Preliminary Report for the Bering Ecosystem Study (BEST) Cruise on the U.S.C.G. Cutter Healy (HLY0701); April 10 through May 12, 2007

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1 Synopsis

The initial cruise of the NSF sponsored Bering Ecosystem Study (BEST) project began on April 10, 2007 aboard the USCG cutter Healy (hereafter HLY0701). The cruise was successful in carrying out the plan that had been developed over the past eight months to sample the shelf region of the eastern Bering Sea during the retreat of the sea ice. All major sections were sampled and no significant logistical or equipment problems detracted from the ship operations or the work of the individual science groups. HLY0701 encountered moderate ice coverage in early April that was similar to that in 2006 and exceeded coverage in the early part of this decade. Further evidence of significant winter cooling was found in the extensive cold pool along the middle shelf that extended into Bristol Bay, conditions that had not been recorded since the late 1990s. Winter-like air temperatures and ice coverage were encountered north of St Matthew Island, so that we were able to follow the transition to spring conditions in the region over the following several weeks. The initial retreat of the ice edge was associated with an extensive (>600 km) phytoplankton bloom along the western and southern flank of the ice pack. This productivity was associated with a shallow mixed layer caused by the melt water. We did not observe a similar bloom along the eastern edge of the pack ice, but fluorescence near the bottom of some of the inshore stations suggested that elevated production had taken place before our sampling in these regions. South of the ice extent, Bristol Bay was productive in early April, and parts of this bloom may have been associated with the early retreat of the ice there. Inner and middle Bristol Bay was much less productive a month later. Several slope regions were sampled and each exhibited evidence of interleaving between slope and shelf waters. A reoccupation of WOCE line P14N provided an opportunity to compare our measurements in the deeper samples. Separate calibration of the conductivity cell and oxygen sensor on the CTD was also done. Extensive collections for zooplankton, trace metals, productivity rates, and isotopic tracers were made across the region. Sediment samples were collected with a multicorer at a number of stations. Sediment oxygen consumption rates were relatively low, an observation that supports the view that we sampled at the early part of the ice-edge bloom and before significant organic matter had reached the sediments. Extensive observations of marine birds and mammals were done. Overall, members of the science party were pleased with the quality and quantity of the information collected.

2 Introduction

The Healy left the dock at 13:30 on April 10, 2007 with all expected 44-science personnel on-board. The members of the science party for the first leg of HLY0701 and a brief summary of their role in HLY0701 are listed in Table 1. Each group contributed to this report and the results from several groups were generously contributed for distribution. Please note however, that these are preliminary results for illustrative purposes only and should not be cited or otherwise used without prior consultation with the scientist(s) involved.

Good communication between the Coast Guard and science party was established through daily meetings in the evening as well as additional meetings and communications on an as-needed basis. The Healy is a great science platform and Captain Lindstrom and his crew have gotten BEST off to a good start. Almost all of the planned sampling activities were carried out successfully and the science party worked to optimize the logistics for each activity. For on-deck activities, a sequence of Fe cast, hydrocast and net tows was adopted to minimize station-time when multiple on-deck activities are done. In addition to on-deck activities, a suite of underway measurements were made that includes temperature, salinity, chlorophyll fluorescence, oxygen and other gases. Helicopter flights for marine mammal and bird surveys and ice reconnaissance were done on most days. We also carried out seven on-ice stations to collect cores for ice physics, chemistry and biology. We completed al of the phases described in the Cruise Plan and highlights of each of these phases will be described below.

Table 1. Science components and personnel during HLY070; week 1.

Science Component	**Personnel**
1) Hydrography and circulation (CDT casts; drifter releases)	Nancy Kachel[2], Dylan Righi, David Kachel, Scott Hiller, Carol Ladd, Parisa Nahavandi
2) ADCP measurements, on-ice operations	Ned Cokelet
3) Nutrient and oxygen fields (Niskin samples; ice sampling)	Cal Mordy
4) Nitrogen productivity and budget, phytoplankton ecology (Niskin samples, incubations, ice sampling)	Ray Sambrotto[1], Didier Burdloff, Kris Swenson,
5) Nitrogen budget, gas measurements, additional isotopic tracers (Niskin samples, underway measurements)	Julie Granger, Masha Prokopenko
6) Iron distribution (Trace metal clean bottles, ice sampling)	Rob Rember, Ana Aguilar-Islas.
7) Sediment fluxes and productivity (Niskin samples, multicorer collections)	Al Devol[2], Bonnie Chang, Chris Holm
8) Benthic composition and fluxes (Niskin samples, multicorer collections)	David Shull, Emily Davenport, Jerry McCormick-Ray

9) Zooplankton & meroplankton (size fractionated plankton net hauls)	Jeff Napp, Robert Fryer, Briana Blaud, A.J. LeFevre, Jay Clark, Ingrid Spies, Rachael Cartwright, Kathy Mier
10) Ice Seals distribution and abundance (aerial & shipboard surveys; satellite tagging)	Michael Cameron, Dave Withrow, Gavin Brady, Shawn Dahle, Josh London, Lee Harris
11) Seabird distributions and abundance (aerial & shipboard surveys)	Kathy Kuletz, Liz Labunski, K. David Hyrenback
12) Walrus distributions and abundance (aerial & shipboard surveys)	Carleton Ray
13) Echo location and estimation of fish and krill (simrad EK60 scientific echosounder)	Alex De Robertis
14) Remote sensing, data analysis and management, networking	Steve Roberts, Tom Bolmer, Janet Scannell
15) Underway bottom profile measurements, science support, computer networking	Steve Roberts, Tom Bolmar
16) Helicopter support	Bill Springer, Charles Sims, Dave Doucet
17) Education & outreach	Robyn Staup, Maggie Prevenas

[1] – Chief scientist; [2] - alternate Chief scientists

3 Meteorological conditions

The cruise began under unusually clear weather conditions. The weather remained fair for most of the first week with the exception of an intense low-pressure system that moved through the region on April 15-18 that brought north winds with speeds that periodically exceeded 25 kts. By this time we were well into the ice pack that dampened most of the wave activity. Air temperatures went below freezing after April 13 and below -10˚C after April 16 at the most northern extent of our sampling.

4 Ice conditions

We were able to follow regional ice conditions with almost daily Radarsat images. Ice extent on the eastern Bering Sea shelf at the start of the BEST 07 was near the maximum extent that was observed in Radarsat and other imagery in mid-March (Fig. 1). However, during the first week of BEST 07, the ice-edge in the southern region, extending in an arc from Cape Newingham to the Pribilof Islands, showed evidence of extensive break-up and melting compared to ice distributions a few weeks earlier. In contrast, the ice pack remained almost continuous north of Nunivak Island over much of the shelf. Exceptions to this generalization included a polynya west of St. Matthew Island and some open water near the Alaskan coast. In general, the ice patterns suggested by the Radarsat images corresponded closely to the observations from the ship. For example, loose and broken ice was first encountered at approximately 58˚N on April 14. These ice conditions persisted in a broad, ~190 km region as we proceeded north before giving way to more dense and continuous pack ice north of about 59.5˚N. The greatest level of sea ice along the 70m line was encountered just southwest of St. Matthew Island where we crossed rounded and jumbled pack-ice that was likely flowing into the region from the north.

Ice coverage began to retreat rapidly during HLY0701. The ice observed initially in the Radarsat images in Bristol Bay and near Cape Newingham within the first week of sampling. After April 20, ice began to retreat throughout the region, particularly in the region northeast of the Pribilof Islands. Ice retreat along the western edge of the original ice pack was slower, but noticeable by early May (Fig. 2). In addition to Radarsat, images from the Defense Meteorological Satellite Program (DMSP) and NOAA AVHRR products were useful in following ice dynamics. These visible images were archived for future use. Also, due to the large role that ice distribution and dynamics play in addressing the BEST science objectives, extensive observations also were recorded by both shipboard and helicopter-borne observers. Shipboard observers included bird and marine mammal biologists as well as the on-board teachers who took turns standing watch on the bridge. They record ice cover, thickness, floe size and other variables into a web-based form every 3 hours. The helicopter also was been used for ice observation, occasionally with dedicated flights and more often by debriefing passengers on ice conditions along their flight paths.

5 Large scale surface salinity and chlorophyll fluorescence

The cruise track for HLY0701 covered much of the eastern Bering shelf south of St. Laurence Island (Fig. 3). Based on the cruise plan, we sampled the late winter mid-shelf conditions along the 70m line, as well as several cross shelf lines that were intended to sample across the ice and to reflect both ice-impacted and non-ice-impacted regions. During the second part of the cruise, particular effort was devoted to sampling the ice-edge fronts around the major ice field north of the Pribilof Islands. The underway system on the Healy continually recorded temperature, salinity and chlorophyll fluorescence at 8 m depth. The distribution of surface salinity clearly showed the freshening effect of the melting ice (Fig. 4). The lowest surface salinities were consistently found in the retreating ice regions. This was the case along the entire western and southern edge of the ice field. The low salinities were particularly evident near Nunivak Island where the melt water was added to the already lower salinity coastal waters. Lower surface salinities were also recorded in our most inshore stations in Bristol Bay. This freshening may have been associated with the early April melt back of the ice to the northeast in this region.

The distribution of surface chlorophyll also was closely associated with the retreating ice edge, particularly in the western and southern regions (Fig. 5). The elevated chlorophyll off Cape Newingham that was recorded early in the cruise also was located at the rapidly retreating edge in this region. Only the elevated chlorophyll sampled in the outer shelf region of Bristol Bay in the early part of the cruise was not associated with a nearby ice-edge or decreased surface salinity.

6 Regional hydrographic and biological sampling

6.1 Bering Canyon and Unimak Pass

This initial four-station line was intended to measure the physical and nutrient characteristics of potential source waters to the southeastern shelf. Only four hours separated our departure from Dutch Harbor and the first station in the slope waters of the Bering Canyon. Each of the major over-the-side operations was done successfully here – deep hydrocast, multicorer and Fe cast. This was an impressive demonstration of the preparedness of the scientists and technicians for the BEST 07 cruise. The temperature, salinity and nutrient profiles both showed significant structure in the 80-250 m range (Fig. 6). The variations in temperature and salinity are compatible with the exchange of water between this canyon and the adjoining shelf region. Important fluxes such as nutrient exchange between the two regions can be inferred from these data and several more deep water, slope stations also showed this structure in Pribilof and Zemchung Canyons. The other stations in this initial set continued across Unimak Pass and recorded relatively warm, low salinity water in the center and the eastern side of the Pass that may have been the Alaska Coastal Current (ACC) as it entered the Bering. Identifying and quantifying the flow of these source waters into the Bering is an important part of BEST nutrient budgets and these initial data will be directly relevant to this task.

6.2 Region 2 – Outer Bristol Bay

Several stations were occupied during the first few days of the cruise in the outer Bristol Bay region along the CN line. We had hoped that these stations would provide information on the late winter/ early spring conditions in this region from which a time series of biological conditions can be constructed during the 2007 season. Importantly, this sampling also included the NOAA M2 mooring that had actively been recording information on temperature, salinity, chlorophyll and currents in the region over the winter. These stations displayed evidence of extremely large rates of primary production in the days prior to sampling. For example, at station 5 in the outer shelf, we recorded a sub-surface maximum in Chl *a* of over 12 mg m^{-3}, based on the as yet uncalibrated fluorometer on the CTD. Surface values remained above 3 mg m^{-3}, and oxygen levels were well above saturation. There was a surface maximum in Chl *a* at the more inshore station 6 near NOAA mooring 2. In both cases however, production was associated with a relatively fresh surface layer that showed evidence of heating from its deeper, and presumably earlier temperature. There was evidence that it began earlier in the outer shelf than in the middle shelf.

6.3 The middle-shelf, 70 m isobath

From April 12 to April 18, BEST 07 sampled along the 70 m line that was the first major section in the BEST 07 cruise plan. This line has been occupied in prior years by NOAA PMEL and provides insight into several important properties of the western Bering shelf, including the position of the ice edge, the extent of the cold pool and the progression of the productivity associated with the ice edge and open water regions. It includes four NOAA moorings that have been collecting data for up to eight years in the southern end of the line. We crossed through low ice, polynya-like conditions directly west of St. Matthew Island and took the opportunity to occupy two additional stations to the east of the 70m line in this region. Thereafter, we crossed through almost continuous pack ice north of St. Matthew Island to the end of the 70m line at 62.2˚N.

In the present sampling, water temperatures below 0˚C extended throughout the section, with bottom water temperatures below -1.5˚C dominating north of 58˚N (Fig. 7). Surface warming was evident south of 59˚N. Bottom water salinities were generally greater than 31.8 except from 59-60˚N. Surface layers also were significantly fresher in this latitude range as well as in Bristol Bay (particularly around the southern-most mooring M2). The results from the 70m line sampled during BEST 07 provide a comparison to the physical conditions recorded when this section was last sampled by NOAA PMEL in May 2005. This comparison indicates that in 2007, water temperatures were significantly colder than in 2005. In May 2005, bottom water temperatures less than 0˚C extended only to approximately 59˚N and bottom temperatures less than -1.5˚C did not extend south of 60.5˚N. Surface temperatures were warmer in the southern half of the 70m line in 2005, although this is likely largely due to the month-later sampling in that year. Surface salinities also were generally lower in May 2005 across the northern half of the 70m section, when surface water with salinities less than 31.8 dominated the entire region north of 59˚. The more extensive lower salinity water in 2005 also may have resulted from the later sampling and hence greater ice melt influence in this region. While surface salinities below 31.8 are less common in April 2007, there were several regions with salinity lower than 31.8, including surface waters of Bristol Bay as well as most of the water column in the region around Nunivak Island. In addition to ice melt, the low salinity coastal current around Nunivak Island may contribute to the lower salinity in this region.

The chlorophyll fluorescence and oxygen sections in Fig. 8 indicate that significantly more production had occurred in Bristol Bay than in the more northern regions by mid-April. The elevated production found on the southern part of the 70 m line is similar to the stations sampled in the outer shelf in this region as well (see prior section). The greatest chlorophyll was recorded in the freshest surface waters (near stations 13 and 19 on Fig. 8). Also, the elevated production coincided with relatively warm surface waters throughout this region. The most likely source for the low salinity surface water is the deteriorating ice to the northeast of the southern part of the 70 m line. Two distinct plumes of broken and rafted ice can be seen extending into this part of the section on the Radarsat image in Fig. 1.

In contrast, the extensive low salinity water near Nunivak Island does not show any evidence of elevated production and is virtually indistinguishable from the low fluorescence levels in the rest of the northern region. Clearly, BEST 07 sampled before significant production began in the region north of 57.5˚N, a region that covers most of the eastern shelf. For the interpretation of the oxygen field, please note that these data have not yet been calibrated to the Winkler oxygen titrations that are being done from each cast. Thus, while the large increase in oxygen levels in Bristol Bay relative to the northern region likely will remain a significant signal even after calibration, no further analysis can be made regarding the more subtle variations in the oxygen in the more northern regions until the calibration is complete.

6.4 The St. Laurence line along 60.2˚N

The most northern of the sections sampled generally was still in winter, low production conditions, judging from the continuous ice cover found there. Some of the thickest and most impenetrable ice of the cruise was encountered at the eastern end of this line where rounded pack ice was found that likely originated from the north. Water temperatures throughout the section were well below 0 and the coldest water of our sampling was encountered at the bottom of the water column roughly south of the western end of St. Laurence Island (Fig. 9). Salinity across this section was large relative to more southern sampling, again suggesting that little ice melt had occurred by April 19-21. The highest salinity (>32.6) was found in the same regions as the lowest temperatures. Such water was either modified slope water that had been cooled on the shelf, or produced by brine exclusion during ice formation. To examine this water further, several stations were occupied north of the SL line toward the west end of St. Laurence Island. These showed increasing salinities at the same near freezing point temperatures and suggested that the water resulted at least in part from brine rejection during ice formation in the St. Laurence Island polynya or from ice formation regions upstream from this region in the Gulf of Anadyr.

There was evidence of only slight spring phytoplankton production based on the fluorescence levels and on the levels of water column oxygen (Fig. 10). Oxygen levels were generally below 100% saturation although the chlorophyll levels to the east suggested that higher production conditions might have been developing. The low water column fluorescence levels contrasted with the very large fluorescence levels observed episodically in the underway system along this line as well as along the northern part of the 70 m line. We suspect that the underway system was sampling ice-algae dislodged from the ice by the passage of the ship. These populations apparently were restricted to the ice matrix itself at this time. Both ship and ice station observations recorded dense patches of ice-algae in these regions and this is an important question that can be addressed with some of the additional data that will be available from the cruise. When the mid-SL and northern 70 m line were revisited on May 7, the ice pack had begun to break up, surface salinities were low and water column fluorescence values were greater.

6.5 The Matthew – Nunivak line along 59.9N

The first obvious ice-edge bloom was sampled along the MN line from April 22-25. Here, a steep gradient in both temperature and salinity separated warmer, saltier offshore waters from the fresher water created by the retreating ice edge (Fig. 11). Temperature decreased by 3 degrees and salinity by 0.9 over ~120 km. These surface fronts extended down in a manner consistent with the thermohaline front found at the shelf break during most of the summer in the eastern Bering Sea, although the structure found along the initial MN line was farther inshore than most instances of it that have been recorded in this region.

This front was associated with an intense surface phytoplankton bloom (Fig. 12). Oxygen was well above saturation with the atmosphere giving evidence for the rapid net growth of the phytoplankton in this region. The early stage of bloom development was also suggested by the lack of significant fluorescence below the shallow mixed layer. This indicates that little if any of the new production had yet reached the bottom. When this bloom region was resampled on May 5, the bloom had intensified still more and moved slightly in an offshore direction. The later sampling also indicated that the region of ice-melt freshened surface water had increased along with the spatial extent of the fluorescence patch. Thus, it is appears likely that we sampled the initial stages of the ice-edge bloom in this region. This enabled us to follow its development over the next several weeks.

6.6 The Pribilof – Nunivak line

This line was sampled from the inshore regions out to the shelf break on April 25-27. Unlike the MN line, there was mush less evidence of ice-melt induced surface stratification across this section (Fig. 13). Most of the ridge east of the Pribilof Islands was well mixed almost to the bottom and showed little vertical change in temperature or salinity. The exception was the shelf break region where there was noticeable vertical change in both properties. The fluorescence and oxygen sections indicated that even slight amounts of surface stratification were followed by increases in production (Fig. 14). Elevated fluorescence levels were apparent at the shelf break region and at a more inshore station that was one of the few shelf regions to show a significant vertical stratification that apparently was associated with a small amount of surface warming, Overall, this line produced more evidence for the view that we sampled early in the production cycle and before any significant trophic and biogeochemical fluxes had begun. An exception to this general pattern was shown by the inner shelf region in which elevated fluorescence was found throughout the water column and biomass was reaching the sediments.

6.7 Cross-ice feature sampling

The good fortune of HLY0701 to encounter extensive early ice-edge bloom conditions provided an opportunity to samples this feature in some detail. This effort was undertaken for a number of reasons. First and foremost the ice edge bloom produces much of the organic matter for the shelf system and the clarification of this impact on shelf biology and nutrient fluxes is of great importance to the testing of BEST hypotheses. Thus we took advantage of the unprecedented opportunity to sample these features in the Bering Sea in some detail with an extensive hydrographic survey. Also, this hydrographic survey was intended to support a range of additional process level measurements that took place on HLY0701 and to ensure that each of the participating research groups had adequate opportunity to sample these important features.

With this in mind, a series of cross-ice sections were occupied whose location and orientation were guided by the near real-time Radarsat imagery provided to the ship. Fig. 15 shows the salinity and fluorometer results from the firsts of these sections that was occupied on April 29 after the community visit and personnel exchange at the Pribilof Islands. As was the case for all of such sections that we did along the western edge of the ice field in late April and early May, there was significant freshening of the surface waters that contributed to a restricted (<30m) mixed layer. This was associated with elevated fluorescence and oxygen, just as the initial sampling of this feature along the MN line indicated. In some of these ice-edge areas, such as those sampled by XI1, the production had only just begun. In other regions, we encountered much more intense features associated with a more advanced ice-edge bloom (Fig. 16). Based on these multiple crossing, each research group was able to sample adequately and the extensive hydrography will provide a valuable context in which to interpret these findings.

7 Salinity, oxygen and other calibrations

The crucial CTD – Niskin sampling aspect of the fieldwork was handled by the Scripps group under the direction of Scott Hiller. Both primary and secondary CTD systems worked properly and initial salinometer calibrations are good. All bottles on the Niskin rosette worked properly. The Healy MSTs quickly became acquainted with our sampling needs and watch standers were competent and cooperative. Sample logs were developed to track all samples taken from the rosette and supervision of the sampling was divided between Dylan Righi from noon to midnight and Nancy Kachel for the other 12 hours. The NOAA PMEL group, the Scripps group and the chief scientist had at least two daily briefs on the progress and status of the hydrographic operations.

Although it is not a calibration per se, the temperature - salinity relationship for the entire data set is one way to assess the internal consistency of the data (Fig. 17). In Fig. 17, the mixing between the warm, salty slope waters (4˚C, 34.5) with cold, fresher shelf waters is clear. The extremely cold, lower salinity water may reflect the brine rejection water from the ice formation regions. These data will be used extensively in the BEST analyses. Although this figure is based only on raw and entirely uncorrected data, it is clear that the quality of these data is good and that after a full calibration procedure they have a high probability of serving their core role in the BEST analysis. Samples were taken for analysis by a salinometer and these will be used to calibrate the conductivity values from the primary CTD unit.

Samples also were taken for oxygen analysis by Winkler titration and the relationship to the oxygen values from the CTD are excellent (Fig. 18). These will provide a calibration for the SBE 46 oxygen electrode on the CTD. In addition, samples for later Chl a analyses were collected both from the Niskin rosette as well as from the underway SCUFA system. These will provide a basis on which to better estimate Chl a levels from these sensors as well.

8 Status of science component operations

8.1 Nutrient analyses

Five nutrients (nitrate, nitrite, ammonium, phosphate and silicate) were analyzed on-board via auto-analyzer methodology by C. Mordy. This aspect of cruise operations was manned by only one person and thus represented a potential single point failure for this critical component. Fortunately, all aspects of these analyses went well. Mordy also supervised the calibration of the oxygen sensors on the SeaBird CTD with automated Winkler titrations for oxygen. A final nutrient report will be ready within four weeks of the end of the cruise.

8.2 Nitrogen productivity and productivity isotopic signatures

Productivity experiments to measure new (nitrate) and regenerated (ammonium and urea) production were done by the group consisting of R. Samrotto, D. Burdloff and C. Swenson from Lamont-Doherty. These incubations were done at least once each day using on-deck incubators on the foredeck to assess rates of new and regenerated production. In parallel, samples for a full isotopic analysis of the nitrogen system on the eastern shelf were collected. This included sample collection by J. Granger and M. Prokopenko for the isotopic composition of the nitrate, dissolved organic nitrogen and ammonium pools. Samples for the isotopic composition of particulate material were collected by the LDEO group. The goal of this component is to develop the ability to diagnose nitrogen fluxes from the isotopic fields and to be better able to construct shelf-wide nitrogen budgets. Most of the samples from this pat of BEST 07 await analysis by mass spectroscopy after the return to the lab. Also, measurements of urea were made as well as counts of the net-plankton and preserved samples were collected for microplankton characterization and enumeration. On-board counts of net plankton indicated that the ice algae were dominated by pennates and that the blooms at the western edge of the ice pack were dominated by the centric *Thallassiosira.* Net plankton community populations in Bristol bay were markedly different than those in the north and contained much grater numbers of the prymnesiophyte *Phaeocystis.*

8.3 Underway measurements of oxygen, nitrogen and carbon dioxide

A small mass spectrometer with a membrane inlet (MIMS) was set up in the biochem lab. by J. Granger and M. Prokopenko. The MIMS worked well during the cruise and augmented the underway data already being collected (Fig. 19). By following multiple bioreactive gases and the inert gas Argon, the system was able to record continuously and isolate biological changes. In the example shown, the ship traveled between a highly productive ice-edge bloom into lower productivity, higher salinity waters. This was associated with a significant drop in oxygen saturation as well as an increase in the level of carbon dioxide in the water. The normalization of these values to Argon helps account for the physical effects to better isolate the biologically induced change.

8.4 Iron concentration and distribution

Casts were done with specially built sampling devices to collect water in a trace metal clean fashion by R. Rember and A. Aguilar-Islas. These casts typically were done at the beginning of a station and take approximately 40 minutes in waters less than 100 m. Sample collection for dissolved iron, total iron and iron speciation has been very successful during the initial BEST cruise. During HLY0701, we more than doubled our goals for seawater collection. In all, 32 profiles were collected using our MITESS vane samplers. These profiles resulted in more than 150 seawater samples from depths ranging from 15 to 2500 m. All seawater samples were processed/filtered in a class 100 laminar flow hood through 0.4 μm nucleopore filters where 1 L was collected for Fe speciation (ligands), 500 ml was collected for archival purposes and duplicate 30 ml samples were collected for total dissolved Fe measurements. The remaining sample was left in the sample bottle for total Fe measurements. In addition to sampling a number of stations along each transect line, we also were able to collect numerous profiles both inside and outside of many of the ice edge blooms that were encountered during the cruise both on the shelf and closer to the slope and the Fe-limiting HNLC waters offshore.

Our group also was able to exceed our goals for ice core collection. Ice samples were collected from a variety of ice types and thicknesses including sediment-laden ice (>3 m) near St Matthew Island to newly formed 'clean' ice (<20 cm). In all, 33 ice cores were collected from seven ice stations. A subset (12) of the ice cores were processed on-board in a class 100 laminar flow hood in one of the available cold rooms. Processed samples were collected still frozen in 1 L fluorinated polyethylene bottles. Ice cores were processed onboard using a titanium chisel to remove the outer layers of the core prior to sample collection. In most cases, >70% of the core 9 cm diameter was removed with only the inner 30% collected for analysis. As the outer layers of the cores were removed, quality control samples were collected to ensure that the inner layers of the cores were free of sampling contaminants.

In summary, HLY0701 has provided our research group with an excellent start to the BEST program. We are looking forward to getting our samples back to the lab at the University of Alaska, Fairbanks to start working up our samples in the coming months. The USCGC Healy provided an excellent platform for our sampling both in the ice and in open water. The professionalism displayed by captain and crew is unmatched and we look forward to working with them again in future years.

8.5 Samples for sediment biogeochemical fluxes and community analysis

Sampling for sediment nitrogen fluxes and benthos was done by A. Devol, D. Shull, Bonnie Chang, Emily Davenport and Jerry McCormick-Ray. Sixteen sites were sampled using an Ocean Instruments MC-800 multicorer equipped with eight 10-cm diameter polycarbonate core tubes. Two drops were made at each station resulting in as many as sixteen cores per station. The actual number of usable samples generally averaged approximately twelve. Cores were processed on deck and, depending upon the number of usable cores recovered, were generally allocated as follows:

3 flux cores (incubated for ca. 5d and overlying water sampled for, N_2/Ar, O_2/Ar, N isotopes, nitrate, nitrite, ammonium, phosphate, and silicate). Following flux measurements, these were frozen for later CT-scanning of burrow distributions

2 squeeze cores
- Profiles of dissolved oxygen measured by microelectrode
- Profiles of dissolved nutrients (nitrate, nitrite, ammonia) by whole-core squeezing

3 section cores cut at 0.5- 1-cm intervals and centrifuged for pore-water nutrients, nitrate, nitrite, ammonium, phosphate, silicate, dissolved iron and manganese to 20 cm. Remaining sediment reserved measurements of solid-phase elements (Fe, Mn, Al, C, N, Pb-210)

2 cores sectioned at 2-cm intervals for measurement of Rn-222/Ra-226 disequilibrium

2 cores sieved over 0.5-mm sieve and preserved in 10% formalin for later enumeration of benthic infauna.

Any remaining cores sieved and examined for live benthic infauna. At twelve stations, water column samples were collected for oxygen isotopes (O-16, -17, and -18) and for Rn-222 and Ra-226. The Rn-222/Ra-226 measurements will be used for determining gas exchange rates and, combined with the oxygen isotope data, rates of net primary production.

Much of the results await further laboratory analyses. Initial results include the identification and abundance of benthic fauna from live samples. Benthic communities were dominated by polychaetes and small deposit-feeding bivalves. Lengths of most individuals were < 5 mm. At shallower water depths, brittle stars were abundant whereas in deeper water (>500m) foraminifera were abundant. Additional results include the estimation of the rates of diffusive flux of oxygen calculated from oxygen profiles measured by microelectrode for Stations 48 – 200 that were as follows.

Stn	Flux (mmoles/m2/d)	Approximate depth (m)
Stn. 74	4.22	51
Stn. 85-1	3.00	82
Stn. 85-2	2.18	82
Stn. 90-1	0.70	2540
Stn. 90-2	0.63	2540
Stn. 65	3.03	68
Stn. 48	2.09	71
Stn 91-1	0.67	682
Stn 91-2	0.50	682
Stn 92-1	3.47	139
Stn 92-2	2.46	139
Stn 105-1	2.30	116
Stn 105-2	2.17	116
Stn 113-1	4.03	57
Stn 132-1	2.61	94
Stn 150-1	1.14	68
Stn 150-2	1.03	68
Stn 152-1	0.81	90
Stn 152-2	1.01	90
Stn 164-1	2.16	142
Stn 164-2	2.59	142
Stn 177-1	6.73	133
Stn 177-2	4.30	133
Stn 177-3	4.46	133

8.6 Zooplankton and meroplankton collections

The NOAA Alaska Fisheries Science Center group made regular collections for zooplankton and meroplankton. Typically, oblique nets were towed except in heavy ice conditions where vertical bongo nets were deployed. Parallel collections of the 153 and 500 mm size fractions were done. At selected stations, Calvet nets were also done. All sampling and on-board processing for this component has been implemented successfully. Most of the identification and abundance on these samples will be analyzed after the return to the lab.

8.7 Ice observations and sampling

Several sources provided information on the sea ice of the eastern Bering Sea that is of central importance to BEST. In addition to the remotely sensed information described below, additional on-board and on-ice measurements were made. On-board observations include an observer program that recorded ice conditions every 2 hours as well as a camera system in the aloft com that continually records images. On-ice observations are done by two groups: R. Rember and A. Aguilar-Islas and the NOAA PMEL group under the direction of N. Cokelet. Deployments are made using either a crane or a brow from the ship. Seven ice deployments were done. At each, multiple cores were collected for physical, chemical and biological analyses. A group experiment to asses the productivity of the ice-algae using a combination of approaches also was done.

8.8 Marine Mammal Observations

From April 13 to May 8, 2007, researchers affiliated with NOAA's National Marine Mammal Laboratory, and the Alaska Native Ice Seal Committee conducted aerial surveys for ice seals (i.e., ribbon ringed, bearded and spotted seals), in the Eastern Bering Sea using a helicopter based off of the USCGC Healy. Helicopter operations were begun with a brief between the participants and Healy command immediately preceding planned flights at which weather conditions, planned way points and flight time are reviewed. Fig. 20 shows the track lines of each flight; different flights are shown in different colors. A downward looking camera took digital pictures of the area underneath the helicopter, while at least two observers recorded any marine mammal sightings. The seal team logged a total of 69.5 hours of helicopter flight time.

Shipboard surveys for ice seals also were done from the bridge of the USCGC Healy. Surveys were conducted from 09:00 to 21:00 whenever the ship was moving and in within sight of sea ice. Fig. 21 shows areas of survey effort. These observations will be linked to their location by time and will be used with the helicopter sighting data to estimate the abundances and describe the distributions and habitat preferences of the different species. In addition, walrus observations were made from the bridge and at times by helicopter by Carleton Ray. A total of over 1000 walrus were observed during HLY0701.

Total of Shipboard sightings:

BEARDED	177
BELUGA	73
FUR SEAL	1
RIBBON	201
RINGED	17
SPOTTED	808
UNKNOWN PINNIPED	112
WALRUS	283 (NMML only)

8.9 Underway data visualization and data management

We are used the web-based, geographical information system developed for the Healy by Steve Roberts to aid in our interpretation of real-time data from the underway system and remotely-sensed data streams. The system is user-friendly and the underway visualization capabilities assisted us in our ice-edge sampling. A data catalog of all BEST activities has been constructed by Janet Scannell who organized summary information from each of the groups on-board into a digital archive.

8.10 Seabird Observations

K. Kuletz, L. Labunski and D. Hyrenback did regular sea bird observations from the bridge.

8.11 Other science observations

These include the SeaBeam bottom acoustics normally collected along Healy tracks. In addition, acoustical observations of fish distributions were done by A. De Robertis. Initially, there was some interference from the ship's acoustic systems but this conflict was removed after discussion with the ship command.

8.12 Education and Outreach Activities

These activities were facilitated by two teachers on the BEST 07 cruise, M. Prevenas and R. Staup. The teachers worked hard to acquaint themselves with the science activities on-board and how they relate to the larger science issues addressed by BEST. They have been assisted in this by Emily Davenport and the chief scientist as well as by the generous efforts of the rest of the science participants. The teachers kept two web sites covering the cruise up-to-date and also produced four live, ask-the-teacher events during the cruise. These events consisted of webinars in which classrooms from across the country were connected to the Healy by phone and also could view PowerPoint slides via a web connection. The teachers also were instrumental in the community outreach activities at the Pribilof Islands. They put together activities related to the BEST cruise that were appropriate for the elementary through high school level students that met with BEST scientists on April 27. Scientist visited classrooms at both islands. At St. George, David Hyrenbach, David Shull, Ned Cokelet and Ray Sambrotto participated in discussions with students and teachers and a follow up meeting with the general community. On St. Paul, Carol Ladd and Ingrid Spies met with students and the exchange was tapped for later airing on the local radio station.

Fig. 1. Ice extent recorded in early April, 2007 in the eastern Bering Sea by Radarsat. Yellow line suggests the maximum extent.

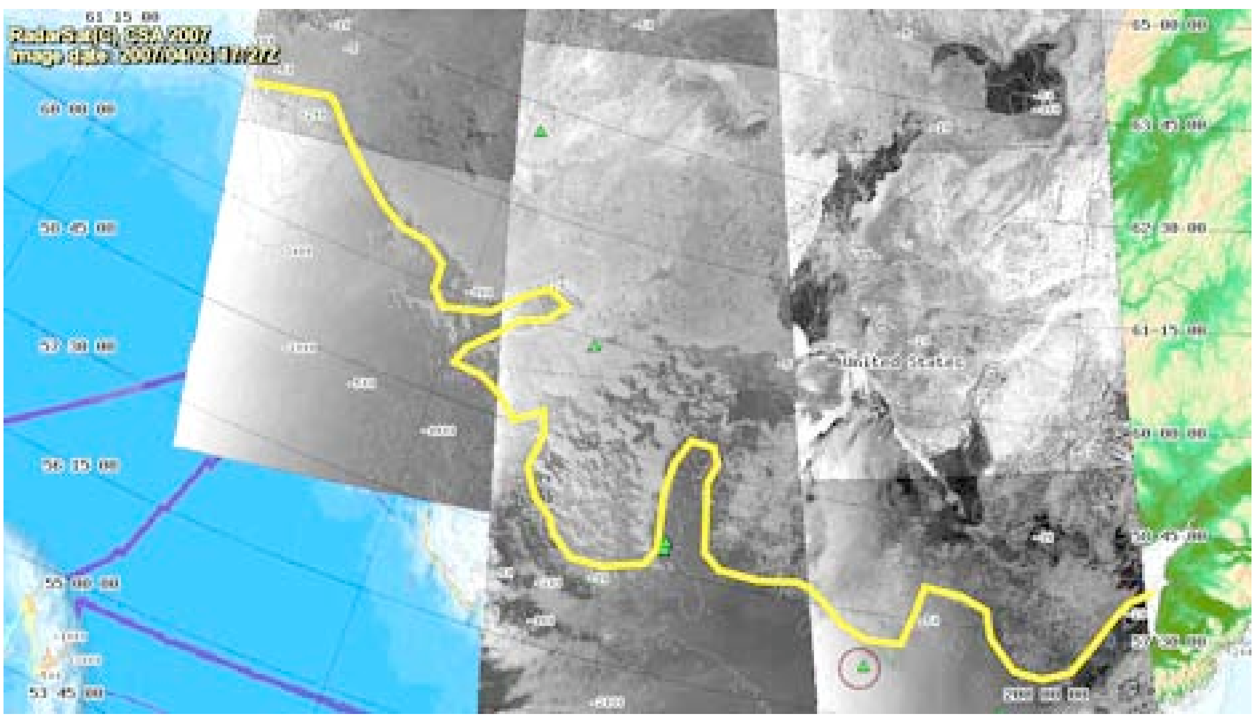


Fig. 2. Ice extent recorded in early May, 2007 in the eastern Bering Sea by Radarsat. Yellow line suggests the maximum extent from Fig. 1.

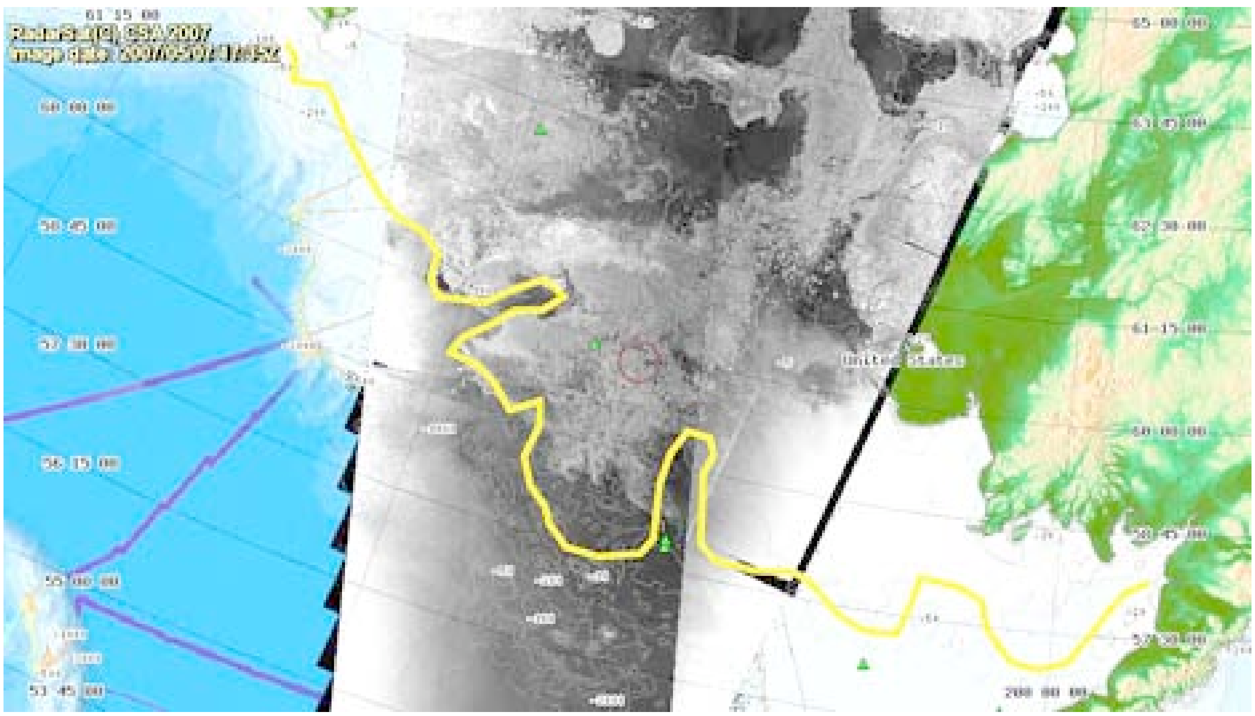


Fig. 3. Map of HLY0701 cruise track with sections and locations that are discussed in the text labeled as follows: CN – Cape Newingham line; 70m – 70 m mid-shelf line; SL – St. Laurence line; MN – St. Matthew – Nunivak Island line; PN – Pribilof – Nunivik Island line; XI1 – Cross ice line 1; XI2 – cross ice line 2; P14N – reoccupation of WOCE line P14N.

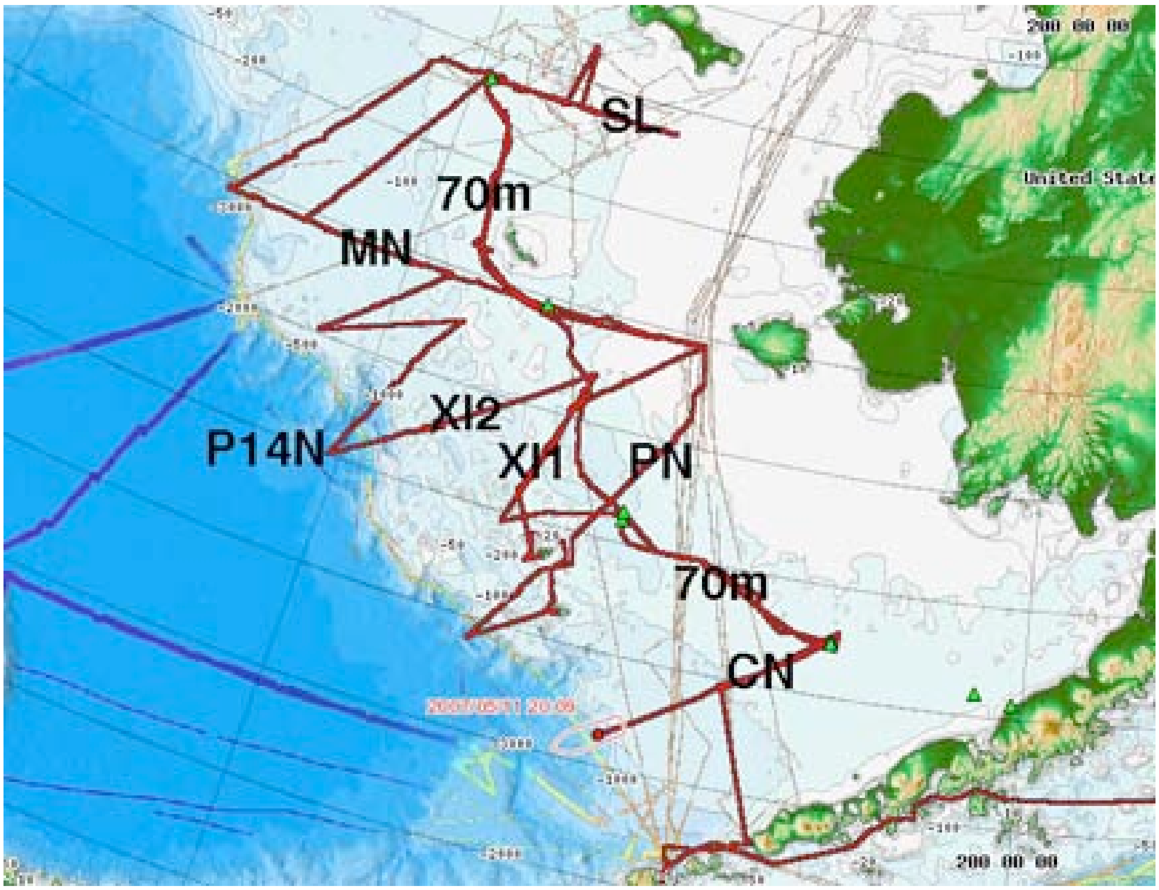


Fig. 4. Surface salinity from the Healy's underway TSG system during the HLY0701 cruise tract. The salinity data has been overlain on the May ice extent and April ice edge from Fig. 2.

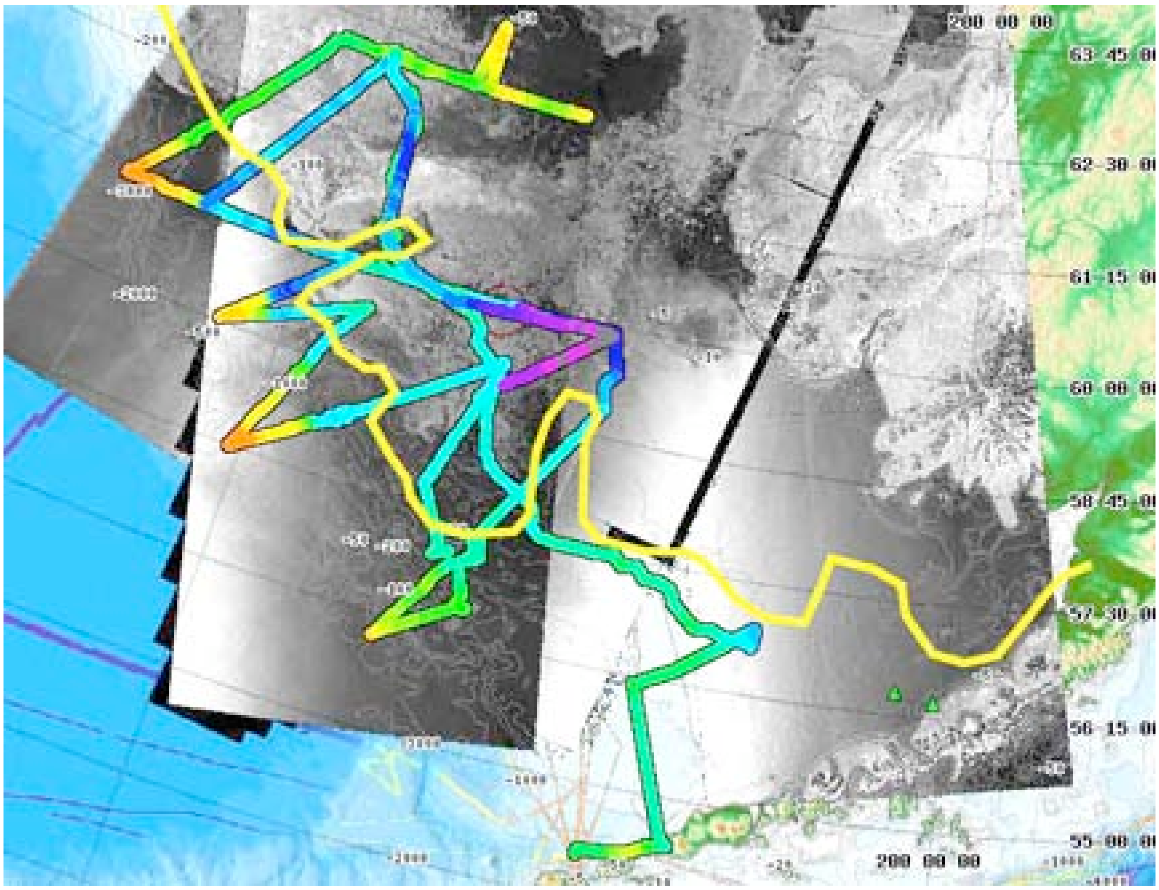


Fig. 5. Surface chlorophyll (not calibrated) from the Healy's underway fluorometer during the HLY0701 cruise tract. The chlorophyll data has been overlain on the May ice extent and April ice edge from Fig. 2.

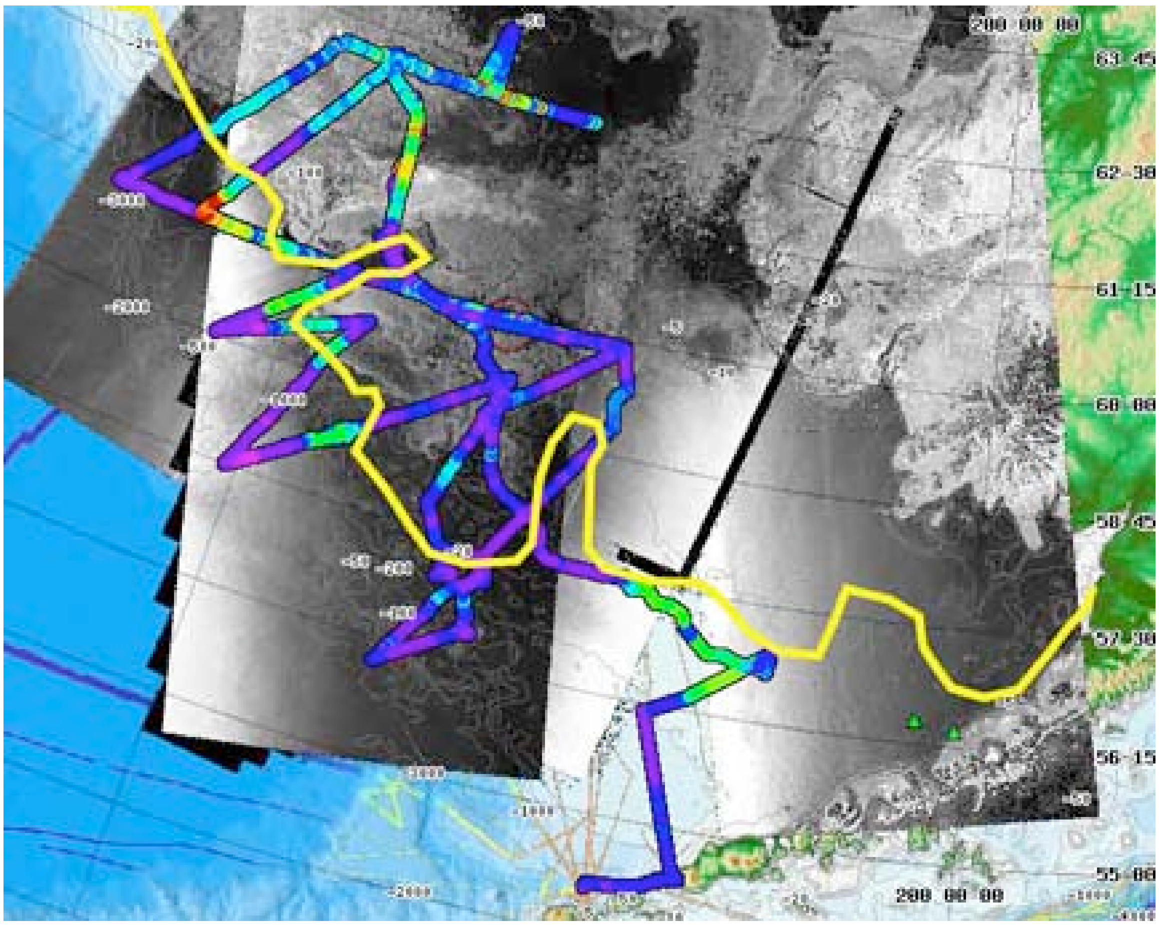


Fig. 6. Profiles for temperature and salinity (left) and nitrate (right) for Stn. 1.

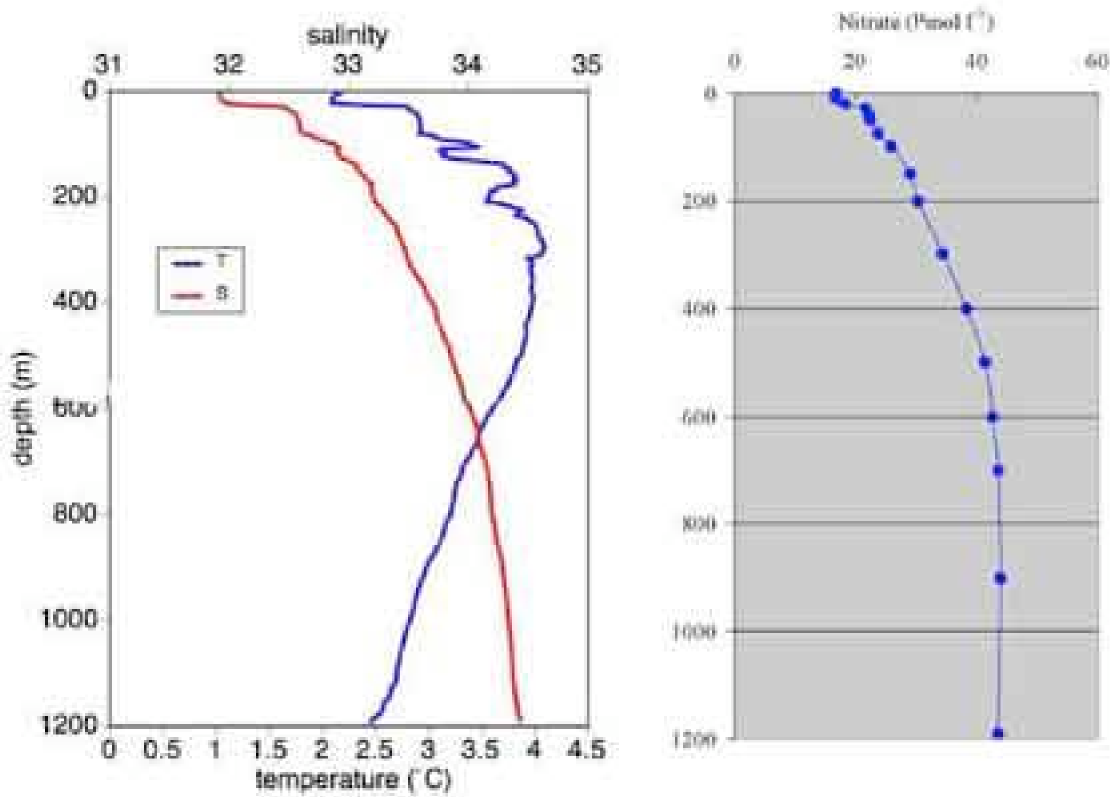


Fig. 7. Results of sampling along 70m line – Temperature (top) and salinity (bottom). The section is presented from south on the left to north on the right

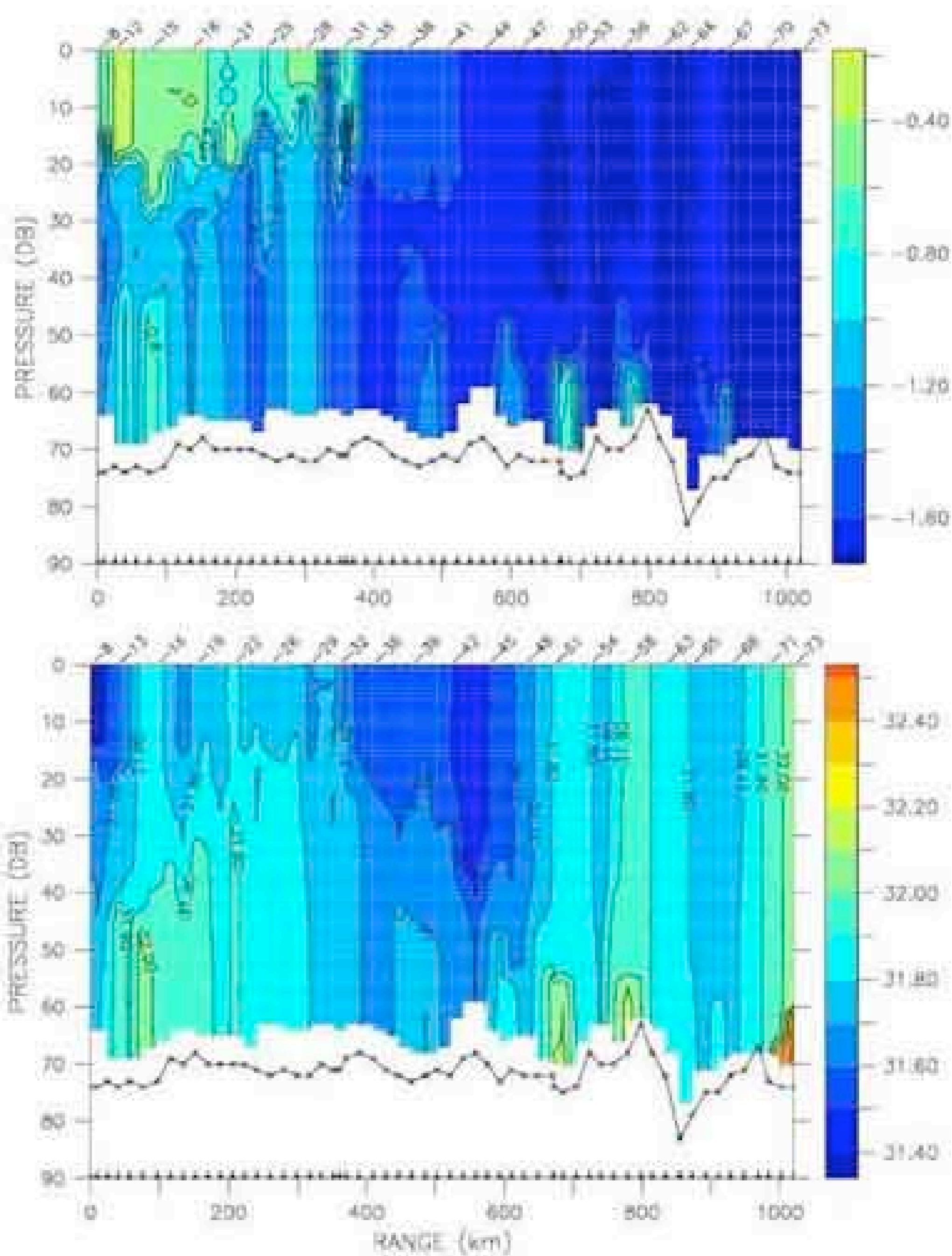


Fig. 8. Results of sampling along 70m line (cont.) – Oxygen saturation (%,; top) and Chl *a* fluorescence (as uncalibrated fluorometer volts; bottom). The section is presented from south on the left to north on the right.

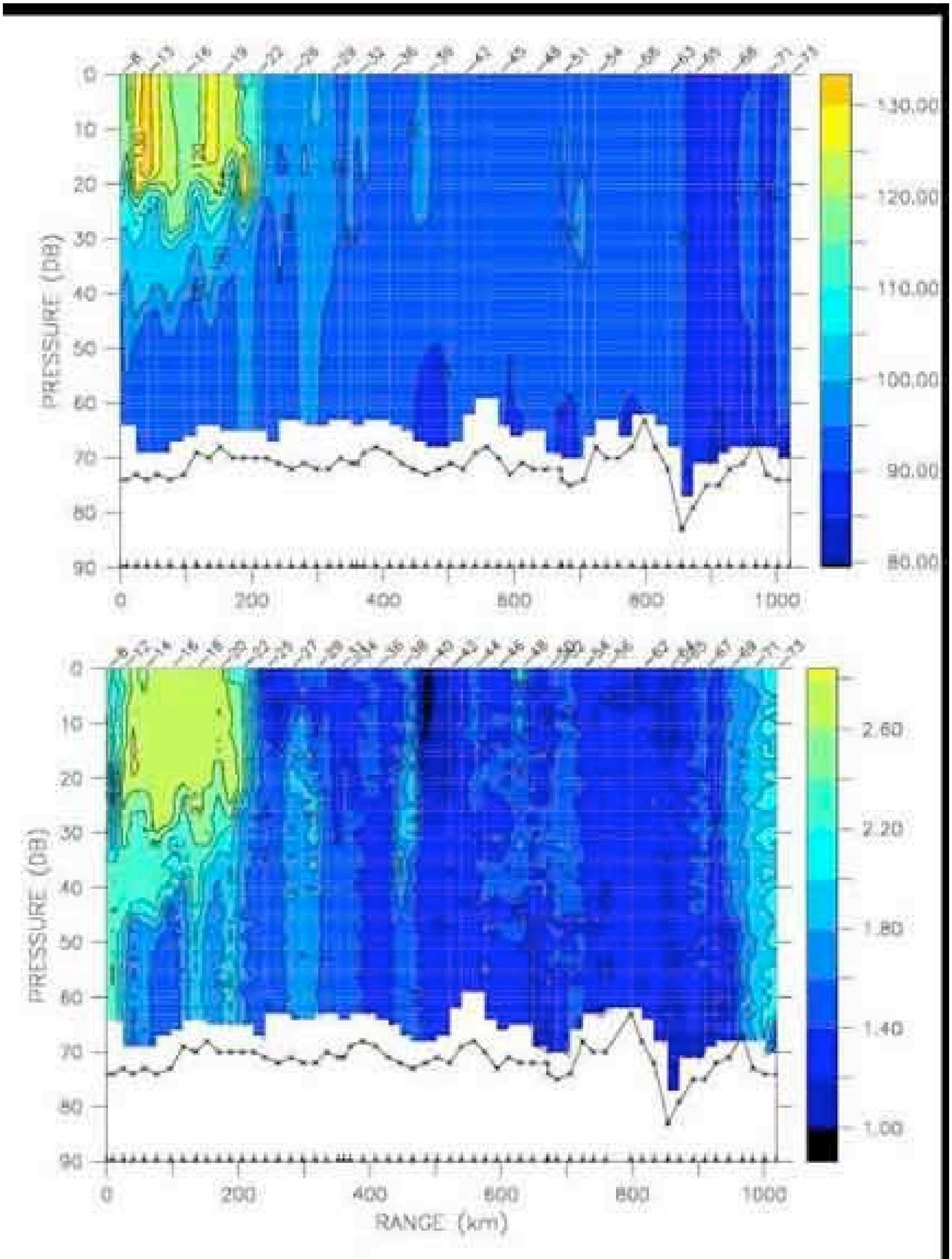
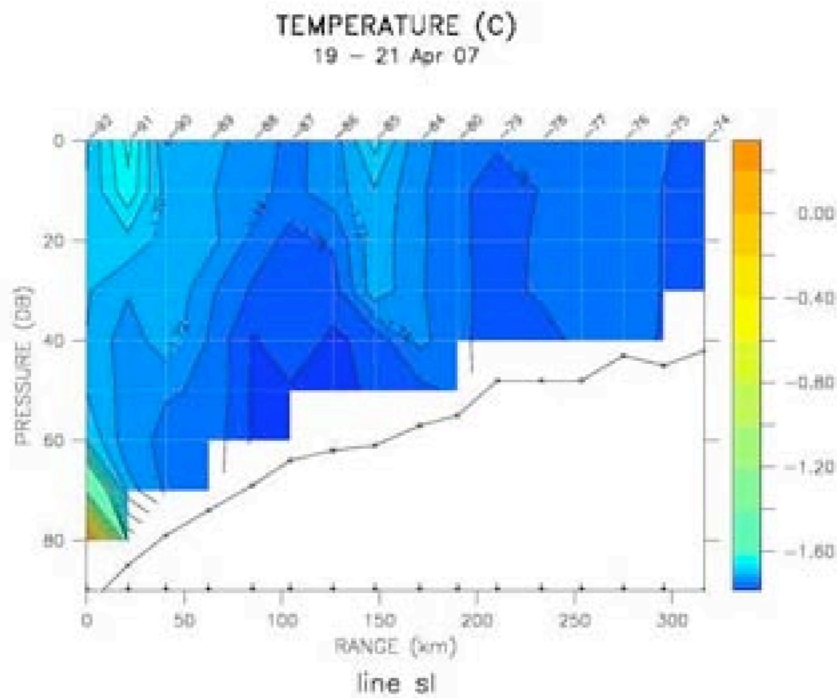


Fig. 9. Results of sampling along the SL line – Temperature (top) and salinity (bottom). The section is presented from west on the left to east on the right.



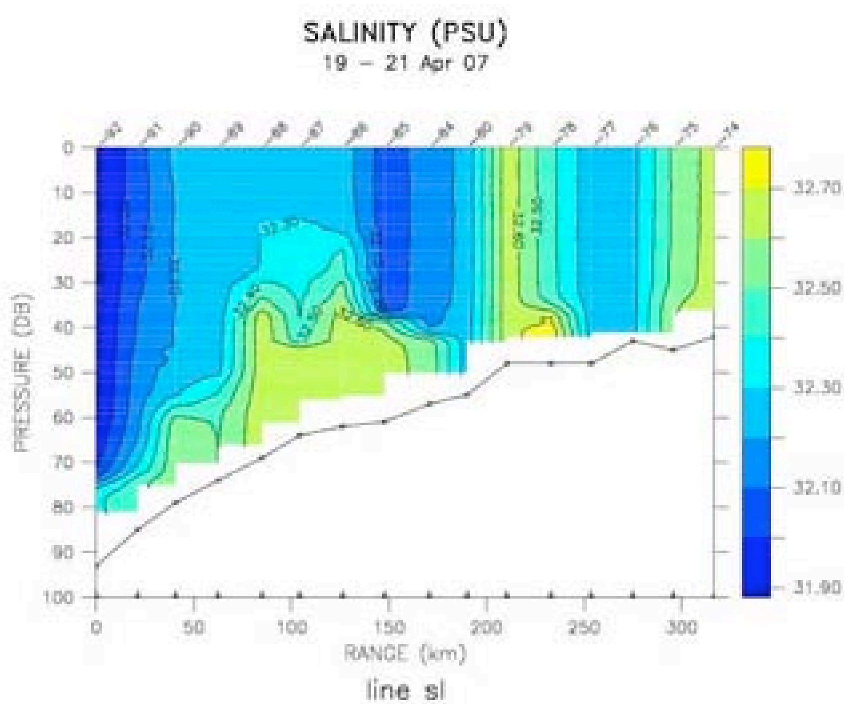
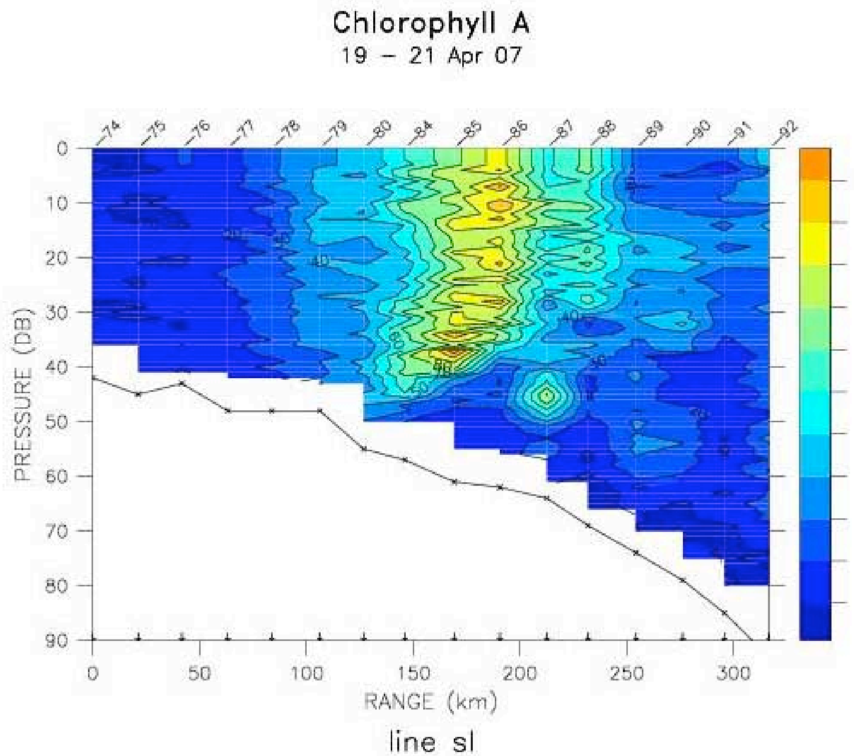


Fig. 10. Results of sampling along the SL line (cont.) – Oxygen saturation (%,; top) and Chl *a* fluorescence (as uncalibrated fluorometer volts; bottom). The section is presented from west on the left to east on the right.



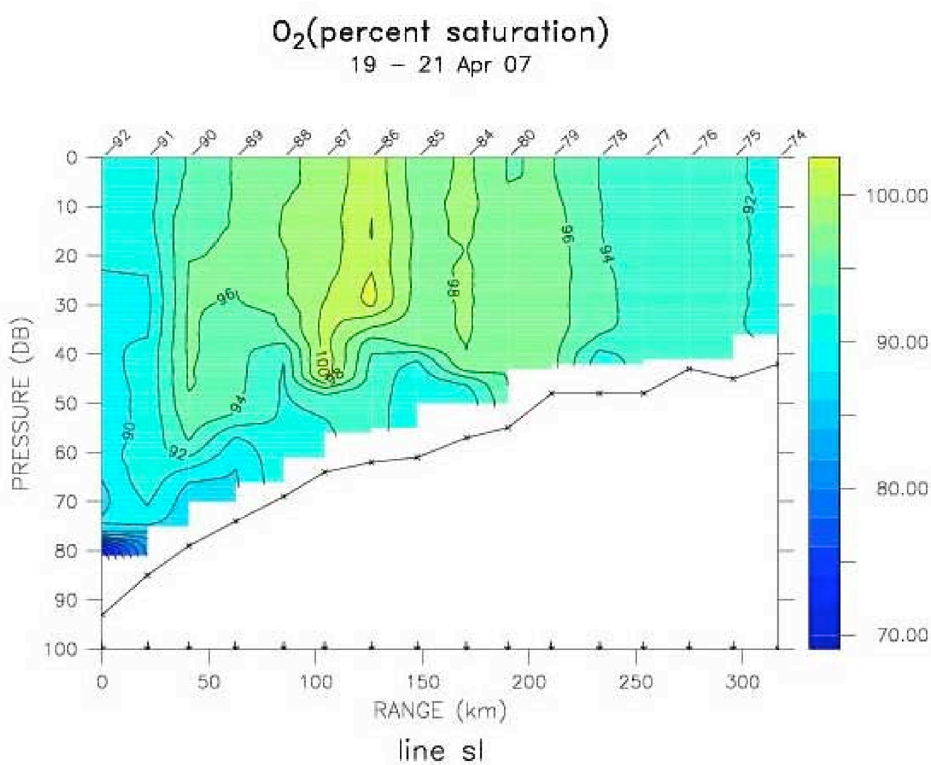
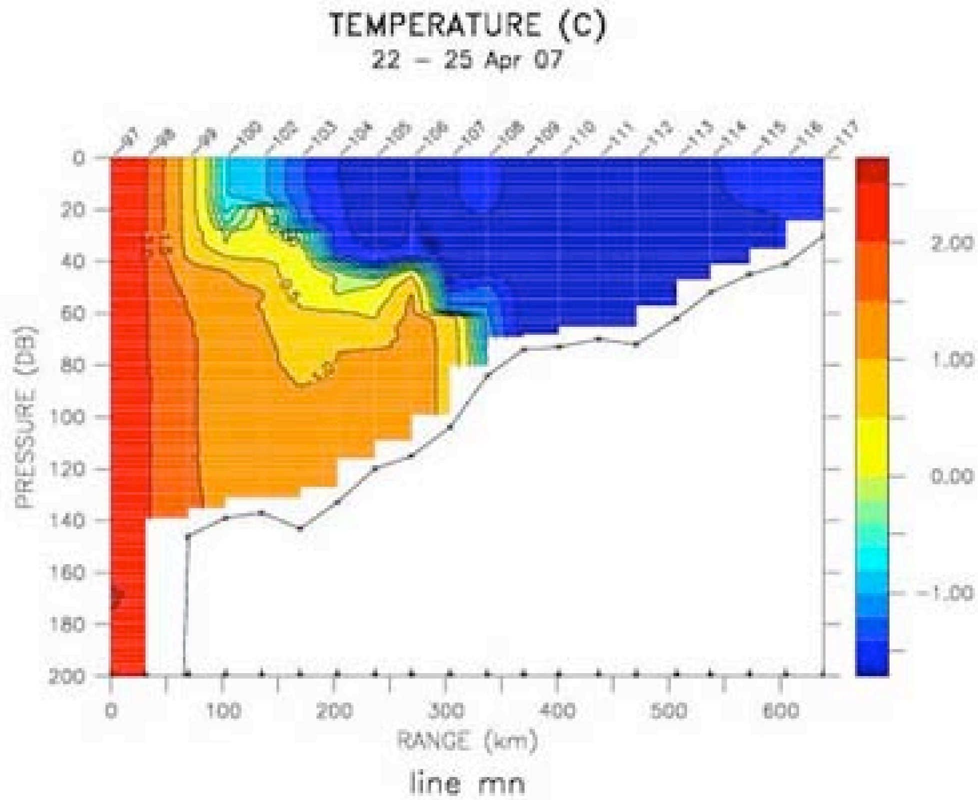


Fig. 11. Results of sampling along the MN line – Temperature (top) and salinity (bottom). The section is presented from west on the left to east on the right.



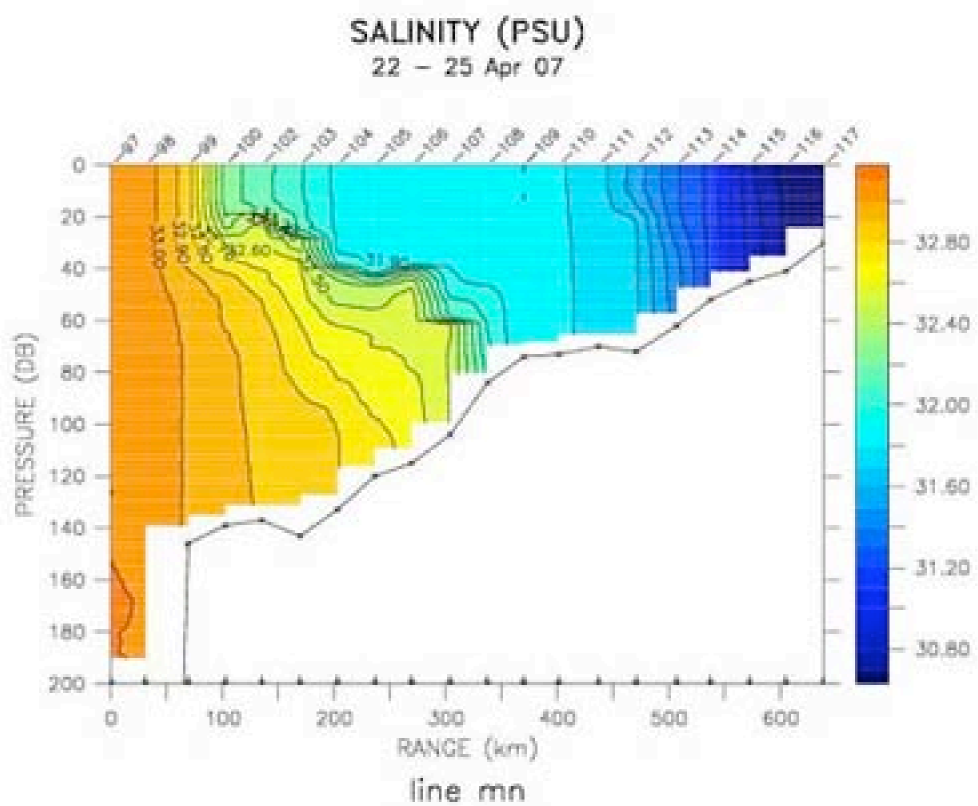
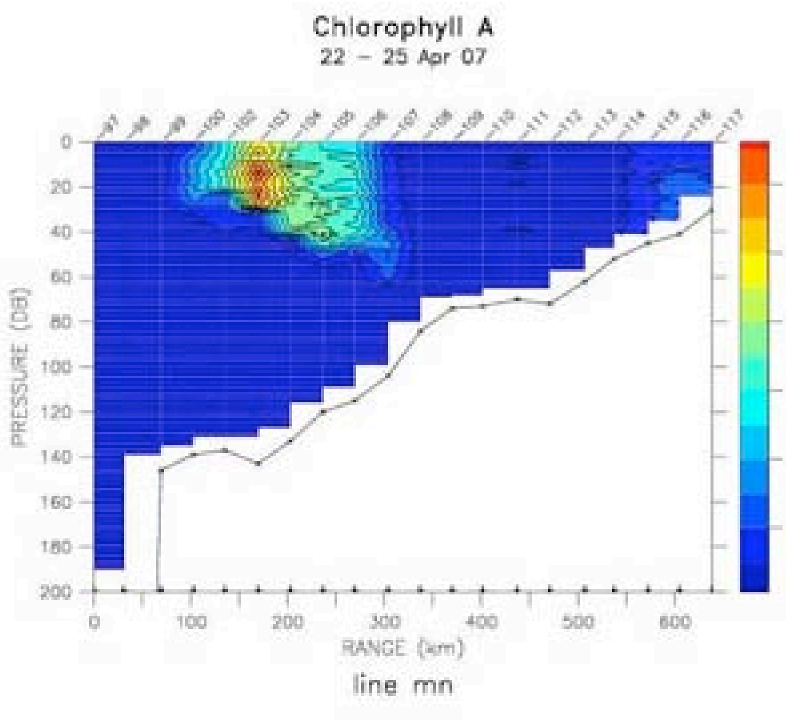


Fig. 12. Results of sampling along the MN line (cont.) – Oxygen saturation (%,; top) and Chl *a* fluorescence (as uncalibrated fluorometer volts; bottom). The section is presented from west on the left to east on the right.



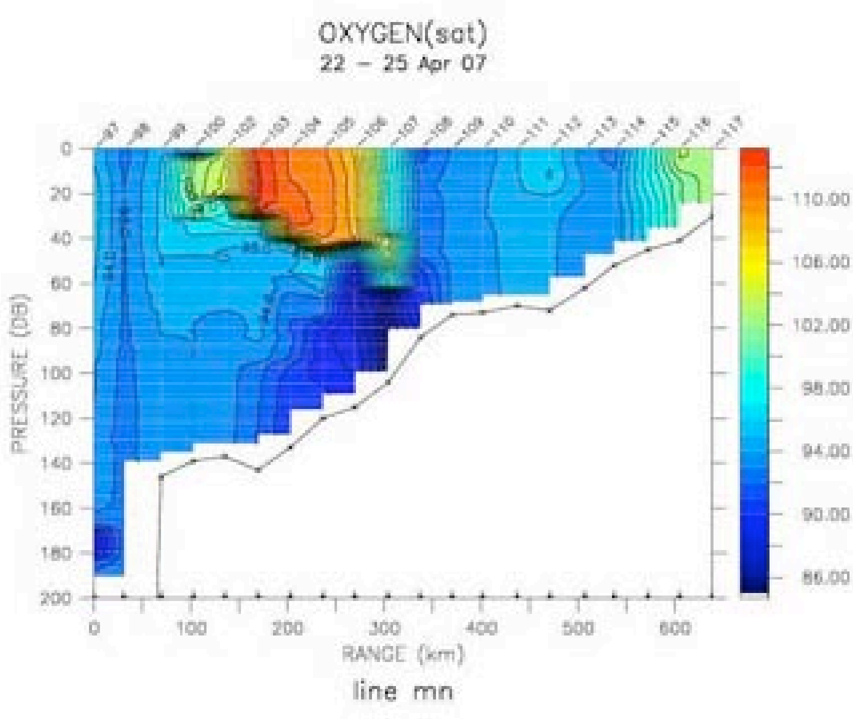
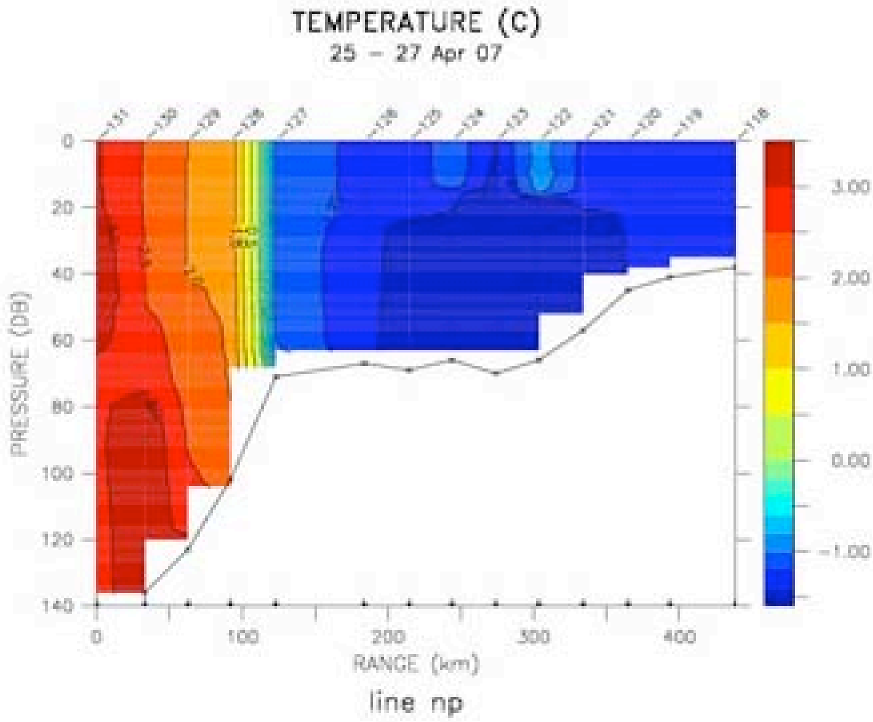


Fig. 13. Results of sampling along the PN line – Temperature (top) and salinity (bottom). The section is presented from west on the left to east on the right.



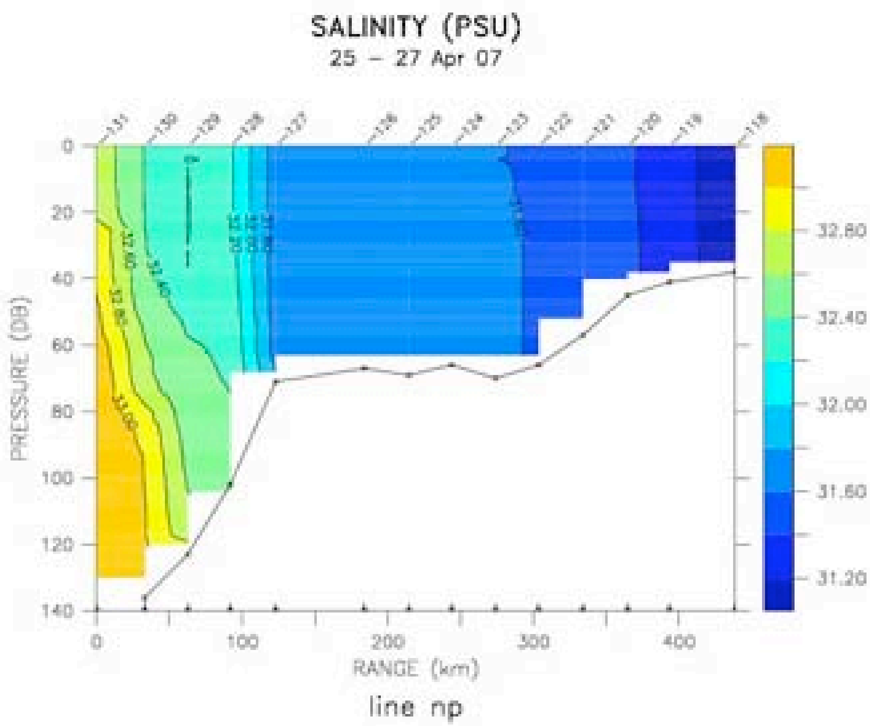
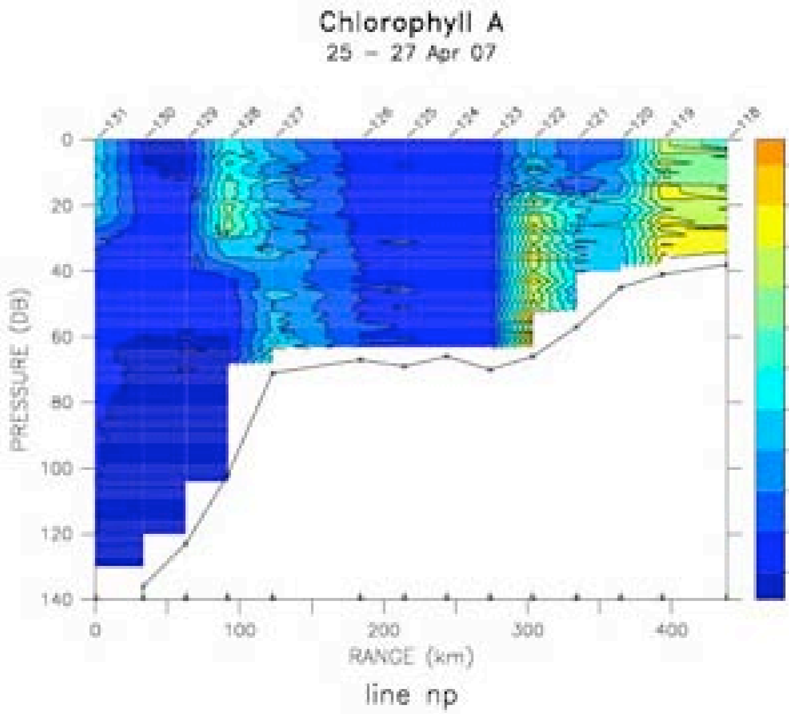


Fig. 14. Results of sampling along the PN line (cont.) – Oxygen saturation (%,; top) and Chl *a* fluorescence (as uncalibrated fluorometer volts; bottom). The section is presented from west on the left to east on the right.



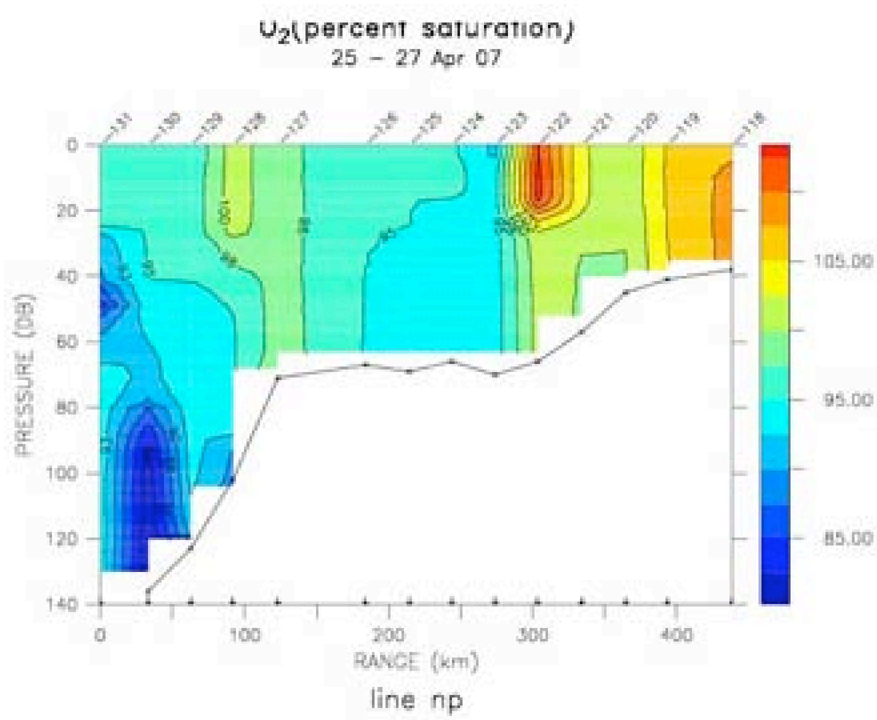
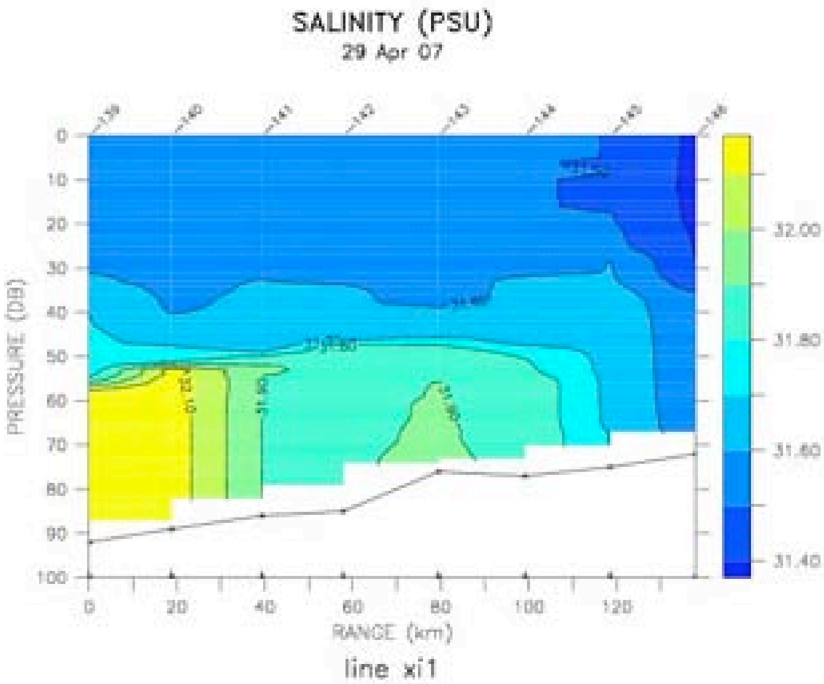


Fig. 15. Results of sampling along the first cross ice line (XI1) – Salinity (top) and Chl *a* fluorescence (as uncalibrated fluorometer volts; bottom). The section is presented from west on the left to east on the right.



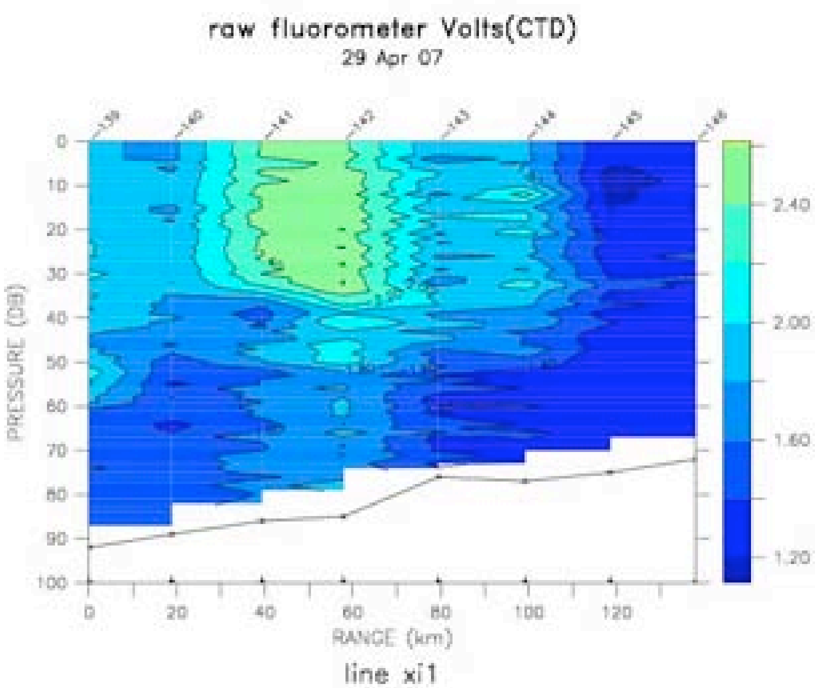
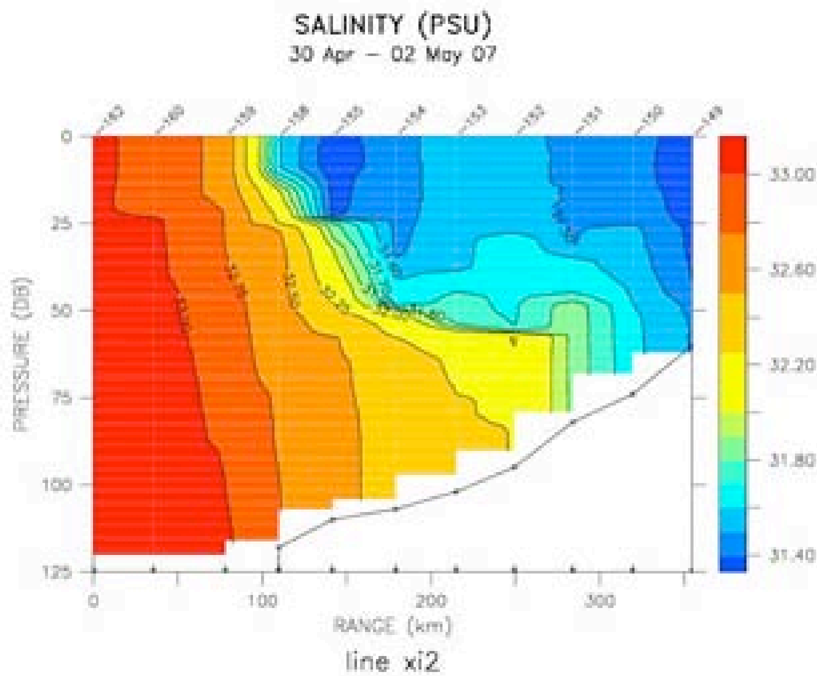


Fig. 16. Results of sampling along the second cross ice line (XI2) – Salinity (top) and Chl *a* fluorescence (as uncalibrated fluorometer volts; bottom). The section is presented from west on the left to east on the right.



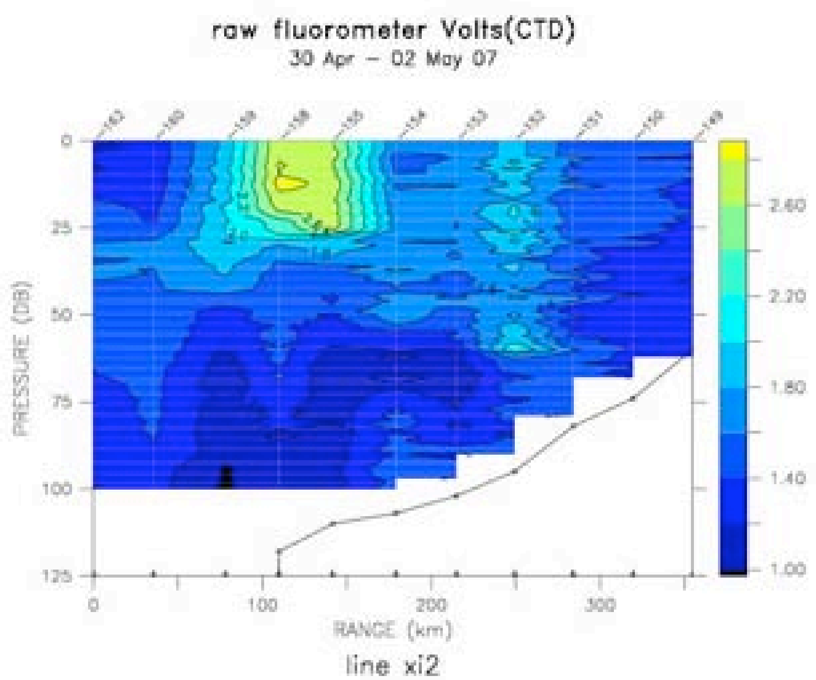


Fig. 17. Temperature - salinity diagram for raw CTD data collected during HLY0701.

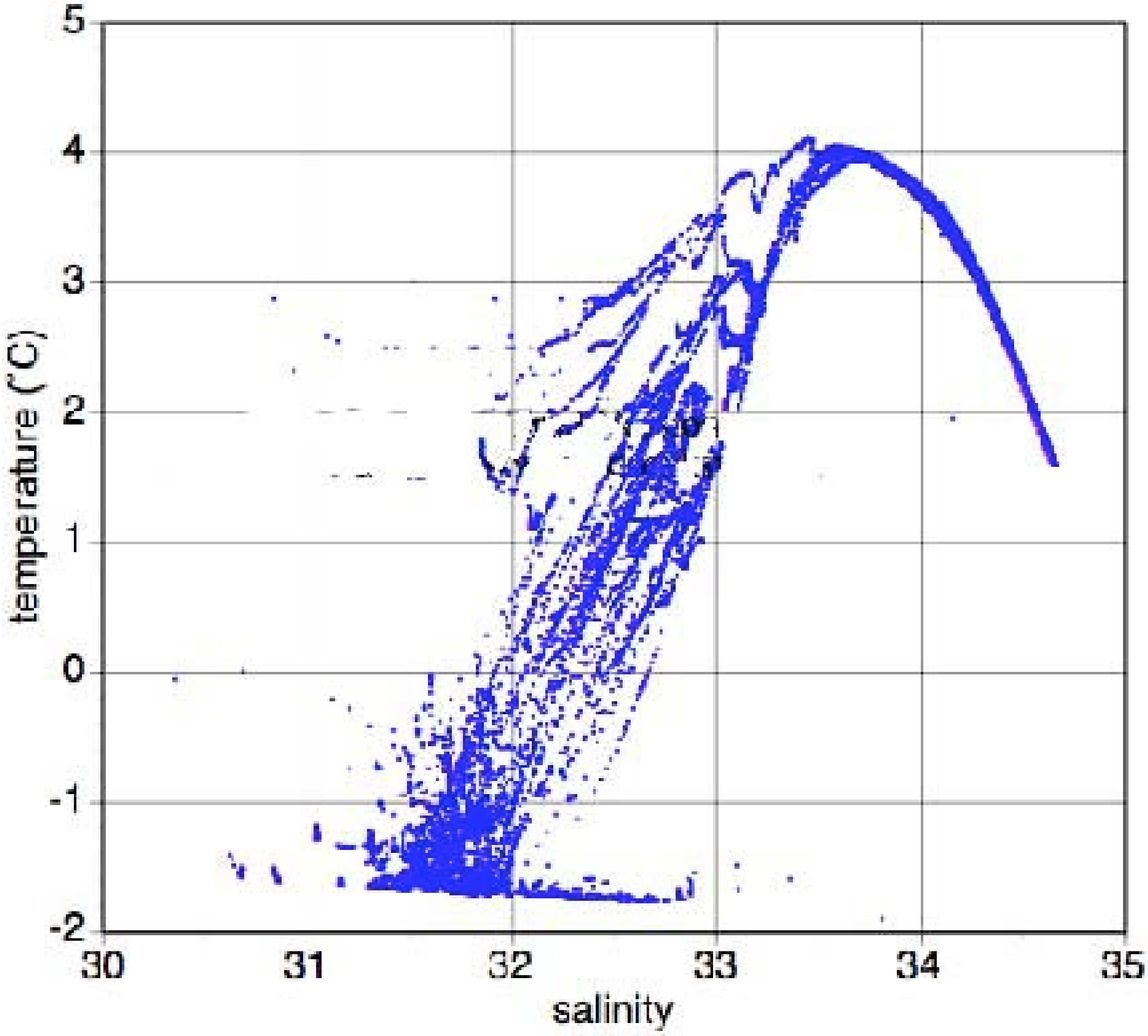


Fig. 18. Calibration curve for SBE 46 oxygen electrode.

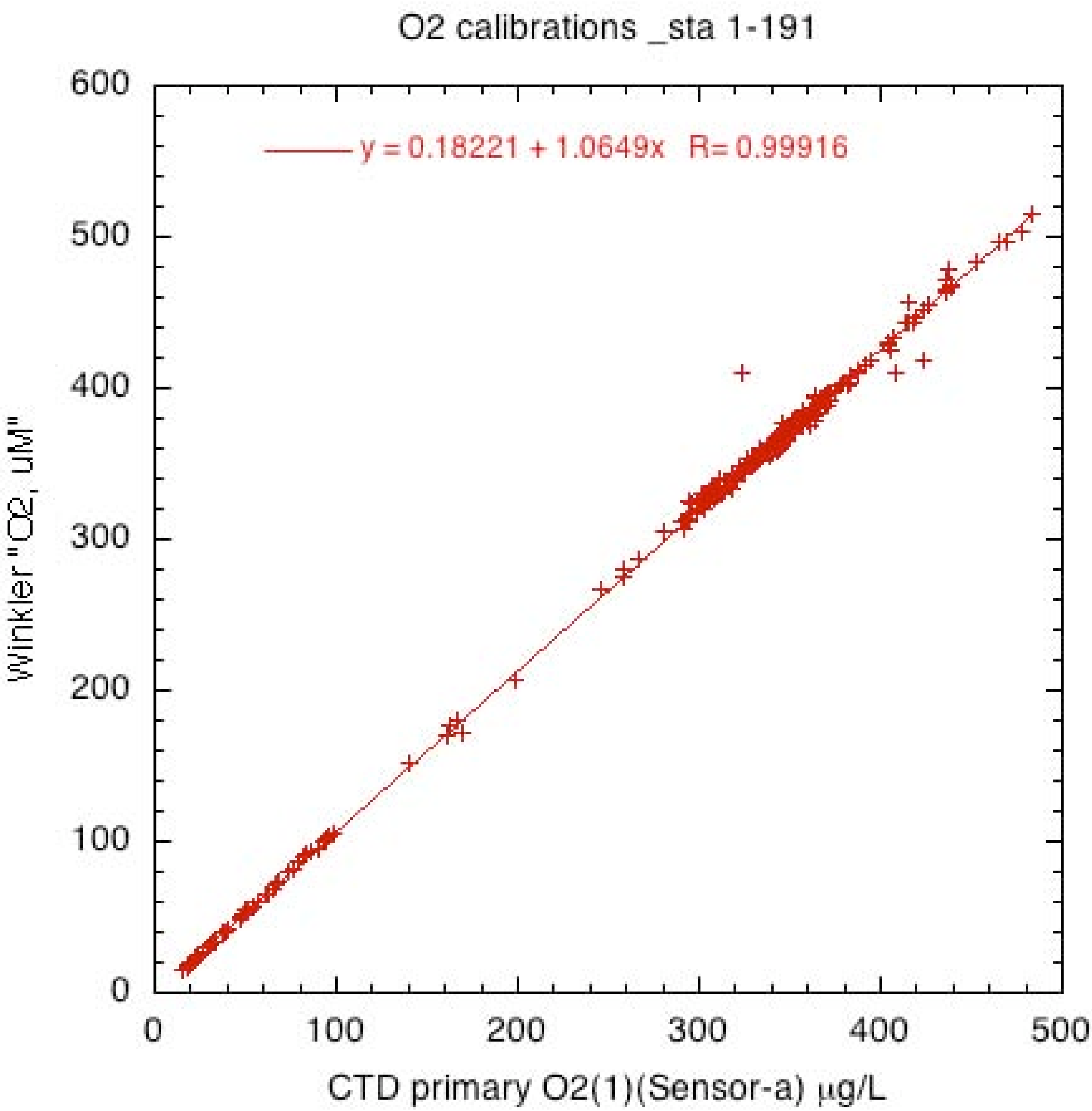


Fig. 19. Results of underway measurements of gases in surface water with the MIMS.

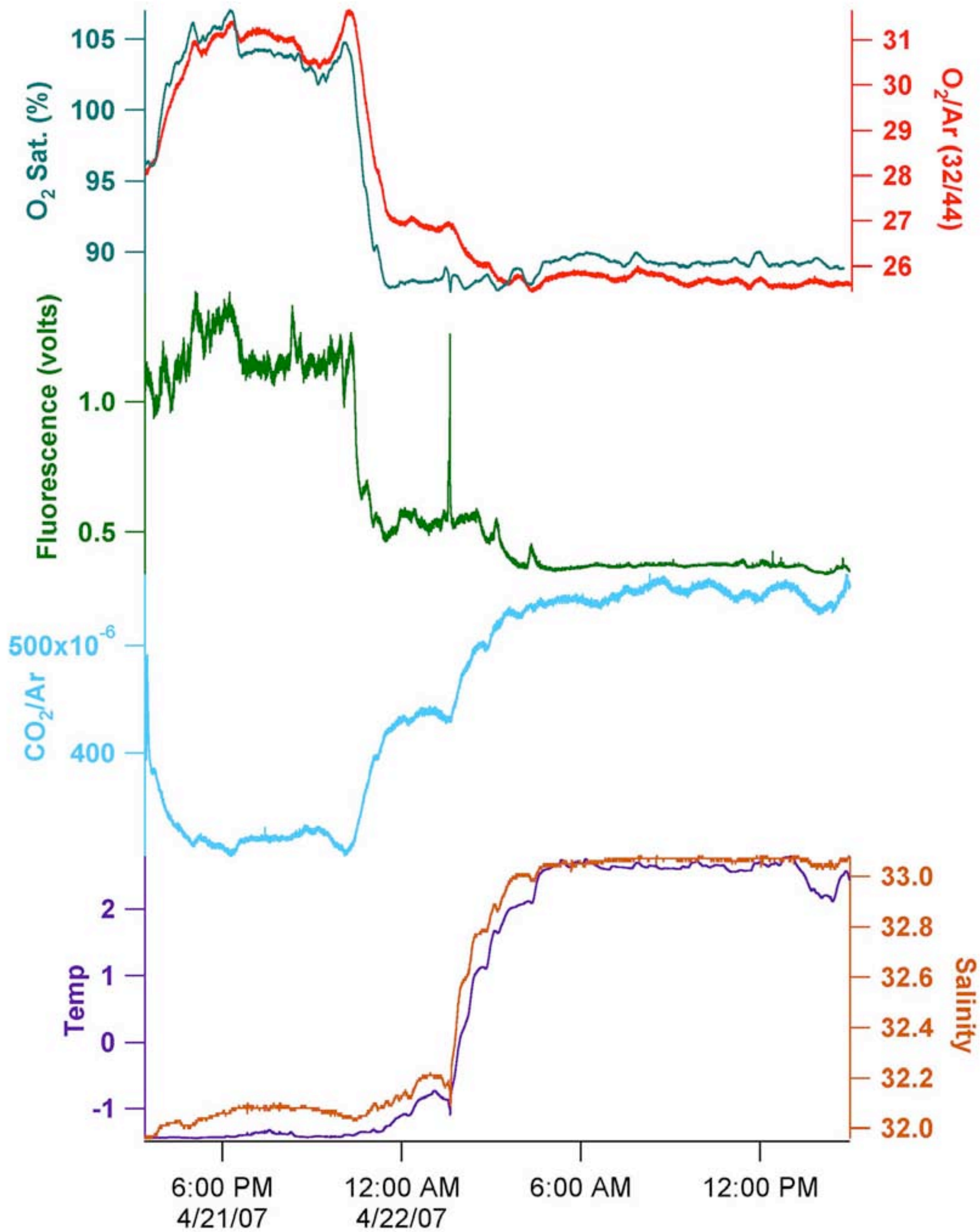


Fig. 20 . Track lines of helicopter flights used for marine mammal observations.

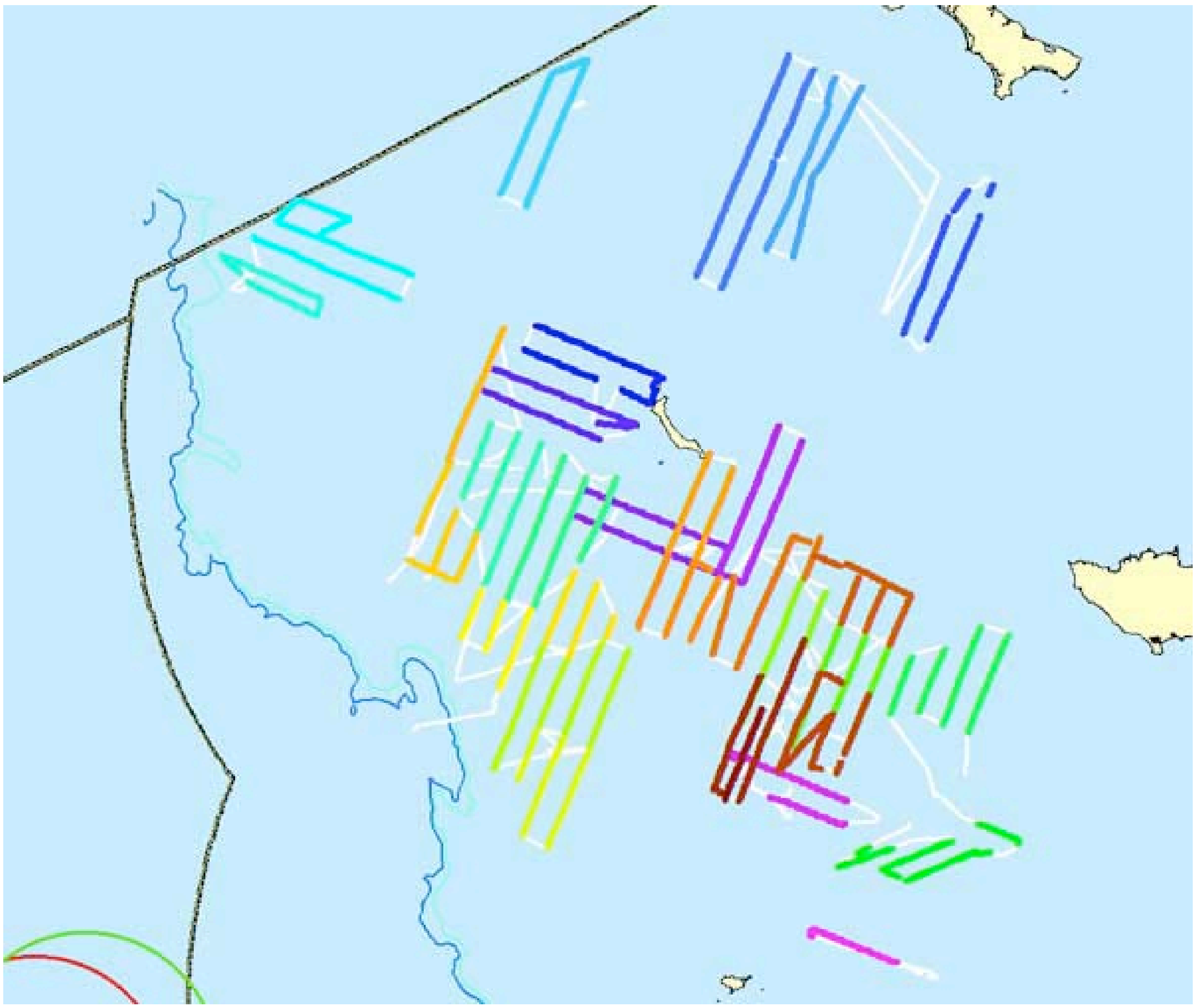


Fig. 21. Regions of survey effort for ice seals and marine mammals from bridge observations.