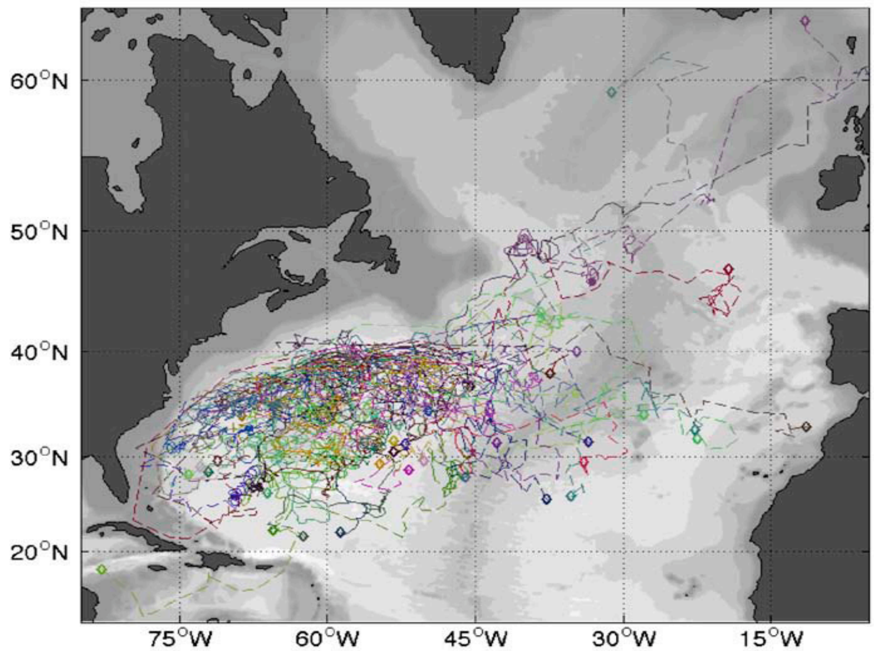
WHOI-2010-03

Woods Hole Oceanographic Institution

CLIMODE Bobber Data Report: July 2005 - May 2009



by

David M. Fratantoni, Theresa K. McKee, Benjamin A. Hodges, Heather H. Furey, John M. Lund

Woods Hole Oceanographic Institution
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Technical Report

Funding was provided by the National Science Foundation under Grant No. OCE-0424492.

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Approved for Distribution:

Robert A. Weller, Chair

Department of Physical Oceanography

Abstract

This report summarizes direct observations of Eighteen Degree Water (EDW) subduction and dispersal within the subtropical gyre of the North Atlantic Ocean. Forty acoustically-tracked bobbing, profiling floats ("bobbers") were deployed to study the formation and dispersal of EDW in the western North Atlantic. The unique bobber dataset described herein provides insight into the evolution of EDW by means of direct, eddy-resolving measurement of EDW Lagrangian dispersal pathways and stratification. Bobbers are modified Autonomous Profiling Explorer (APEX) profiling floats which actively servo their buoyancy control mechanism to follow a particular isothermal surface. The CLIVAR Mode Water Dynamics Experiment (CLIMODE) bobbers tracked the 18.5^{o}C temperature surface for 3 days, then bobbed quickly between the 17^{o}C and 19^{o}C isotherms. This cycle was repeated for one month, after which each bobber profiled to 1000 m before ascending to the surface to transmit data. The resulting dataset (37/40 tracked bobbers; more than half still profiling as of January 2010) yields well-resolved trajectories, unprecedented velocity statistics in the core of the subducting and spreading EDW, and detailed information about the Lagrangian evolution of EDW thickness and vertical structure. This report provides an overview of the experimental procedure employed and summarizes the initial processing of the bobber dataset.

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1. Introduction

Eighteen Degree Water (EDW) is the archetype for the anomalously thick and vertically homogenous mode waters that are typical of all subtropical western boundary current systems. EDW is associated with a shallow overturning circulation that carries heat northward and is an interannual reservoir of anomalous heat, nutrients and CO_2. Understanding the annual cycle of EDW evolution, and in particular its associated circulation pathways and destruction mechanisms, is important because though EDW is isolated beneath the stratified upper-ocean at the end of each winter, it may reemerge in subsequent years to influence mixed layer properties and consequently air-sea interaction and primary productivity. Prior to this experiment, little was known about the physical mechanisms which redistribute EDW from its formation region near the Gulf Stream throughout the subtropical gyre.

The CLIVAR Mode Water Dynamics Experiment (CLIMODE) field campaign included five research cruises conducted between November, 2005 and November, 2007, including two mid-winter cruises in the Gulf Stream. This program resulted in the most comprehensive data set of EDW-related measurements ever collected, including air-sea fluxes, detailed observations within the Gulf Stream, and broader-scale measurements of circulation and stratification throughout the subtropical gyre.

As part of this effort, 40 acoustically-tracked bobbing, profiling floats ("bobbers") were deployed to study the formation and dispersal of EDW in the western North Atlantic. The resulting dataset described herein yields well-resolved trajectories, unprecedented velocity statistics in the core of the subducting and spreading EDW, and detailed information about the Lagrangian evolution of EDW thickness and vertical structure.

2. Methods

The acoustically-tracked bobbers are modified Autonomous Profiling Explorers ((APEX); Teledyne Webb Research, E. Falmouth, MA) profiling floats reprogrammed to actively servo their buoyancy control mechanism to follow a particular isothermal surface (Figure 1). In addition to custom software, the bobbers were outfitted with temperature and pressure sensors and a Receiver in Floats (RAFOS) hydrophone and audio acquisition system which detected and recorded the arrival times of acoustic transmissions from several moored sound sources. The aluminum pressure hulls were also specifically machined for a maximum operating depth of 1000 m.

Figure 1. *Several CLIMODE bobbers being prepared for deployment aboard R/V Oceanus.*

Most of the bobbers were deployed in winter (January, 2006 and February, 2007) along the southern edge of the Gulf Stream (see Figure 2; Table 1). Additional bobbers were deployed during mooring deployment and turn-around cruises in November 2005 and November 2006.

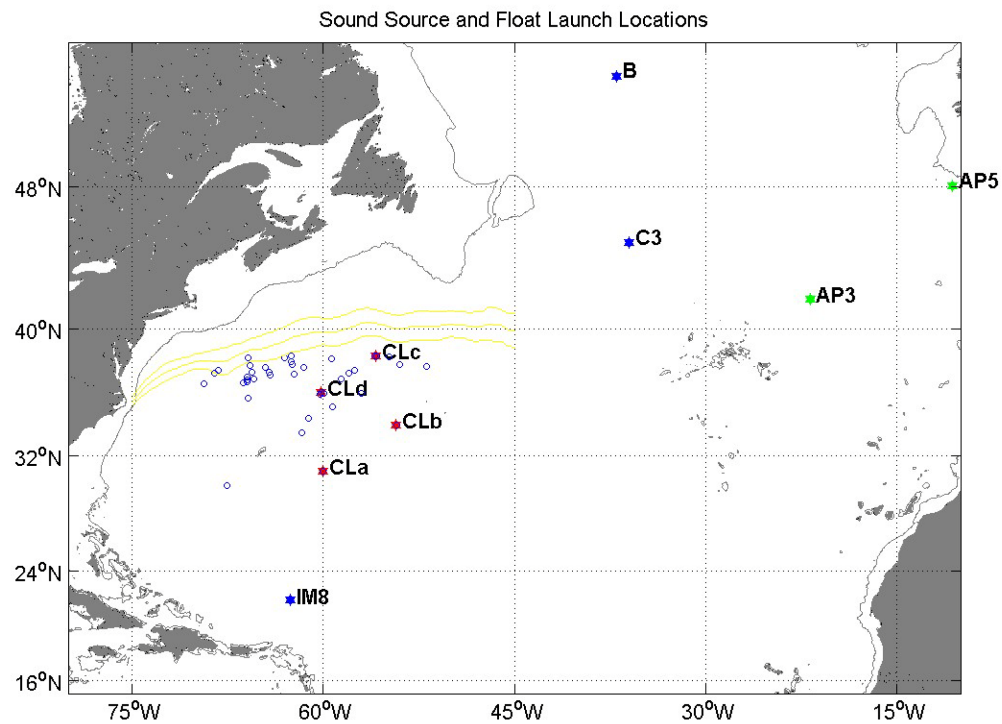


Figure 2. *Location of RAFOS sound sources during the CLIMODE experiment. CLIMODE sound sources (CLa, CLb, CLc, CLd) were clustered in a region south of the Gulf Stream (approximated by the yellow contours) to provide maximum resolution during which EDW subduction and initial dispersal. Other sources used in tracking (WHOI Export Pathways sources B and C3, SHOM Brest sources AP3 and AP5; IFM/Kiel MOVE) are marked in blue. Bobber deployment sites are shown as blue symbols.*

The bobber mission was designed to maximize the number of position (and thus velocity) and temperature measurements within the EDW layer. To this end, the 40 CLIMODE bobbers were programmed to be actively tracked the 18.5°C temperature surface by incrementally adjusting their buoyancy. Previous measurements in the region suggested that this isotherm was representative of the vertical center of the EDW. The bobbers were programmed to drift on this isotherm for 3 days, then bob quickly between the 17°C and 20°C isotherms before returning again to the 18.5°C isotherm. This cycle was repeated for one month, after which each bobber descended to 1000 m before surfacing to transmit data via ARGOS. To compensate for the substantial buoyancy pump activity required to carry out this mission the bobbers were modified to use lithium-based primary batteries instead of the more common alkaline packs. Briefly, the rules used to construct the bobber's mission were as follows:

1. Drift at 18.5°C +/- 0.2°C. Seek target isotherm hourly and adjust if out of band. If the 18.5°C does not exist or is shallower than 50 m, drift at 50 m. (The intent was to prevent bobbers from drifting for extended periods at the sea surface. The 50 m depth was assumed to be removed from the surface, yet representative of the surface mixed layer).

2. Once every 3 days, bob between 17°C and 20°C. If 17°C does not exist, bob to 500 m. If 20°C does not exist, bob to surface.

3. Once every 30 days perform at 1000 m then surface to transmit data.

4. Acquire temperature-depth samples according to a single 40-point lookup table on all upward profiles (including bobs). Vertical measurement resolution varied from 5 m near the surface to 20 m at depth.

5. Acquire one additional temperature-depth sample daily at the conclusion of the acoustic listening window.

6. Allow one, two-hour acoustic listening window per day (0000, 0030, 0100, 0130 Universal Time Coordinated (UTC)) and record the highest four correlation heights and time-of-arrivals (TOAs) within this window.

Two of the bobbers were used for system testing and were programmed to cycle more frequently with deep profiles and surfacing occurring after 12 days instead of the normal 30 days. Bobber 37518 was deployed by Jim Ledwell in July 2005 within a mesoscale eddy south of Bermuda. This unit was deployed prior to installation of the CLIMODE sound source array and did not receive any acoustic transmissions. A second test unit, 39476, was deployed in January 2006.

An acoustic source array consisting of four University of Rhode Island/Graduate School of Oceanography RAFOS sound sources was deployed in November 2005 on *R/V Oceanus* cruise OC419 (Figure 2; Table 2). Additional sources deployed by other investigators from the U.S., France, and Germany were heard by the bobbers and subsequently used during acoustic tracking. The four CLIMODE sound sources were recovered in November, 2007. The bobbers continued to transmit satellite positions through June 1, 2009, when Service ARGOS real-time data delivery was terminated. More than half of the bobbers were still operating as of January 2010. This profile data will be recovered and processed at a later date.

3. System Performance

Figure 3 presents a timeline of the ARGOS transmissions from the 40 CLIMODE bobbers. Overall success rate was quite high with 98% of the transmissions during the bobber's lifetime being complete enough to extract most or all acoustic data and temperature profiles. Thirty seven of the 40 floats could be acoustically tracked for all or some of their lifetime. Three floats (37518, 38575, and 39736) had consistently poor quality acoustic TOAs and could not be tracked. Seven floats (Table 4) were constructed with a faulty pressure sensor that caused only one measurement to be taken during each profile.

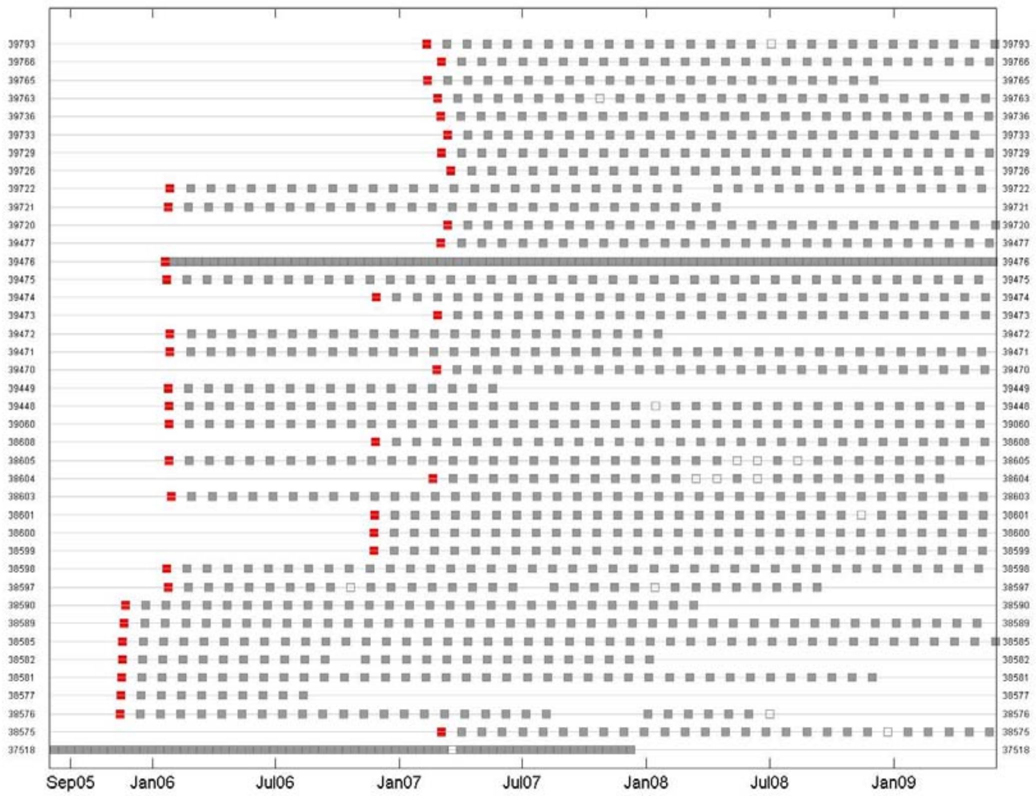


Figure 3. *Timeline of bobber deployments. Red squares indicate deployment times. Filled gray squares indicate successful ARGOS transmissions with acoustic data and profiles. Unfilled gray squares indicate incomplete ARGOS transmissions that did not yield profiles. Blanks indicate failed transmissions, i.e., no message received or the message received was inadequate to provide any acoustic or profile data. Numbers on the vertical axes are bobber ARGOS IDs.*

Occasionally, an incomplete message would require special handling in order to salvage data. In these cases, an attempt was made to manually repair the corrupted hex format to enable the parsing program to decode the acoustic data and profiles. This effort improved the data yield for these floats and transmission dates (Table 3).

4. Data Processing

Initial processing of the ARGOS message was accomplished on a Linux server through an automated process consisting of a series of shell, PERL, and Matlab scripts. Mail messages were read and combined to create a complete package of information, from which could be derived time and engineering information, acoustic signals (TOA and correlation heights), ambient temperature and pressure at the time the acoustic signal was received, and temperature and pressure profiles. Temperature profiles and engineering data were manually quality-controlled to remove obvious outliers.

TOA (with ambient temperature and pressure) and profiles were extracted to separate files, and a float clock offset for each transmission interval was determined by comparing satellite time to float clock time. Start and final offsets were computed to be applied during the tracking process to correct the float clock. Float clocks tended to get slower over their lifetime in a mostly linear progression. A list of the clock offsets for each float can be seen in Table 5. Float clock drift was much larger than traditional RAFOS/DLD2 floats (57 second mean absolute offset versus < 2 second offset over approximately two years).

In addition to correcting for float clock drift, it was essential to supply a correction for sound source clock drift within the sound source information file used as input. The drift was determined by comparing source clock times with UTC from the global positioning system (GPS). All sound source clocks with the exception of Source 21 (Mooring B) were fast. A single drift correction was applied to sources A and B, however source C and D were handled in two pieces since the clocks were reset when the batteries were replaced in November, 2006. Using an equation provided by George Schwartze (Graduate School of Oceanography, University of Rhode Island), the adjustments were computed as follows:

Example: Computing Sound Source Clock Drift using Source A

Calculated clock error from temperature at the end is recorded as -30.956 (rounded to -31, below)

At recovery:

UTC = 15:37:40
Sotime = 15:38:43
Pong Time = Roso Pong Time + (-31) + (UTC - Roso time)
Pong Time = Roso Pong Time -31 + (15:37:40 - 15:38:43)
Pong Time = Roso Pong Time -31 sec – 00:01:03
Pong Time = 00:01:34 distributed over 2 years = -0.128

The CLIMODE sound source information file is included in the Appendix as is full documentation on sound source clock error. Calculations for corrections to all sources are contained in a spreadsheet in the Appendix.

Floats were tracked using Matlab-based ARTOA3 software (Wooding *et al.*, 2005; http://www.whoi.edu/science/PO/rafos/). Prior to tracking, a sound source file containing sound source positions, depth, signal time, schedule, and length was prepared as input. In addition, for each float, a file containing TOAs and correlation heights, daily temperature and pressure, and precise header information identifying start and end times and positions, number of cycles, and float clock offset also was assembled.

After loading these files into the ARTOA program, the first step was to edit pressure and temperature recorded with each acoustic transmission to remove outliers that would adversely influence sound speed calculations. Next, highest quality TOAs were manually selected and applied to the appropriate sound source. TOAs were corrected for the Doppler shift and difference in transmission time, and then interpolated using variable width (10–30 days) linear or cubic-spline filter before tracking. Tracking used a least-squares method if more than two TOAs were available. Satellite positions were plotted over the tracks to check for agreement. The length and type of interpolation were adjusted to improve the agreement between the satellite positions and the tracked position.

Determining sound velocity for these data proved to be challenging. Since floats received acoustic transmissions while traveling through different water masses, sound velocities varied substantially. There was no way to accurately determine these changes, so a certain amount of experimentation was used. The chosen velocities varied between 1.48 and 1.52 km/sec. For some floats, it was necessary to adjust the sound velocity over sections of the track to improve the fit, as floats travelled through very different water regimes (e.g., from the Sargasso Sea to the Iceland Basin). Differences between the tracked positions and the satellite positions were computed regularly during the tracking process, and, if the tracked position was not within 20 km of the satellite position, a section of the track was excised and not interpolated. Average differences were in the 5 to 10 km range overall. This was deemed acceptable and can be explained by resolution of the satellite position and by currents carrying the surfaced float away from the last acoustically-tracked position. Various checks were made to determine if poor agreement was related to incorrect clock drift calculations, distance from source, geographic location, season, or the depth of the float when it received the acoustic signal.

Results indicated that proximity to the Gulf Stream contributed to inaccuracies in the tracking, but more frequently tracking errors were caused by loss of TOAs due to obstructions (Bermuda) or to baseline problems occurring when the float was in a direct line with two sound sources (Figure 4). A German sound source (IM8), located south of Bermuda (at 21.938˚N, 62.569˚W) at a depth of 1100m, proved to be very helpful in tracking many of the floats. Though we could not construct up-to-date information on clock drift for this source, it was often used to locate sections of track that the CLIMODE sources could not resolve. Floats that traveled near Bermuda required sources IM8; north and east of the tail of the Grand Banks required C3 and B. AP8 and AP3 were heard only

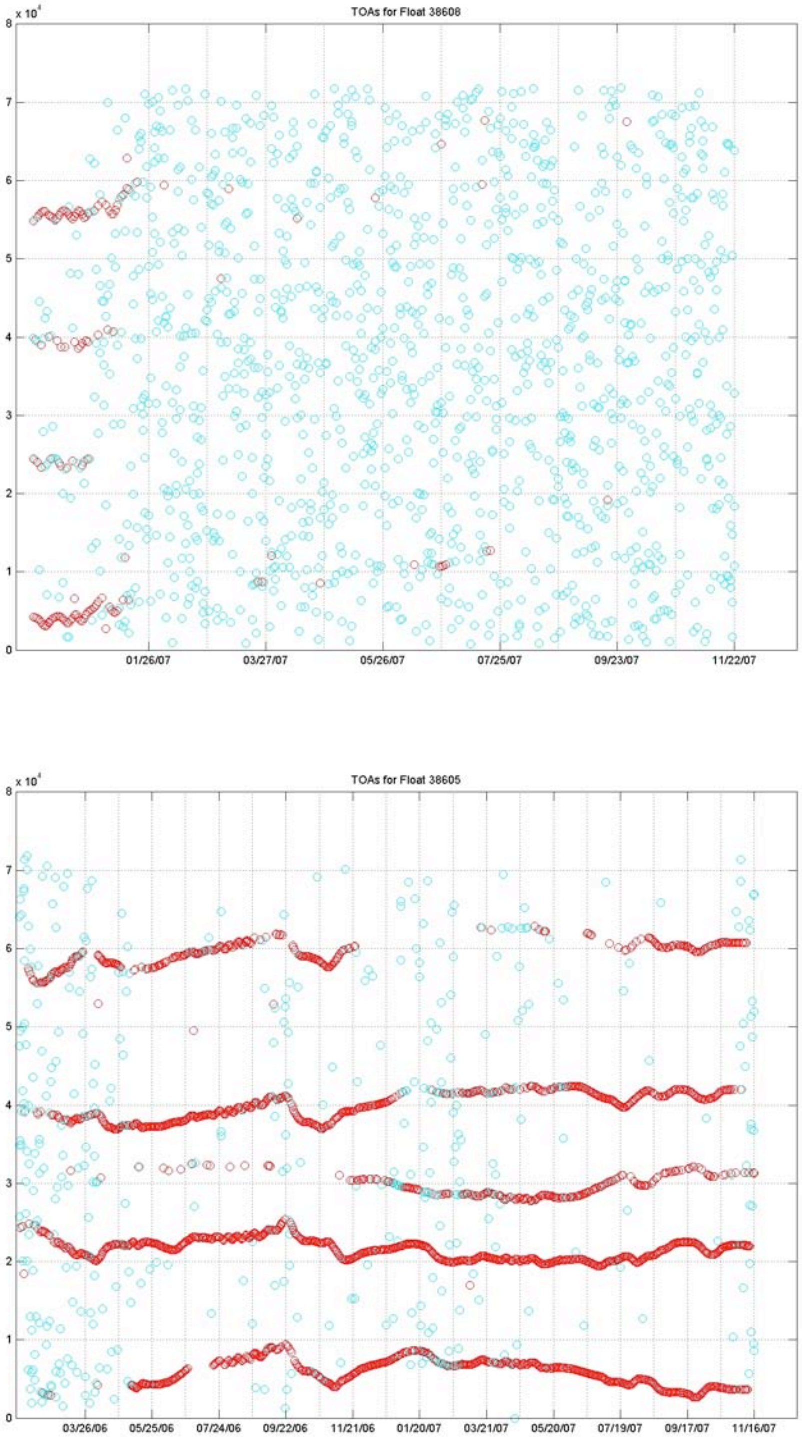


Figure 4. *Sample of poor quality TOAs (top). This float, 38608, could be tracked for only 12% of its duration. Time, on the y-axis, is displayed in tenths of a second. Sample of excellent quality TOAs (bottom). This float, 38605, could be tracked for 96% of its duration.*

by the few floats that travelled east of the Mid-Atlantic Ridge, into the north-east Atlantic.

Sixty percent of the floats could be tracked for 75% or more of their duration. Only 3 floats could be tracked for less than 25% of their duration. Overall, 70% of the available positions were accepted, based on the criteria that the tracked position was within 20 km of the satellite position. Most frequently the difference was in the 5 to 10 km range, as stated above. Details of the tracking success for each bobber are listed in Table 6. The final trajectories for each bobber are shown in Figure 5 and Appendix G.

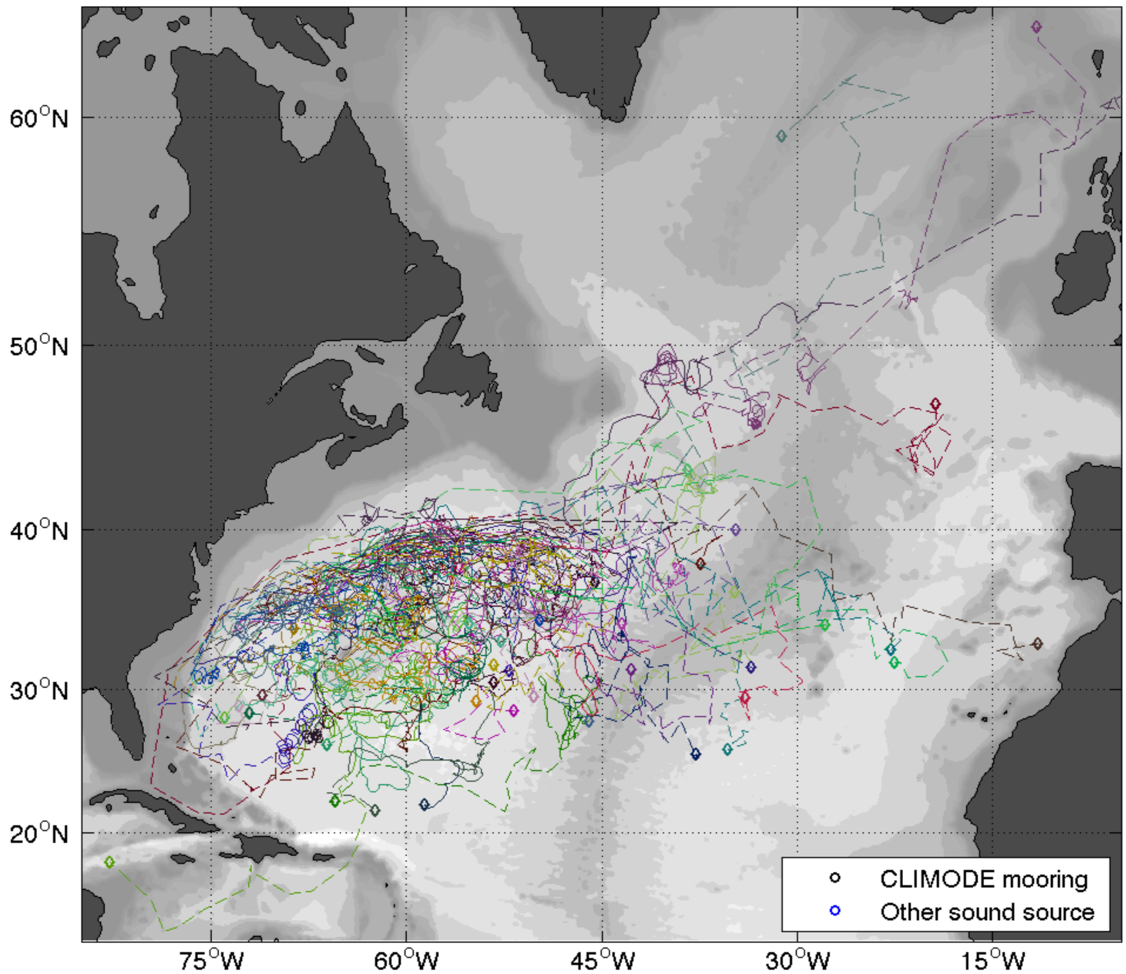


Figure 5. *Trajectories of the CLIMODE bobbers. Dashed lines indicate periods during which acoustic tracking was not possible. The most recent location of each bobber (as of June 2009) is indicated with a diamond.*

5. Acknowledgements

We acknowledge the generous assistance of the Captains and crew of the Research Vessels *Oceanus*, *Knorr*, and *Atlantis*. The CLIMODE moorings were designed by George Tupper. Young-Oh Kwon performed the quality control of the temperature profiles. Ellyn Montgomery built the automated bobber data acquisition and processing system. Financial support was provided by the National Science Foundation through Grant OCE-0424492.

6. References

Wooding, C. M., H. H. Furey, and M. A. Pacheco, 2005. RAFOS Float Processing at the Woods Hole Oceanographic Institution. *Woods Hole Oceanogr. Inst. Tech Rept.*, WHOI-2005-02, 35 pp.

Table 1. Bobber Launch Deployment Times and Positions

Bobber	Launch Date					Latitude	Longitude	3-Day Cycles
ID	Year	Month	Day	Julian	RAFOS	Deg N	Deg W	Per Surfacing
37518	2005	7	28	732521	13580	30.029	67.515	4
38576	2005	11	14	732630	13689	37.260	62.283	10
38577	2005	11	15	732631	13690	36.018	60.234	10
38581	2005	11	16	732632	13691	37.308	57.978	10
38582	2005	11	17	732633	13692	38.349	54.801	10
38585	2005	11	18	732634	13693	34.004	54.236	10
38589	2005	11	20	732636	13695	30.996	60.012	10
38590	2005	11	22	732638	13697	33.508	61.678	10
39476	2006	1	20	732697	13756	36.659	69.384	4
39475	2006	1	22	732699	13758	37.298	68.490	10
38598	2006	1	22	732699	13758	37.518	68.190	10
39449	2006	1	24	732701	13760	36.781	65.978	10
38597	2006	1	24	732701	13760	36.921	65.968	10
39721	2006	1	24	732701	13760	37.076	65.967	10
39060	2006	1	25	732702	13761	37.210	64.122	10
39448	2006	1	25	732702	13761	37.361	64.250	10
38605	2006	1	25	732702	13761	37.652	64.511	10
39722	2006	1	27	732704	13763	37.856	62.458	10
39471	2006	1	27	732704	13763	38.014	62.477	10
39472	2006	1	27	732704	13763	38.366	62.532	10
38603	2006	1	29	732706	13765	38.250	63.045	10
38600	2006	11	24	733005	14064	36.123	60.142	10
38599	2006	11	24	733005	14064	36.951	58.556	10
38601	2006	11	25	733006	14065	37.516	57.523	10
38608	2006	11	27	733008	14067	38.371	55.839	10
39474	2006	11	28	733009	14068	38.236	59.339	10
39793	2007	2	10	733083	14142	37.697	61.541	10
39765	2007	2	11	733084	14143	36.694	66.277	10
38604	2007	2	19	733092	14151	37.859	53.975	10
39470	2007	2	25	733098	14157	36.075	56.971	10
39763	2007	2	26	733099	14158	35.165	59.241	10
39473	2007	2	26	733099	14158	34.428	61.142	10
39736	2007	3	3	733104	14163	35.755	65.856	10
39477	2007	3	3	733104	14163	36.975	65.407	10
39729	2007	3	4	733105	14164	37.392	65.573	10
39766	2007	3	4	733105	14164	37.817	65.767	10
38575	2007	3	4	733105	14164	38.265	65.925	10
39733	2007	3	13	733114	14173	38.371	55.971	10
39720	2007	3	13	733114	14173	37.728	51.854	10
39726	2007	3	18	733119	14178	36.043	59.968	10

Table 2. Sound Source Deployment Positions and Times

All Sound sources transmitted for 80 seconds every 24 hours. Two of the sources, C and D, were recovered and redeployed midway through the experiment. The source clocks were reset during this turn-around.

Mooring Number	Source Number	Depth (m)	Pong Time	Latitude Deg N	Longitude Deg W	Deploy Date	Recovery Date
A	22	400	00:30	30.975	60.011	11/20/2005	11/22/2007
B	21	400	00:00	34.041	54.264	11/18/2005	11/10/2007
C	24	650	01:30	38.371	55.862	11/17/2005	11/26/2006
C-redeploy	24	650	01:30	38.371	55.873	11/27/2006	11/09/2007
D	23	650	01:00	36.090	60.171	11/15/2005	11/22/2006
D-redeploy	23	650	01:00	36.087	60.169	11/23/2006	11/07/2007

Table 3. List of ARGOS Transmissions That Required Manual Repair of Messages

Float ID	Transmission Date		
f38598	2006-11-18		
f38603	2007-07-23	2007-08-22	2007-11-20
f39060	2006-07-24	2007-08-18	
f39448	2007-08-18		
f39470	2007-06-25		
f39471	2007-04-22		
f39473	2007-05-27		
f39721	2007-02-18		
f39722	2007-04-22		
f39729	2007-04-03		
f39763	2007-05-27		
f39766	2007-06-07		2007-08-31

Table 4. Duration (Lifetime) and Rate of Success of ARGOS Transmissions for CLIMODE Bobbers Through May 31, 2009

Float	First Transmission			Last Transmission			Duration	Transmissions		Success
ID	Year	Month	Day	Year	Month	Day	(Days)	Expected	Actual	Rate (%)
37518[1]	2005	8	9	2007	12	9	852	72	71	98.6
38575[1]	2007	4	3	2009	5	22	780	27	26	96.3
38576[2]	2005	12	14	2008	7	1	930	32	27	84.4
38577[2]	2005	12	15	2006	8	12	240	9	9	100.0
38581[2]	2005	12	16	2008	11	30	1080	37	37	100.0
38582[2]	2005	12	17	2008	1	6	750	26	25	96.2
38585[2]	2005	12	18	2009	5	31	1260	43	43	100.0
38589[2]	2005	12	21	2009	5	4	1230	42	42	100.0
38590[2]	2005	12	22	2008	3	11	810	28	28	100.0
38597	2006	2	23	2008	9	10	930	32	29	90.6
38598	2006	2	21	2009	5	6	1170	40	40	100.0
38599	2006	12	24	2009	5	12	870	30	30	100.0
38600	2006	12	24	2009	5	12	870	30	30	100.0
38601	2006	12	25	2009	5	13	870	30	29	96.7
38603	2006	2	28	2009	5	13	1170	40	40	100.0
38604	2007	3	21	2009	3	10	720	25	22	88.0
38605	2006	2	24	2009	5	9	1170	40	37	92.5
38608	2006	12	27	2009	5	15	870	30	30	100.0
39060	2006	2	24	2009	5	9	1170	40	40	100.0
39448	2006	2	24	2009	5	9	1170	40	39	97.5
39449	2006	2	23	2007	5	19	450	16	16	100.0
39470	2007	3	27	2009	5	15	780	27	27	100.0
39471	2006	2	26	2009	5	11	1170	40	40	100.0
39472	2006	2	27	2008	1	18	690	24	24	100.0
39473	2007	3	28	2009	5	16	780	27	27	100.0
39474	2006	12	28	2009	5	16	870	30	30	100.0
39475	2006	2	21	2009	5	6	1170	40	40	100.0
39476	2006	2	1	2009	5	28	1212	102	102	100.0
39477	2007	4	3	2009	5	22	780	27	27	100.0
39720	2007	4	12	2009	5	31	780	27	27	100.0
39721	2006	2	23	2008	4	13	780	27	27	100.0
39722	2006	2	26	2009	5	11	1170	40	39	97.5
39726	2007	4	18	2009	5	7	750	26	26	100.0
39729	2007	4	3	2009	5	22	780	27	27	100.0
39733	2007	4	12	2009	5	1	750	26	26	100.0
39736[1]	2007	4	2	2009	5	21	780	27	27	100.0
39763	2007	3	28	2009	5	16	780	27	26	96.3
39765	2007	3	13	2008	12	2	630	22	22	100.0
39766	2007	4	3	2009	5	22	780	27	27	100.0
39793	2007	3	12	2009	5	30	810	28	27	96.4

[1] Float could not be tracked acoustically due to poor signal quality.

[2] Float collected only one point during each bob due to a bad sensor.

Table 5. Float Clock Drift (ARGOS Time – Float Clock Time) for 37 Tracked Floats

Float	**Date of Last Transmission Used**					**Launch**	**Final**
ID	**Year**	**Month**	**Day**	**Hr**	**Min**	**Offset (sec)**	**Offset (sec)**
38576	2007	08	06	09	48	11.10	-70.320
38577	2006	08	12	10	17	38.435	12.509
38581	2007	01	10	09	06	1.772	-34.708
38582	2007	12	07	14	10	-1.690	-78.999
38585	2007	12	08	13	53	10.171	-67.900
38589	2007	12	11	11	10	3.202	-75.000
38590	2007	11	12	08	14	-5.210	-97.000
38597	2007	11	15	11	49	-0.311	-79.000
38598	2007	12	13	10	23	2.322	-63.999
38599	2007	11	19	11	48	-3.140	-50.999
38600	2007	11	19	13	39	-1.751	-44.999
38601	2007	11	20	09	56	1.368	-45.000
38603	2007	11	20	09	32	10.176	-107.00
38604	2007	11	16	12	56	1.531	-24.999
38605	2007	11	16	11	05	9.253	-92.000
38608	2007	11	22	12	15	-1.2	-59.999
39060	2007	12	16	11	06	7.030	-66.440
39448	2007	11	16	14	38	2.455	-93.999
39449	2007	05	19	12	22	2.646	-66.440
39470	2007	11	22	12	13	1.695	-44.000
39471	2007	11	18	10	17	6.939	-44.990
39472	2007	11	19	13	29	3.098	-47.999
39473	2007	11	23	19	05	-10.845	-43.000
39474	2007	11	23	09	26	0.788	-52.000
39475	2007	12	13	12	03	4.835	-104.999
39476	2007	11	11	13	10	11.355	-37.999
39477	2007	11	29	11	54	-1.803	-32.999
39720	2007	12	08	09	48	-0.018	-36.000
39721	2007	11	15	13	17	-3.898	-87.999
39722	2007	12	18	04	00	0.627	-64.999
39726	2007	12	14	09	55	0.224	-39.999
39729	2007	11	29	10	56	3.227	-25.000
39733	2007	12	08	12	10	2.439	-32.999
39763	2007	11	23	11	53	-11.189	-50.999
39765	2007	12	08	09	47	-7.448	-42.000
39766	2007	11	29	10	55	-15.977	-45.999
39793	2007	12	07	09	58	-6.239	-45.000

Table 6. Percentage of TOAs That Resulted in Acceptable Positions

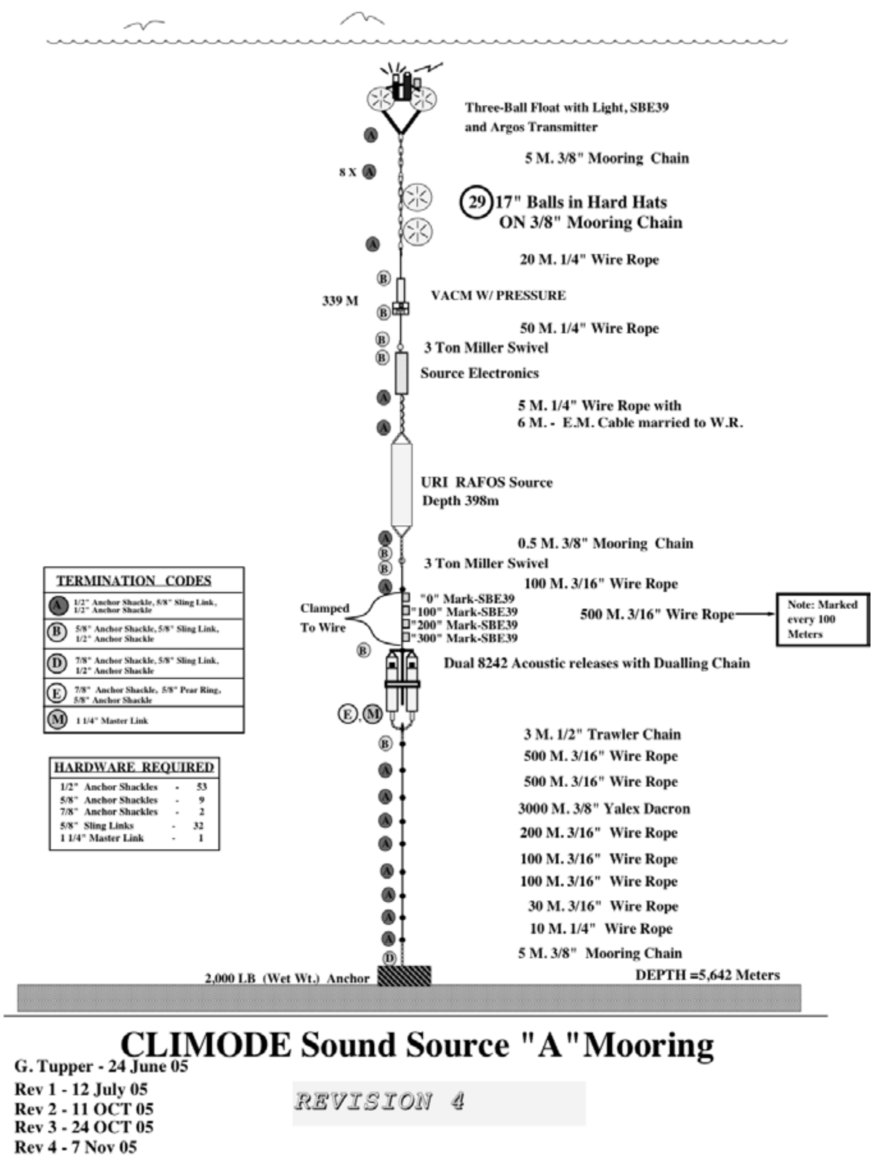
Float	Number of Tracked Positions		
ID	Total	Acceptable	% Acceptable
38576	630	362	57.5
38577	266	115	43.2
38581	419	171	40.8
38582	747	164	22.0
38585	750	677	90.3
38589	751	699	93.1
38590	718	673	93.7
38597	662	560	84.6
38598	688	641	93.2
38599	360	249	69.2
38600	356	332	93.3
38601	356	299	84.0
38603	659	547	83.0
38604	268	243	90.7
38605	661	635	96.1
38608	355	43	12.1
39060	690	164	23.8
39448	660	552	83.6
39449	477	265	55.6
39470	265	84	31.7
39471	658	410	62.3
39472	660	608	92.1
39473	266	248	93.2
39474	357	309	86.6
39475	692	202	29.2
39476	657	366	55.7
39477	268	164	61.2
39720	266	225	84.6
39721	660	589	89.2
39722	689	342	49.6
39726	266	209	78.6
39729	265	223	84.2
39733	266	208	78.2
39763	267	224	83.9
39765	299	251	83.9
39766	266	237	89.1
39793	297	194	65.3

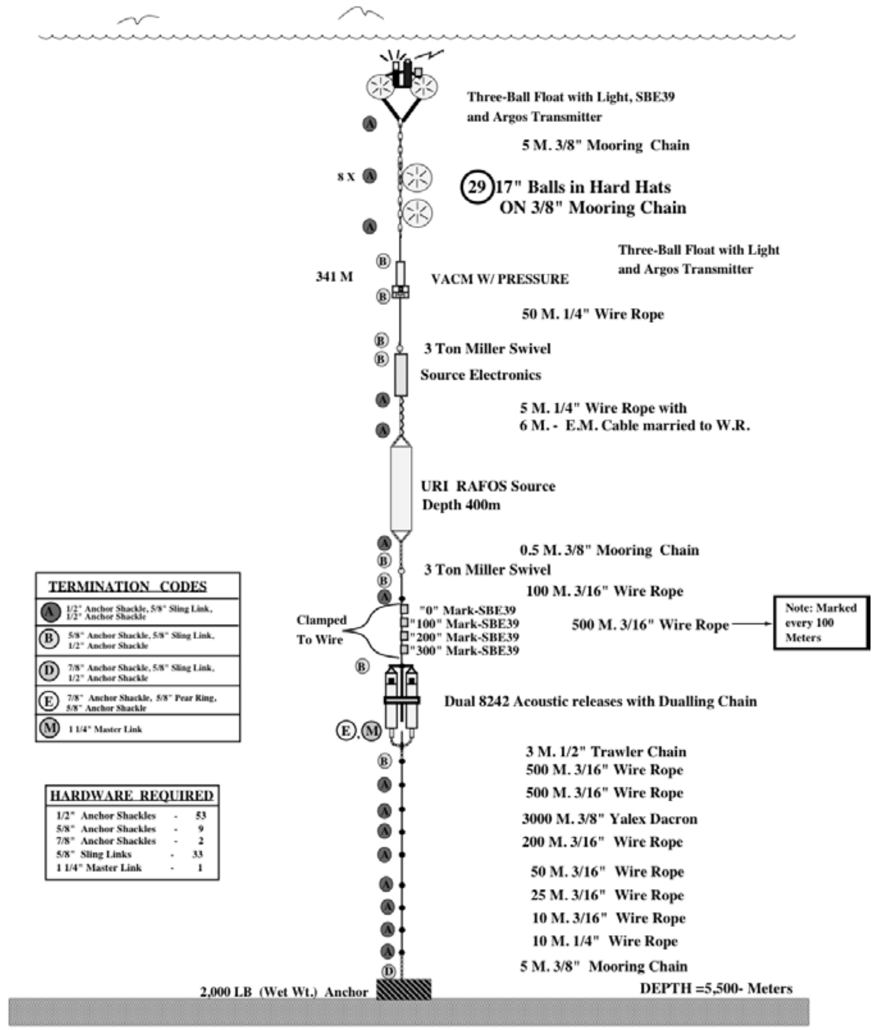
Appendix A: Mooring and Bobber Deployment/Recovery Schedule

Cruise ID	Dates	Chief Scientist(s)	Activity
OC419	Nov 9 – Nov 27, 2005	Fratantoni, Weller	Moorings A, B, C, & D deployed 7 bobbers deployed
AT13	Jan 18 – Jan 31, 2006	Joyce	13 bobbers launched
OC434	Nov 16 – Dec 3, 2006	Weller	Recover, redeploy Moorings C & D 5 bobbers launched
KN188-01	Feb 7 – Feb 27, 2007	Joyce	6 bobbers launched
KN188-02	Mar 2 – Mar 22, 2007	Joyce	8 bobbers launched
OC442	Nov 5 – Nov 19, 2007	Fratantoni	Moorings A, B, C, & D recovered

Appendix B: CLIMODE Mooring Diagrams

The following pages include drawings of the four CLIMODE moorings which hosted RAFOS sound sources. The other instrumentation on these moorings is described in a companion report focusing on the moored observations.

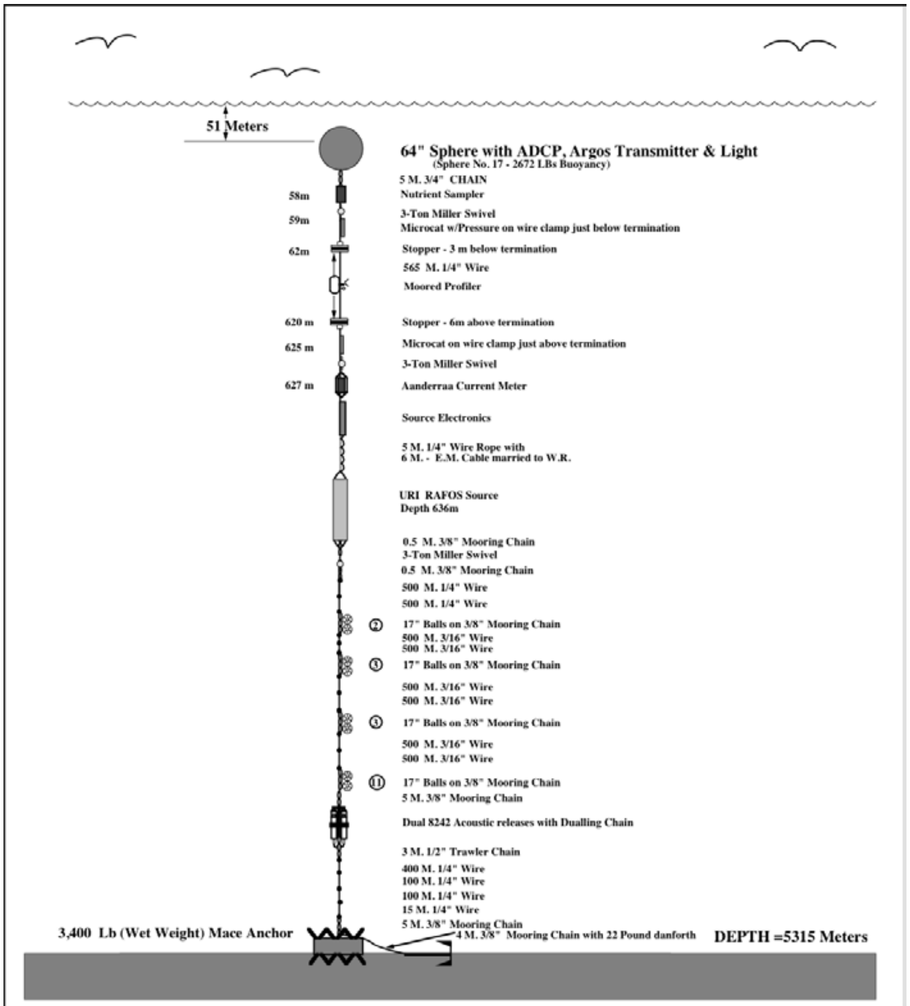




CLIMODE Sound Source "B"Mooring

G. Tupper - 24 June 05
Rev 1 - 12 July 05
Rev 2 - 11 OCT 05
Rev 3 - 24 OCT 05
Rev 4 - 7 Nov 05

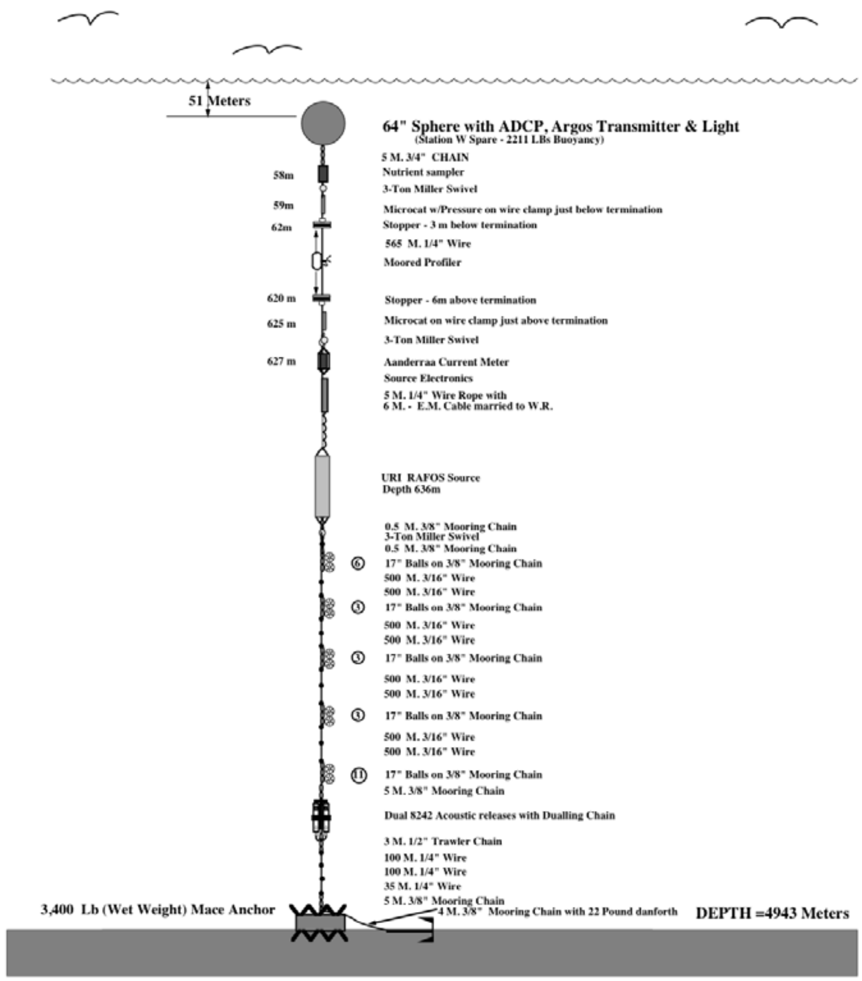
REVISION 4



CLIMODE Source + MMP Mooring C

G. Tupper 24 June 05
Rev 1 - 12 July 05
Rev 2 - 11 OCT 05

REVISION 2



CLIMODE Source + MMP Mooring D

G. Tupper 24 June 05
Rev 1 - 12 July 05
Rev 2 - 11 OCT 05

REVISION 2

Appendix C: Sample Sound Source File Entry

```
[CLa]
-sourcename     CLa
-sourcetype     Rossby
-sourceowner    WHOI/Climode
-position       30.975  -60.011
-depth          400
-begemis        2005 11 20 00  30
-endemis        2007 11 22 00  30
-offset         2005 11 20 0.0
-drift          -0.128
-reftime        00 30
-schedule       24
-signallength   80
-add_offset     NaN
-sound_speed    1480
-comment        Based on source clock check when pulled, HHF.
```

Appendix D: Sample TOA File

```
rfb589.rfb
-floatname        RF589
-type             28 bit WHOI, SEASCAN   DLD2
-projectname      CLIMODE
-pttdec           38589
-ptthex           2A513D4
-pttrep           20.0
-launchpos        30.996 -60.120
-launchtime       2005 11 20 23 55
-comment          above info from log book - deploy not reset time
-recoverpos       23.179 -65.173
-recovertime      2007 12 11 11 10
-comment          above from:
-comment          first fix for 2007-12-11 in all_pos.asc
-offset           2005 11 20 23 55  0.00
-offset           2007 12 11 11 10  -75.00
-cycle            1 30.996 -60.120 2005 11 21 00 00 23.179 -65.173 2007 12 10 00 00
-comment          datenum(2007,12,10) - datenum(2005,11,21) (result 749 phasespercycle)
-comment          time is first surface fix time for 11/20/2005; end time one cycle before last
-comment          NOTE: float time in ARGOS message was
-progdepth        300
-progtemp         18.5
-phasespercycle   750
-schedule         24
-phasereftime     00 00
-windowsperphase  1
-toaperwindow     4
-toaperphase      4
-correlationrange 0 255
-windowrange      0 0
-windowstart      00
-windowlength     120
-field            CP
-tempequation     temp
-tempcoeff        1
-presequation     pres
-prescoeff        1
-signal_length    80
-comment          rfs_2005-12-12 through rfs_2007-12-11 from f38589
-edited_by        Terry McKee
-edited_on        2008 07 30
-variables        11
[VARIABLE_LIST]
-line_number      1
-time_of_arrival  3 5 7 9
-correlation_height 2 4 6 8
-pressure         11
-temperature      10
-pres_counts      11
-temp_counts      10
```

Appendix D: Sample of TOA File (continued)

```
[DATA]
  1  178   1884.0   92   2866.8   54   5273.9   52   1132.8   18.55   219.9
  2  180   1889.5   89   2865.5   55   4195.5   51   4955.0   18.49   222.1
  3  197   1894.5  130   2866.2   52    496.3   50   6078.6   18.46   224.9
  4  131   1899.1   82   2866.5   62    492.6   57   4624.8   18.37   227.2
  5  141   1904.3  106   2868.3   68   4063.9   49   1775.8   18.36   228.5
  6  122   1910.8   87   2871.4   67   4064.5   58    482.4   18.37   228.8
  7  115   2874.8  104   1913.5   51   4862.4   51   6635.8   18.34   232.8
  8  193   1916.0  107   4060.2   69   6066.0   49    522.7   18.39   239.7
  9  164   1920.3   50    771.5   50   4057.7   49   2839.7   18.33   236.5
 10  193   1921.8  126   4056.5   92   6061.1   59   1551.0   18.37   231.0
 11  178   1924.3  122   4053.7   76   2888.3   69   6057.1   18.33   234.1
 12  124   1925.5  119   2893.8   78   4048.8   56    460.6   18.36   232.6
 13  197   1928.6  103   4042.7   59   6042.6   52   2698.9   18.42   216.4
 14  131   1931.4  107   4036.8   97    452.0   94   6037.7   18.46   223.7
 15  186   4027.6  184   1935.0  113   2914.4   76   6026.3   18.47   221.0
 16  153   1941.2  102   6020.8   80   4017.4   66   2924.0   18.45   203.5
 17  184   1949.8  134   4006.7   91   2935.3   71   6009.1   18.45   203.1
 18  140   1960.0   95   3995.6   79   2948.0   51    227.8   18.55   206.1
 19  161   1973.2  129   3984.8   71   2961.8   54   3060.5   18.47   199.2
 20  124   5971.3  111   1986.4   86   2975.9   76   3975.6   18.48   203.4
 21  191   2000.5  151   3970.1   93   5957.1   53   3410.7   18.42   202.1
 22  145   5946.1  120   2016.5  103   3965.8   85   3000.5   18.37   199.6
 23  129   3969.5  106   2029.5   98   3007.9   98   5938.4   18.34   199.8
 24  165   2037.1  124   5937.2  118   3976.5   52    451.1   18.31   204.7
 25  176   2043.3  138   5939.9  131   3989.1   57   3009.8   18.42   203.6
 26  178   2046.1  159   3999.9  134   3006.1  112    336.4   18.35   205.6
 27  152   2049.4  126   5952.5  113    336.4   92   4009.8   18.47   176.7
 28  135   4020.5  130   2043.6   61   2991.6   60   5961.8   18.52   171.6
 29  173   2036.2   54   4891.0   54   5765.3   50    351.4   18.47   168.0
 30  193   2024.8  134   2962.1   97   4040.5   90    366.5   18.44   167.0
 .
 .
 .
748   54    809.0   53   1812.4   52   7134.0   51   2866.2   18.45   268.4
749   58   4795.7   53   2261.0   51   3094.9   51   5107.8   18.52   272.9
750   85   2456.3   55    984.9   53   2206.3   52   1154.6   18.41   274.9
```

Appendix E: Bobber ID Cross-Reference

Several numbers can be used to uniquely identify a bobber. For all purposes hereafter, including the display of data in this report, bobbers are identified by their ARGOS PTT ID (and often by the last 3 digits of the PTT ID). The bobber controller serial number is required when decoding the ARGOS messages. The table below provides a cross-reference between ARGOS PTT number (column 2), bobber serial number (assigned by the manufacturer; column 3), and the bobber's controller ID (column 1).

Bobber's Controller ID	ARGOS PTT No.	Bobber Serial No.
2398	37518	1546
2626	38576	2366
2627	38577	2367
2628	38581	2368
2629	38582	2369
2630	38585	2370
2631	38589	2371
2632	38590	2372
2633	38597	2373
2634	38598	2374
2635	38599	2375
2636	38600	2376
2637	38601	2377
2638	38603	2378
2639	38604	2379
2640	38605	2380
2641	38608	2381
2642	39060	2382
2643	39448	2383
2644	39449	2384
2645	39470	2385
2847	39476	2526
2806	39475	2525
2810	39721	2529
2811	39722	2530
2802	39471	2521
2803	39472	2522
2805	39474	2524
2809	39720	2528
2804	39473	2523
2808	39477	2527
2840	39726	2531
2841	39729	2532
2842	39733	2533
2843	39736	2534
2844	39763	2535
2845	39765	2536
2846	39766	2537
2291	39793	2538
2807	38575	2539

Appendix F: Sound Source Clock Drift Calculations

Source time comparisons at recovery									
Mooring A	Source #22	0:30:00							
Recovered	11/12/2007								
Ship Time	S. Source time	Delta	UTC-SO	Temp Corr	Final corr				
15:37:40	15:38:23	43	-63	-30.956	-94				
15:38:00	15:38:43								
15:38:30	15:39:13								
Mooring B	Source #21	0:00:00							
Recovered	11/10/2007								
Ship Time	S. Source time	Delta							
23:19:00	23:18:46	-14	14	-10.32	3.68				
23:19:20	23:09:06								
23:19:50	23:19:36								
23:20:15	23:20:01								
Mooring C	Source #24	1:30:00							
Recovered	11/9/2007								
Ship Time	S. Source time	Delta					Turnaround	11/26/2006	
16:40:00	16:40:05	5	-5		-5	year 1	14:32:00	14:32:05	-5
16:40:20	16:40:25				-5	year 2			
16:40:40	16:40:45								
16:41:10	16:41:15								
Mooring D	Source #23	1:00:00							
Recovered	11/7/2007						Turnaround	11/23/2006	
Ship Time	S. Source time	Delta		2007 tcorr			Ship Time		
23:24:00	23:24:29	29	-29	-3.6	-32.6	year 1	12:40:00	12:40:26	-27
23:24:20	23:24:49				-27	year 2			
23:24:40	23:25:09								
23:25:00	23:25:29								
23:25:20	23:25:48						2006 tcorr	Not recorded	

Appendix G: Bobber Trajectories and Profiles

The following figures provide an overview of the data collected by each of the 40 CLIMODE bobbers. Bobbers are referenced to by the last 3 digits of their ARGOS PTT ID.

(Left-hand page): Bobber trajectories are shown at two scales: as large as possible, with date markers in *mmyy* format included (*upper panel*), and at a North Atlantic scale which is the same for all bobbers (*lower panel*). Acoustically tracked sections of the trajectories are plotted as solid lines; where acoustic tracking was not possible, satellite fixes are connected by dashed lines. Deployment location is indicated by a small cross inside a circle, and latest known location by a diamond. Bold circles mark CLIMODE sound source mooring locations, with other sound sources denoted by squares. In the lower panel the typical position of the Gulf Stream north wall is indicated by an outlined arrow. Bathymetry is indicated by shading.

(Right-hand page): Temperature profiles, velocity, and park temperature recorded by each bobber are shown. The upper panel is a depth-time contour plot of temperature in the upper 950 meters. Bobber park depth is plotted as a bold black line. Daily average zonal (black) and meridional (gray) current velocities from periods when acoustic float tracking was possible are shown in the third panel. The lower panel depicts the temperature during the bobber's drift period (target = 18.5^{o}C). Time, on the horizontal axis, spans the same range for all panels and all bobbers.

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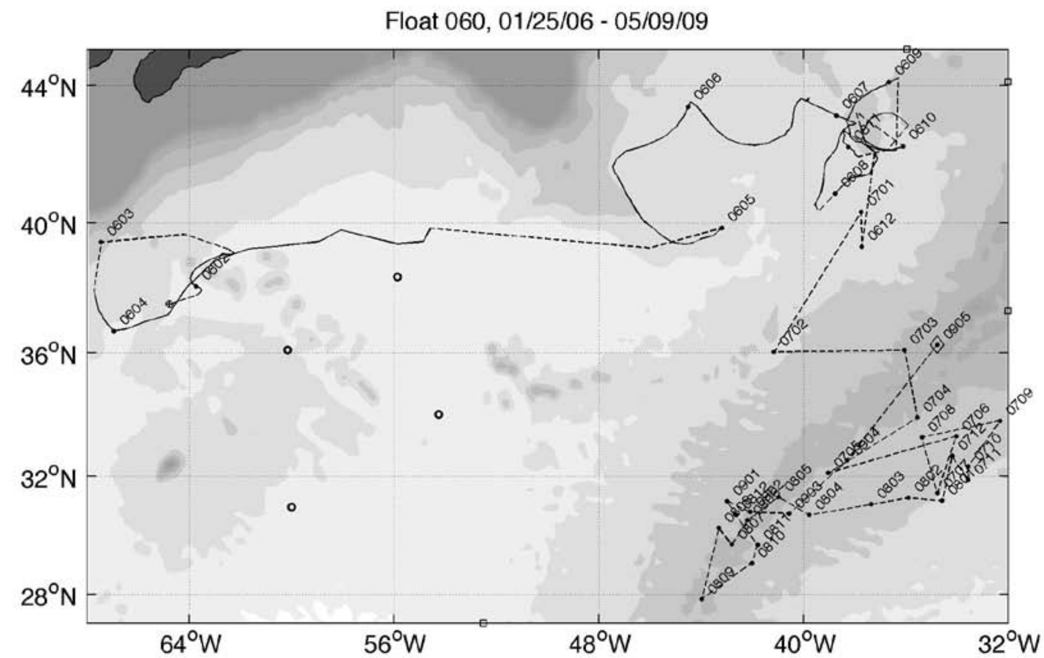
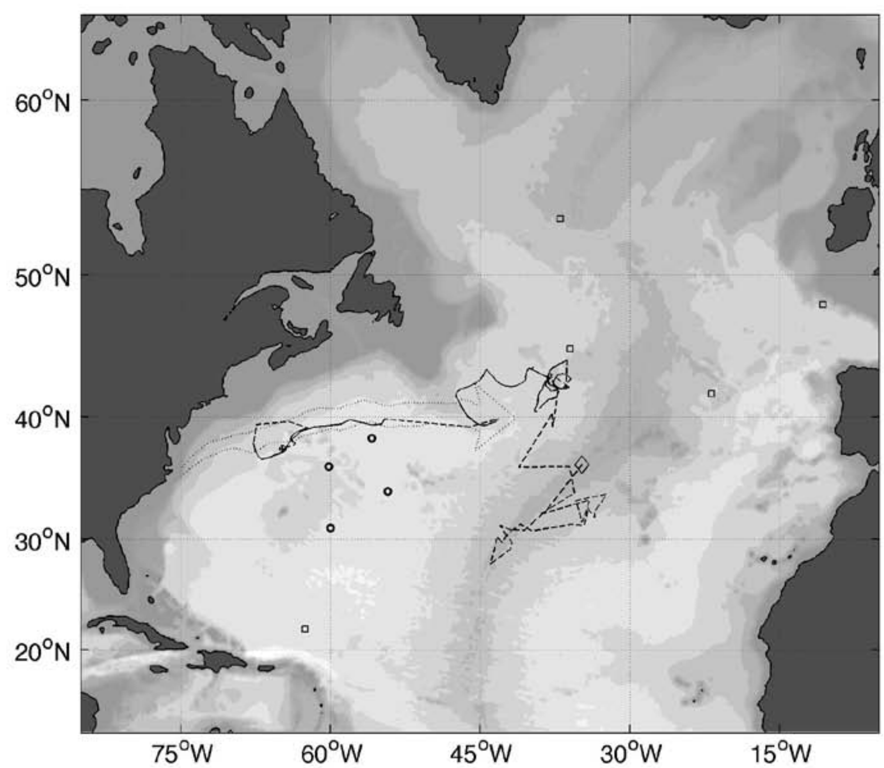
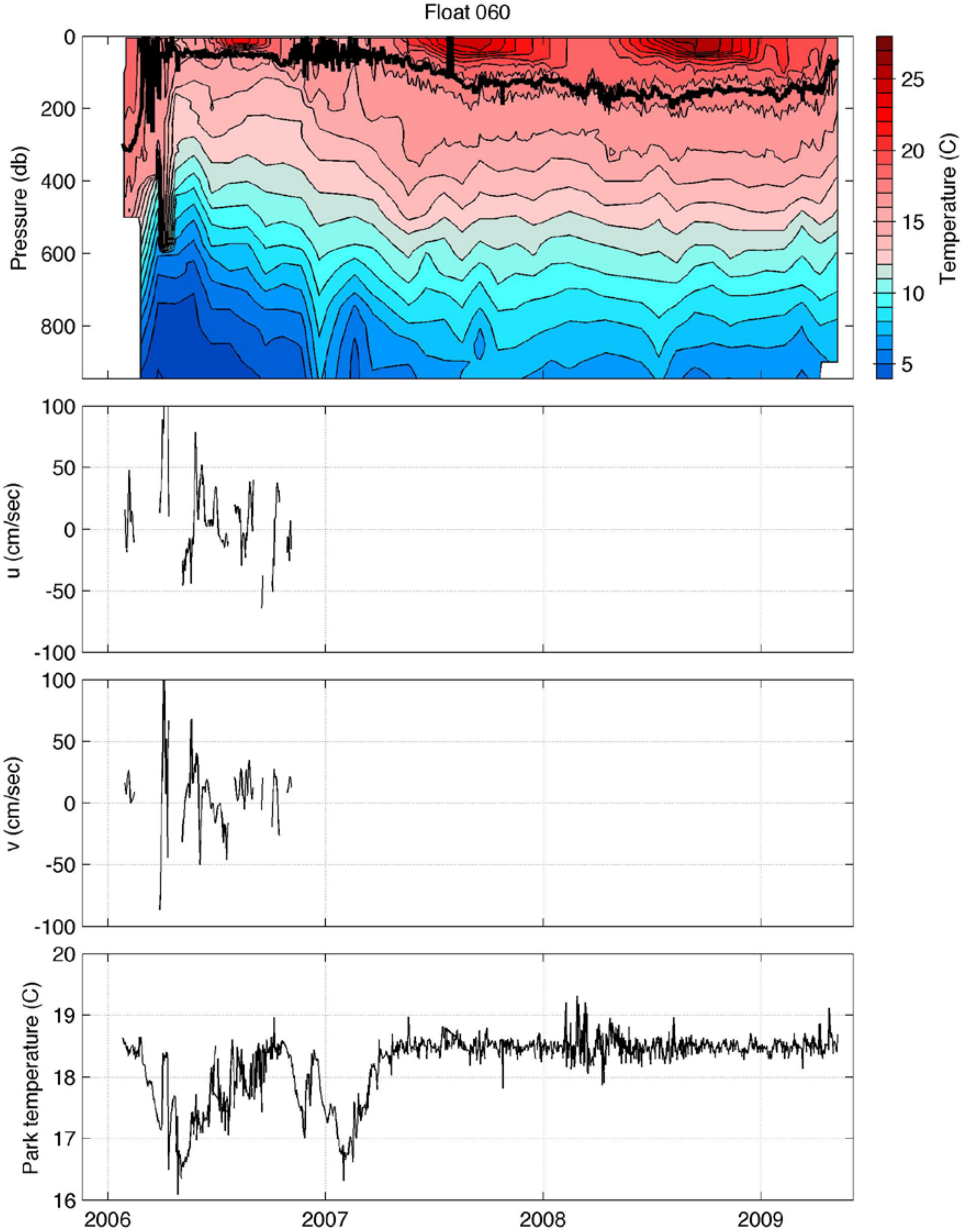
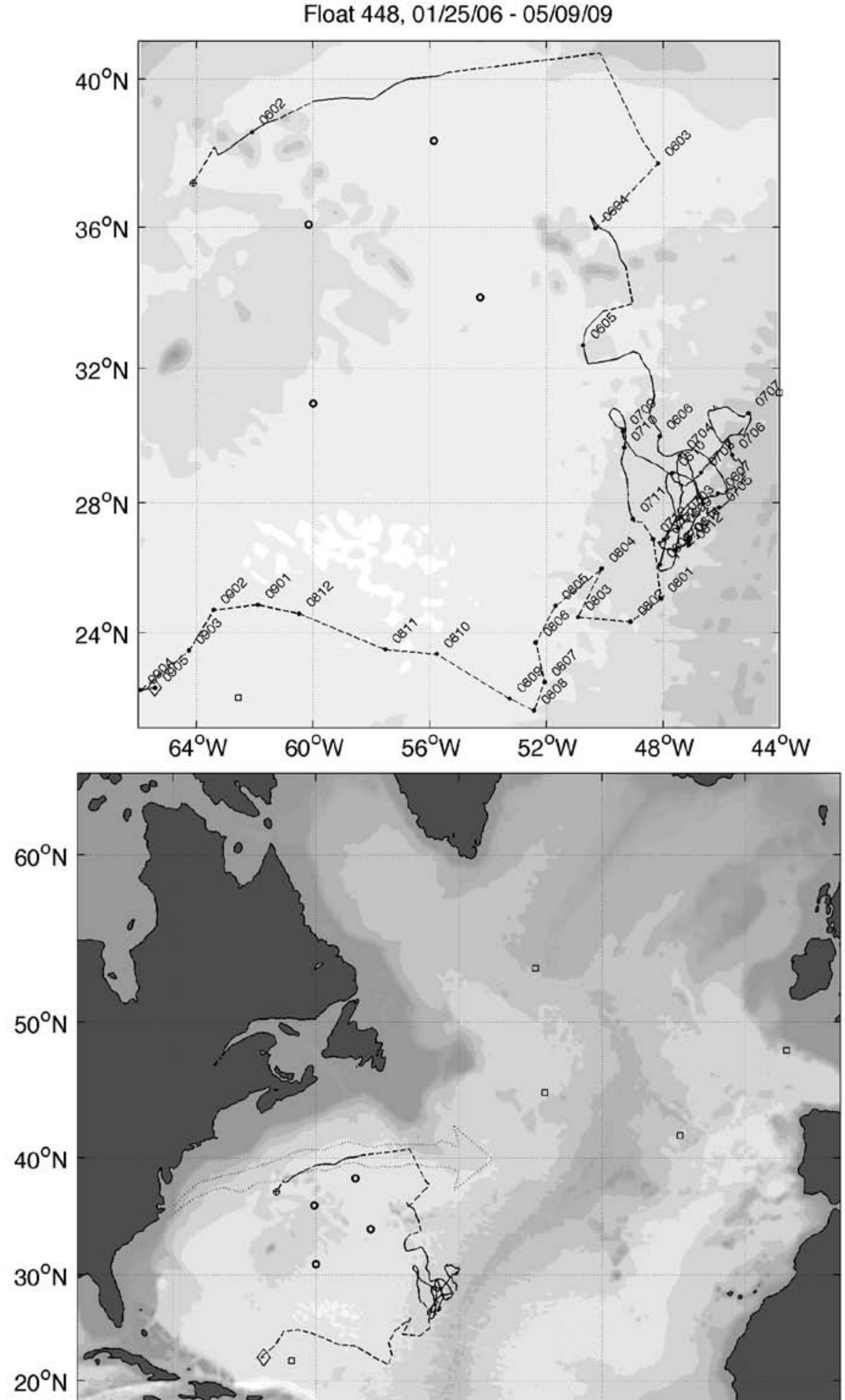
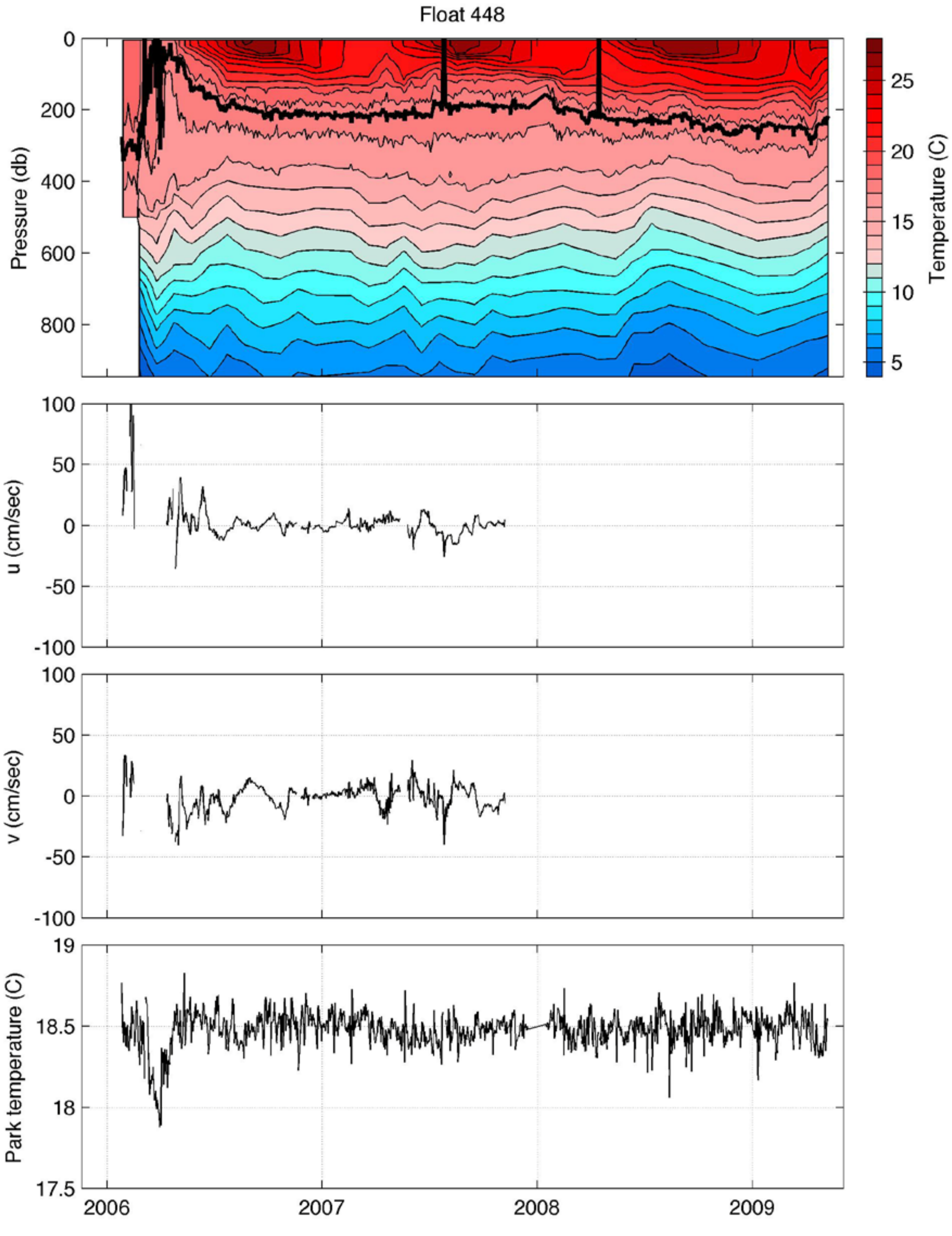

Float 060, 01/25/06 - 05/09/09
44°N
40°N
36°N
32°N
28°N
64°W
56°W
48°W
40°W
32°W


60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W

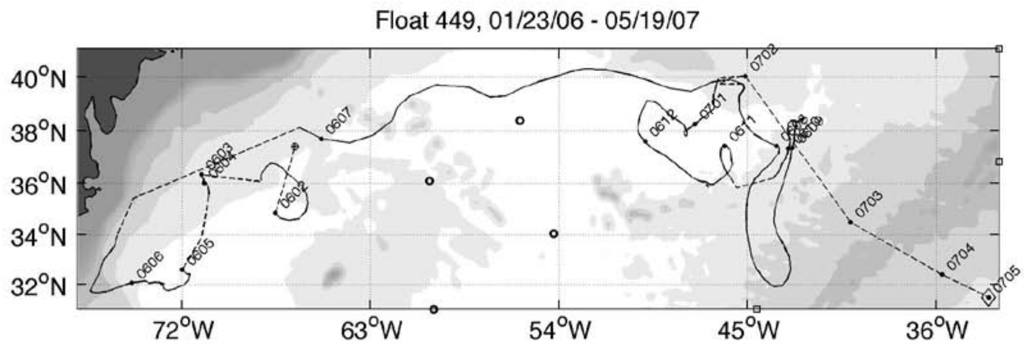


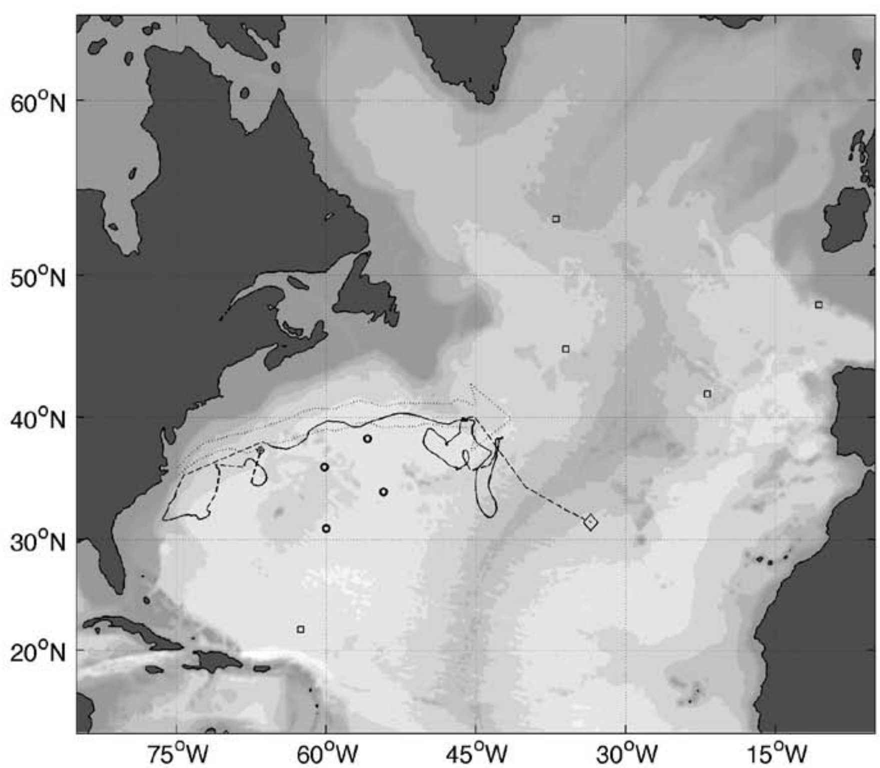
Float 060
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

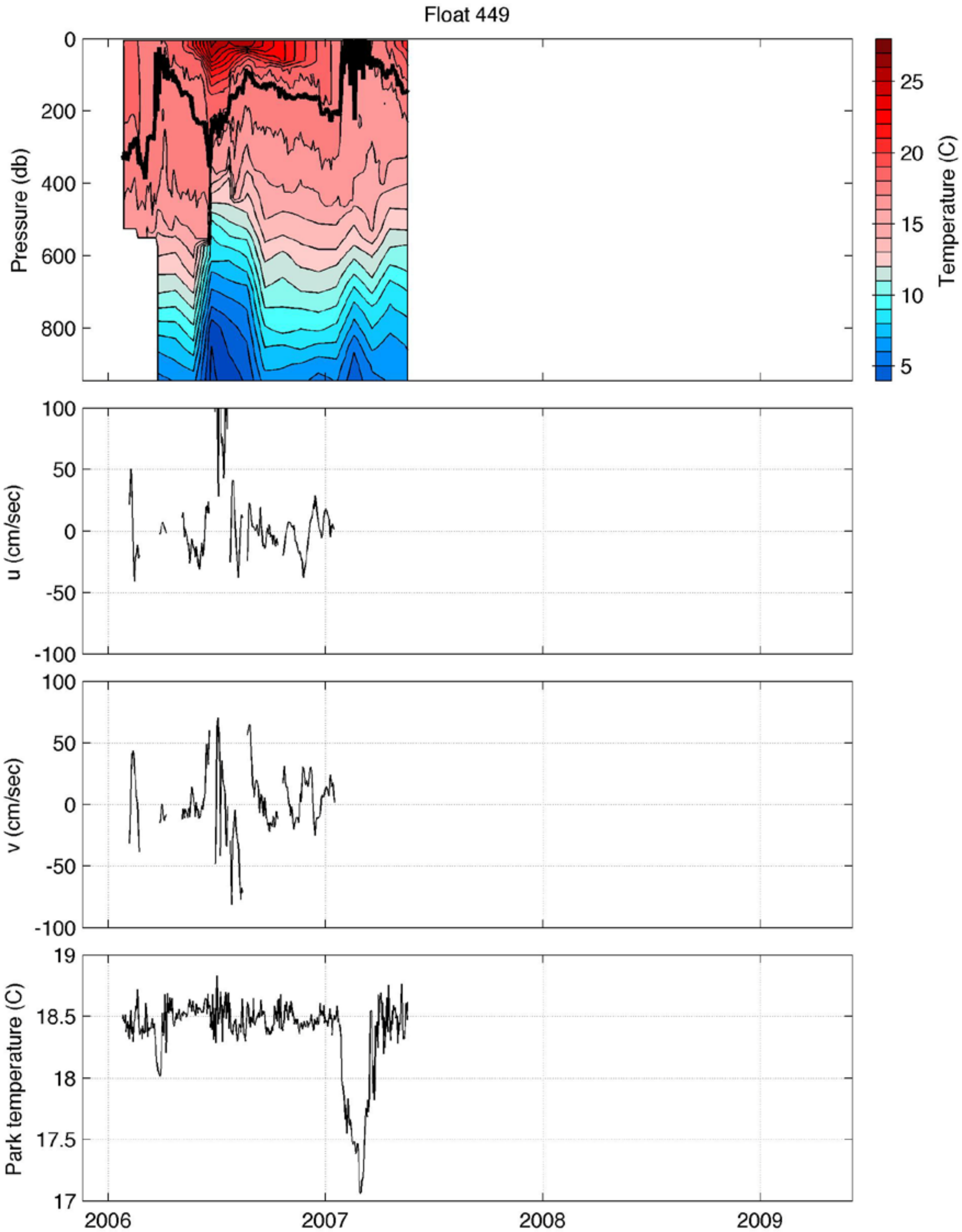

Float 448, 01/25/06 - 05/09/09
40°N
36°N
32°N
28°N
24°N
64°W
60°W
56°W
52°W
48°W
44°W
60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W



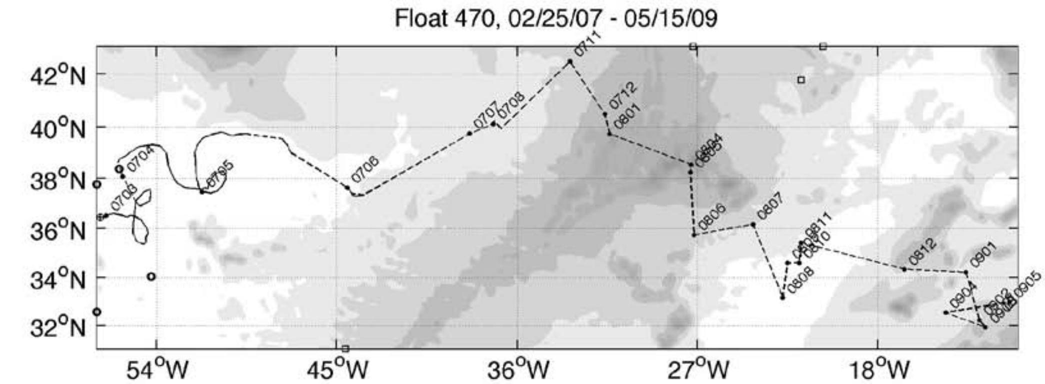
Float 448
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

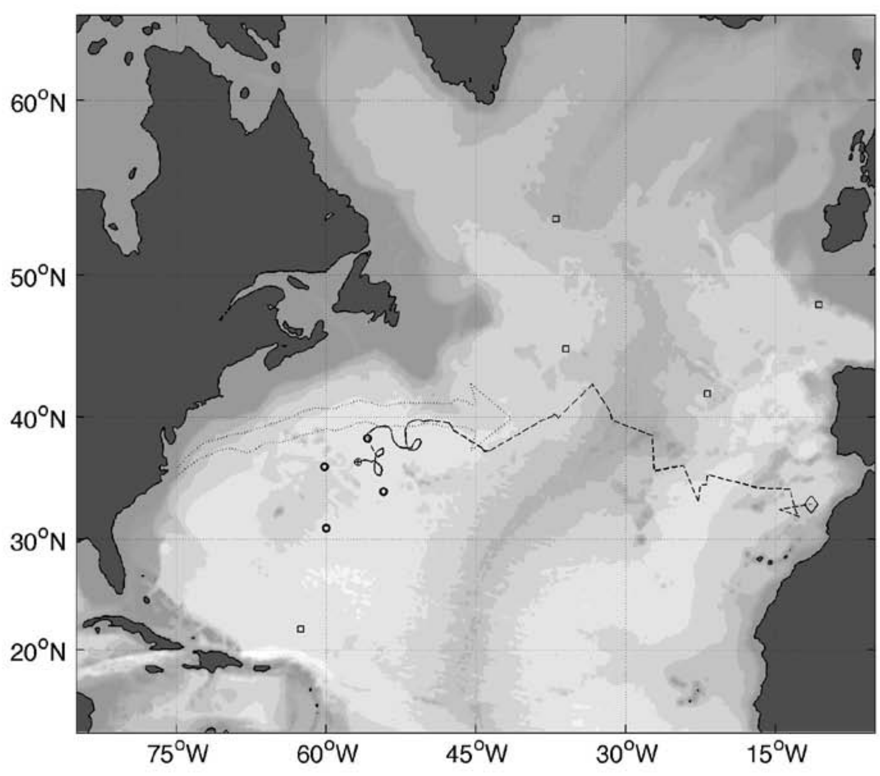

Float 449, 01/23/06 - 05/19/07
40°N
38°N
36°N
34°N
32°N
72°W
63°W
54°W
45°W
36°W

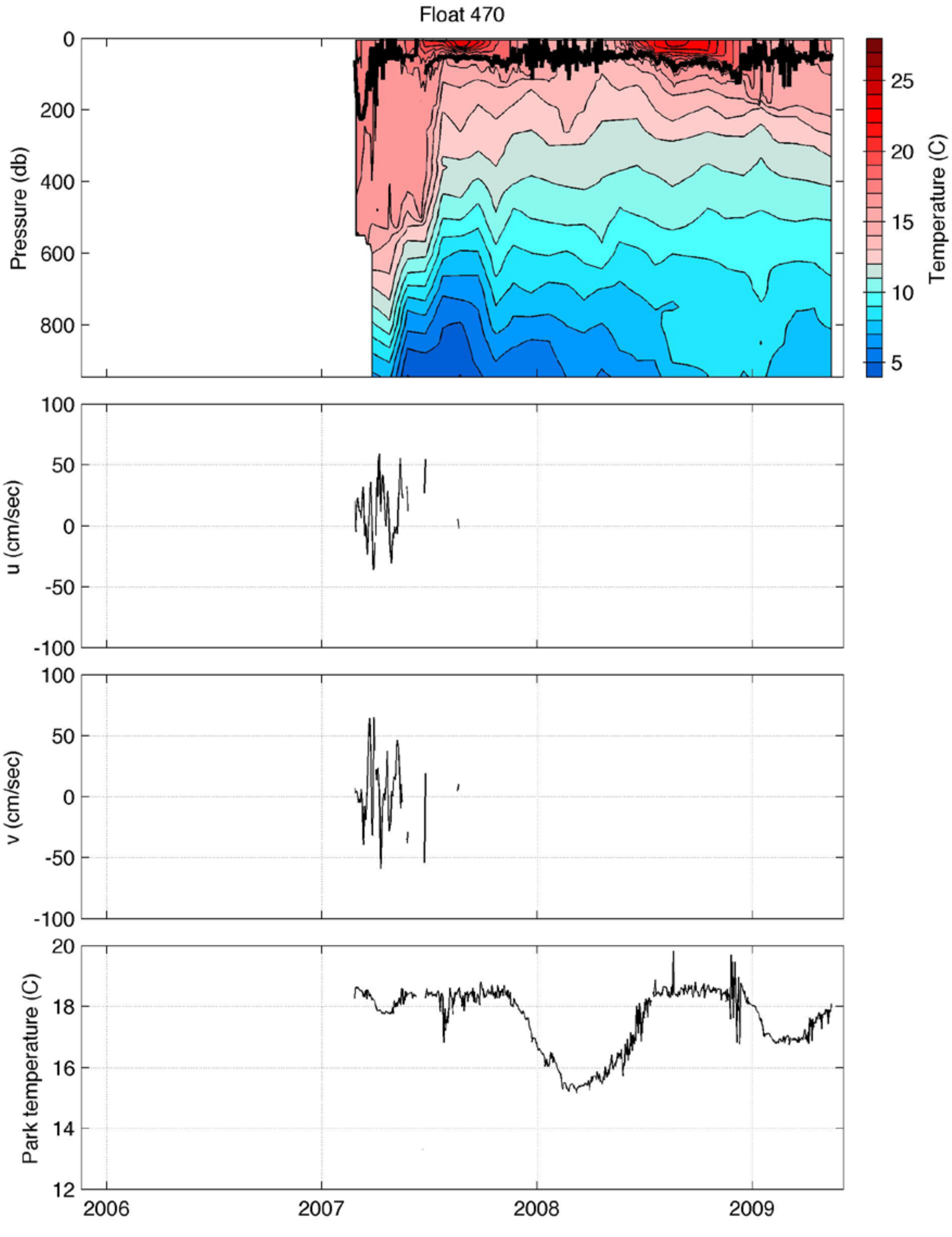

60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W



Float 449
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

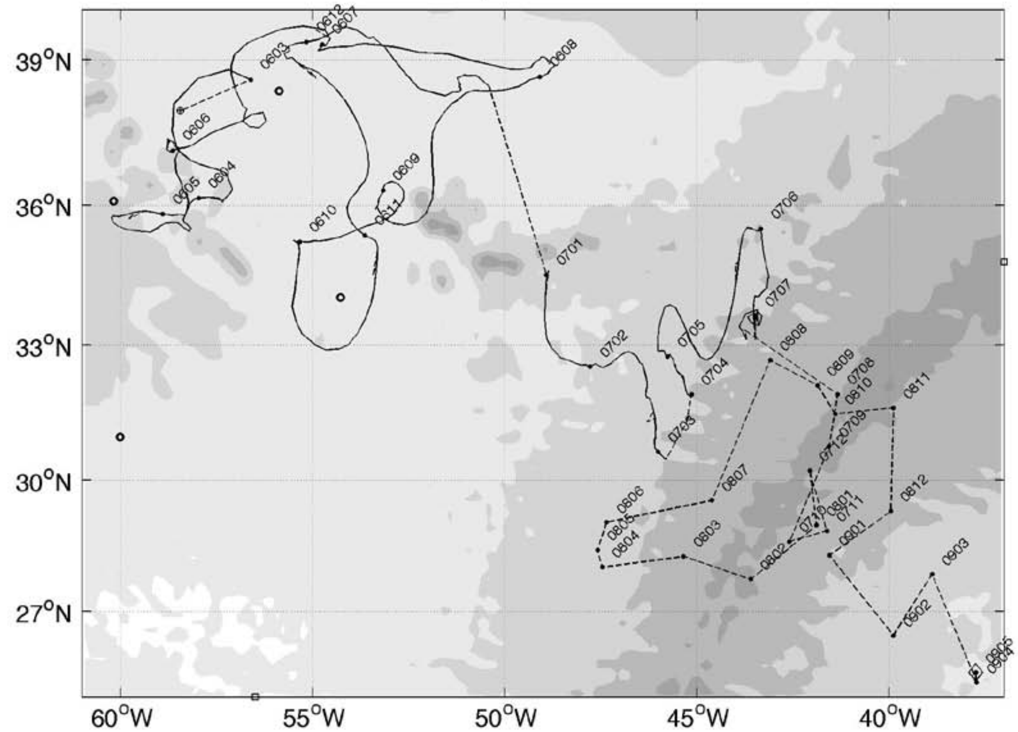

Float 470, 02/25/07 - 05/15/09
42°N
40°N
38°N
36°N
34°N
32°N
54°W
45°W
36°W
27°W
18°W
0704
0705
0703
0706
0707
0708
0711
0712
0801
0806
0807
0808
0811
0812
0901
0904
0905

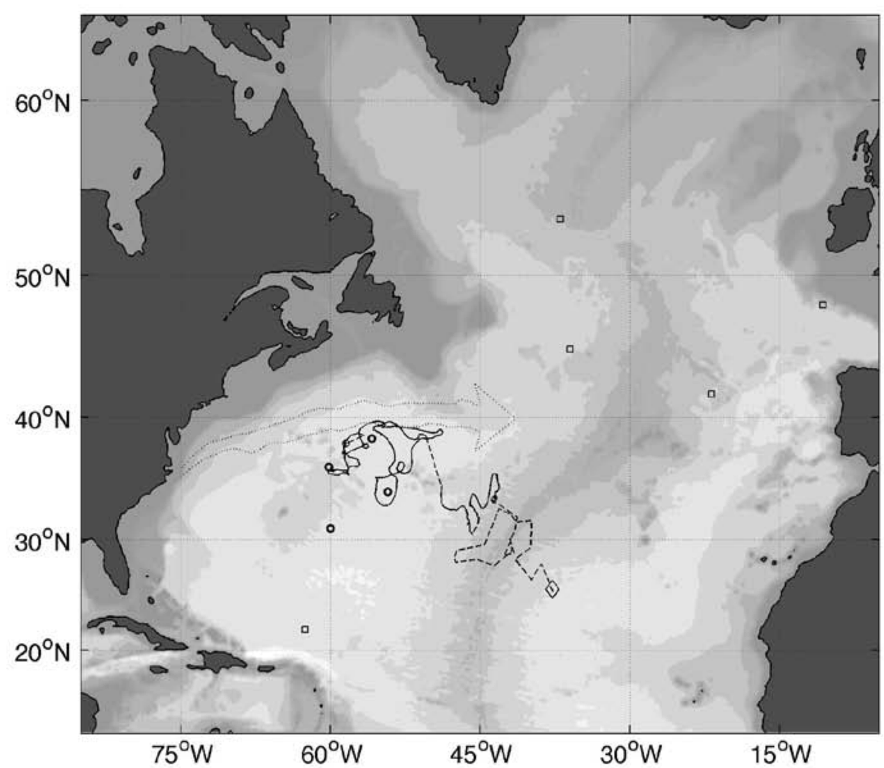

60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W

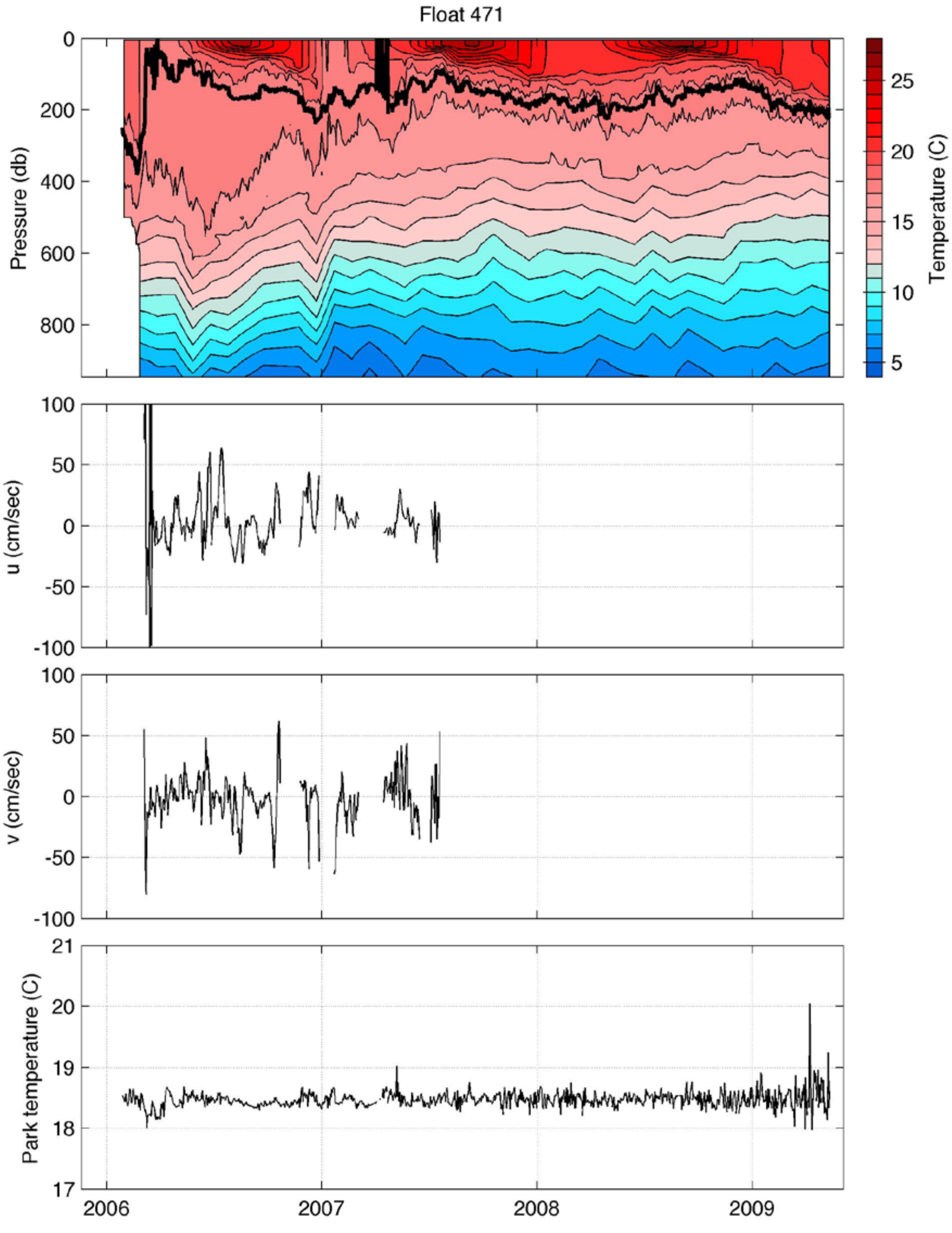


Float 470
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

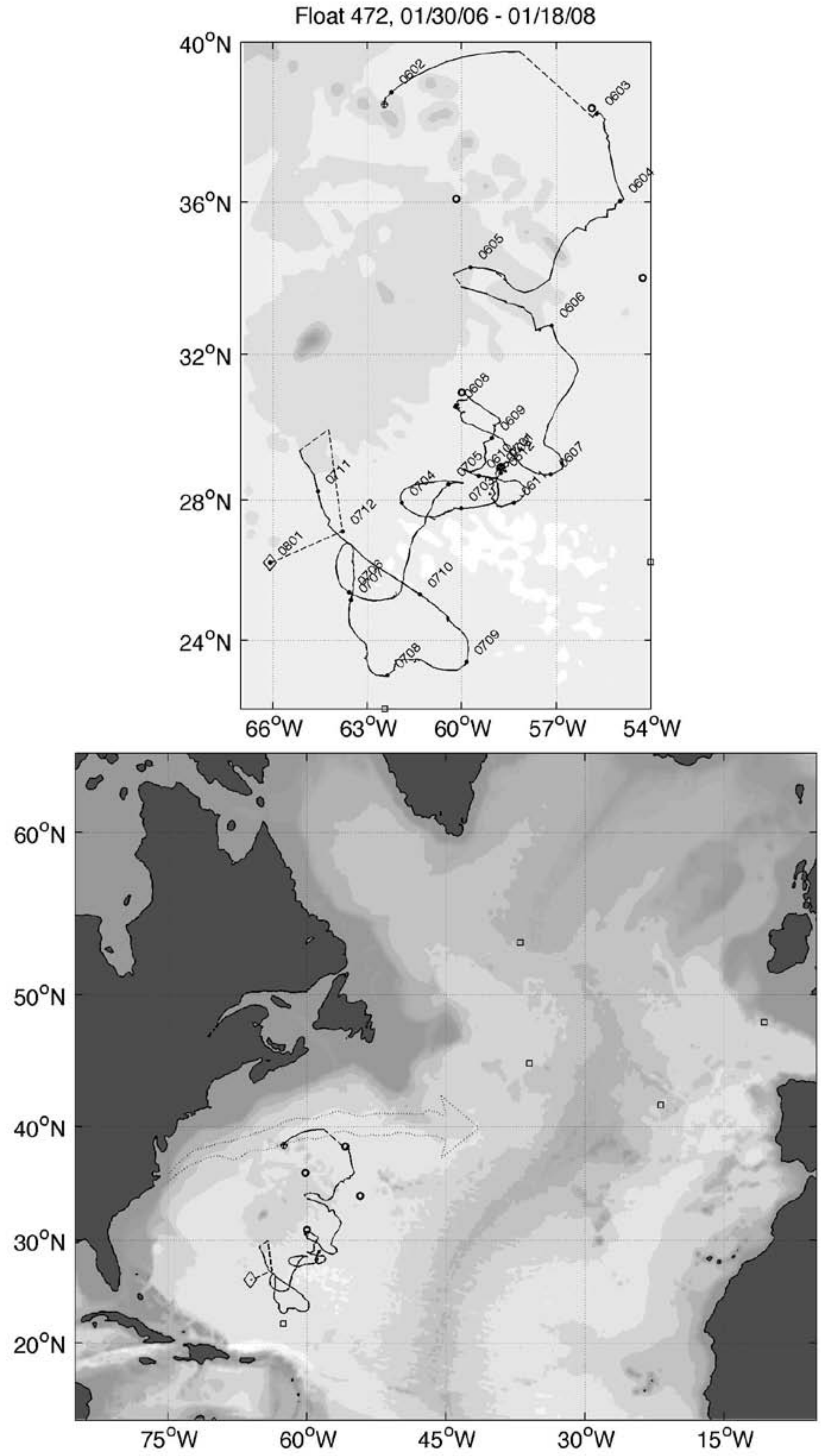
Float 471, 02/26/06 - 05/11/09

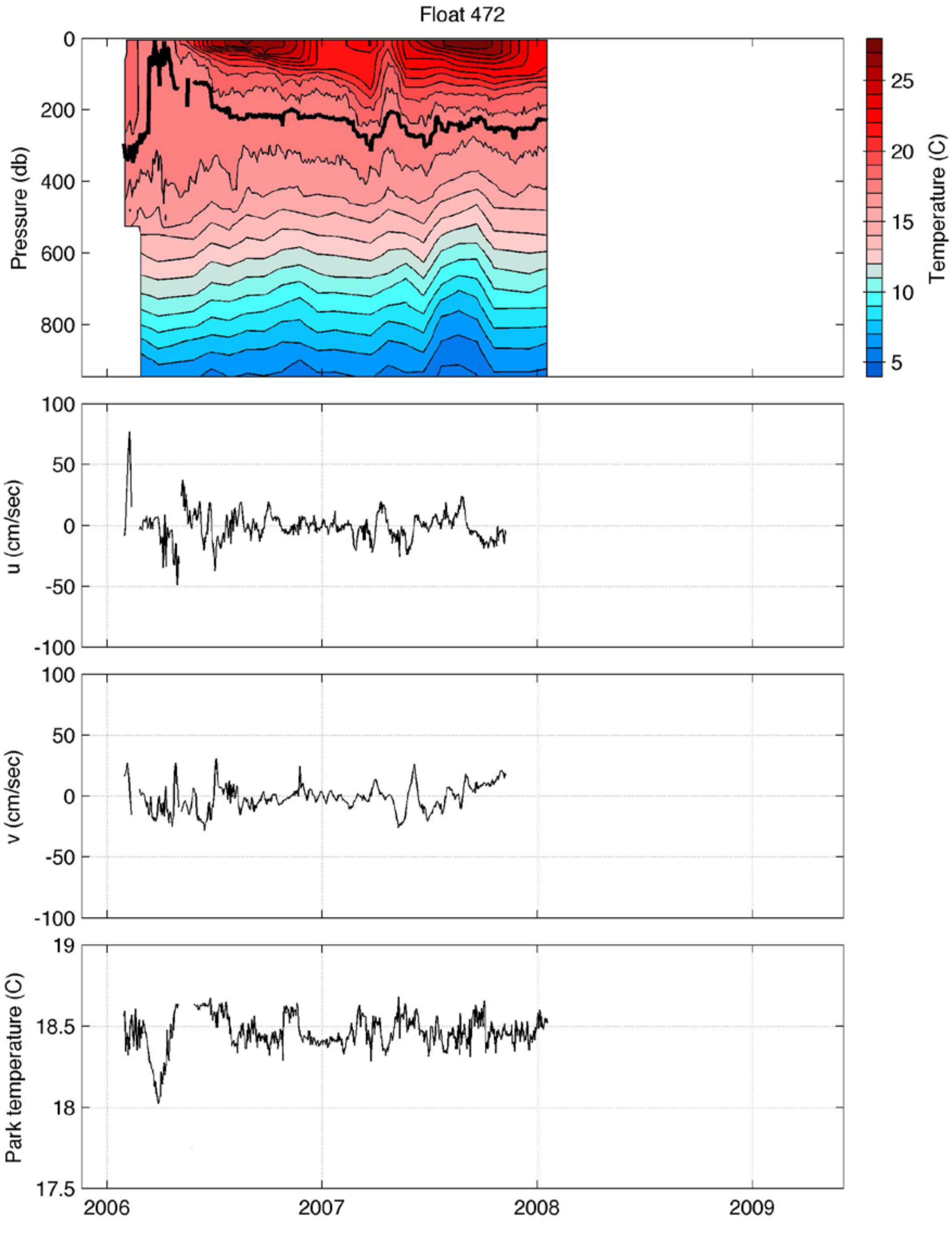


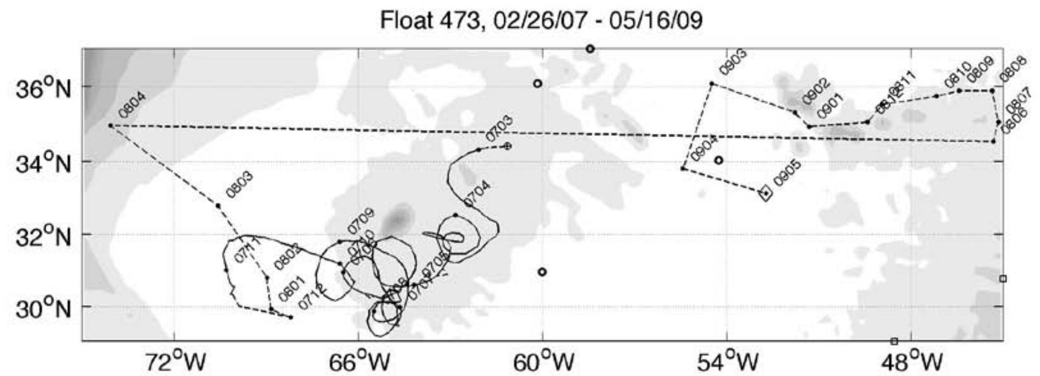




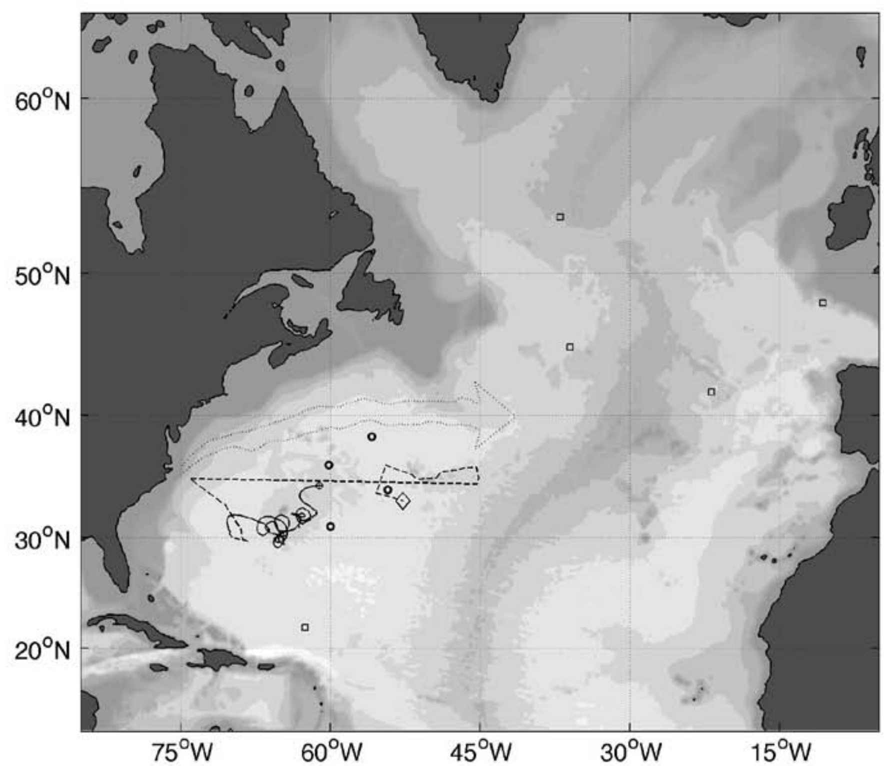
Float 471
Pressure (db)
0
200
400
600
800
Temperature (C)
25
20
15
10
5
u (cm/sec)
100
50
0
-50
-100
v (cm/sec)
100
50
0
-50
-100
Park temperature (C)
21
20
19
18
17
2006
2007
2008
2009


Float 472, 01/30/06 - 01/18/08
40°N
36°N
32°N
28°N
24°N
66°W
63°W
60°W
57°W
54°W
0602
0603
0604
0605
0606
0607
0608
0609
0611
0612
0701
0703
0704
0705
0706
0708
0709
0710
0711
0712
0801
60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W

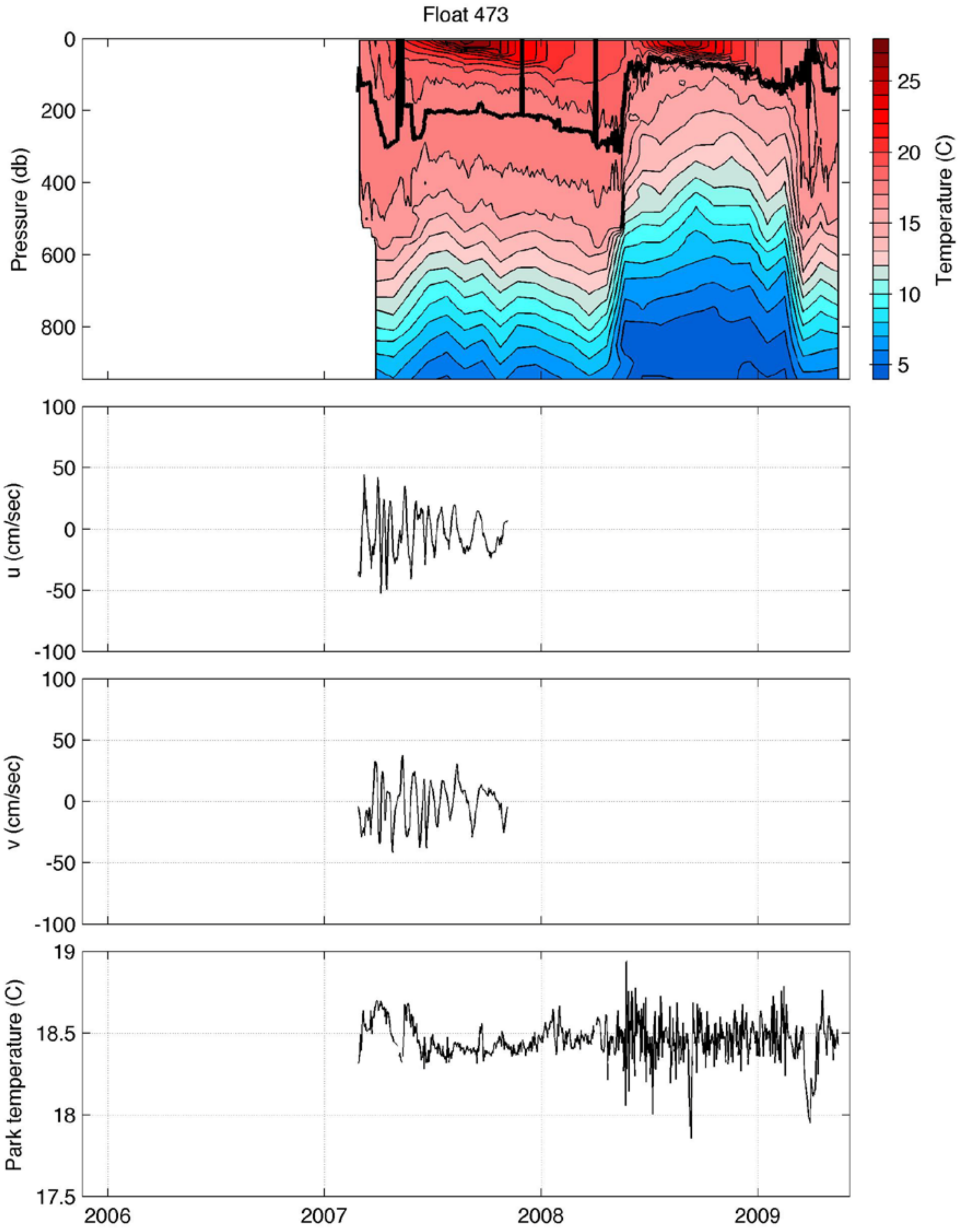

Float 472
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

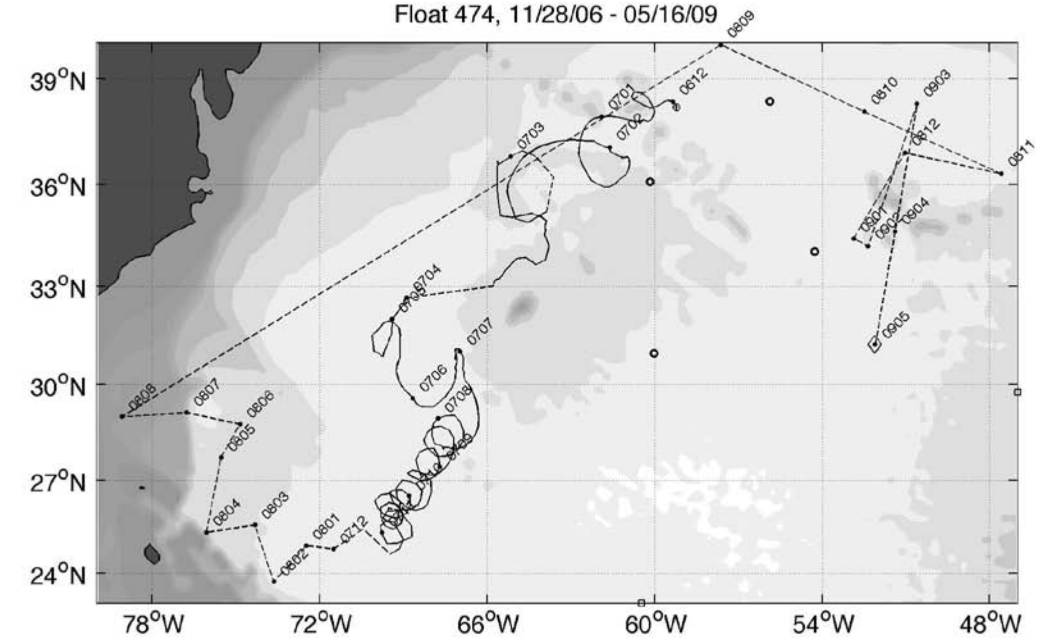


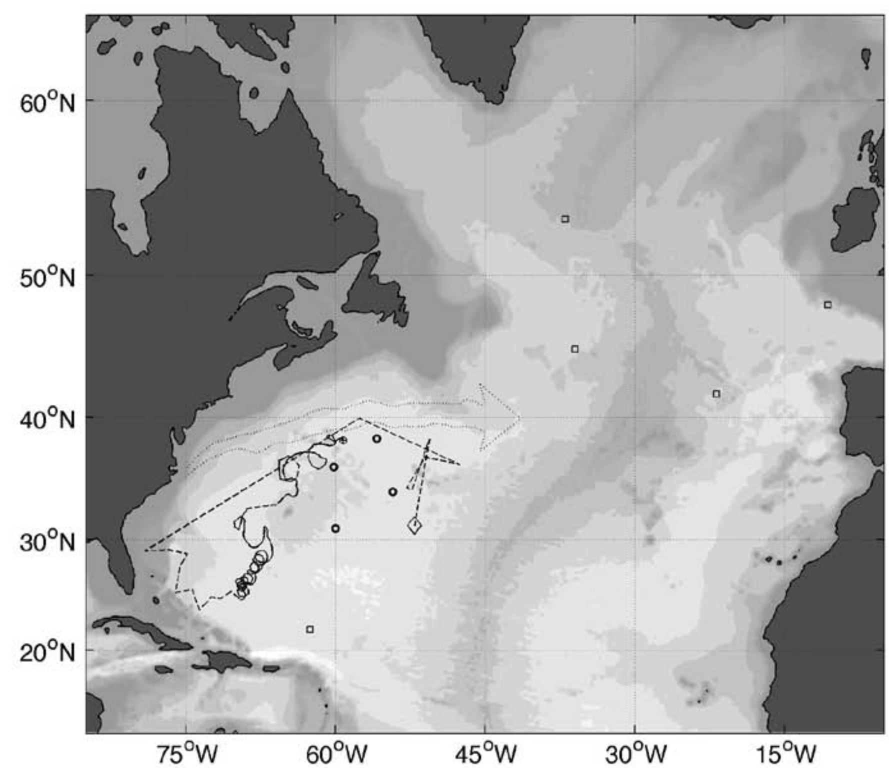
Float 473, 02/26/07 - 05/16/09
36°N
34°N
32°N
30°N
72°W
66°W
60°W
54°W
48°W

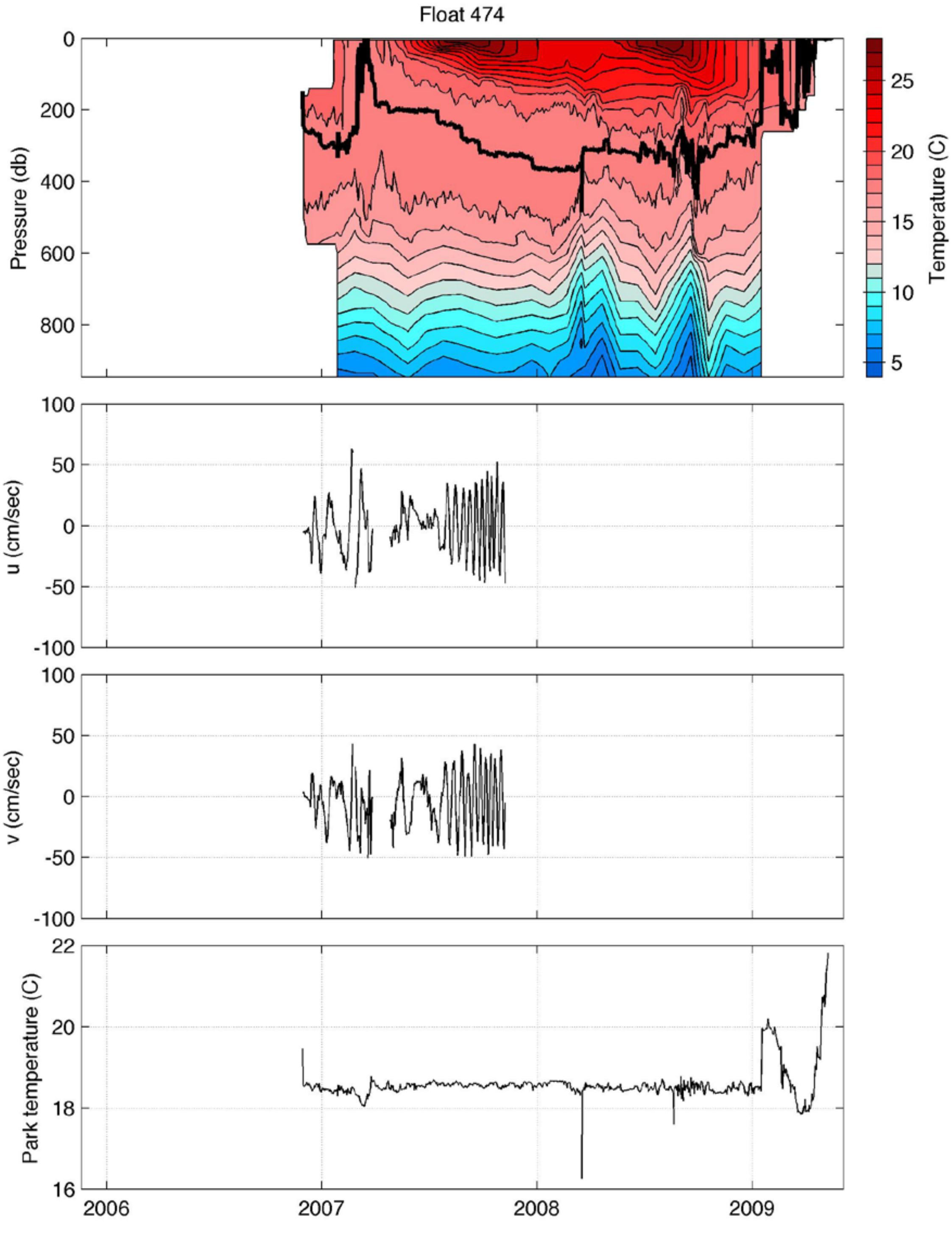


60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W


Float 473
Pressure (db)
0
200
400
600
800
Temperature (C)
25
20
15
10
5
u (cm/sec)
100
50
0
-50
-100
v (cm/sec)
Park temperature (C)
19
18.5
18
17.5
2006
2007
2008
2009

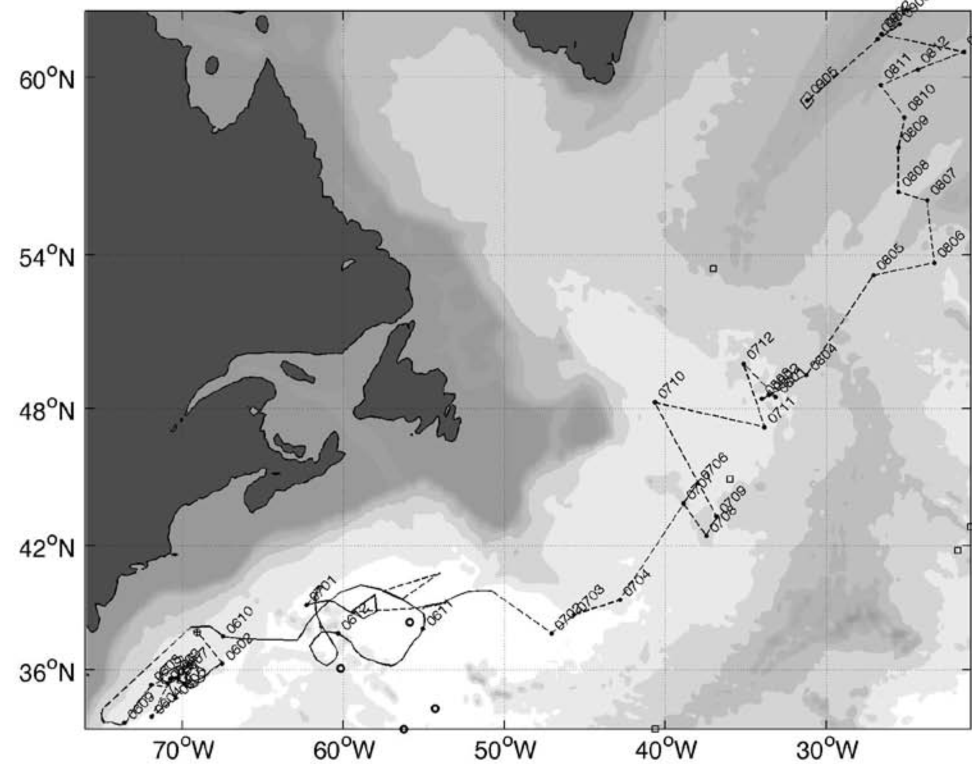

Float 474, 11/28/06 - 05/16/09
39°N
36°N
33°N
30°N
27°N
24°N
78°W
72°W
66°W
60°W
54°W
48°W

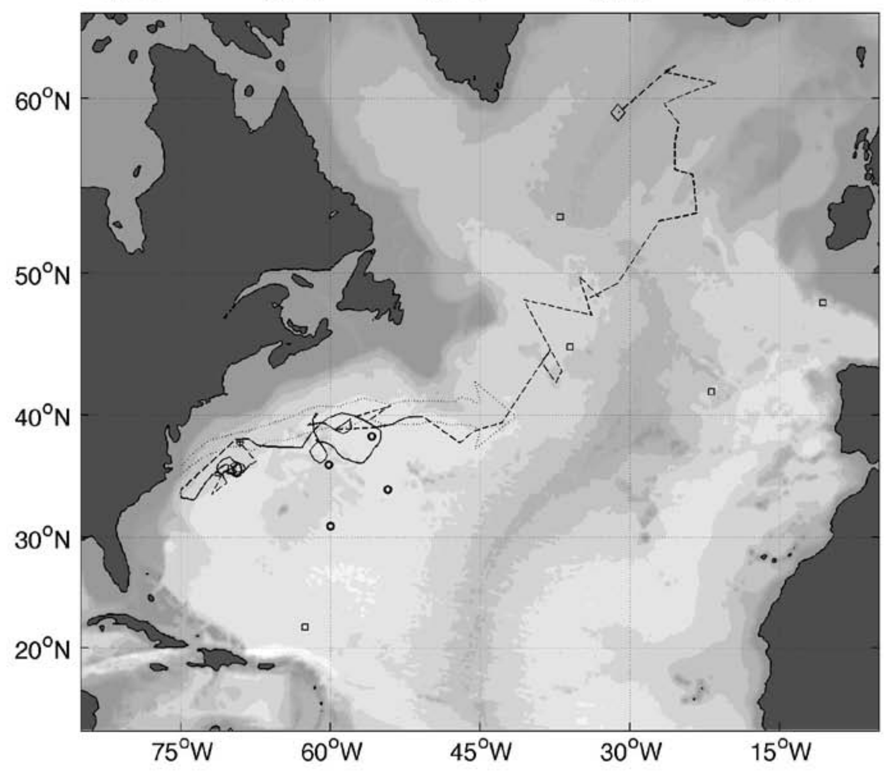

60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W

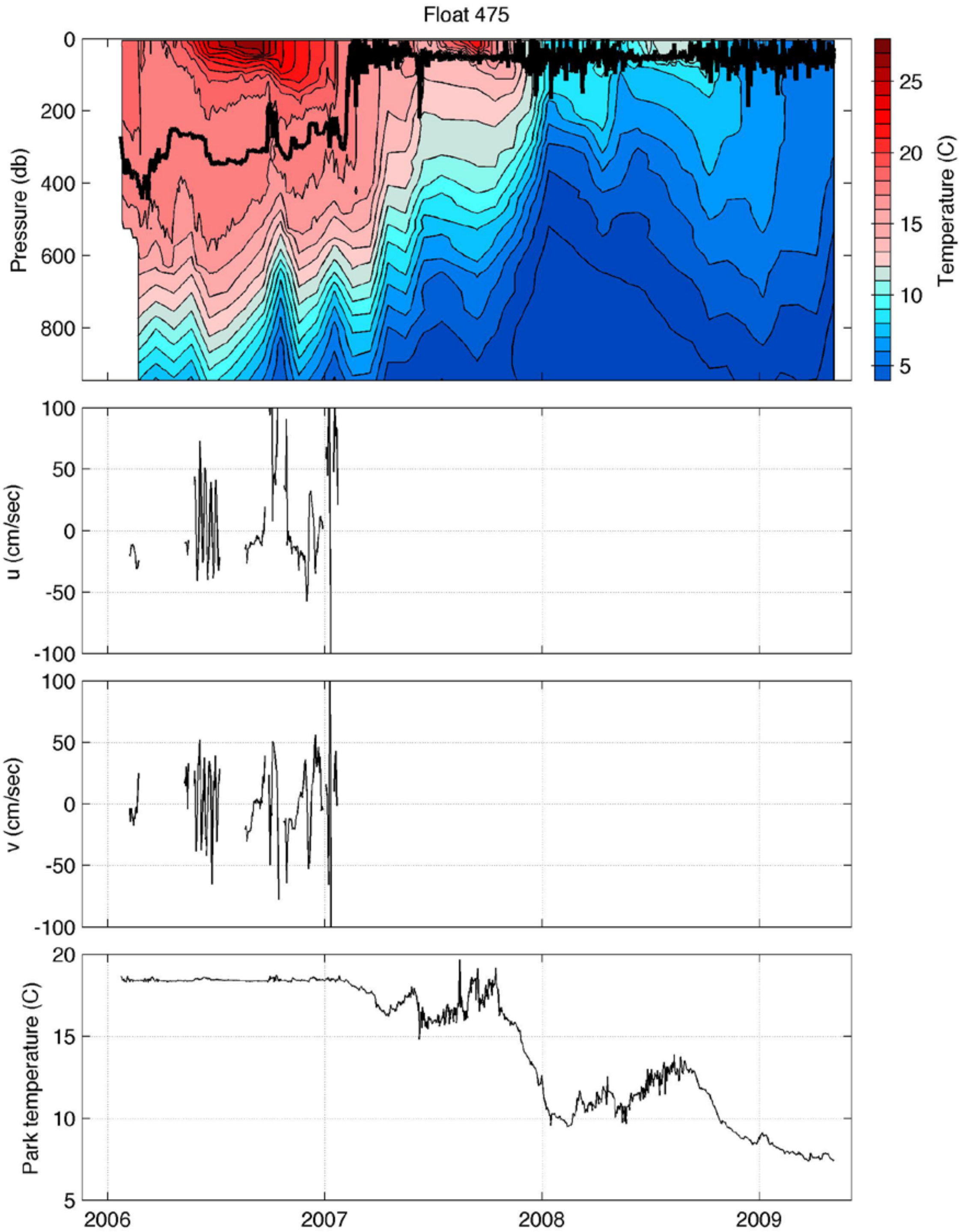


Float 474
Pressure (db)
0
200
400
600
800
Temperature (C)
25
20
15
10
5
u (cm/sec)
100
50
0
-50
-100
v (cm/sec)
100
50
0
-50
-100
Park temperature (C)
22
20
18
16
2006
2007
2008
2009

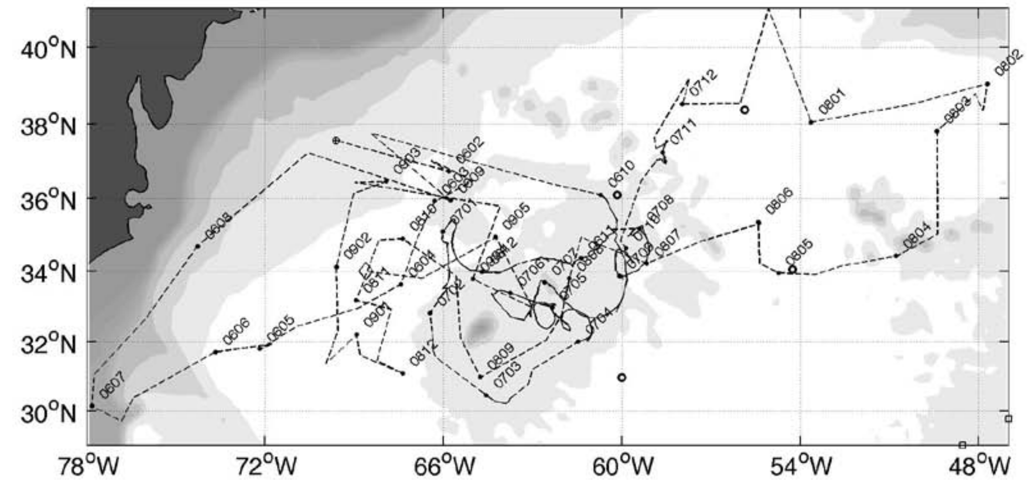
Float 475, 01/22/06 - 05/06/09

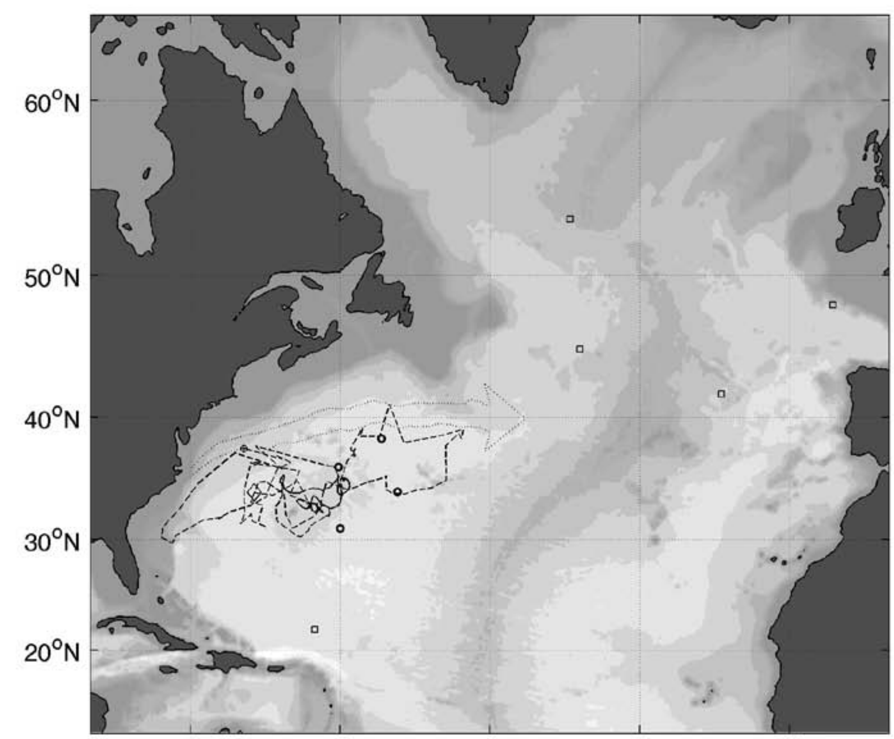


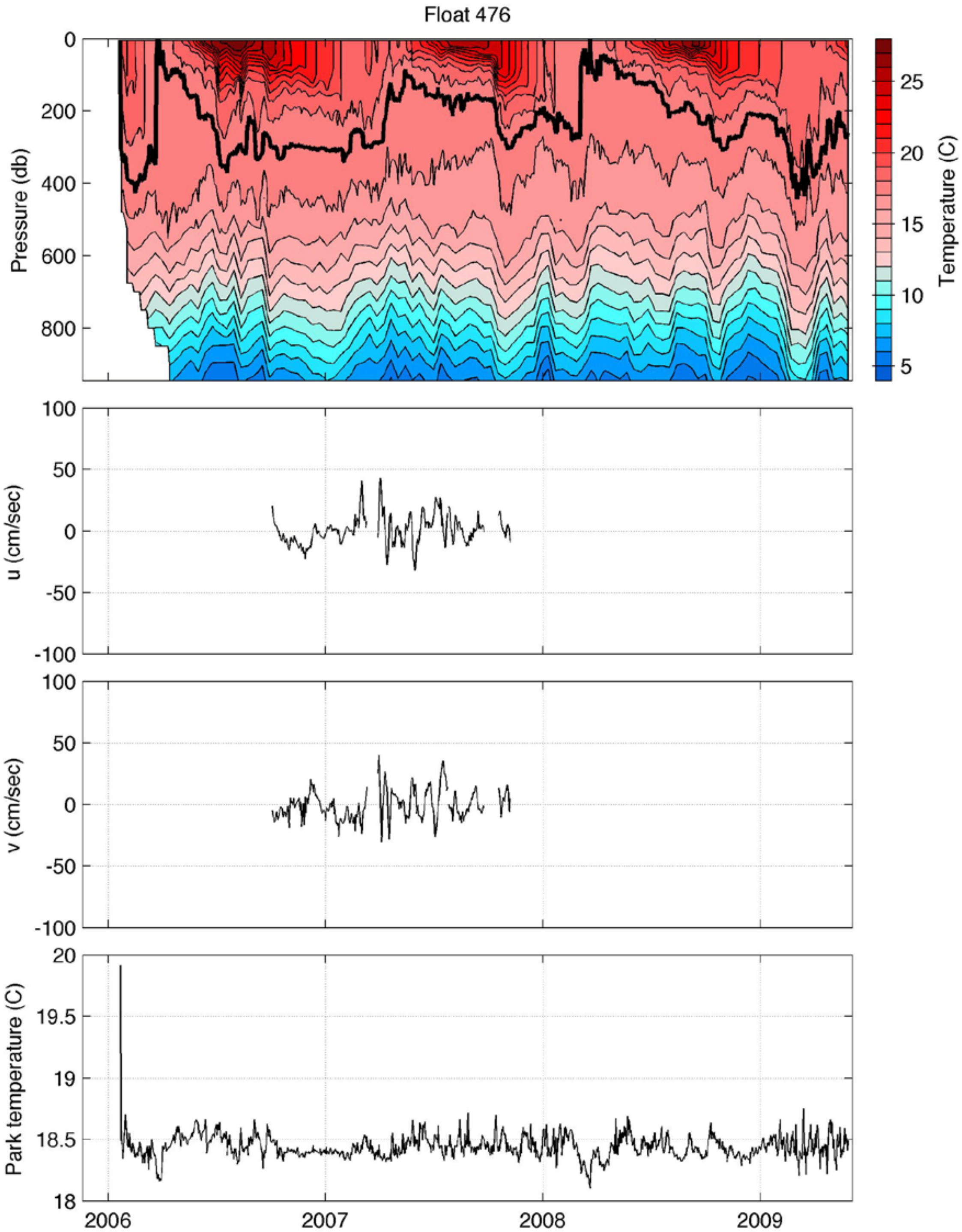



Float 475
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

Float 476, 01/20/06 - 05/28/09

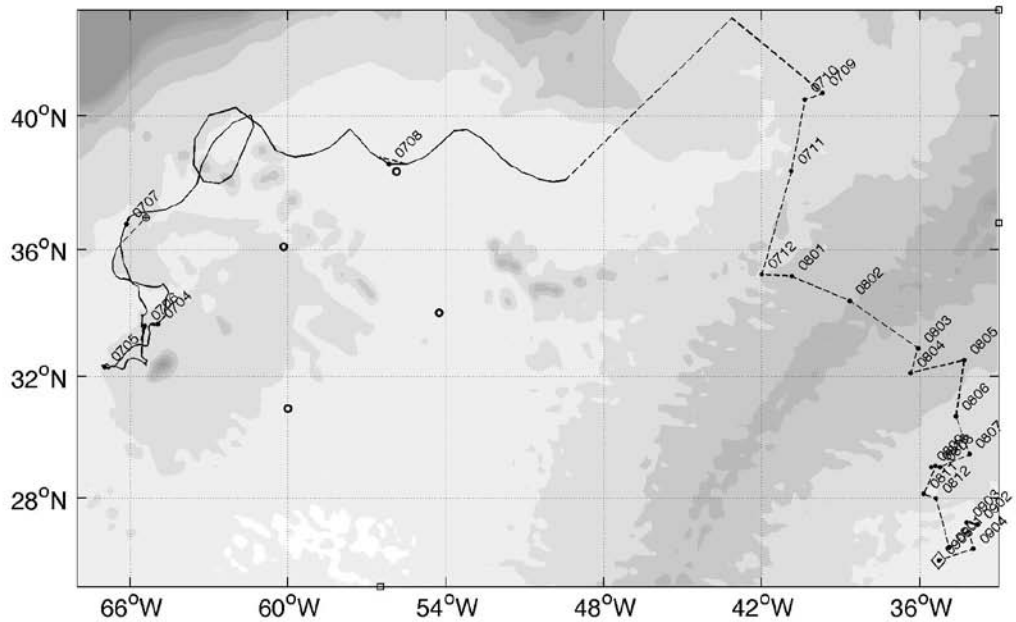


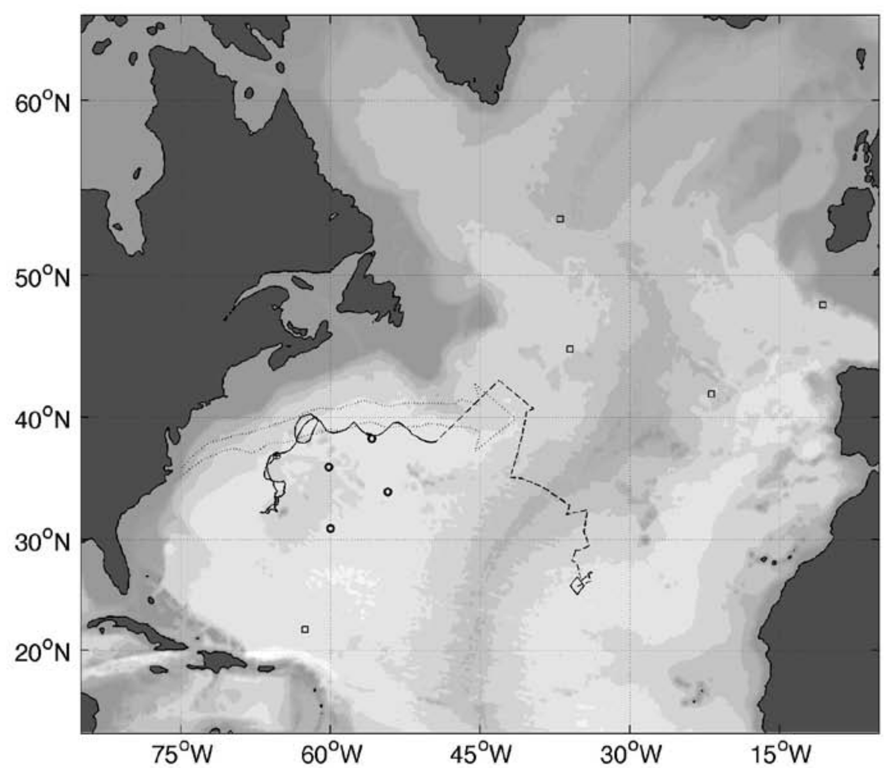


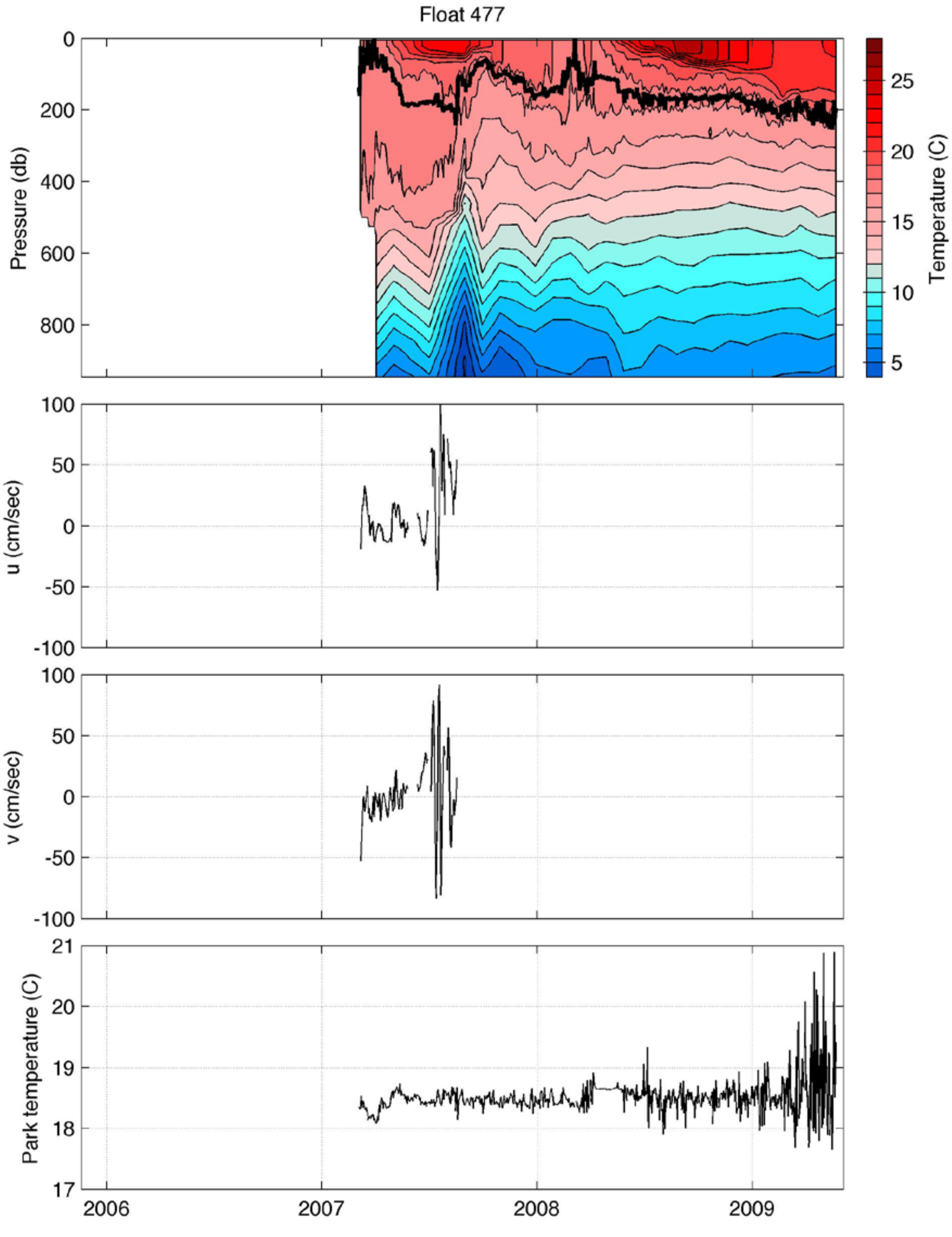


Float 476
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

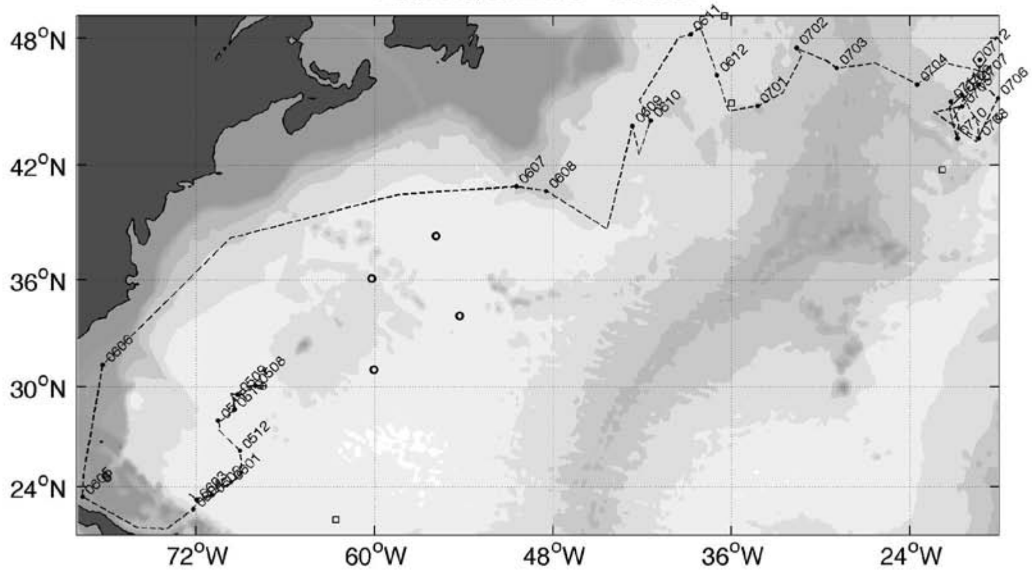
Float 477, 03/03/07 - 05/22/09

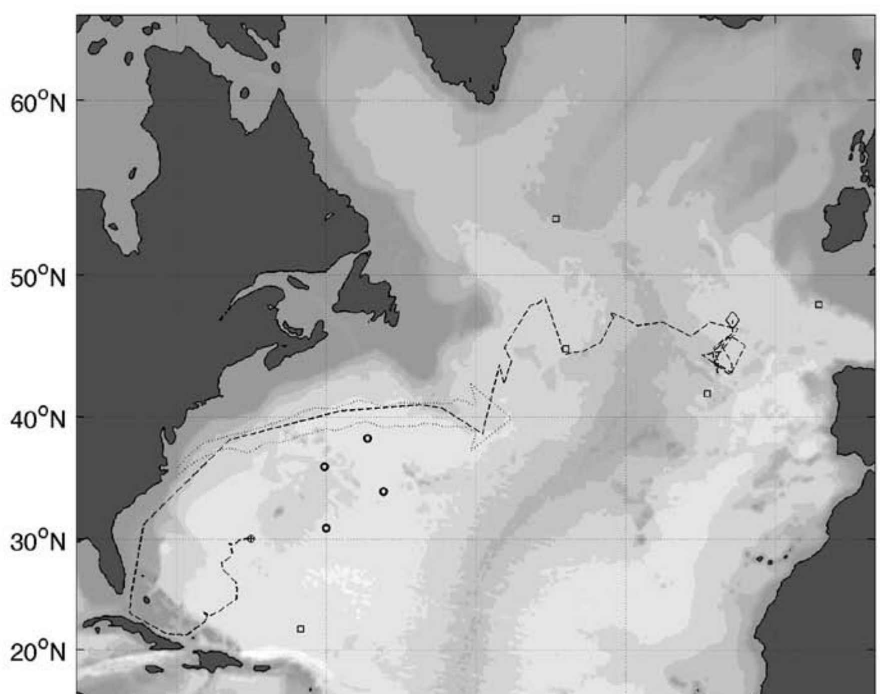


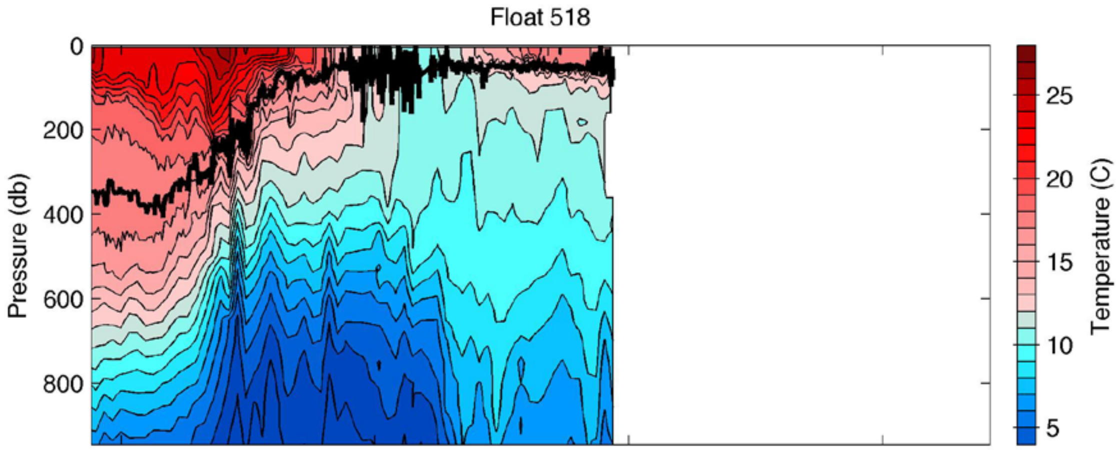



Float 477
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

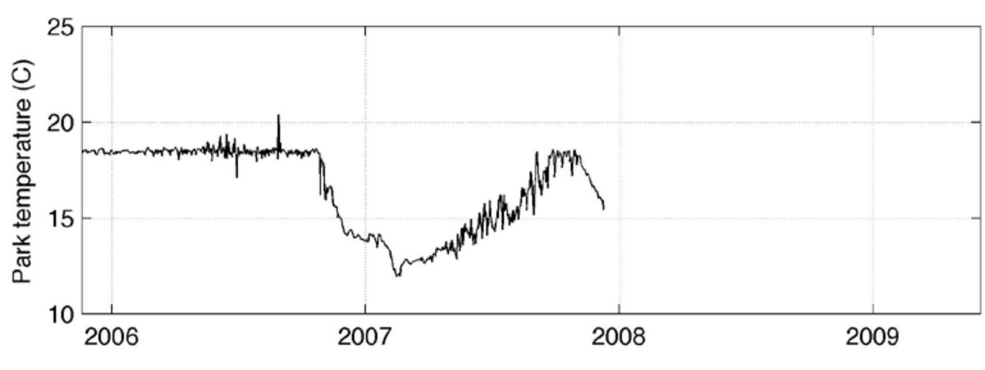
Float 518, 07/28/05 - 12/09/07



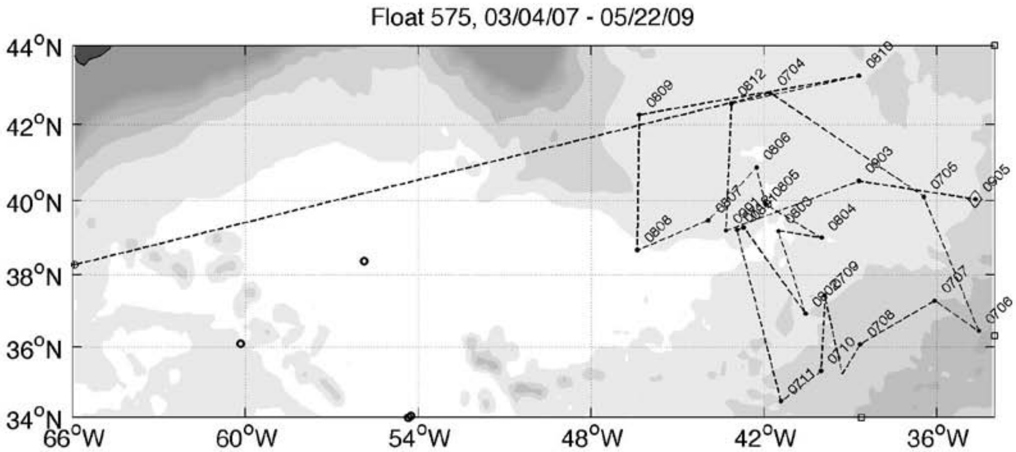


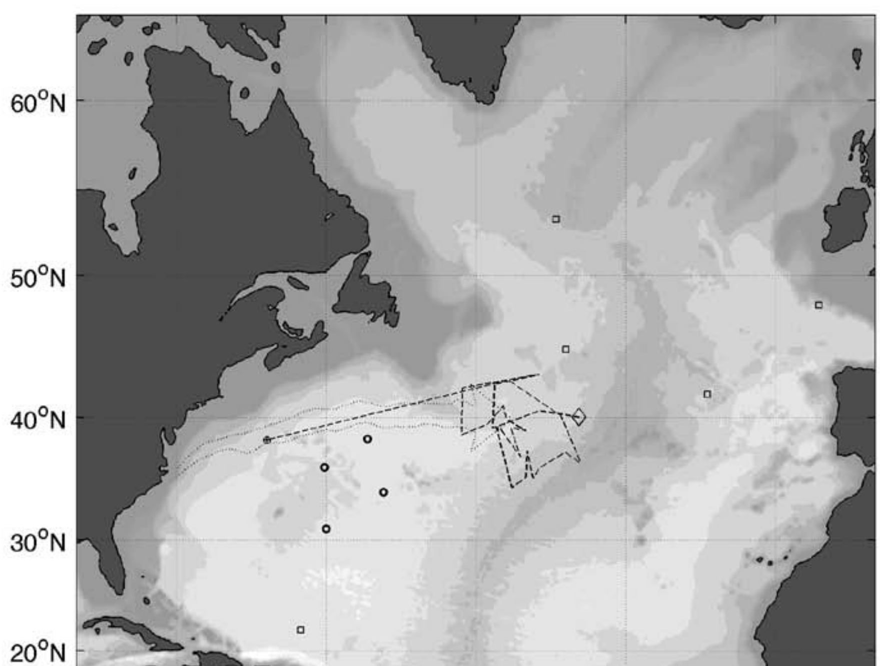


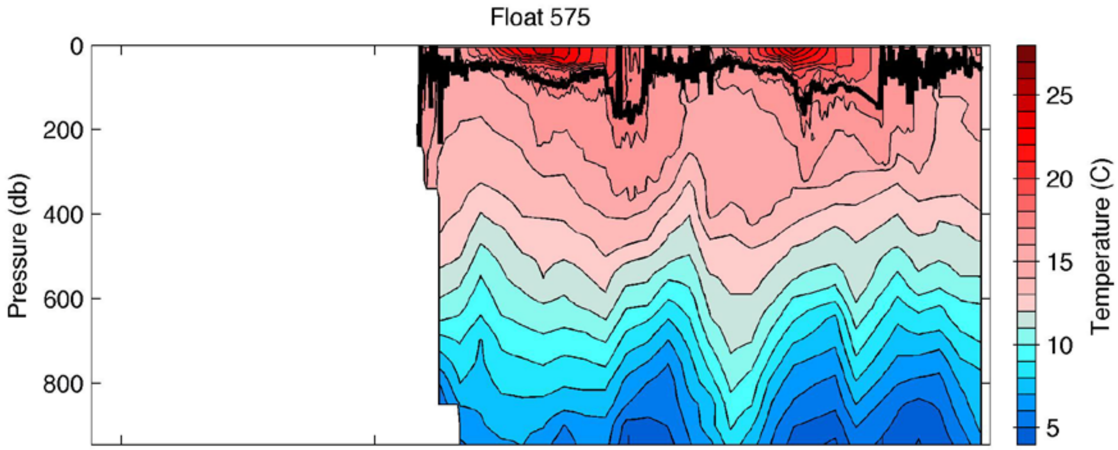
Float 518
Pressure (db)
0
200
400
600
800
25
20
15
10
5
Temperature (C)

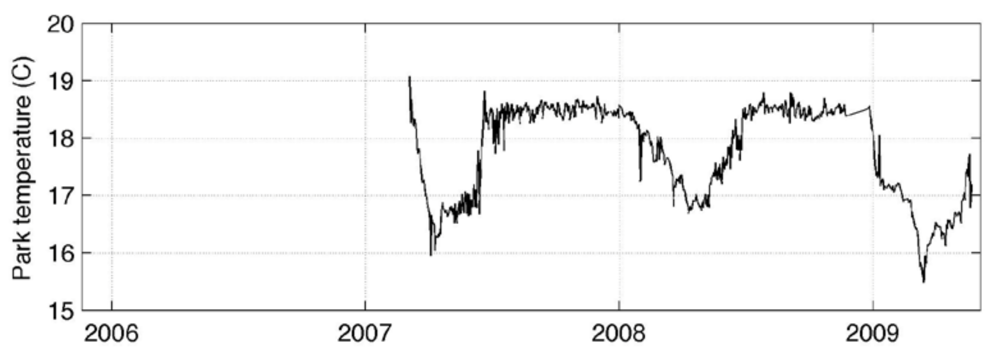


Park temperature (C)
25
20
15
10
2006
2007
2008
2009

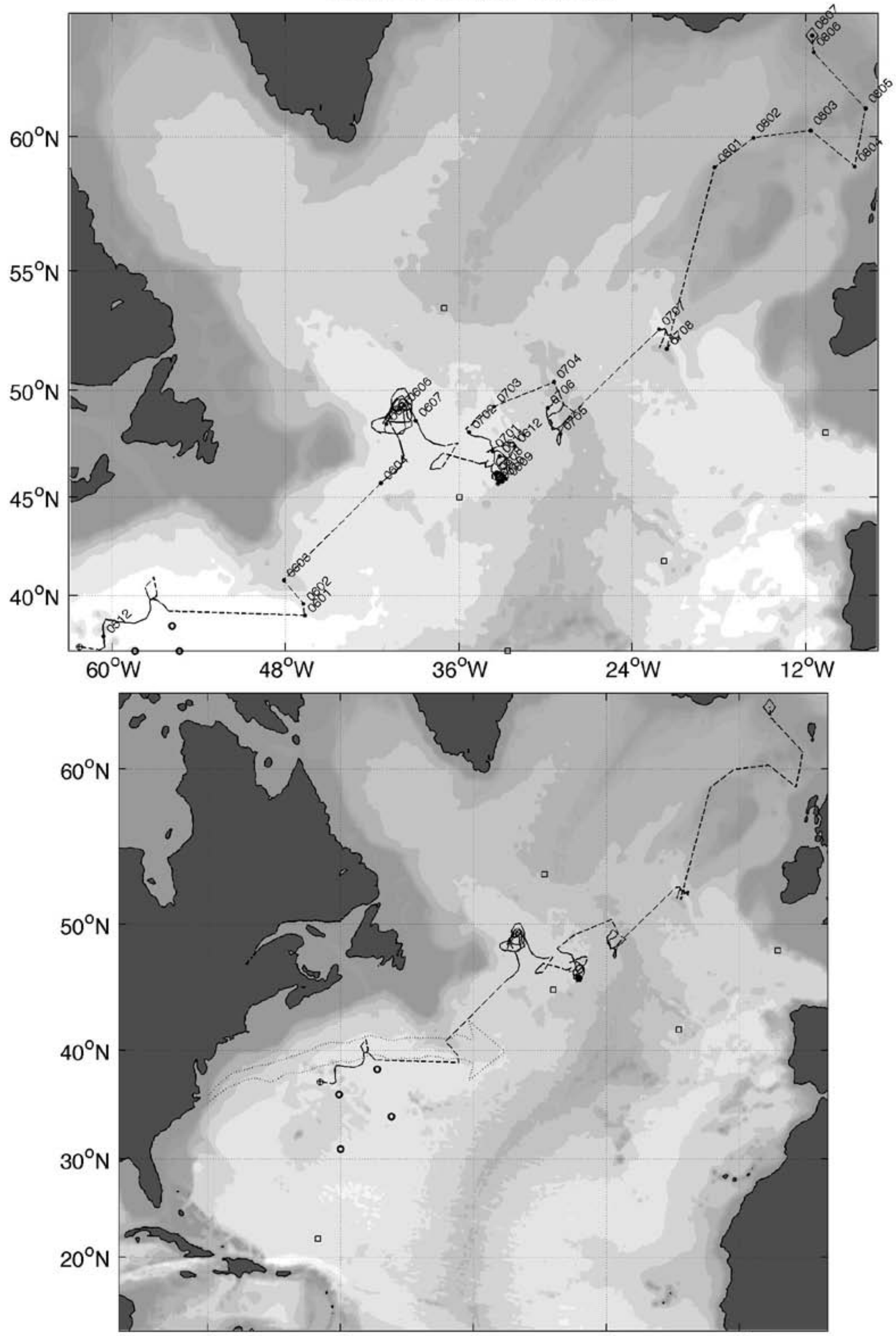

Float 575, 03/04/07 - 05/22/09
44°N
42°N
40°N
38°N
36°N
34°N
66°W
60°W
54°W
48°W
42°W
36°W

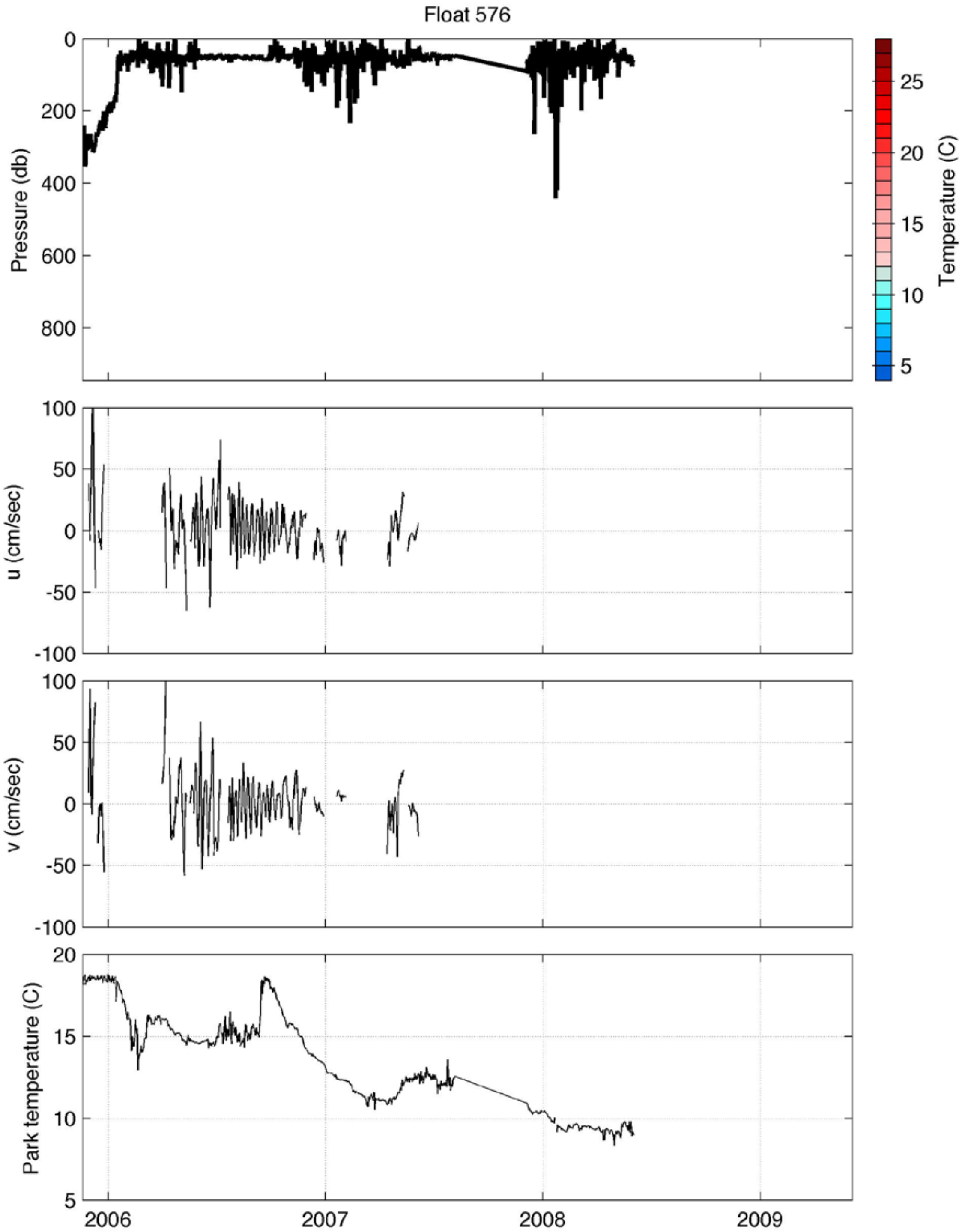

60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W


Float 575
Pressure (db)
0
200
400
600
800
Temperature (C)
25
20
15
10
5

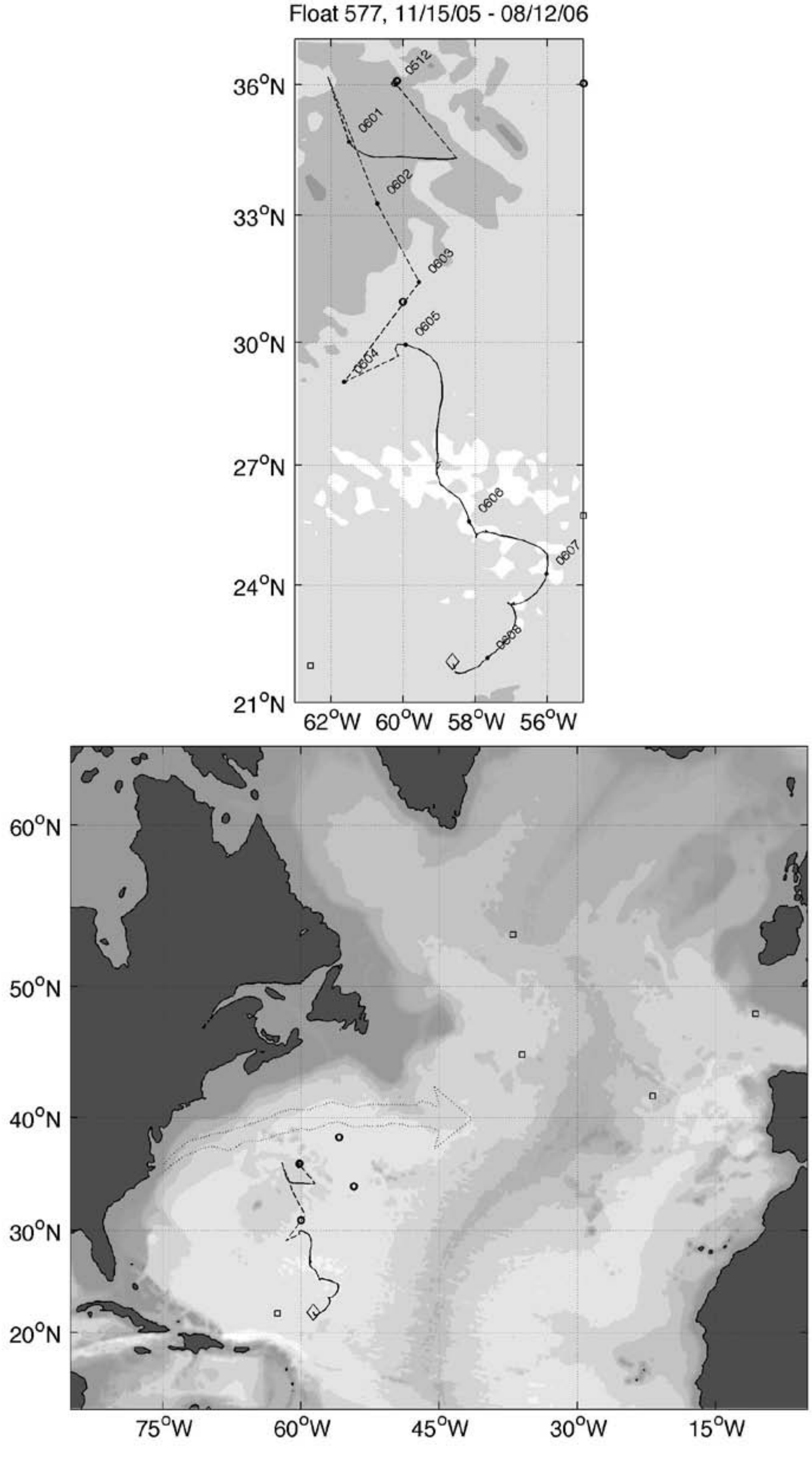

Park temperature (C)
20
19
18
17
16
15
2006
2007
2008
2009

Float 576, 11/14/05 - 07/01/08

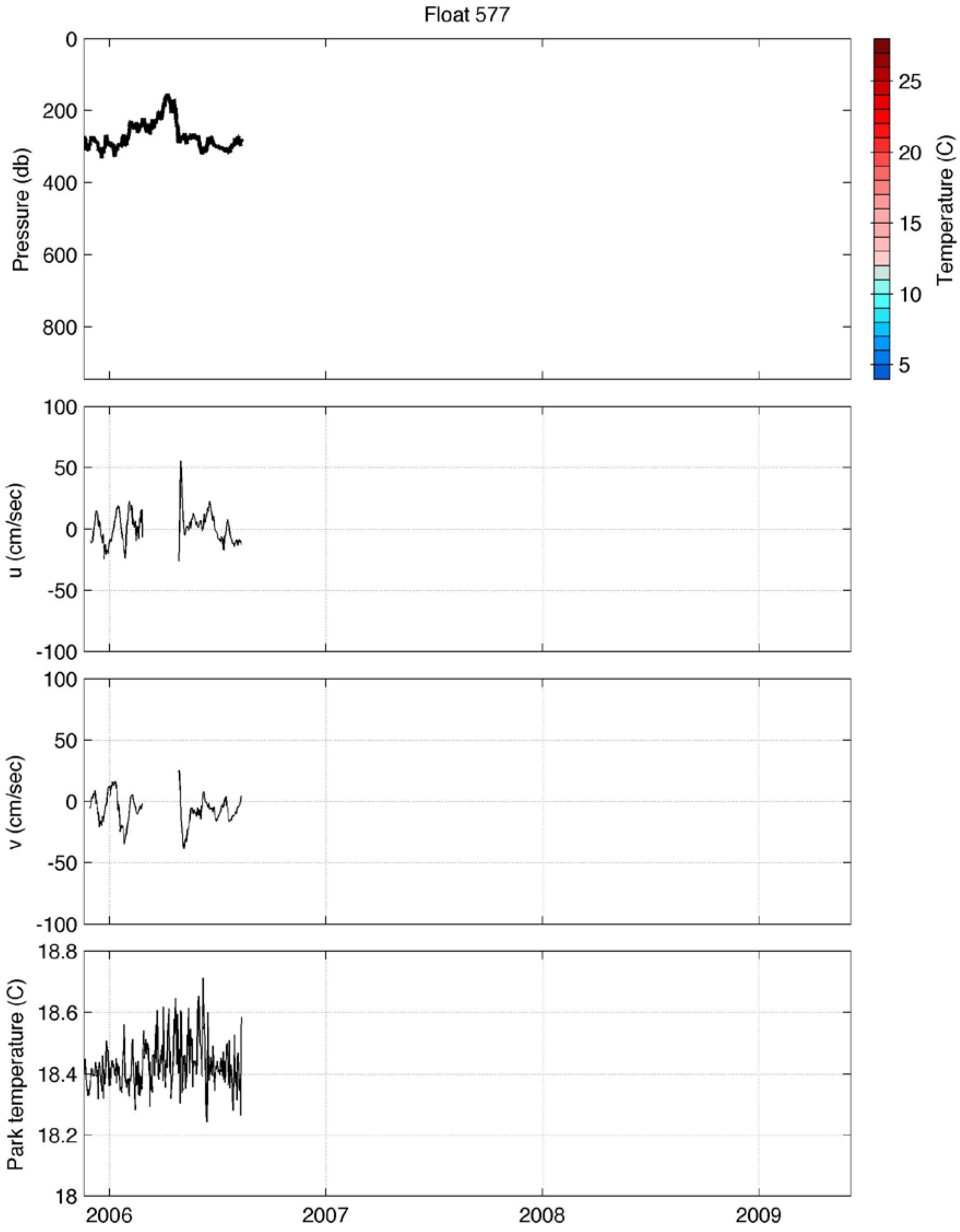


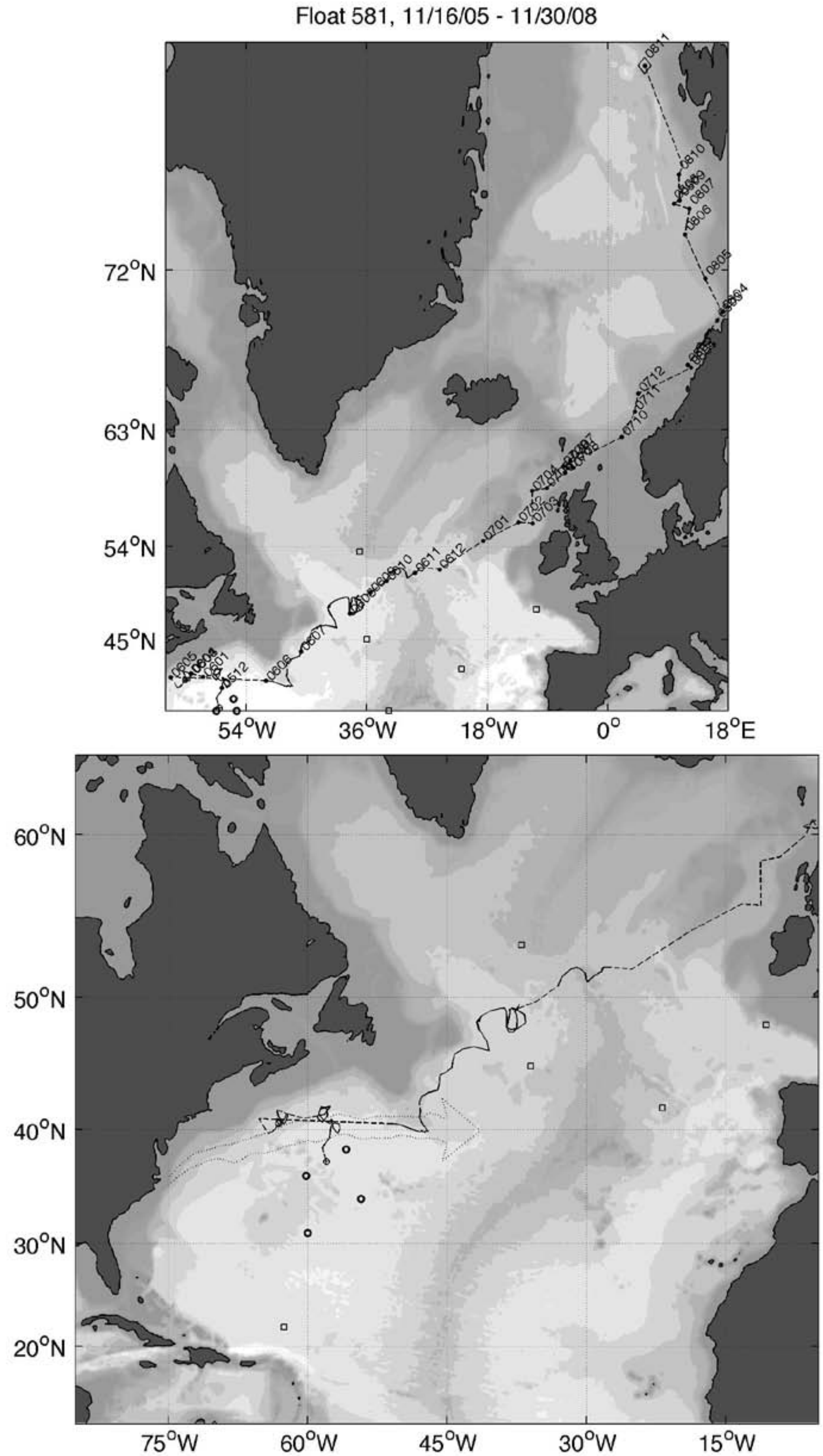


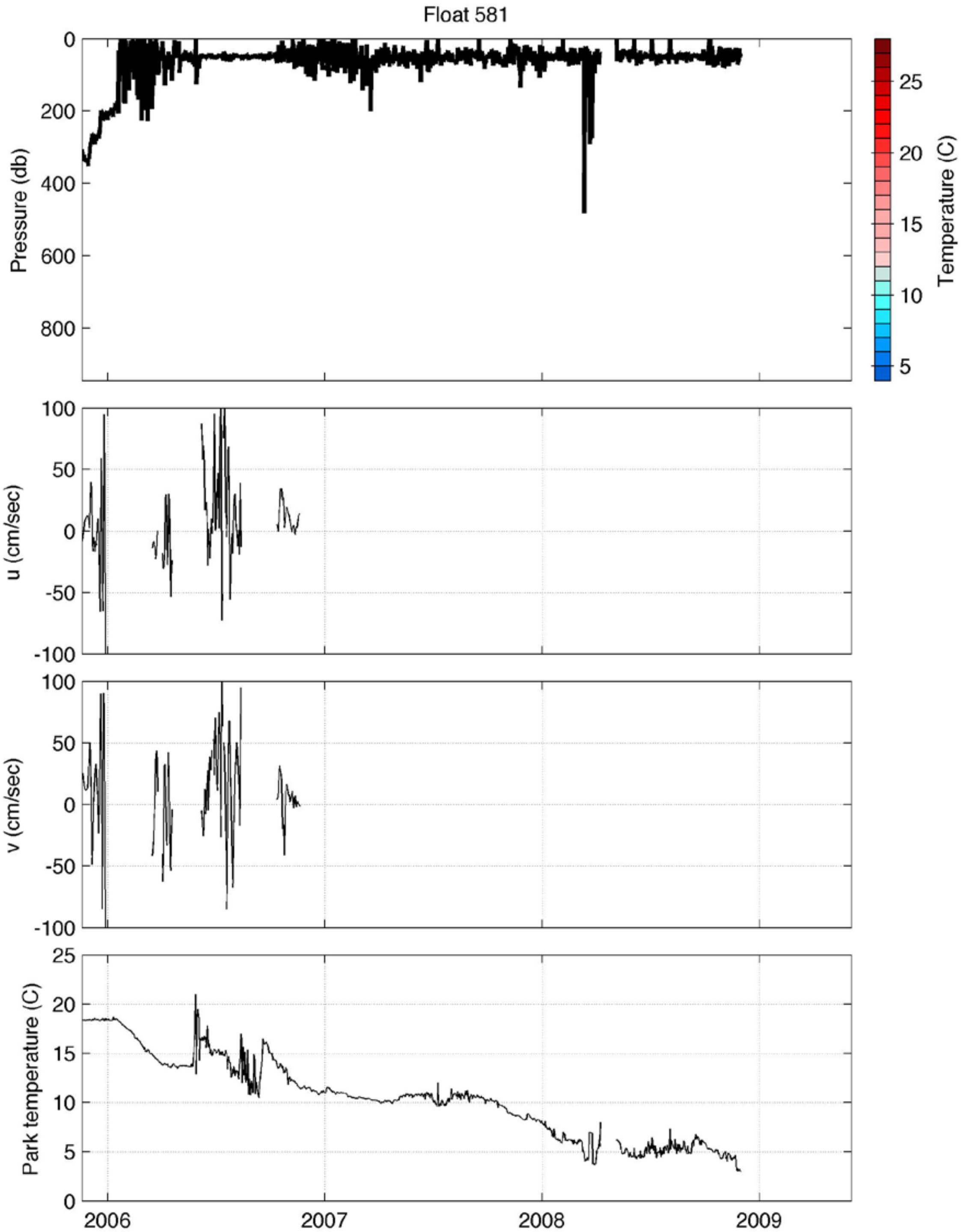
Float 576
Pressure (db)
0
200
400
600
800
Temperature (C)
25
20
15
10
5
u (cm/sec)
100
50
0
-50
-100
v (cm/sec)
100
50
0
-50
-100
Park temperature (C)
20
15
10
5
2006
2007
2008
2009



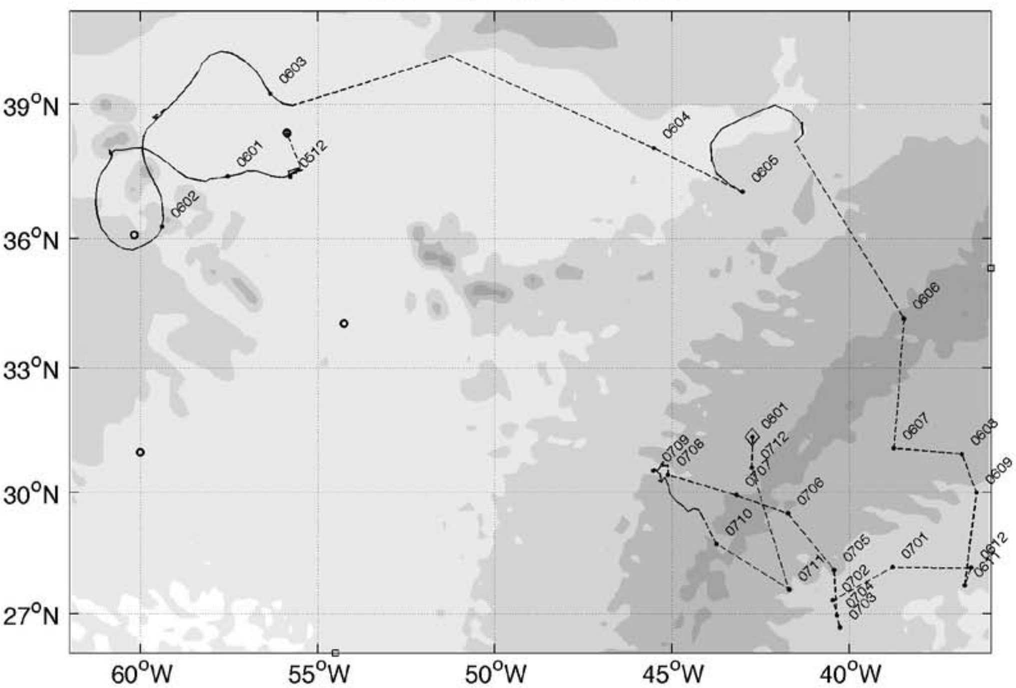
Float 577, 11/15/05 - 08/12/06
36°N
33°N
30°N
27°N
24°N
21°N
62°W
60°W
58°W
56°W
0512
0601
0602
0603
0604
0605
0606
0607
60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W

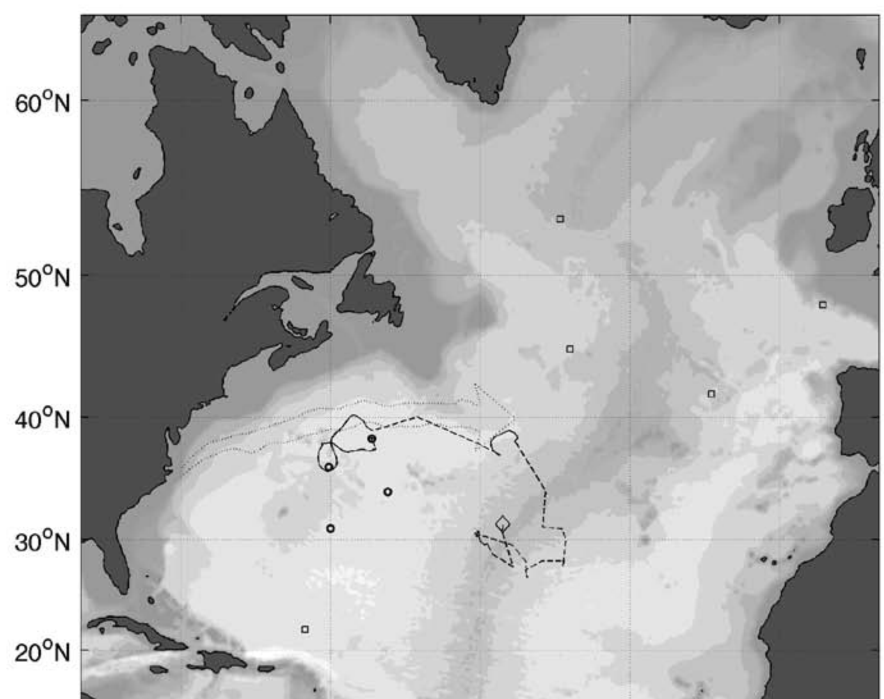

Float 577
Pressure (db)
0
200
400
600
800
Temperature (C)
25
20
15
10
5
u (cm/sec)
100
50
0
-50
-100
v (cm/sec)
100
50
0
-50
-100
Park temperature (C)
18.8
18.6
18.4
18.2
18
2006
2007
2008
2009

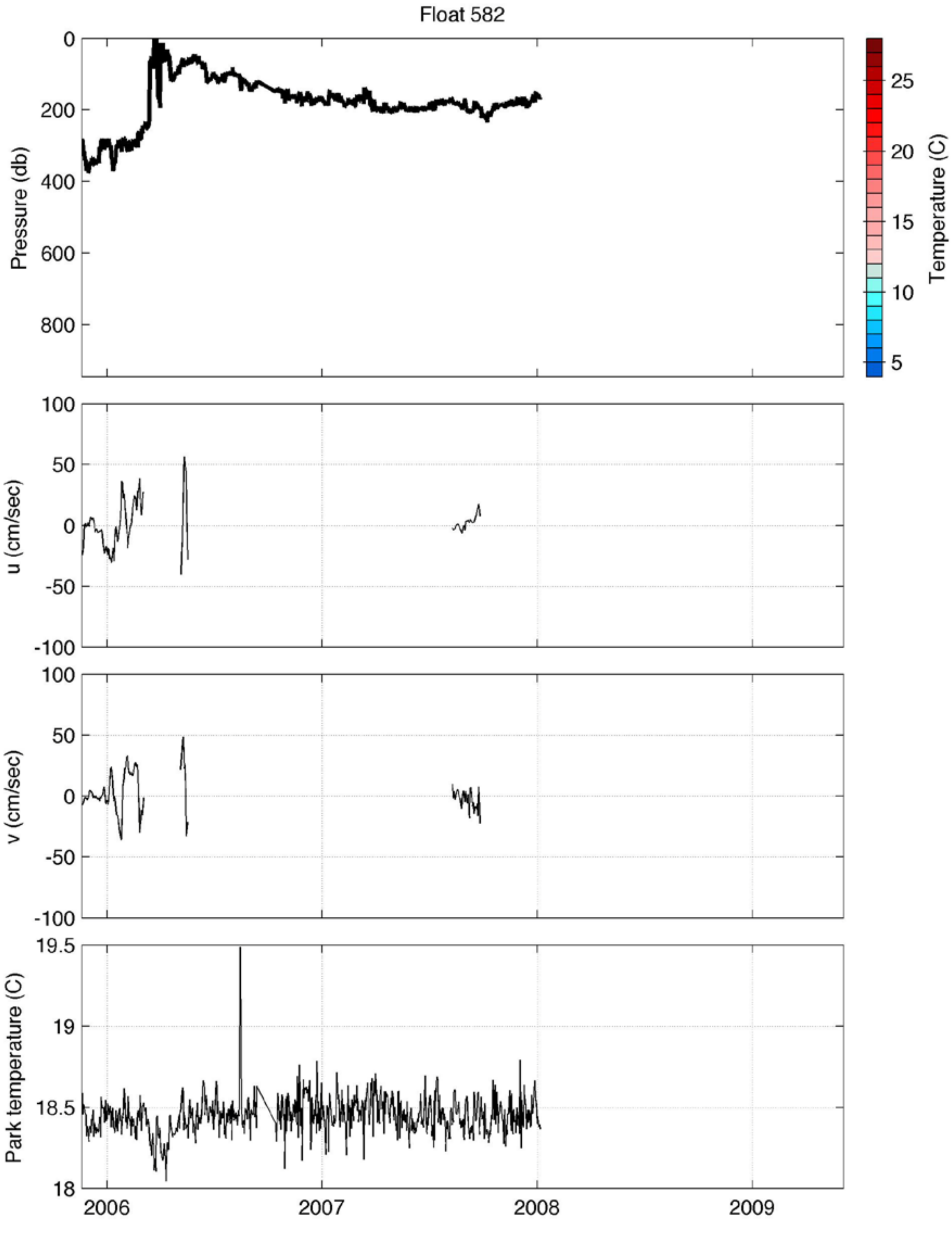

Float 581, 11/16/05 - 11/30/08
72°N
63°N
54°N
45°N
54°W
36°W
18°W
0°
18°E
60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W


Float 581
Pressure (db)
0
200
400
600
800
Temperature (C)
25
20
15
10
5
u (cm/sec)
100
50
0
-50
-100
v (cm/sec)
100
50
0
-50
-100
Park temperature (C)
25
20
15
10
5
0
2006
2007
2008
2009

Float 582, 11/17/05 - 01/06/08

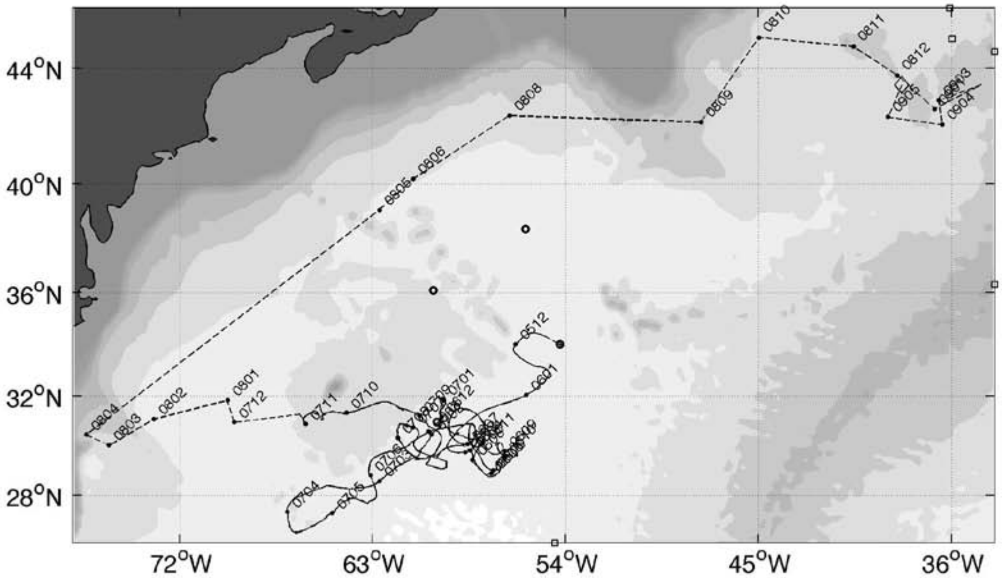


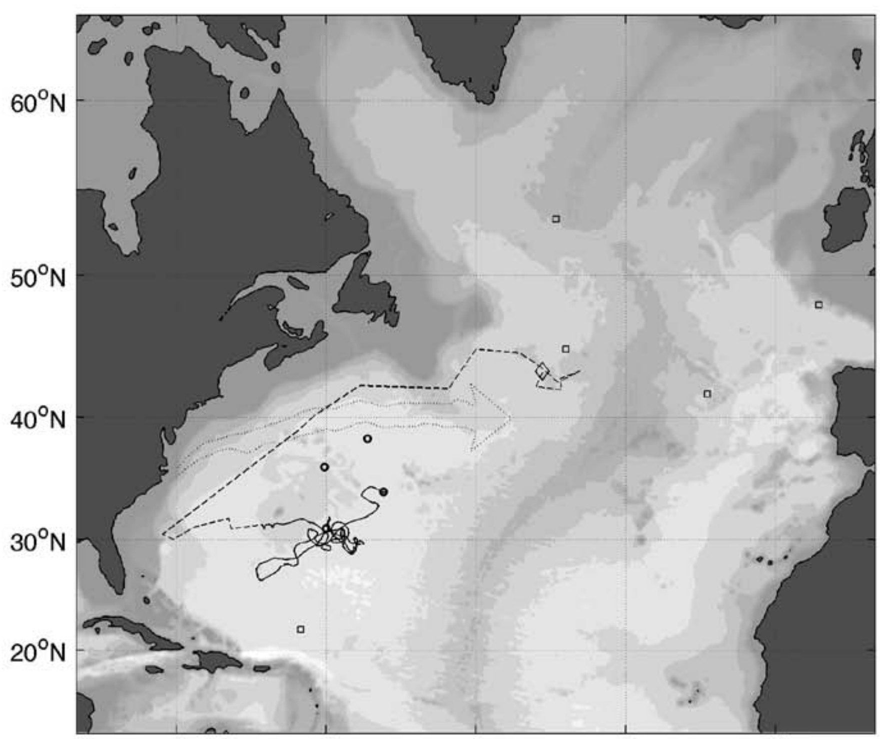


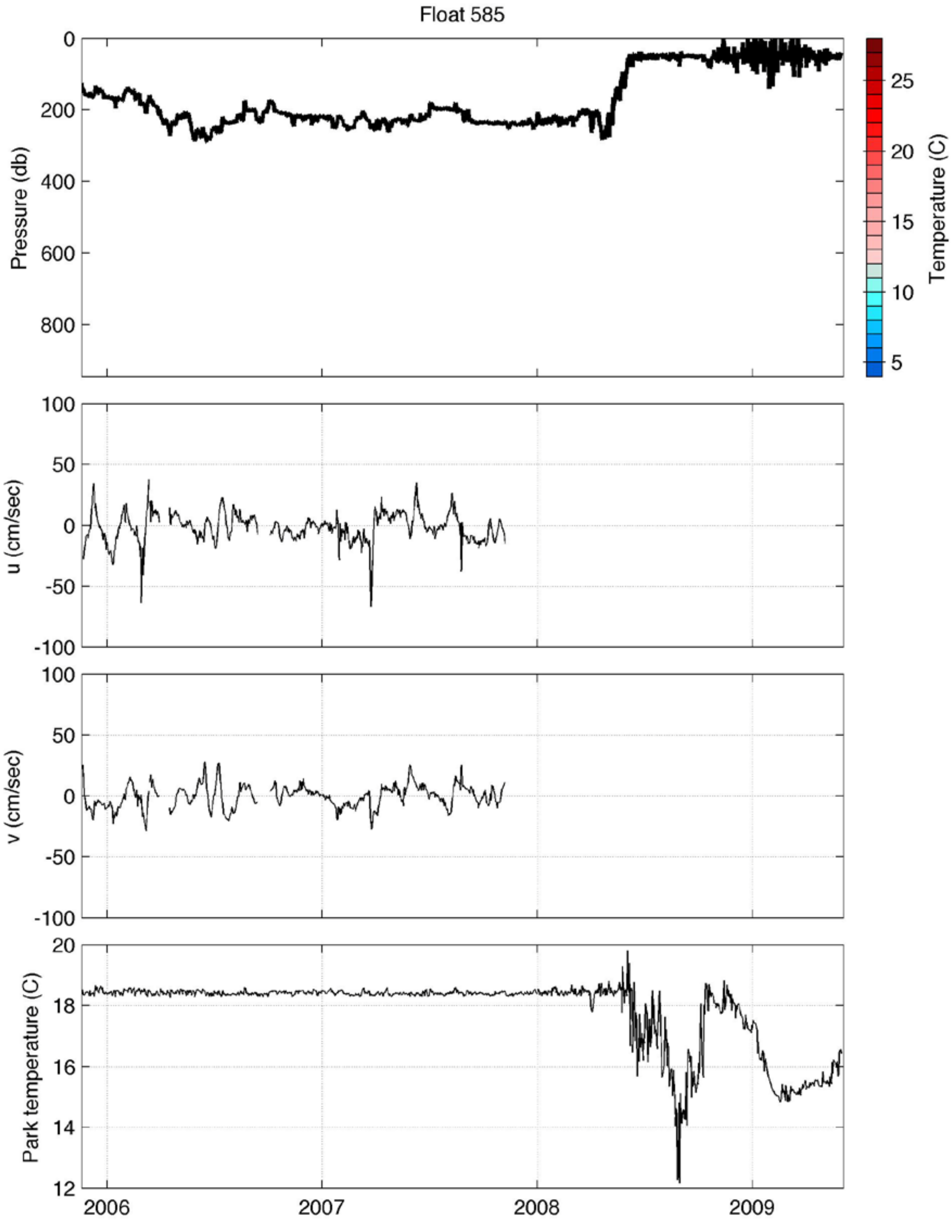


Float 582
Pressure (db)
0
200
400
600
800
Temperature (C)
25
20
15
10
5
u (cm/sec)
100
50
0
-50
-100
v (cm/sec)
100
50
0
-50
-100
Park temperature (C)
19.5
19
18.5
18
2006
2007
2008
2009

Float 585, 11/18/05 - 05/31/09

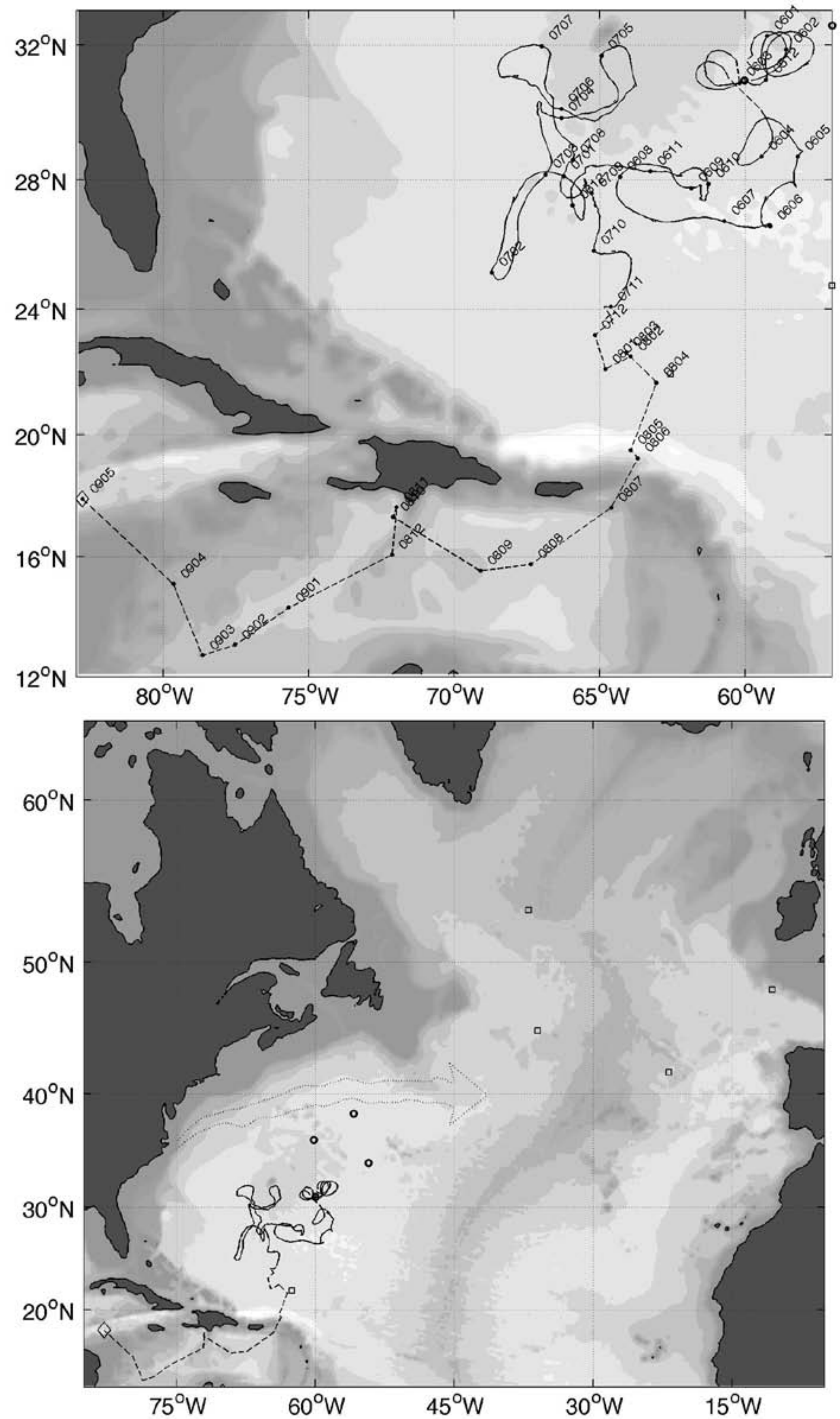


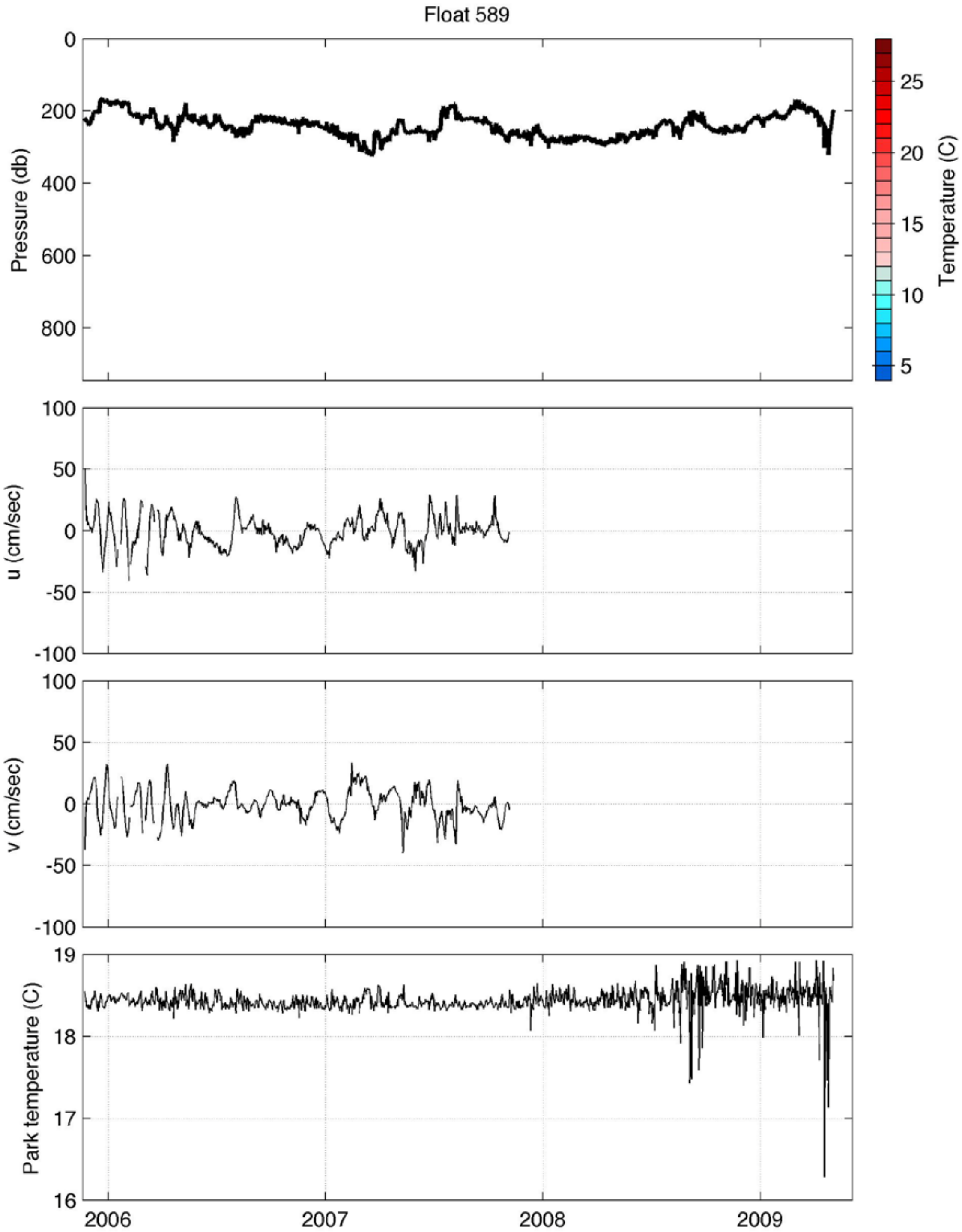




Float 585
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

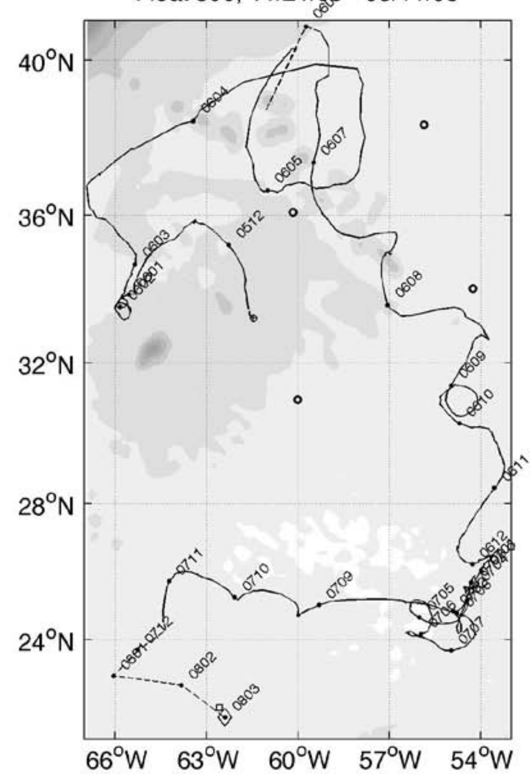
Float 589, 11/20/05 - 05/04/09

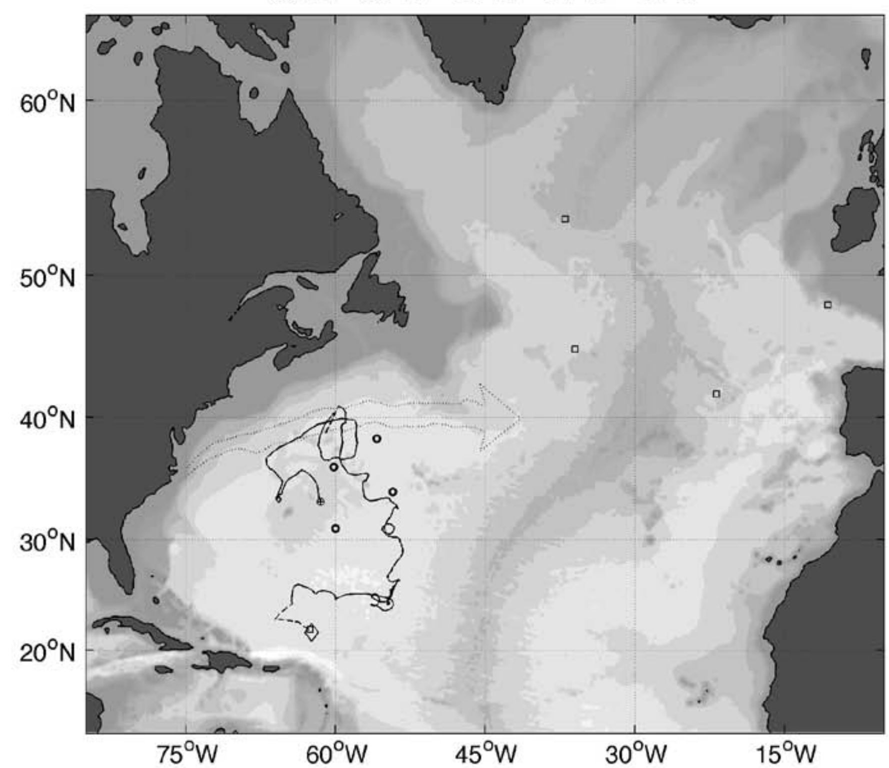


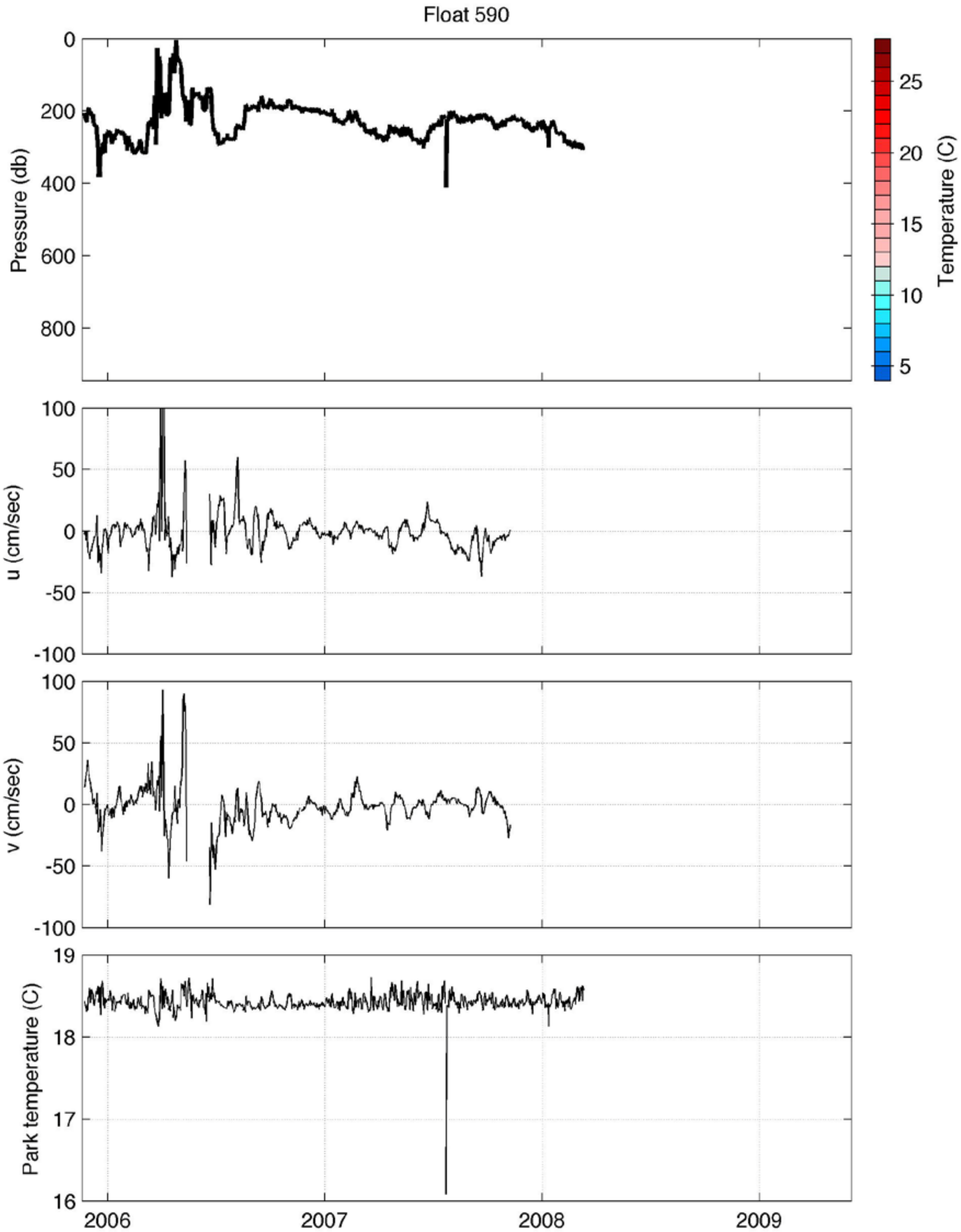


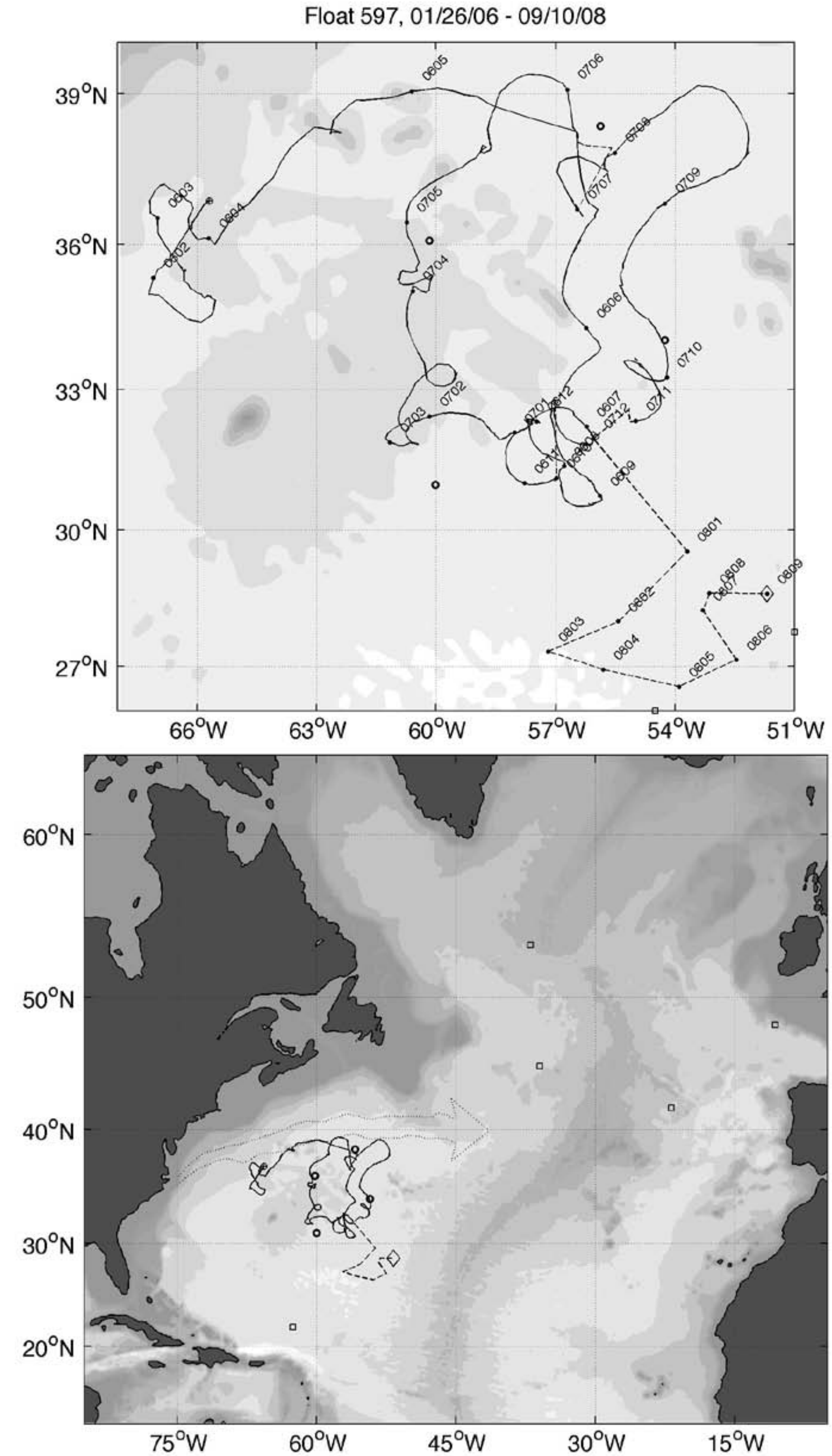
Float 589
Pressure (db)
0
200
400
600
800
Temperature (C)
25
20
15
10
5
u (cm/sec)
100
50
0
-50
-100
v (cm/sec)
100
50
0
-50
-100
Park temperature (C)
19
18
17
16
2006
2007
2008
2009

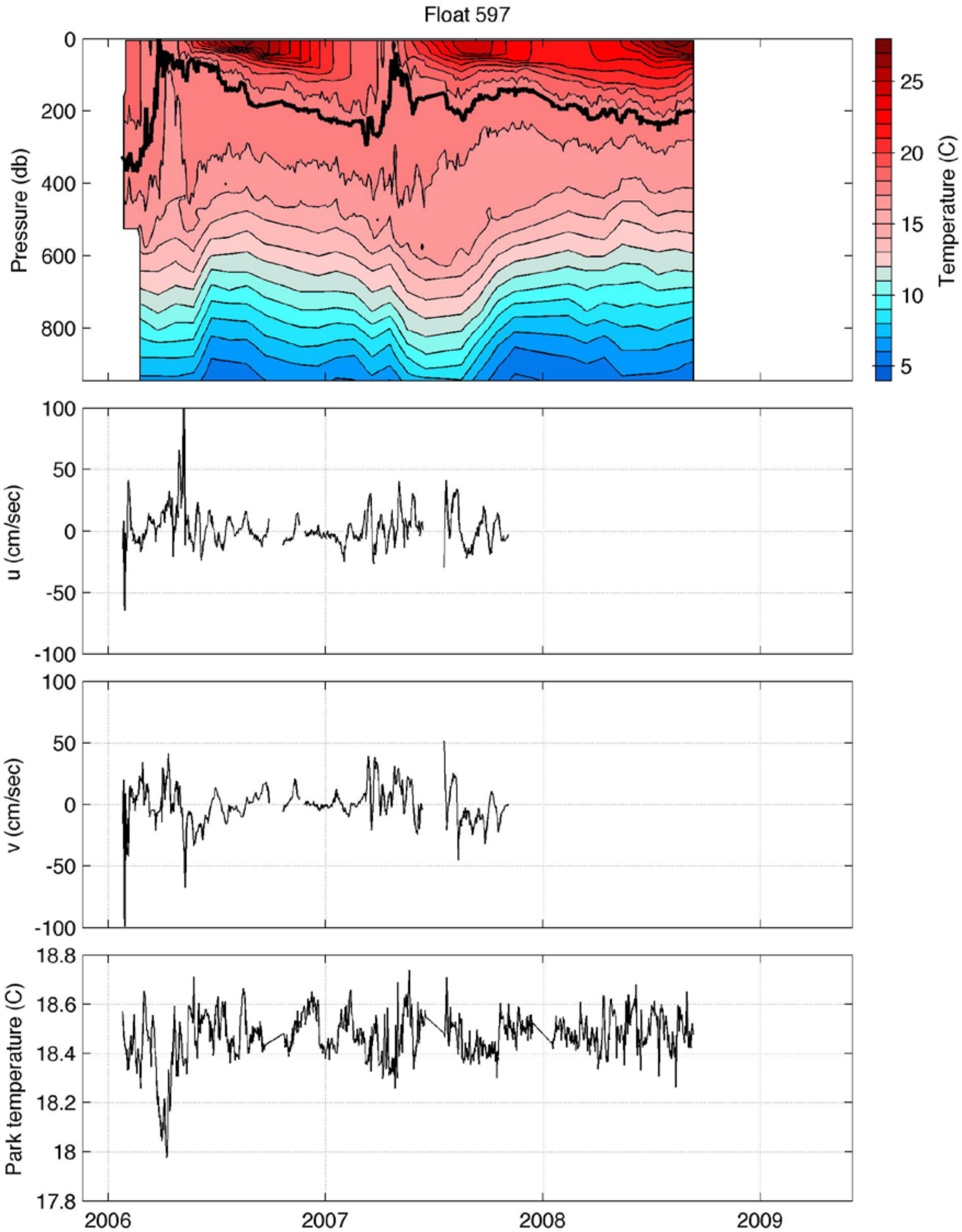
Float 590, 11/21/05 - 03/11/08

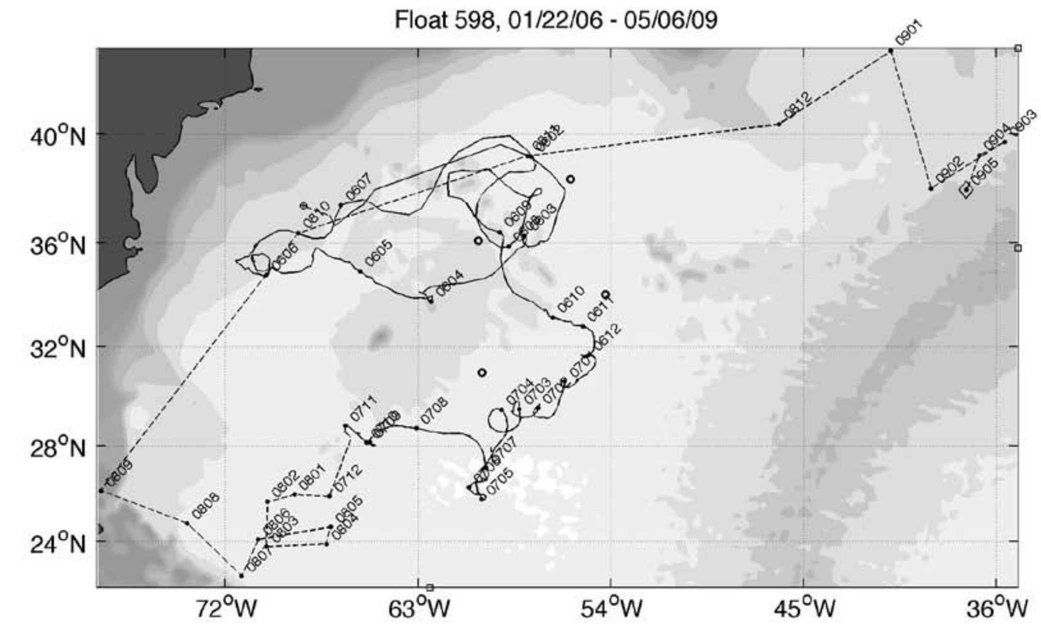


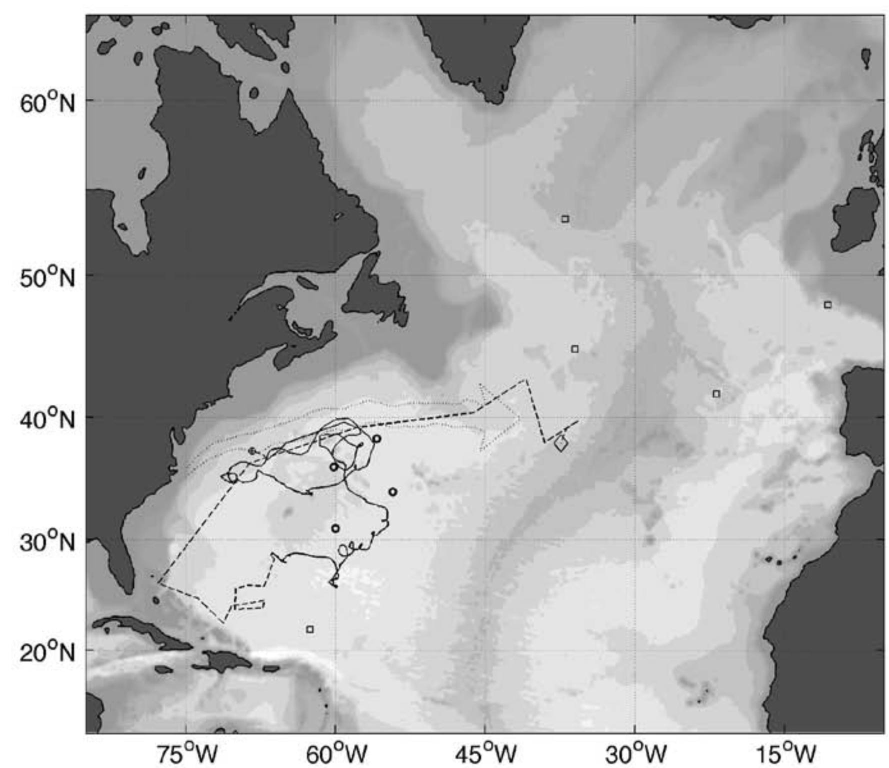


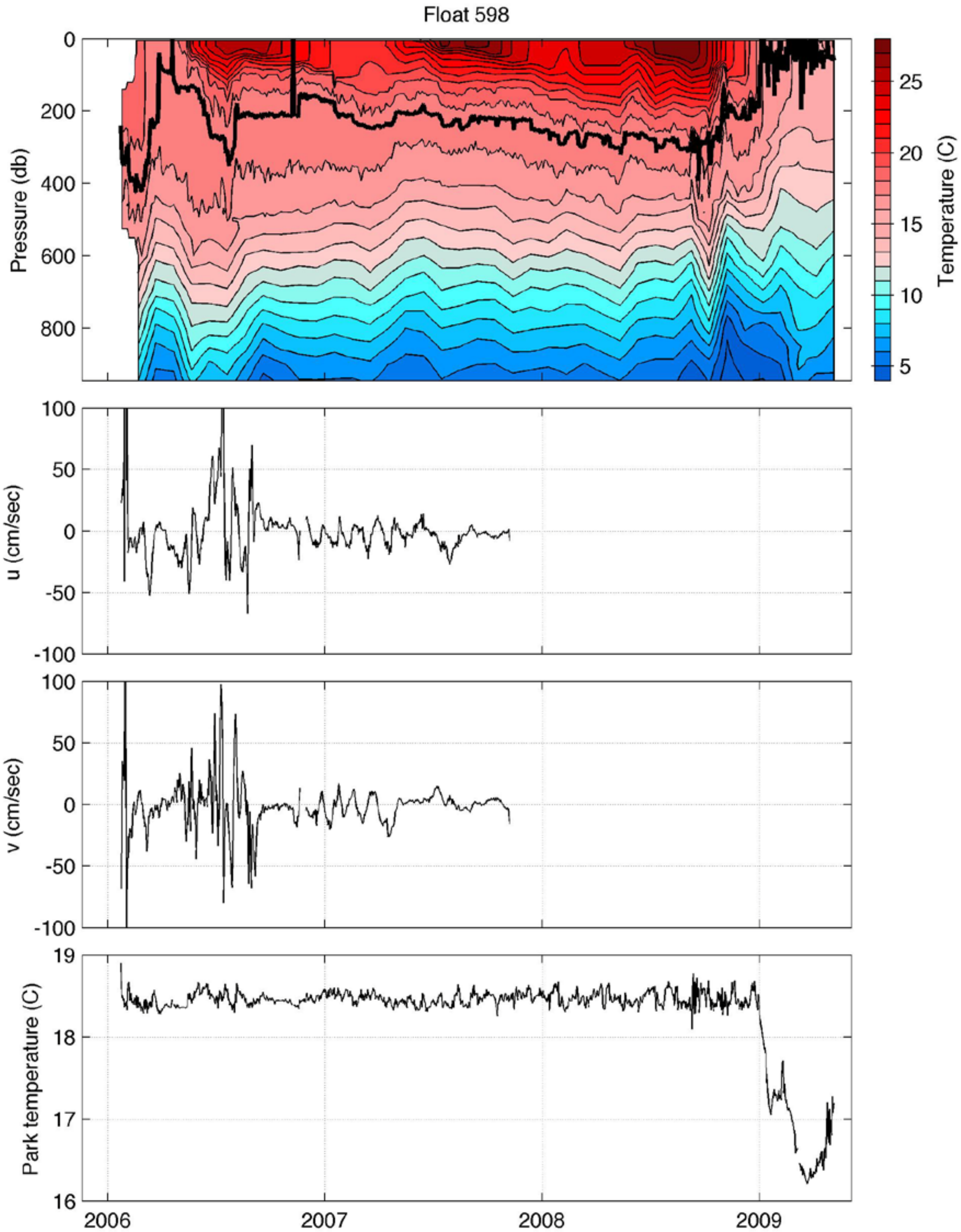

Float 590
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

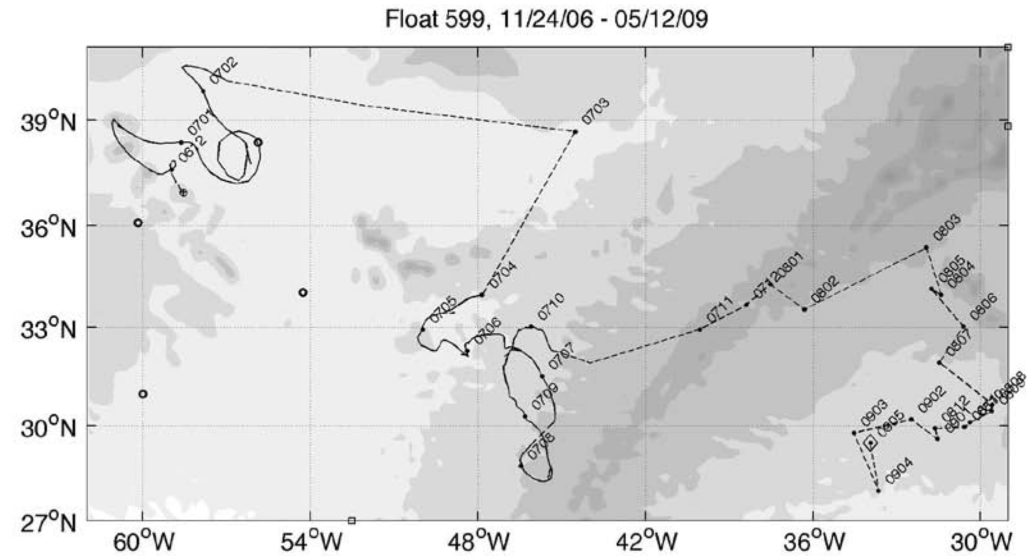

Float 597, 01/26/06 - 09/10/08
39°N
36°N
33°N
30°N
27°N
66°W
63°W
60°W
57°W
54°W
51°W
60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W

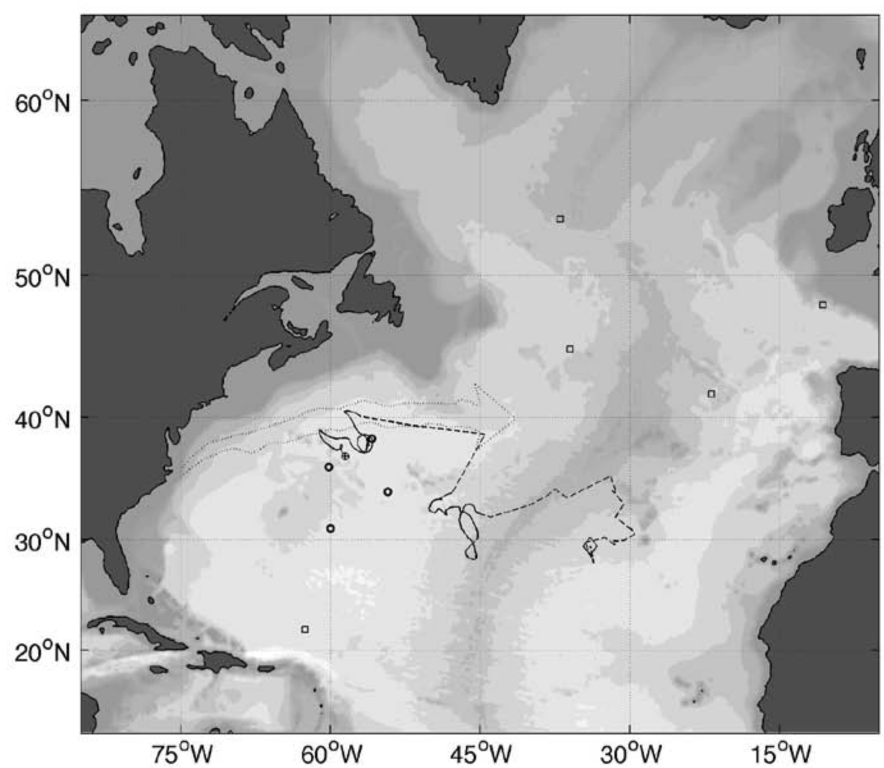

Float 597
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

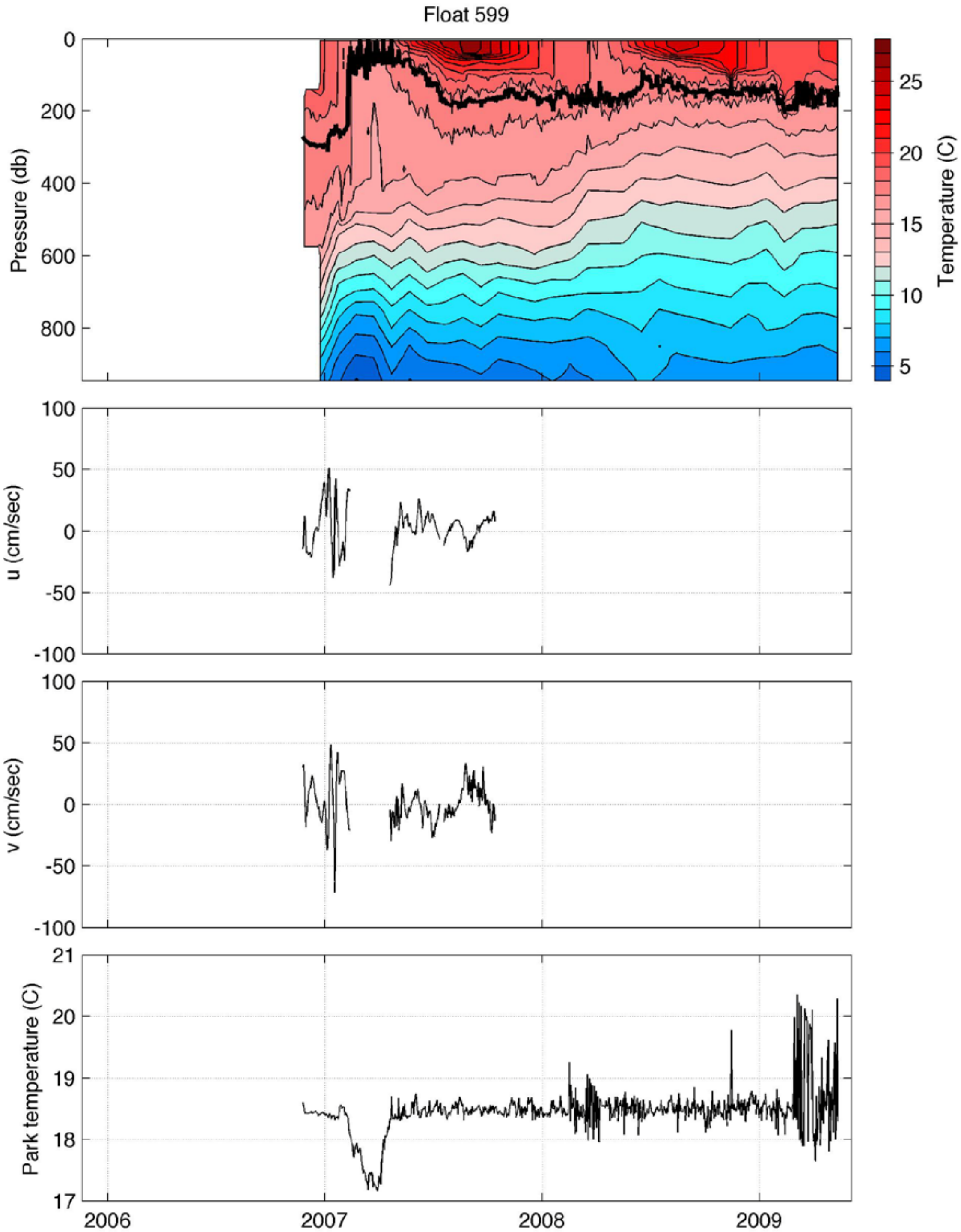

Float 598, 01/22/06 - 05/06/09
40°N
36°N
32°N
28°N
24°N
72°W
63°W
54°W
45°W
36°W


60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W

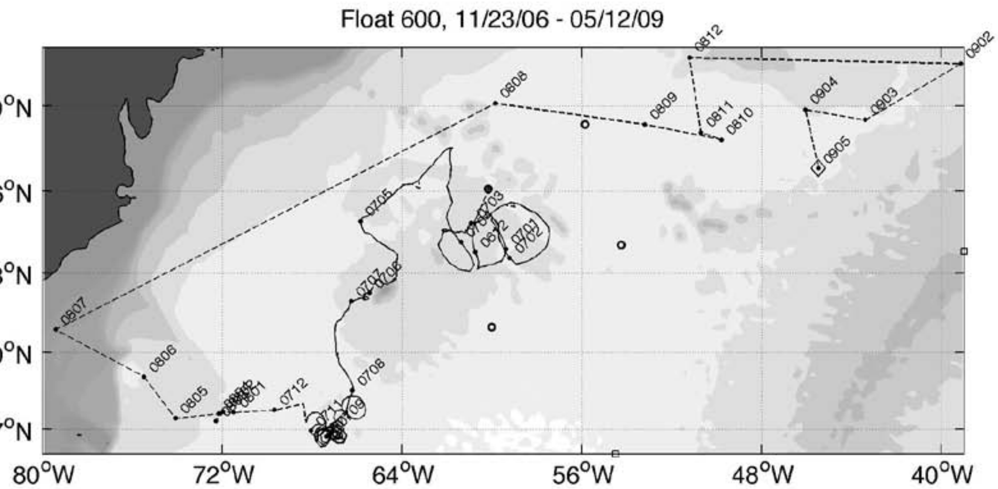

Float 598
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009


Float 599, 11/24/06 - 05/12/09
39°N
36°N
33°N
30°N
27°N
60°W
54°W
48°W
42°W
36°W
30°W

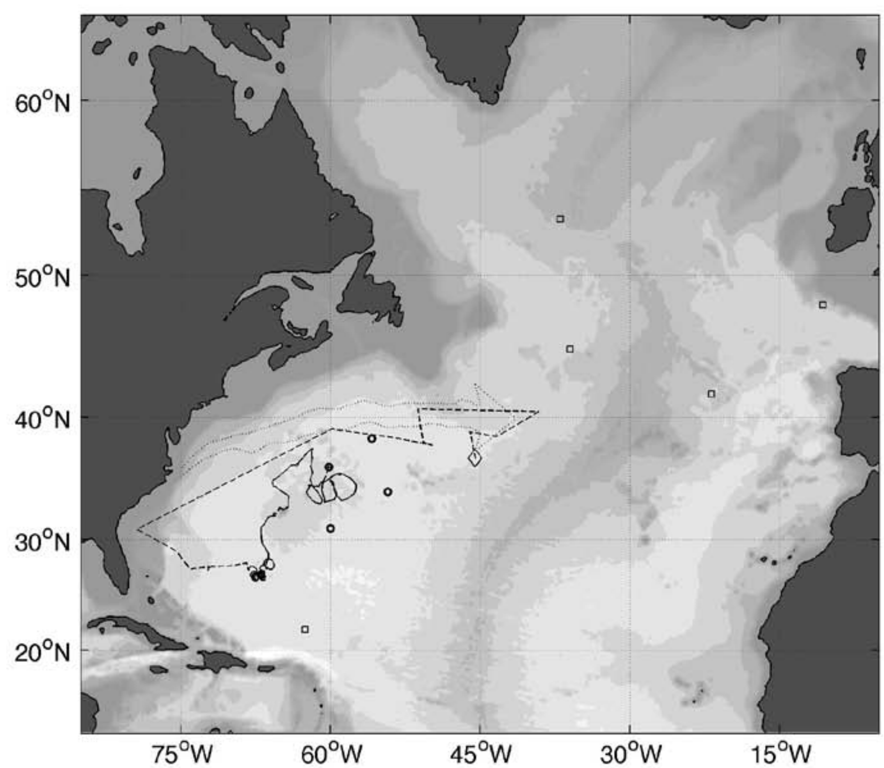

60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W



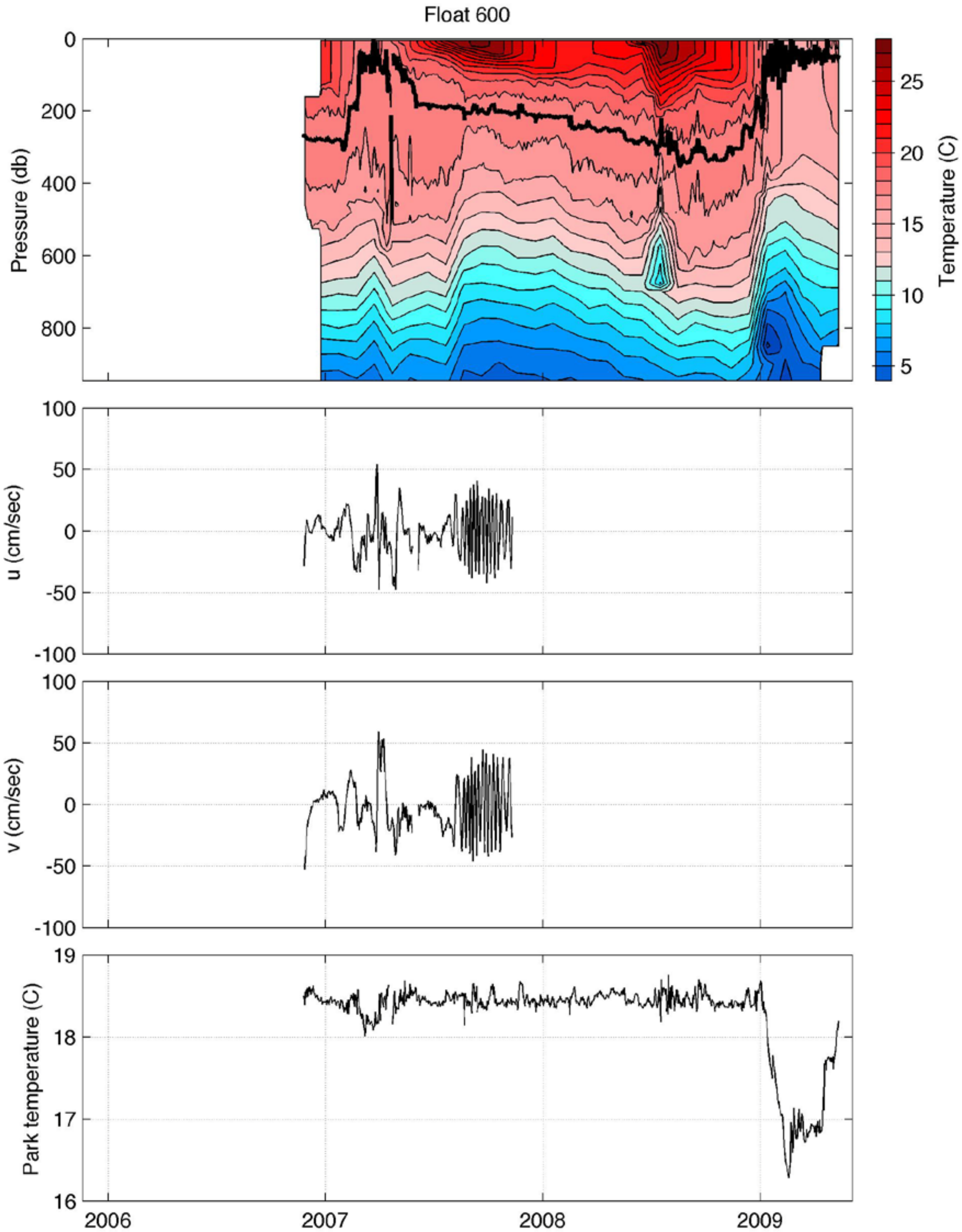
Float 599
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009



Float 600, 11/23/06 - 05/12/09
39°N
36°N
33°N
30°N
27°N
80°W
72°W
64°W
56°W
48°W
40°W

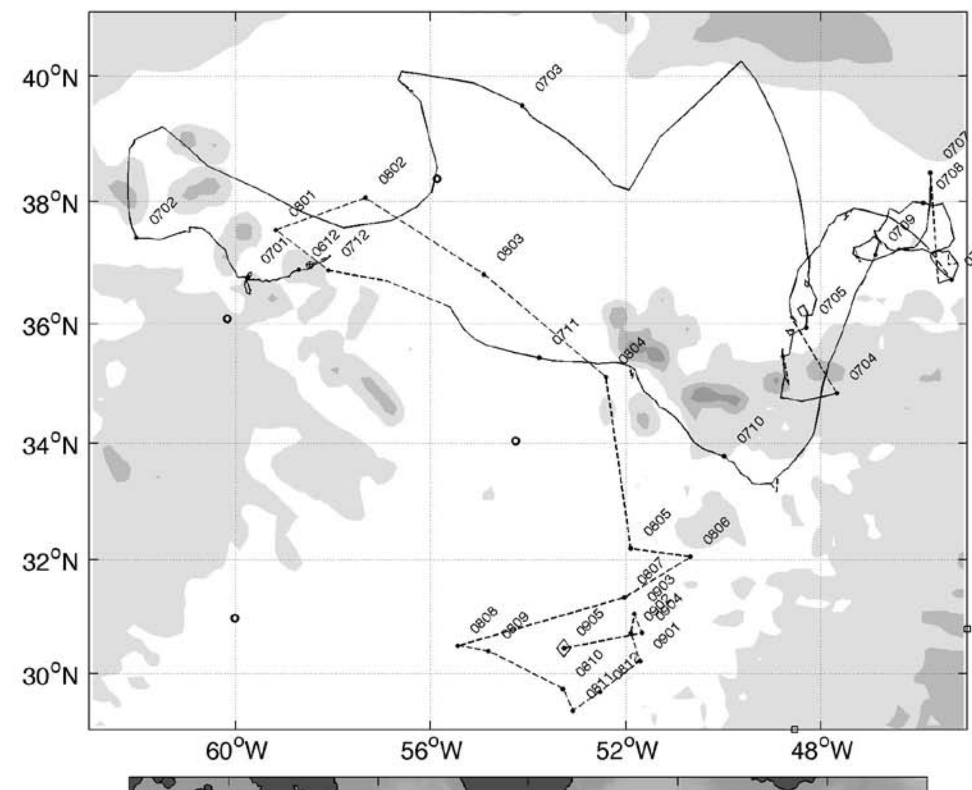


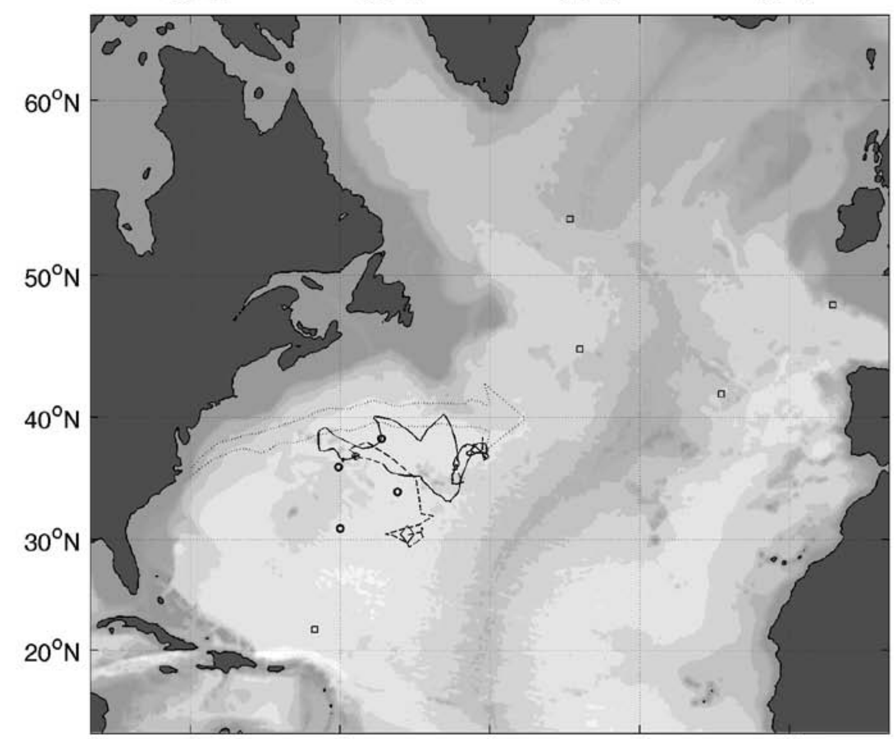
60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W

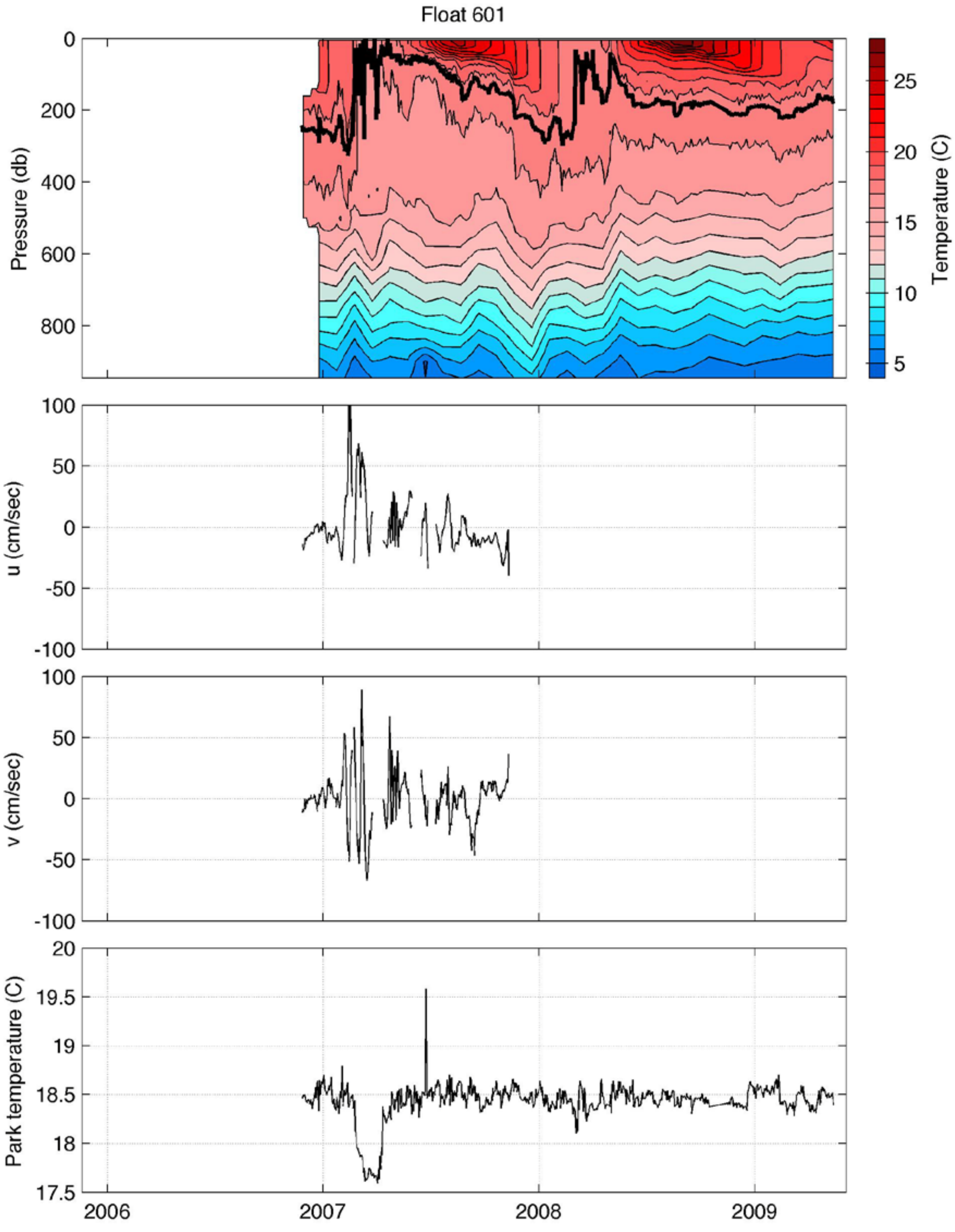


Float 600
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

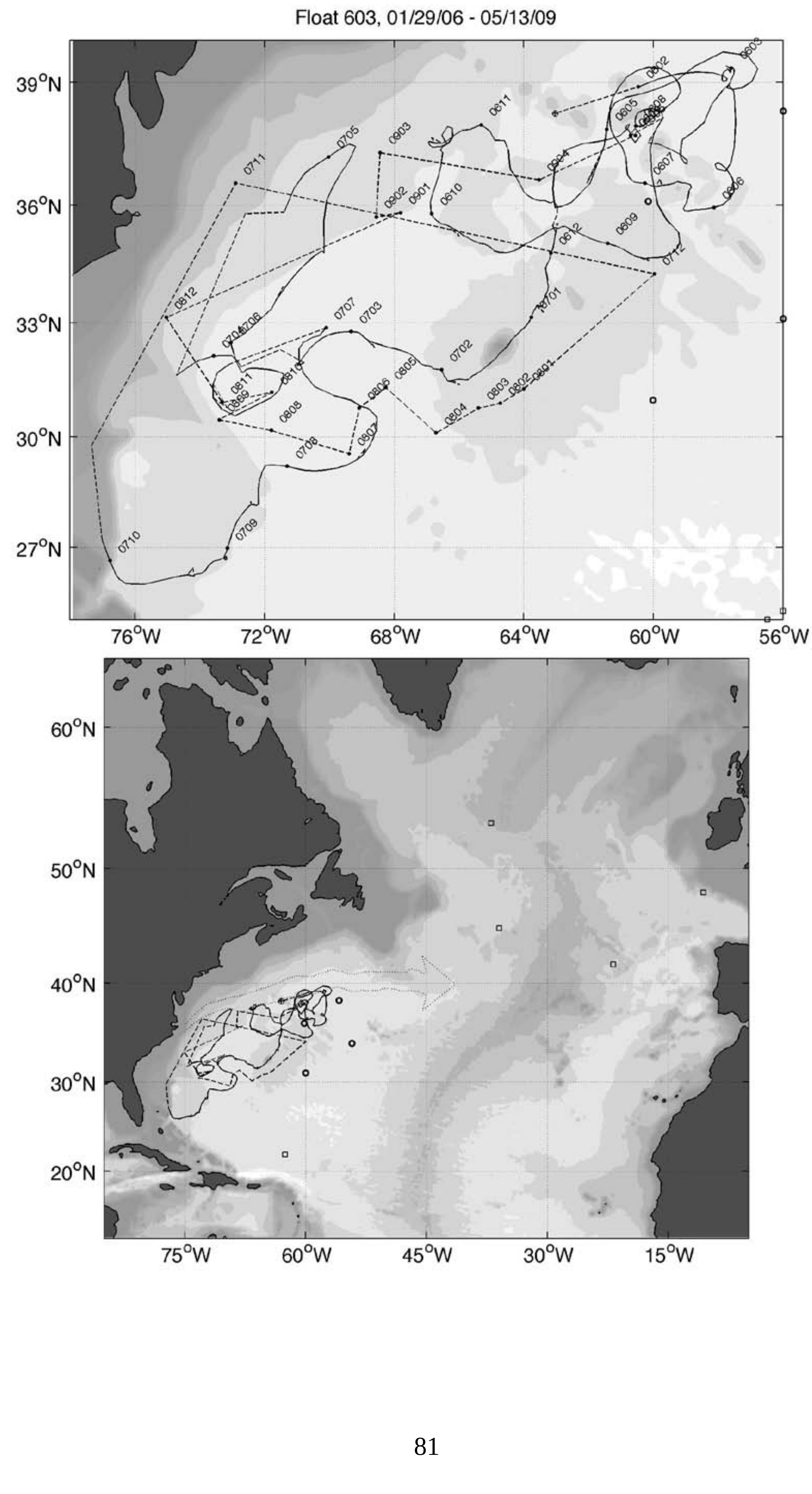
Float 601, 11/24/06 - 05/13/09

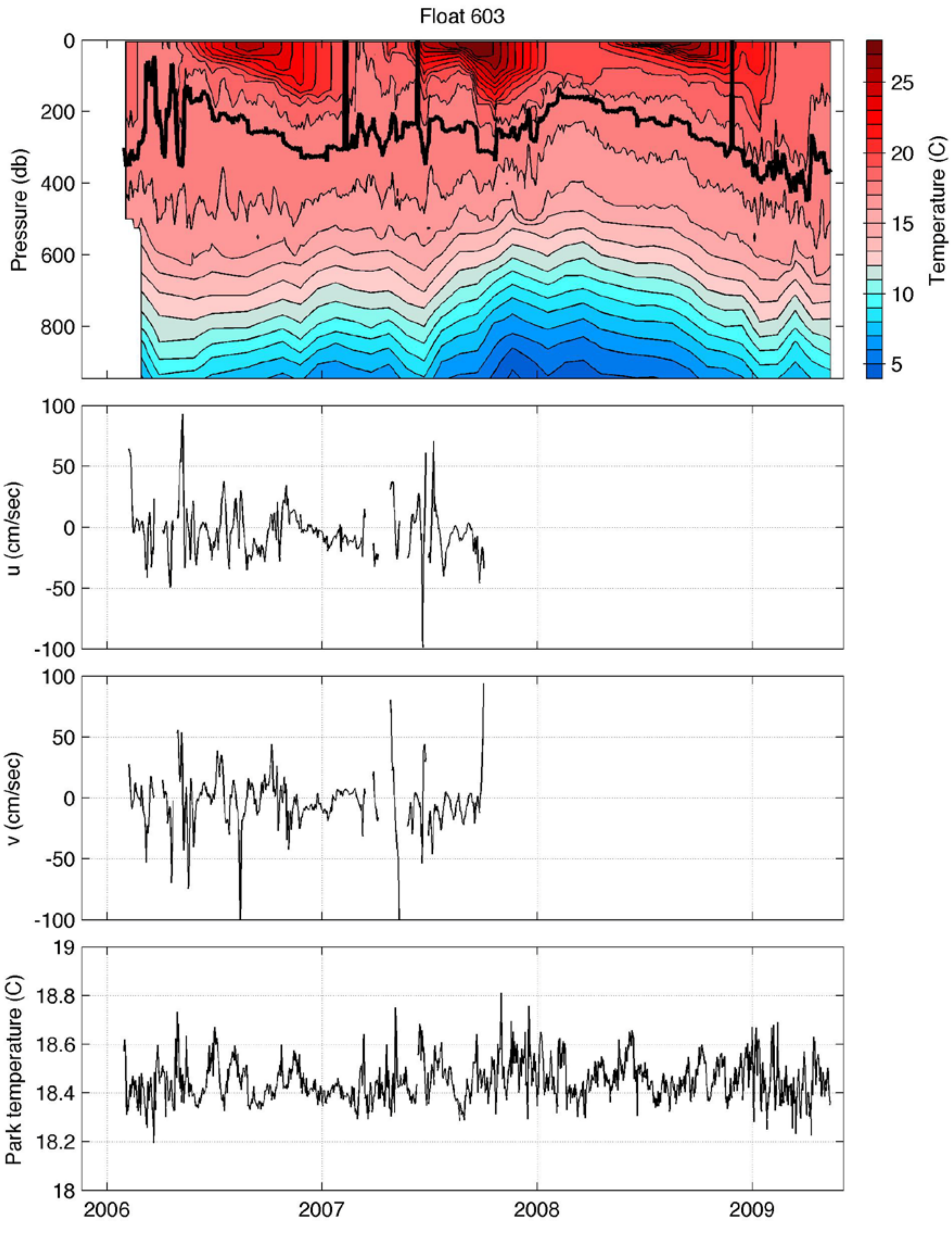




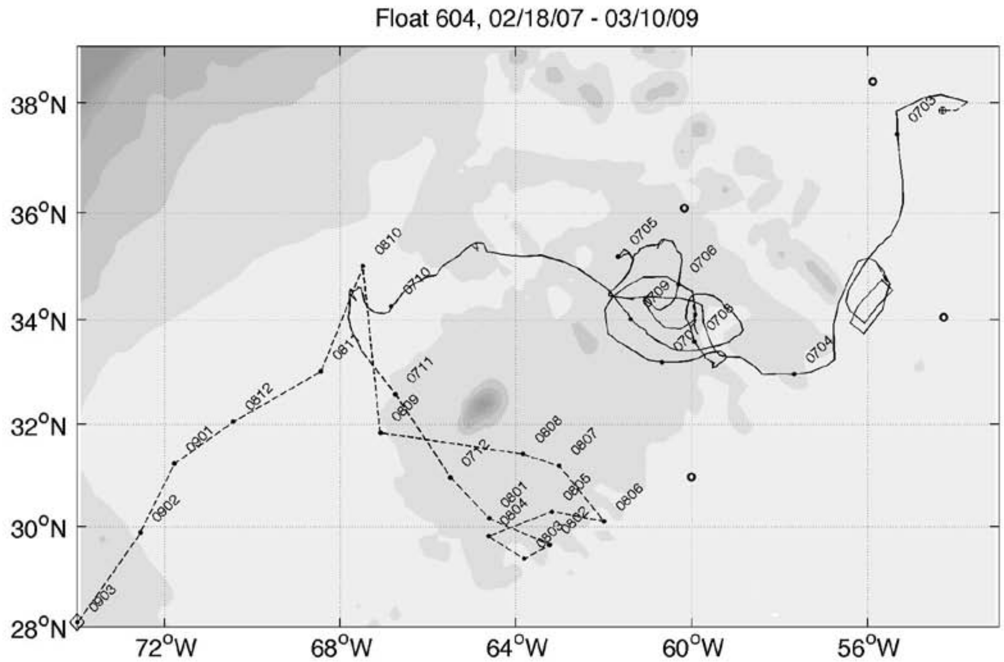


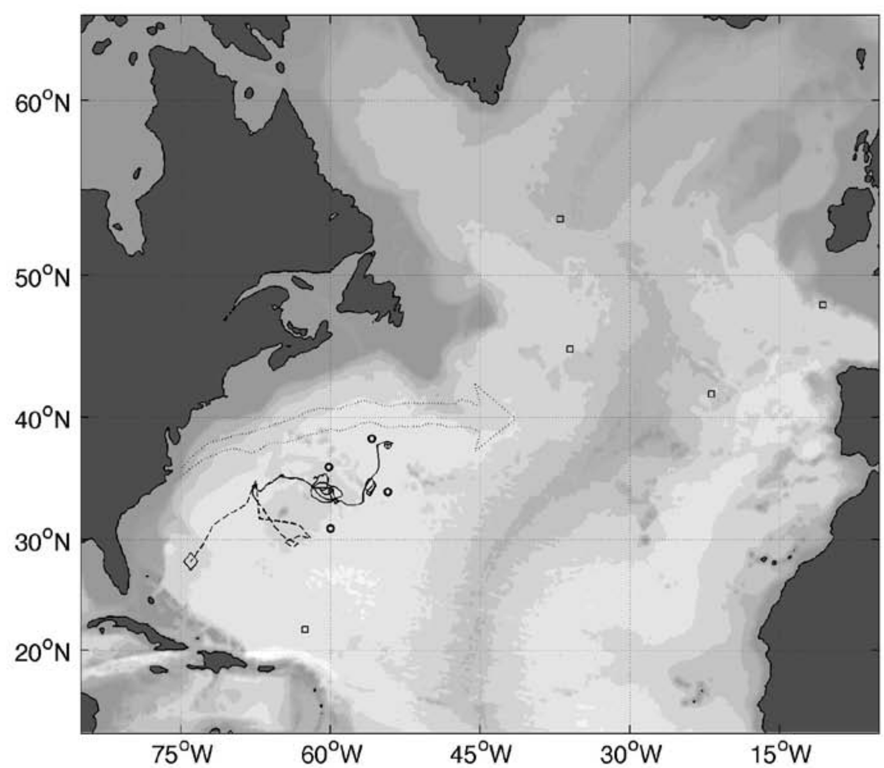
Float 601
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

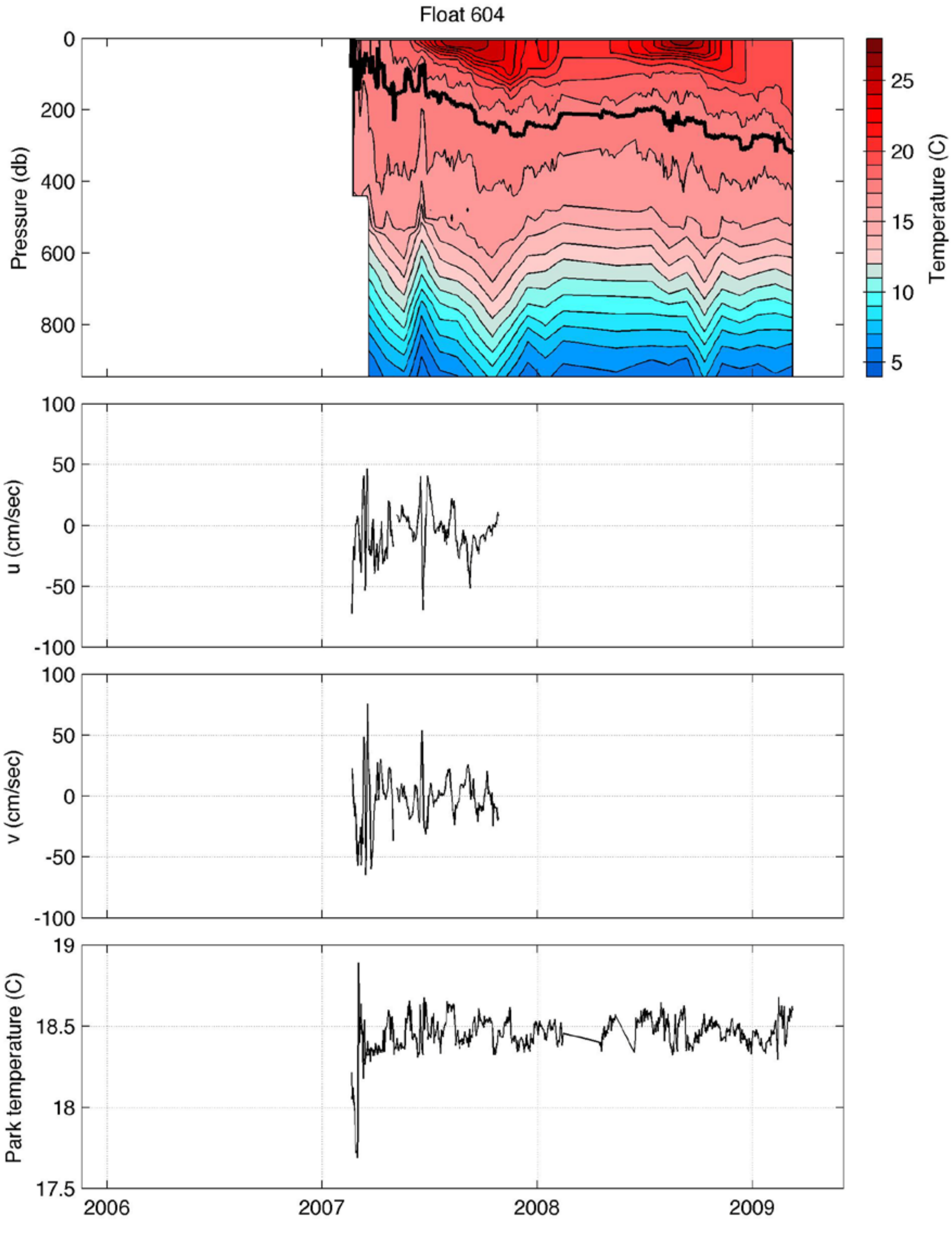

Float 603, 01/29/06 - 05/13/09
39°N
36°N
33°N
30°N
27°N
76°W
72°W
68°W
64°W
60°W
56°W
60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W



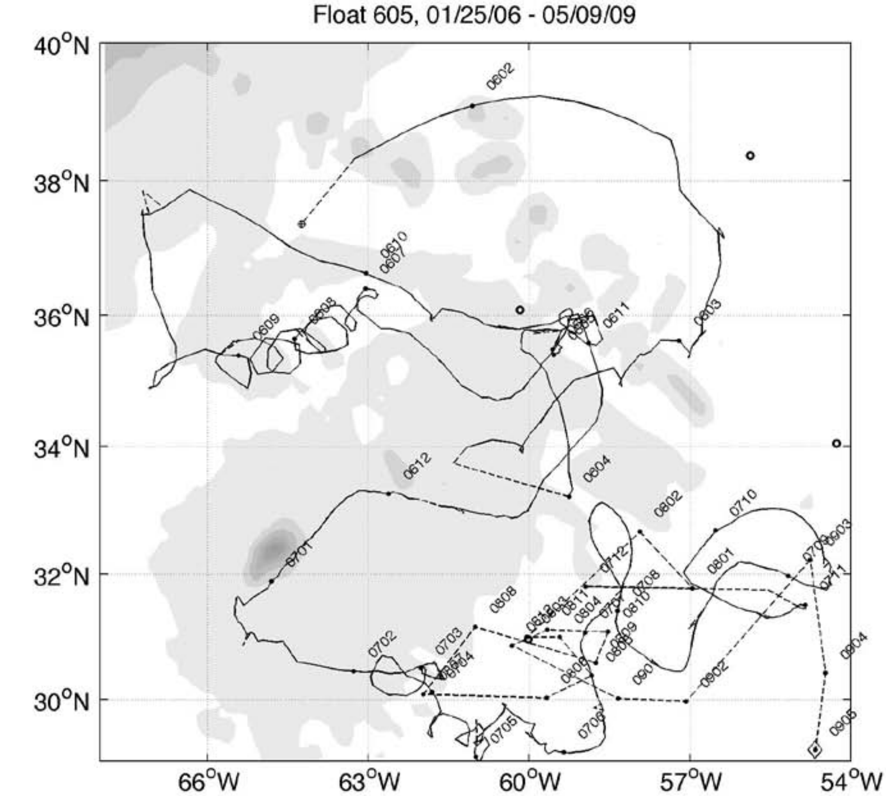
Float 603
Pressure (db)
0
200
400
600
800
Temperature (C)
25
20
15
10
5
u (cm/sec)
100
50
0
-50
-100
v (cm/sec)
100
50
0
-50
-100
Park temperature (C)
19
18.8
18.6
18.4
18.2
18
2006
2007
2008
2009

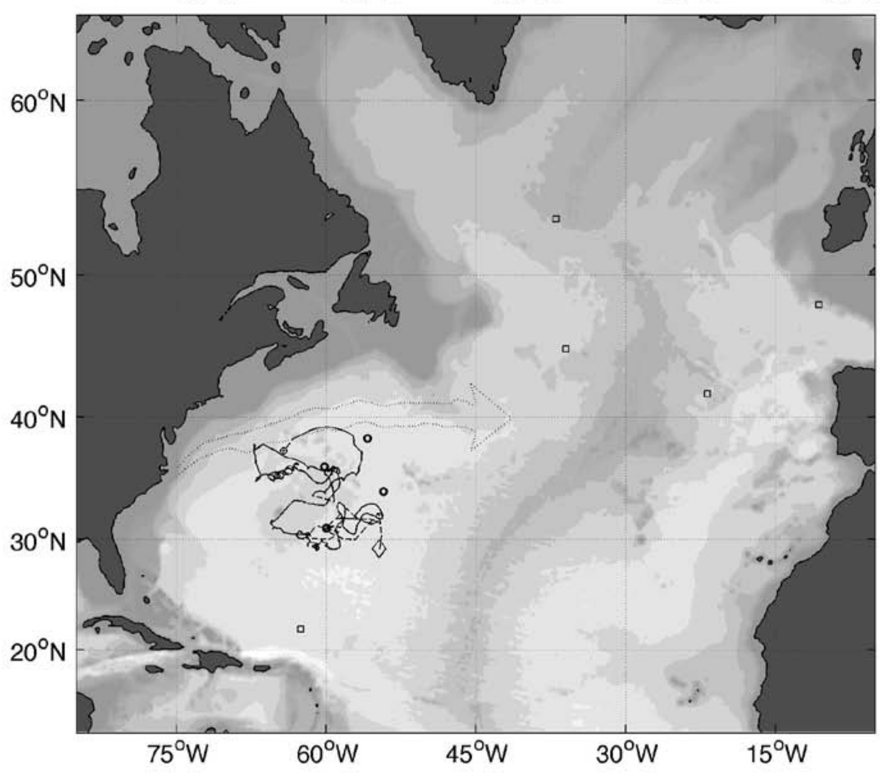

Float 604, 02/18/07 - 03/10/09
38°N
36°N
34°N
32°N
30°N
28°N
72°W
68°W
64°W
60°W
56°W

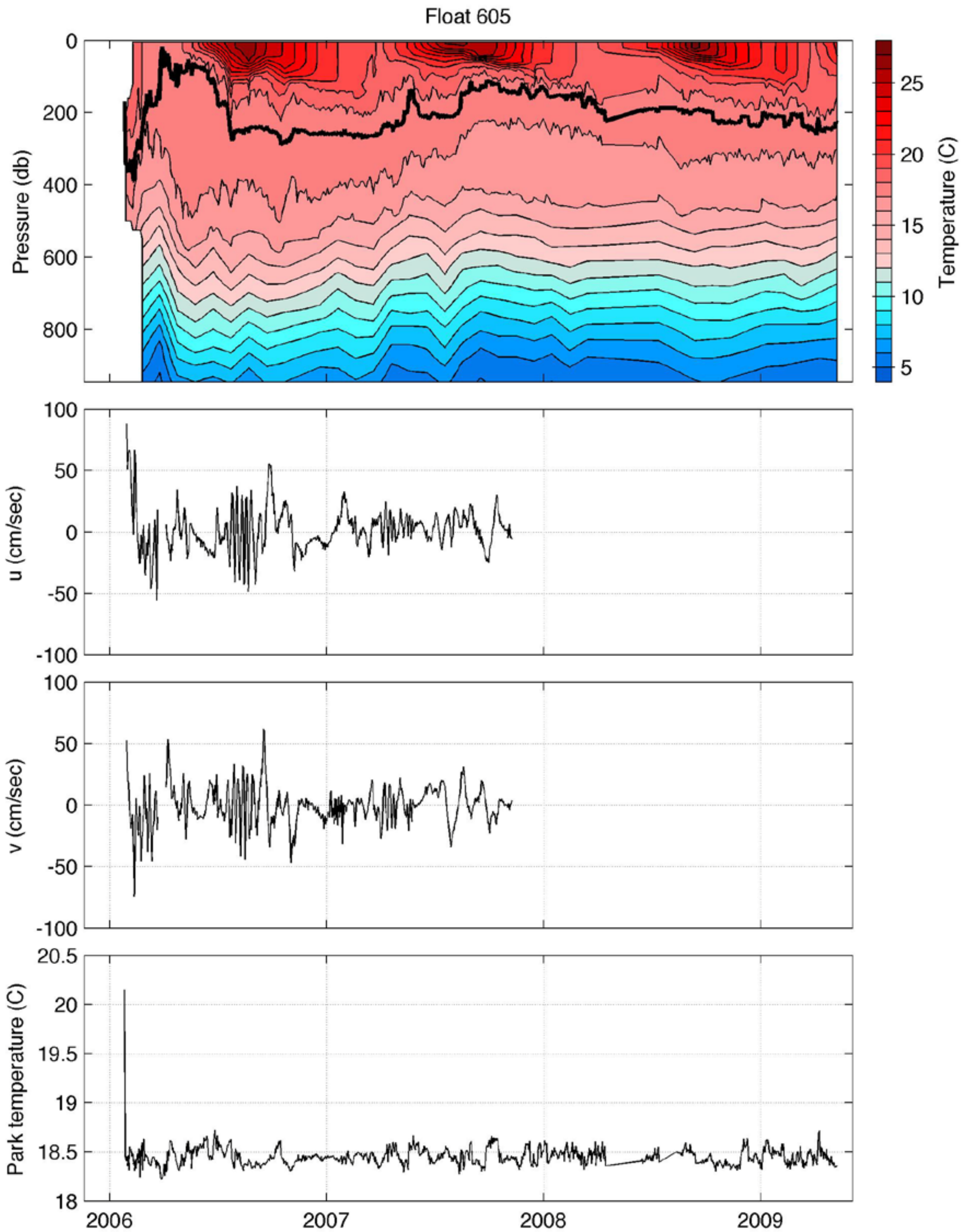

60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W



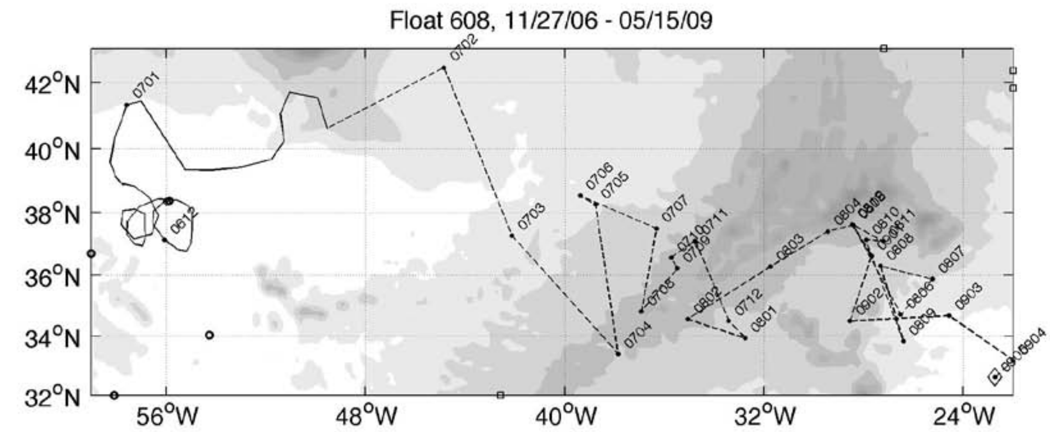
Float 604
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

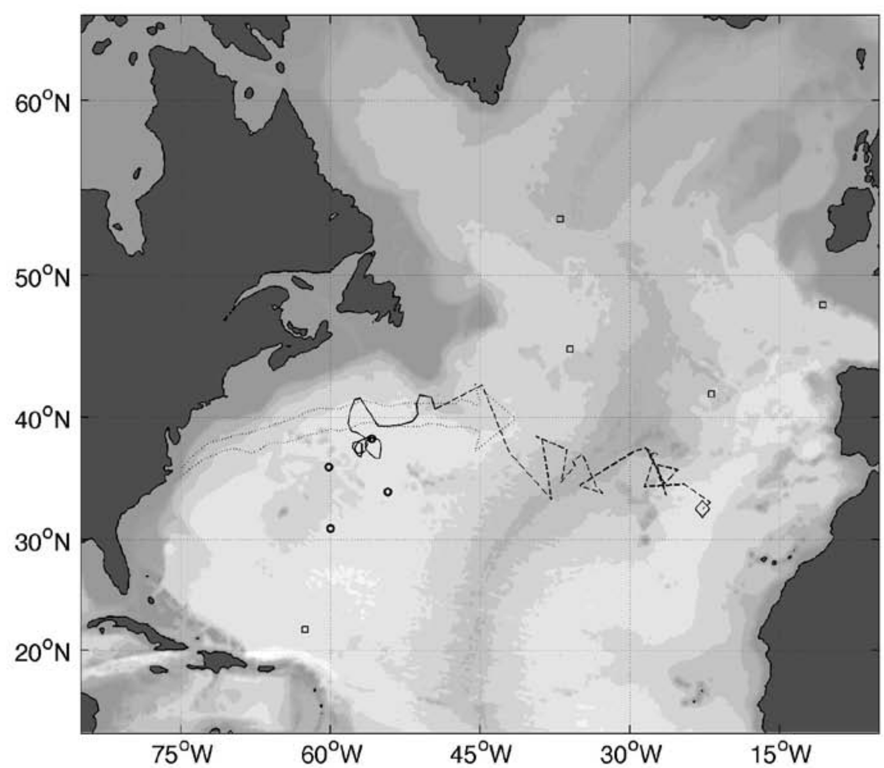

Float 605, 01/25/06 - 05/09/09
40°N
38°N
36°N
34°N
32°N
30°N
66°W
63°W
60°W
57°W
54°W

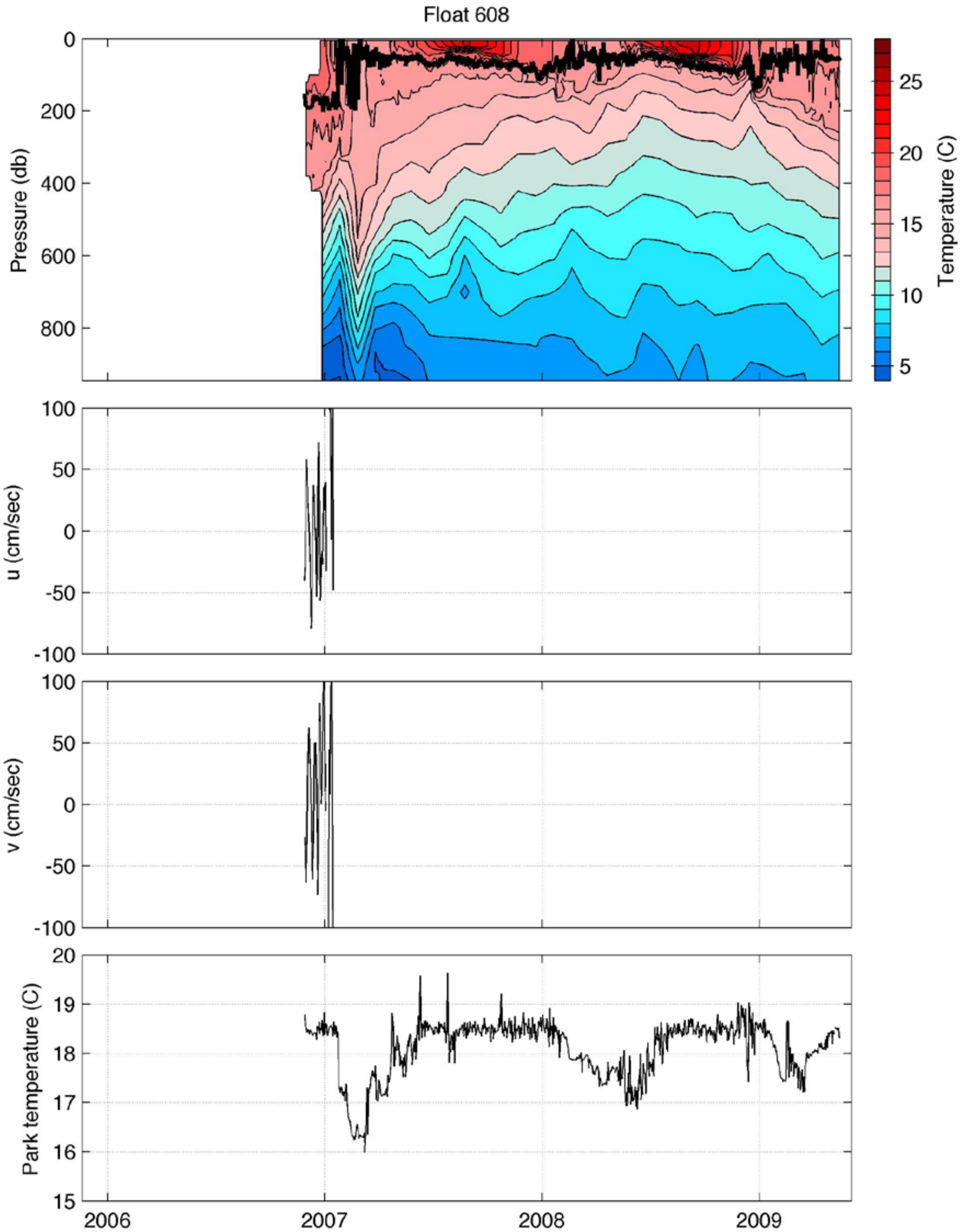

60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W



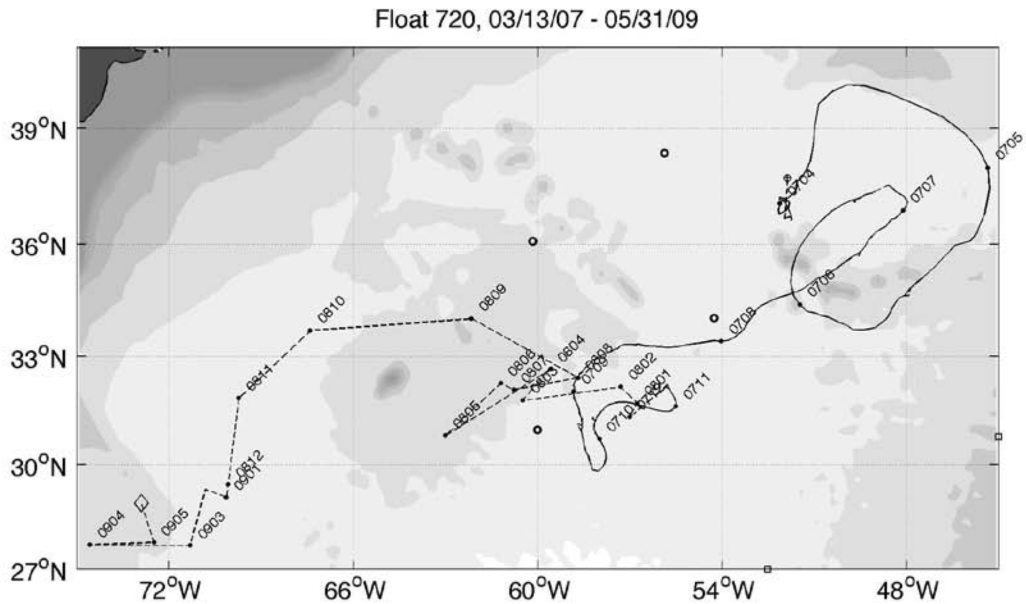
Float 605
Pressure (db)
0
200
400
600
800
25
20
15
10
5
Temperature (C)
u (cm/sec)
100
50
0
-50
-100
v (cm/sec)
100
50
0
-50
-100
Park temperature (C)
20.5
20
19.5
19
18.5
18
2006
2007
2008
2009

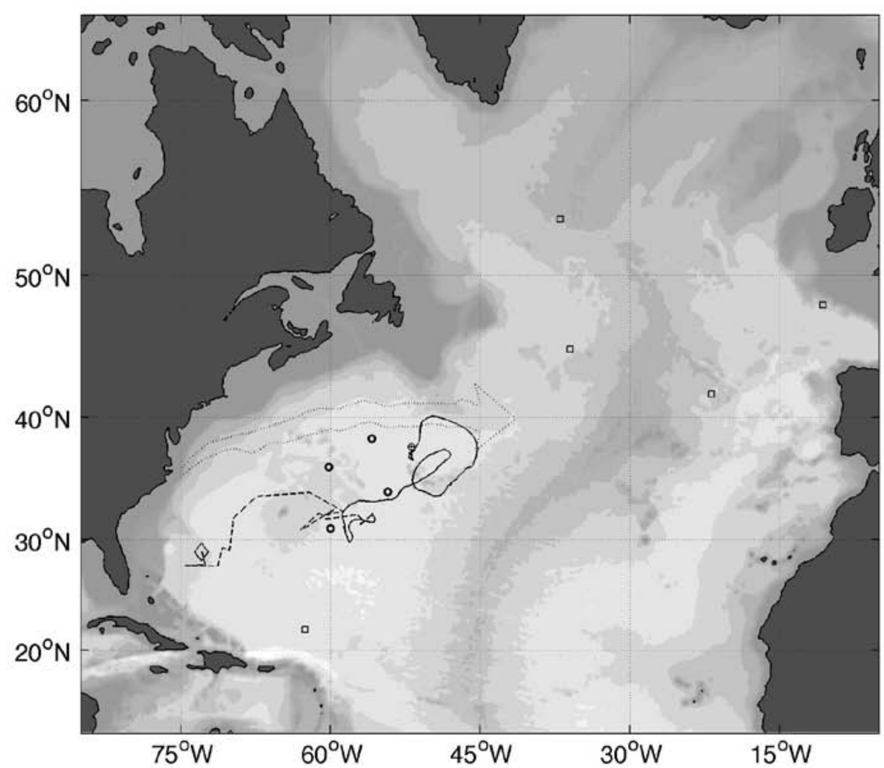

Float 608, 11/27/06 - 05/15/09
42°N
40°N
38°N
36°N
34°N
32°N
56°W
48°W
40°W
32°W
24°W

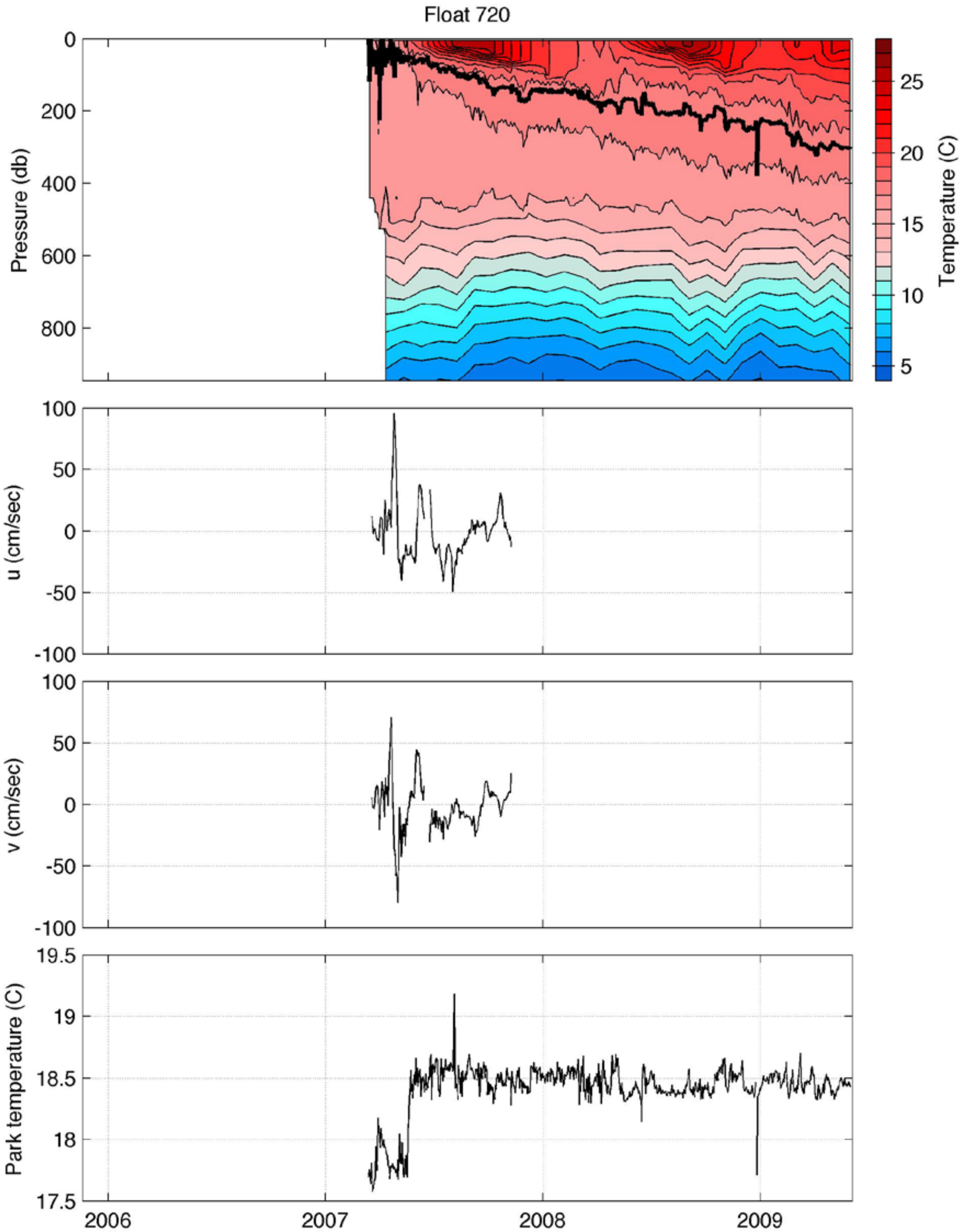

60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W



Float 608
Pressure (db)
0
200
400
600
800
25
20
15
10
5
Temperature (C)
u (cm/sec)
100
50
0
-50
-100
v (cm/sec)
100
50
0
-50
-100
Park temperature (C)
20
19
18
17
16
15
2006
2007
2008
2009

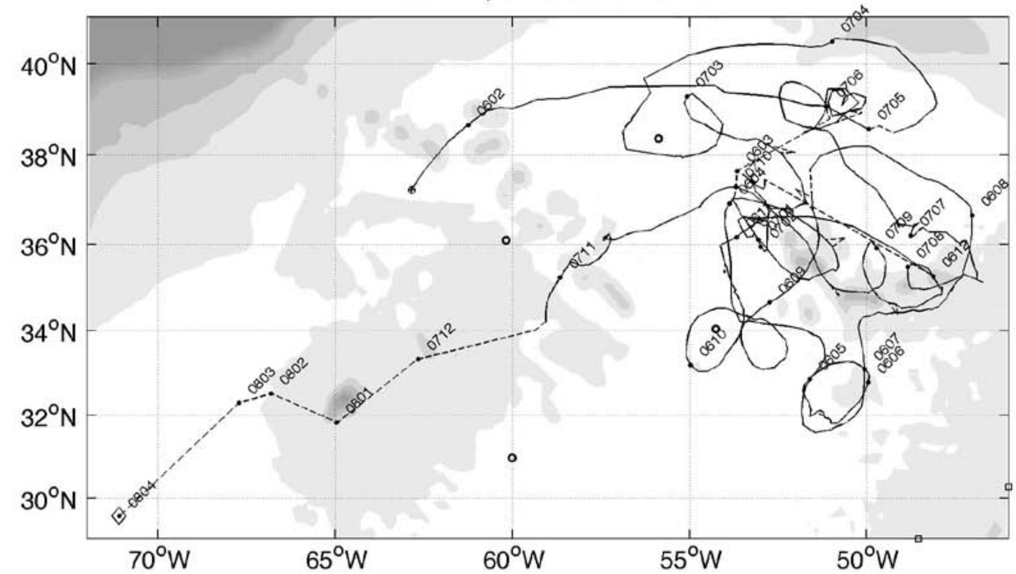

Float 720, 03/13/07 - 05/31/09
39°N
36°N
33°N
30°N
27°N
72°W
66°W
60°W
54°W
48°W
0705
0707
0706
0708
0704
0809
0810
0811
0812
0901
0903
0904
0905
0806
0805
0804
0711

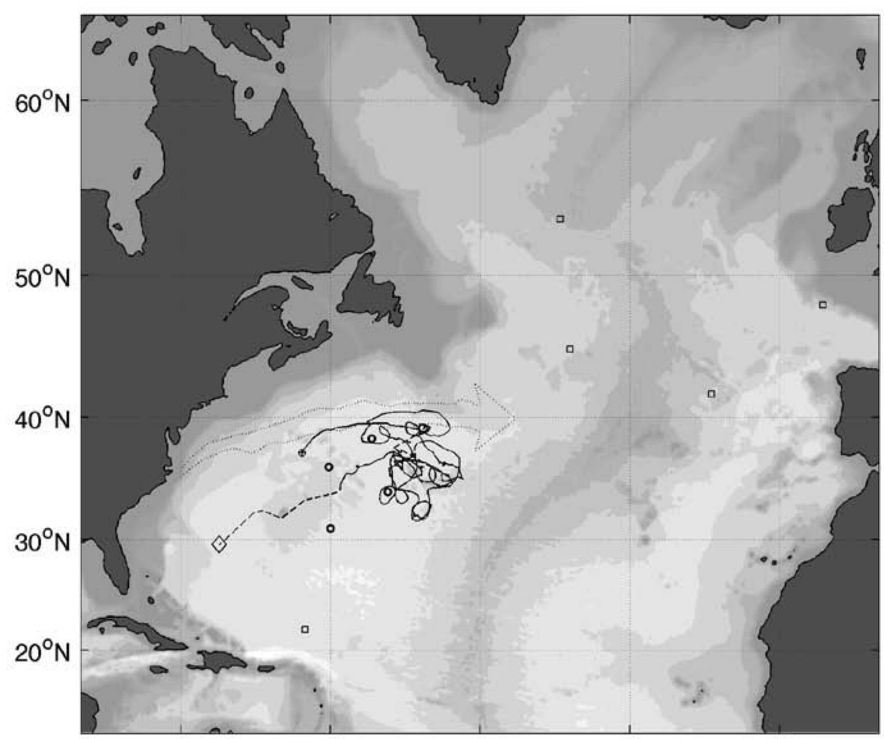

60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W

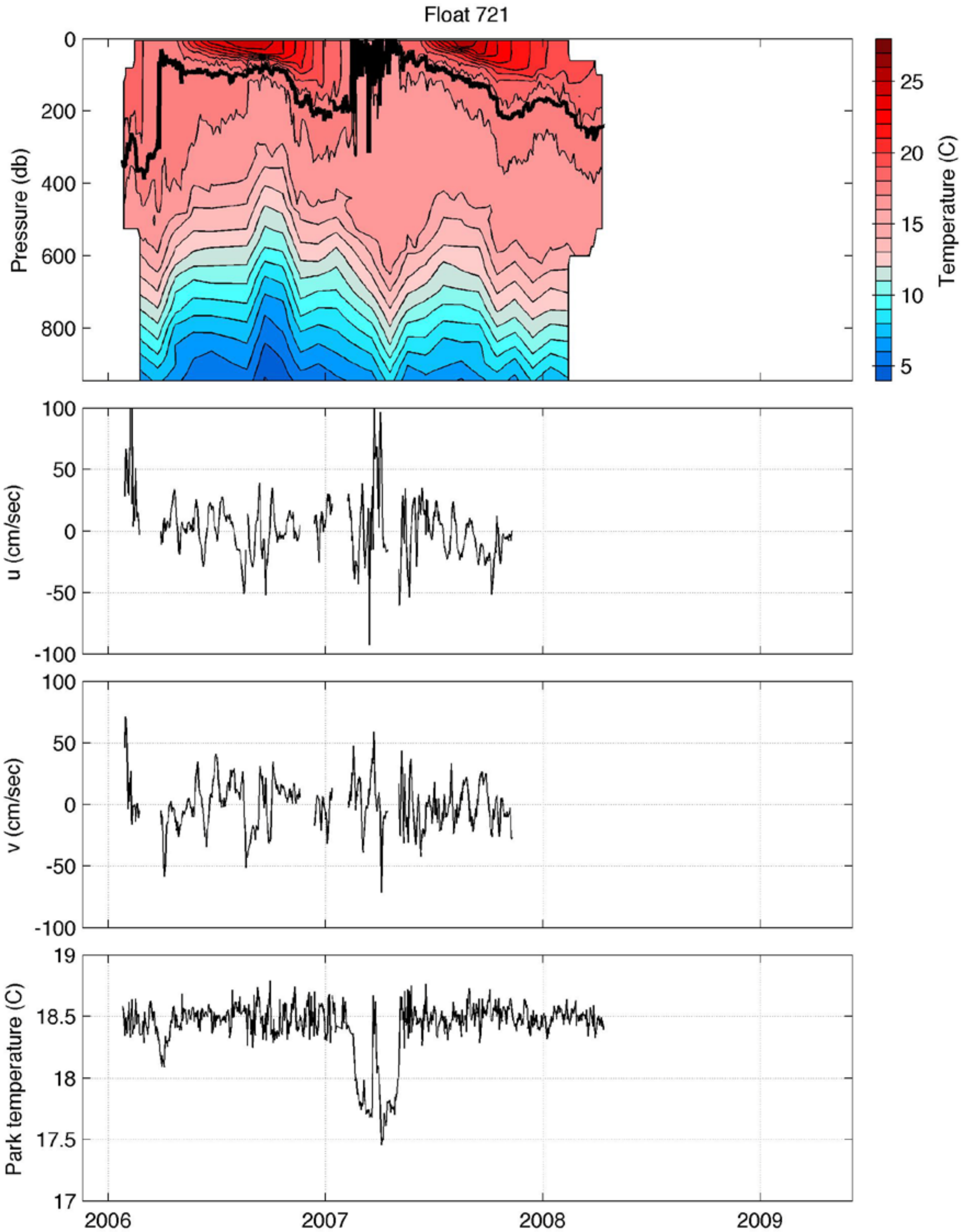


Float 720
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

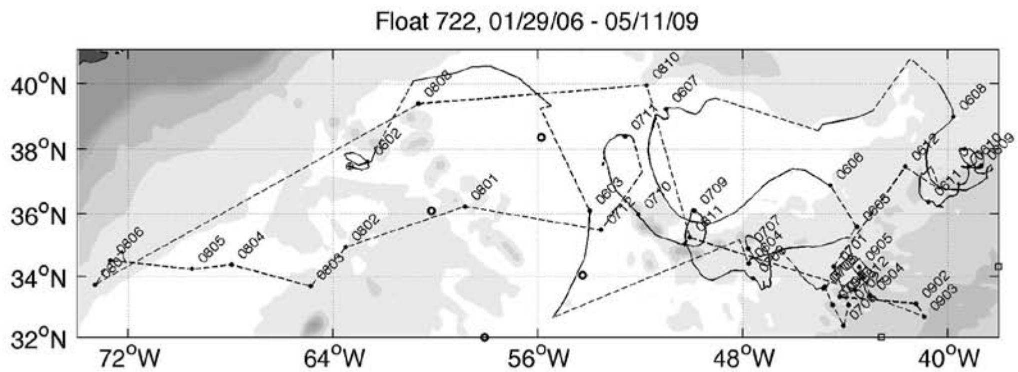
Float 721, 01/29/06 - 04/13/08

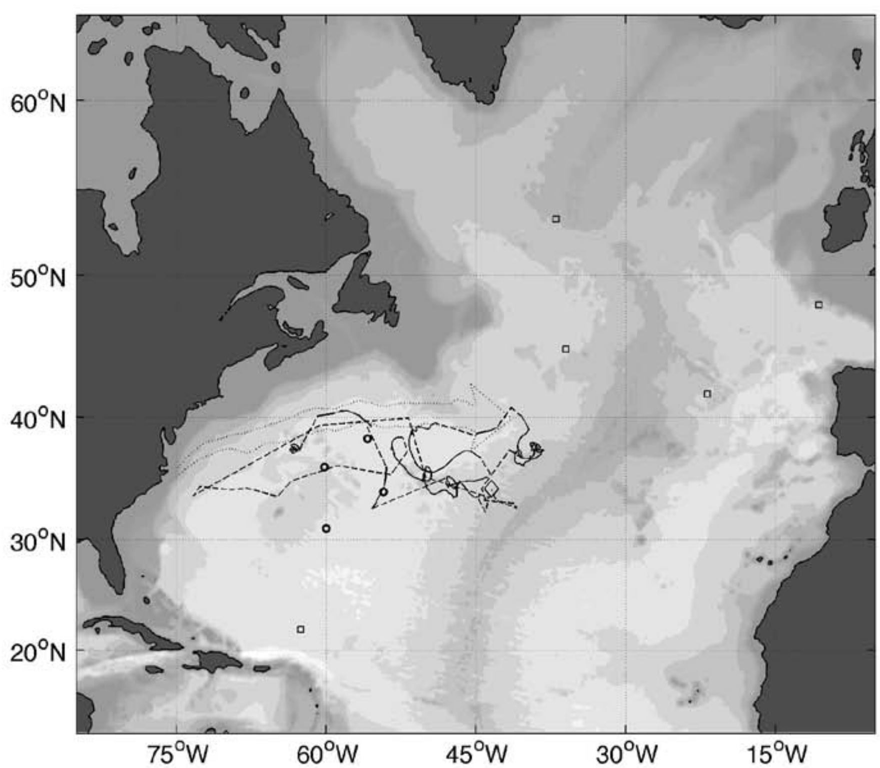


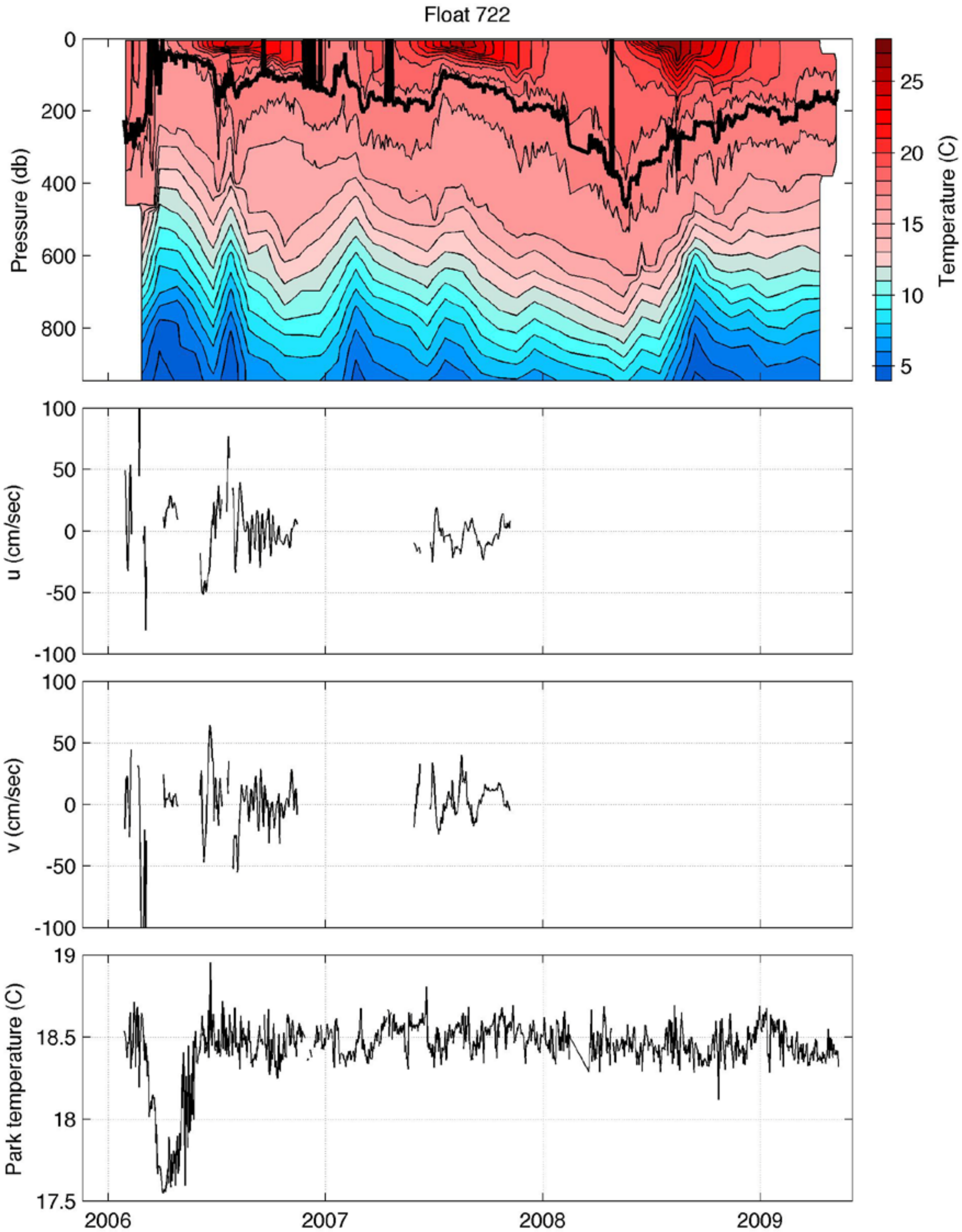




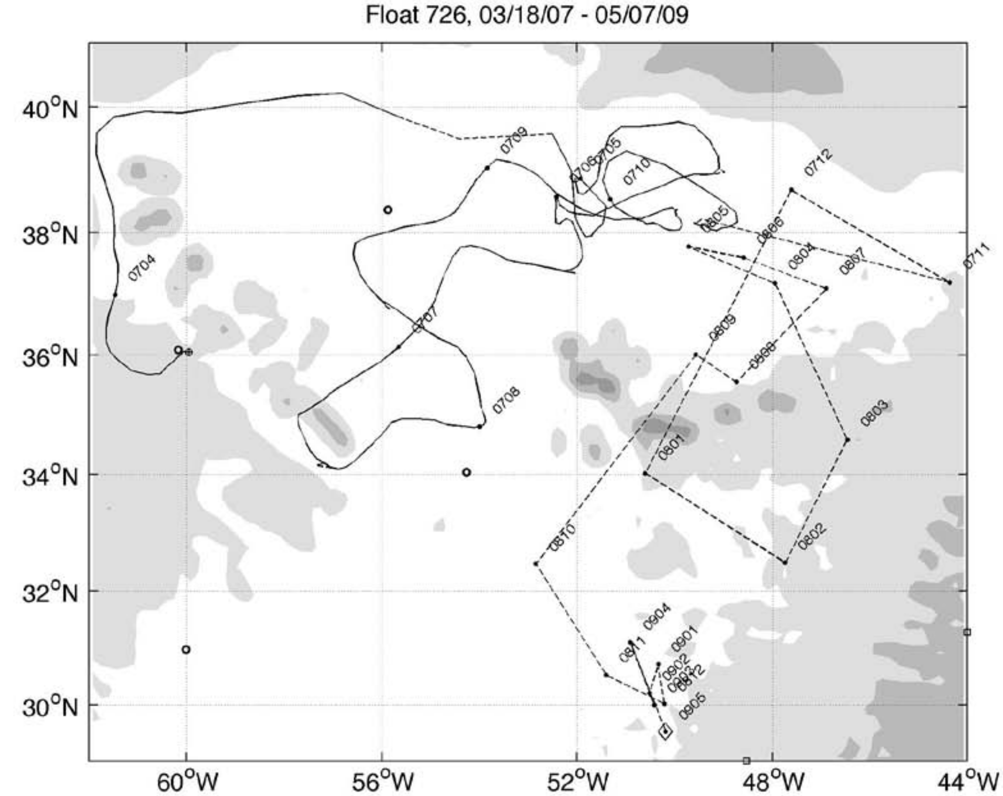
Float 721
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

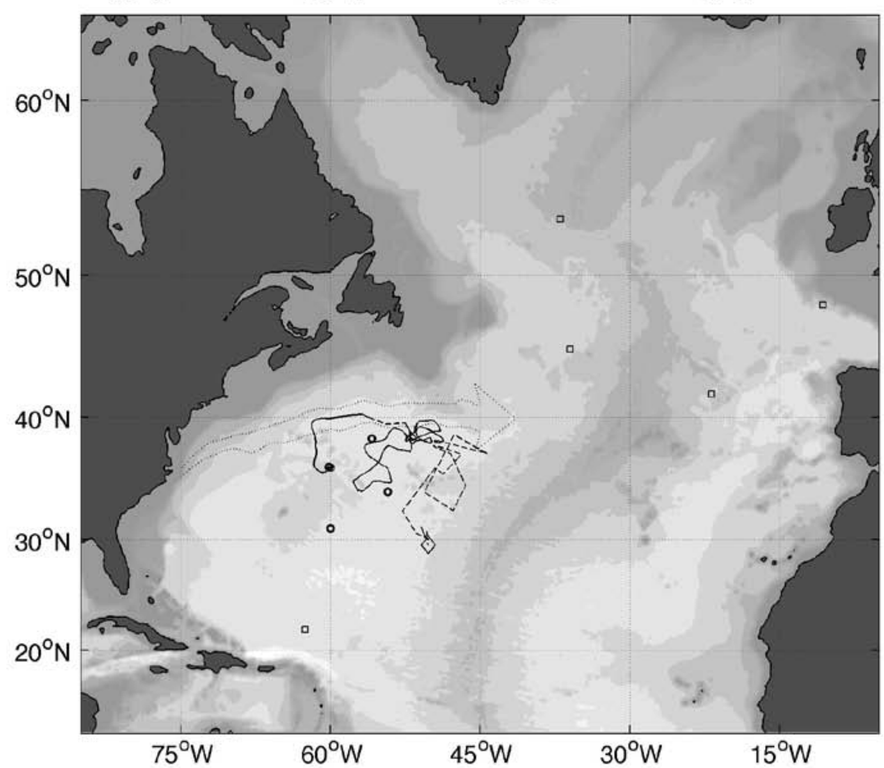

Float 722, 01/29/06 - 05/11/09
40°N
38°N
36°N
34°N
32°N
72°W
64°W
56°W
48°W
40°W

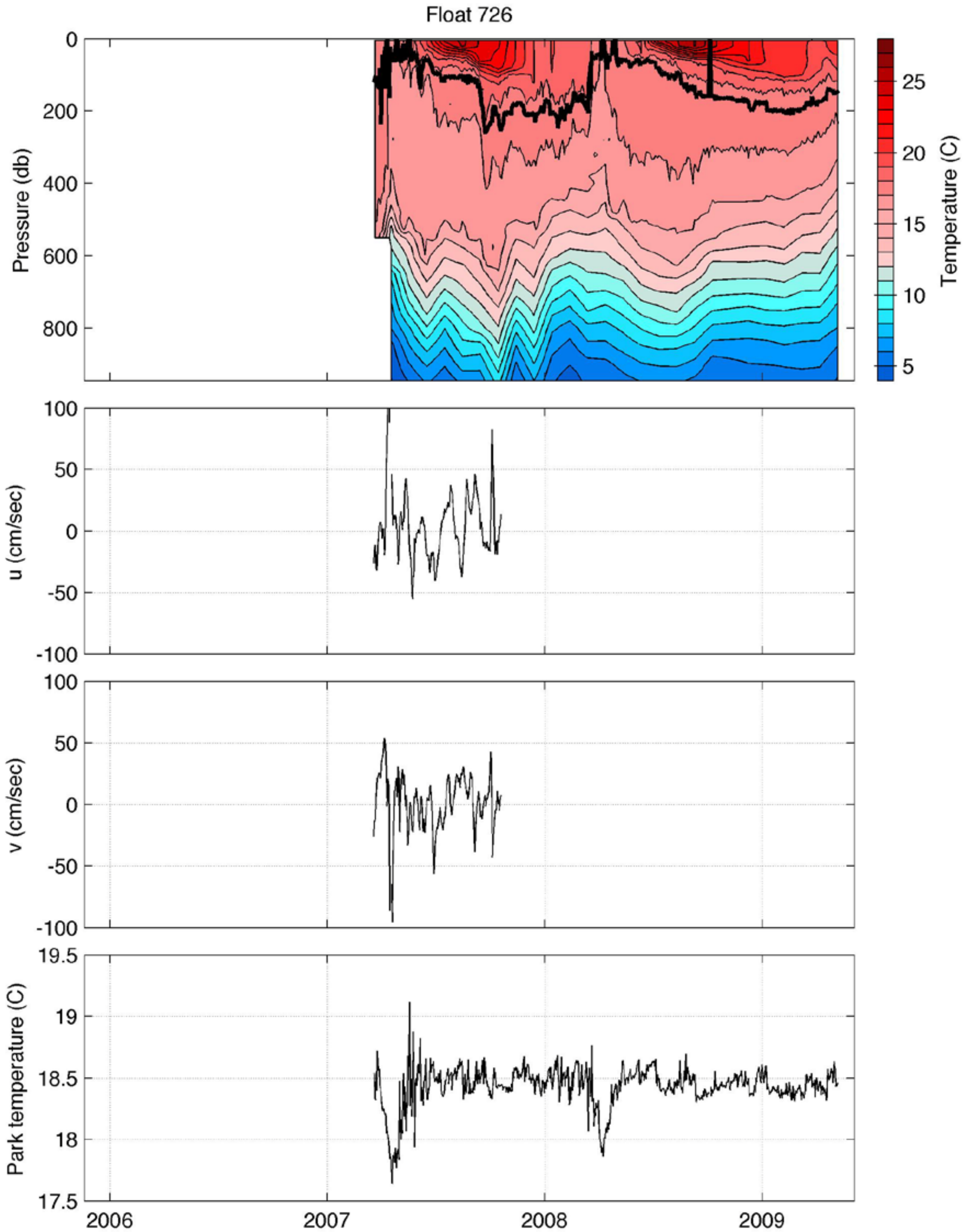

60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W



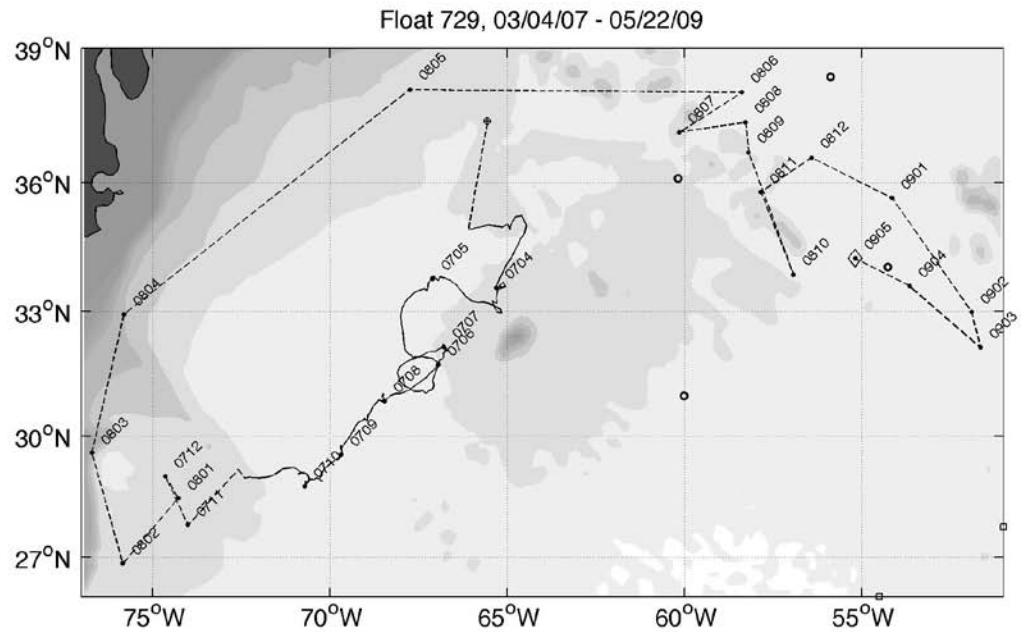
Float 722
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009


Float 726, 03/18/07 - 05/07/09
40°N
38°N
36°N
34°N
32°N
30°N
60°W
56°W
52°W
48°W
44°W
0704
0707
0708
0709
0705
0706
0710
0711
0712
0801
0802
0803
0804
0805
0806
0807
0808
0809
0810
0811
0812
0901
0902
0904
0905

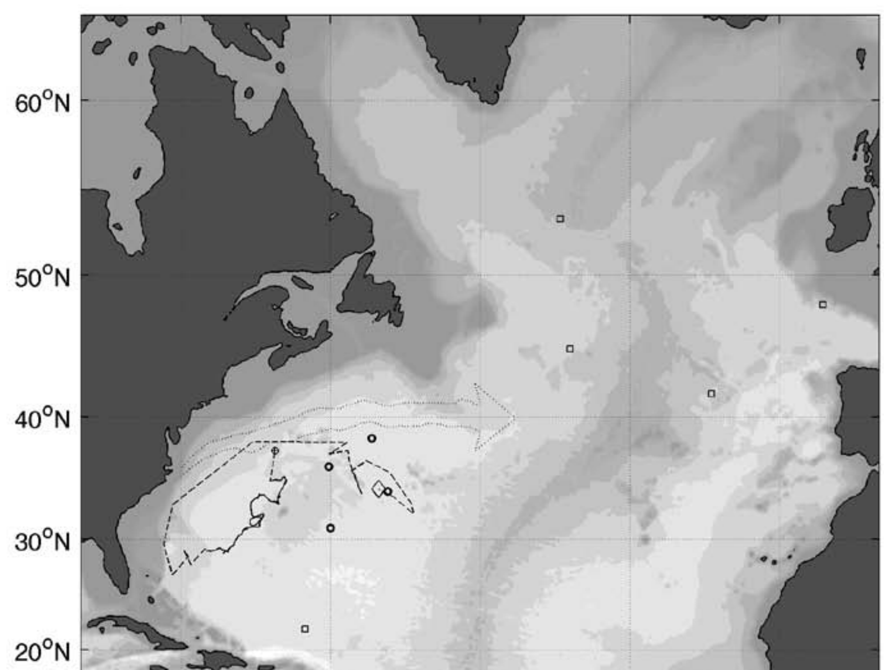

60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W



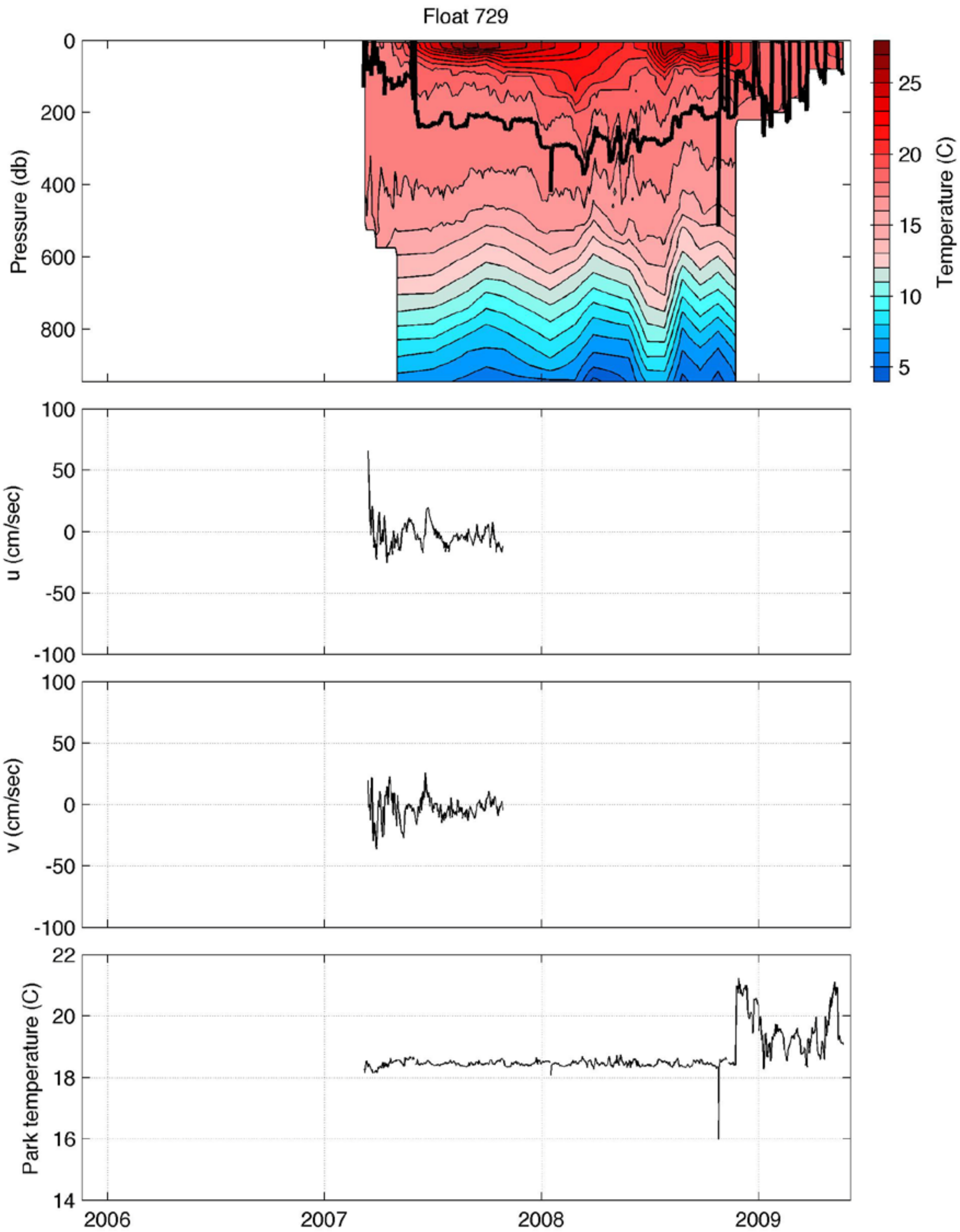
Float 726
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009



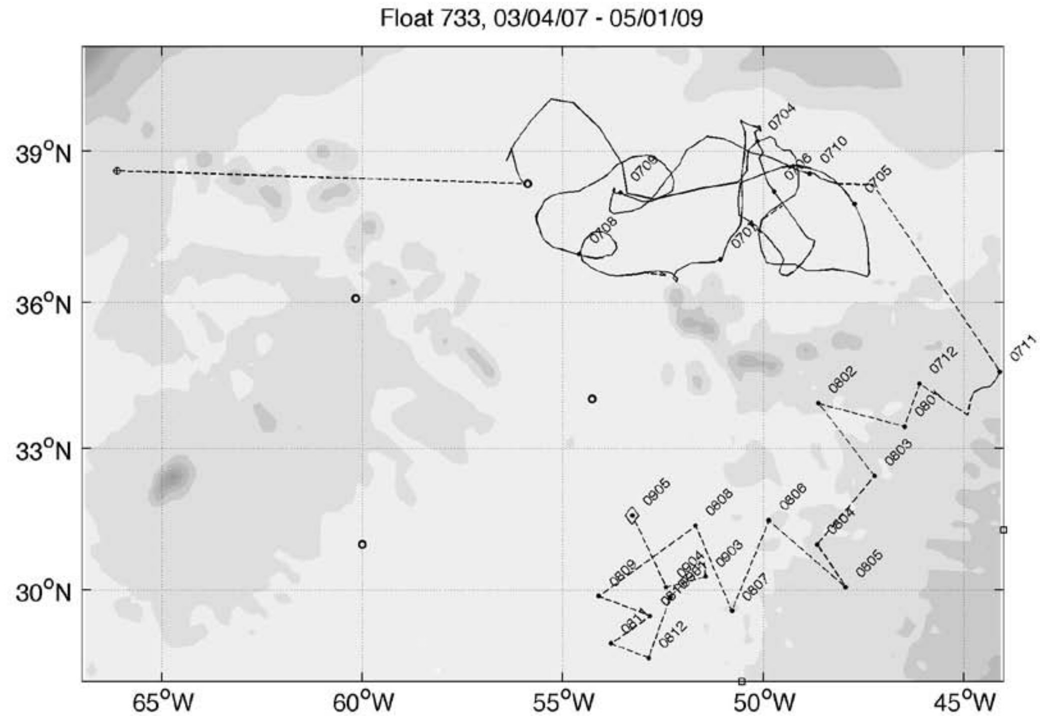
Float 729, 03/04/07 - 05/22/09
39°N
36°N
33°N
30°N
27°N
75°W
70°W
65°W
60°W
55°W

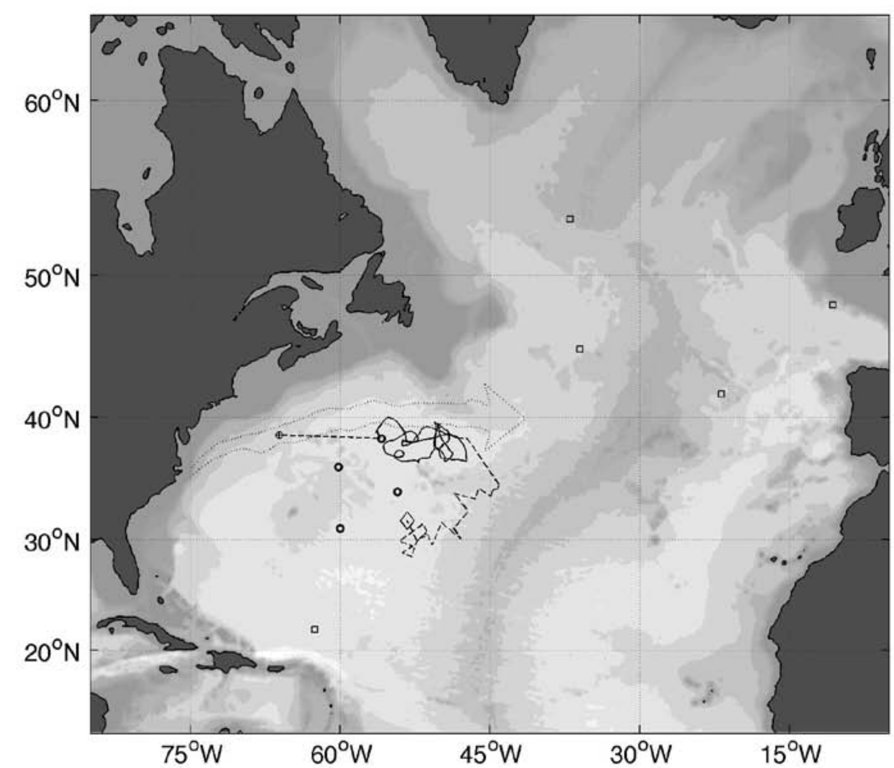


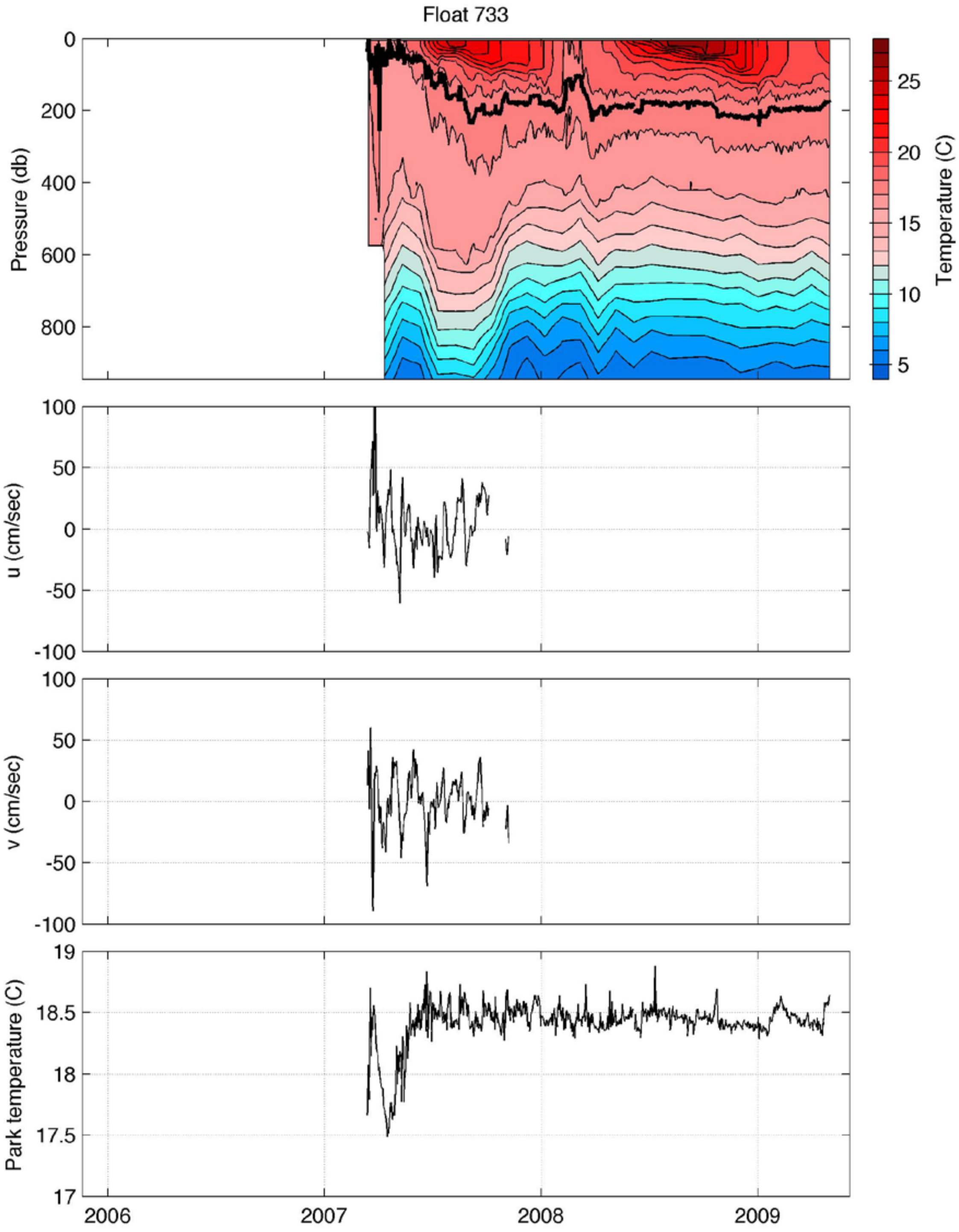
60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W



Float 729
Pressure (db)
0
200
400
600
800
Temperature (C)
25
20
15
10
5
u (cm/sec)
100
50
0
-50
-100
v (cm/sec)
100
50
0
-50
-100
Park temperature (C)
22
20
18
16
14
2006
2007
2008
2009

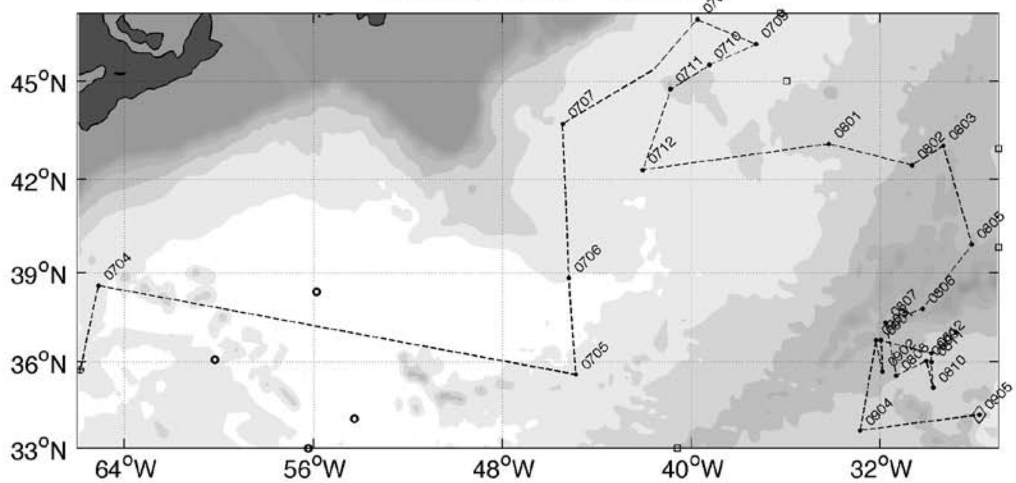

Float 733, 03/04/07 - 05/01/09
39°N
36°N
33°N
30°N
65°W
60°W
55°W
50°W
45°W

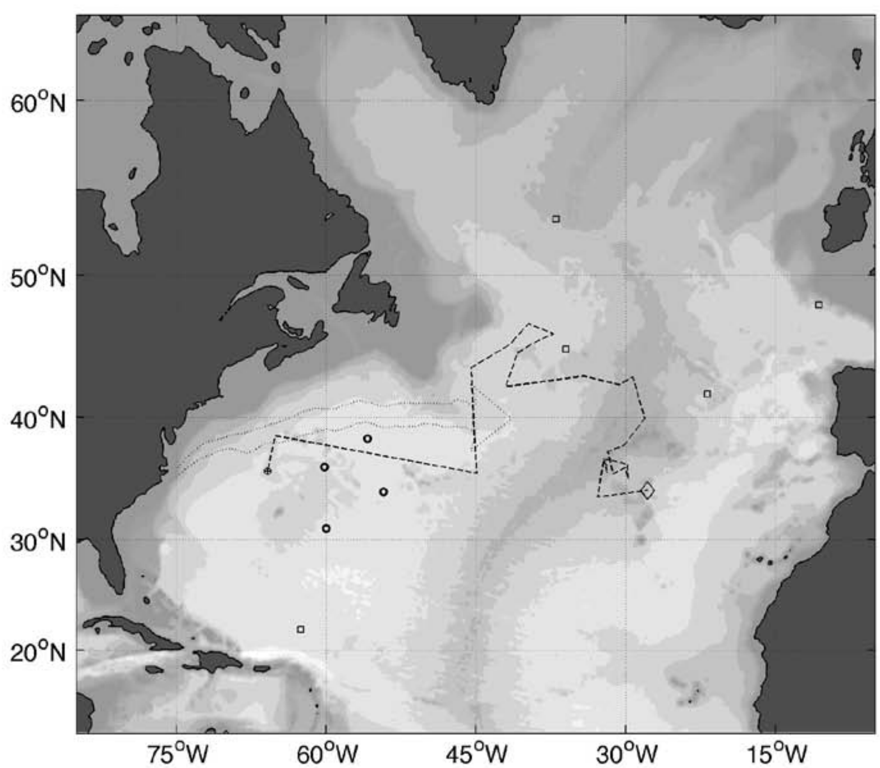

60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W

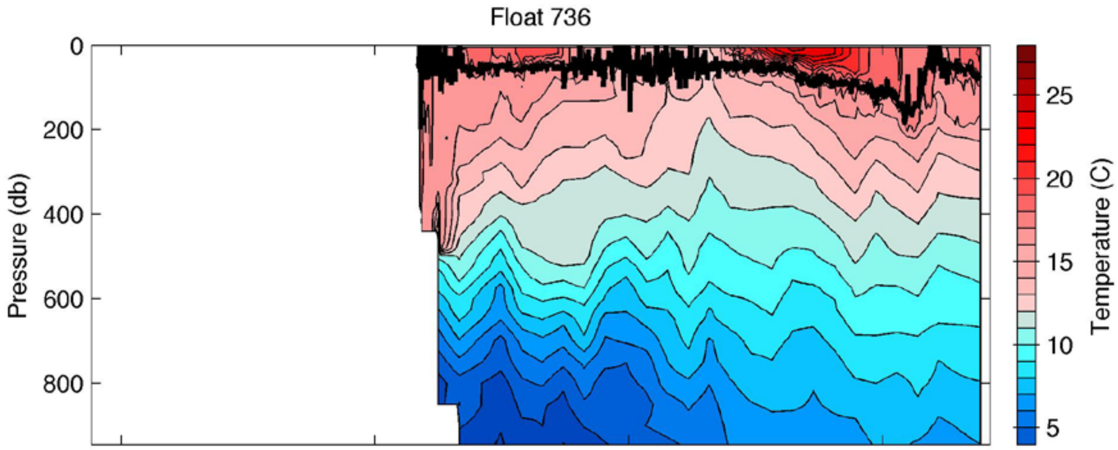


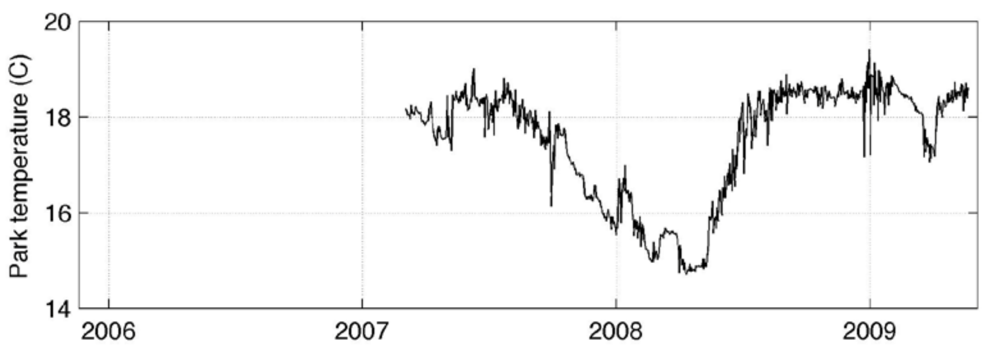
Float 733
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

Float 736, 03/03/07 - 05/21/09

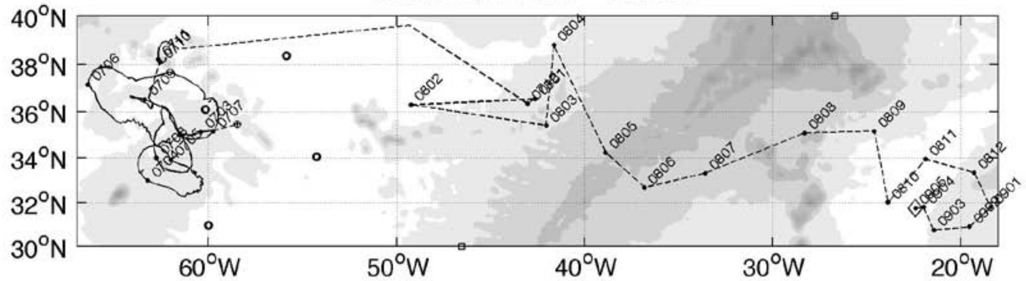


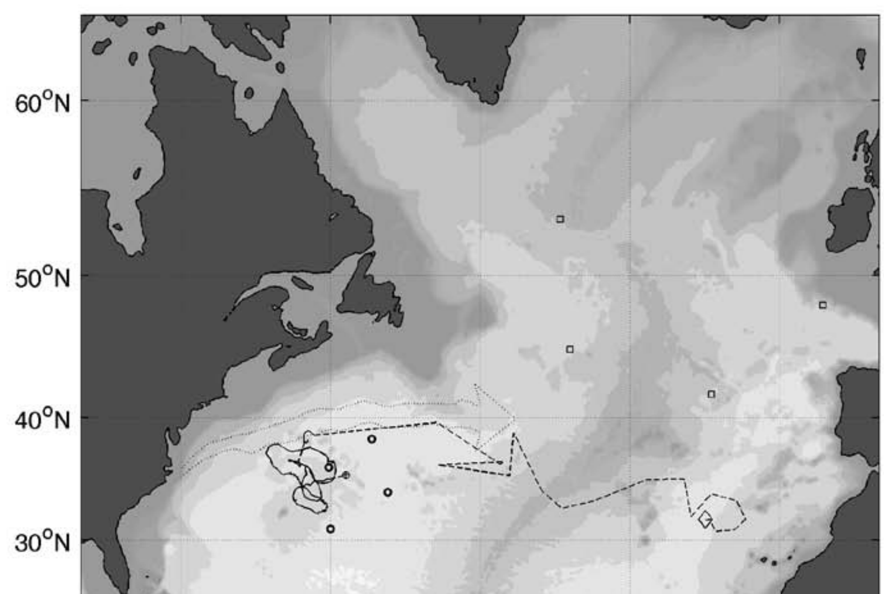


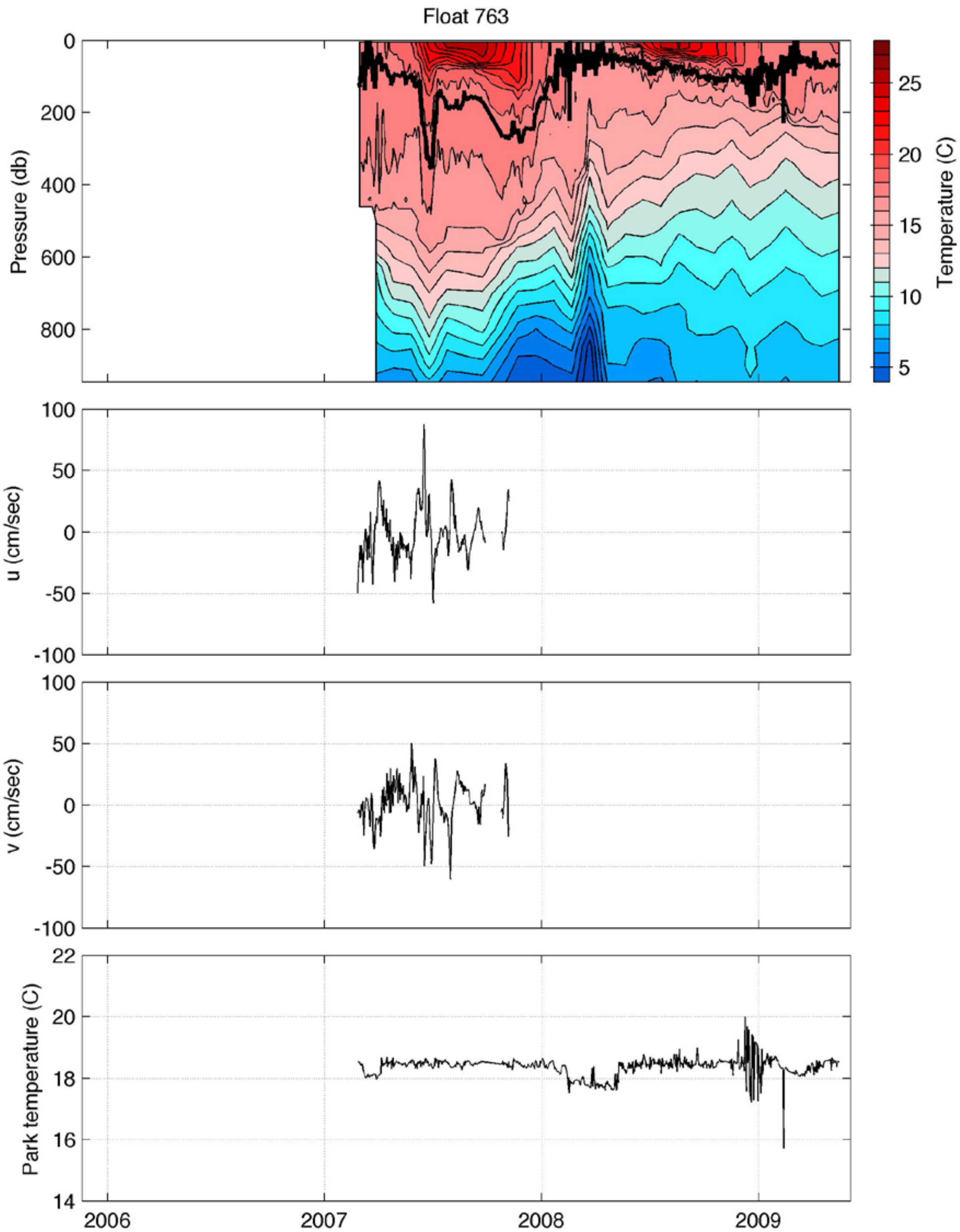

Float 736
Pressure (db)
0
200
400
600
800
Temperature (C)
25
20
15
10
5


Park temperature (C)
20
18
16
14
2006
2007
2008
2009

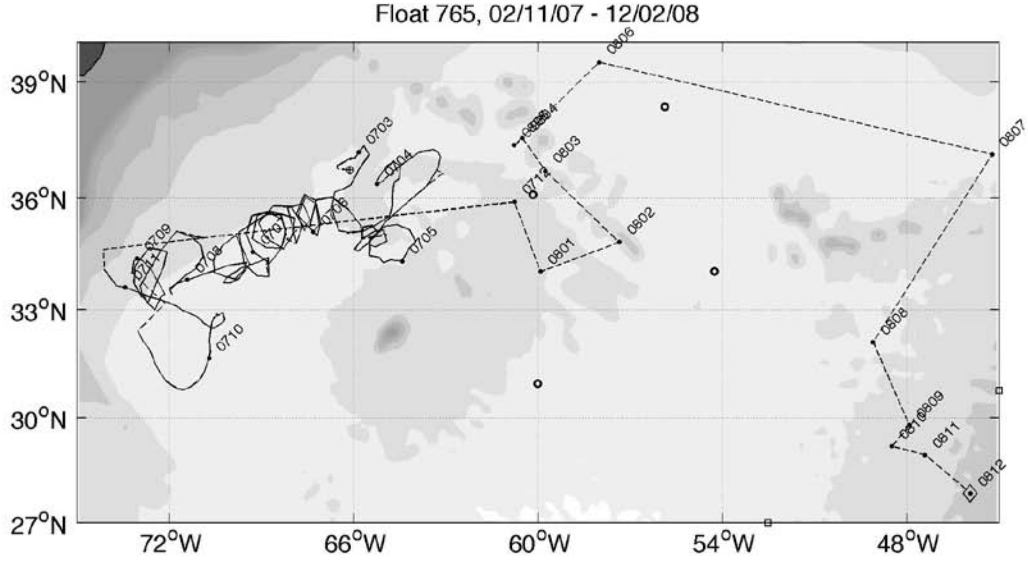
Float 763, 02/25/07 - 05/16/09

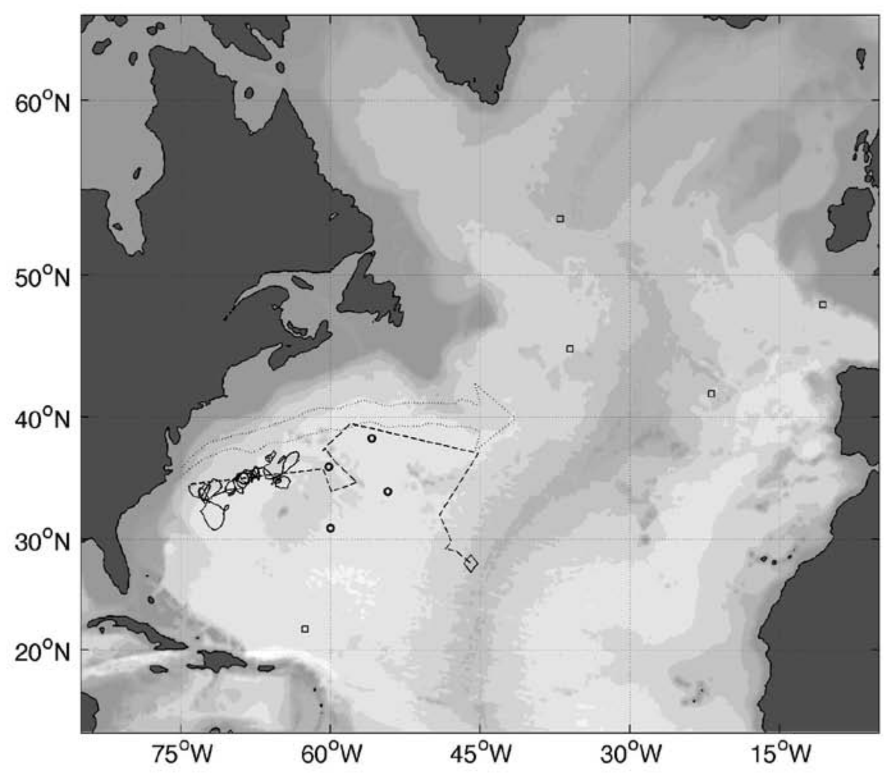


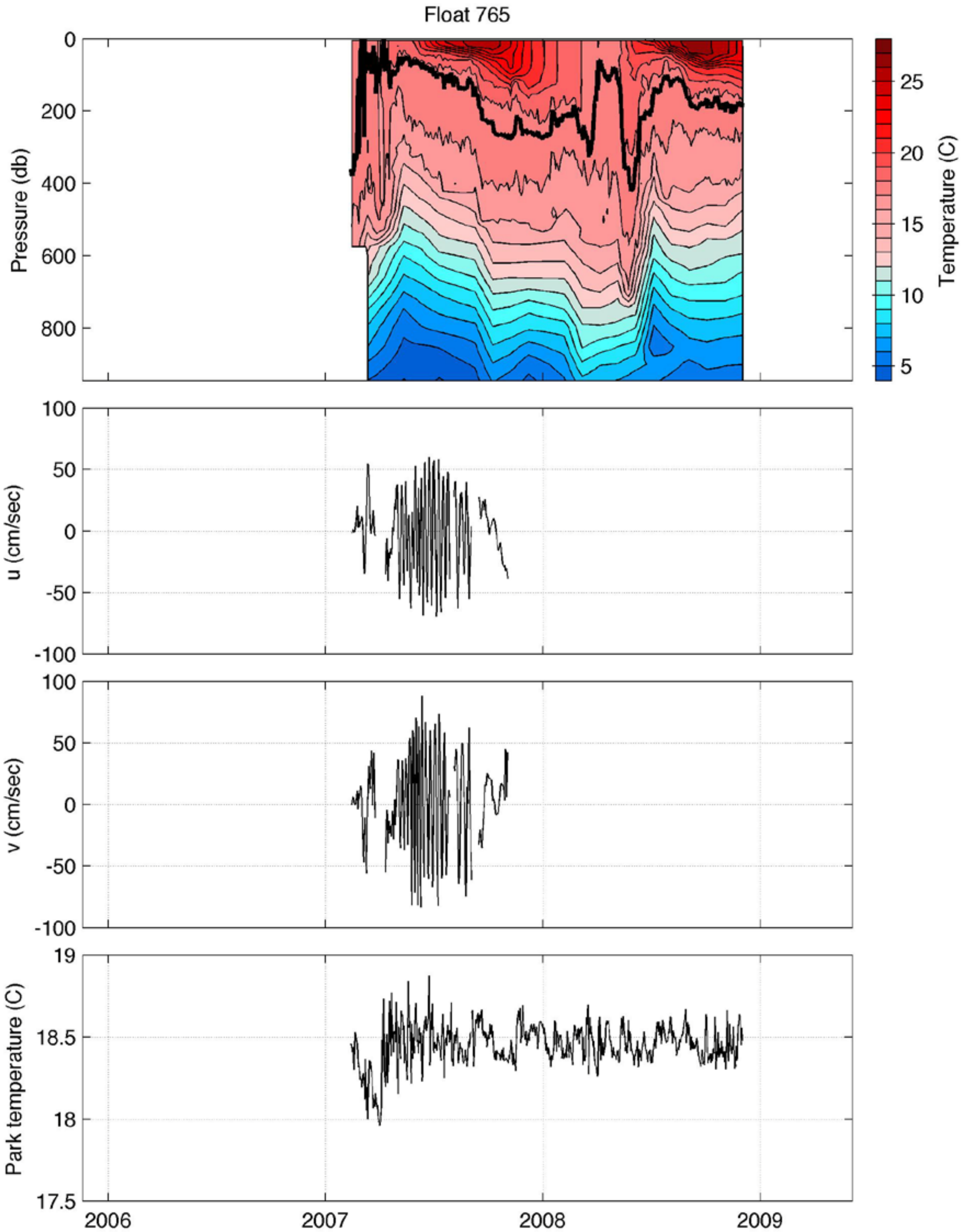



Float 763
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

Float 765, 02/11/07 - 12/02/08

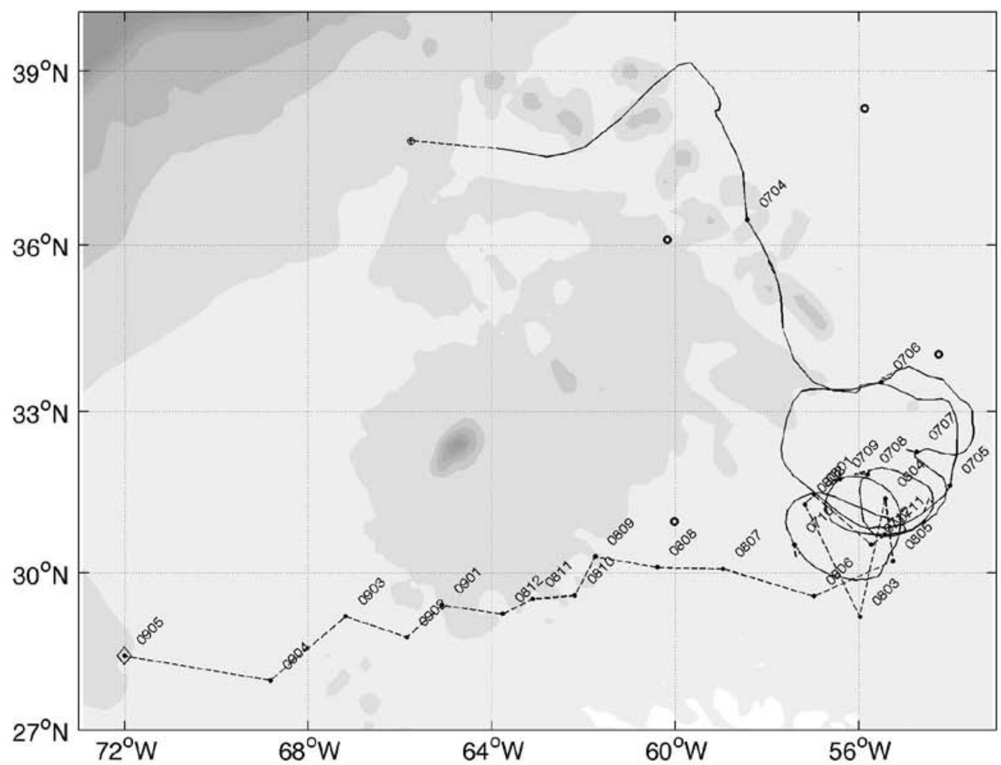


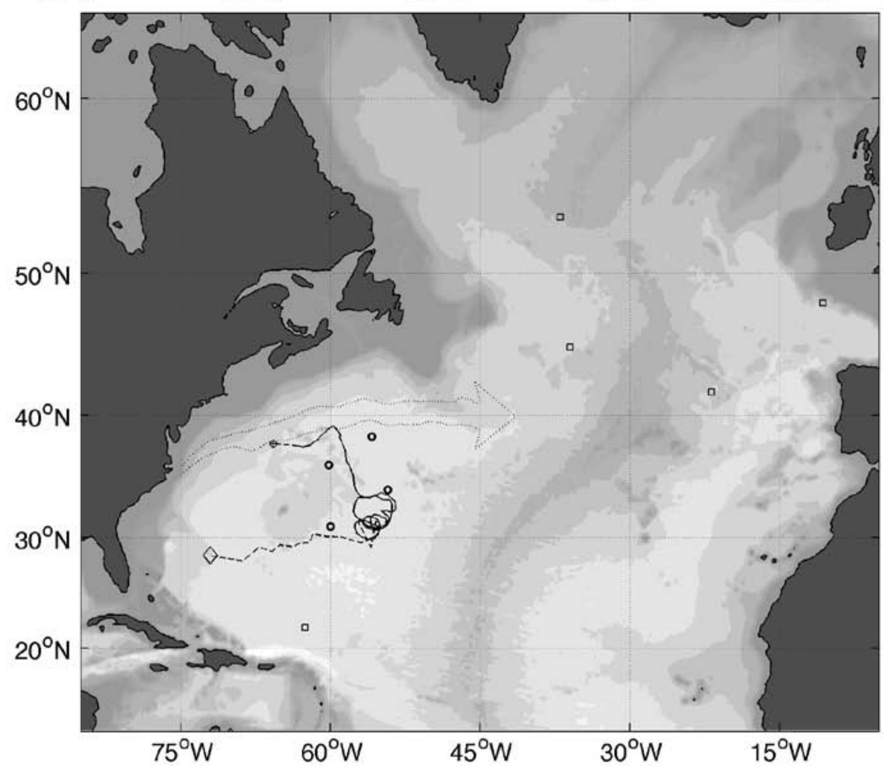


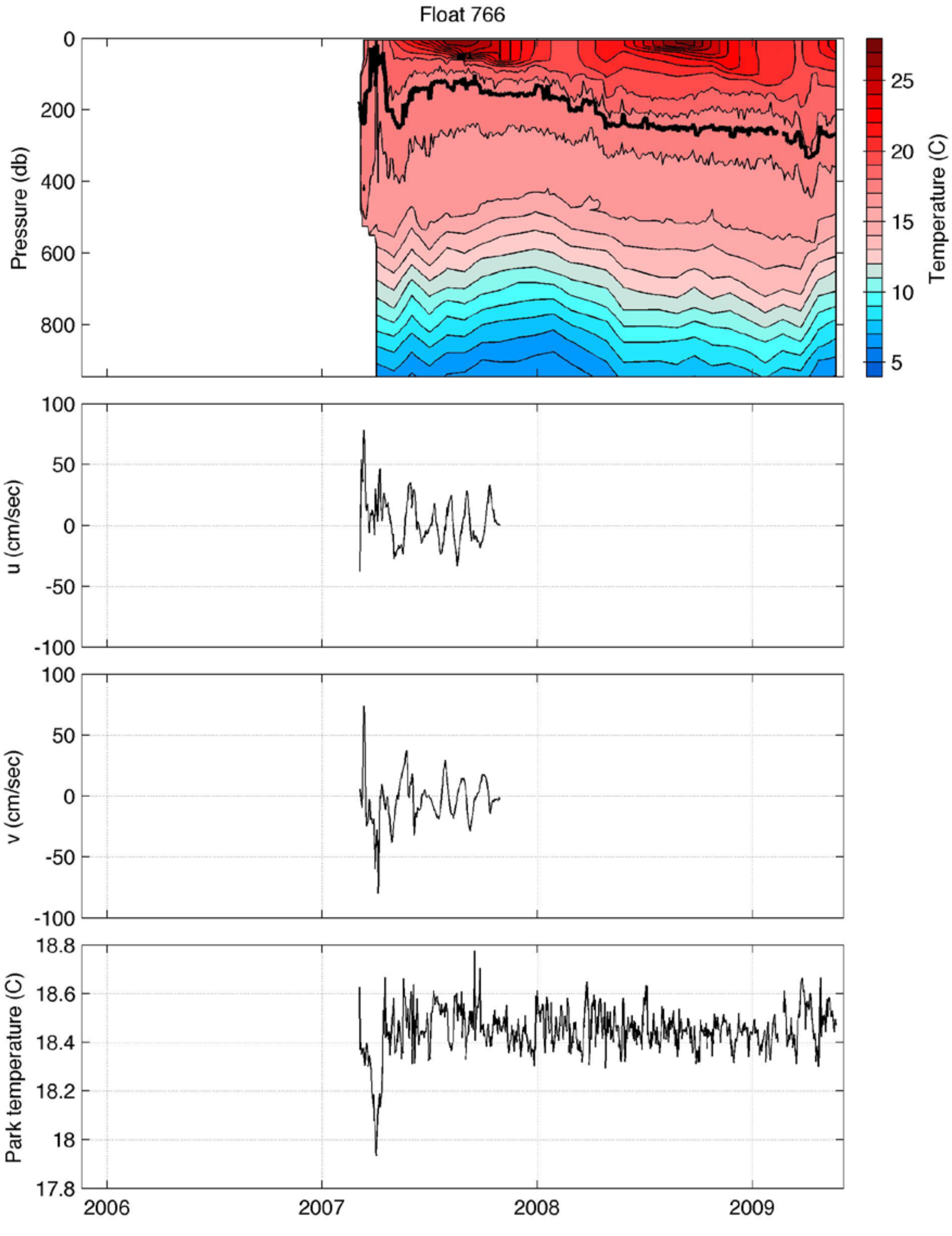


Float 765
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009

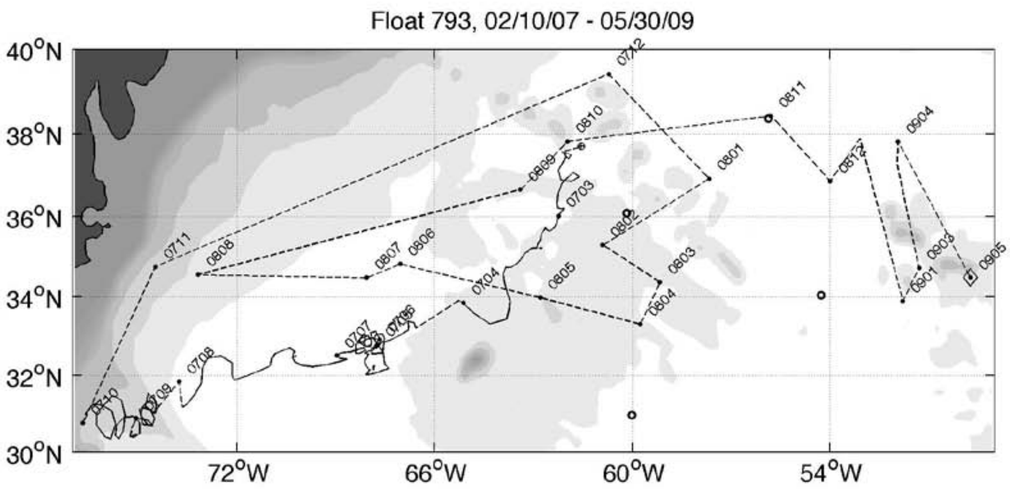
Float 766, 03/04/07 - 05/22/09

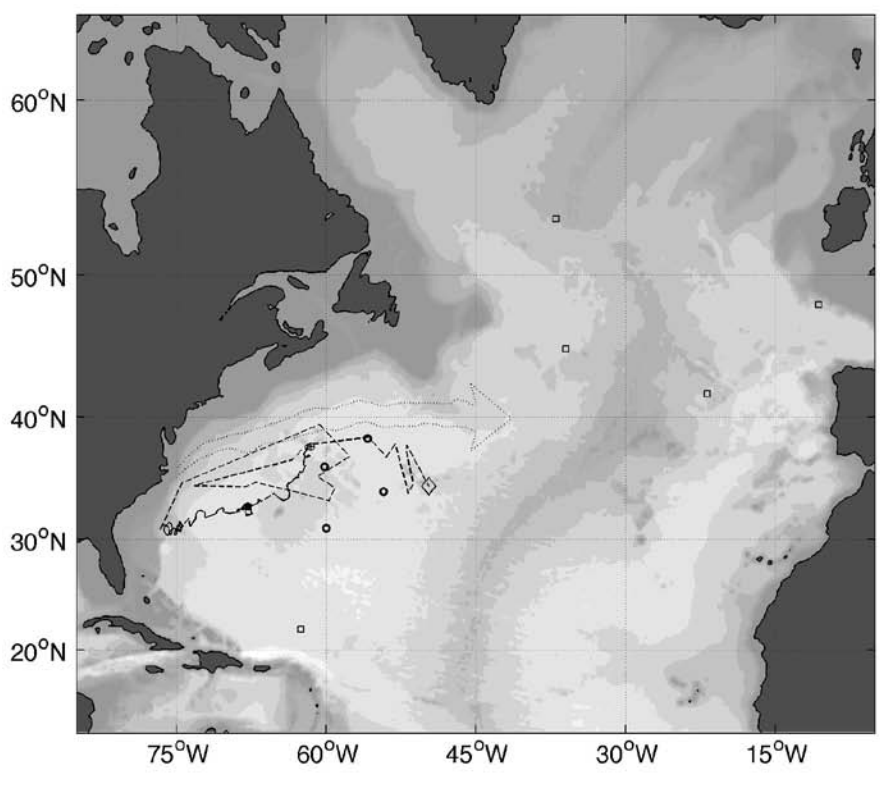


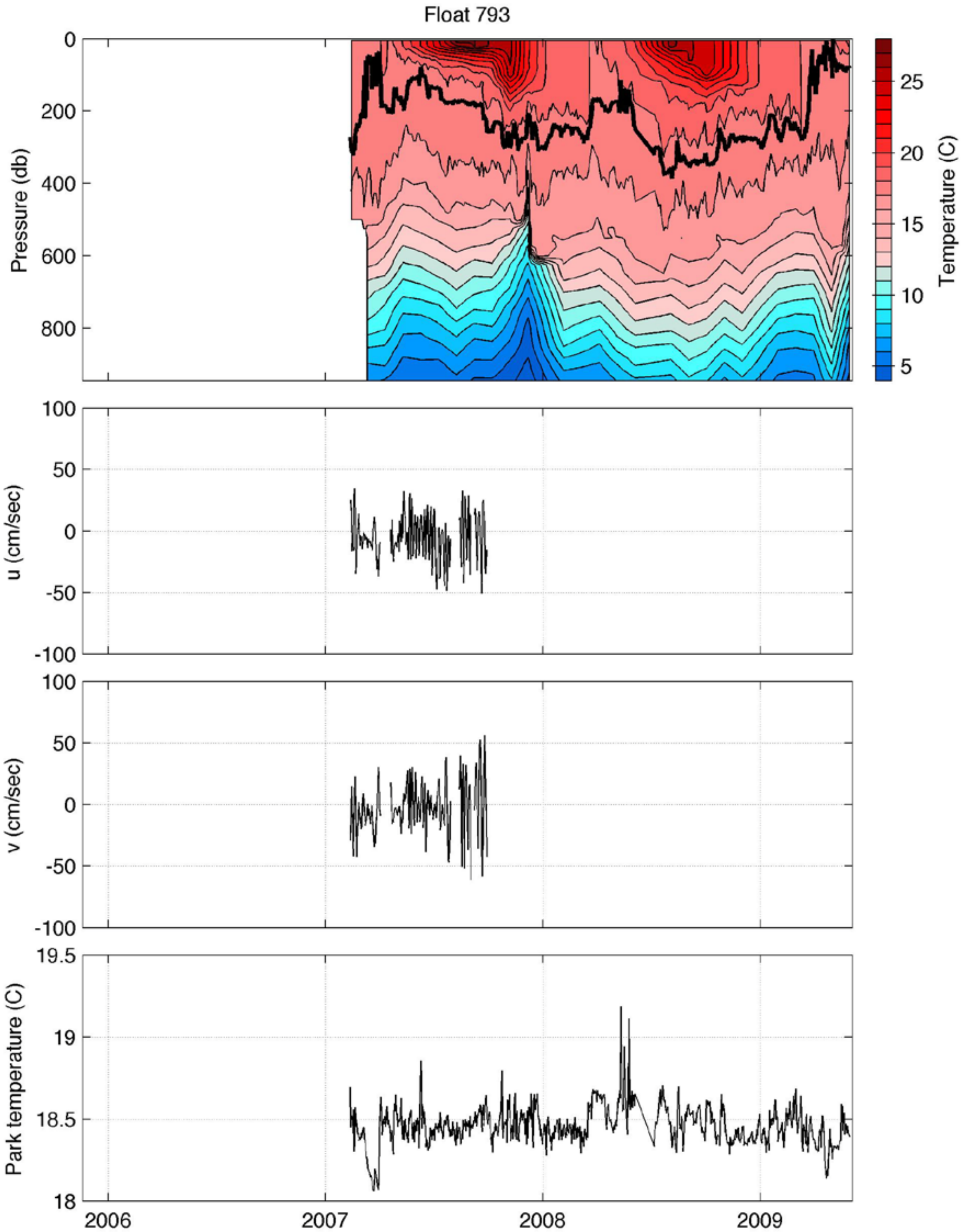




Float 766
Pressure (db)
Temperature (C)
u (cm/sec)
v (cm/sec)
Park temperature (C)
2006
2007
2008
2009


Float 793, 02/10/07 - 05/30/09
40°N
38°N
36°N
34°N
32°N
30°N
72°W
66°W
60°W
54°W


60°N
50°N
40°N
30°N
20°N
75°W
60°W
45°W
30°W
15°W



Float 793
Pressure (db)
u (cm/sec)
v (cm/sec)
Park temperature (C)
Temperature (C)
2006
2007
2008
2009

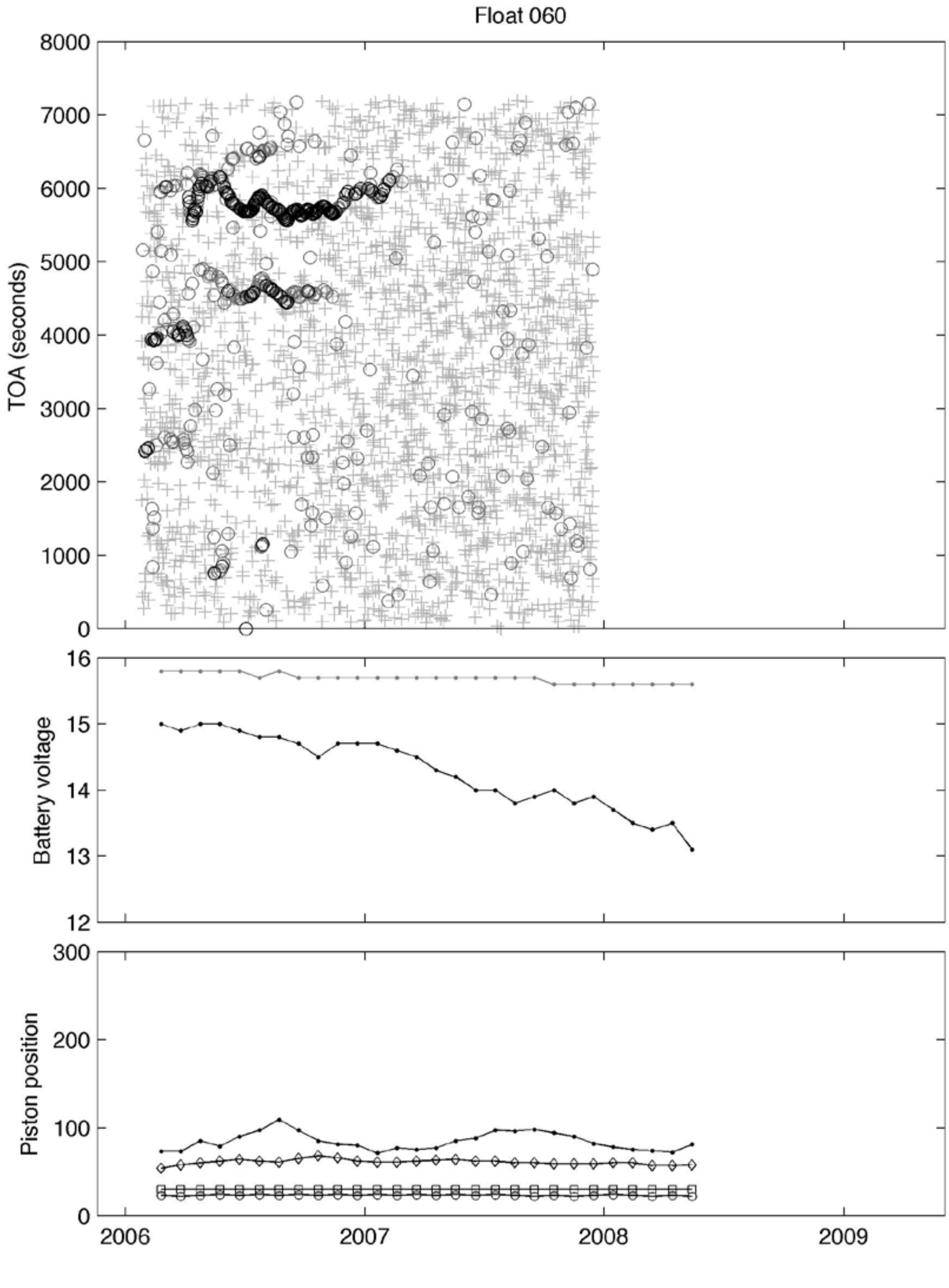
Appendix H: Bobber TOAs and Engineering Data

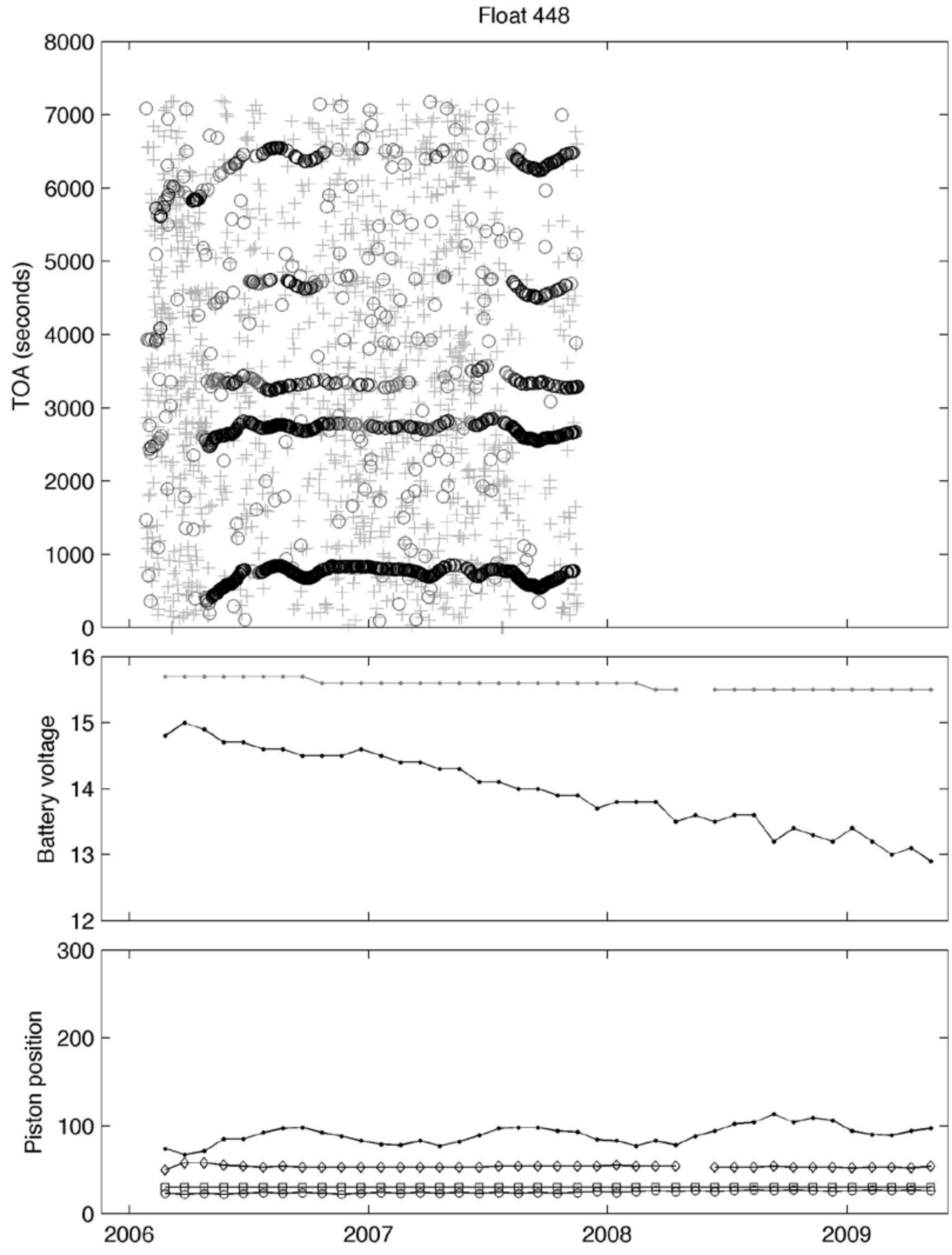
In the plots that follow, bobbers are referenced to by the last 3 digits of their ARGOS PTT ID.

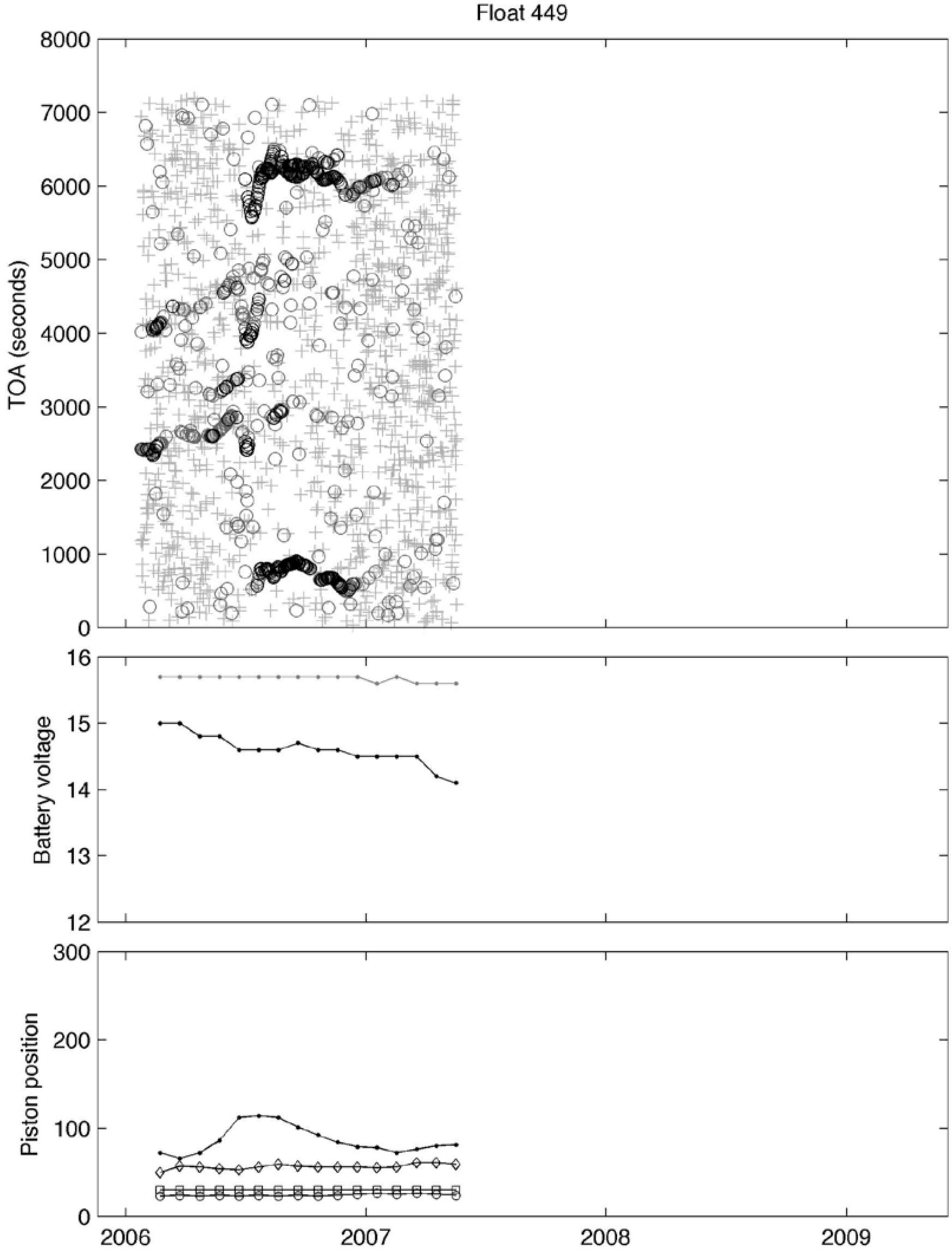
(Upper Panel): Time-of-arrival (in seconds relative to the start of the acoustic listening window) of acoustic pongs from an array of moored sound sources. Circles indicate correlation heights exceeding 55 counts.

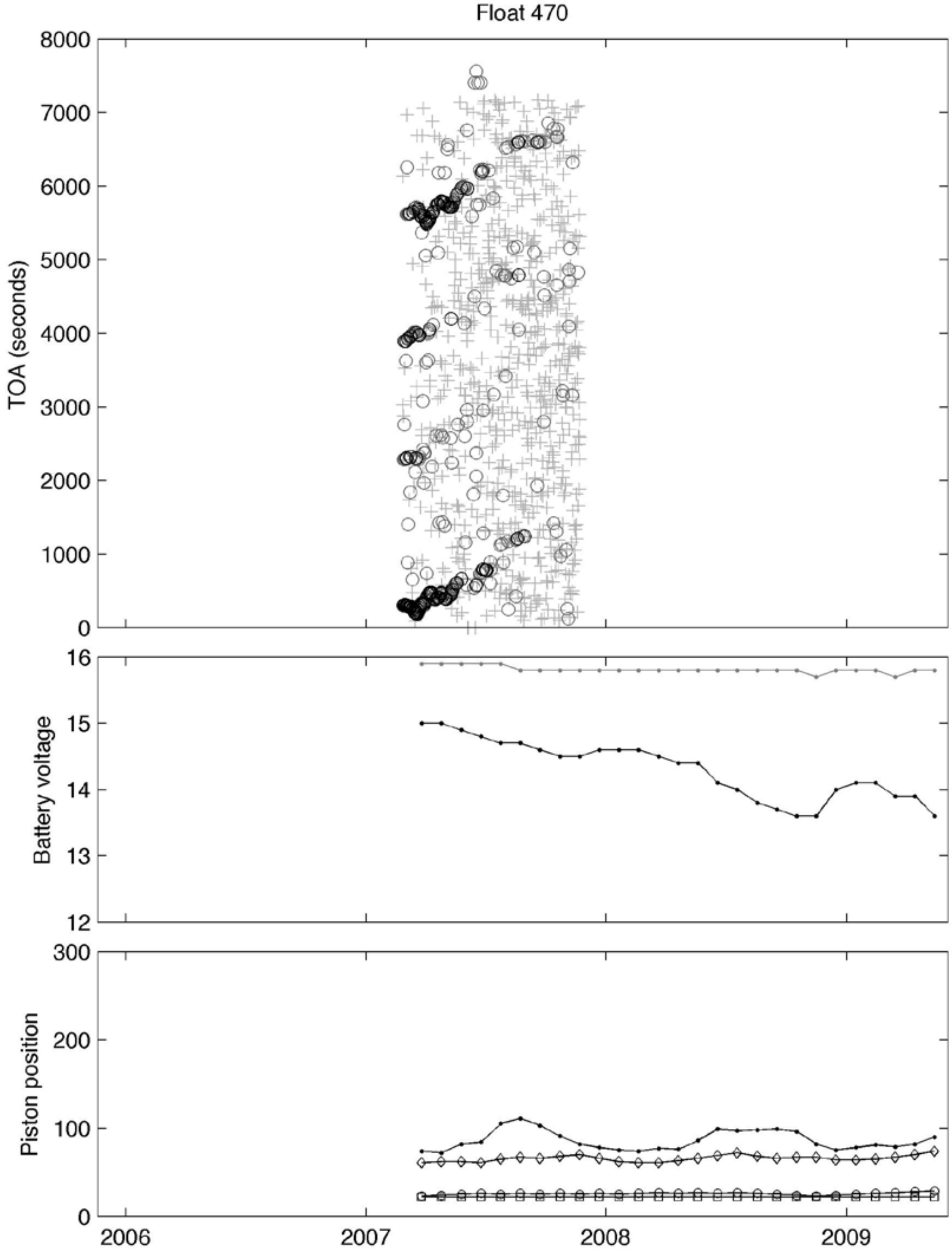
(Middle Panel): Battery voltage during drift (light line) and buoyancy pump activation (dark line).

(Lower Panel): Buoyancy pump piston position during surfacing (small circles), drift periods (diamond) and deep profiles (squares).

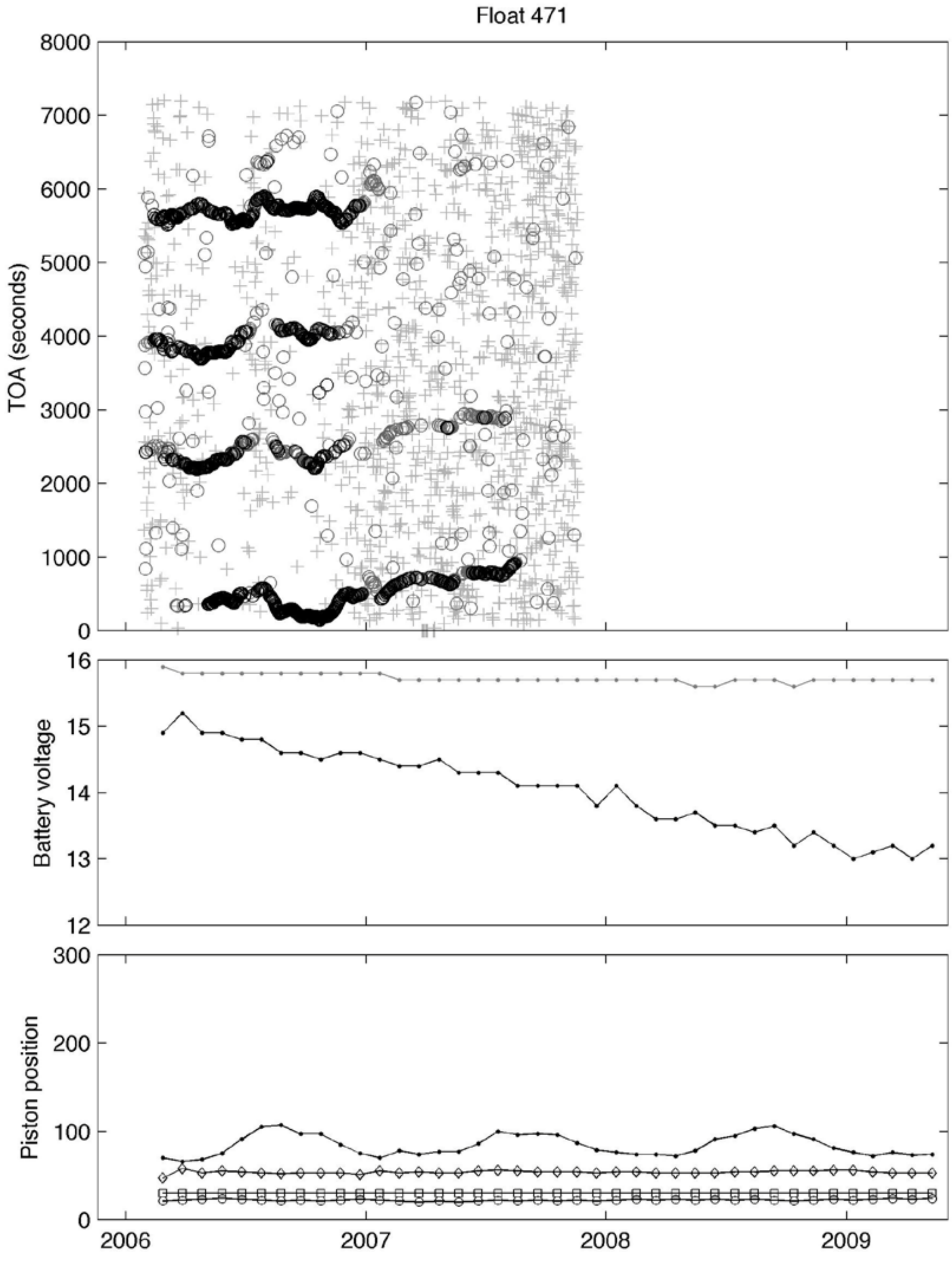

Float 060
TOA (seconds)
Battery voltage
Piston position
2006
2007
2008
2009


Float 448
TOA (seconds)
Battery voltage
Piston position
2006
2007
2008
2009

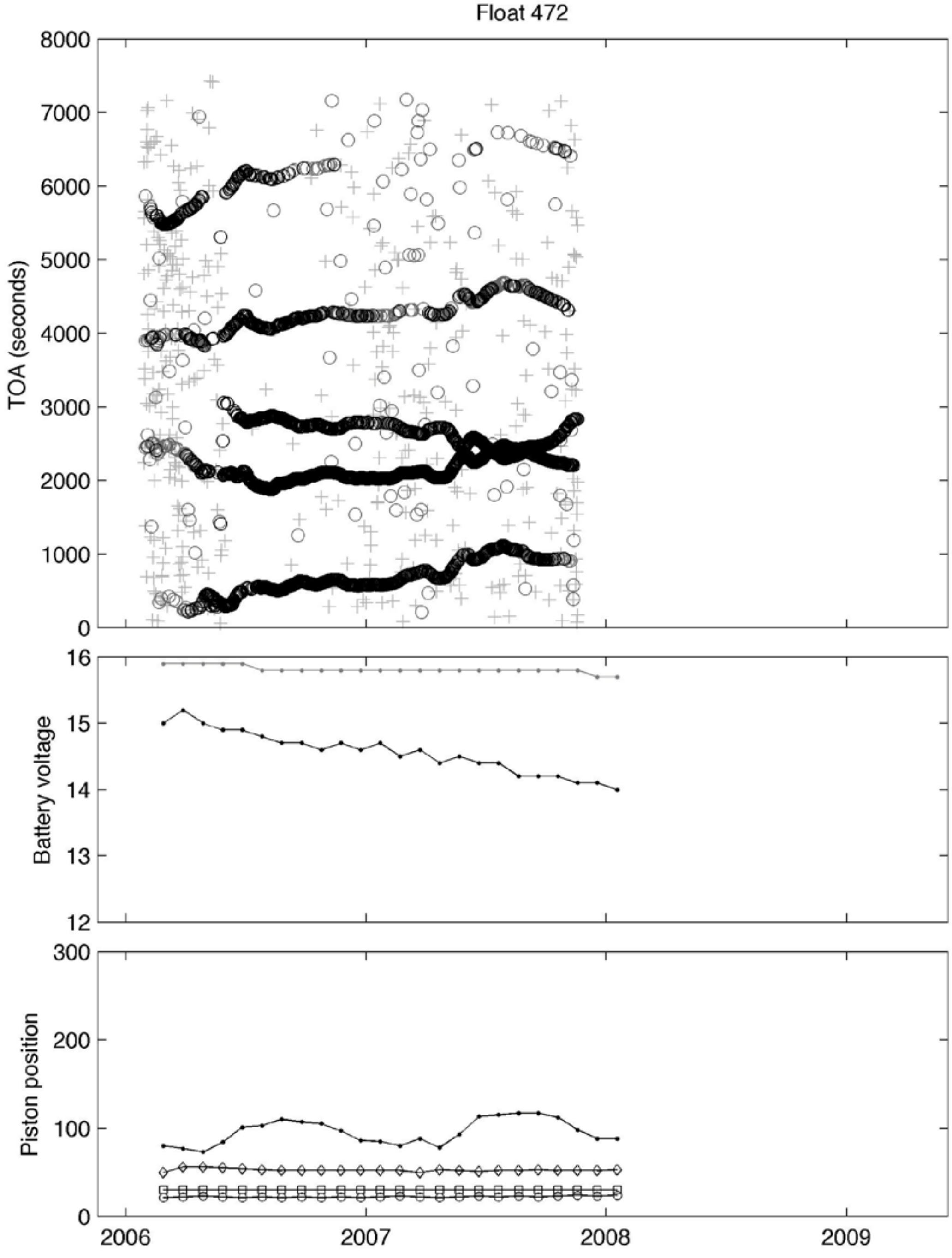

Float 449
TOA (seconds)
Battery voltage
Piston position
2006
2007
2008
2009



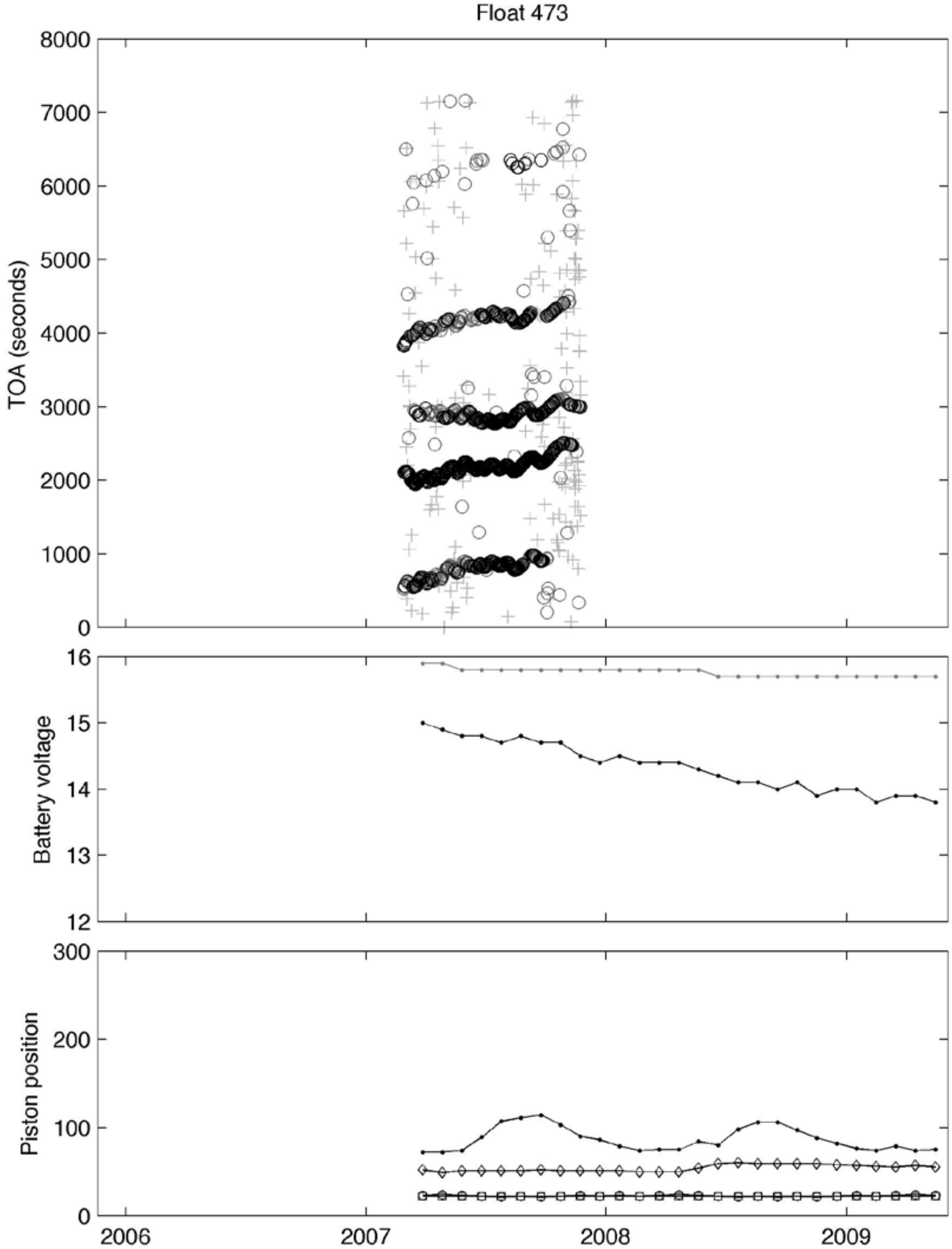
Float 470
8000
7000
6000
5000
4000
3000
2000
1000
0
TOA (seconds)
16
15
14
13
12
Battery voltage
300
200
100
0
Piston position
2006
2007
2008
2009

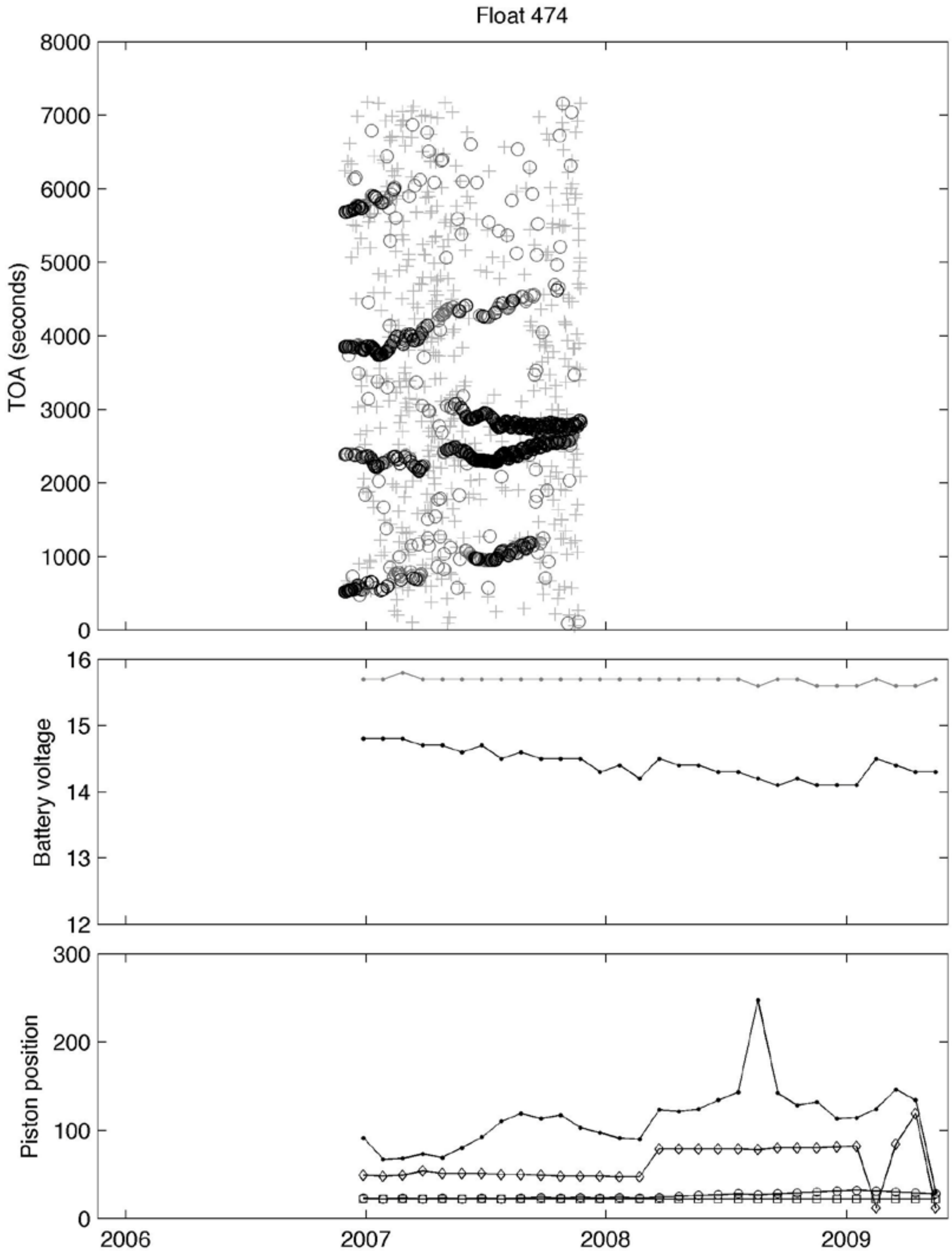


Float 471
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009

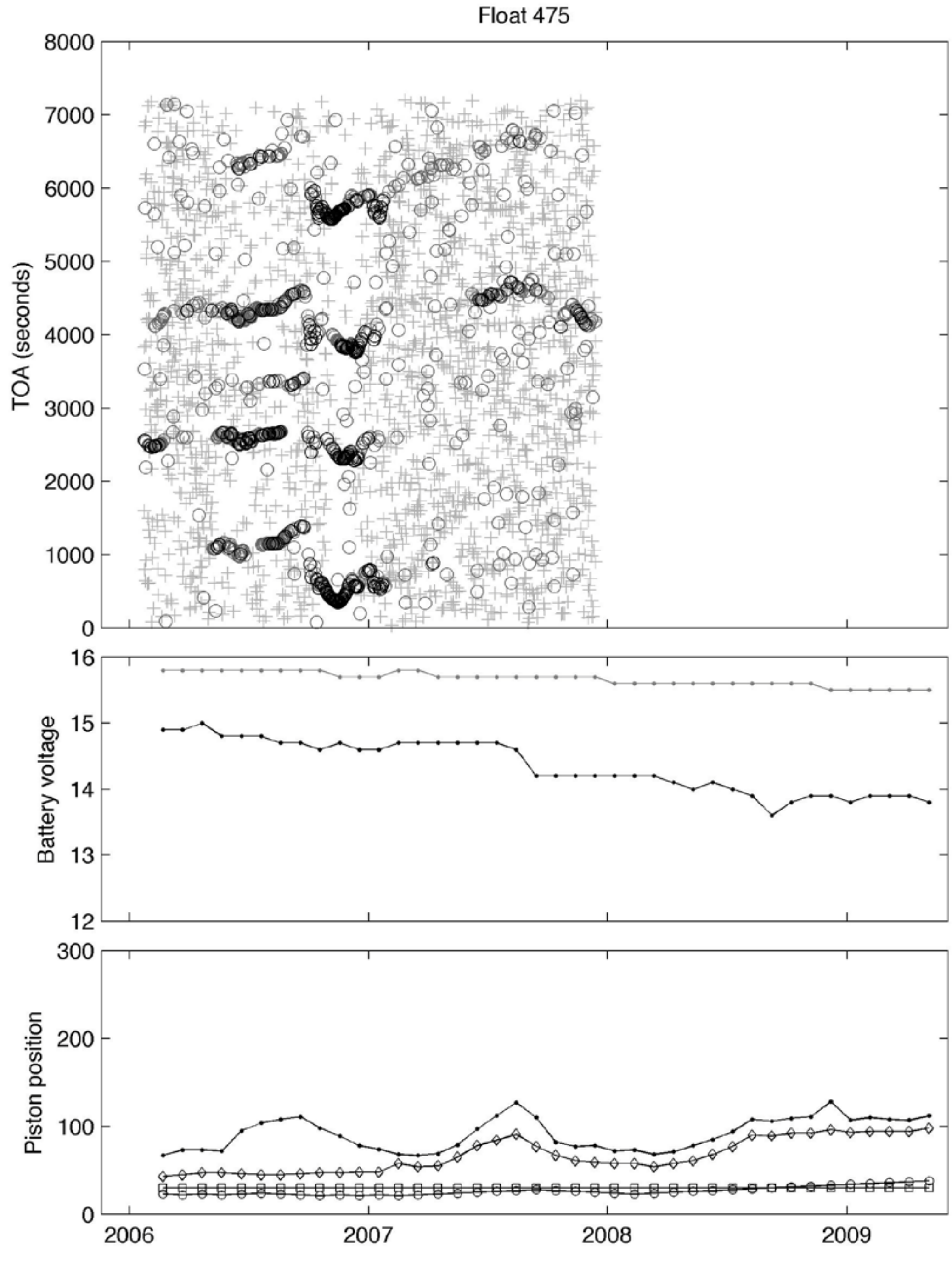


Float 472
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009

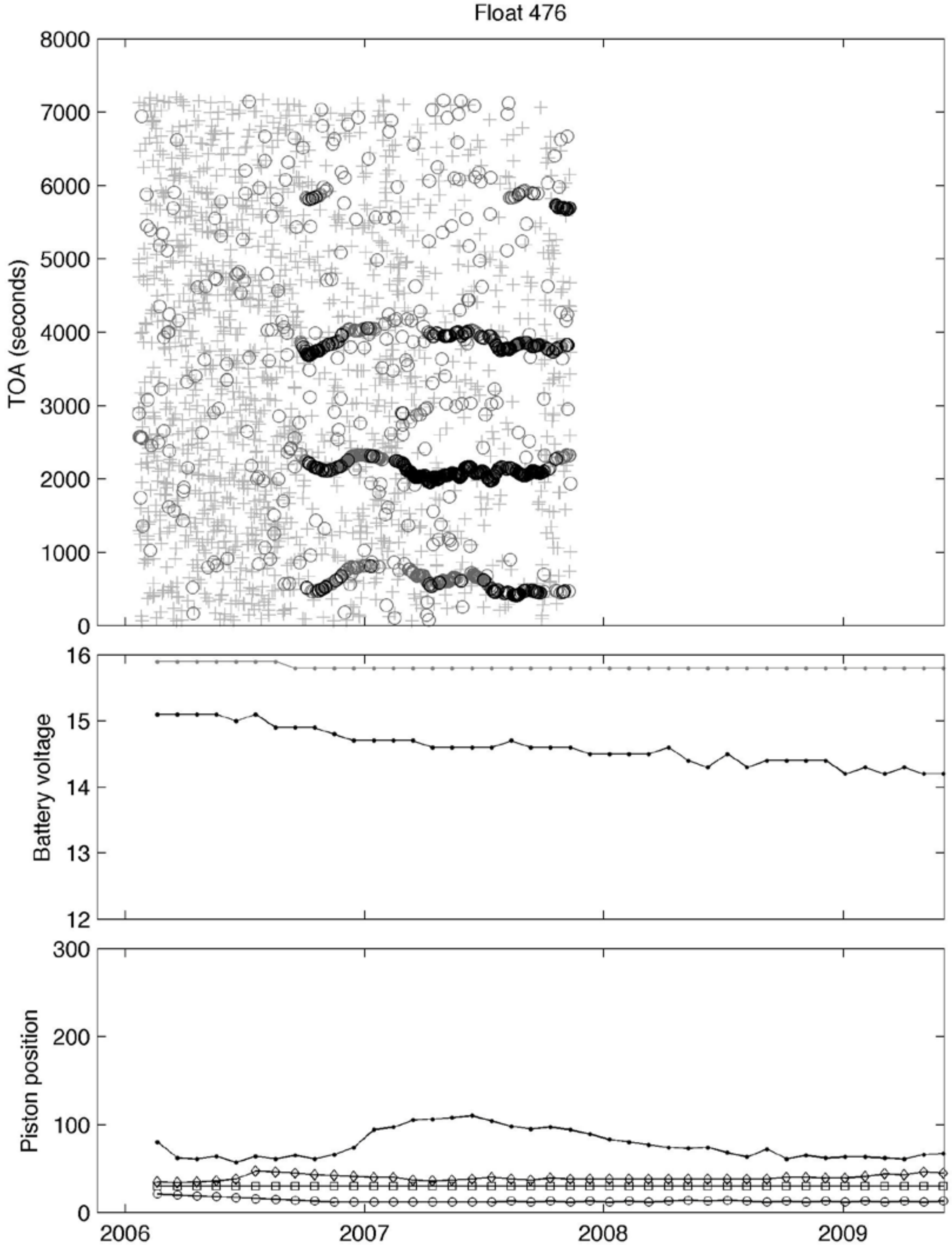

Float 473
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009



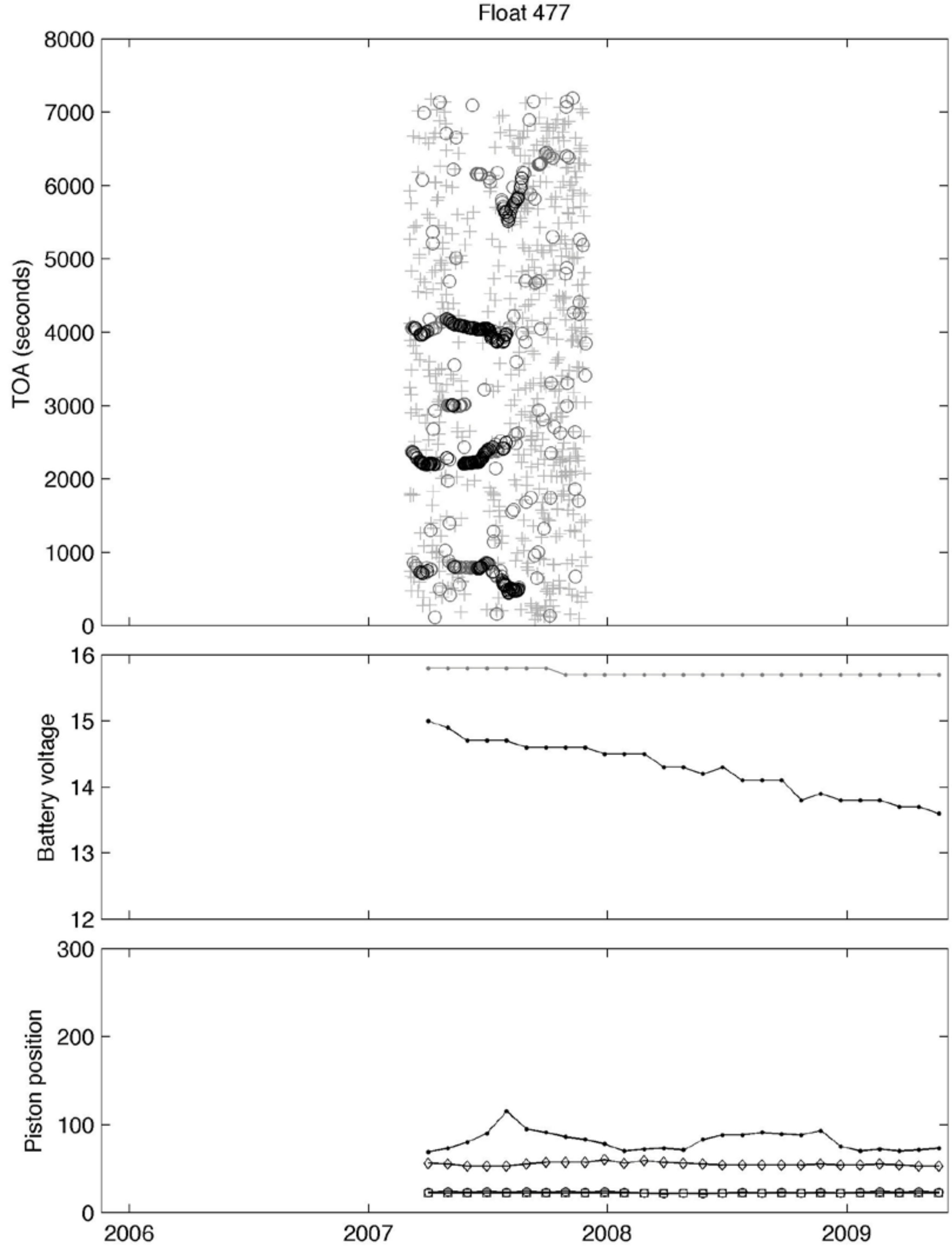
Float 474
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009



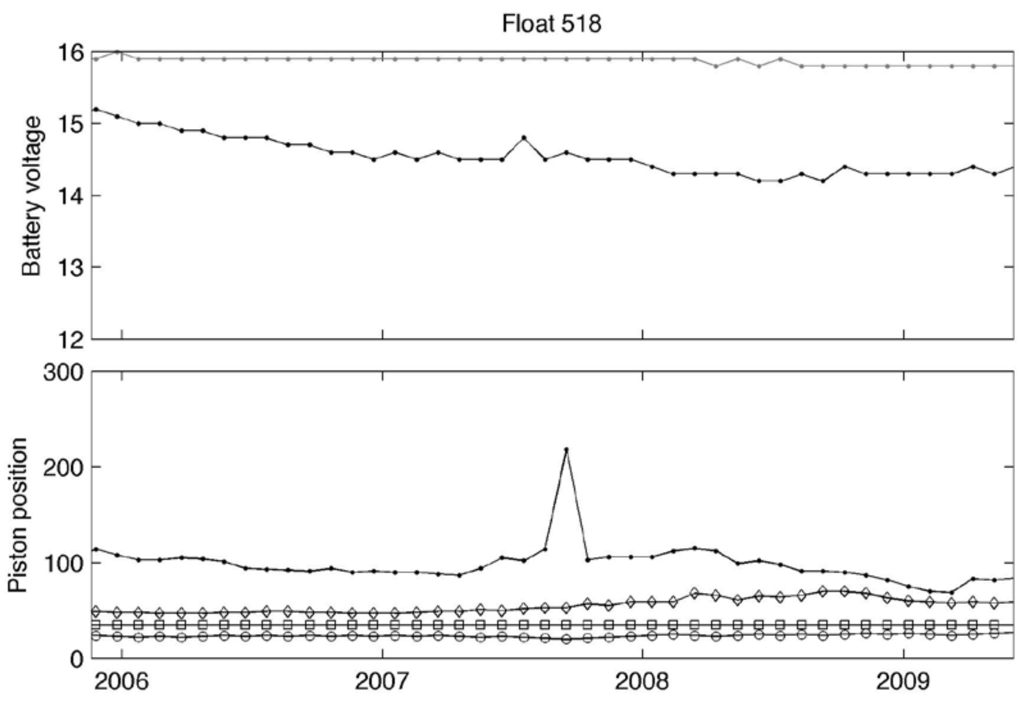
Float 475
TOA (seconds)
Battery voltage
Piston position
8000
7000
6000
5000
4000
3000
2000
1000
0
16
15
14
13
12
300
200
100
0
2006
2007
2008
2009



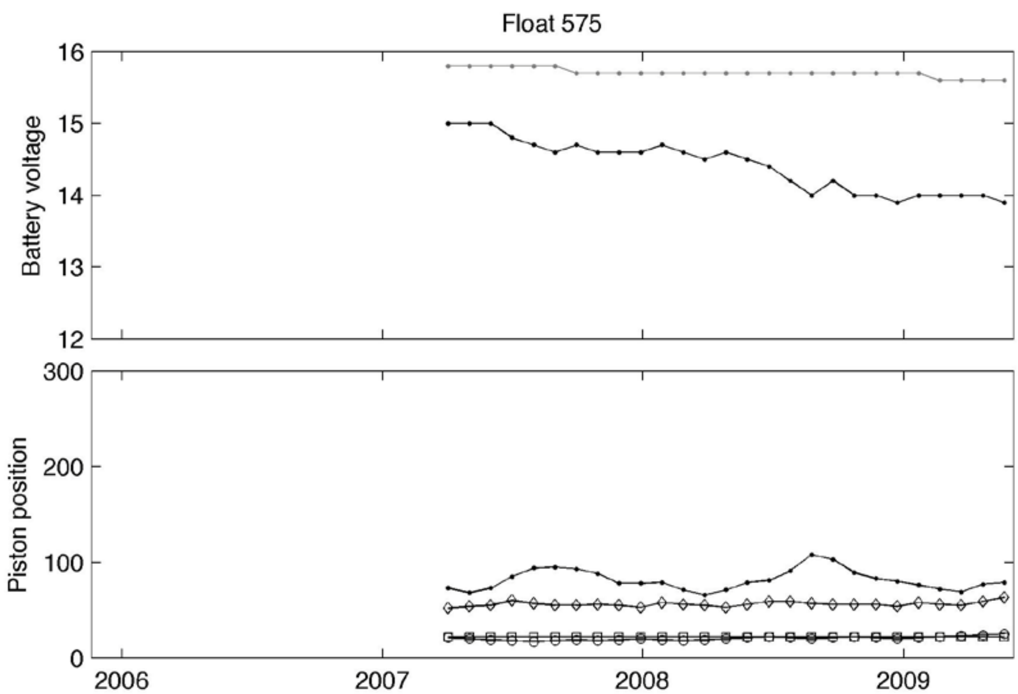
Float 476
TOA (seconds)
Battery voltage
Piston position
2006
2007
2008
2009

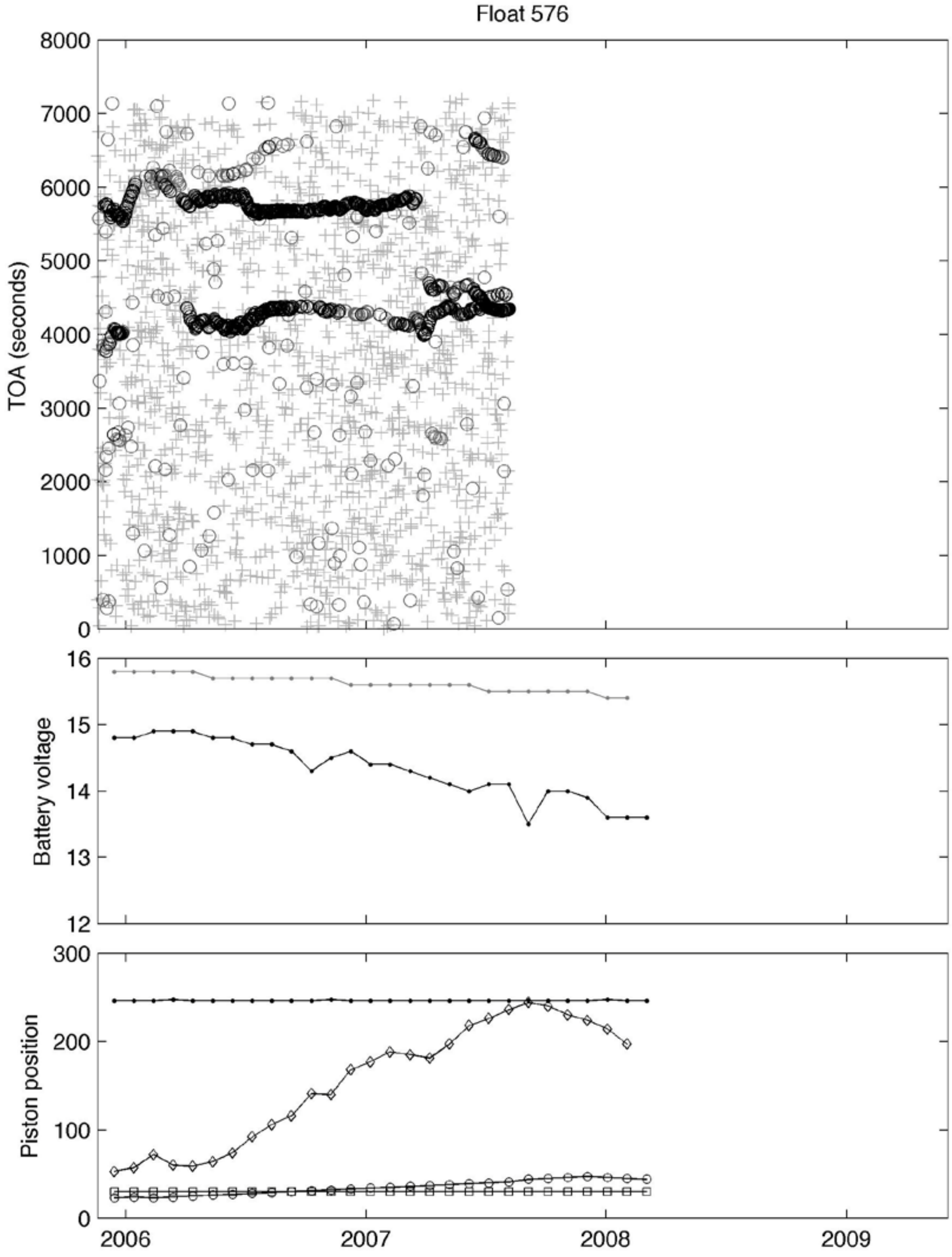


Float 477
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009

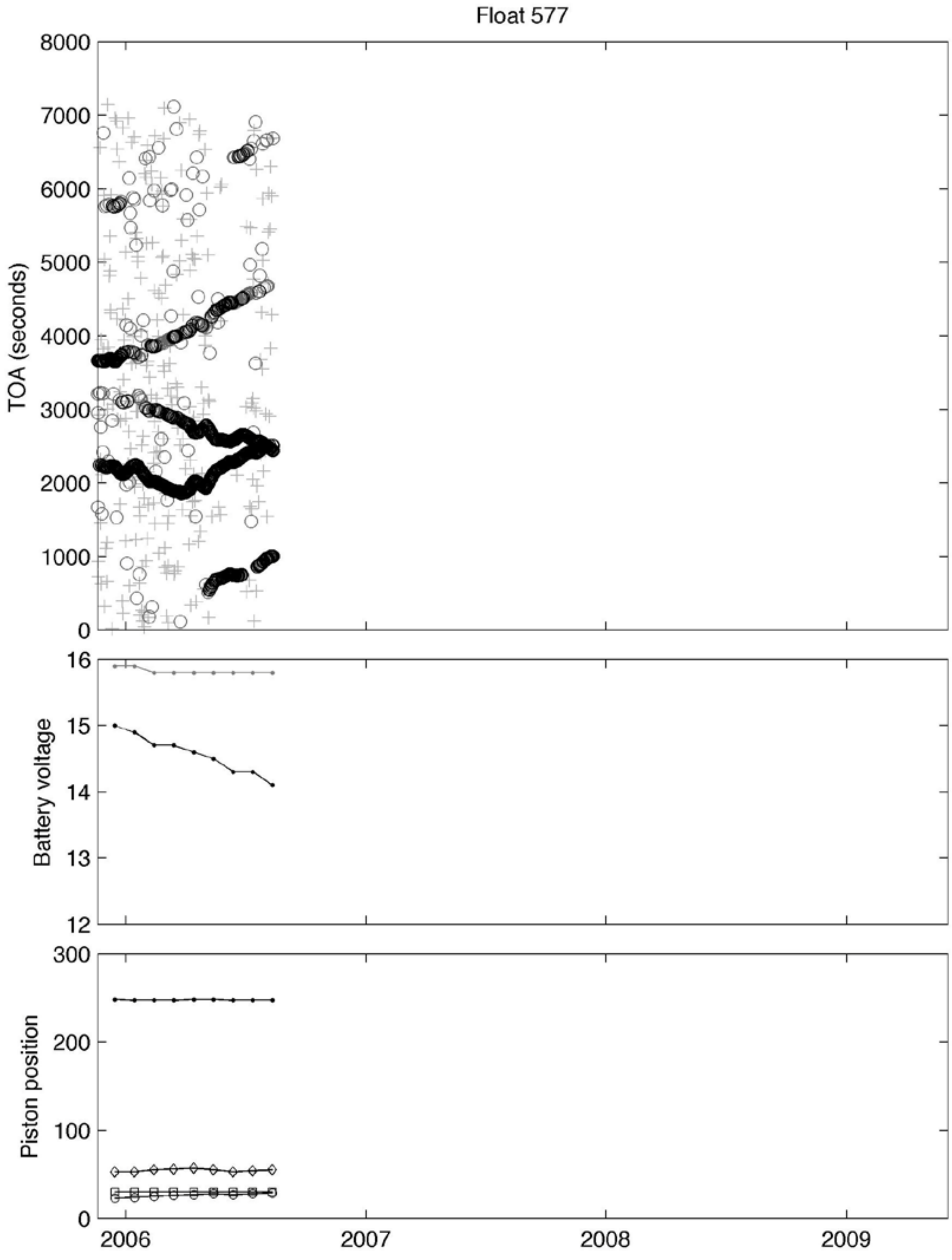


Float 518
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009

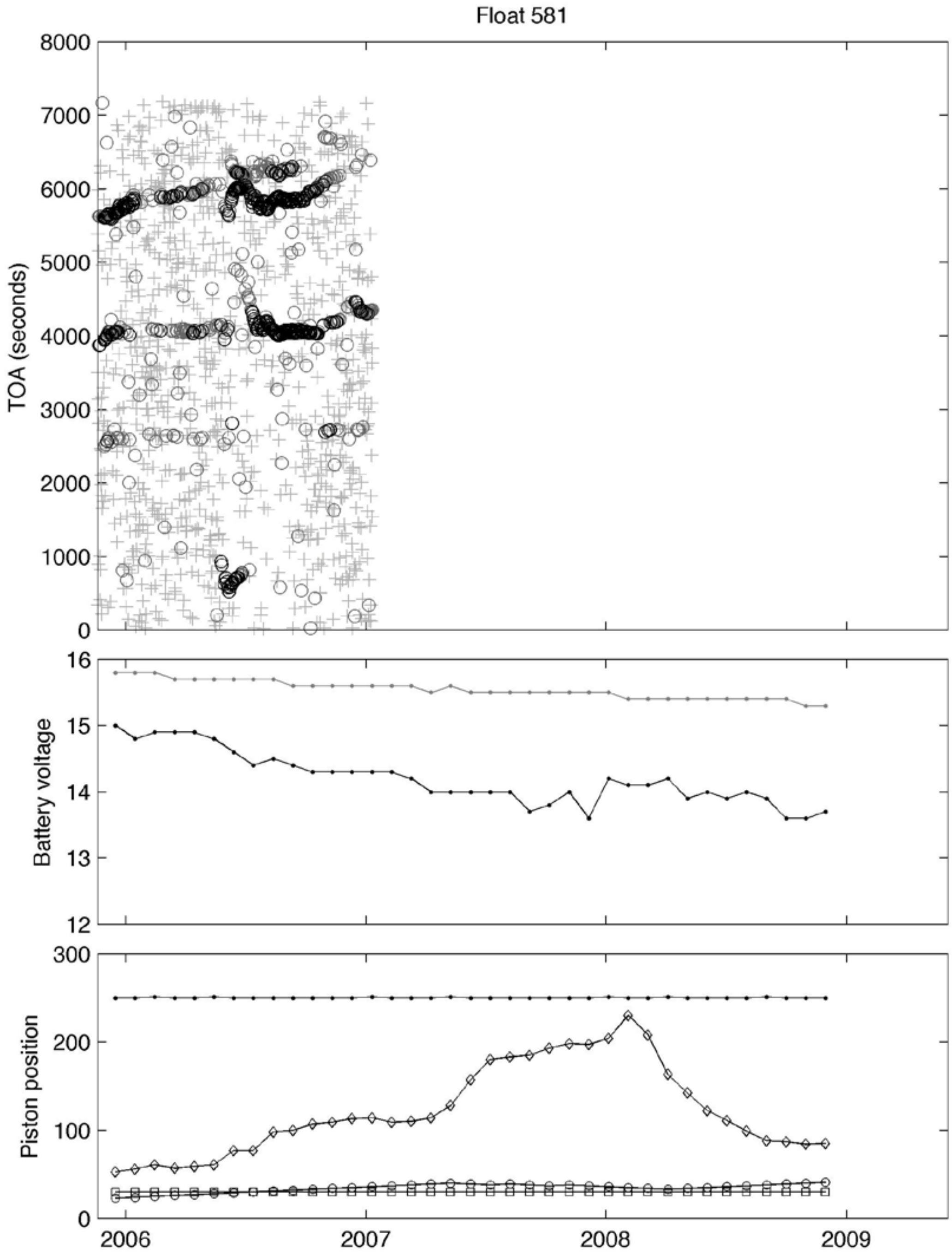

Float 575
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009

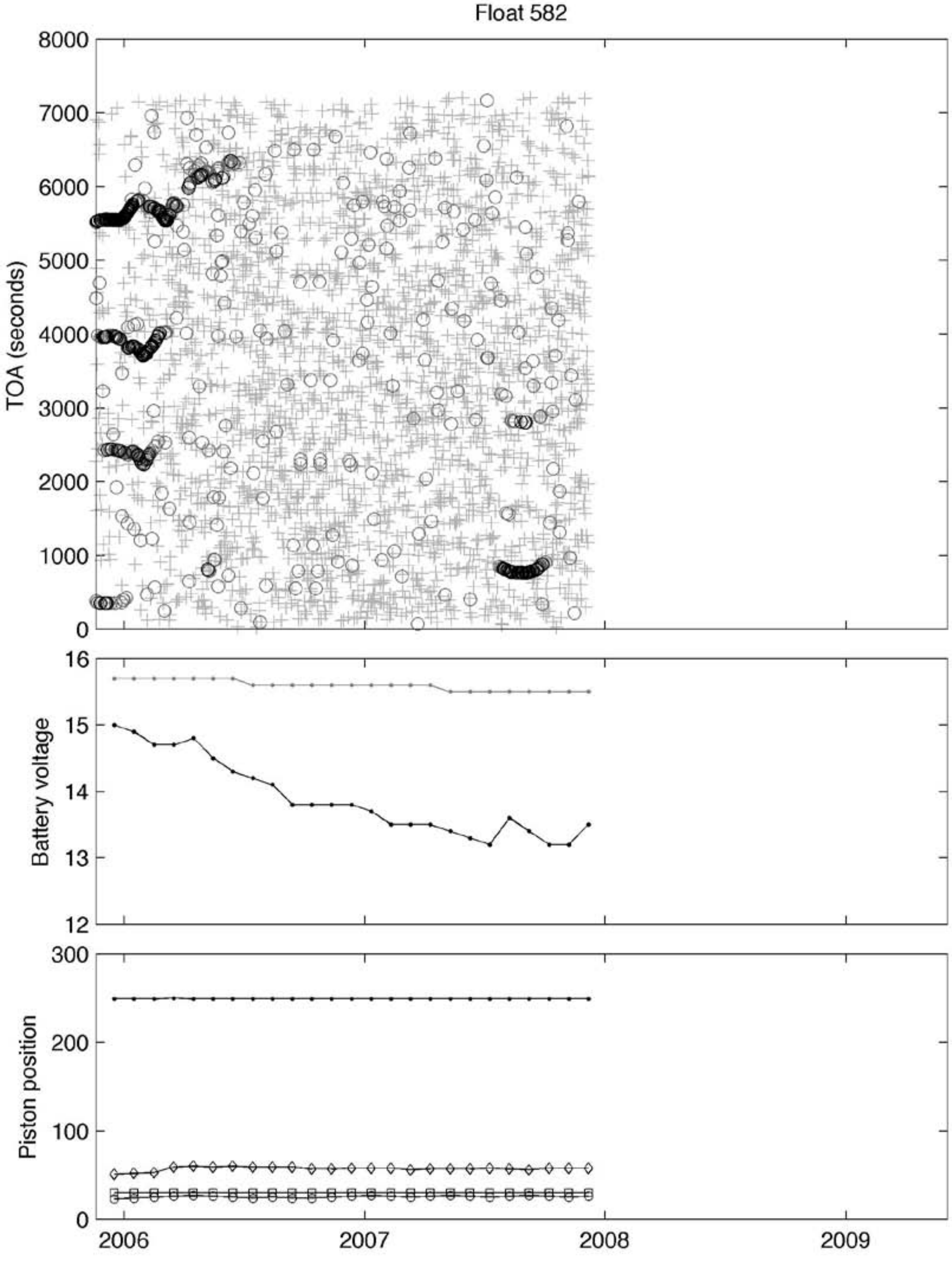


Float 576
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009

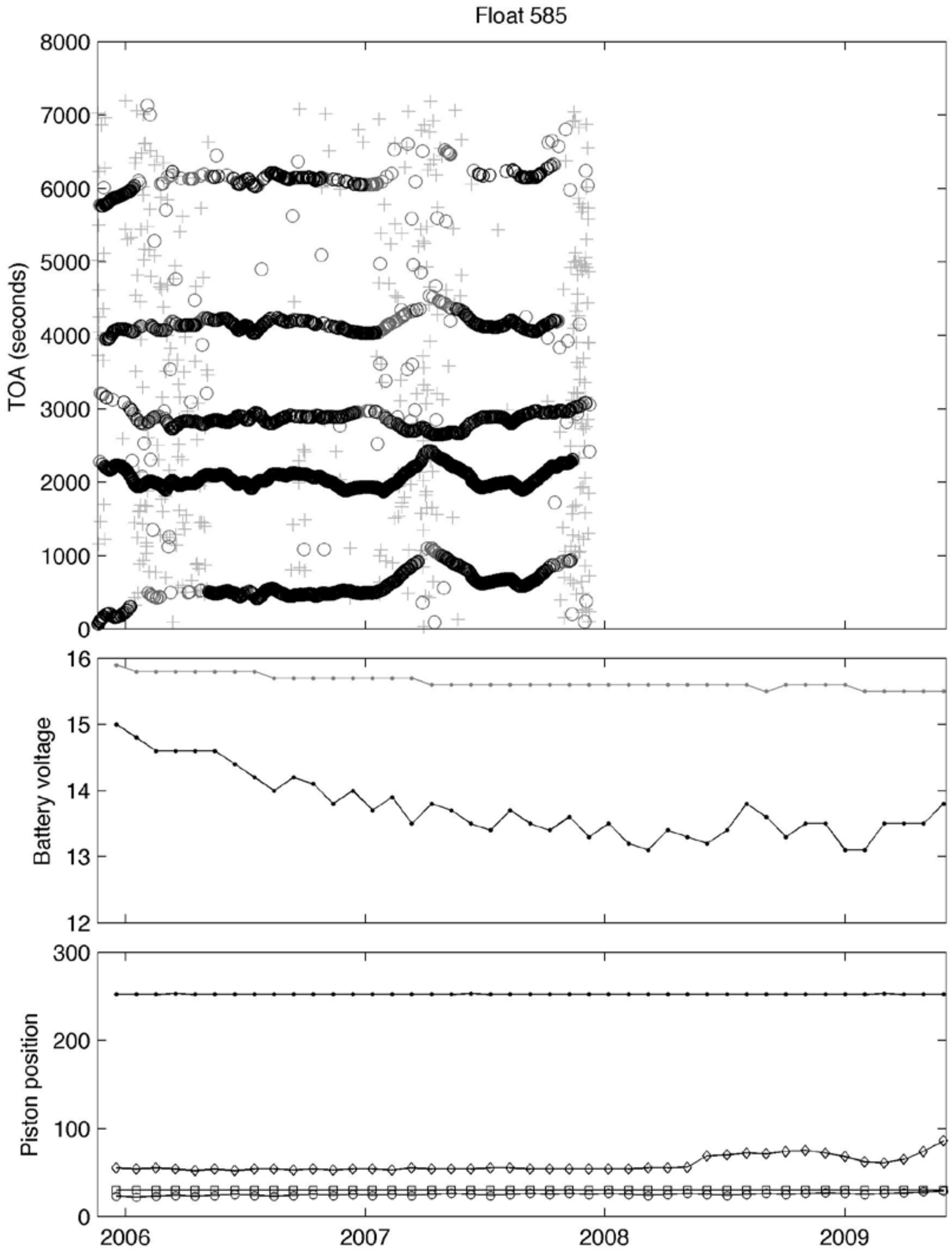


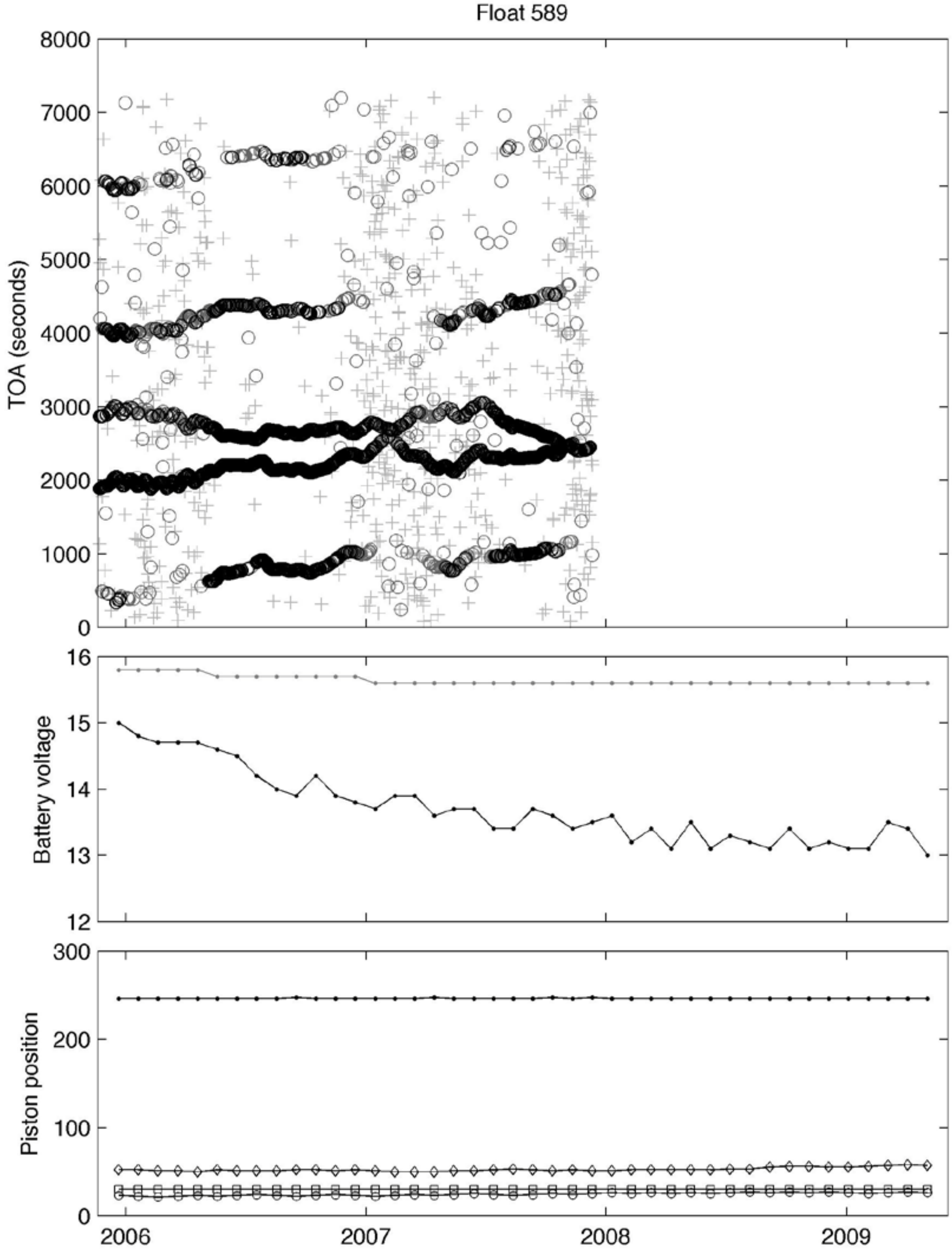
Float 577
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009


Float 581
TOA (seconds)
Battery voltage
Piston position
2006
2007
2008
2009

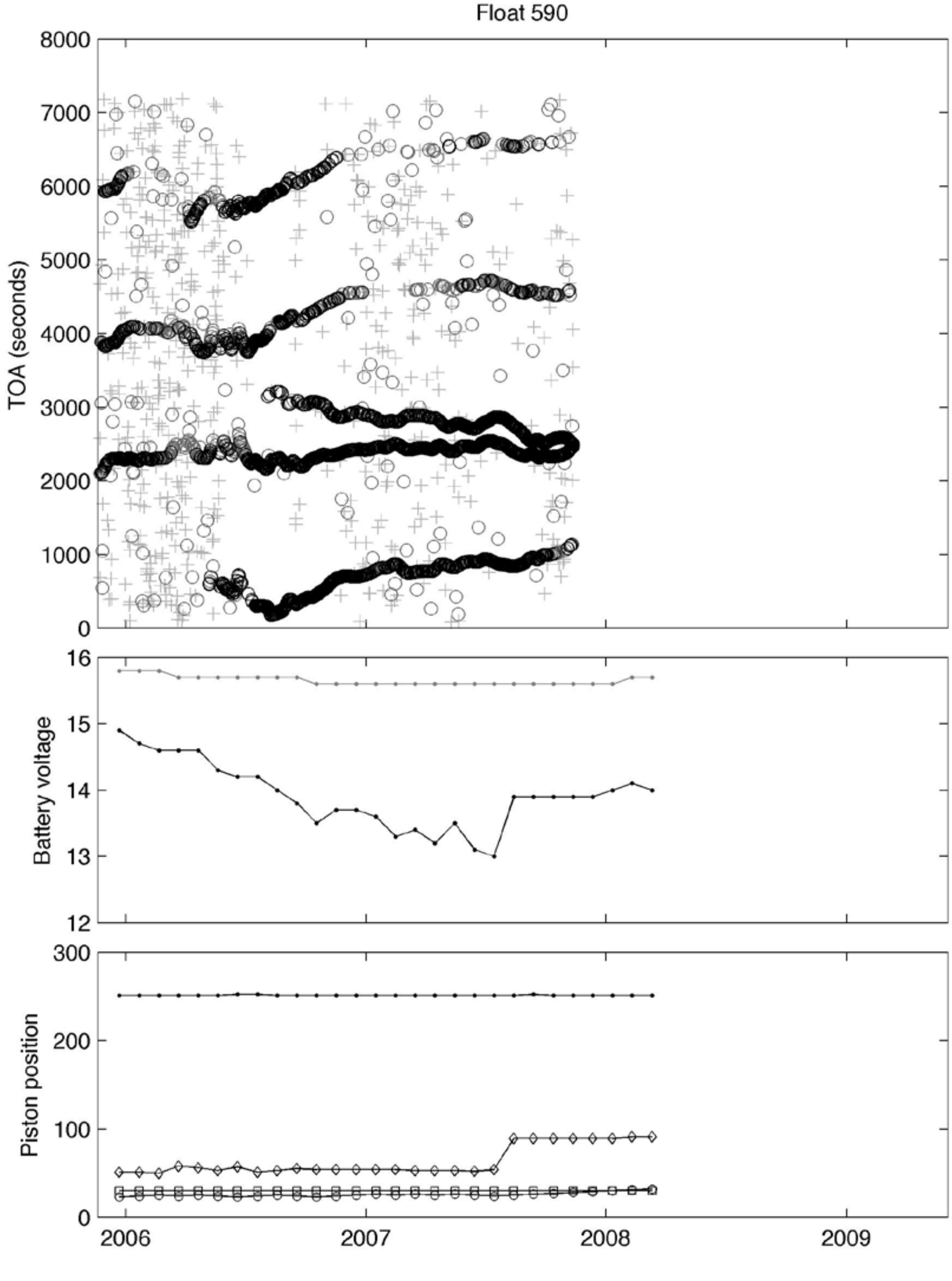


Float 582
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009

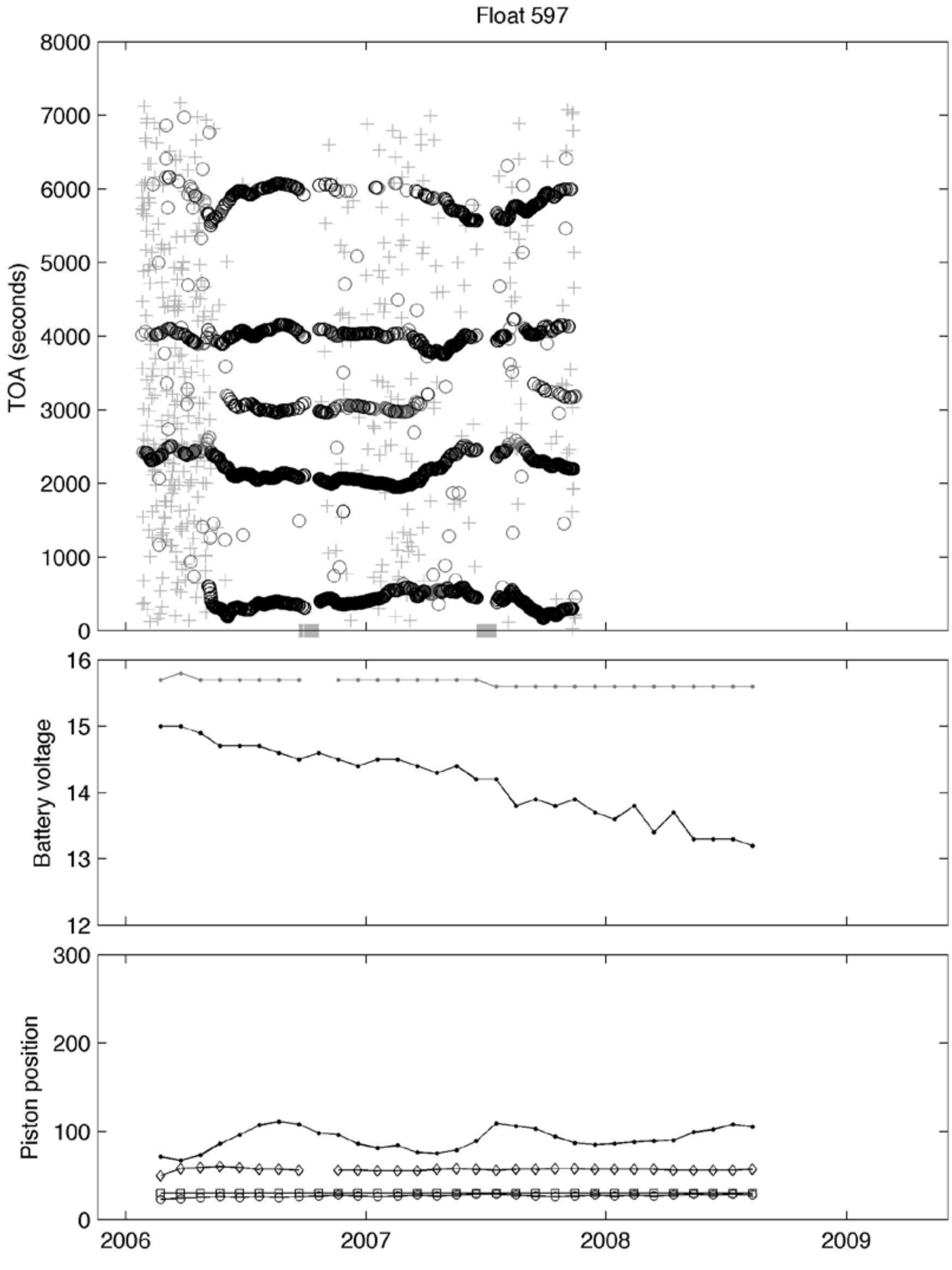

Float 585
TOA (seconds)
Battery voltage
Piston position
2006
2007
2008
2009



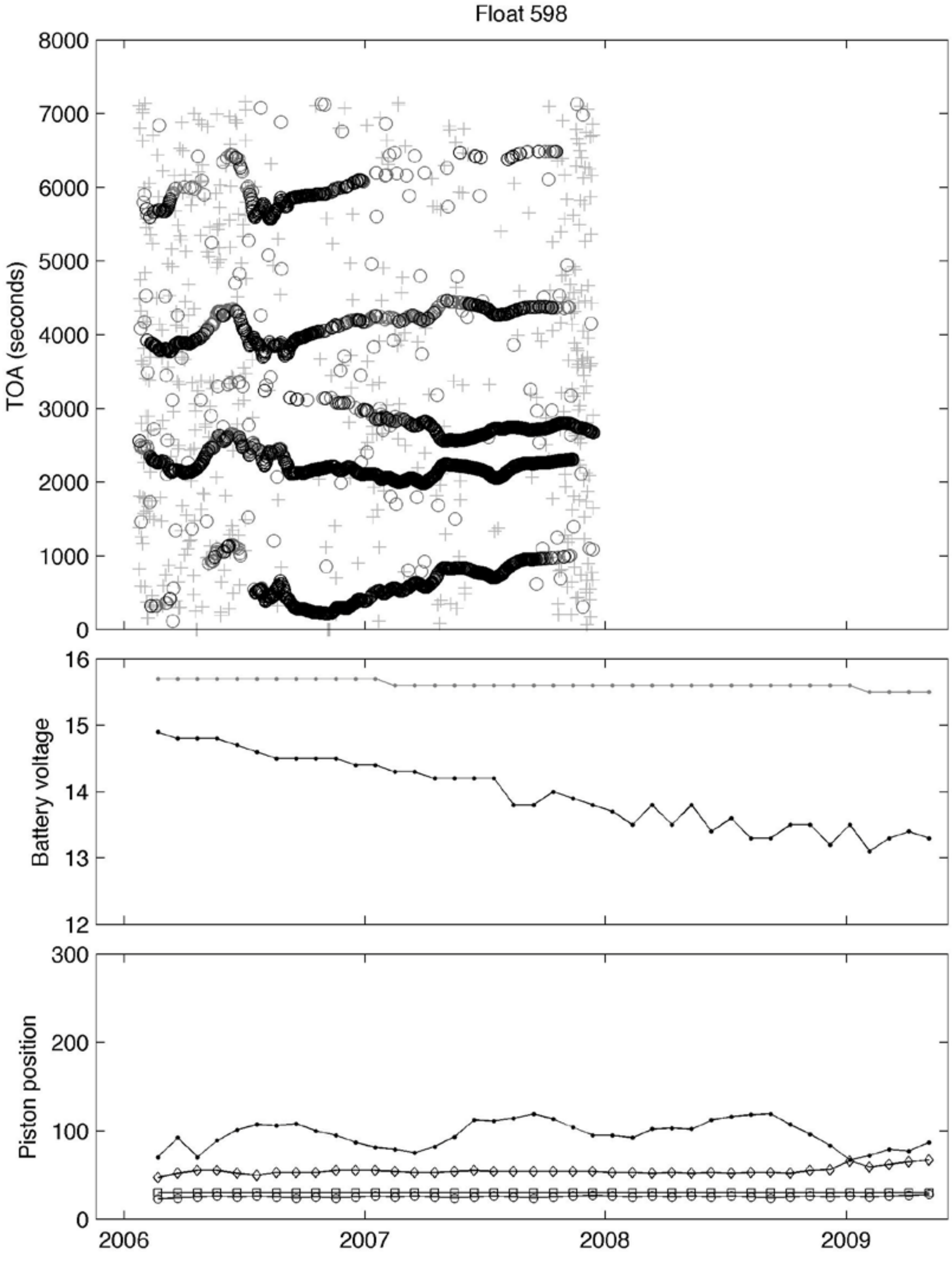
Float 589
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009

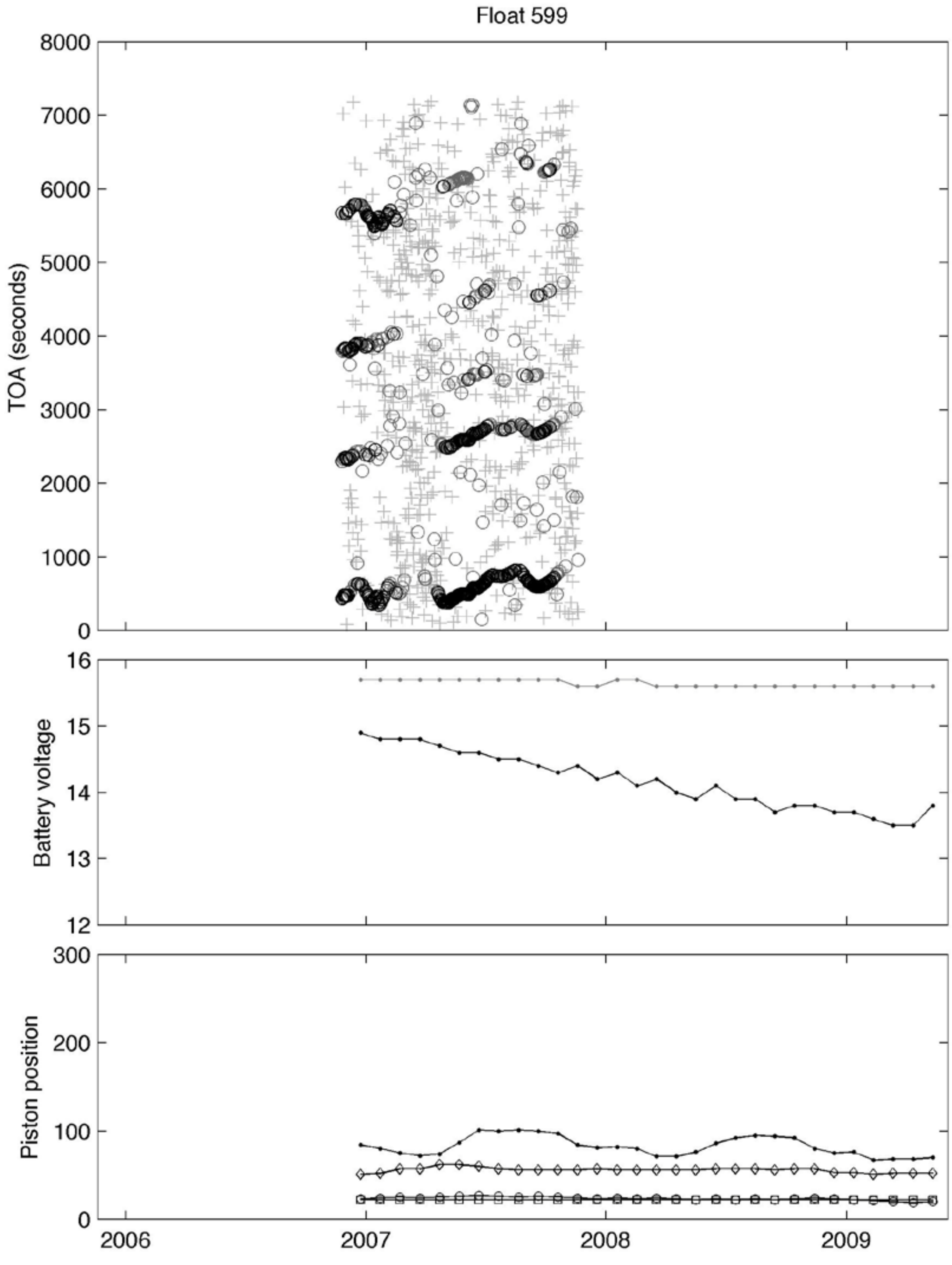


Float 590
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009

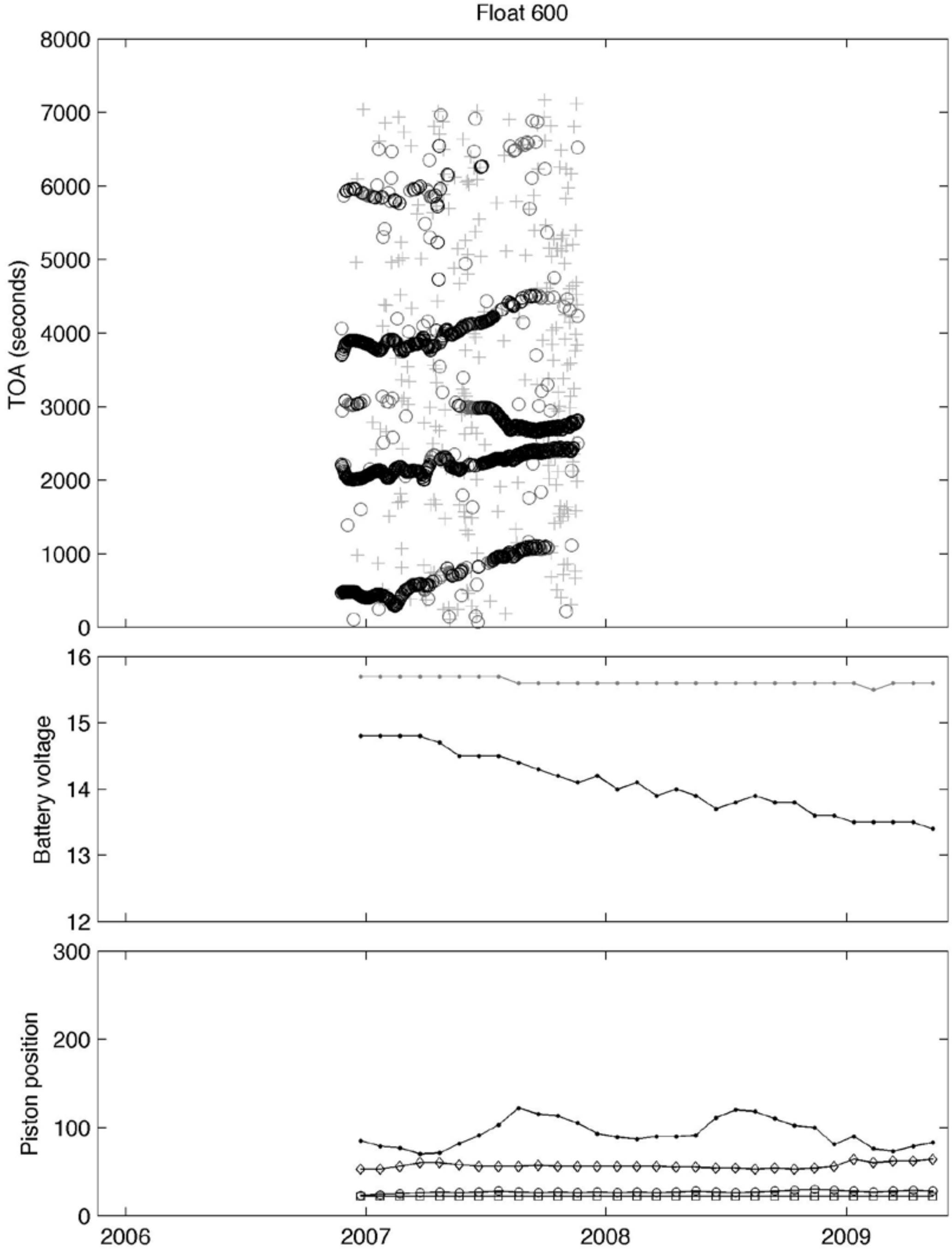


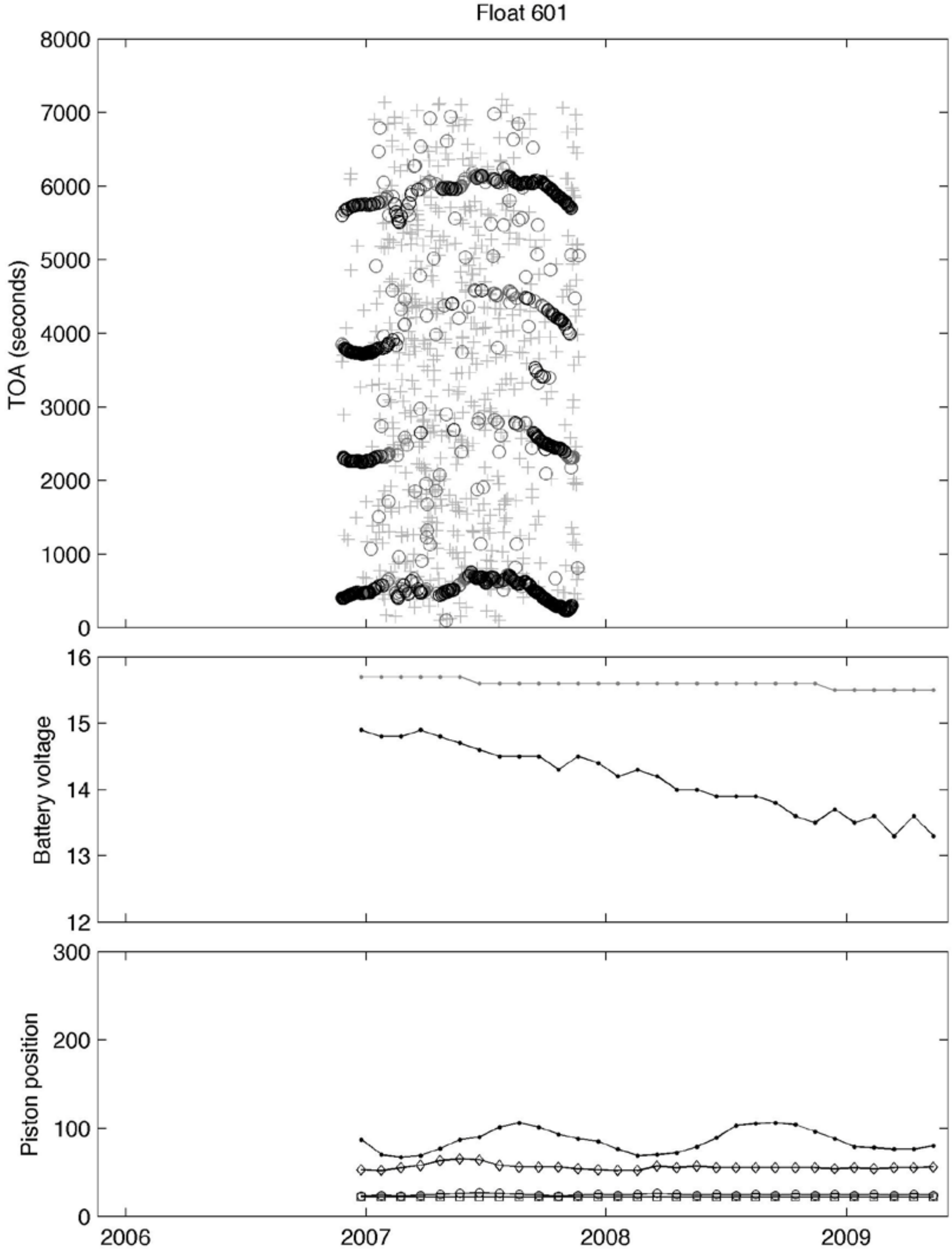
Float 597
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009


Float 598
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009

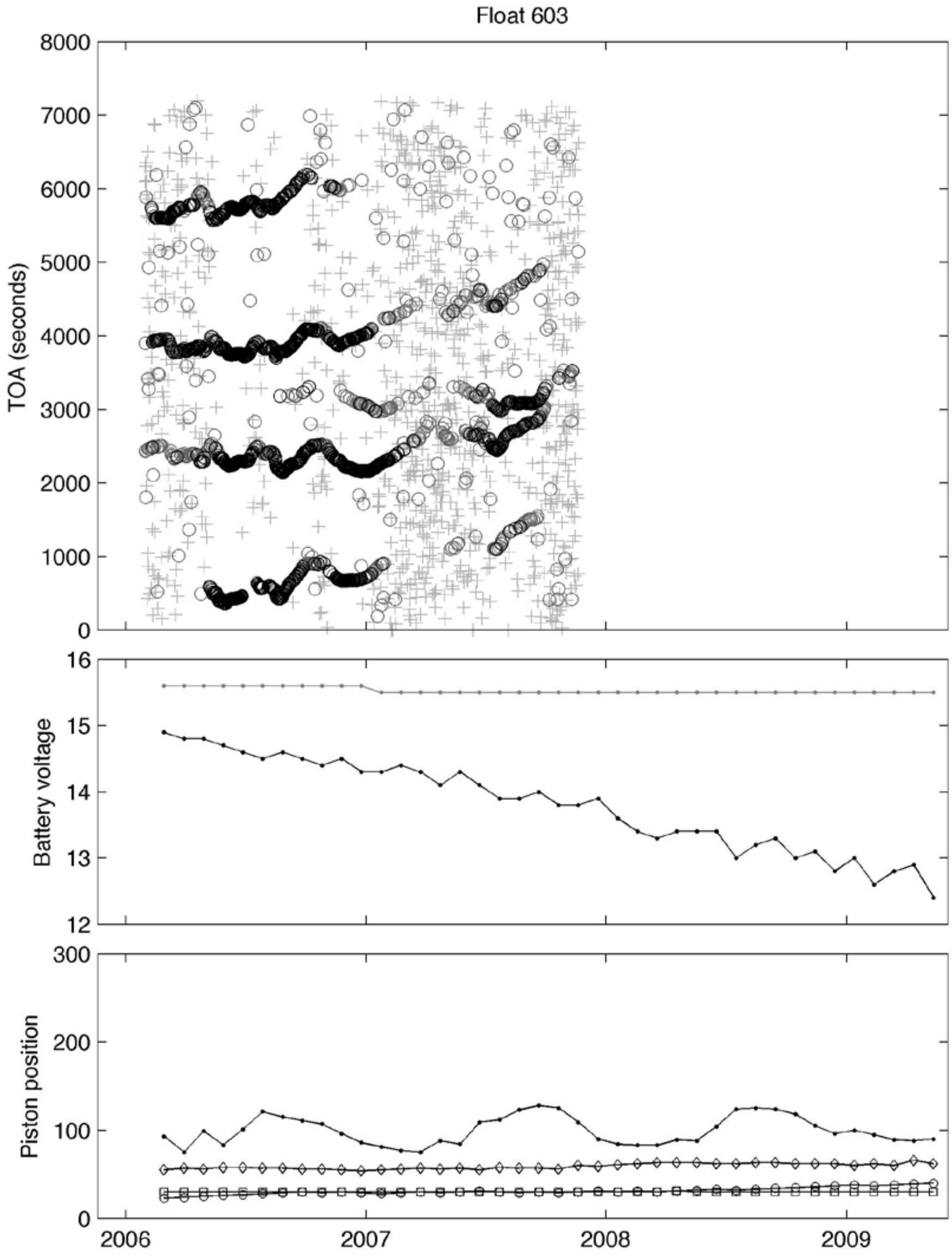


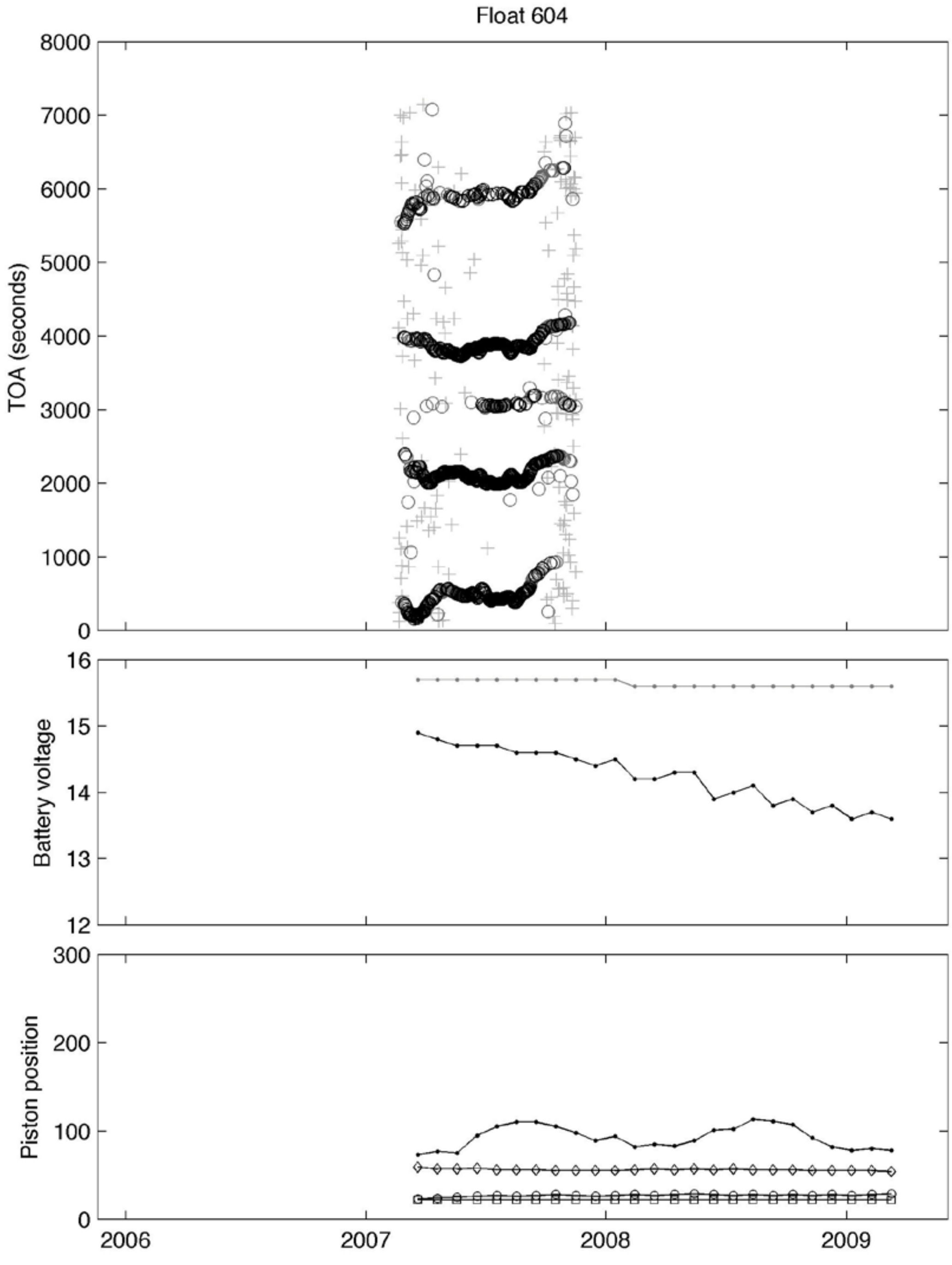
Float 599
TOA (seconds)
Battery voltage
Piston position
2006
2007
2008
2009

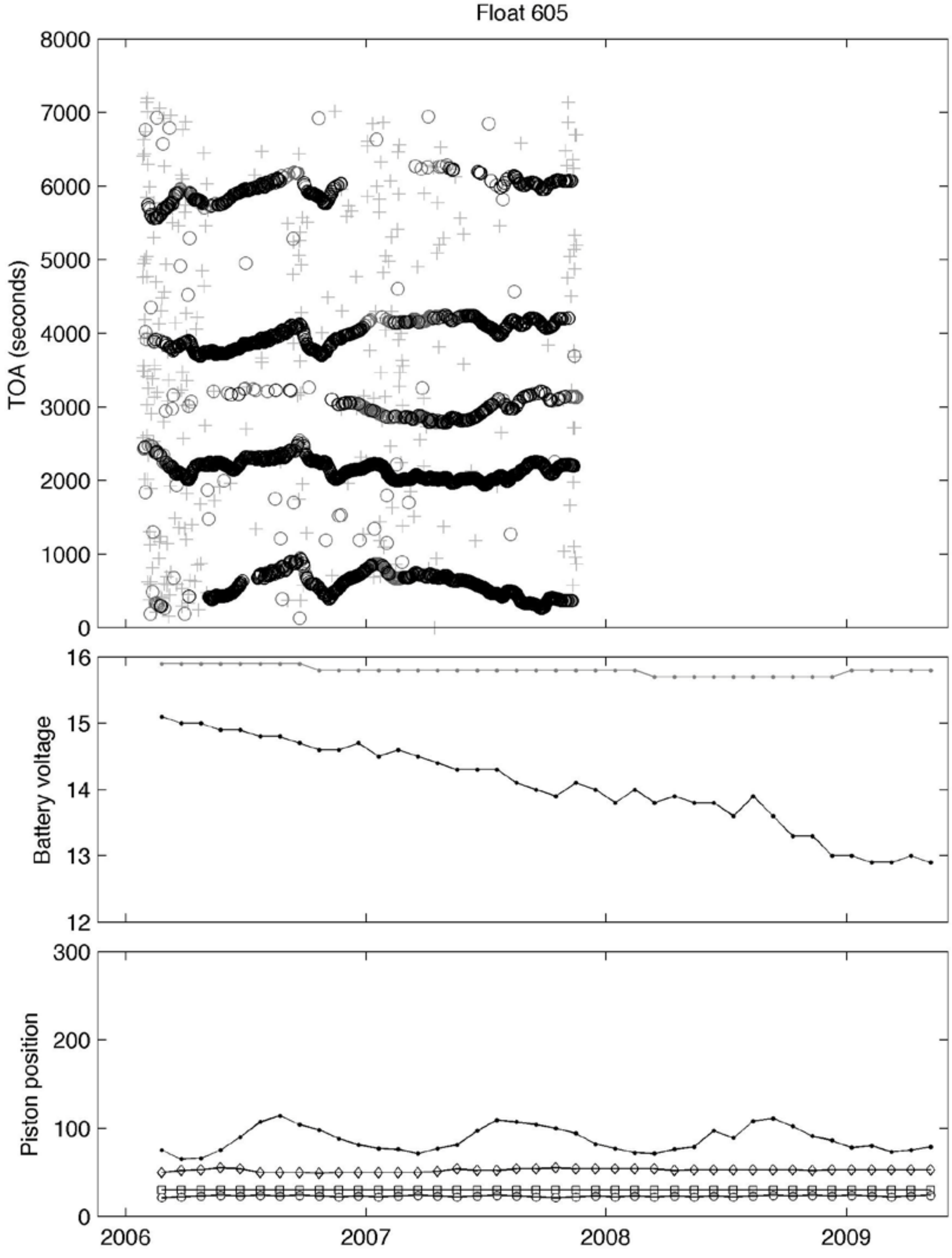

Float 600
8000
7000
6000
5000
4000
3000
2000
1000
0
TOA (seconds)
16
15
14
13
12
Battery voltage
300
200
100
0
Piston position
2006
2007
2008
2009



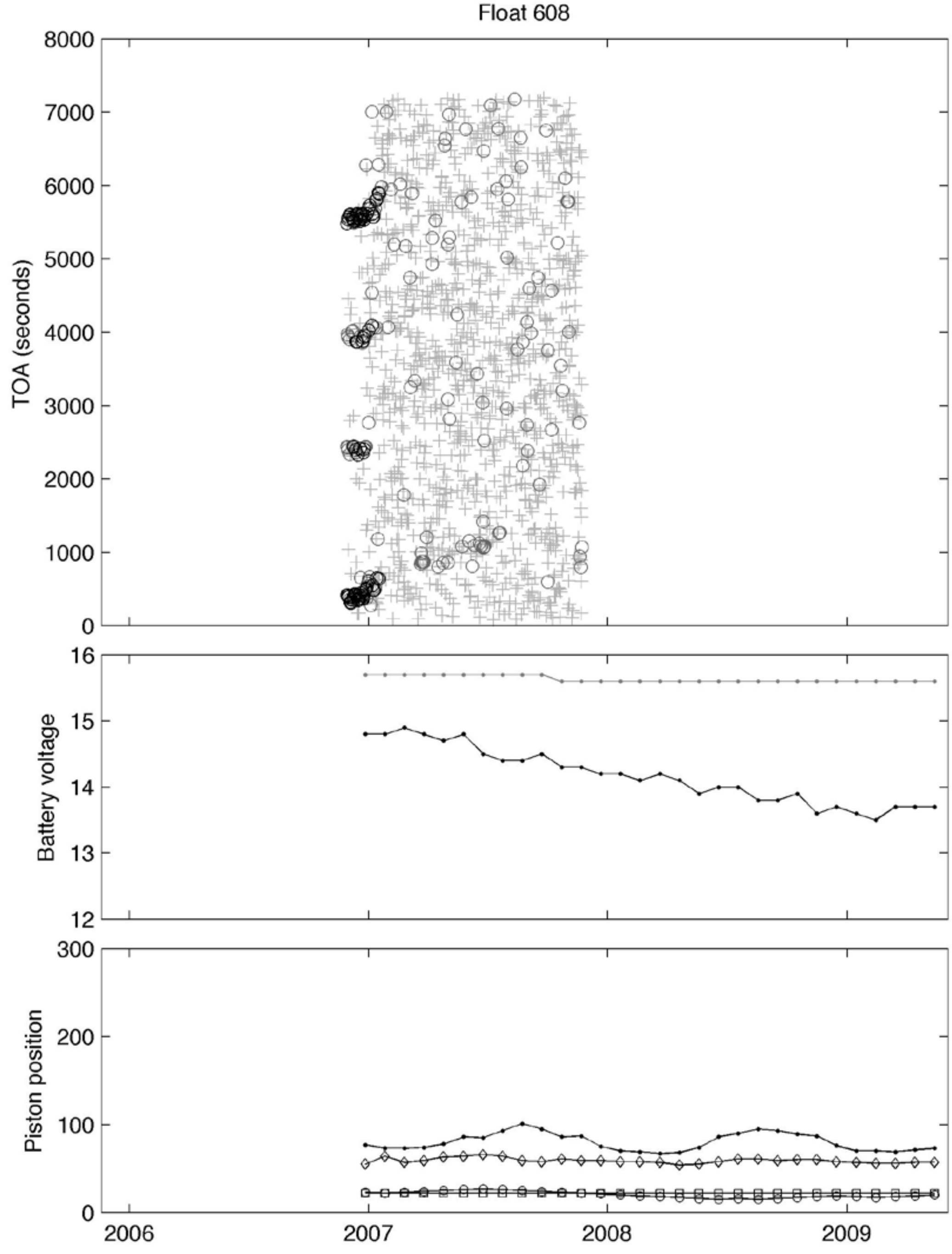
Float 601
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009


Float 603
TOA (seconds)
Battery voltage
Piston position
8000
7000
6000
5000
4000
3000
2000
1000
0
16
15
14
13
12
300
200
100
0
2006
2007
2008
2009

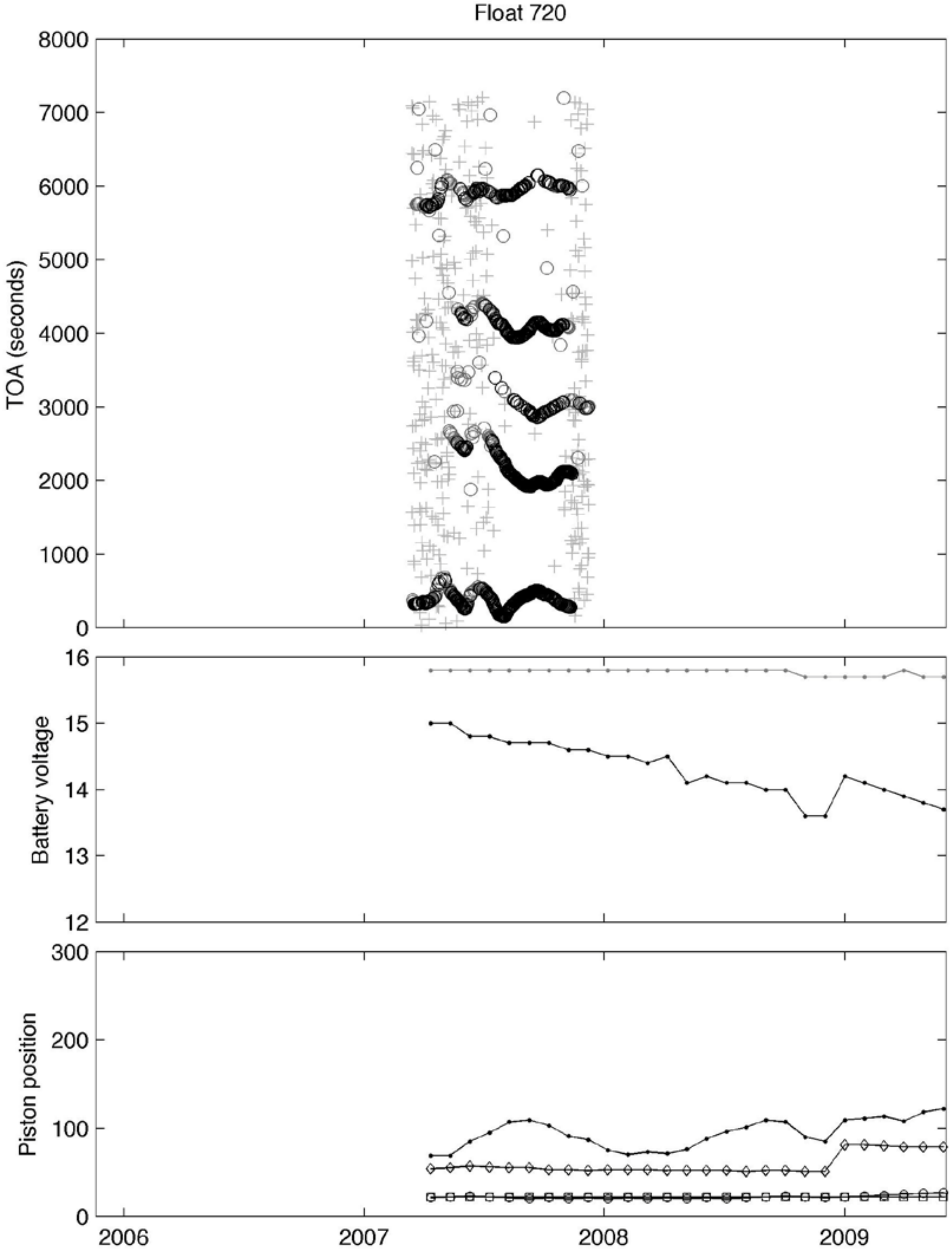

Float 604
8000
7000
6000
5000
4000
3000
2000
1000
0
TOA (seconds)
16
15
14
13
12
Battery voltage
300
200
100
0
Piston position
2006
2007
2008
2009



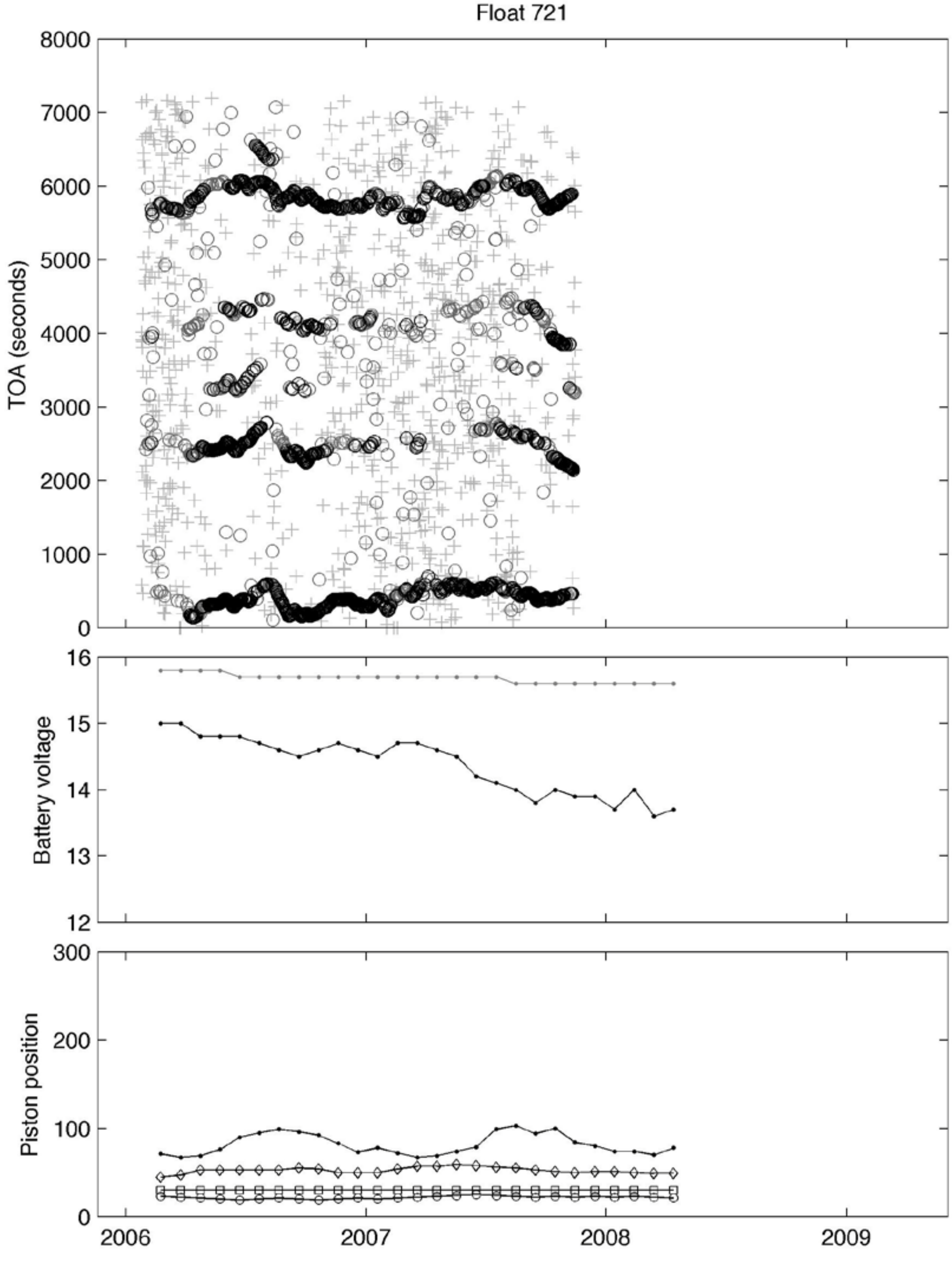
Float 605
8000
7000
6000
5000
4000
3000
2000
1000
0
TOA (seconds)
16
15
14
13
12
Battery voltage
300
200
100
0
Piston position
2006
2007
2008
2009



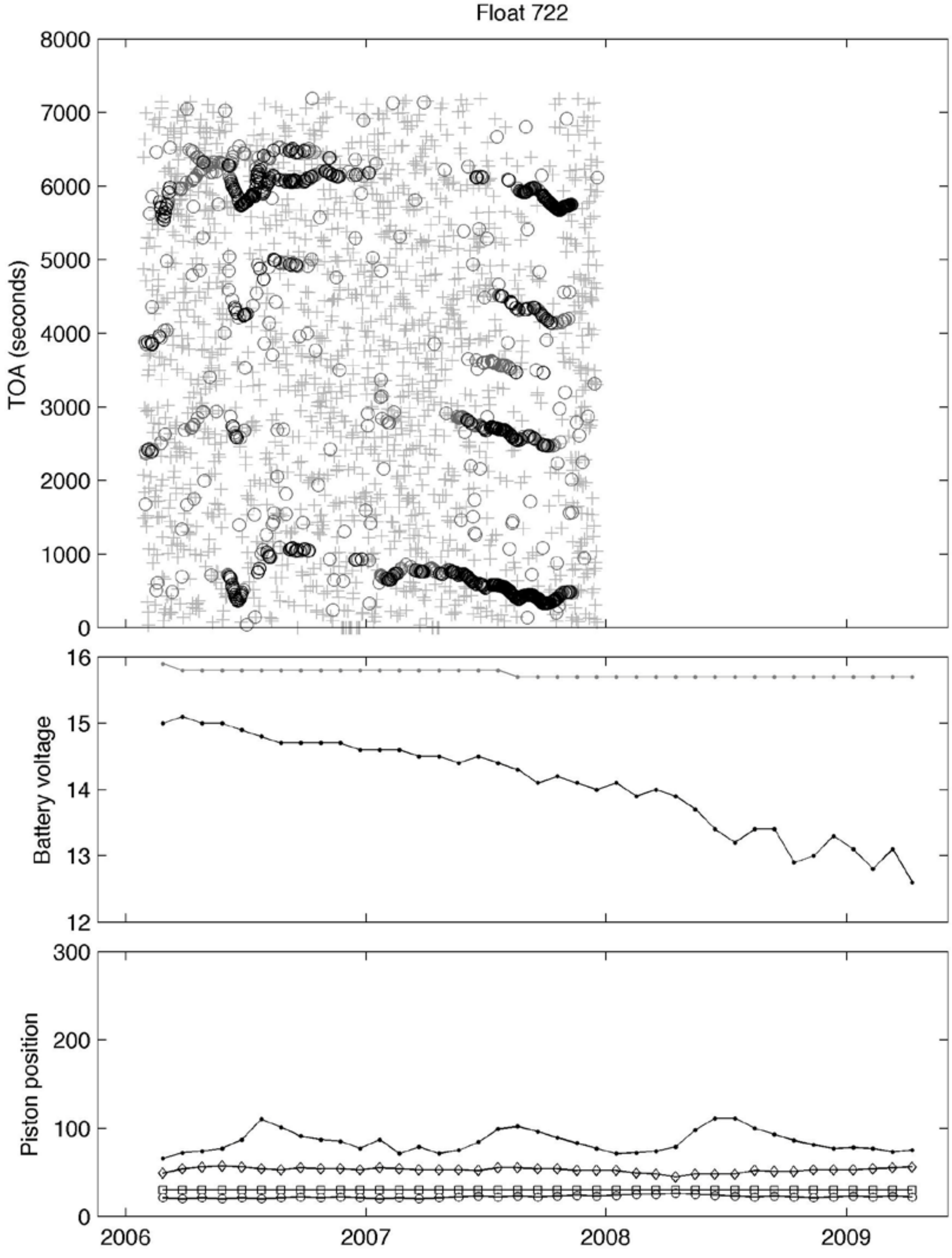
Float 608
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009



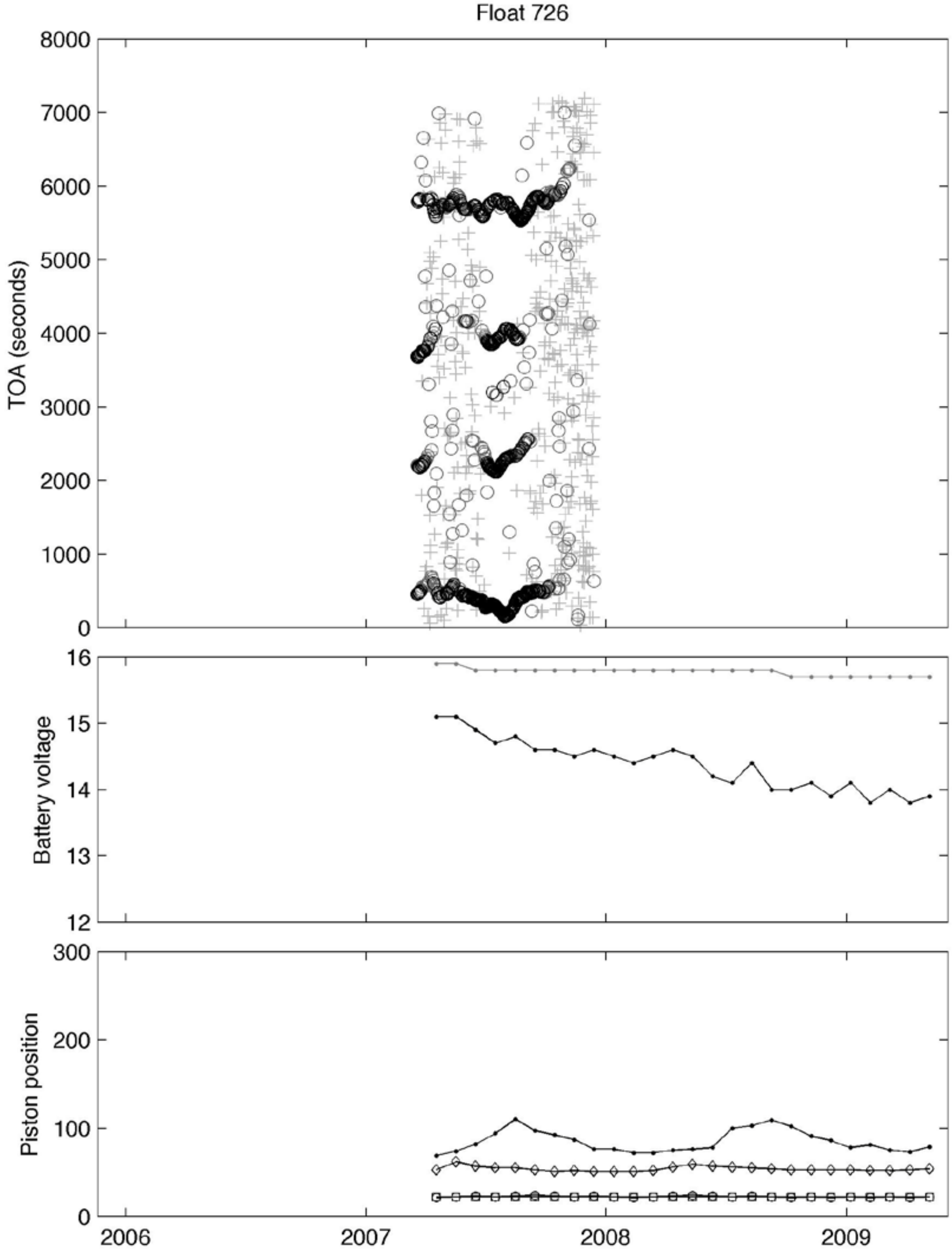
Float 720
8000
7000
6000
5000
4000
3000
2000
1000
0
TOA (seconds)
16
15
14
13
12
Battery voltage
300
200
100
0
Piston position
2006
2007
2008
2009



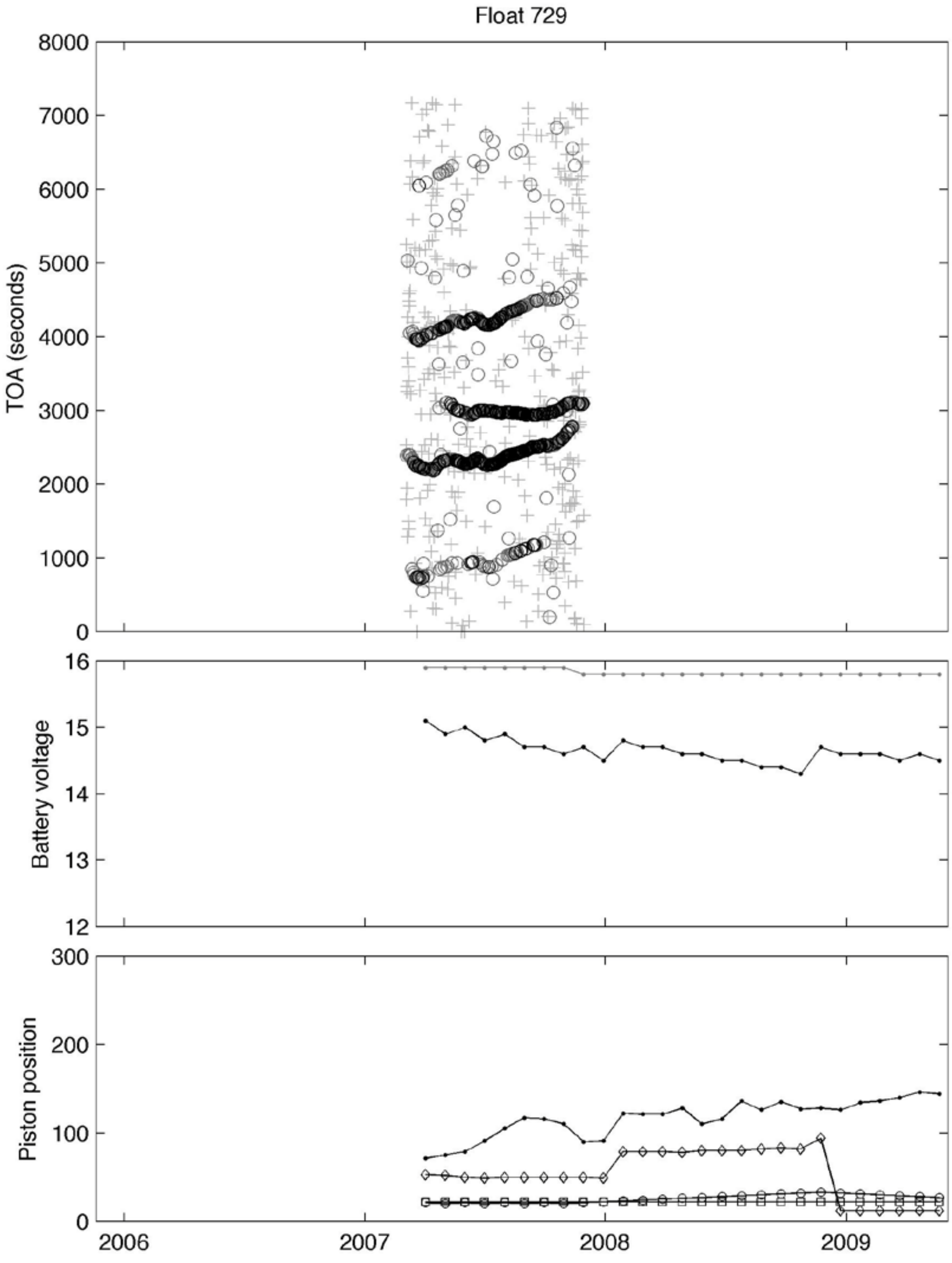
Float 721
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009

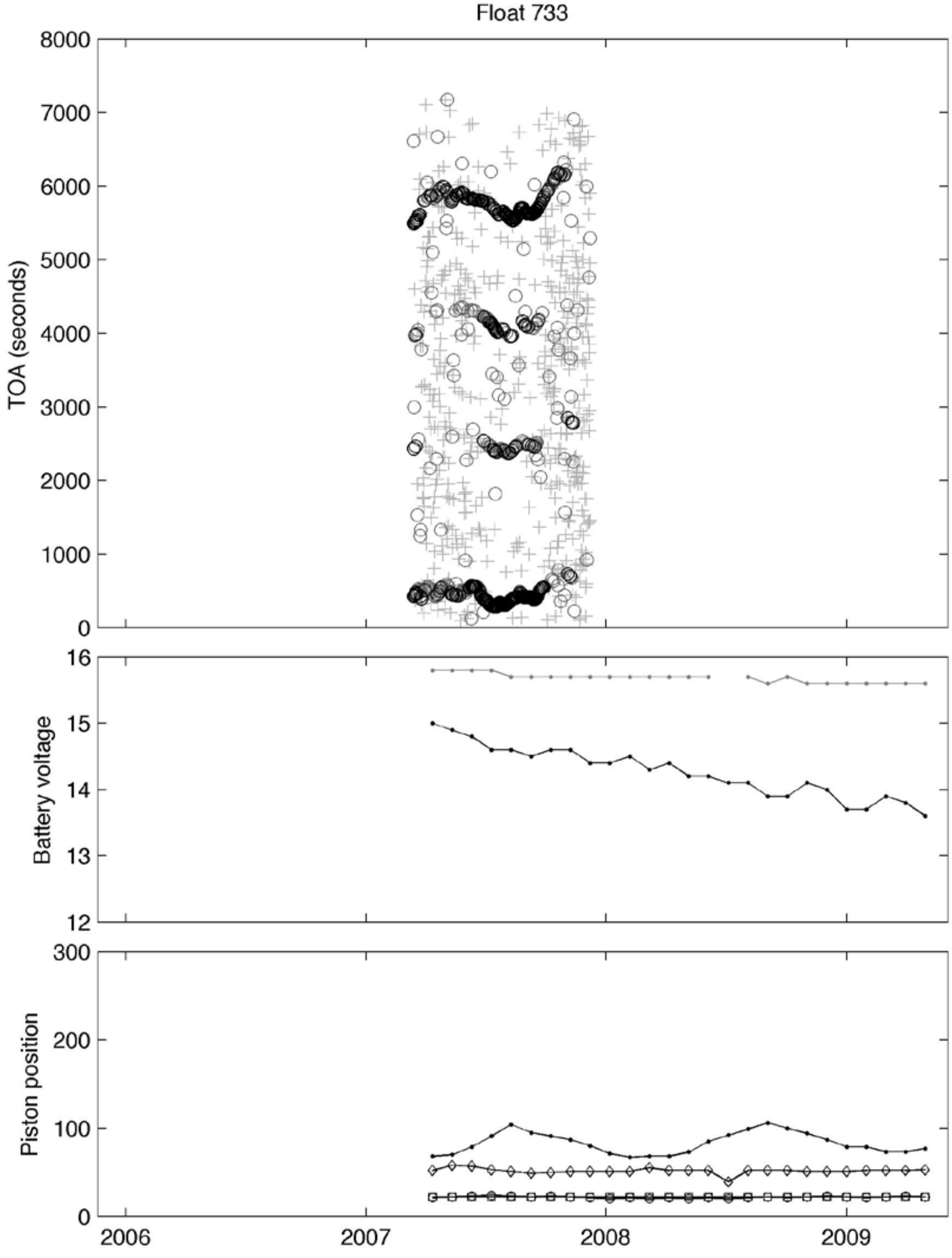


Float 722
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009

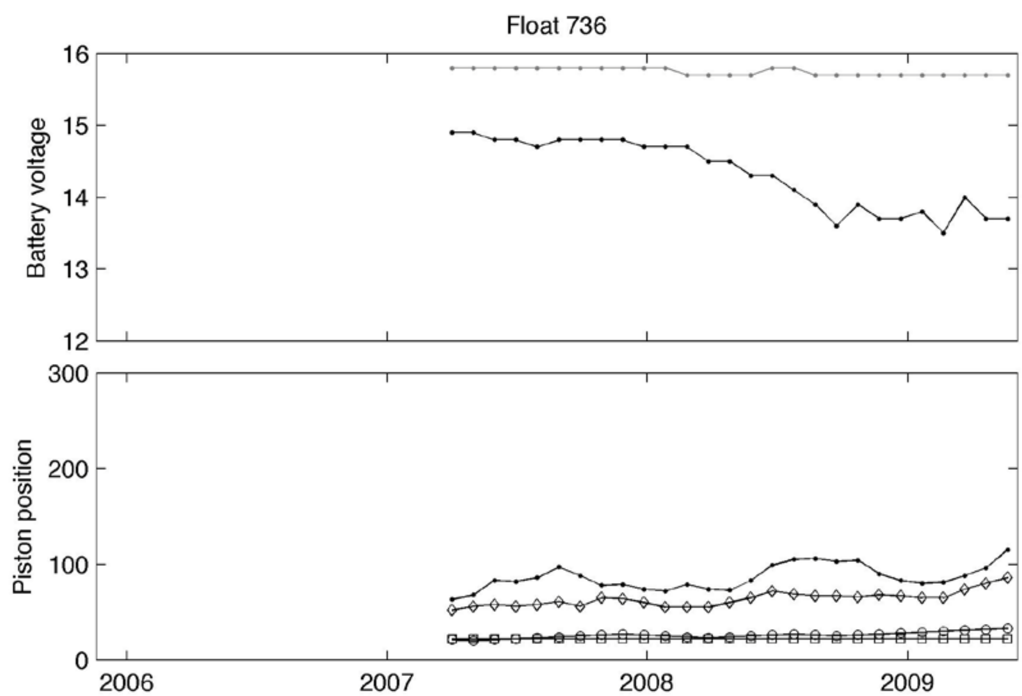


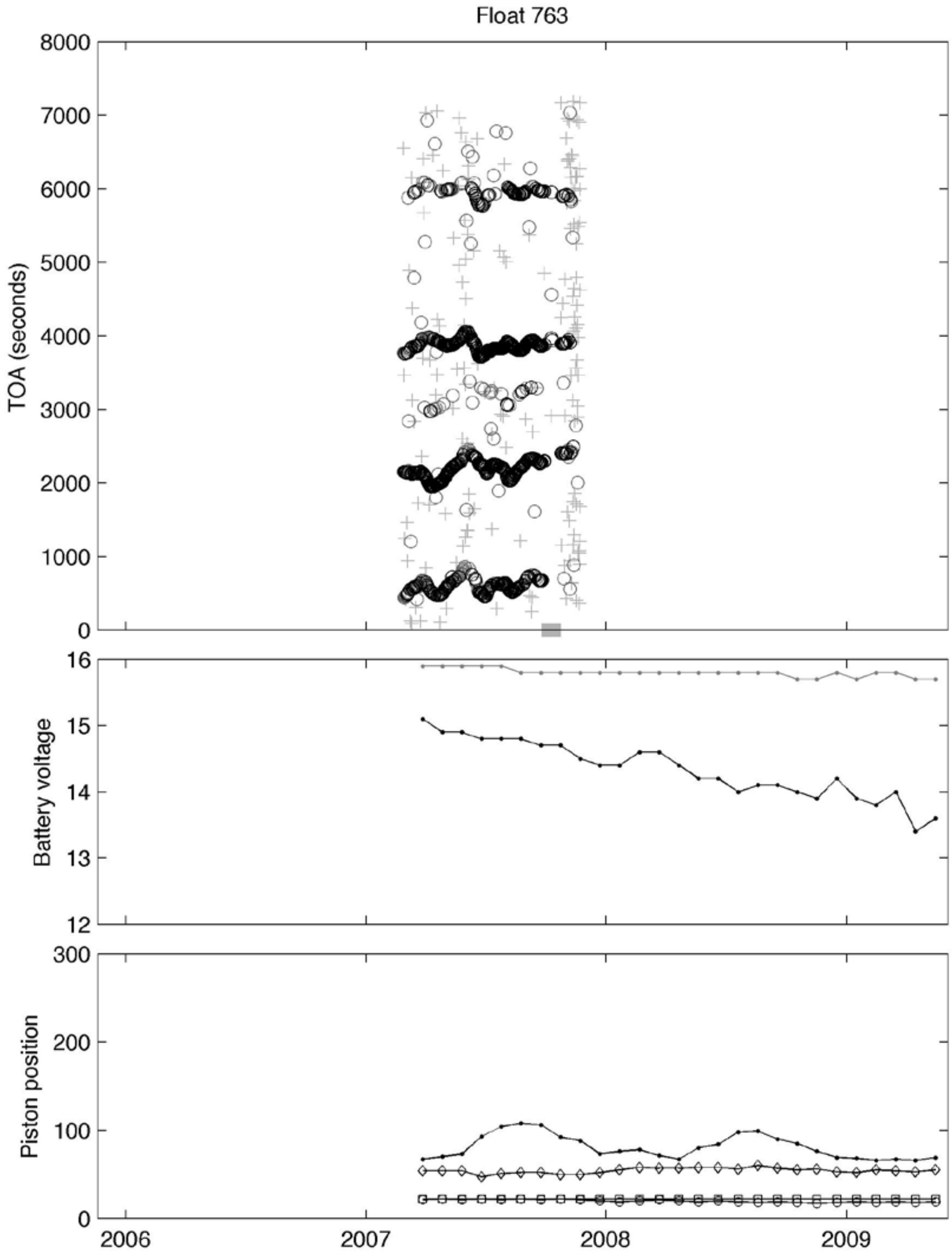
Float 726
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009

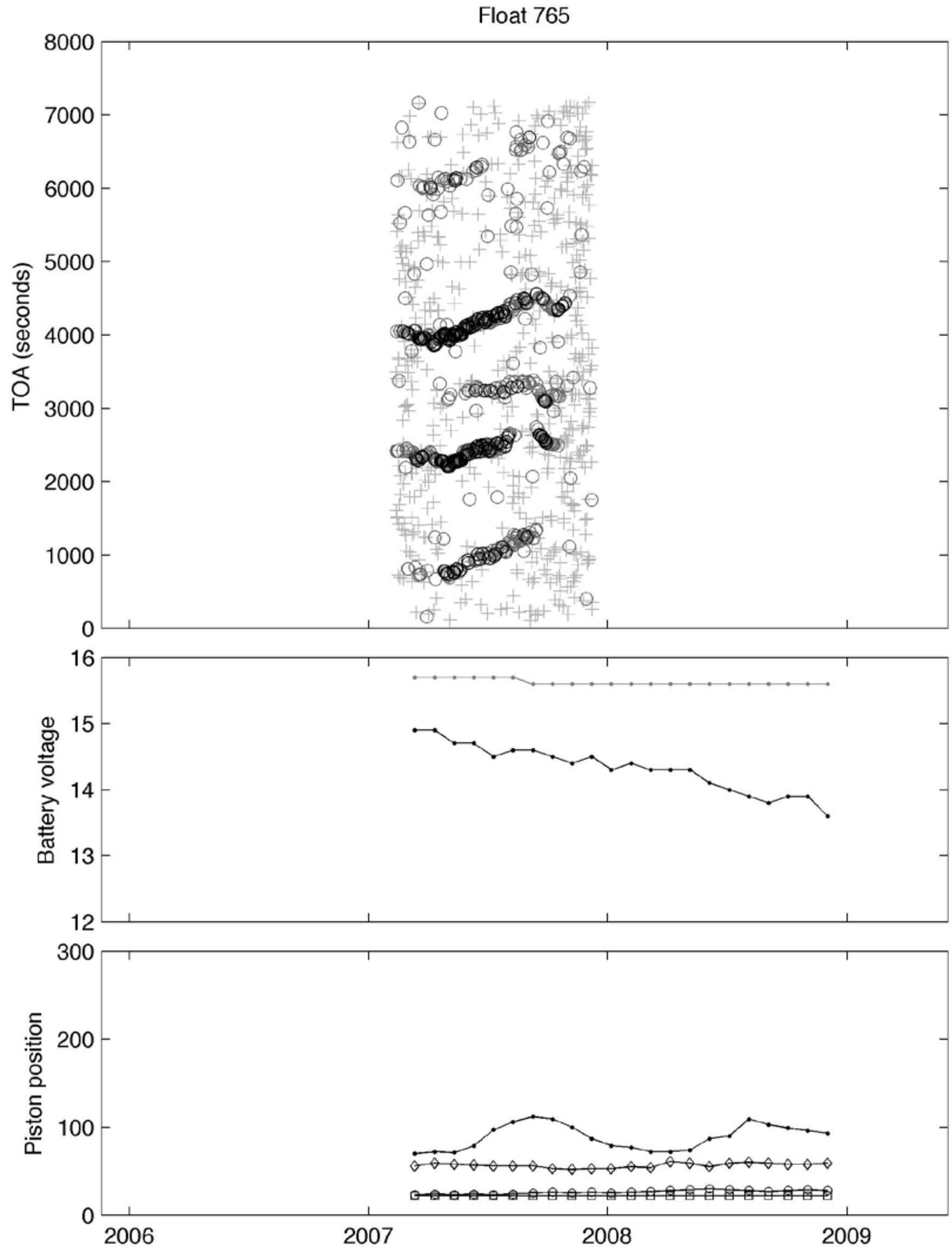

Float 729
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009

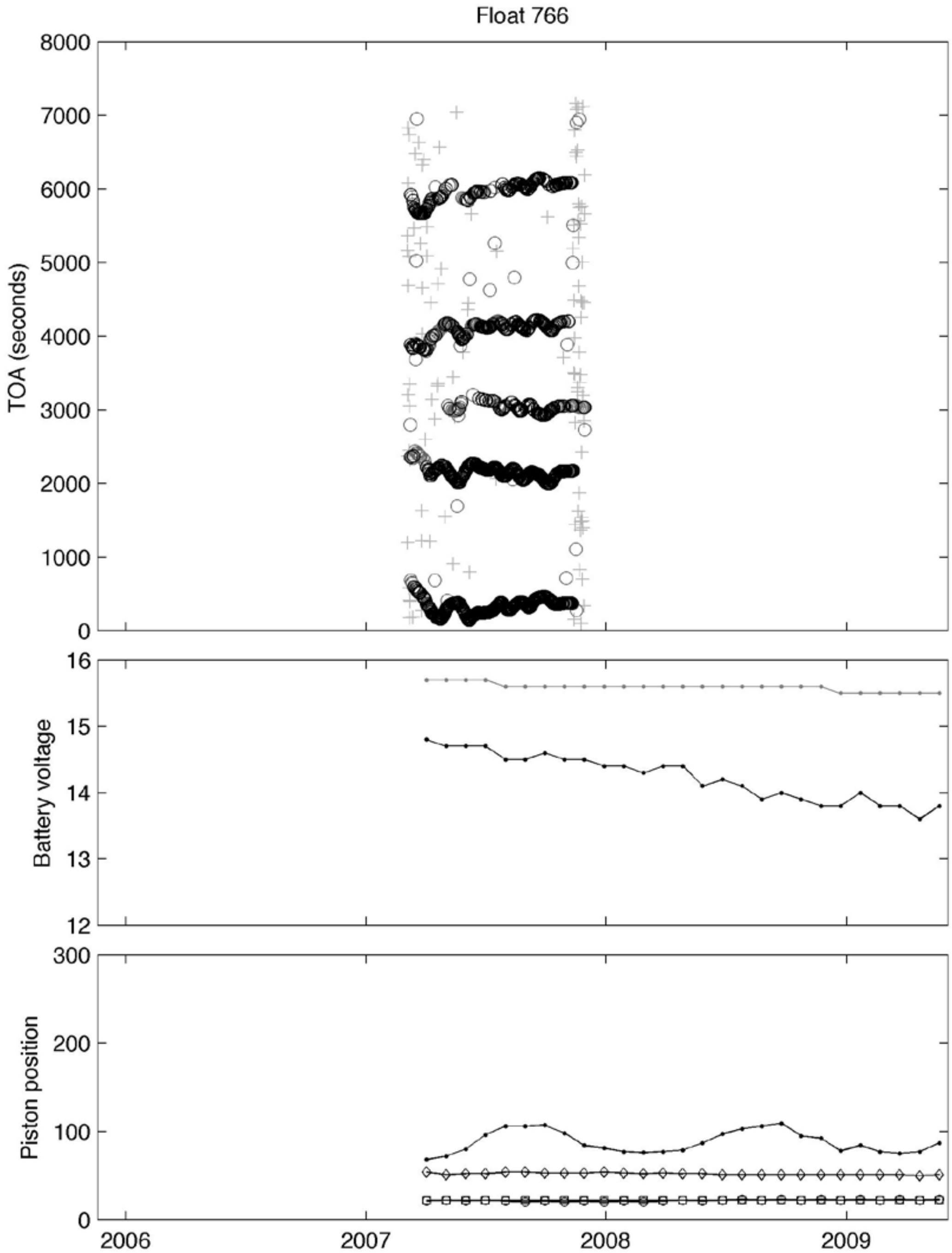


Float 733
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009

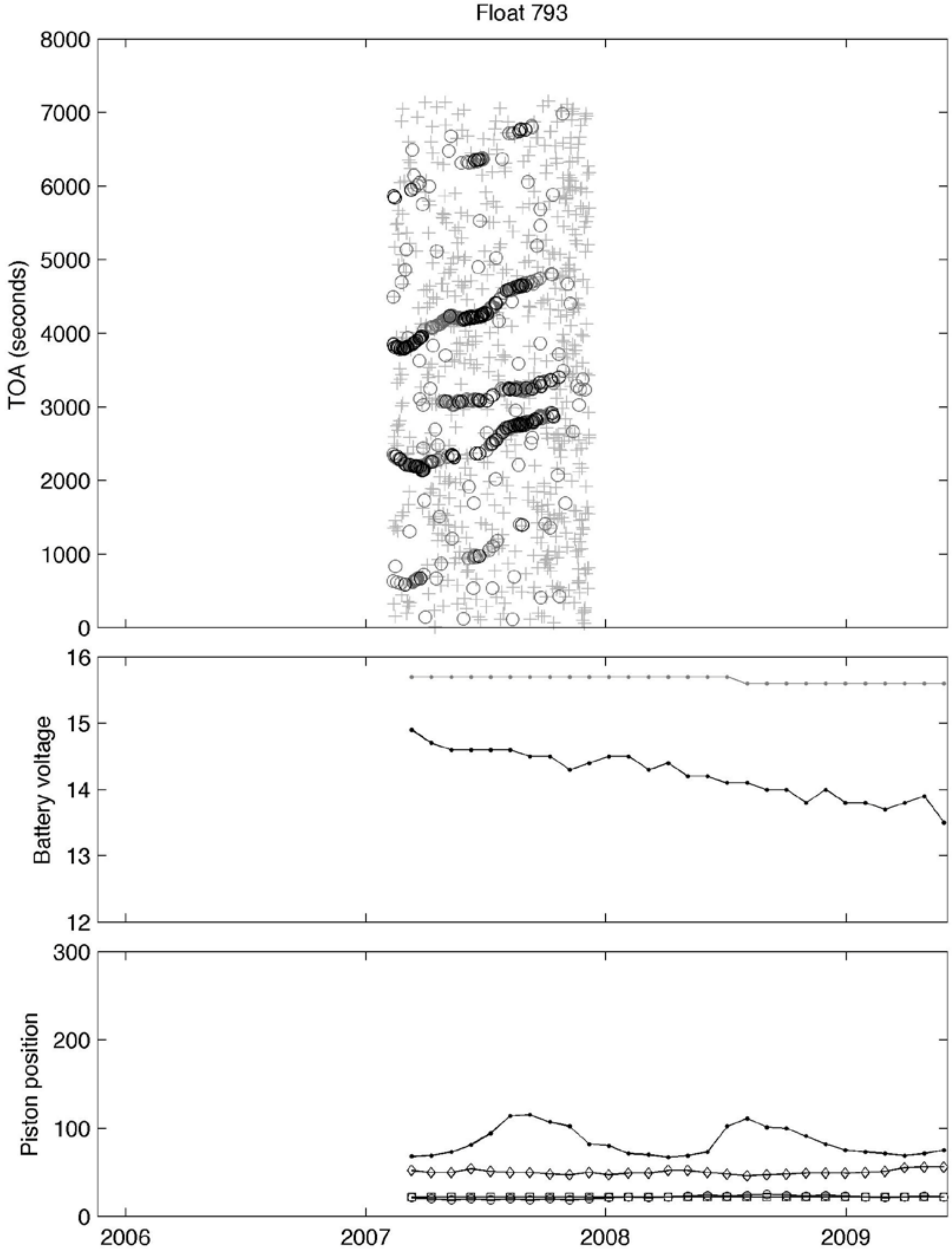

Float 736
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009


Float 763
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009


Float 765
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009



Float 766
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009



Float 793
TOA (seconds)
8000
7000
6000
5000
4000
3000
2000
1000
0
Battery voltage
16
15
14
13
12
Piston position
300
200
100
0
2006
2007
2008
2009

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7. Author(s) David M. Fratantoni, Theresa K. McKee, Benjamin A. Hodges, Heather H. Furey, John M. Lund			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Woods Hole Oceanographic Institution Woods Hole, Massachusetts 02543			10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C)OCE-0424492 (G)
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16. Abstract (Limit: 200 words)

This report summarizes direct observations of Eighteen Degree Water (EDW) subduction and dispersal within the subtropical gyre of the North Atlantic Ocean. Forty acoustically-tracked bobbing, profiling floats (“bobbers”) were deployed to study the formation and dispersal of EDW in the western North Atlantic. The unique bobber dataset described herein provides insight into the evolution of EDW by means of direct, eddy-resolving measurement of EDW Lagrangian dispersal pathways and stratification. Bobbers are modified Autonomous Profiling Explorer (APEX) profiling floats which actively servo their buoyancy control mechanism to follow a particular isothermal surface. The CLIVAR Mode Water Dynamics Experiment (CLIMODE) bobbers tracked the 18.5˚C temperature surface for 3 days, then bobbed quickly between the 17˚C and 19˚C isotherms. This cycle was repeated for one month, after which each bobber profiled to 1000 m before ascending to the surface to transmit data. The resulting dataset (37/40 tracked bobbers; more than half still profiling as of January 2010) yields well-resolved trajectories, unprecedented velocity statistics in the core of the subducting and spreading EDW, and detailed information about the Lagrangian evolution of EDW thickness and vertical structure. This report provides an overview of the experimental procedure employed and summarizes the initial processing of the bobber dataset.

17. Document Analysis a. Descriptors

Atlantic Ocean
Climate
Mode Water

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

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