WHOI-2009-06

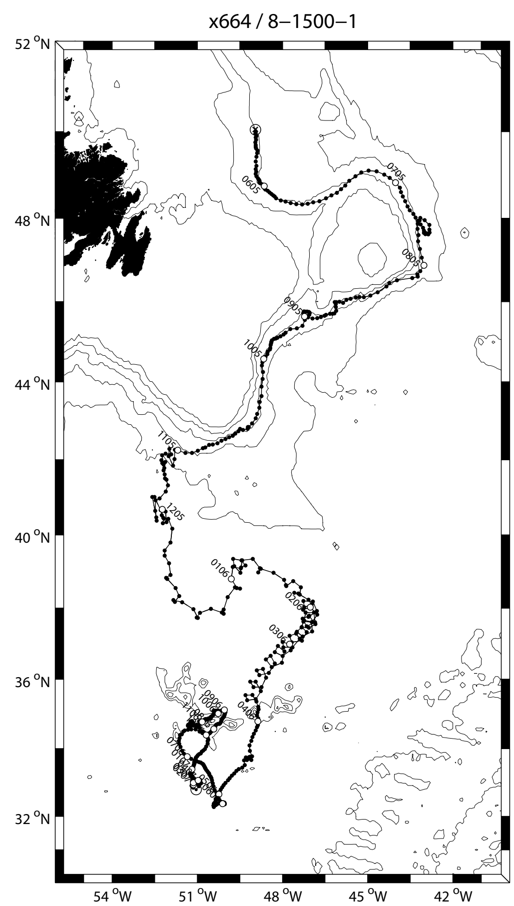
Woods Hole Oceanographic Institution

Export Pathways from the Subpolar North Atlantic: DLD2 RAFOS Float Data Report July 2003–November 2008

by

Heather H. Furey and Amy S. Bower

October 2009



Technical Report

Funding was provided by the National Science Foundation through Grant Nos. OCE-0136215 and OCE-0824652.

Approved for public release; distribution unlimited.

WHOI-09-06

Export Pathways from the Subpolar North Atlantic:
DLD2 RAFOS Float Data Report
July 2003–November 2008

by

Heather H. Furey and Amy S. Bower

October 2009

Technical Report

Funding was provided by the National Science Foundation through Grant Nos. OCE-0136215 and OCE-0824652

Approved for Distribution:

Raymond W. Schmitt (for)

Robert A. Weller, Chair

Department of Physical Oceanography

Abstract

This is the final data report of all acoustically tracked second-generation Deep Lagrangian Drifter (DLD2) Ranging and Fixing of Sound (RAFOS) float data collected by the Woods Hole Oceanographic Institution in 2003-2008 during *Export Pathways from the Subpolar North Atlantic* (ExPath). The objectives of ExPath were to (1) obtain an improved description of the pathways of Labrador Sea Water out of the subpolar region using acoustically-tracked RAFOS floats deployed in the western boundary current in the Labrador Sea; (2) characterize the intermittency/temporal variability in these pathways, and investigate its cause, including North Atlantic Current position, interannual variations in Labrador Sea Water production, and seasonal/interannual variations in wind forcing; and (3) use historical and synoptic hydrographic data to determine low-frequency variations in the penetration of recently-ventilated water masses equatorward along the western boundary. The RAFOS float component of ExPath was comprised of thirteen seedings of the boundary current near 50°N, off of St. John's, Newfoundland. In addition to the initial setting of six floats and four sound sources off the *R/V Oceanus* in July 2003, nine float settings were made by the Northwest Atlantic Fisheries Centre from the Bonavista Line, a repeat hydrographic section that is occupied three times annually as part of the Atlantic Zone Monitoring Program. Three more float settings were accomplished by dual-release float moorings, set in November of each year and programmed to release floats the following February. In sum, 76 isobaric floats were deployed or released quarterly: in November, February, May and July. Half were ballasted for 700 dbars and the other half for 1500 dbars, to target the two main levels of Labrador Sea Water. Fifty-five two-year float trajectories and 59 two-year displacement vectors were obtained.

Front Cover Figure Caption:

The trajectory of RAFOS float x664, ballasted for 1500 decibars. This float was launched in April 2005 from the *CSS Teleost* on the repeat hydrographic section “Bonavista” (see text), and surfaced in April 2007 in the interior subtropical North Atlantic. The float travelled close along the boundary of the Flemish Cap and Grand Banks, until it was pulled away from the boundary in November 2005. Unique to this data set, this float reveals a deep eddy drifting south from the Tail of the Banks into the interior western North Atlantic. Dots represent daily float positions, circle-x the launch location, and circle-dot the surface location. Dates are printed with the open dots on the first of each month: ‘0905’ stands for September 1st, 2005. Bathymetry is contoured at 200 meters, and at 1000 meter intervals. Figure title ‘x664 / 8-1500-1’ refers to ExPath float x664, the 8th float setting, 1500-dbar ballast pressure, and position 1, the inshore station for deep float deployment on the Bonavista Line.

Table of Contents

List of Figures

Page No.

List of Tables

Page No.

1. Introduction

The Export Pathways from the Subpolar North Atlantic Experiment (hereafter, ExPath) consisted of 13 sequential releases of isobaric Deep Lagrangian Drifter (DLD2) Ranging and Fixing of Sound (RAFOS) floats in the subpolar North Atlantic western boundary current over the continental slope near Orphan Knoll (~50°N), off St. John's, Newfoundland (Figures 1, 2). ExPath was a joint effort between Dr. Amy Bower at the Woods Hole Oceanographic Institution (WHOI) and Dr. Susan Lozier at Duke University. The objectives of ExPath were to (1) obtain an improved description of the pathways of Labrador Sea Water out of the subpolar region using acoustically-tracked RAFOS floats deployed in the subpolar western boundary current in the Labrador Sea; (2) characterize the intermittency/temporal variability in these pathways, and investigate its cause, including North Atlantic Current position, interannual variations in Labrador Sea Water production, and seasonal/interannual variations in wind forcing; and (3) use historical and synoptic hydrographic data to determine low-frequency variations in the penetration of recently-ventilated water masses equatorward along the western boundary. The floats were ballasted for 700 and 1500 decibars to target two levels of the Labrador Sea Water. After an initial cruise to set up the sound source tracking array and release the first setting of floats in July 2003, subsequent float releases were performed by the Northwest Atlantic Fisheries Centre in St. John's, Newfoundland along the repeat hydrographic section 'Bonavista', which is part of Canada Fisheries and Oceans Atlantic Zone Monitoring Program (AZMP; http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/azmp-pmza/index-eng.html). In this data report, the DLD2 float data and data processing are described in detail.

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

The DLD2 is a second-generation RAFOS 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 temperature and pressure, 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 valuable for correcting rollover in these properties.

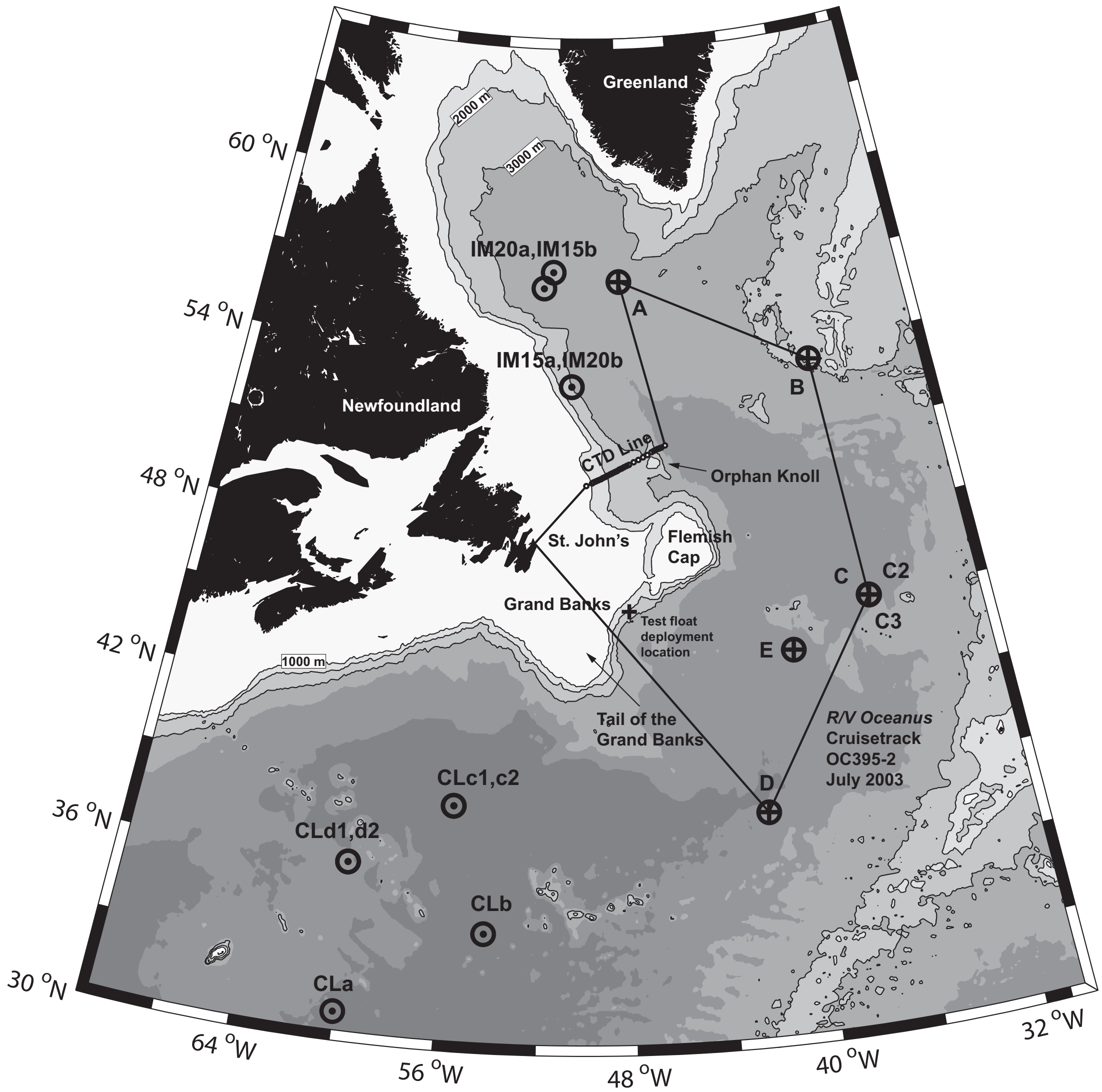


Figure 1: Map of the ExPath study region. Includes the initial *R/V Oceanus* cruise track, from which CTDs were taken, the initial setting of floats was deployed, and the ExPath sound source moorings A-D were deployed. Also shown are locations of replacement sound source moorings C2, C3, and E. Additional sources that were used to track the floats were the IM sources in the Labrador Sea, owned by IFM-GEOMAR, and the CL sources, an array moored for the WHOI CLIMODE experiment. Launch location of floats deployed to test sound sources is shown as an 'X'. Bathymetry is contoured at 1000, 2000, and 3000 meters, and shaded in 1000-meter intervals.

Seventy-four DLD2 floats were purchased from Seascan, Inc., of Falmouth, MA, and assembled, calibrated (temperature and pressure), and ballasted at WHOI. Five additional floats were given to us by Seascan, Inc., to replace those that may have been lost due to burn wire mis-engineering (see 'Section 5. Float Performance' for details), for a total of 79 floats. The floats recorded temperature, 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 CLS America satellite system. The DLD2 floats were set to repeat their listening schedule every 24 hours, and remain open for 8 hours 20 minutes length each cycle, so that one sound signal from each source (on a 24-hourly schedule) was received per cycle. One temperature and pressure measurement was taken in each listening cycle. This resulted in a 24-hourly schedule for the floats, with five windows of one or two TOA/correlation pairs each, and one temperature/pressure (T/P) measurement. Floats in Setting 1 (432:437, Table 1 in Appendix A) were of the one delay/correlation pair per window per cycle, all other floats were programmed to store two correlation/delay pairs per window per cycle. The change in correlation/window from two to one was made by Seascan, Inc., and was returned to two per window at our request after the first float deployment. 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 dbars.

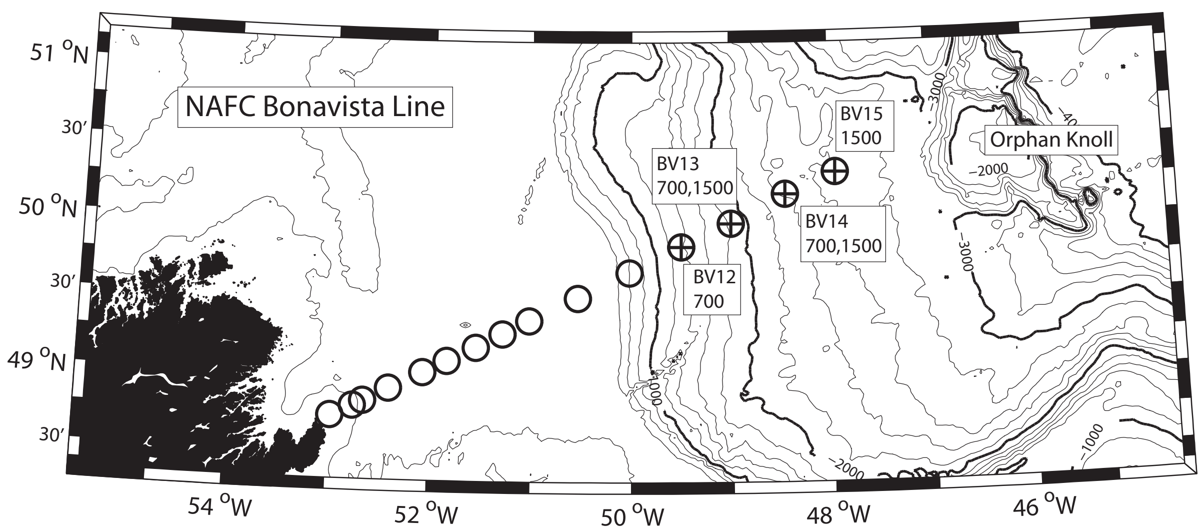


Figure 2: The Bonavista Line, a repeat hydrography line, part of the North Atlantic Fisheries Centre's Atlantic Zone Monitoring Program. CTD station locations are marked as circles, the deep stations where the floats were launched are marked with a circle-x. Bathymetry is contoured every 200 meters, with bold lines at the 1000-meter interval.

Eighteen out of 79 floats in the experiment were deployed as dual-release floats (Table 1 in Appendix A). 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. Three sets of six floats each were moored along the Bonavista Line, and were programmed to release on the following February 15, to complete a winter seeding of the Deep Western Boundary Current in 2004, 2005 and 2006. This technique allowed for four-times-per-year float releases using three-times-per-year AZMP Bonavista cruises.

3. Float Deployment

A total of 76 regular-mission floats were deployed along the Bonavista Line. (Of the 79 floats described in the last section, two were short-mission test floats deployed southwest of Flemish Cap by the Canadian Coast Guard to listen for sound source C (see next Section), and one float in Setting 13, the last deployment, was broken in shipment and never deployed.) Nominally six floats were deployed per setting, yielding 13 independent realizations between July 2003 and November 2006. Three settings (18 floats) were deployed using the dual-release method. These floats were deployed from the ship at the same time as the November setting floats were deployed, but they were temporarily anchored to the sea floor, programmed to release from the anchor into drifting mode on the following February 15th. All floats were isobaric and ballasted for either 700 or 1500 decibars. Table 1 in Appendix A provides launch and surface information for all floats.

In each float setting, three were ballasted for 700 dbars ('shallow') and three for 1500 dbars ('deep'). Launch locations for the six floats were as follows: the floats were deployed at three adjacent hydrographic stations that allowed the floats to equilibrate in boundary current water, but deep enough to accommodate the ballast pressure. This allowed for release of floats at inshore, middle and offshore parts of the western boundary current at two pressure levels, with the inshore floats placed as close to the continental slope as possible without danger of grounding. In practice, the three deep floats in each seeding were deployed at the outer three stations 13, 14, and 15 of the Bonavista Line, and the three shallow floats were deployed at stations 12, 13, and 14 (Figure 2).

Float mission length was two years, so the complete sampling duration of the floats was from July 2003 through November 2008, when the last float seeding 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 floats. All single-release floats were launched using the 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 anchor weight to the float release.

4. Sound Source Array Design and Performance

The original sound source array consisted of four sound sources in a semi-circle around the Flemish Cap (Figure 1; sources A, B, C, and D). This allowed for complete isonification of the launch location, the boundary around Flemish Cap, and south to the Tail of the Grand Banks (TGB) as well as the interior Newfoundland Basin. Proposal funding only allowed for four sources, and this constraint did not allow for isonification to the south or west of the TGB, or for source redundancy. We acknowledged that the array design was sparse, and that we would have to rely on other institutions' sources to provide redundancy in the Labrador Sea (Figure 1; IM sources) and in the eastern North Atlantic (AG2, not shown). In November 2005, the CLIMODE sources were launched (Figure 1; CL sources), providing valuable additional coverage to the south and west of the TGB.

The four ExPath sources were moored in water between 2000 and 5000 meters, and placed at 1200 meters depth. All sources were 260 Hz open-ocean sources, with ranges estimated to be about 2000 km on average. Repetition rate for the sources was 24-hourly; signal length was 80 seconds. The four original sources (A-D) were purchased from Teledyne Webb Research Corp. (TWR), of Falmouth, MA. Table 2 in Appendix A summarizes the sound source information.

Source C failed approximately seven months after it was moored (the failure date was determined from float TOA data), in February 2004. As a result, tracking was lost south of the Flemish Cap along the continental slope, where only one working sound source could be heard. It was eight months after source deployment before we learned that source C had failed, when Autonomous Profiling Exporer floats owned by Leibniz-Institut für Meereswissenschaften (IFM-GEOMAR; Peter Brandt, Andreus Funk) no longer received signal from this source. To make certain of this, two short-mission floats were deployed southwest of the Flemish Cap in February 2004 by the Canadian Coast Guard (Figure 1). At this location, the floats were certain to receive signal from source C if it was still operating. The two test floats surfaced on March 9 and April 25, 2004; neither received the source's signal.

This particular sound source was one of a batch that had experienced a higher than average failure rate. Some sources deployed by Kevin Leaman at Rosenstiel School of Marine and Atmospheric Science (RSMAS) in the Gulf of Mexico and by Tom Rossby at University of Rhode Island (URI) in the eastern North Atlantic also failed after a similar time period. Two unsuccessful attempts were made to recover one of the Gulf of Mexico sources by RSMAS and WHOI/TWR. A second opportunity to recover a sound source from the bad batch came when WHOI received funding from the National Science Foundation to drag for ExPath source C and replace it with a refurbished "loud" (Sparton) sound source held by Tom Rossby at URI. In September 2004, George Tupper (WHOI) went out on the *R/V Endeavor* to deploy the replacement source, C2, and at the same time, drag for the original source C. This time, the drag attempt was successful. The source was shipped back to WHOI and with representatives from Seascan, Inc., URI, TWR and WHOI in attendance, the failed source was opened, and a small amount of salt water (less than one cup) was found inside the electronics pod of the source. The water had diffused through the pressure sensor diaphragm and corroded the electronics. [*]

Although C2 was heard by hydrophone from the ship immediately after deployment, this source flooded and failed after a single day, as discovered three months later when the next set of floats surfaced, in late November 2004. Again, tracking was lost in the critical zone south of the Flemish Cap. Fortunately, German colleagues working in the area on the French ship *N/O Thallassa* generously allowed us to deploy two sources in August 2005, the original C (now called C3) refurbished free of charge by TWR minus the problematic pressure switch, and a redundant source E, an experimental source built by Tom Rossby at URI (Figure 1). Both sources, along with the CLIMODE source array located southwest of the Grand Banks deployed in November 2005, finally provided good tracking for that critical region from August 2005 – November 2008. Tracking close to the slope south of Flemish Cap from late 2003 through August 2005 was not possible; therefore some track reconstruction from the single working source D was necessary in this region during this time (see Section 7 for details on track reconstruction).

The float duration chart (Figure 3) provides notes on the source history on the bottom axis, and specifically details when the sources affected tracking. Sound source A and the IM sources were difficult to pick up in the Labrador Sea in winter, due to deep winter mixing and breakdown of the

[*] The pressure sensors were made by Wasco, Inc., and the batch of sensors used in these sources had been modified at the factory in Germany. TWR had been informed that they performed exactly as they had in the last batch, but the design was not the same. The original sensors were stainless steel with a stainless diaphragm, and the new sensors had a kapton (plastic) diaphragm instead. Although TWR bench tested each pressure sensor and none failed, the long-term affect of seawater was catastrophic. The ExPath source C failed after approximately six months, and TWR concluded that the water was diffusing slowly through the kapton diaphragm, hence the slow failure mode, and lack of failures during bench testing. The amount of seawater was only a few centiliters inside the electronics pod ("the worst place for a leak"). TWR's remedy was to not use the pressure switch in future sound sources (Dan Webb, personal communication).

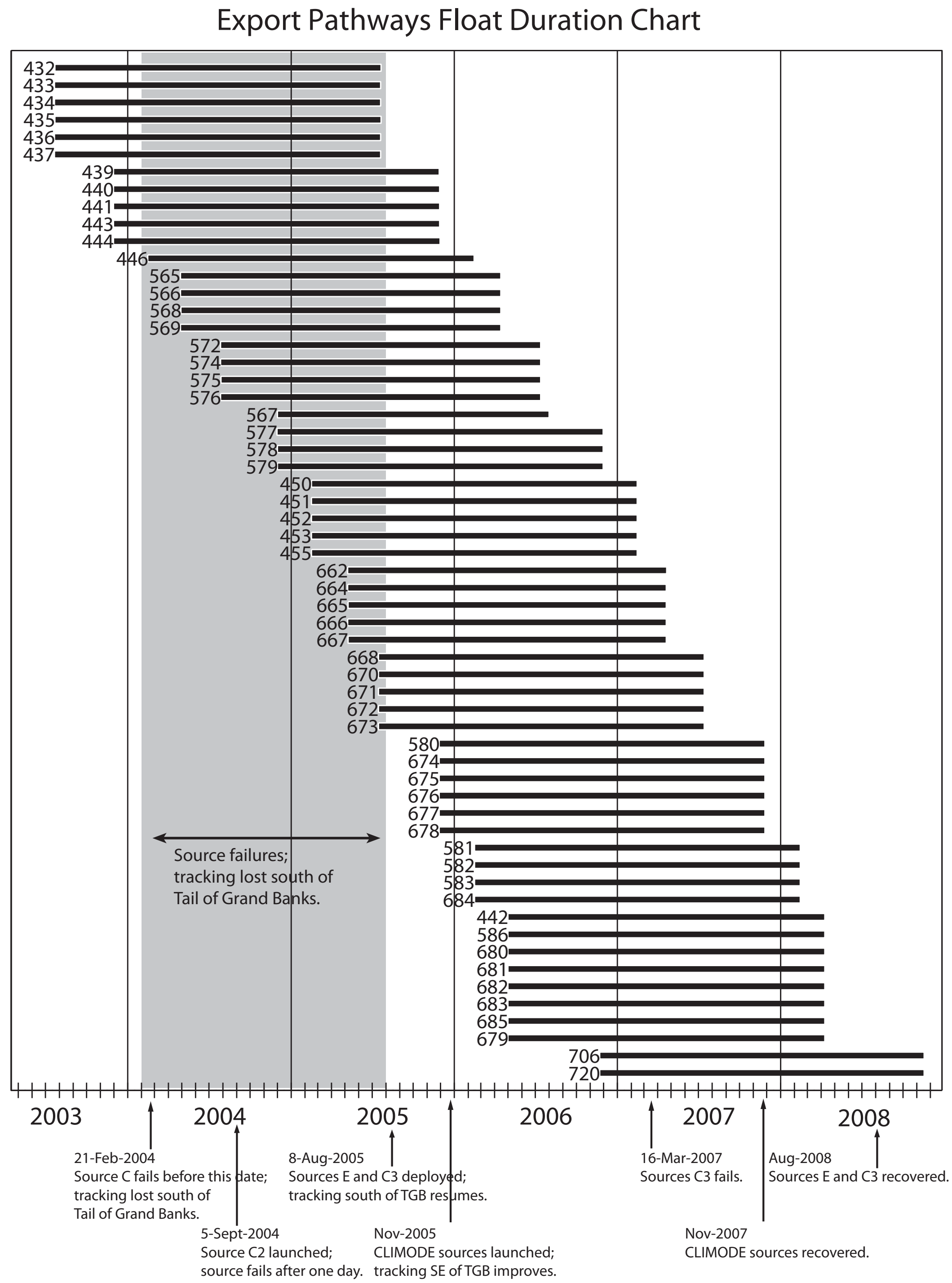


Figure 3: Bar graph showing duration of actual float mission length. Only floats that surfaced are shown. Float IDs are located on the left hand side of each bar, time on the x-axis. Notes on sound source failures and deployments are given below the x-axis.

thermocline. Tracking from the Bonavista Line launch to the Flemish Cap was very poor and often impossible from late November through March of each year. Tracking south of the Flemish Cap was limited by source availability from February 2004 through August 2005.

5. Float Performance

Seventy-six DLD2 floats were deployed from the Bonavista Line for two year (730-day) missions. (The two short-mission DLD2 test floats completed their missions successfully.) Out of seventy-six regular-mission floats deployed, 59 surfaced and 17 were “no-shows”. No-shows were weighted heavily in the dual-release category: Sixteen percent of single–release failed to surface, whereas 44% of dual-release failed to surface. Overall, 78% of floats that were launched surfaced. Although we attribute some of the February ‘no-shows’ to the less-than-ideal launching of the dual-release floats (release of the float and its anchor from the sea surface, after which both plummet rapidly to the sea floor), many floats were delivered to us with a burnwire insufficient for the oceanographic conditions (see Table 1 in Appendix A).[†] Due to this, we received five floats from Seascan, Inc., to replace the five floats lost with a 100 milliampere burnwire, and the thirteenth deployment of floats in November 2006 was made.

Of the 59 floats that surfaced, all but one (567) surfaced on time (see Table 1 in Appendix A). Two returned non-normal mission status, but this did not affect data return or quality. Two floats (583, 682) had broken hydrophones, so that T/P data were normal, but TOA data were noise. Two other floats (451, 455) were weak transmitters, and returned only a couple of data points each before quitting entirely. Float 580 returned good TOA data, but null T/P data. All other floats had data return over 98%, most were 100%. This yielded 55 useable trajectories for data analysis, or 72% good data. Initial and final float clock offsets were very small (Table 3 in Appendix A), on order of 0.0 seconds initial offset, and 0.8 seconds final offset, similar to the Red Sea Outflow Experiment (REDSOX), which also used DLD2 floats.

In general, ballasting of the floats was good, although almost all floats were slightly deeper than intended. Table 3 in Appendix A shows the ballasting performance for each float. Floats were ballasted for either the 700- or 1500-dbar pressure surface, and overall, settling in the first 24

[†] The burnwires on the DLD2 floats were originally specified to be 250 ma circuits. Unknown to us, Seascan, Inc., modified the circuit which limited the burnwire current to ~100 ma. Seascan, Inc., had gone to a surface mount circuit board, and the surface mount resistors could not dissipate the power required without failing, so the current was lowered. The burnwires were tested in the lab, and the wires burned within 22 minutes successfully. Later, however, the WHOI Float Lab heard that a group using DLD2 floats in cold water had a number of no shows and had attributed this to the burnwire. At that point, the Float Lab decided to parallel the resistor, doubling its power rating and increasing the current to 200 ma. Seascan, Inc, acknowledged that this was a design problem and replaced the floats under warranty. Floats released with 100 milliamp circuits are [662:667 453 571:579 648 649], Table 1. All other floats had either 250 ma burn wires, or burn wires modified to 200 ma, which is sufficient for cold weather oceanographic conditions (B. Guest, personal communication).

hours after launch was 28.0 dbars too deep. Ballasting was generally heavier in the dual-release and in the shallow floats, for unknown reasons. Dual release ballasting was twice as deep (49.2 dbars) as single release floats (24.0 dbars), similar to REDSOX dual- and single-release ballasting. Floats ballasted for 700 dbars were 46.9 dbars deep, whereas the 1500-dbar floats were only 7.0 dbars deep. One gram heavy is approximately equivalent to 25 decibars depth (B. Guest, personal communication). All floats for a cruise (whether single- or dual-release) were ballasted at the same time.

6. Sound Source Drift Calculations

Sound sources worked as expected except for source C, which failed and had to be replaced twice. In addition to the recovery of C, two sources were recovered in summer 2008, C3 and E (Straneo, 2008); final source clock value was not possible for C or C3 because the source had failed before recovery, and the final source clock offset for E was 48 seconds late. Sources A, B, and D were never recovered. Source C2, which failed after one day, was recovered, and had flooded. In calculating source clock drifts for the five sources (A, B, C, C3, and D), we used all available floats, 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 24 hours (one record) after launch or before surface. In the end, 38 floats were used, with some floats yielding drift estimates both at launch and surface. A sound velocity of 1.500 km/s was used in calculation, a nominal value – the intercept of the drift fit was not fixed to zero, but let float, so that any sound velocity difference would be a uniform offset. Only the drifts from the sound source drift estimates were used in tracking, not the calculated offsets. All source clocks were checked at deployment, and all had zero offset.

7. Float Data Processing and Tracking

The floats were tracked using ARTOA3 software (Boebel et al. 2005; Wooding et al. 2005) which is maintained at WHOI (http://www.whoi.edu/science/PO/rafos/). ARTOA3, which runs on MATLAB, was used to process the data from CLS America; edit the temperature, pressure and TOA data; and to track the floats. The TOAs were corrected for the Doppler shift and difference in transmission time, then interpolated using variable width (usually 10-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 varied for each source used. The best fit for sound velocity was 1.480 km/sec for sources in the cold Labrador Basin (sources A, IM15, and IM20), and 1.495 km/sec for those sources in the comparatively warmer Newfoundland Basin (B, all C sources, D, E, and the CL sources). We tested several velocity estimates (del Grosso, linear, and several static estimates) to ensure that using sound velocity based on source location was the best fit by checking the first and last track positions against the recorded launch and surface positions, and also the continuity of track at the ‘combination change’ points, the points where trajectory points were calculated using one set of sources shifted to another set of sources. If the source-specific sound velocity (or source drifts) were inaccurate, the trajectory would show a discontinuity at that point, mid-trajectory.

One challenge to float processing in this experiment was the hexidecimal to decimal data processing. Because we purchased the floats in several batches over a five year period from Seascan, Inc., and data delivery occurred over a five year period, unexpected changes were made to both raw data format programmed at Seascan, Inc., and transmitted data packaged by CLS America. The difficulty came when we expected one data format but received something different without notification (e.g., we specified that the floats be programmed with a 12-bit delay, or TOA, but in fact some floats had a 15-bit delay). These changes were difficult to decipher when not expected. Table 4 in Appendix A details the many forms the data took, and how each needed to be treated.

Floats x679 and x684 were mis-programmed with the same PTTID (50673), and raw data had to be separated to track the float that surfaced later in time, float x679. This was only possible due to the fact that x679 was programmed (not by our specifications) to have a different data format, a 15-bit delay instead of the expected 12-bit delay. This allowed us to separate the raw data by hex character criteria. We were unable to separate status data until after processing, and split the status messages by different release T/P data. CLS America received signals from both floats at the same time, so that raw data from both floats were in a packet with a surface fix related only to one of the two floats transmitting. Surface fixes were separated by a visual assessment of the locations on a map, and that criterion being used to bin the surface data. The later float, x679, was the weaker transmitter, even after x684 had been transmitting for 55 days (April 9th –

February 15th, 2007).

Tracking was challenging in this experiment due to the failures of sound source C (Table 2 in Appendix A, Section 4). This source was in a critical location for tracking, east of the Grand Banks, and tracking near the continental slope was not possible south of Flemish Cap when this source was unavailable. During the period fall 2003 – August 2005 (see Figure 3), we reconstructed trajectories from the TOAs received from the single source D for the floats that appeared to follow close to the boundary, floats x565, x568, and x666. Figure 4 illustrates the

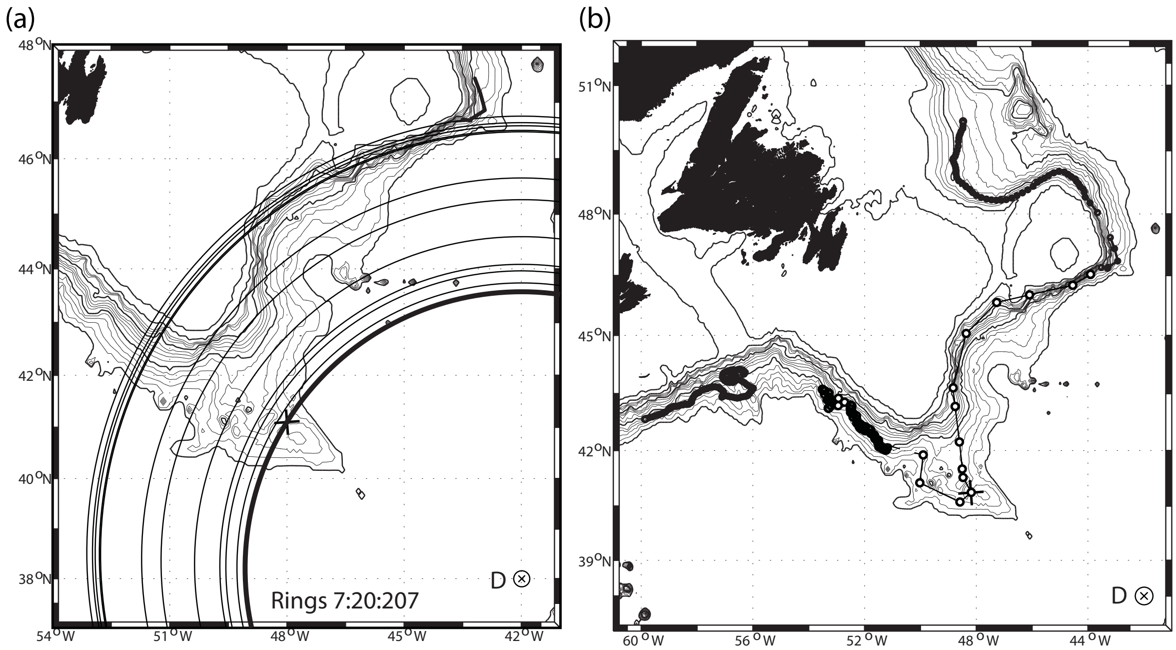


Figure 4: Trajectory reconstruction of float x568. (a) Range circles from TOAs from source D plotted incrementally from the last tracked point at the southeast corner of the Flemish Cap, to the closest point between the float and source D, marked with an ‘X’. Range circles are plotted on the seventh point between the last traditionally tracked point, and every 20th circle thereafter to the closest point. (b) The resultant trajectory. Solid black points are tracked traditionally, open circles are those points chosen using the single source TOAs. Solid line connects the points along the track just in the reconstructed segment. The track corresponding to the range circles plotted in (a) are those between the SE corner of the Flemish Cap and the ‘X’. On both plots, the 200-, 1000-, 2000-, 3000- and 4000-m isobaths are contoured in bold, thin lines are contoured every 200 meters from 1000-m to the 4000-m isobath. The location of sound source D is marked as a circle-x. See text for further details.

process of trajectory reconstruction for float x568. Range circles were calculated for the TOAs for source D, the one available source, using a sound speed of 1.477 m/s, a value used in tracking other floats in this region. The intersection of the circle and the last known bathymetric contour (3000 meters for floats x565 and x568, and 1000 meters for float x666) closest to the last tracked position was chosen as the next point. A limiting criterion that the float speed between points be not more that 50 km/day, chosen from looking at speeds of other floats in the area, was imposed as well. New points were identified using MATLAB programs written to follow the algorithm outlined above. When that algorithm failed (when the bathymetric data became too complex), points were chosen manually using the MATLAB 'ginput.m' function, also following the criteria specified above.

Appendix A contains tables. Appendix B contains the composite displacement vector and trajectory diagrams, and a trajectory gallery organized by setting and cross-shelf deployment position. Appendix C 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.

Acknowledgements

The authors thank the captains and crew of the *CSS Teleost* and *Hudson*, *N/O Thallassa*, and *R/V Oceanus* for their able assistance in carrying out this sea-going experiment. We are indebted to the Northwest Atlantic Fisheries Centre and Dr. Eugene Colburne for deploying floats on nine cruises, and to Jürgen Fischer (IFM-GEOMAR) for generously contributing some ship time for sound source replacement. WHOI engineers Jim Valdes, Brian Guest, Rick Rupan, and Bob Tavares are gratefully acknowledged for the preparation, ballasting, and deployment of the floats. Special thanks to WHOI engineer George Tupper for mooring replacement sources and recovering sound source C. ExPath was funded by the National Science Foundation under Grant Numbers OCE-0136215 and OCE-0824652 to the Woods Hole Oceanographic Institution.

References

Boebel, O., H. Furey, S. Anderson-Fontana, C. Schmitt, and M. Menzel, 2005. ARTOA: Advanced RAFOS Float Tracking Software, Version 3, www.whoi.edu/science/PO/rafos/.

Bower, A., and S. Lozier, 2003. Export Pathways from the Subpolar North Atlantic Ocean: *R/V Oceanus* Cruise OC 395-2, July 9-23, 2003.

Straneo, F., 2008. Cruise Report KN-194-1, *R/V Knorr* Cruise KN-194-1, August 12-29, 2008.

Rossby, T., D. Dorson, and J. Fontaine, 1986. The RAFOS system. *J. Atmos. Oceanic Technol.*, **3**, 672-679.

Tupper, G., 2005. Export Pathways – *N/O Thalassa* Cruise Report, August 13, 2003.

Wooding, C., H. Furey, and M. Pacheco, 2005. RAFOS Float Processing at the Woods Hole Oceanographic Institution. *Woods Hole Oceanographic Institution, Technical Report WHOI-05-02*, Woods Hole, Massachusetts, 35 pp.

Wooding, C. M., P. L. Richardson, M. A. Pacheco, D. A. Glickson, and D. M. Fratantoni, 2002. North Brazil Current Rings Experiment: RAFOS Float Data Report: November 1998 - June 2000. *Woods Hole Oceanographic Institution, Technical Report WHOI-2002-08,* Woods Hole, Massachusetts, 96 pp.

Zenk, W., A. Pinck, S. Becker, and P. Tillier, 2000. The Float Park: A new tool for a cost-effective collection of Lagrangian time series with dual release RAFOS floats. *J. Atmos. Oceanic Technol.*, **17**, 1439-1443.

Appendix A

Tables include Float Summary, Sound Source Summary, Float Ballasting and Clock Performance, and Float Processing Summary.

Table 1. Float Summary

Float ID / PTTID	Ballast Depth (m)	Reset date (mission start, yymmdd)	Launch Date (yymmdd)	Launch Location (˚N,˚W)	Surface Date (yymmdd)	Surface Location (˚N, ˚W)	Status Code (SyStat)
Setting 1 : July 2003 - July 2005							
432/24558	700	030722	030722	49.836 -49.508	050721	48.529 -37.755	0
433/24670	700	030721	030721	50.009 -48.975	050720	33.539 -51.460	0
434/24671	700	030721	030721	50.154 -48.449	050720	52.511 -41.441	0
435/24672	1500	030722	030722	50.010 -48.975	050721	53.078 -41.015	0
436/24710	1500	030721	030721	50.154 -48.449	050720	53.291 -41.442	0
437/24711	1500	030721	030721	50.330 -47.927	050720	41.551 -41.856	0
Setting 2 : November 2003 - November 2005							
439/24732	700	031130	031130	49.899 -49.511	051129	51.485 -25.227	0
440/24747	700	031130	031130	50.000 -48.994	051129	37.105 -36.620	0
441/24785	700	031130	031130	50.189 -48.449	051129	42.057 -40.997	0
442/24787	1500	Hydrophone broken in shipment, sent back to WHOI, not deployed.					
443/24788	1500	031130	031130	50.186 -48.447	051129	53.240 -32.671	2
444/24909	1500	031130	031130	50.328 -47.939	051129	42.509 -46.317	0
Setting 3 : February 2004 - February 2006							
438/24712	700	040215	031130	49.899 -49.511	No show.		
445/24927	1500	040215	031130	50.000 -48.994	No show.		
446/25007	700	040215	031130	50.000 -48.994	060214	51.138 -44.908	0
447/25080	700	040215	031130	50.190 -48.450	No show.		
448/25082	1500	040215	031130	50.188 -48.448	No show.		
449/25242	1500	040215	031130	50.328 -47.939	No show.		
Short-mission test floats launched to listen for Sound Source C.							
563/25282	700	040218	040218	45.362 -48.500	040425	40.909 -50.875	0
564/25316	700	040218	040218	45.315 -48.467	040309	42.845 -49.473	0
Setting 4 : April 2004 - April 2006							
565/25460	700	040416	040428	49.850 -49.499	060415	37.865 -51.360	0
566/25478	1500	040416	040428	49.998 -48.994	060415	39.837 -46.812	0
567/25479	1500	Hydrophone broken in shipment, sent back to WHOI, not deployed.					
568/25481	1500	040416	040429	50.182 -48.470	060415	42.830 -59.858	0
569/25484	700	040416	040428	49.998 -48.994	060415	53.004 -24.938	0
570/25506	700	040416	040429	50.181 -48.471	No show.		
Setting 5 : July 2004 - July 2006							
571/25508	1500	040714	040727	50.335 -47.938	No show. €		
572/25544	1500	040714	040727	50.147 -48.473	060713	49.743 -28.060	0, €
573/25551	700	040714	040727	50.147 -48.475	No show. €		
574/37542	700	040714	040727	50.001 -48.997	060713	51.897 -31.210	0, €
575/37543	700	040714	040728	49.854 -49.495	060713	49.272 -32.250	0, €
576/37544	1500	040714	040727	50.001 -48.996	060713	49.455 -20.470	0, €
Setting 6 : November 2004 - November 2006							
567/25479	1500	041130	041130	50.002 -49.000	060801	51.586 -35.607	36, *
577/37546	700	041130	041130	49.847 -49.496	061129	45.131 -37.189	0, €
578/37553	700	041201	041201	50.175 -48.476	061130	51.719 -41.799	0, €
579/37558	700	041201	041201	50.002 -48.999	061130	47.885 -33.194	0, €
648/37560	1500	041201	041201	50.175 -48.475	No show. €		
649/37561	1500	041130	041201	50.330 -47.947	No show. €		
Setting 7 : February 2005 - February 2007							
450/37545	1500	041201	050215	50.331 -47.746	070214	50.139 -44.101	0
451/37567	700	041201	050215	50.176 -48.473	070214	48.564 -38.624	0, £
452/37564	1500	041201	050215	50.176 -48.474	070214	48.564 -38.624	?
453/37565	700	041201	050215	50.001 -48.999	070214	54.174 -47.732	0, €
454/37562	1500	041201	050215	50.000 -48.999	No show.		
455/37568	700	041130	050215	49.847 -49.494	070214	42.548 -24.370	?, £

Setting 8 : April 2005 - April 2007							
662/39897	700	050421	050507	49.847 -49.496	070420	47.442 -29.288	0, €
663/39898	1500	050421	050508	50.332 -47.946	No show. €		
664/39899	1500	050421	050507	49.998 -49.001	070420	32.799 -51.040	0, €
665/39901	1500	050421	050508	50.147 -48.473	070420	54.671 -42.092	0, €
666/39902	700	050421	050507	49.999 -48.999	070420	48.687 -32.576	0, €
667/39904	700	050421	050508	50.147 -48.473	070420	35.816 -74.762	0, €
Setting 9 : July 2005 - July 2007							
668/39905	700	050715	050715	50.143 -48.472	070714	50.325 -29.365	0
669/50101	700	050715	050715	50.000 -49.000	No show.		
670/50660	700	050715	050715	49.847 -49.502	070714	52.793 -44.542	0
671/50661	1500	050715	050715	50.333 -47.948	070714	43.674 -53.508	0
672/50662	1500	050715	050715	50.193 -48.472	070714	51.689 -42.446	0
673/50663	1500	050715	050715	50.000 -49.000	070714	36.824 -44.269	0
Setting 10 : November 2005 - November 2007							
580/37559	700	051128	051128	50.177 -48.472	071127	42.067 -37.625	0, §
674/50668	700	051128	051128	49.850 -49.499	071127	31.239 -50.645	0, +
675/50669	700	051128	051128	50.000 -48.999	071127	50.611 -36.911	0
676/50670	1500	051128	051128	50.000 -48.999	071127	37.624 -51.219	0
677/50671	1500	051128	051128	50.177 -48.472	071127	50.951 -35.008	0
678/50672	1500	051128	051128	50.332 -47.947	071127	51.085 -34.027	0
Setting 11 : February 2006 - February 2008							
581/37570	700	051130	060215	49.850 -49.499	080214	37.198 -59.872	0
582/50664	700	051130	060215	50.177 -48.472	080214	36.578 -47.738	0
583/50665	700	051130	060215	50.000 -48.999	080214	36.854 -65.905	0, ¥
584/50666	1500	051130	060215	50.000 -48.999	No show.		
585/50667	1500	051130	060215	50.332 -47.947	No show.		
684/50673	1500	051130	060215	50.177 -48.472	080214	55.753 -49.625	0
Setting 12 : April 2006 - April 2008							
442/24787	700	060410	060501	49.850 -49.500	080409	38.300 -68.178	0
586/25316	700	060410	060501	49.850 -49.500	080409	40.851 -56.600	0
679/50673	1500	060410	060501	50.001 -48.995	080409	56.995 -45.864	0
680/50675	700	060410	060501	50.002 -48.993	080409	36.133 -43.199	0, +
681/50676	1500	060410	060501	50.001 -48.994	080409	46.893 -32.903	0,
682/50677	1500	060410	060501	50.176 -48.473	080409	43.534 -54.990	0, ¥
683/25282	1500	060410	060501	50.331 -47.949	080409	53.578 -47.394	0
685/50674	700	060410	060501	50.176 -48.472	080409	52.290 -47.513	0
Setting 13 : November 2006 - November 2008							
706/72419	1500	061117	061122	49.998 -48.962	081115	45.973 -33.829	0
719/72420	700	Hydrophone broken in shipment, sent back to WHOI, not deployed.					
720/72421	1500	061117	061122	49.998 -48.957	081115	47.083 -30.956	0
721/72422	700	061117	061122	50.171 -48.432	No show.		
722/72423	1500	061117	061122	50.297 -47.914	No show.		

0 normal;
2 receiver module failed to address at least once;
36 (32+4) low-battery fault condition, PTMOD failed to address at least once;
*(567, Setting 6) early riser;
£ (451, 455) not enough TOA data to track;
§ (580) null T/P;
¥ (583, 682) broken hydrophone, no track;
+ other system status codes received, but data quality not affected;
? no status message received;
€ 100 milliamp burnwire.

Table 2. Sound Sources

	Moored	Pong schedule (GMT)	Depth (m)	Location (˚N, ˚W)	Drift (sec/day)	Comments
A	18-Jul-03	01:30	1200	56.759, -48.017	0.000*	Eurofloat name 'M4' (http://www.ifremer.fr/lpo/eurofloat); Webb source.
B	16-Jul-03	01:00	1200	53.496, -37.003	0.053	‘M5'; Webb source.
C	14-Jul-03	03:00	1200	45.010, -35.992	0.055	‘M6’; Webb source; Failed February 2004; Recovered September 2004.
C2	5-Sep-04	01:30	1200	45.135, -36.002	n/a	Refurbished Rossby ‘loud’ source; Failed within 24 hours.
C3	8-Aug-05	01:30	1200	45.000, -35.969	0.016	'M6A'; Webb source; Launched from *N/O Thalassa*; Failed 16-Mar-2007; Recovered August 2008.
D	12-Jul-03	02:00	1200	37.999, -41.989	0.044	‘M7'; Webb source.
E	8-Aug-05	02:30	1200	43.504, -40.009	0.010	‘M8'; Rossby ‘experimental’ source; Recovered 18 August 2008; Drift calculated from final source clock offset (48 sec).

*Sign convention of these drifts are late source clock yields a positive drift (corrective) value.

Table 3. Float Ballasting & Clock Accuracy

Float ID	Ballast Depth (m)	Float Initial Pressure (dbars)*	Δ Pressure (dbars)	Initial Float Clock Offset** (seconds)	Final Float Clock Offset (seconds)
Setting 1 : July 2003 – July 2005					
432	700	686.0	-14.0	0.0	-0.4
433	700	682.0	-18.0	0.0	0.0
434	700	711.0	11.0	0.0	0.0
435	1500	1463.0	-37.0	0.0	0.0
436	1500	1478.0	-22.0	0.0	0.7
437	1500	1433.0	-67.0	0.0	0.0
Setting 2 : November 2003 – November 2005					
439	700	779.0	79.0	0.0	-0.9
440	700	754.0	54.0	0.0	0.0
441	700	722.0	22.0	0.0	0.0
443	1500	1526.0	26.0	0.0	0.0
444	1500	1478.0	-22.0	0.0	1.1
Setting 3 : February 2004 – February 2006					
446	700	762.5	62.5	0.0	0.0
Setting 4 : April 2004 – April 2006					
565	700	778.6	78.6	0.0	2.1
566	1500	1482.7	-17.3	0.0	3.1
568	1500	1557.8	57.8	0.0	3.1
569	700	778.6	78.6	0.0	2.1
Setting 5 : July 2004 – July 2006					
572	1500	1515.8	15.8	0.0	0.0
574	700	809.3	109.3	0.0	2.6
575	700	762.0	62.0	0.0	1.9
576	1500	1591.7	91.7	0.0	2.2
Setting 6 : November 2004 – November 2006					
567	1500	1650.4	150.4	0.0	0.0
577	700	766.0	66.0	0.0	1.3
578	700	753.6	53.6	-0.5	0.0
579	700	764.6	64.6	-0.5	0.0
Setting 7 : February 2005 – February 2007					
450	1500	1515.4	15.4	-0.5	0.0
451	700	n/a	n/a	-0.5	4.1
452	1500	1528.4	28.4	-0.5	0.0
453	700	773.2	73.2	0.0	0.0
455	700	768.1	68.1	0.0	0.0
Setting 8 : April 2005 – April 2007					
662	700	741.4	41.4	0.0	2.1
664	1500	1463.2	-36.8	0.0	2.1
665	1500	1489.5	-10.5	0.0	1.1
666	700	743.0	43.0	0.0	2.1
667	700	738.4	38.4	0.0	0.1
Setting 9 : July 2005 – July 2007					
668	700	712.0	12.0	0.0	3.1
670	700	725.8	25.8	0.0	3.1
671	1500	1371.2	-128.8	0.0	0.0
672	1500	1471.7	-28.3	0.0	2.1
673	1500	1464.7	-35.3	0.0	0.1

Table 3. Float Ballasting & Clock Accuracy (continued)

Float ID	Ballast Depth (m)	Float Initial Pressure (dbars)*	Δ Pressure (dbars)	Initial Float Clock Offset** (seconds)	Final Float Clock Offset (seconds)
Setting 10 : November 2005 – November 2007					
580	700	n/a	n/a	0.0	1.1
674	700	743.9	43.9	0.0	-0.9
675	700	730.7	30.7	0.0	2.1
676	1500	1530.6	30.6	0.0	0.0
677	1500	1567.1	67.1	0.0	0.1
678	1500	1526.5	26.5	0.0	0.1
Setting 11 : February 2006 – February 2008					
581	700	745.0	45.0	0.0	0.0
582	700	743.0	43.0	0.0	0.0
583	700	817.3	117.3	0.0	0.0
684	1500	1489.5	-10.5	0.0	0.0
Setting 12 : April 2006 – April 2008					
442	700	713.5	13.5	0.0	0.1
586	700	738.3	38.3	0.0	0.0
679	1500	1549.2	49.2	0.0	2.1
680	700	742.5	42.5	0.0	0.1
681	1500	1532.4	32.4	0.0	1.1
682	1500	1530.9	30.9	0.0	1.1
683	1500	1452.6	-47.4	0.0	2.1
685	700	720.2	20.2	0.0	-1.9
Setting 13 : November 2006 – November 2008					
706	1500	1406.8	-93.2	0.0	0.1
720	1500	1621.5	121.5	0.0	3.1

Mean pressure =	28.0 dbars deep
Mean 1500 pressure =	7.0 dbars deep
Mean 700 pressure =	46.9 dbars deep
Mean dual-release pressure =	49.2 dbars deep
Mean single-release pressure =	24.0 dbars deep
Mean initial float clock offset =	0.0 seconds**
Mean final float clock offset =	0.8 seconds

* From first available pressure record.

** Positive offset means float clock is late.

Table 4. Float Processing Summary

Float ID	Window start times (GMT)	# Corr/TOA pairs per window; window length.	Bit structure; processing notes.
Setting 1 : July 2003 - July 2005			
432:437	01:00, 01:30, 02:00, 02:30, 03:00	One corr/TOA pair per window, five windows; 22-minute window length. Unexpected change from Seascan, Inc. We requested modification to 2 corr/TOA pairs per window for all other shipments of floats.	These floats have 20-bit IDs, but have the new CRC – processed using newarg02.m. All dropped hex characters in ADS data needed to be padded with zeros for processing. Expected parsing pattern.
Setting 2 : November 2003 - November 2005			
439:444	As in Setting 1.	Two corr/TOA pair per window, five windows; 22-minute window length.	As in Setting 1.
Setting 3 : February 2004 - February 2006			
438, 445:449	As in Setting 1.	As in Setting 2.	As in Setting 1.
Short-mission test floats launched to listen for Sound Source C.			
563, 564	As in Setting 1.	Set as in Setting 2.	As in Setting 1.
Setting 4 : April 2004 - April 2006			
565:570	As in Setting 1.	Set as in Setting 2.	Floats have 20-bit IDs, new CRC. Data format from CLS America now padded with zeros for processing. (We did not request this change.) No padding needed. Expected parsing pattern.
Setting 5 : July 2004 - July 2006			
571:576	As in Setting 1.	Set as in Setting 2.	28-bit ID, new CRC. Do not pad. Expected parsing pattern.
Setting 6 : November 2004 - November 2006			
567, 577, 579, 648:649	As in Setting 1.	Set as in Setting 2.	28-bit ID, new CRC. Do not pad. Expected parsing pattern.
Setting 7 : February 2005 - February 2007			
450:455	As in Setting 1.	Set as in Setting 2.	28-bit ID, new CRC. Do not pad. Expected parsing pattern.
Setting 8 : April 2005 - April 2007			
662:667	00:30, 01:00, 01:30, 02:00, 02:30. Windows shifted to take advantage of CLIMODE sources.	Set as in Setting 2.	28-bit ID, new CRC. Do not pad. Expected parsing pattern.
Setting 9 : July 2005 - July 2007			
668, 670:673	As in Setting 8.	Two corr/TOA pairs per window, 5 windows for all. 668 has 22-min window length as expected, but 25 min window length for 670:673; unrequested change from Seascan.	28-bit ID, new CRC. Do not pad. Expected parsing pattern for 668. Parsing pattern is 3-bit correlations, 15-bit delay for 670:673.
Setting 10 : November 2005 - November 2007			
580, 674:678	As in Setting 8.	All have two corr/TOA pairs per window, 5 windows. 580 retains 22-min window length; 674:678 have 25-min window (delay).	28-bit ID, new CRC. Do not pad. 580 has 3-bit correlation, 12-bit delay; 674: 678 has 3-bit correlation, 15-bit delay.
Setting 11 : February 2006 - February 2008			
581:585, 684	As in Setting 8.	As in Setting2.	28-bit ID, new CRC. Do not pad. Expected parsing pattern.
Setting 12 : April 2006 - April 2008			
442, 586, 679:683, 685	As in Setting 8.	All have two corr/TOA pairs per window, 5 windows. All floats retain 22-min window length, except for 679, which has 25-min window (delay).	Floats 442, 586, and 685 were recycled from earlier deployments, so have 20-bit IDs and new CRC; pad as in Setting 1. All others are 28-bit; new CRC; do not pad. All use newarg02.m, but different data structure option within each. Flt 679 has 15-bit delay; all others have 12-bit delay.
Setting 13 : November 2006 - November 2008			
706, 719:722	As in Setting 8.	Two corr/TOA pairs per window, 5 windows. All flts have 25-min window.	28-bit ID, new CRC. Do not pad. All flts have 15-bit delay.

Appendix B

The following figures show the ExPath DLD2 float data in various formats: composite displacement vector diagrams for 700-dbar floats (Figure B1) and for 1500-dbar floats (Figure B2); composite float trajectory diagrams for 700-dbar floats (Figure B3) and for the 1500-dbar floats (Figure B4); and a float trajectory gallery where floats are organized in order of cross-shelf position launched, with one setting (deployment) per page (Figures B5-B17).

Plot bathymetry is contoured at 1000-meter intervals to 4000 meters depth. Untrackable segments of trajectory are drawn with a dashed line. Launch position is marked with a circle-x; surface with a circle-dot. Three floats, x565, x568, and x666, contain segments of track that were constructed from TOAs from a single source. See text for a description of method used. In these three cases, the calculated positions are marked with open triangles, to distinguish them from points derived from the least-squares method and multiple TOAs. In the float setting gallery, subplot titles are as follows: ‘x442 / 12_700_1’ refers to float ID x442, the 12th setting (deployment), 700-dbar ballast pressure, and cross-shelf position 1 (see Figure 2 in text).

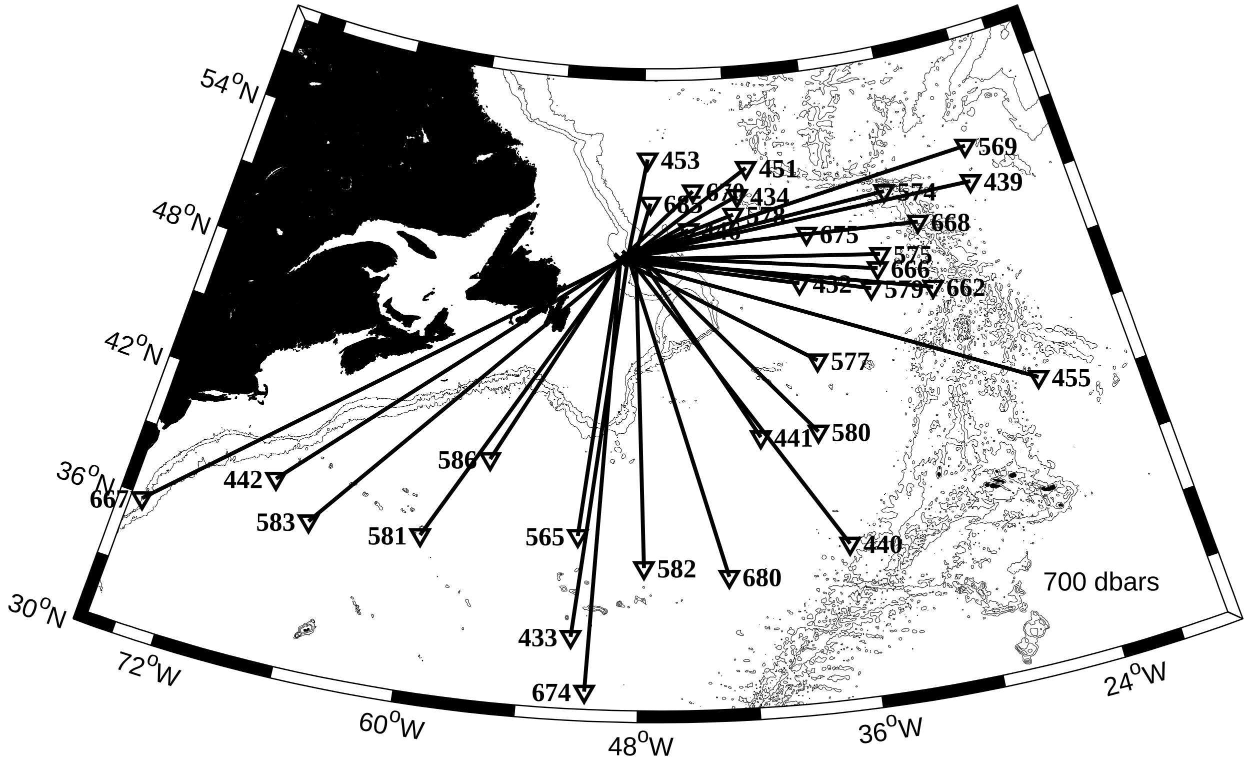


Figure B1: Displacement vectors for 700-dbar floats. Float numbers are placed at surface positions (triangles).

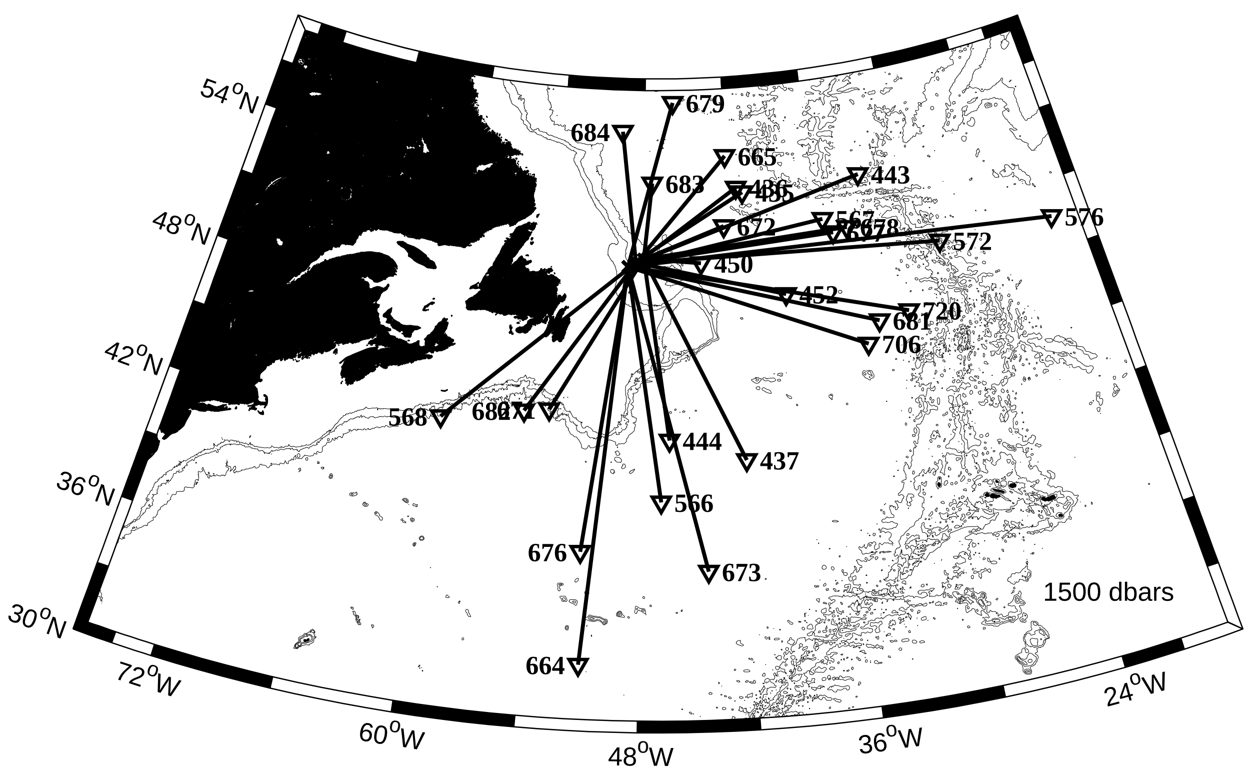


Figure B2: As in Figure B1, but for 1500-dbar floats.

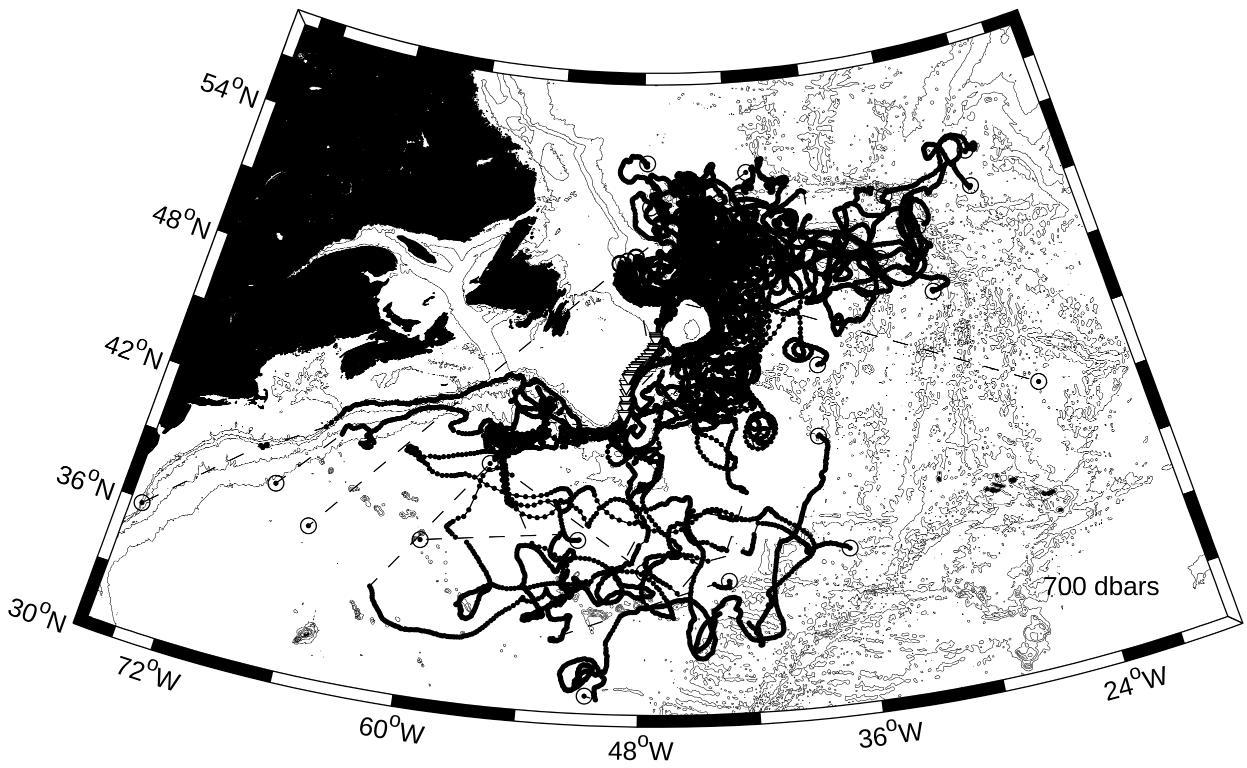


Figure B3: Trajectories for 700-dbar floats. See Appendix B summary for plot details.

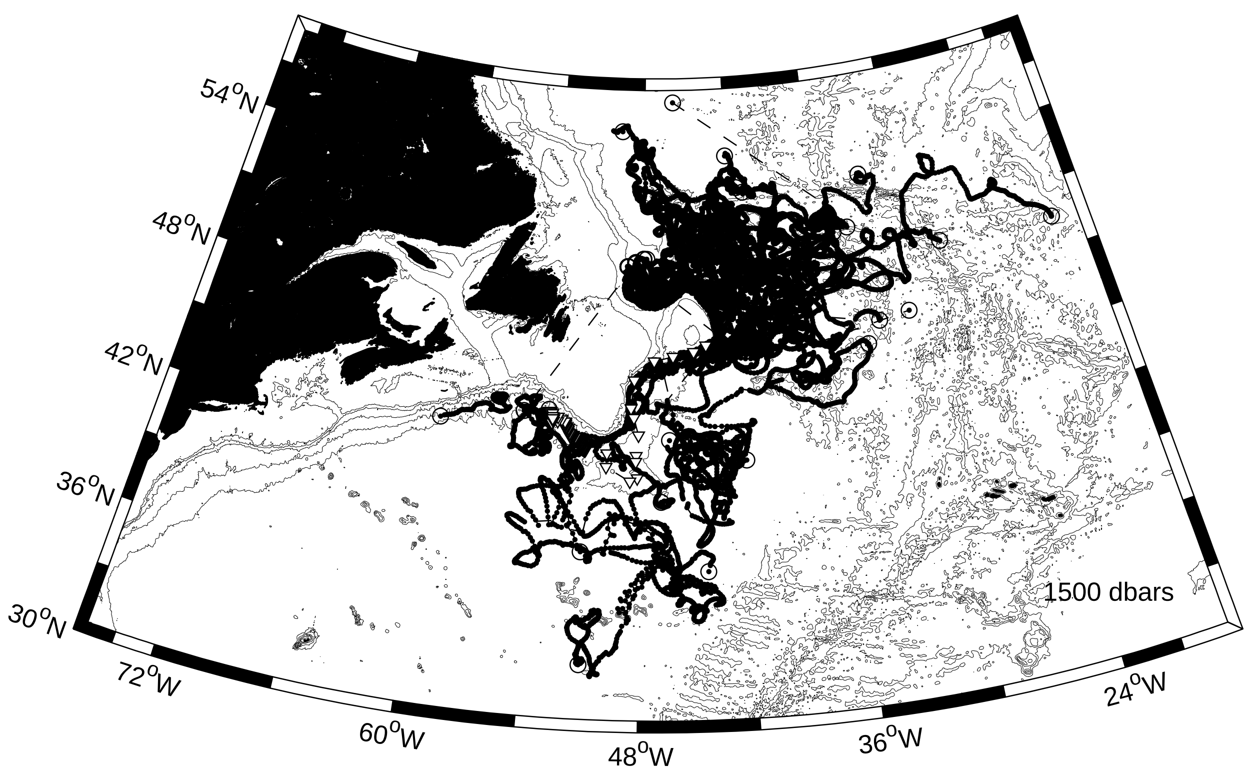


Figure B4: As in Figure B3, but for 1500-dbar floats.

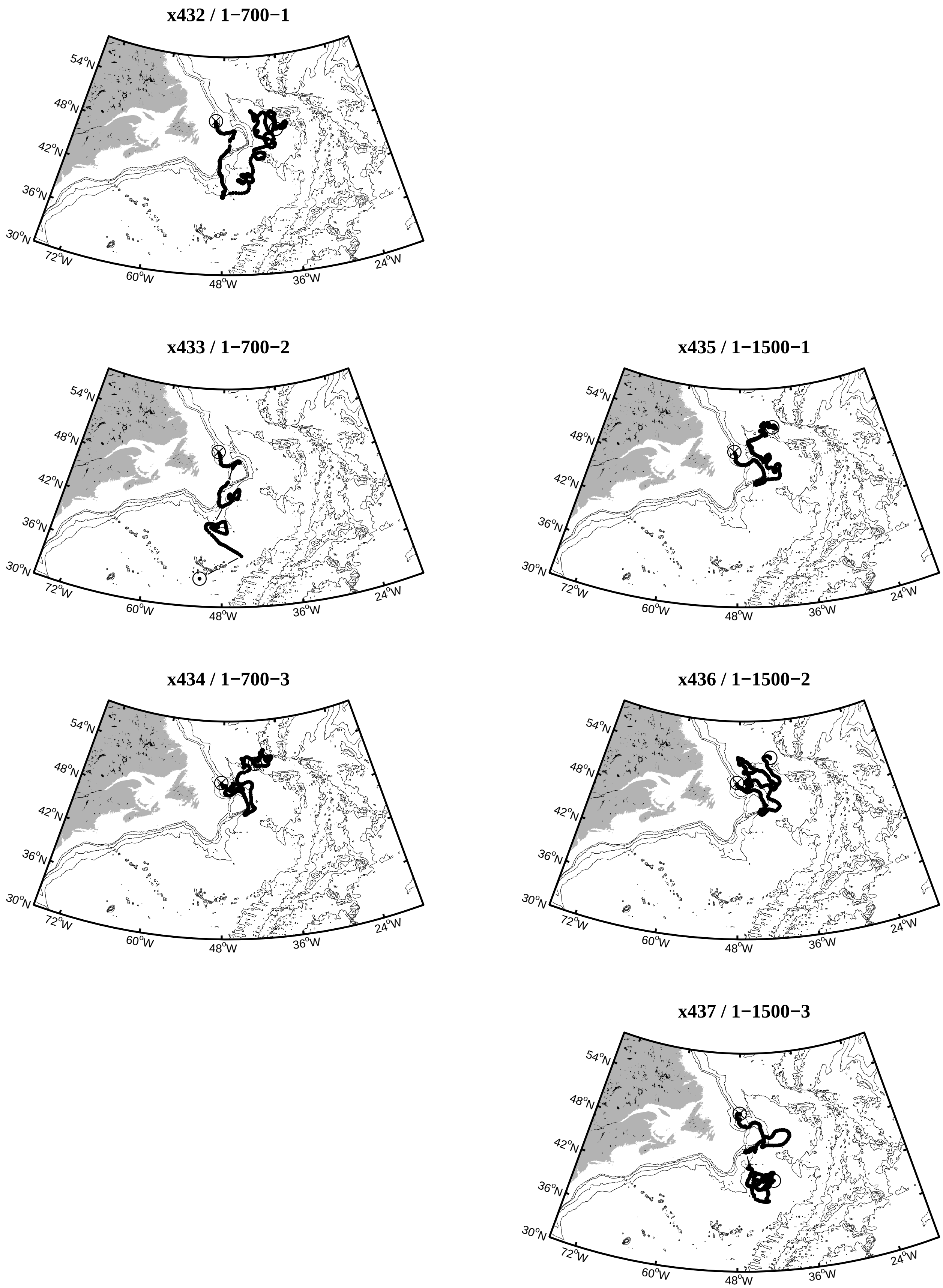


Figure B5: Setting 1 float trajectories, July 2003 – July 2005. See Appendix B summary for plot details.

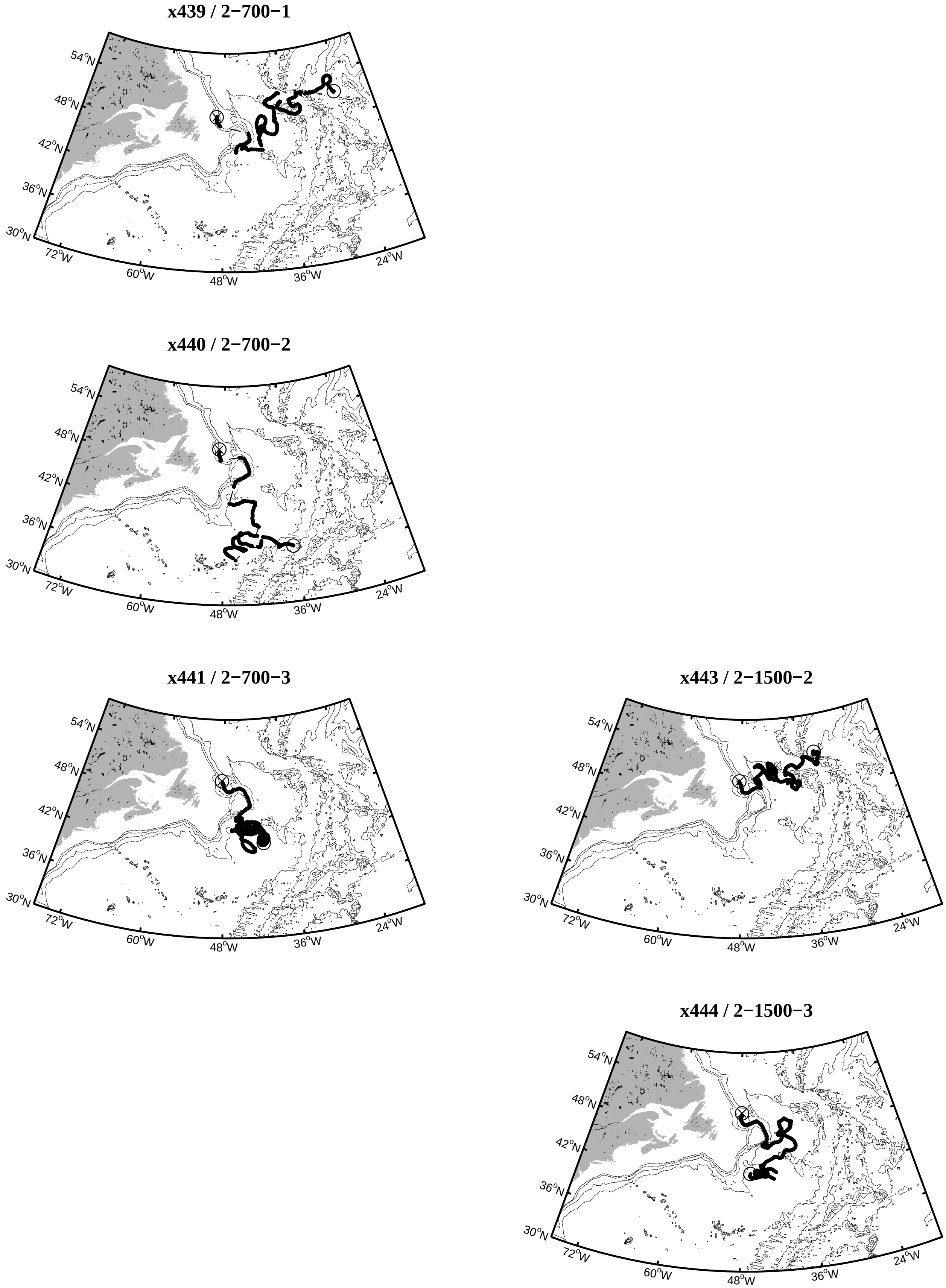


Figure B6. Setting 2 float trajectories, November 2003 – November 2005.

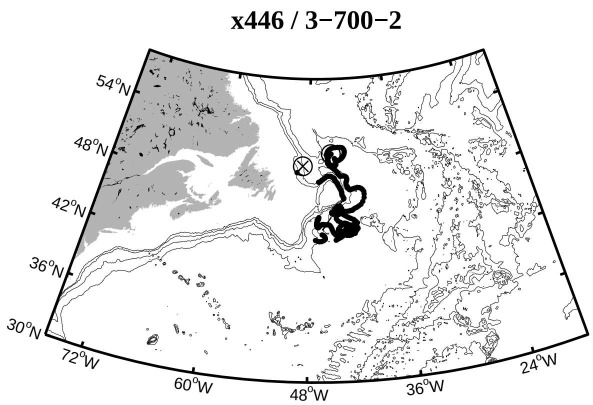


Figure B7. Setting 3 float trajectory, February 2004 – February 2006.

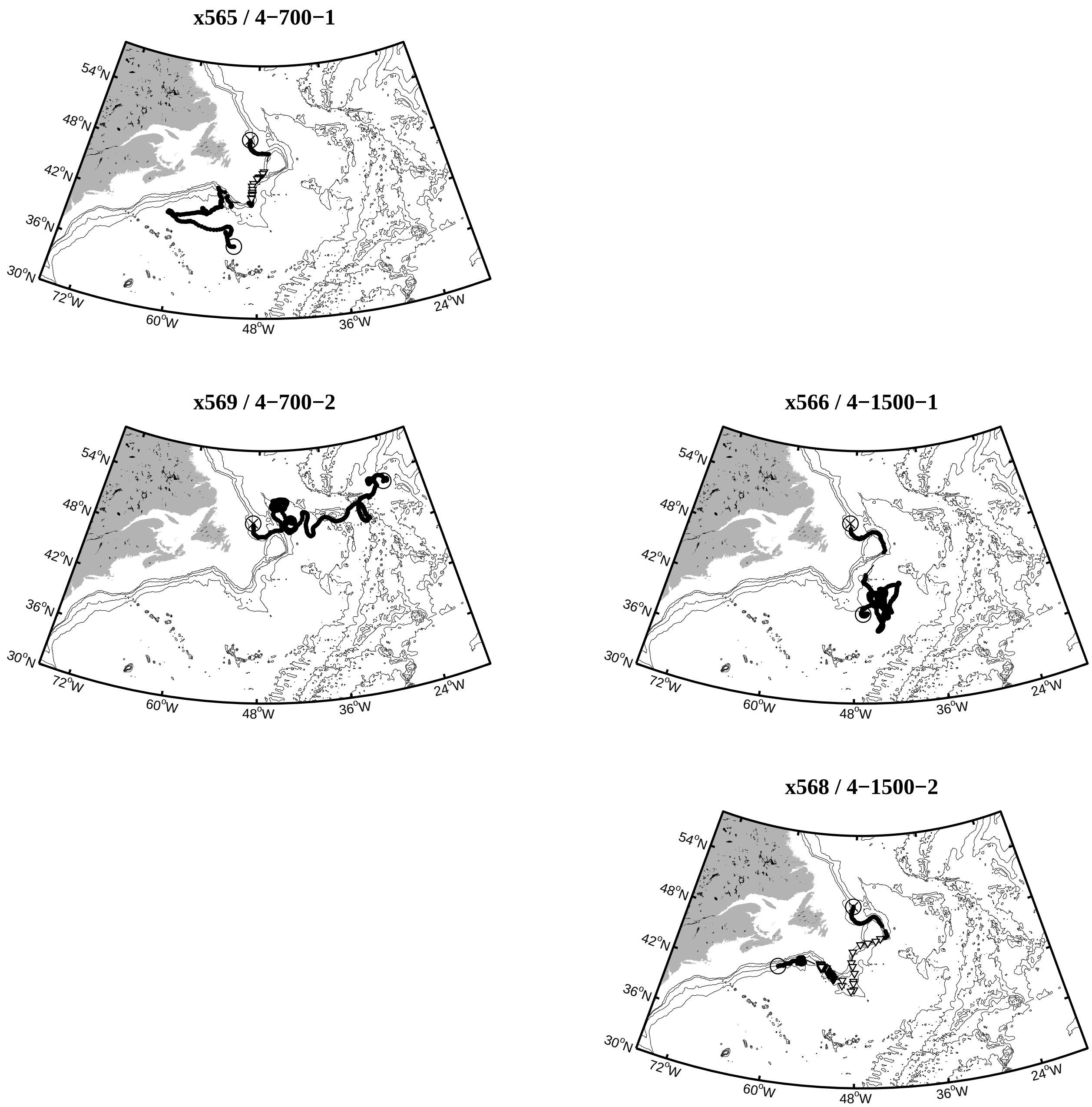


Figure B8: Setting 4 float trajectories, April 2004 – April 2006.

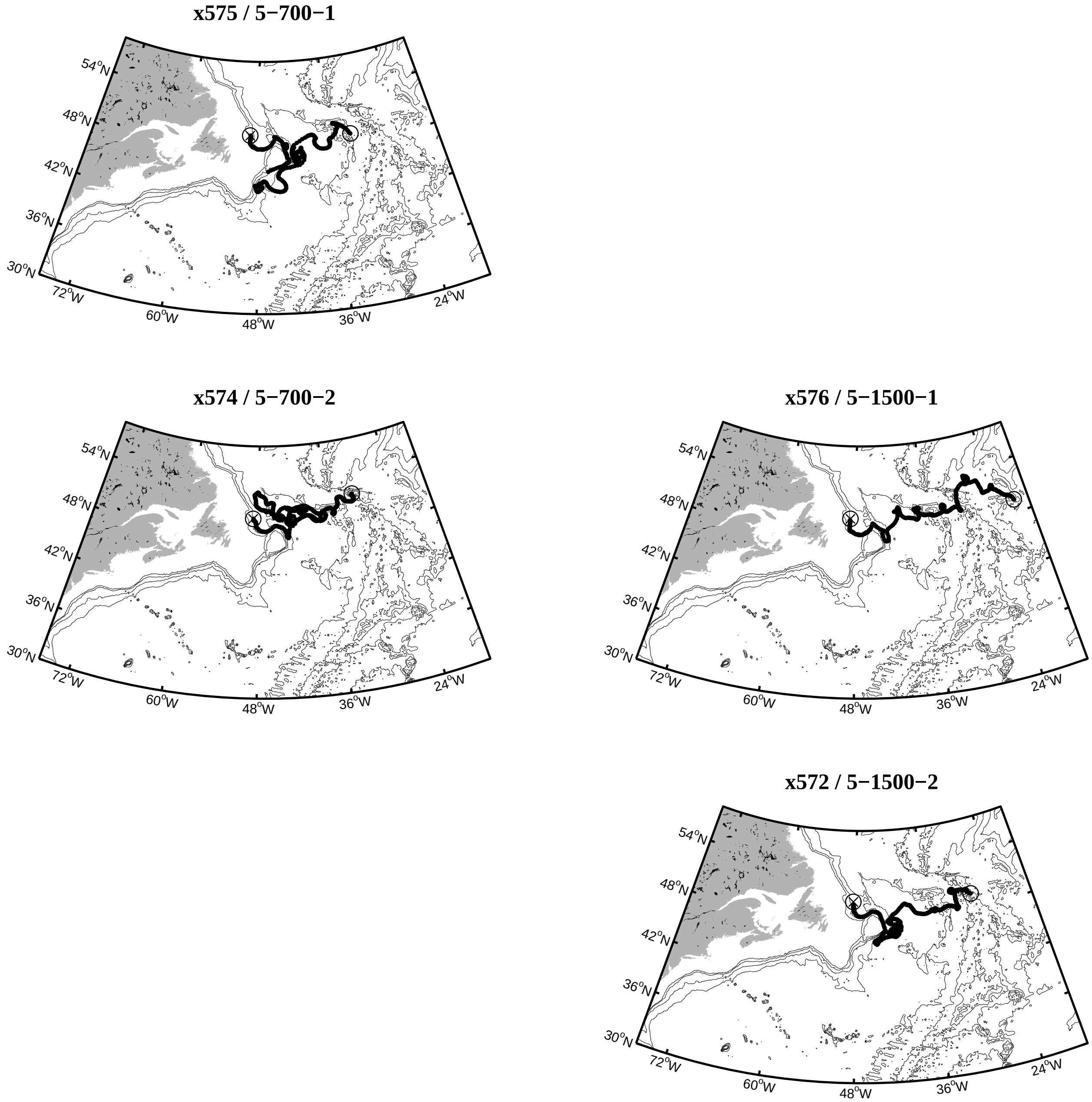


Figure B9: Setting 5 float trajectories, July 2004 – July 2006.

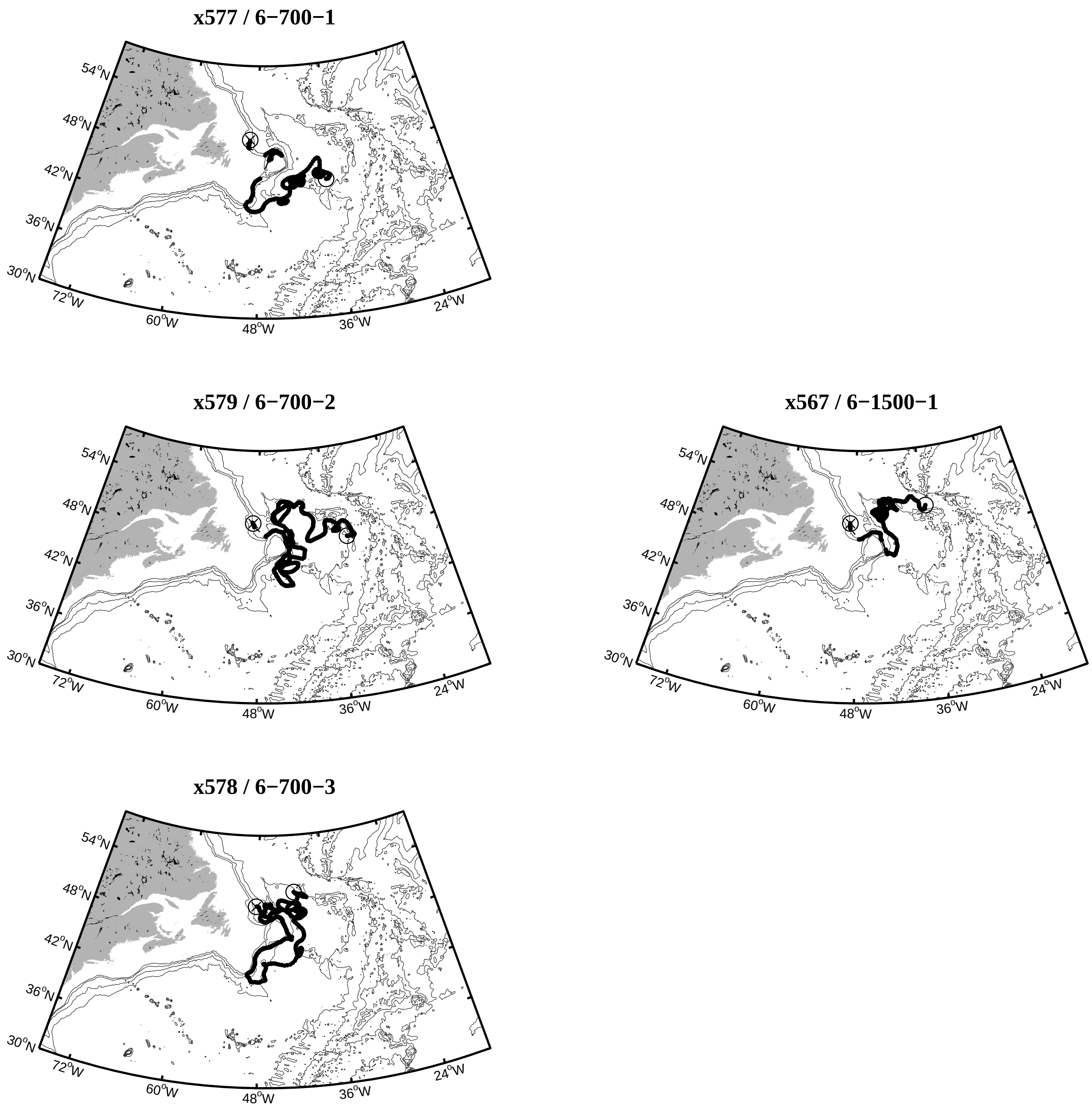


Figure B10: Setting 6 float trajectories, November 2004 – November 2006.

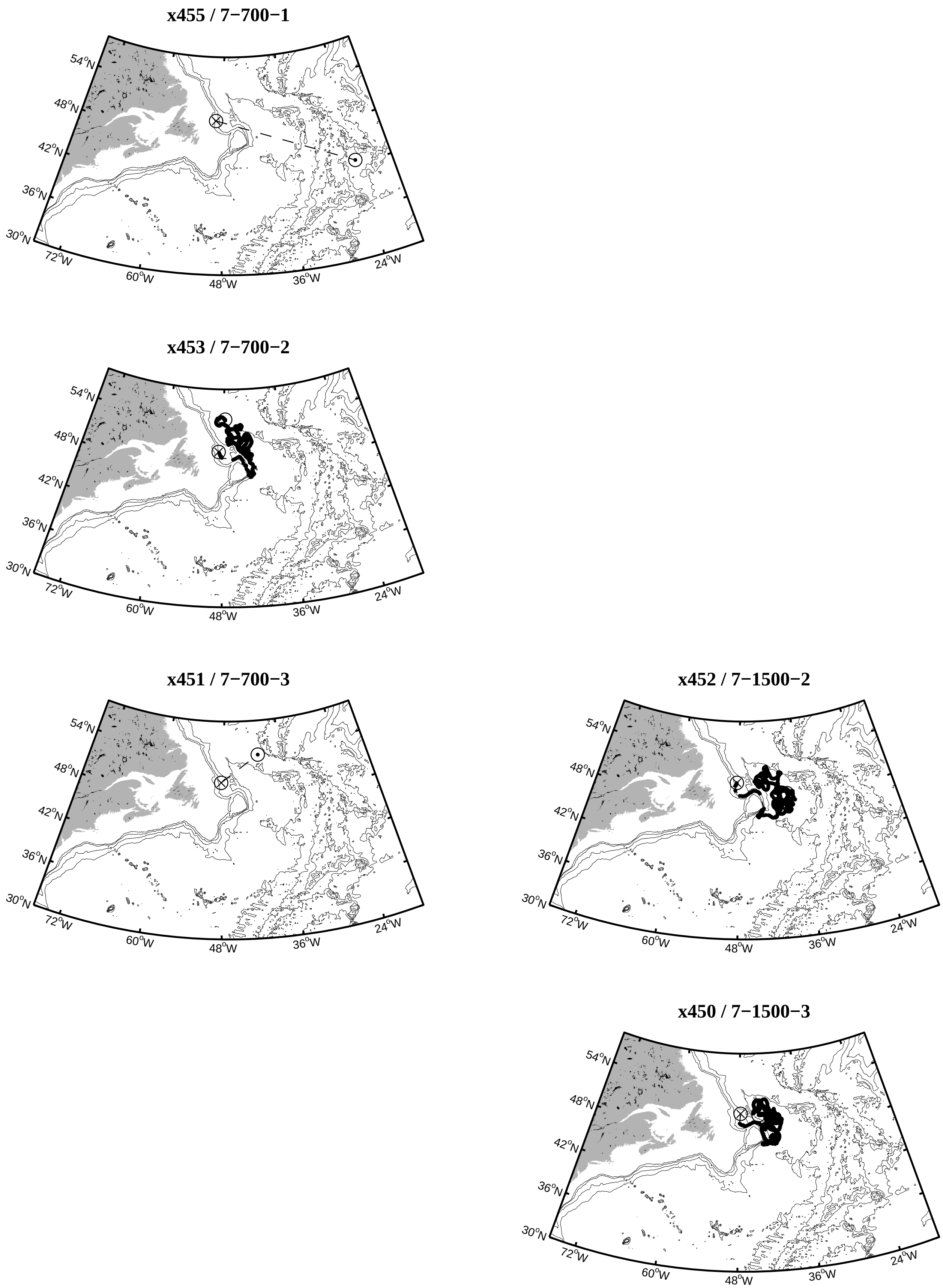


Figure B11: Setting 7 float trajectories, February 2005 – February 2007.

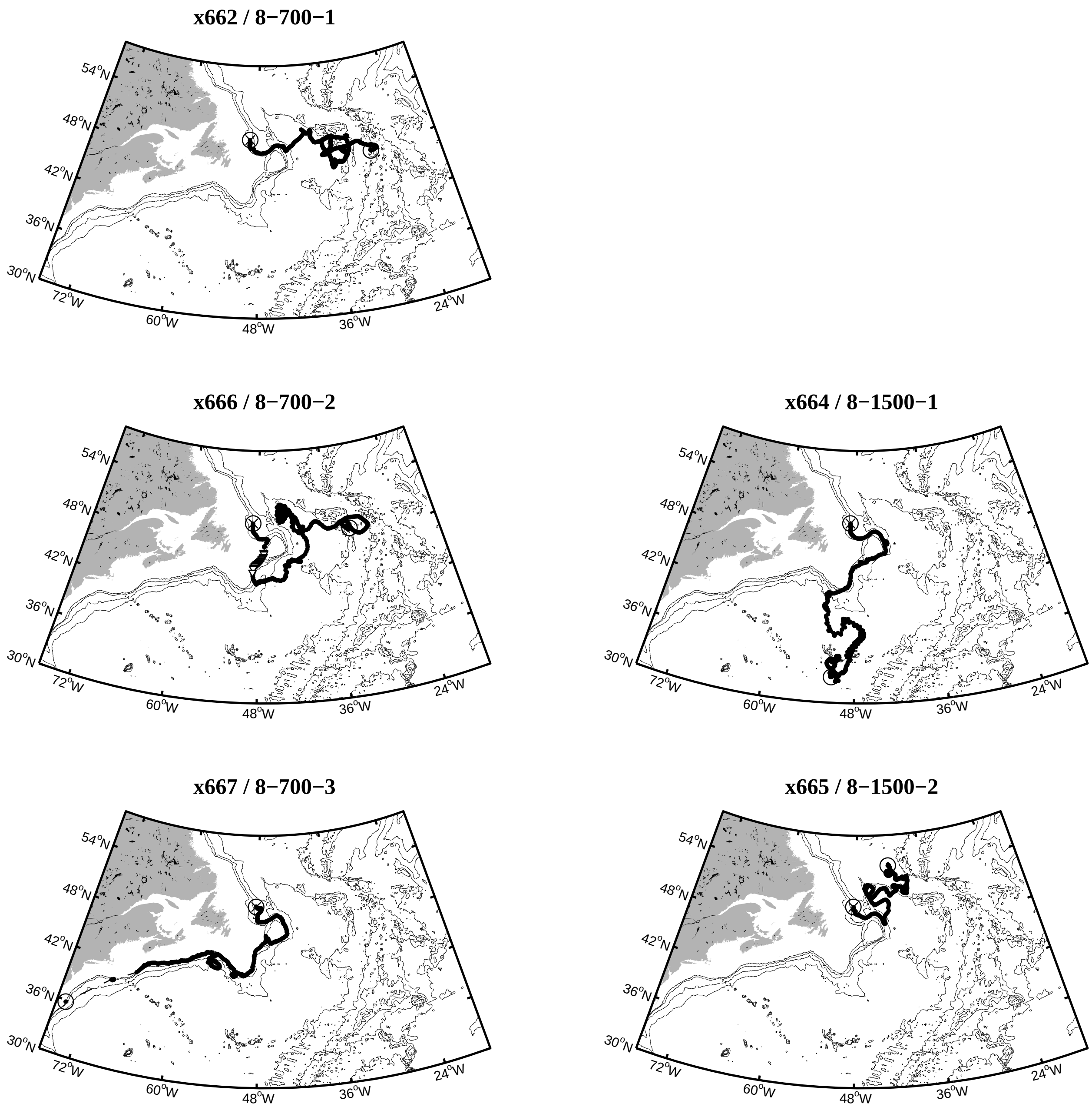


Figure B12: Setting 8 float trajectories, April 2005 – April 2007.

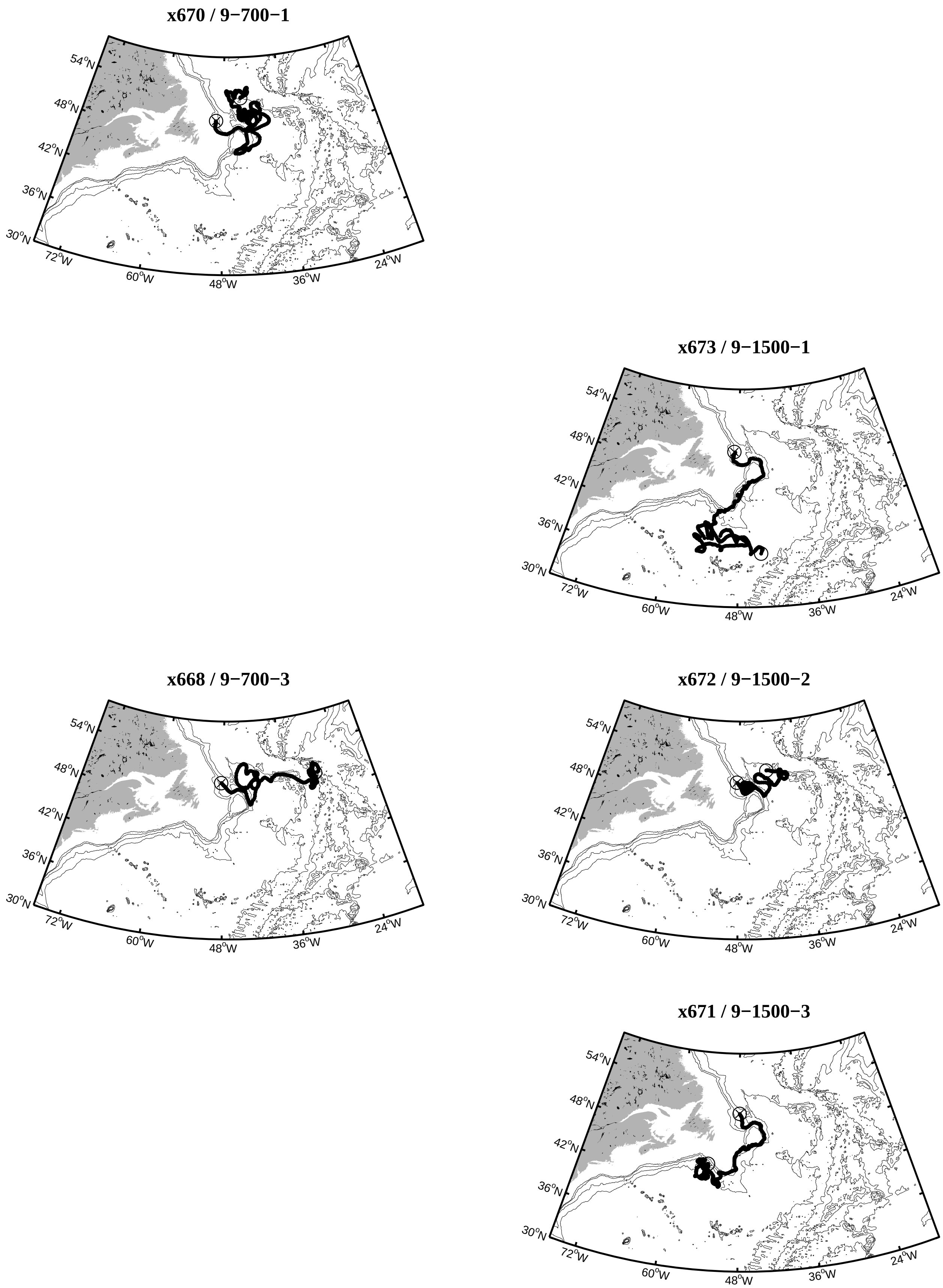


Figure B13: Setting 9 float trajectories, July 2005 – July 2007.

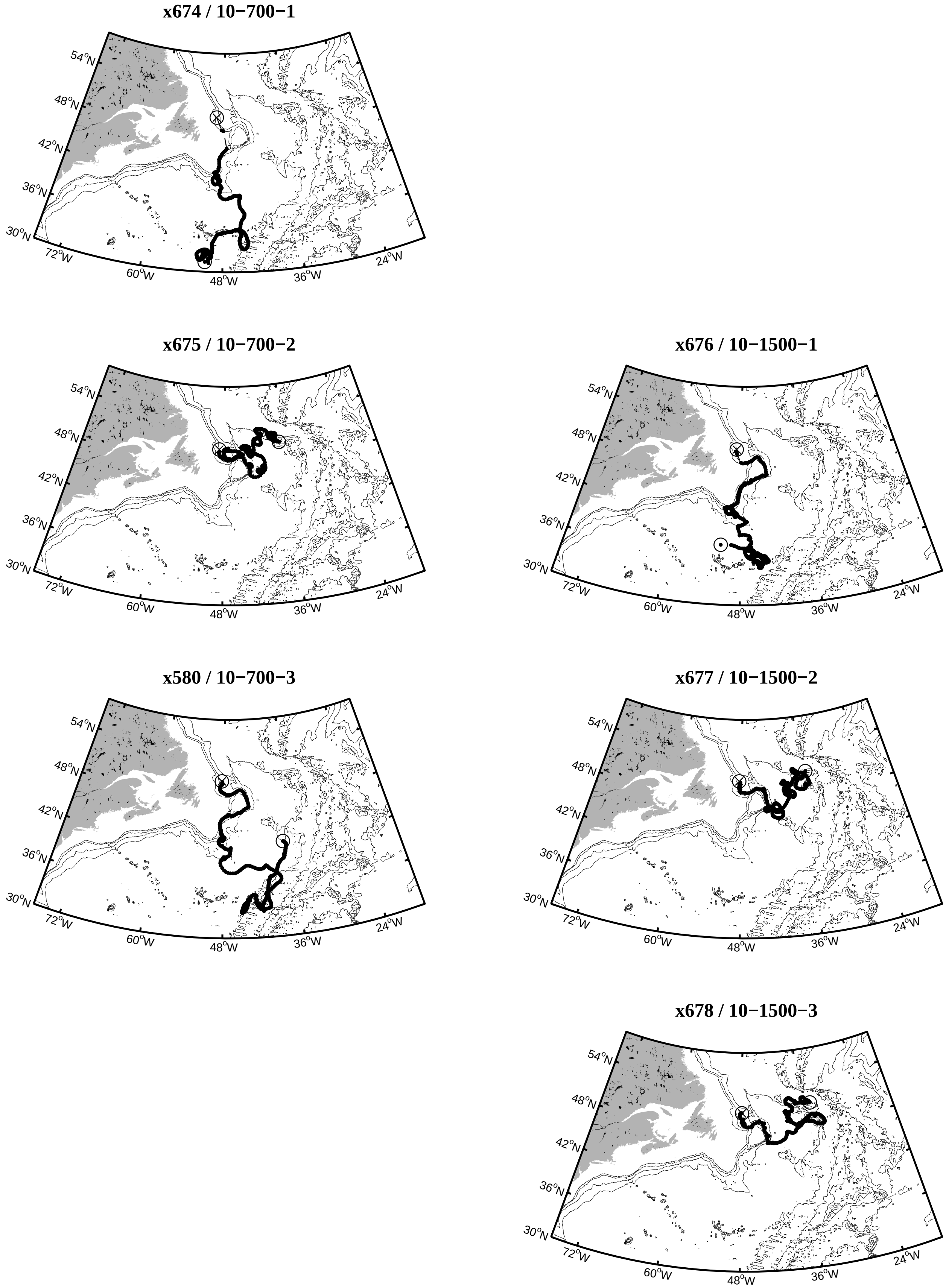


Figure B14: Setting 10 float trajectories, November 2005 – November 2007.

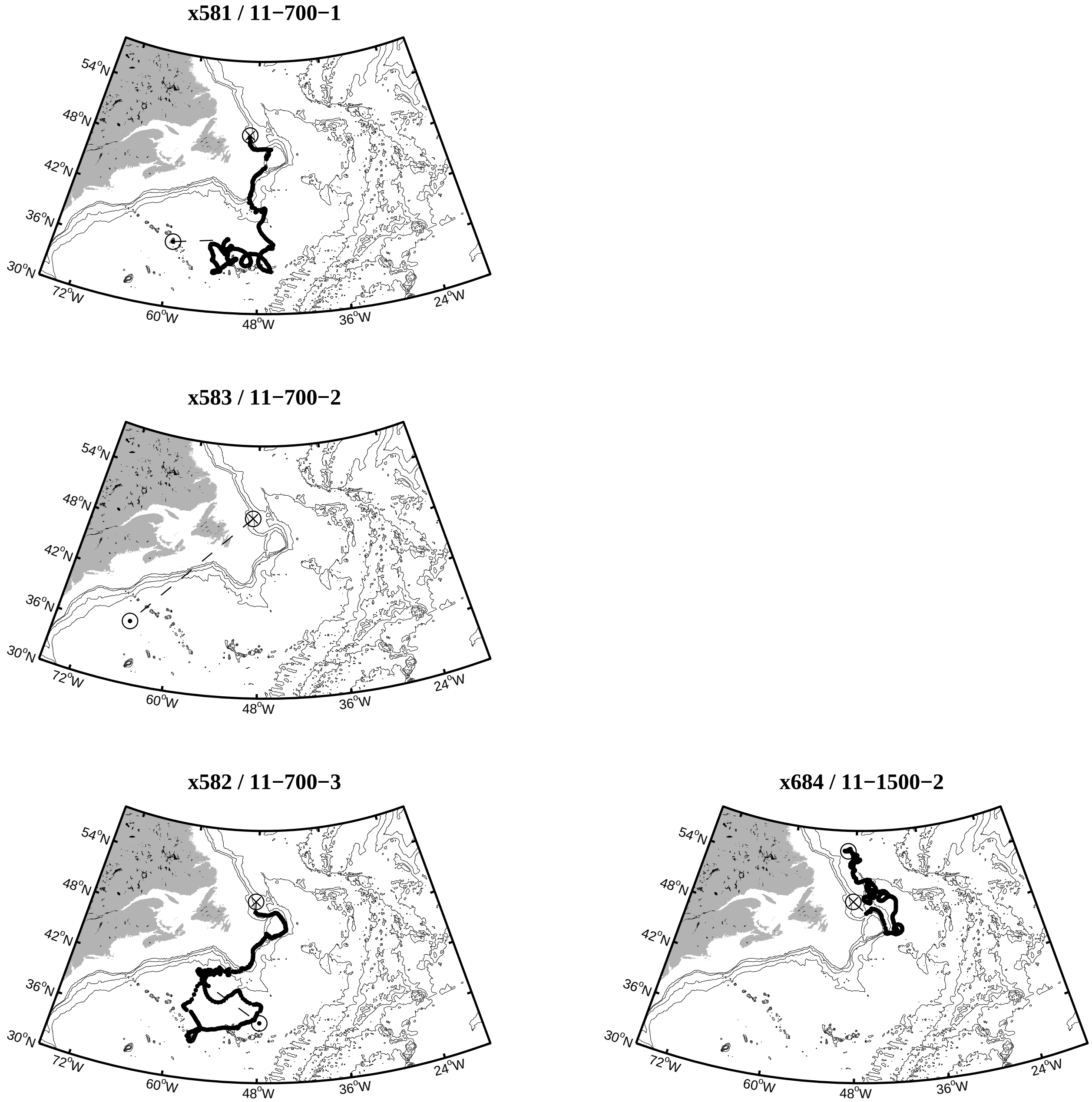


Figure B15: Setting 11 float trajectories, February 2006 – February 2008.

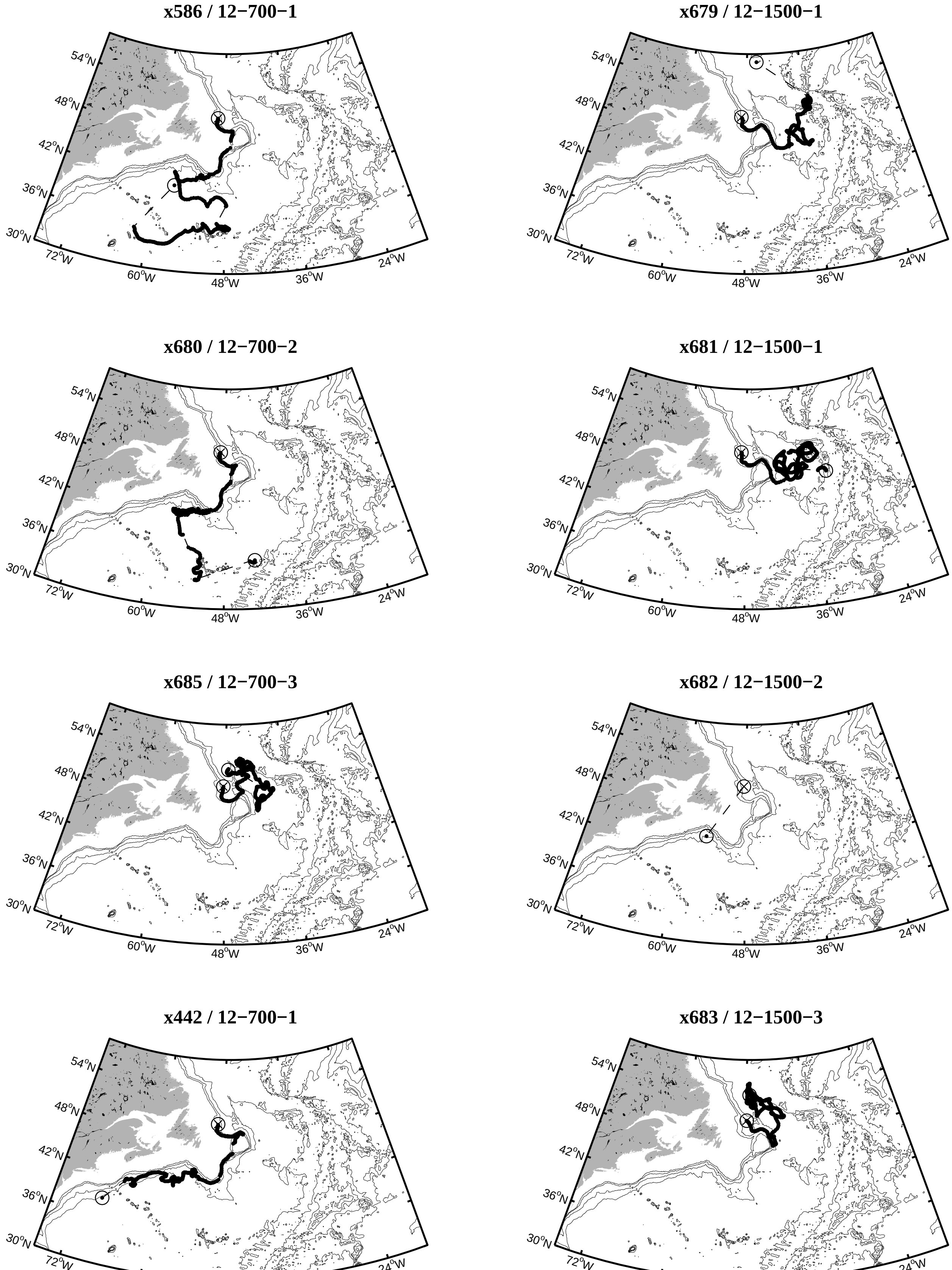
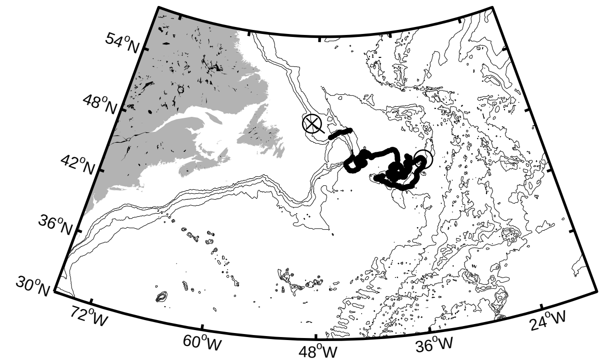


Figure B16: Setting 13 float trajectories, April 2006 − April 2008. Note that there are two additional floats, so that there are two shallow floats (x442 and x586) and two deep floats (x679 and x681) launched at the cross shelf position 1.

x706 / 13−1500−1



x720 / 13−1500−1

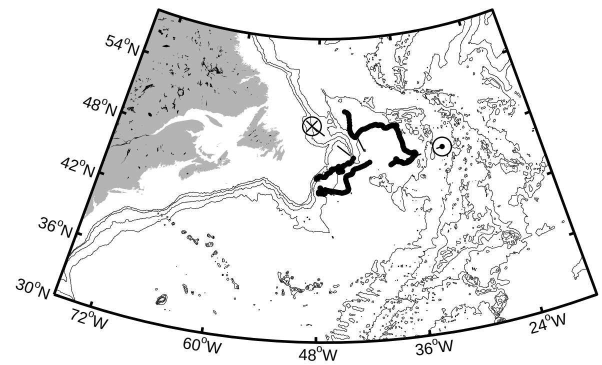


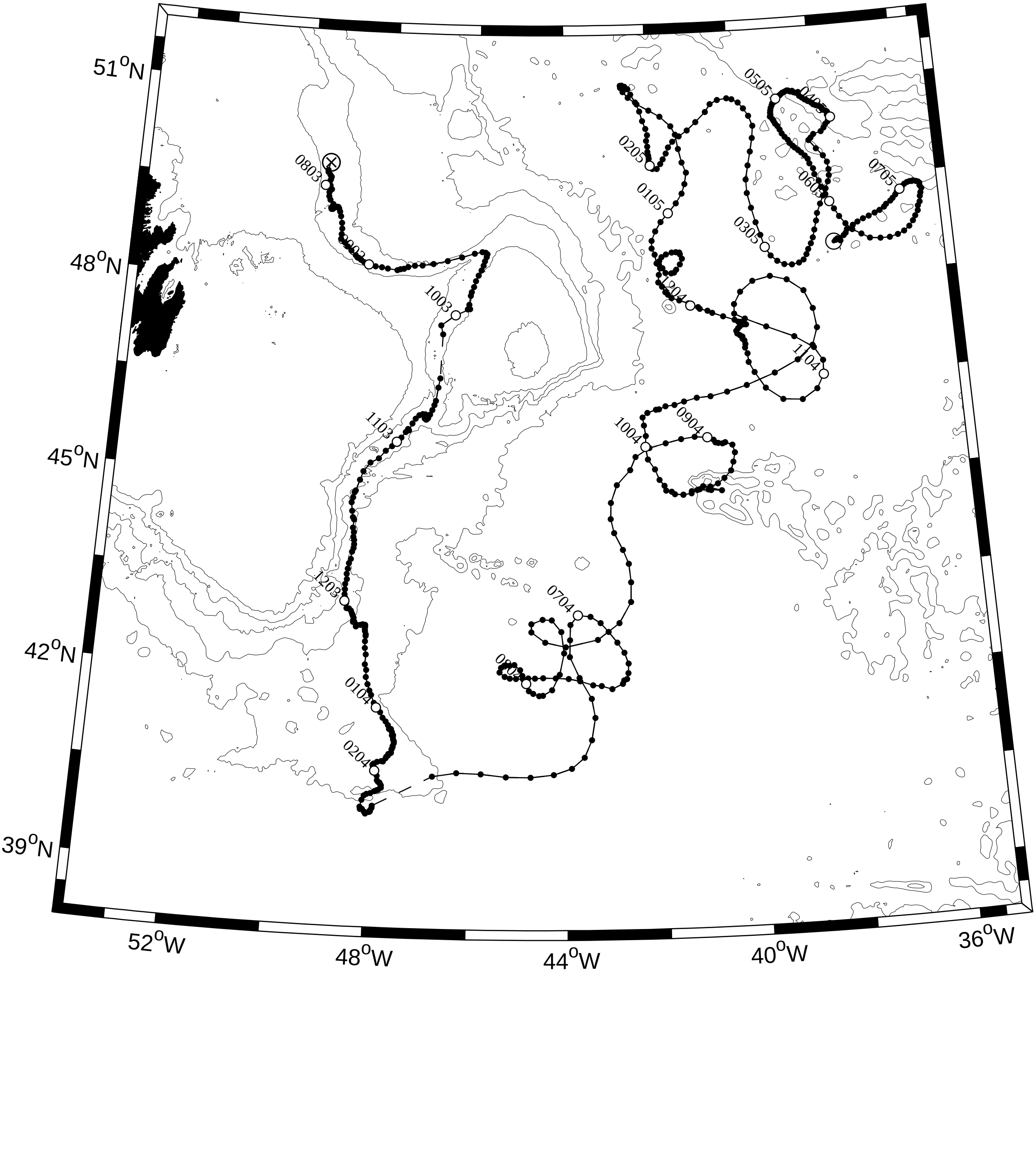
Figure B17: Setting 13 float trajectories, November 2006 – November 2008. Note that both 1500-dbar floats were launched at the same station.

Appendix C

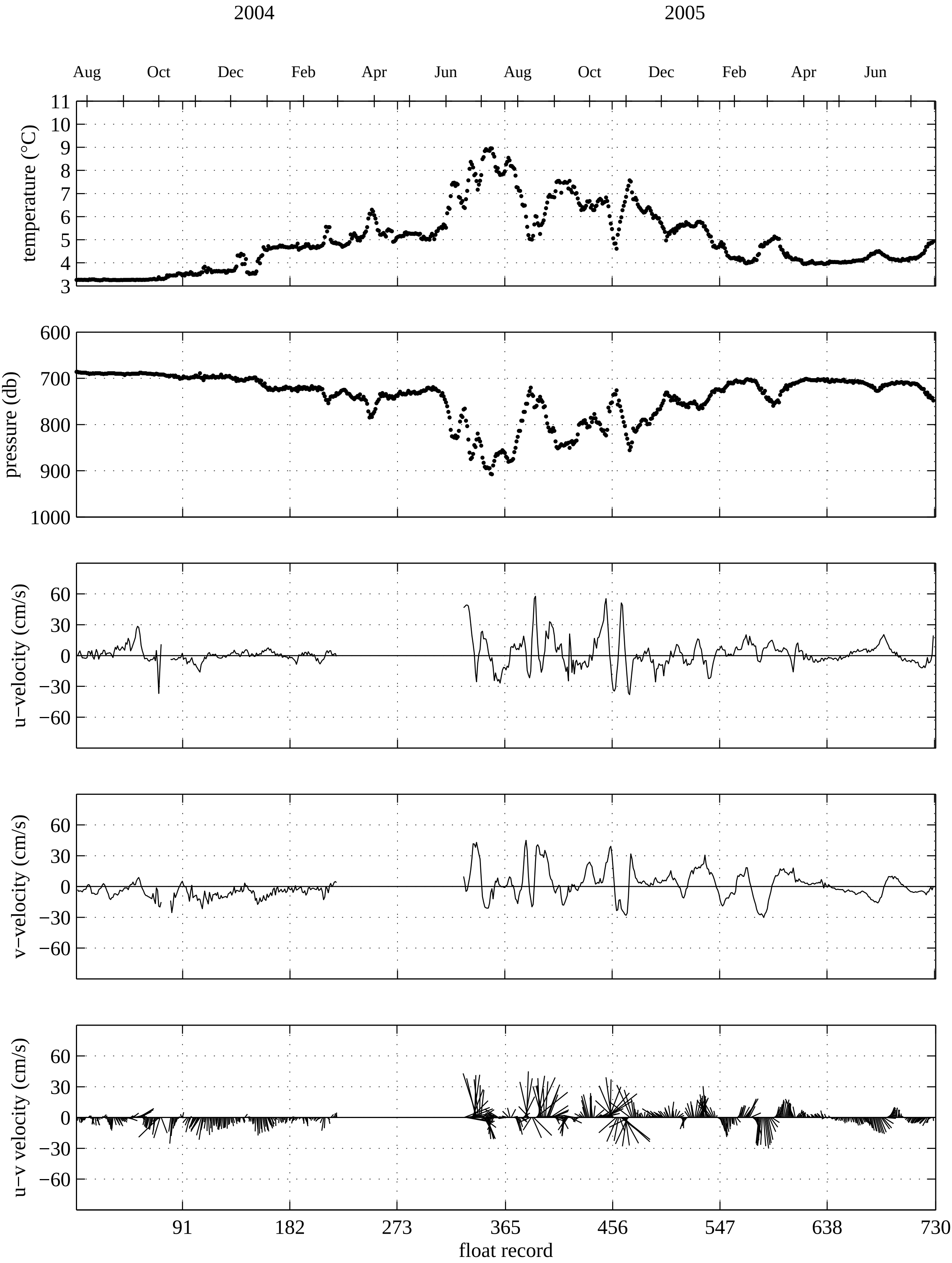
Individual float trajectories and property plots, in numerical order. For each float, the track is shown in one figure, and properties in a companion figure. Plot titles are as follows: 'x442 / 12_700_1' refers to float ID x442; the 12th setting (deployment), 700-dbar ballast pressure, and cross-shelf position 1 (see Figure 2 in text). Trajectory plot bathymetry is contoured at 200 meters, and at 1000-meter intervals to 4000 meters depth. Daily positions are marked with dots, and monthly positions are marked with open white dots and labeled with 'mmyy', marking the first of each month. Untrackable segment are drawn with a dashed line. Launch position is marked with a circle-x; surface with a circle-dot. 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 daily, and is as long as the intended mission length of the float, 730 days.

Three floats, x565, x568, and x666, contain segments of track that were constructed from TOAs from a single source. See text for a description of method used. In these three cases, the calculated positions are marked with open triangles, to distinguish them from points derived from the least squares method and multiple TOAs.

x432 / 1−700−1

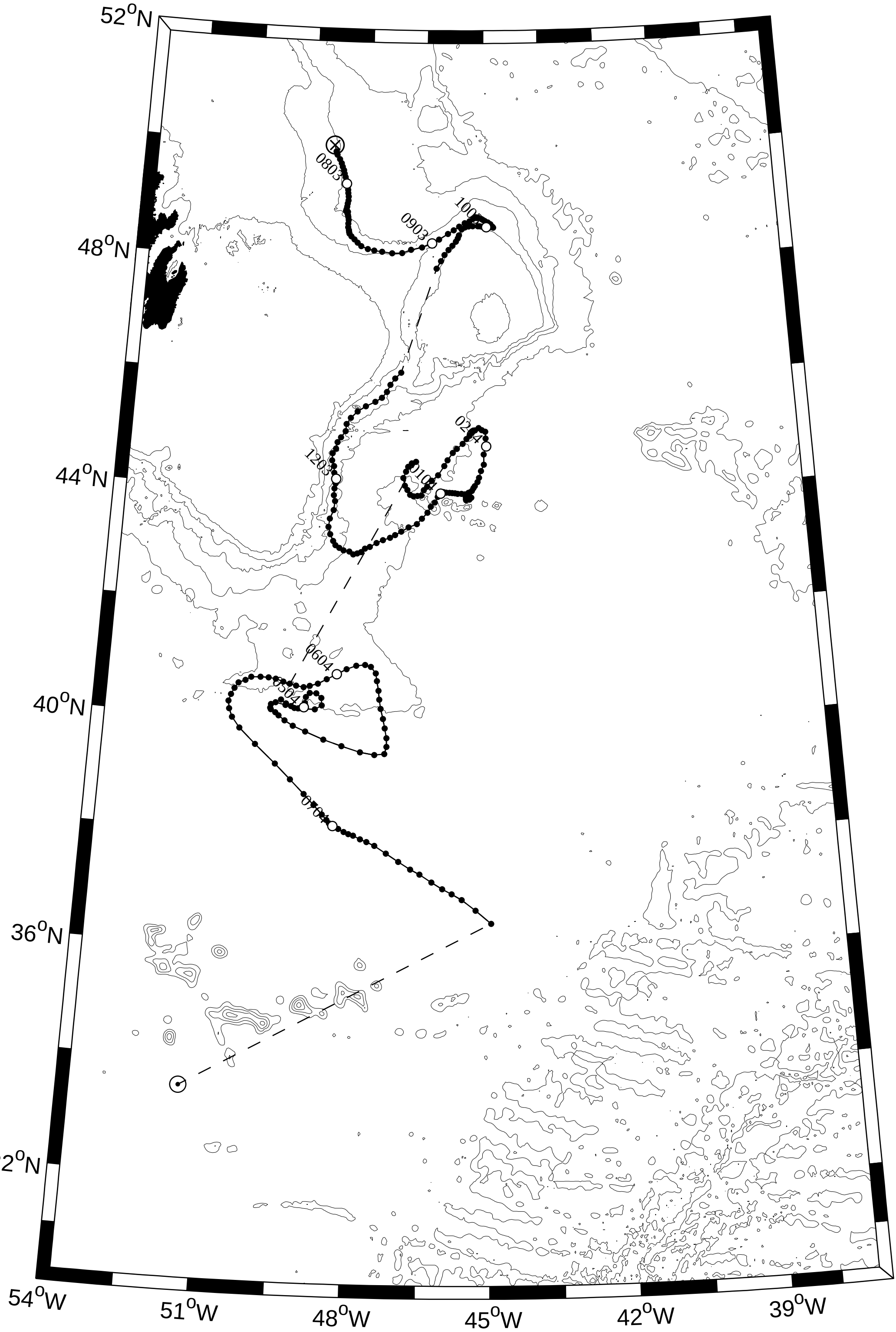

51°N
48°N
45°N
42°N
39°N
52°W
48°W
44°W
40°W
36°W
0803
0903
1003
1103
1203
0104
0204
0505
0405
0205
0105
0305
0605
0705
0904
1004
1104
0704
0804

x432 / 1−700−1



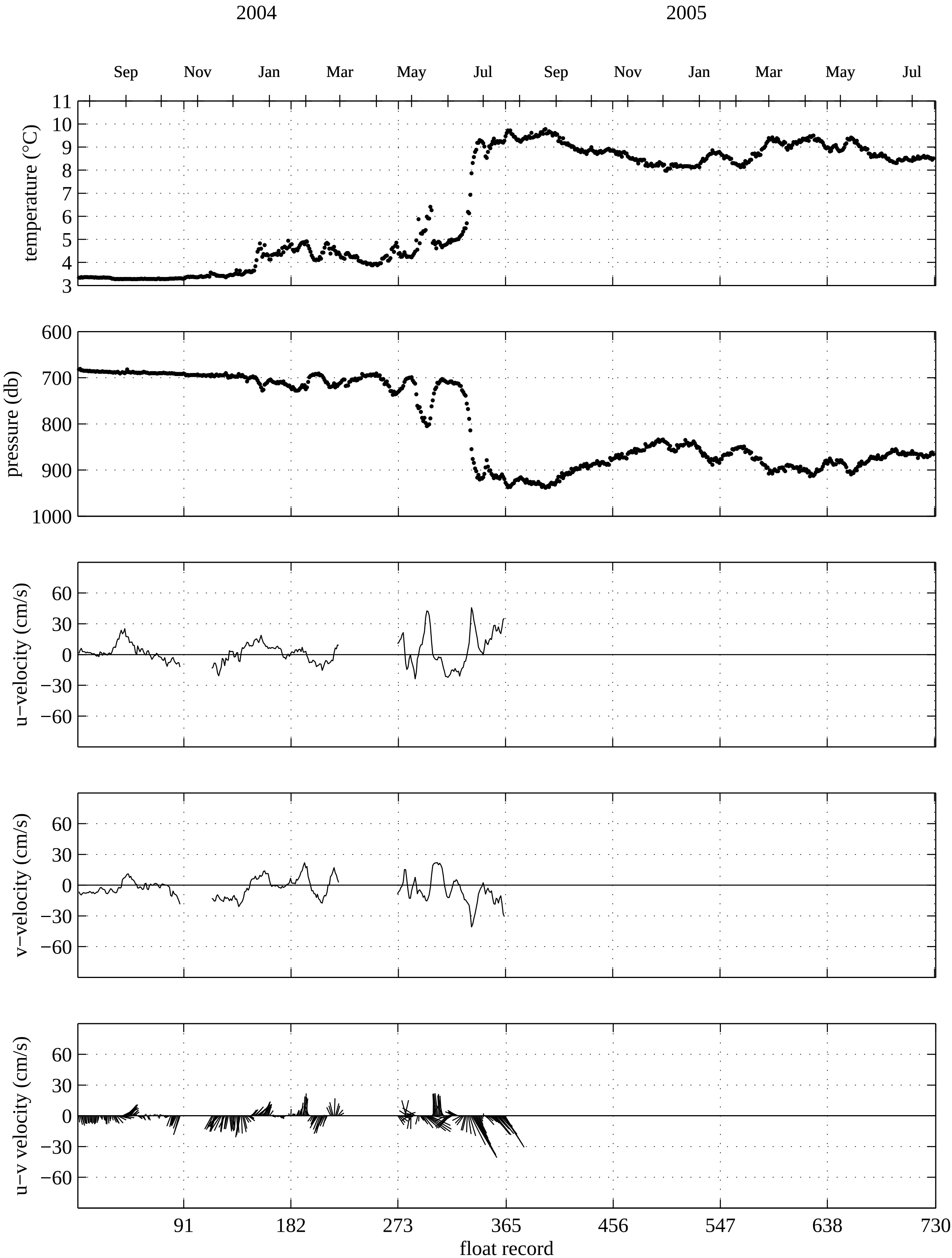
2004
2005
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
Apr
Jun
temperature (°C)
11
10
9
8
7
6
5
4
3
pressure (db)
600
700
800
900
1000
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

x433 / 1−700−2



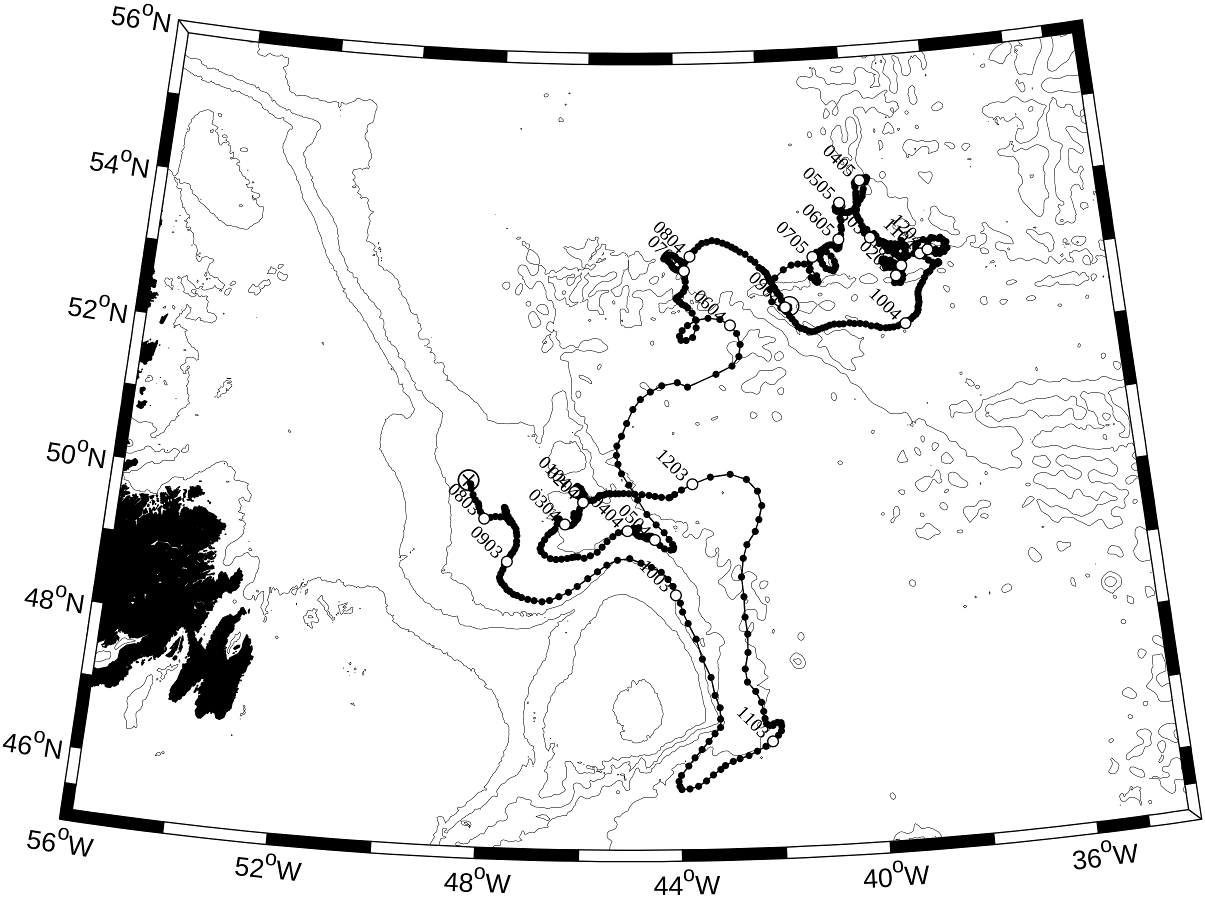
52°N
48°N
44°N
40°N
36°N
32°N
54°W
51°W
48°W
45°W
42°W
39°W
0803
0903
1003
1203
0204
0104
0604
0504
0704

x433 / 1−700−2

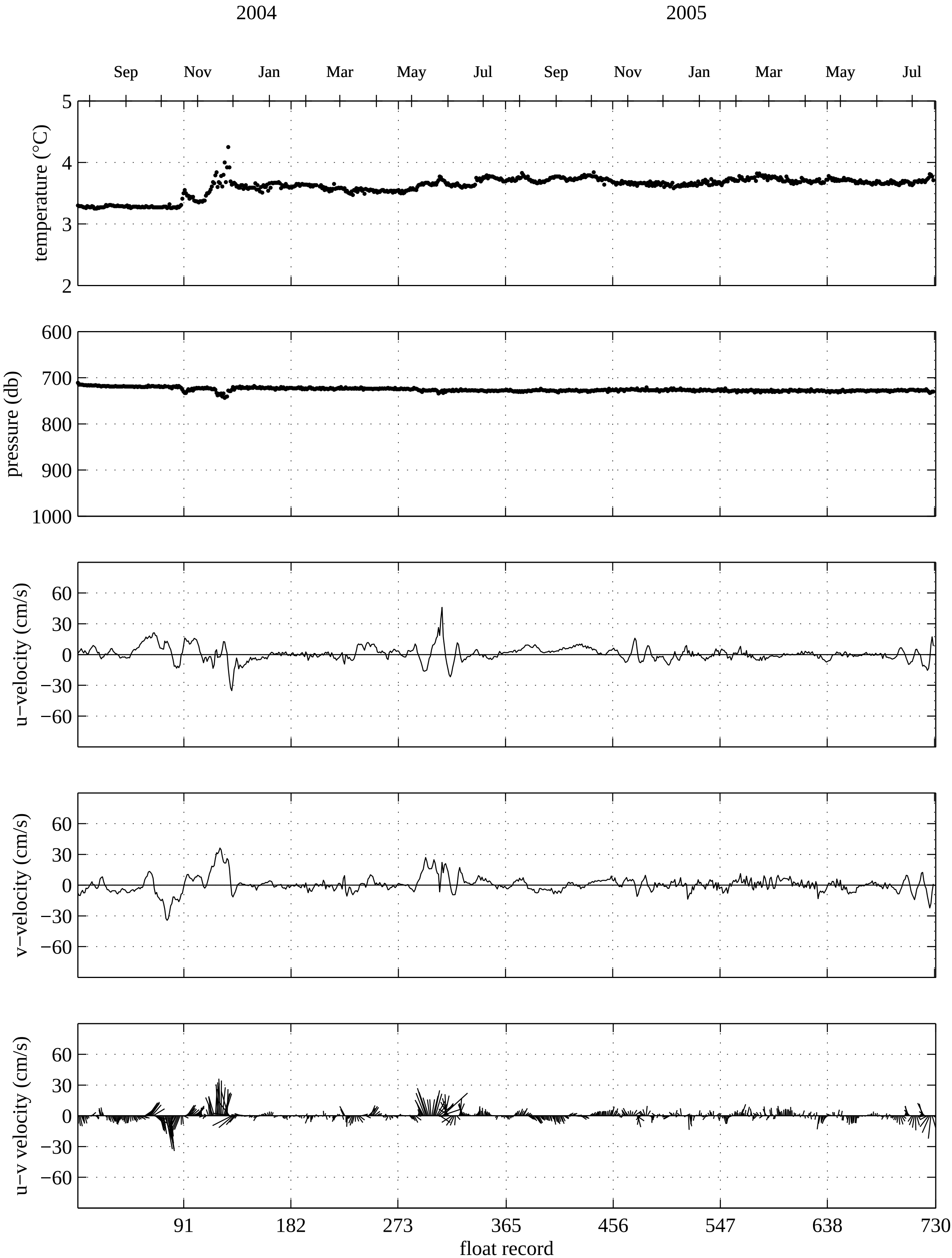


2004
2005
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

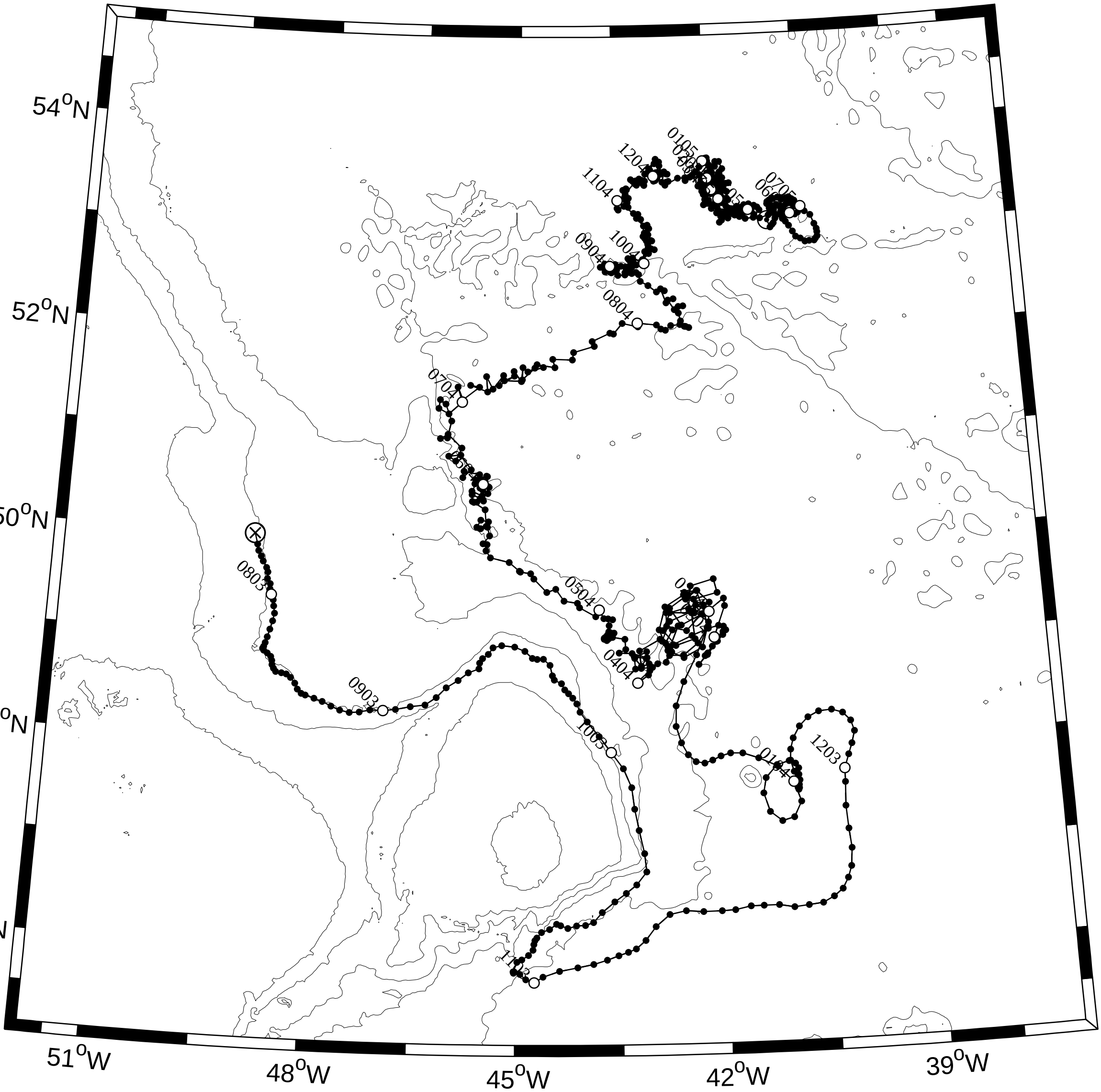
x434 / 1−700−3


56°N
54°N
52°N
50°N
48°N
46°N
56°W
52°W
48°W
44°W
40°W
36°W
0405
0505
0605
0705
0804
0604
1004
1203
0304
0404
0803
0903
1003
1103

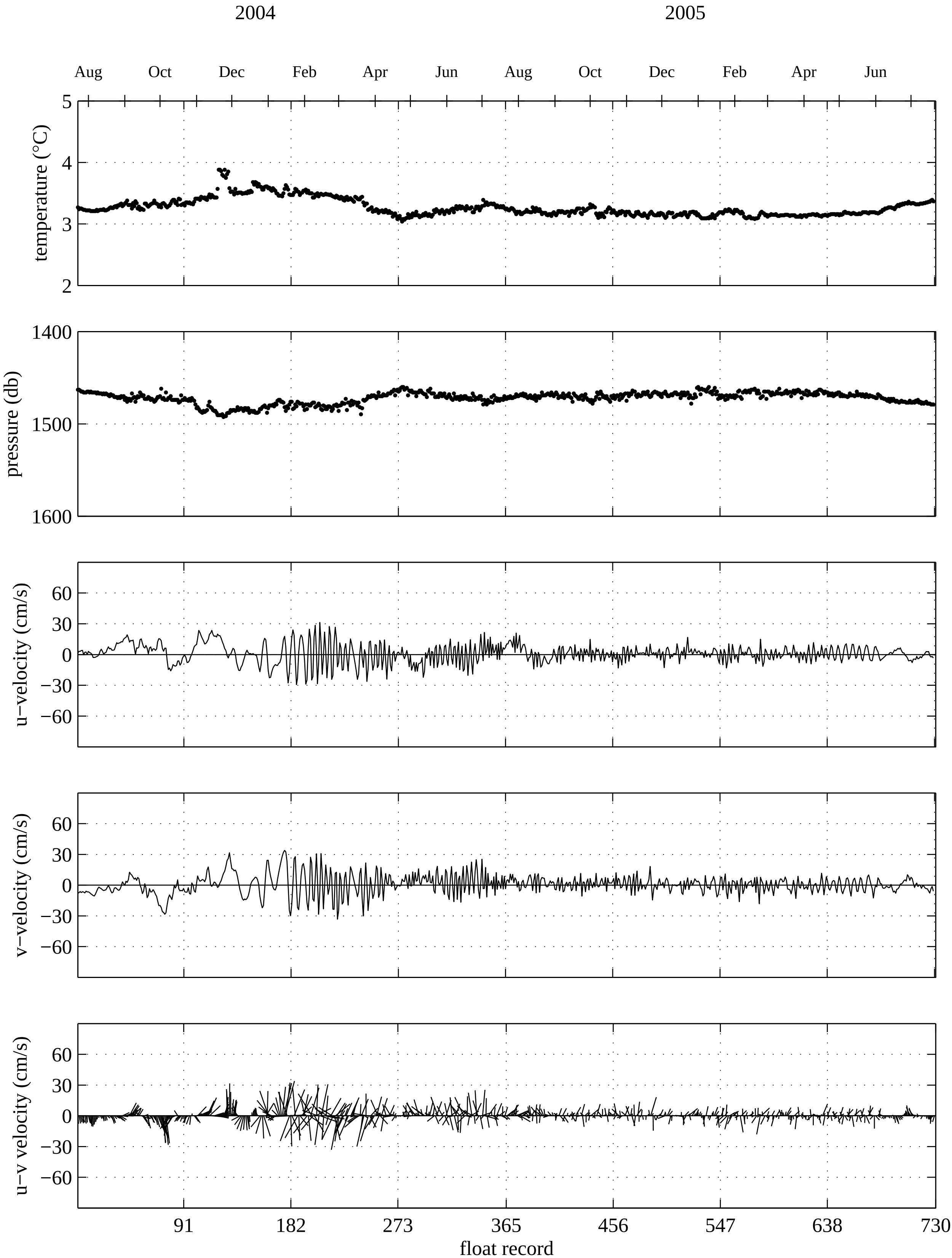
x434 / 1−700−3


2004
2005
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
temperature (°C)
5
4
3
2
pressure (db)
600
700
800
900
1000
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

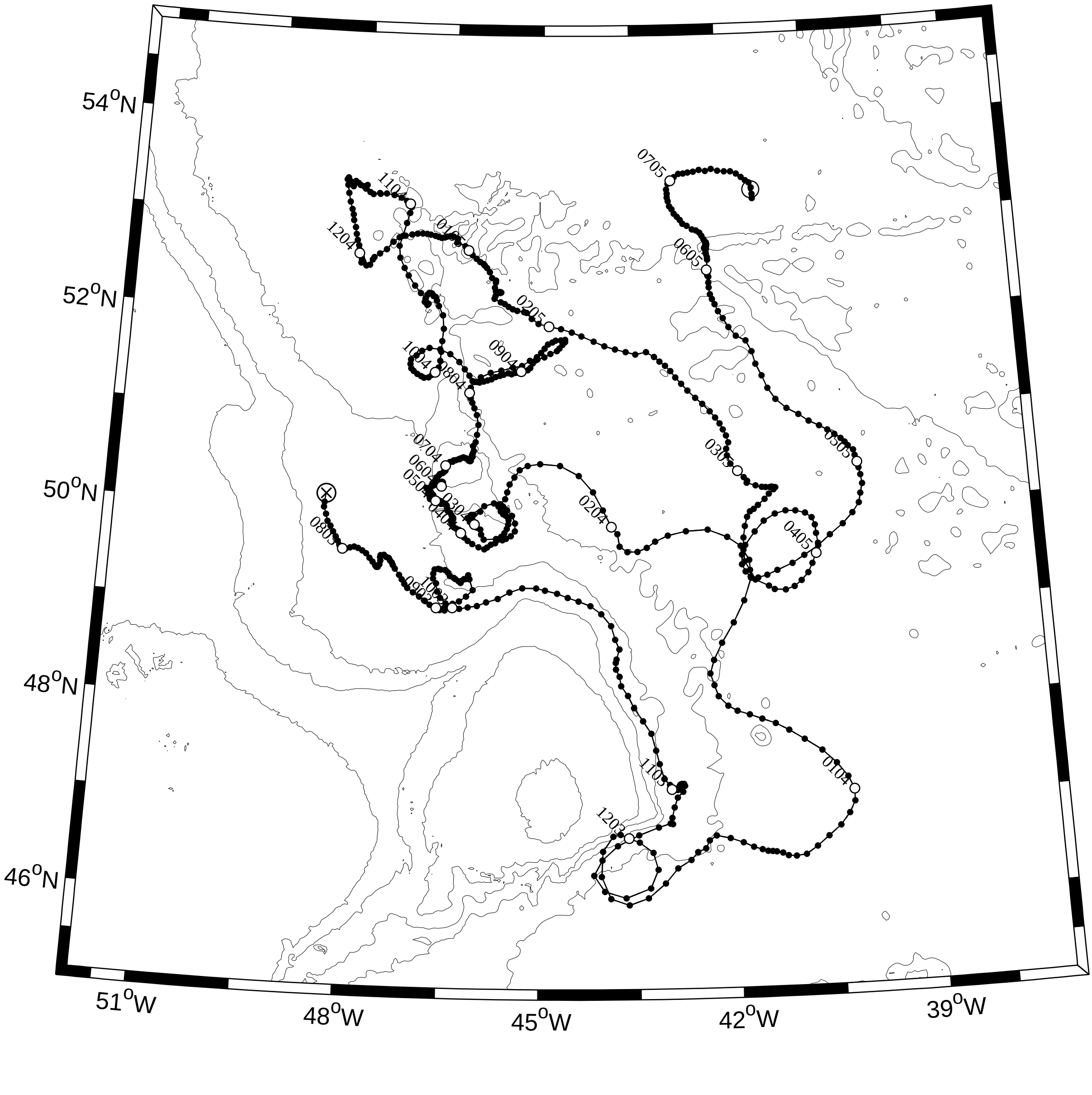
x435 / 1−1500−1

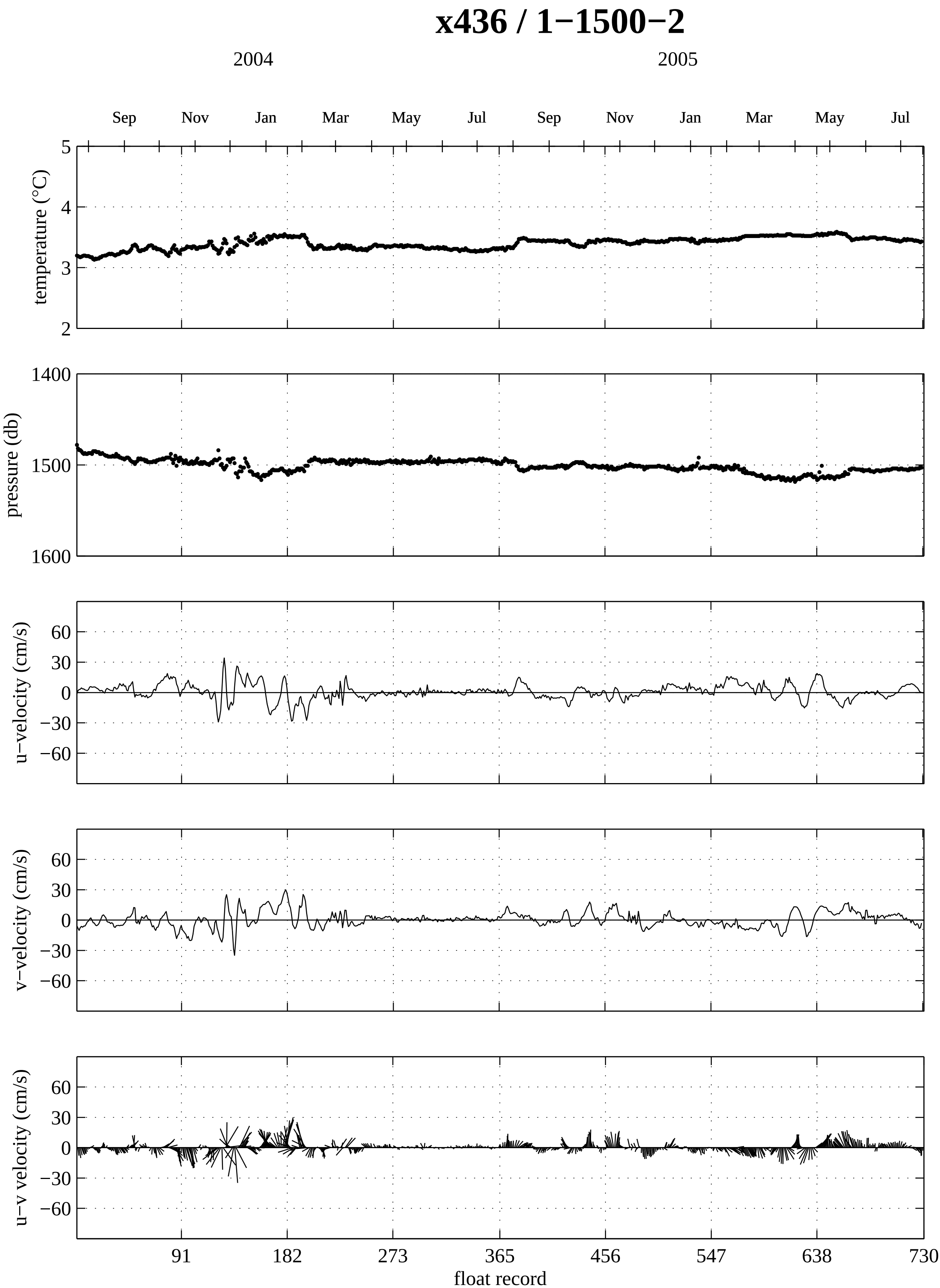

54°N
52°N
50°N
48°N
46°N
51°W
48°W
45°W
42°W
39°W
0105
1204
1104
0705
0605
1004
0904
0804
0704
0504
0404
0803
0903
1003
0104
1203

x435 / 1−1500−1


2004
2005
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
Apr
Jun
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
float record

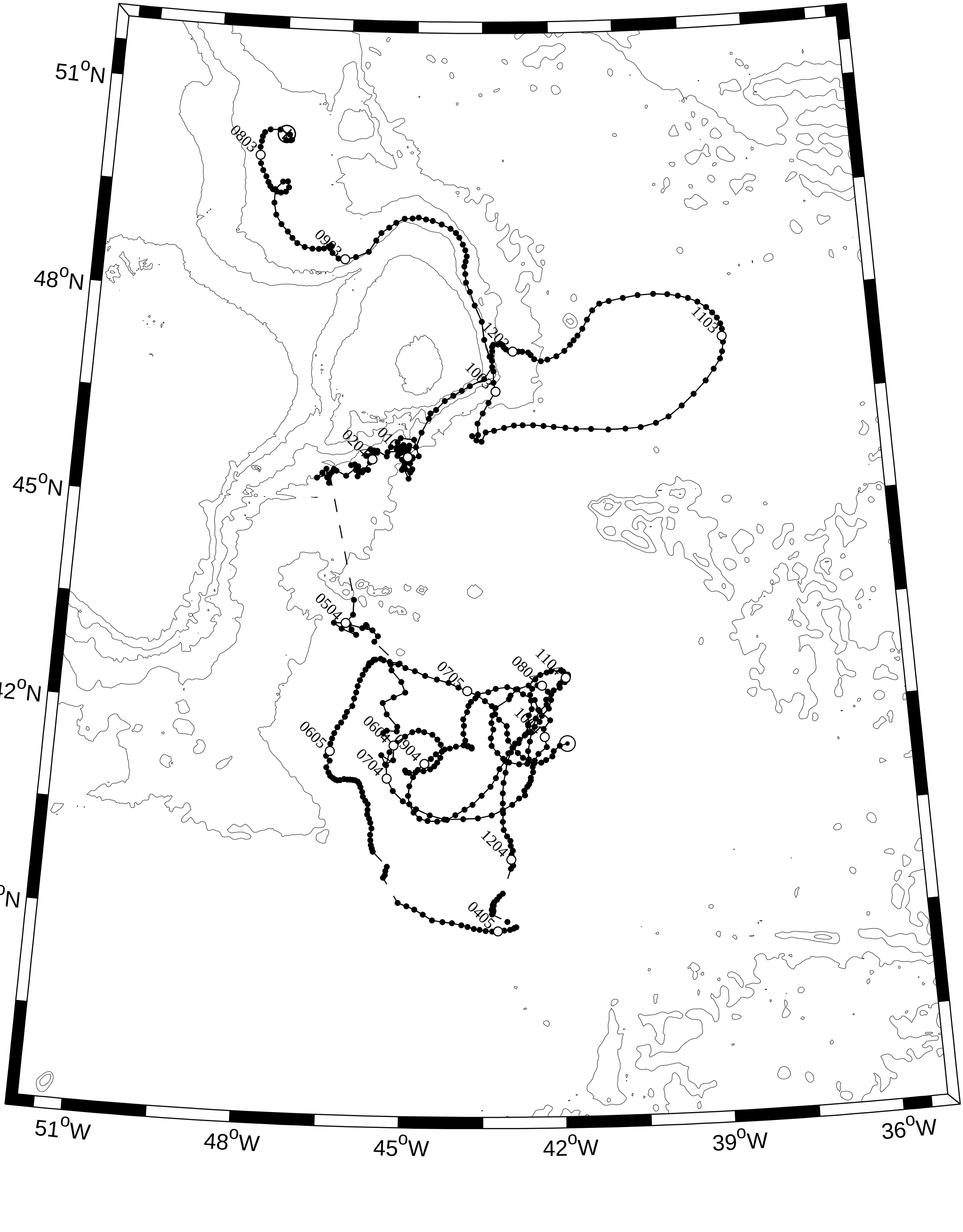
x436 / 1−1500−2


54°N
52°N
50°N
48°N
46°N
51°W
48°W
45°W
42°W
39°W
0705
1104
1204
0605
0205
1004
0904
0804
0704
0204
0405
0505
0805
1105
0104

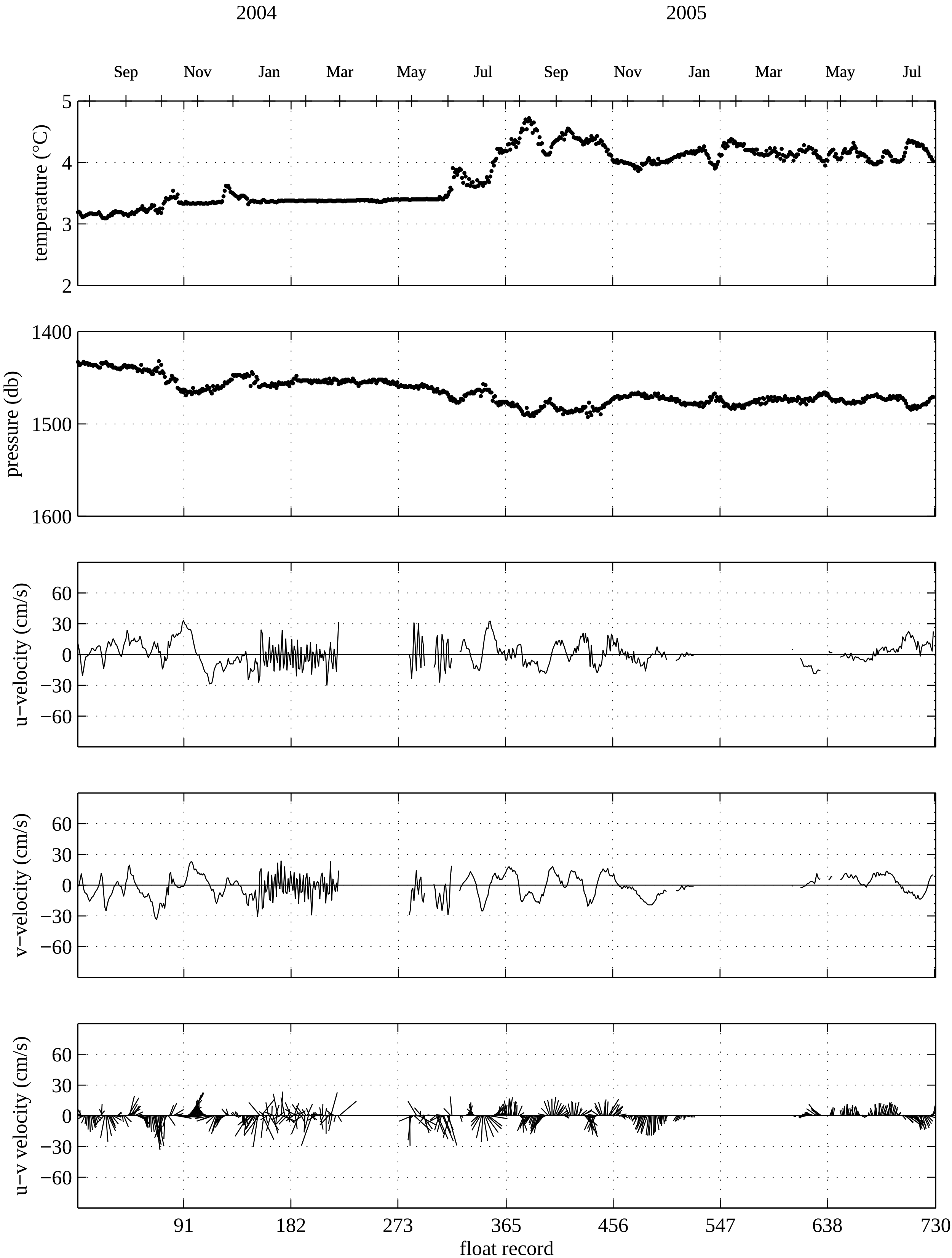


x436 / 1−1500−2
2004
2005
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
temperature (°C)
5
4
3
2
pressure (db)
1400
1500
1600
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

x437 / 1−1500−3

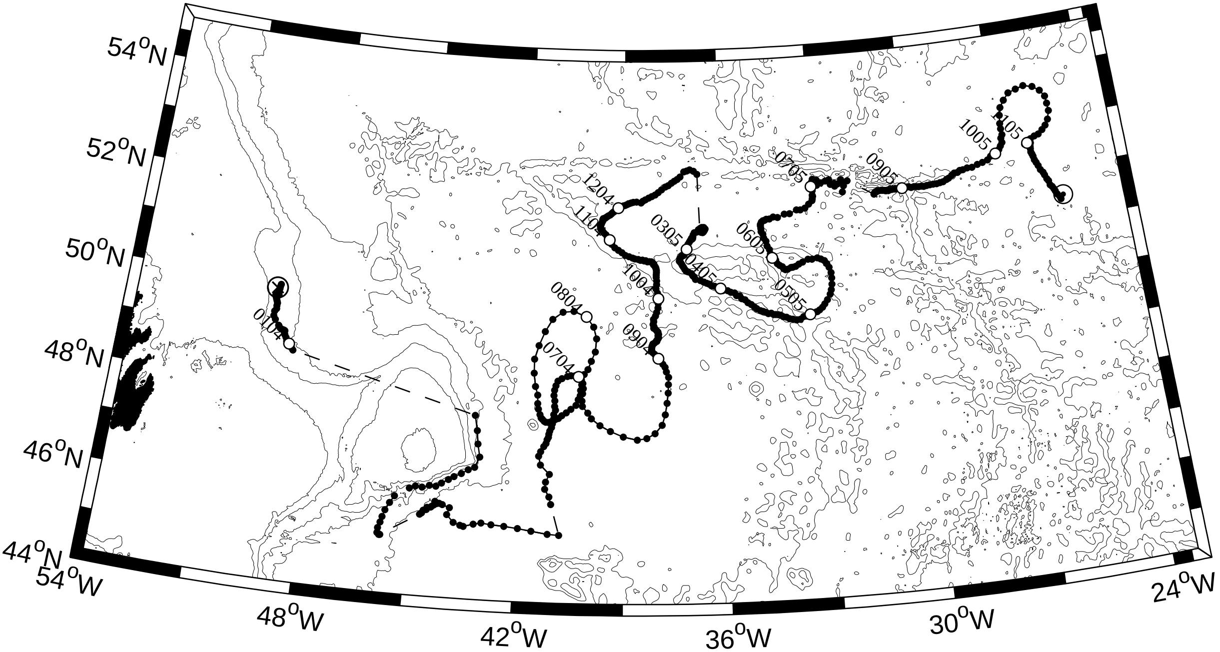

51°N
48°N
45°N
42°N
39°N
36°N
51°W
48°W
45°W
42°W
39°W
36°W
0803
0903
1103
1203
1003
0204
0504
0705
0804
0605
0604
0904
0704
1204
0405

x437 / 1−1500−3



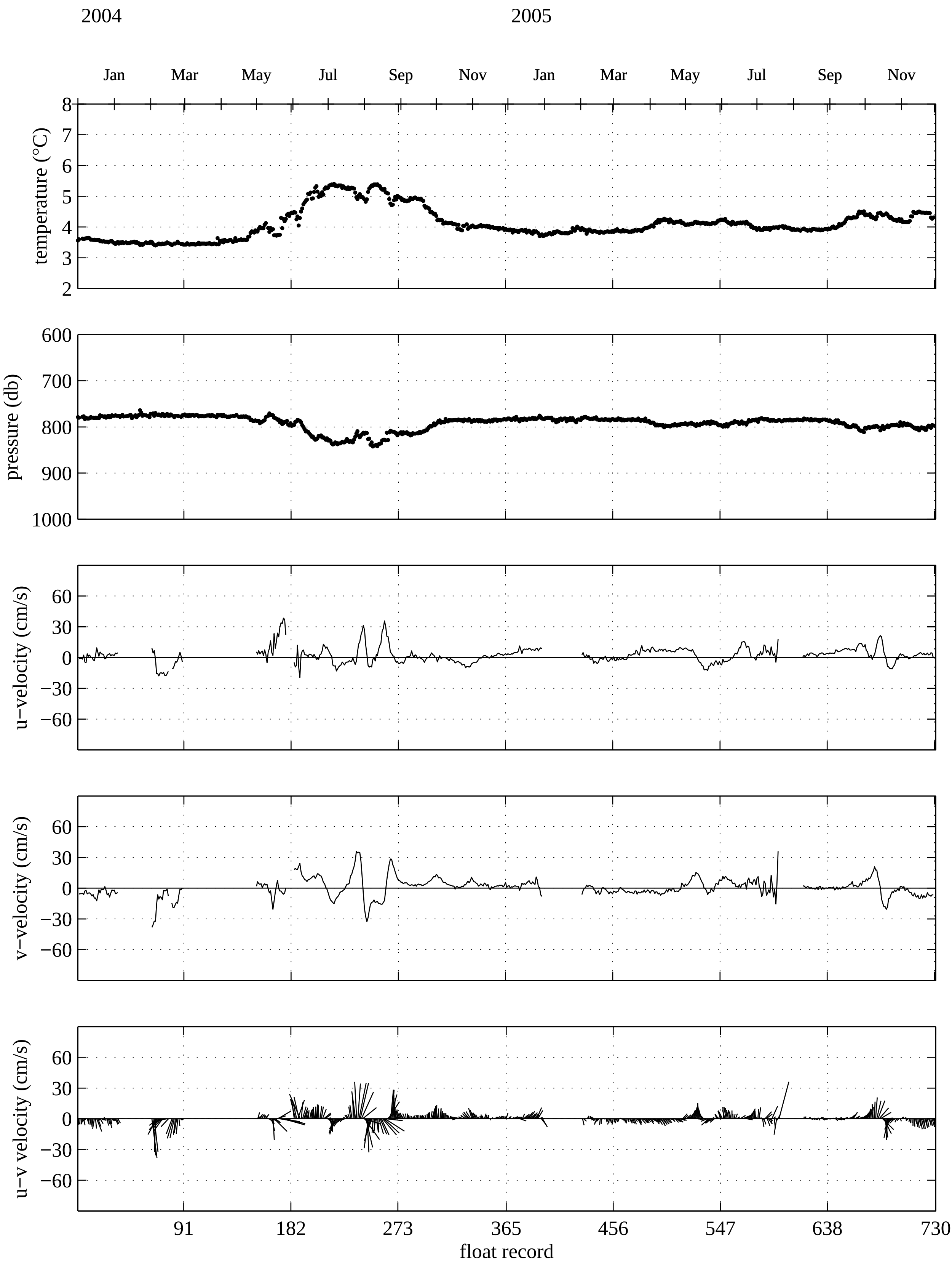
2004
2005
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
temperature (°C)
5
4
3
2
pressure (db)
1400
1500
1600
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

x439 / 2−700−1

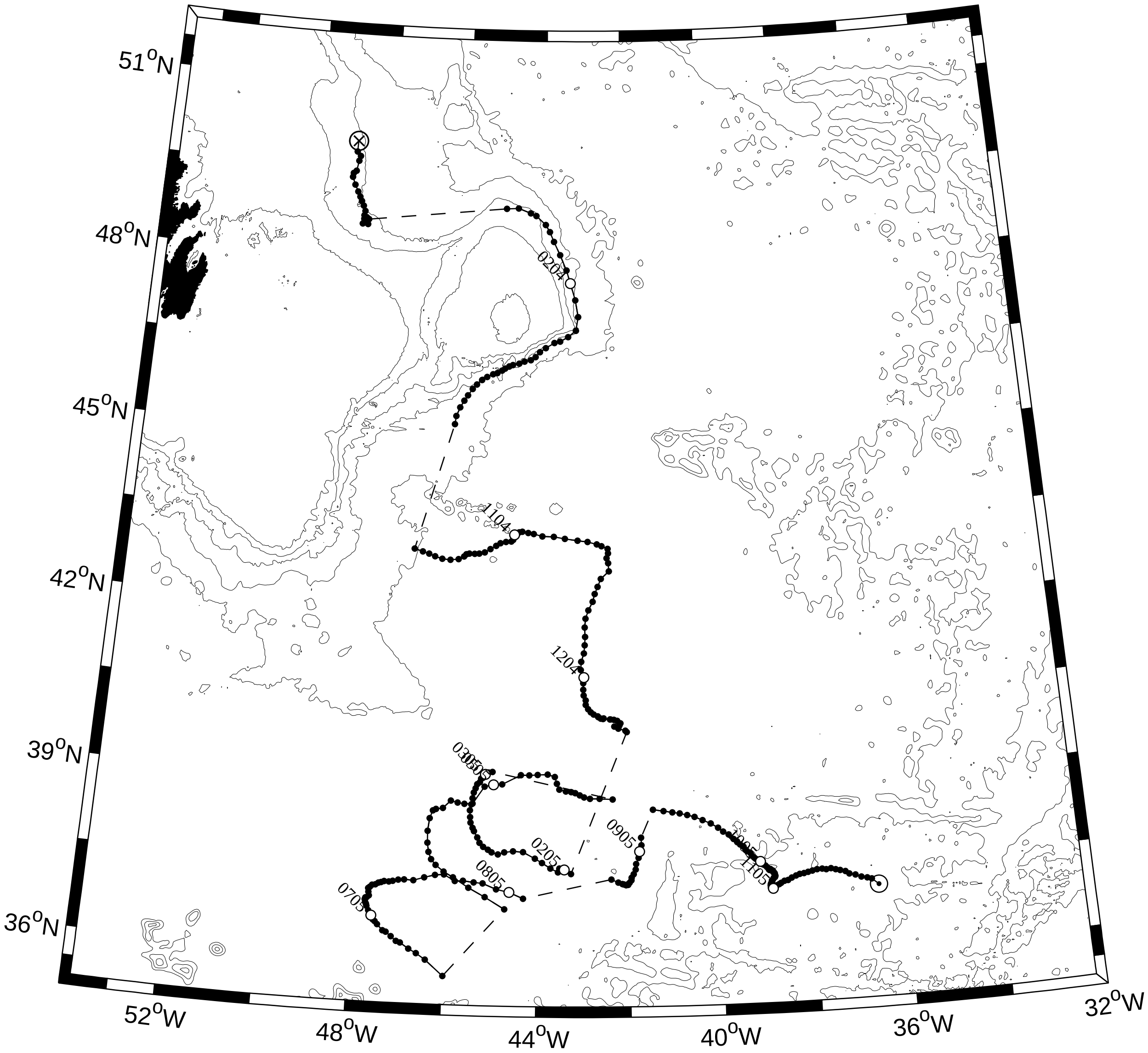


54°N
52°N
50°N
48°N
46°N
44°N
54°W
48°W
42°W
36°W
30°W
24°W
0104
1204
1104
1004
0904
0804
0704
0305
0405
0505
0605
0705
0905
1005
1105

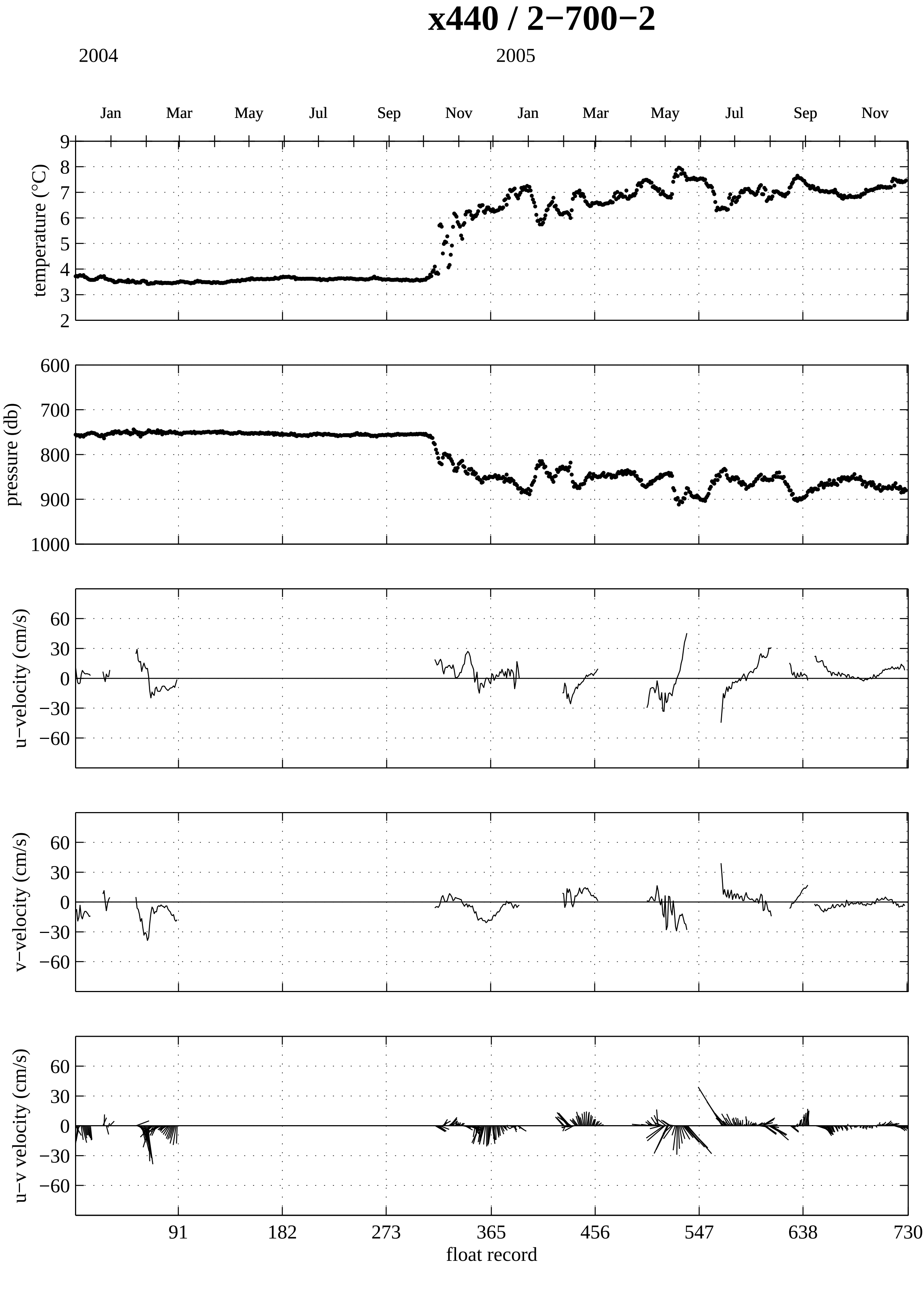
x439 / 2−700−1


2004
2005
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

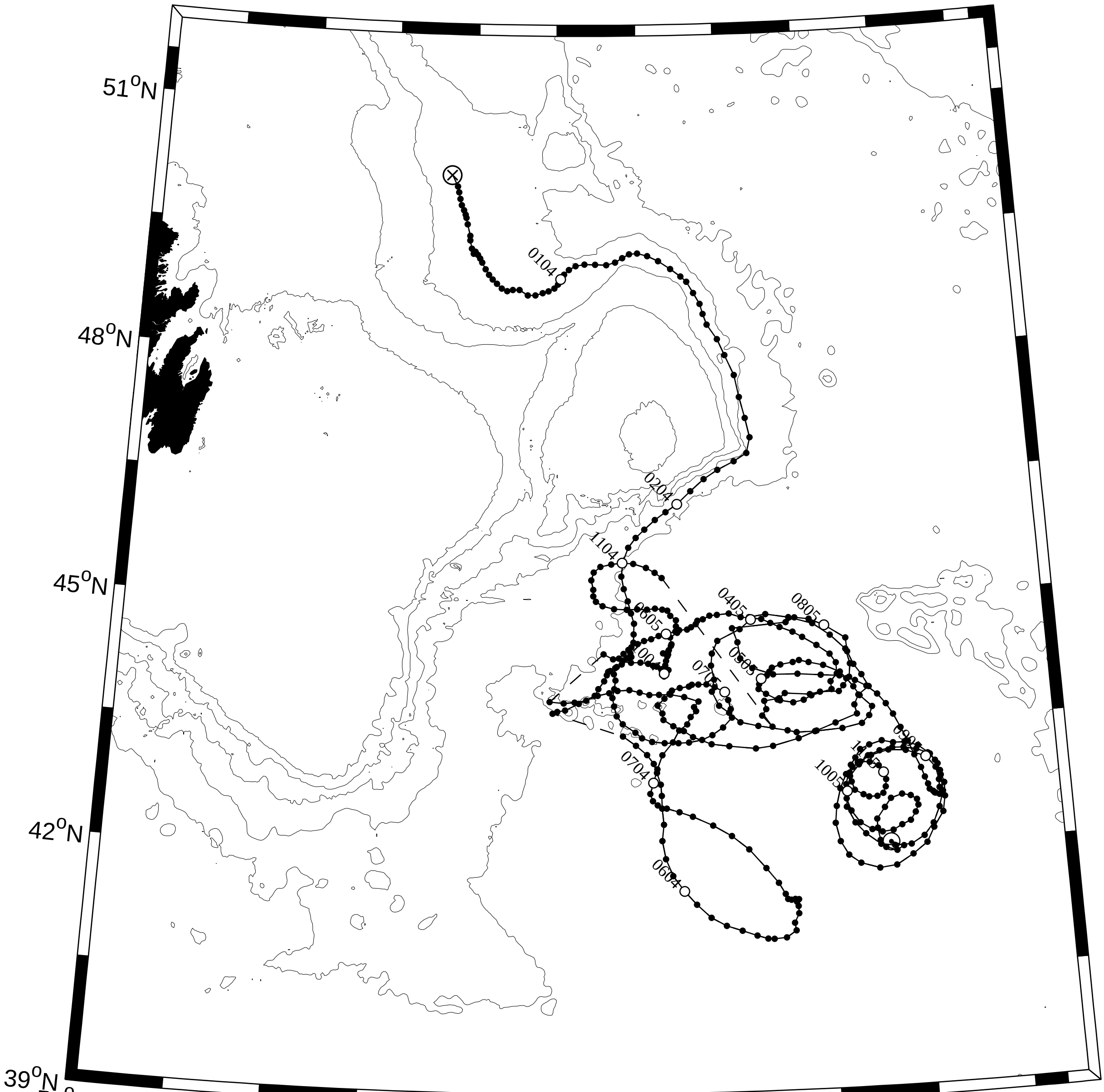
x440 / 2−700−2



51°N
48°N
45°N
42°N
39°N
36°N
52°W
48°W
44°W
40°W
36°W
32°W
0204
1104
1204
0305
0205
0805
0705
0905
1005
1105

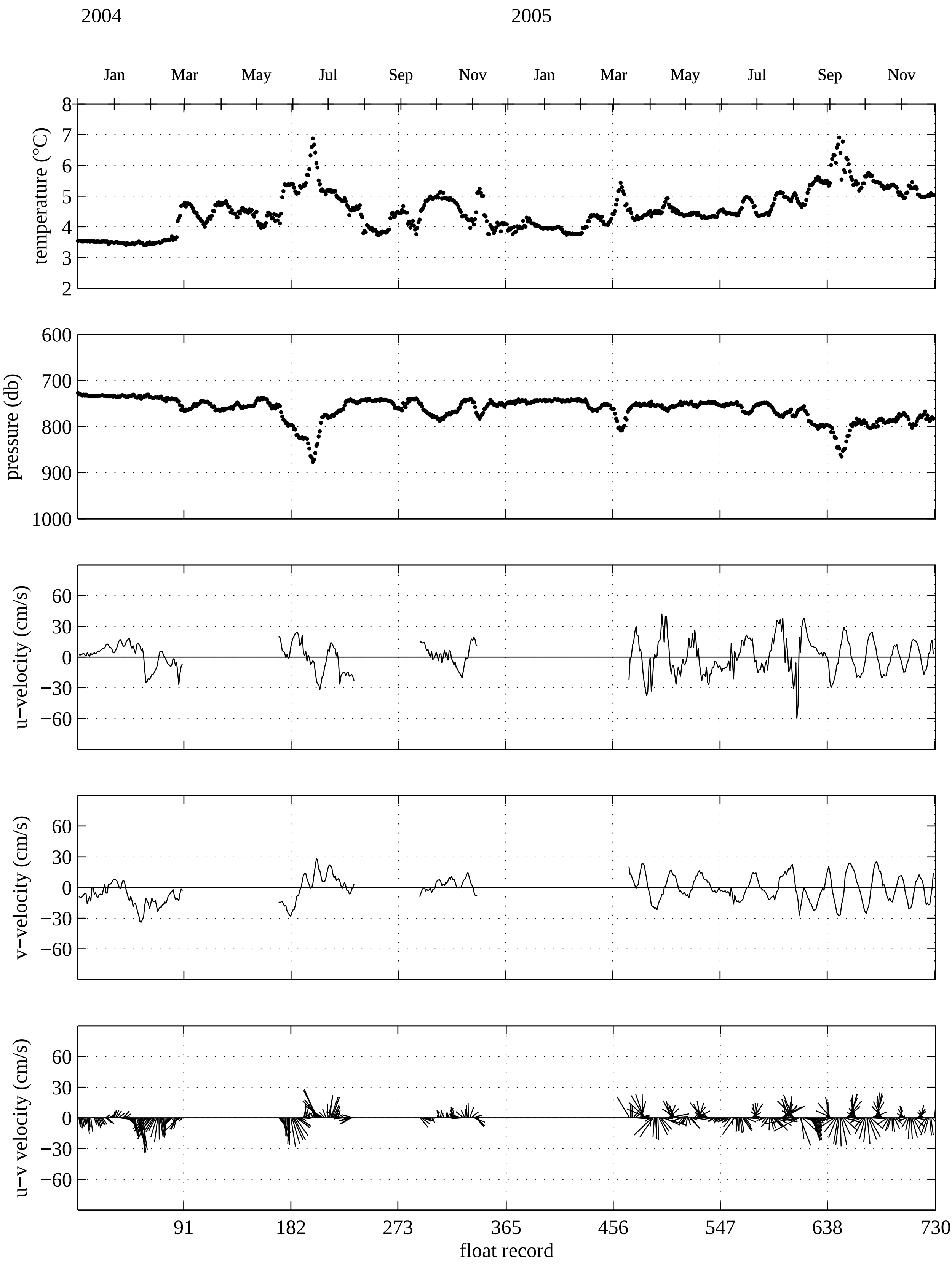

x440 / 2−700−2
2004
2005
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

x441 / 2−700−3



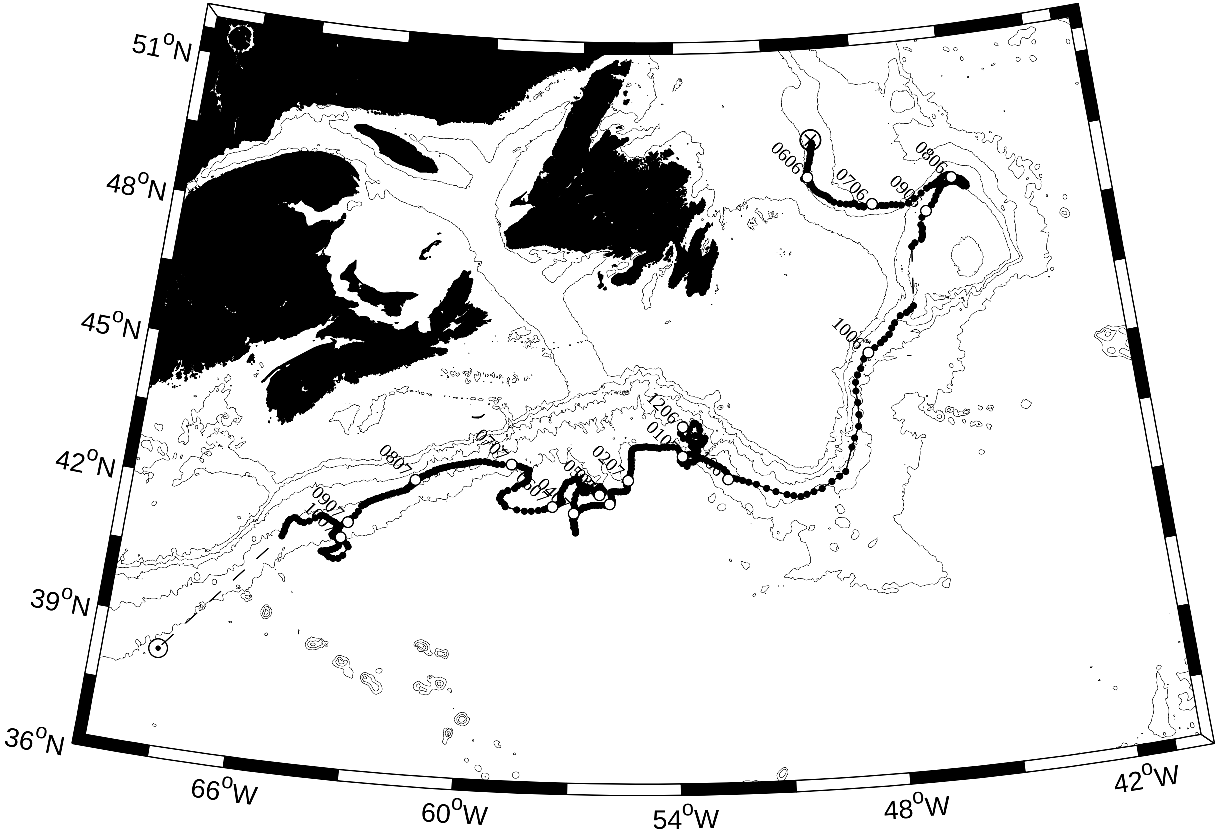
51°N
48°N
45°N
42°N
39°N
54°W
51°W
48°W
45°W
42°W
39°W
0104
0204
1104
0405
0805
0505
0704
0604
1005

x441 / 2−700−3



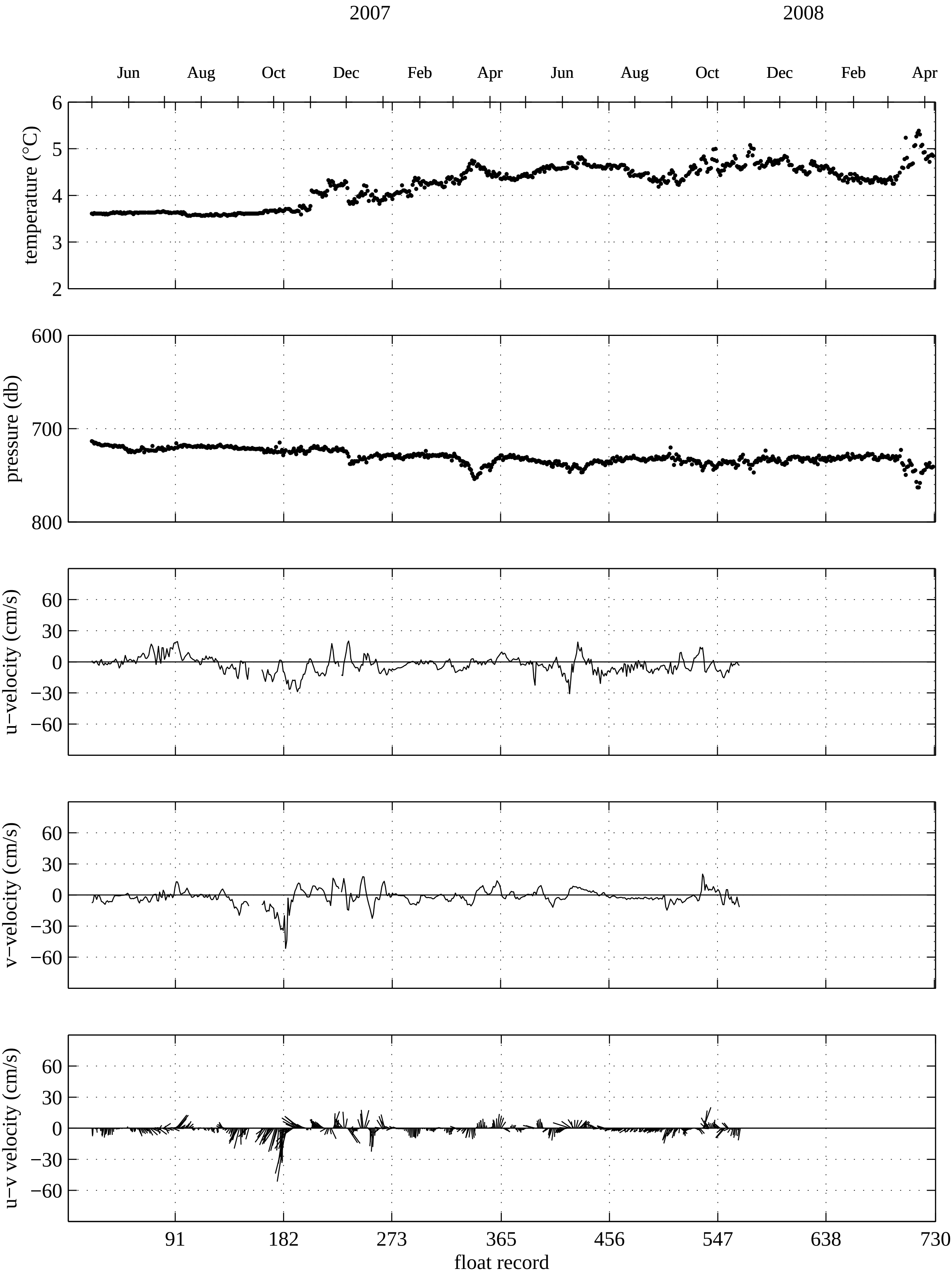
2004
2005
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

x442 / 12−700−1



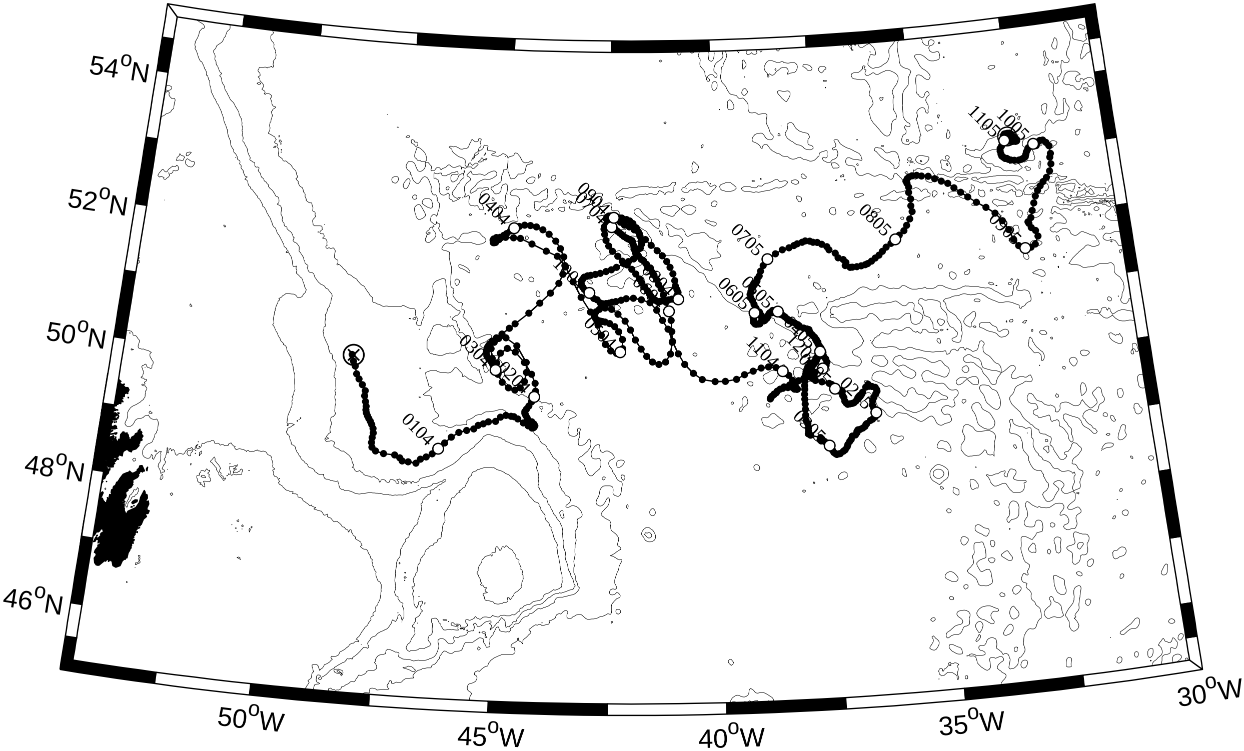
51°N
48°N
45°N
42°N
39°N
36°N
66°W
60°W
54°W
48°W
42°W
0606
0706
0806
0906
1006
1206
0107
0207
0707
0807
0907

x442 / 12−700−1



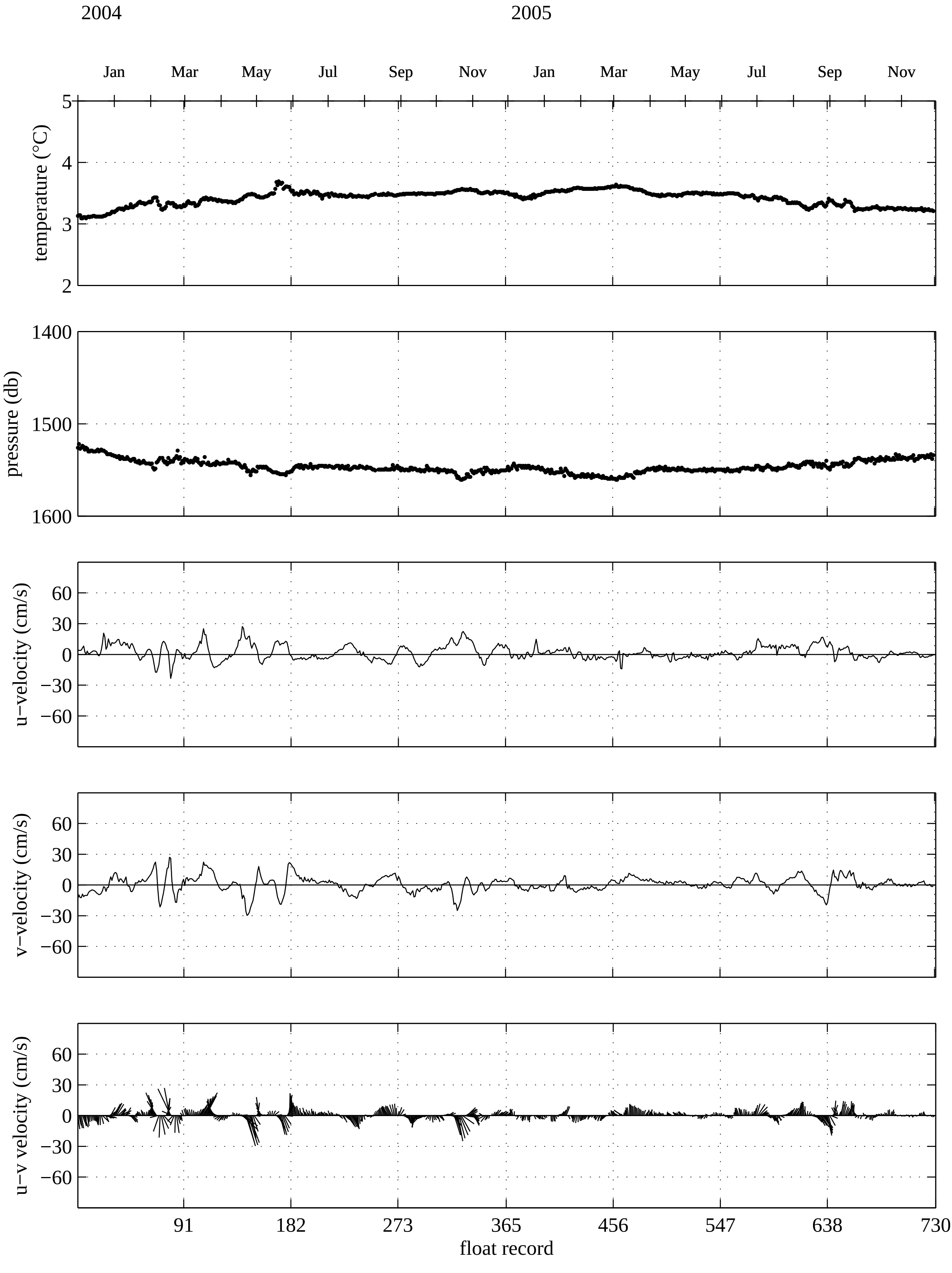
2007
2008
Jun
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
Apr
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

x443 / 2−1500−2

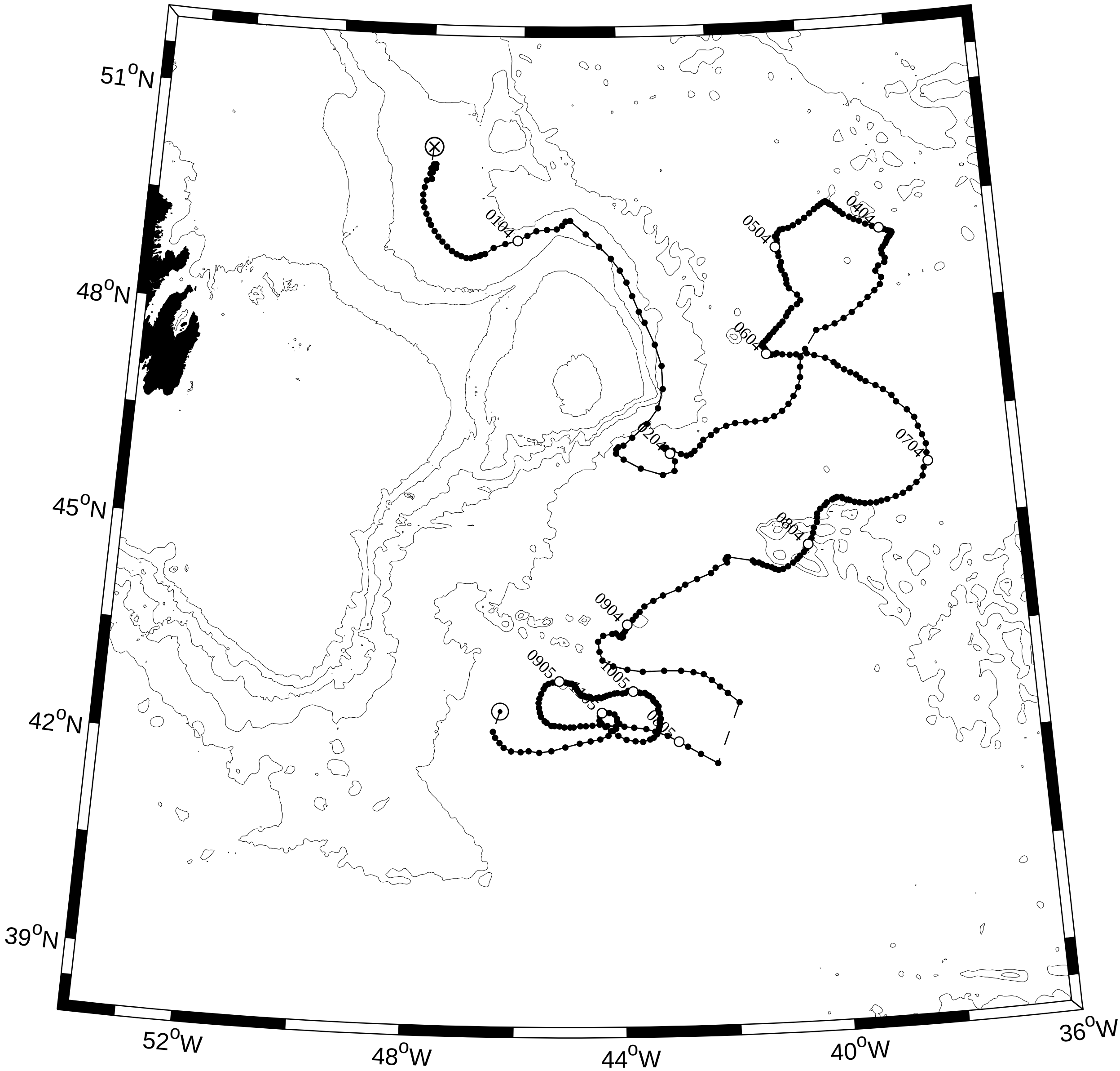


54°N
52°N
50°N
48°N
46°N
50°W
45°W
40°W
35°W
30°W
0104
0204
0304
0404
0504
0704
0904
0605
0705
0805
0905
1005
1105
1104

x443 / 2−1500−2

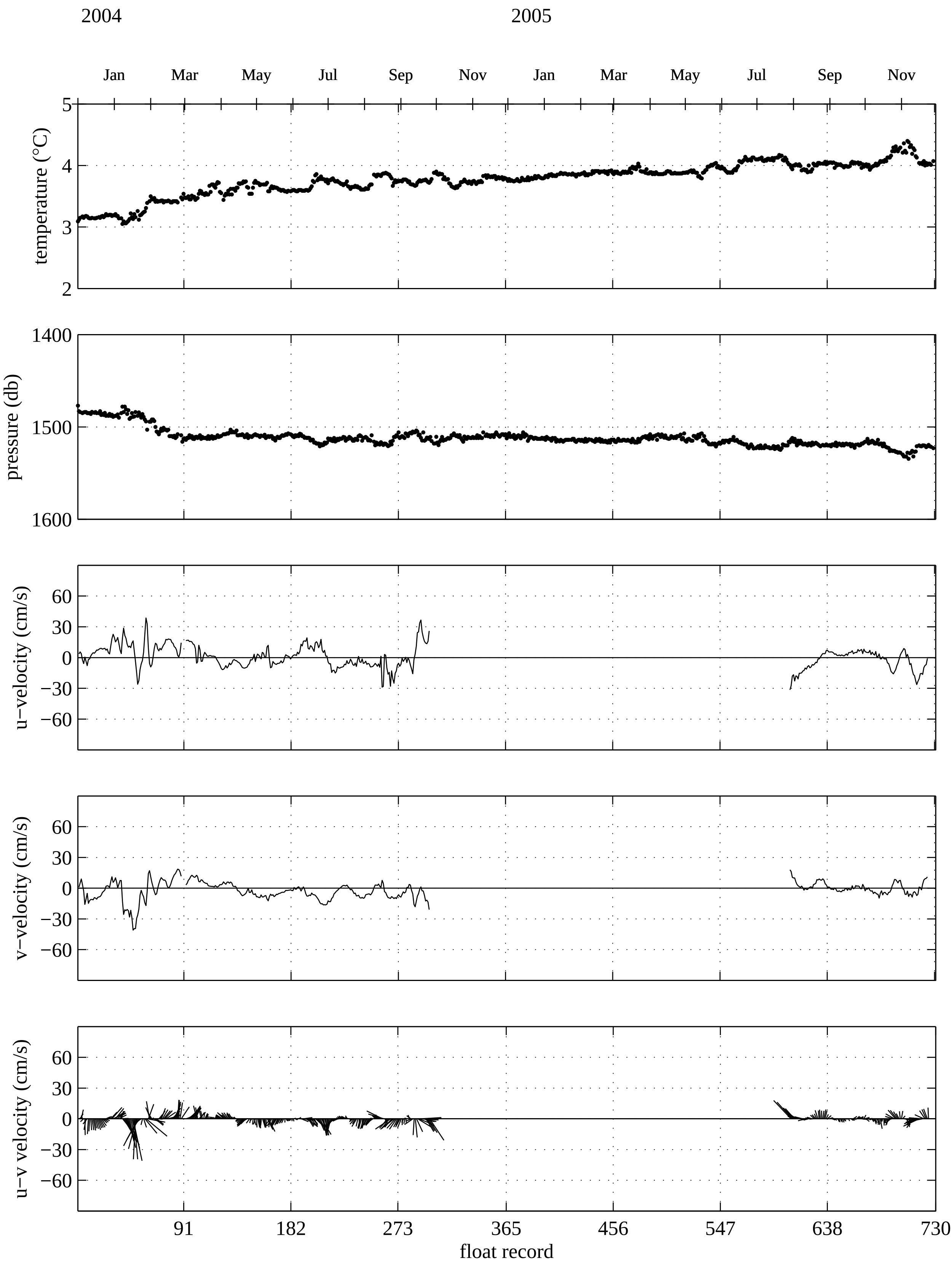

2004
2005
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
temperature (°C)
5
4
3
2
pressure (db)
1400
1500
1600
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

x444 / 2−1500−3



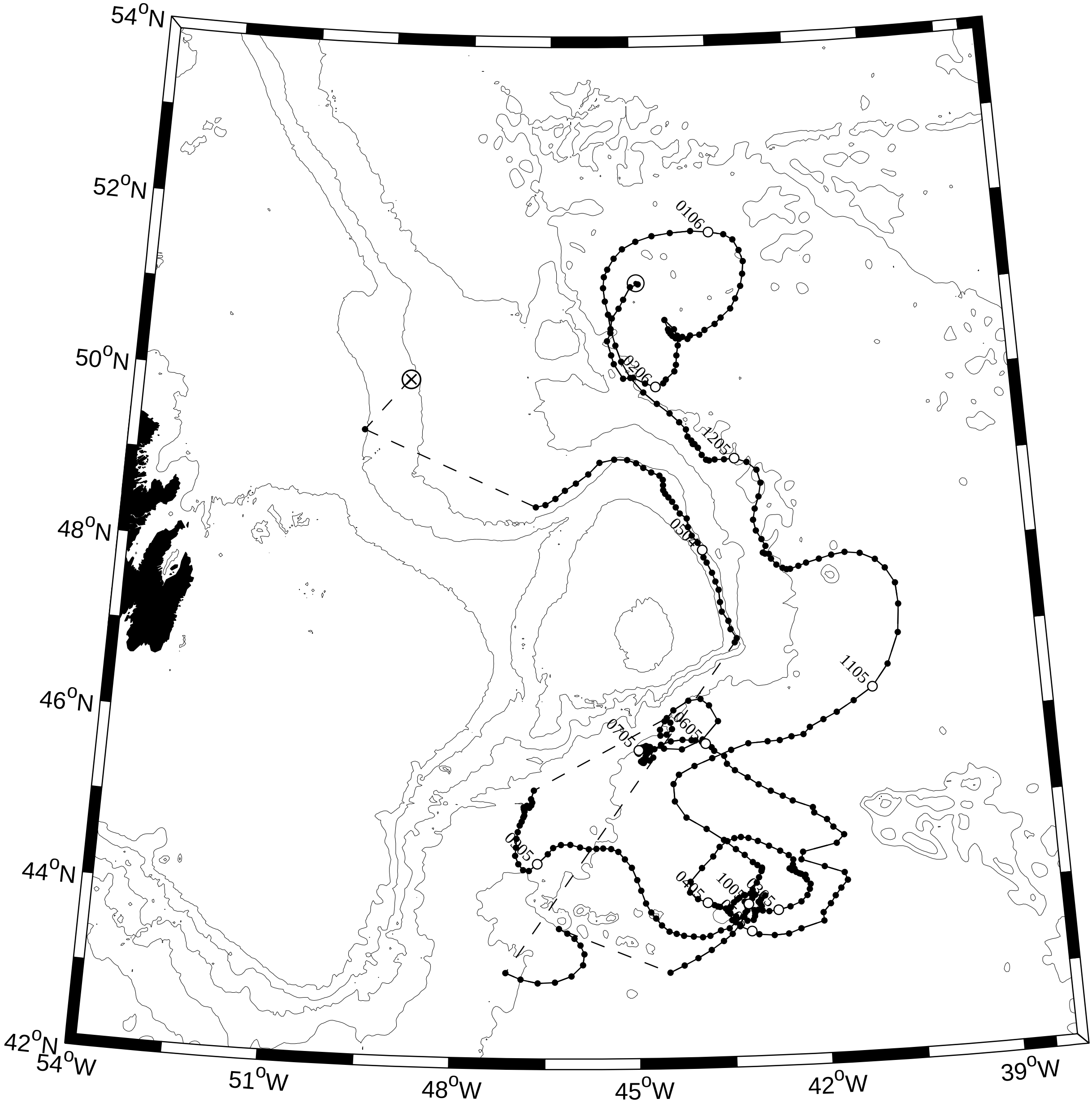
51°N
48°N
45°N
42°N
39°N
52°W
48°W
44°W
40°W
36°W
0104
0204
0404
0504
0604
0704
0804
0904
0905
1005

x444 / 2−1500−3

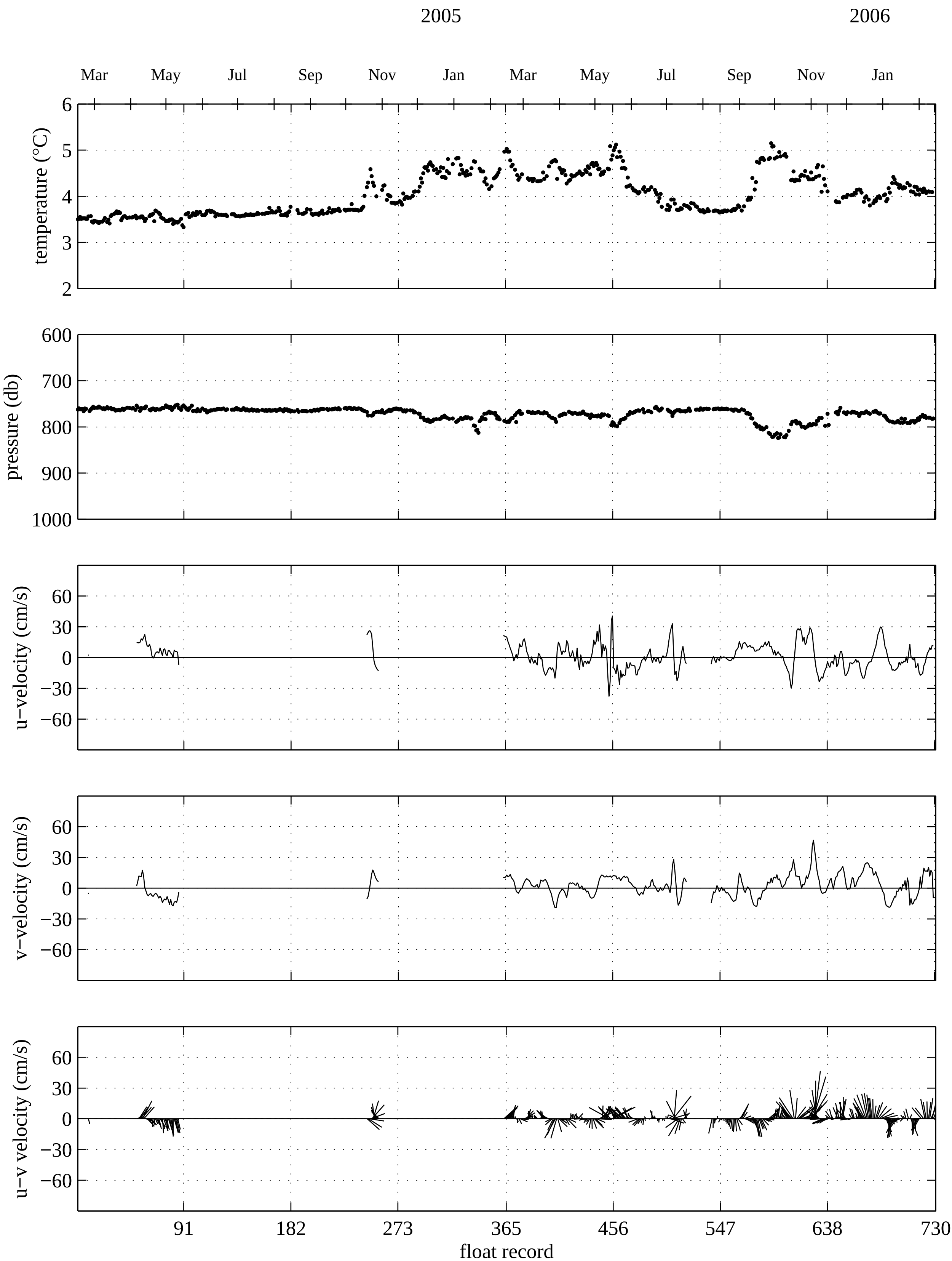


2004
2005
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
temperature (°C)
5
4
3
2
pressure (db)
1400
1500
1600
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

x446 / 3−700−2

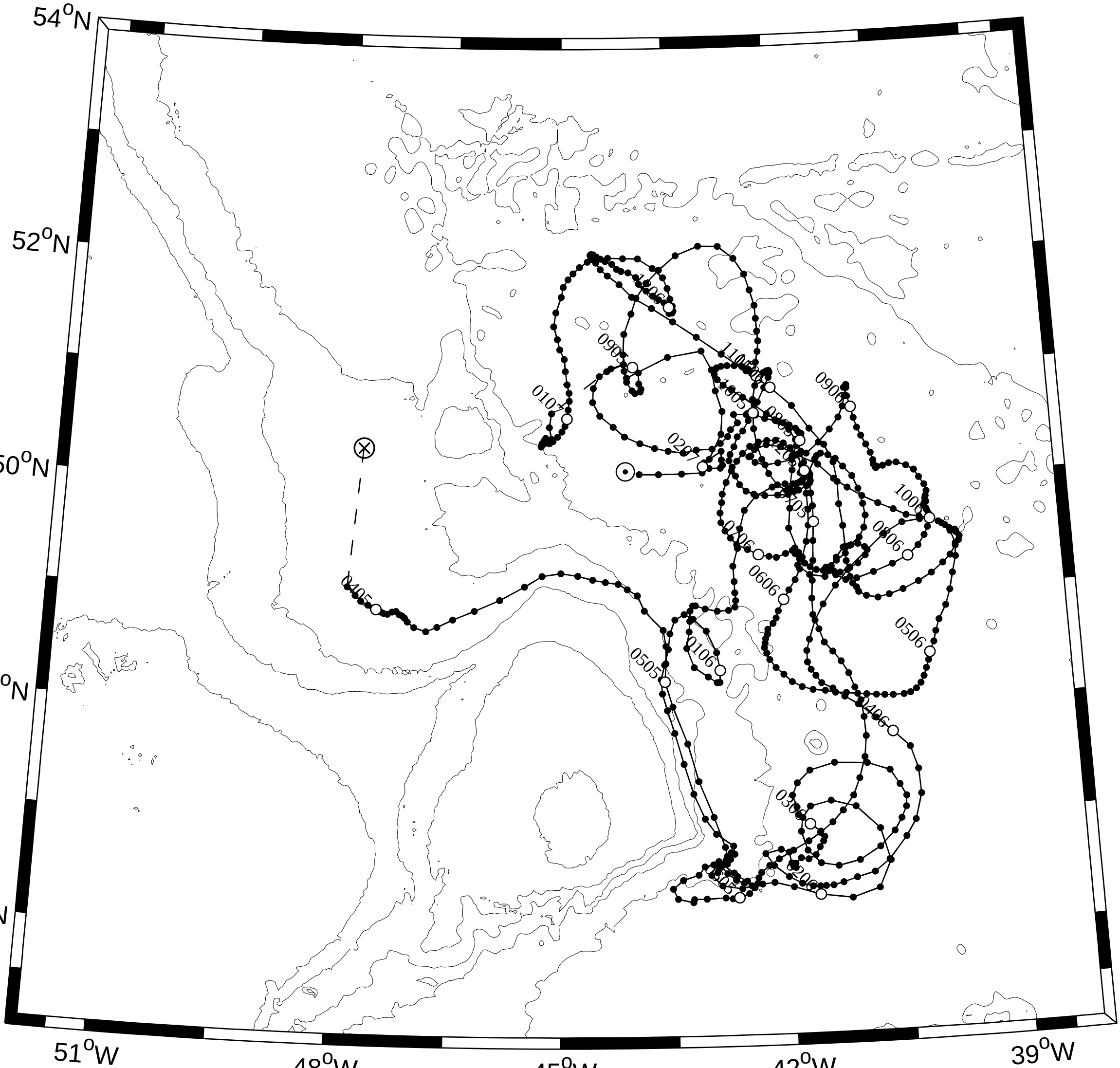

54°N
52°N
50°N
48°N
46°N
44°N
42°N
54°W
51°W
48°W
45°W
42°W
39°W
0106
0206
1205
0504
1105
0605
0705
0305
0405
1005
0905

x446 / 3−700−2



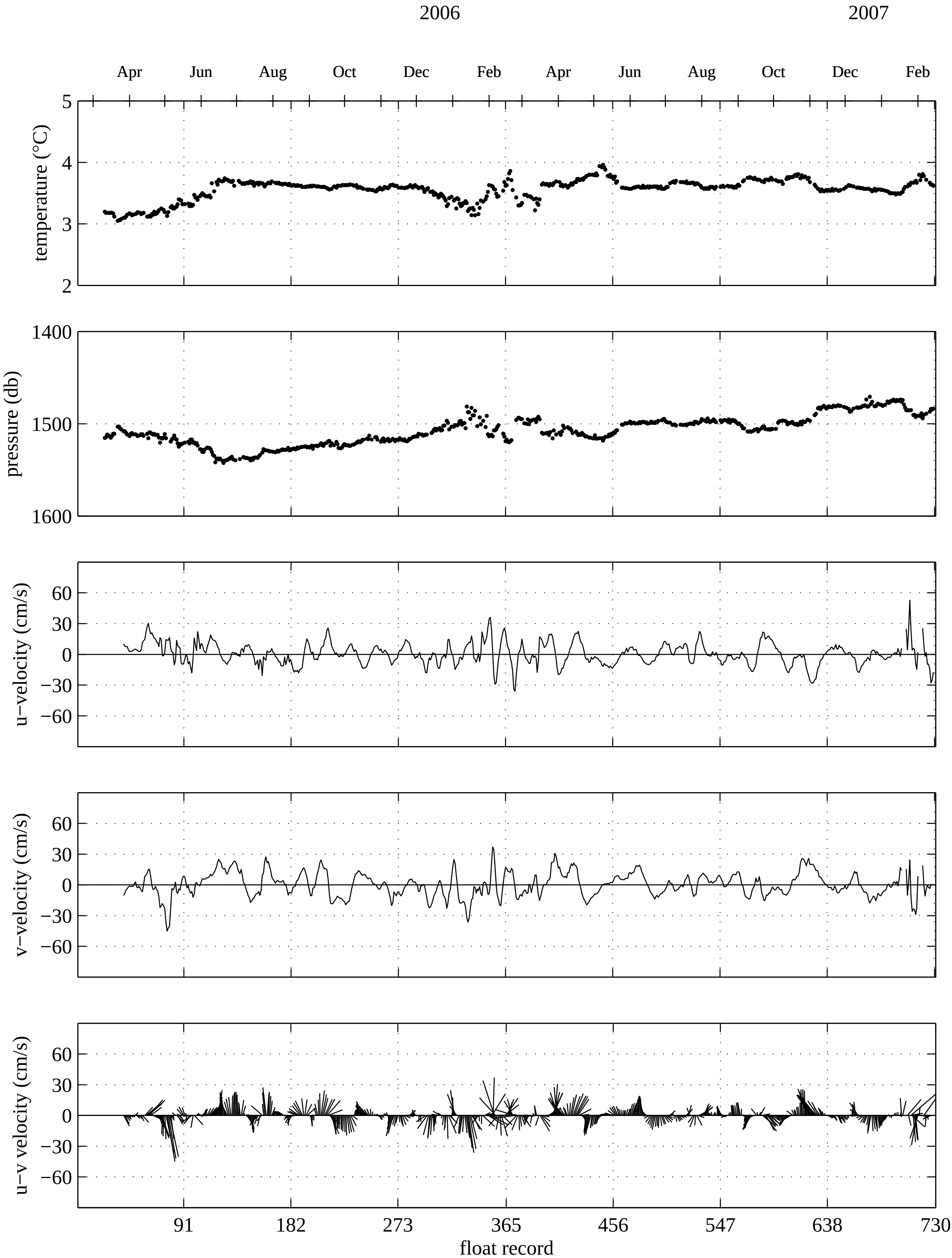
2005
2006
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
temperature (°C)
6
5
4
3
2
pressure (db)
600
700
800
900
1000
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

x450 / 7−1500−3



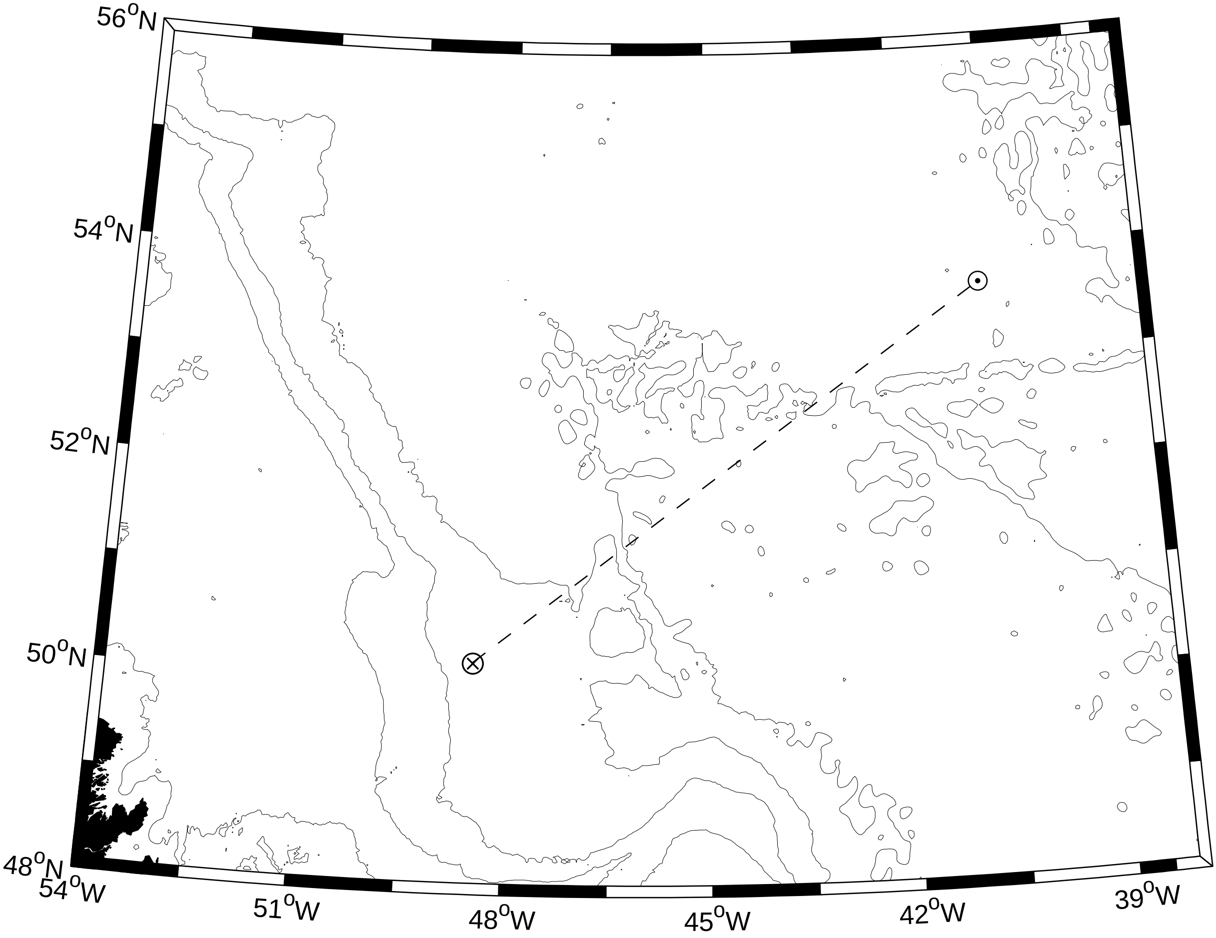
54^{o}N
52^{o}N
50^{o}N
48^{o}N
46^{o}N
51^{o}W
48^{o}W
45^{o}W
42^{o}W
39^{o}W
0405
0505
0506
0106
0606
0406
1006
0906
0107
0207

x450 / 7−1500−3

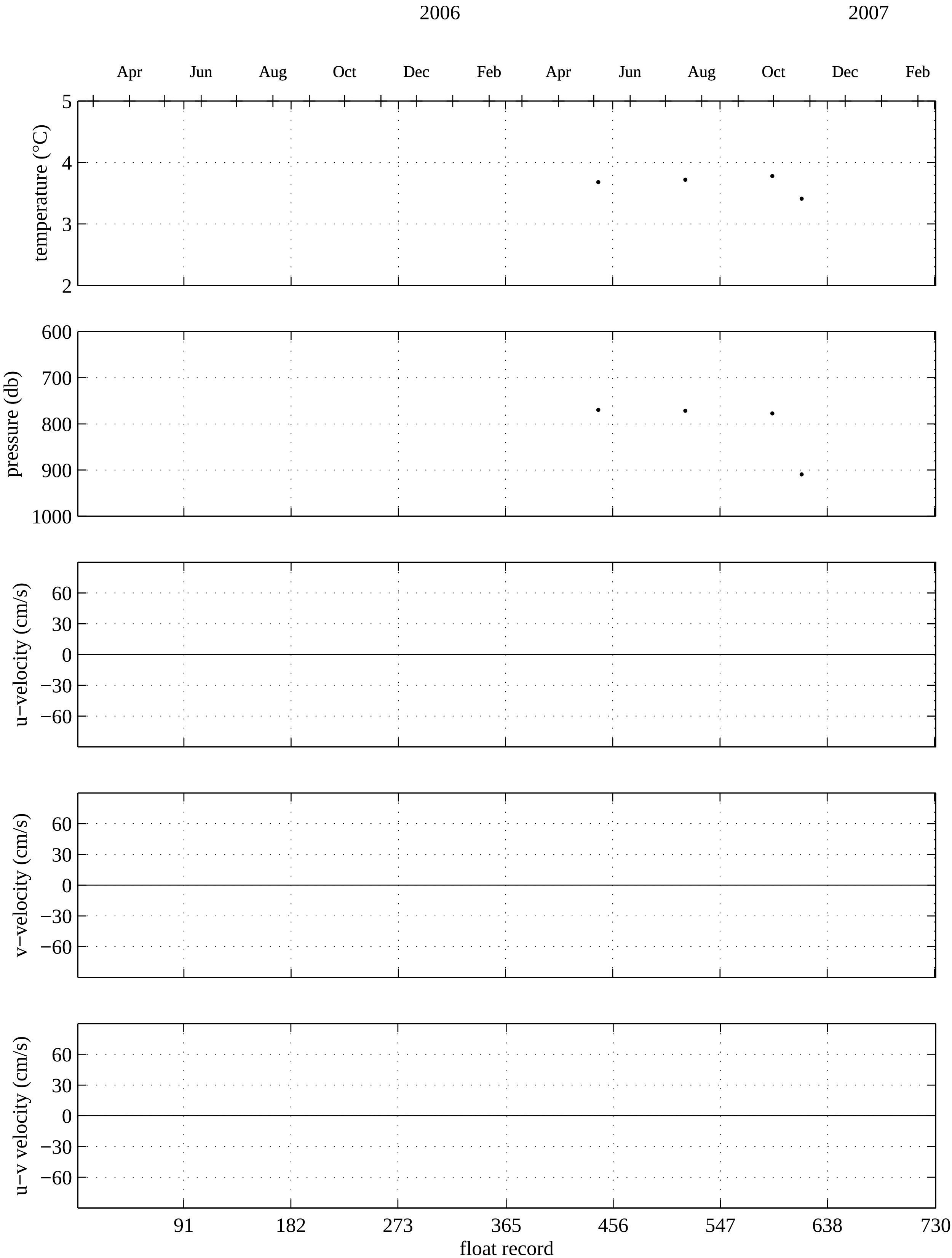


2006
2007
Apr
Jun
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
5
4
3
2
temperature (°C)
1400
1500
1600
pressure (db)
60
30
0
−30
−60
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

x451 / 7−700−3

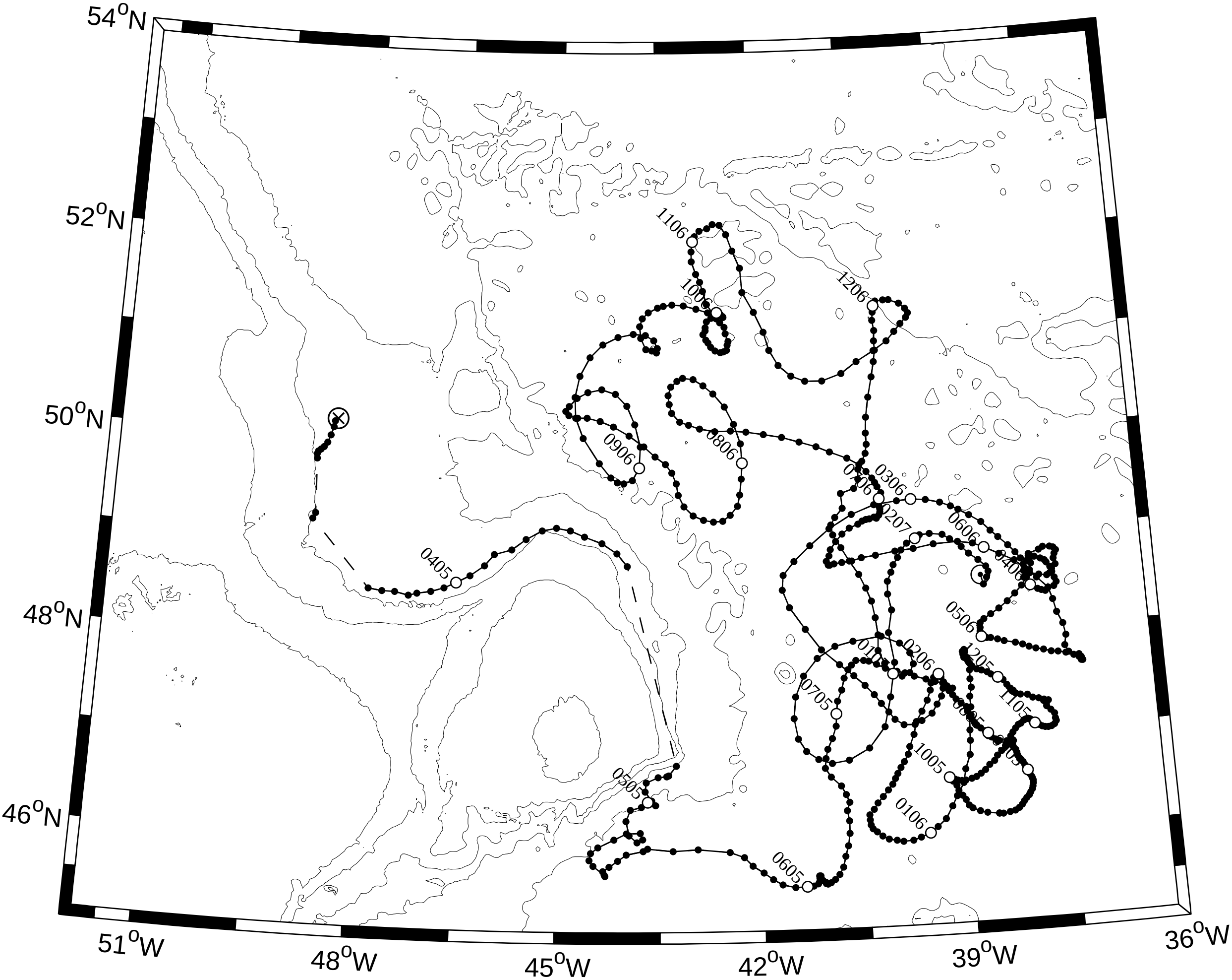


x451 / 7−700−3



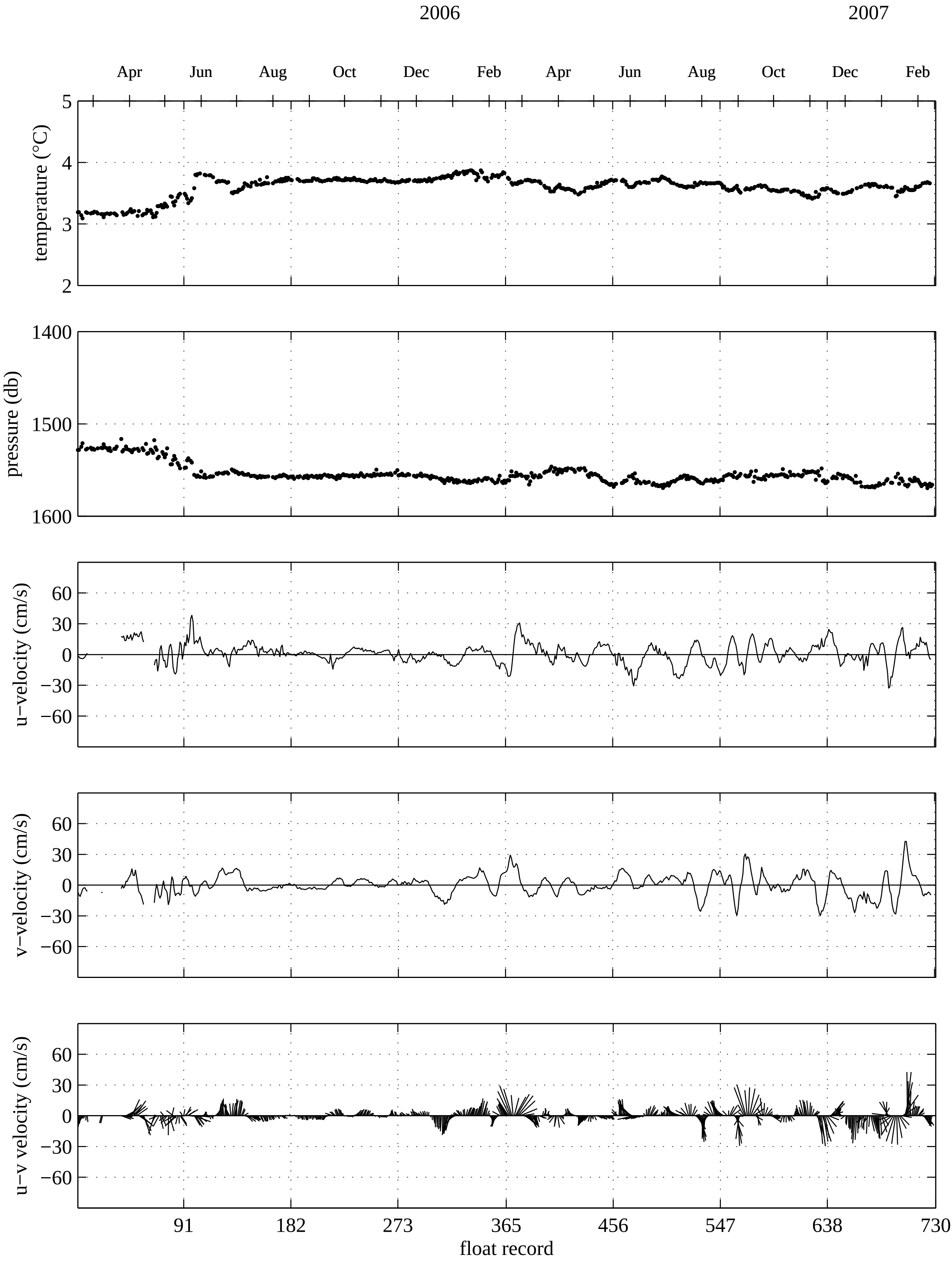
2006
2007
Apr
Jun
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
temperature (°C)
5
4
3
2
pressure (db)
600
700
800
900
1000
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

x452 / 7−1500−2

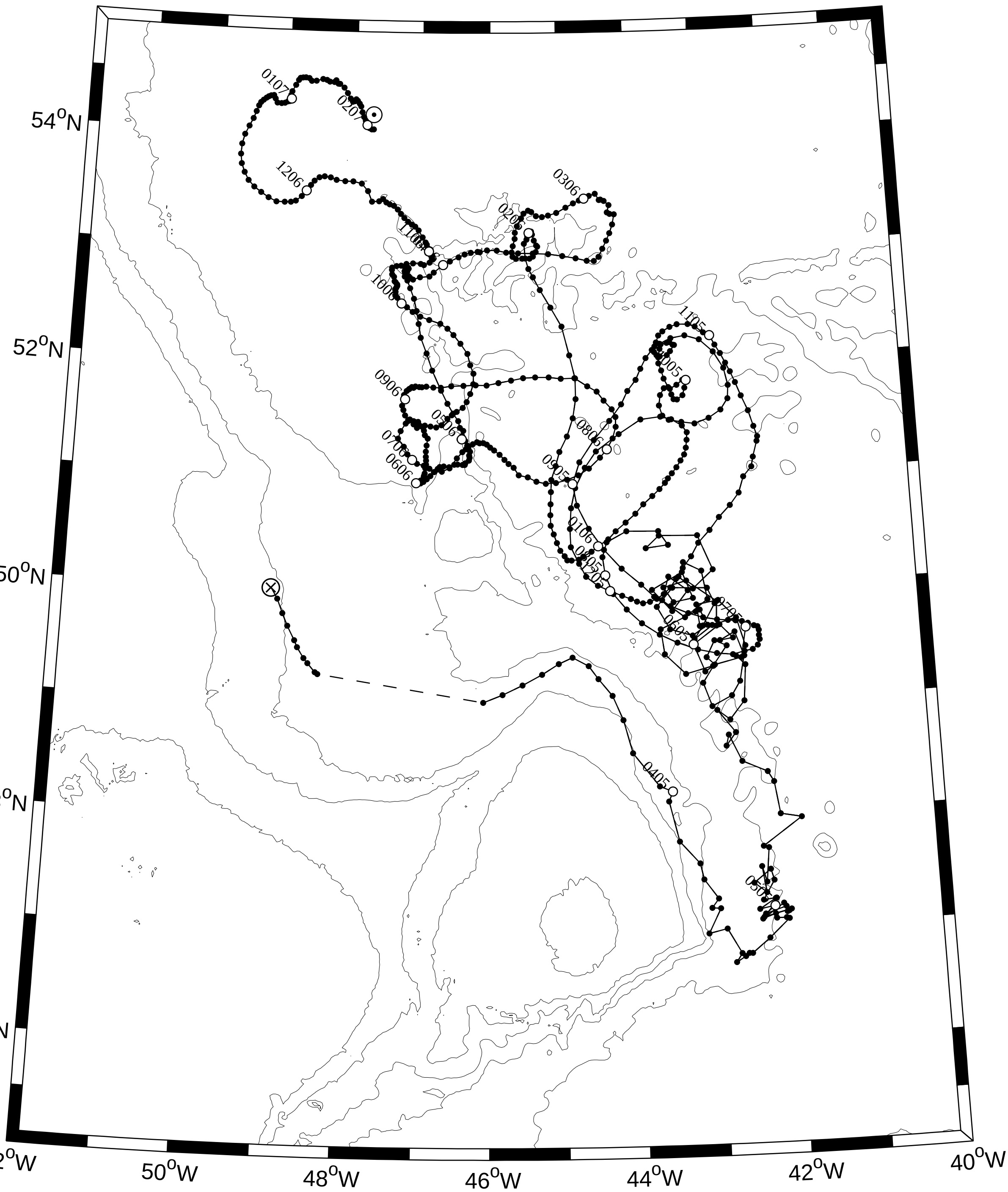


54°N
52°N
50°N
48°N
46°N
51°W
48°W
45°W
42°W
39°W
36°W
1106
1006
1206
0906
0806
0306
0106
0207
0606
0406
0405
0506
0706
0206
1205
0705
1105
1005
0505
0106
0605

x452 / 7−1500−2

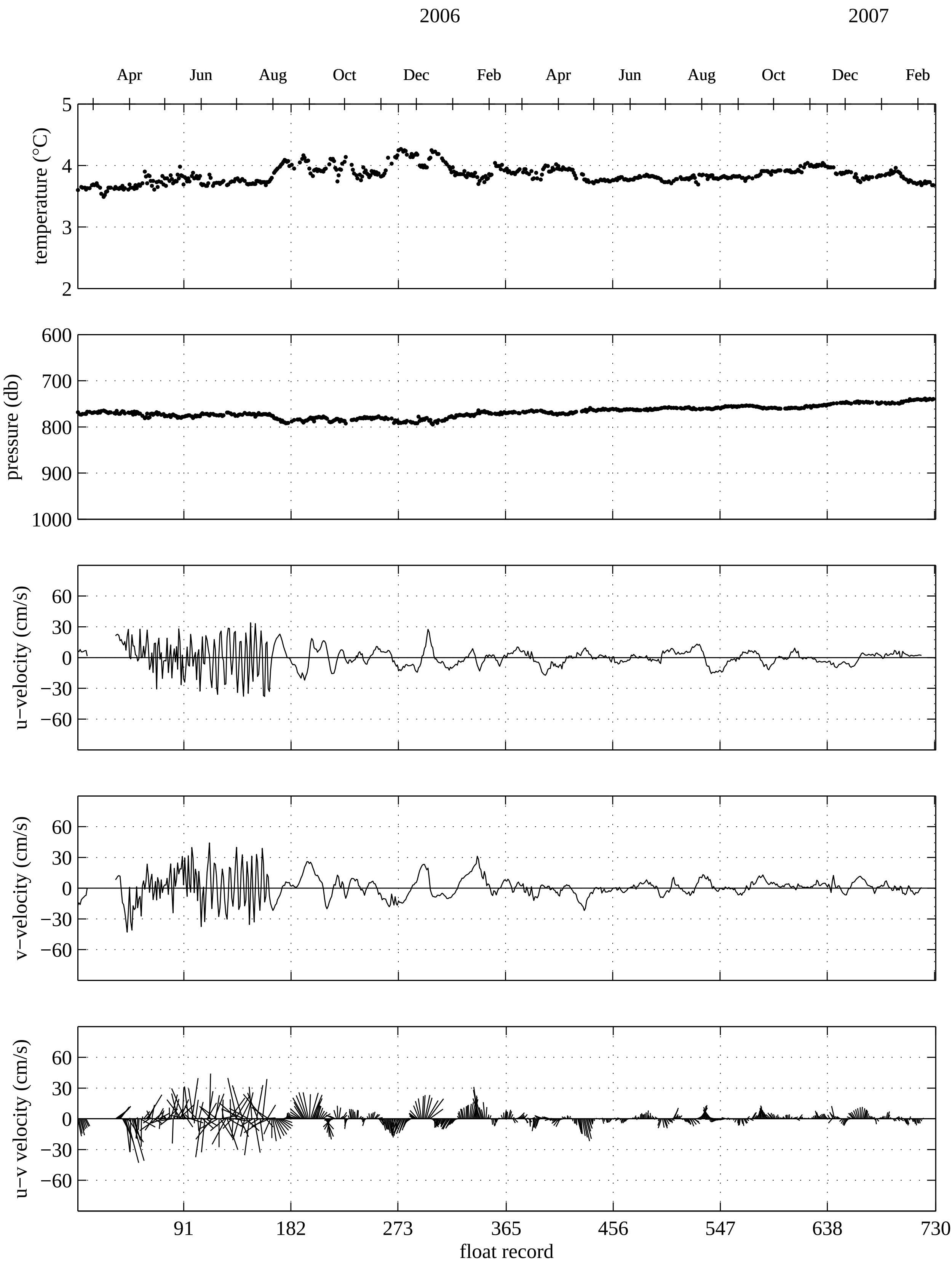

2006
2007
Apr
Jun
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
temperature (°C)
5
4
3
2
pressure (db)
1400
1500
1600
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

x453 / 7−700−2



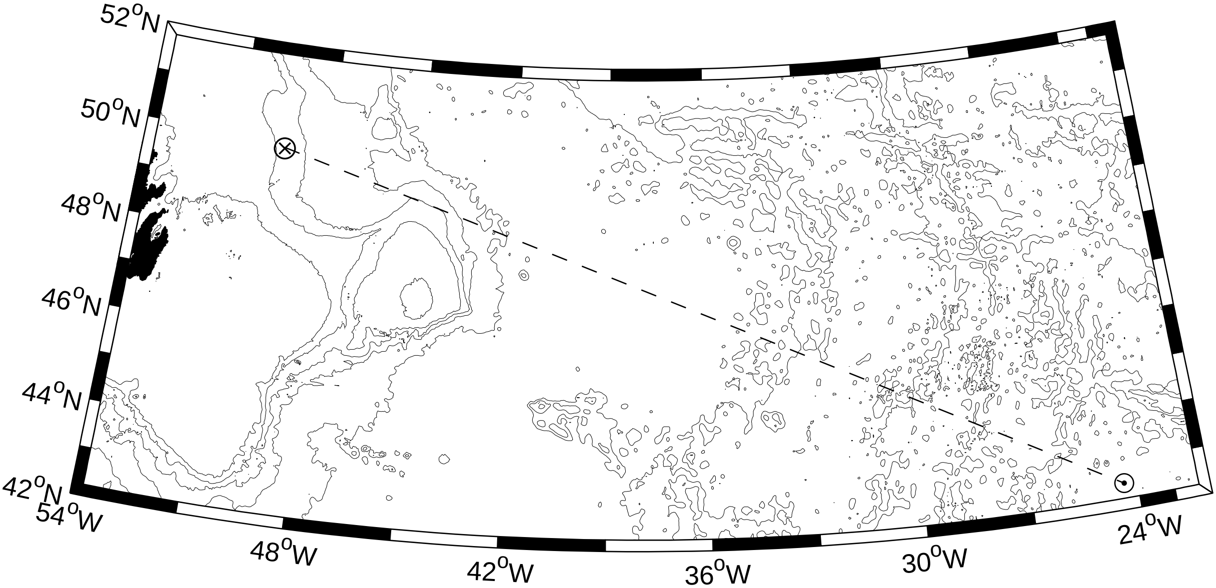
54°N
52°N
50°N
48°N
46°N
52°W
50°W
48°W
46°W
44°W
42°W
40°W
0107
0207
1206
0306
1106
1006
1105
1005
0906
0506
0806
0706
0606
0905
0106
0405

x453 / 7−700−2

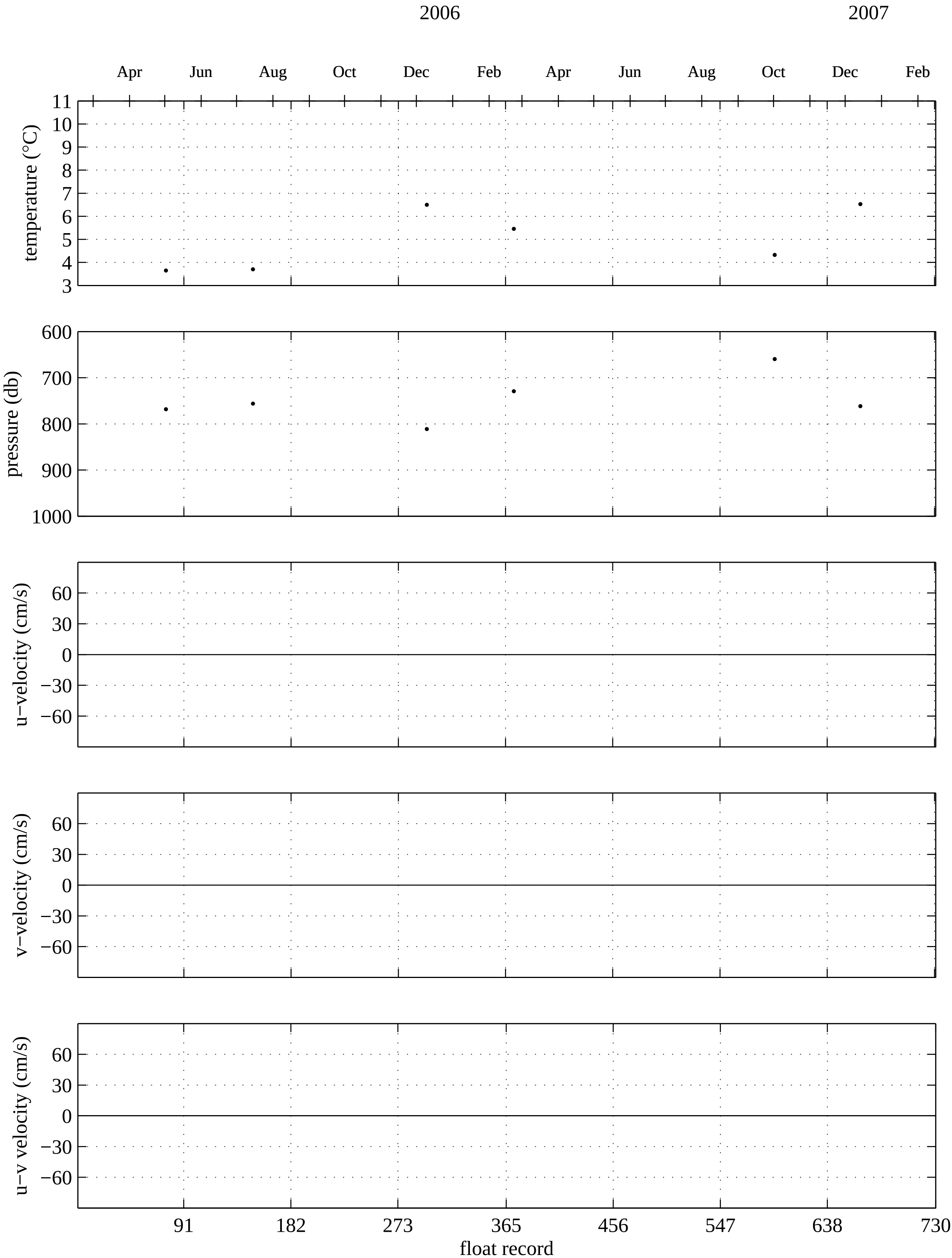


2006
2007
Apr
Jun
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
temperature (°C)
5
4
3
2
pressure (db)
600
700
800
900
1000
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

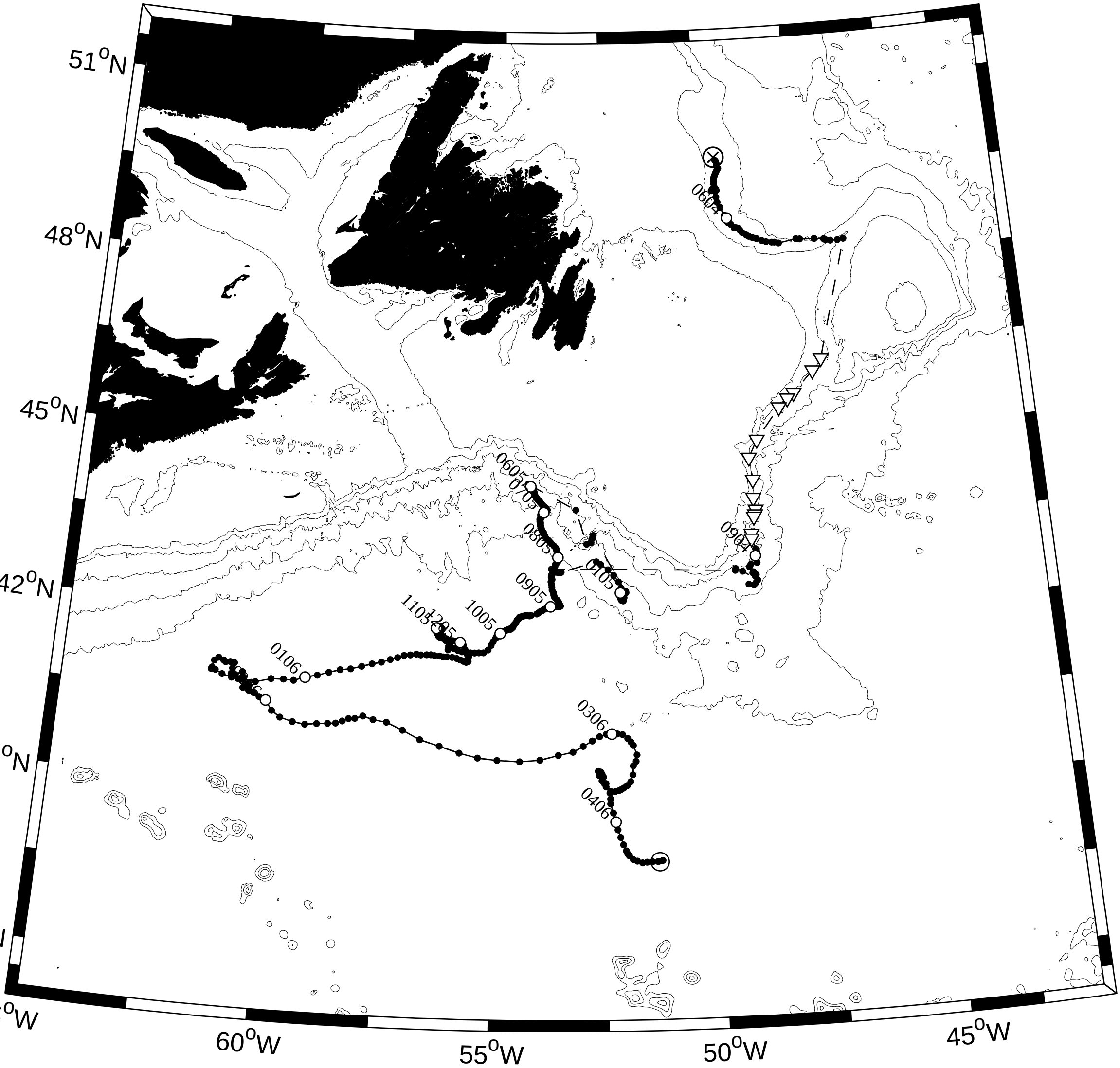
x455 / 7−700−1



x455 / 7−700−1

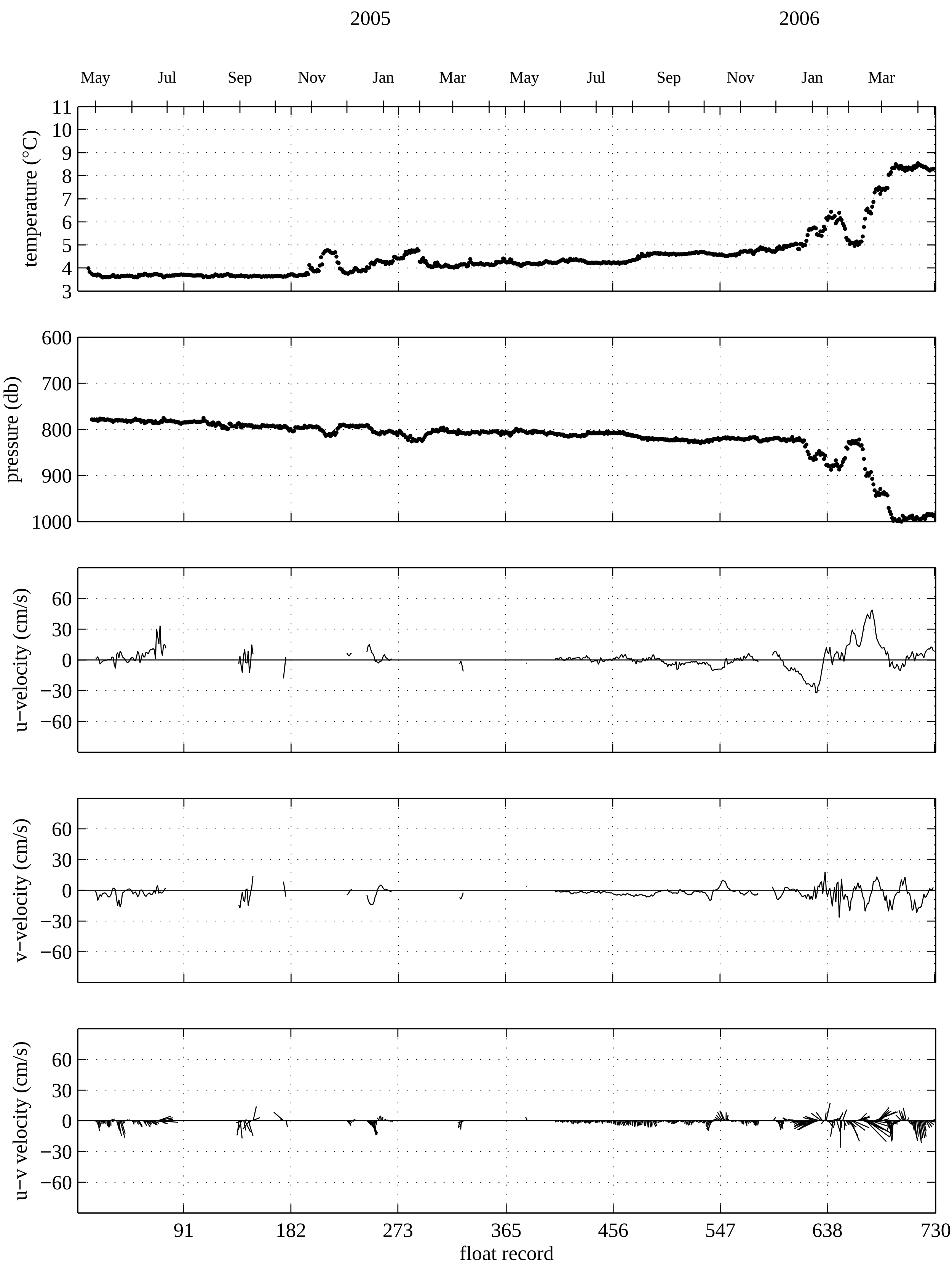

2006
2007
Apr
Jun
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
temperature (°C)
11
10
9
8
7
6
5
4
3
pressure (db)
600
700
800
900
1000
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

x565 / 4−700−1



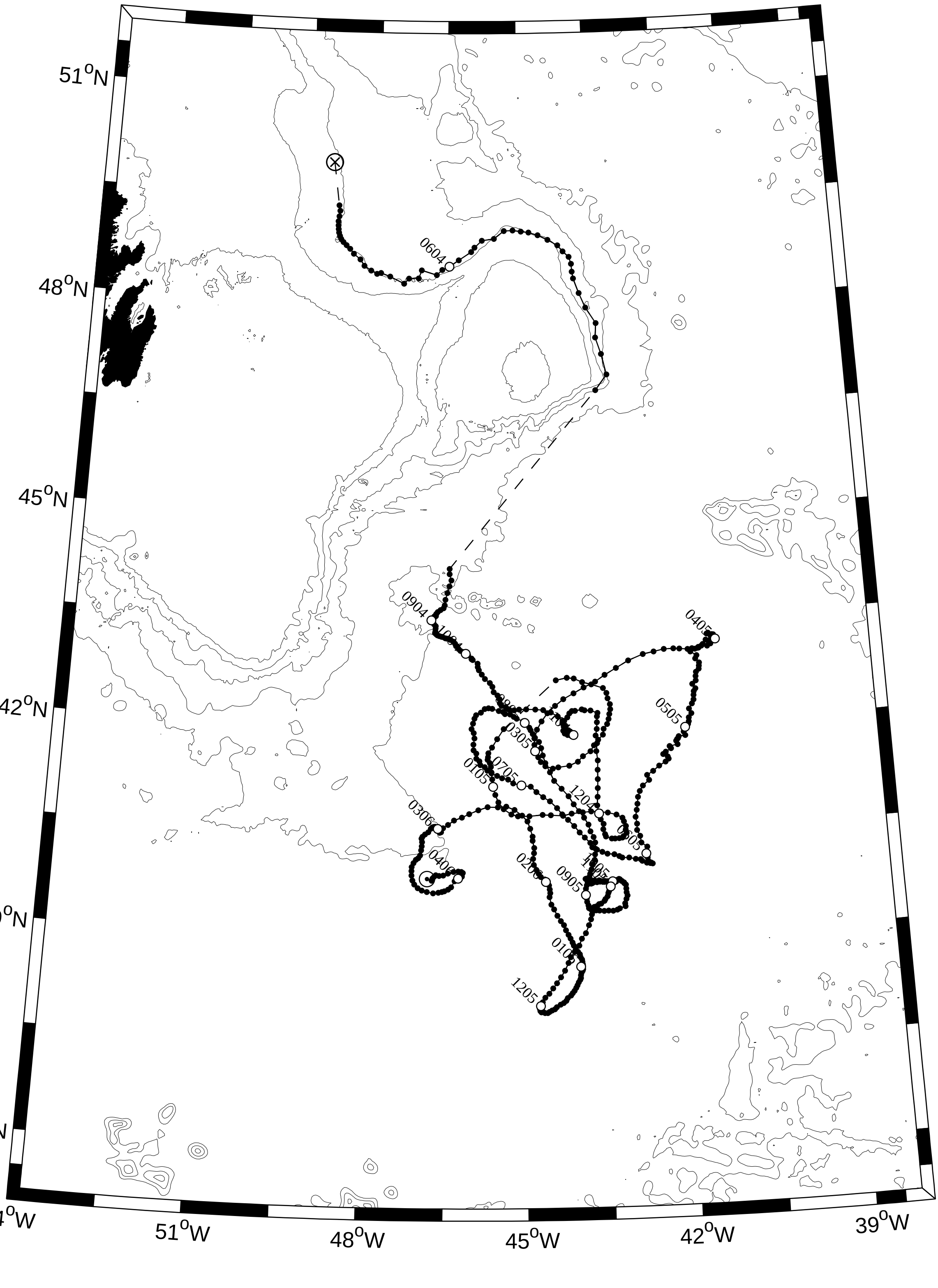
51°N
48°N
45°N
42°N
39°N
36°N
65°W
60°W
55°W
50°W
45°W
0604
0605
0705
0805
0904
0905
1005
1105
1205
0106
0306
0406

x565 / 4−700−1



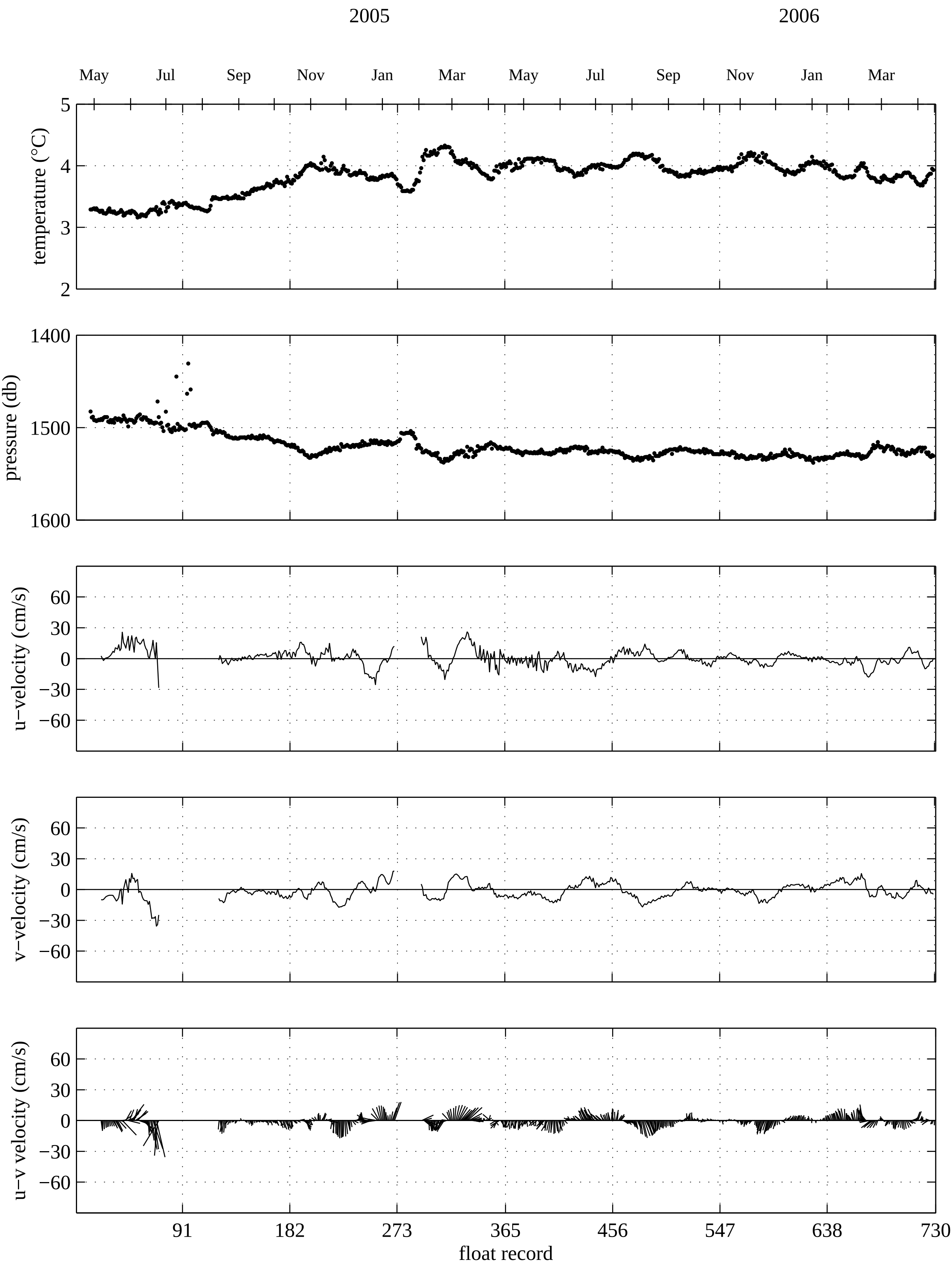
2005
2006
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
temperature (°C)
11
10
9
8
7
6
5
4
3
pressure (db)
600
700
800
900
1000
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

x566 / 4−1500−1



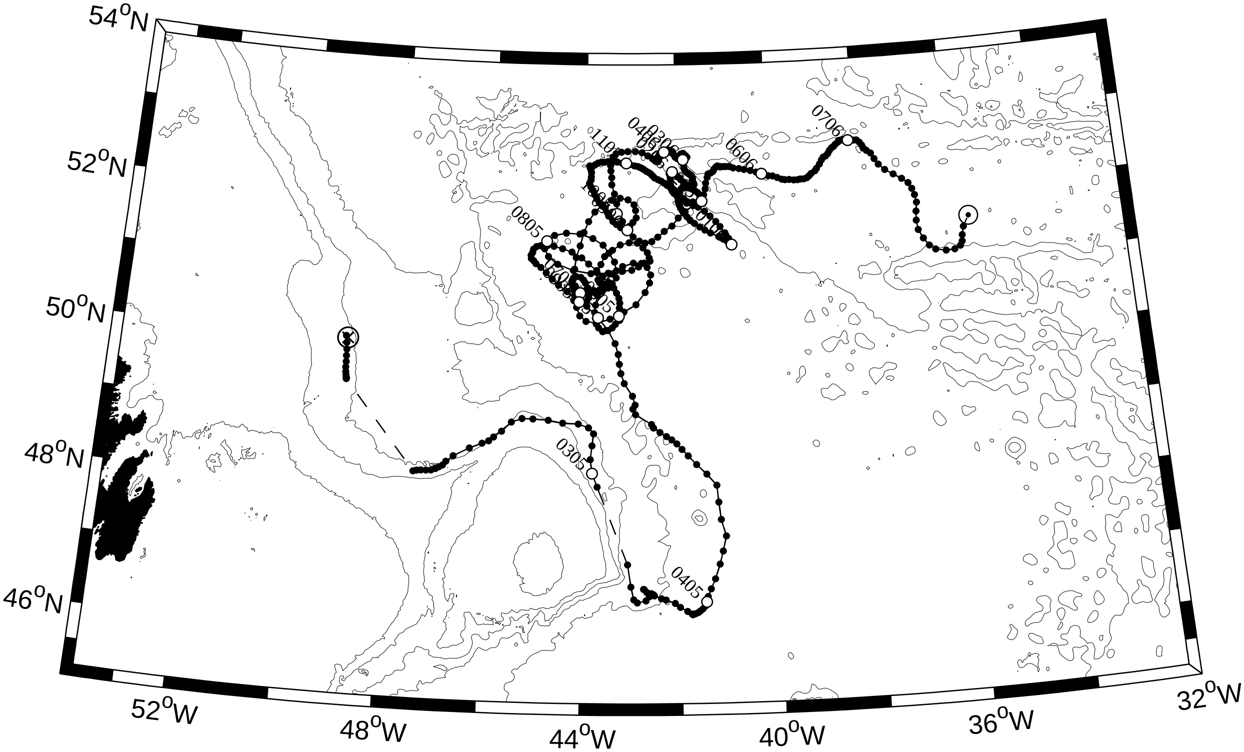
51°N
48°N
45°N
42°N
39°N
36°N
54°W
51°W
48°W
45°W
42°W
39°W
0604
0904
0405
0505
0305
0105
0705
1204
0306
0205
0905
1205

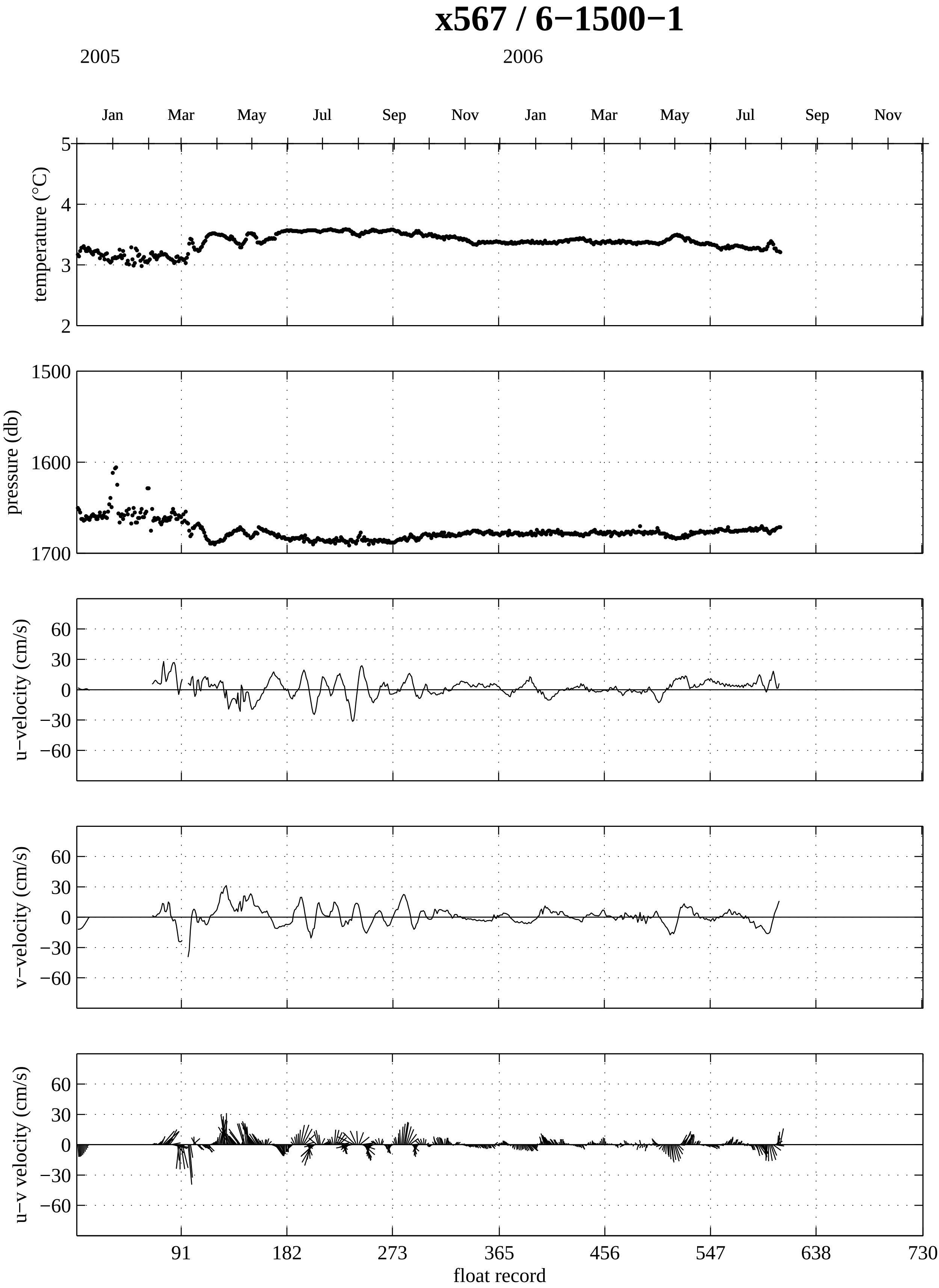
x566 / 4−1500−1



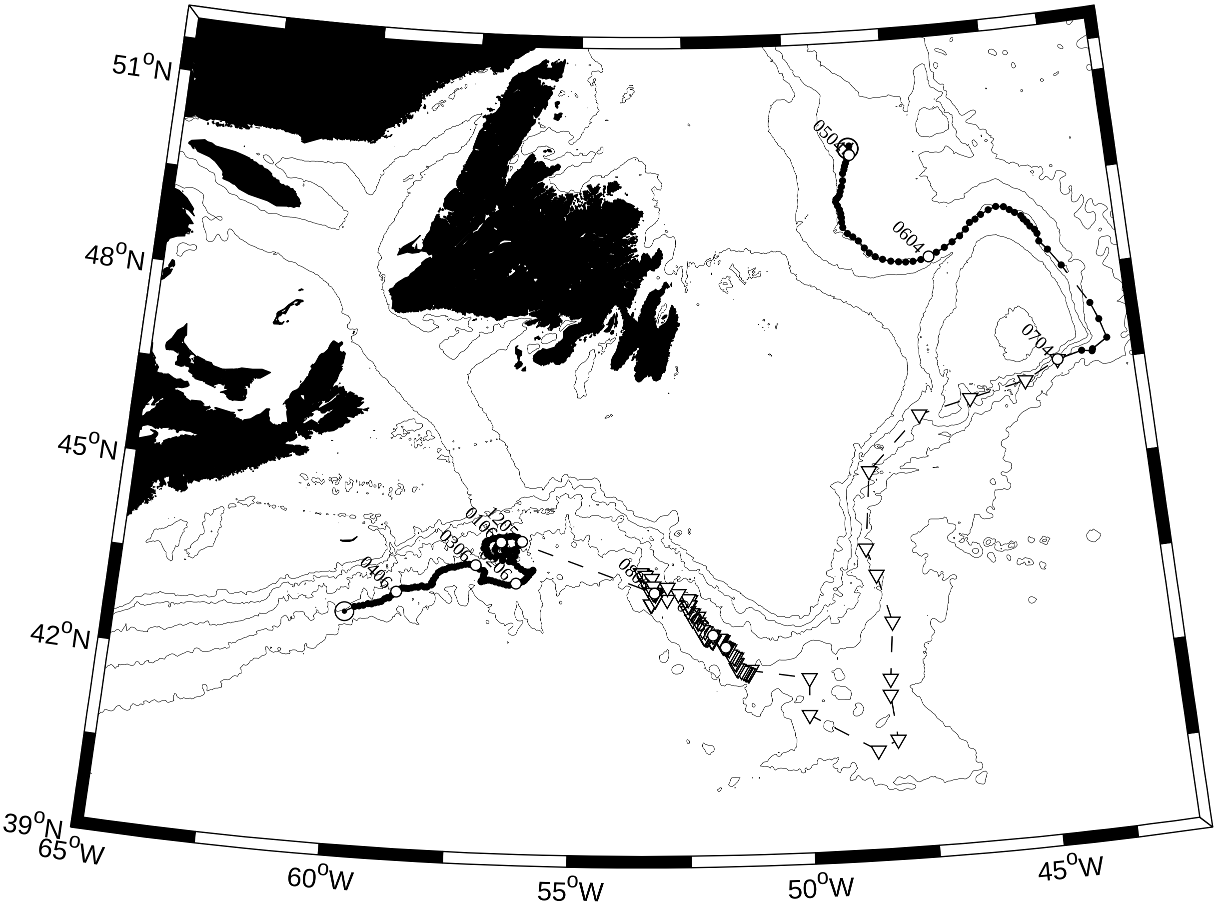
2005
2006
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
temperature (°C)
5
4
3
2
pressure (db)
1400
1500
1600
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

x567 / 6−1500−1

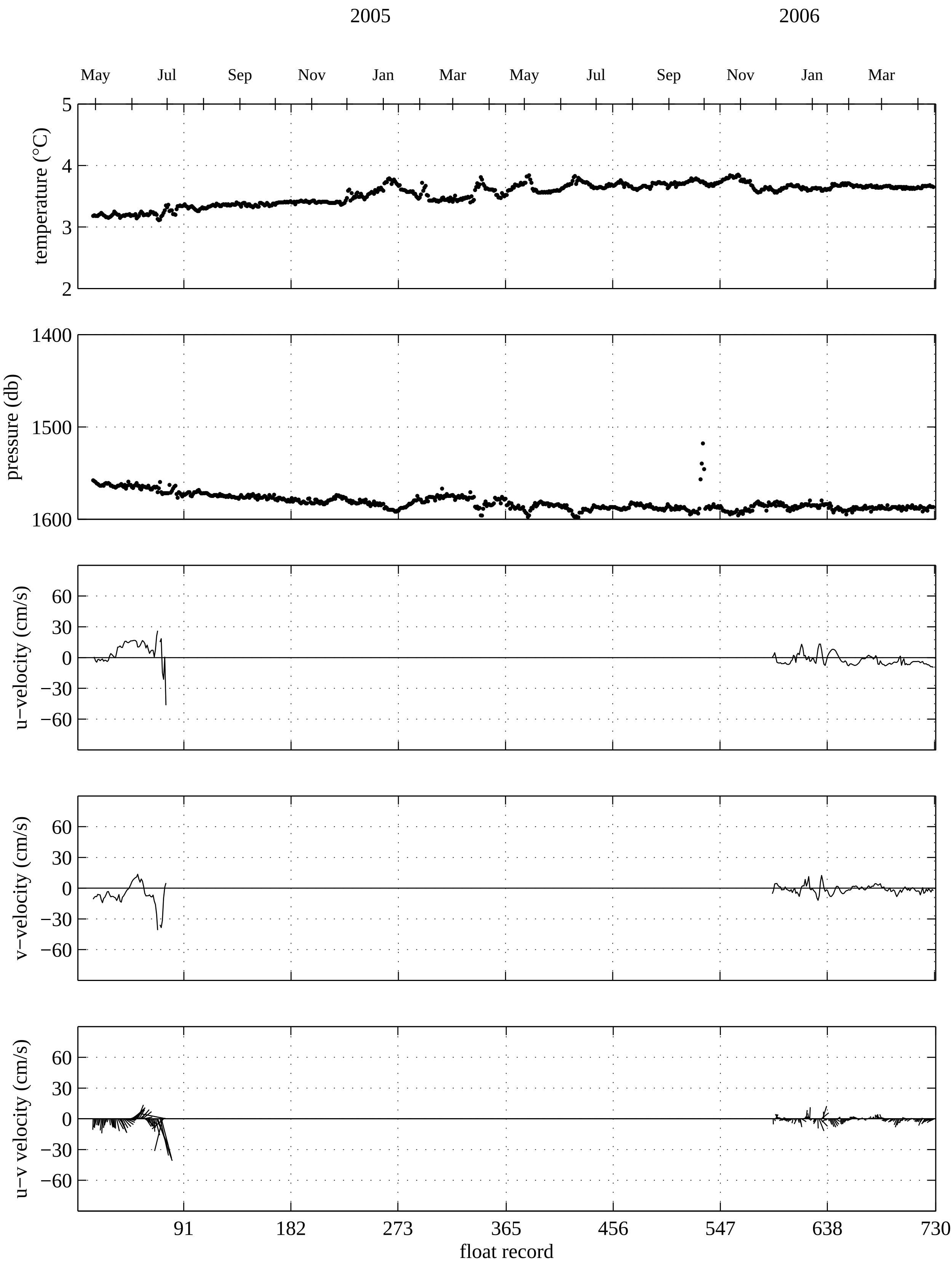

54°N
52°N
50°N
48°N
46°N
52°W
48°W
44°W
40°W
36°W
32°W
0706
0606
0805
0305
0405


x567 / 6−1500−1
2005
2006
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
temperature (°C)
5
4
3
2
pressure (db)
1500
1600
1700
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

x568 / 4−1500−2

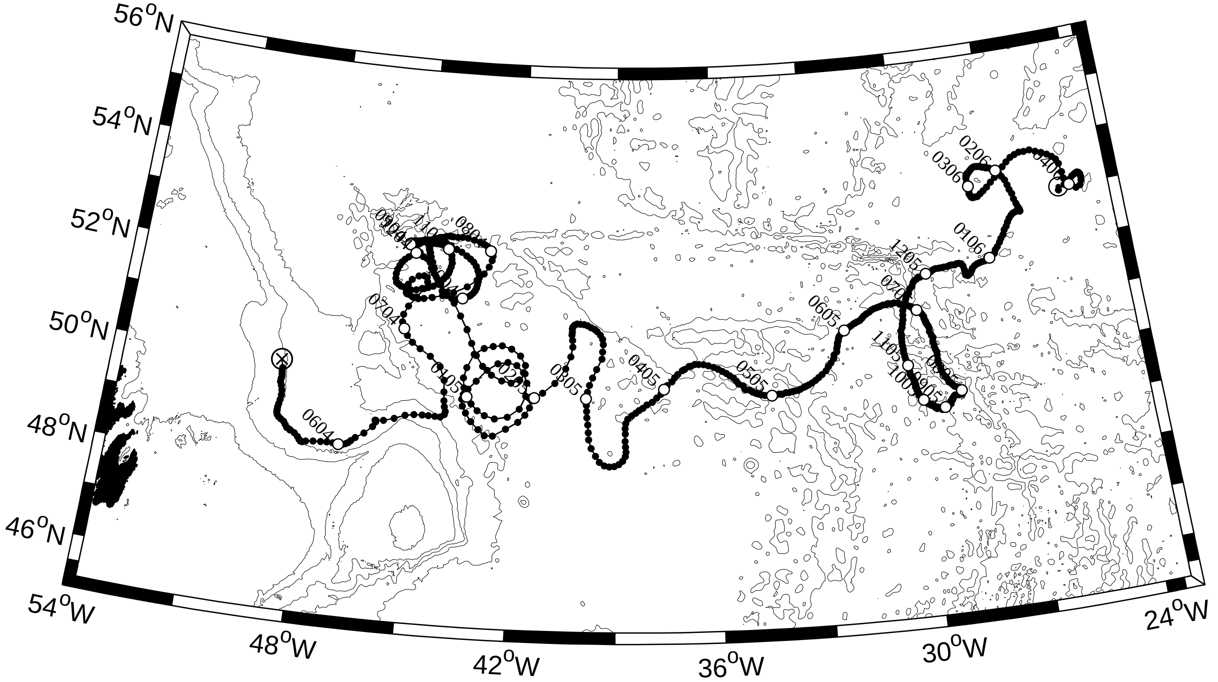


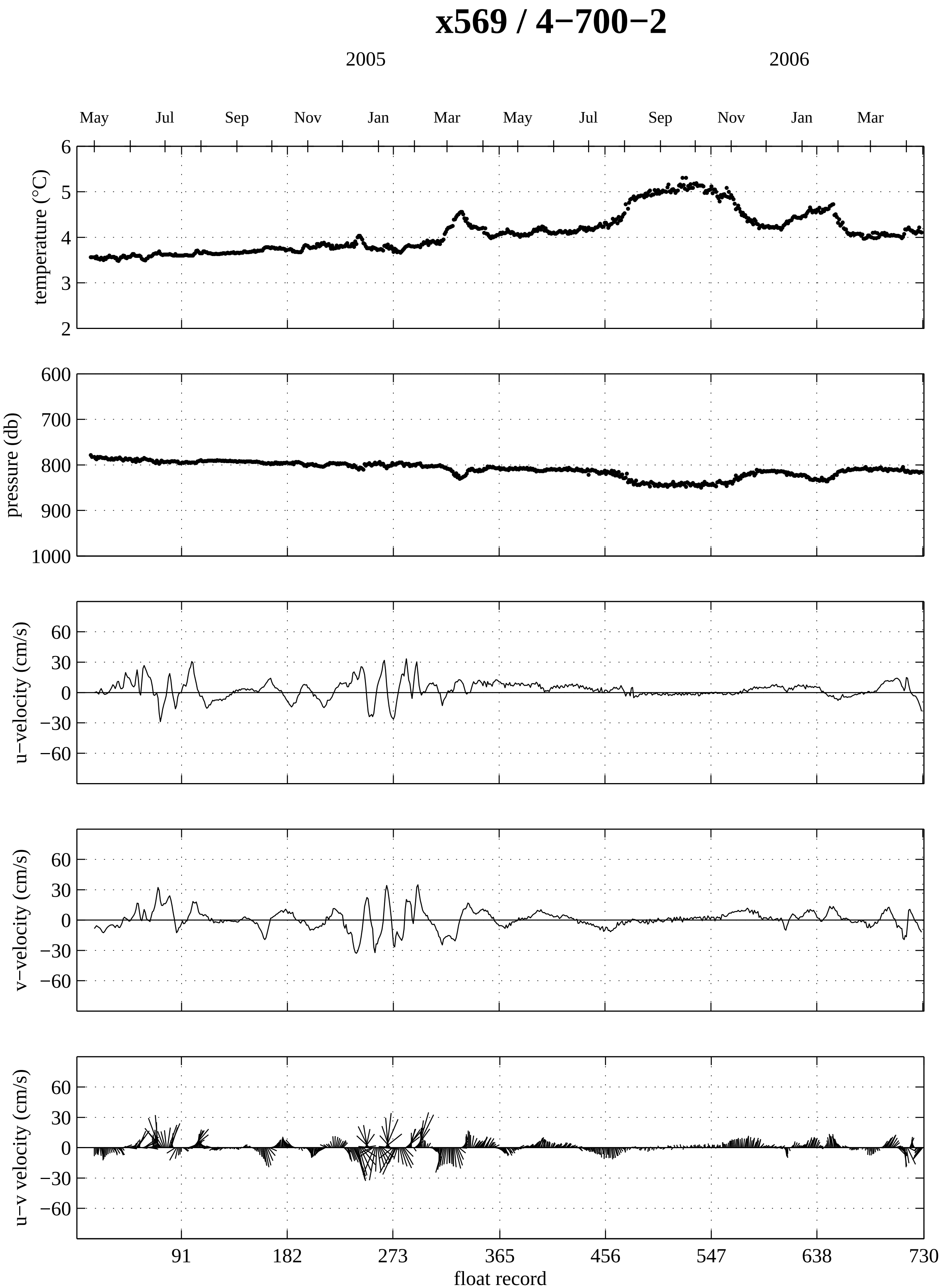
x568 / 4−1500−2



2005
2006
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
temperature (°C)
5
4
3
2
pressure (db)
1400
1500
1600
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

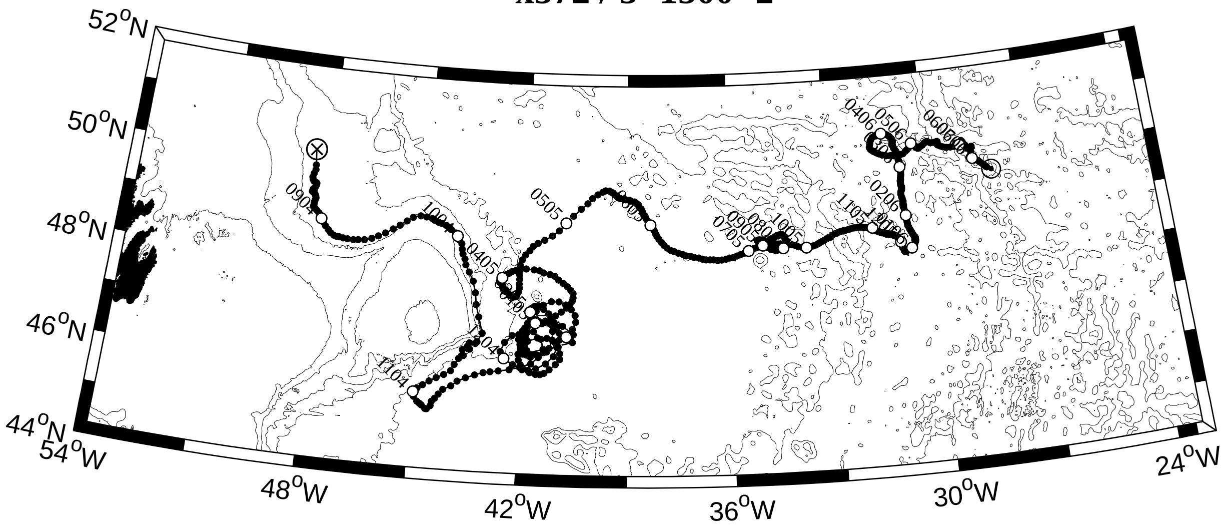
x569 / 4−700−2


56°N
54°N
52°N
50°N
48°N
46°N
54°W
48°W
42°W
36°W
30°W
24°W
0206
0306
0406
0106
1205
0705
0605
1105
1005
0905
0805
0505
0405
0305
0205
0105
0704
0604
0804
0904
1004
1104



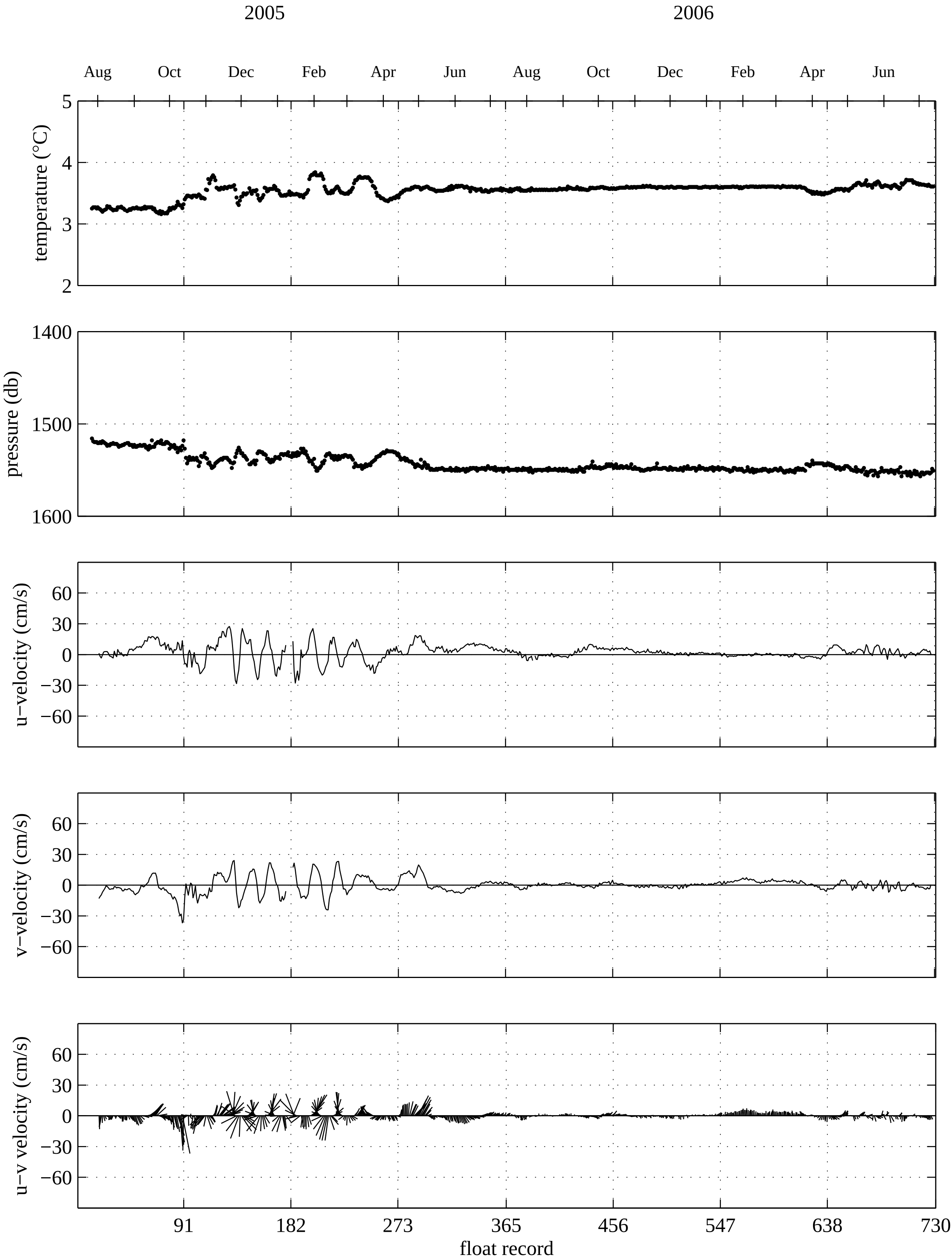
x569 / 4−700−2
2005
2006
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

x572 / 5−1500−2

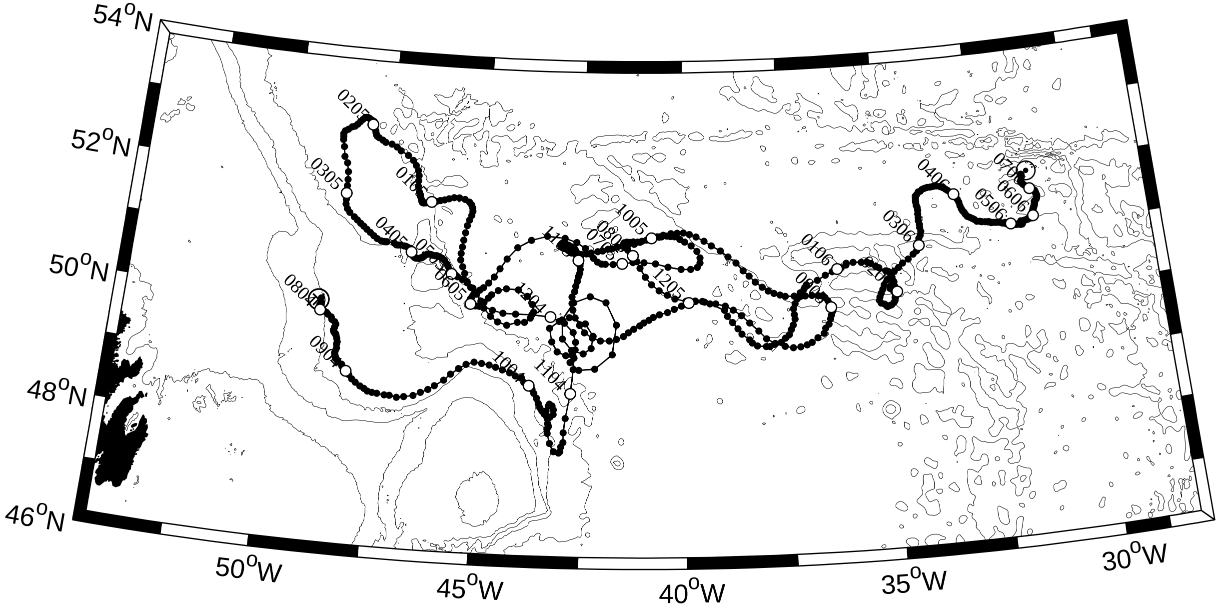


52°N
50°N
48°N
46°N
44°N
54°W
48°W
42°W
36°W
30°W
24°W
0904
1004
0405
0505
0605
1104
0705
0905
1005
1105
0206
0406
0506

x572 / 5−1500−2

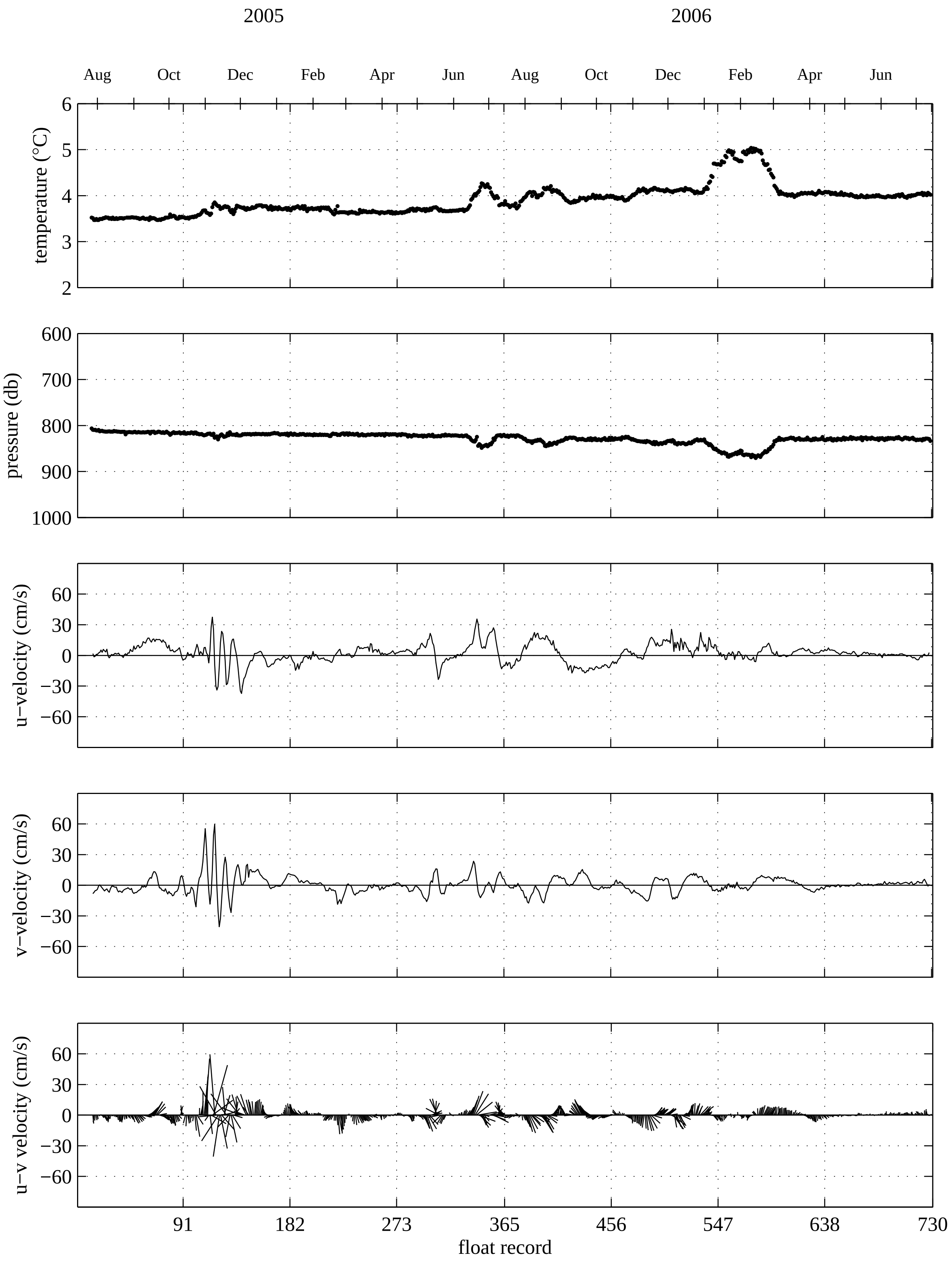

2005
2006
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
Apr
Jun
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

x574 / 5−700−2

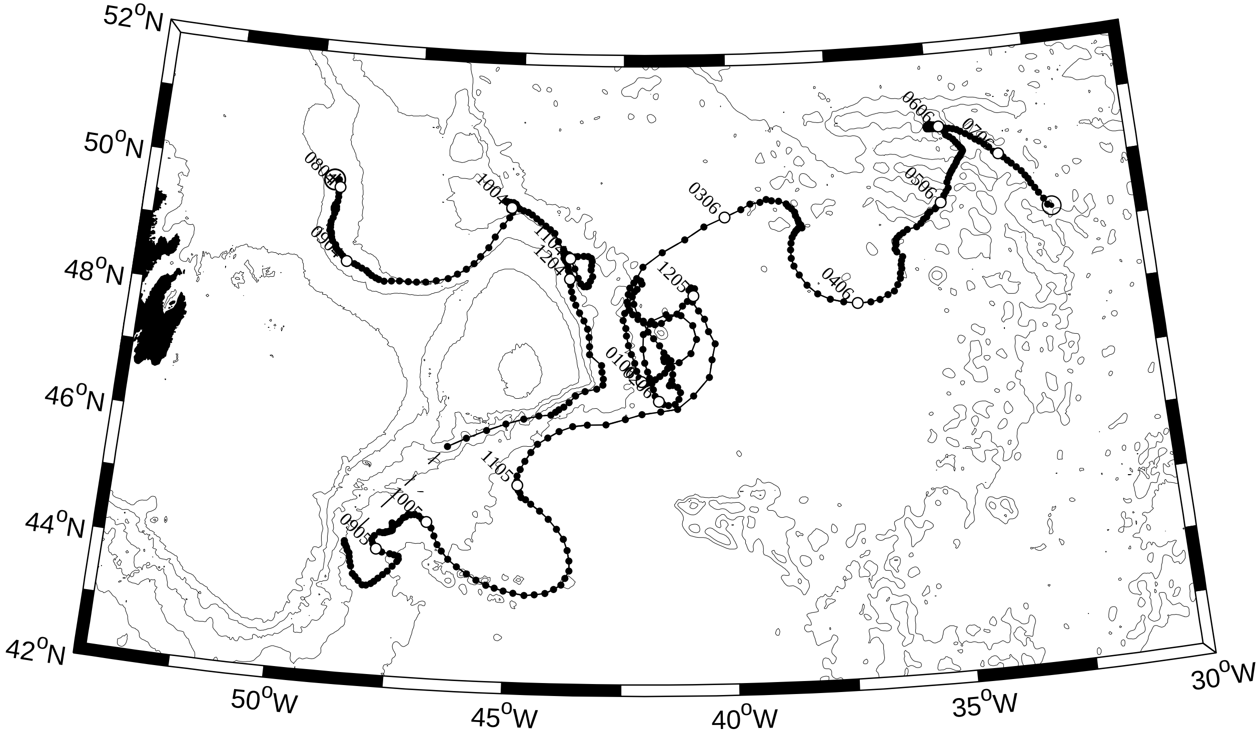


54°N
52°N
50°N
48°N
46°N
50°W
45°W
40°W
35°W
30°W
0205
0305
0105
0405
0505
0605
0804
0904
1004
1104
1204
1105
0805
0705
1005
1205
0106
0206
0306
0406
0506
0606
0706

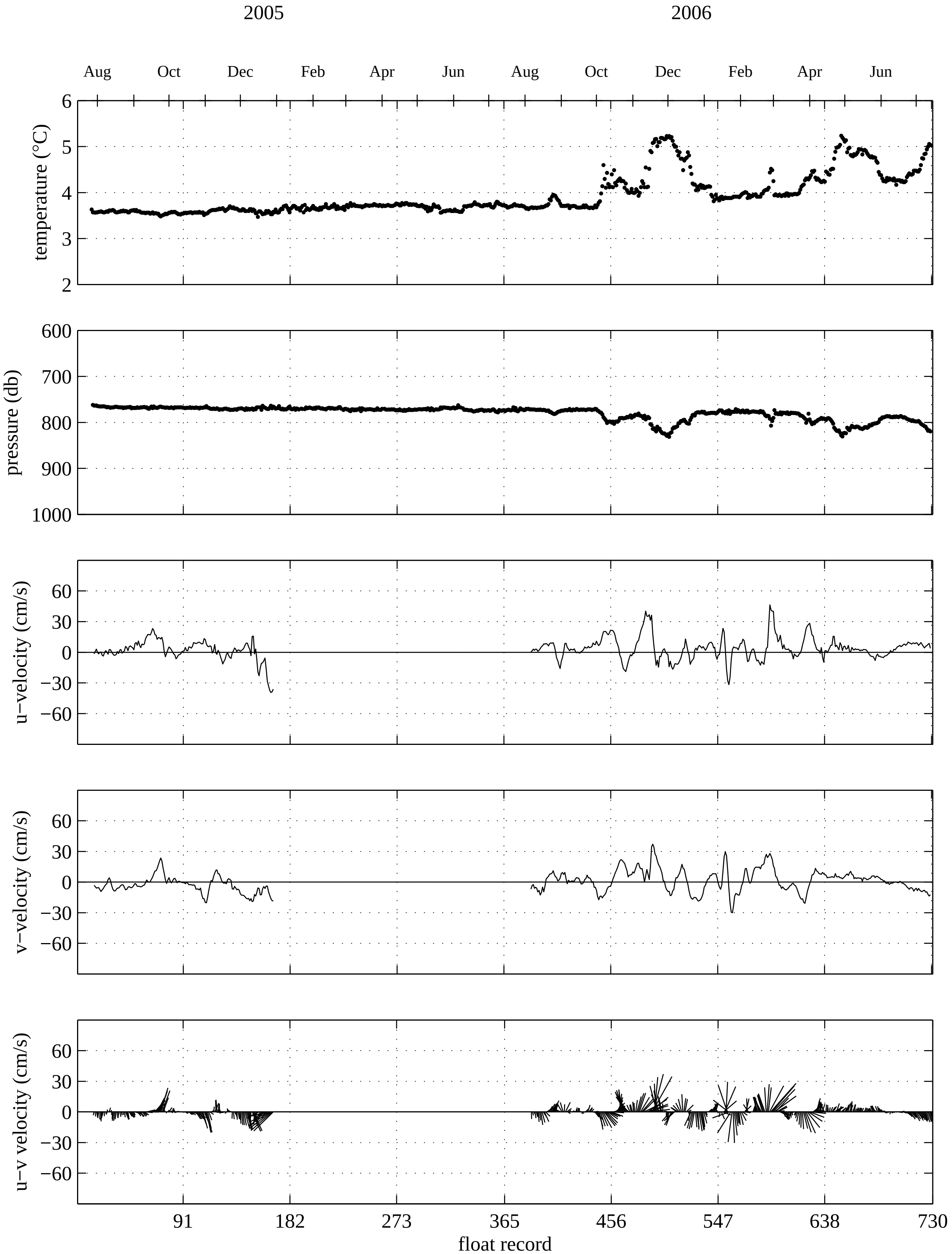
x574 / 5−700−2


2005
2006
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
Apr
Jun
temperature (°C)
6
5
4
3
2
pressure (db)
600
700
800
900
1000
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

x575 / 5−700−1

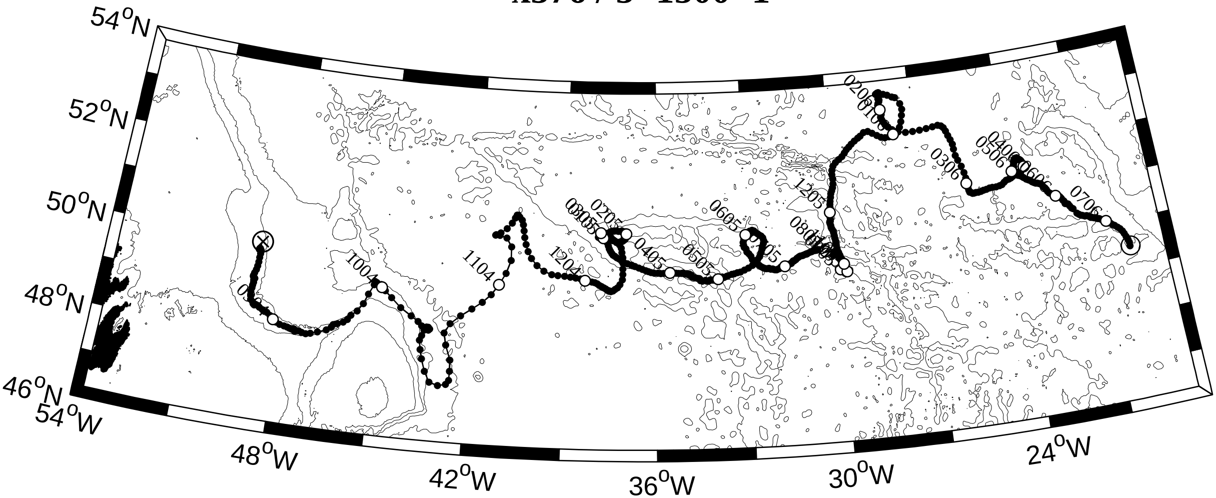

52°N
50°N
48°N
46°N
44°N
42°N
50°W
45°W
40°W
35°W
30°W
0804
0904
1004
1104
1204
0306
0406
0506
0606
0706
1205
0106
0206
1105
1005
0905

x575 / 5−700−1

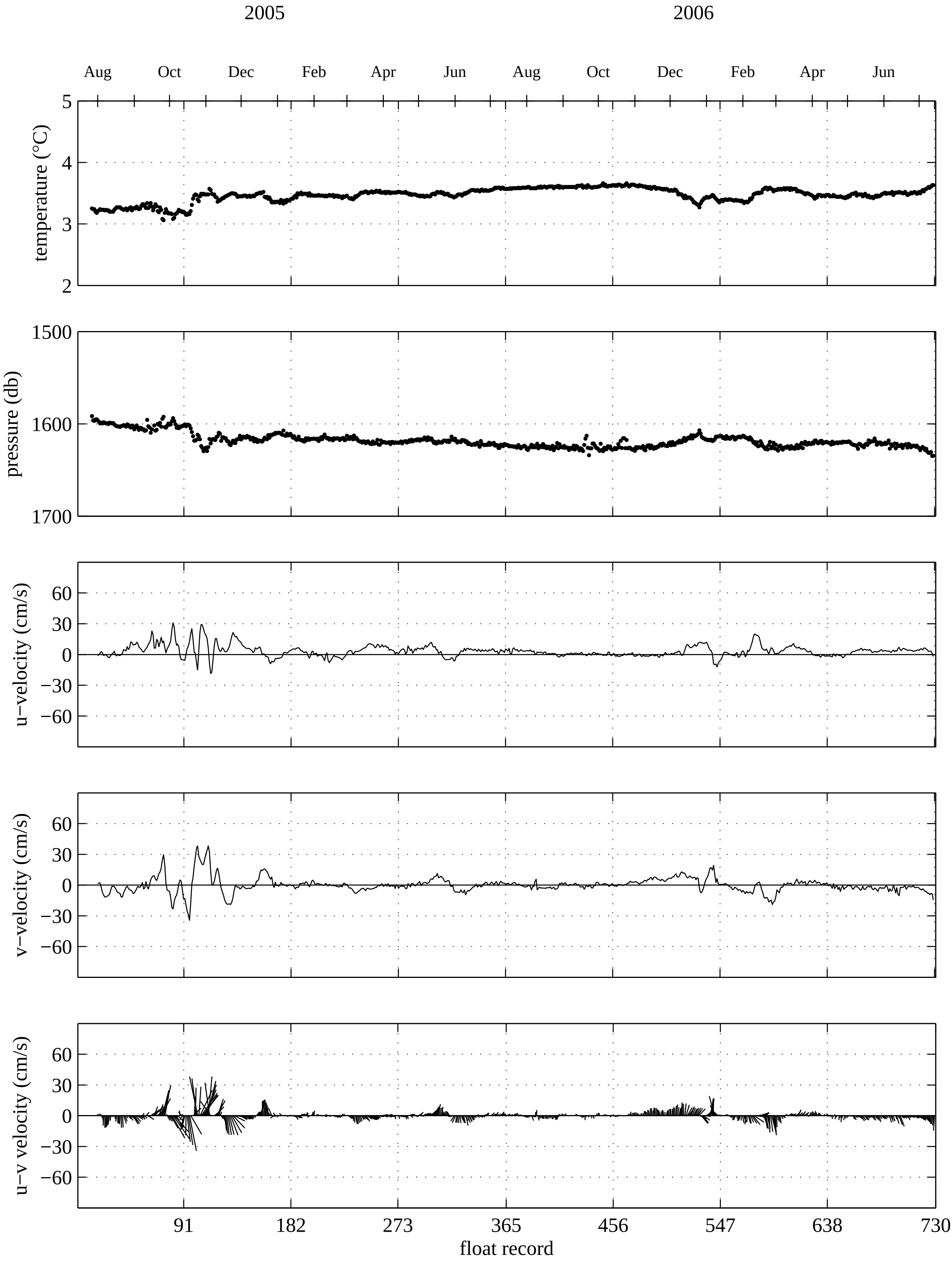


2005
2006
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
Apr
Jun
temperature (°C)
6
5
4
3
2
pressure (db)
600
700
800
900
1000
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

x576 / 5−1500−1

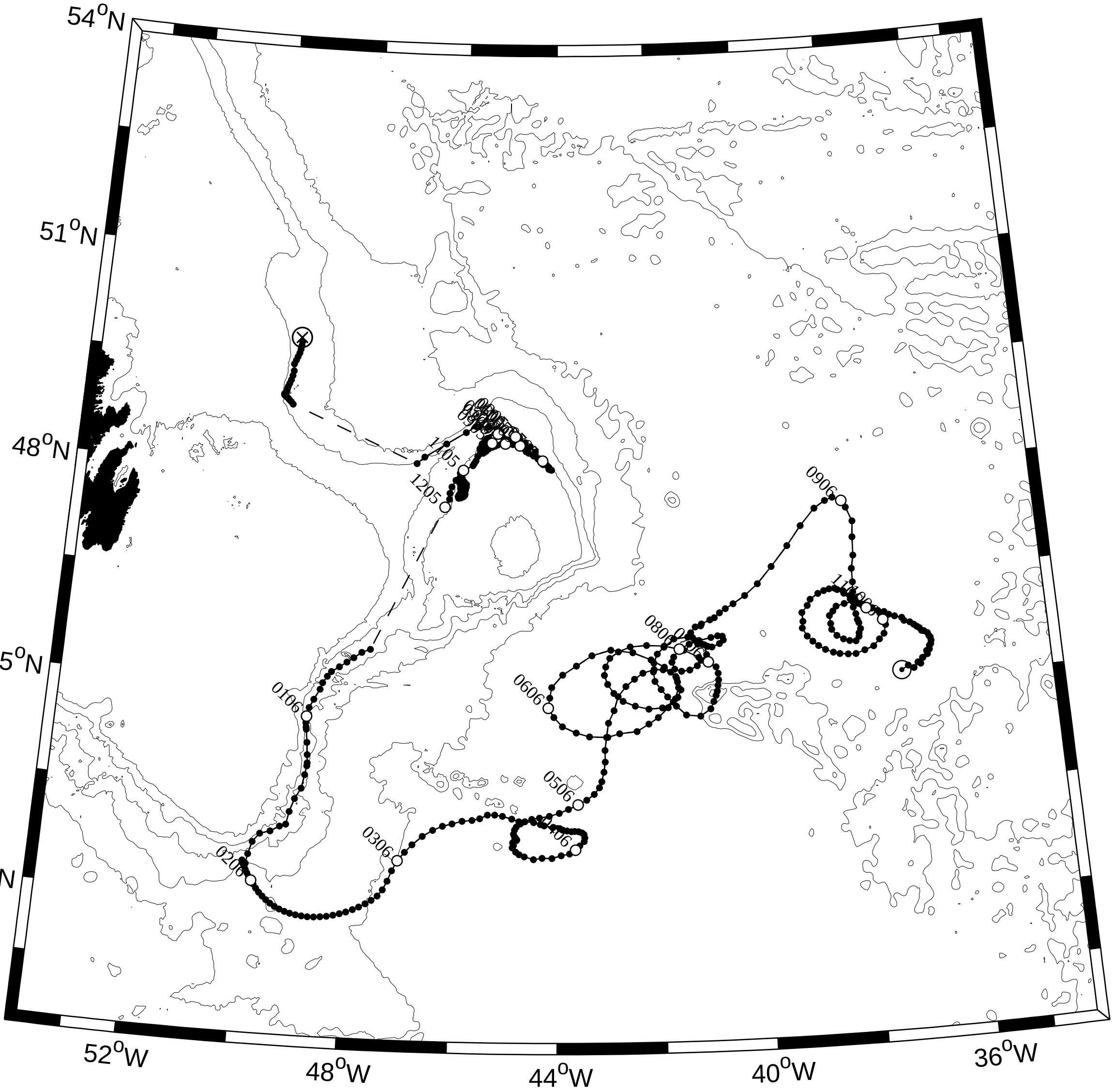

54°N
52°N
50°N
48°N
46°N
54°W
48°W
42°W
36°W
30°W
24°W
1004
1104
1204
0405
0505
0605
1205
0306
0506
0706

x576 / 5−1500−1

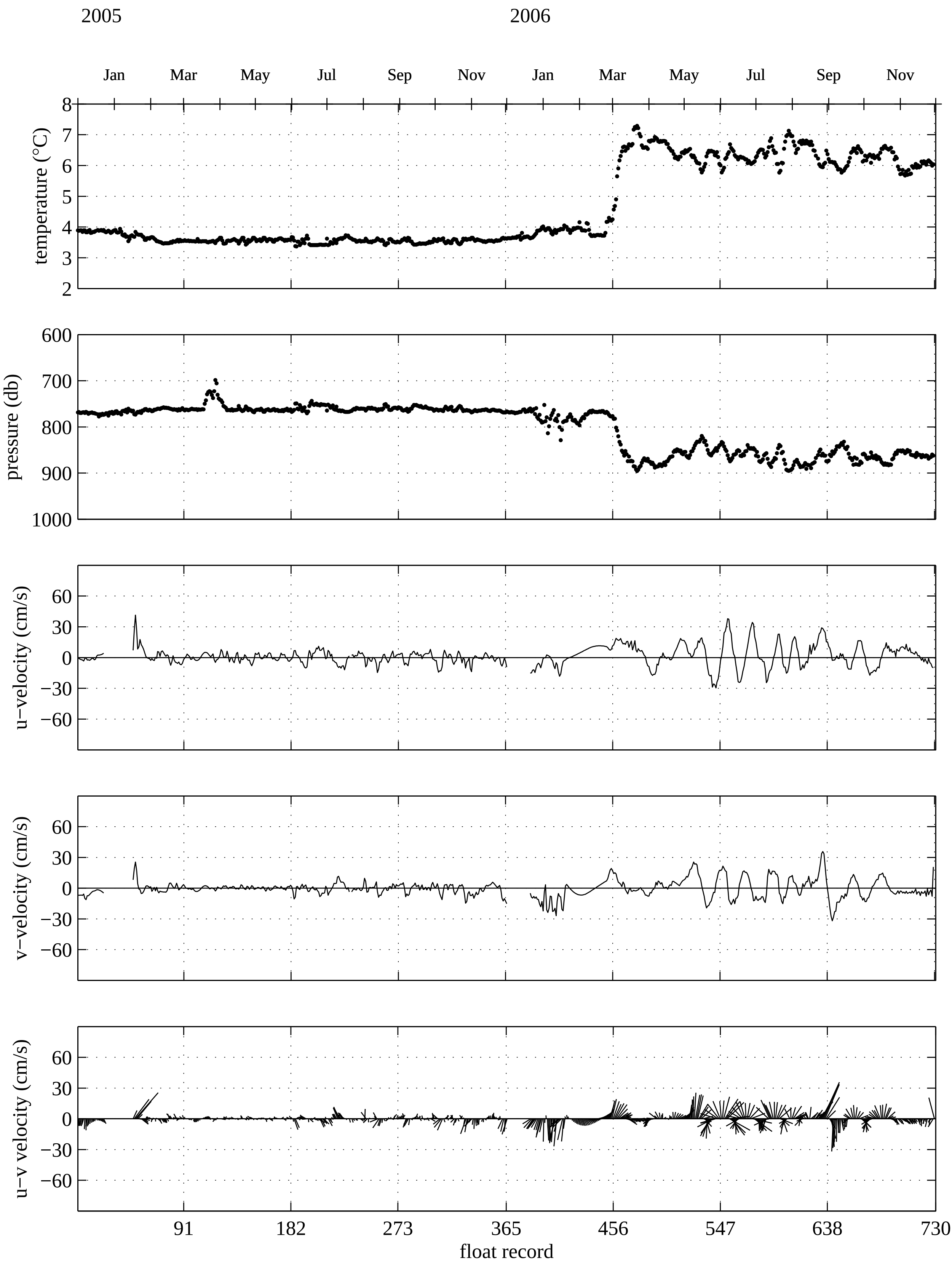


2005
2006
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
Apr
Jun
temperature (°C)
5
4
3
2
pressure (db)
1500
1600
1700
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

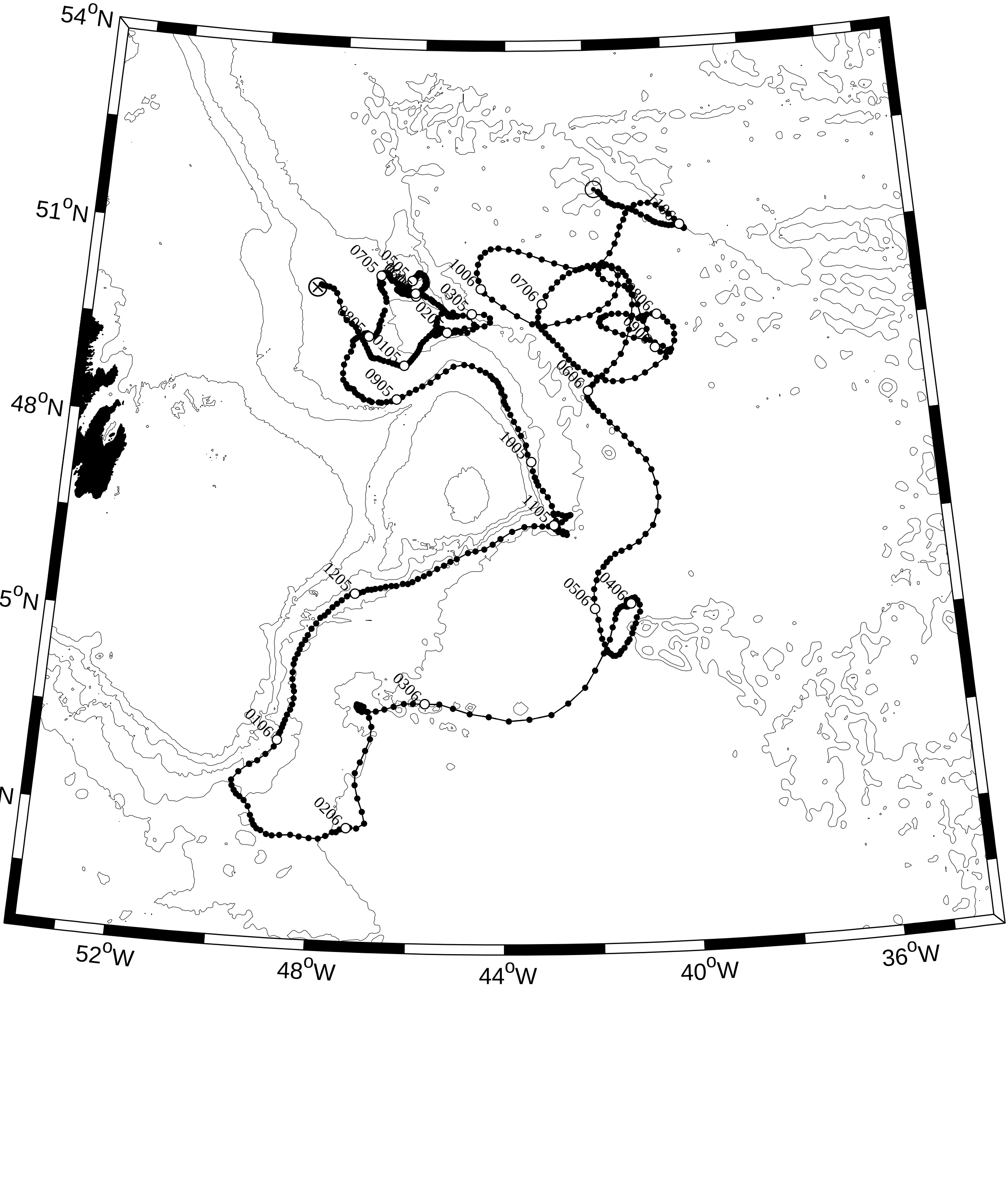
x577 / 6−700−1


54°N
51°N
48°N
45°N
42°N
52°W
48°W
44°W
40°W
36°W
0906
1105
1205
0106
0806
0606
0506
0306
0206

x577 / 6−700−1

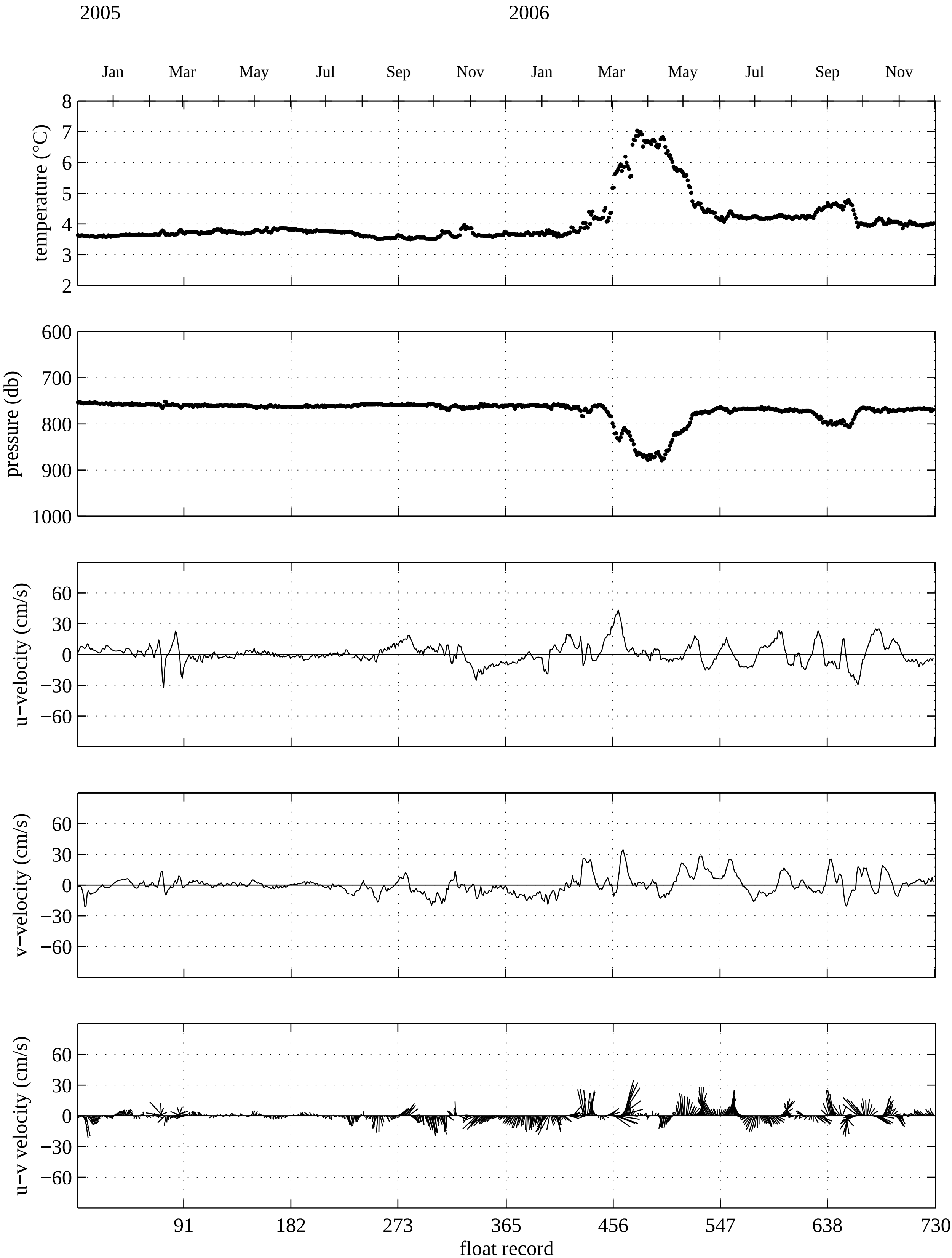

2005
2006
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

x578 / 6−700−3



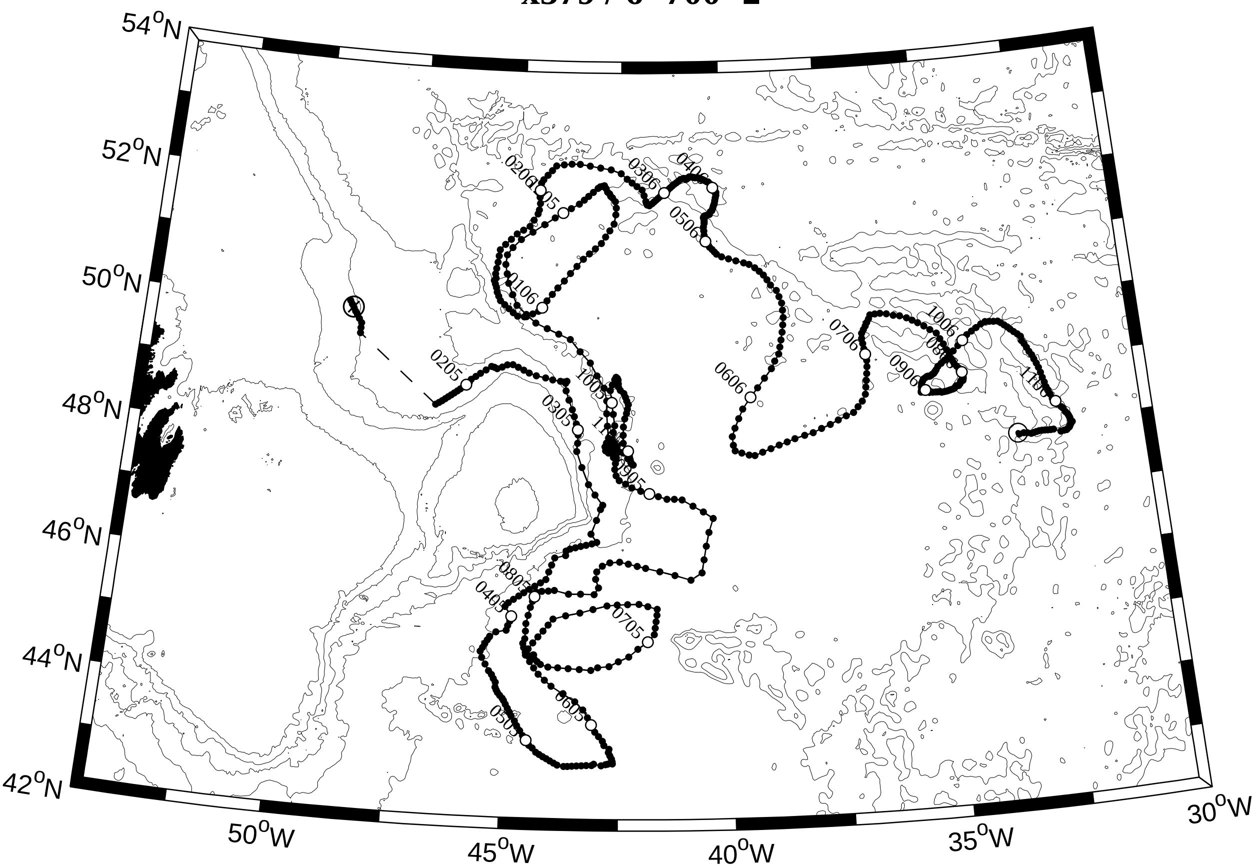
54°N
51°N
48°N
45°N
42°N
52°W
48°W
44°W
40°W
36°W
0705
0505
0305
0805
0105
0905
1006
0706
0606
1005
1105
1205
0506
0406
0306
0106
0206

x578 / 6−700−3

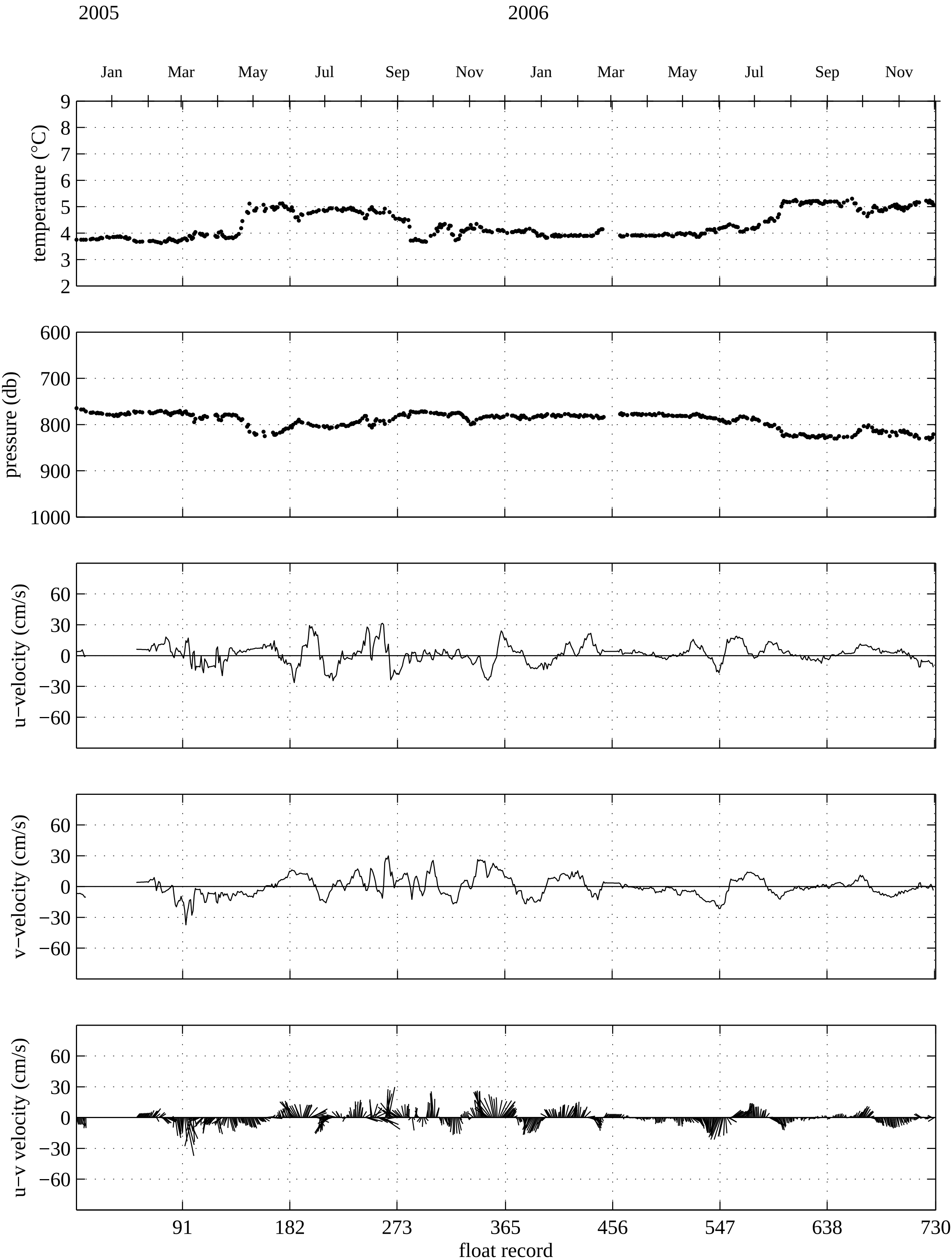


2005
2006
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
temperature (°C)
8
7
6
5
4
3
2
pressure (db)
600
700
800
900
1000
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

x579 / 6−700−2

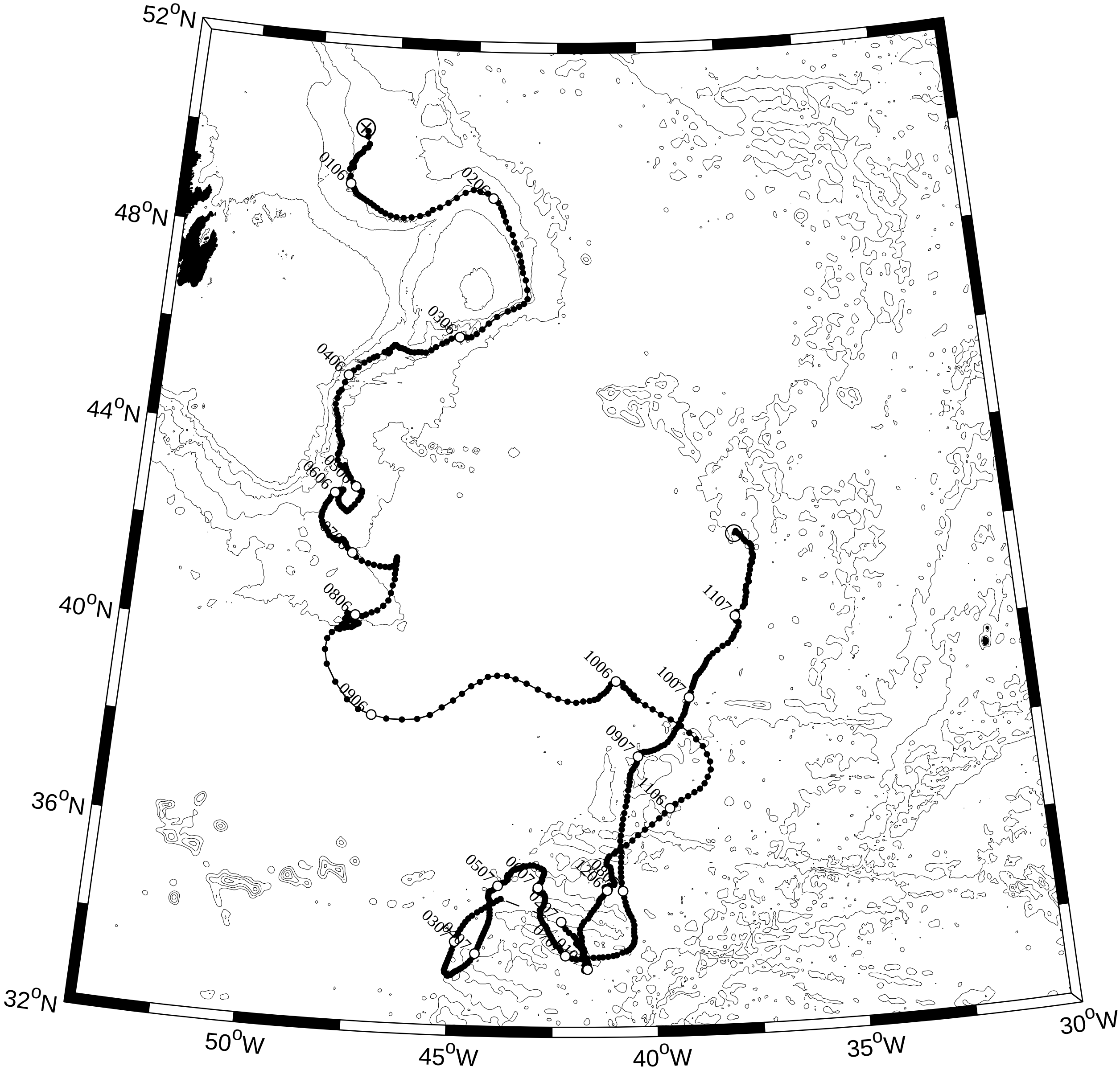

54°N
52°N
50°N
48°N
46°N
44°N
42°N
50°W
45°W
40°W
35°W
30°W
0205
0206
0305
0306
0406
0506
0606
0706
0906
1006
1005
0106
0405
0505
0605
0705
0805
0905

x579 / 6−700−2

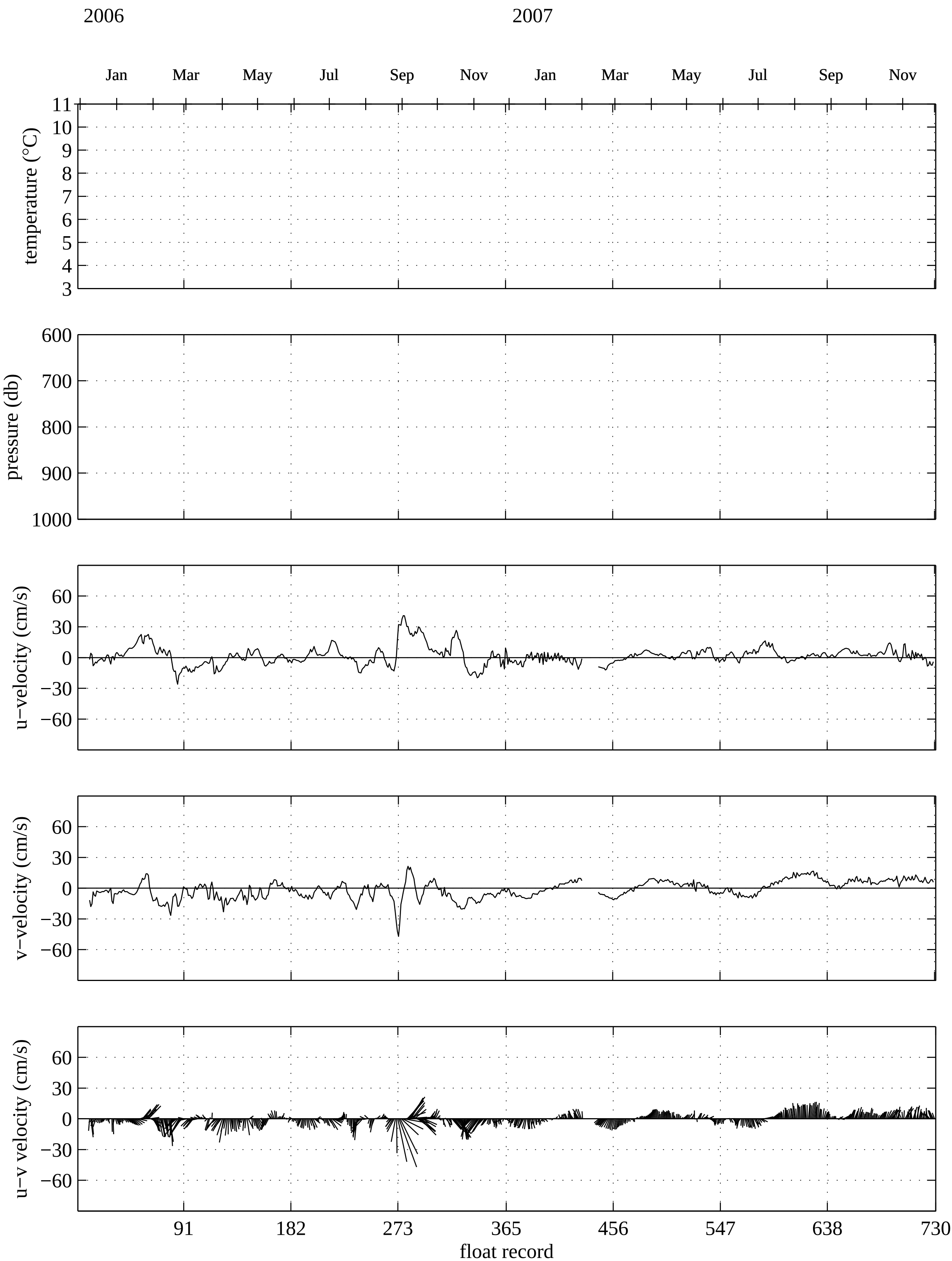


2005
2006
Jan Mar May Jul Sep Nov Jan Mar May Jul Sep Nov
temperature (°C)
9 8 7 6 5 4 3 2
pressure (db)
600 700 800 900 1000
u−velocity (cm/s)
60 30 0 −30 −60
v−velocity (cm/s)
60 30 0 −30 −60
u−v velocity (cm/s)
60 30 0 −30 −60
91 182 273 365 456 547 638 730
float record

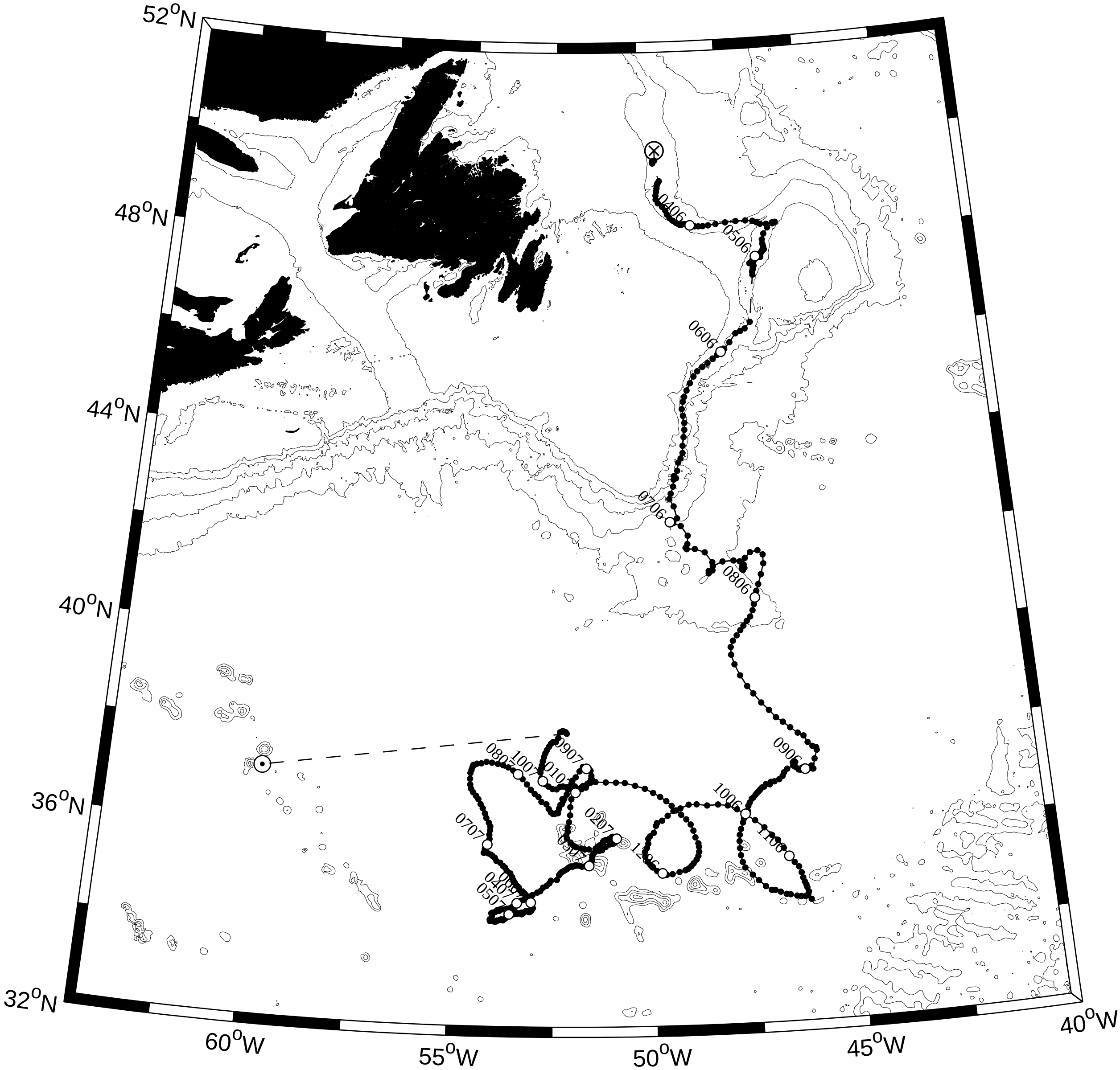
x580 / 10−700−3


52°N
48°N
44°N
40°N
36°N
32°N
50°W
45°W
40°W
35°W
30°W
0106
0206
0306
0406
0506
0606
0806
0906
1006
1007
1107
0907
1106
1206
0507
0307

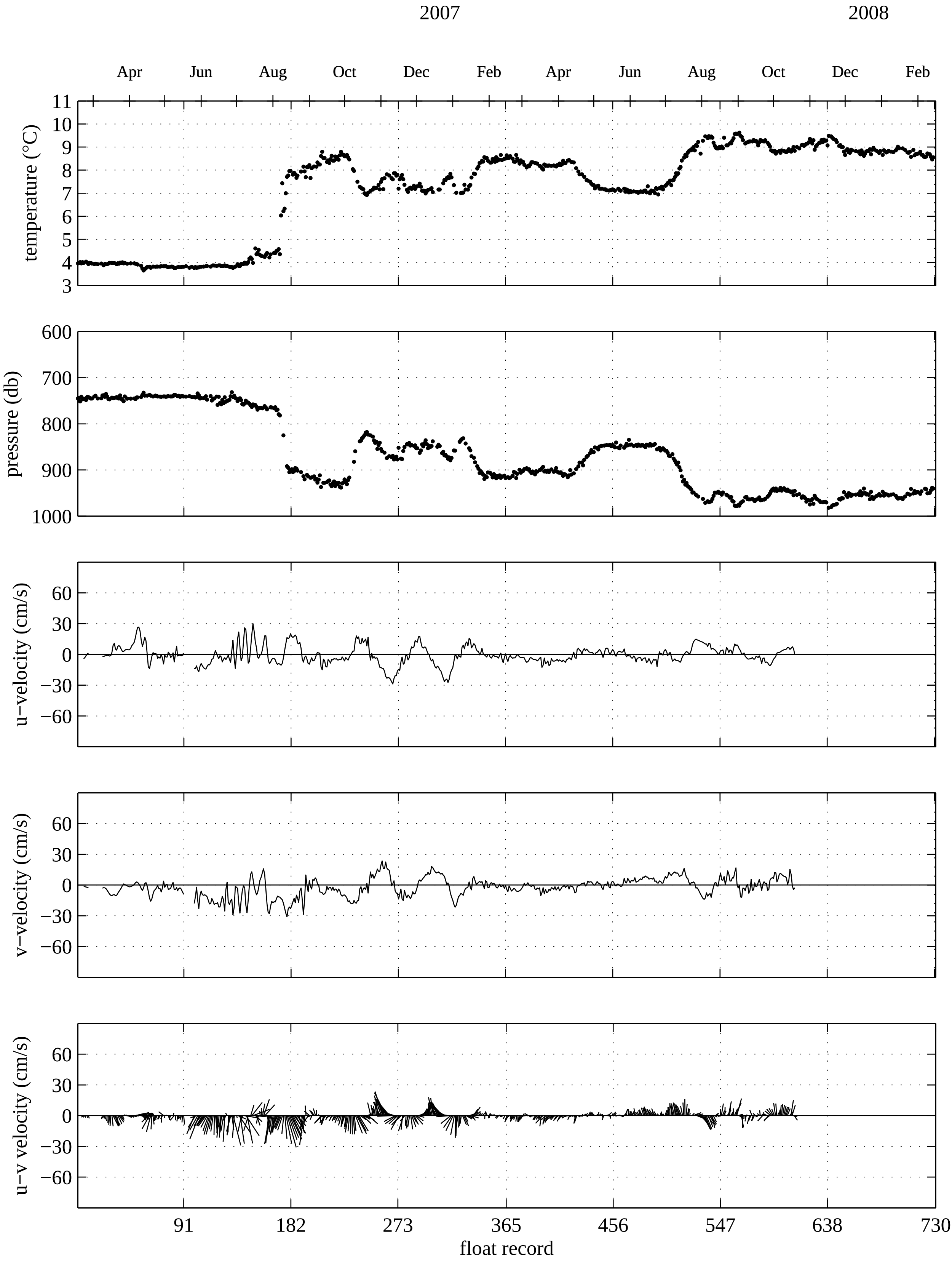
x580 / 10−700−3


2006
2007
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

x581 / 11−700−1

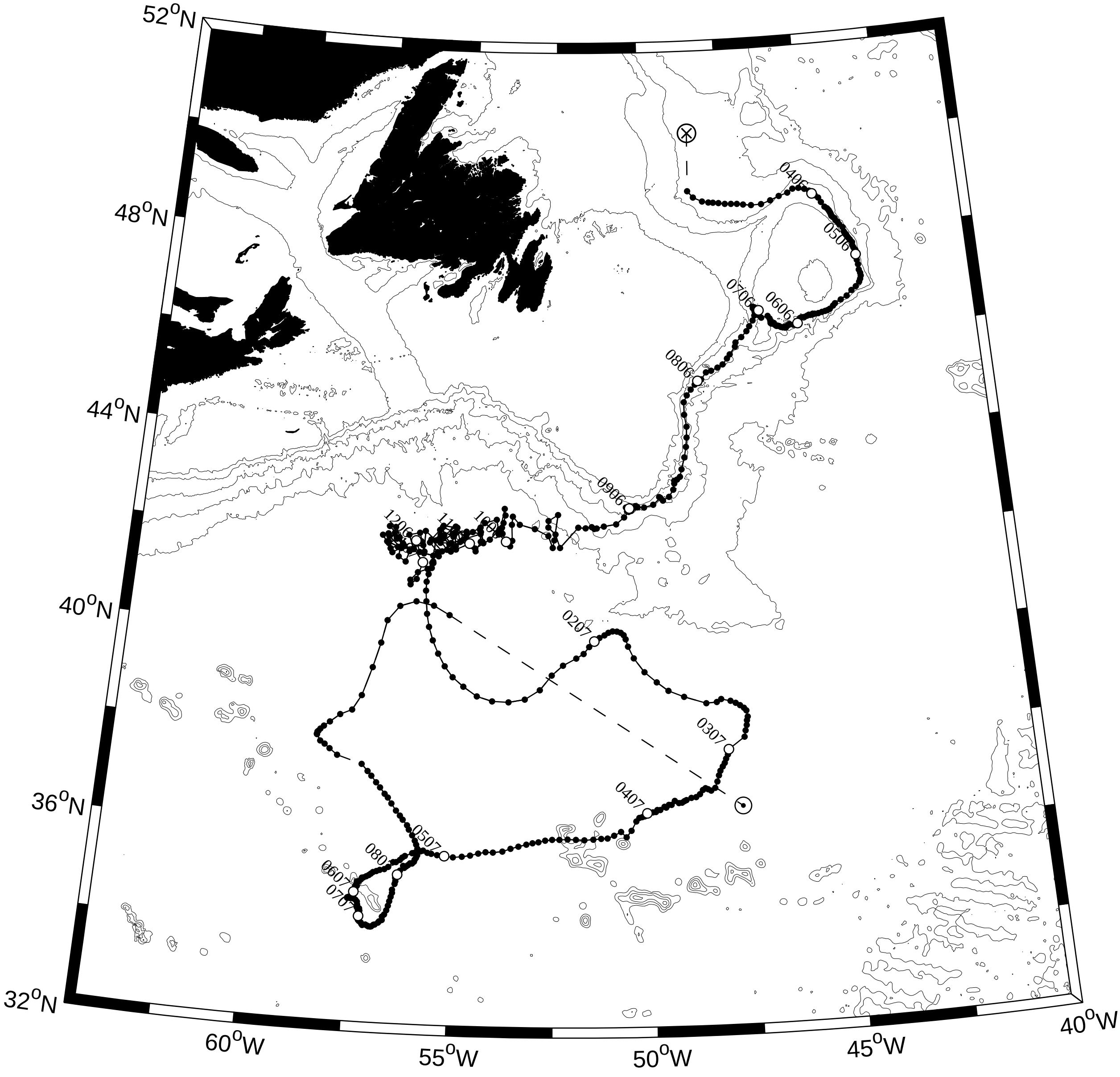

52°N
48°N
44°N
40°N
36°N
32°N
60°W
55°W
50°W
45°W
40°W
0406
0506
0606
0706
0806
0906
1006
1106
1206
0907
1007
0807
0707
0207
0407
0507

x581 / 11−700−1

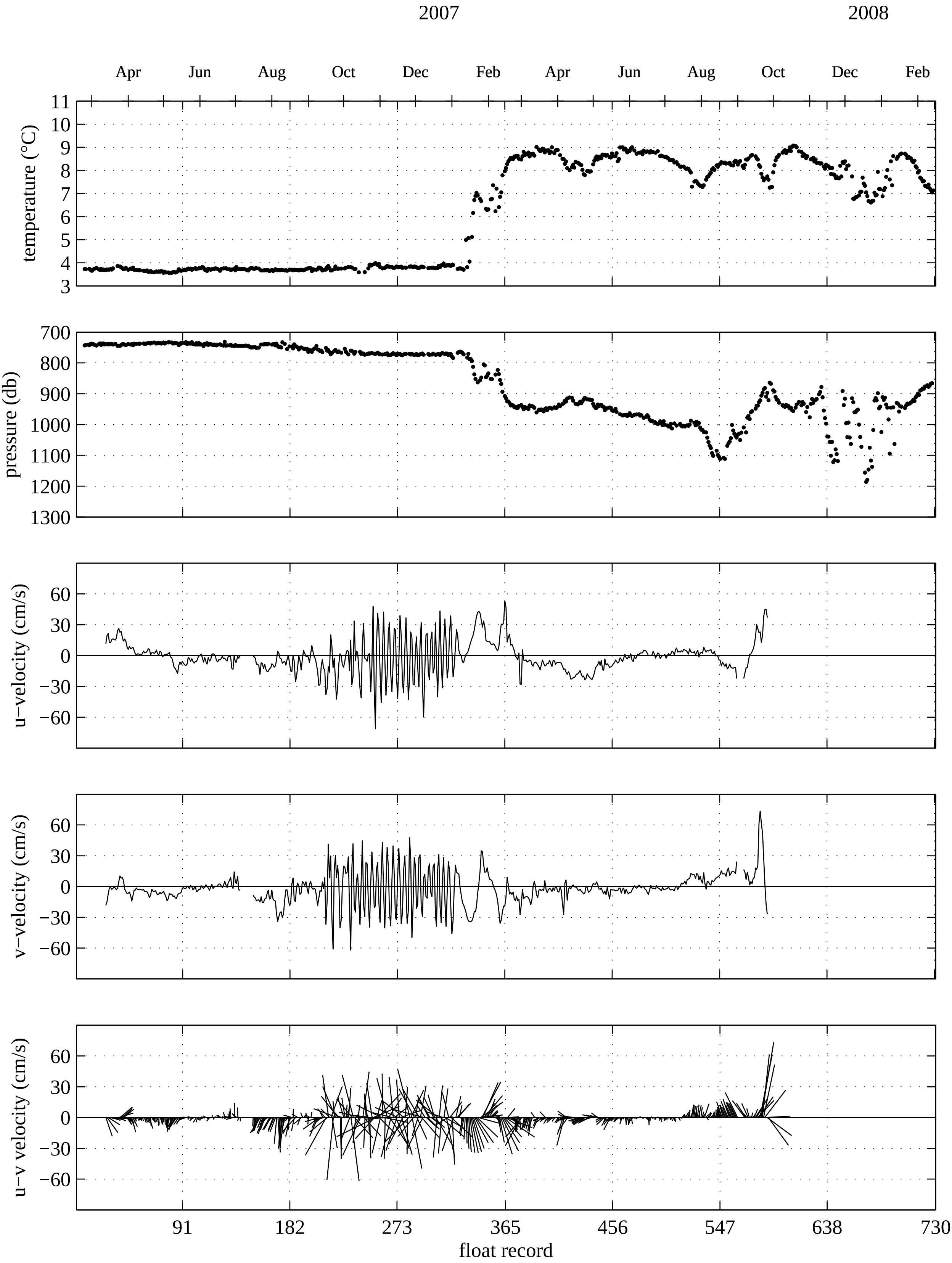


2007
2008
Apr
Jun
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
float record
91
182
273
365
456
547
638
730

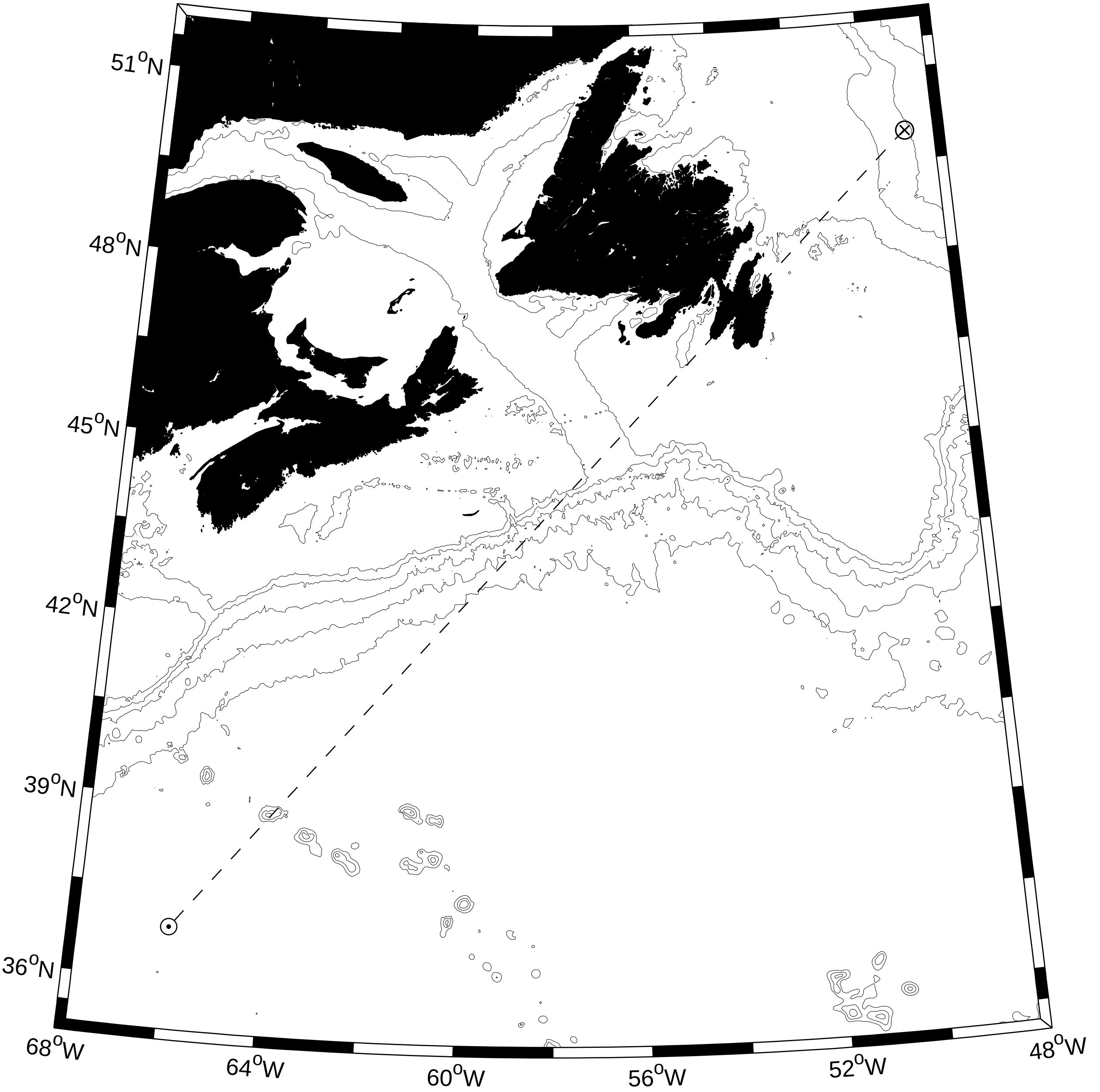
x582 / 11−700−3


52°N
48°N
44°N
40°N
36°N
32°N
60°W
55°W
50°W
45°W
40°W
0406
0506
0606
0706
0806
0906
1206
0207
0307
0407
0507
0607
0707

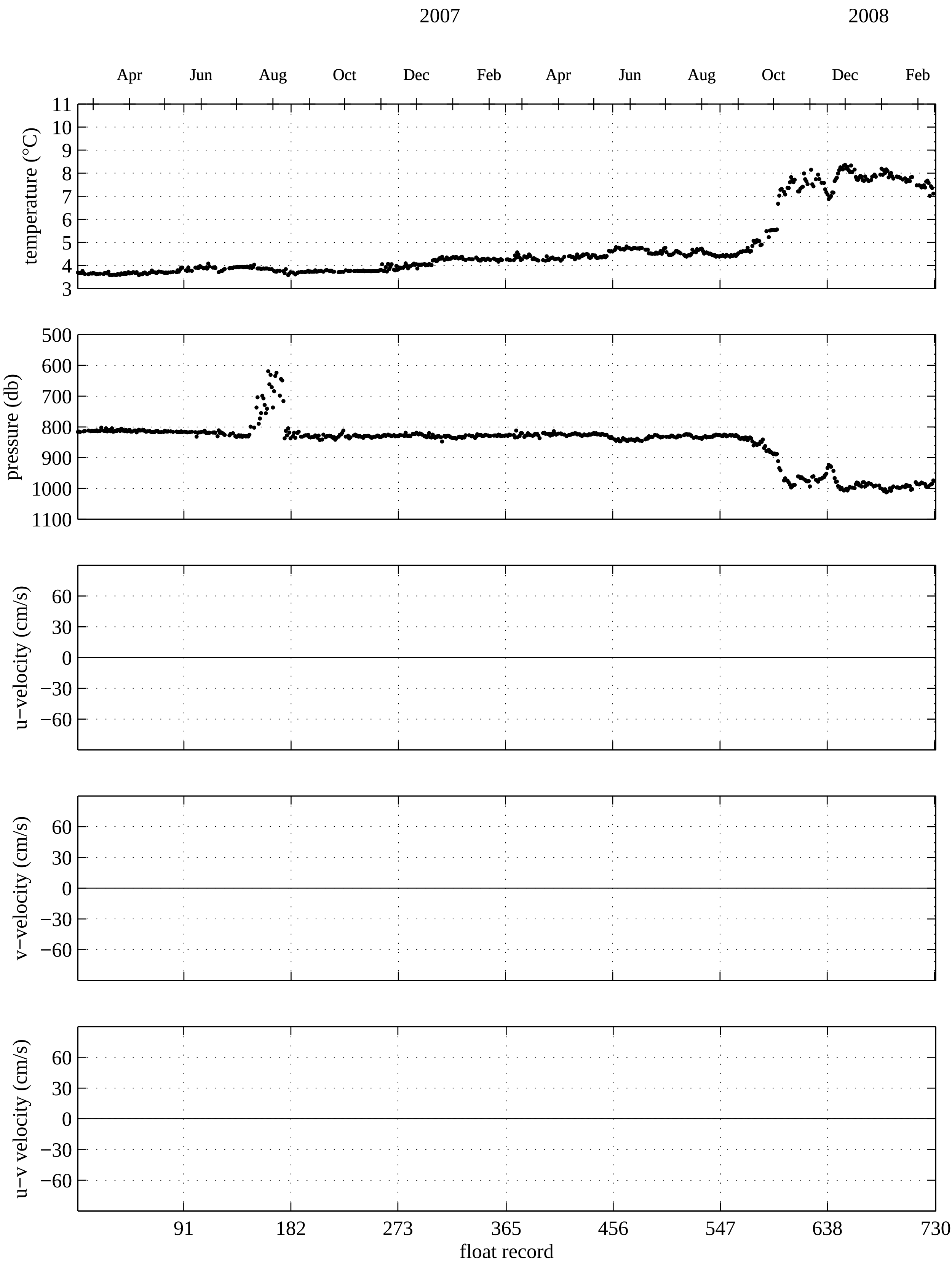
x582 / 11−700−3


2007
2008
Apr
Jun
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
temperature (°C)
11
10
9
8
7
6
5
4
3
pressure (db)
700
800
900
1000
1100
1200
1300
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

x583 / 11−700−2

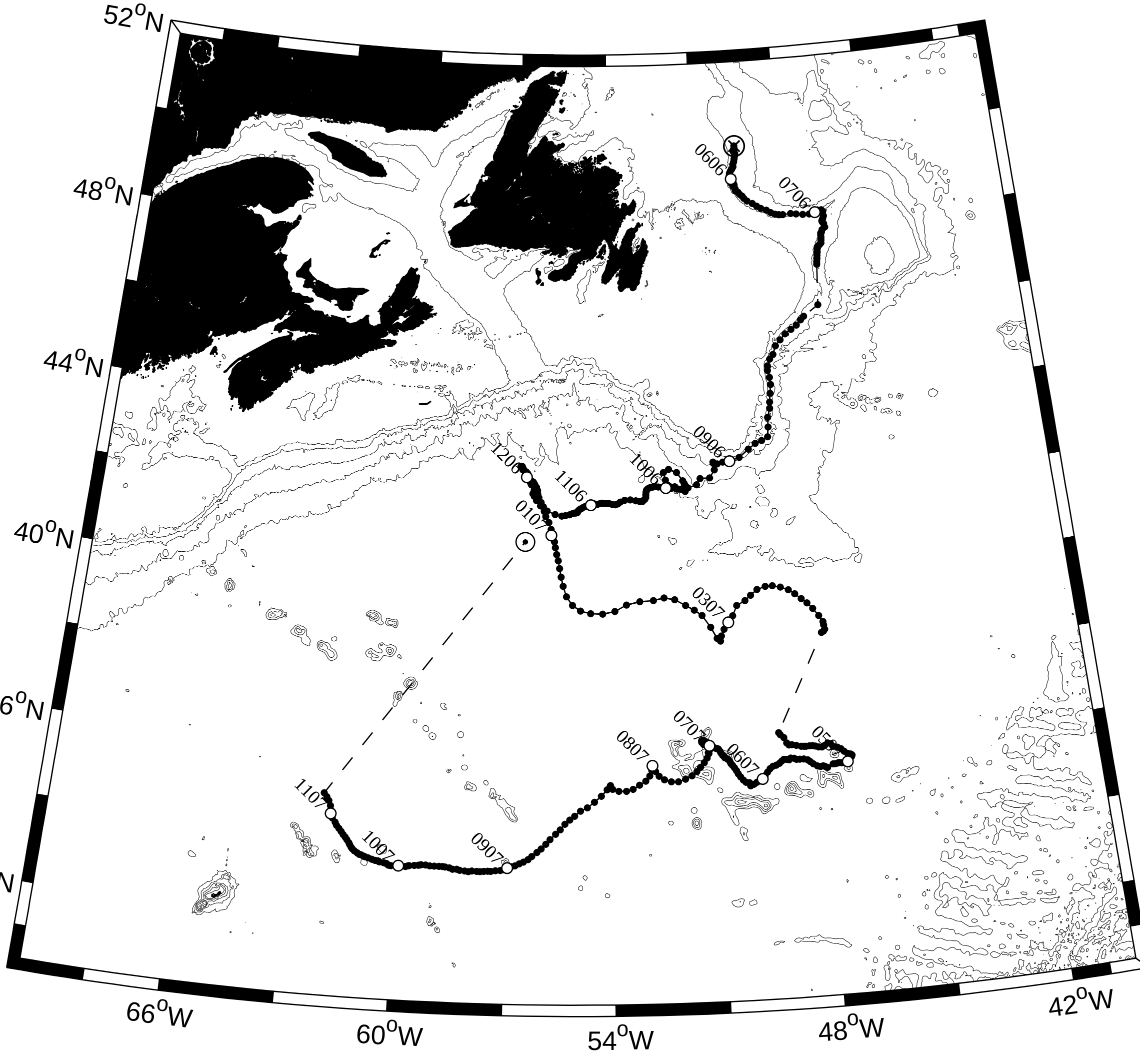


x583 / 11−700−2

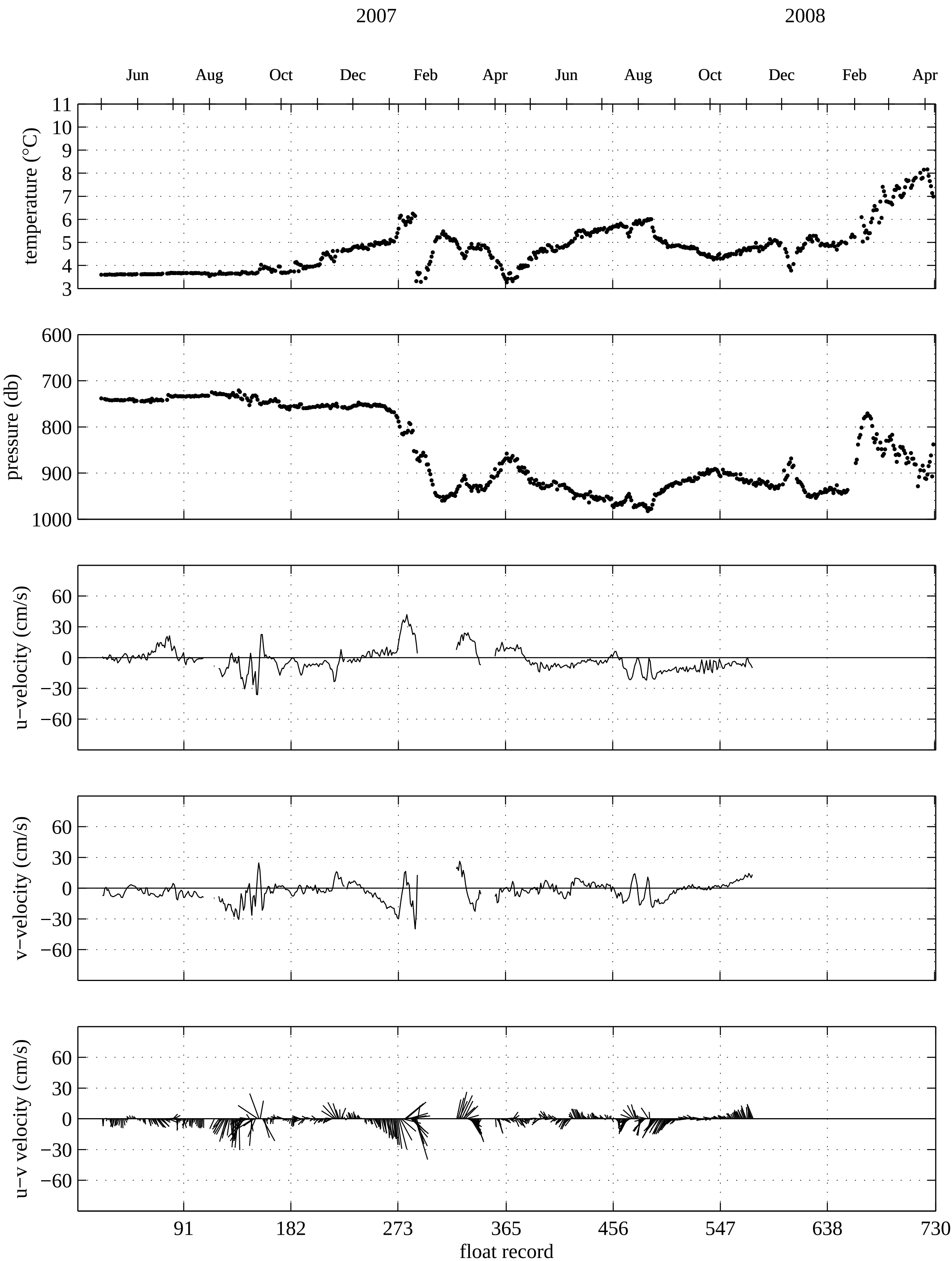


2007
2008
Apr
Jun
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

x586 / 12−700−1

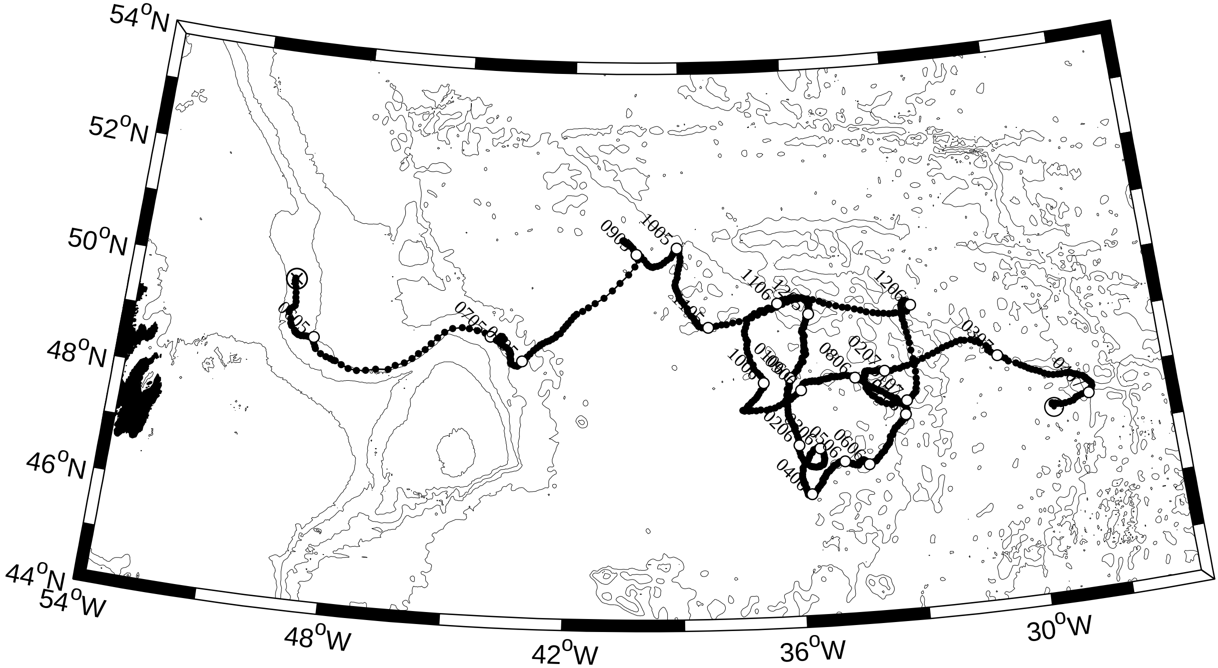

52°N
48°N
44°N
40°N
36°N
32°N
66°W
60°W
54°W
48°W
42°W
0606
0706
0906
1006
1106
1206
0107
0307
0507
0607
0707
0807
0907
1007
1107

x586 / 12−700−1

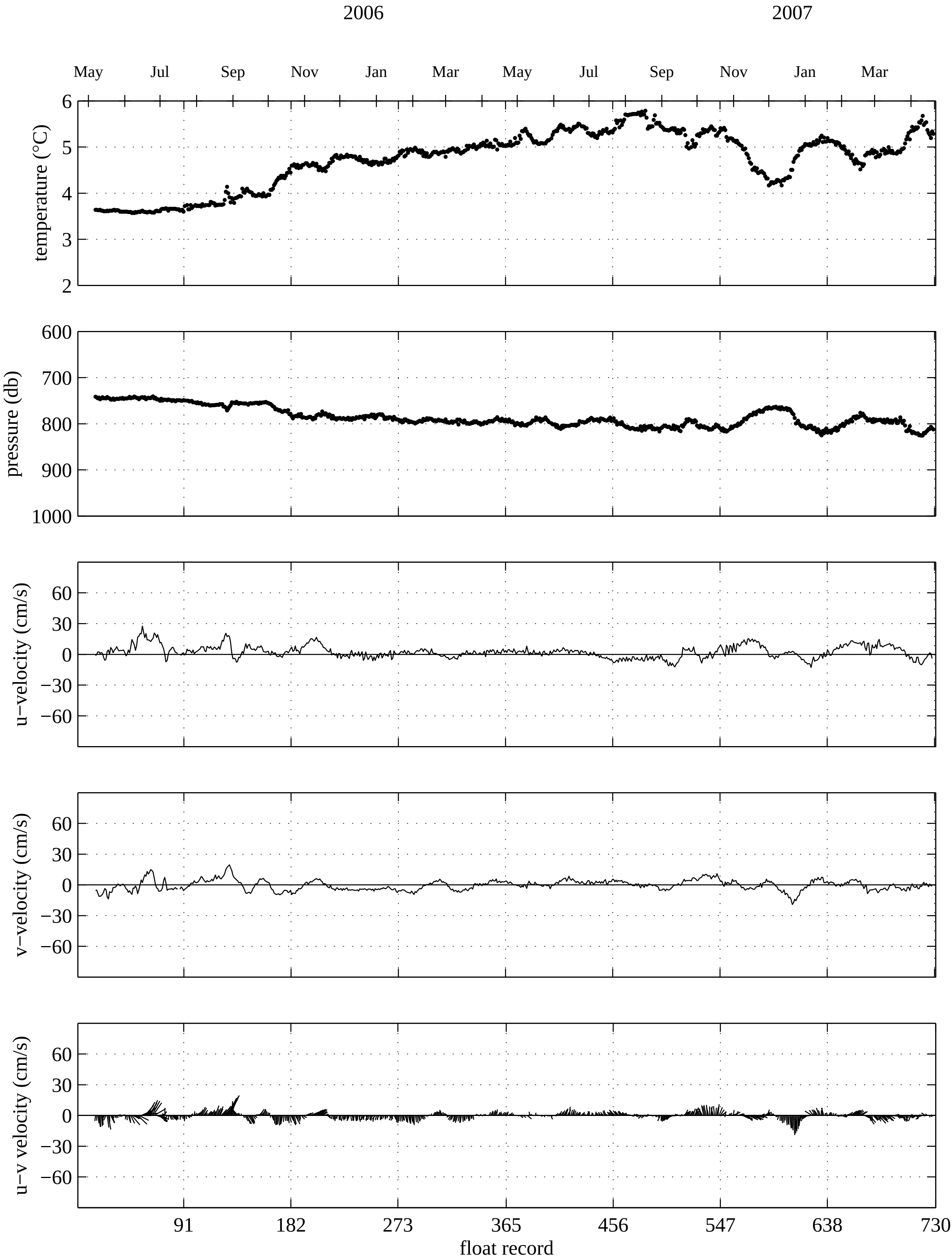


2007
2008
Jun
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
Apr
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

x662 / 8−700−1

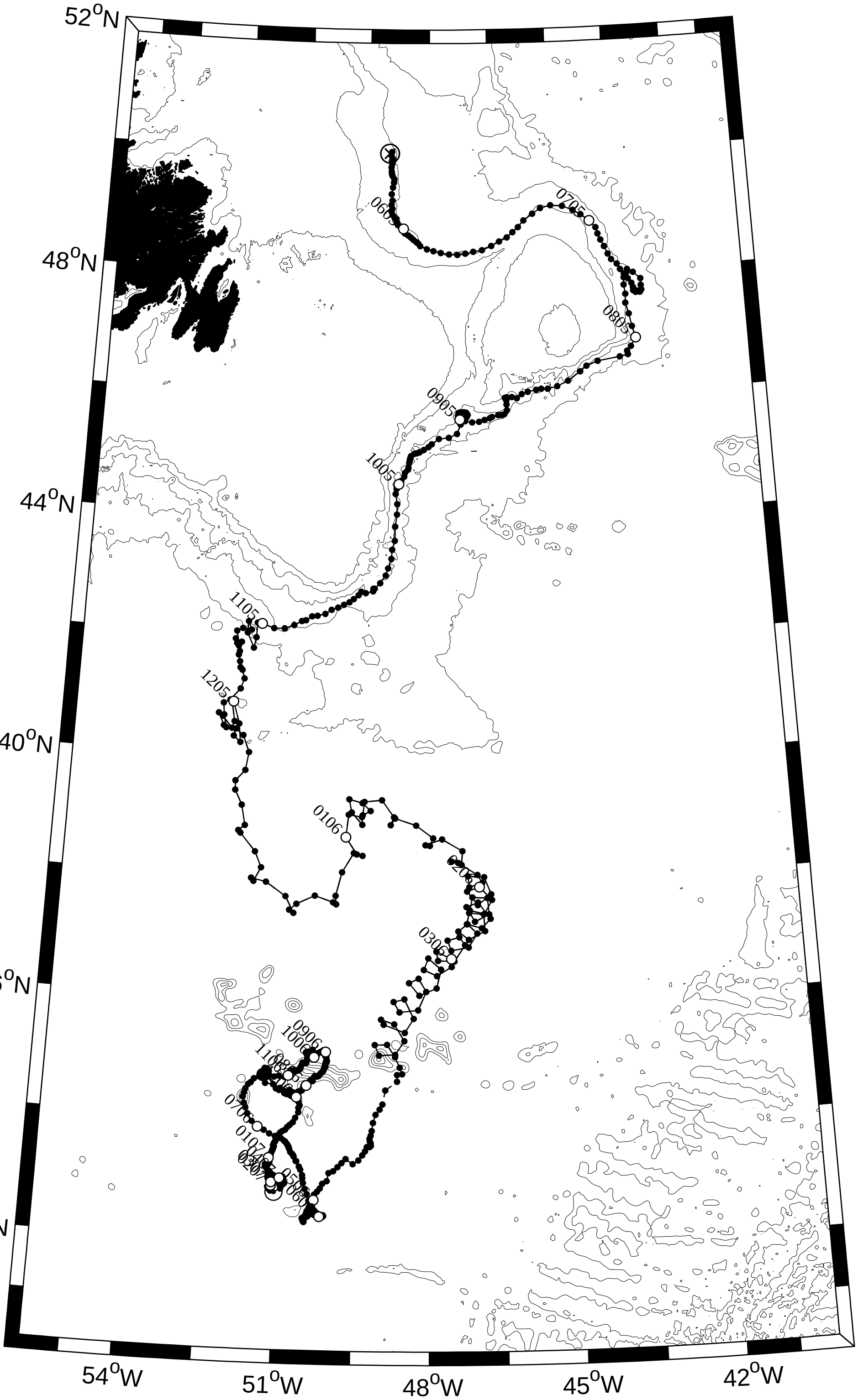


x662 / 8−700−1

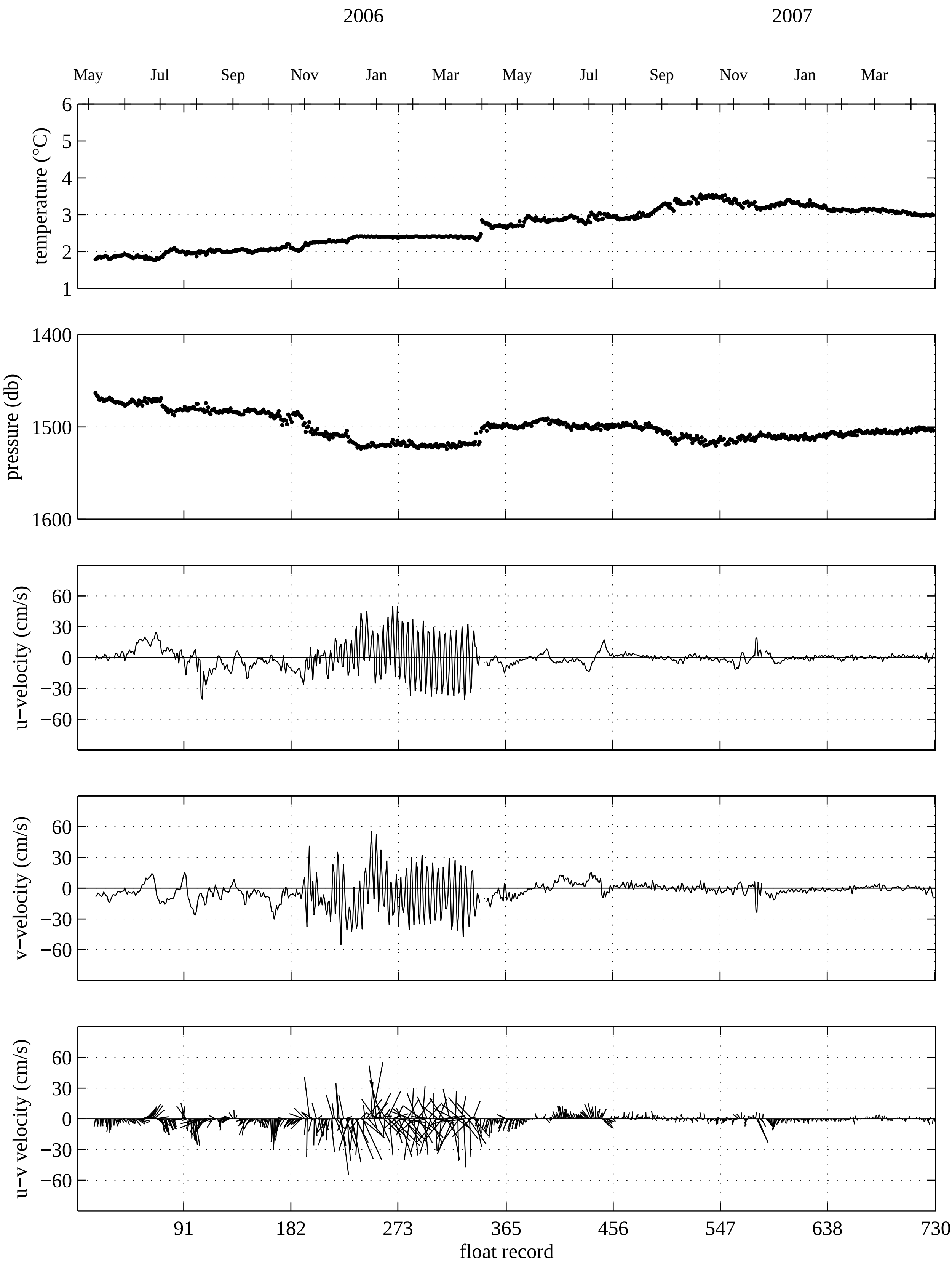


2006
2007
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
float record

x664 / 8−1500−1

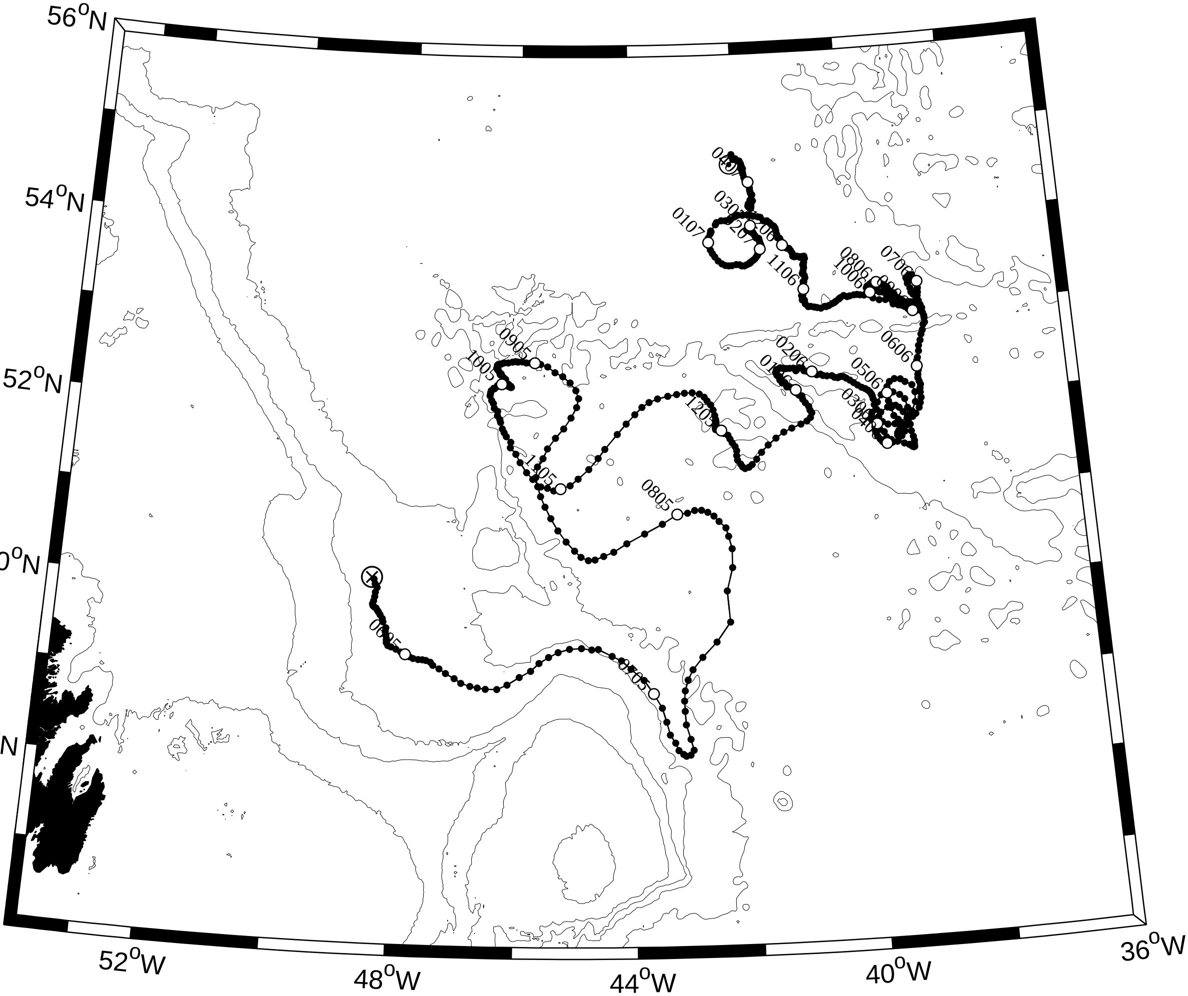

52°N
48°N
44°N
40°N
36°N
32°N
54°W
51°W
48°W
45°W
42°W
0605
0705
0805
0905
1005
1105
1205
0106
0206
0306
0906
1006
1106
0706
0107
0207
0507

x664 / 8−1500−1



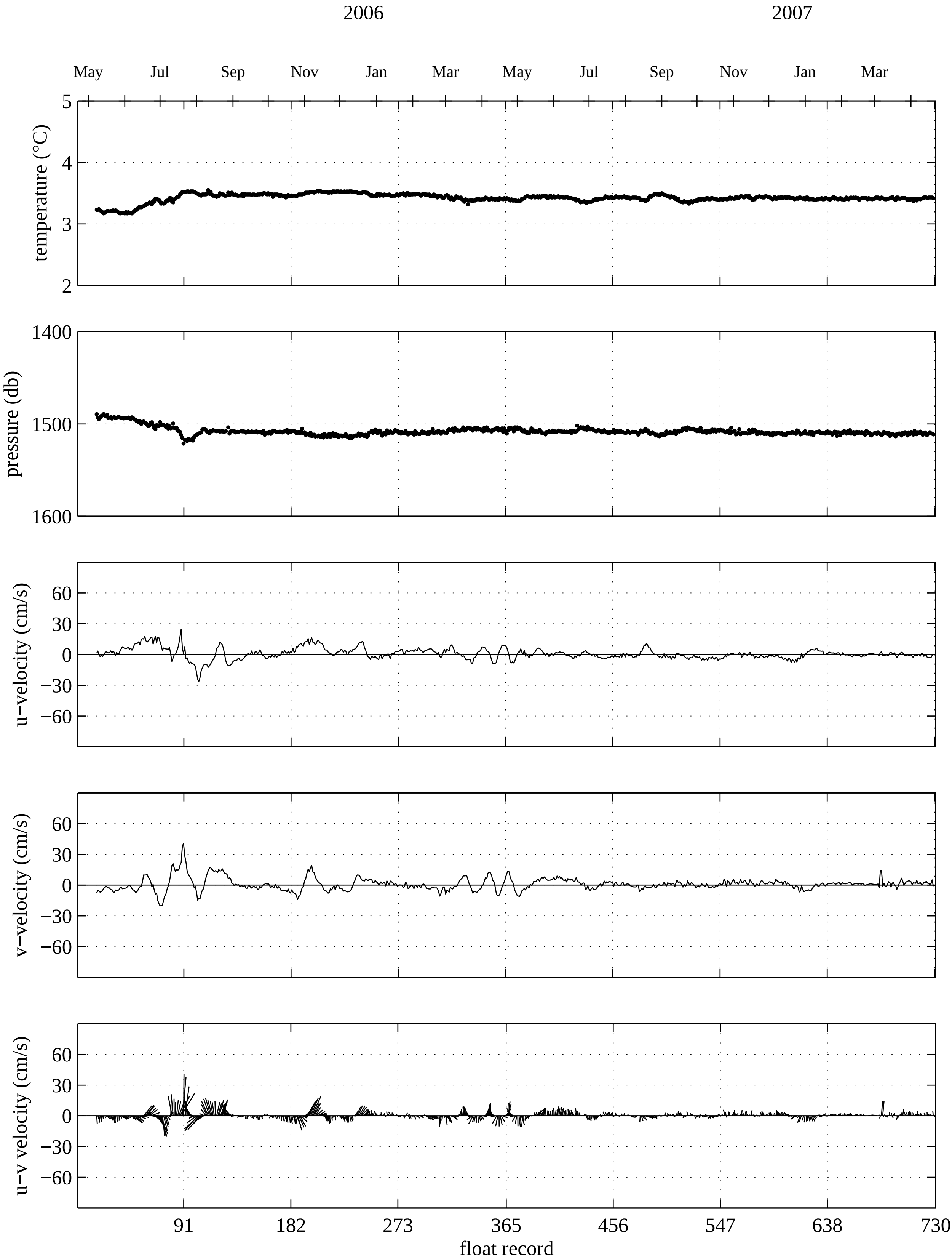
2006
2007
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

x665 / 8−1500−2

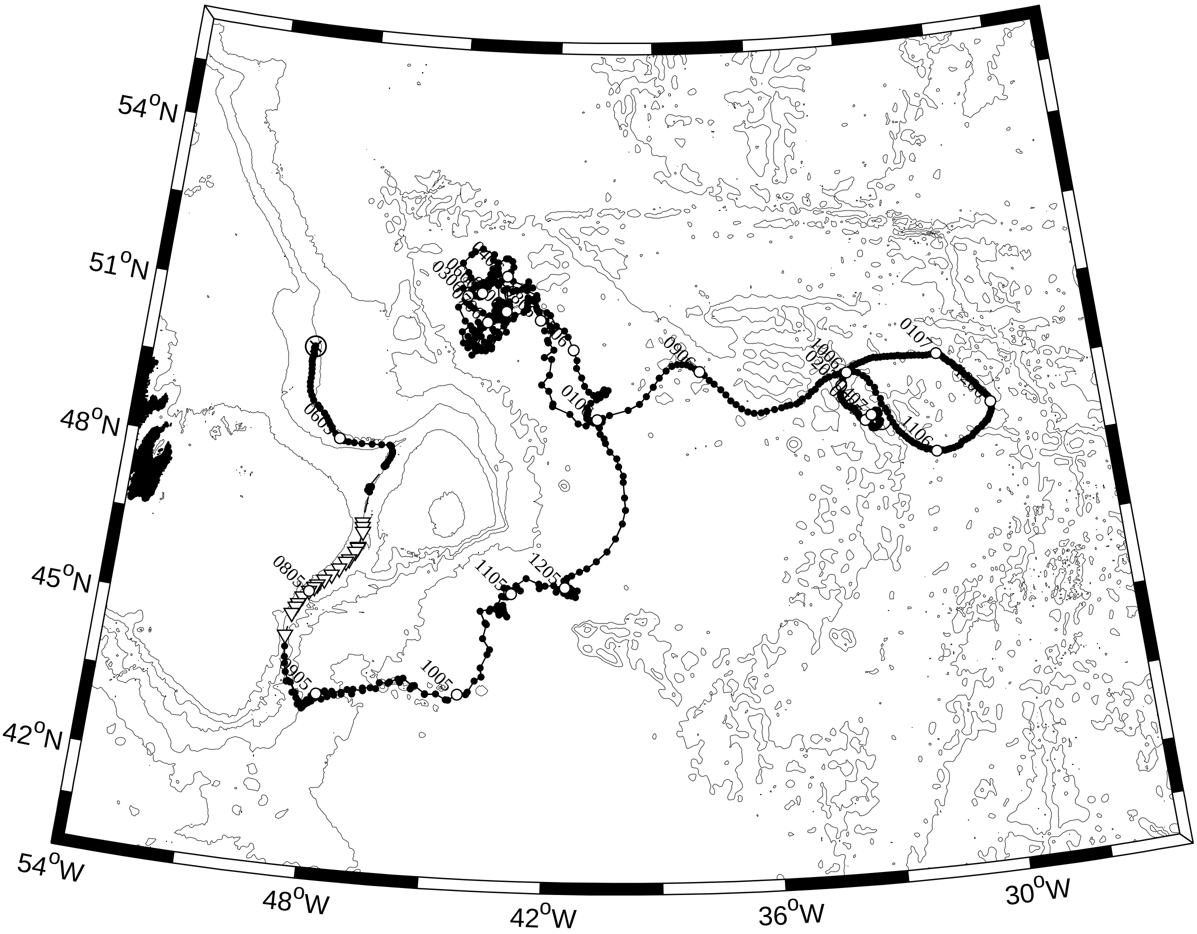


56°N
54°N
52°N
50°N
48°N
46°N
52°W
48°W
44°W
40°W
36°W
0107
1106
1006
0806
0606
0506
0206
0905
1005
1205
1105
0805
0705
0605

x665 / 8−1500−2

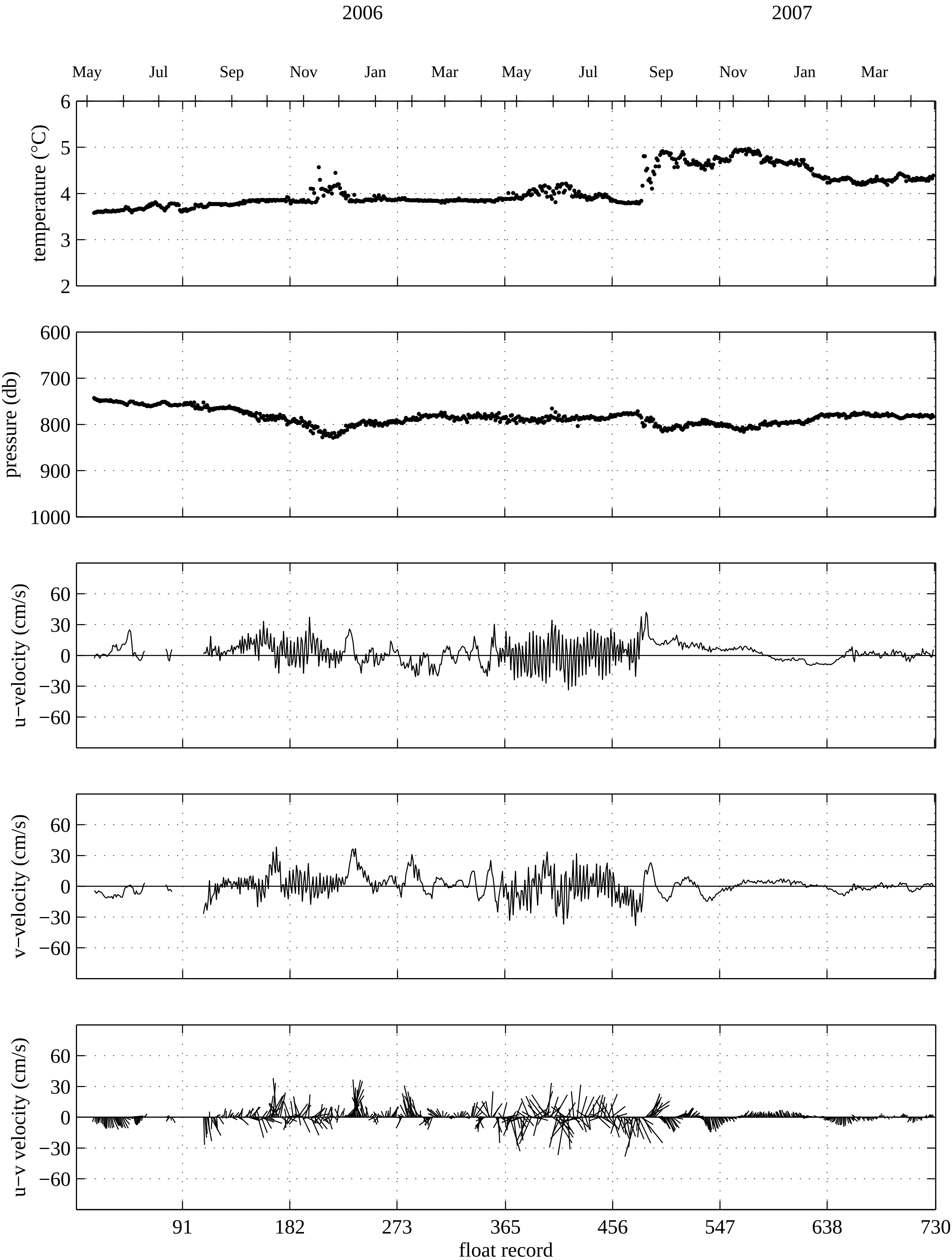

2006
2007
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
5
4
3
2
temperature (°C)
1400
1500
1600
pressure (db)
60
30
0
−30
−60
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

x666 / 8−700−2

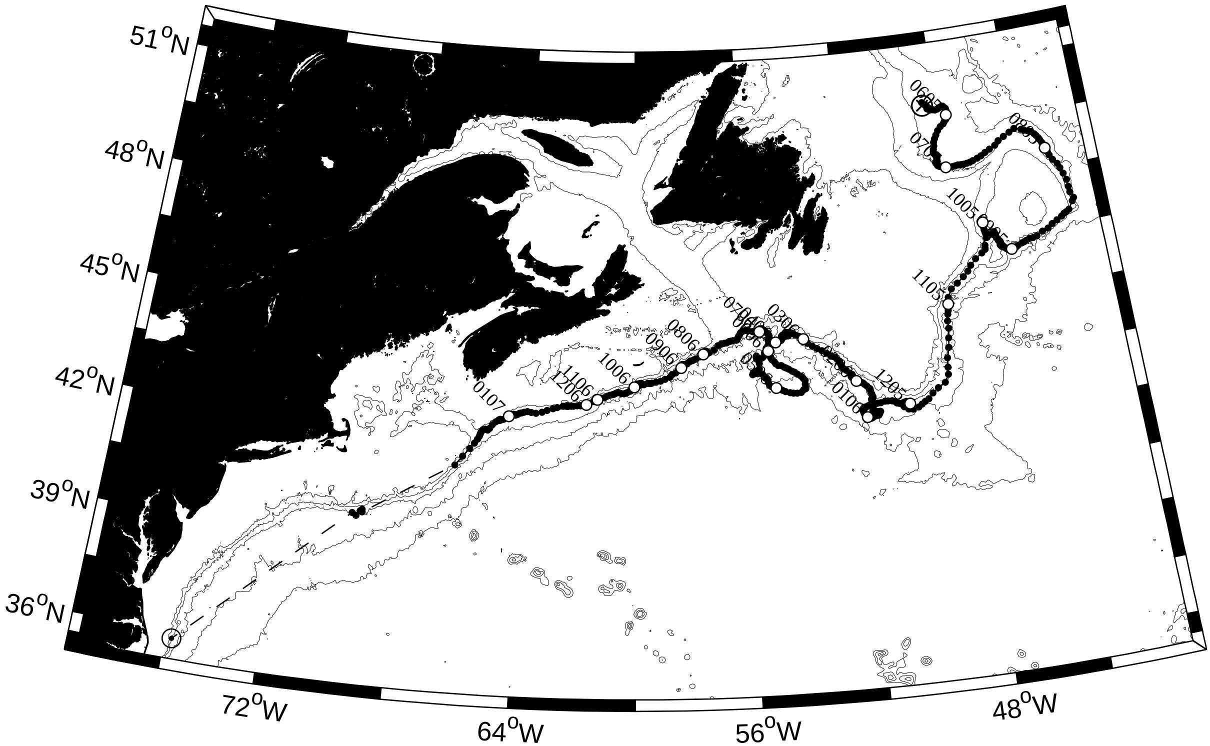


54°N
51°N
48°N
45°N
42°N
54°W
48°W
42°W
36°W
30°W
0605
0805
0905
1005
1105
1205
0106
0906
1006
0107
1106

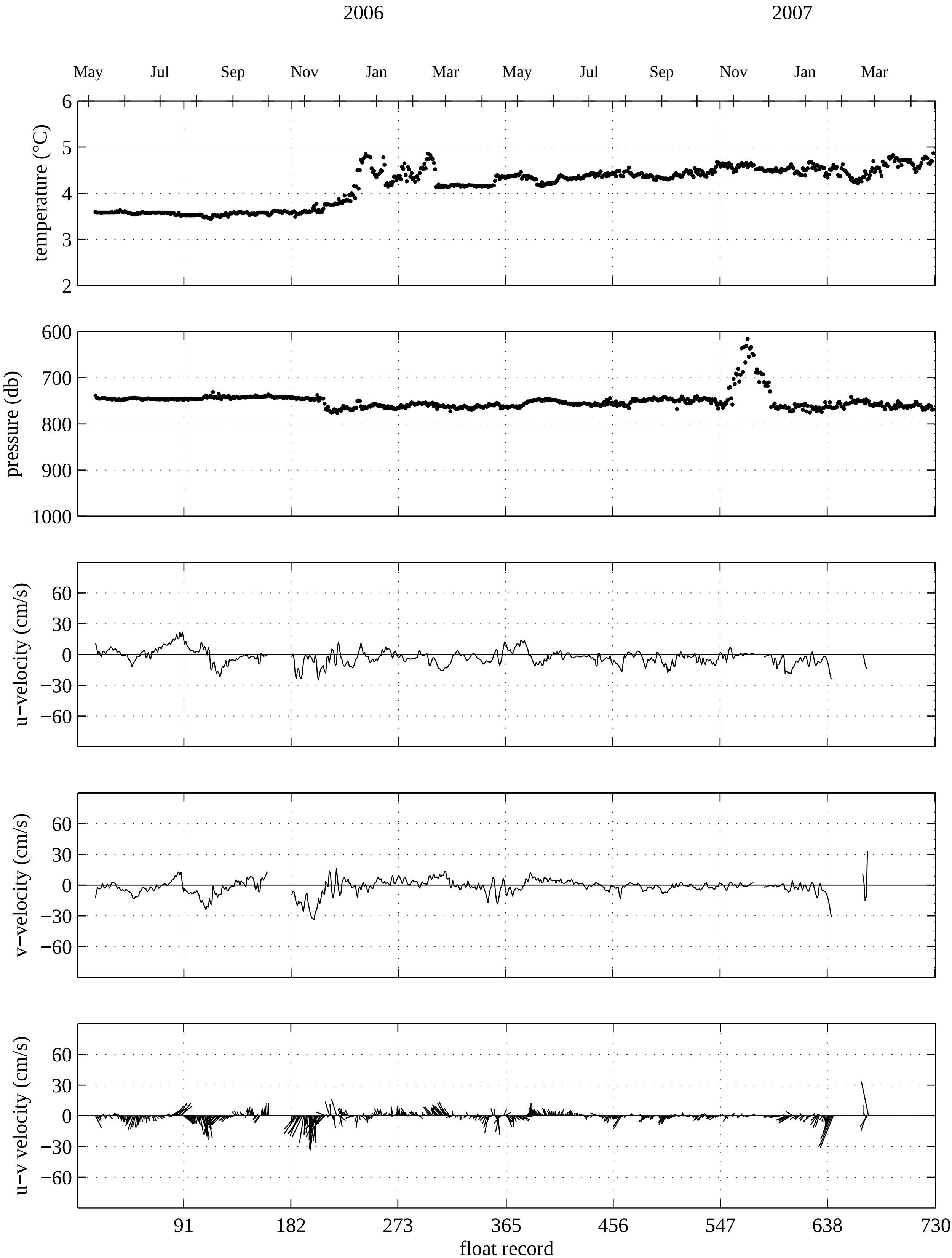
x666 / 8−700−2


2006
2007
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

x667 / 8−700−3

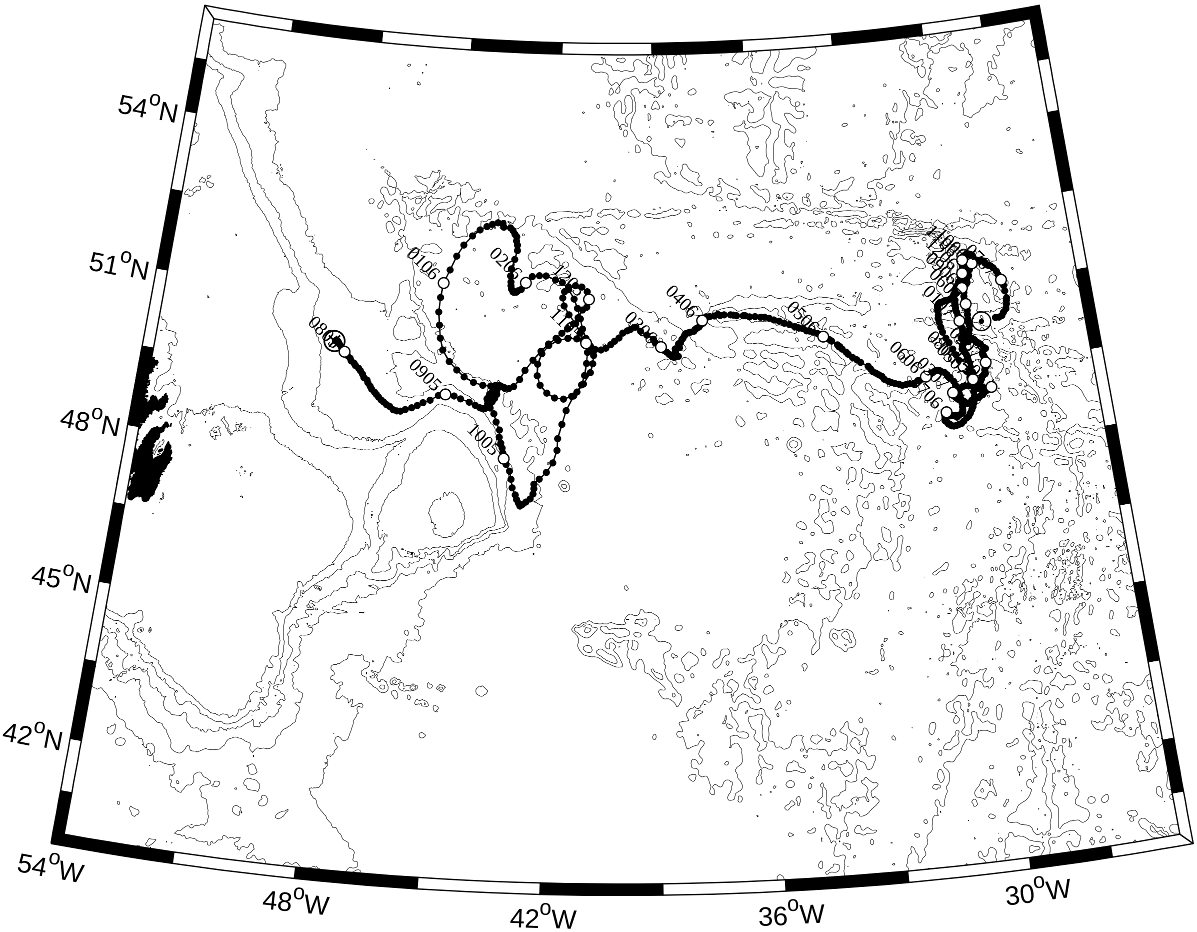

51°N
48°N
45°N
42°N
39°N
36°N
72°W
64°W
56°W
48°W
0605
0705
0805
1005
1105
1205
0106
0306
0806
0906
1006
1106
1206
0107

x667 / 8−700−3



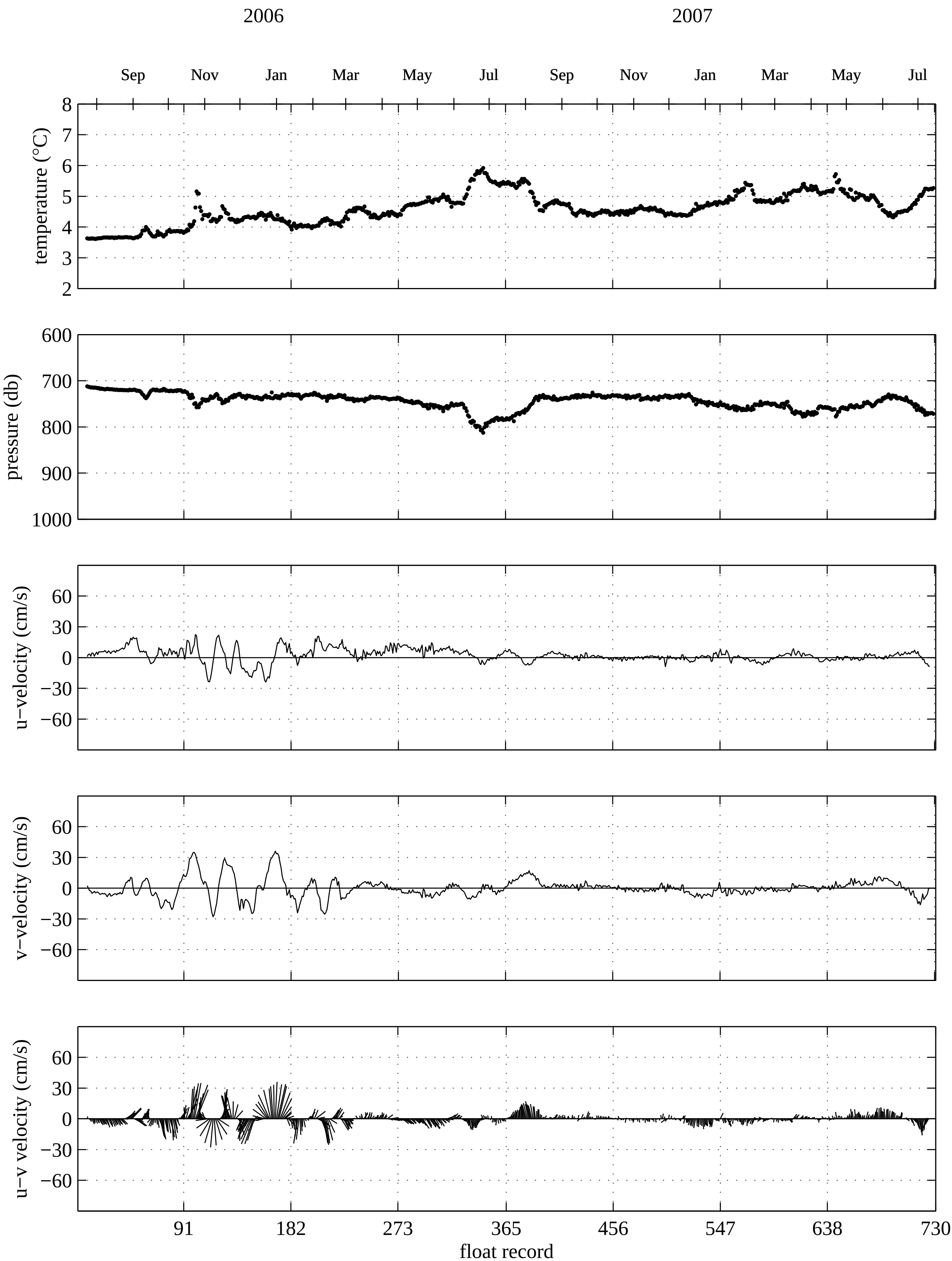
2006
2007
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
float record
91
182
273
365
456
547
638
730

x668 / 9−700−3



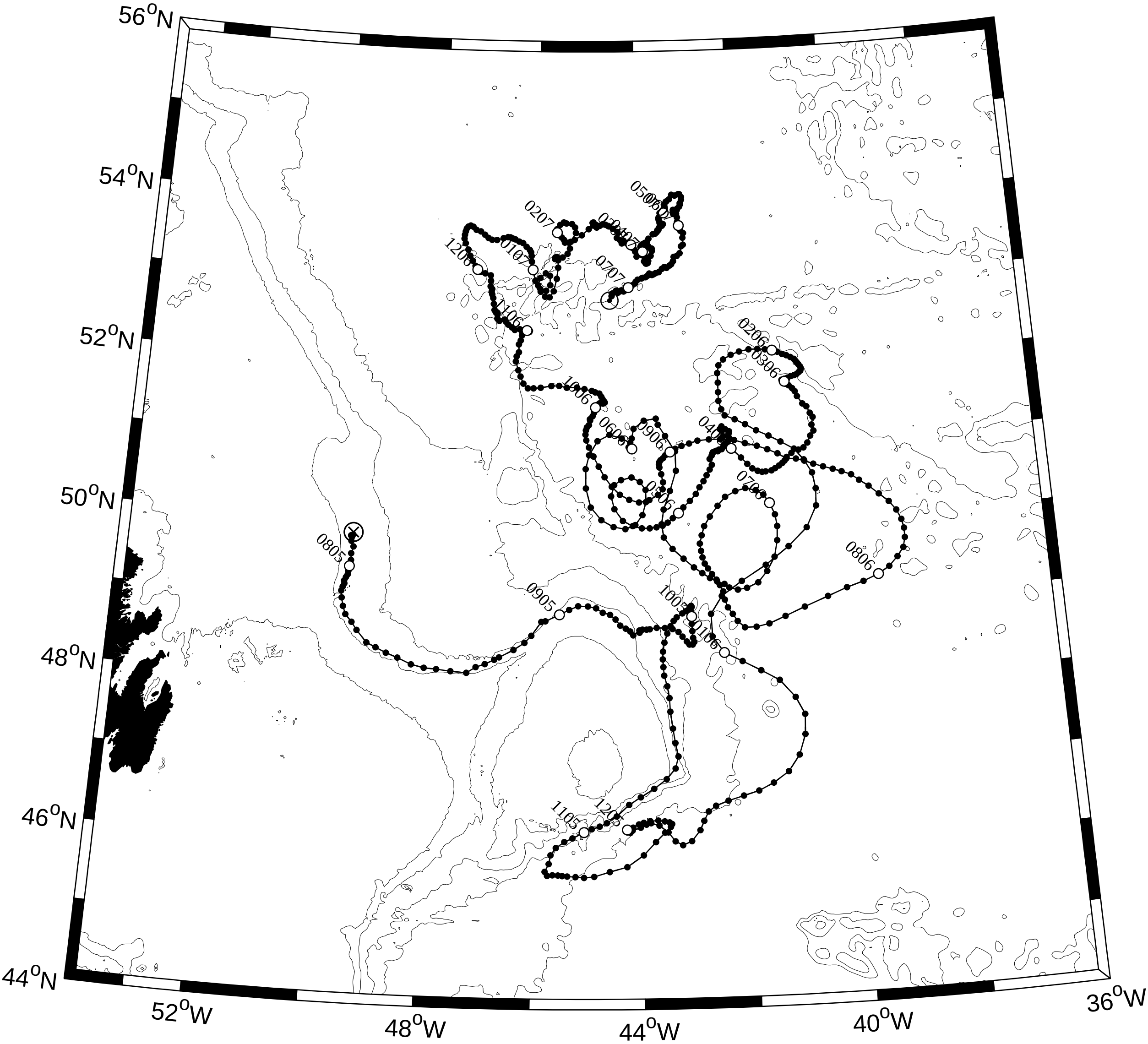
54°N
51°N
48°N
45°N
42°N
54°W
48°W
42°W
36°W
30°W
0106
0206
0306
0406
0506
0606
0706
0805
0905
1005

x668 / 9−700−3

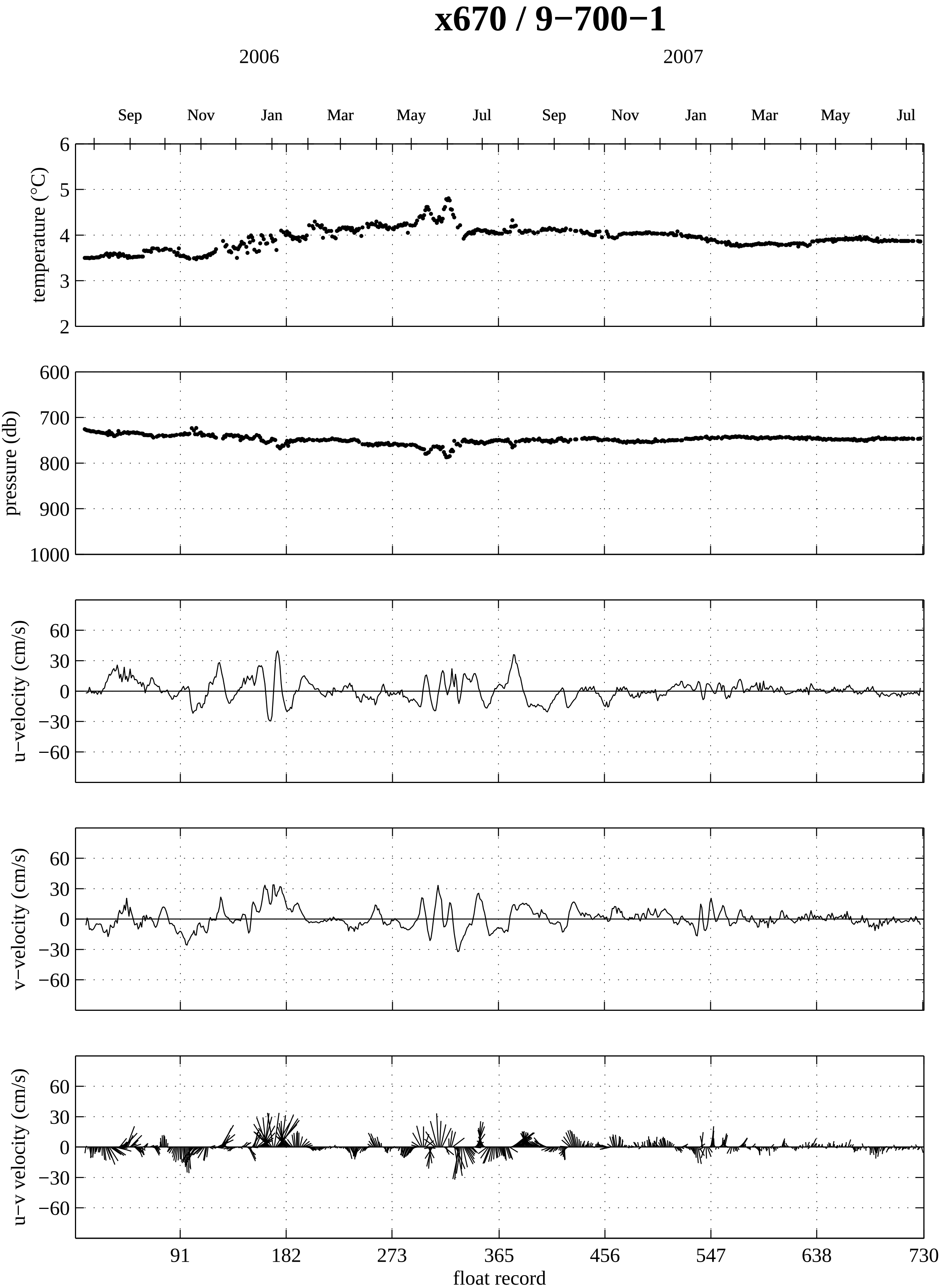


2006
2007
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

x670 / 9−700−1

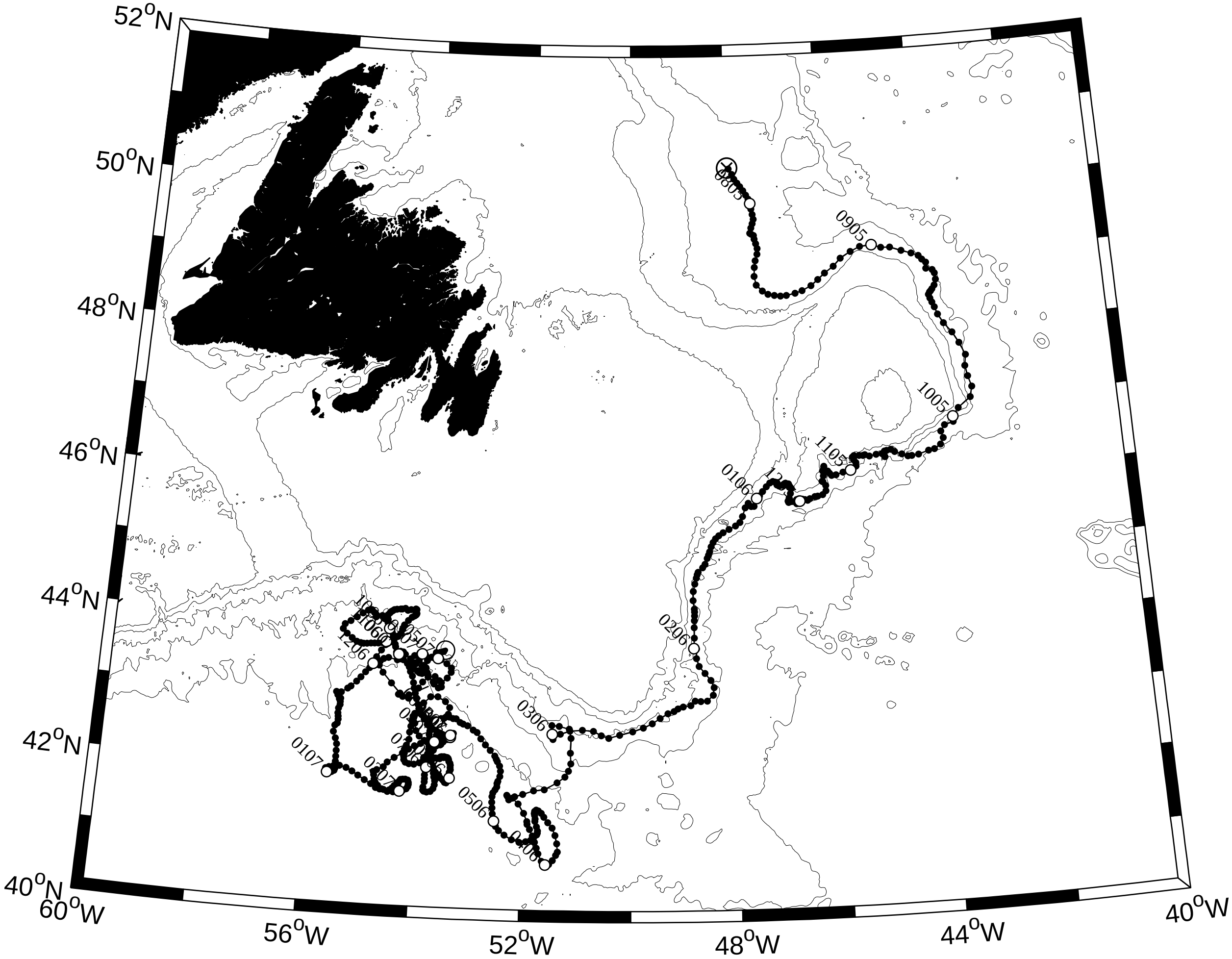


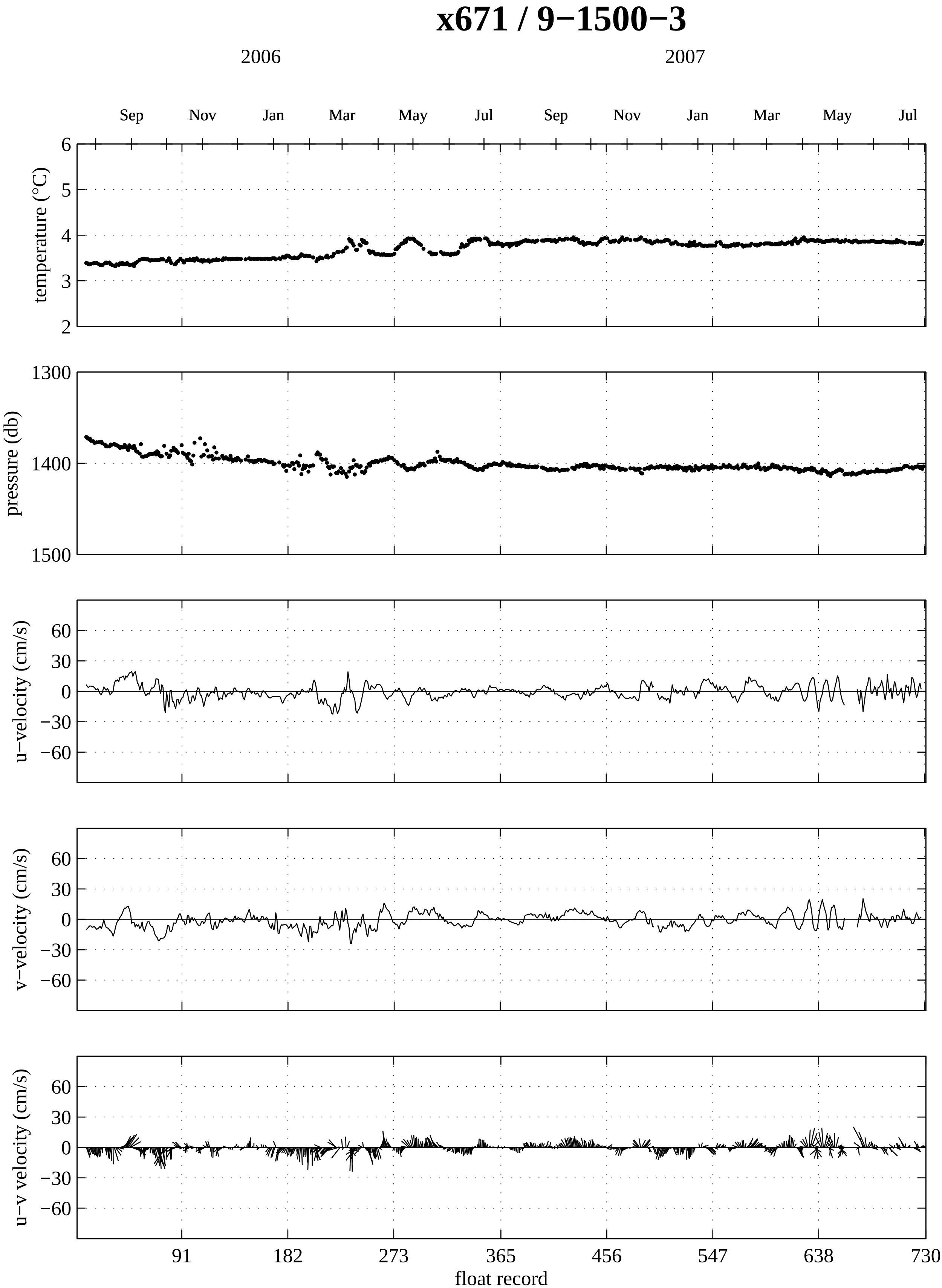
56°N
54°N
52°N
50°N
48°N
46°N
44°N
52°W
48°W
44°W
40°W
36°W
0805
0905
1005
1105
1205
1206
0107
0207
0307
0407
0507
0607
0707
1106
1006
0606
0906
0206
0306
0406
0706
0506
0806
0106



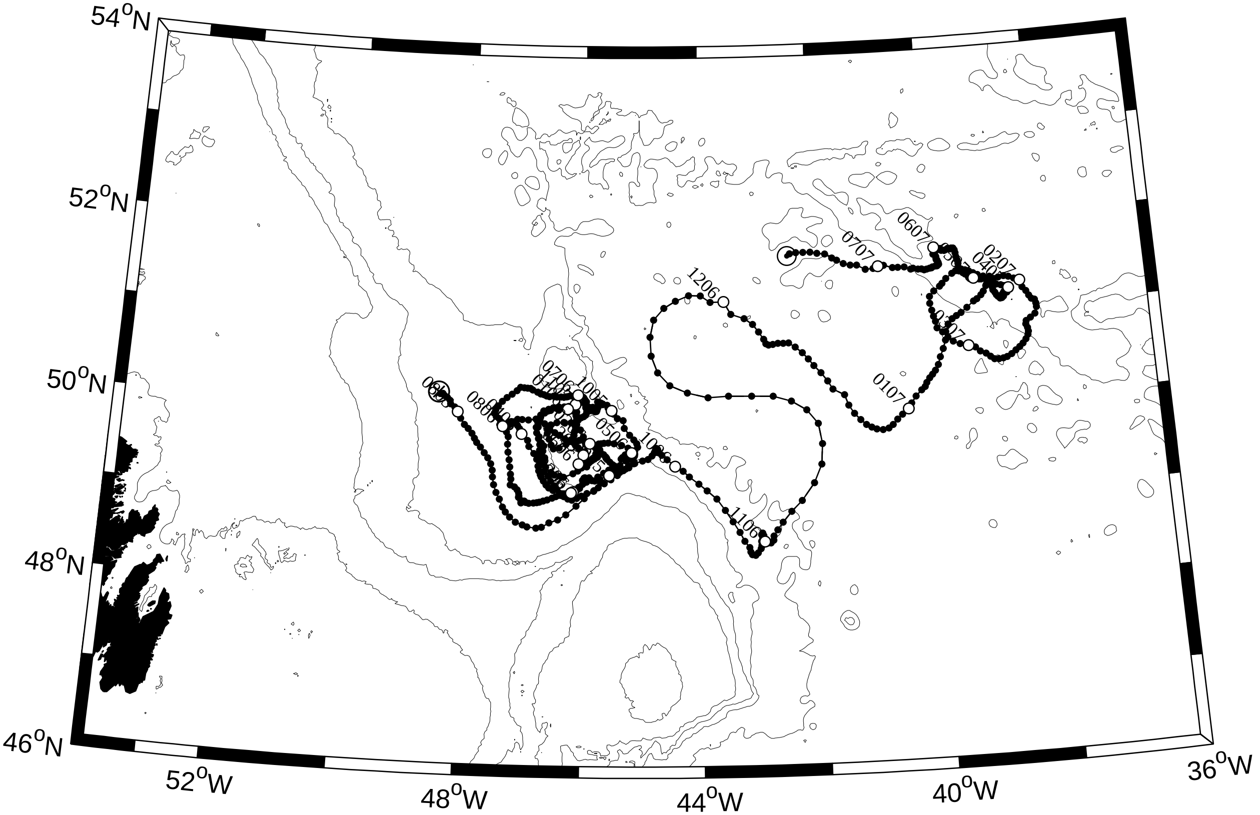
x670 / 9−700−1
2006
2007
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

x671 / 9−1500−3


52°N
50°N
48°N
46°N
44°N
42°N
40°N
60°W
56°W
52°W
48°W
44°W
40°W
0805
0905
1005
1105
0106
0206
0306
0506
0107
1206

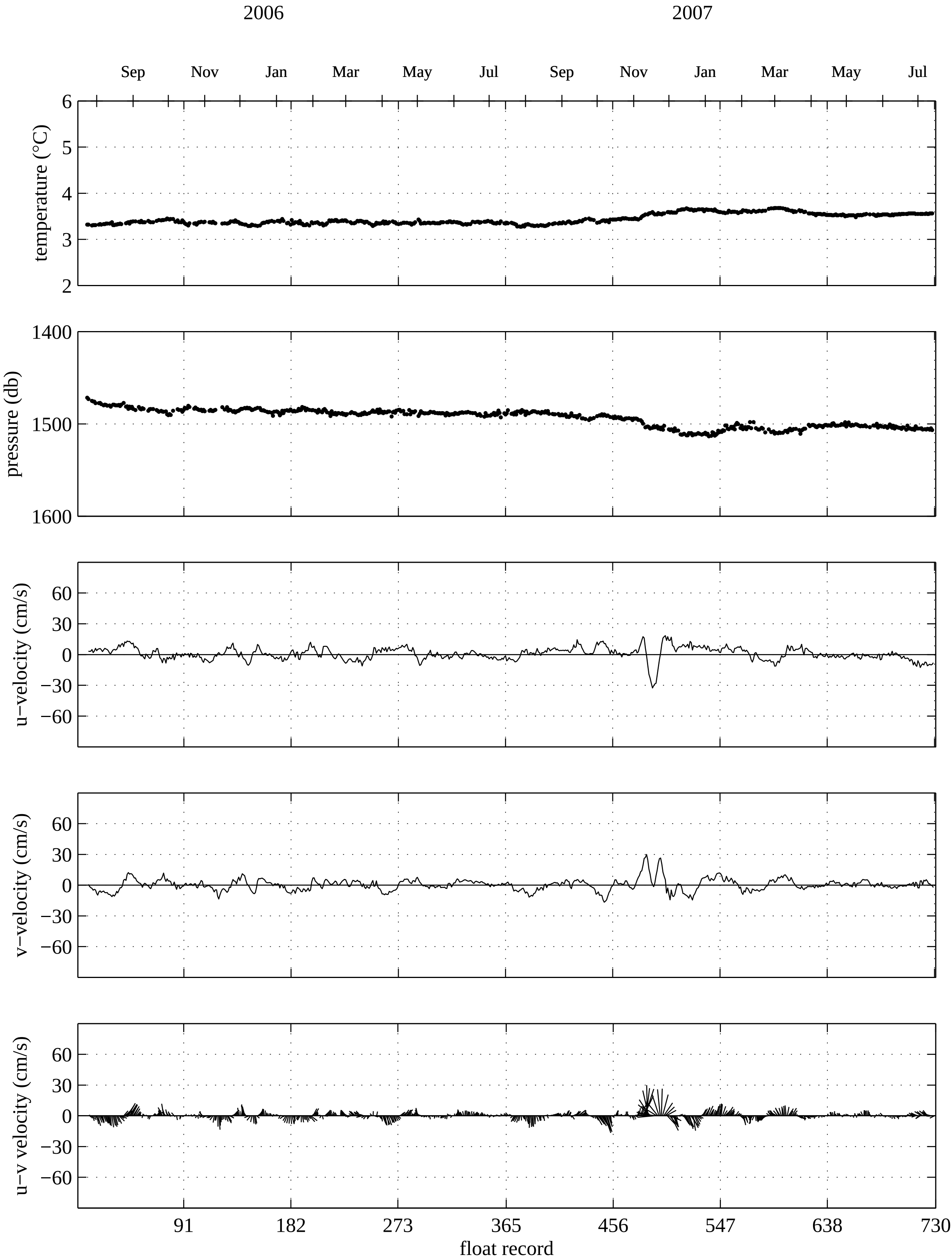

x671 / 9−1500−3
2006
2007
Sep Nov Jan Mar May Jul Sep Nov Jan Mar May Jul
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91 182 273 365 456 547 638 730
float record

x672 / 9−1500−2



54°N
52°N
50°N
48°N
46°N
52°W
48°W
44°W
40°W
36°W
0607
0707
0207
0407
1206
0307
0107
0706
1006
0806
0506
1006
1106

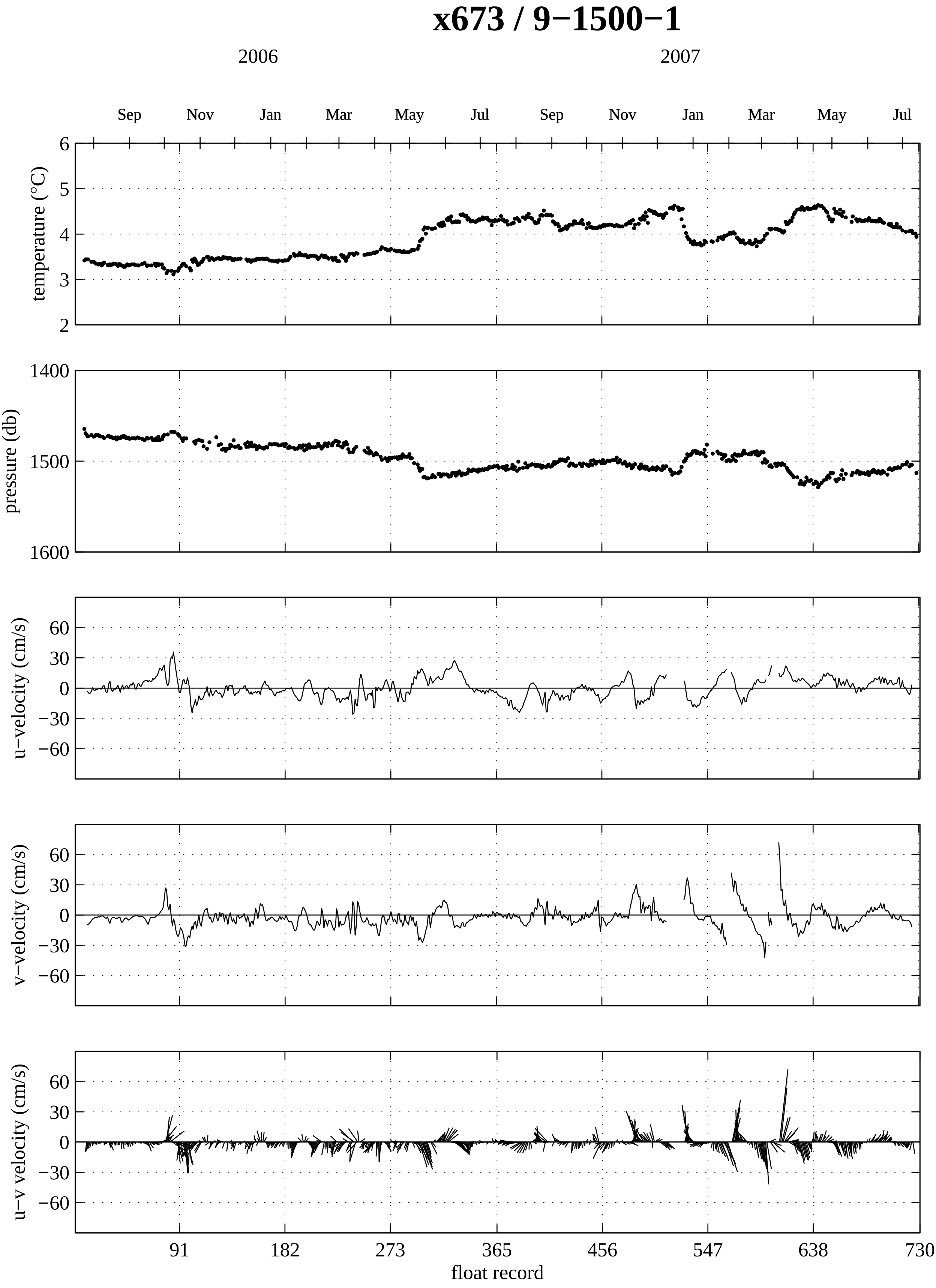
x672 / 9−1500−2



2006
2007
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
temperature (°C)
6
5
4
3
2
pressure (db)
1400
1500
1600
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

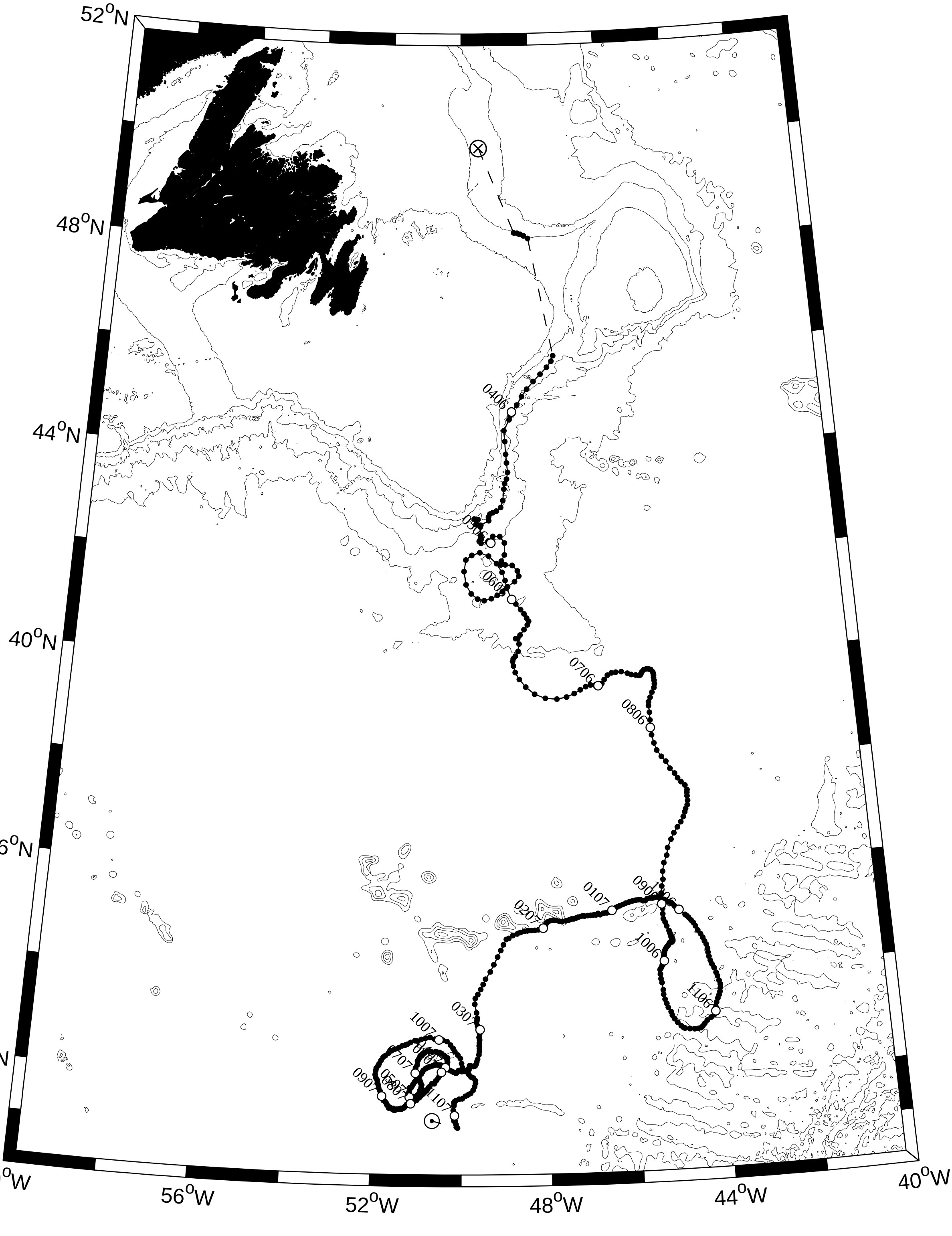
x673 / 9−1500−1


52°N
48°N
44°N
40°N
36°N
60°W
56°W
52°W
48°W
44°W
40°W
0805
0905
1005
1105
1205
0106
0206
0306
0406
0307
0407
0506
0606
0706
0806
0906
1206
0507
0607
0707

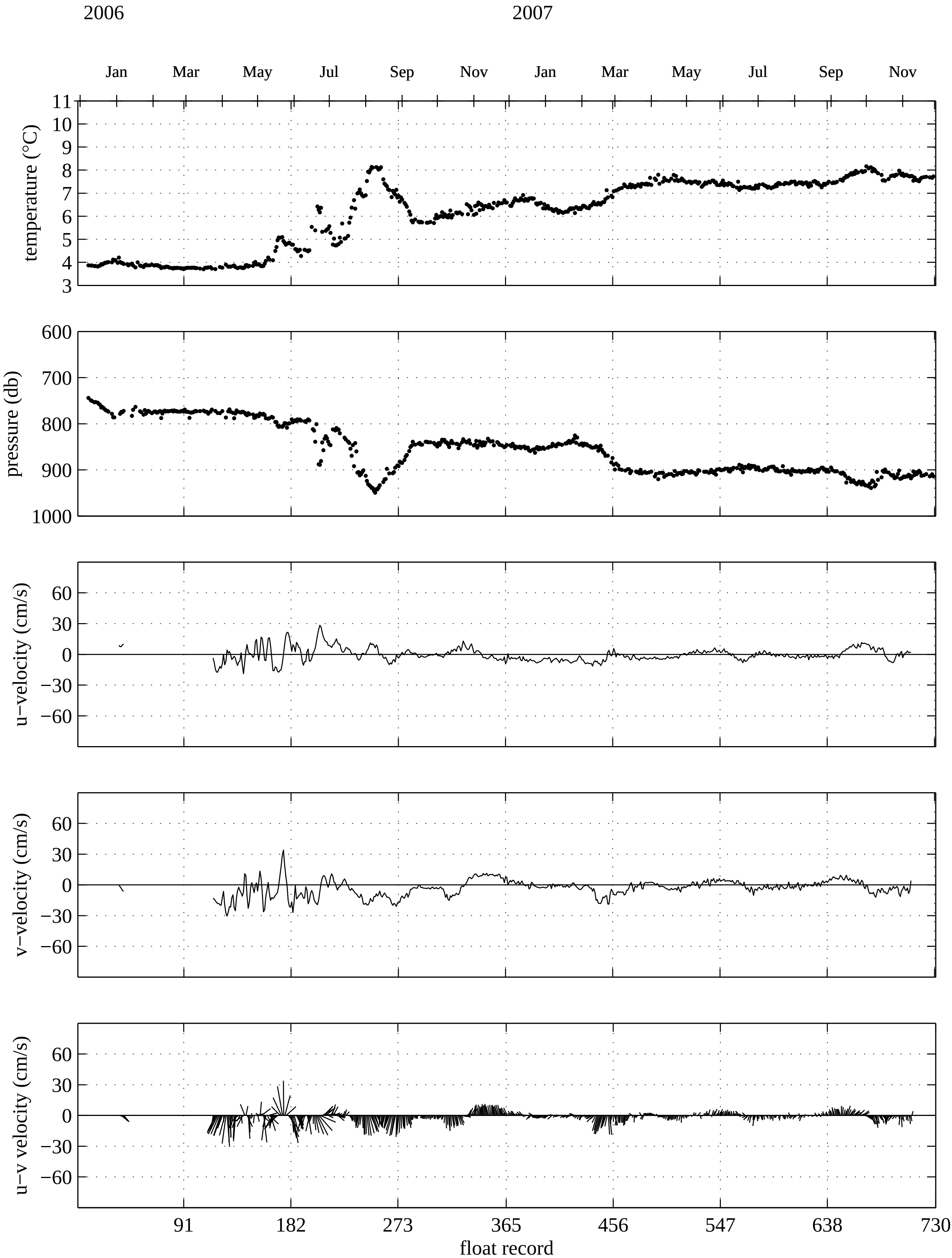


x673 / 9−1500−1
2006
2007
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
temperature (°C)
6
5
4
3
2
pressure (db)
1400
1500
1600
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

x674 / 10−700−1

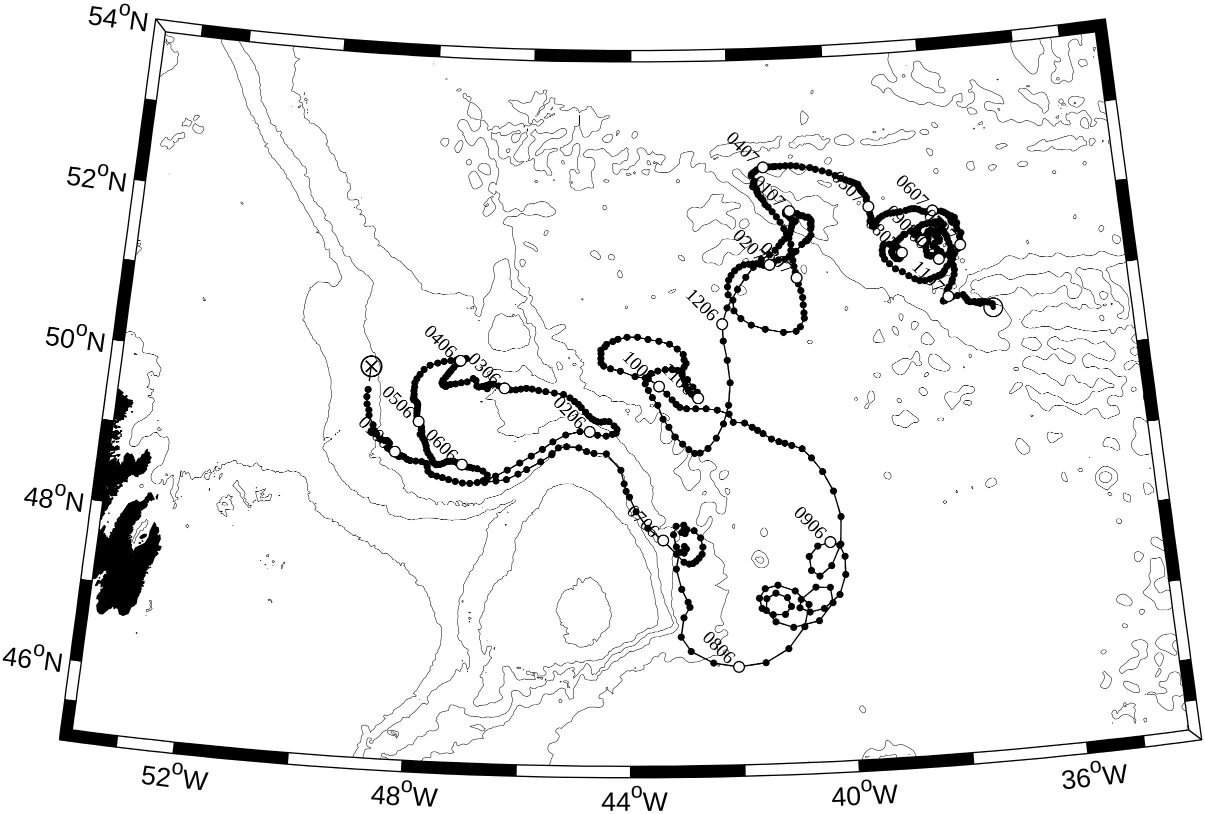

52°N
48°N
44°N
40°N
36°N
32°N
60°W
56°W
52°W
48°W
44°W
40°W
0406
0506
0606
0706
0806
0906
1006
1106
0107
0207
0307
1007
0907
1107

x674 / 10−700−1



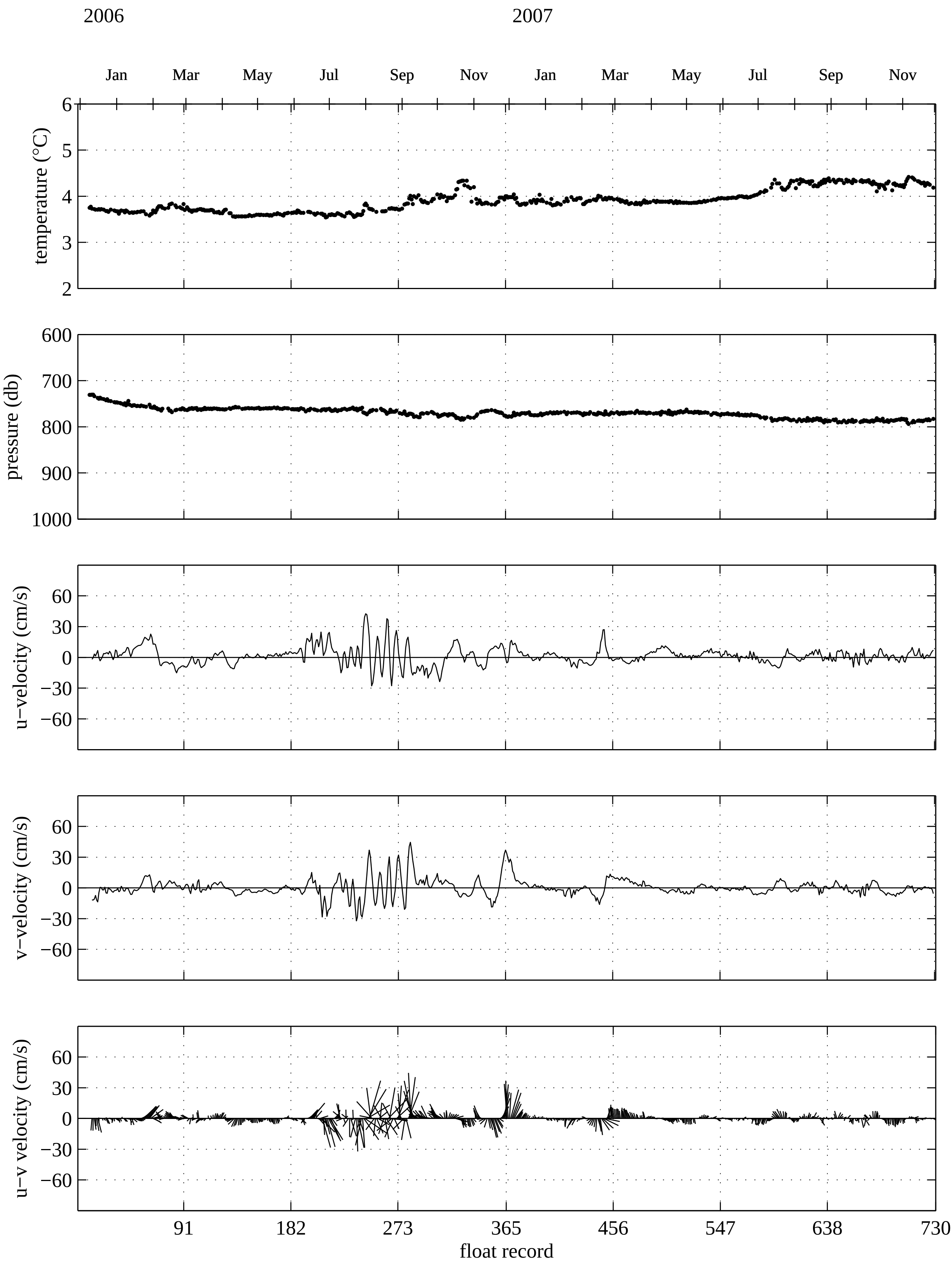
2006
2007
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

x675 / 10−700−2



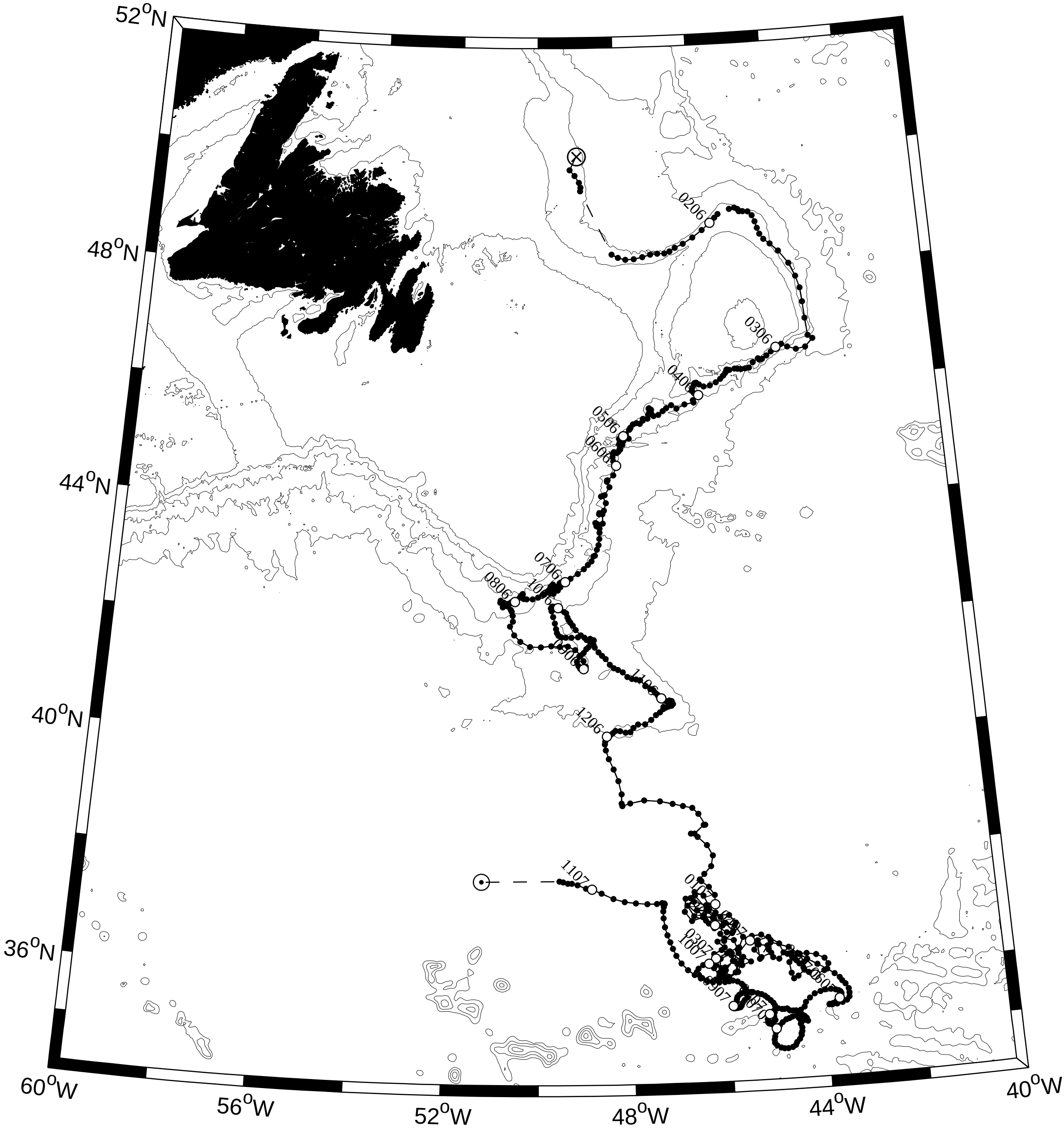
54°N
52°N
50°N
48°N
46°N
52°W
48°W
44°W
40°W
36°W
0407
0107
0607
1206
0406
0306
0506
0606
0206
0906
0806

x675 / 10−700−2

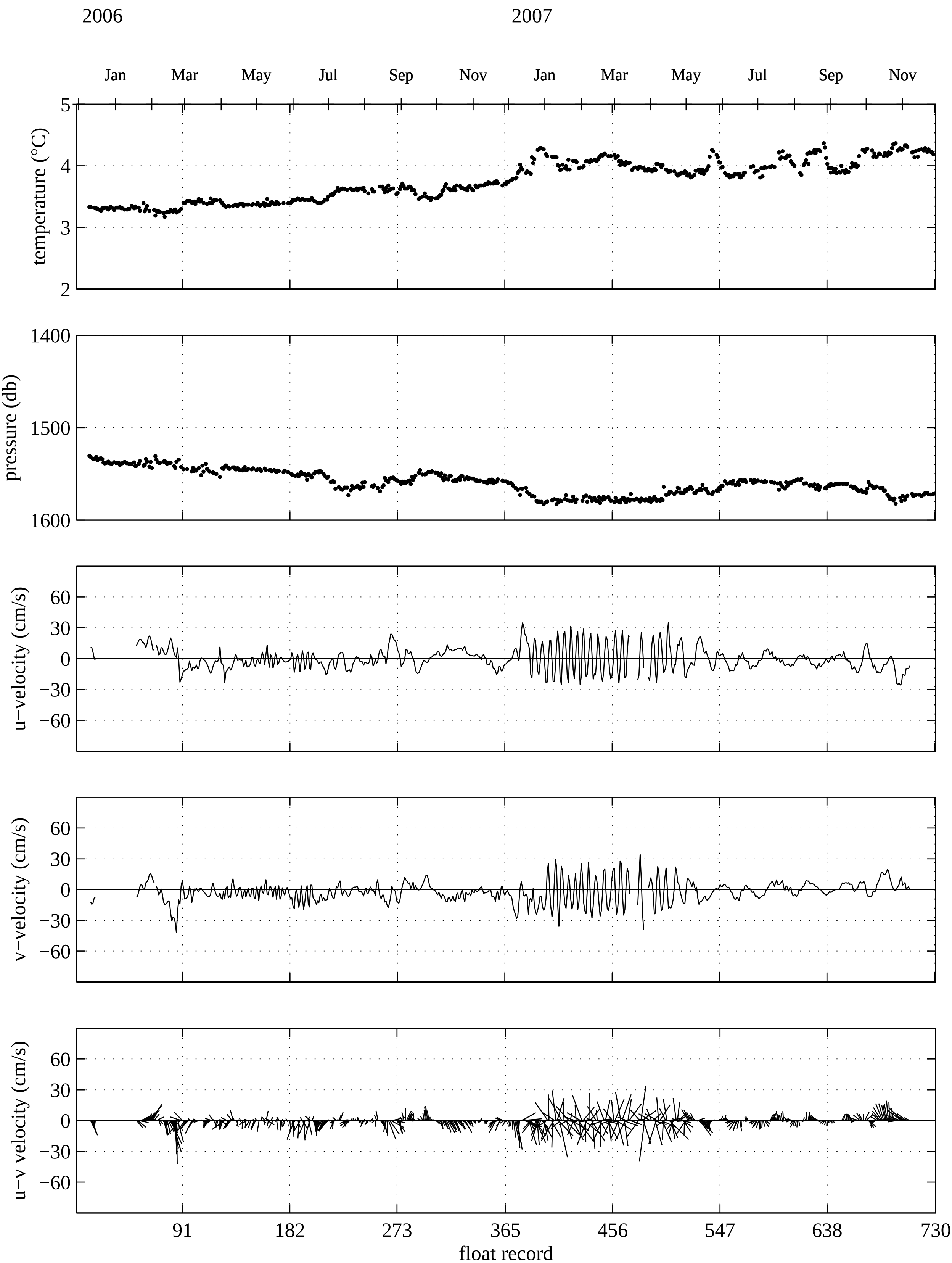


2006
2007
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
temperature (°C)
6
5
4
3
2
pressure (db)
600
700
800
900
1000
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
60
30
0
−30
−60
u−v velocity (cm/s)
60
30
0
−30
−60
91
182
273
365
456
547
638
730
float record

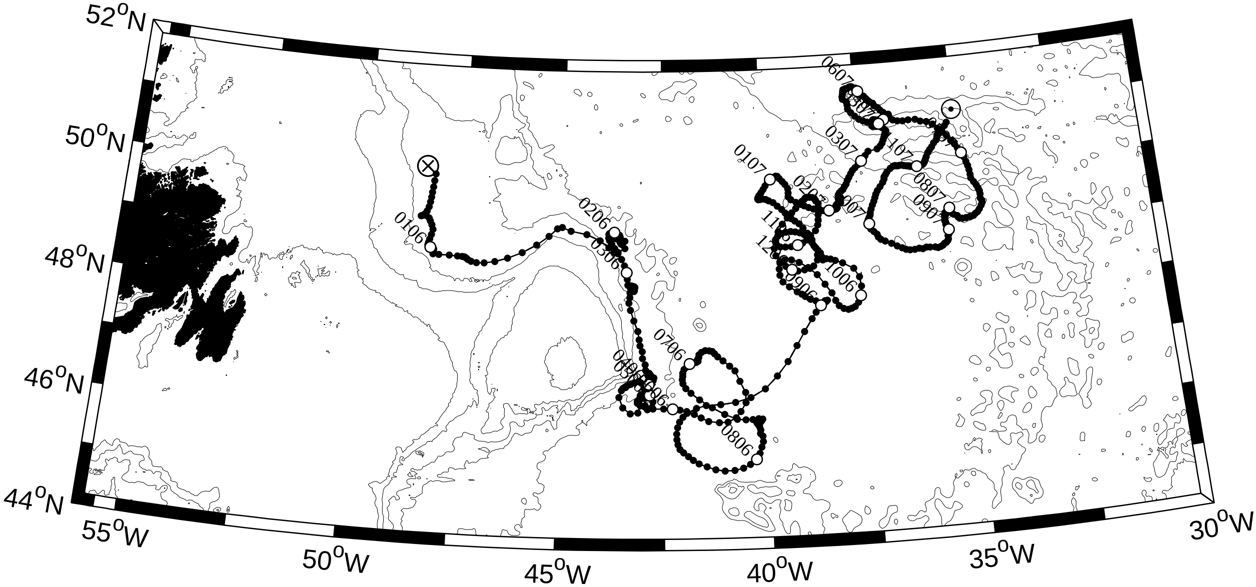
x676 / 10−1500−1



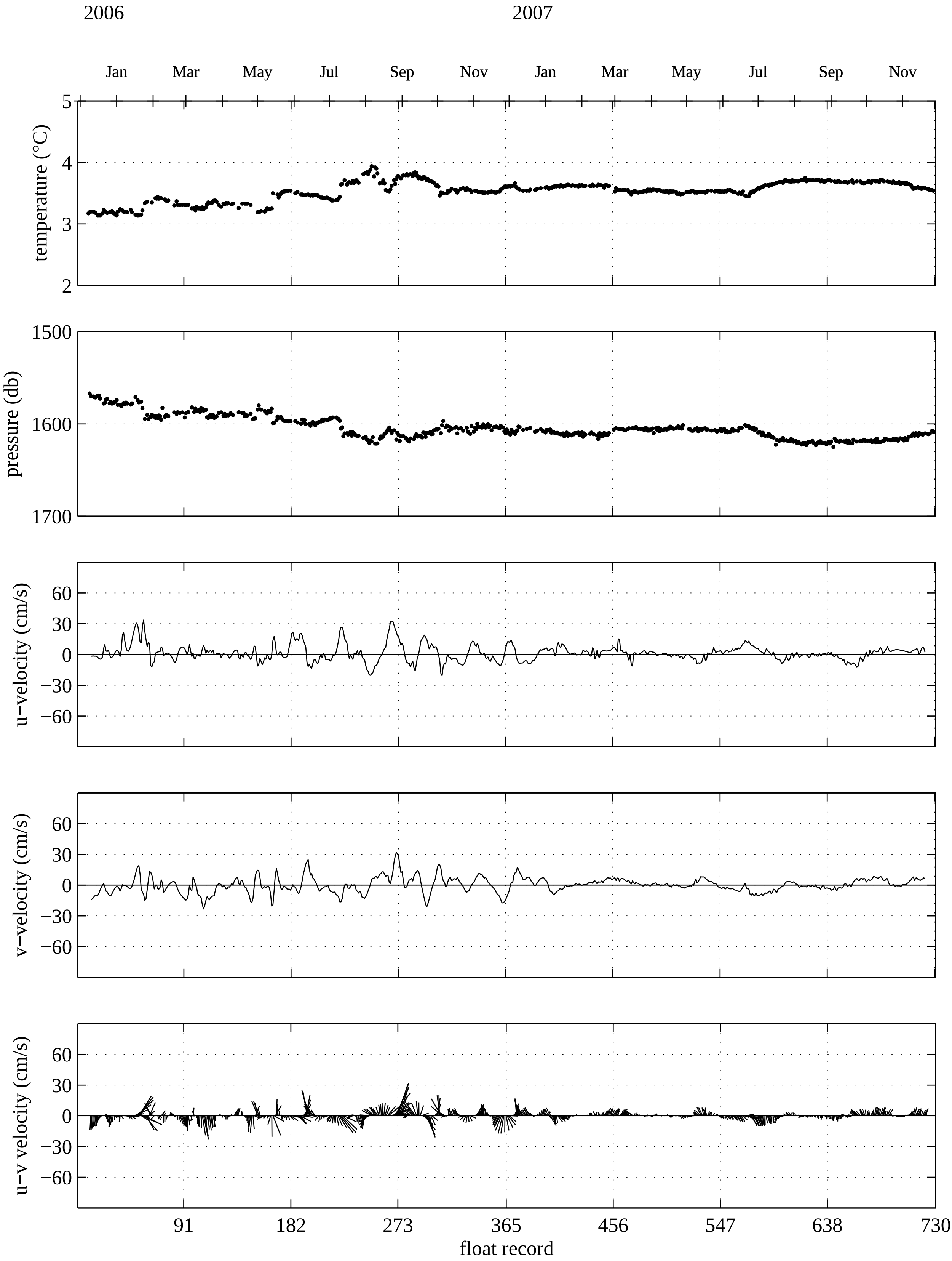
x676 / 10−1500−1



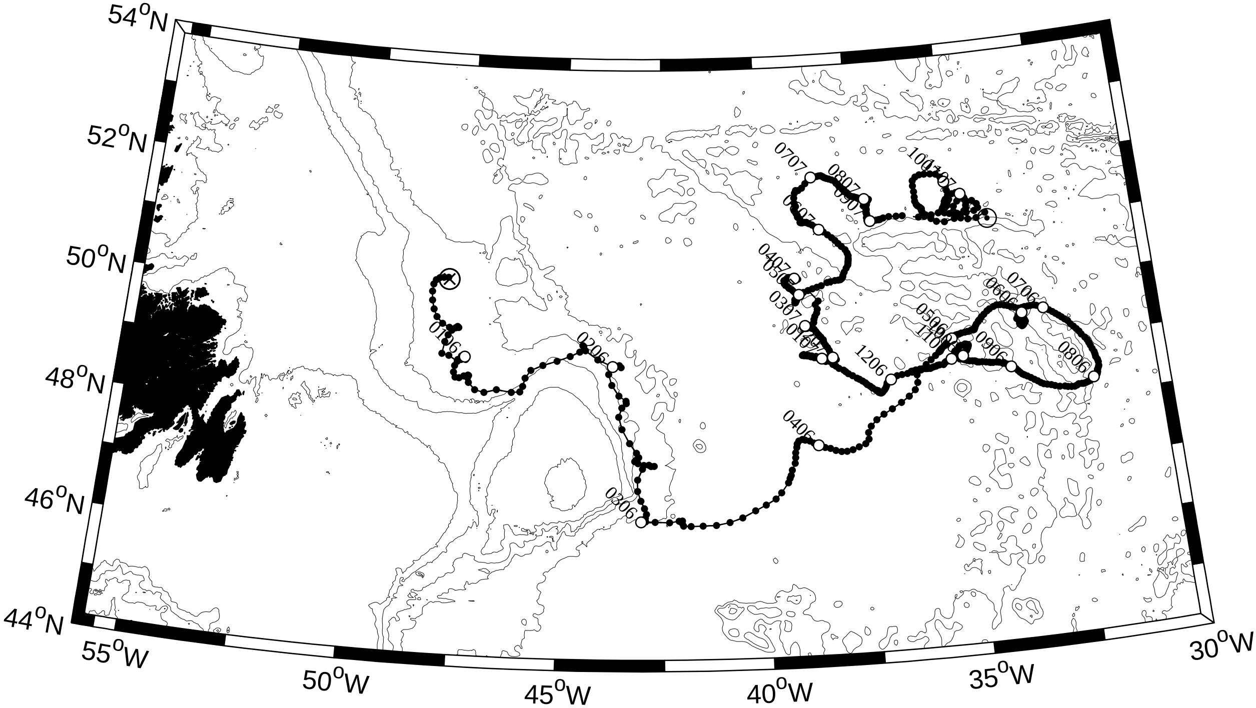
x677 / 10−1500−2

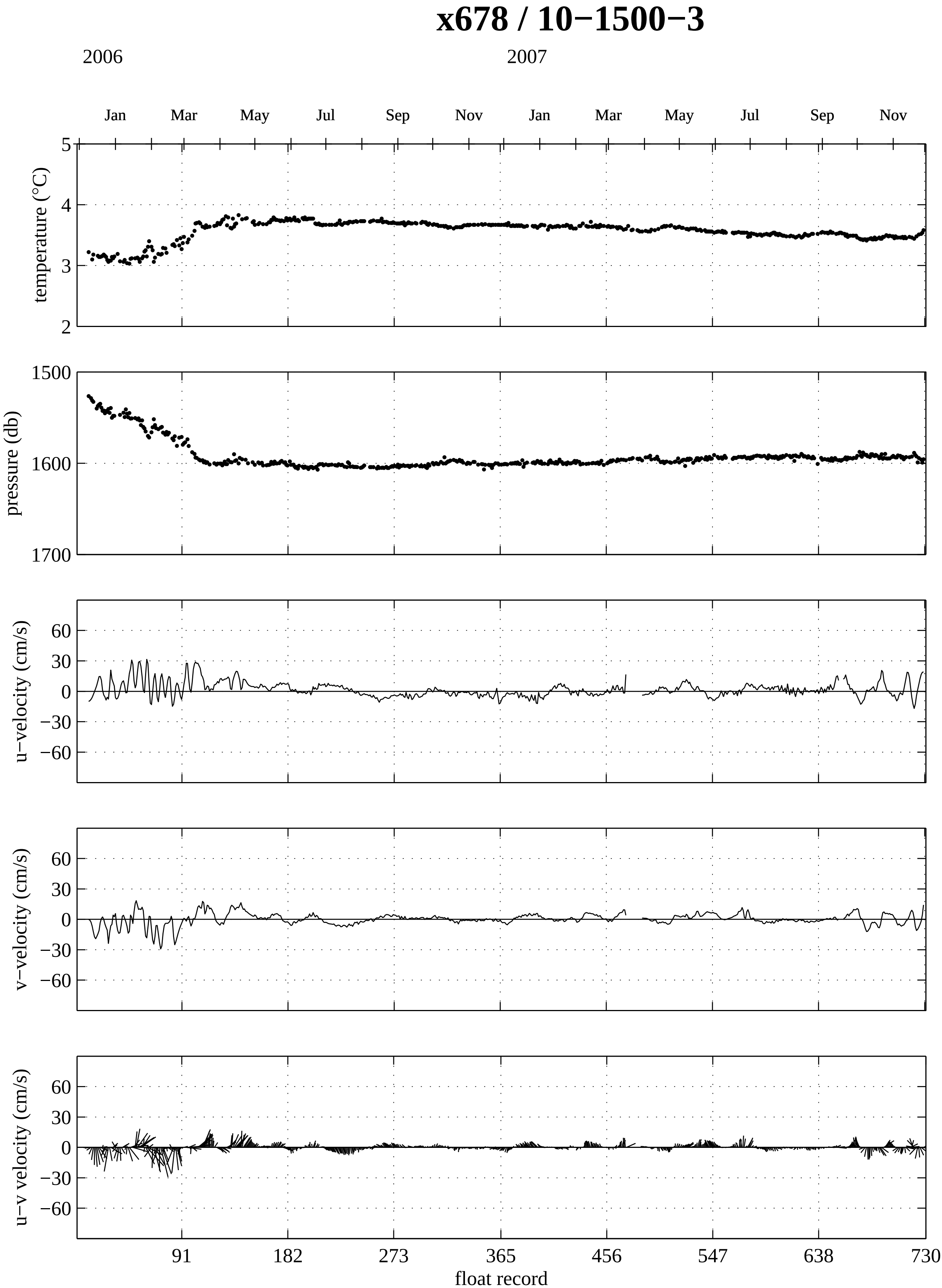


x677 / 10−1500−2



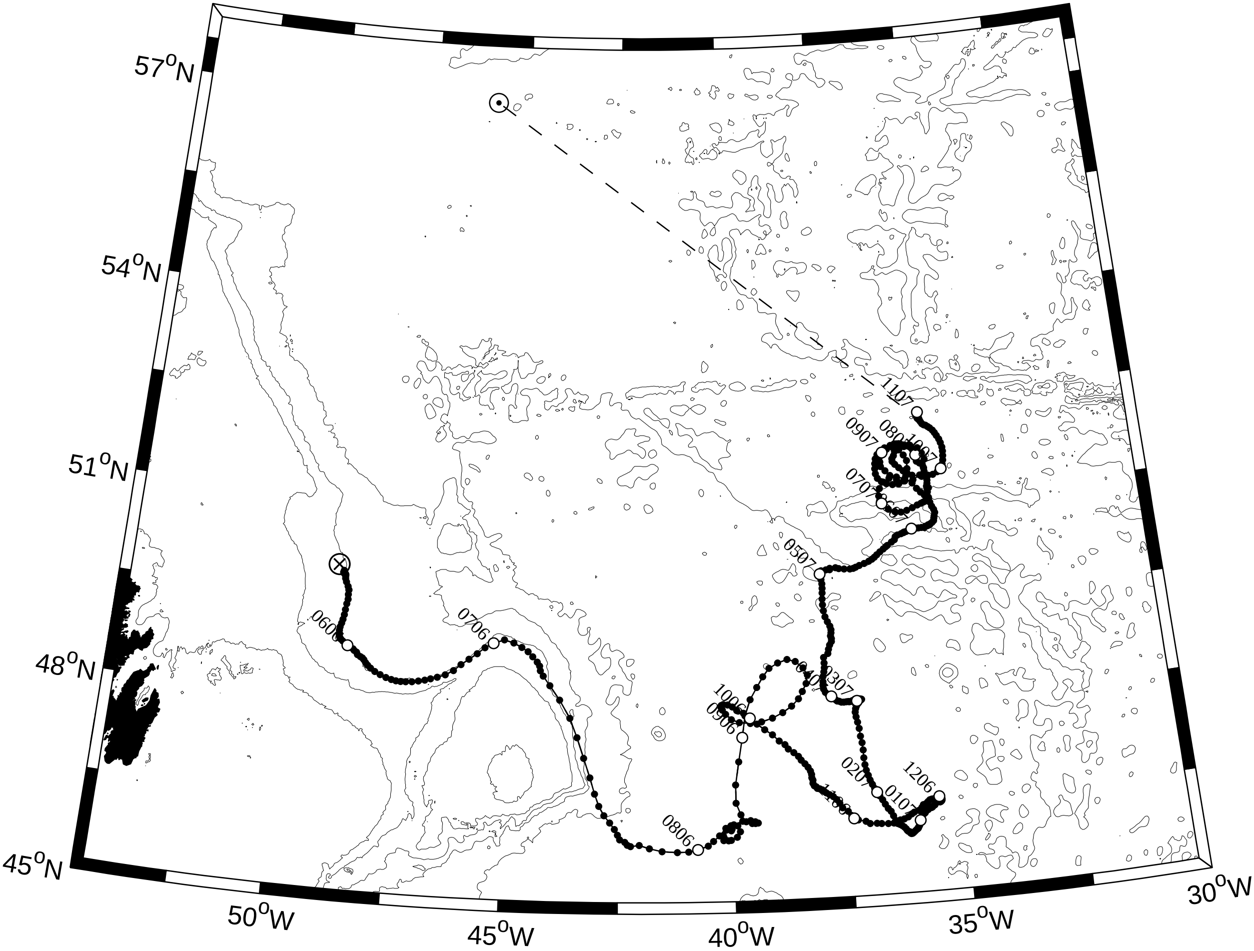
x678 / 10−1500−3



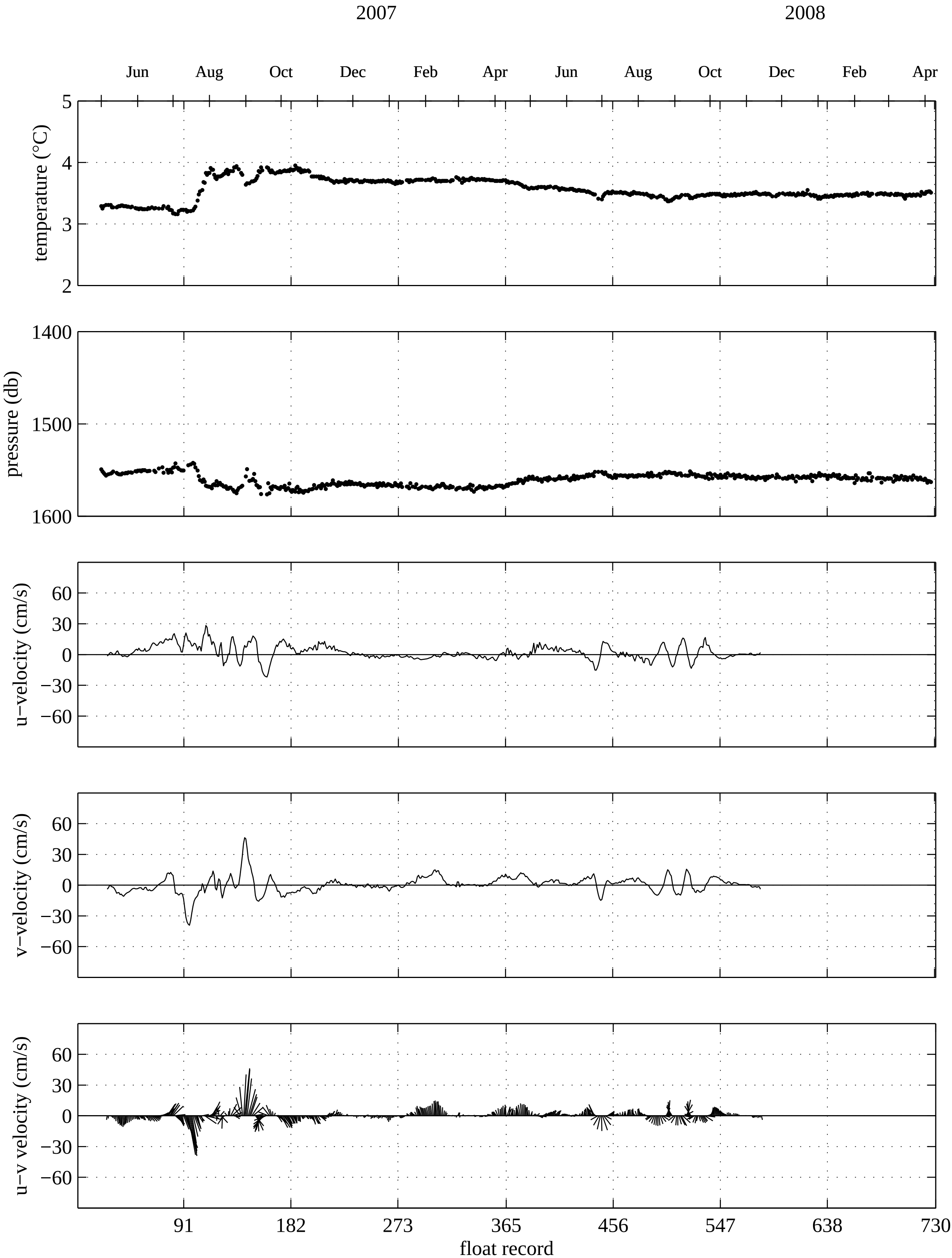


x678 / 10−1500−3
2006
2007
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep
Nov
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

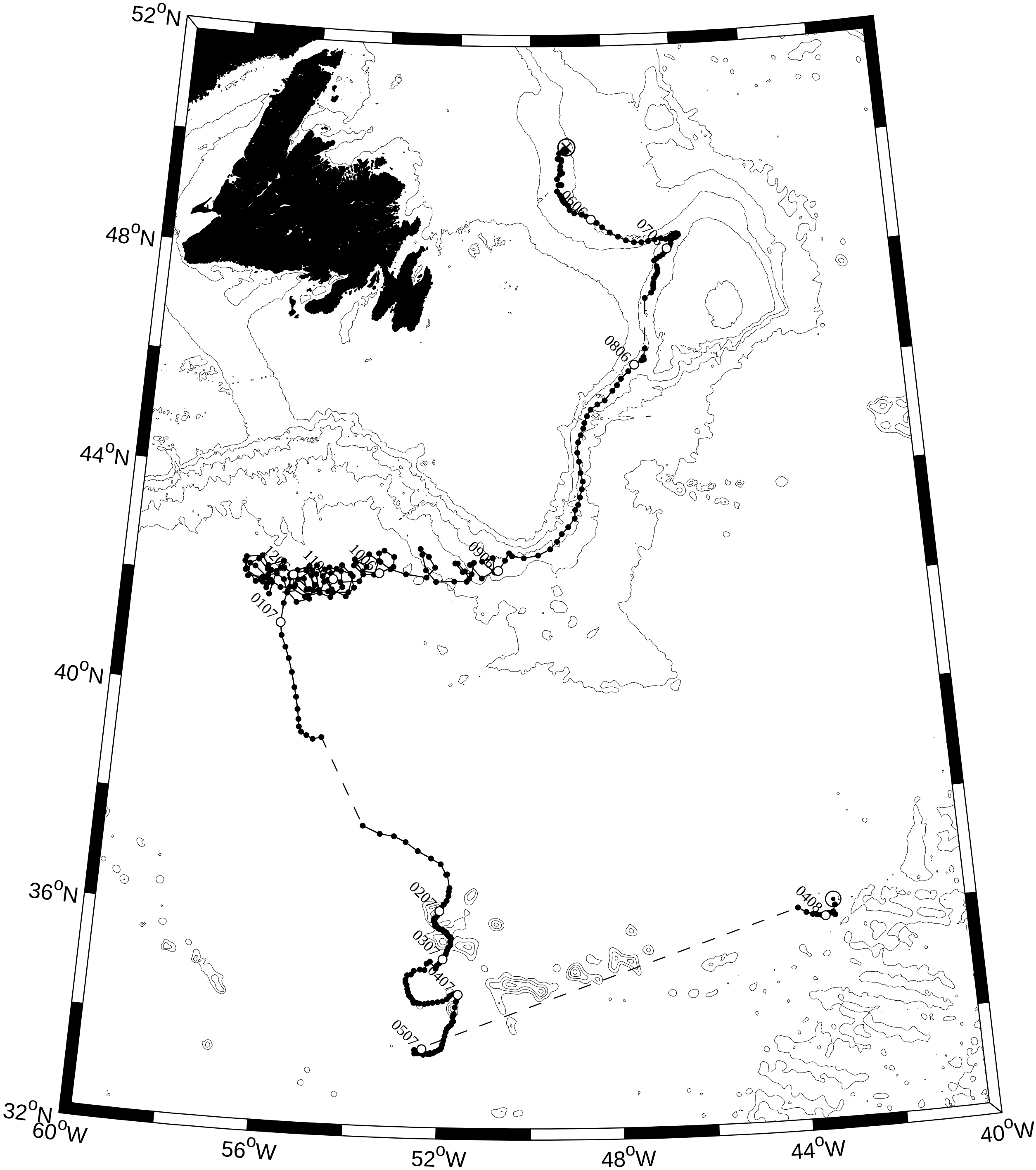
x679 / 12−1500−1



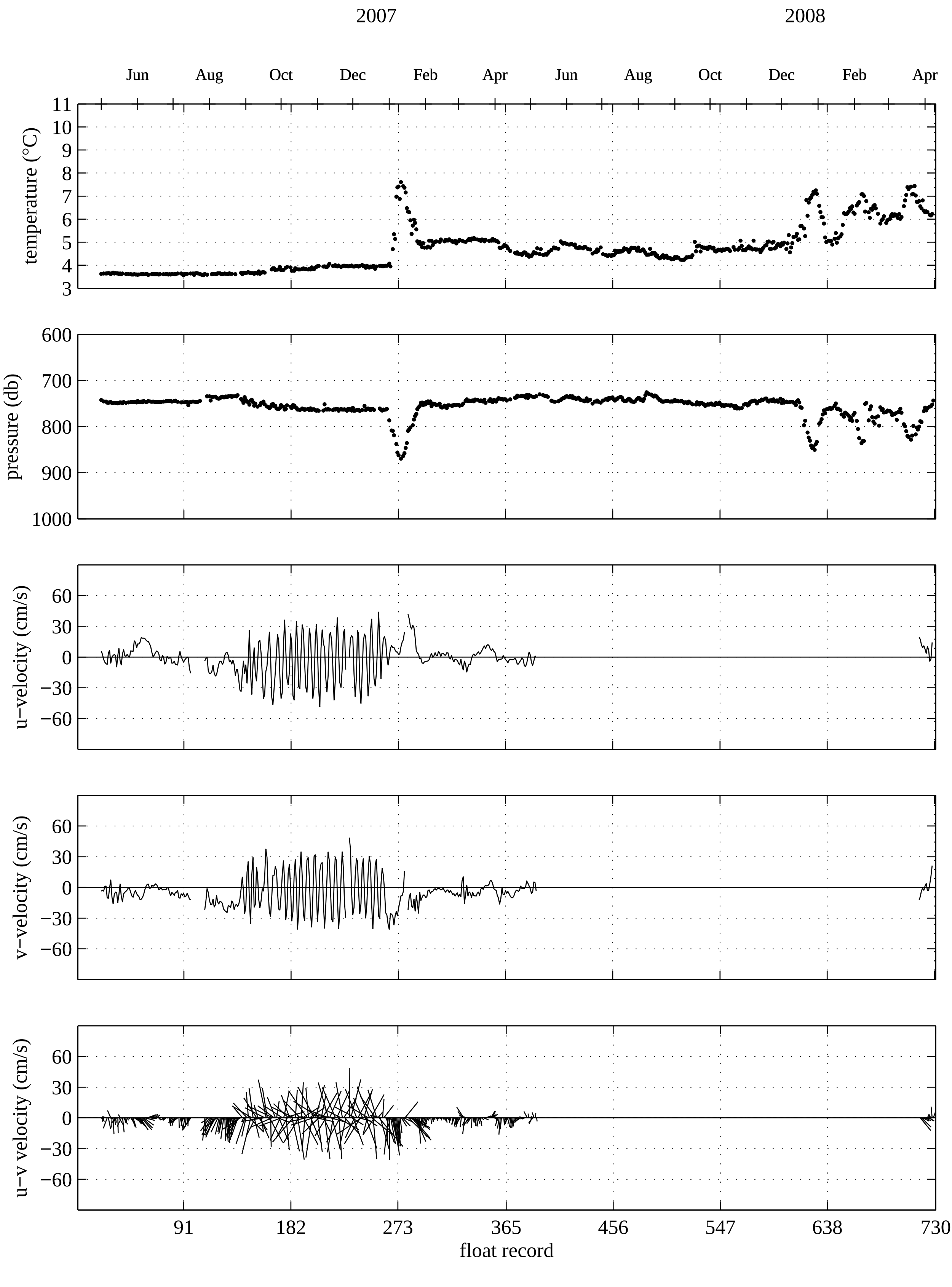
x679 / 12−1500−1



x680 / 12−700−2

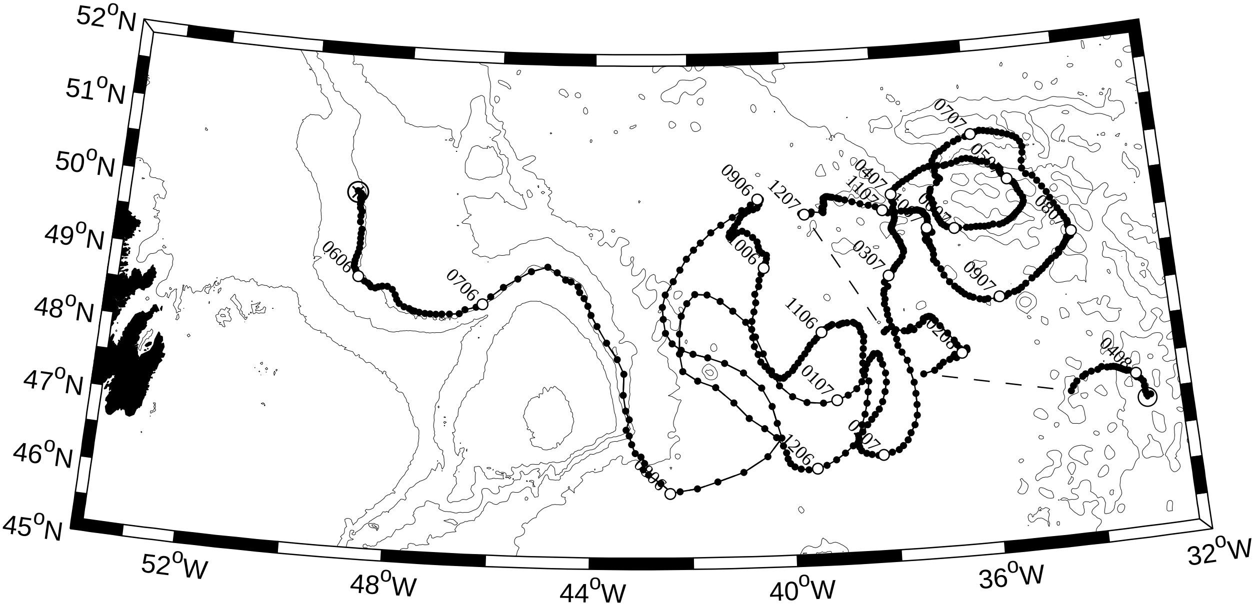

52°N
48°N
44°N
40°N
36°N
32°N
60°W
56°W
52°W
48°W
44°W
40°W
0606
0706
0806
0906
1006
1106
1206
0107
0207
0307
0407
0507
0408

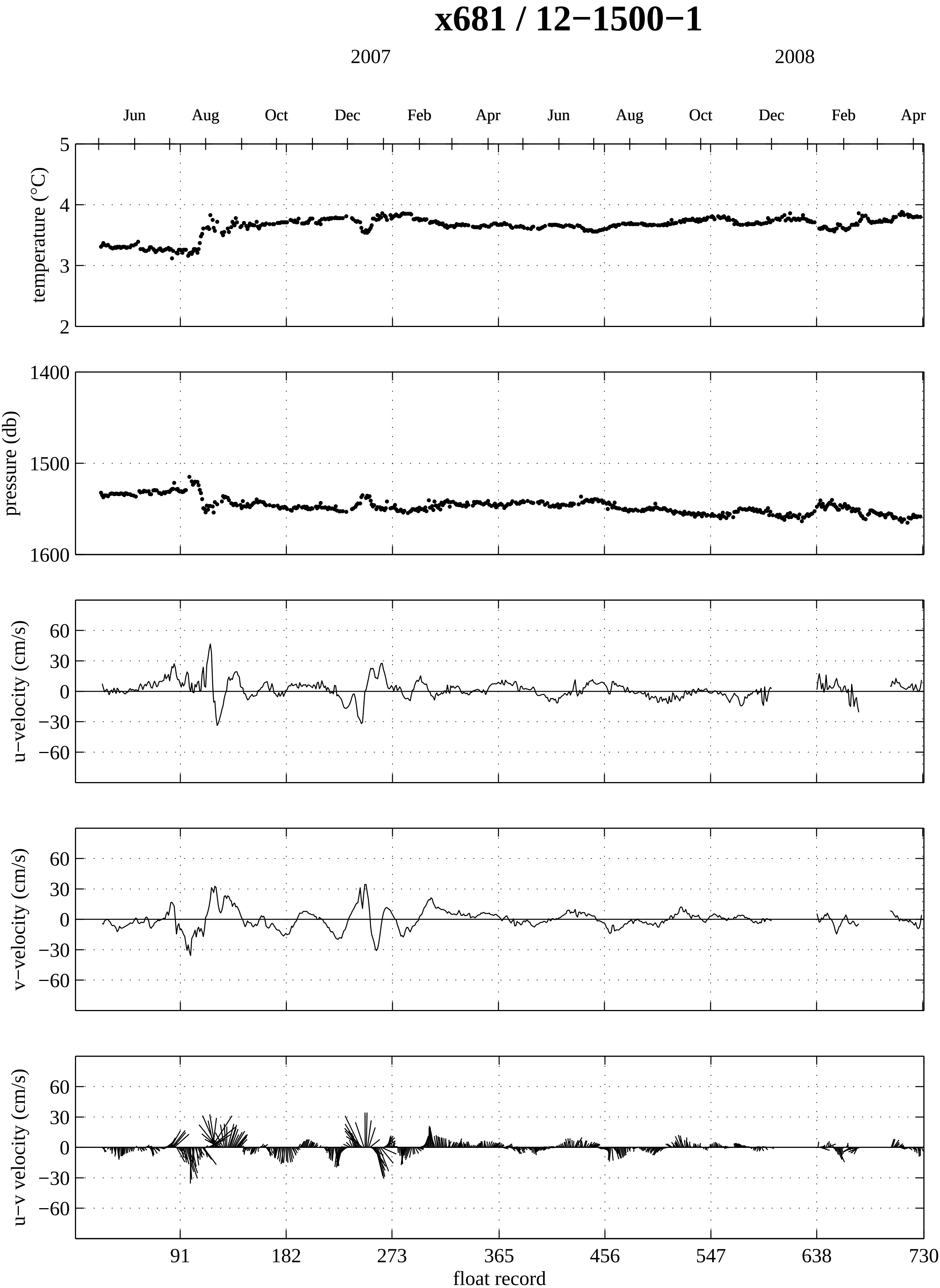
x680 / 12−700−2



2007
2008
Jun
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
Apr
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

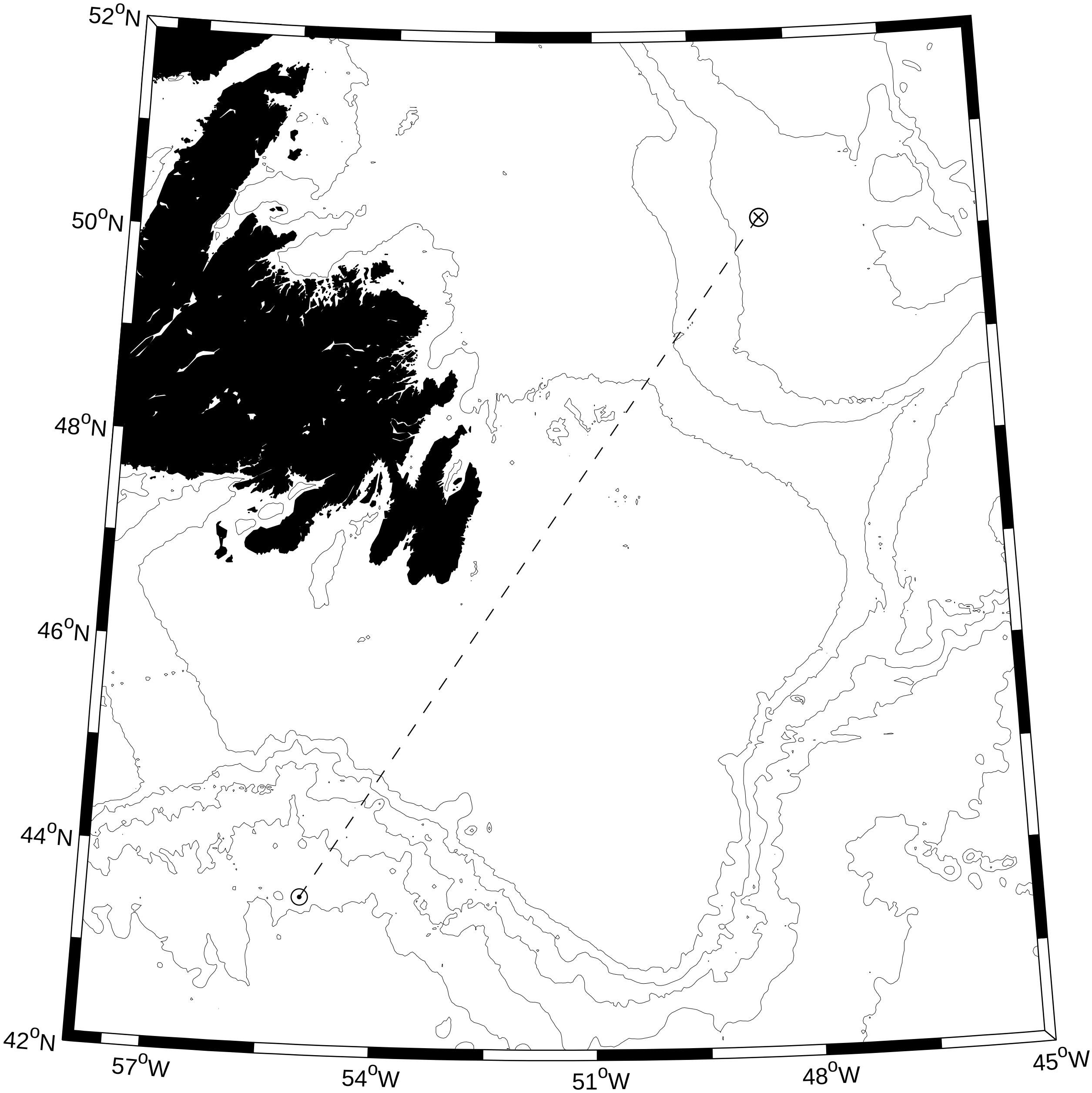
x681 / 12−1500−1



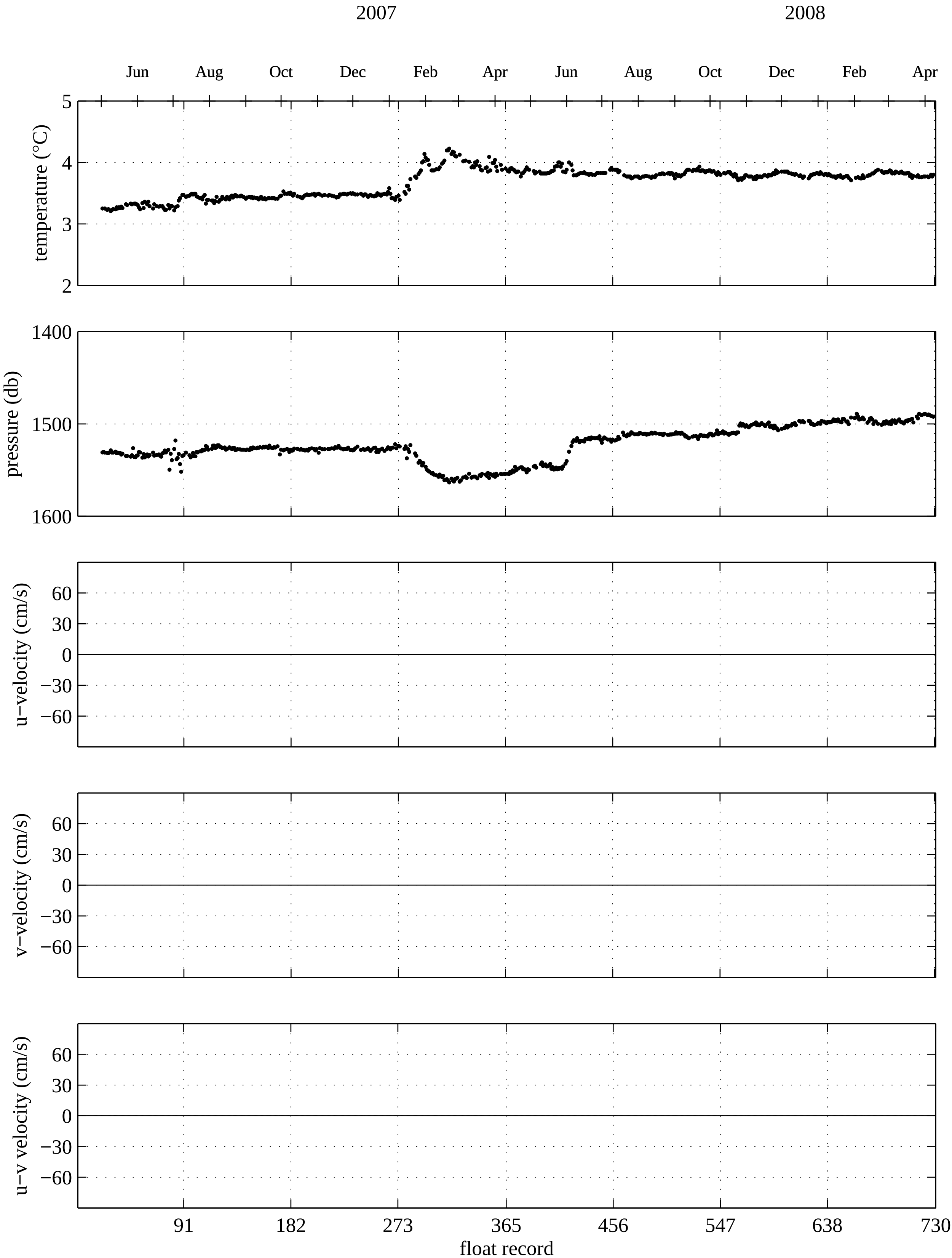


x681 / 12−1500−1
2007
2008
Jun
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
Apr
temperature (°C)
5
4
3
2
pressure (db)
1400
1500
1600
u−velocity (cm/s)
60
30
0
−30
−60
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

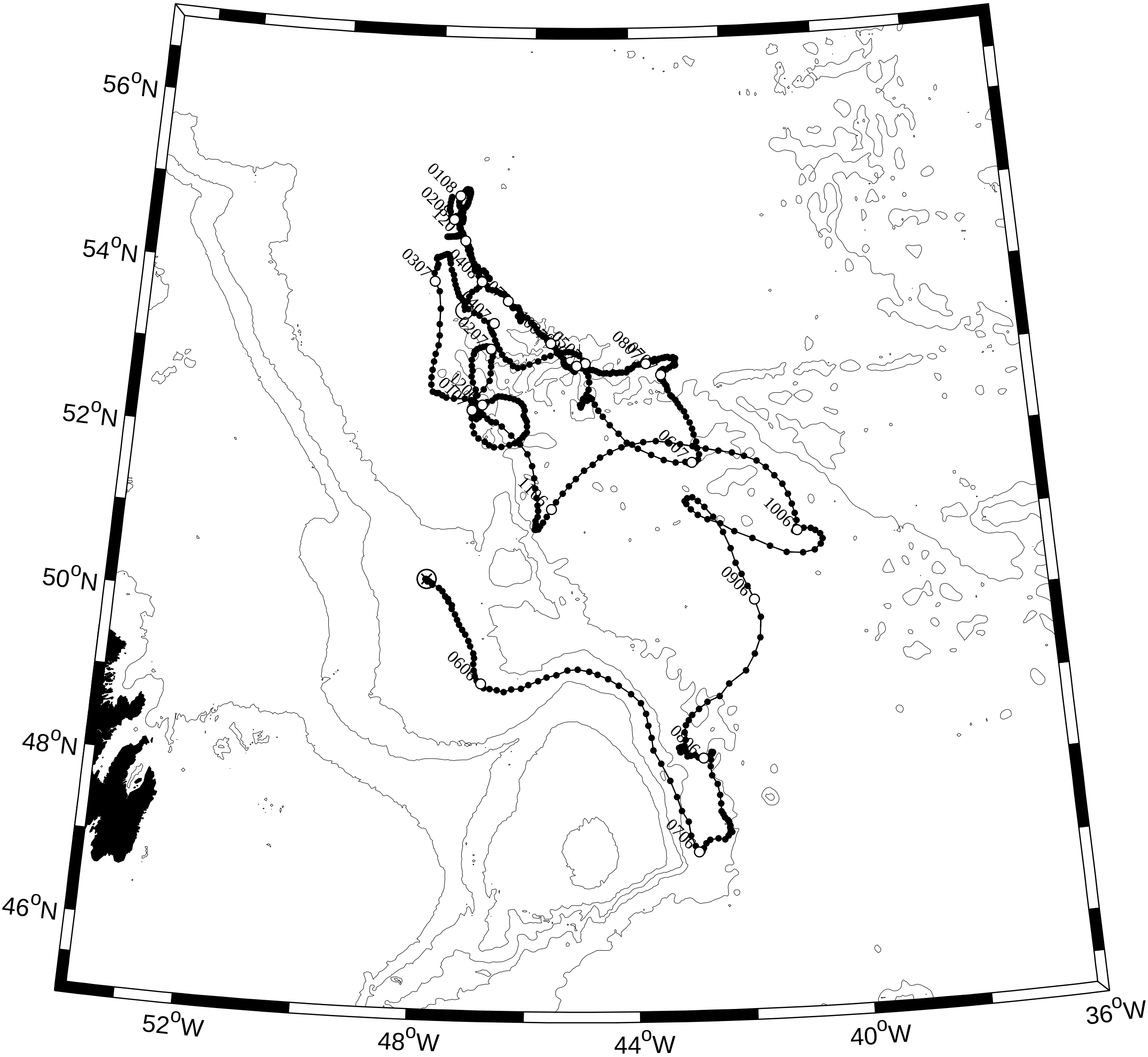
x682 / 12−1500−2



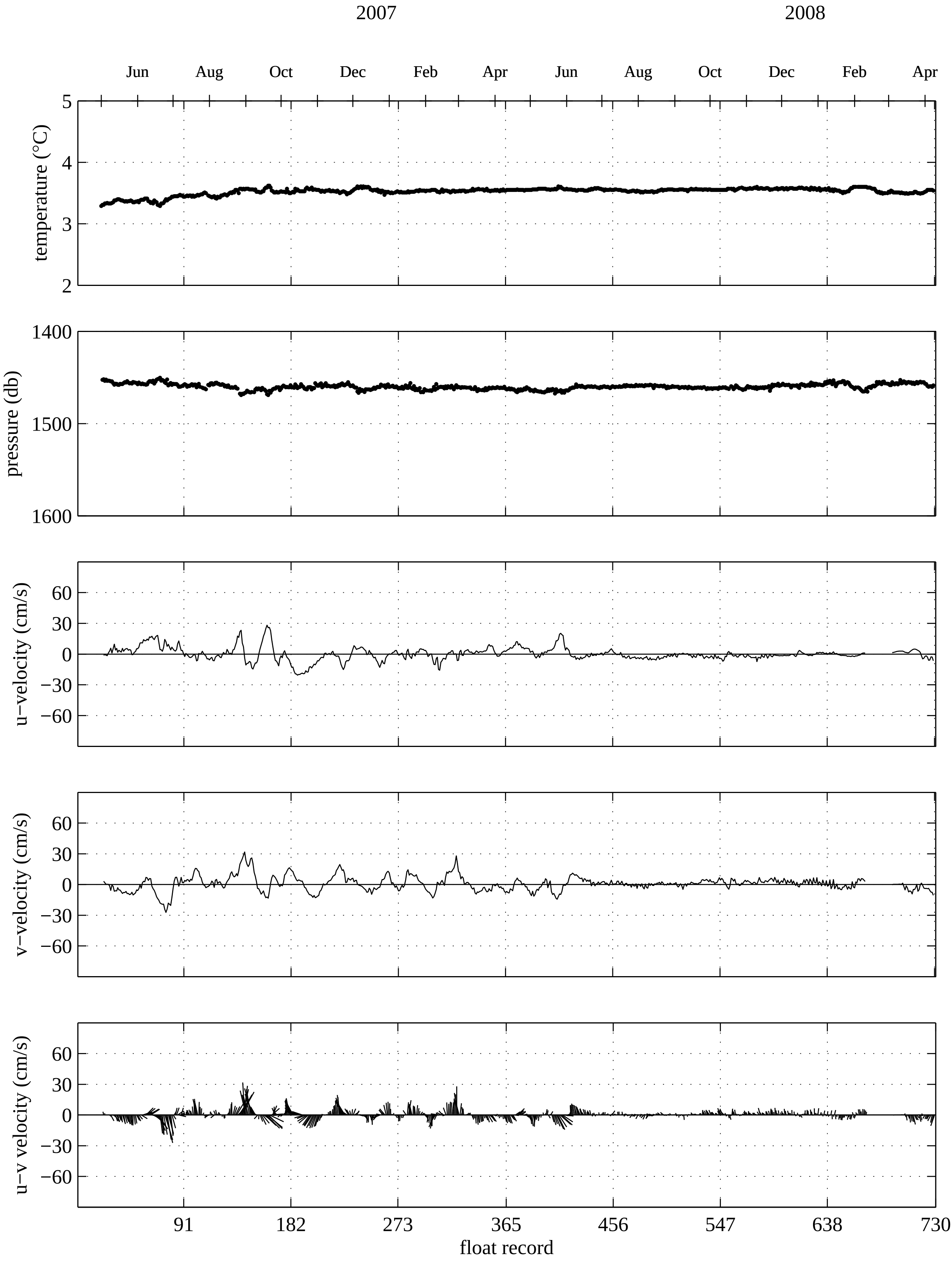
x682 / 12−1500−2



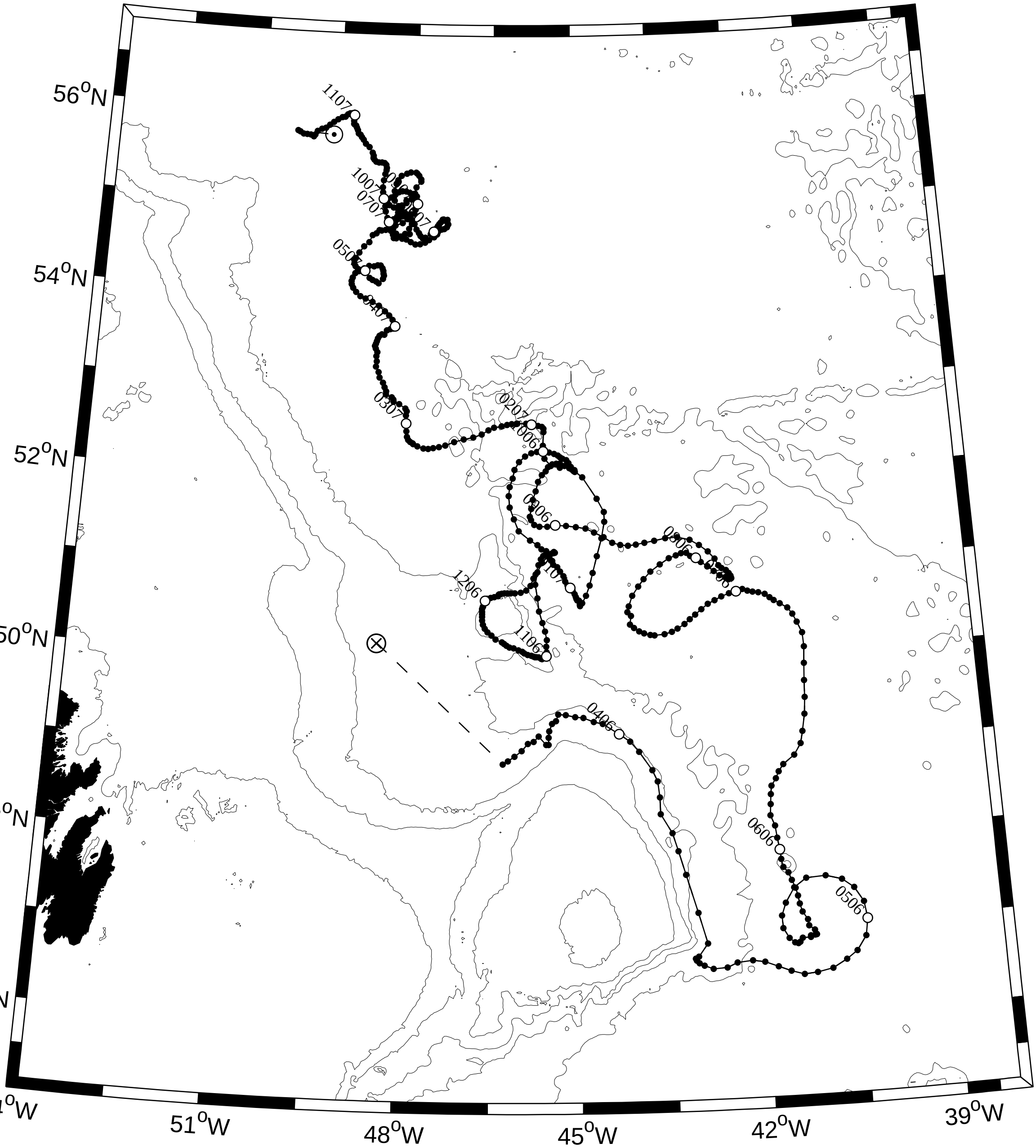
x683 / 12−1500−3



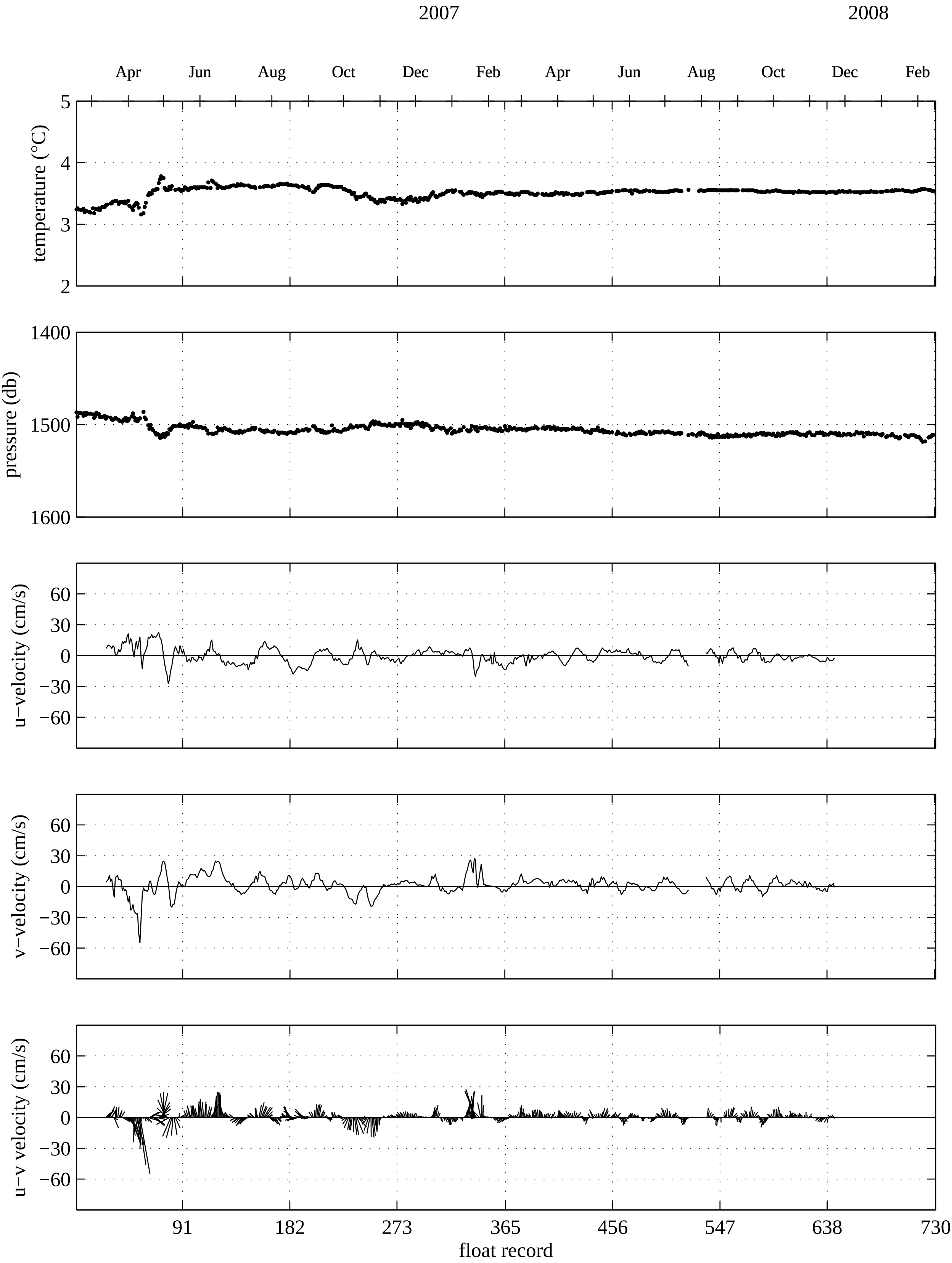
x683 / 12−1500−3



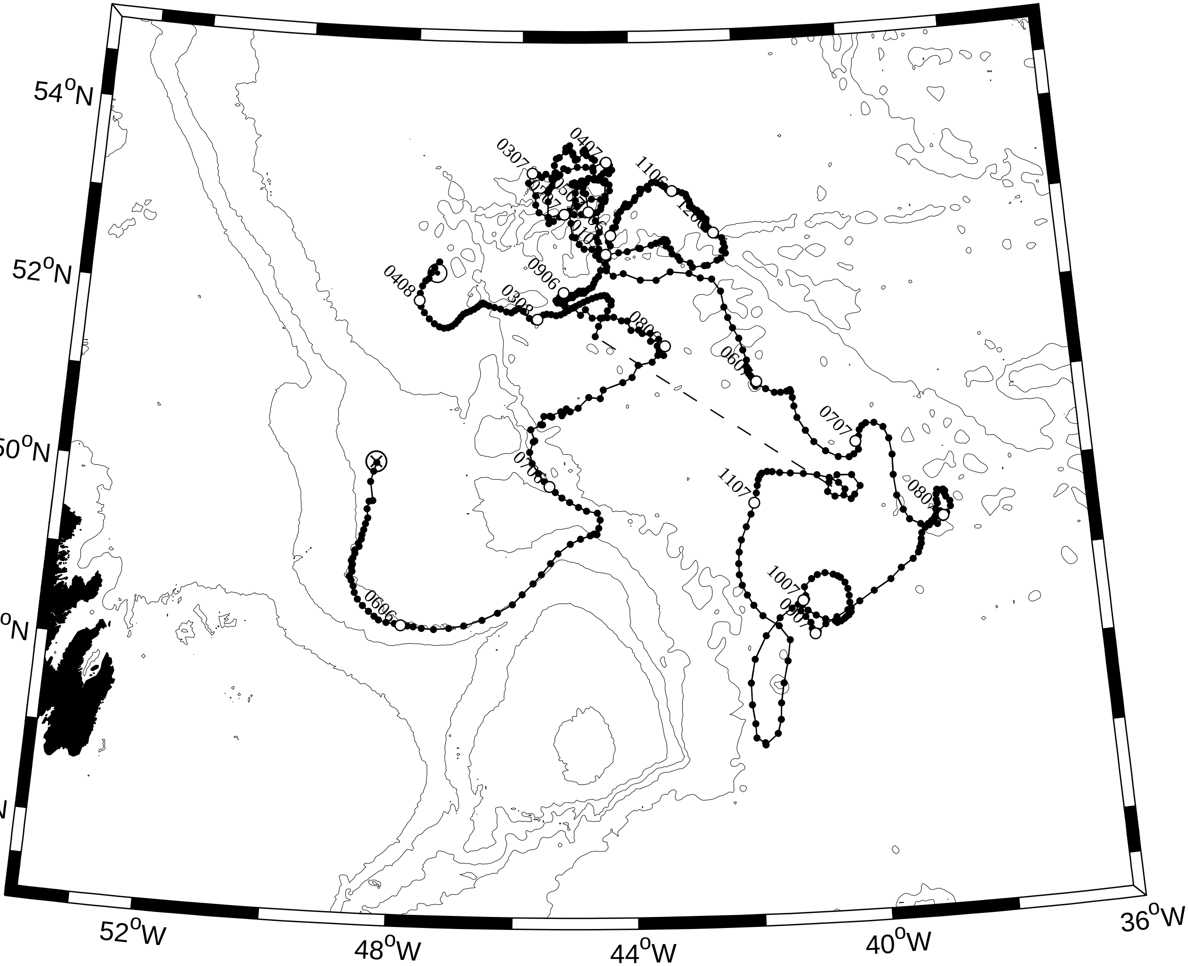
x684 / 11−1500−2



x684 / 11−1500−2

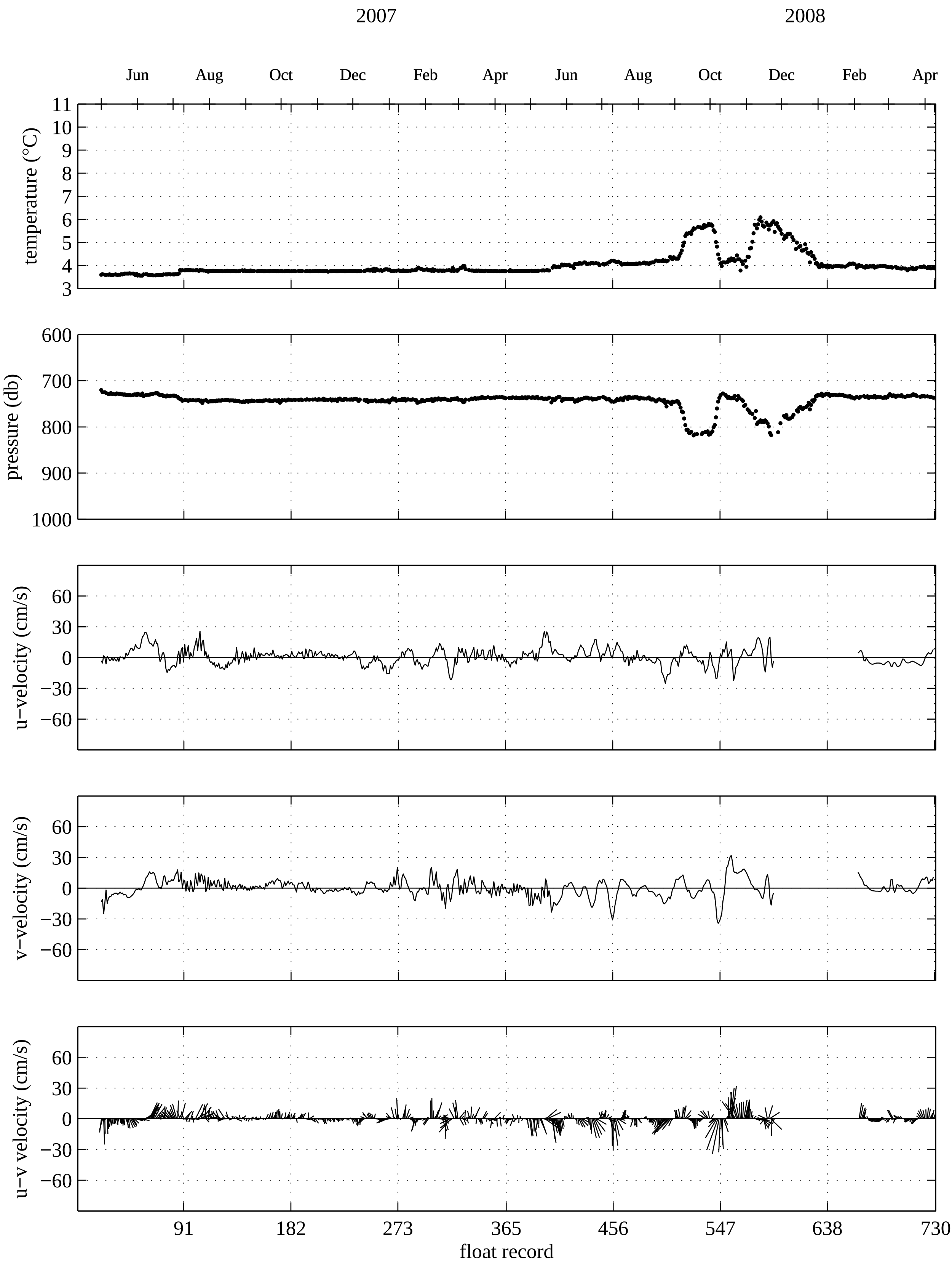


x685 / 12−700−3



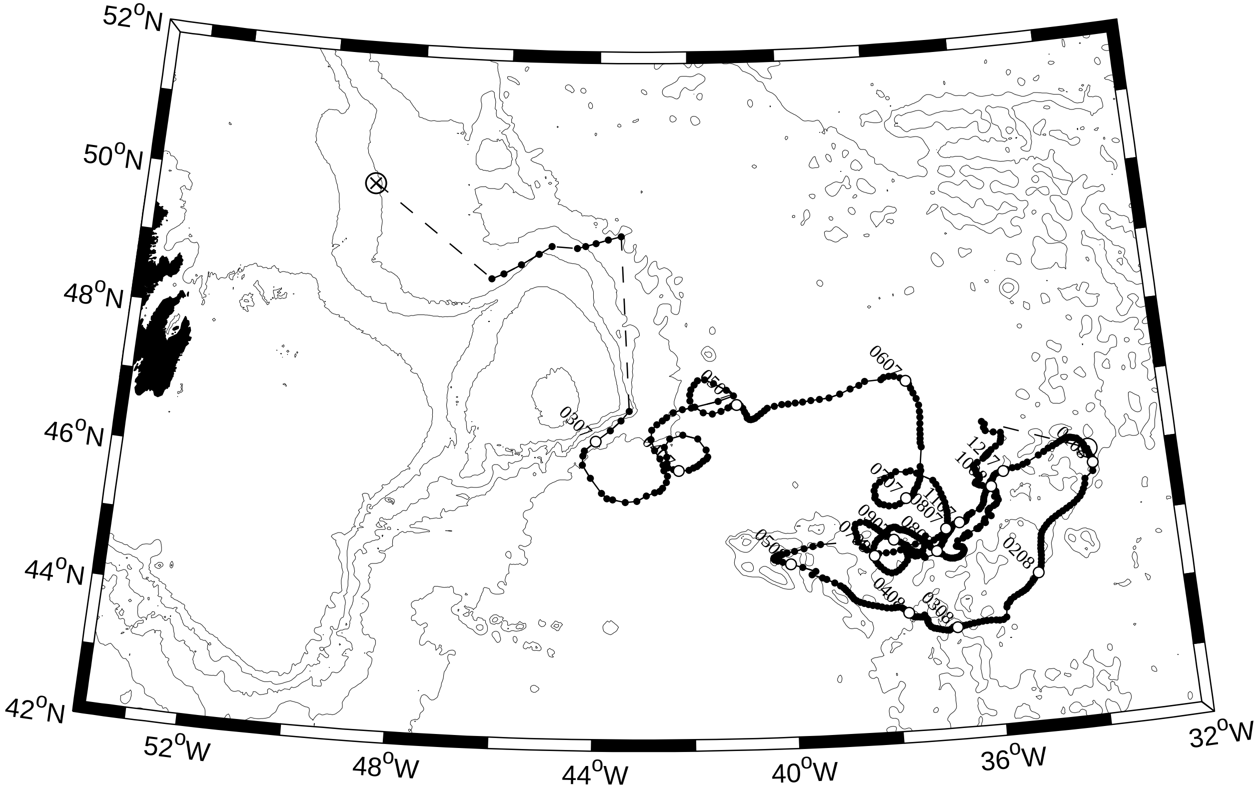
54°N
52°N
50°N
48°N
46°N
52°W
48°W
44°W
40°W
36°W
0307
0407
1106
0408
0906
0308
0806
0707
1107
0606
1007

x685 / 12−700−3

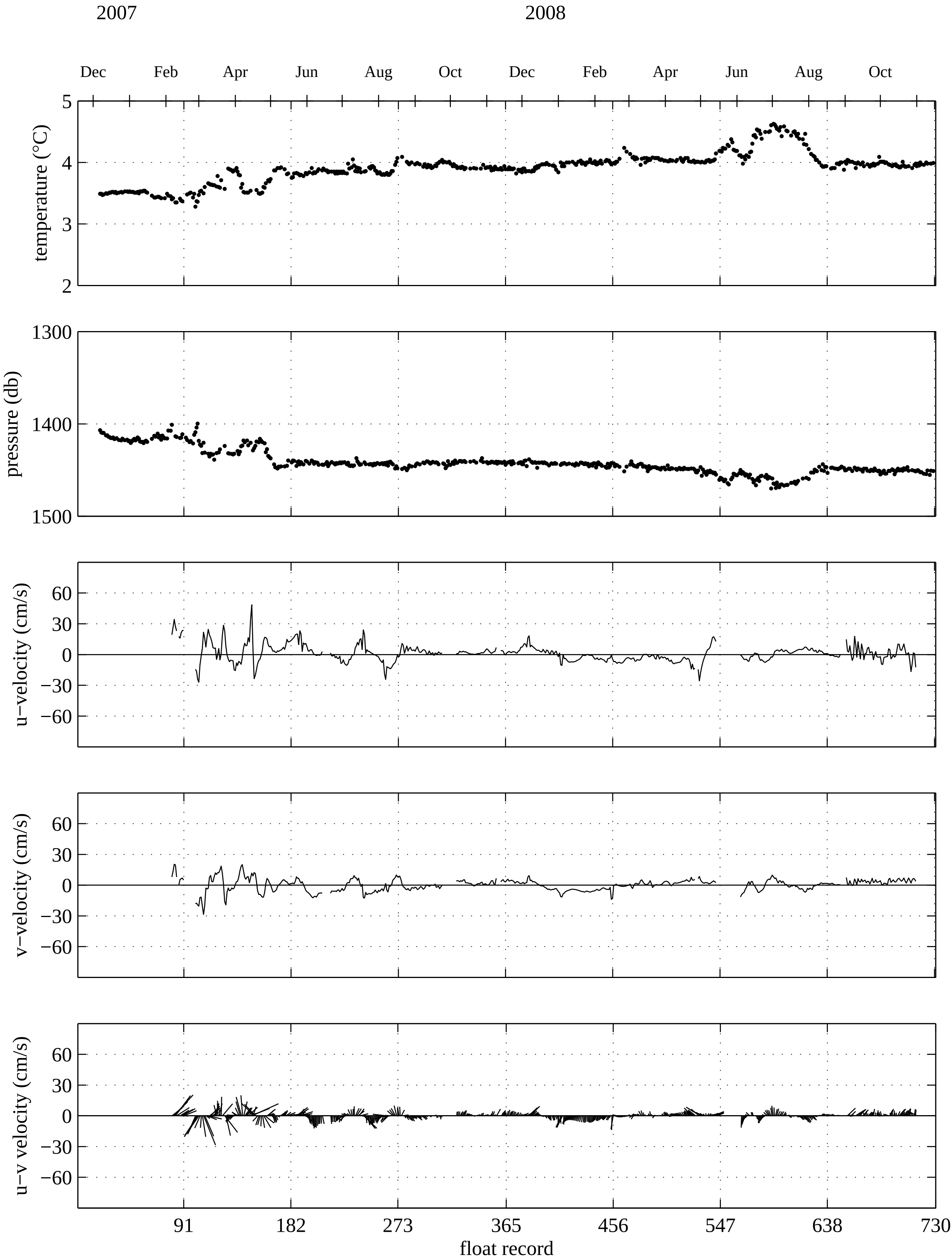


2007
2008
Jun
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
Apr
temperature (°C)
pressure (db)
u−velocity (cm/s)
v−velocity (cm/s)
u−v velocity (cm/s)
91
182
273
365
456
547
638
730
float record

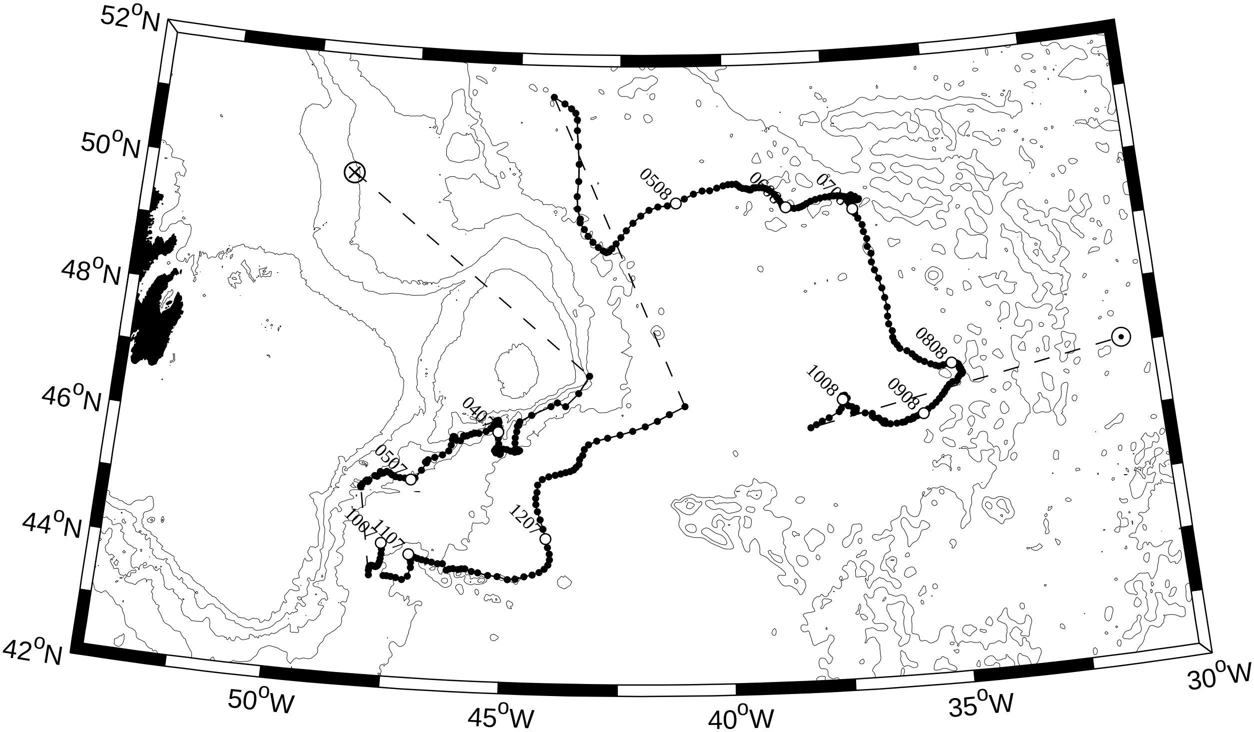
x706 / 13−1500−1



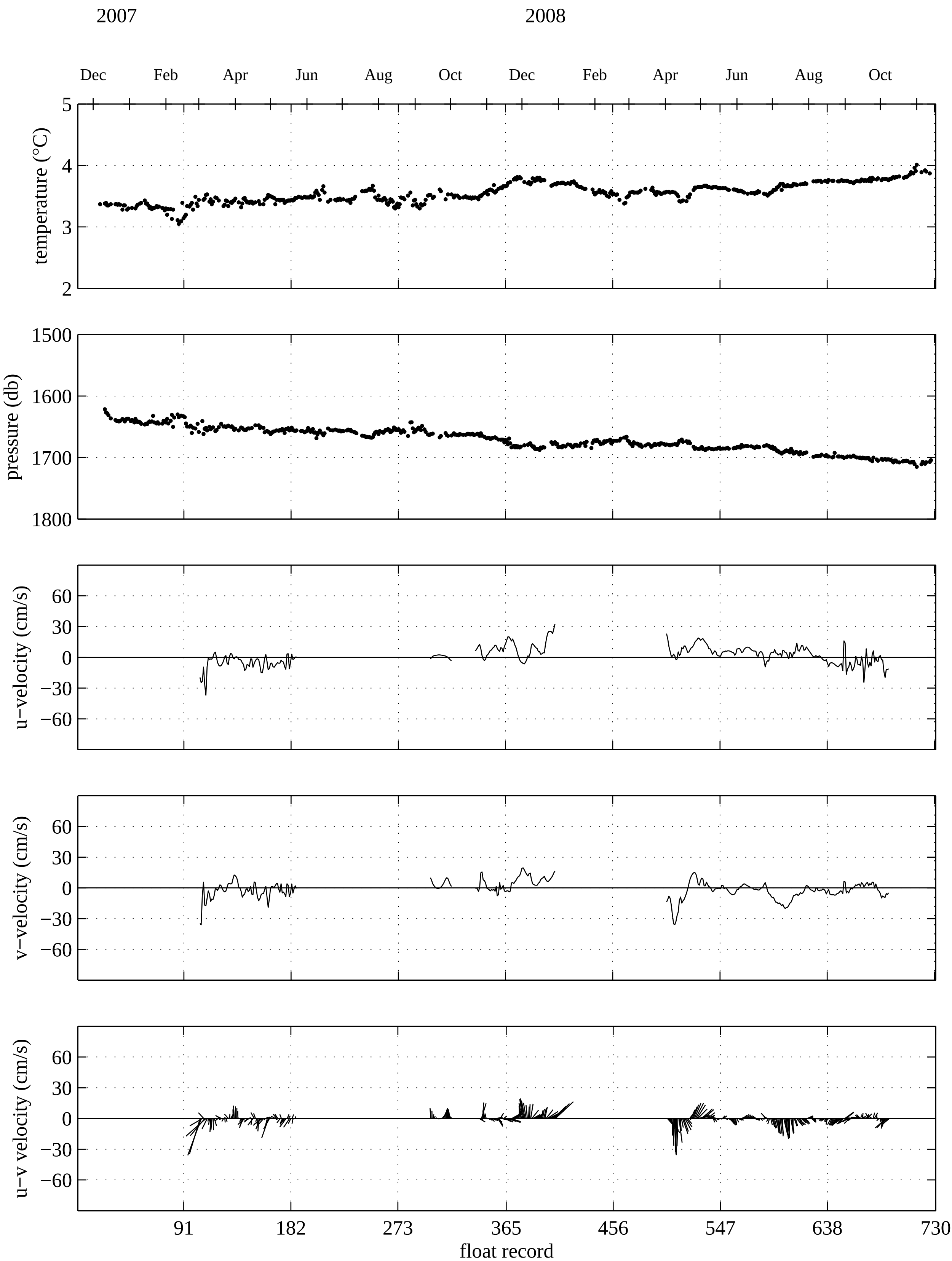
x706 / 13−1500−1



x720 / 13−1500−1



x720 / 13−1500−1



50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. WHOI-09-06	2.	3. Recipient's Accession No.
4. Title and Subtitle Export Pathways from the Subpolar North Atlantic: DLD2 RAFOS Float Data Report July 2003–November 2008			5. Report Date October 2009 6.
7. Author(s) Heather H. Furey and Amy S. Bower			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-0136215 (G)OCE-0824652
12. Sponsoring Organization Name and Address National Science Foundation			13. Type of Report & Period Covered Technical Report 14.

15. Supplementary Notes

This report should be cited as: Woods Hole Oceanog. Inst. Tech. Rept., WHOI-09-06.

16. Abstract (Limit: 200 words)

This is the final data report of all acoustically tracked DLD2 RAFOS float data collected by the Woods Hole Oceanographic Institution in 2003-2008 during *Export Pathways from the Subpolar North Atlantic* (ExPath). The objectives of ExPath were to (1) obtain an improved description of the pathways of Labrador Sea Water out of the subpolar region using acoustically-tracked RAFOS floats deployed in the western boundary current in the Labrador Sea; (2) characterize the intermittency/temporal variability in these pathways, and investigate its cause; and (3) use historical and synoptic hydrographic data to determine low-frequency variations in the penetration of recently-ventilated water masses equatorward along the western boundary. The RAFOS float component of ExPath was comprised of thirteen seedings of the boundary current near 50°N, off of St. John's, Newfoundland. In addition to the initial setting of six floats off the R/V *Oceanus*, nine float settings were made by the Northwest Atlantic Fisheries Centre. Three more float settings were accomplished by dual-release float moorings. In sum, 76 isobaric floats were deployed or released quarterly: in November, February, May and July. Half were ballasted for 700 dbars and the other half for 1500 dbars, to target the two main levels of Labrador Sea Water.

17. Document Analysis a. Descriptors

North Atlantic circulation
Labrador Sea Water export
floats

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Approved for public release; distribution unlimited.	UNCLASSIFIED	166
	20. Security Class (This Page)	22. Price

(See ANSI-Z39.18) *See Instructions on Reverse* OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce