Technical Report

Seafloor Mapping for the Seabed Characterization Experiment

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SeaBat 7125-SV2/200 kHz Bathymetry Survey Report

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1 Summary of Progress and Accomplishments

This report describes the swath bathymetry survey of an area of the New England continental shelf centered at about 40.475º N, 70.603º W, and spanning roughly 30 km east-west and 10 km north-south. The data were collected with a Teledyne-RESON SeaBat 7125-SV2 multibeam echo sounder installed aboard University of Delaware R/V Sharp (cruise HRS1510, July 22-Aug 2, 2015) and comprised:

- 41 east-west swath bathymetry lines, each roughly 30 km long
- 6 north-south swath bathymetry lines, each roughly 10 km long
- 19 conductivity, temperature, depth (CTD) casts
- shipboard GPS navigation and surface mapping system (SMS) data.

Before they could be used, all these data required remedial processing described in the report. It will not been possible to overcome refraction correction errors due to internal waves, thus leaving gaps in the swath bathymetry coverage of the area surveyed. However, a bathymetry surface was compiled from near-nadir soundings collected along each survey line and gridded on a regular rectangular grid (cell size: 40 m northings, 20 m eastings). As a whole, this surface is uniform and slopes gently (~0.05%) down to the southwest over a depth range of about 66 m to 82 m.

Software was developed to edit out loops in the CTD data introduced during the casts by the ship's heave and roll. Edited downcast data were used to produce depth profiles of temperature, conductivity, practical salinity, density, and sound speed, as well as TS diagrams [Conservative temperature (ºC at 0 dbar) vs. absolute salinity (g/kg) over contours of potential density anomaly (kg/m^3 at 0 dbar – 1000)]. These profiles and diagrams illustrate a dynamic oceanographic environment with significant variations in time and space. There is evidence of intrusion of continental slope water along the bottom layer of the continental shelf roughly 50 m below mean sea level. In this area, continental slope water is generally warmer and more saline than continental shelf water.

The shipboard GPS navigation files have been realigned in time, and the shipboard SMS files have been synchronized to the GPS clock by matching GPS fixes in the GPS file and the SMS file.

2 Data description

In support of the ONR-sponsored Seabed Characterization Experiment 2015, swath bathymetry data were collected in July 2015, concurrently with CHIRP subbottom profiles, over an area of the New England Continental Shelf known as the “mud patch”. The survey area is centered at 40.475º N, 70.603º W, and spans about 30 km east-west by 10 km north-south, with an average depth of about 74 m (Figure 1).

A Teledyne-RESON SeaBat 7125-SV2 multibeam echo sounder installed aboard R/V Sharp and operated at 200 kHz was used for the swath bathymetry. This sonar is deployed on a pod through the center well of the vessel, resulting in a nominal transducer draft of 5.5 m. A towed EdgeTech SB-0512i sonar (CHIRP frequency range 500 Hz – 12 kHz) was used for concurrent subbottom profiling. Ancillary measurements included 19 profiles of conductivity-temperature-depth (CTD) taken with a Sea-Bird Electronics 9plus CTD package (Table 1, Figure 1).

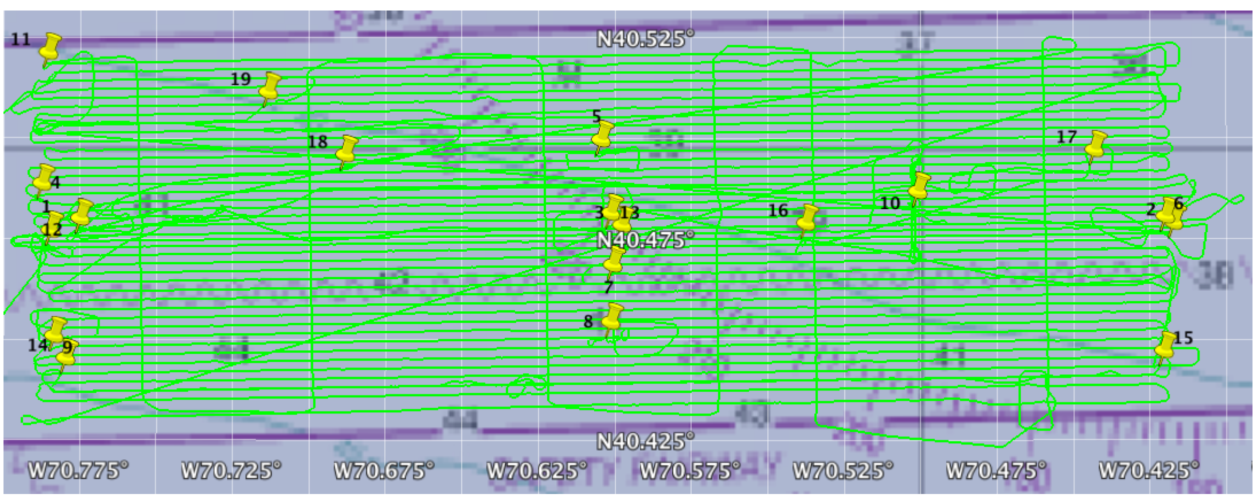

Figure 1 – Overall ship track and location of CTD casts (Table 1) taken during the survey.

2.1 *Multibeam swath bathymetry data*

SeaBat 7125-SV2 multibeam swath bathymetry and seafloor acoustic backscatter data were collected on 41 east-west lines and 6 north-south lines (Figure 2). The corresponding bathymetry surface is shown in Figure 3. This surface is obtained by retaining the sounding closest to nadir in each ping and by gridding all such soundings on a regular rectangular grid with cell having dimensions of 20 m in eastings by 40 m in northings.

Total recorded data volume exceeds 319 GB. All data for the survey fit in UTM zone 19T (40º-48ºN / 72º-66º W). For ease of readability, all grids shown in this report are offset by 347293 m in eastings and 4475930 m in northings relative to the (0,0) origin of zone 19T at 40ºN / 72ºW.

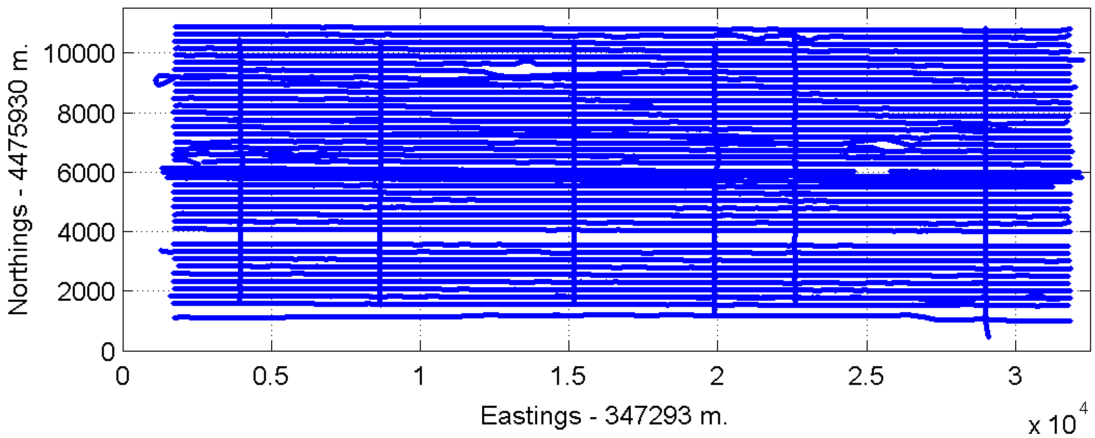

Figure 2 – SeaBat 7125-SV2 survey tracks as logged by the SeaBat 7125 SV2 multibeam echosounder. UTM coordinates zone 19T.

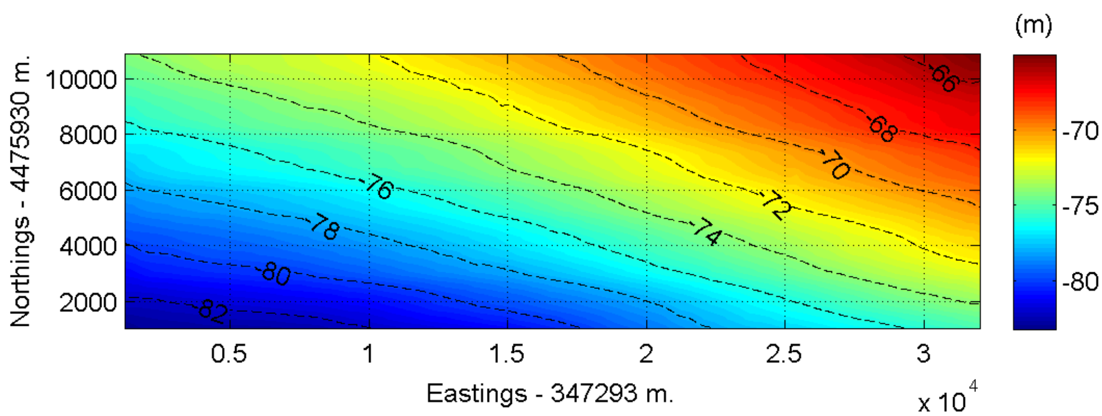

Figure 3 Gridded bathymetry surface compiled from 2,022,490 near-nadir soundings along the EW track shown in Figure 2. Grid cells are 20 m in eastings by 40 m in northings.

For unexplained reasons, the raw data files for east-west line 23 were corrupted during copy operations at the end of the sea trip and attempts to obtain readable copies from the shipboard computers have yet to be successful - hence the gap below relative northing 4000 m in Figure 2.

2.2 *CTD data*

A total of 19 CTD casts were taken during the survey (Figure 1). Plots the processed downcasts and the corresponding temperature-salinity diagrams are found in the appendices.

The towed sub-bottom profiler made it impractical to stop for CTD casts along east-west survey lines. Therefore, 9 casts were taken at the end points of east-west survey lines. 5 casts (3,5,7,8,13) were taken near the middle of the survey box in conjunction with a pilot acoustic propagation experiment involving an array of hydrophones moored near the center of the survey box and transmissions from a combustible sound source deployed over the side of the vessel at various distances from the moored array. One cast (#10) was taken in conjunction with in situ measurements of angle offsets for the multibeam sonar, and the remaining 4 casts (16-19) were taken during bathymetry gap filling runs without the subbottom profiler in tow towards the end of the survey. The survey plan of 6/26/2015 that called for "CTD casts every 6 h or so, depending on oceanographic conditions", was not followed for lack of available time when the pilot acoustic experiment was added to the objectives of the sea trip.

Table 1 - Inventory of CTD casts

Cast	Latitude (ºN)	Longitude (ºW)	Depth (m)	GMT Date	GMT Time
1	40.473167	-70.785667	73	7/23/15	19:21:50
2	40.475167	-70.419167	63	7/24/15	0:03:10
3	40.474500	-70.599167	69	7/24/15	16:30:37
4	40.484833	-70.788500	73	7/25/15	8:35:13
5	40.495667	-70.606000	68	7/25/15	22:34:59
6	40.476667	-70.421833	63	7/26/15	13:34:04
7	40.464667	-70.602167	69	7/27/15	4:35:11
8	40.450500	-70.602833	73	7/27/15	16:48:13
9	40.447000	-70.784500	76	7/27/15	20:25:05
10	40.482833	-70.502667	66	7/28/15	17:23:37
11	40.517333	-70.786500	69	7/29/15	14:44:12
12	40.476167	-70.776000	72	7/30/15	4:24:44
13	40.477500	-70.602833	67	7/30/15	17:03:41
14	40.441500	-70.780667	73	7/31/15	16:04:59
15	40.443333	-70.422333	64	7/31/15	18:57:38
16	40.475000	-70.539167	67	7/31/15	20:19:24
17	40.493167	-70.445000	66	7/31/15	21:19:01
18	40.492000	-70.689500	71	8/1/15	0:44:06
19	40.507500	-70.714667	68	8/1/15	18:02:01

2.3 *Tides*

All soundings must be reported to a common vertical datum, which requires knowledge of sea surface elevation changes over time due to tides. Tidal elevation must also be taken into account when comparing data from the CTD casts taken during the survey.

The nearest tidal station to the survey area is on Nantucket Island, MA, station IDs 8449130, (41.285ºN / 70.09667ºW) http://tidesandcurrents.noaa.gov/stationhome.html?id=8449130. However, this station is on the North side of the island, at the boundary between the New England continental shelf and the near-resonant Gulf of Maine. As a result, the phases of the tidal constituents at this station are very different from those on the New England continental shelf at the survey area (S. J. Lentz, personal communication, Nov. 2015).

Shearman and Lentz (2004) estimated the six principal sea level tidal constituents M2, N2, S2, K1, O1, and P1 (Table 2) from data collected between August 1996 and June 1997 at moored arrays deployed in the vicinity of the survey area during the ONR-sponsored Coastal Mixing and Optics (CMO) experiment. "*The central site was located at 40º 29.50'N, 70º 30.50' W in 70 m of water, and the three surrounding sites (inshore, offshore and alongshore) were located about 11 km inshore in 64 m of water, 12.5 km offshore in 86 m of water, and 14.5 km east along the 70 m isobath.*" No tidal constituents data were available at the central site, but amplitude and phases at the other three moorings are consistent.

Table 2 - Principal sea level tidal constituents at CMO arrays and NOAA tidal stations. Amplitudes in meters, phases in degrees referenced to GMT.

Constituent	CMO Inshore		CMO Offshore		CMO Alongshore		GPS Buoy Station 8448875		Nantucket Station 8449130	
	Amp	Phz G	Amp	Phz G	Amp	Phz G	Amp	Phz G	Amp	Phz G
M2	0.411	352.0	0.420	350.3	0.408	351.4	0.402	354.9	0.439	134.7
N2	0.098	334.8	0.098	332.5	0.097	334.1	0.101	338.5	0.113	102.5
S2	0.092	17.2	0.092	16.0	0.091	17.2	0.08	17.7	0.047	166.7
K1	0.071	173.2	0.076	174.3	0.073	173.7	0.054	167.8	0.113	102.5
O1	0.052	184.2	0.055	182.6	0.054	182.9	0.042	203.9	0.084	215.9
P1	0.024	175.2	0.025	175.3	0.024	175.7	0.018	170.5	0.031	225.8

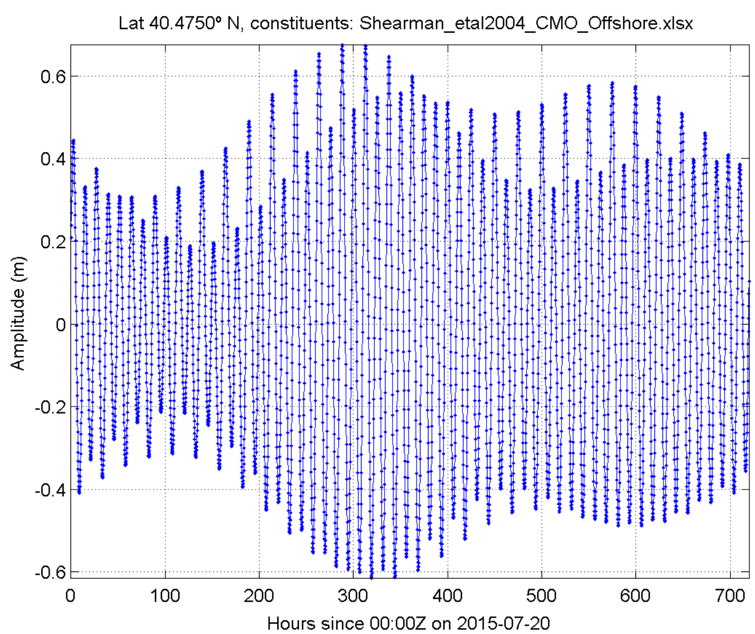

Figure 4 – Estimation of sea level tidal amplitude at 40.475º N for the survey area from 20 July to 19 August 2015 computed with the CMO offshore constituents in Table 2. On this plot, the time frame of the seafloor survey corresponds to hours 91 to 310.

We used the CMO offshore constituents (Table 2) and prediction algorithms by Pawlowicz et al. (2002) to estimate sea level tidal amplitudes for the time period July 20-August 19, 2015 (Figure 4). During the seafloor survey (hours 91 to 310) the maximum tidal amplitude (peak to trough) is about 1.27 m near the end of the survey (Figure 5).

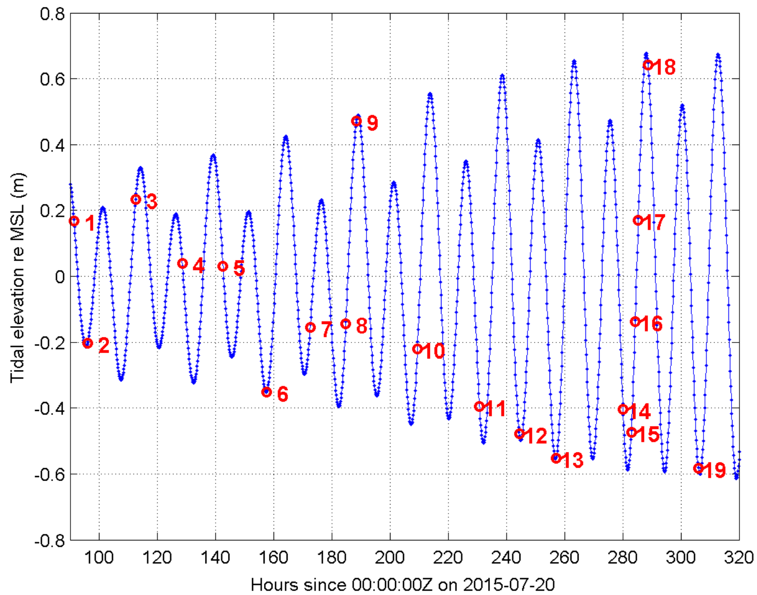

Figure 5 Tidal elevations during the seafloor survey. Numbered red circles represent CTD casts.

After the cruise, we learned that NOAA had deployed a GPS buoy south of Martha's Vineyard (station ID 8448875, 41.3262º N, -70.5903º W Martha's Vineyard GPS Buoy for NOAA surveys conducted in July through September 2015. As of December 12, 2015, verified data were only available through 7/25/2015. At this station, the datum difference between mean sea level and mean low low water is (MSL – MLLW) = 0.439 m.

3 Data Issues

A number of challenges were encountered during the survey work. They include (1) issues with time tagging of data logged by shipboard computers, (2) acoustic refraction compensation errors due to internal waves, (3) time varying gain recording malfunction in the SeaBat echo sounder, (4) CTD cast data with significant vertical excursions due to the ship's heave and roll motion, and (4) crash of a data disk causing loss of 6 days of SeaBat data editing with CARIS professional bathymetry processing software. Combined, these issues prevented us from producing a preliminary bathymetry map aboard ship by the end of the sea trip as planned.

3.1 *Time tagging of shipboard data*

At the end of the sea trip, R/V Sharp's resident shipboard technicians copied to DVDs and distributed to the scientific party the ship's data logging files including (1) the ship's GPS navigation collected at 1 Hz, (2) the ship's "surface mapping system" (SMS) data collected at 0.1 Hz.

Post-cruise inspection of these data revealed that the naming convention for the GPS files is a number followed by the suffix GPS in the form YYMMDDHH.GPS that represents year, month, day, and hour in **local time** on the logging computer, presumably at file creation time. The hour field increments from 01 to 12, rather than 00 to 23. Files for hours 13 to 24 are presumably appended to files for hours 01 to 12 with some unexpected results, highlighted in Table 3. As provided, these data require extensive sorting to obtain a monotonically increasing time sequence.

Table 3 - Time tagging of shipboard GPS data. The data file name contains only the hour field. The first ZDA data string of each hourly batch of GPS data is reported along the row corresponding to the file in which it is found.

Data File Name		First ZDA String in File		Start of Appended Data	
Local date time		ZDA date time		ZDA date time	
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22-Jul-2015	02:00:00	22-Jul-2015	18:03:55		
22-Jul-2015	03:00:00	22-Jul-2015	19:03:55		
22-Jul-2015	04:00:00	22-Jul-2015	20:03:55		
22-Jul-2015	05:00:00	22-Jul-2015	21:03:55		
22-Jul-2015	06:00:00	22-Jul-2015	22:03:55		
22-Jul-2015	07:00:00	22-Jul-2015	23:00:59		
22-Jul-2015	08:00:00	23-Jul-2015	00:01:01		
22-Jul-2015	09:00:00	23-Jul-2015	00:59:03		
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22-Jul-2015	12:00:00	22-Jul-2015	16:03:55		
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23-Jul-2015	02:00:00	23-Jul-2015	05:59:01	23-Jul-2015	17:59:03
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23-Jul-2015	12:00:00	23-Jul-2015	03:59:01	23-Jul-2015	15:59:03
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30-Jul-2015	12:00:00	30-Jul-2015	04:00:14	30-Jul-2015	16:00:14
31-Jul-2015	01:00:00	31-Jul-2015	05:00:16	31-Jul-2015	17:00:16
31-Jul-2015	02:00:00	31-Jul-2015	06:00:16	31-Jul-2015	18:00:16
31-Jul-2015	03:00:00	31-Jul-2015	07:00:16	31-Jul-2015	19:00:16
31-Jul-2015	04:00:00	31-Jul-2015	08:00:16	31-Jul-2015	20:00:18
31-Jul-2015	05:00:00	31-Jul-2015	09:00:16	31-Jul-2015	21:00:18
31-Jul-2015	06:00:00	31-Jul-2015	10:00:16	31-Jul-2015	22:00:18
31-Jul-2015	07:00:00	31-Jul-2015	11:00:16	31-Jul-2015	23:00:18
31-Jul-2015	08:00:00	31-Jul-2015	12:00:16	01-Aug-2015	00:00:18
31-Jul-2015	09:00:00	31-Jul-2015	13:00:16	01-Aug-2015	01:00:18
31-Jul-2015	10:00:00	31-Jul-2015	14:00:16	01-Aug-2015	02:00:18
31-Jul-2015	11:00:00	31-Jul-2015	15:00:16	01-Aug-2015	03:00:18
31-Jul-2015	12:00:00	31-Jul-2015	04:00:16	31-Jul-2015	16:00:16
01-Aug-2015	01:00:00	01-Aug-2015	05:00:18	01-Aug-2015	17:00:20
01-Aug-2015	02:00:00	01-Aug-2015	06:00:18	01-Aug-2015	18:00:20
01-Aug-2015	03:00:00	01-Aug-2015	07:00:18	01-Aug-2015	19:00:18
01-Aug-2015	04:00:00	01-Aug-2015	08:00:18	01-Aug-2015	20:00:20
01-Aug-2015	05:00:00	01-Aug-2015	09:00:18	01-Aug-2015	21:00:20
01-Aug-2015	06:00:00	01-Aug-2015	10:00:18	01-Aug-2015	22:00:20
01-Aug-2015	07:00:00	01-Aug-2015	11:00:18	01-Aug-2015	23:00:20
01-Aug-2015	08:00:00	01-Aug-2015	12:00:18	02-Aug-2015	00:00:20
01-Aug-2015	09:00:00	01-Aug-2015	13:00:18	02-Aug-2015	01:00:20
01-Aug-2015	10:00:00	01-Aug-2015	14:00:18	02-Aug-2015	02:00:20
01-Aug-2015	11:00:00	01-Aug-2015	15:00:18	02-Aug-2015	03:00:20
01-Aug-2015	12:00:00	01-Aug-2015	04:00:18	01-Aug-2015	16:00:20
02-Aug-2015	01:00:00	02-Aug-2015	05:00:20		
02-Aug-2015	02:00:00	02-Aug-2015	06:00:20		
02-Aug-2015	03:00:00	02-Aug-2015	07:00:20		
02-Aug-2015	04:00:00	02-Aug-2015	08:00:20		
02-Aug-2015	05:00:00	02-Aug-2015	09:00:20		
02-Aug-2015	06:00:00	02-Aug-2015	10:00:20		
02-Aug-2015	07:00:00	02-Aug-2015	11:00:20		
02-Aug-2015	12:00:00	02-Aug-2015	04:00:20		

With only the hour of the local time in the file name, it is not possible to estimate the time offset between the logging computer clock and the GPS time field in the first ZDA data string found in each file. This would not be an issue if there were no gaps in the GPS sequence. However data gaps are present, lasting up to 9 minutes in one instance. In addition, a file name with 12 in the local hour field corresponds to local midnight and local noon. Unfortunately, this creates a backward jump of 11 hours in the data sequence at every local midnight. A file naming convention that uses a 24-hour

GMT clock rather than a drifting local time clock would alleviate all these issues except data drops.

The ship's SMS data are time-tagged by the logging computer clock, which is not synchronized to any time standard. This becomes a concern when one discovers that the field labeled "GMT time" in the SMS file is in fact the local time of the logging computer offset by the local time zone. Therefore, for the survey area we have (SMS GMT field = local time + 4 h).

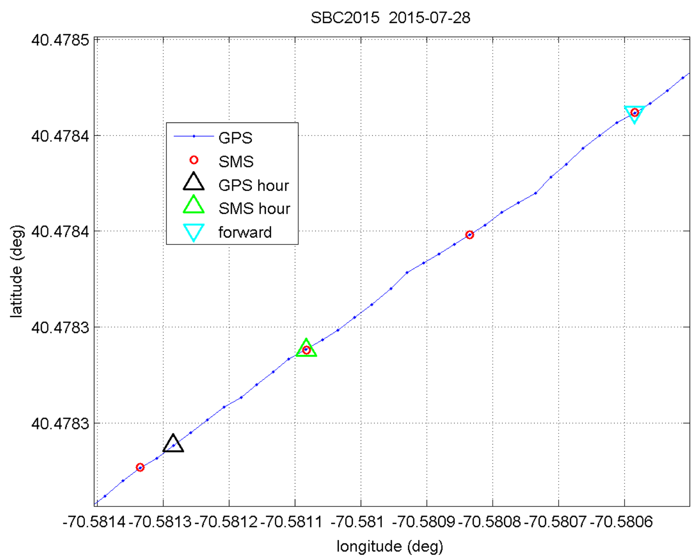


Figure 6 Time synchronization of R/V Sharp's SMS data (0.1 Hz) and GPS data (1 Hz), using the GPS clock as a reference.

Comparison (Figure 6) of the 1 Hz GPS position fixes in the ship's GPS files with the 0.1 Hz GPS fixes time-tagged by the logging computer clock in the ship's SMS files revealed that the SMS time tags were lagging behind the corresponding GPS fixes by 59 s at the beginning of the seafloor survey on 7/23/2015 at 20:20:00Z. The lag becomes 1 s by 01:00:00Z on 7/24/2015 and zero by 17:00:00Z on 7/24/2015. Subsequently, the SMS time tags were ahead of the GPS fixes with a lead gradually increasing to 18 s by the end of the seafloor survey at 19:00:00Z on 08/01/2015. At the average survey speed of 4.5 kn (2.25 m/s) a timing error of 59 s corresponds to an along-track distance offset of about 133 m. If not corrected, such an offset compromises attempts at co-registration of the SeaBat sonar data and the associated ship's motion (specifically heave), with the keel-depth temperature and salinity data found in the SMS files. Co-registration of these data is useful when looking for clues to the presence of internal waves in the water column.

3.2 *SeaBat 7125-SV2 time varying gain*

The SeaBat 7125-SV2 multibeam echosounder was operated at 200 kHz and running under software/firmware version numbers:

- SeaBat - 4.2.0.5,

- 7K control center - 6.1.0.3

As shown in Figure 7, sample values of the time varying gain (TVG) presumably applied to received echoes, and stored for every ping in record 7010, do not match the corresponding curve obtained with RESON's DSP firmware TVG formulas obtained previously from Teledyne-RESON through a non-disclosure agreement (2011/03). In addition, TVG coefficients, pulse duration, and transmit power were observed to change overly frequently when operating the sonar in automatic bottom tracking mode over a fairly uniform bottom in 74 m of water depth.

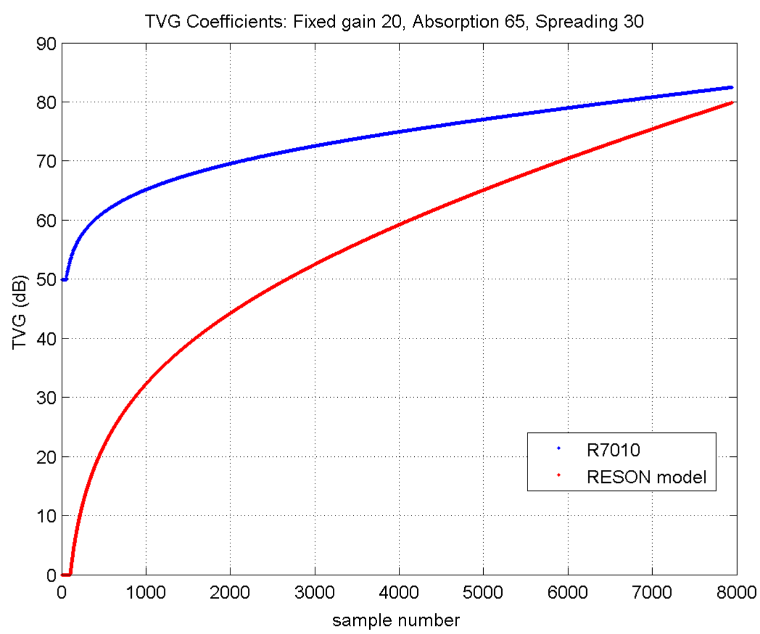


Figure 7 - Comparison of TVG data stored in record R7010 with TVG curve computed from RESON Firmware formulas with the coefficients used at data acquisition time: G = 20 (gain), A = 65 (absorption), and S = 30 (spreading).

Knowledge and control of the gains applied to the received echoes is paramount to any seafloor acoustic backscatter data processing. Fortunately, depths in the survey area spanned roughly 66 m to 82 m with a mean of about 74 m (nominal sonar altitudes 60 m to 76 m, mean 68 m). An altitude variation of ± 8 m about a mean altitude of 68 m is small enough to run the sonar with fixed gain parameters, constant transmit power, and constant pulse duration. Therefore, we use fixed values that had worked in our previous experiences with this type of sonar. However, operating the sonar in fixed mode meant more bottom tracking errors to be edited during post-processing.

The TVG mismatch was reported to the sonar manufacturer during the survey. A week after the end of the sea trip, the manufacturer informed us that the problem reported is a bug in their data logging and display software and thanked us for pointing it out. Until further notice by the manufacturer, TVG record 7010 should be ignored and RESON's proprietary TVG formula should be used to estimate the gains applied to the received echoes.

3.3 *Refraction compensation errors due to internal waves*

The first four east-west survey lines have swath widths of roughly 250 m. Lines 1-3 overlap by about 80 m in northings, whereas lines 3 and 4 overlap by about 25 m in northings (Figure 8). The overlap regions show variable mismatches along track. Inspection of the outer 75 m on either side of each swath reveals patterns of along-track highs and lows that are out of phase across track. This is symptomatic of refraction compensation errors due to internal waves that cause azimuthal dependent refraction. Whenever the instantaneous ship's heading is not perpendicular to the underlying internal wave fronts, all the beams formed across-track for a given ping go through different water masses and the assumption of horizontal stratification for the water column is violated. There is no mitigation for such survey conditions because frequent sampling of the sound-speed profile along track, as would be obtained with an underway sound-speed profiling system, does not provide information on the water masses on either side of the track. Nonetheless, near-nadir soundings suffer few refraction errors, making it possible to compile a map with such soundings as was done in Figure 3. In addition, the central 80-100 m segment of each swath appears to be less affected by refraction errors and might also be usable for map making.

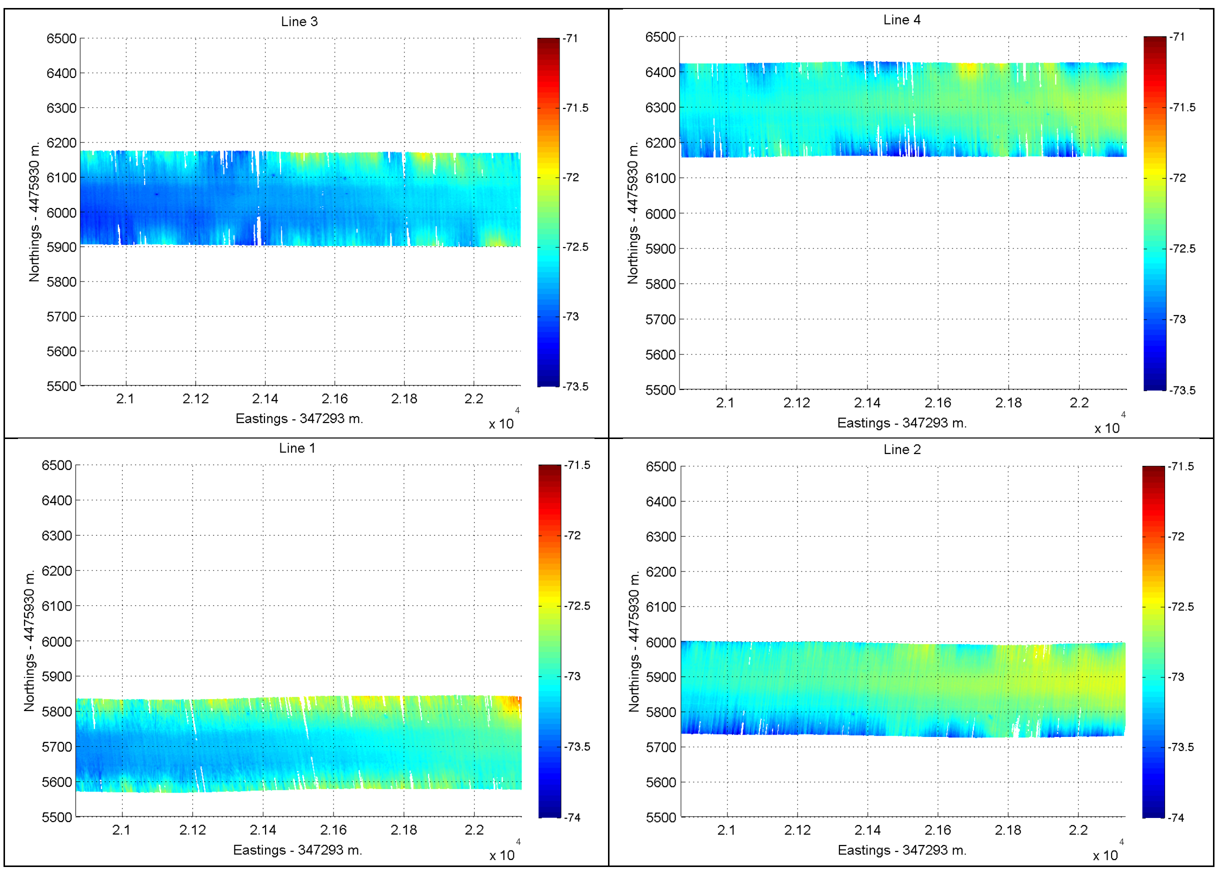


Figure 8 Overlapping swath bathymetry segments from the first 4 east-west lines of the survey between relative eastings 20 km and 23 km showing variable mismatches in the regions of overlap because of internal waves.

Depth profiles of temperature, practical salinity, density, and sound speed from the three CTD casts that were taken for lines 1-4 are shown in Figure 9. Casts 1 and 2 are about 30 km and 4.5 h apart. They were taken at the start and end of the first east-west survey line. Cast 3 was taken 16.5 h after cast 2, and it lies roughly at the mid-point between casts 1 and 2.

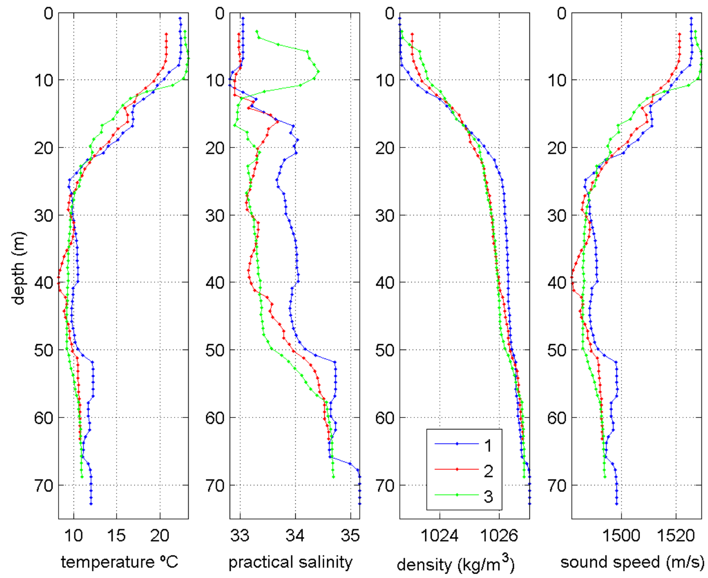


Figure 9 Depth profiles of temperature, practical salinity, density, and sound speed referenced to mean sea level for casts 1, 2, and 3 (Figure 1, Table 1).

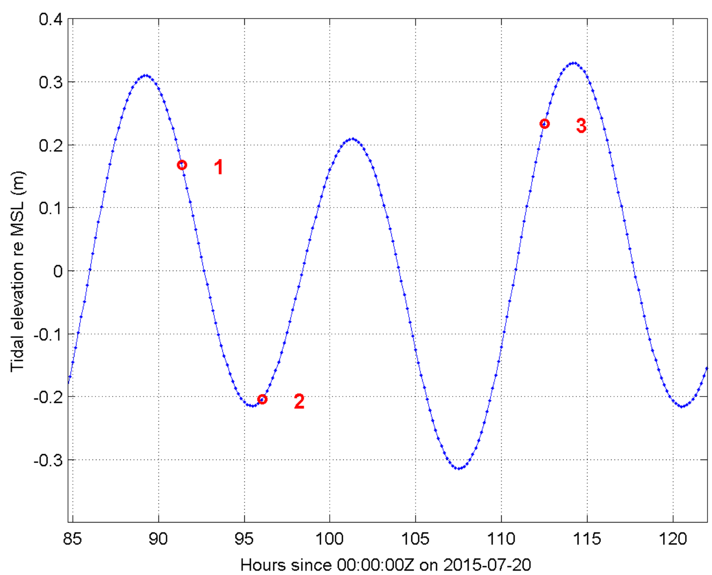


Figure 10 Tidal elevations relative to mean sea level for CTD casts 1-3 (red circles).

The depths in the profiles have been adjusted for tidal elevation at the time of each cast (Figure 10) and are referenced to mean sea level. The profiles for all 3 casts exhibit a mixed layer extending 10 m below the sea surface, a thermocline between 10 m and 25 m, and evidence of intrusion of continental slope water (warmer, more saline) along the bottom layer of the shelf roughly 50 m below mean sea level. Such intrusions appear to be variable in time and space.

3.4 *Errors in CTD data due the ship motion*

Unless a heave compensation mechanism is used, the ship's heave motion is always prominent in CTD casts taken in less than 100 m of water depth. R/V Sharp has no heave compensation mechanism and no station keeping capability. Therefore, CTD deployments are made on the windward side, with the ship broadside to the wind and waves. This deployment scheme introduces at least two additional complications: (1) roll-induced heave is also prominent in CTD data collected in any kind of swell, and (2) the instrument package is often not vertical because it is towed as the ship drifts sideways. The ship was drifting at 0.5 kn to 1 kn in most casts taken during the cruise.

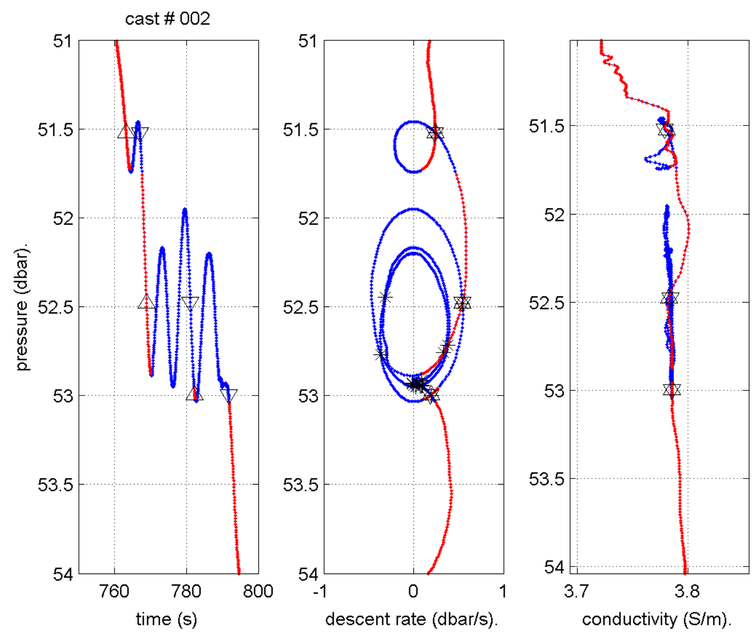


Figure 11 - Effects of the ship's motion on CTD data. Oscillations with a period of about 7 s in the pressure time series shown in the left panel are most likely due to the ship's roll (6.8 s period). The oscillations become loops when plotted as pressure vs. descent rate (dbar/s) in the middle panel, and the resulting errors in the conductivity data are seen in the right panel. Raw data in blue overlaid by red dots corresponding to data samples retained by the editing algorithm developed in this work.

Sea-Bird Electronics provides a "loop edit" module in its post-processing software. This module is intended to remove heave artifacts by flagging CTD data samples associated with descent rates below a specified threshold. The threshold is either fixed at roughly 25% of the nominal descent rate for the entire cast, or it varies as a specified percentage of the mean descent rate computed over a sliding time window of specified duration. Neither option works properly for the 19 casts taken during the cruise because in shallow water (< 100 m) the downcast takes less than 200 s at the nominal descent rate of 0.5 m/s recommended by the manufacturer. In addition, manual control of the winch resulted in variable descent rates and nested loops (Figure 11) at the roll, and heave periods of the vessel (respectively 6.8 s and 8.2 s).

A modified version of the salinity despiking algorithm described by Giles and McDougall (1989) has been developed here to handle nested loops that are prevalent in the CTD data collected during this cruise. We consulted the CTD manufacturer for advice on dealing with prominent spikes remaining in the data for some casts after loop removal (Figure 12). Such spikes are most likely caused by a tilt of the instrument away from vertical while the package is being towed during the downcast.

The pressure, temperature, and conductivity data from each downcast, originally sampled at 24 Hz, were processed and reduced to profiles regularly sampled at 1 m depth intervals. They were used also to compute depth profiles of practical salinity, density, and sound speed. The corresponding plots are found in the appendices.

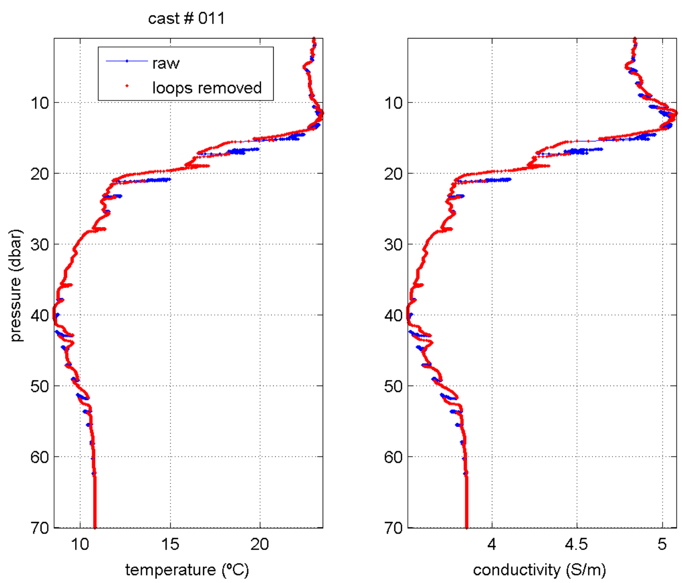


Figure 12 Residual spikes in the temperature and conductivity vs. pressure profiles after loop editing in cast # 11.

3.5 *Disk crash during CARIS editing.*

A short-term license (1 month) of the CARIS HIPS-SIPS commercial bathymetry processing software package was purchased before the cruise for use aboard ship. The CARIS software was used to check swath coverage and perform preliminary assessment of the data quality, with the intention of producing a full bathymetry map by the end of the survey. Initial survey results were used to select a site suitable for in-situ calibration of the roll, pitch, and yaw angle offsets between the local reference frame of the multibeam echo sounder transducer arrays and the local reference of the shipboard inertial motion sensor. The angles offsets must be estimated every time the sonar pod is deployed below the keel. Swath bathymetry data were collected for this calibration on July 28, 2015.

On July 30, 2015, we experienced a failure of the 2-TB Western Digital USB external disk drive used to store and process the SeaBat 7125-SV2 data in CARIS. As a result data editing done for the first 6 days of the survey was no longer available and had to be redone. The disk drive was new at the start of the survey and we were unable to diagnose the failure mode while at sea. Consequently, we were unable to produce a bathymetry map by the end of the survey as planned.

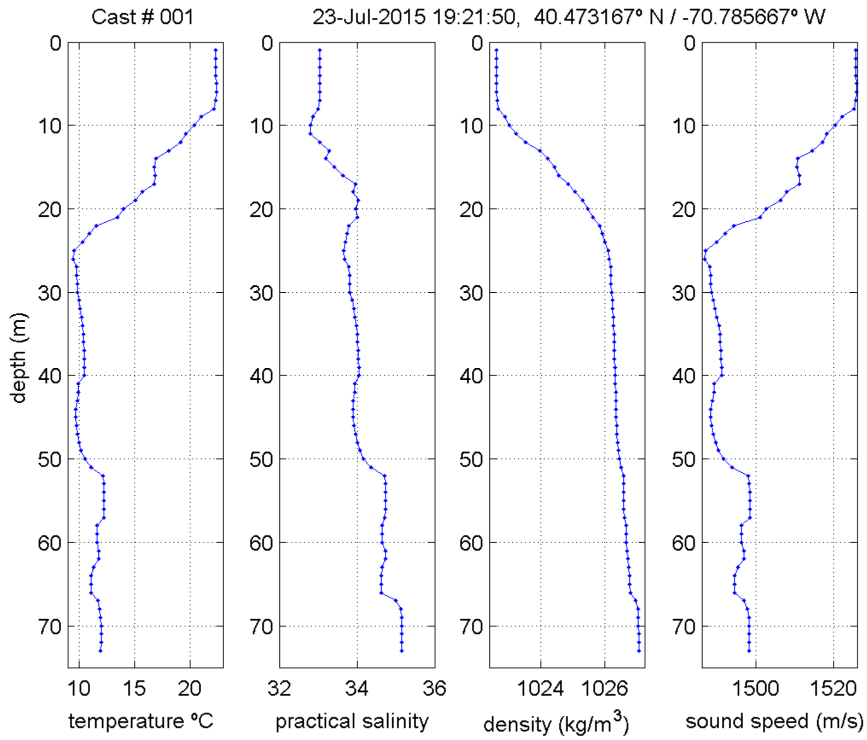
4 References

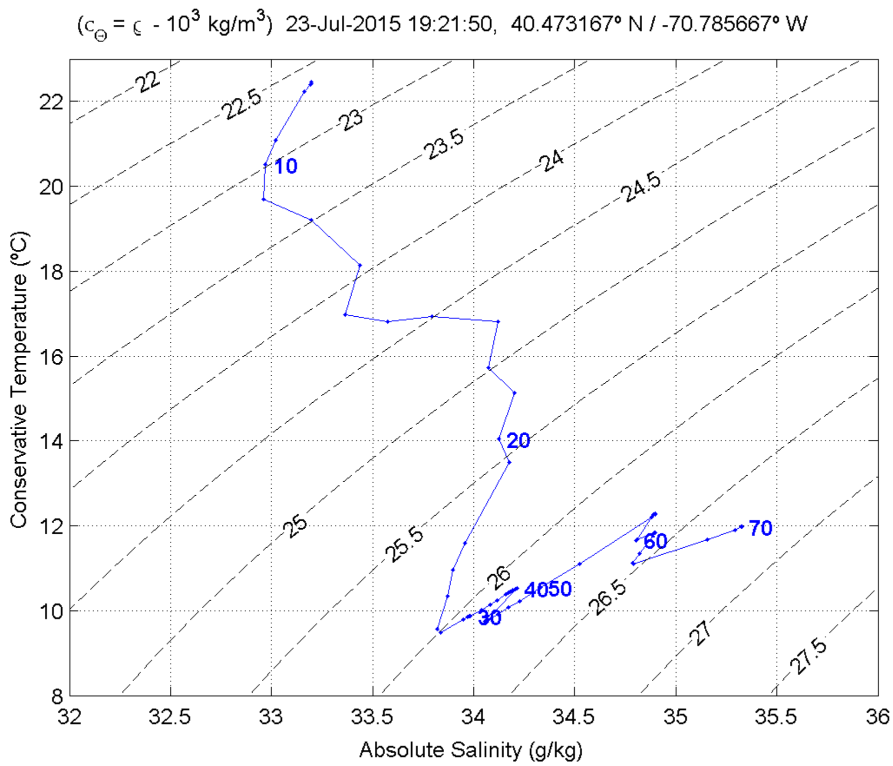
Giles, A. B., and McDougall, T. J., “Two methods for the reduction of salinity spiking of CTDs”, Deep-Sea Research 33(9), 1253-1274, 1986

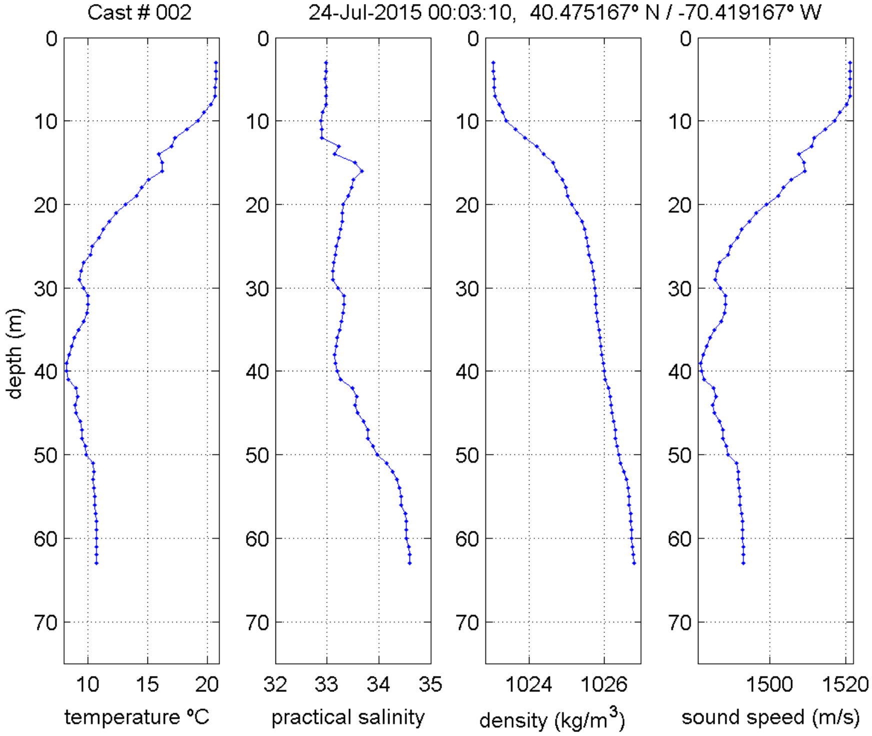
Pawlowicz, R., Beardsley, B. and Lentz, S. J., "Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE", Computers and Geosciences, 28, 929-937. 2002.

Shearman, R. K., and Lentz, S. J., “Observations of tidal variability on the New England shelf”, J.G.R. Vol. 109, C06010, doi:10.1029/2003JC001972, 2004.

5 Appendices



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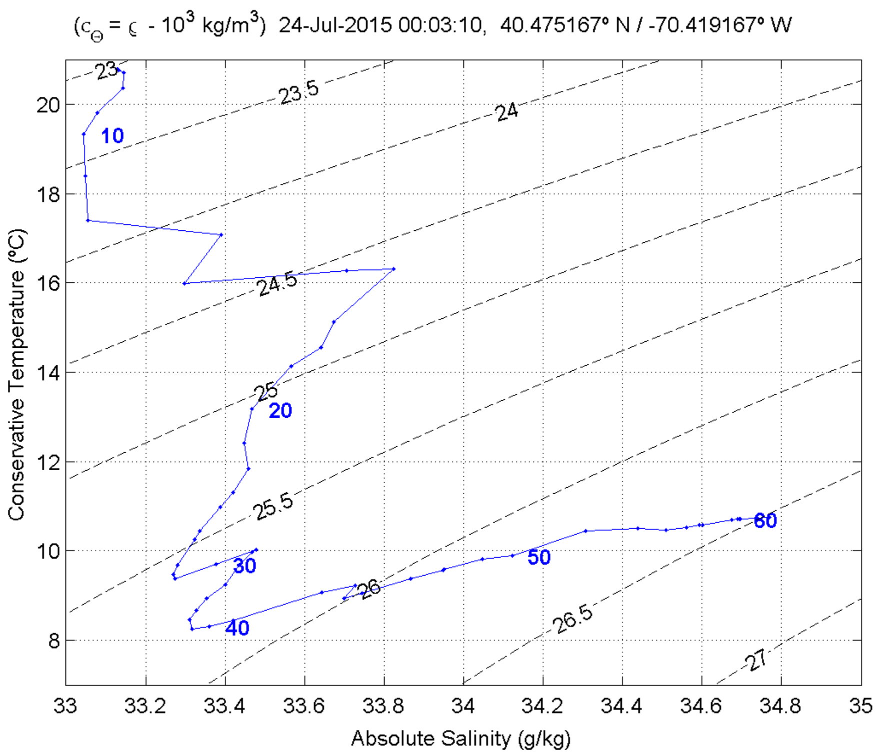
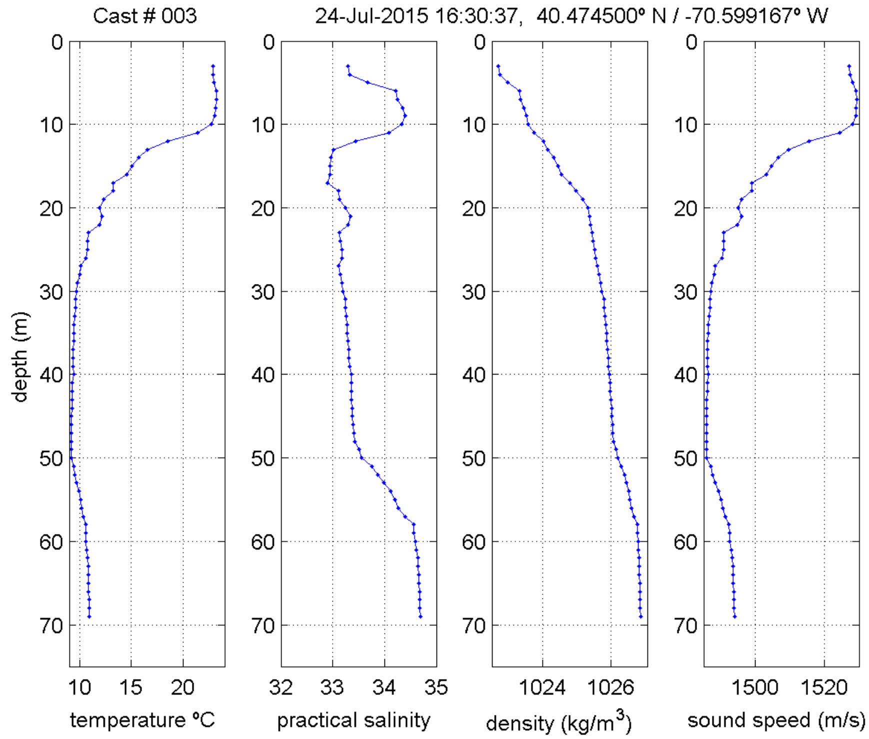
depth (m)
temperature °C
practical salinity
density (kg/m3)
sound speed (m/s)


(c_Θ = ϱ - 10^3 kg/m^3) 24-Jul-2015 00:03:10, 40.475167° N / -70.419167° W
Conservative Temperature (°C)
Absolute Salinity (g/kg)
23
23.5
24
24.5
25
25.5
26
26.5
27
10
20
30
40
50
60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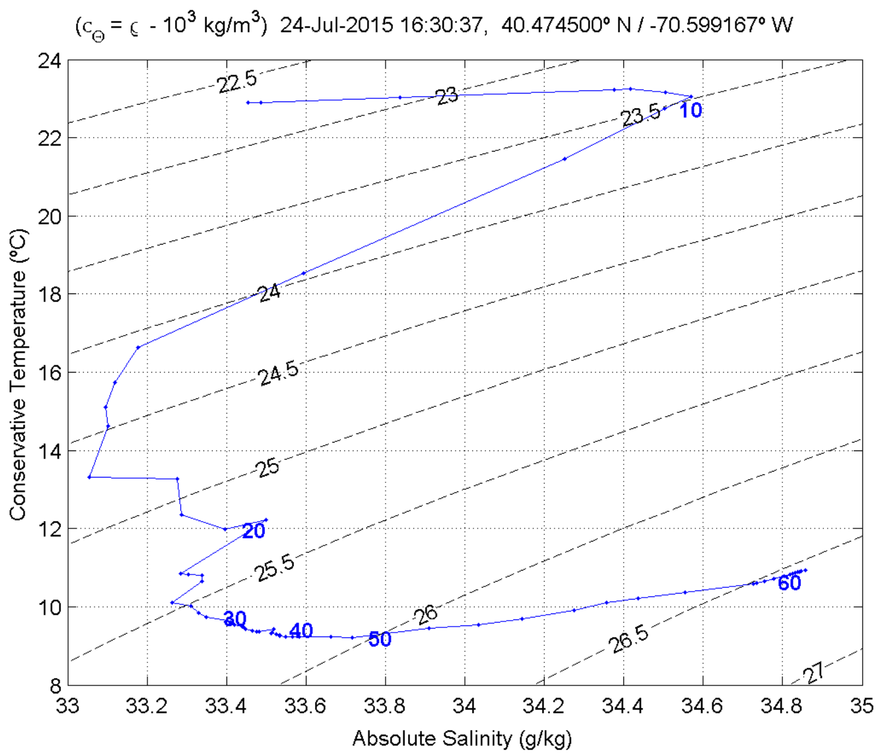
temperature °C
practical salinity
density (kg/m3)
sound speed (m/s)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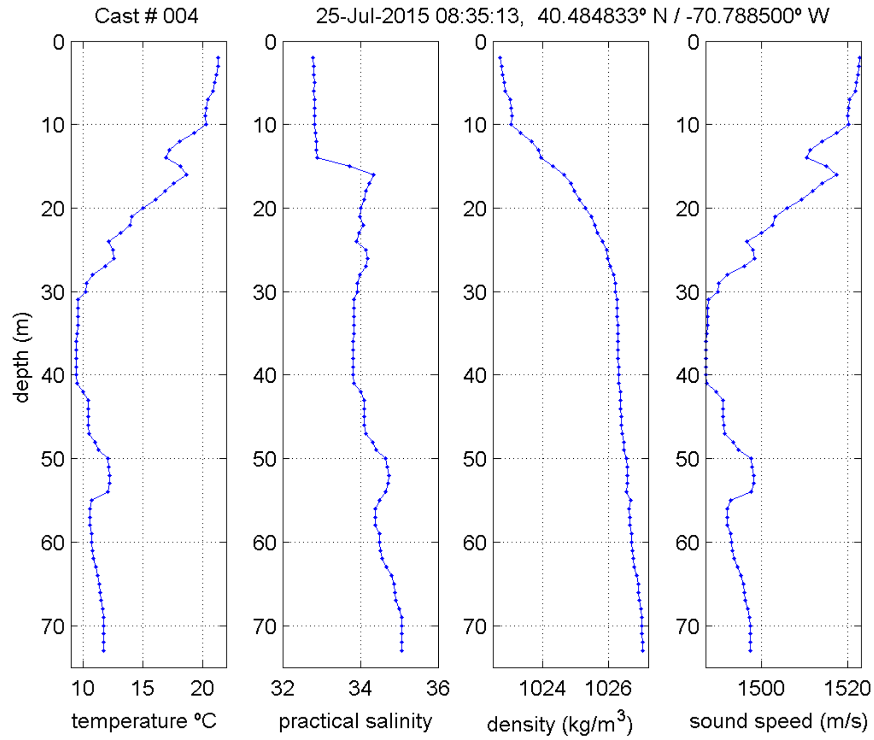
Absolute Salinity (g/kg)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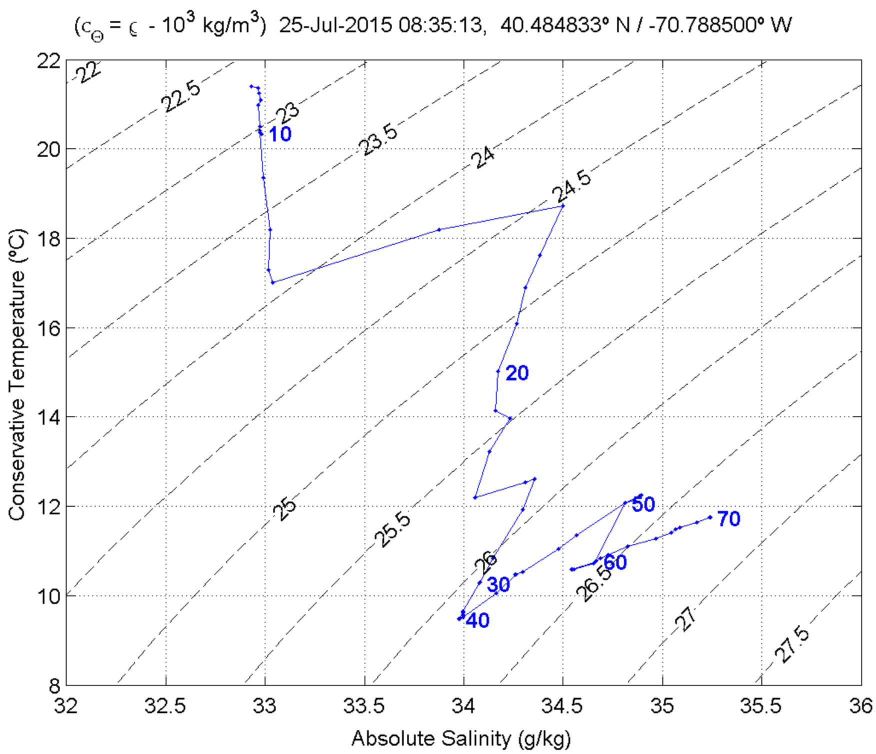
depth (m)
temperature °C
practical salinity
density (kg/m³)
sound speed (m/s)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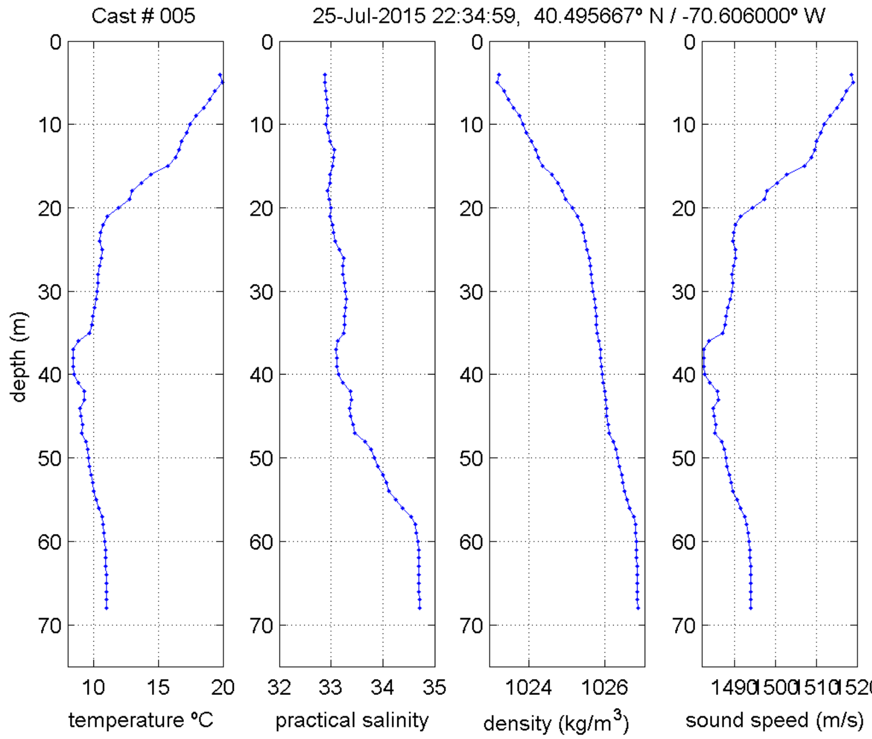
Conservative Temperature (°C)
Absolute Salinity (g/kg)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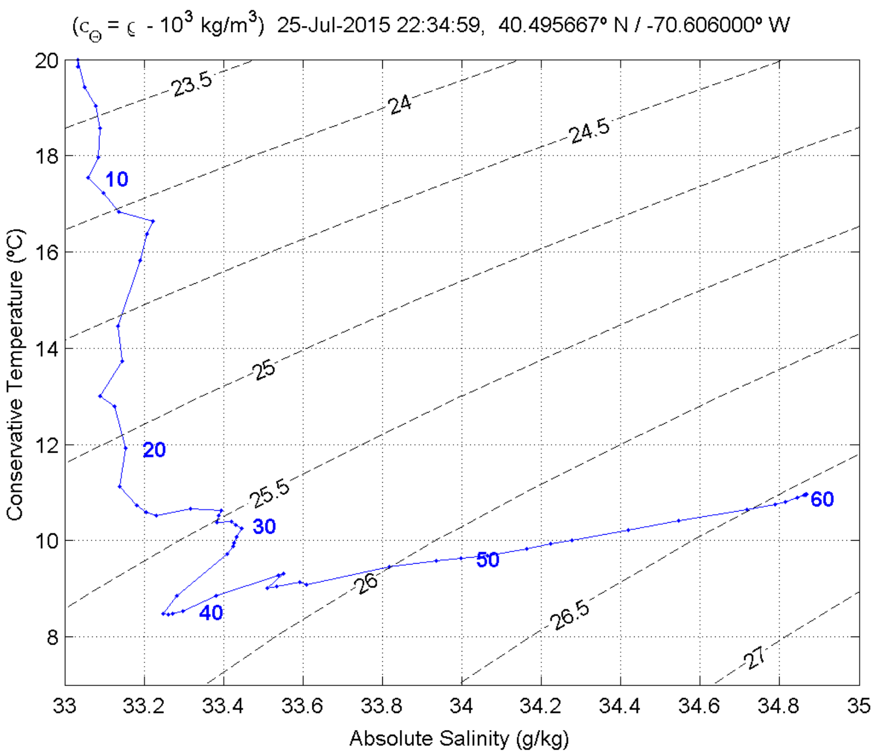
depth (m)
temperature °C
practical salinity
density (kg/m³)
sound speed (m/s)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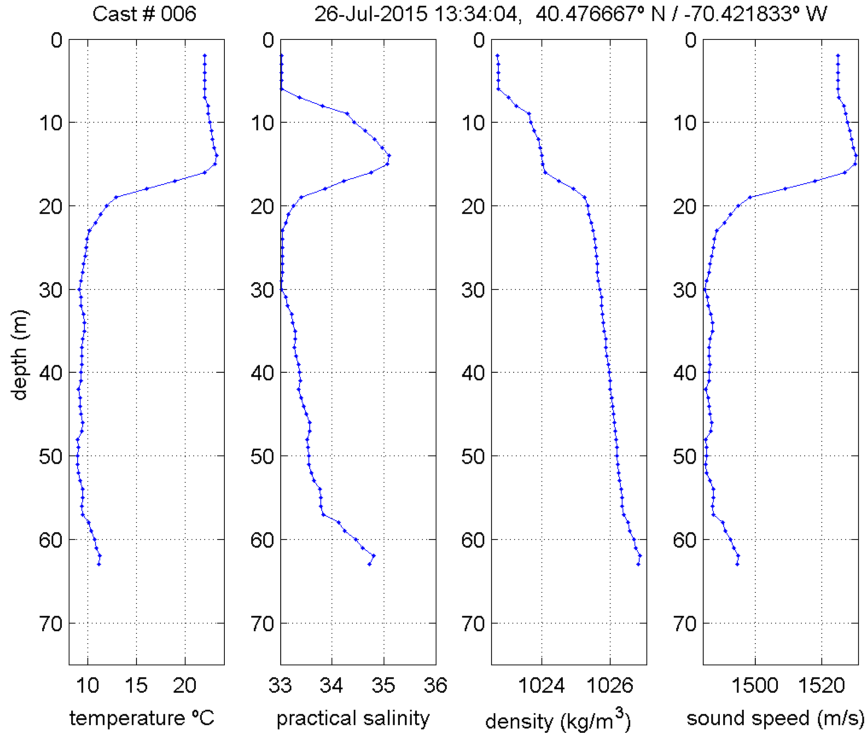
Conservative Temperature (°C)
Absolute Salinity (g/kg)
23.5
24
24.5
25
25.5
26
26.5
27
10
20
30
40
50
60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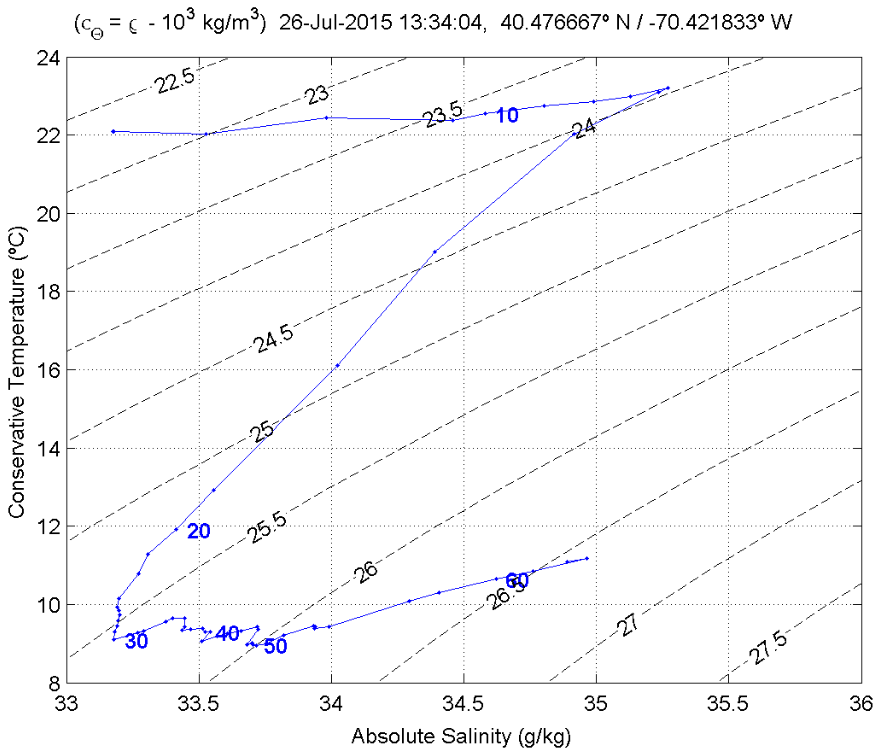
depth (m)
temperature °C
practical salinity
density (kg/m^3)
sound speed (m/s)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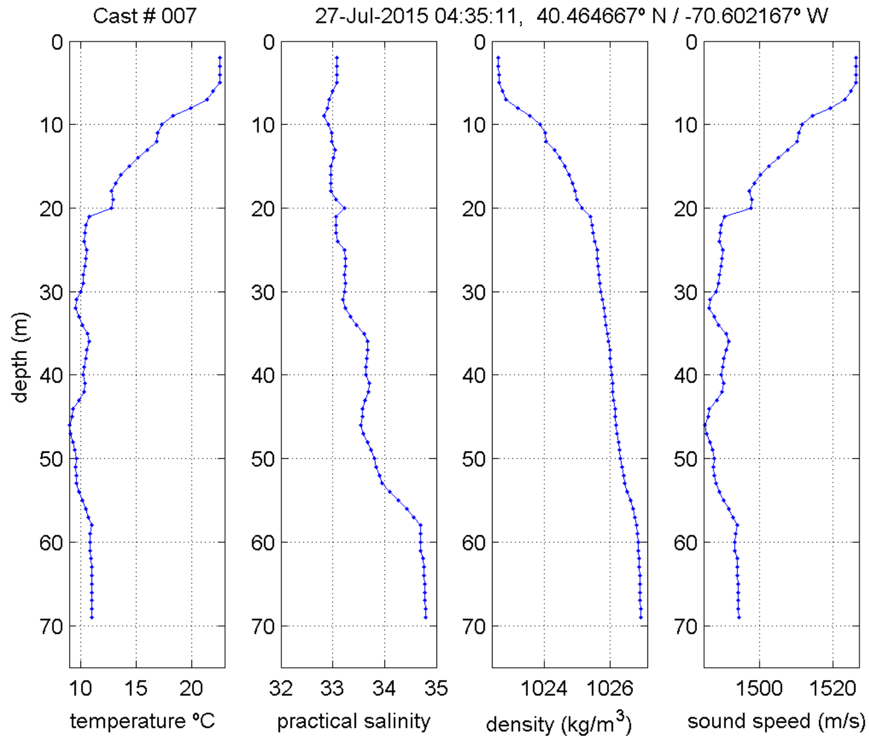
Conservative Temperature (°C)
Absolute Salinity (g/kg)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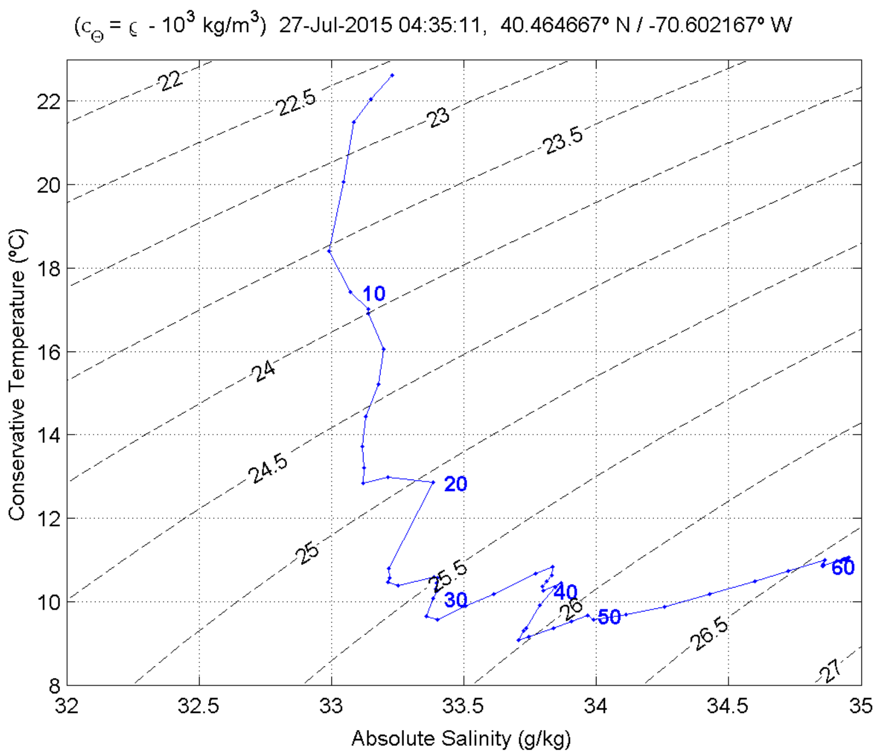
temperature °C
practical salinity
density (kg/m3)
sound speed (m/s)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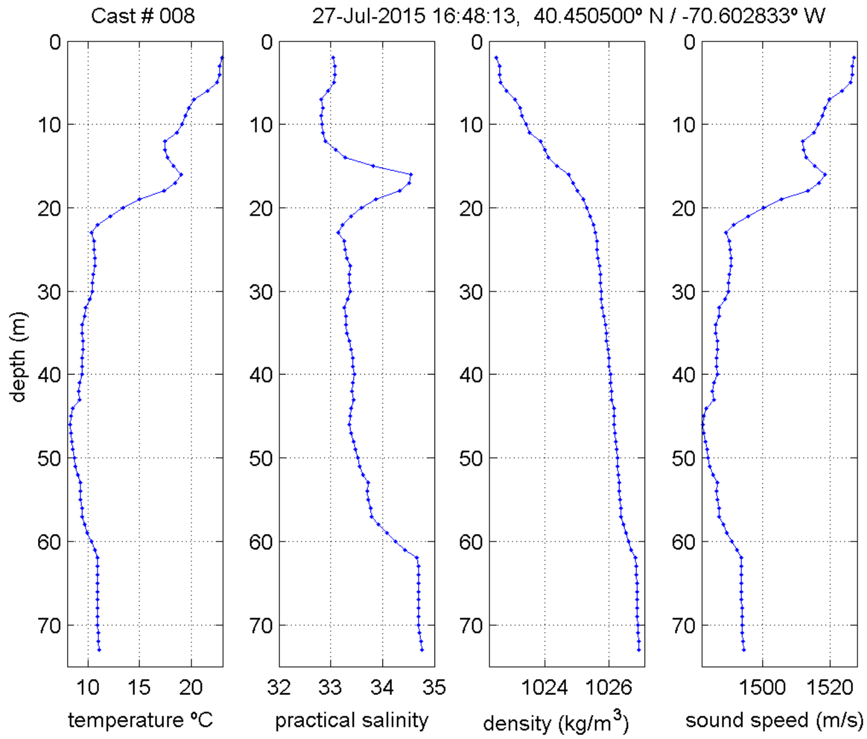
Conservative Temperature (°C)
Absolute Salinity (g/kg)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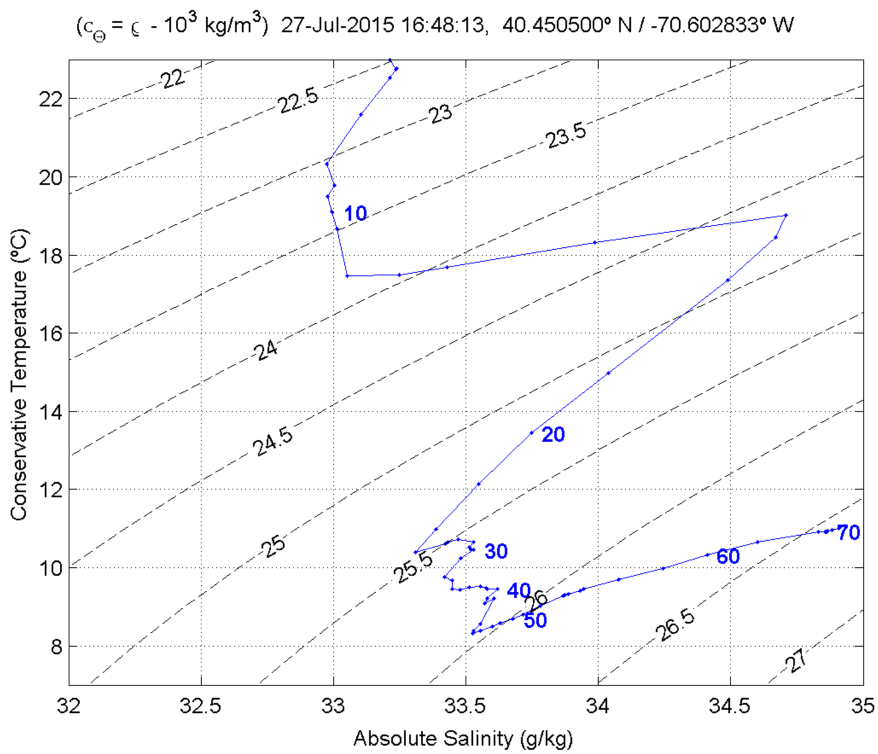
temperature °C
practical salinity
density (kg/m3)
sound speed (m/s)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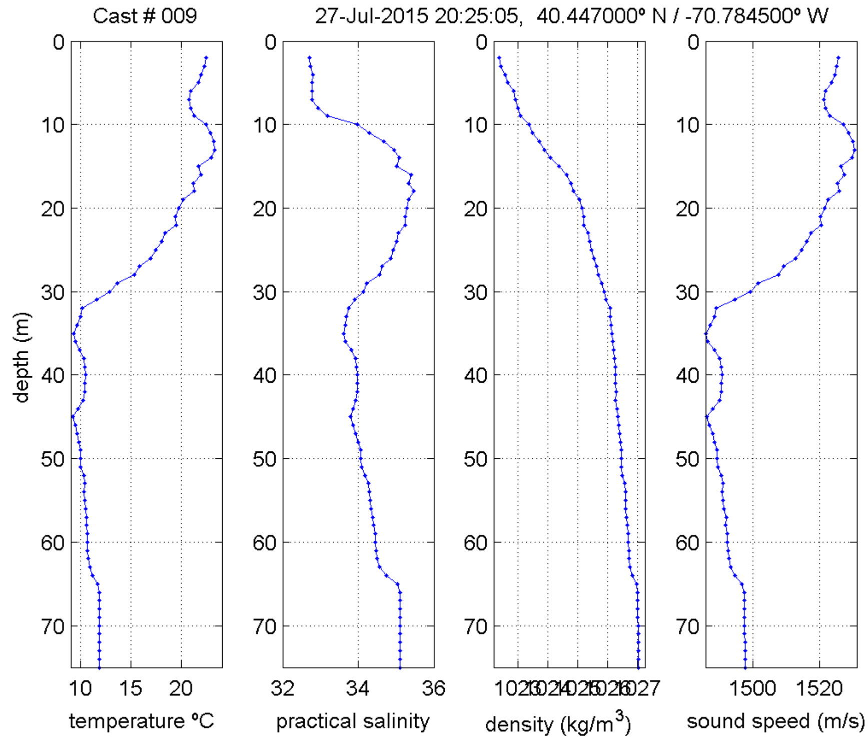
Absolute Salinity (g/kg)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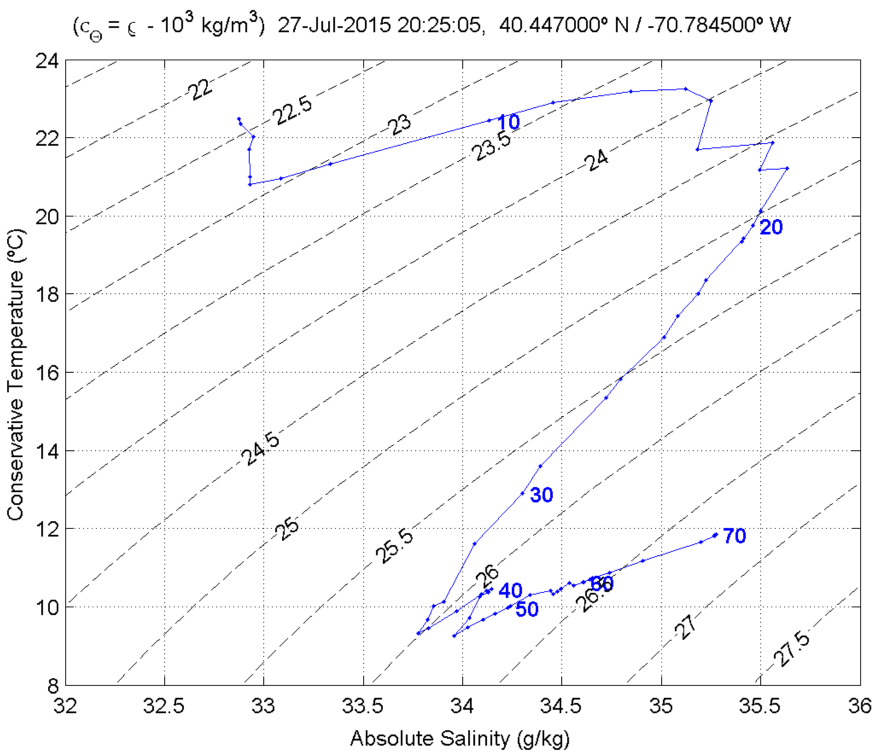
temperature °C
practical salinity
density (kg/m^3)
sound speed (m/s)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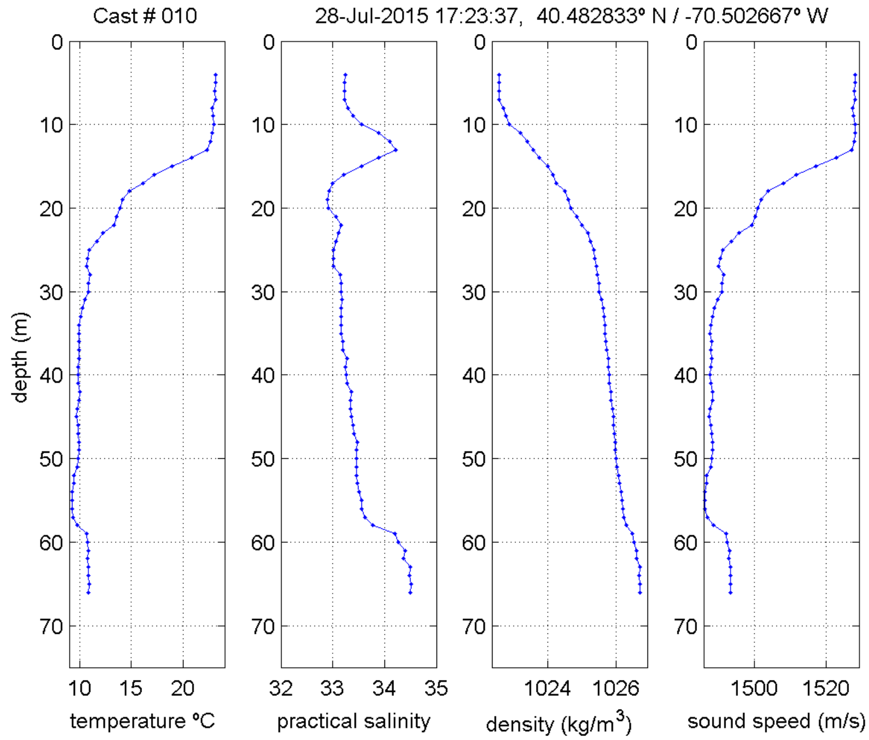
Absolute Salinity (g/kg)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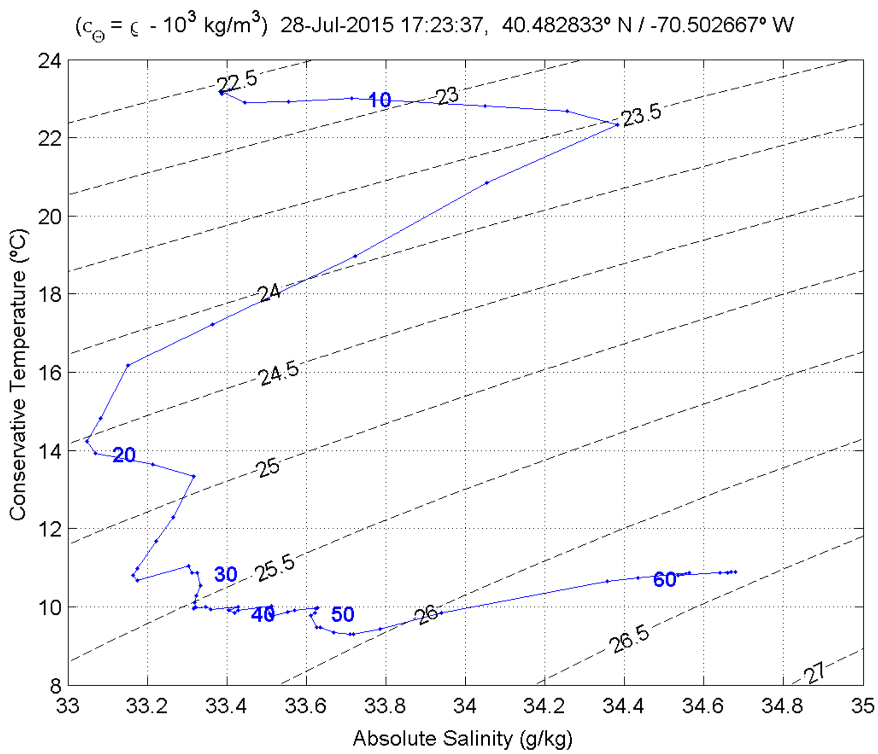
temperature °C
practical salinity
density (kg/m³)
sound speed (m/s)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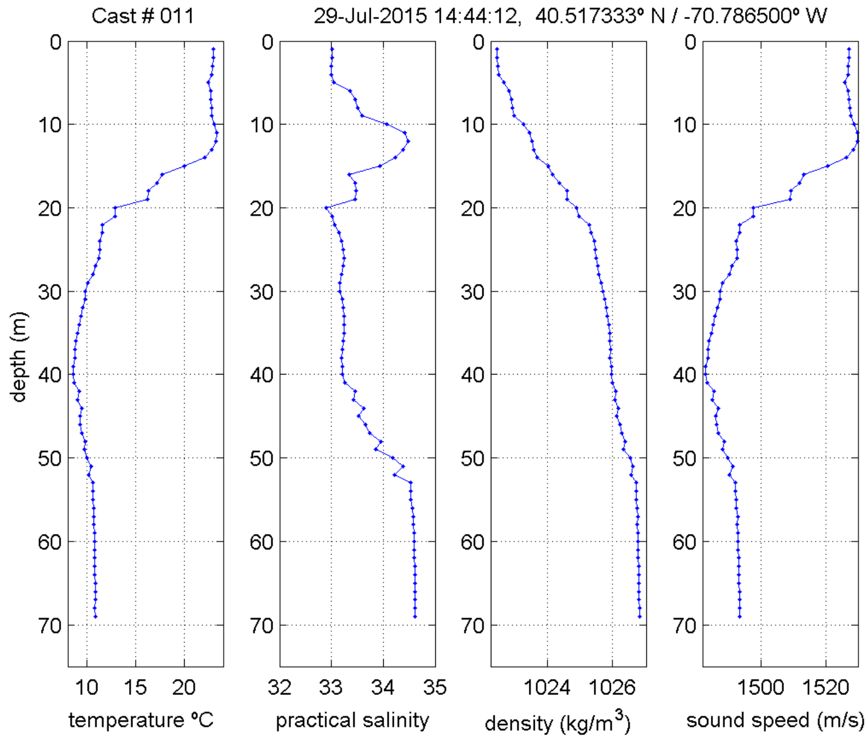
Absolute Salinity (g/kg)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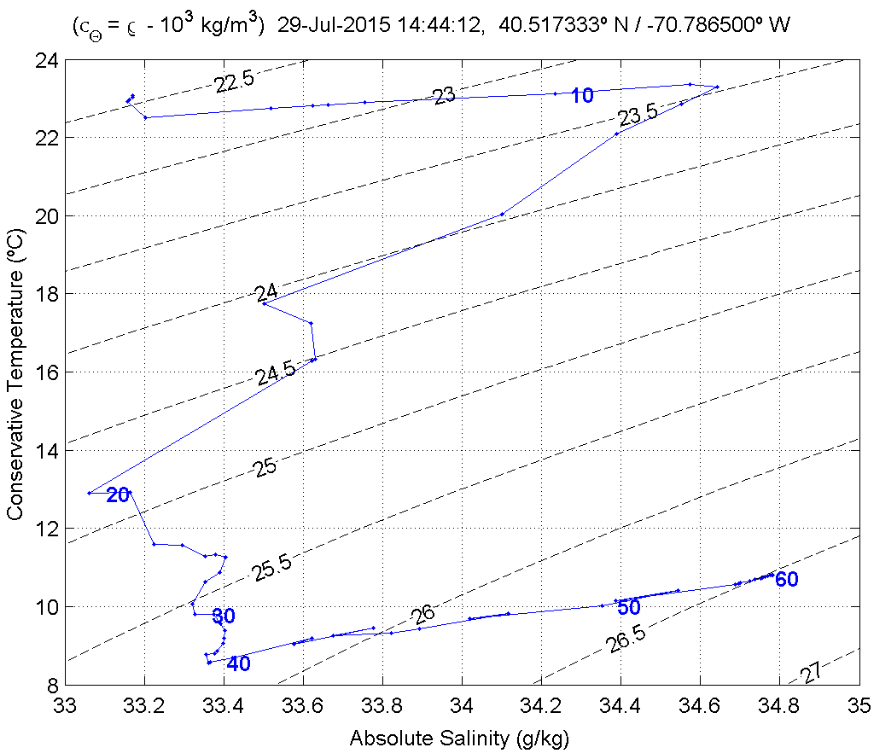
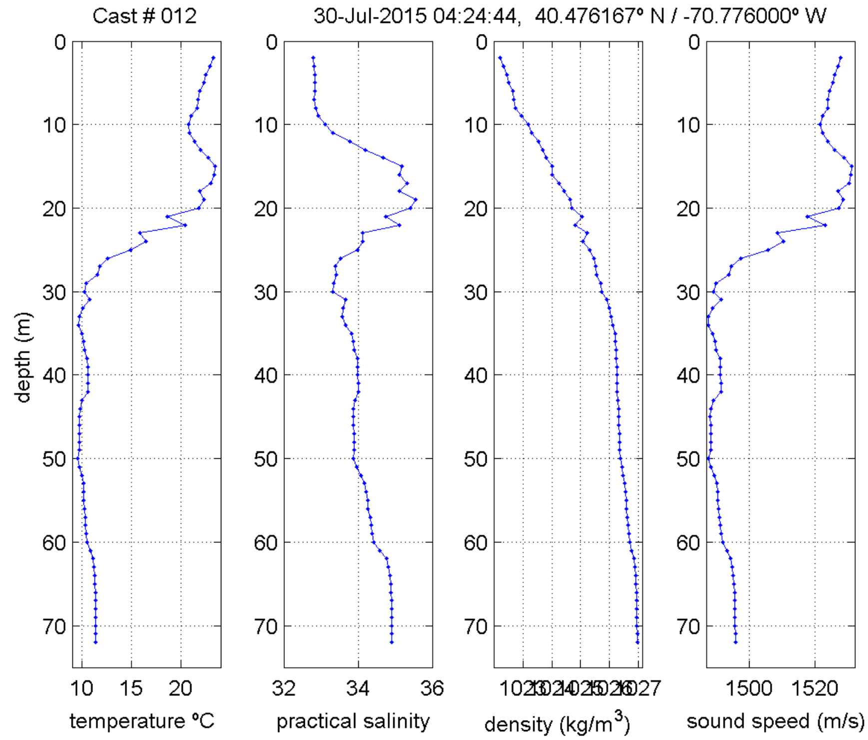
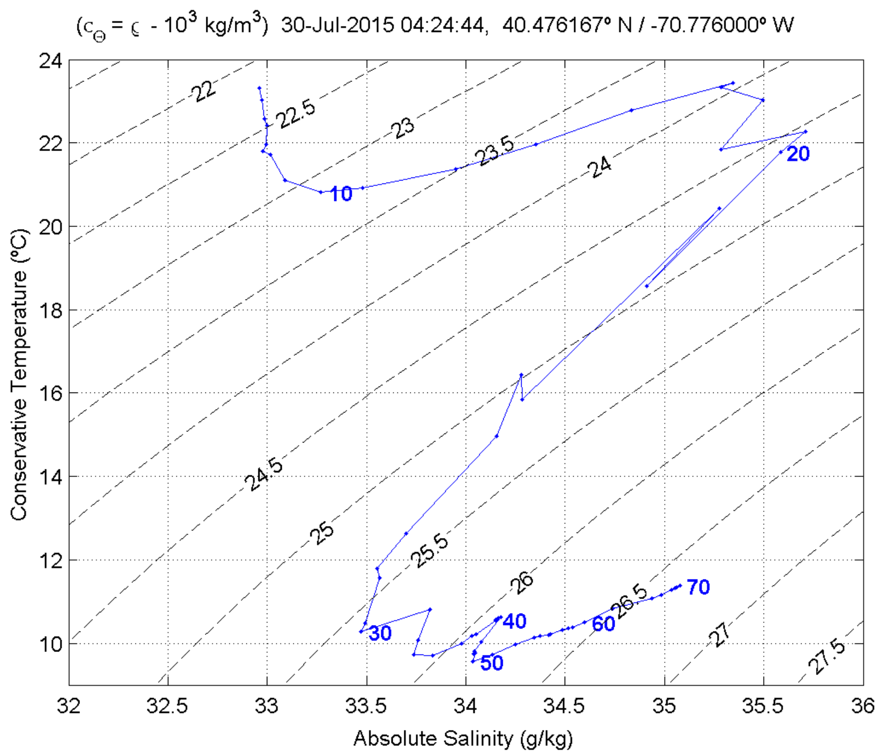
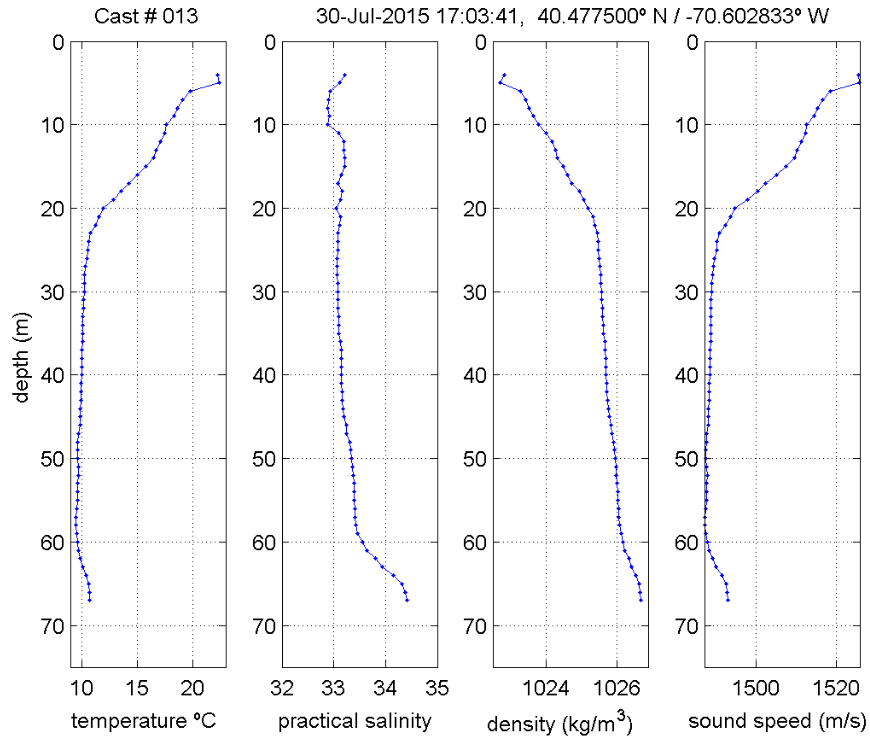
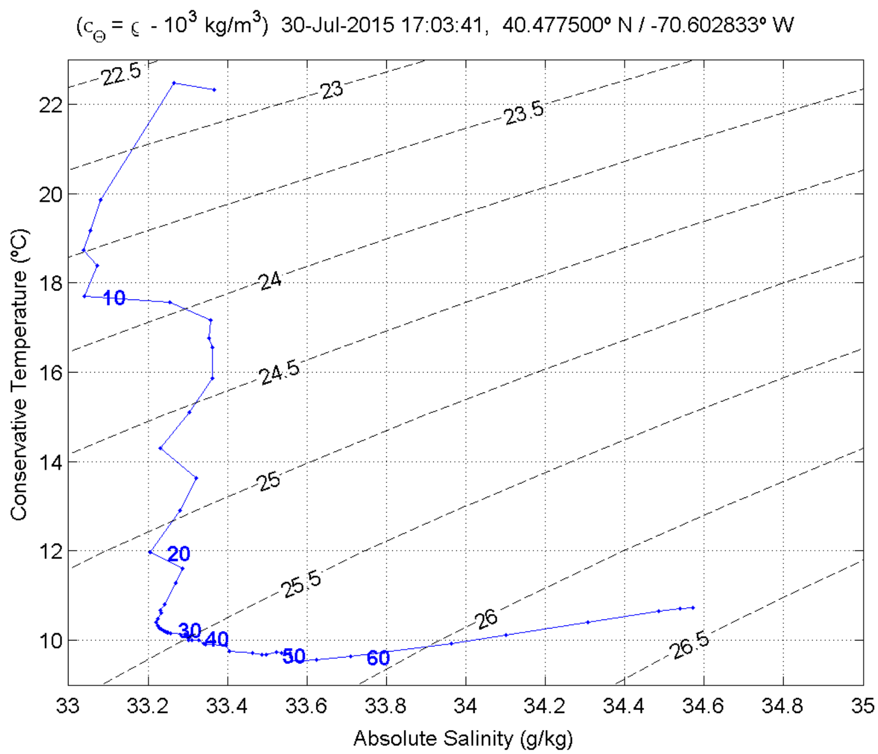
temperature °C
practical salinity
density (kg/m3)
sound speed (m/s)

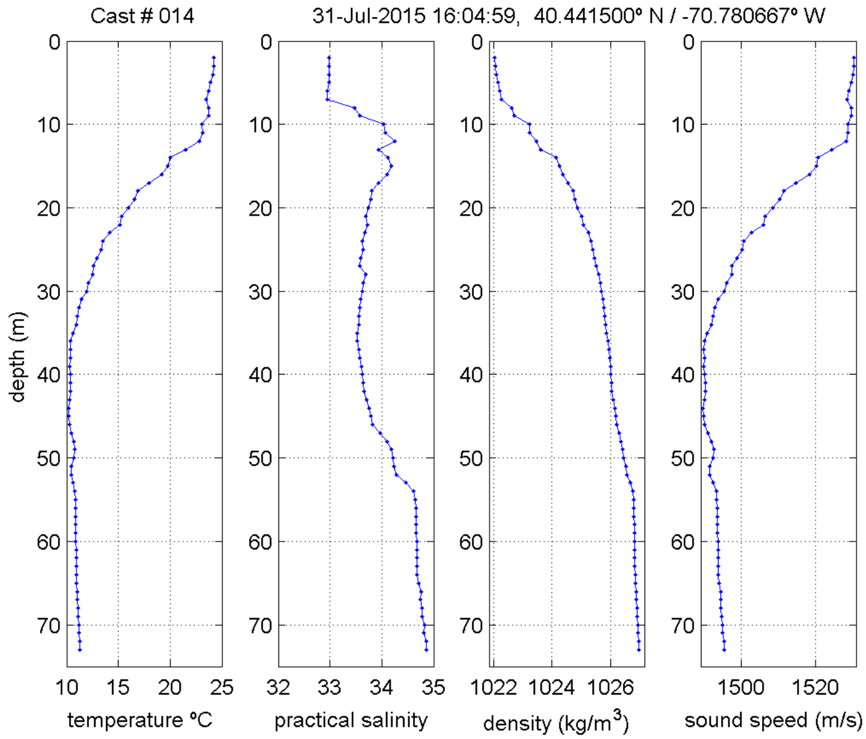

(σΘ = ρ - 10³ kg/m³) 29-Jul-2015 14:44:12, 40.517333° N / -70.786500° W
Conservative Temperature (°C)
Absolute Salinity (g/kg)
22.5
23
23.5
24
24.5
25
25.5
26
26.5
27
10
20
30
40
50
60

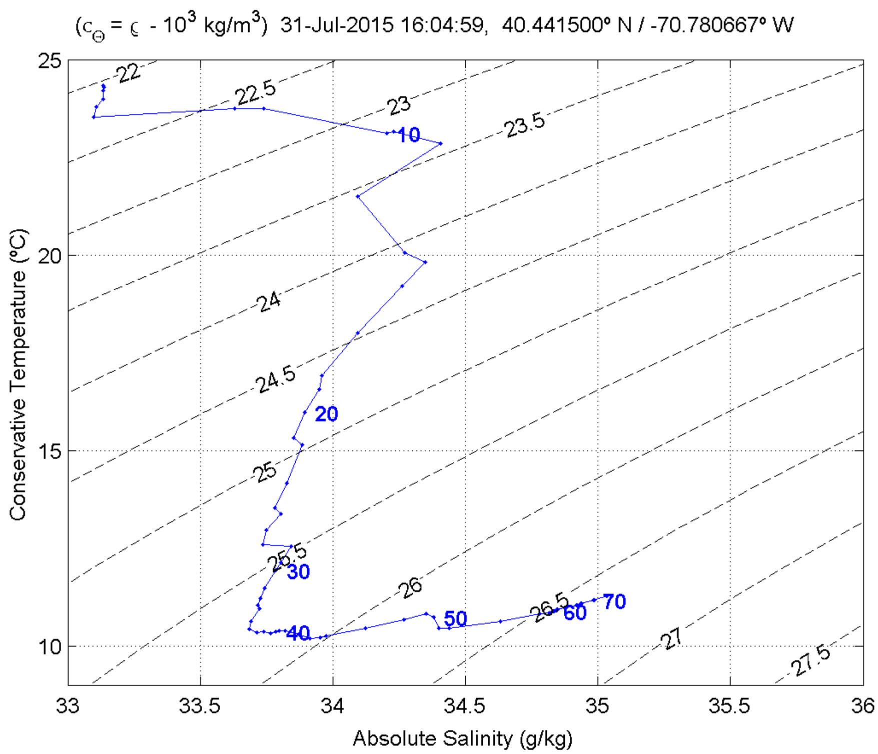

Cast # 012
30-Jul-2015 04:24:44, 40.476167° N / -70.776000° W
depth (m)
temperature °C
practical salinity
density (kg/m³)
sound speed (m/s)

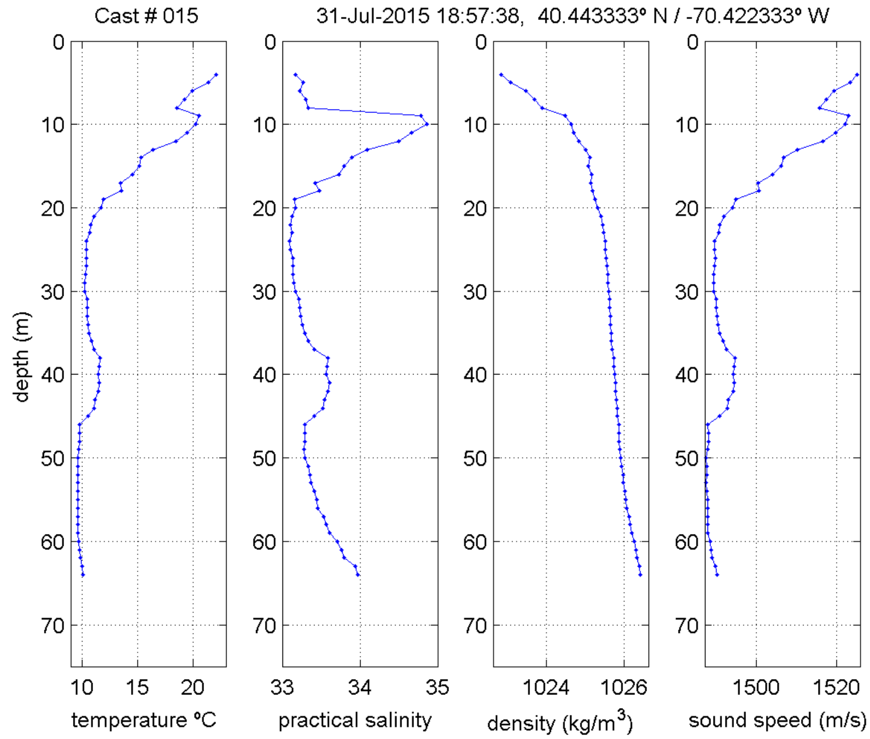

(c$_\Theta$ = ς - 10³ kg/m³) 30-Jul-2015 04:24:44, 40.476167° N / -70.776000° W
Conservative Temperature (°C)
Absolute Salinity (g/kg)

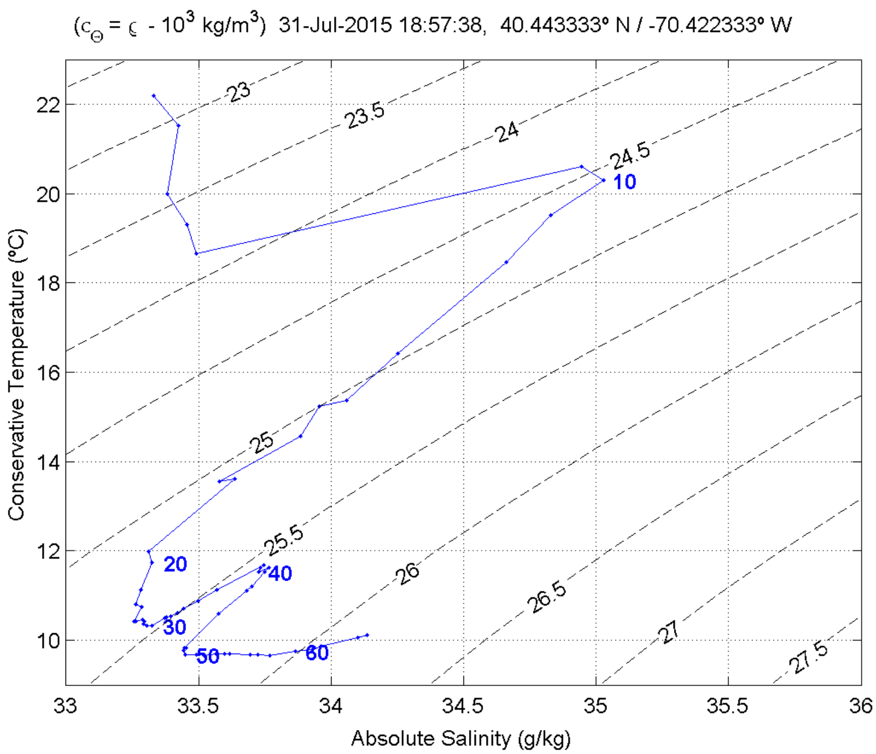

Cast # 013
30-Jul-2015 17:03:41, 40.477500° N / -70.602833° W
depth (m)
temperature °C
practical salinity
density (kg/m3)
sound speed (m/s)

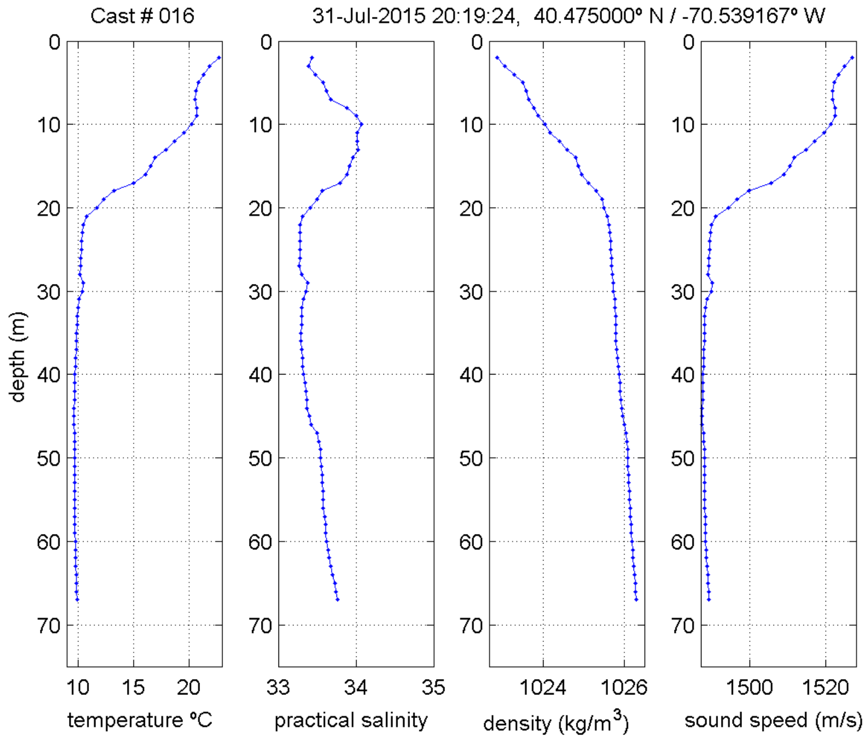

(cΘ = ς - 10^3 kg/m^3) 30-Jul-2015 17:03:41, 40.477500° N / -70.602833° W
Conservative Temperature (°C)
Absolute Salinity (g/kg)
22.5
23
23.5
24
24.5
25
25.5
26
26.5
10
20
30
40
50
60

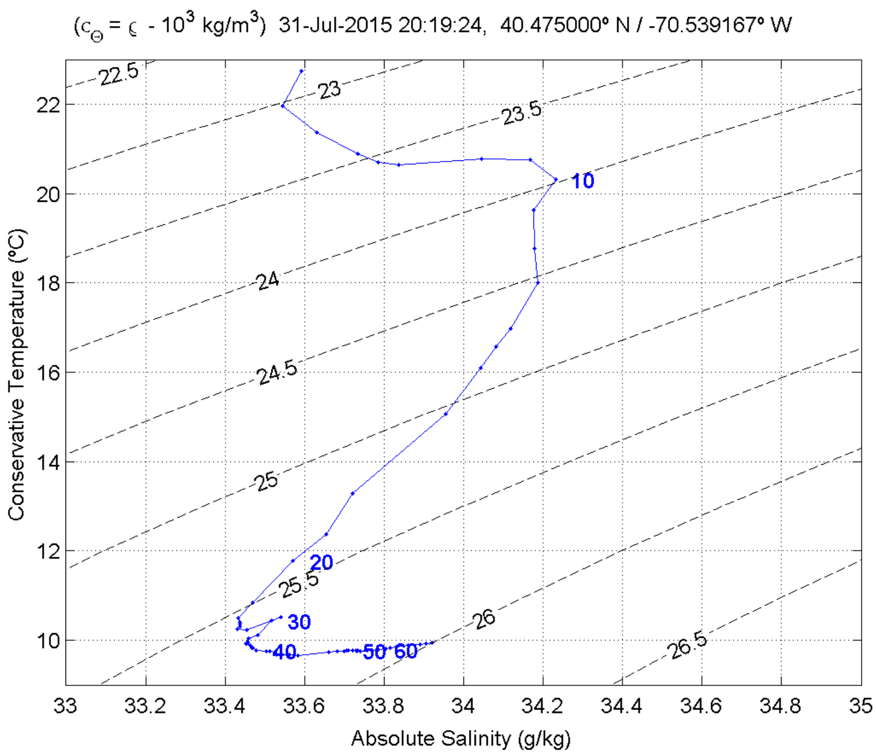

Cast # 014
31-Jul-2015 16:04:59, 40.441500° N / -70.780667° W
depth (m)
temperature °C
practical salinity
density (kg/m3)
sound speed (m/s)
0
10
20
30
40
50
60
70
10 15 20 25
32 33 34 35
1022 1024 1026
1500 1520

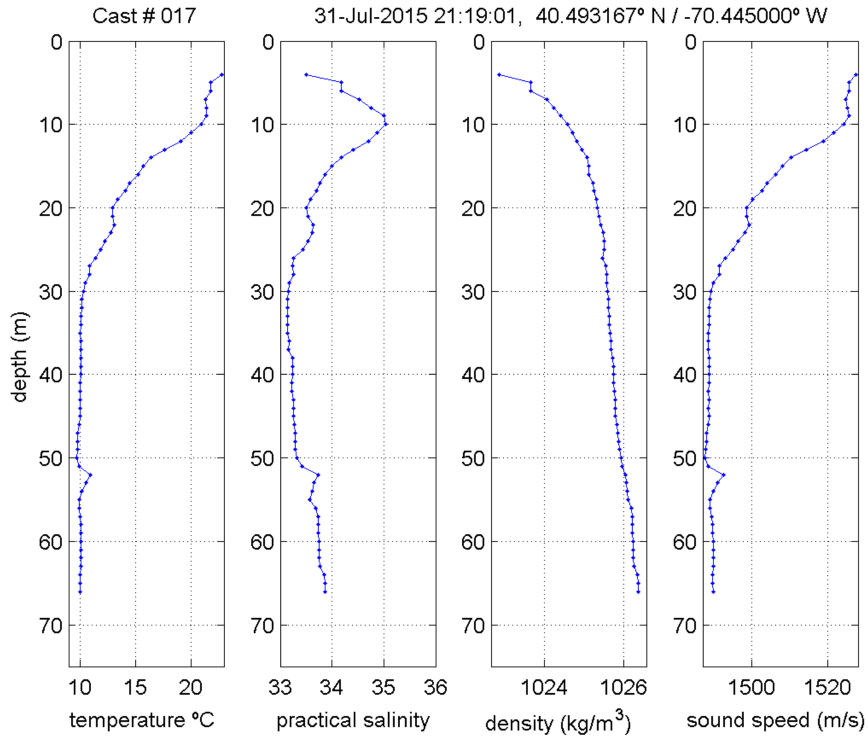

(cΘ = ς - 10³ kg/m³) 31-Jul-2015 16:04:59, 40.441500° N / -70.780667° W
Conservative Temperature (°C)
Absolute Salinity (g/kg)
25
20
15
10
33 33.5 34 34.5 35 35.5 36
22
22.5
23
23.5
24
24.5
25
25.5
26
26.5
27
27.5
10
20
30
40
50
60
70

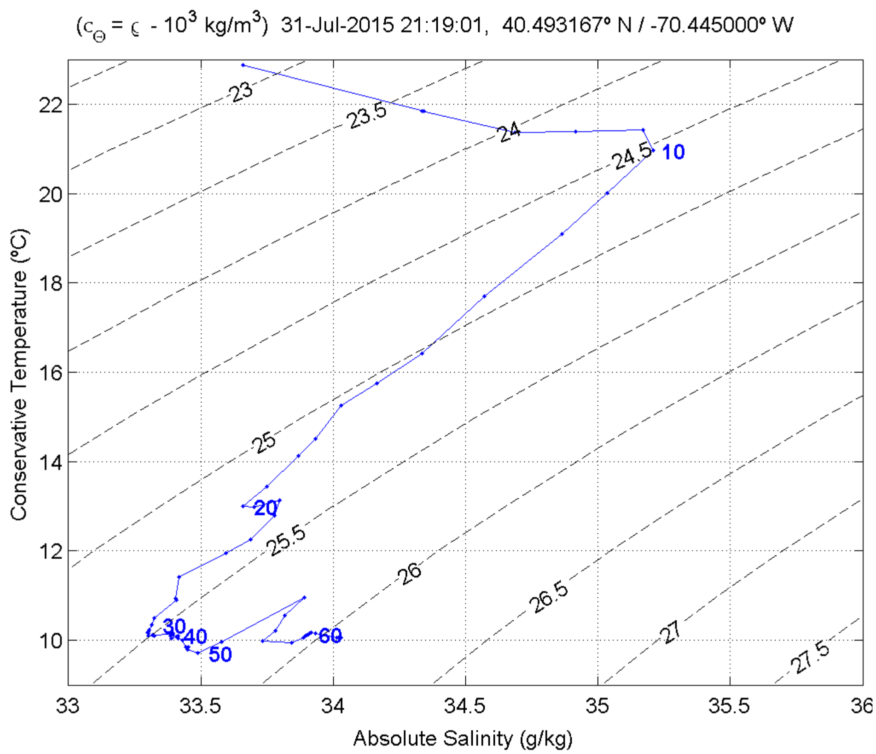

Cast # 015
31-Jul-2015 18:57:38, 40.443333° N / -70.422333° W
depth (m)
temperature °C
practical salinity
density (kg/m3)
sound speed (m/s)

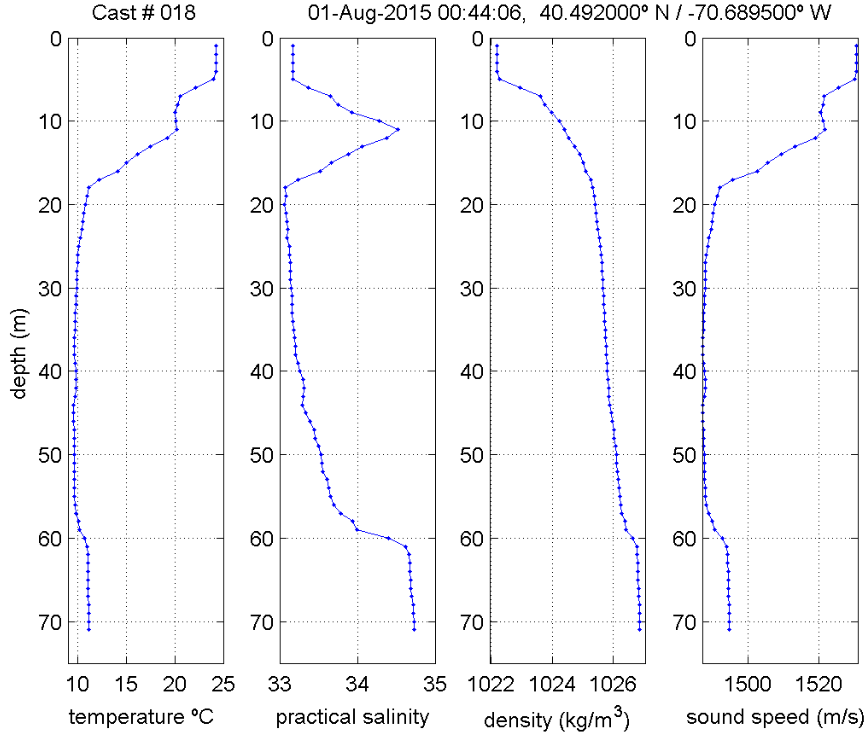

(cΘ = ϱ - 10³ kg/m³) 31-Jul-2015 18:57:38, 40.443333° N / -70.422333° W
Conservative Temperature (°C)
Absolute Salinity (g/kg)
23
23.5
24
24.5
25
25.5
26
26.5
27
27.5
10
20
30
40
50
60

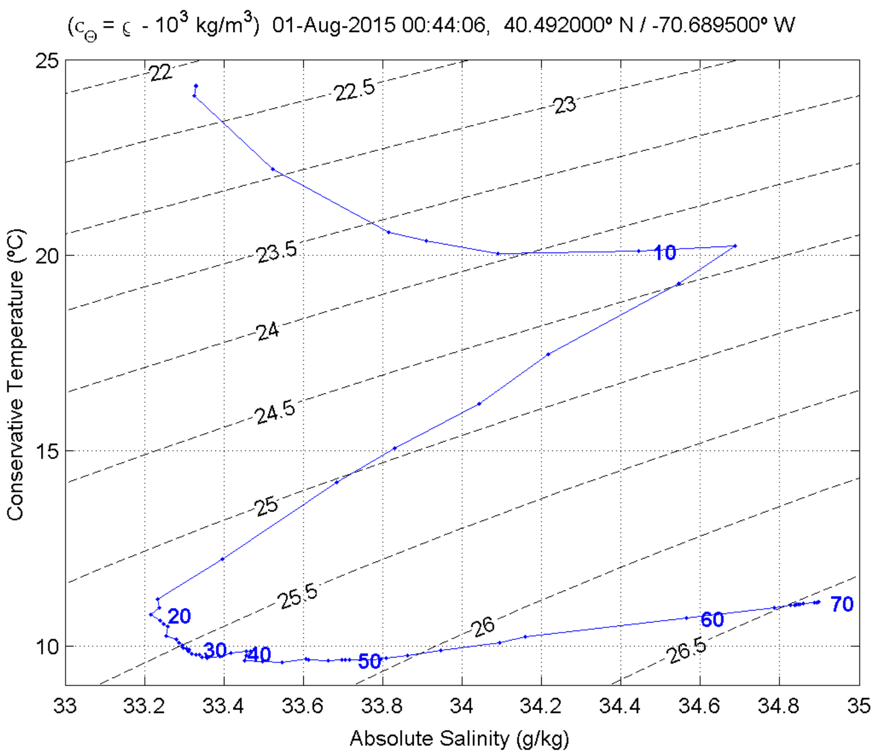

Cast # 016
31-Jul-2015 20:19:24, 40.475000° N / -70.539167° W
depth (m)
0
10
20
30
40
50
60
70
10 15 20
temperature °C
33 34 35
practical salinity
1024 1026
density (kg/m3)
1500 1520
sound speed (m/s)

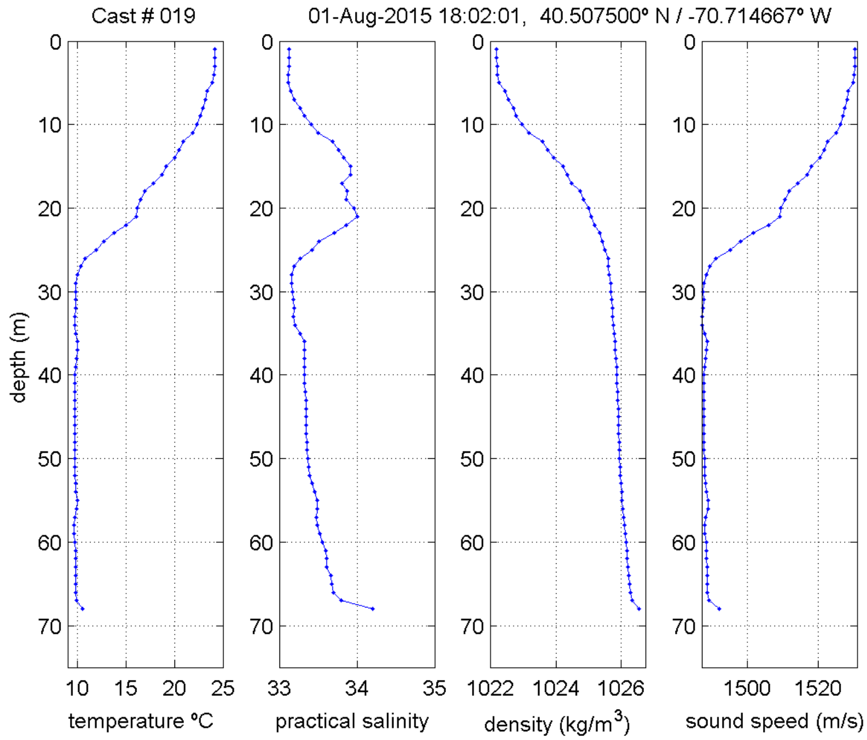

(cΘ = ς - 103 kg/m3) 31-Jul-2015 20:19:24, 40.475000° N / -70.539167° W
Conservative Temperature (°C)
10
12
14
16
18
20
22
22.5
23
23.5
24
24.5
25
25.5
26
26.5
10
20
30
40
50
60
33 33.2 33.4 33.6 33.8 34 34.2 34.4 34.6 34.8 35
Absolute Salinity (g/kg)

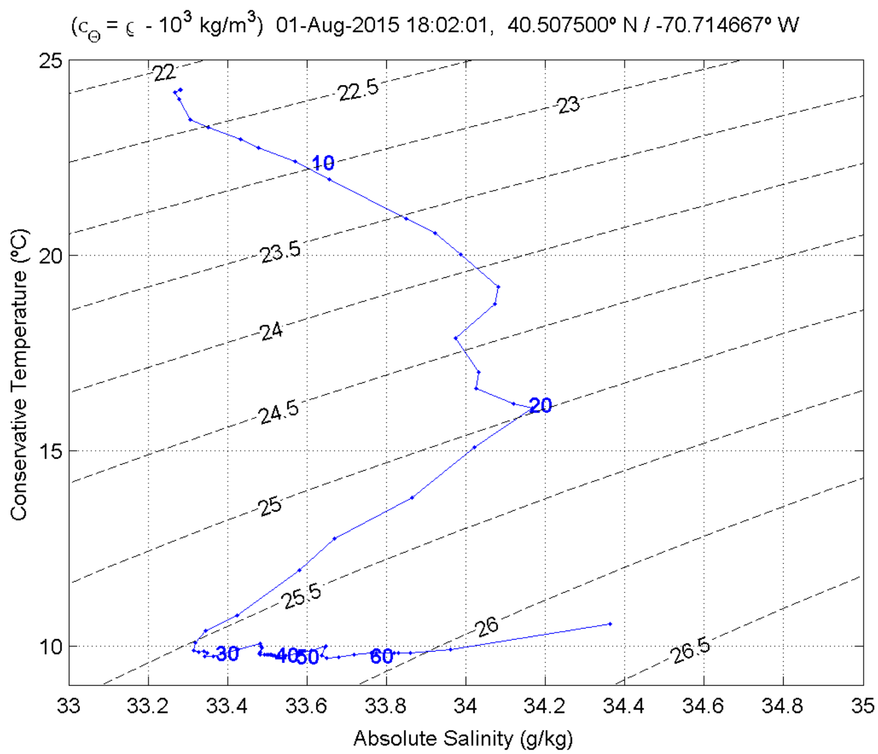

Cast # 017
31-Jul-2015 21:19:01, 40.493167° N / -70.445000° W
depth (m)
temperature °C
practical salinity
density (kg/m^3)
sound speed (m/s)


(σ_Θ = ρ - 10^3 kg/m^3) 31-Jul-2015 21:19:01, 40.493167° N / -70.445000° W
Conservative Temperature (°C)
Absolute Salinity (g/kg)


Cast # 018
01-Aug-2015 00:44:06, 40.492000° N / -70.689500° W
depth (m)
temperature °C
practical salinity
density (kg/m3)
sound speed (m/s)


(cΘ = ς - 10³ kg/m³) 01-Aug-2015 00:44:06, 40.492000° N / -70.689500° W
Conservative Temperature (°C)
Absolute Salinity (g/kg)


Cast # 019
01-Aug-2015 18:02:01, 40.507500° N / -70.714667° W
depth (m)
temperature °C
practical salinity
density (kg/m3)
sound speed (m/s)


(cΘ = ς - 10³ kg/m³) 01-Aug-2015 18:02:01, 40.507500° N / -70.714667° W
Conservative Temperature (°C)
Absolute Salinity (g/kg)
22
22.5
23
23.5
24
24.5
25
25.5
26
26.5
10
20
30
40
50
60