2012 Orange County Sanitation District (OCSD) Outfall Diversion – Summary Report

Eric Terrill, Principal Investigator
SCCOOS Technical Director
Scripps Institution of Oceanography
University of California, San Diego
9500 Gilman Drive, Mail Code 0214
La Jolla, CA 92093-0213
(858) 822-3101
eterrill@ucsd.edu

Leslie Rosenfeld, Principal Investigator
CeNCOOS Program Director
Monterey Bay Aquarium Research Institute
7700 Sandholdt Road
Moss Landing, CA 95039
(831) 775-2126
role@mbari.org

Julie Thomas, Co-Investigator
SCCOOS Executive Director
Scripps Institution of Oceanography
University of California, San Diego
9500 Gilman Drive, Mail Code 0214
La Jolla, CA 92093-0214
(858) 534-3034
jothomas@ucsd.edu

John Largier, Co-Investigator
Professor / CeNCOOS Principal Investigator
Bodega Marine Laboratory
University of California, Davis
P.O. Box 247
Bodega Bay, CA 94923
(707) 875-1930
jlargier@ucdavis.edu

Anne Footer, Financial Representative
Marine Physical Laboratory (MPL)
Scripps Institution of Oceanography
University of California, San Diego
291 Rosecrans Street
San Diego, CA 92106
(858) 534-1802
afooter@ucsd.edu

Danielle Williams, Lead Author
SCCOOS Program Coordinator
Scripps Institution of Oceanography
University of California, San Diego
9500 Gilman Drive, Mail Code 0214
La Jolla, CA 92093-0214
(858) 534-9808
d3williams@ucsd.edu

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1 Diversion Overview

The Orange County Sanitation District (OCSD) has two ocean outfalls located on the San Pedro shelf (Figure 1.1). Under normal operations, OCSD discharges its treated effluent from a 120-inch ocean outfall that terminates in 200 ft (60 m) of water, approximately 4.5 miles (7 km) offshore Newport Beach and Huntington Beach (henceforth denoted as the long outfall). The discharged plume typically stays well below the ocean surface and away from recreational (water contact) use areas (SAIC 2009, 2011; Tetra Tech 2002, 2008.

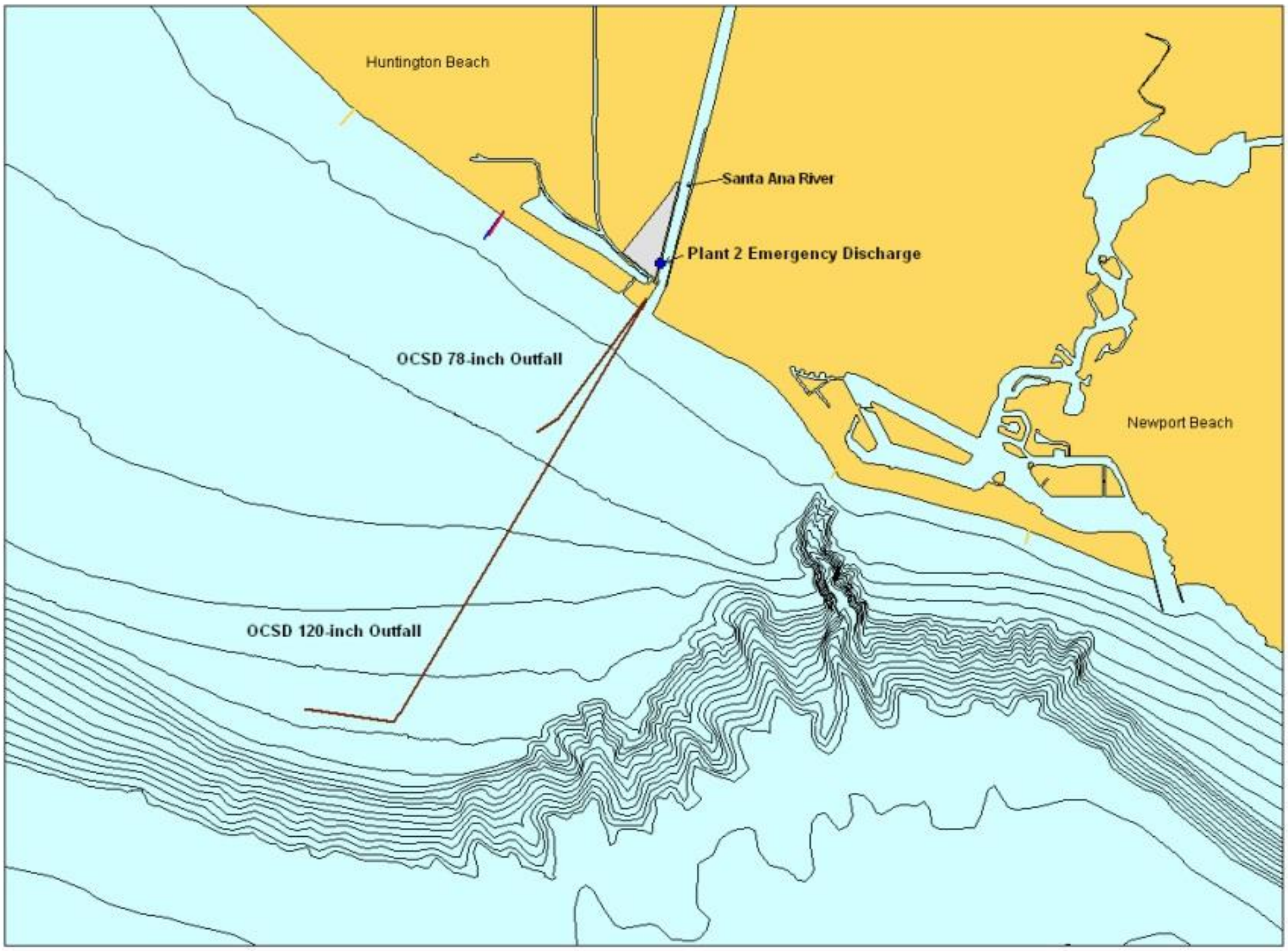


Figure 1.1 *Geography of OCSD Outfalls*

OCSD has a secondary, 78-inch outfall, located approximately 2.2 km offshore at a depth of 18 m (henceforth denoted as the short outfall) that was operational from the 1950's until 1971. From this discharge point, it was expected that the discharged effluent would rise to the water surface and into recreational use areas (ESA, 2012). Until June 2012 with the issuance of a new discharge permit, only emergency discharges were allowed. Under its July 20, 2012 NPDES (National Pollutant Discharge Elimination System) ocean discharge permit (Order Number R8-2012-0035, Permit Number CA011 0604), OCSD is allowed to use the 78-inch outfall for non-emergency plant operations. The basic difference between the two discharge points is the fate and transport of the effluent. When discharged from the long outfall, the plume remains well below the ocean surface and remains away from areas used for recreation. Additional details of the two discharge points and expected water quality impacts can be found in the ESA (2011, 2012).

To minimize potential impacts to public health, the treated wastewater received enhanced disinfection so that state bacterial water contact standards (i.e. AB411) would be met at the final sampling point at Plant 2, prior to discharge and subsequent dilution. The discharged effluent was a significant source of nutrients to the coastal zone and had the potential to stimulate phytoplankton growth. An environmental monitoring and modeling plan was developed to track the discharged plume, measure the effectiveness of the enhanced disinfection program, and determine environmental effects.

From September 11 to October 4, 2012, OCSD diverted flow from the 120-inch outfall to the 78-inch outfall as part of a project to inspect, assess, and rehabilitate the Outfall Land Section and Ocean Outfall Booster Pump Station Piping (Capital Improvement Project J-112). This Synthesis Report fulfills the request from OCSD that Southern California Coastal Ocean Observing System (SCCOOS) and the Central and Northern California Ocean Observing System (CeNCOOS) provide the results of the diversion's modeling and monitoring activities.

A separate lesson learned report highlights successes, failures, lessons learned and provides recommendations for improving monitoring during any future diversions to the short outfall.

2 Introduction

2.1 Study Objectives

This report focuses on the OCSD-sponsored efforts to measure and document changes in microbiology and nutrients within state waters and the impact to public and environmental health. This report isn't editorialized in anyway; rather it was developed only as a summary of activities completed for OCSD under the J-112 environmental monitoring program. Analysis was not a funded component of this effort.

The overall goal of the J-112 environmental monitoring program was to characterize the temporal and spatial extent of the discharged effluent and anticipated impacts to the receiving water during the diversion to the short outfall. Near-real-time and daily data collected were used to identify areas of potentially higher risk, allow for adaptive sampling, document the effectiveness of the enhanced effluent disinfection process on protecting recreational waters (e.g., public bathing beaches), and detect changes to biologic communities (e.g., algal species). Other data sets (e.g., self-contained current meters) were used in post-diversion analysis to better interpret results.

2.2 Participant Responsibilities

The J-112 environmental monitoring program ran concurrently with other funded research before, during, and after the OCSD diversion. Even though the contents of this report only describe the J-112 program, Table 2.1 calls out all research and monitoring activities that resulted from the OCSD J-112 grant, a National Science Foundation (NSF) Grant, National Oceanic and Atmospheric Administration Ecology and Oceanography of Harmful Algal Blooms (NOAA ECOHAB) grant, and Southern California Coastal Water Research Project (SCCWRP) Grant. Contact information and a brief description for all these projects are in Appendix II.

Table 2.1 *OCSD 2012 Diversion Participant List*

Principle Investigator	***Affiliation***	***Work Performed***	***Funding***
Dave Caron/Caron Laboratory	University of Southern California (USC)	Phytoplankton Response	J-112 and NOAA ECOHAB

Yi Chao	Remote Sensing Solutions, Inc. (RSS)	Regional Ocean Modeling System (ROMS)	J-112
Ben Holt	Jet Propulsion Laboratory (JPL)	Satellite Support Imagery	J-112
Meredith Howard	Southern California Coastal Water Research Project (SCCWRP)	Project Management and investigator on the NOAA ECOHAB grant	NOAA ECOHAB and SCCWRP
Burt Jones/Jones Laboratory	University of Southern California (USC)	Slocum Gliders and near real-time water quality moorings	J-112 and NOAA ECOHAB Grant
Raphael Kudela	University of California, Santa Cruz (UCSC)	Robotic submarine gliders, surface glider and other moored instruments	NOA ECOHAB and NSF Grant
Andrew Lucas	Scripps Institution of Oceanography (SIO)	Wire Walkers	NOAA ECOHAB Grant
Carter Ohlman	University of California, Santa Barbara (UCSB)	Drifters	J-112
George Robertson	Orange County Sanitation District (OCSD)	Offshore Sampling	J-112
John Ryan	Monterey Bay Aquarium Research Institute (MBARI)	Environmental Sample Processor (ESP)	NOAA ECOHAB
Eric Terrill	Scripps Institution of Oceanography (SIO)	HF Radar, Telemetered Buoy, and AUV Mission	J-112
Michael Von Winklemann	Orange County Sanitation District (OCSD)	In-Plant Sampling and Nearshore Sampling	J-112

3 Study Assets

Observational study assets included data with three different reporting modes (Figure 3.1):

- Near-real-time: Data from electronic sensors transmitted to shore every hour.
- Delayed: Data from gliders and field sampling that were available the day after sampling.
- Self-contained: Data from instruments deployed at the start of the project and recovered after the diversion.
- Models: Data were provided daily and included a predictive (36-72 hours) component.
- Web Portal: Provided an overall summary of OCSD's diversion sampling program, graphical maps of field sampling locations based upon Google mapping services, as well as near real-time and in-situ environmental observations or links to those observations.

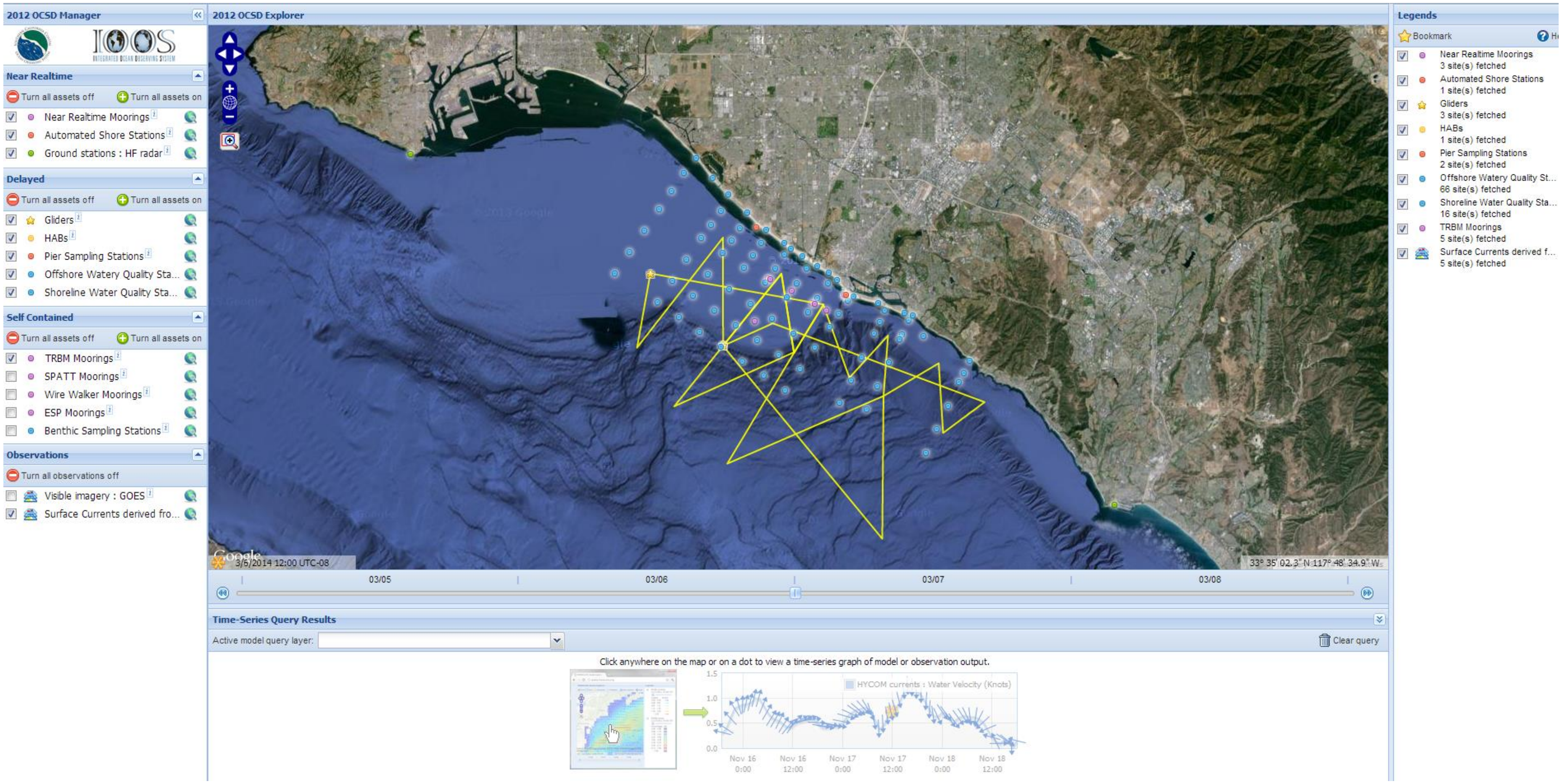


Figure 3.1 *2012 OCSD Diversion asset map*

3.1 Near Real-Time

A) High Frequency (HF) Radar Derived Surface Currents – Eric Terrill, SIO

Overview

Existing displays of High Frequency (HF) radar derived surface current maps and surface "particle plume tracking" were provided by the Coastal Observing Research and Development Center (CORDC), located at SIO, were made available for data assimilation into the ROMS model and as a decision aid to help guide water quality sampling, respectively (Figure 3.2).

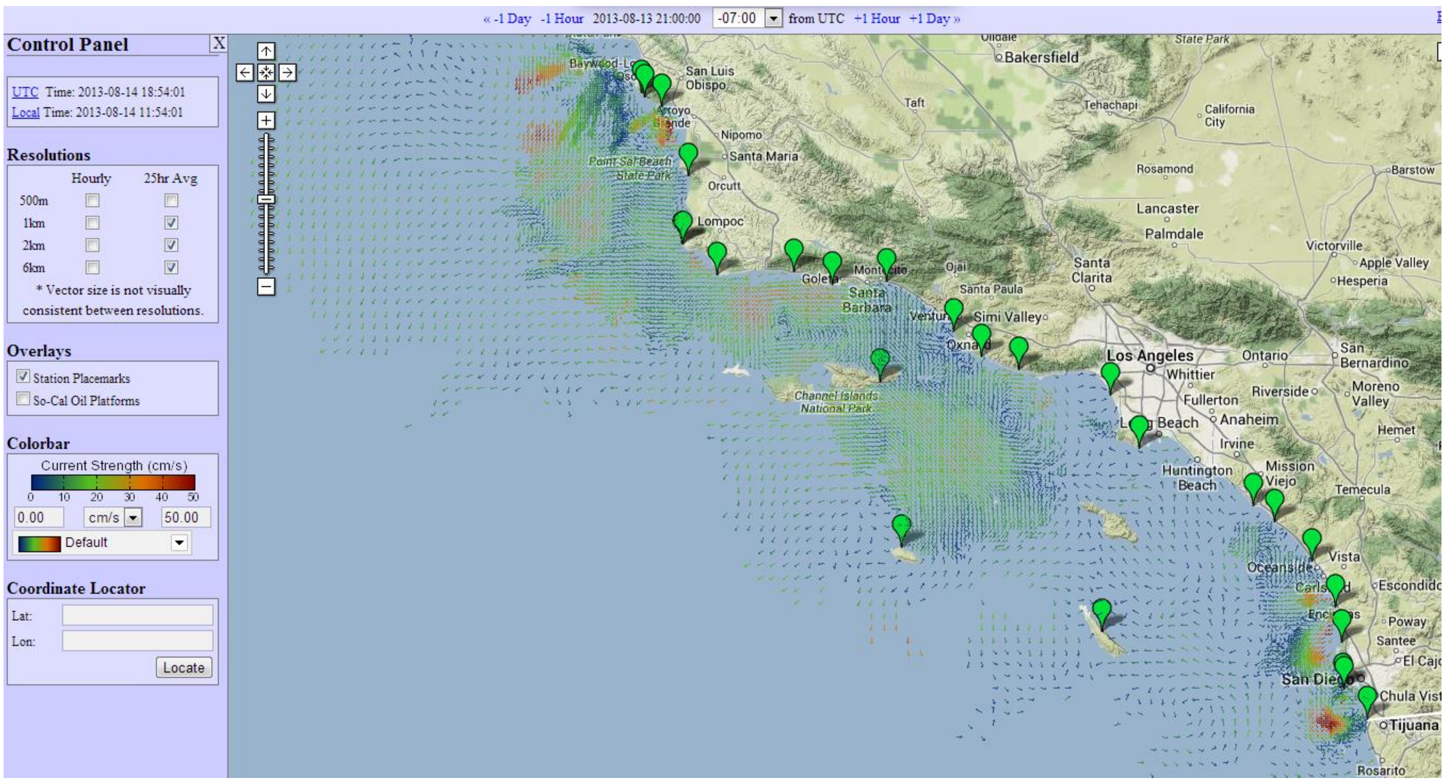


***Figure 3.2** HF radar derived surface currents, provided by CORDC. The green balloons are where the radars are located on the California coast and nearby Channel Islands.*

Methods

Estimates of surface water trajectories originating from the outfall's location were produced in near real-time. Trajectories were based on six kilometer resolution surface current measurements obtained from the HF radar network. Estimates were run hourly with hourly temporal resolution and used a two centimeter per second random walk model. Fifty particles are released at the origin every hour and were tracked for a maximum of three days. Near the coastline, the velocity field is reduced by 30% and projected along the coast to prevent particles from making 'landfall'.

Results

Existing surface current observations from HF radar were used daily to determine general circulation patterns within the observational domain.

B) Moorings

Three telemetered moorings were deployed to measure and transmit ocean currents and water quality conditions (Figure 3.3). One mooring was deployed at the short outfall to measure currents and water temperature. The other two moorings, deployed up and downcoast[1] of the short outfall, measured biologic and optical (bio-optical) properties of the surface waters (Table 3.1).

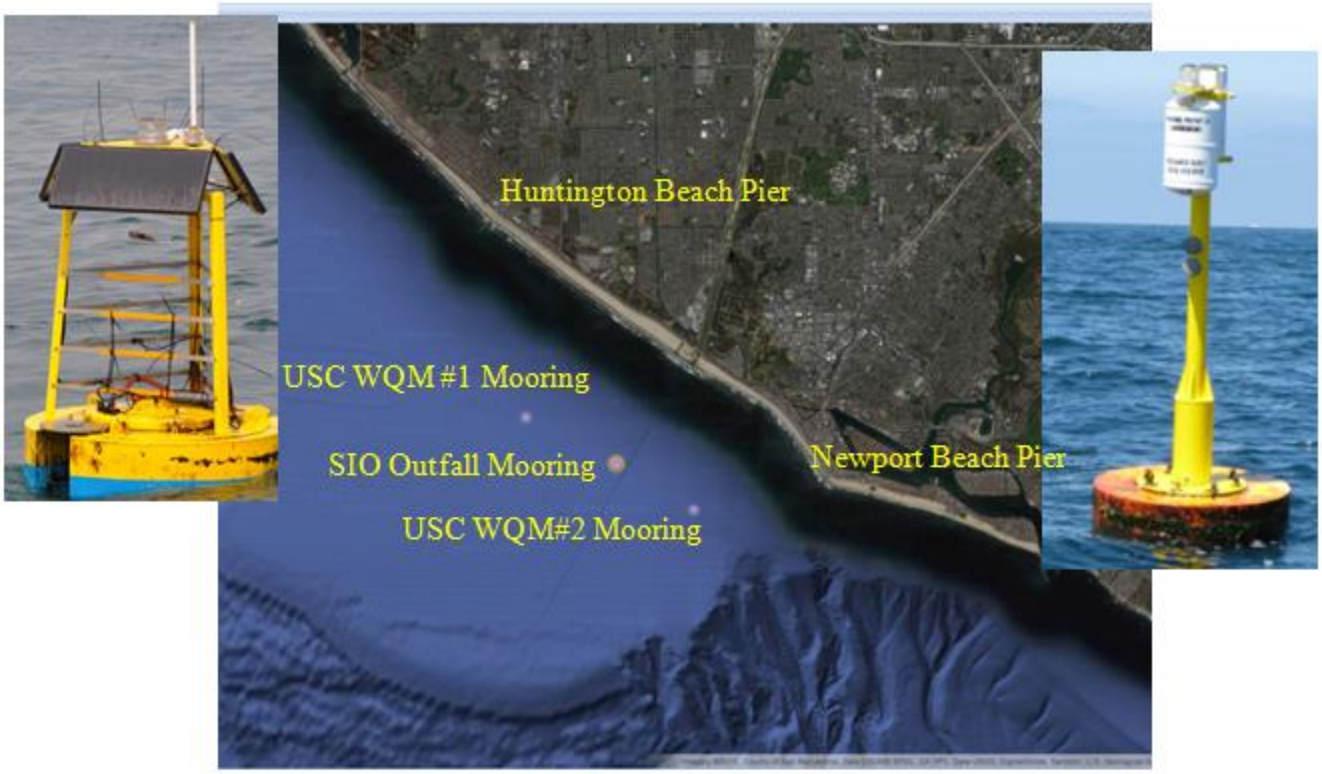


Figure 3.3 *SIO Outfall (right photo) and USC water quality mooring (WQM, left photo) locations. The white cylinder to the right on the SIO mooring is a radar reflector and the cylinder on the left is a Global Positioning System (GPS) tracking device.*

Table 3.1 Mooring locations	**Latitude**	**Longitude**	**Depth (meters)**	**Sampling Frequency (minutes)**	**Sampling Bins (meters)**
Mooring WQM#1*	33.618487	-117.995863	20	6	1
Mooring WQM#2*	33.601250	-117.958481	20	6	1
SIO Outfall Mooring	33.60995	-117.975633	22	6	1
*WQM ADCPs were self-recording					

I) SIO Outfall Mooring - Eric Terrill, SIO

Overview

The approximate depths of temperature measurements were 1.8 m, 5.5 m, 8.2 m, 10.9 m, 12.9 m, 15.2 m, 17.6 m. Data were transmitted to shore once each hour for the computation of near-real-time plume trajectory

[1] Note: Upcoast, as it is used throughout this document means northwest of the outfall. Downcoast means southeast of the outfall.

estimates. Trajectories representing the bulk transport of the water for the entire water column were computed for 24 hours of data and updated on an automated basis with the receipt of the next hour of data (Figure 3.4).

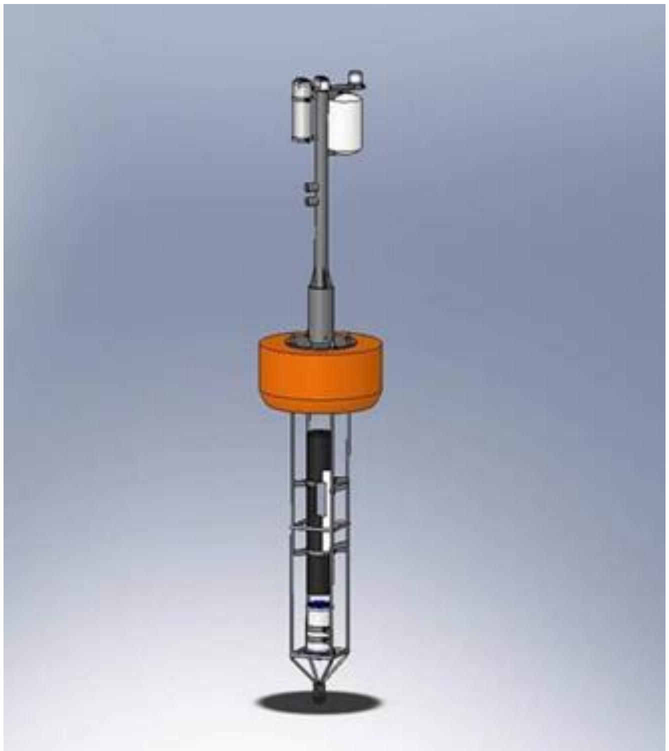


Figure 3.4 *Drawing and a photograph of the Scripps-designed coastal buoy system for measuring stratification and currents at the OCSD diversion site.*

Methods

The buoy was originally deployed on August 15, 2012. Approximately one-week after the deployment, the ADCP stopped functioning due to a memory card error. Thus, the ADCP was replaced on August 31, 2012 and recovered on March 4, 2013. The OCSD R/V NERISSA was used to deploy the buoy. A pre-deployment compass calibration was conducted to ensure proper referencing of subsurface currents.

Trajectories representing the bulk transport of the water for the entire water column were computed for 72 hours of data and updated on an automated basis with the receipt of the next hour of data. Trajectories were computed from the time series of u and v velocities from the buoy ADCP. Quality assurance checks included 1.) Check for valid timestamp and ensemble 2.) Clip data below seafloor 3.) Filter out velocity magnitudes greater than 2 m/s. This web-accessible spatial information served as a key decision aid for horizontal path planning of the survey to maximize chances of sampling the plume. When used in conjunction with a 5-hour averaged current profile, the REMUS autonomous underwater vehicle mission paths were developed to spatially optimize plume sampling and minimize measurements outside of the plume. Hourly current velocity profiles were also monitored in the hours leading up to the vehicle deployment to assess if the plume orientation was changing and determine if adjustments were necessary.

The mooring consisted of a surface buoy that contained an ADCP (TRDI Instruments, San Diego, CA), a temperature chain (Precision Measurement Engineering, Encinitas, CA), data logger, satellite telemetry unit, GPS receiver, and a battery pack (Table 3.2). The downward looking ADCP profiled ocean currents from 4.3 m deep to the seafloor. All mechanical aspects of the buoy, mooring, and anchoring system were fabricated by SIO. The settings for the ADCP are listed in Table 3.3.

Table 3.2 Platform/Type	**SIO Outfall Mooring**		
Sensor	Acoustic Doppler Current Profiler	Temperature Chain	Temperature Loggers
Make	Teledyne RDI	PME Temperature Chain	Richard-Brancker (RBR) Temperature Loggers
Model	600kHz ADCP		RBR TR-1060
Firmware	51.4		N/A
Accuracy	±0.3% of measured velocity	±0.01°C	±0.002°C
Precision	0.1 cm/s	N/A	N/A
Sample rate	6 seconds	1/min	1/min
Sample interval	Intermittent (every 6 sec)	Continuous	
Constituents measured	Current Velocity	Temperature	Temperature
Quantity	1	7	7
Additional Comments	This was a fixed buoy. Iridium near real-time data delivery with hourly updated data. ADCP & Brancker t-loggers were self-contained		

Table 3.3 *Settings for the ADCP on the SIO outfall mooring.*

System Parameter	**Setting**
Acoustic frequency	600 kHz
Pings per ensemble	50
Ensemble interval	5 minutes
Range cell size	1 meter
Measurement standard deviation	1.4 cm/s
Number of depth cells	25

Results

Buoy position, currents, and ocean temperature data were transmitted to shore once each hour using an Iridium Satellite modem which allowed for the computation of near-real-time plume trajectory estimates. Trajectories representing the bulk transport of the water for the entire water column were computed for 24 hours of data and updated on an automated basis with the receipt of the next hour of data (Figure 3.5). Trajectories were computed from the time series of *u* and *v* velocities from the buoy ADCP (Figure 3.6). This web-accessible spatial information served as a key decision aid for OCSD in-situ sampling.

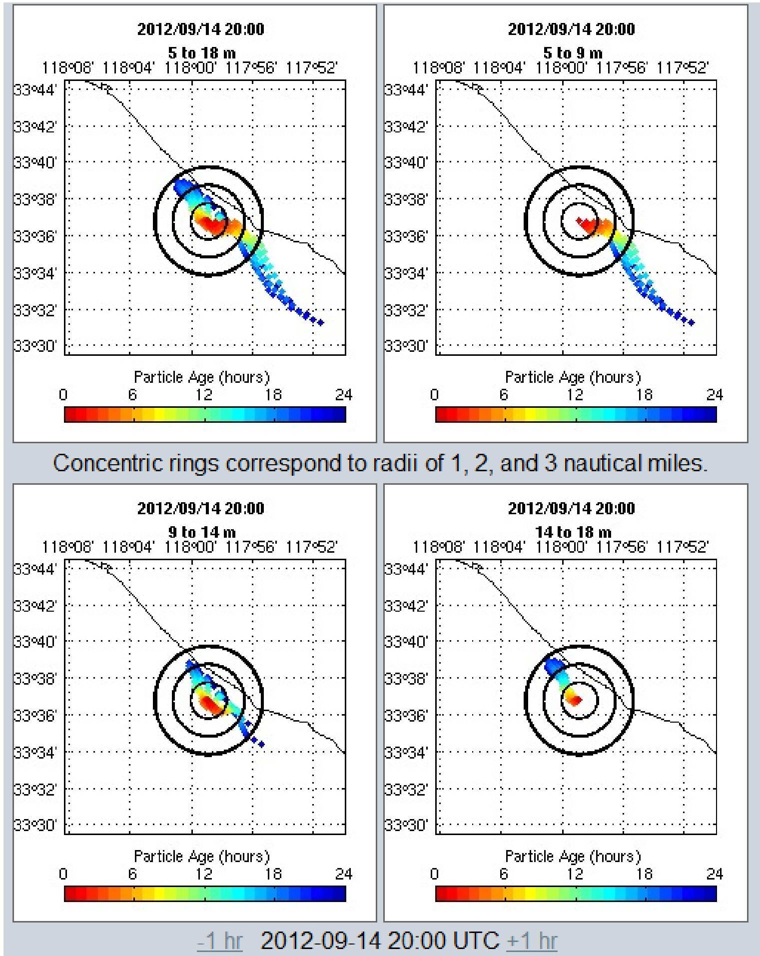


Figure 3.5 *Example of near real-time OCSD plume trajectory "progressive-vector diagram" estimated for depths between 5 – 18 m from the SIO mooring on September 14, 2012*

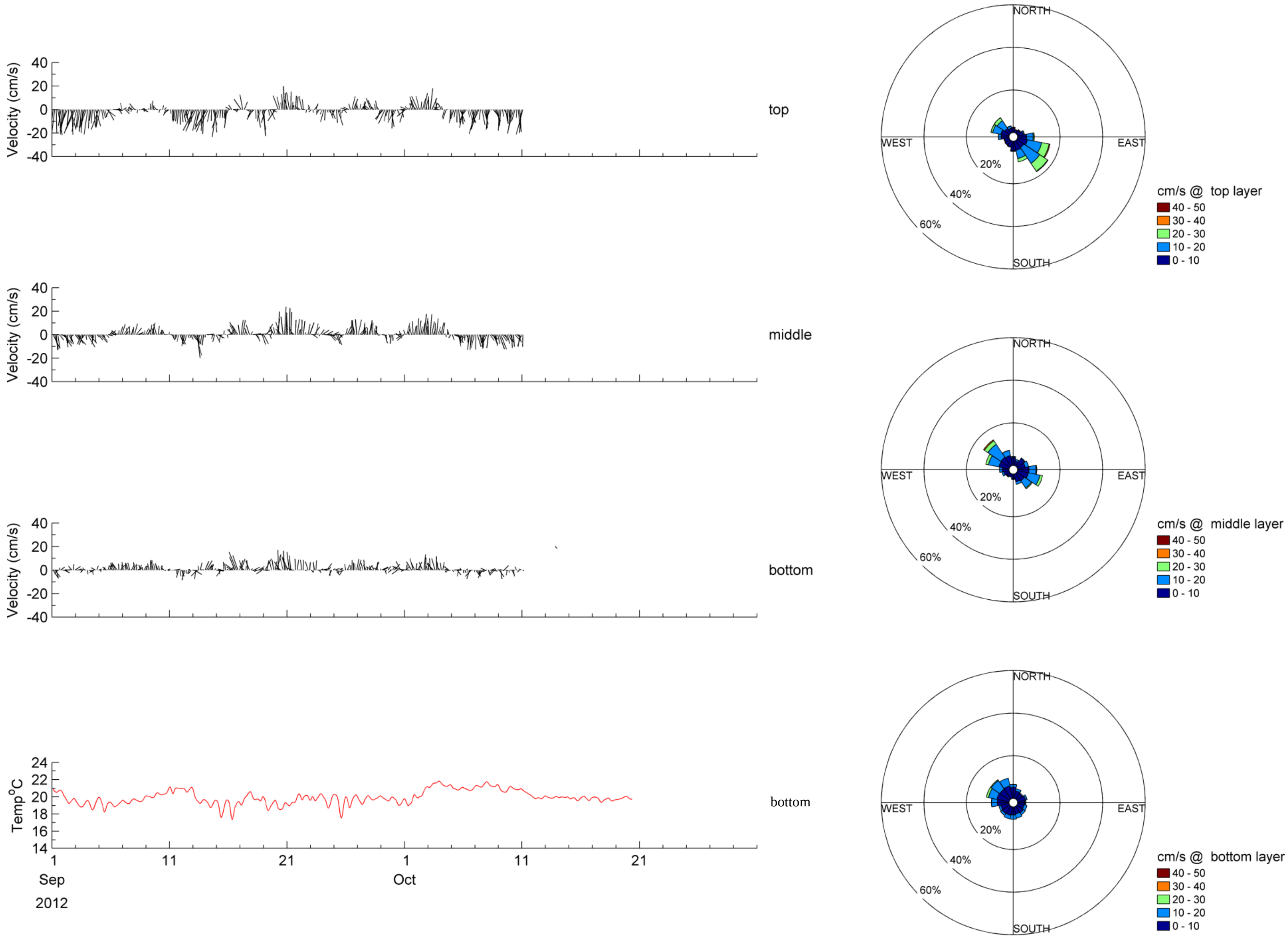

Velocity (cm/s)
40
20
0
-20
-40
top
middle
bottom
Temp °C
24
22
20
18
16
14
1
11
21
1
11
21
Sep
Oct
2012
NORTH
WEST
EAST
SOUTH
20%
40%
60%
cm/s @ top layer
cm/s @ middle layer
cm/s @ bottom layer
40 - 50
30 - 40
20 - 30
10 - 20
0 - 10

Figure 3.6 *Feather plot and current rose for SIO Mooring Station. Feather plot data rotated 302° so that up is upcoast and right is onshore. Current rose direction based on true north. This is a polar histogram plot that shows the percentage of time that the current flowed in a particular direction. Each bar is broken up into different speeds.*

II) Water Quality Moorings (WQM) - Burt Jones, USC

Overview

To supplement glider operations, the Jones Laboratory worked with OCSD to deploy two moored buoys with scientific instrumentation, one upcoast of the short outfall and one downcoast (Figure 3.3). These two moorings were each equipped with a WET Labs water quality monitor and a WET Labs cycle-phosphate sensor. The WQMs were equipped to measure chlorophyll fluorescence, turbidity, dissolved oxygen, temperature, and salinity (Table 3.5).

Methods

The data had quality assurance and quality control (QA/QC) applied, but more rigorous QA/QC will be applied for a final version of the data. Salinity, in particular, experienced numerous spikes, some of which may be difficult to distinguish from "real" events. For this report, we consider the chlorophyll concentrations to be "relative" concentrations, as post-deployment calibration has yet to be applied on the sensors.

Deployment information

Table 3.4	**WQM#1**
Date of deployment	09/06/2012 – 11/01/2012
Overview	Buoys were deployed from the R/V Nerissa
Challenges	N/A
	WQM#2
Date of deployment	09/06/2012 – 11/01/2012
Overview	Buoys were deployed from the R/V Nerissa
Challenges	The cycle-phosphate sensor on the Southern mooring (WQM #2) did not record data due to technical malfunction.

Instrument Specifications

Table 3.5	**Water Quality Mooring #1 (North)**	
Sensor	WET Labs Package	WET Labs CYCLE Phosphate
Make	WET Labs	WET Labs
Model	WQM	CYCLE Phosphate
Sample rate	3/ hr	1/ hr
Sample interval	Continuous	continuous
Constituents measured	Temperature, salinity, chlorophyll fluorescence, turbidity, dissolved oxygen	Phosphate
Quantity	1	1
Additional Comments	Data delivery in near real-time. Data output are ASCII	
	Water Quality Mooring #2 (South)	
Sensor	WET Labs Package	WET Labs CYCLE Phosphate
Make	WET Labs	WET Labs
Model	WQM	CYCLE Phosphate
Sample rate	3/ hr	1/ hr
Sample interval	Continuous	continuous
Constituents measured	Temperature, salinity, chlorophyll fluorescence, turbidity, dissolved oxygen	Phosphate
Quantity	1	1
Additional Comments	Data delivery in near real-time. Data output are ASCII	

Results

The Water Quality Monitors (WQMs) on both the Northern and Southern moorings recorded during the entirety of the diversion. These two datasets have a large amount of agreement. The plots of dissolved oxygen, chlorophyll fluorescence, turbidity, temperature, and salinity are shown for both moorings below. The cycle-phosphate sensor on the northern mooring recorded phosphate data for the duration of the diversion, which are displayed below. Unfortunately, the cycle-phosphate sensor on the southern mooring (WQM#2) did not record data due to technical malfunction (Table 3.4).

The data from the two moorings are plotted in figures 3.7 and 3.8 with the data time series in blue. The black bar across the top of each panel indicates the period of the diversion.

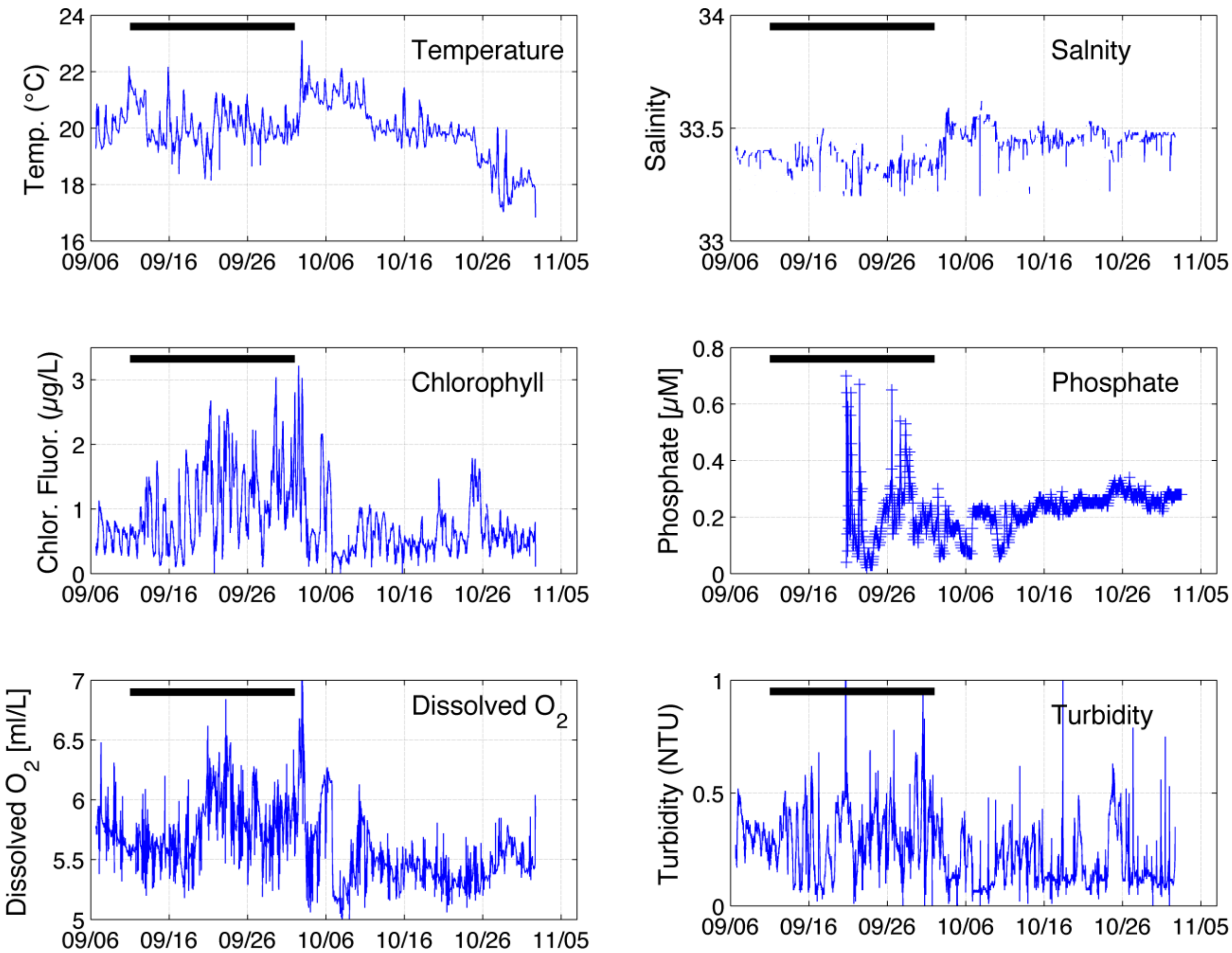


Figure 3.7 *WQM#1 (North mooring) results*

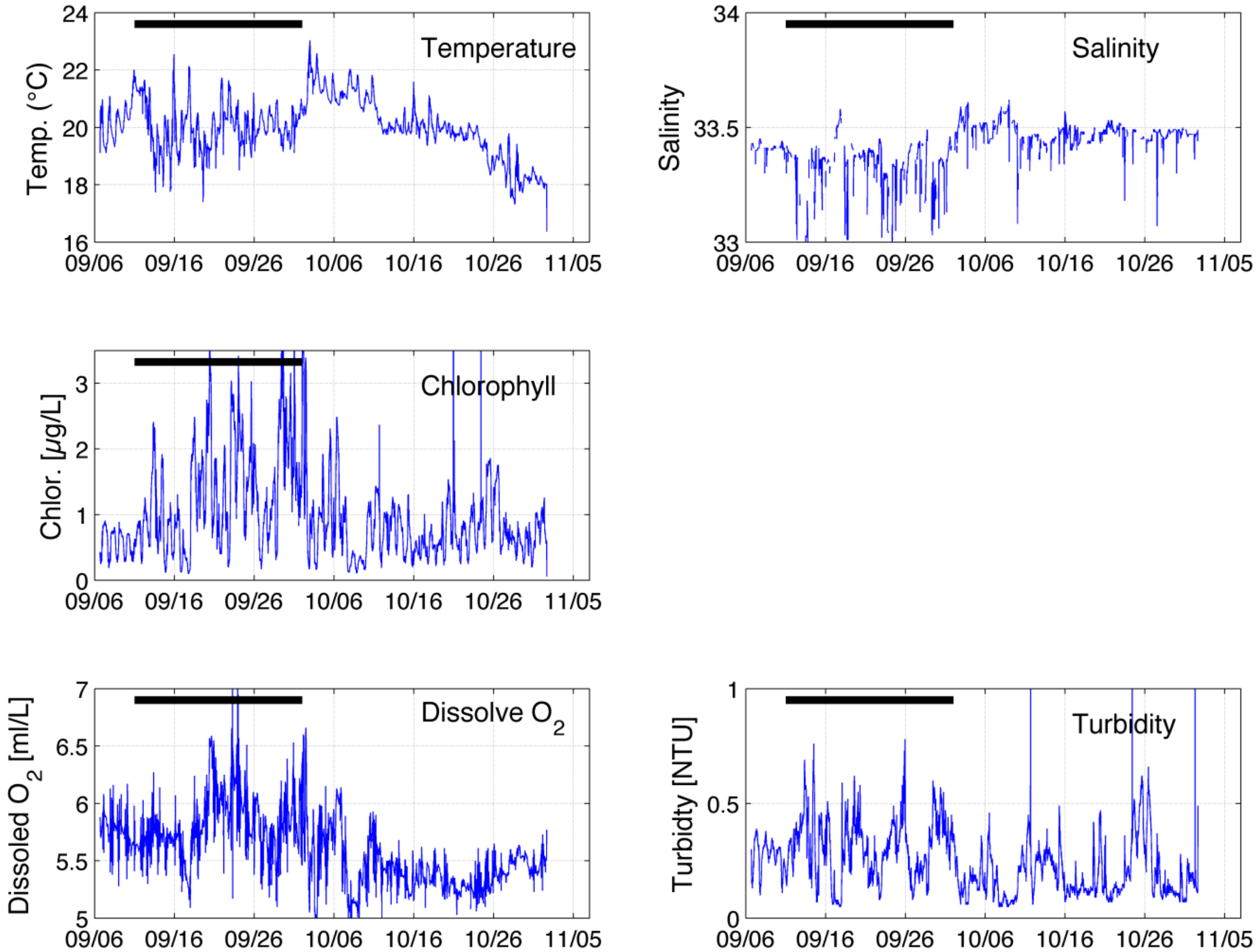


Figure 3.8 *WQM#2 (South mooring) results*

Several conclusions can be made from these two time series measurements from the near-surface (~1 m) layer.

First, once the nearshore discharge began, both sites dropped in both temperature and salinity. The temperature drop is most likely due to entrainment of near bottom water as the discharge plume rose to the surface, and the reduced salinity is due to mixing of the fresh effluent into the ambient seawater. Both temperature and salinity increased almost immediately when the diversion was completed.

Second, we expect that the effluent contains elevated concentrations of ammonium nitrogen and phosphate, both breakdown products of human fecal material. During the diversion, the phosphate sensor at the northern buoy detected higher concentrations of phosphate. The concentration was variable rising to as high as 0.7 µM/L. Once the diversion stopped, phosphate concentrations returned to relatively stable ambient concentrations between 0.2 and 0.3 µM/L. A third observation is that chlorophyll concentrations in the surface layer rose almost immediately in response to the diversion. Initially, the maximum increase was from about 0.5 to 1.5 µg/L chlorophyll. This initial increase may have resulted from entrainment of chlorophyll from the subsurface chlorophyll maximum probably located near the bottom in this nearshore environment. As the diversion continued, the chlorophyll concentrations increased and were quite variable. Maximum concentrations were more than 3 µg/L. Although not identical, the near surface dissolved oxygen concentrations co-varied with the chlorophyll, consistent with the production of dissolved oxygen due to photosynthesis by the phytoplankton. Turbidity also varied similarly to the chlorophyll. Turbidity levels increased at both moorings during the diversion and were quite variable. A regression of chlorophyll versus turbidity (figure not shown) indicates that a significant fraction of the suspended particulate matter was phytoplankton particles. However, based on the glider observations shown in the next section, not all turbidity (indicated by optical backscatter on the gliders) is due to phytoplankton. Some of the particles contributing to the turbidity come from the effluent and some from bottom re-suspension.

The fact that both moorings detected the presence of the plume indicates the variability in the coastal currents with advection occurring at different times in both directions from the outfall. Both moorings displayed a spiky pattern in the variables that were affected by the discharged effluent indicating a patchy distribution of the plume water and/or variability in the advection from the discharge point.

3.2 Delayed Mode

A) Autonomous Profiling Gliders – Burt Jones, USC

Table 3.6 Glider Transects	Bounding box	Latitude	Longitude
Fall 2012 OCSD North	Upper west lat/lon	33˚ 38.808	-118˚ 06.263
	Upper east lat/lon	33˚ 38.808	-117˚ 56.951
	Lower west lat/lon	33˚ 34.003	-118˚ 06.263
	Lower east lat/lon	33˚ 34.003	-117˚ 56.951
Fall 2012 OCSD South	Upper west lat/lon	33˚ 37.308	-118˚ 01.967
	Upper east lat/lon	33˚ 37.308	-117˚ 48.879
	Lower west lat/lon	33˚ 30.666	-118˚ 01.967
	Lower east lat/lon	33˚ 30.666	-117˚ 48.879

Overview

Gliders can effectively detect an effluent plume and phytoplankton blooms. The Jones Laboratory at USC worked closely with OCSD, Southern California Coastal Water Research Project (SCCWRP), University of California, Santa Cruz (UCSC), University of California Los Angeles (UCLA), and JPL to monitor the dispersion and effects of wastewater during the Fall 2012 Orange County wastewater diversion. The Jones Lab deployed and maintained three Webb Slocum electric gliders (Figure 3.9), two actively deployed and one being serviced at any given time.

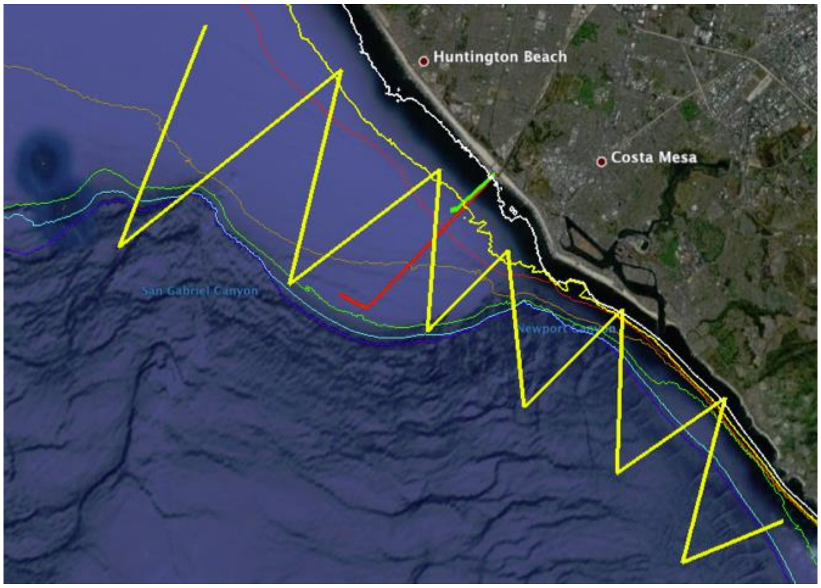


Figure 3.9 *(Left) Fall 2012 Idealized Glider Deployment track: Two gliders split the transect, one glider to the south and one to the north with overlap near the outfall pipe. The red line extending from shore is the OCSD 120-inch outfall. The light green line is the OCSD 78-inch outfall. The colored lines indicate isobaths: white line closest to shore is 10m, yellow line is 20m, red line is 30m, orange line is 40m, green line is 50 m, and blue line is 60 m. (Right) Slocum glider.*

Methods

The gliders were equipped with a Sea-Bird conductivity-temperature-depth (CTD) sensor, a GPS, satellite phone allowing daily data transmission, and optical instruments (Tables 3.7-3.9). The optical sensors included up to three fluorometers with unique excitation/emission channels that measured chlorophyll a (470nm/695nm), colored dissolved organic matter (CDOM) (370nm/460nm) and phycoerythrin/ rhodamine (540nm/570nm), a backscatter sensor at three wavelengths (532nm, 660nm, and 880nm) for measuring suspended particles, and one glider had an oxygen sensor. With this suite of measurements, the gliders could effectively detect an effluent plume and phytoplankton blooms. The effluent plume was identified by the combination of elevated CDOM fluorescence and low salinity anomaly, defined as the difference between the measured salinity and the ambient salinity at comparable temperature and density away from the outfall and influence of the plume.

The gliders' CDOM and chlorophyll fluorometers were calibrated pre and post deployment with a protocol developed in the Jones lab using a local mix of phytoplankton species (Cetinić et al., 2009). The CDOM units are in μg QUE (quinine unit equivalents) per liter. During each recovery barnacles growing on the glider exterior were collected, and their tissue analyzed for the presence of domoic acid. If sufficient biomass was collected the barnacles were ground by the Caron Laboratory at USC and an enzyme-linked immunosorbent assay (ELISA) performed to detect the presence of domoic acid. Glider recoveries were based from the USC's Wrigley Institute for Environmental Studies on Catalina Island where calibrations and battery replacement could occur, thus quickly minimizing breaks in the data due to glider servicing. The facilities at SCCWRP were also used for glider calibrations and servicing. These calibrations were completed approximately every 3 to 4 weeks for each of the gliders from USC and SCCWRP. All gliders used during the diversion were co-calibrated on August 27^{th} at the Wrigley Center. After deployment, the glider data were analyzed as a single set to look for instrument drift over time. No instrument drift was found.

Matlab and python scripts were used to convert the glider data from its native format to Matlab readable structured array files and ASCII files. Matlab was used for all further downstream data processing and analysis.

Additionally, the Jones Laboratory and SCCWRP deployed two gliders in the Spring of 2012, which were the same as the Fall 2012 deployment (Figure 3.9), to acquire background data that were used by the McWilliams laboratory at UCLA for nearshore modeling of the Newport Beach and Huntington Beach area. Two gliders split the transect, one glider to the south and one to the north with overlap near the outfall pipe (Table 3.6).

Instrument specifications

Table 3.7	**Webb Slocum Electric Glider 076 (Hehape/USC)**		
Sensor	Eco Puck Fluorometer	Eco Puck Backscatter	Sea-Bird CTD
Make	WET Labs	WET Labs	Sea-Bird
Model	Eco Puck FL3	Eco Puck BB3	CTD
Sample rate	As needed, usually 1/ second	As needed, usually 1/ second	As needed, usually 1/2 second
Sample interval	Continuous	Continuous	Continuous
Constituents measured	Chlorophyll fluorescence, rhodamine fluorescence, CDOM fluorescence	Optical backscatter at wavelengths of 532nm, 660nm, and 880nm	Conductivity, temperature, and depth
Quantity	1	1	1
Additional Comments	Platform data delivery is in near real-time. Data output is in ASCII[2], txt[3], and images. Data access is email, ftp, and website		

Table 3.8	**Webb Slocum Electric Glider 108 (Rusalka) USC**		
Sensor	Sea-Bird CTD	Eco Puck Fluorometer	Sea-Bird CTD
Make	Sea-Bird	Wet Labs	Sea-Bird
Model	CTD	Eco Puck FL3	CTD
Sample rate	As needed, usually 1/2 second	As needed, Usually 1/ second	As needed, usually 1/2 second
Sample interval	Continuous	Continuous	Continuous
Constituents measured	Conductivity, temperature, and depth	Chlorophyll fluorescence, rhodamine fluorescence, CDOM fluorescence	Conductivity, temperature, and depth
Quantity	1	1	1
Additional Comments	Platform data delivery is in near real-time. Data output is in ASCII, txt, and images. Data access is email, ftp, and website		

[2] Glider data in ASCII files are transmitted while the glider is in the water or transferred after the glider is recovered. These data are processed into images.

[3] Text messages are how to get information on how the glider is performing on its deployment. For example: if a glider encounters a problem and has to abort its mission, the pilots receive an alert text message that allows a pilot to respond to the glider itself.

Table 3.9	Webb Slocum Glider (Carmen) /SCCWRP		
Sensor	Sea-Bird CTD	Eco Puck Fluorometer	Oxygen Optode
Make	Sea-Bird	Wet Labs	
Model	CTD	Eco Puck FL3	
Sample rate	As needed, usually 1/2 second	As needed, usually 1/ second	
Sample interval	Continuous	Continuous	
Constituents measured	Conductivity, temperature, and depth	Chlorophyll fluorescence, rhodamine fluorescence, CDOM fluorescence, acoustic backscatter (532nm)	
Quantity	1	1	1
Additional Comments	Platform data delivery is in near real-time. Data output is in ASCII, txt, and images. Data access is email, ftp, and website		

Deployment information

Table 3.10	Webb Slocum Electric Glider 076 (Hehape) USC
Date of deployment	08/29/12-09/18/12 deployed on OCSD North transect
Date of deployment	09/20/12-10/17/12 deployed on OCSD South transect
Date of deployment	10/17/12-11/07/12 deployed on OCSD South transect
Overview	Deployed and recovered via the S/V Sundiver II
Challenges	Conductivity sensor clogged with biofouling, which required cleaning on 09/28/12

Table 3.11	Webb Slocum Electric Glider 108 (Rusalka)/USC
Date of deployment	03/02/12 – 04/10/12 deployed on nearshore Spring transect
Date of deployment	09/06/12 – 09/18/12 deployed on OCSD South transect
Date of deployment	10/03/12 - 10/11/12 deployed on FRONT transect
Date of deployment	10/12/12 – 11/07/12 deployed on OCSD South (10/12/12 – 10/17/12) and OCSD Offshore (10/18/12 – 11/05/12)
Overview	Deployed and recovered via the S/V Sundiver II and R/V Nerissa
Challenges	n/a

Table 3.12	Webb Slocum Glider (Carmen) /SCCWRP
Date of deployment	08/29/12 – 08/30/12 deployed on OCSD South transect
Date of deployment	09/18/12 – 09/26/12 deployed on OCSD North transect
Date of deployment	10/03/12 – 10/11/12 deployed on OCSD North transect
Date of deployment	10/12/12 – 11/07/12 deployed on OCSD North transect
Overview	Deployed and recovered via the S/V Sundiver II and the OCSD R/V Nerissa
Challenge 1	Emergency recovery required on 08/30/12 due to malfunctioning GPS unit.
Challenge 2	Emergency recovery required on 09/26/12 due to dislodged internal battery pack.

Results

Three gliders provided good temporal and spatial coverage north and south of the outfall pipe and offshore of the outfall starting 11 days before the diversion and extending weeks after the diversion ended. Tandem gliders split the pre-planned transect (Figure 3.9), with one glider to the south and one to the north with overlap near the outfall pipe. A summary of deployment dates, deployment locations, and the glider affiliation are listed in Tables 3.10-3.12. The effluent plume was identified using the combination of elevated CDOM fluorescence and low salinity anomaly.

From late August into October the region experienced warm surface waters and stratified conditions. Although the coastal ocean remained stratified throughout the diversion, observable changes in phytoplankton community occurred. Prior to the diversion surface water temperatures were 22 ˚C and the water column was strongly stratified. Chlorophyll fluorescence in surface waters was extremely low. Below the surface layer, the chlorophyll distribution was patchy with some areas having >10 µg chlorophyll/L. Once the diversion began, the offshore subsurface chlorophyll signal declined, and the overall chlorophyll distribution changed in both the subsurface and surface layers. A subsurface signal remained and high surface concentrations were sometimes observed. The response was not constant, but varied both spatially and temporally throughout the diversion (Figures 3.10-3.12).

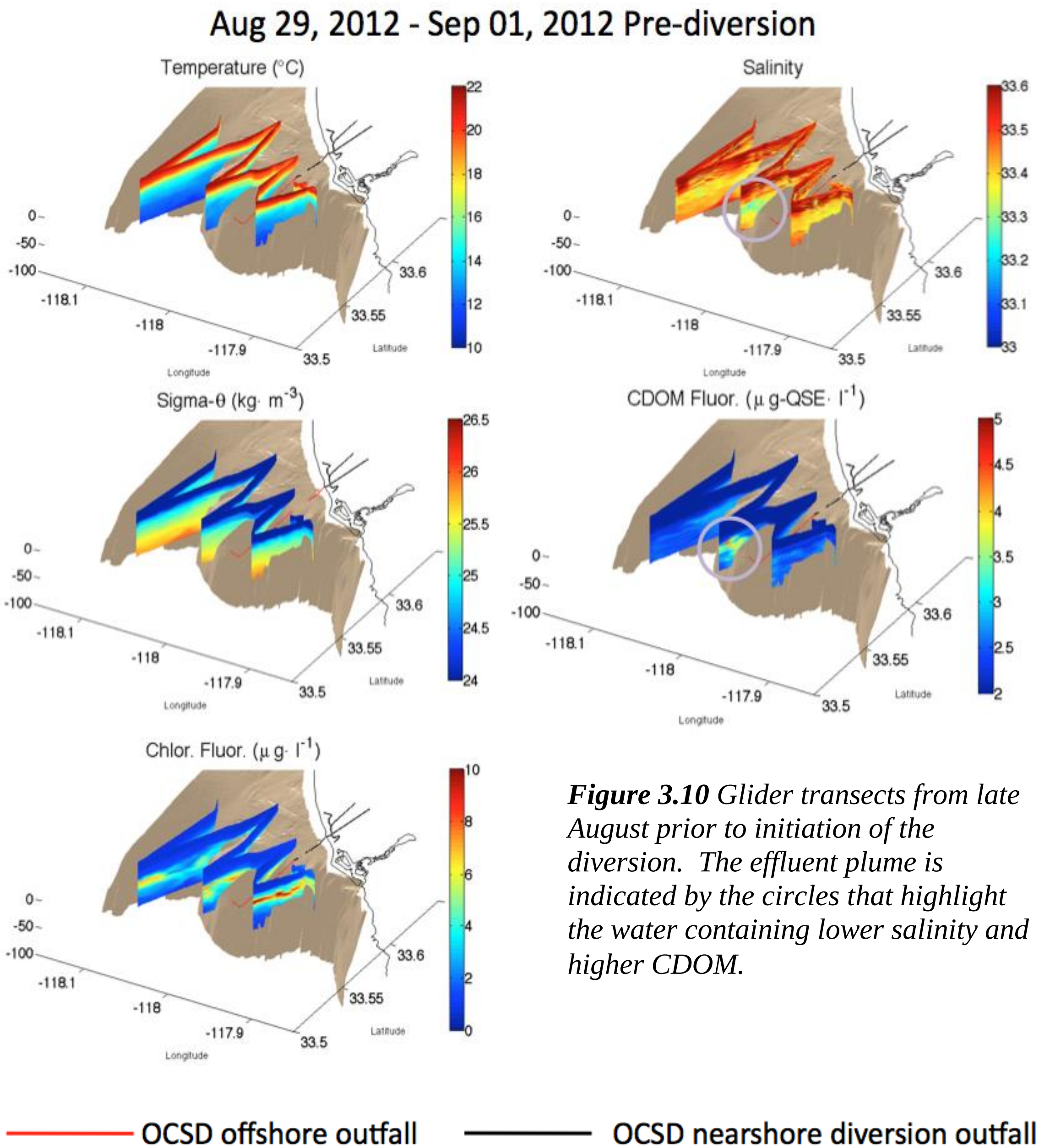


Figure 3.10 *Glider transects from late August prior to initiation of the diversion. The effluent plume is indicated by the circles that highlight the water containing lower salinity and higher CDOM.*

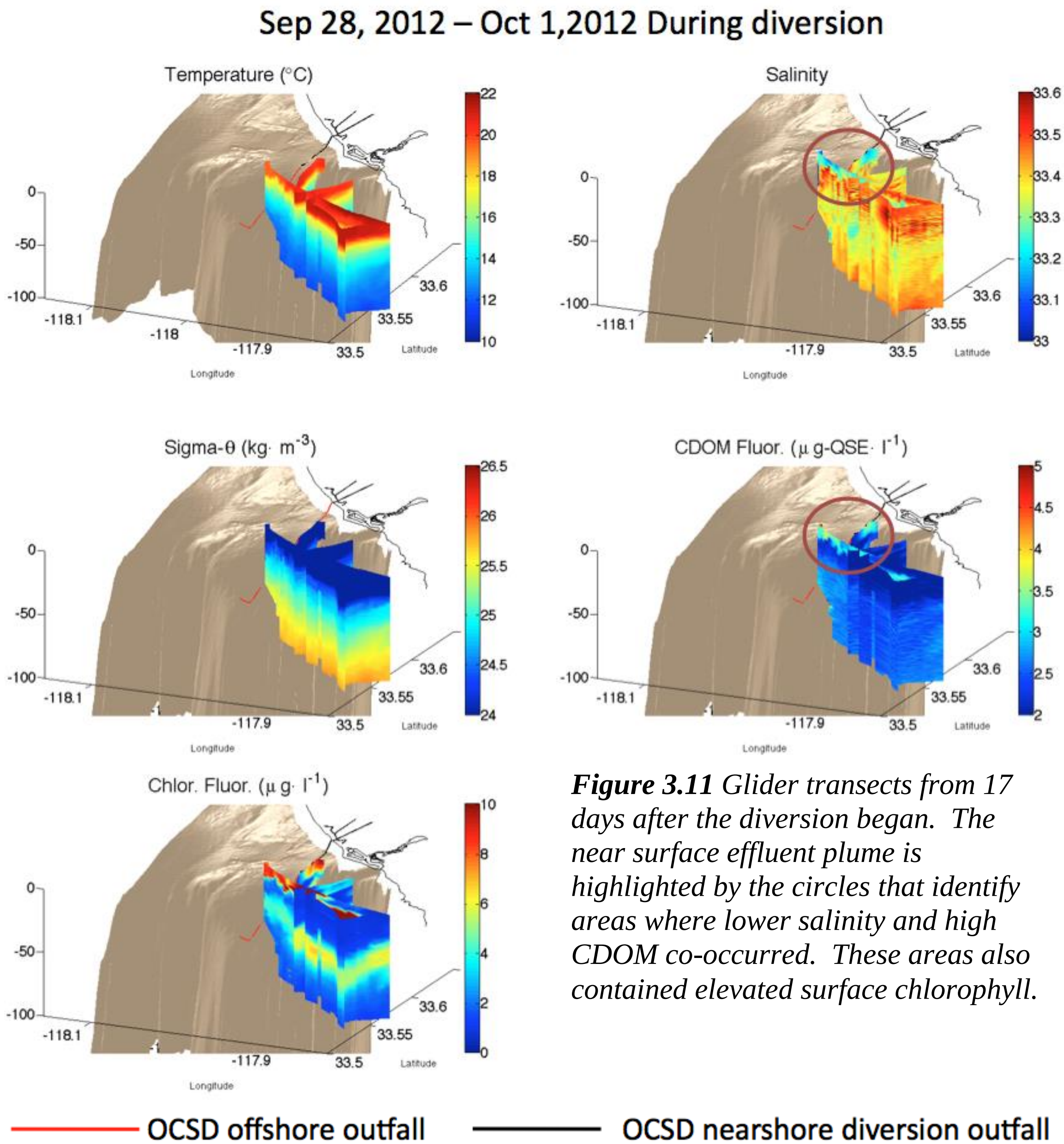


Figure 3.11 *Glider transects from 17 days after the diversion began. The near surface effluent plume is highlighted by the circles that identify areas where lower salinity and high CDOM co-occurred. These areas also contained elevated surface chlorophyll.*

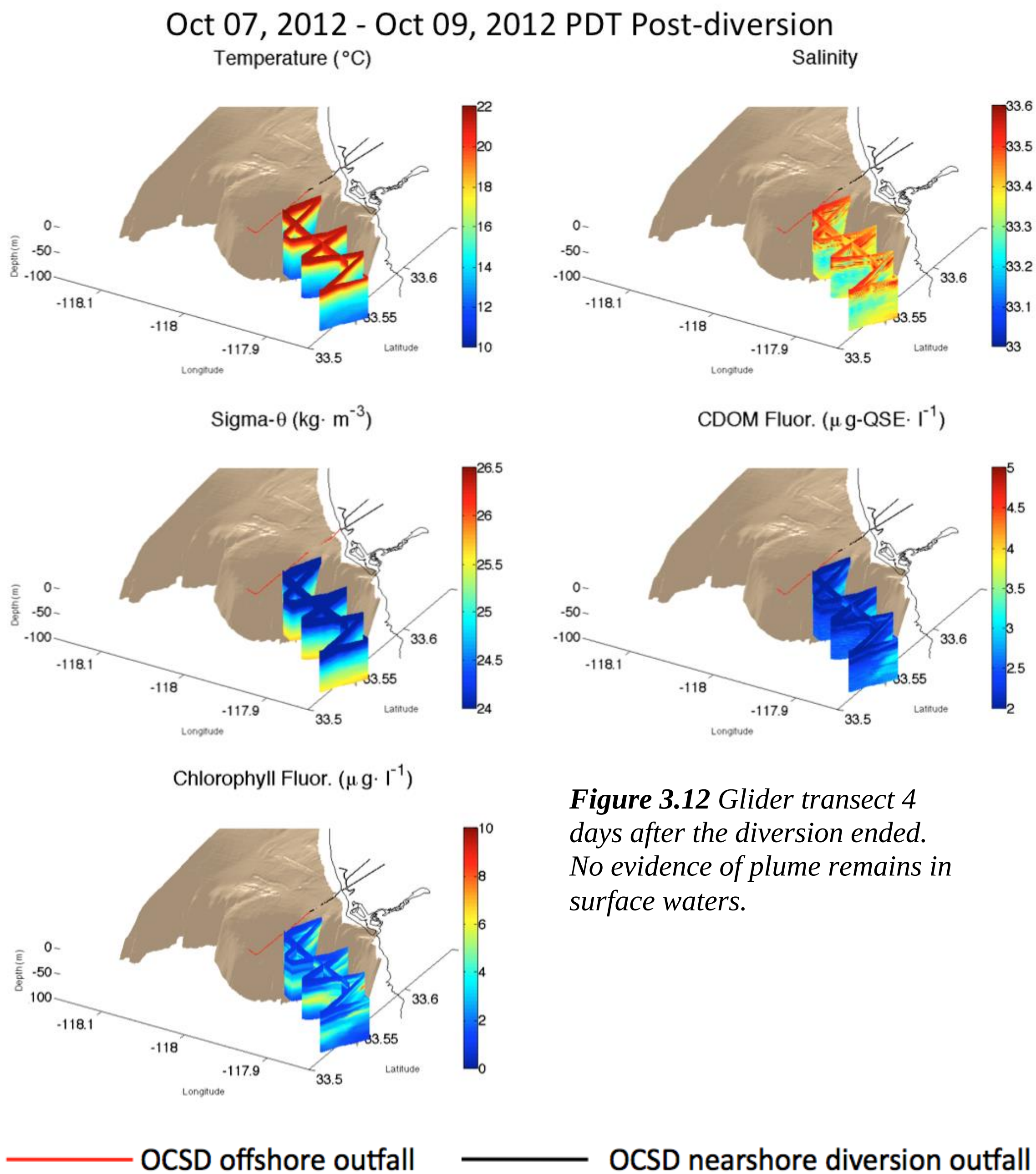


Figure 3.12 *Glider transect 4 days after the diversion ended. No evidence of plume remains in surface waters.*

Refer to Appendix III – Burt Jones: Complete Glider Results for diversion figures. This section will cover glider observations in detail over the entire monitoring period August 29 through November 2, 2012.

B) Drifters – Carter Ohlmann, UCSB

Overview

Sampling was performed by UCSB researchers in the vicinity of OCSD's 78-inch shallow water outflow diffuser. Sampling consisted of deploying water-following drifters (Figure 3.13 and 3.14 A & B) just above the end of the outfall pipe, and performing CTD casts to obtain depth-profiles of temperature, salinity, turbidity and CDOM, following drifter motion. Together these data show transport of the surface plume away from the source and track the rate of plume dilution through mixing with ambient ocean waters.

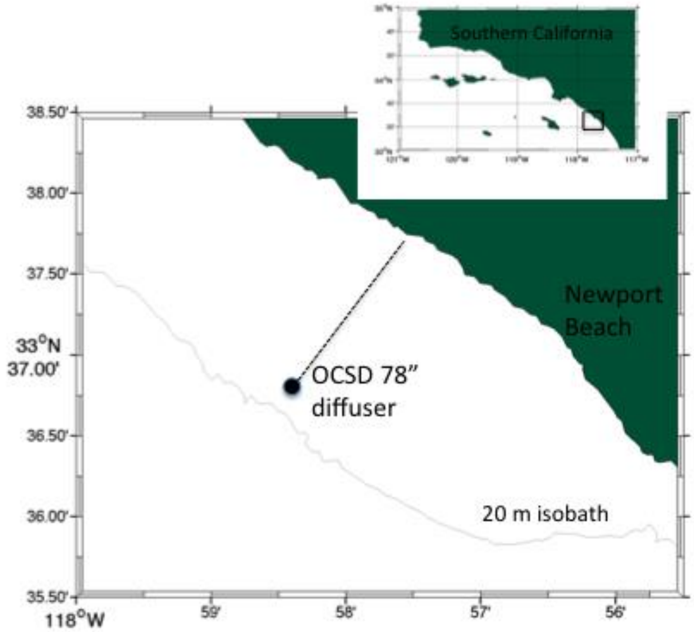
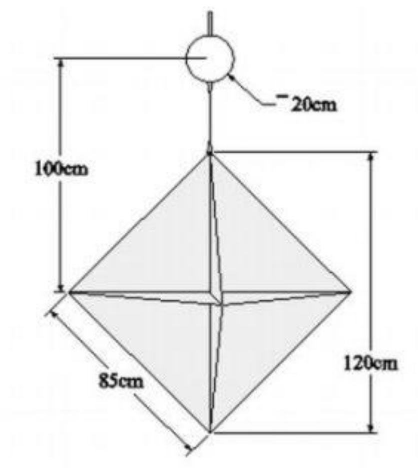


Figure 3.13 *Location of the OCSD 78-inch shallow water diffuser off the Southern California coast. Light gray line shows the 20 m isobath. Inset map shows rough location of study site (small black box in lower right corner of inset map) within the Southern California Bight.*

A) 

B) 

Figure 3.14 A & B: *Schematic diagram of the Microstar drifters (left) and a typical drifter deployment (right). The drifter deployment picture shows the stern of a 21ft skiff in the foreground to provide a sense of scale.*

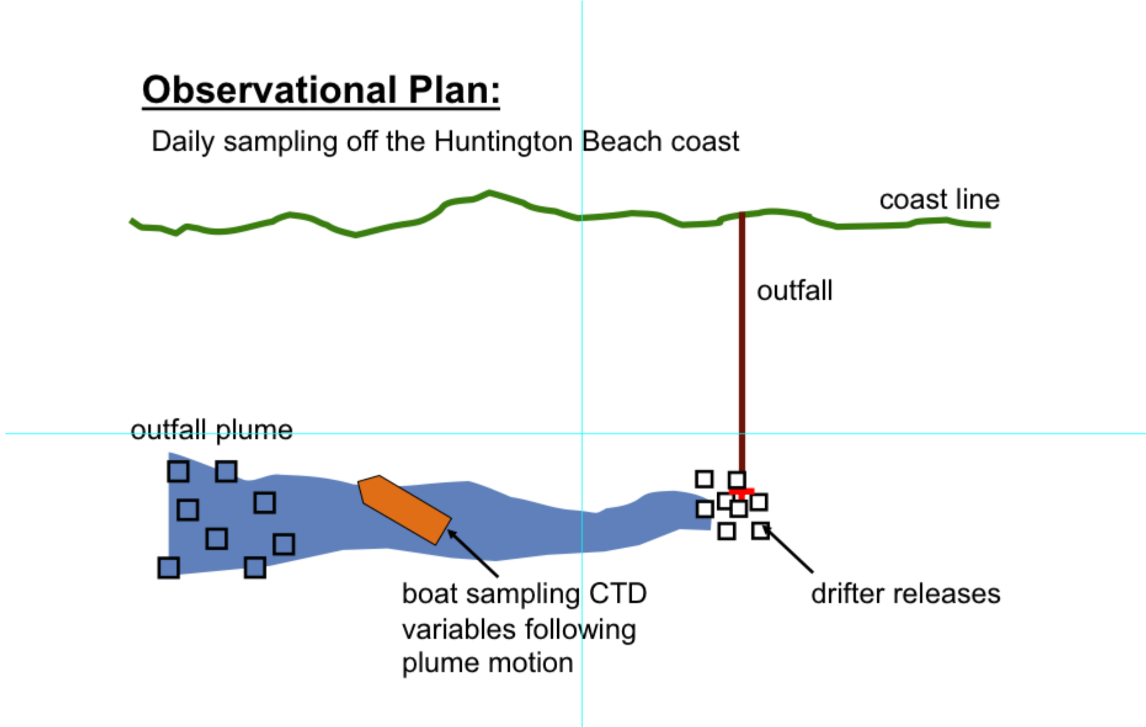


Figure 3.15 *Cartoon showing the observational plan. Drifters follow plume waters allowing the evolution of the effluent plume to be tracked in both time and space.*

At the shallow (~18 m water depth) OCSD 78-inch outflow discharge location, fresh (i.e. buoyant compared with ambient ocean saltwater) plume waters are expected to quickly rise to the ocean surface (top few meters). Drifters drogued at 1 m depth provide a direct measure of transport pathways taken by surface water parcels. Horizontal eddy diffusion values (i.e. mixing rates) are accurately obtained from the relative motion of drifters. CTD (Figure 3.16) measurements following drifter motion give a direct measure of plume dilution as fresh plume waters mix with ambient saltwater.

Primary goals of the drifter study were to:

- Make repeated direct measurements of wastewater plume pathways from the diffuser location with water-following drifters.
- Make repeated direct measurement of plume concentration (via salinity) following plume (drifter) motion.
- Quantify rates of horizontal plume mixing (dilution).
- Identify where (and if) plume waters (as tracked with drifters) reach the offshore edge of the surfzone and indicate corresponding plume concentration.
- Provide an independent ocean current data set that can be used to evaluate numerical ocean circulation model performance.

Figure 3.16 *Picture of CTD system used for sampling. White cylindrical instrument in center is CTD, small black cylindrical instrument (upper left) is CDOM fluorometer, and black instrument on right is transmissometer. Lab bench to right of instrument (shown for scale) is roughly 30 inches high.*

Methods

Instrument Information

Table 3.13	**Microstar Drifter**
Make	Pacific gyre corporation
Accuracy	Within 5 m
Sample interval	Position data are recorded every 10 minutes
Constituents measured	Track the horizontal motion of near surface water parcels between 0.5 - 1.5 m depth
Quantity	12
Additional Comments	Iridium satellite communications network. Data transmission is near real-time allowing drifter positions to be monitored from any computer with Internet access. In addition, near real-time data can be received in the field (aboard a boat) with an Iridium antenna

Deployment Information

Field data were collected on 11 days – 9 days while the shallow outfall was in operation (16-19, 21, 25-26 September and 1-2 October) and 2 days after the shallow discharge had been shut off (9-10 October). Note that on October 9, limited data only were collected due to real-time data server malfunction.

A drifter study with CTD profiles following drifter motion was performed to achieve the project goals. At the beginning of each sampling day, a set of 4 - 6 drifters was deployed in a rectangular grid configuration with 10 to 50 m spacing just above the effluent diffuser. Immediately after the drifter deployment, a CTD cast was performed at the effluent diffuser to obtain temperature, salinity, density, CDOM and beam transmission characteristics of plume waters just after discharge. The direction of drifter motion was then observed to determine the general direction of plume motion. A CTD cast was then performed at a location upstream of the effluent plume to measure characteristics of the ambient background seawater that mixes with (dilutes) the discharged effluent. Subsequently, CTD casts were performed at the location of drifters as they move from the diffuser location. These CTD casts provide a measure of the evolution of water parcel (as tagged by drifters) properties as they move from the effluent discharge location and mix with the ambient seawater. All drifters were recovered at the end of each sampling day, giving tracks that are hours in length.

The core of the CTD system was a Sea-Bird SBE19-plus, which sampled at 2 Hz. Salinity data are calculated from conductivity and temperature data, and water density data are calculated from salinity and temperature data. Depth is obtained from a pressure sensor. Connected to the CTD were a transmissometer (WET Labs C-Star), which measured the attenuation of light transmission as a measure of turbidity, and a fluorometer (WET Labs WETStar), which measured fluorescence at wavelengths that provide a measure of the CDOM concentration. Immediately after each drifter deployment a profile was obtained at the source (providing a measure of the initial properties of the surface plume) and a second profile obtained upstream of the source (providing a measure of the properties of the ambient surface ocean water). Subsequent profiles were obtained approximately hourly at each drifter as it was advected by the ambient currents and as plume waters were diluted by mixing with ambient ocean waters (Figure 3.15). A total of 156 10 m-deep profiles were obtained from 11 days of field sampling. The level of dilution D of a freshwater plume with ambient seawater can be calculated from $D = S_{oc}/(S - S_{oc})$, where S is the salinity of the sample and S_{oc} is the salinity of the ambient ocean water.

The entire observational plan described above (deploy drifters, perform CTD casts above the diffuser and upstream of effluent plume, and CTD casts following drifter motion) was repeated at one or two other times during the day to capture temporal variations in the advection and eddy diffusion of plume waters. Individual drifter trajectories indicate absolute motion of plume water. This quantity allows the goal of plume water pathways to be realized. Deploying drifters in clusters allows the motion of drifters relative to other drifters to be observed. Both relative dispersion and eddy diffusivity are easily computed from relative drifter motion observations. These quantities inform on horizontal mixing, and enable the horizontal mixing goal to be realized.

Horizontal mixing is hypothesized to be the primary physical process that drives plume dilution. Measuring salinity (a generally conservative plume tracer) in a Lagrangian frame (i.e. following plume waters via drifter observations) provides a direct measurement of plume concentration as the plume evolves in both time and space. Horizontal mixing values quantified with drifter observations can then be reconciled with the directly observed plume concentration (salinity) values. The quantities enable the goal of quantifying plume mixing/dilution to be realized in two ways, each from independent observations.

1. Drifters have known limited slip (< 0.01% of the wind speed).
2. Drifter position is measured by GPS to a standard deviation of roughly 3 m.
3. CTD calibration occurred within the last 3 years.
4. CDOM fluorometer calibration occurred on 2 December 2010.

Velocity is computed as a centered difference in drifter position (first difference at endpoints). CTD data are analyzed using the recommended sequence of Sea-Bird's *SeaSoft* software modules and settings. Downcast and upcast profile data are separated and only downcast data (with a near constant decent rate) are presented. Depth averaging is not performed to maximize vertical resolution. Drifter and CTD data are analyzed together using Matlab software. CDOM data will be compared with similar data collected by other project investigators. A number of issues regarding the CDOM data are to be subsequently investigated, including CDOM values < 0 (see Figure 3.23).

Obtaining a small boat (skiff) for the proposed work was a significant challenge. A recent change to University of California (UC) policy recommends that all boats chartered by UCSB carry five million dollars of liability insurance coverage. A small boat with the recommended insurance could not be found. Attempts to increase the insurance coverage of small boats with lesser coverage failed as the recommended policy could not be found by numerous insurance agencies contacted. The challenge was overcome by using boats owned by the UC system. However, such boats were available for limited use. Eventually UCSB Risk Management waived the recommended liability coverage and allowed the charter of a boat with one million dollars of liability insurance.

Results

A total of 123 drifter trajectories were collected during 11 sampling days. Drifter observations indicate primarily onshore and alongshore movement away from the diffuser (Figure 3.17). The number of trajectories moving up-coast is similar to that moving down-coast. Net offshore drifter motion, where the ending position of drifter tracks was seaward of the diffuser, was only clearly observed on a single day (01 October 2012; Figure 3.18). Velocities range from a few cm/s to roughly 35 cm/s (Figure 3.19). The largest velocities generally appear at locations relatively distant from the diffuser and late in the day when the local sea breeze was relatively large. The observed flow patterns are consistent with the regional circulation forced primarily by local winds and a large-scale pressure gradient. The general onshore motion is consistent with the local sea breeze that typically blows onshore during midday and afternoon. Some of the onshore drifter movement is likely the result of Stokes drift. Tides also play a role in the circulation.

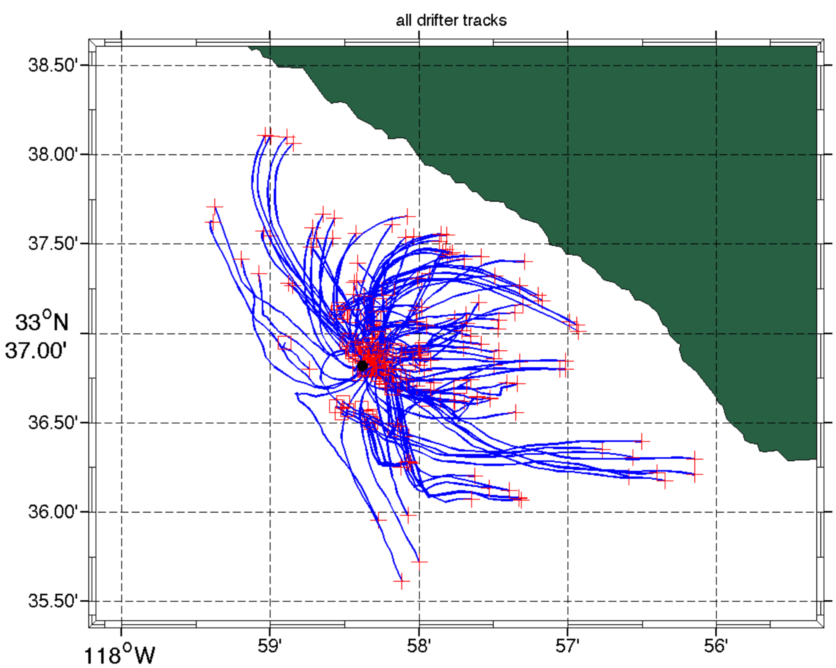


Figure 3.17 *All drifter data collected during the project are included. The vast majority of drifters were deployed at the OCSD diffuser location indicated with a black dot. The first position recorded by each drifter is shown with an open red square. The ending position of each drifter track is indicated with a red plus.*

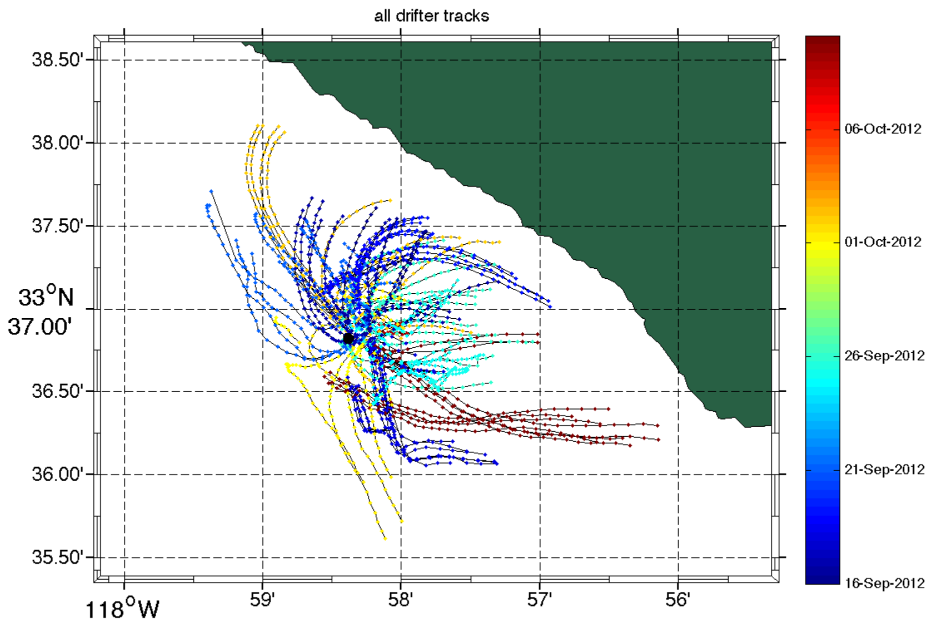


Figure 3.18 *All drifter data collected during the project are included. Dots show position data collected every 10 minutes. Color indicates sampling time of the various trajectories. The black dot gives the diffuser location where drifters were generally deployed. Drifter tracks were hours in length*

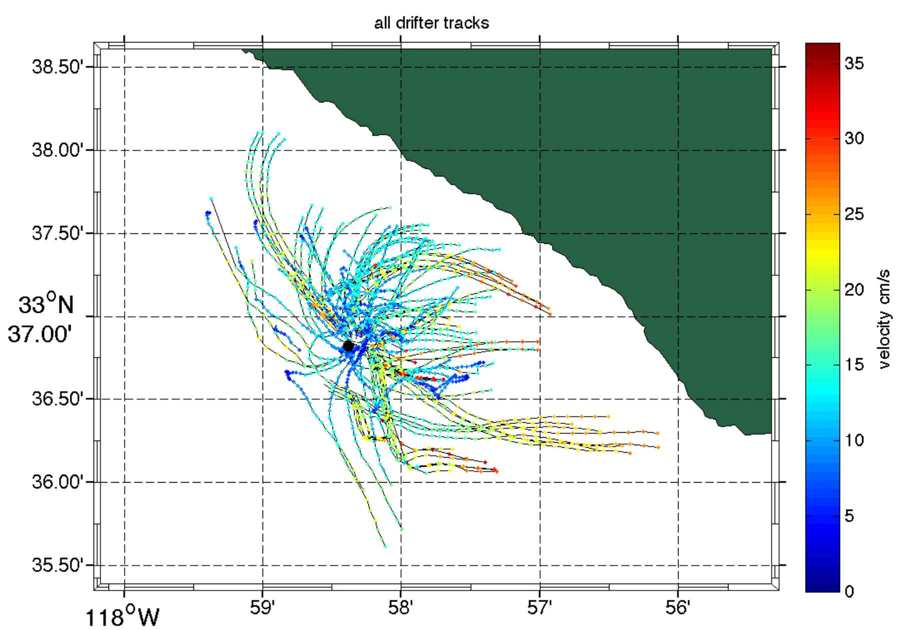


Figure 3.19 *All drifter data collected during the project. Dots show position data collected every 10 minutes. Color indicates velocity (cm/s), computed as a centered difference in position observations. The black dot gives the diffuser location where drifters were generally deployed.*

I) CTD Data

As the effluent plume is mainly fresh water, its density is less than the saltier ocean waters and it is driven upward to the surface by buoyancy forces. As the plume rises, its salinity steadily increases as it mixes with ambient ocean waters. Water parcels consisting of mixtures of effluent and ocean waters may be identified by their lower salinity compared with background ocean waters. The salinity difference between the background ocean salinity Sb and the measured salinity of a mixture of effluent and ocean water Sm is related to the dilution D according to the equation D = (Se-Sb)/(Sm-Sb) = Sb/ΔS, where Se is the salinity of the effluent and ΔS = Sb-Sm. Calculations of dilution considering both salinity and CDOM are forthcoming.

A total of 156 CTD profiles were collected during 11 sampling days. Lower salinity water due to the presence of the fresh effluent plume is clearly evident in the temperature-salinity (T-S) diagram. Observed salinity values range from 31.9 to 33.7 psu (Figure 3.20). The freshest waters observed are from CTD casts taken at the diffuser location. Further, the freshest waters are generally near the surface, consistent with fresh buoyant effluent plume dynamics and a shallow water diffuser (Fischer et al. 1979). Fresh waters appear to be relatively cool. This is consistent with the idea of discharged effluent mixing with relatively cool water near the bottom, and effluent dynamics forcing the movement of cool bottom waters toward the sea surface. As an example, consider the observations in Figure 3.20 where salinity is near 32 psu and T is near 18 C. Those values are observations made near the surface as they indicate the lowest sigma-t values (~22.87) for the profile. T-S diagrams are given for each day in Appendix IV Section C. Occasionally, during low wind conditions, the buoyant effluent plume water was visible with the naked eye (Figure 3.21).

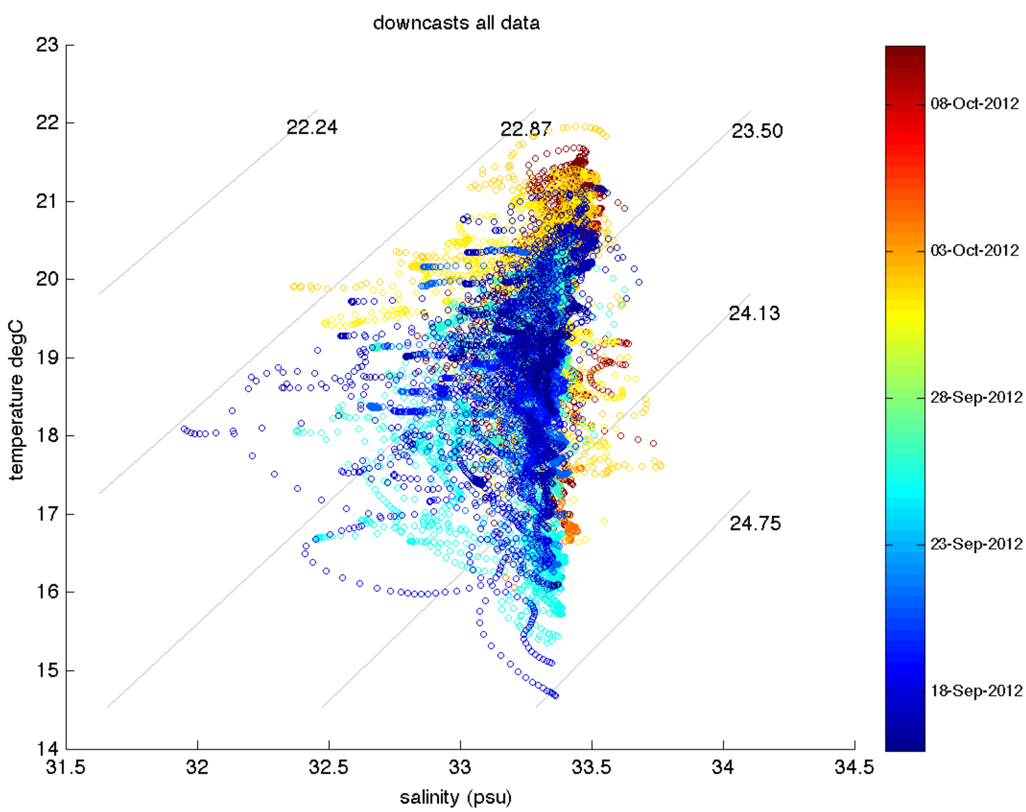


Figure 3.20 *T-S diagram from all downcast CTD data collected during the project. Data are from CTD casts collected at the diffuser, upstream of the diffuser, and at locations of drifters as they move from the diffuser. CTD casts from two days with no discharge from the 78-inch diffuser are also included. Color indicates CTD cast time. The range of salinity values clearly illustrates the presence of the fresh salinity plume. Light grey lines give density (sigma-t) contours.*

__Figure 3.21__ Photograph showing the effluent plume front on 17 September 2012. Green-brown water on right side of image is relatively fresh effluent plume water. Blue water on left side of image is background ocean water. The drifter and "foam line" show surface convergence at the front.

II) CDOM Data

CDOM typically arises during the decomposition of both marine and terrestrial plant material. When present in high concentrations, it gives water a yellowish-brown color. CDOM in the coastal ocean comes largely from rivers containing decomposed organic materials, but can also come from discharged effluent. The freshwater source suggests an inverse relationship with salinity so that CDOM can be used as a natural plume tracer. A recent study by Rogowski et al. (2012) made laboratory measurements of CDOM concentration as a function of effluent dilution and shows that for every ten-fold increase in effluent dilution, CDOM concentration decreases by roughly a factor of 10 (Figure 3.22).

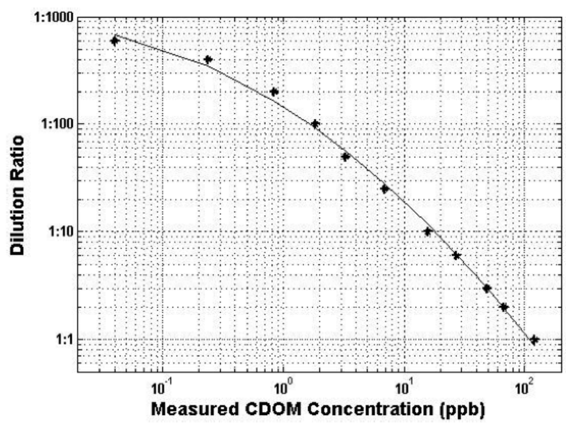


__Figure 3.22__ Laboratory measurements of CDOM concentration as a function of the dilution of effluent obtained from the Point Loma Wastewater Treatment Plant. Figure taken from Rogowski et al. (2012). Figure shows the sensitivity of CDOM to effluent concentration.

CDOM measurements during the 11 days of sampling generally range from < 0 to roughly 20 ppb (Figure 3.23). Given the dry (i.e. no rain and no freshwater run-off from land) conditions during the sampling, the large CDOM values observed are presumably associated with the discharged effluent plume. CDOM values are typically elevated near the surface and decrease with depth, consistent with the buoyancy of effluent plume waters. CDOM values recorded outside the effluent plume are generally a few ppb.

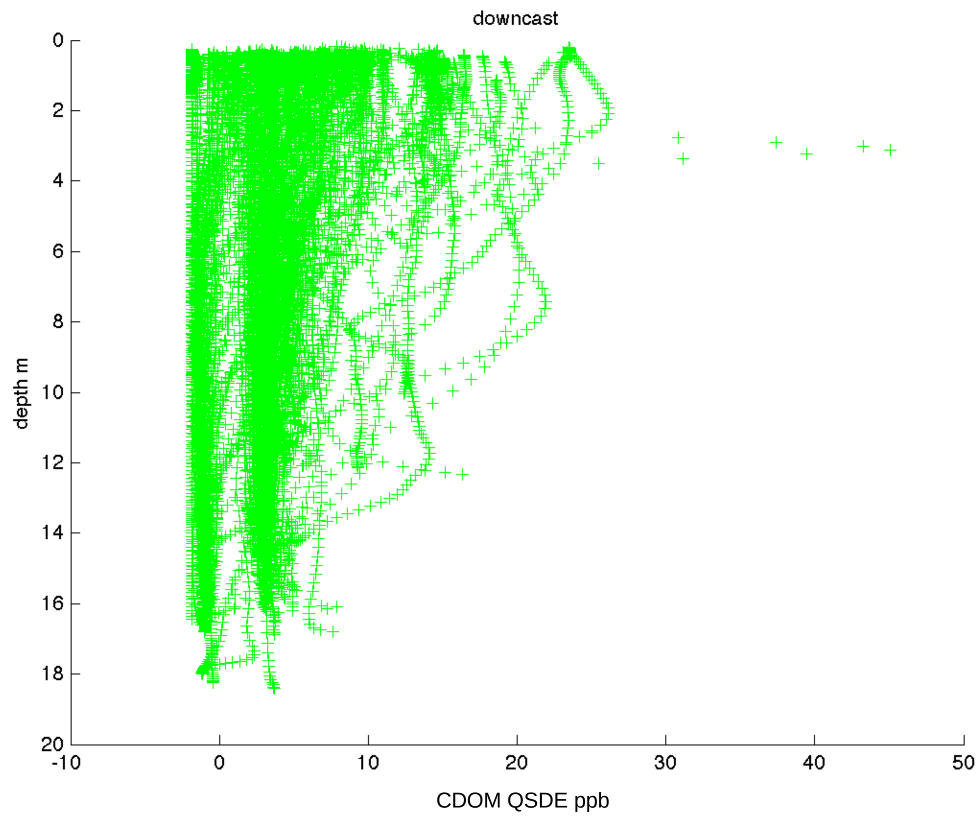


Figure 3.23 *CDOM concentration as a function of depth from all 156 CTD downcasts performed during the observation period. CDOM concentration is expressed as Quinine Sulfate Dihydrate Equivalent in parts per billion (ppb). CDOM values < 0 thus indicate an issue with instrument performance and/or calibration.*

Interestingly, CDOM values observed on 9 and 10 October, after the OCSD diversion ended, are occasionally large (> 10 ppb; see figures for 9 and 10 October in Appendices IV Section B and Appendix IV Section D) despite the presumed absence of the shallow diversion plume. While these large values exist in the upper ocean, they do not typically extend to the sea surface as is the case for CDOM data collected during the diversion. Further, the large values are patchy in space (see last figure in Appendix IV Section B). It is hypothesized that the large CDOM values are associated with effluent discharged from the deep diffuser. Since there was neither monitoring at the deep diffuser, nor following of drifters moving from the location of the deep diffuser, data are insufficient to test the aforementioned hypothesis.

A number of issues regarding the CDOM data are to be subsequently investigated. First and foremost, a significant number of CDOM values are < 0 (Figure 3.23); and negative concentration values are not possible in nature. The CDOM fluorometer does not directly measure CDOM. Rather, it records a voltage that is converted to CDOM concentration through an empirical calibration formula. The negative values can arise if the "clean water offset" parameter in the calibration formula is erroneous. Also, poor cable connections between the fluorometer and CTD can result in an erroneous voltage being recorded. It is hypothesized that both the cable connection and clean water offset contribute to the existence of negative CDOM values.

The Rogowski et al. (2012) laboratory study indicates that the CDOM value for a 1:100 dilution of effluent is roughly 2 ppb (Figure 3.22). Data collected as part of this study give CDOM values that can be a factor of 10 larger (Figure 3.23). Despite the relatively large CDOM values observed, it is doubtful that plume waters are less diluted than 1:100. The effluent diffuser is expected to give a near-field dilution of at least 1:100 (Fischer et al. 1979), and back of the envelope calculations using salinity data as a tracer suggest similar. The last obvious issue with CDOM data is the anomalously large spike in CDOM to near 45 ppb. It remains to be determined when, where and why this spike occurred.

As previously mentioned an inverse correlation between CDOM and salinity is expected and both parameters are expected to have utility as natural plume tracers. Subsequent analyses that include computation of correlations and dilutions using both parameters are expected to inform on the verity of CDOM observations. Comparison with CDOM measurements made by other investigators during the effluent diversion period will also inform on the CDOM observations presented here.

III) Plume Concentration Following Plume Motion

Examination of CTD data following drifters that tag plume waters gives direct observation of the Lagrangian (i.e. time and space) evolution of plume concentration. This combined information is extremely important as it serves to link tracer concentrations at locations distant from the effluent diffuser to effluent plume waters. Salinity and CDOM concentrations following plume motion on 16 September 2012 are shown in Figures 3.24 and 3.25, respectively. Data for this day are used as an illustration because there are relatively few observations during the day, making for ease and clarity of description. Similar figures for all observation days are given in Appendix IV Section A (salinity) and Appendix IV Section B (CDOM).

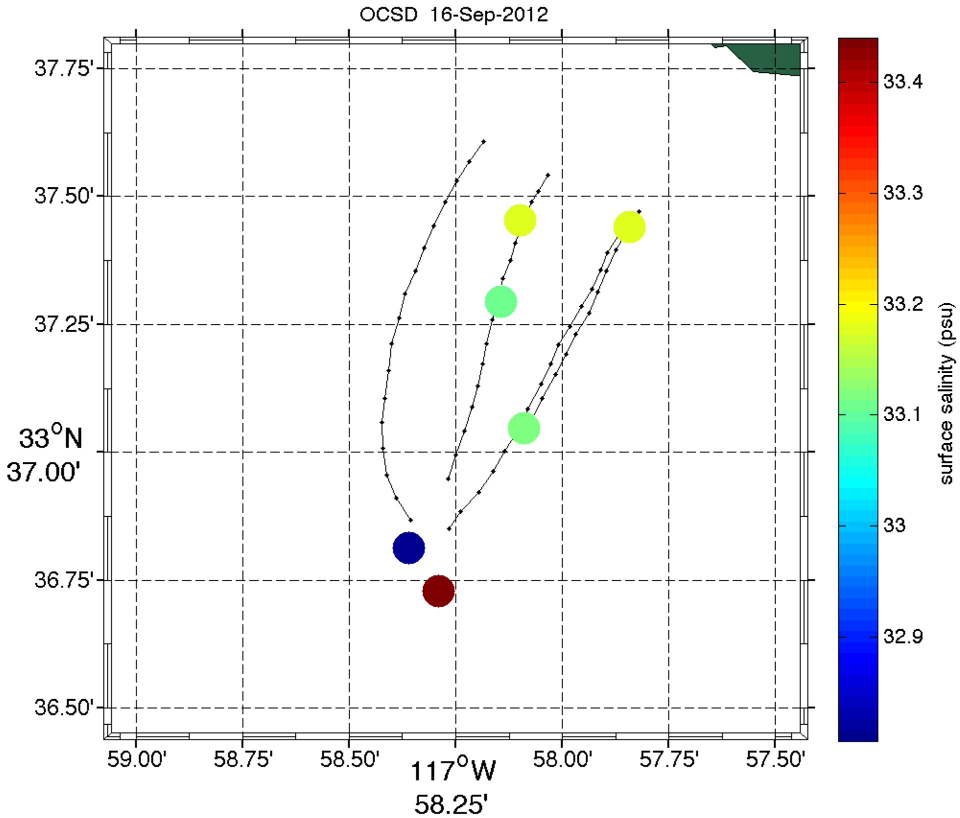


Figure 3.24 *Surface salinity concentration following drifter (plume) motion on 16 September 2012. Black lines give the tracks of 4 drifters that move northward from the effluent diffuser location. Black dots give drifter positions recorded every 10 minutes. Surface (top 2 m) salinity concentration following drifter (plume) motion is given by large colored dots. Large red dot gives background ocean salinity (~33.4 psu) just upstream of effluent discharge. Discharged effluent is essentially fresh. Large blue dot gives salinity (~32.9 psu) above effluent diffuser just after discharge. The progression of salinity values from ~32.9 psu (blue), to ~33.1 psu (green) to 33.2 psu (yellow) during the first 2 hrs after discharge is consistent with background seawater (33.4 ppt) diluting relatively fresh effluent.*

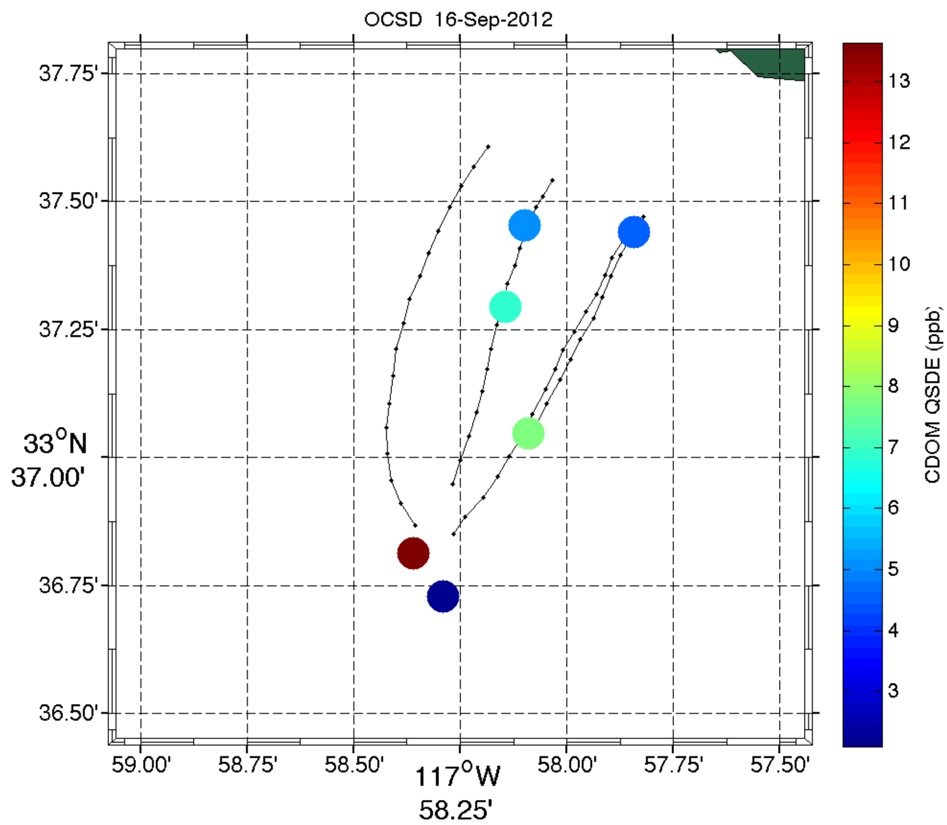


Figure 3.25 *As in Figure 3.24 with CDOM used as a tracer. CDOM decreases following drifter (motion) as discharged effluent that is high in CDOM is diluted with background ocean water that is low (~3 ppb) in CDOM concentration.*

Data for 16 September 2012 shows surface salinity = ~32.9 psu above effluent diffuser just after discharge (discharged effluent is essentially fresh). Background water upstream (south) of the discharged effluent has surface salinity = 33.4 ppt. The progression of surface salinity from ~32.9 psu (blue dot in Figure 3.24), to ~33.1 psu (green dot in Figure 3.24) to 33.2 psu (yellow dot in Figure 3.24) during the first 2 hrs after discharge is consistent with background seawater (33.4 psu) diluting relatively fresh effluent. Similar dilution following plume motion is evident in CDOM (Figure 3.25). Just after discharge above the diffuser, surface CDOM in the plume = 13 ppb. Background water upstream (south) of the discharged effluent has surface CDOM = 3 ppb. The progression of surface CDOM from 13 ppb (red dot in Figure 3.25), to ~7 ppb (green/aqua dots in Figure 3.25) to ~5 ppb (blue dots in Figure 3.25) during the first 2 hrs after discharge is consistent with background seawater diluting effluent water. Corresponding vertical profiles of salinity and CDOM show how plume waters are mostly confined to the surface region (Figure 3.26).

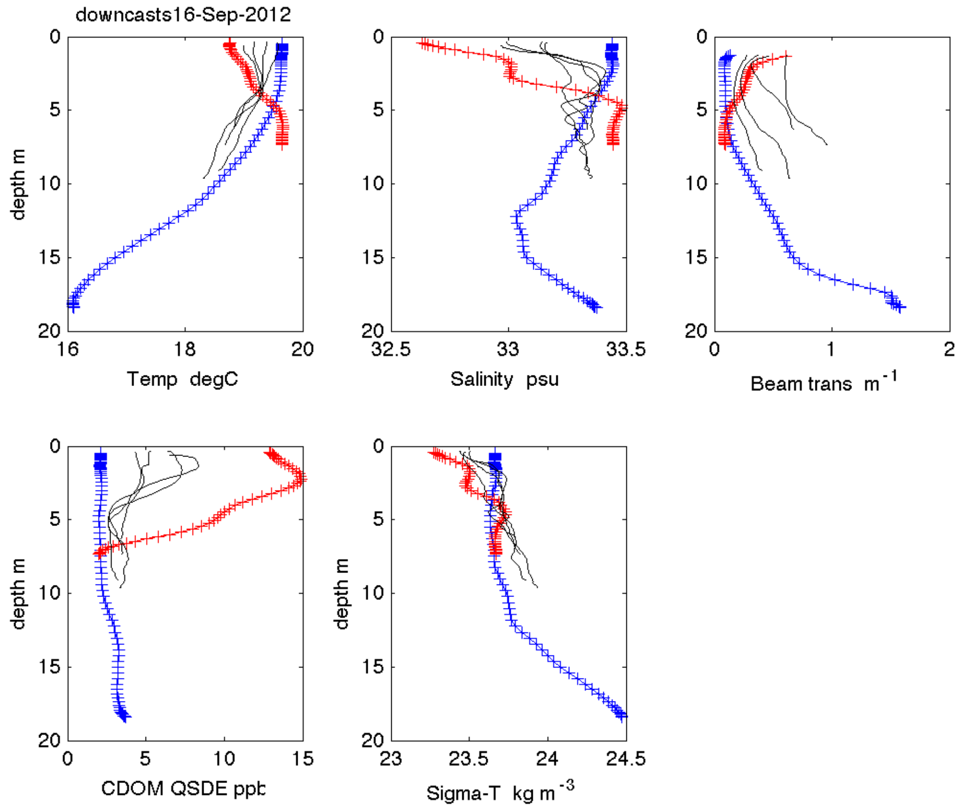


Figure 3.26 Vertical profile data on 16 September at the CTD locations (colored dots shown in Figures 3.24 and 3.25. Variables shown in top row are temperature, salinity, and transmission. Variables shown in the bottom row are CDOM and density. In all panels blue profiles show data just upstream of the effluent plume (i.e. high salinity and low CDOM), red profiles show data just above the diffuser (i.e. relatively fresh water with high CDOM concentration), and black curves show a mixing of background and plume water following drifter (plume) motion.

C) REMUS AUV – Eric Terrill, SIO

Overview

One REMUS Autonomous Underwater Vehicle (AUV) mission was performed on 9/28/2012 (Figure 3.27) to monitor the fate and transport of the diverted discharge.

Table 3.14 REMUS AUV Bounding Box	**Latitude**	**Longitude**
Upper West Lat/Lon	33º 37.800	-118º 1.200
Upper East Lat/Lon	33º 37.800	-117º 57.600
Lower West Lat/Lon	33º 36.00	-118º 1.200
Lower East Lat/Lon	33º 36.00	-117º 1.200

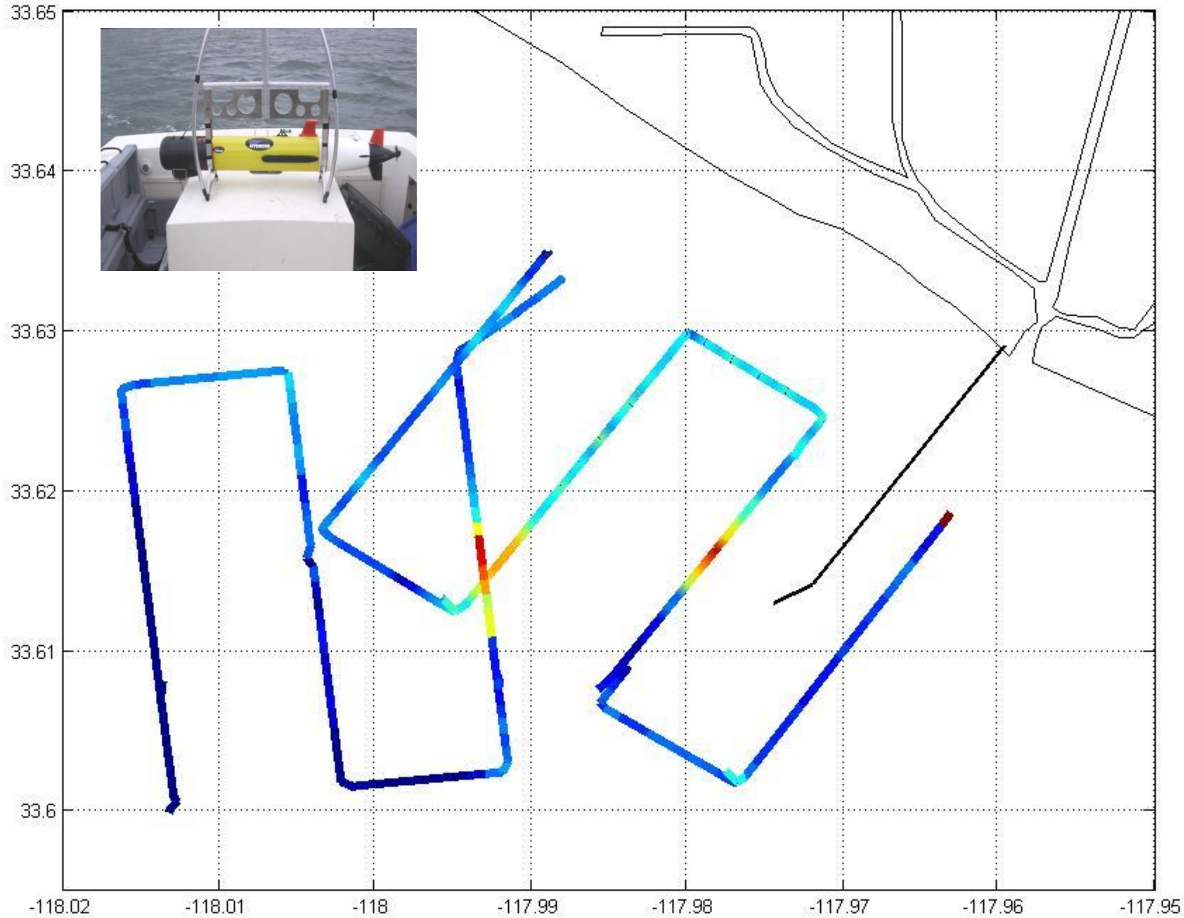


__Figure 3.27__ REMUS AUV and its mission path

Methods

For monitoring the fate and transport of plume discharges, CORDC scientists utilize velocity and temperature profile sets to accurately program the REMUS to capture the advecting plume signature. Datasets are reviewed daily to determine whether conditions indicated either northward or southward advection of the plume. The most probable missions would be planned prior to sampling based on near real-time oceanographic conditions at the outfall as monitored by the buoy.

One REMUS AUV (Figure 3.27) survey was performed on September 28, 2012 to monitor the fate and transport of the diverted discharge. The AUV has a 100 m depth rating and 22 hour battery capacity when transiting at 3 knots. It has a diameter of 0.2 m, a length of 1.8 m, a weight of 38 kg, and is ballasted to be slightly buoyant. Survey life is a function of speed, and decreases to 8 hours at maximum speeds of approximately 5 knots. The system uses a compass for heading, Doppler Velocity Log (DVL) for speed and altitude over seafloor, pressure sensor for depth, GPS for surface navigation, and optional acoustic transponders for precise navigation (Table 3.15). Survey mission profiles can be uploaded and data downloaded through a computer interface using a wireless connection. The vehicle is hand launched by a crew of two operating from a small boat. At start, the vehicle obtains a GPS fix to initialize its navigation prior to diving. During the mission, the vehicle relays its position, status, and engineering data using an underwater acoustic modem message to a receiver in the boat on a preconfigured interval, typically every 2 to 3 minutes. In addition, the shipboard system allows ranging to the vehicle as well as having the capability to send low level commands (start, stop, and abort). Upon completion of the mission, the vehicle is recovered from the surface. The sensors used for these surveys include a 1200-kilohertz (kHz) Acoustic Doppler Current Profiler (ADCP, Teledyne, RD Instruments, Poway, CA), a fast response, high resolution, Conductivity, Temperature, and Depth (CTD, Neil Brown Instruments, Falmouth, MA) sensor and optical fluorometers calibrated to measure backscatter at 650 nm and 880 nm, and CDOM with a range of 0-375 ppb and a sensitivity of 0.09 ppb.

Instrument Information

Table 3.15	**REMUS AUV**	
Sensor	**CDOM**	**ADCP**
Make	WET Labs	Teledyne RDI
Model	ECO Puck	1200kHz ADCP
Firmware	N/A	
Accuracy	±2% accuracy at CDOM fluorescence equivalent to 10 ppb QuSO4 Backscatter 650 & 880 nm: 0.005m̄¹ at 1Hz	±0.3% of measured velocity
Precision	CDOM: 0.09 ppb QS	0.1 cm/s
Sample rate	2 Hz	1Hz
Sample interval	Continuous	Continuous
Constituents measured	CDOM and Backscatter at 650nm & 880 nm	Current Velocity
Quantity	1	1
Additional Comments	1 mobile mission	Data delivery is self contained ASCII

Results

AUV Far-Field Survey

Near real-time plume trajectory estimates from the SIO buoy were monitored for the days preceding the September 28, 2012 monitoring mission. Due to the variability of the currents in the hours leading up to the mission, the final AUV path was not finalized until just before deployment of the vehicle. The final path was optimized to sample the most probable locations of the plume over the previous 12-hour period (Figure 3.28). After completion of the initial path (Figure 3.28a), CDOM observations were downloaded and analyzed to determine the effectiveness of the initial path at capturing the advecting plume. The analysis revealed that the northwestward alongshore advection of the plume extended to approximately 1.5 km from the 78-inch discharge (Figure 3.29). Instead of continuing in the alongshore direction, a new AUV path was programmed into the vehicle in an attempt to capture the plume's advection offshore (Figure 3.28b). CDOM observations from the new path show minimal additional movement offshore, thus confirming the location of the stalled plume (Figure 3.30).

The elevated CDOM signature within the plume also reveals that the plume did not fully surface, with a significant portion of the plume remaining at a depth of ~10 m. A contour plot of CDOM concentration versus depth illustrates the spatial patchiness of the plume in both the horizontal and vertical directions (Figure 3.31).

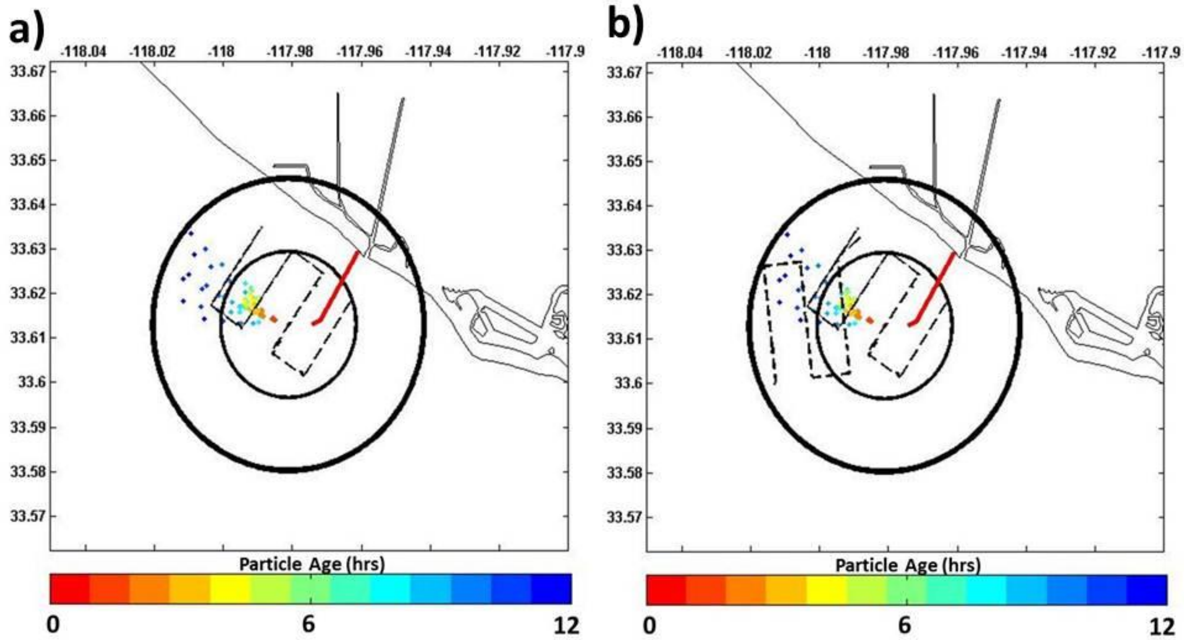


Figure 3.28 *a) Optimized REMUS path based on September 28, 2012 plume trajectory estimates derived from SIO buoy for a depth range of 5 - 10 m and b) adaptive path planning during the mission based on mid-mission downloaded AUV observations*.

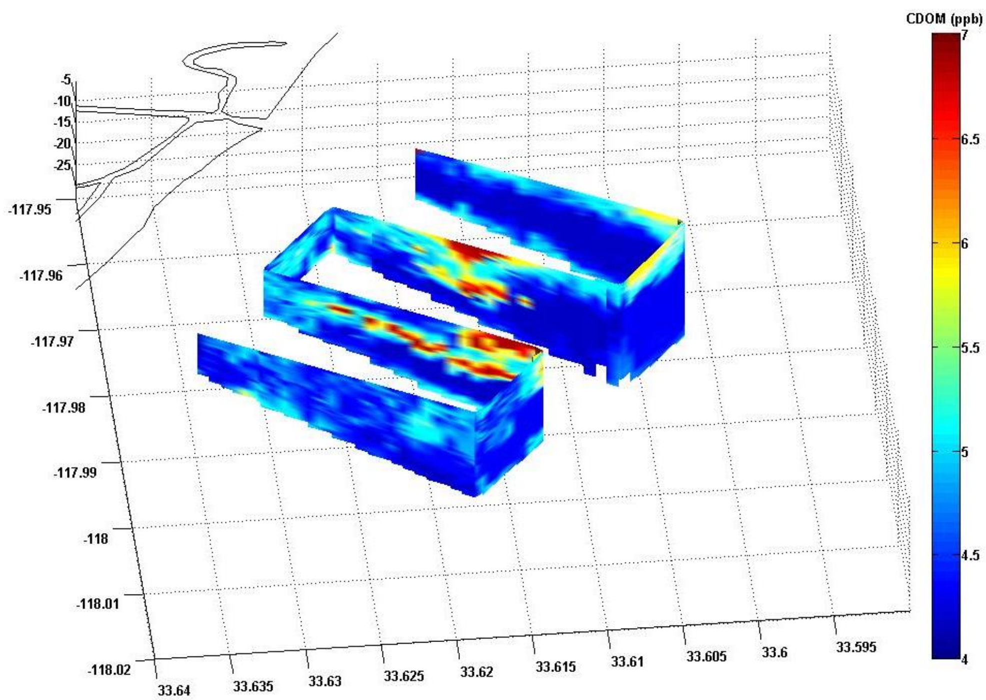


Figure 3.29 *The elevated CDOM signature of the plume denotes its characteristics as it advects in the alongshore direction.*

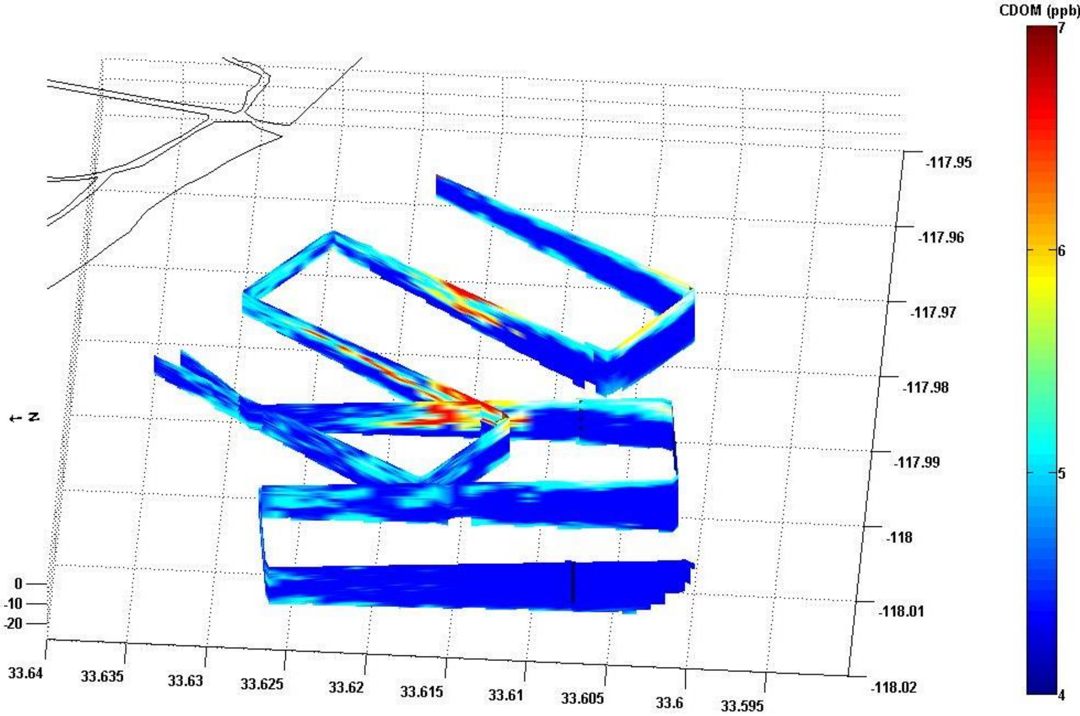


Figure 3.30 *CDOM observations from secondary AUV monitoring path.*

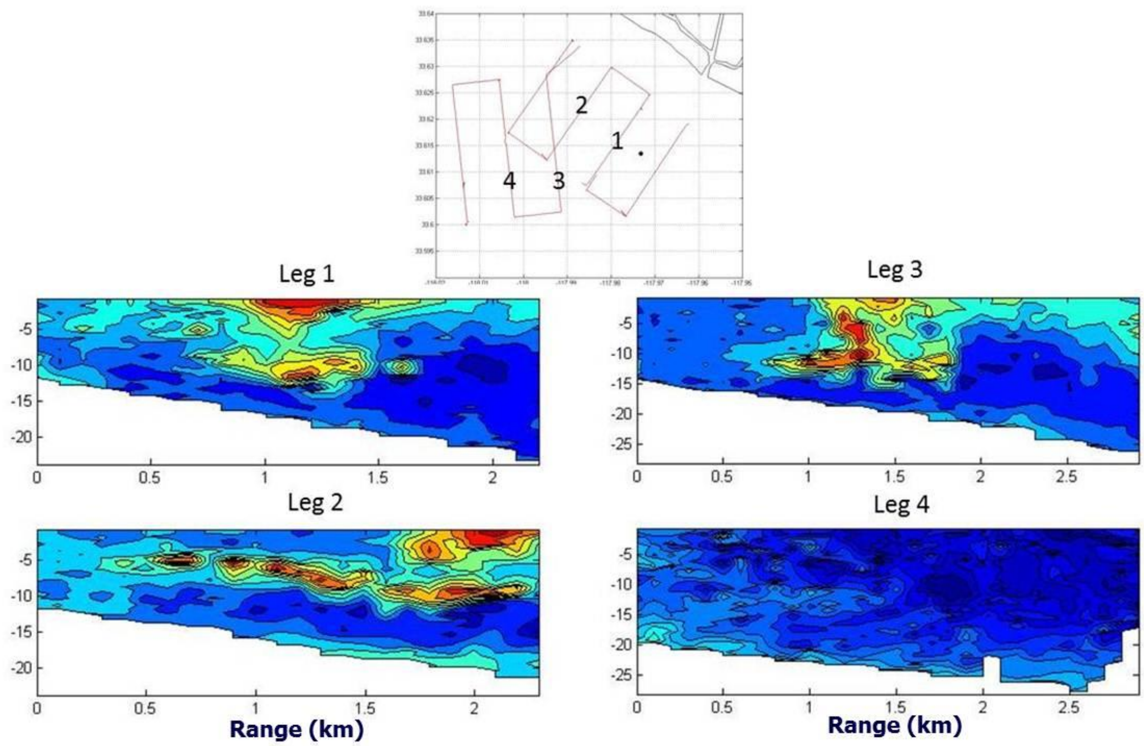


Figure 3.31 *Contour map of CDOM profiles illustrating the plume suspension.*

Post-mission analysis of the pre-, during-, and post-mission particle trajectory estimates revealed that the AUV monitoring mission was performed during a transition from a northwestward alongshore flow to a southeastward alongshore flow, resulting in a dynamic current field in the OCSD study region. The observed currents from the AUV-mounted ADCP confirm the complexity of the current field. While not synoptic (~5 hr mission time), the observations suggest the forcing mechanisms responsible for the reversal of the front (Figure 3.32). At the onset of the mission, significant northwestward currents were measured offshore. They diminished with each successive survey leg. The final leg of the initial mission (leg 4) saw a current reversal resulting in the stalled plume front. Approximately 1.5 hrs later the depth averaged currents towards the southern end of leg 5 have shifted to a westward direction, however 1 km west of leg 5; the currents are again reversed toward an eastward direction (leg 6). The current field suggests that the plume is being stalled by these reversals in current directions from leg 3 to leg 4 and from leg 5 to leg 6.

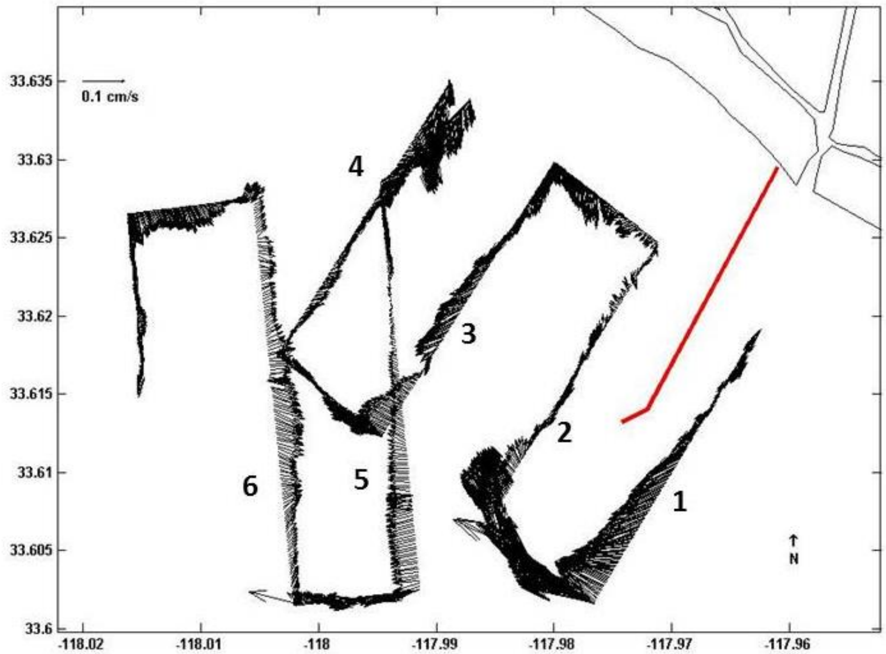


Figure 3.32 *Depth averaged currents from REMUS ADCP.*

AUV Near-Field Surveys

A near-field mission consisting of 4 - 100 m spaced survey lines was performed directly over and adjacent to the diverted discharge from the 78-inch outfall. Mission deployment was approximately 6 hours after the initial far-field monitoring mission yielding a consistent southeastward alongshore current direction (Figure 3.33). Peak CDOM concentrations of ~25 ppb were observed directly over and just southeast of the 78-inch outfall. The lack of "old" plume in the northern survey lines suggests that the earlier observed plume to the north of the discharge had advected south of the outfall at the time of this survey. We note a position error that resulted in leg 4 being just north of leg 3 (~10 m horizontal difference), but the legs are shown with 100 m spacing for better plume visualization (Figure 3.34). This minimal positional difference led to significantly different plume profile observations with leg 3 still showing the rising plume, while observations during leg 4 show the plume has predominantly surfaced, illustrating the challenge in capturing the dynamic near-field plume environment (Figure 3.34).

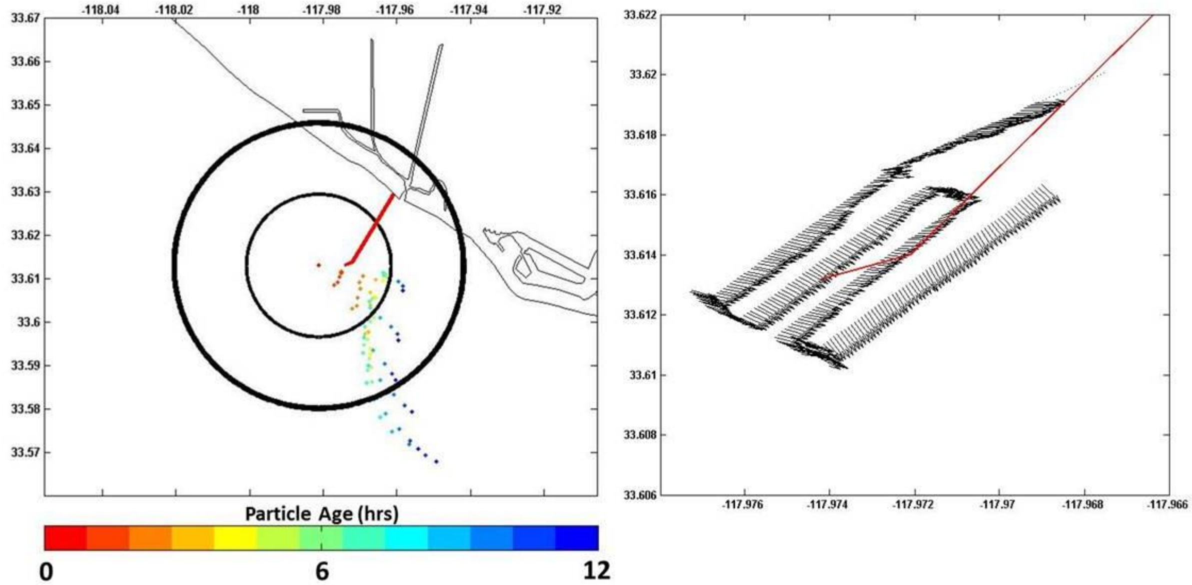


Figure 3.33 *a) Plume trajectory estimate for 12-hour period starting at beginning of near-field mission and b) observed depth averaged currents from AUV.*

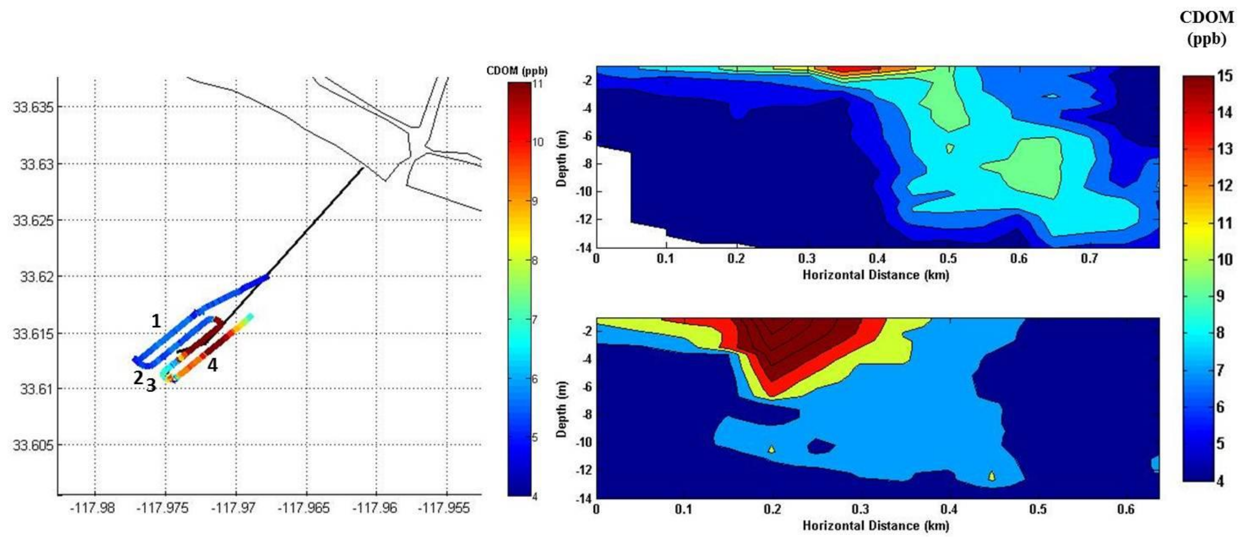


Figure 3.34 *AUV CDOM observations during the near-field monitoring mission shown in a) plan view and b) profile for legs 3 (top) and 4 (bottom).*

The September 28, 2012 REMUS AUV monitoring mission successfully tracked the initial northwestward alongshore movement of the discharge plume using the natural plume tracer CDOM. The variability of the currents affecting plume advection on hourly timescales was evident as a reversal of the currents to a southeastward direction was observed during the far-field survey. The subsequent near-field survey confirmed that the currents had reversed from earlier observations measured in the vicinity of the outfall thus advecting the plume in a southeastward direction. Adaptive mission planning based on the near real-time current data from the OCSD diversion buoy and near real-time data downloads from the AUV were essential in tracking the discharge.

D) Satellites – Ben Holt, NASA JPL

Overview

Two satellite sensor collections were organized, intended to identify sea surface temperature and ocean optical properties that were related to the diversion; ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) and NASA's EO-1.

Figure 3.35 *Artist's concept of Terra satellite. Image credit: NASA*

Methods

The first instrument is ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer), an imaging instrument flown on NASA's Terra satellite, which was launched in December 1999 (Figure 3.35). ASTER is a cooperative effort between NASA and Japan's Ministry of Economy and has been designed to acquire land surface temperature, emissivity, reflectance, and elevation data. ASTER has both visible and near infrared channels as well as thermal infrared (TIR), with the latter of primary interest due to its capability to detect SST at 90 m resolution, which we thought would be advantageous over the coarser resolution MODIS SST data (250 m resolution) because of the fine-scale nature of the anticipated signals. The TIR channels range from 8.125 to 11.65 microns. Each ASTER frame is 60 by 60 km and adjacent frames are collected upon user request.

The second satellite is NASA's EO-1, which carries two sensors, Advanced Land Imager (ALI), and Hyperion. ALI is a multispectral sensor with 30 m resolution and a 37 km swath. The Hyperion sensor is a hyperspectral sensor also with 30 m resolution with a narrow swath of 8 km, which is contained within the ALI swath. There was also an image from HICO, a hyperspectral imager focused on ocean color which is carried onboard the International Space Station.

Instrument Information

Table 3.16	NASA Terra Satellite	NASA EO-1 Satellite	International Space Station
Sensor	ASTER (advanced spaceborne thermal emission and reflection radiometer)	Advanced Land Imager (ALI) and Hyperion	HICO
Constituents measured	Sea surface temperature Thermal infrared (TIR) detected SST at 90 m resolution. TIR channels range from 8.125 to 11.65 microns. Each ASTER frame is 60 x 60 km	Multispectral sensor with 30 m resolution and a 37 km swath. The Hyperion sensor is a hyperspectral sensor also with 30 m resolution with a narrow swath of 8 km that is contained within the ALI swath.	Ocean color
Quantity	1	1	1
Additional Comments	These acquisitions were obtained upon user request in conjunction with John Ryan from MBARI		

Deployment Information
Two satellite sensor collections were organized (Tables 3.17-3.19), intended to identify sea surface temperature and ocean optical properties that were related to the diversion.

Table 3.17 ASTER satellite collections for OCSD Diversion **Aster:** http://asterweb.jpl.nasa.gov/		
Date – Day of the year	Time UTC	Description
9/06/12 - 249	05:59:25	Cloudy
9/07/12 – 250	18:45	Clear
9/16/12 – 260		Not acquired
9/22/12 – 266	05:59	Cloudy
9/23/12 – 267	18:45	Clear
9/29/12 – 273	06:05	Santa Monica Bay, partial clouds
10/01/12 – 275	05:53	No coverage
10/02/12 – 276	Day	
10/08/12 - 282	05:59	

Table 3.18 EO-1/Hyperion satellite for OCSD Diversion **EO-1/Hyperion:** http://eo1.usgs.gov/			
Date – Day of the year	Time UTC	Location	Description
9/13/12 – 257	17:59	39.29 EAST	Cancelled
9/16/12 – 260	18:13	38.08 WEST	Not planned
9/21/12 – 265	18:04	40.69 NADIR	Partial clouds
9/24/12 – 268	18:19	39.77 WEST2	Not obtained
9/26/12 – 270	17:55	43.32 EAST2	Clear
10/09/12 - 283	17:51	47.58 EAST2	Collected

Table 3.19 HICO satellite for OCSD Diversion **HICO: http://hico.coas.oregonstate.edu/schedule/schedule.php**			
Date – Day of the year	Time UTC	Location	Description
9/22/12 - 266	17:27:07	Platform Eureka	Clear

Results

Three ASTER images were processed to SST (Figure 3.36). The pre-diversion image illustrates the general character of SST in the region, with warmer water to the south. The September 23 image shows fine temperature structure extending offshore and to the south of OCSD. An enlargement is shown in Figure 3.37. The outfall plume was identified upon close inspection as a cold signature. The post-diversion image seems to indicate slightly colder water in the Newport Harbor region, which may be remnants from the diversion.

Useful imagery of the diversion region was not obtained from EO-1 due to clouds and difficulty of processing for ocean information (Figure 3.38).

No satellite Synthetic Aperture Radar (SAR) imagery was obtainable, as the three satellites stopped working within a year of the diversion. Such imagery was successfully obtained during the Hyperion diversion in 2006 and should be available the next time a local diversion takes place.

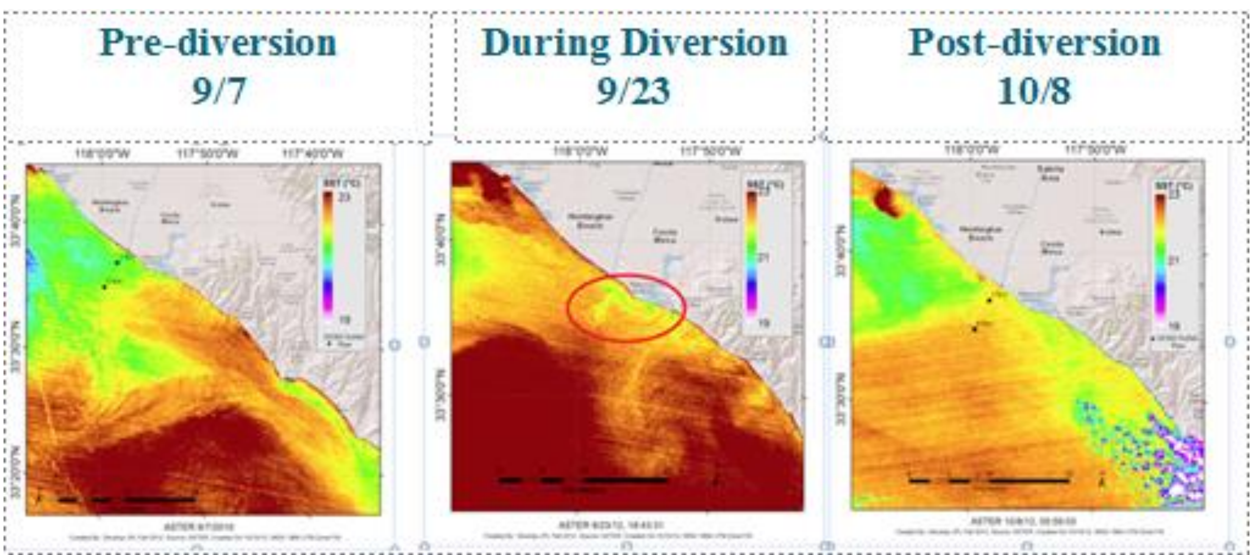


Figure 3.36 *ASTER image from September 7 (pre-diversion), September 23 (during the diversion), and October 8 (post-diversion).*

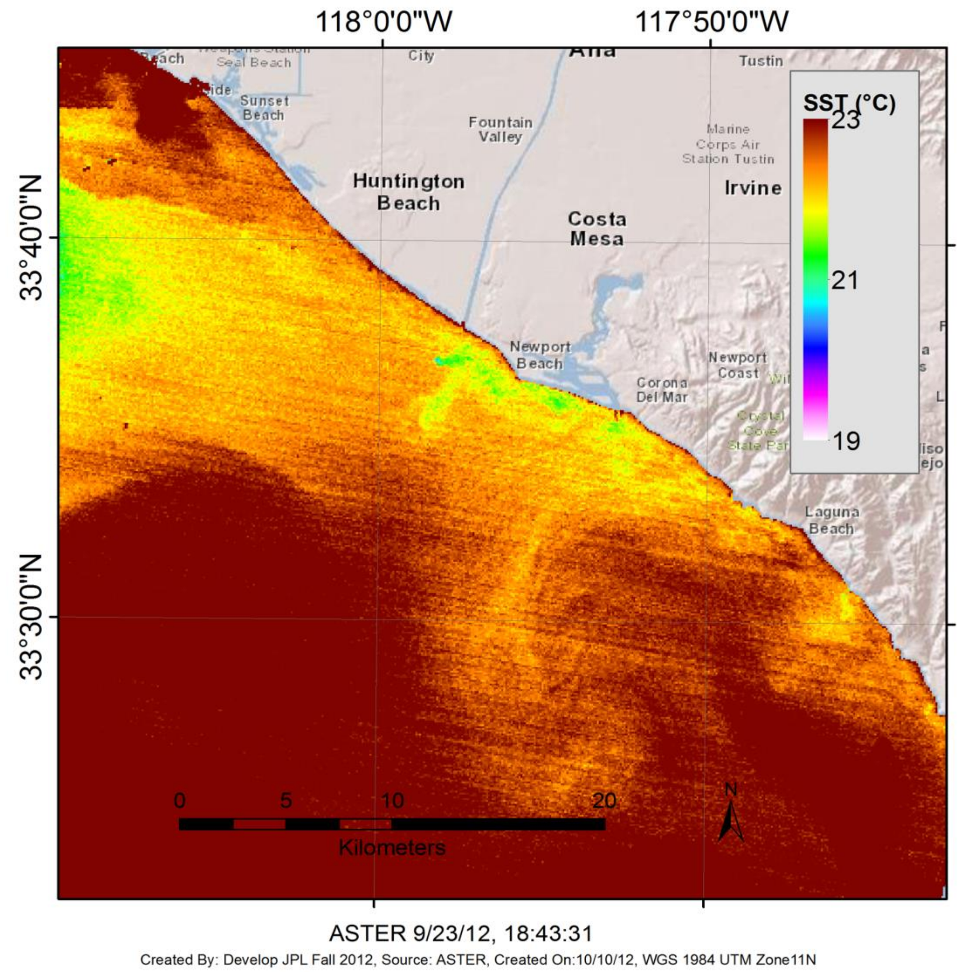


Figure 3.37 *ASTER image from September 23, 2012*

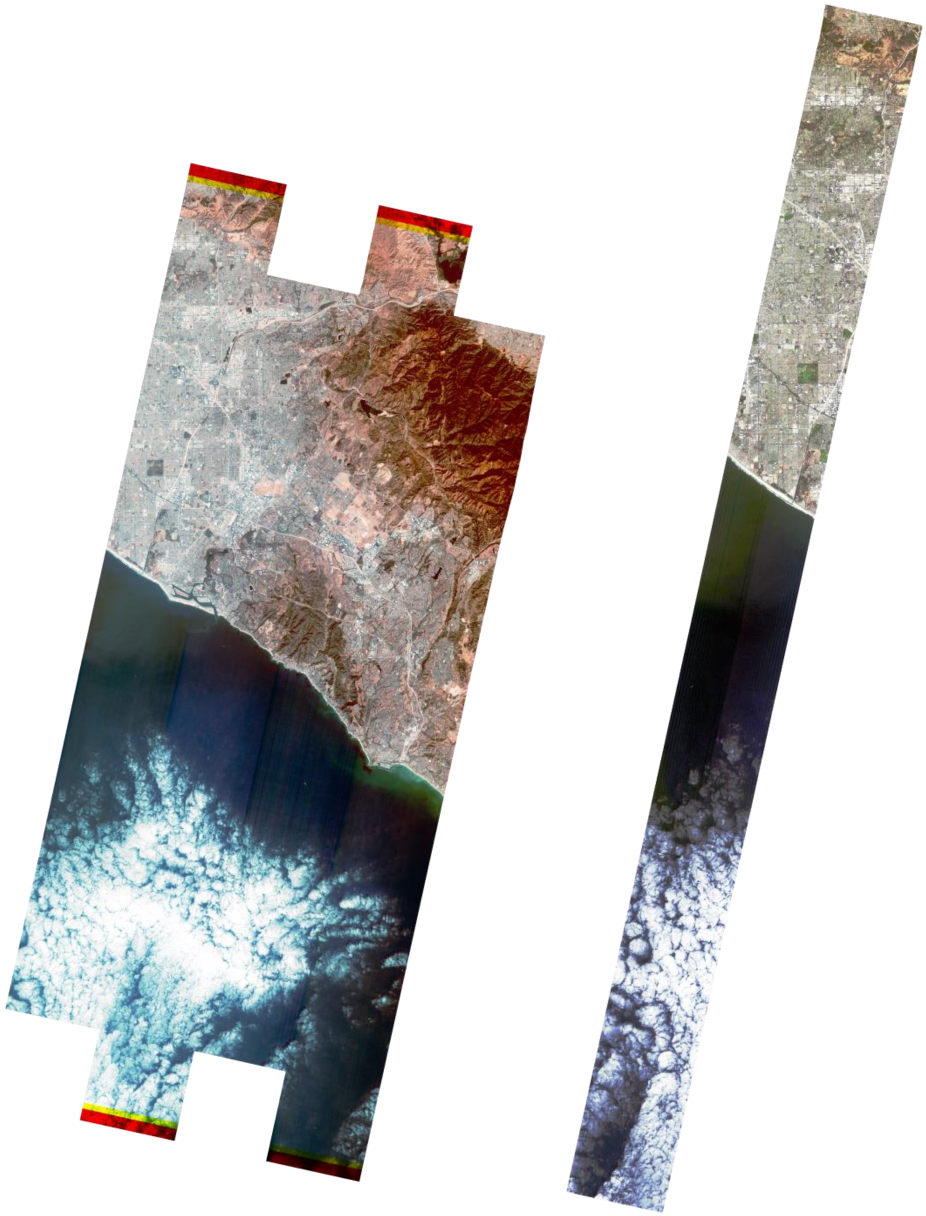


Figure 3.38 *EO-1 imagery from ALI (left) and Hyperion (right) sensors collected on September 26, 2012.*

E) Water Quality Sampling Stations

Nearshore and offshore sampling zones described here correspond with those defined in the California Ocean Plan. Nearshore waters extend out to the 10 m depth contour or 305 m from shore. Offshore waters extend from the nearshore zone out to the limit of state waters (3 nm). The bounding box for both nearshore and offshore water quality sampling stations is given in Table 3.20.

Table 3.20 Nearshore/Offshore bounding box		
Casts (bounding box)	**Latitude**	**Longitude**
Upper west lat lon	33º 41.848	-118º 3.351
Upper east lat lon	33º 34.892	-117º 51.517
Lower west lat lon	33º 39.987	-118º 5.204
Lower east lat lon	33º 33.836	-117º 52.123

I) Nearshore Water Quality Sampling Stations - George Robertson, OCSD

Overview

Daily shoreline sampling was conducted at the surfzone for three fecal indicator bacteria (FIB; total coliform, fecal coliform and enterococci), temperature and salinity at 17 stations from Sunset Beach to Crystal Cove (Figure 3.39). Weekly CTD and discrete FIB and NH3-N samples were collected at 19 10-m stations (Picketline sampling).

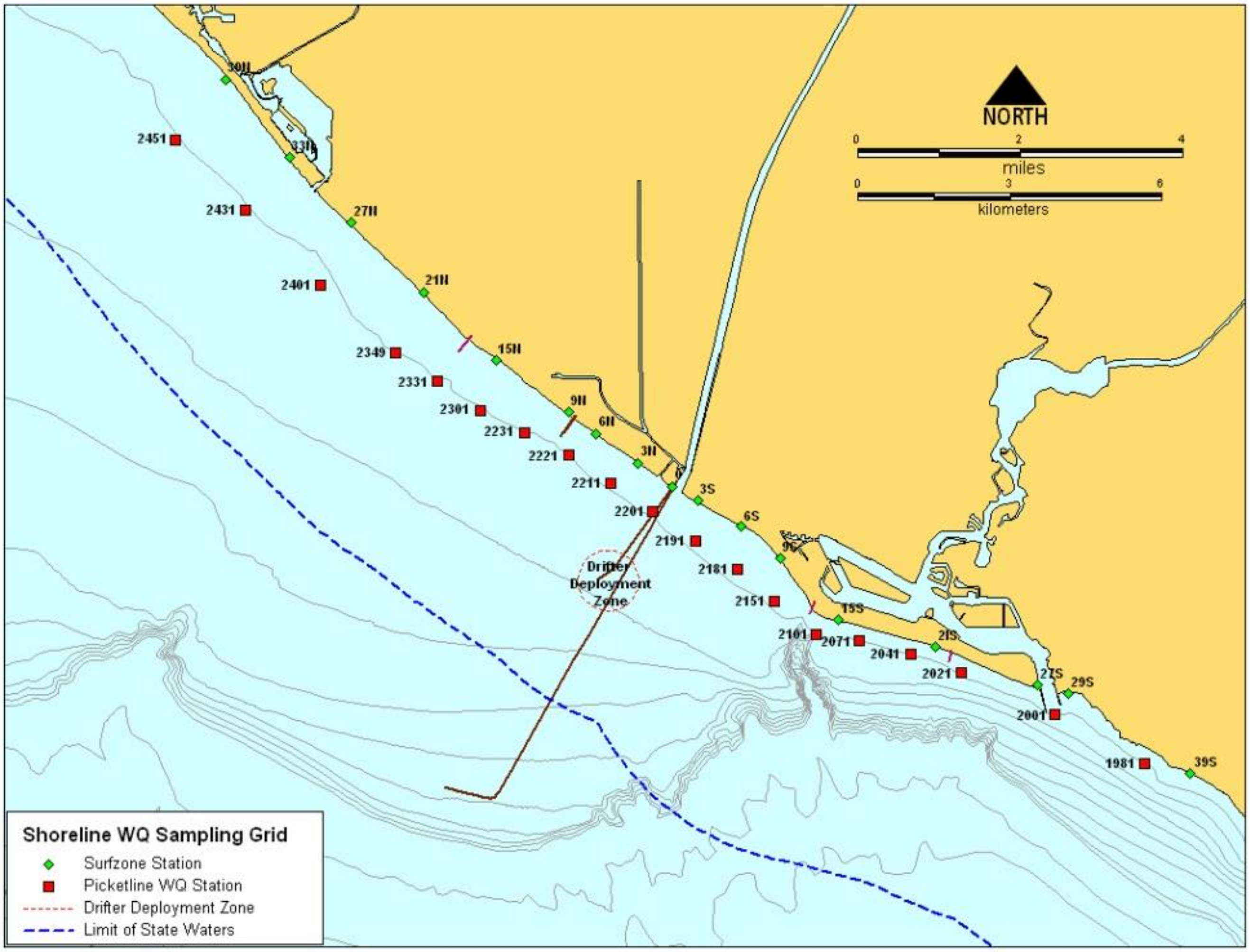


Figure 3.39 *Nearshore Shoreline (green dots) and Picketline (red squares) Water Quality Sampling Stations*

Methods

Shoreline samples were collected in ankle-deep waters, on an incoming wave, with the sampler downstream and away from the bottle, and the mouth of the bottle facing into the current. Sterile sample bottles were used and the sampler used aseptic techniques, making certain that the bottle does not touch the ocean bottom (nearshore) or rosette sampler (picketline). After the samples were taken, bottles were tightly capped and promptly stored on ice in the dark. Laboratory analysis began within 6 hours of sample collection.

Offshore water quality (CTD) surveys included measurements of pressure (from which depth is calculated), water temperature, conductivity (from which salinity is calculated), dissolved oxygen (DO), pH, water clarity (light transmissivity), chlorophyll-a, colored dissolved organic matter (CDOM), and photosynthetically active radiation (PAR). Profiling was conducted from the surface (1 m below) to ~2 m from the bottom.

Measurements were conducted using a Sea-Bird Electronics SBE9-03/SBE 11 Deck Unit (SBE9/11) CTD (conductivity-temperature-depth) profiling system. SEASOFT (2012) software was used for data acquisition, data display, and sensor calibration (Table 3.21A & B).

Discrete sampling for ammonia, total coliforms, fecal coliforms, Escherichia coli (E. coli), and enterococci was conducted using a Sea-Bird Electronics Carousel Water Sampler (SBE32/SBE33) equipped with Niskin bottles. Bacteriology samples were kept on wet ice in coolers and transported to the District's laboratory within 6-hours of collection for analysis. Samples were collected at 1, 3, and 8 m depths.

Laboratory analyses of ammonia and bacteriology samples followed standard EPA guidelines. QA/QC procedures included analysis of laboratory blanks, duplicates, and spikes. All data underwent at least three separate reviews prior to being included in the final database used for statistical analysis, comparison to standards, and data summaries. The same challenges existed as for the nearshore sampling, including 1.) Determining subset of stations to sample on each survey day. 2.) Including adaptive sampling to pre-selected sampling routines. 3.) Conducting multiple program elements on the same day (e.g., deploy/recover drifters while doing CTD surveys).

Raw CTD data were processed using both SEASOFT, (2010b) and third party (IGODS, 2010) software. The steps included retaining downcast data and identifying outliers by flagging the data if it exceeded specific criteria limits. Flagged data were removed if it was considered to be due to instrument failures, electrical noise (e.g., large data spikes), or physical interruptions of sensors (e.g., by bubbles) rather than by actual oceanographic events. After outlier removal, averaged 1 m depth values were prepared from the downcast scan data; if there were any missing 1 m depths, then the upcast data were used as a replacement. CTD and discrete data were then combined to create a single data file that contained all sampled stations for each survey day. Spatial and seasonal patterns in water quality data are summarized in 2- and 3-dimensional color plots of temperature, salinity, DO, pH, transmissivity, CDOM and chlorophyll-*a*. The 2- and 3-dimensional plots were produced using IGODS (2012) software (a locally developed product that is used locally).

For this report, eight water quality metrics were evaluated to determine the transport of the discharge plume during the diversion and to evaluate potential impacts to public health and the environment. These measurements were temperature, density, salinity, colored dissolved organic matter (CDOM), ammonia (NH_3-N), chlorophyll-a (Chl-a), fecal coliform (FC), and enterococci (ENT) bacteria.

Instrument Specifications

Table 3.21A	**CTD SBE11Plus**				
Sensor	**Temperature**	**Conductivity**	**Pressure**	**Oxygen**	**pH**
Make	SBE3 plus	SBE4C	Digiquartz	SBE43	SBE18
Model	Serial # 032456	Serial # 042118	Serial # 89073	Serial # 430659	Serial # 180406
Additional Comments	All data collected at 24 scans per second				

Table 3.21B	CTD SBE11Plus (cont.…)				
Sensor	**CDOM Fluorometer**	**Chlorophyll Fluorometer**	**Transmissometer**	**PAR/Irradiance**	**SPAR/Surface Irradiance**
Make	Wetlabs Wetstar	Wetlabs Wetstar	Wetlab Cstar	Biospherical	Biospherical
Model	Serial # WSCD-1216	Serial # WS3S-436P	Serial # CST-514PR	4638	20243
Additional Comments	All data collected at 24 scans per second				

Results

Previous studies off Huntington Beach and Newport Beach have shown the importance of tidal impacts on bacterial counts along the shore. During the diversion two spring tides occurred on September 16 and September 30 (Figure 3.40).

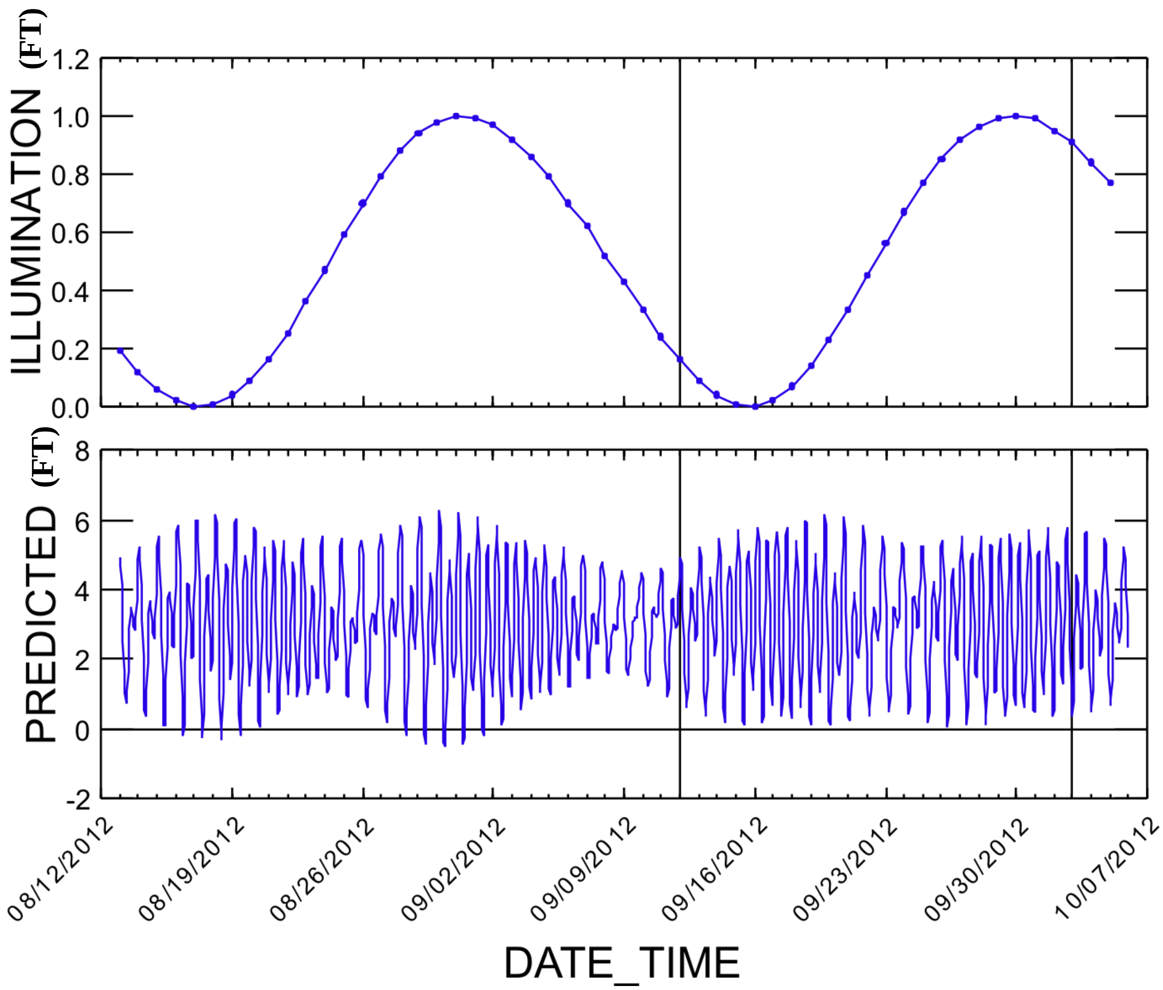


Figure 3.40 *Moon phase (percent illuminated) and tides. The vertical lines denote the start and end of the diversion in this figure as well as in Figures 3.42-3.46.*

Total coliform counts along the coast were all below the single sample standard of 10,000 MPN/100 mL and with few exceptions below the 30-day geometric mean standard of 1,000. No changes were seen in either the temporal or spatial patterns due to the diversion. Greater variability and higher values were seen primarily from 9N to 3N and were consistent with the occurrence of spring tide events (e.g., 3N on August 31; Figure 3.42). Similar patterns were seen in fecal coliform bacteria counts (Figure 3.43).

Enterococci bacteria showed more variability than either total or fecal coliform bacteria. In addition single sample standards were exceeded on several occasions and at multiple stations. However, similar to the two coliform bacteria, the temporal and spatial patterns did not change during the diversion (Figure 3.44).

Surfzone water temperatures typically ranged between 17 and 21 °C and did not appear to be affected by the discharge plume. Regionally two drops in water temperature were seen on September 15 and 29, coinciding with spring tides (Figure 3.45). Salinity also did not illustrate impacts from the discharge plume with similar changes noted regionally both up- and downcoast of the 78-inch outfall (Figure 3.46)

For the three Picketline sampling dates (9/13, 9/17 and 9/25), all FIBS were below state single sample limits. Maximum counts were 771 MPN/100 mL for total coliform, 83 MPN/100 mL for fecal coliform, and 63 MPN/100 mL for enterococci (Figure 3.41). The majority of fecal coliform and enterococci counts were below method detection limits (92% and 88%, respectively), while 49% of total coliform counts were below detection. Similar spatial patterns were seen during all three Picketline surveys with low total coliform counts seen at most stations. Highest counts were measured the surface inshore of the discharge (e.g., Station 221) and downcoast off Crystal Cove State Beach (e.g. Station 1901). There was poor correlation between the three FIBs (R=0.15 to 0.35)

Ammonia was largely (88%) undetected along the 10-m contour Picketline stations. No NH3-N was detected on September 13, while elevated (up to 0.17 mg/L) values were seen directly inshore (Station 2201) and upcoast (Station 2301) with the highest value (0.2 mg/L) seen at Station 1901 off Crystal Cove State Beach. On September 25, elevated values (.33 mg/L) were seen directly in shore at Station 2201. There was no correlation between NH3-N and the three FIBs (R=-0.01 to 0.00).

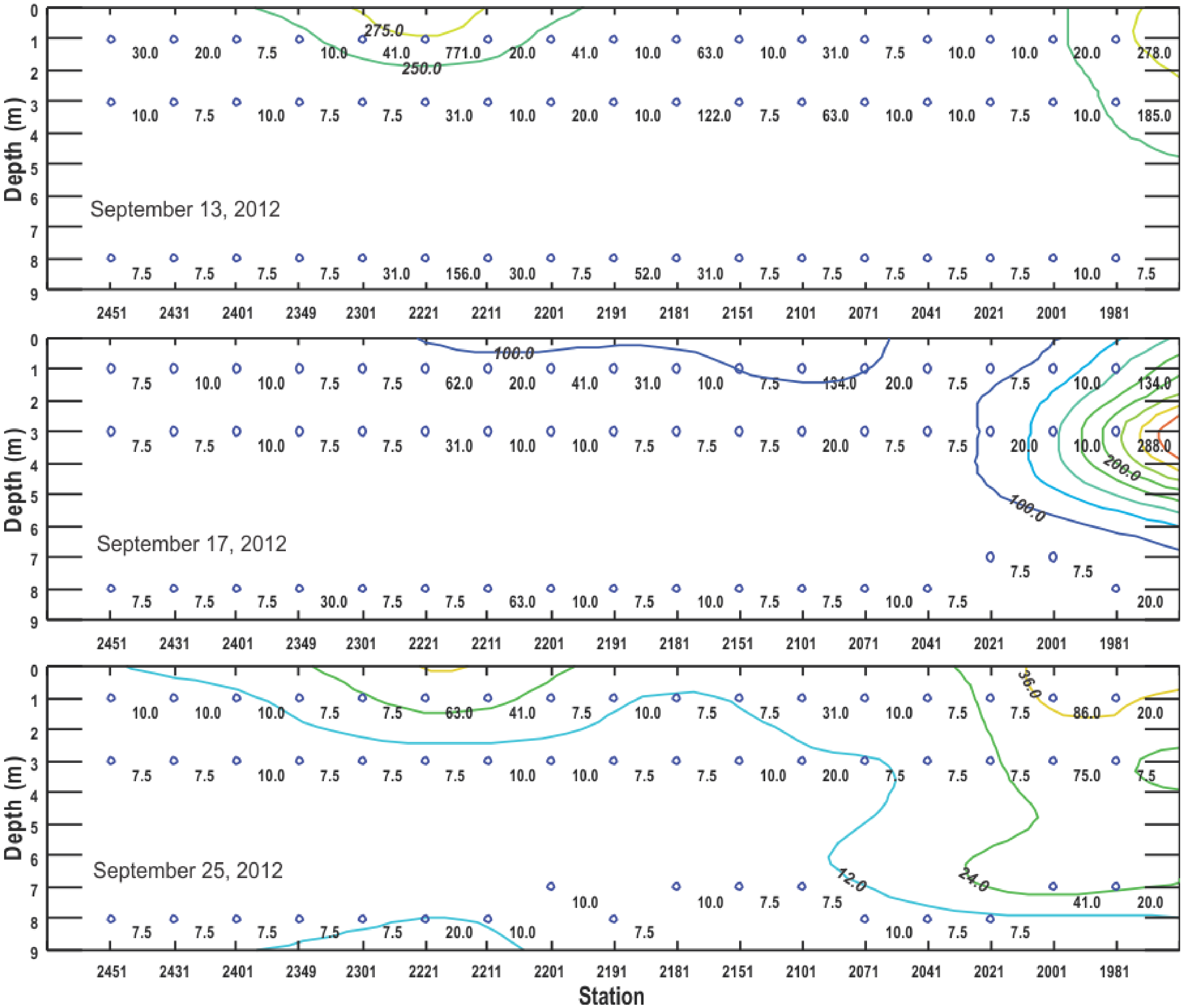


Figure 3.41*: Total Coliform for 3 picketline surveys*

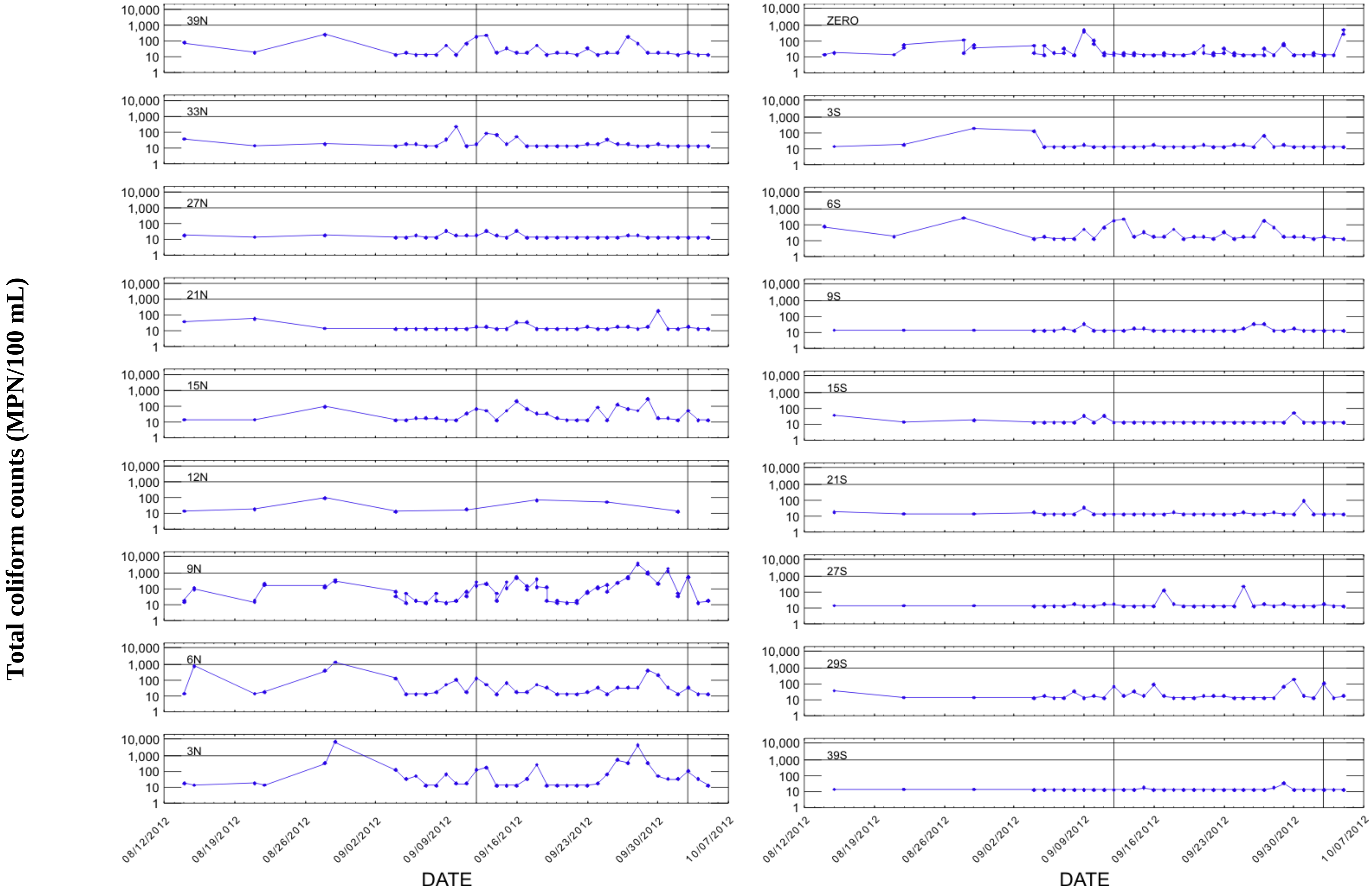


Figure 3.42 Nearshore (surfzone) total coliform bacteria counts MPN/100 mL. Vertical bars represent diversion period. Horizontal solid lines represent State single sample and geometric mean limits[4].

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[4] Many wastewater dischargers, as well as regulators who monitor swimming beaches and shellfish areas, must test for and report fecal coliform bacteria concentrations. Often the geometric mean (a type of average) of all the test results obtained during a reporting period. Typically, public health regulations identify precise geometric mean concentration at which shellfish beds or swimming beaches must be closed.

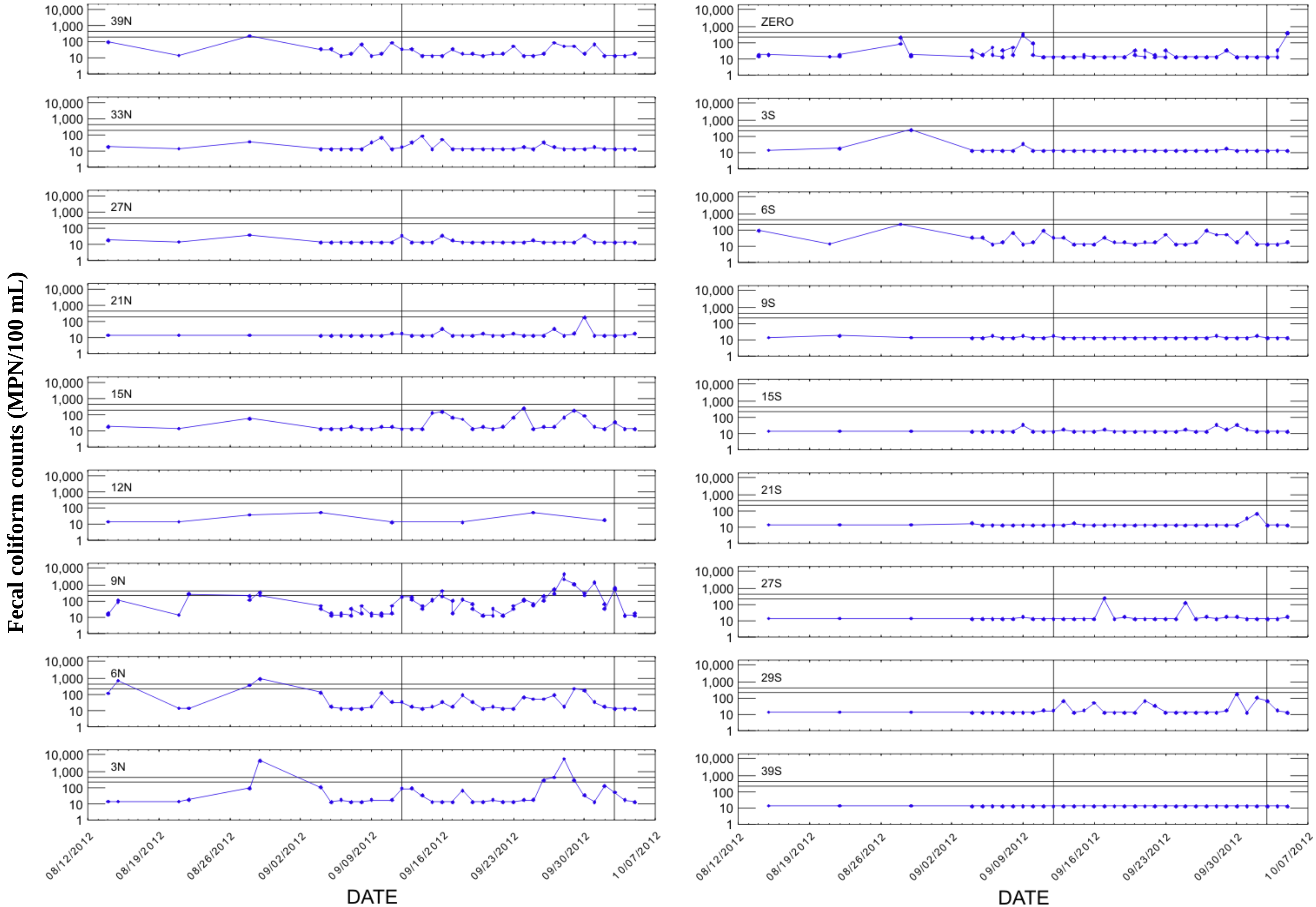

Figure 3.43 Nearshore (surfzone) fecal coliform bacteria counts MPN/100 mL. Vertical bars represent diversion period. Horizontal solid lines represent State single sample and geomean limits.

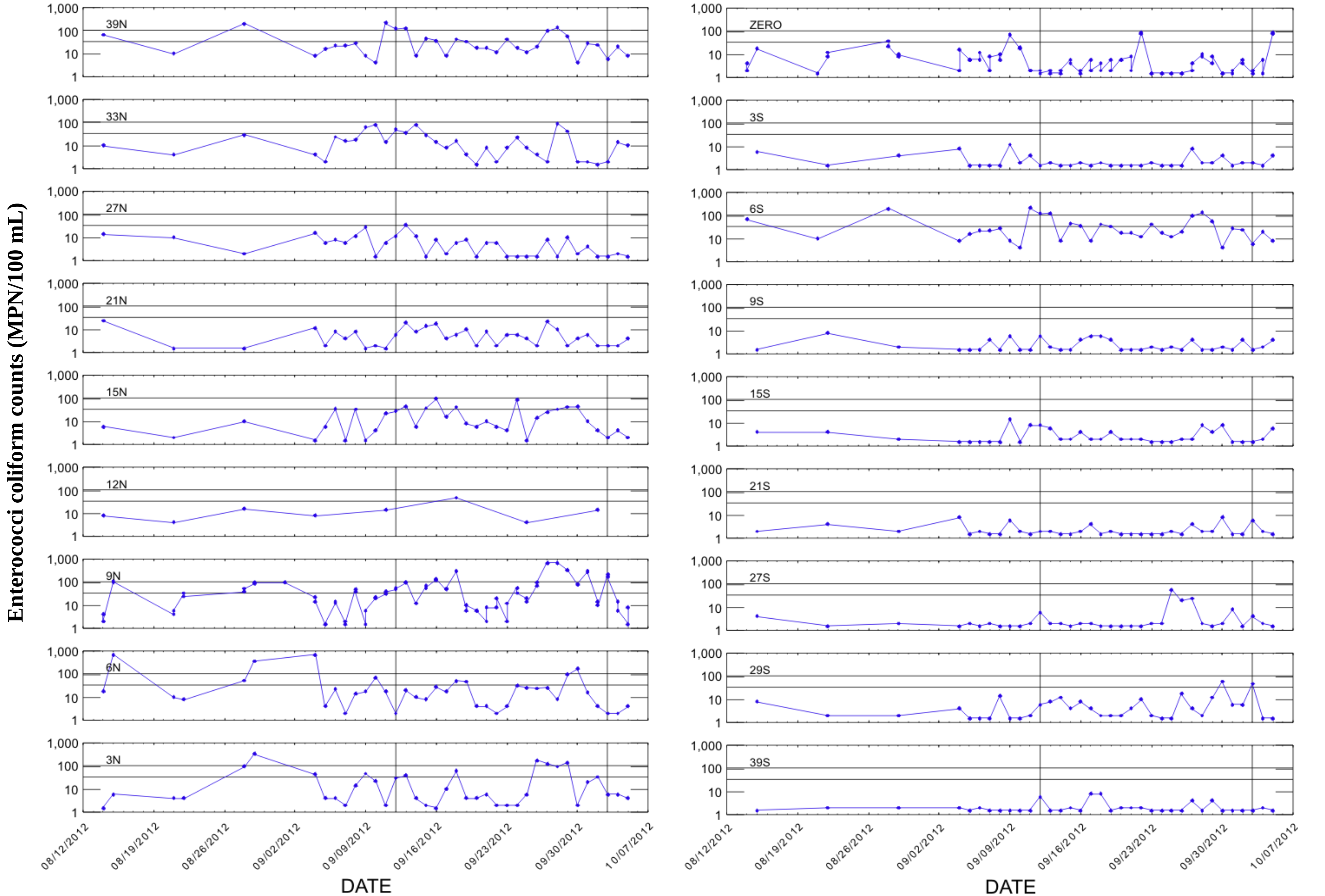

***Figure 3.44** Nearshore (surfzone) enterococci bacteria counts* (MPN/100 mL). *Vertical bars represent diversion period. Horizontal solid lines represent State single sample and geomean limits.*

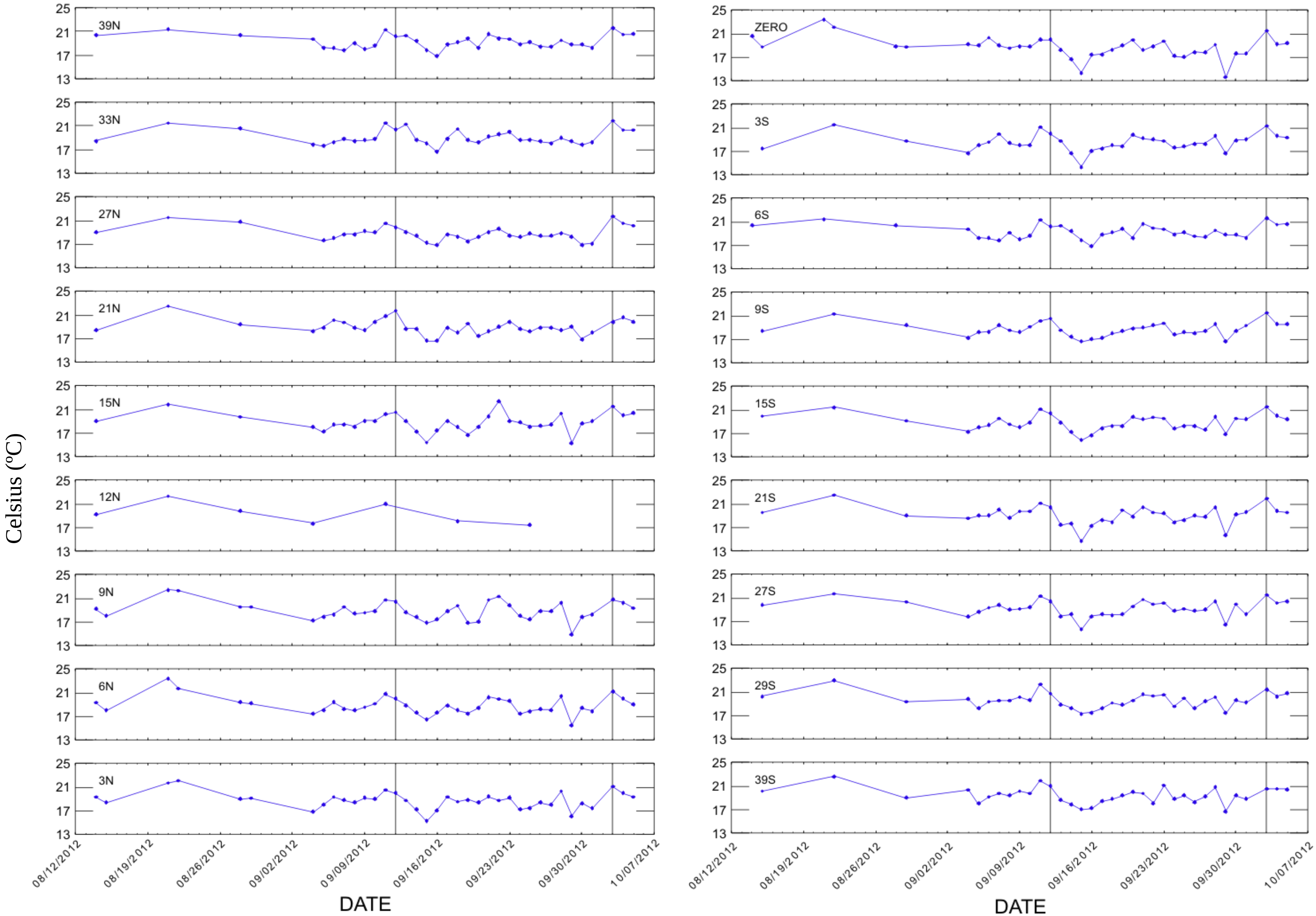

Figure 3.45 *Nearshore (surfzone) water temperature (C).*

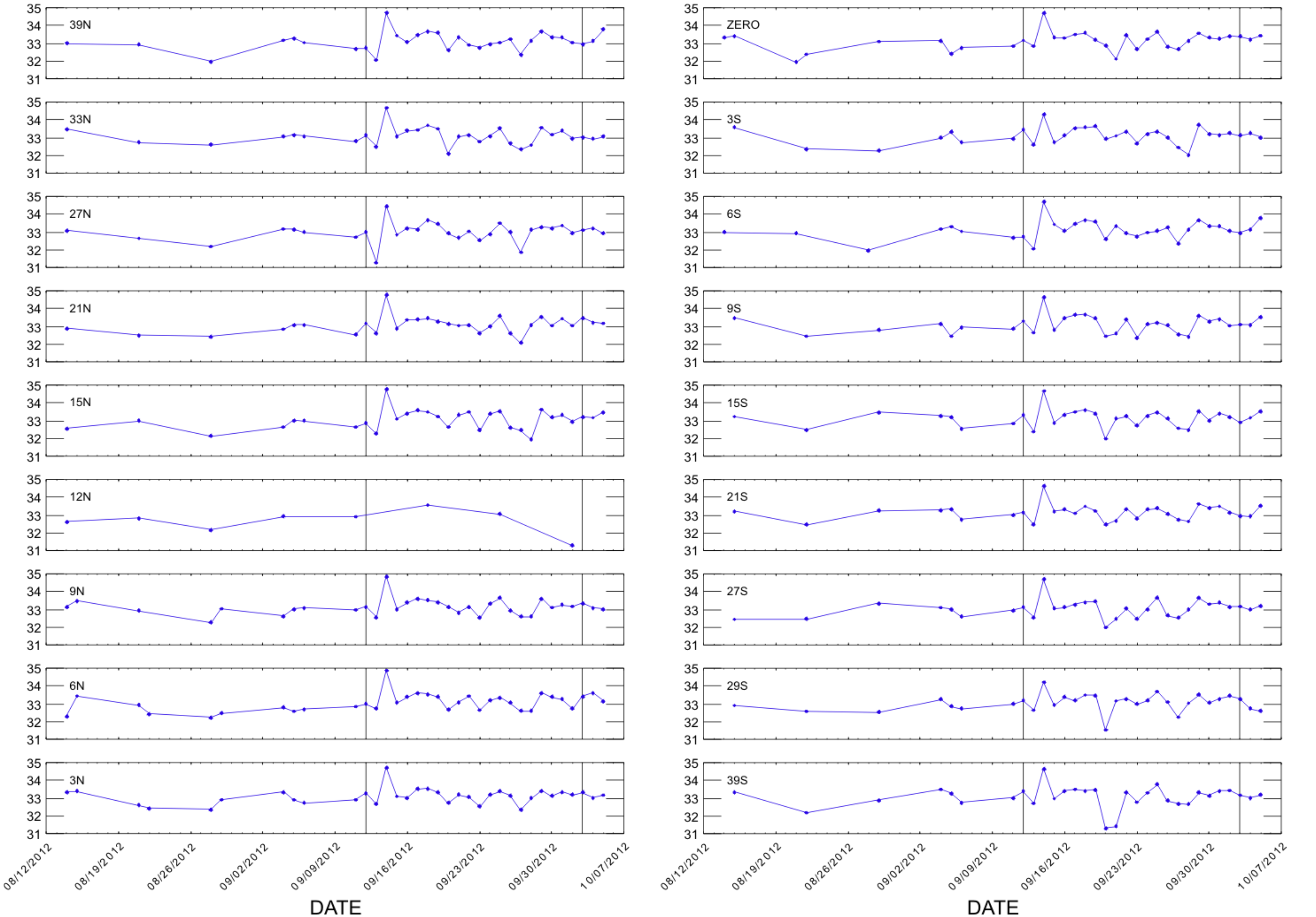

Figure 3.46 *Nearshore (surfzone) water salinity (psu).*

II) Offshore Water Quality Sampling Stations - George Robertson, OCSD

Overview

This program element included water column profile sampling with a CTD instrument and discrete water sampling for FIBs and NH3-N (Figure 3.47).

- Sampling at a subset of 48 stations located at, and downcurrent of, the short outfall. Stations are located in two, overlapping 12x4 grids (up and downcoast of the short outfall). Maximum CTD depths were 60 m.

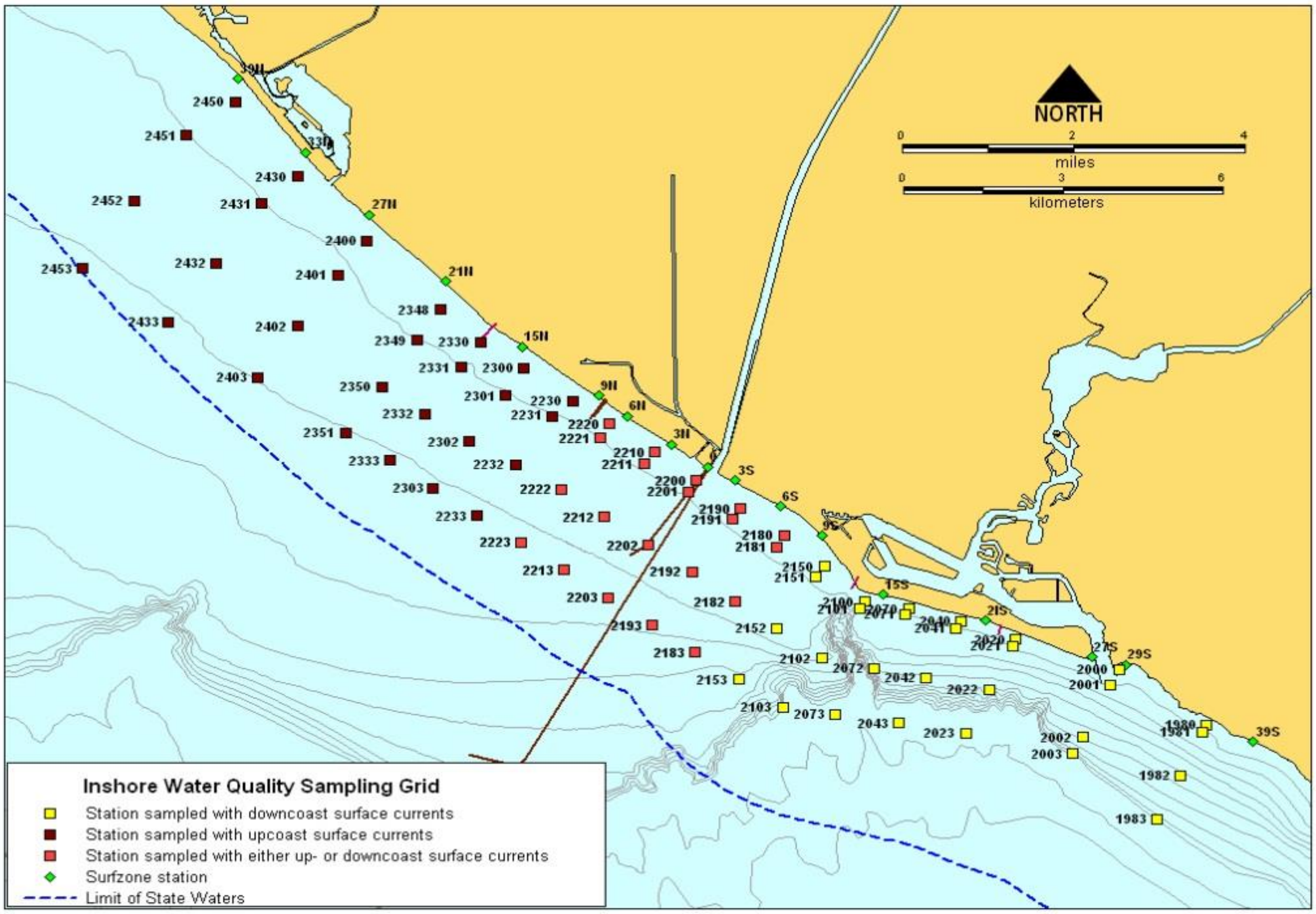

Figure 3.47 *Plume tracking water quality sampling*

Two other water quality efforts were made to better understand the temporal and spatial extent of the discharged effluent.

- <u>In-Plant Final effluent sampling</u>: An enhanced disinfection program was conducted during the diversion to the 78-inch outfall with sampling occurring up to four times daily.
- <u>Sediments</u>: With a rising plume and a high-quality effluent, impacts to inshore sediments are not expected. However, sediments were collected before and after the discharge from the short outfall to verify this. Analysis and reporting of these data will occur at a later date

Methods

Offshore water quality sampling followed the same equipment and methods as used in the Nearshore CTD sampling. Maximum CTD sampling depth was 60 m (Table 3.22).

Table 3.22 *OCSD J-112 Water Quality Cruises*

Year	Month	Cruise Number	Sample Date	Purpose	Data Type	Vessel	# of Days	Bacteria Samples	Ammonia Samples
2012	Aug	OC-2012-038	08/09/2012	REC-1 WQ Cruise (# 3)/J-112 Pre-survey	Pre-Diversion	Nerissa	1	Yes	Yes
2012	Aug	OC-2012-039	08/13/2012	J-112 WQ - South Route Test Run	Pre-Diversion	Nerissa	1	No	No
2012	Sep	OC-2012-044	09/10/2012	J-112 Plume Tracking Survey (Upcoast)	Diversion	Nerissa	1	Yes	Yes
2012	Sep	OC-2012-049	09/11/2012	J-112 Plume Tracking Survey (Downcoast)	Diversion	Nerissa	1	Yes	Yes
2012	Sep	OC-2012-045	09/12/2012	J-112 Plume Tracking Survey (Downcoast)	Diversion	Nerissa	1	Yes	Yes
2012	Sep	OC-2012-047	09/13/2012	J-112 Picketline Survey	Diversion	Nerissa	1	Yes	Yes
2012	Sep	OC-2012-048	09/17/2012	J-112 Picketline Survey	Diversion	Nerissa	1	Yes	Yes
2012	Sep	OC-2012-046	09/18/2012	J-112 Plume Tracking Survey (Downcoast)	Diversion	Nerissa	1	Yes	Yes
2012	Sep	OC-2012-050	09/19/2012	Water Quality Cruise #3 (Ammonia only)	Diversion	Nerissa	1	No	Yes
2012	Sep	OC-2012-051	09/24/2012	J-112 Picketline Survey	Diversion	Nerissa	1	Yes	Yes
2012	Sep	OC-2012-053	09/25/2012	J-112 Plume Tracking Survey (Downcoast)	Diversion	Nerissa	1	Yes	Yes
2012	Sep	OC-2012-054	09/27/2012	ECOHAB Cruise (Ammonia only)	Diversion	Nerissa	1	No	Yes
2012	Oct	OC-2012-055	10/01/2012	J-112 Plume Tracking Survey (Offshore/Inshore)	Diversion	Nerissa	1	Yes	Yes
2012	Oct	OC-2012-056	10/02/2012	J-112 Plume Tracking Survey (Offshore/Inshore)	Diversion	Nerissa	1	Yes	Yes
2012	Oct	OC-2012-057	10/03/2012	J-112 Plume Tracking Survey (Offshore/Inshore)	Post-Diversion	Nerissa	1	Yes	Yes
2012	Oct	OC-2012-060	10/09/2012	J-112 Plume Tracking Survey (Offshore/Inshore)	Post-Diversion	Nerissa	1	Yes	Yes
2012	Oct	OC-2012-061	10/10/2012	ECOHAB Cruise	Post-Diversion	Nerissa	1	No	No
2012	Oct	OC-2012-069	10/17/2012	ECOHAB Cruise	Post-Diversion	Nerissa	1	No	No

Results

Effluent Sampling

Values for total and fecal coliform and enterococci bacteria demonstrated the effectiveness of the enhanced disinfection process used for the diversion. Counts were predominantly below their respective geometric and single sample means until October 2, 2012, which was the initial target date for the end of the diversion. No trends or changes were seen in ammonia values. (Figure 3.48)

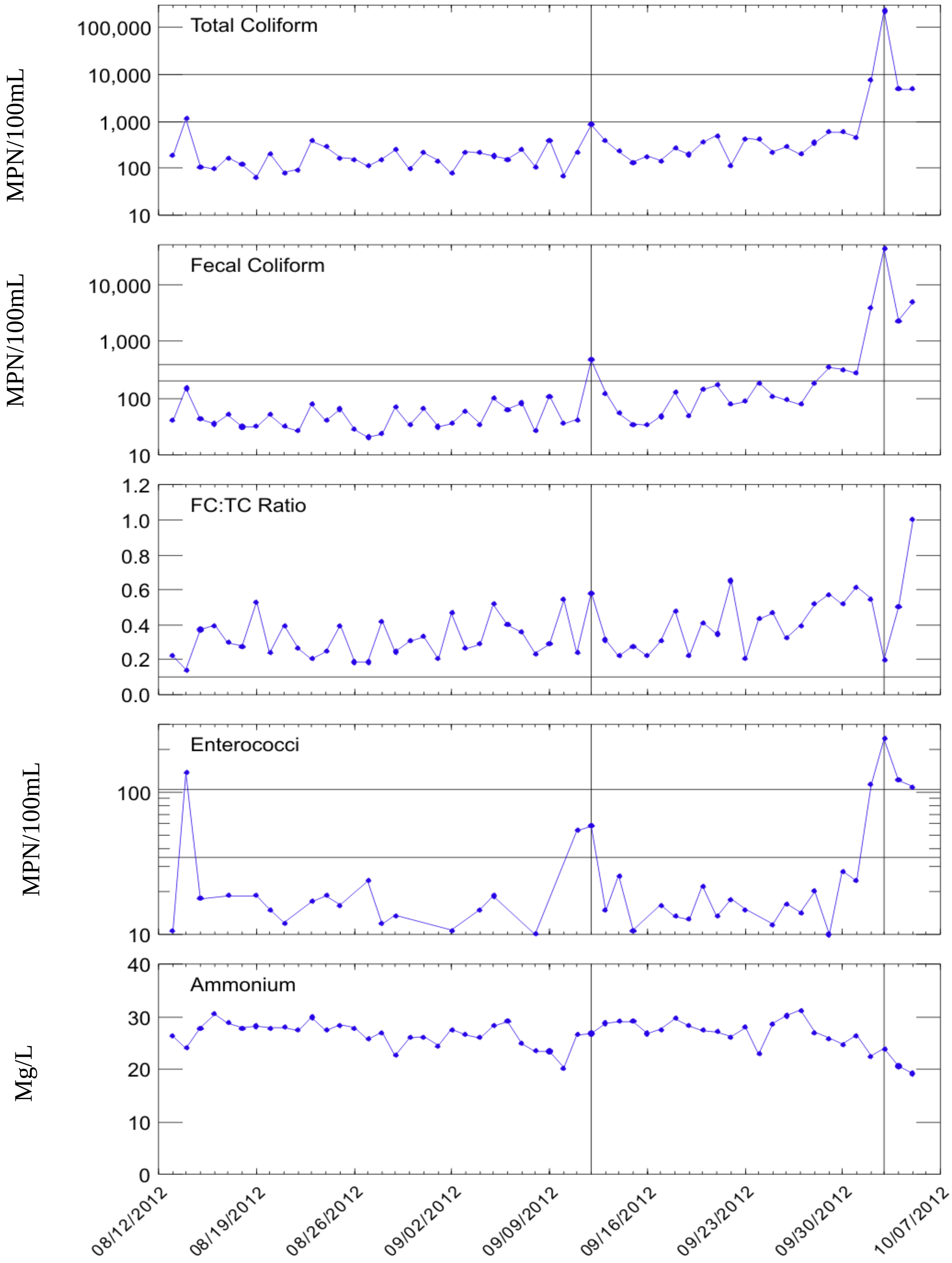

Figure 3.48 *Final effluent values for total and fecal coliform and enterococci bacteria, fecal: total coliform ratio, and ammonia.*

Offshore Sampling
NH3-N, FC, and ENT are often used as direct proxies for the plume. For the diversion, the vast majority of the samples were below detection (Table 3.23) which limited their utility in tracking/delineating the discharge effluent plume.

Ammonia				
<.02	≥0.2			Totals
1,377(86.6%)	213(13.4%)			1,590(100%)
Fecal Coliform				
<10	10 to 199	200 to 399	≥400	Totals
1,106(96.0%)	46(4.0%)	0 (0%)	0 (0%)	1,152(100%)
Enterococci				
<10	10 to 343	35 to 103	≥1044	Totals
1,026(89.1%)	120(10.4%)	3(0.3%)	3(0.3%)	1,152(100%)

Table 3.23 Counts and percentages for ammonia and total coliform, fecal coliform and enterococci bacteria.

Pre-Diversion
Three surveys were conducted on August 9, August 13, and September 10 prior to the diversion to the 78-inch outfall. All surveys showed strong stratification (temperature and density) at stations beyond the 10 m contour with the August 9 and September 10 surveys being stratified into 5 m of water. Salinity was generally uniform throughout the region with the exception of lower salinity seen at depth downcoast[5] of the two OCSD outfalls; this is probably due to the discharge from the 120-inch ocean outfall. Additionally, during the September cruise, areas of lower salinity were seen at the surface at all of the upcoast stations; previous studies have indicated that flows from the San Gabriel River are the source of this fresh water off Huntington Beach. Elevated CDOM was seen in areas of lower salinity. For the two surveys where NH3-N, FC, and ENT were measured, no elevated values were observed. Elevated Chl-a was observed at depth at the downcoast 15 and 20 m contour stations in August and at the upcoast 5 and 10 m stations.

Diversion
A total of eleven water quality surveys were conducted during the diversion (September 11 to October 2), most were specific to the diversion, while others (e.g., September 19) were part of the District's permit sampling program or support for other program participants (e.g., September 27, October 10 and 17).

- Stratification - Overall, stratification was evident throughout the diversion at all 15- and 20-m stations. Through September, temperature and density gradients were seen into the 5 m contour. By the October 1st and 2nd surveys, stratification was seen primarily at the 20 m contour stations.
- Plume Tracking - Evidence of the plume was evident in salinity and CDOM. Initially, lower salinity and higher CDOM waters associated with the discharge were seen subsurface at the outfall (Station 2202), rising to the surface and moving downcoast and offshore of the outfall (September 12-18). On September 24 and 25, there was evidence of the plume being present directly inshore at the 10 m contour. Upcoast transport was noted for October 1st and 2nd. Spatial patterns of elevated NH3-N associated with the discharge were more constrained and variable than that seen with CDOM and salinity. However, when present, elevated NH3-N values were typically co-located with higher CDOM and lower salinity.
- Environmental and Public Health Impacts - No phytoplankton blooms were seen during the time the short outfall was in operation. Values remained low through September 18 when values increased at the

[5]For reference 'downcoast' and 'upcoast' directions use the 78-inch outfall as the reference.

downcoast/offshore station, consistent with plume transport at that time. Values remained relatively low until October 1st and 2nd when values >8 mg/L were seen downcoast and offshore. Due to the enhanced disinfection of the effluent prior to discharge and subsequent dilution and die-off, very few occurrences of elevated fecal indicator bacteria (FIB; exemplified by FC and ENT) were seen in the receiving waters. Only a few instances of elevated ENT (>88 MPN 100 mL) were seen such as the two locations on September 12; one was offshore and at depth associated with the residual discharge from the 120-inch outfall and the other was upcoast and inshore due to an upcoast source such as the San Gabriel River.

Post-Diversion

The day after the diversion ended (October 3) stratification was seen at the 20 m contour and deeper stations. No evidence of the plume discharged from the 78-inch outfall was seen in salinity, CDOM, NH3-N, or FIBs. The elevated ENT count seen inshore and at depth at Station 2101 appears to be an anomaly. Chl-a values were greatly reduced from the previous day, with some elevated values seen upcoast and offshore. Subsequent surveys (October 9, 10, and 17) showed water quality changes associated with the 120-inch outfall.

III) Phytoplankton Response Sampling - Dave Caron, USC

Overview

The diversion discharge constituted a significant, localized input of nutrients to the nearshore environment with potentially major implications for phytoplankton blooms in the nearshore region (See report submitted to OCSD by Jones and Caron, "Anticipated Biological Response to Extended Discharge from a Nearshore, Shallow Outfall").

Two types of studies were conducted to evaluate the response of the local phytoplankton community to this event:

- Experimental studies were conducted twice using natural plankton assemblages contained in bottles to examine the response of the community over the course of several days when subjected to different levels of effluent enrichment;
- Monitoring (via shipboard and shore sampling and sensing) of the response of the natural phytoplankton community in the vicinity of the discharge pipe for response to the discharged effluent.

Figure 3.49 *Map of the locations of the experiments and pier sampling.*

Experimental Field Studies

Two experimental field studies were conducted prior to the diversion event ('pre-diversion') and during the diversion event ('mid-diversion') to examine the quantitative and qualitative effects of the OCSD effluent on natural assemblages of phytoplankton. Seawater for these experiments was collected offshore of the short outfall (Figure 3.49) at 2 depths for the 'pre-diversion experiment, the surface (5m) and at the subsurface or deep chlorophyll maximum (DCM; depth varied) and at 1 depth for the 'mid-diversion' experiment, at the DCM.

Monitoring Studies: Pier Phytoplankton

Water samples were collected weekly from the Newport and Huntington Beach municipal piers situated north and south of the location of the OCSD effluent pipe sampling to monitor nutrients and phytoplankton composition.

Monitoring Studies: Vessel Sampling

Offshore samples were collected approximately weekly at a routine grid of stations during OCSD's offshore water quality sampling surveys (from OCSD ship Nerissa) and at several stations during additional research cruises aboard the R/V Yellowfin. Samples were collected near-surface and from the subsurface chlorophyll maximum if one was apparent.

A total of 24 pier samples, 110 samples from the Nerissa, and 72 samples from the Yellowfin were collected as part of the monitoring studies.

Methods

To determine the response of microalgal and microzooplankton assemblages, samples were processed as follows:

- Extracted chlorophyll;
- Cell counts of major taxa by light microscopy;
- Flow cytometry for minute algae,
- FlowCAM analysis for imaging of abundant taxa – Fluid Imaging.

Samples were also analyzed for specific, quantitative counts of potentially harmful algal species (e.g., Alexandrium and Pseudo-nitzschia species) and toxin analyses for samples with toxin-producing species (domoic acid, saxitoxins; by ELISA).

E*xperimental Field Studies*

Two experimental field studies were conducted, one prior to the diversion event and one during the diversion event to examine the quantitative and qualitative effects of the OCSD effluent on natural assemblages of phytoplankton. The seawater samples for the experimental field studies at the 'pre-diversion' timepoint were collected from two depths, surface and DCM in the offshelf area off Newport Beach (Figure 3.49). The 'mid-diversion' study only sampled from the DCM is off of the shelf. The study assessed the response of the natural phytoplankton community to three different dilutions of the effluent (1:10, 1:100, 1:1000 diluted with natural, filtered seawater) and control treatments (a true control of unfiltered natural seawater and a control of natural seawater with deionized water added at the same volume as the effluent additions). The natures of the response (magnitude and changes in species composition) were monitored periodically over a period of seven (pre-diversion) or six days (mid-diversion). The quantitative response was determined via changes in total phytoplankton biomass, as measured by extracted chlorophyll a, while qualitative changes were monitored by microscopical determination of microalgal species composition and abundance.

Monitoring Studies: Pier Phytoplankton

Water samples were collected weekly from two shore locations situated north and south of the location of the OCSD effluent pipe (Huntington Beach pier and Newport Beach pier) to monitor phytoplankton (Figure 3.49). Samples were collected from near-surface using a bucket. Samples were collected and processed for determinations of response of the microalgal and microzooplankton assemblages (extracted chlorophyll a; cell counts of major taxa by light microscopy; flow cytometry for minute algae, FlowCAM analysis for imaging of abundant taxa). Samples are also being analyzed for specific, quantitative counts of potentially harmful algal species (*Alexandrium, Pseudo-nitzschia spp. Dinophysis spp. Lingulodinium polyedrum, Cochlodinium spp. Prorocentrum spp. and Akashiwo sanguinea*), and toxin analyses for samples with toxin-producing species (domoic acid, saxitoxins; by ELISA).

Vessel Sampling

Water samples were collected approximately weekly at a routine gridded set of stations aboard the OCSD ship Nerissa, and at several stations during six cruises aboard the R/V Yellowfin to monitor phytoplankton.

Samples were collected from near-surface, or from near-surface and the subsurface chlorophyll maximum (if one was apparent) at each station. Samples were collected and processed for determinations of response of the microalgal and microzooplankton assemblages (extracted chlorophyll a; cell counts of major taxa by light microscopy; flow cytometry for minute algae, FlowCAM analysis for imaging of abundant taxa). Samples are also being analyzed for specific, quantitative counts of potentially harmful algal species (*Alexandrium, Pseudo-nitzschia spp. Dinophysis spp. Lingulodinium polyedrum, Cochlodinium spp. Prorocentrum spp. and Akashiwo sanguinea*), and toxin analyses for samples with toxin-producing species (domoic acid, saxitoxins; by ELISA).

Instrument Specifications

Table 3.24A	CTD with 12x12-L Ninskin bottles		
Sensor		Temperature	Conductivity
Make	Sea-Bird Electronics (SBE) Carousel make - SBE	SBE	SBE
Model	911 plus Carousel model 32	3plus	4C
Firmware		Seasoft v2	Seasoft v2
Sample rate		0.065±0.010 seconds	0.060 seconds pumped
Sample interval		Continuous	Continuous
Constituents measured	Temperature, Conductivity, Oxygen, Dual fluorometer & turbidity	Temperature	Conductivity
Quantity	1	2	2
Additional Comments	CTD Data output - .hex, .ASCII, .xls		

Table 3.24B	CTD with 12x12-L Ninskin bottles	
Sensor	Transmissometer	FlowCAM
Make	WET labs	Fluid Imaging
Model	C-star	Portable flowCAM
Firmware	Seasoft v2	Visual Spreadsheet 10x
Sample rate	to 8 Hz	7 frames per second
Sample interval	Continuous	Continuous for 10-15 min per sample
Constituents measured	Beam transmission	Community composition of <80ųm
Quantity	1	1
Additional Comments	Data Output: .hex, ASCII, .xls	Mobile, with images as data output. Discrete net tow samples collected at surface filtered through 80 ųm nitex. Platform data delivery in near real-time images

Results

The virtually imperceptible response of the natural phytoplankton community in the coastal ocean during the diversion event was surprising, given the potential for effluent nutrients to spike phytoplankton production and biomass increases as demonstrated in the experimental studies. Overall, our observations and results are consistent with the scenario that water movement was effective in diluting and dispersing effluent nutrients.

Preliminary findings from the experimental studies clearly indicated the potential for the addition of effluent to dramatically increase phytoplankton biomass and phytoplankton and microzooplankton community assemblages of natural plankton communities. Experiments for the pre-diversion period were carried out with seawater collected at the surface and at the depth of the subsurface chlorophyll maximum. Both communities responded dramatically to effluent at 1:10 dilution, following a 3-day lag in the buildup of chlorophyll.

Effluent addition at 1:10 dilution during the pre-diversion experiment resulted in increases in chlorophyll a concentrations by nearly 100-fold (up to concentrations of approximately 200 µg/l; see Figures 3.50 and 3.51). Chlorophyll also increased with the addition of effluent at 1:100 dilution, but no lag in the increase in chlorophyll as was observed in the 1:10 treatment, and the maximum chlorophyll concentration attained in the 1:100 treatment was only approximately 10-fold greater than in the controls (treatments receiving no effluent). Maximum chlorophyll concentrations observed in the treatment with effluent added at 1:1000 dilution were not substantially elevated relative to control treatments, suggesting that 1:1000 dilution did not result in any quantitative response of the phytoplankton community.

Results of the experimental study carried out mid-diversion (Figure 3.52) closely mirrored results of the pre-diversion experiment. However, the magnitude of the phytoplankton community response (i.e. buildup of chlorophyll) was less dramatic than observed for the pre-diversion experiment (maximum of approximately 60 µg/l).

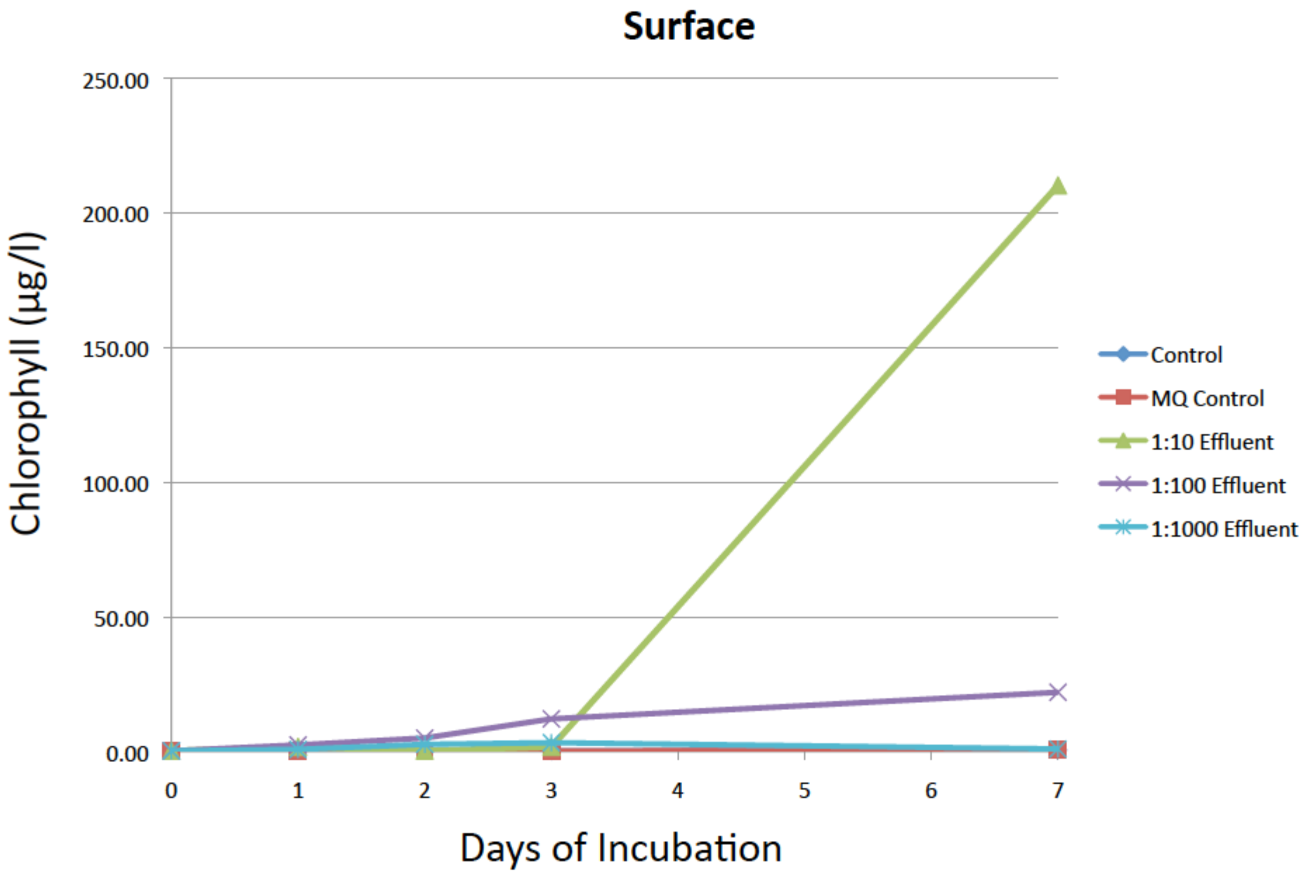

Figure 3.50 *Response of microalgal biomass (i.e. chlorophyll concentration) from an experiment examining the effect of OCSD effluent on a natural phytoplankton community collected at the surface from the coastal ocean off Newport Beach. The experiment was carried out prior to the diversion event. Treatments are (a) Control - natural unfiltered seawater; (b) MQ Control - natural unfiltered seawater receiving the same amount of deionized water as all effluent treatments; (c) 1:10 Effluent - natural unfiltered seawater receiving effluent at a 1:10 final dilution; (d) 1:100 Effluent - natural unfiltered seawater receiving effluent at a 1:100 final dilution; (e) 1:1000 Effluent - natural unfiltered seawater receiving effluent at a 1:1000 final dilution.*

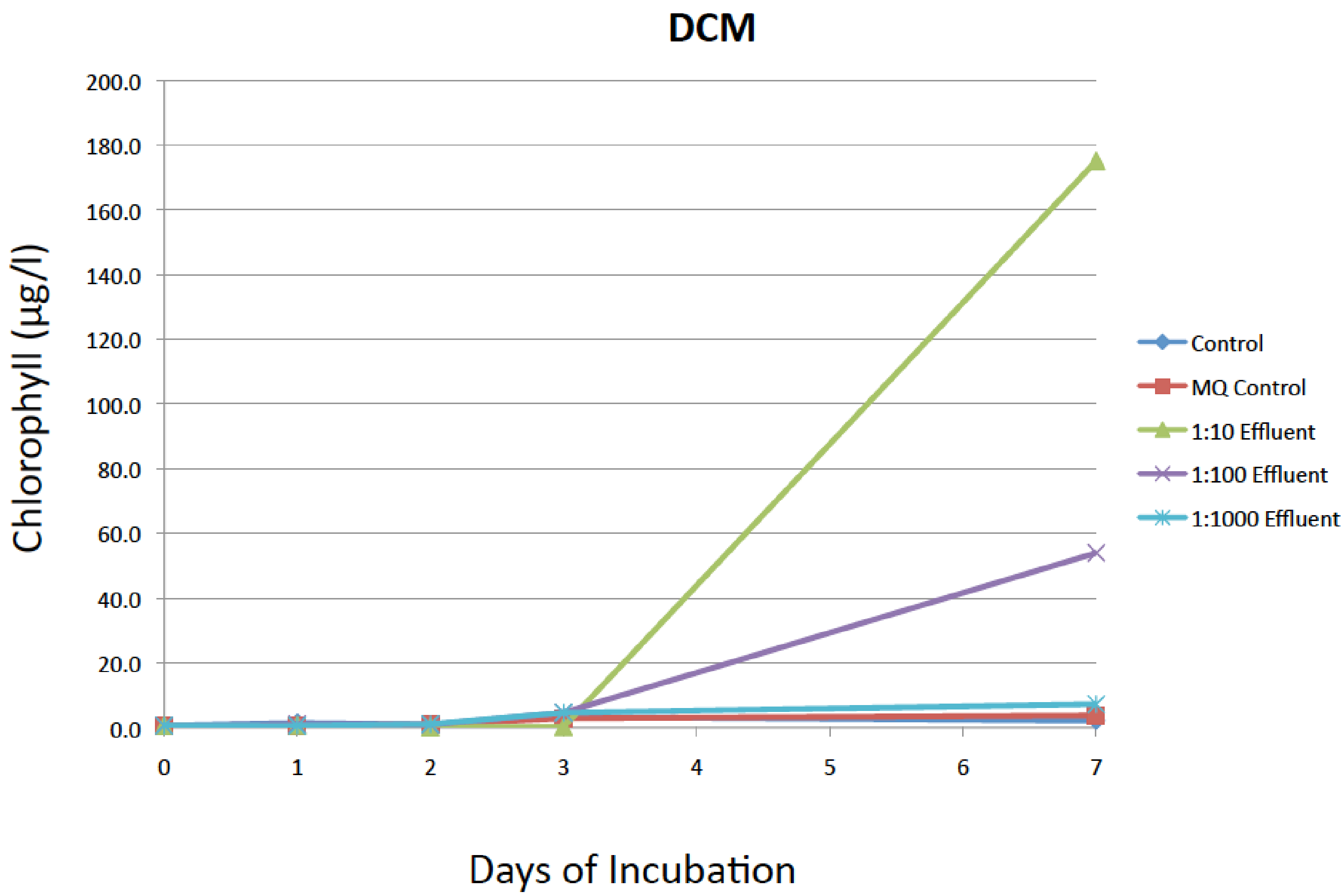

Figure 3.51 *Response of microalgal biomass (i.e. chlorophyll concentration) from the experiment examining the effect of OCSD effluent on a natural phytoplankton community collected at the subsurface chlorophyll maximum from the coastal ocean off Newport Beach. The experiment was carried out prior to the diversion event. Treatments are (a) Control - natural unfiltered seawater; (b) MQ Control - natural unfiltered seawater receiving the same amount of deionized water as all effluent treatments; (c) 1:10 Effluent - natural unfiltered seawater receiving effluent at a 1:10 final dilution; (d) 1:100 Effluent - natural unfiltered seawater receiving effluent at a 1:100 final dilution; (e) 1:1000 Effluent - natural unfiltered seawater receiving effluent at a 1:1000 final dilution.*

Results of the experimental study carried out mid-diversion closely mirrored results of the pre-diversion experiment. However, the magnitude of the phytoplankton community response (i.e. buildup of chlorophyll) was less dramatic than observed for the pre-diversion experiment (maximum of approximately 60 µg/l).

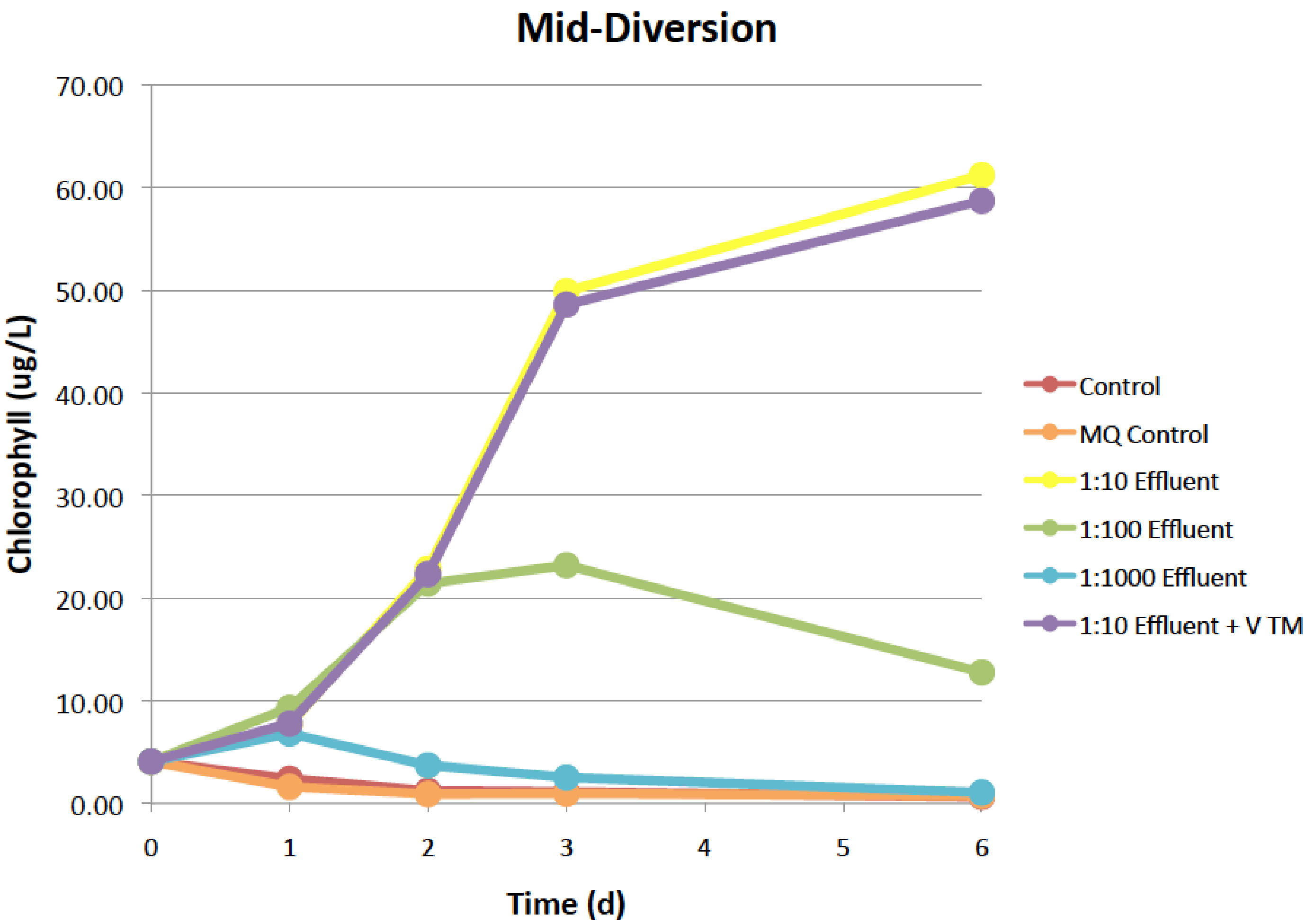

Figure 3.52 *Response of microalgal biomass (i.e. chlorophyll concentration) from the experiment examining the effect of OCSD effluent on a natural phytoplankton community collected at the subsurface chlorophyll maximum from the coastal ocean off Newport Beach. The experiment was carried out during the diversion event. Treatments are (a) Control - natural unfiltered seawater; (b) MQ Control - natural unfiltered seawater receiving the same amount of deionized water as all effluent treatments; (c) 1:10 Effluent - natural unfiltered seawater receiving effluent at a 1:10 final dilution; (d) 1:100 Effluent - natural unfiltered seawater receiving effluent at a 1:100 final dilution; (e) 1:1000 Effluent - natural unfiltered seawater receiving effluent at a 1:1000 final dilution (f) 1:10 Effluent + V TM - an additional treatment to examine the effect of the addition of a vitamin and trace metal mixture in addition to the effluent at a 1:10 final dilution. That treatment had very little effect.*

Samples are still being analyzed for phytoplankton and microzooplankton composition, but preliminary information indicates that the phytoplankton assemblages during the experimental studies were dominated by diatoms. Dinoflagellates were also common, and in particular, abundances of ciliates increased during the 6/7 day incubations. The latter observation indicates that *much of the phytoplankton biomass appears to have moved quickly into the pelagic food web in these communities*.

Only spot-checking has been conducted to date on the presence of domoic acid, a powerful neurotoxin that causes amnesic shellfish poisoning and numerous marine animal deaths sporadically in the region. Only minor amounts of domoic acid in a few samples have been detected thus far in the experimental treatments on the final day of the experiments. *Pseudo-nitzschia* spp. (diatoms capable of the production of domoic acid) were a component of the phytoplankton community during both experiments, but there was no clear, dramatic enhancement of the abundances of these species. These results thus far indicate that *there is no evidence that* *effluent addition led to dramatic increases in the abundances of potentially toxic alga or the toxin during the experiments*.

The total numbers of samples collected during the field study were 24 pier samples (Newport Beach and Huntington Beach piers), 110 samples from the coastal grid of stations aboard the Nerissa, and 72 samples along onshore-offshore transects aboard the Yellowfin. Much of the analyses for these samples are still being completed (see Table 3.25 below, which indicates the date of samples collected and status of analysis).

Table 3.25
ECOHAB/OCSD Fall 2012

DATE	VESSEL	# OF STATIONS	DEPTH	CTD	P DA	D DA	CHL	FLOW CYTOM	NUTRIENTS	CELL COUNTS	FLOW CAM
9/4/12	Piers	2	surface		✓	✓	✓	✓	✓	✓	□
9/6/12	Yellowfin	5	surface/dcm	✓	✓	✓	✓	✓	✓	✓	✓
9/10/12	Piers	2	surface		✓	✓	✓	✓	✓	✓	□
9/11/12	Nerissa	11	surface/dcm	✓	✓	✓	✓	✓	✓	✓	✓
9/12/11	Yellowfin	5	surface/dcm	✓	✓	✓	✓	✓	✓	✓	✓
9/17/12	Piers	2	surface		✓	✓	✓	✓	✓	✓	□
9/18/12	Nerissa	11	surface/dcm	✓	✓	✓	✓	✓	✓	✓	✓
9/20/12	Yellowfin	6	surface/dcm	✓	✓	✓	✓	✓	✓	✓	✓
9/24/12	Piers	2	surface		✓	✓	✓	✓	✓	✓	□
9/25/12	Nerissa	10	surface/dcm	✓	✓	✓	✓	✓	✓	✓	✓
9/27/12	Yellowfin	5	surface/dcm	✓	✓	✓	✓	✓	✓	✓	□
9/27/12	Nerissa	2	surface/dcm	✓	✓	✓	✓	✓	✓	✓	□
10/1/12	Piers	2	surface		✓	✓	✓	✓	✓	✓	□
10/2/12	Nerissa	10	surface/dcm	✓	✓	✓	✓	✓	✓	✓	✓
10/8/12	Piers	2	surface		✓	✓	✓	✓	✓	✓	□
10/9/12	Nerissa	10	surface/dcm	✓	✓	✓	✓	✓	✓	✓	✓
10/10/12	Nerissa EcoHAB	11	surface/dcm	✓	✓	✓	✓	✓	✓	✓	✓
10/15/12	Piers	2	surface		✓	✓	✓	✓	✓	✓	□
10/17/12	Nerissa EcoHAB	5	surface/dcm	✓	✓	✓	✓	✓	✓	✓	✓
10/22/12	Piers	2	surface		✓	✓	✓	✓	✓	✓	□

updated 11/13/12

completed
to be analyzed
partially analyzed
below detection
results pending
not being analyzed

Based on our present level of sample analysis (primarily chlorophyll concentrations; some phytoplankton composition analyses, FlowCAM analysis for surface samples, toxin analyses on several samples), it is clear that *there was no major response of the phytoplankton in the region as a consequence of the diversion event*. Phytoplankton response (chlorophyll concentrations) at the Newport Beach and Huntington Beach piers showed maximal concentrations of 5-6 µg/l, values that are well within seasonal and annual ranges in this region (Figure 3.51; compare with weekly-to-annual ranges observed for Newport Beach pier and available through the SCCOOS HAB website; URL: http://www.sccoos.org/data/habs/index.php). Similarly, *abundances of Pseudo-nitzschia spp. were within ranges of these cells observed during non-bloom periods in the region* (Figures 3.54 and 3.55). *All samples were below detection for particulate domoic acid.*

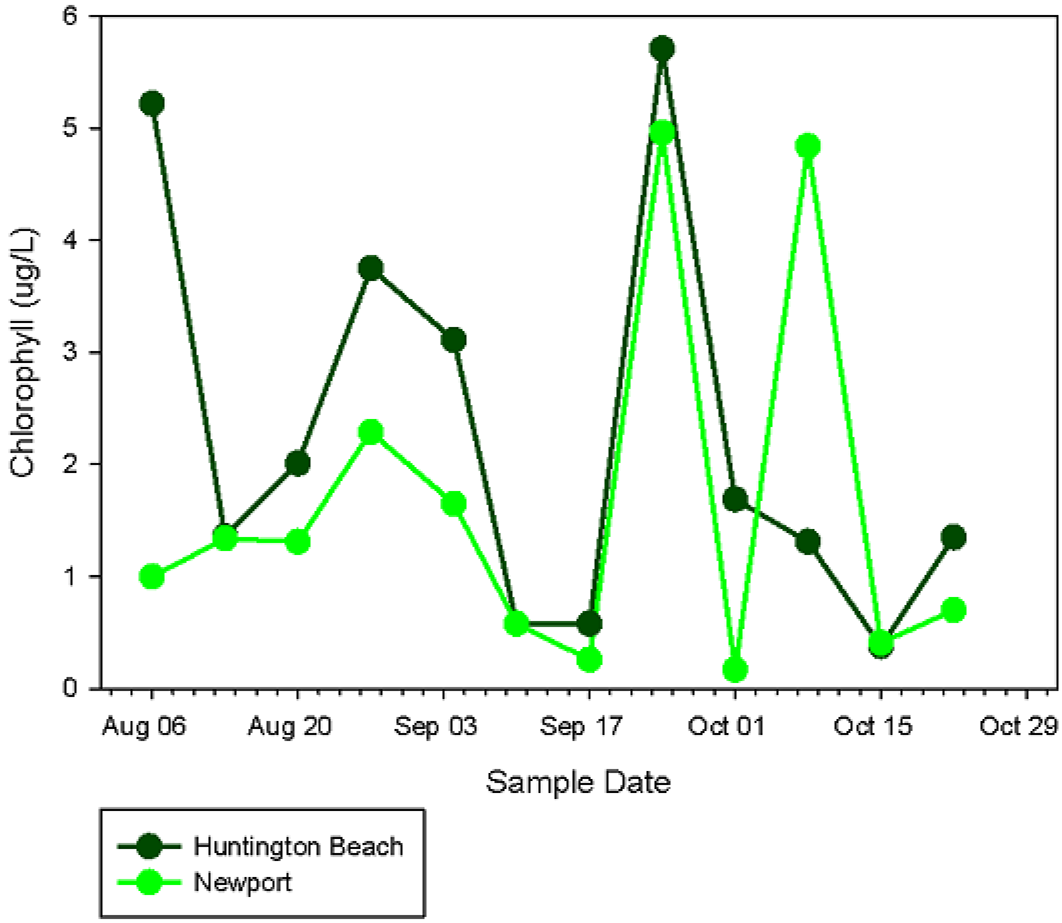

Figure 3.53 *Pier chlorophyll*

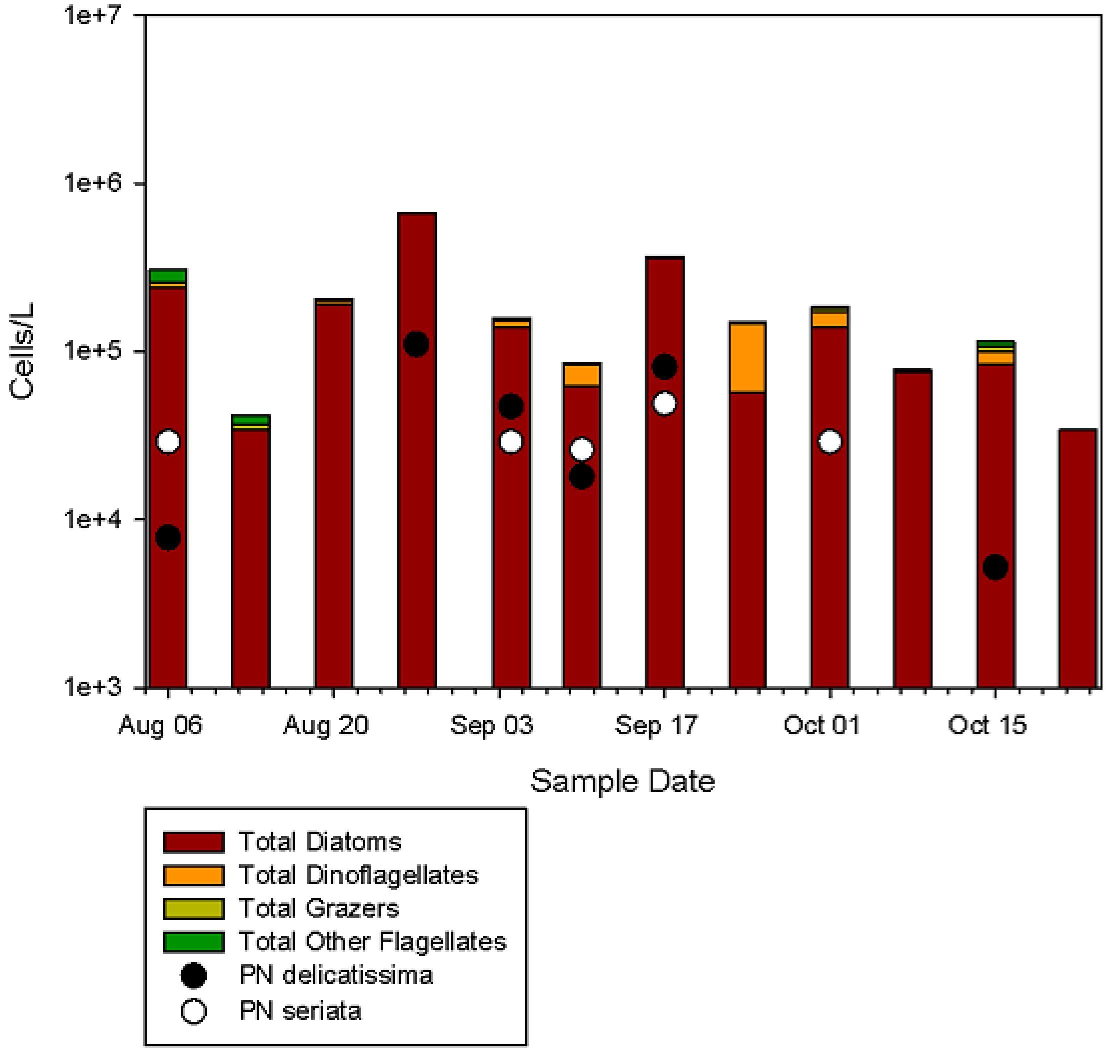

Figure 3.54 *Huntington Beach Pier*

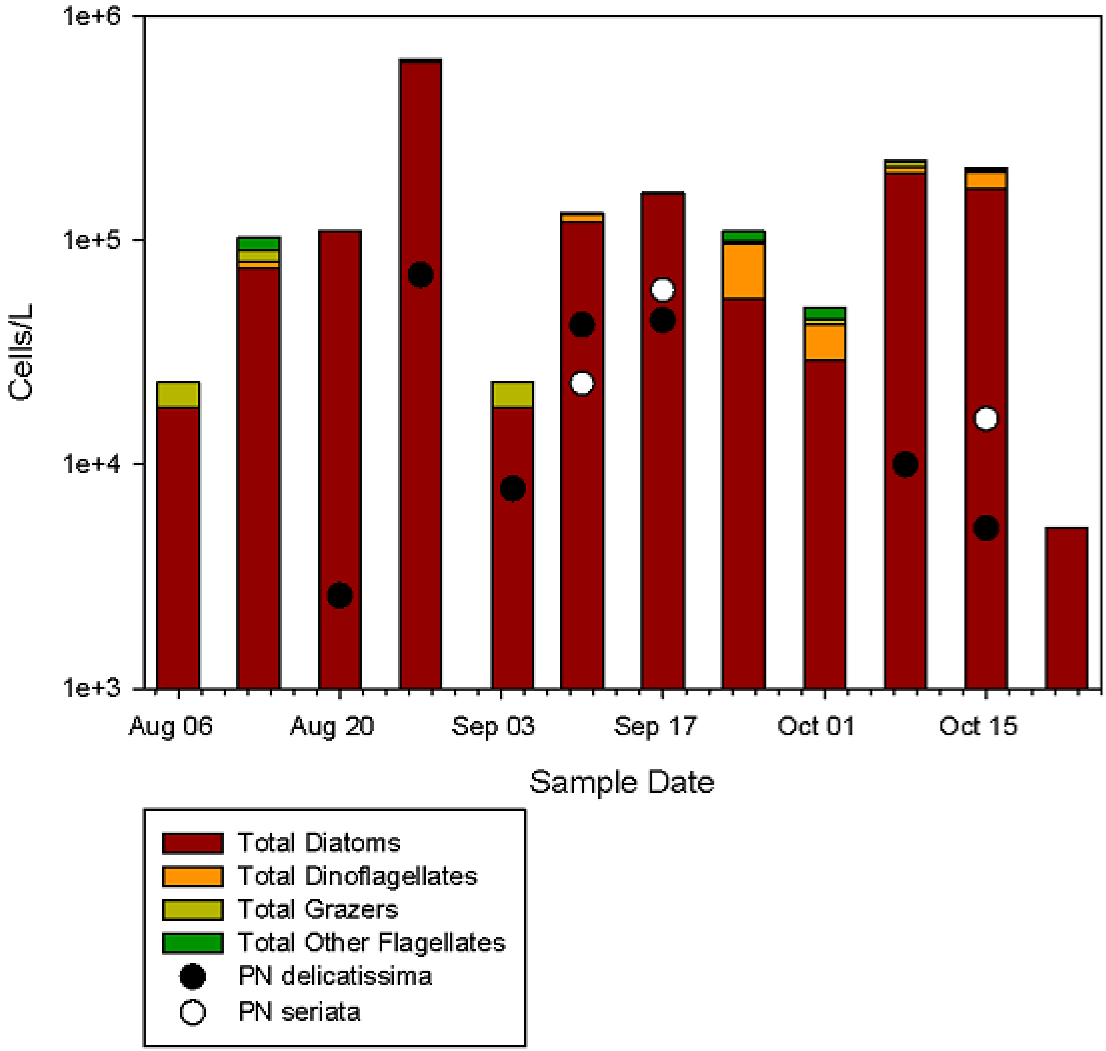

Figure 3.55 *Newport Beach Pier*

Phytoplankton biomass (i.e. chlorophyll concentration) remained low throughout the geographical region prior to, during and immediately following the 3-week diversion event. Summed over all shipboard samples collected, and over both depths, chlorophyll concentrations ranged from <0.1 to 5.5 µg/l. These values are consistent with values of phytoplankton biomass within the region at this time of year, and they are 5- to 10-fold lower than chlorophyll concentrations that have been observed during phytoplankton blooms in the region.

Phytoplankton assemblages in surface waters prior to, during and post diversion event were unremarkable in their composition. Species of diatoms or dinoflagellates that are common to the area were dominant taxa during the diversion (see attached picture collage generated from one FlowCAM analysis; Figure 3.56). Potentially harmful species have been sporadic and rare in abundance in the samples examined to date.

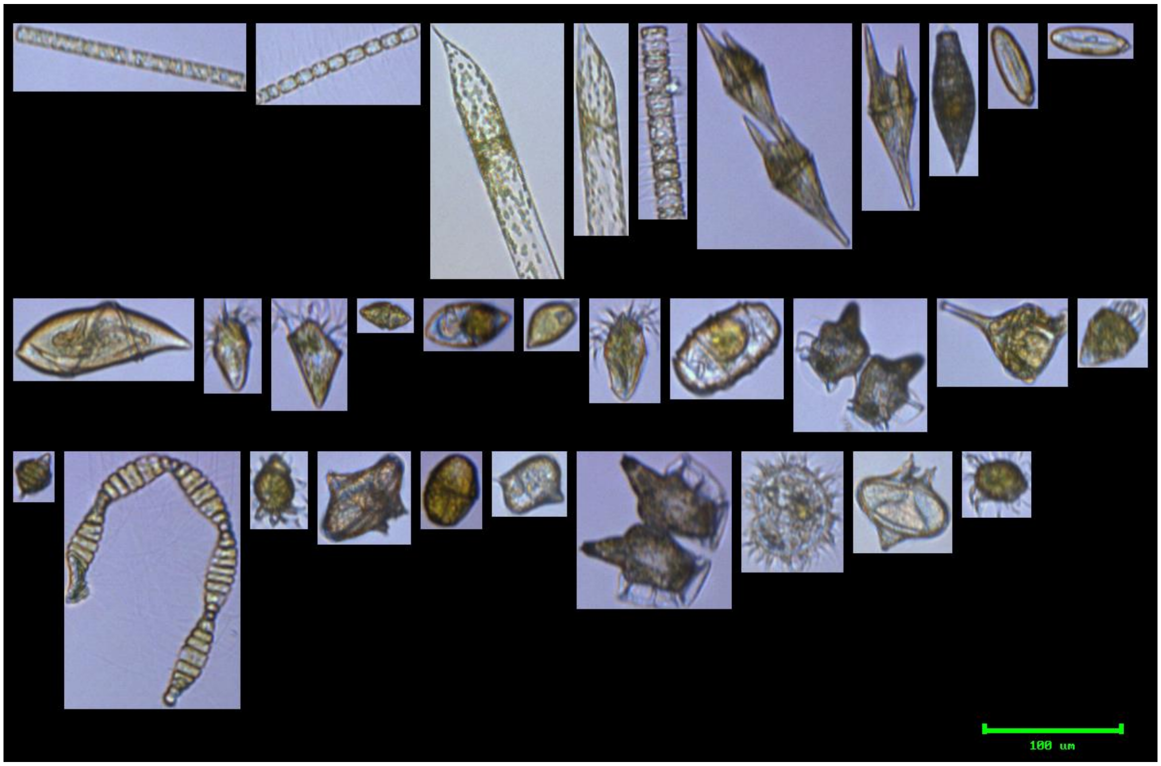

Figure 3.56 *An example of FlowCAM imagery of the natural phytoplankton community observed in coastal waters near the diversion discharge point during the diversion event. Common phytoplankton taxa at this station included several diatoms (Chaetoceros, Rhizosolenia), phototrophic dinoflagellates (Ceratium), heterotrophic dinoflagellates (Dinophysis, Protoperidinium) and oligotrichous ciliates.*

3.3 Self Contained

A) Current Profilers – George Robertson, OCSD

Overview

Five self-contained current profilers were deployed in trawl-resistant bottom mounts (TRBMs) or tripods (Figure 3.57). There were two types of current meters; Acoustic Doppler Current Profilers (ADCP) developed by Teledyne RD Instruments and the Nortek AWAC current profile, wave height, and direction instrument. The instruments were named after the moorings that they were deployed next to and the type of instrument installed in the TRBM (Table 3.26). Three of the moorings that they were named after were part of another funded project that ran concurrently to the J-112 OCSD funded project and those moorings are not expanded on in this synthesis report.

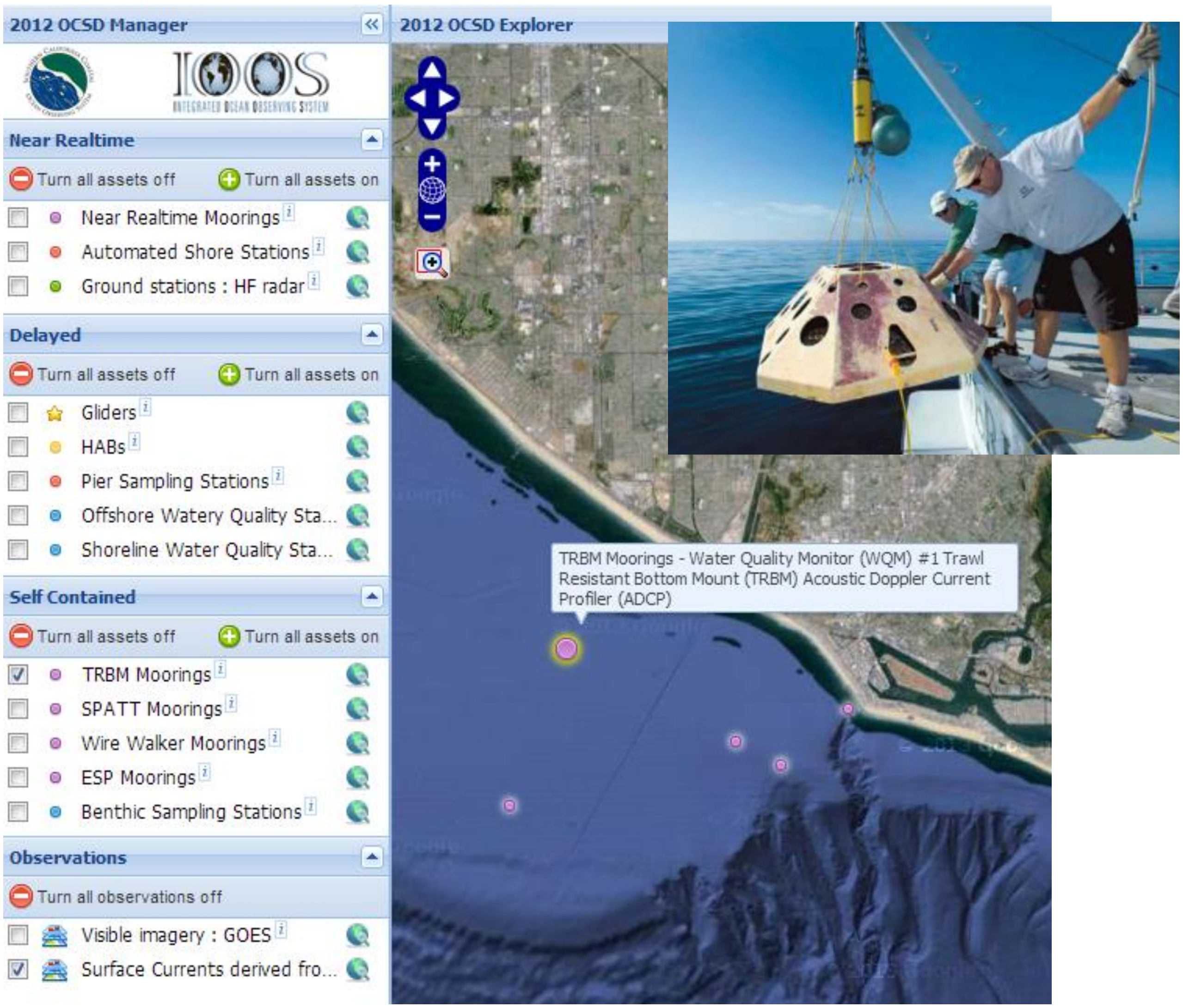

Figure 3.57 *Trawl Resistant Bottom Mounted (TRBM) self-contained current profiler mooring locations. Upper right - George Robertson, left, and Michael Mengel, with the OCSD deploy one of three trawl resistant bottom mounts loaded with current meters about 4 ½ miles off the coast near Newport Beach. Photo credit Joshua Sudock, the Orange County Register.*

Table 3.26 Deployment depth, orientation, and strata ranges of OCSD current meters enclosed in a TRBM					
Current Meter	MBARI/ADCP	UCI/AWAC	M19/ADCP	WQM#1/ADCP	WQM#2/ADCP
Latitude	33° 35.7710 N	33° 36.3730 N	33° 35.4250 N	33° 37.0760 N	33° 36.0860 N
Longitude	-117° 56.8140 W	-117° 56.1110 W	-117° 59.0910 W	-117° 59.7690 W	-117° 57.4440 W
Orientation	Upward	Upward	Upward	Upward	Upward
Depth	20	10	40	20	20
Upper (m)	1-6	2-4	2-13	1-6	1-6
Middle (m)	7-12	5-7	14-25	7-12	7-12
Lower (m)	13-18	8-10	26-37	13-18	13-18

Methods

Teledyne RD Instruments Workhorse Acoustic Doppler Current Profiler (ADCP) and Acoustic Wave and Current profiler (AWAC)

Current meter data were converted into scientific units using WinADCP (2003). Pitch and roll values were checked to see if there was a serious tilt on the instrument during the deployment procedure. If the tilt exceeded 10°, current data were excluded from further analysis, and only temperature data were used. The time base for each instrument was checked for agreement with the projected number of records and for agreement with the logged deployment and recovery times for these sampling events. The remainder of the data processing was conducted in MATLAB (2007). All non-usable data points and outliers were replaced with a "NaN" data flag. These data points were then replaced with linearly interpolated data before applying the low-pass filter. A Finite Impulse Response (FIR) filter was used to perform a zero-phase distortion, forward and reverse digital filter that minimizes start-up and ending transients by matching the initial conditions.

Graphical data were shown as vector plots ("stick plots") with the lines pointing in the direction of the current and the length proportional to the current magnitude. Because current vectors generally tend to follow the local bathymetry, the frame-of-reference for the figures is rotated so that upward-directed "sticks" correspond to upcoast flows and sticks directed to the right correspond to onshore flows. For this presentation, the bathymetric orientation is 302° or 310° (specific mooring orientations are included in their figure), consistent with bathymetry orientation values used for prior studies in the District's study region. Current rose plots are based on true north.

Results

Current data from all five of these sites ranged from 10–40 m were binned into three depth strata — top, middle, and bottom (Table 3.26). Current roses from all five current meters showed consistent alongshore flow with little cross-shelf transport (Figures 3.58 to 3.62). The 20 m MBARI /ADCP off of the Newport Pier had surface flows biased toward the southeast direction, while middle and bottom currents were predominantly northwestward. The 10 m UCI/AWAC surface currents were biased slightly in the upcoast direction while the middle and bottom currents tended to be more evenly distributed. Finally, the 40 m M19/ADCP showed a slight downcoast bias at the surface, but a strong upcoast (northwest) and offshore (west) flow in the lower two layers.

Feather plots (Figures 3.51 and 3.62) from current meters located in proximity of the WQM's, WQM#1/ADCP and WQM#2/ADCP show that at the onset of the diversion, current flows were consistently downcoast for the first week in the upper and middle water layers. Bottom currents showed some reversals towards the end of the first week, especially at WQM#2/ADCP. Current directions were predominantly alongshore (southeast to northwest). Surface currents had a southeast bias at both stations, while bottom currents tended to the northwest.

Mid-column currents at WQM#2 were mostly in the northwest direction, with an approximately equal southeast/northwest distribution at WQM#1/ADCP.

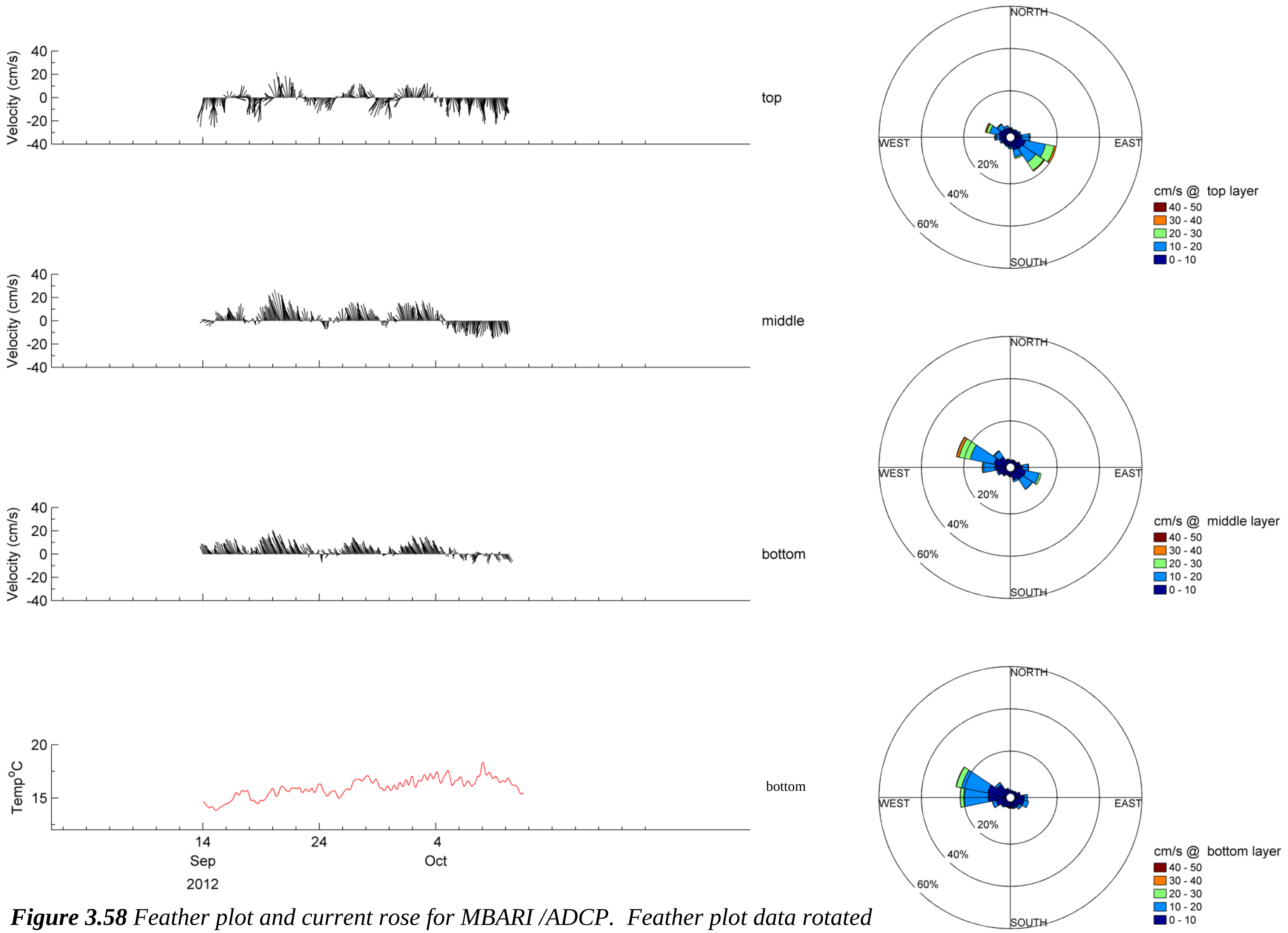

Figure 3.58 *Feather plot and current rose for MBARI /ADCP. Feather plot data rotated 302° so that up is upcoast and right is onshore. Current rose direction based on true north.*

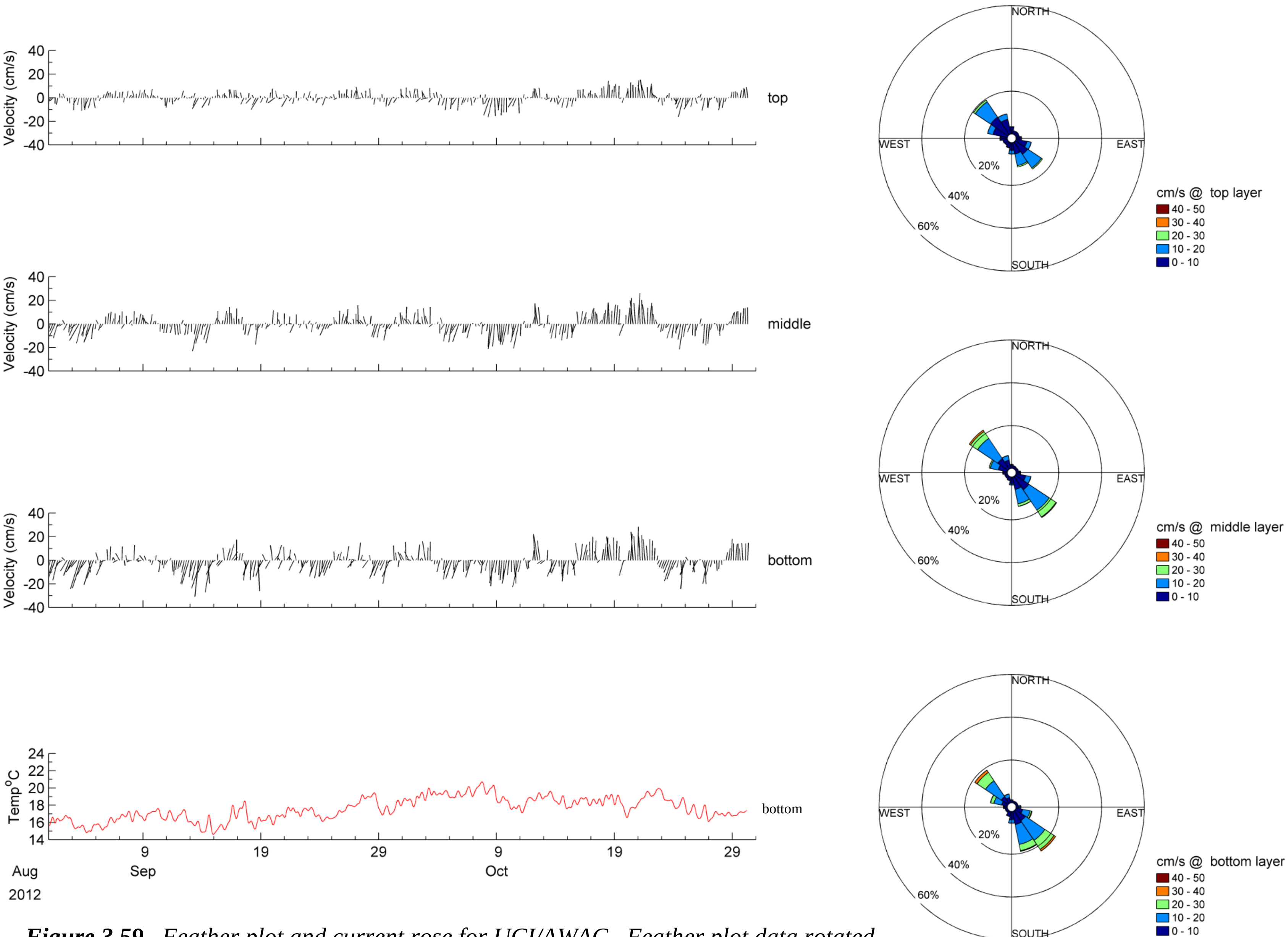

Figure 3.59 *Feather plot and current rose for UCI/AWAC. Feather plot data rotated 310° so that up is upcoast and right is onshore. Current rose direction based on true north*

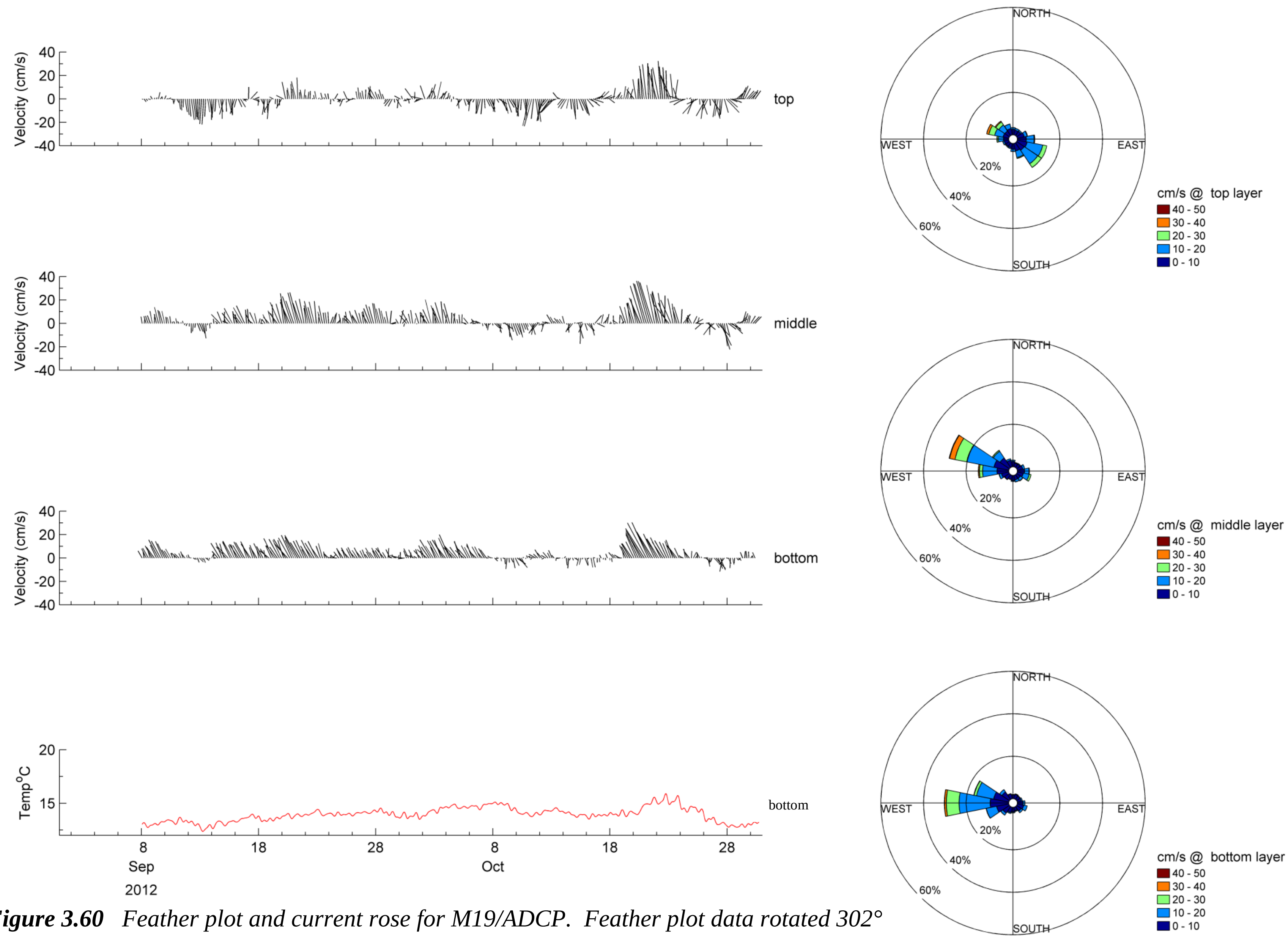

Figure 3.60 *Feather plot and current rose for M19/ADCP. Feather plot data rotated 302° so that up is upcoast and right is onshore. Current rose direction based on true north*

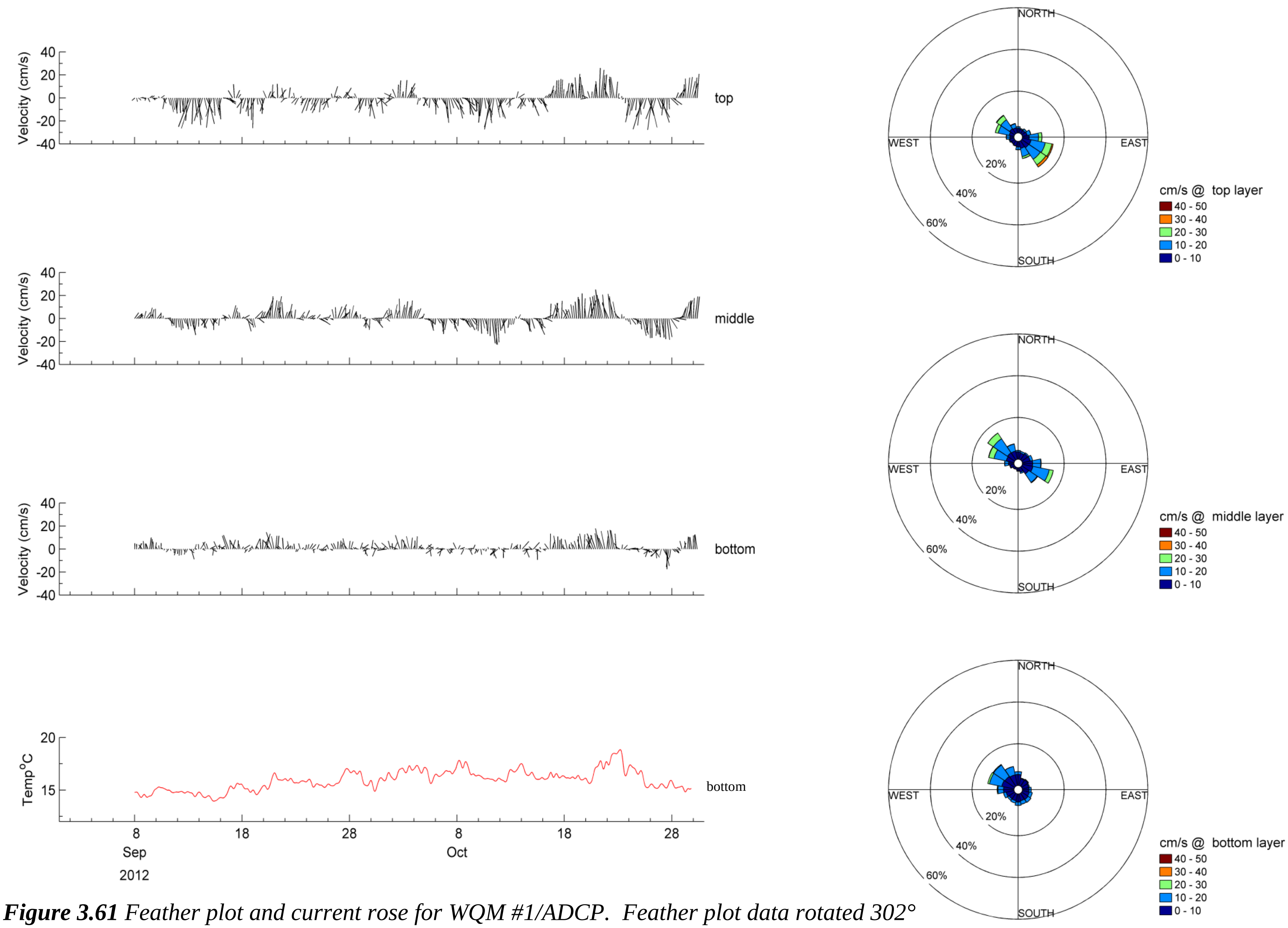

Figure 3.61 *Feather plot and current rose for WQM #1/ADCP. Feather plot data rotated 302° so that up is upcoast and right is onshore. Current rose direction based on true north. Depth layers are defined in Table 4.2.*

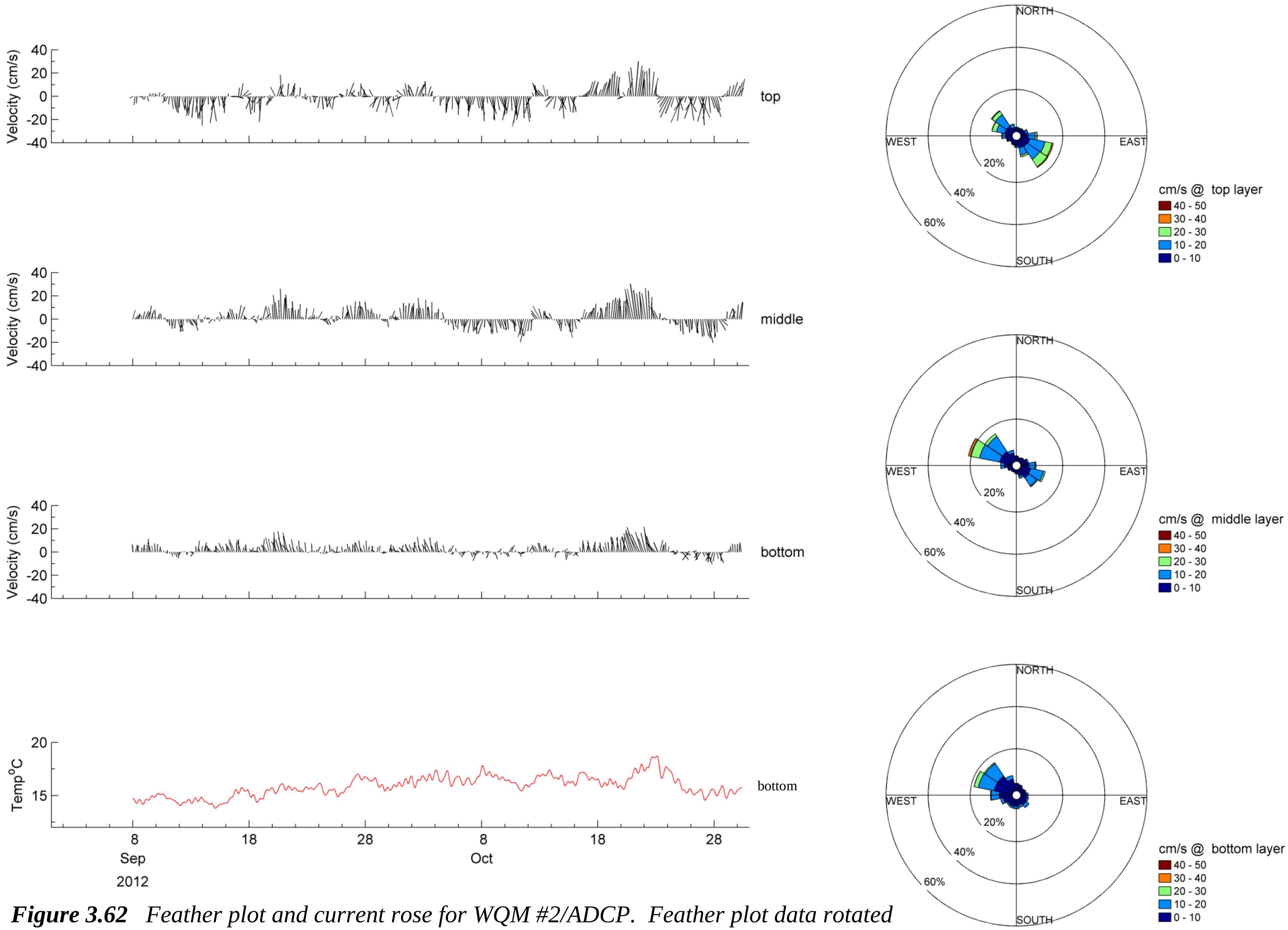

Figure 3.62 *Feather plot and current rose for WQM #2/ADCP. Feather plot data rotated 302° so that up is upcoast and right is onshore. Current rose direction based on true north.*

3.4 Models – Yi Chao, RSS

A) Southern California Bight (SCB)

Overview

Early in the project, it was realized that it was not feasible to implement data assimilation in the proposed higher resolution Regional Ocean Modeling System (ROMS), mostly because of the limited time and resources. Instead, it was decided that the real-time data assimilative ROMS currently being run in the SCB with 1 km resolution would be used to provide the lateral boundary conditions for a 3 domain nested ROMS configuration with increasing spatial resolutions of 750 m, 250 m and 75 m over the region of interest (Figure 3.63). This serves to transmit the broader effects of the winds and the California Current System and its spontaneous mesoscale eddies down to the local shelf circulation with its submesoscale vortices, surface fronts and filaments, separating topographic currents, and drag-induced lateral shear in shallow-water approaching the shoreline.

It should be emphasized that this proposed effort was closely coordinated with the USC and University of California, Los Angeles (UCLA) activities on the glider deployment and ROMS development, respectively. Additional support from OCSD and SCCOOS are also acknowledged.

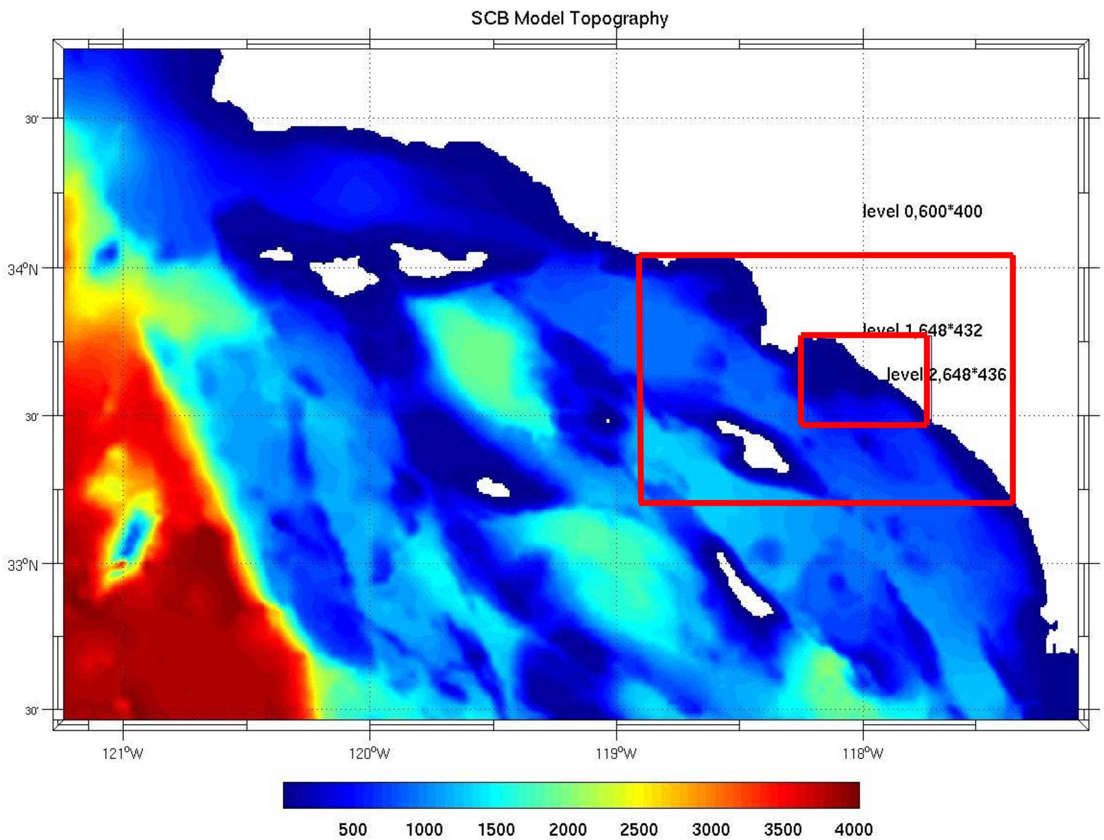

Figure 3.63 *Hierarchy of three nested grids on which the OCSD outfall simulations are based. The outermost grid is for the Southern California Bight, and it has a horizontal grid spacing of dx = 750 m. The middle grid has dx = 250 m. The innermost San Pedro Bay grid with dx = 75 m. Color indicates the bathymetry with unit in meters.*

Methods

The ROMS is a hydrostatic simulation code with realistic surface wind and buoyancy forcing, bottom topography, equation of state, tides, surface gravity waves, sediment transport, river inflow, and open boundary conditions that are derived from data analysis or global circulation model solutions (Shchepetkin and McWilliams, 2005). For particular applications only relevant subsets of these capabilities are employed. The original design purpose for ROMS was mean and mesoscale circulations and material distributions on regional scales of 10s-100s km, but for several years ROMS has been undergoing an evolution toward also encompassing smaller scales and shallower, nearshore phenomena (Capet et al., 2008; Uchiyama et al., 2010; Colas et al., 2011). A particular focus region is the Southern California Bight (SCB) (Dong et al., 2009; Mitarai et al., 2009; Idica, 2010; Buijsman et al., 2011). An essential aspect of our approach is the technique of nested computational grids (Mason et al., 2010), to be able to calculate the evolution of local phenomena under the partial control of highly variable regional circulations.

Data Assimilated

The following observational data sets are assimilated into the SCB ROMS at 1 km resolution.

1. HF Radar/SIO Parameter: Surface current from HFR/SIO
2. Glider/SIO Parameter: Vertical profiles of temperature and salinity
3. Satellite/RSS Parameter: Sea Surface temperature

Since April 2007, we have transitioned the 1 km SCB ROMS model (developed by the UCLA group) from a research mode to real-time operations. Data from a variety of in situ and remotely sensed platforms are assimilated in near real-time (within hours) into this model through the 3DVAR data assimilation scheme described here. We are now assimilating the surface current data collected from a network of HF radars. The ROMS nowcast (also known as analysis) is issued every six hours at 03, 09, 15, and 21 GMT hours. Using the nowcast as the initial condition, a 2-day forecast is made with hourly output saved.

Results

Leveraging the current funding from SCCOOS, Remote Sensing Solutions (RSS) has performed the following tasks during 2012:

- Maintained and published the results of the 3-dimensional variational (MS-3DVAR) data assimilative SCB ROMS
- Developed a 3-domain nested ROMS with resolutions of 750 m, 250 m, and 75 m, respectively
- Performed the nowcast and forecast runs of this 3 domain nested ROMS during September 2012
- Published images, movies as well as customized products on a ROMS web site that is linked by the SCCOOS project web page
- Provided summary interpretations of the data products and tools on the regular basis (daily if needed) to support decision making during the outfall diversion effort of September-October 2012
- Evaluated the performance of the developed ROMS nowcast and forecast fields based on the available observations

During the September diversion effort, a daily report was published on the JPL web page to summarize the ROMS modeling effort. It was posted manually during the start of the diversion effort. By the middle of September, we implemented an automated reporting procedure where the ROMS developers can post reports and status, while the outside users can post comments and suggestions. See Appendix VI for a sample report.

During the model development and implementation phase, we have conducted a number of hindcast runs during periods when there are historical observations. The results, as shown in Figure 3.64**,** show that the 75 m ROMS is capable of producing many fine scale features while showing a general agreement with the large-scale patterns as identified by the ship survey data.

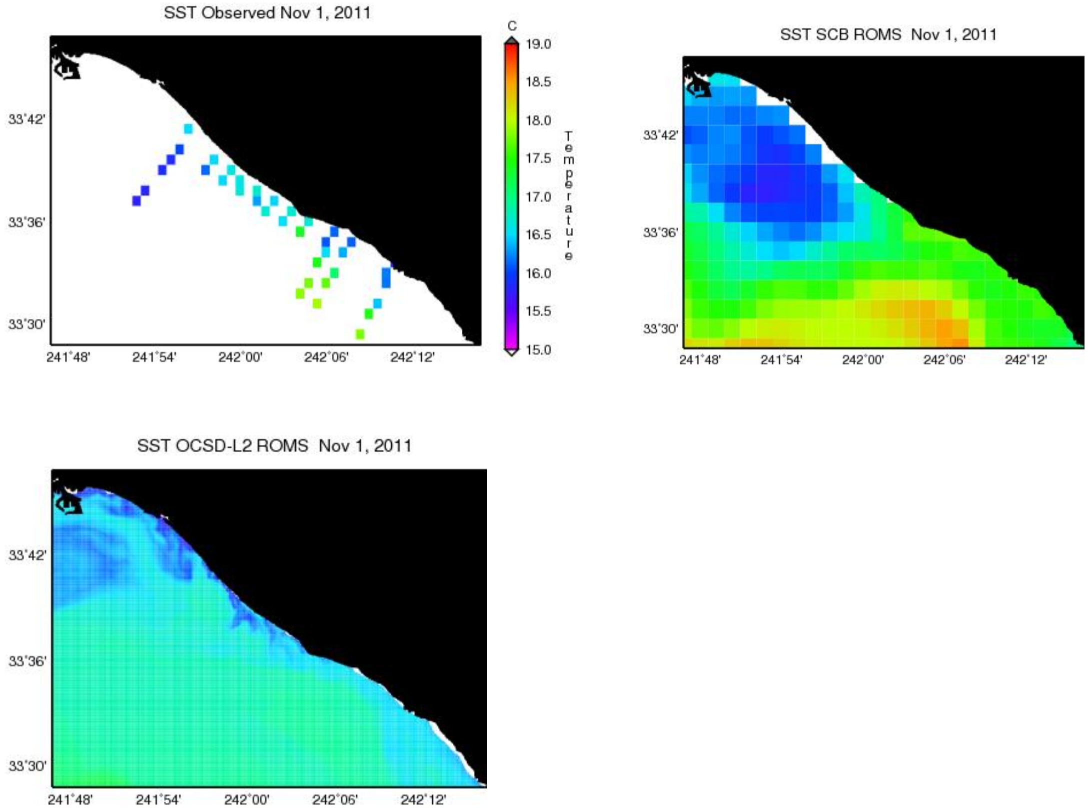

Figure 3.64 *Sea surface temperature as observed by ship surveys (top-left panel) and simulated by the 1 km SCB ROMS (top-right panel) and the 75 m downscaled ROMS (bottom-left panel). The same color scheme is used in all plots.*

During the diversion effort in September, we are using the HF radar derived surface current data (at 6 km, 2 km, and 1 km resolution as shown in Figure 3.65) to validate the 1 km SCB ROMS and 75 m ROMS nowcast as well as forecast results (Figure 3.66)

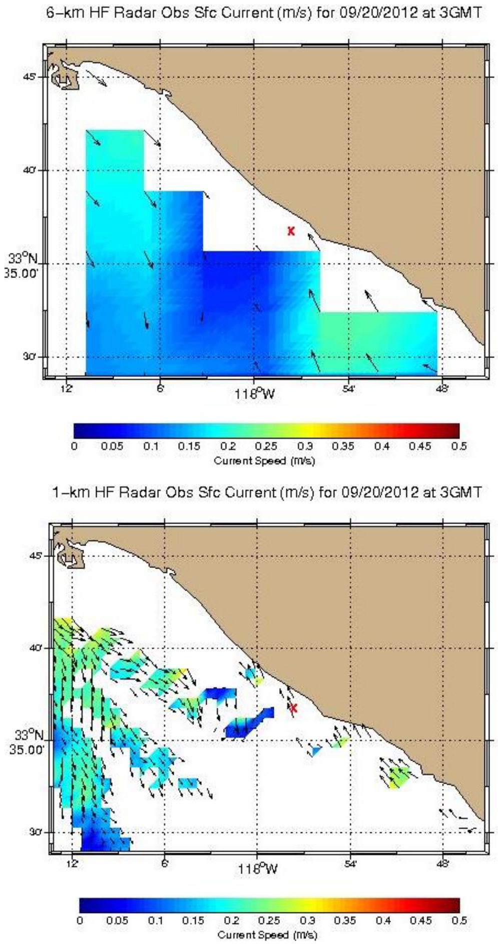

Figure 3.65 *Sea surface current as derived from HF radar observations at the spatial resolution of 6 km (top-left panel), 2 km (top-right panel), and 1 km (bottom-left panel). The same color scheme is used in all plots.*

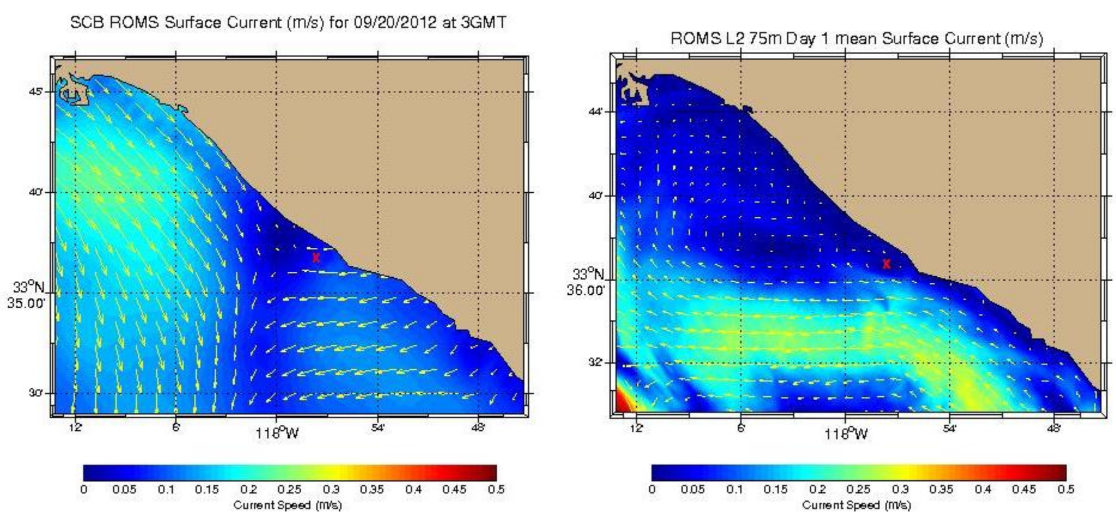

Figure 3.66 *Sea surface current as simulated by the 1 km SCB ROMS and 75 m ROMS.*

The original plan was to implement the 3-dimensional variational (3DVAR) data assimilation method into the 75 m ROMS as well as the 1 km SCB ROMS. Given the delayed start and the short implementation period left before the diversion effort, there was not enough time to implement the 3DVAR data assimilation in the outmost ROMS domain. Instead, we are simply using the 1 km SCB ROMS to force the 750 m ROMS without explicit data assimilation.

After a preliminary evaluation of the 75 m ROMS hindcast simulations during several periods when there are historical observations, it was tested in a real-time nowcast and forecast mode shortly before the September diversion effort. Both the 1 km SCB ROMS and 75 m ROMS output are published at a JPL web page that is linked from the SCCOOS diversion web page. Using the ROMS output, we have also produced and published the movie animations of the particle trajectories during the 48 hours forecast period. During the diversion effort, a daily summary with interpretations of the various data products and tools provided by the JPL/UCLA/RSS ROMS team was also provided with a goal to support decision making.

The major findings include:

- The 1 km SCB ROMS with the HF radar data assimilation demonstrated a relatively more stable and robust solution.
- The 75 m ROMS without the data assimilation, even constrained by the lateral boundary conditions from the 1 km SCB ROMS, occasionally showed different behaviors as compared to the available observations such as HF radar derived current and ADCP measurements.
- Pre-defined images over the relatively smaller region of interest are very useful to aid decision making during the field experiment.
- Movie animations showing the trajectories of a cluster of particles released at the outfall location during the 48 hours forecast period were very useful to anticipate the future evolutions of the local circulation.

4 Web Portal

The OCSD diversion web portal (Figure 4.1) provided an overall summary of OCSD's diversion sampling program, graphical maps of field sampling locations based upon Google mapping services, as well as near real-time and in-situ environmental observations or links to those observations. An administrative interface was be designed to allow for upload and posting of additional nearshore sampling and ocean modeling, including a daily summary of environmental conditions for regulators and environmental managers provided by OCSD.

The OCSD diversion web portal was developed to provide a centralized, interactive web presence for performers, decision makers, and the general public to access information and observations and plays an integral role in a diversion monitoring program. The portal supported daily use of an online webpage that displayed near real-time observations that guided daily monitoring activities for making improved measurements in support of the diversion.

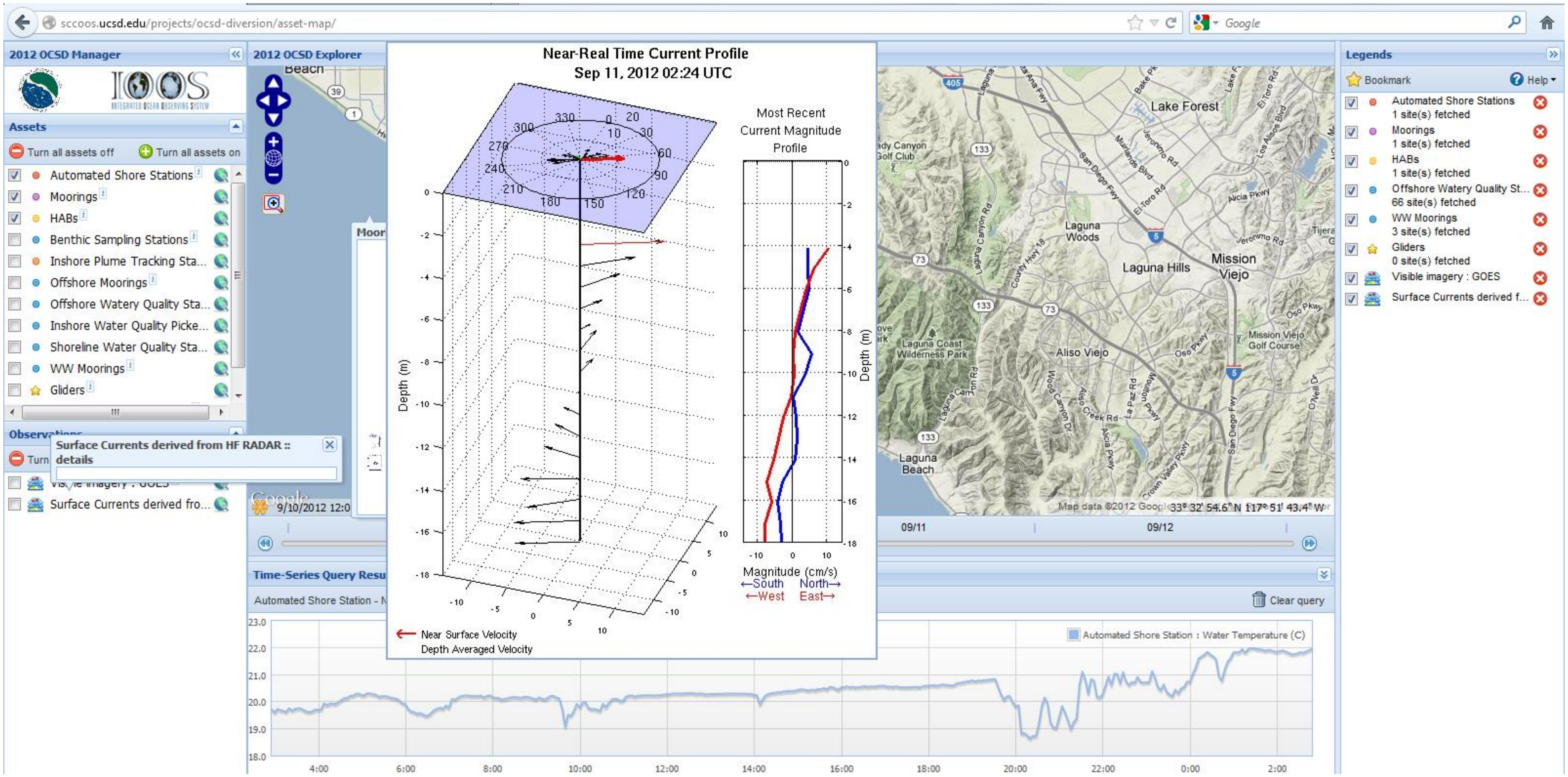

Figure 4.1 *The OCSD web portal provided access to observations which allowed for participants and program managers to make educated decisions regarding asset placement and go/no go field operations.*

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AB 411 - AB 411 would require the State Department of Health Services to adopt regulations requiring the testing of all beaches for total coliform, fecal coliform, enterococci, and streptococci bacteria, establish protective minimum standards for the location of monitoring sites and monitoring frequency, to require posting in clearly visible points along affected beaches whenever state standards are violated, and to require that beaches be tested for total coliform, fecal coliform, enterococci, and streptococci bacteria and chemical pollutants including, but not limited to, PCBs, PAHs, and mercury on a weekly basis from April 1 to October 31, inclusive, of each year if certain conditions are met. AB 411 would require the local health officer to notify the Director of Parks and Recreation within 24 hours of any beach posting, closure, or restriction, and would require the Director of Parks and Recreation to establish a telephone hotline and update it daily to inform the public of beach postings, closures, and restrictions.

Appendix I – Statement of Work Task I: Synthesis Report

The Orange County Sanitation District (OCSD) Diversion Project synthesis report was compiled by Southern California Coastal Ocean Observing System (SCCOOS) based upon reports from the various groups performing effluent, shoreline, and offshore sampling, as well as nearshore and offshore modeling.

Components of the report include:

- An overview of the project, including a project description
- List of participants and their affiliations
- Description of the monitoring, including a map of geographic location of the instrumentation, available metadata of the instrument specifications, sample rate and resolution of data collection, data analysis techniques, and quality control performed
- Description of the modeling efforts including model descriptions with forcing functions and validation
- Summary of the online visualization and data dissemination
- A summary of the findings from all the supplemental measurement and modeling components, as well as from the routine measurement programs

The supplemental monitoring and modeling efforts include:

- Daily shoreline sampling for the three fecal indicator bacteria (FIB; total coliform, fecal coliform, and enterococci), and salinity occurred at 17 stations from Sunset beach to Crystal Cove. This was a weekly picketline sampling along the 10meter (~30 ft) bottom contour, performed in conjunction with the nearshore (shoreline) sampling from R/V Nerissa. Discrete FIB and NH3-N samples were collected at each station.
- 19 conductivity-temperature-depth (CTD) field stations located along the 10 m contour from Bolsa Chica to Crystal Cove State Beaches
- 48 offshore CTD and discrete water sampling stations located at and downcurrent of the short outfall. Stations were located in two, overlapping 12x4 grids (up and downcoast). Maximum CTD depths were 60 m. Discrete FIB and NH3-N samples were collected at each station.
- 12 Microstar surface drifters deployed at the 78 inch outfall from 16 September 2012 to 9 October 2012
- An enhanced disinfection program was conducted during the diversion to the 78 inch outfall, and the final effluent was sampled up to four times a day.
- 2 glider tracks ran continuously along the coastline from San Pedro shelf south to Crystal Cove State Beach, measuring temperature, conductivity, chlorophyll fluorescence, CDOM, phycoerythrin fluorescence and backscatter (absorption wavelengths 550, 650, and 880 nm)
- Deploy three telemetered moorings to measure and transmit ocean currents and water quality conditions. One mooring was deployed to measure at the short outfall to measure currents and water temperature. Two moorings were deployed up and downcoast of the short outfall that measured biologic and optical water properties in surface waters.
- Harmful Algal Bloom data collection at the existing SCCOOS Newport and Huntington Pier stations
- Sediments were collected before and after the discharge from the short outfall. Analysis of this data will occur at a later date.
- Real-time data assimilative Regional Ocean Modeling System (ROMS) of the Southern California Bight (SCB) with 1 km resolution as well as a triply-nested non-assimilating model.
- Satellite support for the diversion

A more complete description of the efforts outlined above may be found in the Ocean Modeling and Receiving Waters Monitoring Work Plan available from OCSD. Data that are normally collected, including HF radar-derived surface currents, are included in the Synthesis Report. Additionally, the Jones Laboratory and Southern

California Coastal Water Research Project (SCCWRP) deployed two gliders in the Spring of 2012 to acquire background data that was used by the McWilliams laboratory at UCLA for nearshore modeling of the Newport Beach and Huntington Beach area through collaboration with the ECOHAB project, “A Regional Comparison of Upwelling and Coastal Land Use Patterns on the Development of Harmful Algae Bloom Hotspots along the California Coast”.

The synthesis report provides the foundation for further technical review as to the effectiveness and efficiency of the overall plan.

Appendix II - Point of Contact for Observational Assets that Participated in the OCSD diversion

The data collected by the below observational assets were collected from three funded projects that ran concurrently to the OCSD J-112 funded project. Please contact the principle investigators listed below for requests of data or information.

The links provided below were created for June 13, 2013 OCSD diversion workshop hosted by Meredith Howard at Southern California Coastal Water Research Project (SCCWRP).

The summary power point for this meeting:
http://data.sccwrp.org/owncloud/apps/files_sharing/get.php?token=61b3525848935b9fe4f52713199e0b871f4da15e&path=/McLaughlin.pdf

1. Dave Caron, Caron Laboratory at University of Southern California (USC)

Funding provided by NOAA ECOHAB grant and J-112

USC Biological Sciences Department
3616 Trousdale Parkway – Allan Hancock Foundation Building
Los Angeles, CA 90089
dcaron@usc.edu
213-740-0203

Two studies were conducted to evaluate the response of the local phytoplankton community to this event:

- Benchtop studies were conducted using natural plankton assemblages contained in bottles to examine the response of the community over the course of several days when subjected to different levels of effluent enrichment;

Shipboard **Assets**

Two large sensor moorings with SPATT bags

Main role is to characterize the algal community composition and use gliders to track the effluent plume and any algal blooms that develop.

Investigation summary power point
http://data.sccwrp.org/owncloud/apps/files_sharing/get.php?token=61b3525848935b9fe4f52713199e0b871f4da15e&path=/Caron.pdf

Information regarding the SPATT bags included in Dave Caron's Report not included in J-112 Report

Moorings equipped with SPATT (Solid Phase Adsorption Toxin Tracking) units were also deployed to examine integrated toxin concentrations in surface waters. Samples were collected and processed for determination of response of the microalgal and microzooplankton assemblages (extracted chlorophyll; cell counts of major taxa by light microscopy; flow cytometry for minute algae, FlowCAM analysis for imaging of abundant taxa). Samples are also being analyzed for specific, quantitative counts of potentially harmful algal species (most importantly, *Alexandrium* and *Pseudo-nitzschia* species), and toxin analyses for samples with toxin-producing species (domoic acid, saxitoxins; by ELISA).

Most toxin analyses have yet to be below detection or very low in concentration, not an usual finding for this region and season. Thus far, *there is no indication that effluent release resulted in increased production of domoic acid*. Only one SPATT sample analyzed to date has shown significant concentrations of domoic acid. This sample is being run independently in another laboratory to confirm the concentrations.

2. Yi Chao, Remote Sensing Solutions (RSS)

Funded by J-112 program

Principle Scientist

2824 East Foothill Blvd.
Los Angeles, CA 91107
ychao@remotesensingsolutions.com
(626)-421-7970

Observational assets
Provided modeling and daily predictions of ocean conditions and particle transport using Regional Ocean Modeling System (ROMS). Model provided a nested solution down to 75-m resolution.

Investigation summary power point
http://data.sccwrp.org/owncloud/apps/files_sharing/get.php?token=61b3525848935b9fe4f52713199e0b871f4da15e&path=/Chao.pdf

3. Ben Holt, National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL)
Funded by J-112 Program
JPL Oceans and Ice Department
Jet Propulsion laboratory M/S 300-323
4800 Oak Grove Drive
Pasadena, CA 91109
benjamin.m.holt@jpl.nasa.gov
(818) 354-5473

Observational assets
Provided satellite imagery.

Investigation summary power point
http://data.sccwrp.org/owncloud/apps/files_sharing/get.php?token=61b3525848935b9fe4f52713199e0b871f4da15e&path=/Holt.pdf

4. Meredith Howard, Southern California Coastal Water Research Project (SCCWRP)
Investigator on NOAA ECOHAB Grant and also helping OCSD to coordinate all science groups
Funding provided by NOAA ECOHAB Grant and SCCWRP
mhoward@sccwrp.org
714-755-3263

Observational Assets
Robotic submarine gliders, research vessels, drifters, water quality samples

Investigation summary power point
http://data.sccwrp.org/owncloud/apps/files_sharing/get.php?token=61b3525848935b9fe4f52713199e0b871f4da15e&path=/McLaughlin.pdf

5. Burt Jones, Burt Jones Laboratory University of Southern California (USC)
Burt Jones and Bridget Seegers
Funding provided by NOAA ECOHAB grant and J-112
USC Marine and Environmental Biology, Biological Sciences
3616 Trousdale parkway
Allan Hancock Foundation Building
Los Angeles, CA 90089-0371

seegers@usc.edu
213-740-5809

Observational assets:
Robotic submarine gliders conducted plume tracking monitoring. Two telemetered moorings were deployed in support of the gliders and measured and transmitted ocean currents and water quality conditions

Investigation summary power point
http://data.sccwrp.org/owncloud/apps/files_sharing/get.php?token=61b3525848935b9fe4f52713199e0b871f4da15e&path=/Seegers.pdf

6. Raphe Kudela, University of California, Santa Cruz
Lead Investigator on the NOAA ECOHAB grant and the National Science Foundation grant.
kudela@ucsc.edu
831-459-3290

Observational assets:
Robotic submarine gliders, research vessels, the surface glider and other moored instruments

Investigation summary power point
http://data.sccwrp.org/owncloud/apps/files_sharing/get.php?token=61b3525848935b9fe4f52713199e0b871f4da15e&path=/KudelaLab.pdf

7. Andrew Lucas, Scripps Institute of Oceanography (SIO)
Funding provided by NOAA ECOHAB Grant
drew@coast.ucsd.edu
858-663-0133

Observational Assets
Moored Instruments – wirewalkers

Investigation summary power point
http://data.sccwrp.org/owncloud/apps/files_sharing/get.php?token=61b3525848935b9fe4f52713199e0b871f4da15e&path=/Lucas.pdf

8. Carter Ohlman, University of California, Santa Barbara (UCSB)
Funded by J-112 program
Earth Research Institute
University of California
Santa Barbara, CA 93106
carter@eri.ucsb.edu
(626) 602-6186

Observational Asset
Deployed surface drifter to track near-field transport, mixing and dilution.
Investigation Summary Power Point
http://data.sccwrp.org/owncloud/apps/files_sharing/get.php?token=61b3525848935b9fe4f52713199e0b871f4da15e&path=/Carter.pdf

9. Orange County Sanitation District (OCSD)

George Robertson
Funded by J-112 program
Environmental and Ocean Monitoring Department
10844 Ellis Ave
Fountain Valley, CA 92708
grobertson@ocsd.com
(714) 593-7468

Observational Asset

- Offshore Sampling – Deployment and recovery of self-contained current meters, water quality, and sediments sampling. Offshore waters extend from the nearshore zone out to the limit of state waters (3 miles).
- During the Diversion OCSD provided moorings that were borrowed from their academic partners. The mooring stations were used as a reference point for ADCP deployments, and are referenced in the synthesis report and technical review.

The moorings were provided by:
University of California, Irvine – UCI mooring station
Monterey Bay Aquarium Research Institute – MBARI/ESP mooring station
Orange County Sanitation District – M19 mooring station

Mike von Winklemann
Funded by J-112
Environmental and Ocean Monitoring Department
10844 Ellis Ave
Fountain Valley, CA 92708
mwinklemann@ocsd.com
(714) 962-2411

Observational Asset

- In-Plant Sampling – Final effluent sampling for fecal indicator bacteria and ammonia
- Nearshore Sampling – Shoreline and vessel sampling for fecal indicator bacteria, water temperature and salinity. As defined by California Ocean Plan, nearshore waters extend out to 30 ft depth contour or 1,000 ft from shore.

Investigation Summary Power Point
http://data.sccwrp.org/owncloud/apps/files_sharing/get.php?token=61b3525848935b9fe4f52713199e0b871f4da15e&path=/Robertson.pdf

10. Jack Ryan, Monterey Bay Aquarium Research Institute (MBARI)

Funding provided by NOAA ECOHAB Grant
ryjo@mbari.org
831-775-1978

Observational assets:
The Environmental Sample Processor instrument that collects water quality and algae information is their main role.

Investigation summary power point
http://data.sccwrp.org/owncloud/apps/files_sharing/get.php?token=61b3525848935b9fe4f52713199e0b871f4da15e&path=/Demir-Hilton.pdf

11. Eric Terrill, Coastal Observing Research and Development Center (CORDC) at Scripps Institution of Oceanography (SIO)
Funding provided by J-112
8855 Biological Grade
Isaacs Hall Rm 300
La Jolla, 92093
eterrill@ucsd.edu
(858) 822-3101

Observational assets

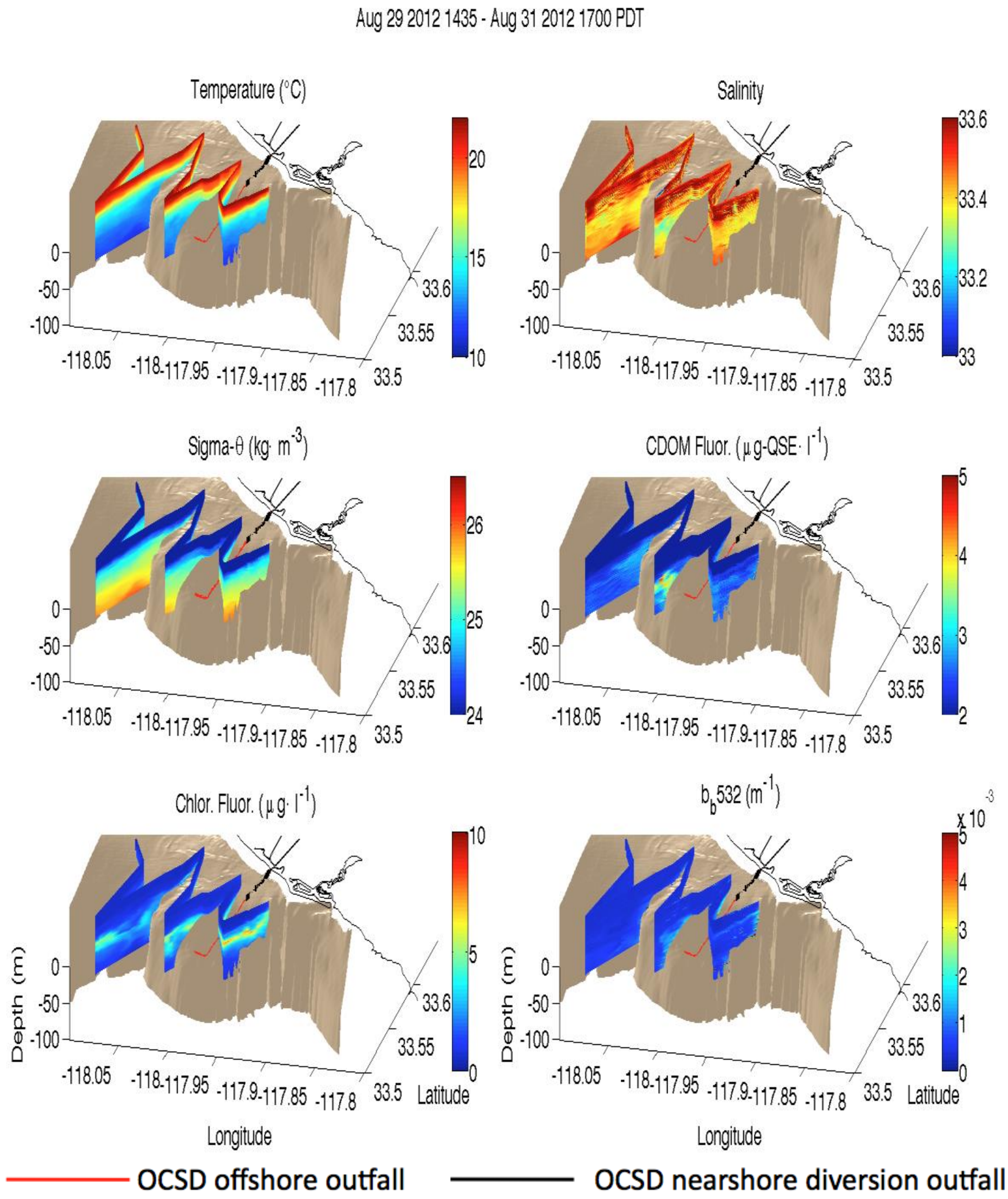
- Deployed one near-real time oceanographic buoy to measure currents and water temperature at the terminus of the short outfall
- Provided hourly current, temperature and particle tracking data products.
- Developed and maintained project web page that integrated project data, data products, and modelling along with existing regional assets (e.g., High Frequency Radar (HFR) data feed
- Conducted one REMUS Autonomous Underwater Vehicle (AUV) mission to monitor the fate and transport of the diverted discharge.

Investigation Summary Power Point
http://data.sccwrp.org/owncloud/apps/files_sharing/get.php?token=61b3525848935b9fe4f52713199e0b871f4da15e&path=/Rogowski.pdf

Appendix III – Burt Jones, Burt Jones Laboratory, USC Complete Autonomous Profiling Glider Results

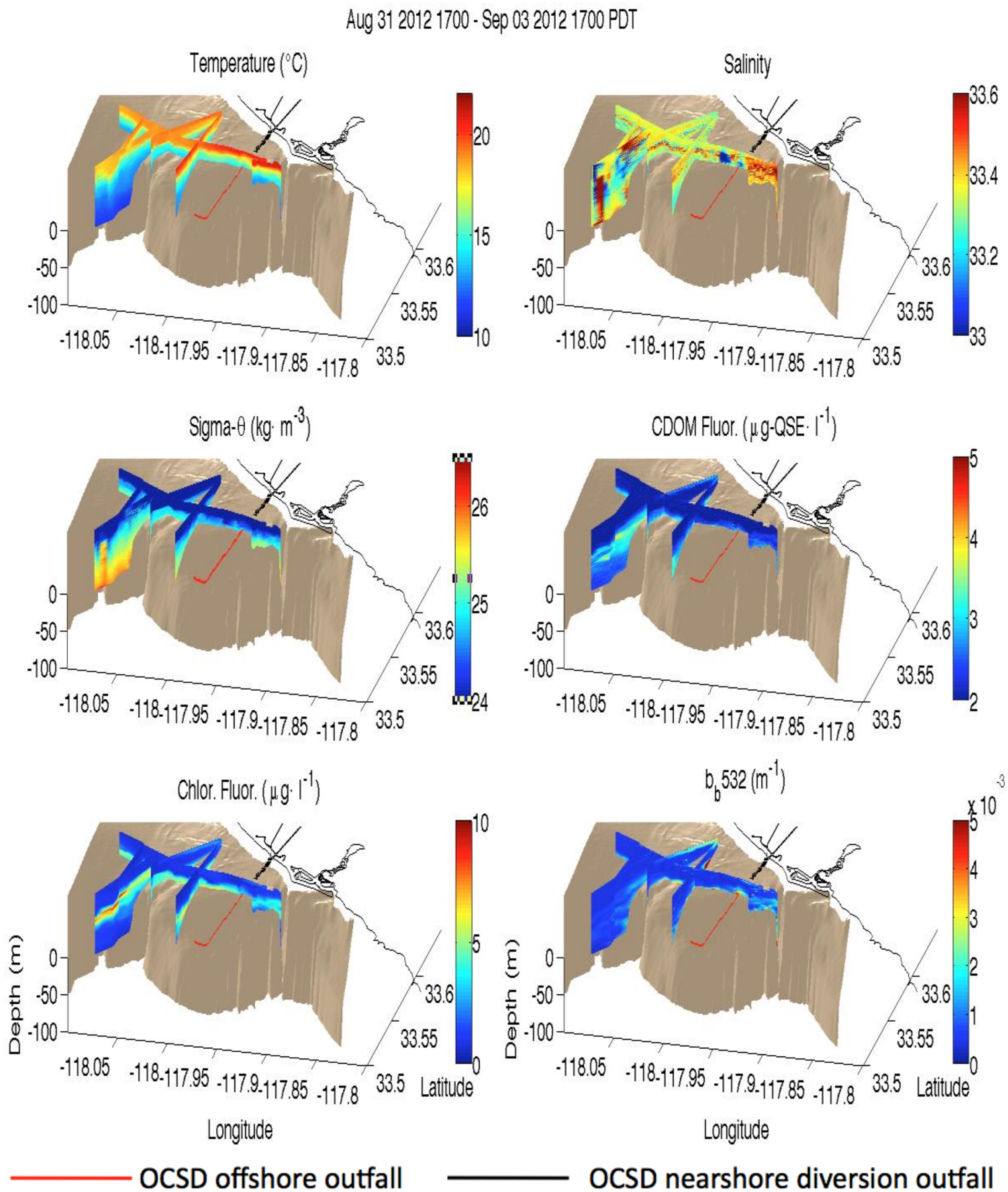
This section will cover glider observations in detail over the entire monitoring period August 29 through November 2, 2012. Most figures are a combination of two gliders' observations from the region. Quality control of data resulted in certain figures and variables having only a single glider's results on selected dates.

Pre-Diversion – August 29 – August 31



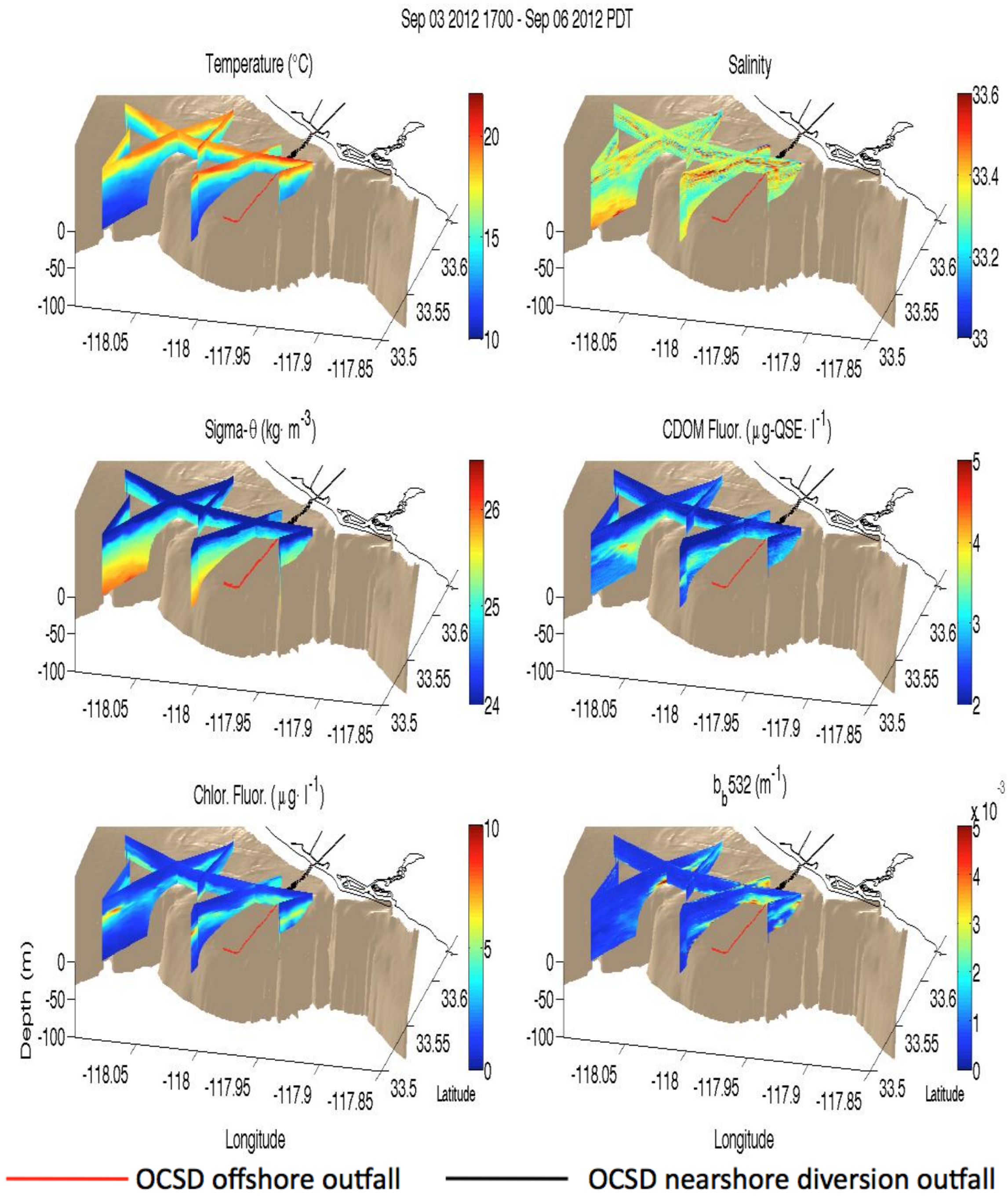
The glider observations began on August 29 nearly 2 weeks before the diversion began allowing for baseline observations. The system was strongly stratified with the subsurface chlorophyll maximum, a dominant biological feature, ranging from 5 to 7 μg l^{-1} at a depth of 25 to 50 m. 50 m is quite deep for the chlorophyll maximum layer in this region. The elevated CDOM fluorescence and low salinity measurements are used to track outfall effluent shown here associated with the deep 60 m offshore pipe and remained subsurface. Optical backscatter (bb532) is indicative of suspended particle concentration and tends to be higher where low salinity, higher CDOM water is observed.

Pre-Diversion – August 31 – September 3



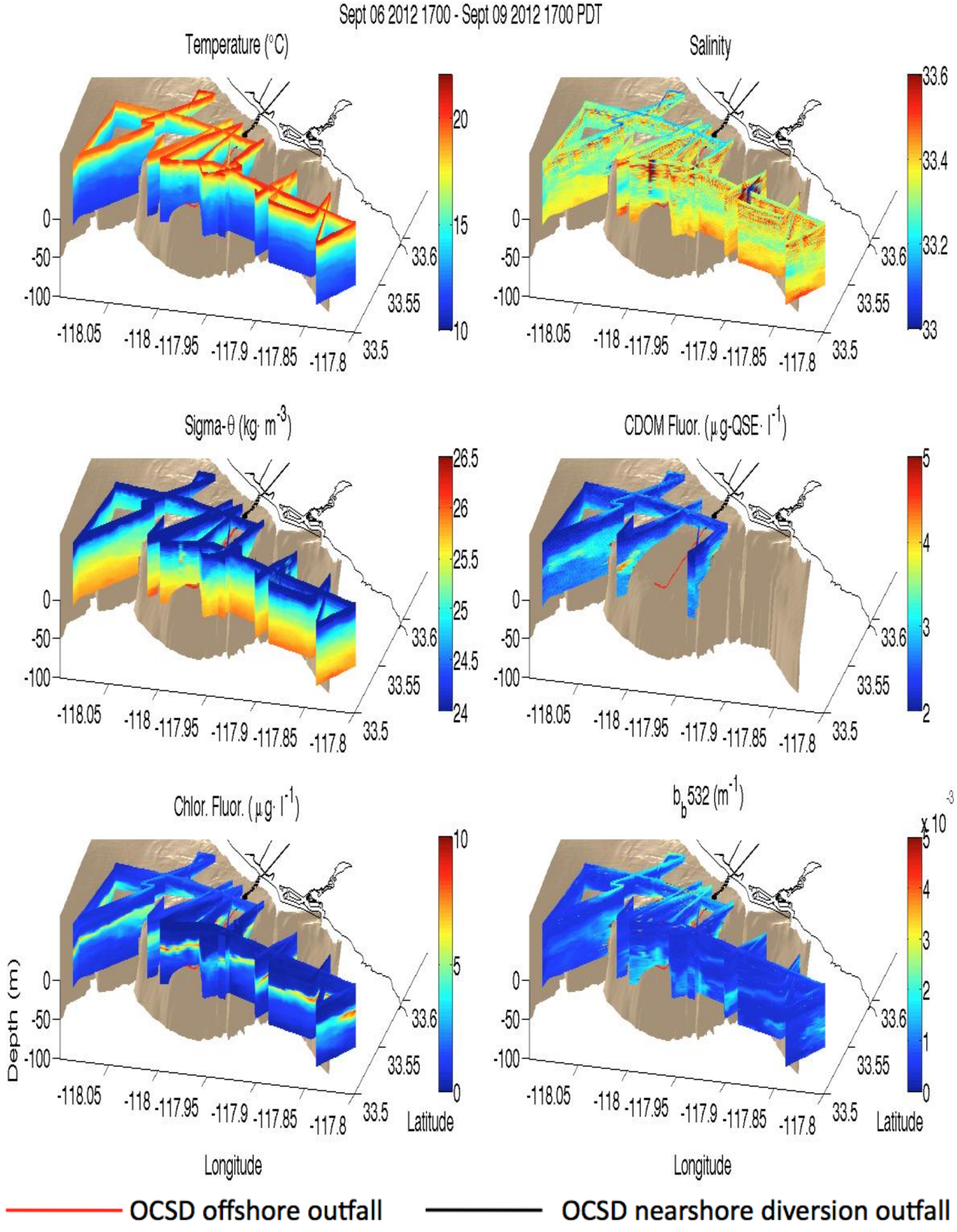
The system remained strongly stratified. However, a slight cooling event resulted in cooler surface temperatures, decreased surface salinity, and a shallowing of the subsurface chlorophyll maximum to depths ranging from 20 m to 40 m. There is also an on-shelf surface signal of slightly increased chlorophyll, CDOM, and b_b532. The effluent plume was still subsurface and showed a significant signal upcoast from the outfall.

Pre-Diversion – September 3-6



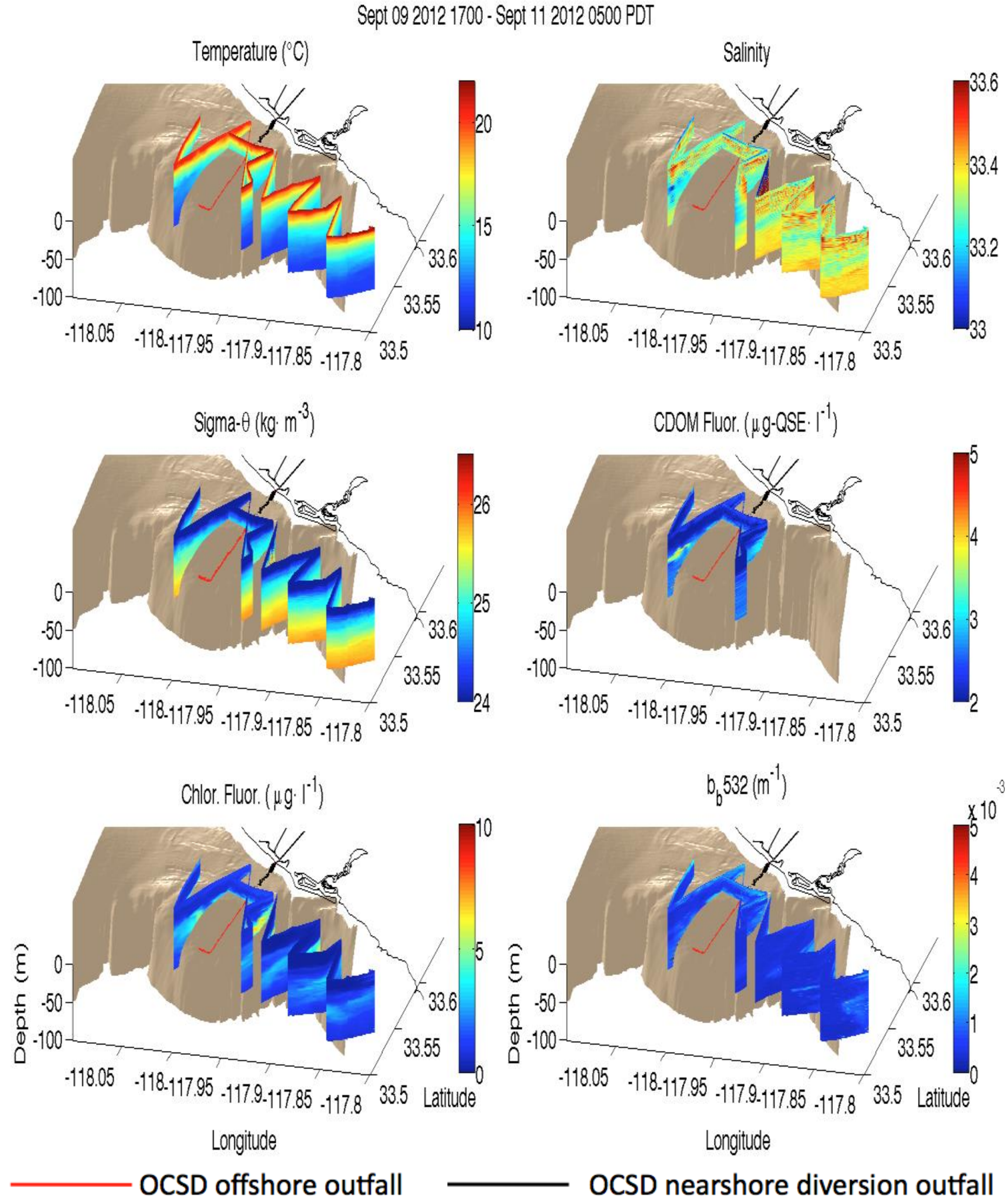
Again although the system remained strongly stratified there was continued surface cooling and shallowing of the subsurface chlorophyll maximum. In the area close to the nearshore outfall cooling to less than 17.5 ˚C is associated with increased CDOM, backscattering, and chlorophyll.

Pre-Diversion – September 6-9



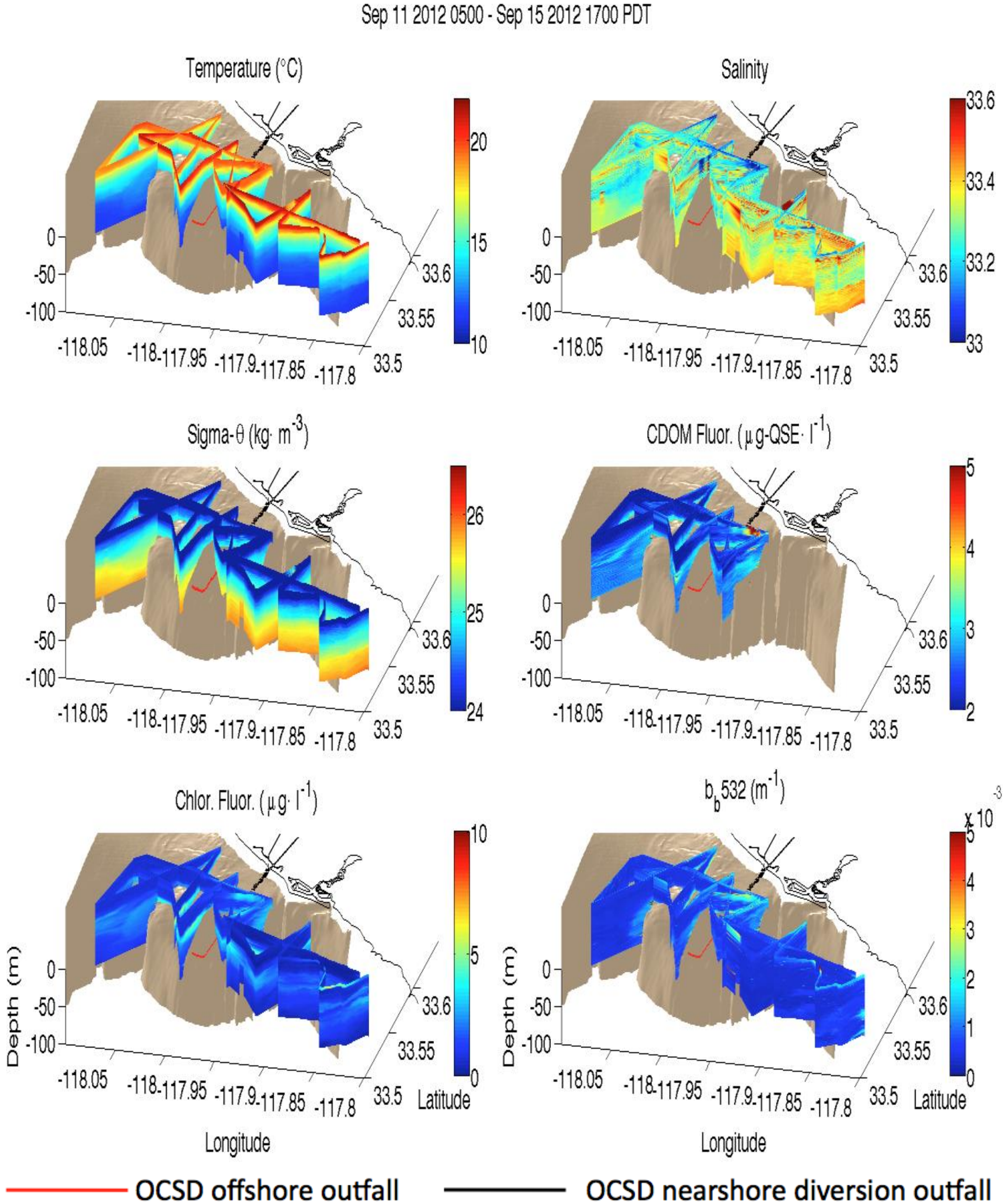
The system remained strongly stratified with some surface warming relative to the previous snapshot for Septmeber 3-6. A weak surface feature was apparent on the shelf upcoast from the outfall with elevated CDOM, backscatter, and chlorophyll. Generally the plume from the offshore outfall was evident as a subsurface layer below 20 m that was present both upcoast and downcoast from the outfall. The subsurface chlorophyll maximum was relatively deep and present throughout the area.

Pre-Diversion – September 9-11



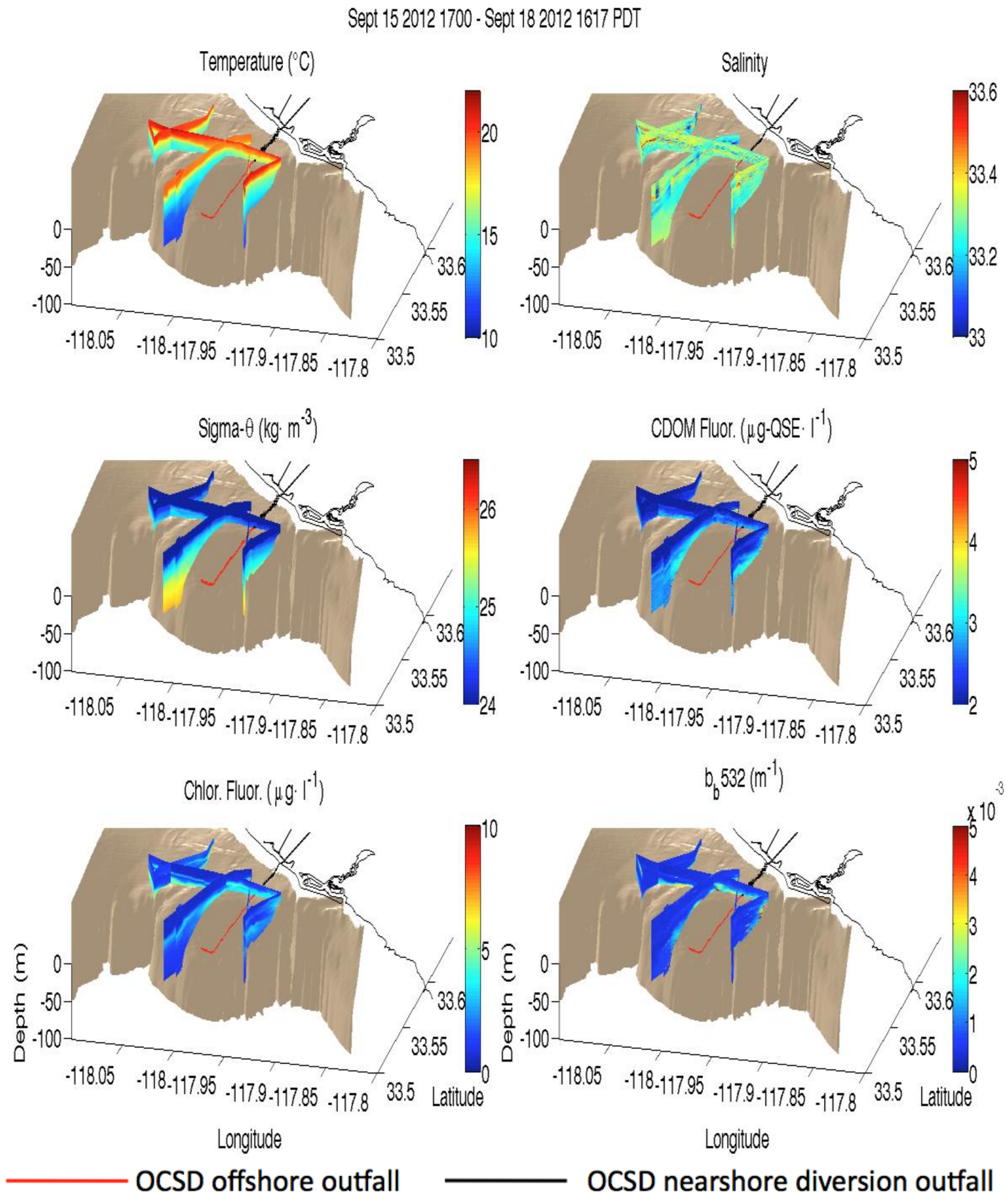
Stratification remained relatively strong during this period. Although there is an incomplete view of the plume with CDOM, the low salinity feature suggests that the plume extended through the length of the sampling area in the depth range of 30-50 m. The maximum concentrations within the subsurface chlorophyll maximum have diminished and the feature is more dispersed vertically than in the previous snapshot.

Initial Diversion – September 11-15



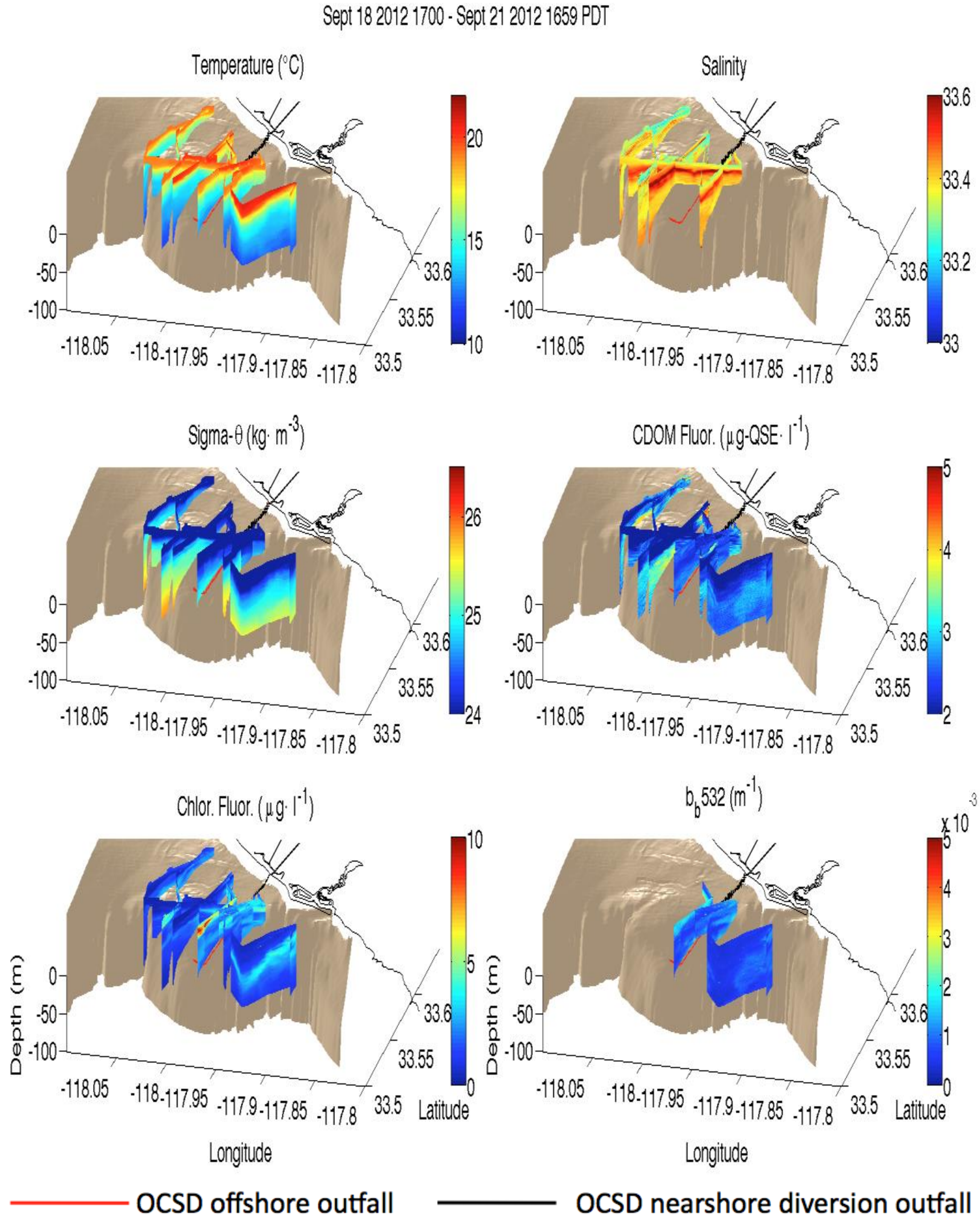
Day 1-4. The diversion began on September 11th. In the surface waters close to the nearshore outfall pipe the glider observed decreased salinity and greatly increased CDOM levels, which are tracers for effluent. There is also a slight increase in surface chlorophyll and backscattering, which are indicative of algae in the water. CDOM is still observed subsurface but the concentrations were lower than were observed prior to the diversion.

Diversion – September 15-18



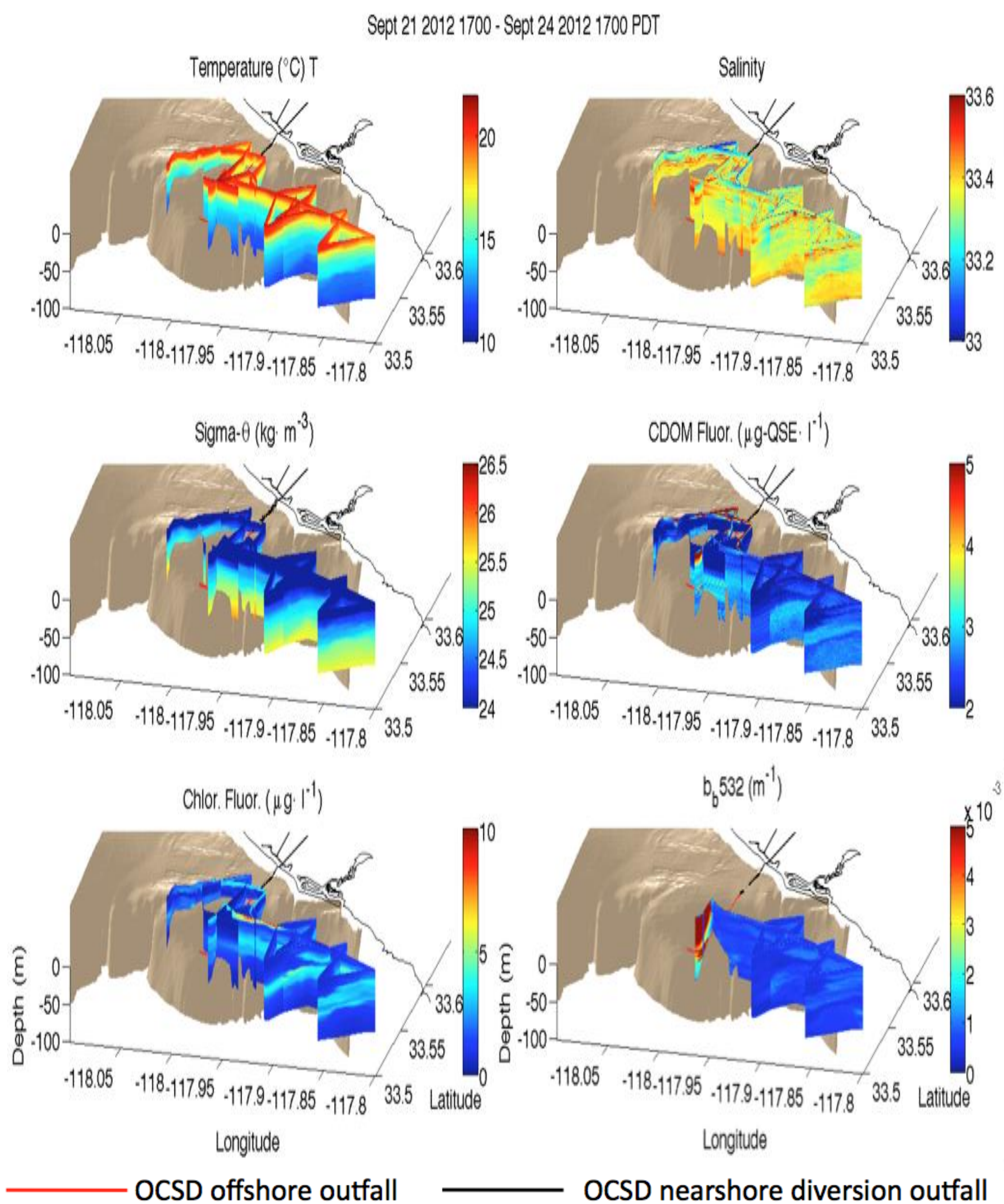
Day 4 – 7. The system remained strongly stratified. The surface plume was not readily apparent in this snapshot, although there seems to be some subsurface evidence of low salinity and high CDOM near the 1 mile discharge. The subsurface chlorophyll maximum remains the dominant biological feature. While CDOM is still present in the subsurface region, surprisingly little CDOM is observed in the surface layer. CDOM, bb532, and chlorophyll suggest that there might be a signature of the nearshore discharge near the bottom extending downcoast from the nearshore outfall. There is still a CDOM signature over the outer shelf below about 20 m, which is likely residual from 5 mile outfall prior to the diversion.

Diversion – September 18-21



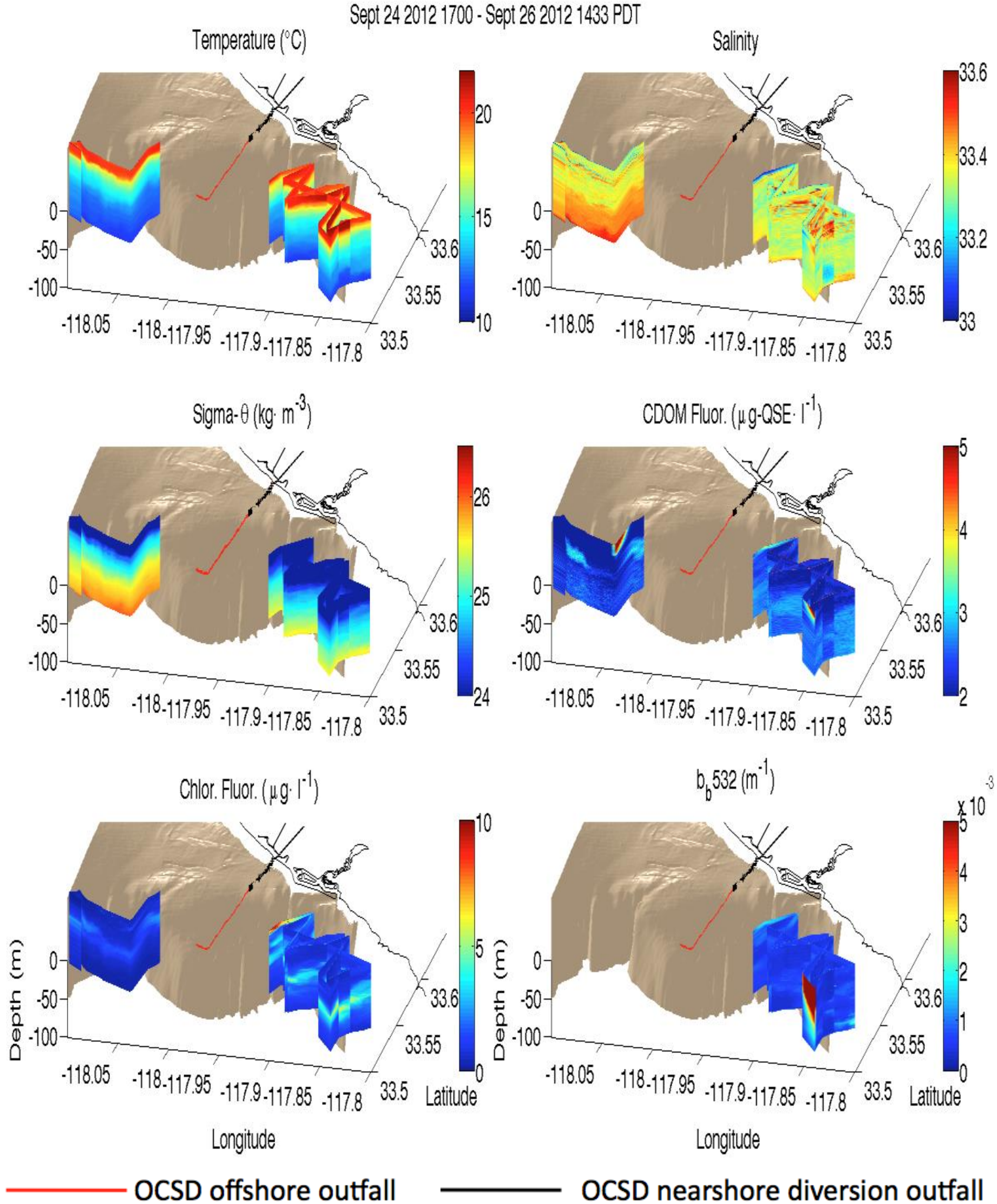
Day 7- 10. The region surface layer cools with reduced salinity and increased CDOM on the shelf. Just north of the outfall there is a patch of low salinity and high CDOM (~4.5 μg QUE l^{-1}) at the surface. Higher chlorophyll concentrations in the nearshore and near-surface area are evident in the middle part of this set of sections. However, the subsurface chlorophyll concentrations are much lower than were observed prior to the diversion. As with a set of observations, the subsurface chlorophyll is less well structured, and lower in concentration than was observed prior to the diversion.

Diversion – September 21-24



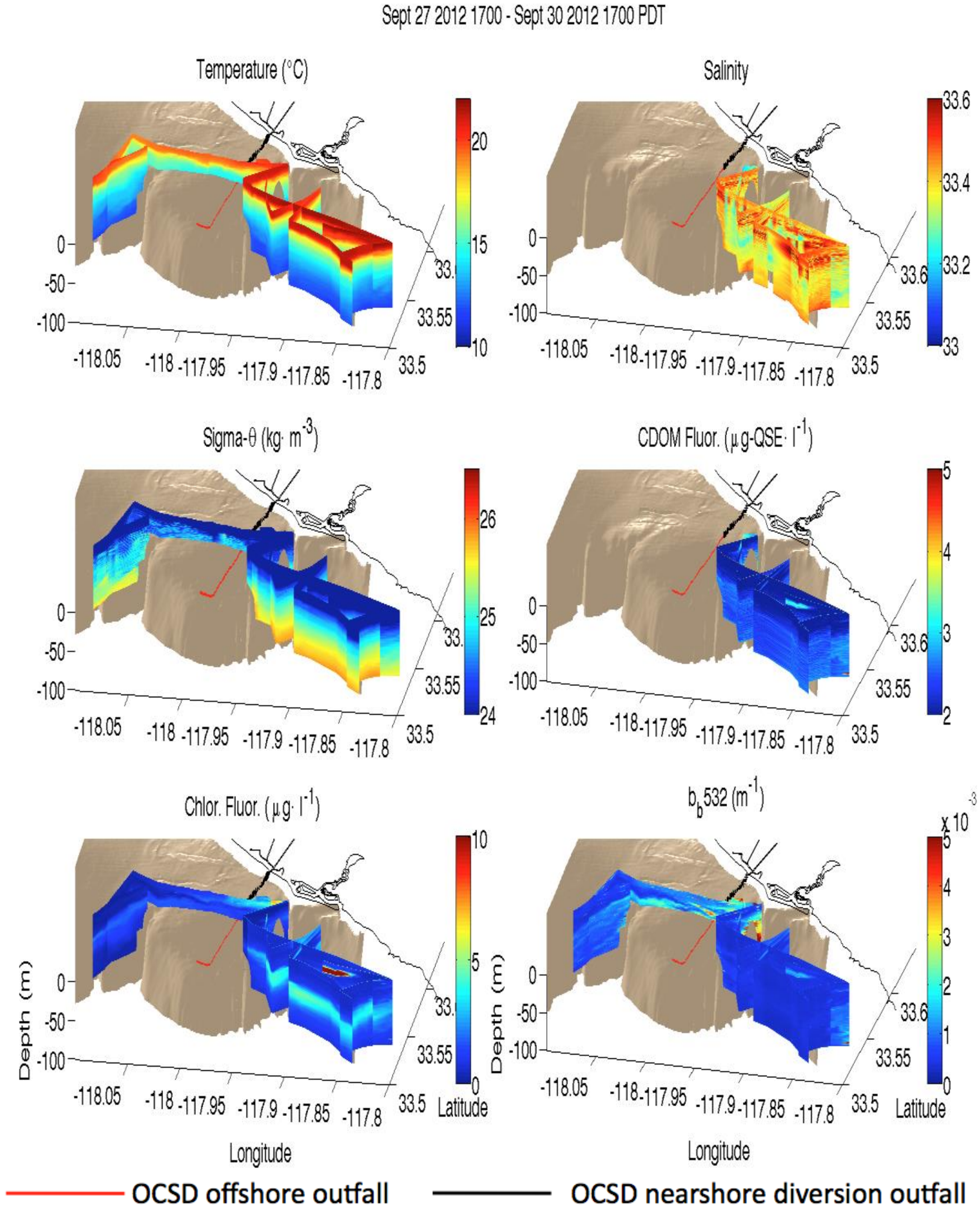
Day 10 -13. A thin (1-5 m) surface plume was observed north and south of the outfall pipe with the effluent characteristics of reduce salinity and elevated CDOM signal. There was a correspondingly high chlorophyll signal in this surface layer.

Diversion – September 24-26



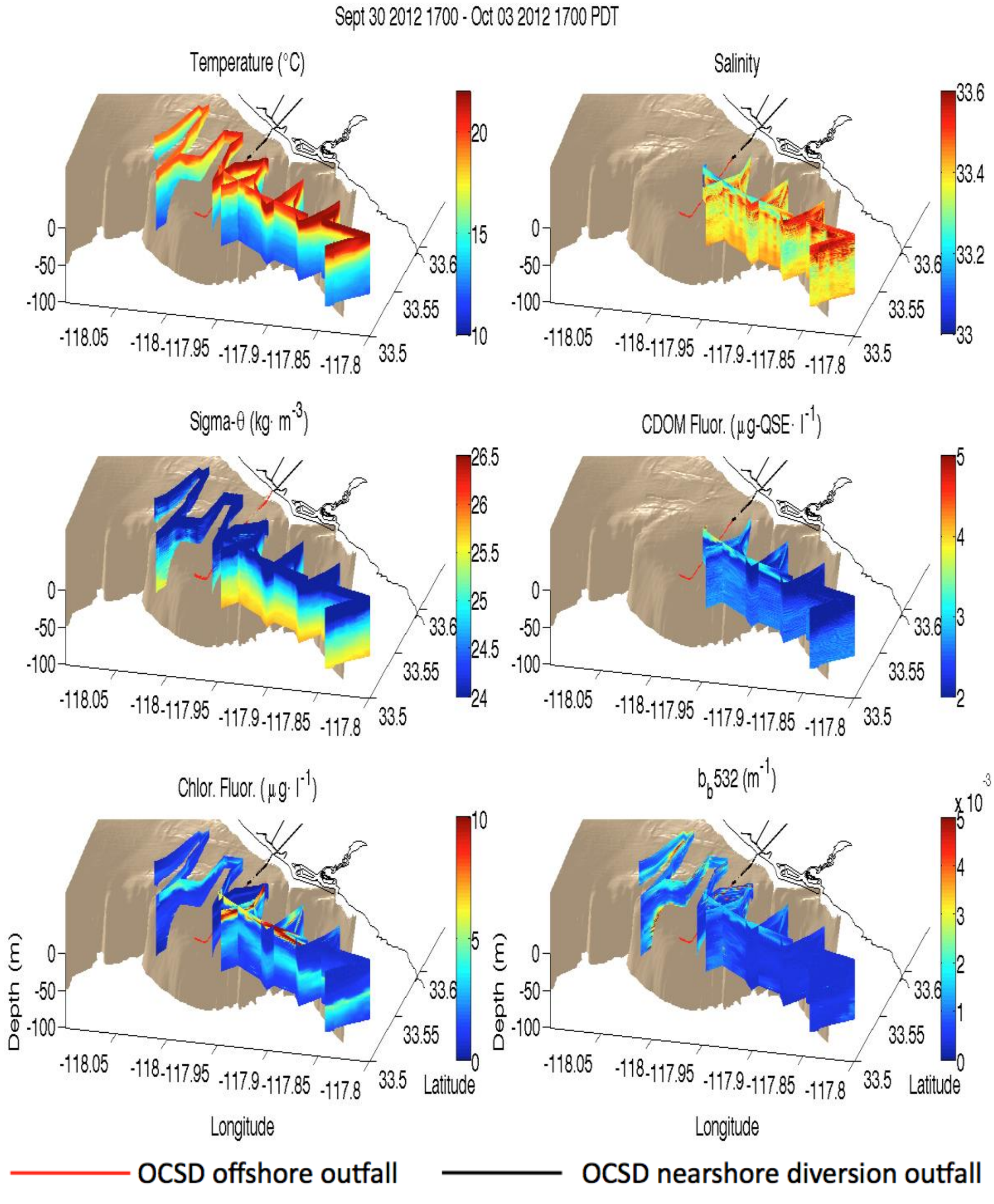
Day 13-16. A thin (1-5 m) surface plume continued to be observed south of the nearshore outfall with effluent characteristics of reduce salinity and elevated CDOM signal. There was a correspondingly high chlorophyll signal in this surface layer. North of the outfall a characteristic effluent signal of low salinity and elevated CDOM was observed, however no elevated chlorophyll was observed.

Diversion – September 27-30



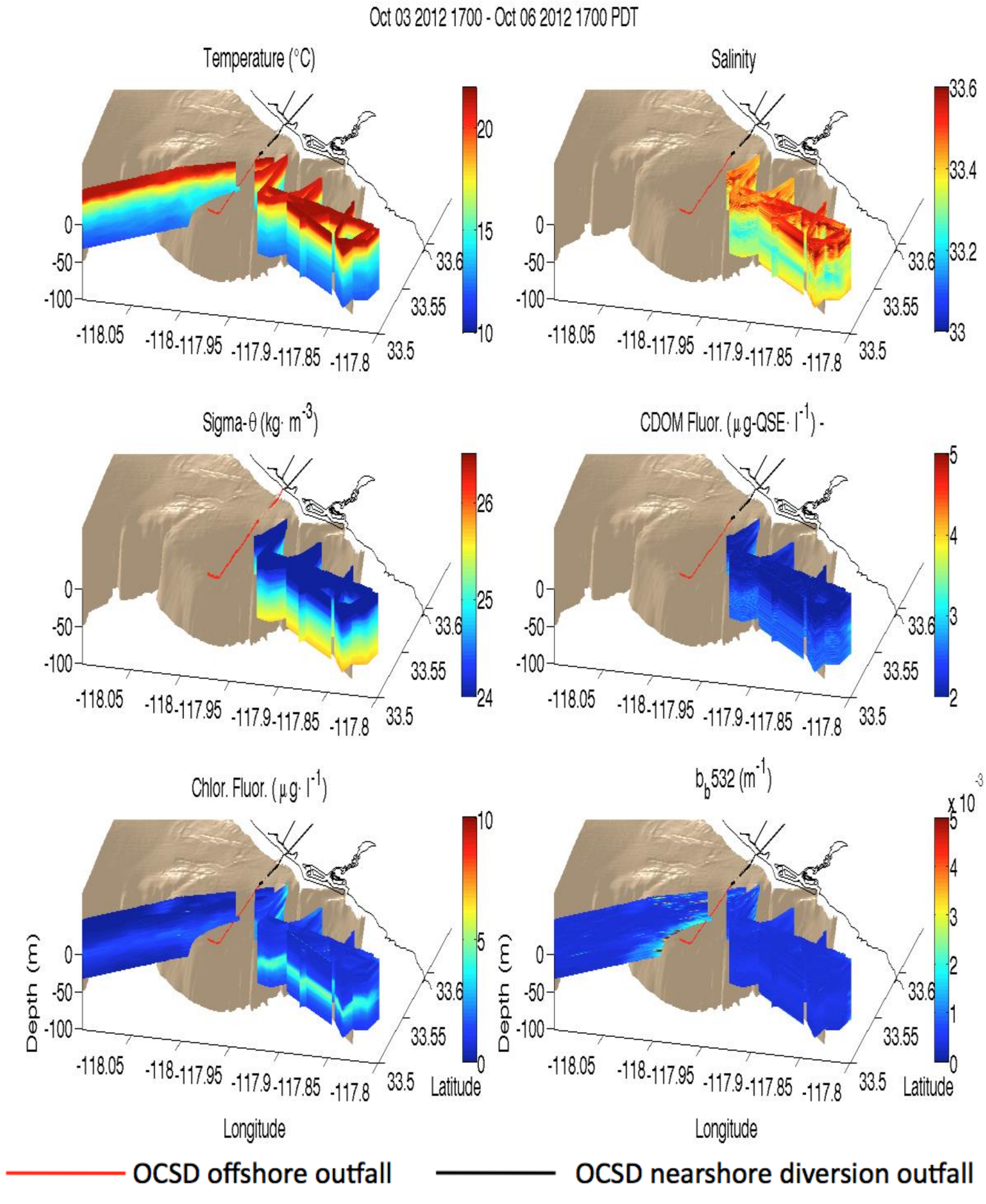
Day 16 – 19. Surface waters near the outfall showed effluent water characteristics and high chlorophyll. South of the nearshore outfall at a depth of 5 m a plume of reduced salinity and high CDOM water was associated with estimated chlorophyll concentrations greater than 10 μg l^{-1} and elevated backscatter.

Diversion – September 30 – October 3



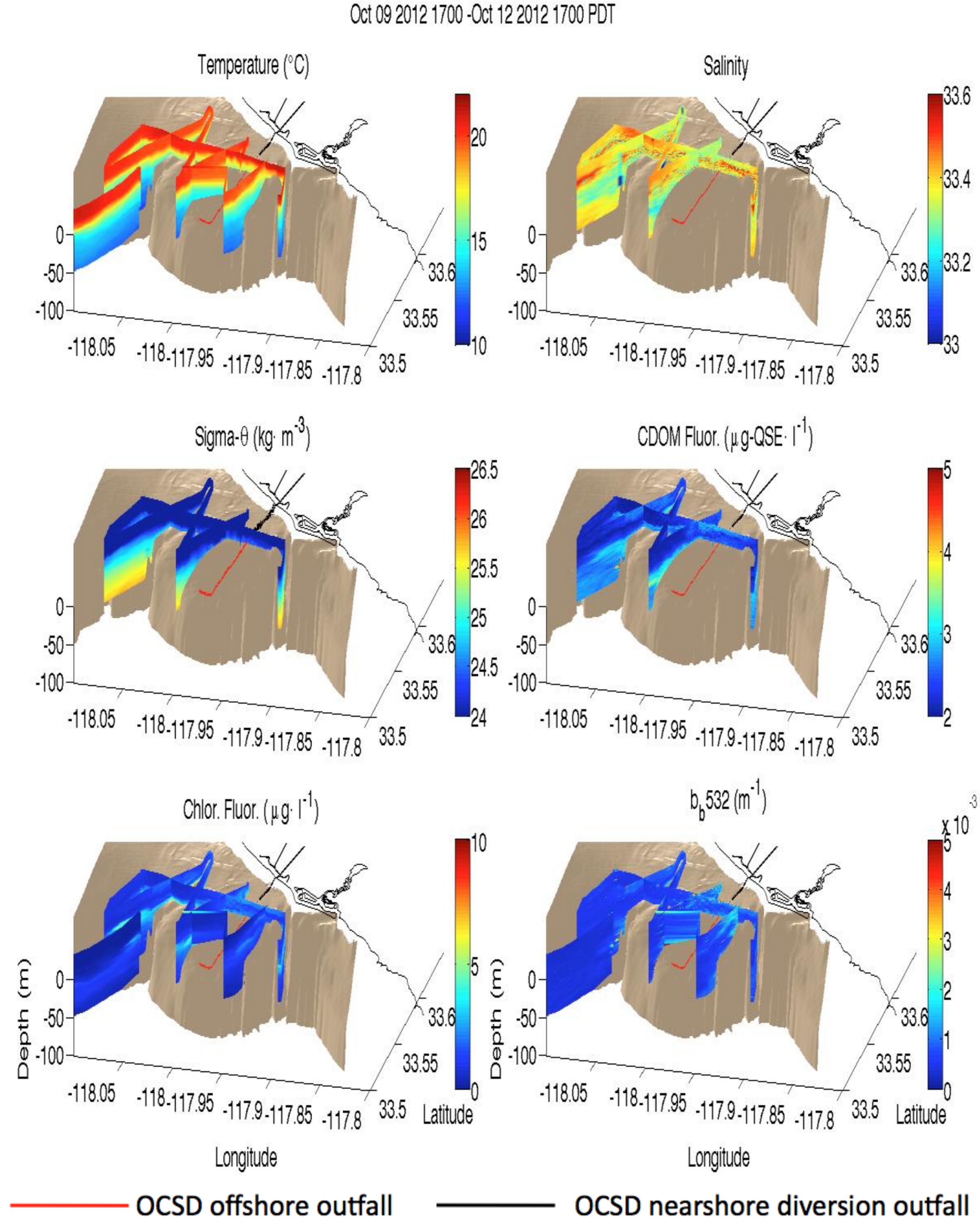
Day 19-21. The surface plume continued to be observed by the glider south of the outfall along with the corresponding elevated chlorophyll and backscatter in the surface 0-10 m. This surface layer signal is isolated from the subsurface chlorophyll maximum. The nearsurface chlorophyll concentrations were above 7.5 mg/m^3, but the subsurface concentrations were generally less than 3 mg/m^3.

Post-Diversion – October 3-6



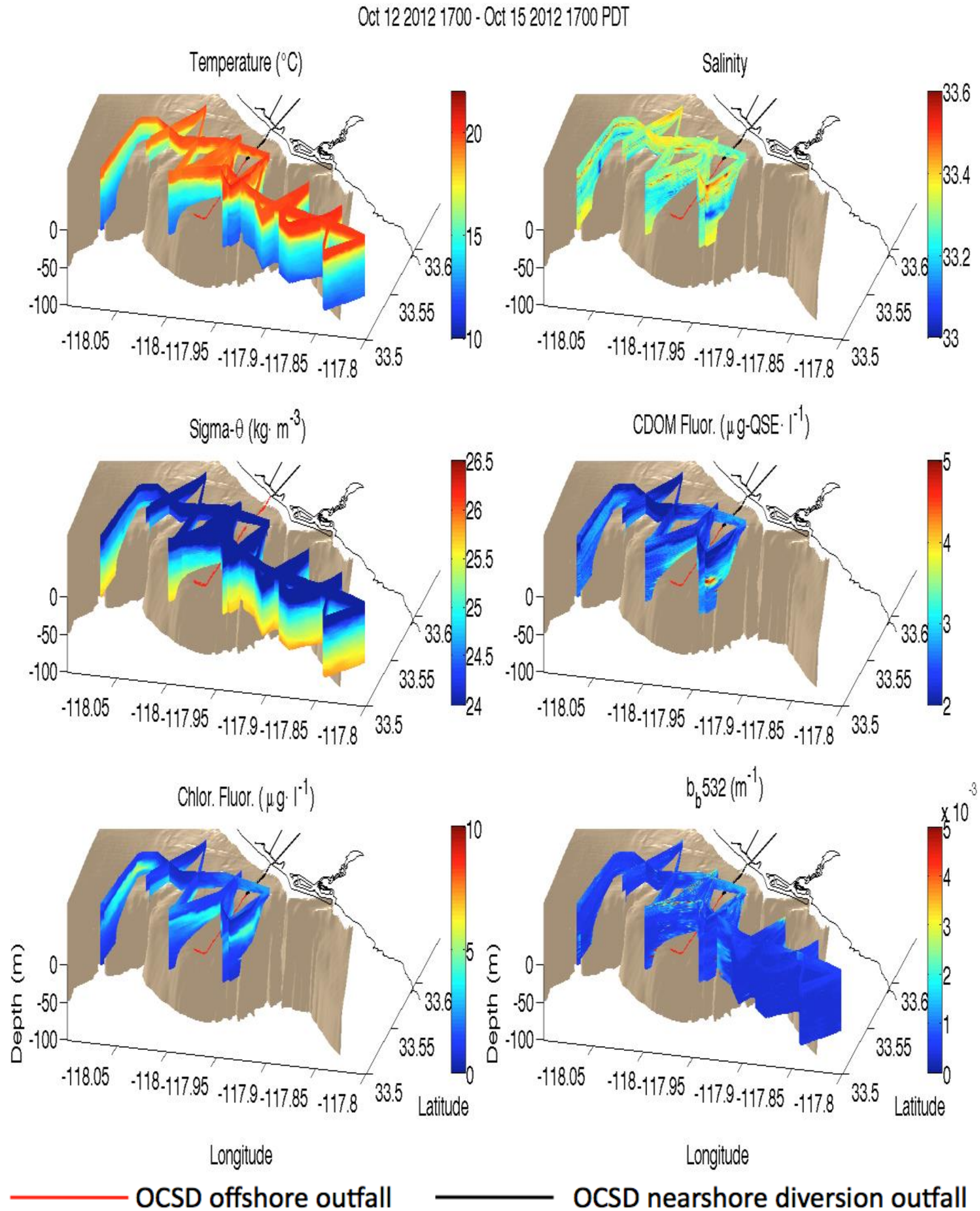
The system remains strongly stratified. The glider observed no residual outfall plume water and elevated chlorophyll and backscatter signals in the upper layer, presumably due to advection of this water away from the area. As in the pre-diversion period, the subsurface chlorophyll maximum is quite deep.

Post-Diversion – Ocotober 9-12



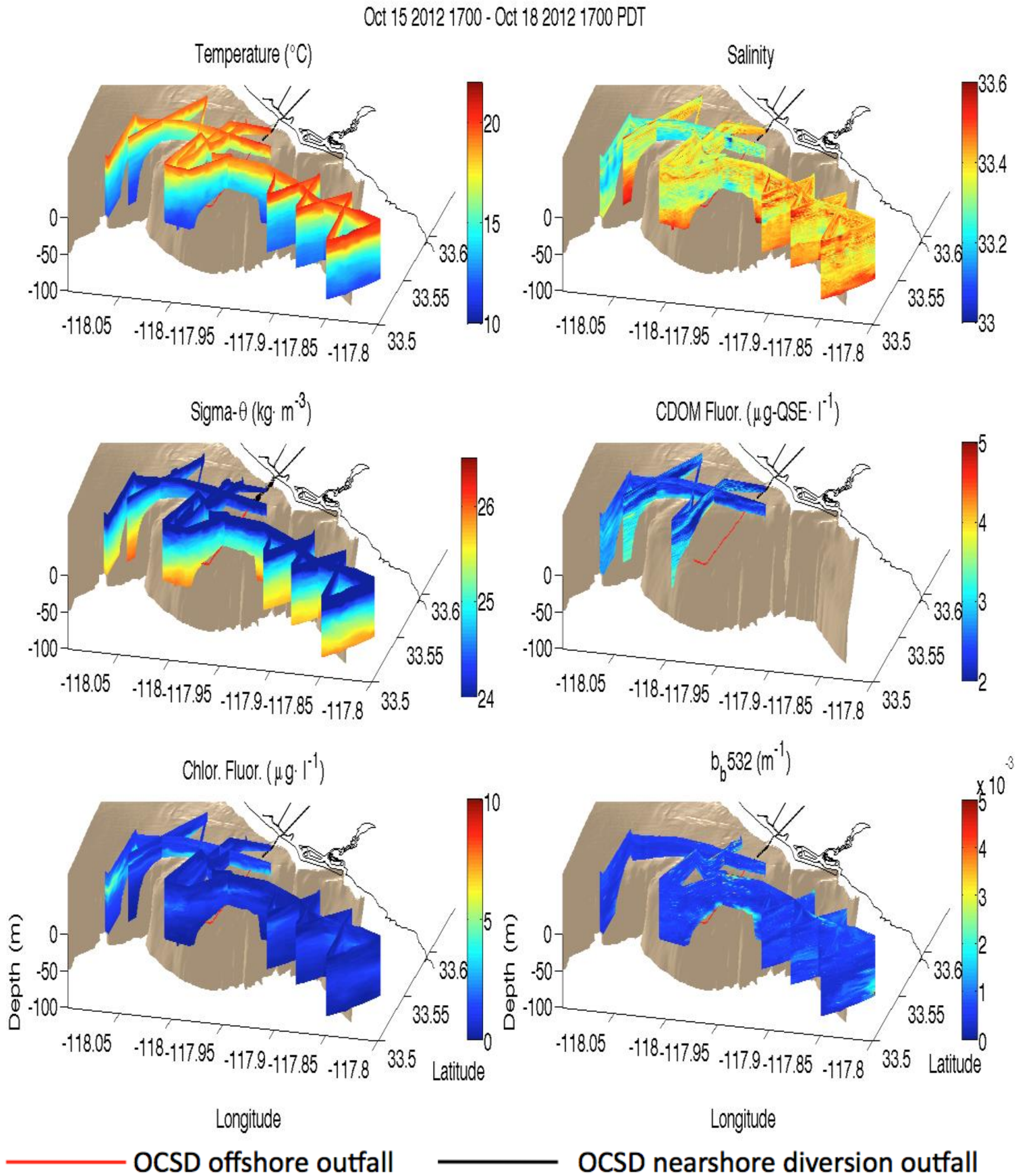
The effluent signal is observed associated with the deep offshore pipe, indicating the re-establishment of the subsurface effluent plume. There are no observable changes between pre and post diversion conditions.

Post-Diversion – October 12-15



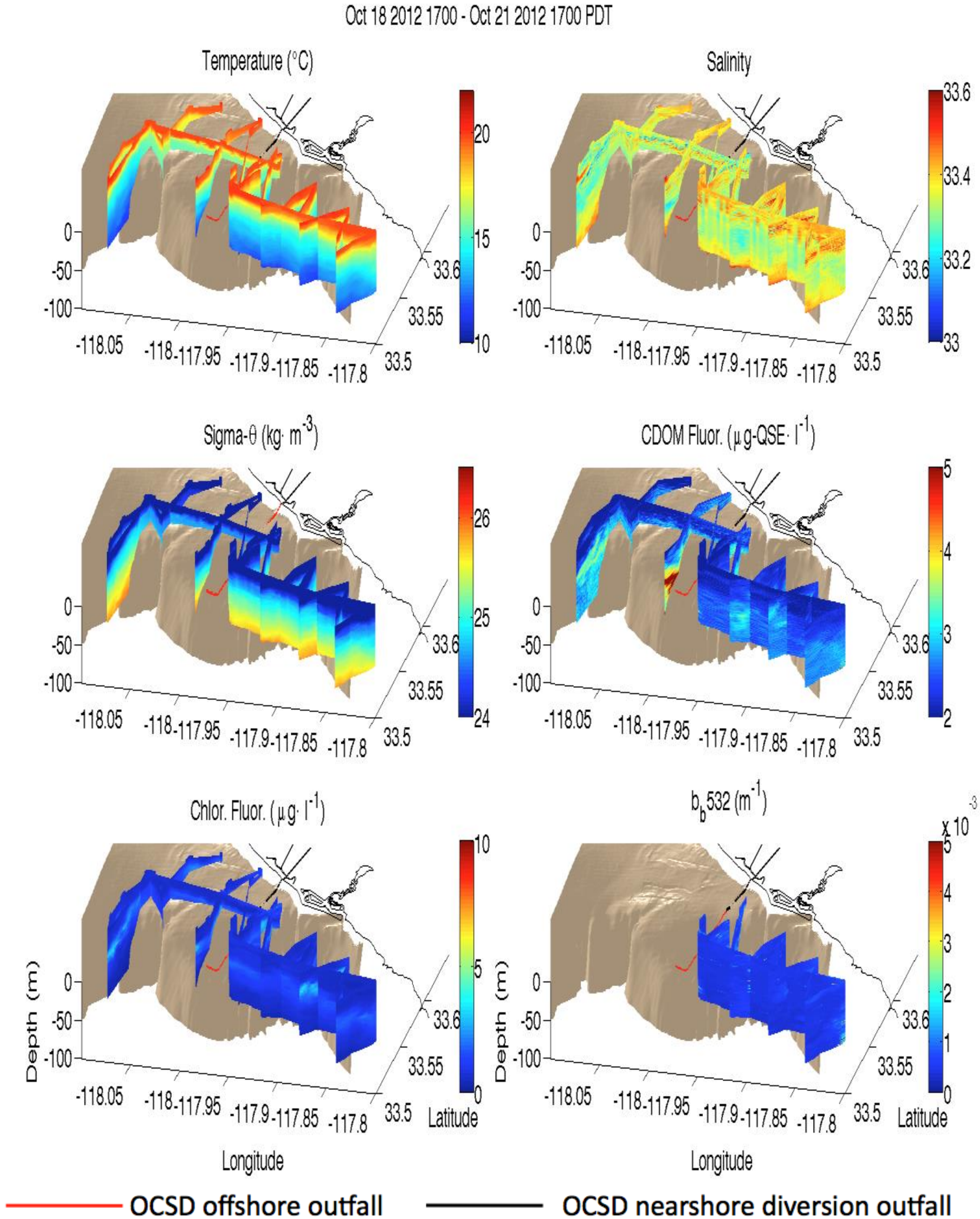
The effluent signal is observed associated with the deep offshore pipe. In this snapshot, it appears that the plume is advecting downcoast (toward the right in the image). The chlorophyll maximum appears to sit above the plume in this particular snapshot.

Post-Diversion – October 15-18



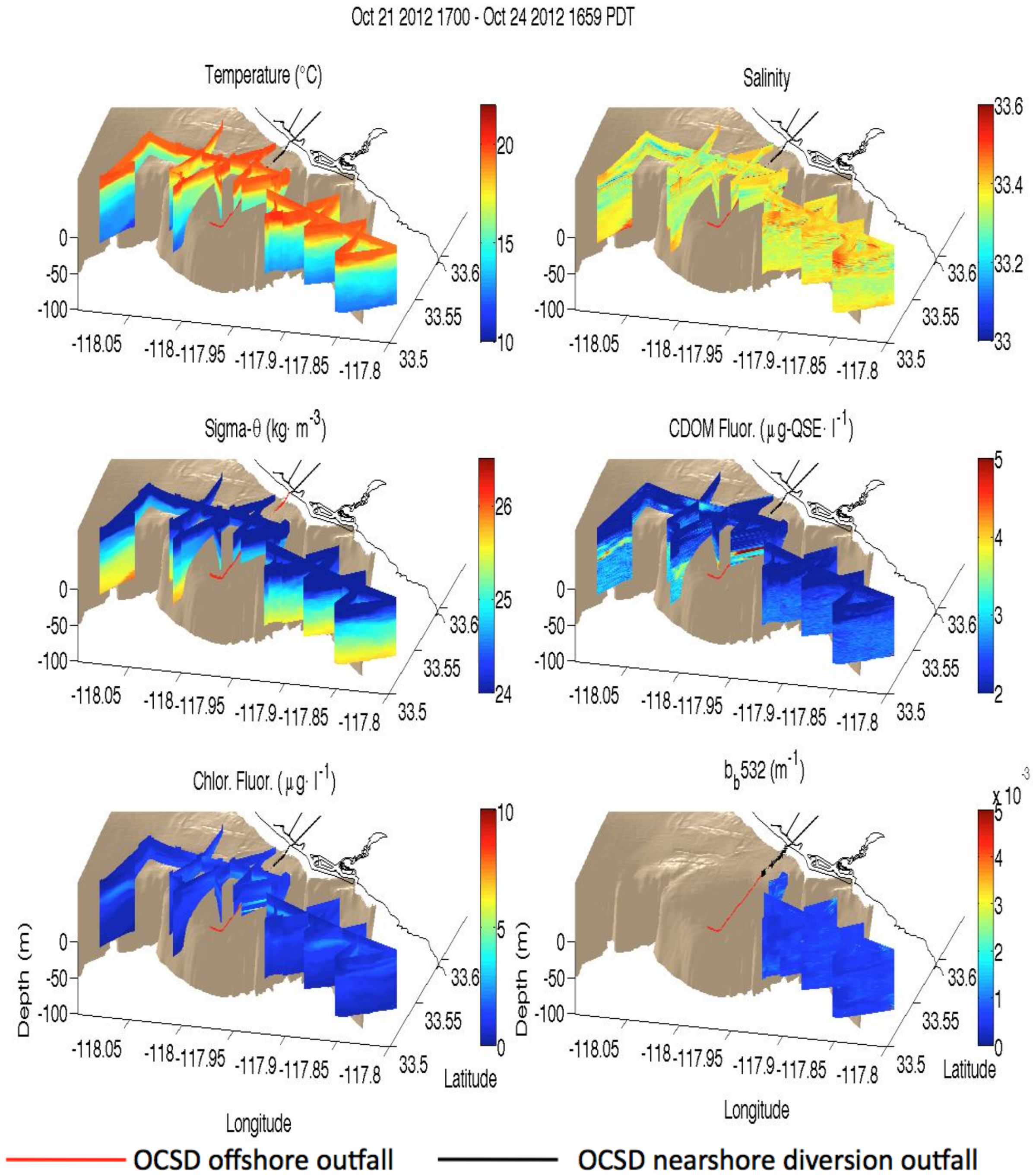
Surface temperature has decreased some, particularly in the north during this period. Although there was not a complete picture of CDOM for this period, based on salinity, the plume appears to be predominantly upcoast form the outfall diffuser. Chlorophyll concentrations have decreased from the previous pass and predominantly found in the subsurface chlorophyll maximum.

Post-Diversion – October 18-21



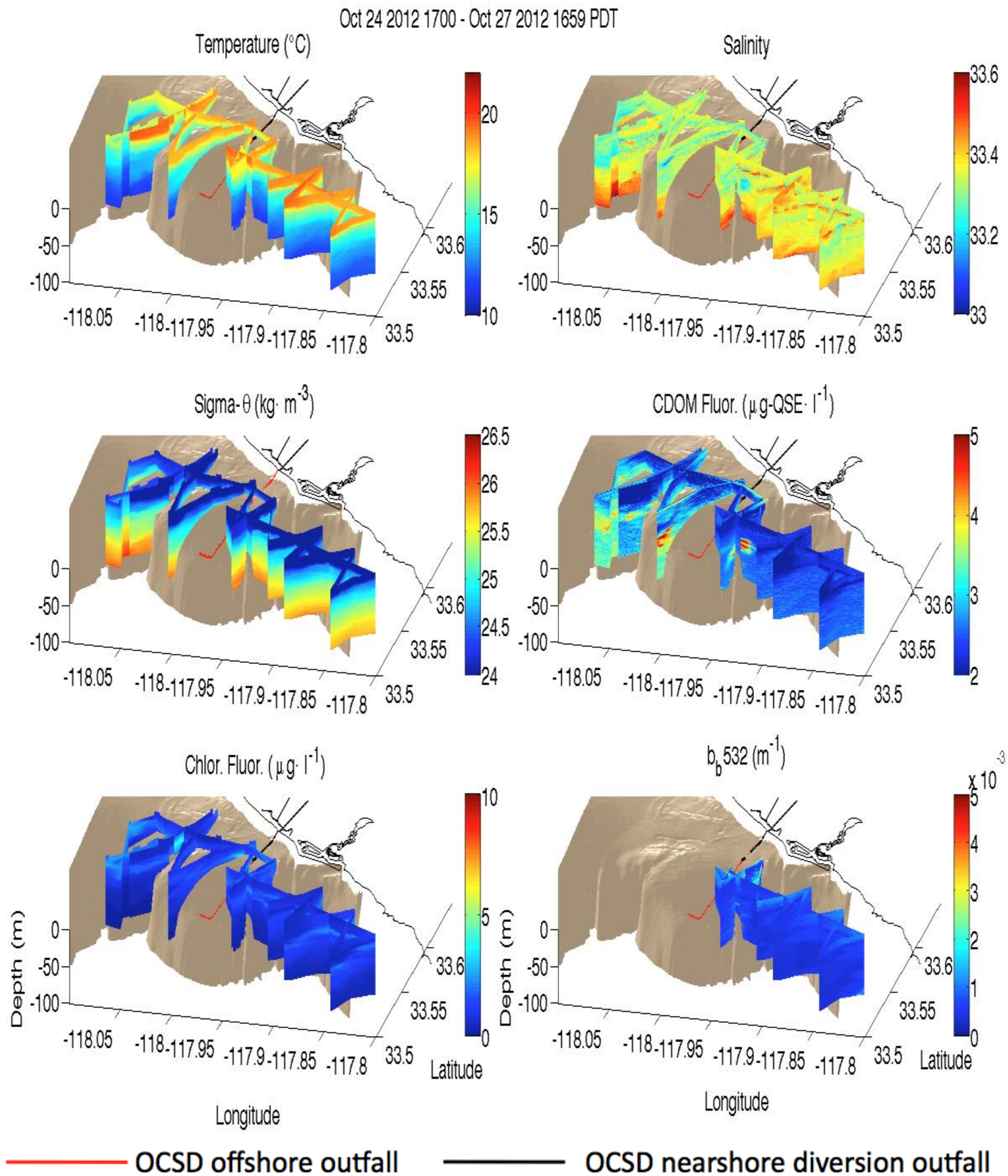
In this particular snapshot, the plume appears to be distributed in both directions from the outfall. Consistent with the previous snapshot, the chlorophyll concentrations continue to be low throughout the area.

Post-Diversion – October 21-24



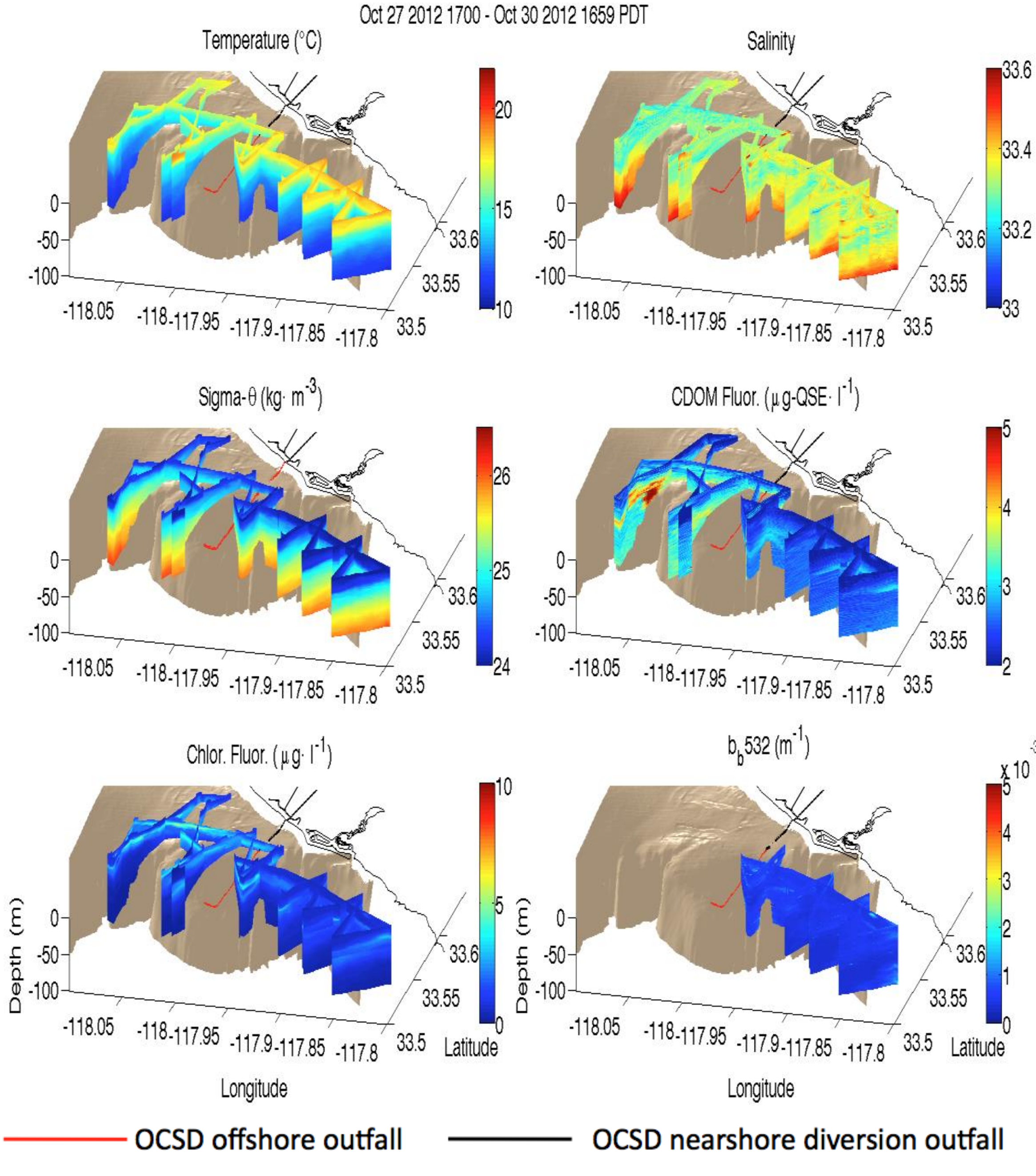
During this pass, both salinity and CDOM suggest that the effluent plume is predominantly upcoast from the outfall. Chlorophyll concentrations to be low in the upper layer, and are depressed in general from pre-diversion concentrations.

Post-Diversion – October 24-27



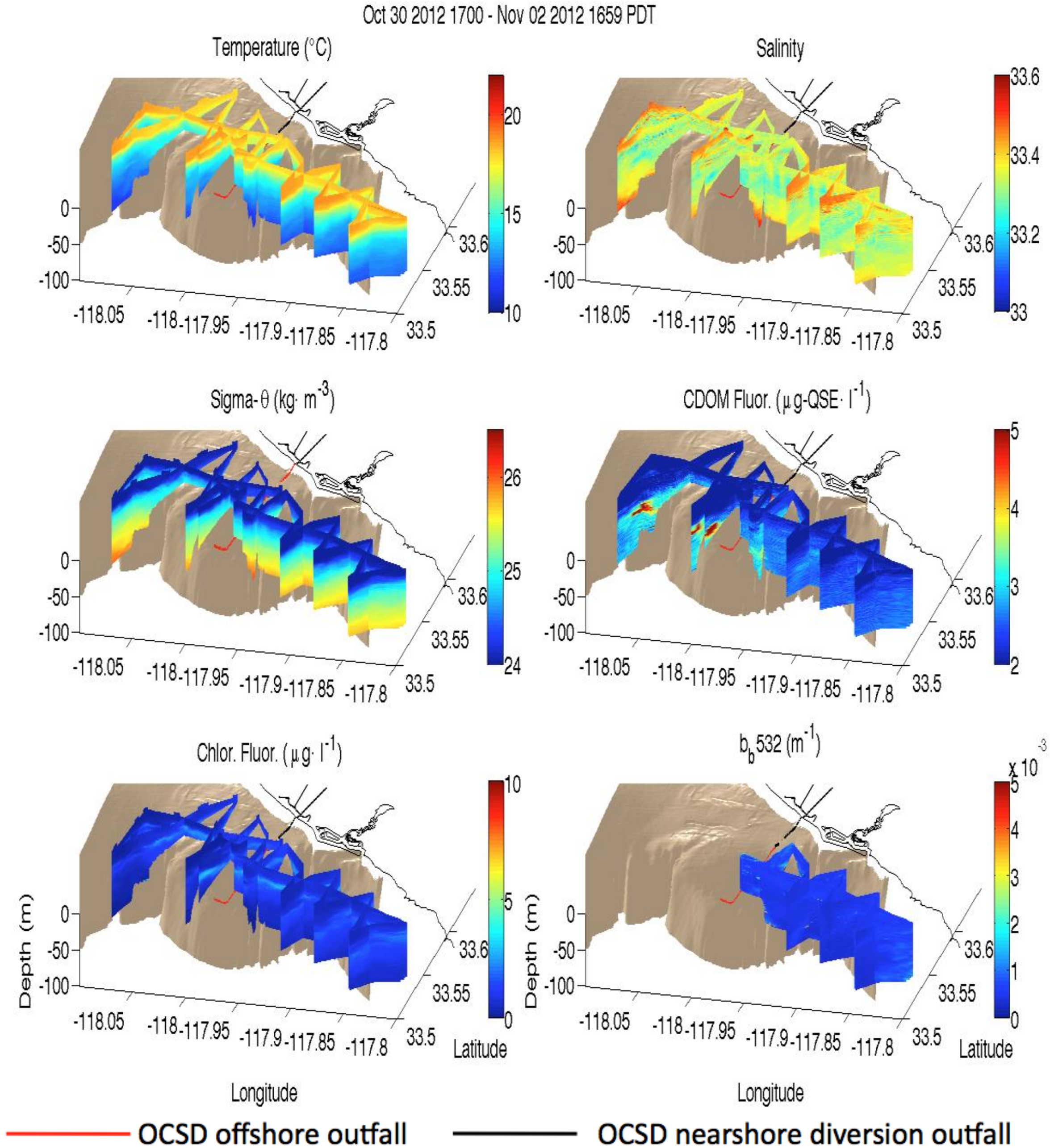
Some surface cooling is apparent during this pass. As with the previous snapshot, it appears that the effluent is located predominantly upcoast from the outfall, although patches of plume are found downcoast from the outfall. Chlorophyll continues to be low throughout the area.

Post-Diversion – October 27-30



The effluent plume in this snapshot, based on CDOM, is present directly over and to the north of the outfall. But a significant amount of CDOM is found in a subsurface region below the chlorophyll maximum to the south of the outfall. Significant cooling of the upper layer particularly on the upcoast end of the sections is correlated with a shallower (nearsurface) chlorophyll maximum region.

Post-Diversion – October 30-November 2

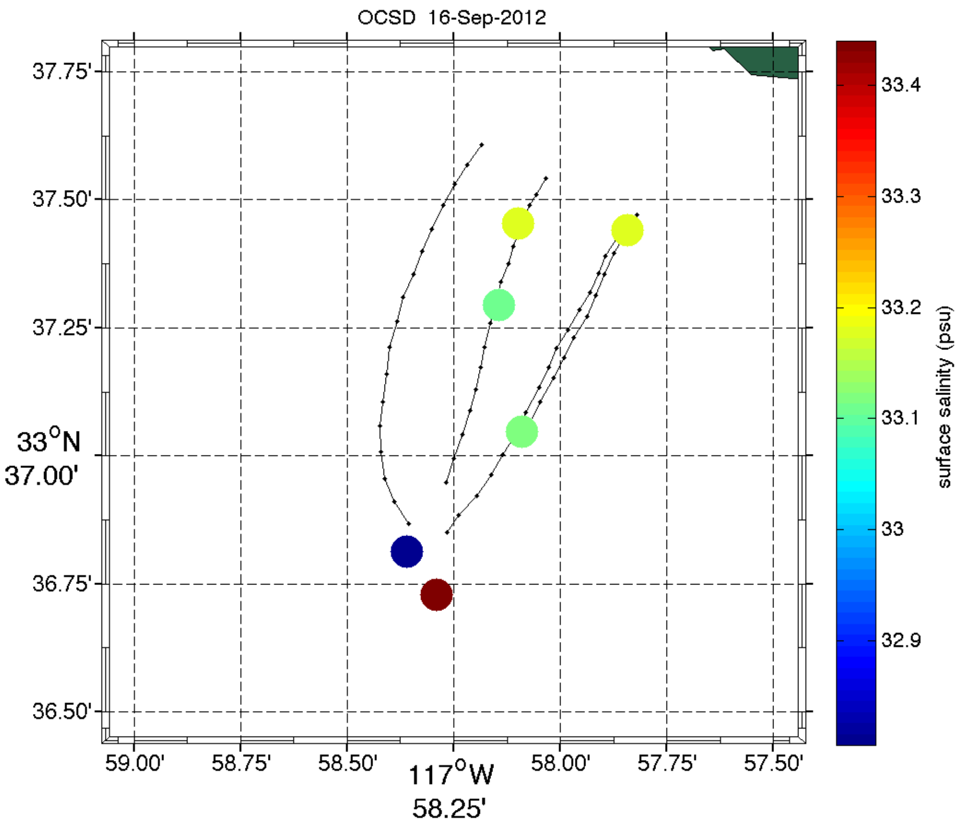


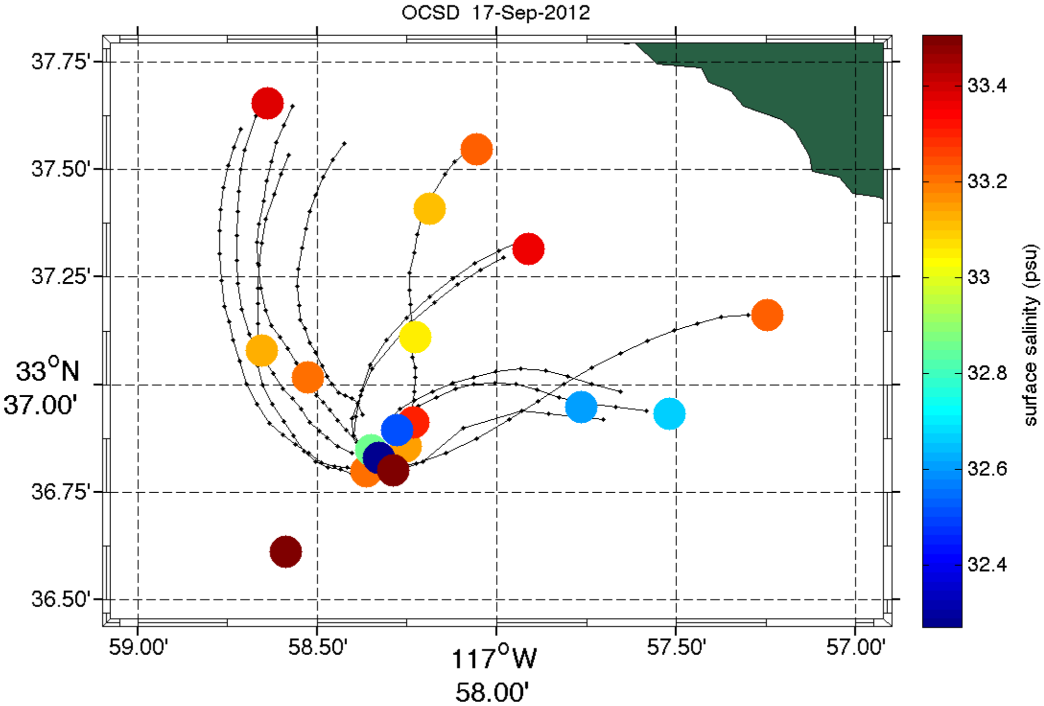
The effluent plume, based on CDOM, shows a distinctive upcoast transport along the outer edge of the shelf. Coupling this snapshot with the previous two indicates an extended period of upcoast transport of the effluent plume along the shelf edge. A weak subsurface chlorophyll maximum is present throughout the area.

Appendix IV –Drifters, Carter Ohlmann, UCSB

A) Surface Salinity Values

Figures showing surface salinity values (colored dots) at locations along drifter tracks on each sampling day. Salinity observations were recorded at the effluent diffuser location when drifters were deployed (generally the freshest water indicated by blue dots), upstream of the effluent plume in “background” ocean water (generally the most saline water indicated by red dots), and along drifter tracks during the time when background waters are mixing with effluent plume waters. Generally, salinity values following drifters increase as relatively salty ocean water mixes with effluent which is relatively fresh when initially discharged. On 9 and 10 October 2012 effluent was not being discharged from the 78” diffuser. As such, casts were performed in a cross-shore pattern, not following plume waters.

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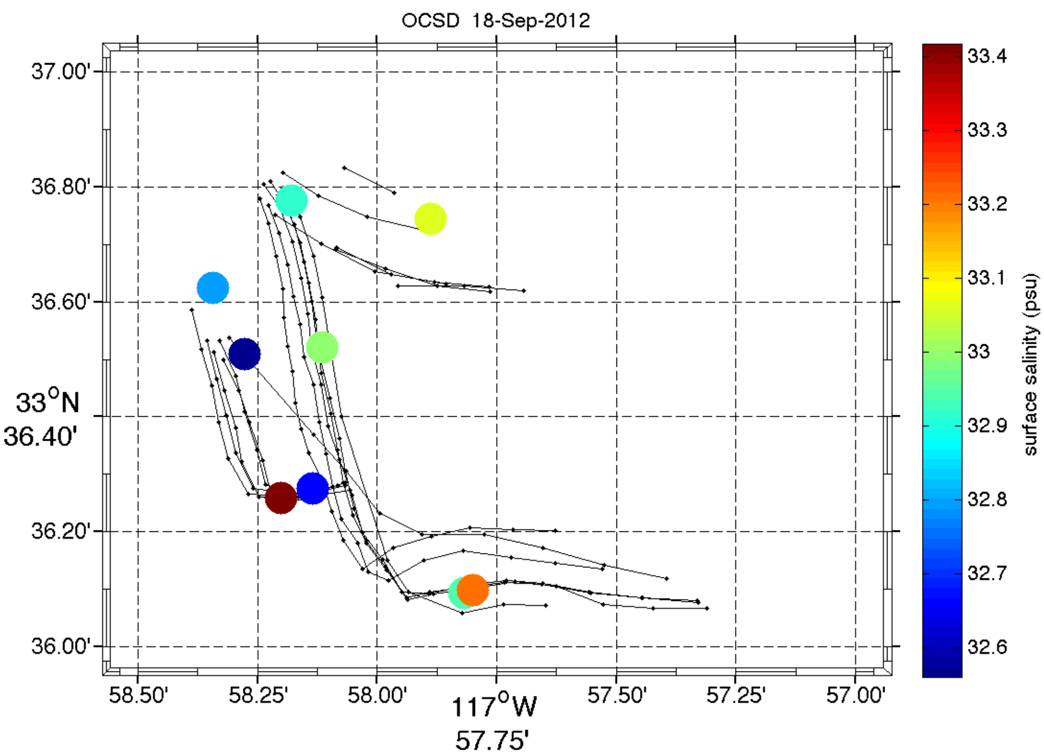
37.50'
37.25'
33°N
37.00'
36.75'
36.50'
59.00'
58.50'
117°W
58.00'
57.50'
57.00'
33.4
33.2
33
32.8
32.6
32.4
surface salinity (psu)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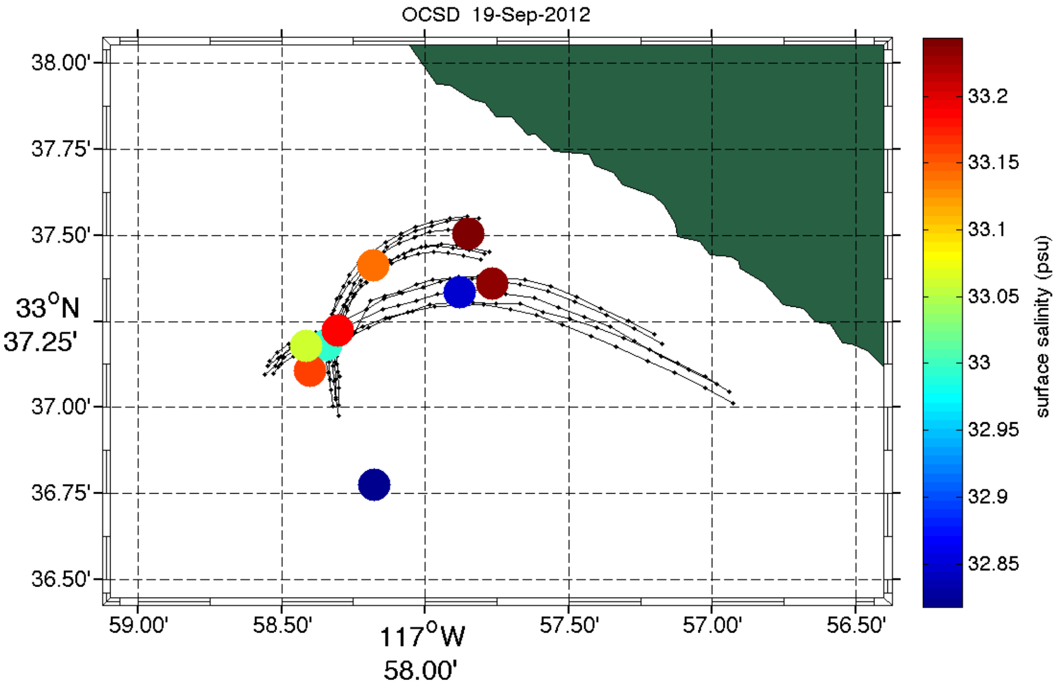
36.00'
58.50'
58.25'
58.00'
117°W
57.75'
57.50'
57.25'
57.00'
33.4
33.3
33.2
33.1
33
32.9
32.8
32.7
32.6
surface salinity (psu)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58.50'
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57.00'
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33.15
33.1
33.05
33
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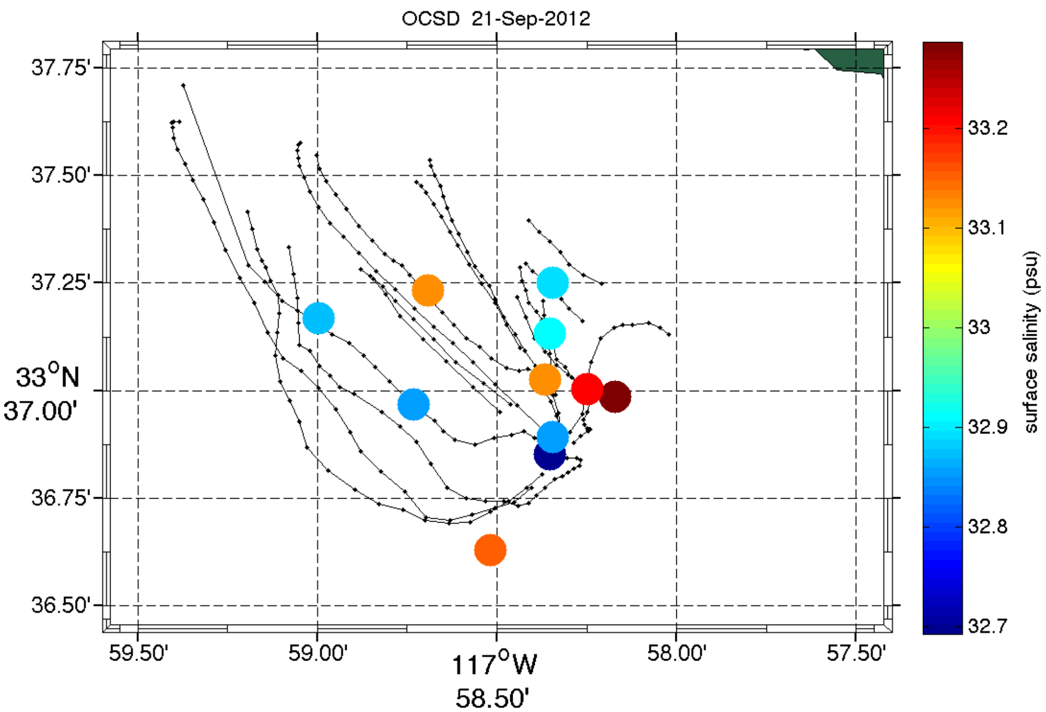
32.85
surface salinity (psu)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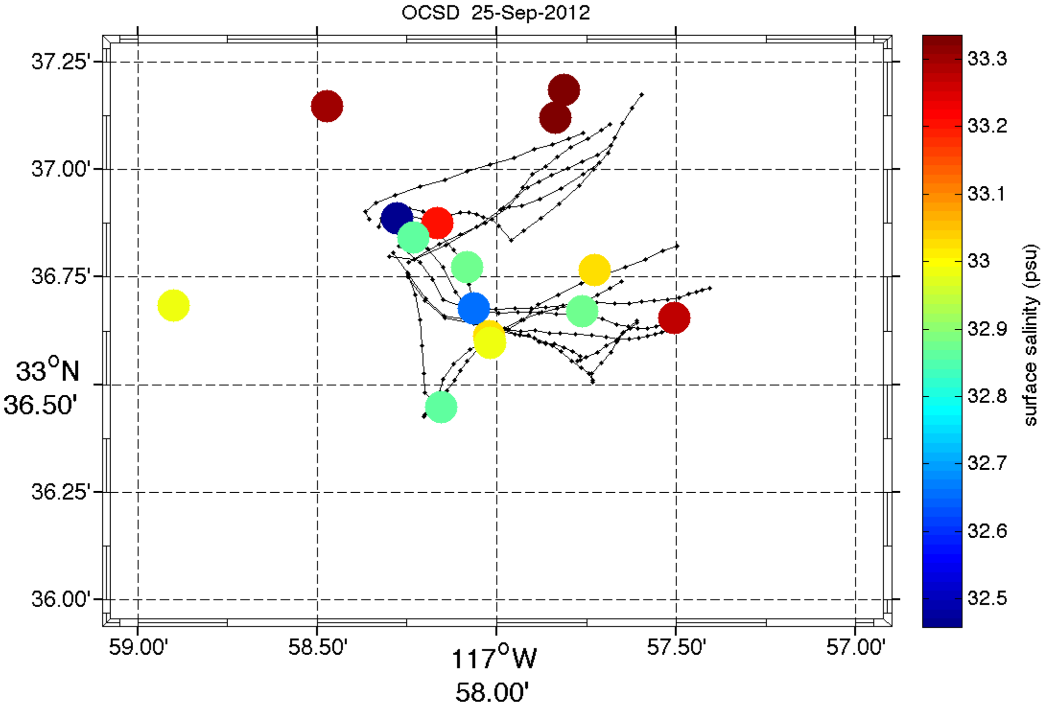
33.2
33.1
33
32.9
32.8
32.7
surface salinity (psu)



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57.50'
57.00'
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33.2
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33
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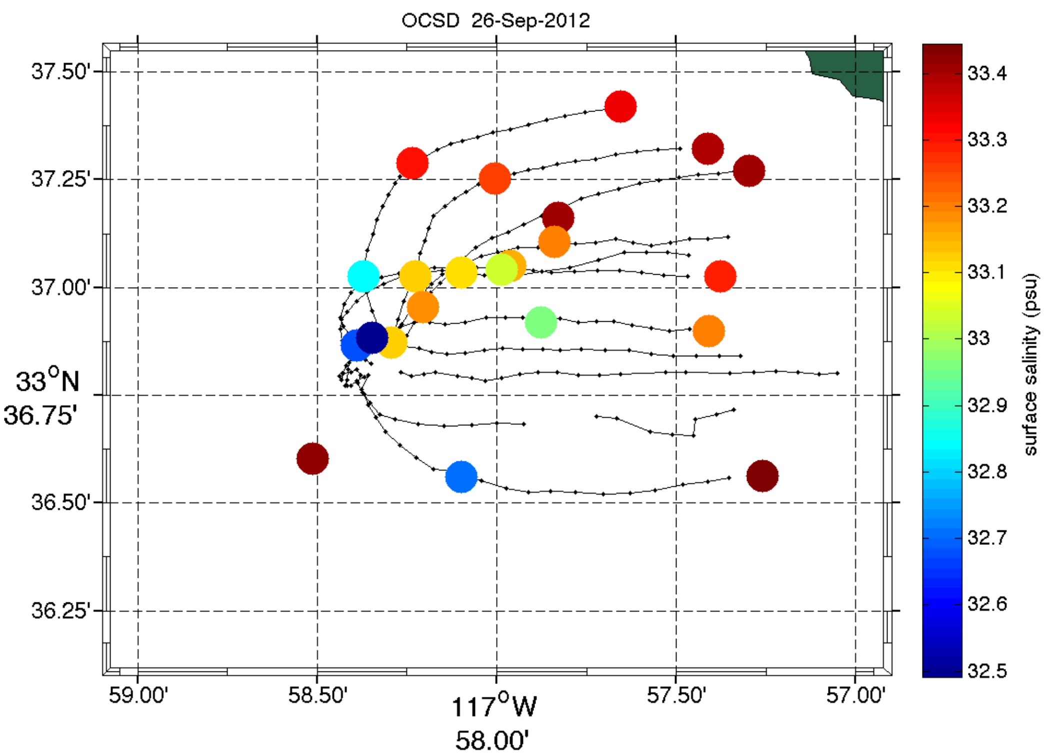
32.7
32.6
32.5
surface salinity (psu)



OCSD 26-Sep-2012
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36.25'
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117°W
58.00'
57.50'
57.00'
33.4
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33.1
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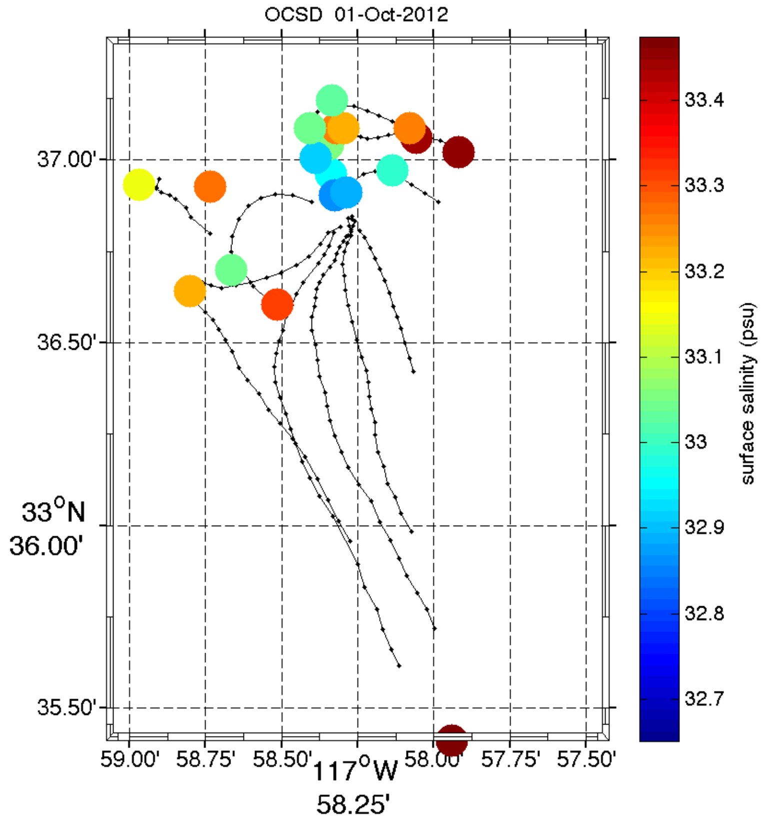
32.7
32.6
32.5
surface salinity (psu)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58.00'
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33.3
33.2
33.1
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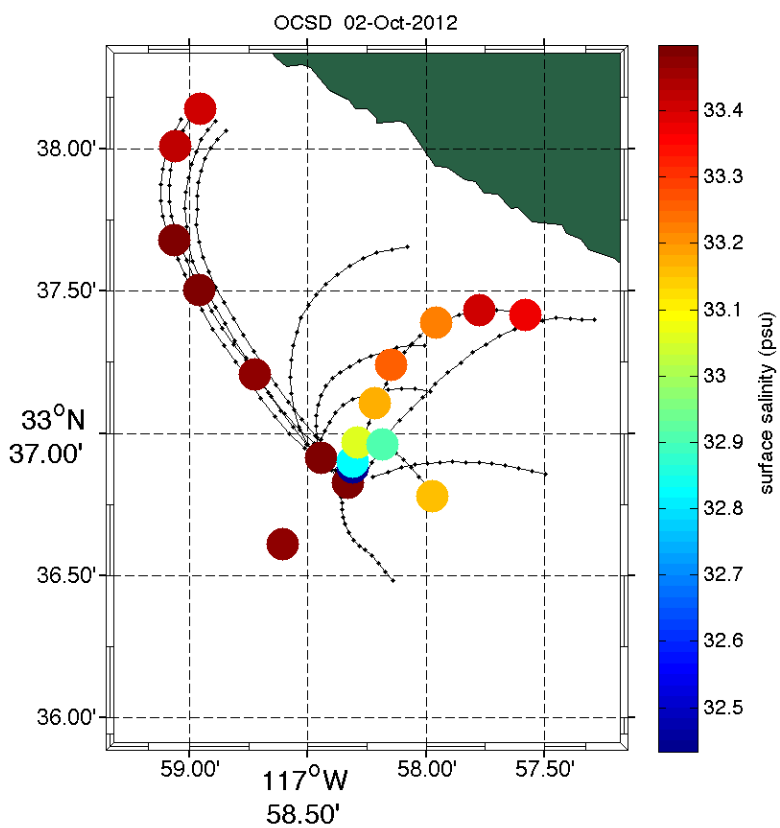
32.9
32.8
32.7
surface salinity (psu)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33.1
33
32.9
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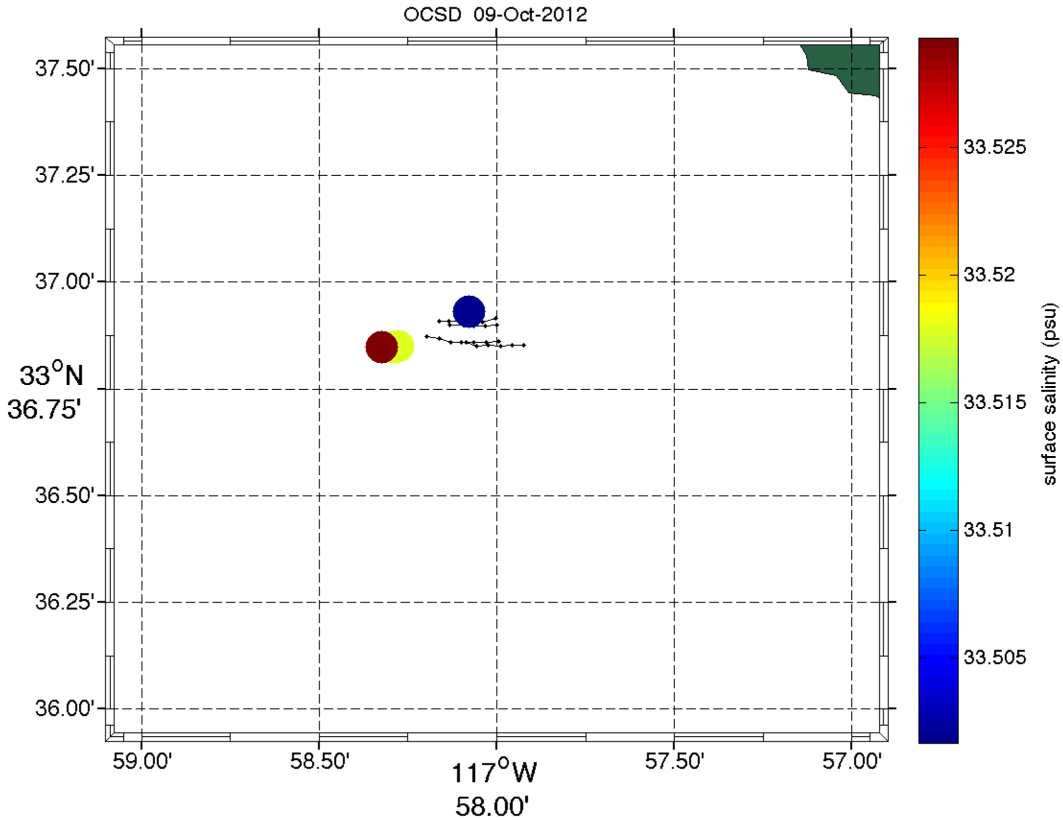
32.7
32.6
32.5
surface salinity (psu)



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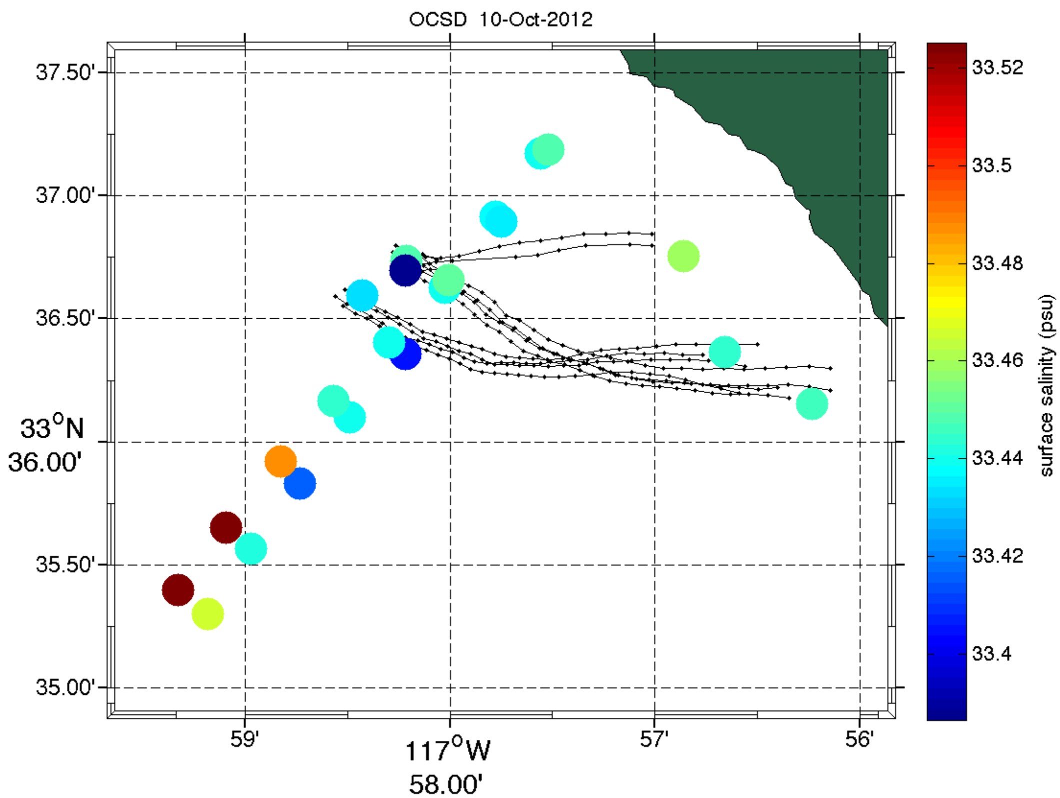
33.515
33.51
33.505
surface salinity (psu)



OCSD 10-Oct-2012
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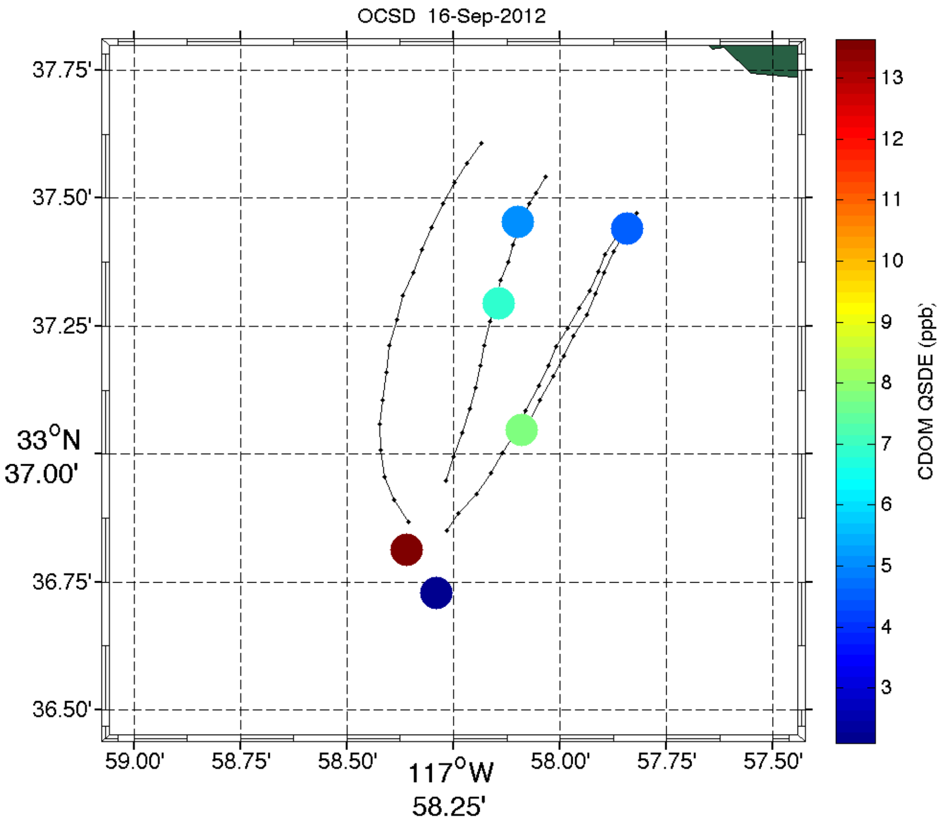
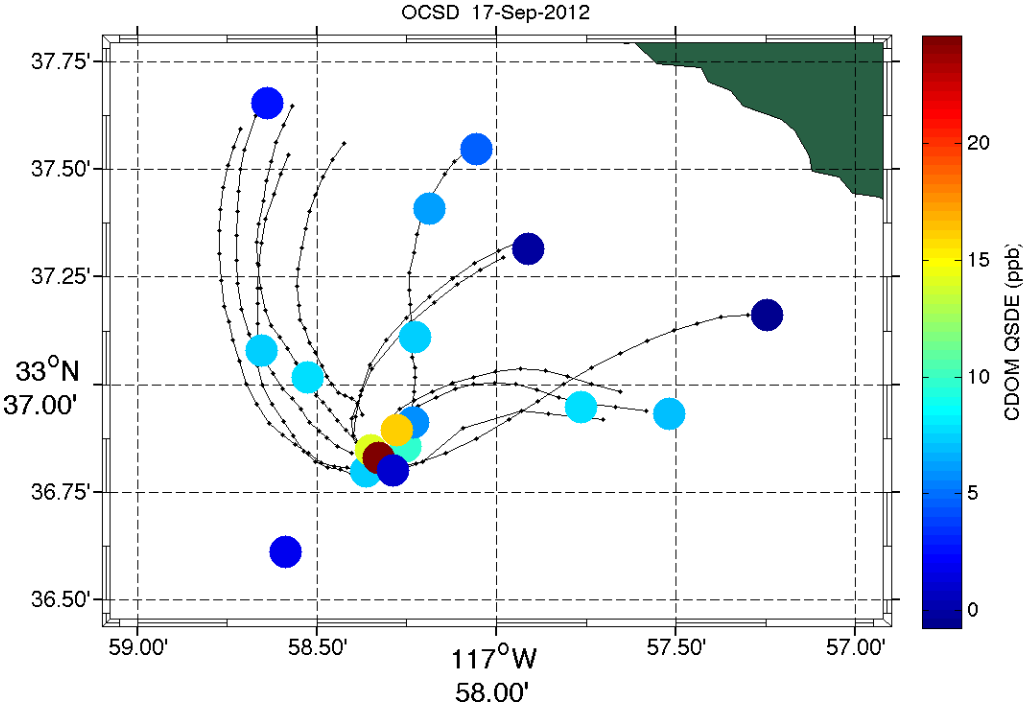
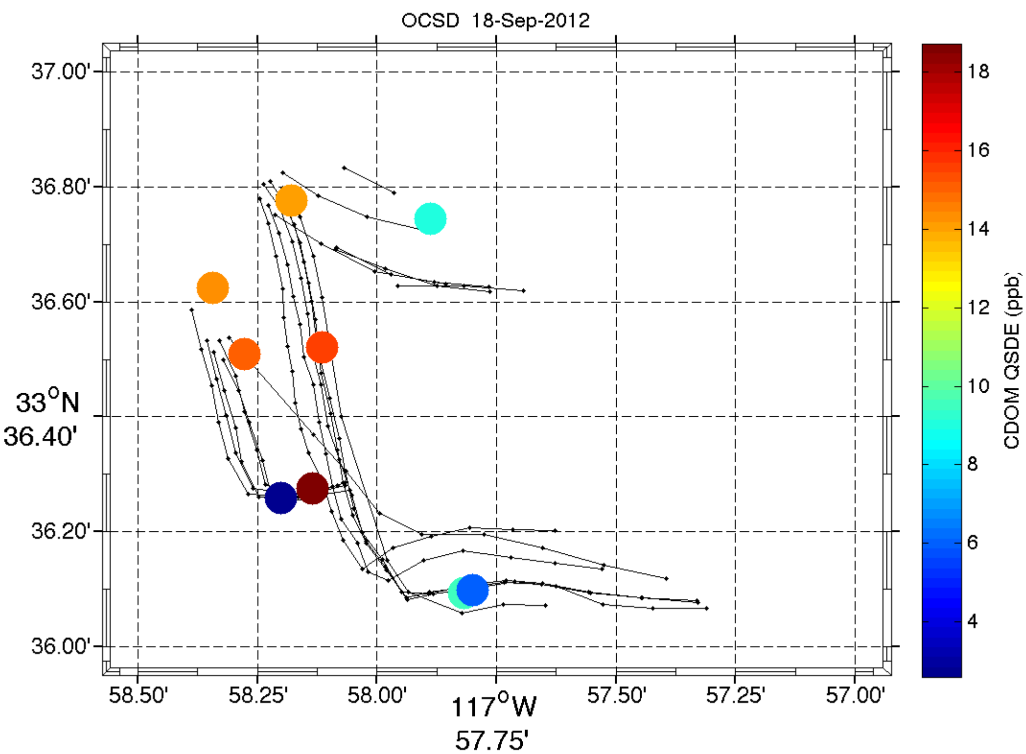
36.50'
33°N
36.00'
35.50'
35.00'
59'
117°W
58.00'
57'
56'
33.52
33.5
33.48
33.46
33.44
33.42
33.4
surface salinity (psu)

B) CDOM Concentration
Figures showing surface CDOM concentration (colored dots) at locations along drifter tracks on each sampling day. CDOM observations were recorded at the effluent diffuser location when drifters were deployed (generally the largest CDOM values indicated by red dots), upstream of the effluent plume in “background” ocean water (generally the smallest CDOM values indicated by blue dots), and along drifter tracks during the time when background waters are mixing with effluent plume waters. CDOM generally decreases following drifter motion as “background” ocean water mixes with discharged effluent.




OCSD 17-Sep-2012
37.75'
37.50'
37.25'
33°N
37.00'
36.75'
36.50'
59.00'
58.50'
117°W
58.00'
57.50'
57.00'
CDOM QSDE (ppb)
20
15
10
5
0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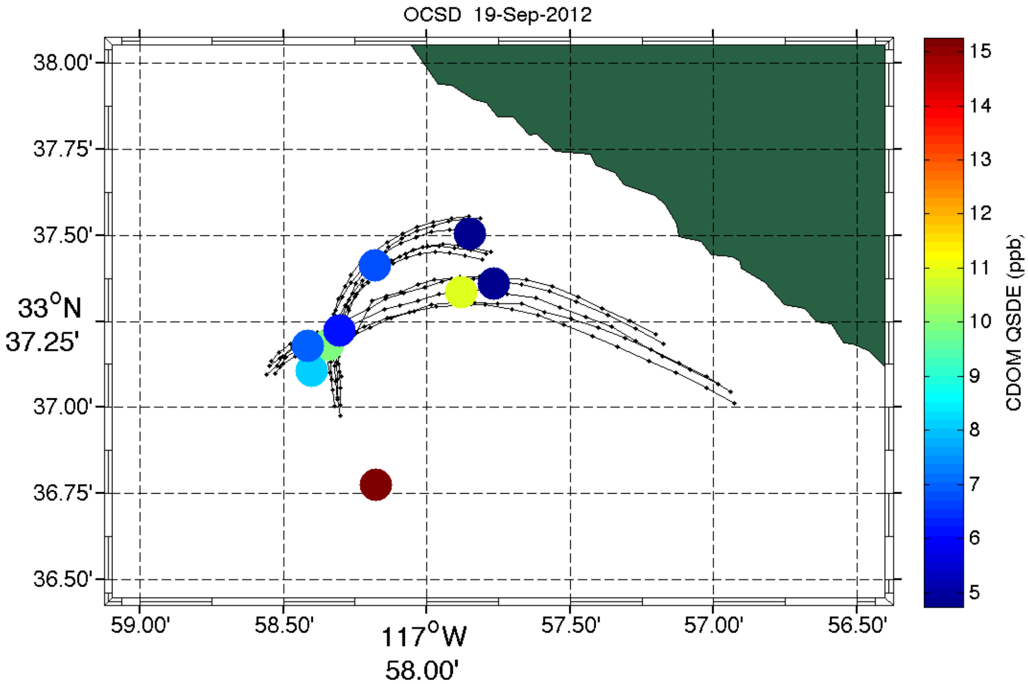
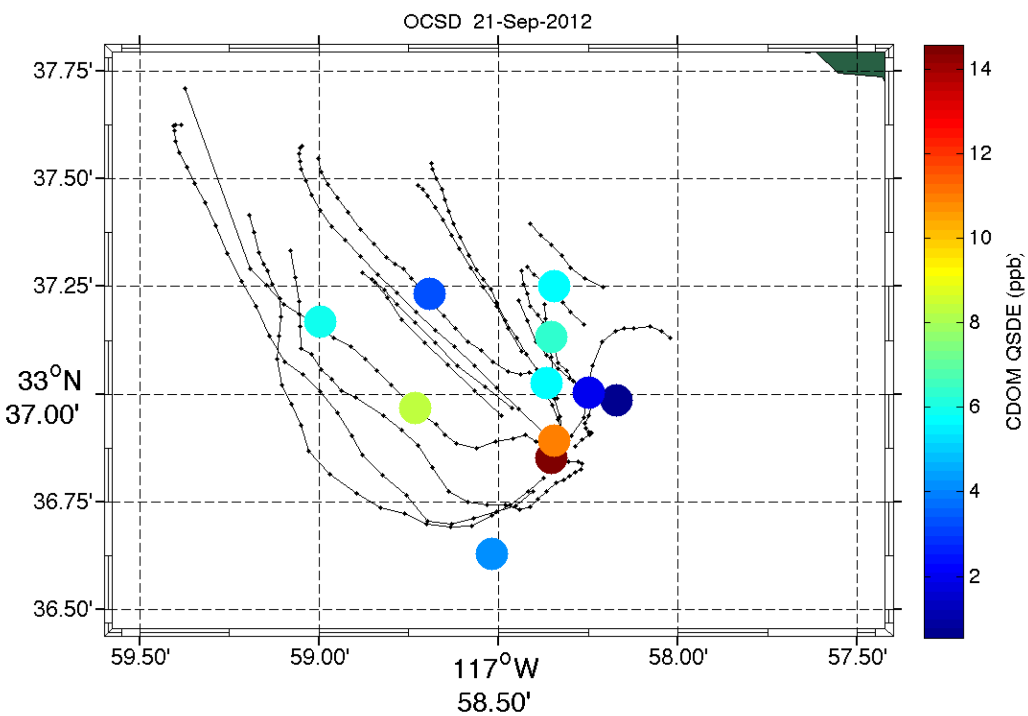
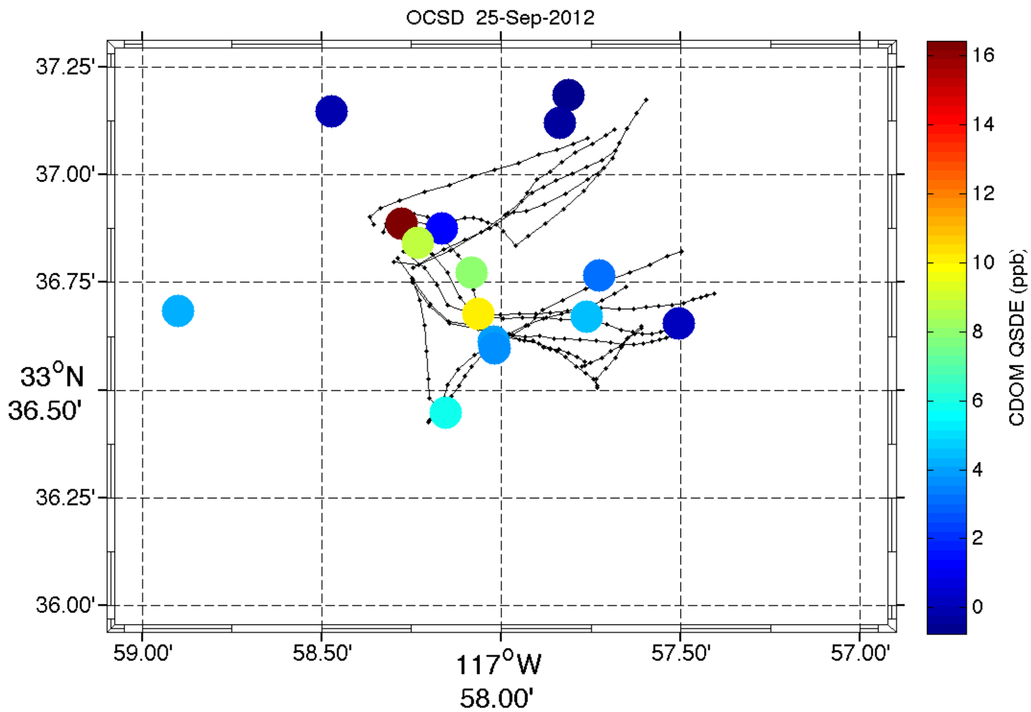
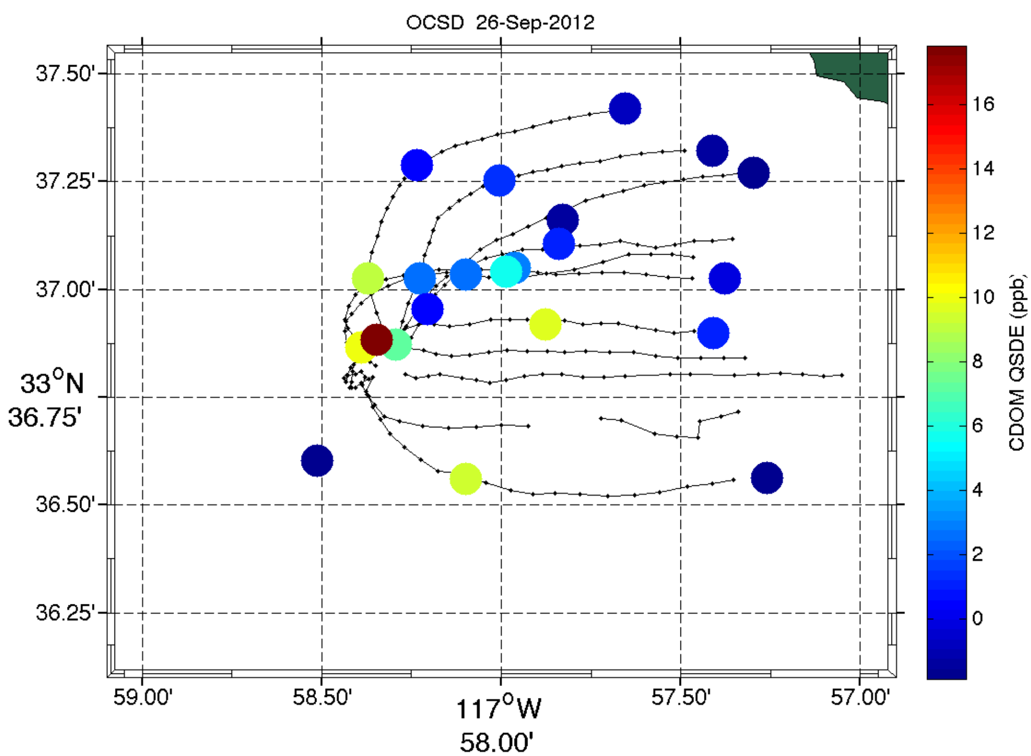
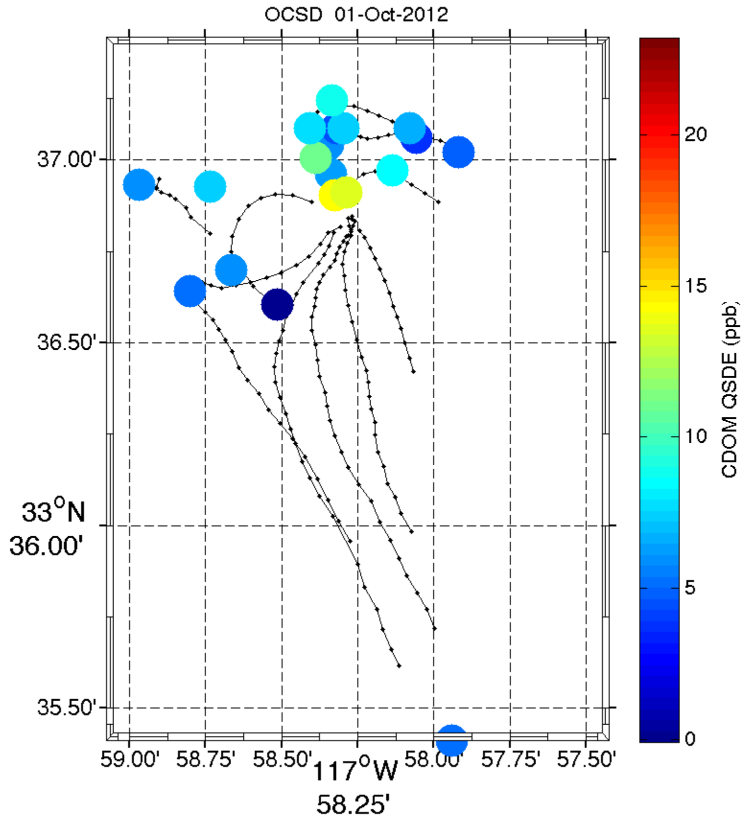
36.40'
36.20'
36.00'
58.50'
58.25'
58.00'
117°W
57.75'
57.50'
57.25'
57.00'
CDOM QSDE (ppb)
18
16
14
12
10
8
6
4

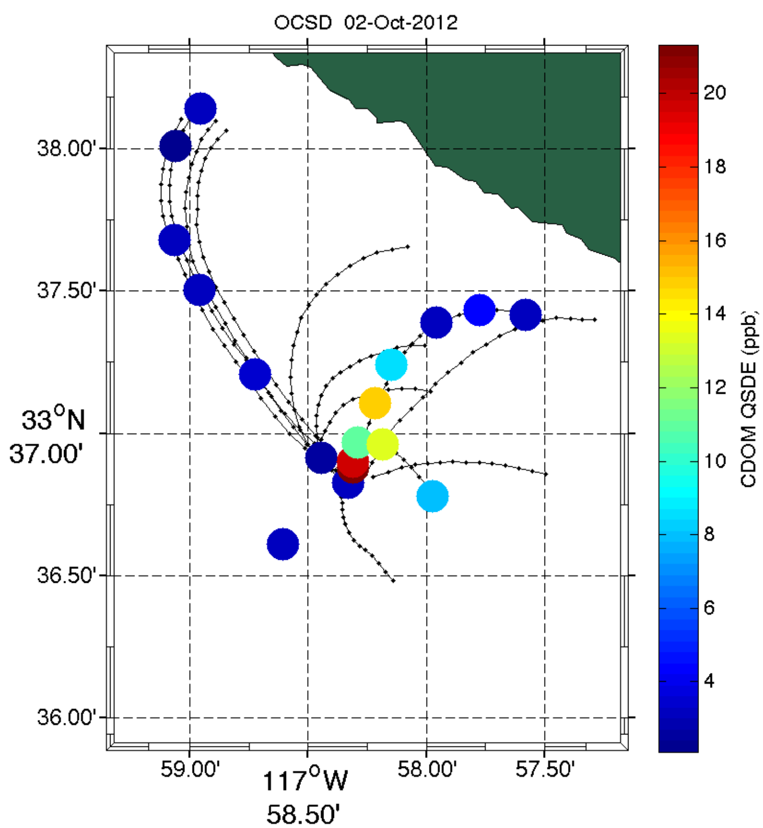

OCSD 19-Sep-2012
38.00'
37.75'
37.50'
33°N
37.25'
37.00'
36.75'
36.50'
59.00'
58.50'
117°W
58.00'
57.50'
57.00'
56.50'
CDOM QSDE (ppb)
15
14
13
12
11
10
9
8
7
6
5

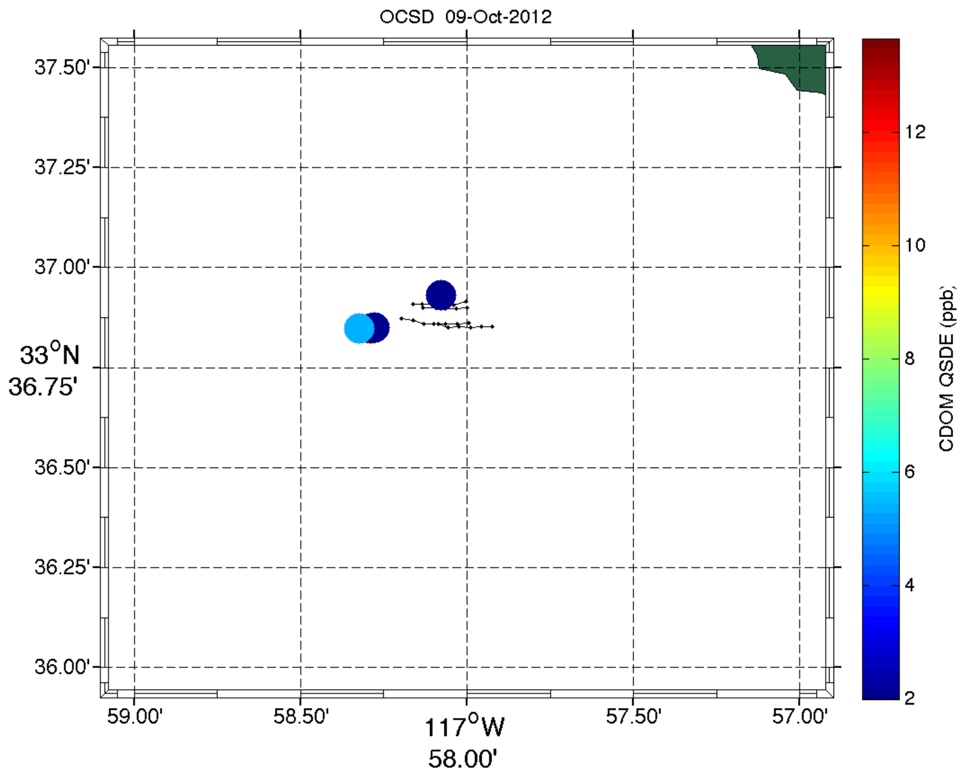

OCSD 21-Sep-2012
37.75'
37.50'
37.25'
33°N
37.00'
36.75'
36.50'
59.50'
59.00'
117°W
58.50'
58.00'
57.50'
CDOM QSDE (ppb)
14
12
10
8
6
4
2

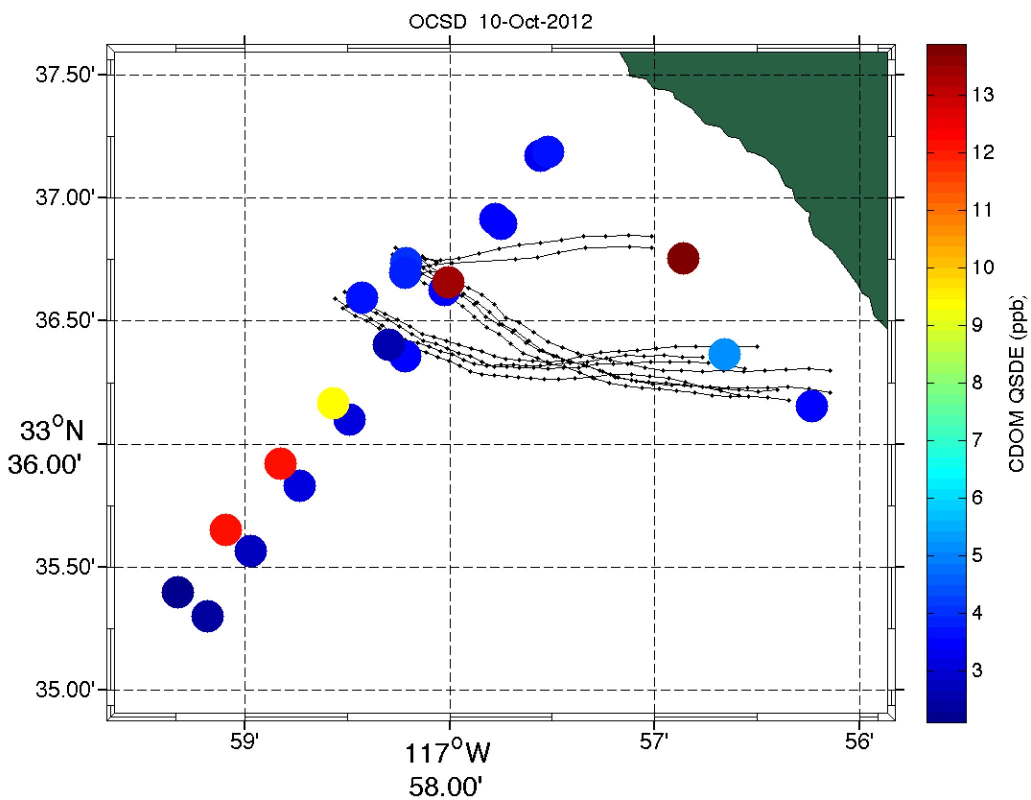

OCSD 25-Sep-2012
37.25'
37.00'
36.75'
33°N
36.50'
36.25'
36.00'
59.00'
58.50'
117°W
58.00'
57.50'
57.00'
CDOM QSDE (ppb)
16
14
12
10
8
6
4
2
0


OCSD 26-Sep-2012
37.50'
37.25'
37.00'
33°N
36.75'
36.50'
36.25'
59.00'
58.50'
117°W
58.00'
57.50'
57.00'
CDOM QSDE (ppb)
16
14
12
10
8
6
4
2
0

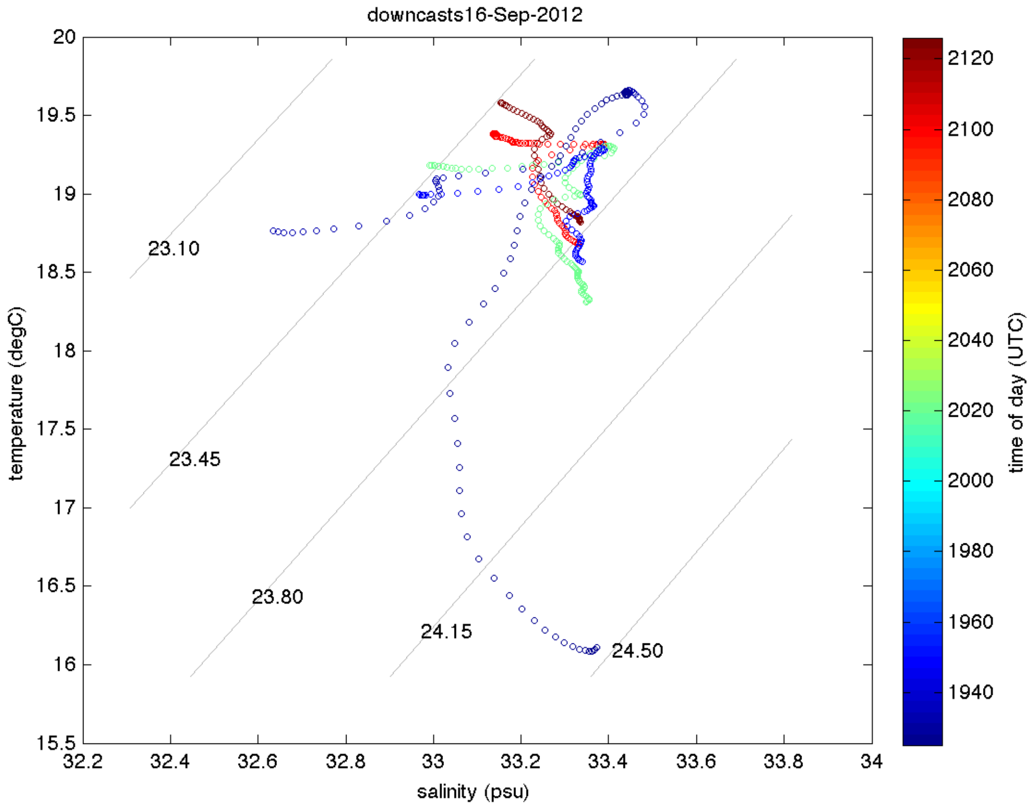

OCSD 01-Oct-2012
37.00'
36.50'
33°N
36.00'
35.50'
59.00'
58.75'
58.50'
117°W
58.25'
58.00'
57.75'
57.50'
0
5
10
15
20
CDOM QSDE (ppb)

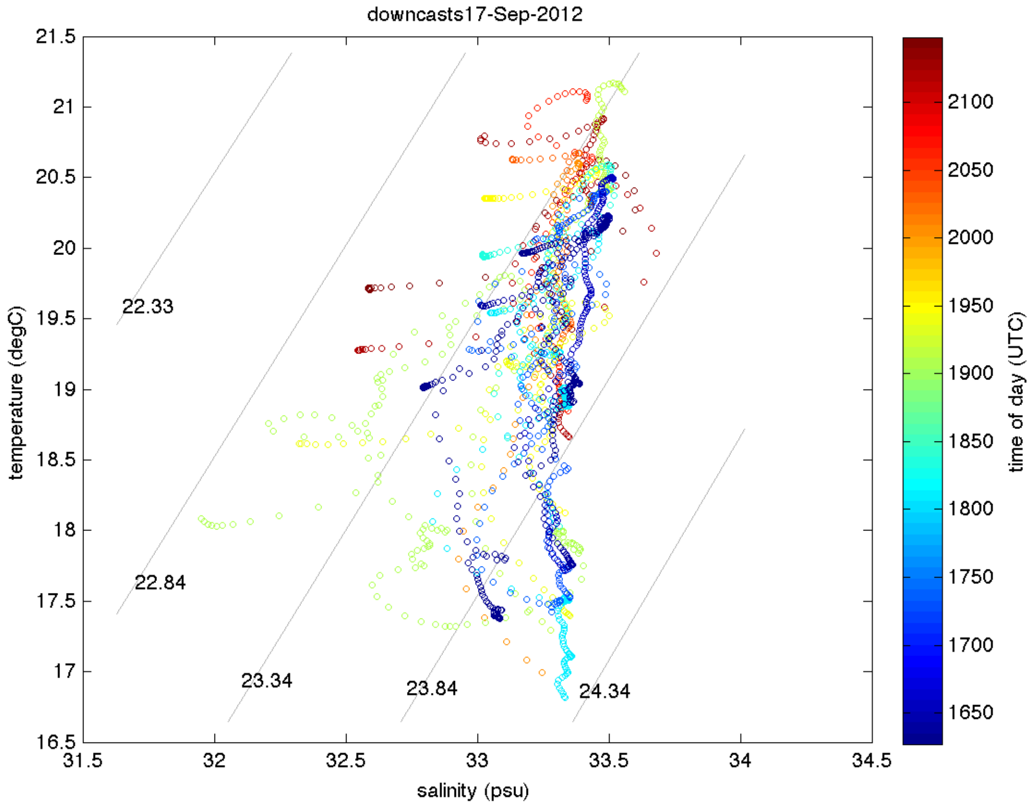

OCSD 02-Oct-2012
38.00'
37.50'
33°N
37.00'
36.50'
36.00'
59.00'
117°W
58.50'
58.00'
57.50'
4
6
8
10
12
14
16
18
20
CDOM QSDE (ppb)

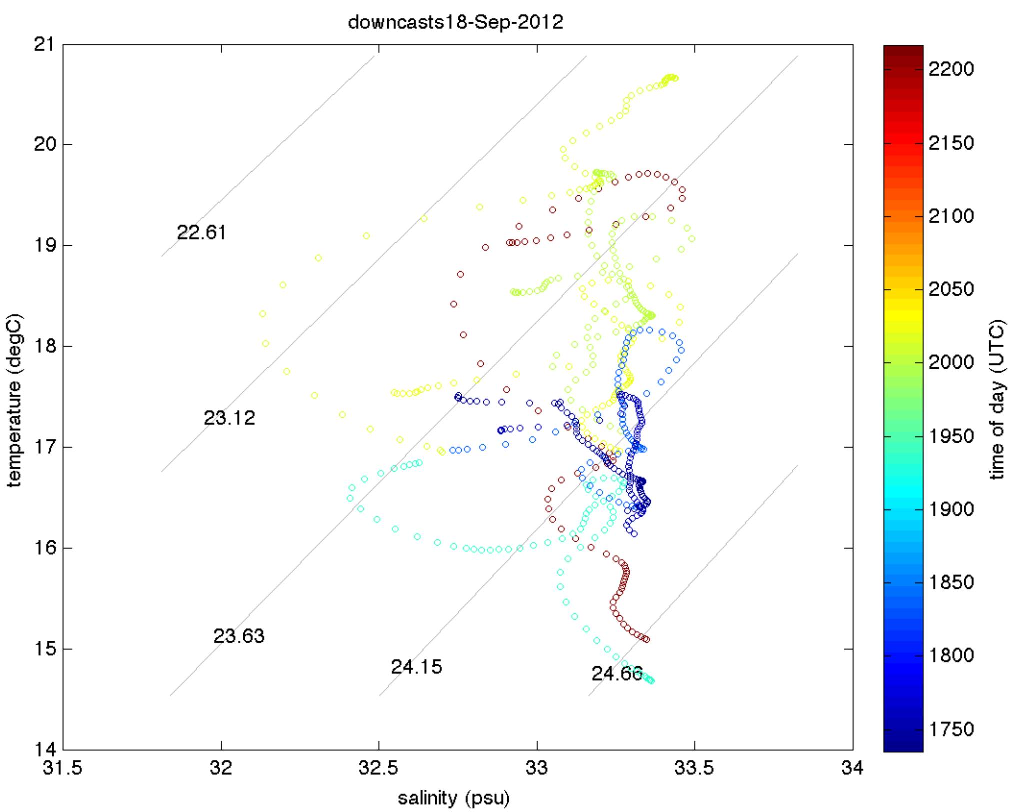

OCSD 09-Oct-2012
37.50'
37.25'
37.00'
33°N
36.75'
36.50'
36.25'
36.00'
59.00'
58.50'
117°W
58.00'
57.50'
57.00'
CDOM QSDE (ppb)
12
10
8
6
4
2

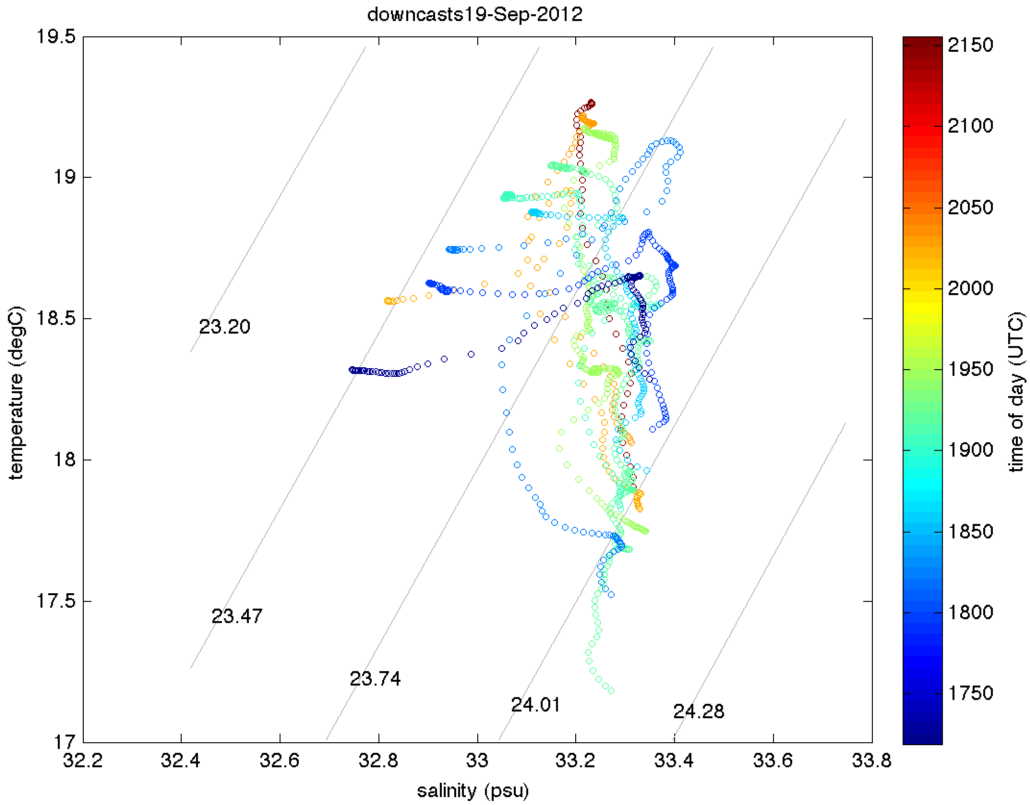

OCSD 10-Oct-2012
37.50'
37.00'
36.50'
33°N
36.00'
35.50'
35.00'
59'
117°W
58.00'
57'
56'
CDOM QSDE (ppb)
13
12
11
10
9
8
7
6
5
4
3

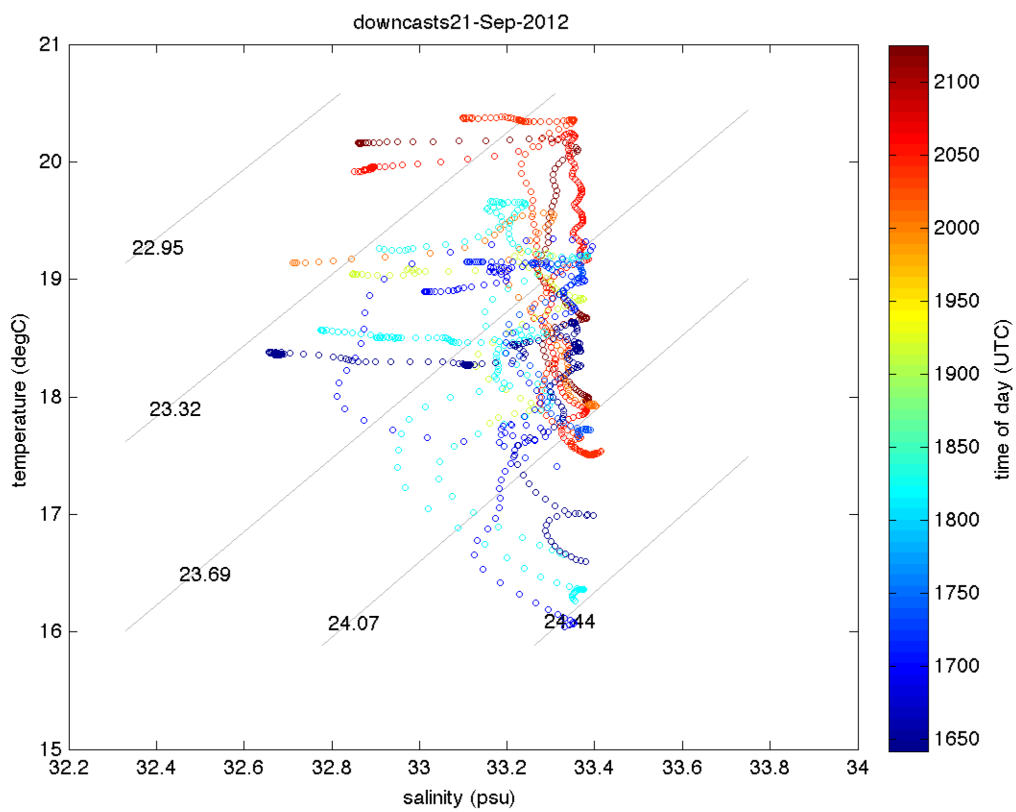
C) Temperature/Salinity Diagrams by Sampling Day
Figures showing T-S diagrams by sampling day. Color indicates time of day the cast was performed.

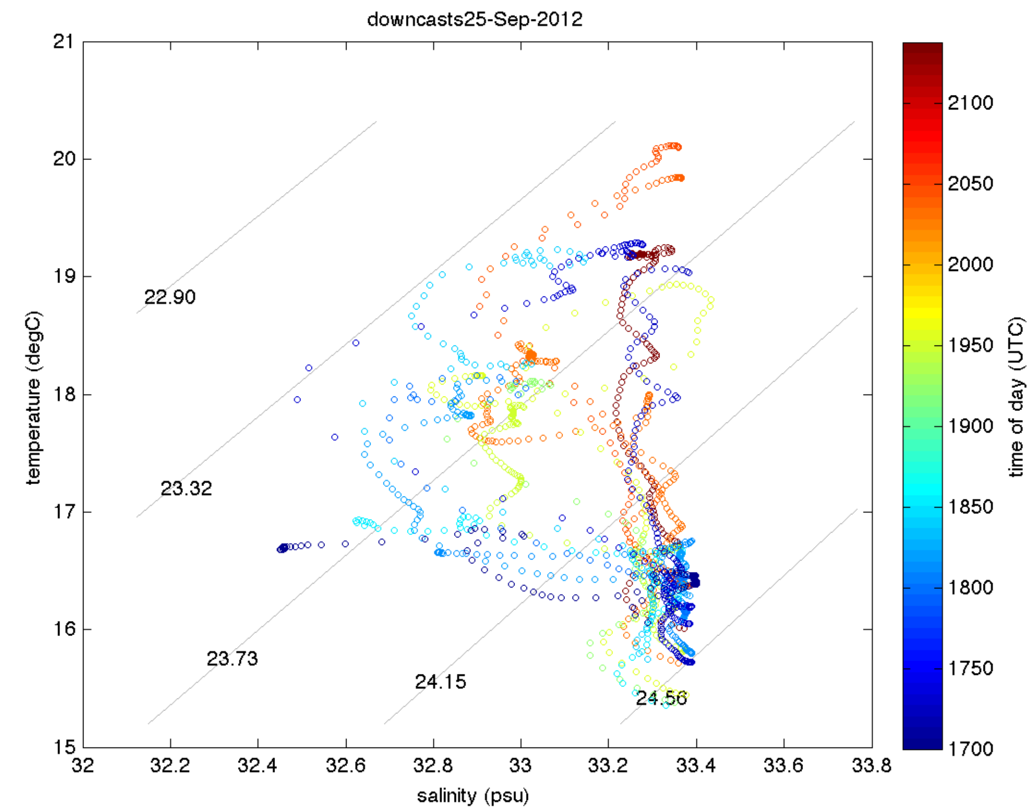


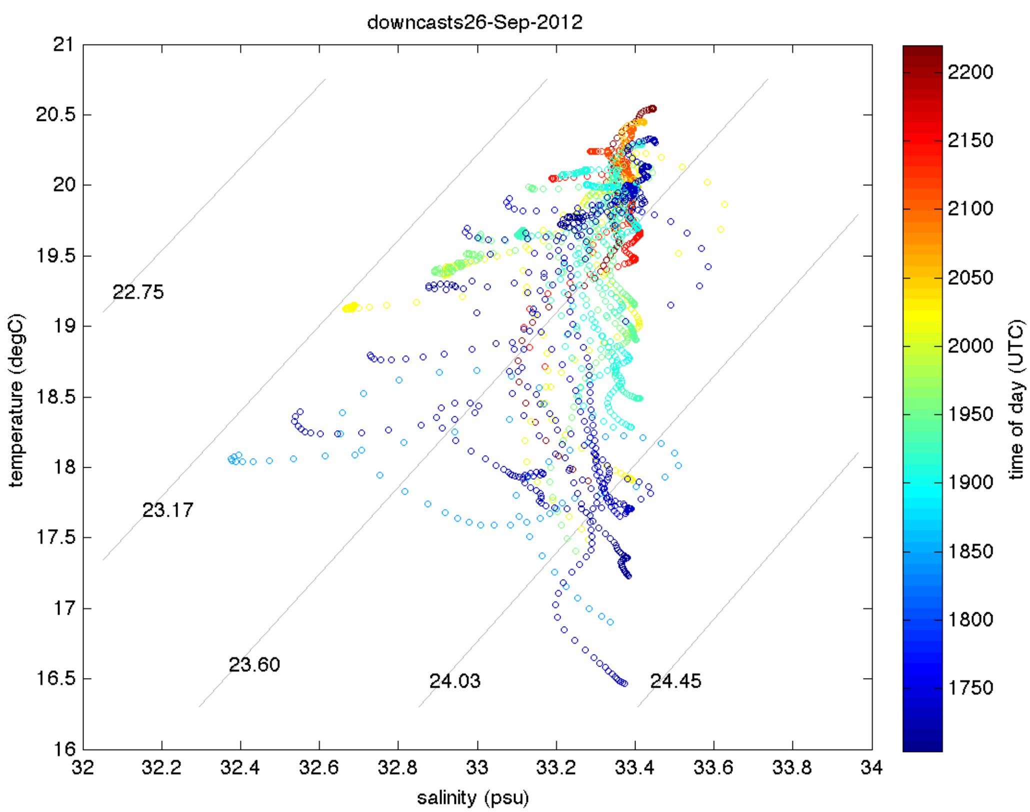

downcasts17-Sep-2012
temperature (degC)
salinity (psu)
time of day (UTC)
22.33
22.84
23.34
23.84
24.34

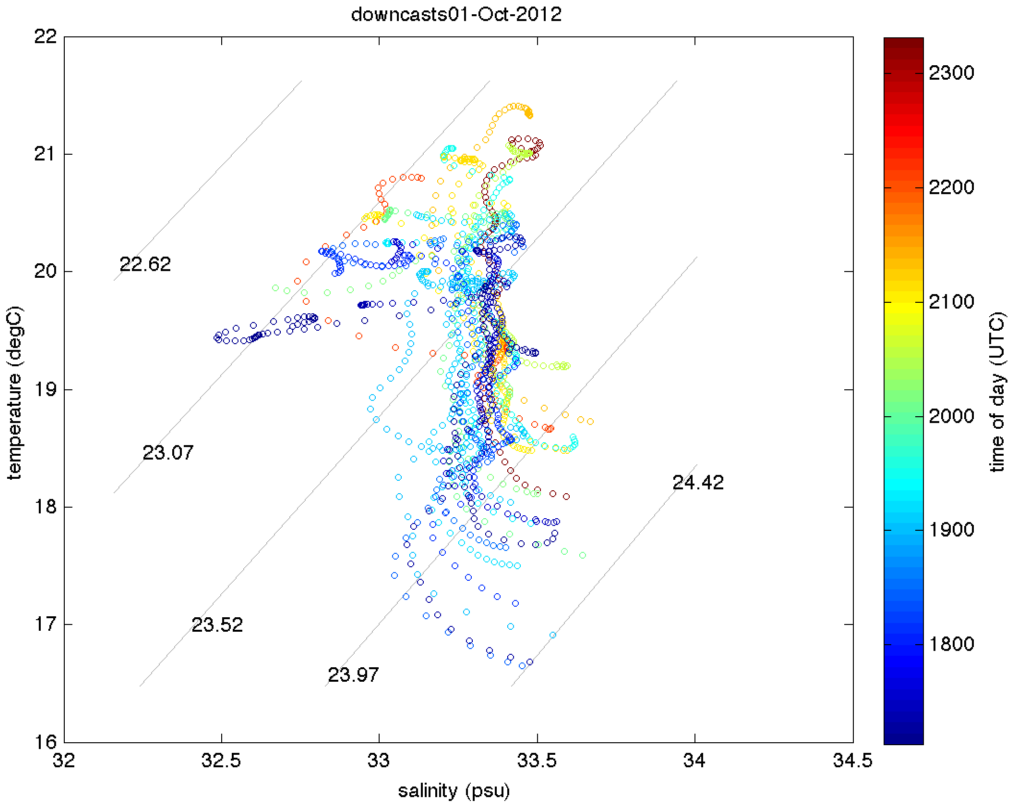

downcasts18-Sep-2012
temperature (degC)
salinity (psu)
time of day (UTC)
22.61
23.12
23.63
24.15
24.66

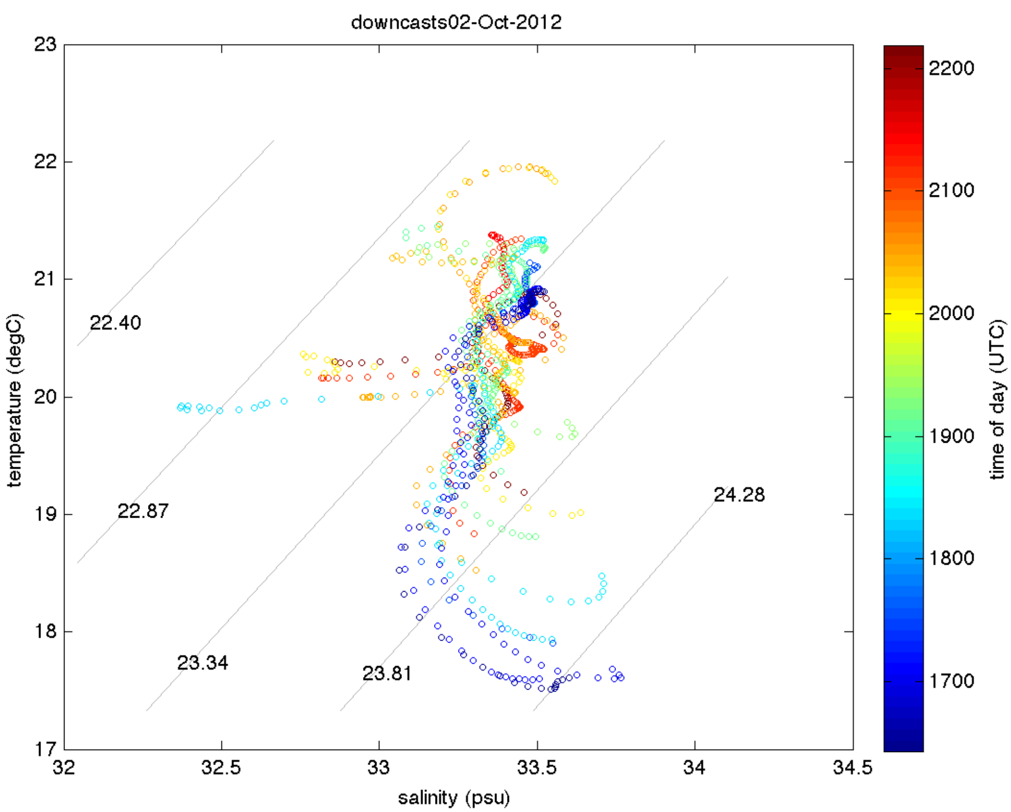

downcasts19-Sep-2012
temperature (degC)
salinity (psu)
time of day (UTC)
23.20
23.47
23.74
24.01
24.28

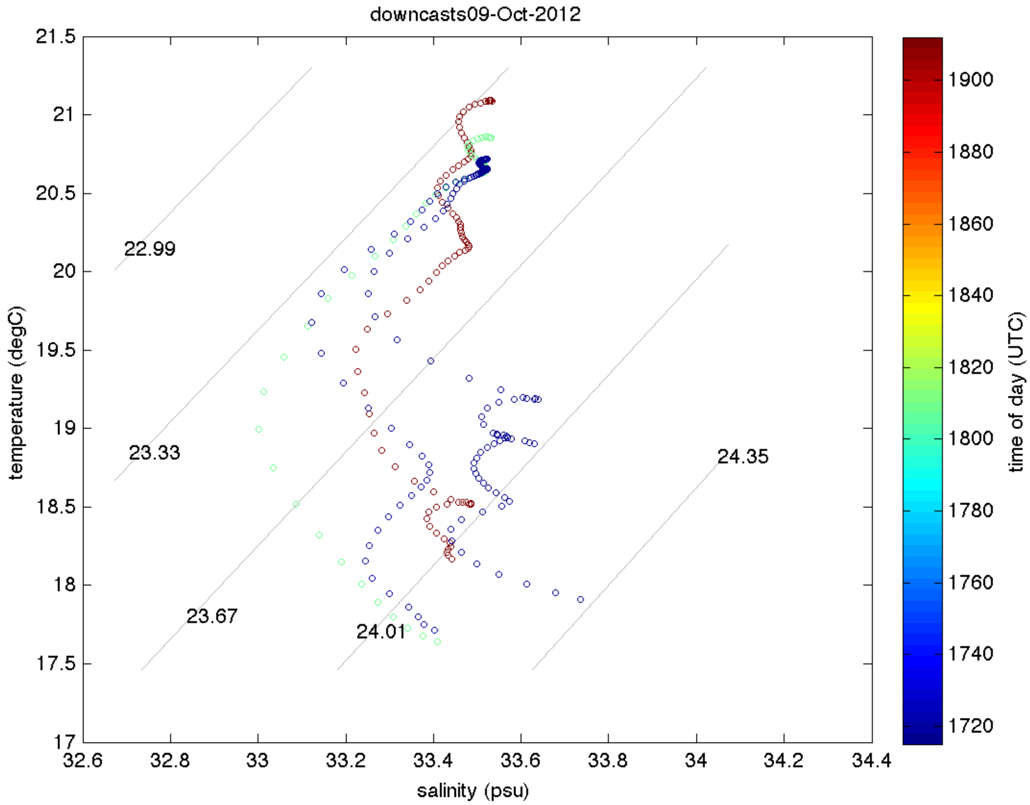

downcasts21-Sep-2012
temperature (degC)
salinity (psu)
time of day (UTC)
22.95
23.32
23.69
24.07
24.44

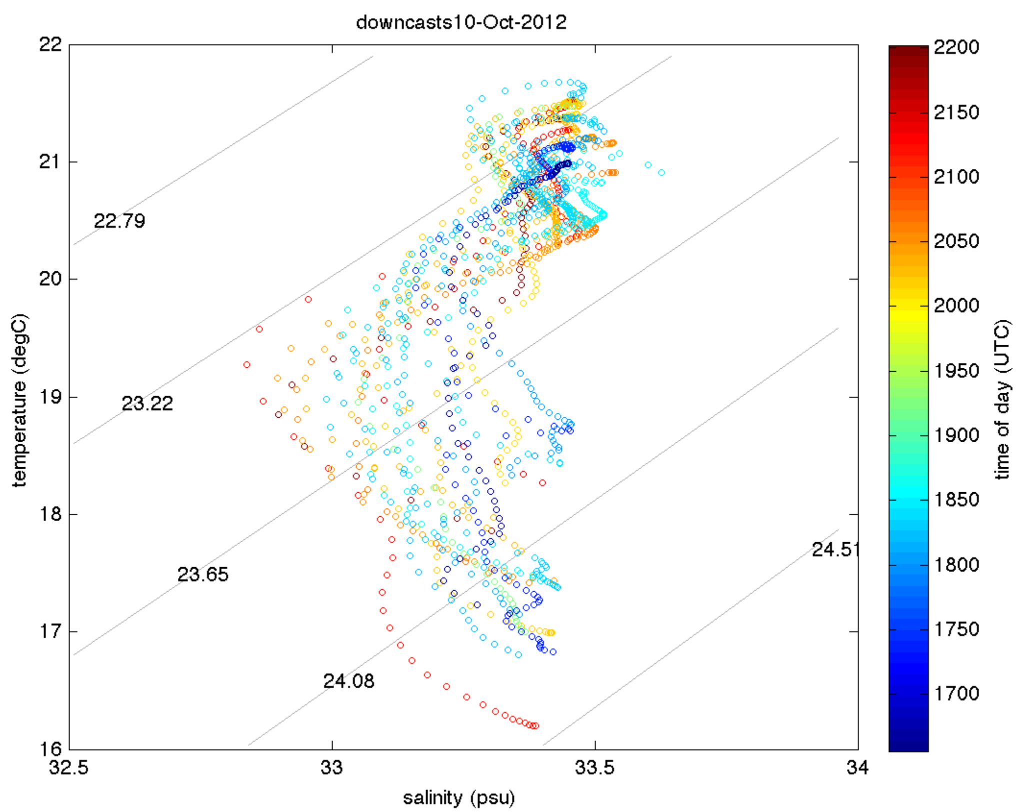

downcasts25-Sep-2012
temperature (degC)
salinity (psu)
time of day (UTC)
22.90
23.32
23.73
24.15
24.56
21
20
19
18
17
16
15
32
32.2
32.4
32.6
32.8
33
33.2
33.4
33.6
33.8
2100
2050
2000
1950
1900
1850
1800
1750
1700


downcasts26-Sep-2012
temperature (degC)
salinity (psu)
time of day (UTC)
22.75
23.17
23.60
24.03
24.45
21
20.5
20
19.5
19
18.5
18
17.5
17
16.5
16
32
32.2
32.4
32.6
32.8
33
33.2
33.4
33.6
33.8
34
2200
2150
2100
2050
2000
1950
1900
1850
1800
1750


downcasts01-Oct-2012
temperature (degC)
salinity (psu)
time of day (UTC)
22.62
23.07
23.52
23.97
24.42
22
21
20
19
18
17
16
32
32.5
33
33.5
34
34.5
2300
2200
2100
2000
1900
1800

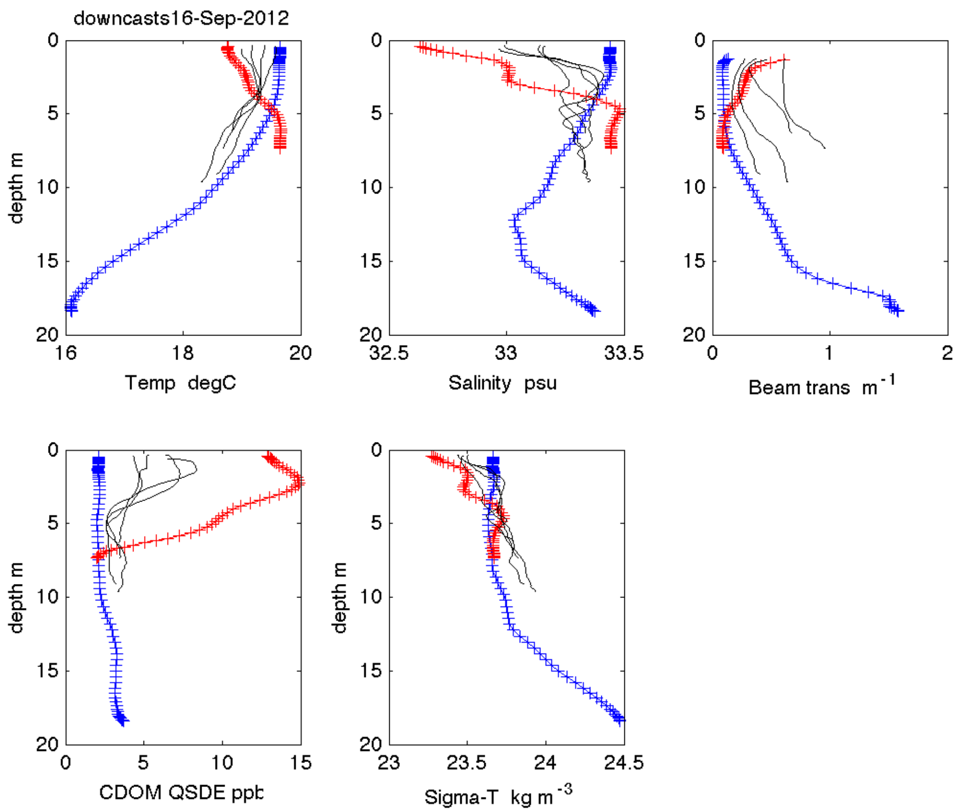

downcasts02-Oct-2012
temperature (degC)
salinity (psu)
time of day (UTC)
22.40
22.87
23.34
23.81
24.28
23
22
21
20
19
18
17
32
32.5
33
33.5
34
34.5
2200
2100
2000
1900
1800
1700

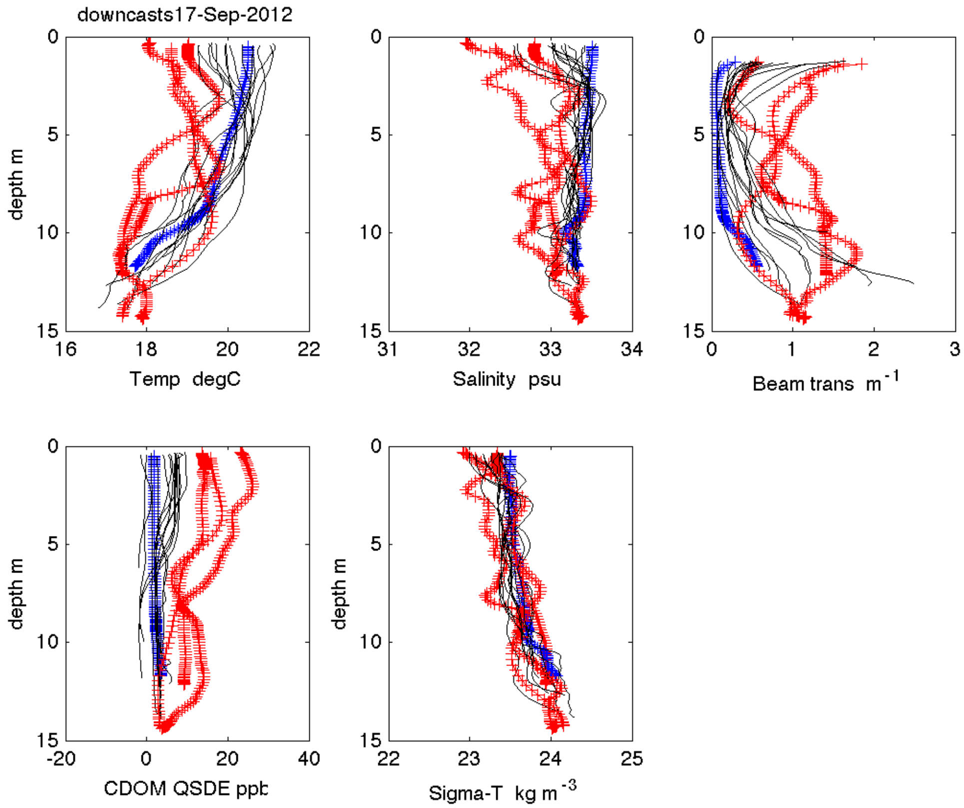

downcasts09-Oct-2012
temperature (degC)
salinity (psu)
time of day (UTC)
22.99
23.33
23.67
24.01
24.35
21.5
21
20.5
20
19.5
19
18.5
18
17.5
17
32.6
32.8
33
33.2
33.4
33.6
33.8
34
34.2
34.4
1900
1880
1860
1840
1820
1800
1780
1760
1740
1720

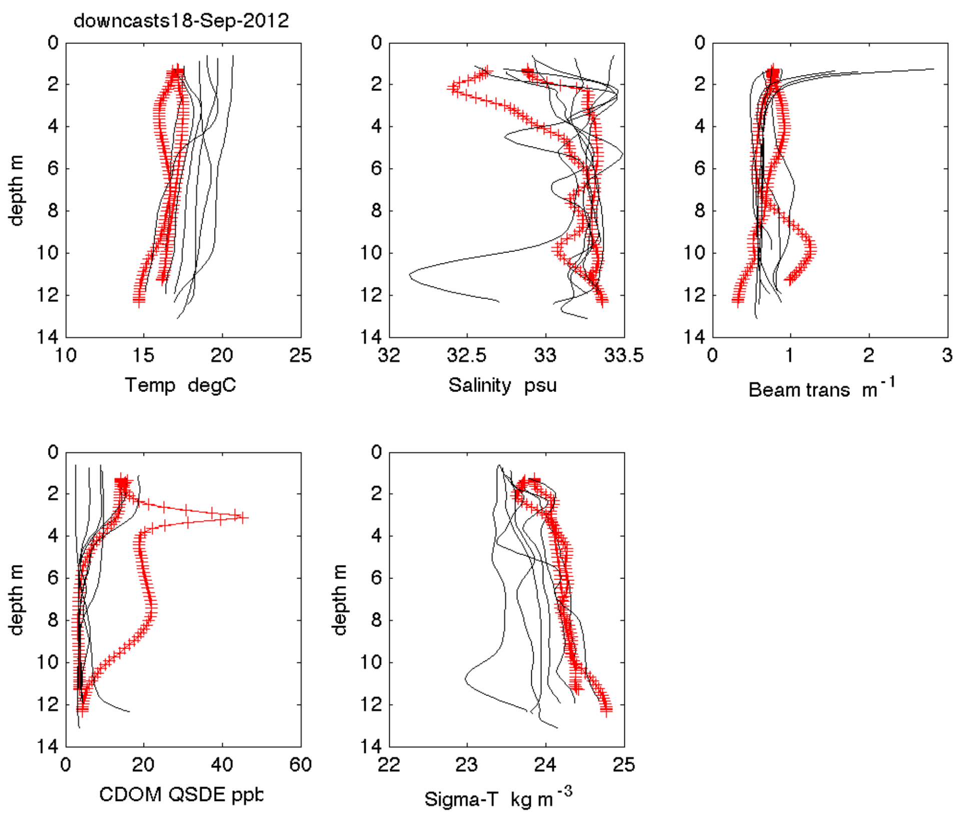

downcasts10-Oct-2012
temperature (degC)
salinity (psu)
time of day (UTC)
22.79
23.22
23.65
24.08
24.51
22
21
20
19
18
17
16
32.5
33
33.5
34
2200
2150
2100
2050
2000
1950
1900
1850
1800
1750
1700

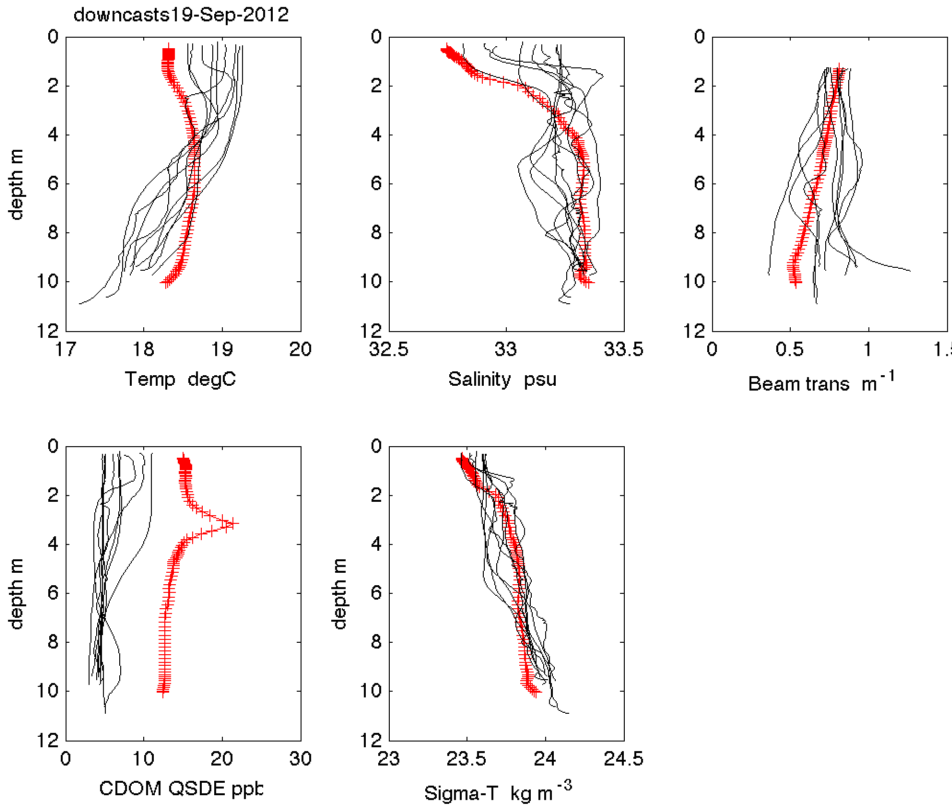
D) Downcast CTD data (Temperature, Salinity, Transmission, CDOM, and Density) by Sampling Day

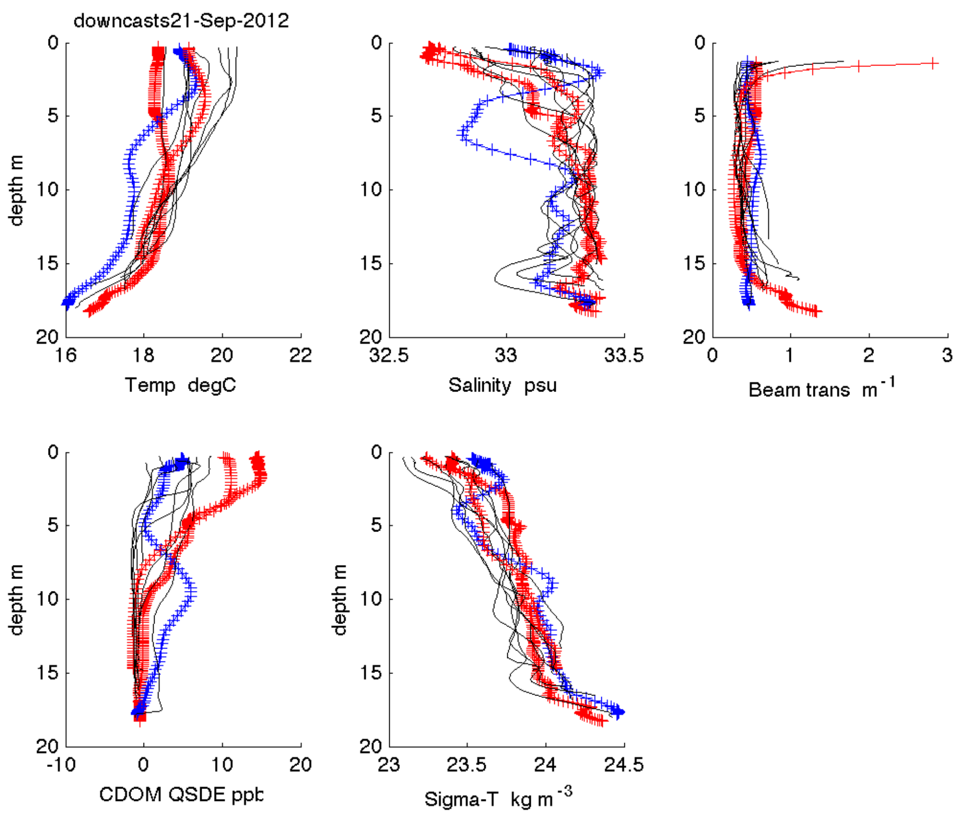
Figures showing all the downcast CTD data (temperature, salinity, transmission, CDOM, and density) by sampling day. Red profiles are at the diffuser location and presumably sample plume waters just after discharge. Blue profiles are upstream of the effluent plume and presumably sample the background ocean water that dilutes the effluent. Black lines are at locations following drifters that tag plume water. On 9 and 10 October 2012 effluent was not being discharged from the 78” diffuser. As such, casts were performed in a cross-shore pattern, not following plume waters.

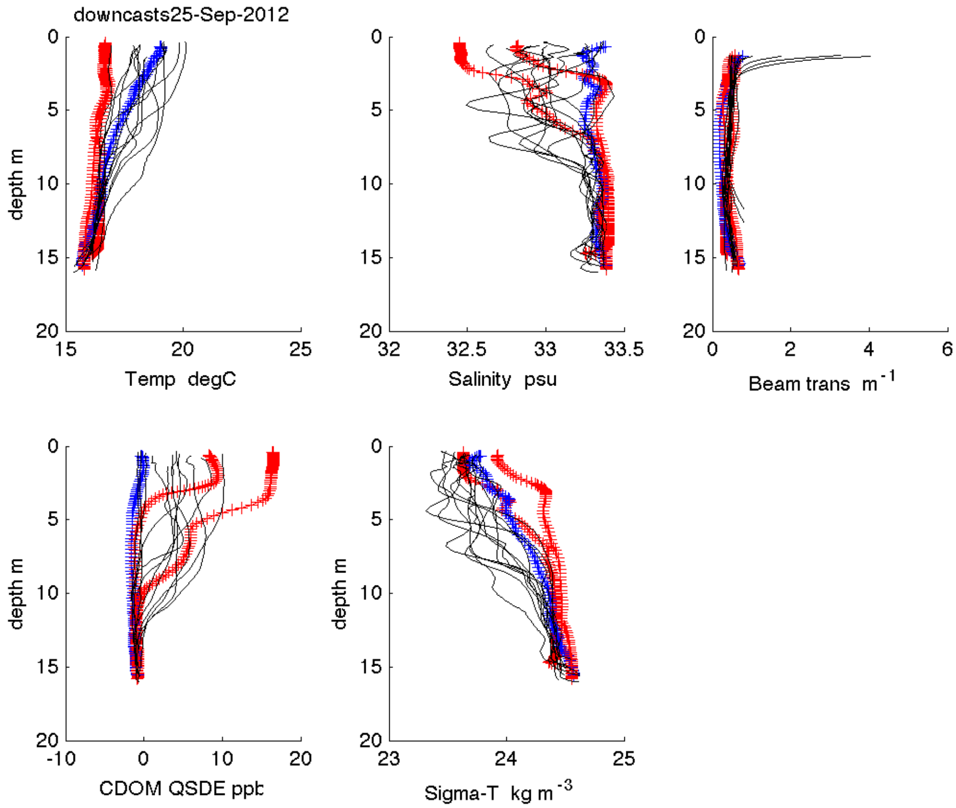


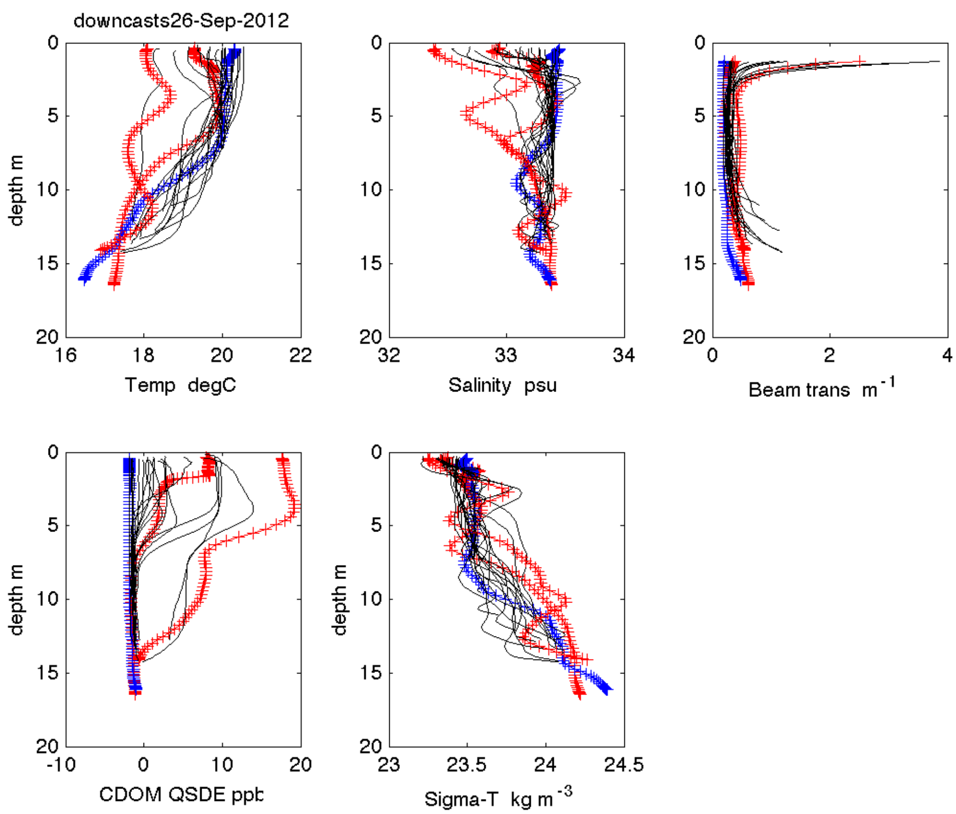

downcasts17-Sep-2012
depth m
Temp degC
Salinity psu
Beam trans m-1
CDOM QSDE ppb
Sigma-T kg m-3

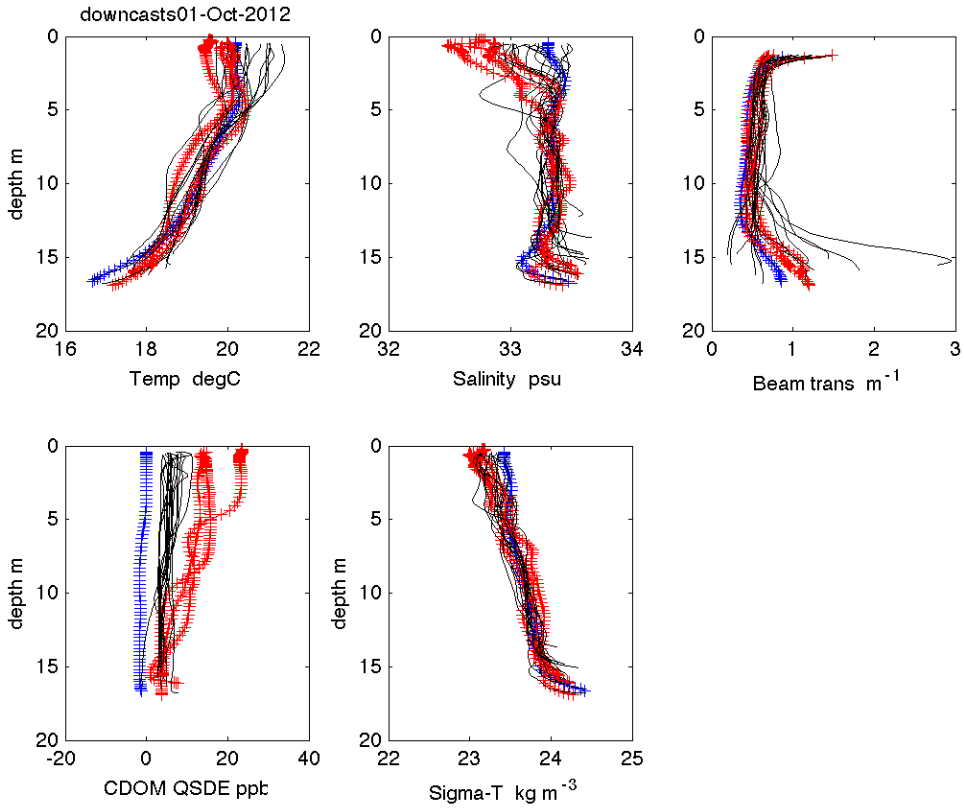

downcasts18-Sep-2012
depth m
Temp degC
Salinity psu
Beam trans m-1
CDOM QSDE ppb
Sigma-T kg m-3

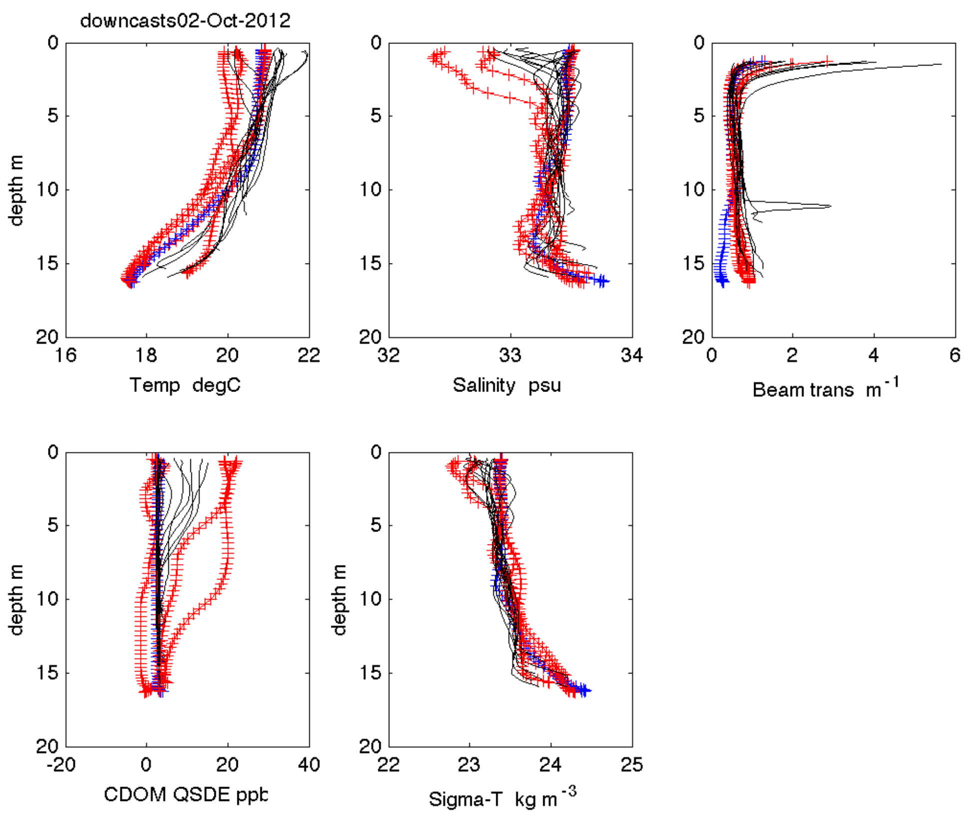

downcasts19-Sep-2012
depth m
Temp degC
Salinity psu
Beam trans m^{-1}
CDOM QSDE ppb
Sigma-T kg m^{-3}

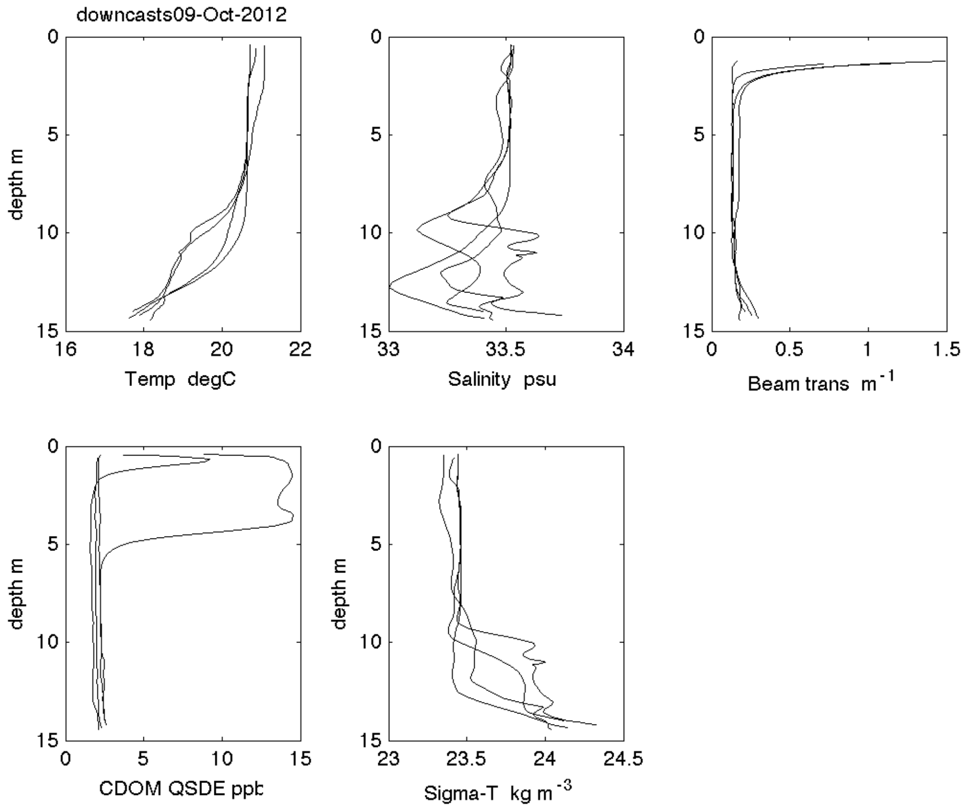

downcasts21-Sep-2012
depth m
Temp degC
Salinity psu
Beam trans m^{-1}
CDOM QSDE ppb
Sigma-T kg m^{-3}

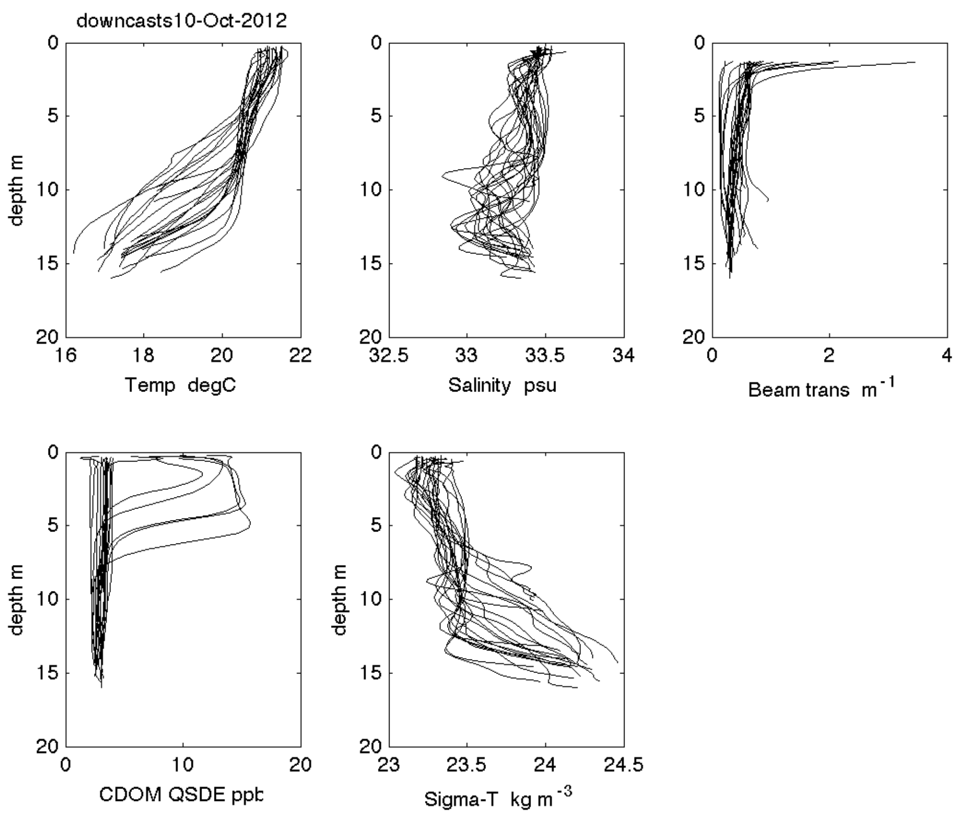

downcasts25-Sep-2012
depth m
Temp degC
Salinity psu
Beam trans m-1
CDOM QSDE ppb
Sigma-T kg m-3


downcasts26-Sep-2012
depth m
Temp degC
Salinity psu
Beam trans m-1
CDOM QSDE ppb
Sigma-T kg m-3


downcasts01-Oct-2012
depth m
Temp degC
Salinity psu
Beam trans m-1
CDOM QSDE ppb
Sigma-T kg m-3

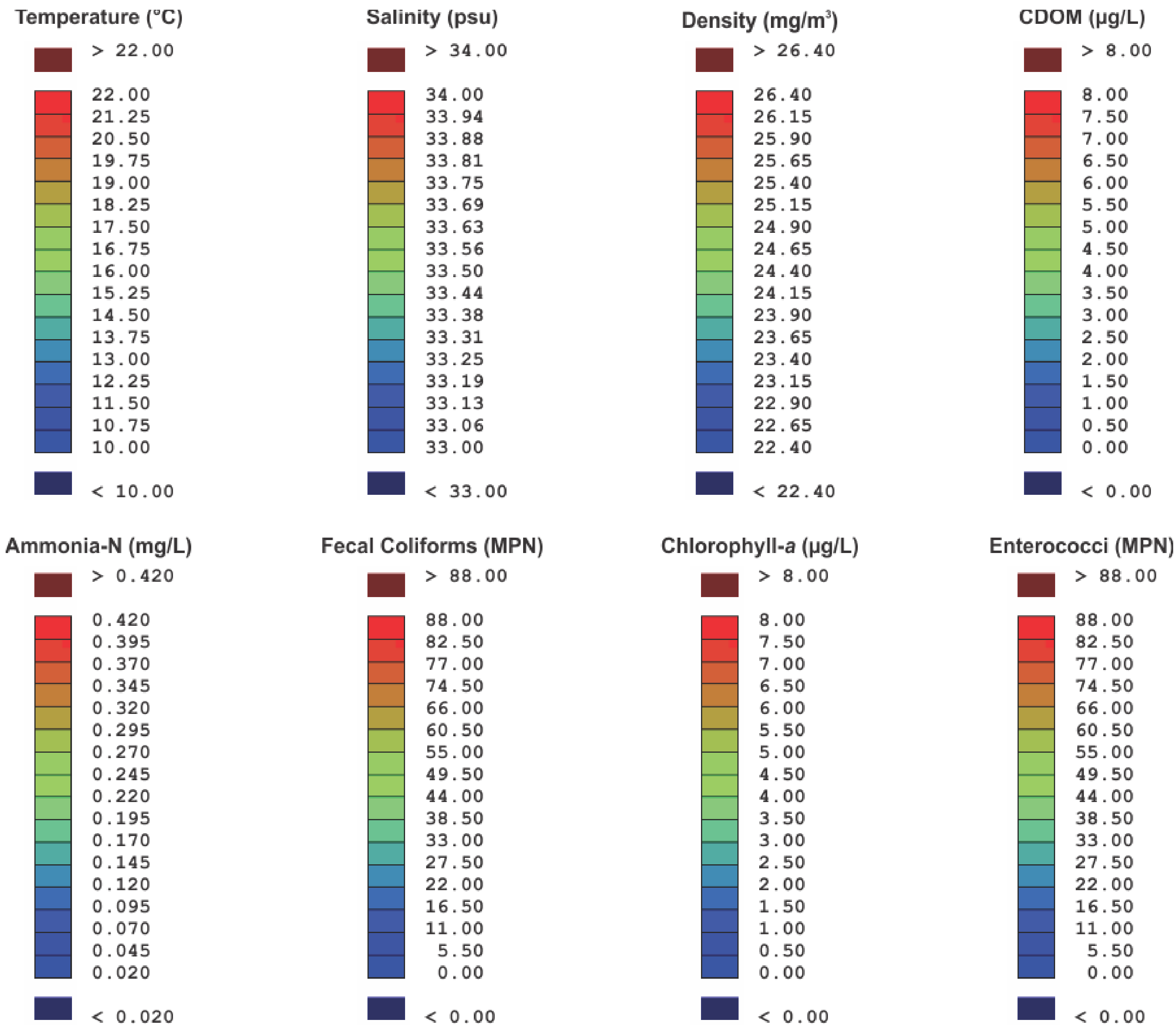

downcasts02-Oct-2012
depth m
Temp degC
Salinity psu
Beam trans m-1
CDOM QSDE ppb
Sigma-T kg m-3

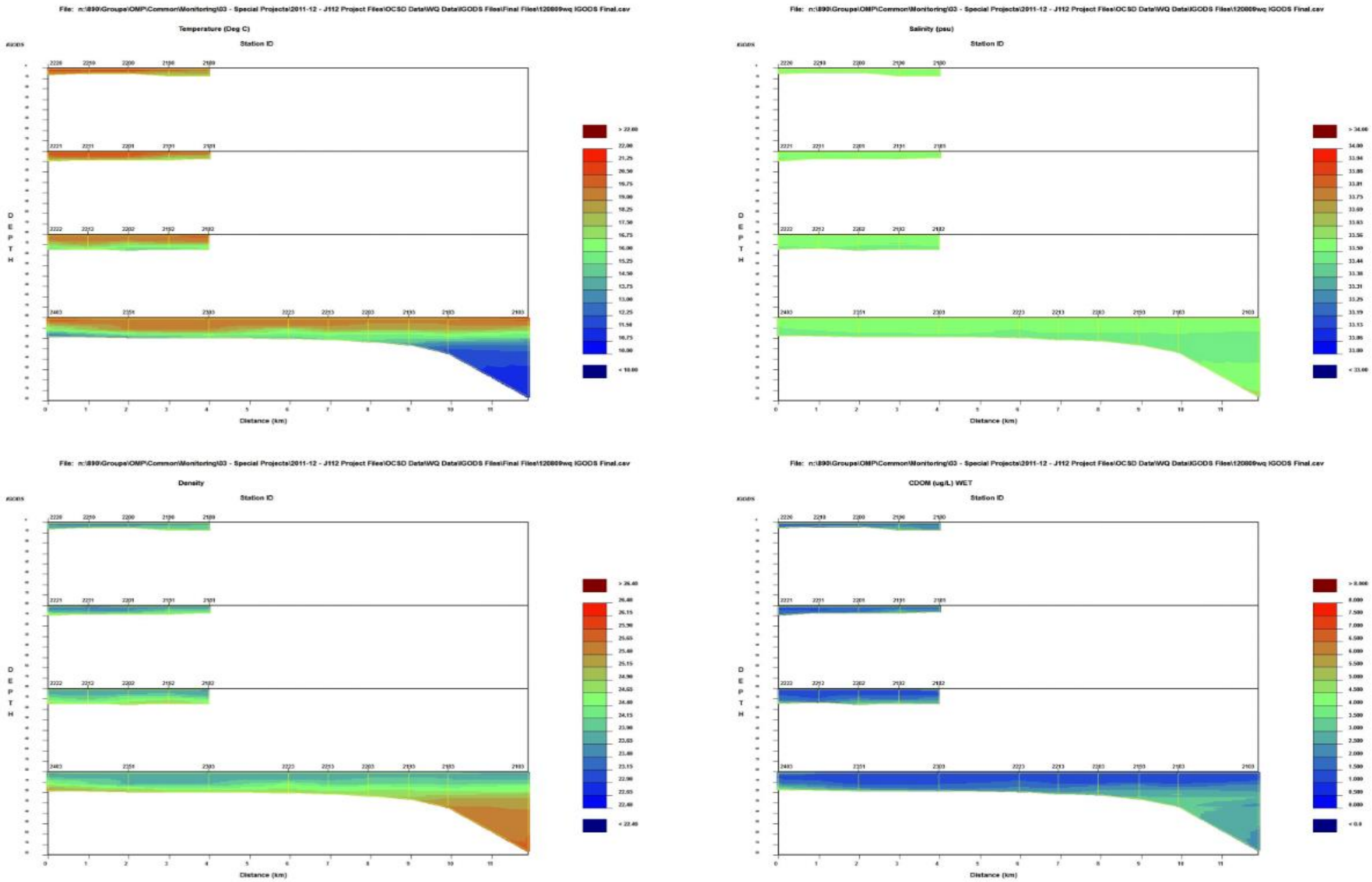

downcasts09-Oct-2012
depth m
Temp degC
Salinity psu
Beam trans m -1
CDOM QSDE ppb
Sigma-T kg m -3


downcasts10-Oct-2012
depth m
Temp degC
Salinity psu
Beam trans m -1
CDOM QSDE ppb
Sigma-T kg m -3

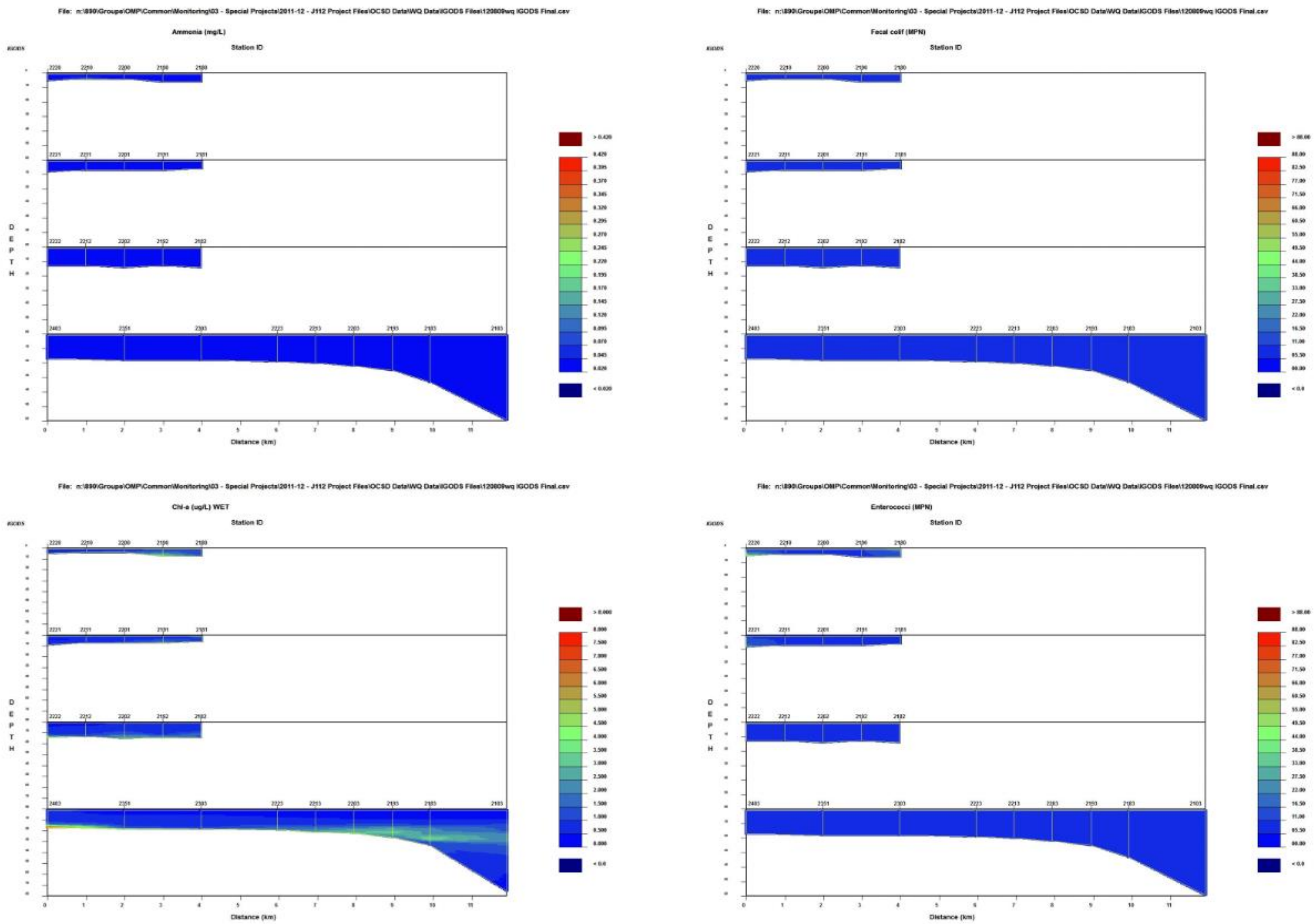
Appendix V – OCSD Data Figures, George Robertson

Water quality scales for temperature, salinity, density, CDOM, Ammonia-N), fecal coliforms), chlorophyll-*a*, and enterococci.

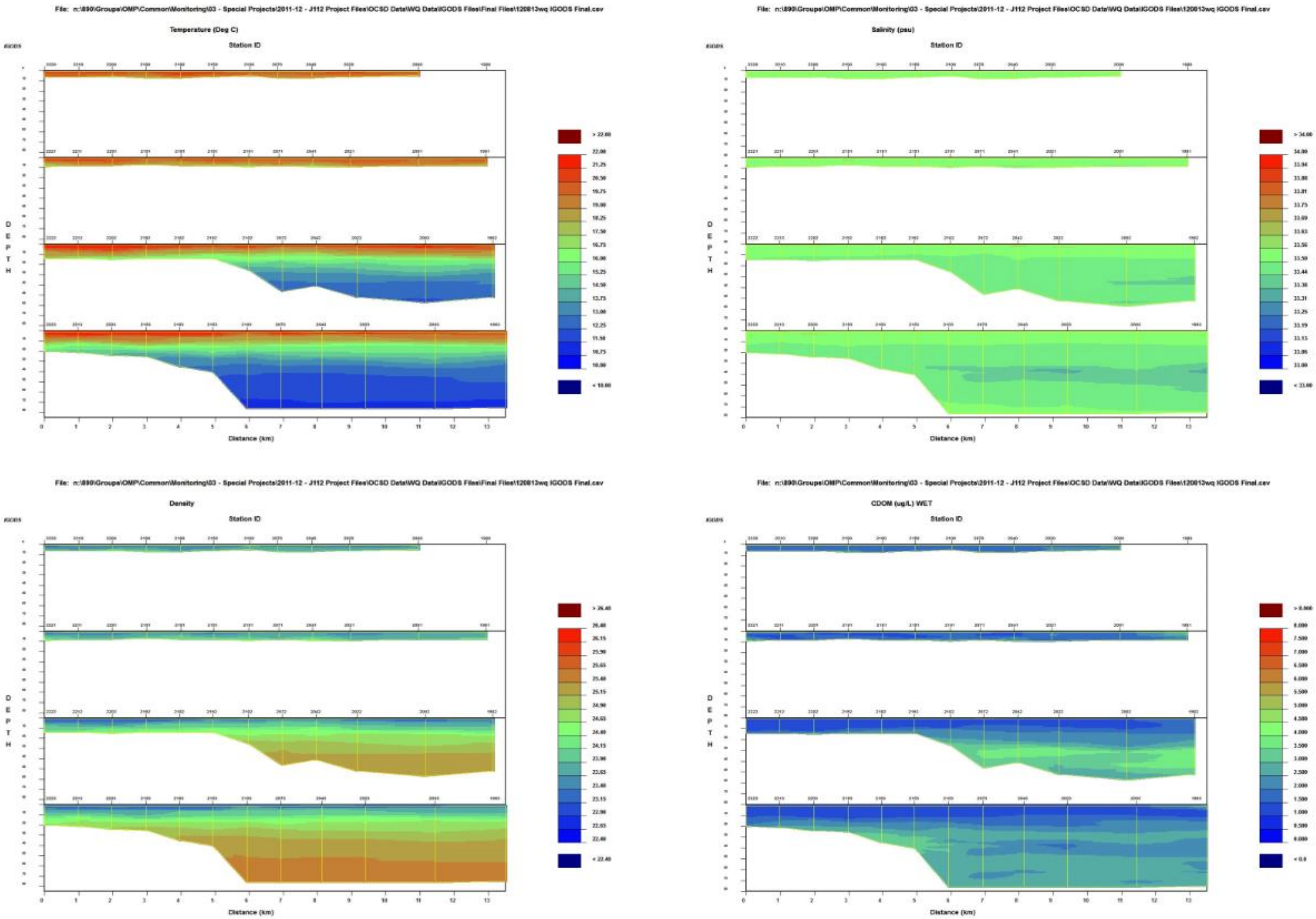




Temperature (top left), salinity (top right), density (bottom left), and CDOM (bottom right) on August 8, 2012.



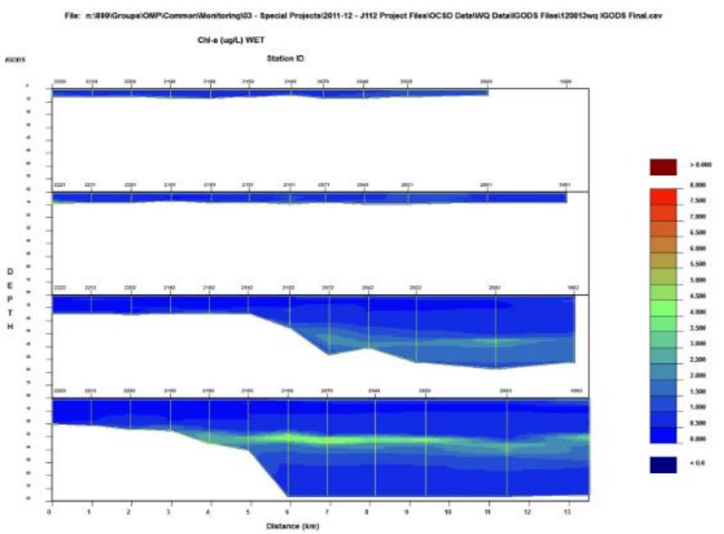
Ammonia-N (top left), fecal coliforms (top right), chlorophyll-*a* (bottom left), and enterococci (bottom right) on August 8, 2012.



Temperature (top left), salinity (top right), density (bottom left), and CDOM (bottom right) on August 13, 2012.

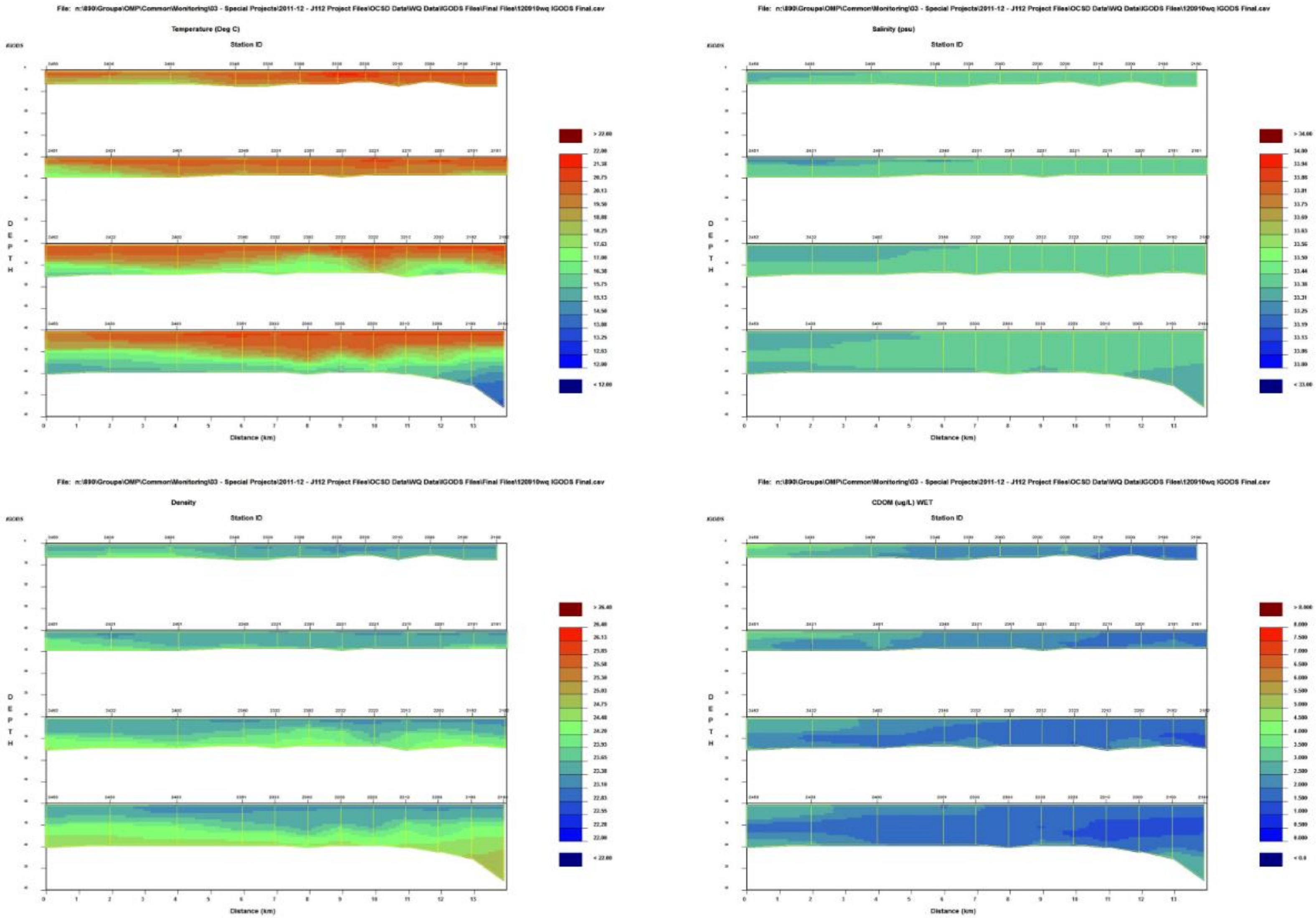
NO DATA

NO DATA

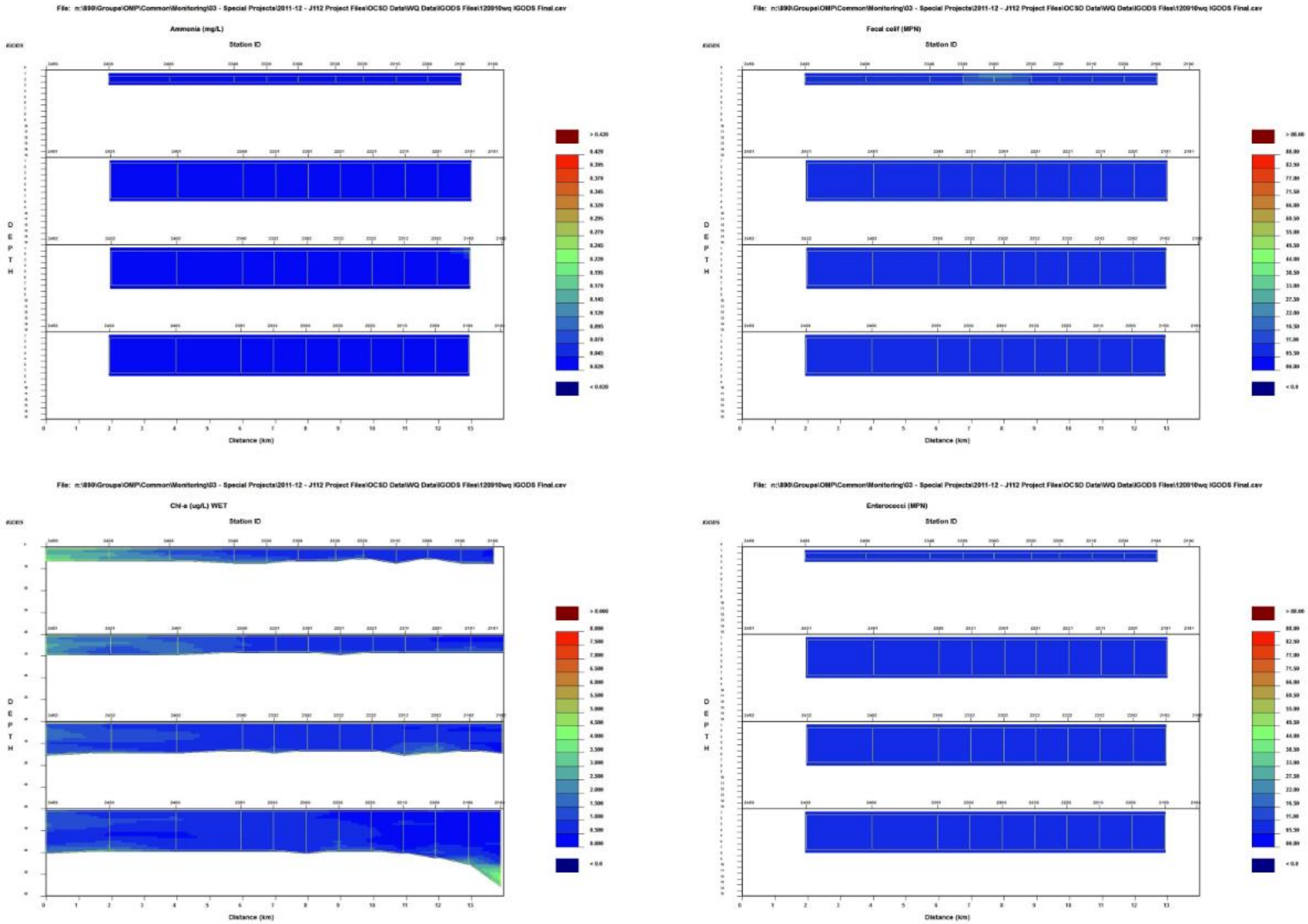


NO DATA

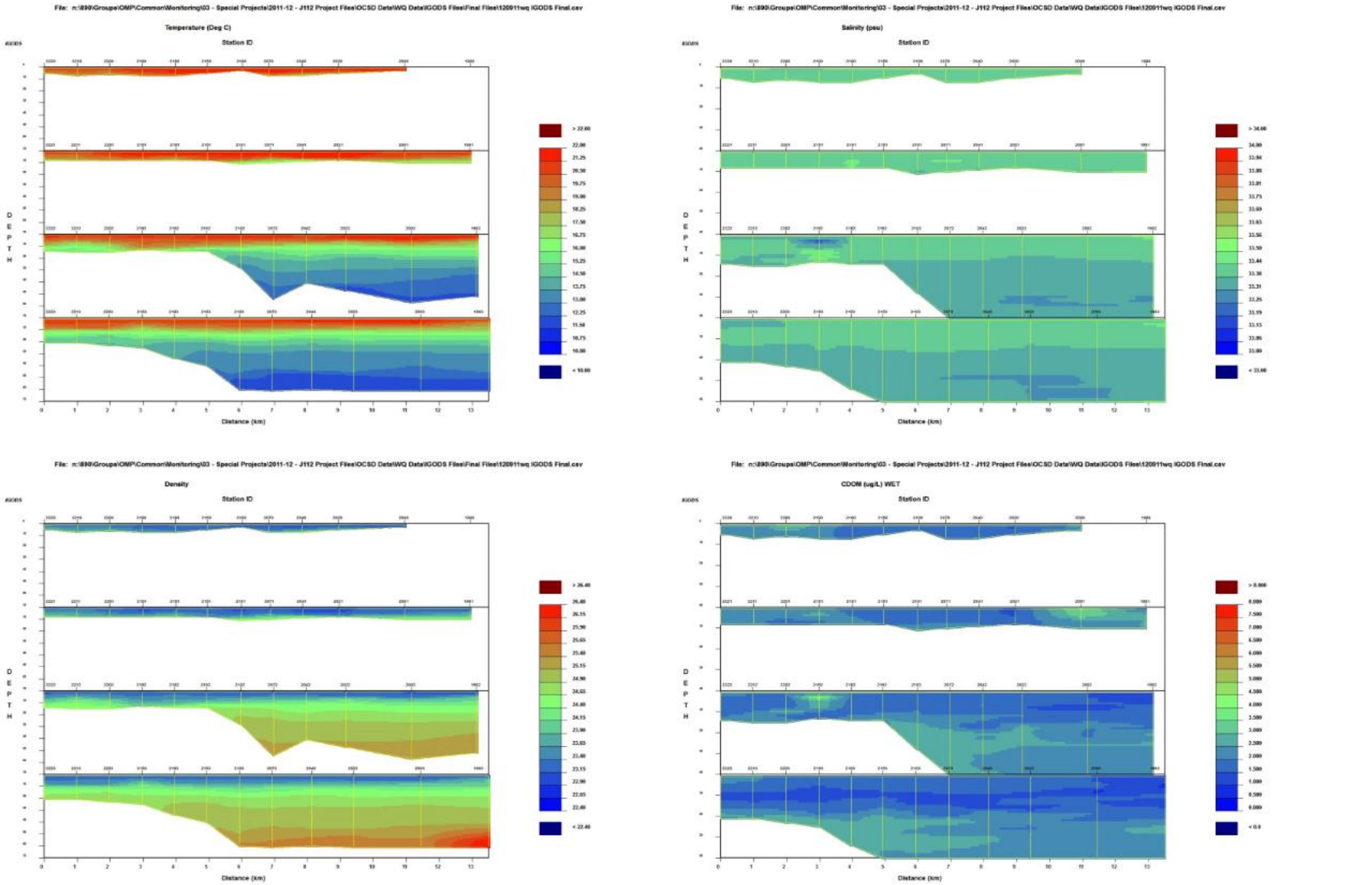
Ammonia-N (top left), fecal coliforms (top right), chlorophyll-*a* (bottom left), and enterococci (bottom right) on August 13, 2012.



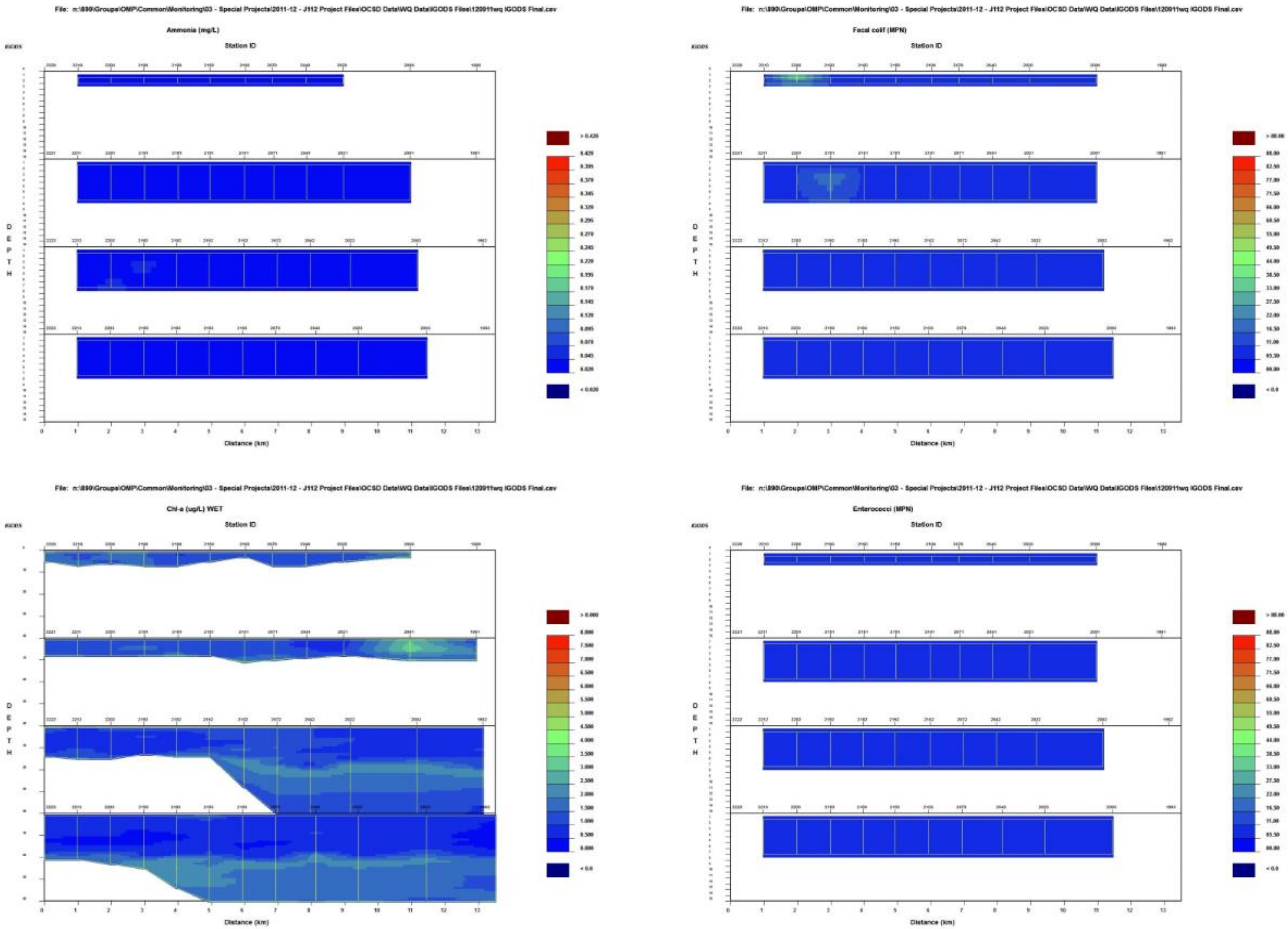
Temperature (top left), salinity (top right), density (bottom left), and CDOM (bottom right) on September 10, 2012.



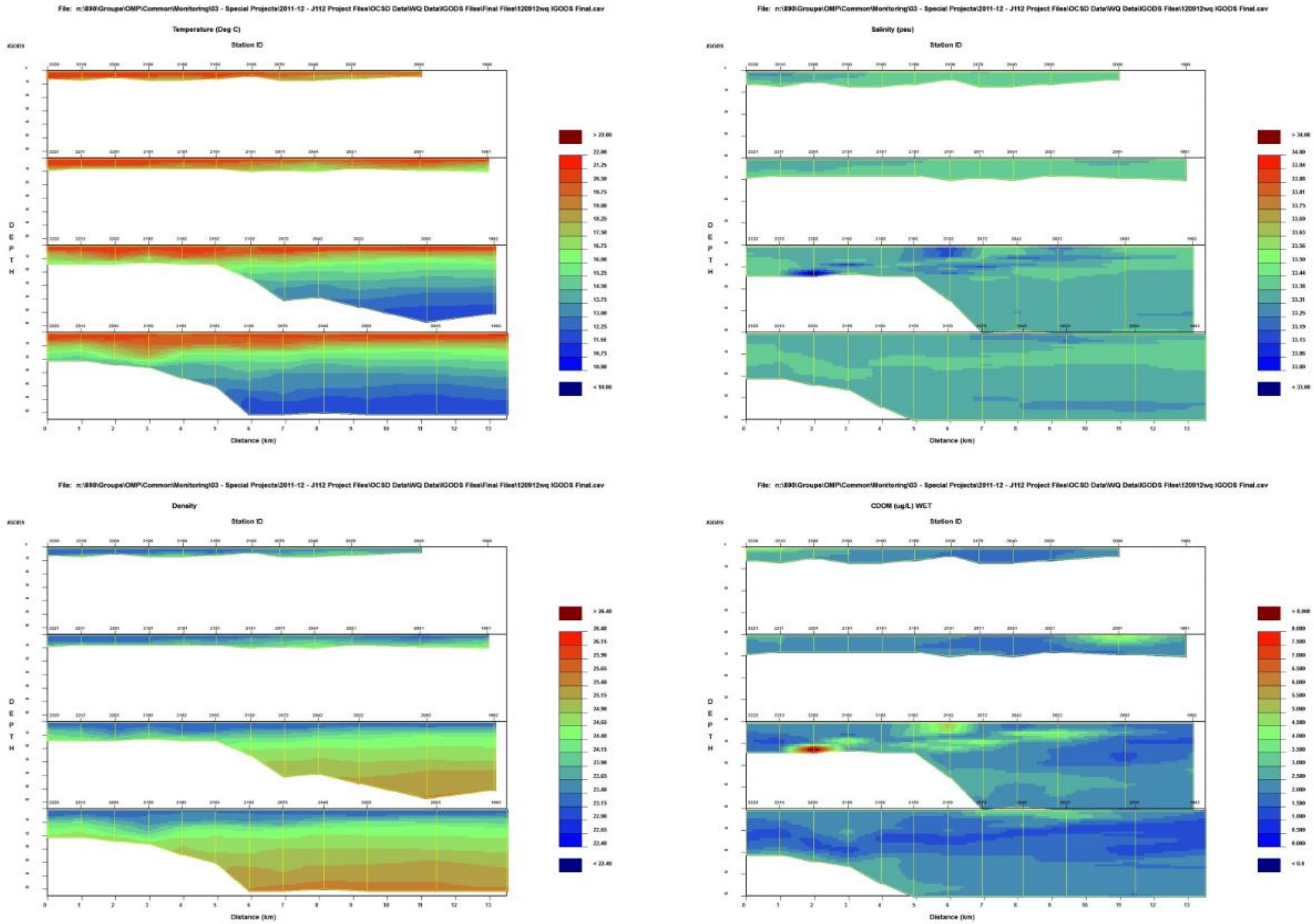
Ammonia-N (top left), fecal coliforms (top right), chlorophyll-*a* (bottom left), and enterococci (bottom right) on September on 10, 2012.



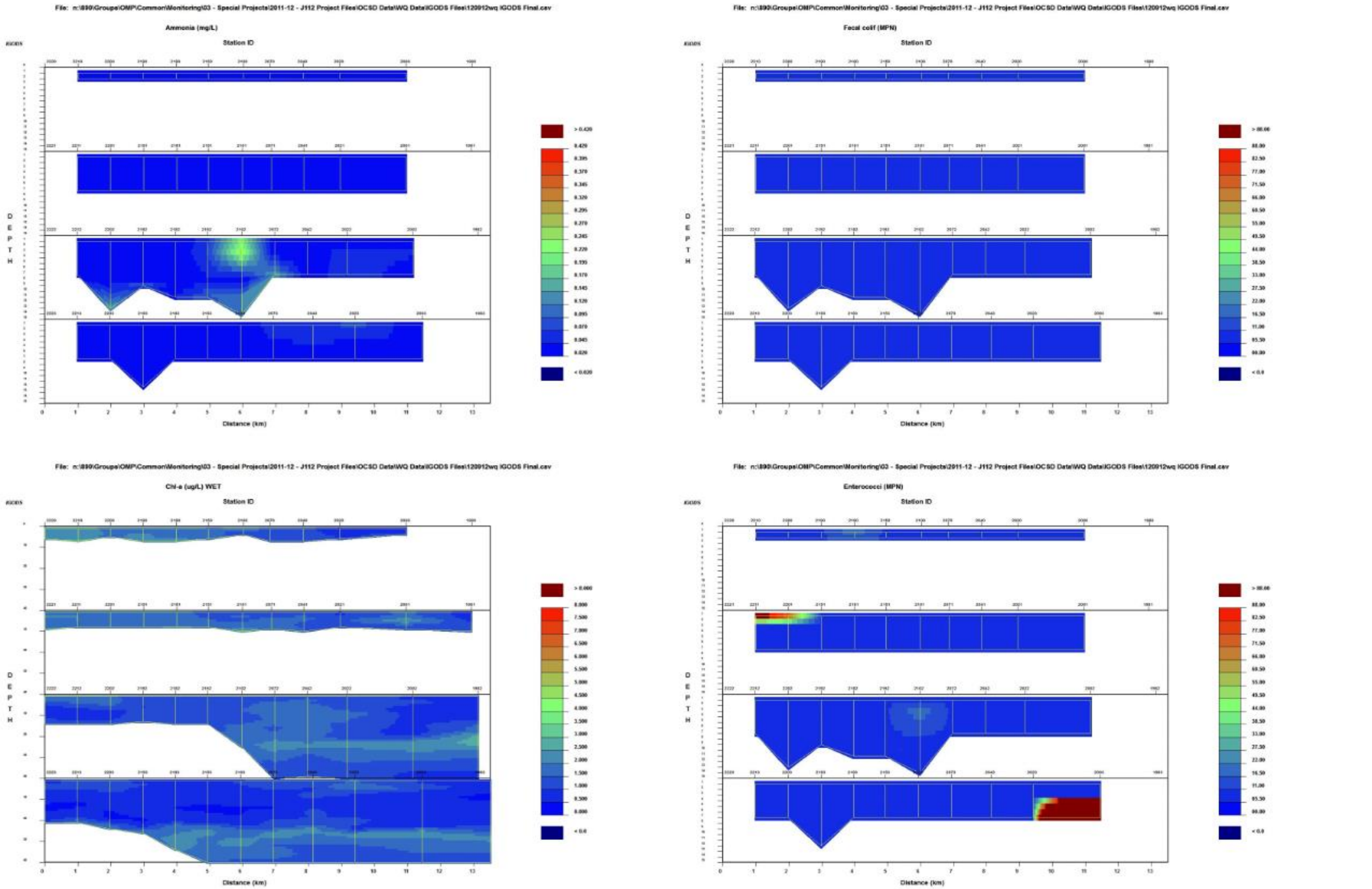
Temperature (top left), salinity (top right), density (bottom left), and CDOM (bottom right) on September 11, 2012.



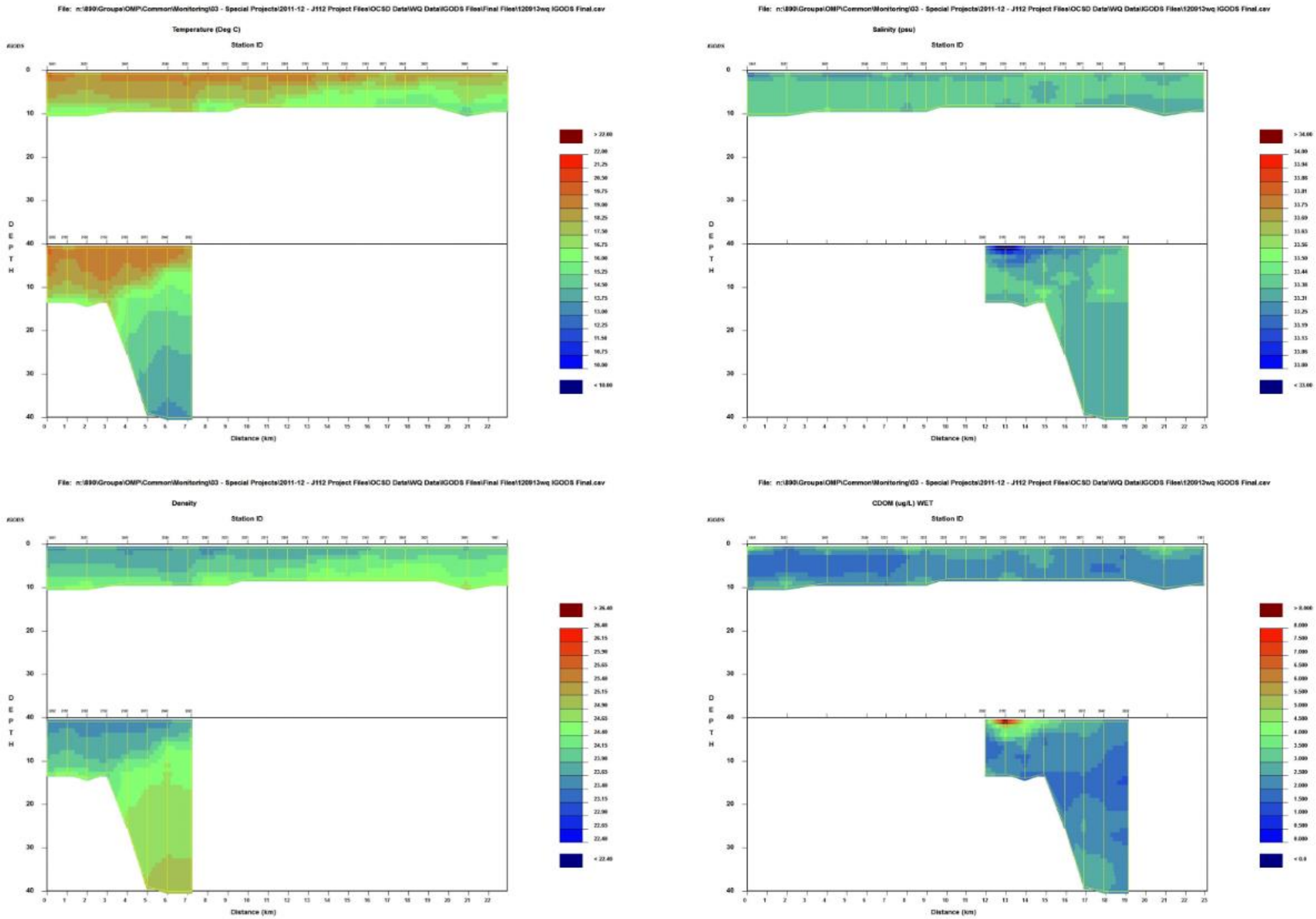
Ammonia-N (top left), fecal coliforms (top right), chlorophyll-*a* (bottom left), and enterococci (bottom right) on September 11, 2012.



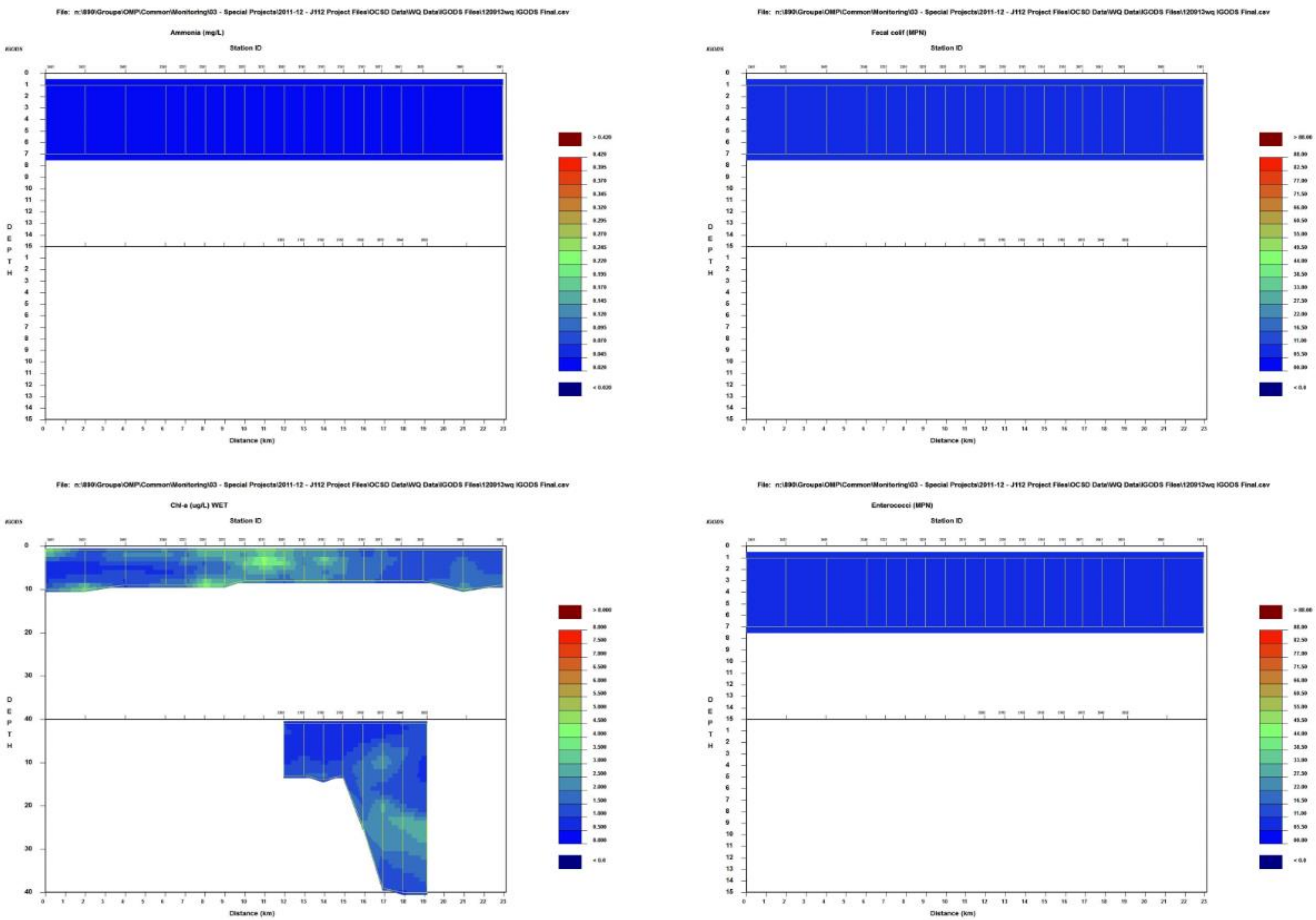
Temperature (top left), salinity (top right), density (bottom left), and CDOM (bottom right) on September 12, 2012.



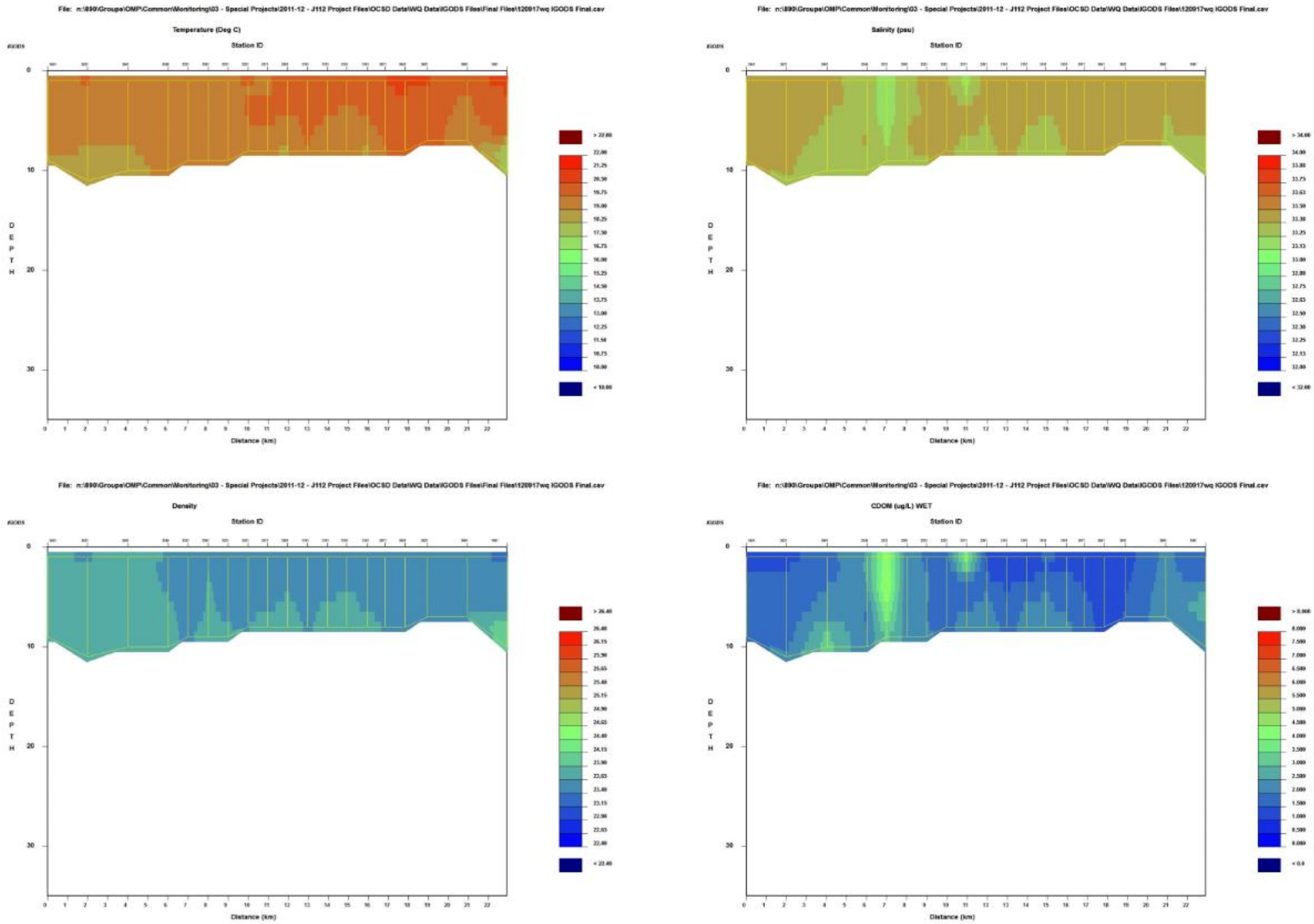
Ammonia-N (top left), fecal coliforms (top right), chlorophyll-*a* (bottom left), and enterococci (bottom right) on September 12, 2012.



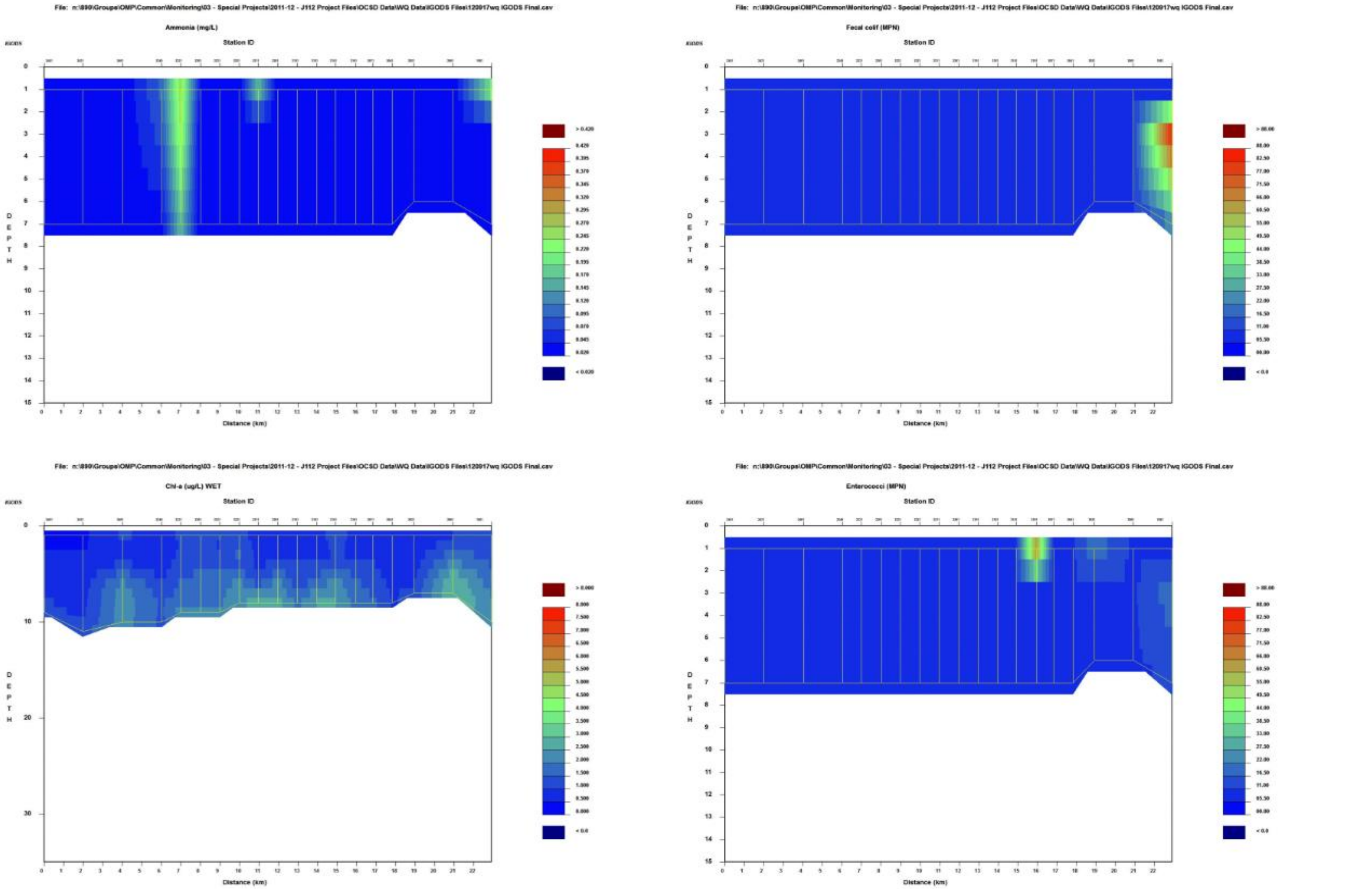
Temperature (top left), salinity (top right), density (bottom left), and CDOM (bottom right) on September 13, 2012.



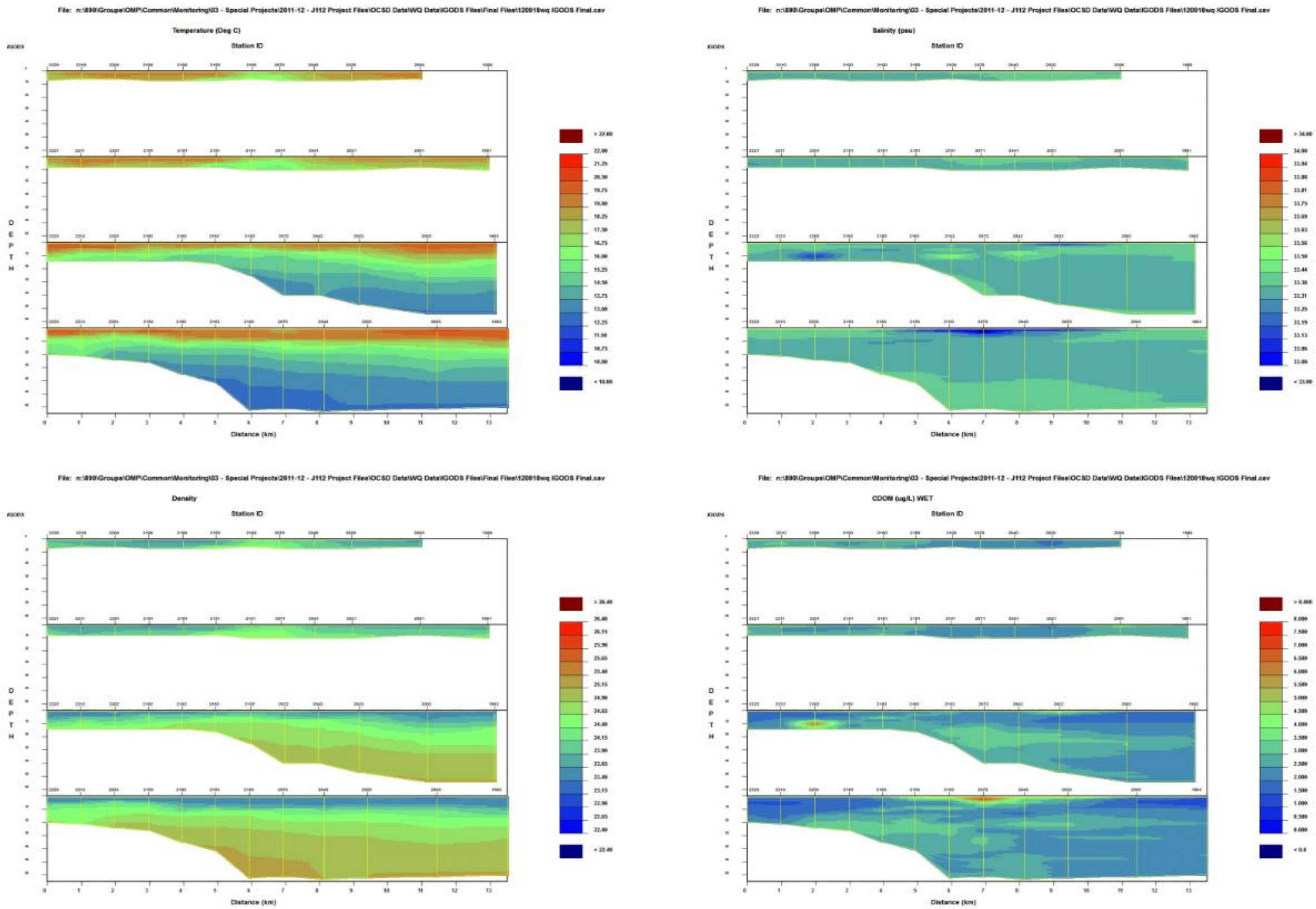
Ammonia-N (top left), fecal coliforms (top right), chlorophyll-*a* (bottom left), and enterococci (bottom right) on September 13, 2012.



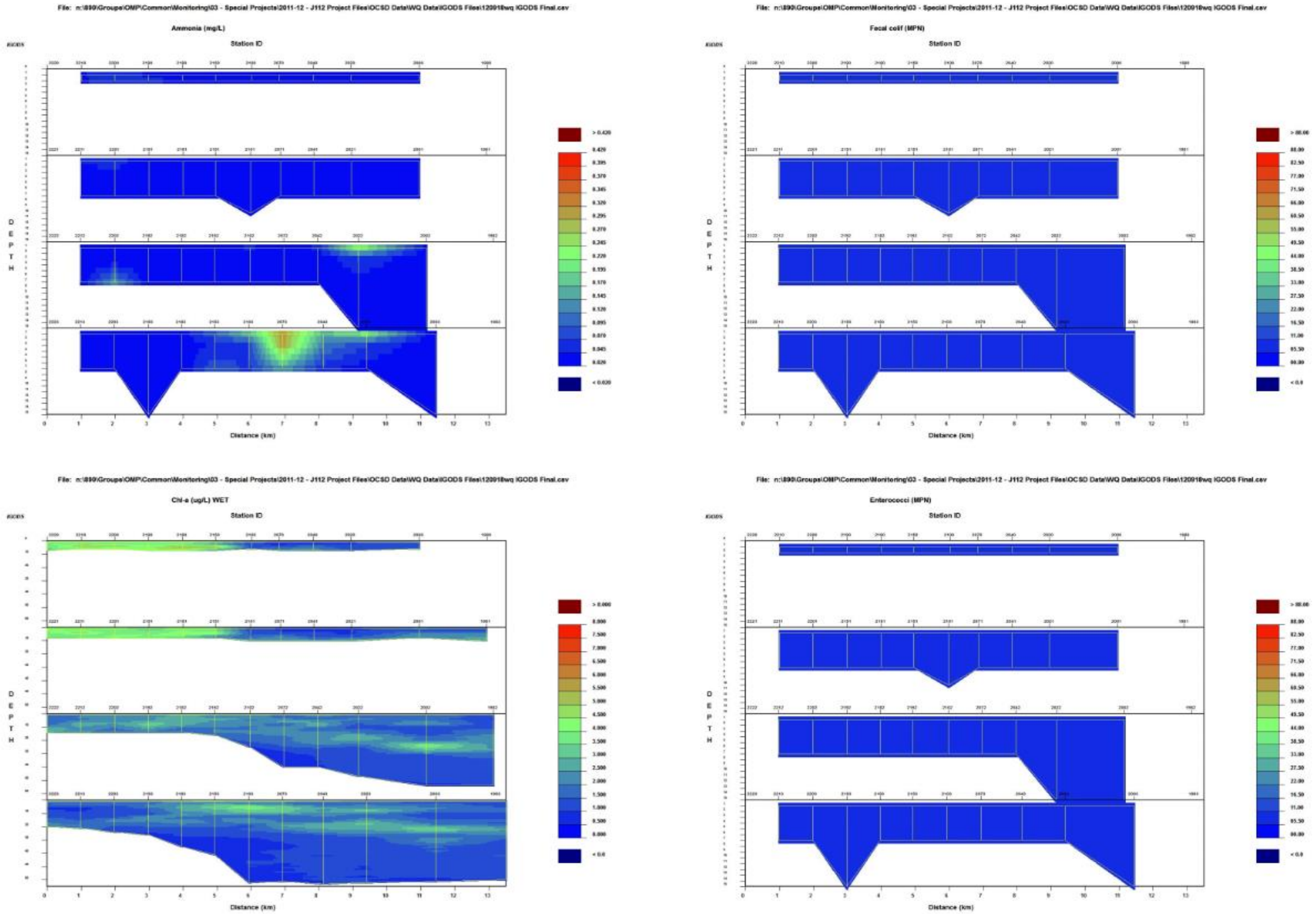
Temperature (top left), salinity (top right), density (bottom left), and CDOM (bottom right) on September 17, 2012.



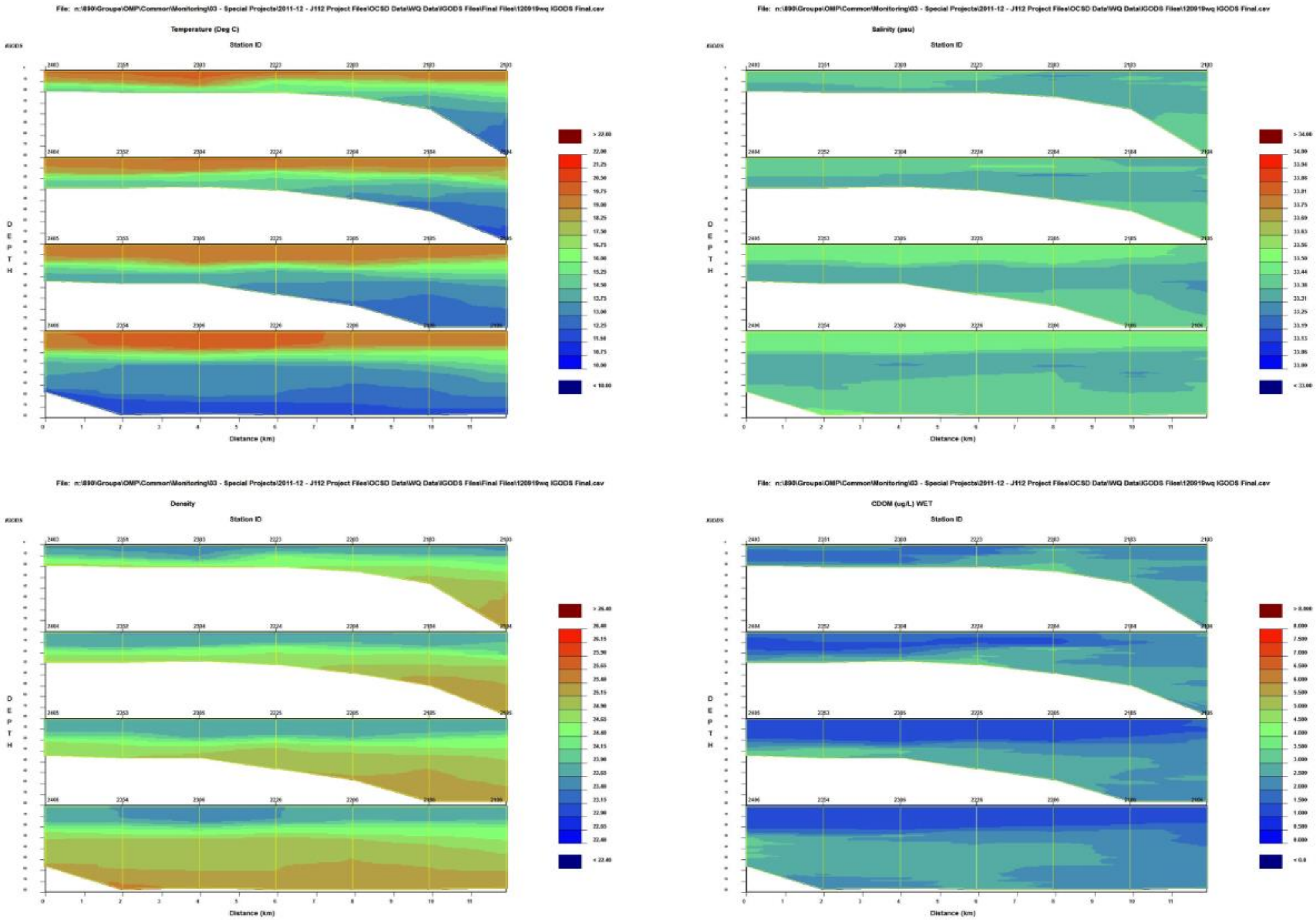
Ammonia-N (top left), fecal coliforms (top right), chlorophyll-*a* (bottom left), and enterococci (bottom right) on September 17, 2012.



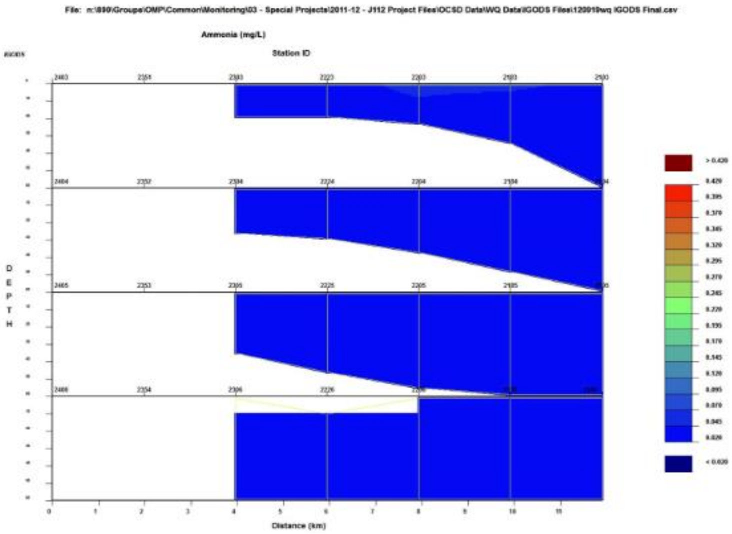
Temperature (top left), salinity (top right), density (bottom left), and CDOM (bottom right) on September 18, 2012.



Ammonia-N (top left), fecal coliforms (top right), chlorophyll-*a* (bottom left), and enterococci (bottom right) on September 18, 2012.



Temperature (top left), salinity (top right), density (bottom left), and CDOM (bottom right) on September 19, 2012.



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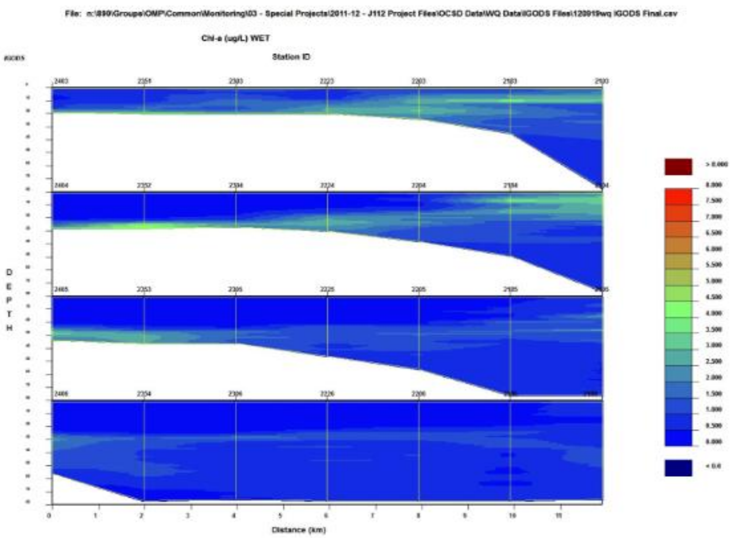

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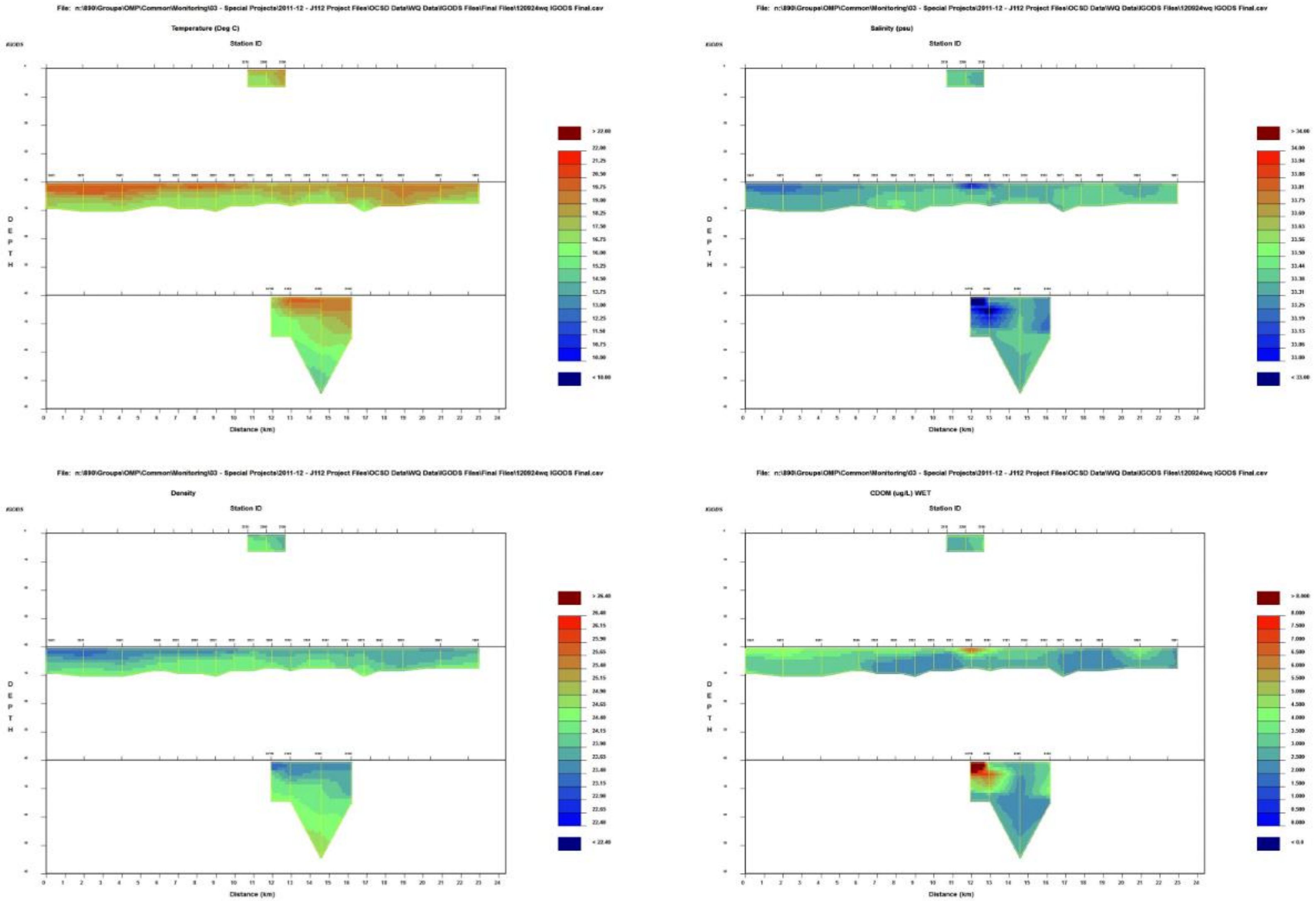
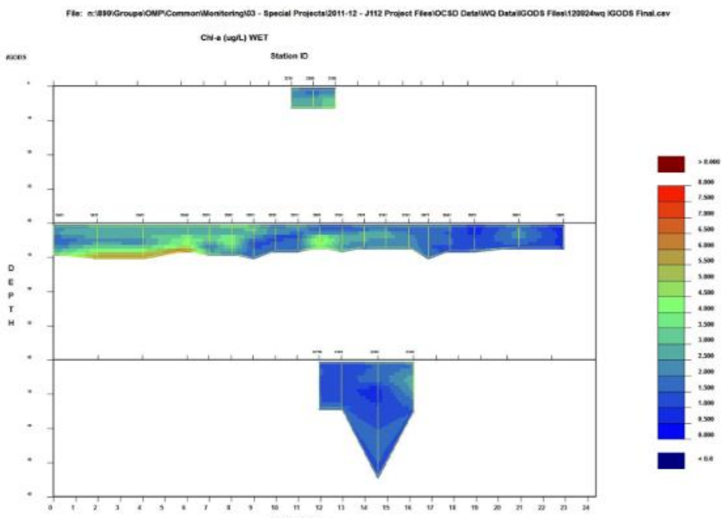
Ammonia-N (top left), fecal coliforms (top right), chlorophyll-*a* (bottom left), and enterococci (bottom right) on September 19, 2012.



Temperature (top left), salinity (top right), density (bottom left), and CDOM (bottom right) on September 24, 2012.

NO DATA

NO DATA



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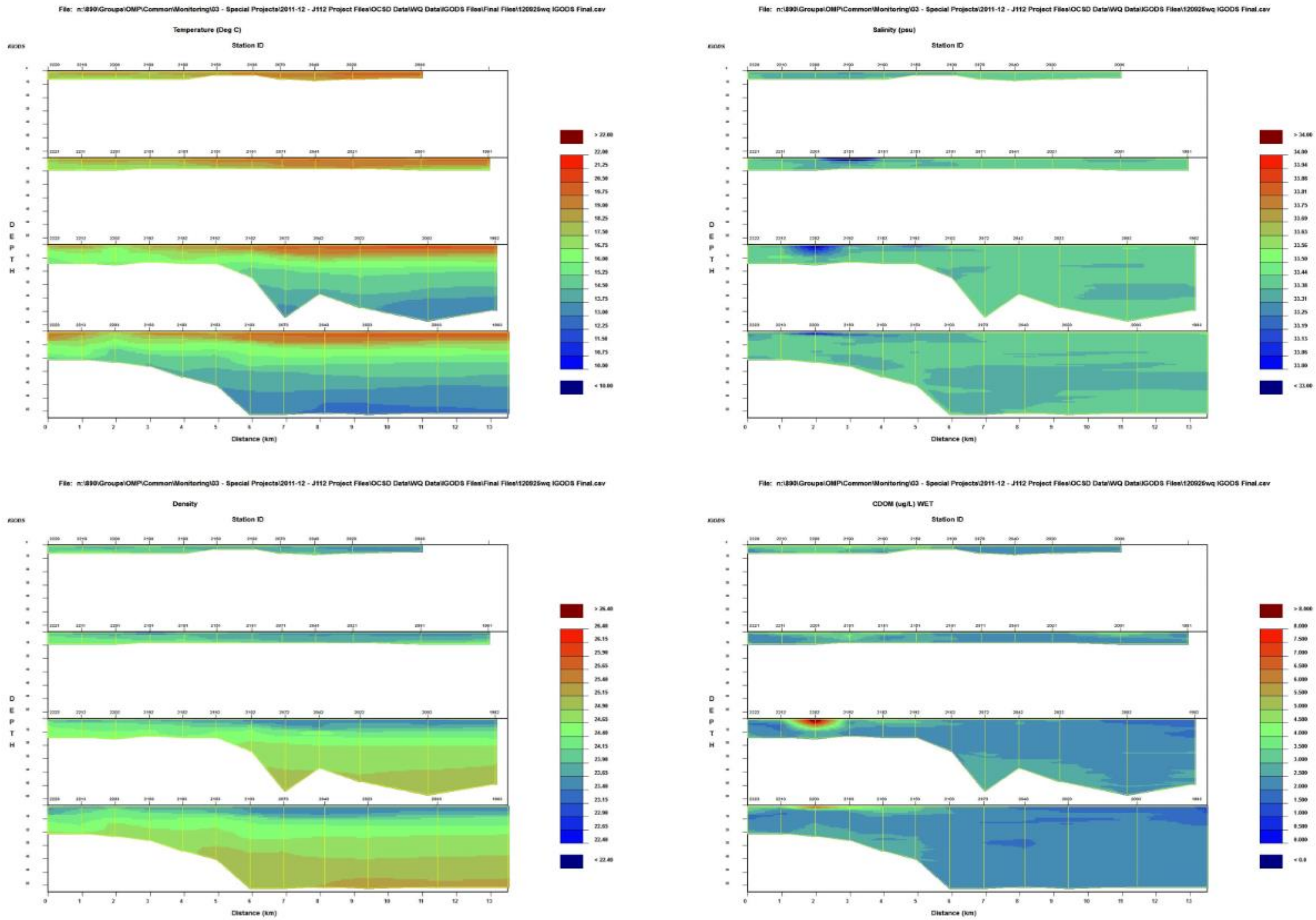
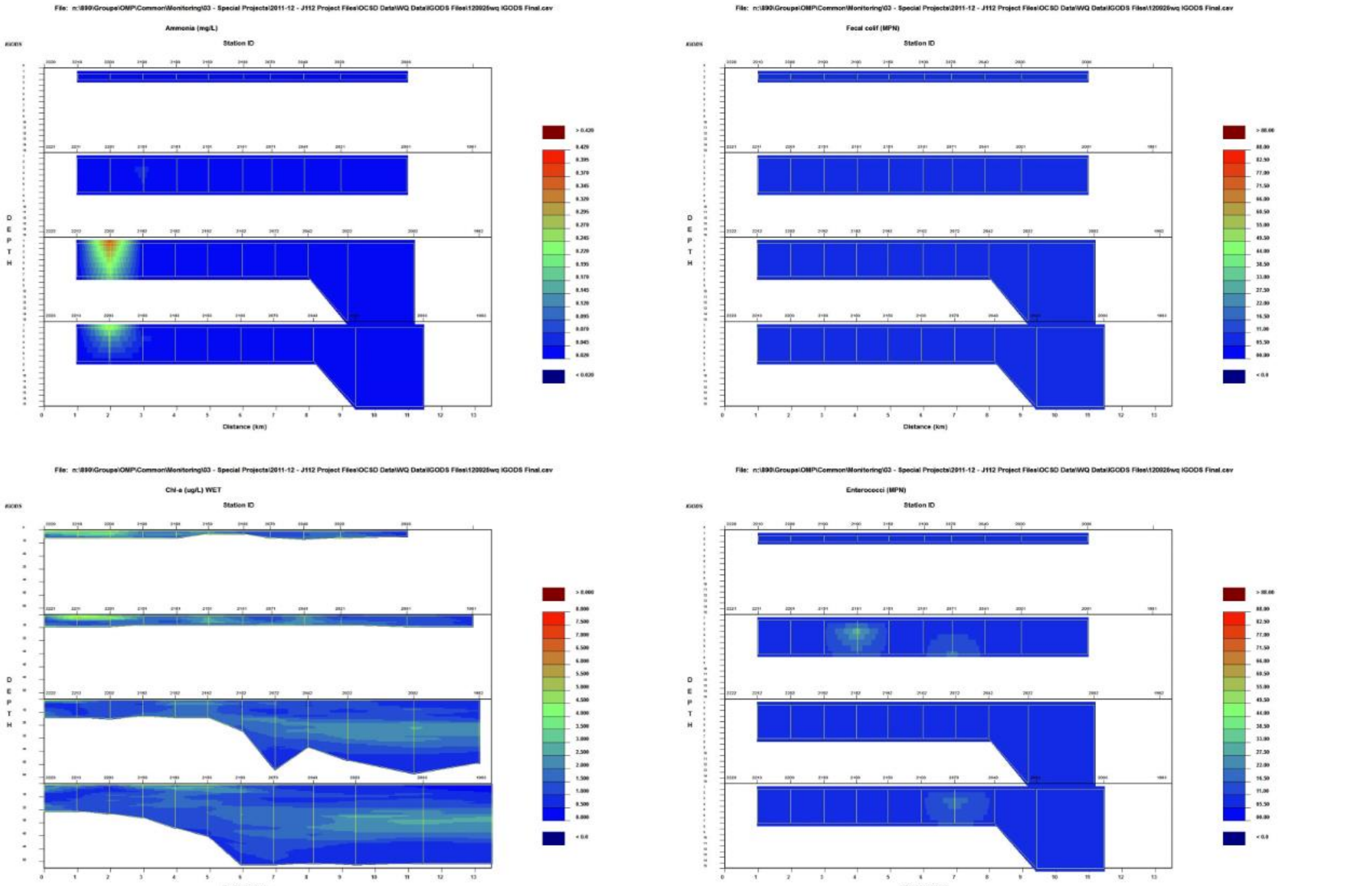
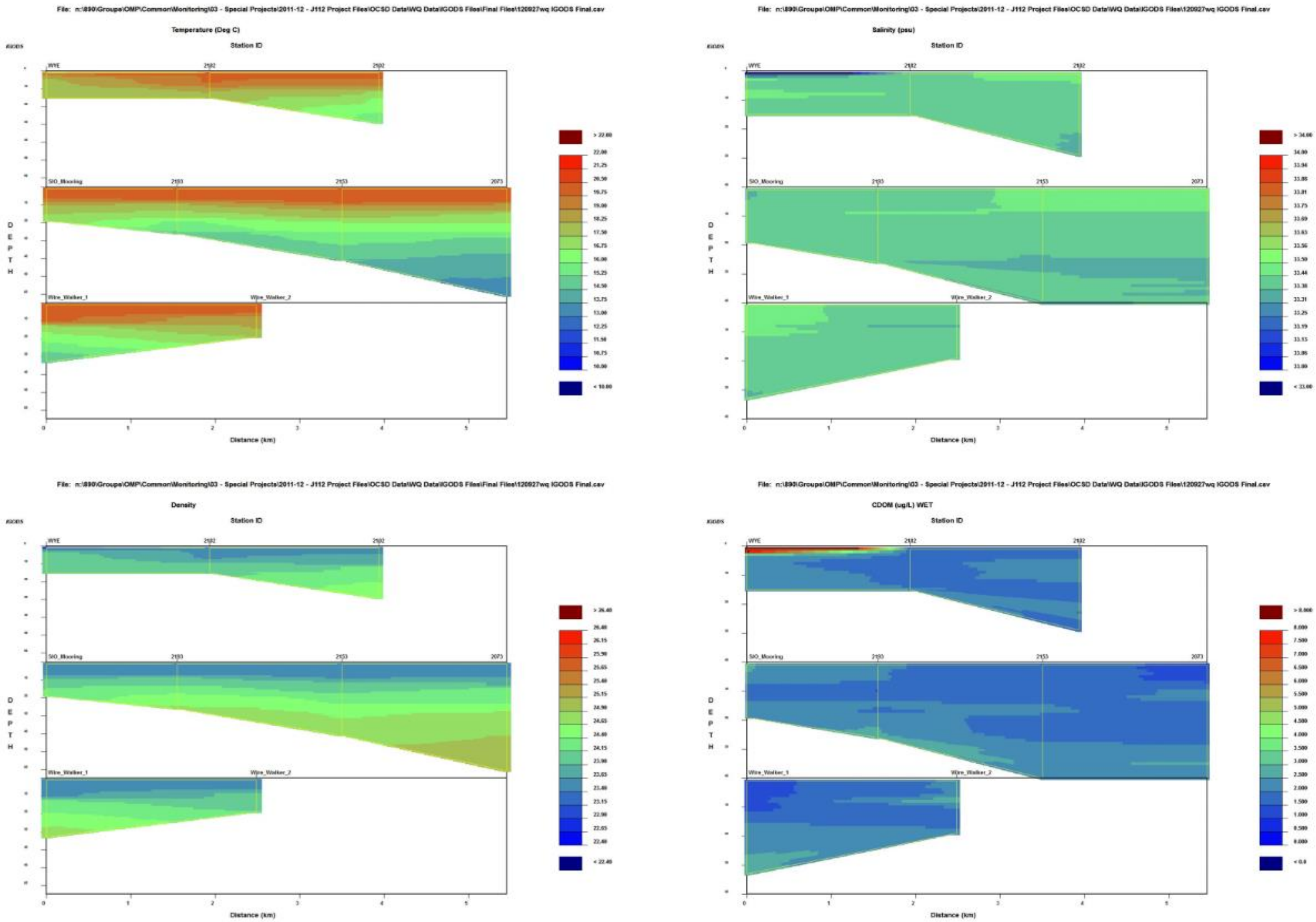
Ammonia-N (top left), fecal coliforms (top right), chlorophyll-*a* (bottom left), and enterococci (bottom right) on September 24, 2012.



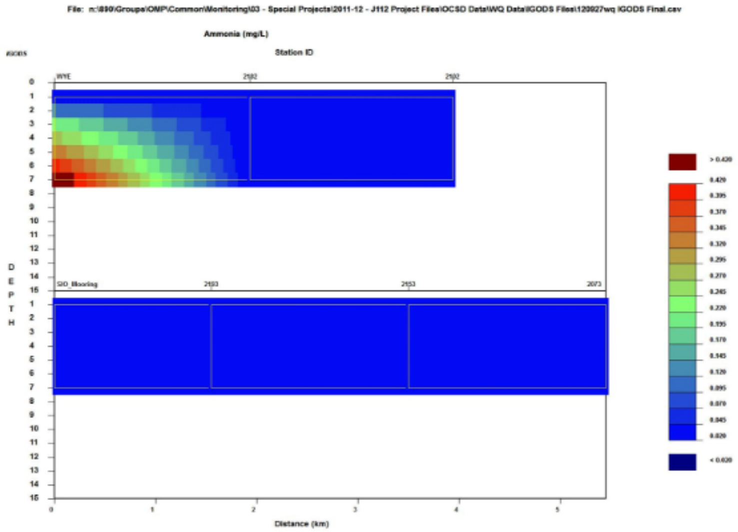
Temperature (top left), salinity (top right), density (bottom left), and CDOM (bottom right) on September 25, 2012.



Ammonia-N (top left), fecal coliforms (top right), chlorophyll-*a* (bottom left), and enterococci (bottom right) on September 25, 2012.



Temperature (top left), salinity (top right), density (bottom left), and CDOM (bottom right) on September 27, 2012.



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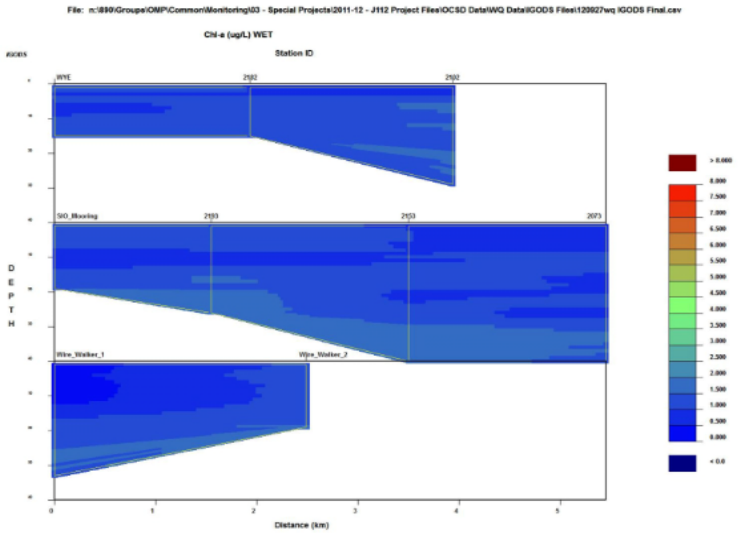
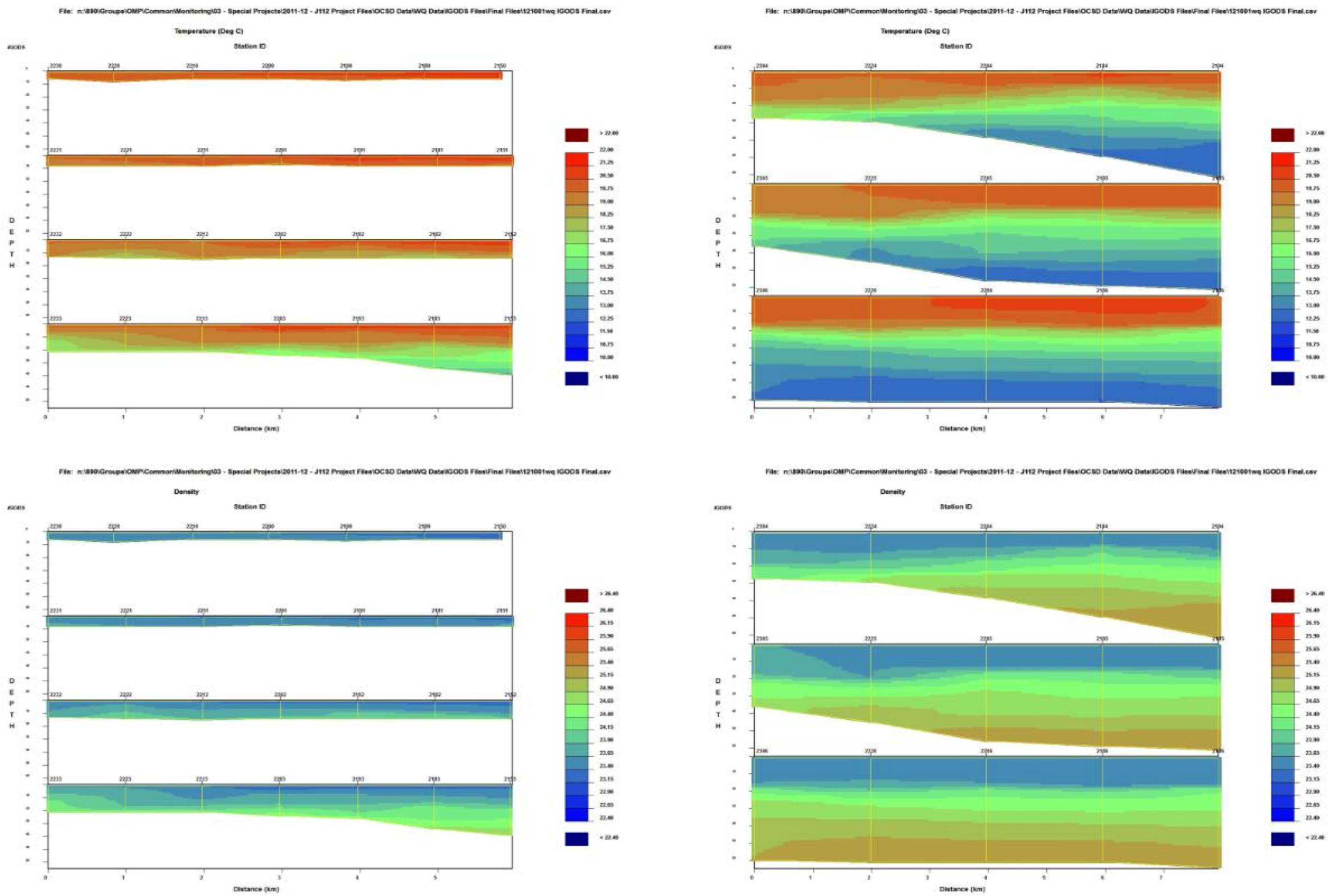
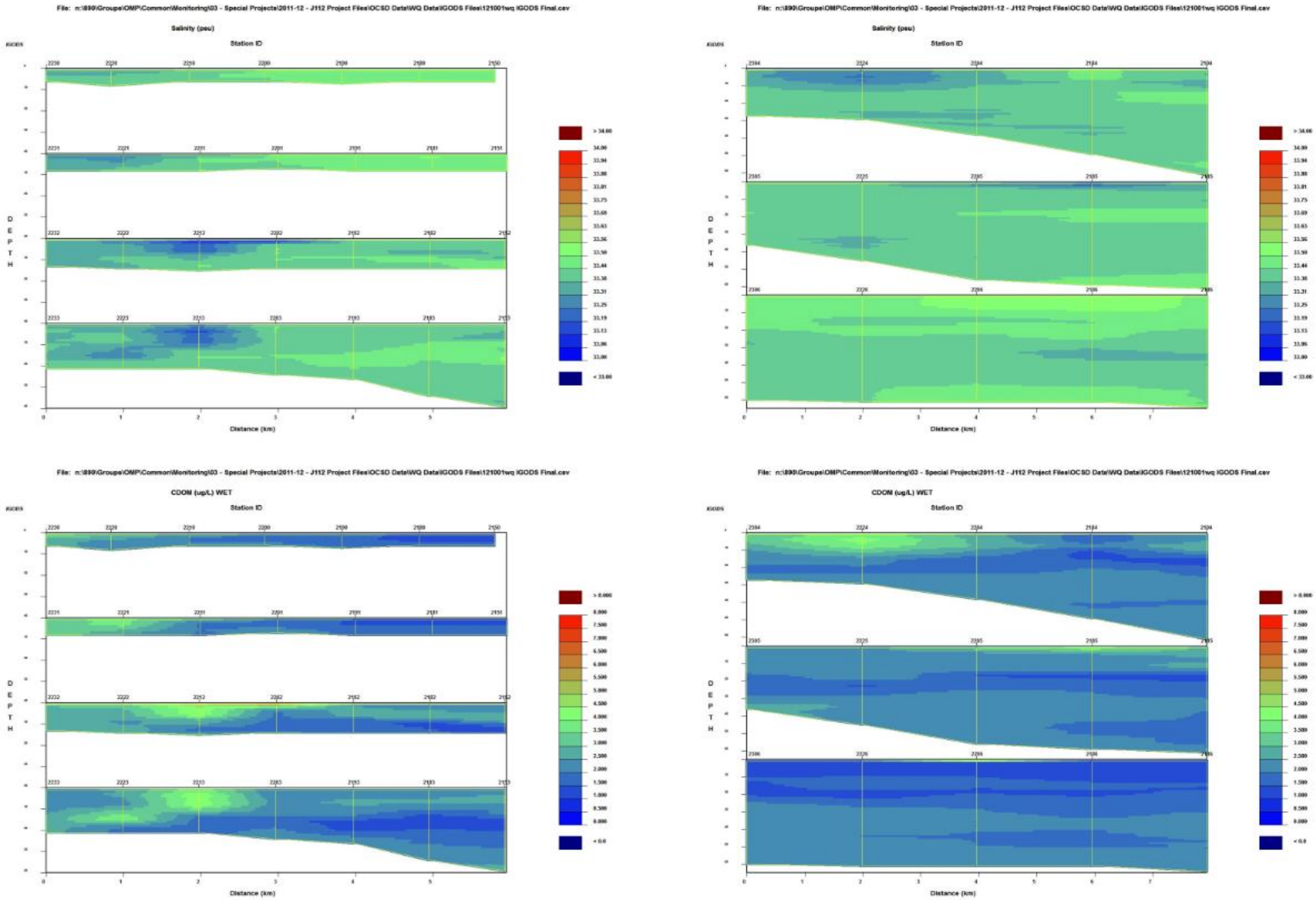


NO DATA

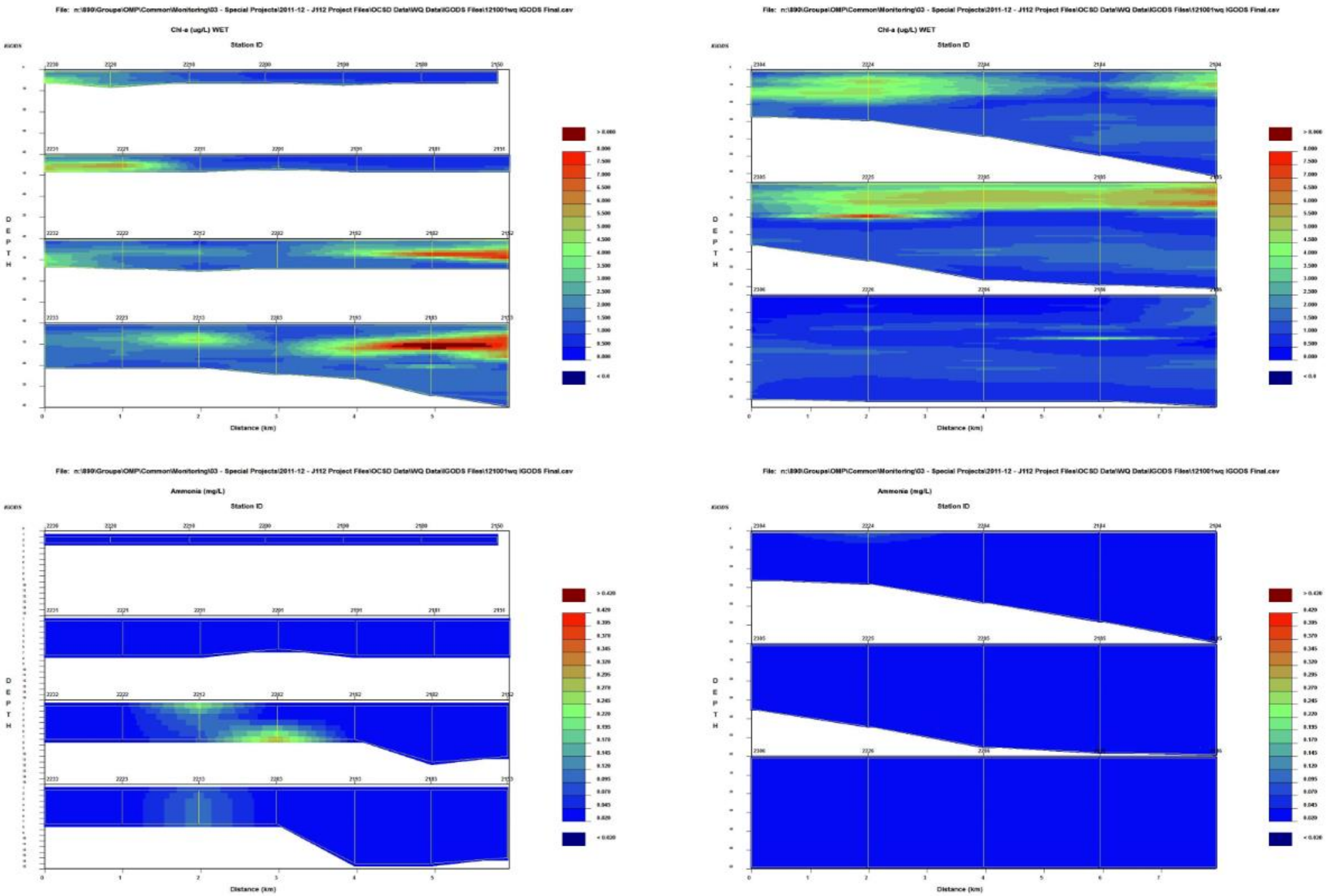
Ammonia-N (top left), fecal coliforms (top right), chlorophyll-*a* (bottom left), and enterococci (bottom right) on September 27, 2012.



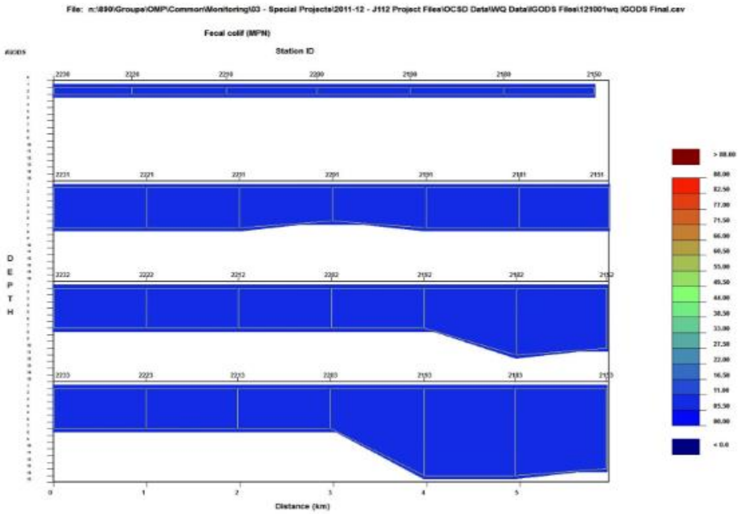
Temperature-inshore (top left), temperature-offshore (top right), density-inshore (bottom left), and density-offshore (bottom right) on October 1, 2012



Salinity-inshore (top left), salinity-offshore (top right), CDOM-inshore (bottom left), and CDOM-offshore (bottom right) on October 1, 2012.



Chlorophyll-*a*-inshore (top left), chlorophyll-*a* -offshore (top right), ammonia-N-inshore (bottom left), and ammonia-N-offshore (bottom right) on October 1, 2012.



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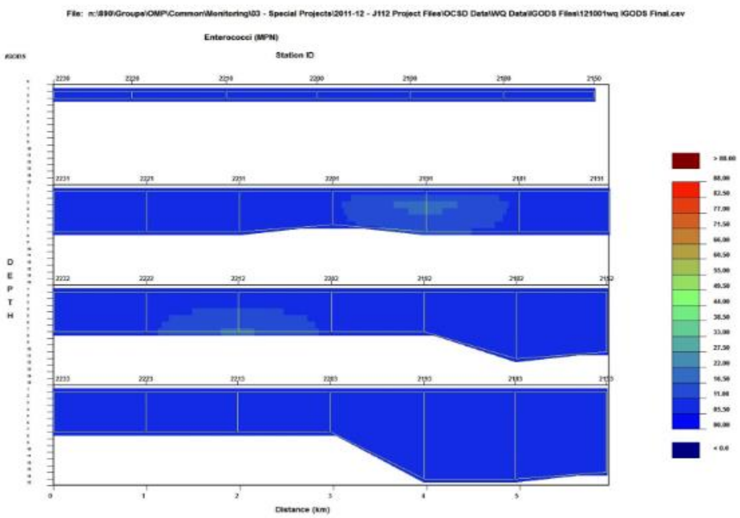
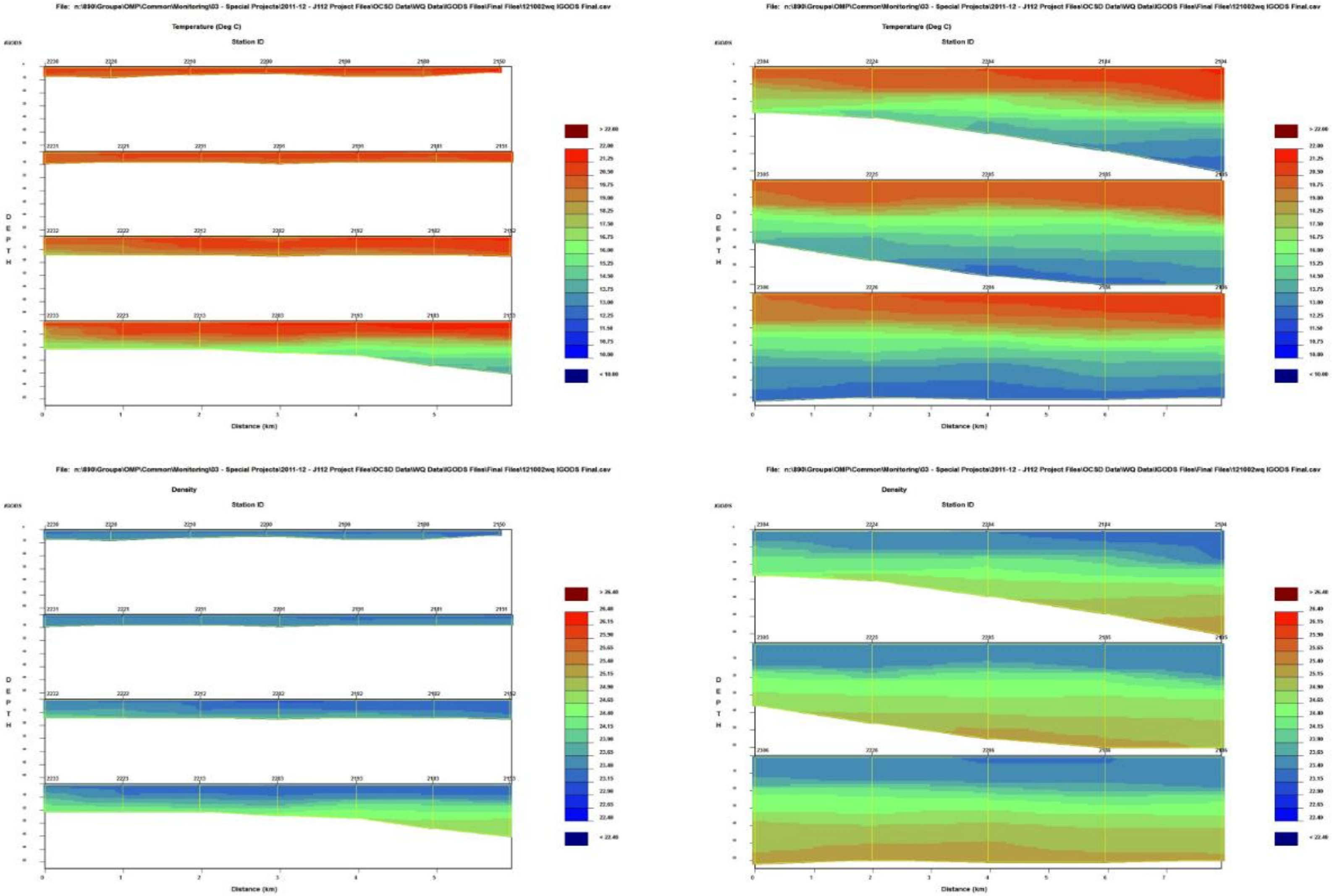
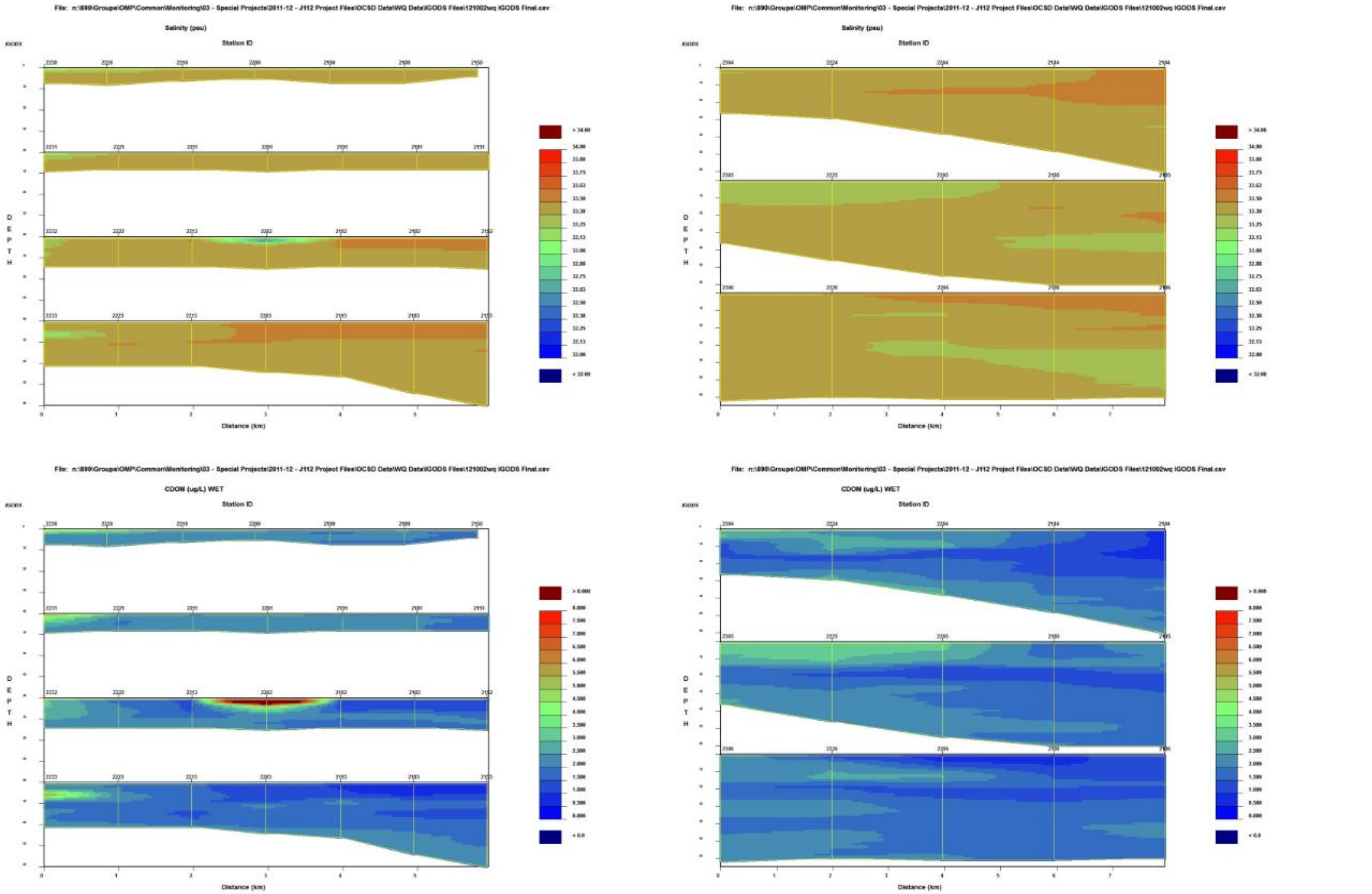


NO DATA

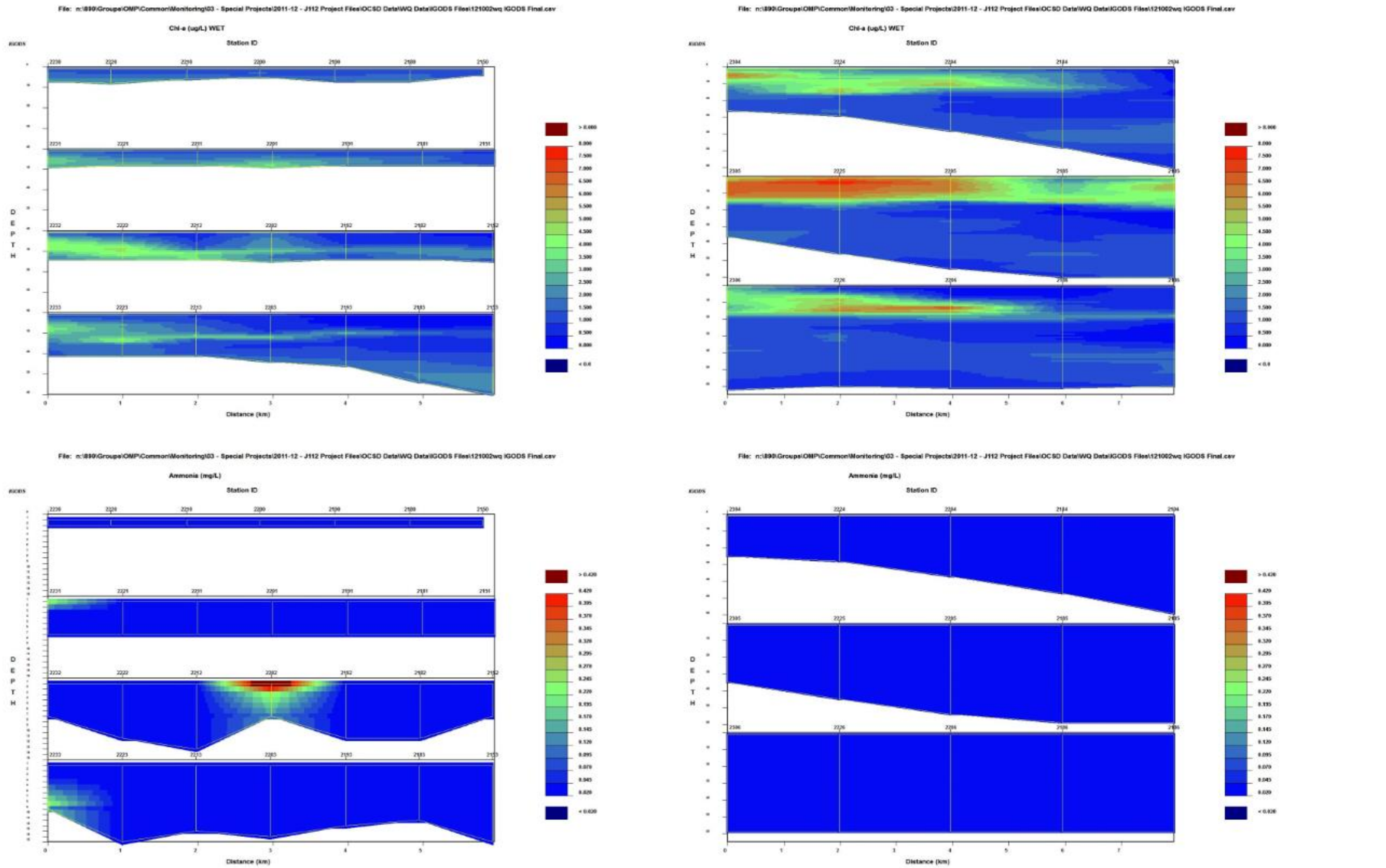
Fecal coliforms-inshore (top left), fecal coliforms-offshore (top right), enterococci-inshore (bottom left), and enterococci-offshore (bottom right) on October 1, 2012.



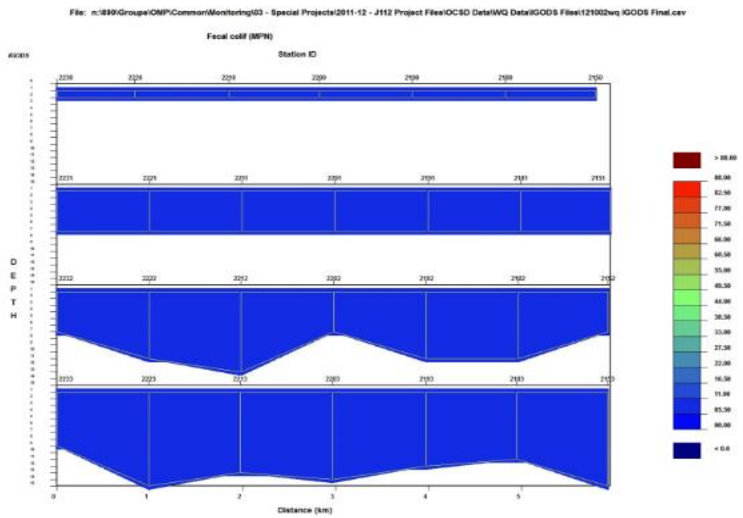
Temperature-inshore (top left), temperature-offshore (top right), density-inshore (bottom left), and density-offshore (bottom right) on October 2, 2012.



Salinity-inshore (top left), salinity-offshore (top right), CDOM-inshore (bottom left), and CDOM-offshore (bottom right) on October 2, 2012.



Chlorophyll-*a*-inshore (top left), chlorophyll-*a* -offshore (top right), ammonia-N-inshore (bottom left), and ammonia-N-offshore (bottom right) on October 2, 2012.



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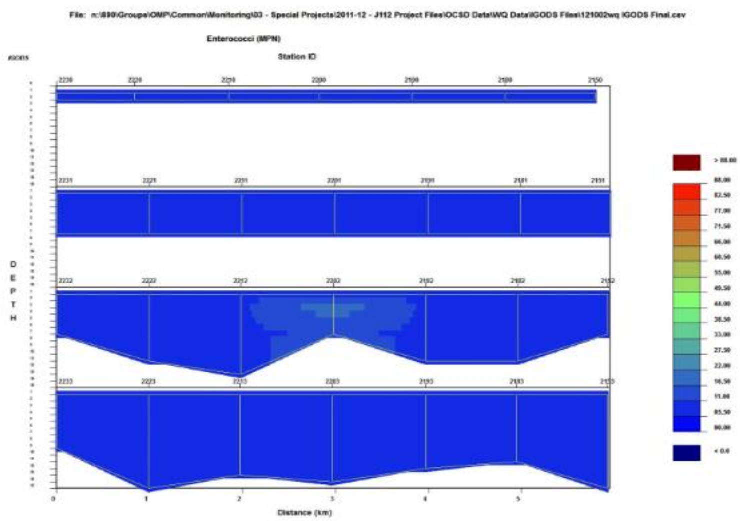
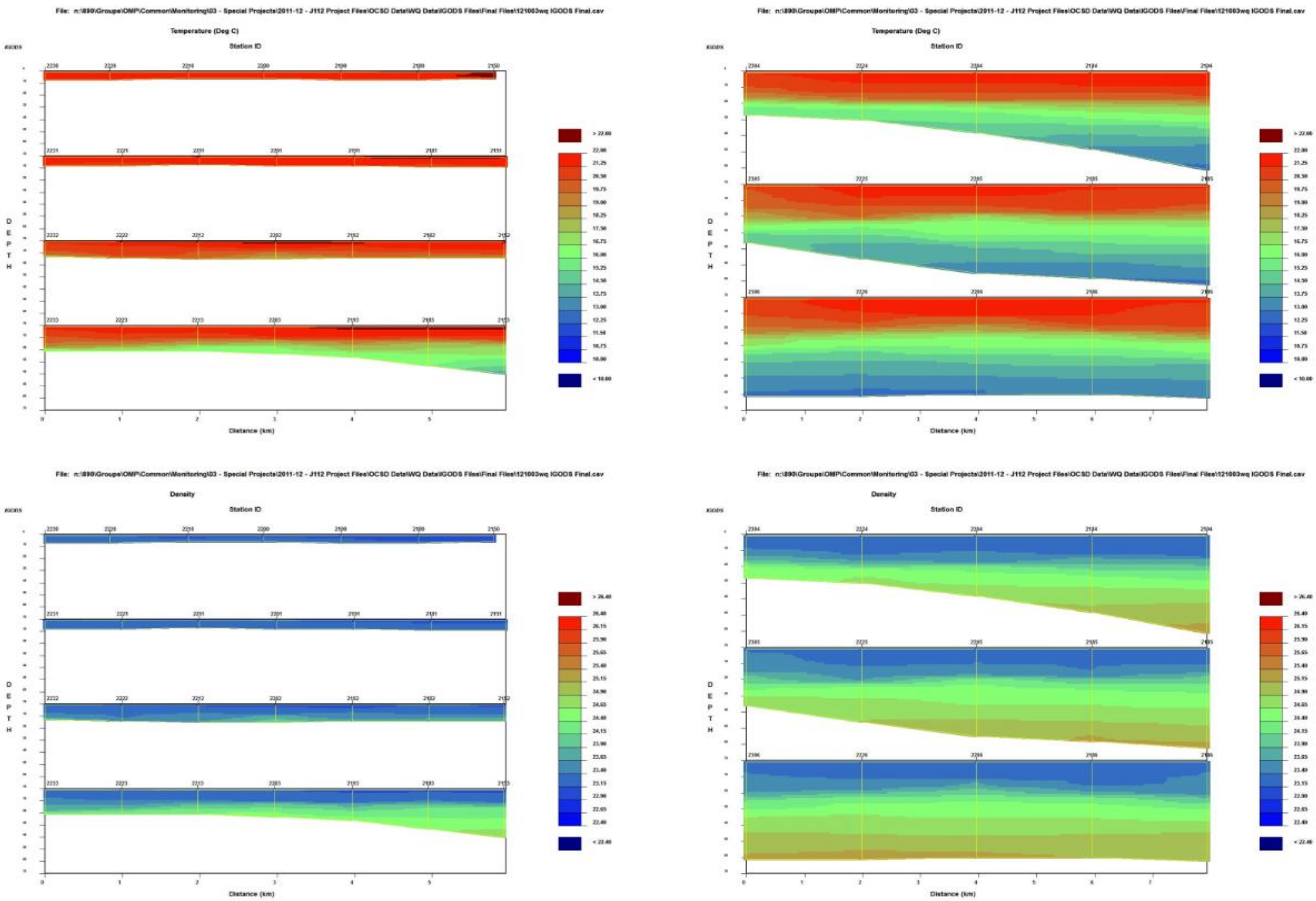
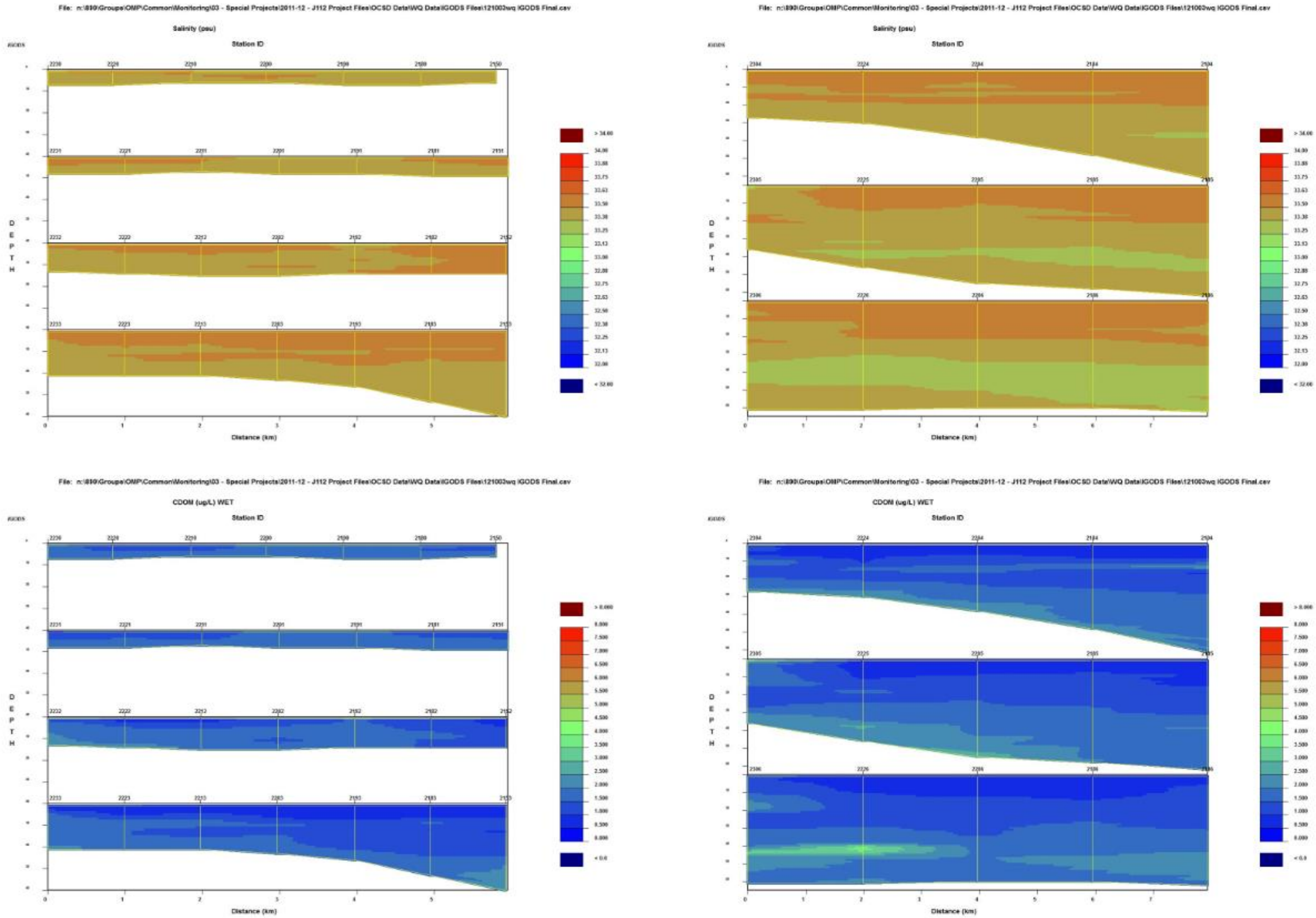


NO DATA

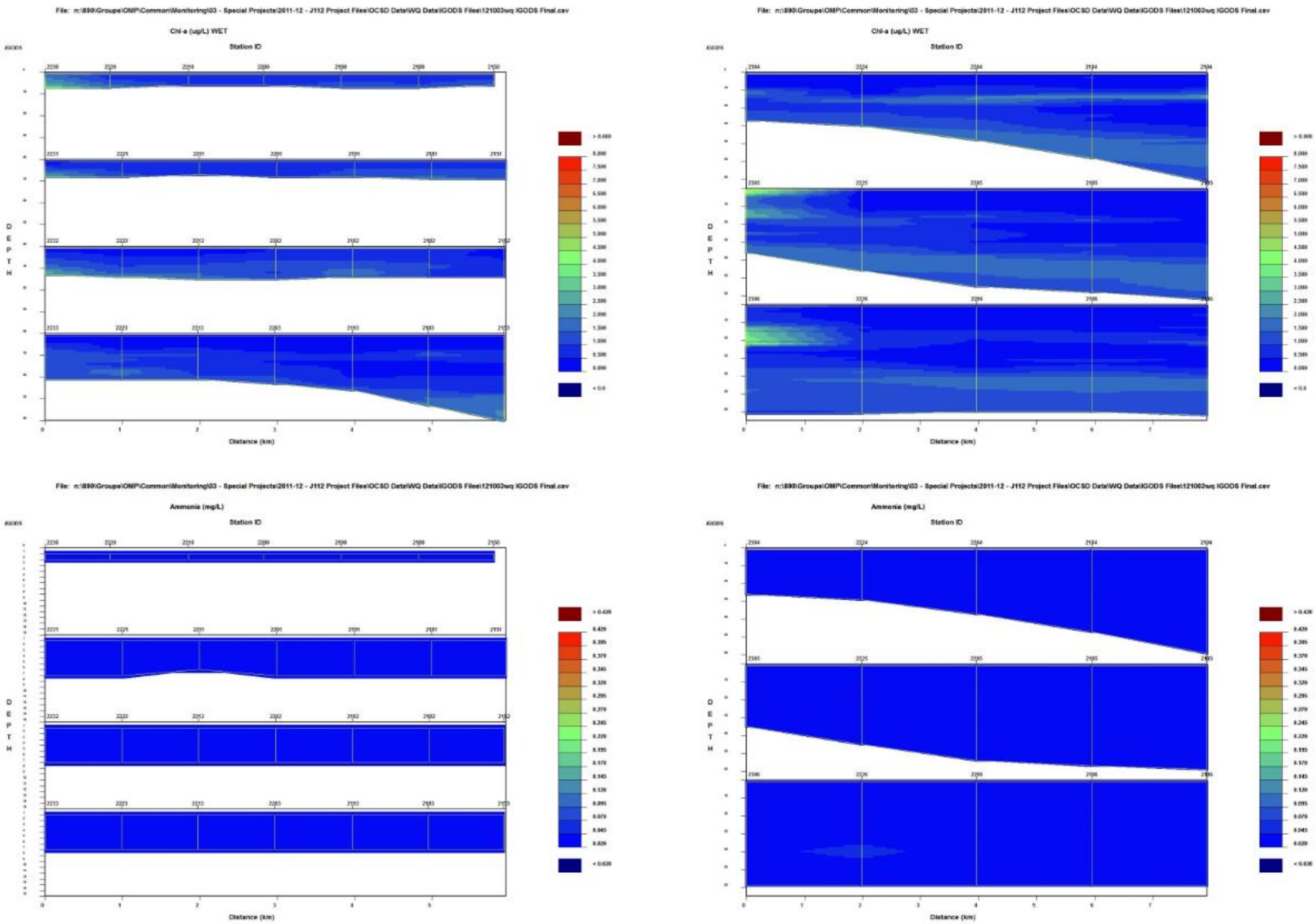
Fecal coliforms-inshore (top left), fecal coliforms-offshore (top right), enterococci-inshore (bottom left), and enterococci-offshore (bottom right) on October 2, 2012.



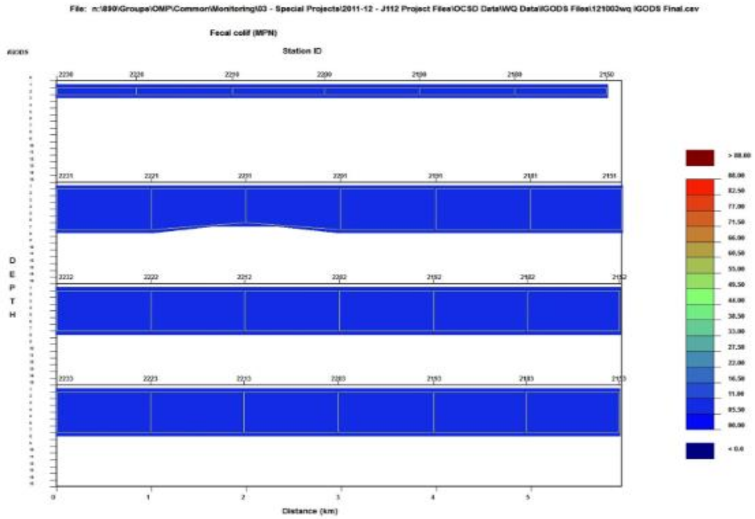
Temperature-inshore (top left), temperature-offshore (top right), density-inshore (bottom left), and density-offshore (bottom right) on October 3, 2012.



Salinity-inshore (top left), salinity-offshore (top right), CDOM-inshore (bottom left), and CDOM-offshore (bottom right) on October 3, 2012.



Chlorophyll-*a*-inshore (top left), chlorophyll-*a* -offshore (top right), ammonia-N-inshore (bottom left), and ammonia-N-offshore (bottom right) on October 3, 2012.



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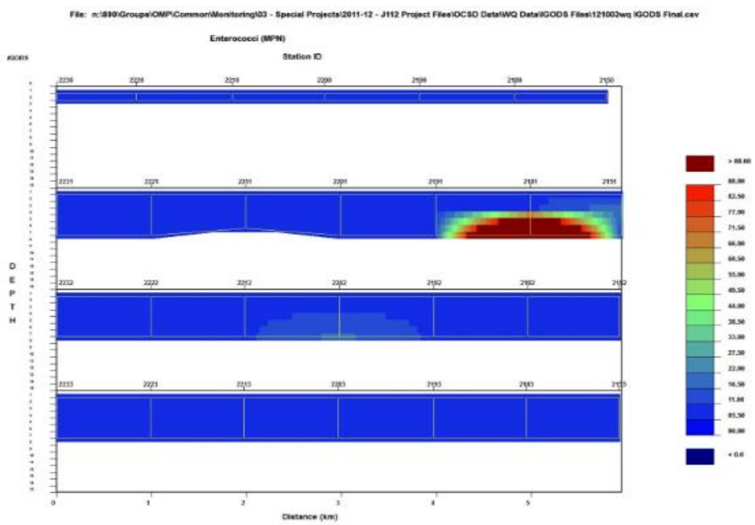
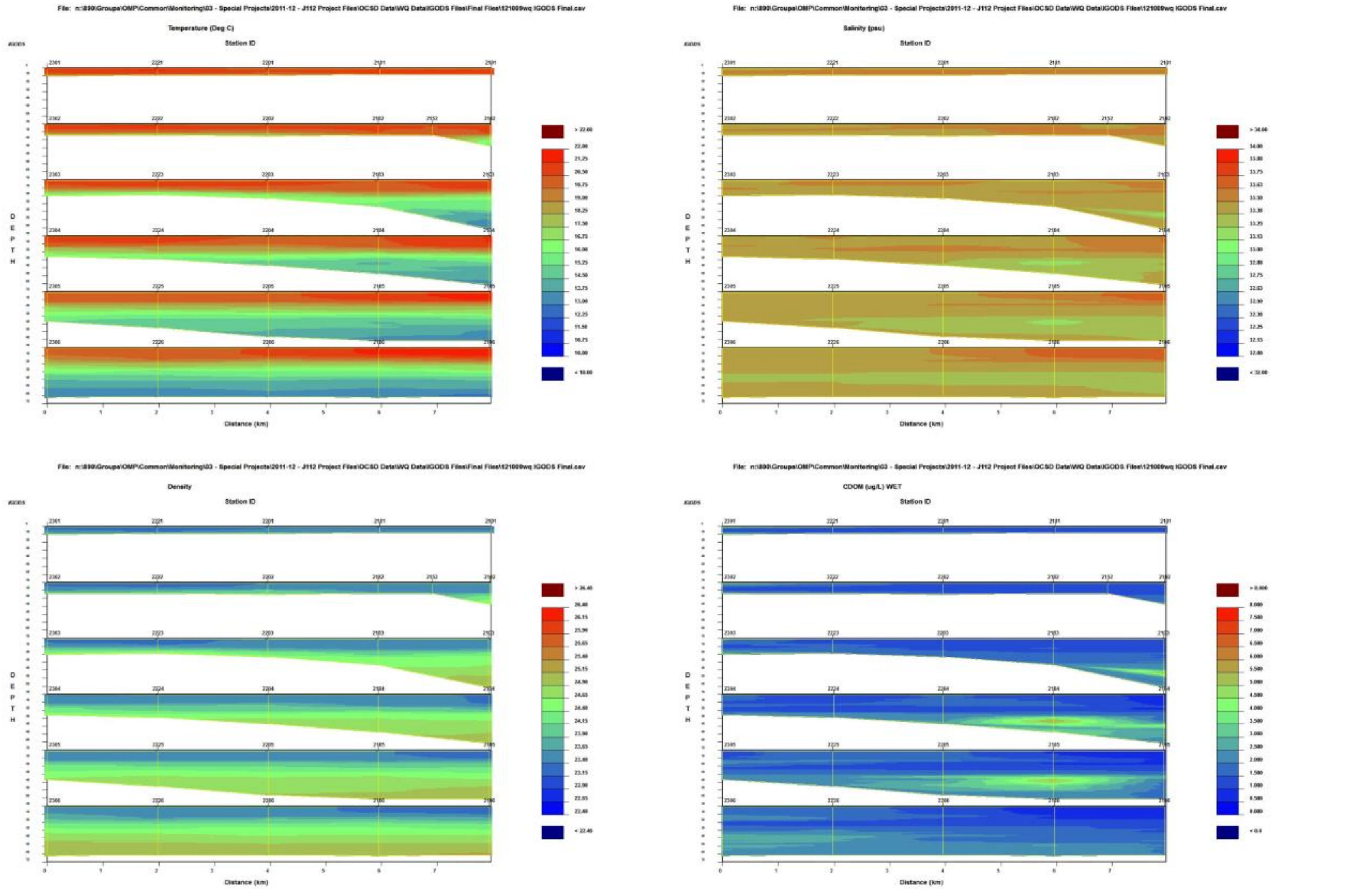
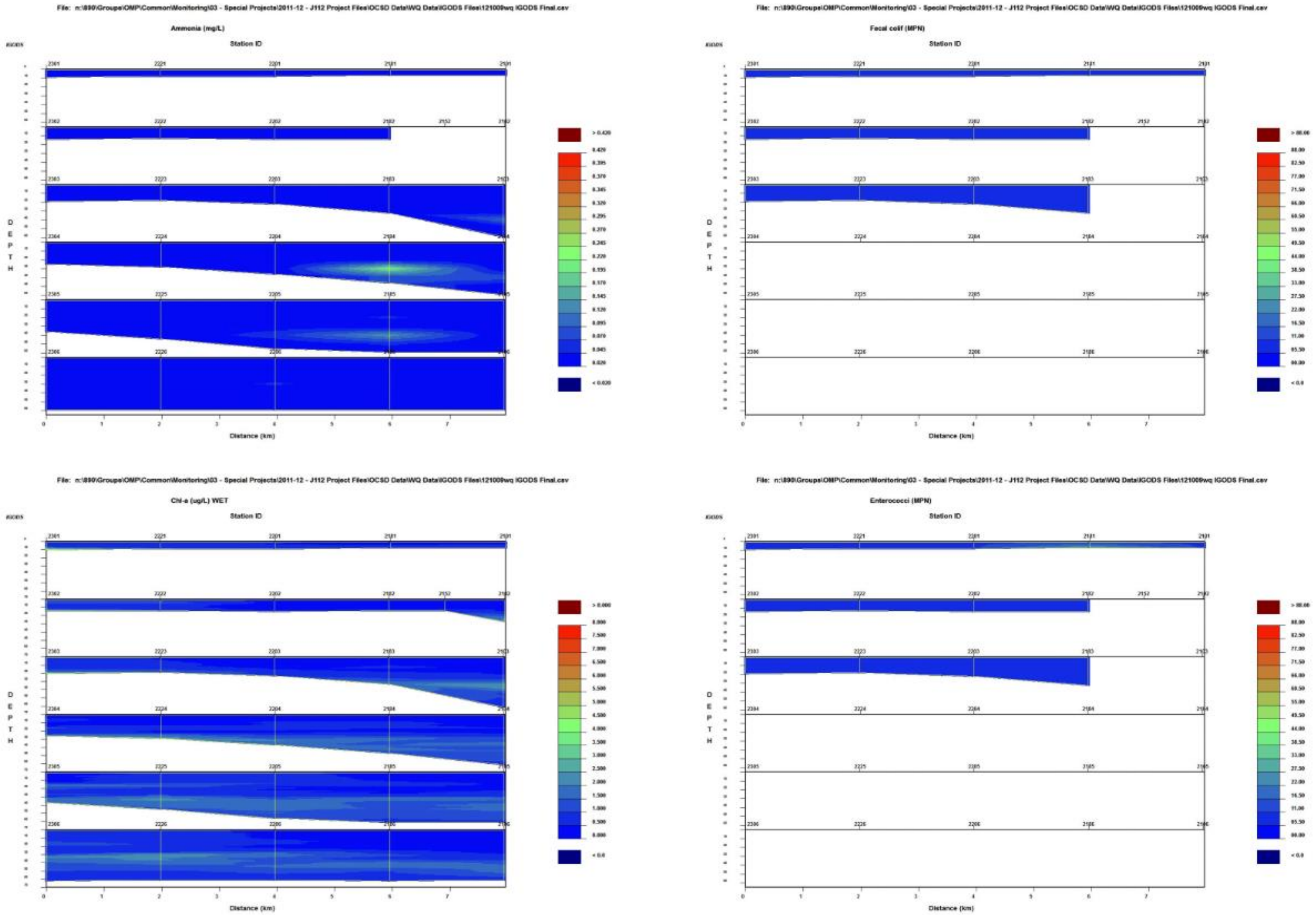


NO DATA

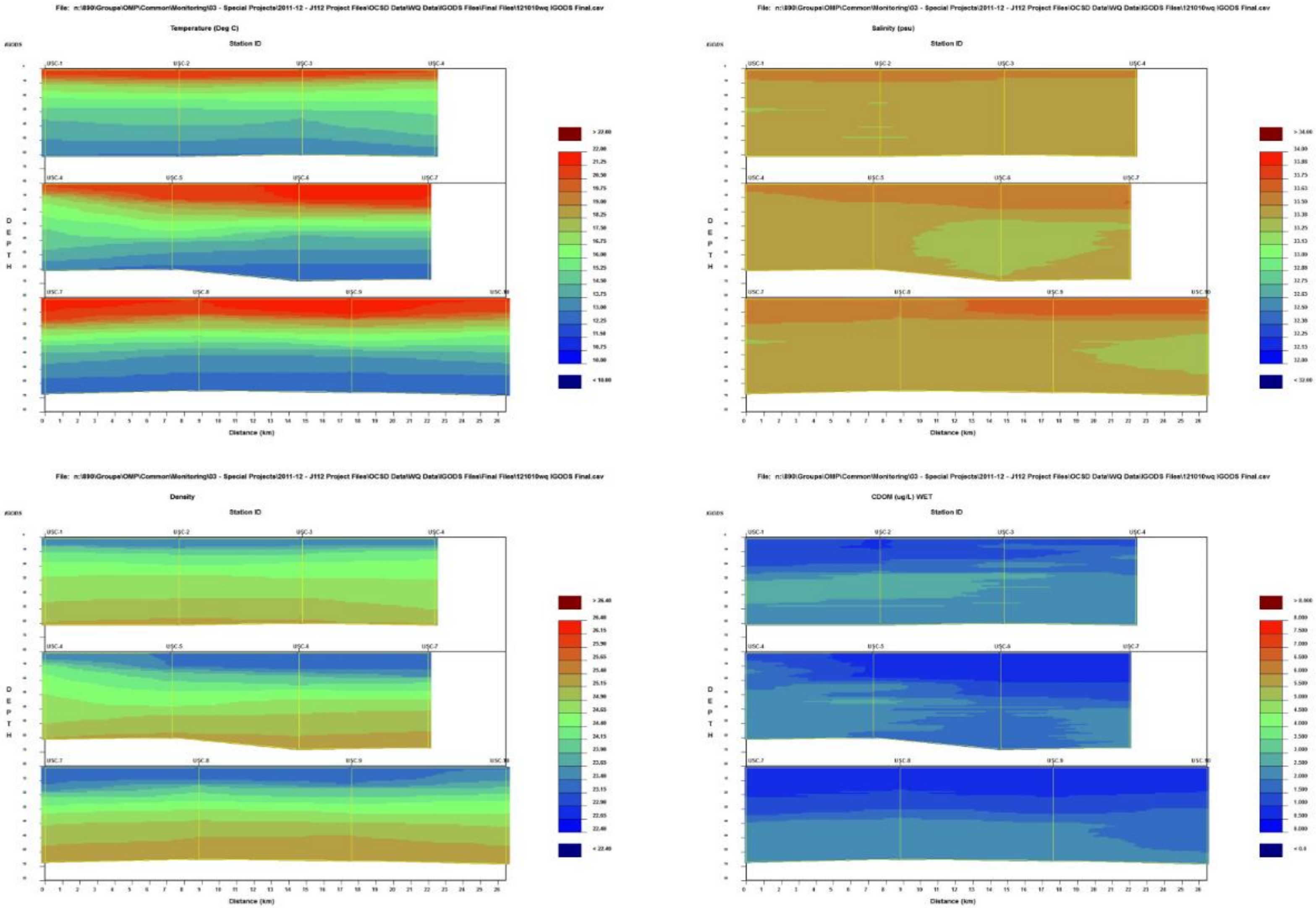
Fecal coliforms-inshore (top left), fecal coliforms-offshore (top right), enterococci-inshore (bottom left), and enterococci-offshore (bottom right) on October 3, 2012.



Temperature (top left), salinity (top right), density (bottom left), and CDOM (bottom right) on October 9, 2012.



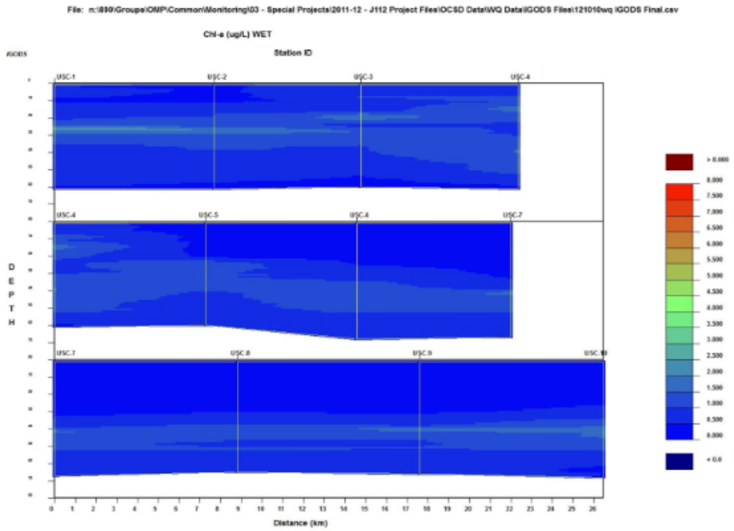
Ammonia-N (top left), fecal coliforms (top right), chlorophyll-a (bottom left), and enterococci (bottom right) October 9, 2012.



Temperature (top left), salinity (top right), density (bottom left), and CDOM (bottom right) on October 10, 2012.

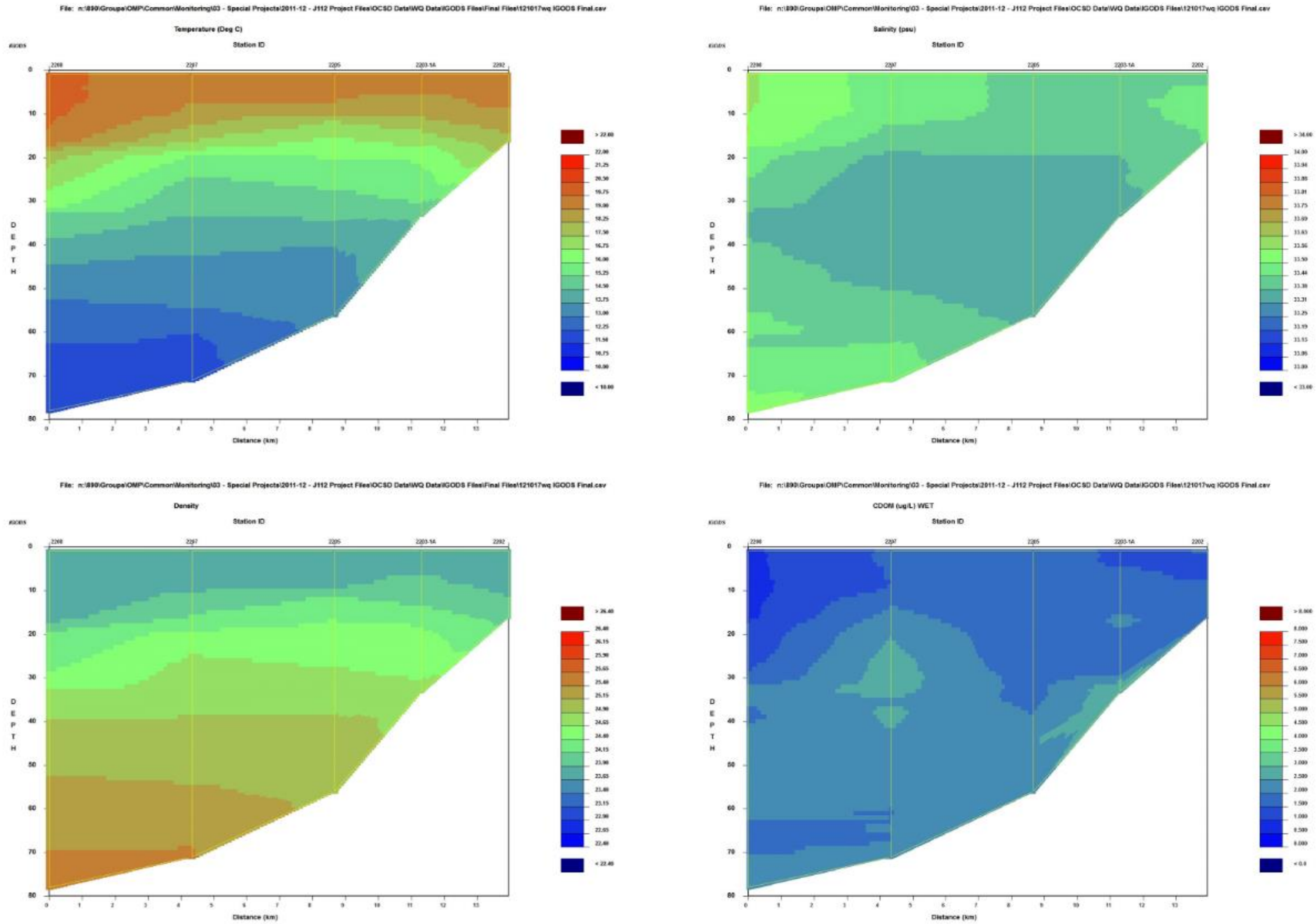
NO DATA

NO DATA



NO DATA

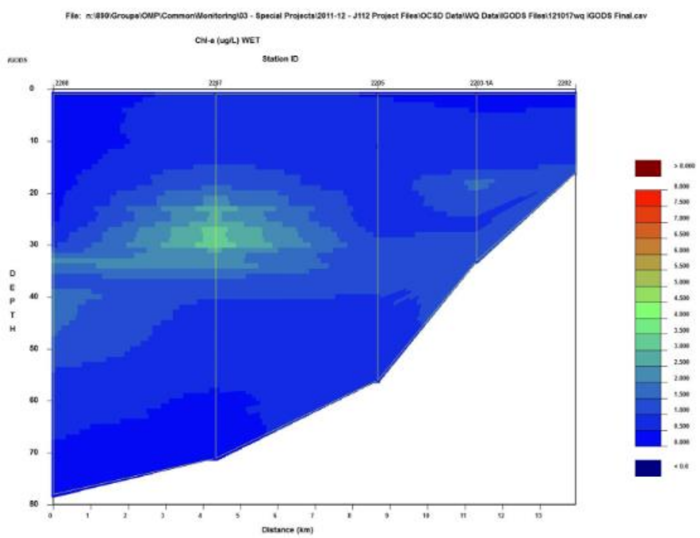
Ammonia-N (top left), fecal coliforms (top right), chlorophyll-*a* (bottom left), and enterococci (bottom right) October 10, 2012.



Temperature (top left), salinity (top right), density (bottom left), and CDOM (bottom right) on October 17, 2012.

NO DATA

NO DATA



NO DATA

Ammonia-N (top left), fecal coliforms (top right), chlorophyll-*a* (bottom left), and enterococci (bottom right) October 17, 2012

Appendix VI – Sample ROMS Report: Yi Chao, RSS

Thursday, September 20, 2012

- Meteorology: Diurnal fluctuations of winds continue to dominate with a peak amplitude around 4 m/s, typical and comparable to the past few days. The 72-hour forecast by the WRF model calls for similar wind patterns in the next 3 days.
- Observations: The surface current as observed by the high-frequency (HF) radar shows a similar convergence near the outfall location: downcoast current to the north and upcoast current to the south. Right at the outfall, the current is upcoast.
- ROMS Nowcast: Both the 1-km and 75-m ROMS shows weak current near the outfall, with slight upcoast current right at the outfall.
- ROMS Forecast: The 1-km ROMS is forecasting a continuous upcoast current for Thursday September 20 and a downcoast current for Friday September 21, as part of the clockwise circulation pattern around of the outfall.
- Particle Trajectories: Particles released today near the outfall at the surface are drifted initially upcoast and then turn downcoast as shown by both the 1-km and 75-km ROMS.