Physical and Chemical Data from the Beaufort Sea and Canada Basin, August 16 to September 5, 2002

F. McLaughlin, E. Carmack, M. O'Brien, J. Barwell-Clarke, G. Gatien, J. Harris, M. Itoh, G. Lichiota, K. Shimada, D. Sieberg, M. Steel, S. Toews, B. VanHardenberg, L. White, J. Smith, S. Zimmermann and M. Corkum

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Canadian Data Report of Hydrography and Ocean Sciences

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Regional and headquarters establishments of the former Ocean Science and Surveys sector ceased publication of their various report series in December 1981. A complete listing of these publications and the last number issued under each title are published in the *Canadian Journal of Fisheries and Aquatic Sciences*, Volume 38: Index to Publications 1981. The current series began with Report Number 1 in January 1982.

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Les établissements de l’ancien secteur des Sciences et Levés océaniques dans les régions et à l'administration centrale ont cessé de publier leurs diverses séries de rapports en décembre 1981. Vous trouverez dans l'index des publications du volume 38 du *Journal canadien des sciences halieutiques et aquatiques*, la liste de ces publications ainsi que le dernier numéro paru dans chaque catégorie. La nouvelle série a commencé avec la publication du rapport numéro 1 en janvier 1982.

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PHYSICAL AND CHEMICAL DATA FROM THE BEAUFORT SEA AND CANADA BASIN, AUGUST 16 TO SEPTEMBER 5, 2002

by

F. McLaughlin, E. Carmack, M. O'Brien, J. Barwell-Clarke, G. Gatien, J. Harris,
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ABSTRACT

McLaughlin, F., Carmack, E., O'Brien, M., Barwell-Clarke, J., Gatien, G., Harris, J., Itoh, M., Lichiota, G., Shimada, K., Sieberg, D., Steel, M., Toews, S., VanHardenberg, B., White, L. Smith, J., Zimmermann, S. and Corkum, M. 2009. Physical and Chemical Data from the Beaufort Sea and Canada Basin, August 16 to September 5, 2002. *Can. Data Rep. Hydrogr. Ocean Sci*. 181: vii + 223 p.

The physical and chemical water properties of the Canada Basin were measured during an expedition aboard the *CCGS Louis S. St-Laurent* from August 16th to September 5th, 2002 (Institute of Ocean Sciences Mission Number 2002-23). The objective of this cruise was to conduct a survey of the water mass distribution and composition across the southern Canada Basin and to observe the biological community structure found at three hydrographically different regions of the deep Canada Basin. Oceanographic data reported include conductivity-temperature-depth (CTD), salinity, dissolved oxygen, nitrate plus nitrite, silicate, orthophosphate, ammonium, halocarbons including CFCs, hexachlorocyclohexane, iodine and cesium radionuclides, oxygen isotope ratio, dissolved inorganic carbon, alkalinity, particulate organic carbon and particulate organic nitrogen, chlorophyll-a and phaeopigments. Sampling and analysis methods are described for all data reported here. Other samples collected during the expedition, not reported here, are also listed.

Résumé

McLaughlin, F., Carmack, E., O'Brien, M., Barwell-Clarke, J., Gatien, G., Harris, J., Itoh, M., Lichiota, G., Shimada, K., Sieberg, D., Steel, M., Toews, S., VanHardenberg, B., White, L., Smith, J., Zimmermann, S. and Corkum, M. 2009. Physical and Chemical Data from the Beaufort Sea and Canada Basin, August 16 to September 5, 2002. *Can. Data Rep. Hydrogr. Ocean Sci*. 181: vii + 223 p.

Les propriétés physiques et chimiques de l'eau du bassin Canada ont été évaluées lors d'une expédition à bord du NGCC *Louis S. St-Laurent*, du 16 août au 5 septembre 2002 (mission numéro 2002-23 de l'Institut des sciences de la mer). L'expédition visait à effectuer un relevé de la répartition et de la composition de la masse d'eau dans la partie sud du bassin Canada, et à observer la structure de la communauté biologique dans trois zones différentes sur le plan hydrographique, dans le profond bassin Canada. Les données océanographiques rapportées concernent la conductivité-température-profondeur (CTP), la salinité ainsi que la teneur en oxygène, en nitrates (et nitrites), en silicates, en orthophosphates, en ammoniaque, halocarbures, y compris les CFS, en hexachlorocyclohexane, en radionucléides de l'iode et du césium, le ratio des isotopes de l'oxygène, en carbone inorganique dissous, l'alcalinité, en carbone et en azote organique particulaire, en chlorophylle *a* et en phéopigments. Les méthodes d'échantillonnage et d'analyse sont décrites pour toutes les données présentées dans le document. D'autres échantillons prélevés au cours de l'expédition mais non traités dans ce rapport sont également mentionnés.

ACKNOWLEDGEMENTS

We would like to thank Captain Marsden, Chief Officer MacEwan and Boatswain Blinkhorn and the officers and crew of the *CCGS Louis S. St-Laurent* for their many and diverse skills that contributed to the success of our science program.

This work was jointly supported by the Natural Resources Canada Federal Panel on Energy Research and Development (PERD), the Ocean Climate Program (OCP), and Fisheries and Oceans Canada. Support was also provided through the collaboration with researchers from the Japan Marine Science and Technology Center (JAMSTEC) and the U.S. National Oceanic and Atmospheric Administration (NOAA).

1. INTRODUCTION

On August 14th, 2002, 46 scientists from Canada, Japan and the US joined the icebreaker *CCGS Louis S. St-Laurent* (*LSSL*) in Kugluktuk and began a 24 day, 2440 Nautical Mile expedition to survey waters in the deep Canada Basin (Institute of Ocean Sciences Mission Number 2002-23). A Search and Rescue operation took place in the Kugluktuk area from August 14th to 15th; the missing persons were located. The science program continued from August 16th to September 5th.

The Joint Western Arctic Climate Study (JWACS) is a bilateral research initiative (Canada and Japan) to study the Canada Basin of the Arctic Ocean. The principal agencies are the Japan Marine Science and Technology Centre (JAMSTEC) and the Canadian Department of Fisheries and Oceans Institute of Ocean Sciences (DFO-IOS). In 2002, the study was conducted simultaneously in both the ice-covered and ice-free zones of the southern Canada Basin in late summer. The scope was multi-disciplinary, embracing study of seabed geomorphology, physical oceanography, sea ice, tracer geochemistry and marine biology in the benthic, pelagic and epontic domains. Collaborators joined from university and other governmental agencies in Canada, Japan, USA and the UK (Appendix 4.1). Three ships were involved in JWACS in 2002: the RV *Mirai*, the *CCGS LSSL* and the *CCGS Sir Wilfrid Laurier* (*SWL*). The *Mirai* worked in the ice-free part of the study area, the *LSSL* in the heavy ice and the *SWL* along the interface between the two zones.

The science program aboard the *CCGS LSSL* was also a collaboration between DFO-IOS and the U.S. National Oceanic and Atmospheric Administration Ocean Exploration (NOAA) to investigate the composition of Canada Basin waters and to observe the biological community structure found at three hydrographically different regions of the deep Canada Basin. The objectives of the hydrographic survey were:

- to observe physical and geochemical properties across the southern Canada Basin,
- to determine changes in the extent and thickness of overlying Pacific-origin waters and changes in Atlantic-origin water properties,
- to investigate pathways of Pacific-origin inflow and
- to estimate boundary current transport rates.

A combination of conductivity-temperature-depth (CTD)/Rosette and Expendable CTD (XCTD) deployments provided data collection every 10 to 30 km along the section track. Moorings, both stationary and drifting, were deployed with instruments to record temporal changes in ice thickness, current speed and direction, temperature and salinity.

As little is known about life in the deep Canada Basin, the objective of the biology program was to collect data from three distinct regions of the basin:

- the deep Beaufort Sea, a topographically flat region, removed from the boundary current and downstream of Pacific and Atlantic-origin water inflow;
- the Northwind Ridge slope, a steeply-sloped region within the higher energy boundary current domain;
- and the Northwind Abyssal Plain, a shallower isolated sub-basin in the Chukchi Plateau region, downstream of Pacific-origin water inflow.

At these locations, productivity, pigment, bacteria and phytoplankton samples were collected from the ice and water column, plankton samples were collected from the upper water column using various nets, and sediment samples were collected by boxcore. Divers also collected under-ice biota and photographed the under-ice environment. A Remotely Operated Vehicle (ROV) was deployed, for the first time in the Canada Basin, to take video and photographs of life under the ice, throughout the entire water column and on the seafloor. As conditions allowed, ice sampling was conducted at locations along the cruise track. Because the ice was much thinner than expected, much of the ice-sampling program was conducted using the ship's Fast Rescue Craft (FRC).

The data assembled in the present report include the standard supporting oceanographic determinations of CTD profiles (including dissolved oxygen, light transmission and chlorophyll fluorescence sensor data) and bottle measurements for salinity, dissolved oxygen, nitrate plus nitrite, reactive silicate, orthophosphate, ammonium, halocarbons including CFC-11, CFC-12, CFC-113 and carbon tetrachloride (CCl_4), hexachlorocyclohexane (HCH), iodine and cesium radionuclides (^{129}I and ^{137}Cs), oxygen isotope ratio ($\delta^{18}O$), dissolved inorganic carbon, alkalinity, particulate organic carbon and particulate organic nitrogen, chlorophyll-a and phaeopigments. Other samples collected during the expedition, not reported here, are also listed.

1.1 FIELD WORK SUMMARY

Mission #2002-23 activities and accomplishments are listed below. Data summarized in this report are outlined in **bold font**.

All scientific objectives were completed, including:

- **Completed 44 CTD stations, 39 rosette casts and 73 XCTD casts in the Beaufort Sea and Canada Basin** to study sub-basin circulation.

- Collected PAR measurements at two stations.

- Collected 12 boxcore samples from Amundsen Gulf, the deep Beaufort Sea, Northwind Ridge slope and Northwind Abyssal Plain to estimate sedimentation rates and carbon fluxes.

- Collected three phytoplankton net tows, 12 small and 24 large bongo net tows in Amundsen Gulf, Beaufort Sea and Canada Basin to identify population constituents.

- Conducted 12 fine mesh live net deployments.

- Deployed one mooring in the deep Beaufort Sea for a two-year-long collection of samples to estimate seasonal productivity.

- Deployed three moorings for JAMSTEC: one JAMSTEC Arctic drifting buoy in the Canada Basin interior, one stationary mooring on the slope of the Northwind Abyssal Plain and one stationary mooring on the slope of the Northwind Ridge.

- Conducted eight ROV deployments to take video recordings and photographs of the under ice, water column and benthic environments.

- Conducted 5 ice camps to sample snow and ice and 6 dive team activities to collect under-ice biota, photograph and videotape the under-ice environment.

- Collected information on birds and mammals at and in-between science stations.

1.2 STUDY AREA

Figure 1 shows the cruise track with CTD/Rosette, XCTD, mooring, JCAD Ice Buoy and zooplankton net station locations during the 2002-23 mission. The locations for CTD casts were taken from the ship's GPS navigation system on the bridge. Table 10 in Appendix 4.2 provides a chronological list of CTD/Rosette station locations at the start of the cast as well as a summary of all other sampling activities conducted at each station. Where more than one cast was done at a station, separate coordinates are given for each cast. Figure 2 shows boxcore, ice, ROV and PAR station locations.

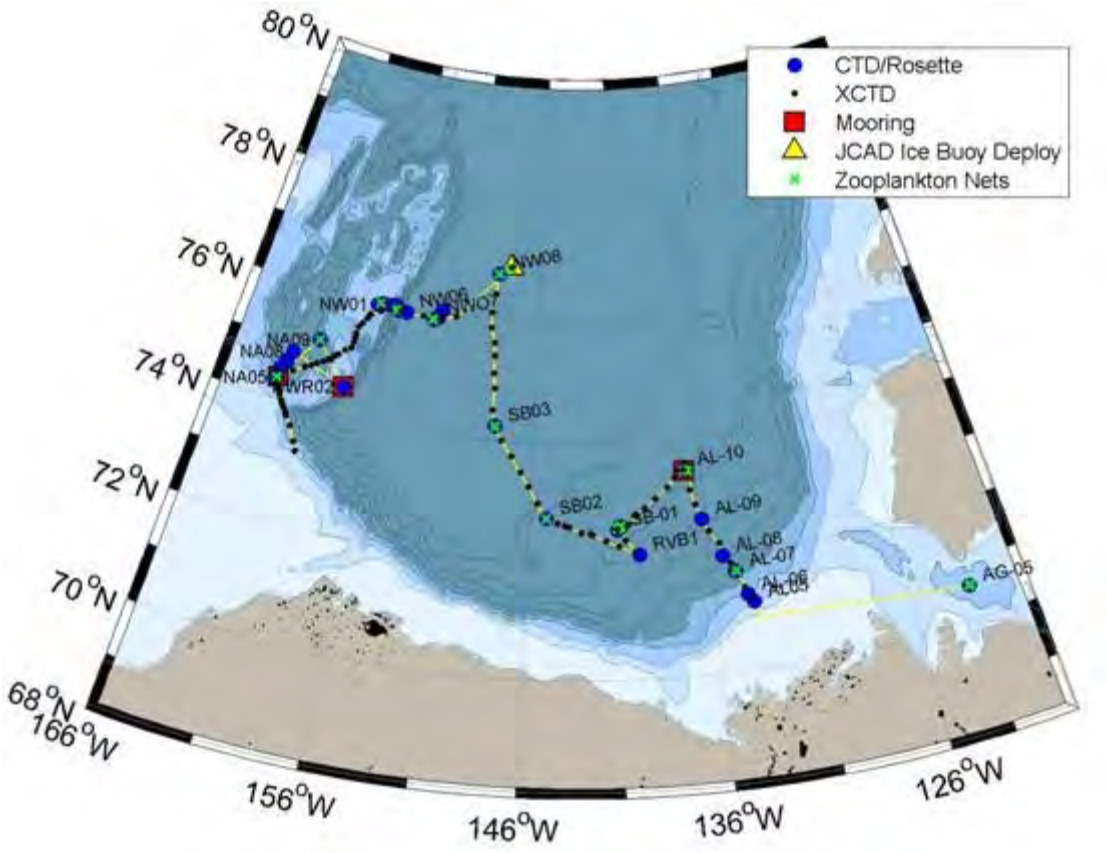

Figure 1. Mission 2002-23 CTD/Rosette, XCTD, mooring, JCAD Ice Buoy and zooplankton net station locations.

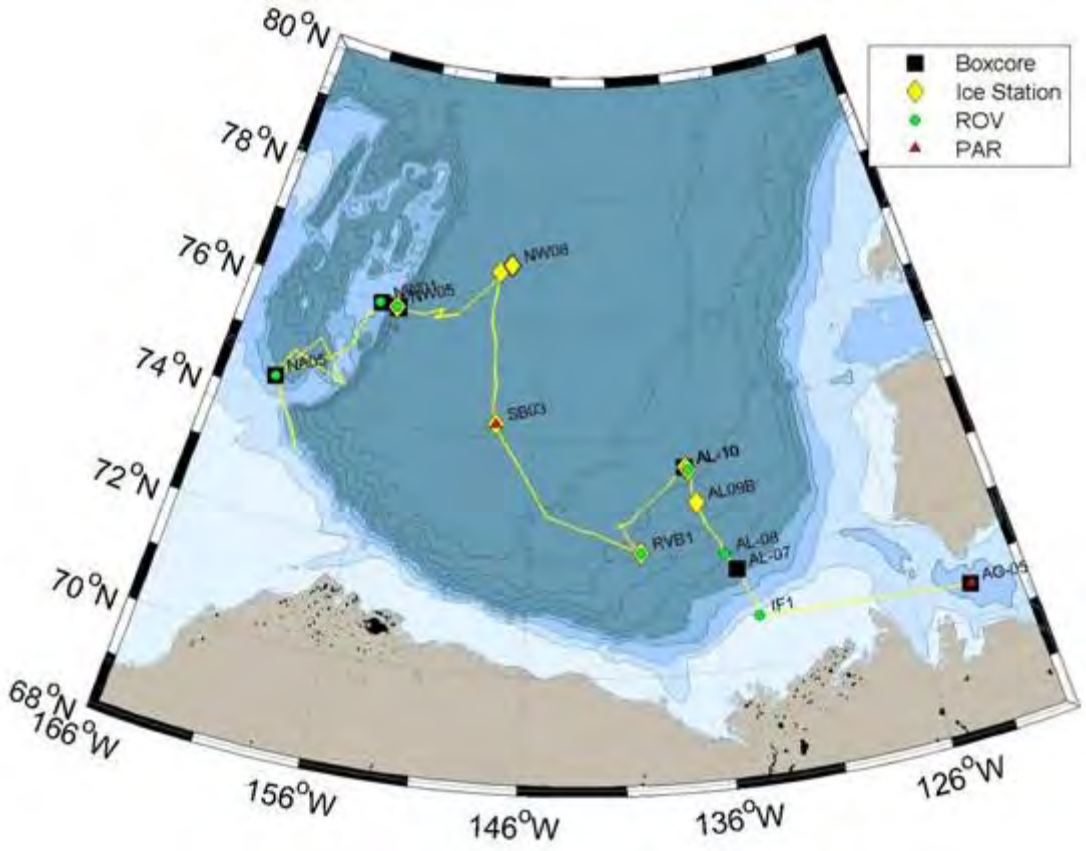

Figure 2. Mission 2002-23 boxcore, ice, ROV and PAR station locations.

1.3 RESEARCH PROGRAMS: OBJECTIVES & SAMPLE COLLECTION

Following is a summary of the research programs operating together with the CTD and water chemistry program during Mission 2002-23, including study objectives and sampling completed. For a summary of station locations and sampling activities see Table 10, Appendix 4.2.

1.3.1 Hydrography

PI McLaughlin, IOS

Team: B. Van Hardenberg, M. O'Brien, L. White, J. Barwell-Clarke, J. Harris, G. Lichiota, S. Toews and M. Steel (IOS); K. Shimada and M. Itoh (JAMSTEC)

Objectives

The primary objective of the research in 2002 was an improved understanding of the character and causes of variability and change in Canada Basin waters and to investigate the relationship between ocean, ice and atmosphere. The data of this program form the basis of this report; details are provided in the Methods and Analysis section and in the Appendices.

Water properties were surveyed to assist in the identification and mapping of five important components of the Canada Basin water column, in particular: river inflow, ice, Pacific-origin inflows and Atlantic-origin inflows via both Fram Strait and the Barents Sea. The balance between inflows from various sources and outflows establishes the present oceanographic climate of the Canada Basin, its ice cover and its biological productivity. One goal was to investigate the volume and distribution of Pacific-origin waters; another to investigate the distribution of oxygen and halocarbons (CFCs) in the Atlantic-origin lower halocline and Barents Sea Branch.

Yet another goal was to explore the physical properties of seawater deeper than the depth of the Alpha-Mendeleyev Ridge (about 2400 m). This deep water is isolated from the rest of the Canada Basin and has likely been in isolation for about 500 years. Hence, it is possible to detect the effects of geothermal heating from the seafloor. The bottom layer of water, which has a thickness of up to 1000 m, is completely mixed, likely by convection from this heating. Small changes in temperature of this well-mixed layer may indicate how long the water has been there and whether the geothermal heat remains in the deep layer or escapes through the top. Preliminary temperature measurements over the past 10 years indicate that most of the heat is indeed escaping – and by obtaining measurements on a basin-wide scale it may be possible to investigate how the geothermal heat is escaping and where.

Above the bottom layer, casts from previous Arctic expeditions indicate a striking "staircase" structure (about 300 m thick) in which there are well-mixed layers of water, or steps. Each step is about 40 m thick and differs by only a few millidegrees in temperature from the next. Data from CTD casts together with data from the mooring at AL10 will be used to investigate these staircase layers.

Publications

McLaughlin, F., Shimada, K., Carmack, E., Itoh, M. and Nishino, S. 2005. The hydrography of the southern Canada Basin, 2002. Polar Biol. **28**(3):182-189.

Timmermans, M.-L., Melling, H. and Rainville, L. 2006. Dynamics in the deep Canada Basin, Arctic Ocean, inferred by thermistor-chain time series. *Journal of Physical Oceanography*. **37**(4): 1066-1076. doi: 10.1175/JPO3032.1.

Timmermans, M.-L. and Garrett, C. 2006. Evolution of the deep water in the Canadian Basin in the Arctic Ocean. *Journal of Physical Oceanography.* **36**(5): 866-874.

1.3.2 Moorings

PIs Melling (IOS), Timmermans (UVic) – AL10; and Shimada (JAMSTEC; CHP02, NWR02, J-CAD)

Team: D. Sieberg (IOS), D. Huntley (IOS/UD); H. Uno, T. Kikuchi and H. Sumata (JAMSTEC)

Objectives

Instruments deployed on moorings measured the following oceanic properties over 12-24 months: temperature, salinity, current and acoustic back-scattering (related to zooplankton abundance). Locations of IOS and JAMSTEC mooring deployments are reported in Table 1. See Figure 3 for AL-10 mooring diagram and Figure 4 for J-CAD buoy diagram.

Table 1. Summary of mooring deployments.

Station	Date	Latitude (°N)	Longitude (°W)	Deployments
AL-10	8/22/2002	73 28	137 00	Mooring – 3000 m
C6BN	8/28/2002	76 53	148 03	J-CAD
CHP02	9/3/2002	74 22	162 06	Mooring – 1480 m
NWR02	9/4/2002	74 29	158 00	Mooring – 1550 m

Mooring at Station A (IOS)

A mooring was deployed in deep (3000-m) water in the Beaufort Sea and was operational for two years before recovery. The primary purpose of the mooring was to support an IPS and an ADCP for ice-thickness monitoring. The IPS and ADCP were located at 50-m and 100-m depth, respectively. A tandem release-transponder assembly was included below the ADCP to facilitate precise location of the top of the mooring at recovery. These releases could be activated to recover the important instruments at the top of the mooring if the single release at the seabed was inoperable.

The mooring also included an Aanderaa RCM9 sonic current meter at 500-m depth, provided by Jamstec (Shimada), and a Brancker thermistor chain at 2625 m depth, provided by University of Victoria (Timmermans, Garrett, Dewey). A vertical line of temperature recorders (a string of thermistors and temperature loggers) was deployed at station AL10 as part of the anchored mooring. These precise instruments will provide continuous readings of temperature in the bottom and staircase layers for two years and allow for the investigation of the staircase layers.

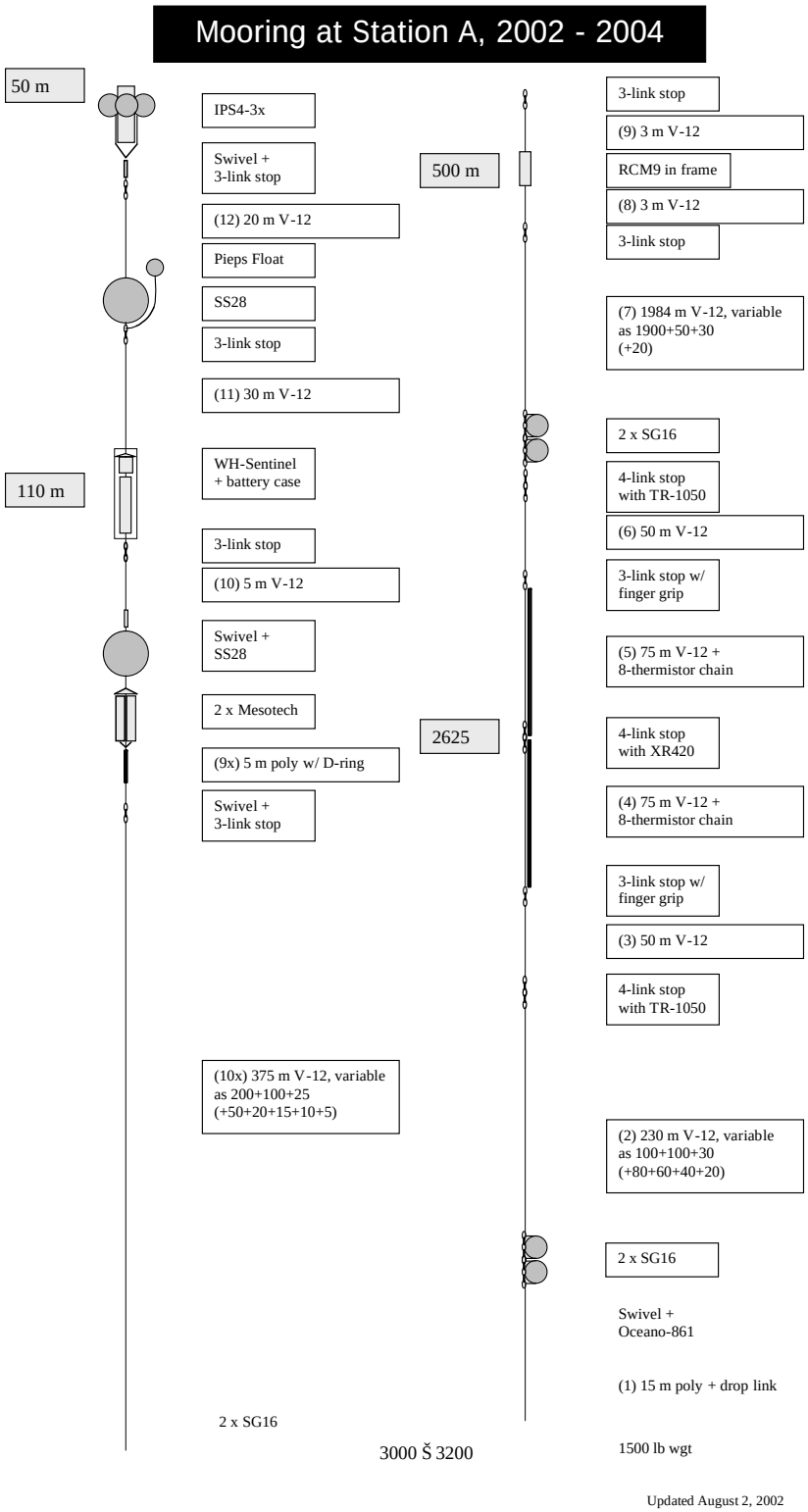

Figure 3. Mooring diagram for Station AL-10.

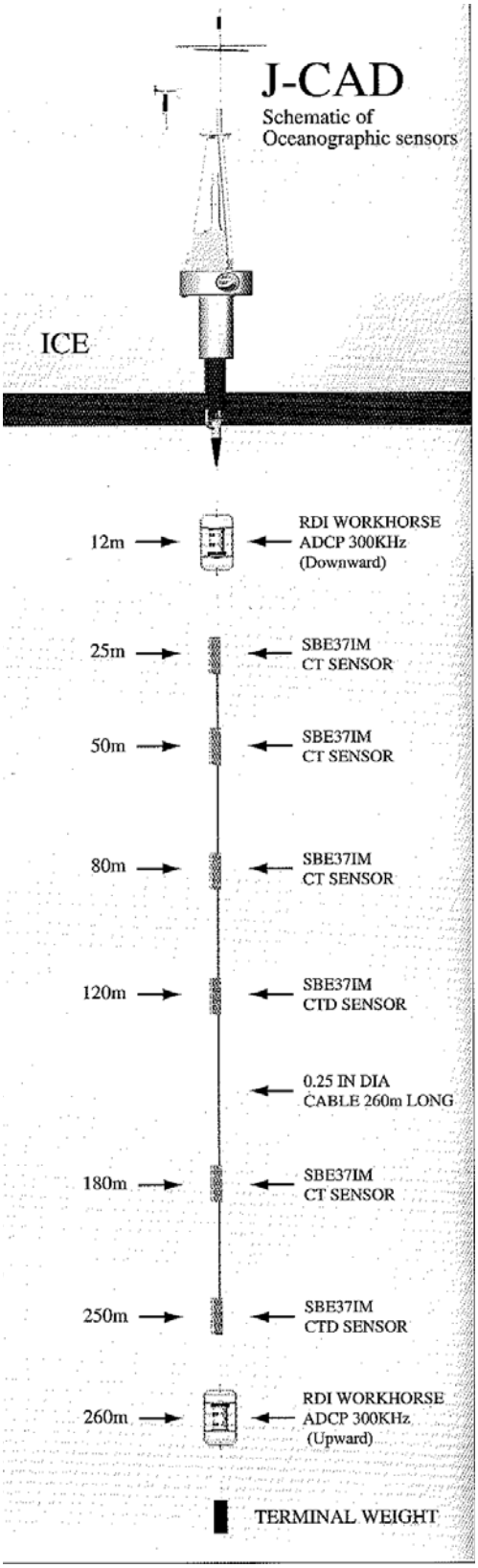

Figure 4. Diagram of J-CAD (JAMSTEC Compact Arctic Drifter) buoy deployed at station C6BN.

1.3.3 Sea-Ice Biota

PI Gradinger, UAF

Team: B. Bluhm (UAF), G. Plumley (UAF), Q. Zhang (PRC)

Objective

The objective of this study was to investigate the composition of marine communities related to sea ice. In the Arctic, about 50% ($7 \cdot 10^6$ km^2) of the winter sea ice melts during the summer. The remaining summer sea ice has unique characteristics with respect to its temperature, salinity and porosity. A specialised so-called sympagic community has adapted to the variable conditions of the ice environment and exists year round associated with the sea ice. A unique, partially endemic fauna, mainly comprising several amphipod species, thrive permanently at the underside of the ice floes. Moving along the bottom of the ice they feed on the ice bottom community and use larger brine channels and crevasses as shelter against predators. Studies on Arctic sea ice communities are an urgent issue not only because of the small amount of published data but also due to the observed and predicted substantial loss of ice over the last and coming decades.

On ice sampling

Sampling was conducted at nine stations with sampling times of ~1 to 4 hours at each station. See Table 10 in Appendix 4.2 for a summary of station locations and sampling activities. Sampling efforts were divided into two major components: (a) sampling on the ice and (b) sampling under the ice by divers. At four locations sea ice was sampled by means of ice coring; all other locations were sampled with the help of the dive team of the National Geographical Society/DFO Canada. On ice sampling was conducted in joint co-operation with the plankton/nutrients working group of Whitledge (Section 1.3.6).

On ice sampling turned out to be a difficult enterprise on this cruise. Ice floes were small and thin and were covered with melt water puddles at about 40 to 60%. The ice-breaking vessel could rarely position itself close enough to the ice to allow a safe transport of scientists and equipment onto the ice. Most study efforts were, therefore, conducted using an FRC (fast recovery craft).

Fast recovery craft transporting scientists and equipment onto the ice.

Ship regulations limited the number of scientists working simultaneously on the ice to four. In addition, sampling time was restricted by ship operations, so that fewer samples than expected were collected. All ice core samples were collected in the period August 19 to 27, 2002.

On ice sampling included the collection of water from melt ponds and brine holes as well as coring 5 to 8 ice cores per station. The top, one intermediate and the bottom section (each 15 cm in length) of the ice cores were collected and brought back to the ship for melting.

In situ primary production experiments were conducted on three ice floes with melt pond water and brine in conjunction with Whitledge's group using stable isotopes (^{13}C, $^{15}NO_3$). Whitledge also conducted PAR light measurements below the sea ice with our LICOR 4π light sensor as well as under-ice water sampling with our small water sampler. A YSI85 temperature and salinity probe was lowered through the core holes to study the hydrography in the top 15 m of the water column below the sea ice.

Sampling by divers

Sampling by divers was conducted at 8 stations. First, video transects of ~ 30 m in length were recorded while the diver swam approximately 30 cm from the ice. A PVC pipe attached to the camera housing provided a scale as well as consistent distance from the ice. The recordings were made on a MiniDV system and were used to estimate abundances and diversity of under-ice amphipod fauna. The divers also recorded the occurrence and abundance of arctic cod (*Boreogadus saida*) in the range of their visibility along the edges of the ice floes.

Ice related fauna was collected in two size fractions (>200 µm, 20-200 µm) using an under-ice suction hose driven by an on ice pump and filtration system developed specifically for that purpose. In addition, 4 L of non-concentrated under-ice water was collected for cell counts and chlorophyll measurements.

Under-ice sampling by divers.

Analysis of collected material

Brine, melt pond water and melted ice sections were analyzed onboard for algal pigment composition by HPLC, algal activity (PAM fluorometry; Table 2) and salinity. Subsamples were preserved for algal counts. Unpreserved meiofauna samples were sorted and counted using a dissecting scope. Representatives of all metazoan groups were imaged using a video camera and photographic equipment provided by Dr. Hopcroft. Further analysis in the home lab focused on stable isotope composition (^{13}C, ^{15}N), particulate organic carbon, particulate organic nitrogen, and the structure of the algal and meiofaunal communities. Part of the material was provided to Chen Bo for his study of bacterial species composition. Station time was sufficient only once to lower a small video camera through a core hole and record two hours of under-ice video. Specimens from the under-ice pump as well as several zooplankton taxa were stored deep-frozen for later analysis of lipids and fatty acids.

Table 2. Summary of ice station samples collected.

Date	Station	Depth/type
18/08/2002	AL07	50 m
		75 m
19/08/2002	AL09	62 m
19/08/2002	Ice Station 1	melt pond water
		under ice water 1
		brine
		under ice water 2
20/08/2002	Ice Station 2	melt pond water
		under ice water
		brine
21/08/2002	AL10	55 m
		30 m
		17 m
		10 m
19/08/2002	Ice Station 1	top 15 cm
		mid 55-70 cm
		bottom 15 cm
21/08/2002	Ice Station 3	melt pond water
		brine
		under ice water
23/08/2002	SB01	75 m
		50 m
		25 m
		10 m
24/08/2002	Ice Station 4	melt pond water
		under ice water

Date	Station	Depth/type
24/08/2002	Station ROV	55 m
26/08/2002	SB03	50 m
		48 m
		25 m
		14 m
		8 m
26/08/2002	Ice Station 5	melt pond water
		under ice water
26/08/2002	Ice Station 5	MPW for experiment white
		MPW for experiment black
27/08/2002	Ice Station 6	melt pond water
		under ice water
27/08/2002	Ice Station 7	melt pond water
		Brine
28/08/2002	Ice Station 8	melt pond water
		under ice water
27/08/2002	Ice Station 7	top 15 cm
		mid 55-70 cm
		bottom 15 cm
30/08/2002	NW06	75 m
		46 m (chl-a max)
		25 m
		10 m
		5 m
03/09/2002	NA05	75 m
		46 m (chl-a max)
		25 m
		5 m
04/09/2002	NWR02	75 m
		40 m (chl-a max)
		25 m
		5 m
04/09/2002	NA09	75 m
		45 m (chl-a max)
		25 m
		5 m

Preliminary Observations

No visible coloration of the sea ice by algae or sediment was detected at any location during the entire cruise. Melt ponds covered between 40 to 70% of the surface of the ice floes and the puddles were partially refrozen. Ice floes sampled by ice coring varied in thickness from 1.6 m to more than 4 m.

Measurements on algal photosynthetic parameters with the PAM fluorometer were hampered by the low algal biomass in many samples. Reliable data were collected from melt ponds and brine and will be compared with measurements from phytoplankton communities in the water column chlorophyll-*a* maximum layer (about 40 to 60 m depth). No reliable measurements were possible for most surface water samples as the algal fluorescence was too low.

Preliminary data was collected on the abundance of metazoan animals within and below the sea ice. The sea ice meiofauna consisted mainly of turbellarians, nematodes and harpacticoid copepods. Diversity was low with each of the three groups represented by one species. Total abundance was less than 100 individuals per liter melted sea ice, and the occurrence was restricted to the lowermost 15 cm of the ice floes. Several female copepods had egg sacks indicating reproduction during the late arctic summer. The collected specimens will be used for species identification. Single individuals were fixed in 70% ethanol for later RNA analysis.

Amphipods caught by the divers either directly or with the suction pump belonged to the species *Apherusa glacialis*, *Onisimus spp.* and *Gammarus wilkitzkii*. For *A. glacialis* and *G. wilkitzkii*, both adult animals and juveniles were present. One female *G. wilkitzkii* released a total of 32 juveniles from her marsupium within several days in a tank onboard the ship. The video transects of the first stations (02/08/19, 02/08/20) showed very low abundances of amphipods. Only single specimens of *G. wilkitzkii* were recorded which were either hiding under thin platelets of ice or were free moving along the ice surface. Recordings from the more westerly stations revealed higher abundances of amphipods of all three species. Recordings are of sufficient quality to distinguish adult individuals of *Onisimus* and *Apherusa*. After an initial observation of the occurrence of Arctic cod in gaps along the edges of the ice floes, later systematic surveys proved that this species uses this habitat for resting and/or hiding.

This study documented that algal and animal biomass within the summer sea ice is low in the Canadian Basin. Representatives of all major taxa, however, which are known from studies in the transpolar drift, were encountered. At this point in the analyses, the most interesting and novel ecological findings are (a) the observed reproduction of copepods and amphipods in late summer (rather than in the spring), and (b) the so far unknown use of a spatial niche in melting summer sea ice by the polar cod, *Boreogadus saida*. A detailed study on the ecological significance of this supposedly critical cod habitat within the life cycle of offshore cod would be a challenging and important topic for future investigations. Under-ice amphipods and polar cod are the most important links of carbon from the sea ice to the water columns and higher trophic level and, therefore, deserve special attention.

Sampling for sea ice community study.




Clockwise from top left: Channel of water between walls of ice; Arctic cod, Boreogadus saida, in a gap along the edge of a floe; Under-ice amphipod Apherusa glacialis; Under-ice amphipod Gammarus wilkitzkii.

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1.3.4 Pelagic Biota

(PI Hopcroft, UAF)

Team: M. Vecchione (NMNH), K. Raskoff (MBARI) and J. Purcell (WWU) in collaboration with J. Nelson (UVic)

Objective

The objective of this study was to explore zooplankton communities in the Canada Basin using a combination of techniques including large (57 cm diameter; 236 µm mesh) and small (23 cm diameter; 50 µm mesh) bongo nets routinely deployed to 100 m depth, live net hauls (mesh size 60 µm), SCUBA divers collecting in the surface waters, and the Remotely Operated Vehicle (ROV) to reach depths of up to 2800 m. For details on ROV operations see benthic biota sampling description below (Section 1.3.5).

Sampling and preliminary observations

Jellyfish and kin

Many gelatinous organisms were documented throughout the cruise track (Table 12, Appendix 4.7). The living specimens were photographed and preserved for further documentation and for molecular identification. Video, digital still camera records, and specimens of many gelatinous species were obtained from the ROV during 2 test dives, 2.5 pelagic dives and 2.5 benthic dives. The various taxa were layered in the water column, with ctenophores and large scyphomedusae predominating in surface waters, siphonophores at 350 to 400 m, and mesopelagic medusae mostly below 1000 m.

The scyphomedusae *Chrysaora melanaster* observed by the ROV.

Cephalopods and other mollusks

All ROV dives, both pelagic and benthic, were monitored from launch to recovery for observations of cephalopods. None were seen.

Zooplankton tows were examined for specimens of thecosome and gymnosome pteropods. Live specimens were photographed and tissue was preserved in ethanol for future phylogenetic studies of the Thecosomata.

This, of course, does not mean that there are no cephalopods in the Canada Basin because the volume of water searched by the ROV was small, due to time restraints. Given the very low abundances of all types of organisms studied during the cruise, it is not surprising that predators such as cephalopods are few and far between. However, many fishes were sometimes encountered, particularly in the North Wind Basin, indicating that within the habitats with numerous fishes the ecological importance of cephalopods appears to be low.

Zooplankton tows were examined for specimens of thecosome and gymnosome pteropods. Only a single specimen of gymnosome (naked pteropod) was found, a larval *Clione limacina* which was photographed through the dissecting microscope. One species of thecosome (shelled pteropod), *Limacina helicina*, was collected in low numbers. Live specimens were photographed and tissue was preserved in ethanol for future phylogenetic studies of the Thecosomata.

The pteropod *Limacina helicina*

Other gelatinous groups (pelagic tunicates, chaetognaths & polychaetes)

The pelagic tunicates were only represented by several species of larvaceans; the absence of salps and doliolids is unusual in comparison to other oceans. The large-bodied larvacean, *Oikopleura vanhoeffeni* (tentative ID), was present in low number in all nets and appeared to occur through much of the water column based on observations from the ROV. The specimens collected were at variance in some respects to the formal description and this shall be pursued post cruise. At the first station, a tail of what appears to be a *Bathochordaeus* species was located in the sample (to be confirmed by molecular techniques) and on the last ROV a house was observed consistent in structure with this genus. These represent the first observation of this genus in the Arctic. The small larvacean *Fritillaria borealis typica* was observed in later collections.

Low numbers of chaetognaths, almost entirely comprised of *Eukrohnia hamata,* occurred in all nets and were observed throughout the water column by the ROV. During the cruise we discovered that the species lays an egg sack that is held in a marsupium until hatching.

Crustaceans

Net hauls were dominated in terms of biomass by adults of the copepod *Calanus hyperboreus,* that appeared to be concentrated in the upper 100 m.

Summary

Because a rich set of observations on deep benthic fishes was assembled during this cruise, efforts will be made to coordinate with the systematic ichthyology community, both at the US National Museum and elsewhere, to identify the species observed based on video and digital-still photographic records. Only a single specimen of gymnosome (naked pteropod) was found, a larval *Clione limacine*, which was photographed through the dissecting microscope. One species of thecosome (shelled pteropod), *Limacina helicina*, was collected in low numbers.

The large-bodied larvacean, *Oikopleura vanhoeffeni* (tentative ID), was present in low number in all nets and appeared to occur through much of the water column based on observations from the ROV. The specimens collected were at variance in some respects to the formal description and this will be pursued. At the first station a tail of what appears to be a Bathochordaeus species was located in the sample (to be confirmed by molecular techniques) and on the last ROV dive a house consistent in structure with this genus was observed. These represent the first observation of this genus in the Arctic. The small larvacean *Fritillaria borealis typica* was observed in later collections.

Low numbers of chaetognaths, almost entirely comprised of *Eukrohnia hamata,* occurred in all nets and were observed throughout the water column by the ROV. During the cruise we discovered that the species lays an egg sack that is held in a marsupium until hatching.

In most oceans, several species of pelagic polychaets are routinely present in plankton net collections. With the exception of a few meroplanktonic forms, they were not present in any of the collections, nor observed from the ROV.

As expected, there were no surprises in terms of the crustacean zooplankton.

Several species of the predatory copepod *Euchaeta* were also prominent. In terms of abundance, small species of copepods dominated, most notably the genus *Oncaea*, followed by *Oithona similis* and *Mormonilla sp.* The importance of these smaller species is not currently appreciated. Between one and two dozen other copepod species were observed, but at least one genus reported to be abundant in the arctic, *Pseudocalanus*, was only rarely observed in the samples. One species of shrimp, *Hymendora glacialis,* was colleted by the nets and the ROV. A total of four species of amphipods were encountered, the deeper water species (as yet unidentified) was readily attracted to the lights of

the ROV, allowing easily collection specimens by the ROV's suction sampler. A single species of ostracod occurred commonly in the plankton net collections.

Ctenophores were present in surface waters (<20 m) throughout the cruise track. Large scyphomedusae (*Chrysaora melanaster*) were usually present in surface waters (<50 m), and one *Cyanea sp.* was seen. Physonect siphonophores (*Nanomia cara* tentative id) were observed at depths corresponding to the intrusion of Atlantic water at 350 to 400 m depth. Calycophoran siphonophores were also observed, but definitive identification has not been made yet. Some of these species may be new records for the Arctic. Mesopelagic scyphomedusae (*Atolla tenella* tentative id) were extremely numerous at 1100 to 1500 m depth. This may be the highest abundance ever observed of this genus.

Hydromedusae were the most numerous gelatinous species, occurring abundantly below 1000 m. The trachymedusae were the most abundant order, accounting for 4 of the 5 species observed with the ROV. *Sminthea arctic* was found over a very wide depth range (500 to 1607 m) while *Botrynema ellinorae* and *Aglantha digitale* were observed in the upper 500 m. Numerous trachymedusae were seen on or just off the bottom at the first benthic site. These specimens appeared to be a species of *Crossota*, but a detailed view or collection could not be made. One specimen of a narcomedusae was collected with the ROV in the first pelagic dive. It appears to be a new species, distinct in its three stomach pouches, four tentacles and, most importantly, presence of secondary tentacles on the margin of the bell. This species is unrecorded from this region and preliminary work suggests it is new to science.

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Stein, D.L., Felley, J.D. and Vecchione, M. 2005. ROV observations of benthic fishes in the Northwind and Canada Basins, Arctic Ocean. *Polar Biol.* **28**(3): 232-237, doi: 10.1007/s00300-004-0696-z.

1.3.5 Benthic Biota

(PI Bluhm, UAF)

Team: C. Debenham (UAF), K. Iken (UAF) and I. MacDonald (TAMU)

Objectives

Benthic communities below the photic zone (i.e. greater than about 300 m depth) depend in general on food supplied from the water column. In high latitudes, growth and survival of deep-sea benthic organisms in the Arctic is constrained by the flux of food particles to the bottom rather than the low water temperature *per se*. In addition to the supply of organic carbon from the water column, down-slope transport of organic carbon along the bottom boundary layer occurs at the margins of the Arctic basins. The objectives for this work related to the benthos in the deep Canadian Basin were as follows:

- Identify habitats, species diversity/composition, abundance and biomass of major components of the deep benthic fauna in the Canadian Basin and adjacent continental slope using Remotely Operated Vehicle (ROV) *in situ* imaging in conjunction with analysis of ROV and box core samples.
- Investigate the food web structure of the benthic community using stable isotope analysis, gut content analysis, and ROV *in situ* imaging.
- Investigate trophic links between the benthic, pelagic and ice-associated food webs of the deep Arctic Ocean, using stable isotope analysis.
- Measure levels of pollutants to assess the anthropogenic impact on this remote basin.
- Evaluate skeletal remains in the benthos for possible long-term climate records.

Stations occupied and samples collected

The box core and ROV stations sampled by the benthic team were distributed along the overall cruise track of the *LSSL* in stations selected from among the overall suite of cruise stations (Figure 2). Constraints on sampling occurred due to logistic difficulties encountered during the course of a multidisciplinary program. In addition, malfunctions and lack of spare parts for the coring winches limited the number of box cores taken and the depth of the stations that could be cored. Fortunately, sufficient samples were collected to provide preliminary comparisons among several geographic locations.

Samples were collected for the following analysis at shore-based labs: stable isotopes (calcium carbonate and lipids removed prior to analysis); persistent organic pollutants in tissue and sediment; total organic carbon; total inorganic carbon; and sediment grain size.

Shipboard methodology and sample processing

(a) Box coring

A 50 x 50 cm box core with a spade closure was used to collect samples of benthic sediment (Figure 5). The corer was deployed from an A-frame on the starboard bow of the *LSSL*. Station depth was measured with an Elac echosounder. A tilt-activated, acoustic pinger mounted on the spade arm gave a continuous indication of the depth of the corer and provided confirmation that the core had successfully tripped on the bottom. A numbered marker made of buoyant plastic and reflective tape was attached to each core and was rigged so it would be released when the spade arm closed.

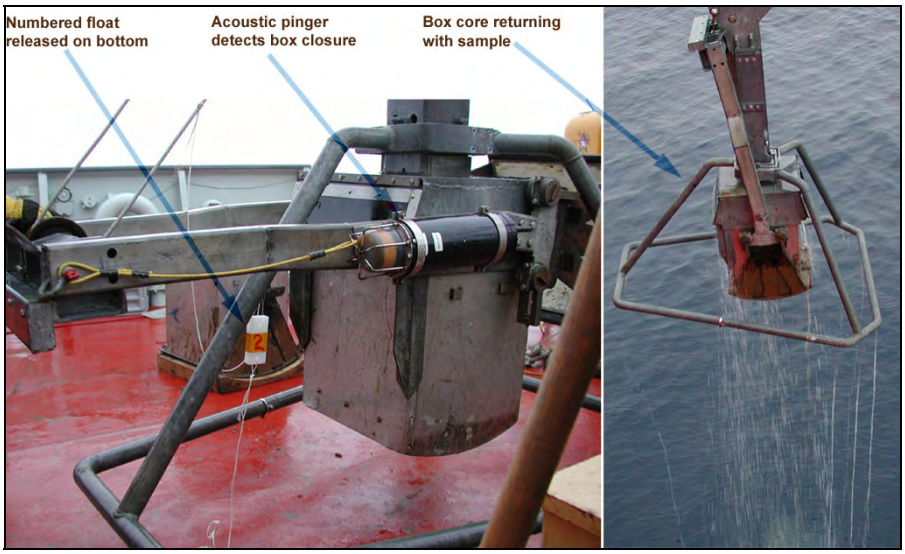


Figure 5. Deck shots of box corer used to collect benthic samples. Left: corer on deck in cocked position. Right: core recovered with spade arm closed.

Upon recovery to the deck, the box cores were photographed and described in a log that noted the color, apparent grain size, and other features. Each box core was sub-sampled for a quantitative macrofauna sample (20 x 20 cm), a quantitative meiofauna sample (2 x 50 cc syringes) and tissue samples (remaining organic surface layer). In addition, various surface sediment samples were taken for analyses of bacteria, foraminifera, carbon dating etc. Figure 6 shows how the recovered materials were divided among different sampling programs. The quantitative macrofauna and tissue samples were sieved through 250 µm and 500 µm sieves, respectively.

Table 3 summarizes the details of box core sampling. Note that subsamples were taken for ancillary investigators in all of the cores.

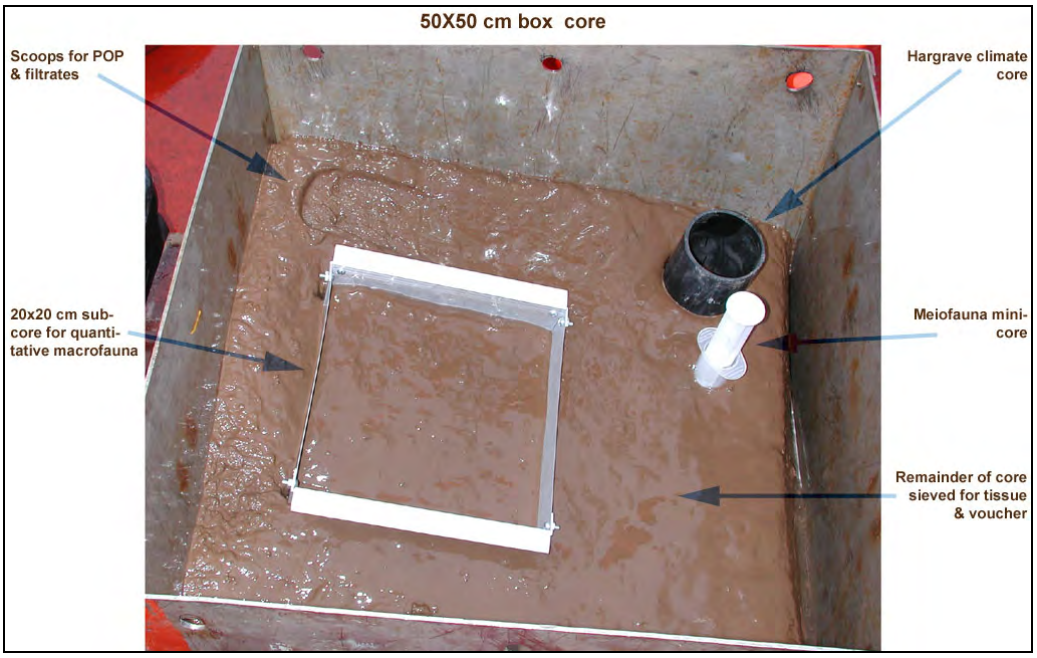


Figure 6. Subsampling of box core. Subcore was sieved with 250 µm mesh; remainder with 500 µm mesh.

Table 3. Box core samples.

Station	Core	Depth	Description	Samples Collected		
				Quant macro	Quant meio	Tissue
AG05	1	625	Silt over clay, light tan, 15d 70% filled, surface water lost	yes	Yes	yes
AL07	1	1568	Foraminiferan ooze-silt over clay, 10d angle, surface water lost	yes	Yes	hardly any
AL10	1	3250	Silt over clay, silt ca. 3-7 cm, 60-70%	yes	Yes	no (too little)
AL10	2	3250	Silt over clay, silt ca. 3-7 cm, 40cm out of 55cm	yes	Yes	no (too little)
NW05	1	ca 2000	Surface water, gastropod shells, hair?, coarse with rocks	yes	Yes	no (too little)
NW05	2	1850	Surface water, anemone, hexactinnelid on rocks	yes	Yes	no (too little)
NW05	3	1850	Surface water, rock with calcareous tubes and cnidarian tubes	yes	Yes	no (too little)
NW01	1	800	60%, slight angle, 2-3 cm organic over clay, surface water	yes	Yes	no (too little)
NA05	1	1350	Soft, liquid mud, 5-7 cm, ophiuroid, 60%	yes	Yes	some
NA05	2	1350	Soft, liquid mud, ca 5 cm, worm tubes, 70%, water still on	yes	Yes	some
NA05	3	1350	Same, some water	yes	Yes	some
6 St.	11 cores					

Quantitative samples were preserved in 4% formaldehyde-seawater solution while tissue samples were sorted on ice for voucher specimens as well as stable isotope and pollutant samples. Several stations were so low in biomass and/or did not have sufficient replicates to provide any tissue samples. At stations where sufficient material was present, specimens were so small that several complete individuals were in most cases pooled to obtain sufficient mass. Reference for the benthic food web will be phytoplankton and ice algae produced in the euphotic zone. Water and ice samples for this purpose were filtered onto pre-combusted glass-fiber filters in cooperation with the sea ice group (Dr. Gradinger et al.). Organisms from the pelagic realm, to be used for stable isotope based food web and pollutant analyses, were kindly provided by the pelagic group (Dr. Hopcroft et al.) from their net tows.

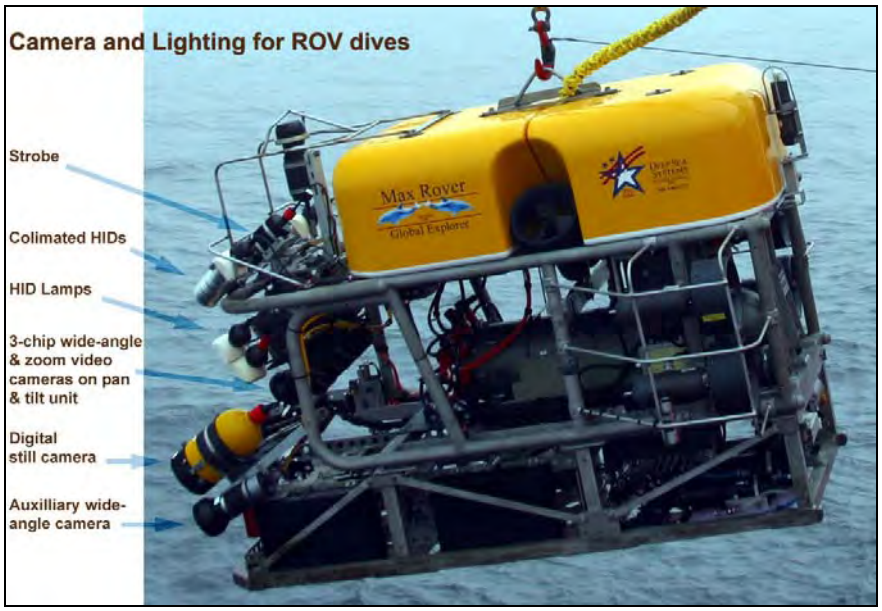
(b) Remotely Operated Vehicle Operations

The Deep Sea Systems ROV was used to photograph and observe the benthic environment. Three formal benthic surveys were completed with the ROV system during the cruise. A test dive reached the bottom at the beginning of the cruise, but did not complete useful survey. During each dive, the ROV was essentially dragged along track as the ship moved either under power or with wind and current. The ROV pilot would endeavor to keep the ROV oriented so that cameras could image the bottom without disturbing the sediments. Cameras comprised the following:

1) 3-chip, wide angle video camera
2) 1-chip, zoom video camera
3) 1-chip, compact video camera
4) Canon G1 digital still camera

Lighting and camera configurations were modified during each dive. Generally flood lighting was supplied by a bank of four HID lamps, augmented as needed with quartz lamps. Strobe lighting for the digital still camera was supplied by ~50 watt-sec flash mounted on the upper bar of the ROV. The cameras were mounted to accommodate anticipated dive objectives prior to each dive. Figure 7 shows the final camera and lighting configuration. For dive 4, the digital still camera was mounted on the pan and tilt unit and the auxiliary wide-angle camera was aimed straight down from a mounting on the lower left corner of the ROV. For dive 5, the auxiliary wide-angle camera was removed. For dive 6, the digital still camera was moved to a fixed mounting on the lower left corner and set at an angle of 30°. For dive 7, the final dive, the auxiliary wide-angle camera was mounted below the digital still, also at a 30°angle.

Table 4 summarizes the details of the benthic ROV dives. Because outputs from two video channels were recorded, the lengths of tapes recorded for a dive exceed the total dive time. Video tapes recorded during the benthic ROV dives are listed in Table 5.



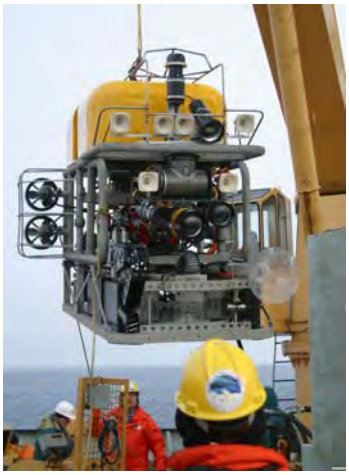


Figure 7. Camera and lighting configuration for ROV dive 7.

Table 4. ROV dive locations.

Station	Activity	Dive no. (depth m)	Date	Time in midwater (hrs)	Time on bottom (hrs)	Midwater photos	Benthic photographs
IF1	Test	1 (surface)	17/8/02	uncertain	n/a	n/a	n/a
AL08	Test	2 (~100)	18/8/02	n/a	n/a	n/a	n/a
AL10	pelagic	3 (2800)	22/8/02	8	n/a	n/a	n/a
RVB1	benthic	4 (2760)	24/8/02	1	3	n/a	348
NA05/4	combined	5 (1800)	31/8/02	7.5	0.5	250	33
NW01	combined	6 (800)	1/9/02	3	1.5	72	145
NA05	combined	7 (1380)	5/9/02	3.5	3.2	99	327

Table 5. List of video tapes recorded during ROV dives.

Station	ROV Dive	Tape no.	Time	Date	Depth (m)
AL10	4	A1	908	Aug-24-2002	surface
AL10	4	A2	1009	Aug-24-2002	2760
AL10	4	A3	1110	Aug-24-2002	2760
AL10	4	A4	1211	Aug-24-2002	2850
AL10	4	A5	1311	Aug-24-2002	2850
AL10	4	A6	1412	Aug-24-2002	2850
AL10	4	A7	1512	Aug-24-2002	
AL10	4	A8	1615	Aug-24-2002	1300
AL10	4	A9	1718	Aug-24-2002	surface
AL10	4	AA1	1117	Aug-24-2002	2850
AL10	4	AA2	1216	Aug-24-2002	2850
AL10	4	AA3	1317	Aug-24-2002	2850
AL10	4	AA4	1418	Aug-24-2002	2850
NW01	4	Rov 5 Benthic edit	1241	Aug-31-02	1850
RVB1	6	Benthic2 1	1623	Sept-1-2002	
RVB1	6	Benthic2 2	1724	Sept-1-2002	
RVB1	6	Benthic2 3	1825	Sept-1-2002	
NA 05	7	Rov7 4 4	1540	Sept-5-2002	1350
NA 05	7	Rov7 4 5	1642	Sept-5-2002	1350
NA 05	7	Rov7 4 6	1743	Sept-5-2002	1350
NA 05	7	Rov7 4 7	1844	Sept-5-2002	1350

During dive 4, a limited amount of sediment was collected with the suction sampler. This device was rendered inoperative during dive 5 and subsequent attempts to collect specimens by other means were unsuccessful. A fish trap was deployed with the ROV on dive 4, but it had to be jettisoned when it fouled the camera system.

The general plan of the dives was to take photos whenever the ROV was close enough to the bottom for effective lighting. There was no attempt to randomize the photography; conspicuous animals, burrows, and other features were actively targeted for photography. Dives continued until scheduling issues or meal times required termination. None of the benthic dives was terminated due to technical problems with the ROV.

Dives 5 and 6 were helpful in completing the characterization of a site with coarse sediments and relatively few infaunal species. Whereas the boxcores from the NW05/4 and NW01 sites were relatively depopulated, the ROV imaging revealed a diverse community of epifauna associated with cobbles and small boulders.

Dive 7 was particularly successful in terms of combined ROV and box-coring operations. The three cores were completed efficiently prior to the launch of the ROV. The camera and lighting configuration proved adequate for successful imaging of mobile and sessile fauna. The ROV was able to find the site of one box core number 3 by sighting the reflective marker (Figure 8). This novel observation provided a confirmation that the box core was a representative sample of the benthic environment.

Back in the shore-based lab, the photographic material was evaluated with respect to species identification, abundance and distribution, species associations and habitat description (sediment, rocks, lebensspuren etc.).

Figure 8. Marker and box core imaged by ROV during dive 7.

A selection of images of conspicuous fish species is shown in Figure 9; Figure 10 shows a similar collection of invertebrates.

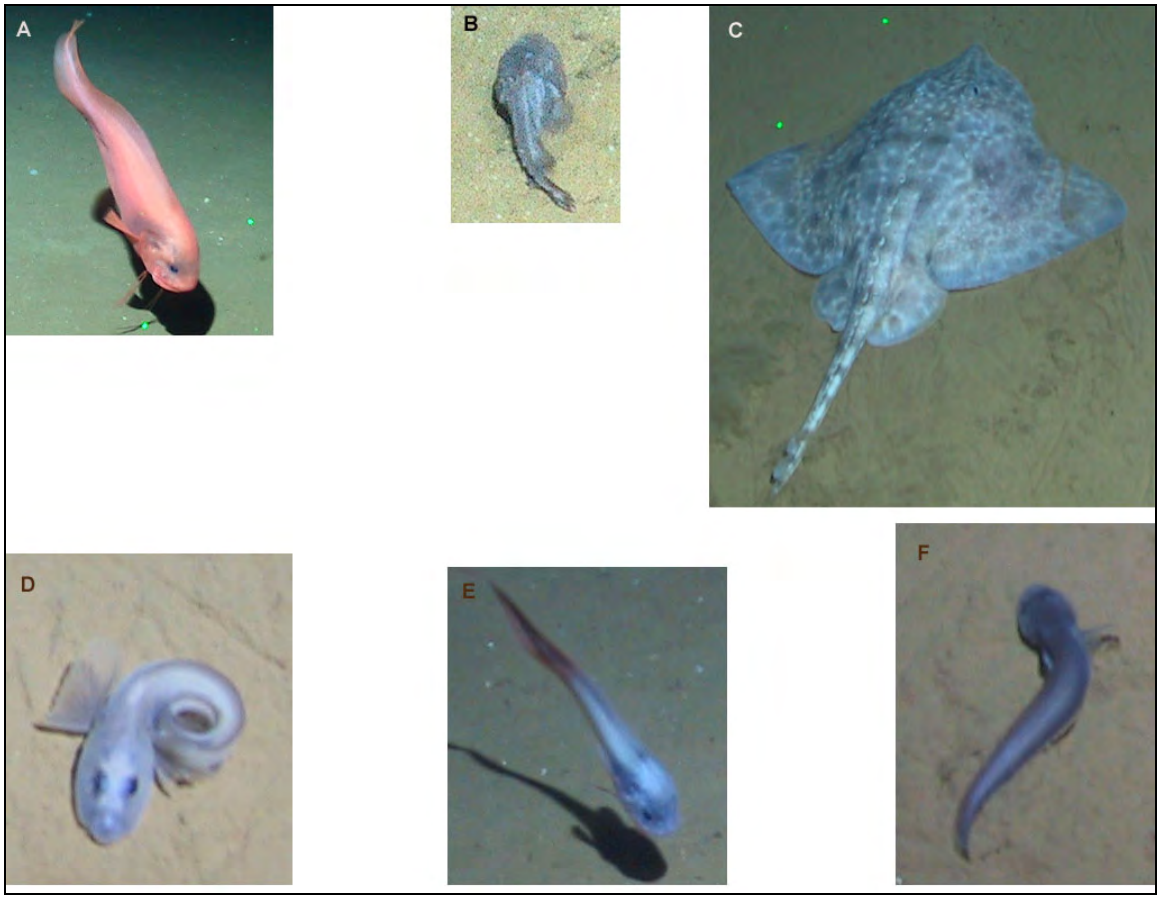


Figure 9. Fish photographed during ROV dives: A) snail fish; B) sculpin C) skate; D-F) three views of common eel pout.

Figure 10. Invertebrate species imaged by ROV: A) stalked cnidarian; B) polychate with overlapping scales; C & H) common isopod and linear trail; D) octocorals; F) anemone; I) tunicate; J) ophiuroid; K) swimming polychaetes; L) crinoid; M) asteroid (buried).

Preliminary conclusions

Macrofauna abundances and species richnesses were low, but appeared to vary significantly among stations. Sediment grain size was a constraint on macrofaunal abundance and richness at the Northwind Ridge stations, where sand and gravel comprised a major component of the sediments.

The dominant infaunal taxa were as follows: polychaetes, crustaceans (cumaceans, amphipods, isopods, tanaids; eastern Canadian basin), and bivalves. Our results as the dominant infauna are consistent with publications from the Eurasian Arctic deep sea.

The dominant epifauna taxa were as follows: crustaceans (shrimps, amphipods), fish, polychaetes (mobile in western Canadian basin, sessile in eastern basin), anemones and tunicates (western basin). Noteworthy differences between the western/eastern basin include the following: higher energy environment on western slope, more rocks, less lebensspuren, coarser sediment, more suspension feeders, eastern side: low energy, lebensspuren persist for long time, more deposit/opportunistic feeders.

Paleontology observations included otoliths on North Wind Ridge slope (2000 m), large number of other dead remnants such as bivalve, gastropod and scaphopod shells. These accumulations were not found in other stations and are consistent with information suggesting that this region is a frontal boundary between water masses of Pacific and Atlantic origin. The collection is also noteworthy because of the possibility that the calcareous remains can be carbon dated and analyzed for ^{18}O. If this proves possible, the collection could provide a record of water mass characteristics during recent geologic time.

Publication

Bluhm, B.A., MacDonald, I.R., Debenham, C. and Iken, K. 2005. Macro- and megabenthic communities in the high Arctic Canada Basin: initial findings. *Polar Biol.* **28**(3): 218-231, doi: 10.1007/s00300-004-0675-4.

1.3.6 Primary Productivity

PI Whitledge, UAF

Team: S.H. Lee (UAF)

Objective

The Arctic is currently changing at a very rapid rate. Higher temperatures have decreased the amount of ice cover in the Arctic Ocean over the past 40 years and have produced more open water, especially in coastal areas. It is unclear how this change from extensive ice cover to mostly open water will affect phytoplankton and, consequently, the other organisms that depend on them for food. Open water phytoplankton communities may differ from under-ice communities and may not be as nutritious or palatable. There have already been satellite observations that indicate currents are bringing organisms called coccoliths into the Arctic Ocean from the Bering Sea but it is not known whether these coccoliths are growing in the Arctic waters. We hope our measurements will provide data to be compared to future samples which will answer some of these questions.

All animal life in the ocean requires food to eat in order to grow and reproduce. Phytoplankton are microscopic, single-celled primary producers that form the base of the food chain supporting life in the Arctic. Phytoplankton float suspended in the seawater with the highest concentrations generally near the surface where the sunshine is most abundant. Phytoplankton grow rapidly for only a short time during the Arctic summer when nutrients are plentiful and daylight hours are long, with nearly continuous sunlight that can penetrate the patches of open water.

The objective of this study was to conduct *in situ* primary production experiments using stable isotopes (^{13}C and ^{15}N tracers) in order to determine phytoplankton biomass and growth rates.

Samples collected and methodology

Carbon and nitrogen productivity was determined at 13 locations during the cruise, three of which were ice stations. A hole was drilled through the ice to obtain water samples from various depths below. An ice drill cut a hole 4 inches in diameter through as much as 14 feet of ice. Drilling location was chosen based on ice thickness, i.e. ice greater than 4 feet thick and less than 15 feet thick. When the drill broke through the bottom of the ice, water flooded the hole to within a few inches of the surface. Samples were collected by lowering a water sampler through the hole down to the desired depth. The sampler was a plastic pipe that closed on both ends when a messenger was dropped down the rope. Samples were collected from a few inches below the bottom edge of the ice to depths as great as 100 feet below the ice.

Small amounts of ^{13}C and ^{15}N tracers were added to the water in order to measure phytoplankton growth with a mass spectrometer. The sample bottles were then tied to a rope with a weight at the bottom and lowered to the depth where they were originally collected in order to maintain normal temperature and light levels for 3 to 6 hours.

When it was not possible to sample from the ice flow or suspend the bottles in situ, rosette samples were obtained at the surface and the light and dark bottles were incubated in an ice-filled pool in full sunlight. The rope and sample bottles were removed from the ice hole or pool at the end of the incubation period. The final step in the field process was filtration of the water and phytoplankton through a micropore filter. The phytoplankton particles were

retained on the filter which was gently dried and analyzed in a mass spectrometer after combustion to determine the quantity of carbon, nitrogen and chlorophyll pigments contained in the water sample as well as the quantity of carbon and nitrogen that the phytoplankton absorbed during the incubation period.

Publication

Lee, S.H. and Whitledge, T.E. 2005. Primary and new production in the deep Canada Basin during summer 2002. *Polar Biol.* **28**(3): 190-197, doi: 10.1007/s00300-004-0676-3.

1.3.7 Microbiology

There were two separate microbiology programs conducted on this cruise, one from the University of Washington and one from Polar Research Institute of China. They are described separately below.

University of Washington
PIs D. Allen & J. Deming (UW)

Team: C. Bo (PRC)

Objectives

The primary goal of this study was to collect a variety of different sample types in order to enrich for, isolate, and bring into culture novel microorganisms that are adapted to extremely cold (psychrophiles), saline (halophiles), and high pressure (barophiles) environments. Water samples were obtained from the deepest cast possible to profile microbial abundance in terms of absolute counts (AODC - acridine orange direct counts), and the abundance of Archaea, Bacteria and the *Colwellia* (from the Bacteria group). Finally, water samples were collected from the deep site for genetic analysis (DNA). The diversity of the microorganisms at NW-08 was catalogued by looking at the genetic signatures of all organisms present. By combining novel culturing techniques with genetic tools, the aim of this research was to obtain novel organisms and understand the community context they came from.

Sampling methodology/shipboard processing

The most fundamental part of our sampling effort was the maintenance of a low temperature environment for all sample processing and storage; this was achieved by working in a cold room. AODC samples were collected by adding a fixative solution to an aliquot of sample. These samples were taken back to the laboratory and stained with DAPI, a DNA-staining compound, in order to quantify the number of cells per milliliter of a given sample directly from the environment before processing.

Samples for FISH (fluorescent in-situ hybridization) analysis were taken from the deep cast at NW08 from the rosette. The shipboard process involved filtering a given volume of sample and fixing it with a combination of paraformaldehyde and ethanol. The samples were taken back to the laboratory where oligonucleotide probes for Bacteria, Archaea, and *Colwellia* (Bacteria) were applied to them. This test provides information about the types of microorganisms present and their abundance. Samples from a suite of eight depths were collected from the cast in order to produce a water column profile in terms of those parameters as well.

Sterivex samples were also taken on board the ship. On-board processing involved filtering a large volume of water through a 0.2-µm filter unit, applying a buffer solution and storing it frozen. Ultimately DNA was extracted

from the filter unit, describing the entire microbial community present at the time of sampling.

The culturing effort was an attempt to apply novel isolation techniques to traditional samples in order to culture microorganisms that are uniquely adapted to environmental extremes such as high salinities, high pressure and low temperature. This end was achieved by utilizing a high pressure incubation apparatus that created hydrostatic pressures mimicking those of the deepest parts of the global ocean. In order to select for organisms adapted to high salinity environments, samples were incubated with highly saline brine solutions prepared in the laboratory before the cruise. Additionally, a number of different media types were utilized in order to selectively enrich for organisms that produce extracellular polysaccharides, extracellular enzymes, and degrade polycyclic aromatic hydrocarbons as well as standard microbiological media such as 2216 marine broth and tween 80. See Table 6 for a summary of samples collected.

Table 6. List of samples collected.

Station	Depth	Sample Type (live net, CTD, etc)	Sample Number	Notes
AL-07	N/A	Sea Ice Brine	1	Culturing
AL-08	N/A	Melt Pond	2	Culturing
AL-09	N/A	Under Ice Water	3	Culturing
AL-07	500m	Larvacean, Live Net	4	Culturing
AL-10	N/A	Brine	5	Culturing
AL-10	N/A	Melt Pond	6	Culturing
AL-10	N/A	Under Ice Melt Pond	7	Culturing
AL-10	N/A	Brine Sample	8	Culturing
SB01	500m	Net Tow, Fecal Pellets	9	Culturing
SB01	200m	Fecal Pellets	10	Culturing
SB01	100m	Fecal Pellets	11	Culturing
SB01	1000m	Fecal Pellets	12	Culturing
SB01	500m	Larvacean, Live Net	13	Culturing
NW08	3400m	Rosette	N/A	AODC, DNA, FISH
NW08	3000m	Rosette	N/A	AODC, DNA, FISH
NW08	2500m	Rosette	N/A	AODC, DNA, FISH
NW08	2000m	Rosette	N/A	AODC, DNA, FISH
NW08	1000m	Rosette	N/A	AODC, DNA, FISH
NW08	500m	Rosette	N/A	AODC, DNA, FISH
NW08	100m	Rosette	N/A	AODC, DNA, FISH
NW08	~42m, Chlmax	Rosette	N/A	AODC, DNA, FISH
NW08	3400m	Rosette	14	Culturing
NW08	3000m	Rosette	15	Culturing
NW07	1500m	Net Tow	16	Culturing

Polar Research Institute of China
(PI Chen Bo)

Team: K. Crane (NOAA), C. Lovejoy (ICM), D. Allen (UW), J. Deming (UW)

The NOAA funded oceanographic research expedition in the Canada Basin during summer of 2002 provided us with a good opportunity to conduct the field work plan of the CAA (Chinese Arctic and Antarctic Administration) funded research project. The project research plan involved shipboard sampling, pre-processing of seawater, sediment and sea-ice samples, subcultivation of bacteria, and follow-up laboratory efforts to analyze the 16S rDNA sequences of marine bacteria by PCR amplification and DGGE fingerprint. The overall goal was to study the molecular and phylogenetic analyses of whole communities of marine bacteria in the area of Canada Basin.

Water column samples were collected from the CTD/Rosette at 8 Stations (AL06, AL10, SB01, SB02, SB03, NW08, NW01, NA08) listed in Table 7. The samples were filtered onboard and stored at -80 °C.

In addition, 4 brine samples from 4 ice stations, 2 sub-ice water samples (divers), 1 sea ice core sample and 7 surface sediment samples (by box corer) from 5 stations will be analyzed for bacterial DNA and 16S rDNA sequences at the laboratory in China.

Table 7. Bacterial DNA sampling locations.

STATION	ACTIVITY	Latitude (°N)	Longitude (°W)	DATE	SAMPLING
AL-06	CTD Rosette	71 17	134 15	18/8/02	Bacterial DNA analysis
AL-10	CTD Rosette	73 30	136 59	20/8/02	Bacterial DNA analysis
SB-01	CTD Rosette	72 33	141 00	23/08/02	Bacterial DNA analysis
SB-02	CTD Rosette	72 44	145 02	25/08/02	Bacterial DNA analysis
SB-03	CTD/rosette - deep	74 14	148 22	26/08/02	Bacterial DNA analysis
NW-O7	CTD Rosette - deep	75 53	153 07	8/29/2002	Bacterial DNA analysis
NW01	CTD Rosette-deep	75 58	156 51	9/2/2002	Bacterial DNA analysis
NWR02	CTD Rosette-deep	74 49	161 38	9/4/2002	Bacterial DNA analysis

1.3.8 Inuvialuit Wildlife

PI Harwood, DFO Western Arctic Area, Yellowknife

Team: J. Illasiak (Box 33, Paulatuk, NT) and J. Alikamik (Box 10, Holman, NT)

J. Illasiak and J. Alikamik, wildlife monitors.

Objectives

Both J. Illasiak and J. Alikamik were hired as wildlife monitors by the Department of Fisheries and Oceans to record observations of marine mammals and birds during Mission 2002-23.

Wildlife watches

Watches took place for 2 hours in the morning, 3 to 4 hours in the afternoon and 2 hours in the evening from "Monkey's Island" (elevation of 70 feet). If the weather was good for making observations, the watch period was extended. If the weather was poor (i.e. foggy) the watch period was cut short.

Observations were recorded onto data sheets throughout the watch period. Locations were determined using a GPS and time was recorded using a digital watch, and cloud cover (broken, scattered, clear), seastate (Beaufort Scale of Windforce), ice concentration (0, 1-3/10, 4-6/10, 7-9/10, 9+/10), fog, and wind strength according to standardized categories. 8 x 40 Nikon binoculars and 10 x 50 Tasco binoculars were used.

Ice work

Wildlife was also monitored when the scientists were doing work out on the ice. John was responsible for the firearm and did a constant patrol for polar bears. Joe helped with the various activities of the ice-scientists. The ship was often moored in the ice for up to 8 hours or longer. On the ice, Joe assisted with the ice core drilling and also with tending the line for the divers.

Details about the sightings were entered into a database by DFO and worked up with results from other shipboard surveys. See Table 17, Appendix 4.12 for wildlife counts.

Publication

Harwood, L.A., McLaughlin, F., Allen, R.M., Jr, J.I. and Alikamik, J. 2005. First-ever marine mammal and bird observations in the deep Canada Basin and Beaufort/Chukchi seas: expeditions during 2002. *Polar Biol.* **28**(3): 250-253, doi: 10.1007/s00300-004-0691-4.

2. METHODS AND ANALYSIS

2.1 FIELD SAMPLING – CTD/ROSETTE CASTS

A CTD/Rosette system (CTD/R) was used to obtain profile data on water mass properties and to collect in situ water samples from discrete depths for bio-geochemical analysis (Figure 11). See Table 10 in Appendix 4.2 for CTD/Rosette cast locations. The main CTD used was a Seabird Electronics model SBE-911+ S/N 0443 with a Paroscientific Digiquartz temperature-compensated pressure sensor S/N 63507, and dual ducted temperature (T) and conductivity (C) sensors (primary T&C sensors S/N 4044 & 2232, secondary T&C sensors S/N 4109 & 2676, respectively). See Table 11 in Appendix 4.3.1 for CTD calibration information. In addition, the CTD also collected data from a number of external sensors: dissolved oxygen levels were measured with a Seabird D.O. sensor SBE-43 S/N 0052 added to the pumped duct of the secondary C/T sensor pair; chlorophyll concentrations were measured with a Seapoint Fluorometer S/N 2336; this sensor was not pumped, and its gain was set for maximum resolution with a range of 0 to 5 mg/L with a 30X cable. Light transmission levels were measured with a SeaTech transmissometer, however the initial sensor with high pressure housing (S/N D192) failed and was removed before cast #18. It was replaced with sensor (S/N 139) before cast #28, but this sensor was rated for maximum 2000 meters depth, thus only used on casts in water shallower than this.

The Seabird SBE-911+ was used with SBE-11 S/N 0424 deck unit. Station co-ordinates and UTC time and date at the start of each cast were automatically entered into the header of the data file by the NMEA interface that was connected to a feed of the ship's GPS system. The deck unit was connected to two serial ports on a Dell-200 MHz computer, one port to capture the data stream, the other to communicate with the rosette water sampler pylon and close sample bottles when the CTD reached the desired depth. The data acquisition was done using the Seabird "Seasave" software (v. 1.24) with a configuration file that included the latest calibration coefficients for all the above sensors. During each cast, the data were displayed on screen both as a plot and in numerical form to ensure that sensors were behaving within expected parameters. The CTD cage containing the sensors and electronics housing, was mounted in the centre of a General Oceanics (GO) 24-position water sampling rosette frame, equipped with a Seabird Carousel pylon used to trigger the 10-L Brooke Ocean Technology (BOT) Niskin sampling bottles. A hydrographic winch with approximately 3400 m of conducting cable was used to lower the CTD/rosette system, to obtain a live data stream from the CTD sensors, and to transmit control commands to the pylon to close sample bottles at depth.

Before each cast, when approaching the location of a science station, the CTD/rosette package was rolled out of the heated sampling container, the protective water-filled plugs removed from the temperature, conductivity and oxygen sensors, and the CTD turned on while on deck to record in-air information. The rosette was prepared for launching by emptying all sampling bottles, hooking the lanyards from the top and bottom lids of each bottle into the

carousel pylon, and closing the valves and vents on the bottles. The station name and location, cast particulars, sounding and information about sea state were entered in the CTD log book, as well as any other factors that might affect or alter how the system behaved.

For each cast, the CTD data acquisition system was turned on to start collecting data prior to lowering the CTD/R system over the side. The CTD/R was held for one minute just below the surface of the water to allow temperature and electronics to stabilize and air to escape from the sensor ducts. The two T/C duct pumps were then turned on by software command and the unit held for another minute to flush all air out of the lines before starting the descent. The unit was then lowered at a nearly constant speed of one meter per second to ensure optimal response from the sensors. However, at depths over ~2000 m, the added weight of the conducting cable required that the descent speed be reduced to around 0.6 m/s to avoid the winch hydraulics surging. A bottom alarm was activated when a trip weight, hanging below the CTD/R on a 5 m monofilament line, touched the ocean bottom.

Bottles were closed on the fly during the downcast at the first 5 stations (AG-5 to AL-08). From stations AL-09 onward, all bottles were closed on the fly during the upcast because the closed bottles, when taken to depth, leaked on the way up. Samples affected were in the upper ~150 m and these data are not reported.

VFH radios were used to relay depth information from the CTD lab to the winch operator. During the return to the surface, the CTD/R was stopped at each of the selected pressure values and held for 30 s before activating the trigger on the acquisition deck unit to close one of the 10 L Niskin bottles at that depth. Niskin bottles were checked for integrity and leaks, and water samples were then drawn from each bottle (see Section 2.3 for sampling order).

After each cast, plots were produced of the data from the electronic sensors in order to check their behavior, and the Ocean Data View software was used to provide a preliminary contour view of the measured and calculated parameters at successive stations along the ship's track. Raw values of bottle trip depths, and corresponding temperatures, salinities, oxygen etc. were produced at the request of the geochemical analysis team, and the preliminary CTD plots were displayed in the main lab.

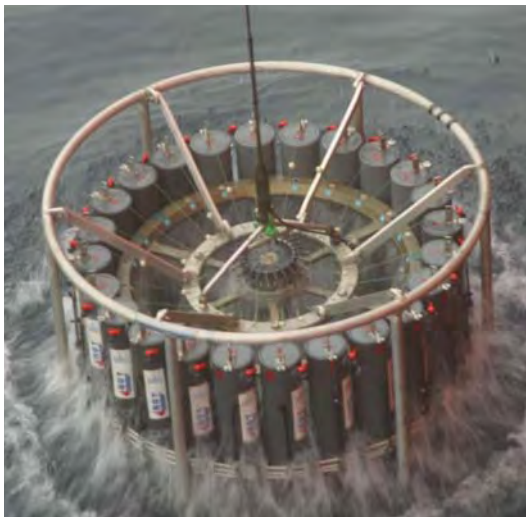


Figure 11. CTD/Rosette set up.

2.2 CTD DATA ACQUISITION, PROCESSING AND VALIDATION

Overview

The main issues requiring attention in the data processing:

- The bottle samples were compromised by significant leakage when bottles were closed on the downcast and affected the upper ~5 bottles at the first 5 stations (AG-5 to AL-08). Bottle #3 leaked during the entire cruise and data from this bottle are generally not included. On return to IOS, the primary conductivity cell was found to be cracked.
- Transmissivity – data are unedited. Calibrations for transmissometer #192D could not be confirmed.
- Fluorescence – data are nominal and unedited.
- Oxygen sensor data quality is limited by poor time-response, the significant pressure hysteresis below 1000 db, and the problems with bottles mentioned above. Errors in oxygen are:
  - ±0.4 mL/L from 0 to 100 m
  - ±0.15 mL/L from 100 to 2500 m
  - 0 to -0.25 mL/L below 2500 m
- All ways of looking at the data suggest that the CTD salinity is low, by an average of about 0.007 units for the primary and by 0.001 for the secondary. There is some hint of time-dependence especially in the primary.

2.2.1 Processing Steps

The steps outlined below were performed as required in processing data from each CTD cast. The protocols for processing the CTD data are documented in detail in an IOS internal document by Pearson (1995). Derived oceanographic quantities were calculated from the pressure, temperature and salinity data using the algorithms given by Fofonoff and Mallard (1983). See Appendix 4.3 for a CTD calibration and processing summary and Appendix 4.4 and 4.5 for plots of the CTD data.

Processing of the CTD data involved the following general steps:

- verification of calibration coefficients for all sensors
- verification against log sheets of data files produced by the acquisition programs
- checking and editing the header information
- conversion of the CTD data files from their acquired format into IOS HEADER format
- application of sensor calibrations to the “raw” data
- creation of profile plots throughout the processing
- removal of data spikes and corrupted data
- correction for differences in temperature and conductivity time responses (method used is dependent on CTD type)
- deletion of swells, upcast and unwanted surface records
- removal of salinity spikes
- manual editing of other data problems where required
- reduction of the data to one meter averaged values (data set has only one record per decibar)
- production of final test plots
- creation of overlay plots and comparison of CTD data with bottle data, other reference data and historical data
- adjustment of the processed CTD data to agree with reference data

Refer to Appendix 4.3.2 for Germaine Gatien’s Guildline CTD processing notes.

2.3 WATER CHEMISTRY SAMPLE COLLECTION AND ANALYSIS

Samples were drawn from 10 L BOT bottles on the 24 bottle rosette in the heated rosette room. Water sampling took place immediately after each cast and the order of sampling was: CFC; dissolved oxygen; dissolved inorganic carbon; alkalinity; phytoplankton; nutrients; barium; oxygen isotope; salinity; chlorophyll a; virus and bacteria. CTD and water chemistry data are illustrated in Appendix 4.4 and 4.5. See Appendix 4.6 for dynamic height and section plots.

2.3.1 Laboratory Methods

The precision of the methods was estimated by analyzing replicates and expressed as the pooled standard deviation (s_p) using the equation:

$$S_{\mathrm{p}} = \sqrt{\frac{\sum [c(1) - c(2)]^2}{2n}}$$

where $c(1)$ and $c(2)$ were the concentrations of duplicate samples and n refers to the number of pairs. See Table 8 below for summary of water sample precision.

Table 8. Water sample precision.

Chemistry Sample	Precision (s_p)	Number of Duplicate Pairs
Salinity	N/A	None
Dissolved Oxygen	0.11 mL/L	33
Nitrate plus Nitrite	0.4 mmol/m^3	103
Silicate	0.1 mmol/m^3	103
Orthophosphate	0.02 mmol/m^3	104
CFC-12	0.06 nmol/m^3	4
CFC-11	0.06 nmol/m^3	4
CCl_4	0.06 nmol/m^3	4
Dissolved Inorganic Carbon	1.5 µmol/kg	4
Alkalinity	1.9 µmol/kg	4

2.3.2 Salinity

Salinity samples were drawn from the Niskin bottle into 200 mL glass salinity bottles that had been rinsed with sample water three times. The samples were then tightly capped and transported back to IOS for analysis. Samples were analyzed by Mary Steele, Sheila Toews and Doug Sieberg at IOS on a Guildline Portasal (model 8410; Serial number 59724). The salinometer was standardized using IAPSO standard seawater. Samples were run at IOS in December of 2002 (IAPSO batch P140; conductivity = 0.99991; salinity = 34.997) and in January of 2003 (IAPSO batch P141; conductivity = 0.99993; salinity = 34.997). Select samples were re-run at IOS in March and May of 2003. No duplicate samples were taken. Data are reported in practical salinity units (PSU; Lewis and Perkin 1978).

Duplicate salinity samples collected from 1500 to 3500 m at most stations were taken to the RV Mirai by Koji Shimada and analyzed on an Autosal onboard ship in late September. Salinity data reported here are primarily those analyzed at IOS, however if IOS salinity data were suspect, as identified by the difference between the CTD and bottle salinity, values from samples analyzed on the Mirai were used as available. There was drift encountered with the Portasal at IOS towards the end of the analysis and there were some questions about the integrity of the BOT bottles, in particular bottle #3 (see G. Gatien's CTD processing report; Appendix 4.3.2).

2.3.3 Dissolved Oxygen

Samples for dissolved oxygen were drawn after the CFC samples. Water was drawn through rubber tubing into a calibrated volume glass flask with attached stopper. The sample was immediately pickled with 1.0 mL of manganous chloride and 1.0 mL alkaline iodide, the stopper was inserted and the flask was shaken to mix the contents. Dissolved oxygen samples were analyzed on board by Janet Barwell-Clarke within 24 hrs of collection using an automated version of the Micro-Winkler Technique as described in Carpenter (1965). The titration was performed using a Metrohn Dosimat 665 and the end point was detected using a Brinkmann probe colorimeter PC900. The methodology is described in an internal IOS document (Minkley and Chase 1997).

The thiosulphate line was sporadically leaking at the beginning of the cruise and data from Stations AL08 (cast 8), AL09 (cast 9), AL09 (cast 10), AL10 (cast 11), AL 10 (cast 12), and SB01 (cast 14) may have been affected. Data from these stations have been examined and are included in the report if there was good agreement with the sensor. Standard pooled deviation for 33 duplicates is 0.11 mL/L. Note: only the first replicate of each duplicate pair is reported in the IOS data archive.

2.3.4 Nutrients

Sampling

Water samples for nutrient determination were collected into glass and polystyrene test tubes after the tube and cap had been rinsed three times with the sample water. If analysis could be performed within 24 hours the samples were stored at 4 °C, if not they were frozen at -20 °C.

Analysis and Results

Nutrients (nitrate + nitrite, silicate and orthophosphate) were analyzed onboard by Linda White using a three channel Technicon Auto Analyzer, following the methods described by Barwell-Clarke and Whitney (1996). Ammonium samples, collected by Terry Whitledge, were analysed using a Technicon Auto Analyzer following methods also described by Barwell-Clarke and Whitney (1996). Reagents were prepared onboard using water from a NANOpure system that produced 17 to 18 mega ohm-cm resistance Type I reagent grade water. The system was supplied with ship's distilled water. A 3.2% weight-to-volume solution of sodium chloride was prepared daily and used to rinse the system between samples and to prepare working standards. Pump tubing was changed after approximately 500 samples. One cadmium column was used for all samples unless noted below. The Auto Analyzer was cleaned every other day as follows; rinsed with 3N NaOH and 10% HCl, sequentially, for approximately 5 minutes and rinsed with DMQ for over 20 minutes after all reagents and salt were disconnected at the end of the day. Data were logged by analog (chart) and digitally using the IOS "Newget" program.

Standards and blanks:

NANOpure water was analyzed daily before connecting the reagents and analyzing the initial standards and after the last set of standards to establish the baseline and record the purity of the reagents. A set of working standards (low, medium and high) were prepared from the stock standard solution, using freshly prepared 3.2% sodium chloride (Anachemia) solution. The stock solutions were prepared from: Potassium nitrate (Fisher); Sodium silicofluoride (Anachemia); and Dihydrogen potassium phosphate (Johns Mathey). The working standards were analyzed at the start and close of each day or, if more than 60 samples were to be analyzed in a day, standards were also run mid-day or after three hours. Concentrations of the standards were selected to bracket the expected nutrient levels in the samples. A medium standard for each nutrient was analyzed between stations consisting of 12 to 27 samples and as an unknown sample followed by two zero standards.

Standards purchased from Wako (0 µm/L and 20 µm/L nitrate and 0 µm/L and 50 µm/L silicate) were analyzed at the end of each day. See below for specific details. An onboard reference sample was collected at sea, stored at 4 °C in the dark, and analyzed daily to provide an operational check.

The order of the sample analysis was from the surface to depth and sample peaks that appeared to be out of order were re-analyzed. Duplicate

samples were collected approximately every 10 samples. The results of the replicate and standards comparisons are listed below.

The turbidity of surface samples where salinity is less than 27 PSU were analyzed through the phosphate channel with no reagents being added to the sample. When the nitrate level in surface samples was the same or slightly lower than the 3.2% sodium chloride solution it was reported as zero.

A subset of the samples were analyzed in duplicate: the pooled standard deviation for nitrate is s_p = 0.351 mmol/m^3, n = 103; silicate s_p = 0.122 mmol/m^3, n = 103; and phosphate s_p = 0.02 mmol/m^3, n = 104. Note: only the first replicate of each duplicate pair is reported in the IOS data archive. Data for ammonium samples are reported in Table 13, Appendix 4.8.

2.3.5 Halocarbons (CFC-11, CFC-12, CFC-113, CCl_4)

After the Niskin bottle integrity was checked the first sample to be drawn was the CFC sample. The sample was collected into a 250 mL glass syringe that had been rinsed three times, without the intake of any bubbles. John Harris analyzed CFC-12, CFC-11, CFC-113 and CCl_4 samples using the IOS custom-built automated purge and trap system onboard ship. Separation and detection of the components was achieved using a 60 m, 0.32 mm GasPro Gas fused silica column installed in a Hewlett Packard gas chromatograph and electron capture detector. Standardization was done using a gas standard (S14) prepared at Brookhaven National Laboratories and standardized at Scripps Institute of Oceanography. Data are reported with respect to the SIO98 scale. Air samples were collected as a secondary check on the operation of the system. Only four samples were collected in duplicate: the pooled standard deviation for CFC-12 is s_p = 0.064 nmol/m^3, where n = 4 pairs; CFC-11 s_p = 0.059 nmol/m^3 where n = 4; and CCl_4 s_p = 0.058 nmol/m^3, where n = 4.

The daily routine for CFC analysis is summarized below:

1. Changed water trap and ran a blank until peaks were normal – usually by the second run.
2. Woke-up the instrument by running 2 x 15 mL calibration gas injections or two surface seawater samples.
3. Ran the calibration curve, highest to lowest.
4. Ran a blank.
5. Ran a 6 mL standard.
6. Ran 8 seawater samples – included 1 atmosphere sample and at least 2 duplicates per station.
7. Changed water trap.
8. Repeated 4-7 as necessary.
9. When the sample run was finished:
    a) ran a blank and a 2, 6 and 12 mL standard or
    b) if the unit was in continuous use, ran a complete calibration curve.

With this routine, about 65 injections per 24 hours could be made, including about 40 water samples. The trap and GC were baked out for about two hours each (at the same time) once per week or when needed. Molecular sieves were baked out at the start of the cruise and only again if there were signs of contamination.

2.3.6 Hexachlorocyclohexane

Transport of organochlorine-contaminants to the Western Arctic

Application in southern agricultural regions, atmospheric currents and seasonal warming are responsible for the global transport of pesticides northward to the Arctic Ocean. Compounds such as hexachlorocyclohexanes (HCHs) are very soluble in cold northern Pacific and Atlantic waters and, subsequently, enter the Arctic Ocean. Once in the Arctic Ocean, factors such as ice cover and rates of circulation play an important role in transport. The top 150 m of the Canada Basin water column contain among the highest concentrations of the pesticide lindane in the world.

Measurements made from 1986 onwards have shown that the Eastern Pacific Ocean is vulnerable to chemicals released in Asia in much the same way the Arctic is vulnerable to chemicals released in Eurasia and is simply due to rapid and direct atmospheric transport. Furthermore, it appears that atmospheric transport, precipitation and ocean currents work in concert to deliver some pesticides to the Bering Sea and some pesticides to the Arctic.

General handling notes

Hexachlorocyclohexane concentrations are higher in ambient air than in subsurface water samples so it is important to minimize air contact. For this reason, the sample bottles were filled with argon prior to sampling. Where possible, the HCH samples were drawn from the Niskin before other non-gas samples were collected, i.e. after CFCs and oxygens and before nutrients or salt. A salinity sample was collected from the same Niskin as the HCH sample. The ends of the specially cleaned (hexane rinsed) tygon tube were kept covered with aluminum foil and in a zip-lock bag between samplings. When handling the tube, fingers were kept away from the end that goes into the bottle.

Sampling

Hexachlorocyclohexane samples were collected by Gillian Lichiota. The cleaned tygon tube was connected to the Niskin, then rinsed with sample water and any bubbles were removed from the tube (much like taking an oxygen sample). Then, with the water flowing, the tube was pushed to the bottom of the bottle and the bottle filled up to the top of the shoulder on the bottle (approximately 4" down from the top). Next, 200 mL of dichloromethane was added and the remaining air space flushed with nitrogen (with hydrocarbon trap in line). The teflon liner was replaced and the cap firmly closed. The bottle was inverted three times to provide the initial extraction into the dichloromethane.

Samples were stored in the ship's cooler at 4 °C and returned to IOS for extraction and analysis.

Extraction and analysis

At IOS each 4 L sample was spiked with 100 µL of internal standard (200 ng/mL each of tetrachloro-m-xylene and PCB 209) and shaken thoroughly. The sample was transferred to a 4 L separatory funnel, the stopper of which had been wrapped in teflon tape and rinsed with acetone and dichloromethane. The sample was shaken vigorously for five minutes with frequent venting and allowed to settle for approximately 30 minutes before the DCM was drawn off into a 500 mL Erlenmeyer flask. The sample bottle was rinsed with 100 mL of dichloromethane which was transferred to the separatory funnel and the sample was extracted for 5 minutes. The sample was allowed to settle and the DCM added to a second Erlenmeyer flask. The bottle rinse and extraction was repeated a second time with 100 mL DCM. The DCM extracts from one sample were contained in two flasks, each containing ~200 mL of DCM to facilitate drying over sodium sulphate. Sufficient sodium sulphate was added to each flask to remove any residual water and then allowed to stand for approximately 20 minutes with occasional swirling. After drying, the DCM extracts were transferred to a 500 mL Kuderna-Danish (KD) flask and the Erlenmeyer flasks were each rinsed three times with 10 mL of DCM. An aliquot (10 mL) of hexane was then added to each sample together with a few boiling chips, a reflux chimney filled with glass reflux chips was attached to each KD flask and the samples were placed in a hot water bath at approximately 70 °C and allowed to evaporate down to a volume of approximately 2 to 3 mL. The chimneys of each sample flask were rinsed with a small volume of hexane and the sample was allowed to cool before being transferred (with three hexane rinses) to a 15 mL centrifuge tube. The volume is reduced to 1 mL under nitrogen and then put through an 8 gm Florosil (baked, 1.2% deactivated) column, eluted with hexane for F1, 15% DCM in hexane for F2 and 1:1 DCM in hexane for F3 (volumes required were pre-determined per batch of Florosil). For HCH and HCB analysis F1 and F2 were combined and, because the internal standard elutes in F1, 10 µL of the internal standard was added to F3. Solvent volumes were reduced to 2 to 3 mL in a water bath at 75 °C and transferred to centrifuge tubes where they were reduced to 250 µL under nitrogen. A 100 µL aliquot of recovery standard (200 ng/µL each of 4,4' dibromo-octafluorobiphenyl and PCB 204) was added immediately prior to GC analysis. The GC was a HP 5890 with an Electron Capture detector and a 60 m DB-5, 0.25 mm film thickness, column was used. The carrier gas was helium and the make-up gas was argon-methane. A 1 µL aliquot of the sample was injected, splitless for 1 minute. The GC program was as follows:

Oven temperature 100 °C for 2 minutes, heated at 10 °C /m in to 200 °C, heated at 3 °C/min to 300 °C, hold for 5 minutes. The total program was 50 minutes. The injector temperature was 250 °C and the detector temperature 320 °C. Peak areas were quantitated using response factors generated from a linear regression fit to a areas from the standard at different concentrations (~10,

25, 50, 62.5 ng/mL). The standard contained α-HCH, β-HCH, γ-HCH and HCB and was calibrated against a certified reference standard Z-014C-R.

Data are reported in Table 14, Appendix 4.9.

2.3.7 Iodine and Cesium Radioisotopes

Water samples for ^{129}I analyses were collected in one litre PVC bottles that had been pre-rinsed with seawater to remove any foreign debris and returned to the laboratory of the Atlantic Environmental Radioactivity Unit (AERU) at the Bedford Institute of Oceanography (BIO). In the laboratory, a NaI carrier was added to a 200 mL aliquot of the seawater sample, it was slightly acidified, purified using multiple hexane extractions and iodine was precipitated as NaI. The NaI precipitate was shipped to the IsoTrace Laboratory at the University of Toronto where ^{129}I analyses were performed by accelerator mass spectrometry (Smith et al. 1998; 1999; 2005). The sample data were normalized to the IsoTrace Reference Material #2 ($^{129}I/^{127}I = [1.313 \pm 0.017] \times 10^{-11}$ atom ratio) which is calibrated using the NIST 3230 I and II standard reference material. The blank (KI carrier added to distilled and deionized water) for this procedure is $0.75 \pm 0.10 \times 10^{7}$ at/L and the standard deviation (one sigma) ranged from 5 to10% (Edmonds et al. 1998). ^{129}I concentrations in seawater are generally expressed in units of 10^{7} atoms/litre. IsoTrace has participated in a number of ^{129}I International intercomparison exercises, including the NIST SRM 4359 Seaweed, the Lawrence Livermore ^{129}I intercomparison, phases I and II and the IAEA-0375 Radionuclides in Soil intercomparison. IsoTrace ^{129}I procedures and sample handling protocol have been approved by the United States Office of Civilian Radioactive Waste Management, through on-site inspections by Bechtel SAIC Inc.

Seawater samples were collected using 10 L Niskin bottles attached to a rosette system. Approximately 20-30 L of seawater were collected in 10 L plastic carboys for ^{137}Cs analyses. The water samples were passed through a potassium ferrocyanide (KCFC) packed resin column in the laboratory which quantitatively extracts ^{137}Cs from seawater (Smith et al. 1990; Smith & Ellis 1995). A second column was occasionally aligned in series to confirm that extraction efficiencies for ^{137}Cs were close to 100%. The KCFC resin was deployed in a standard geometry and measured using a hyperpure Ge detector having an efficiency of 25%. ^{137}Cs concentrations in seawater are expressed either as Bq/m^3 or mBq/L. Numerous analytical intercomparisons (including publicly reported blind exercises) have been carried out with other laboratories by the (AERU) over the past 30 years for quality assurance purposes. Intercomparison samples have been provided by the United States Environmental Protection Agency (USEPA), the United States Environmental Measurements Laboratory (EML) and the United States Department of Energy as part of their Mixed Analyte Performance Evaluation Program, MAPEP. Marine environmental samples (e.g. IAEA-315; IAEA-326; IAEA-327) provided by the IAEA (International Atomic Energy Agency) have been analyzed to insure compliance with international standards in the marine radioactivity community. NIST (National Institute of Standards and Technology)

ocean and river sediment reference materials are analyzed on the detectors on a regular basis as a calibration check.

Data are reported in Appendix 4.10, Table 15.

2.3.8 Oxygen Isotope Ratio ($\delta^{18}O$)

Samples collected for determination of oxygen isotope ratio were not analysed.

2.3.9 Dissolved Inorganic Carbon (DIC) & Alkalinity

Sampling Instructions

Seawater was transferred to a glass sample bottle (250 or 500 mL) as soon as possible after the rosette cast to minimize gas exchange. The sampling tube was connected to the spigot of the Niskin bottle and, by holding the tube above the spigot, was rinsed by flowing approximately one tube volume of sea water through the tube. Any trapped air bubbles were removed by tapping or squeezing the tube. The bottle was filled smoothly from the bottom (tubing touching the bottom of the bottle) and the bottle overflowed by two times its volume. The tubing was withdrawn to the neck and the spigot valve closed or the flow in the tubing squeezed off before the tubing was removed from the bottle. One percent of the stoppered sample volume was removed to leave a headspace (about 1% of the bottle volume -- i.e., 5 mL for a 500 mL bottle) by inserting a nylon plug into the bottle. A volume of 100 µL of saturated mercuric chloride solution ($HgCl_2$) was added to the bottle (both 250 mL and 500 mL). A greased stopper was inserted and sealed with elastic bands or electrical tape. Samples were stored at 4 °C until analysis back on shore. DIC then alkalinity were measured from the same sample.

DIC Analysis

Samples were analyzed at the Institute of Ocean Sciences (IOS) by Marty Davelaar using a SOMMA (Single-Operator Multi-Metabolic Analyzer) - Coulometer system to determine the concentration of dissolved inorganic carbon (or total carbon dioxide). The SOMMA is a sea-going, computer-controlled automated dynamic headspace analyzes, constructed at IOS by Ken Johnson (University of Rhode Island) and Keith Johnson (IOS). The current design of the SOMMA system is similar to the one described by Johnson et al. (1993). The SOMMA is interfaced with an IBM compatible computer and a coulometric detector (UIC Coulometrics, model 5011). The SOMMA dispenses and acidifies a known volume of seawater, strips the resultant CO_2 from solution, dries it and delivers it to the coulometric detector.

At the start of each day, seawater was run through the system to condition the cell. Once the system appeared to be working well, standard water or a known sample was run to confirm proper operation. For each analysis (standard

or sample) CO_2 in nitrogen was used to push liquid out of the sample bottle and into the water-jacketed calibrated pipette. The water from the pipette was then drained into a scrubber compartment to which approximately 0.5 mL of 8.5% σ-phosphoric acid had been added. The CO_2 was stripped from the water by the acid and then passed into the coulometer cell where it was measured. The coulometer was operated in the µg C mode. Using the SOMMA software, this mode takes the coulometer's voltage to frequency converter output along with constants supplied by the user and calculates µmol *C* titrated. For each sample or standard, the analysis was run twice. The first analysis was considered a rinse and the second analysis the final value. The final concentrations are calibrated with the daily measured standard where:

$$\textit{corrected value} = \frac{\textit{(raw value * measured standard)}}{\textit{(standard value * correction for mercuric chloride volume)}}$$

The mercuric chloride correction is either 1.0002 or 1.0004, depending on whether the sample volume was 250 or 500 mL. DIC values are reported in units of µmol/kg.

DIC standards, blanks and precision

The accuracy of DIC analysis was assured by daily analysis of IOS standard sea water (batch 11, concentration 2177.5 µmol/kg) which had been calibrated using certified reference material (batch 48 with a concentration of 1991.91 µmol/kg: DOE 1994; Dickson 2001; Dickson et al. 2003) supplied by Andrew Dickson (Scripps Institute of Oceanography, San Diego, USA). The difference between the measured value and calibrated value of the IOS standard seawater was less than ±1 (0.05%).

Precision is given by the pooled standard deviation of sample replicates. s_p = 0.75 µmol/kg, where n = 8 pairs.

Alkalinity Analysis

Samples were analyzed at the Institute of Ocean Sciences (IOS) by Marty Davelaar using an automated potentiometric titration system to determine the total alkalinity. The pH was measured using a Ross combination electrode acid was dispensed with a Dosimat 665. A program written by the University of Hawaii was used to control the Dosimat.

At the start of each day, seawater was run through the system to condition the instruments. Once the system appeared to be working well, standard water was run to confirm proper operation. For each analysis (samples and standard), a known amount (~75 g) of sample was weighed in an open beaker. An initial amount of 0.7N (0.6N NaCl, 0.1N HCl) acid (IOS batch 3, concentration 0.09676), was added to the seawater to take its pH to approximately 3.5. After an eight minute period in which CO_2 was stripped from the seawater, 0.025 mL aliquots of acid were added to the seawater until a final pH of approximately 3.0 was obtained. The University of Hawaii program was used to calculate the alkalinity of the seawater by use of a Gran plot. The final concentrations are calibrated with the daily measured standard where:

*corrected value = (raw value * measured standard)*
*(standard value * correction for mercuric chloride volume)*

The mercuric chloride correction is either 1.0002 or 1.0004, depending on whether the sample volume was 250 or 500 mL. Alkalinity values are reported in units of µmol/kg.

Alkalinity standards and precision

The accuracy of the alkalinity analysis was assured by daily analysis of certified reference material (batch 57, concentration of 2230.33 ± 0.66 µmol/kg) (DOE 1994; Dickson 2001; Dickson et al. 2003) supplied by Andrew Dickson (Scripps Institute of Oceanography, San Diego, USA).

Precision is given by the pooled standard deviation of sample replicates. s_p = 1.12 µmol/kg, where n = 8 pairs.

2.3.10 Particulate Organic Carbon and Particulate Nitrogen (POC/PON)

The methodology followed JGOFs protocols (June 1994) and CEC 440 Elemental analyser Operations Manual. Particulate organic carbon and particulate nitrogen concentrations were determined for a known volume of seawater filtered through a 47 mm Glass Fibre Filter. Samples were analyzed by Linda White at IOS. Results are reported as µgrams POC/Litre and µgrams PN/Litre in Appendix 4.11, Table 16.

Pre-treatment of GFF and labware

47 mm Glass fibre filters were placed in a glass Petri dish and combusted at 450 °C for 2 hours. Groups of a dozen filters and dishes were then wrapped in combusted aluminium foil and placed in a clean tote ready for use onboard ship. Filtration castles were acid cleaned in 10% HCl and rinsed three times with double de ionised water, air dried and wrapped in baked foil.

Stainless steel forceps were combusted at the same time as the GF filters.

Sample collection and filtration onboard ship

Samples were collected in 2 L Nalgene bottles that had been 10% HCl acid washed. The bottle was rinsed 3 times and then filled. The samples were filtered onto a pre-combusted GFF filter using glass filter castles. After filtration the filters were stored in a baked Petri dish with a lid taped down and labelled. Labels consist of: Cruise ID, Station ID, Sample number and volume filtered.

Analysis

At IOS the filters were oven dried overnight to stable weight at 60 °C. Each sample was exposed to concentrated hydrochloric acid fumes in a tightly sealed container for 24 hours to remove inorganic carbon. The filters were then oven dried at 60 °C for 1 hour to remove moisture introduced by the addition of acid.

The analysis was performed using a Control Equipment Corporation (CEC) 440 Elemental analyser. The instrument was calibrated against an acetanilide standard.

The filters were halved and each half was folded to fit into a nickel sleeve for analysis (a 47 mm GFF was too large to fit into the sleeve). A tamping rod with a slightly smaller diameter than the sleeves was used to press the filter into place. The results from each half were combined to provide the final concentration.

Calculation and expression of results

The carbon load on the sample filter is:

$$\mu g\ C = (R-Z-B) / KC$$

where R = signal of sample; Z = baseline reading; B = blank instrument reading which includes the tin cup and ladle; and KC = calibration factor for Carbon.

The value is corrected for the filter blank and adjusted by the volume of seawater filtered:

$$\mu g\ C/L = \mu g\ C_{sample} - \mu g\ C_{filter} / L_{Volume\ filtered}$$

The nitrogen signal values were substituted to determine µg N and µg N/L.

Standards

Calibration Factors (instrument response KC and KN) for the standard acetanilide were determined at the beginning of an analytical run. These values are entered into the Analyser's program and sample signal responses are compared to these factors to calculate percent organic carbon and nitrogen. An instrument blank for both Carbon and Nitrogen was determined. KC and KN values vary daily as consumables are used up.

The total numbers of samples run with the reduction tube and combustion tube is monitored daily as consumables are depleted.

Standard acetanilide contains 71.09% Carbon and 10.36% Nitrogen. Acetanilide was analyzed as an unknown throughout the runs:

71.04 ± 0.74% POC
10.32 ± 0.2% PN;
where *n* = 26 replicates.

There were no duplicate samples collected.

Filter Blank

47 mm Glass Fibre filters (Millipore)
Carbon: 20.62 µg C; Nitrogen 1.94 µg N; where *n* = 2

Cleaning procedures in the CEC 440 Elemental analyser manual for CHN analysis were followed for the nickel sleeves, tin cups, combustion and reduction tubes.

Reference Material				
BCSS - 1 contains 2.09 ± 0.10 µg Carbon				
Nitrogen not reported (material not decalcified)				
Date	**µvolts**	**µg sample**	**% carbon**	
Nov.20, 03	2085	4238	2.16	
Nov.21, 03	3371	6933	2.18	
Nov.23, 03	1381	2871	2.09	
Nov.26, 03	2006	4230	2.10	
Nov.27, 03	1663	3284		*2.21*
Nov.28, 03	940	1936	2.09	
		average	2.12	
		stdev	0.04	
		CV%	**2.01**	

Quality assurance and control					
Acetanilide standard analyzed as a sample contains					
71.09% C and 10.36% N					
Date	Carbon µvolts	Acetanilide µg	Carbon %	Nitrogen µvolts	Nitrogen %
Nov.20, 03	4554	285	70.93	245	10.31
Nov.20, 03	9221	578	71.19	489	10.30
Nov.20, 03	18476	1185	69.75	984	10.18
Nov.21, 03	14588	920	71.92	776	10.45
Nov.23, 03	13652	876	70.42	733	10.27
Nov.23, 03	7741	491	71.00	408	10.06
Nov.23, 03	9819	635	69.75	521	10.00
Nov.23, 03	14116	894	71.36	754	10.36
Nov.23, 03	21548	1349	72.30	1143	10.46
Nov.23, 03	17763	1138	70.60	935	10.12
Nov.23, 03	17576	1129	70.42	931	10.16
Nov.23, 03	17146	1082	71.67	904	10.29
Nov.26, 03	21011	1346	71.30	1120	10.42
Nov.26, 03	9969	642	70.69	535	10.36
Nov.26, 03	11698	751	70.98	622	10.32
Nov.26, 03	13243	836	72.23	708	10.57
Nov.26, 03	18080	1170	70.55	966	10.33
Nov.26, 03	17482	1118	71.38	939	10.50
Nov.27, 03	23253	1471	71.38	1253	10.41
Nov.27, 03	16504	1065	69.91	880	10.06
Nov.27, 03	13550	865	70.61	721	10.13
Nov.27, 03	13722	872	70.94	737	10.27
Nov.27, 03	20036	1272	71.10	1069	10.26
Nov.28, 03	8313	520	72.46	462	10.97
Nov.28, 03	20404	1321	70.28	1095	10.31
Nov.28, 03	24154	1537	71.53	1285	10.41
		average	**71.02**		**10.32**
		sdev	**0.74**		**0.20**
		CV%	**1.04**		**1.89**
		n	**26**		**26**

2.3.11 Chlorophyll-a and Phaeopigment

Sampling

Sampling, filtration and analysis were performed onboard by Sheila Toews. Sample bottles were rinsed 3 times with sample prior to filling, then 1000 mL of seawater was drawn into clean brown nalgene bottles and capped. Sample bottles had been previously acid cleaned with 10% hydrochloric acid and rinsed two times with de-ionised water and a third time with double deionised water, air dried and capped. The samples were kept cool and filtered onto 25 mm glass fiber filters as soon as possible under 5 psi vacuum and placed in clean scintillation vials. The volume of water filtered was recorded; most of the samples filtered were 500 mL. Filter blanks were treated in the same manner as samples. The area around the filtration setup was maintained under very low lighting and the actual filtration apparatus was covered with dark plastic. The sides of the castle were not rinsed down for fear of lysing the cells and contents being lost in the filtrate. The filter was either folded in quarters and wrapped in aluminum foil and frozen, or placed into a scintillation vial and analysed immediately on board ship.

Extraction with acetone

10 mL of 90% acetone/10% double-milli-q water were added to the scintillation vials. The samples were shaken vigorously and placed in a tray along with a couple of filter blanks. Extraction took place in a -20 °C freezer for 24 hours. Filtration, extraction and reading of the samples were done in the dark as much as possible.

Reading the extracts

The samples were removed in small batches to equilibrate for 1 hour in the dark and in the same lab as the fluorometer. The Turner Designs 10 AU – 005 Field Fluorometer serial #5152 FRXX was calibrated with Sigma C6144 – 1 mg chlorophyll-a extracted from *Anacystis nidulans* algae May 28, 2002, by Linda White. It was not calibrated again until June of 2003.

There were no duplicates or filter blanks analyzed.

2.3.12 Barium

Barium samples were collected but have not been analysed to date (December 2009).

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4. APPENDIX

4.1 SCIENCE PARTICIPANTS

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Mike Nicholson (ROV – DSSI)
Mike Cole (ROV – DSSI)
Salvatore Ciampra (ROV – DSSI)
Emory Kristof (NGS)
Paul Nicklen (Dive Team leader – still photo and sampling)
Jeremy Stuart (Diver support: DFO-FWI)
Wayne Smith (Diver: DFO-FWI)

Communications
Jeremy Potter (NOAA – Outreach)
Jennifer Steinberg (NGS)

Table 9. Affiliation abbreviations

DFO	Department of Fisheries and Oceans
DSSI	Deep Sea Systems International
FWI	Fresh Water Institute, Winnipeg
ICM	Institut de Ciéncies del Mar
IOS	DFO, Institute of Ocean Sciences, BC
JAMSTEC	Japan Marine Science & Technology Center
MBARI	Monterey Bay Aquarium Research Institute
NGS	National Geographic Society
NOAA	National Oceanic and Atmospheric Administration
PRC	Polar Research Institute of China
SIO	Scripps Institution of Oceanography
TAMU	Texas A&M University
UAF	University of Alaska Fairbanks
UD	University of Delaware
UVic	University of Victoria
UW	University of Washington
WWU	Western Washington University

4.2 LOCATION OF SCIENCE STATIONS

Table 10. Mission 2002-23 list of station activities including CTD/Rosette casts.

Station	CTD Cast no.	XCTD Cast no.	Trip U/D	Depth (m)	Lat (N) dec	Long (W) dec	Date	Activity	NOAA Sampling
AG-05	1		D	650	70.58	122.98	16/8/02	**CTD Rosette**	Pigment analysis, C/N Prod, POC/N, 13C/15N, T Chl, SF Chl, Alk, DON
AG-05					70.58	122.98	16/8/02	Bongo 236 µm to 100 m	
AG-05					70.60	122.93	16/8/02	Bongo 236 µm to 100 m	
AG-05					70.60	122.93	16/8/02	PAR	
AG-05					70.58	122.98	16/8/02	Box core	On bottom 2059
AG-05					70.58	122.98	16/8/02	Bongo 236 µm to 100 m	
					70.58	122.98	16/8/02	Bongo 150 µm & 53 µm to 100 m	
AG-05(2)	2		U	650	70.58	122.98	16/8/02	**CTD Rosette - shallow**	
IF1					70.87	133.87	18/8/02	ROV dive to bottom (100 m)	
AL05	3		D	509	71.15	133.95	18/8/02	**CTD Rosette**	Pigment analysis
XC01		22			71.22	134.05	18/8/02	XCTD	
AL-06	4		D	1000	71.28	134.25	18/8/02	**CTD Rosette**	Bacterial DNA analysis; pigment analysis
XC02		23			71.41	134.33	18/8/02	XCTD	
AL-07	5		D	1550	71.70	134.68	18/8/02	**CTD Rosette**	
AL-07					71.70	134.68	18/8/02	Bongo 236 µm to 100 m	
AL-07					71.70	134.68	18/8/02	Bongo 236 µm to 100 m	
AL-07					71.70	134.68	18/8/02	Live net 60 µm to 200 m	
AL-07					71.70	134.68	18/8/02	Live net 60 µm at 500 m	Larvacean sampling
AL-07					71.70	134.68	18/8/02	Bongo 150 µm & 53 µm to 100 m	
AL-07					71.70	134.70	18/8/02	Box core	On bottom 2000
AL-07(2)	6		U	1600	71.70	134.73	18/8/02	**CTD Rosette - shallow**	
XC03		24			71.84	134.95	18/8/02	XCTD	
AL-08					71.98	135.28	19/8/02	ROV Deploy	
AL-08					71.98	135.28	19/8/02	ROV Shallow dive ~300 m	
AL-08	7		U	2100	71.98	135.32	19/8/02	**CTD Rosette - shallow**	
AL-08(2)	8		D	2100	71.98	135.32	19/8/02	**CTD Rosette**	
XC04		25			72.21	135.42	19/8/02	XCTD	
XC05		26			72.42	135.92	19/8/02	XCTD	
AL-09	9		D	2600	72.63	136.23	19/8/02	**CTD Rosette - shallow**	Pigment analysis, C/N Prod, POC/N, 13C/15N, T Chl, SF Chl, Alk, DON
AL-09					72.63	136.23	19/8/02	Box core - winch test only	
AL-09(2)	10		U	2600	72.63	136.23	19/8/02	**CTD Rosette**	

Station	CTD Cast no.	XCTD Cast no.	Trip U/D	Depth (m)	Lat (N) dec	Long (W) dec	Date	Activity	NOAA Sampling
XC06		27			72.89	136.53	19/8/02	XCTD	
AL09B					72.88	136.52	20/8/02	Ice Camp	Ice coring, melt ponds, brine, bacterial culturing & dive team video, pump
XC07		28			73.13	136.75	20/8/02	XCTD	
*					73.23	136.65	20/8/02	ROV cable spooling	
AL-10					73.50	136.98	20/8/02	Ice Camp	Ice coring, melt ponds, brine, pigment analysis, bacterial culturing, C/N Prod, POC/N, 13C/15N, T Chl, SF Chl, Alk, DON, dive team video
AL-10	11		D	3200	73.50	136.98	20/8/02	**CTD Rosette**	Bacterial DNA analysis, pigment analysis, C/N Prod, POC/N, 13C/15N, T Chl, SF Chl, Alk, DON, C pathways
AL-10					73.48	137.00	20/8/02	Bongo 236 µm to 100 m	Fecal pellet sampling
AL-10					73.48	137.00	20/8/02	Bongo 150 µm & 53 µm to 100 m	Fecal pellet sampling
AL-10					73.48	137.00	20/8/02	Bongo 150 µm & 53 µm to 100 m	Fecal pellet sampling
AL-10					73.48	137.00	20/8/02	Live net 60 µm at 500 m	Fecal pellet sampling
AL-10					73.50	137.00	20/8/02	Box core #1	On bottom 2200
AL-10					73.50	137.00	21/08/02	Box core #2	On bottom 130
AL-10(2)	12		D	3200	73.48	137.00	21/08/02	**CTD Rosette**	
ShortXC08		29			73.49	137.00	20/8/02		
XC08		30			73.49	137.00	21/08/02	XCTD	
AL-10					73.47	137.00	22/08/02	Mooring	
AL-10(3)	13		U	3200	73.48	136.82	22/08/02	**CTD Rosette**	
AL-10					73.45	136.83	22/08/02	ROV (pelagic dive)	
AL-10					73.45	136.83	22/08/02	Ice Camp	Ice coring, melt ponds, brine, bacterial culturing, C/N Prod, POC/N, 13C/15N, T Chl, SF Chl, Alk, DON, C pathways, dive team video, pump

Station	CTD Cast no.	XCTD Cast no.	Trip U/D	Depth (m)	Lat (N) dec	Long (W) dec	Date	Activity	NOAA Sampling
AL-10					73.45	136.70	22/08/02	Dive team	
AL-10					73.47	136.78	23/08/02	Phyto	
AL-10					73.47	136.78	23/08/02	Phyto	
AL-10					73.47	136.78	23/08/02	Phyto	
AL-10					73.47	137.00	23/08/02	Mooring release check	
XC09		31			73.37	137.58	23/08/02	XCTD	
XC10		32			73.21	138.06	23/08/02	XCTD	
XC11		33			73.04	138.80	23/08/02	XCTD	
XC12		34			72.90	139.43	23/08/02	XCTD	
not logged		35			72.77	139.91	23/08/02		
XC13		36			72.63	140.34	23/08/02	XCTD	
SB-01	14		U	3200	72.55	141.00	23/08/02	**CTD Rosette**	Bacterial DNA analysis
SB-01					72.57	141.00	23/08/02	Bongo 236 µm to 100 m	
SB-01					72.57	141.00	23/08/02	Bongo 150 µm & 53 µm to 100 m	
XC14		37			72.56	140.99	23/08/02	XCTD	
SB-01					72.58	140.90	23/08/02	Live net 60 µm at 500 m	
SB-01					72.58	140.90	23/08/02	Bongo 236 µm to 100 m	
SB-01(2)	15		U	3200	72.60	140.87	23/08/02	**CTD Rosette - large volumes**	
SB-01					72.60	140.82	23/08/02	Live net 60 µm to 1000 m	
SB-01(3)	16		U	3200	72.60	140.82	24/08/02	**CTD Rosette - large vol & shallow**	
XC15		38			72.37	140.56	24/08/02	XCTD	
RVB1					72.10	139.83	24/08/02	ROV - benthic dive	
RVB1					72.10	139.83	24/08/02	Ice camp: diving & video	
RVB1	17		U	2800	72.12	139.80	25/08/02	CTD	
XC16		39			72.15	140.08	25/08/02	XCTD	
XC17		40			72.26	140.96	25/08/02	XCTD	
XC18		41			72.36	141.66	25/08/02	XCTD	
not logged		42			72.46	142.38	25/08/02		
XC19		43			72.49	142.55	25/08/02	XCTD	
XC20		44			72.50	143.02	25/08/02	XCTD	
XC21		45			72.59	143.68	25/08/02	XCTD	
XC22		46			72.62	143.99	25/08/02	XCTD	
XC23		47			72.66	144.38	25/08/02	XCTD	
SB02	18		U	3550	72.73	145.03	25/08/02	**CTD Rosette**	Bacterial DNA analysis
SB02					72.73	145.03	25/08/02	Bongo 236 µm to 100 m	
SB02					72.73	145.03	25/08/02	Bongo 236 µm to 100 m	
SB02					72.73	145.03	25/08/02	Bongo 150 µm & 53 µm to 100 m	
SB02					72.73	145.03	25/08/02	Live net 60 µm to 1000 m	
XC48		48			72.98	145.56	26/08/02	XCTD	
XC49		49			73.26	146.12	26/08/02	XCTD	
XC50		50			73.49	146.62	26/08/02	XCTD	
XC51		51			73.75	147.25	26/08/02	XCTD	
XC52		52			74.00	147.90	26/08/02	XCTD	
SB03	19		U	3850	74.23	148.37	26/08/02	**CTD/rosette - shallow at PAR**	Pigment analysis, C/N Prod, POC/N, 13C/15N, T Chl, SF Chl, Alk, DON
SB03					74.23	148.37	26/08/02	Dive team	
SB03					74.23	148.37	26/08/02	PAR	
SB03(2)	20		U	3850	74.23	148.37	26/08/02	**CTD/rosette - deep**	Bacterial DNA analysis

Station	CTD Cast no.	XCTD Cast no.	Trip U/D	Depth (m)	Lat (N) dec	Long (W) dec	Date	Activity	NOAA Sampling
SB03					74.23	148.37	26/08/02	Bongo 236 µm to 100 m	
SB03					74.23	148.37	26/08/02	Bongo 236 µm to 100 m	
SB03					74.23	148.37	26/08/02	Bongo 150 µm & 53 µm to 100 m	
SB03					74.23	148.37	26/08/02	Live net 60 µm to 1000 m	
XC53		53			74.50	148.59	26/08/02	XCTD	
XC54		54			74.87	148.55	26/08/02	XCTD	
XC55		55			75.12	148.68	27/08/02	XCTD	
XC56		56			75.41	148.76	27/08/02	XCTD	
not logged		57			75.63	148.82	27/08/02	XCTD	
XC58		58			75.87	149.13	27/08/02	XCTD	
XC59		59			76.12	149.18	27/08/02	XCTD	
XC60		60			76.43	149.01	27/08/02	XCTD	
NW08	21		U	3850	76.77	148.95	27/08/02	**CTD Rosette - deep**	Bacterial community DNA analysis, deep water culturing
NW08					76.77	148.95	27/08/02	Ice sampling -Dive team	
NW08					76.77	148.95	27/08/02	Bongo 236 µm to 100 m	
NW08					76.77	148.95	27/08/02	Bongo 236 µm to 100 m	
NW08					76.77	148.95	27/08/02	Bongo 150 µm & 53 µm to 100 m	
NW08					76.77	148.95	27/08/02	Live net 60 µm to 500 m	Larvarean sampling
NW08					76.77	148.95	27/08/02	Ice sampling: coring	C/N Prod, POC/N, 13C/15N, T Chl, SF Chl, Alk, DON, C pathways
NW08					76.87	148.17	8/28/02	Live net 60 µm to 1500 m	
NW08					76.88	148.13	8/28/02	Ice sampling -Dive team	
NW08					76.88	148.05	8/28/02	J-CAD Deployment	
NW08					76.88	148.08	8/28/02	Ice sampling	
XC61		61			76.89	148.10	8/29/02	XCTD	
XC62		62			75.99	151.64	8/29/02	XCTD	
XC63		63			75.93	152.50	8/29/02	XCTD	
NWO7	22		U	3900	75.88	153.12	8/29/02	**CTD Rosette - deep**	Bacterial DNA analysis, pigment analysis
NW07					75.88	153.13	8/29/02	Bongo 236 µm to 100 m	
NW07					75.88	153.13	8/29/02	Bongo 236 µm to 100 m	
NW07					75.88	153.13	8/29/02	Bongo 150 µm & 53 µm to 100 m	
NW07					75.88	153.13	8/29/02	Live net 60 µm to 500 m	Bacterial culturing
NW07(2)	23		U	3900	75.92	152.92	8/30/02	**CTD Rosette - 1500**	
NW07(3)	24		U	3900	75.92	152.83	8/30/02	**CTD Rosette - 1000**	
NW07(4)	25		U	3900	76.05	152.58	8/30/02	**CTD Rosette - 1000**	
XC64		64			75.91	153.86	8/30/02	XCTD	
NW06	26		U	3900	75.92	155.02	8/30/02	**CTD Rosette - biology**	Pigment analysis, C/N Prod, POC/N, 13C/15N, T Chl, SF Chl, Alk, DON
NW05					75.93	155.32	8/30/02	Box coring (did not trip)	

Station	CTD Cast no.	XCTD Cast no.	Trip U/D	Depth (m)	Lat (N) dec	Long (W) dec	Date	Activity	NOAA Sampling
XC65		65			75.92	155.39	8/31/02	XCTD	
NW05					75.95	155.65	8/31/02	Box Core	On bottom 303
NW05					75.95	155.65	8/31/02	Box Core	on bottom 1345
NW05	27		U	2040	75.93	155.63	8/31/02	**CTD Rosette - 2100**	Pigment analysis, C/N Prod, POC/N, 13C/15N, T Chl, SF Chl, Alk, DON
NW05					75.95	155.77	8/31/02	ROV- pelagic and benthic	
NW05					75.95	155.77	8/31/02	Ice sampling - dive team	
NW05					75.93	155.65	9/1/02	Box Core	On bottom 223
NW05					75.93	155.65	9/1/02	Box Core	On bottom 325
NW05					75.93	155.70	9/1/02	Bongo 236 µm to 100 m	
NW05					75.93	155.70	9/1/02	Bongo 236 µm to 100 m	
NW05					75.93	155.70	9/1/02	Bongo 150 µm & 53 µm to 100 m	
NW05					75.93	155.70	9/1/02	Live net 60 µm to 500 m	
NW04	28		U	1590	76.00	155.80	9/1/02	CTD	
NW03	29		U	1240	75.98	156.18	9/1/02	**CTD Rosette - deep**	Bacterial DNA analysis, pigment analysis
NW02	30		U	1020	75.98	156.63	9/1/02	CTD	
NW01	31		U	800	75.95	157.02	9/1/02	**CTD Rosette - suface**	C/N Prod, POC/N, 13C/15N, T Chl, SF Chl, Alk, DON, C pathways
NW01(2)	32		U	800	75.95	157.02	9/1/02	**CTD Rosette - deep**	HCH and Cs
NW01					75.97	156.92	9/1/02	ROV- benthic	
NW01(3)	33		U	800	75.97	156.85	9/2/02	**CTD Rosette - deep**	
NW01					75.98	156.87	9/2/02	Bongo 236 µm to 100 m	
NW01					75.98	156.87	9/2/02	Bongo 236 µm to 100 m	
NW01					75.97	156.82	9/2/02	Box Core	On bottom 324
XC66		66			75.86	156.76	9/2/02	XCTD	
XC67		no data file			75.77	157.38	9/2/02	XCTD	
XC68		68			75.69	157.54	9/2/02	XCTD	
XC69		69			75.60	157.76	9/2/02	XCTD	
XC70		70			75.52	157.94	9/2/02	XCTD	
XC71		71			75.41	158.01	9/2/02	XCTD	
XC72		72			75.33	158.01	9/2/02	XCTD	
XC73		73			75.25	158.03	9/2/02	XCTD	
XC74		74			75.15	158.12	9/2/02	XCTD	
XC75		75			75.08	158.45	9/2/02	XCTD	
XC76		76			74.99	158.79	9/2/02	XCTD	
XC77		77			74.96	159.04	9/2/02	XCTD	
XC78		78			74.88	159.34	9/2/02	XCTD	
XC79		79			74.82	159.65	9/2/02	XCTD	
XC80		80			74.76	159.99	9/2/02	XCTD	
XC81		81			74.71	160.32	9/3/02	XCTD	
XC82		82			74.65	160.67	9/3/02	XCTD	

Station	CTD Cast no.	XCTD Cast no.	Trip U/D	Depth (m)	Lat (N) dec	Long (W) dec	Date	Activity	NOAA Sampling
XC83		83			74.54	161.34	9/3/02	XCTD	
NA05(1)	34		U	1450	74.35	162.17	9/3/02	**CTD Rosette - shallow**	C/N Prod, POC/N, 13C/15N, T Chl, SF Chl, Alk, DON, C pathways
NA05					74.35	162.17	9/3/02	Bongo 236 µm to 100 m	
NA05					74.35	162.17	9/3/02	Bongo 236 µm to 100 m	
NA05					74.35	162.17	9/3/02	Bongo 150 µm & 53 µm to 100 m	
NA05(2)	35		U	1450	74.35	162.18	9/3/02	**CTD Rosette - deep**	Bacterial DNA analysis, C/N Prod, POC/N, 13C/15N, T Chl, SF Chl, Alk, DON, C pathways
CHP02					74.37	162.10	9/3/02	Mooring-1480m	
NA05B	36		U	1540	74.38	162.23	9/3/02	**CTD Rosette - deep**	
NA06	37		U	1650	74.52	162.13	9/3/02	CTD	
NA07	38		U	1900	74.67	161.83	9/3/02	**CTD Rosette**	
NA08	39		U	1950	74.83	161.63	9/4/02	CTD	
NWR02(1)	40		U	1840	74.48	158.02	9/4/02	**CTD Rosette - surface**	Bacterial DNA analysis, pigment analysis
NWR02(2)	41		U	1550	74.48	158.02	9/4/02	**CTD Rosette**	C/N Prod, POC/N, 13C/15N, T Chl, SF Chl, Alk, DON, C pathways
NWR02					74.48	158.00	9/4/02	Mooring Deployment	
XC84		84			74.88	159.22	9/4/02	XCTD	
NA09-1	42		U	2000	75.15	160.20	9/5/02	**CTD Rosette - deep**	Bacterial DNA analysis, pigment analysis
NA09-2	43		U	2000	75.15	160.20	9/5/02	**CTD Rosette - shallow**	
NA09					75.15	160.18	9/5/02	Bongo 236 µm to 100 m	
NA09					75.15	160.18	9/5/02	Bongo 236 µm to 100 m	
NA09					75.15	160.18	9/5/02	Bongo 150 µm & 53 µm to 100 m	
NA09					75.15	160.18	9/5/02	Live net 60 µm to 500 m	
NA05					74.33	162.32	9/5/02	Box Core	
NA05					74.33	162.32	9/5/02	Box Core	
NA05					74.33	162.32	9/5/02	Box Core	
NA05(4)	44		U	1500	74.33	162.32	9/5/02	**CTD Rosette - surface**	Productivity
NA05					74.33	162.32	9/5/02	ROV Pelagic and benthic	
XC85		85			74.27	162.11	9/6/02	XCTD	
short xc86		86			74.18	161.90	9/6/02		
XC86		87			74.17	161.88	9/6/02	XCTD	
XC87		88			74.09	161.72	9/6/02	XCTD	
XC88		89			74.01	161.54	9/6/02	XCTD	
XC89		90			73.96	161.41	9/6/02	XCTD	
XC90		91			73.90	161.26	9/6/02	XCTD	
XC91		92			73.83	161.10	9/6/02	XCTD	
XC92		93			73.77	160.94	9/6/02	XCTD	

Station	CTD Cast no.	XCTD Cast no.	Trip U/D	Depth (m)	Lat (N) dec	Long (W) dec	Date	Activity	NOAA Sampling
XC93		94			73.63	160.59	9/6/02	XCTD	
XC94		95			73.39	160.15	9/6/02	XCTD	
XC95		96			73.24	159.91	9/6/02	XCTD	

Key:

Alk	Alkalinity
C/N Prod	Carbon/Nitrogen Productivity
$^{13}C/^{15}N$	Carbon-13/Nitrogen-15 Ratio
C Pathways	Carbon Pathways
DON	Dissolved Organic Nitrogen
PAR	Photosynthetically Active Radiation
POC/PON	Particulate Organic Carbon/Particulate Organic Nitrogen Ratio
SF Chl	Size-fractionated Chlorophyll
T Chl	Total Chlorophyll

4.3 CTD CALIBRATION AND PROCESSING SUMMARY

4.3.1 CTD Calibration

Table 11. Calibration information for SEABIRD CTD Model 911+, S/N 0443.

Sensor		Pre-Cruise	
Name	**Serial No.**	**Date**	**Location**
Temperature	**4044**	**15/02/02**	**Factory**
Conductivity	**2232**	**07/03/02**	**Factory**
Secondary Temp.	**4109**	**14/03/02**	**Factory**
Secondary Cond.	**2676**	**14/03/02**	**Factory**
Fluorometer – pumped	**2336**	**08/01**	**IOS**
Oxygen SBE43	**0052**	**06/08/01**	**Factory**
Transmissometer-1	**192DR**	**02/08/01****	**IOS**
Transmissometer-2	**139**	**23/04/01**	**IOS**
Pressure Sensor	**63507**	**11/01/96**	**Factory**

** *calibration not on file*

4.3.2 Processing Notes

Cruise: 2002-23
Agency: IOS, Ocean Science and Productivity, Sidney, B.C.
Location: Western Arctic
Project: Joint Western Arctic Climate Study
Party Chief: Fiona McLaughlin
Platform: CCGS *LSSL*
Date: 16 August 2002 –5 September 2002
Processed by: Germaine Gatien
Date of Processing: 30 January 2003 – 17 March 2003
Number of original CTD casts: 44
Number of casts processed: 41 (+ bottle files for 3 casts that had data only at the surface)

INSTRUMENT SUMMARY
A SeaBird Model SBE 911+ CTD (#0443) was mounted with Transmissometer 192DR (for casts 1 to 27) and 139 (for casts 28 to 44), SBE 43 Dissolved Oxygen Sensor S/N #0052 and Seapoint Fluorometer S/N #2336 with a 30X cable. The deck unit was S/N 0424. The oxygen sensor was mounted on the secondary pump. The fluorometer was unpumped.

SUMMARY OF QUALITY AND CONCERNS
Samples were collected on the fly during the downcast for the first 5 stations and bottle sampling was compromised by major leakage during downcast sampling in the upper 5 bottles. The primary conductivity cell was cracked.

Transmissivity data are unedited. Calibrations for transmissometer #192D could not be confirmed.

Fluorescence data are nominal and unedited.

Oxygen sensor data quality is limited by poor time-response, the significant pressure hysteresis below 1000 db and the problems with bottles mentioned above.
The anticipated errors in oxygen are:

- ±0.4 mL/L from 0 to 100 m
- ±0.15 mL/L from 100 to 2500 m
- 0 to -0.25 mL/L below 2500 m

PROCESSING SUMMARY

1) Seasave
This step was completed at sea; the raw data files have extension DAT.

2) Preliminary Steps
The Log Book was obtained.
Salinity, dissolved oxygen and chlorophyll calibration data were obtained.
The cruise summary sheet was completed.
The configuration files were obtained and the calibration constants were checked (except for transmissometer #192D and oxygen sensor #52 for which information was not available. Those for transmissometer #139 are not the ones on file and differ from those used during 2002-20. The date given for the calibration is 20 June, 2002.
Test conversions were done to decide which calibrations are correct. The ones in the con files used at sea give maxima above that possible for distilled water, so the calibrations were changed to those on file for a calibration done in 23 April, 2001.
The con files used for casts 1 to 26 are the same; those from 30 to 44 have a different transmissometer but are otherwise the same. The con file for cast #27 is not appropriate for this instrument. The con files for #28 and #29 look the same as for #30 in all details that pertain to conversion. According to the CTD

log a new transmissometer was installed before cast #28. A few test conversions established that was true.

The fluorometer gain is entered as 30X for this cruise and, according to Bon van Hardenberg, 30X is correct.

There is no history available for either the conductivity or oxygen sensors prior to 2002-20.

3. Conversion of Raw Data

Files CTD0443-192.con and CTD0443-139.con were created (copies of the con files from casts #1 and #30, respectively but with a correction to the transmissivity calibration as mentioned above.
The raw data were converted using CTD0443-192.con for casts 1 to 27, and CTD0443-139.con for casts 28 to 44.
A preliminary check shows all expected channels present, but the data was full of spikes. Initial checks of data will be attempted after WILDEDIT.

4. WILDEDIT

Program WILDEDIT was run to remove spikes in the pressure channel only, but this was insufficient as there were many spikes in most of the other variables. So WILDEDIT was rerun with all variables included.
Parameters used were: Pass 1 Std Dev = 2
Pass 2 Std Dev = 5
Points per block = 50
Initial checks show that the transmissivity values are very odd for both instruments. For #192D which was used during the early part of the cruise there is very little variation even when the fluorescence suggests there should be significant change. During cast #14 the transmissivity malfunctioned and there is nothing useful from casts 15-28. After the change to #139 the transmissivity shows more reasonable variations, but the up and downcasts are quite different. The other variables look reasonable. The oxygen shows the usual time-response problems.
The pressure at the surface is about -1 db.

5. ALIGNCTD

ALIGNCTD was used to advance the secondary conductivity by +0.073 s since this deck unit advances only the primary sensor. Fine-tuning of the alignment will be done using SHIFT later in the processing.

6. CELLTM

Tests were run on casts #6 and 30 to find the optimal parameter choice for CELLTM. Runs using (0.02,7), (0.02,9), (0.02,7), (0.03,9),(0.03,7), (0.0245,7),(0.0245,9) and (0.0245,9.5) were used for (alpha, 1/beta). The best choice for both primary and secondary was (0.3,9).
CELLTM was run on all casts using (0.03,9) for both conductivity sensors.

7. DERIVE
Program DERIVE was run twice:
1. on all casts to calculate primary and secondary salinity.
2. on all casts to calculate the differences between primary and secondary channels for temperature, conductivity and salinity and to calculate the descent rate. These were placed in a test directory and will not be archived.

8. Test Plots and Channel Check
Three deep casts were plotted to check for agreement between the pairs of T and C sensors. The differences were higher than during 2002-20 and showed the same depth dependence.
Fluorescence was found for all casts, but oxygen and transmissivity have null values for some.

Cast No.	Press	T1-T0	C1-C0	S1-S0	Descent Rate
8	500	-0.0006	+0.00035	+0.0055	
8	1900	-0.0009	+0.0004	+0.006	~1
17	500	-0.0004	+0.00035	+0.005	
17	1900	-0.0006	+0.00045	+0.006	~.9
39	500	-0.0004	+0.00035	+0.005	
39	1900	-0.0008	+0.00043	+0.006	~.8 very noisy

The differences during this cruise are similar to those found during 2002-21, but the conductivity and salinity differences do not resemble those of 2002-20. It is known that the primary conductivity cell was cracked by the end of 2002-23. It seems likely that this occurred after cast #27 of 2002-20 and before cast #1 of 2002-23. The casts in between are too shallow for a sensitive analysis of differences and the effects of the cracked cell are probably much greater at higher pressure. But the evidence suggests that we should expect problems with the primary salinity from this data set.

9. Conversion to IOS Headers
The IOSSHELL routine was used to convert SEA-Bird 911+ data to IOS Headers. CLEAN was run to add event numbers to the headers. The ROS files were converted to IOS files; CLEAN was run to add event numbers.

10. Checking Headers
A header summary and a header check were produced. The station name of cast #20 was changed to match the Daily Log.
The surface check routine shows an average surface pressure of -0.7 db. A close examination of a few casts (beginning of downcast and end of upcast) indicates that there is a small pressure offset (about -0.8 db) with no indication of hysteresis. The offset for 2002-20 was ~ -0.6 db; for 2002-21 it was ~ -0.9 db.
The cruise track was plotted and looked reasonable.

11. Test Plots

All casts were plotted and checked for evidence of problems with the processing or instruments. The pairs of sensors compared well on the downcasts, but there are significant differences during upcasts as noted in during 2002-20.
Transmissivity values below 300 db are on the order of 65-70% with the deep transmissometer and closer to 60% after the change to the shallow one. The deep transmissometer failed at about 200 db during the downcast of cast #14.
Cast #28, the first with the shallow instrument has very odd data – the downcast shows a large feature entirely absent in the upcast. There is no suggestion of such a feature in the fluorometry.
Fluorometer dark values were 0.08 to 0.09 µg/L.
The dissolved oxygen trace has a fairly slow time-response as noted during other cruises using SBE 43 sensors, but this sensor has a better response than sensor #47.

12. COMPARE

The cleaned rosette files were copied to *.BOT. These were examined for errors. The following casts required editing due to spikes in secondary temperature and salinity: #1,27,32,33,36,38,42 and 43. Cast #43 required editing to the primary salinity as well. Comments were entered in the headers giving details of editing. The edited files were saved as ED1 or ED2. These were copied to BOT so that the BOT files are a full set, edited or not as needed.

Before beginning the routine runs of COMPARE the question of leaking bottles was investigated. A plot of differences between CTD and bottle salinity vs. rosette bottle number showed huge differences, up to 7 units of salinity, for bottles #1 to 4. These would usually have been fired in the top 100 db when doing downcast sampling. There must have been massive leakage into the bottles near the bottom of casts to account for the errors. Ignoring extreme outliers, there are other bottles that give data that looks bad compared to neighbouring bottles, the worst being from bottles #5, 8, and 12; these must have been more prone to leaking than the others. Looking at bottles fired on the upcast, the only problems associated with a particular bottle are for #3, which had consistently low salinity. Note was made in the rosette logs about leaking bottles; many of these were for upcast sampling but the differences are not notable. Presumably any leaking was outward due to pressure differences. However, for #3 it seems likely that there was serious damage to the seals allowing some leakage even during upcasts. During 2002-20 bottle #3 was considered way off for cast #24 so the problem started earlier. Another possibility is that there was a delay between the firing and the bottles actually closing.

The worst errors due to bad bottles will be removed by any method since they are extreme outliers. The questions that must be answered are whether to exclude all data from bottles that are frequently bad and whether to exclude all downcast bottle sampling for recalibration purposes. So COMPARE will be run three times.

SALINITY COMPARISON

a) COMPARE was run first using both upcast and downcast bottles. When only bottles from 200 db downwards are included in the fit and points rejected so that differences more than 0.001 from the average are excluded, the primary salinity was found to be low by about 0.0065 and the secondary low by 0.0016. There is some evidence of time-dependence in both pairs of sensors. However the scatter is large so the choice of fit parameters makes a big difference in how the data is interpreted.

b) COMPARE was run again on the primary salinity using only downcast bottles from below 500 db. Data was excluded for which the standard deviation of the CTD salinity was greater than 0.0005. Since the average was roughly -0.005, points were excluded with differences < -0.015 and >+0.005. This left only 32 data points with an average of ~ -0.0063, the CTD being lower than the bottles. The trend line showed little pressure-dependence but the scatter was tremendous. Selecting the same data points and doing a fit against file pair number shows no time-dependence, but that is based on very little data. It is possible that there was some leakage into all these bottles so the CTD salinity may not be as low as it appears. A similar analysis of the secondary salinity indicates that the CTD is low by 0.0010 and there is no clear pressure or time-dependence, but again there is not much data and a lot of scatter.

c) COMPARE was next run on upcast (including bottom sampling) salinity. Rosette bottle #3 was excluded. Data was selected only if pressure was >500 db and standard deviation of CTD salinity <0.0005. For the primary, data was excluded for -0.017 <salinity differences <0.003. (This was based on a rough average of -0.007). The average difference was about -0.007. The fit against file pair number does suggest time-dependence (starting at about -0.004 to ending at about -1.0), but again the scatter is large. Looking at individual bottles there is reason to doubt many of them. The big errors jump out but whatever caused those may be causing many small errors as well. The same points chosen for the primary salinity comparison were included in a fit for secondary salinity and the CTD was found to be low, on average, by 0.0011 and again there was time-dependence with values changing from about +0.002 to -0.005. However, when the later shallow casts were not included the time-dependence disappeared.

d) COMPARE was run examining only sampling at the bottom of the cast to see if there really is any time- or pressure-dependence. When samples from 500 db down are selected and bottle #3 rejected and two other bottles for which problems were noted, there remained two extreme outliers. Once these were excluded there is no obvious pressure dependence, but a lot of scatter. There does seem to be some time-dependence with differences from about -0.0055 at the beginning to -0.008 at the end. Is this a drift in the CTD or developing problems in the bottles?

e) If the problem is that the bottles are not closing properly, then it may be reasonable to check only the upcast shallow bottles. So a comparison was done using shallow upcast data only. The scatter was so large that any conclusions are dubious. For what it is worth, using data from 24 to 200 db and excluding outliers so that there were no differences greater than 0.02, the average difference was about -0.004; the time-dependence remained.

Conclusions:
1) Use of downcast bottles for comparison is ill-advised for this data set, with the possible exception of those that are within a few hundred metres of the bottom of the cast.
2) Bottles #1,2,3,4,5,8, and 12 performed particularly badly during downcasts and should not be used even if near the bottom of the cast.
3) Bottle #3 performed badly even during upcasts so should be excluded from all comparisons.
It is likely that similar problems will be seen in the oxygen and chlorophyll sampling.

DISSOLVED OXYGEN COMPARISON

From previous experience with SBE 43 instruments we expect problems with time-response. So it is important to separate the issues of calibration and time-response. The best we can do to address the time-response is to use SHIFT to realign the data in such a way that the upcast oxygen trace overlies the downcast one in about the same way as the temperature trace does. To address the calibration we look at bottles after stops long enough for the instrument to equilibrate. We know that this can take a long time. For sensor #0047 the time was at least 20 s before it was repaired and more like 8 to 10 s after repairs. A quick look at this data is confusing. The offset of distinctive features in oxygen vs Pressure is reasonable at all depths, but the differences in values at depth are quite large even in low gradient areas. SeaBird do mention in their manual that there is pressure-hysteresis below 1000 db so that probably accounts for the offset values between upcast and downcast which are most noticeable below 2000 db.

COMPARE was run on the data from the SeaBird dissolved oxygen sensor and the downcast bottles were excluded from the analysis. The results indicate considerable pressure-dependence but no significant time-dependence. In the top 500 db the differences reflect the complex gradient in DOX, reading low in zones of decreasing DOX and high where DOX increases. From 500 db to 1500 db the differences vs pressure are quite flat, but below that they increase notably even though the local gradients are low. Because problems were noted in the salinity analysis with bottle #3 it was decided to drop that bottle from the analysis which removed most 2500 db data. The data has a lot of scatter but is tightest for differences vs DOX. The trendline for that fit was used to create a calibration control file 2223RCAL1.ccf, which was then applied to the bottle files. (See DOXcomp.xls)

CALIBRATE was rerun and the results show a reasonably good fit vs DOX, and again no significant time-dependence. Some pressure dependence remains with the sensor reading low by up to 0.2 ml/L near the surface and high by 0.2 ml/L at 3500 db. Given there were problems with bottles during this cruise it should be kept in mind that the deep differences may not be entirely due to the sensor. But there is evidence that the instrument did not equilibrate well at all at depth. For example at the bottom of cast #18, at 3533 db, the SBE43 oxygen is increasing slowly as it approaches the bottom, but when stopped the oxygen decreases and after a stop of over 2 minutes it still appears to be decreasing. It continues to decrease during the early part of the upcast although the bottles suggest that it should be increasing. The vertical displacement of notable features in the profiles is not particularly large but the differences in values between up and downcast is on the order of 0.1 mL/L. This problem appears to be pressure hysteresis which is known to occur for this instrument below 1000 m.

The initial calibration is based on upcast observations. The downcast is notably different from the upcast so it may be necessary to do a further recalibration to account for that. This will need to be done after the oxygen data is shifted.

CHLOROPHYLL & FLUORESCENCE COMPARISON

Comparisons were made between extracted chlorophyll and the CTD fluorometer data. The downcast sampling contains many suspiciously low chlorophyll values. When these are removed the ratio of Fl/CHL is, on average, about 2.4. It has been noted elsewhere that this ratio is higher at low concentrations and reduces to about 1 near the top of the range. Bad chlorophyll values were identified as those for which the FL/CHL ratio was more than 5.5 and FL>0.2. Below 0.2 the values are so small that the ratio was not considered a reliable guide. Of the many samples that failed this test, only one was from an upcast. However, this is just a rough guide and will not detect small errors in chlorophyll. See Figures 12 and 13 below.

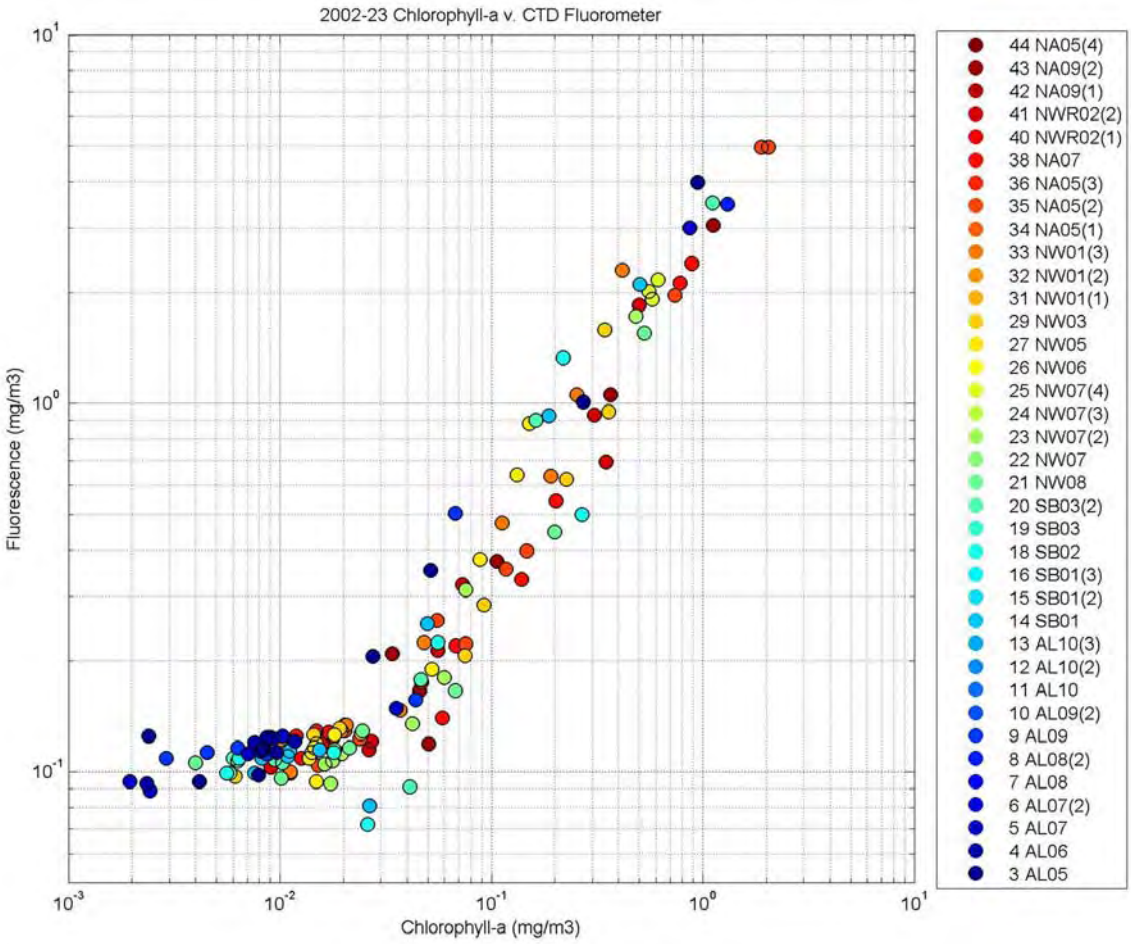

Figure 12. Chlorophyll-a v. CTD Fluorometer.

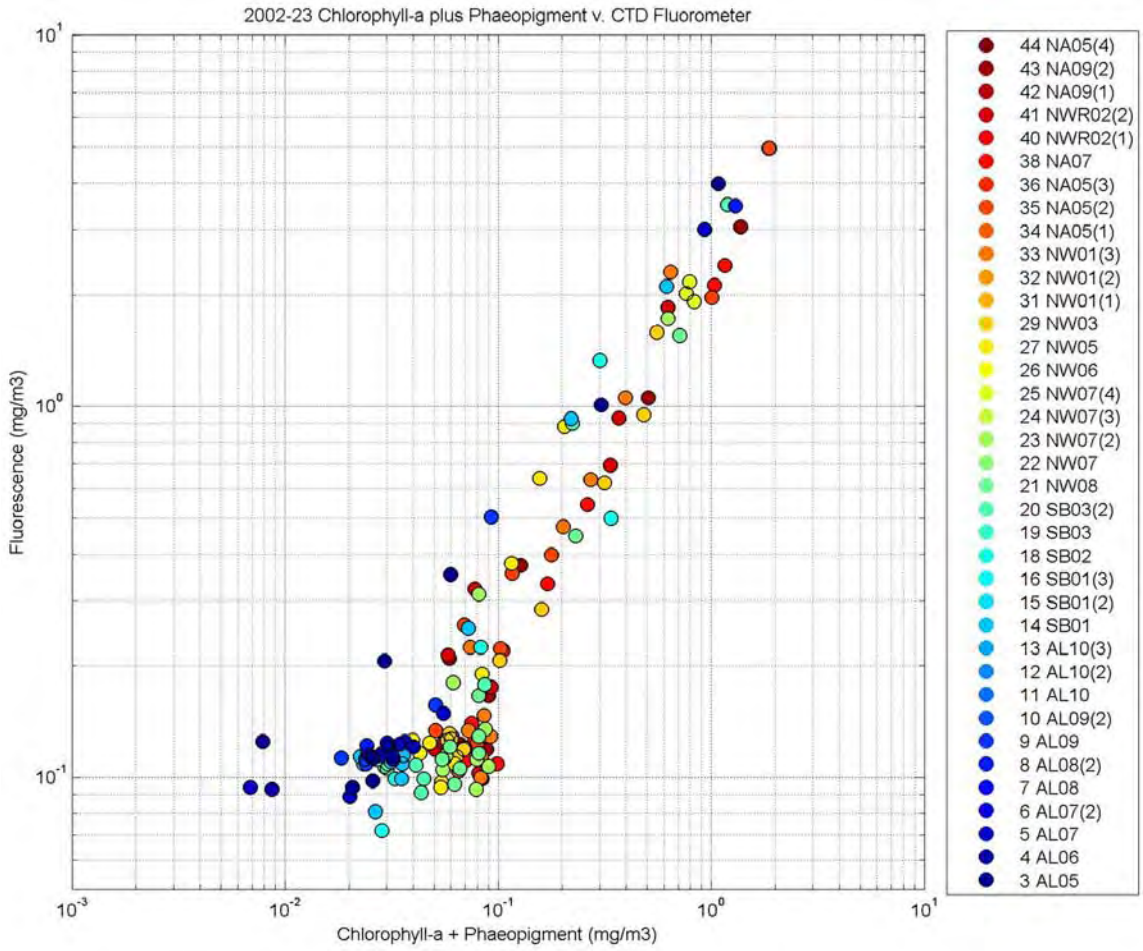

Figure 13. Chorophyll-a plus Phaeopigment v. CTD Fluorometer.

13. SHIFT

Tests were done on a few casts to see if shifting the conductivity channel improves the spikiness of the salinity. T-S plots were made to judge the setting that "just" removes unstable features without oversmoothing. The results were similar to those found for 2002-20 & 2002-21 which were +0.2 and -0.6 records for the primary and secondary respectively.

A first guess for the oxygen shift was made by comparing up and downcast temperature and oxygen. For a cast that had a temperature trace separation of about 4m, the oxygen separation was about 16 m. So a shift is needed that will move the upcast down about 6m and the downcast up 6 m. That is about +150 records. (Because the resolution was reasonably good, similar features in upcast and downcast could be picked out to judge the vertical separation.) Test runs were done using settings from +120 to +170 and the best results were found using +150. SHIFT was run on all casts using an advancement of +150 records.

After running SHIFT the downcast CTD files were metre-averaged, thinned, recalibrated using 2223RCAL1.ccf and COMPARE rerun. A 3rd order polynomial trendline was fitted to the differences vs. pressure and that relationship used to create a second recalibration file 2223RCAL2.ccf. The thinned files were recalibrated using that file and COMPARE was run again. This time the fit versus pressure, dissolved oxygen and time were reasonable with sensor values a little high near the surface, a little low from 100 to 300 db and a little high from 300 to 1000 db. Below that the scatter is great. Error analysis is problematic given uncertainties in the bottle sampling. Assuming that the titrated bottle values are correct sensor errors are on the order of ±0.4 mL/L near the surface and about ±0.15 from 100 to 2000 m. Below 2500 m the oxygen is low by up to 0.25 mL/L. This method of recalibration makes the downcast data match the bottles reasonably well.

14. DELETE

CALIBRATE was run to add 0.8 db to the pressure so that surface data will not be lost in DELETE.
CLEAN was run to replace pad values in pressure with interpolated values.
The following DELETE parameters were used:

Surface Record Removal: Last Press Min
Maximum Surface Pressure (relative): 10.00
Minimum Salinity: 10 Pressure Tolerance: 1.0
Pressure filtered over 15 points
Swells deleted. Warning message if pressure difference of 2.00
Drop rates < 0.3 m/s (calculated over 11 points) was deleted between 10 db and 10 db above the maximum pressure.
Sample interval = .042 seconds (taken from header)

The only warnings referred to 3 casts with sampling only at the surface. The CTD files from those casts will not be processed further, but the bottle files will be processed and archived.

15. DETAILED EDITING

The DEL files were copied to EDT files.
The secondary sensors were chosen based on calibration studies described in JWACS-2002-sal-calibration.doc.

Page plots were produced using T1,S1. These plots were examined for spikes and instabilities and used to guide the use of CTDEDIT. Where unstable features were clearly due to shed wakes the data was removed. Salinity was cleaned where large spikes occurred. Small spikes (mostly "overshoots" in large T gradient areas) were cleaned only if it was clear they were due to imperfect alignment of T and C.
The descent rate was generally quite steady and fairly high minimizing shed wakes. There were a lot of unstable features in the top 22 db which are believed to be due to overturning caused by the ship's propellers, bubblers etc. Heavy editing of secondary temperature and salinity was done near the surface but little was needed below that. All casts required some editing.
CTDEDIT was used to remove the transmissivity data below 1934 db for cast #14.

16. BIN AVERAGE

The following Bin Average values were applied to the edited files:
Bin channel = pressure
Averaging interval = 0.250
Minimum bin value = .000
Average value will be used.
Interpolated values are NOT used for empty bins.
The same values were used for the BOT files except that the Bin Channel = Bottle Number and averaging interval =1.
After averaging, page plots were examined on screen and no further editing was deemed necessary.

17. Other comparisons

Previous experience with these sensors - None. The same sensors were used during 2002-20 and 2002-21 which preceded this one.
Historic ranges - None available.
Post-cruise calibration - There was a post-cruise calibration showing the following drifts:

primary conductivity	+0.0006 units
secondary conductivity	+0.0001
primary temperature	+0.00047 °C/yr
secondary temperature	+0.00102 °C/yr

There is no net effect on secondary salinity but the primary salinity should be low by 0.007 at the time of the post-cruise calibration. This is close to what was found in COMPARE so it appears that the drift mostly occurred by the mid-point of this cruise.

Comparisons of nearby sites: Multiple cast T-S plots were produced for casts from nearby sites. The variations at depth were small. For example there were 3 casts at station AL10. The first two were within 1 km of each other and the third about 7 km from those two. The differences along a line of constant σ_t (at a depth of about 250 m) were ~0.0005 units of salinity and ~0.01 °C for the two casts that were 1 km apart and double that for casts 7 km apart.

18. Recalibration

See report in section 0 below for an analysis of salinity calibration information from 2002-20, 2002-23 and 2002-21. Based on this analysis the secondary salinity will be archived and will not be recalibrated.

See report in section 0 below for an analysis of the dissolved oxygen calibration information from 2002-20, 2002-23 and 2002-21. Based on this analysis the dissolved oxygen data will be recalibrated using the results of cruise 2002-23. The rosette files (BOT) will only be recalibrated using 2223rcal1.ccf since they are not subject to the time-response problem. The CTD files will be recalibrated using 2223rcal1.ccf and 2223rcal2.ccf.
The fluorescence data will be not be recalibrated.

The surface pressure (as judged by upcast conductivity) was recalibrated earlier.

19. REMOVE and REORDER

The following channels were removed from final bottle and CTD casts:
Scan_Number, Temperature:Primary, Salinity:T0:C0, Conductivity:Primary, Conductivity:Secondary and Flag.
For casts #15 to 27 the transmissivity channel was also removed.
The channels were reordered and formats corrected as needed.
The Standard Check routine was run and problems fixed.

EDIT HEADERS was used to add the following notes to the CTD files:
Transmissivity – The data are unedited.
Fluorescence:URU:Seapoint – The data are nominal.
Oxygen:Dissolved:SBE – This channel was processed by shifting +150 records with respect to pressure before removal of any records. Recalibration was done in two steps, using files 2223rcal1.ccf and 2223rcal2.ccf as described in the REMARKS section of the header.
The anticipated errors in oxygen are:
±0.4 ml/L from 0 to 100 m
±0.15 ml/L from 100 to 2500 m
0 to -0.25 ml/L below 2500 m (pressure hysteresis leads to low sensor values)
The final files were named CTD and RAC.

20. Final Plots
THIN and DERIVE were run to obtain values for tables and page plots were prepared using the edited data. Profile plots of temperature, transmissivity, dissolved oxygen and fluorescence were prepared.

21. Producing final files
A cross-reference listing was produced.
The sensor history was updated.
A separate set of files were prepared in which the full edited files were recalibrated, channels removed and reordered and header notes added as described above; these plus the RAC files were saved on CD-ROM for Fiona McLaughlin.

Particulars
14. Transmissometer malfunctioned at about 1930 b.
15 to 27. Transmissometer not functioning
28. Transmissometer replaced
31. Surface sampling only. Delete CTD file, keep bottle file
40. Surface sampling only. Delete CTD file, keep bottle file
44. Surface sampling only. Delete CTD file, keep bottle file

Report: JWACS 2002 Arctic Data Calibration Question

Order of cruises: 2002-20, 2002-23 and 2002-21.
From three cruises we have log notes, sensor comparisons, bottle comparisons and pre-cruise and post-cruise calibrations.

1. *Calibrations from SeaBird* – As part of the calibration after the JWACS cruises SeaBird reported on the sensor drift since the previous calibration. They were as follows:

primary conductivity	+0.0006 units
secondary conductivity	+0.0001
primary temperature	+0.00047 °C/year
secondary temperature	+0.00102 °C/year

The net effect of these drifts on salinity is produce primary salinity low by about 0.007 units and there is no effect on secondary salinity.
If we assume the drift in the primary salinity was gradual then by August 2002, about 5 months after the 1st calibration, the salinity would be low by about 0.003.
SeaBird also commented that the primary conductivity cell was cracked which might suggest that the change in calibration was not gradual.

2. *Notes from the CTD and rosette logs* – Only notes of possible relevance to calibrations:

2002-20:
all bottles fired on upcast, most after 20-30s wait
problems with winch on upcasts – surging, some bottles tripped without stop on upcast
cast # 38: "bottle #12 does not close all the way at the top"
cast #47: rosette dropped hard on the deck - "popped about half the plungers that hold BOTs below retaining ring"
cast #51: "tightened set screws in upper caps of BOTs – replaced 2 missing screws"
cast #55: "bungy snapped"
cast #62: water drips for bottles #12 and 14
cast #63: "bungy repair"
csat #64: leak from bottle #14
cast #65: "o leak" bottle #14
cast #69: "bottom valve on Bot #3 broken?"
cast #71: "replaced another bungy"
2002-23:
cast #9: bottle #12 leaking
cast #12: bottles #10 & 12 – LD O-RINGS installed
cast #13: bottle #5 leaking from bottom
cast #13: repairs made to rosette because of problems affecting proper bottle closure. Replacement of bottom spigot on #23, to bungee cord for bottle #15, repair to bungee on #24. Small screws on bottle lids checked for tightness
cast #18: bottle #2 leaking and #6 did not close
cast #21: bottle #9 spigot loose
cast #22: bottle #20 did not close
cast #23: bottle #2 leaking from bottom and #21 did not close
cast #24: bottle #24 did not close
cast #25: bottle #18 did not close
cast #27: bottle #2 leaking from bottom, and #16-oil on spigot
cast #29: bottles #2 &17 leaking
cast #33: bottle #17 bottom leaking
cast #35: bottles #1,2 and 17 leaking
cast #36: bottles #1,2 and 17 leaking
cast #38: bottle #2
cast #41: bottle #1 did not close
2002-21:
no relevant notes found

3. *Sensor comparisons*
A routine part of processing is to compare primary and secondary sensors at depth. No significant changes were noted in the temperature differences during the JWACS cruises, but there was a change in the conductivity and salinity differences. These occurred between cast #27 of 2002-20 and cast #1 of 2002-23. There were no deep casts between these two casts. The variations in shallow water are too large to be able to track when the change occurred or whether it was sudden or gradual. For cast #27 of 2002-20 the salinity differences were about 0 at 500 db and +0.0045 at 2100 db. During 2002-23 the salinity differences were on the order of 0.005 at 500 db and 0.006 at 1900 db.

From the beginning there was unusual pressure dependence in the salinity differences. During 2002-20 that was not seen in upcast data, but probably that was because of the winch problems causing less sensitivity in the upcast measurements. This usually suggests at least one malfunctioning sensor.

4. *Bottle comparison*

2002-20:

The salinity was found to be low by about 0.002 for the primary and about zero for the secondary. The differences were fairly flat versus pressure but there are few data points and a huge scatter. An apparent time-dependence is largely based on very shallow casts. If we include only data from 500 db down there are only 3 points. Moreover, the upcasts were extremely noisy due to winch problems, and the CTD rosette files have very high standard deviations so the CTD values are suspect.

The comparison done for 2002-20 used different standards from the other two cruises since excluding bottles with high standard deviations left almost nothing to compare.

Bad bottles: two samples were found to be extreme outliers and came from bottles #1 and 3

2002-23:

The sampling for this cruise was very complex with downcast and upcast sampling.

COMPARE was run separately on upcast only and downcast only. Data were selected from 500 db downwards and points were rejected so that differences more than 0.001 from the average were excluded.

For the upcast sampling the primary salinity was found to be low by 0.0067 and the secondary low by 0.0011. The primary is remarkably flat versus pressure but the secondary has some pressure-dependence (low by 0.002 near 500 db, about 0 at 2500 db and high by 0.001 at 3500 db). However, the scatter is huge (standard deviation in the fit of both pairs is on the order of 0.003 units of salinity). The time-dependence is the same for both sensor pairs (-0.0002 * file pair number). That is significant for the primary but when later shallow casts are not included the secondary time-dependence disappears.

For the downcast sampling the primary salinity was found to be low by 0.0063 and the secondary low by 0.0010. Both sensors are remarkably flat versus pressure, but the scatter is huge (standard deviation in the fit of both pairs is on the order of 0.003 units of salinity). There are not enough casts to make time-dependence worth looking at.

After removing outliers there is remarkably little difference between the upcast and downcast sampling except that so much data was lost from the downcast sampling due to bottle problems.

Bad bottles: Where do we begin? Many bottles gave terrible results, clearly due to bottle malfunction. The downcast sampling produced terrible results. A comparison was done versus bottle numbers, which identified bottles 1,2,3,4,5,8 and 12 as extremely bad producing differences of 1 to 7 units of salinity during downcast sampling. The other bottles may well have more subtle problems. On the upcast bottle #3 gave notably bad results.

2002-21:

All sampling was done during downcasts on the fly and none deeper than 650 m. The primary salinity was found to be low by about 0.002 when outliers were rejected. There is more pressure-dependence than during 2002-20 and 2002-23 with a tendency towards lower CTD values relative to bottles at depth. The secondary sensors were high by about 0.001 with a little less pressure dependence than the secondary and a tendency towards zero difference between CTD and bottle at depth. Both sensors show more time-dependence than during 2002-20 pr 2002-23, but there are only 7 casts below 250 db and the scatter is huge. When only results from 350 db were compared there was no noteworthy time-dependence.

A second approach was tried with small rosette files, 5 records per bottle firing to see if better results were obtained. The primary looked about the same and the secondary differences were a little higher (~0.002). The pressure dependence was similar. If we assume that the secondary differences should be zero, than the water in the bottles must represent conditions from about 9 m above the sensor.

Bad bottles: Bottles 1,2,3 and 5 generally gave poor results. Bottle #4 was very bad once and #9 poor twice. The differences were not nearly as large as during 2002-23, but the sampling was not so deep so if the errors are pressure-dependent they will not be as obvious.

Conclusions
There are 4 questions that arise from this analysis:

1. When did the conductivity cell crack and does it matter?
The evidence that it cracked early, before the deep casts of 2002-20, is the pressure-dependence of the differences between sensors. We normally expect very little pressure-dependence below 200-500 db.
The evidence of it cracking later, after the deep casts of 2002-20 and before 2002-23, is that the differences between pairs of conductivity and salinity sensors changed between casts #7 of the former and #1 of the latter. A likely time for that to happen is when the rosette hit the deck hard. The salinity calibration shifted from one cruise to the next but a simple pattern does not emerge. The primary calibration appears to shift between 2002-20 and 2002-23, while the secondary shifts between 2002-23 and 2002-21. Given the different methods of bottle collection and noisy and limited data for 2002-20, and the different depths involved, there is no clear evidence of a sudden shift in calibration.

Does it matter? There was a lot of drift in the primary calibration over 2002. Whatever the cause we don't know when or how gradually the calibration changed. It probably means we have to use the secondary data.

2. What bottles can be counted on for a bottle comparison?
The worst can certainly be picked out. Using the others requires a lot of faith, but there does seem to be some consistency.

3. How do we recalibrate?
Use the secondary salinity and assume no drift. The bottle comparisons suggest an error of no worse than ±0.001 units of salinity.

4. Can we learn anything from these results?
If we assume that the secondary salinity calibrations did not drift then the fact that they are about zero during 2002-20, varied with pressure for 2002-23 and high by 0.0013 during 2002-21 may tell us something about sampling techniques. During 2002-21 the casts were relatively shallow and there are no notes about big problems with bottles. If the bottles are not an issue then we expect that the CTD would measure deeper water than that sampled by the bottles. If the sensors are holding their calibration well the size of that difference might be a measure of the different depths at which the bottle and CTD sampling was done. Such analysis suggests that the water in the bottles comes from about 9m above the sensor.

The upcast sampling during 2002-23 was done with bottle stops and we expect no significant differences between the bottles and CTD. The differences gradually decrease with pressure. At depth they are slightly high but given the scatter it is not significant. But why does the CTD look low down to 1500 db? Is it possible that there was some leakage into the bottles during upcasts? Could the tendency to leak decrease with the pressure at which the bottle was closed? The difference is not huge given the scatter but it is puzzling and in the absence of

any reports of damage to the secondary conductivity cell, it may suggest problems with the bottles even during upcasts.

A possible explanation is that there was a delay in the firing of the bottles leading to apparently high salinity during downcast sampling and low salinity during upcast sampling. To study this possibility the performance of one bottle was analysed for the 3 cruises. Bottle #3 performed badly during all three cruises and during both upcast and downcast sampling. During 2002-20 the bottle was rarely used for salinity sampling but on the two occasions when it was fired below 50 m (during upcasts), the bottle gave salinity low by +0.01 and +0.04. During 2002-23 downcast sampling it gave extremely high salinity (by up to 7 units) and, during upcasts, low salinity (by up to 0.25 units) although there are a few exceptions to the latter. During 2002-21 bottle #3 performed badly as well with salinity bottle reading lower than the CTD by at least 0.05 units for 6 out of 8 firings in casts deeper than 125 m.

There are other bottles that stand out as bad, for example bottle #5 generally looks worse than its neighbours on the rosette during both 2002-23 and 2002-21. There is insufficient evidence to say whether that was true during 2002-20.

The fact that the differences were approximately zero for 2002-20 might suggest that the major bottle problems did not arise until after cast 2002-20-0027. The dropping of the rosette on the deck during 2002-20 or the exposure to much higher pressures during 2002-23 might account for the bottle trouble. However, the bottles with the worst results during 2002-23 were not used much during 2002-20 so the results may be accidentally good. The problems were not severe during 2002-21 suggesting that whatever the cause, the effect was worst in high-pressure sampling.

Report: JWACS 2002 DISSOLVED OXYGEN COMPARISON

From previous experience with SBE 43 instruments we expect to deal with time-response problems as well as basic calibration of the sensor. We can address the basic calibration of the sensors by comparing rosette files with bottles. To address the time-response problem we first SHIFT the data to realign the DOX in such a way that the upcast oxygen trace overlies the downcast one in about the same way as the temperature trace does. Then we apply the calibration correction based on bottles to the shifted downcast CTD files; we metre-average those, thin them and compare them to the bottles. From this comparison we develop a scheme to reduce the errors due to time-response and up/down differences.

This analysis concerns three JWACS cruises; there is little calibration information for 2002-20, none for 2002-21 and a lot for 2002-23. So the analysis will be based on 2002-23. For the JWACS data the time-response problems are less severe than found for sensor #0047 and consequently, the resolution of features much better. Something noted during this cruise that has not been observed previously is that there are differences on the order of 0.1mL/L between downcast and upcast data with upcasts showing notably lower values. There is no sign of this problem in shallower water, but with rapidly varying gradients it could be there, but masked by other errors. SeaBird do warn that hysteresis from pressure cycling is significant below 1000 m. Hence, it is hoped that this is just a problem in deep water.

For 2002-23 COMPARE was run on the data from the SeaBird dissolved oxygen sensor. The downcast bottles were excluded from the analysis because of problems noted during salinity calibration analysis. The results indicate considerable pressure-dependence but no significant time-dependence. In the top 500 db the differences reflect the complex gradient in DOX, reading low in zones of decreasing DOX and high where DOX increases. From 500 db to 1500 db the differences vs pressure are quite flat, but below that they increase notably even though the local gradients are low. Because problems were noted in the salinity analysis with bottle #3 it was decided to drop that bottle from the analysis which removed most 2500 db data. The data has a lot of scatter but is tightest for differences vs DOX. The trendline for that fit was used to create a calibration control file 2223RCAL1.ccf, which was then applied to the bottle files. (See DOXcomp.xls).

CALIBRATE was rerun and the results show a reasonably good fit vs DOX, and again no significant time-dependence. Some pressure dependence remains with the sensor reading low by up to 0.2 mL/L near the surface and high by 0.2 mL/L at 3500 db. Given there were problems with bottles during this cruise it should be kept in mind that the deep differences may not be entirely due to the sensor. But there is evidence that the instrument did not equilibrate well at all at depth. For example at the bottom of cast #18, at 3533db, the SBE43 oxygen is increasing slowly as it approaches the bottom, but when stopped the oxygen decreases and after a stop of over 2 minutes it still appears to be decreasing. It

continues to decrease during the early part of the upcast although the bottles suggest that it should be increasing. The vertical displacement of notable features in the profiles is not particularly large but the differences in values between up and downcast is on the order of 0.1 mL/L. This is probably due to the pressure hysteresis described by SeaBird in the manual for the SBE43. (See DOXcom2.xls).

This initial recalibration is based on upcast observations during stops for bottles. So this takes into account neither time-response effects nor other differences between the downcasts and upcasts. To address the first issue the oxygen data is realigned.

A first guess for the oxygen shift was made by comparing up and downcast temperature and oxygen. For a cast that had a temperature trace separation of about 4 m, the oxygen separation was about 16m. (Because the resolution was reasonably good, similar features in upcast and downcast could be picked out to judge the vertical separation). So a shift is needed that will move the upcast down about 6m and the downcast up 6 m. That is about +150 records. Test runs were done using settings from +120 to +170 and the best results were found using +150. SHIFT was run on all casts using an advancement of +150 records.

Next, the shifted downcast CTD files were metre-averaged, thinned and recalibrated using 2223RCAL1.ccf; those files and the titrated values were used in another run of COMPARE . A polynomial trendline (order 3) was fitted to the differences vs. pressure and that relationship used to create a second recalibration file 2223RCAL2.ccf. (See DOXcom3.xls). The thinned files were recalibrated using that file and COMPARE was run again. This time the fit versus pressure, dissolved oxygen and time were reasonable with sensor values a little high near the surface, a little low from 100 to 300 db and a little high from 300 to 1000 db. (See DOXcom4.xls). This method of recalibration makes the downcast data match the bottles reasonably well. Given the uncertainties arising from bottle sampling problems error analysis is problematic. Assuming that the titrated data is correct then the DOX sensor errors are on the order of ±0.4 mL/L near the surface and about ±0.15 from 100 to 2000 m. Below 2500 m the oxygen is low by up to 0.25 mL/L.

For cruises 2002-21 there was no oxygen sampling. For cruise 2002-20 there was sampling but it was limited to a few shallow casts in very well-mixed waters. For cast #31 the recalibration method developed for 2002-23 produced higher values (high by 0.33 on average whereas we got high by 0.1 for 2002-23 at those depths). But oxygen values were very high and oxygen gradients very low and they do not reflect most of the casts from this cruise. Also the differences fit within the expected errors. It is a pity that there was no dissolved oxygen sampling from a deeper cast of 2002-20.

4.4 INDIVIDUAL STATION PLOTS

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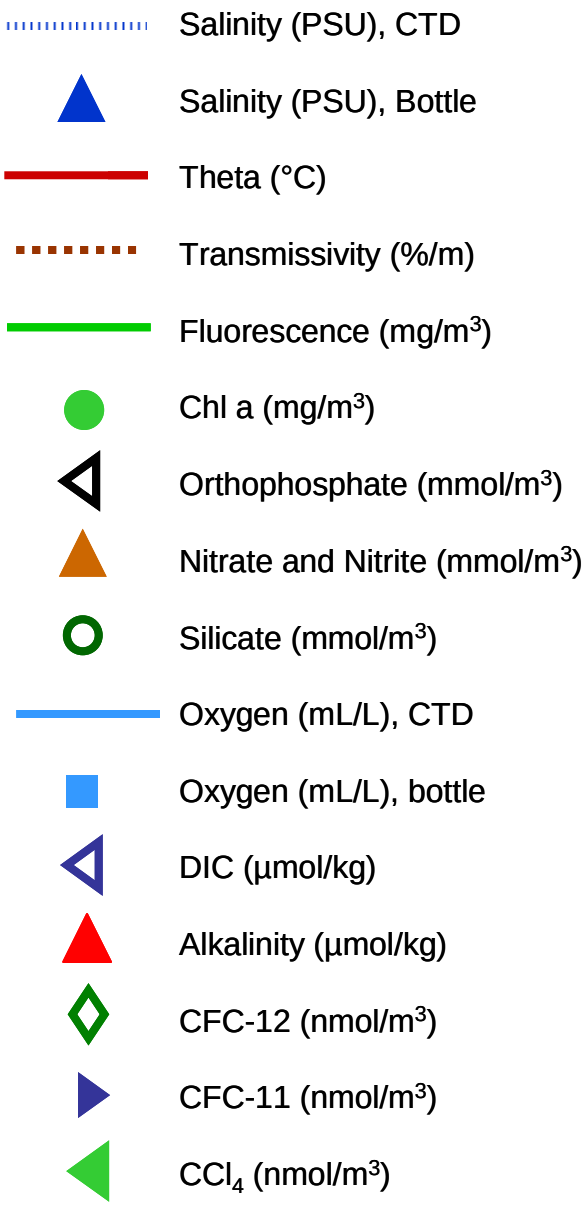

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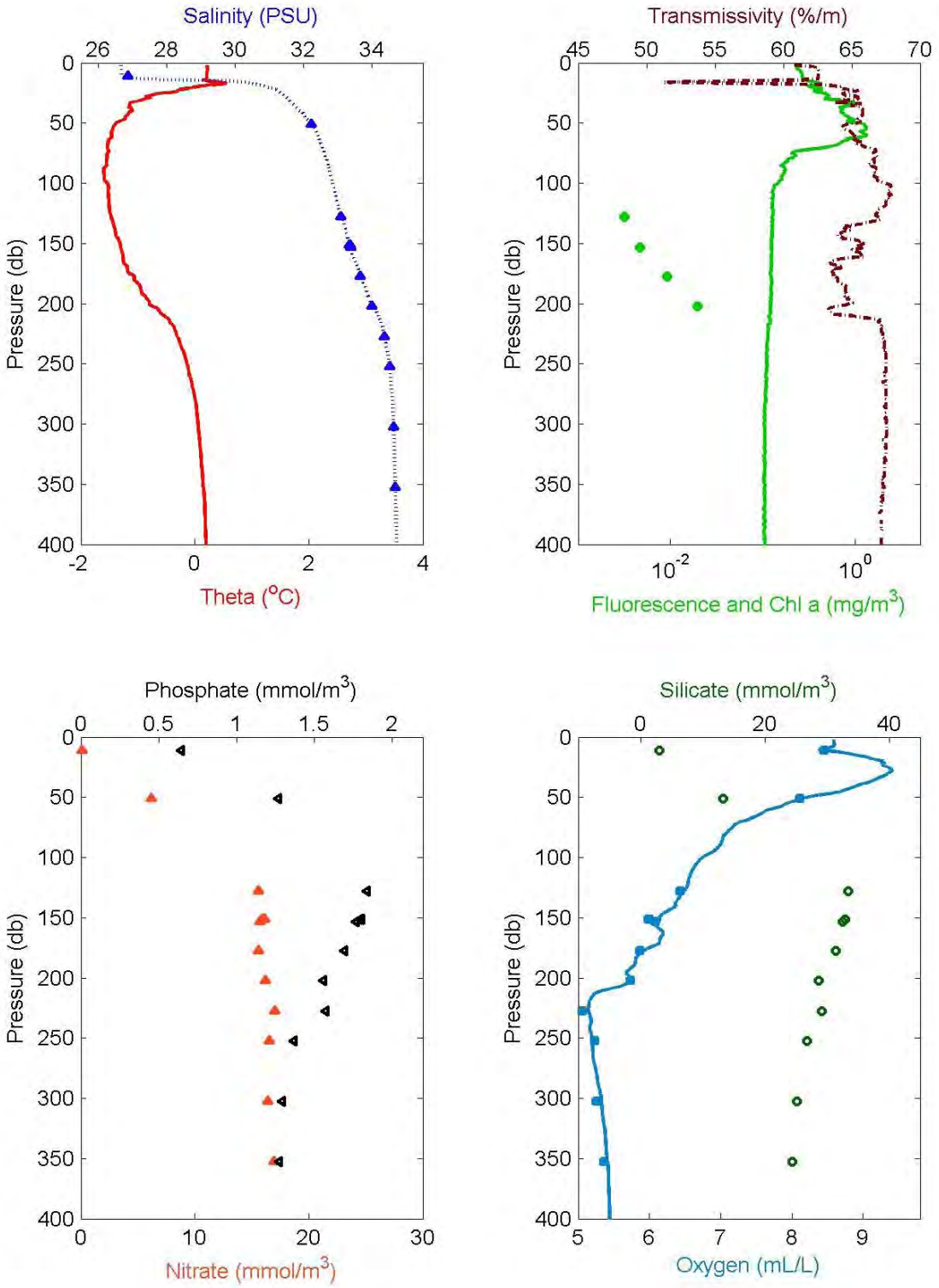

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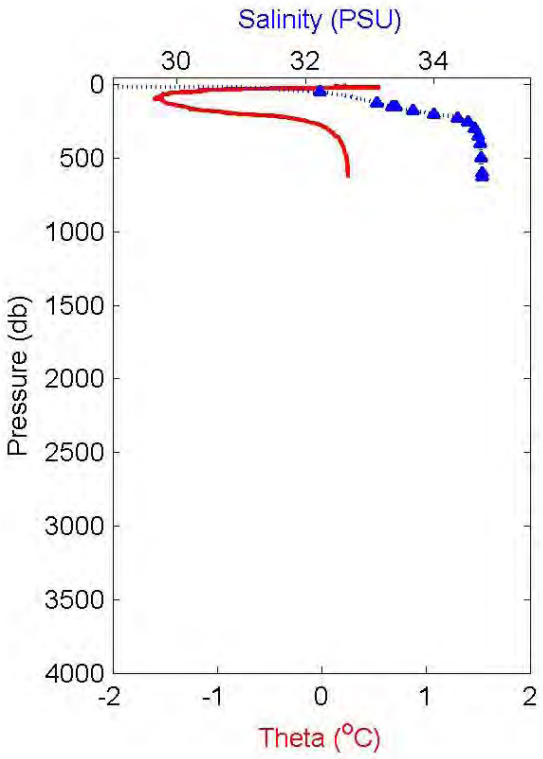

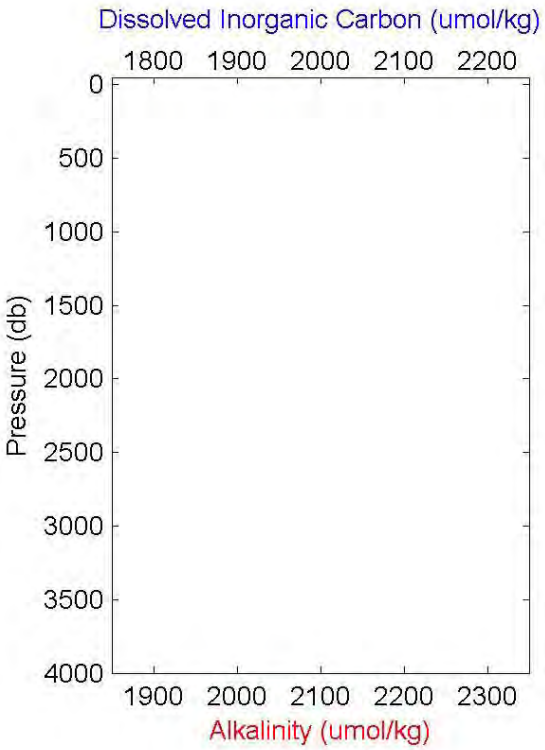

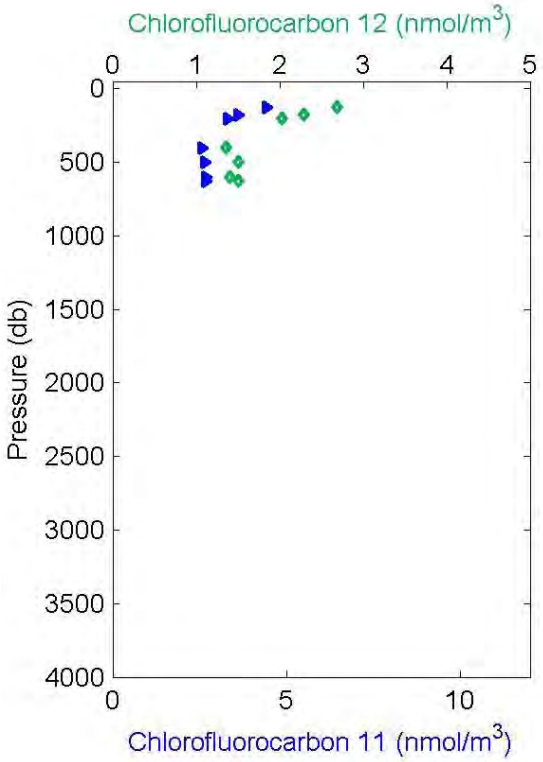

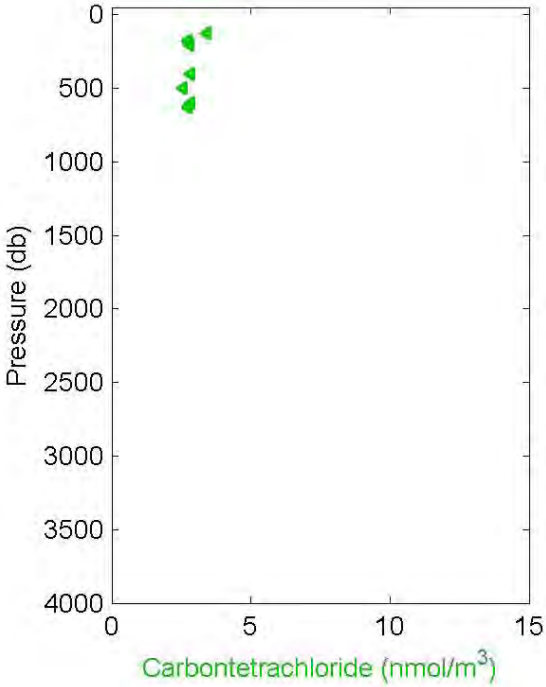

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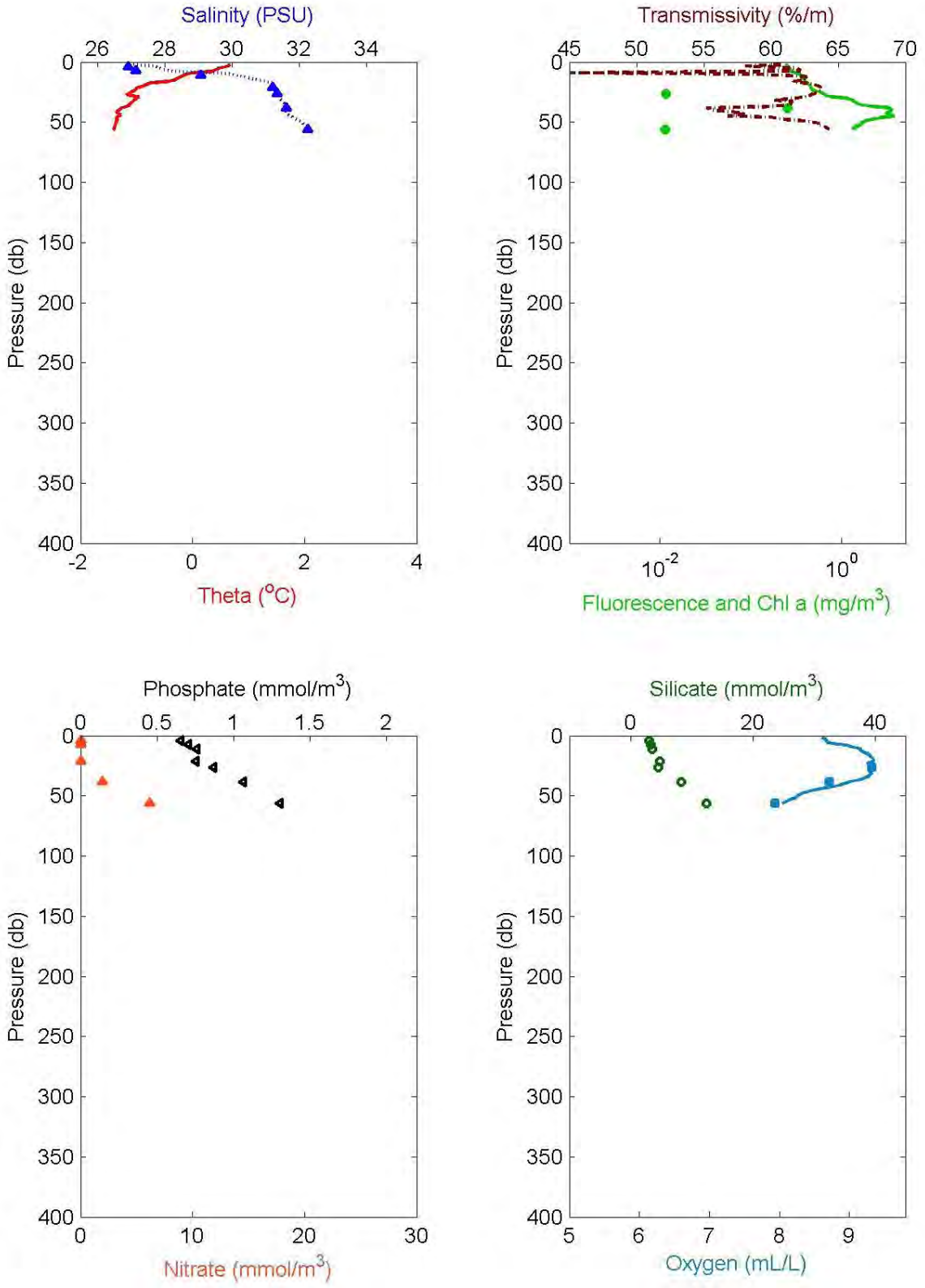

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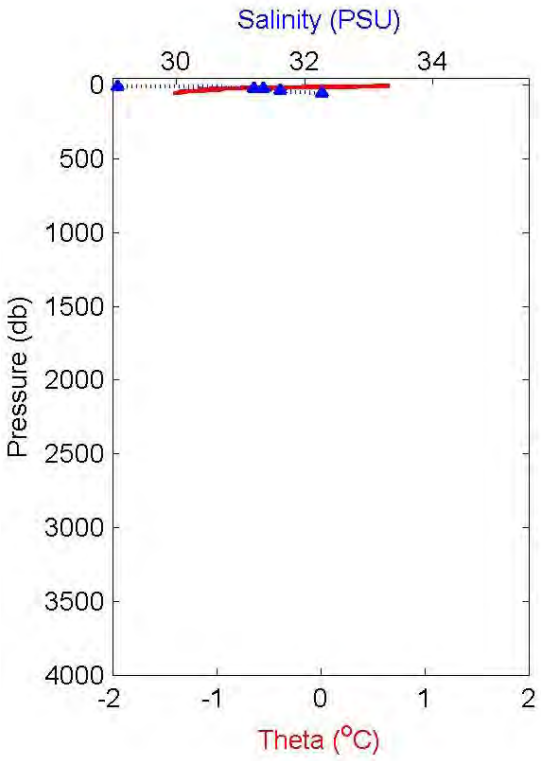

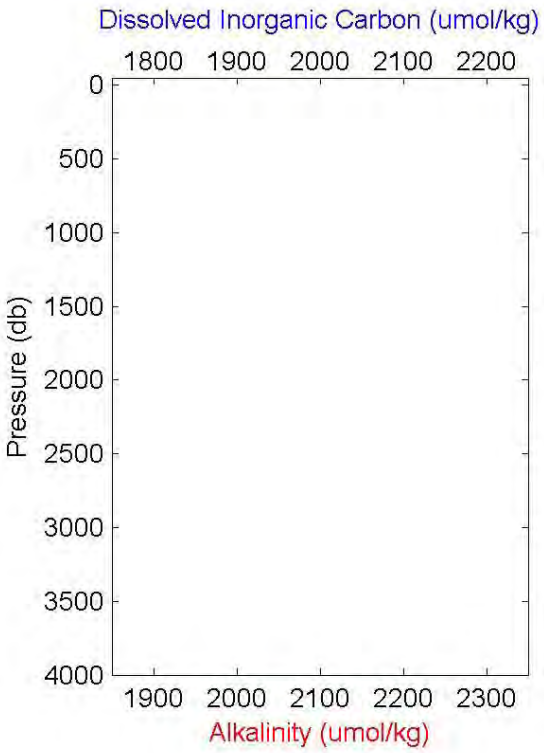

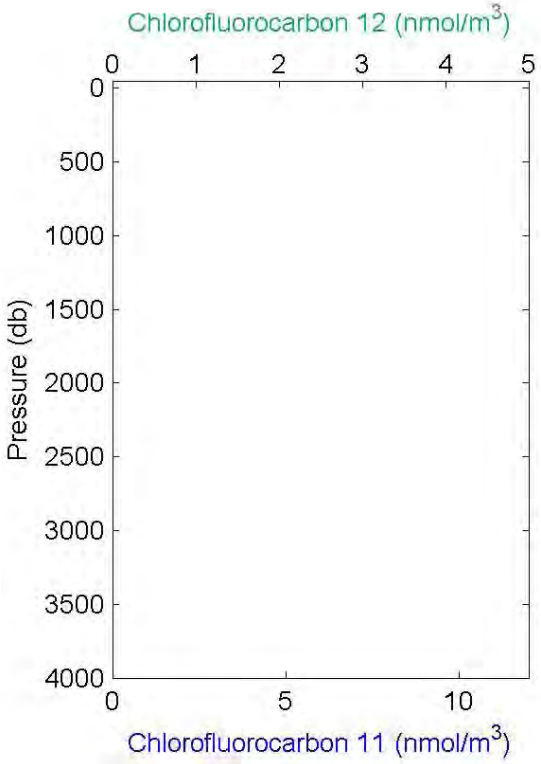

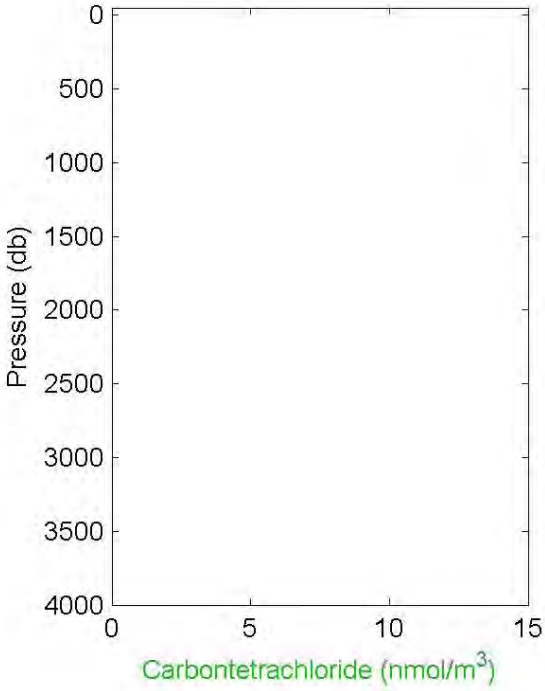

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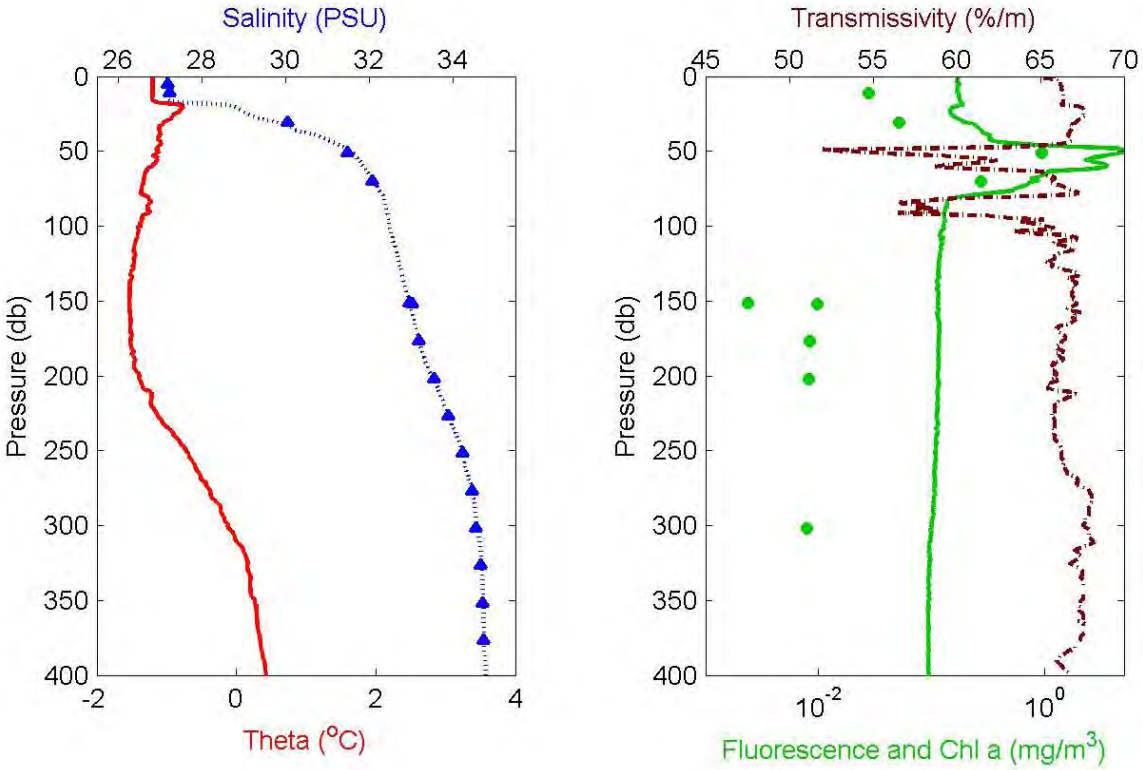

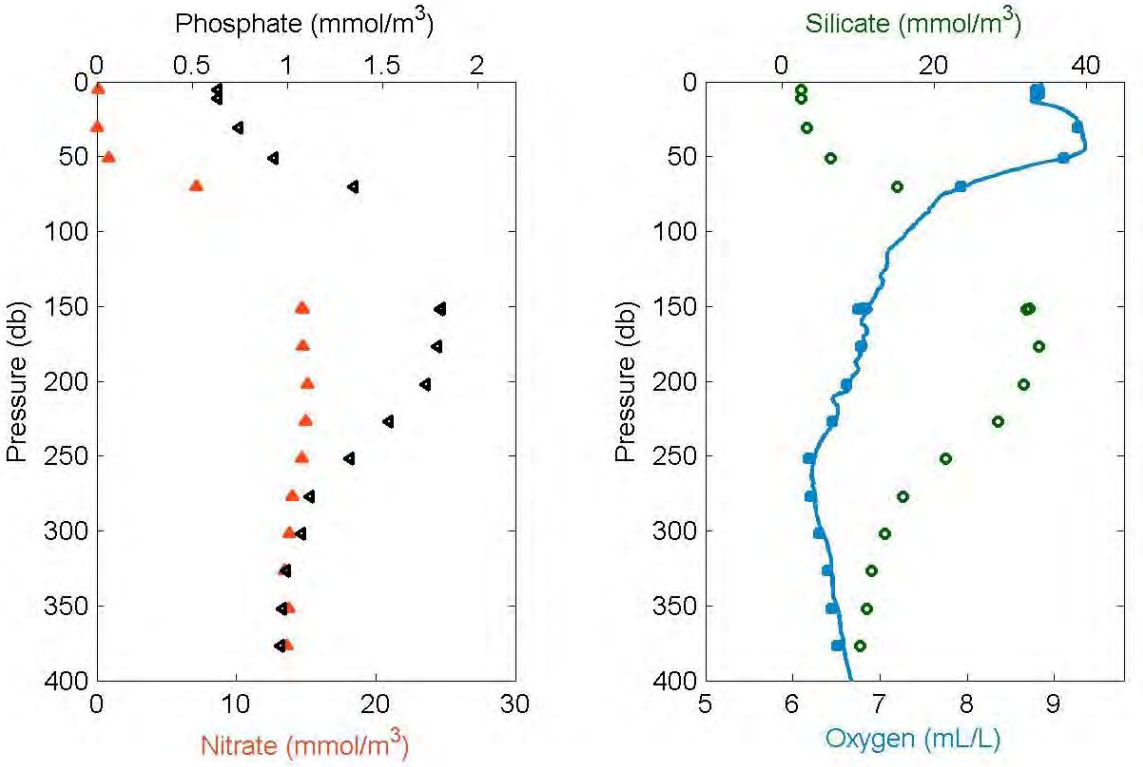

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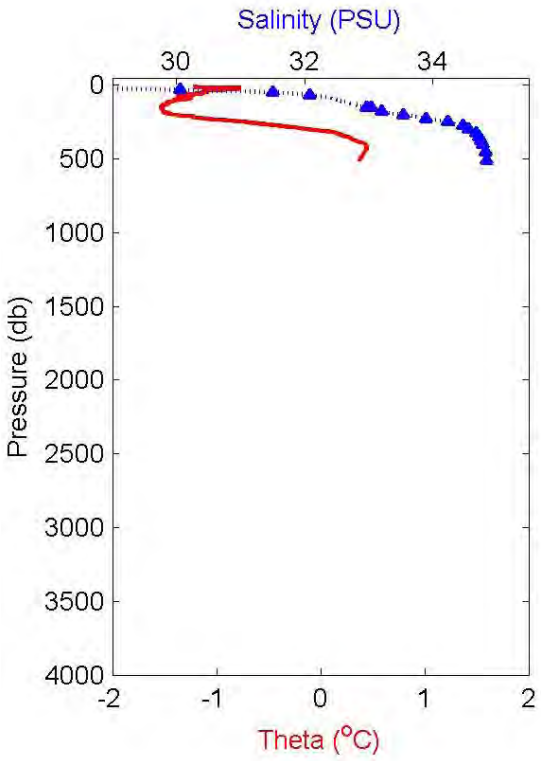

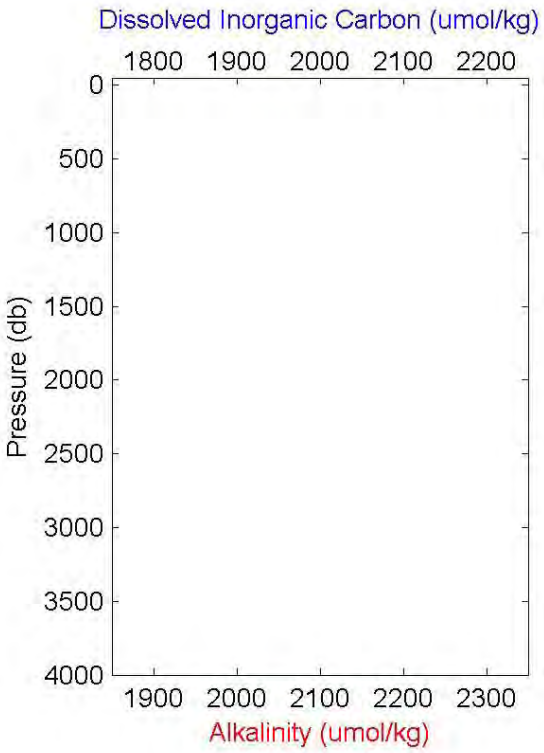

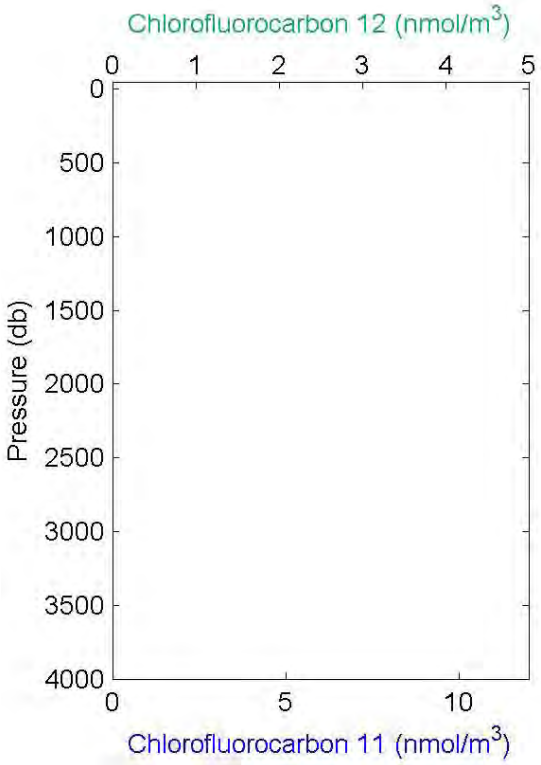

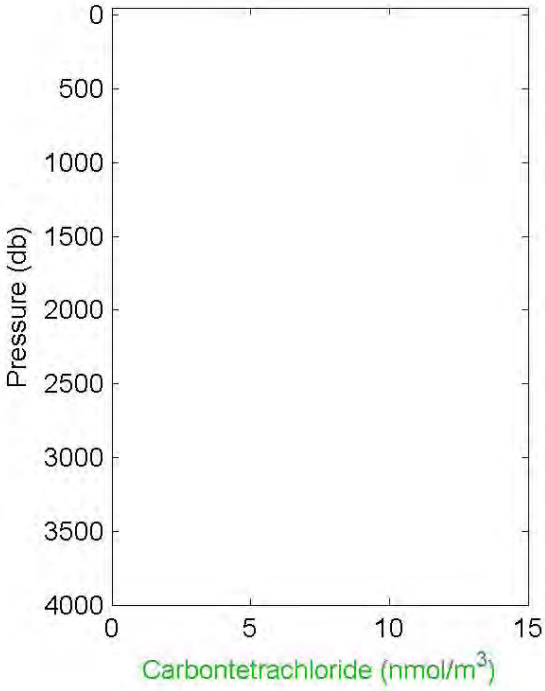

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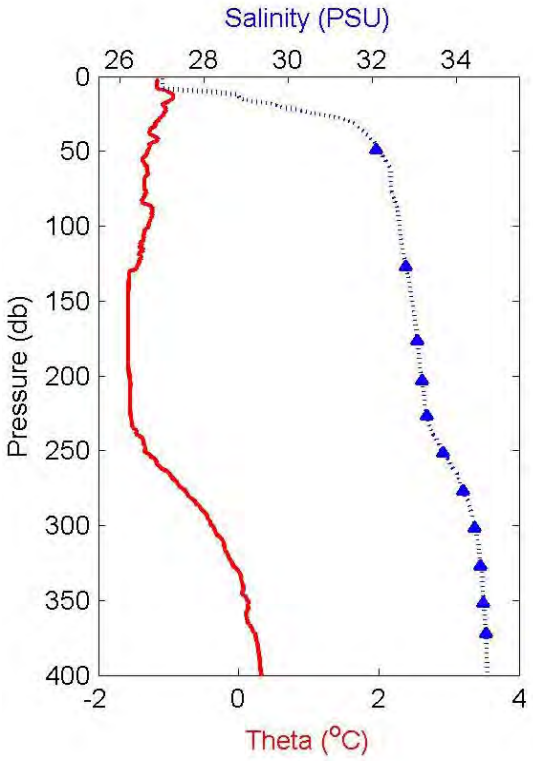

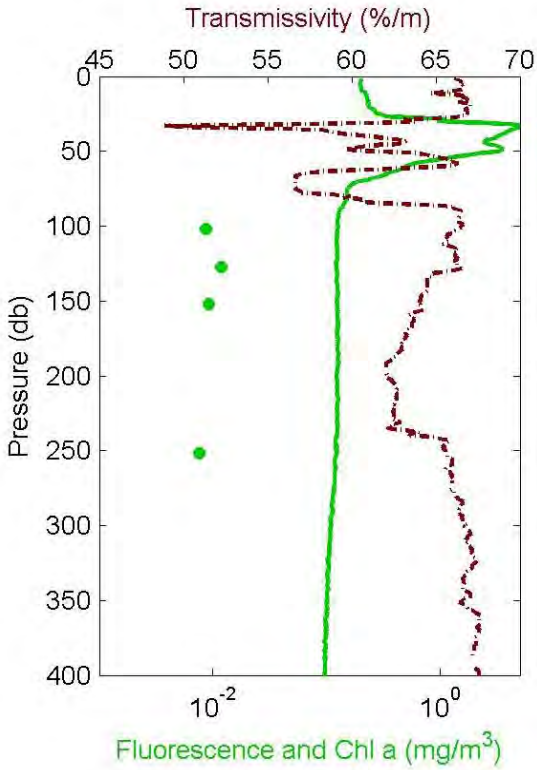

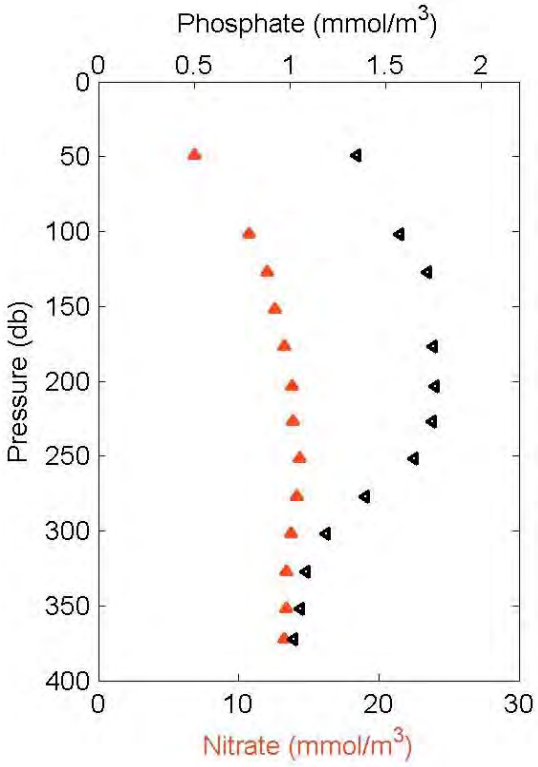

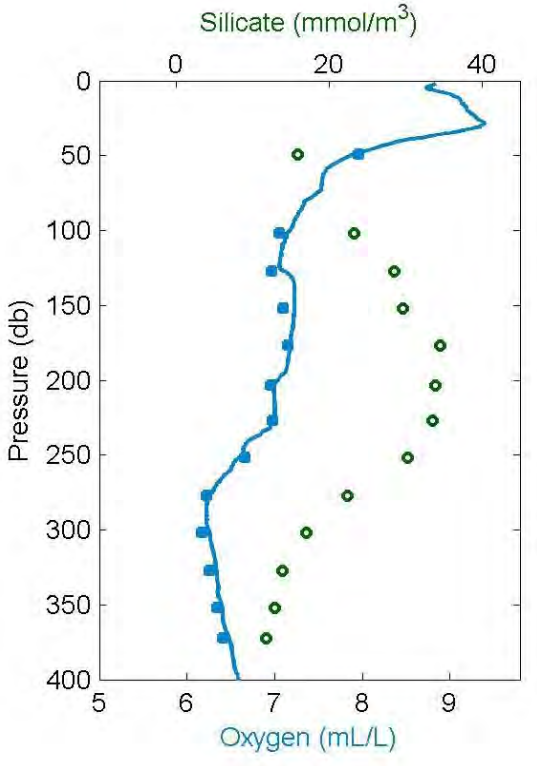

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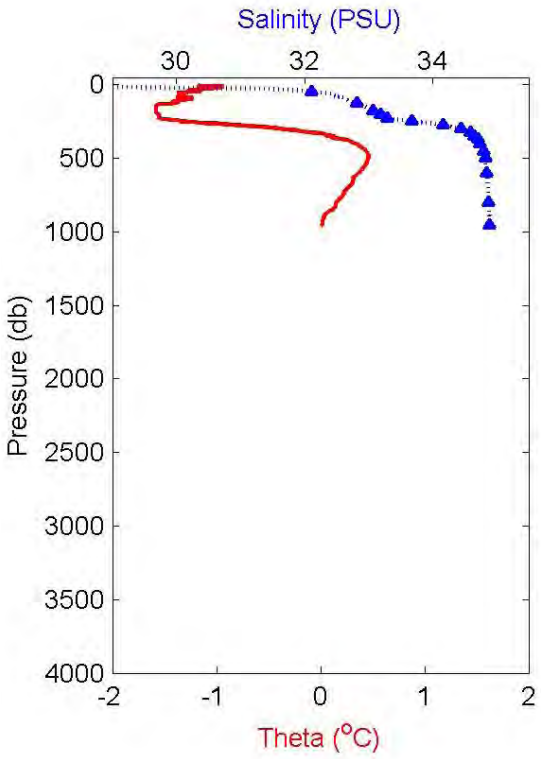

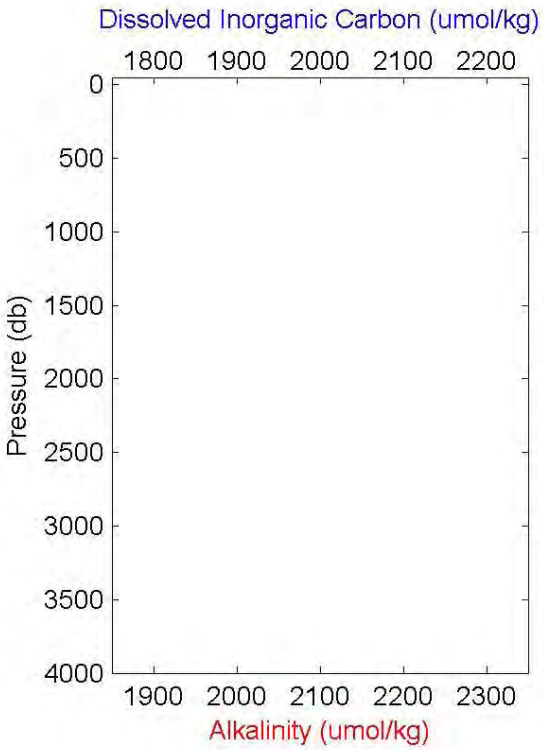

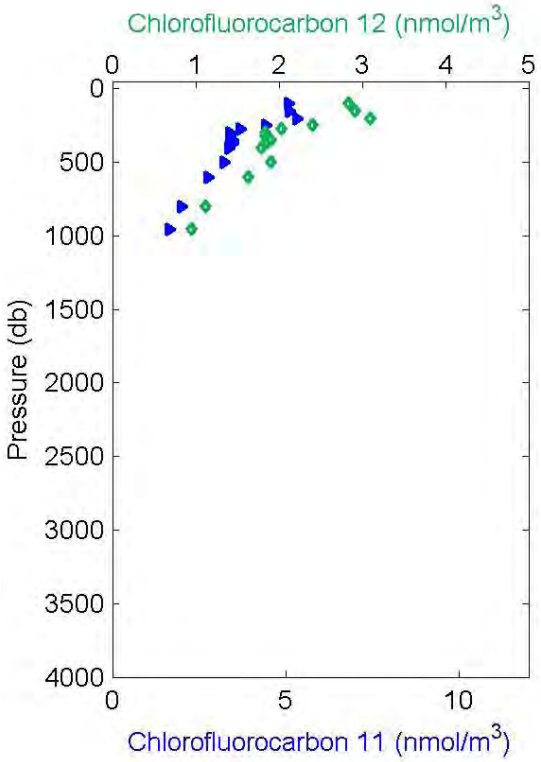

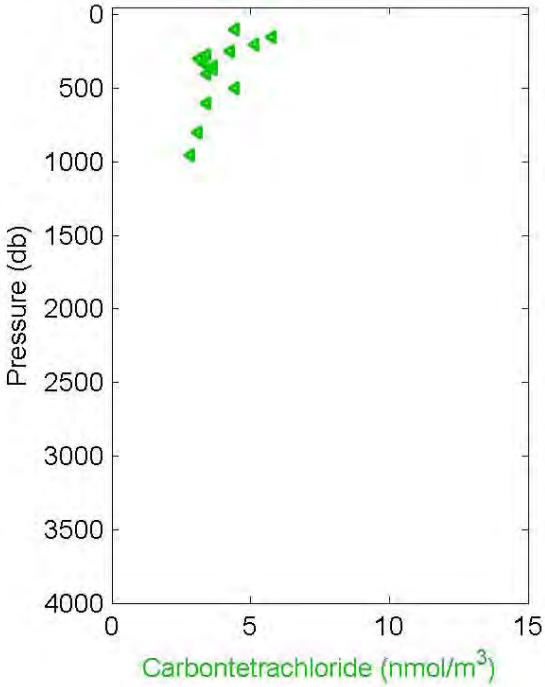

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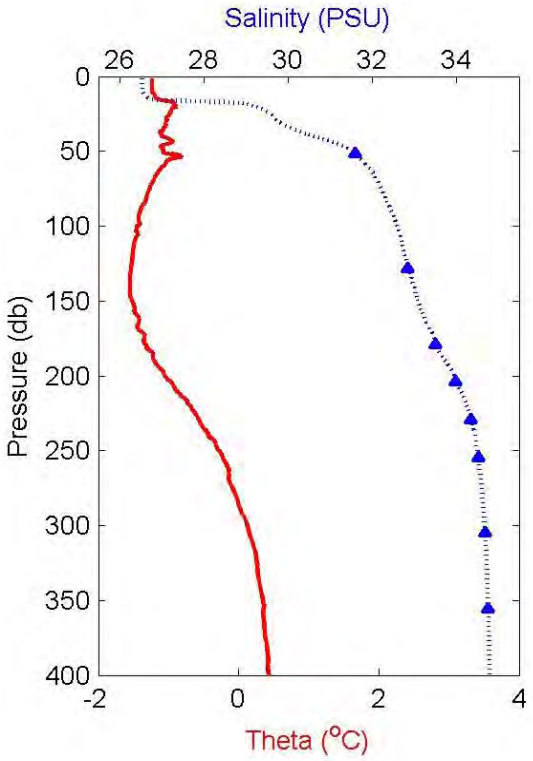

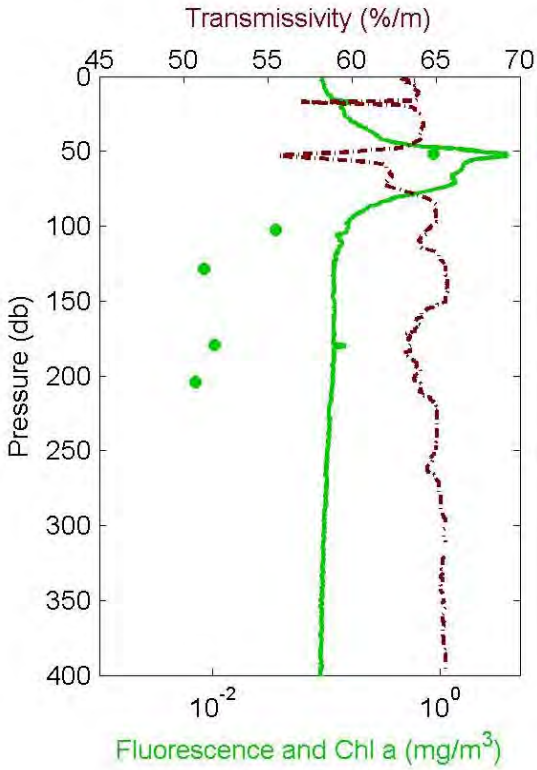

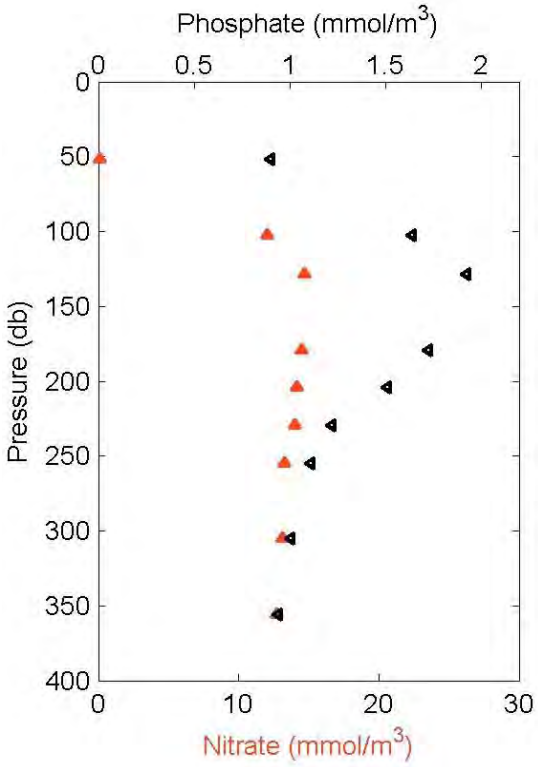

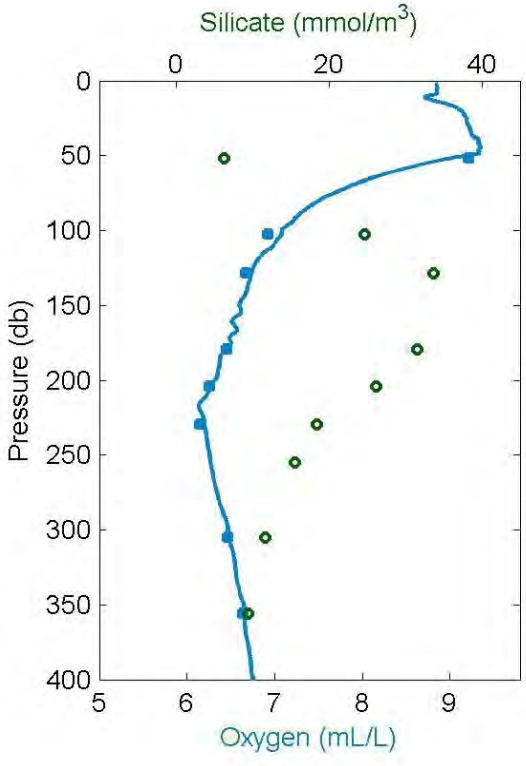

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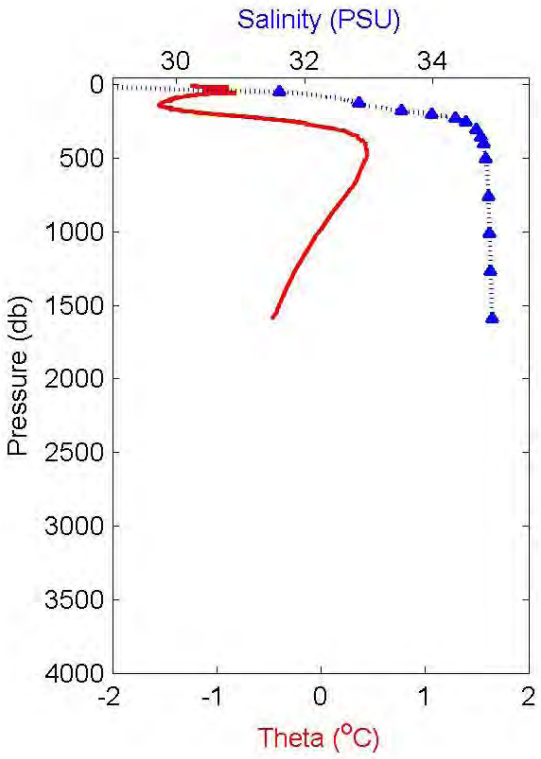

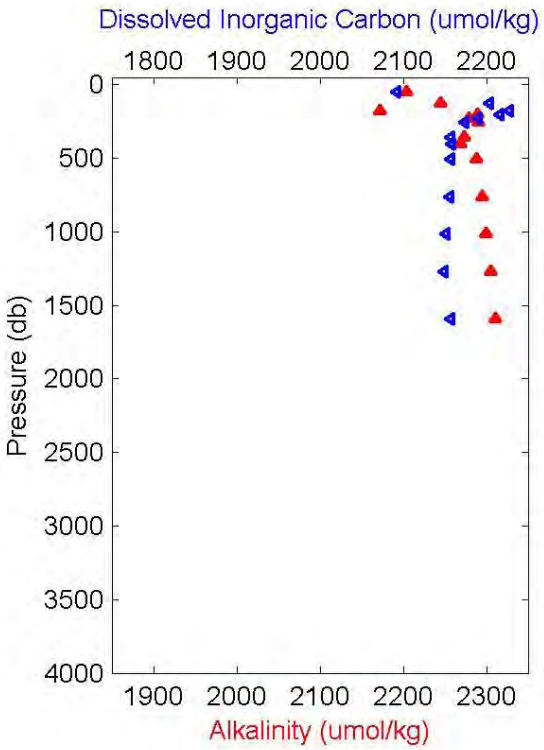

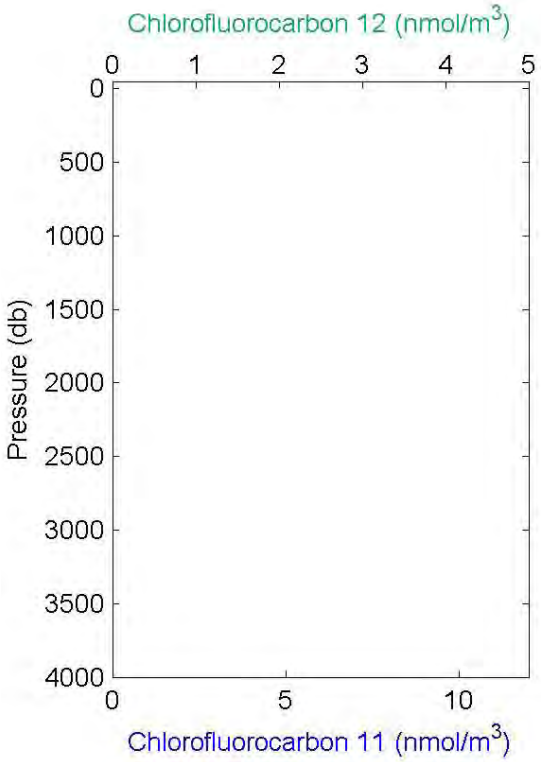

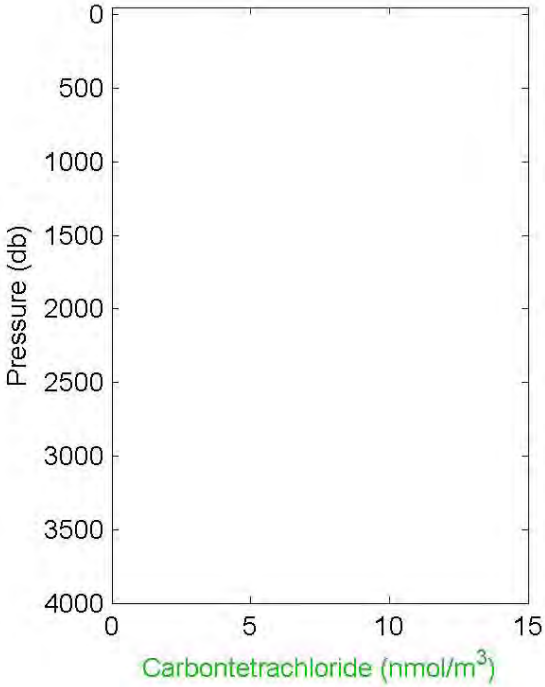

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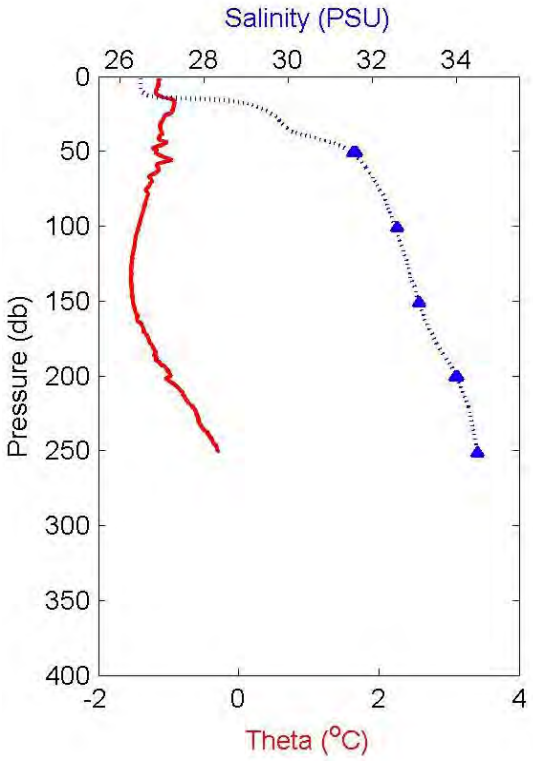

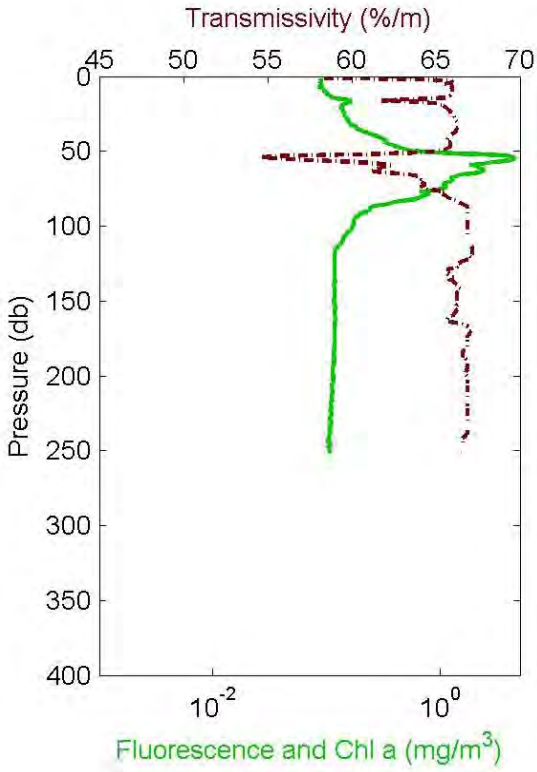

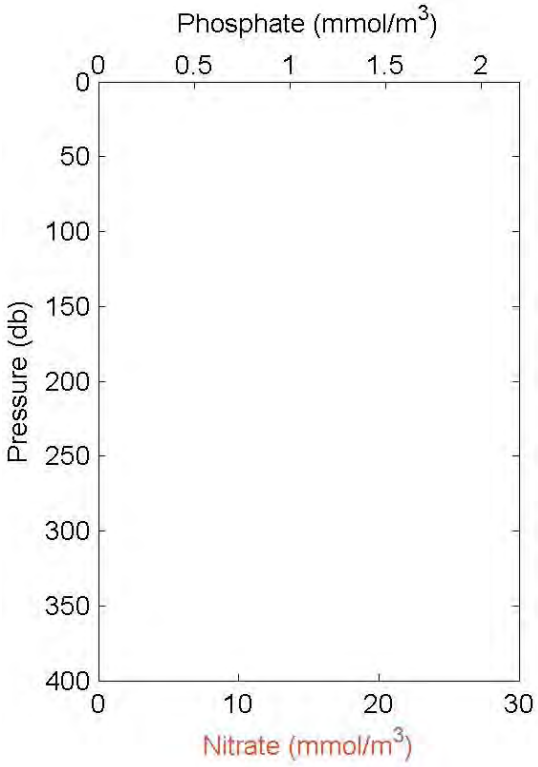

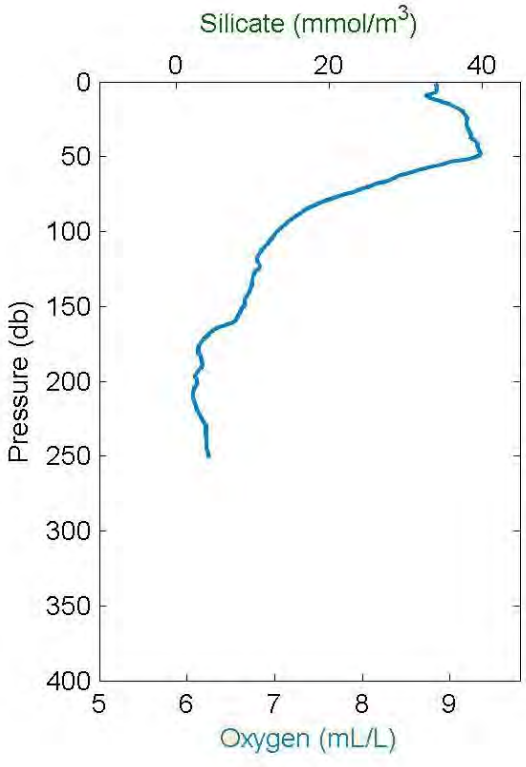

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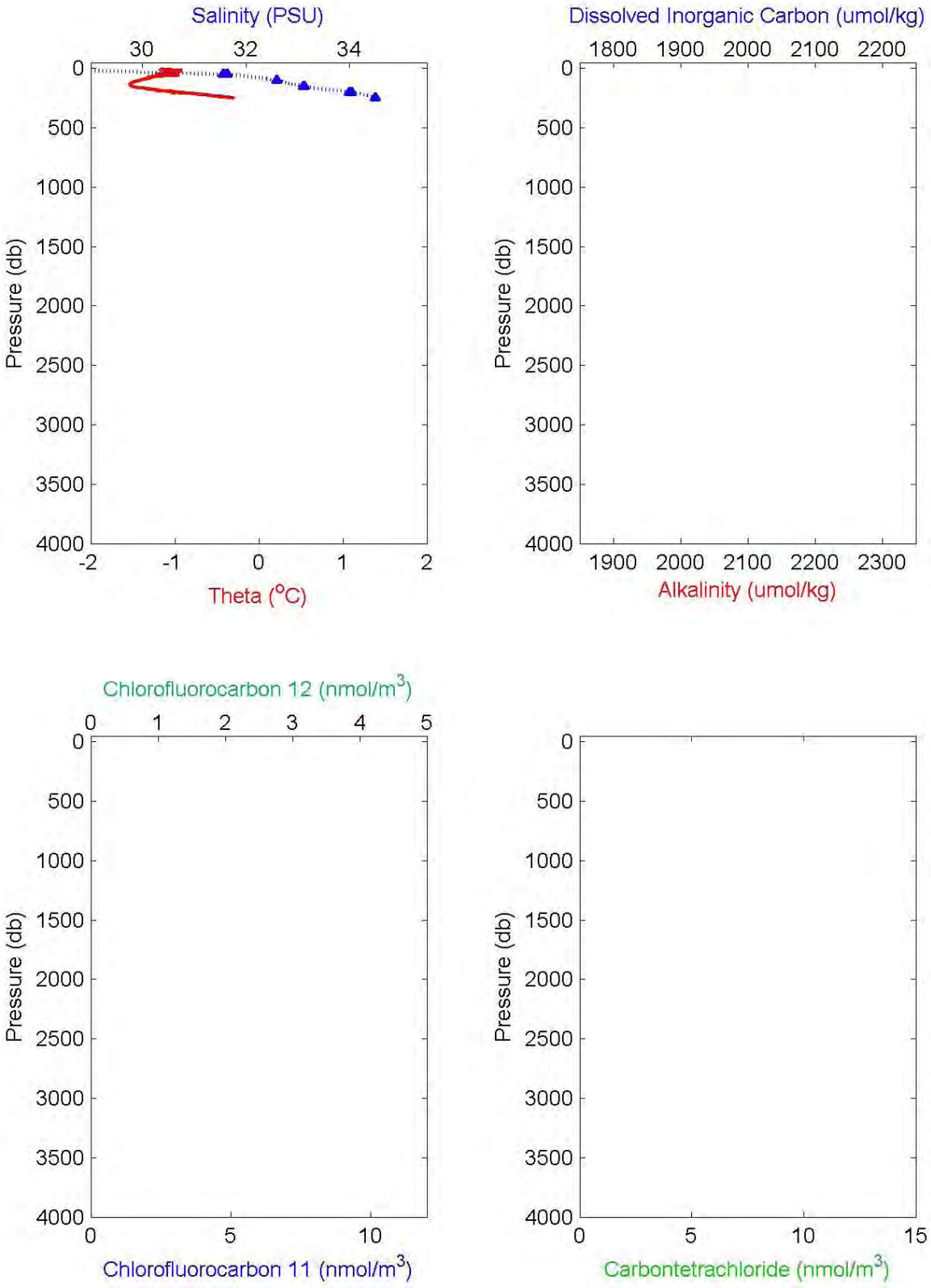

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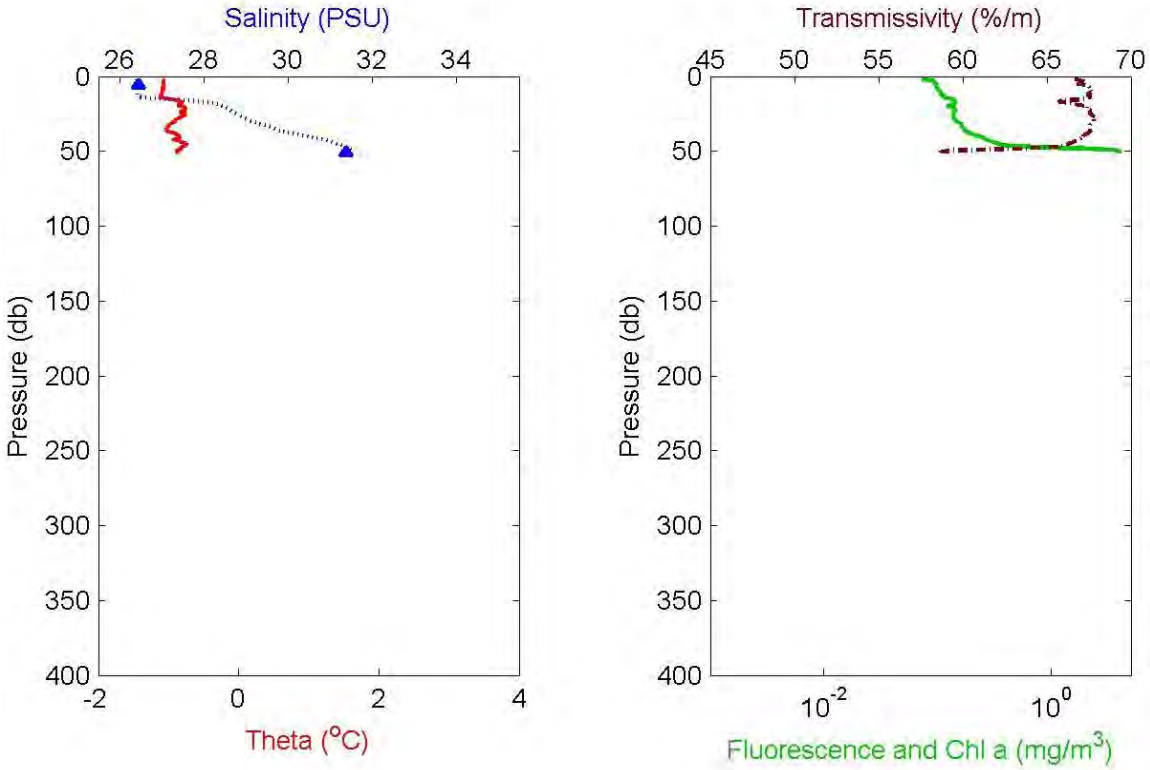

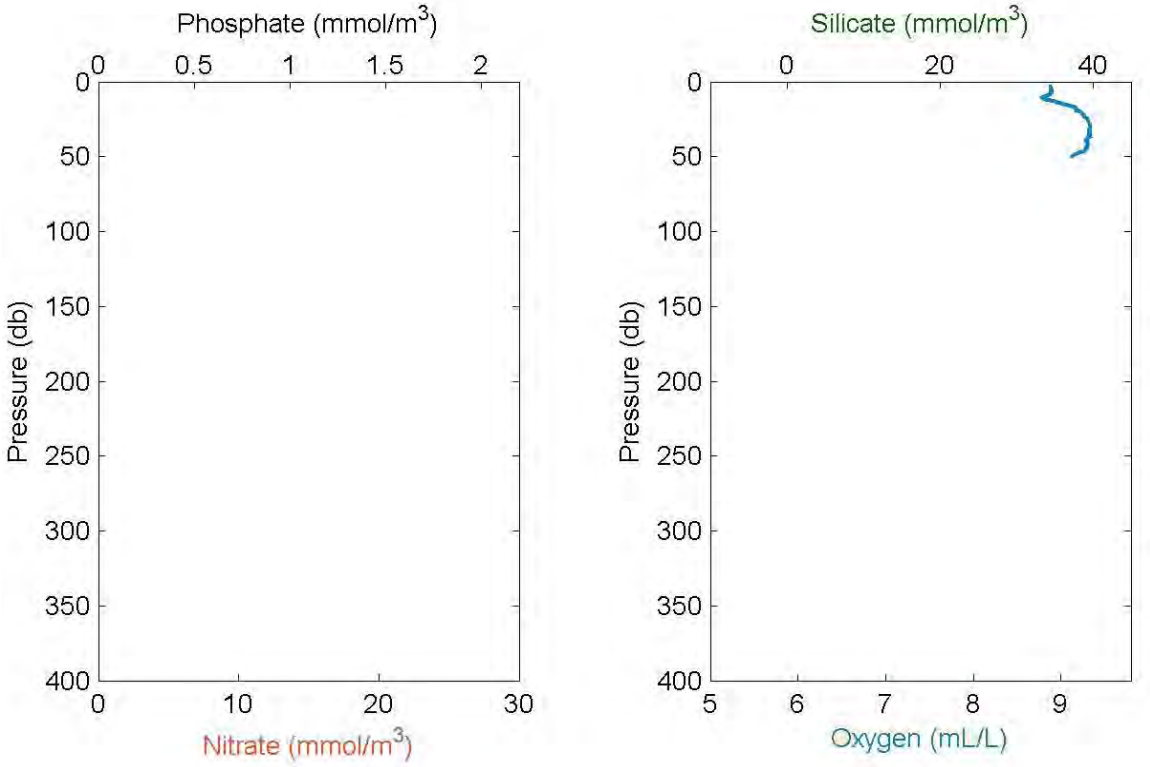

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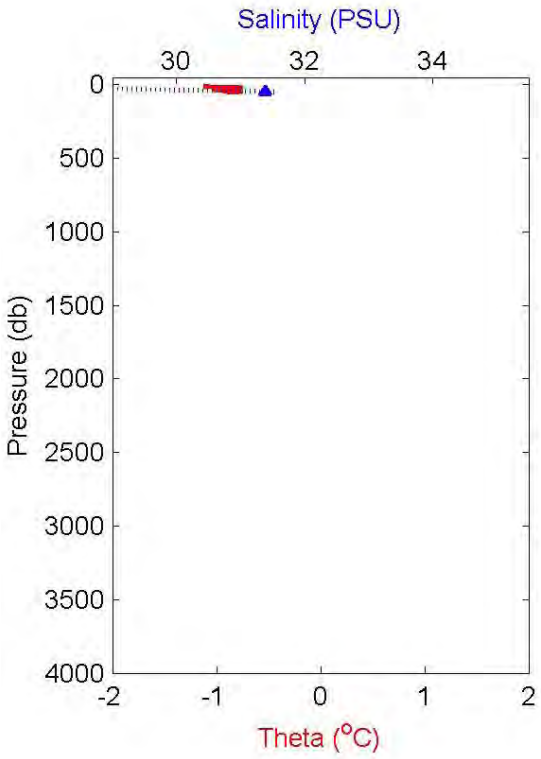

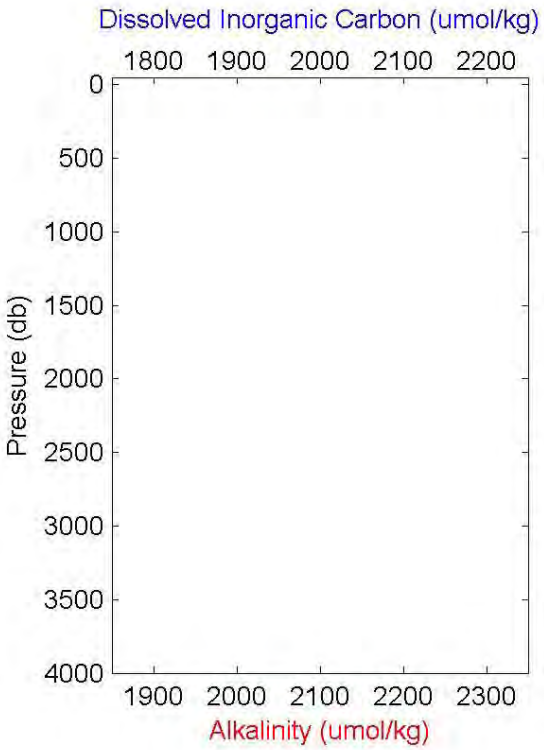

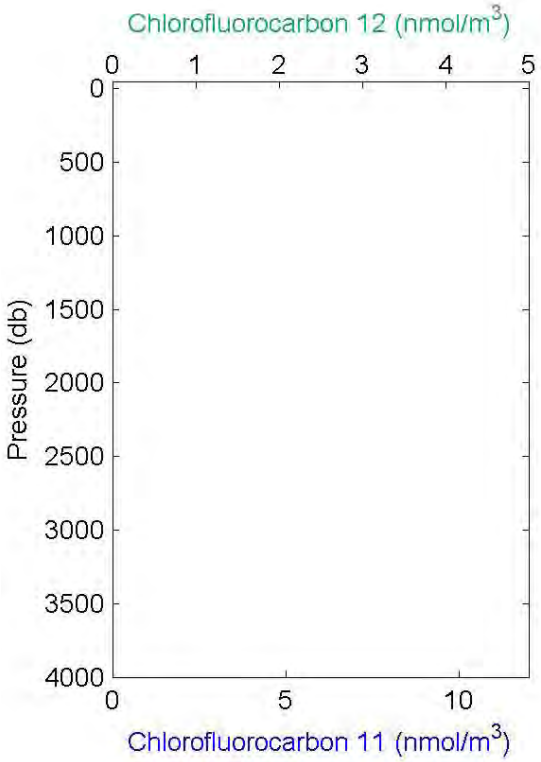

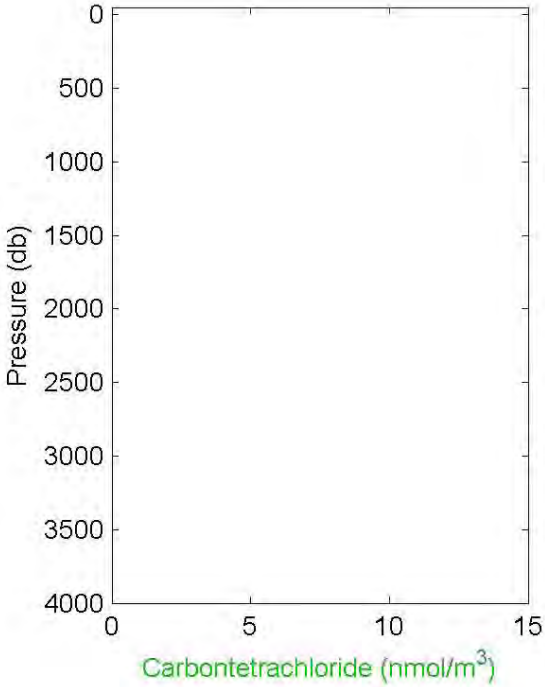

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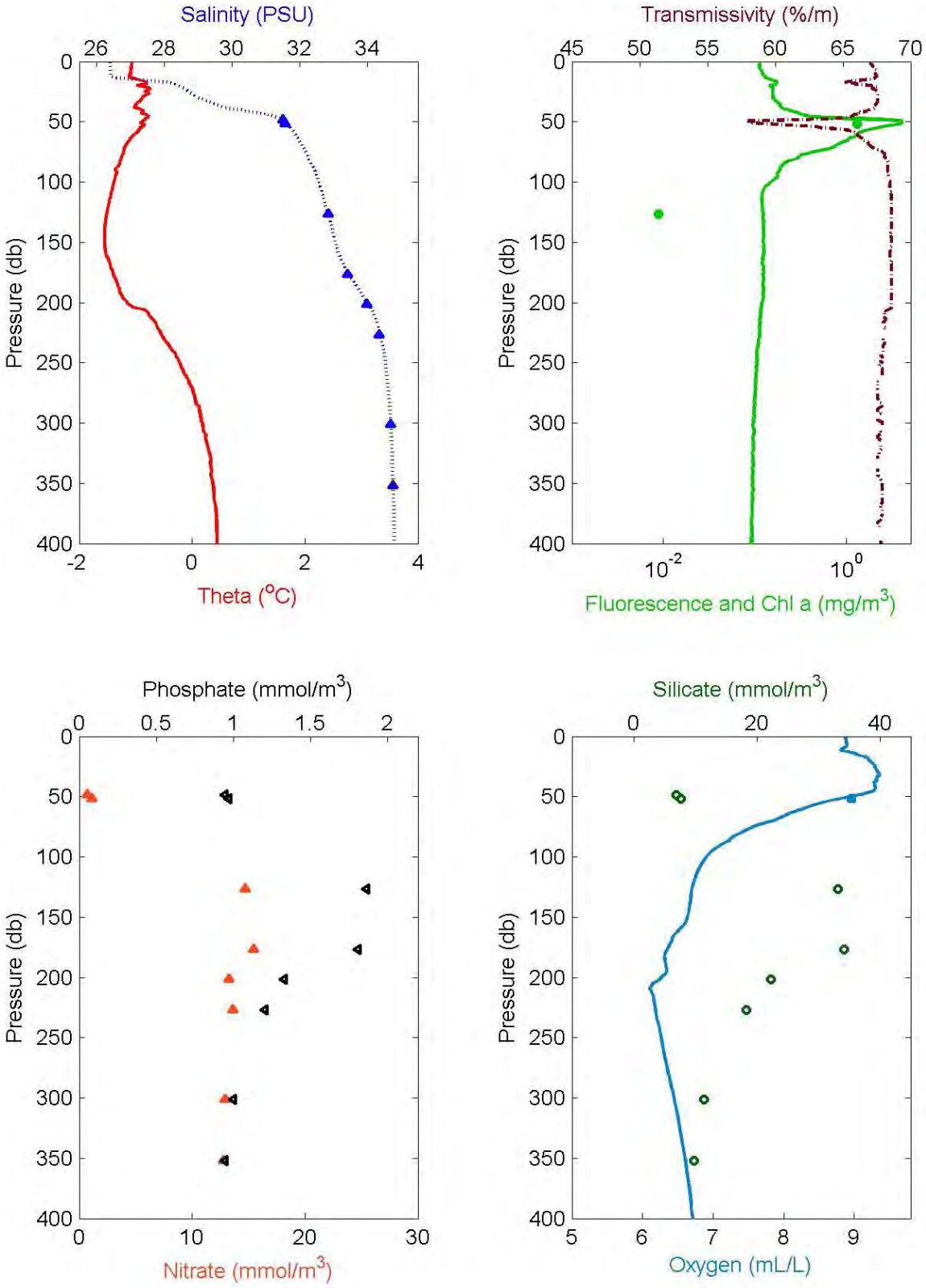

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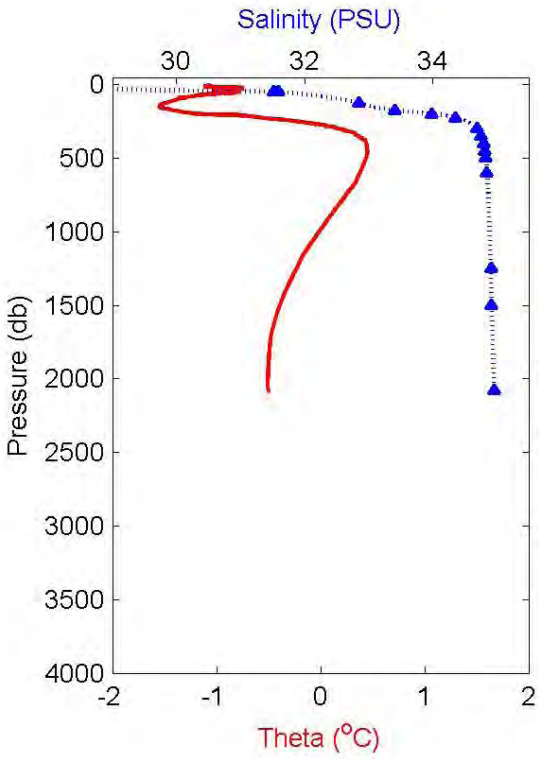
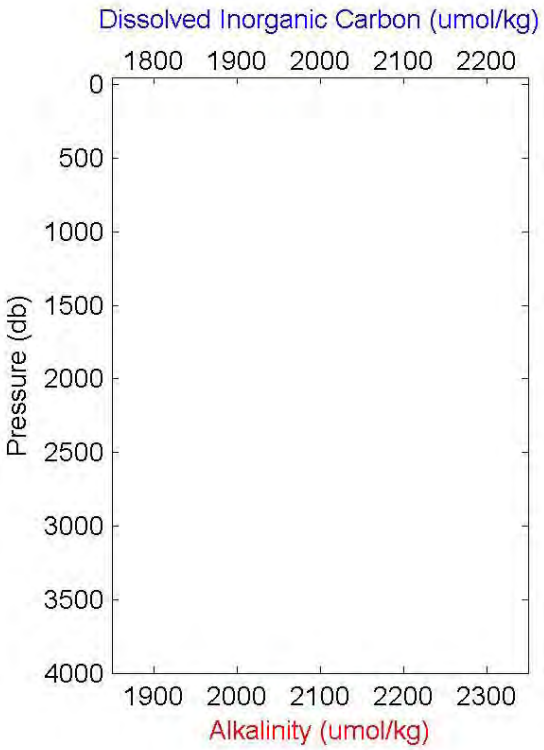
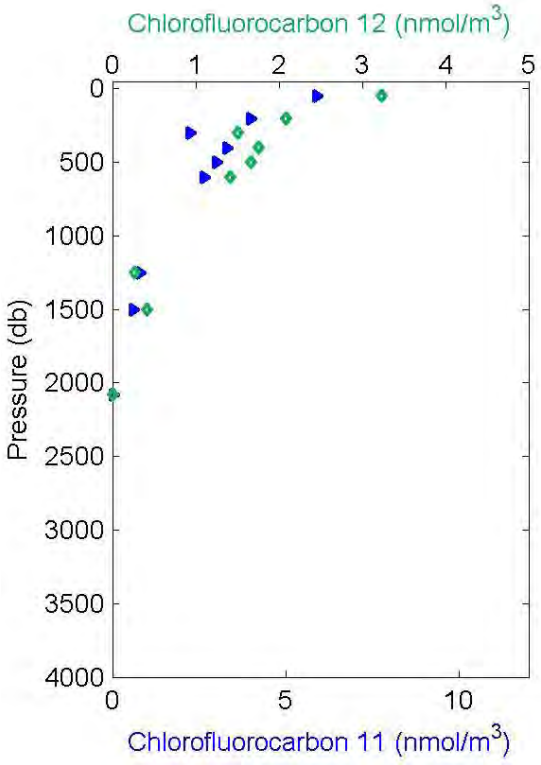
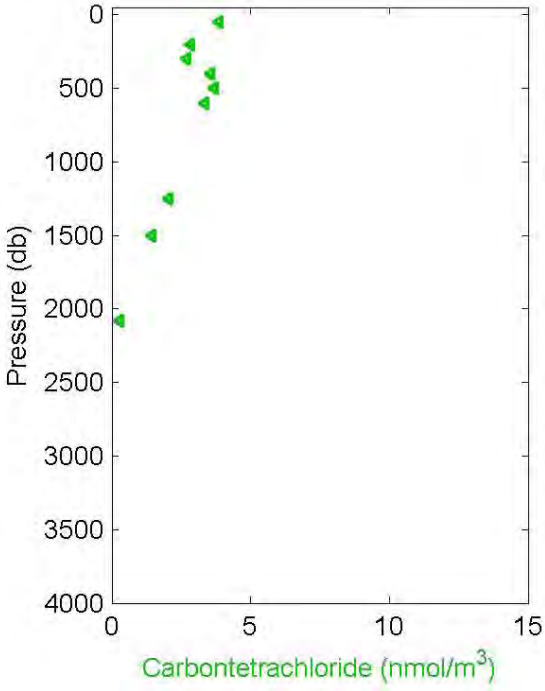
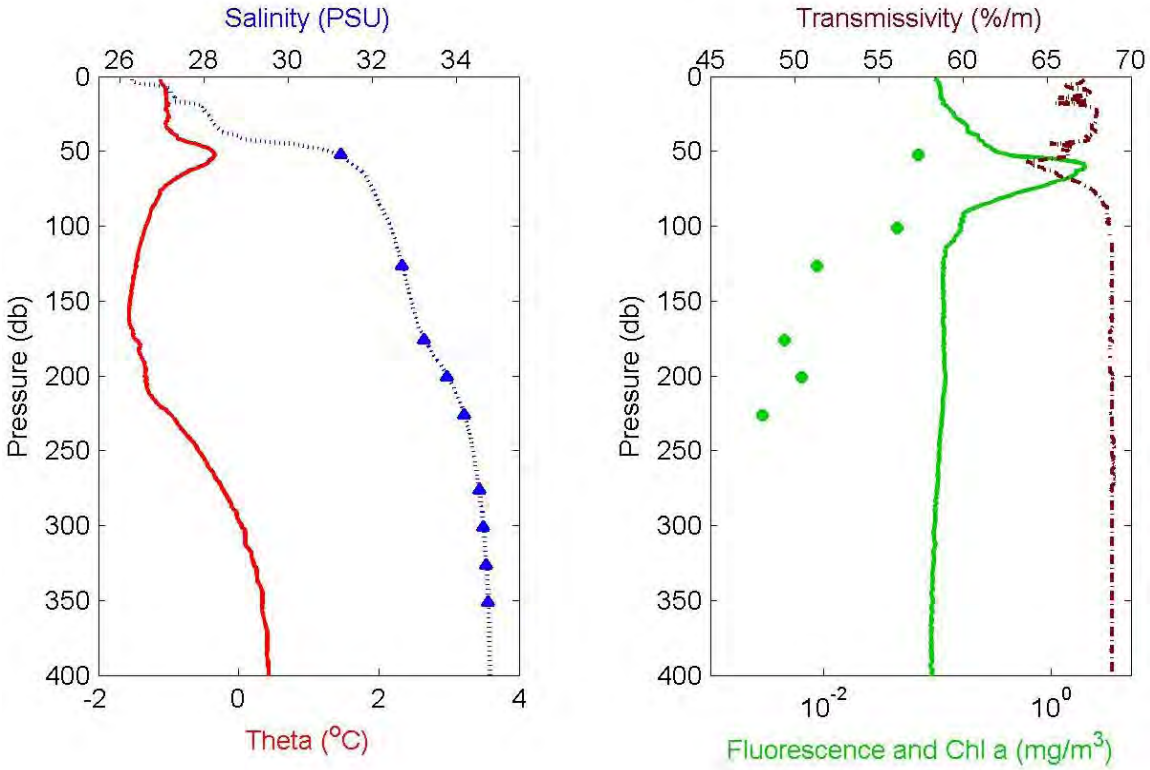


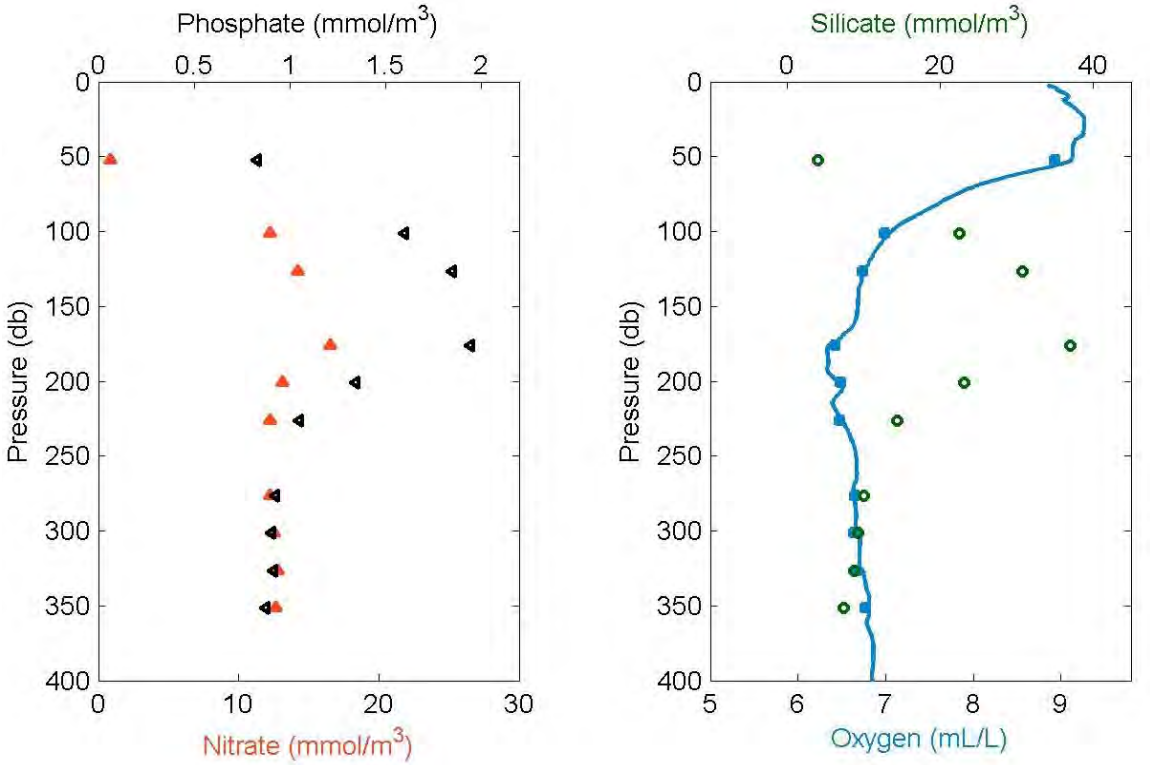




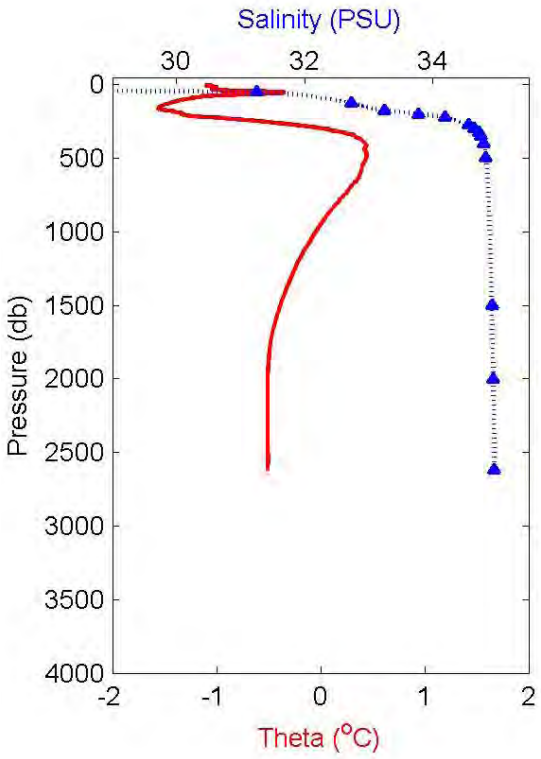


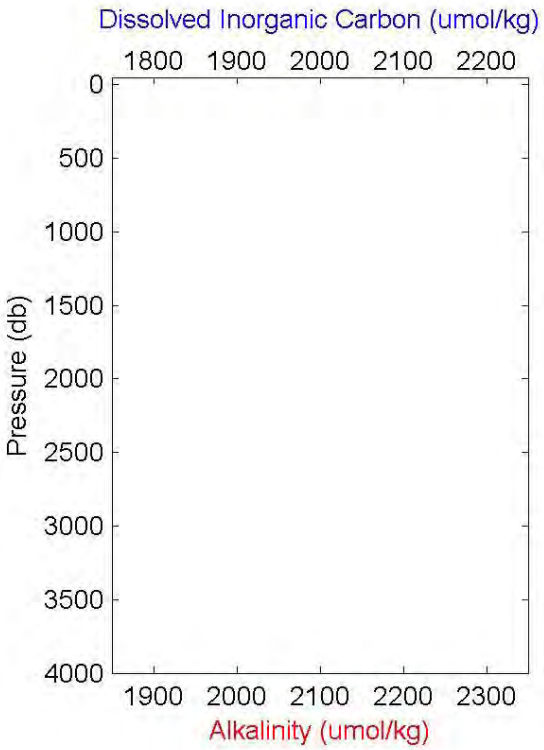
2002-23: Cast 9 Station AL09

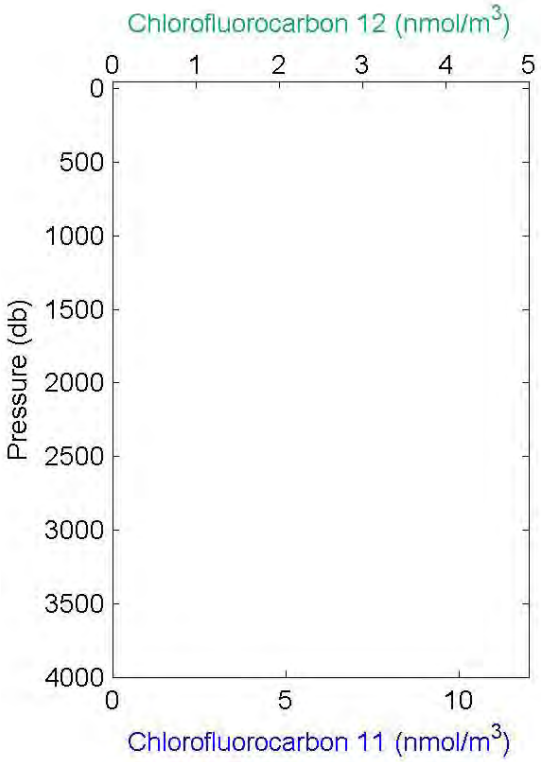


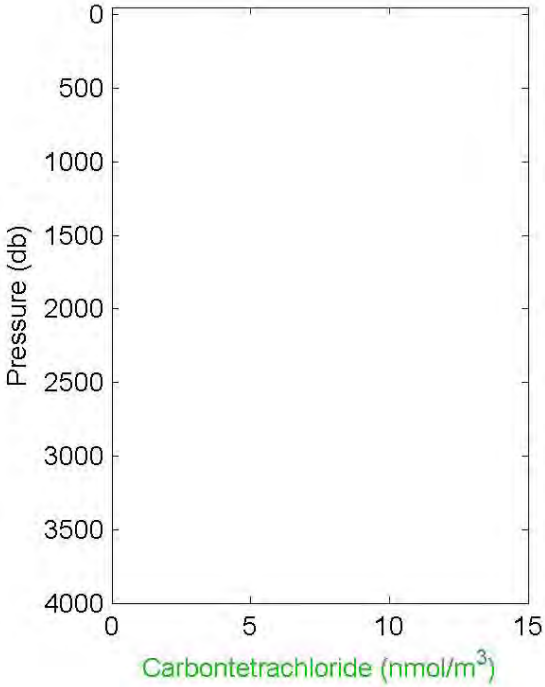


2002-23: Cast 9 Station AL09

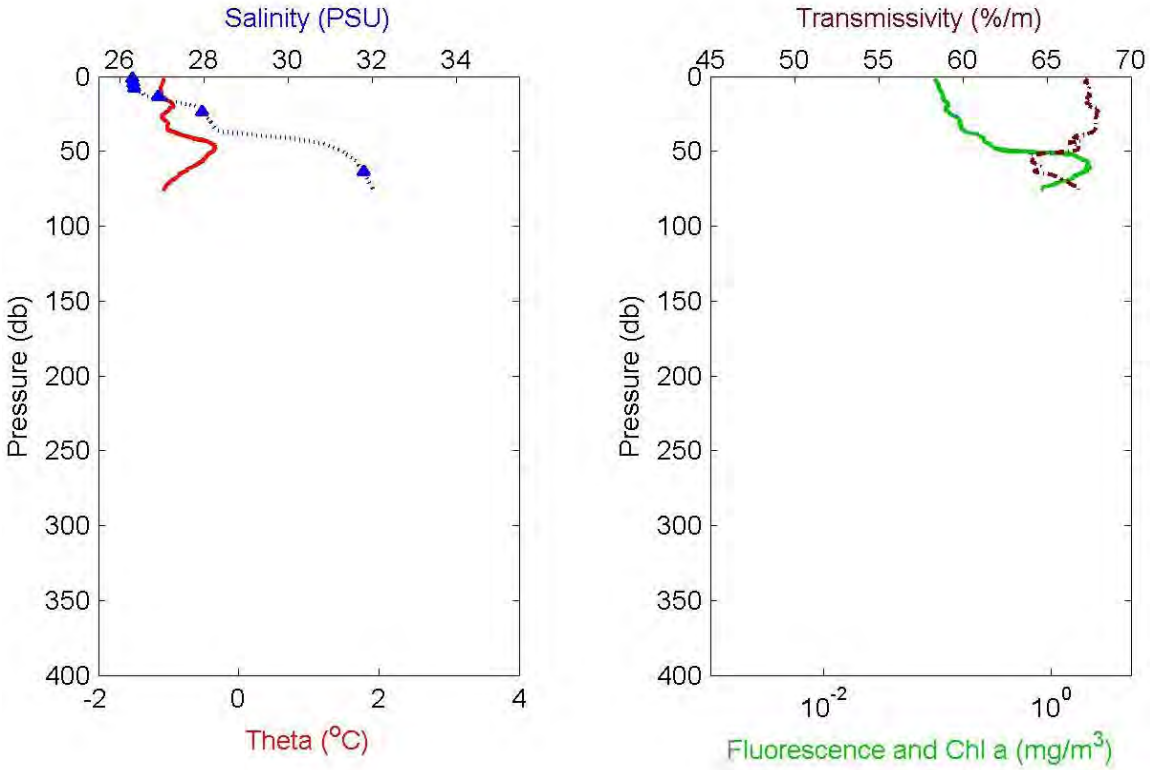




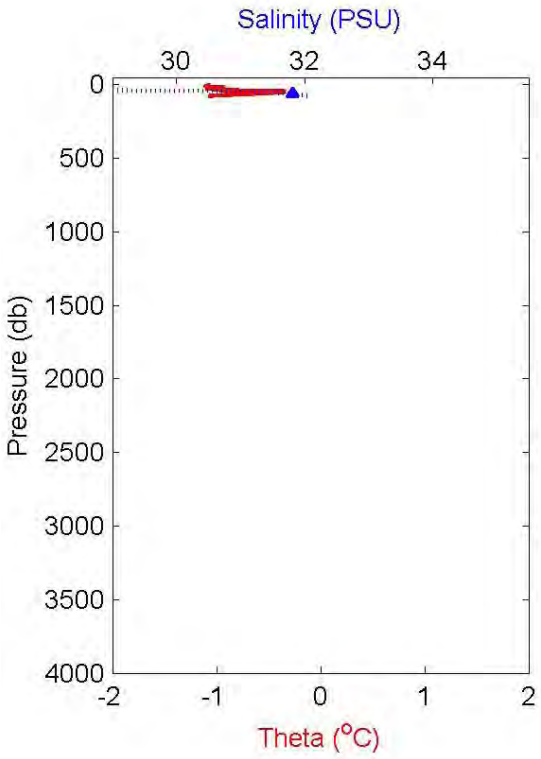


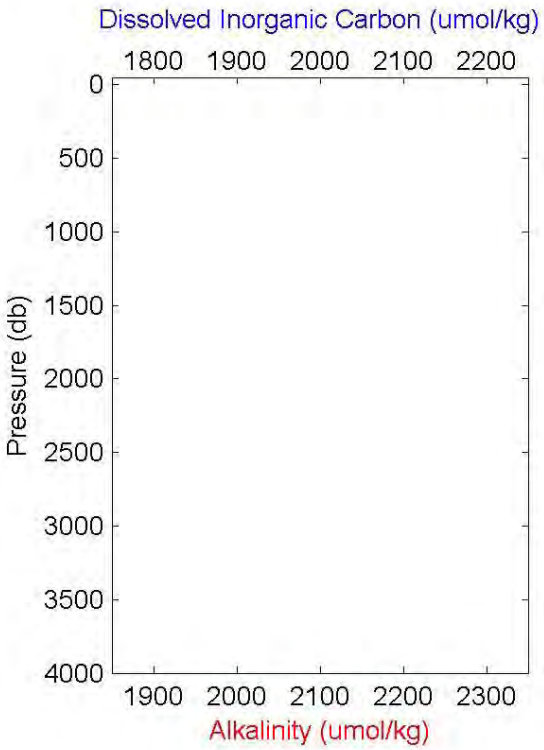


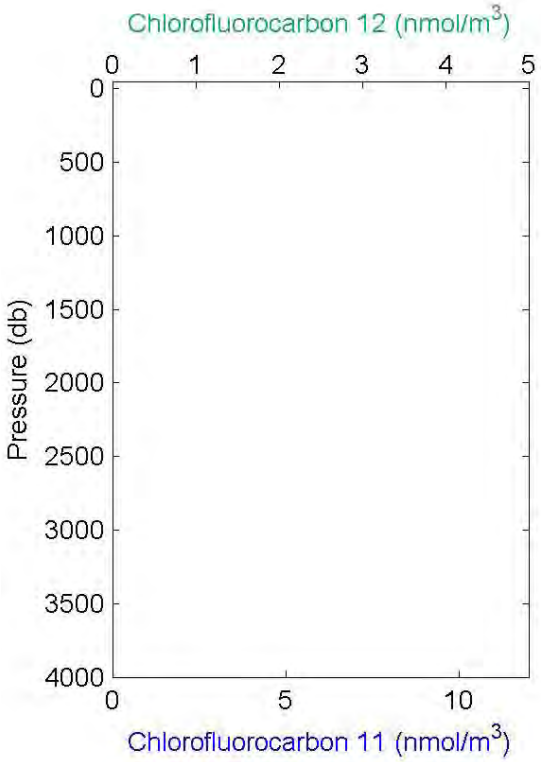
2002-23: Cast 10 Station AL09 (2)

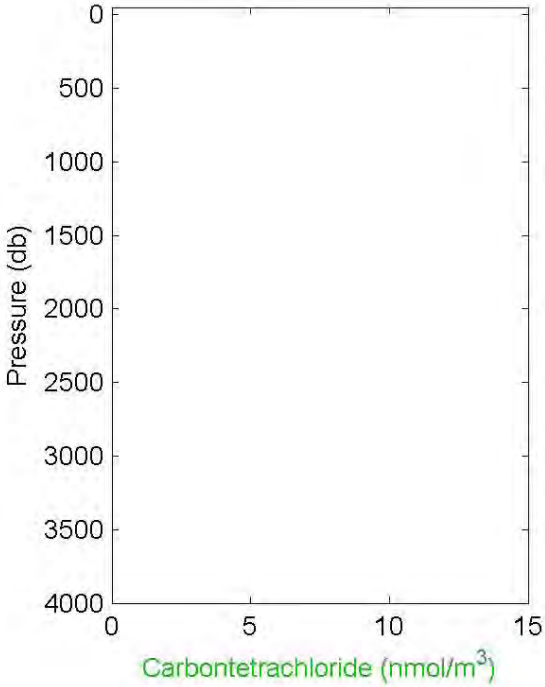


2002-23: Cast 10 Station AL09 (2)

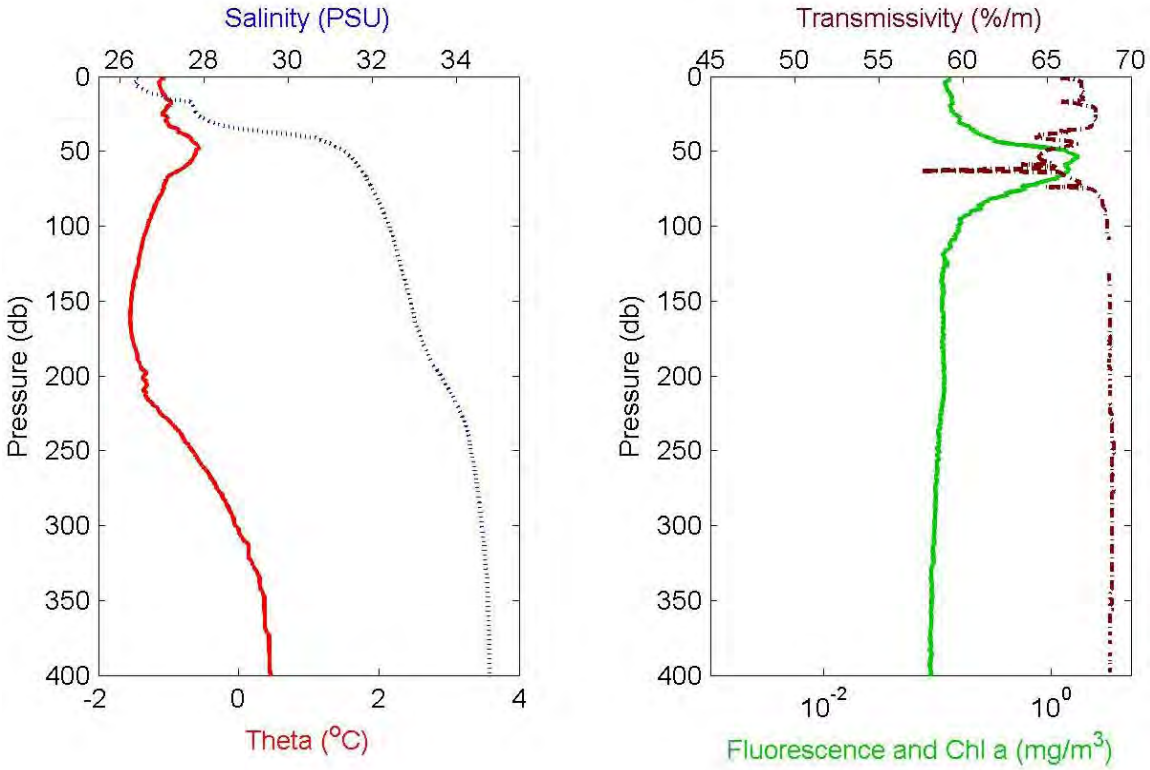


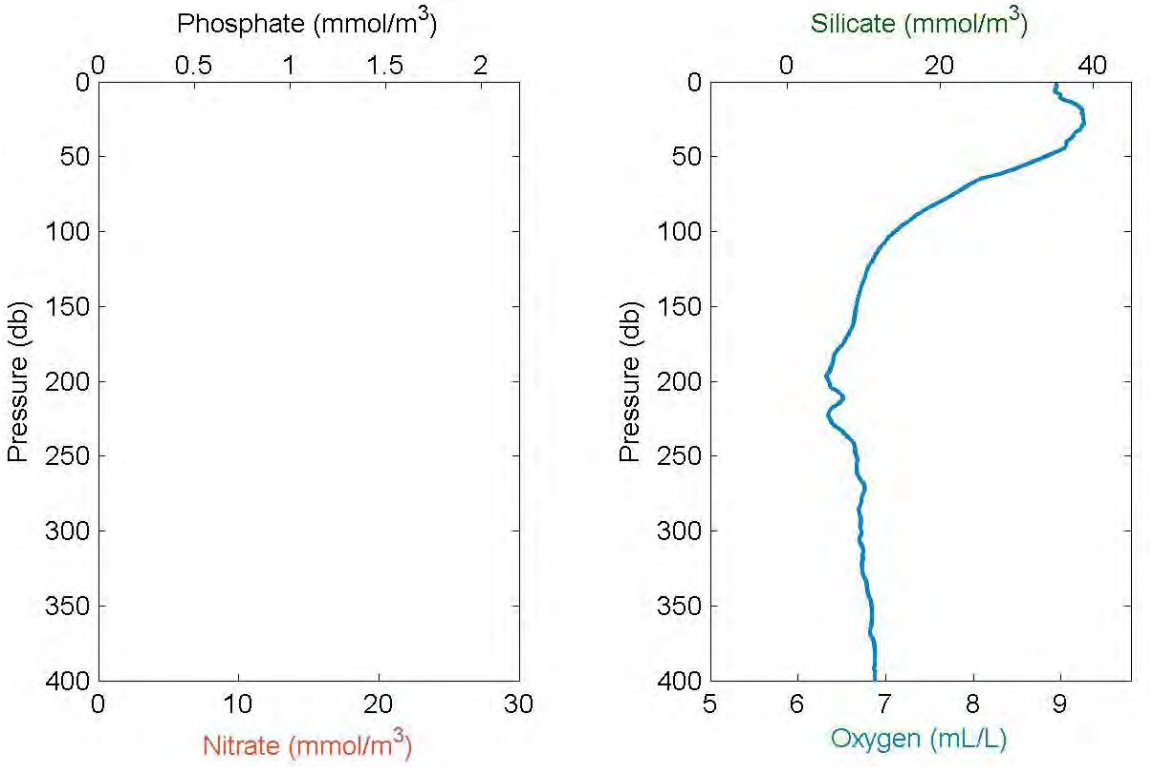




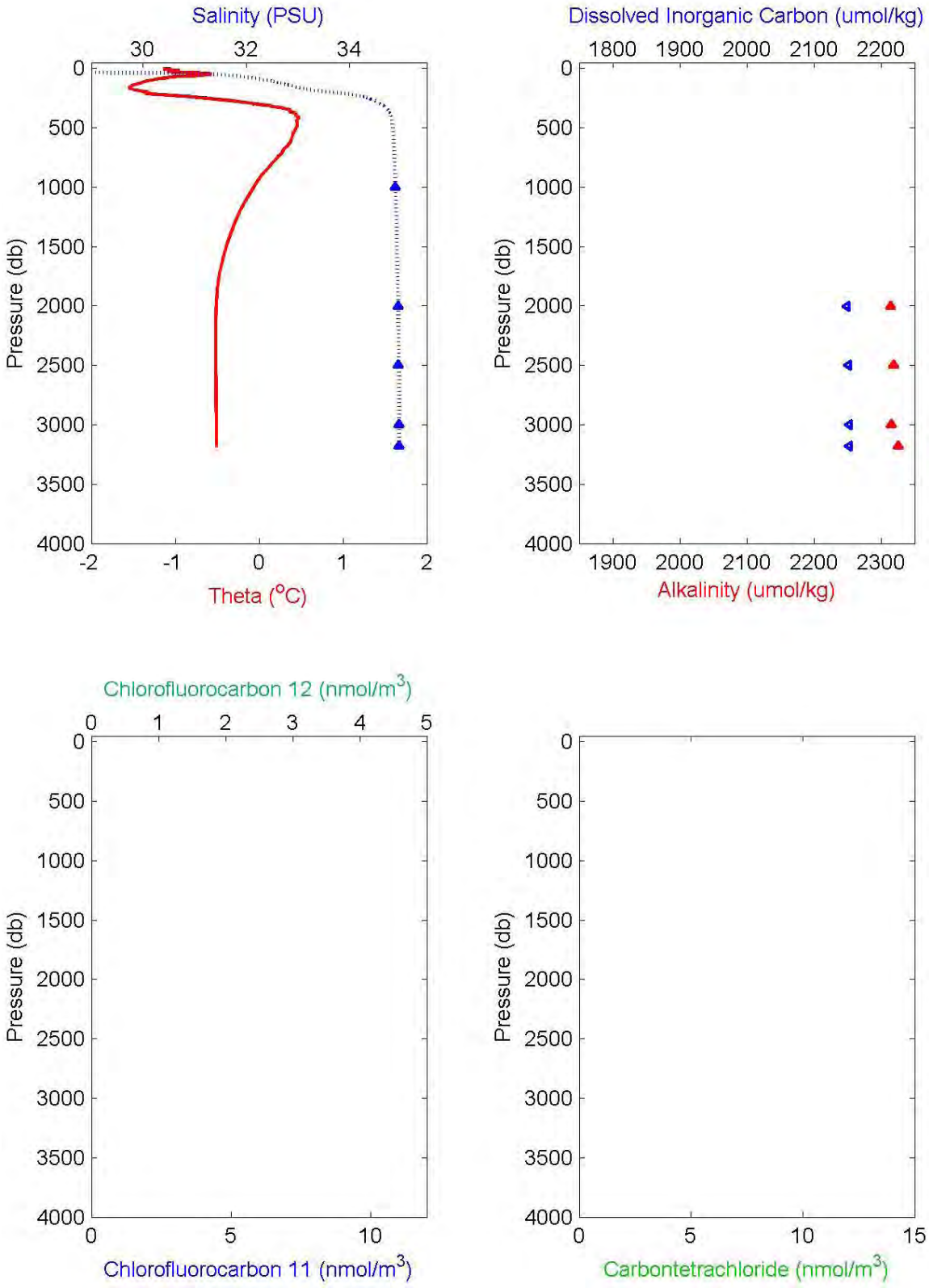


2002-23: Cast 11 Station AL10

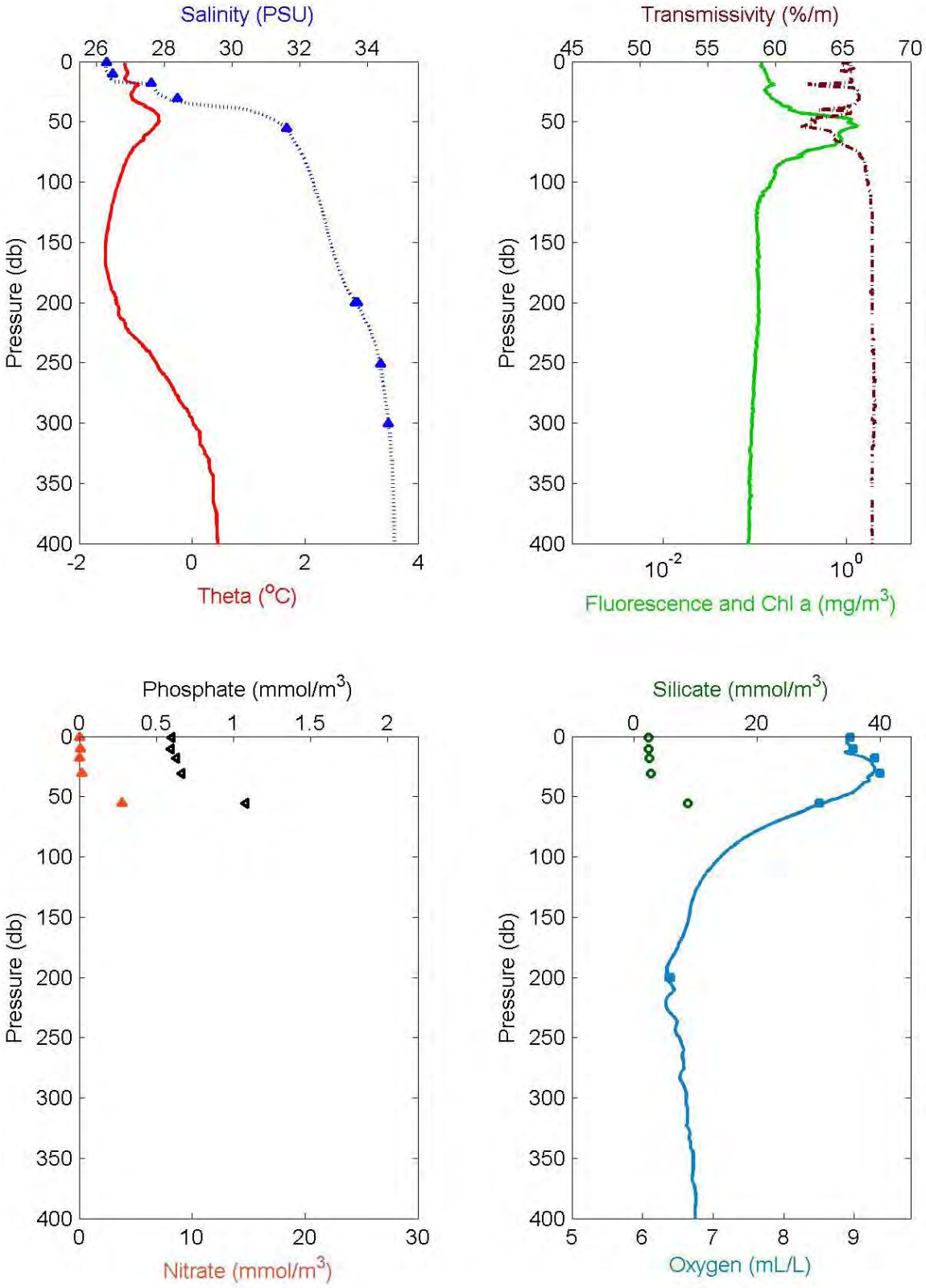




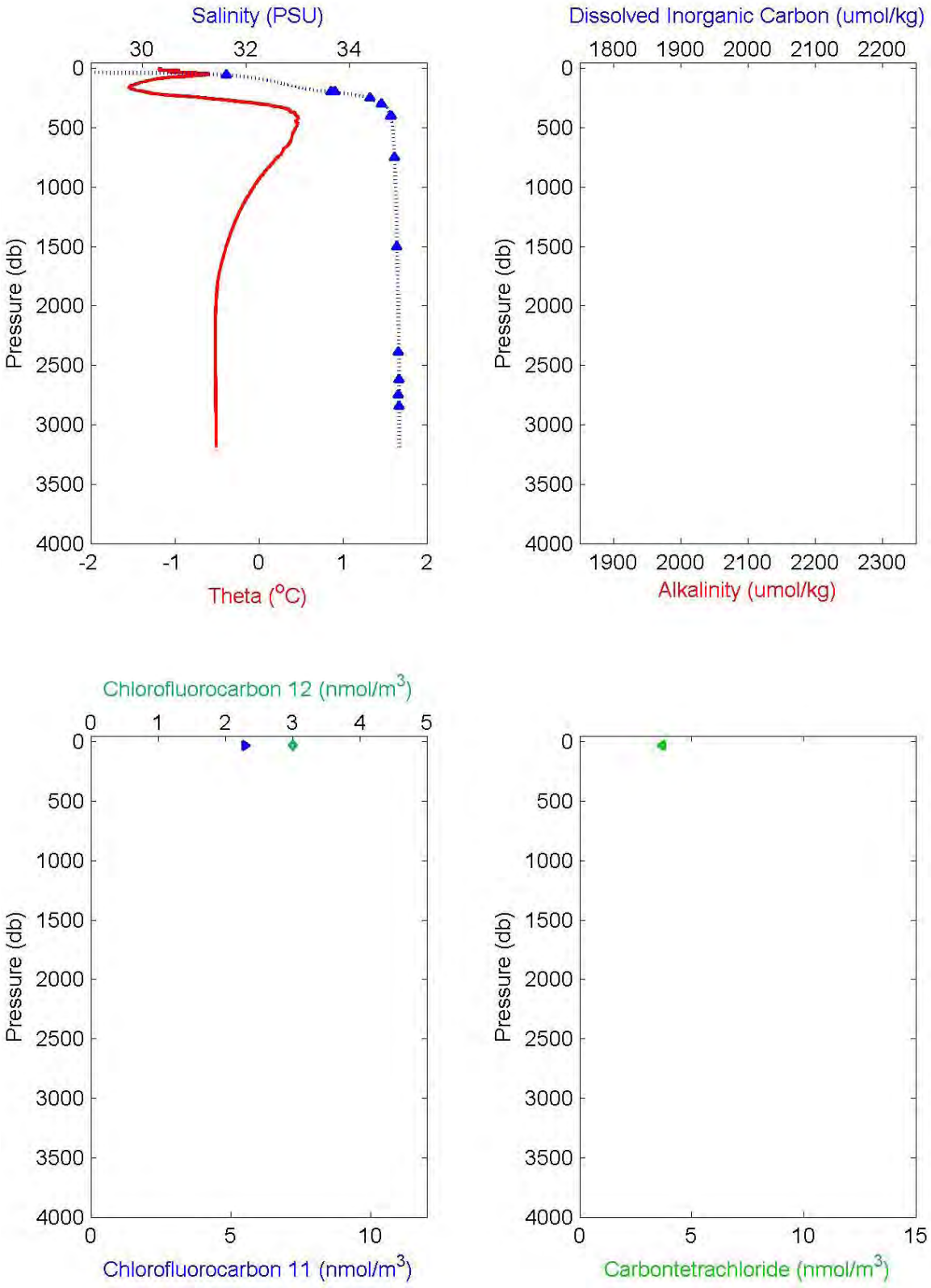
2002-23: Cast 11 Station AL10



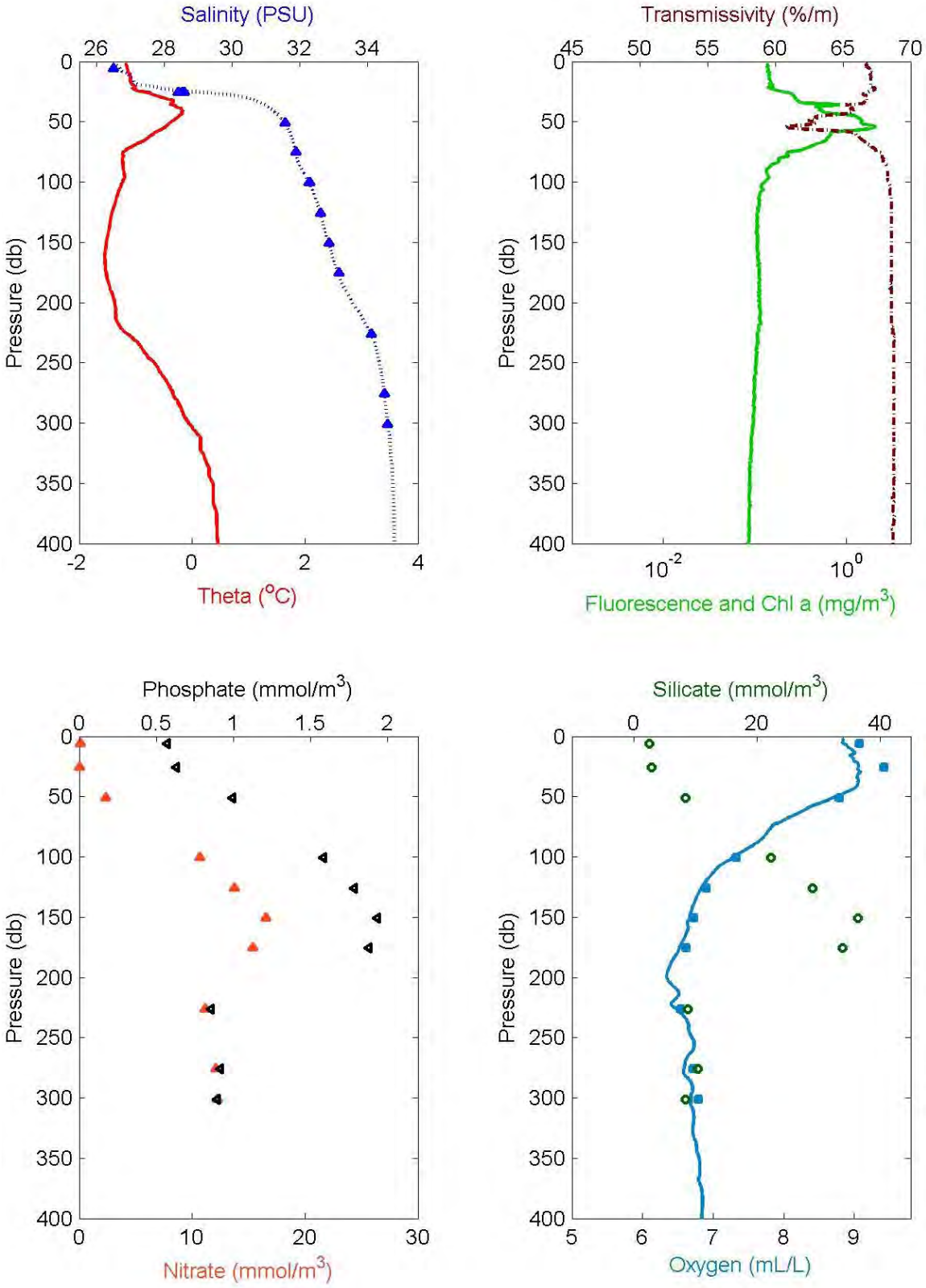
2002-23: Cast 12 Station AL10 (2)



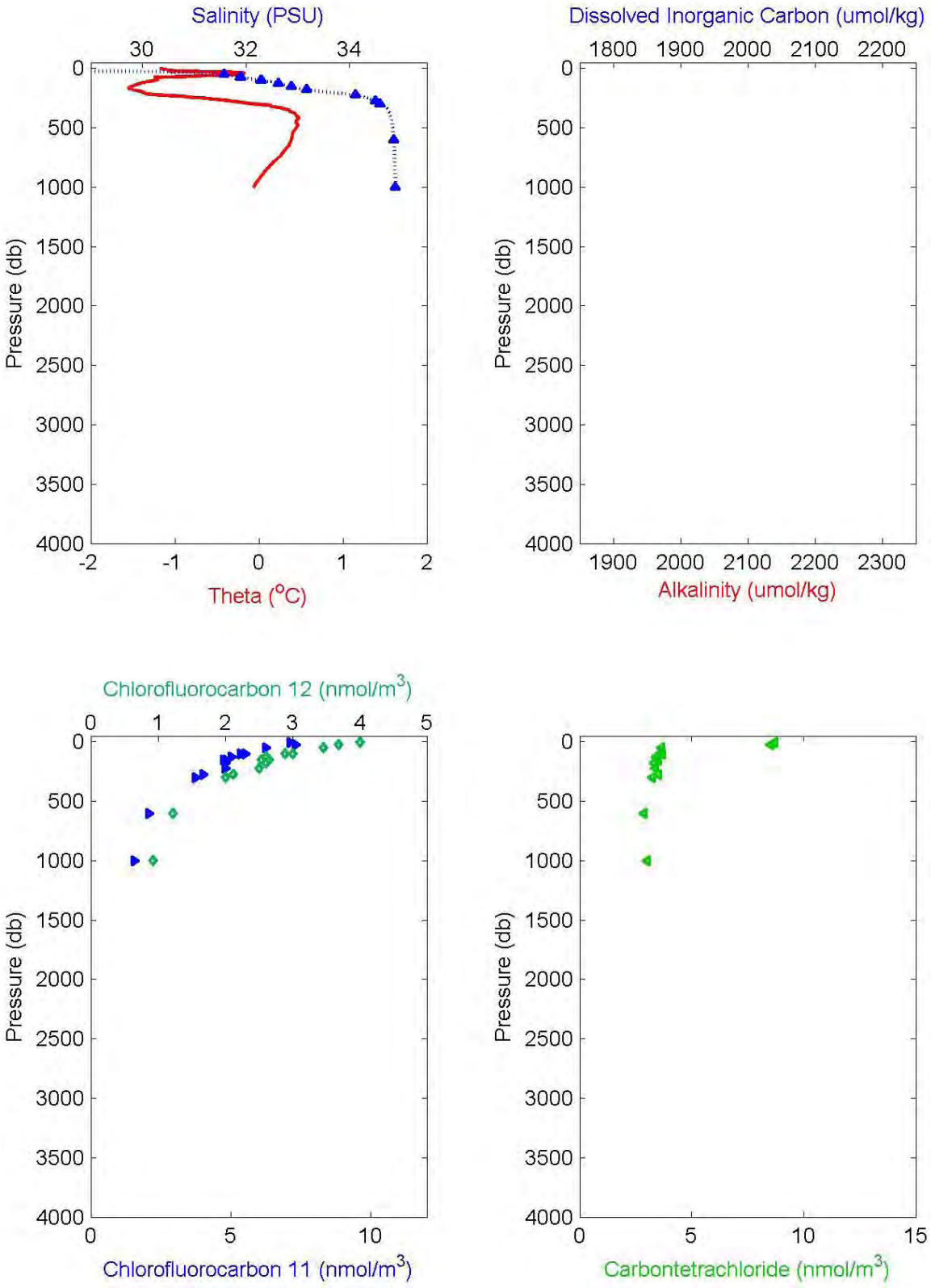
2002-23: Cast 12 Station AL10 (2)



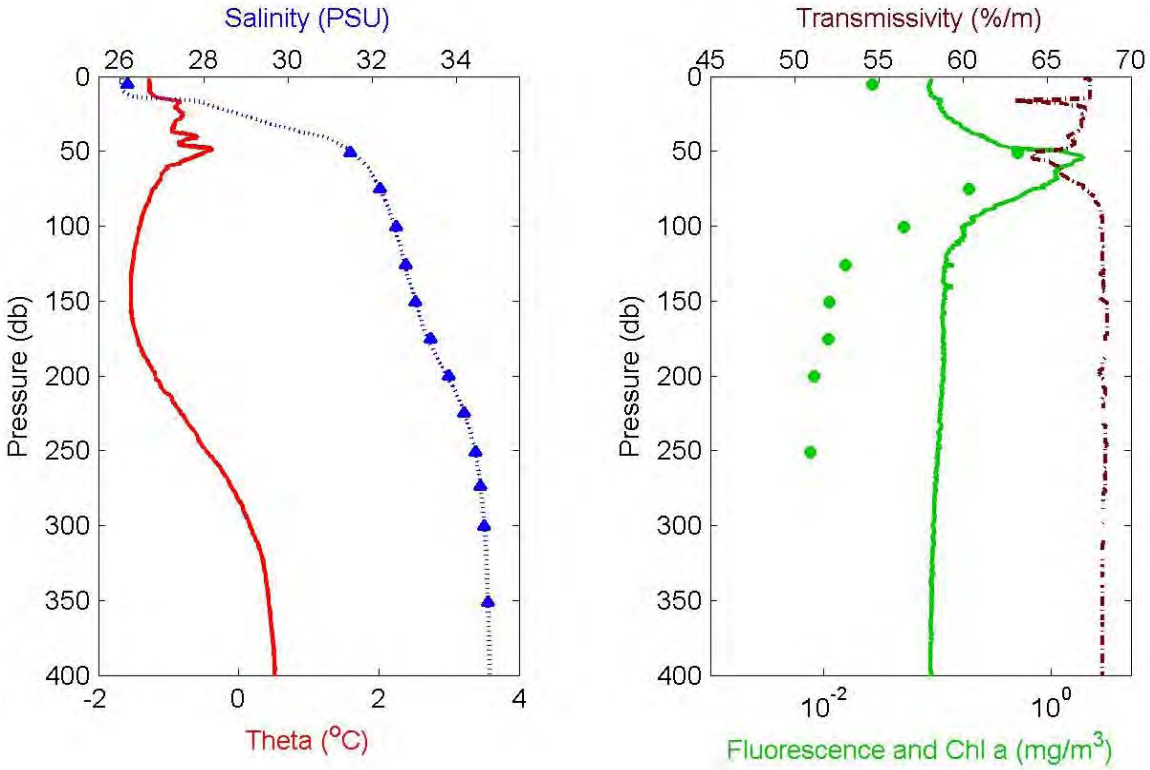
2002-23: Cast 13 Station AL10 (3)

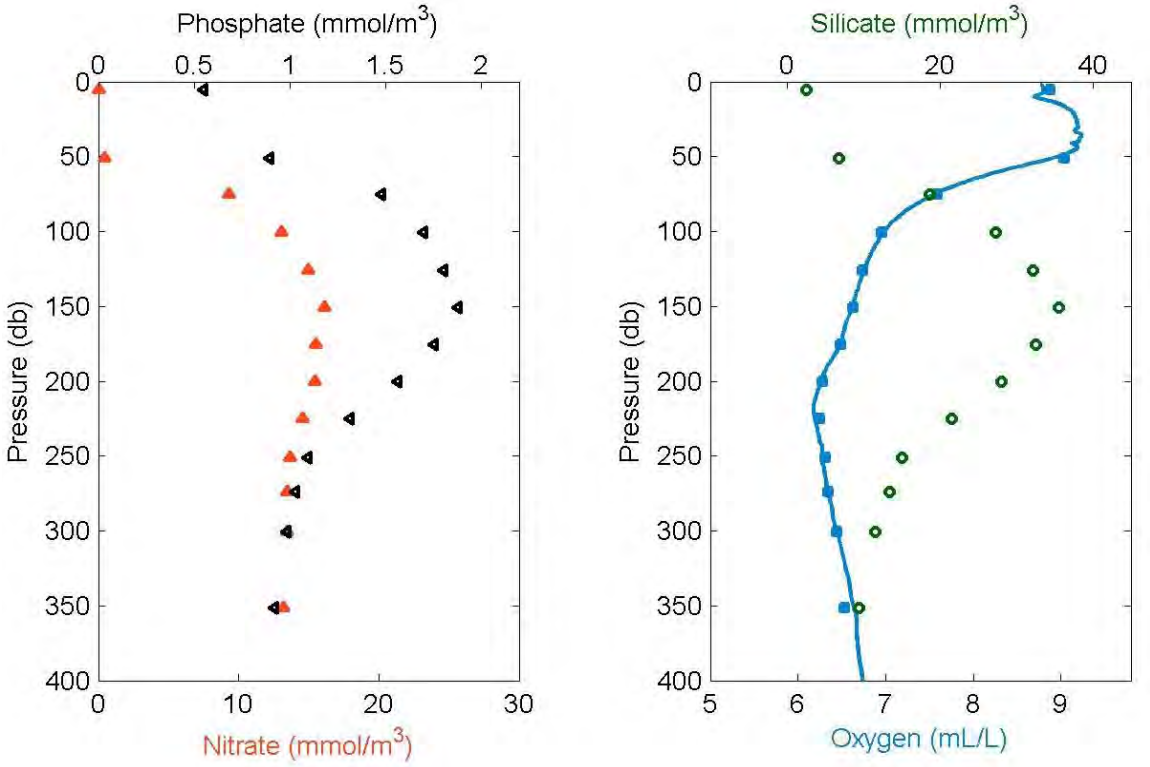


2002-23: Cast 13 Station AL10 (3)

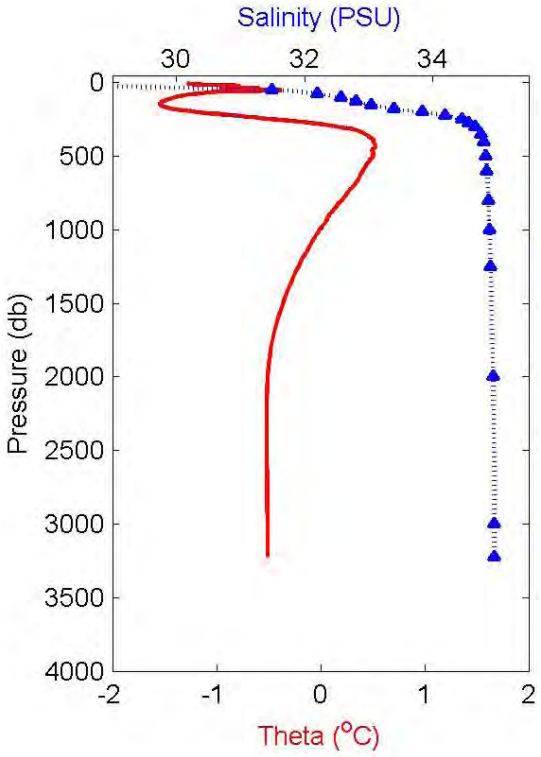


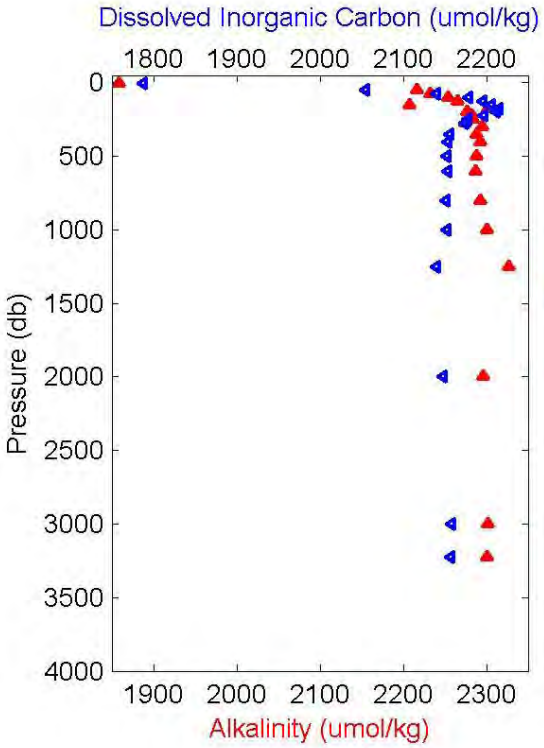
2002-23: Cast 14 Station SB01

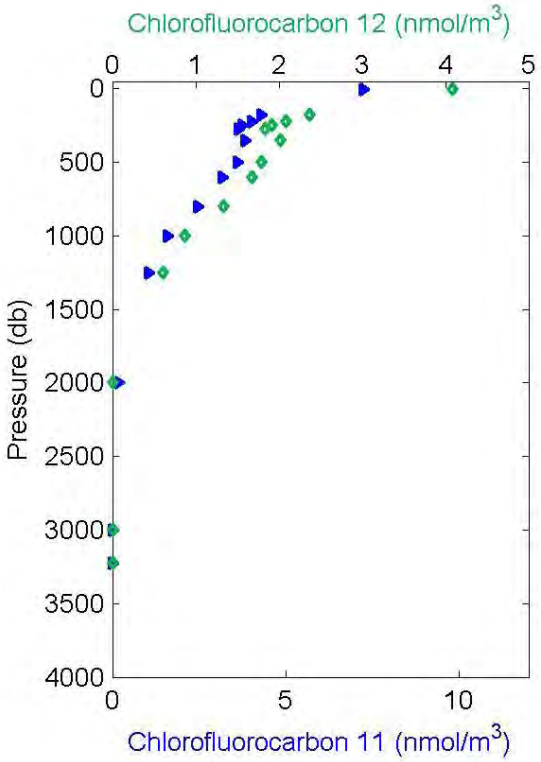


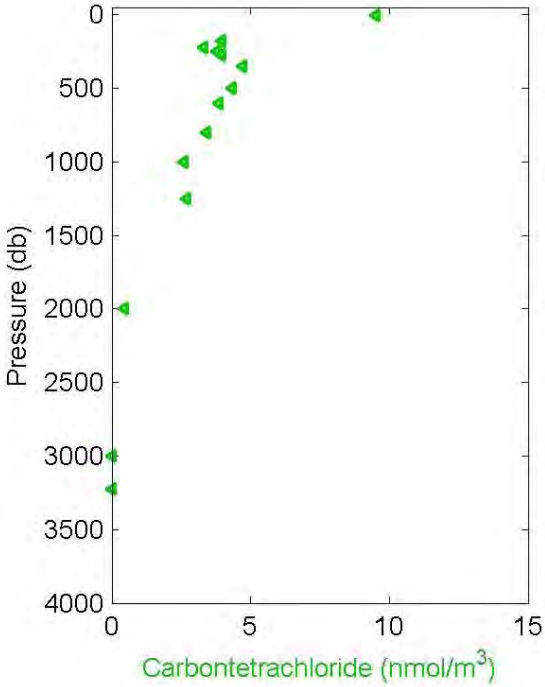


2002-23: Cast 14 Station SB01

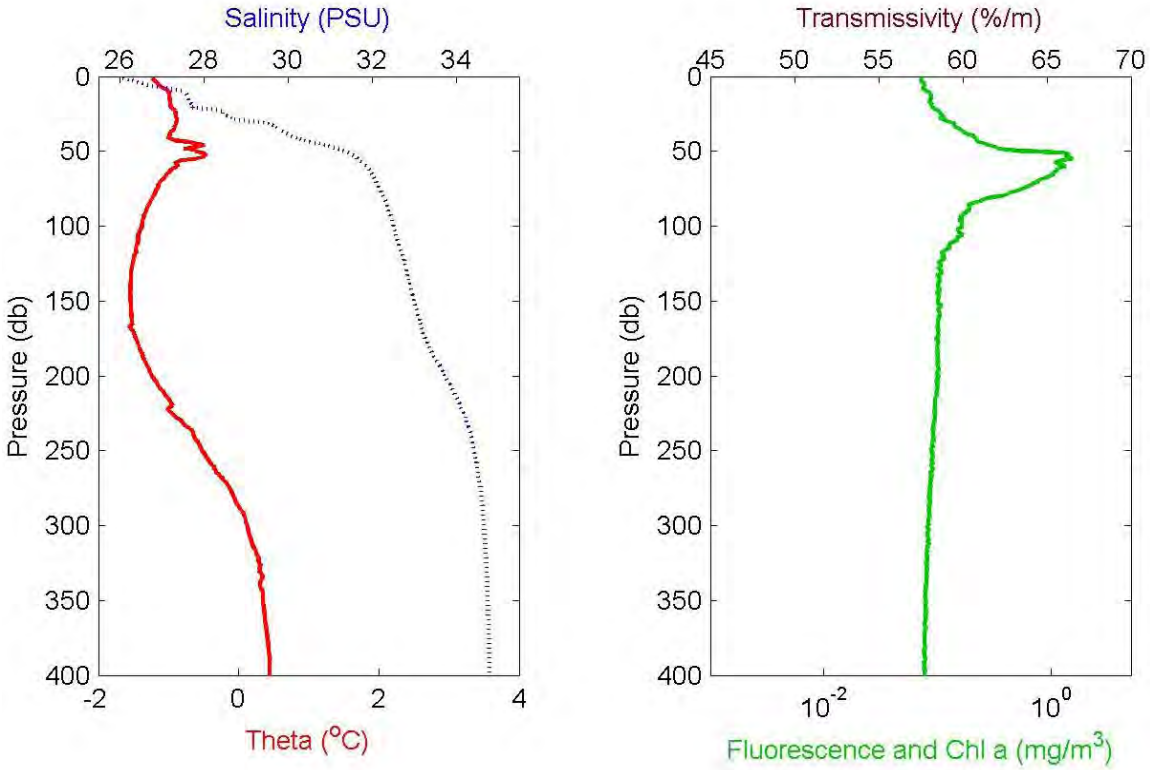


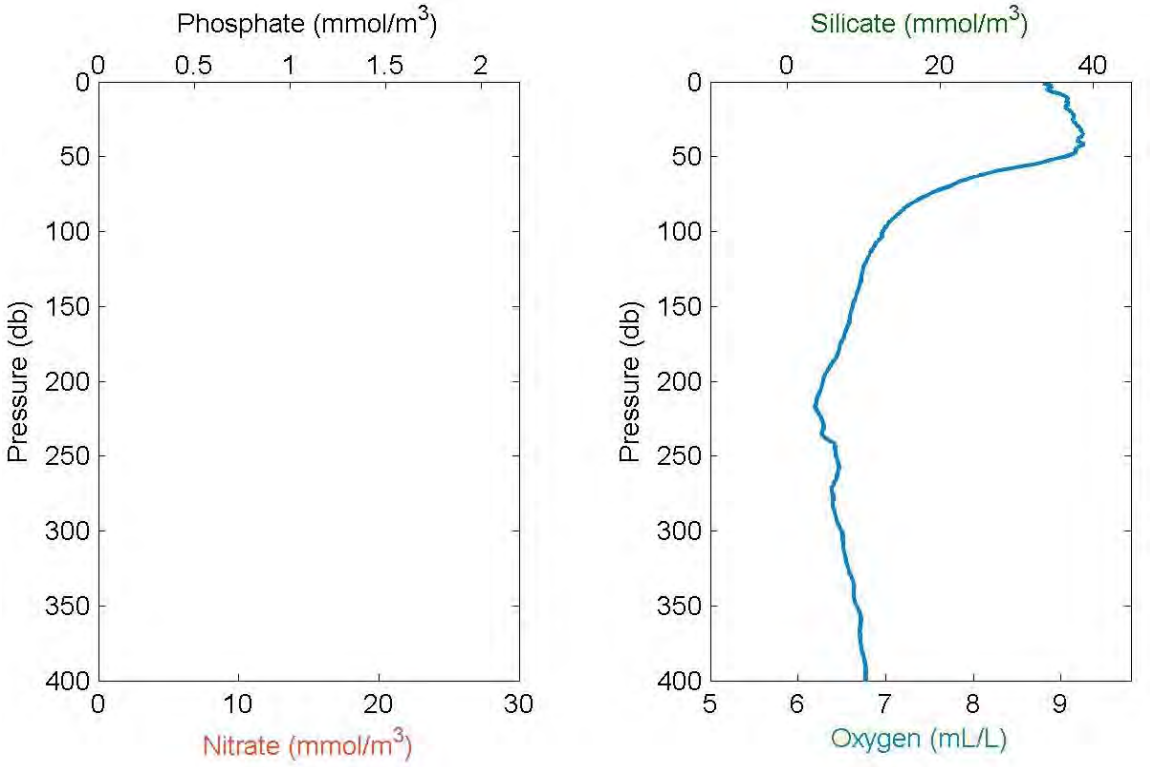




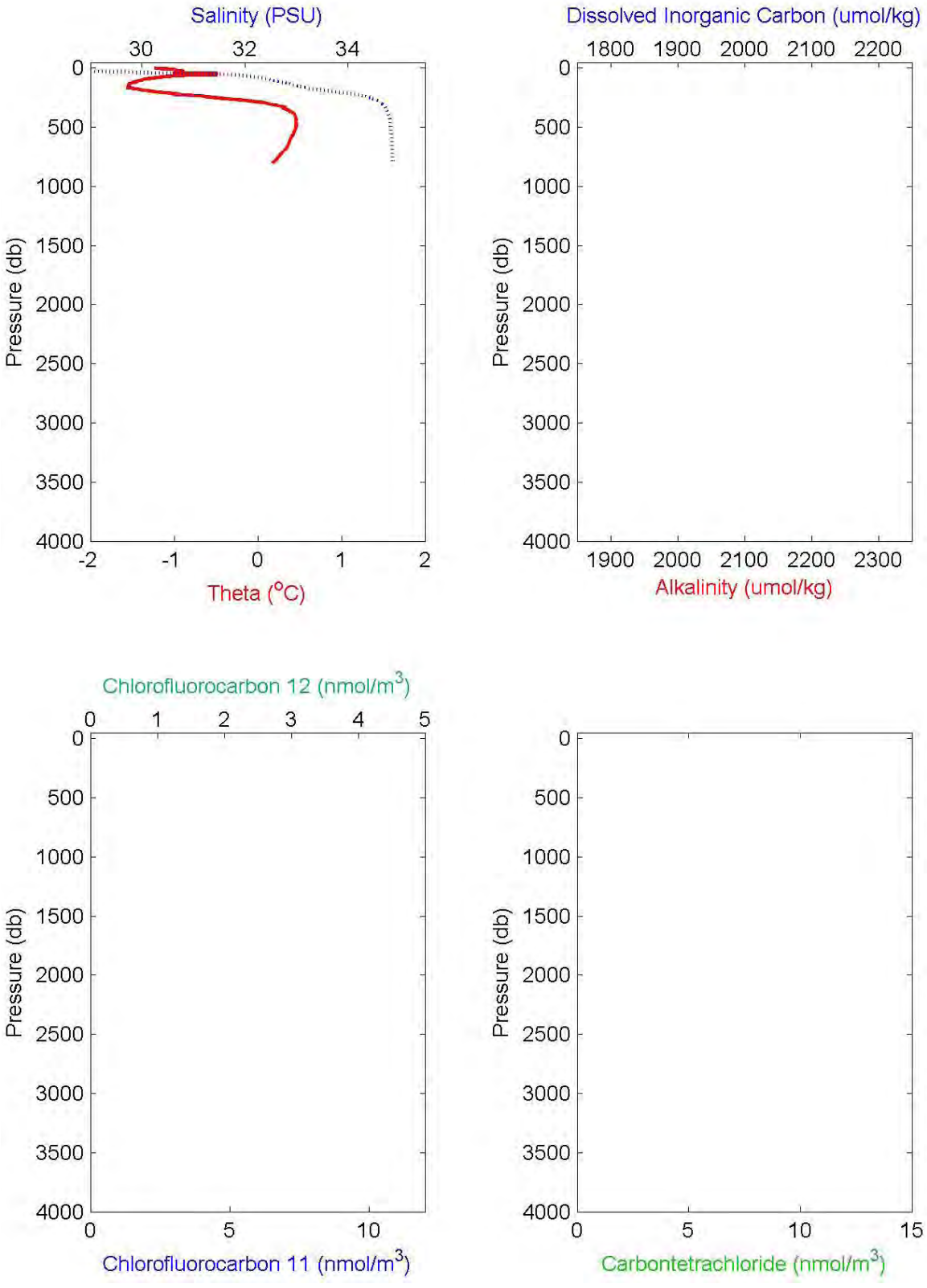


2002-23: Cast 15 Station SB01 (2)

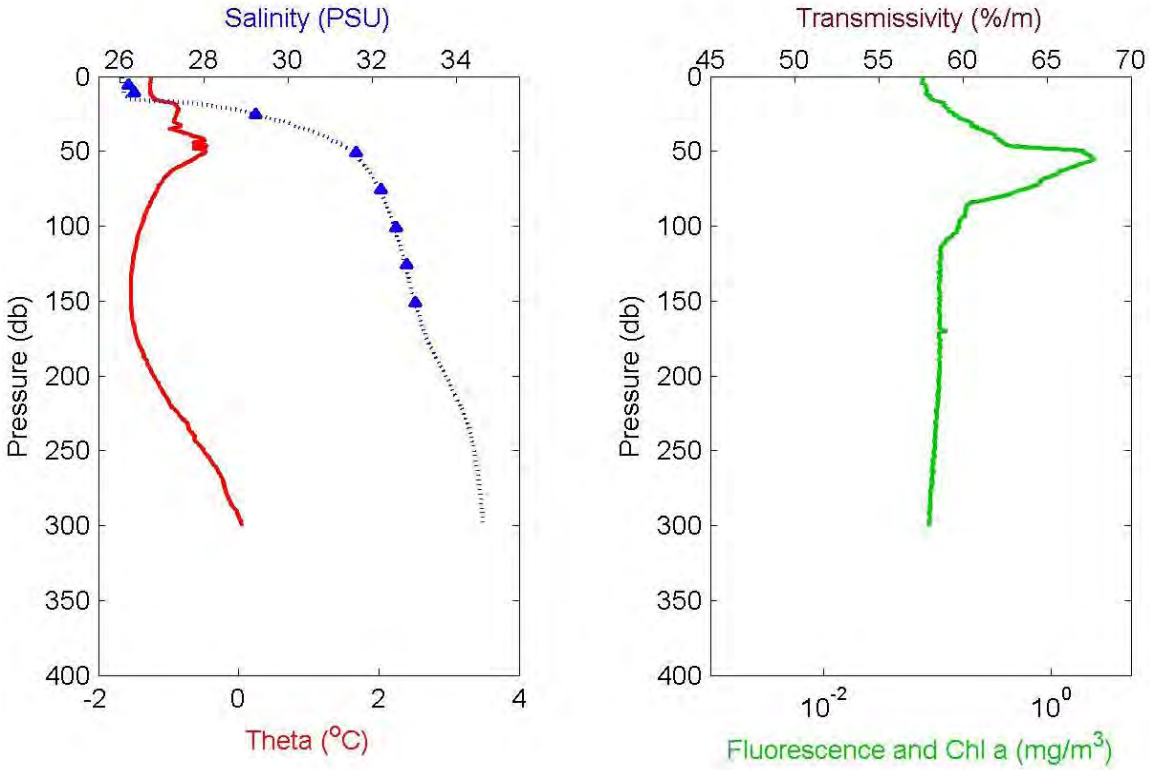


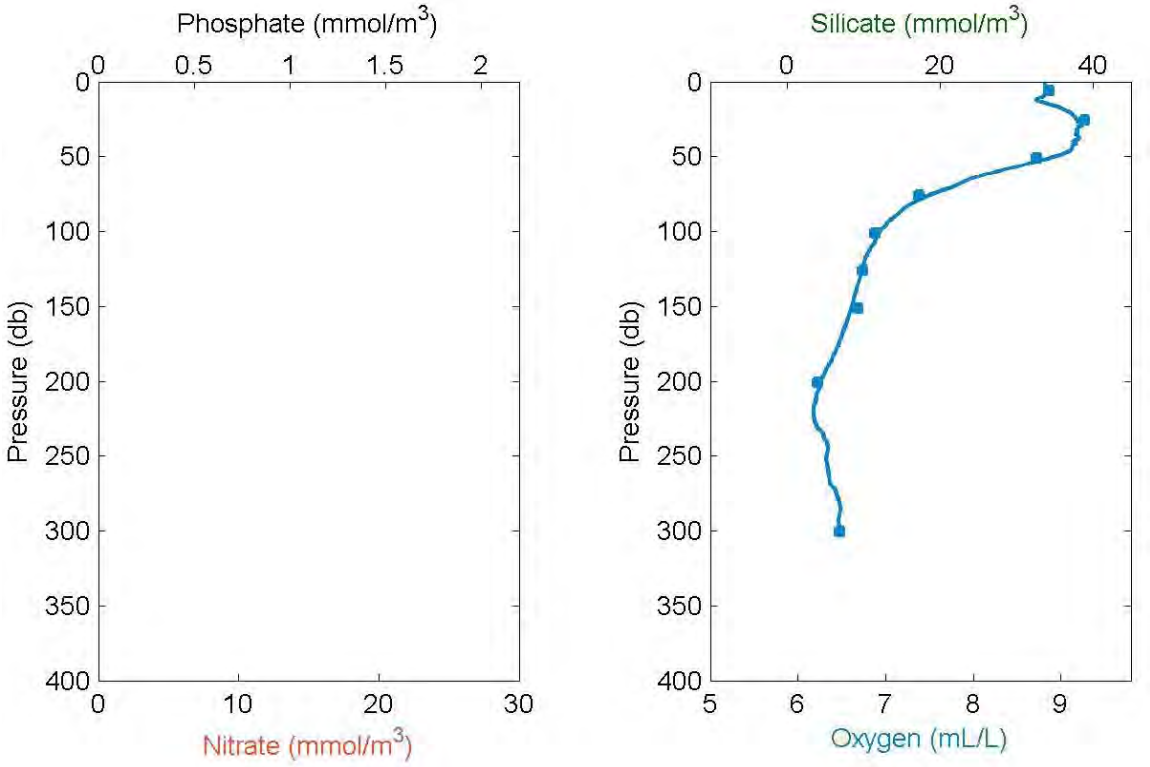


2002-23: Cast 15 Station SB01 (2)

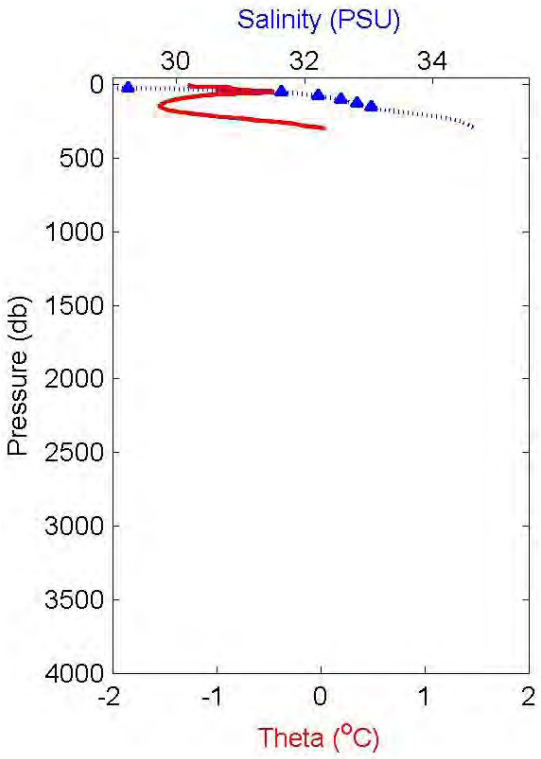


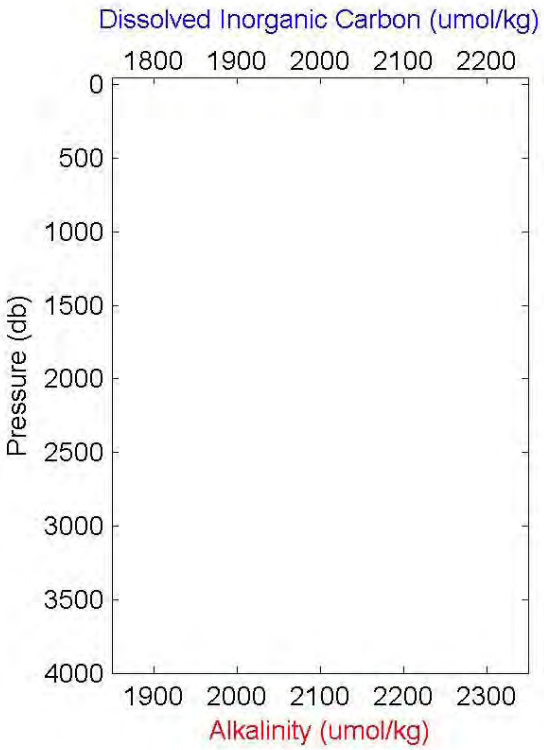
2002-23: Cast 16 Station SB01 (3)

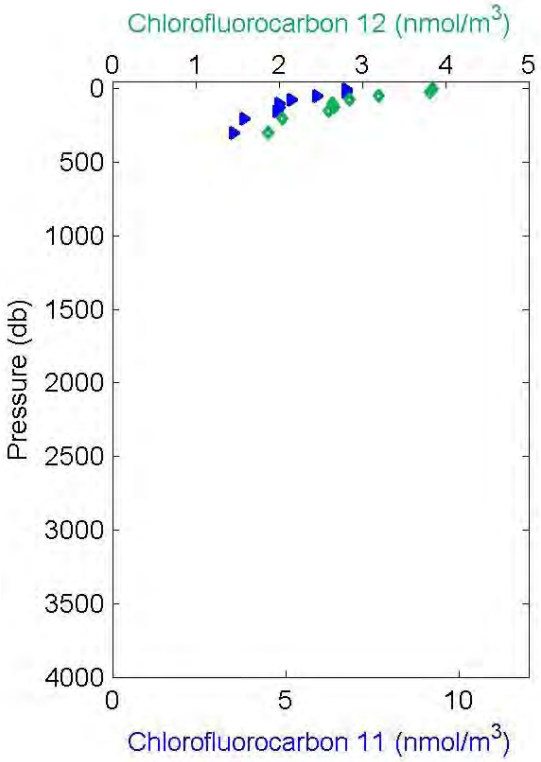


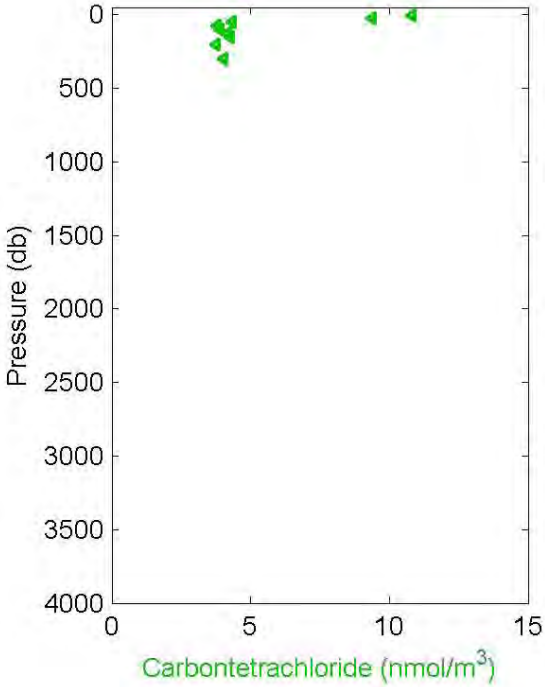


2002-23: Cast 16 Station SB01 (3)

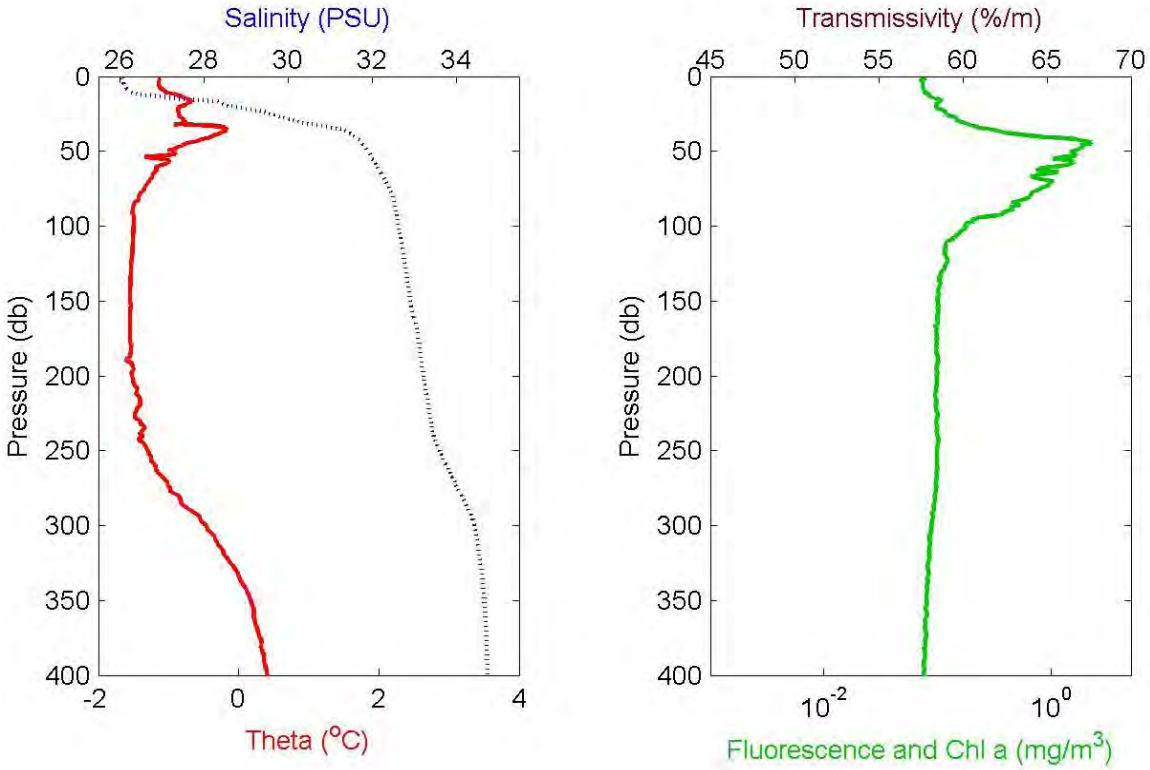


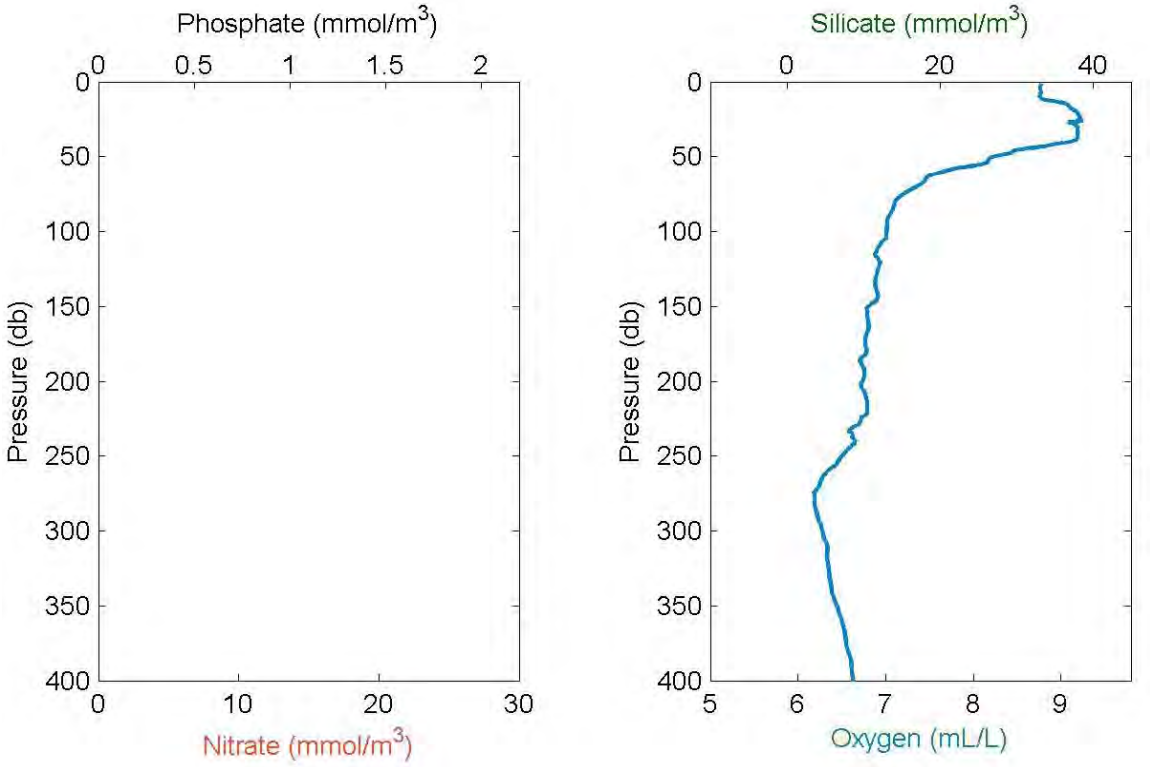




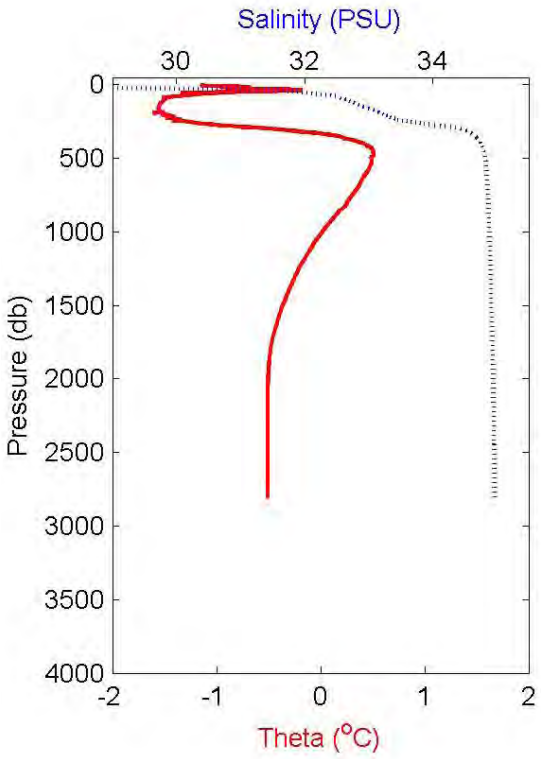


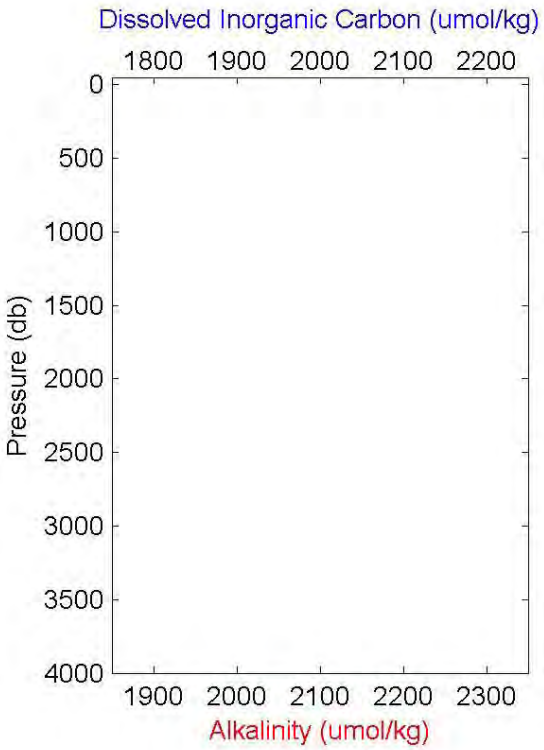
2002-23: Cast 17 Station RVB1

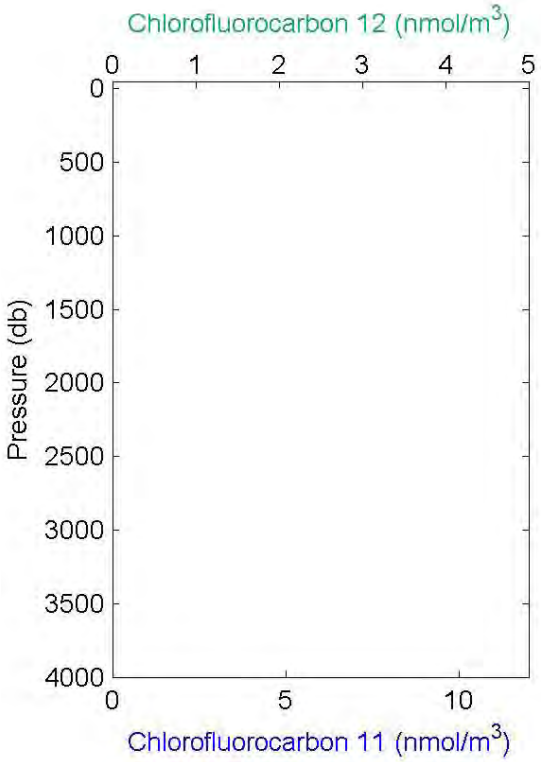


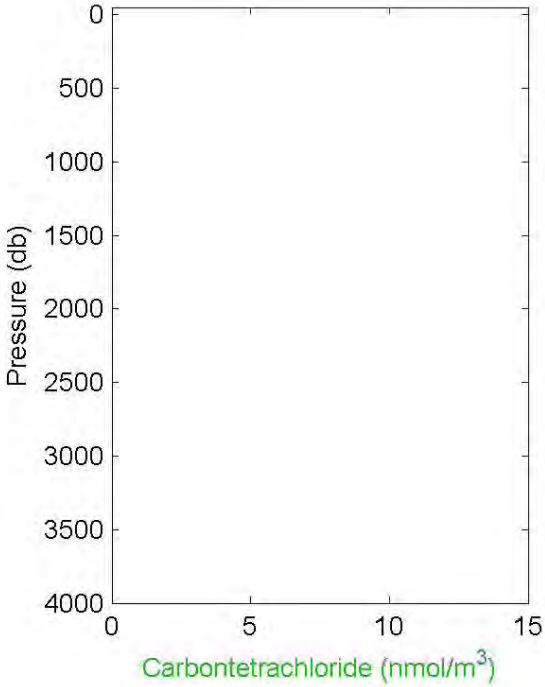


2002-23: Cast 17 Station RVB1

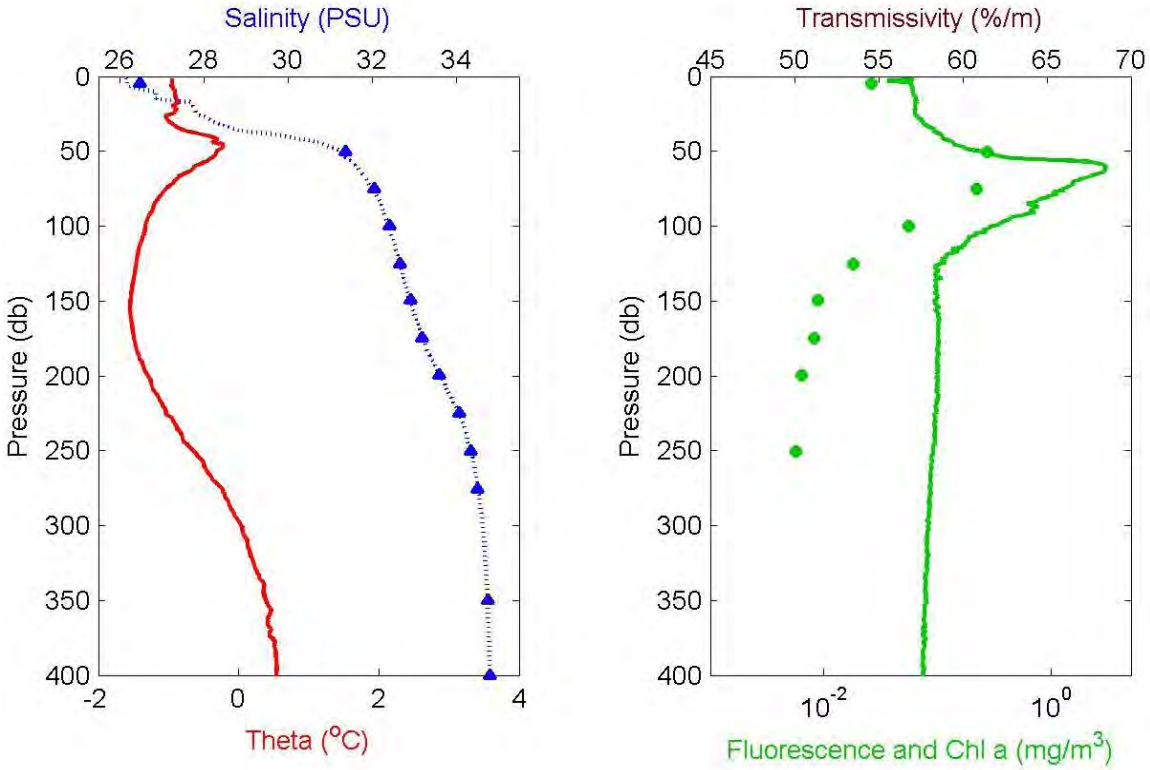


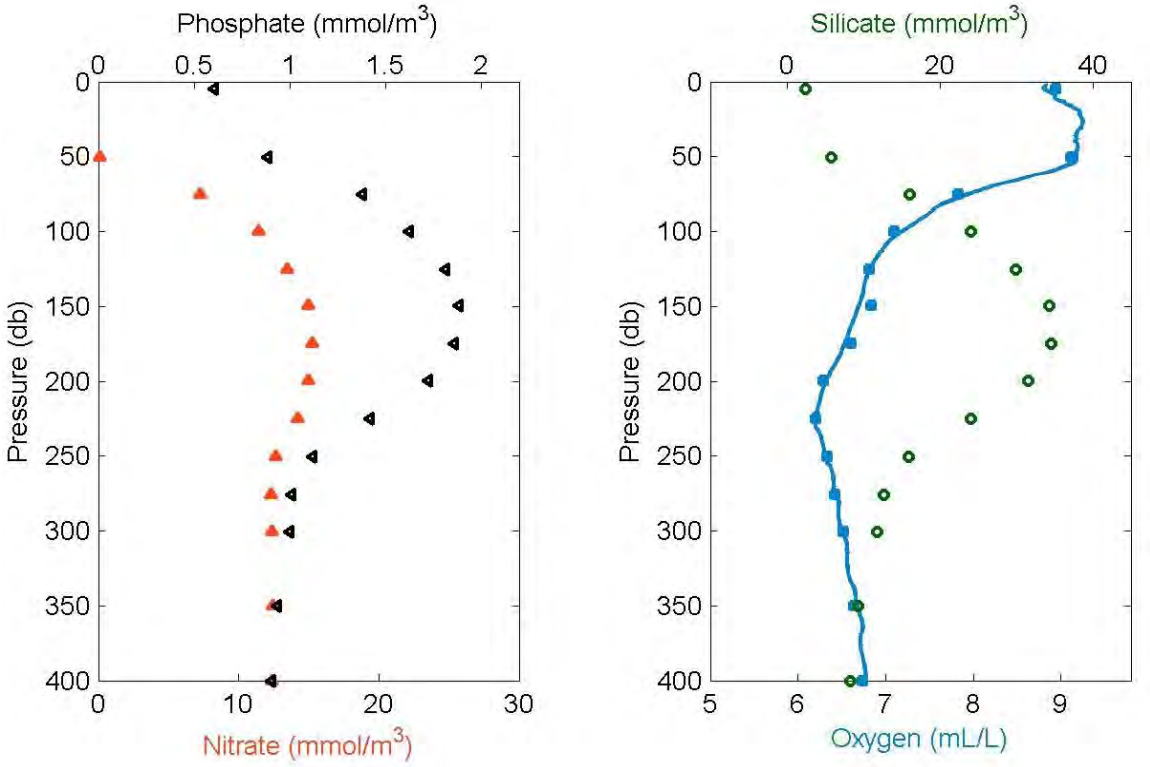




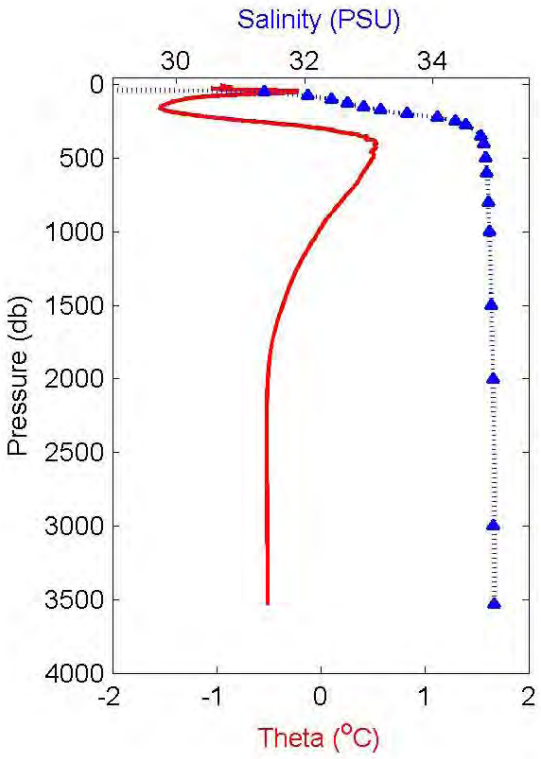


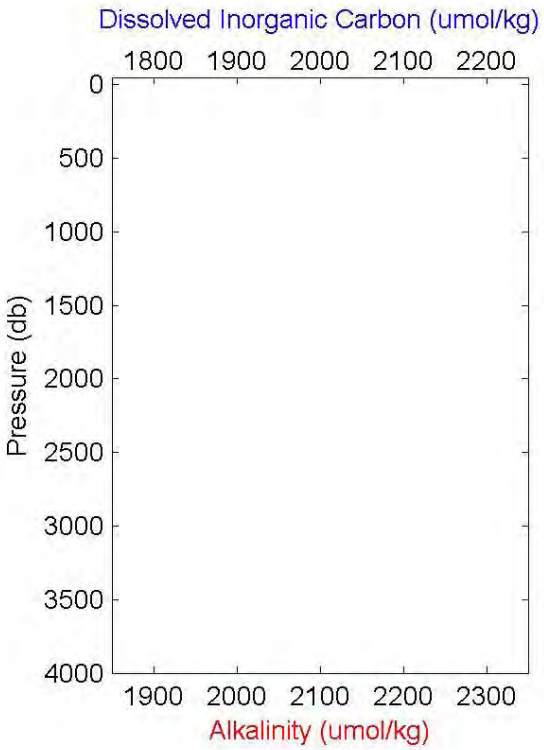
2002-23: Cast 18 Station SB02

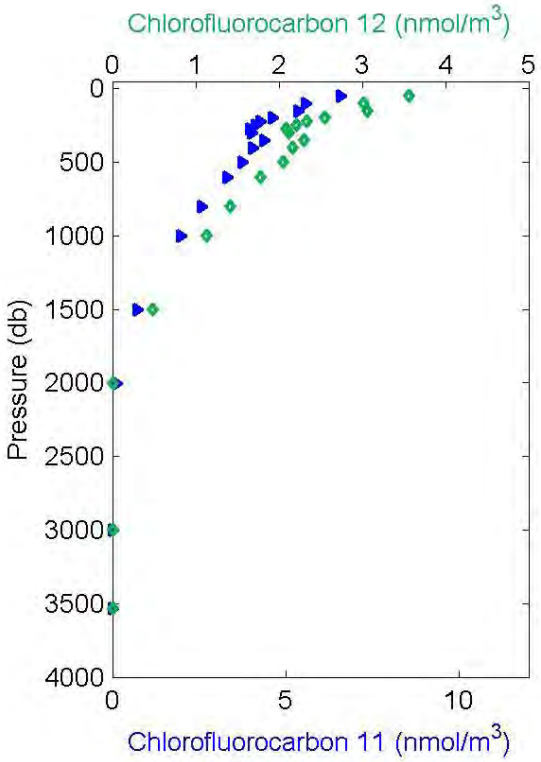


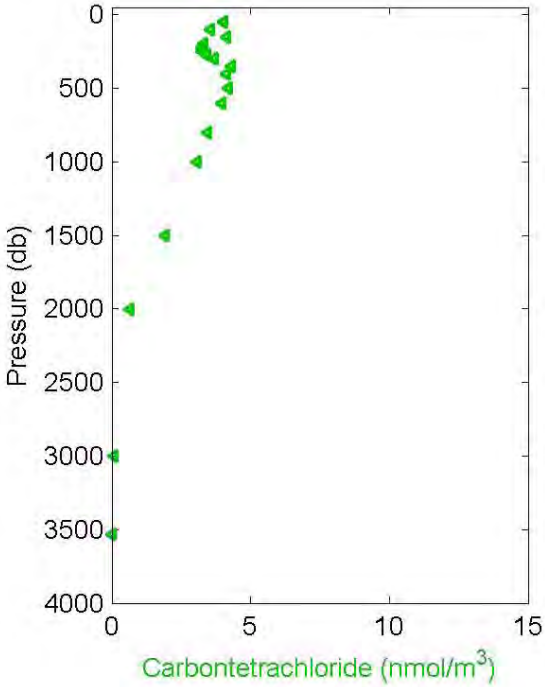


2002-23: Cast 18 Station SB02

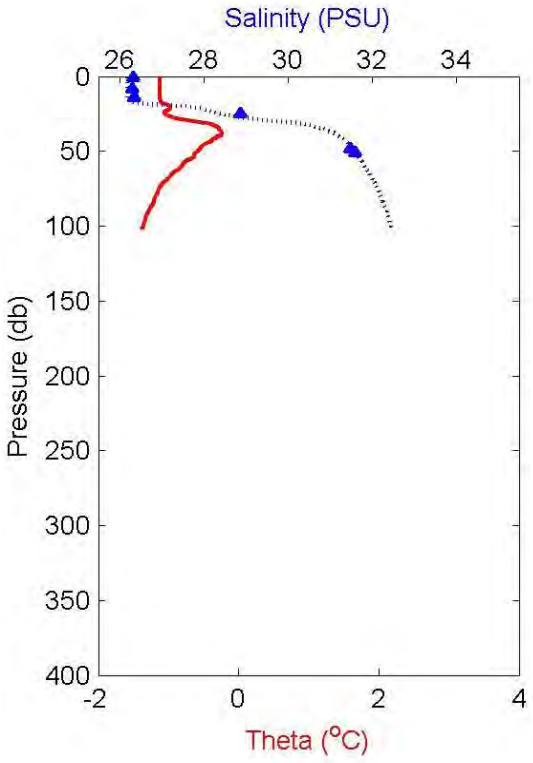


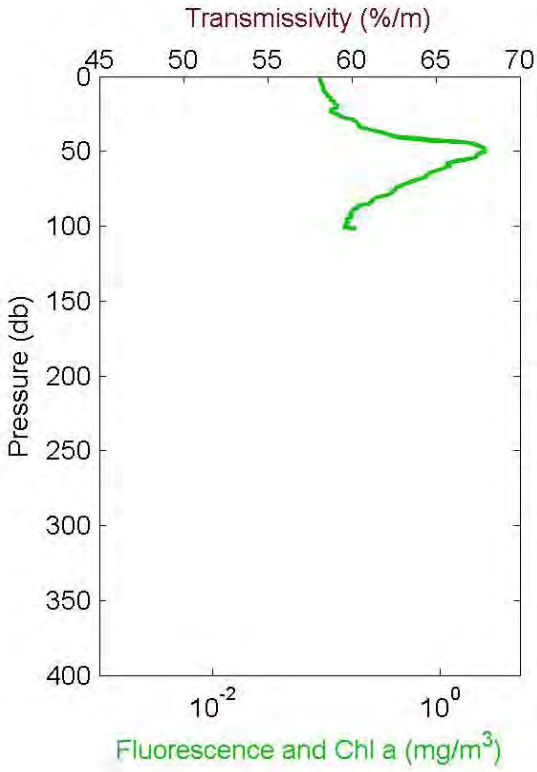


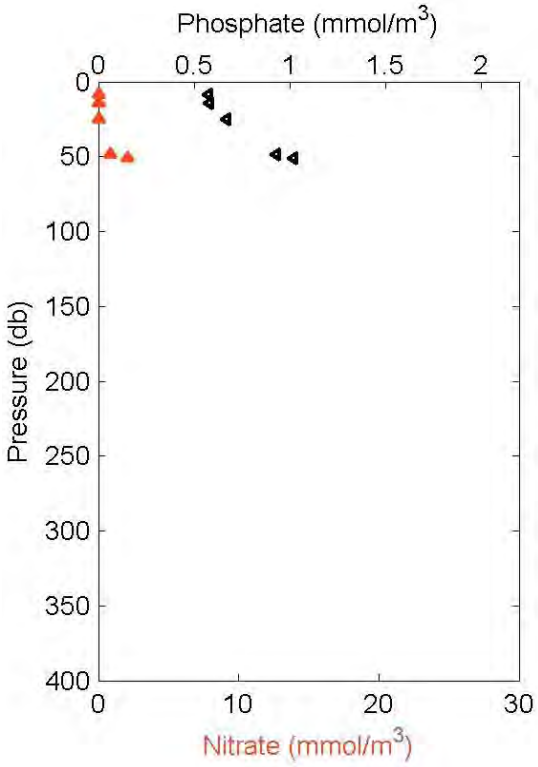


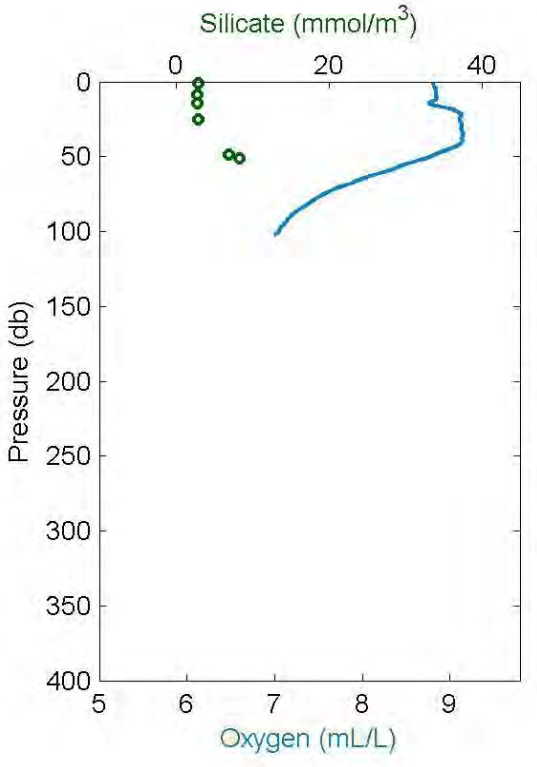


2002-23: Cast 19 Station SB03

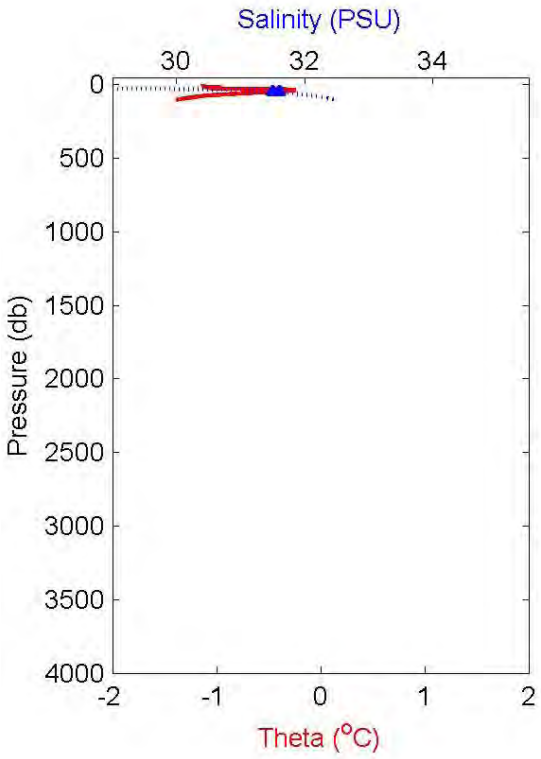


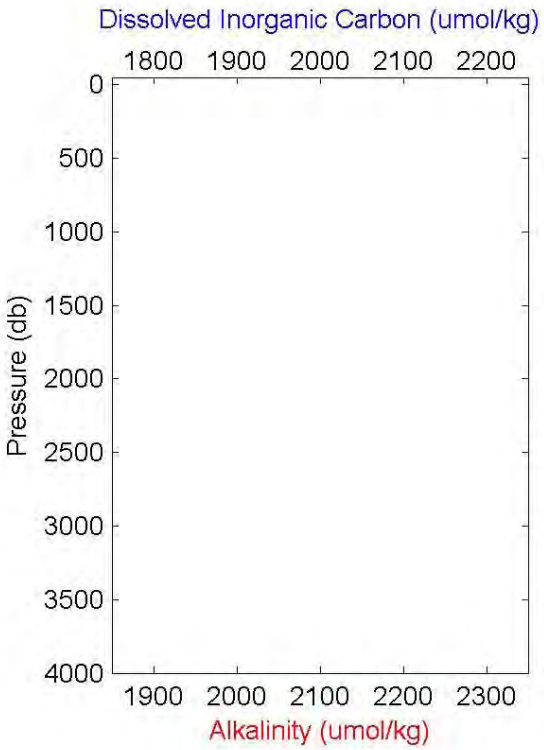


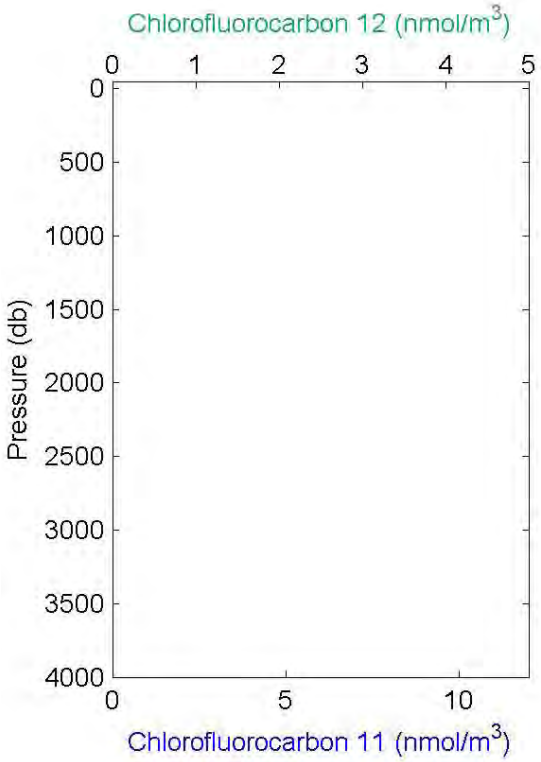


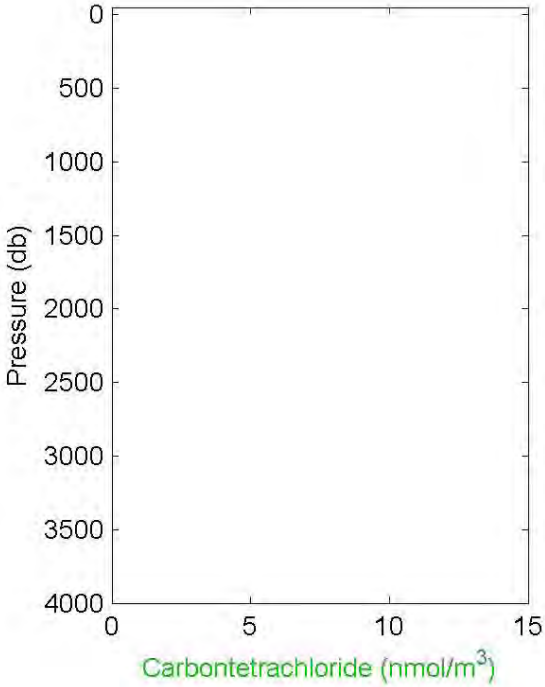


2002-23: Cast 19 Station SB03

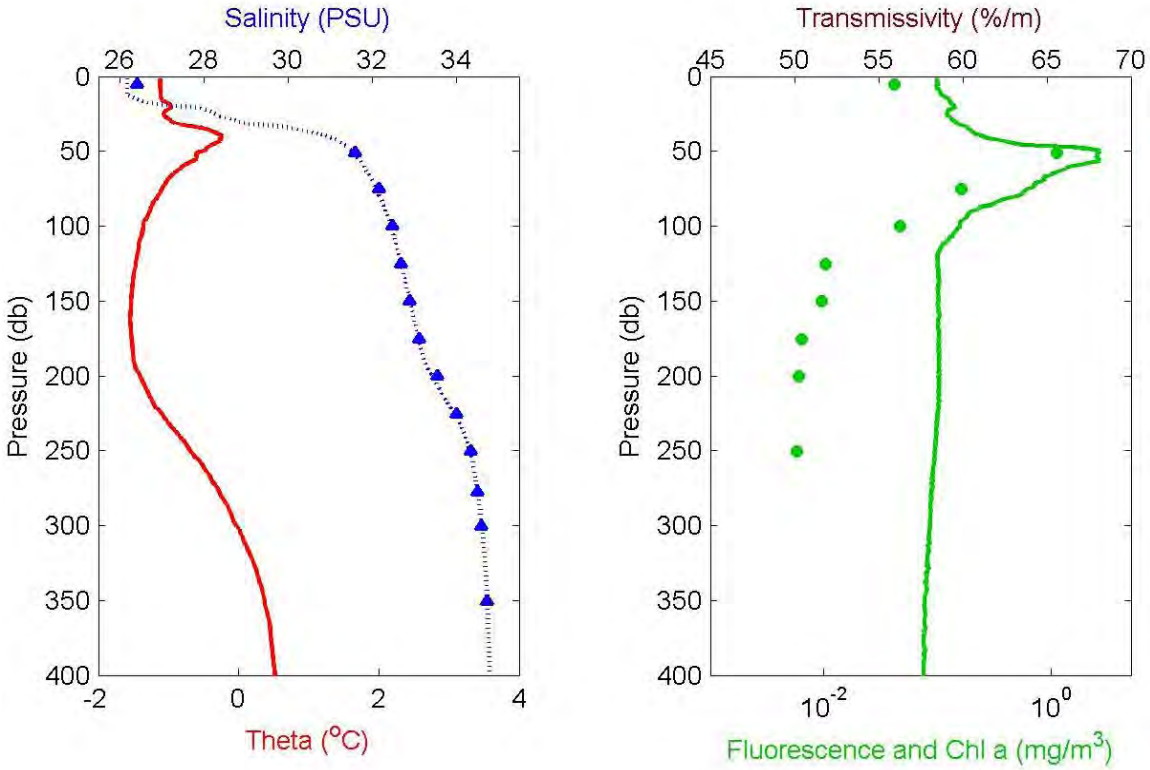


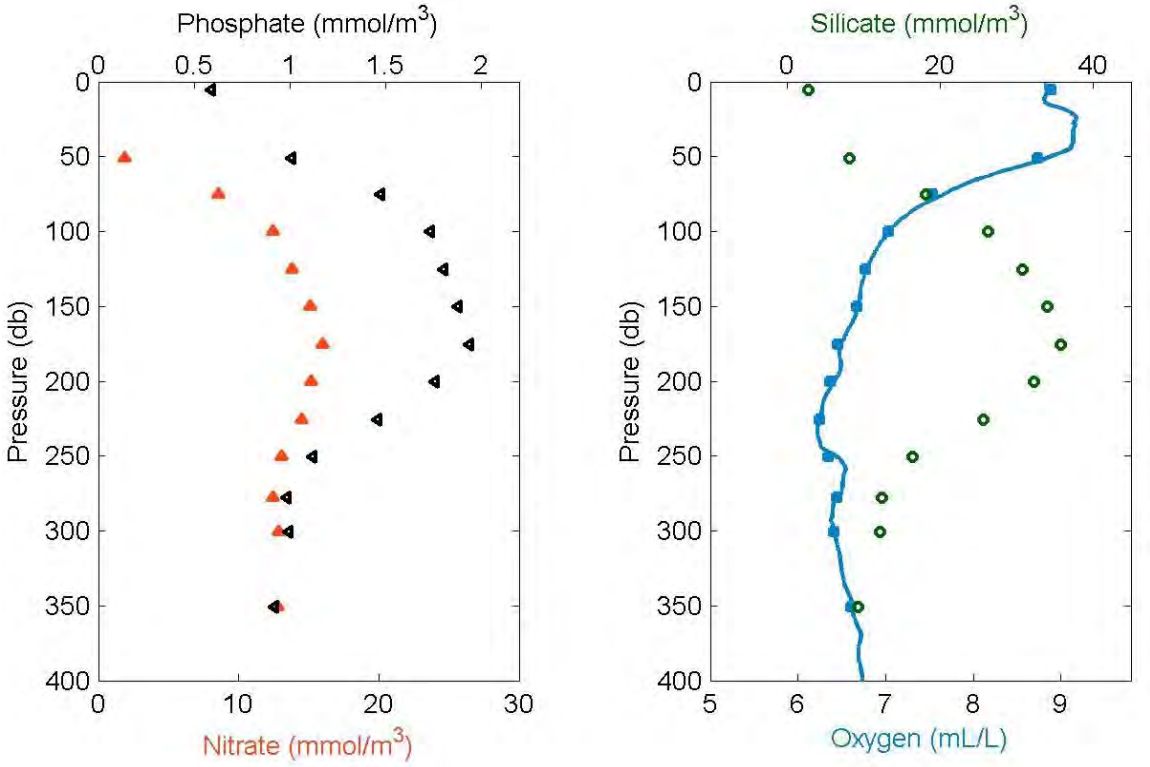




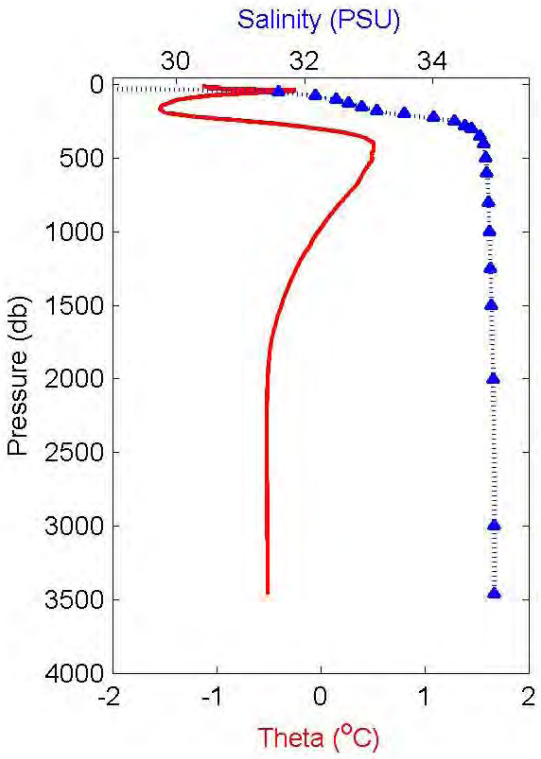


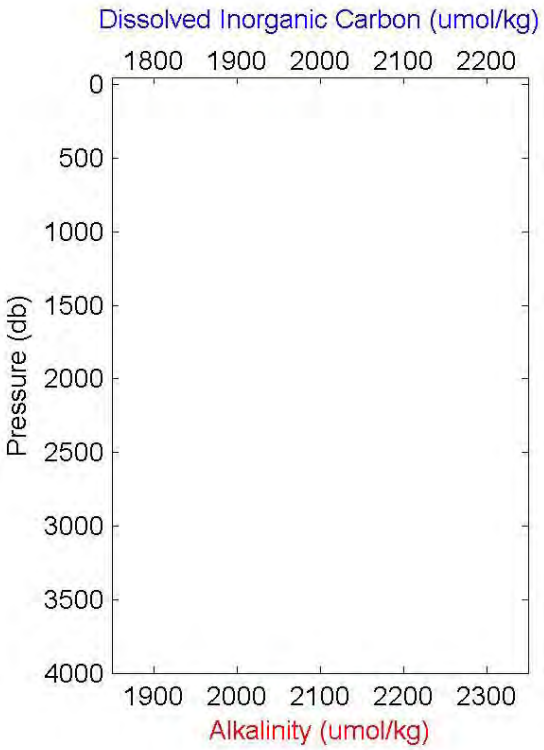
2002-23: Cast 20 Station SB03(2)

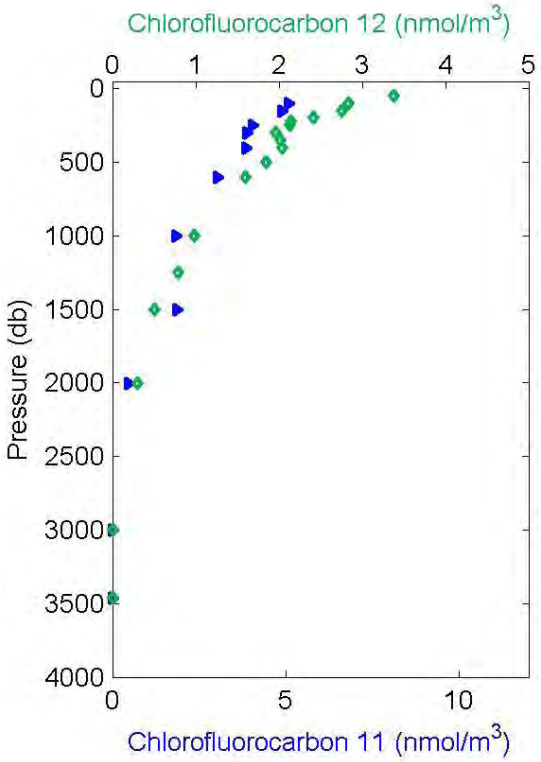


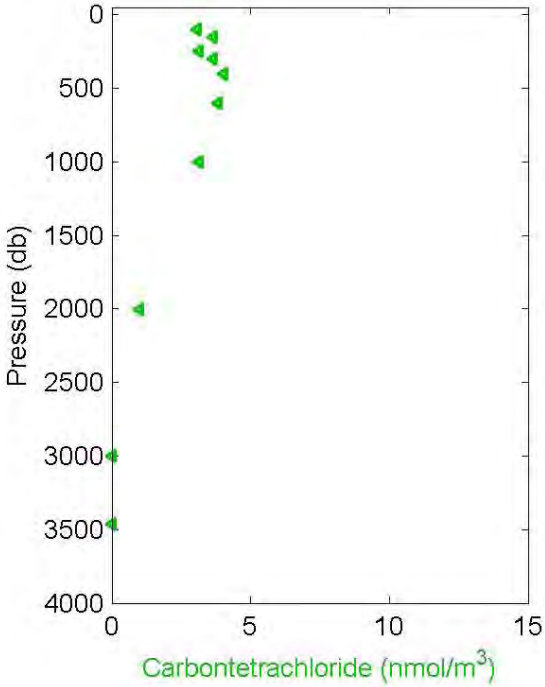


2002-23: Cast 20 Station SB03(2)

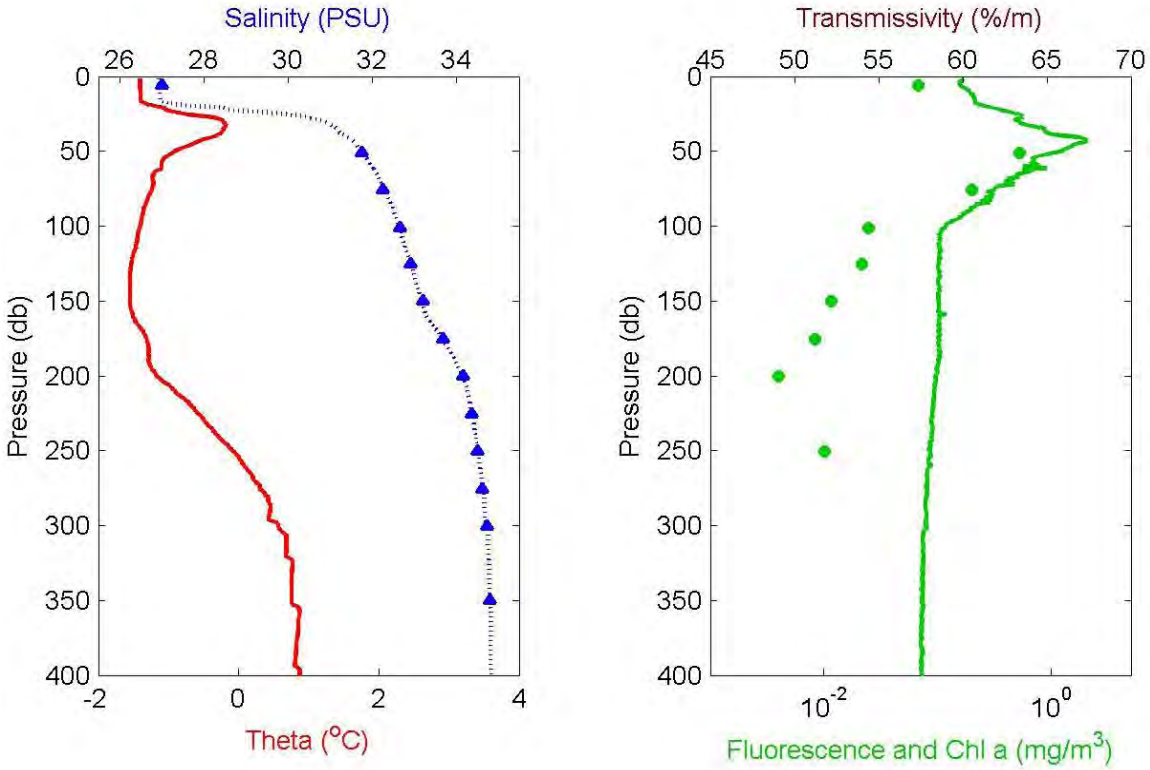


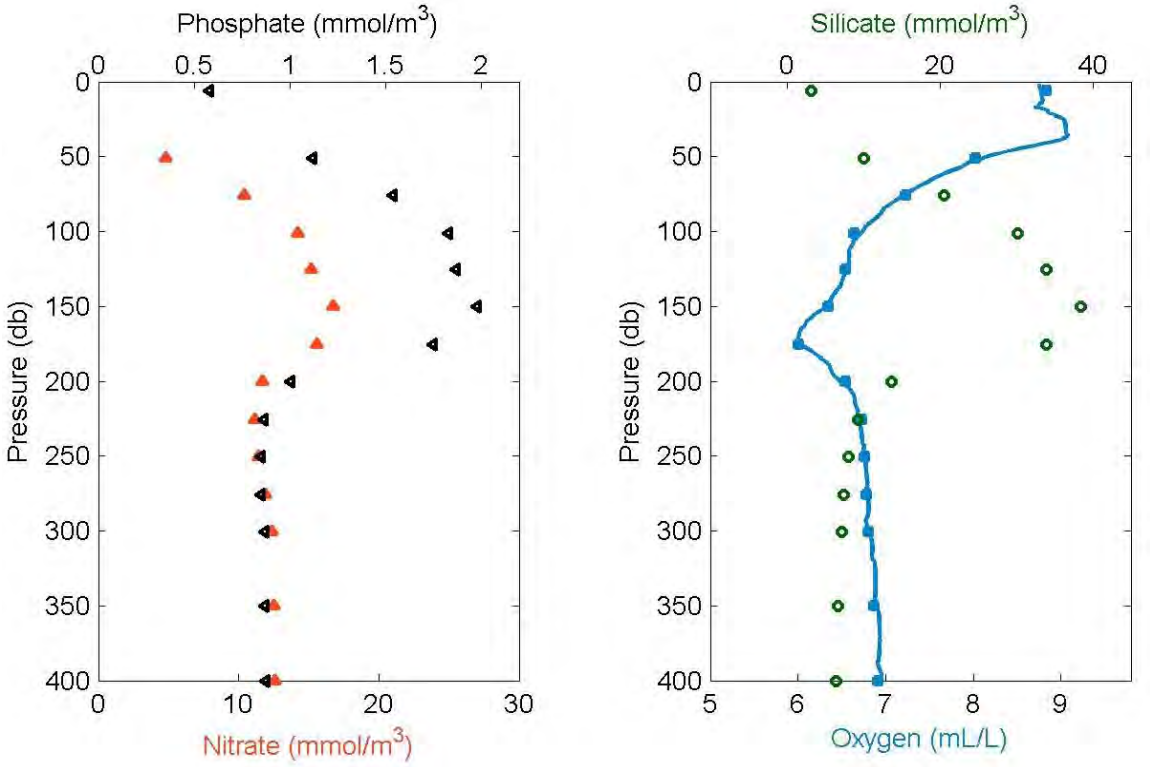




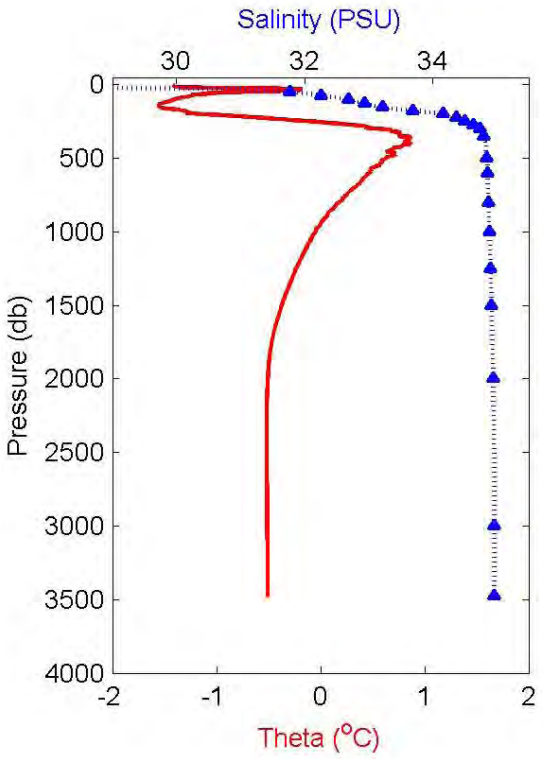


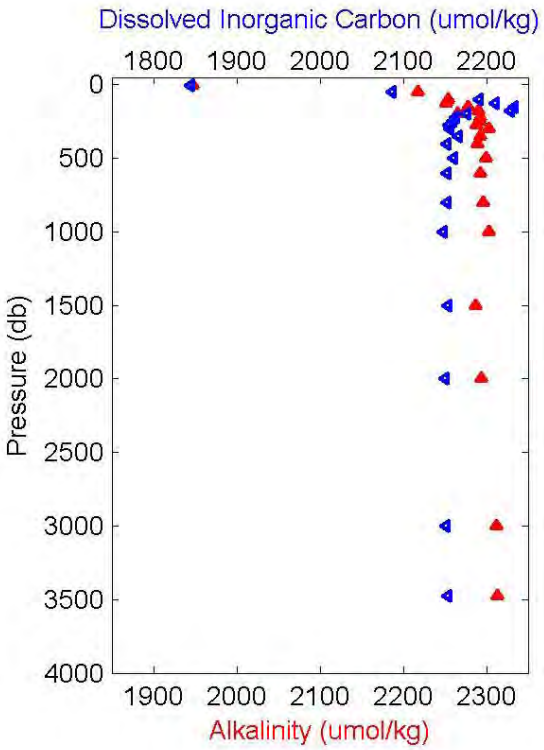
2002-23: Cast 21 Station NW08

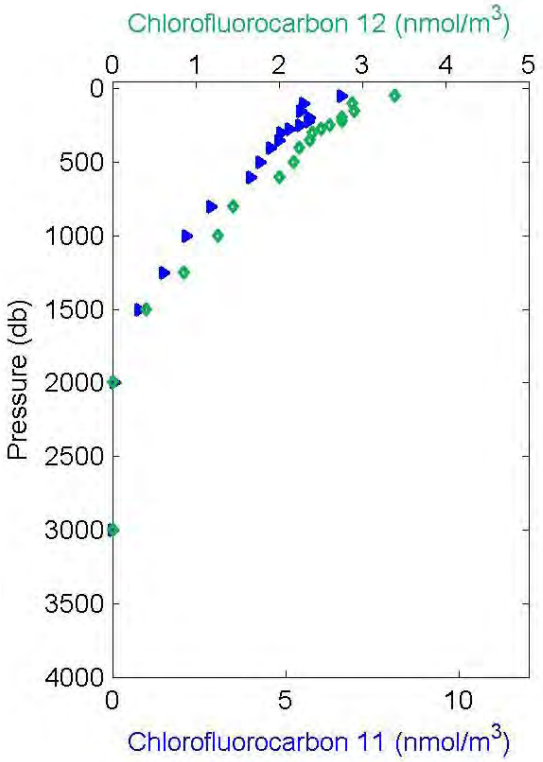


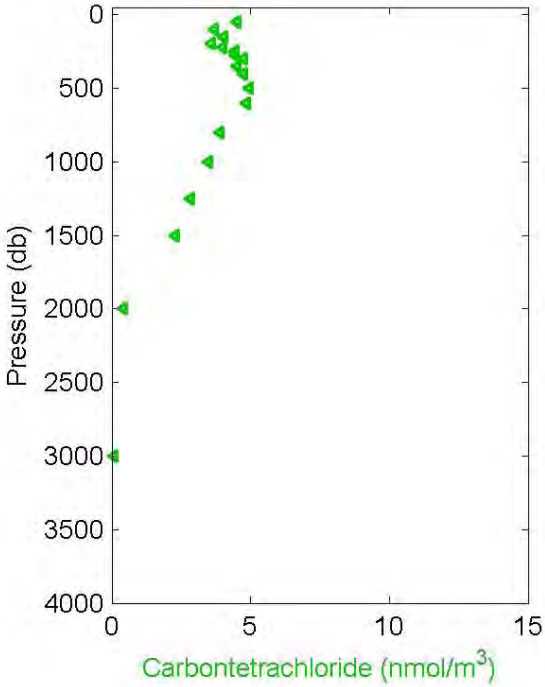


2002-23: Cast 21 Station NW08

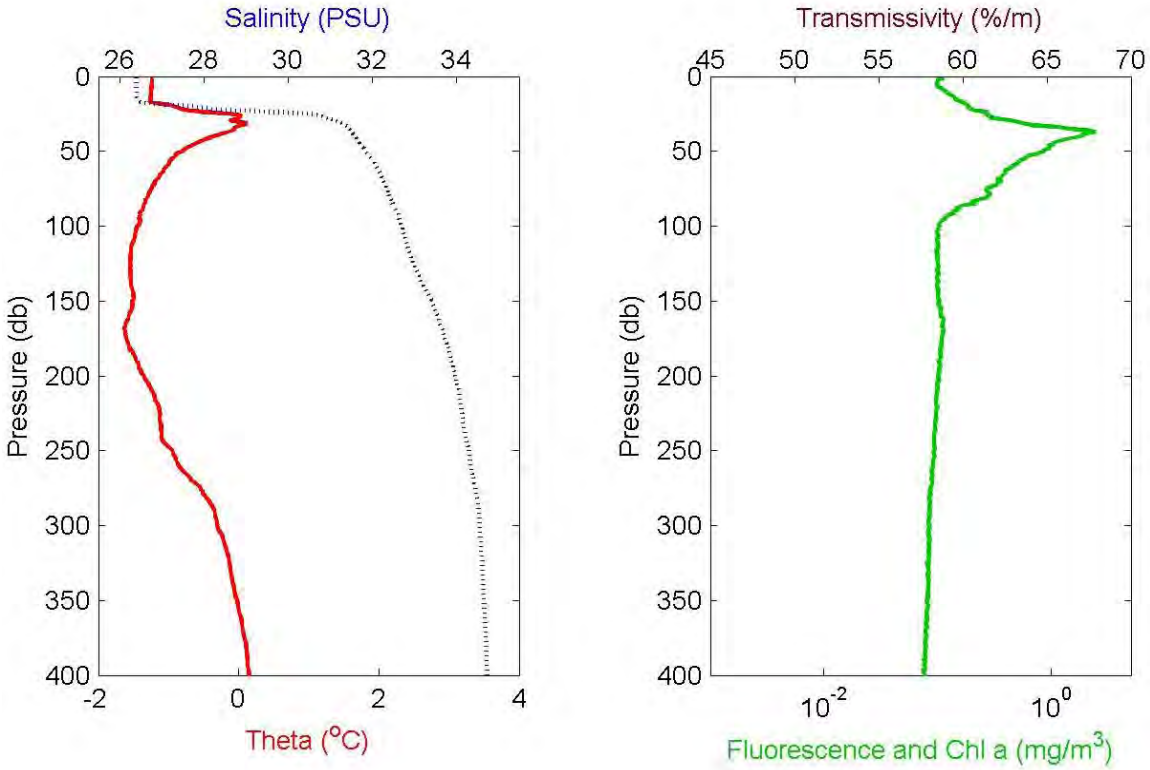


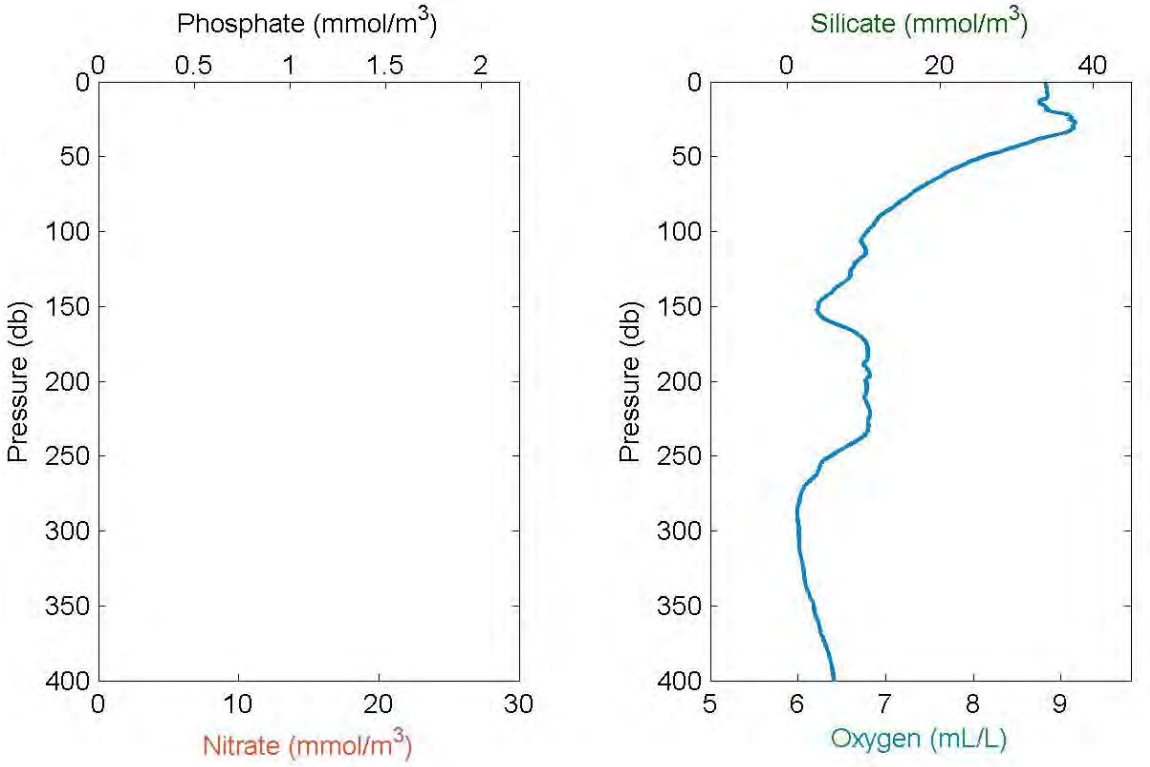




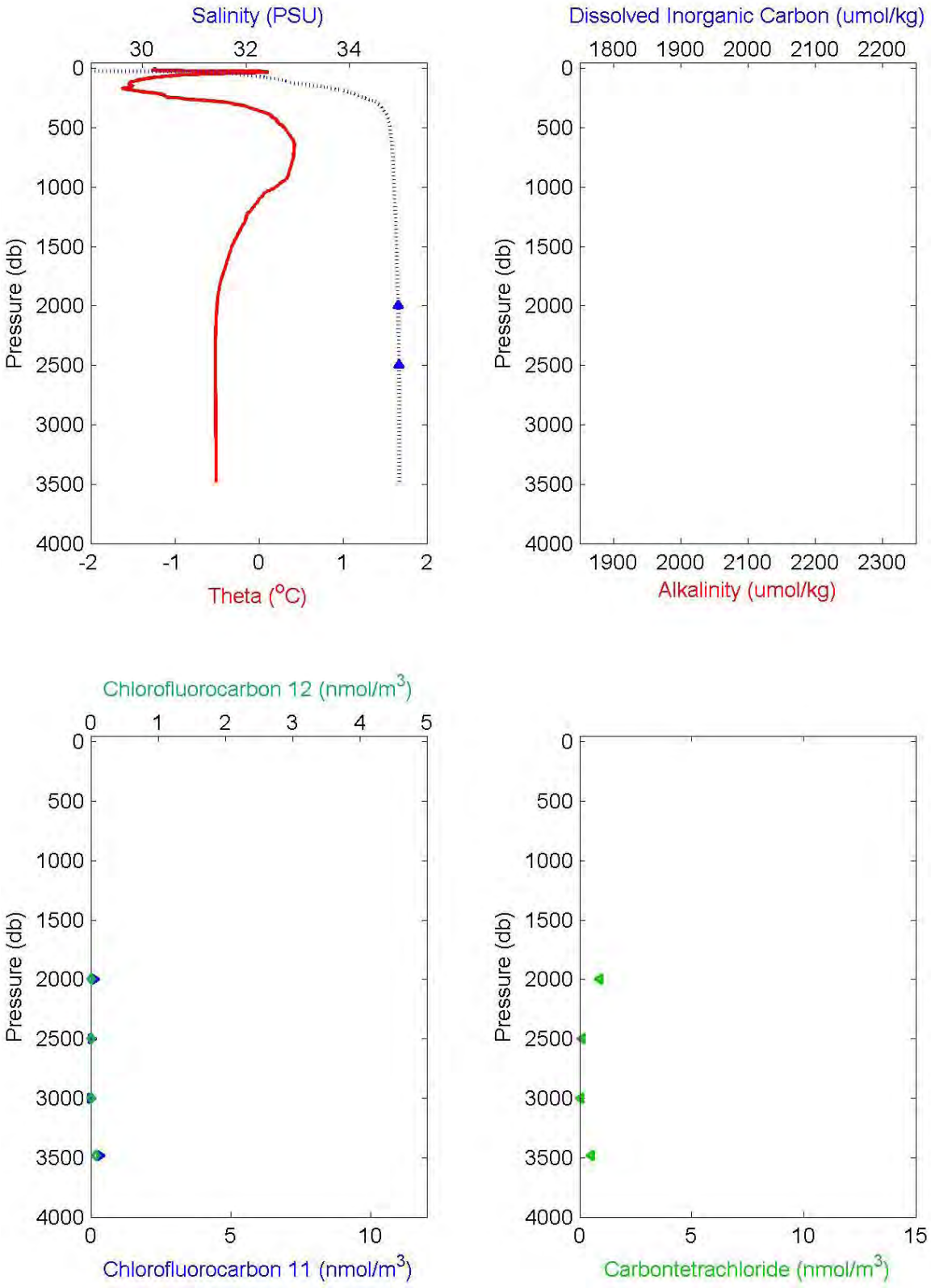


2002-23: Cast 22 Station NW07

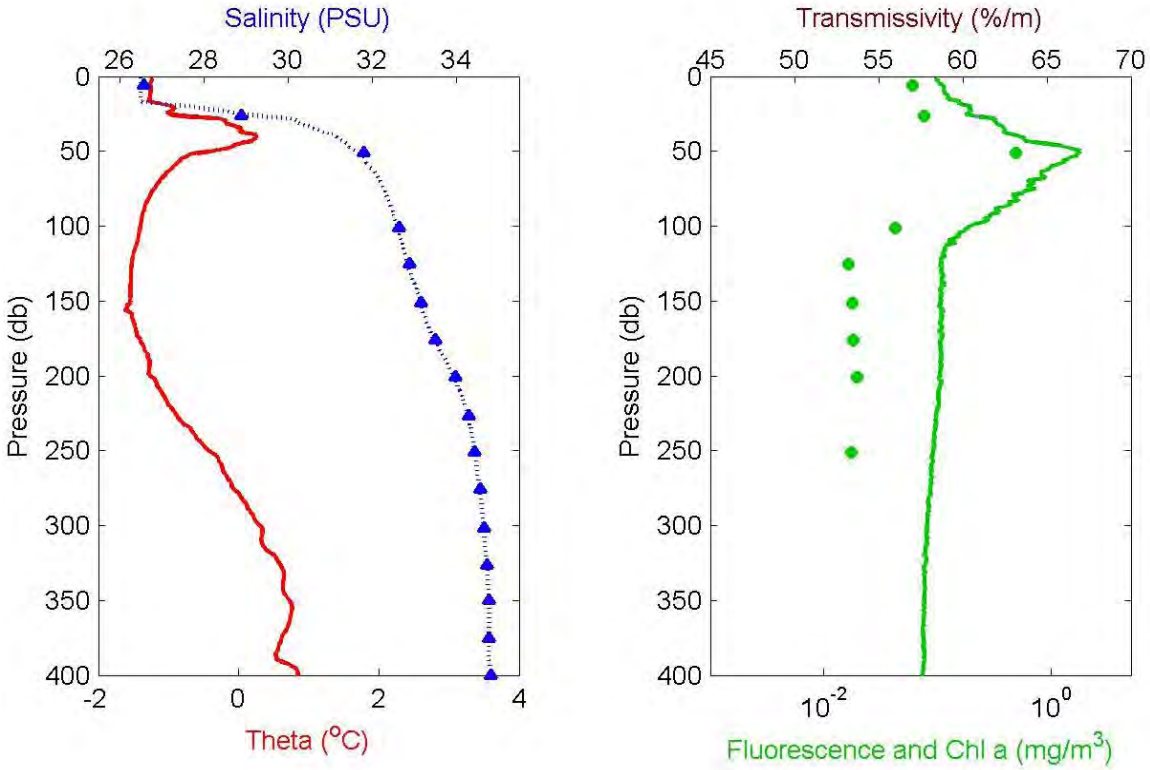


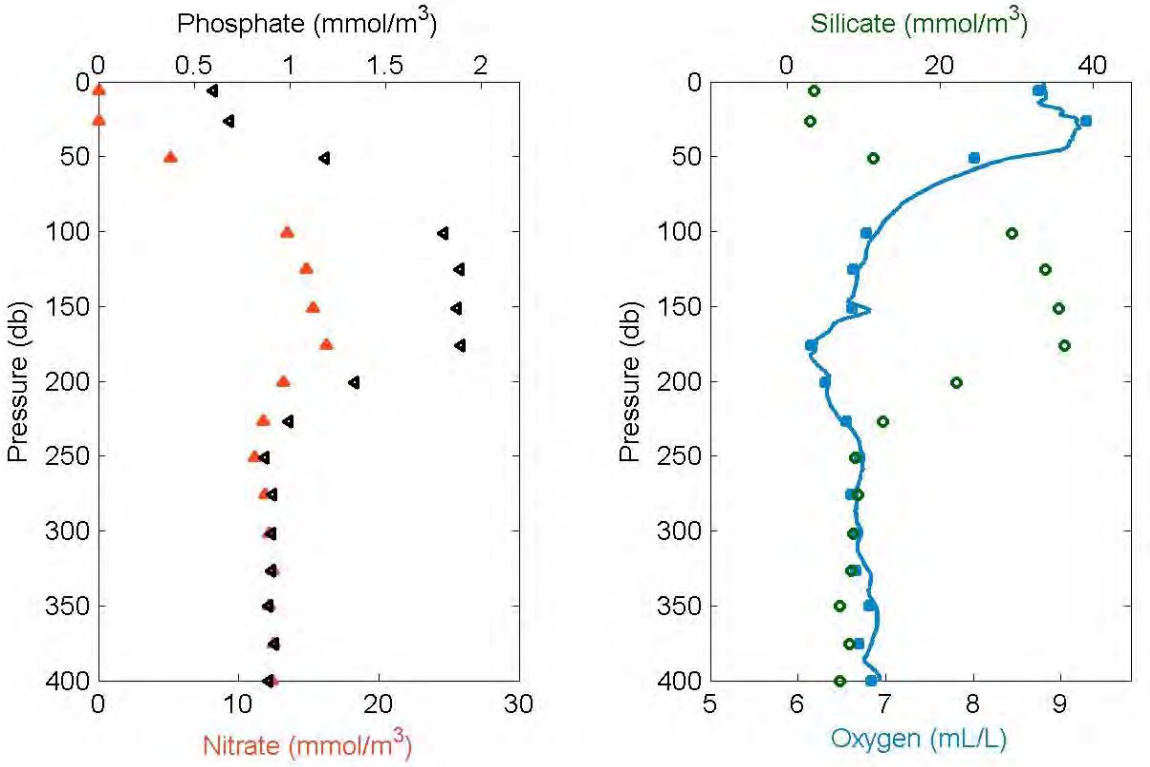


2002-23: Cast 22 Station NW07

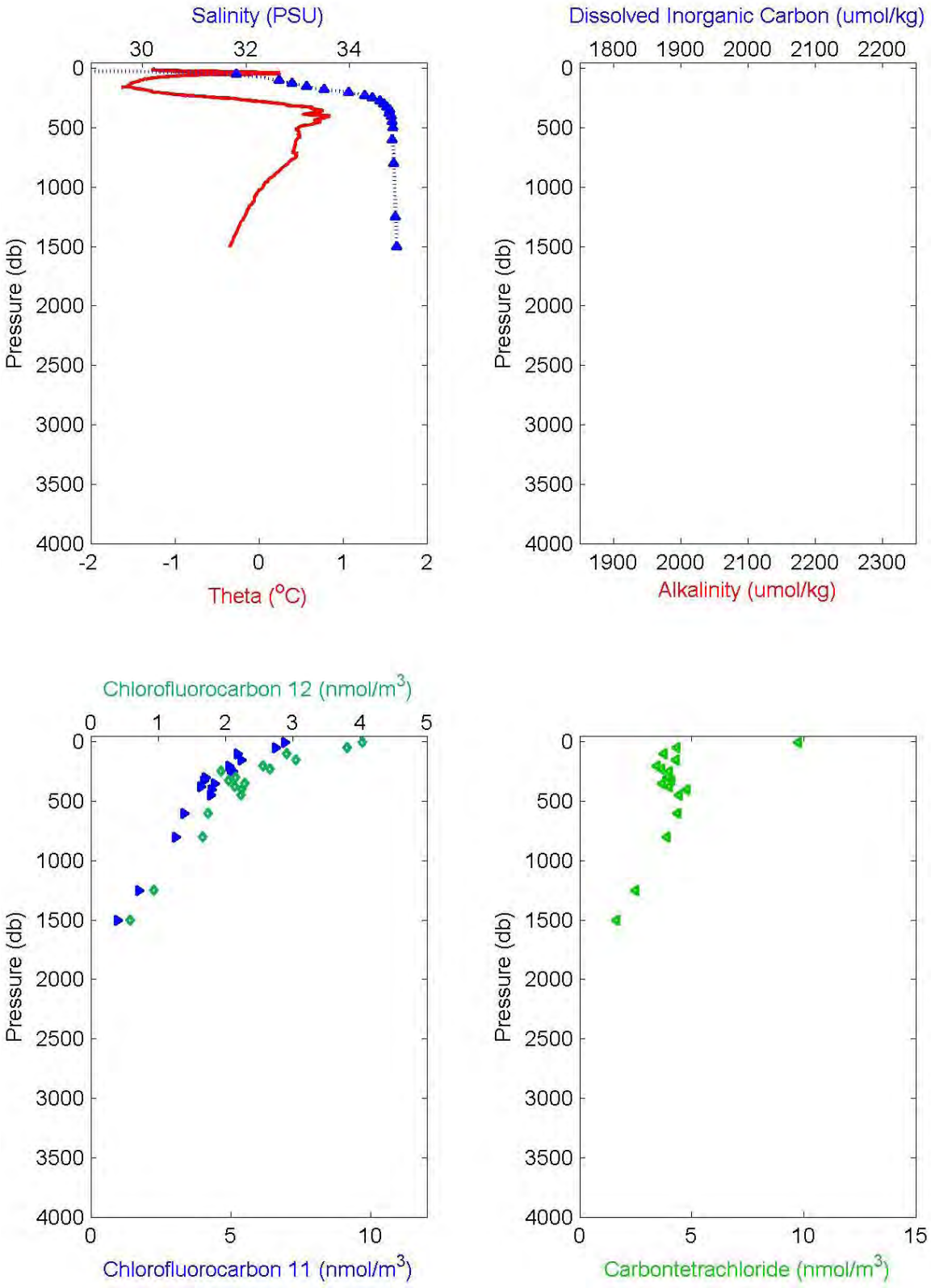


2002-23: Cast 23 Station NW07 (2)

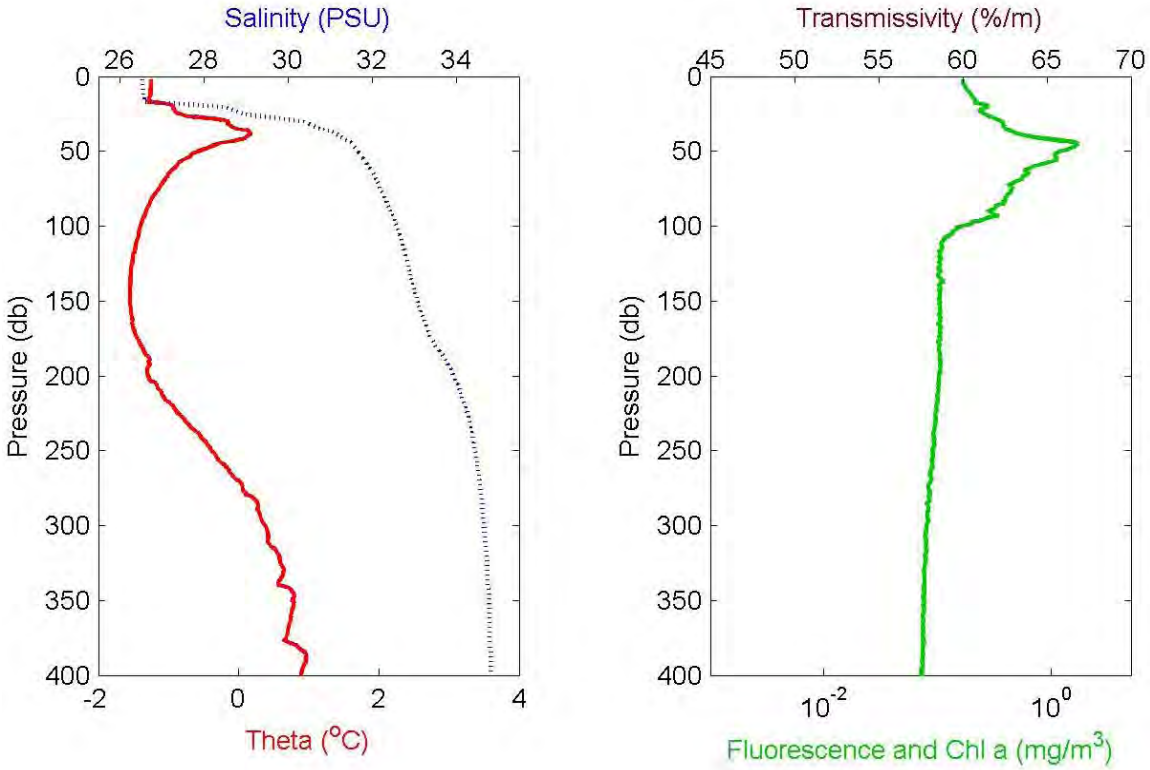


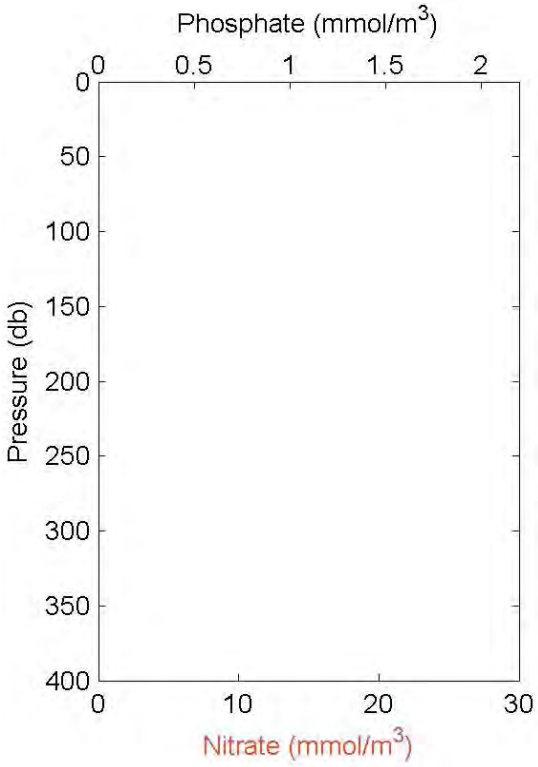


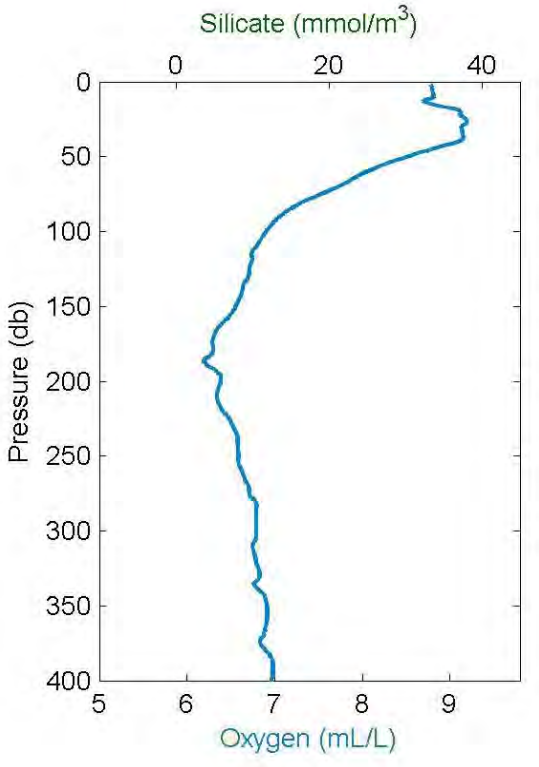
2002-23: Cast 23 Station NW07 (2)



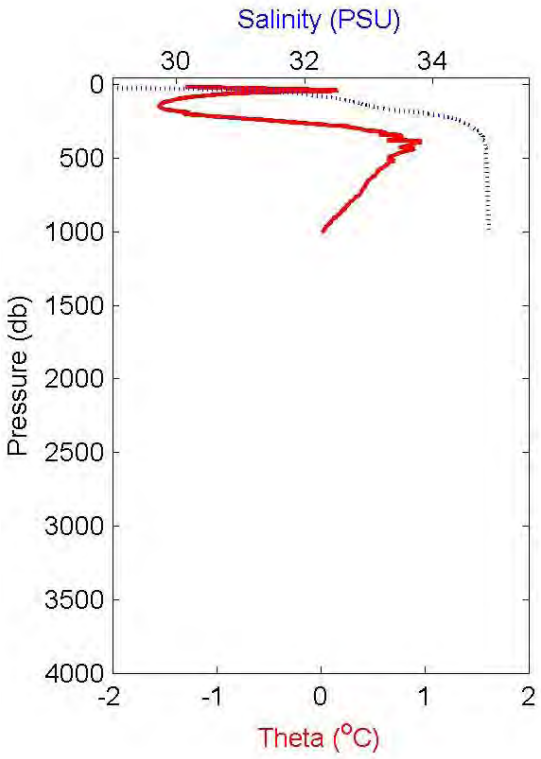
2002-23: Cast 24 Station NW07 (3)

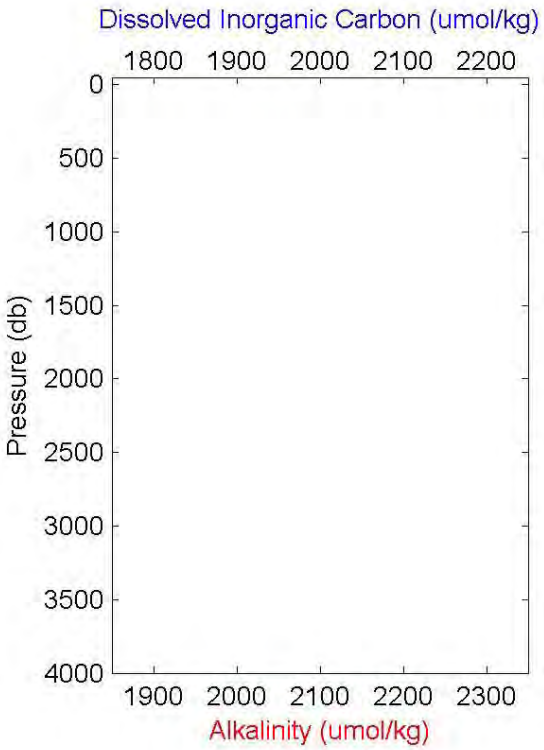


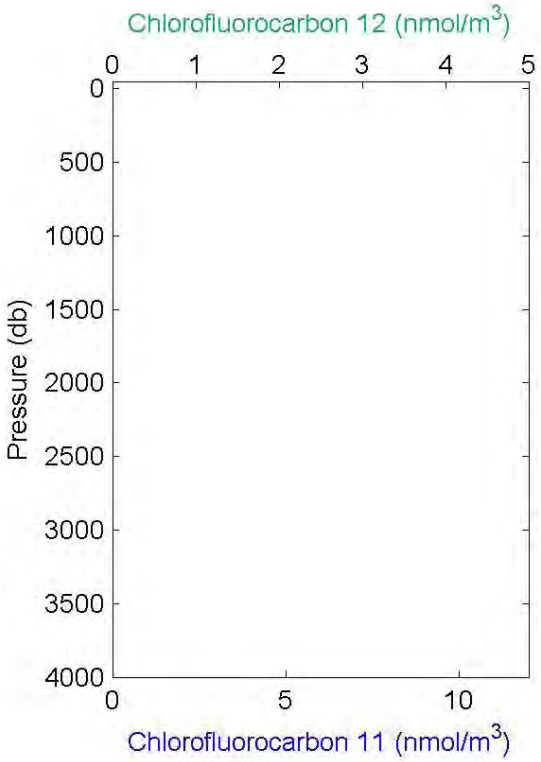


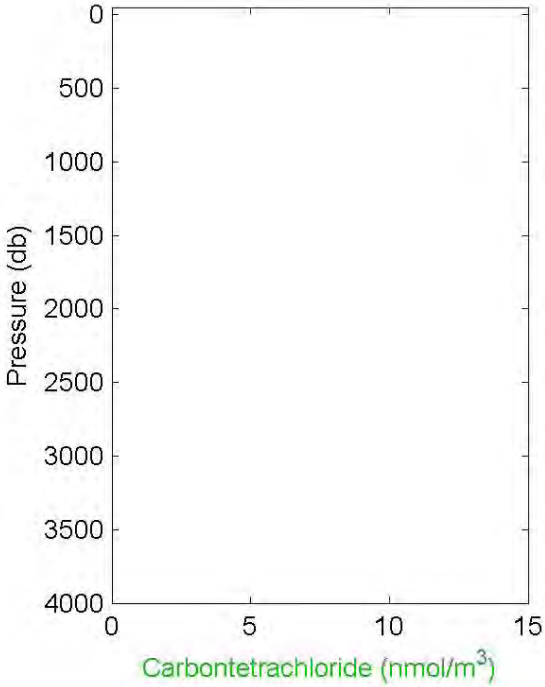


2002-23: Cast 24 Station NW07 (3)

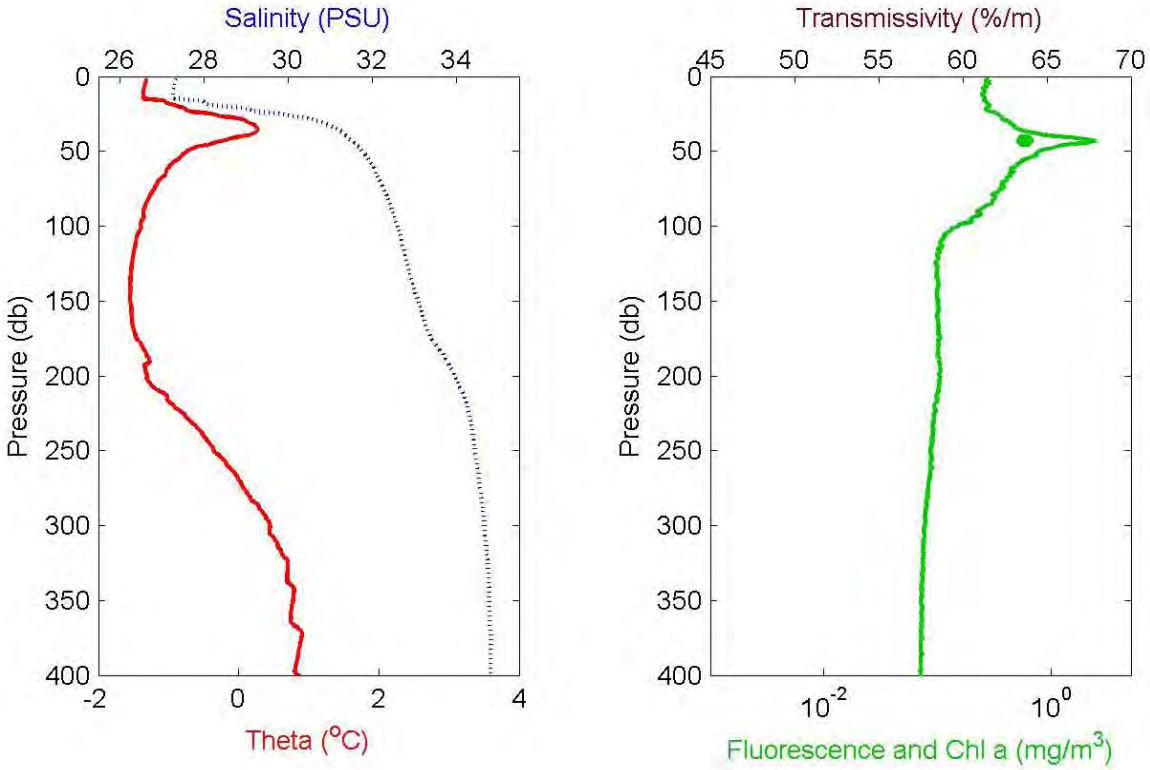


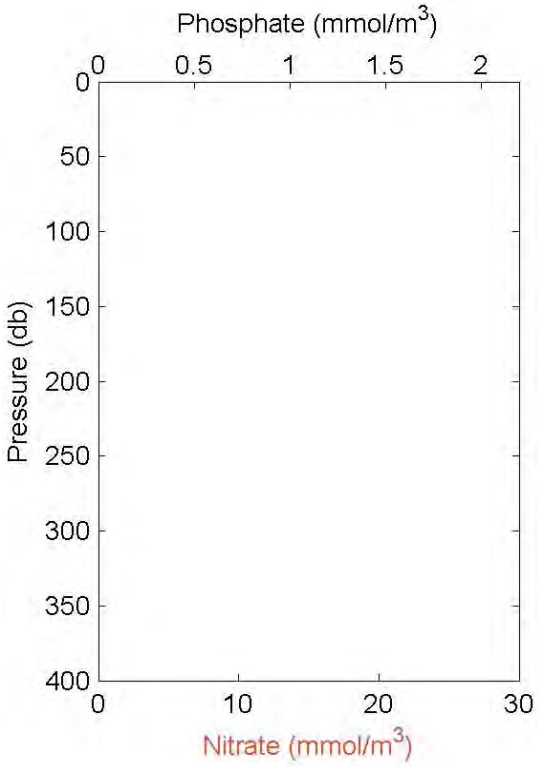


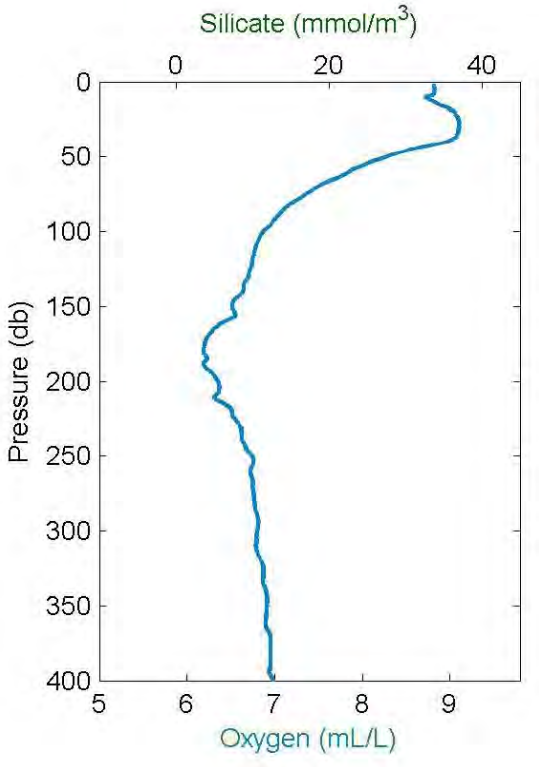




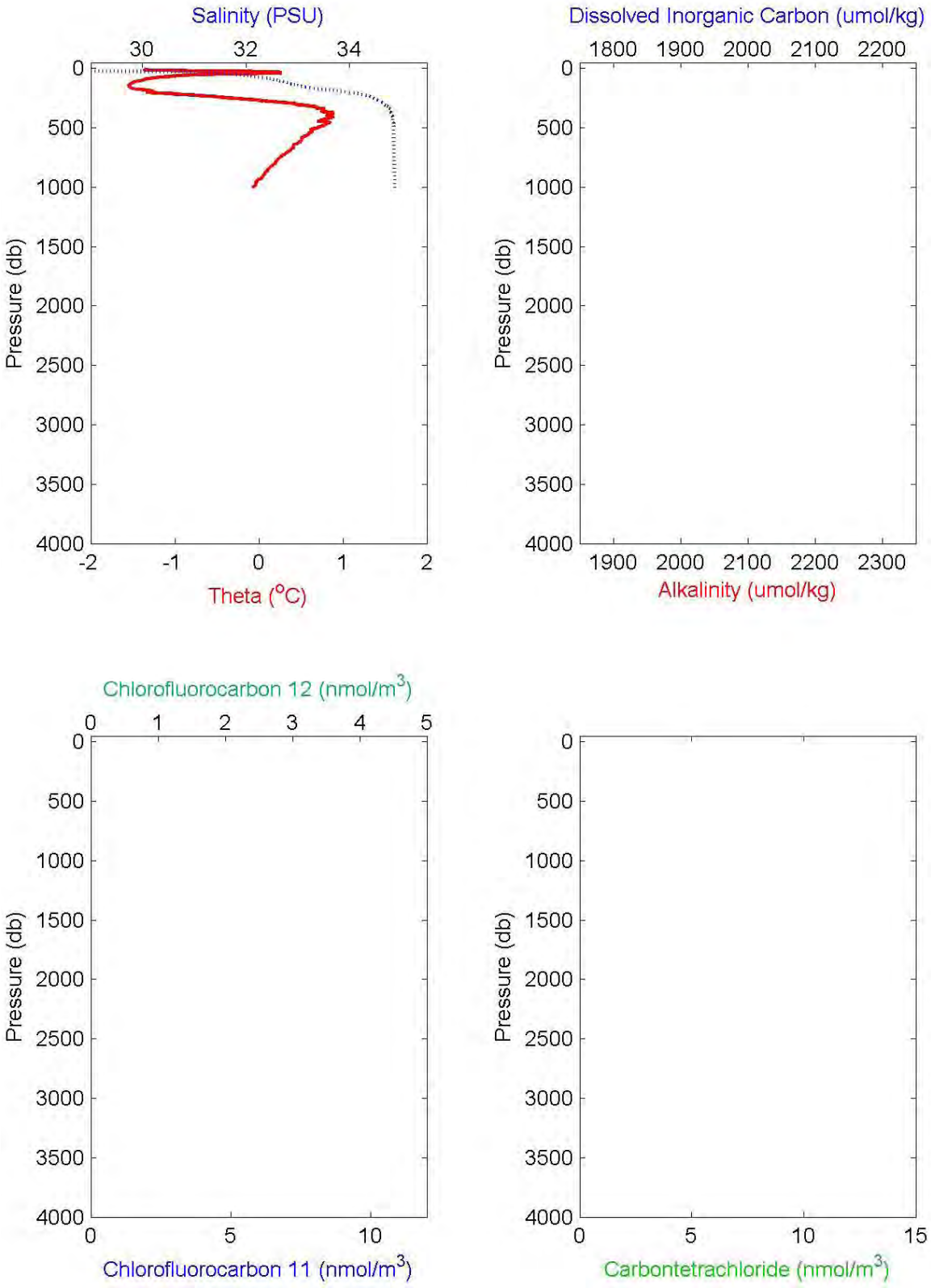
2002-23: Cast 25 Station NW07 (4)



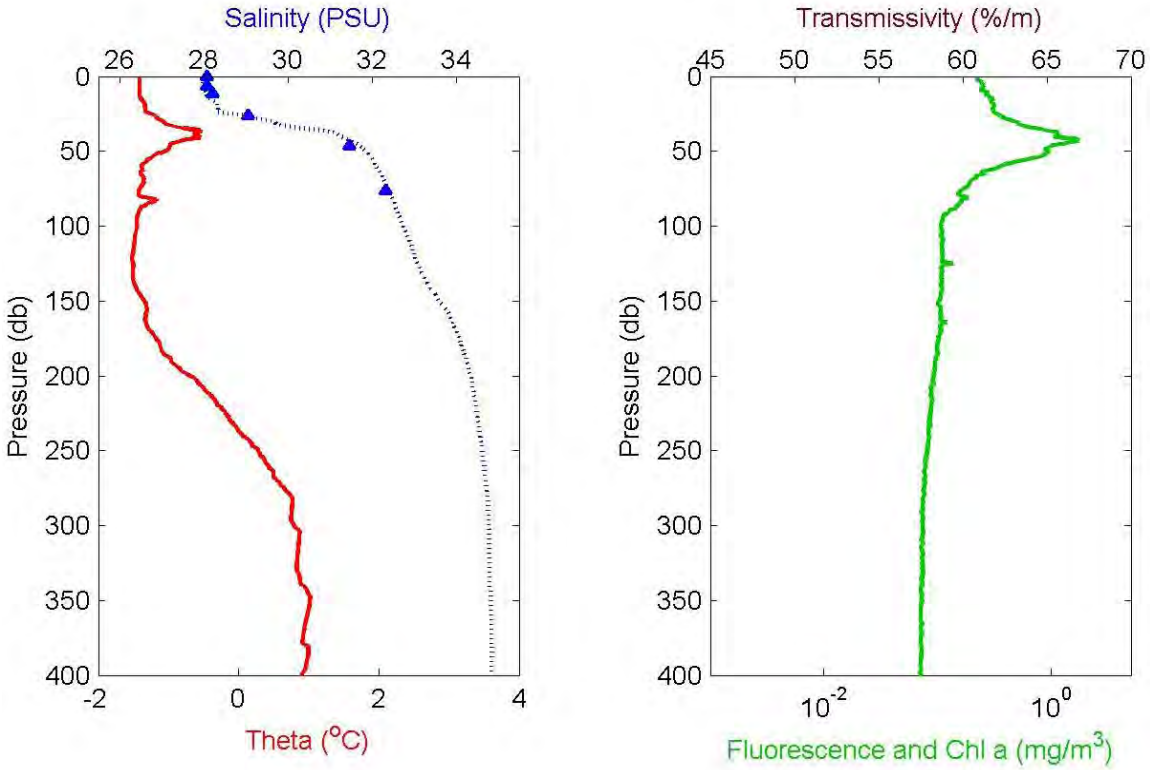


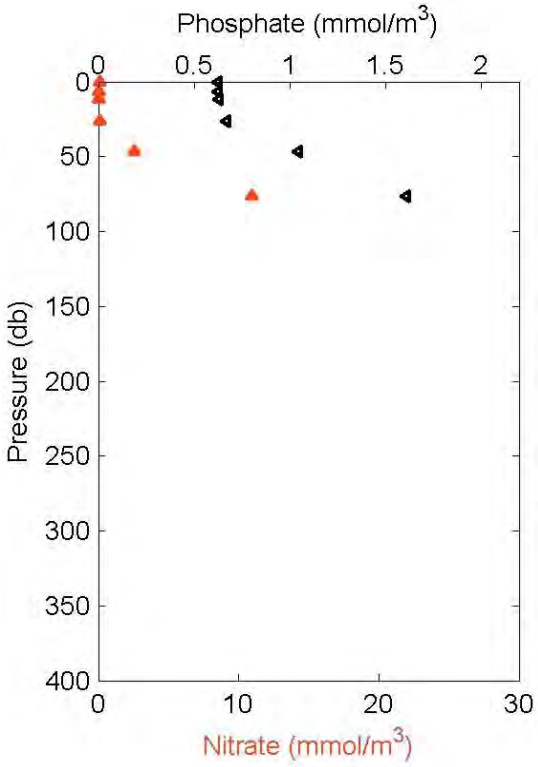


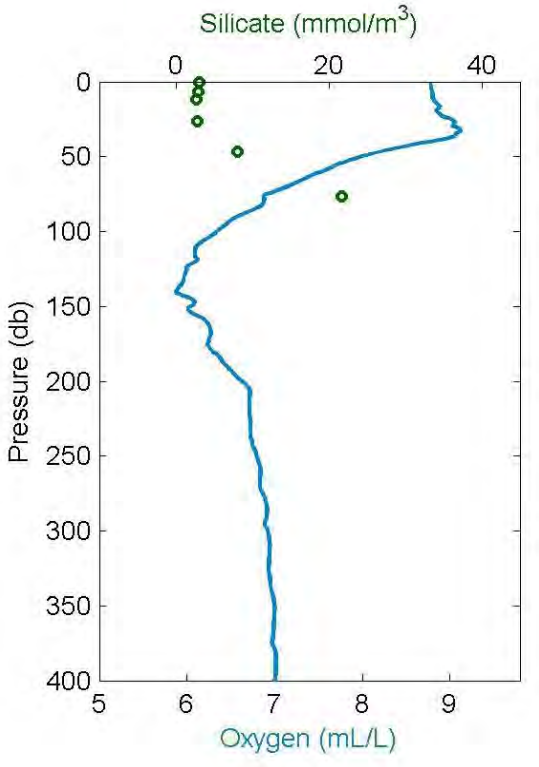
2002-23: Cast 25 Station NW07 (4)



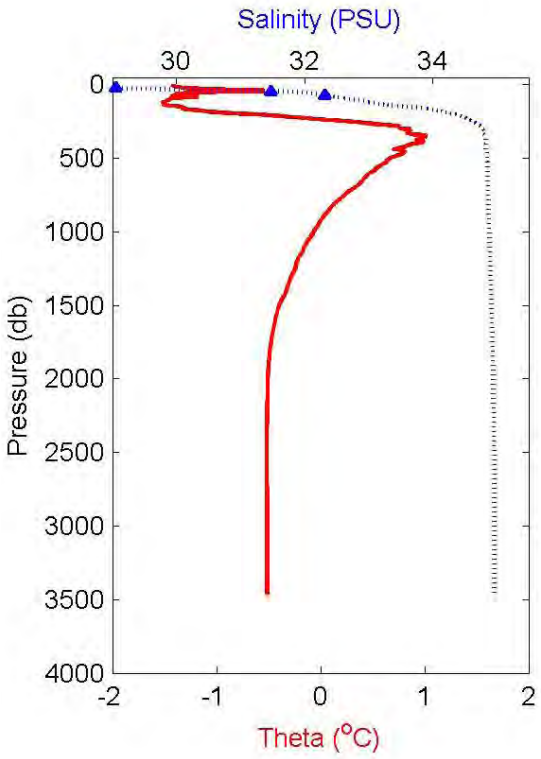
2002-23: Cast 26 Station NW06

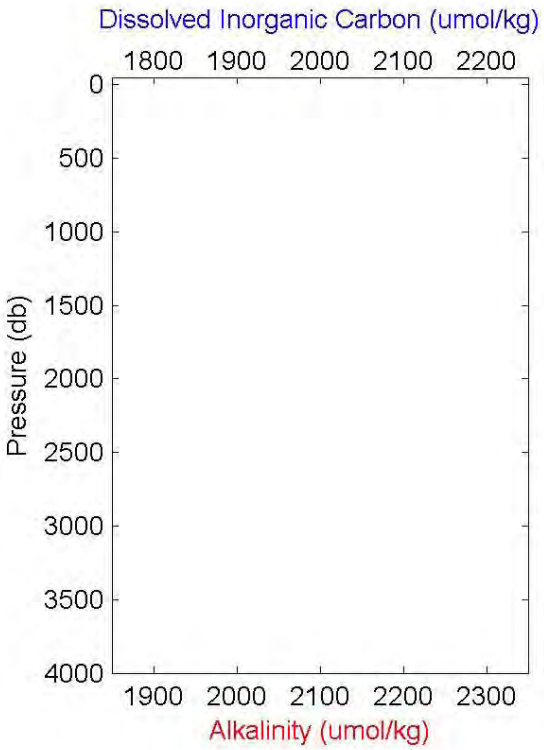


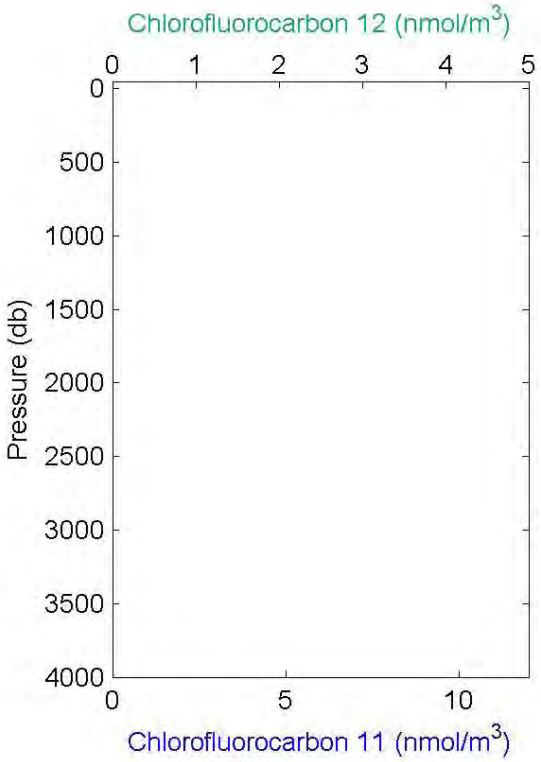


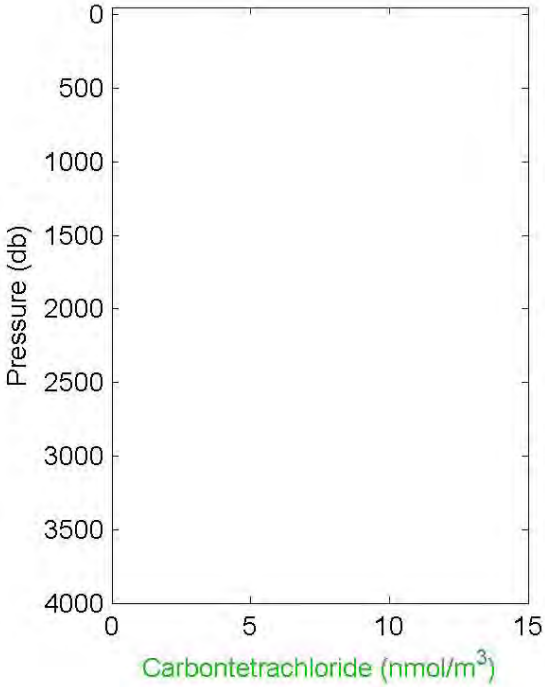


2002-23: Cast 26 Station NW06

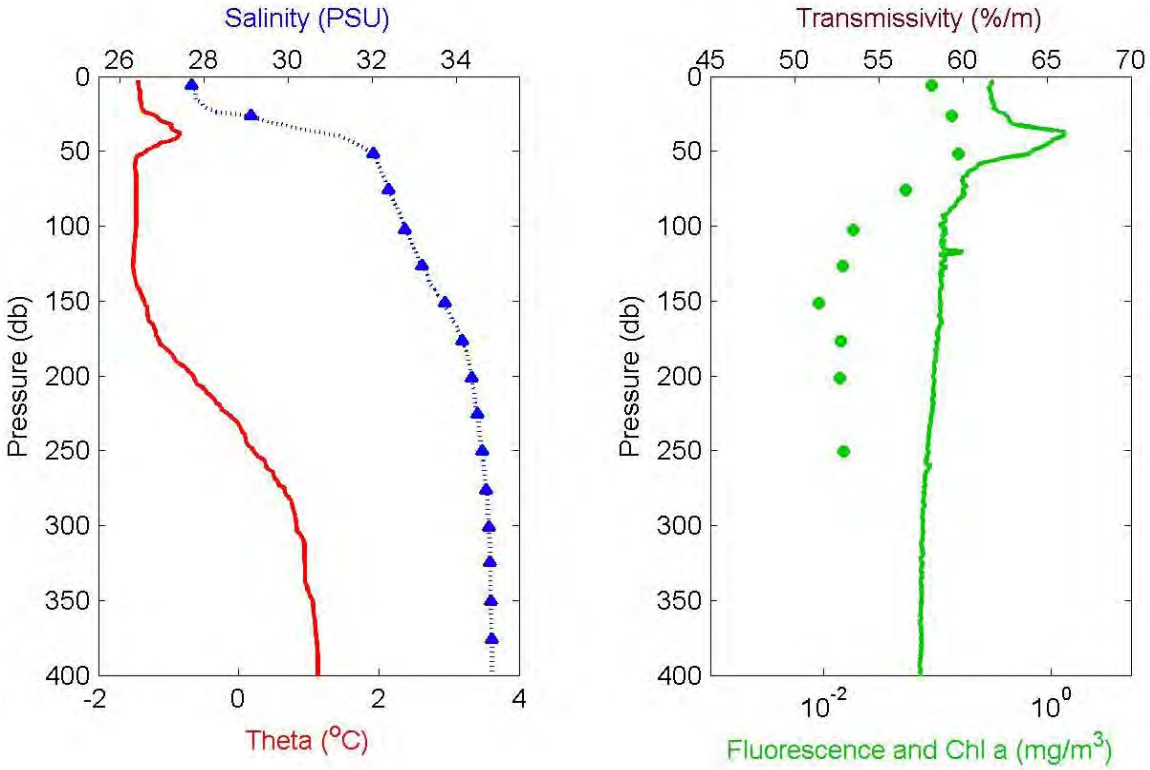


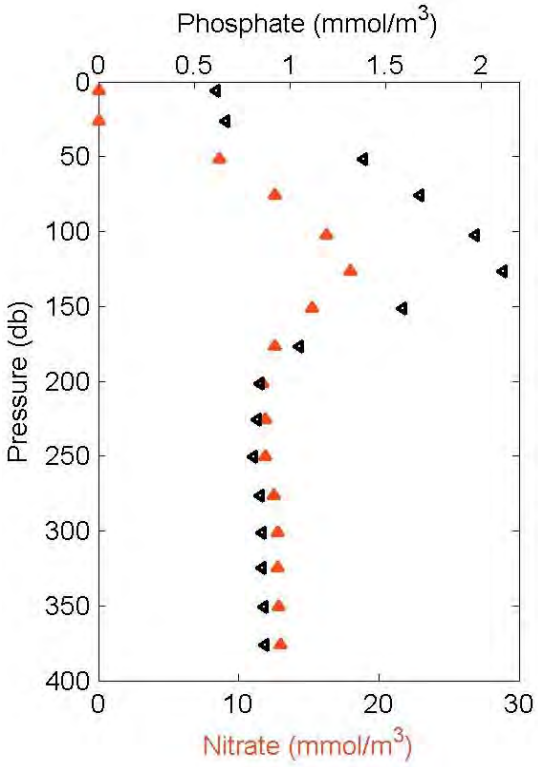


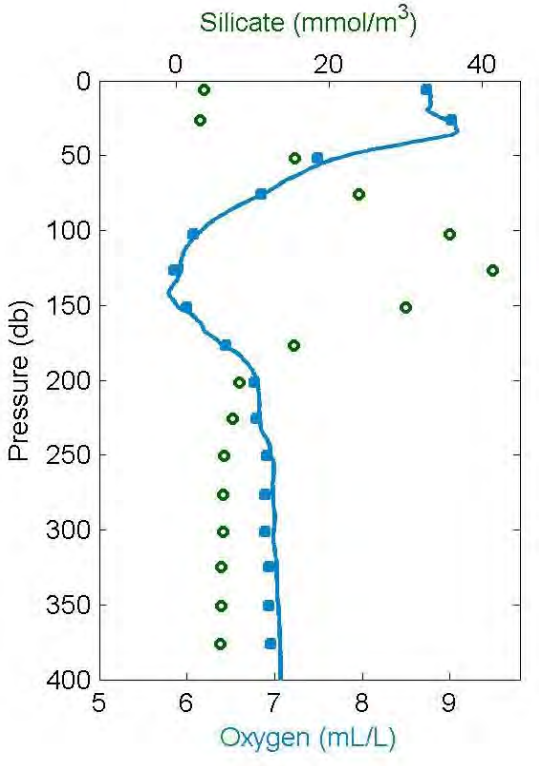




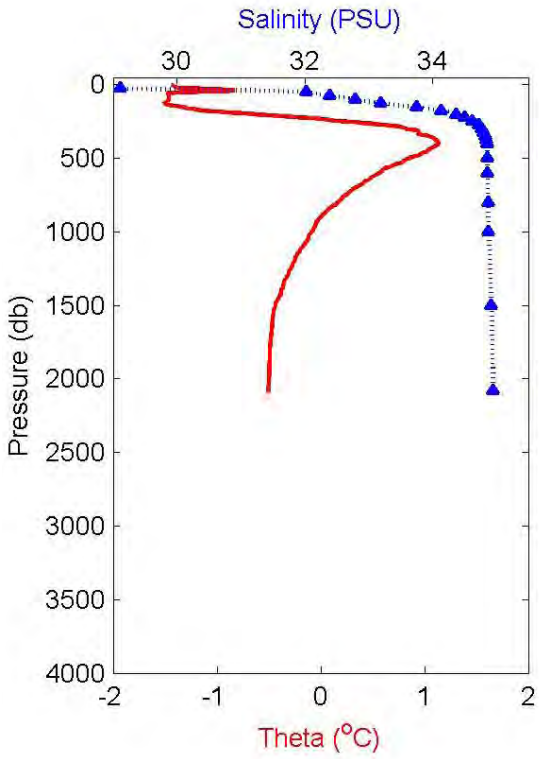
2002-23: Cast 27 Station NW05

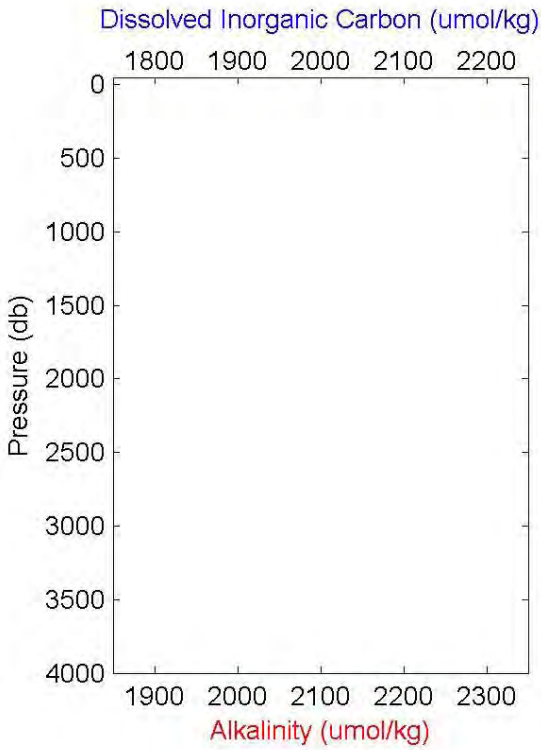


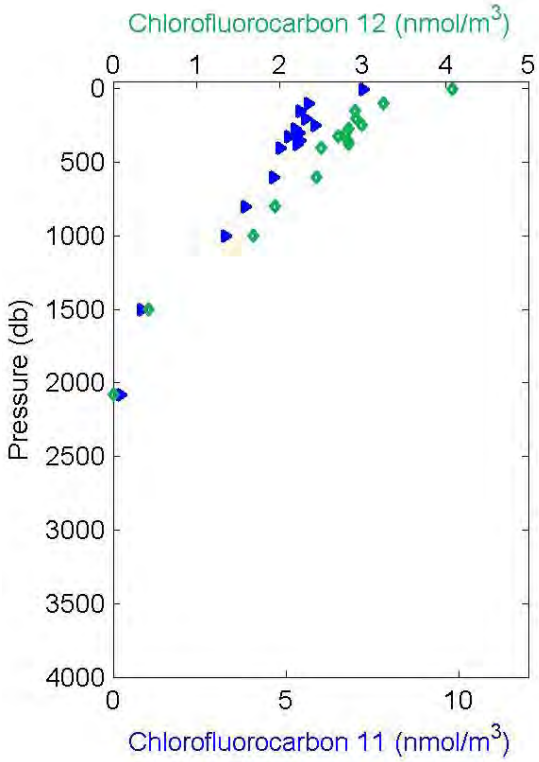


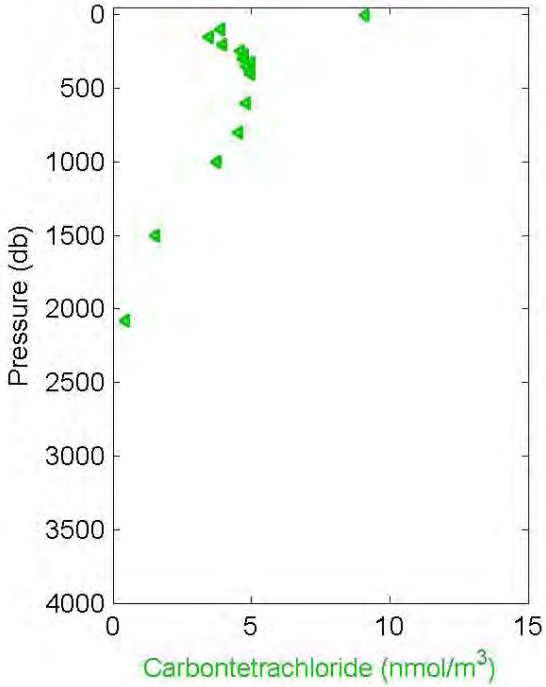


2002-23: Cast 27 Station NW05

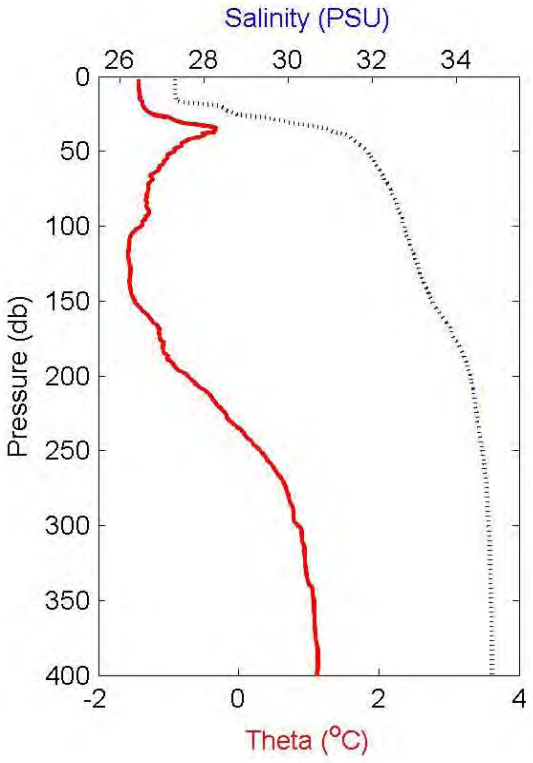


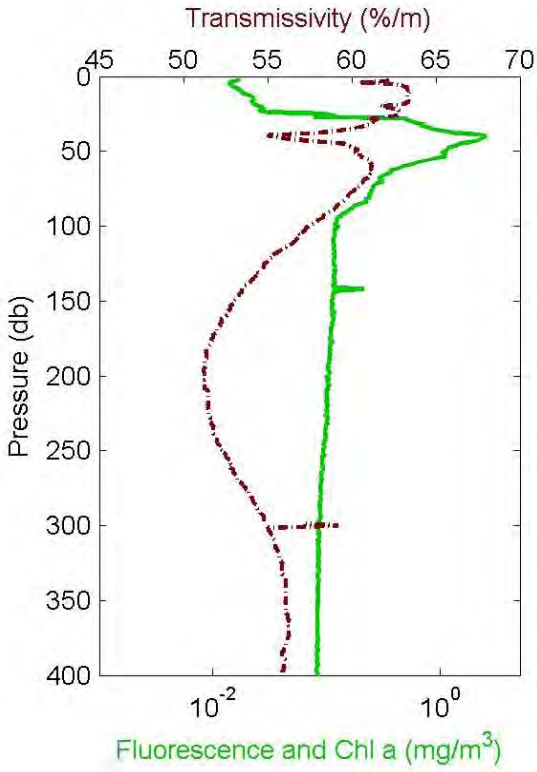


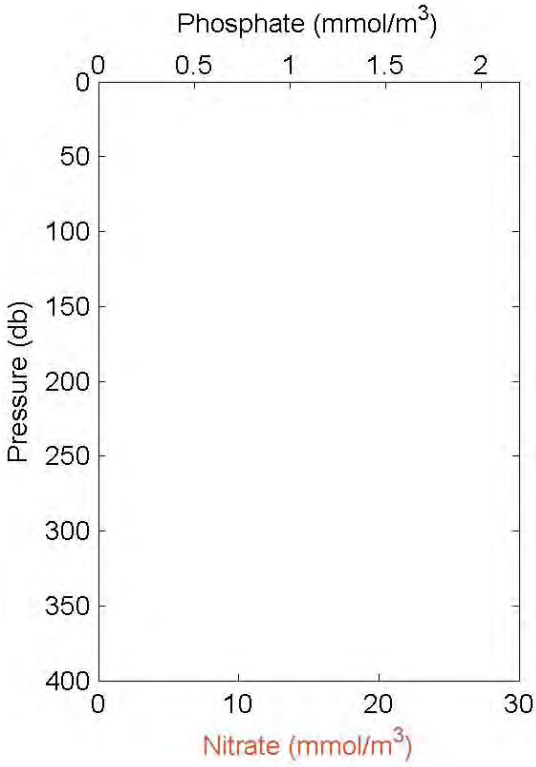


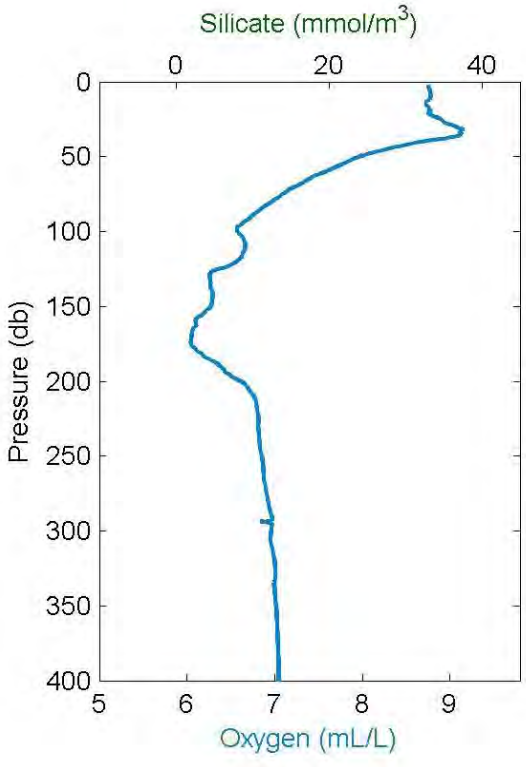


2002-23: Cast 28 Station NW04

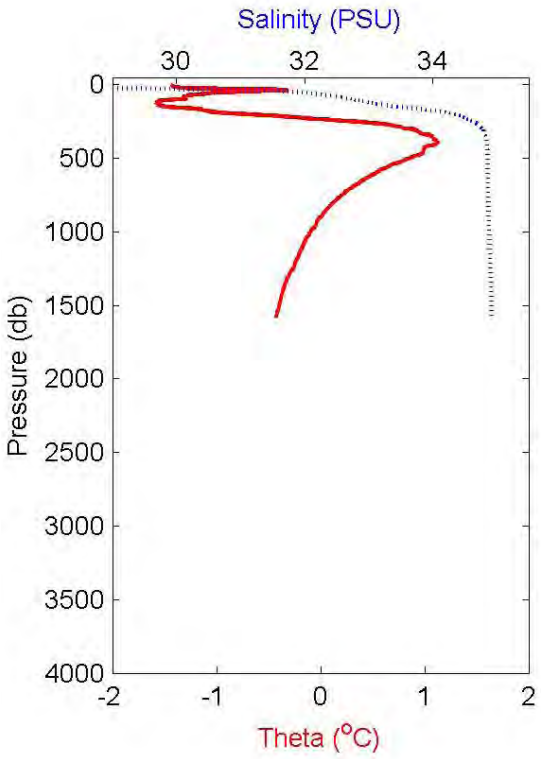


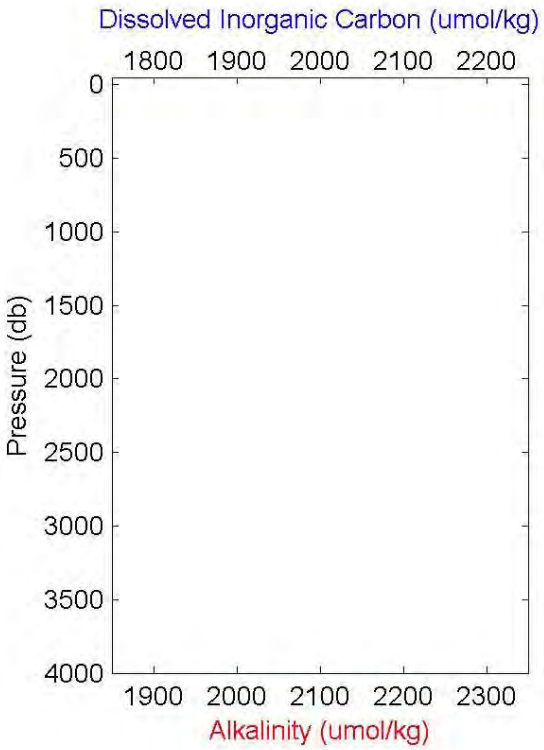


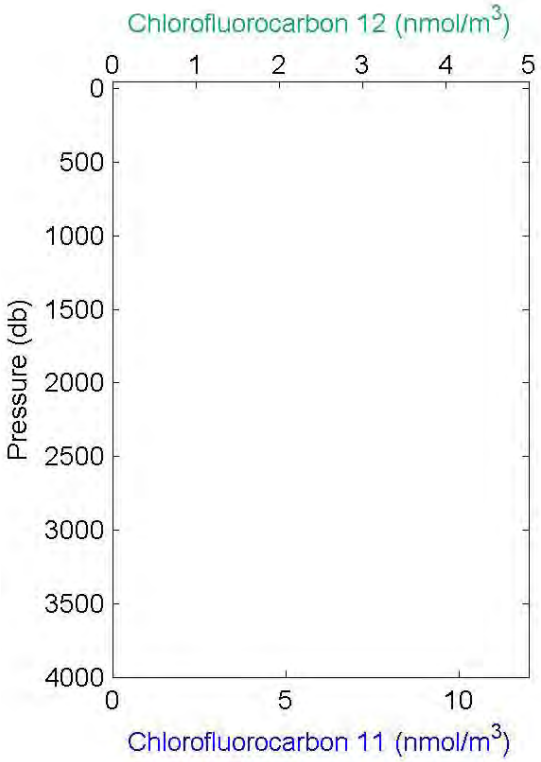


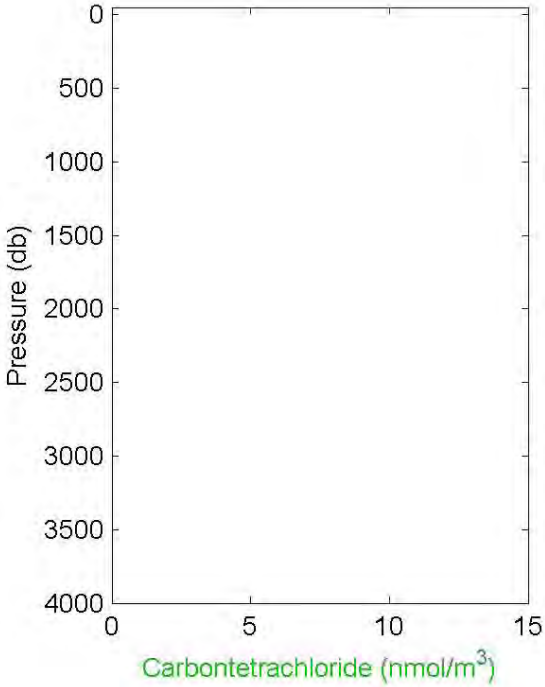


2002-23: Cast 28 Station NW04

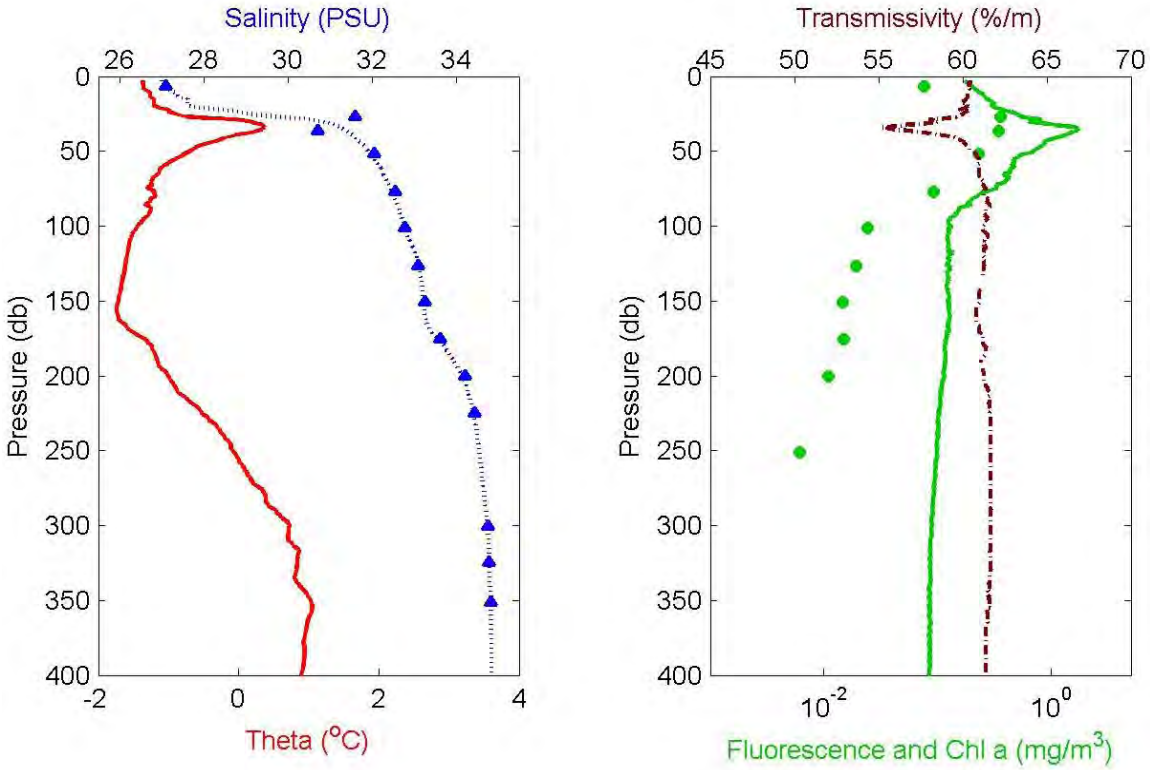




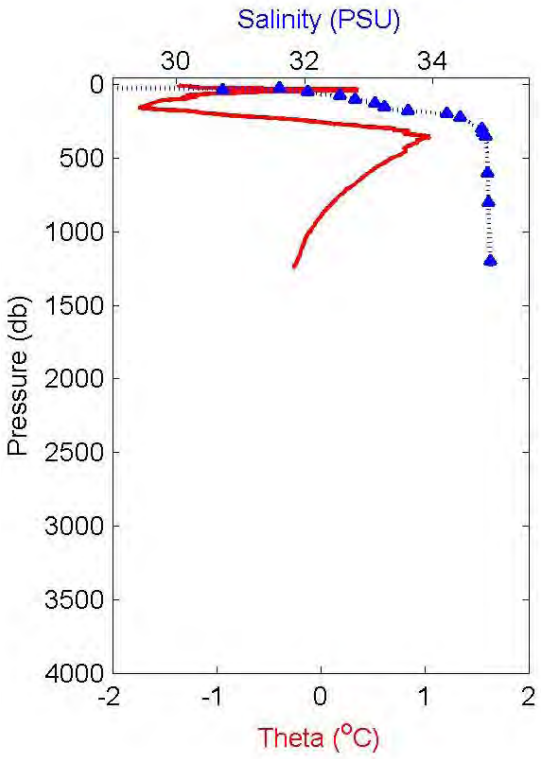


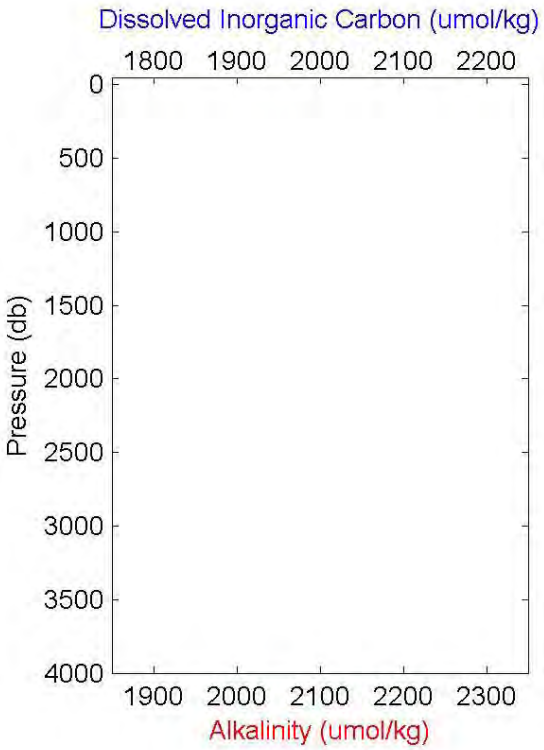


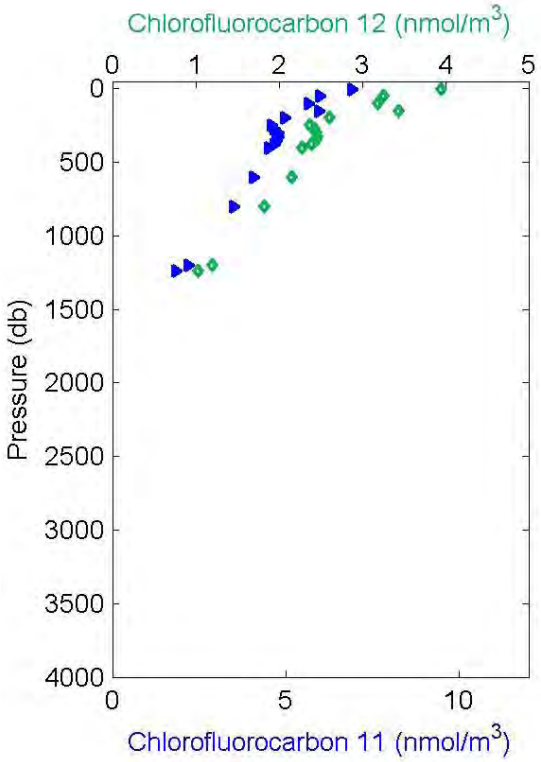
2002-23: Cast 29 Station NW03

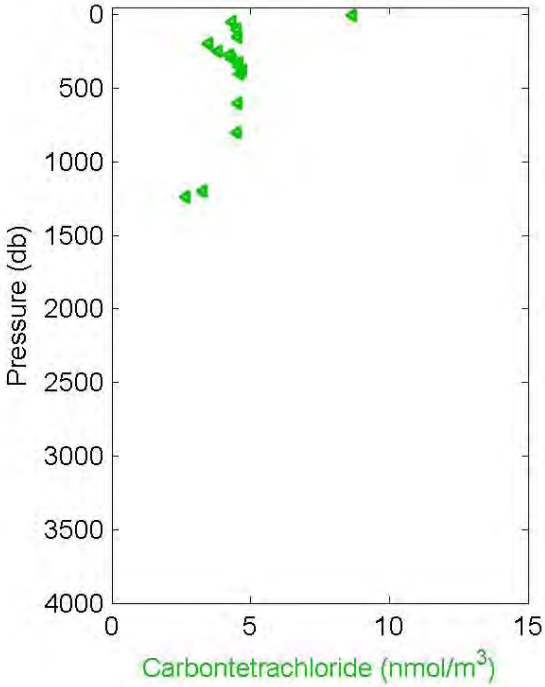


2002-23: Cast 29 Station NW03

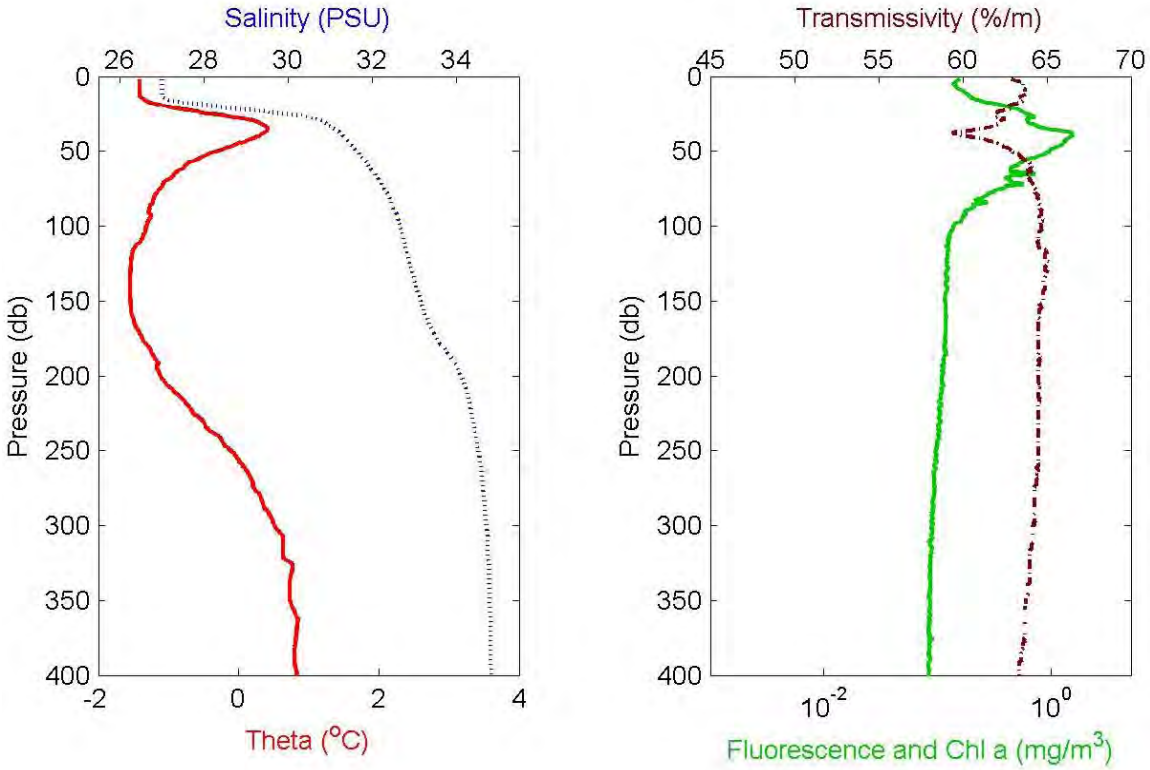




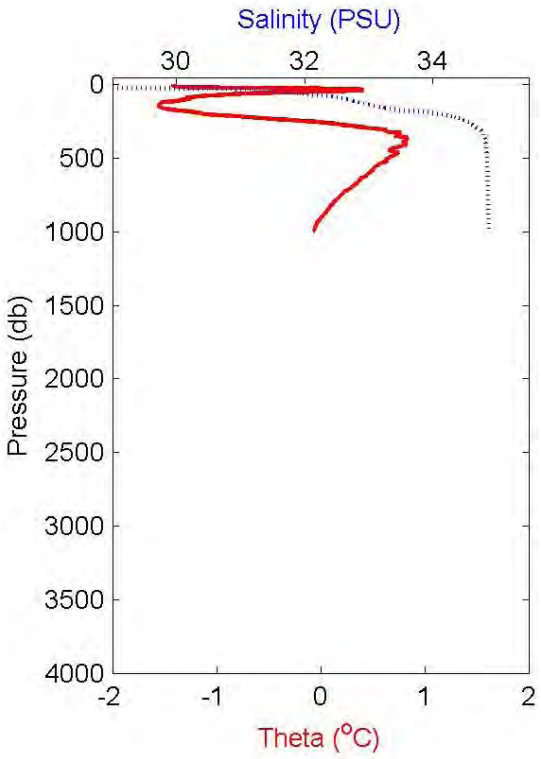


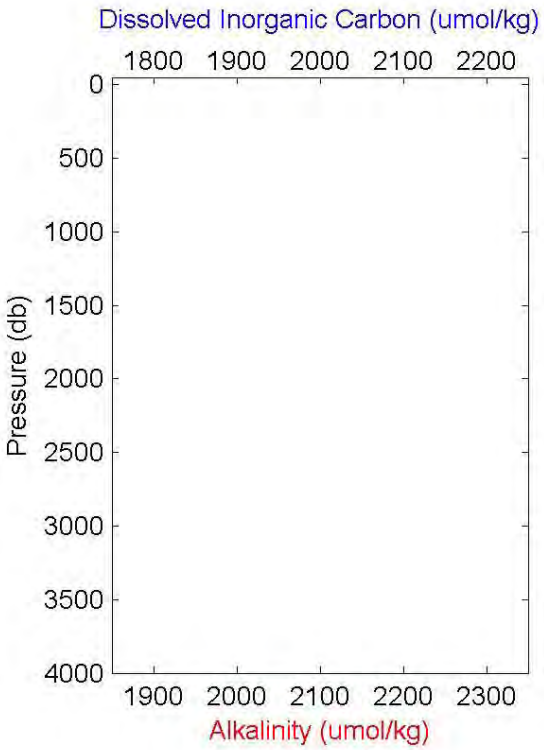


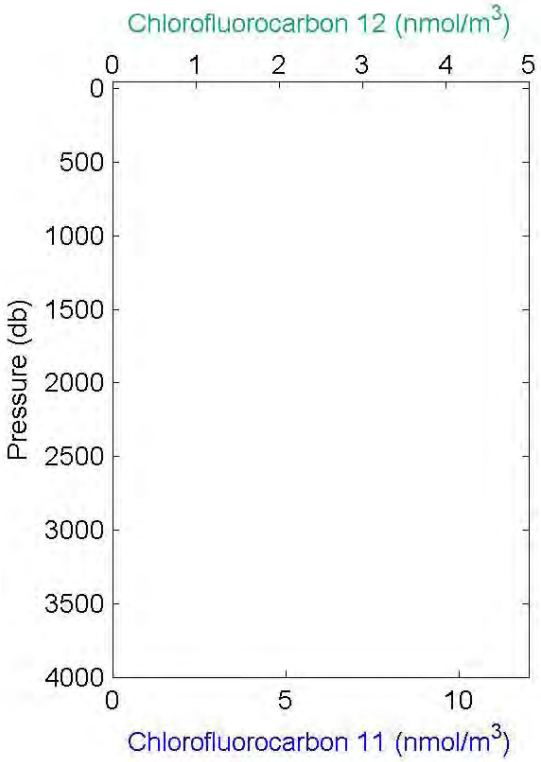
2002-23: Cast 30 Station NW02

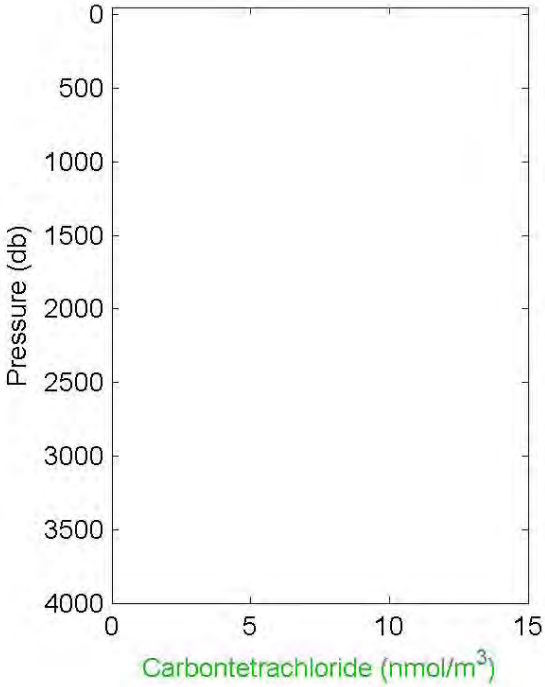


2002-23: Cast 30 Station NW02

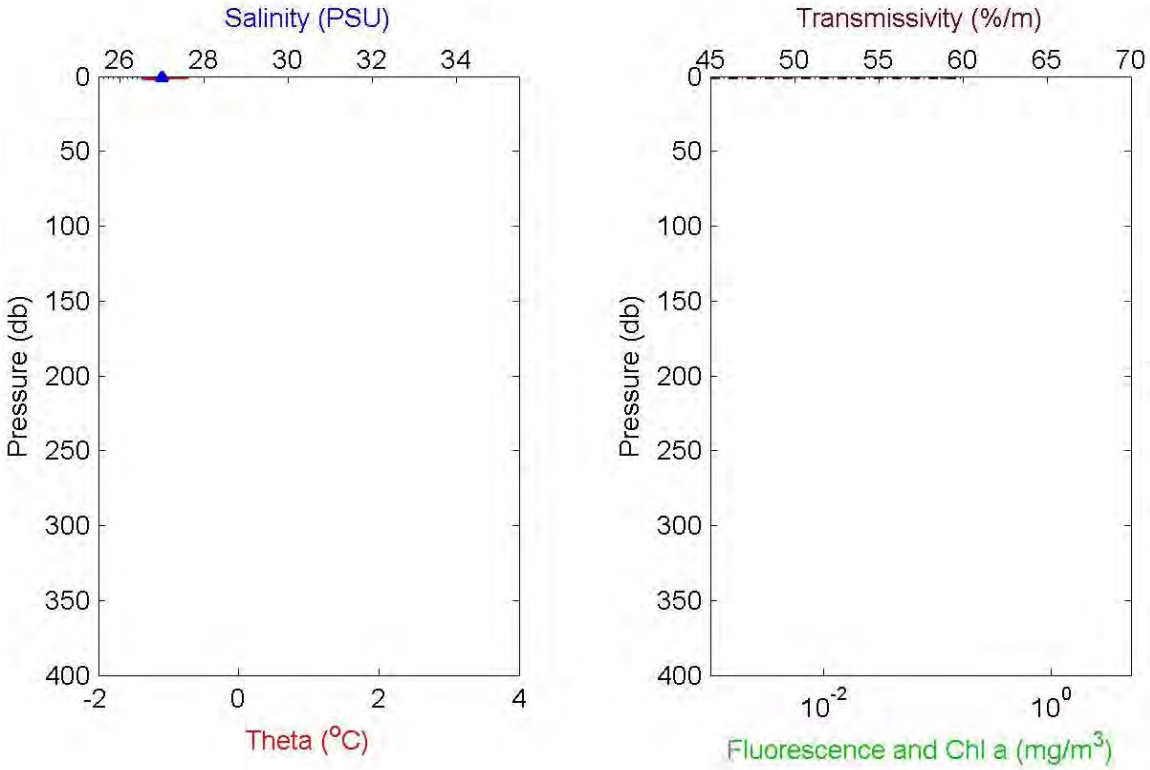


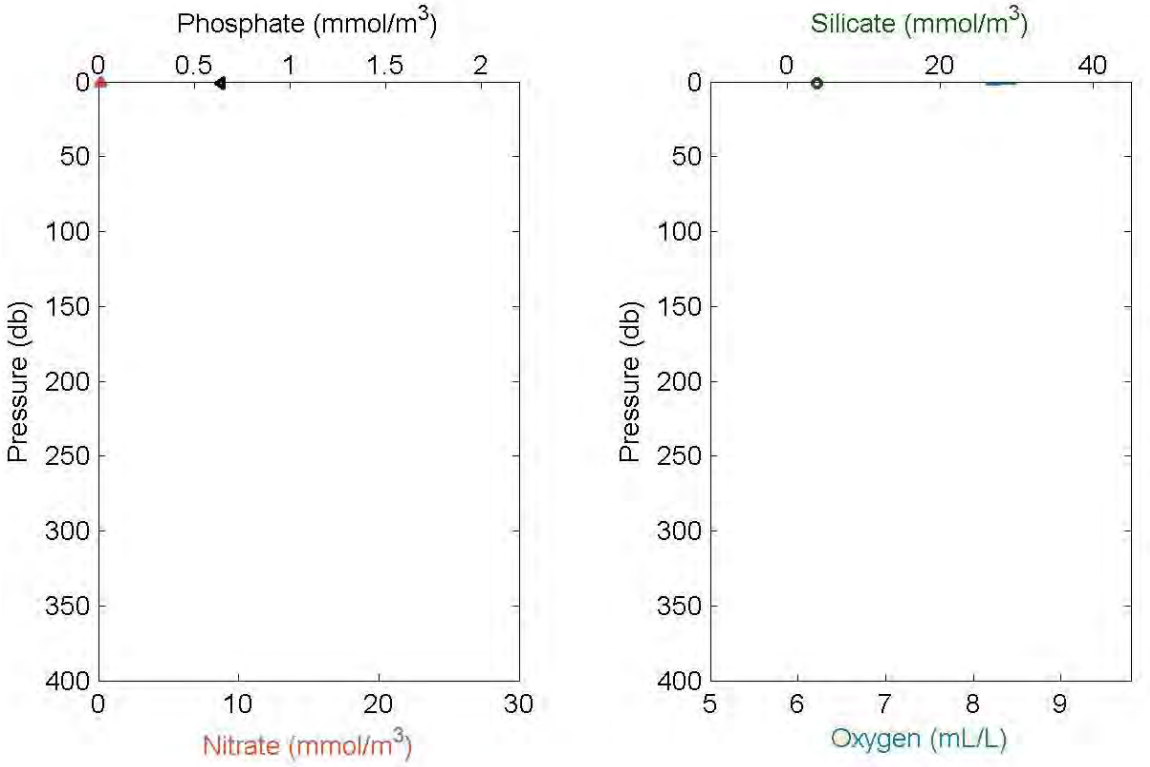




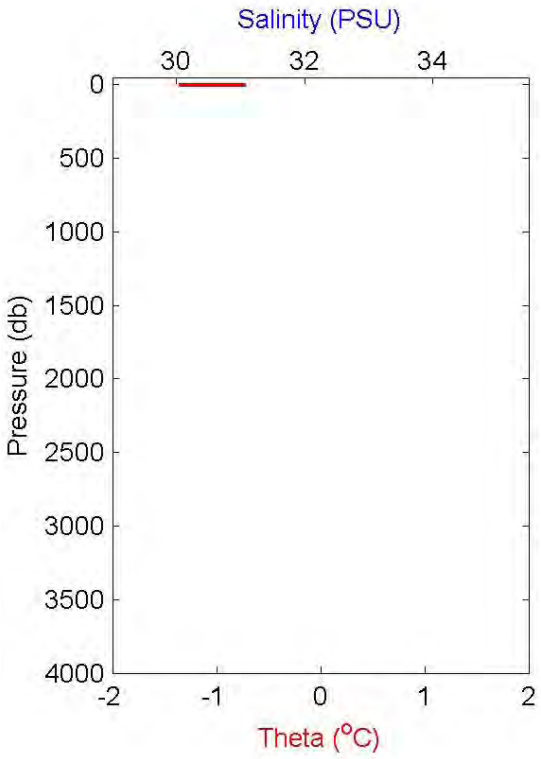


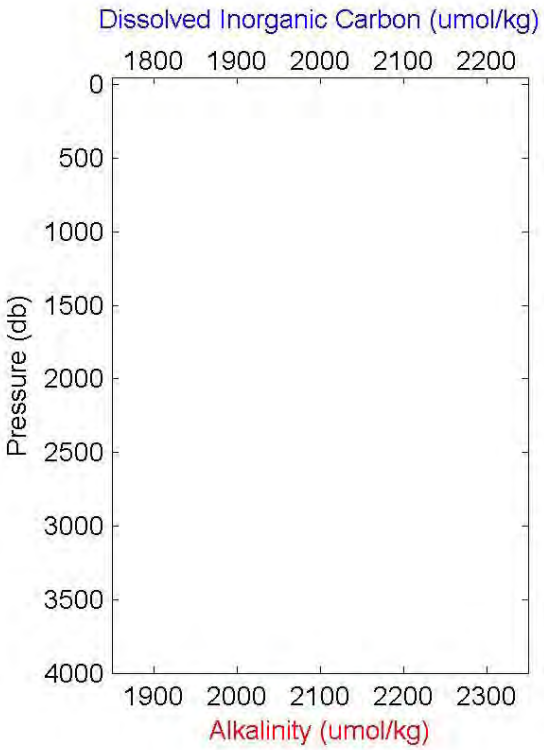
2002-23: Cast 31 Station NW01 (1)

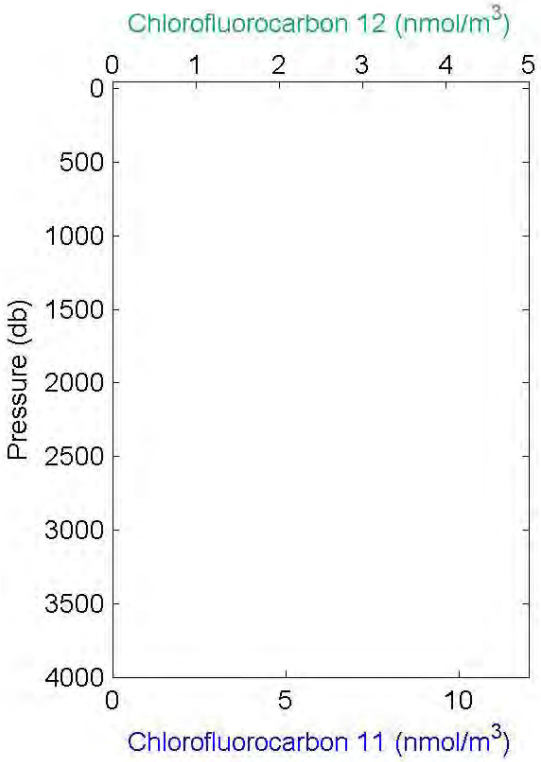


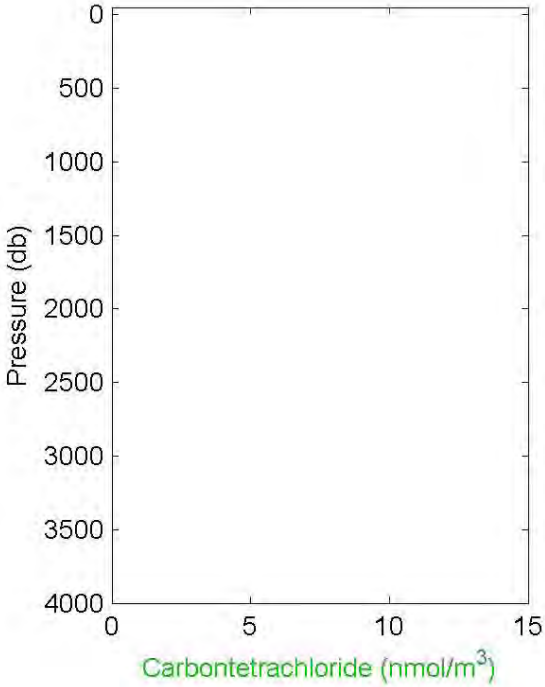


2002-23: Cast 31 Station NW01 (1)

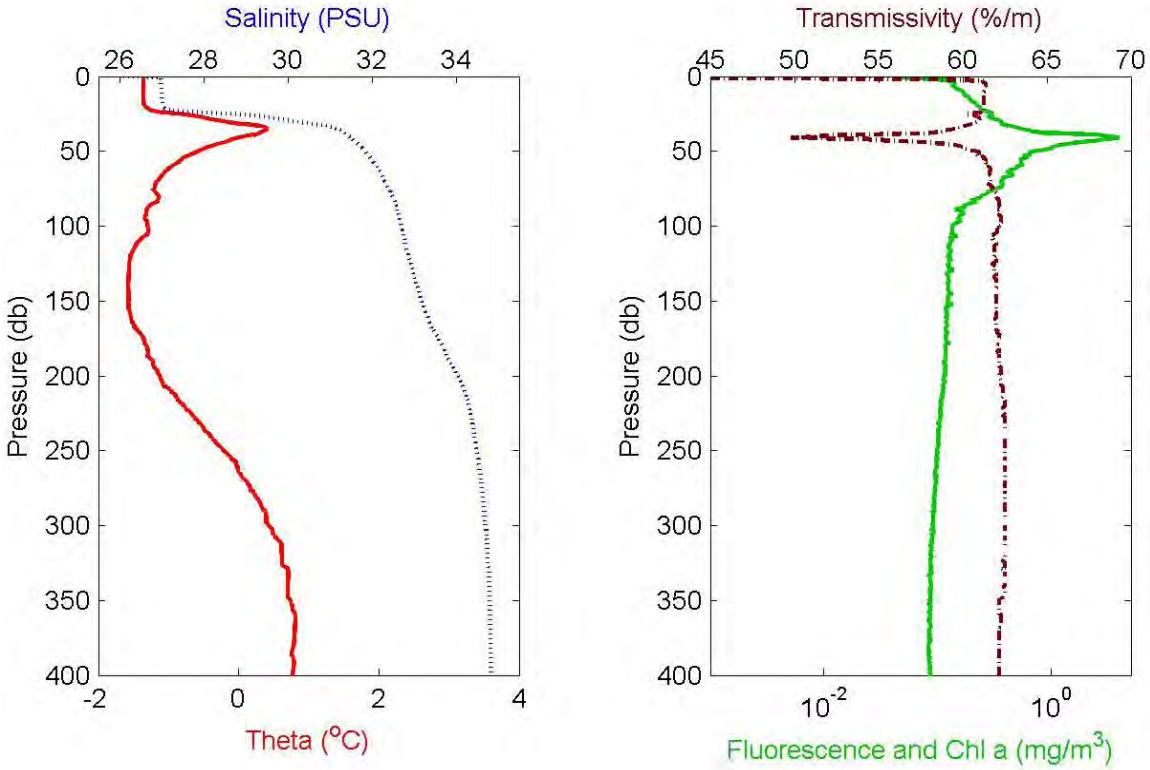


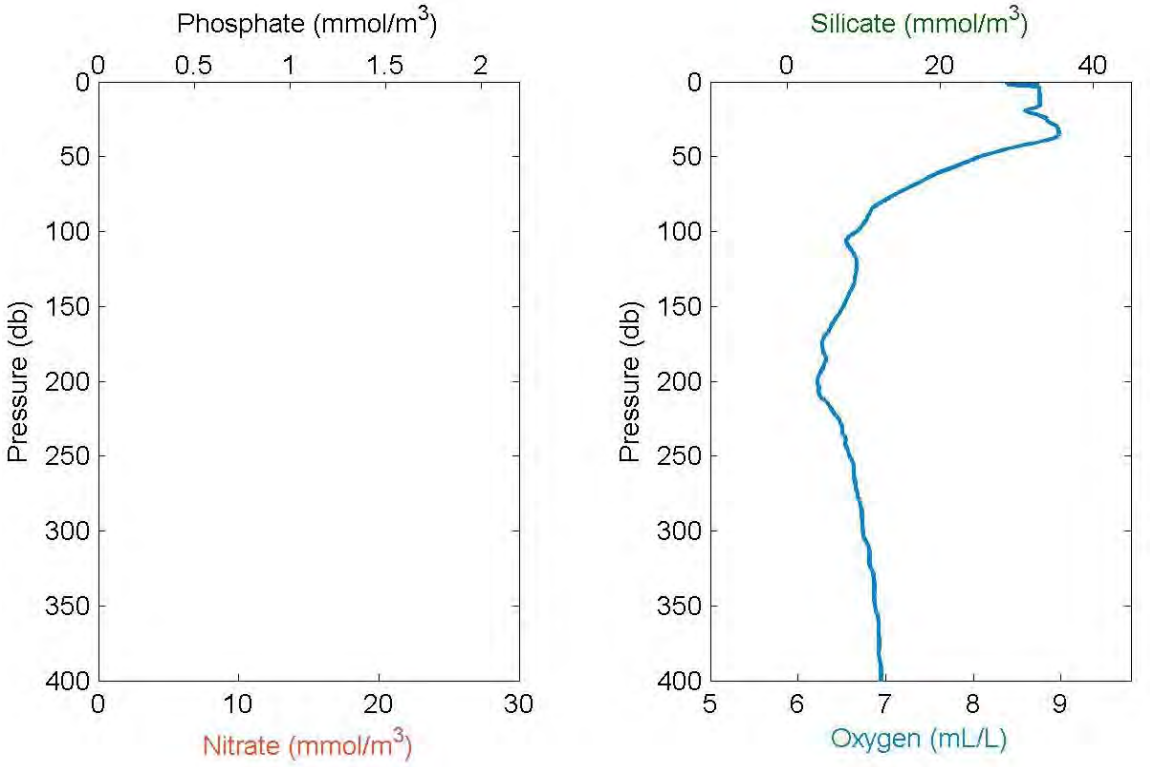




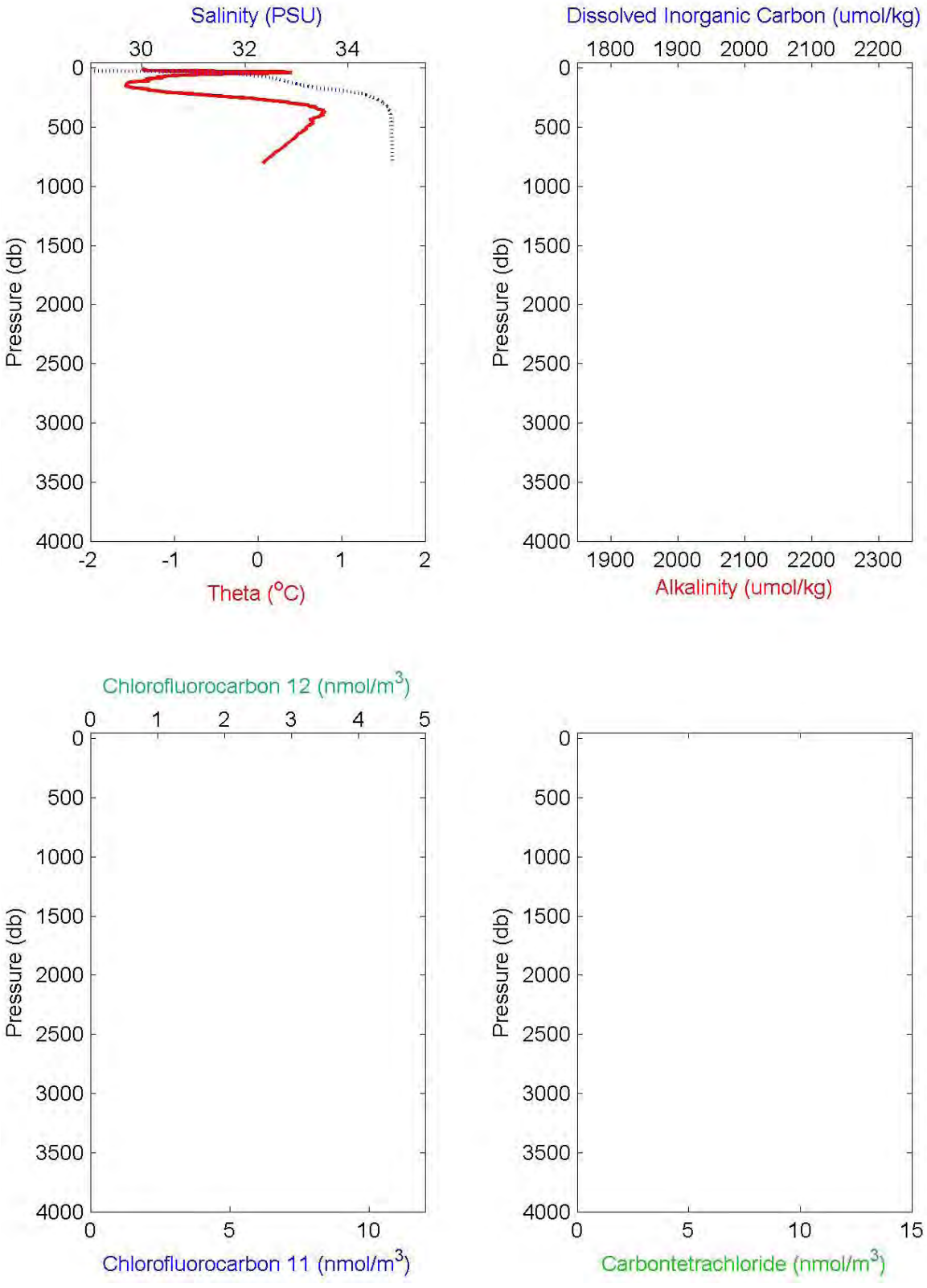


2002-23: Cast 32 Station NW01 (2)

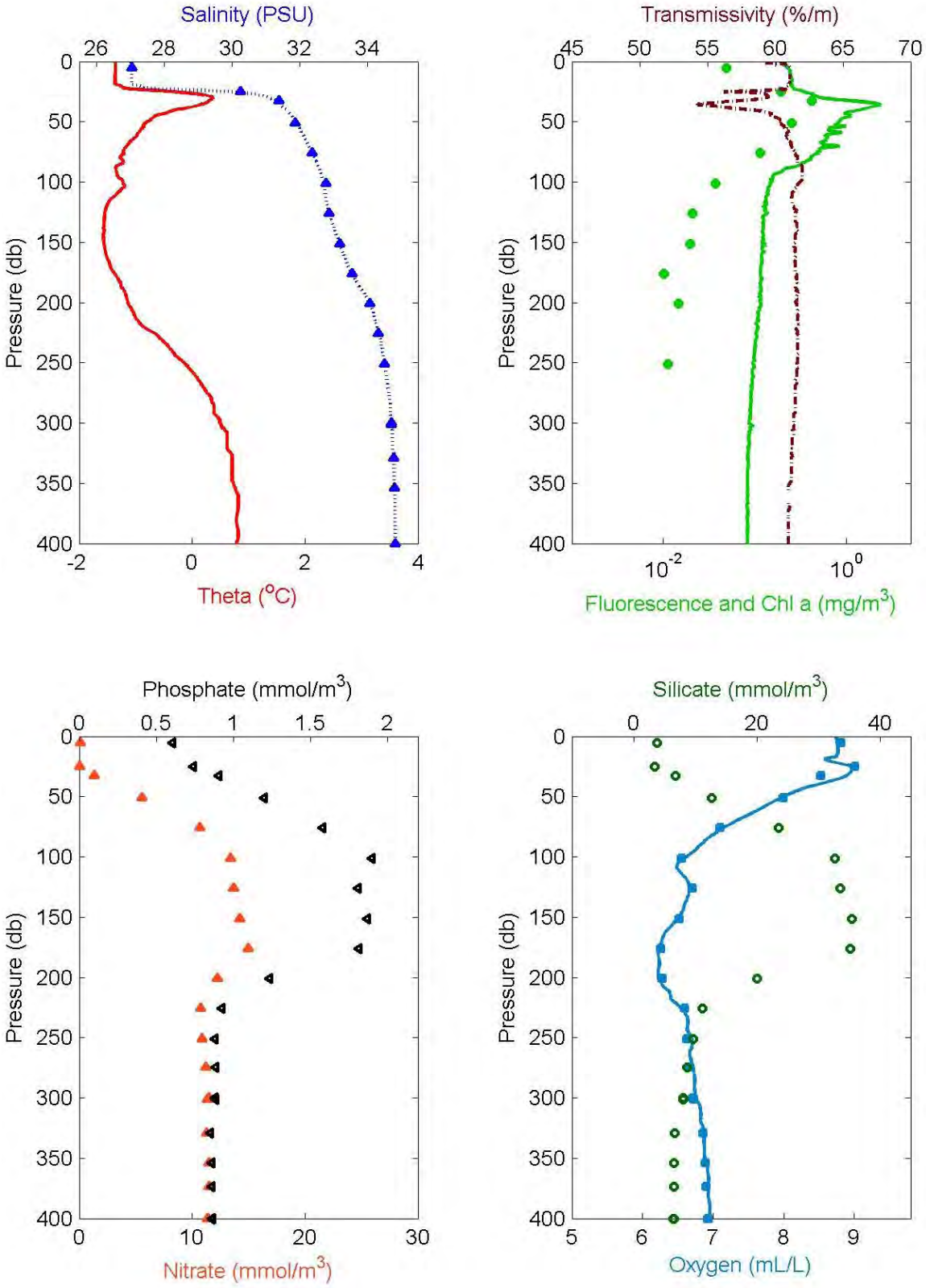




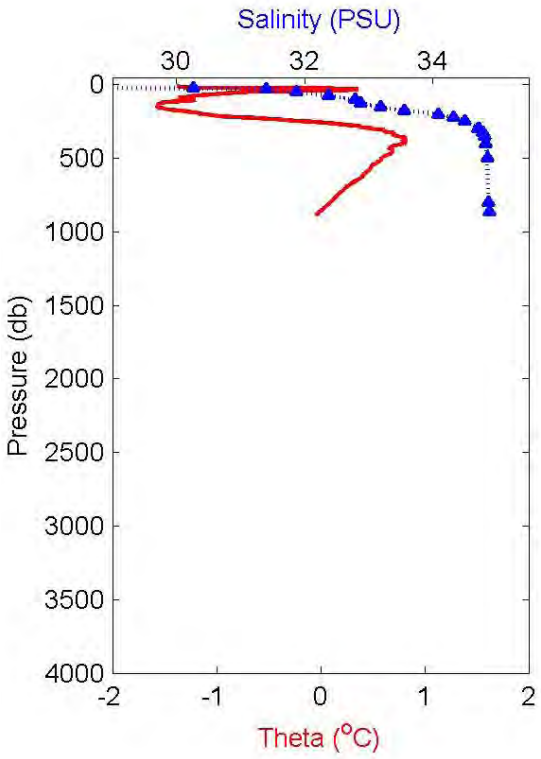
2002-23: Cast 32 Station NW01 (2)

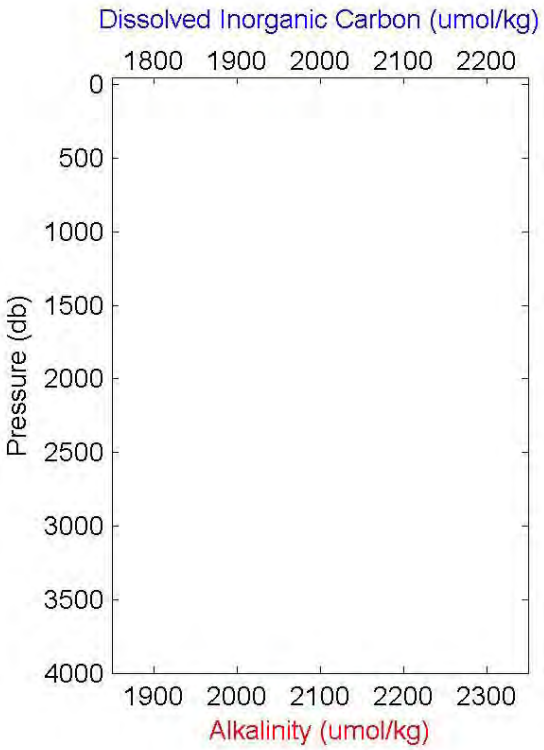


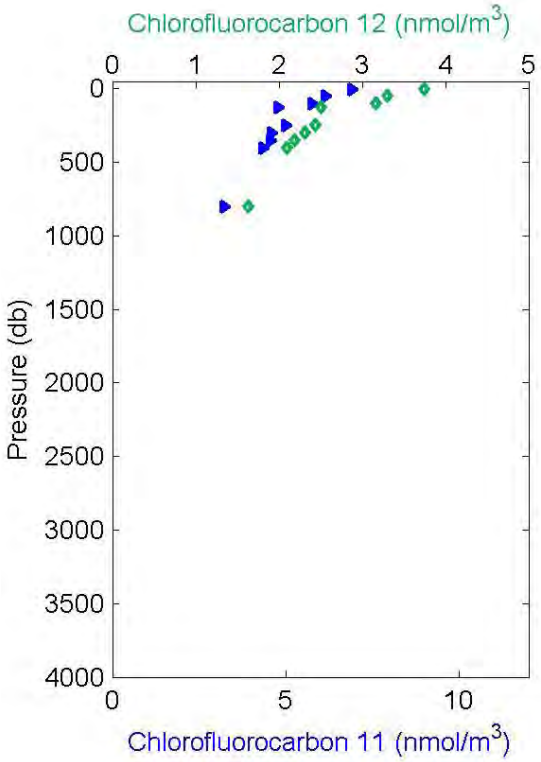
2002-23: Cast 33 Station NW01 (3)

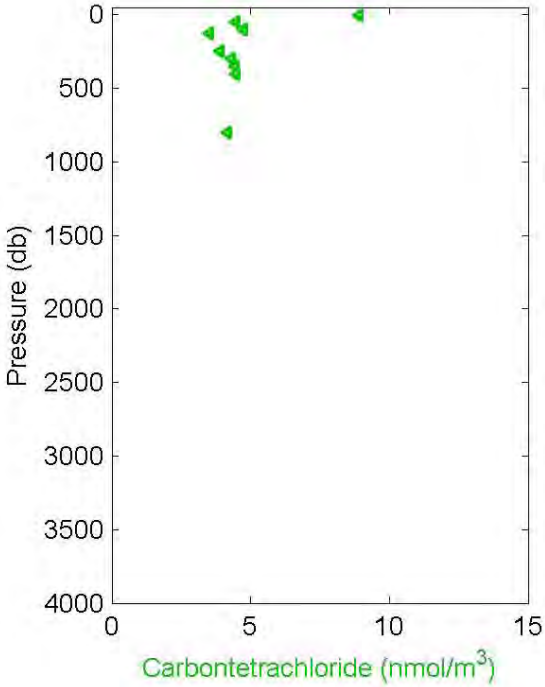


2002-23: Cast 33 Station NW01 (3)

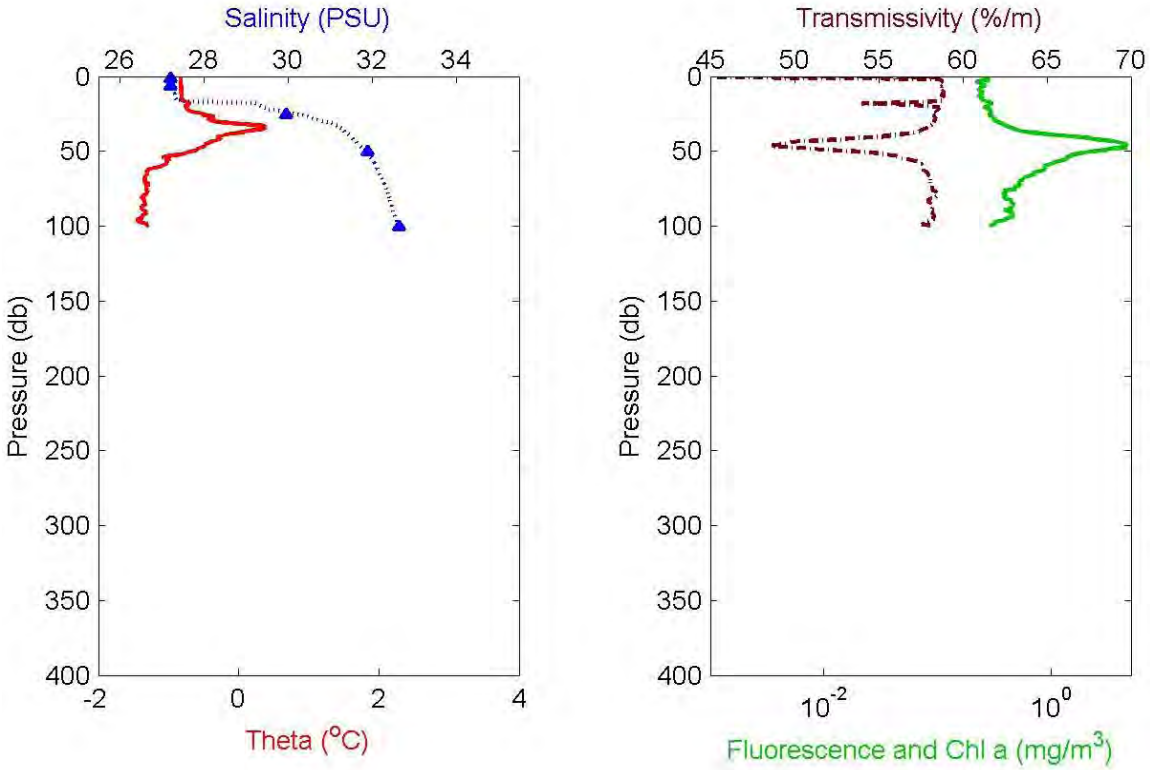


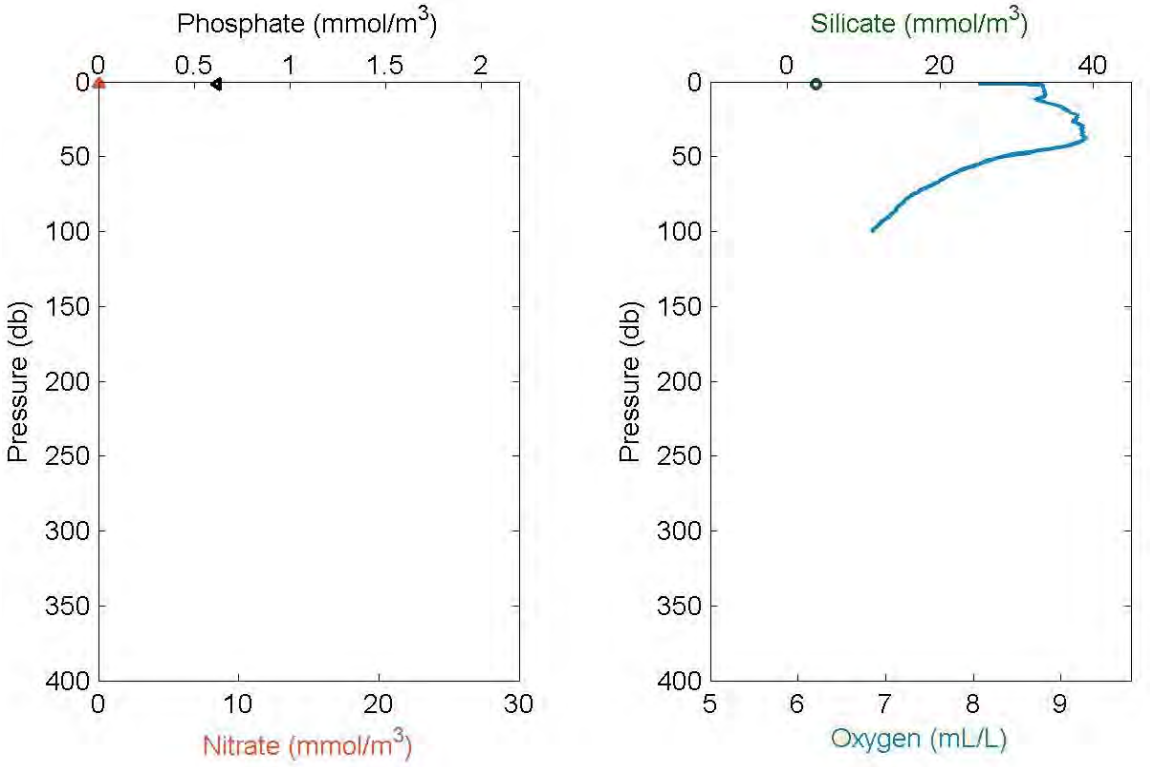




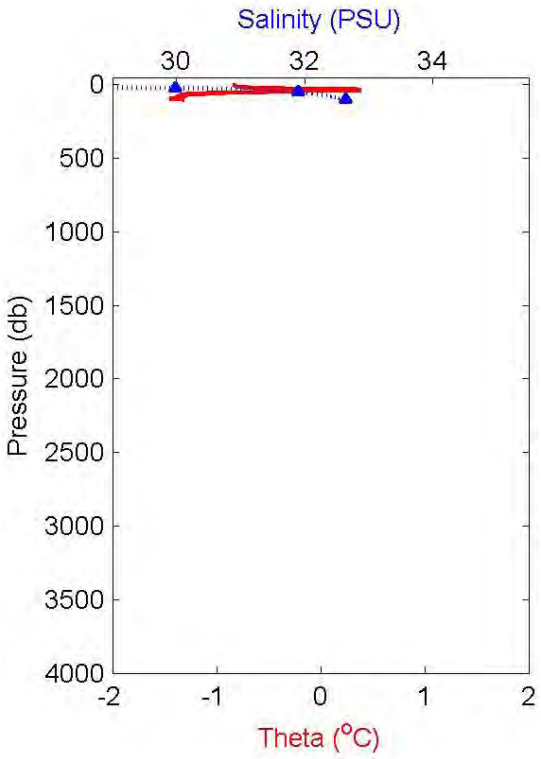


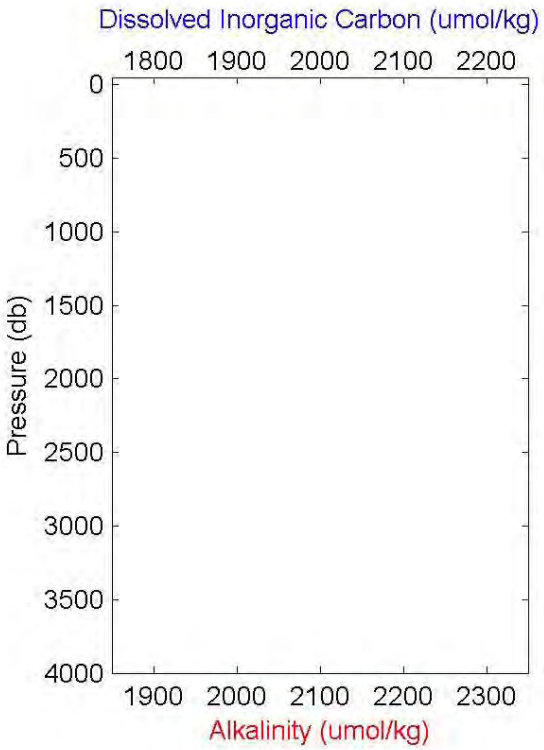
2002-23: Cast 34 Station NA05 (1)

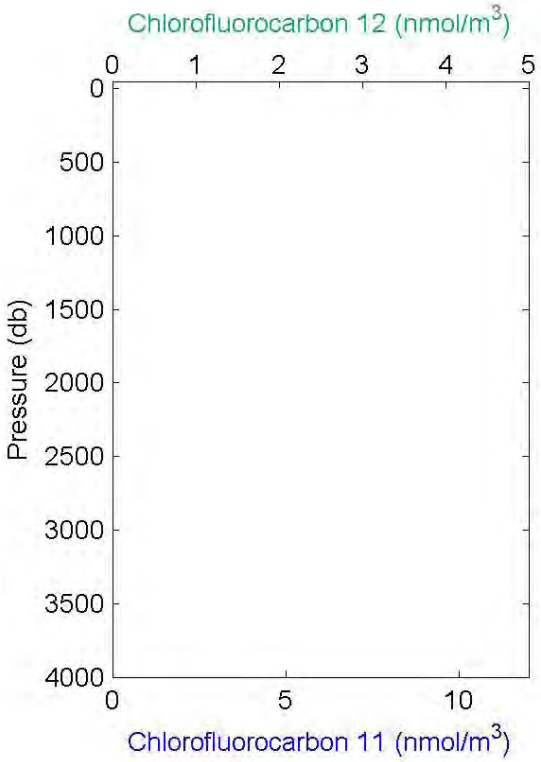


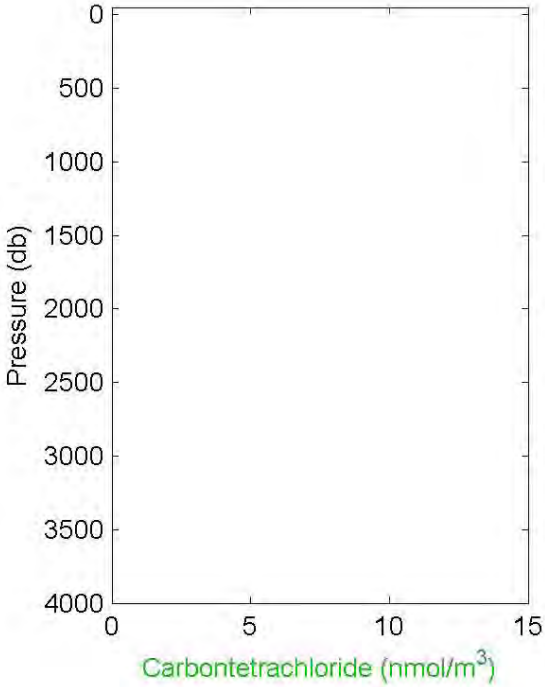


2002-23: Cast 34 Station NA05 (1)

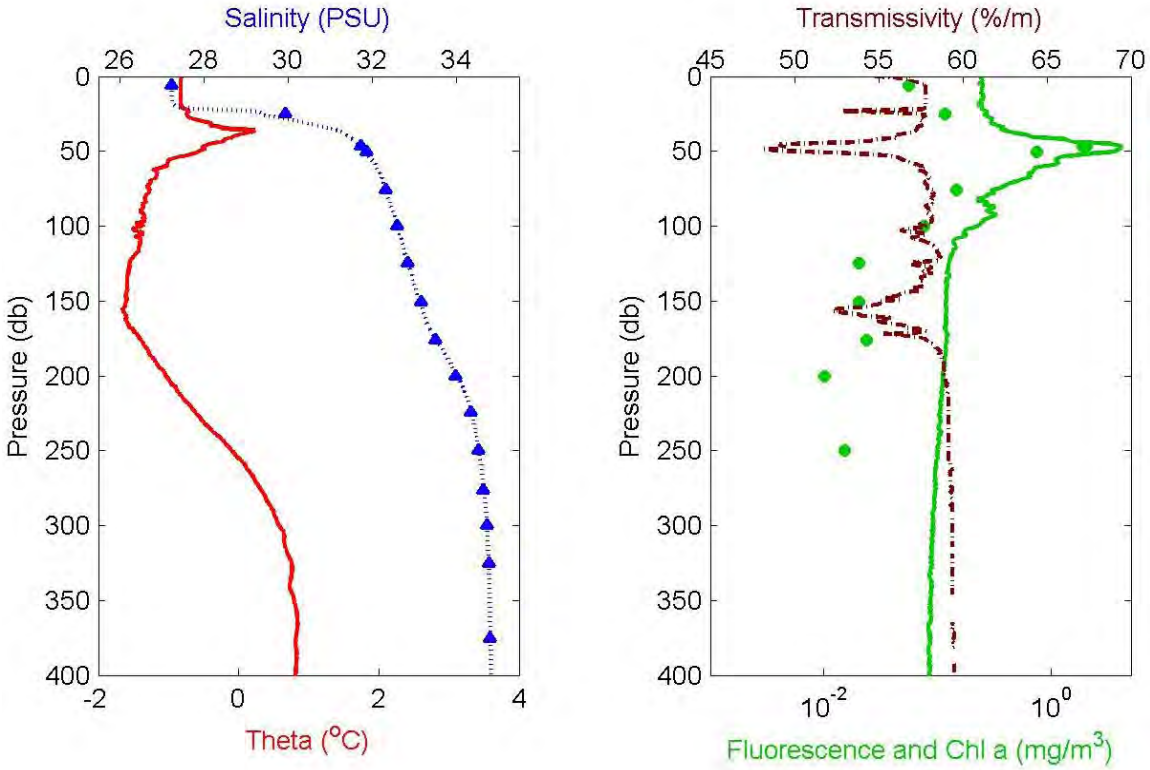




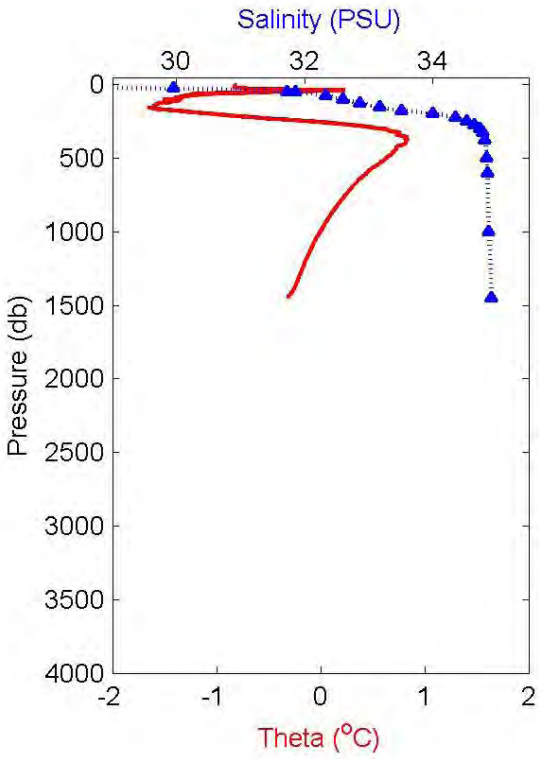


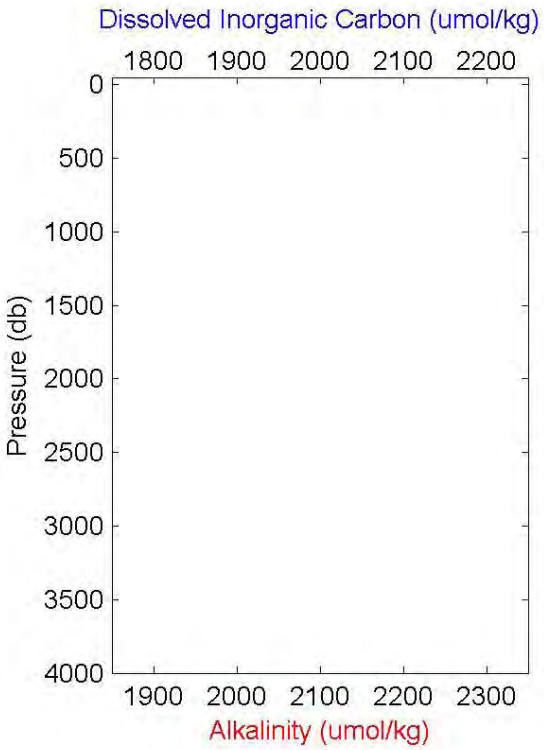


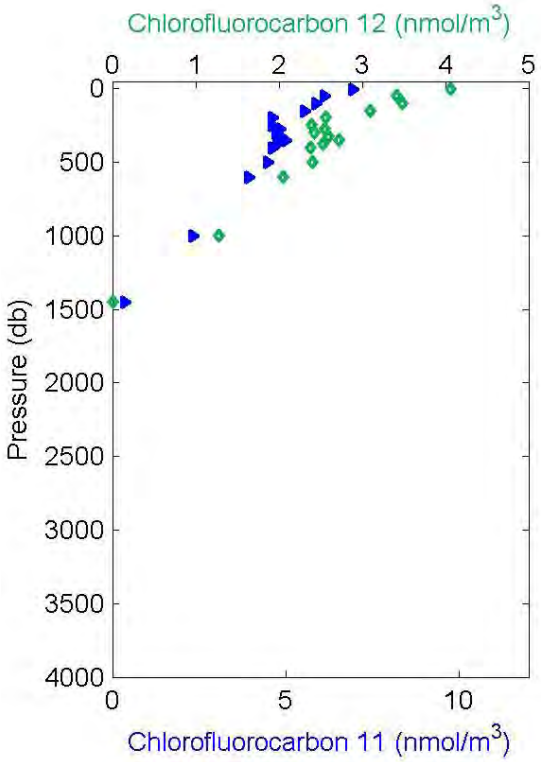
2002-23: Cast 35 Station NA05 (2)

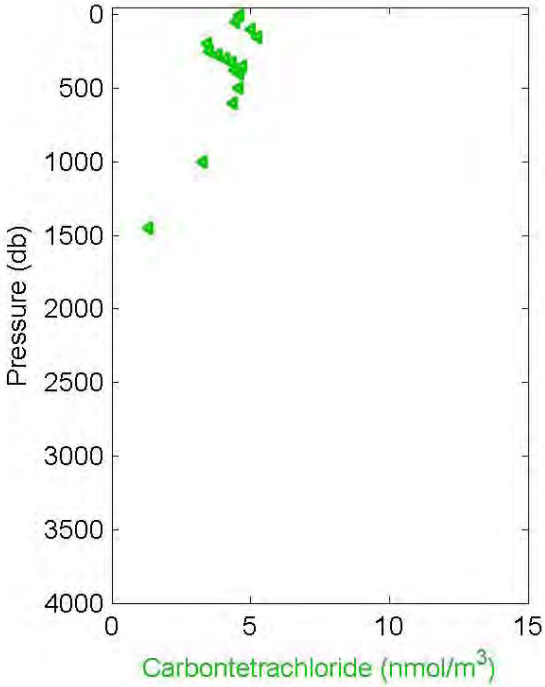


2002-23: Cast 35 Station NA05 (2)

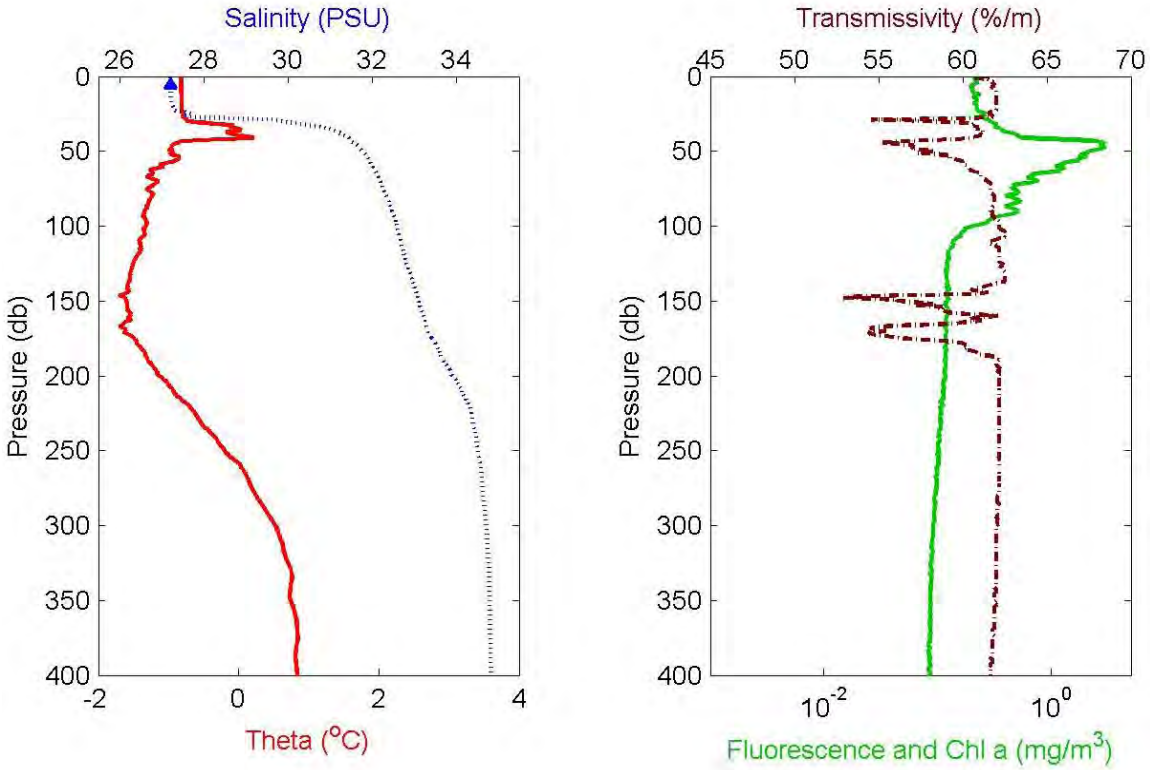


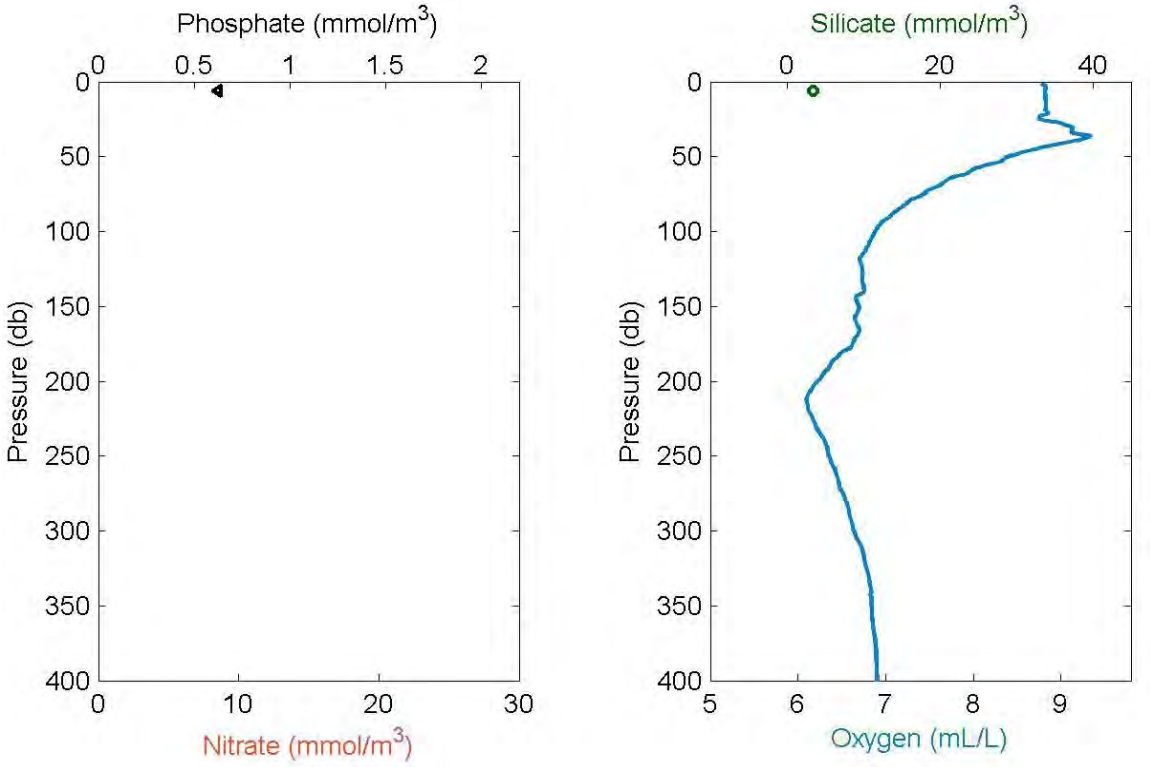




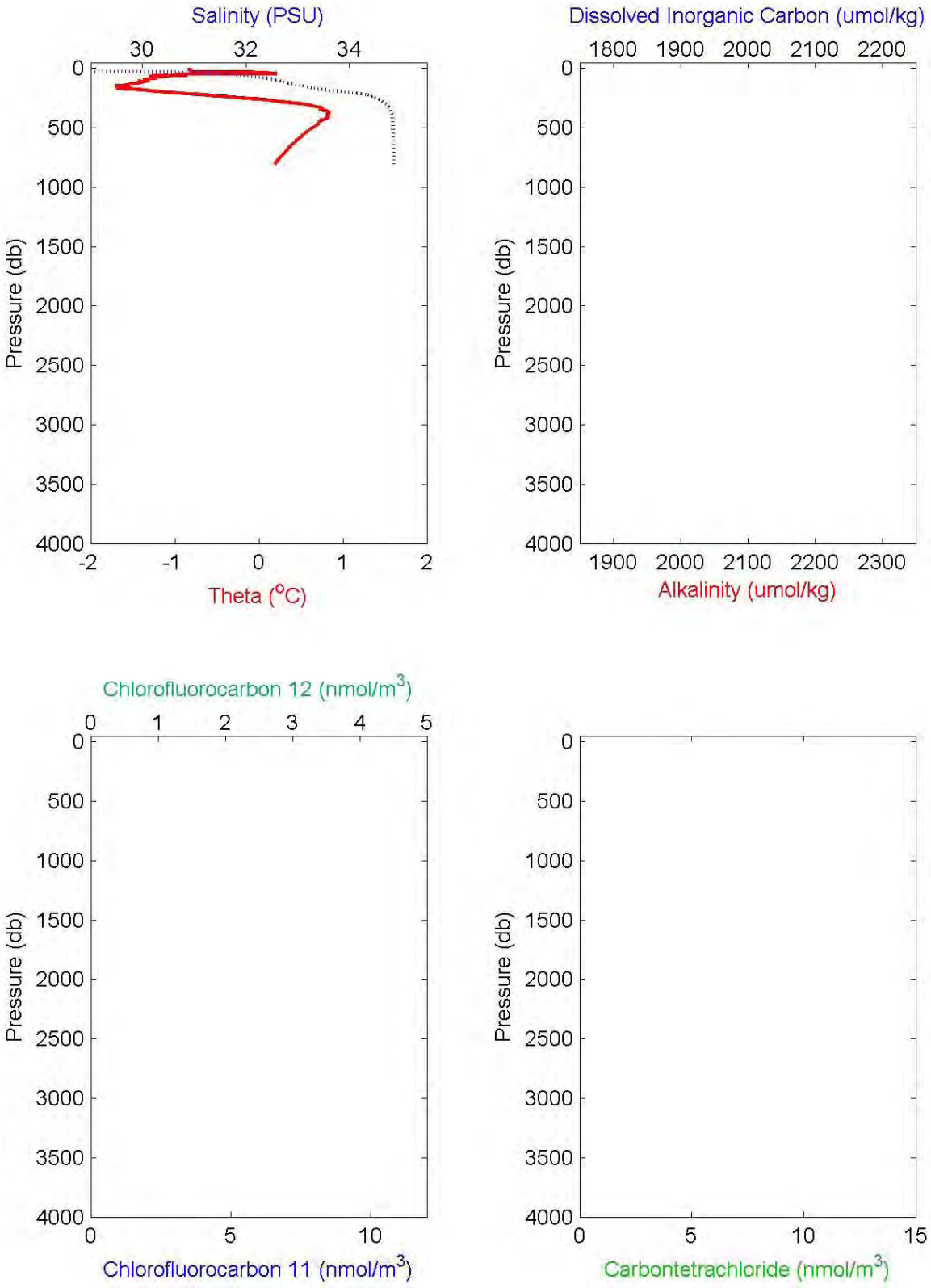


2002-23: Cast 36 Station NA05 (3)

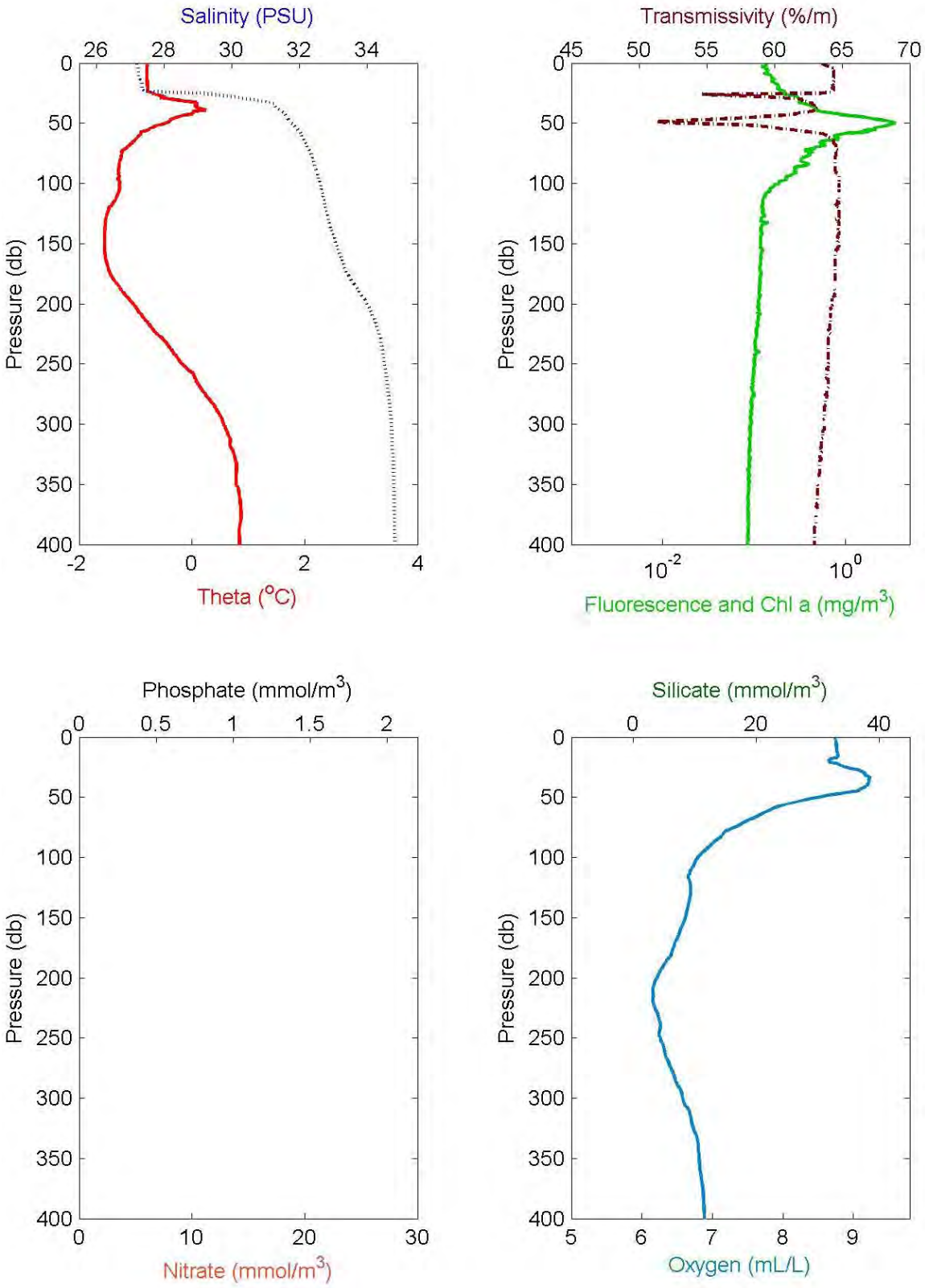




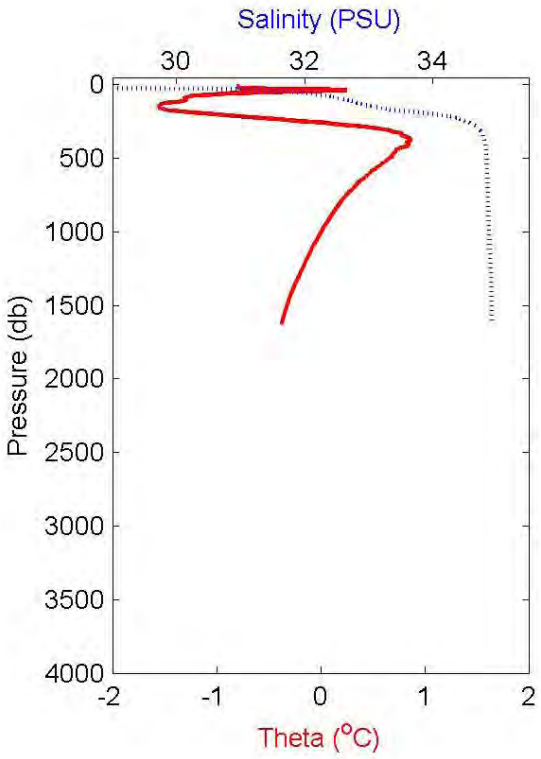
2002-23: Cast 36 Station NA05 (3)

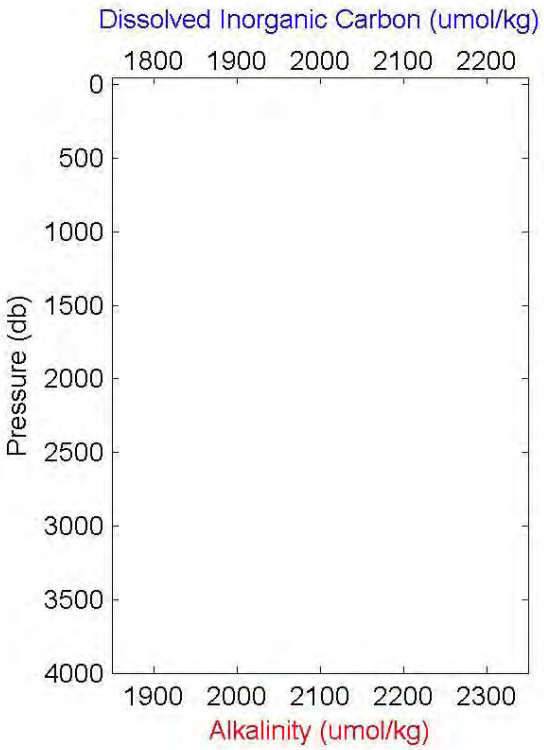


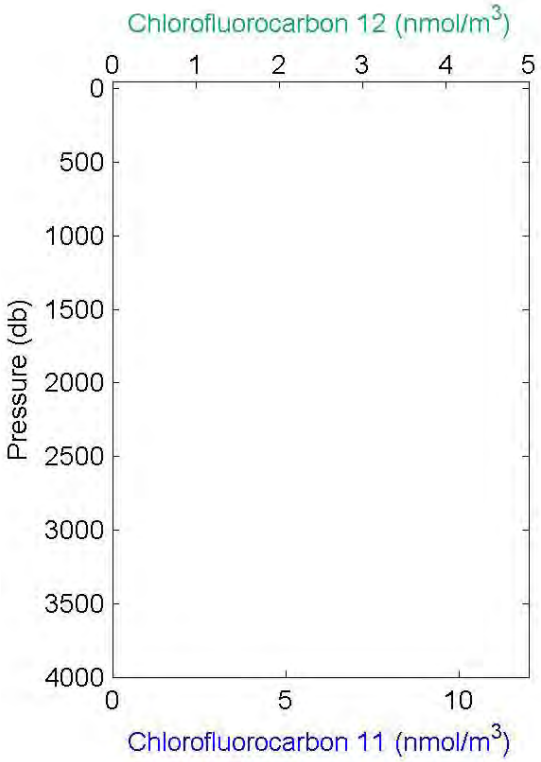
2002-23: Cast 37 Station NA06

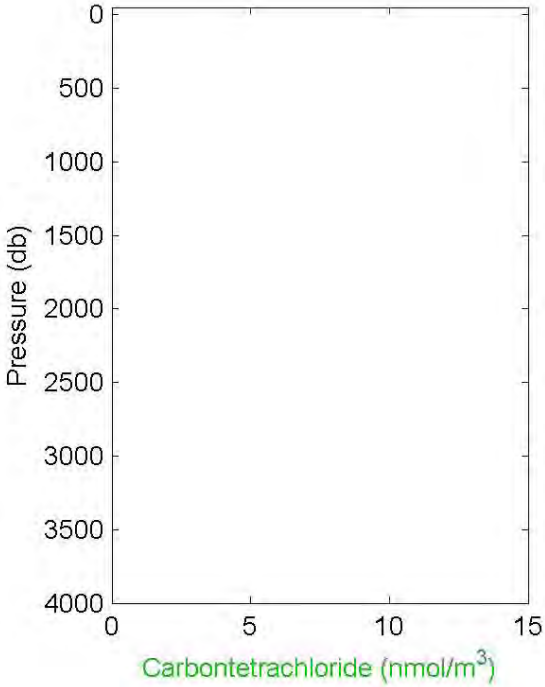


2002-23: Cast 37 Station NA06

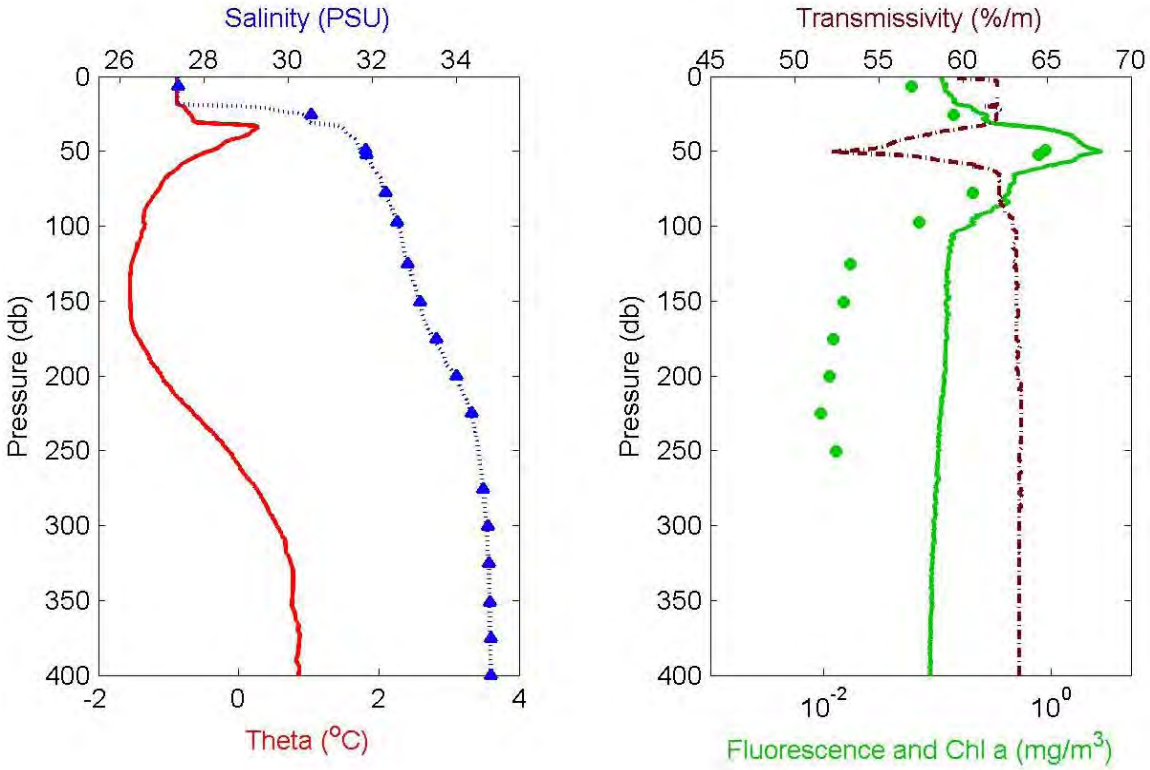


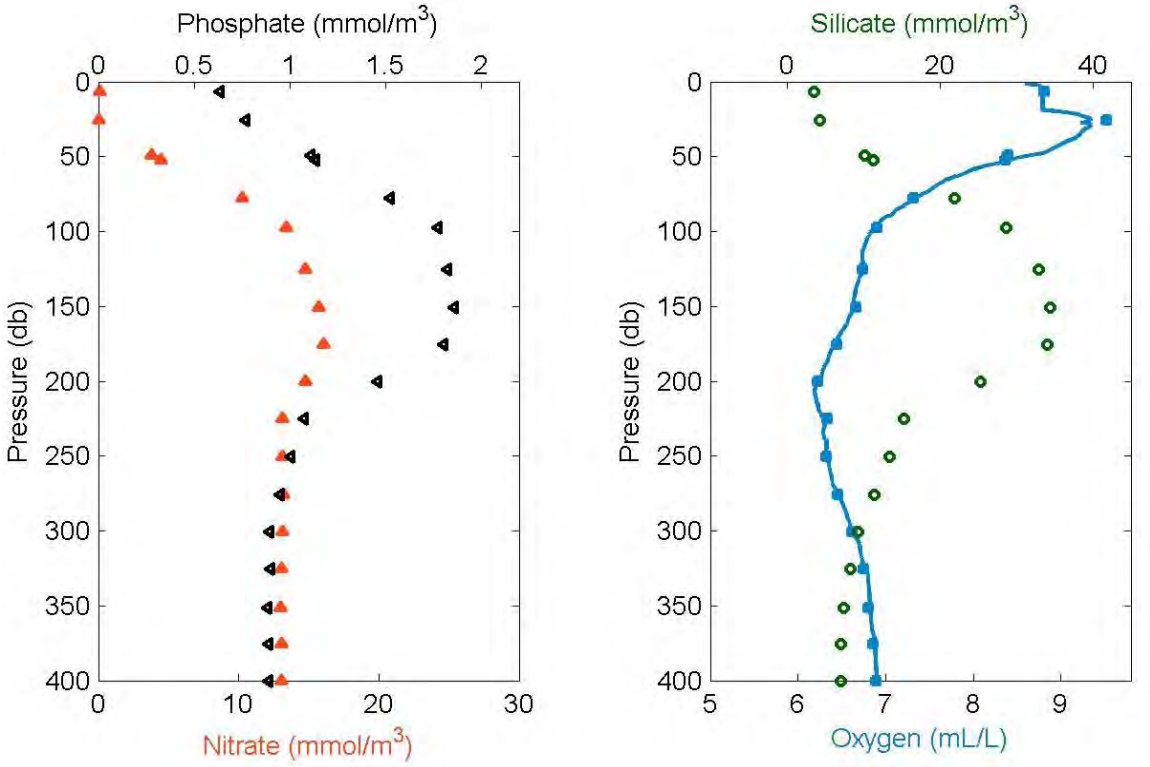




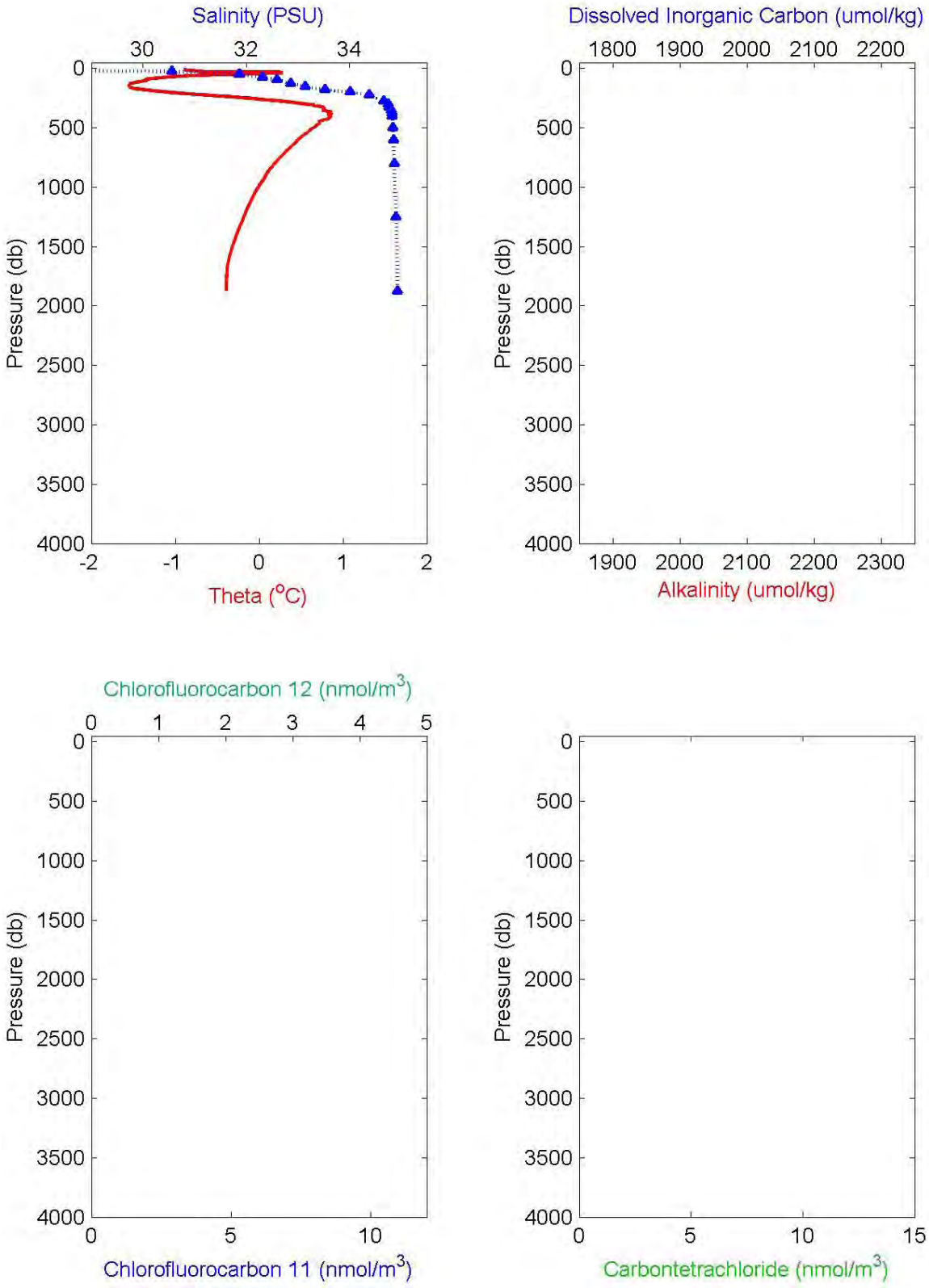


2002-23: Cast 38 Station NA07

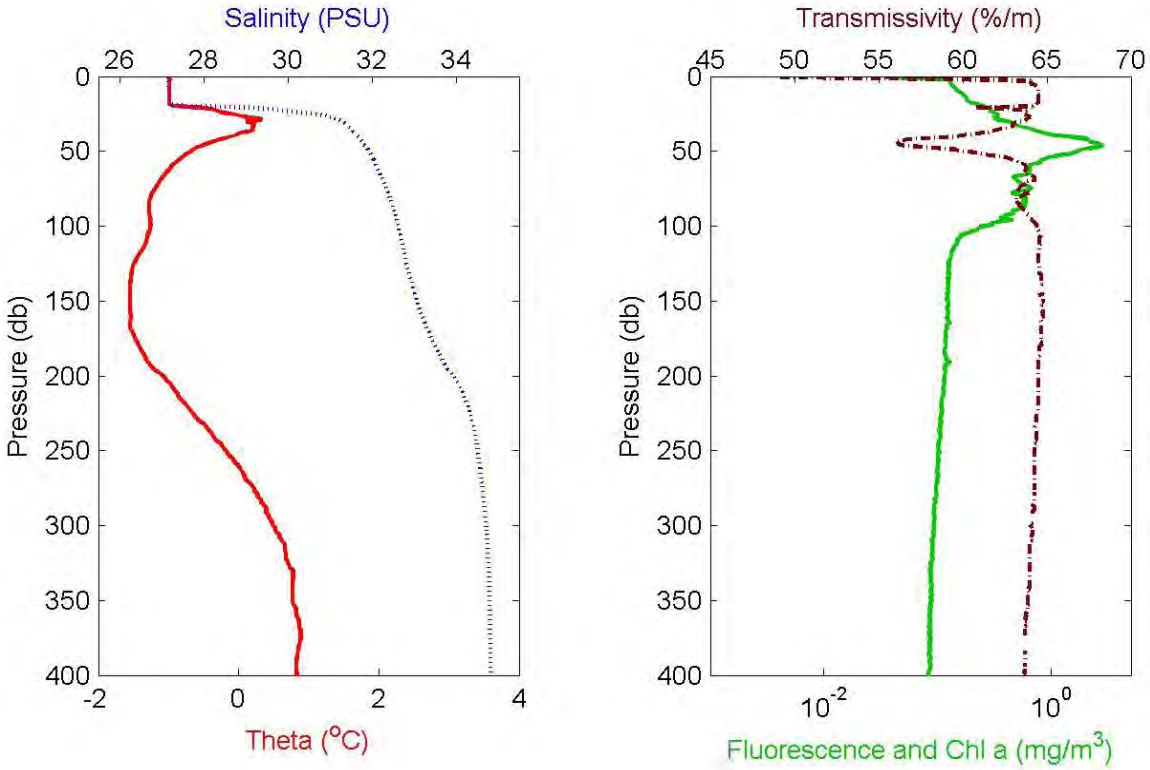


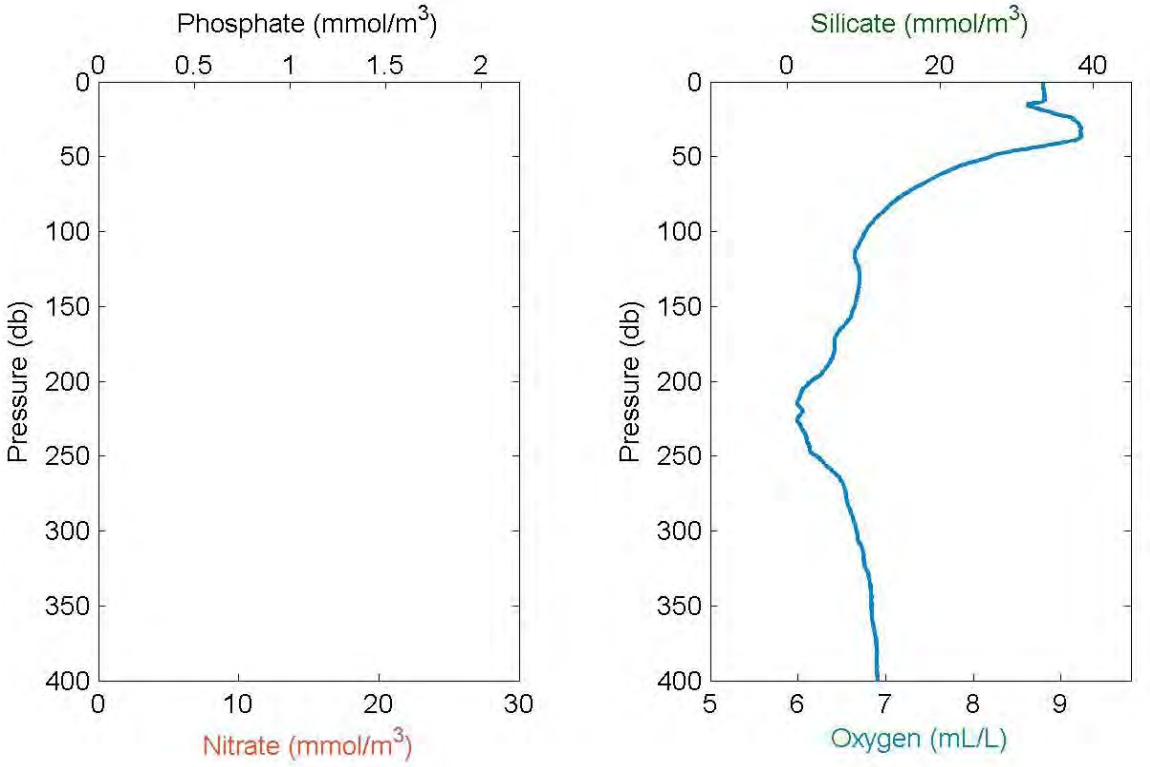


2002-23: Cast 38 Station NA07

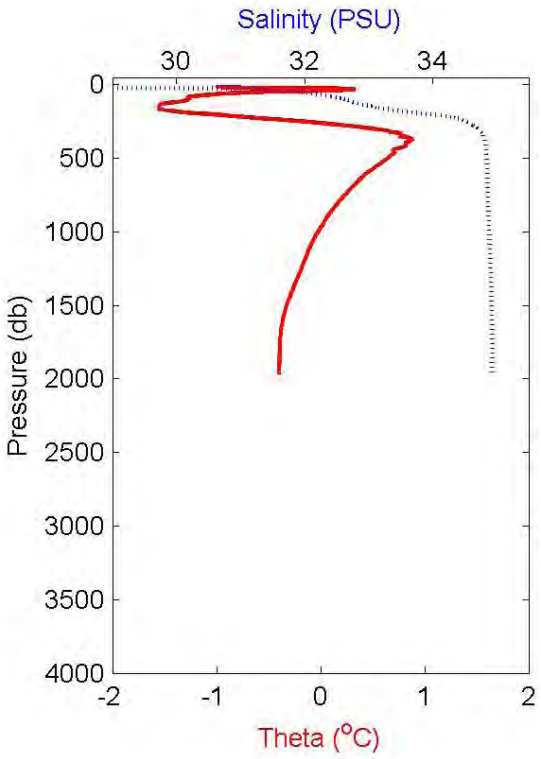


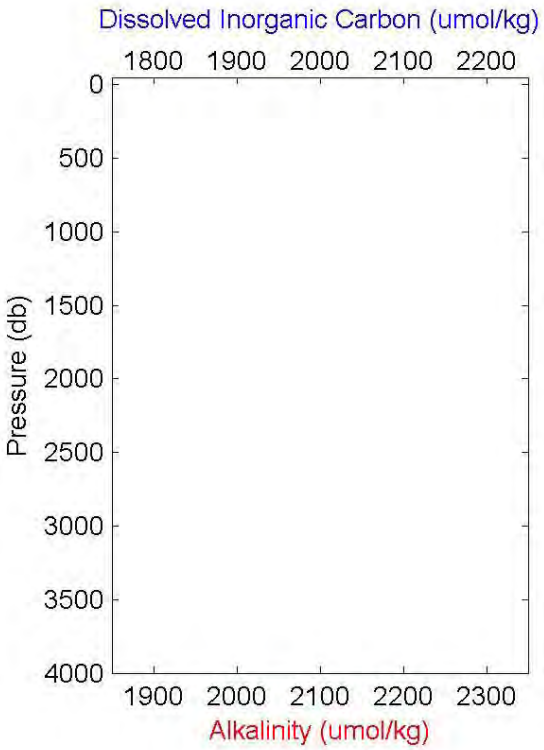
2002-23: Cast 39 Station NA08

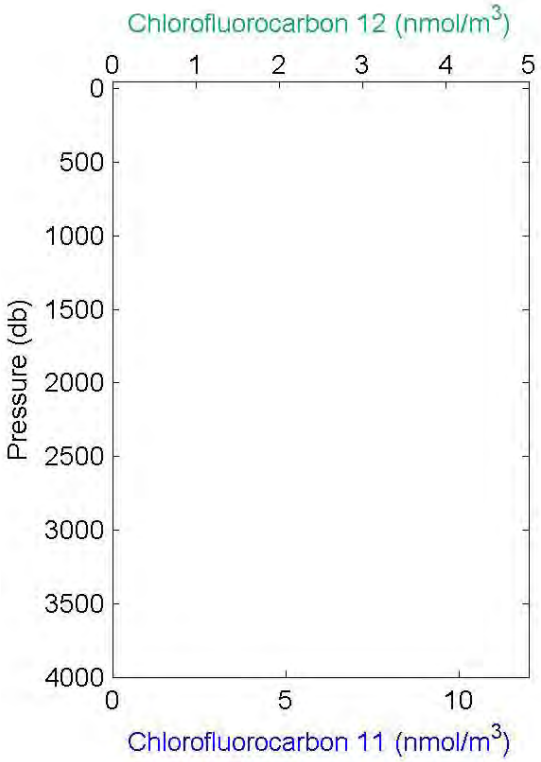


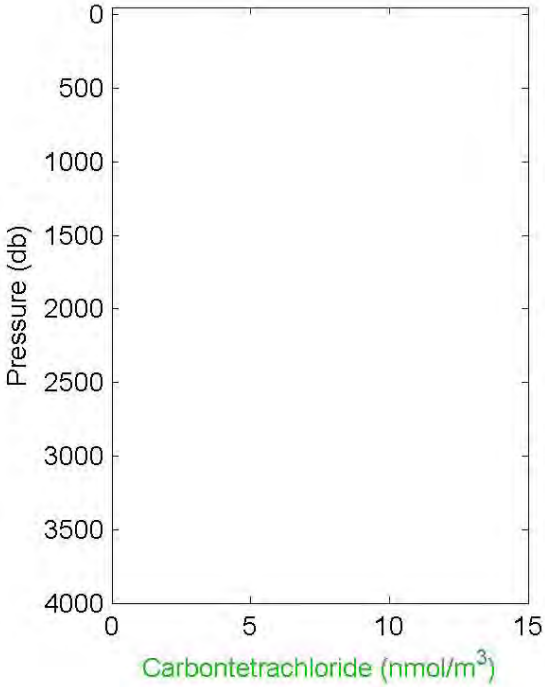


2002-23: Cast 39 Station NA08

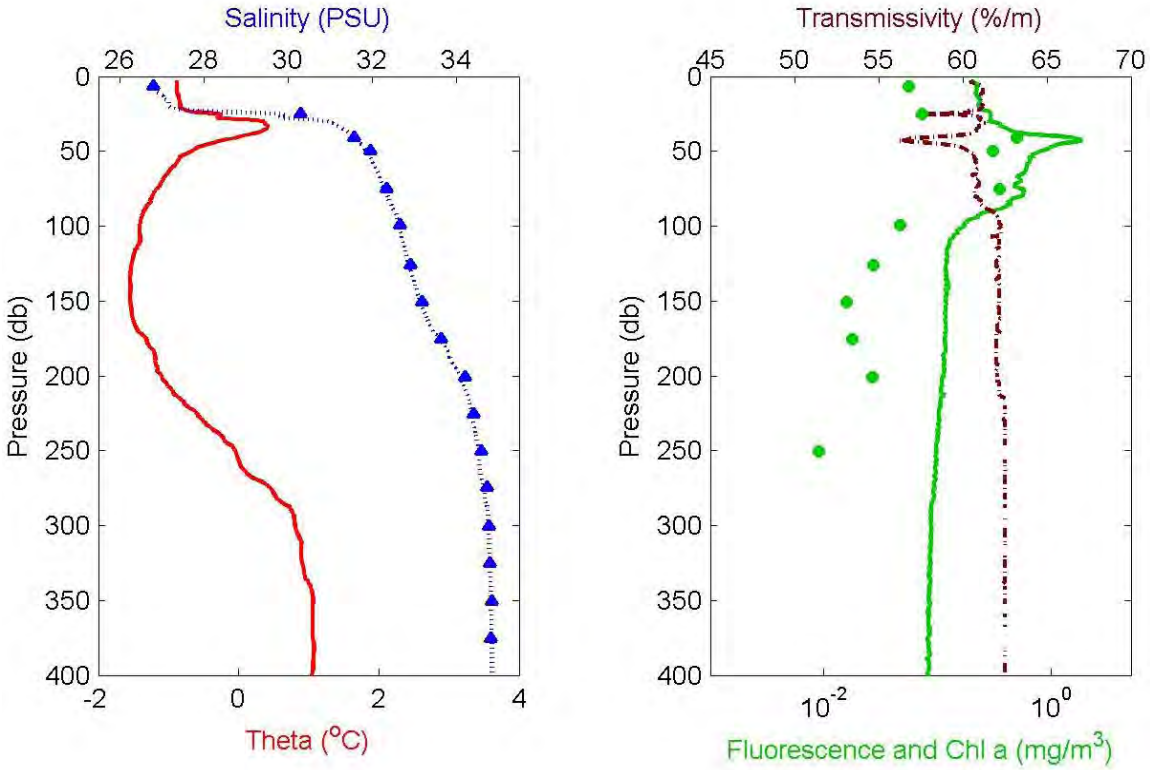


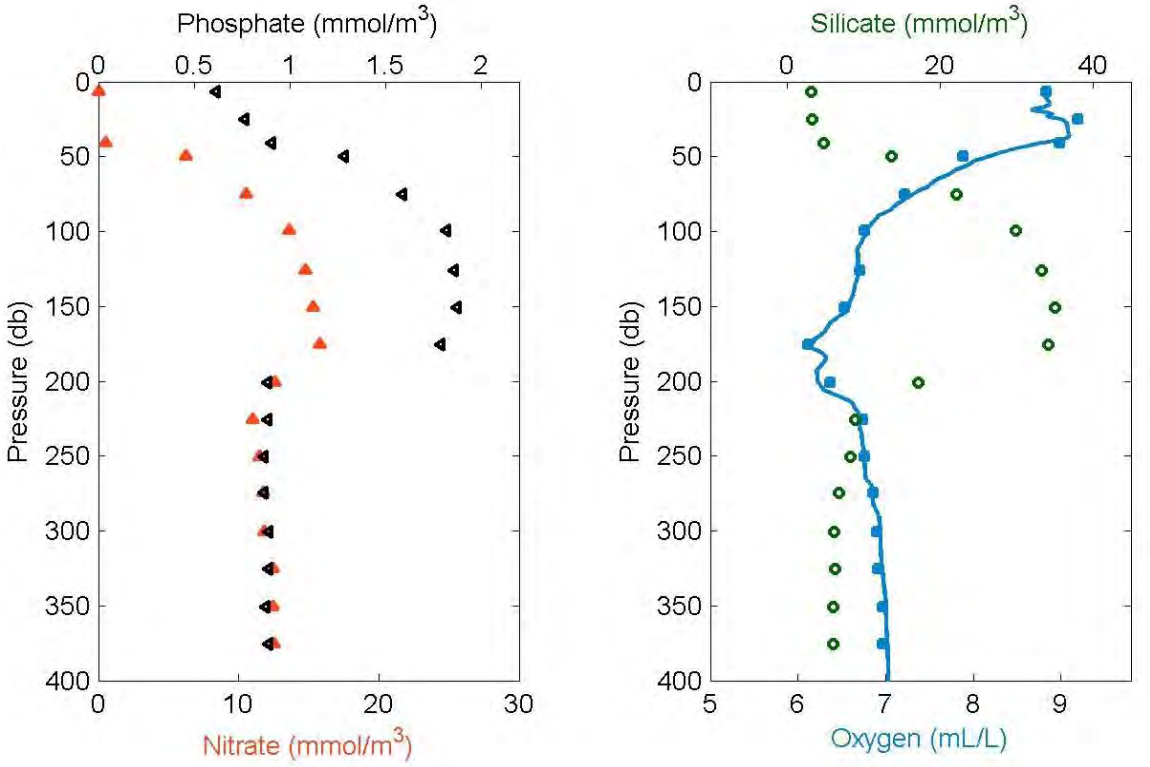




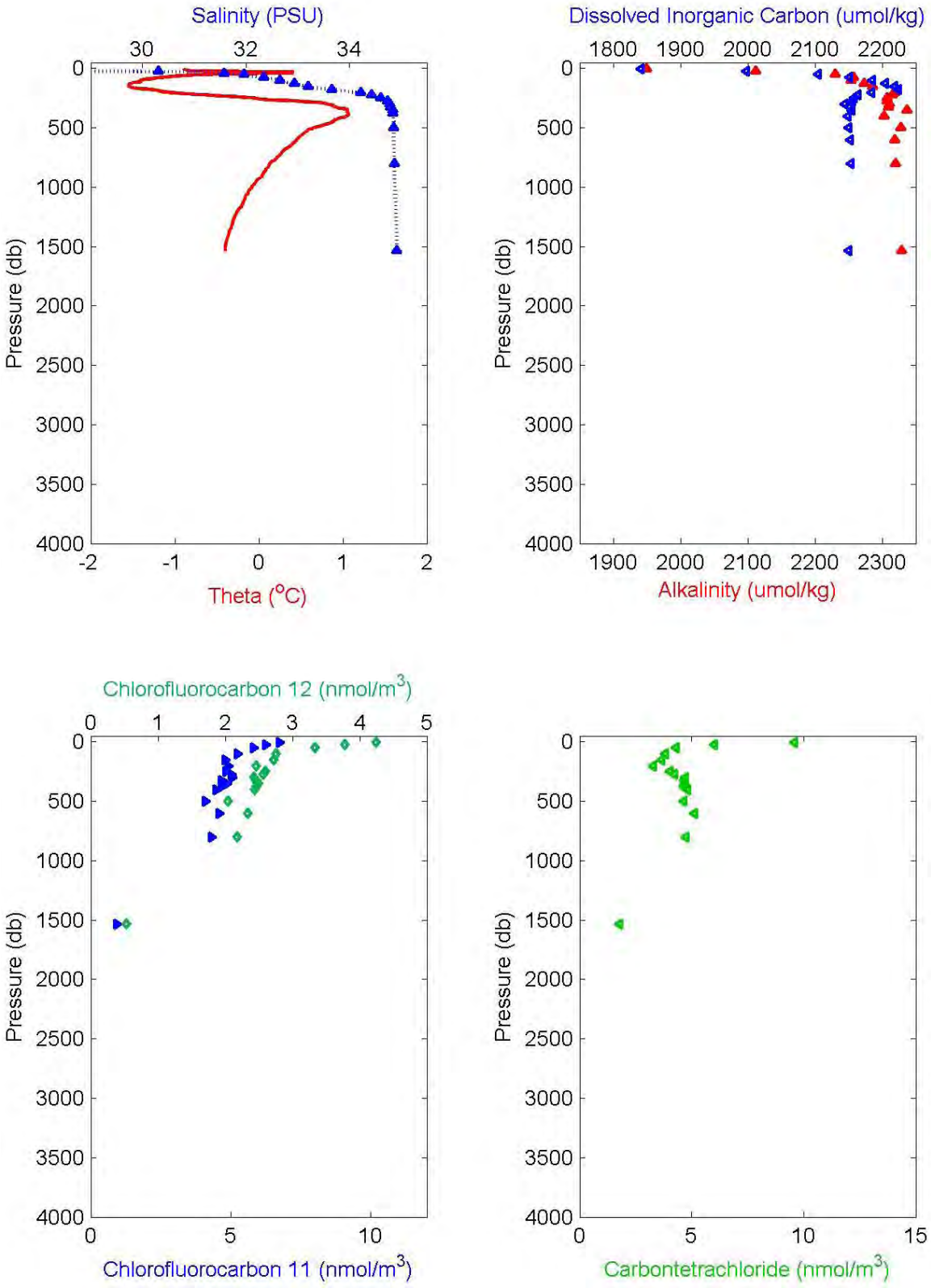


2002-23: Cast 41 Station NWR02(2)

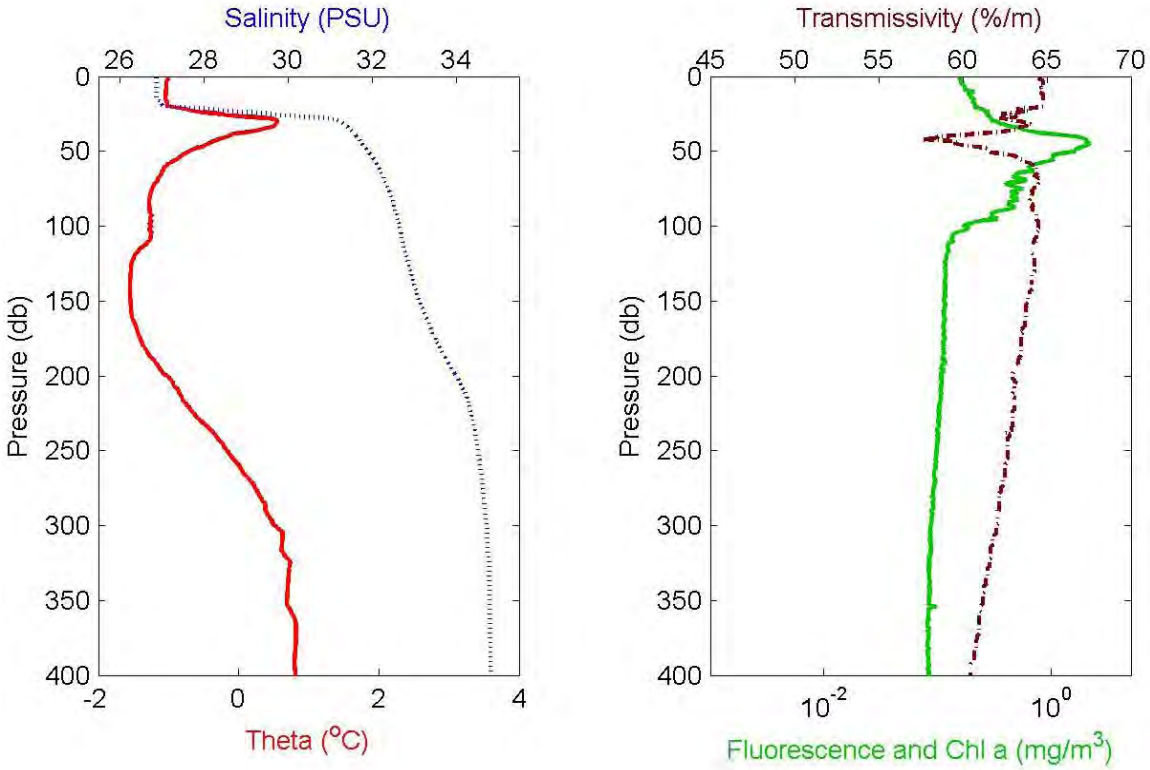


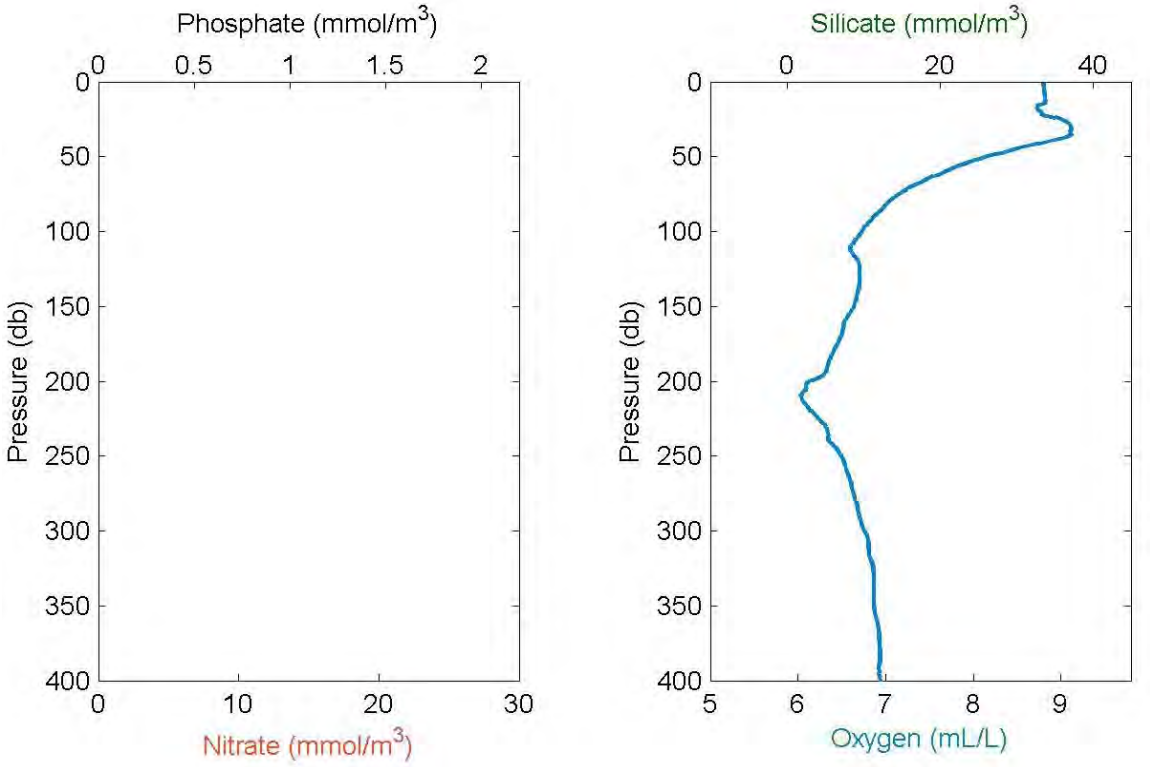


2002-23: Cast 41 Station NWR02(2)

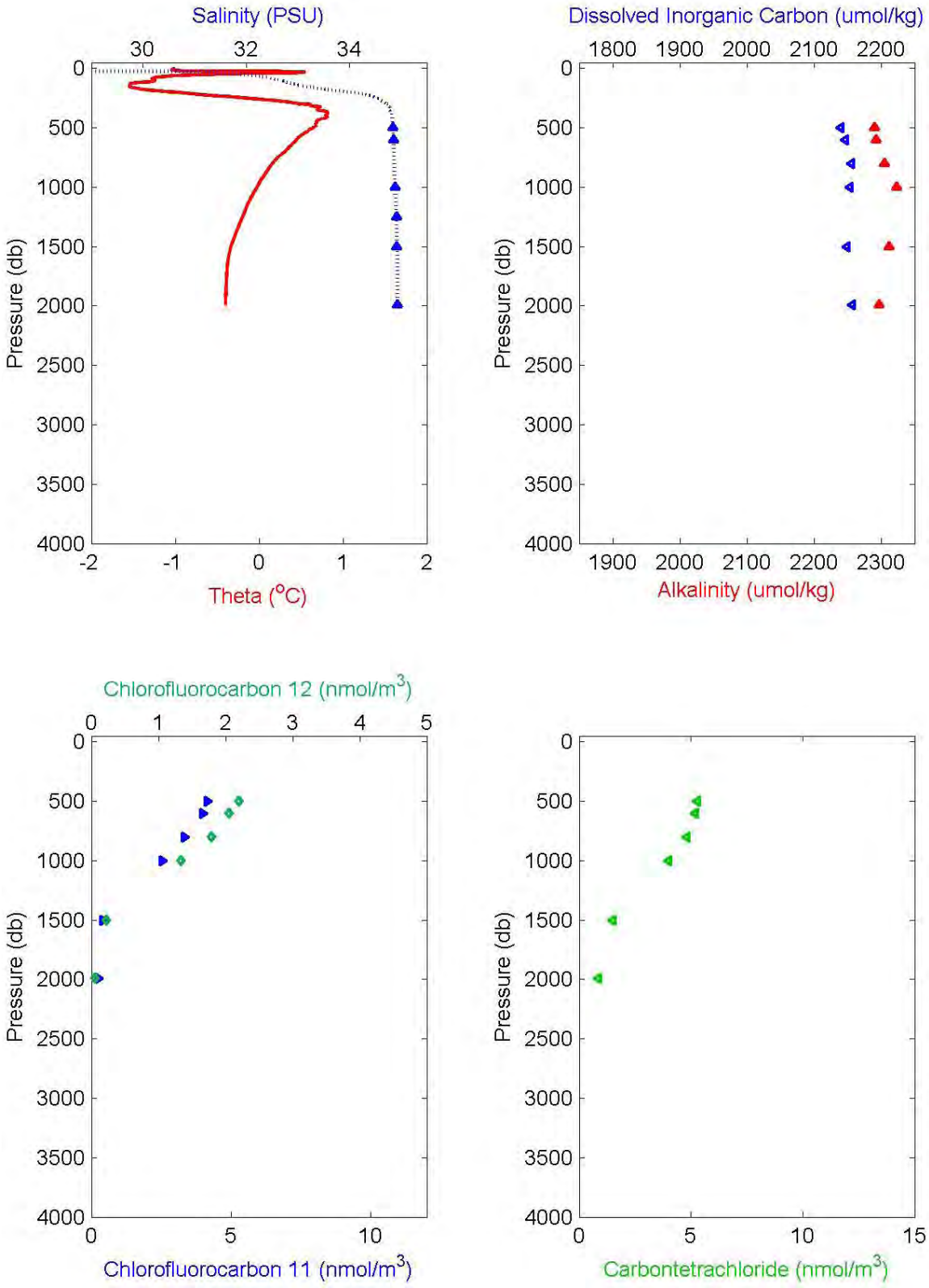


2002-23: Cast 42 Station NA09 (1)

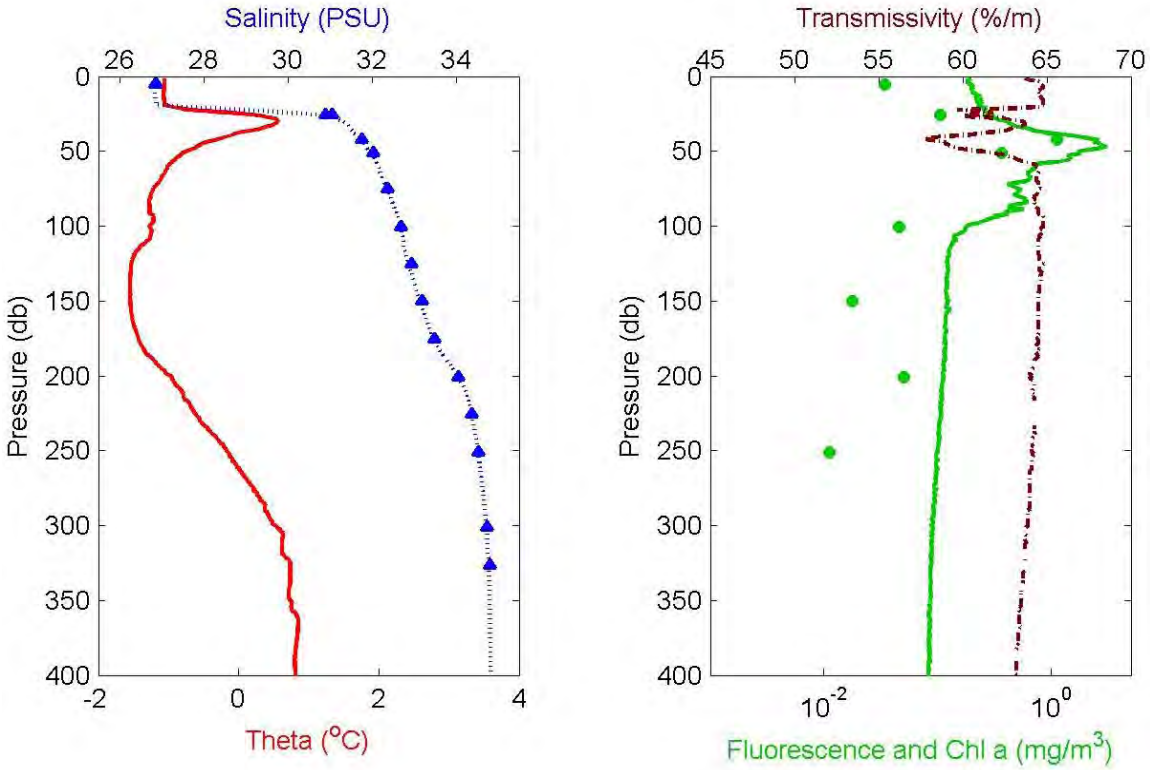




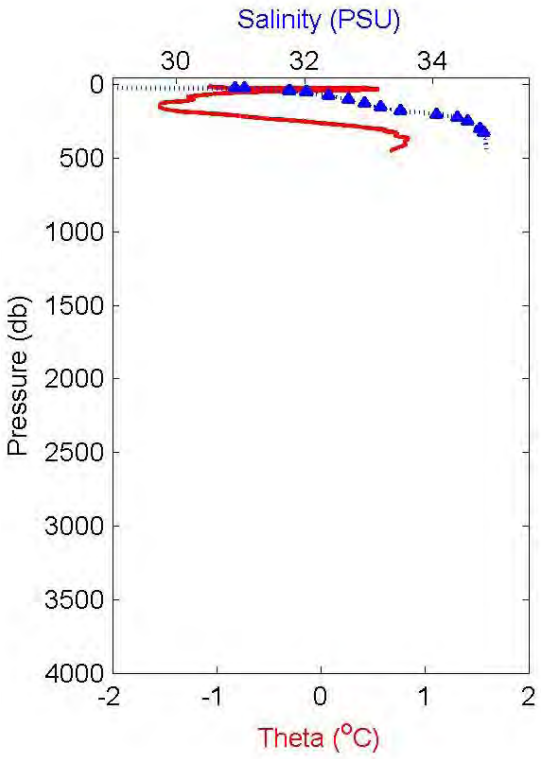
2002-23: Cast 42 Station NA09 (1)

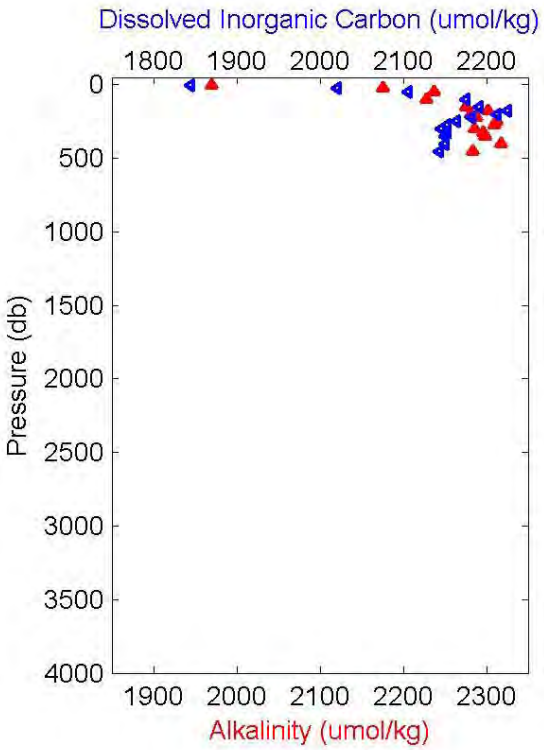


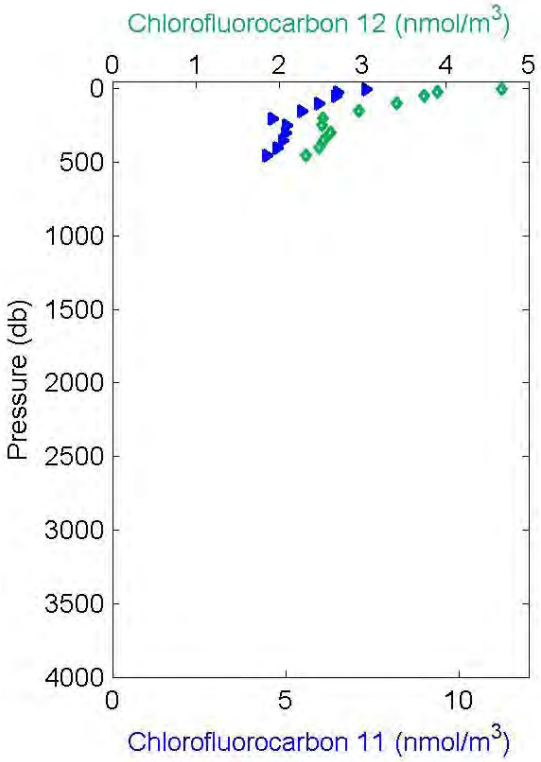
2002-23: Cast 43 Station NA09 (2)

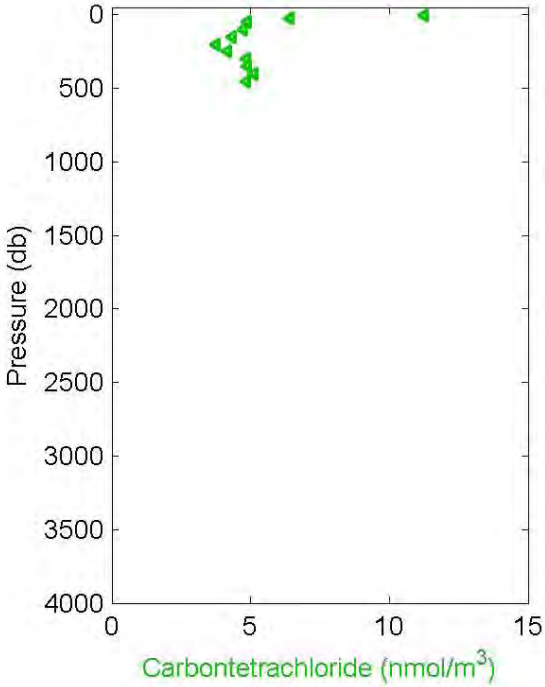


2002-23: Cast 43 Station NA09 (2)

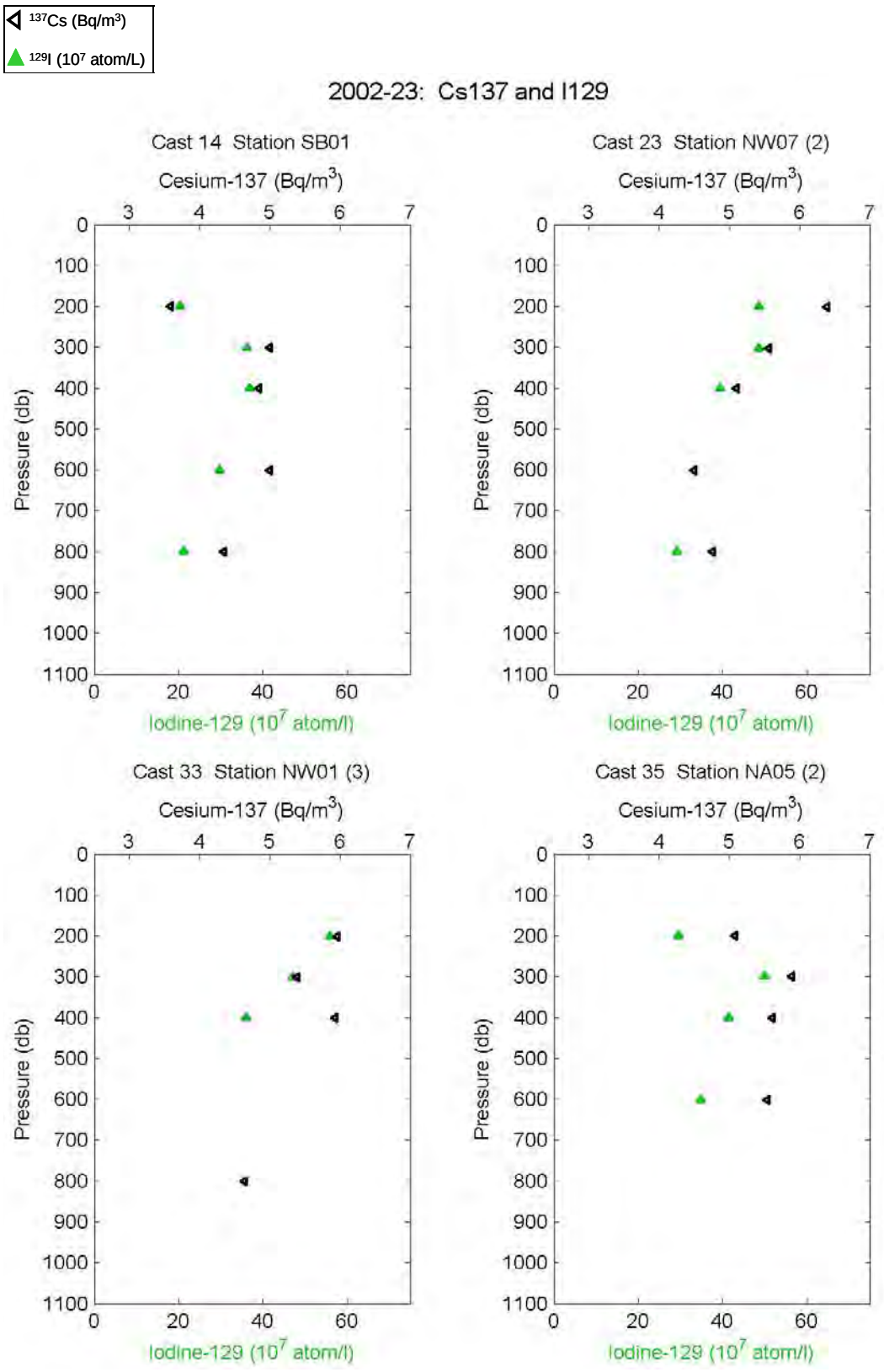




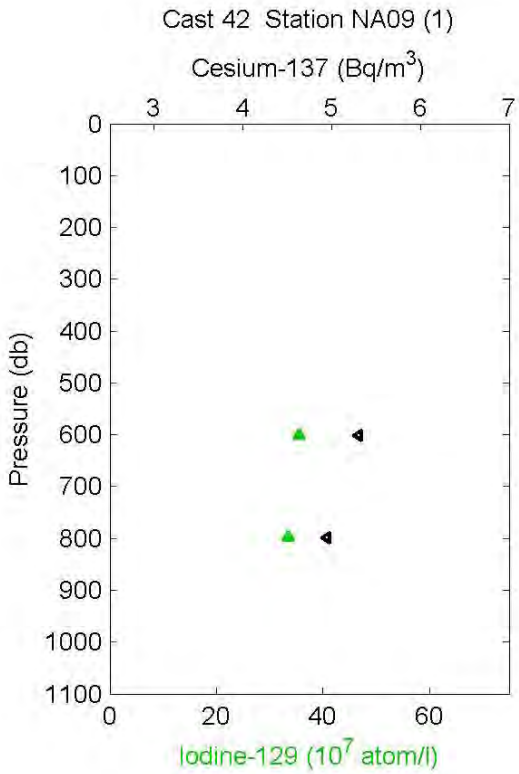


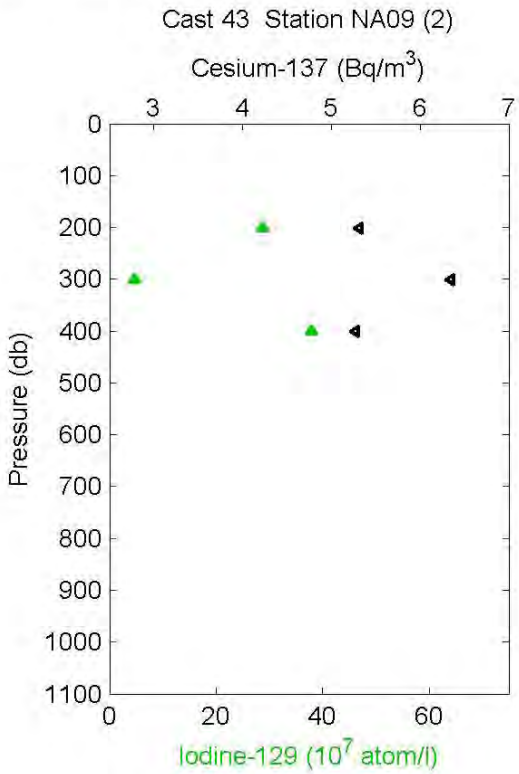


4.4.1 Cesium and Iodine Radioisotopes

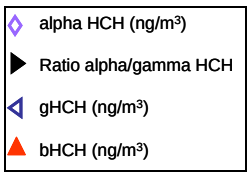


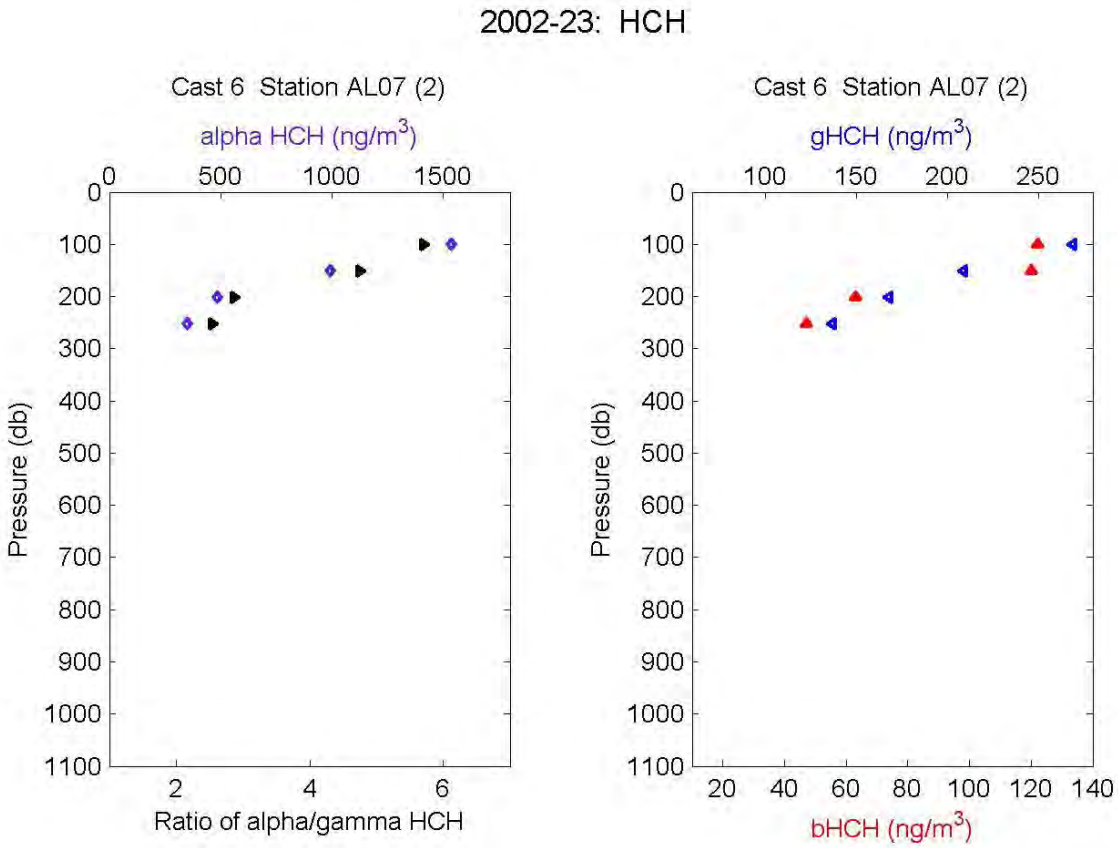
2002-23: Cs137 and I129

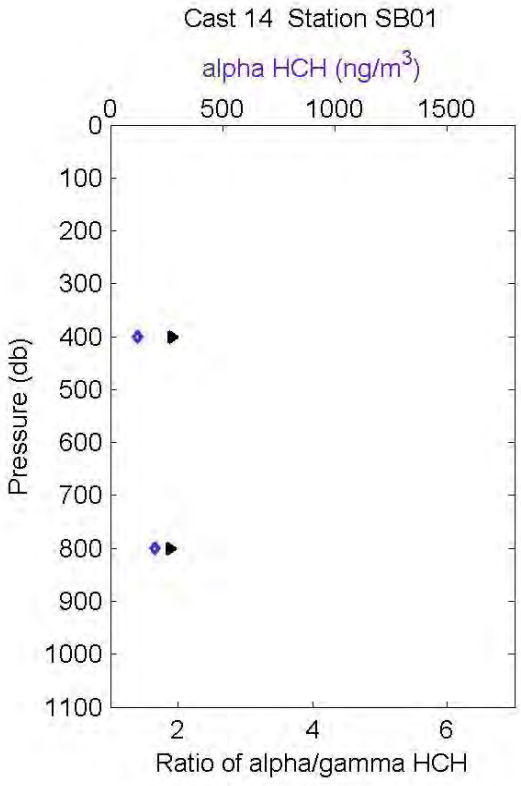


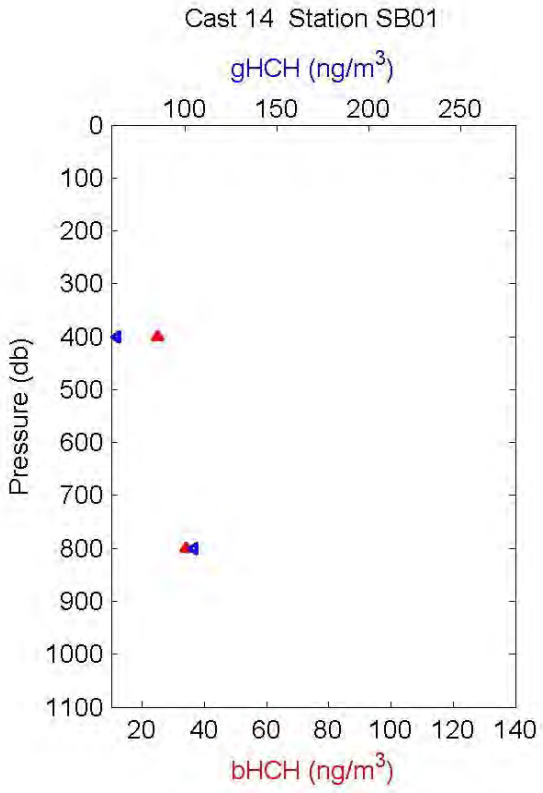


4.4.2 Hexachlorocyclohexane

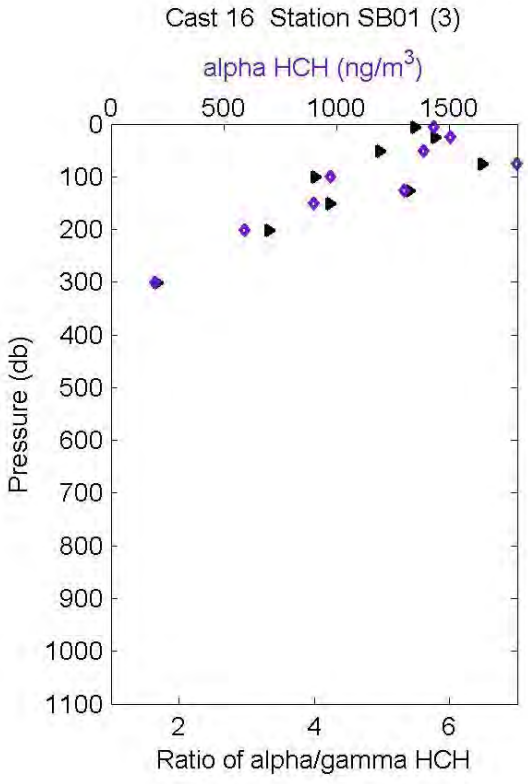


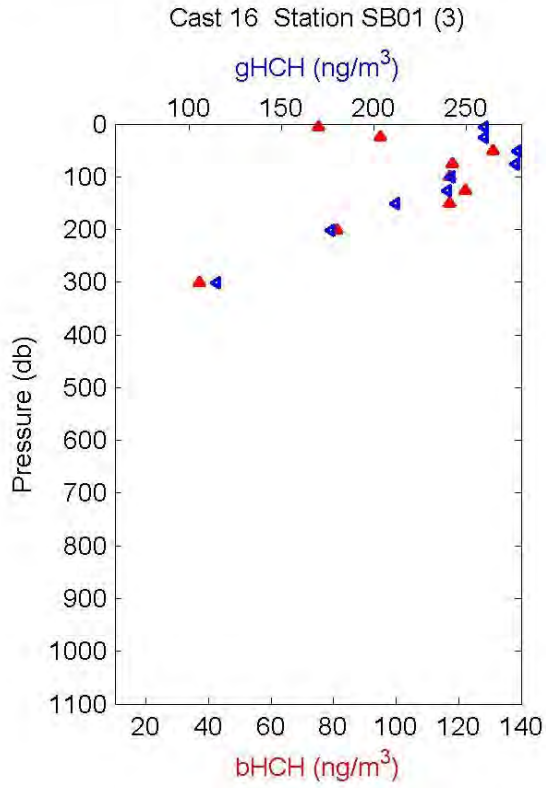


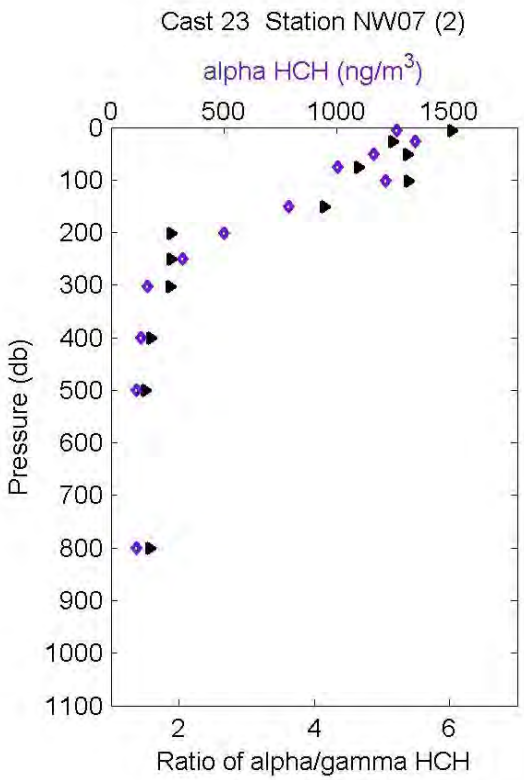

Cast 14 Station SB01
alpha HCH (ng/m3)
0
500
1000
1500
0
100
200
300
400
500
600
700
800
900
1000
1100
Pressure (db)
2
4
6
Ratio of alpha/gamma HCH

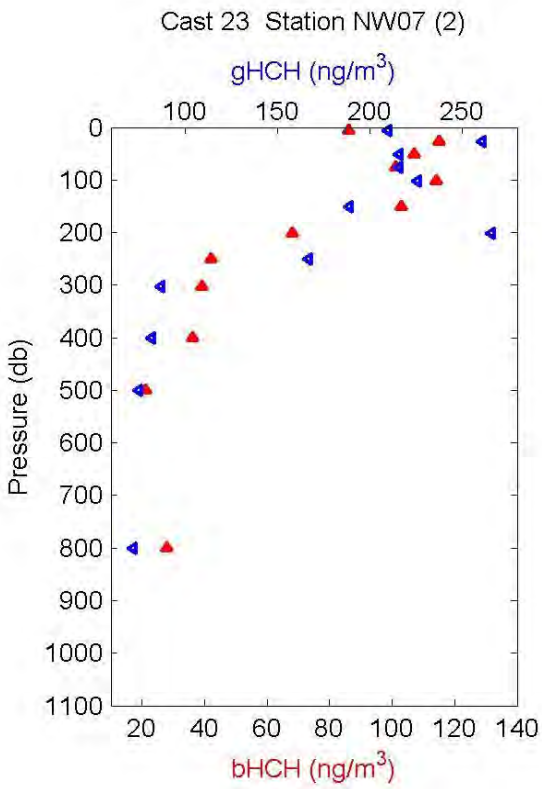

Cast 14 Station SB01
gHCH (ng/m3)
100
150
200
250
0
100
200
300
400
500
600
700
800
900
1000
1100
Pressure (db)
20
40
60
80
100
120
140
bHCH (ng/m3)

2002-23: HCH

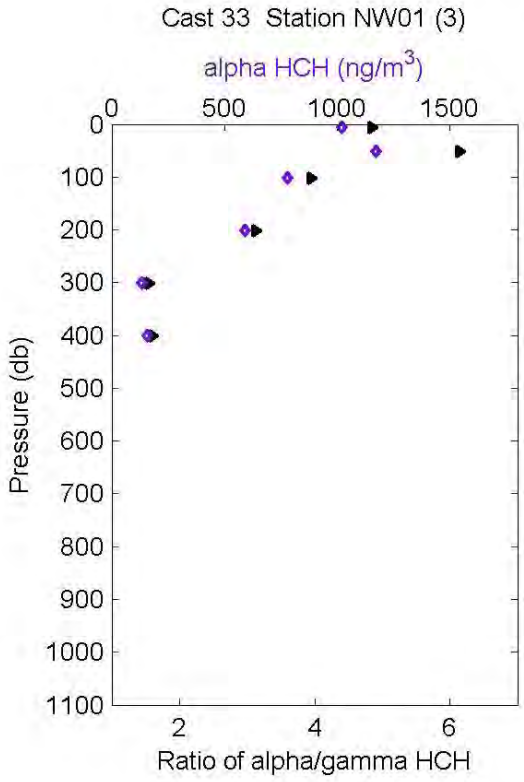

Cast 16 Station SB01 (3)
alpha HCH (ng/m3)
0
500
1000
1500
0
100
200
300
400
500
600
700
800
900
1000
1100
Pressure (db)
2
4
6
Ratio of alpha/gamma HCH

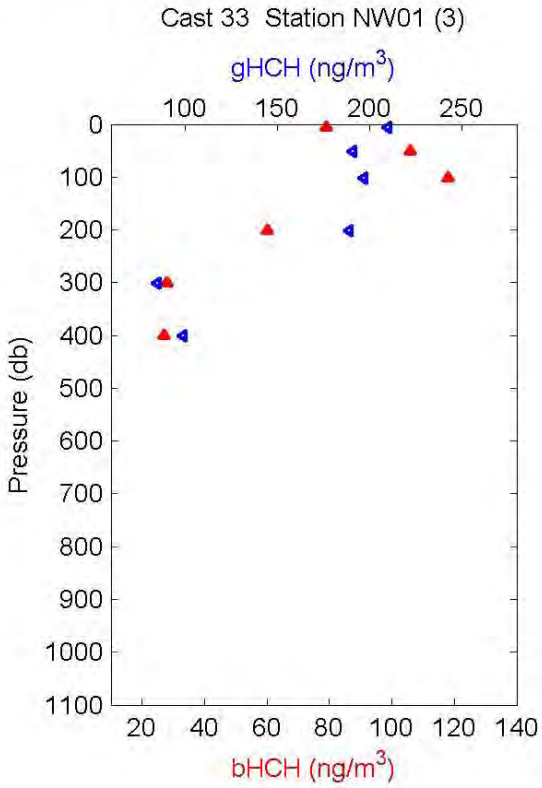

Cast 16 Station SB01 (3)
gHCH (ng/m3)
100
150
200
250
0
100
200
300
400
500
600
700
800
900
1000
1100
Pressure (db)
20
40
60
80
100
120
140
bHCH (ng/m3)


Cast 23 Station NW07 (2)
alpha HCH (ng/m3)
0
500
1000
1500
Pressure (db)
0
100
200
300
400
500
600
700
800
900
1000
1100
2
4
6
Ratio of alpha/gamma HCH

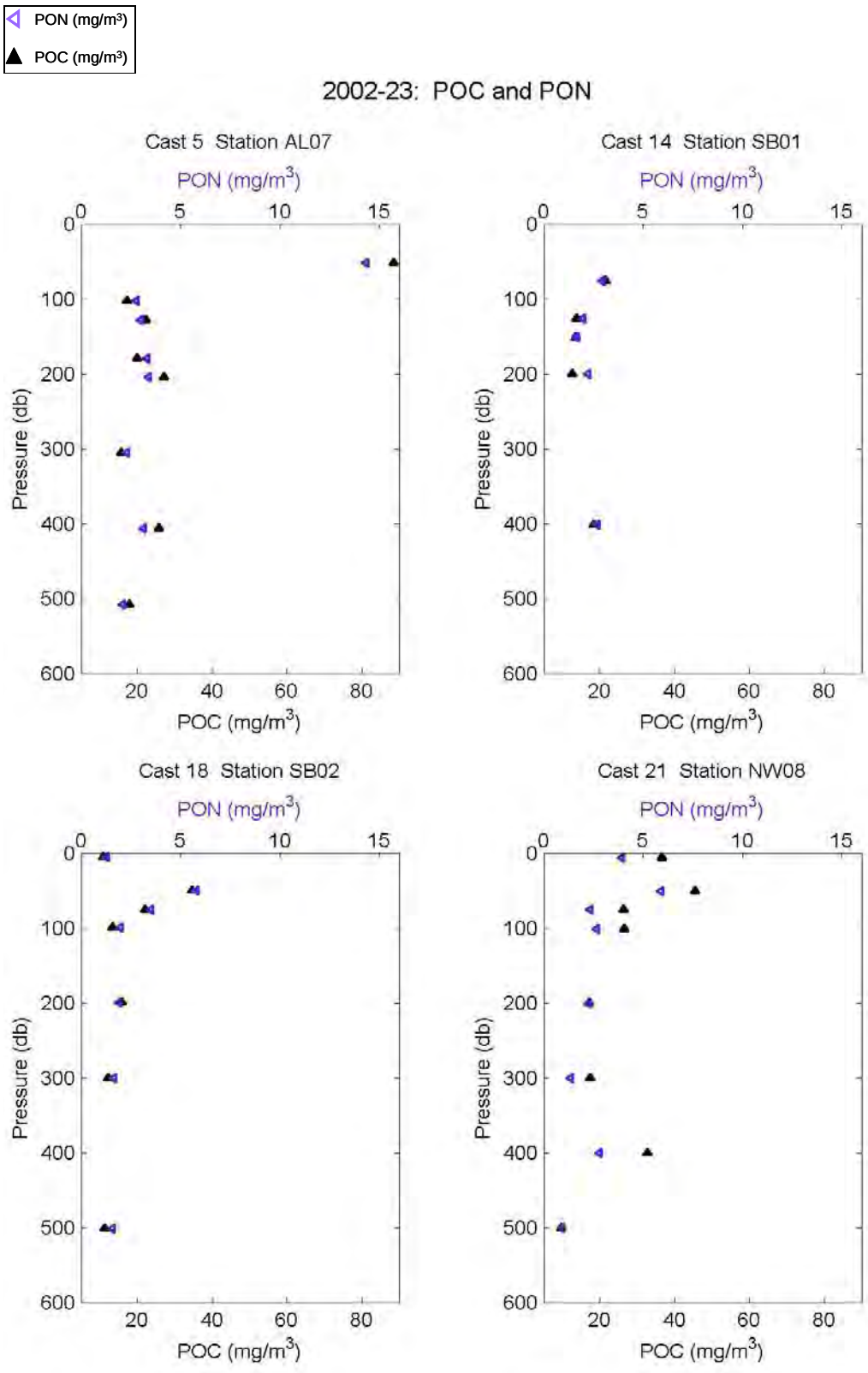

Cast 23 Station NW07 (2)
gHCH (ng/m3)
100
150
200
250
Pressure (db)
0
100
200
300
400
500
600
700
800
900
1000
1100
20
40
60
80
100
120
140
bHCH (ng/m3)

2002-23: HCH

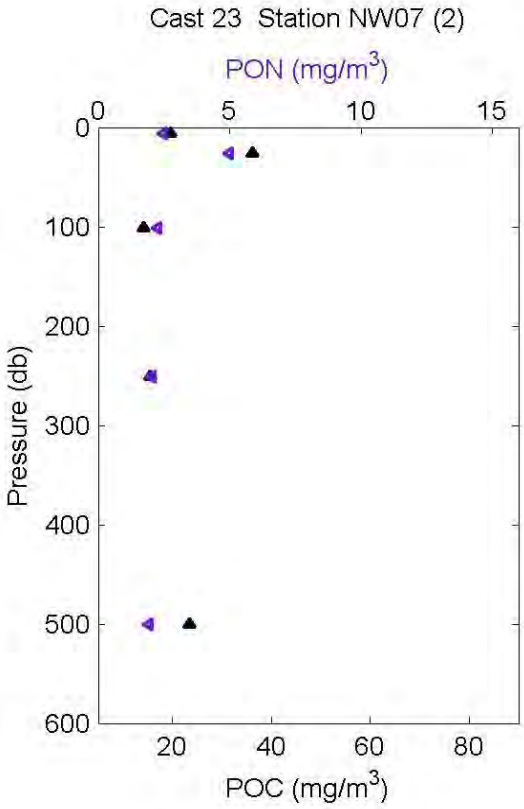

Cast 33 Station NW01 (3)
alpha HCH (ng/m3)
0
500
1000
1500
Pressure (db)
0
100
200
300
400
500
600
700
800
900
1000
1100
2
4
6
Ratio of alpha/gamma HCH

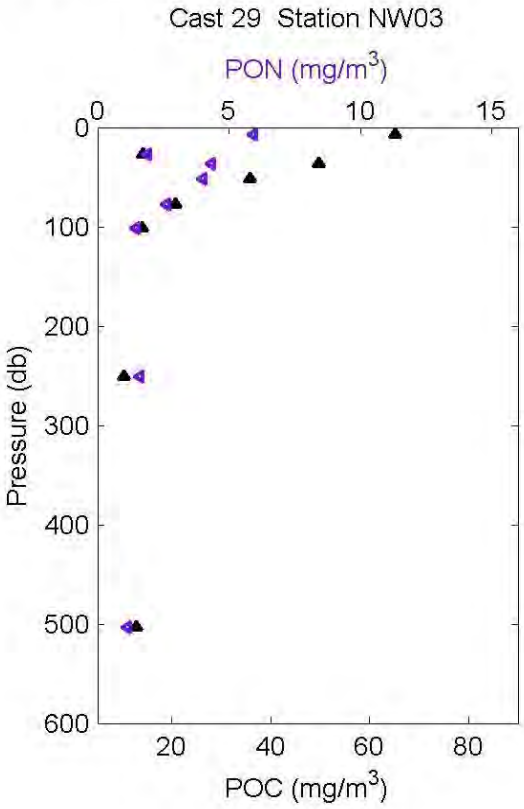

Cast 33 Station NW01 (3)
gHCH (ng/m3)
100
150
200
250
Pressure (db)
0
100
200
300
400
500
600
700
800
900
1000
1100
20
40
60
80
100
120
140
bHCH (ng/m3)

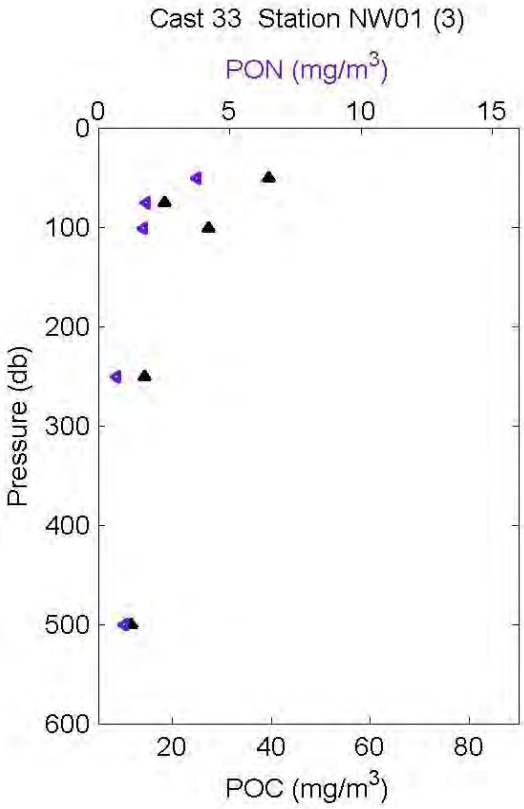
4.4.3 Particulate Organic Carbon and Particulate Organic Nitrogen

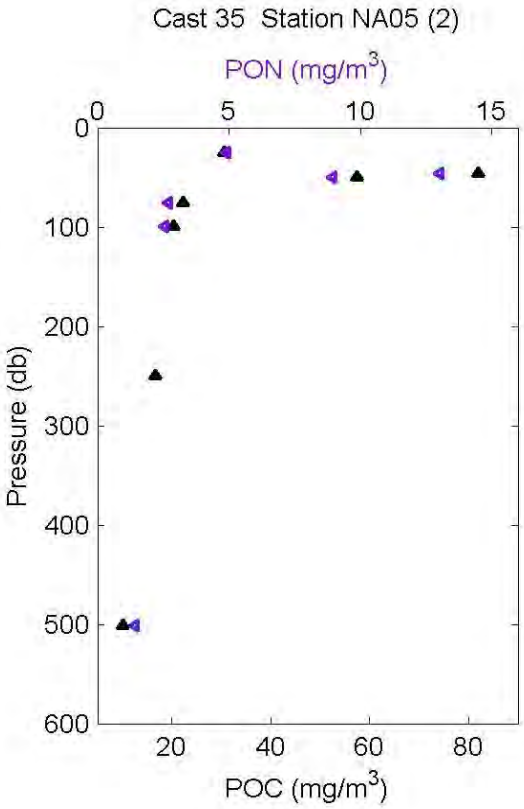


2002-23: POC and PON

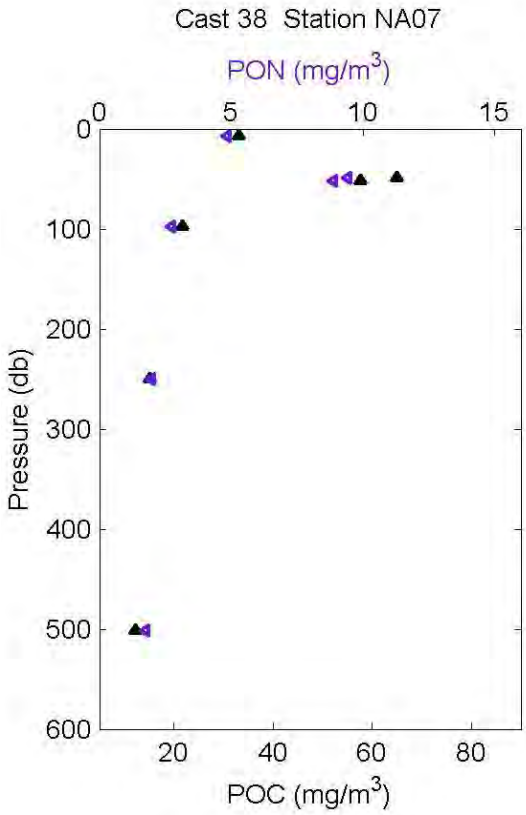


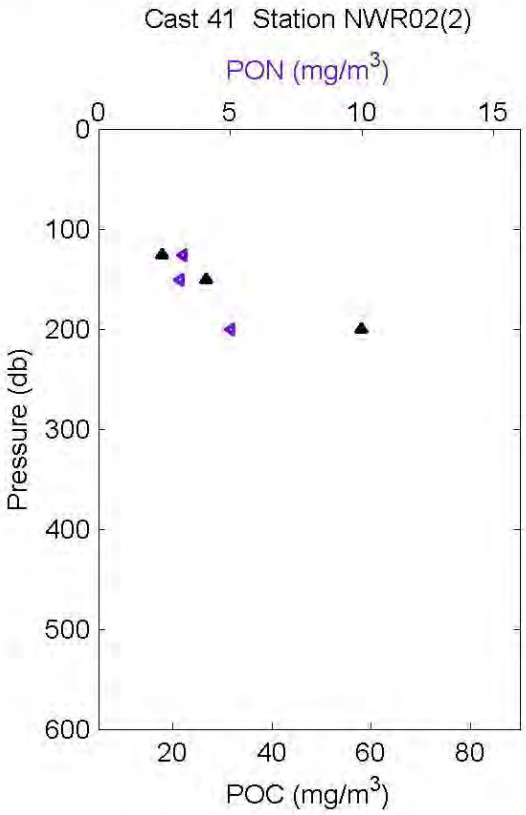


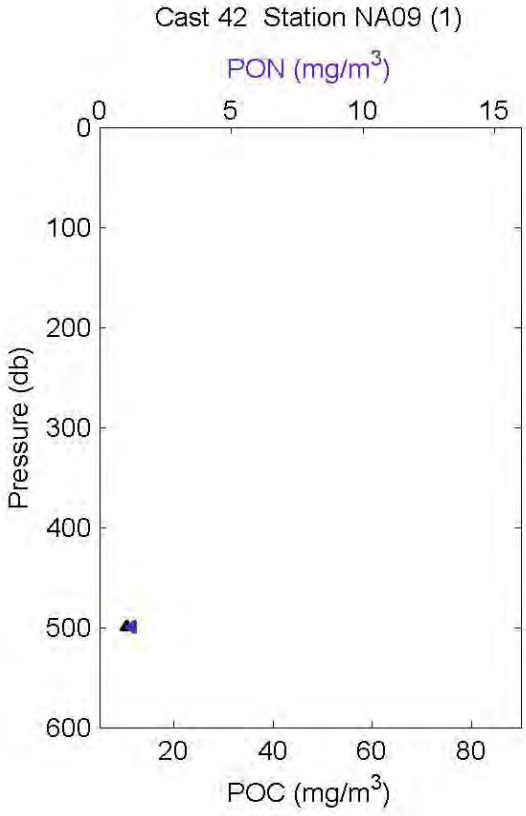


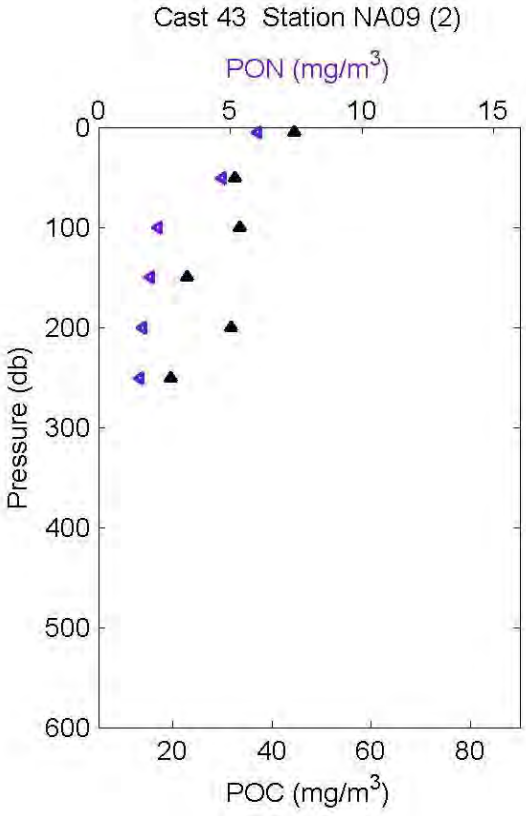


2002-23: POC and PON



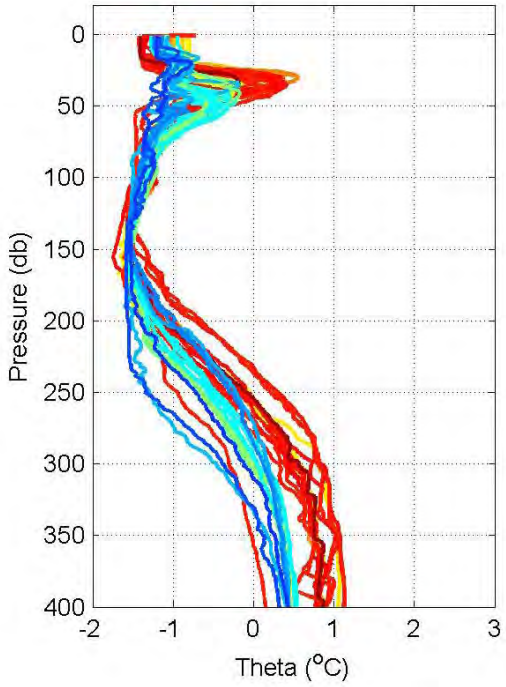


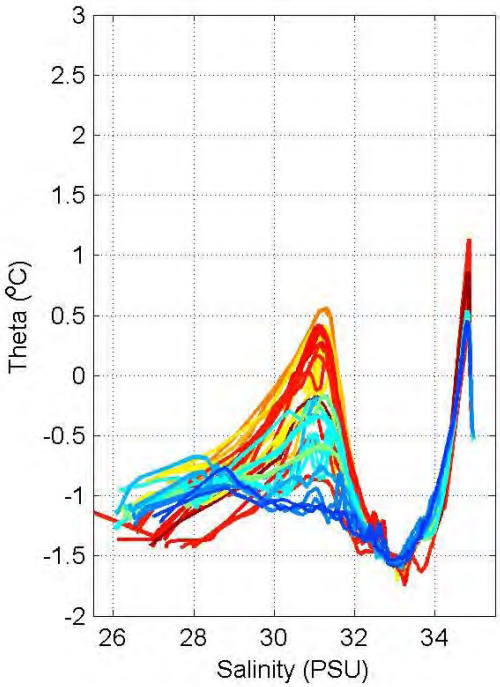


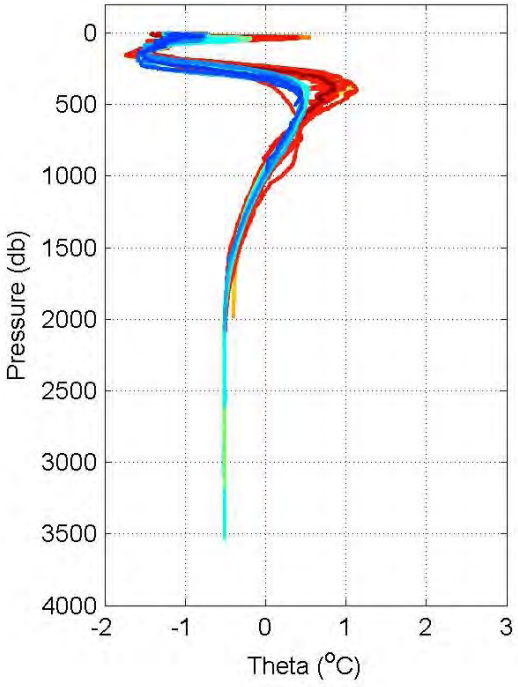


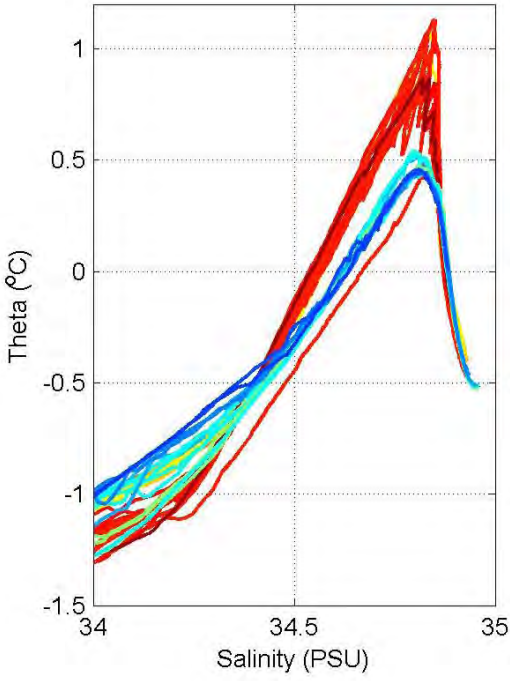
4.5 PROPERTY PLOTS

2002-23 Group: Canada Basin, Property: Theta

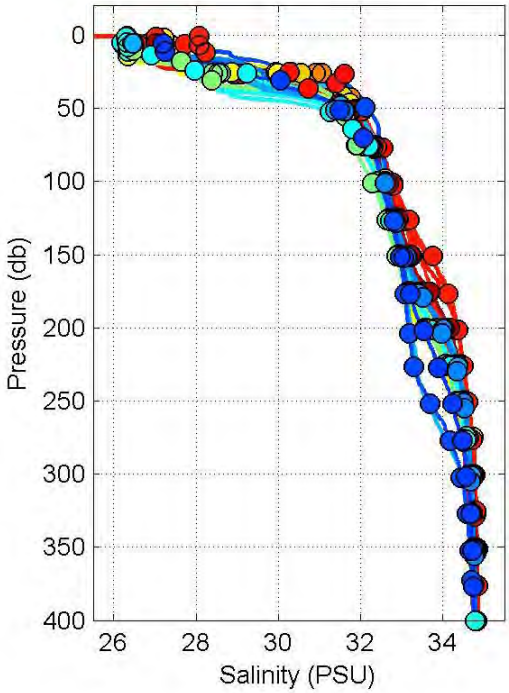


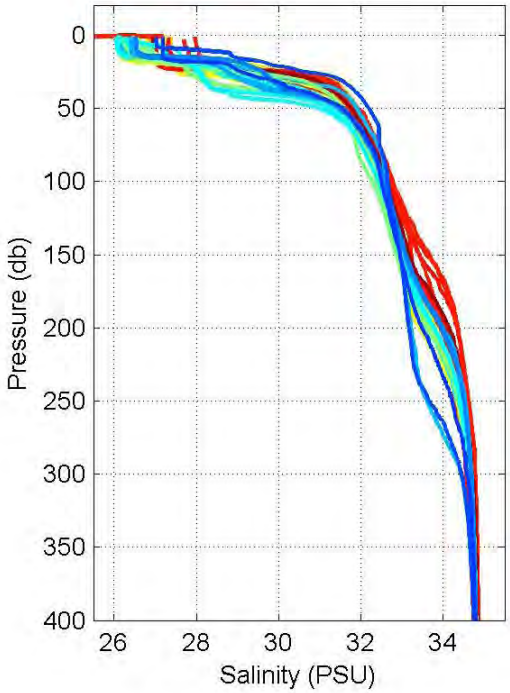


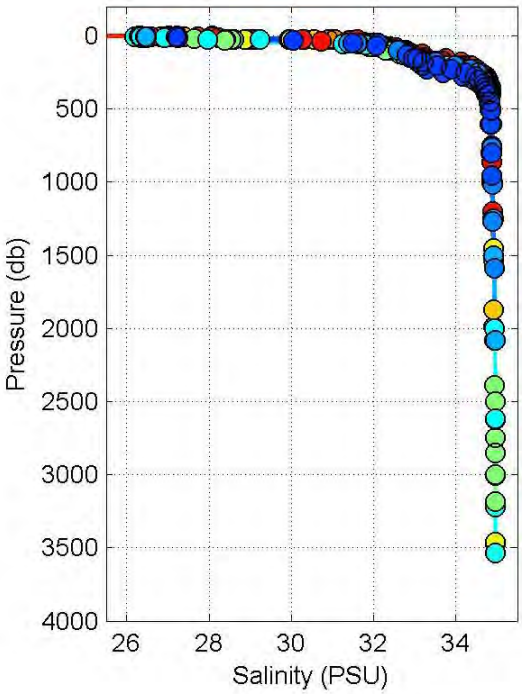


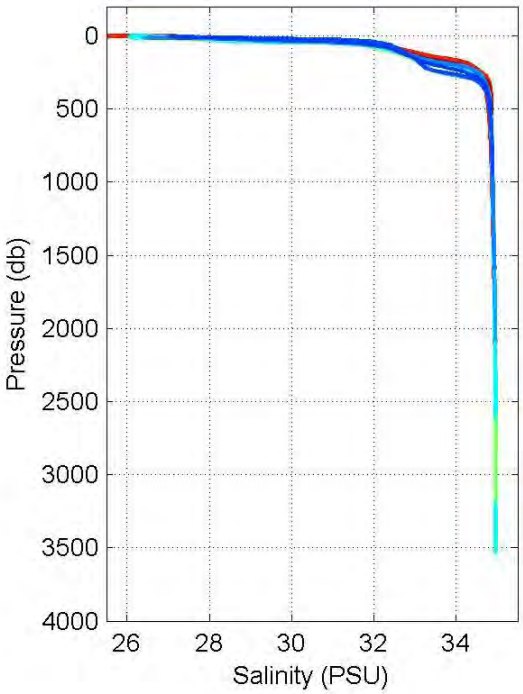


2002-23 Group: Canada Basin, Property: Salinity

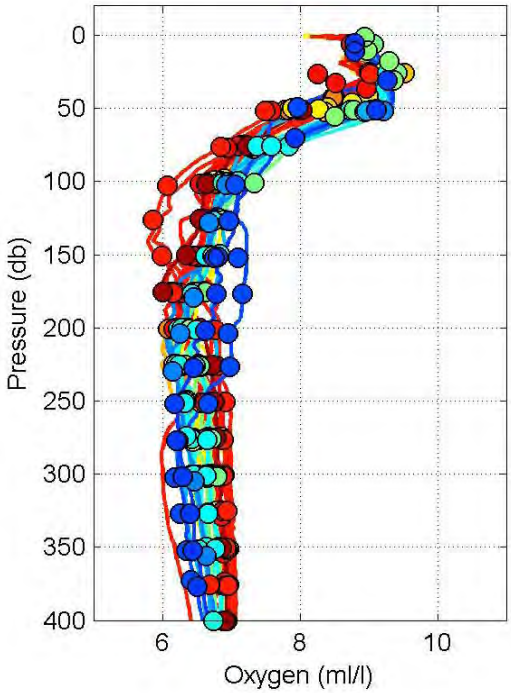


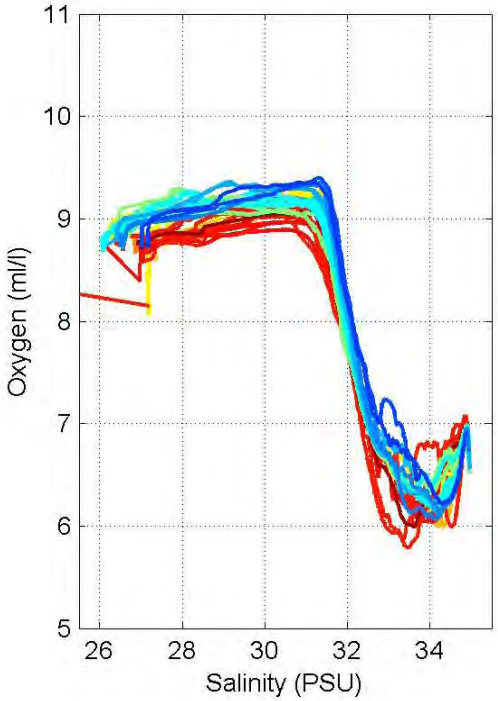


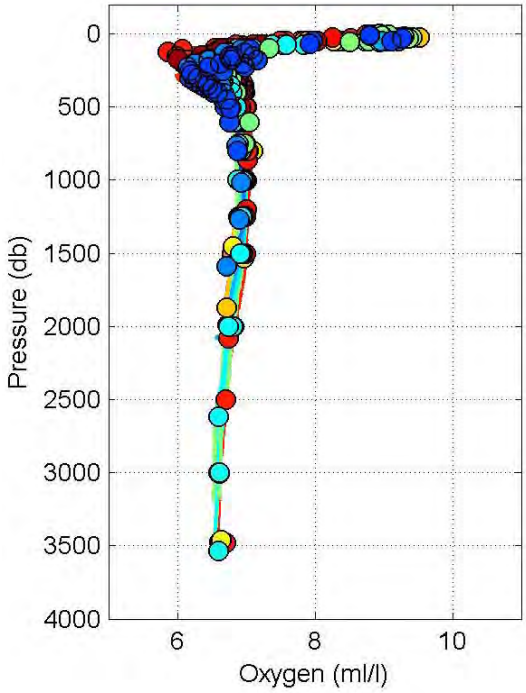


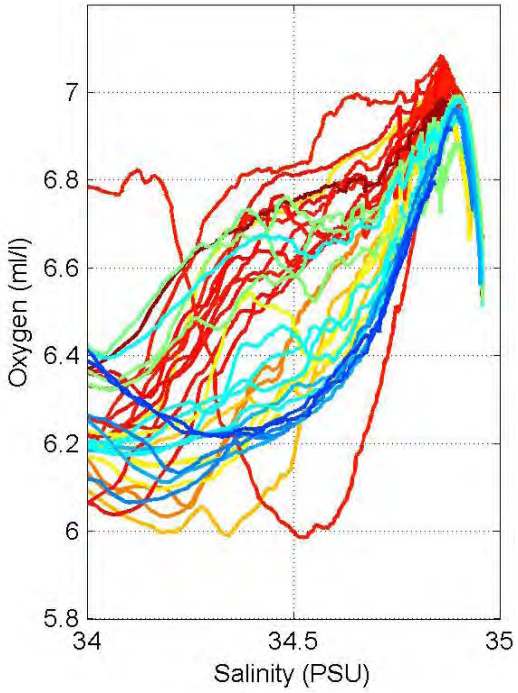


2002-23 Group: Canada Basin, Property: Oxygen

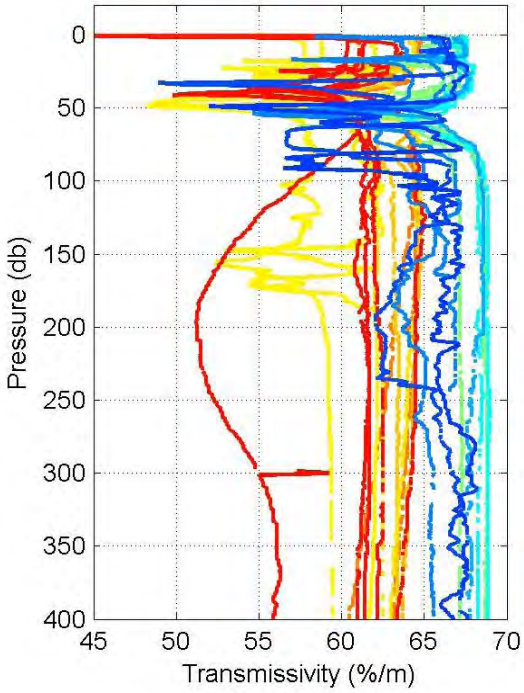


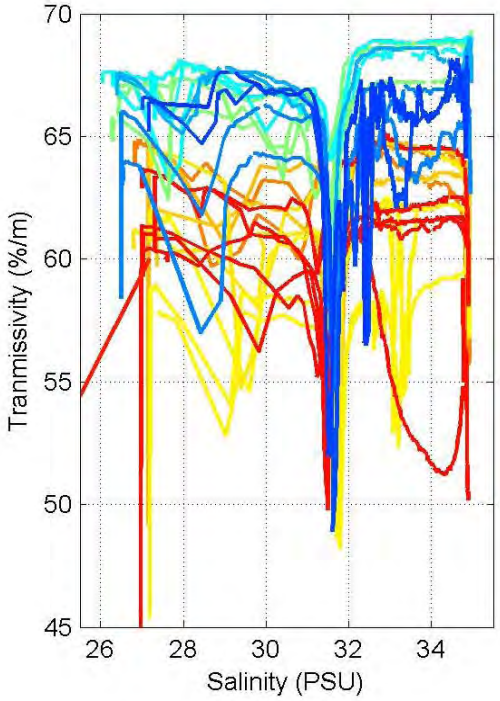


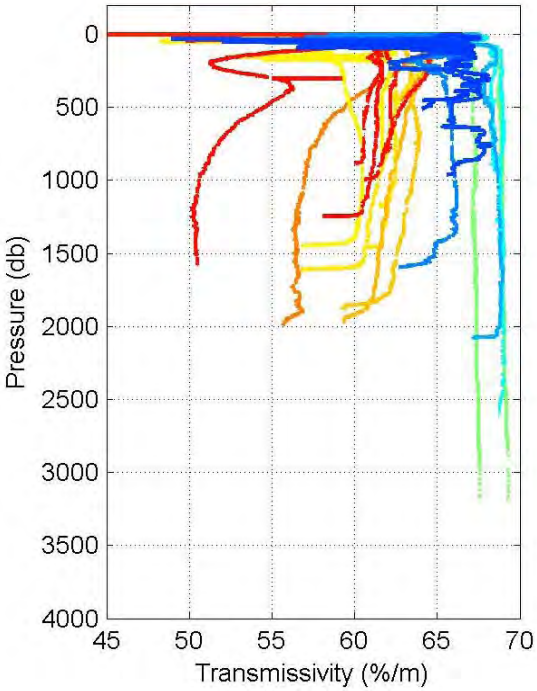


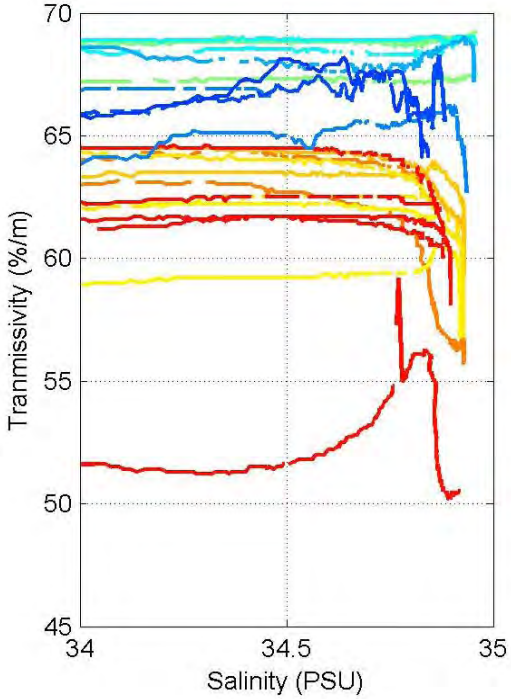


2002-23 Group: Canada Basin, Property: Transmissivity

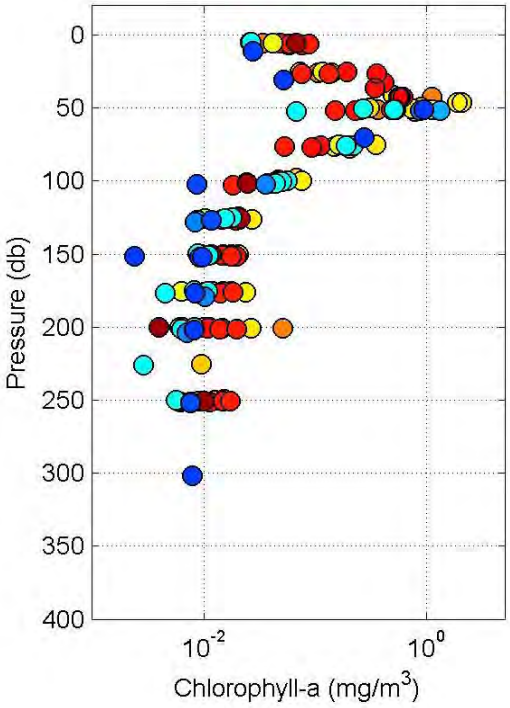


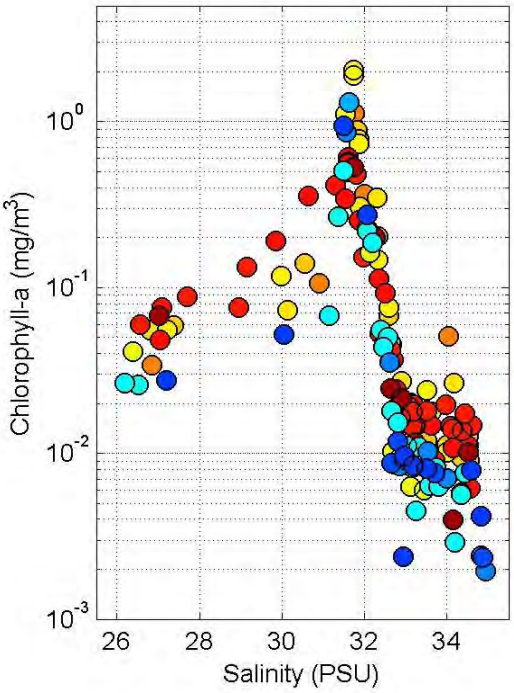


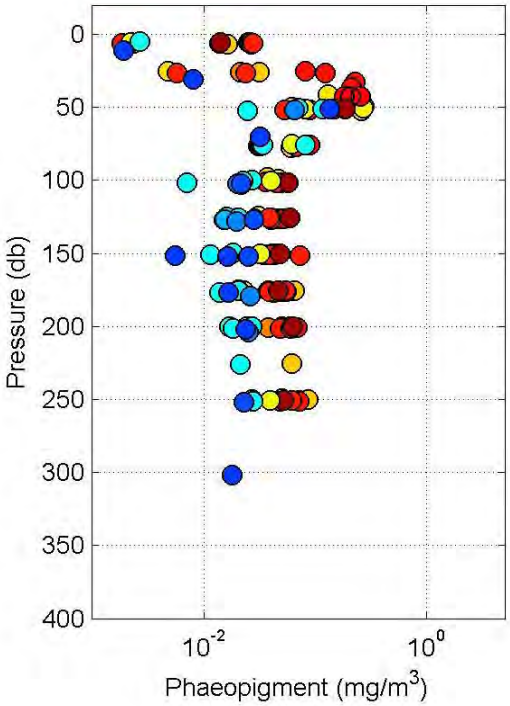


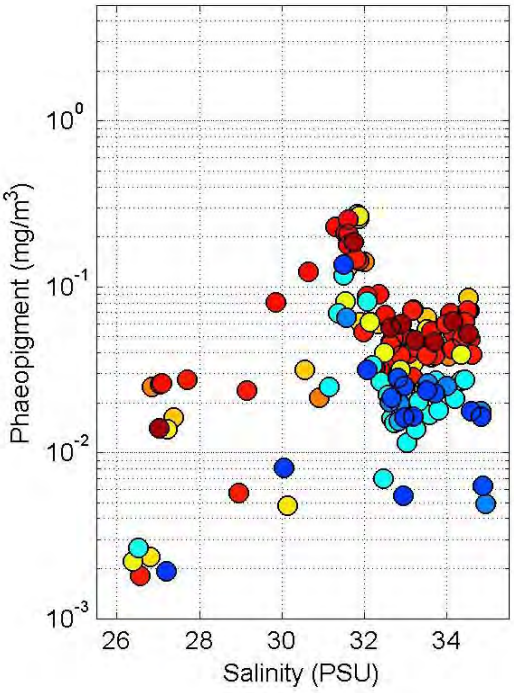


2002-23 Group: Canada Basin, Property: Chlorophyll-a, Phaeopigment

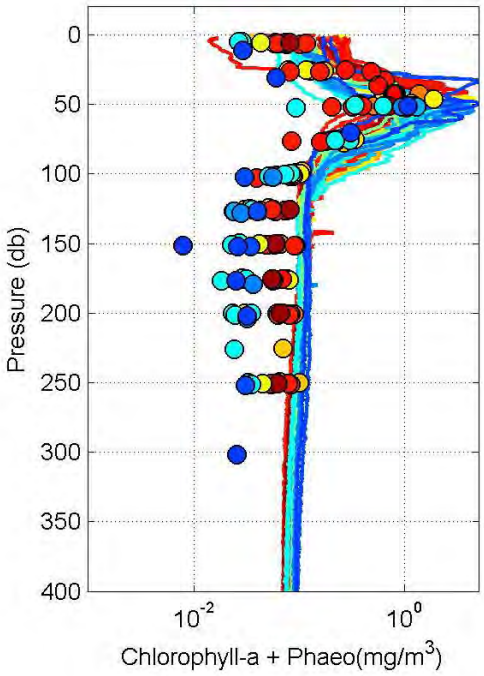


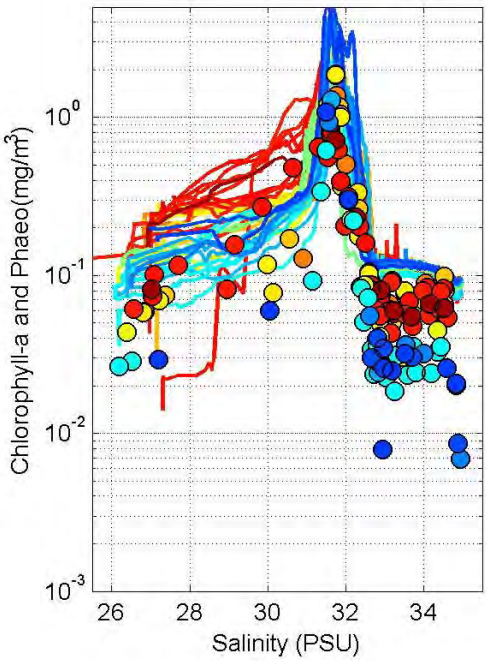




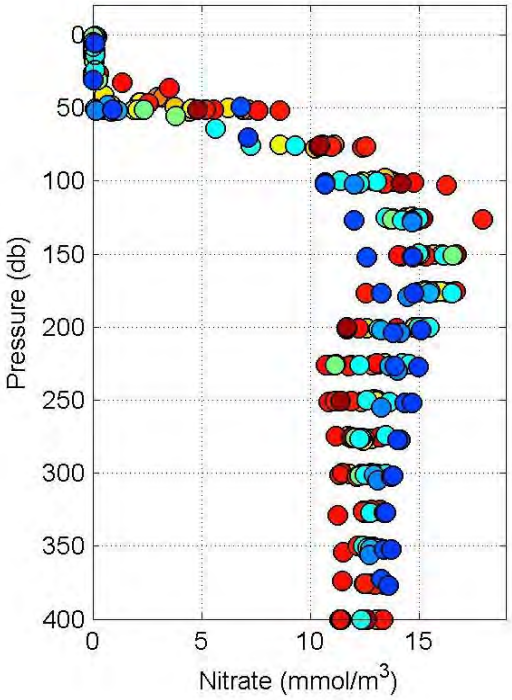


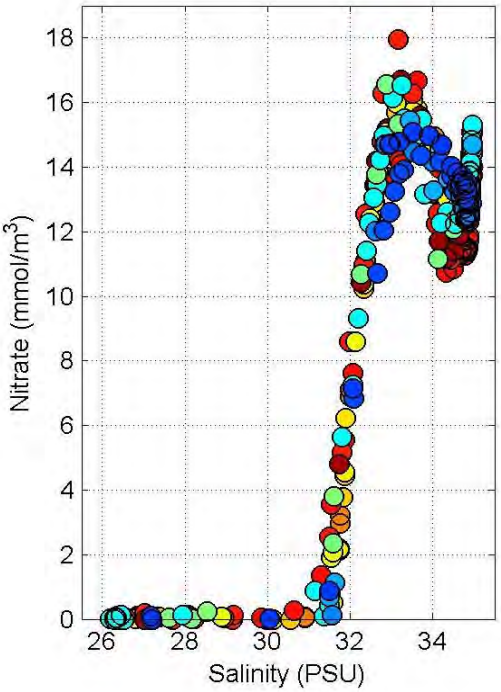
2002-23 Group: Canada Basin, Property: Combined Chlorophyll-a and Phaeopigment

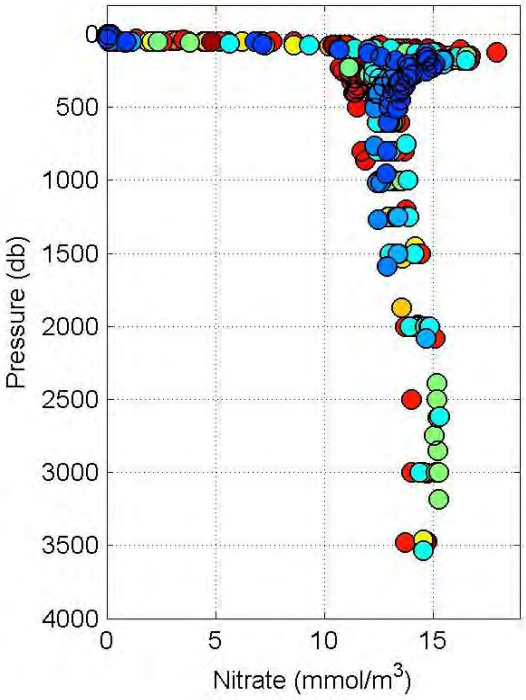


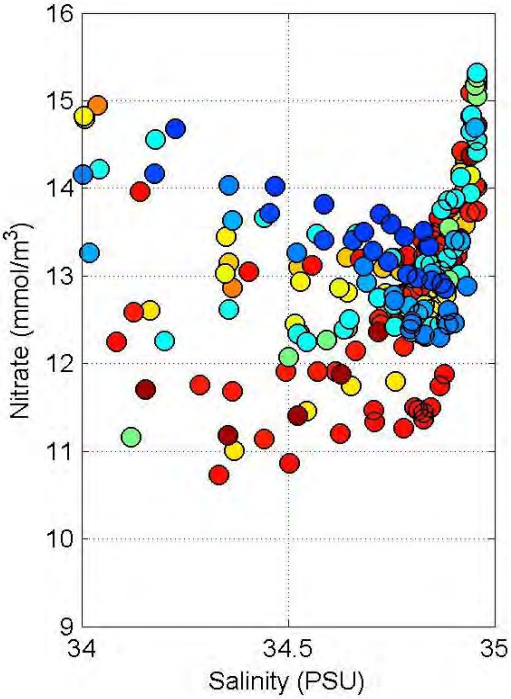


2002-23 Group: Canada Basin, Property: Nitrate and Nitrite

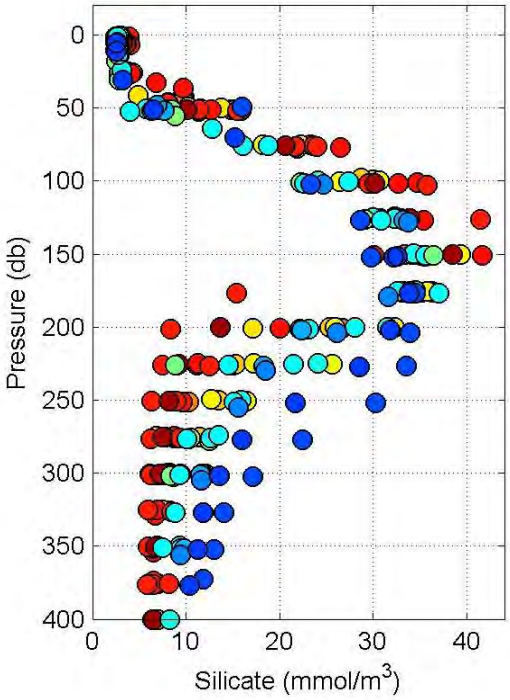


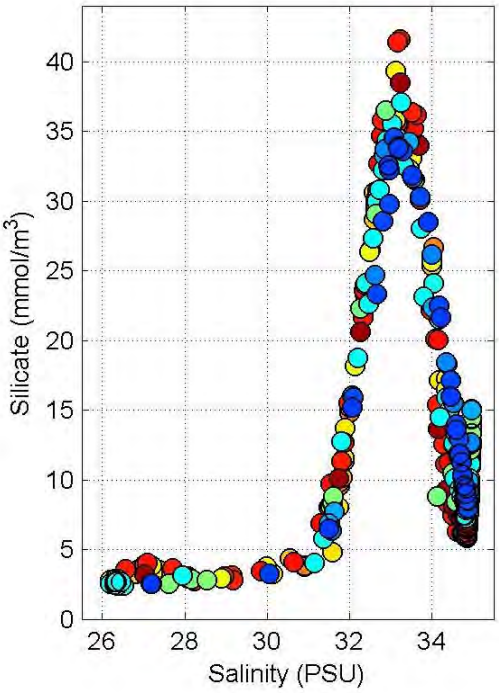


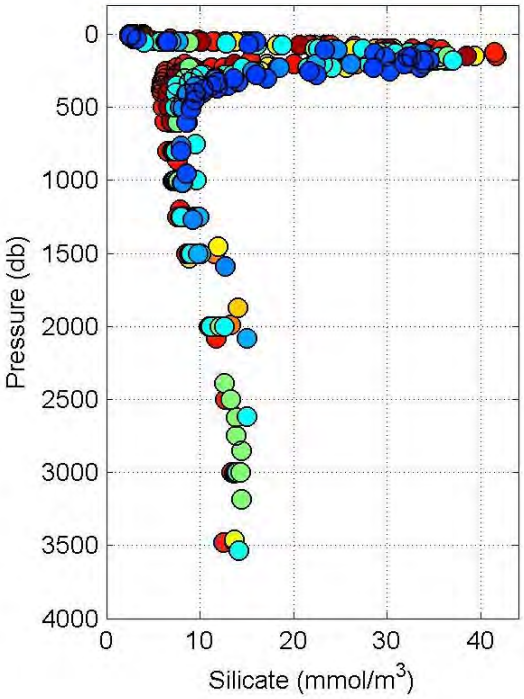


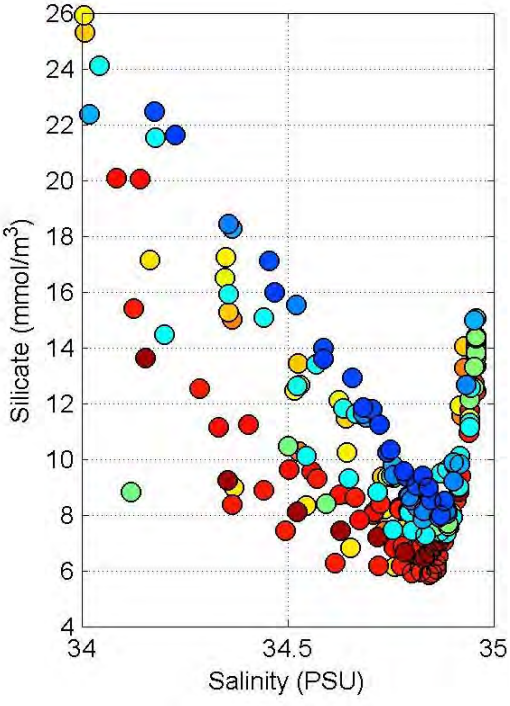


2002-23 Group: Canada Basin, Property: Silicate

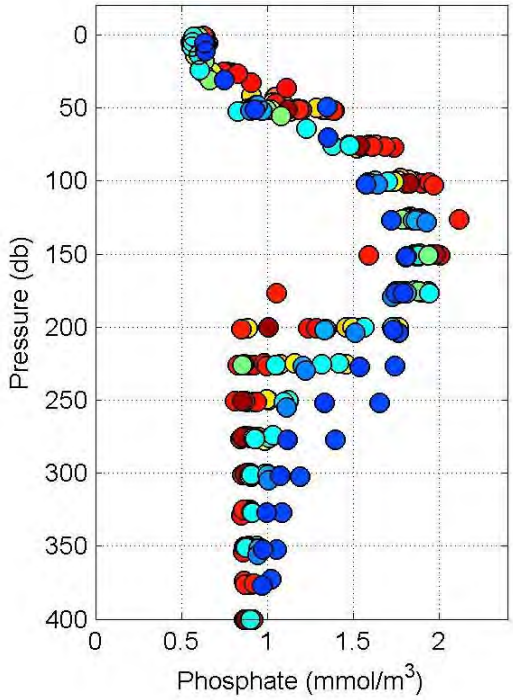


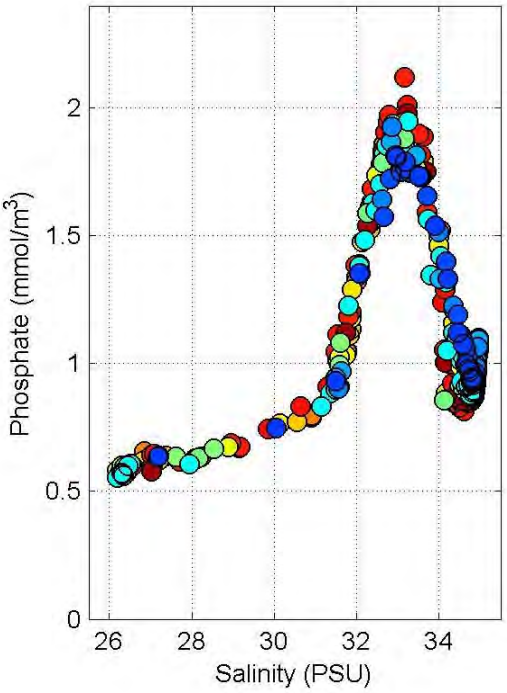


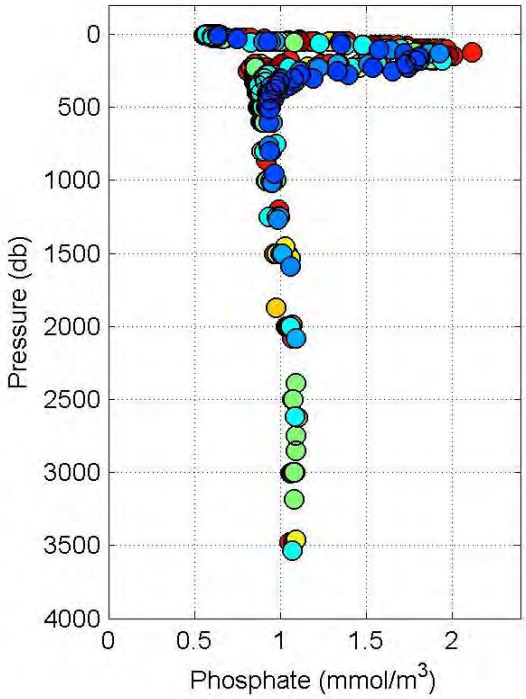


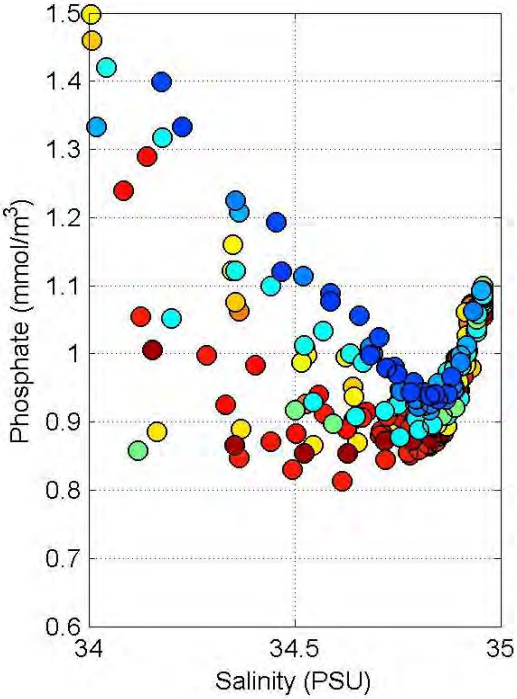


2002-23 Group: Canada Basin, Property: Phosphate

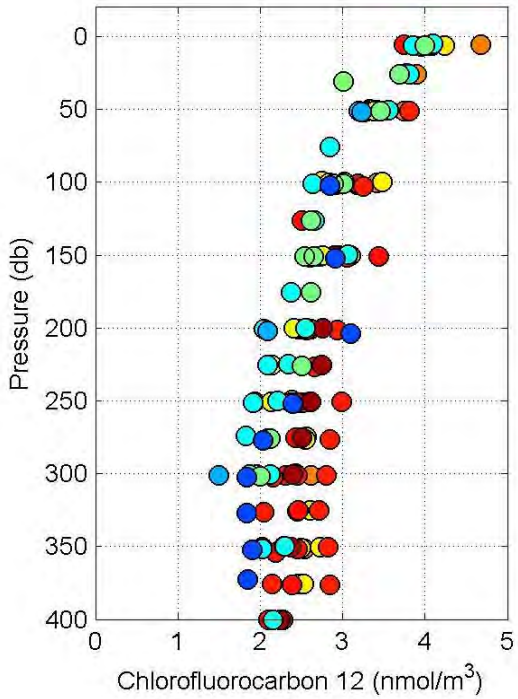


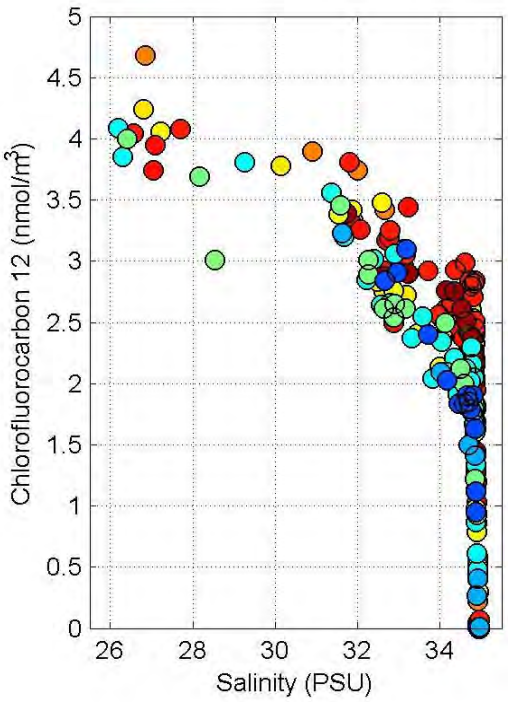


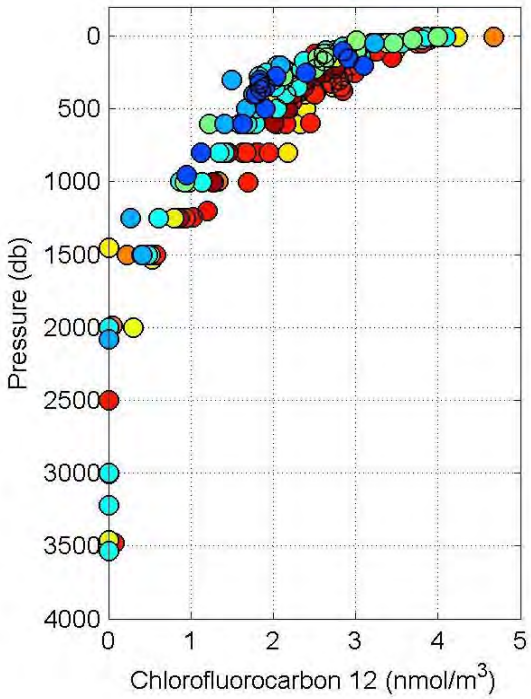


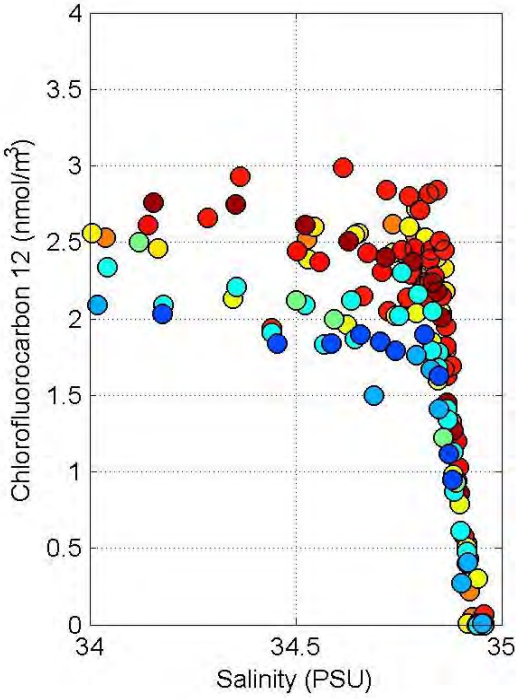


2002-23 Group: Canada Basin, Property: Chlorofluorcarbon-12

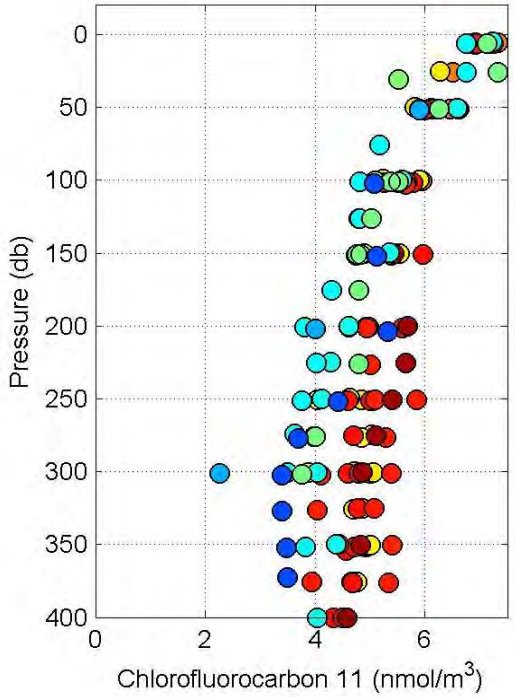


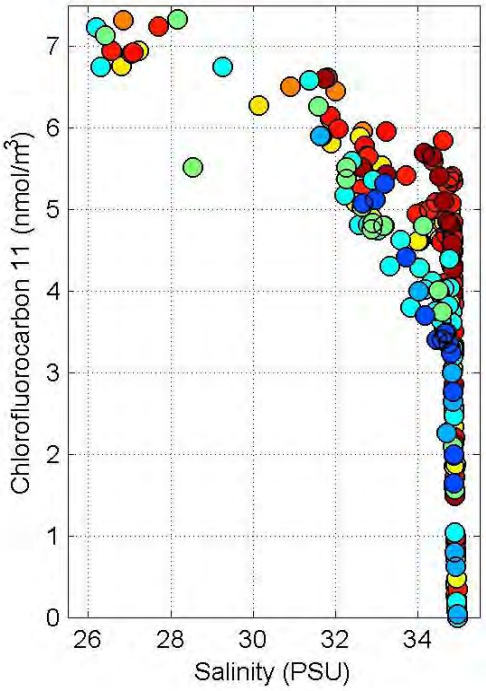


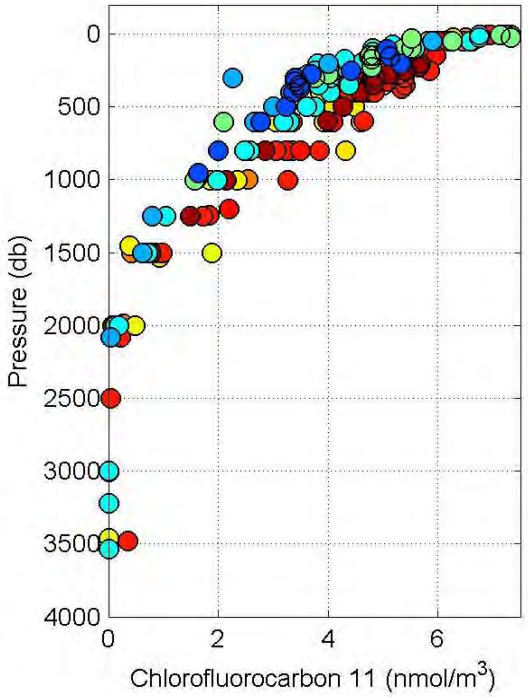


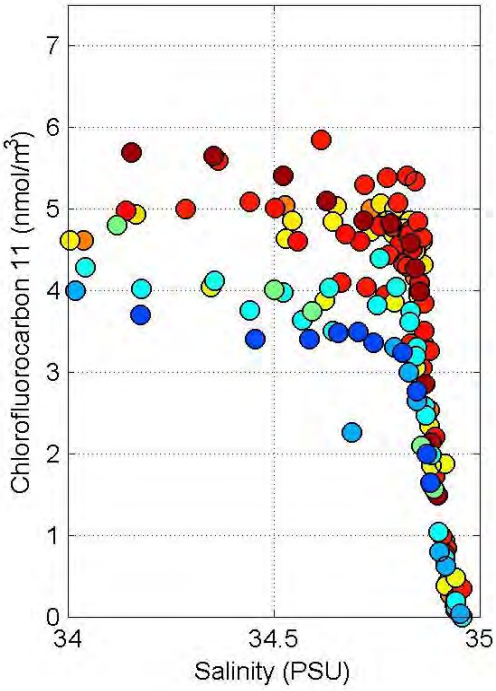


2002-23 Group: Canada Basin, Property: Chlorofluorcarbon-11

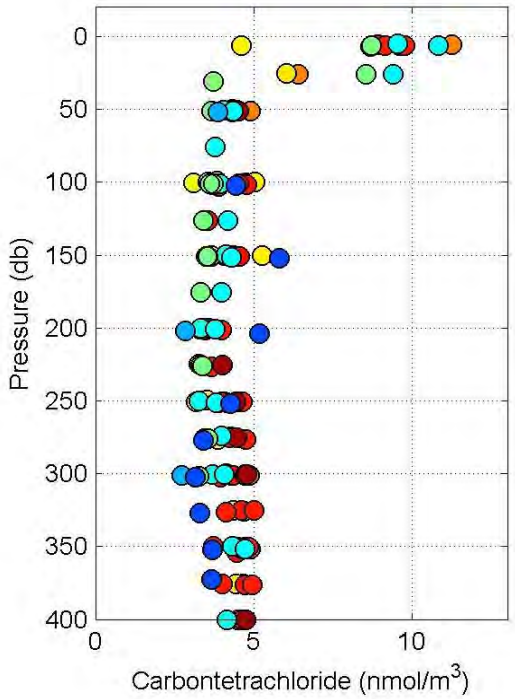


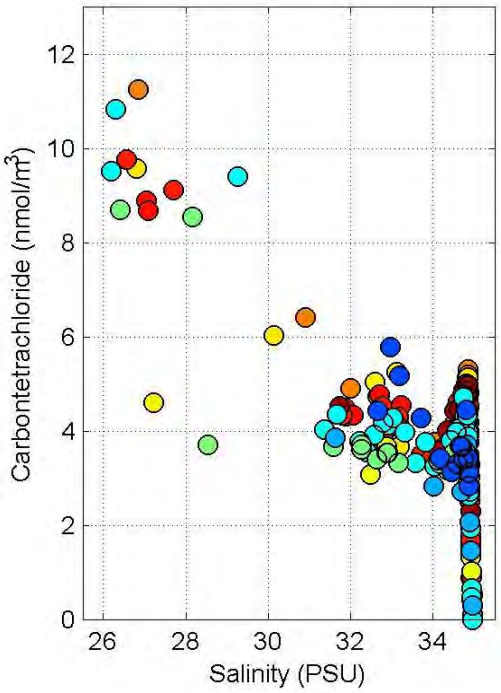


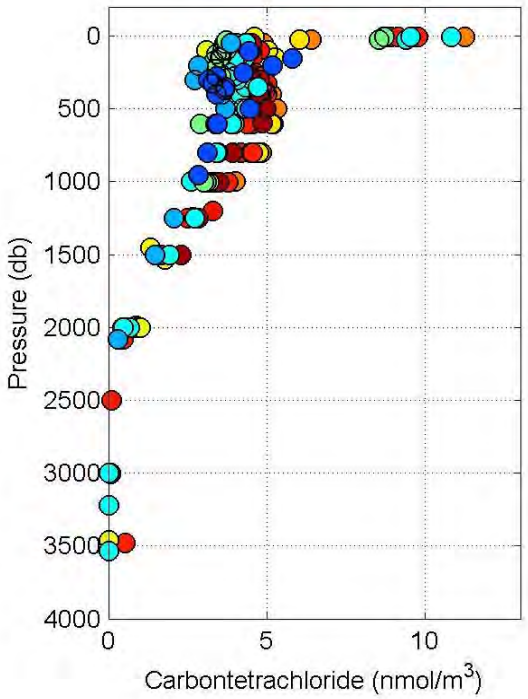


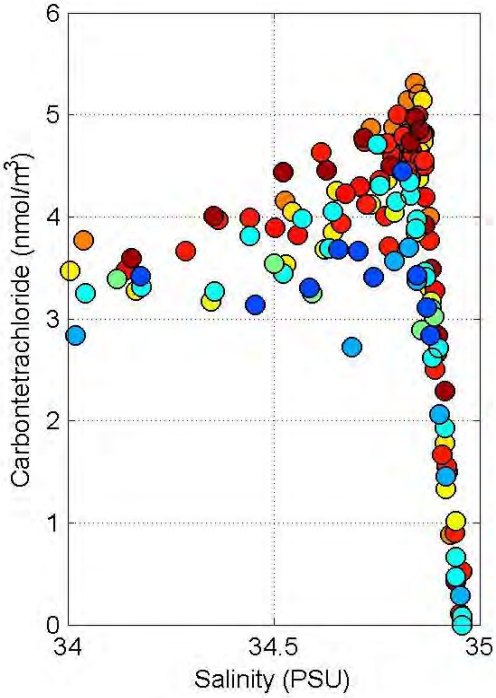


2002-23 Group: Canada Basin, Property: Carbontetrachloride

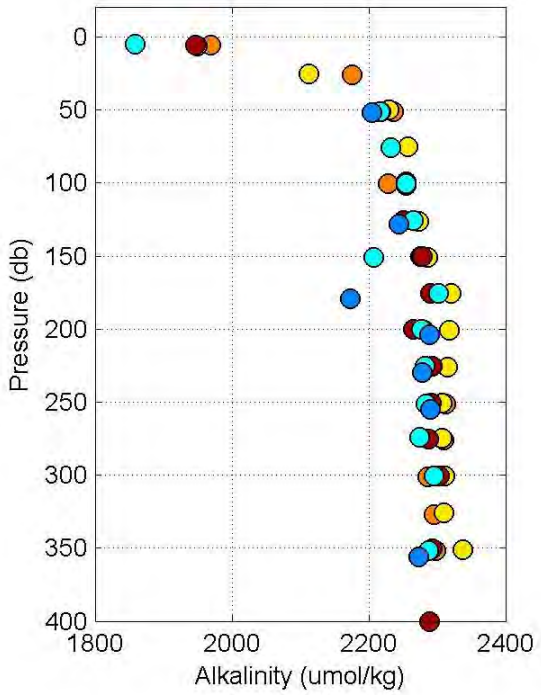


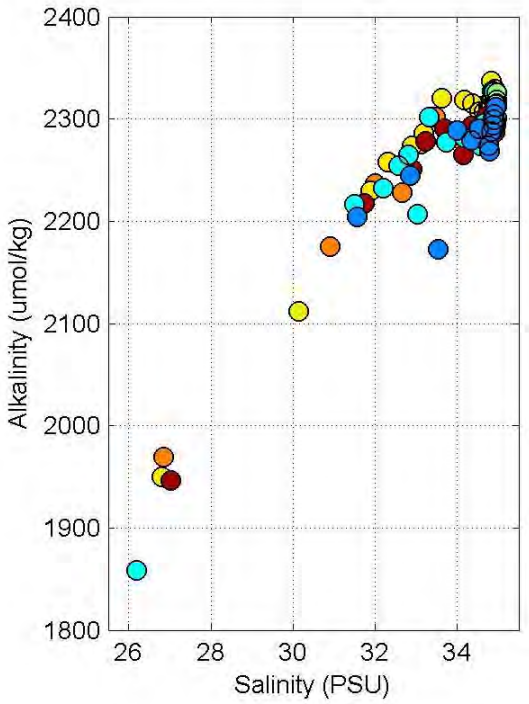


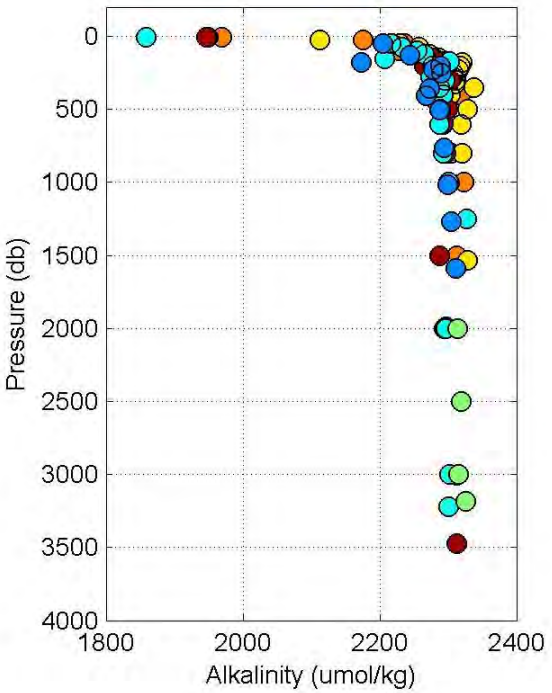


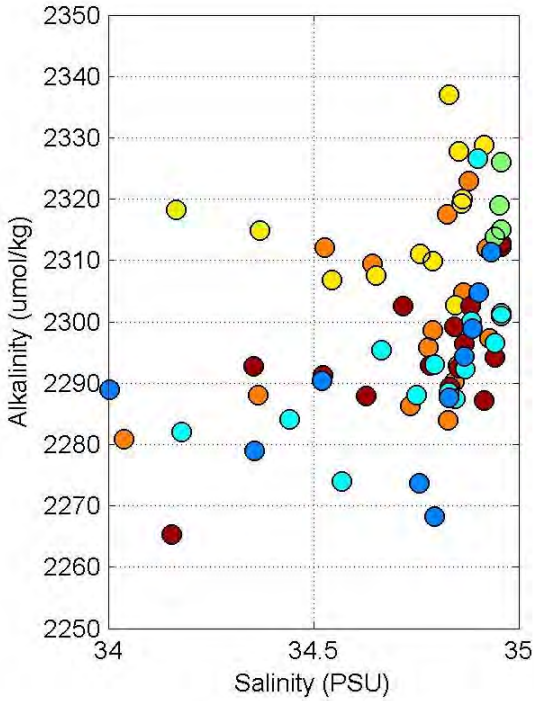


2002-23 Group: Canada Basin, Property: Alkalinity

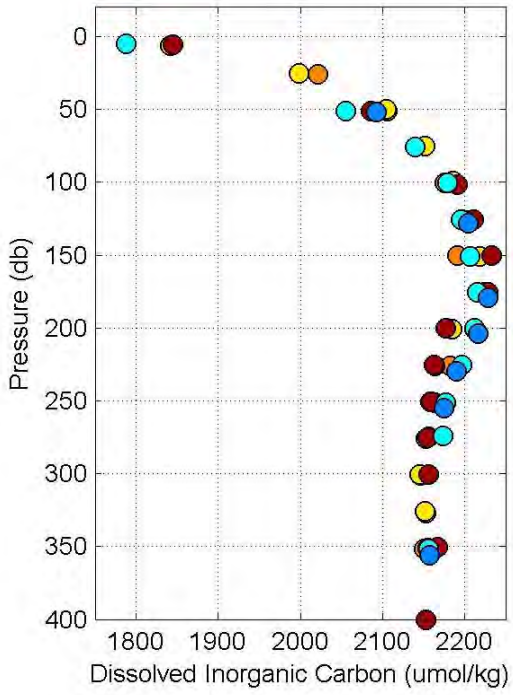


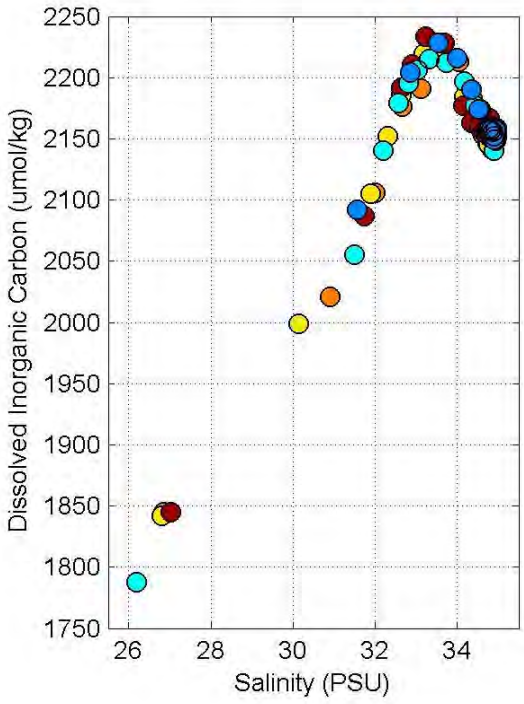


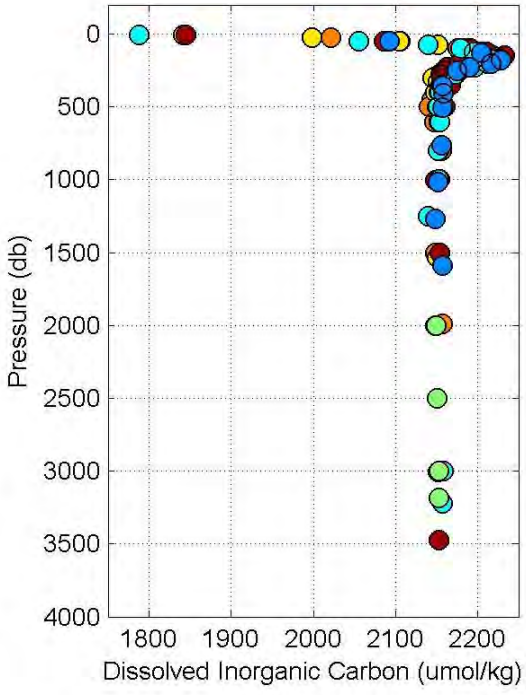


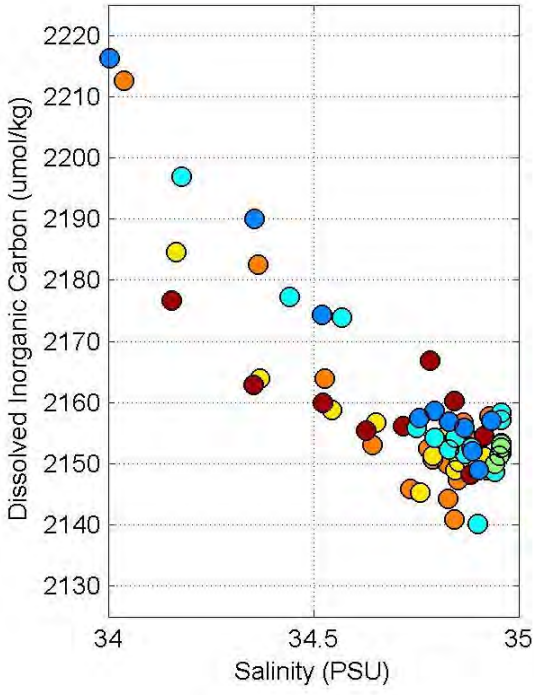


2002-23 Group: Canada Basin, Property: Dissolved Inorganic Carbon

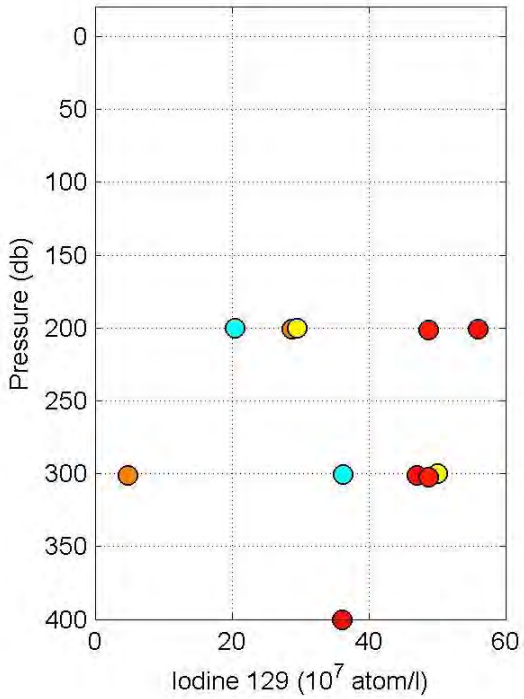


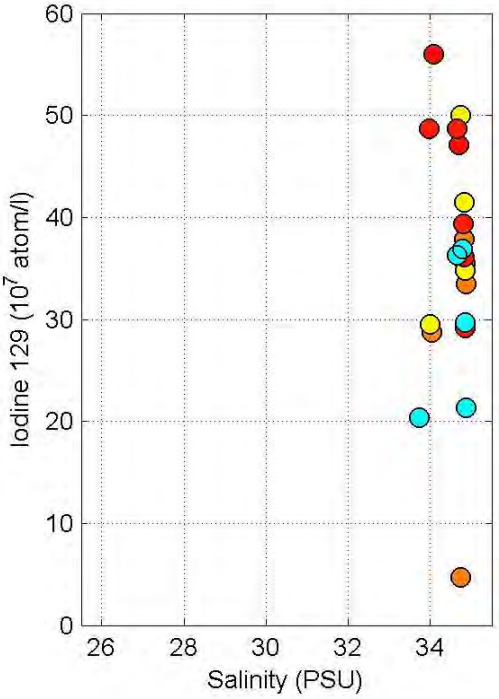


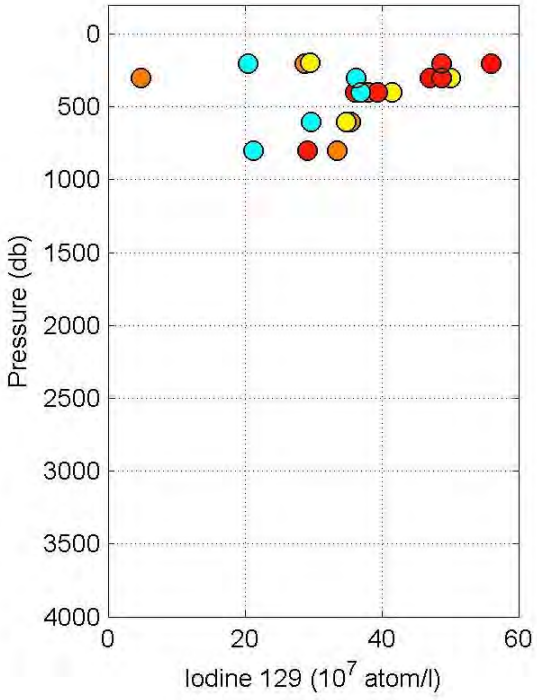


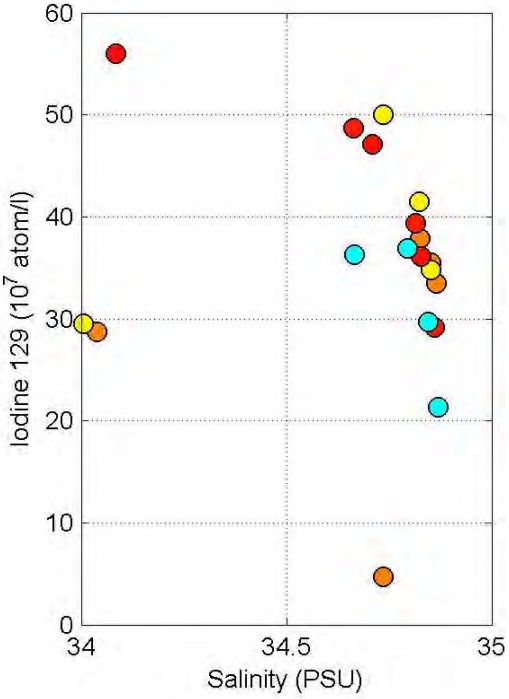


2002-23 Group: Canada Basin, Property: Iodine-129

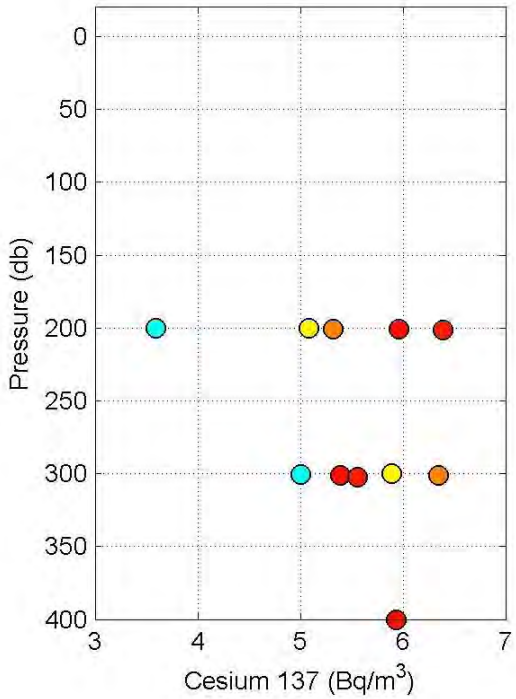


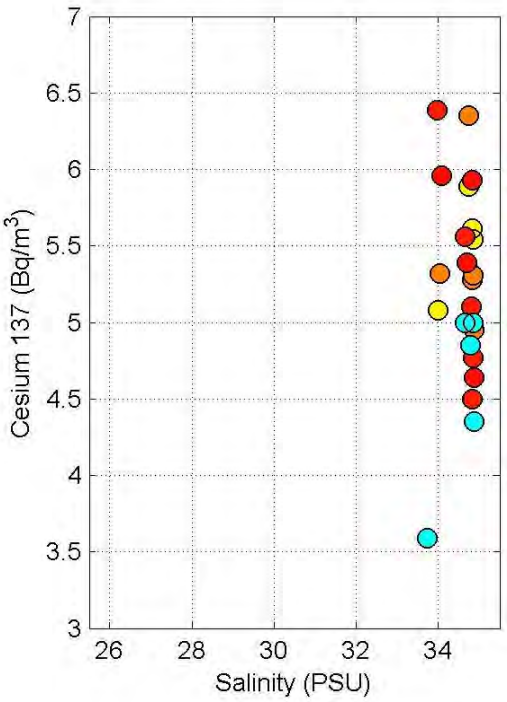


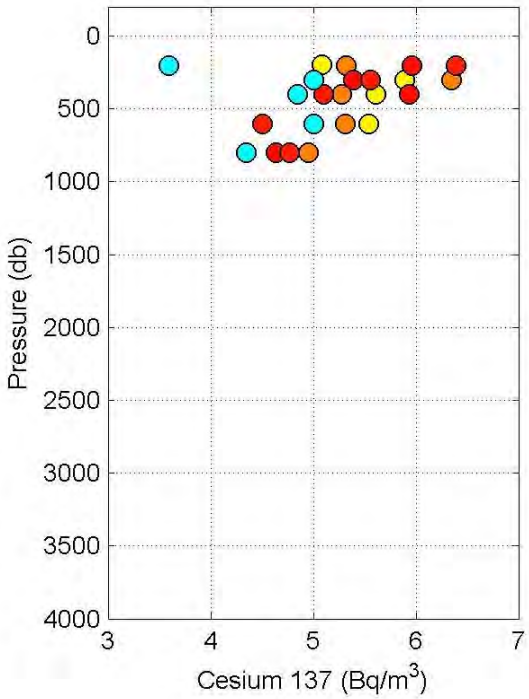


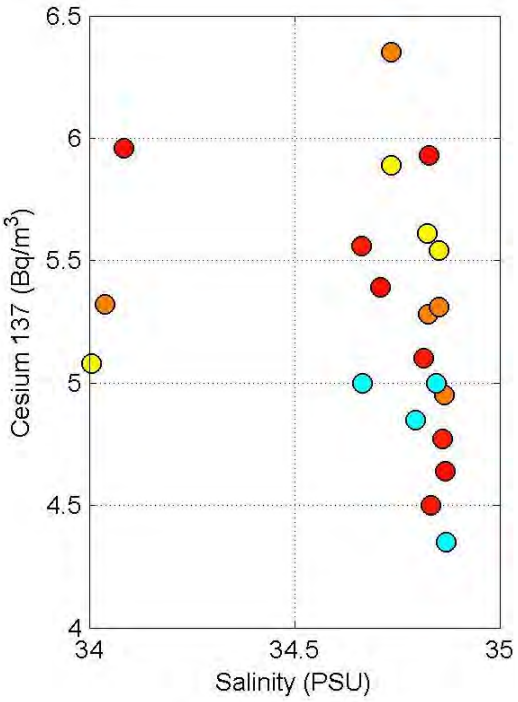


2002-23 Group: Canada Basin, Property: Cesium-137

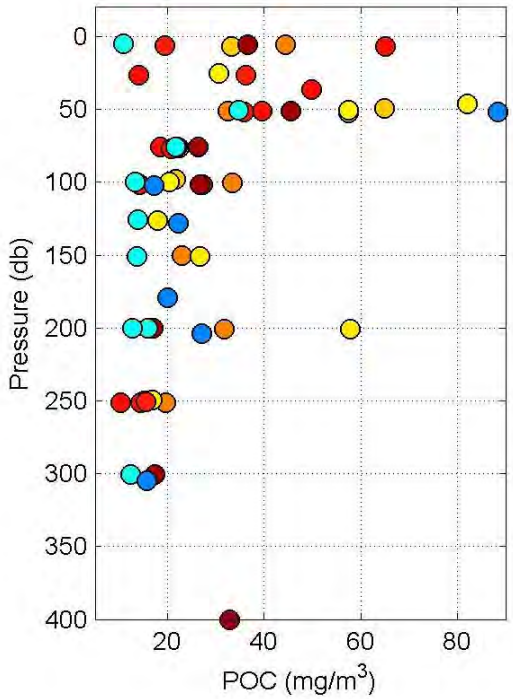


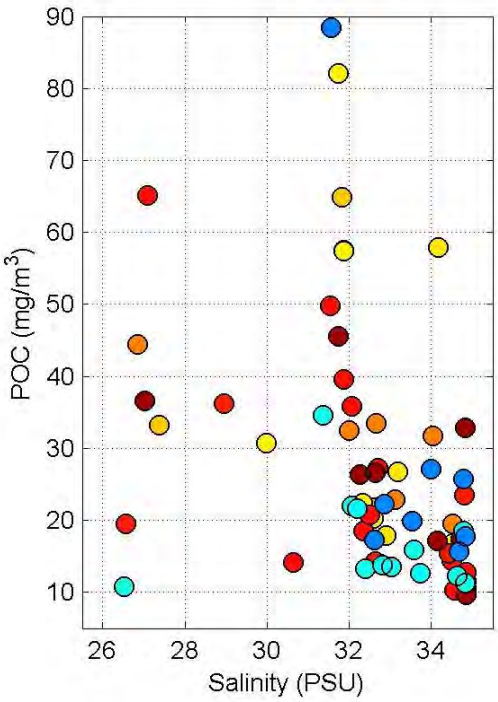


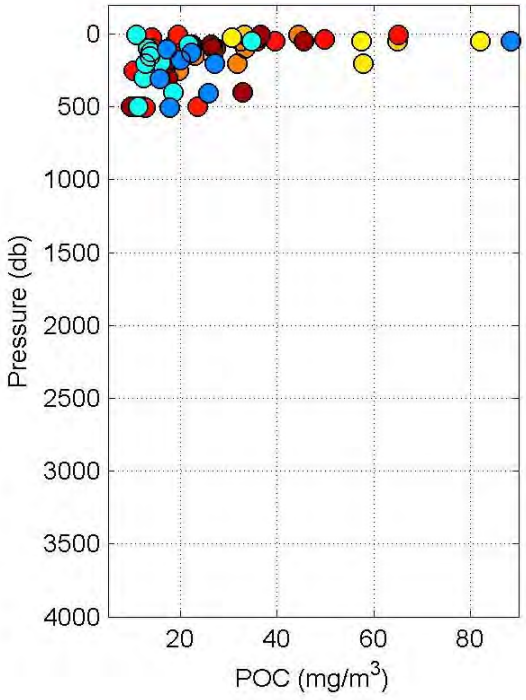


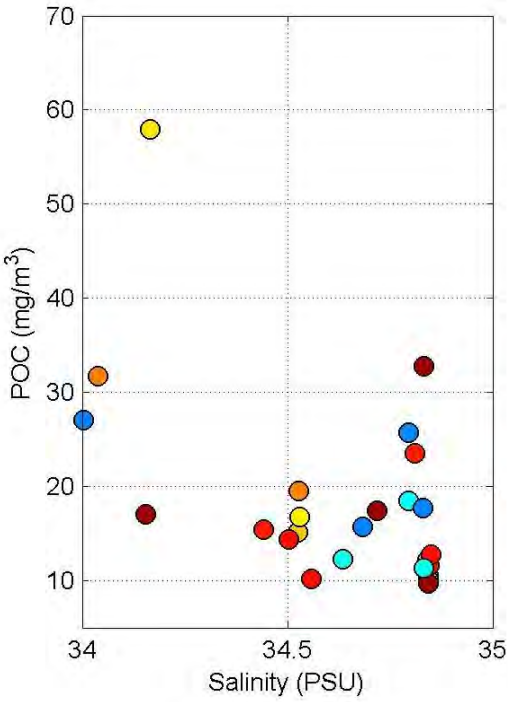


2002-23 Group: Canada Basin, Property: Particulate Organic Carbon

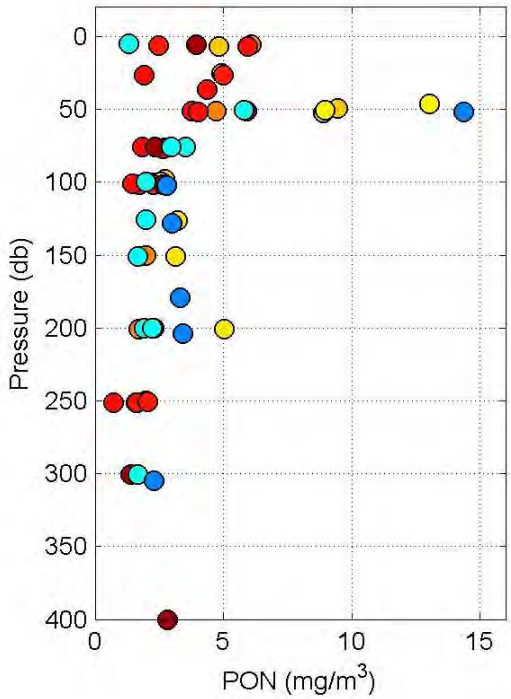


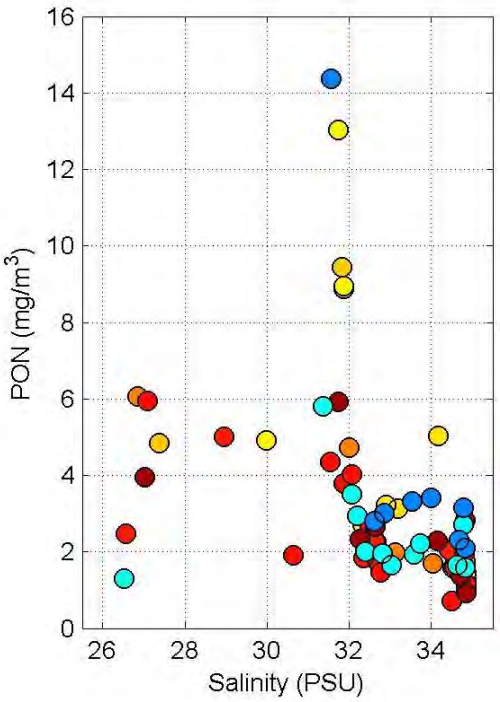


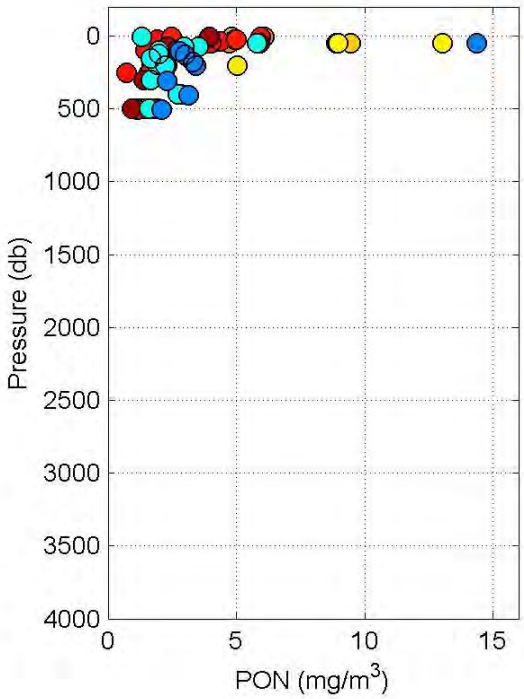


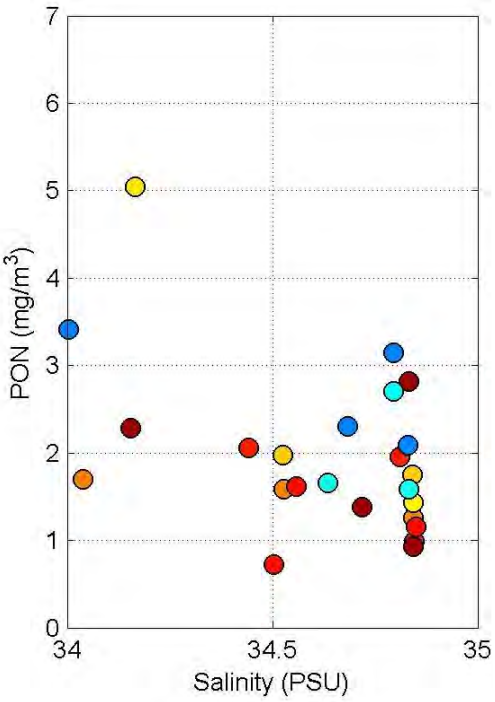


2002-23 Group: Canada Basin, Property: Particulate Organic Nitrogen

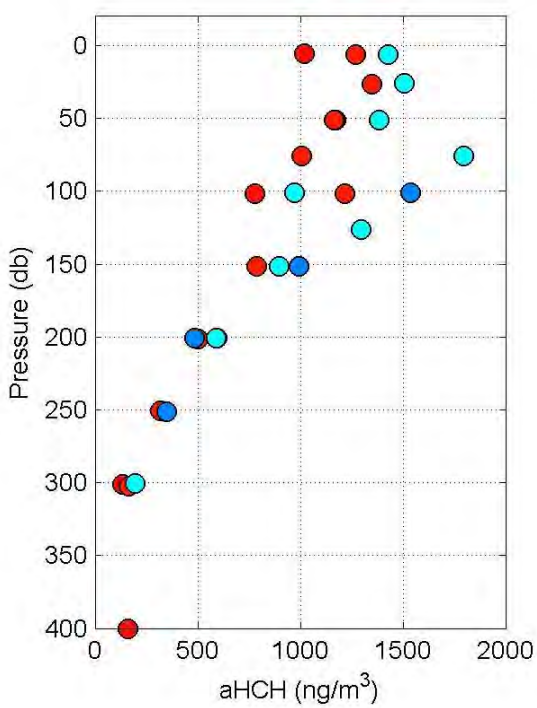


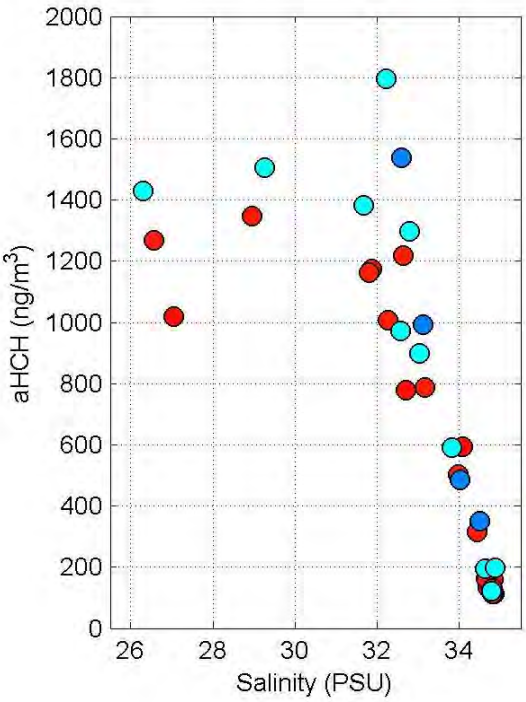


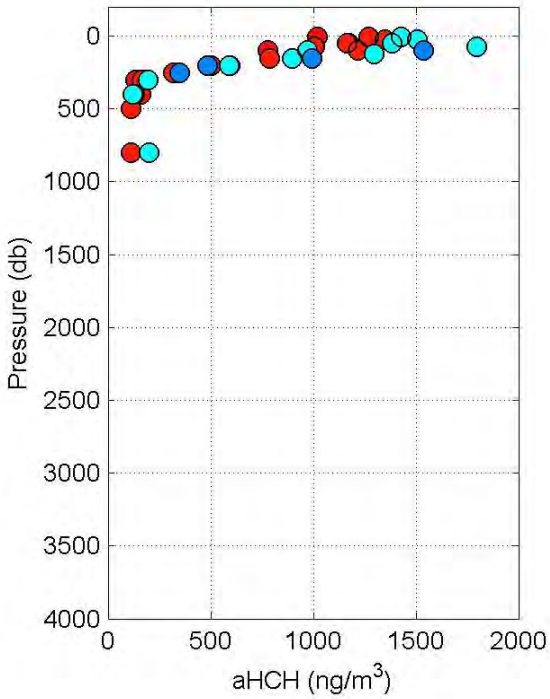


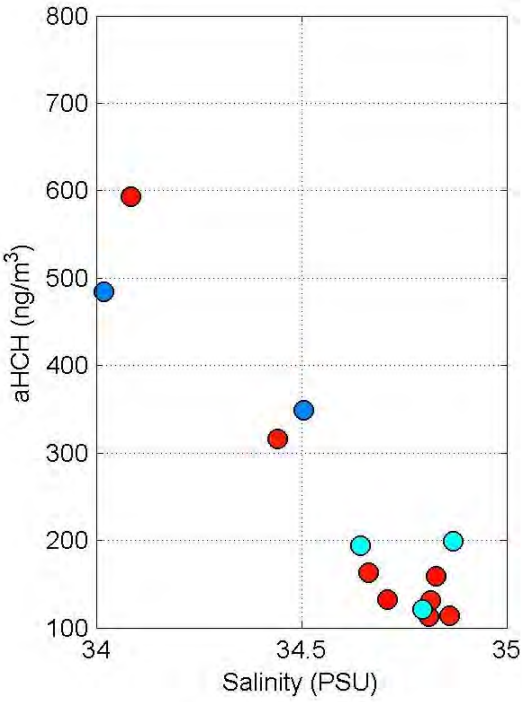


2002-23 Group: Canada Basin, Property: aHCH

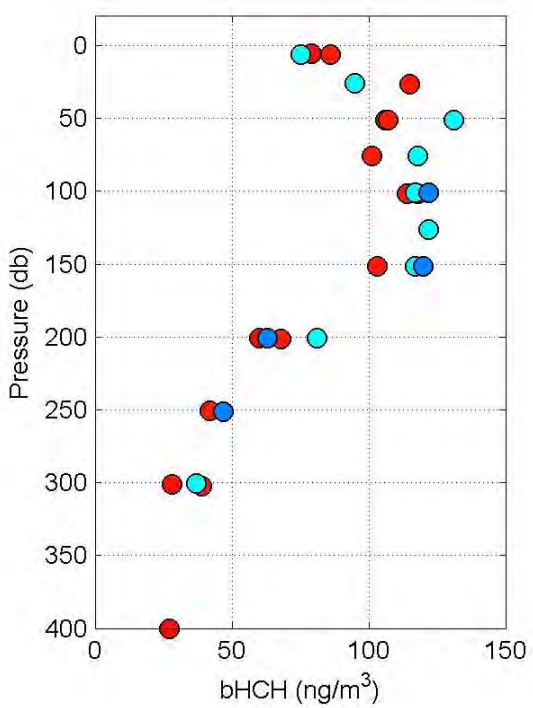


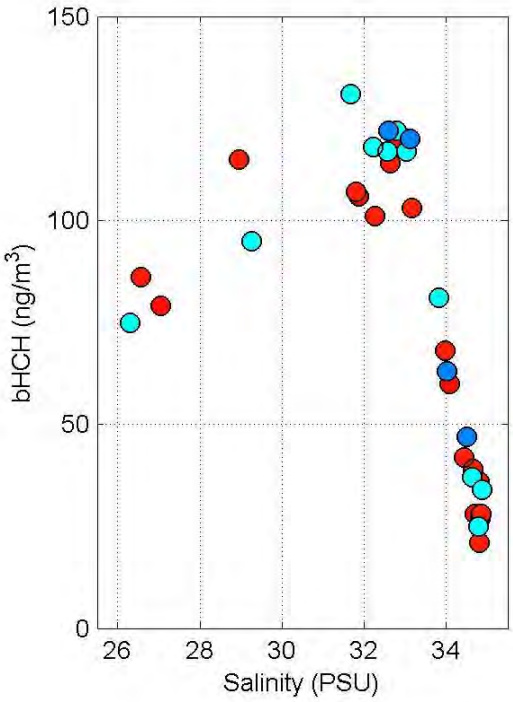


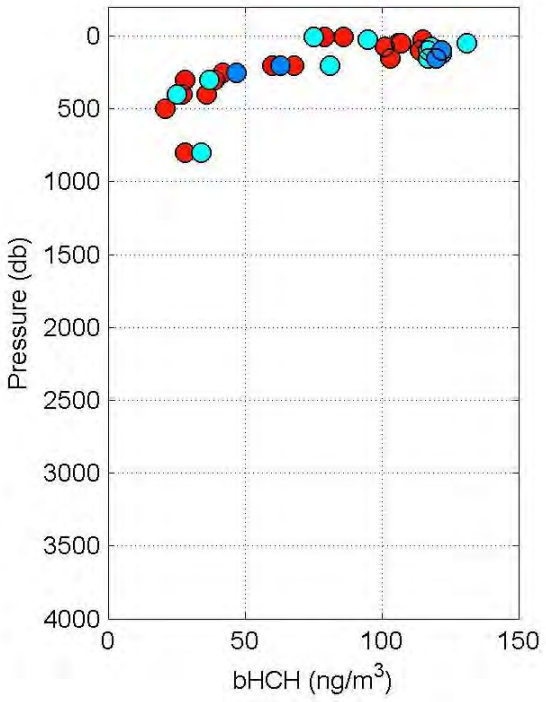


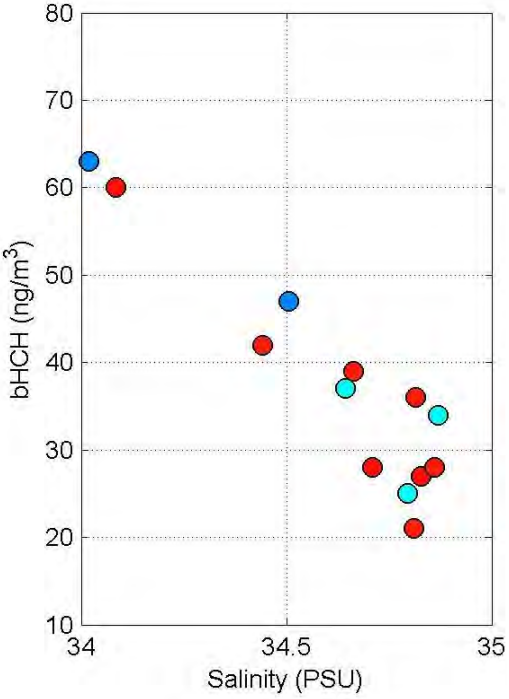


2002-23 Group: Canada Basin, Property: bHCH

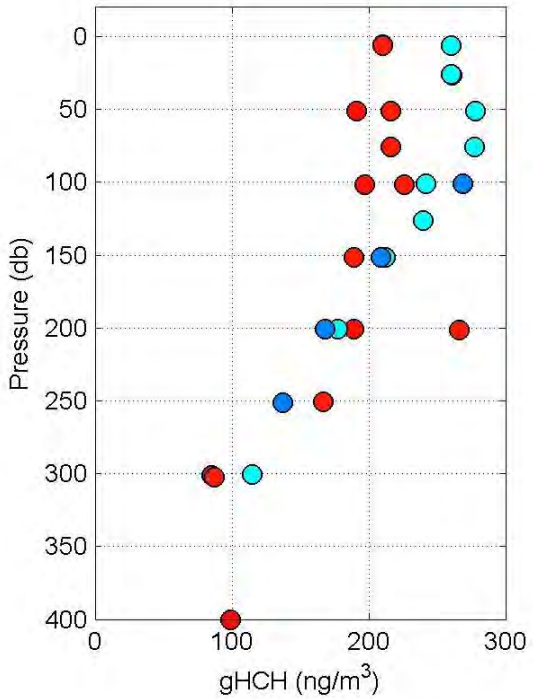


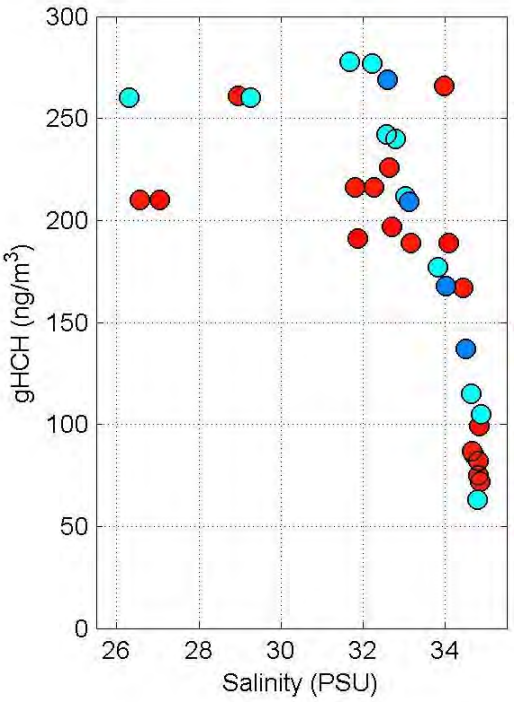


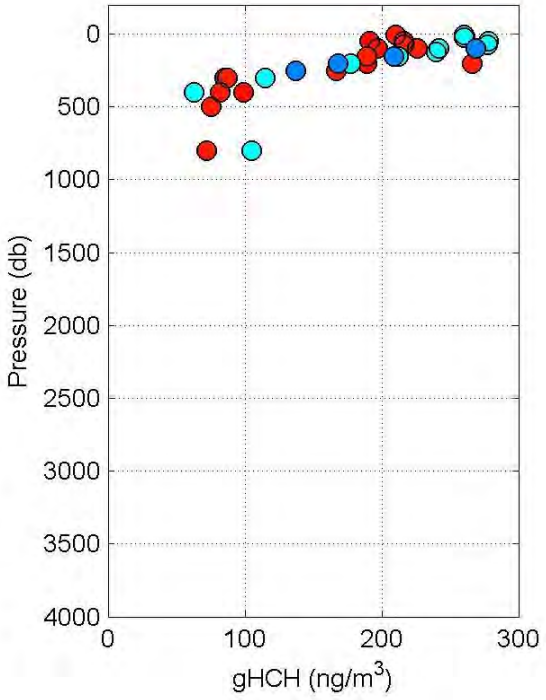


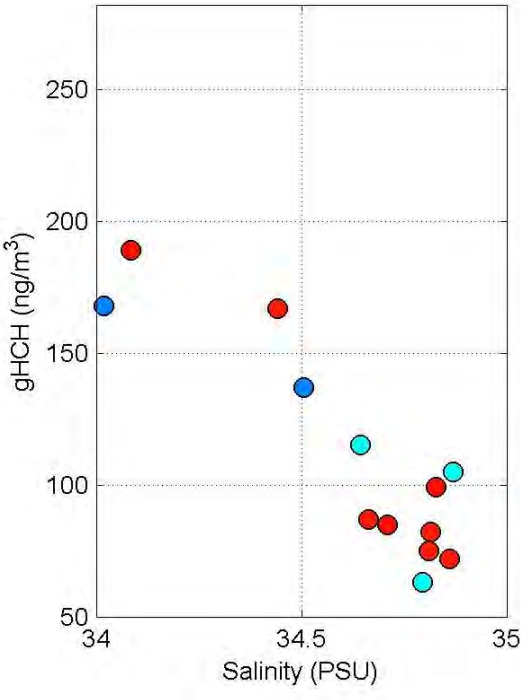


2002-23 Group: Canada Basin, Property: gHCH

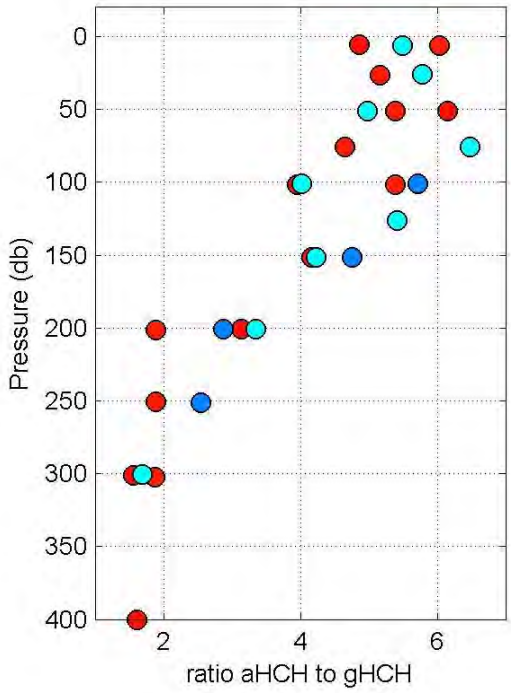


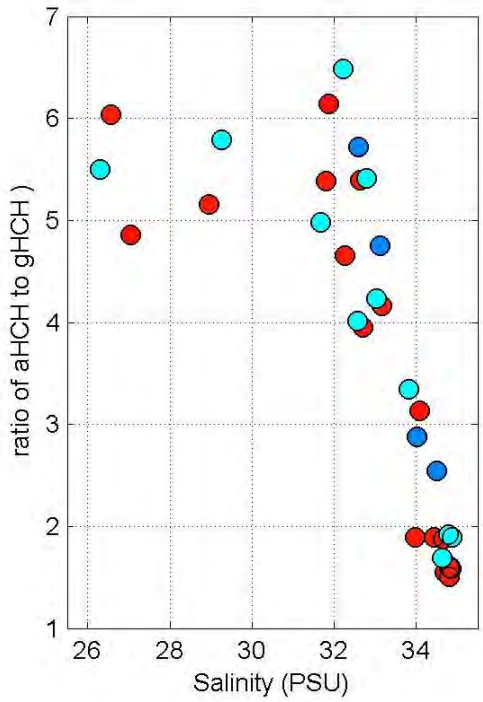


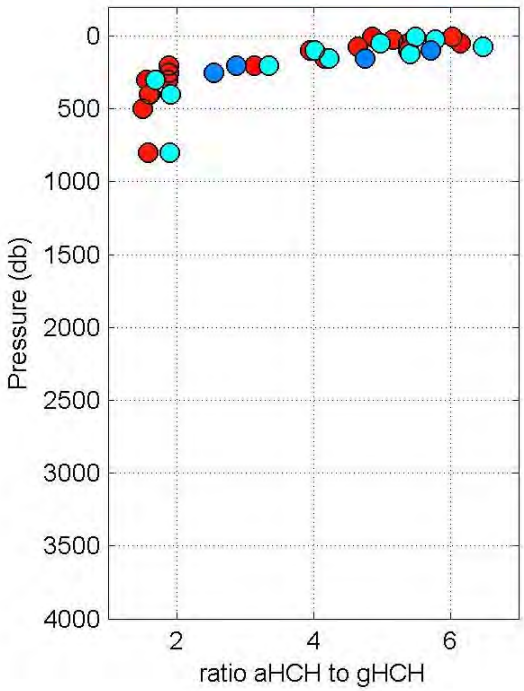


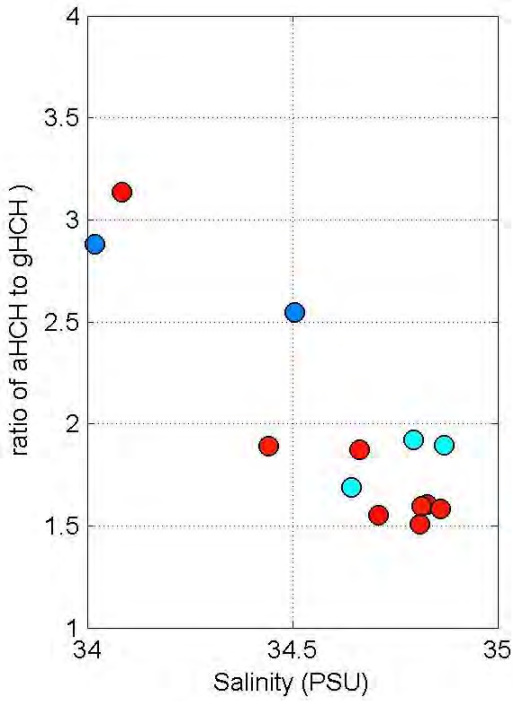


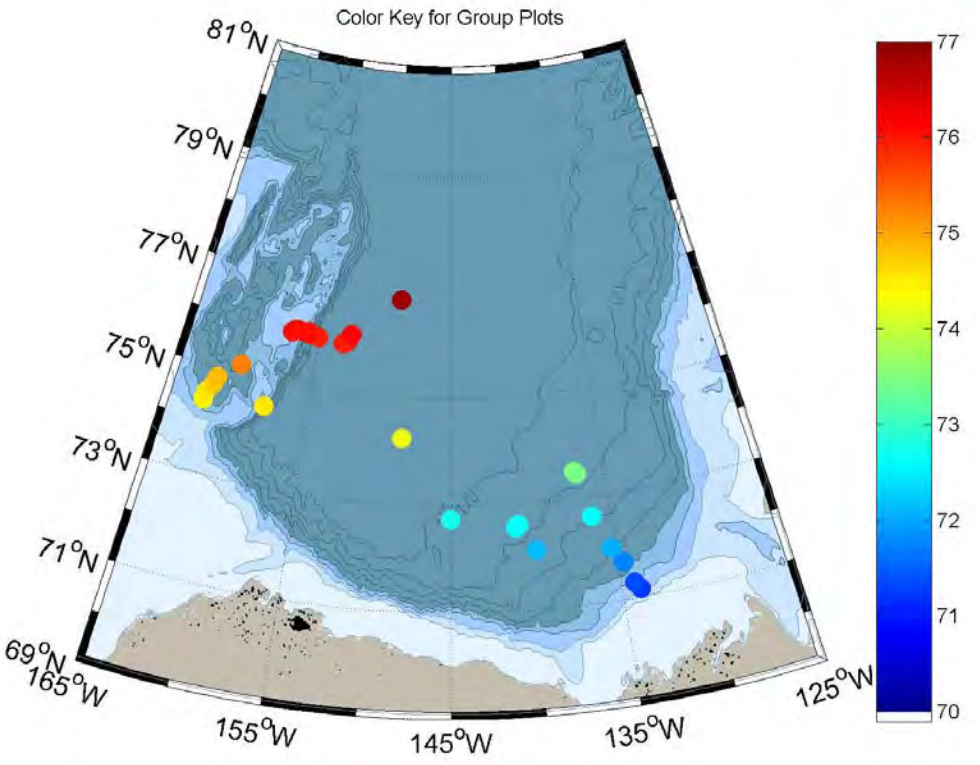
2002-23 Group: Canada Basin, Property: Ratio aHCH to gHCH





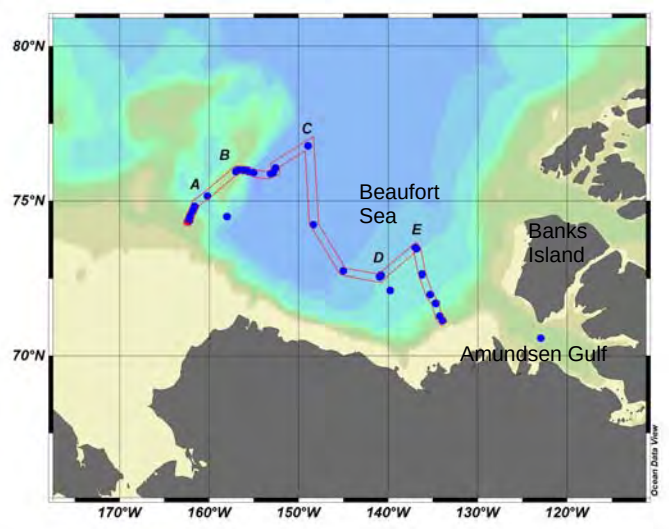




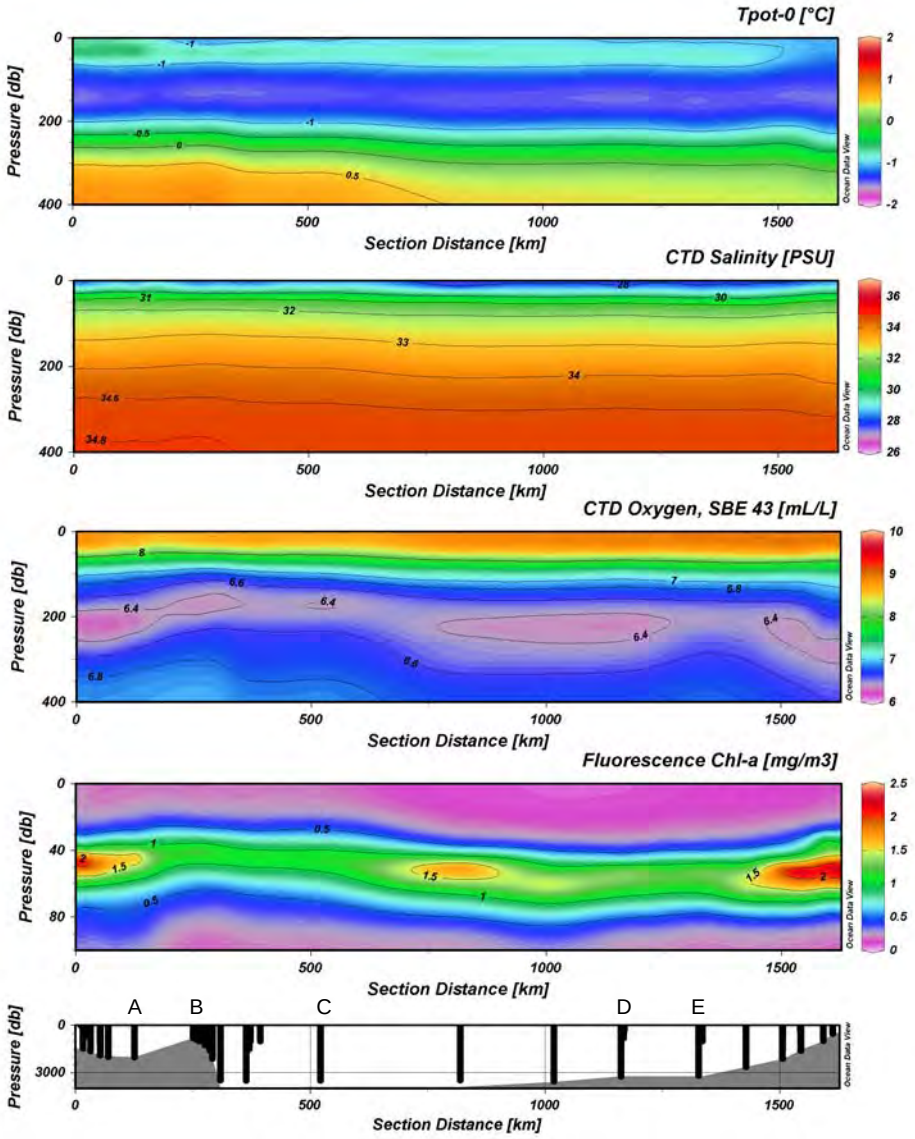

Color Key for Group Plots
81°N
79°N
77°N
75°N
73°N
71°N
69°N
165°W
155°W
145°W
135°W
125°W
77
76
75
74
73
72
71
70

4.6 DYNAMIC HEIGHT AND SECTION PLOTS

Mission 2002-23 ODV Sections

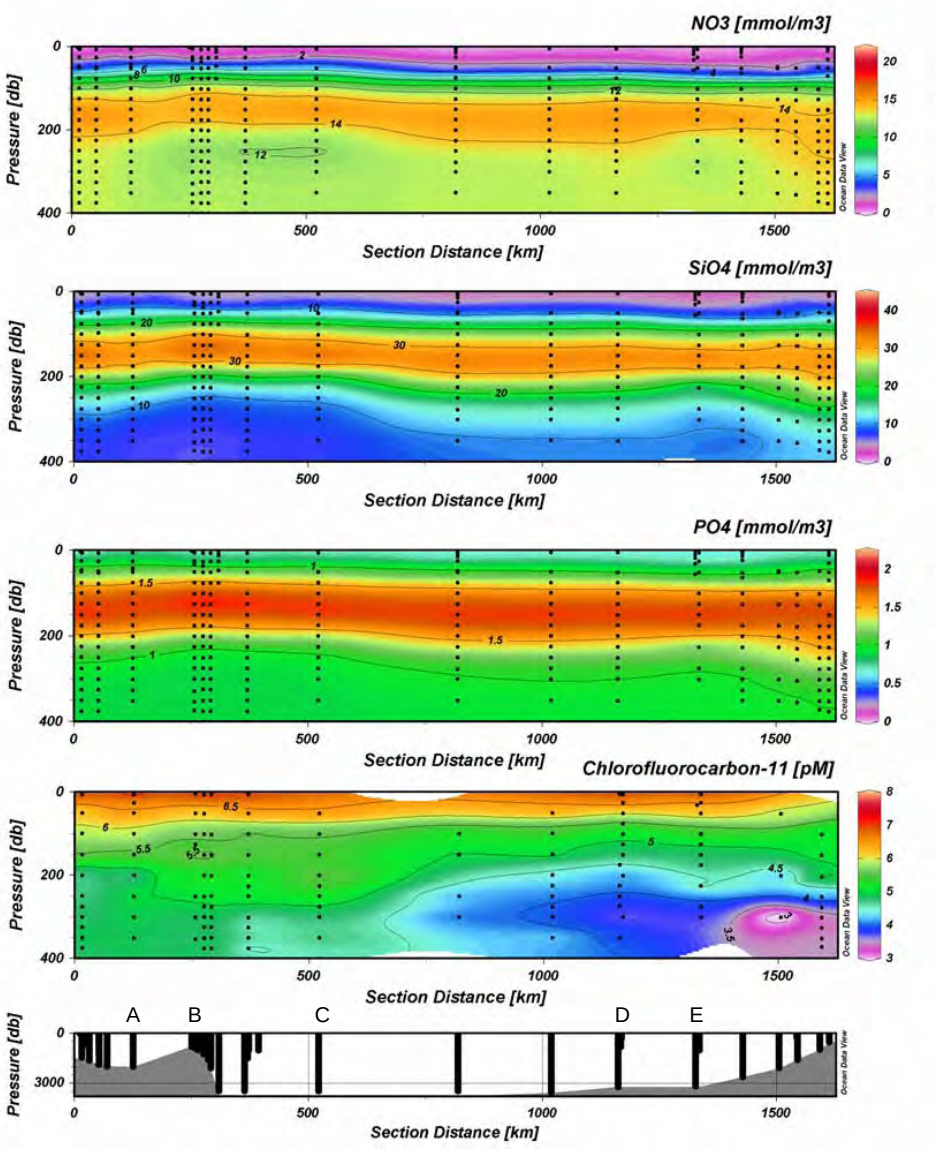


CTD, 0 to 400 db

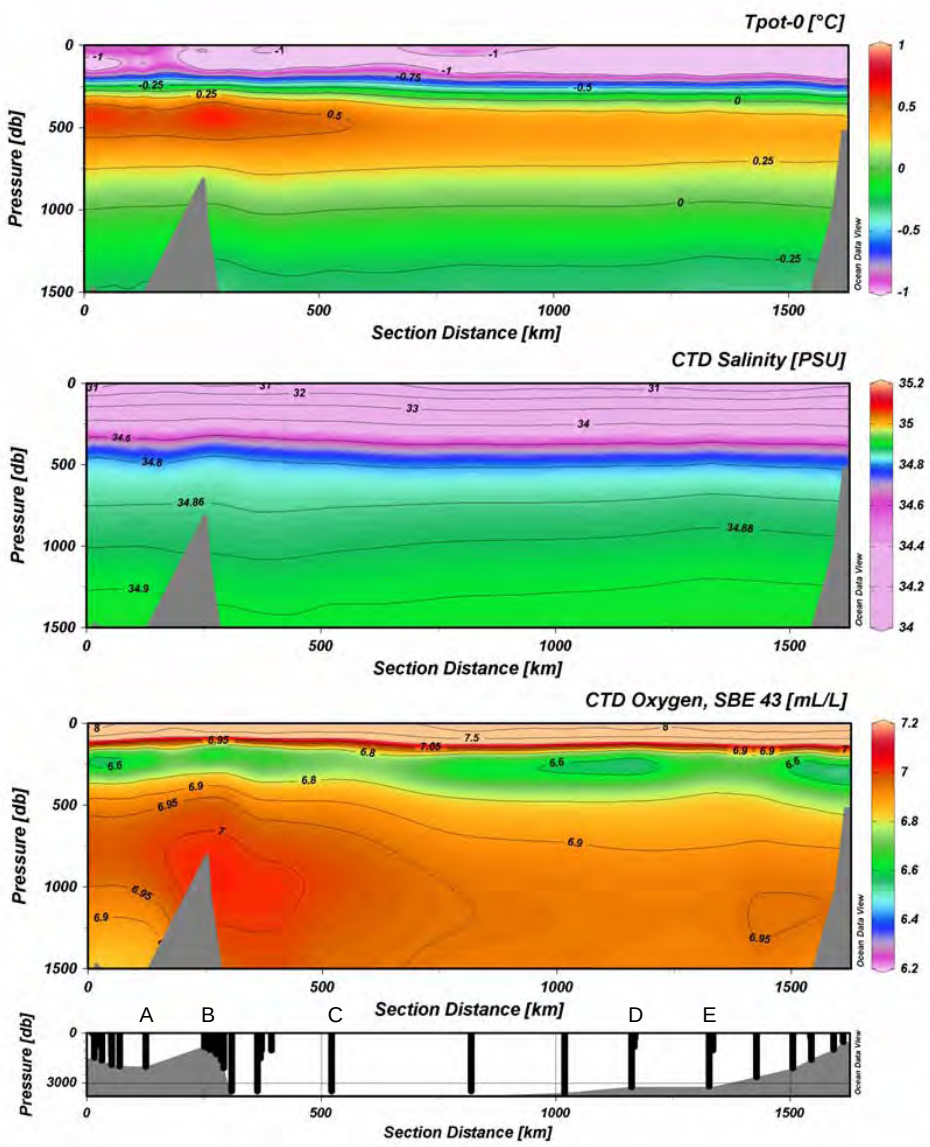


* **Note: vertical axis differs from others with pressure range from 0 to 100 db.**

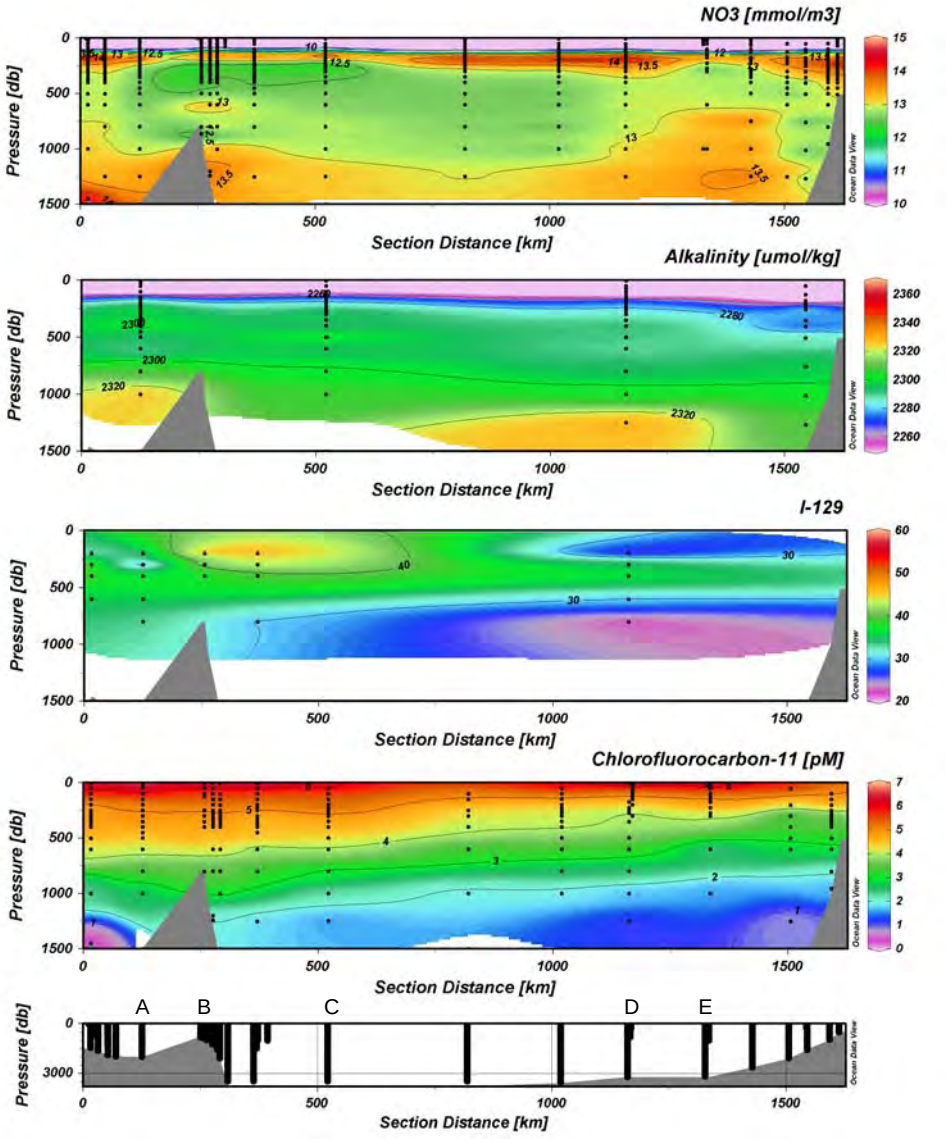
Chemistry, 0 to 400 db



CTD, 0 to 1500 db



Chemistry, 0 to 1500 db



4.7 ZOOPLANKTON

Table 12. Gelatinous zooplankton observed.

Date	Station	Gear	Organism
16/8/02	AG-05	Live net	*Aglantha digitale*
			Aeginopsis laurentii
			Bolinopsis vitrea (?)
17/8/02	AG-05	ROV test	*Aglantha digitale*
			cydippid ctenophore
18/8/02	AL-07	Live net	*Dimophyes arctica*
18/8/02	AL-08	ROV test	*Cyanea sp.*
			Nanomia cara (?)
			Dimophyes arctica (?)
			Bolinopsis vitrea
19/8/02	AL-09	Divers	*Medusae seen*
20/8/02	AL-10	Live net	*Aglantha digitale*
			Botrynema ellinorae
22/8/02	AL-10	ROV pelagic	*Chrysaora melanaster*
			Trachymedusae (Sminthia ?)
			New species of Narcomedusae collected
23/8/02	SB-01	Live net	*Aglantha digitale*
			Sminthia arctica
24/8/02	RVB1	ROV benthic	*Uncollected Crossota sp. on bottom*
		Divers	*Bolinopsis vitrea*
			Mertensia ovum
25/8/02	SB-02		
26/8/02	SB-03	CTD	*Scyphomedusa tentacles for molecular id (Chrysaora?)*
27/8/02	NW-08	Divers	*Bolinopsis vitrea*
			Chrysaora melanaster
28/8/02	NW-08	Bongo	*Aglantha digitale*
			Botrynema ellinorae
			Sminthia arctica
			Dimophyes arctica
		Divers	*Bolinopsis vitrea*
			Beroe cucumis
			Cydippid ctenophore
29/8/02	NW-07	Live net	*Botrynema ellinorae*
			Aglantha digitale
			Sminthia arctica
31/8/02	ROV-05	ROV pelagic	*Chrysaora melanaster*

Date	Station	Gear	Organism
			Atolla tenella (?)
			Nanomia cara (?)
			Dimophyes arctica (?)
			Bolinopsis vitrea
			Mertensia ovum
			Cydippid ctenophore
			Beroe cucumis
			Botrynema ellinorae
			Sminthia arctica
	NW-05	Divers	*Mertensia ovum*
		Live net	*Dimophyes arctica*
			Aglantha digitale
			Botrynema ellinorae
			Sminthia arctica
		CTD	*Scyphomedusa tentacles for molecular id (Chrysaora?)*
1/9/2002	ROV-06	ROV benthic	*Chrysaora melanaster*
			Mertensia ovum
			Lobate ctenophore
			Atolla tenella (?)
			Sminthia arctica
4/9/2002	NA-08	Live net	*Dimophyes arctica*
			Aglantha digitale
			Sminthia arctica
5/9/2002	ROV-07	ROV	*Chrysaora melanaster*
	NA-05		*Mertensia ovum*
			Nanomia cara (?)
			unident. Calycophoran siphonophore sp. 1
			unident. Calycophoran siphonophore sp. 2
			unident. Physonect siphonophore sp. 1
			Sminthia arctica
			Bolinopsis vitrea
7/9/2002	Off Barrow		*Cyanea sp.*
			Aurelia sp.

4.8 AMMONIUM DATA

Table 13. Ammonium data.

Cast No.	Station	Sample No.	Pressure (dbars)	Date (mm/dd/yyyy)	NH4 (mmol/m3)	QA/QC code
3	AL05	60	510	8/18/2002	0.06	
3	AL05	63	51	8/18/2002	0.06	
3	AL05	65	11	8/18/2002	1.05	
4	AL06	72	102	8/18/2002	0.27	
4	AL06	86	502	8/18/2002	0.27	
4	AL06	90	49	8/18/2002	0.78	
5	AL07	94	52	8/18/2002	0.13	
5	AL07	96	102	8/18/2002	0.26	
5	AL07	100	204	8/18/2002	0.76	
5	AL07	106	508	8/18/2002	0.22	
5	AL07	108	1015	8/18/2002	0.82	
9	AL09	162	53	8/19/2002	0.00	
9	AL09	164	101	8/19/2002	0.13	
9	AL09	165	127	8/19/2002	0.42	
9	AL09	176	501	8/19/2002	0.11	
9	AL09	181	2001	8/19/2002	0.57	
12	AL10(2)	238	56	8/21/2002	1.09	
12	AL10(2)	239	31	8/21/2002	0.39	
12	AL10(2)	240	18	8/21/2002	0.82	
12	AL10(2)	241	11	8/21/2002	0.21	
12	AL10(2)	242	1	8/21/2002	0.21	
14	SB01	275	501	8/23/2002	0.19	
14	SB01	282	200	8/23/2002	0.04	
14	SB01	283	175	8/23/2002	0.10	
14	SB01	284	151	8/23/2002	0.01	
14	SB01	285	126	8/23/2002	0.20	
14	SB01	286	100	8/23/2002	0.11	
14	SB01	287	76	8/23/2002	0.13	
14	SB01	288	51	8/23/2002	0.00	
14	SB01	289	5	8/23/2002	0.09	
19	SB03	362	51	8/26/2002	0.48	
19	SB03	363	48	8/26/2002	0.52	
19	SB03	364	25	8/26/2002	0.34	
19	SB03	365	14	8/26/2002	0.30	
19	SB03	366	8	8/26/2002	0.21	
19	SB03	367	1	8/26/2002	0.53	
23	NW07(2)	454	227	8/30/2002	0.36	
23	NW07(2)	455	201	8/30/2002	0.22	
23	NW07(2)	456	176	8/30/2002	0.13	

Cast No.	Station	Sample No.	Pressure (dbars)	Date (mm/dd/yyyy)	NH4 (mmol/m3)	QA/QC code
23	NW07(2)	457	151	8/30/2002	0.16	
23	NW07(2)	458	125	8/30/2002	0.20	
23	NW07(2)	459	101	8/30/2002	0.28	
23	NW07(2)	462	26	8/30/2002	0.27	
23	NW07(2)	463	6	8/30/2002	0.19	
26	NW06	513	47	8/30/2002	0.21/0.08	c
26	NW06	514	26	8/30/2002	0.11	c
26	NW06	515	12	8/30/2002	0.10	c
26	NW06	516	7	8/30/2002	0.40/0.28	c
26	NW06	517	1	8/30/2002	0.16	c
27	NW05	531	251	8/31/2002	0.10	
27	NW05	533	202	8/31/2002	0.18	
27	NW05	534	177	8/31/2002	0.10	
27	NW05	535	151	8/31/2002	0.01	
27	NW05	536	126	8/31/2002	0.06	
27	NW05	537	103	8/31/2002	0.17	
27	NW05	538	76	8/31/2002	0.15	
27	NW05	539	51	8/31/2002	0.14	
27	NW05	540	26	8/31/2002	0.21	
27	NW05	541	6	8/31/2002	0.08	
29	NW03	554	251	9/1/2002	0.24	
29	NW03	556	201	9/1/2002	0.32	
29	NW03	557	176	9/1/2002	0.23	
29	NW03	558	151	9/1/2002	0.49	
29	NW03	559	127	9/1/2002	0.07	
29	NW03	560	101	9/1/2002	0.23	
29	NW03	561	77	9/1/2002	0.15	
29	NW03	562	52	9/1/2002	0.52	
29	NW03	563	27	9/1/2002	0.19	
29	NW03	564	36	9/1/2002	0.38	
29	NW03	565	7	9/1/2002	0.08	
31	NW01(1)	590	1	9/1/2002	0.19	
33	NW01(3)	606	251	9/2/2002	0.41	
33	NW01(3)	608	201	9/2/2002	0.22	
33	NW01(3)	609	176	9/2/2002	0.22	
33	NW01(3)	610	151	9/2/2002	0.29	
33	NW01(3)	611	126	9/2/2002	0.16	
33	NW01(3)	612	102	9/2/2002	0.29	
33	NW01(3)	613	76	9/2/2002	0.24	
33	NW01(3)	614	51	9/2/2002	0.23	
33	NW01(3)	615	33	9/2/2002	0.26	
33	NW01(3)	616	25	9/2/2002	0.36	
33	NW01(3)	617	5	9/2/2002	0.32	
34	NA05(1)	623	2	9/3/2002	0.20	

Cast No.	Station	Sample No.	Pressure (dbars)	Date (mm/dd/yyyy)	NH4 (mmol/m3)	QA/QC code
35	NA05(2)	628	501	9/3/2002	0.36	
35	NA05(2)	633	300	9/3/2002	0.12	
35	NA05(2)	634	276	9/3/2002	0.14	
35	NA05(2)	635	250	9/3/2002	0.09	
35	NA05(2)	636	225	9/3/2002	0.08	
35	NA05(2)	637	200	9/3/2002	0.13	
35	NA05(2)	638	176	9/3/2002	0.13	
35	NA05(2)	639	151	9/3/2002	0.14	
35	NA05(2)	640	125	9/3/2002	0.07	
35	NA05(2)	641	100	9/3/2002	0.10	
35	NA05(2)	642	76	9/3/2002	0.13	
35	NA05(2)	643	50	9/3/2002	0.23	
35	NA05(2)	644	46	9/3/2002	0.47	
35	NA05(2)	645	46	9/3/2002	0.23	
35	NA05(2)	646	25	9/3/2002	0.10	
35	NA05(2)	647	6	9/3/2002	0.12	
38	NA07	676	601	9/3/2002	0.05	
38	NA07	682	301	9/3/2002	0.12	
38	NA07	683	276	9/3/2002	0.11	
38	NA07	684	250	9/3/2002	0.12	
38	NA07	685	225	9/3/2002	0.09	
38	NA07	686	200	9/3/2002	0.23	
38	NA07	687	176	9/3/2002	0.11	
38	NA07	688	151	9/3/2002	0.08	
38	NA07	689	125	9/3/2002	0.09	
38	NA07	690	98	9/3/2002	0.19	
38	NA07	691	78	9/3/2002	0.14	
38	NA07	692	52	9/3/2002	0.18	
38	NA07	693	49	9/3/2002	0.19	
38	NA07	694	26	9/3/2002	0.38	
38	NA07	695	7	9/3/2002	0.52	

4.9 HEXACHLOROCYCLOHEXANE DATA

Table 14. HCH data: salinity values shown in red indicate CTD salinity used instead of HCH bottle salinity.

Sample No.	Station	Date m/d/y	Pressure (dbars)	Salinity (PSU)	αHCH (pg/L)	βHCH (pg/L)	γHCH (pg/L)
115	AL07(2)	8/18/2002	251.53	34.503	349	47	137
117	AL07(2)	8/18/2002	200.88	33.9992	484	63	168
119	AL07(2)	8/18/2002	151.31	33.1342	993	120	209
121	AL07(2)	8/18/2002	101.1	32.5936	1538	122	269
273	SB01	8/23/2002	801.07	34.8698	199	34	105
276	SB01	8/23/2002	401.35	34.7933	121	25	63
314	SB01(3)	8/24/2002	300.74	34.6428	194	37	115
315	SB01(3)	8/24/2002	200.93	33.8294	592	81	177
316	SB01(3)	8/24/2002	151.23	33.0336	898	117	212
319	SB01(3)	8/24/2002	125.99	32.8193	1298	122	240
322	SB01(3)	8/24/2002	101.02	32.572	972	117	242
331	SB01(3)	8/24/2002	25.62	29.2418	1505	95	260
325	SB01(3)	8/24/2002	75.95	32.2112	1796	118	277
328	SB01(3)	8/24/2002	51.24	31.6336	1384	131	278
335	SB01(3)	8/24/2002	6.29	26.205	1429	75	260
443	NW07(2)	8/30/2002	801.34	34.863	114	28	72
447	NW07(2)	8/30/2002	400.62	34.8183	131	36	82
451	NW07(2)	8/30/2002	302.17	34.6686	163	39	87
445	NW07(2)	8/30/2002	500.38	34.8479	113	21	75
453	NW07(2)	8/30/2002	250.87	34.4479	316	42	167
457	NW07(2)	8/30/2002	151.25	33.1663	786	103	189
459	NW07(2)	8/30/2002	101.45	32.6409	1219	114	226
455	NW07(2)	8/30/2002	201.1	33.9863	503	68	266
460	NW07(2)	8/30/2002	75.85	32.2758	1006	101	216
461	NW07(2)	8/30/2002	51.24	31.8134	1164	107	216
462	NW07(2)	8/30/2002	26.24	28.9015	1347	115	261
463	NW07(2)	8/30/2002	6.32	26.5765	1268	86	210
598	NW01(3)	9/2/2002	400.37	34.8269	159	27	99
603	NW01(3)	9/2/2002	300.99	34.7261	132	28	85
608	NW01(3)	9/2/2002	200.88	34.0897	593	60	189
612	NW01(3)	9/2/2002	101.56	32.7858	779	118	197
614	NW01(3)	9/2/2002	50.92	31.8721	1174	106	191
617	NW01(3)	9/2/2002	5.34	27.0496	1020	79	210

4.10 CESIUM AND IODINE RADIOISOTOPE DATA

Table 15. ^{137}Cs and ^{129}I data.

Station	Cast	Depth	Cs-137	uncert	I-129	uncert
SB01	14	200	3.59	0.35	20.4	0.9
	14	300	5.00	0.51	36.3	1.4
	14	400	4.85	0.56	36.9	1.1
	14	600	5.00	0.36	29.7	1
	14	800	4.35	0.44	21.3	0.8
NW01	33	200	5.96	0.57	56	1.7
	33	300	5.39	0.53	47.1	1.4
	33	400	5.93	0.51	36.1	1.5
	33	800	4.64	0.39		
NW07	23	200	6.39	0.56	48.7	2.1
	23	300	5.56	0.41	48.7	1.9
	23	400	5.10	0.46	39.4	1.5
	23	600	4.50	0.5		
	23	800	4.77	0.42	29.2	1
NA09	43	200	5.32	0.47	28.7	1.3
	43	300	6.35	0.59	4.74	1.4
	43	400	5.28	0.55	37.9	1.3
	43	600	5.31	0.47	35.5	1.5
	43	800	4.95	0.55	33.5	1.5
NA05	35	200	5.08	0.42	29.5	1.4
	35	300	5.89	0.47	50	1.6
	35	400	5.61	0.44	41.5	1.7
	35	600	5.54	0.39	34.8	1.5

(John Smith)

4.11 PARTICULATE ORGANIC CARBON AND PARTICULATE ORGANIC NITROGEN DATA

Table 16. Particulate organic carbon and particulate organic nitrogen data.

Cast No.	Station	Sample No.	Pressure (dbars)	Carbon (µg/L)	Nitrogen (µg/L)	C/N ratio
5	AL07	94	52	88.50	14.36	6.16
5	AL07	96	102	17.22	2.80	6.16
5	AL07	97	128	22.26	3.02	7.38
5	AL07	99	179	19.93	3.31	6.02
5	AL07	100	204	27.11	3.41	7.95
5	AL07	103	305	15.70	2.30	6.82
5	AL07	105	406	25.73	3.15	8.17
5	AL07	106	508	17.76	2.09	8.51
14	SB01	276	401	18.50	2.70	6.84
14	SB01	282	200	12.65	2.22	5.69
14	SB01	284	151	13.59	1.67	8.16
14	SB01	285	126	13.85	1.97	7.04
14	SB01	287	76	21.60	2.95	7.32
18	SB02	347	501	11.33	1.58	7.16
18	SB02	350	301	12.30	1.66	7.43
18	SB02	354	200	15.92	1.93	8.26
18	SB02	358	100	13.32	2.00	6.66
18	SB02	359	76	22.04	3.52	6.27
18	SB02	360	50	34.64	5.80	5.98
18	SB02	361	5	10.86	1.30	8.34
21	NW08	401	501	9.71	0.93	10.48
21	NW08	402	400	32.81	2.82	11.65
21	NW08	404	300	17.44	1.38	12.66
21	NW08	408	200	17.09	2.29	7.48
21	NW08	412	101	26.63	2.66	10.01
21	NW08	413	76	26.35	2.34	11.24
21	NW08	414	51	45.51	5.92	7.69
21	NW08	415	6	36.65	3.96	9.25
23	NW07(2)	445	500	23.52	1.95	12.04
23	NW07(2)	453	251	15.46	2.06	7.52
23	NW07(2)	459	101	14.26	2.27	6.29
23	NW07(2)	462	26	36.17	5.00	7.23
23	NW07(2)	463	6	19.51	2.48	7.87
29	NW03	547	503	12.74	1.15	11.05
29	NW03	554	251	10.24	1.62	6.34
29	NW03	560	101	13.96	1.47	9.52
29	NW03	561	77	20.78	2.64	7.86
29	NW03	562	52	35.79	4.02	8.90
29	NW03	563	27	14.11	1.90	7.42
29	NW03	564	36	49.81	4.36	11.42
29	NW03	565	7	65.17	5.94	10.97
33	NW01(3)	597	501	11.58	0.99	11.70
33	NW01(3)	606	251	14.35	0.72	19.93
33	NW01(3)	612	102	27.23	1.73	15.70

Cast No.	Station	Sample No.	Pressure (dbars)	Carbon (µg/L)	Nitrogen (µg/L)	C/N ratio
33	NW01(3)	613	76	18.47	1.85	9.98
33	NW01(3)	614	51	39.56	3.78	10.47
35	NA05(2)	628	501	10.09	1.43	7.04
35	NA05(2)	635	250	16.76	14.99	1.12
35	NA05(2)	641	100	20.31	2.57	7.91
35	NA05(2)	642	76	22.37	2.71	8.26
35	NA05(2)	643	50	57.46	8.95	6.42
35	NA05(2)	646	25	30.69	4.92	6.24
38	NA07	677	502	12.16	1.75	6.95
38	NA07	684	250	15.13	1.97	7.68
38	NA07	690	98	21.73	2.74	7.94
38	NA07	692	52	57.56	8.88	6.48
38	NA07	693	49	64.92	9.45	6.87
38	NA07	695	7	33.18	4.84	6.85
41	NWR02(2)	711	201	57.94	5.04	11.49
41	NWR02(2)	713	151	26.71	3.12	8.55
41	NWR02(2)	714	126	17.87	3.21	5.56
42	NA09(1)	735	500	10.59	1.26	8.43
43	NA09(2)	752	251	19.57	1.58	12.36
43	NA09(2)	754	201	31.71	1.70	18.67
43	NA09(2)	756	150	22.94	1.98	11.58
43	NA09(2)	759	101	33.50	2.26	14.81
43	NA09(2)	762	51	32.51	4.73	6.88
43	NA09(2)	768	5	44.43	6.07	7.32

4.12 WILDLIFE DATA

Table 17. Wildlife observations.

Quantity	Wild life	Latitude		Longitude	
		hrs	min	hrs	min
1	polar bear	70	53	124	30
1	polar bear	72	7	139	48
1	polar bear	72	45	145	1
1	polar bear	74	16	140	22
3	polar bear	70	35	122	56
1	bearded seal	70	49	124	12
1	bearded seal	70	47	133	46
1	arctic fox	76	52	149	10
1	ring seal	70	47	130	40
1	ring seal	70	47	130	50
1	ring seal	70	30	133	30
1	ring seal	70	39	133	43
1	ring seal	71	42	134	41
1	ring seal	72	25	135	55
2	ring seal	72	37	136	13
1	ring seal	73	29	137	1
1	ring seal	72	7	139	46
1	ring seal	72	7	139	48
1	ring seal	75	59	157	1
2	herring gull	70	34	122	59
1	herring gull	70	43	131	25
1	herring gull	70	30	133	28
3	herring gull	70	30	133	30
1	herring gull	70	31	133	41
23	herring gull	70	51	133	49
1	herring gull	71	42	134	40
2	herring gull	71	42	134	41
5	herring gull	71	42	134	42
1	herring gull	73	28	136	59
2	glaucous gull	70	49	124	8
1	glaucous gull	71	42	134	42
2	glaucous gull	72	33	140	59
1	glaucous gull	72	35	140	52
2	glaucous gull	72	6	139	49
1	glaucous gull	72	6	139	46
1	glaucous gull	72	7	139	47
1	glaucous gull	72	28	142	22
4	glaucous gull	72	35	143	41
1	glaucous gull	72	45	145	1
1	glaucous gull	75	10	148	40
1	common murre	70	51	124	21
2	old squaws	74	22	162	8
3	eider	70	50	133	48
2	ross gulls	72	33	140	59
1	black-legged kittiwake	72	36	140	49
1	black-legged kittiwake	72	7	139	47
1	black-legged kittiwake	72	39	144	23

Quantity	Wild life	Latitude		Longitude	
		hrs	min	hrs	min
9	black-legged kittiwake	75	45	145	1
1	black-legged kittiwake	74	33	148	39
1	black-legged kittiwake	76	47	148	28
3	black-legged kittiwake	76	52	148	10
15	black-legged kittiwake	76	52	148	9
2	black-legged kittiwake	76	2	151	23
9	black-legged kittiwake	75	55	155	14
2	black-legged kittiwake	75	57	155	44
2	black-legged kittiwake	75	57	155	46
2	black-legged kittiwake	75	56	155	38
4	black-legged kittiwake	76	0	156	38
4	black-legged kittiwake	75	23	162	13
1	black-legged kittiwake	74	23	162	13
4	black-legged kittiwake	75	31	162	8
1	arctic tern	74	30	148	35
1	long-tailed jaeger	70	35	123	5
1	long-tailed jaeger	70	59	124	55
1	long-tailed jaeger	72	6	139	49
1	mew gull	75	59	152	57
1	common loon	70	33	133	41
1	common loon	70	38	133	41
50+	northern fulmars	75	56	155	37
2	northern fulmars	76	0	156	38
14+	northern fulmars	75	58	155	41
20+	northern fulmars	75	56	155	39
2	Ivory gull	76	52	148	15
9	Ivory gull	76	52	149	9
2	Ivory gull	75	56	151	51
4	Ivory gull	75	55	152	57
1	Ivory gull	75	55	155	14
2	Ivory gull	75	55	155	13
1	Ivory gull	76	0	156	38
2	gulls not identifiable	752	33	140	59
1	gulls not identifiable	72	33	140	59
1	gulls not identifiable	72	33	140	59
2	gulls not identifiable	72	35	140	52
7	gulls not identifiable	72	7	139	48
20+	gulls not identifiable	75	57	155	45
50+	gulls not identifiable	75	59	155	39

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