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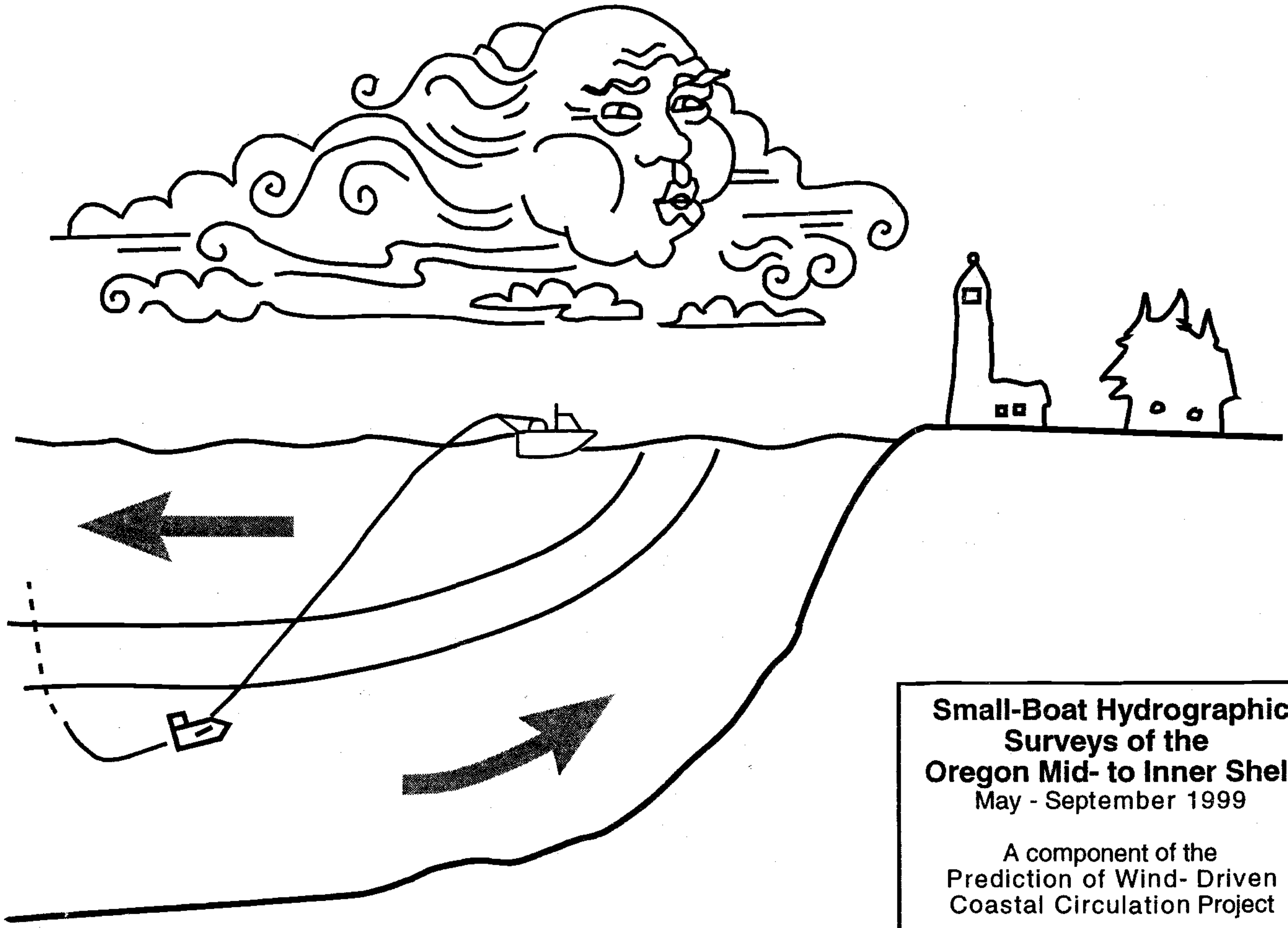

Small-Boat Hydrographic Surveys of the Oregon Mid- to Inner Shelf
May - September 1999

A component of the Prediction of Wind- Driven Coastal Circulation Project

by
Jay A. Austin
John A. Barth
Stephen D. Pierce

Reference 00-2
April 2000
Data Report 178

Funded by NOPP (National Oceanographic Partnership Program)

OREGON STATE UNIVERSITY

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Jay A. Austin
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Oregon State University
College of Oceanic and Atmospheric Sciences
104 Ocean Admin Bldg
Corvallis, OR 97331

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Contents

1 Introduction

During Spring and Summer 1999, as part of the Oregon State University National Oceanographic Partnership Program (OSU-NOPP) field program, 20 successful hydrographic surveys were undertaken on the Oregon mid- to inner shelf, all near Yaquina Bay. These consisted of 17 cross-shelf sections along the Newport Hydrographic line (extending approximately 30 km offshore), two "radiator"-type patterns, and one 40-km long alongshore section. These surveys were made with a Guildline "MiniBAT" (Figure 1), a small towed vehicle equipped with a Sea-Bird Electronics SBE-25 Conductivity-Temperature-Depth (CTD) instrument and a WetLabs transmissometer and fluorometer. This package was towed on a 200-m cable behind the R/V *Sacajawea* (Figure 2), OSU's 10-meter research boat. This report summarizes the instrumentation used, the cruise procedure, specific cruise summaries and details, the data processing procedure, and the data collected.

The cruises were spaced approximately two weeks apart, from the beginning of May to the end of September, except during July, when up to two cruises a week were carried out (Figure 3). This corresponded with the OSU-NOPP intensive observation period, and specifically with the SeaSoar cruises, carried out from the R/V *Wecoma*. The MiniBAT cruises served not only to provide reasonable temporal resolution over a long period of time, but also were able to sample into much shallower water than the SeaSoar did. The SeaSoar tended to sample into approximately 50m of water,

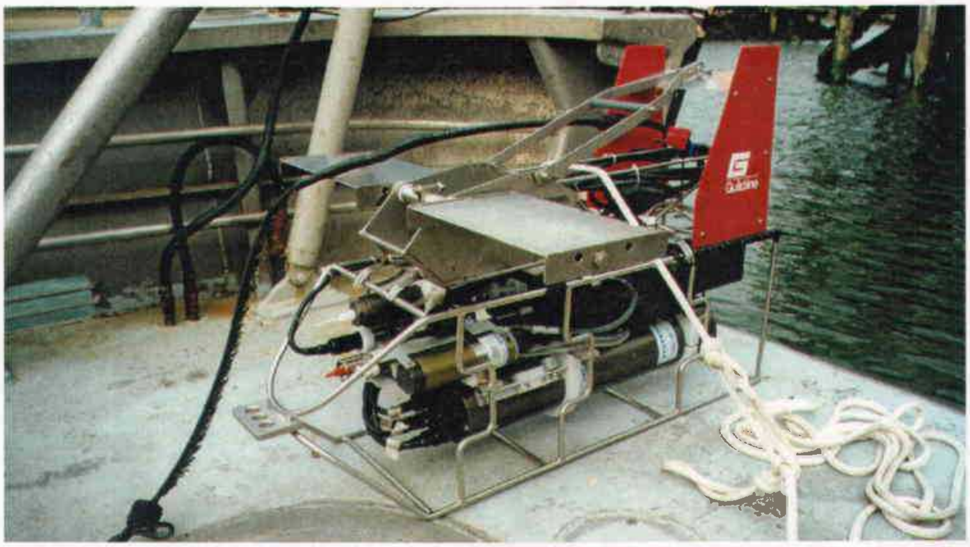

Figure 1: The MiniBAT towed vehicle with an SBE-25 CTD strapped underneath. The wings shown are the older, smaller wings.

stopping due to the increased density of crabgear and the rapidly shoaling bottom inshore. The MiniBAT sampled into approximately 8m, depending on the sea state. The disadvantage of the MiniBAT/*Sacajawea* operation was the limited sea state in which measurements could be made (more than 2 meters of wind-generated waves make operations on the *Sacajawea* difficult) and the limited amount of time that the *Sacajawea* could spend on the water. Each cruise took approximately 7 hours on the water, and it was not practical to spend much more time than that, given the *Sacajawea's* limit to daylight operation.

Spatially, the cruises focused on repeated transects along the Newport Hydrographic (hereafter NH) line, at 44°39.1′N, a standard hydrographic line used by many groups (Figure 4). This line was sampled 17 times with the MiniBAT, from approximately 30 km offshore (NH-15), in addition to 10 CTD surveys along the line by Bill Peterson's group (pers. comm.), several times by the SeaSoar group, and twice by the GLOBEC Long Term Observation Program (LTOP) program. The MiniBAT transects typically had 30 full undulations, resulting in an approximate cross-shelf resolution of 500 m. These undulations, once the instrument was operating to our satisfaction (all cruises after June 29), would typically sample from the surface to within 5m from the bottom. In addition to the simple cross-shelf surveys, two "radiator" patterns were performed (on July 20 and 27) during the intensive sampling period, designed to complement the concurrent SeaSoar surveys. Finally, on August 18, an alongshore survey of 40 km length was performed, largely along the 30m isobath, to help determine alongshore scales in shallow water.

Figure 2: Preparation for a cruise on the deck of the R/V *Sacajawea*.

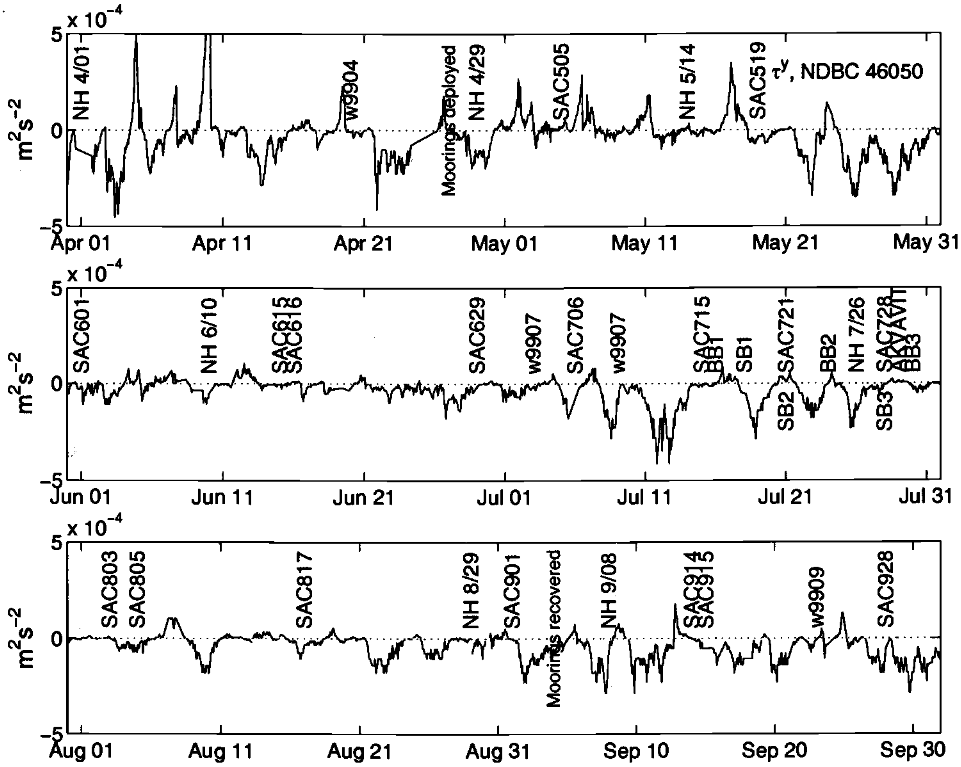

Figure 3: Timeline of alongshore wind stress from NDBC 46050, along with Mini-BAT/*Sacajawea* cruises (SACXYY, where X=month and YY=day), Wecoma SeaSoar Surveys (BB=Big Box surveys, SB=Small Box surveys), GLOBEC LTOP cruises (w9904, w9907, and w9909), Bill Peterson's NH line surveys (NH X/YY), a survey done by the F/V *Akvavit*, and the mooring deployment and recovery schedule.

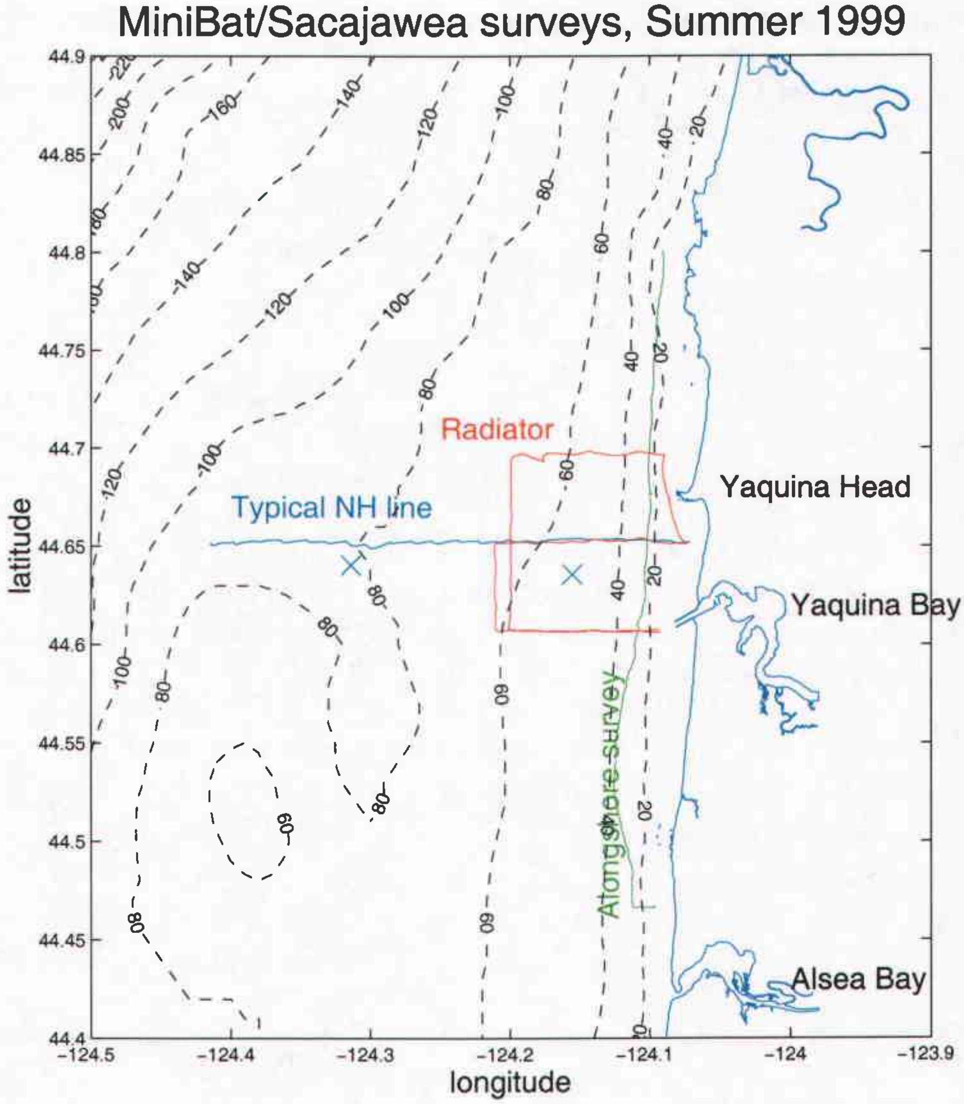

Figure 4: Map detailing cross-shelf survey line, radiator pattern, and alongshore survey. The locations of the OSU-NOPP inner-shelf and mid-shelf moorings indicated by x. Bottom topography is in meters.

2 Instrumentation

The Guildline "MiniBAT" is a towed vehicle with a set of wings controlled from the deck, which allows the user to "fly" the instrument package up and down through the water column. Data from both the MiniBAT vehicle (pressure, wing angle) and data from the CTD package (temperature, conductivity, pressure, fluorometer voltage, and transmissivity) are sent up the cable and recorded on a set of laptops in the ship's cabin. In addition, the sea cable goes over a block attached to the ship's A-frame, and a tension cell measures the tension applied to the block. This number is displayed in the lab, but is not recorded. This aids in the early detection of snags or any other problem the instrument package might encounter. Specifics about the instrumentation are covered in this section and summarized in Table 1.

2.1 The MiniBAT

The MiniBAT vehicle consists of a rigid steel frame, stabilizing fins, a tow yoke, and a pair of wings that are actuated by a control unit on the vehicle. The wings can be rotated through an arc of 30°, and take approximately 15s to do so. Starting with the cruise on July 6, the original wings were replaced with a set of larger, more hydrodynamically shaped wings provided *gratis* by Guildline in return for our "beta test" evaluation. The old wing area was $500\,\text{cm}^2$; the new wing area is $680\,\text{cm}^2$. These wings dramatically improved the flying characteristics of the MiniBAT as loaded with our payload (see section 2.2). We also made changes to the position from which the MiniBAT is towed, drilling new tow-points farther forward (toward the wing axle) on the tow body. This also improved the flying characteristics.

The system is operated from the ship's cabin using a control box which takes the data signal from the sea cable, a GPS, and an echosounder and sends it to the laptops. It also takes signals and passes them to the instrument in the water, in order to control CTD operations and the flight performance of the MiniBAT through the adjustable wing angle. The MiniBAT software package, "In-Tow", allows the vehicle to be flown automatically by setting depth preferences. Unfortunately, line noise between the MiniBAT vehicle and the controller made this prohibitively difficult, and the vehicle was "flown" manually for all of the cruises.

2.2 The CTD package

The CTD package is a standard Sea-Bird SBE-25 unit with pressure, temperature and conductivity sensors. A pump takes in water in front of the package, where it is first routed to the temperature sensor, then ducted directly to the conductivity sensor. The water is then routed to a WetLabs WetStar fluorometer, with a lag of approximately 3 seconds after its temperature and conductivity were measured (this lag is accounted for in the post-processing). The fluorometer had an excitation wavelength of 455 nm, and detects fluorescence at 695 nm. In addition, there is a WetLabs C-Star transmissometer with a path length of 25 cm, which is not pumped, and samples water flowing past the open light path. All of the instruments sample at 8 Hz. There is a main controller unit, which takes the signals from the individual sensors, collects, digitizes and multiplexes them before sending them up the cable to the computer on deck via RS-485 protocol. This unit also internally records the data in the CTD. All of this is mounted on a standard Sea-Bird 316 stainless steel frame, which is lashed underneath the MiniBAT with eight steel hose clamps. The CTD unit is internally powered by 9 rechargeable Ni-Cad D-cells. It has a weight in air of approximately 21 kg. Post-calibration of the temperature and conductivity cells in March 2000 showed insignificant drift over the course of the field season.

2.3 The cable and winch

The MiniBAT is towed behind the ship with 200 m of cable, supplied by the Cortland Cable Company. It is eight conductor (7 insulated, one drain lead), with a 24-strand kevlar weave for tensile strength (2000 lb breaking strength) and a nylon outer weaving with a short "fuzzy" fairing to decrease drag. After the August 18 cruise, 13m of this cable was cut off of the sea-end after an on-deck mishap damaged the cable. The cable has Sea-Con 8-conductor underwater connectors at both ends.

The winch is an Inter-Ocean model powered by two 12-volt deep cycle marine batteries. It takes approximately 10 minutes to bring in 200m of cable (the amount of time to unreel the 200m depends on the ship speed). The winch is sufficiently portable that it is mounted to the deck before a cruise and removed after each cruise. The winch has a set of slip rings on it and Sea-Con wet connectors to connect to the MiniBAT deck unit.

2.4 Tension cell

A Revere tension cell was placed above the block to determine the tension being applied to the block. The actual tension in the line was estimated to be approximately three times this, due to the geometry of the cable running through the block. As a rule of thumb, we tried to keep the tension of the cell less than 300 lbs.

2.5 GPS equipment

To determine position and depth, we used an APELCO GPS receiver and 120 kHz depth transducer/fish finder. The GPS antenna was lashed to the starboard rail just outside the lab, and the transducer was mounted on the end of a 2x4, which was c-clamped to the starboard transom. The transducer was approximately 1 m below the surface of the water.

2.6 Shipboard computers

In the ship's cabin, we had two laptops, one which controlled the MiniBAT vehicle and one which recorded the data from the CTD. Both of these received data through the serial port. After the cruise, data was moved onto a iomega 250MB "Zip" drive.

2.7 Deck CTD

For four of the cruises (May 19, June 1, 15, and 16), a CTD (SBE-19) was used on deck to record the near-surface temperature and salinity. This was done since the undulating package was not reaching the surface. The water was provided by the ship's saltwater pump (Jabsco), pumped into a 6" diameter PVC pipe (closed at one end) into which the CTD was placed. The data was internally recorded and downloaded at the end of the cruise. This data will be displayed here both as part of the sections and separately as line plots.

3 Cruise Procedure

Upon arriving in Newport from Corvallis (an approximately 75 minute drive) with the equipment, the ship would be prepared for the cruise. This consisted of: mounting the winch to the deck, loading the winch power supply batteries, mounting the echosounder transducer on the transom, placing the MiniBAT vehicle on the fantail and lashing it down, mounting the GPS antenna, hanging the tension cell and block (which are then lashed off to the A-frame) and setting up the electronics. This procedure typically takes about 45 minutes. We then transit to the beginning of the survey. For the NH-line surveys, this entails steaming out to NH-15, which takes approximately 2 hours. It was decided to steam out and tow back in so that we had the swell at our backs when we had the instrument in the water. During the transit, the MiniBAT is temporarily connected to the control unit so the following checks can be made. The CTD is interrogated, its memory cleared, clock checked, and battery

Table 1: Instruments used during the 1999 OSU-NOPP MiniBAT sampling

Instrument	Company and Model	SN	Comments
CTD	Sea-Bird SBE-25	227	
Thermistor	Sea-Bird SBE 3-F	2455	Calibrated 2/98
Conductivity Cell	Sea-Bird SBE 4-C	2107	Calibrated 2/98
Pressure Sensor	Sea-Bird SBE-29	185113	Calibrated 3/98
Water Pump	Sea-Bird SBE 5-T	52055	
Transmissometer	WetLabs C-Star	CST-186R	Calibrated 11/97
Fluorometer	WetLabs WetStar	WS3S-377P	Calibrated 6/99
Surface CTD	Sea-Bird SBE-19	2333	
MiniBAT	Guildline 8820	63796	
Cable	Cortland Cable		200m, 8-conductor
Winch	Inter-Ocean 721-24	OS29901	
GPS/Echosounder	APELCO FishFinder/Plotter 530	HB81977	120 kHz
Tension Cell	Revere BSP-B6-2.5K-30P5	EX5495	
Tension Display	Scale Systems 350	318475	
CTD laptop	Dell Latitude XPi	02961	
MiniBAT laptop	IBM Thinkpad 560	78-ACD27	
mass storage	iomega 250MB Zip	P7CW061339	

voltage checked. The MiniBAT is activated to make sure the wings are working. The laptop clocks are checked and synchronized. If the surface CTD was being used its clock would be checked, memory cleared, and turned on before reaching station (the time at which it is turned on is recorded to facilitate merging with the GPS time and location data stream).

Once on station, the cable is fed through the block, and attached to the MiniBAT, both electronically and mechanically. The mechanical connection consists of a "D" or anchor shackle. A safety ring is placed through the shackle and pin to ensure that the pin does not become loose. The CTD is turned on, and the recording computers are started while the MiniBAT is on deck, to make sure they are correctly recording data before deployment. The pump plumbing is plugged into the T/C cells, removing the freshwater storage syringe. Once it is ensured that everything is working, the MiniBAT is unlashed from the deck. The ship is placed at idle, to ensure very slow forward motion. One scientist handles the winch and the other the MiniBAT controls, while the captain handles the vessel. The wire is pulled in so that the MiniBAT comes clear of the deck, at which point it is handled overboard, and the wire let out so that the vehicle is submerged. It is left at the surface for approximately 1 minute while the pump turns on and clears air out of the plumbing.

At this stage, the winch operator starts letting wire out until the vehicle is close to the bottom (roughly 5 m). The ship is brought up to 6kts, and the vehicle climbs. The wire is let out until there are only a few (5-10) wraps left on the winch, at which point the winch speed is turned to zero and the direction to "in" as well as putting the brake on. When the vehicle reaches the surface, the wings are turned to the down position and the vehicle commences diving. Through experience, we have found that setting the wing position all the way down does not necessarily produce the deepest depths, the vehicle stalling out at some intermediate depth. Instead, a wing angle of approximately $-10°$ (which presumably would vary from instrument to instrument depending on trim and payload) tended to produce the deepest dives. The dives typically took the instrument to 55-60 m depth, depending on current shear, wave state, wire out, and a number of other conditions. Once it was clear that the instrument had stopped diving, the ship was slowed down to idle, and the instrument would sink through the water column, until it came close to the bottom, at which point the ship sped up to 6 knots again. This was repeated across the shelf. In sufficiently shallow water there was no need to slow the ship since the undulations span the entire water column. The maximum dive and climb rates occurred at the beginning of a dive or climb and were typically on the order of $1\,\mathrm{m\,s^{-1}}$, similar to the average SeaSoar dive/climb rate [Barth et al., 2000]. Average dive and climb rates were on the order of $0.3\,\mathrm{m\,s^{-1}}$.

As the cruise enters shallower water, cable is pulled in during each climb (the cable tensions are too high during dives to allow cable to be pulled in efficiently). The shallowest extent of the cruise was typically determined by the wave state. A reef, located at $124°5.1'W$, at approximately the 17 m isobath, which has a minimum depth of approximately 10 m, was the onshore limit of surveys if there was significant surface wave activity (frequently the waves would break on the reef). On smooth days we were able to sample inside the reef. Once the survey was done, the MiniBAT would be pulled onboard, lashed down, and the CTD turned off. The data recorders on the laptops were shut off. The A-frame is moved forward, and the ship headed back in. During the transit, the data from both the CTD computer and the MiniBAT computer is moved onto mass storage for safety. Upon reaching the dock, equipment is rinsed off, the CTD T/C cell freshwater storage syringe is reattached, and all of the equipment is offloaded and returned to Corvallis.

4 Cruise Summaries and Details

In this section, details of the individual cruises are discussed. Cruises are along the Newport hydrographic line (from NH-15 in) unless otherwise noted.

- 4/15: A test cruise to explore the flying properties of the instrument. Unfortunately, the CTD computer was configured to not record data and the internal

Table 2: Cruise summary table

date (1999)	participants	cruise type	comments
4/15	Austin/Pierce	NH line	No CTD data collected
5/05	Austin/Pierce	NH line	Failed fluorometer
5/18	Austin/Pierce	aborted	
5/19	Austin/Pierce	NH line	
5/28	Austin/Barth	aborted	Added surface CTD
6/01	Pierce/Barth	NH line	Added surface CTD
6/15	Austin/Barth	NH line	Added surface CTD
6/16	Austin/Dale	NH line	Added surface CTD
6/29	Austin/Oke	NH line	
7/06	Austin/Pierce	NH line	
7/15	Austin/Brodeur	NH line	
7/20	Austin/Kurapov	Radiator	
7/21	Austin/Pierce	NH line	
7/27	Austin/Pierce	Radiator	
7/28	Austin/Jayne	NH line	Failed depth transducer
8/03	Austin/Waldorf	NH line	Failed MB power supply
8/05	Austin/Emmett	NH line	Failed laptop
8/17	Austin/Barth	NH line	
8/18	Austin/Oke	Alongshore	
9/01	Austin/Pierce/Feinberg	NH line	
9/14	Austin/Minor	NH line	
9/15	Austin/Pierce	NH line	
9/28	Austin/Pierce	NH line	
9/29	Austin/Dale	aborted	

CTD memory was full, so that nothing was recorded. However, we did get engineering data back from the MiniBAT and experience in flying it.

- 5/05: First cruise with successful data return. However, the depth range (approximately 30 m) was poor. This is also the first cruise where we encountered crabgear. As soon as tension dramatically increases, the brake starts to slip. Stop the ship as quickly as possible and use the winch to recover the instrument and release the crabgear. The fluorometer was not working during this cruise.
- 5/18: We made it outside the jetty only to decide it's too rough to deploy.
- 5/19: First cruise with the surface CTD.
- 5/28: As with 5/18, had to turn back once outside the jetty.
- 6/01: Successful section with the advent of the "stop and drop" technique.

- 6/15: We started trying out new tow points in an attempt to get better depth range. We found that moving the towpoint further forward improved the vehicle behavior. Two crabpots were snagged during this cruise.

- 6/16: First of the "back-to-back" cruises. Uneventful. We stopped using the surface CTD after this cruise since the vehicle was reaching the surface.

- 6/29: Uneventful. The first cruise with coverage right to the surface.

- 7/06: First cruise with the new and improved wings. Much better diving characteristics- from the surface to 60m without much problem.

- 7/15: A joint cruise with Bill Peterson's lab. They did their net tows on the way out and we towed the MiniBAT on the way back in. This worked just fine and should be remembered for the future.

- 7/20: The first of two small radiator patterns. We sampled along three lines, 2.5km south of NH, NH, and 2.5km north of NH. We sampled from about NH-5 in. Also proved that it's not too difficult to turn with the MiniBAT in the water.

- 7/21: Another NH survey, another crabpot.

- 7/27: Another radiator pattern- same track as the 7/20 cruise. In this case the recording instruments were left on the entire time, which makes the eventual data processing much easier.

- 7/28: An NH line survey. We had problems with the depth transducer on this cruise.

- 8/03: Part of the way through this cruise, the wings on the MiniBAT stopped responding. Later it was determined that the MiniBAT power supply failed causing the wings to stop moving. The rest of the cruise was completed CTD-cast style.

- 8/05: On the way out, the computer that controls the MiniBAT had a hard-drive failure. The entire cruise was run in CTD-cast mode. Another joint effort with Bill Peterson's lab.

- 8/17: We tried a new fairing on the cable today, which made the flying performance worse (smaller depth range and higher tensions). We were also using new software for the MiniBAT which cut out a lot of the noise problems we'd been having up to this point.

- 8/18: An alongshore section, primarily along the 30m isobath, From Depoe Bay to Alsea Bay. South of Yaquina Bay we moved offshore to the 40m isobath to avoid tricky bottom bathymetry. At the end of this cruise, the cable was accidentally pulled into the winch brake, seriously damaging the cable. The vehicle had to be recovered by hand, and we lost approximately 13m of cable in the repair.

- 9/01: A joint effort with Peterson's lab. Tried the fairing again, with no luck.

- 9/14: Forgot to install pump line to T/C cells, which affects the T/C only during the sinking. The fluorescence data is fine and while the instrument was being towed it appears that enough water was being rammed through that the data is fine.

- 9/15: Tension cell readout malfunctioning on this cruise- returning tensions twice as high as expected.

- 9/28: Still some problems with the tension cell, but otherwise a smooth cruise.

- 9/29: Got about 8km offshore before we decided to head back- fairly rough day.

5 Data Processing

The data come in two streams, the data from the MiniBAT (depth, wing angle, water depth, GPS latitude and longitude, wire out) and from the CTD (temperature, pressure, conductivity, fluorometer voltage, and transmissivity). These data need to be processed, combined, deglitched, and eventually gridded for display. This section covers those steps.

5.1 CTD processing

The CTD data are processed following the methods detailed in *Barth et al.* [1996]. The conductivity signal is lagged by 0.6 scan (1 scan = $1/8\,\mathrm{s}$), to correct for the lag between when the temperature is measured and when the conductivity is measured. Then, the conductivity is corrected for the thermal mass of the conductivity cell. The fluorometer is lagged by 20 scans (approximately $3.25\,\mathrm{s}$), this lag determined by matching fluorometer voltage maxima from up and down casts.

The lack of a second conductivity cell on the instrument platform makes determining segments of poor conductivity data difficult. However, it is possible to check for flaws in the data by comparing the conductivity and temperature time series, since conductivity is a strong function of temperature. These two time series should be fairly well correlated in the absence of large variations in salinity. In fact, in early surveys the variations in salinity are large enough to render this method ineffective, but later cruises with stronger thermal stratification allow verification of the lag between the temperature and conductivity. To check the lag, the original 8-Hz data were used (corrected for the 0.6 scan sensor lag and thermal mass), broken into 10000-sample blocks (approximately 20 minutes of data, enough for at least one full undulation), and the correlations computed at several lags centered around zero-lag. This procedure is detailed in *Huyer et al.* [1993]. There is a fair amount of noise associated with this procedure and is limited in utility as a check of data quality. This is due primarily to two reasons: first, often the salinity variations were sufficiently large that they played a major role in determining the conductivity. Second, the inner shelf is fairly heterogeneous. During only one cruise, that of July 27, did the conductivity significantly lag the temperature while the correlation between the two were high. During this cruise, it appeared that something interfered with the normal flow through the T/C duct as the lag slowly increased to roughly 25 scans, or 3.1 s. In this case, a correction was applied in the CTD processing step by regridding the conductivity data onto a new grid which reflected this lag.

Standard routines are used to compute salinity and density time series given the temperature, conductivity, and pressure data. The CTD data are then low-pass filtered (8-point Hanning filter) and subsampled down to 1-Hz data to match the data from the MiniBAT.

5.2 Combining data

To match the CTD data to the MiniBAT data, the lag between the MiniBAT and CTD record data must be determined. This is simply a function of when the recording instruments are turned on. Since the computer clocks are typically only set to the nearest minute, this step is necessary. Since both the CTD and the MiniBAT record pressure, lag correlations of the pressure time series are calculated and the lag with the maximum correlation is used. Then the time series are appropriately padded so that they are the same length and on the same time-base. These files are saved as "pre-processed" data.

5.3 Post-processing

Several steps are involved in "post-processing", mostly concerned with cleaning noise out of the time series. The CTD pressure "drifts" from the beginning of the cruise to the end, typically registering -5m when initially on deck and -2.5m when brought out of the water (it should read zero at both times). This is taken out of the data using a linear trend. Second, the time series are clipped according to the following limits: $0 < T < 30$, $20 < S < 35$, $44 < \text{lat} < 45$ (north latitude), $-125 < \text{lon} < -123.8$ (east longitude), $0 < H < 100$ (where H is water depth in m), $0 < P < 100$ (where P is the CTD pressure). Finally, the data are hand-checked to pick out obvious glitches. There was a portion of data from the August 18 cruise where the conductivity cell stopped working and it appeared that the plumbing was clogged. However, without two conductivity cells it is difficult to determine with any certainty other times that this may have occurred. Obvious faults like density inversion are inspected and if it is clear which portion of the data is bad, it is removed. However, without corroborating evidence, the data are left alone.

5.4 Gridding

Once time series of all of the measured parameters are determined, the data must be put on a regular grid for presentation and further analysis. The time series are broken up into "casts" (the uptrace and downtrace of the instrument do not appear to differ in quality). Data from each of these casts is then averaged into 1-meter bins. Objective analysis [*Bretherton et al.*, 1976] is used to take data from a given depth from all of the casts and place it on a regular grid. The objective analysis was performed individually on 1-m binned pressure surfaces, with a normal distribution with a horizontal decorrelation scale of 2 km. The cruises on August 3 and 5 are gridded using a decorrelation scale of 6 km, since the cross-shelf spacing of the casts was much greater. The alongshore survey was gridded with an alongshore scale of 1 km. This length was chosen to be short enough to emphasize features with small spatial scales but long enough that the gridded data have high confidence levels across the domain. The data are then cropped using a criterion based on the expected error of the data, so that data with a confidence level less than 90% are excluded (data is gridded assuming a confidence at the location of the data of 98%).

6 Data Presentation

The rest of this report consists of the gridded data from all 20 successful cruises (i.e. data from cruises on 4/15, 5/18, 5/28, and 9/29 are not presented).

The following is displayed for each section:

- The vehicle path: This shows the depth as a function of cross-shelf distance of the MiniBAT.

- The ship path shows the plan-view path of the cruise relative to bathymetry and to the OSU-NOPP mid- and inner shelf moorings of *Levine et al.* [2000], which are marked with stars.

- The winds for the four days previous to the cruise from NOAA NDBC buoy 46050, 37 km offshore. The time of the cruise is marked with a red bar.

- Surface T, S, σ_t: for cruises on 5/19, 6/01, 6/15, and 6/16, line plots of the surface properties. The vertical axes have not been standardized between these cruises, to emphasize the variation within each cruise.

- Temperature: Cross-shelf section. Two contour intervals are used: 0.2 C from 6-9 C, and 1 C from 9-15 C.

- Salinity: Cross-shelf section. Contour interval 0.2 PSU.

- Potential density anomaly : Cross-shelf section, computed from salinity and temperature, contour interval $0.2\,\mathrm{kg\,m^{-3}}$.

- Transmissivity: Percent of light that traverses the 25-cm path length of the instrument. Contour interval 3%.

- Fluorometer voltage: Since the relationship between fluorometer voltage and actual chlorophyll concentration is approximate at best, and depends on many parameters which we do not measure, we only display the voltage. Higher voltages generally correspond to higher concentrations of chlorophyll. Contour interval 1 volt.

7 Acknowledgements

The authors would like to thank several people without whom the project would not have been successful. First and foremost is Ron Barrell, the capable and enthusiastic captain of the R/V *Sacajawea.* Mike Kosro helped with instrument acquisition and early test cruises. Walt Waldorf provided much technical expertise in the lab. Fred Jones assisted with dockside help, crane operations, and allowed us to store equipment at the Newport docks. Bill Peterson's lab allowed us to tag along on a few of their cruises and sent people along to help. Many people helped by going "to sea" for the day. These include: Andy Dale, Peter Oke, Alexander Kurapov, Ric Brodeur, Steve Jayne, Robert Emmett, Leah Feinberg, and Elizabeth Austin-Minor. The MiniBAT was purchased under an ONR DURIP grant (N00014-97-1-0469), and the work described here was funded by a NOPP grant (N00014-98-1-0787). Postscript copies of this data report are available at `http://eccles.oce.orst.edu/jay/papers/dr.ps`.

8 References

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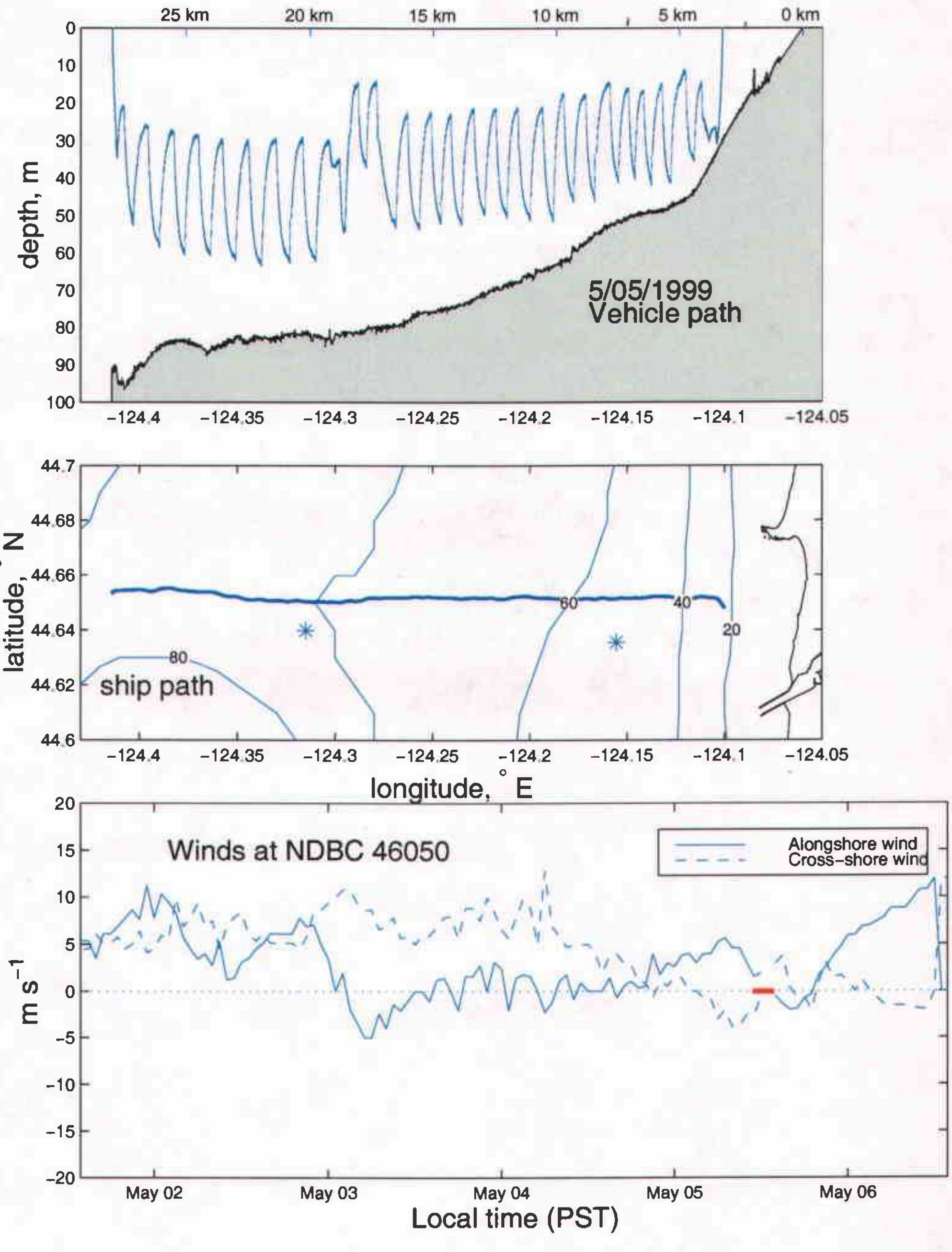
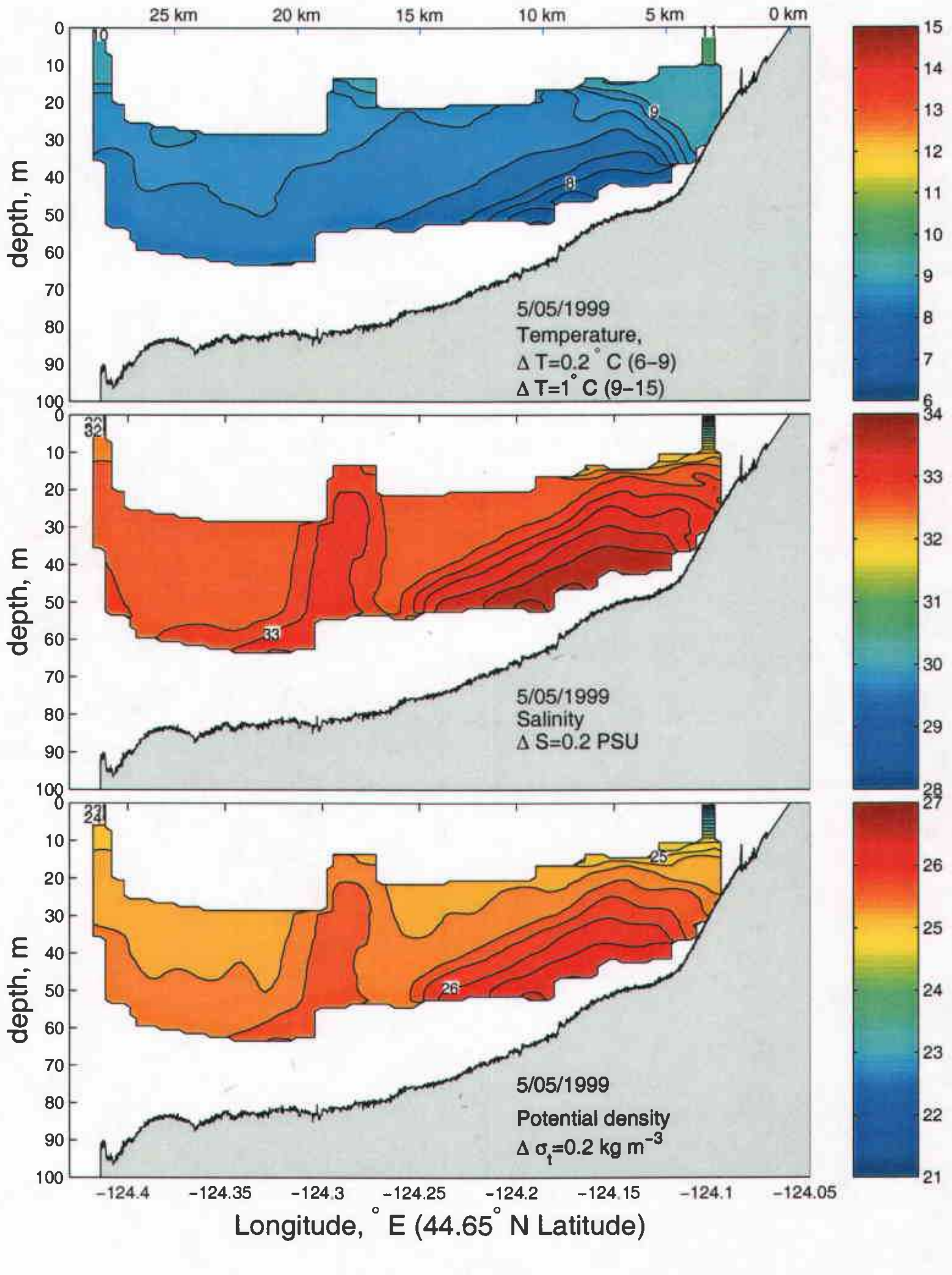
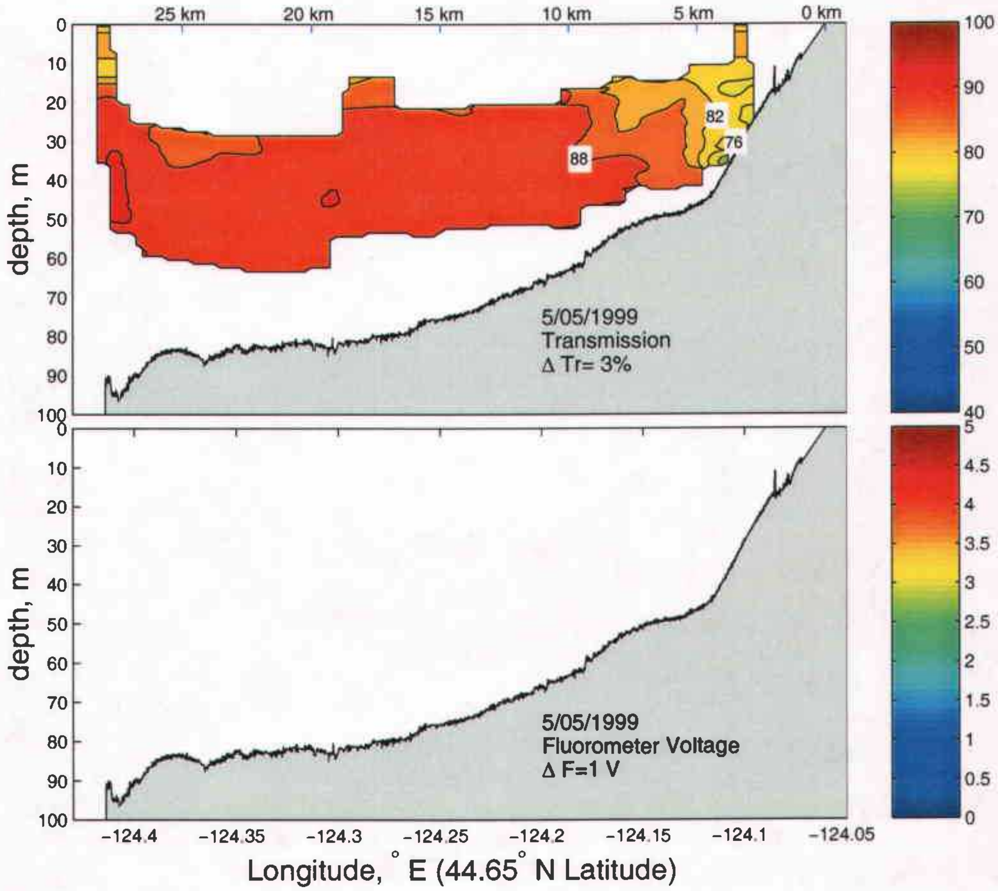
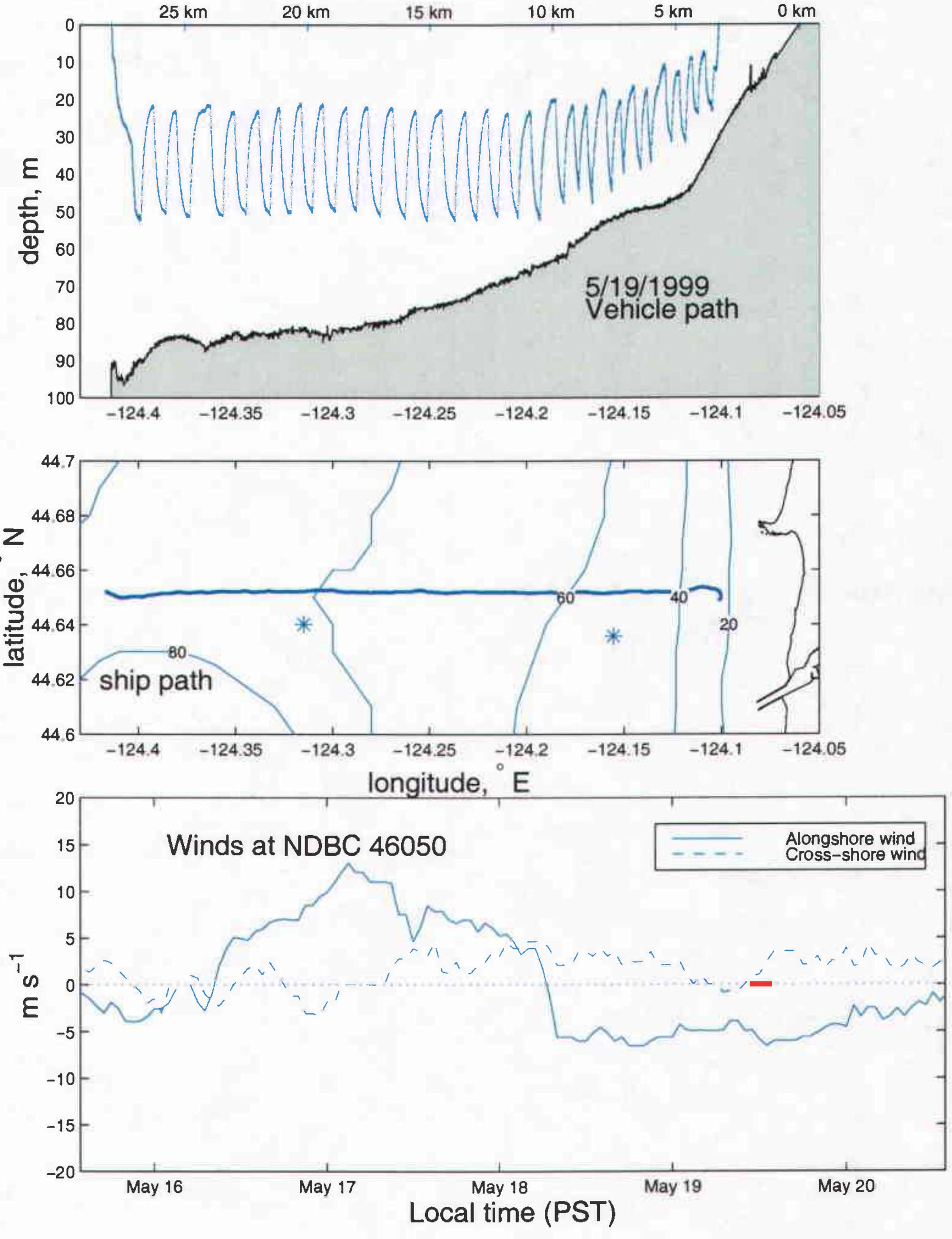


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
5/05/1999
Vehicle path
latitude, ° N
ship path
80
60
40
20
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s^{-1}
May 02
May 03
May 04
May 05
May 06
Local time (PST)


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
5/05/1999
Temperature,
Δ T=0.2 ° C (6–9)
Δ T=1° C (9–15)
5/05/1999
Salinity
Δ S=0.2 PSU
5/05/1999
Potential density
Δ σt=0.2 kg m−3
Longitude, ° E (44.65° N Latitude)


25 km
20 km
15 km
10 km
5 km
0 km
82
76
88
5/05/1999
Transmission
Δ Tr= 3%
depth, m
5/05/1999
Fluorometer Voltage
Δ F=1 V
depth, m
-124.4
-124.35
-124.3
-124.25
-124.2
-124.15
-124.1
-124.05
Longitude, ° E (44.65° N Latitude)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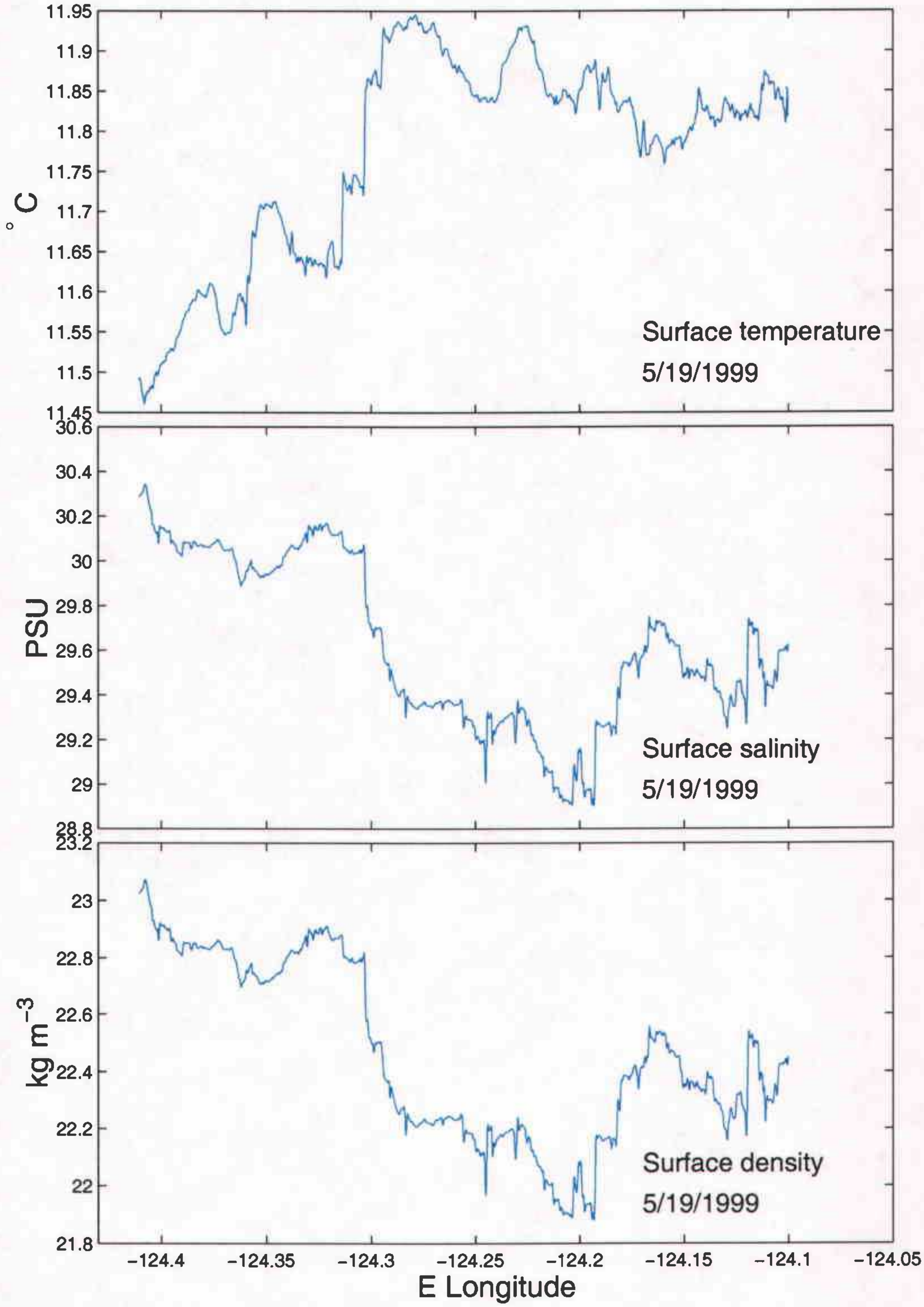
20 km
15 km
10 km
5 km
0 km
depth, m
5/19/1999
Vehicle path
latitude, ° N
ship path
80
60
40
20
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s-1
May 16
May 17
May 18
May 19
May 20
Local time (PST)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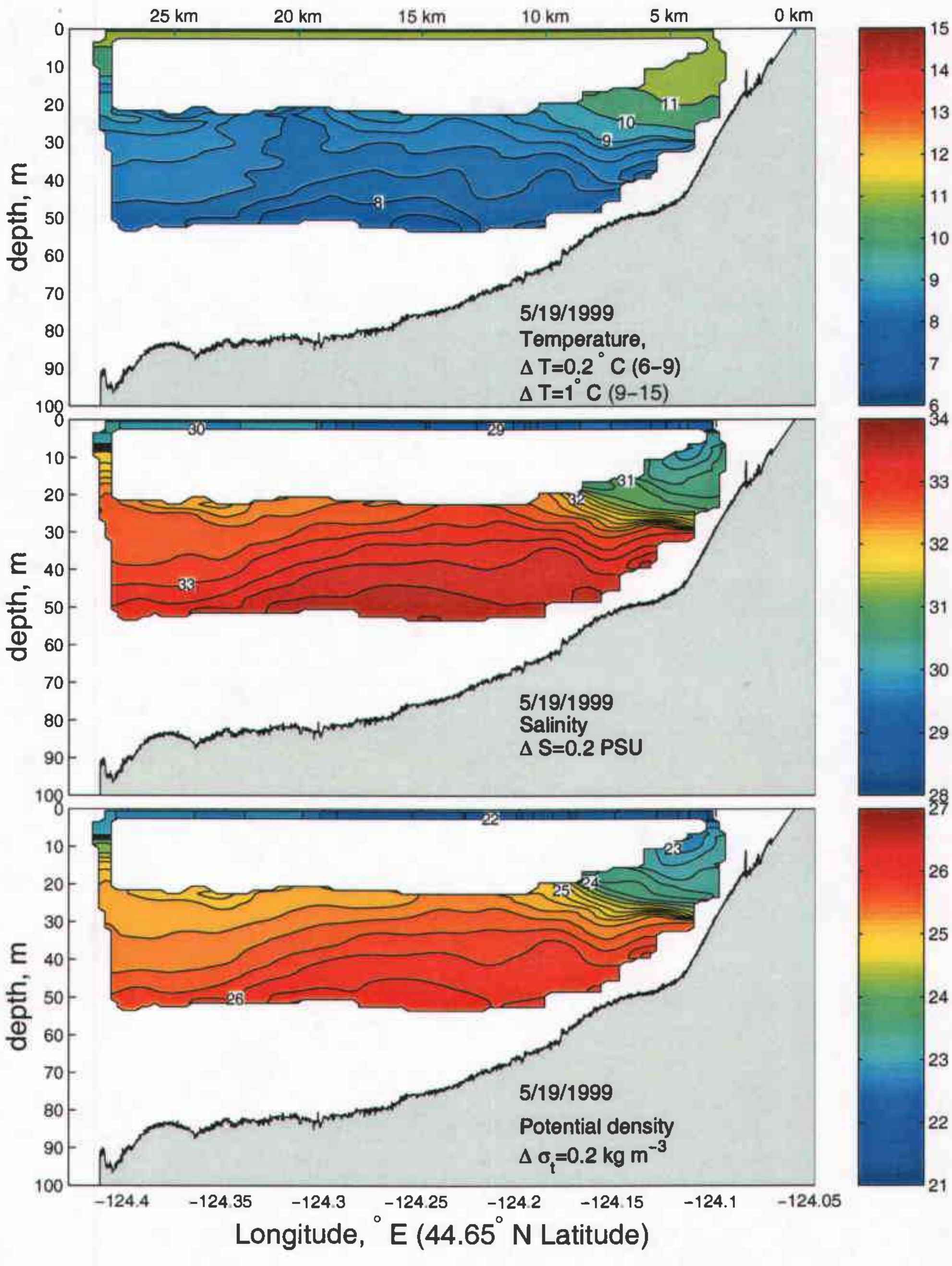
11.9
11.85
11.8
11.75
11.7
11.65
11.6
11.55
11.5
11.45
° C
Surface temperature
5/19/1999
30.6
30.4
30.2
30
29.8
29.6
29.4
29.2
29
28.8
PSU
Surface salinity
5/19/1999
23.2
23
22.8
22.6
22.4
22.2
22
21.8
kg m^-3
Surface density
5/19/1999
−124.4
−124.35
−124.3
−124.25
−124.2
−124.15
−124.1
−124.05
E Longitude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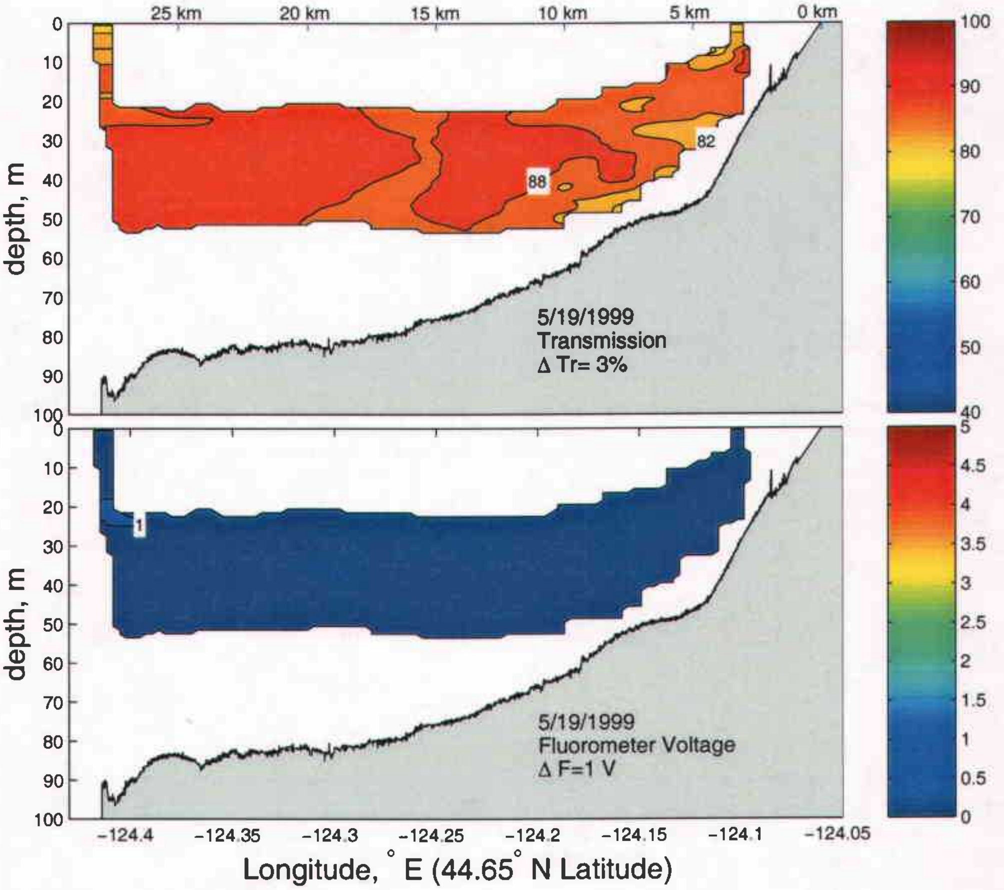
depth, m
5/19/1999
Temperature,
Δ T=0.2 ° C (6–9)
Δ T=1° C (9–15)
5/19/1999
Salinity
Δ S=0.2 PSU
5/19/1999
Potential density
Δ σt=0.2 kg m^-3
−124.4
−124.35
−124.3
−124.25
−124.2
−124.15
−124.1
−124.05
Longitude, ° E (44.65° N Latitude)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depth, m
82
88
5/19/1999
Transmission
Δ Tr= 3%
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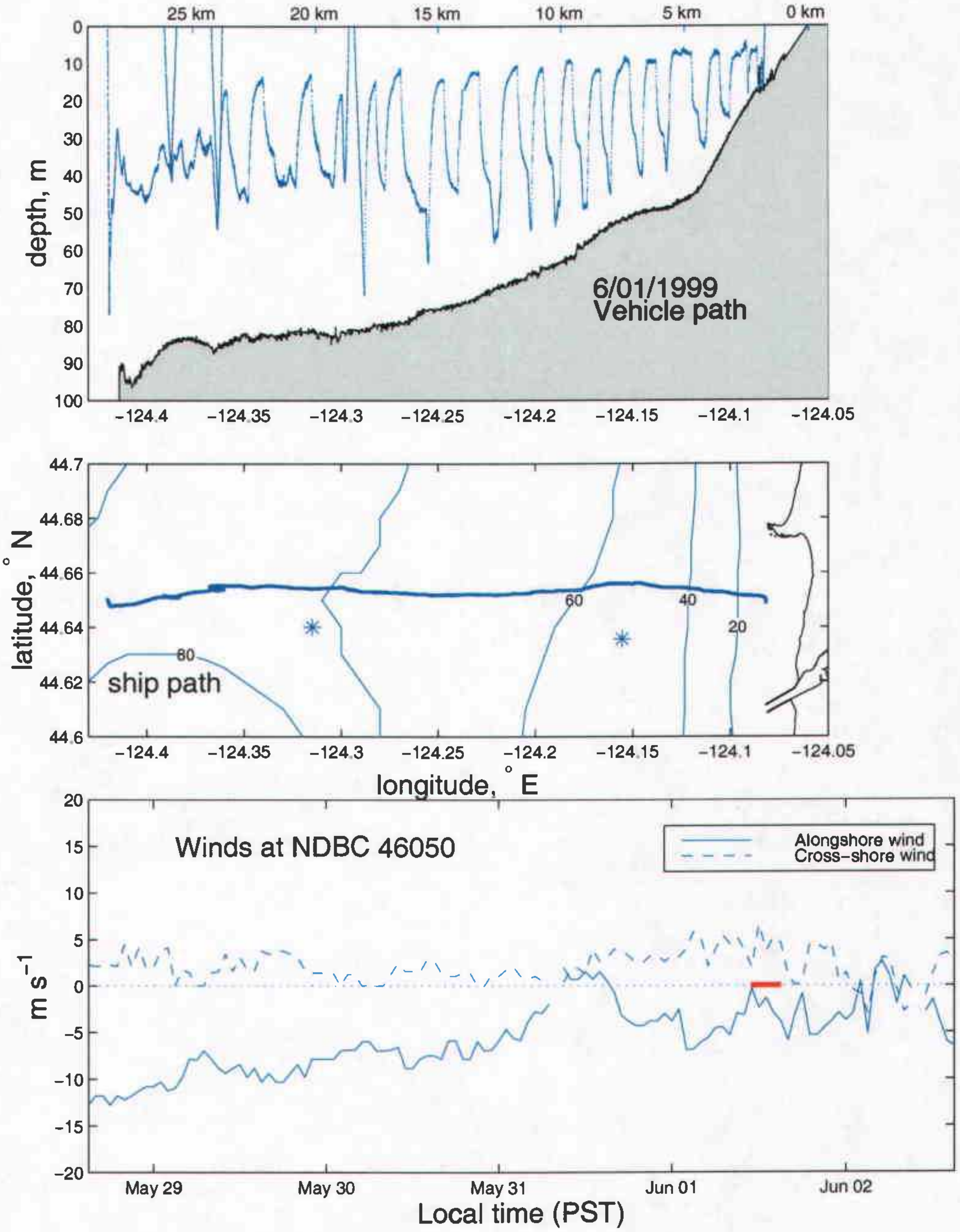
5/19/1999
Fluorometer Voltage
Δ F=1 V
Longitude, ° E (44.65° N Latitude)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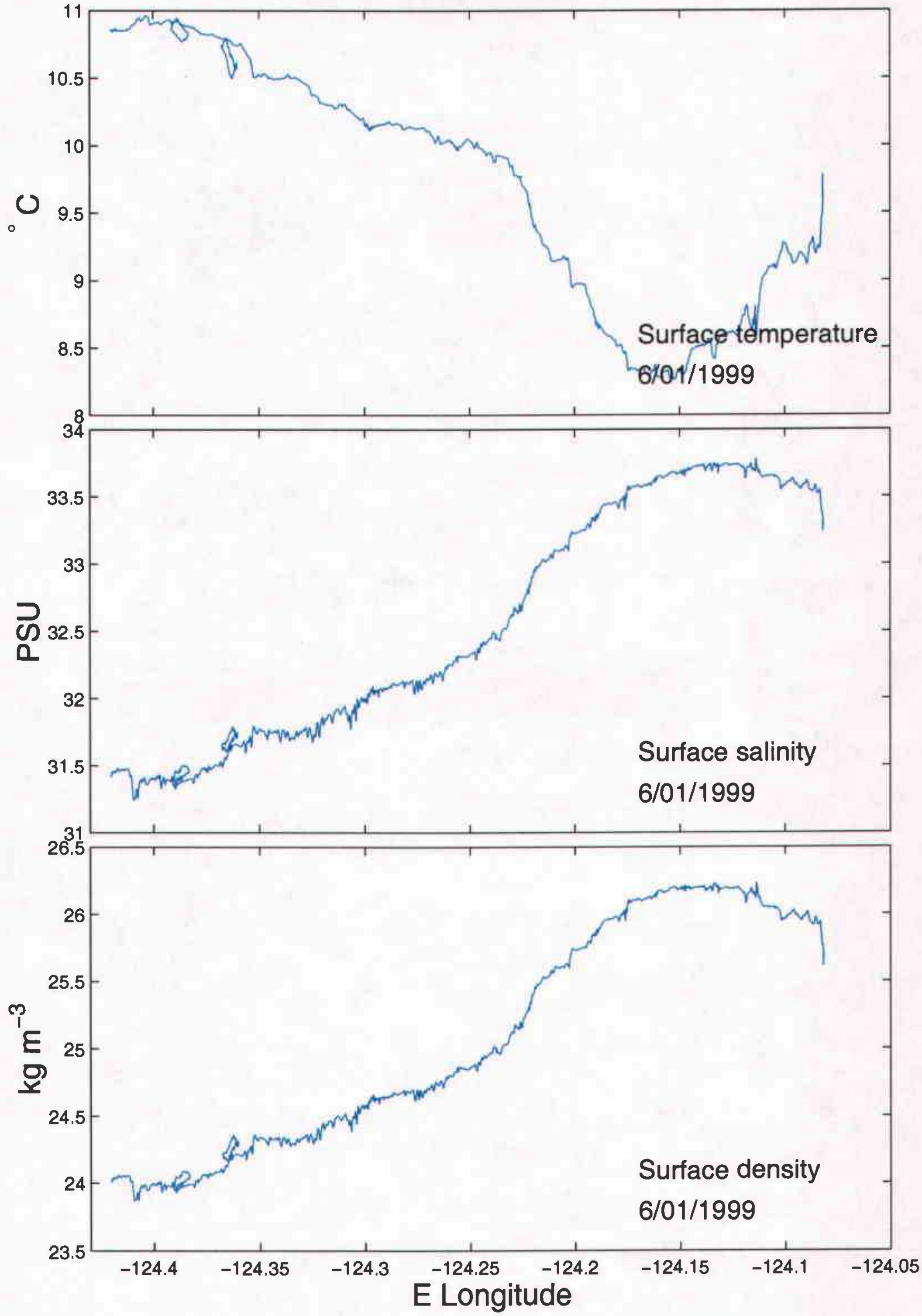
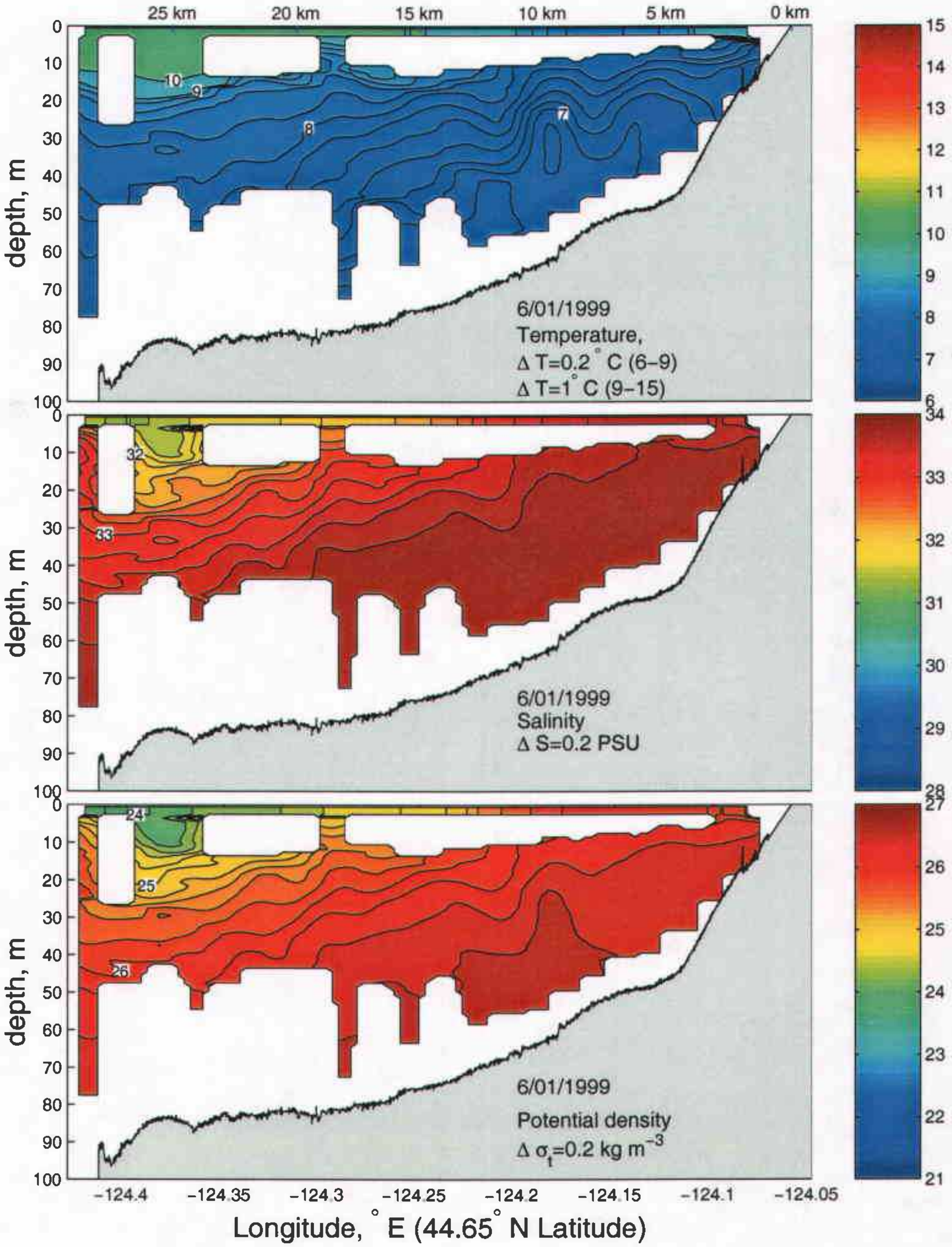
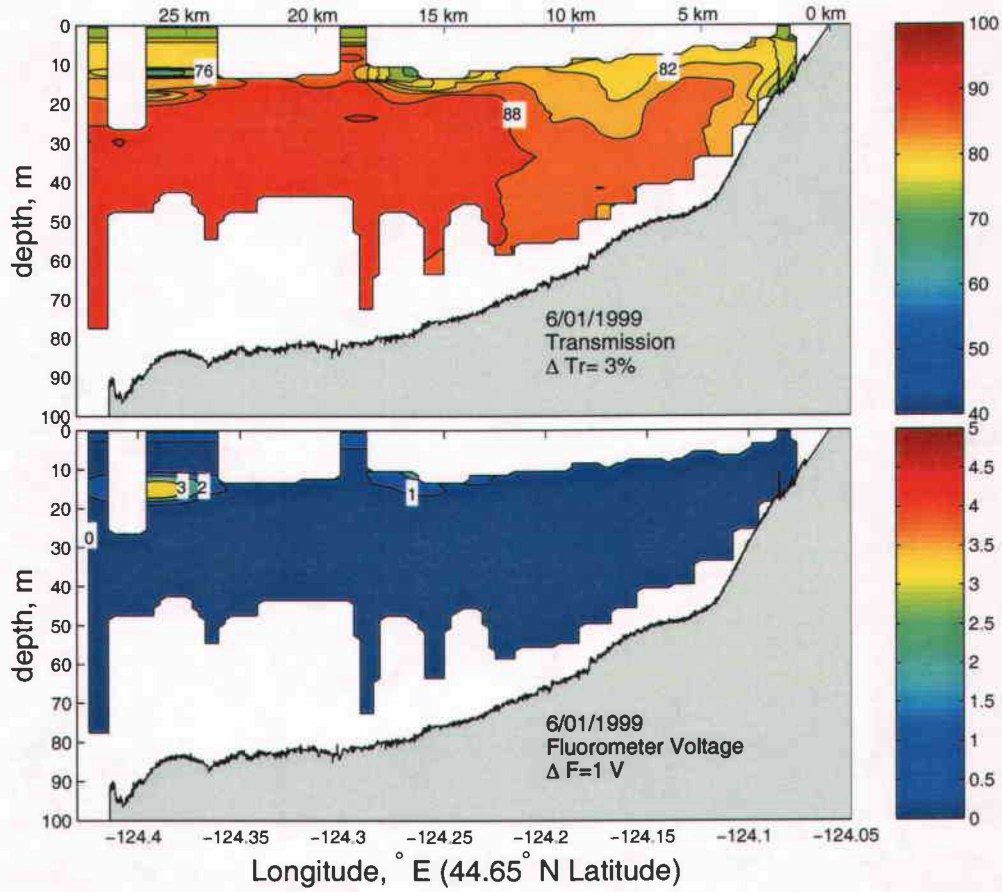
10 km
5 km
0 km
depth, m
6/01/1999
Vehicle path
latitude, ° N
ship path
80
60
40
20
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s^{-1}
May 29
May 30
May 31
Jun 01
Jun 02
Local time (PST)

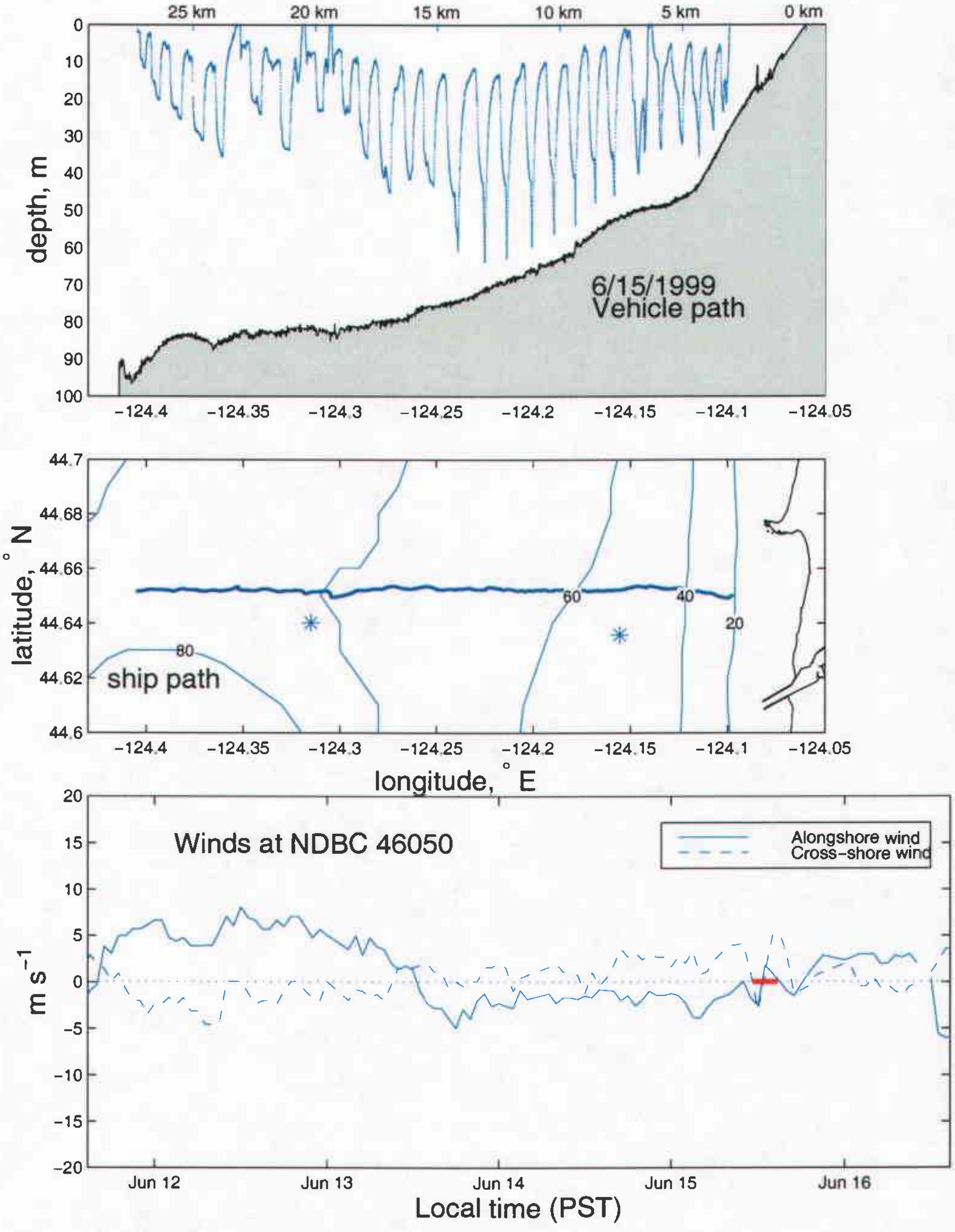

11
10.5
10
9.5
9
8.5
8
° C
Surface temperature
6/01/1999
34
33.5
33
32.5
32
31.5
31
PSU
Surface salinity
6/01/1999
26.5
26
25.5
25
24.5
24
23.5
kg m^{-3}
Surface density
6/01/1999
−124.4
−124.35
−124.3
−124.25
−124.2
−124.15
−124.1
−124.05
E Longitude

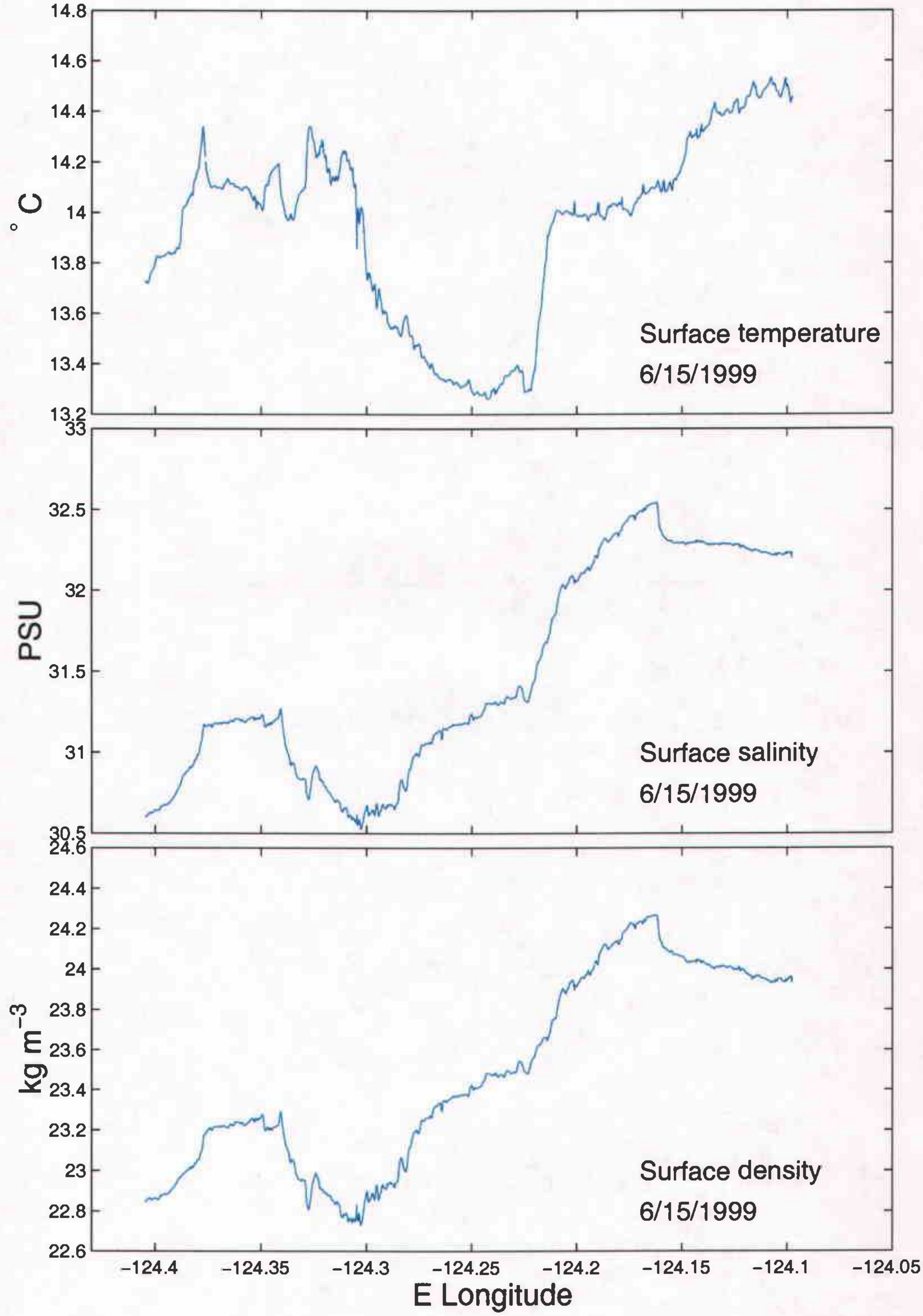


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
6/01/1999
Temperature,
Δ T=0.2 ° C (6–9)
Δ T=1 ° C (9–15)
6/01/1999
Salinity
Δ S=0.2 PSU
6/01/1999
Potential density
Δ σt=0.2 kg m−3
−124.4
−124.35
−124.3
−124.25
−124.2
−124.15
−124.1
−124.05
Longitude, ° E (44.65° N Latitude)



25 km
20 km
15 km
10 km
5 km
0 km
76
82
88
depth, m
6/01/1999
Transmission
Δ Tr= 3%
3
2
1
0
6/01/1999
Fluorometer Voltage
Δ F=1 V
-124.4
-124.35
-124.3
-124.25
-124.2
-124.15
-124.1
-124.05
Longitude, ° E (44.65° N Latitude)


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
6/15/1999
Vehicle path
latitude, °N
ship path
longitude, °E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s⁻¹
Jun 12
Jun 13
Jun 14
Jun 15
Jun 16
Local time (PST)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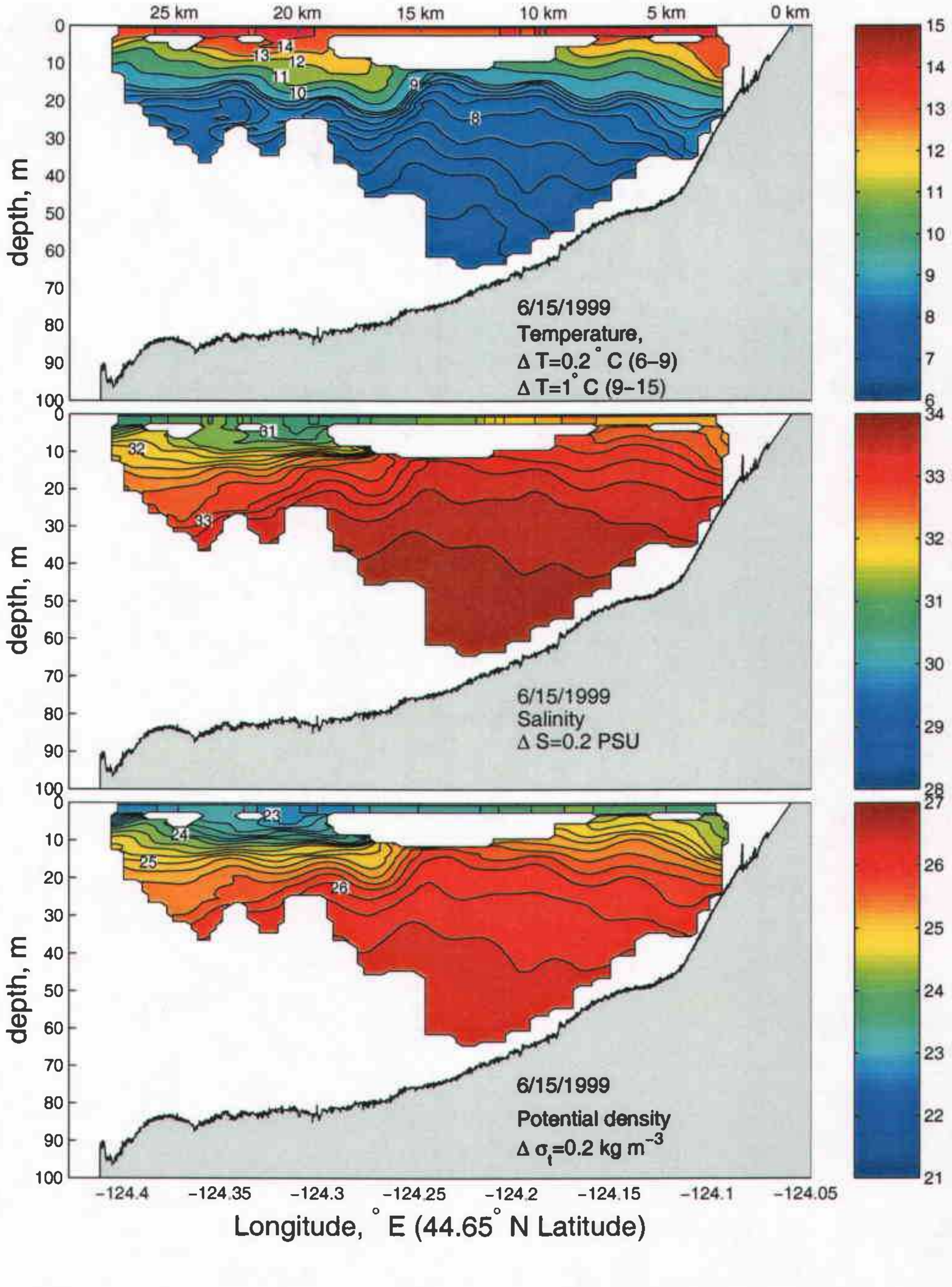
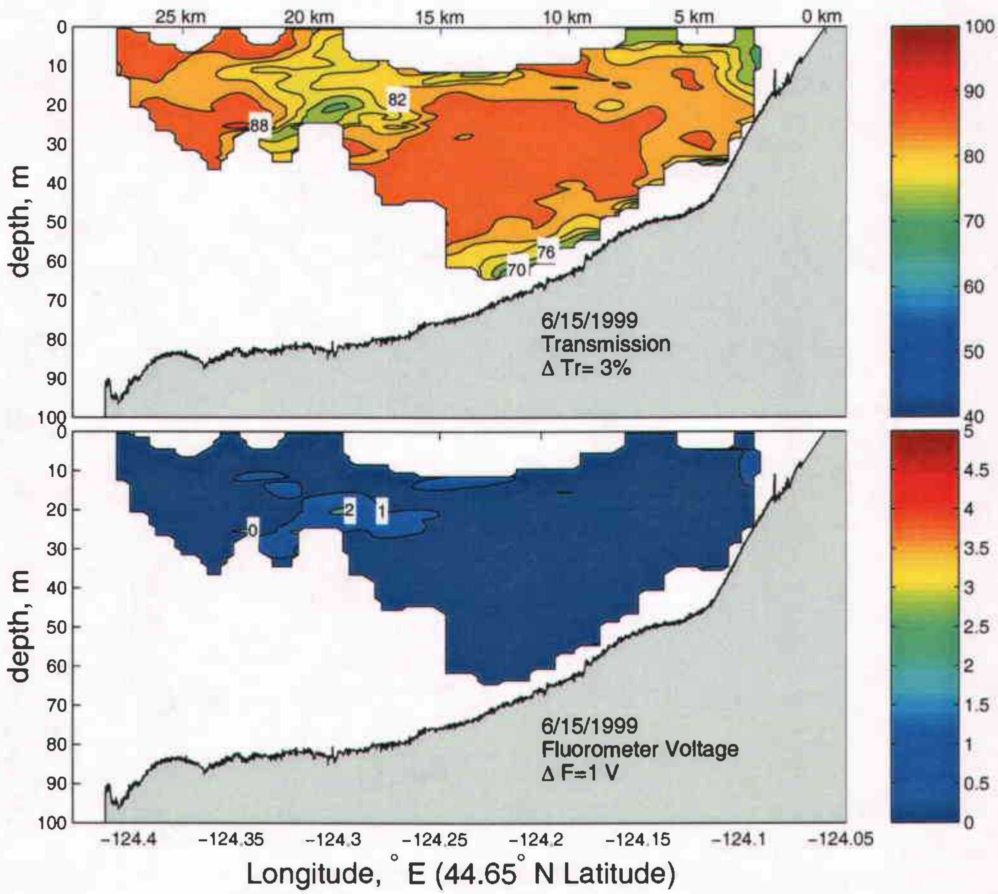
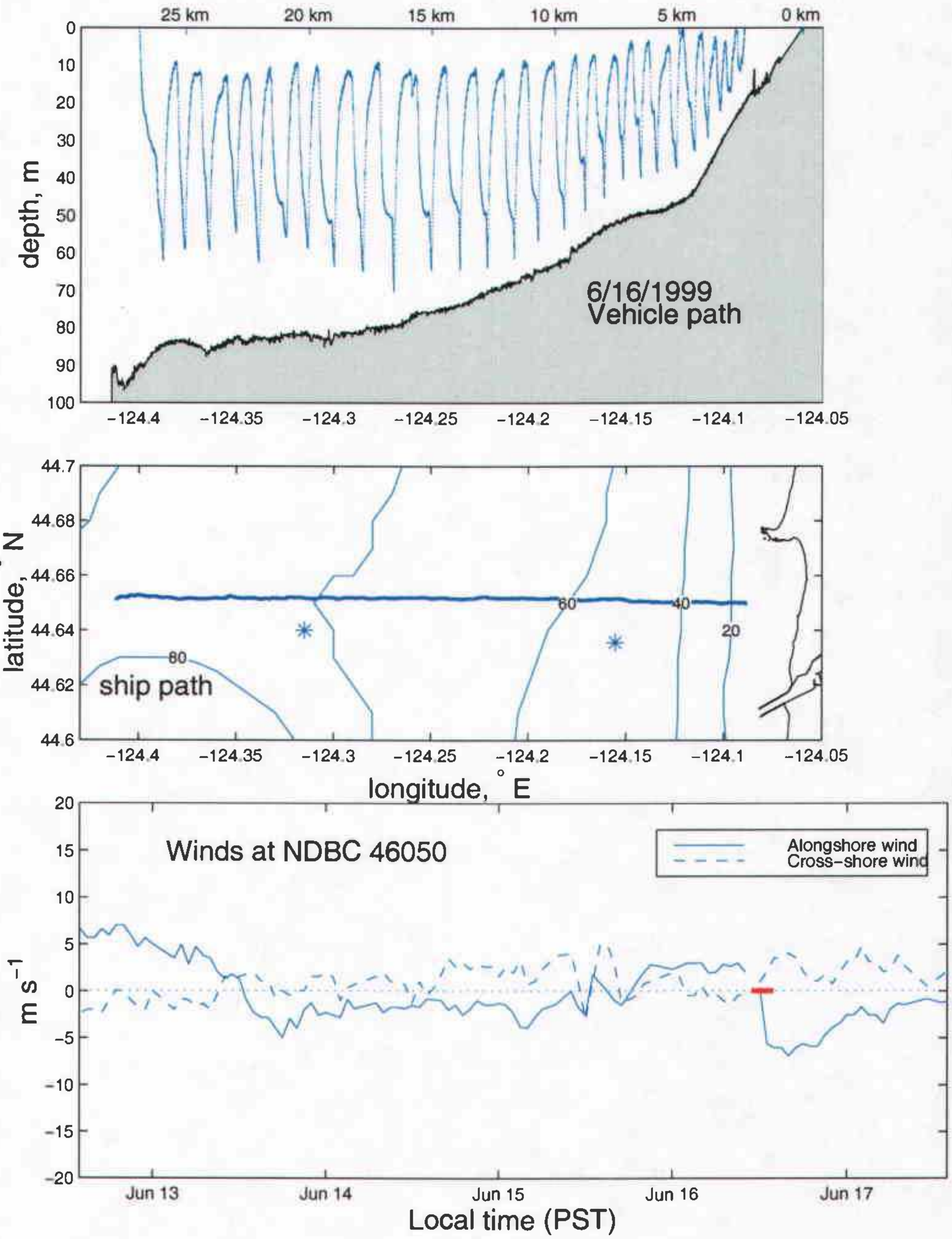
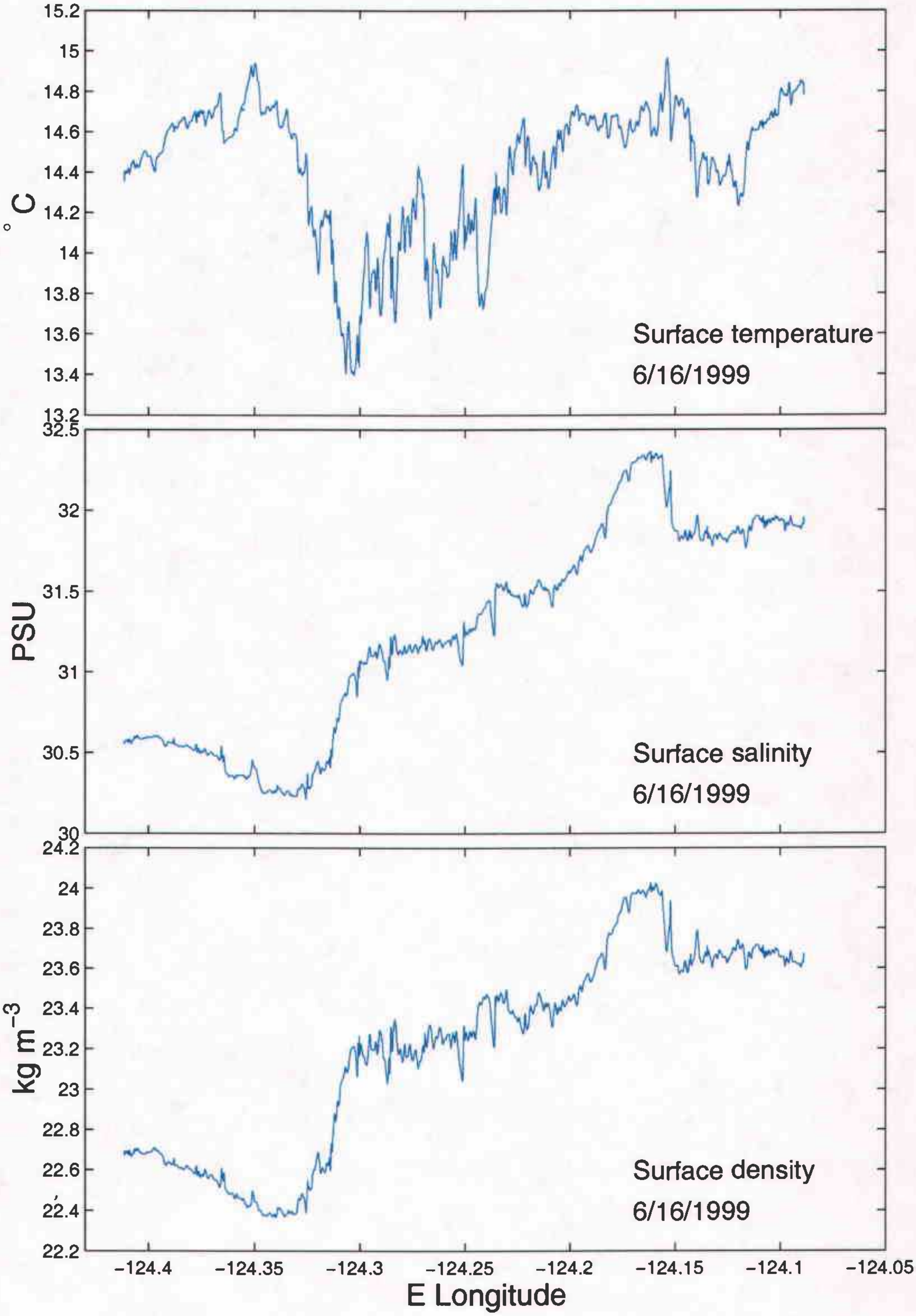
14.6
14.4
14.2
14
13.8
13.6
13.4
13.2
° C
Surface temperature
6/15/1999
33
32.5
32
31.5
31
30.5
PSU
Surface salinity
6/15/1999
24.6
24.4
24.2
24
23.8
23.6
23.4
23.2
23
22.8
22.6
kg m^{-3}
Surface density
6/15/1999
−124.4
−124.35
−124.3
−124.25
−124.2
−124.15
−124.1
−124.05
E Longitude


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
6/15/1999
Temperature,
Δ T=0.2 ° C (6–9)
Δ T=1° C (9–15)
6/15/1999
Salinity
Δ S=0.2 PSU
6/15/1999
Potential density
Δ σt=0.2 kg m−3
Longitude, ° E (44.65° N Latitude)

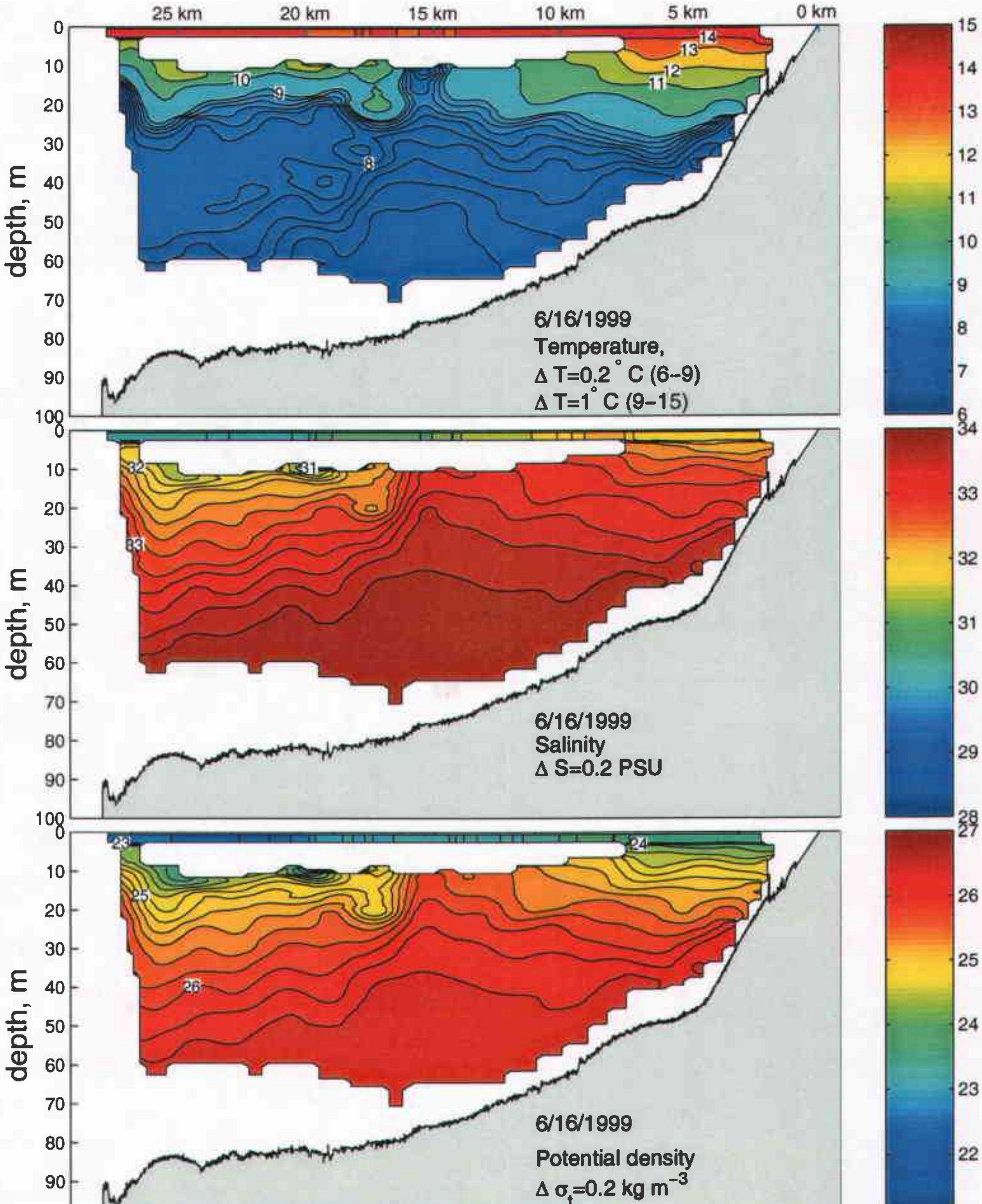


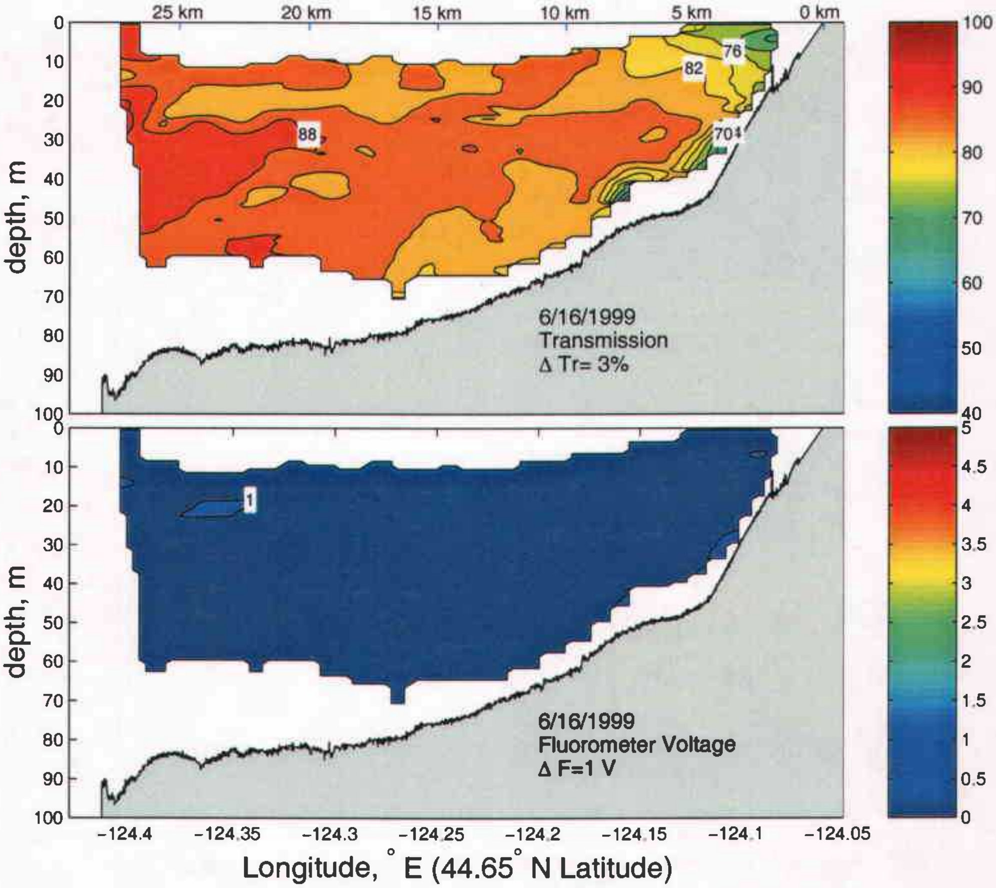
25 km
20 km
15 km
10 km
5 km
0 km
depth, m
6/15/1999
Transmission
Δ Tr= 3%
6/15/1999
Fluorometer Voltage
Δ F=1 V
Longitude, ° E (44.65° N Latitude)

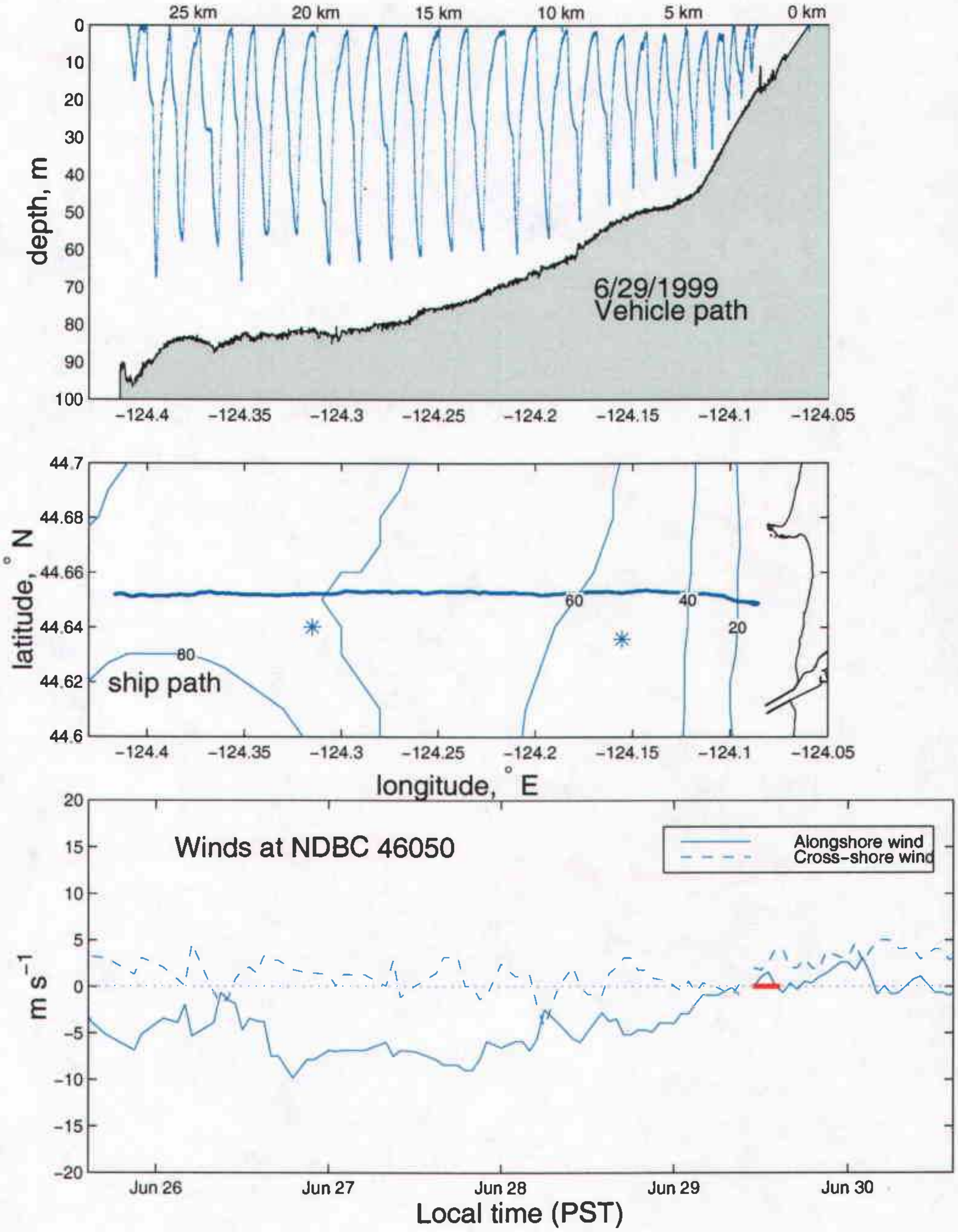

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
6/16/1999
Vehicle path
latitude, ° N
ship path
80
60
40
20
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s^{-1}
Jun 13
Jun 14
Jun 15
Jun 16
Jun 17
Local time (PST)

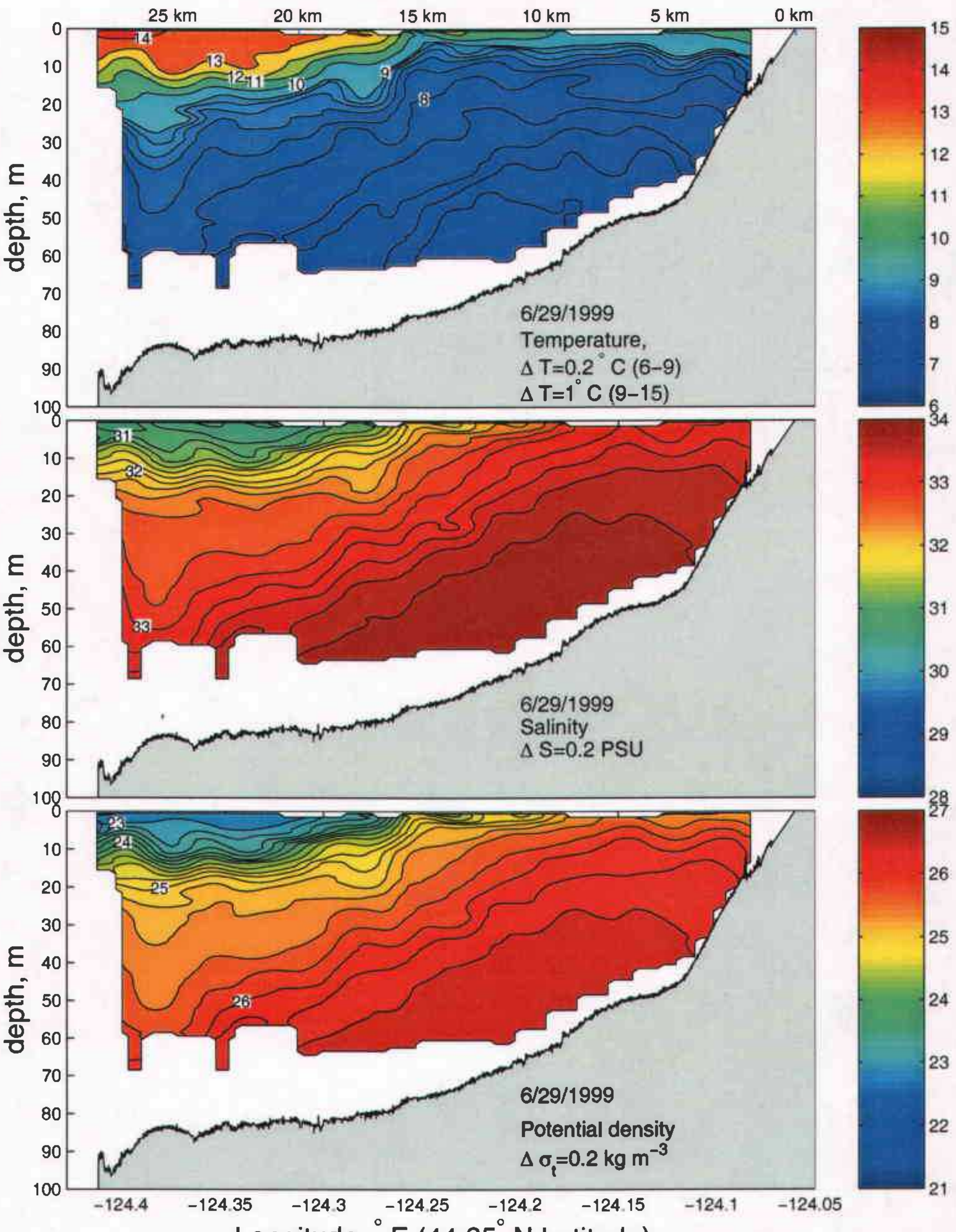


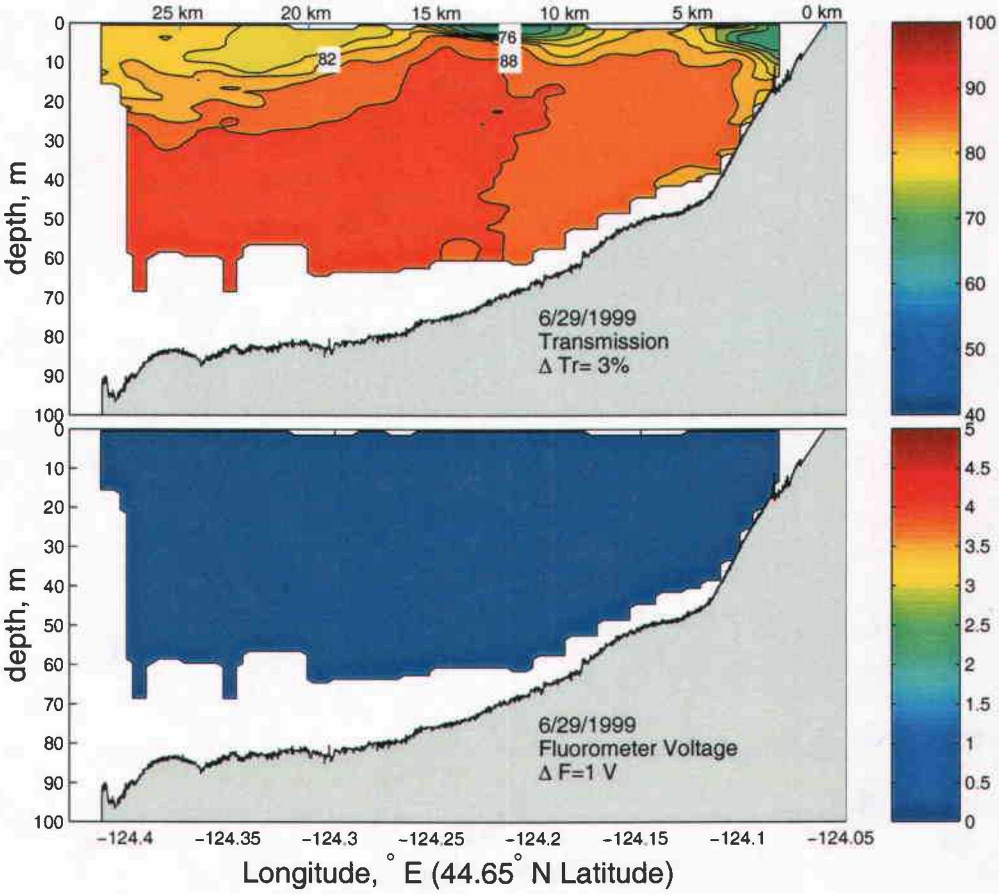
°C
Surface temperature
6/16/1999
PSU
Surface salinity
6/16/1999
kg m^{-3}
Surface density
6/16/1999
E Longitude


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
6/16/1999
Temperature,
Δ T=0.2 ° C (6–9)
Δ T=1 ° C (9–15)
6/16/1999
Salinity
Δ S=0.2 PSU
6/16/1999
Potential density
Δ σt=0.2 kg m−3
Longitude, ° E (44.65° N Latitude)

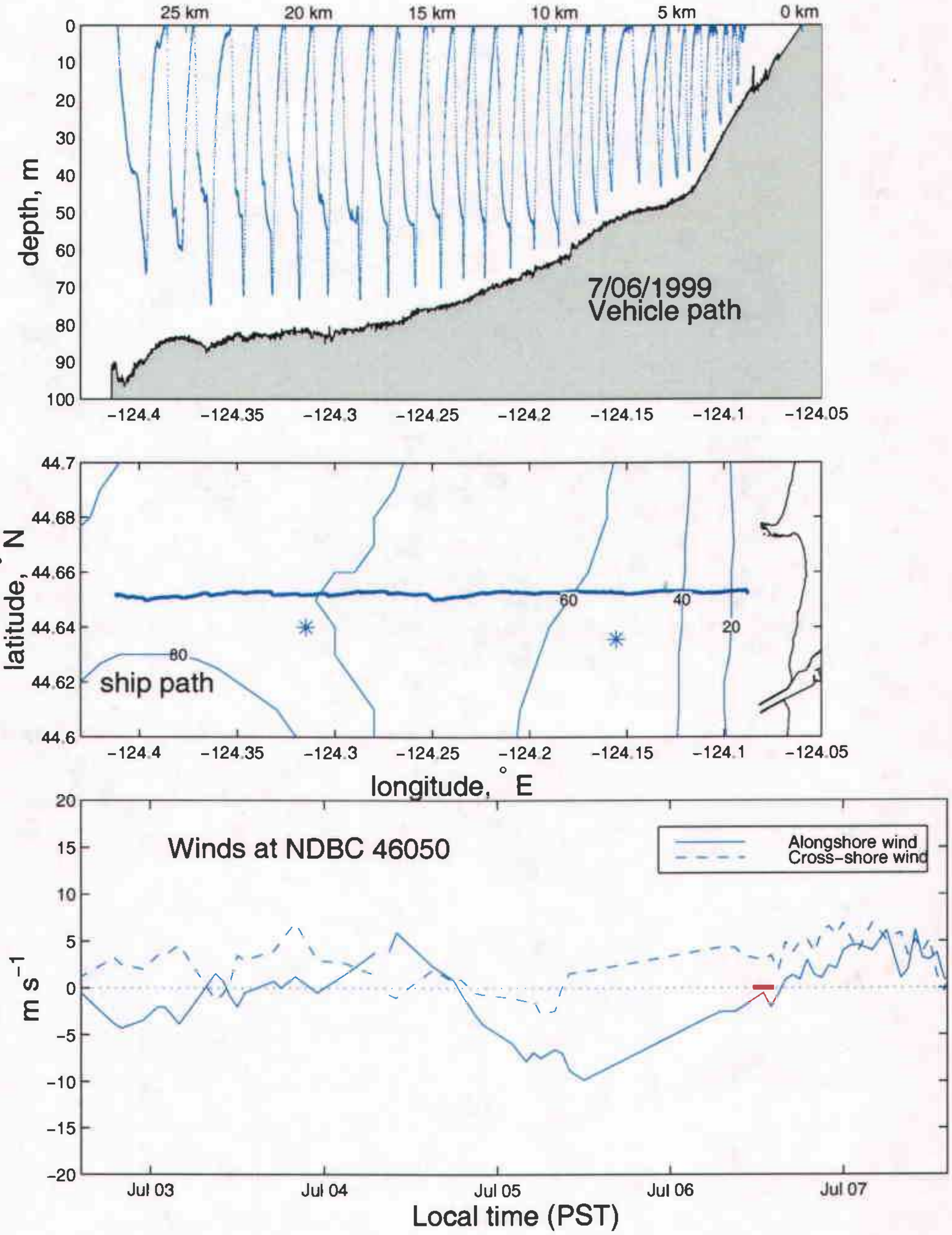

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
6/16/1999
Transmission
Δ Tr= 3%
88
82
76
70
6/16/1999
Fluorometer Voltage
Δ F=1 V
1
-124.4
-124.35
-124.3
-124.25
-124.2
-124.15
-124.1
-124.05
Longitude, ° E (44.65° N Latitude)

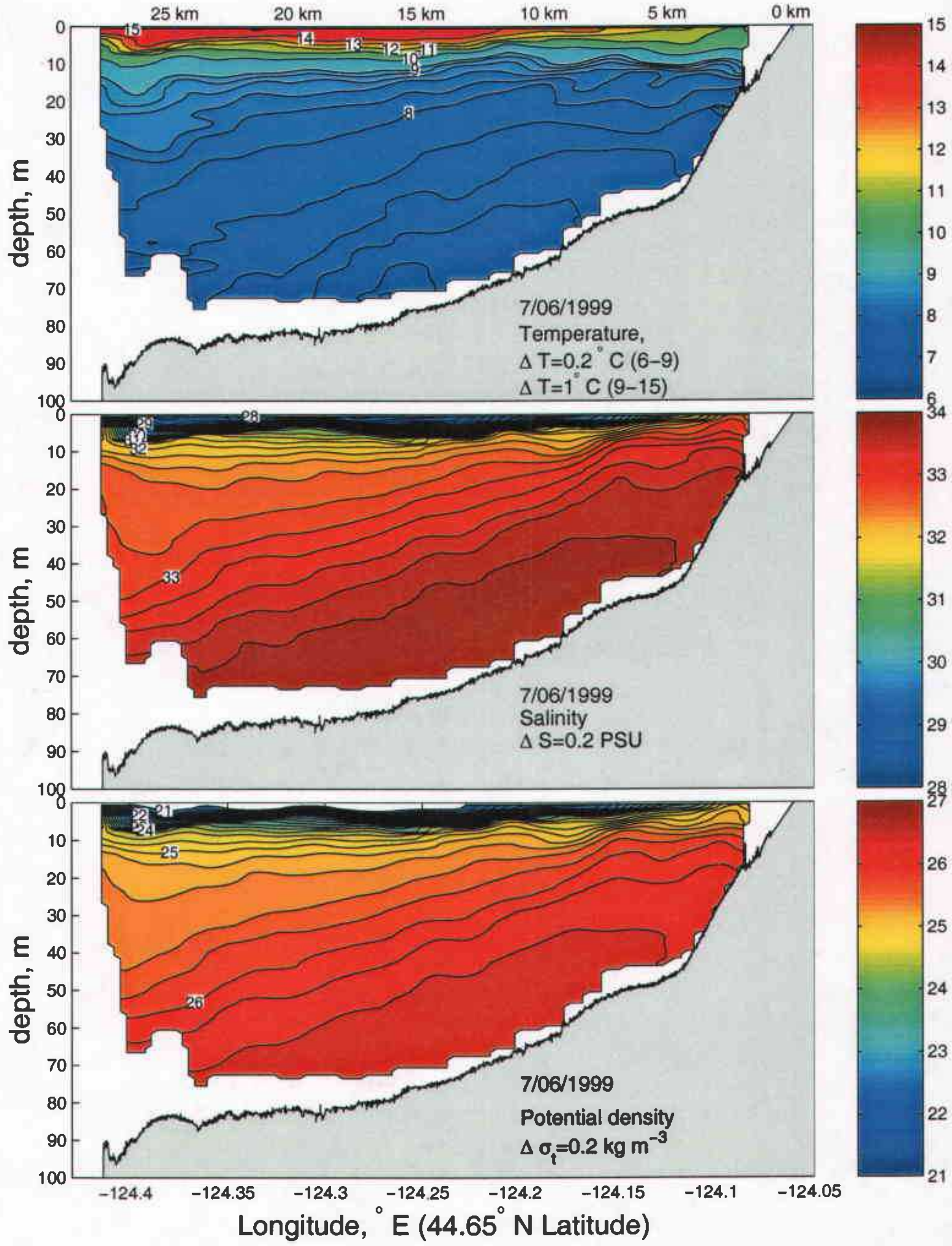

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
6/29/1999
Vehicle path
latitude, ° N
ship path
80
60
40
20
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s^-1
Jun 26
Jun 27
Jun 28
Jun 29
Jun 30
Local time (PST)

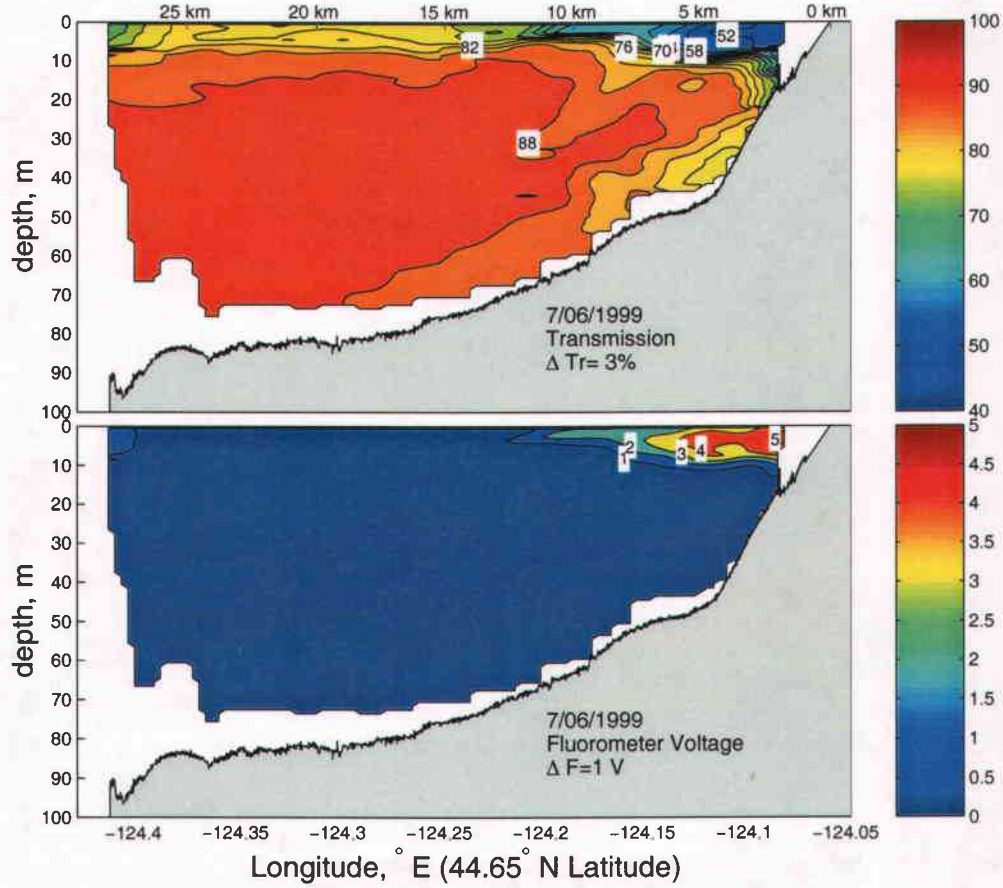

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
6/29/1999
Temperature,
Δ T=0.2° C (6–9)
Δ T=1° C (9–15)
6/29/1999
Salinity
Δ S=0.2 PSU
6/29/1999
Potential density
Δ σt=0.2 kg m−3
−124.4
−124.35
−124.3
−124.25
−124.2
−124.15
−124.1
−124.05
Longitude, ° E (44.65° N Latitude)

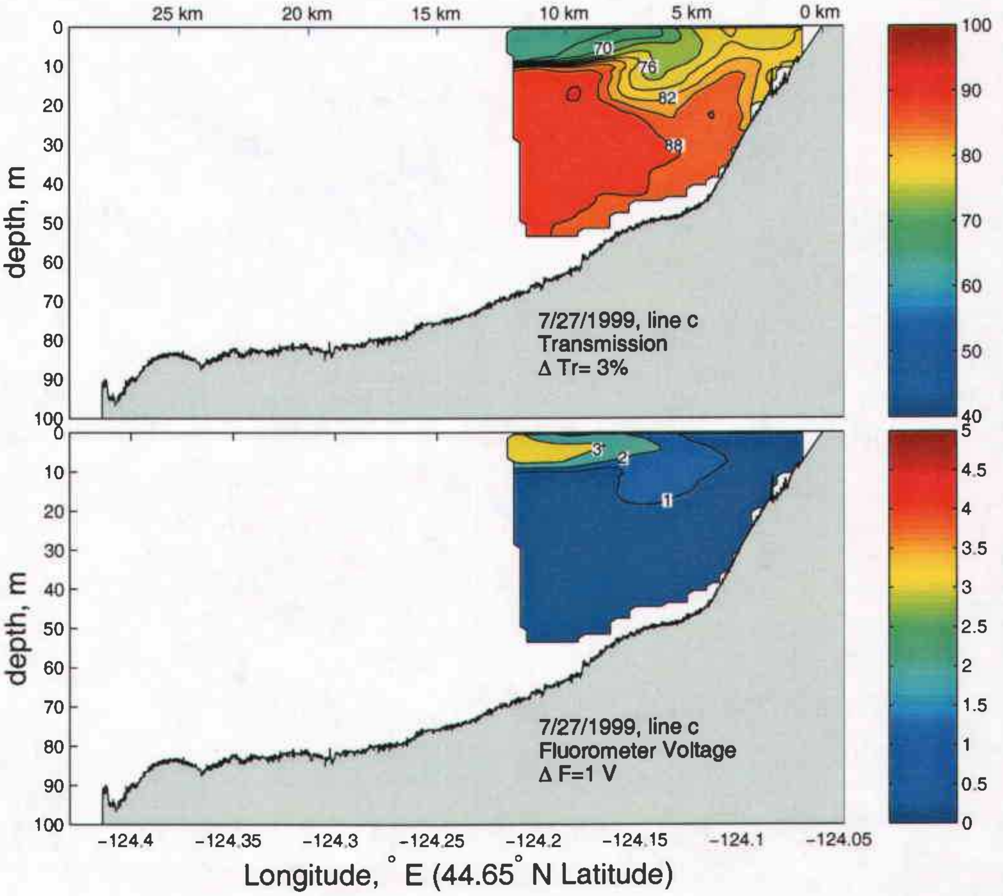


25 km
20 km
15 km
10 km
5 km
0 km
76
82
88
depth, m
6/29/1999
Transmission
Δ Tr= 3%
6/29/1999
Fluorometer Voltage
Δ F=1 V
−124.4
−124.35
−124.3
−124.25
−124.2
−124.15
−124.1
−124.05
Longitude, ° E (44.65° N Latitude)

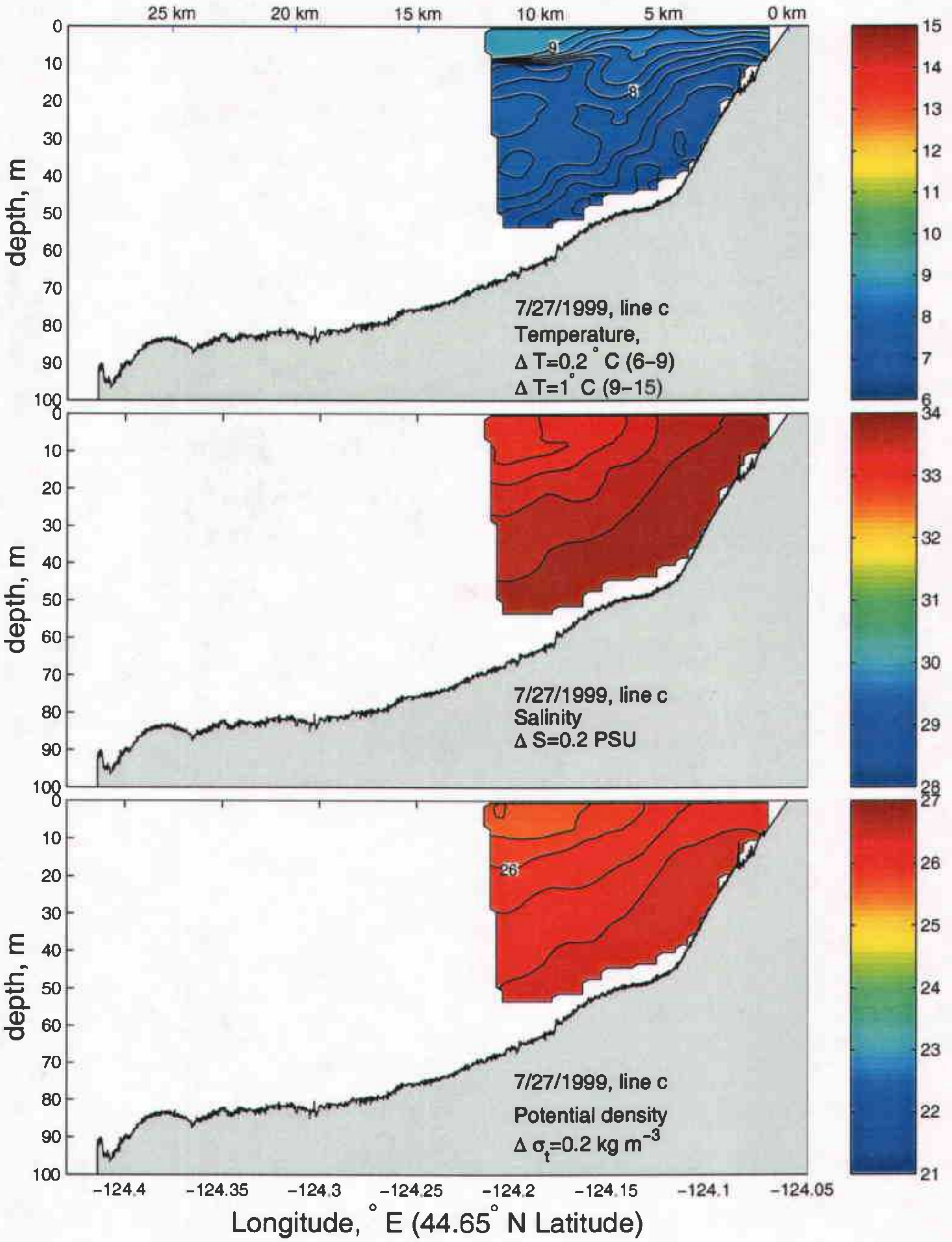

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/06/1999
Vehicle path
latitude, ° N
ship path
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s-1
Local time (PST)
Jul 03
Jul 04
Jul 05
Jul 06
Jul 07


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/06/1999
Temperature,
Δ T=0.2 °C (6–9)
Δ T=1 °C (9–15)
7/06/1999
Salinity
Δ S=0.2 PSU
7/06/1999
Potential density
Δ σt=0.2 kg m^-3
Longitude, ° E (44.65° N Latitude)

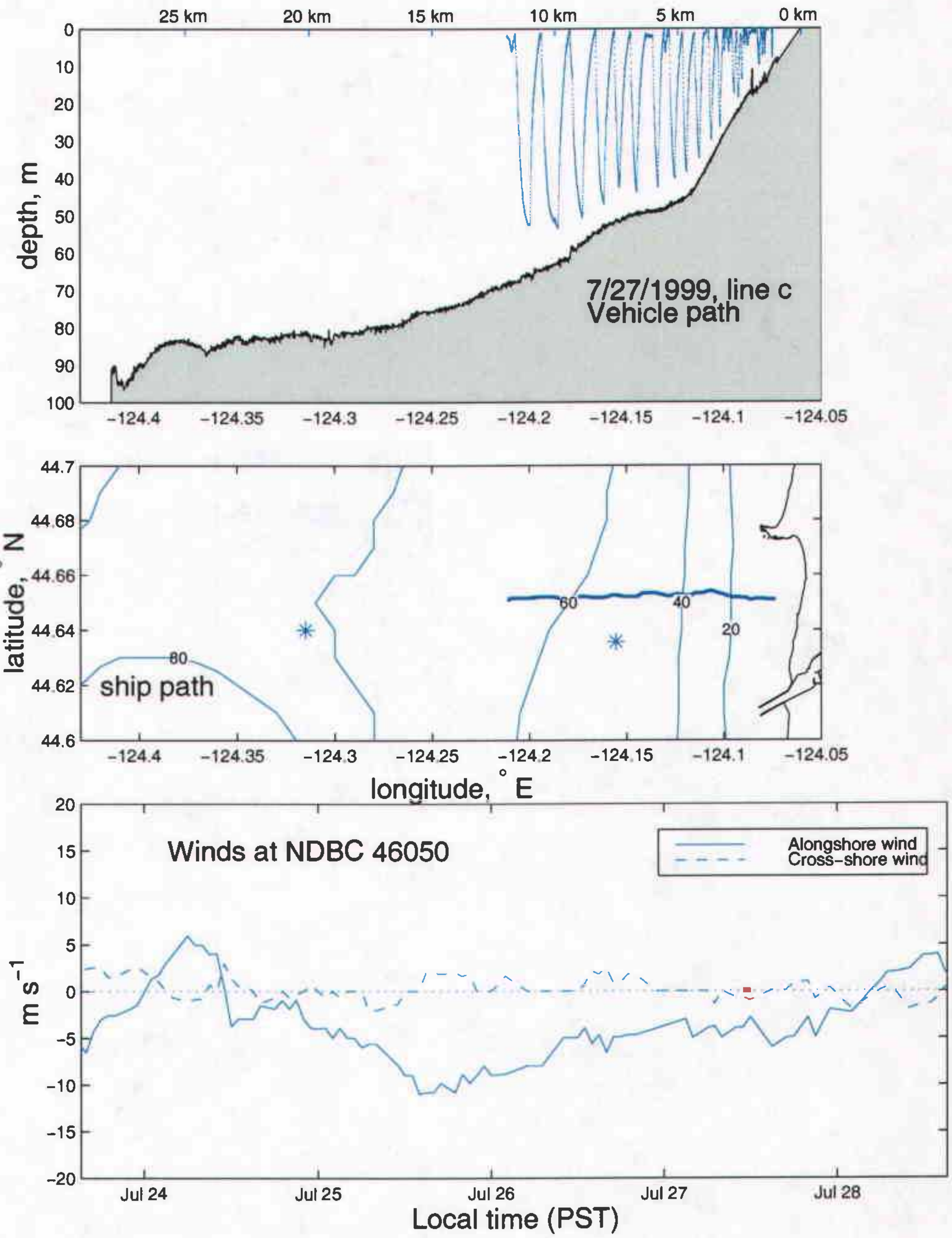

25 km
20 km
15 km
10 km
5 km
0 km
82
76
70
58
52
88
7/06/1999
Transmission
Δ Tr= 3%
depth, m
7/06/1999
Fluorometer Voltage
Δ F=1 V
depth, m
Longitude, ° E (44.65° N Latitude)



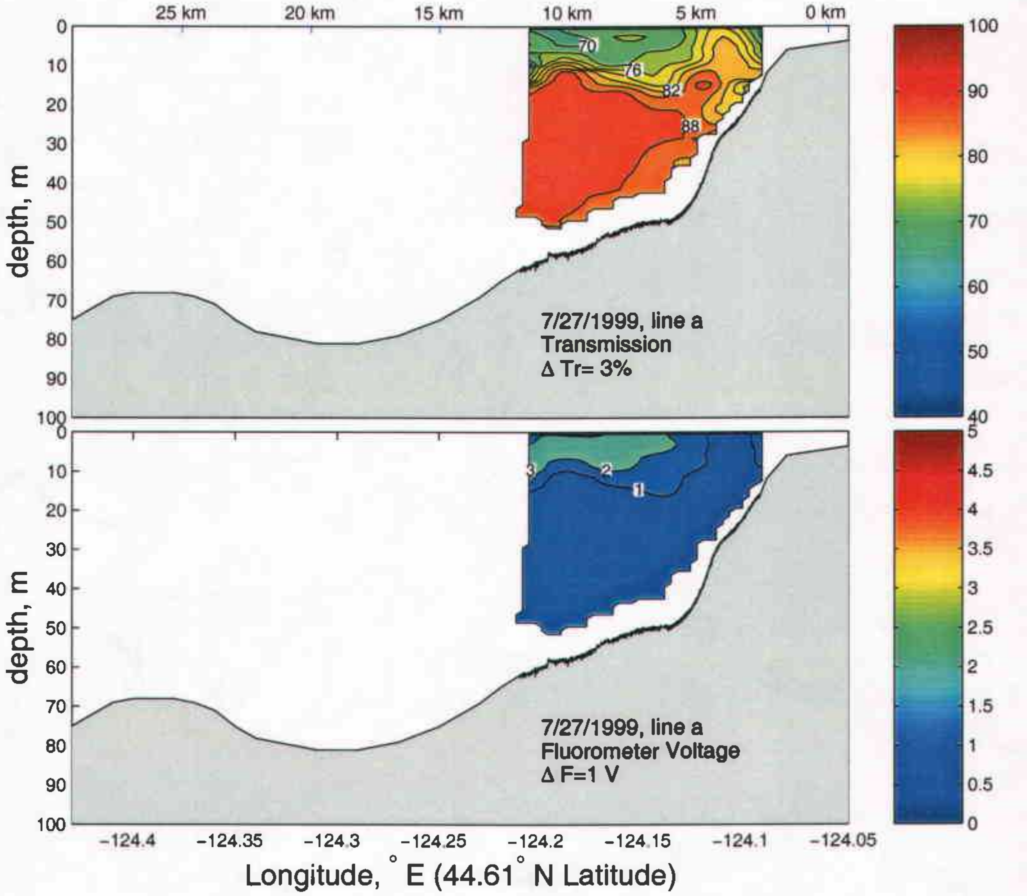
25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/27/1999, line c
Transmission
Δ Tr= 3%
7/27/1999, line c
Fluorometer Voltage
Δ F=1 V
Longitude, ° E (44.65° N Latitude)

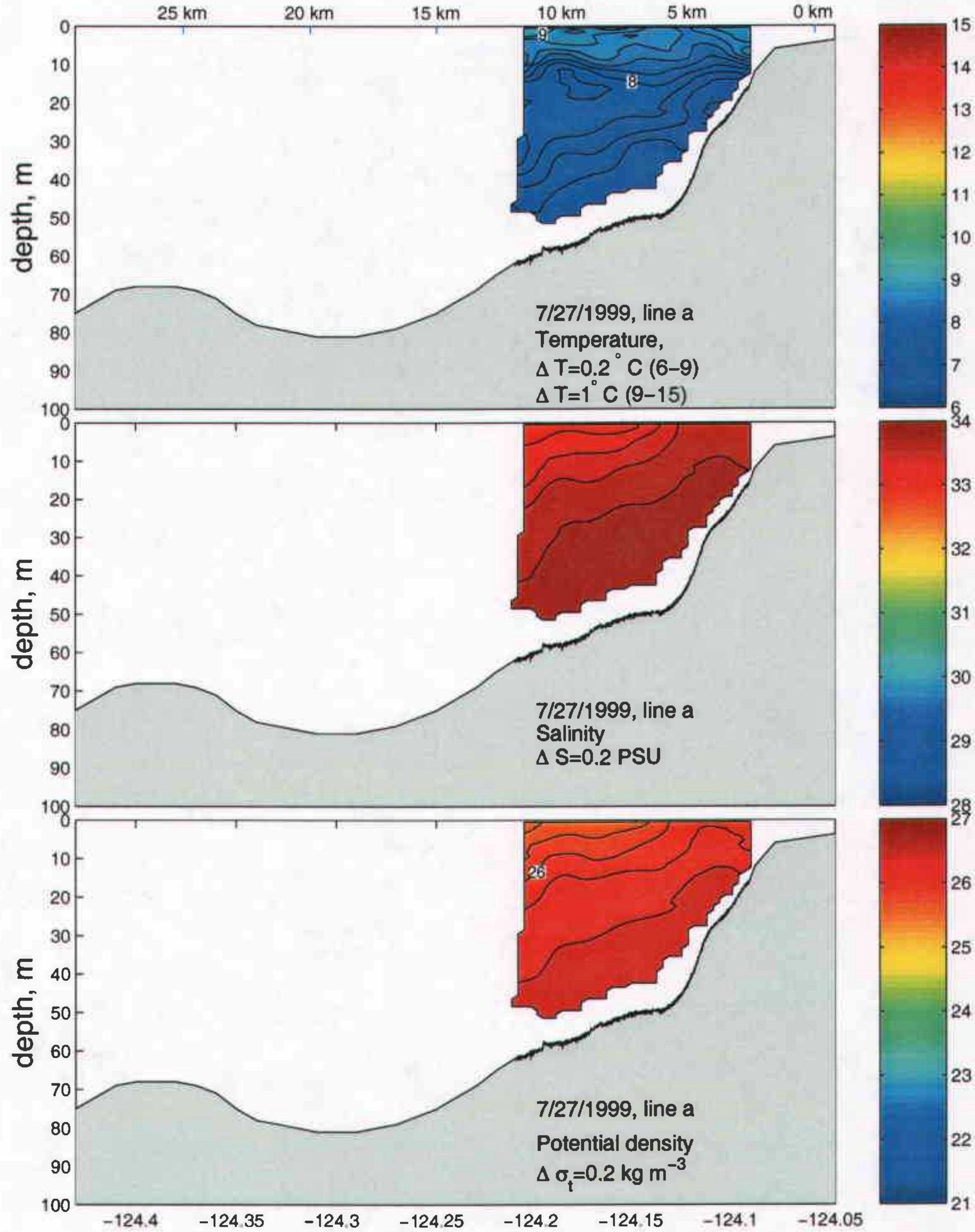


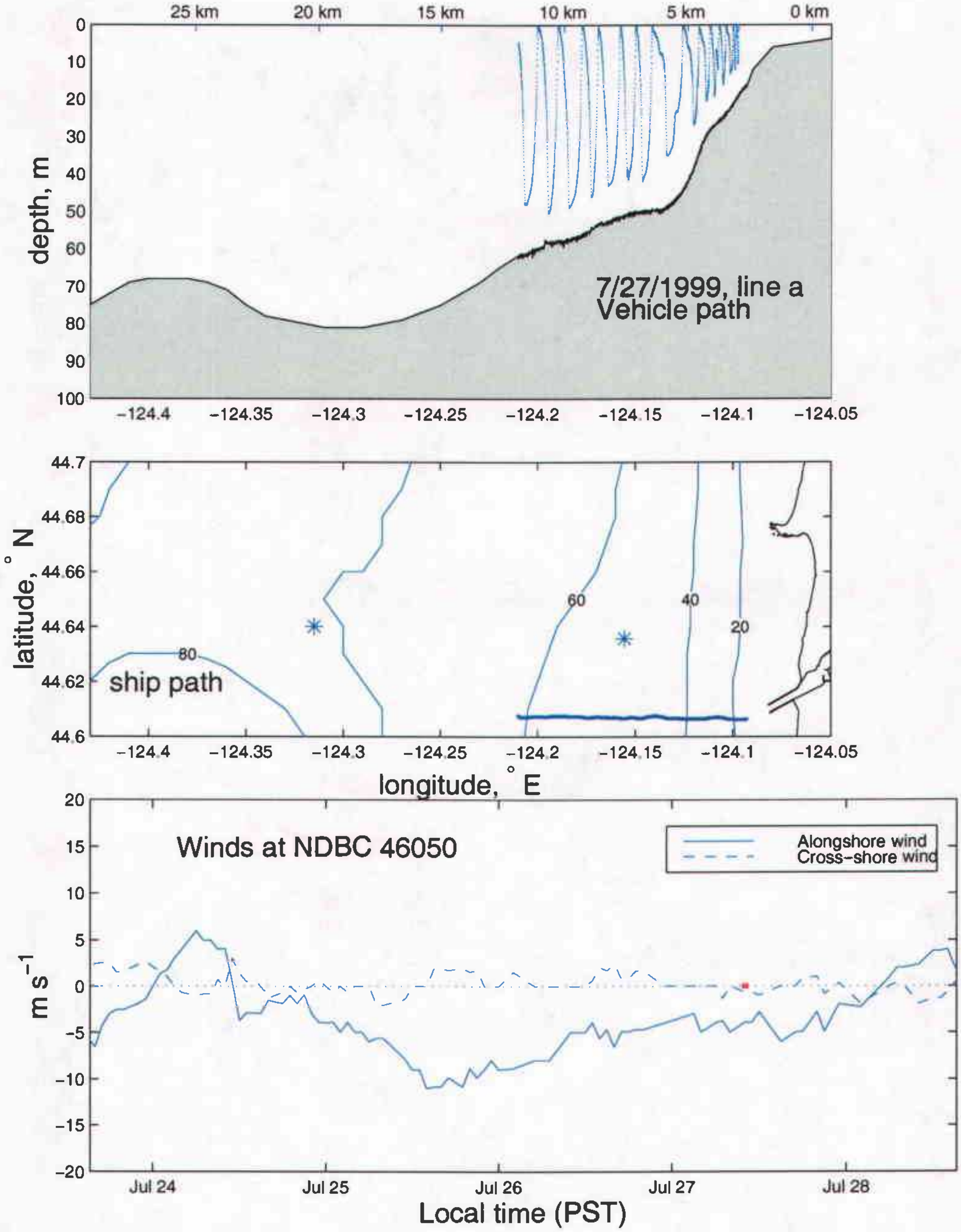
25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/27/1999, line c
Temperature,
Δ T=0.2 ° C (6–9)
Δ T=1° C (9–15)
7/27/1999, line c
Salinity
Δ S=0.2 PSU
7/27/1999, line c
Potential density
Δ σt=0.2 kg m−3
Longitude, ° E (44.65° N Latitude)



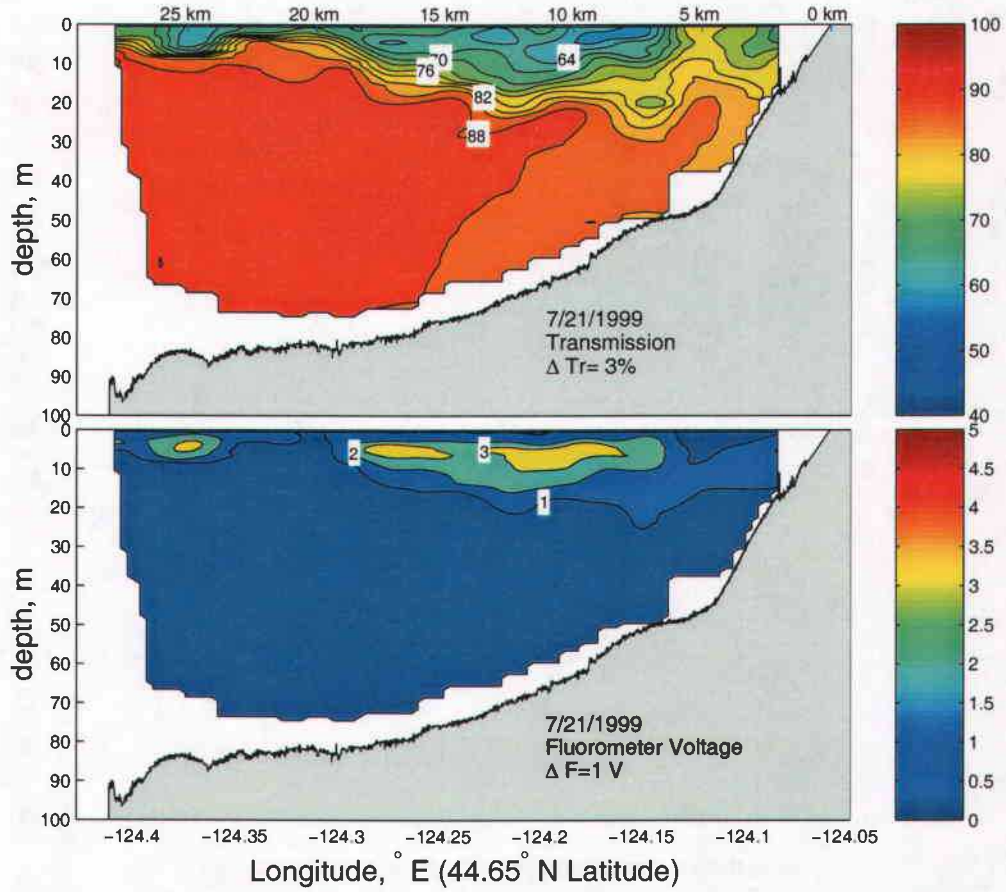
25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/27/1999, line c
Vehicle path
latitude, ° N
ship path
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s^{-1}
Jul 24
Jul 25
Jul 26
Jul 27
Jul 28
Local time (PST)


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/27/1999, line a
Transmission
Δ Tr= 3%
7/27/1999, line a
Fluorometer Voltage
Δ F=1 V
Longitude, ° E (44.61° N Latitude)

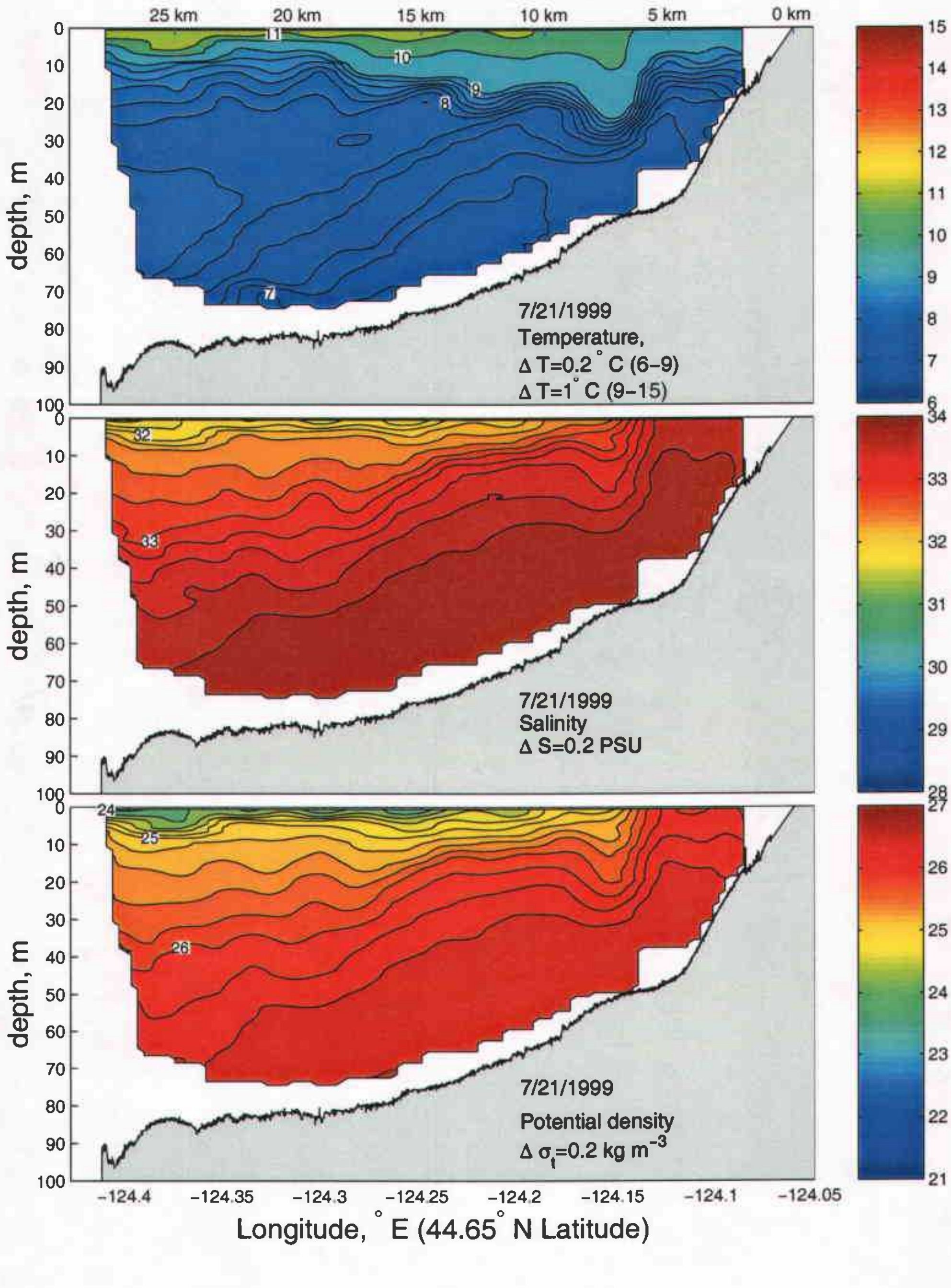

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/27/1999, line a
Temperature,
Δ T=0.2 ° C (6–9)
Δ T=1° C (9–15)
7/27/1999, line a
Salinity
Δ S=0.2 PSU
7/27/1999, line a
Potential density
$\Delta\ \sigma_t$=0.2 kg m^{-3}
−124.4
−124.35
−124.3
−124.25
−124.2
−124.15
−124.1
−124.05
Longitude, ° E (44.61° N Latitude)

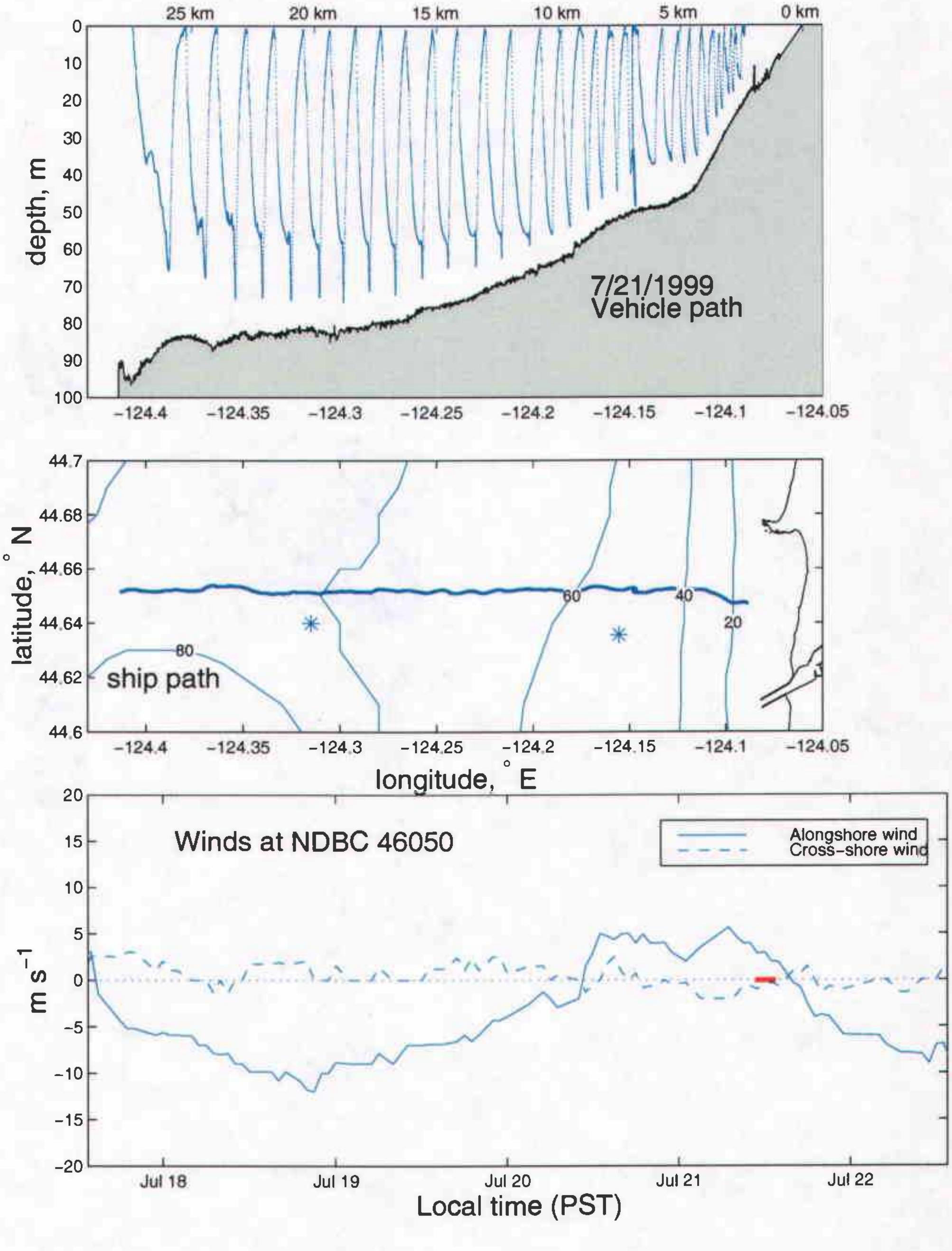


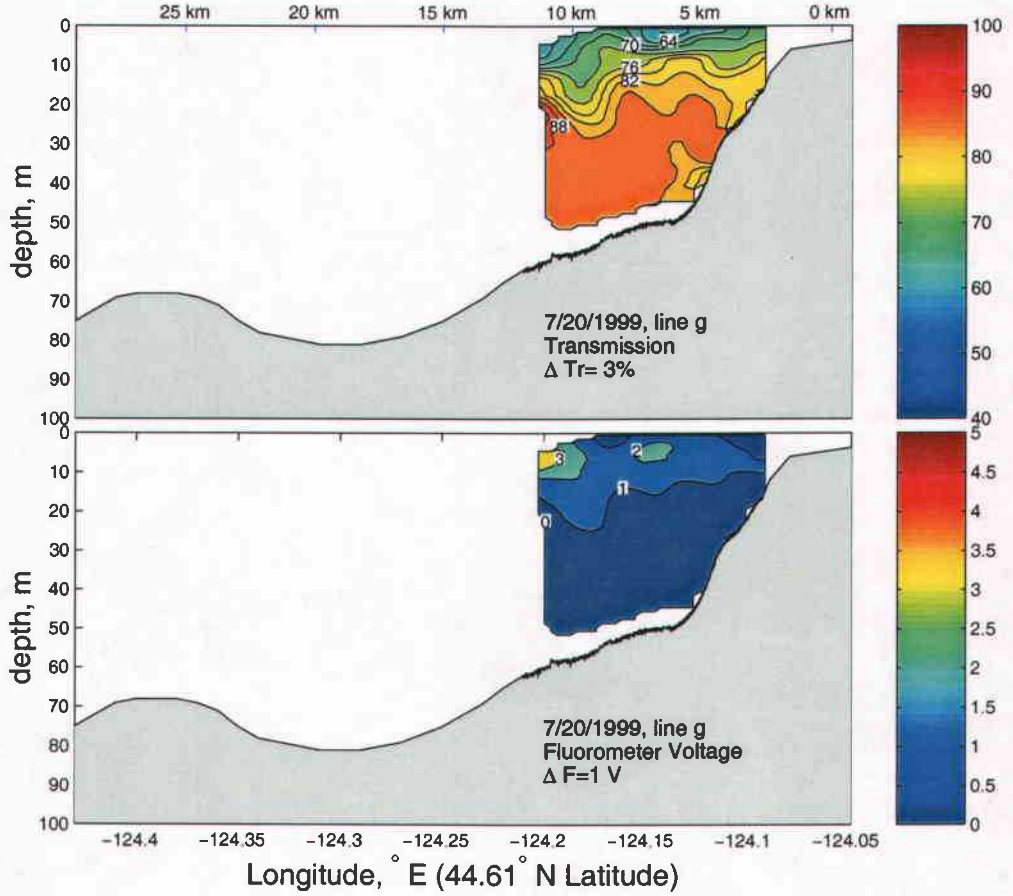
25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/27/1999, line a
Vehicle path
latitude, ° N
ship path
60
40
20
80
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s^{-1}
Jul 24
Jul 25
Jul 26
Jul 27
Jul 28
Local time (PST)

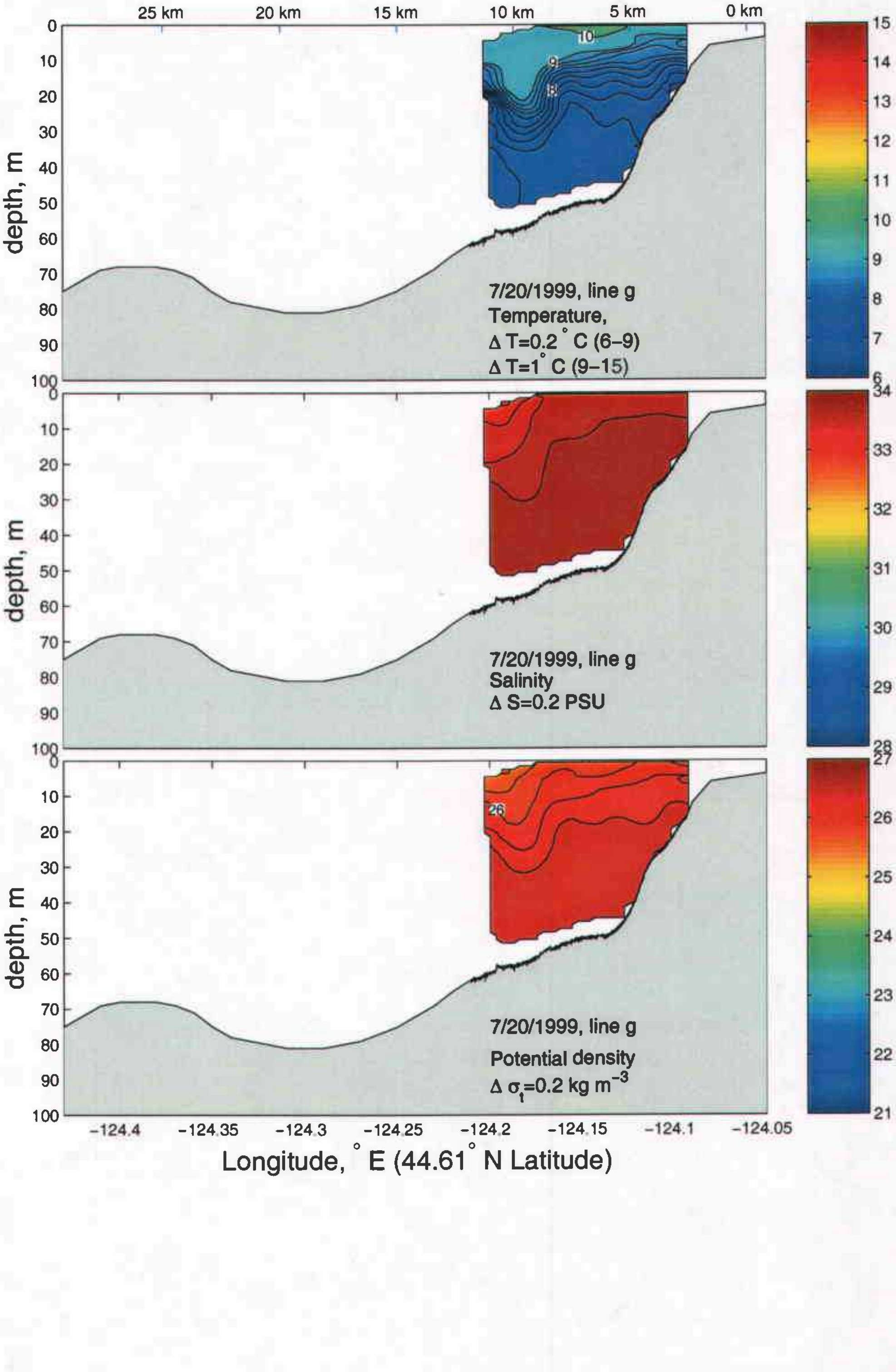


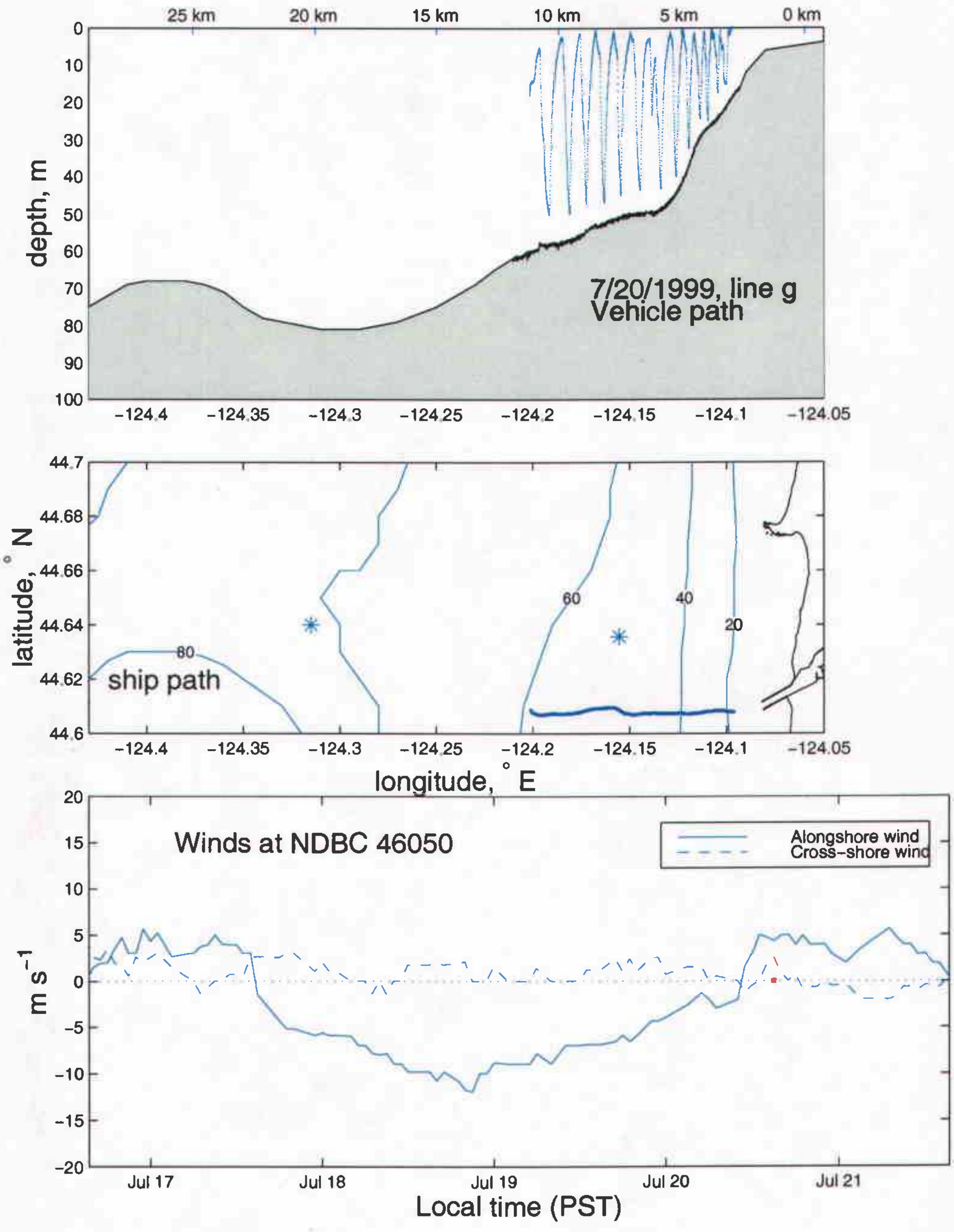
25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/21/1999
Transmission
Δ Tr= 3%
7/21/1999
Fluorometer Voltage
Δ F=1 V
Longitude, ° E (44.65° N Latitude)

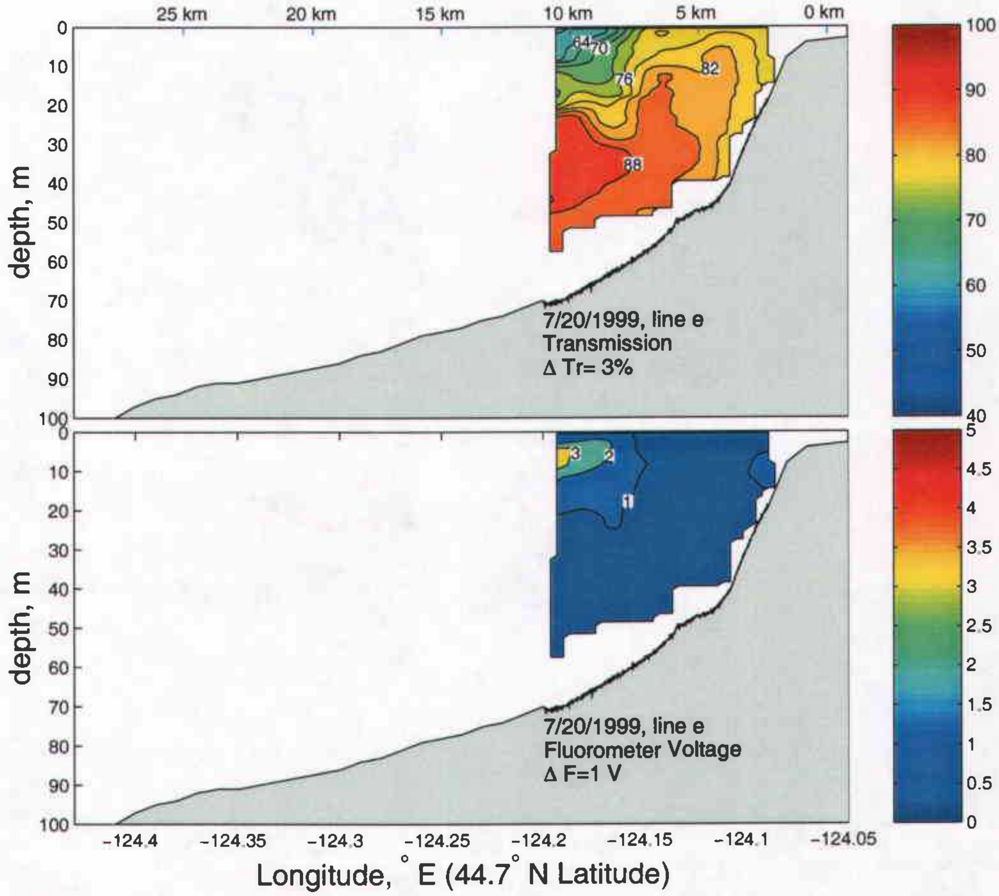

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/21/1999
Temperature,
Δ T=0.2 ° C (6–9)
Δ T=1° C (9–15)
7/21/1999
Salinity
Δ S=0.2 PSU
7/21/1999
Potential density
Δ σt=0.2 kg m−3
Longitude, ° E (44.65° N Latitude)


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/21/1999
Vehicle path
latitude, ° N
ship path
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s-1
Jul 18
Jul 19
Jul 20
Jul 21
Jul 22
Local time (PST)

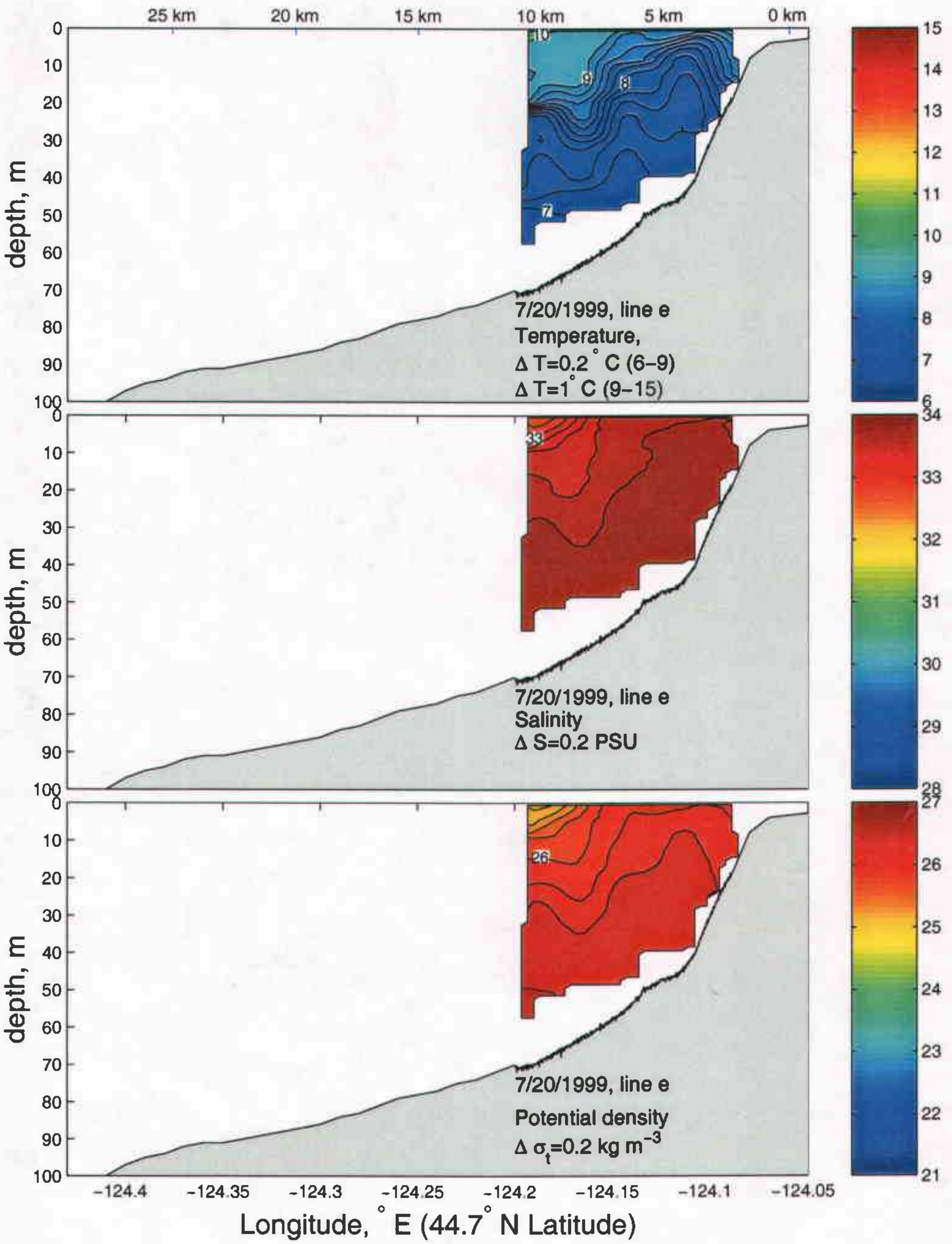

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/20/1999, line g
Transmission
Δ Tr= 3%
7/20/1999, line g
Fluorometer Voltage
Δ F=1 V
Longitude, ° E (44.61° N Latitude)

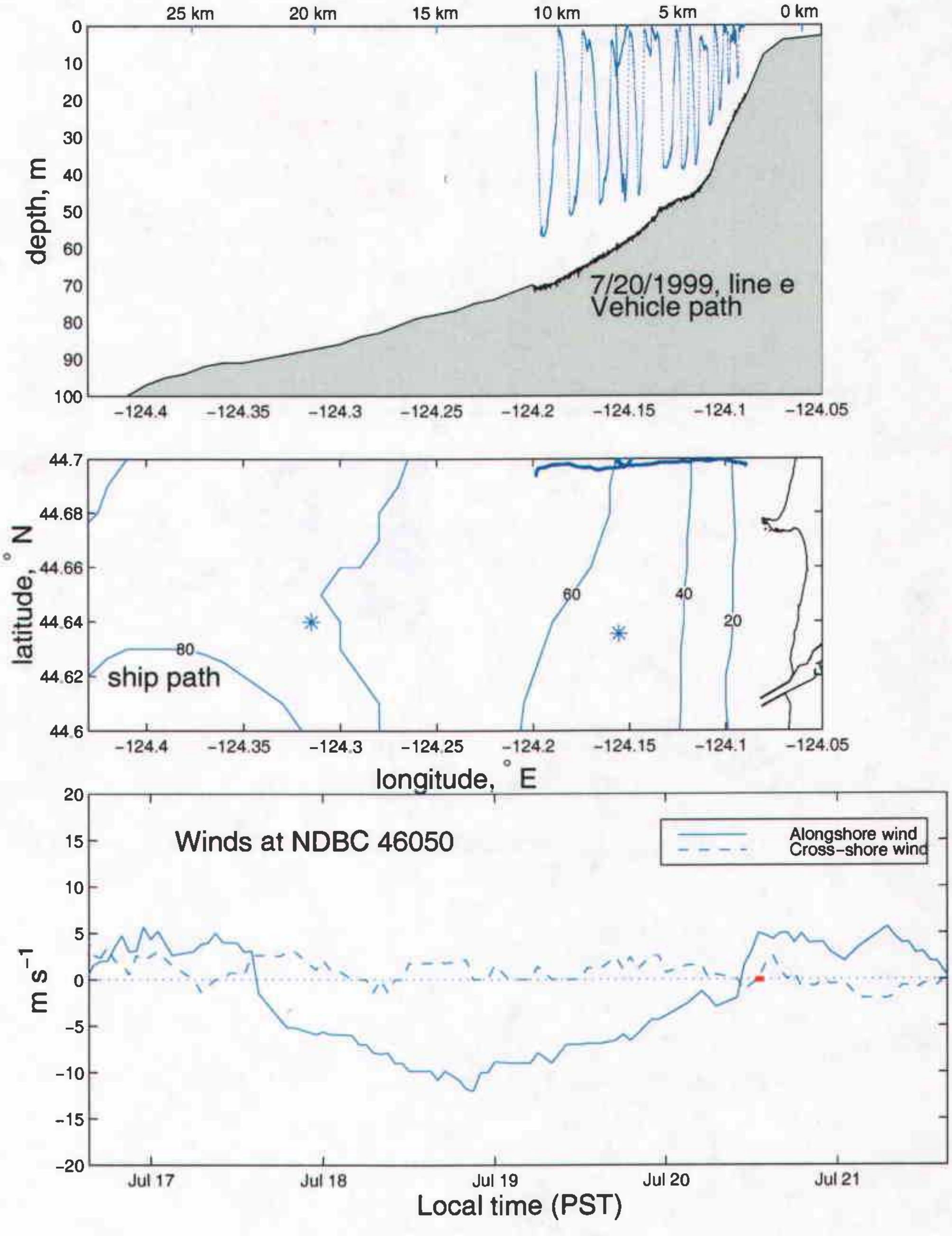

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/20/1999, line g
Temperature,
Δ T=0.2 °C (6–9)
Δ T=1 °C (9–15)
7/20/1999, line g
Salinity
Δ S=0.2 PSU
7/20/1999, line g
Potential density
Δ σ_t=0.2 kg m^{-3}
Longitude, °E (44.61° N Latitude)


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/20/1999, line g
Vehicle path
latitude, ° N
ship path
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s-1
Local time (PST)

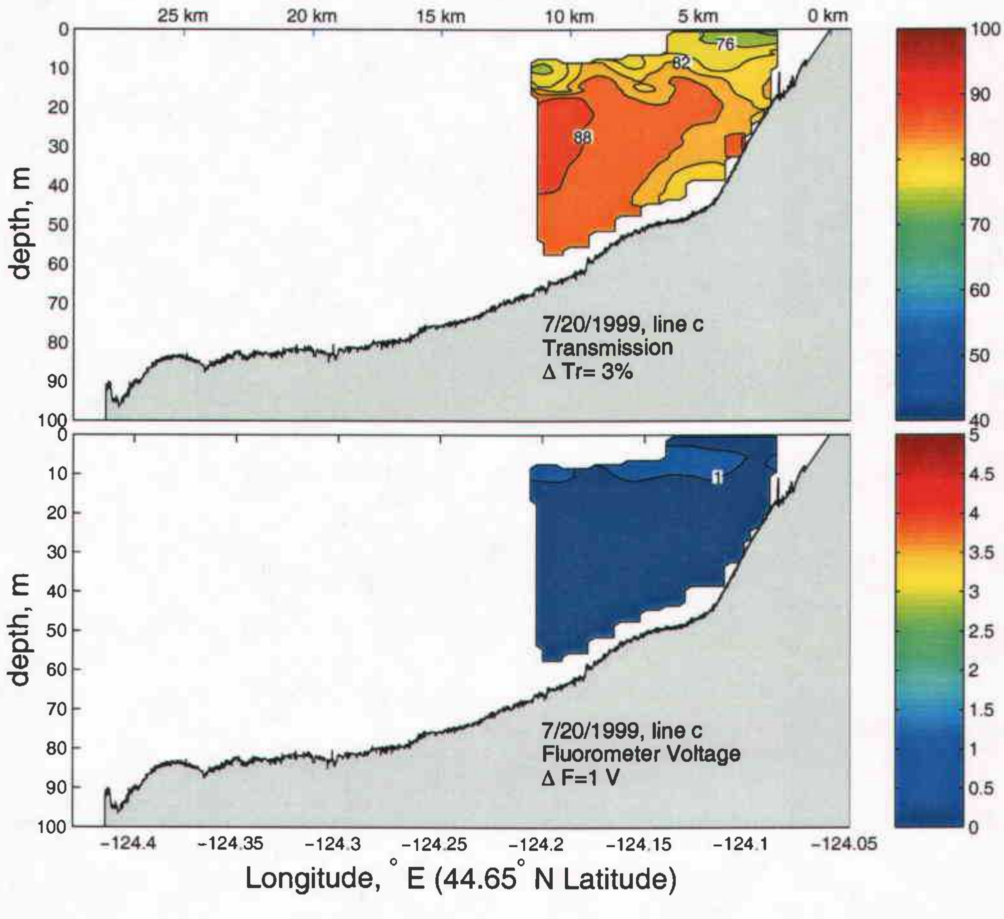


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/20/1999, line e
Transmission
Δ Tr= 3%
7/20/1999, line e
Fluorometer Voltage
Δ F=1 V
-124.4
-124.35
-124.3
-124.25
-124.2
-124.15
-124.1
-124.05
Longitude, ° E (44.7° N Latitude)

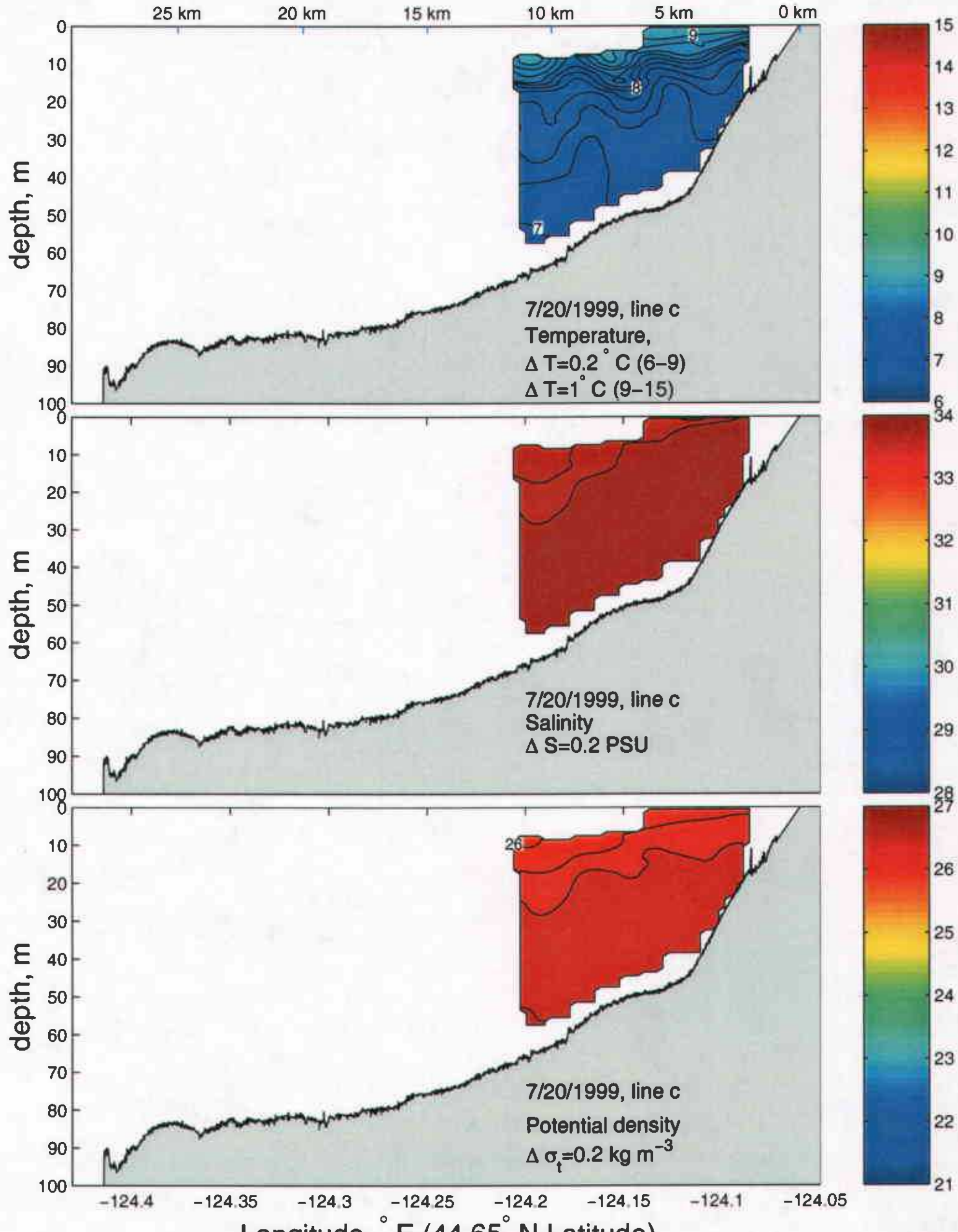

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/20/1999, line e
Temperature,
Δ T=0.2 ° C (6–9)
Δ T=1° C (9–15)
7/20/1999, line e
Salinity
Δ S=0.2 PSU
7/20/1999, line e
Potential density
Δ σt=0.2 kg m-3
Longitude, ° E (44.7° N Latitude)



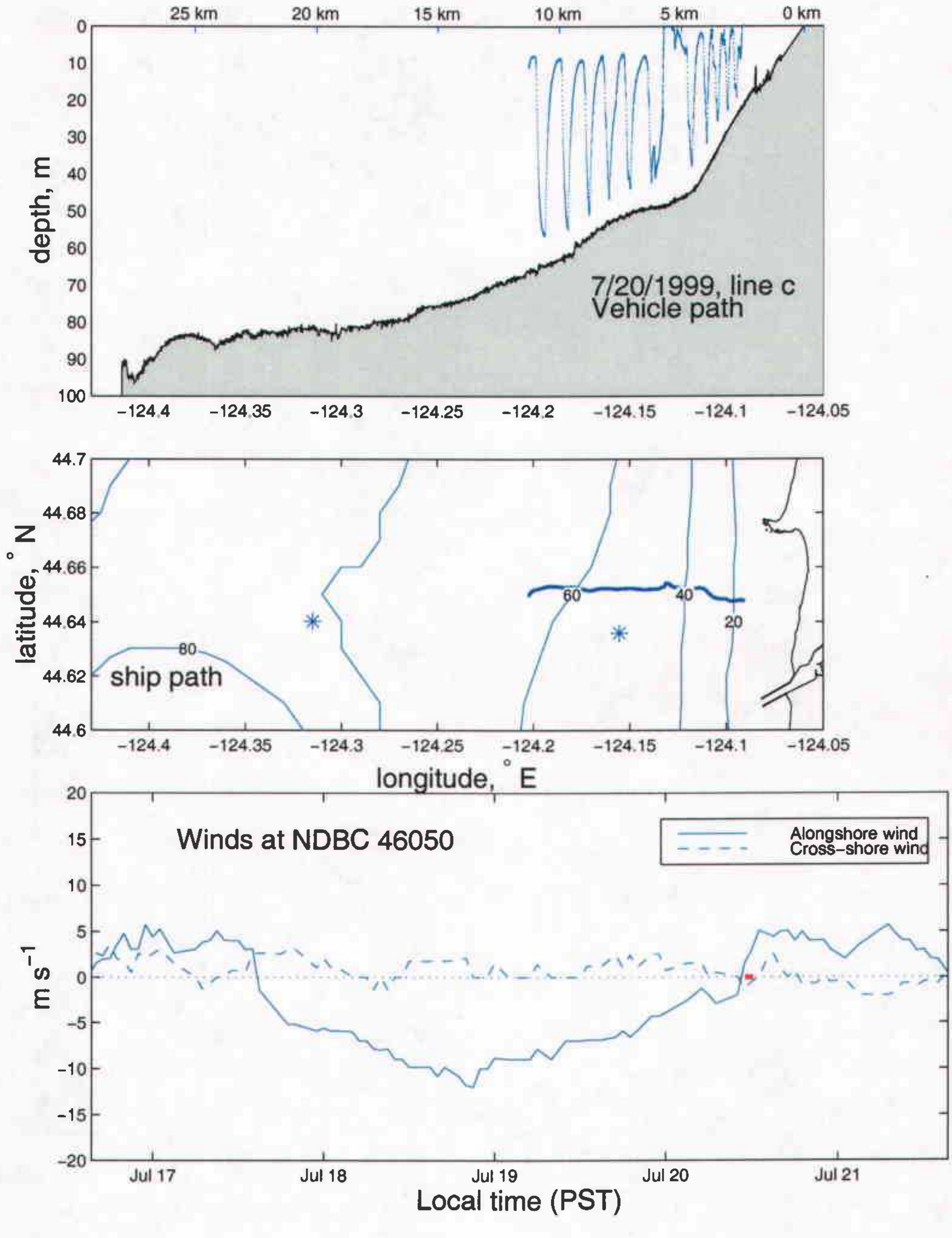
25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/20/1999, line e
Vehicle path
latitude, ° N
ship path
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s-1
Local time (PST)

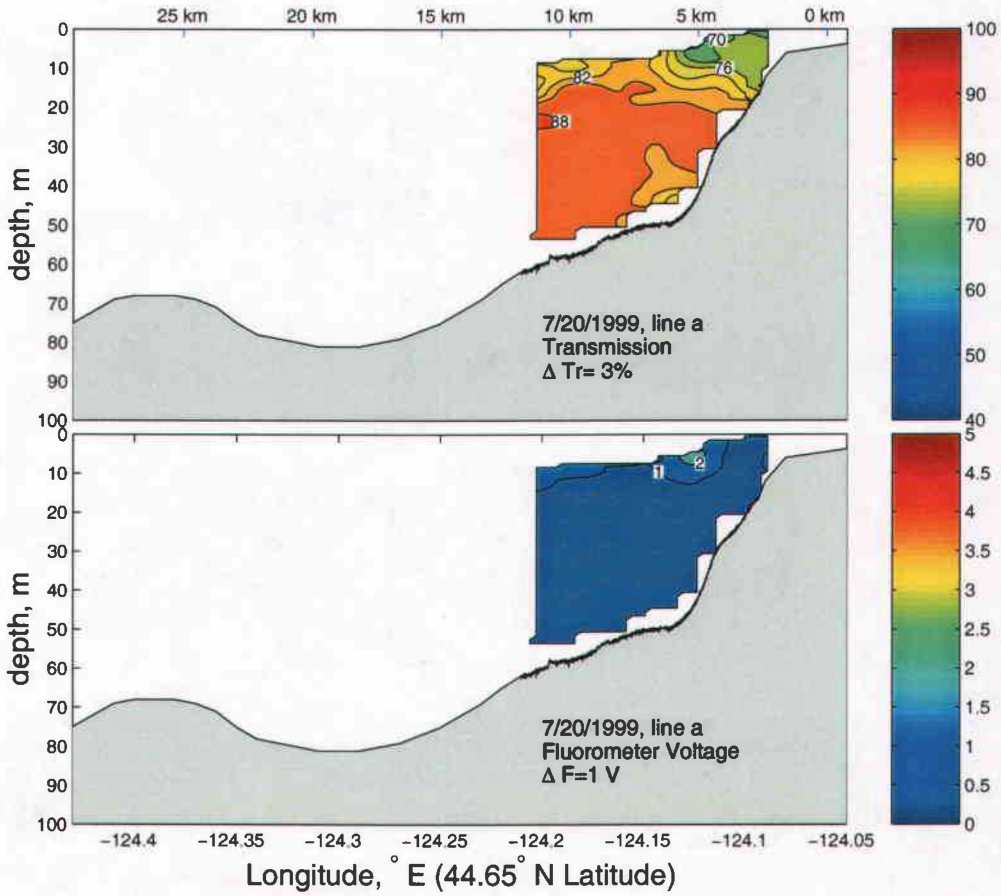


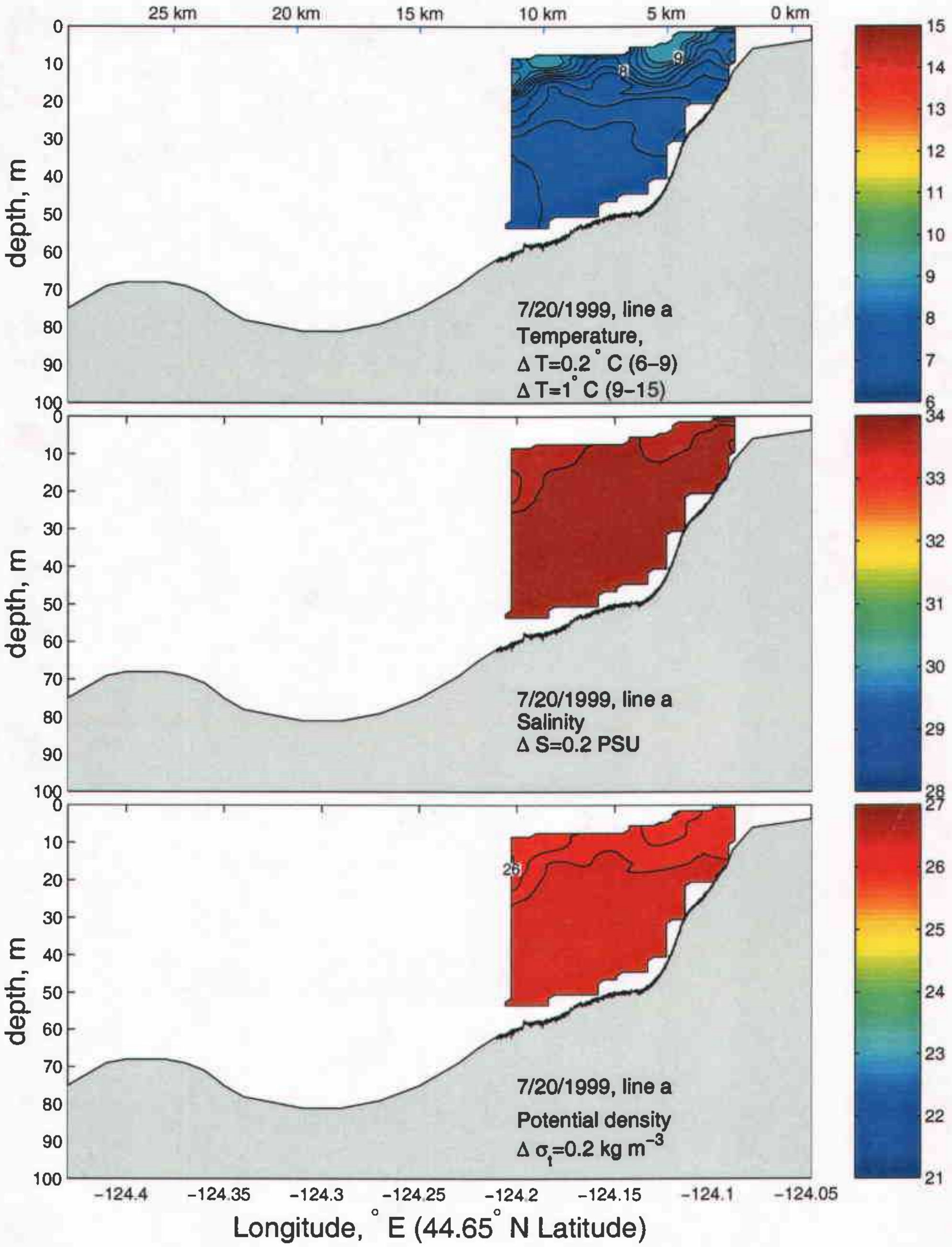
25 km
20 km
15 km
10 km
5 km
0 km
76
82
88
7/20/1999, line c
Transmission
Δ Tr= 3%
depth, m
1
7/20/1999, line c
Fluorometer Voltage
Δ F=1 V
-124.4
-124.35
-124.3
-124.25
-124.2
-124.15
-124.1
-124.05
Longitude, ° E (44.65° N Latitude)

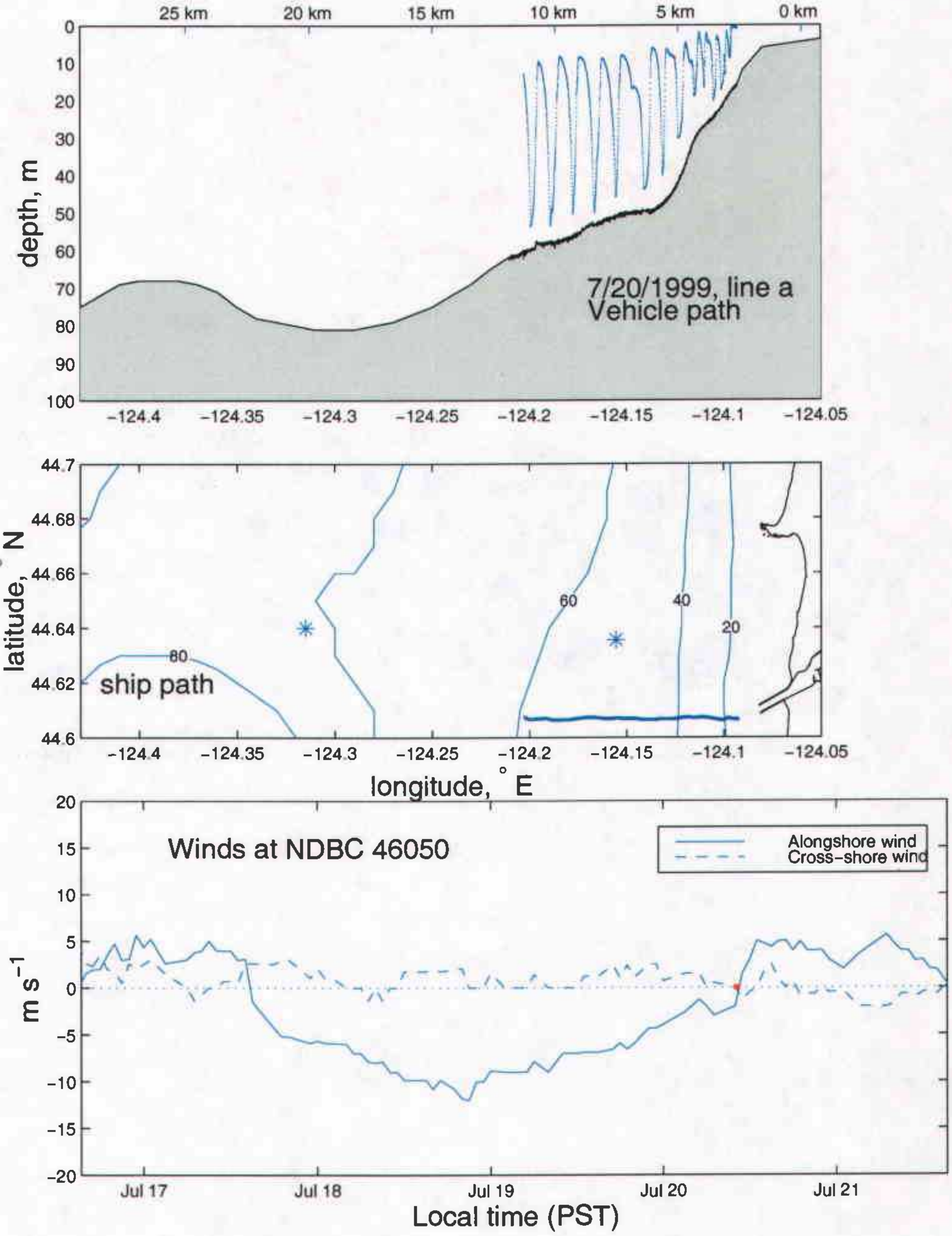


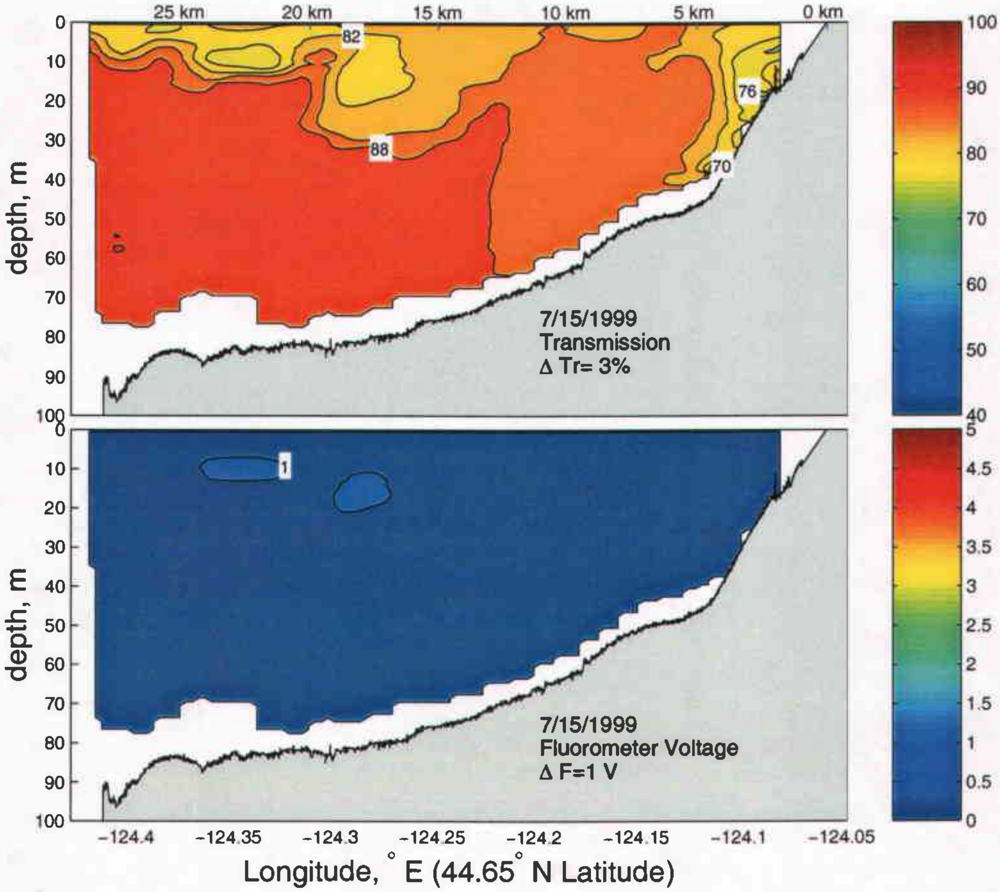
25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/20/1999, line c
Temperature,
Δ T=0.2 ° C (6–9)
Δ T=1 ° C (9–15)
7/20/1999, line c
Salinity
Δ S=0.2 PSU
7/20/1999, line c
Potential density
Δ σt=0.2 kg m−3
Longitude, ° E (44.65° N Latitude)

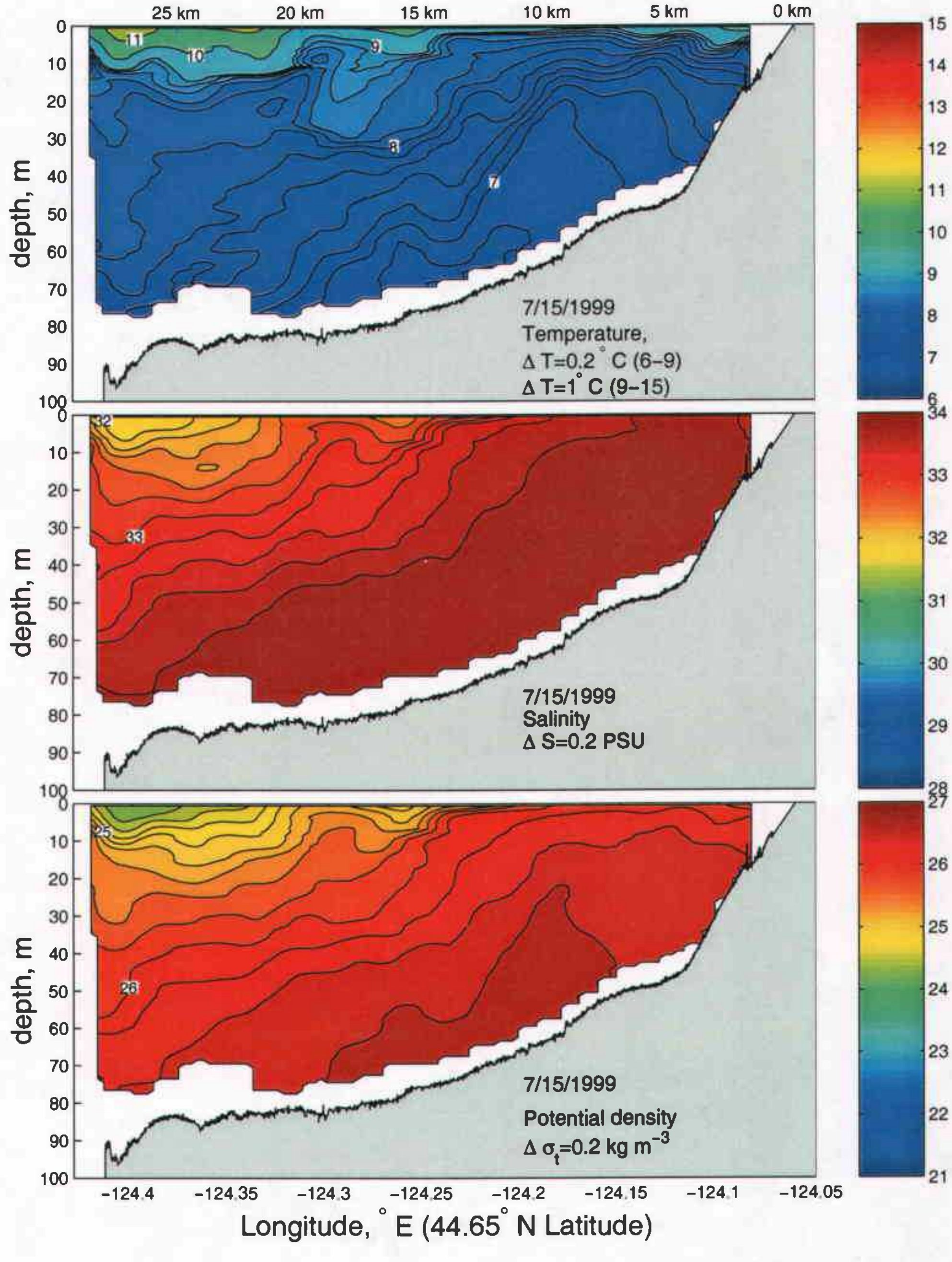

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/20/1999, line c
Vehicle path
latitude, ° N
ship path
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s^{-1}
Jul 17
Jul 18
Jul 19
Jul 20
Jul 21
Local time (PST)

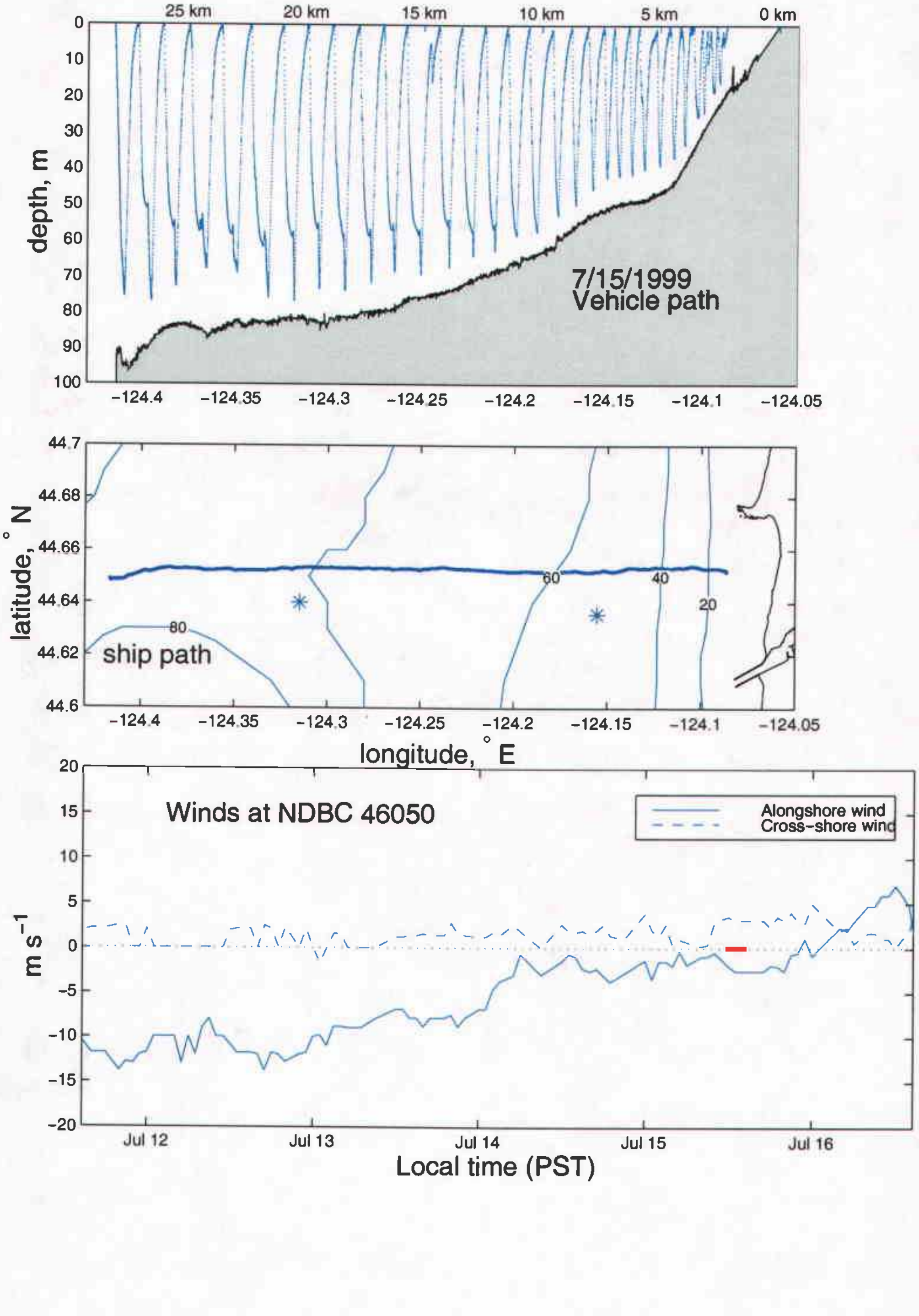

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
70
76
82
88
7/20/1999, line a
Transmission
Δ Tr= 3%
1
2
7/20/1999, line a
Fluorometer Voltage
Δ F=1 V
Longitude, ° E (44.65° N Latitude)


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/20/1999, line a
Temperature,
Δ T=0.2 ° C (6–9)
Δ T=1° C (9–15)
7/20/1999, line a
Salinity
Δ S=0.2 PSU
7/20/1999, line a
Potential density
Δ σt=0.2 kg m−3
−124.4
−124.35
−124.3
−124.25
−124.2
−124.15
−124.1
−124.05
Longitude, ° E (44.65° N Latitude)

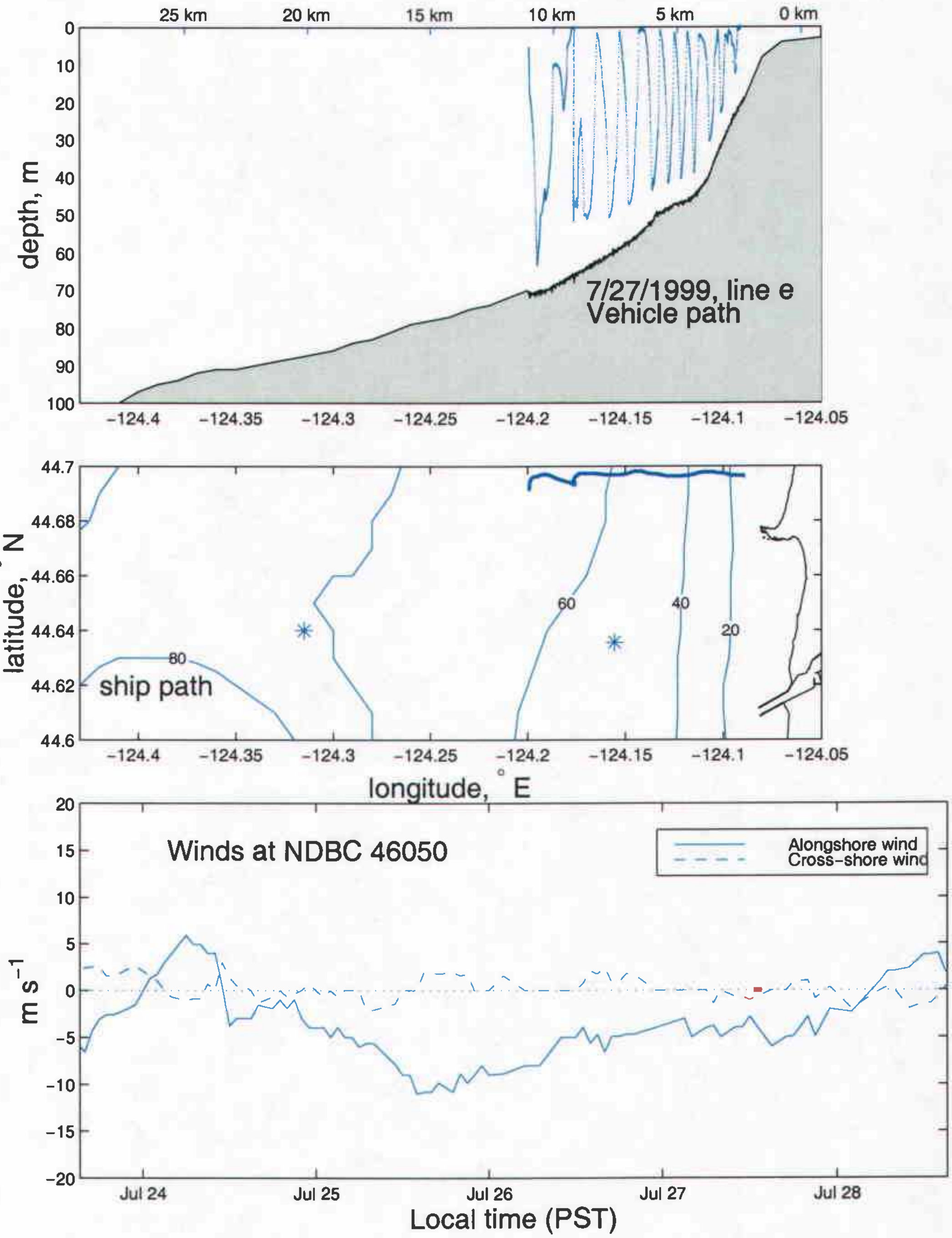

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/20/1999, line a
Vehicle path
latitude, ° N
ship path
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s⁻¹
Jul 17
Jul 18
Jul 19
Jul 20
Jul 21
Local time (PST)

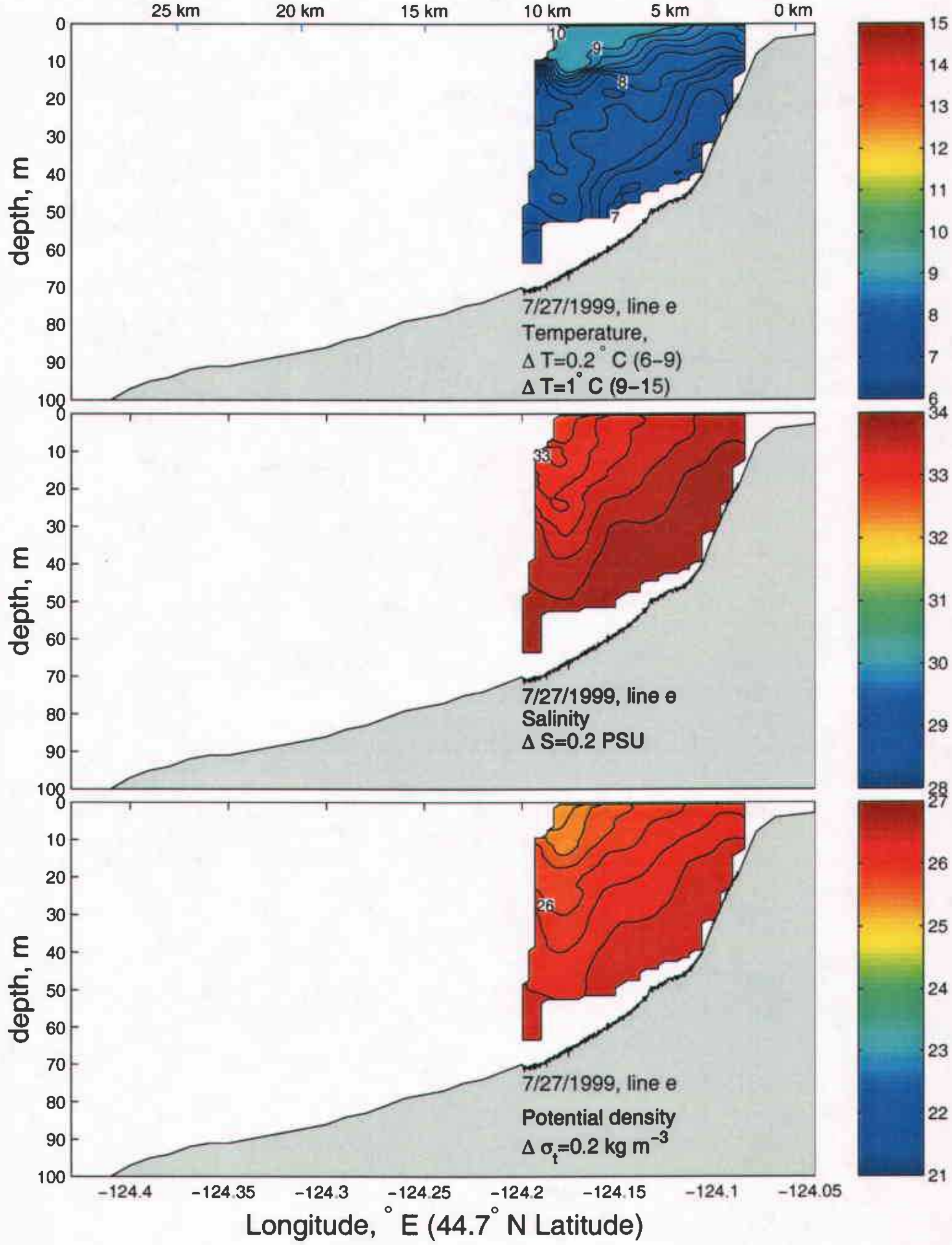

25 km
20 km
15 km
10 km
5 km
0 km
82
76
88
70
depth, m
7/15/1999
Transmission
Δ Tr= 3%
1
7/15/1999
Fluorometer Voltage
Δ F=1 V
Longitude, ° E (44.65° N Latitude)


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/15/1999
Temperature,
Δ T=0.2 °C (6–9)
Δ T=1 °C (9–15)
7/15/1999
Salinity
Δ S=0.2 PSU
7/15/1999
Potential density
Δ σt=0.2 kg m-3
Longitude, ° E (44.65° N Latitude)

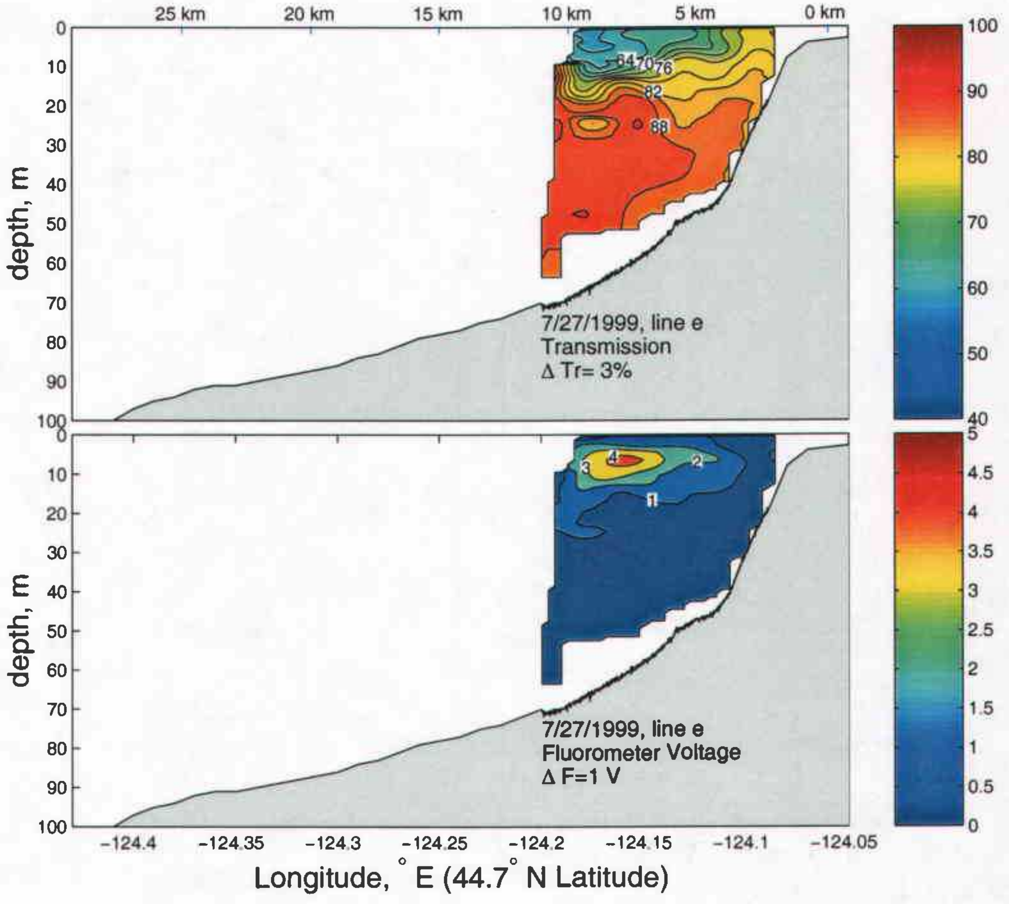


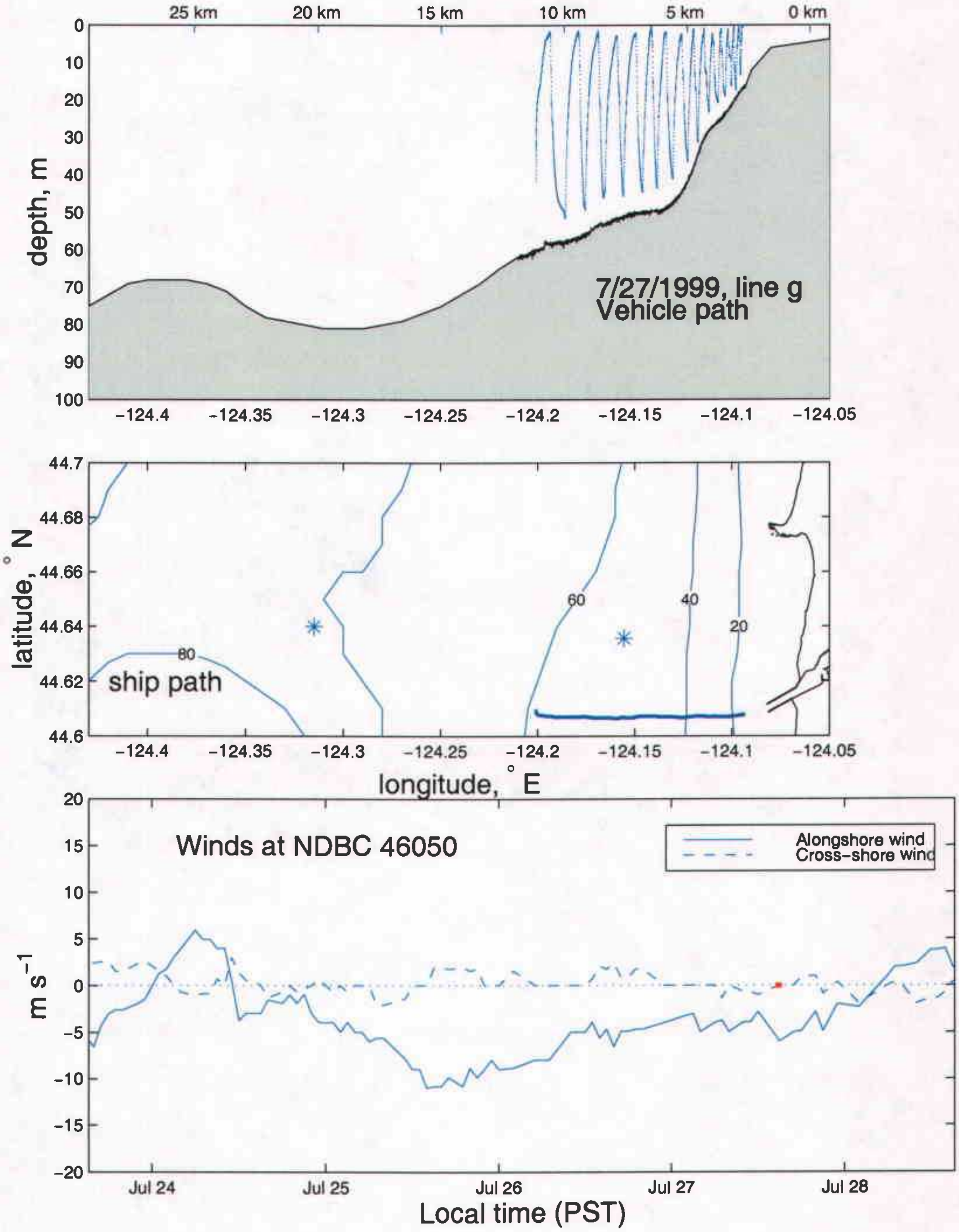
25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/15/1999
Vehicle path
latitude, ° N
ship path
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s^{-1}
Jul 12
Jul 13
Jul 14
Jul 15
Jul 16
Local time (PST)

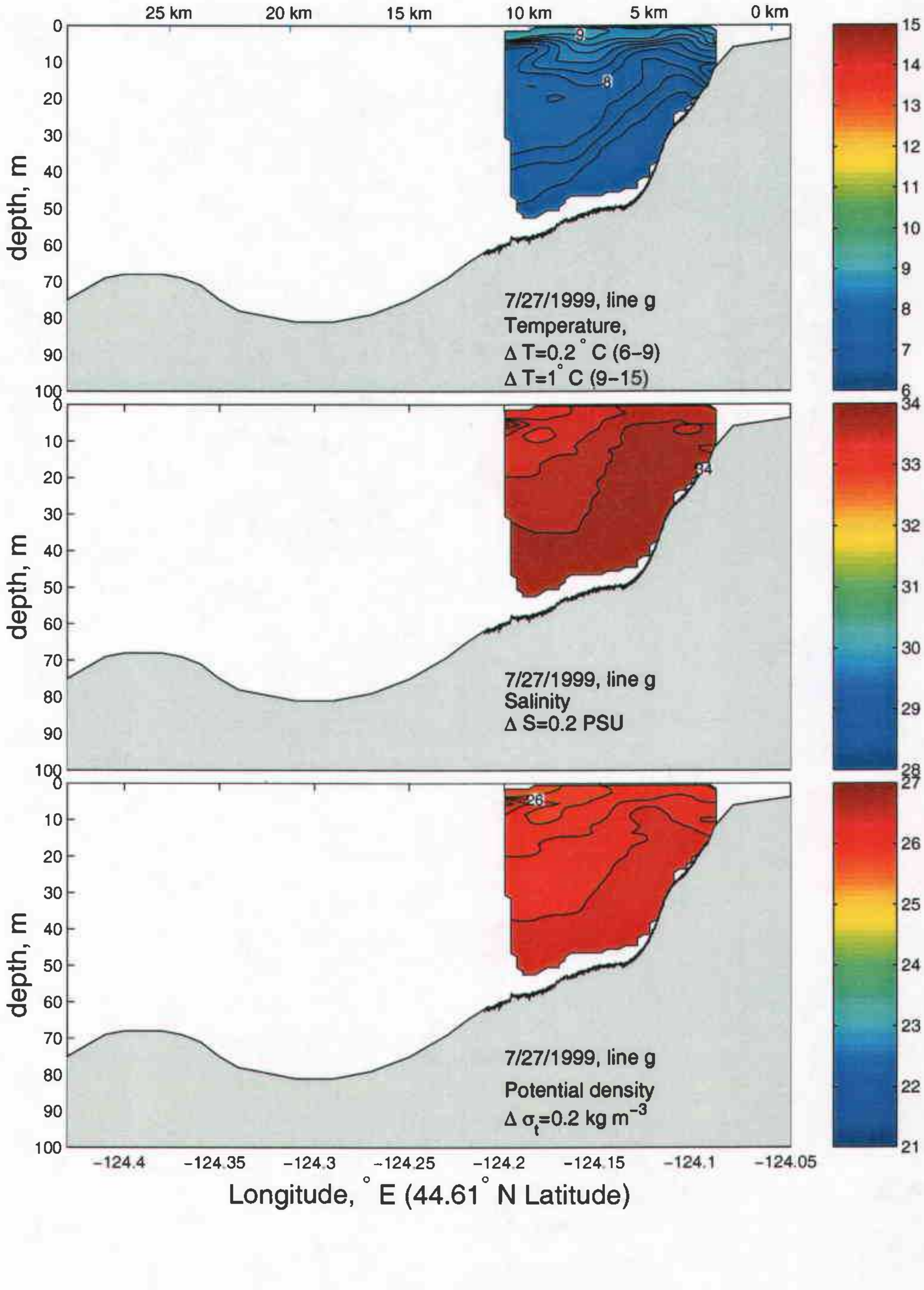

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/27/1999, line e
Vehicle path
latitude, ° N
ship path
80
60
40
20
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s-1
Jul 24
Jul 25
Jul 26
Jul 27
Jul 28
Local time (PST)

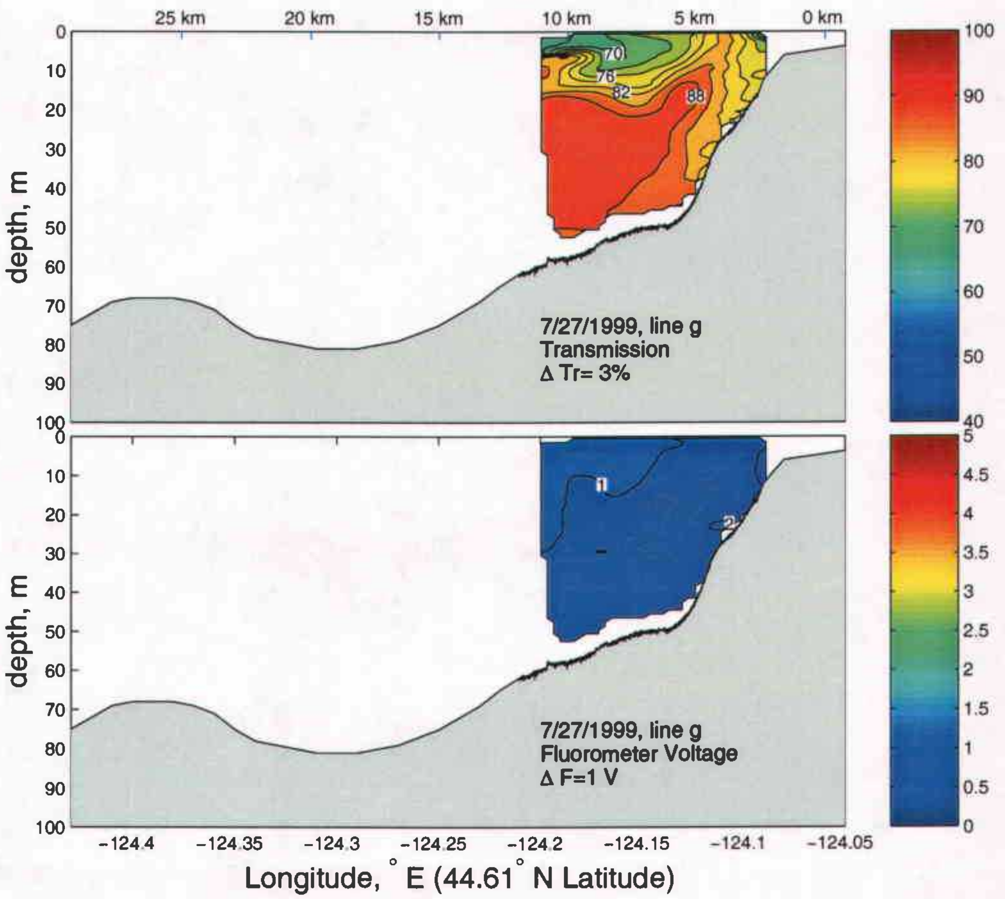


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/27/1999, line e
Temperature,
Δ T=0.2 °C (6–9)
Δ T=1 °C (9–15)
7/27/1999, line e
Salinity
Δ S=0.2 PSU
7/27/1999, line e
Potential density
Δ σt=0.2 kg m−3
Longitude, ° E (44.7° N Latitude)

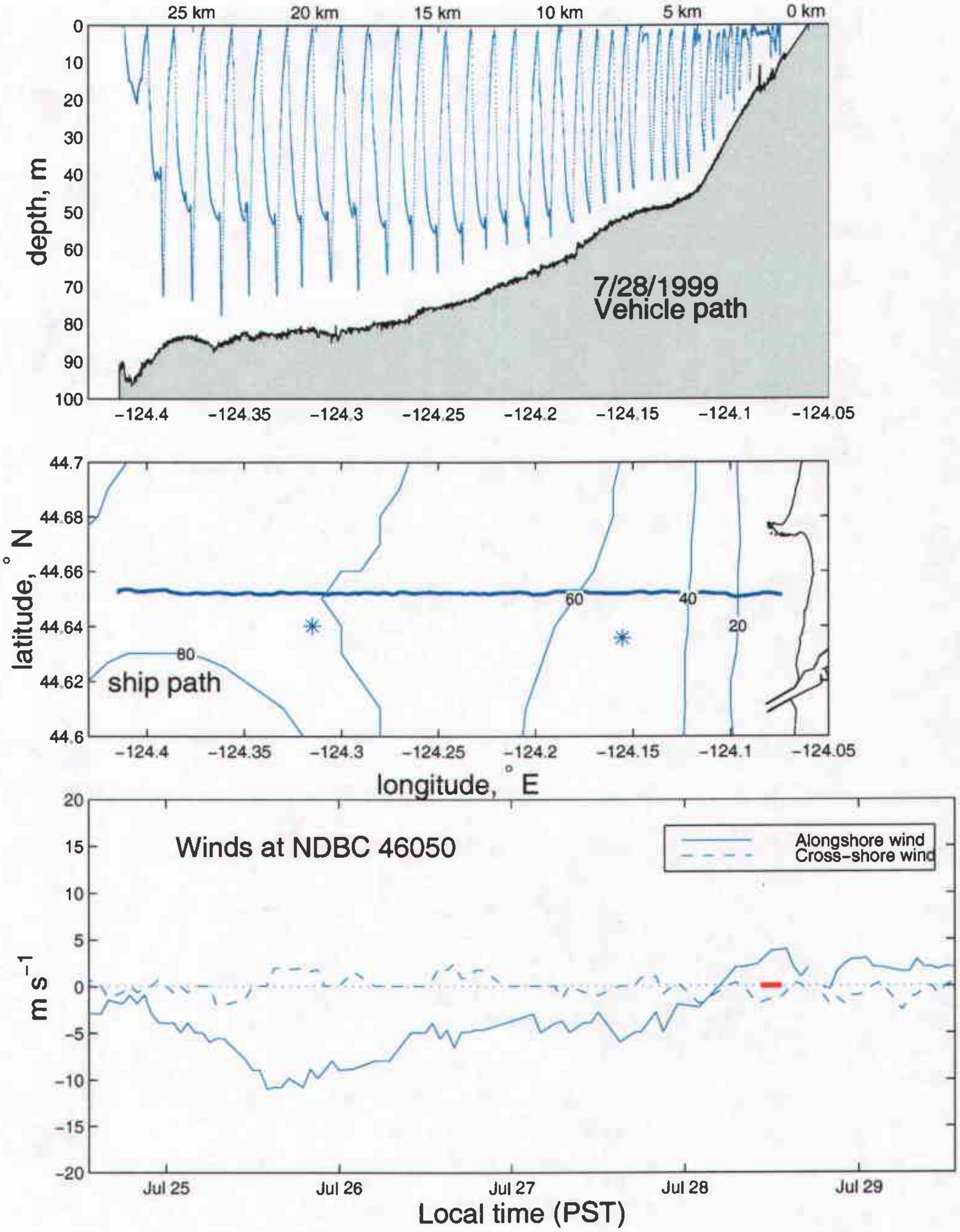

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/27/1999, line e
Transmission
Δ Tr= 3%
7/27/1999, line e
Fluorometer Voltage
Δ F=1 V
Longitude, ° E (44.7° N Latitude)

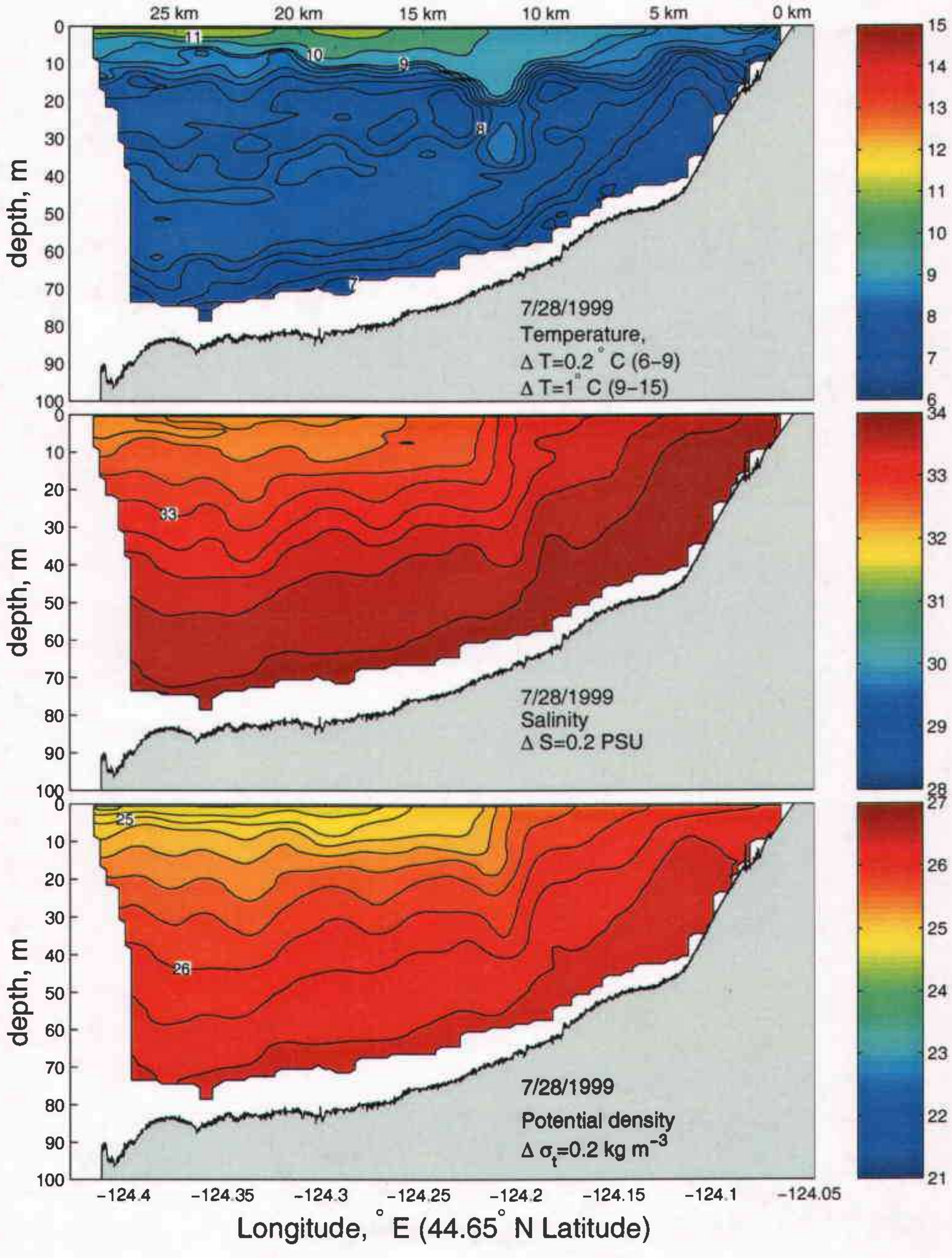

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/27/1999, line g
Vehicle path
-124.4
-124.35
-124.3
-124.25
-124.2
-124.15
-124.1
-124.05
latitude, ° N
ship path
80
60
40
20
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s^{-1}
Jul 24
Jul 25
Jul 26
Jul 27
Jul 28
Local time (PST)

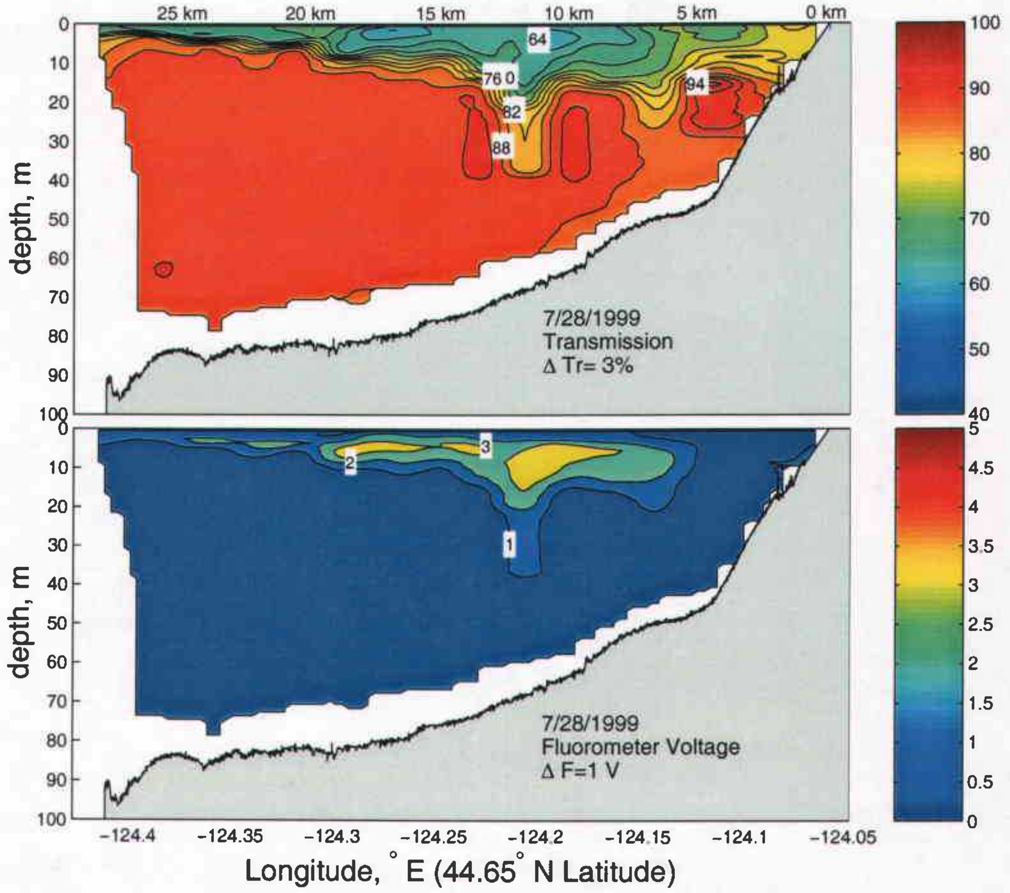

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/27/1999, line g
Temperature,
Δ T=0.2 ° C (6–9)
Δ T=1 ° C (9–15)
7/27/1999, line g
Salinity
Δ S=0.2 PSU
7/27/1999, line g
Potential density
Δ σt=0.2 kg m−3
Longitude, ° E (44.61 ° N Latitude)



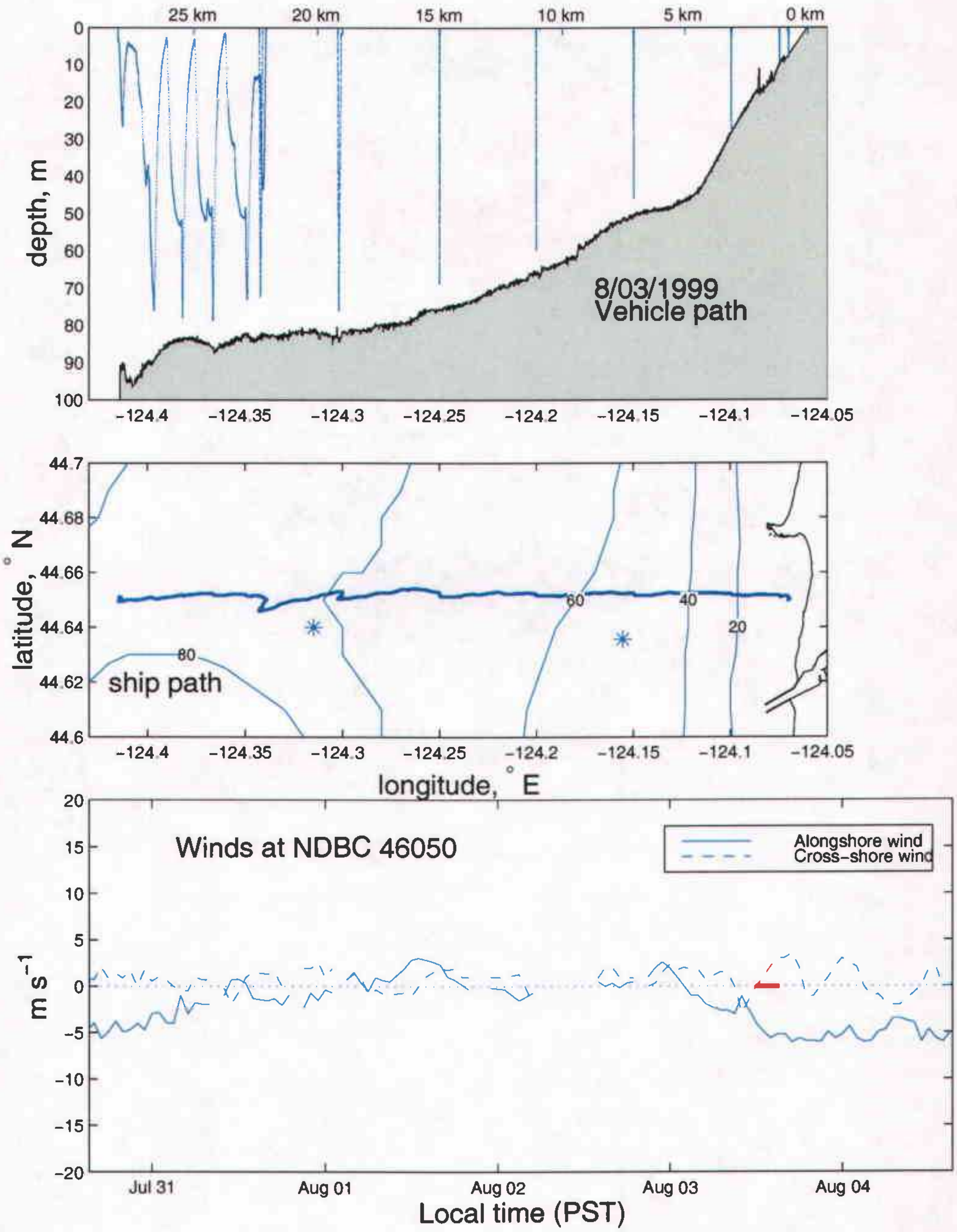
25 km
20 km
15 km
10 km
5 km
0 km
depth, m
70
76
82
88
7/27/1999, line g
Transmission
Δ Tr= 3%
1
2
7/27/1999, line g
Fluorometer Voltage
Δ F=1 V
-124.4
-124.35
-124.3
-124.25
-124.2
-124.15
-124.1
-124.05
Longitude, ° E (44.61° N Latitude)

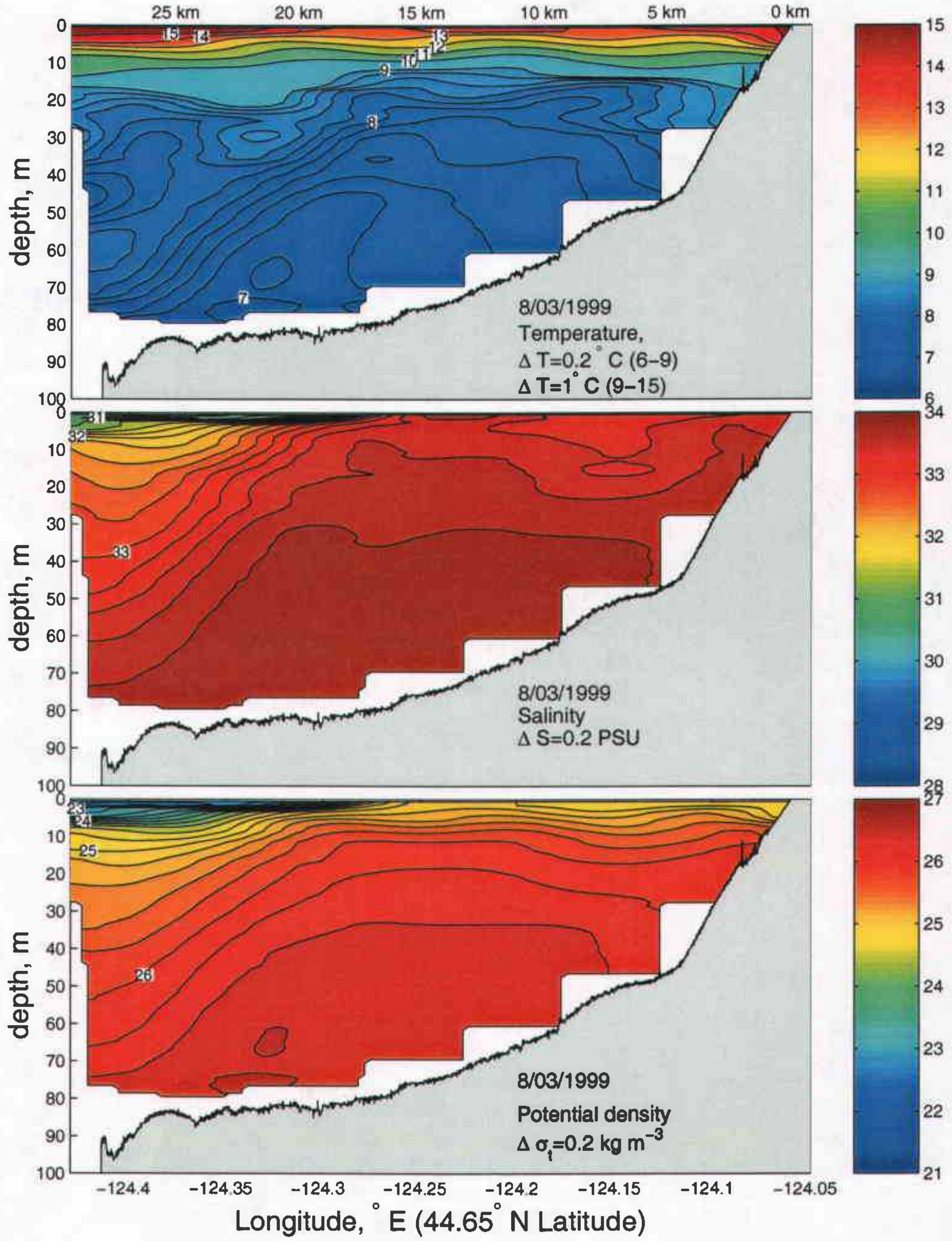

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/28/1999
Vehicle path
latitude, ° N
ship path
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s^-1
Jul 25
Jul 26
Jul 27
Jul 28
Jul 29
Local time (PST)


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
7/28/1999
Temperature,
Δ T=0.2 ° C (6–9)
Δ T=1° C (9–15)
7/28/1999
Salinity
Δ S=0.2 PSU
7/28/1999
Potential density
Δ σt=0.2 kg m−3
Longitude, ° E (44.65° N Latitude)

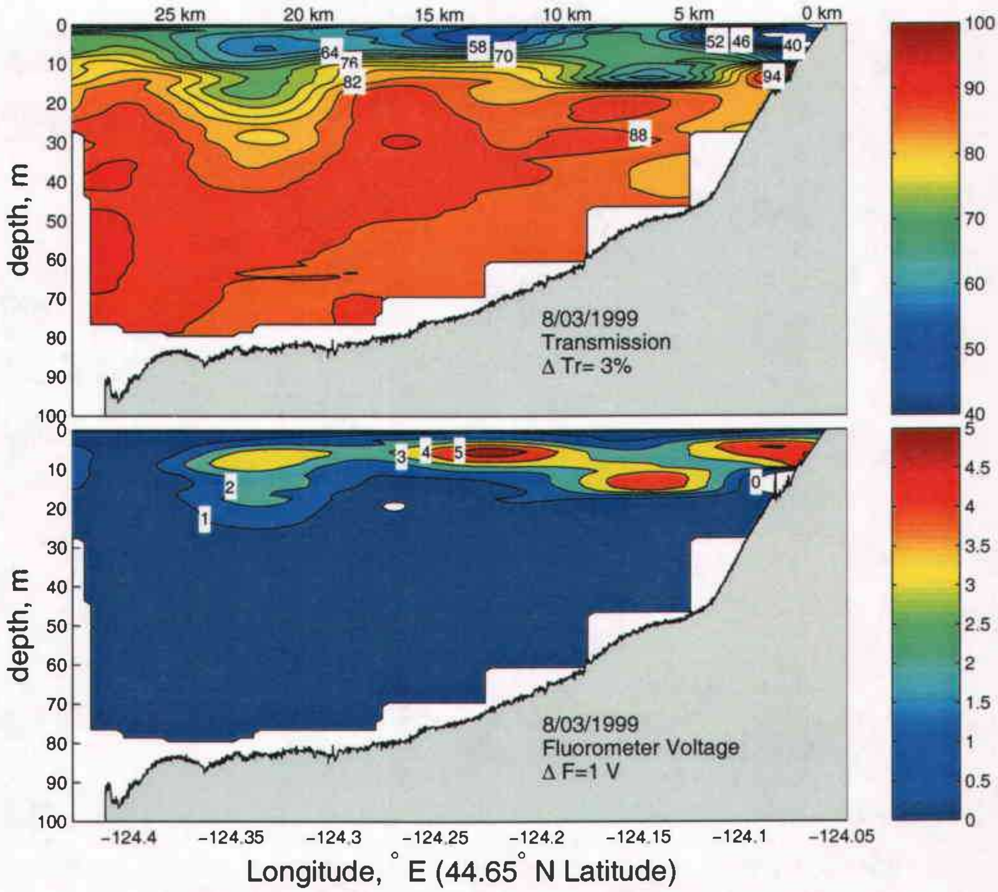


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
64
76
82
88
94
7/28/1999
Transmission
Δ Tr= 3%
3
2
1
7/28/1999
Fluorometer Voltage
Δ F=1 V
−124.4
−124.35
−124.3
−124.25
−124.2
−124.15
−124.1
−124.05
Longitude, ° E (44.65° N Latitude)

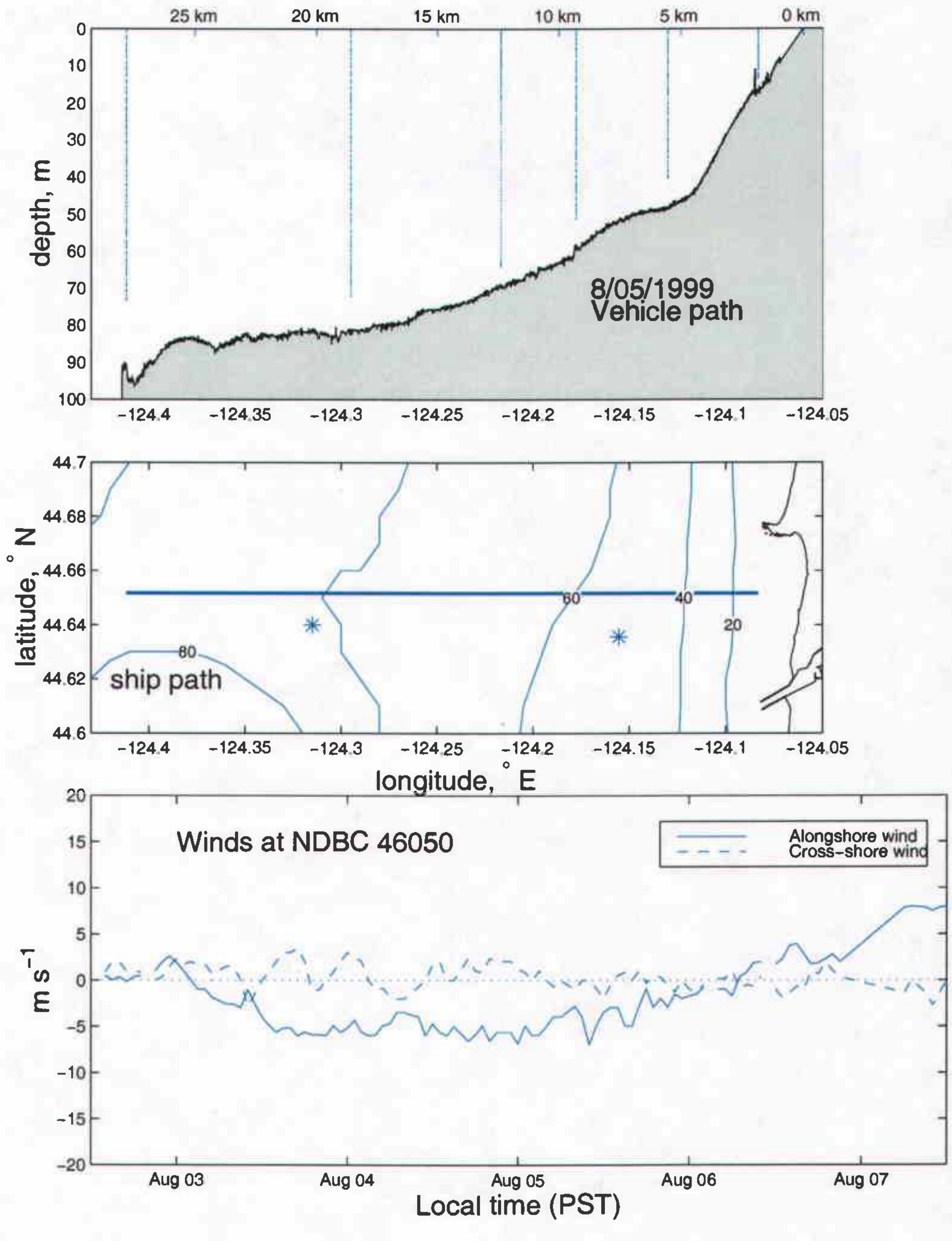

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
8/03/1999
Vehicle path
latitude, ° N
ship path
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s⁻¹
Jul 31
Aug 01
Aug 02
Aug 03
Aug 04
Local time (PST)

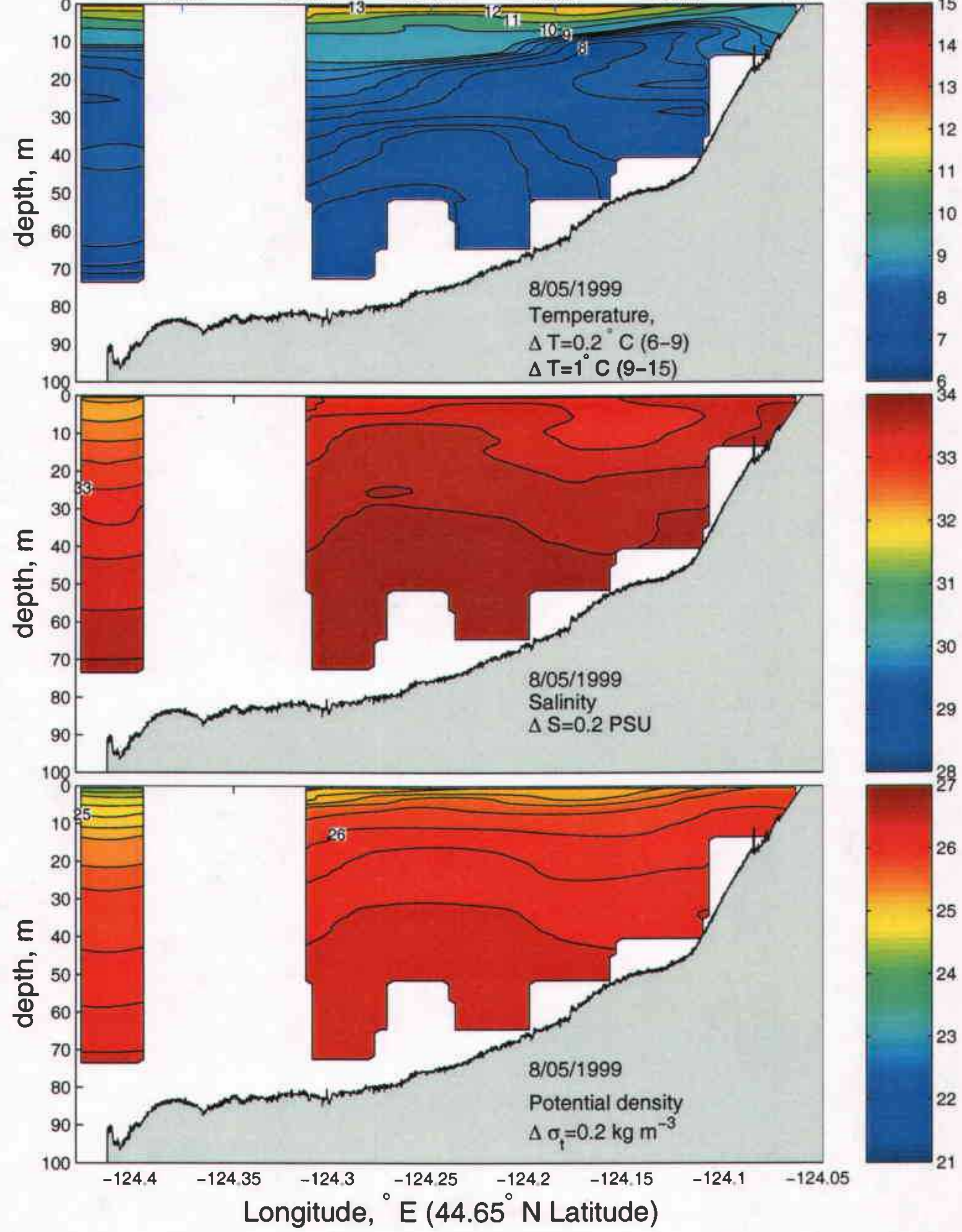


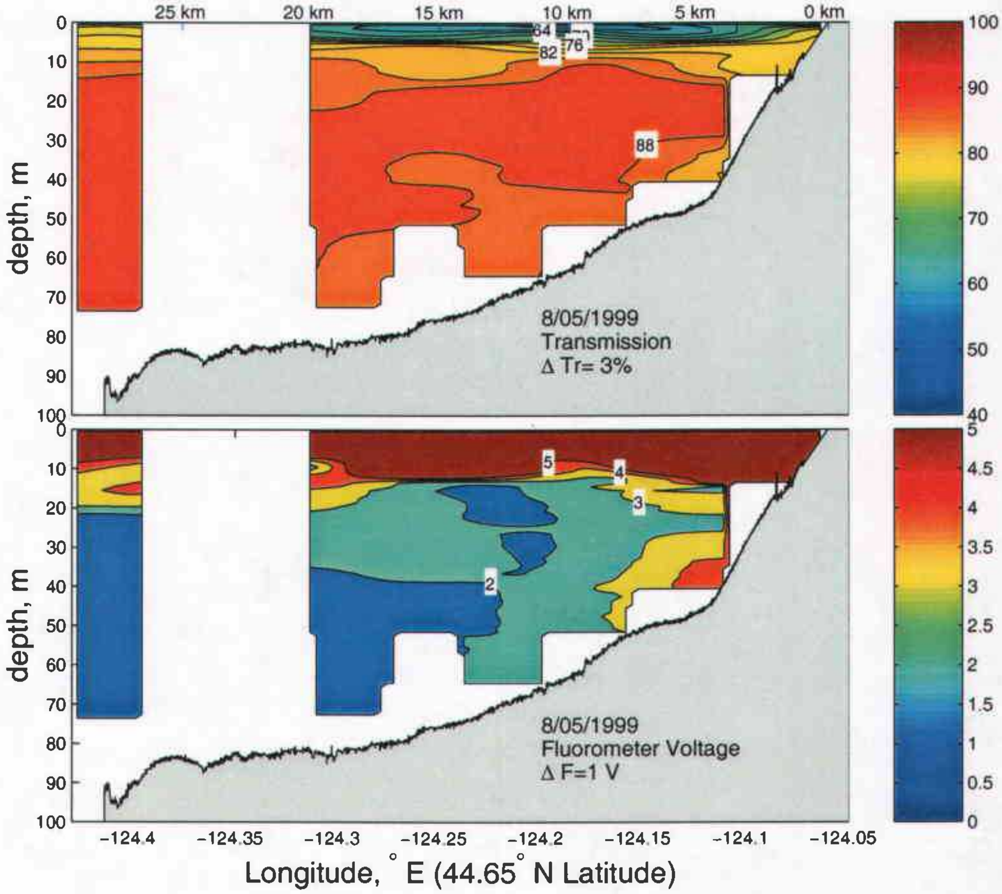
25 km
20 km
15 km
10 km
5 km
0 km
depth, m
8/03/1999
Temperature,
Δ T=0.2 °C (6–9)
Δ T=1 °C (9–15)
8/03/1999
Salinity
Δ S=0.2 PSU
8/03/1999
Potential density
Δ σt=0.2 kg m−3
Longitude, ° E (44.65° N Latitude)



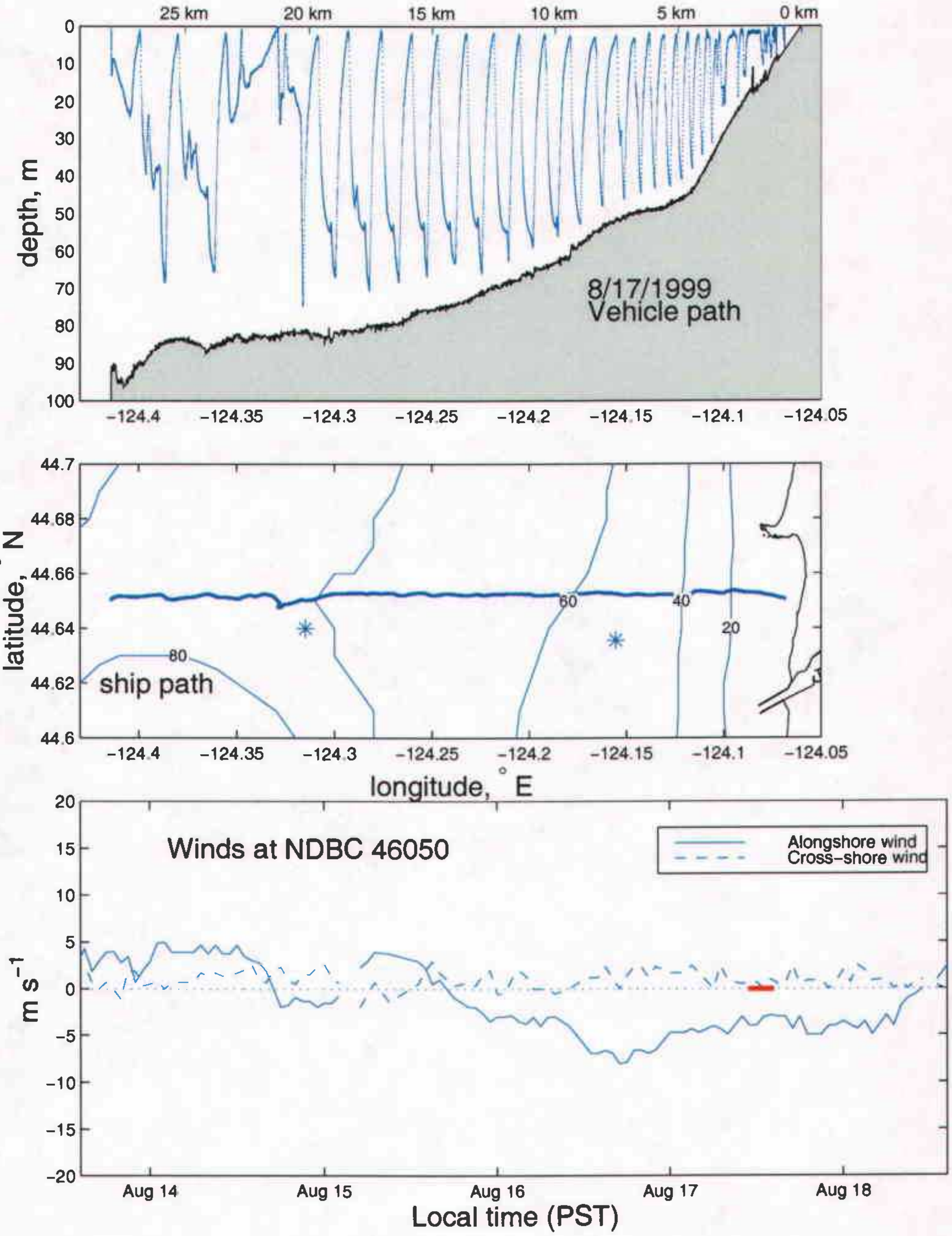
25 km
20 km
15 km
10 km
5 km
0 km
depth, m
8/03/1999
Transmission
Δ Tr= 3%
8/03/1999
Fluorometer Voltage
Δ F=1 V
Longitude, ° E (44.65° N Latitude)

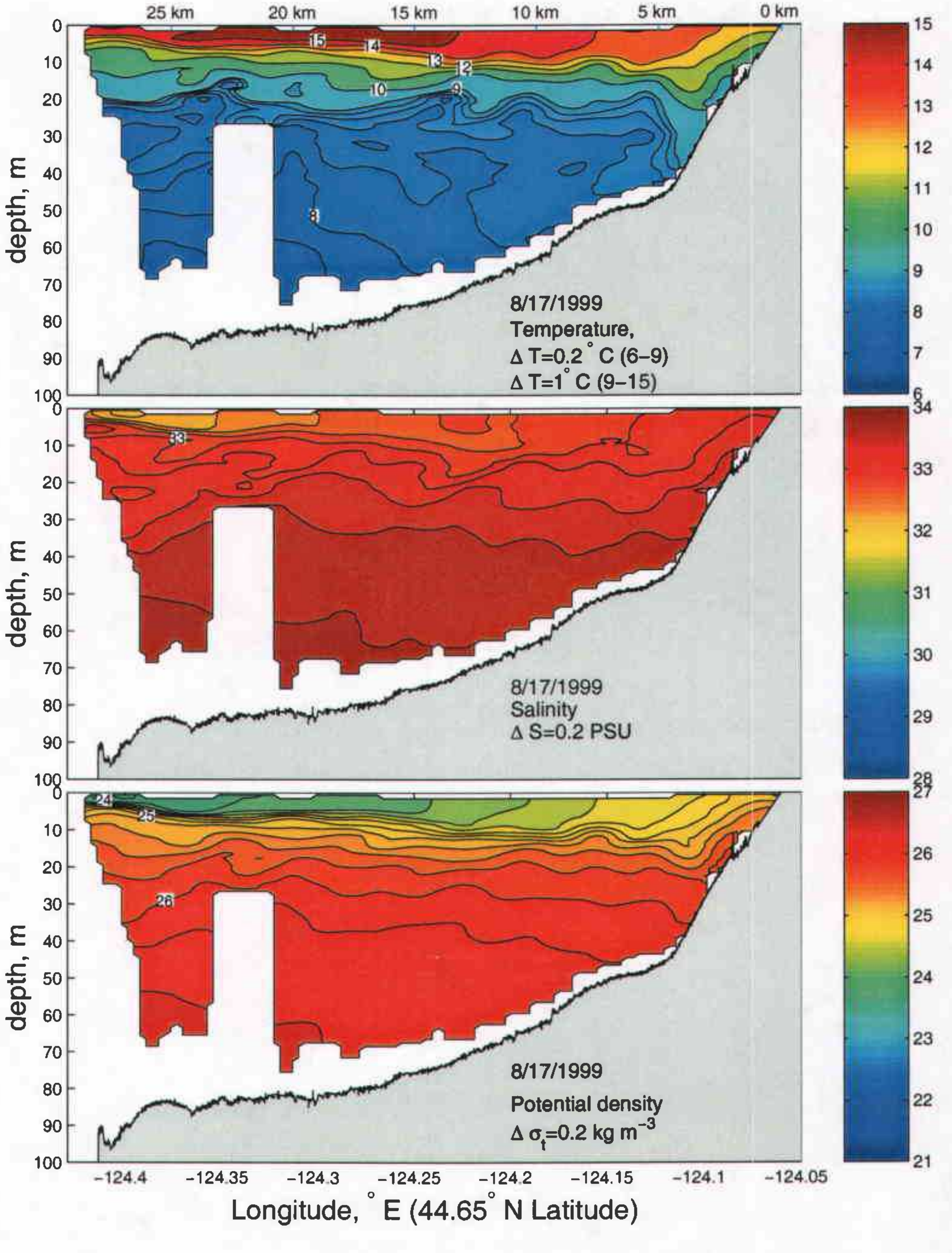

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
8/05/1999
Vehicle path
latitude, ° N
ship path
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s^{-1}
Aug 03
Aug 04
Aug 05
Aug 06
Aug 07
Local time (PST)

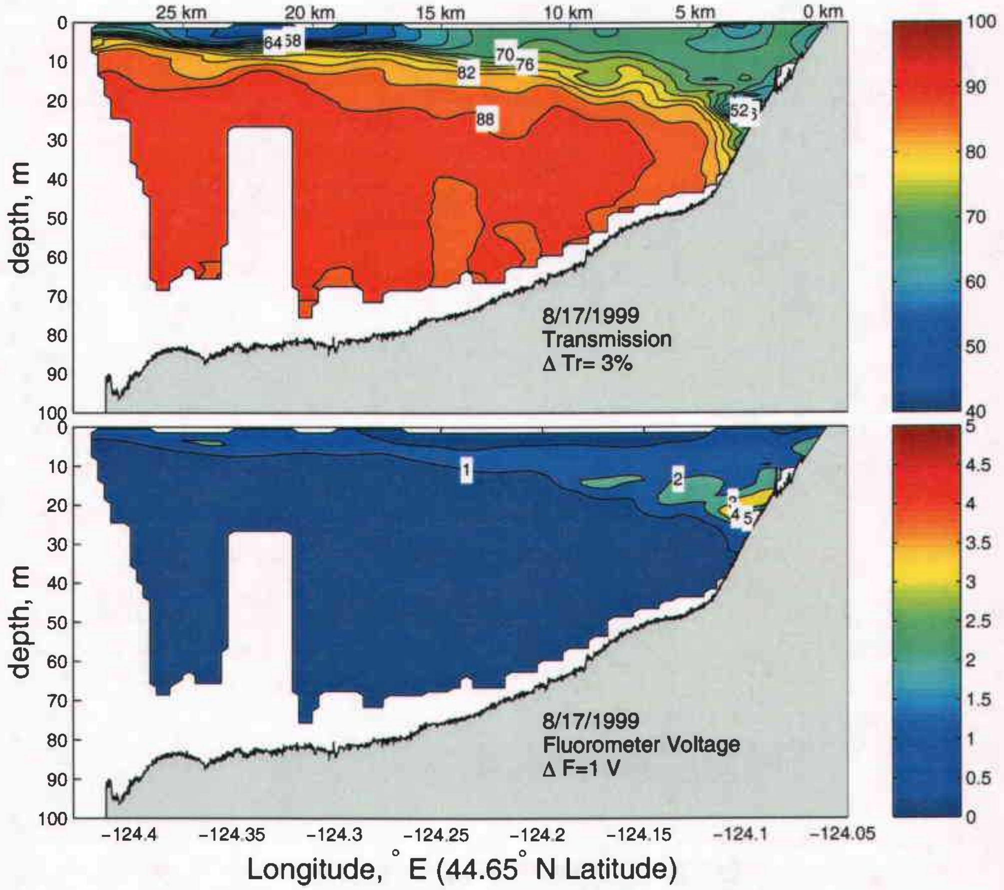

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
8/05/1999
Temperature,
Δ T=0.2 ° C (6–9)
Δ T=1° C (9–15)
8/05/1999
Salinity
Δ S=0.2 PSU
8/05/1999
Potential density
Δ σt=0.2 kg m−3
Longitude, ° E (44.65° N Latitude)



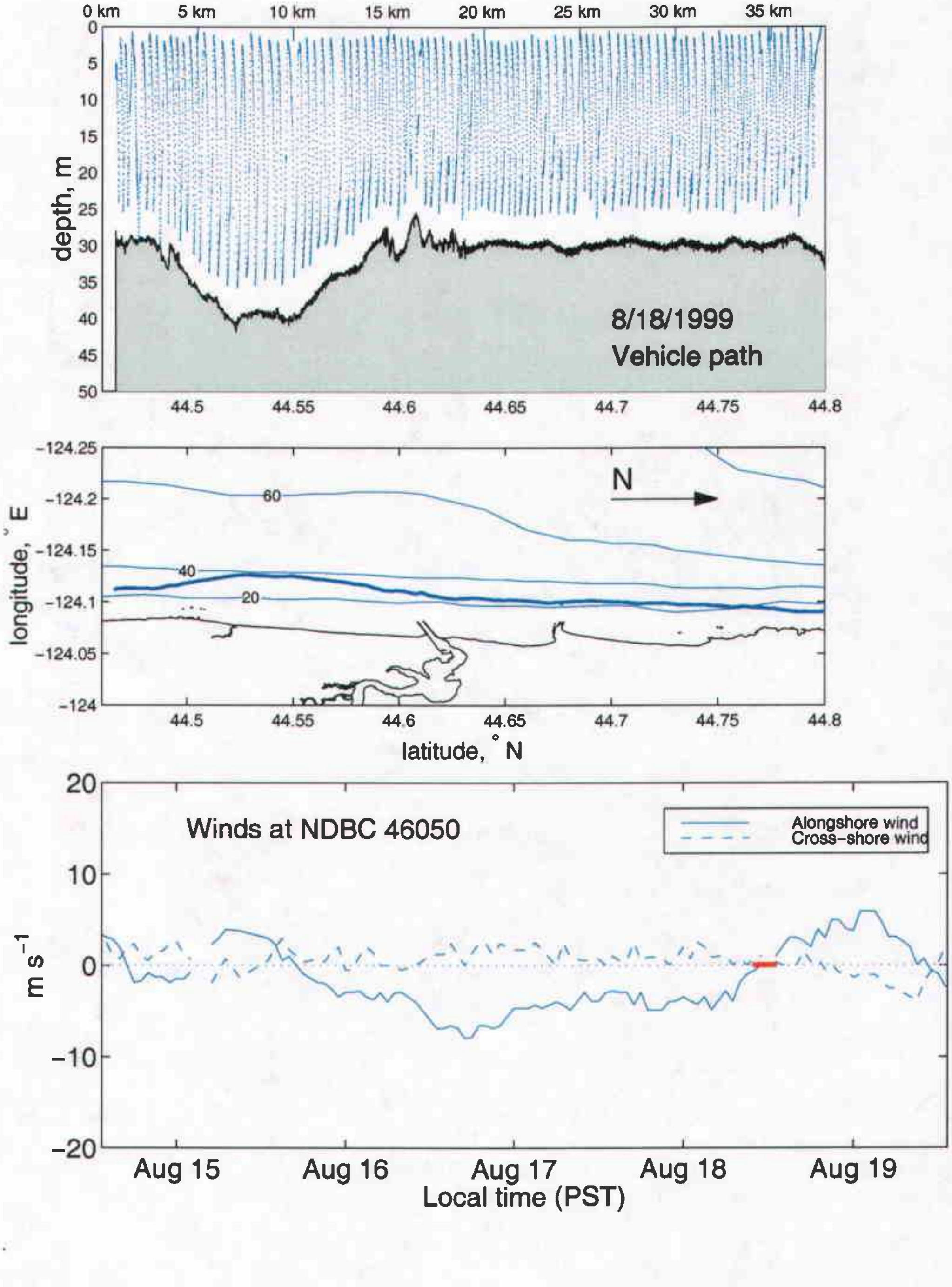
25 km
20 km
15 km
10 km
5 km
0 km
depth, m
8/05/1999
Transmission
Δ Tr= 3%
8/05/1999
Fluorometer Voltage
Δ F=1 V
Longitude, ° E (44.65° N Latitude)

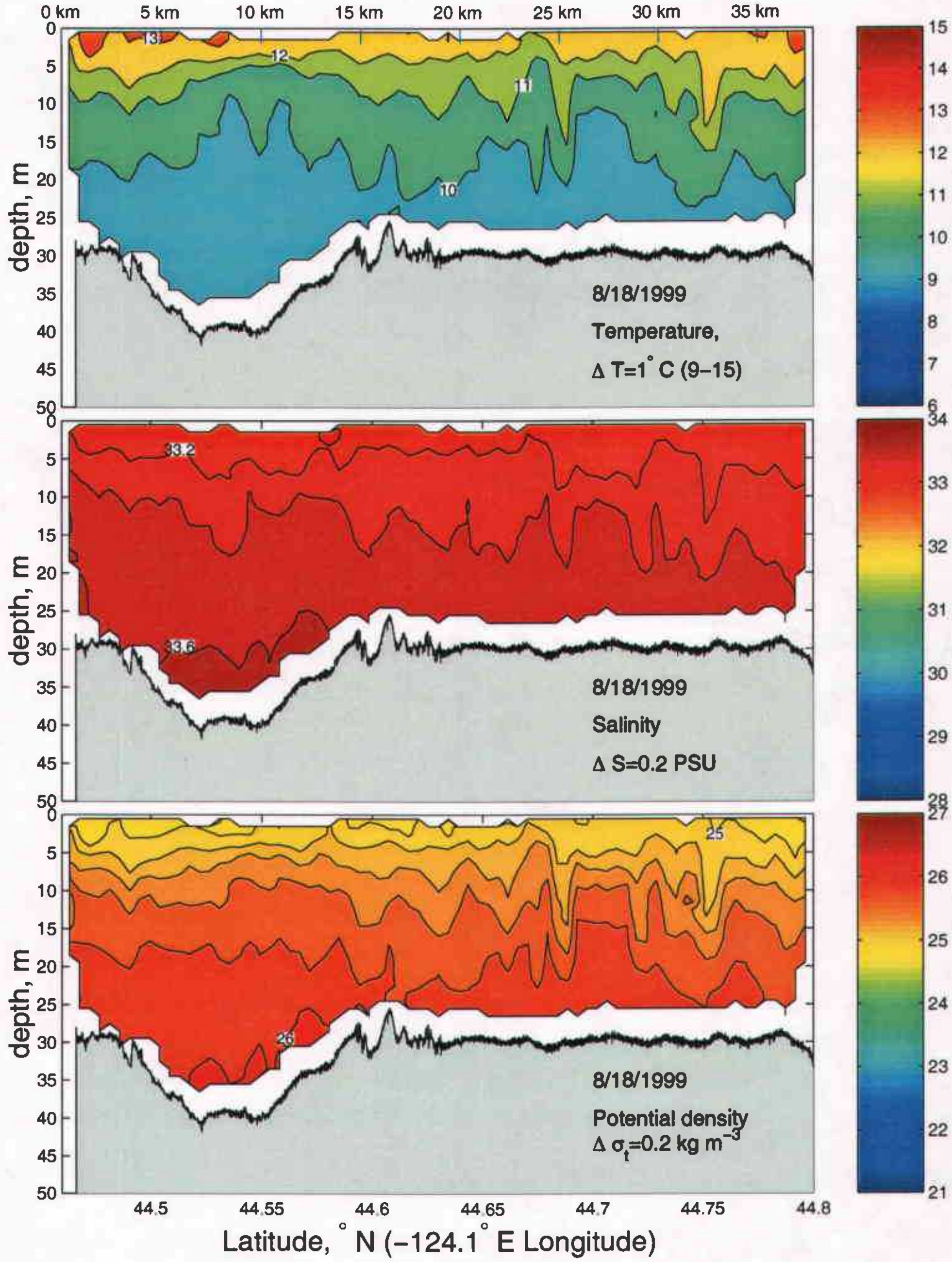

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
8/17/1999
Vehicle path
latitude, ° N
ship path
80
60
40
20
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s-1
Aug 14
Aug 15
Aug 16
Aug 17
Aug 18
Local time (PST)

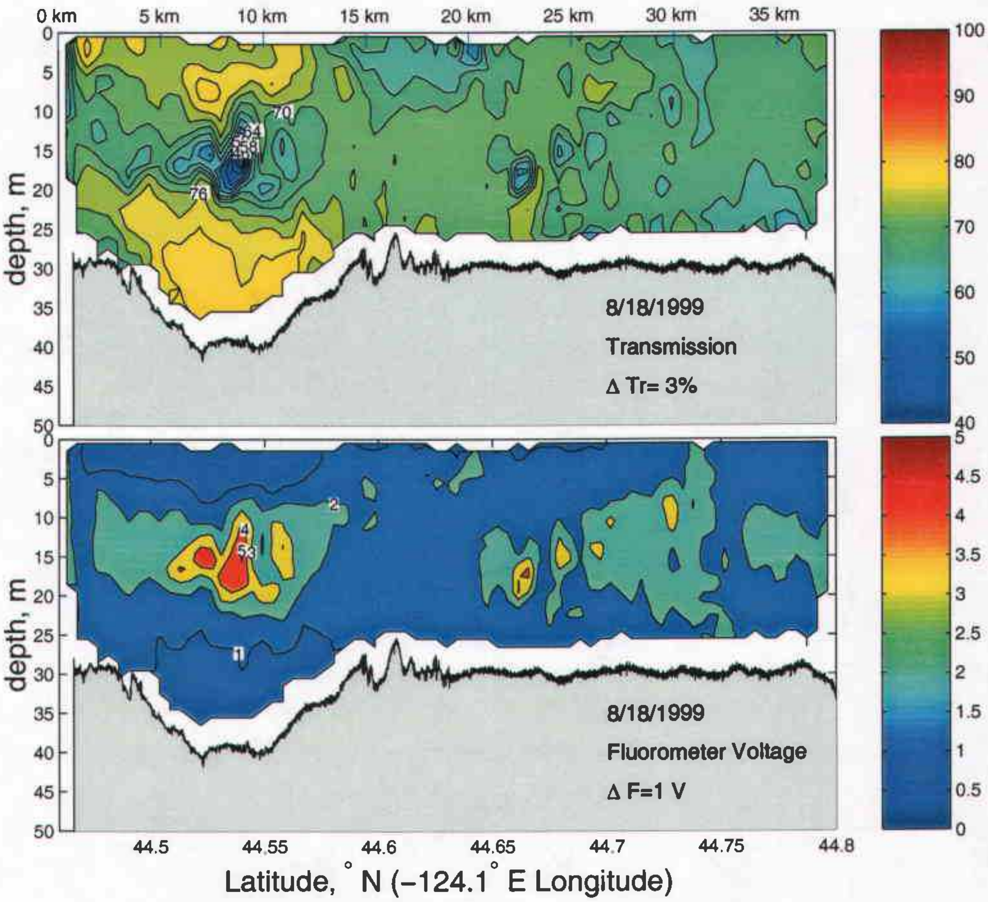

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
8/17/1999
Temperature,
Δ T=0.2 ° C (6–9)
Δ T=1° C (9–15)
8/17/1999
Salinity
Δ S=0.2 PSU
8/17/1999
Potential density
Δ σt=0.2 kg m−3
Longitude, ° E (44.65° N Latitude)

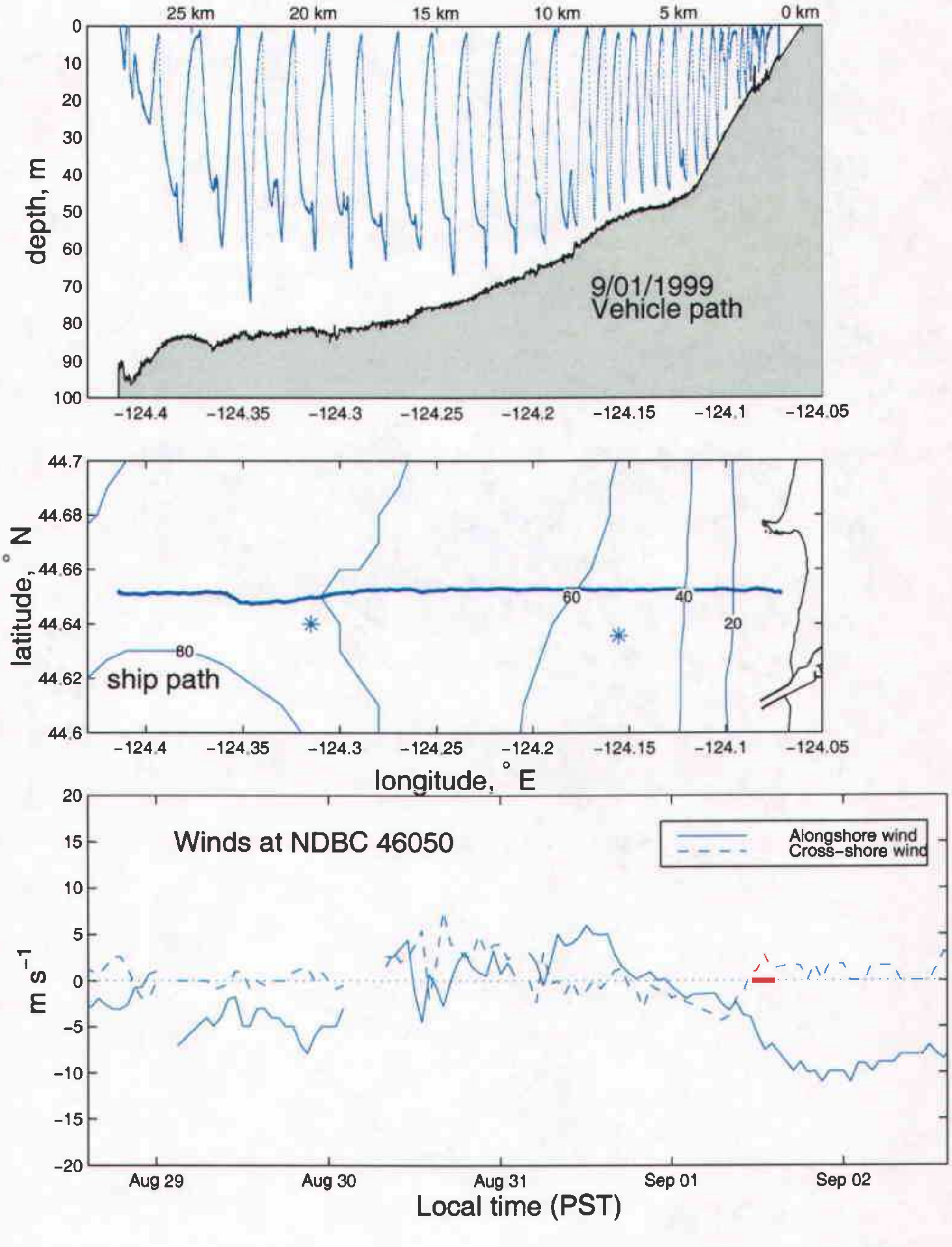


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
8/17/1999
Transmission
Δ Tr= 3%
8/17/1999
Fluorometer Voltage
Δ F=1 V
Longitude, ° E (44.65° N Latitude)

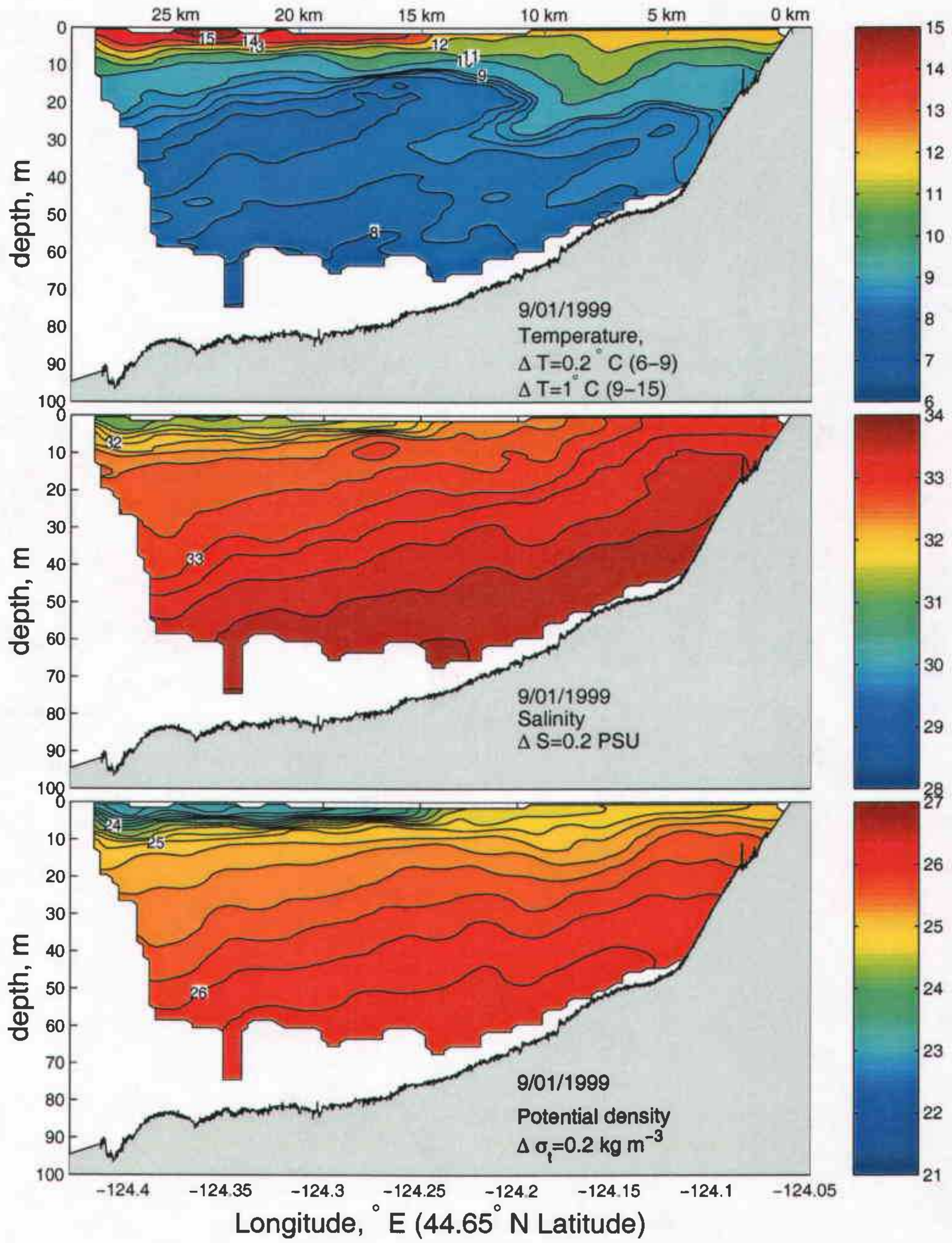

0 km
5 km
10 km
15 km
20 km
25 km
30 km
35 km
depth, m
8/18/1999
Vehicle path
longitude, ° E
N
60
40
20
latitude, ° N
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s⁻¹
Aug 15
Aug 16
Aug 17
Aug 18
Aug 19
Local time (PST)


0 km
5 km
10 km
15 km
20 km
25 km
30 km
35 km
depth, m
8/18/1999
Temperature,
Δ T=1° C (9–15)
8/18/1999
Salinity
Δ S=0.2 PSU
8/18/1999
Potential density
Δ σt=0.2 kg m−3
44.5
44.55
44.6
44.65
44.7
44.75
44.8
Latitude, ° N (−124.1° E Longitude)

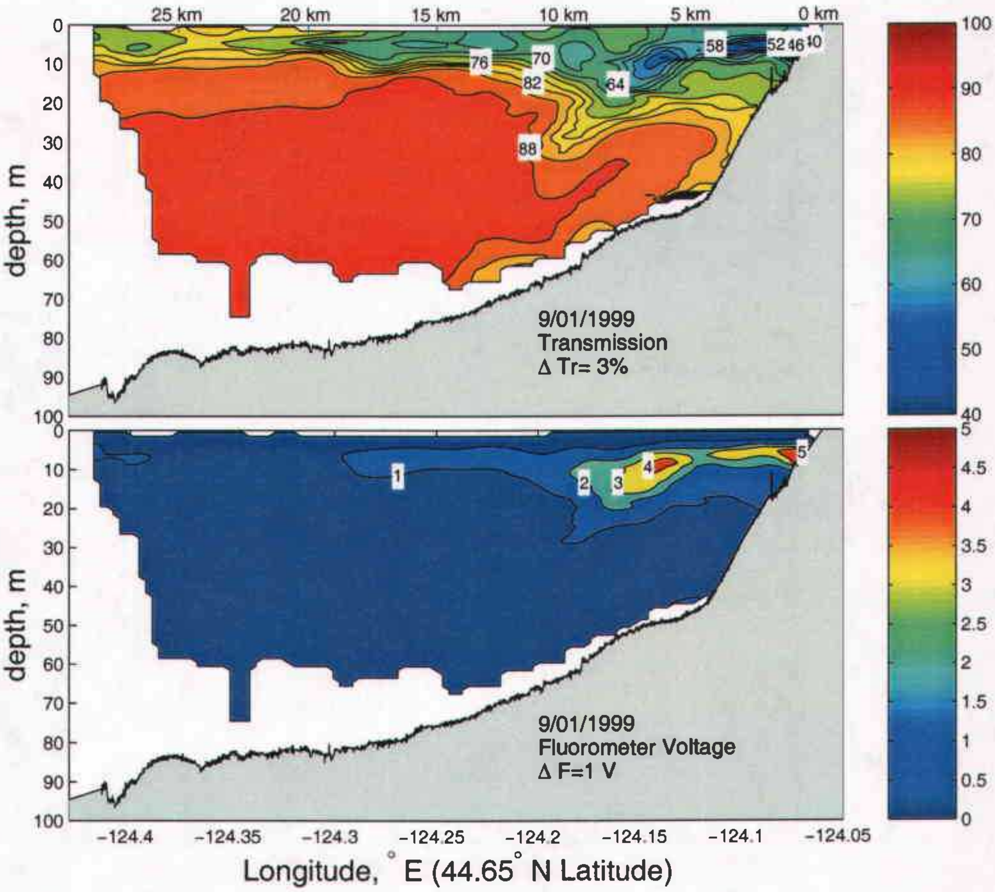

0 km
5 km
10 km
15 km
20 km
25 km
30 km
35 km
depth, m
8/18/1999
Transmission
Δ Tr= 3%
8/18/1999
Fluorometer Voltage
Δ F=1 V
Latitude, ° N (−124.1° E Longitude)

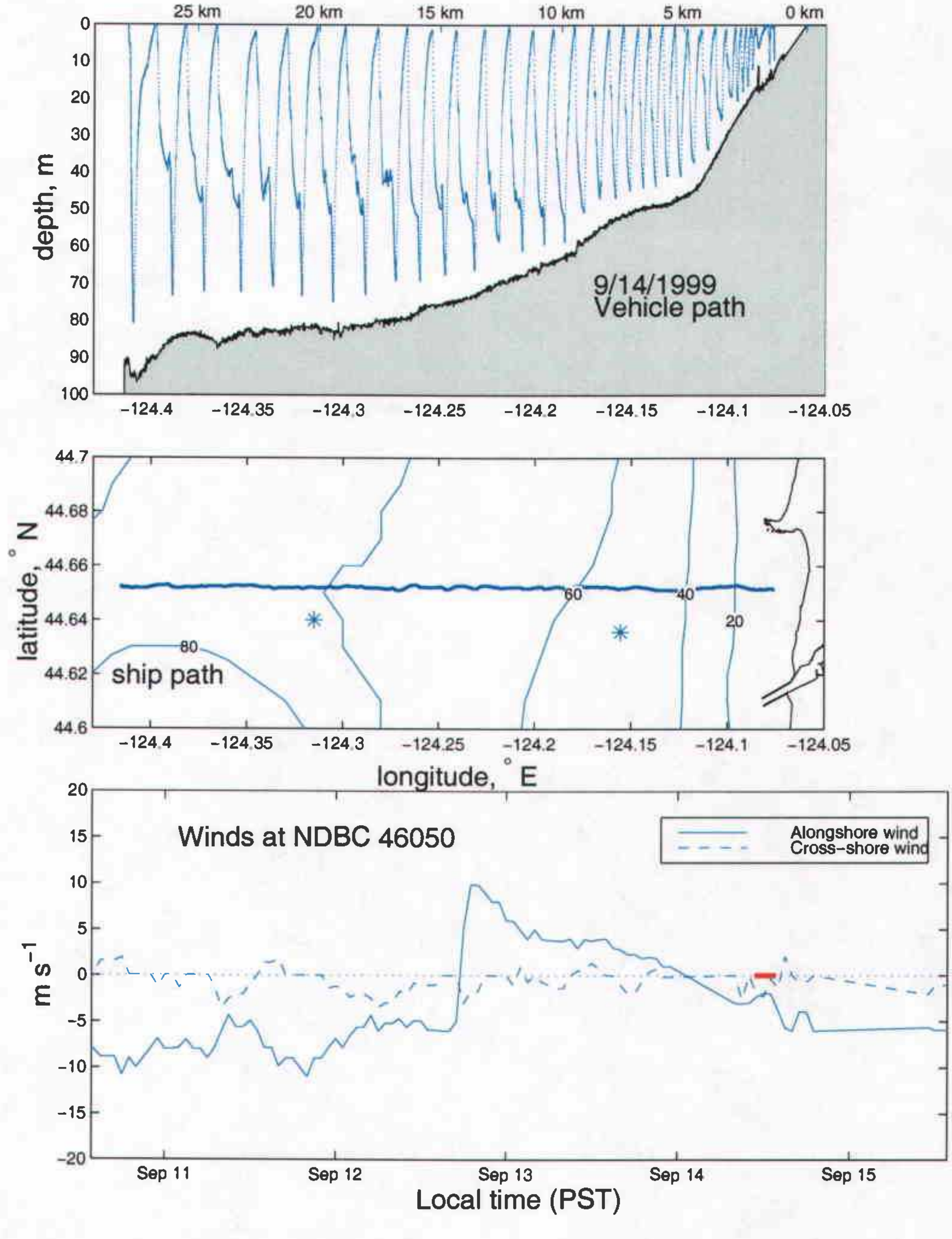


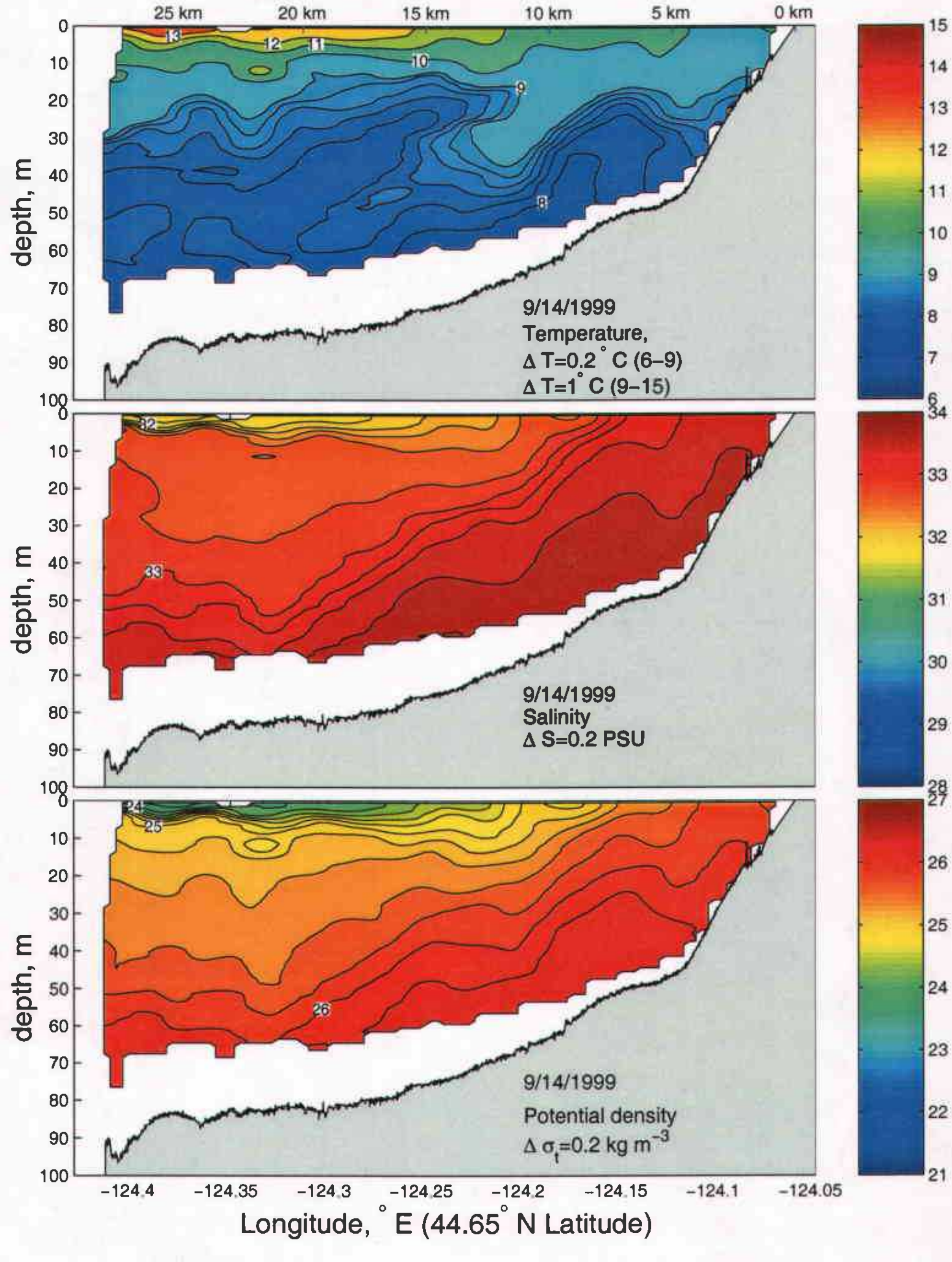
25 km
20 km
15 km
10 km
5 km
0 km
depth, m
9/01/1999
Vehicle path
latitude, ° N
ship path
longitude, ° E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s^{-1}
Aug 29
Aug 30
Aug 31
Sep 01
Sep 02
Local time (PST)



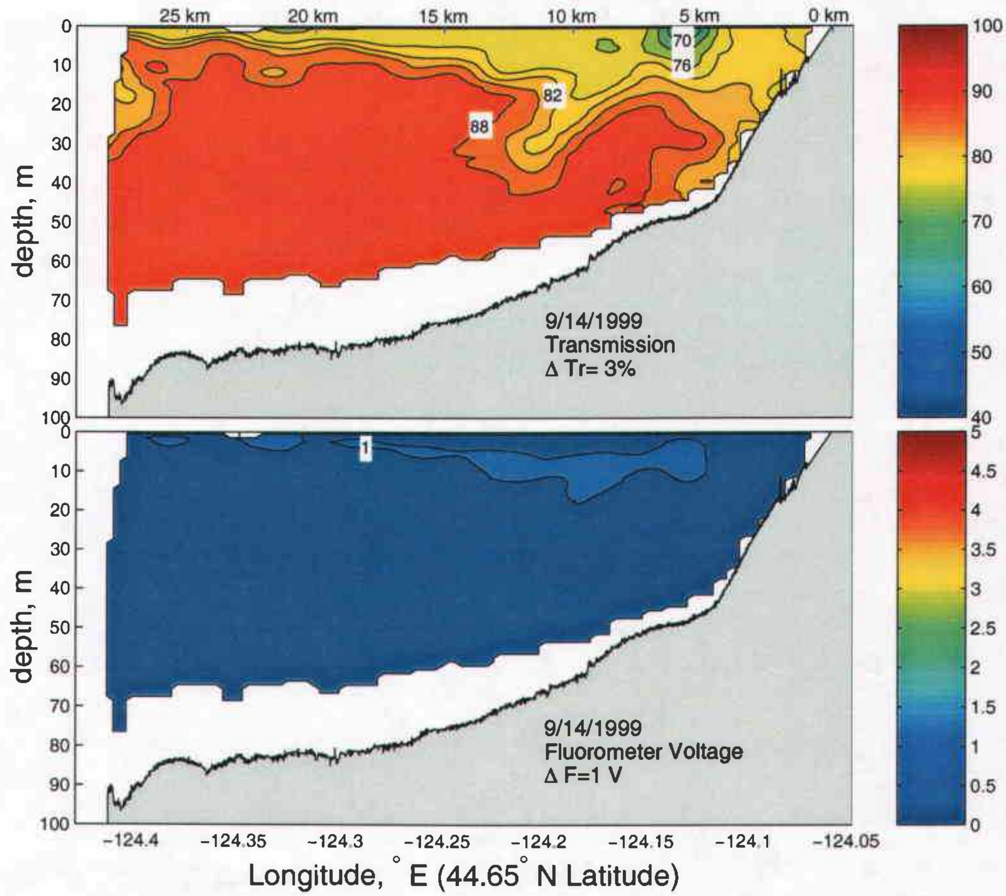
25 km
20 km
15 km
10 km
5 km
0 km
depth, m
9/01/1999
Temperature,
Δ T=0.2 °C (6–9)
Δ T=1 °C (9–15)
9/01/1999
Salinity
Δ S=0.2 PSU
9/01/1999
Potential density
Δ σt=0.2 kg m-3
Longitude, ° E (44.65° N Latitude)

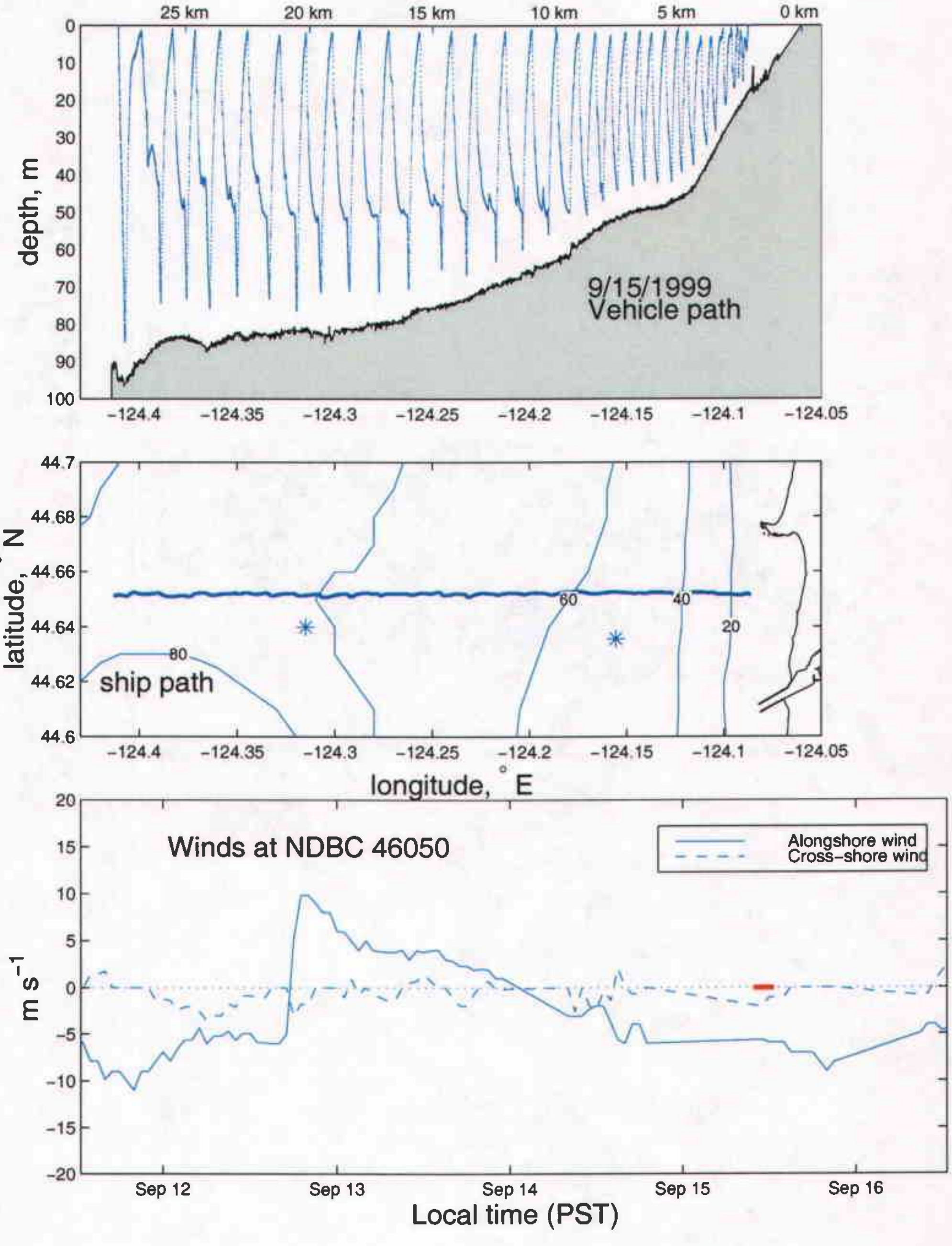

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
9/01/1999
Transmission
Δ Tr= 3%
9/01/1999
Fluorometer Voltage
Δ F=1 V
Longitude, ° E (44.65° N Latitude)

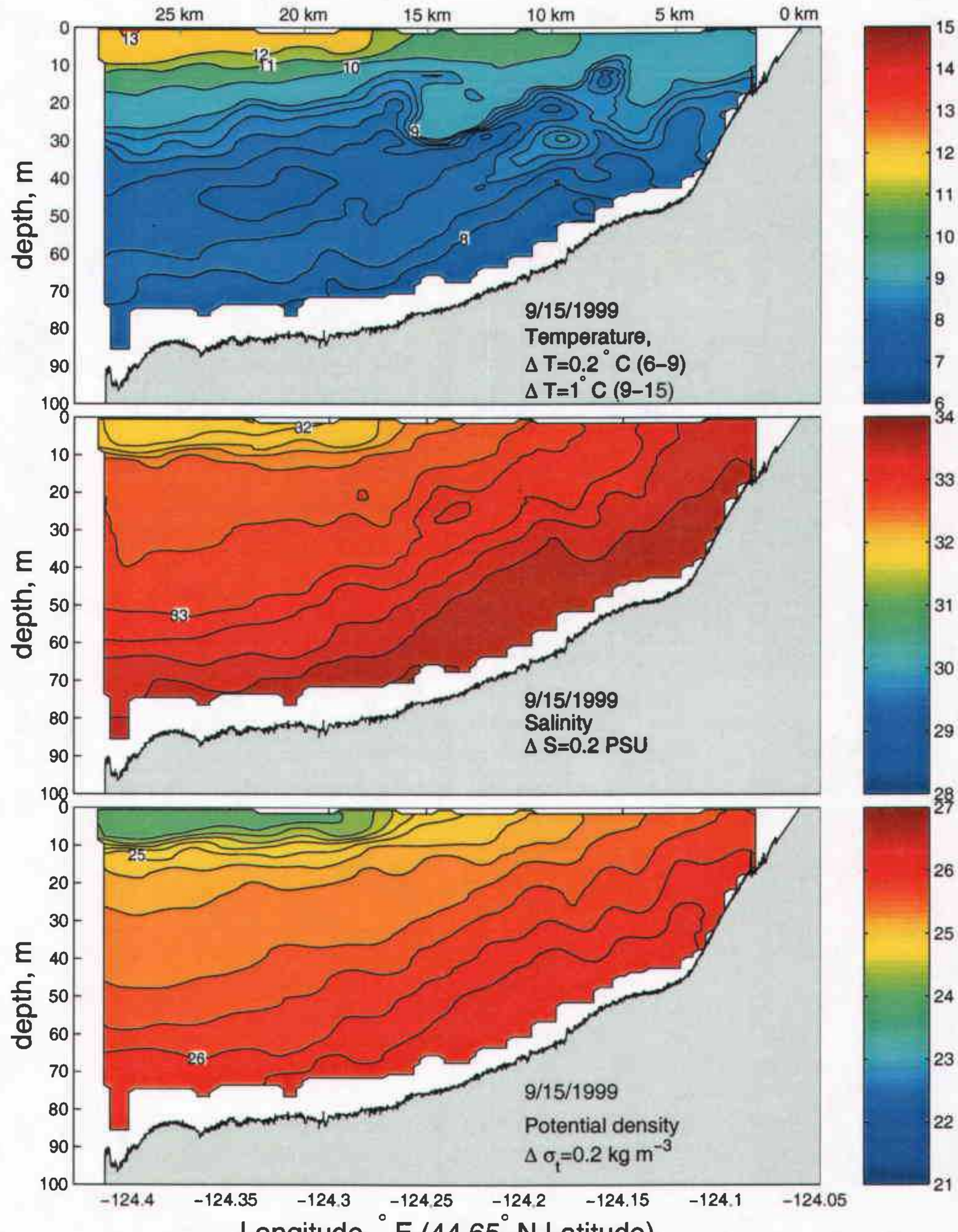

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
9/14/1999
Vehicle path
ship path
latitude, °N
longitude, °E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s^{-1}
Sep 11
Sep 12
Sep 13
Sep 14
Sep 15
Local time (PST)

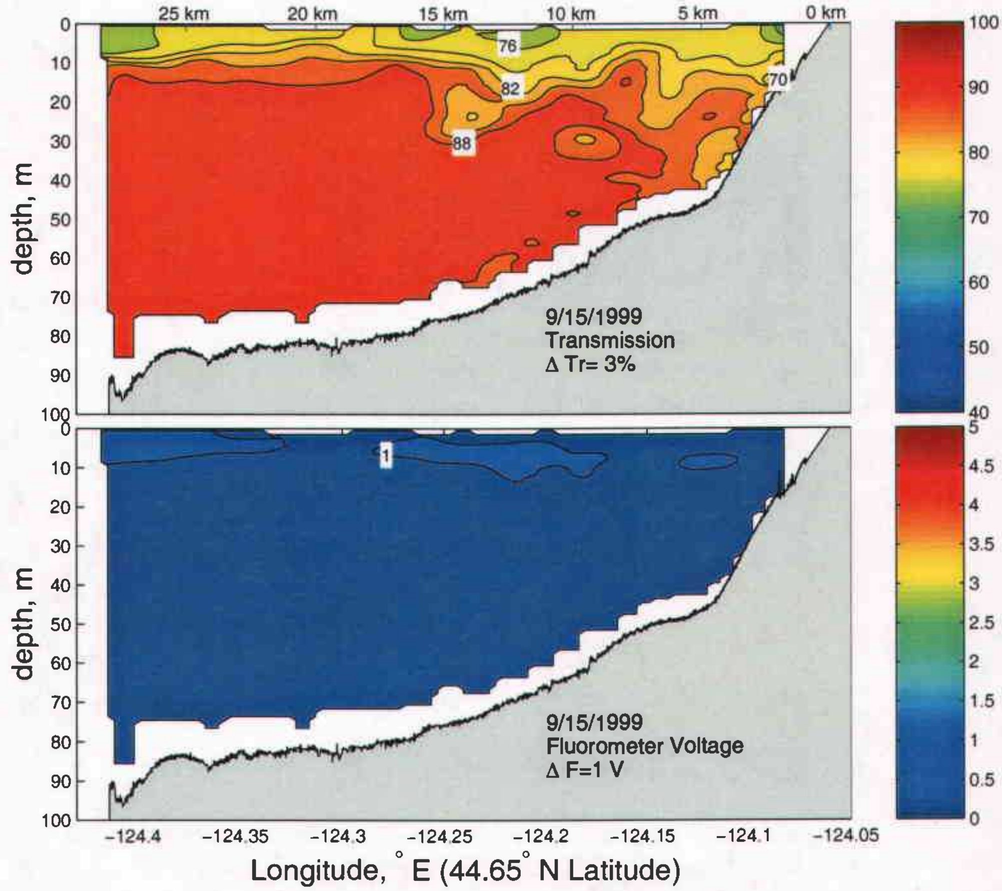


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
9/14/1999
Temperature,
Δ T=0.2 ° C (6–9)
Δ T=1° C (9–15)
9/14/1999
Salinity
Δ S=0.2 PSU
9/14/1999
Potential density
Δ σt=0.2 kg m−3
Longitude, ° E (44.65° N Latitude)

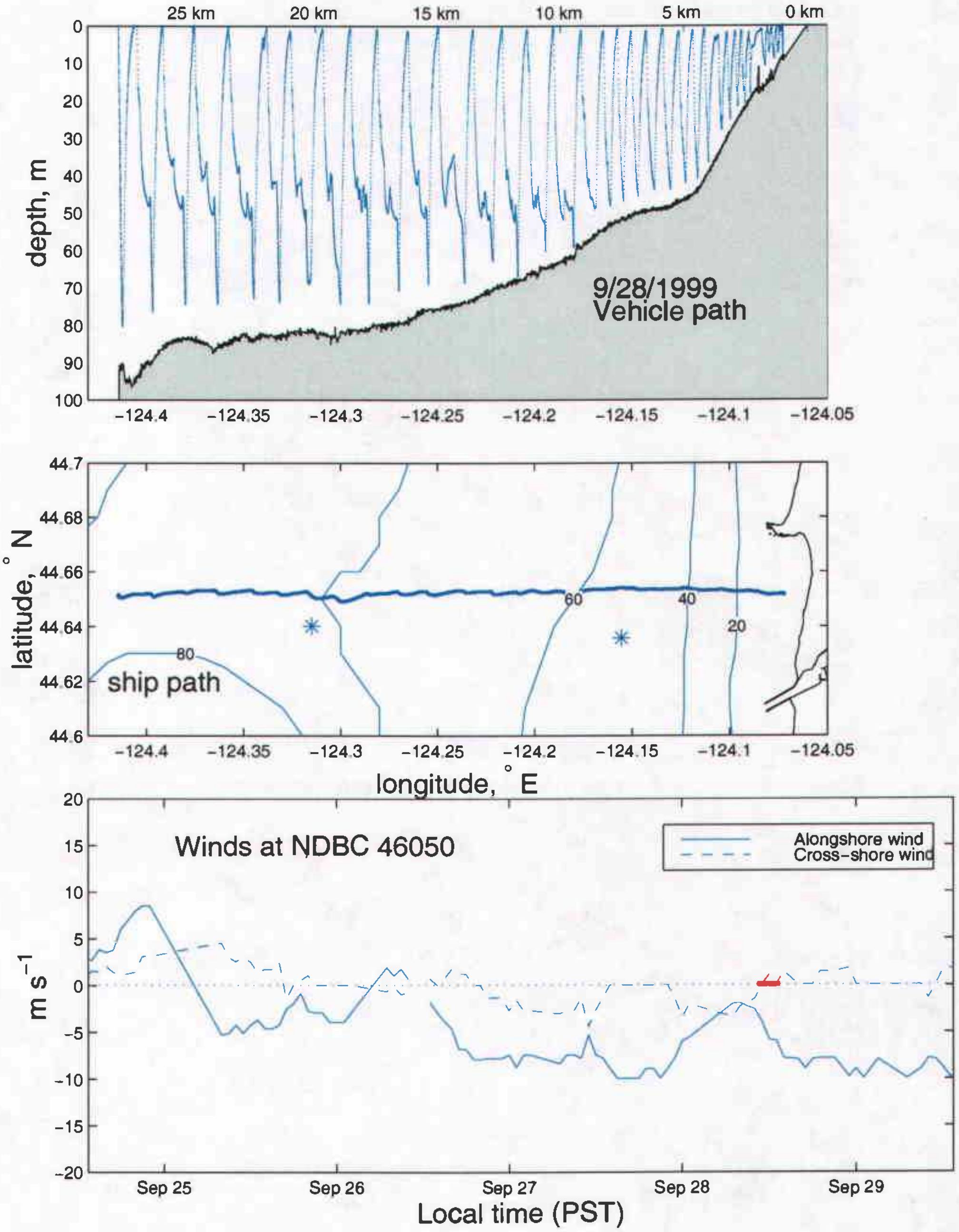

25 km
20 km
15 km
10 km
5 km
0 km
70
76
82
88
9/14/1999
Transmission
Δ Tr= 3%
depth, m
1
9/14/1999
Fluorometer Voltage
Δ F=1 V
depth, m
-124.4
-124.35
-124.3
-124.25
-124.2
-124.15
-124.1
-124.05
Longitude, ° E (44.65° N Latitude)

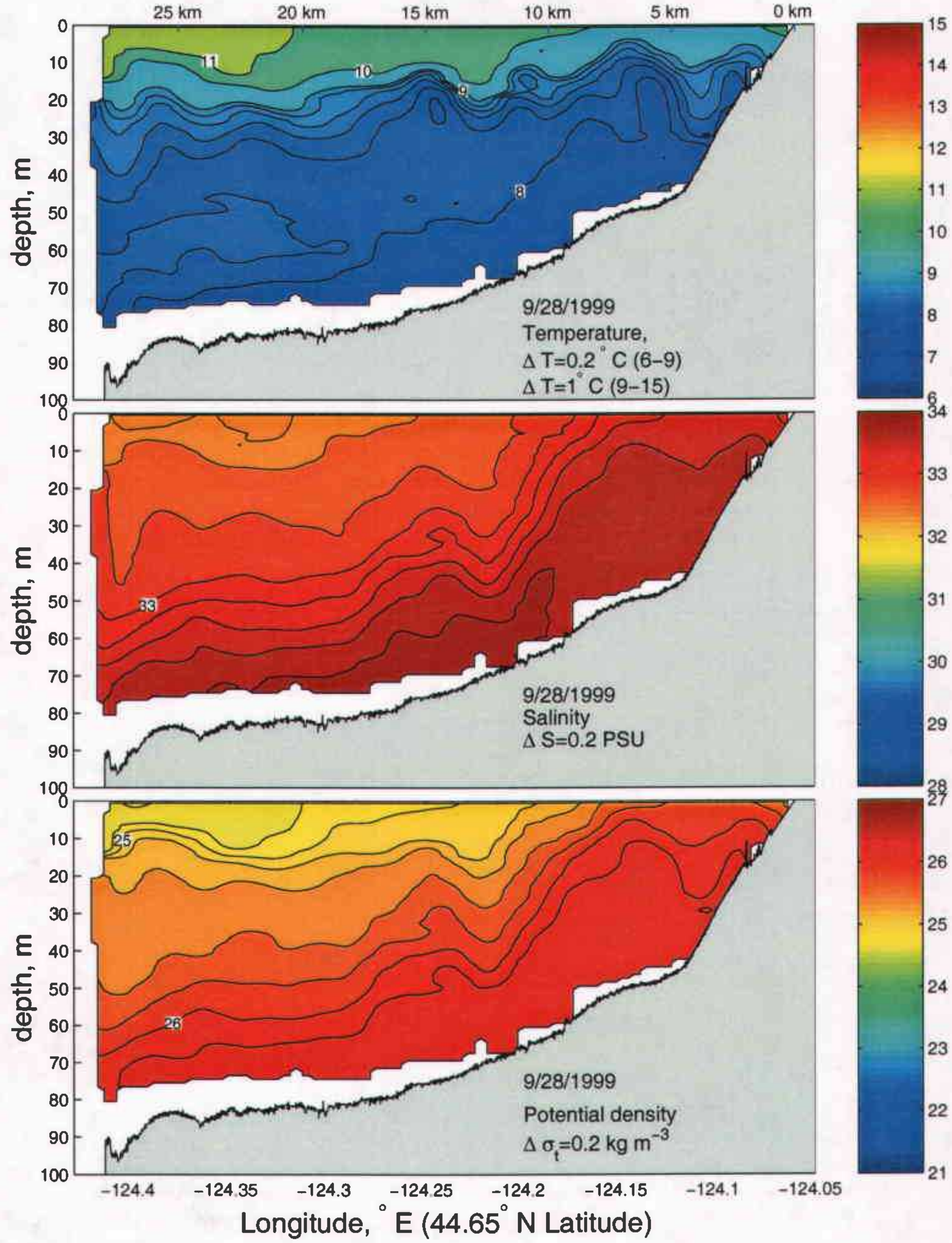

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
9/15/1999
Vehicle path
latitude, °N
ship path
longitude, °E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s^{-1}
Sep 12
Sep 13
Sep 14
Sep 15
Sep 16
Local time (PST)

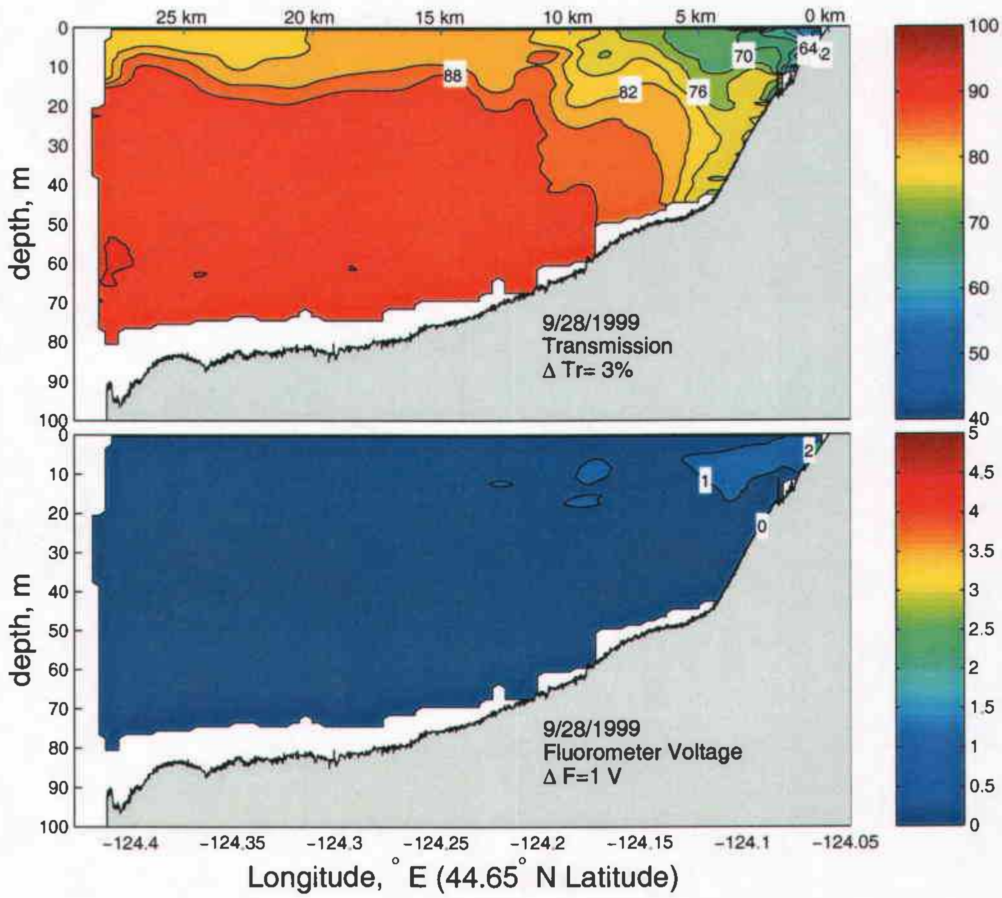

25 km
20 km
15 km
10 km
5 km
0 km
depth, m
9/15/1999
Temperature,
Δ T=0.2° C (6–9)
Δ T=1° C (9–15)
9/15/1999
Salinity
Δ S=0.2 PSU
9/15/1999
Potential density
Δ σt=0.2 kg m-3
Longitude, ° E (44.65° N Latitude)



25 km
20 km
15 km
10 km
5 km
0 km
76
82
70
88
depth, m
9/15/1999
Transmission
Δ Tr= 3%
1
9/15/1999
Fluorometer Voltage
Δ F=1 V
-124.4
-124.35
-124.3
-124.25
-124.2
-124.15
-124.1
-124.05
Longitude, ° E (44.65° N Latitude)


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
9/28/1999
Vehicle path
latitude, °N
ship path
longitude, °E
Winds at NDBC 46050
Alongshore wind
Cross-shore wind
m s^{-1}
Sep 25
Sep 26
Sep 27
Sep 28
Sep 29
Local time (PST)


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
9/28/1999
Temperature,
Δ T=0.2 ° C (6–9)
Δ T=1 ° C (9–15)
9/28/1999
Salinity
Δ S=0.2 PSU
9/28/1999
Potential density
Δ σt=0.2 kg m−3
−124.4
−124.35
−124.3
−124.25
−124.2
−124.15
−124.1
−124.05
Longitude, ° E (44.65° N Latitude)


25 km
20 km
15 km
10 km
5 km
0 km
depth, m
9/28/1999
Transmission
Δ Tr= 3%
9/28/1999
Fluorometer Voltage
Δ F=1 V
Longitude, ° E (44.65° N Latitude)