Symposium on Cold Halocline, High Productivity and Hypoxia in the Northern California Current

On 19 November 2002, oceanographers from the U. S. GLOBEC North East Pacific (NEP) Program and invited colleagues gathered in Corvallis, Oregon to discuss the remarkable phenomena observed in the coastal upwelling ecosystem of the northern California Current in spring and summer 2002. These included a major die-off of benthic fauna on a shallow reef, hypoxic bottom waters on the inner shelf, anomalously cold waters at mid-depth over the shelf, high concentrations of nutrients in the permanent halocline, and very high fluorescence in the surface layer. These phenomena had initially been observed independently by scientists working in separate programs. Informal communication soon led to the idea that they might be related. The one-day symposium was organized (under the auspices of the GLOBEC NEP program) to explore these relationships further, and to consider possible causes. Participants were excited to see how their own limited observations beginning to fit into a larger picture, and agreed to continue collaboration on a series of papers.

Symposium participants included scientists from universities, federal and state government agencies, and the Canadian Institute of Ocean Sciences (Table 1). Results were presented from several research programs including the Long-Term Observation Program (LTOP) of the GLOBEC NorthEast Pacific (NEP) Program, the Intensive Process Program of GLOBEC NEP, the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), and the Coastal Ocean Advances in Shelf Transport (COAST) program. The GLOBEC NEP program [Batchelder et al., 2002] has made hydrographic surveys off Oregon seasonally since July 1997, maintained mid-shelf moorings off Newport, Grays Harbor and the Rogue River since 1998, supported bi-monthly sampling off Newport since 1996, and conducted intensive mesoscale studies in the summers of 2000 and 2002. PISCO has been studying the rocky shores of Oregon and California since 1998, with particular emphasis on two inner-shelf sites at 44.3ºN and 45 N. COAST included repeated sections off Cascade Head and across Heceta Bank during the summer of 2001 to study wind-driven transport across the Oregon shelf.

Most presentations were oral, but there were also a few poster papers. Oral papers were arranged (as much as possible) to proceed from the simpler physical phenomena to the most complex biological phenomena (Table 2). Presentations addressed a wide range of space scales, ranging from strictly local observations at moorings to basin-wide fields of winds and sea surface elevation. Regional aspects were addressed by Gatien et al., Huyer et al., Wheeler, and Bograd et al., who together presented results from Line P (which extends from the Strait of Juan de Fuca to the central Gyre of Alaska), from the GLOBEC LTOP program off Oregon, and from the CalCOFI program off southern California. Large-scale aspects were addressed by Strub et al. (satellite altimeter data) and by Bograd et al., (large-scale sea-surface temperature and wind fields). Local aspects were addressed by Barth and Hales (physical and chemical measurements over Heceta Bank), and by Kosro, Hickey and Ramp (current observations from radar and moorings).

Ecosystem consequences were discussed by Thomas & Brickley (chlorophyll fields), and by Peterson & Feinberg (biweekly sampling off Newport), by Fox (benthic fauna), and by Grantham, Nielsen and Chan (inner shelf enrichment & hypoxia).

Several posters complemented oral presentations, repeating some results and providing more evidence for others. Two posters were independent of any oral presentations: Fleischbein et al. showed maps of fluorescence based on data from underway sampling during LTOP surveys off Oregon. Huyer et al. provided an update of their ongoing study of the ocean climate off Oregon.

Individual Abstracts (Ordered Alphabetically by Senior Author)

Temperature, salinity and fluorescence over Heceta Bank (Talk)
Jack Barth, Tim Cowles and Steve Pierce
The Heceta Bank region has been sampled each year from 1999 through 2002 through a combination of NOPP (1999), GLOBEC NEP (2000 and 2002) and CoOP (2001) field programs. Heceta Bank widens the continental shelf off central Oregon (43.8-45.0N) to about 60 km from a narrower (25 km) shelf to the north and south. Towed undulating vehicle and shipboard ADCP measurements have been made along several E-W lines on the Bank over these years: 44.652N (GLOBEC Mesoscale Line 1 = Newport Hydrographic Line) ; 44.475N (Line 2), 44.25N (Line 3; near PISCO Strawberry Hill nearshore site) and 44.0N (Line 4 = Heceta Head Hydrographic Line). Vertical sections of temperature, salinity, chlorophyll fluorescence and velocity along these lines over the years will be presented. The deflection of the equatorward upwelling jet around the Bank and the formation of a high-chlorophyll, sometimes warm, pool inshore on the Bank will be demonstrated. T/S diagrams will be used to examine year-to-year variability and to highlight the anomalous conditions (low temperature halocline) during 2002. In addition to vertical sections made with SeaSoar, a few vertical profiles made with a CTD/rosette equipped with an oxygen sensor were made in this region during these same years. The hypoxic conditions observed in the lower water column over the Bank during 2002 are related to the hydrographic and chlorophyll fluorescence fields and are contrasted to normal oxygen levels of previous years.

[No figures provided.]

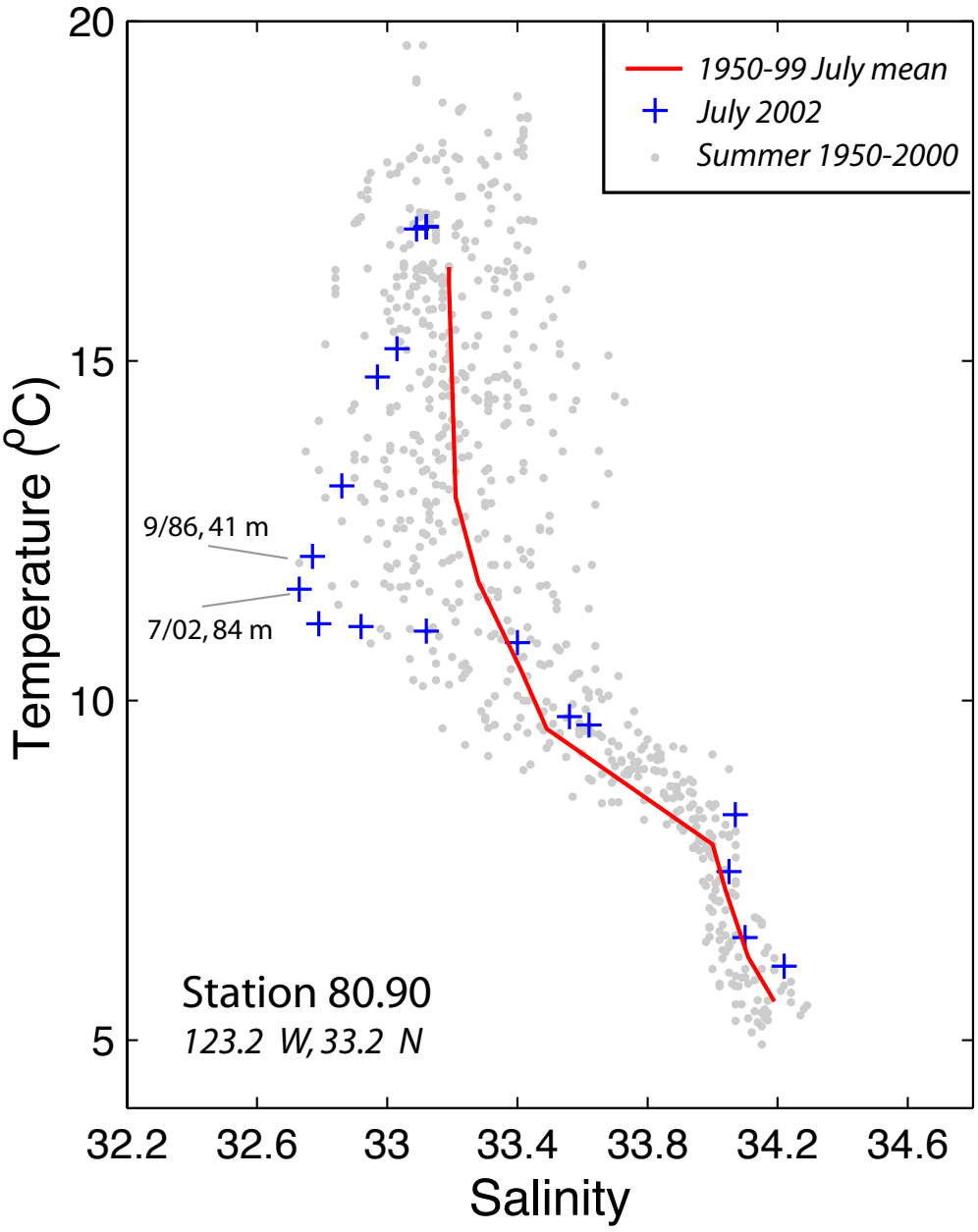
Hydrographic Conditions in the Southern California Current System and Large-Scale Forcing Conditions in Summer 2002 (Talk)

Steven J. Bograd, Franklin B. Schwing, Tom Murphree, Ronald J. Lynn

We describe anomalous water property observations from the southern California Current System (CCS) during summer 2002 based on CalCOFI hydrography. An unusual feature characterized by low spiciness and high oxygen was confined to a narrow ribbon within the core of the California Current in the July 2002 CalCOFI survey. This appears to be the same feature observed in the northern CCS during the concomitant LTOP and Line P surveys. The feature off California was approximately 100 km wide and 50 m thick, and centered a few hundred km offshore within the 60-110 m depth range. Some stations recorded the lowest summer temperatures and salinities observed at this depth in the 50-year CalCOFI record. We use *in situ* and satellite data to record the biological response to this feature. The large-scale atmospheric and oceanic conditions in the northeast Pacific prior to and during summer 2002 were similar to those from the previous three years. Coastal upwelling was anomalously strong, particularly off northern California and Oregon, and SSTs were 2-4°C below normal. In addition, an offshore region of unusually warm SST expanded toward the coast during summer 2002, confining the cool anomalies nearshore. A possible result of these conditions may have been greatly enhanced primary production that was contained over the continental shelf and slope. These patterns also imply an enhanced equatorward transport, displacing low spiciness water throughout the CCS.

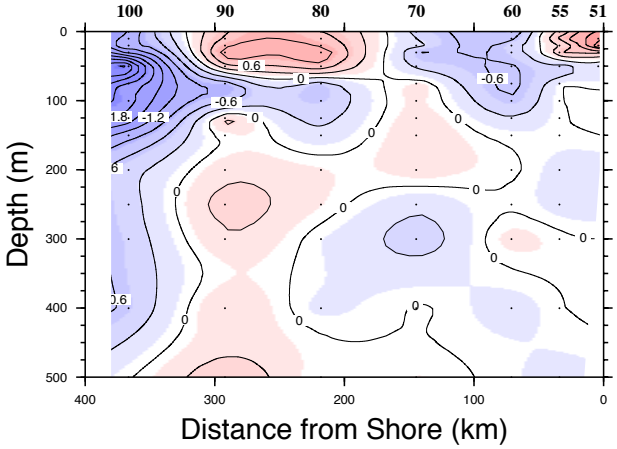
[Six figures are reprocuced on following pages]

Station 80.90 --- T-S plot

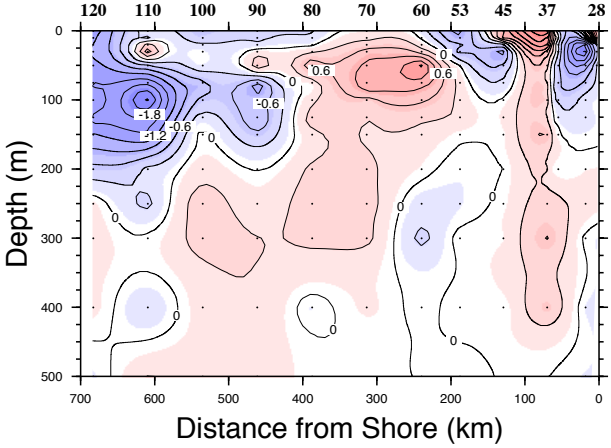


July 2002 CalCOFI Anomalies

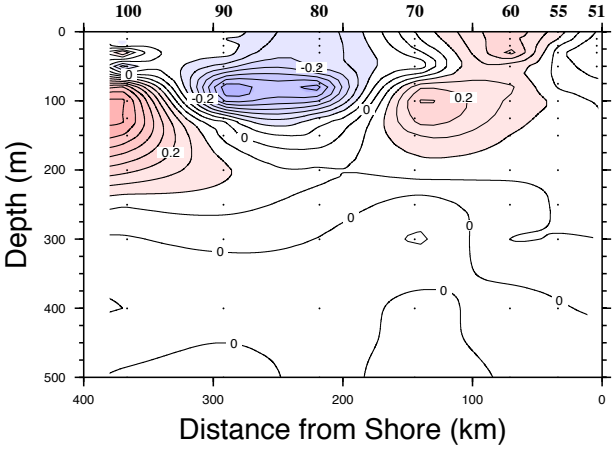
Line 80 -- Temperature Anomaly



Line 90 -- Temperature Anomaly



Line 80 -- Salinity Anomaly



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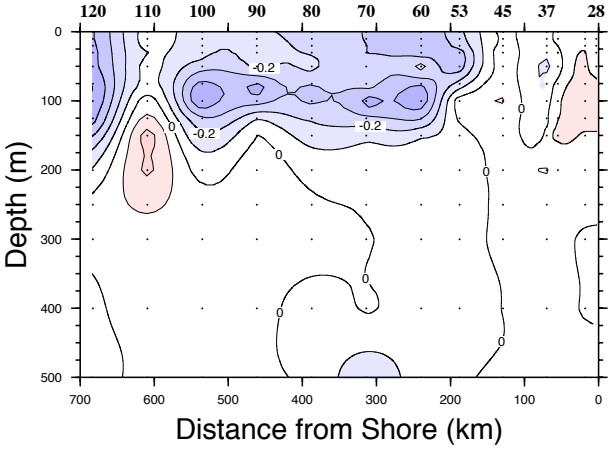
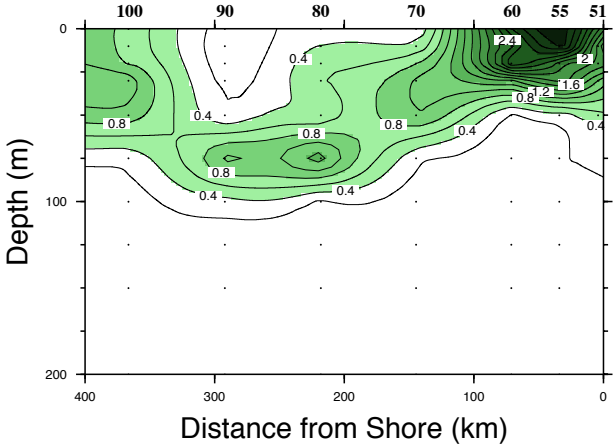
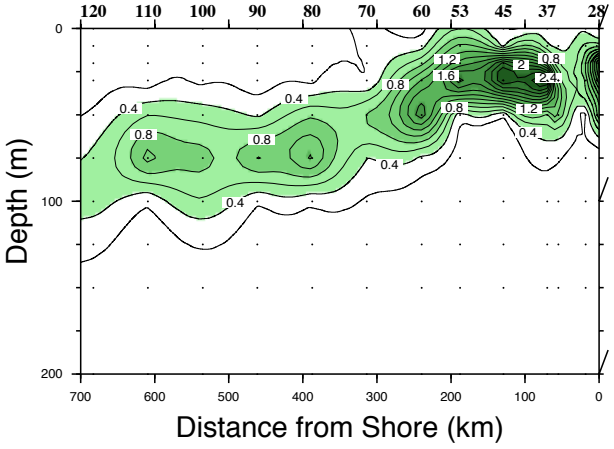


July 2002 CalCOFI Anomalies

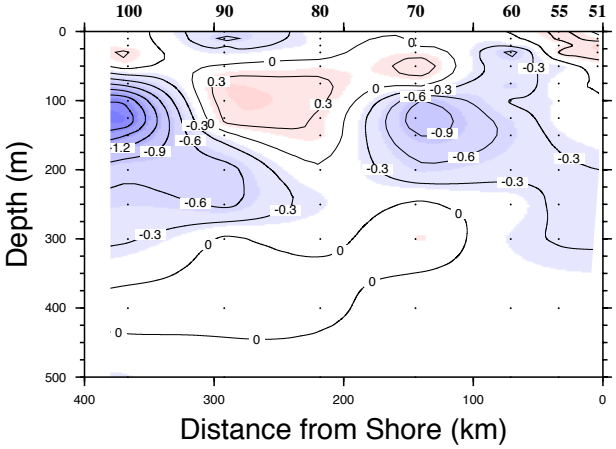
Line 80 -- Fluorescence



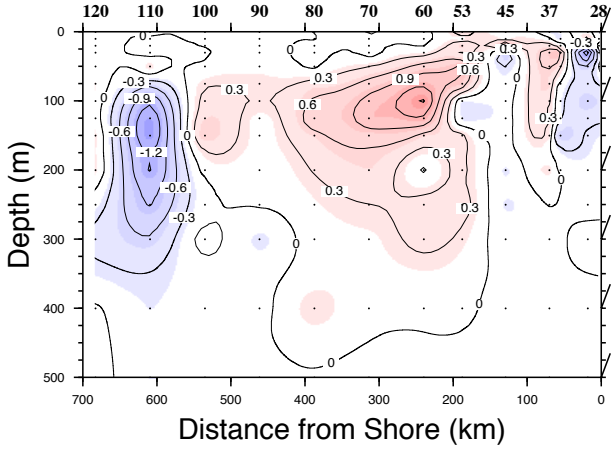
Line 90 -- Fluorescence



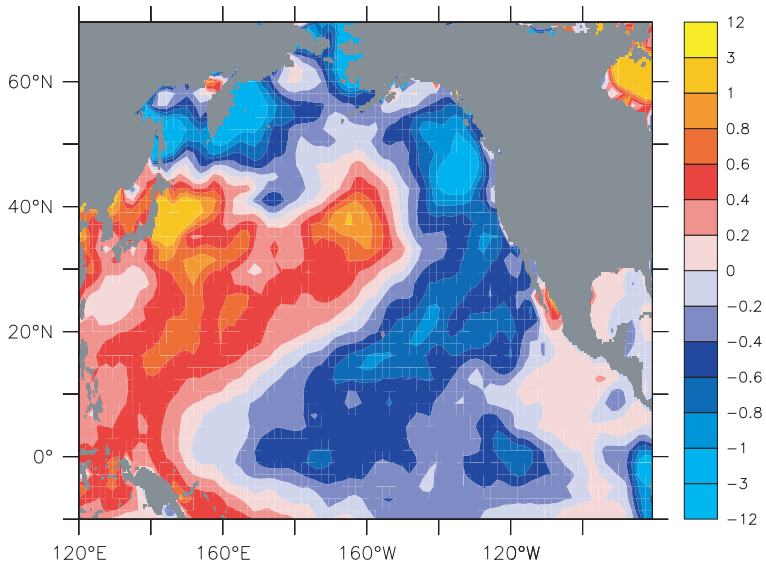
Line 80 -- Oxygen Anomaly



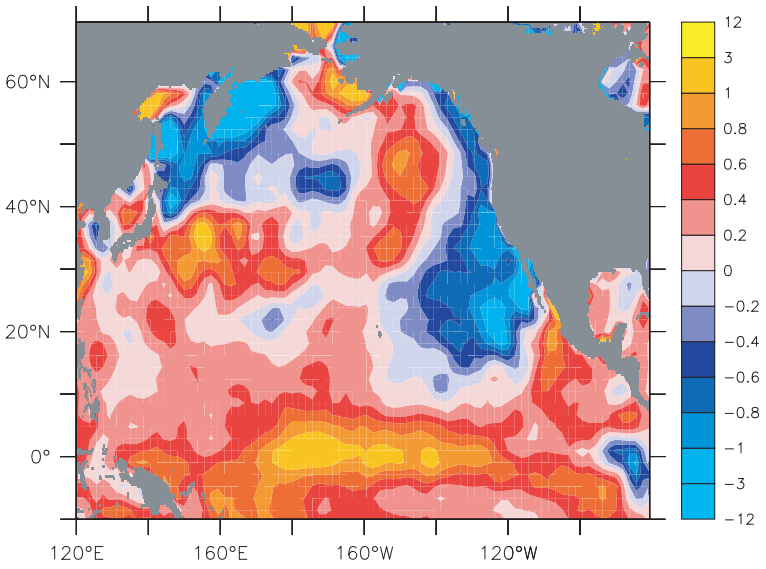
Line 90 -- Oxygen Anomaly



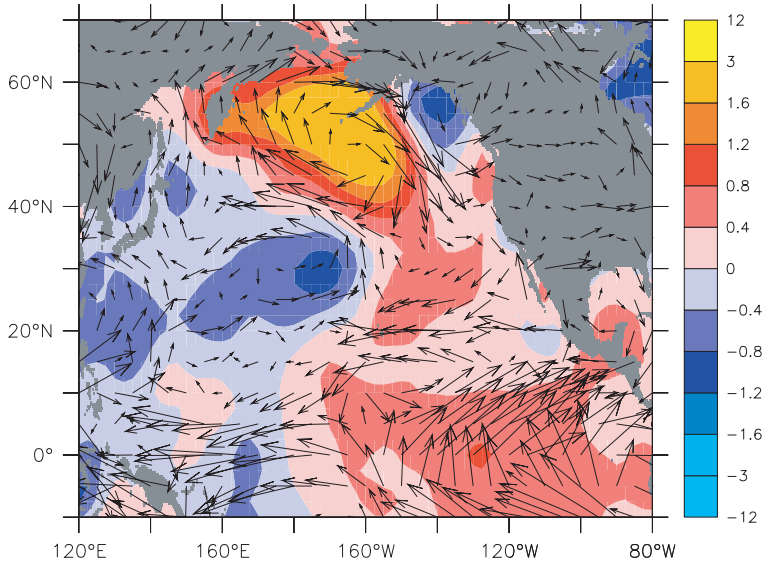
Summer 1999-2001 (May-Aug)
Sea Surface Temperature Anomaly



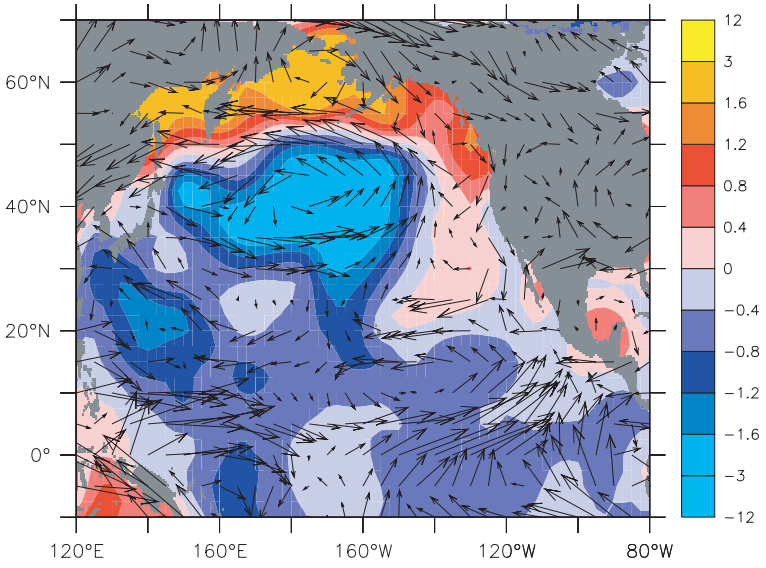
Summer 2002 (May-Aug)
Sea Surface Temperature Anomaly



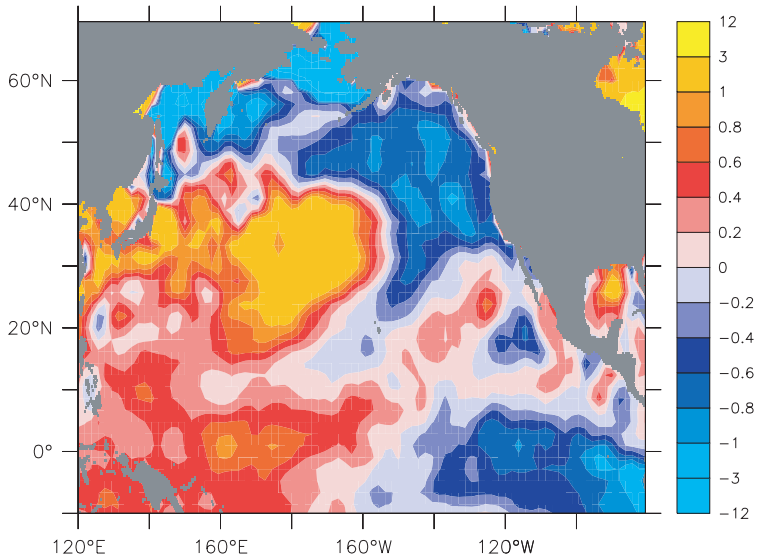
Summer 1999-2001 (May-Aug)
Sea Level Pressure Anomaly
With Vector Wind Anomaly Overlay



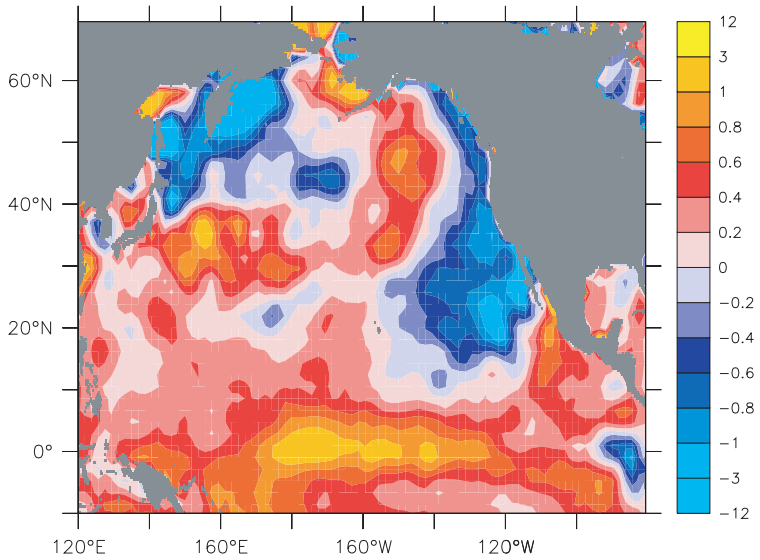
Summer 2002 (May-Aug)
Sea Level Pressure Anomaly
With Vector Wind Anomaly Overlay



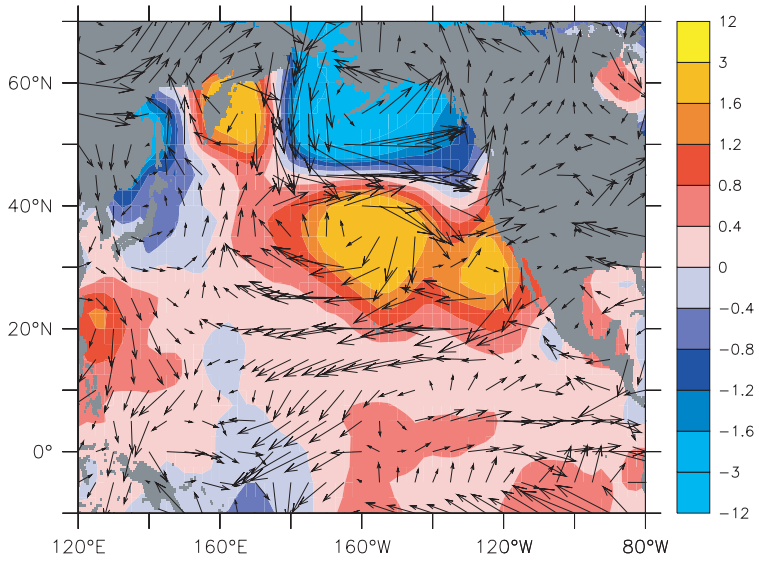
Winter 2001-2002 (Nov-Feb)
Sea Surface Temperature Anomaly



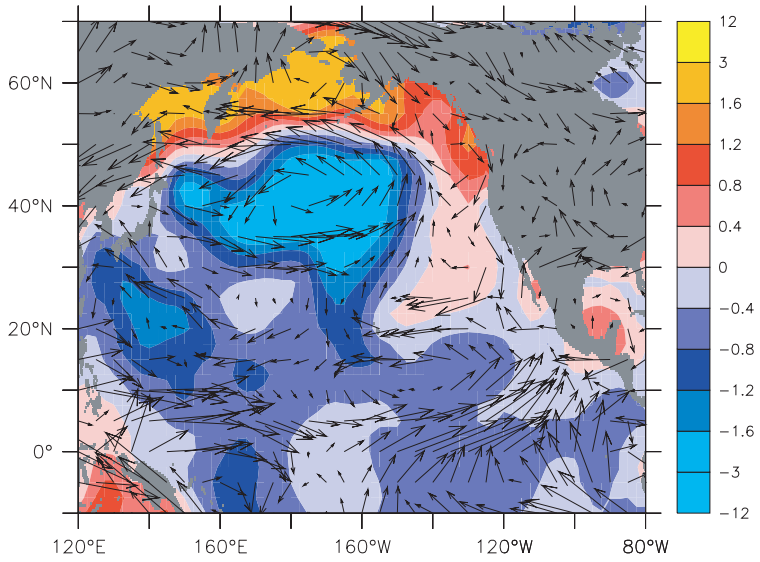
Summer 2002 (May-Aug)
Sea Surface Temperature Anomaly



Winter 2001-2002 (Nov-Feb)
Sea Level Pressure Anomaly
With Vector Wind Anomaly Overlay



Summer 2002 (May-Aug)
Sea Level Pressure Anomaly
With Vector Wind Anomaly Overlay



Summary

- **The Large-Scale Environment, 2001-2002**

  --> Still within a cool regime (?)
  --> Strong convergence at WWD, winter 2001-02
  --> Anomalous $\mathscr{H}$ shifted northeast, summer 2002
  --> Strong upwelling, El Niño development, summer 2002

- **Summer 2002 Anomalies in the Southern CCS**

  --> Anomalously cool, fresh waters within offshore ribbon, on offshore CalCOFI grid
  --> High productivity within anomalous waters, low oxygen below
  --> Importance of monitoring:
  (1) coherence within the CCS
  (2) appreciation of anomalies

Enhanced Fluorescence in the Northern California Current System, July 2002

Jane Fleischbein, Adriana Huyer and Robert L. Smith

Underway measurements of fluorescence, temperature and salinity data from the ship's 5-m intake during GLOBEC LTOP surveys off central and southern Oregon show much higher values of fluorescence in July 2002 than in July 2001 and July 2000 (Figures 1, 2), though both of these were also La Nina years during a cold phase of the Pacific Decadal Index. Salinity values were higher in July 2001 than the preceding and following years, presumably because of the drought in the winter of 2000-01. Temperature differences among the three years are relatively subtle.

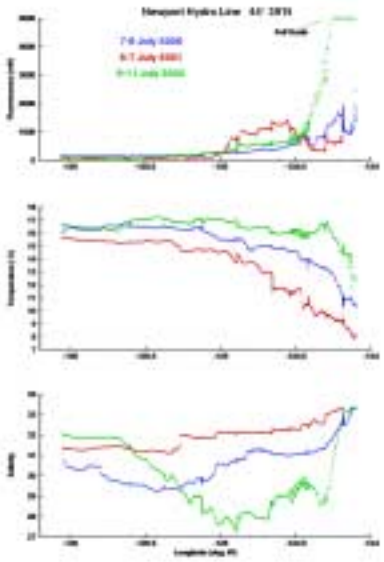


Figure 1. Offshore profiles of near-surface fluorescence along the NH-line measured continuously by Turner fluorometer from the ship's 5-m intake.

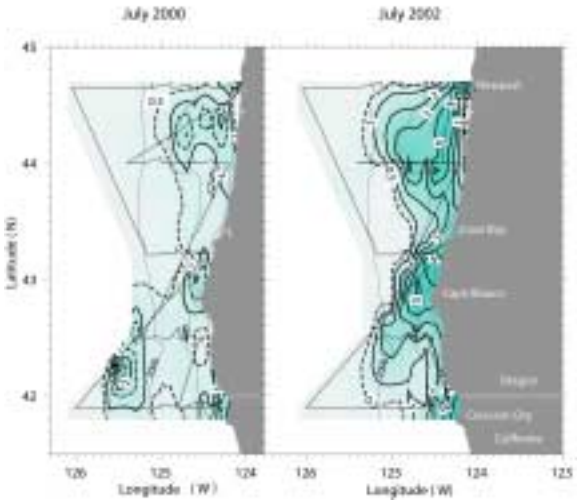


Figure 2. Maps of near-surface fluorescence along the NH-line measured continuously by Turner fluorometer from the ship's 5-m intake.

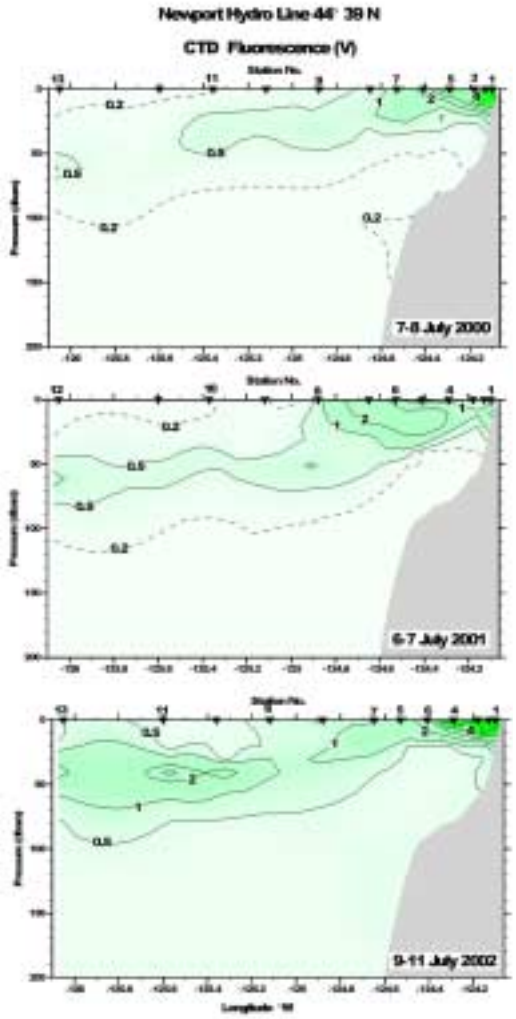


Figure 3. Subsurface fluorescence voltage along the NH-line measured by a SeaTec fluorometer on the CTD/rosette.

The 2002 sub-arctic intrusion off the coast of Vancouver Island

Extended Abstract: From Germaine Gatien, Institute of Ocean Sciences
(GatienG@pac.dfo-mpo.gc.ca)
With assistance from Howard Freeland and Frank Whitney.

After Jane Huyer informed us during the summer of 2002 of a possible sub-arctic intrusion in the Newport Line data we examined conditions along Line-P. There was a survey along Line-P extending over the end of June and the beginning of July, the TS-curve shown in red. The blue lines are all TS curves from Line-P surveys at this station since it was first included in Line-P surveys. The station MP3 is deeper than the Newport Line station 25, nominal depth 800 metres or so, but is the first station seaward of the continental slope and so is the closest analogue to NH-25.

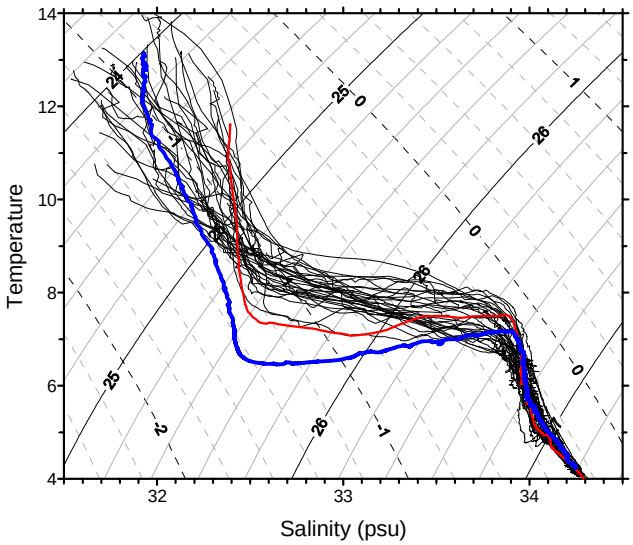


Figure 1: TS Profiles from Line-P station 3 on the continental slope off Vancouver Island. The background curves are sigma-t and "spiciness" contours.

This shows that we are seeing the same type of behaviour as was brought to our attention by Jane during the summer. In particular we see that the recent survey lies completely outside the envelope of all previous observations at this station, which is really rather surprising. As shown in Figure 2 below, the highly anomalous water lies roughly between depths of about 25 metres and 125 metres.

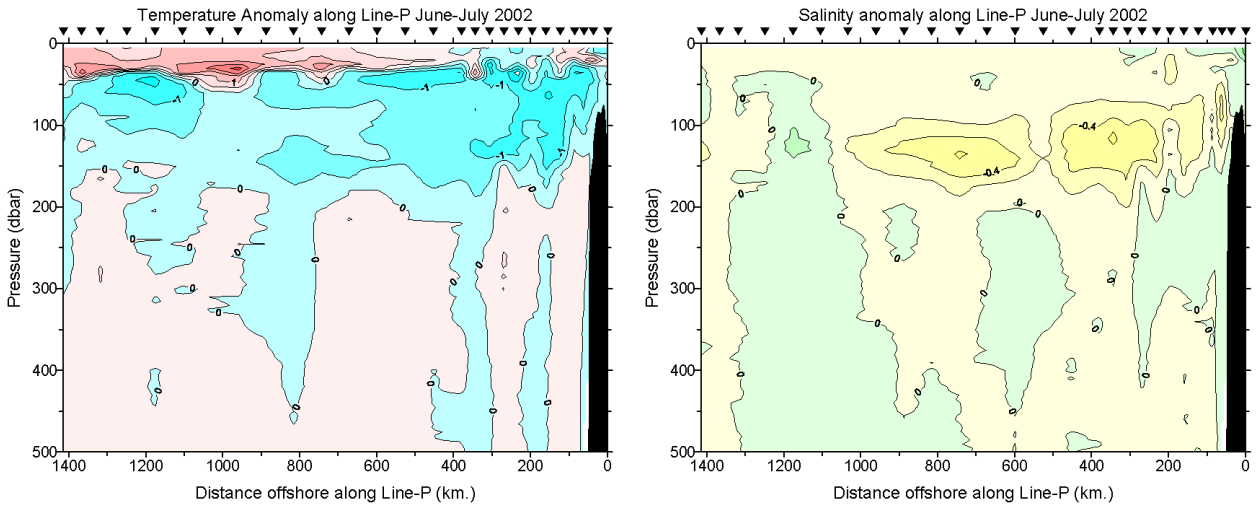


Figure 2: Temperature (left) and salinity (right) anomalies along Line-P during the survey that took place June-July 2002. Anomalies are computed relative to a climatology that uses observations from 1956 to 1999.

The plots of figure 2 suggest that a significant T and S anomaly is present between the continental shelf and a position roughly 1000 km offshore, near Line-P station 17. We have used observations from Argo floats to interpolate surveys along Line-P, the data are sufficient to create credible artificial Line-P surveys from June 2001 to the present time. These show the evolution of conditions during 2002. We conclude that though the major anomaly developed after March 2002, conditions were not entirely normal during 2001. Indeed the red TS curve on figure 1 does suggest that in June 2001 conditions were already tending towards the unusual. The plots also indicate that at the time of writing (November 2002) the anomaly is persisting along Line-P and perhaps even intensifying.

Repeated observations at a station called BI01 8 days apart during May 2002 shows evidence of some very rapid changes with temperature dropping by up to 1°C. The changes are also evident at station P4 where we also see a significant increase in Si:NO_3 and dissolved oxygen concentrations (Fig. 3) in the anomaly. Such changes also suggest intrusion of subarctic waters into the region. A higher Si:NO_3 ratio favours diatom populations which provides favourable conditions for energy transfer to higher trophic levels. Chlorophyll levels were very high during our August surveys (up to 19 ug/L on the shelf) and diatoms were a large part of the phytoplankton population.

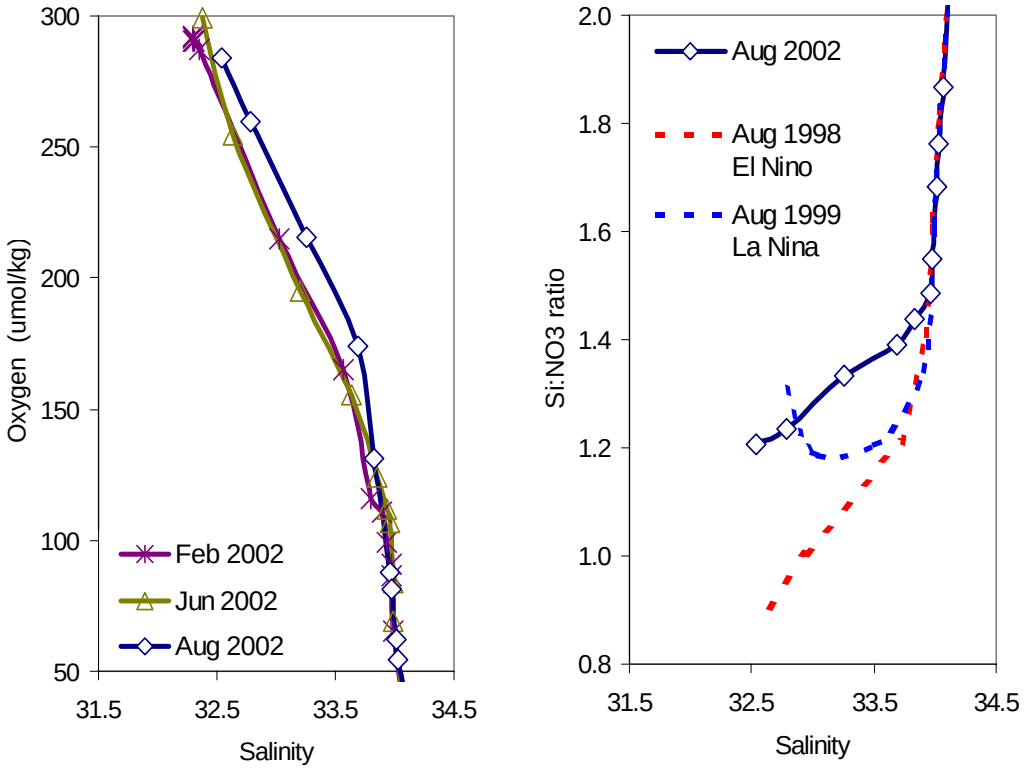


Figure 3. Oxygen levels and ratios of Si:NO_3 vs salinity at Station P4 on the continental slope

Hypoxia and enrichment of inshore waters at 44.3N (Talk)
Brian A. Grantham, Karina J. Nielsen, and Francis Chan (all at Oregon State University)

On July 10, 2002 Oregon Department of Fish and Wildlife (ODFW) scientists conducting an annual ROV survey of rockfish and rockfish habitat found only dead fish and invertebrates on a previously well- populated rocky reef near Cape Perpetua. Shortly thereafter, commercial crab fishermen began pulling up crab pots filled with dead rockfish, crabs and other invertebrates and dead fish washed up on local beaches. During the same period scientists from the College of Oceanic and Atmospheric Sciences at Oregon State University measured unusually low oxygen water within 10 km of shore on the Newport and Cape Perpetua survey lines. Based on these observations, the hypoxic zone was estimated to cover more than 700 km2. Following these reports, researchers from the Partner- ship for Interdisciplinary Studies of Coastal Oceans (PISCO) at OSU began repeated sampling of temperatures, conductivity, nutrients, chl-a, and dissolved oxygen along a cross-shore transect near the site of the ODFW observations (34.3N). Four transects extending from depths of 8-65 meters were occupied between July 19 and September 5, 2002. On all transects a layer of hypoxic (<1.4 ml O2/l) water 10-20 meters thick was observed along the bottom. This hypoxic water extended into water as shallow as 8 meters. Elevated nitrate concentrations (30-35 uM) were coincident with this layer. Bottle samples revealed the presence of extremely high chlorophyll a levels, with our most nearshore samples exceeding 220 ug/l on the August 12 transect. Further data from PISCO moorings deloyed from April--September and located along the transect lines indicate the persistent presence of very cold, saline water bottom layer and high chlorophyll a concentrations beginning near the estimated start time of this event. These temperatures were colder and the salinities and fluorescence measurements from these moorings were among the highest observed at this location over the past five years. It is hypothesized that an influx of anomalously cold, saline water with high nutrient concentrations, and perhaps lower-than-normal dissolved oxygen levels, fueled extremely high productivity on the inner shelf, leading to increased decomposition rates that depleted oxygen concentrations to hypoxic levels. It is estimated that these conditions persisted for at least 2 months. This is the first documentation of a hypoxic zone and associated die-off in shallow waters off the Oregon coast.

[No figures provided].

Cold halocline and Hypoxia in the northern California Current

Adriana Huyer, Robert L. Smith and Jane Fleischbein
(College of Oceanic and Atmospheric Sciences, Oregon State University)

Subsurface upper ocean waters off Oregon were about 1ºC cooler in July 2002 than in July 2001 (Fig. 1) when temperatures and salinity values were near normal. The anomalously cool layer coincides with the permanent halocline which has salinities of 32.2 to 33.8 (Fig. 2, 3), and this suggests an invasion subarctic waters. The anomalously cool halocline lies at 50-180 m deep offshore, and intersects the sea surface in the seasonal coastal upwelling front (Fig. 4). The cool anomaly is likely caused by stronger southward flow in the California Current and weaker northward flow in the Alaska and Davidson Currents during spring 2002. Other contributing factors may include reduced coastal downwelling in late winter and early spring 2002, enhanced eastward flow in the subarctic Current, and enhanced winter mixing.

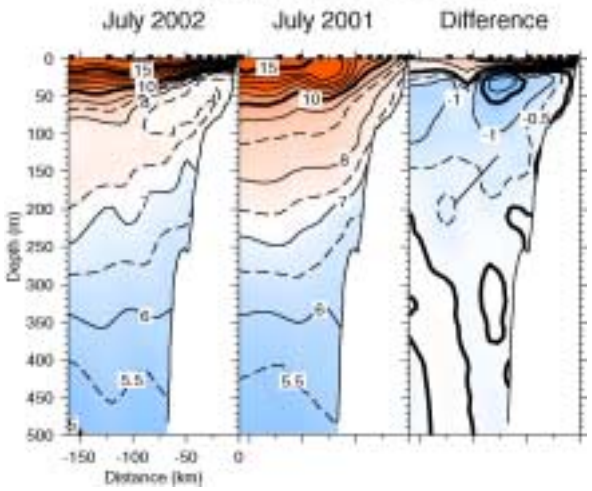


Figure 1. Temperature in July 2002, July 2001 and the difference (2002 minus 2001) along the NH-Line at 44.65 N off central Oregon.

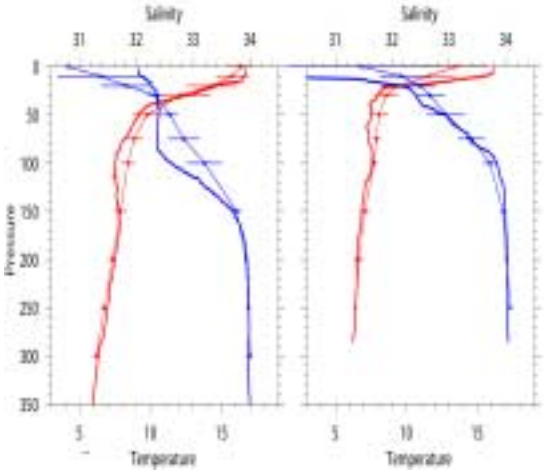


Figure 2. Temperature and salinity profiles at NH-85 (157 km from shore, left) and at NH-25 (over the shelf-break, 46 km from shore, right).

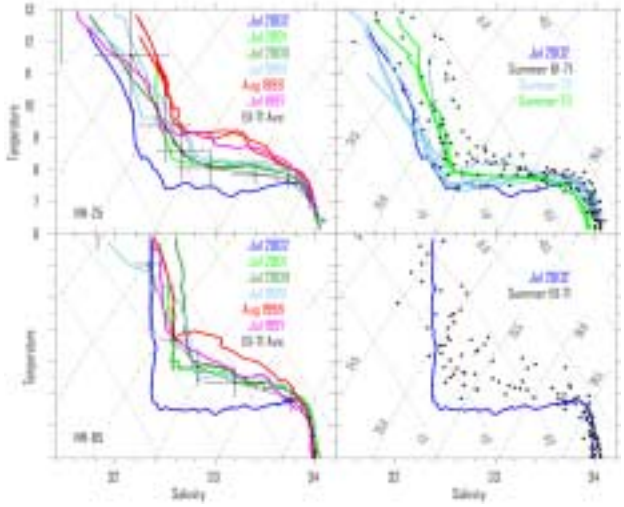


Figure 3. T-S curves at NH-25 (top) and NH-85 (bottom) compared to recent years (left) and to historical data from 1961-1973 (right).

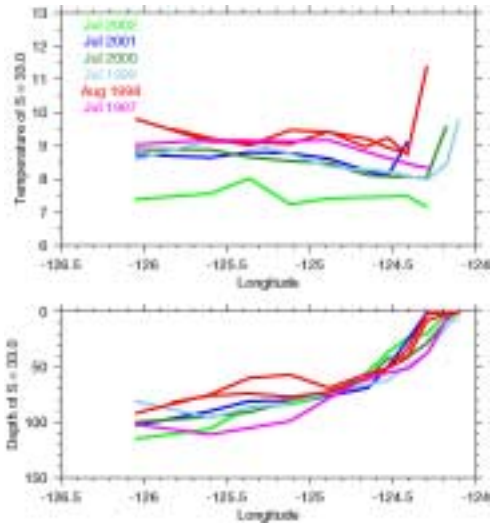


Figure 4. Offshore profiles of temperature and depth of the surface whose salinity is 33.0, along the NH-Line,summers 1997-2002.

During our July 2002 GLOBEC LTOP cruise, we also noticed the presence of very low values of dissolved oxygen in the near bottom waters over the continental shelf: these values were less than 1.0 ml/l (Fig. 5). Very low values of dissolved oxygen are normal at depths below 300 m over the continental slope, but we know of no prior observations of values this low over the mid-shelf and inner shelf off Oregon.

Plotting oxygen concentration versus salinity (Fig. 6) shows that low values of oxygen at the inner-shelf stations occur at a lower salinity than those at offshore stations. This indicates these values are not just the result of vertical advection, but instead must have been modified somehow after upwelling. The very high (supersaturated) values of oxygen in the near-surface layer at the inshore stations indicate very high primary productivity there. We think it likely that respiration of this enhanced plankton biomass contributed to the hypoxic waters near the bottom.

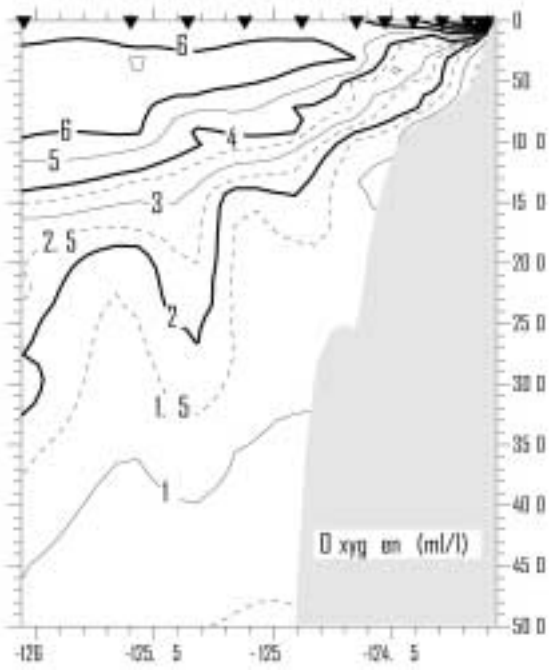


Figure 5. Dissolved oxygen concentration (ml/l) along the NH-Line, July 2002.

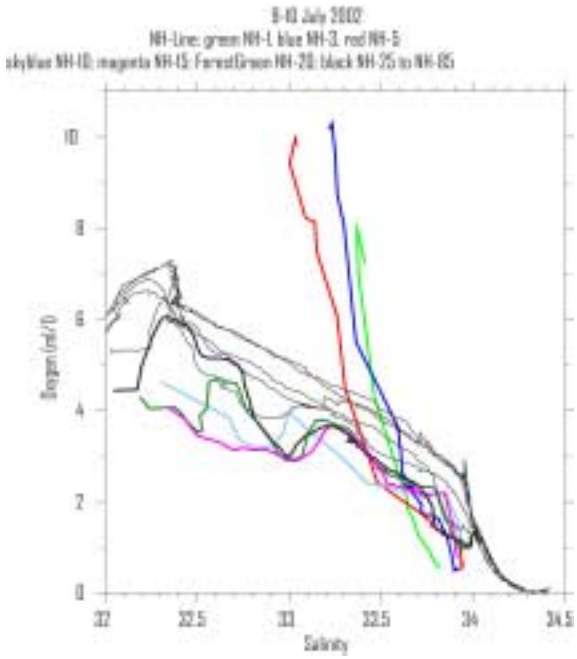


Figure 6. Dissolved oxygen concentration versus salinity, for individual stations along the NH-line, July 2002. Colored curves are for stations over the continental shelf.

Oregon Ocean Climate Update, Nov 2002 (Poster)
Adriana Huyer, Robert L. Smith, Jane Fleischbein (COAS, Oregon State University)

As part of the GLOBEC NEP Long Term Observation Program (LTOP) in the northern California Current system, the Newport Hydrographic (NH-Line) has been sampled five times per year since July 1997. The poster showed 26 vertical sections of temperature, salinity and geostrophic velocity. Also shown were the normalized temperature anomaly (difference from 1961-71 seasonal average divided by 1961-71 seasonal standard deviation) for each section, and T-S curves at NH-25 (over the shelf-break). Figures 1-3 show the temperature, normalized temperature anomalies along the NH-line for the LTOP cruises between January 2001 and September 2002. Striking features in the 2002 sections are: very cool subsurface waters over the shelf and shelf-break in summer; a cool anomaly in the upper halocline in spring and summer (April, July and September); a cool surface layer in late winter (February) and early fall (September); and warm near-bottom water at the shelf-break in September. The cool halocline waters are likely advected from the Subarctic Pacific. The warm anomaly at the shelf-break is likely an early signal from El Niño 2002-3 in the Equatorial Pacific Ocean.

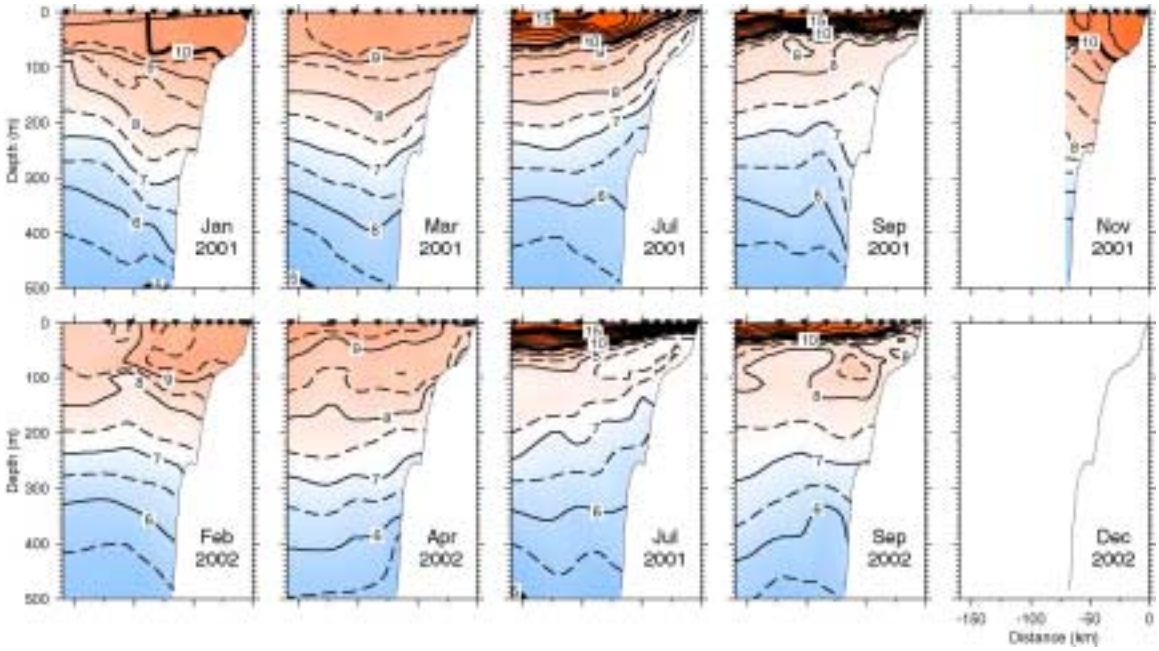


Figure 1. Temperature along the NH-line off central Oregon, 2001-2002.

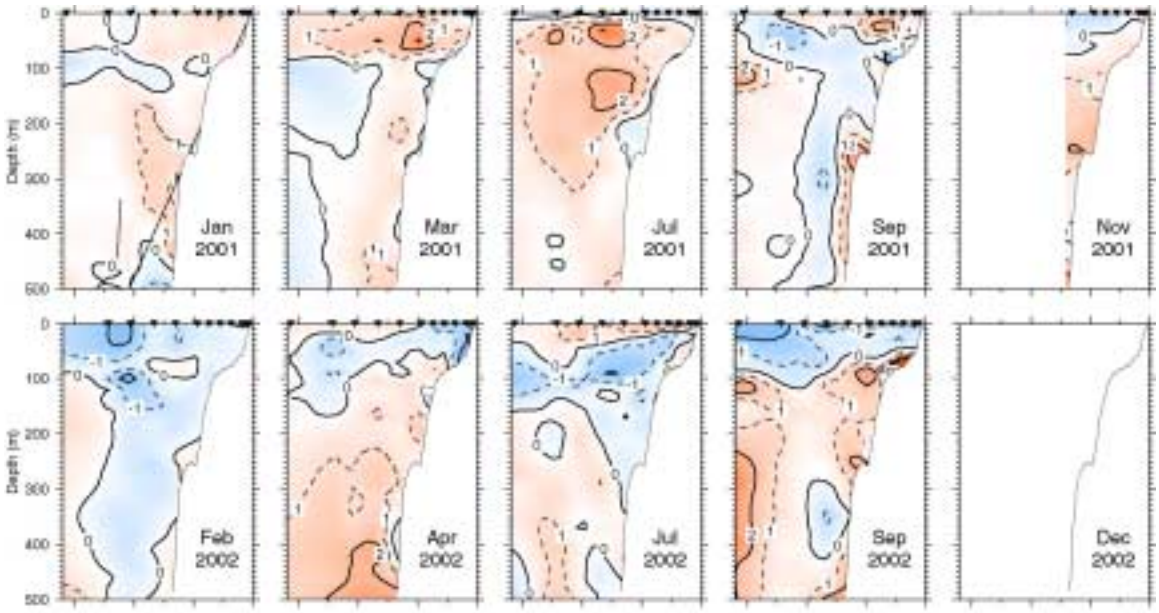


Figure 2. Normalized temperature anomaly along the NH-line off central Oregon.

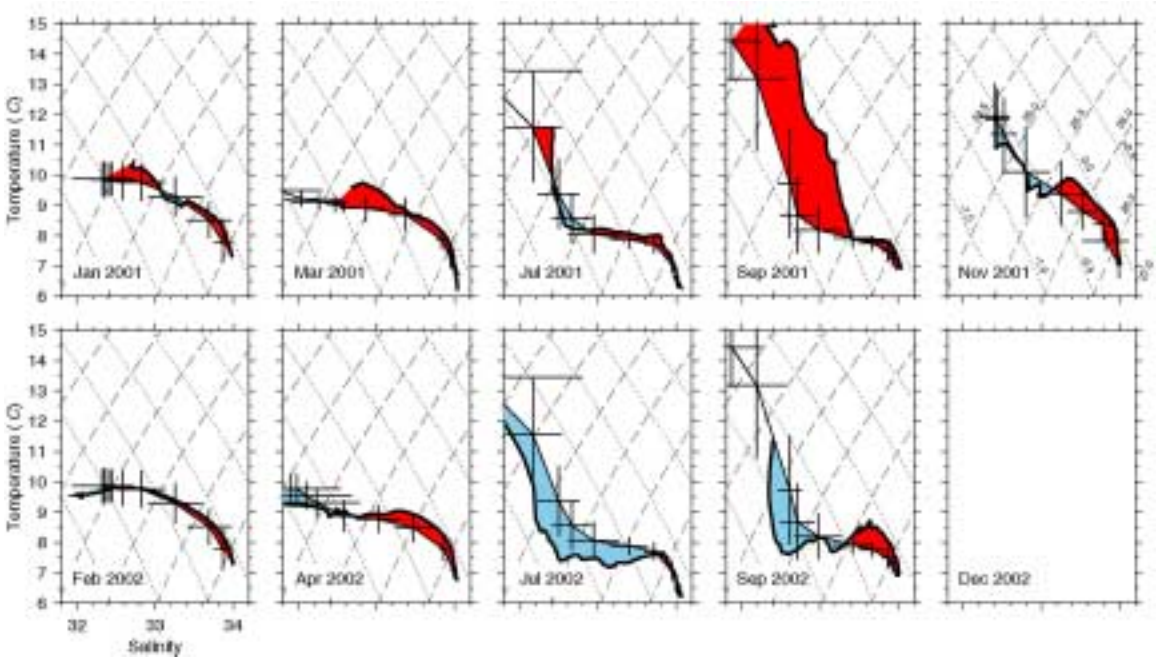


Figure 3. T-S characteristics at NH-25 (over the shelf-break).

Temperature, salinity and advection from time-series measurements off Oregon
Mike Kosro

A current mooring has been maintained at NH-10 since July 1997, and long time series of currents, temperature and salinity are now available. The current data have been used to calculate 5-yr daily averages, and to estimate the seasonal cycle by fitting annual and semi-annual harmonics (Figure 1), and to calculate daily values of current anomalies. Figure 2 shows that there was a tendency for current anomalies to be negative during late windter and spring 2002. Figure 3 shows the cumulative affect of the anomalous currents amounts to a net anomalous southward displacement of about 1400 km of near-surface waters between January 1 and July 1. Figure 4 shows that the spring and early summer cumulative displacement for 2002 was much stronger than in each of the three preceding La Niña years.

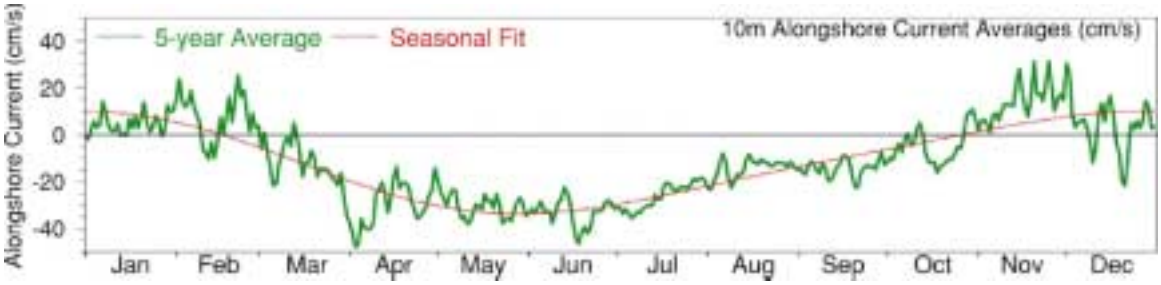


Figure 1. Five-year daily mean values of the along-shore current, and the seasonal cycle estimated by fitting annual and semi-annual harmonics .

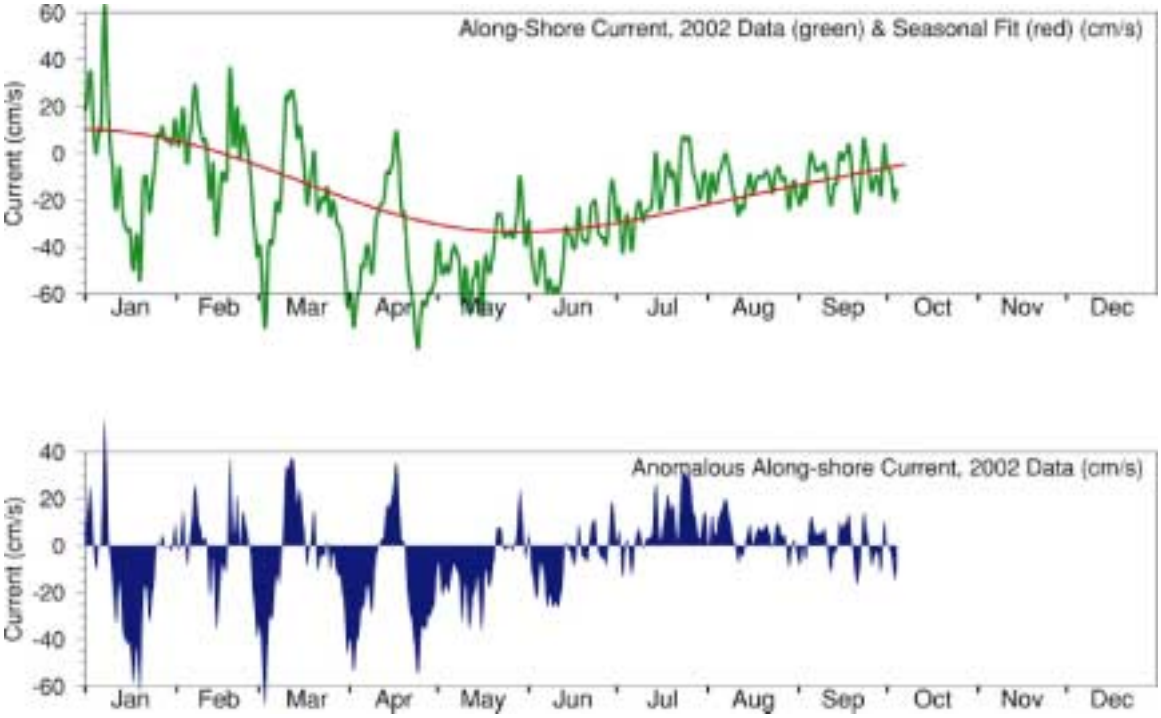


Figure 2. Alongshore currents and current anomalies for 2002, at 10 m depth, NH-10, relative to the 5-year seasonal cycle.

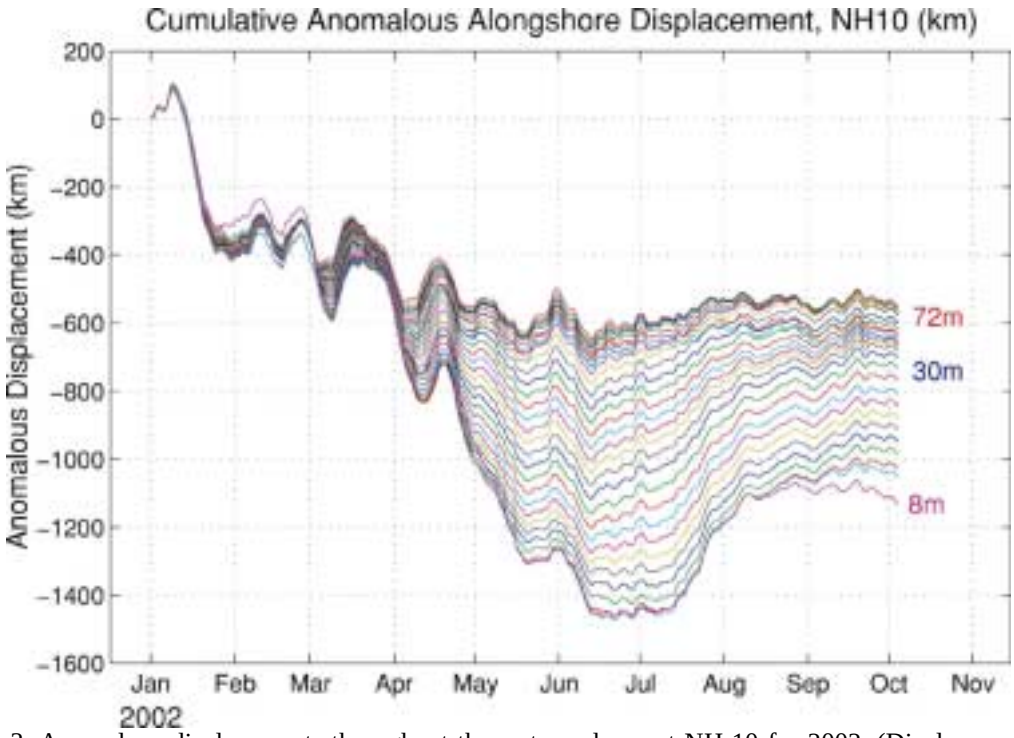


Figure 3. Anomalous displacements throughout the water column at NH-10 for 2002. (Displacements are the time integral of alongshore current anomalies beginning on 1 January 2002

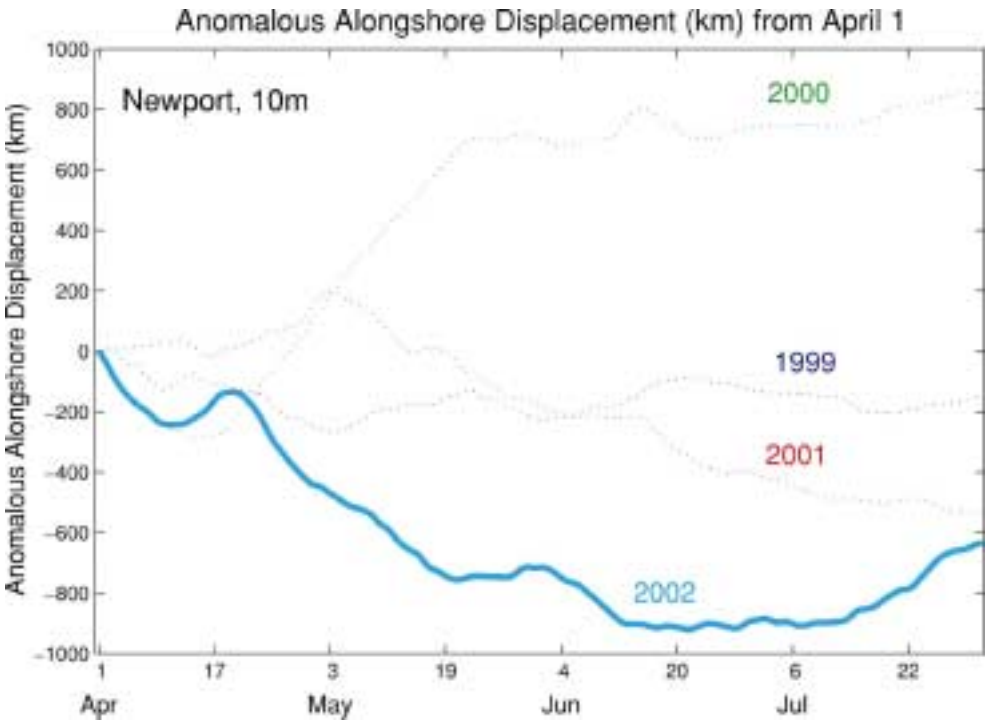


Figure 4. Anomalous displacements at 10 m depth, NH-10, for spring and early summer, 1999-2002. (Displacements are the time integral of alongshore current anomalies beginning on 1 April of each year).

Interannual variations in the seasonal cycles of temperature, salinity, chlorophyll and zooplankton biomass and species composition on the Newport Line 1996-2002: was summer 2002 different from the other summers?

Bill Peterson[1] and Leah Feinberg[2]
[1]National Marine Fisheries Service
[2]Cooperative Institute for Marine Resource Studies
Hatfield Marine Science Center
Newport OR

Introduction. We have been sampling the Newport Line since May 1996 on cruises conducted biweekly at several shelf stations. Others who have been sampling to the south of Newport on Hecate Bank near Cape Perpetua during summer 2002 noted the occurrence of low oxygen water as well as fish kills at several stations. Due to this unusual event, we examined our data for evidence of unusual hydrographic conditions or unusual chlorophyll or zooplankton concentrations. Here we show data both from the Newport line collected during our biweekly trips as well as data collected on the southern Hecate Bank during a GLOBEC 2002 Mesoscale cruise.

Figure 1 shows for our NH 5 station (five miles off Newport) that the deep water (sampled at a depth of 50 m) was somewhat unusual during the summer of 2002 in that we had several sampling dates in which the water was a bit warmer and fresher than "normal". The dates when the warm-fresh water was observed were 9, 20 May and 3, 23 July and 30 August. At the time of this writing, the CTD data from the August Mesoscale cruise were not yet available to determine if the warm-fresh water persisted through all of August. Water of normal temperature-salinity (approx 7 deg C and 33.9 salinity units) was seen during the first Mesoscale cruise (6-17 June, and on 9 July).

Figure 2 shows all of our chlorophyll data collected at NH 5 since 1997. It is clear from that chlorophyll concentrations reach very high levels only during summer and autumn (June-October) with maxima ranging between 10 and 20 micrograms chl-a per liter. There is no evidence for any great enhancement of chlorophyll during summer 2002 off Newport at NH 5.

Figure 3 shows chlorophyll concentrations along the Hecate Head and Cape Perpetua (Bob Creek) lines as sampled during the two mesoscale cruises. During three of the four cruises, chlorophyll was always higher on either Hecate or Bob Creek lines than off Newport. Highest values were seen in August.

Table 1 lists chlorophyll data from the August mesoscale for the 10 highest ranked stations. 8 of the 10 stations were on southern Hecate Bank, usually along the HH-line. Values are approximately double those usually observed off Newport.

Date	Station	Sampling Depth	Chlorophyll concentration
8-19-02	NH 5	1.7 m	20.0 µg per liter
8- 2-02	Bob 4	12 m	20.2 "
8-12-02	4A-3	12 m	20.6 "
8- 9-02	NH 5	1.3 m	20.8 "
8-17-02	HH 2	8.5 m	23.3 "
8-12-02	4a-3	1.8 m	23.3 "
8-11-02	HH-3	12.3 m	24.7 "
8-17-02	HH-2	1.7 m	34.2 "
8-11-02	HH-3	1.1 m	34.8 "
8-11-02	HH-3	7.7 m	36.3 "

Figure 4 shows the copepod biomass at NH 5 for 2002 in comparison with a 7-year climatology. The climatology is based on monthly averages of samples taken over the period 1996-2002 at this station. An unusual pattern emerged from this analysis. Copepod biomass began to decline after the first week of June and declined through July. By the end of July, copepod biomass began to recover and reached values comparable to the 7-year climatology by September. Most of the decline in biomass was due to a decline in numbers of the dominant species, *Pseudocalanus mimus*.

Discussion. Water that was slightly warmer and fresher was present on the shelf off Newport during much of the summer of 2002. The degree to which this was correlated with high chlorophyll on southern Hecate Bank is not known. We also do not know if the unusually low copepod biomass is related to the warmer-fresher water. We do know though that copepod biomass was reduced by half or more during June and July, a phenomena that could have led to a reduction in grazing pressure. Lower grazing pressure could explain the enhanced levels of chlorophyll. As for a reason why copepod biomass was reduced, we suggest that this was due to the unusually high numbers of jellyfish present in Oregon's coastal waters during summer of 2002. Others within our group have since determined that the jellies eat copepods and euphausiid eggs (C. Suchman, personal communication), therefore we make the very tentative suggestion that the reduction in copepod biomass was due predation by jellyfish. Moreover we suggest that the jellyfish caused a trophic cascade in that by eating the copepods, they reduced copepod biomass significantly such that grazing pressure was reduced and phytoplankton biomass increased to very high levels. A second contributing factor is that the largest phytoplankton biomass was seen over southern Hecate Bank, a region widely-believed to be highly retentive with long residence times relative to the northern Bank such as off Newport. If significant portions of the "bloom" on the southern Bank sank to the bottom, the decay of dead phytoplankton could have contributed to reduced levels of oxygen in the bottom waters.

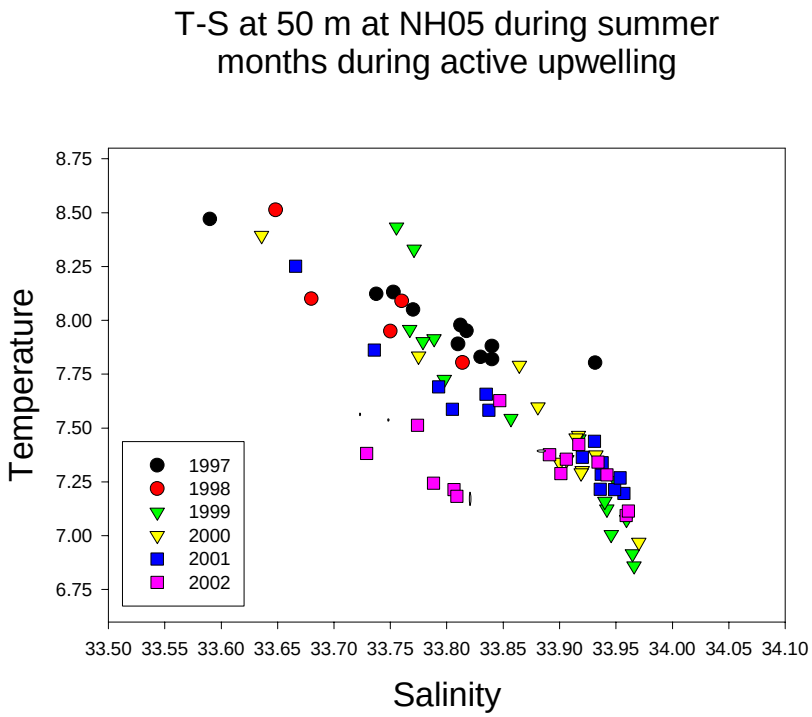


Figure 1.

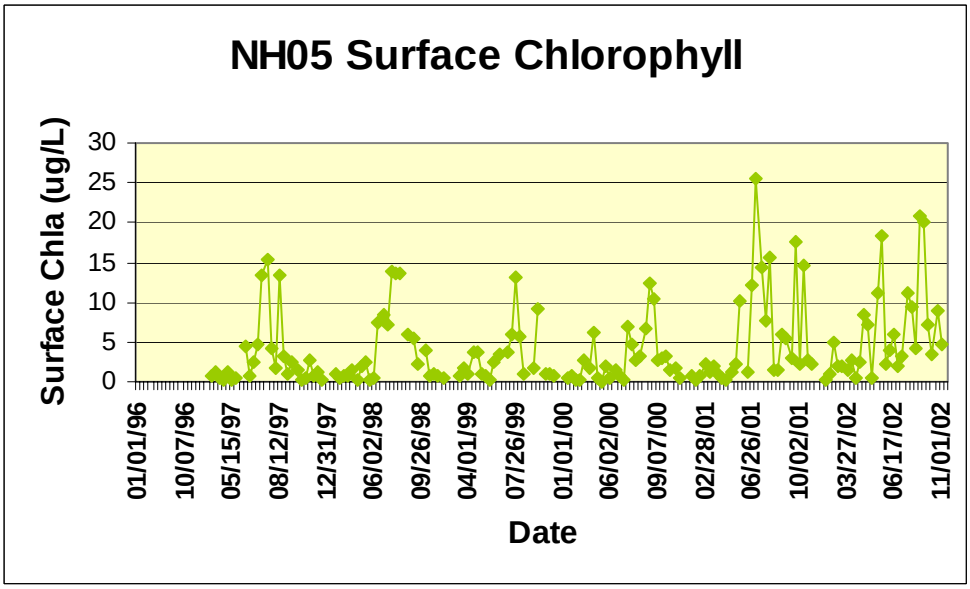


Figure 2.

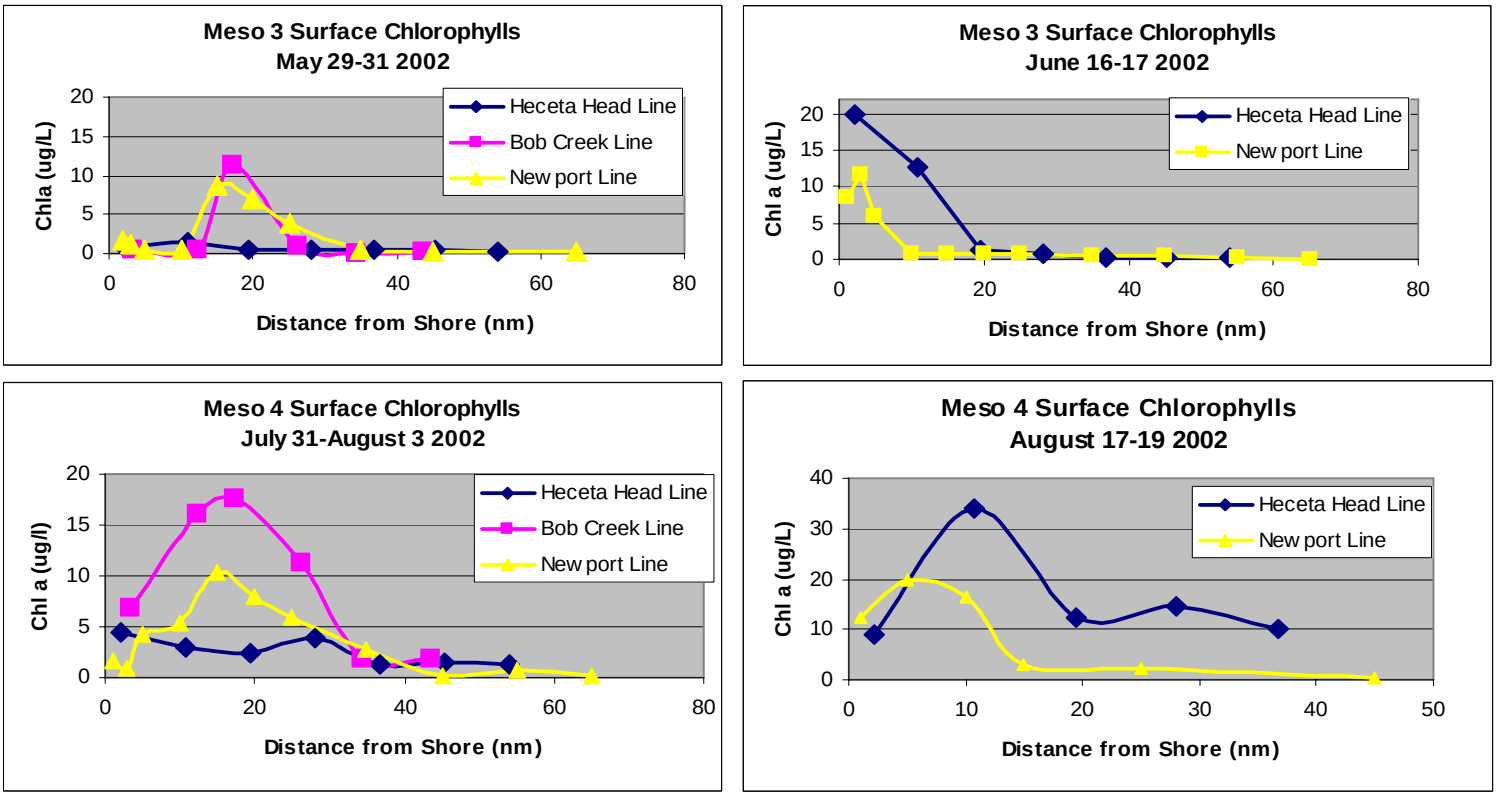


Figure 3.

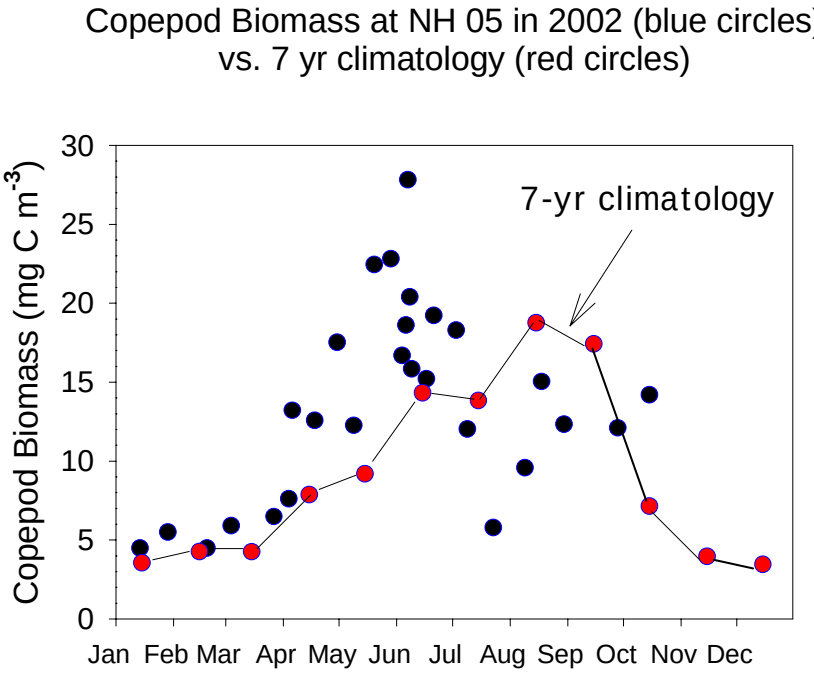


Figure 4.

Cold, Fresh Halocline South of Cape Blanco?

Steve Ramp and Fred Bahr
(Department of Oceanography, Naval Postgraduate School, Monterey, CA 93943)

The currents, temperature, and salinity at the Rogue River mooring site were compared for the "summer" period (May to October) 2000, 2001, and 2002 to examine the regional extent of the anomalous conditions off the Oregon coast. The overlaid low-passed temperature time series appear event-driven and don't exhibit any particular long term trend. Temperatures did appear lower during most of July 2002 by about 0.5 C (eyeball estimate) than July 2000 or 2001. The corresponding salinities were not anomalously fresh except during two events which can clearly be identified as across-shore excursions of warm, fresh water from offshore (see poster). Monthly averages were computed to reduce the event-by-event character of the records. The monthly mean temperatures were cooler than previous years during May, June, and July at all depths but returned to near-normal in August and September. The deltas at 22, 35, and 66 m were 0.8, 0.6, and 0.4 C respectively. The alongshore near-surface currents were anomalously equatorward in 2002 by about 5 cm s^{-1} (-15 vs. –10 cm s^{-1}) during May, June, and July but poleward by a similar value during August. The deeper currents were not significantly different from year to year. The T-S plots for the three years formed overlapping envelopes at 22 and 35 m. At 66 m, the water colder than 7.5 C was saltier during 2002 by about 0.1 psu. As an aside, we note that solitons observed at 22 m provide an indication of the true surface temperature and salinity above, allowing the extremes during the "fresh events" to be observed. These are waves of depression at this site off Oregon and push the surface water down to the 22 m depth as they pass by.

[No figures received.]

Anomalous Transports into the California Current as Seen in Cross-Track Altimeter Surface Velocities (Talk/Poster)

Ted Strub, Andrew Thomas and Corinne James

After the 1997-1998 El Niño, oceanic conditions along the Pacific Northwest (PNW) changed in a number of ways: oceanic temperatures were generally cooler and sea surface heights (SSH) were lower, while zooplankton distributions revealed an increase in boreal species. However, calculations of surface transports, made using altimeter SSH data, did not reveal a simple increase in equatorward flow along the coasts of BC and the PNW that would indicate equatorward transport of cooler water and boreal zooplankton species. While surface water was cooler, the water mass properties in the pycnocline approximately 100m deep) during 1999-2001 were similar to historical values during non-El Niño periods (Jane Huyer, personal communication). During July 2002, however, temperatures in the pycnocline off Oregon became anomalously cold and fresh, while nutrients became anomalously high (Jane Huyer, Pat Wheeler, personal communication). Colder pycnocline temperatures were also observed along Line P, off Vancouver Island (Howard Freeland and Frank Whitney, personal communication), implying a source farther north for the pycnocline anomalies. In this presentation, we extend the analysis of altimeter-derived surface transports and satellite estimates of surface chlorophyll concentrations to determine whether these satellite-derived fields can detect an increase in equatorward flow into the PNW during the first half of 2002, or an anomalous increase in chlorophyll concentrations in the PNW by summer.

[No figures received.]

Interannual variability of surface chlorophyll concentrations in the California Current (1997-2002): the broad-scale satellite view (Talk/Poster)

Andrew Thomas and Peter Brickley

A five year time series of monthly composite SeaWiFS images over the California Current (Sept 1997 - Aug 2002) shows the large-scale patterns of interannual variability in surface chlorophyll concentrations. Inspection of the time series of concentrations as well as cross-shelf distributions show that seasonal cycles were relatively regular and similar over the period 1999 - 2001, with differences apparent in both 1997-98 and in 2002. A 12 month climatological seasonal cycle was formed using the 3-year period 1999-01 and anomalies of the entire time series calculated from these. The anomaly time series is dominated by maxima during two periods. Low anomalies through most of the California Current were present during the first year, strongest off Oregon and Central California, weakest and actually positive off Baja. These are associated with the end of the 1997-98 El Nino event. Strong positive anomalies off the Pacific Northwest are present in the time series beginning in May 2002. An EOF decomposition of the dominant patterns shows these elevated concentrations extend from at least northern Vancouver Island (50N) to Point

Conception, strongest in the Pacific Northwest. Cross shelf profiles highlight these anomalous concentrations at specific latitudes. Figures 1 and 2 show the time-longitude distributions of chlorophyll concentration and chlorophyll anomalies off Newport, Oregon.

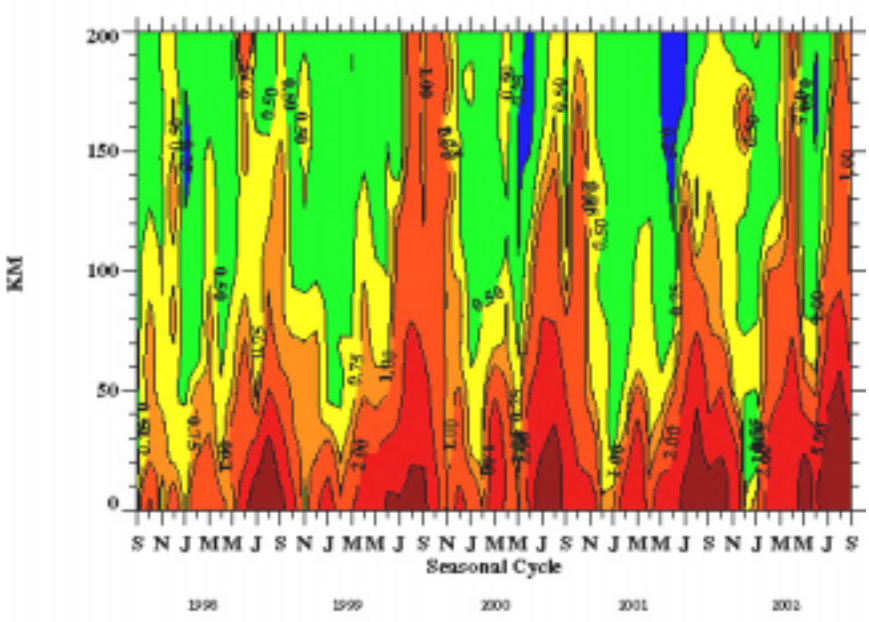


Figure 1. Chlorophyll concentration off Newport, Oregon, Sept 1997 to Sept 2002, Calculated from SeaWIFS data.

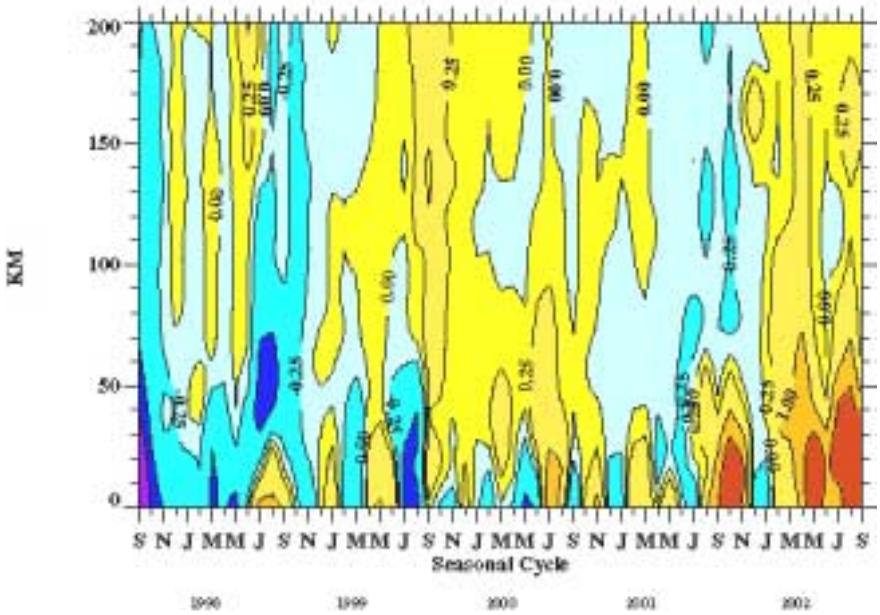


Figure 2. Anomalies of chlorophyll concentration off Newport, Oregon, Sept 1997 to Sept 2002, relative to a 3-year seasonal cycle (1999-2001), calculated from SeaWIFS data.

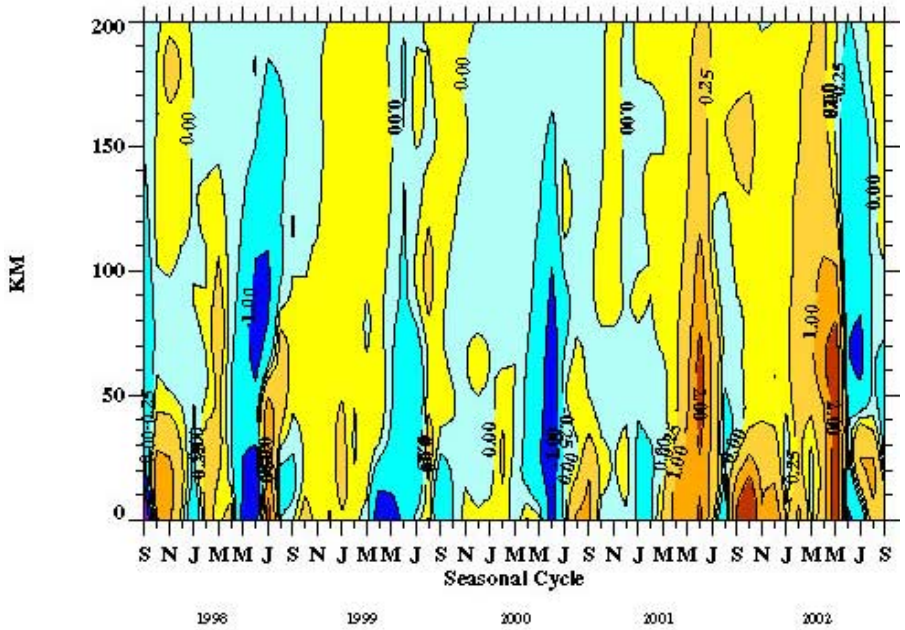


Figure 3. Anomalies of chlorophyll concentration off Cresent City, Oregon, Sept 1997 to Sept 2002, relative to a 3-year seasonal cycle (1999-2001), calculated from SeaWIFS data.

Nutrient enrichment and high fluorescence off Newport (44.65N)
Pat Wheeler

Hydrographic, chemical and biological sampling off Oregon has been carried out since 1997 as part of the NEP-GLOBEC Long-term Observation Program (LTOP). In 2002 the halocline water was about 1 C colder than usual and somewhat fresher. This talk will present some of the hydrographic data documenting the changes in temperature and then present the concentrations of the major nutrients in the halocline along the Newport line 44.65 N and along the Heceta Head line 44.00 N. Both transect lines show a substantial increase in nitrate, phosphate and silicate at 33 psu in 2002 compared to 1998-2001. Along the Newport line the increase in nutrients is greatest between 47 and 65 km offshore while along the Heceta Head line the greatest increases are between 37 and 53 km offshore with another increase at 100 km offshore. The halocline water is the source of upwelled nutrients and increases in nutrients are also seen closer inshore but appear to be more transient due to utilization by phytoplankton. Underway fluorescence levels during the summer of 2002 are higher inshore than observed in the preceding three years. The halocline waters are derived from the subarctic and significant temperature anomalies were also observed in 2002 along the Canadian P-transect. The cooler waters off Canada were also accompanied with increased nitrate levels. Estimates of primary production based on nutrient supply need to take into consideration the increased nutrient level in the upwelled water, any differences in intensity and frequency of upwelling, as well as diffusive fluxes across the nutricline between upwelling events. Our initial estimates indicate that productivity is at least four times greater during the summer of 2002 compared with the preceding five years. This change may be related to a weakening of the Alaska coastal current and a strengthening of the California Current.

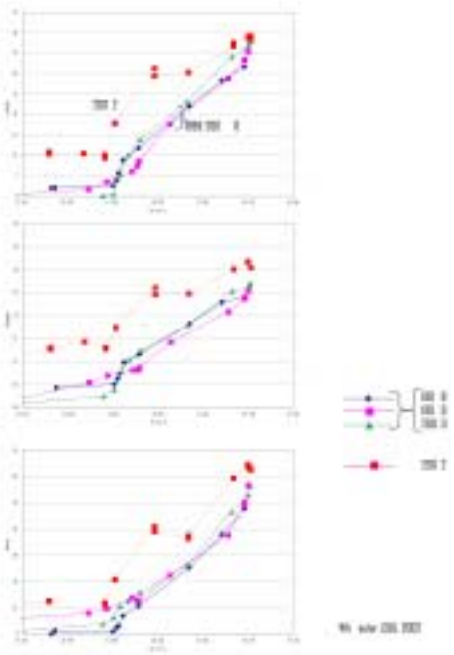
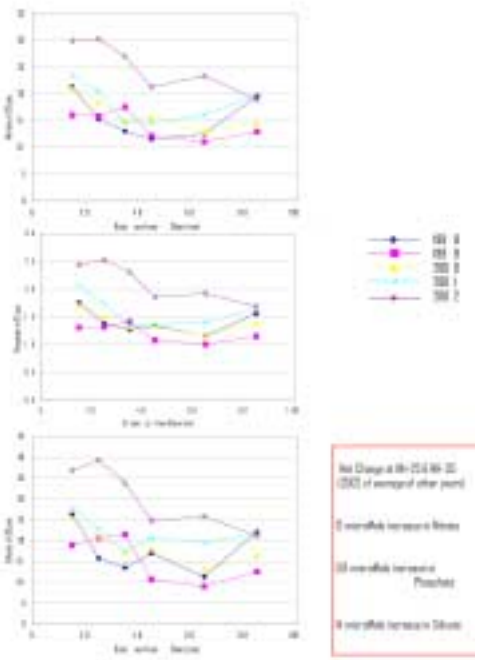


Figure 1.Nutrients vs salinity at NH-25 over the shelf-break off Newport.



Fiugre 2. Nutriest on the 33.0 isohaline in the halocline along the NH-line.

no abstract available for: Nutrients and pCO2 off central Oregon
Burke Hales

no abstract available for: Fish-kills and hypoxia of inshore waters at 44.3N
Dave Fox

no abstract available for: Summer 2002 conditions off Washington and southern Oregon
Barbara Hickey

no abstract available for: Chlorophyll, fluorescence and MODIS, summer 2002
Ricardo Letelier

Table 1. Authors of symposium presentations (oral and poster), by home institution.

Institute of Ocean Sciences	H.J. Freeland*, G. Gatien, F. Whitney*
Naval Postgraduate School	F. Bahr, T. Murphree, S. R. Ramp
Oregon State University	
College of Oceanic and Atmospheric Sciences	J. A. Barth, T. J. Cowles, J. Fleischbein, B. Hales, A. Huyer, C. James, P. M. Kosro, R. Letelier, R. L. Smith, S. D. Pierce, P. T. Strub, P. A. Wheeler
Department of Zoology	F. Chan, B. A. Grantham, K. J. Nielsen
Hatfield Marine Science Center	L. Feinberg, W. T. Peterson
Oregon Department of Fish and Wildlife	D. Fox
Pacific Fisheries Environmental Laboratoratory	S. J. Bograd, F. B. Schwing
San Francisco State University	N. J. Garfield*
Southwest Fisheries Center, La Jolla	R. J. Lynn
University of Maine,	P. Brickley, A. Thomas
University of Washington, Seattle	B. Hickey

*Results sent by proxy; unable to attend in person.

Agenda

Mini-Symposium: ***"Cold Halocline, Hypoxia and High Productivity off Oregon, 200***2"

Oral Papers

The cold halocline off Newport (44.65N) — Huyer & Smith

Nutrient enrichment and high fluorescence off Newport (44.65N) — Wheeler

The 2002 sub-arctic intrusion off the coast of Vancouver Island — Gatien, Freeland & Whitney

Hydrographic conditions in the southern CCS and large-scale forcing conditions during summer 2002 — Bograd, Schwing, Murphree & Lynn

Anomalous transports into the California Current as seen in cross-track altimeter surface velocities — Strub, Thomas & James

Temperature, salinity and fluorescence over Heceta Bank — Barth, Cowles & Pierce

Nutrients and pCO2 off central Oregon — Hales

Temperature, salinity, and advection from time-series measurements off Oregon — Kosro

Summer 2002 conditions off Washington and southern Oregon — Hickey

Cold, fresh halocline south of Cape Blanco? — Ramp& Bahr

Interannual variability of surface chlorophyll concentrations in the California Current (1997-2002): the broad-scale satellite view — Thomas & Brickley

Fish-kills and hypoxia of inshore waters at 44.3N — Fox

Hypoxia and enrichment of inshore waters at 44.3N — Grantham, Chan & Nielsen

Interannual variations in the seasonal cycles of temperature, salinity, nutrients, chlorophyll and zooplankton biomass and species composition on the Newport Line, 1996-2002: was summer 2002 different from the other years? — Peterson & Feinberg

Chlorophyll, fluorescence and MODIS, summer 2002 — Letelier

Independent Poster Papers

Enhanced Fluorescence in the Northern California Current System, July 2002 — Fleischbein, Huyer & Smith

Oregon Ocean Climate Update, Nov 2002 — Huyer, Smith & Fleischbein