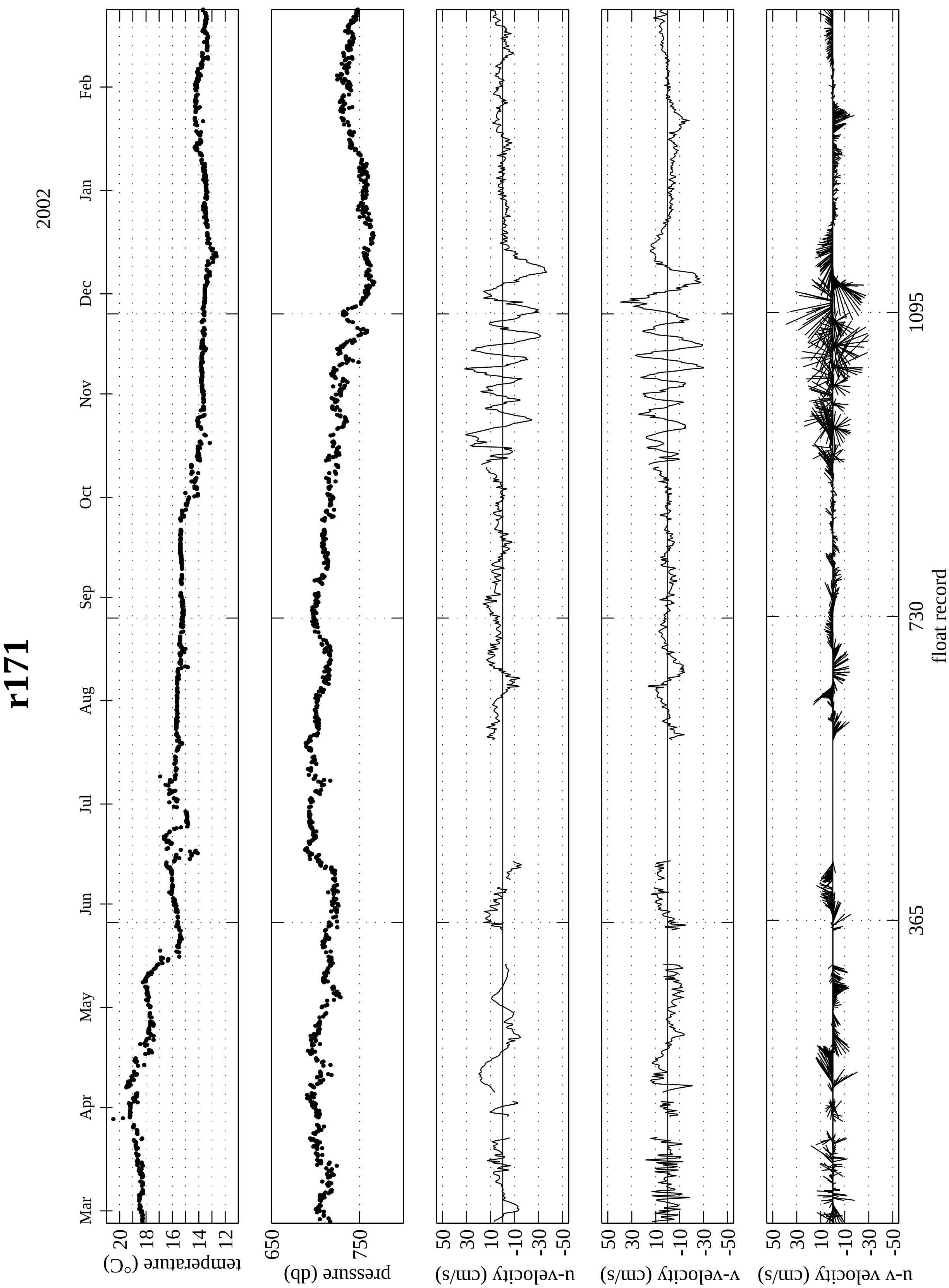



r170
2002
Mar
Feb
Jan
Dec
Nov
Oct
Sep
Aug
Jul
Jun
May
Apr
temperature (°C)
17 16 15 14 13 12
pressure (db)
650 750
u-velocity (cm/s)
50 30 10 -10 -30 -50
v-velocity (cm/s)
50 30 10 -10 -30 -50
u-v velocity (cm/s)
50 30 10 -10 -30 -50
1095
730
365
float record

r171: 69% msg return

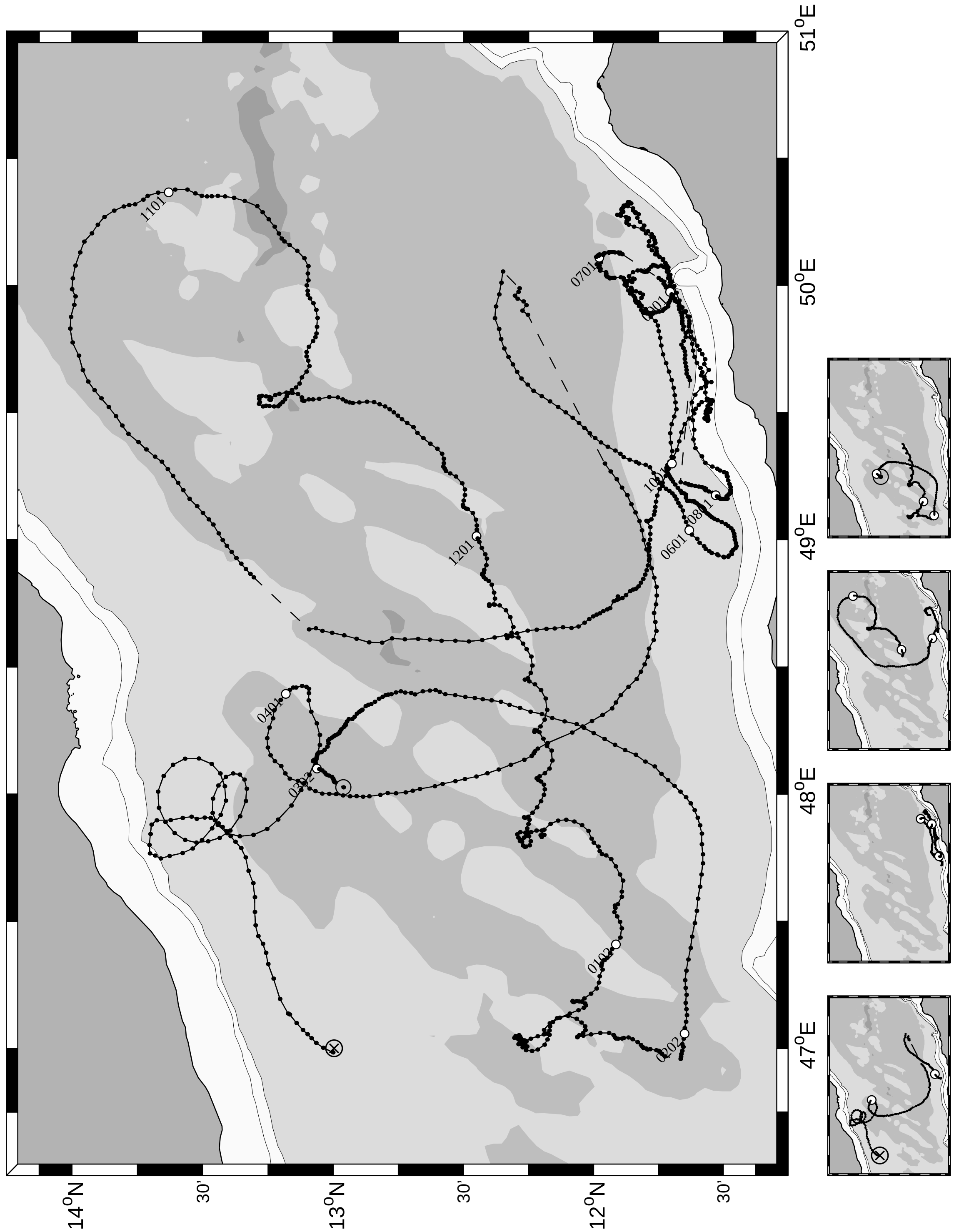


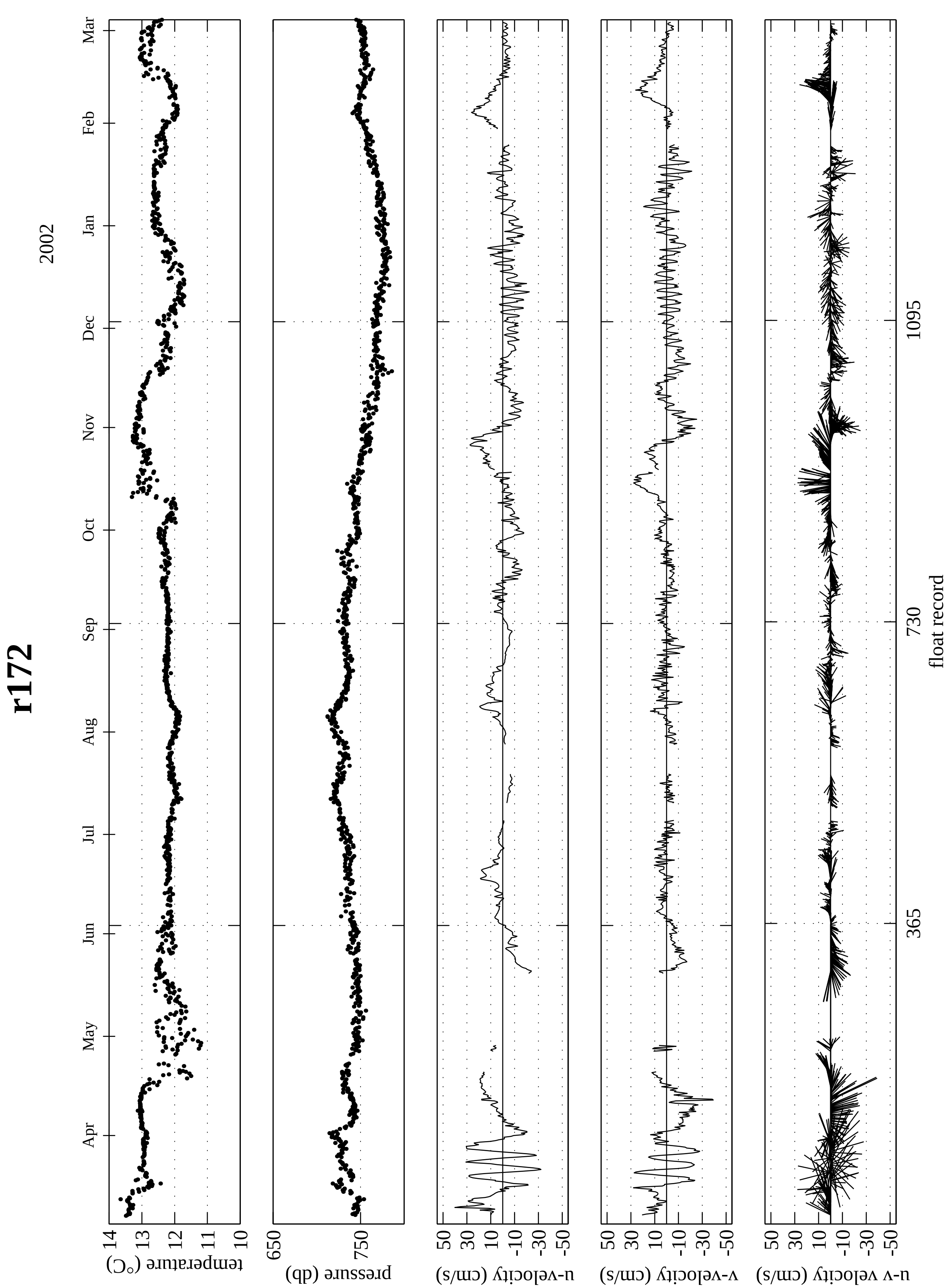




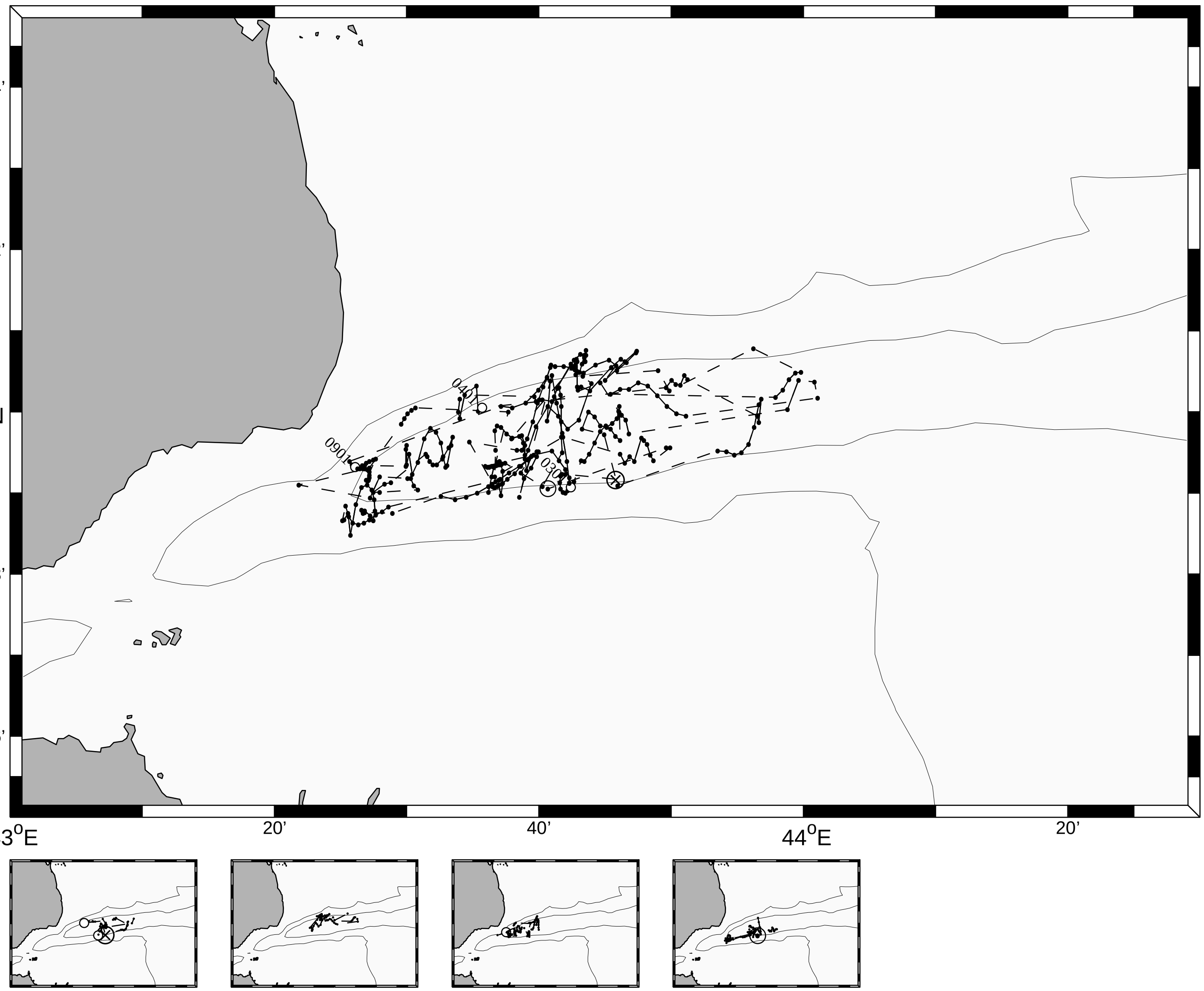
r171
2002
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
temperature (°C)
pressure (db)
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
365
730
1095
float record

r172: 77% msg return

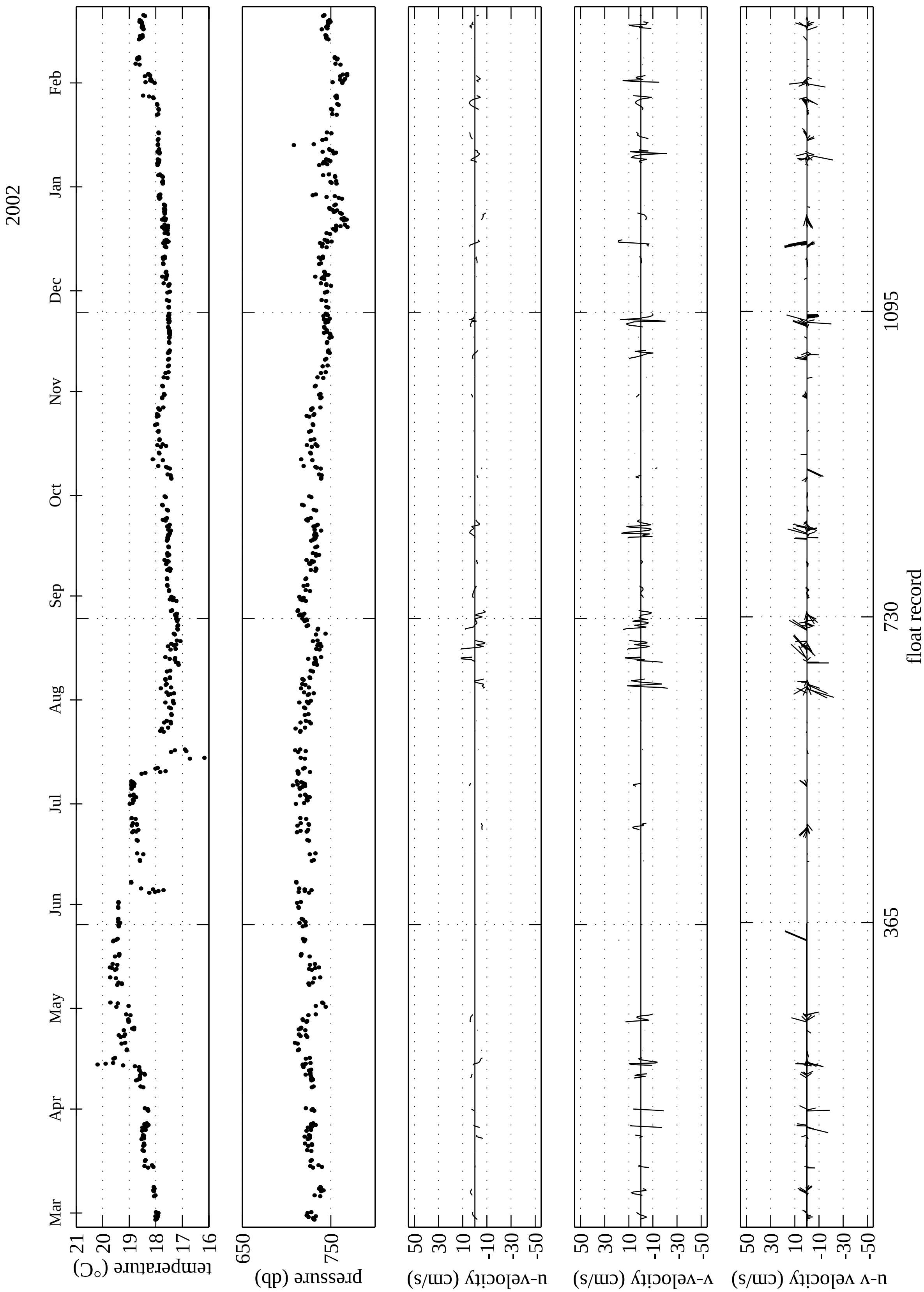



r172
2002
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
temperature (°C)
pressure (db)
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
365
730
1095
float record

r173: 34% msg return

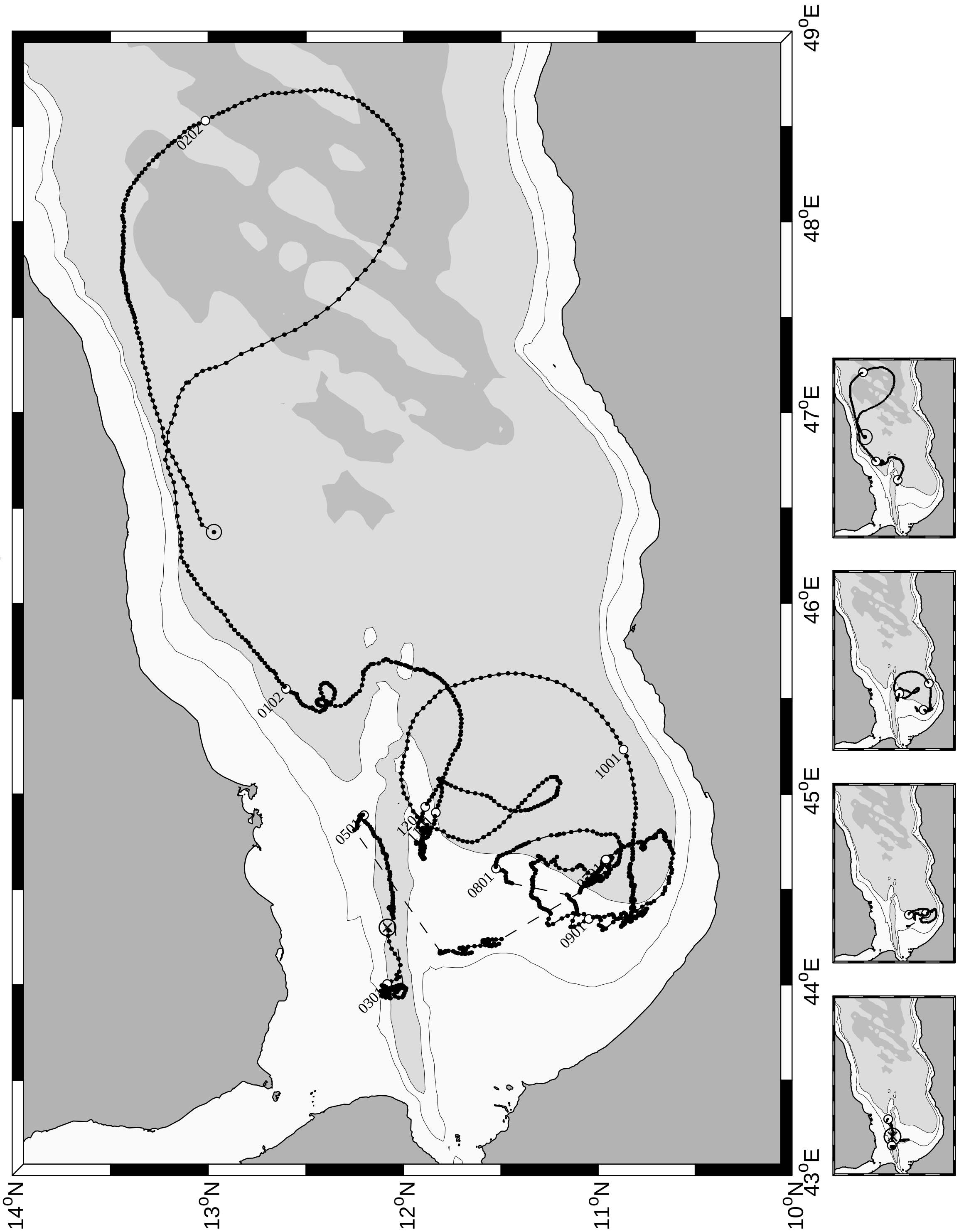


r173

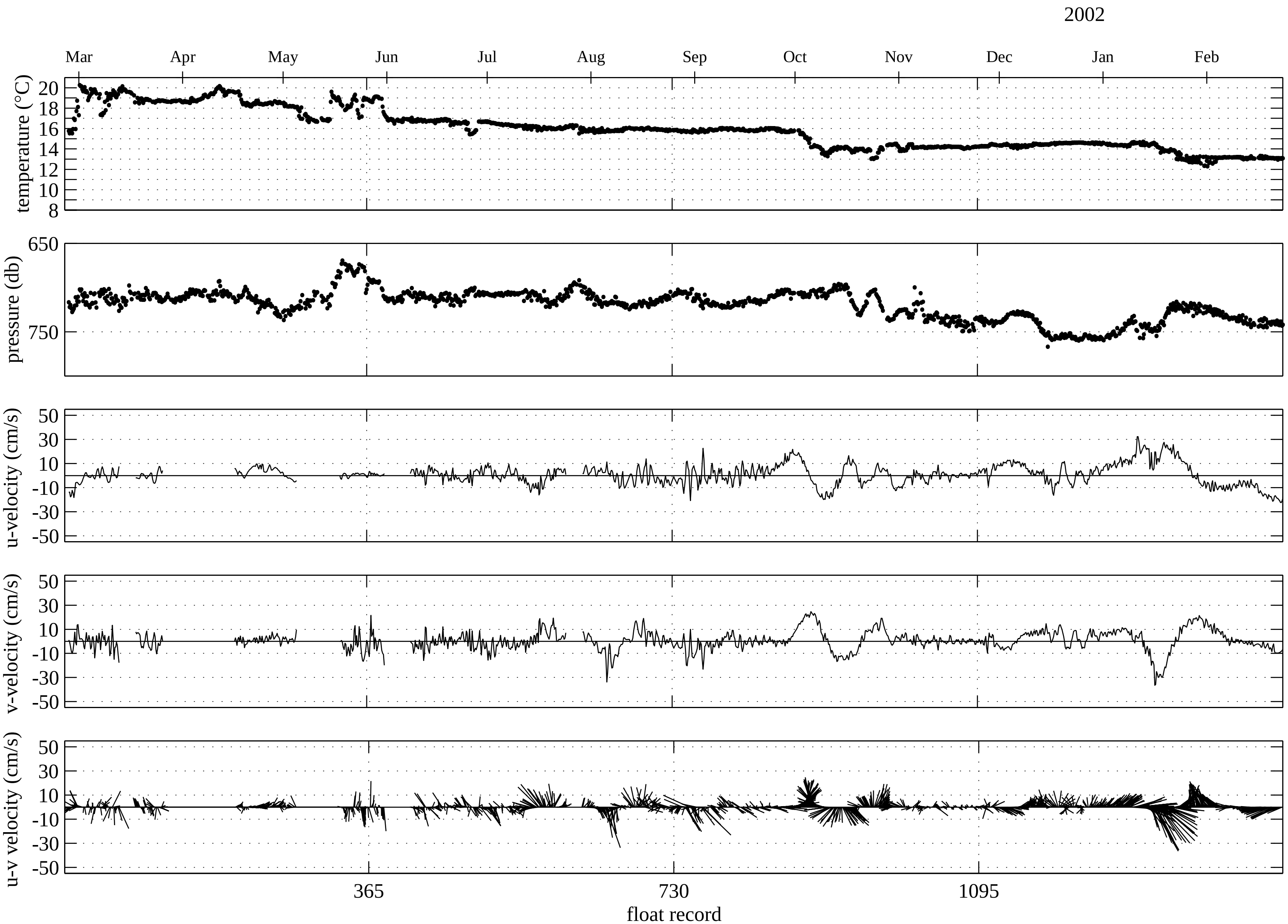


2002
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
temperature (°C)
21 20 19 18 17 16
pressure (db)
650 750
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
50 30 10 -10 -30 -50
365
730
1095
float record

r174: 92% msg return

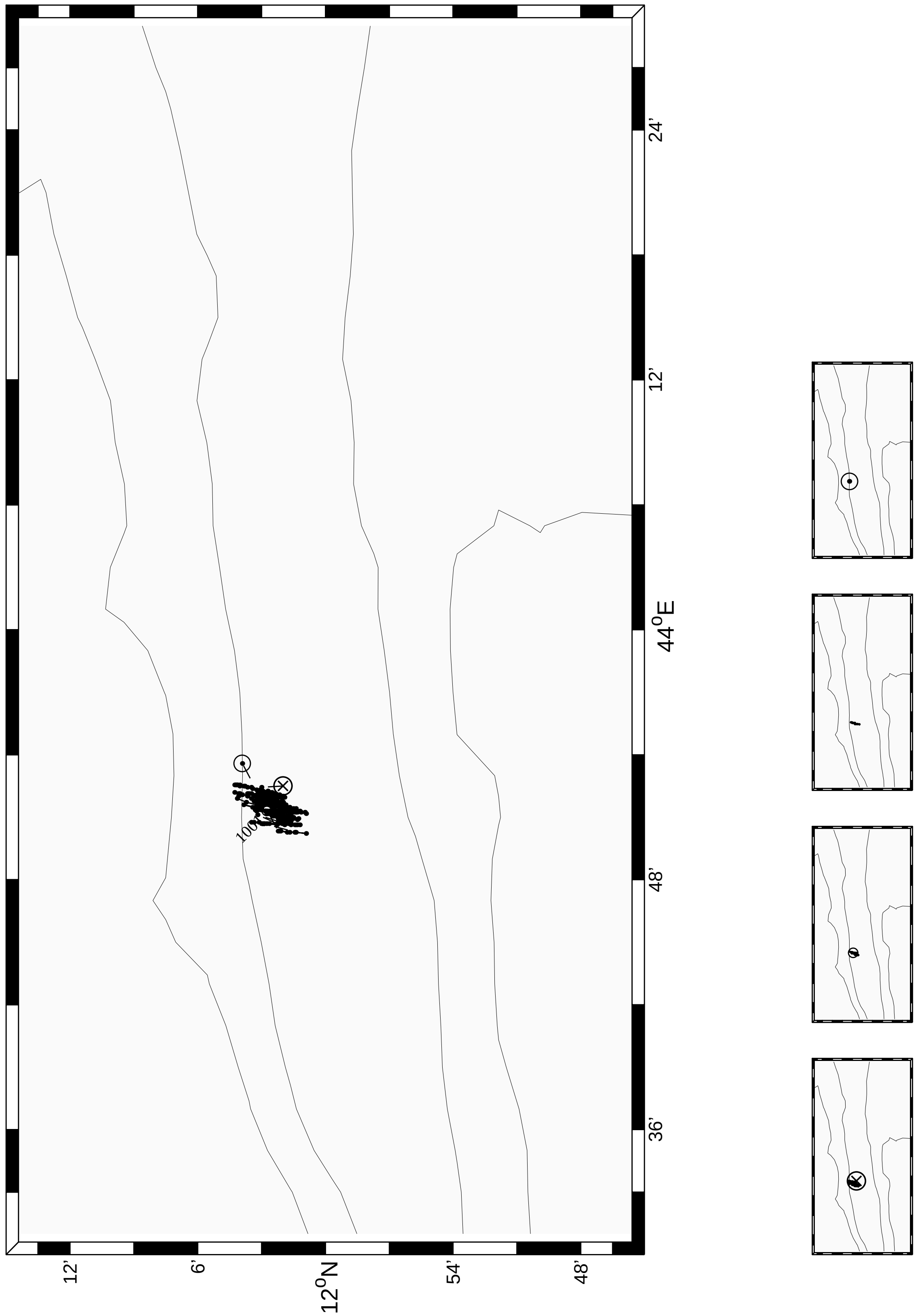


r174



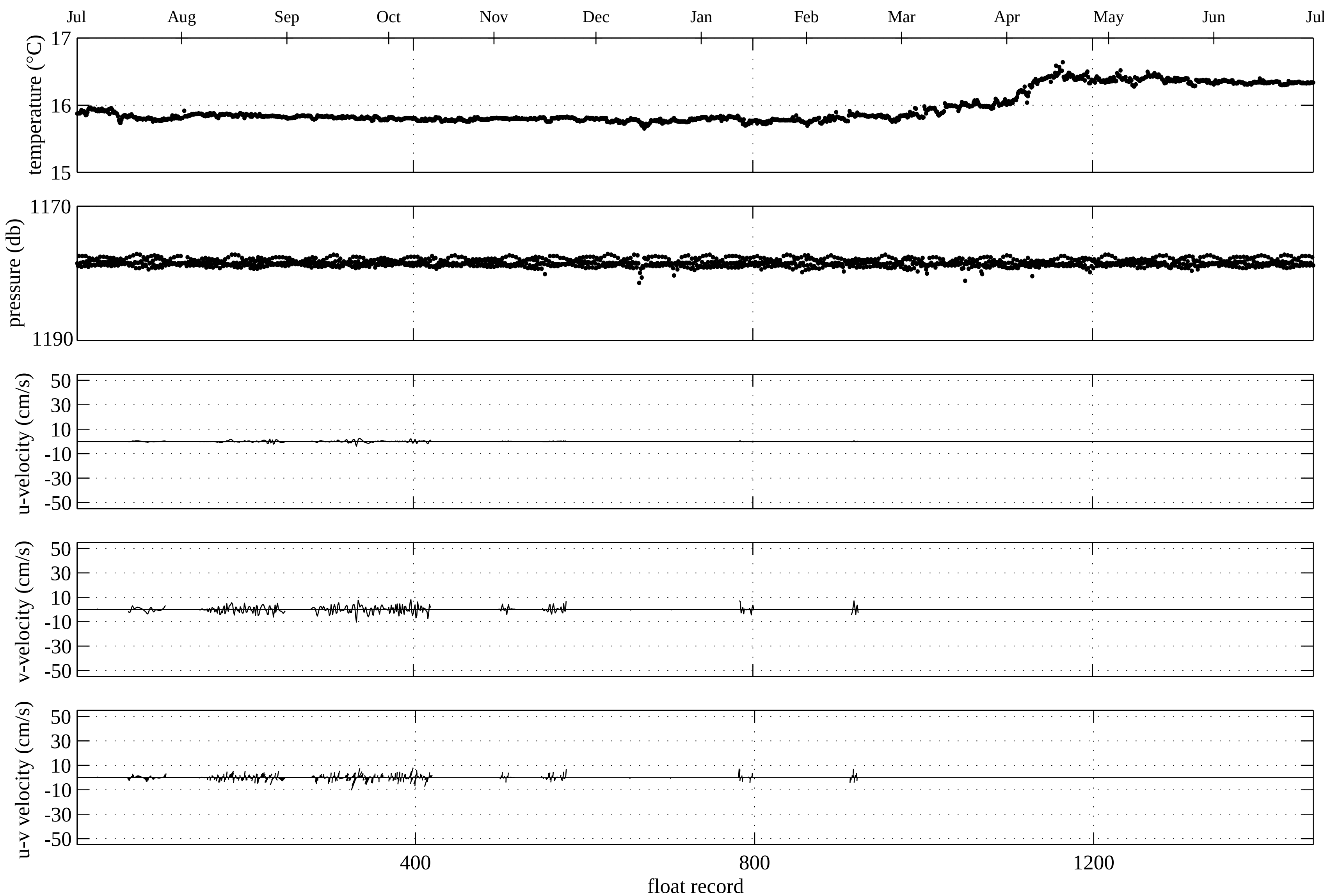
2002
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
temperature (°C)
pressure (db)
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
365
730
1095
float record

r208: 100% msg return

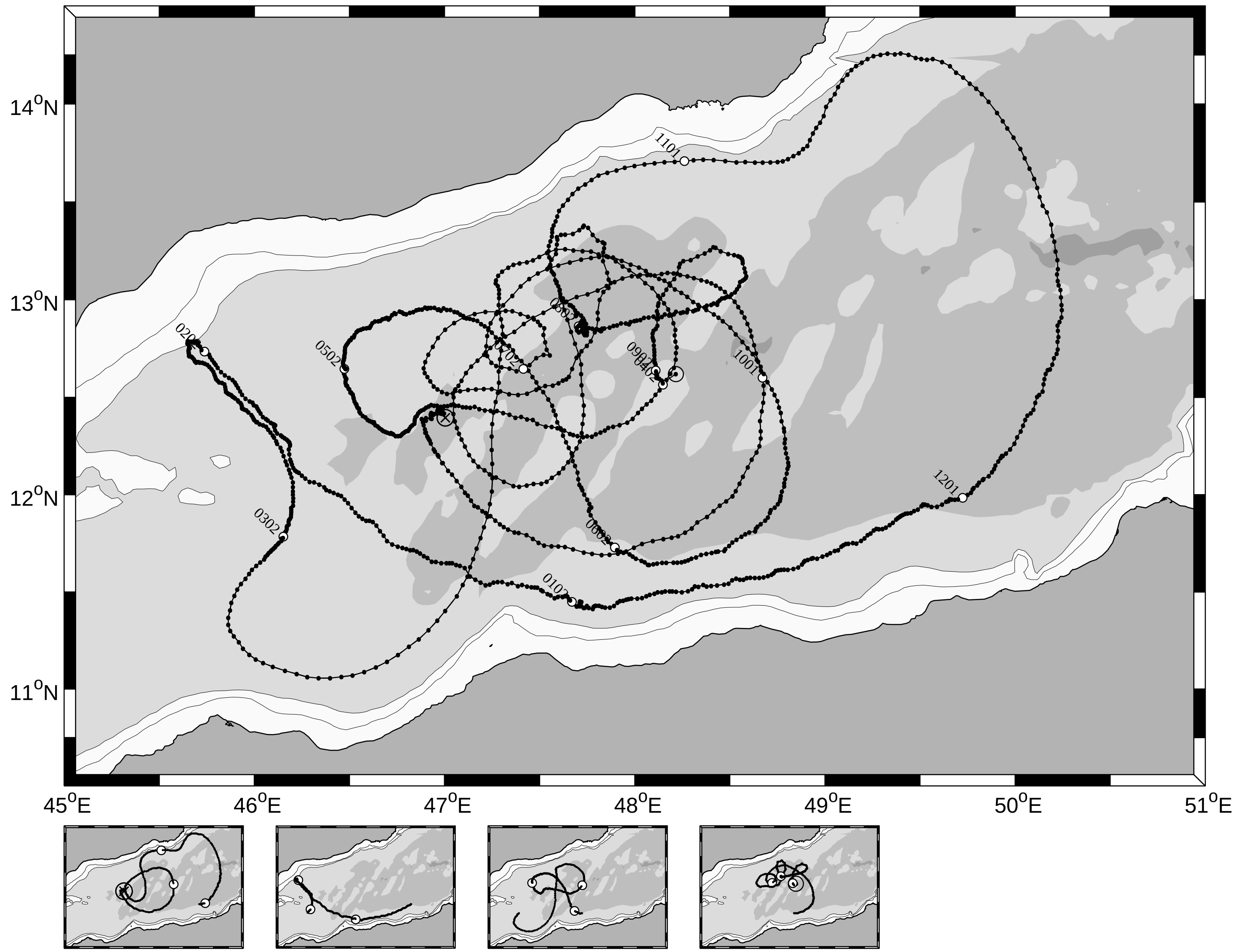


r208

2002

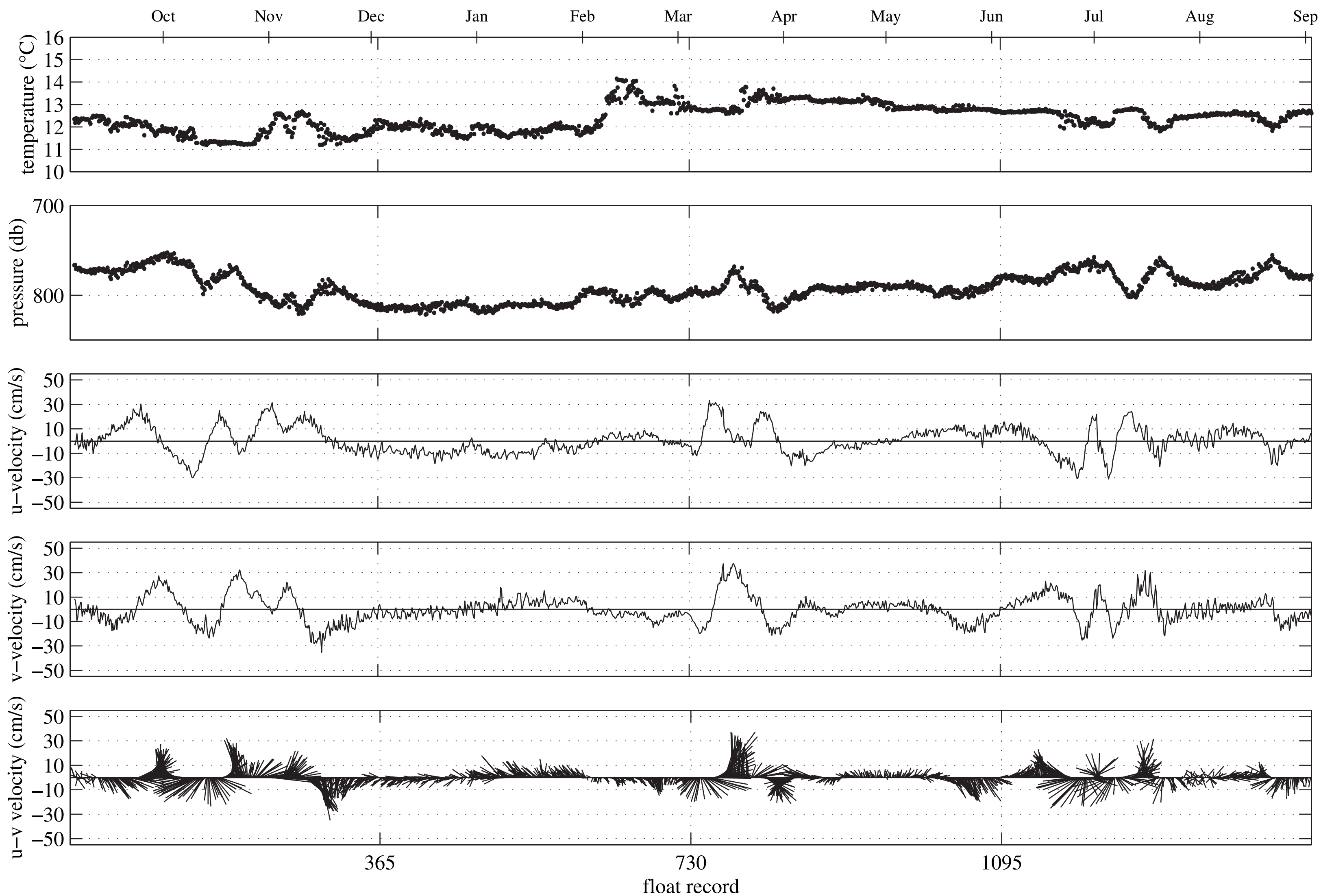

Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
temperature (°C)
17
16
15
pressure (db)
1170
1190
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
50
30
10
-10
-30
-50
400
800
1200
float record

r210: 100% msg return



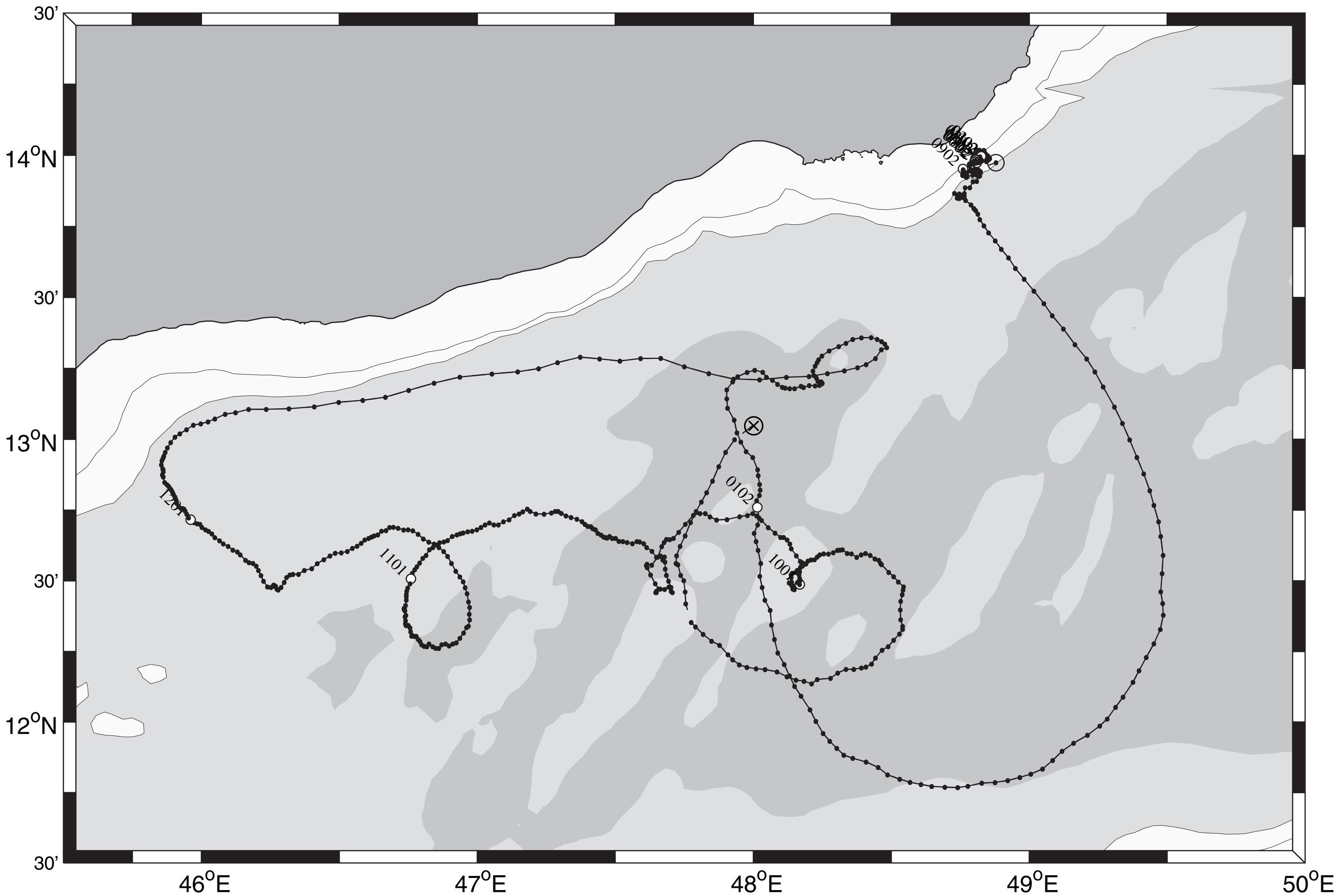
r210

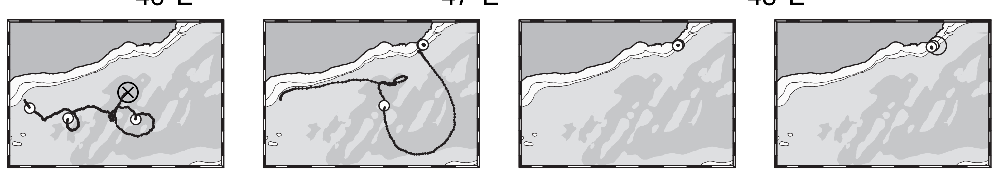
2002



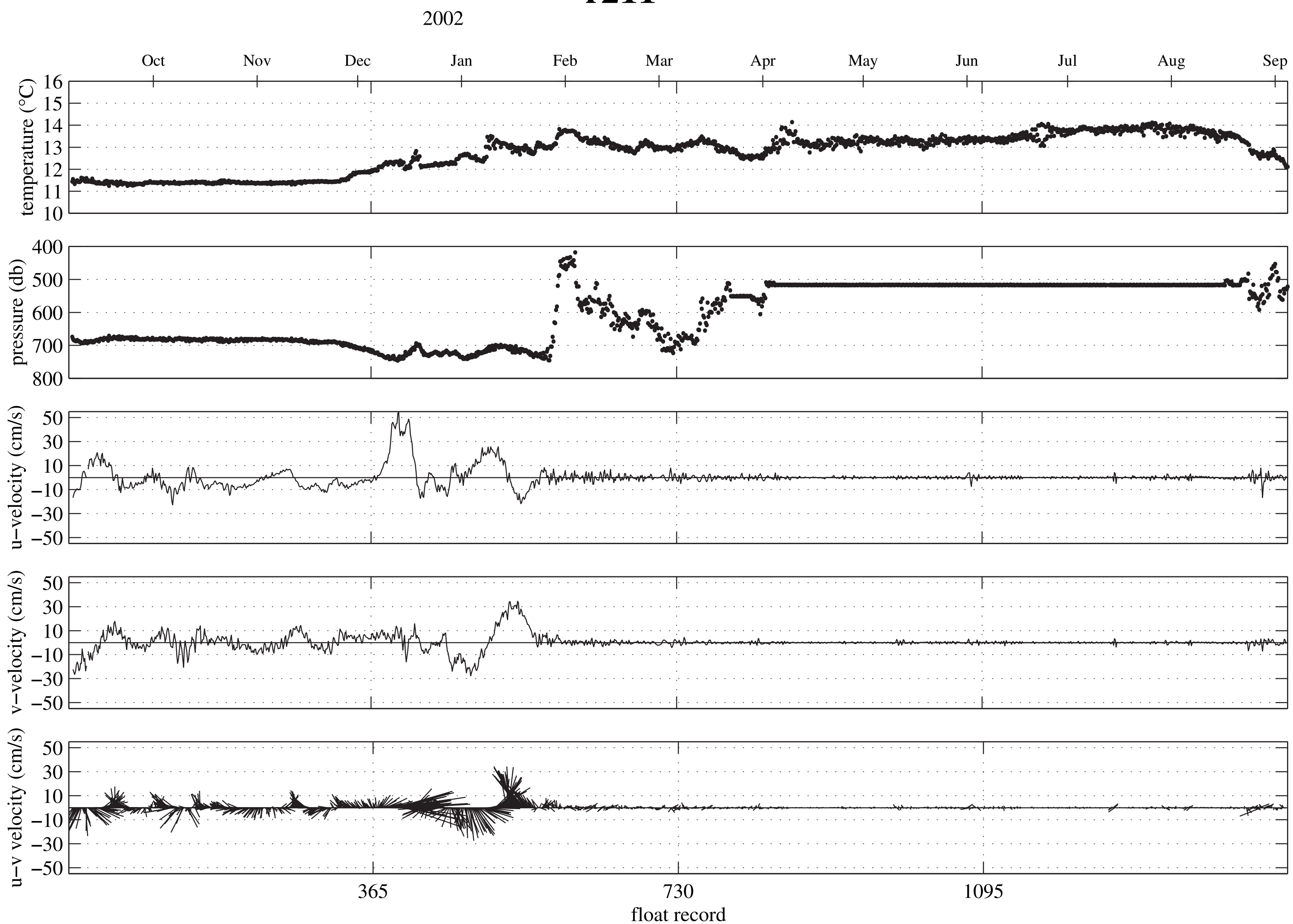
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
temperature (°C)
16
15
14
13
12
11
10
pressure (db)
700
800
u−velocity (cm/s)
50
30
10
−10
−30
−50
v−velocity (cm/s)
u−v velocity (cm/s)
365
730
1095
float record

r211: 100% msg return

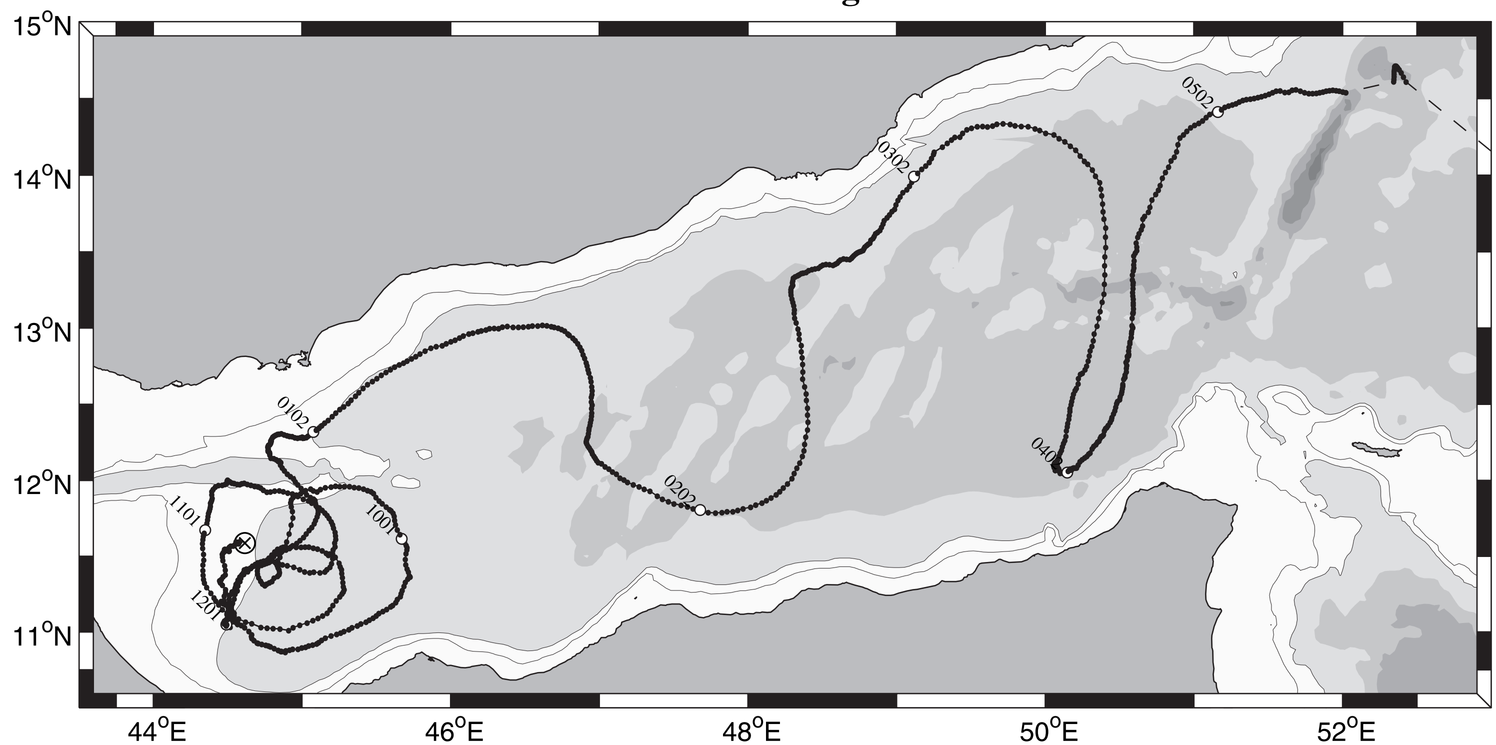


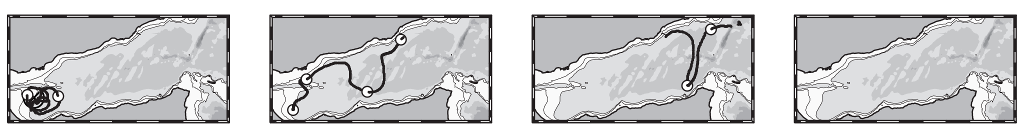


r211

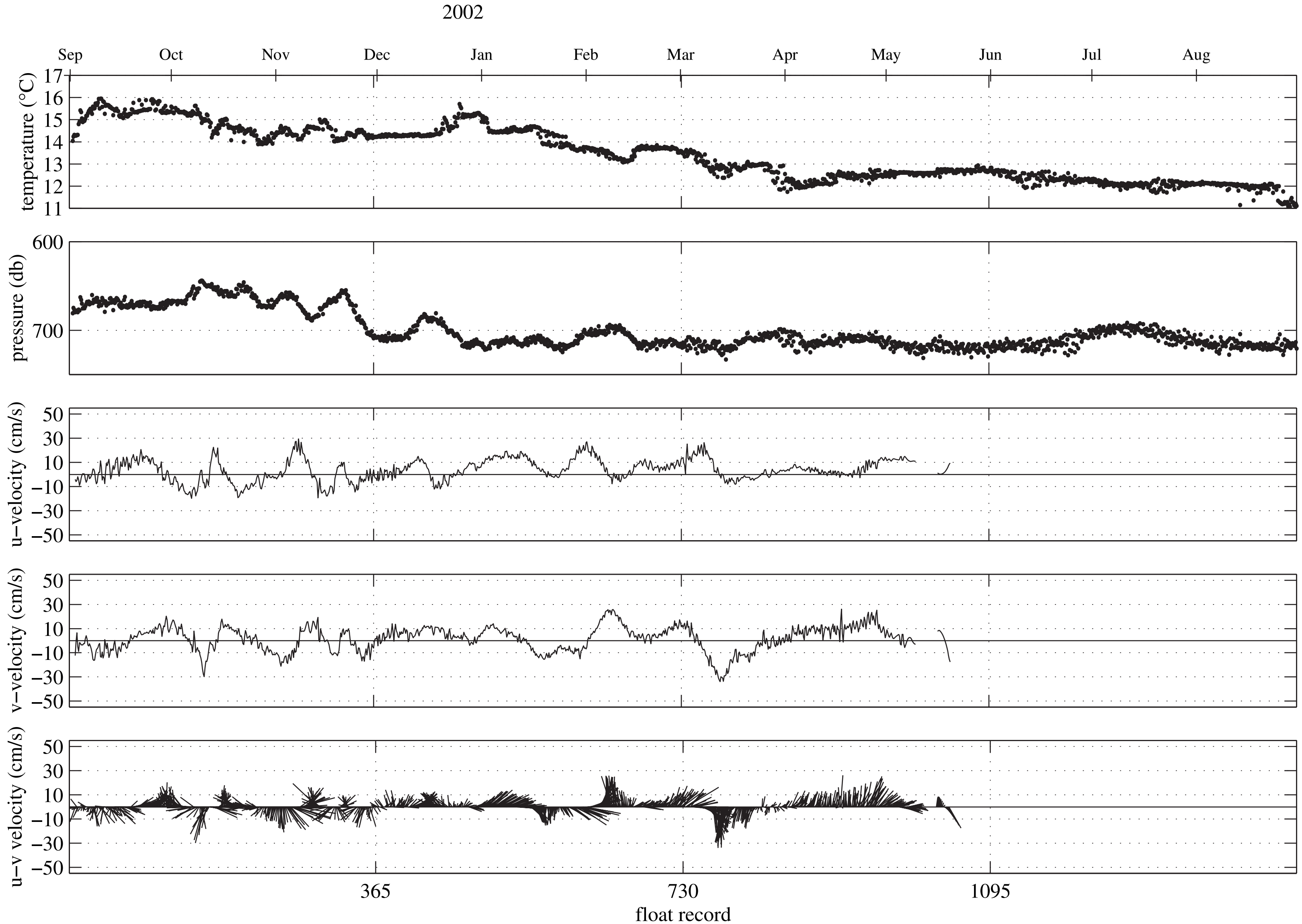

2002
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
365
730
1095
float record

r212: 100% msg return

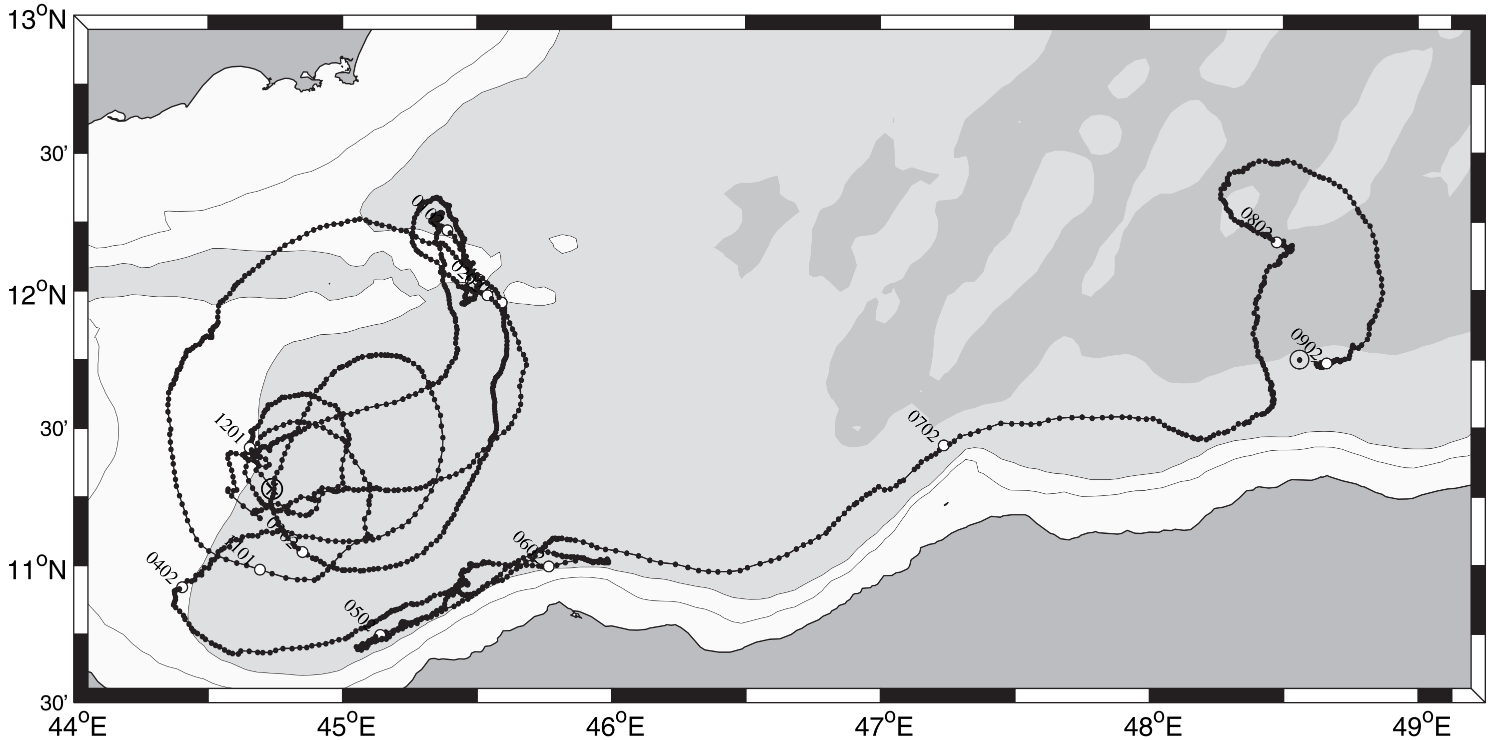


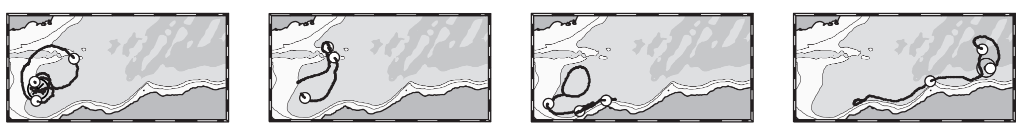


r212

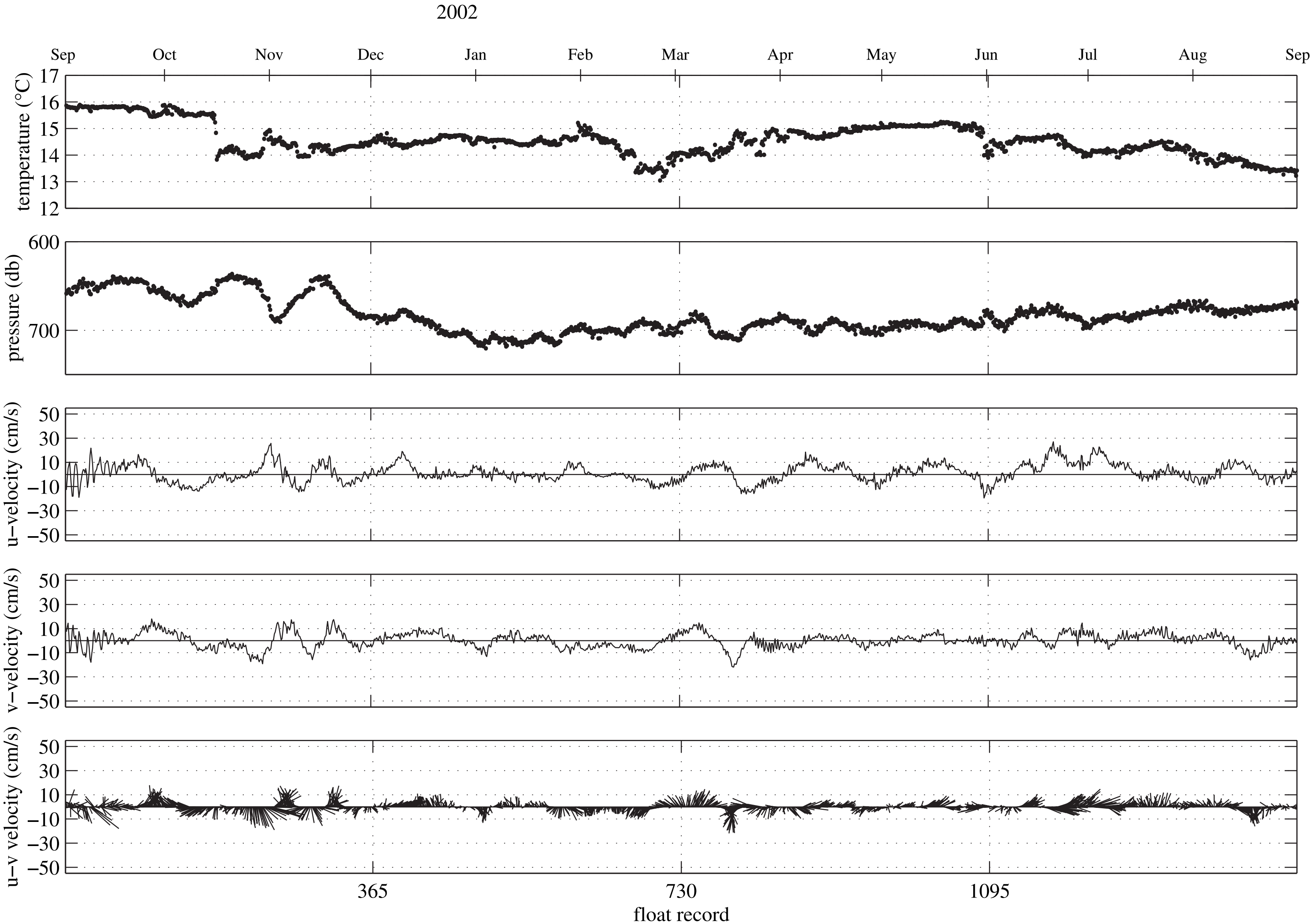

2002
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
365
730
1095
float record

r213: 100% msg return



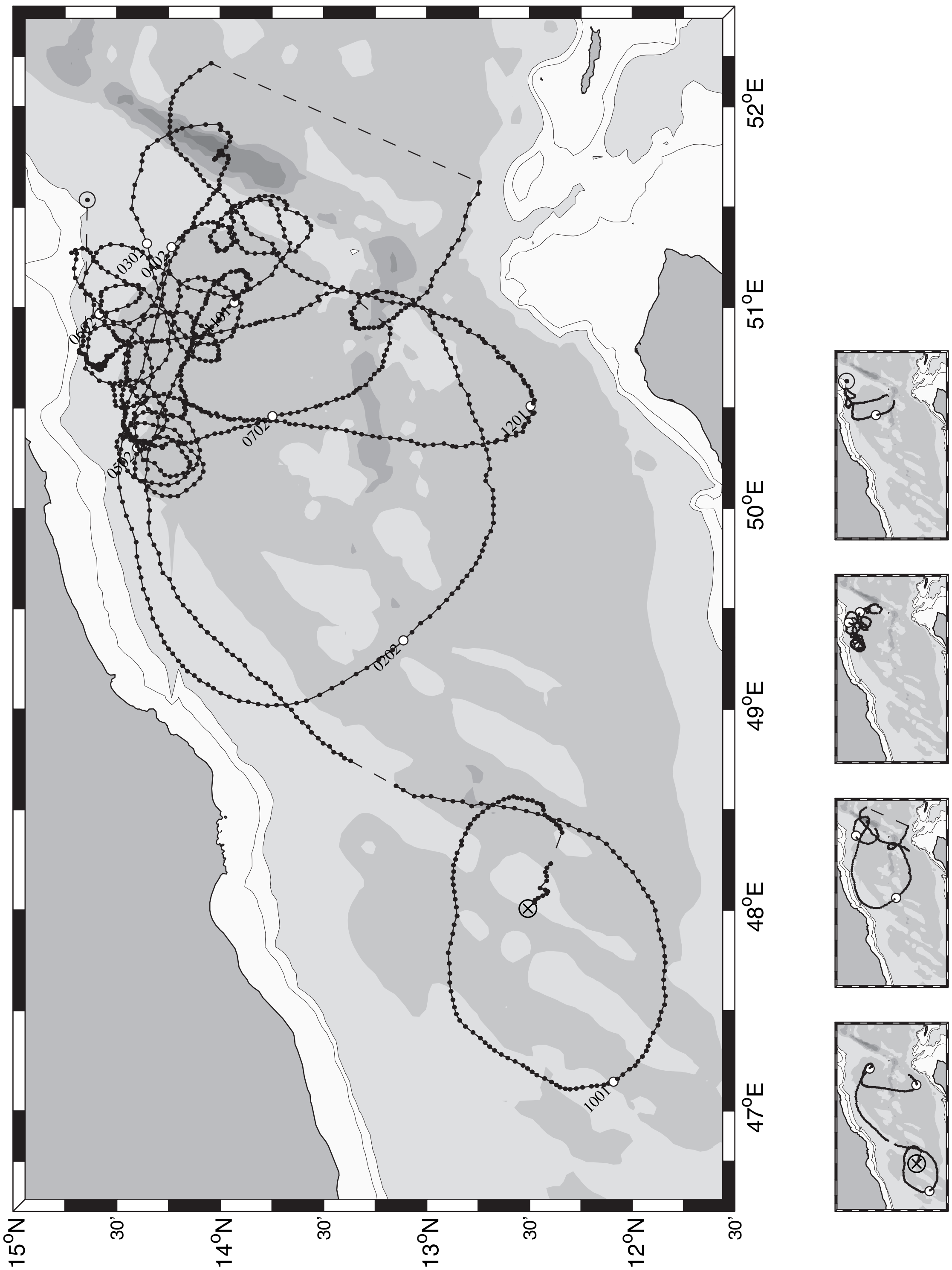


r213

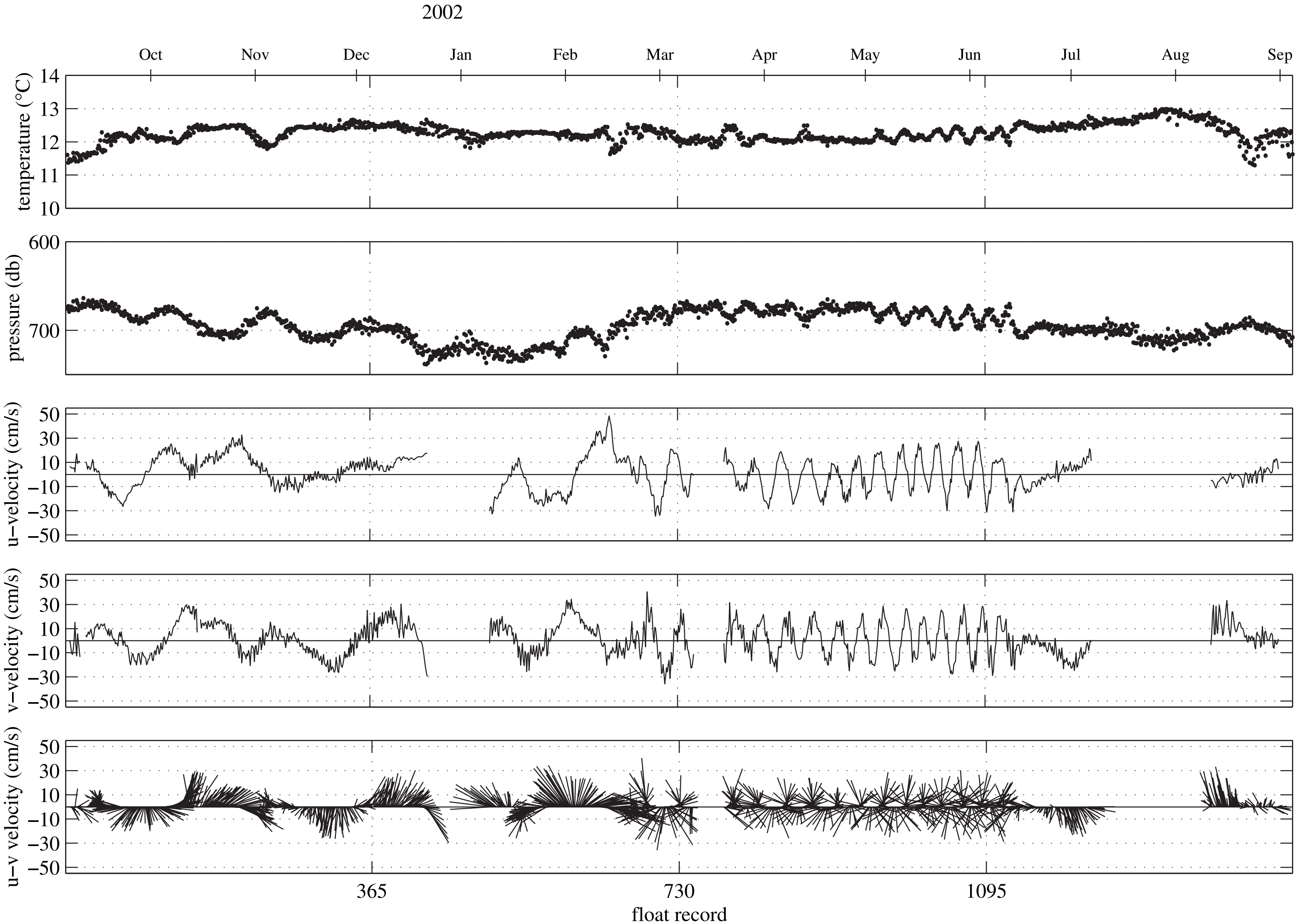


2002
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
temperature (°C)
17
16
15
14
13
12
pressure (db)
600
700
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
50
30
10
−10
−30
−50
365
730
1095
float record

r214: 100% msg return

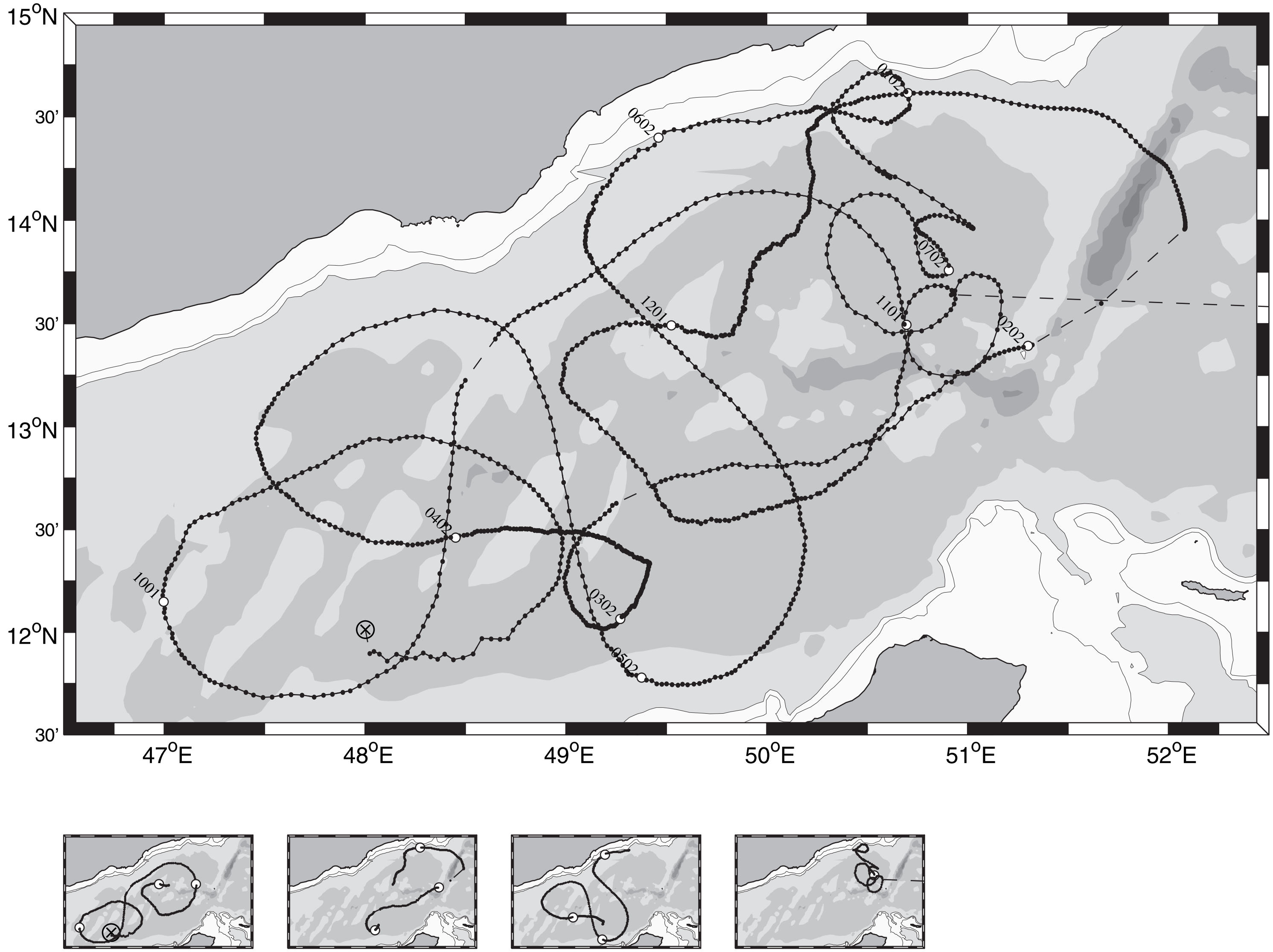


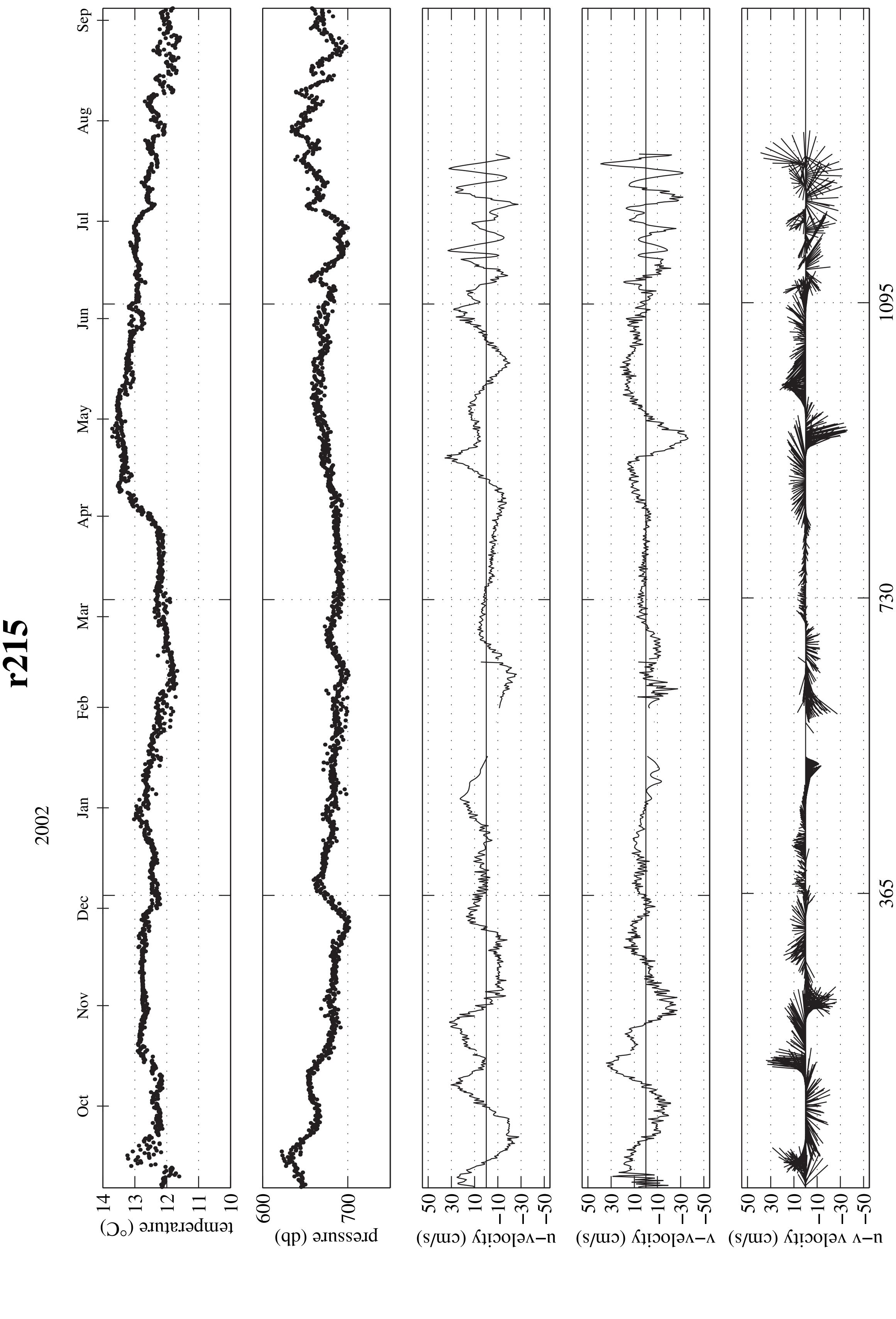
r214



2002
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
365
730
1095
float record

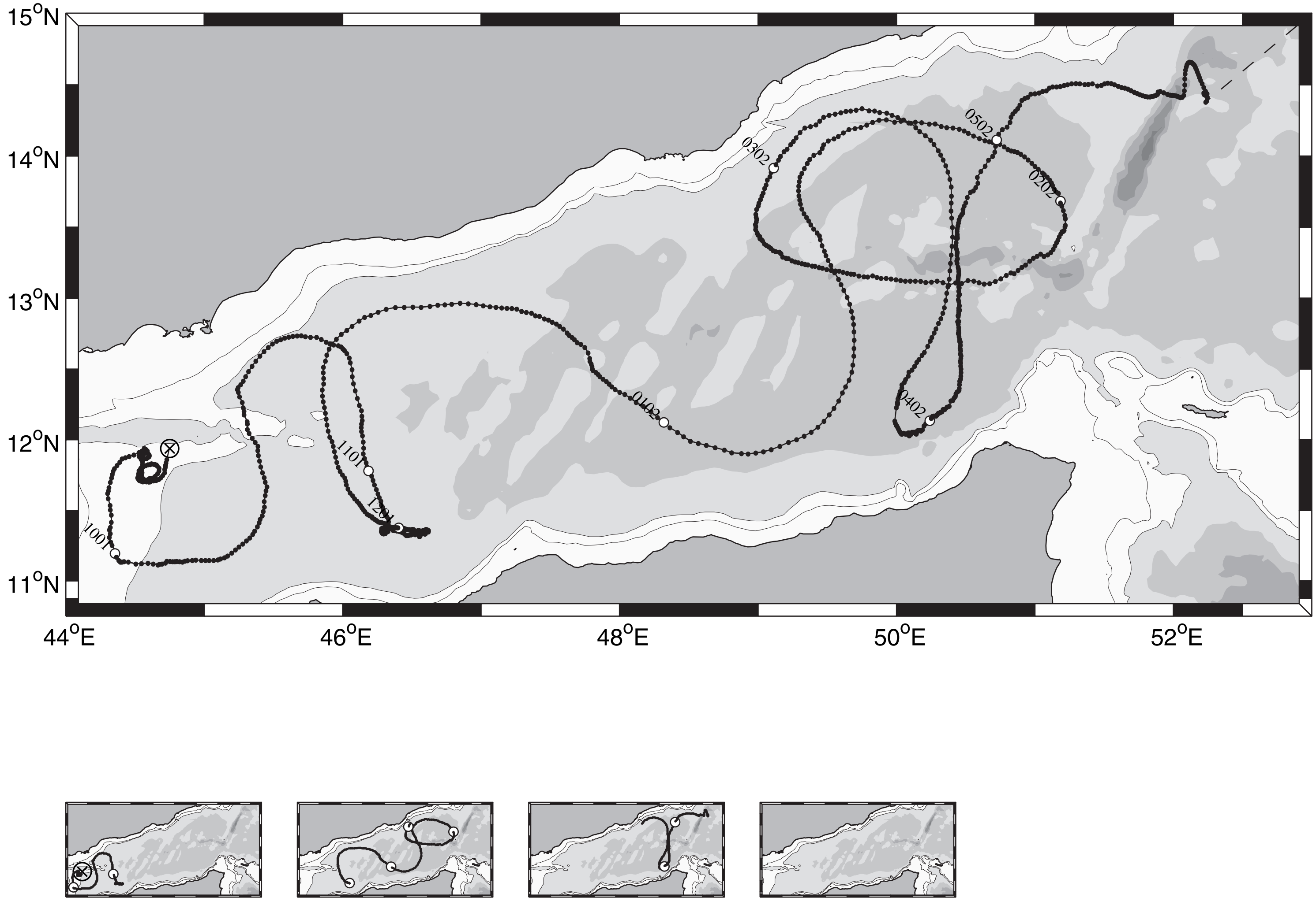
r215: 100% msg return



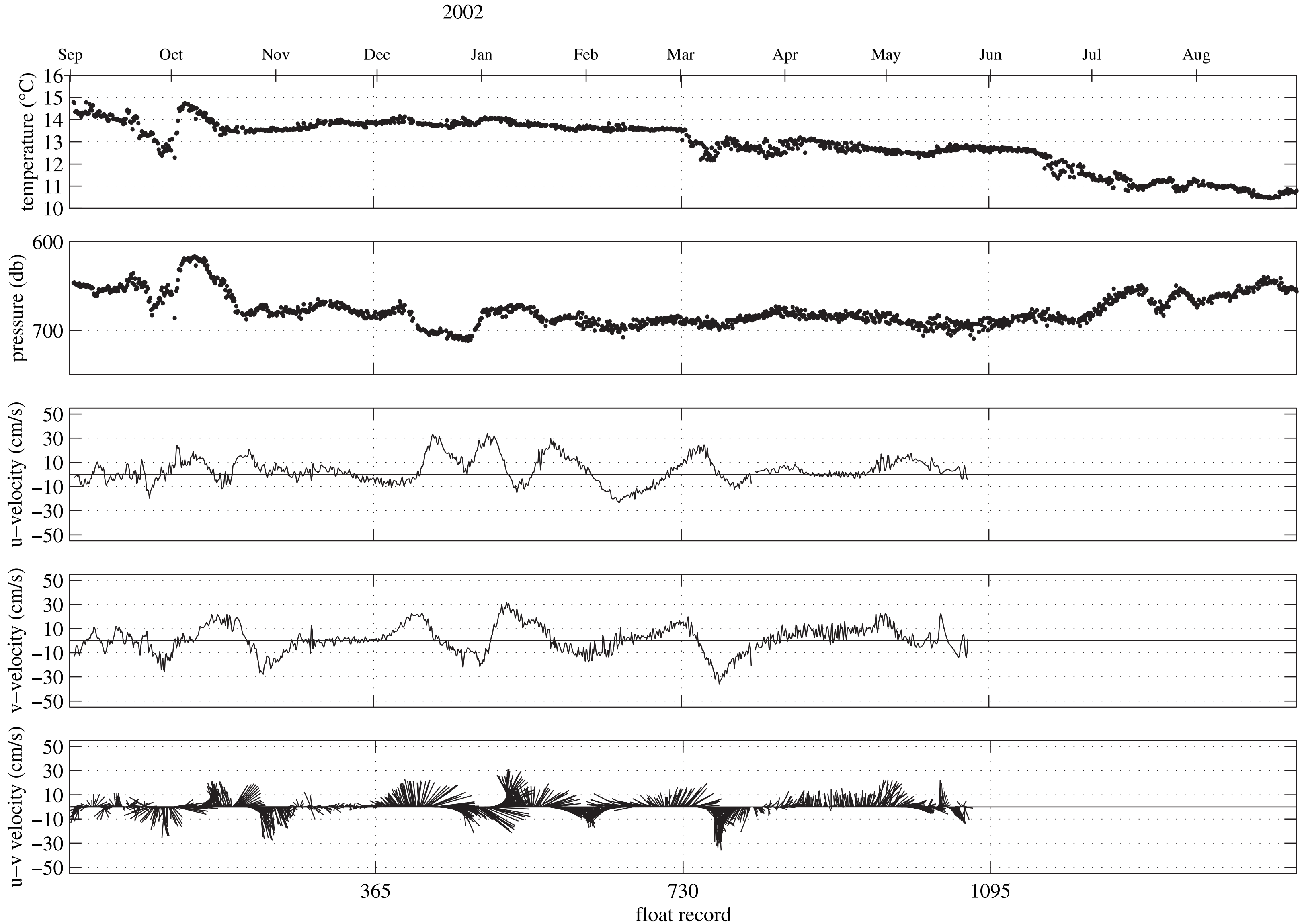


r215
2002
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
365
730
1095
float record

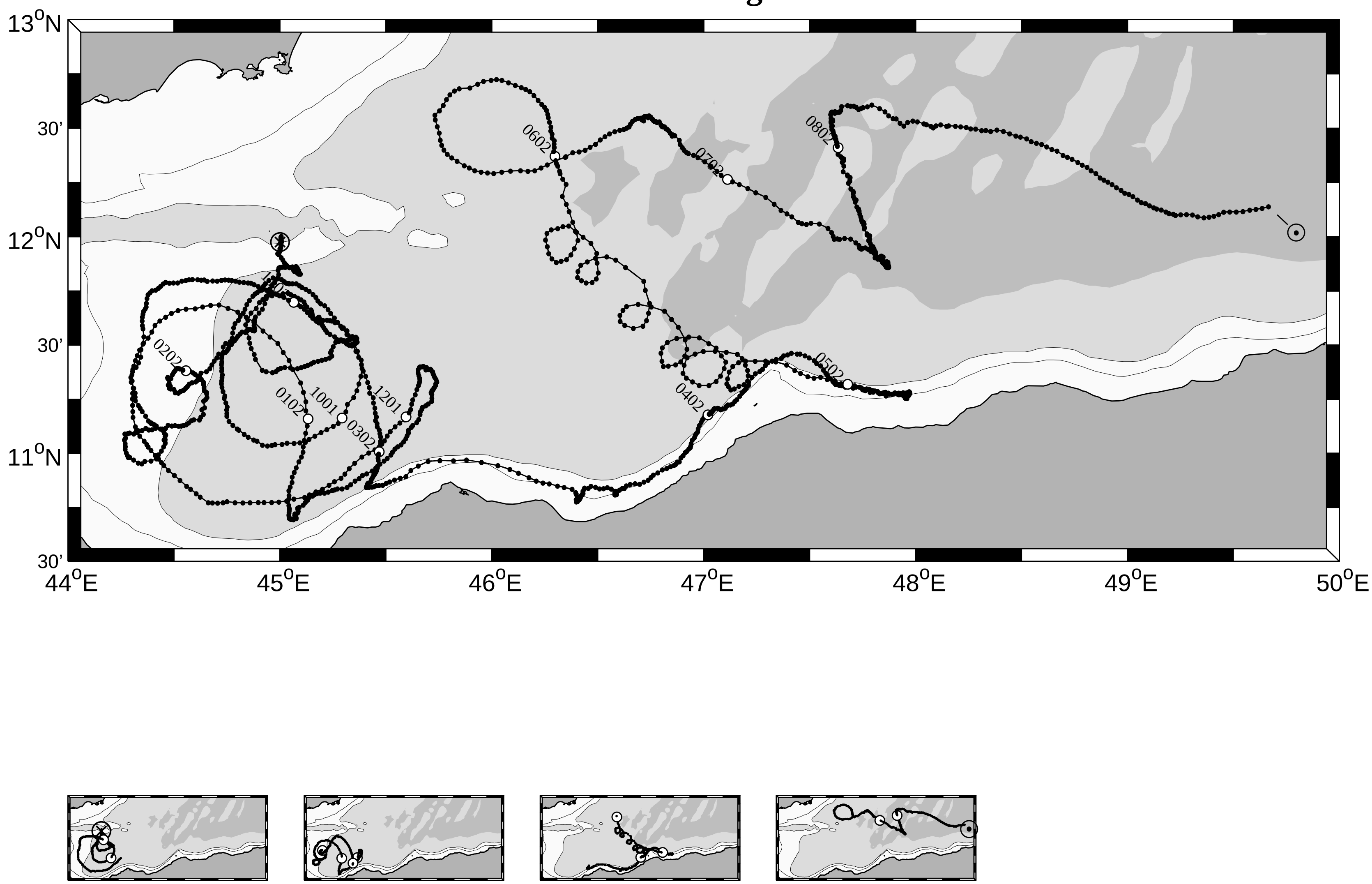
r216: 89% msg return

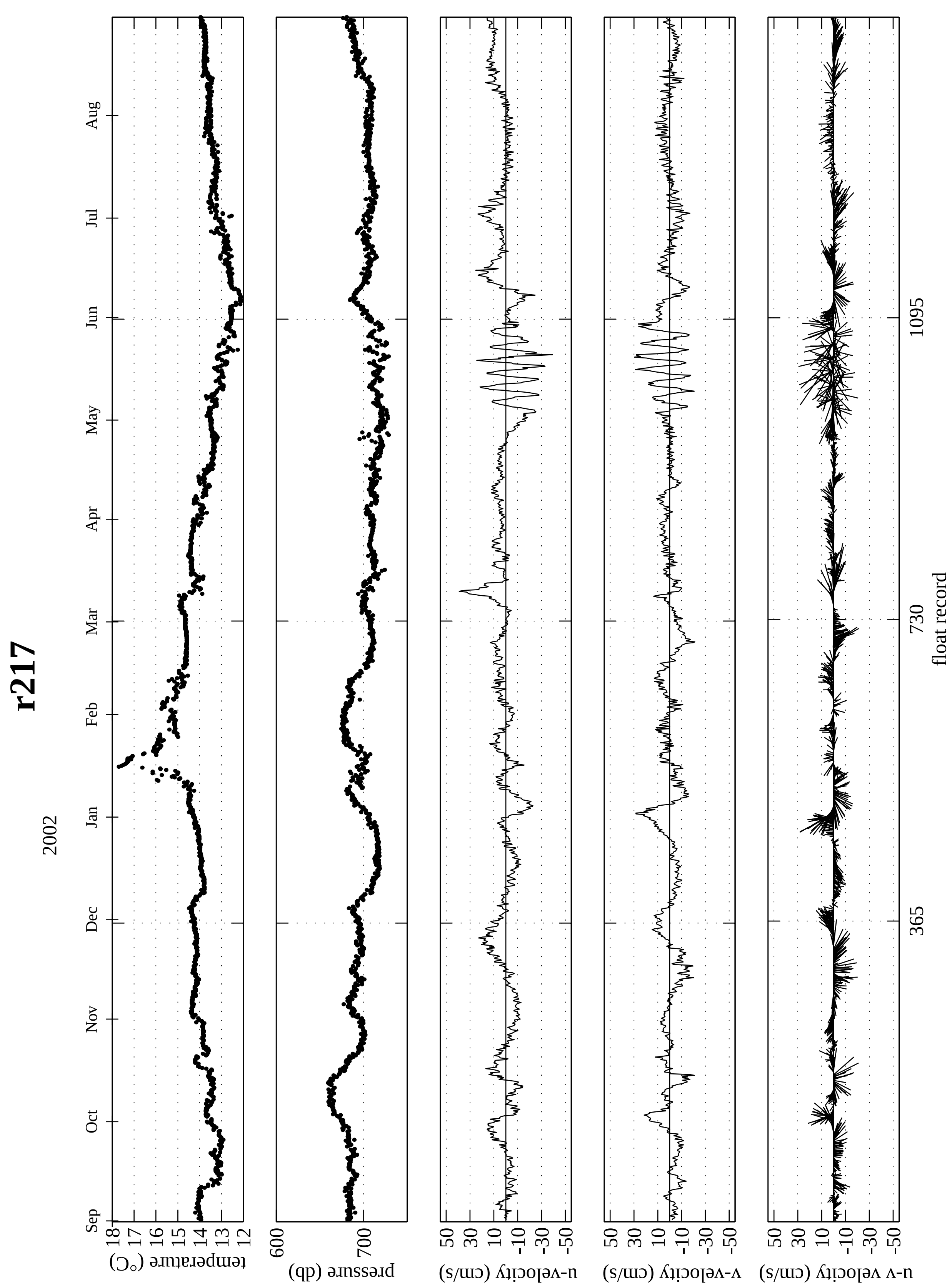


r216


2002
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
temperature (°C)
16
15
14
13
12
11
10
pressure (db)
600
700
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
50
30
10
−10
−30
−50
365
730
1095
float record

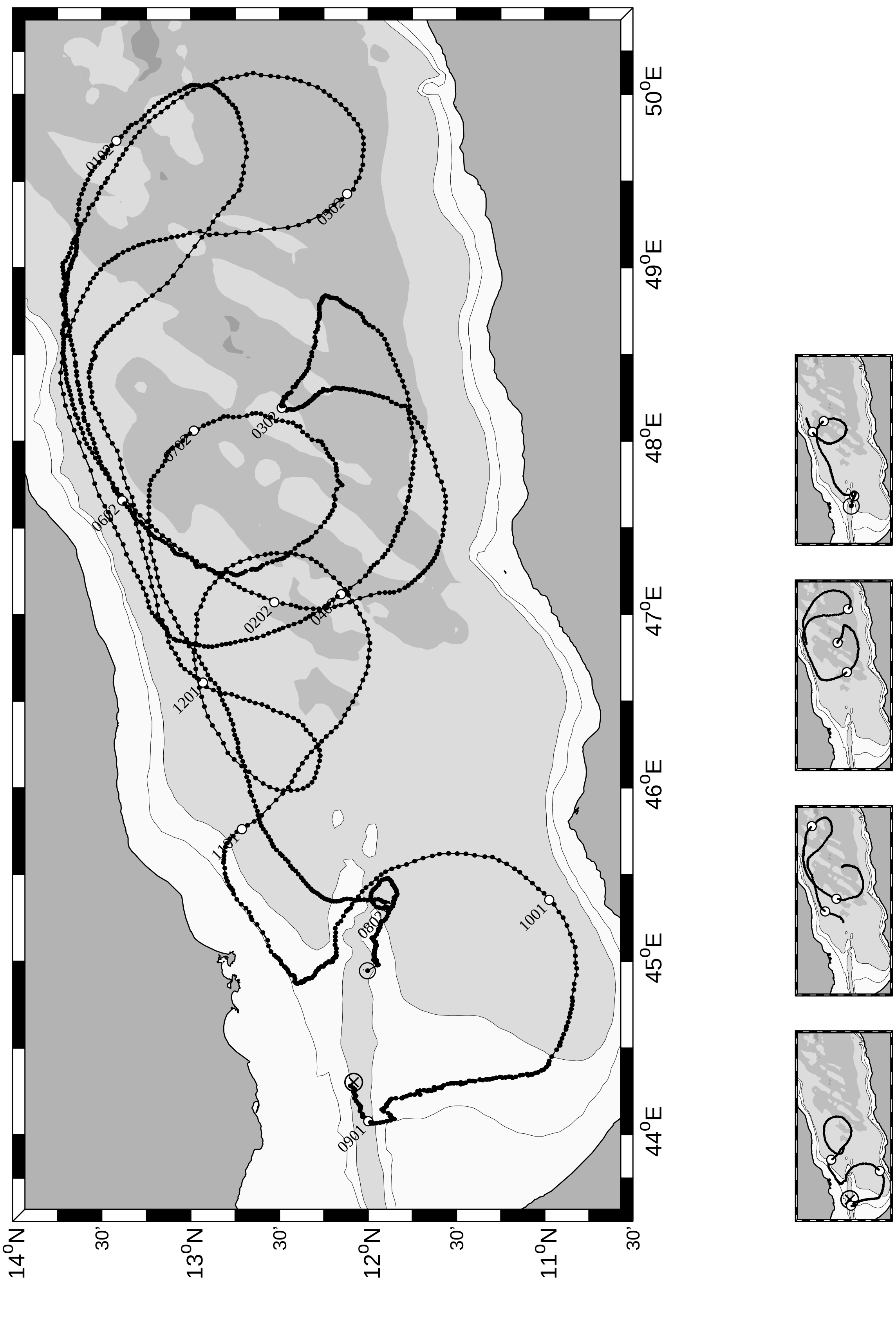
r217: 91% msg return

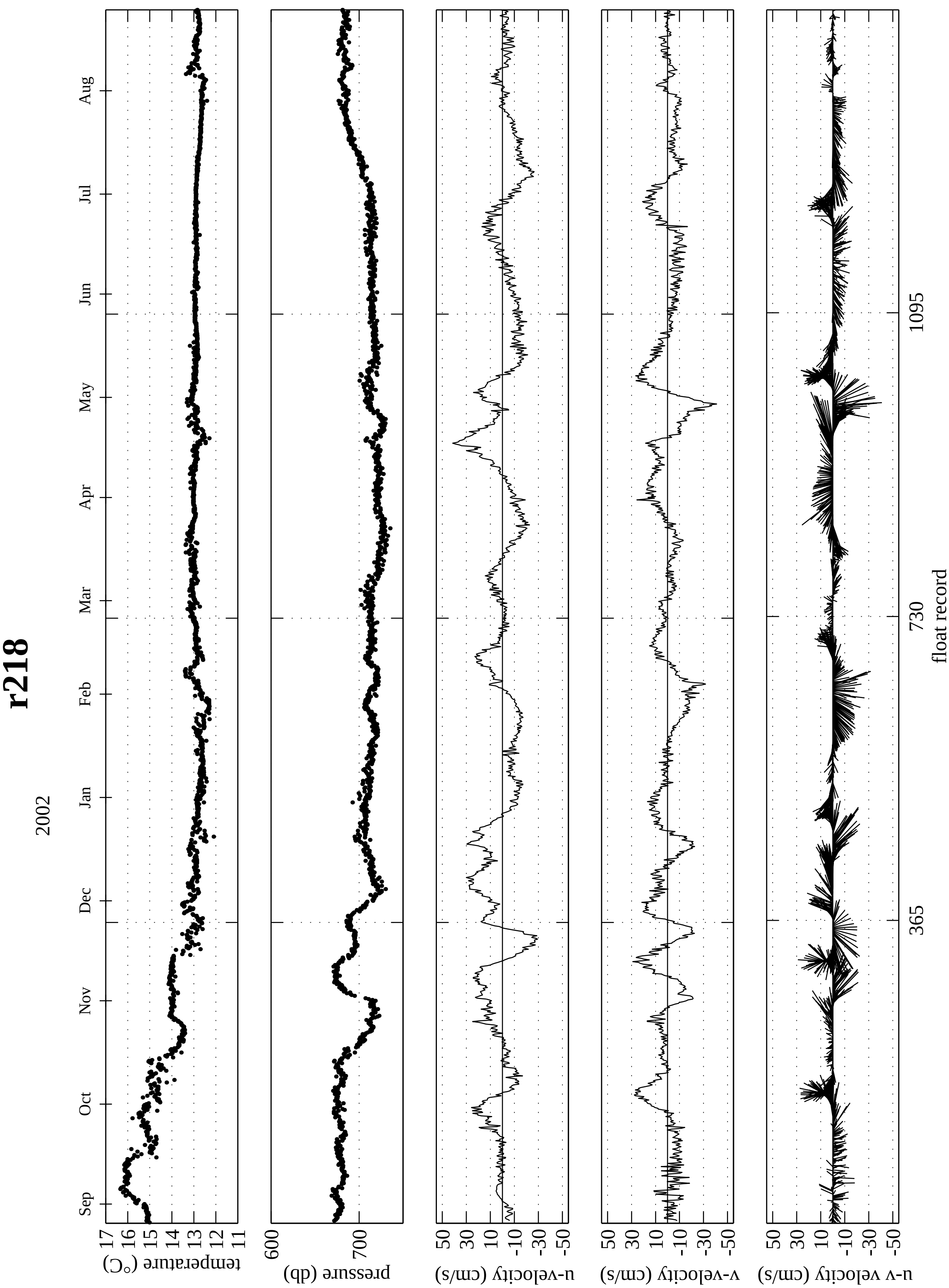




r217
2002
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
temperature (°C)
pressure (db)
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
365
730
1095
float record

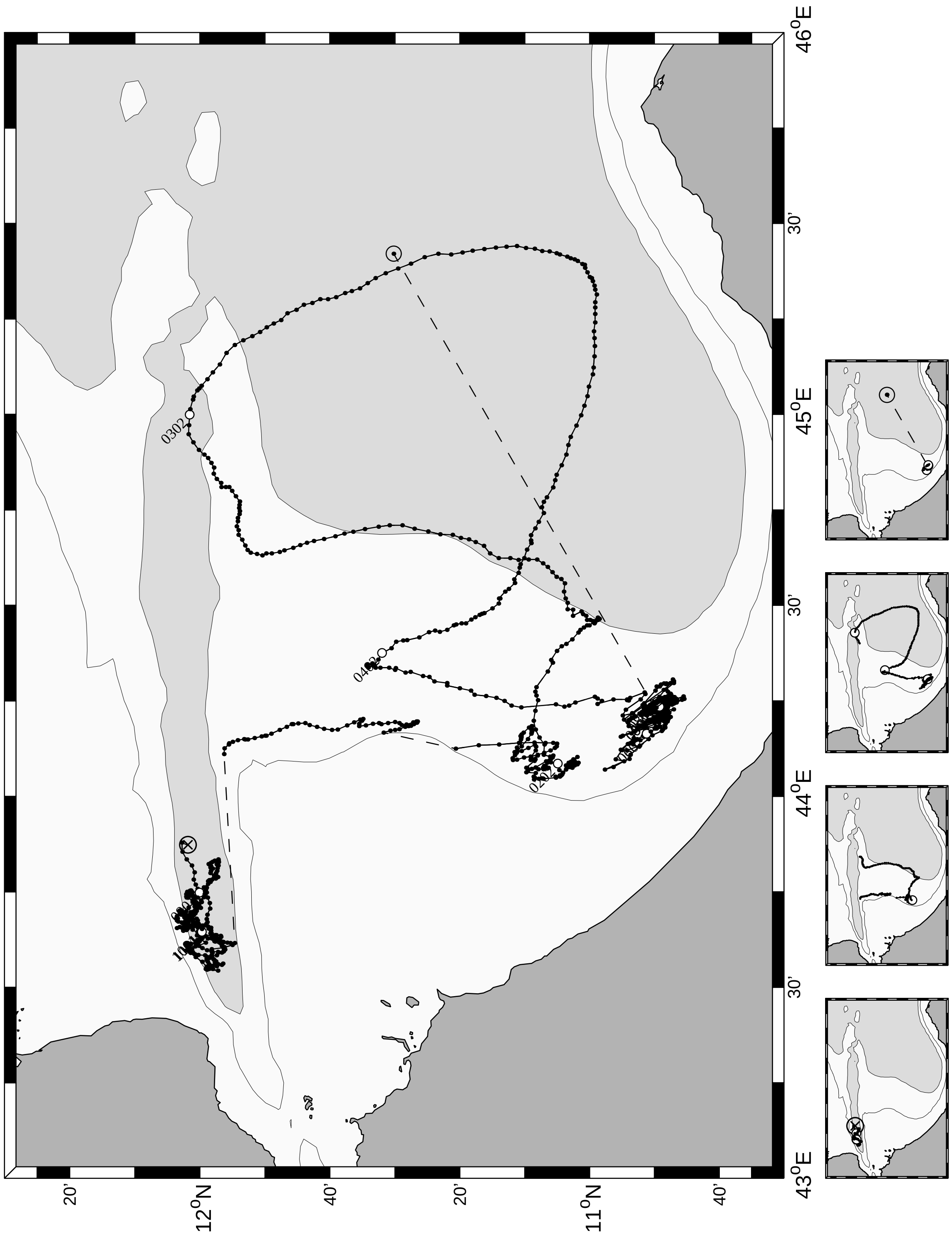
r218: 98% msg return

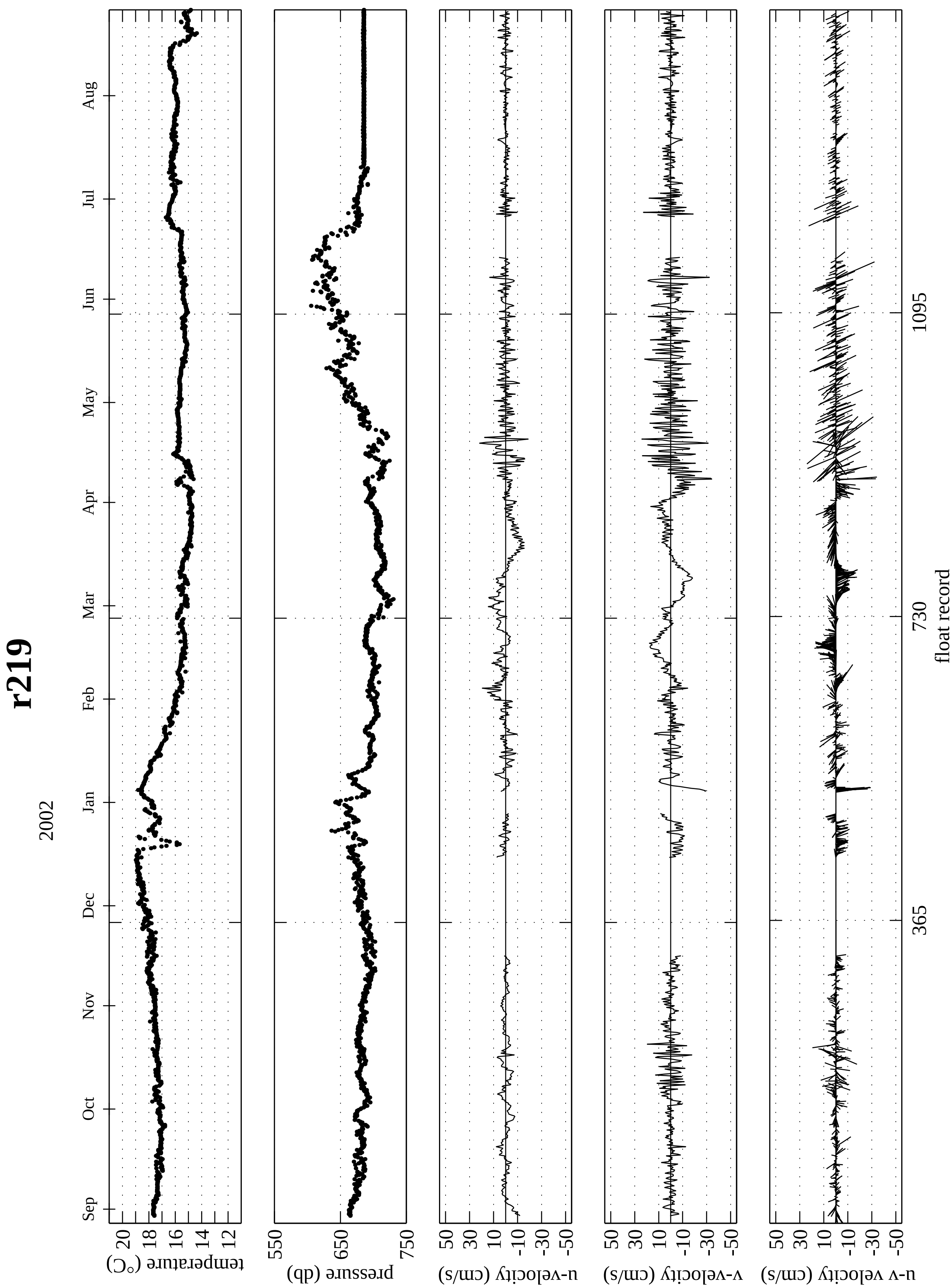




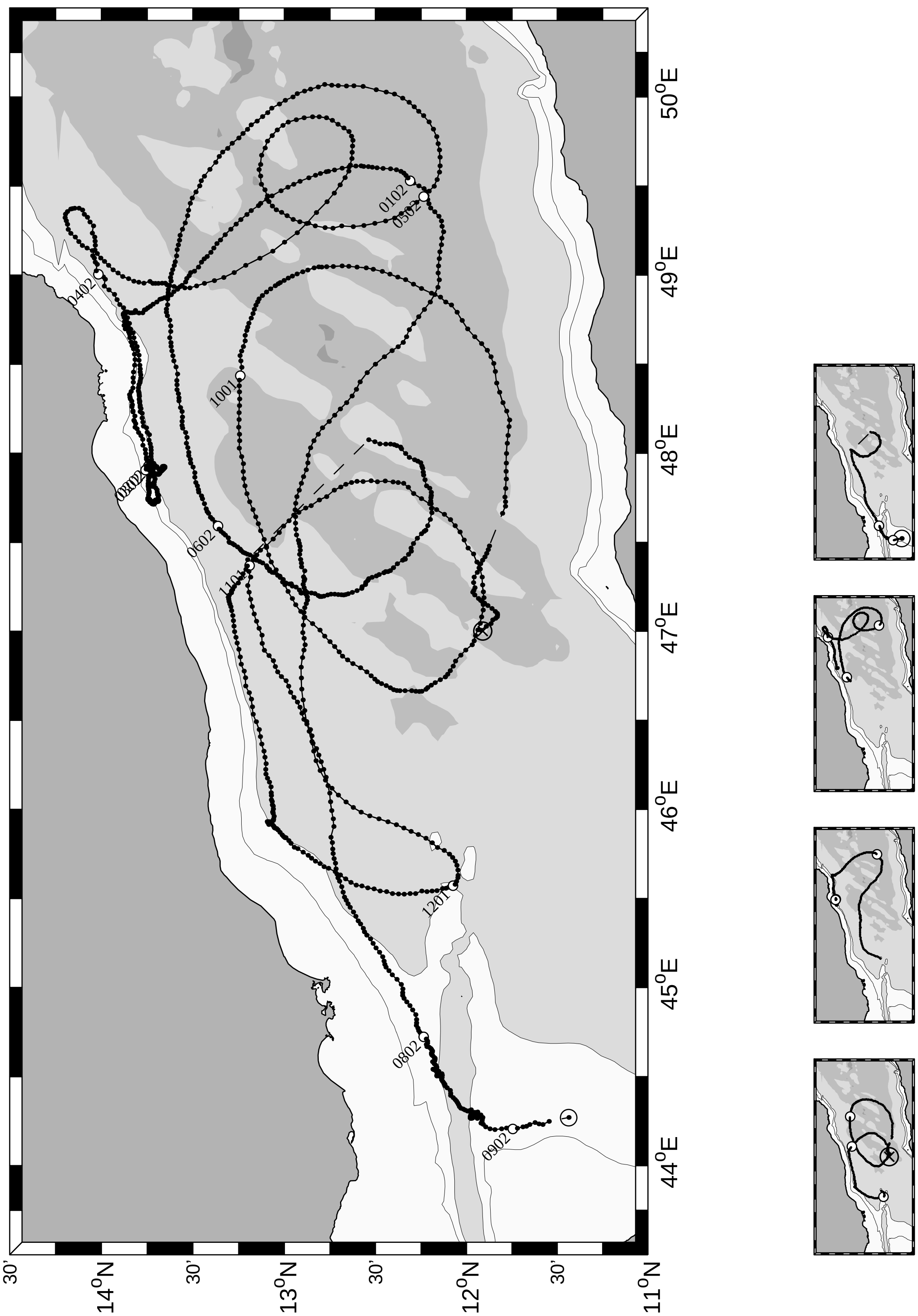
r218
2002
temperature (°C)
pressure (db)
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
float record
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
365
730
1095

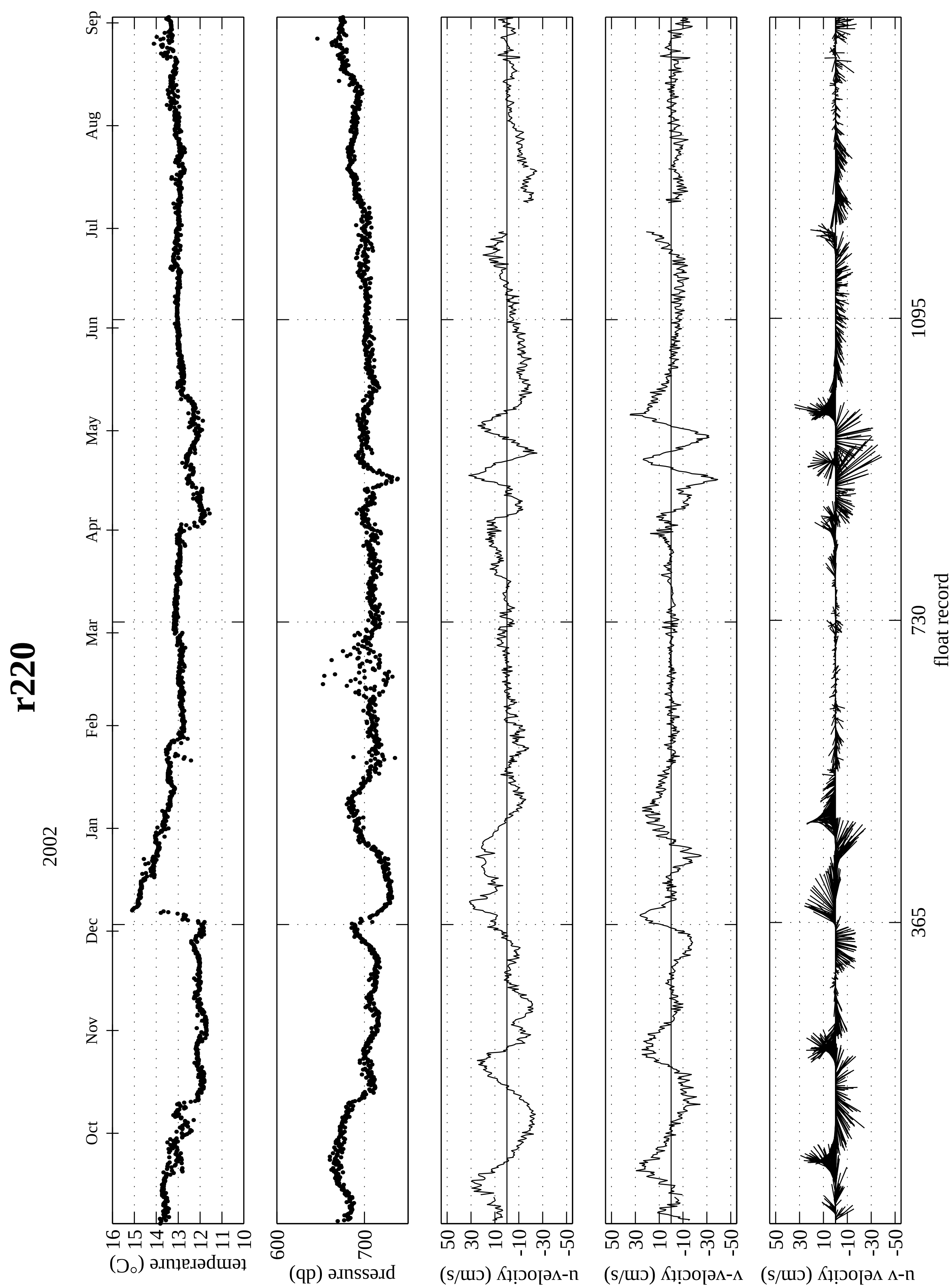
r219: 100% msg return



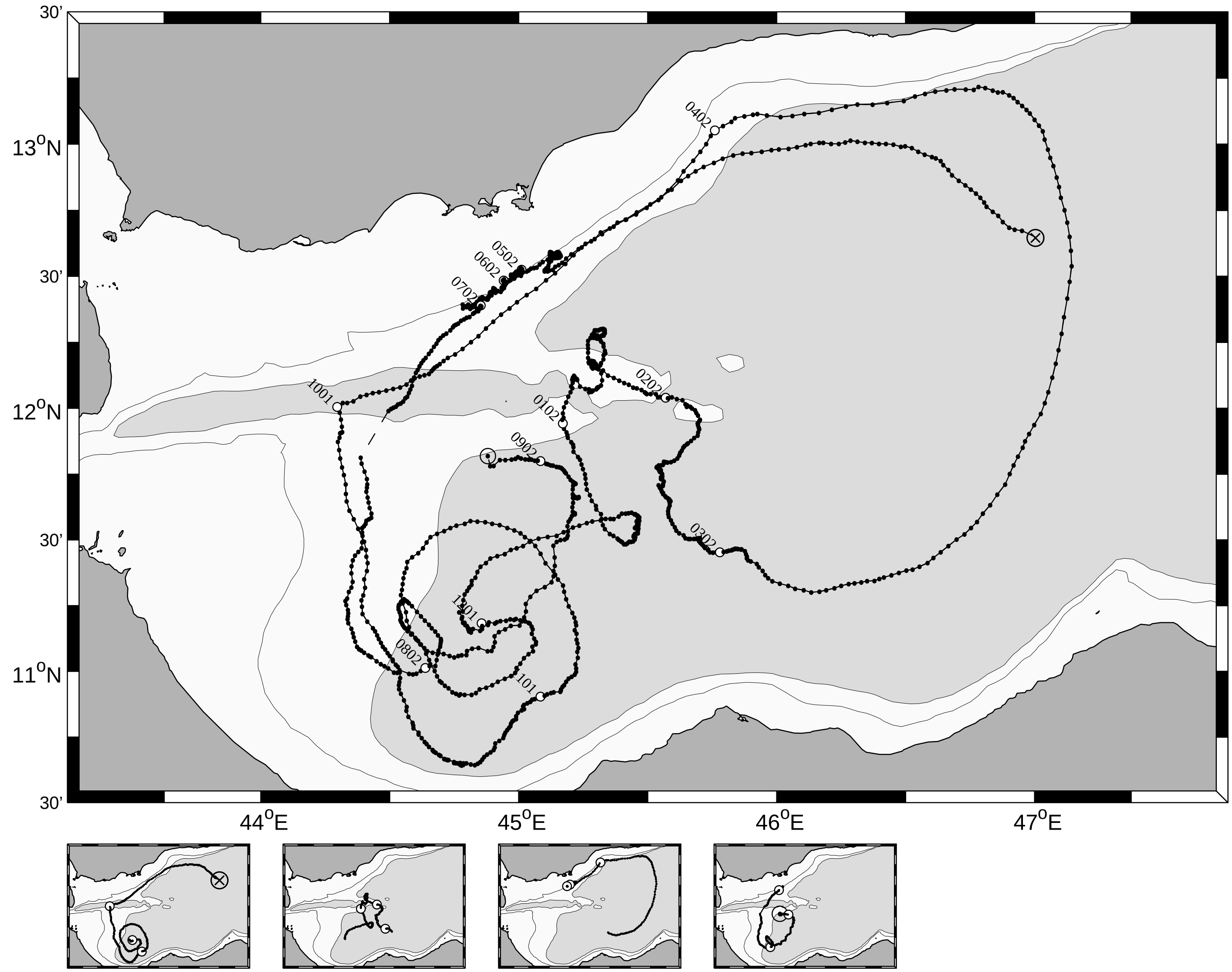

r219
2002
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
temperature (°C)
pressure (db)
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
365
730
1095
float record

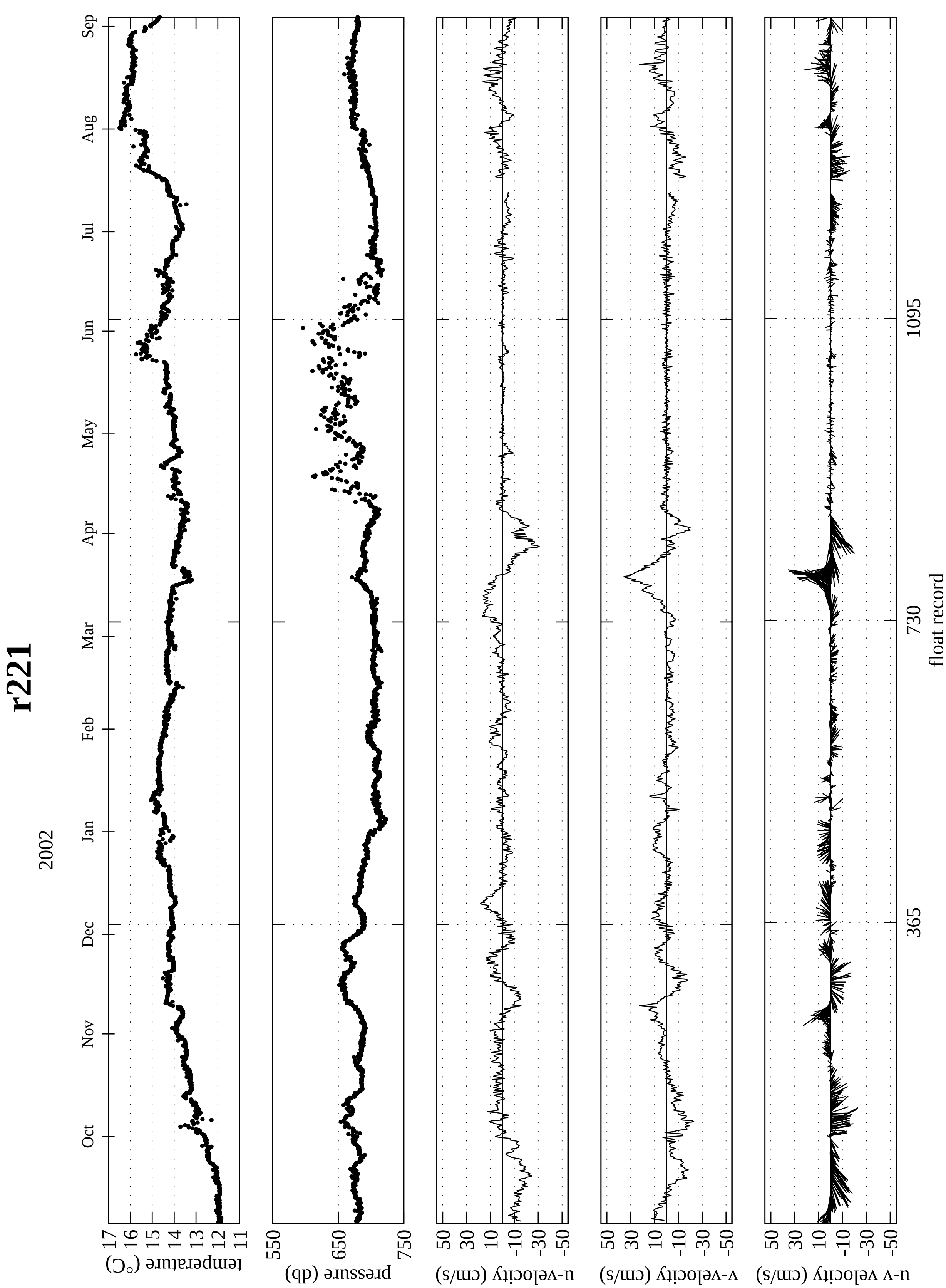
r220: 100% msg return




r220
2002
Sep
Aug
Jul
Jun
May
Apr
Mar
Feb
Jan
Dec
Nov
Oct
16 15 14 13 12 11 10
temperature (°C)
600 700
pressure (db)
50 30 10 -10 -30 -50
u-velocity (cm/s)
50 30 10 -10 -30 -50
v-velocity (cm/s)
50 30 10 -10 -30 -50
u-v velocity (cm/s)
1095
730
365
float record

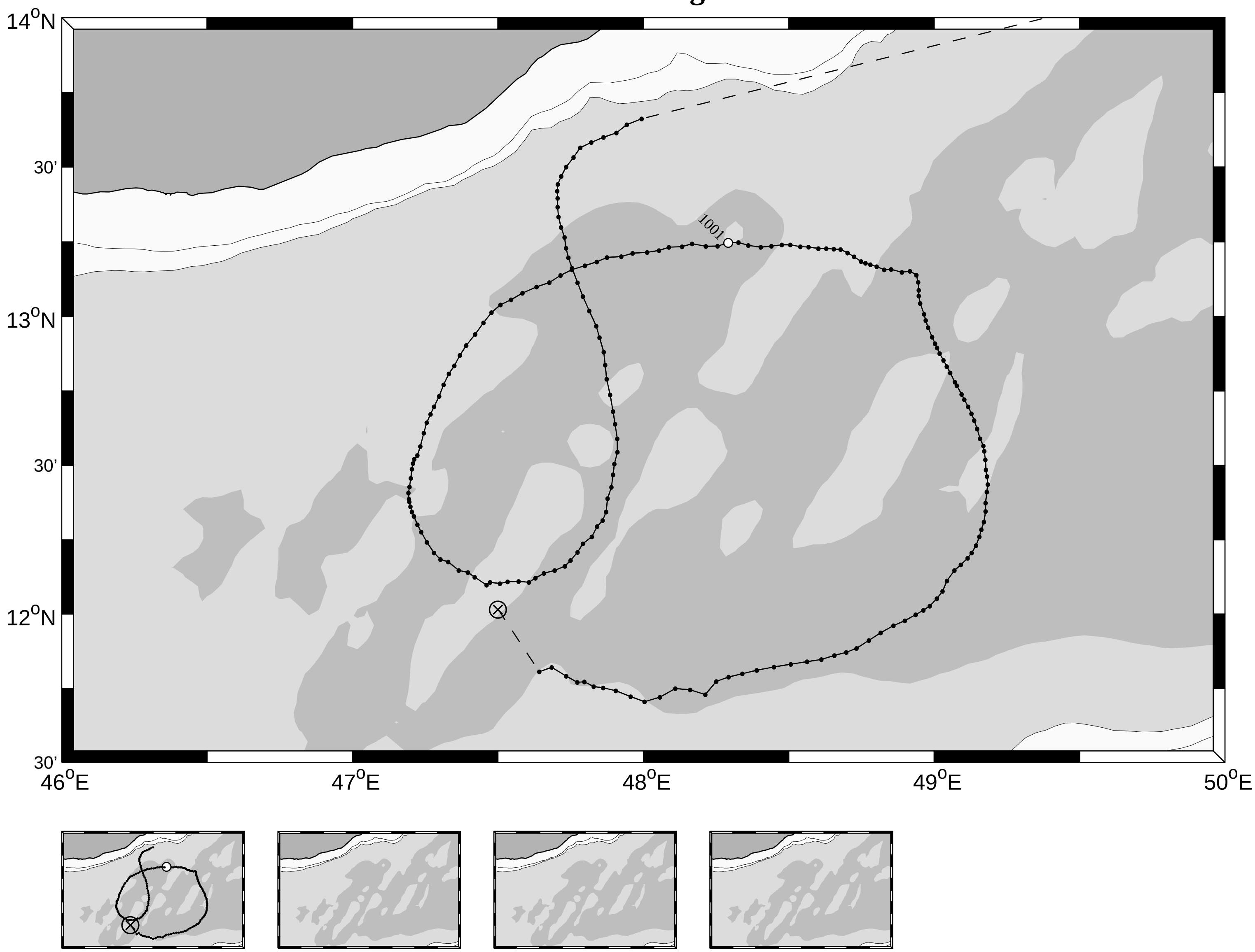
r221: 100% msg return

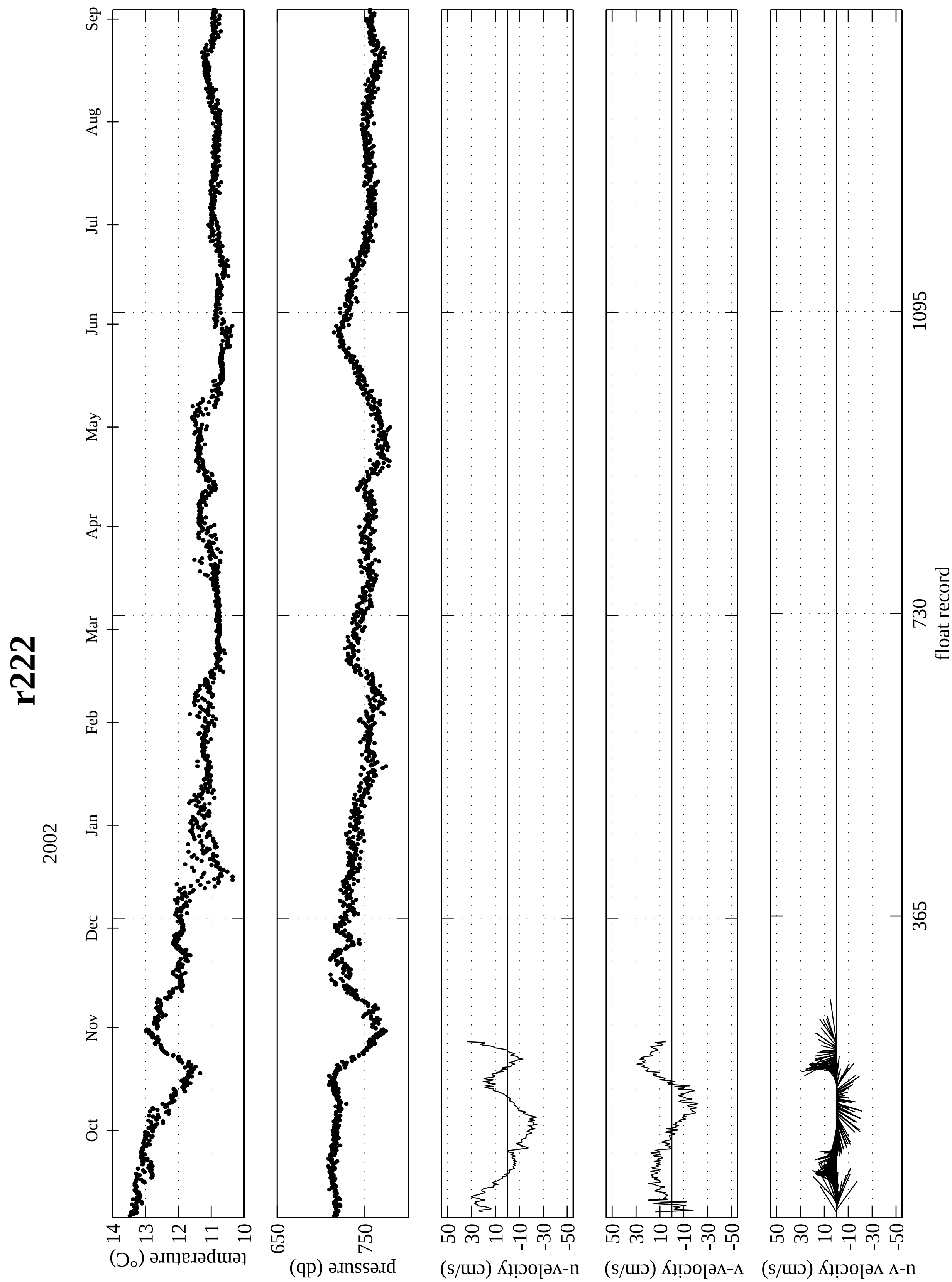




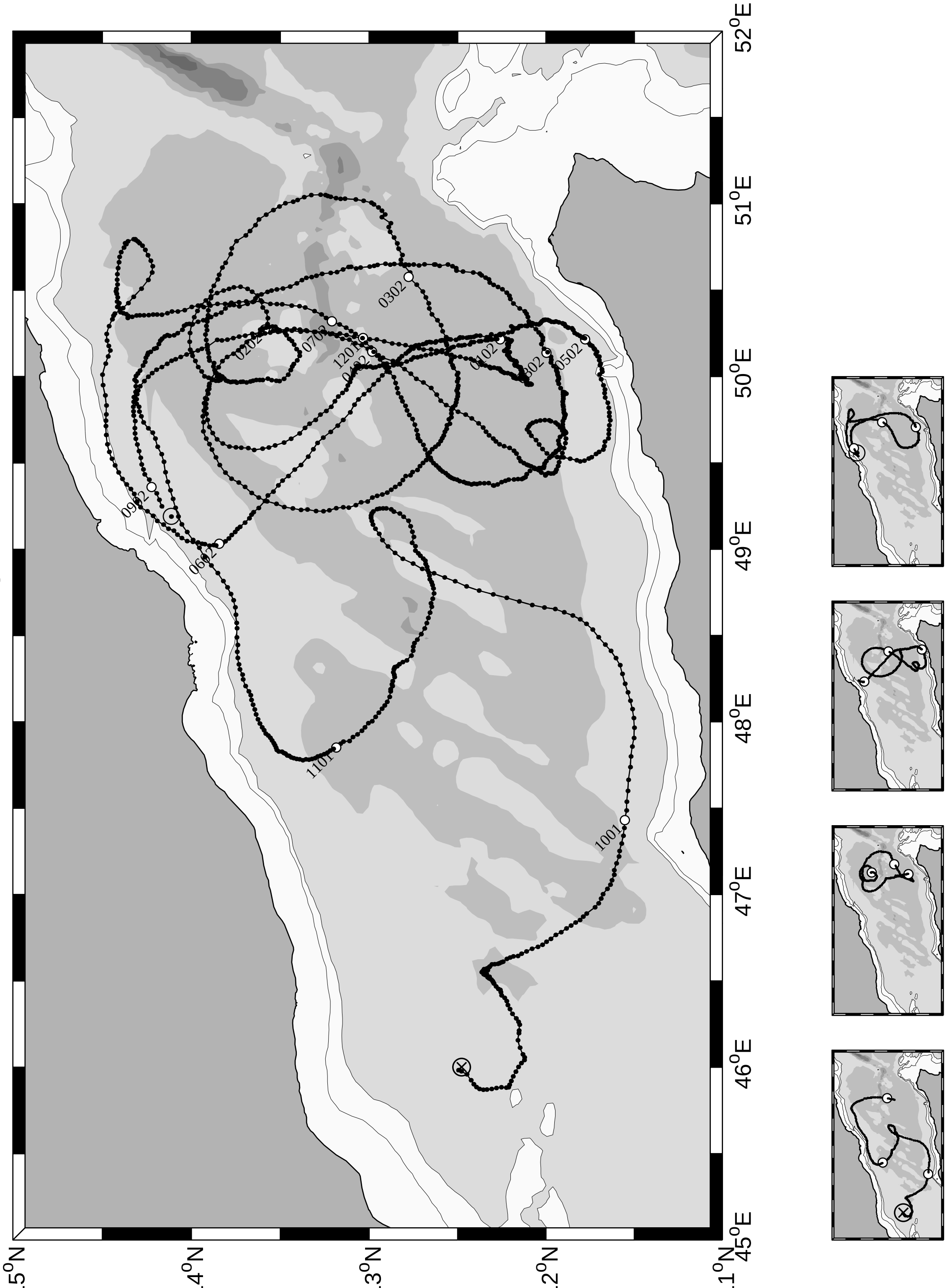
r221
2002
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
temperature (°C)
pressure (db)
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
365
730
1095
float record

r222: 100% msg return

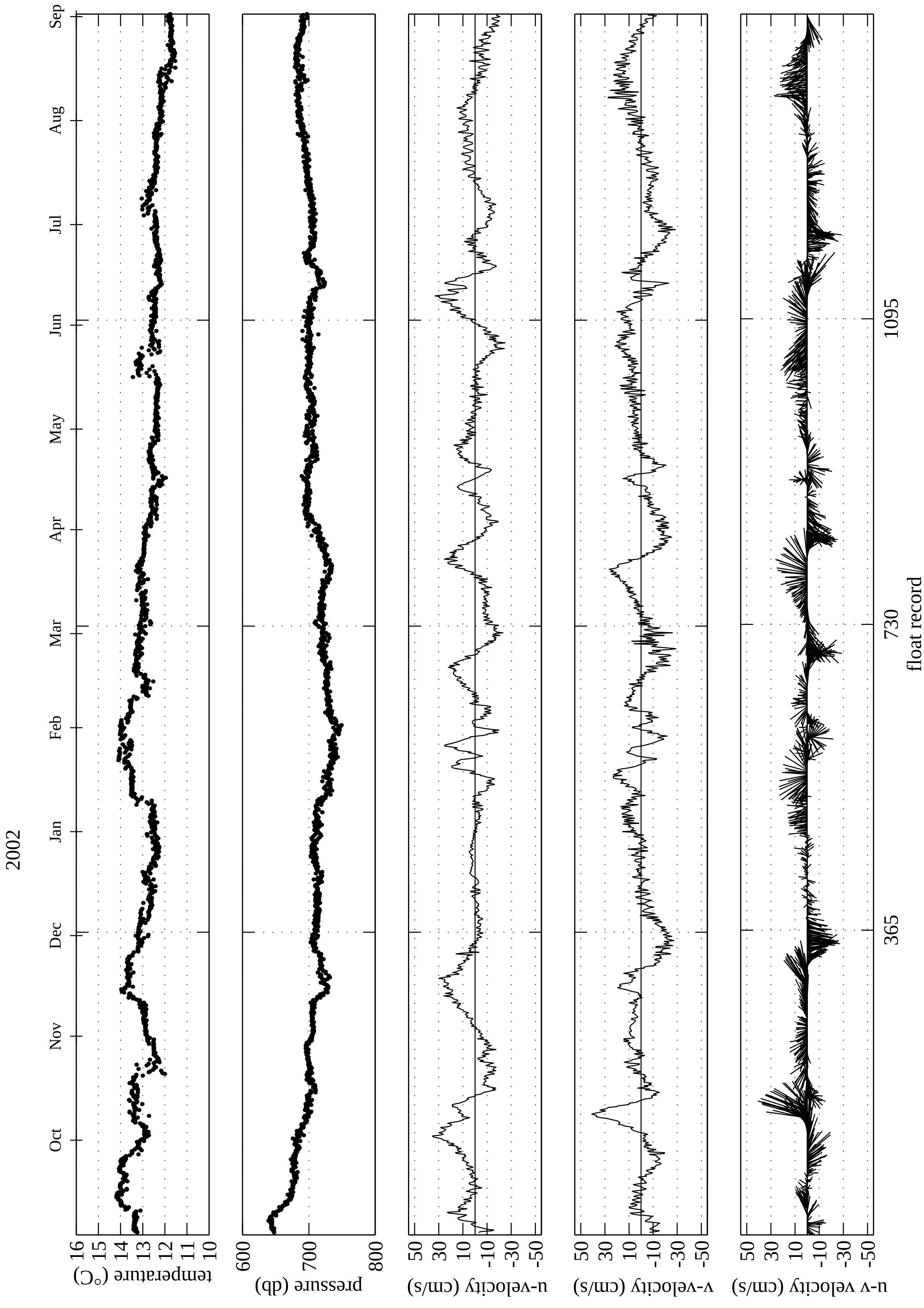


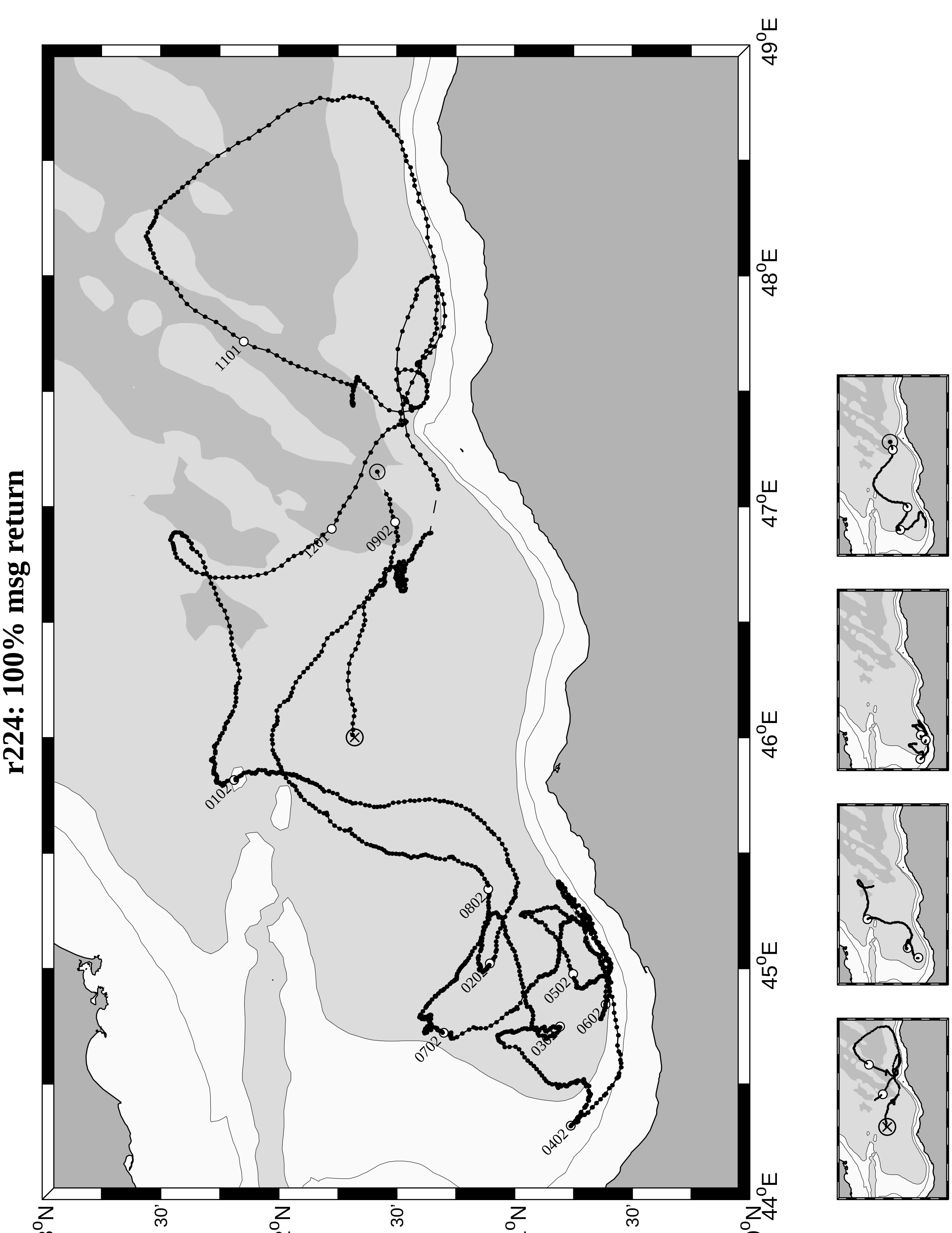

r222
2002
Sep
Aug
Jul
Jun
May
Apr
Mar
Feb
Jan
Dec
Nov
Oct
temperature (°C)
pressure (db)
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
1095
730
365
float record

r223: 100% msg return



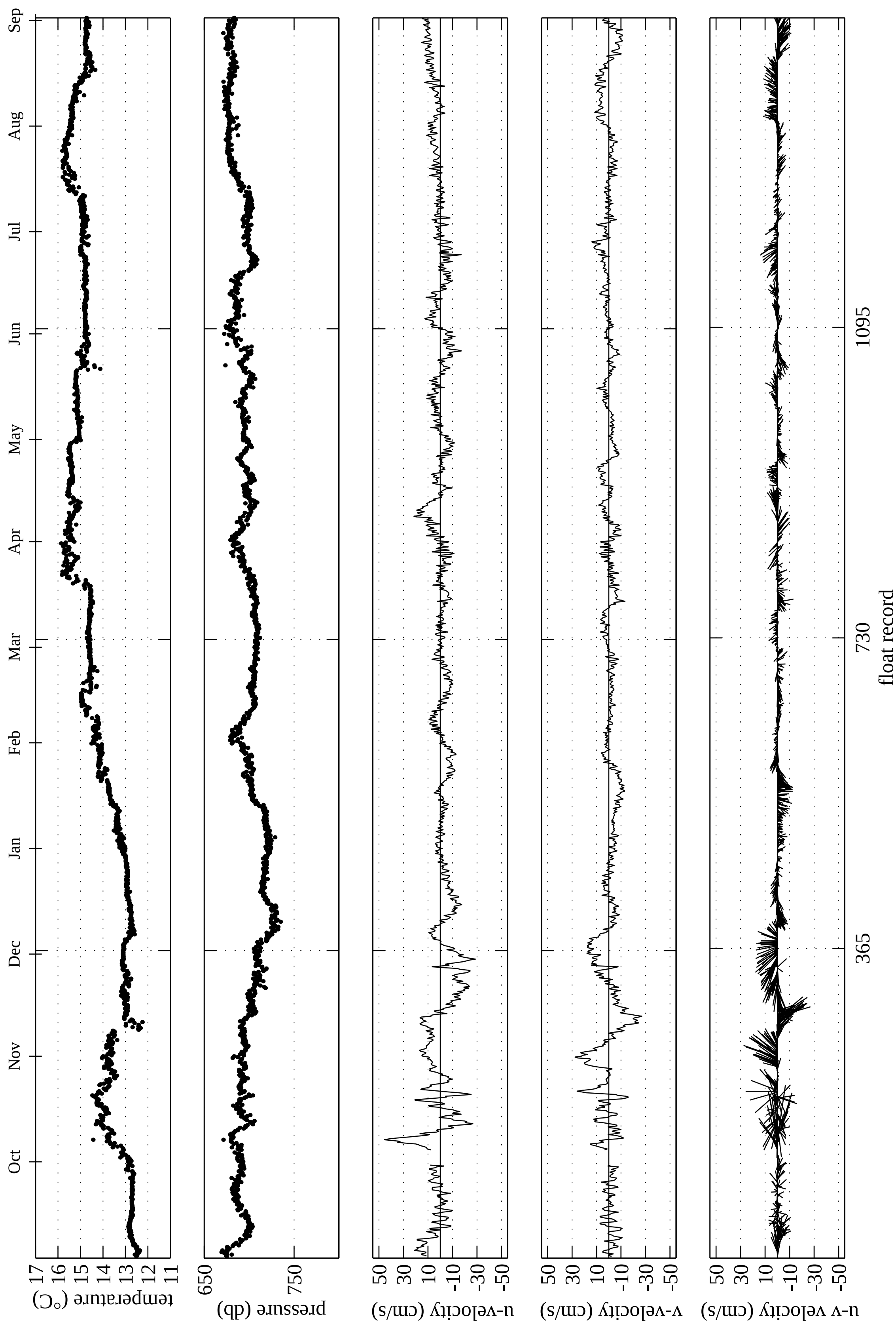
r223


2002
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
temperature (°C)
16
15
14
13
12
11
10
pressure (db)
600
700
800
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
50
30
10
-10
-30
-50
365
730
1095
float record


r224: 100% msg return
13°N
30'
12°N
30'
11°N
30'
10°N
44°E
45°E
46°E
47°E
48°E
49°E
1101
1201
0902
0102
0802
0202
0502
0302
0602
0702
0402

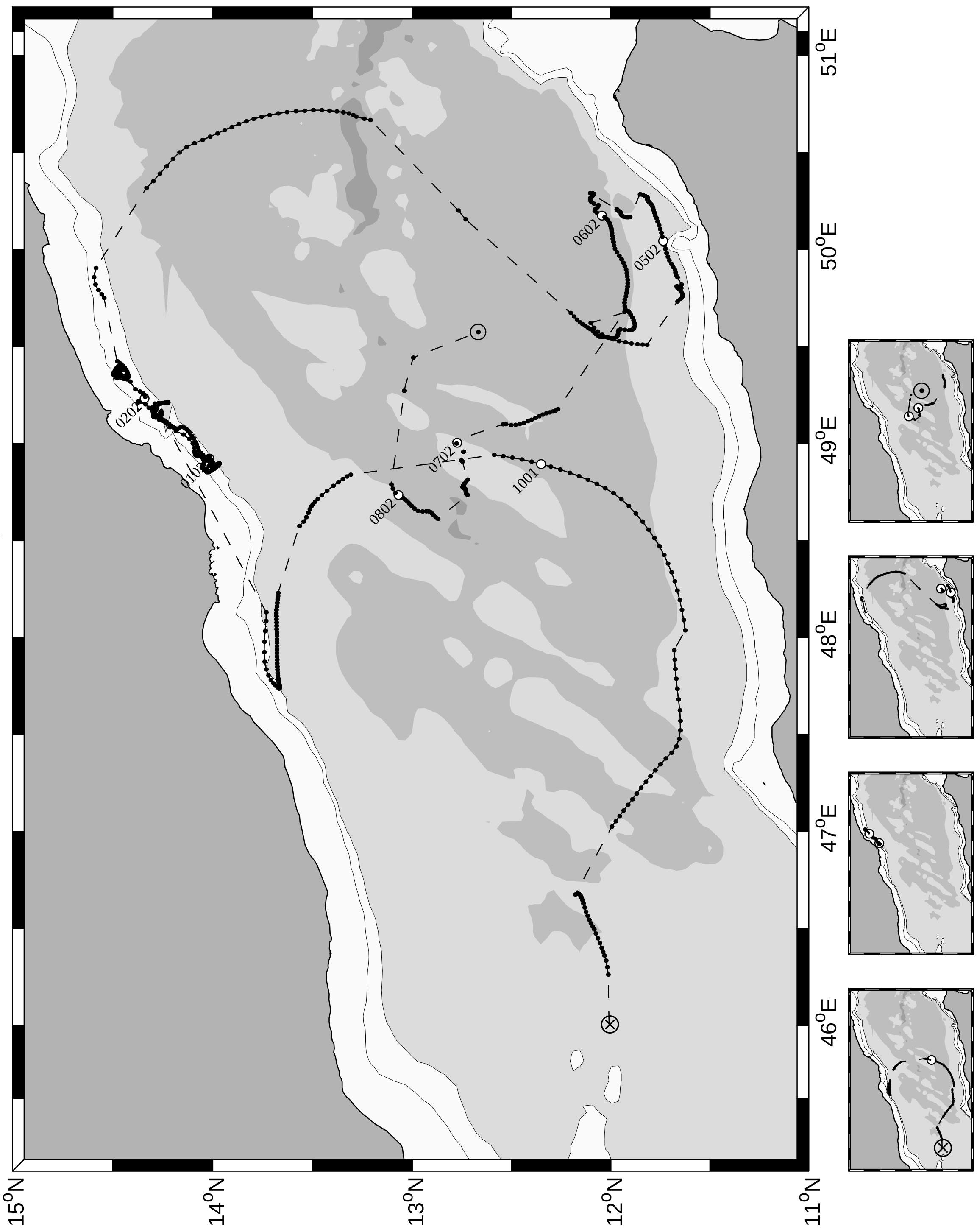
r224

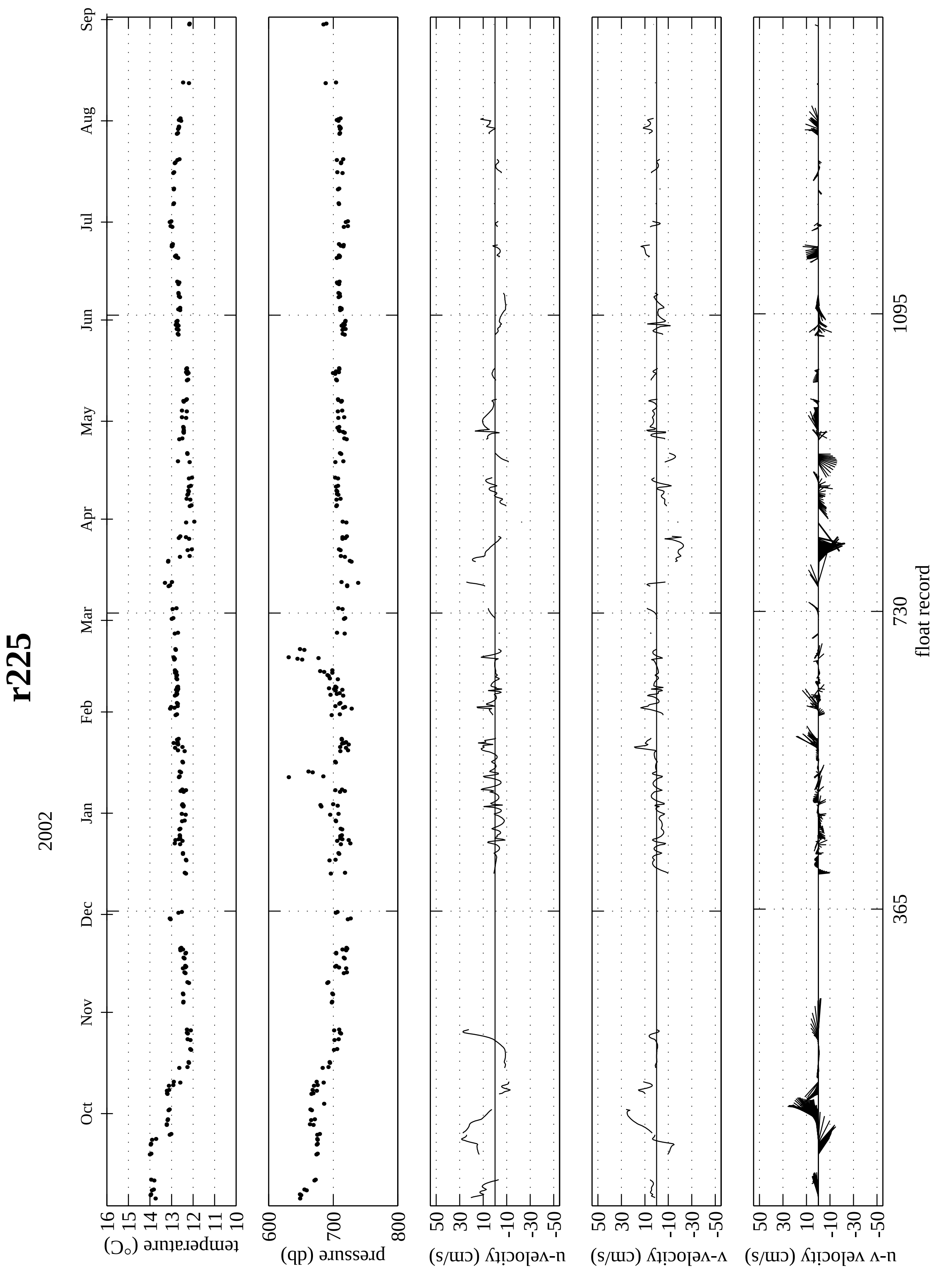
2002



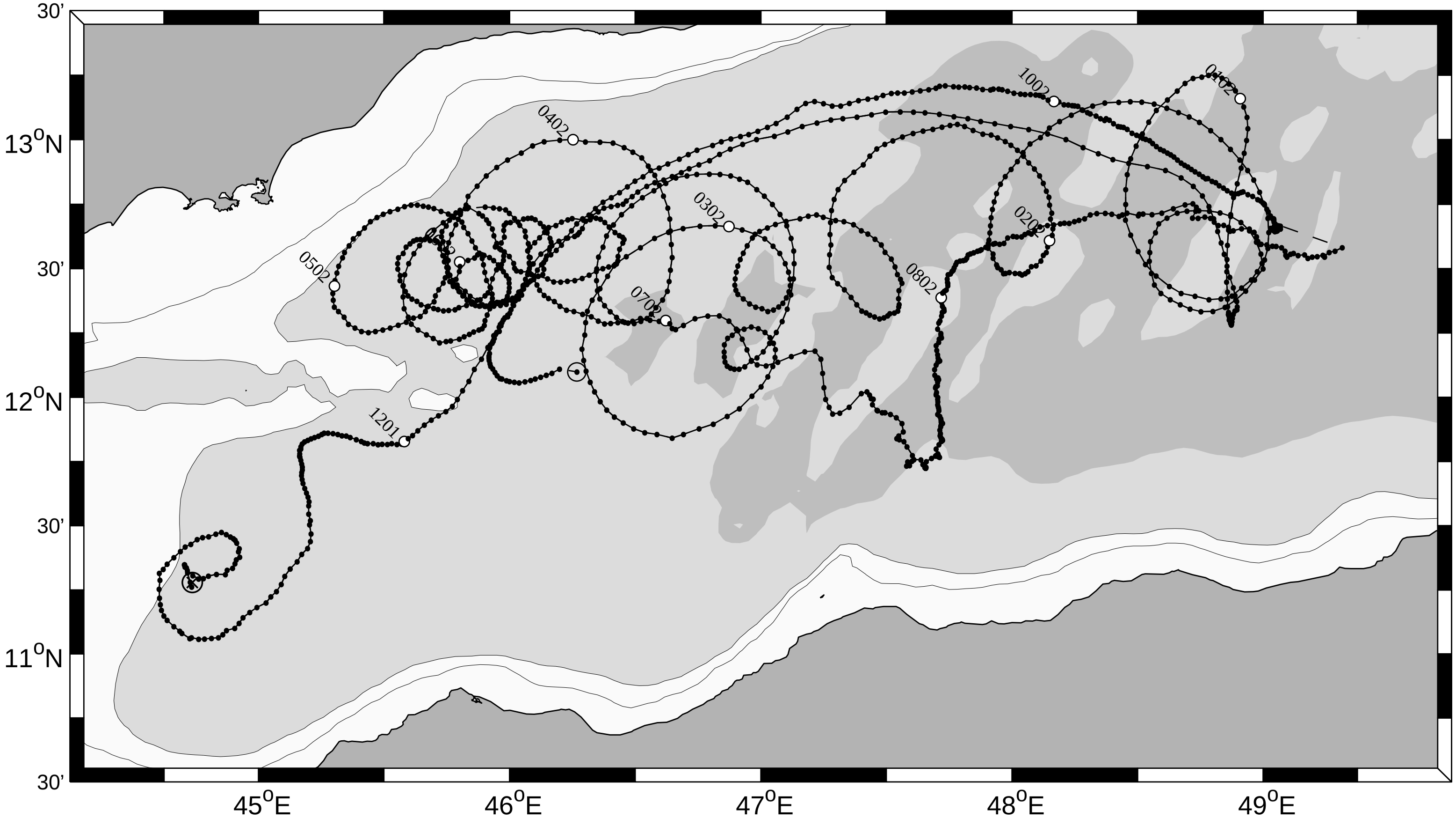
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
temperature (°C)
17
16
15
14
13
12
11
pressure (db)
650
750
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
50
30
10
-10
-30
-50
365
730
1095
float record

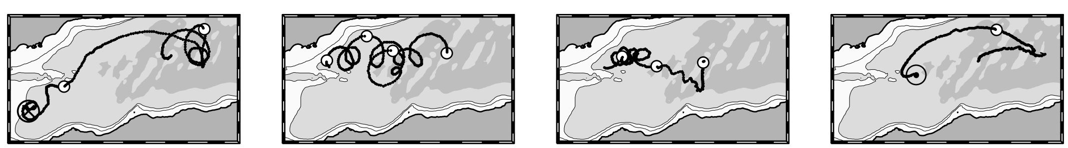
r225: 100% msg return

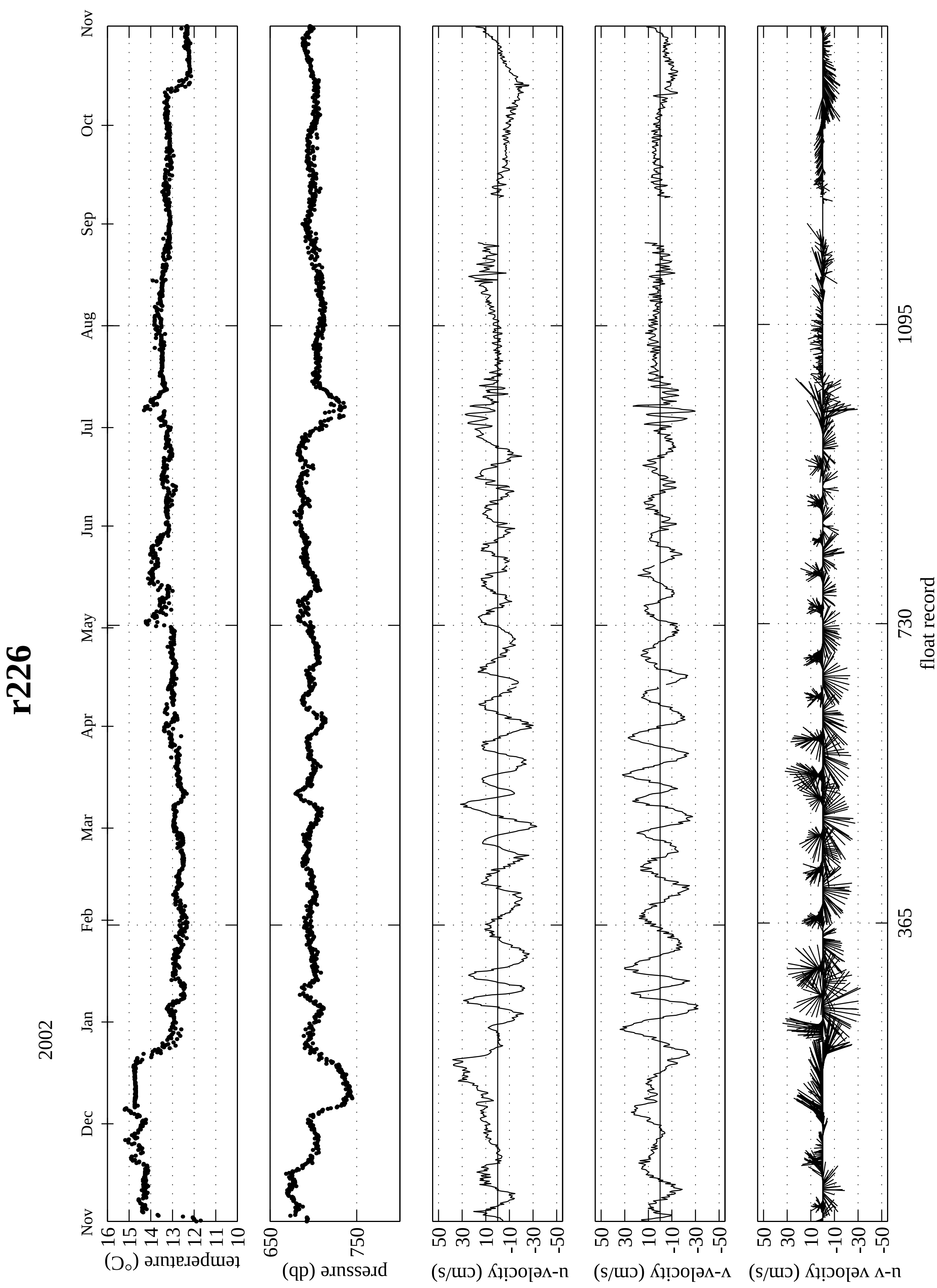



r225
2002
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
temperature (°C)
pressure (db)
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
365
730
1095
float record

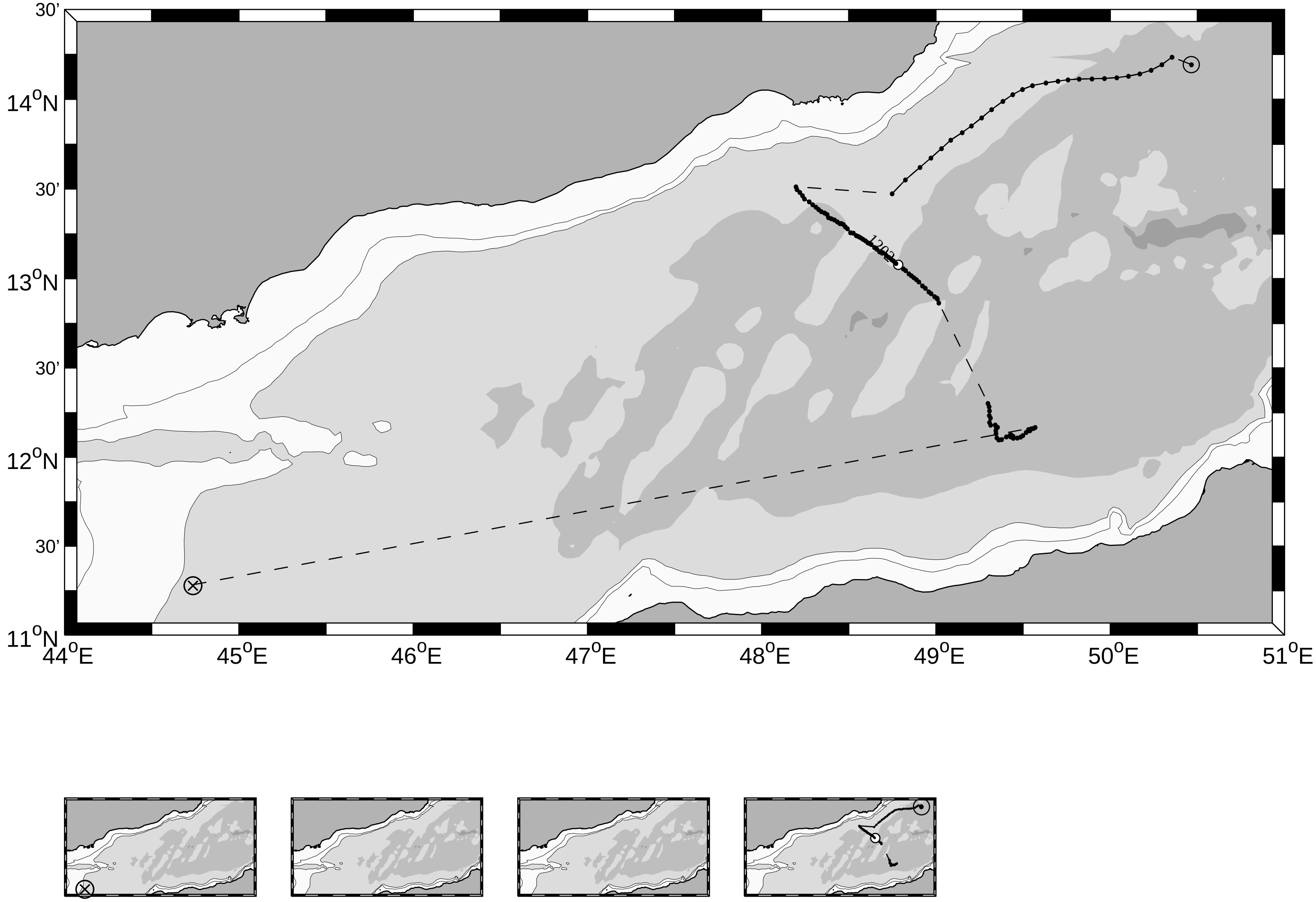
r226: 13% msg return



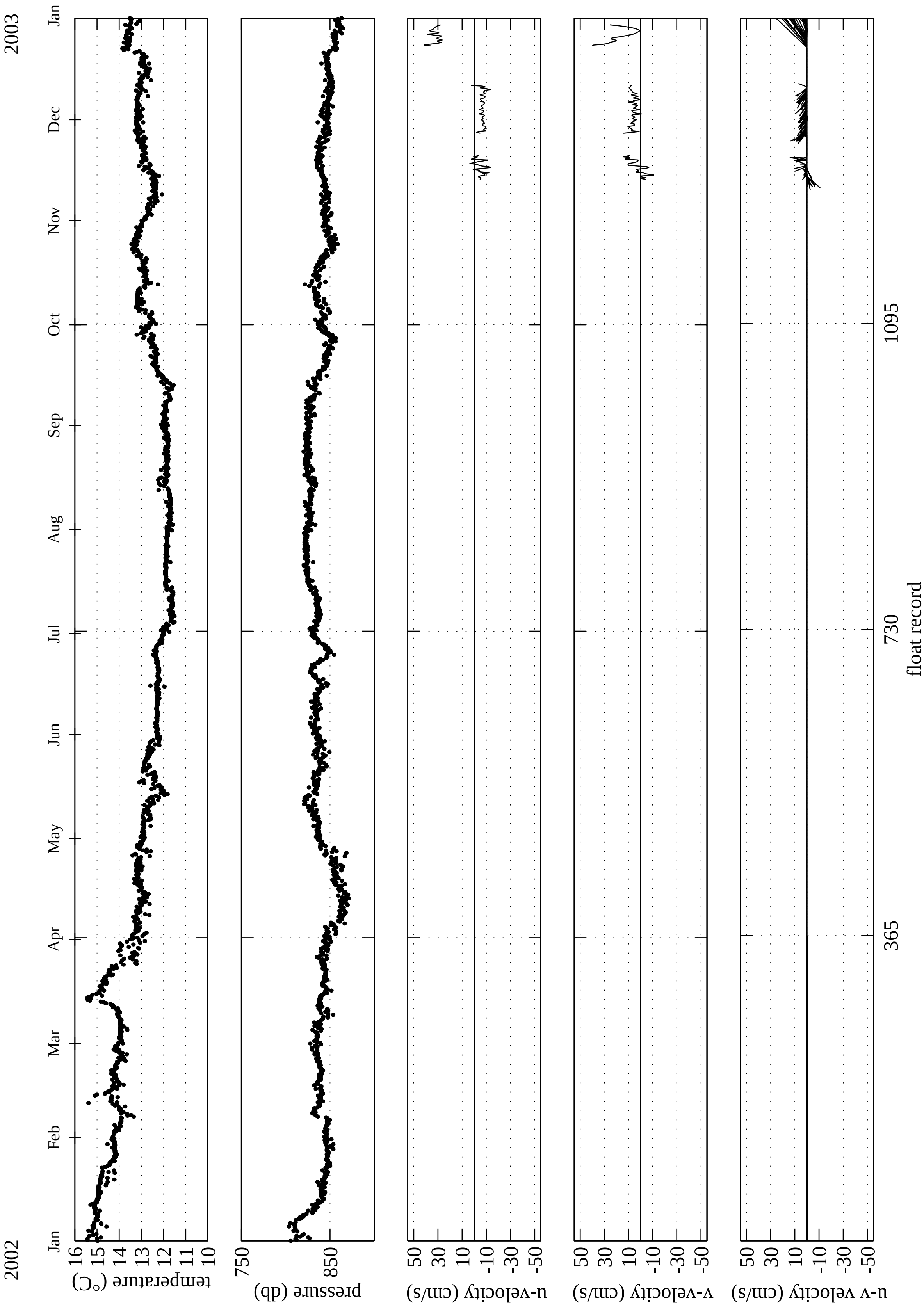



r226
2002
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
temperature (°C)
pressure (db)
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
365
730
1095
float record

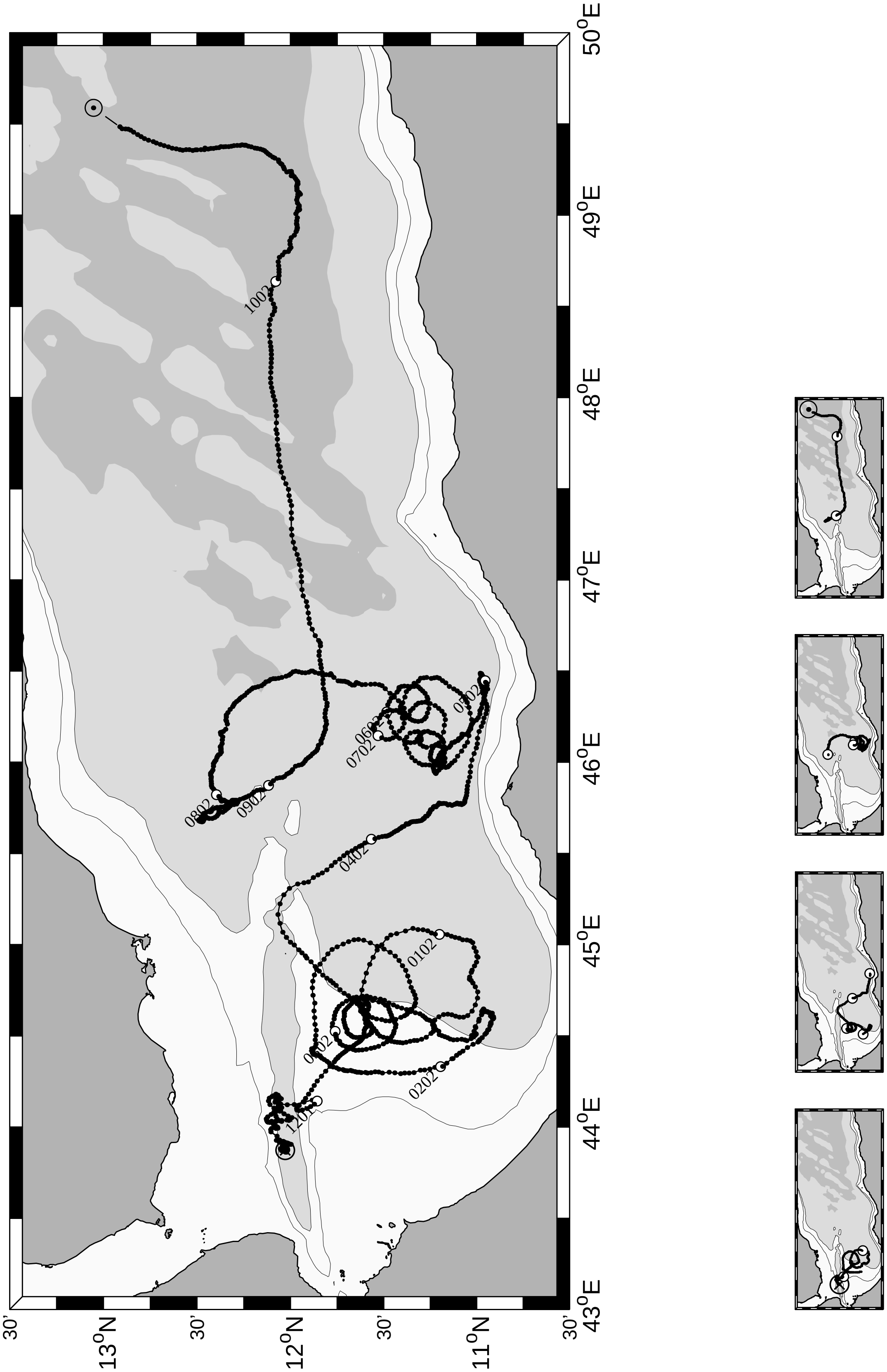
r227: 99% msg return



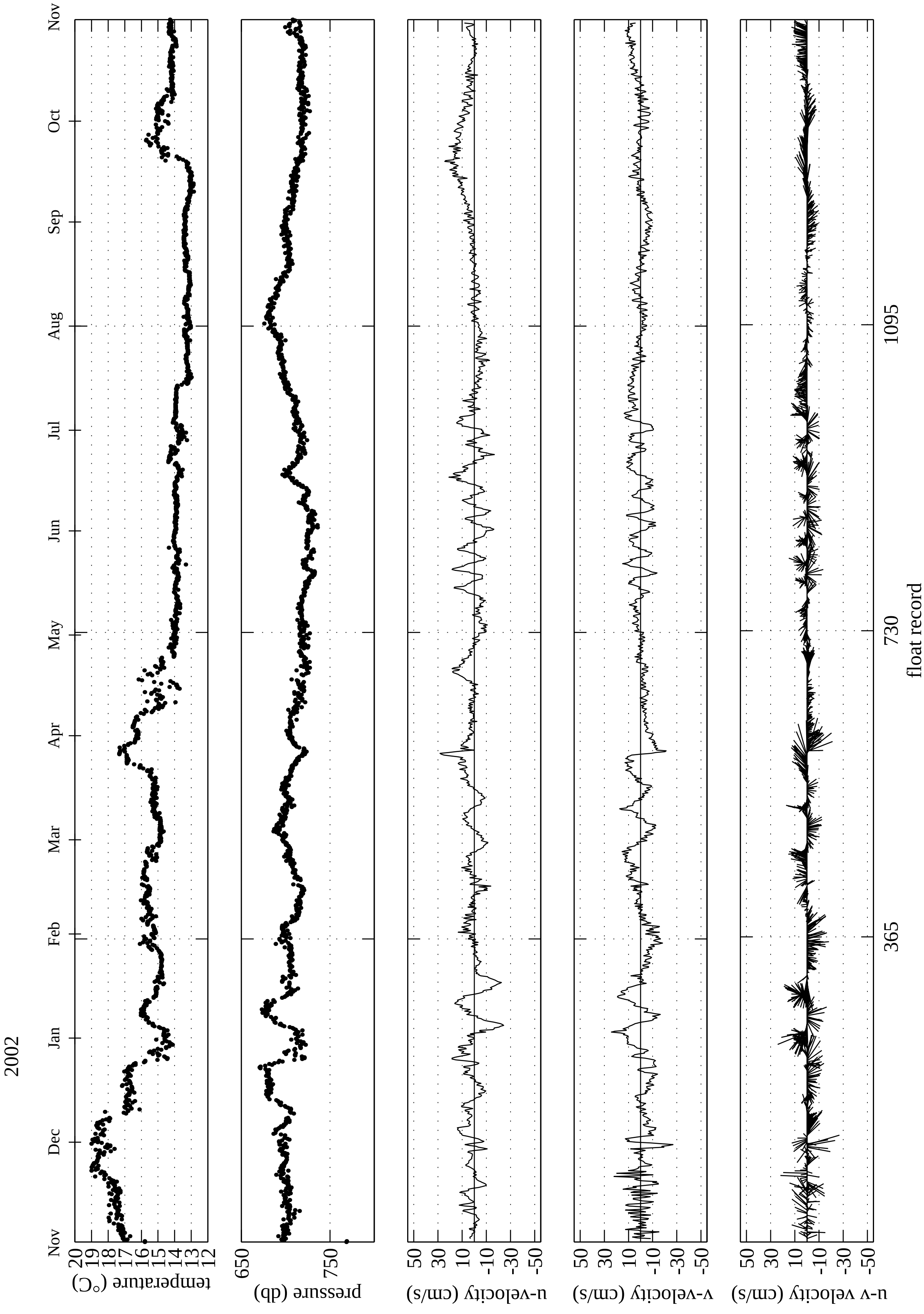
r227


2002
2003
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
temperature (°C)
16 15 14 13 12 11 10
pressure (db)
750
850
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
50 30 10 -10 -30 -50
365
730
1095
float record

r228: 92% msg return

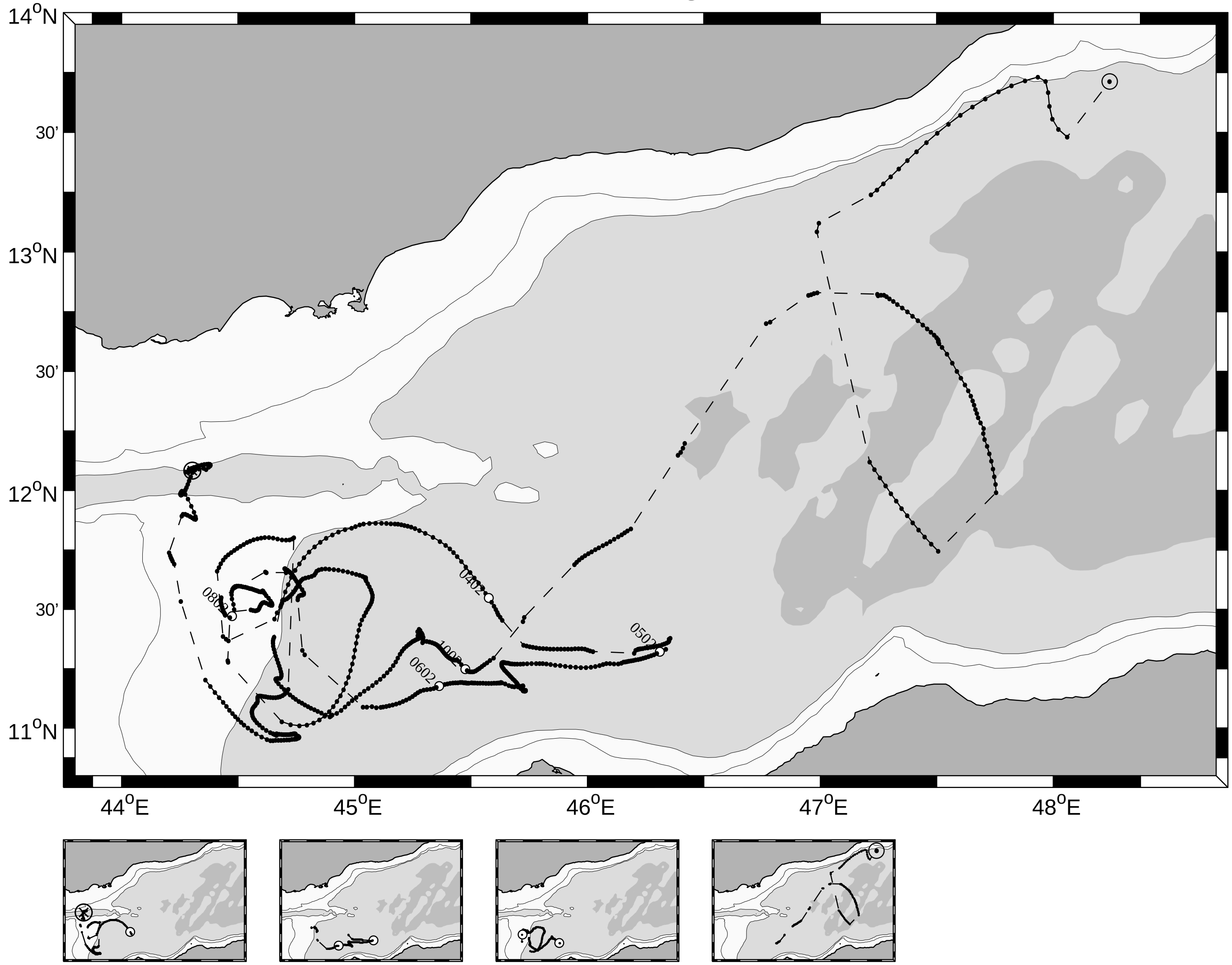


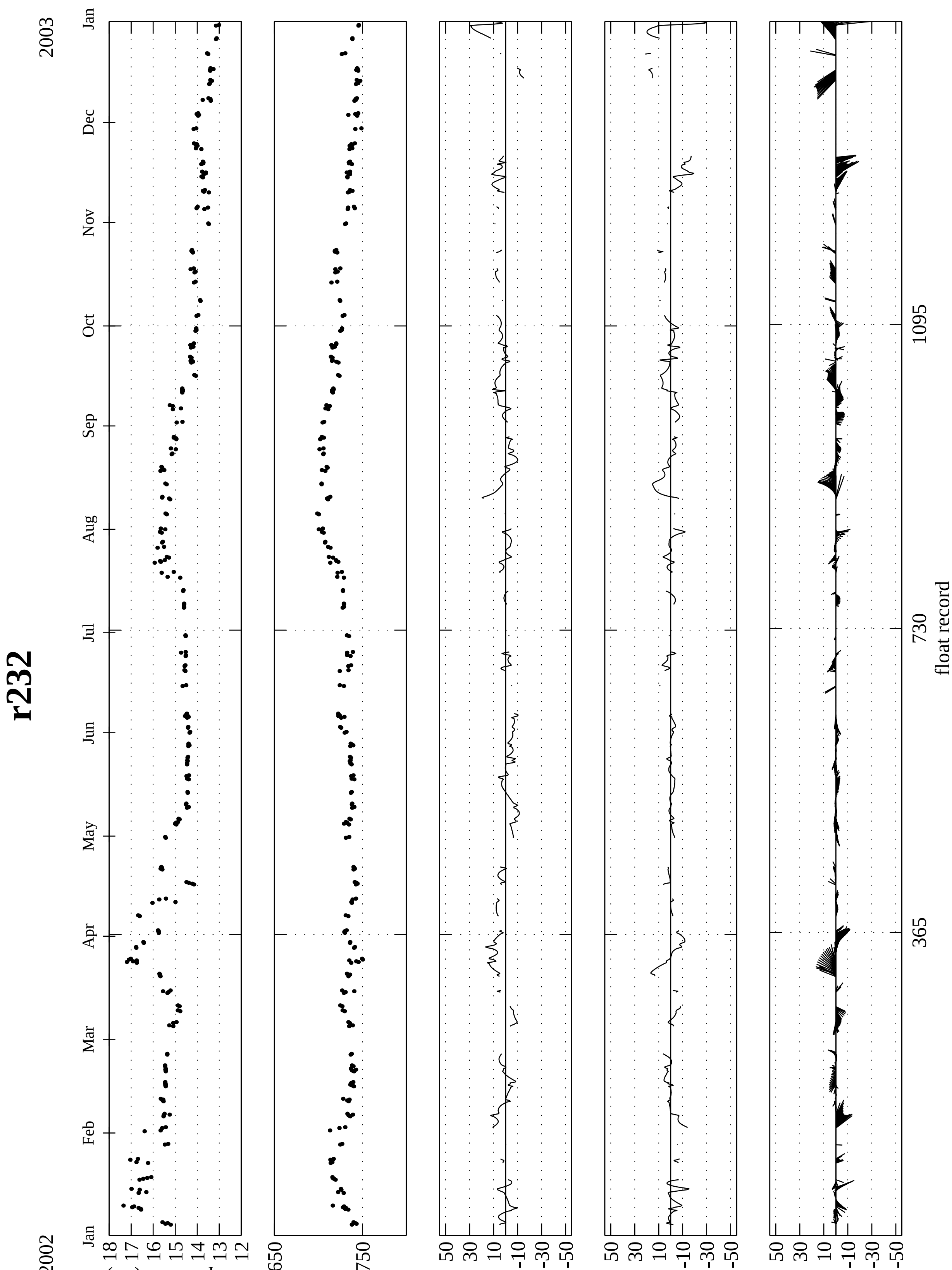
r228



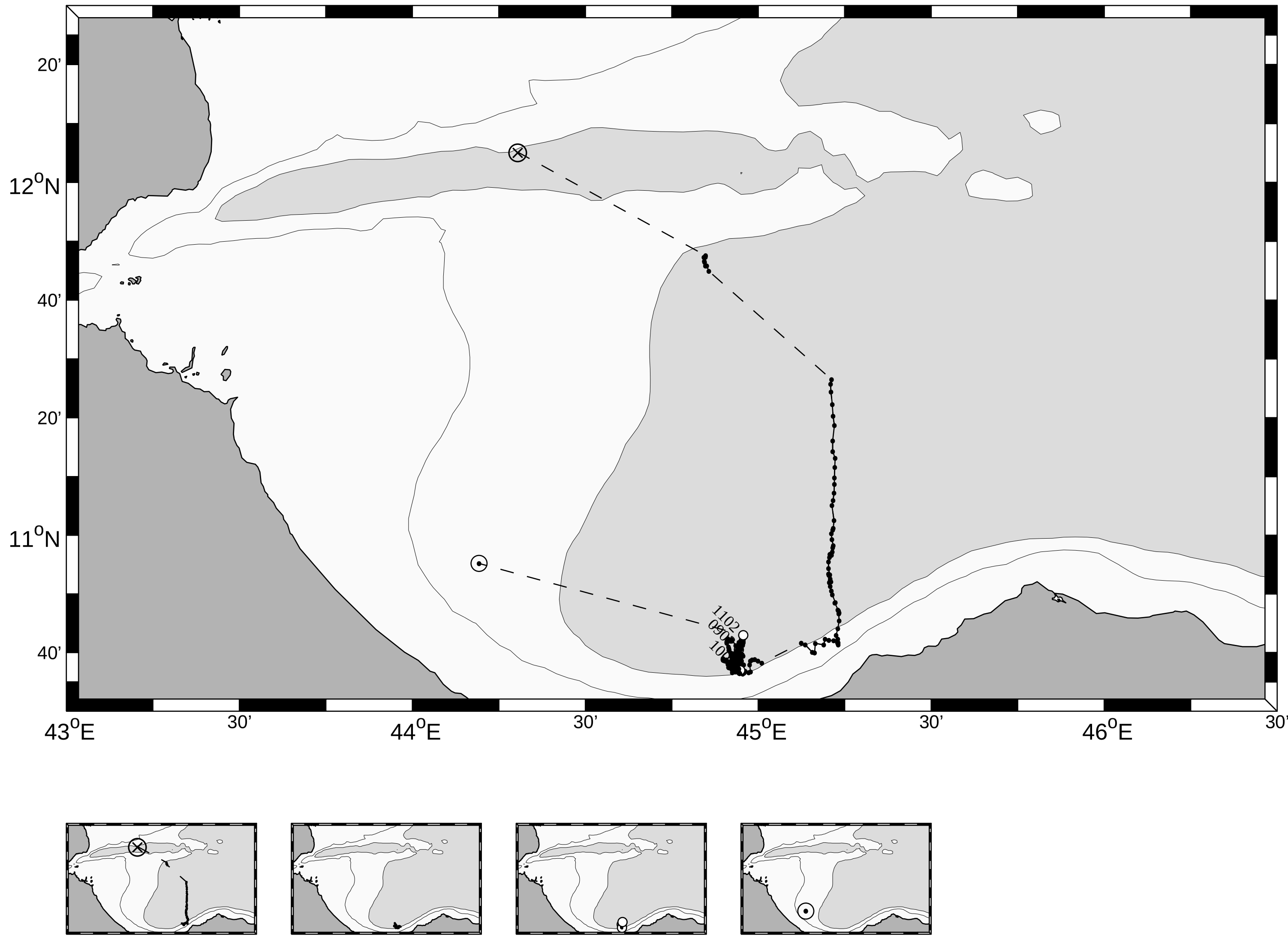
2002
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
temperature (°C)
20 19 18 17 16 15 14 13 12
pressure (db)
650
750
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
50 30 10 -10 -30 -50
365
730
1095
float record

r232: 19% msg return

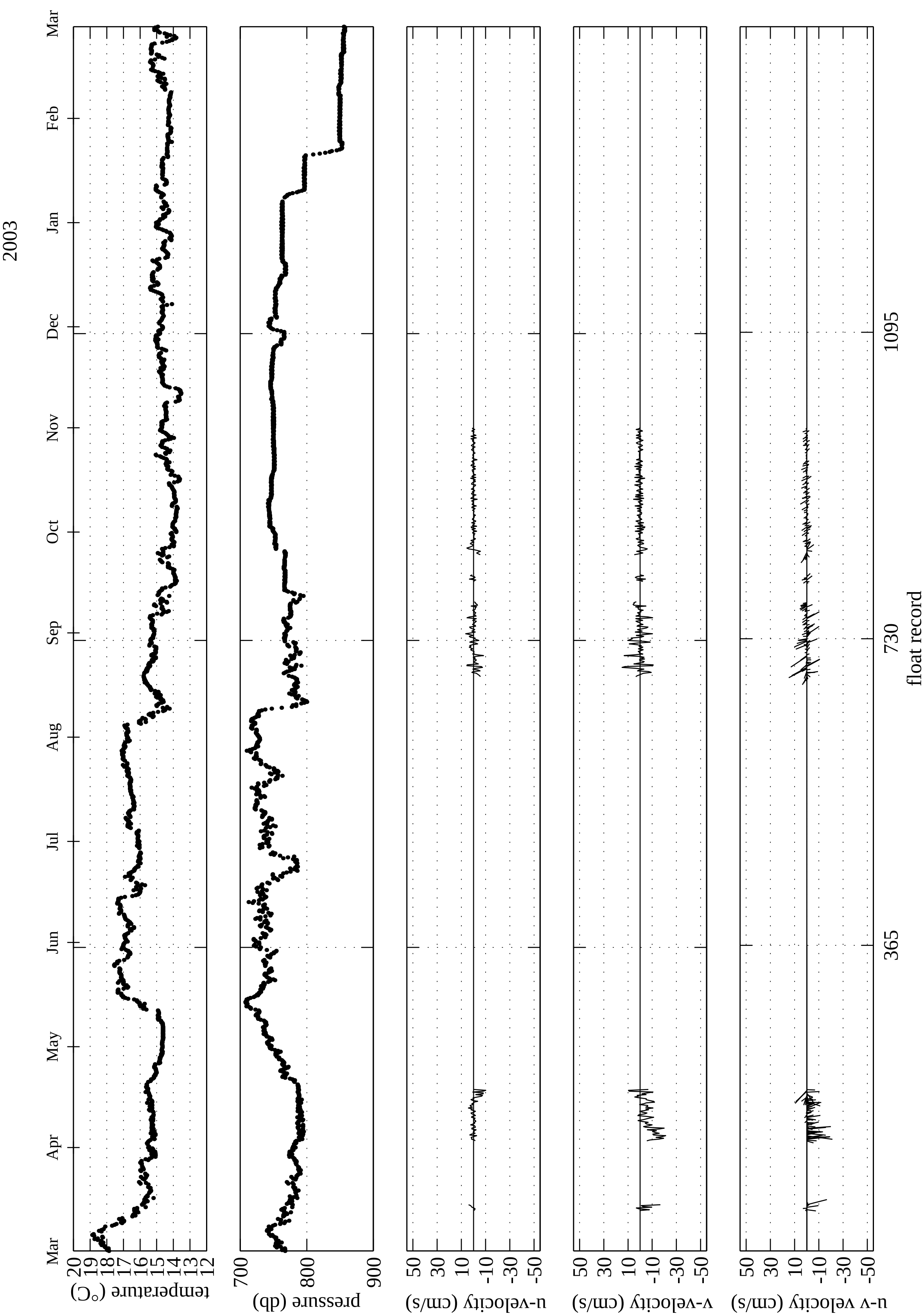



r232
2002
2003
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
temperature (°C)
18 17 16 15 14 13 12
pressure (db)
650 750
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
50 30 10 -10 -30 -50
365
730
1095
float record

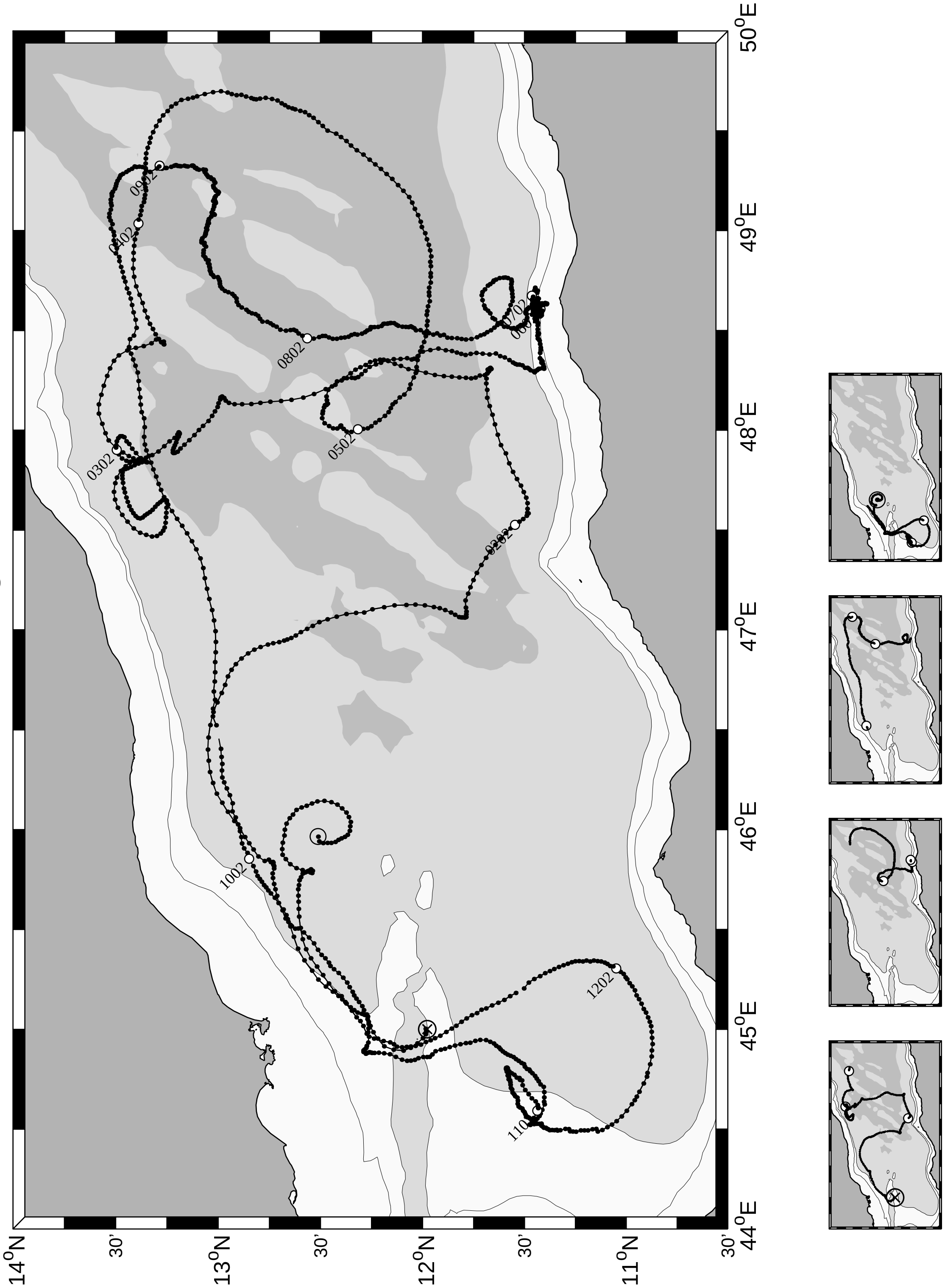
r233: 94% msg return



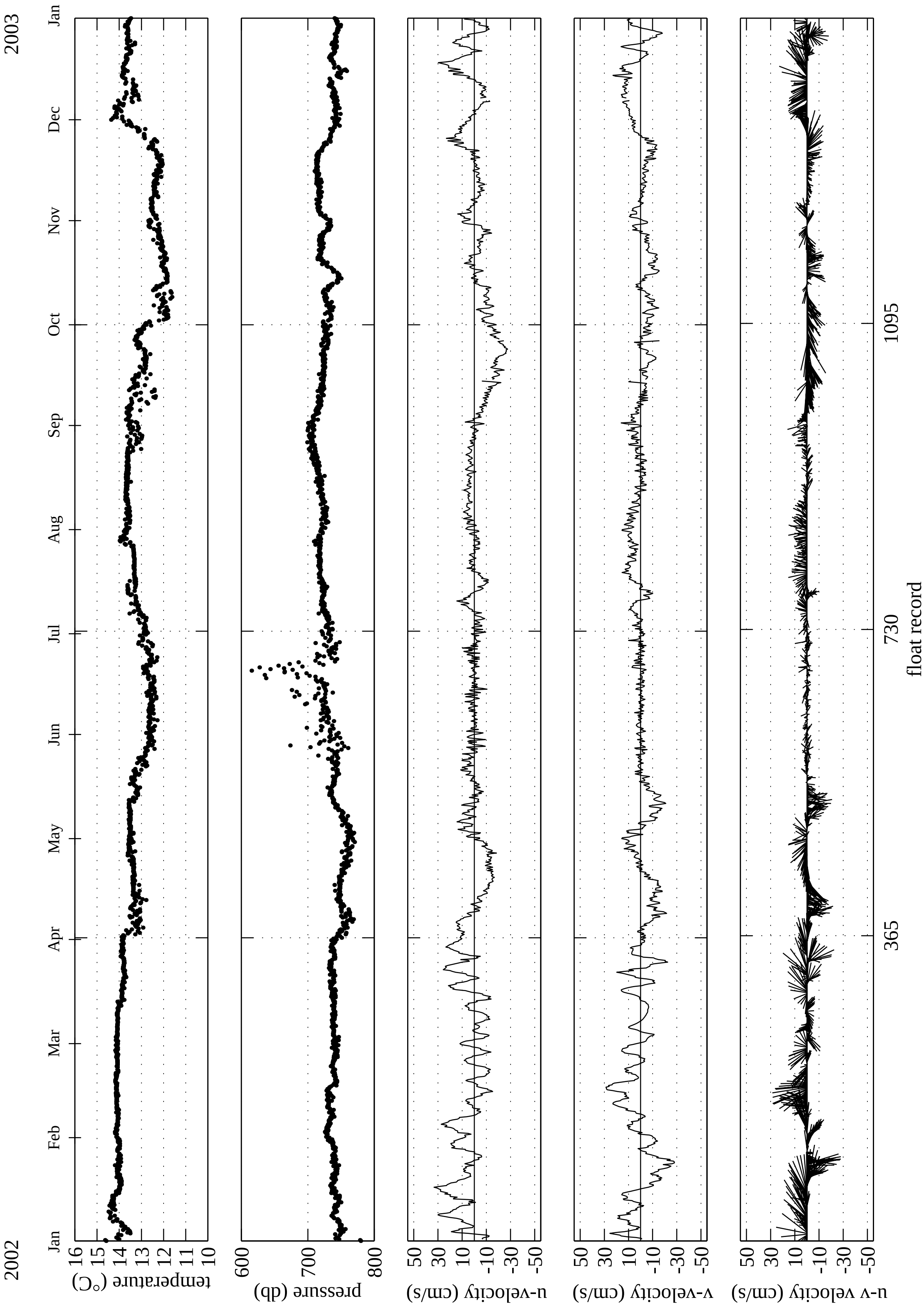
r233


2003
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
temperature (°C)
20
19
18
17
16
15
14
13
12
pressure (db)
700
800
900
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
50
30
10
-10
-30
-50
365
730
1095
float record

r234: 97% msg return

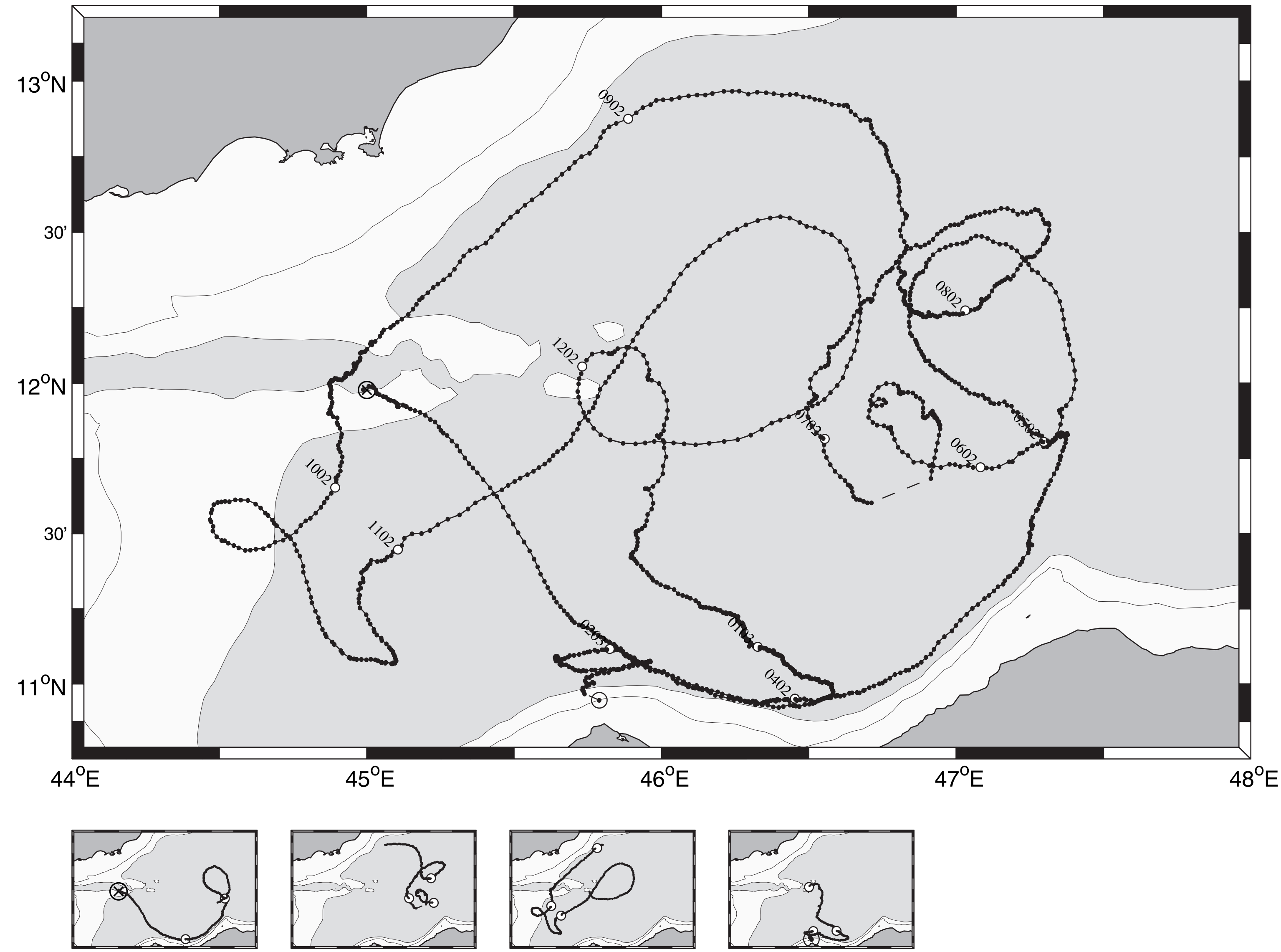


r234

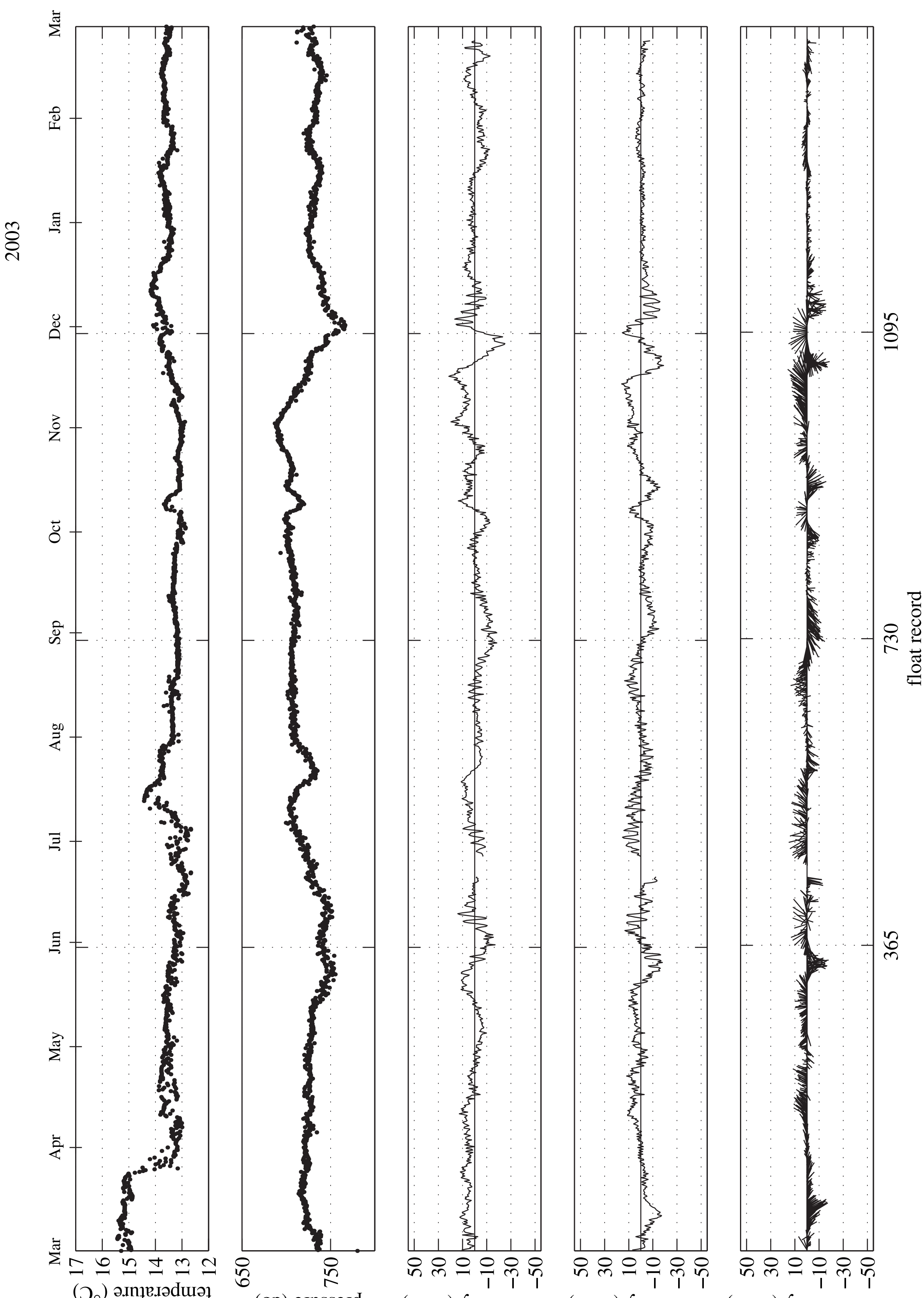


2002
2003
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
temperature (°C)
16 15 14 13 12 11 10
pressure (db)
600 700 800
u-velocity (cm/s)
v-velocity (cm/s)
u-v velocity (cm/s)
50 30 10 -10 -30 -50
365
730
1095
float record

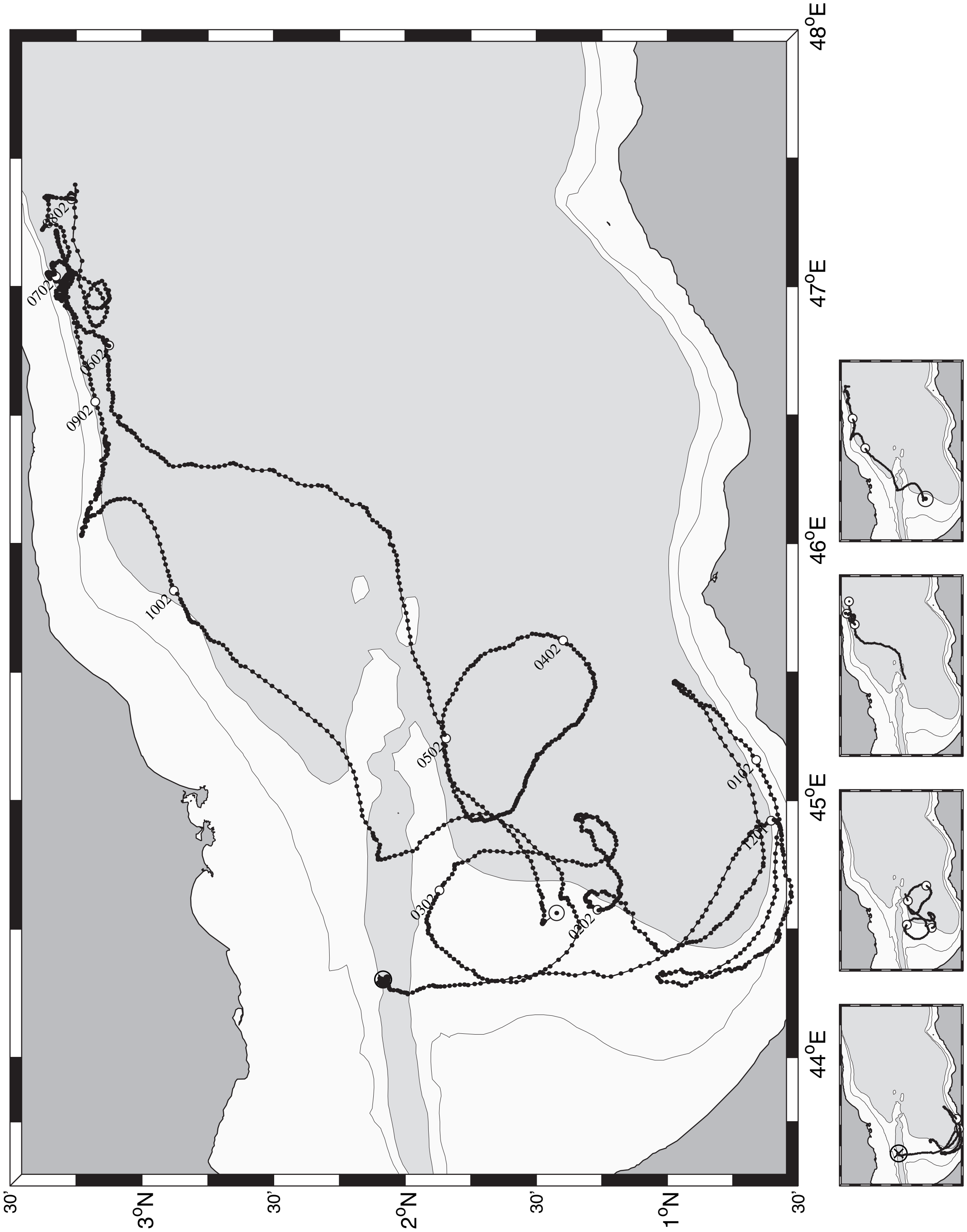
r235: 100% msg return

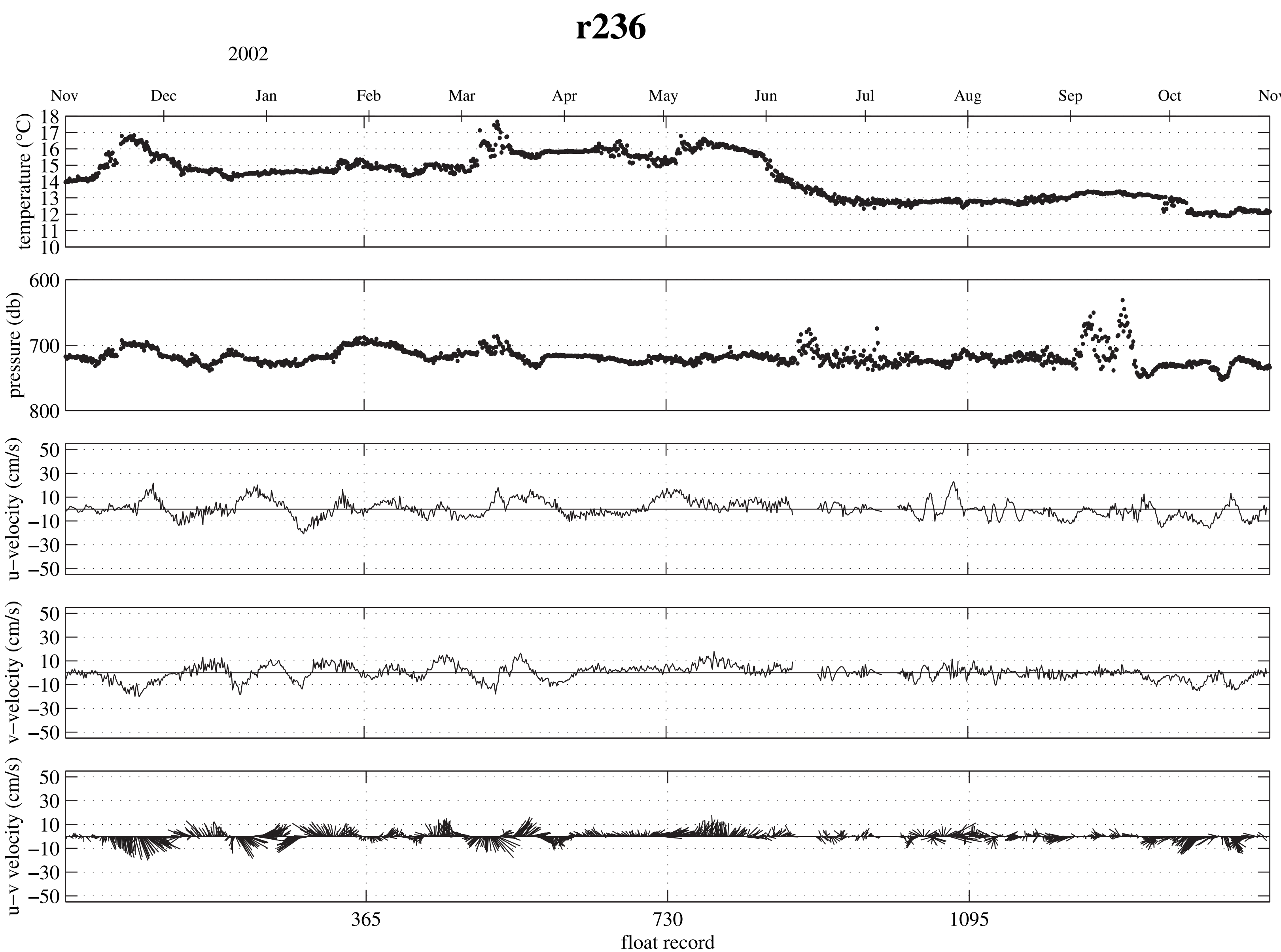


r235


2003
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
temperature (°C)
17 16 15 14 13 12
pressure (db)
650 750
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
50 30 10 −10 −30 −50
365
730
1095
float record

r236: 96% msg return




r236
2002
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
temperature (°C)
18
17
16
15
14
13
12
11
10
pressure (db)
600
700
800
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
50
30
10
−10
−30
−50
365
730
1095
float record

50272-101

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16. Abstract (Limit: 200 words)

This is the final data report of all acoustically tracked second-generation Deep Lagrangian Drifter (DLD2) RAFOS float data collected by the Woods Hole Oceanographic Institution in 2001-2003 during the Red Sea Outflow Experiment (REDSOX). The float component of REDSOX was comprised of two deployments on the R/V *Knorr* and R/V *Ewing:* the first in February-March 2001, with 26 floats, and the second in August-September 2001, with 27 floats. The isobaric floats were ballasted for 650 decibars to target the intermediate-depth, high-salinity outflow waters from the Red Sea. The objectives of the Lagrangian float study were (1) to identify the spreading pathways of the equilibrated Red Sea outflow, and to quantify the velocities and eddy variability typical of this outflow and of the background oceanic environment in the Gulf of Aden, and (2) to identify and describe the mesoscale processes which contribute to the seaward transport of Red Sea Overflow Water properties through the Gulf of Aden and into the western Indian Ocean. In addition to floats activated and launched during the two cruises, four time-series sites were chosen for dual-release float moorings. The dual-release floats were released every two months between cruises and every two months after the second cruise, with the final release in March 2002. A pirate attack on the R/V *Ewing* forced some modification of the float deployment plan during the second cruise.

17. Document Analysis a. Descriptors

marginal sea overflow
float
Indian Ocean

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

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