RISE 2004 – R/V Pt Sur Cruise Report

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Thanks to Aaron Raciot, OGI/OHSU, for these Pt Sur pictures

Purpose and Context

RISE hypothesizes that the Columbia River plume is more productive than adjacent coastal waters, that it facilitates cross-margin transport of particles and biota, and that the iron supplied by the plume is important to Pacific Northwest coastal primarily production, especially off Washington. Understanding the impact of the highly mobile Columbia River plume on coastal production and transport patterns requires that measurements be made on a variety of scales from turbulence to internal waves and fronts, to those of the plume and the underlying shelf circulation. RISE emphasizes, therefore, rapid surveys with the Triaxus towfish and detailed process investigations.

The RISE field program nominally consists of three high-flow cruises (spring 2004, 2005 and 2006), and one low-flow cruise (August 2005). Each cruise is to be carried out by two vessels, the R/V Wecoma (biological and chemical studies) and the R/V Pt Sur (plume surveys, mixing processes and zooplankton dynamics).

The first RISE cruise was in part an exploratory venture, testing our approach to project hypotheses, and the suitability of sampling gear to the environments. It was nominally a high-flow cruise, but took place under post-freshet, low-moderate, decreasing flow conditions 8-28 July 2004, due to ship scheduling difficulties. During the cruise river flow decreased from ~5,600 to 3,800 m^3s^{-1} (Figure 1). Although Bonneville flows rebounded to 4,250 m^3s^{-1} by the end of the cruise, the impacts of this increase probably did not reach the plume during the sampling period. Winds, shown in Figure 2, were initially light or variable (up to d. 196), but then were downwelling favorable for d. 196-202 (except d. 198). Consistent upwelling conditions prevailed during the final week of sampling (after d. 202).

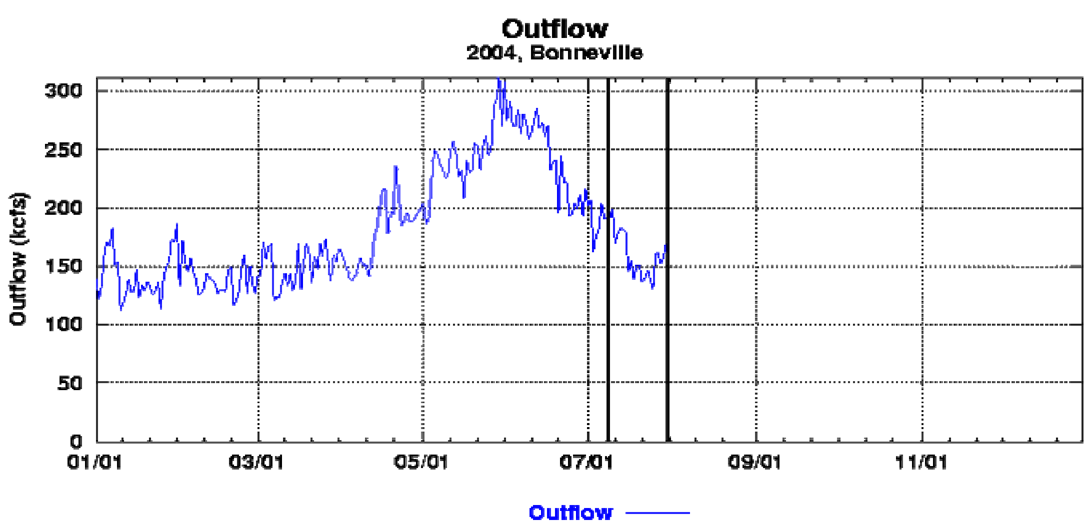


Figure 1: Daily Columbia River flow at Bonneville Dam, 10^3 fts^{-1}; the flow at Bonneville represents the entire flow from the Eastern sub-basin, >90% of the total basin area. Contributions from the Willamette and other Coastal sub-basin tributaries are small during summer. The cruise period is indicated by the vertical lines, but there is a lag of several days between flows at Bonneville Dam and those at the estuary mouth.

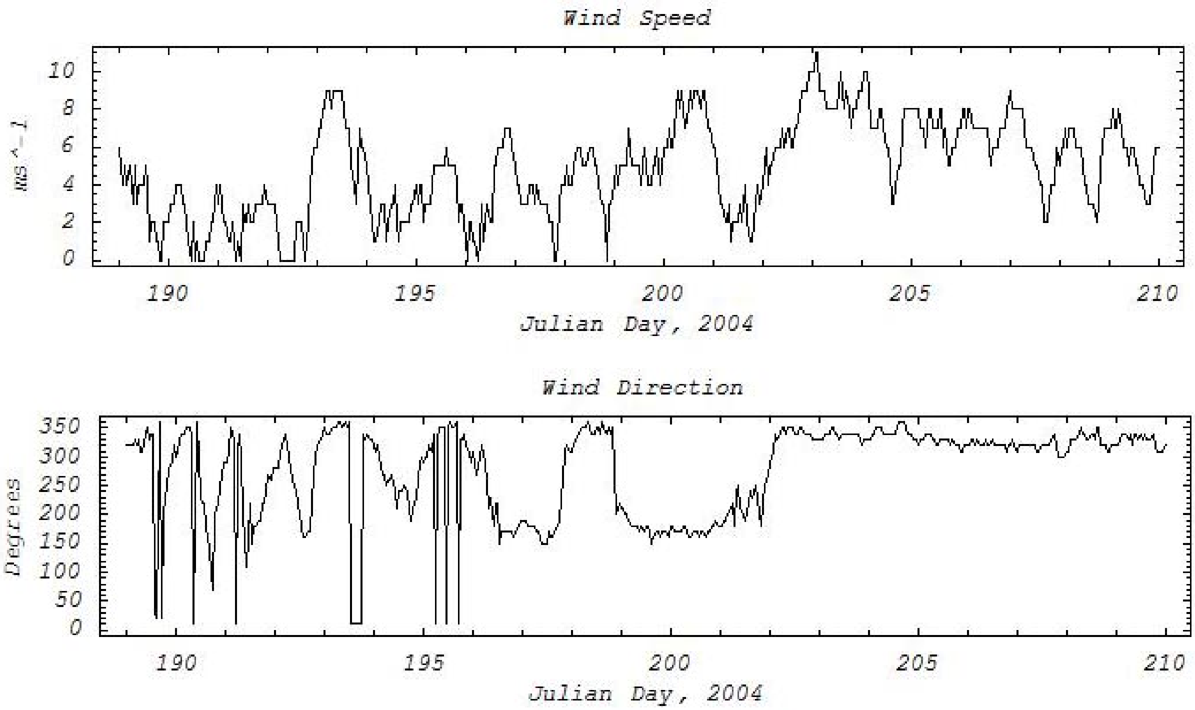


Figure 2: Winds observed during the cruise period at the NOAA MCR buoy 46029

Three RISE research groups carried out work on the R/V Pt Sur during Rise 2001:

1) Jay group (OGI/OH&SU): Triaxus surveys of the plume and frontal studies (Figure 3a,b). Triaxus surveys seek to characterize the mesoscale fields of near-surface velocity, salinity, temperature, nitrate, chlorophyll, transmissivity, optical particle size and zooplankton characteristics. Large-scale maps were carried out under variable or downwelling conditions at the beginning of the cruise, and under fully-developed upwelling conditions at the end of the cruise. Frontal surveys were carried out under downwelling conditions in mid-cruise. The fronts observed to the south of the plume jet at this time were broader and less sharp than the fronts on the north side of the plume (Figure 3c) observed during the turbulence studies and during previous cruises. We also looked for fronts (during upwelling conditions) between the inshore side of plume and recently upwelled water south of the estuary entrance. The plume was very thin (2-4 m), but fronts were rather diffuse.

2) The Ocean Mixing Group (Nash and Moum, COAS/OSU): turbulence studies. The Ocean Mixing Group seeks to characterize and quantify the mechanisms by which oceanic water is entrained into the freshwater plume. To accomplish this, high frequency/ high wavenumber motions must be identified and the dynamics responsible for generating turbulence must be understood. Measurements of chlorophyll, optical backscatter, acoustic backscatter, density, velocity and turbulence are obtained rapidly and with high vertical and horizontal resolution using the Chameleon turbulence profiler (Figure 4b). They span the full water column (from 1 m beneath the ocean surface to 3 cm from the bottom) and capture both near-surface fluxes and bottom boundary layer (BBL) dynamics. Four lines were selected for sampling (Lines 1-4, Table 2, Figure 4a), over a full tidal day in most cases. There were no major instrument failures; 4300 vertical profiles were obtained during our nine days of profiling. Microstructure observations (surface through

BBL) were obtained across and along the plume axis in (a) the plume nearfield, (b) the plume farfield, (c) near the three RISE moorings.

3) The NOAA Zooplankton group (Peterson, NOAA): Zooplankton dynamics. RISE studies of zooplankton dynamics examine the spatial variation of zooplankton species and life stages as well as their rates of growth, grazing, and mortality, in the coastal regions impacted by the Columbia River plume. A two component approach is being used to look at zooplankton process rates, abundance and distribution across the Columbia River plume. The first component focuses on rate processes and involves sampling aboard the R/V Wecoma (see the R/V Wecoma cruise report). The Pt. Sur. component focuses high resolution surveys of plankton distribution and size using a Laser Optical Plankton Counter (LOPC) incorporated into a Triaxus tow body operated. The LOPC gathered data on the abundance and distribution of particles between 100 um and 35mm in equivalent spherical diameter (ESD) throughout the region surveyed by the Triaxus (see cruise tracks below). Zooplankton size and abundance data is gathered real-time in association with GPS, salinity, temperature, depth and fluorescence data.

*Figure 3a: The Triaxus towfish, showing the two OS-200 CTDs and LOPC; the Rem*us-configuration *1200 kHz ADCP is mounted in the top right pontoon and looks upward.*

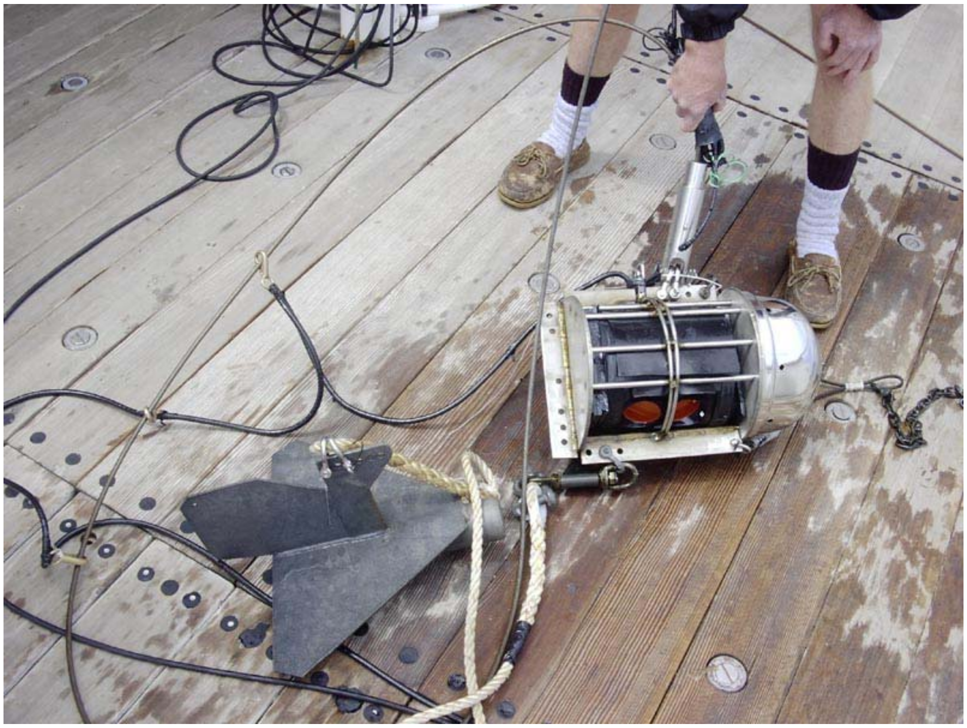


Figure 3b: The downward looking Remus-configuration 1200 kHz ADCP towed along side the vessel, with a depressor foot for stability.

Figure 3c: The surface expression of a very sharp front north of the entrance during upwelling conditions, 23 July 2004.

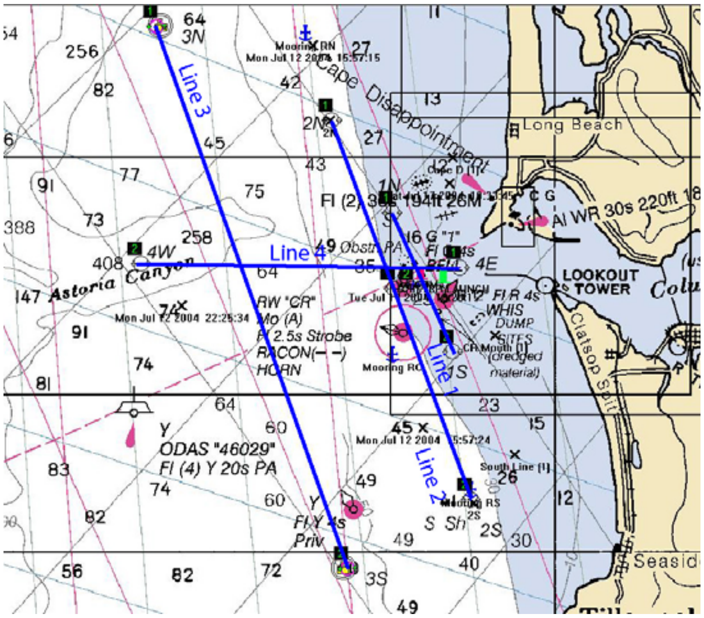


Figure 4a: Sampling lines 1 to 4, along which detailed turbulence profiling was carried out.

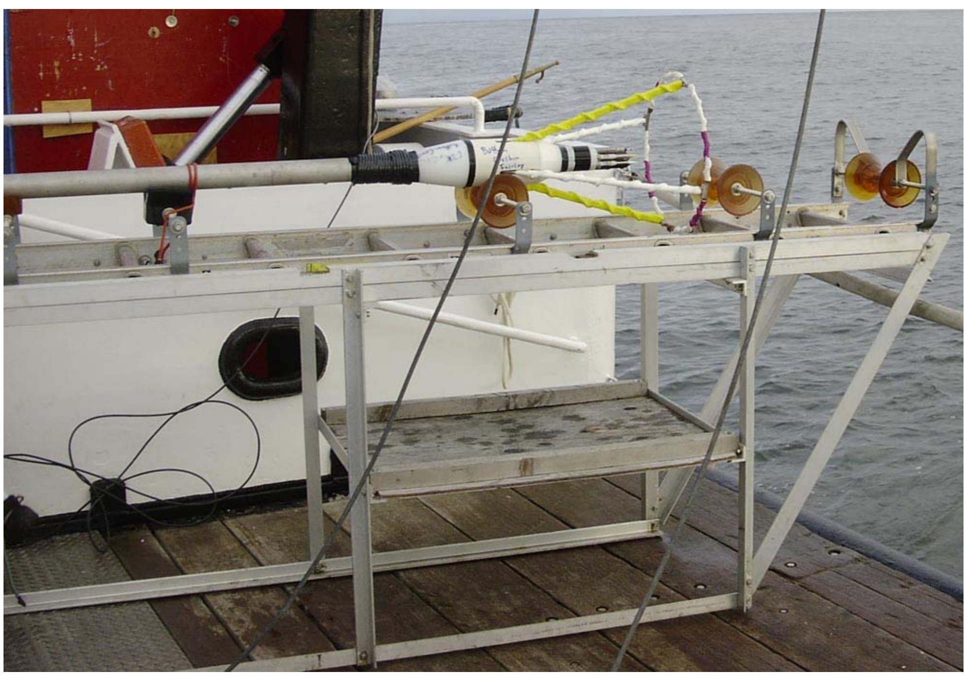


Figure 4b: The Chameleon turbulence profiler (with bottom lander) on its recovery table.

Cruise Personnel

Name	Institution	Position (chief scientist, student, technician, etc.)	Dates on Board
David Jay	OGI/OHSU	Chief Scientist	6-29 July
Tom Chisholm	OGI/OHSU	Post-doc	6-29 July
Alex-Horner Devine	Stanford	Post-doc	6-18 July
Robin Bjorkquist	OGI/OHSU	Student intern	6-29 July
Alex Cigan	OGI/OHSU	Student intern	18-29 July
Jonathan Nash	COAS/OSU	Co-Chief Scientist	6-29 July
Alexander Perlin	COAS/OSU	Research Scientist	6-29 July
Ray Kreth	COAS/OSU	Senior Scientist	6-29 July
Levi Kilcher	COAS/OSU	Grad student	6-29 July
Satoshi Kimura	COAS/OSU	Grad student	6-29 July
Jay Peterson	NOAA	Research Scientist	6-29 July

RISE July 2004 Cruise Itinerary

Date	Pt Sur
0830 6 July -1230 6 July	Pt Sur refuels and transfers winch
1230 6 July -1600 9 July	Mobilization (3 d)
1600 9 July -0830 10 July	Shakedown, steam to N. end of map 1
0830 10 July -2200 10 July	Initial turbulence sampling near entrance
2200 10 July -0000 13 July	Triaxus Map 1 survey N to S (3) (partial)
0000 13 July -0000 16 July	Turbulence studies along lines 1 and 2, and near entrance
0000 16 July -1400 18 July	Line 1 turbulence studies
1400 18 July -0000 19 July	Personnel swap in Astoria (0.25)
0000 19 July -0000 21 July	Triaxus frontal studies; fronts S. of entrance, transitional to downwelling (2)
0000 21 July -1800 22 July	Short Triaxus map, near entrance (partial)
1800 22 July -1800 23 July	Line 2 and frontal turbulence studies N. of entrance, upwelling (1)
1800 23 July -1800 24 July	OR upwelling/plume frontal interactions (Triaxus) (1)
1800 24 July -1700 27 July	Final Triaxus Survey (N to S, ~3 d)
1700 27 July -0300 28 July	Steam to Newport (0.4)
0300 28 July -1500 28 July	Offload

List of Sensors/Data Sets Acquired

Shipboard:

1) Vessel 300 kHz RDI acoustic Doppler current profiler (ADCP), downward looking; horizontal velocity profiles.
2) Pole-mounted 300 kHz RDI ADCP, downward looking; horizontal velocity profiles.
3) Sled-mounted 1200 kHz RDI ADCP, downward looking; high resolution, near-surface horizontal velocity profiles.
4) Pole-mounted 120 kHz Biosonics echo sounder; echo intensity.
5) CTD casts:
    a. Seabird 911 CTD with transmissometer, and fluorometer; conductivity, temperature, depth, optical transmission, Chlorophyll.
    b. Laser in-situ scattering transmissometer, LISST-Floc; volume concentration in 32 size bins, 10-1500 micron.
    c. Bottle samples for nutrients; $N0_3$.

d. Bottle samples for total SPM in two settling velocity classes, gravimetric mass concentration, percent organic matter.

Triaxus Tow Fish:

1) Seabird 911 CTD with transmissometer, fluorometer, ISUS NO_3 sensor; conductivity, temperature, depth, optical transmission, Chlorophyll, $N0_3$.
2) 1200 kHz RDI ADCP, upward looking; high resolution, near-surface horizontal velocity profiles
3) Laser-optical plankton counter (LOPC); abundance and distribution of particles between 100 μm and 35mm in equivalent spherical diameter (ESD)
4) LISST-25; volume concentration in 2 size bins, 3-500 micron
5) Two OS-200 CTDs; conductivity temperature and depth (for stratification).

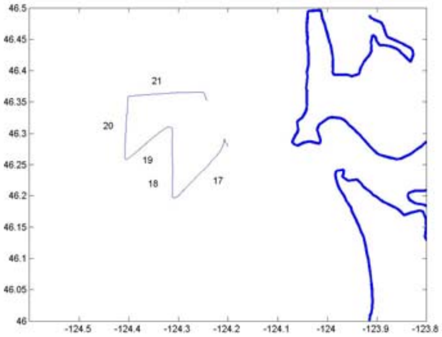
Turbulence Sampling:

Instrument	**Sensor**	**Measurement**
Chameleon (a loosely-tethered vertical microstructure profiler)	Airfoil shear probes 3-component accelerometers (IC sensors)	turbulent energy dissipation rate turbulent eddy diffusivity turbulent buoyancy flux
	PME Accurate Conductivity, Thermometrics FP07 thermistor, Endevco 500 psi pressure	CTD, 3 cm salinity, density; 1 cm temperature
	Seapoint Sensors 880 nm optical backscatter	suspended sediment plus plankton
	Seapoint Sensors Chlorophyll sensor (Fluorometer)	proxy for chlorophyll; <10 cm vertical scales
Biosonics Echosounder	120 kHz acoustic transceiver, pole mounted at 1-m depth , 0.1 msec pulse length, 2 m to 110 m (or bottom), 2 Hz sample rate.	Images salinity microstructure and biological layers with 10 cm vertical and 1-m horizontal resolution
300 kHz RDI Workhorse ADCP	Pole mounted at 1-m depth; 0.5 m blank distance; 1-m depth bins; 1 second time bins, all ping data saved.	velocity from z=2 to 120 m with 15-second (10-30 m) horizontal and 1-m vertical resolution

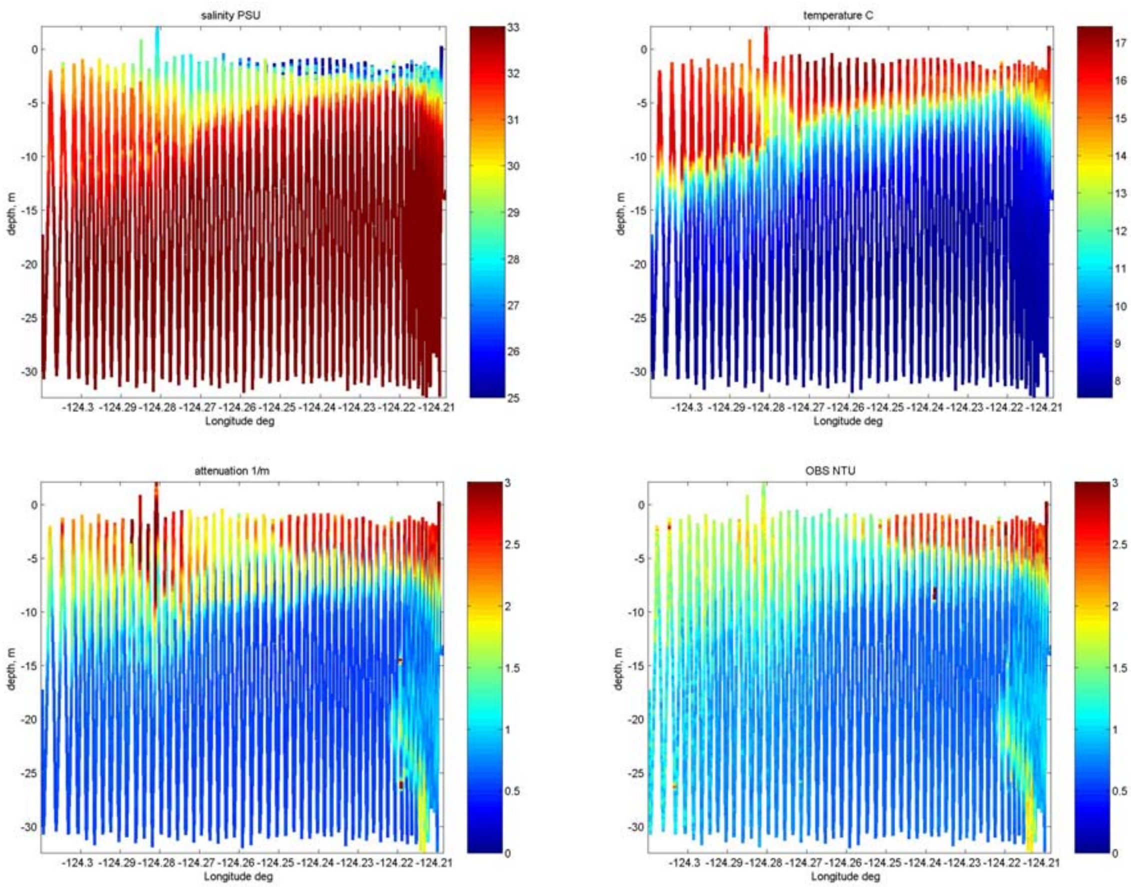
Selected Results

Triaxus Surveys:

a)



b)



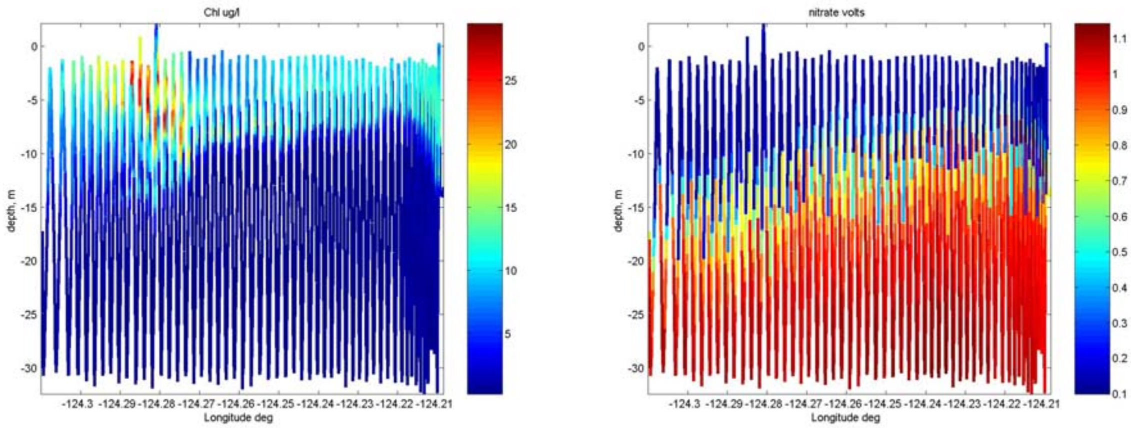


Figure 5: a) Triaxus cross-frontal sampling lines on the south side of the plume during downwelling conditions 20 July; b) salinity (PSU), temperature (ºC), attenuation (m^{-1}), optical backscatter (OBS) in natural turbidity units, Chlorophyll ($\mu g l^{-1}$;) and NO_3 (volts) for line 17.

The front shown in Figure 5b) at 124.28º W has a marked surface expression in every parameter except NO_3, which is depleted above ~12 m. Chl and attenuation are particularly strong at the front, whereas turbidity is higher at the landward end of the transect, closer to the estuary mouth. This suggests that fines emerging from the estuary (which excite a strong backscatter signal) are settling out of the plume or being converted to coarser material with a weaker backscatter signature.

<u>Turbulence Sampling</u>

The transect shown in Figure 6 highlights a few features typical of this plume system:

1) Nonlinear internal waves are ubiquitous. In this transect, packets are observed at 46.16 N and 46.23 N. These produce 20-m vertical displacements, have strong horizontal and vertical velocities (panel 7), and appear to dominate the mixing and dissipation in the 10-20 m depth range (panel 5). Layers of chlorophyll are transported vertically by these features (panel 1).
2) The bottom boundary layer (BBL) is well-mixed, often 20-m thick (panel 4) and is rapidly mixing (panels 5,6). Sediment concentrations are high in this layer (panel 2).
3) mixing is intense in the near-field plume base. Although difficult to see in this small figure, velocity shear at 46.25-46.35 N and at 5-10 m depth drives high near-surface energy dissipation and buoyancy fluxes. These decay with offshore distance (not shown in this transect).

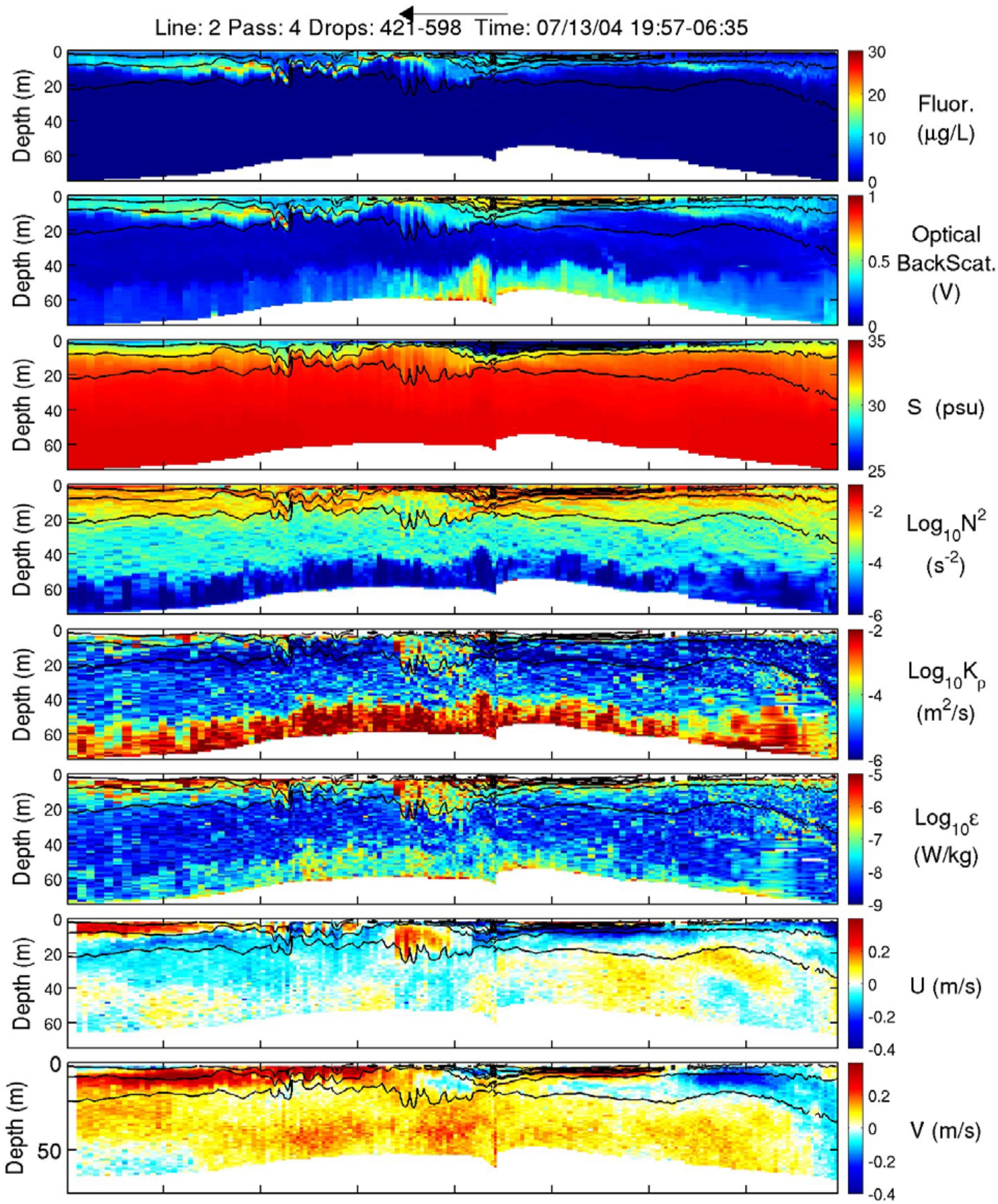


Figure 6: An example of profiler measurements along line 2. Data represent 177 profiles over a 6.5 hour duration. Plotted are chlorophyll fluorescence, optical backscatter, salinity, stratification, turbulent diffusivity, turbulent energy dissipation rate, East and North components of velocity. Isopycnals are contoured on each plot.

Non-linear internal wave packets are sometimes released by plume fronts as their propagation slows. The associated convergences/divergences are strong enough to be visible in surface radar, as the example from ship's radar in Figure 7 shows. Similar features are also seen in SAR images.

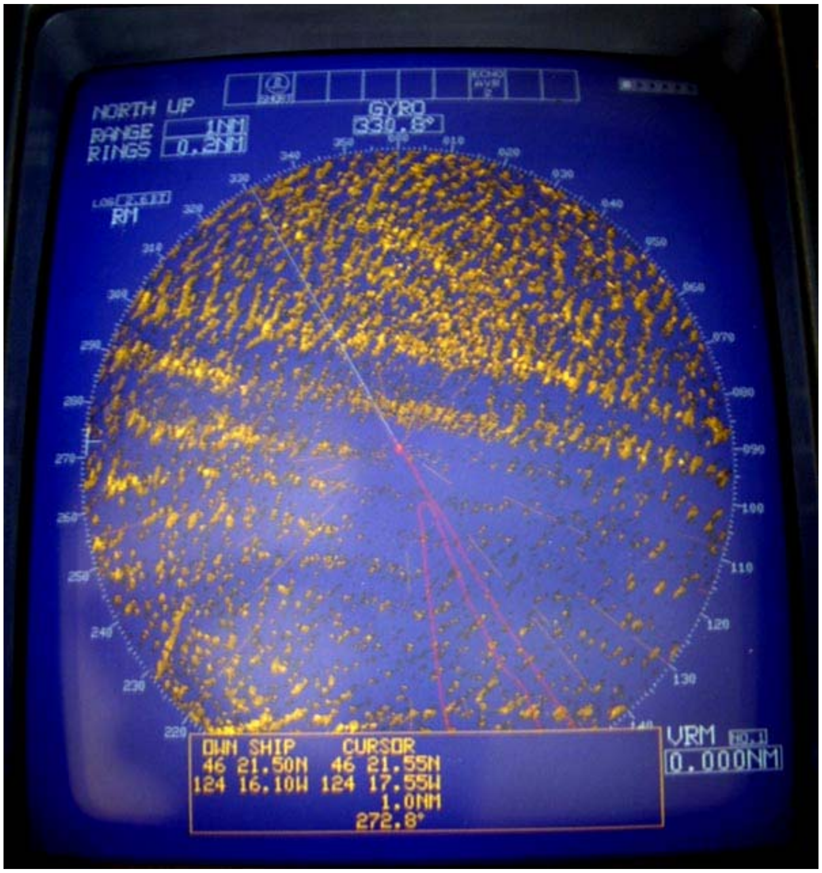


Figure 7: Ship's radar image of a non-linear internal wave train.

LOPC Results

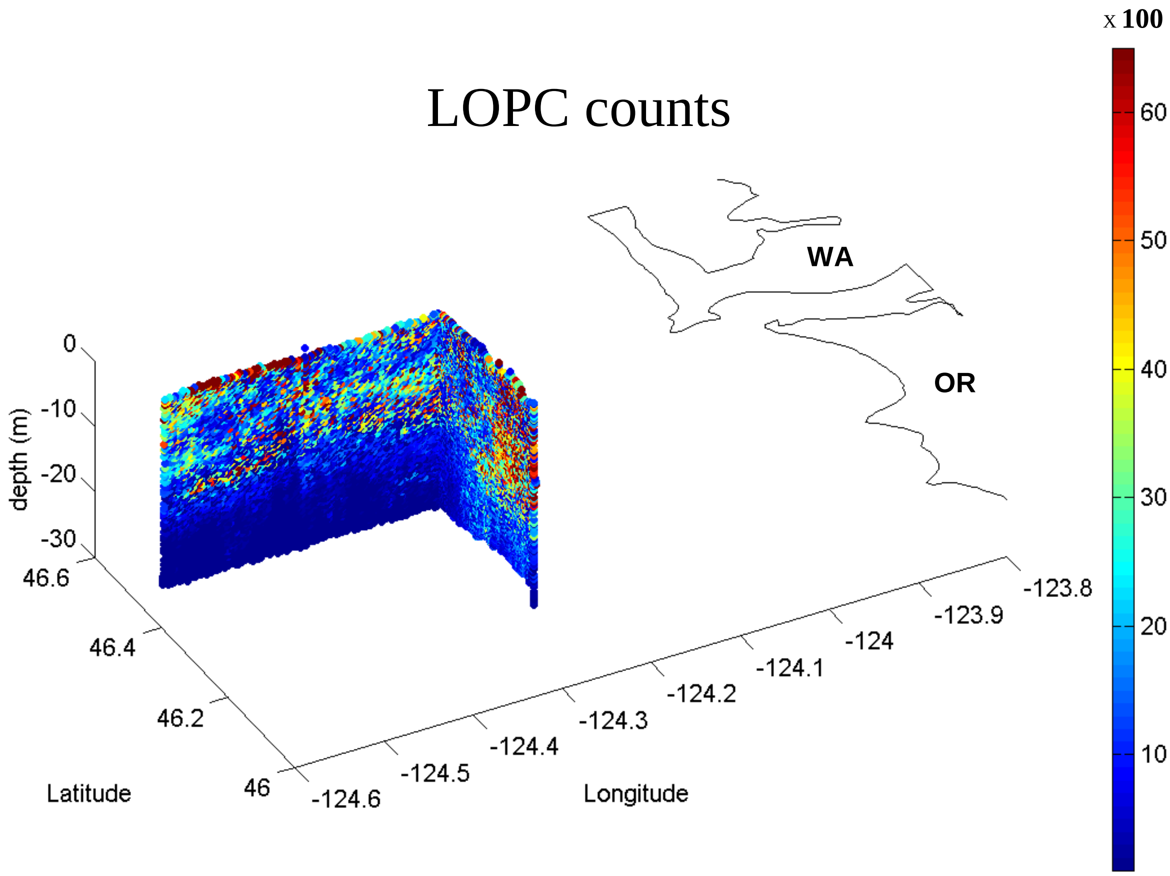


Figure 7: Raw data from the Laser Optical Plankton Counter (LOPC) during a transect on July 22nd. The LOPC detects plankton in the 100 m – 35mm diameter size range.

Cruise Tracks and 3-m Salinity

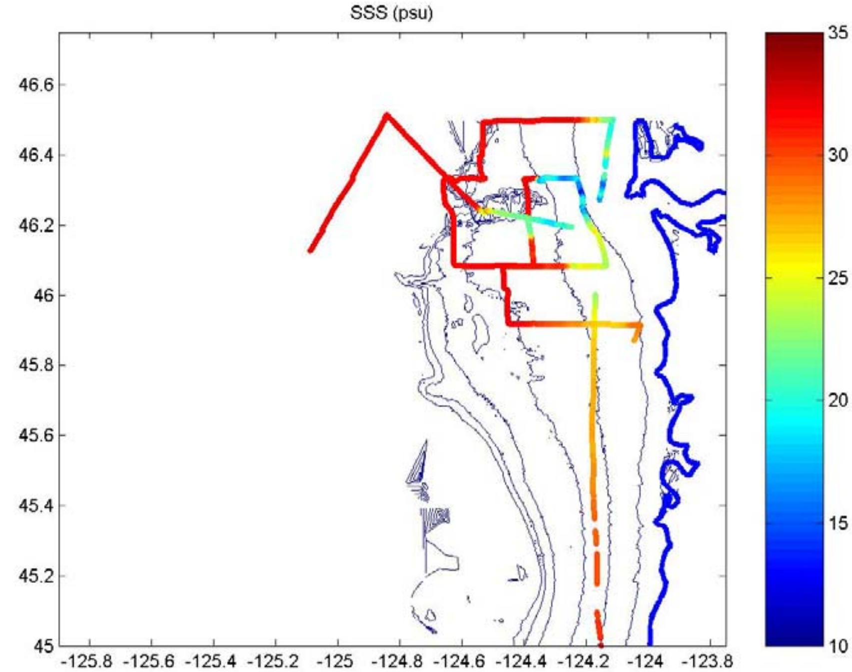


Figure 8: Salinty at 3 m during the initial Triaxus survey 10-12 July, under conditions of light and variable winds following a downwelling episode. There are plume remnants from earlier upwelling favorable conditions along the Oregon Coast.

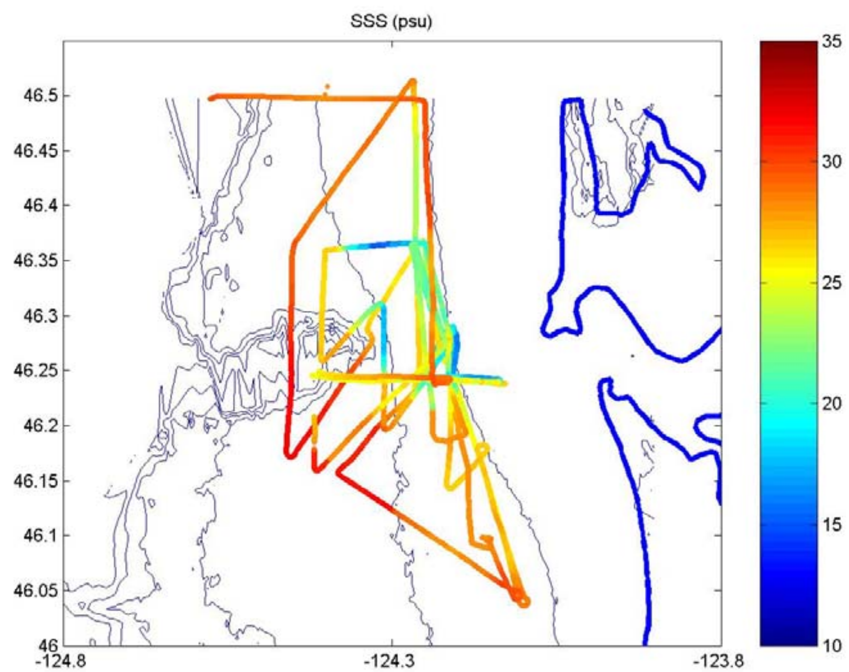


Figure 9: Salinity at 3 m during the second plume survey 21-22July, under transitional conditions, with the plume moving offshore.

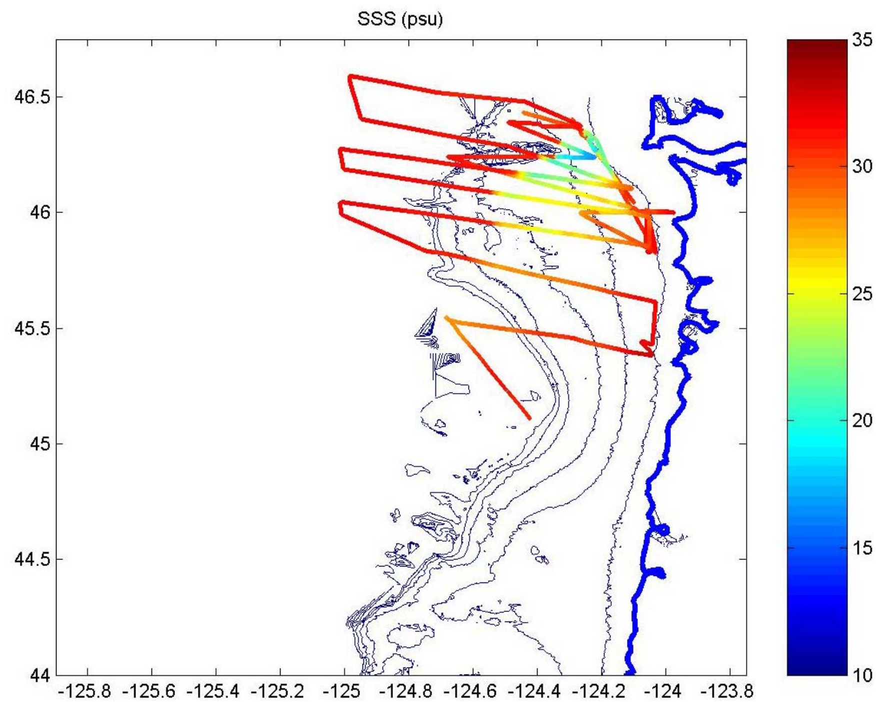


Figure 10: Salinity at 3 m during the final Triaxus plume survey 24-27 July, under upwelling conditions. The plume moves south and offshore.

Appendix – Turbulence Sampling Transects

Line 1

Pass	Start Time (GMT)	End Time (GMT)	Chameleon first profile	Chameleon last profile
Pass: 1	07/15 03:34	07/15 05:52	991	1067
Pass: 2	07/15 06:13	07/15 08:40	1077	1158
Pass: 3	07/15 08:42	07/15 10:53	1159	1225
Pass: 4	07/15 10:56	07/15 14:09	1226	1318
Pass: 5	07/15 14:11	07/15 17:48	1319	1458
Pass: 6	07/15 17:50	07/15 20:31	1459	1527
Pass: 7	07/15 21:46	07/15 23:59	1528	1619
Pass: 8	07/16 00:01	07/16 02:47	1620	1701
Pass: 9	07/16 09:49	07/16 10:02	1702	1711
Pass: 10	07/16 10:04	07/16 11:30	1712	1768
Pass: 11	07/16 11:32	07/16 15:07	1769	1897
Pass: 12	07/16 15:09	07/16 19:19	1898	2052
Pass: 13	07/17 07:42	07/17 09:40	2268	2327
Pass: 14	07/17 09:42	07/17 10:56	2328	2381
Pass: 15	07/17 10:57	07/17 12:04	2382	2408

Line 2

Pass	Start Time (GMT)	End Time (GMT)	Chameleon first profile	Chameleon last profile
Pass: 1	07/13 01:56	07/13 05:01	123	176
Pass: 2	07/13 05:05	07/13 11:04	177	265
Pass: 3	07/13 11:08	07/13 17:18	266	356
Pass: 4	07/13 19:57	07/14 06:35	421	598
Pass: 5	07/14 06:40	07/14 13:10	599	703
Pass: 6	07/14 13:13	07/14 20:32	704	854
Pass: 7	07/14 20:35	07/15 02:55	855	978
Pass: 8	07/17 01:40	07/17 04:28	2146	2217
Pass: 9	07/23 01:37	07/23 07:11	3747	3864
Pass: 10	07/23 07:14	07/23 14:45	3865	4021
Pass: 11	07/23 14:48	07/23 17:38	4022	4092
Wave Tracking	07/23 17:38	07/24 01:20	4092	4307

Line 4

Pass: 1	07/16 22:20	07/17 01:40	2053	2150
Pass: 2	07/17 11:30	07/17 17:52	2390	2575
Pass: 3	07/18 12:16	07/18 14:50	2949	3019
Pass: 4	07/21 12:59	07/21 15:09	3086	3177
Pass: 5	07/21 15:13	07/21 17:52	3178	3233
Pass: 6	07/21 17:55	07/21 23:44	3234	3383
Pass: 7	07/21 23:46	07/22 03:48	3384	3503
Pass: 8	07/22 03:51	07/22 08:57	3504	3653
Pass: 9	07/22 08:58	07/22 11:56	3654	3746