

**Annual Report for Period:**01/2001 - 12/2001

**Submitted on:** 12/04/2001

**Principal Investigator:** Barth, John A.

**Award ID:** 9907854

**Organization:** Oregon State University

**Title:**

Collaborative Research: Coastal Ocean Advances in Shelf Transport (COAST)

### Project Participants

#### Senior Personnel

**Name:** Barth, John

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Allen, John

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Wheeler, Patricia

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Abbott, Mark

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Co-PI with R. Letelier on component to study phytoplankton physiology.

**Name:** Boyd, Timothy

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Co-PI with M. Levine and P. M. Kosro on mooring component of COAST.

**Name:** Caldwell, Douglas

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Co-PI with J. Moum on turbulence component of COAST.

**Name:** Cowles, Timothy

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Co-PI on bio-optical component of COAST.

**Name:** Desiderio, Russell

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Research Associate working with T. Cowles on bio-optics component of COAST.

**Name:** Hales, Burke

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Co-PI working on macronutrient component of COAST.

**Name:** Kosro, P

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Co-PI with M. Levine and T. Boyd on mooring component of COAST.

**Name:** Letelier, Ricardo

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Co-PI with M. Abbott on phytoplankton physiology component of COAST.

**Name:** Moum, James

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Co-PI with D. Caldwell on turbulence component of COAST.

**Name:** Peterson, William

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

co-PI on zooplankton component of COAST.

**Name:** Pierce, Stephen

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Research Associate working with J. Barth on hydrographic, velocity, bio-optical and bioacoustic mapping component of COAST.

**Name:** Samelson, Roger

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Co-PI on atmospheric and oceanic modeling components of COAST.

**Name:** Spitz, Yvette

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Co-PI working with J. Allen on ecosystem modeling component of COAST.

**Name:** Levine, Murray

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Co-PI working on mooring component of COAST.

**Name:** Pegau, Scott

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Assistant Professor involved with bio-optics data collection and analysis. Supported by this grant.

**Name:** Dale, Andrew

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Research Associate involved with pilot dye tracking experiment. Supported by this grant and by OSU funds.

**Name:** Erofeev, Anatoli

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Research Associate involved with microstructure from SeaSoar (MicroSoar) data collection and analysis. Supported by this grant.

**Name:** Kurapov, Alexandre

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Research Associate involved with physical circulation modeling and data assimilation.

**Post-doc****Name:** Gan, Jianping**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Postdoc working with J. Allen on ocean modeling component of COAST.

**Name:** Perlin, Alexander**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Postdoc working with J. Moum and D. Caldwell on turbulence component of COAST.

**Name:** Bielli, Soline**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Postdoc working with R. Samelson on atmospheric modeling component of COAST.

**Name:** Karp-Boss, Lee**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Postdoc working with P. Wheeler on characterizing particulate and dissolved organic material as part of COAST.

**Name:** Klymak, Jody**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Postdoc working on microstructure profiler data collection and analysis. Supported by this grant.

**Name:** Ott, Michael**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Postdoc involved with microstructure from SeaSoar (MicroSoar) data collection and analysis. Supported by this grant.

**Name:** Crouch, Scott**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Postdoc working on physical circulation modeling in the CoOP WEST project. Supervised by J. Allen at OSU.

**Name:** Perlin, Natalie**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Postdoc working with R. Samelson on atmospheric modeling.

**Graduate Student****Name:** O'Keefe, Sheila**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Graduate Student working with P.M. Kosro on mapping of surface currents by land-based radar as part of COAST.

**Name:** Eisner, Lisa**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Graduate student working with T. Cowles on bio-optics component of COAST.

**Name:** Bandstra, Leah**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Graduate student working on nutrients.

**Name:** Bosch, Jennifer

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Graduate student working on organic carbon and nitrogen.

**Name:** Castelao, Renato

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Graduate student working on physical circulation and hydrography. Supported by Brazilian government fellowship.

**Name:** Gunderson, Gunnar

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Graduate student working with J. Moum on microstructure.

**Name:** Howard, Cidney

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Graduate student working with T. Cowles on bio-optics.

**Name:** Sanders, Rachael

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Graduate student working with R. Letelier on phytoplankton physiology.

**Name:** Sutor, Malinda

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Graduate student working with T. Cowles on bioacoustic detection of zooplankton.

**Name:** Wetz, Mike

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Graduate student working with P. Wheeler on organic nitrogen and carbon.

### Undergraduate Student

**Name:** Boehland, Tiffany

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Undergraduate working on phytoplankton physiology.

**Name:** Harman, Jennifer

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Undergraduate working on organic carbon and nitrogen.

**Name:** Reser, Katie

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Undergraduate working on organic carbon and nitrogen.

### Research Experience for Undergraduates

## Organizational Partners

### **University of North Carolina at Chapel Hill**

John Bane is a co-PI on our COAST project. He is providing remote sensing and atmospheric measurements from a small plane. Dr. Bane will participate in the 2001 field experiment staged using OSU facilities.

### **Columbia University Lamont Doherty Earth Observatory**

Dr. Alexander van Geen is a co-PI on our COAST project. He is responsible for iron measurements. Dr. van Geen and his graduate student, Zanna Chase, will participate in the 2001 and 2003 field experiments using OSU research facilities.

### **Woods Hole Oceanographic Institution**

Kathleen Ruttenberg is investigating the role of phosphate in a coastal upwelling system. She is funded by her own NSF grant and participated in our 2001 field work.

### **Monterey Bay Aquarium Research Institute**

Zanna Chase is now a postdoc at MBARI after graduating from LDEO. She is responsible for the iron measurements during COAST. She, Kenneth Johnson (MBARI PI), Luke Coletti (MBARI technician) and Jack Barth collaborated on flying a spectrophotometer aboard SeaSoar for the detection of nitrate. The spectrophotometer was developed and built at MBARI.

### **Mote Marine Laboratory**

Gary J. Kirkpatrick used his DOC instrument during the 2001 R/V Thomas G. Thompson COAST cruises. His instrument provides a second independent optical measurement for DOC and we will be comparing both optical measurements to the direct chemical measurements of DOC.

## Other Collaborators or Contacts

Our project is one of two funded under the CoOP Northeast Pacific program. We have had extensive contact with the other project, Wind Events and Shelf Transport (WEST), headed up by John Largier at Scripps Institution of Oceanography. These include a meeting of the PIs at a CoOP Scientific Steering Committee meeting (May 2000), a visit to OSU by two WEST colleagues (April 2000) and a meeting of several COAST and WEST co-PIs at the Oct 2000 Eastern Pacific Ocean Conference. There have also been many email conversations between COAST and WEST co-PIs who are working on similar aspects under each project (e.g., zooplankton collection, modeling, etc.). The intent of the collaboration is to compare and contrast our results for two different wind-driven west coast shelf regions.

## Activities and Findings

### **Research and Education Activities:**

With the recovery of the moored array in late August, the summer 2001 Coastal Ocean Advances in Shelf Transport (COAST) field season came to a successful conclusion. Before the main field season we carried out two test cruises, one aboard R/V Wecoma in January when a new fiber-optic SeaSoar tow cable was successfully tested and one aboard R/V Thomas G. Thompson in March when the microstructure and pumped profilers were operated simultaneously. We started the main field season with an instrumented aircraft flight on 16 May, one of 27 flights throughout the summer, during the week of the moored array deployment. The field effort peaked during two intensive observation periods in May-June (early in the upwelling season) and August (late in the upwelling season) when two ships, R/V Wecoma and R/V Thomas G. Thompson, a coastal research vessel, R/V Elakha, and the instrumented aircraft all focussed efforts off the Oregon coast. Thousands of profiles measuring physical, biological and chemical properties were collected across the shelf and slope. Near real-time results were communicated between the ships, between ships and shore, and between a surface mooring and shore via cell phones and a shore-based web server. At the beginning of the second intensive observation period in August, we hosted an Open House with tours of the two large research vessels docked in Newport as they loaded for the COAST cruises. Over 500 people attended and learned about COAST, CoOP and OSU coastal research. The summer field season included nice examples of upwelling, flow-topography interaction and even a preview of our planned 2003 downwelling experiment when a remnant Pacific typhoon transited the study region in August packing 40 knot winds from the south. The COAST modeling efforts, both physical and ecosystem, continue and details are reported below. We are now concentrating on data processing, dissemination and analysis. Some preliminary results will be presented at the 2002 Ocean Sciences Meeting. Updates on COAST activities can be found at our web site (<http://damp.coas.oregonstate.edu>).

The following are short reports from the COAST subcomponents.

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The high-resolution survey component of COAST (Barth) successfully flew SeaSoar over the continental shelf and slope off Oregon during the two summer cruises. On each 21-day cruise we collected over 10,000 high-quality vertical profiles of physical (temperature, salinity, pressure), bio-optical (chlorophyll fluorescence, nine wavelengths of light attenuation and absorption - see Cowles' group summary) and microstructure parameters. At the same time, shipboard ADCP was used to measure water velocity and a towed, four-frequency bioacoustics package (HTI) recorded backscatter from zooplankton and larval fish. Other groups on the survey vessel measured nutrients (Hales), iron (van Geen/Chase) and zooplankton (Peterson). On each cruise we made repeated large-area maps roughly 150 km alongshore and 80 km offshore. Interspersed with these maps were fine-resolution studies centered around the two mooring lines and the cross-shelf transects occupied by the profiling vessel R/V Thomas G. Thompson. We also participated in a pilot dye tracking experiment during the August 2001 cruise to try and directly measure the cross-shelf velocity field.

During August 2001, the oceanic and ecosystem response off Oregon to strong summertime downwelling was observed. During the downwelling event, northward winds lasted 3-4 days and reached speeds of up to 40 knots. The surface layer warmed by about 4C over the entire continental shelf as warm oceanic surface water was advected onshore. The southward upwelling jet and the accompanying tilted isopycnals that existed before the downwelling event persisted, but were located over the mid- to outer shelf. Downwelled isopycnals were found within 15 km of the coast. Northward currents in excess of 0.2 m/s were found inshore of the 70 m isobath and were continuous over the entire study region (130 km alongshore). Prior to the downwelling event, chlorophyll fluorescence was confined to the upper 20 m and was highest adjacent to the coast. During strong northward winds, high chlorophyll was downwelled with the isopycnals near the coast. Chlorophyll was distributed throughout the water column in water depths less than about 70 m. Details of the time evolution of the coupled physical and biological response to summertime downwelling will be presented at the 2002 Ocean Sciences Meeting (Barth and Pierce, 2002). A comparison of the SeaSoar-based microstructure measurements to both traditional microstructure measurements made by the Moum/Caldwell group and to mesoscale circulation and bottom topographic features will be presented at the 2002 Ocean Sciences Meeting (Ott et al., 2002).

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The zooplankton group (Peterson) participated in the two, three-week long COAST cruises onboard R/V Wecoma and collected a total of 360 zooplankton samples. These were in the form of vertical and MOCNESS net tows. There were 33 total tows in June (22 vertical, 11 MOCNESS) and 53 total in August (35 vertical, 18 MOCNESS). The vertical plankton net had a 0.5 m opening and 0.333 um mesh, and was towed vertically from the surface to 100 m (or to within 10 m of the bottom for shallow stations) and then back to the surface. The MOCNESS was equipped with nets 0-4 having 0.333 um mesh and nets 5-9 having 0.150 um mesh in order to trap smaller plankton found higher in the water column. The net sampling alternated with SeaSoar grid towing. During the two cruises, our sampling was done on two main transect lines - Cascade Head in the north and Cape Perpetua in the south. Net sampling was done concurrently with measurements from the HTI bioacoustics system. A few day/night comparison tows were made at the same station to document the diurnal migration of zooplankton.

In June, the preliminary at-sea findings were typical of the plankton community. Adult euphausiids were mostly concentrated on the shelf break, while juvenile euphausiids were found up on the shelf. The inshore community was mostly inhabited by copepods. These observations were made from acoustic observations along with our on-board processing of MOCNESS net samples. Almost all of the vertical nets from this cruise have been counted, with the MOCNESS samples still to be enumerated.

In August, the preliminary at-sea findings showed very large numbers in the zooplankton community, especially the sampling done on August 11th/12th on the Cape Perpetua line. In the inshore stations, we needed to use half-gallon (sometimes gallon) jars on a couple of nets in order to accommodate the very high numbers of copepods. On the 18th and 19th, there was a strong jet along with high chlorophyll concentrations found flowing off Heceta bank in a north to south direction. We made two, small, north to south transect lines in the position of the high chlorophyll readings. As we were sampling off the bank on the 19th, it appeared from the HTI readings that a large patch of the zooplankton community, who are usually on the bottom during daytime, were getting 'pushed off' the bank by the strong jet. As they were moved into deeper water of the shelf, they seemed to maintain their depth of around 60 meters, which reflects the depth of the bank. Toward the end of the cruise, after a storm that produced unseasonably strong southerly, downwelling-favorable winds, we made vertical net tows at 11 cross-shelf stations and MOCNESS tows at three stations. Presently, we are working up some specific MOCNESS samples from the August cruise to compare with a 6-frequency bioacoustic instrument (TAPS: Tracor Acoustic Profiling System) which was mounted on the MOCNESS frame in order to do combined net/acoustic tows. The results of this work will be shown at the 2002 Ocean Sciences Meeting (Sutor et al., 2002). After the aforementioned work is complete, we will

be busy working up all of the MOCNESS samples for a similar comparison with the HTI profiling system on zooplankton cross-shelf and vertical distributions.

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During this past year, the ocean mixing component of COAST (Moum/Caldwell) successfully completed three cruises. In March 2001, we executed an engineering cruise in Puget Sound to determine: 1) how best to operate our turbulence profiler, Chameleon, on R/V Thomas G. Thompson; 2) how to coordinate a two wire operation with Hales' pumped profiler. This was successful in determining how to modify Hales' operation so that we could operate simultaneously. It was also successful in obtaining a data set with Chameleon and shipboard ADCP to examine a pinned lee wave off Three Tree Point south of Seattle. This data set has been processed and consolidated and we are working with Parker MacCready and his group at University of Washington in analysis (MacCready et al., 2001; Edwards et al., 2002).

Two scientific cruises were completed in May/June and August 2001. We were fortunate to obtain two full upwelling cycles in the spring cruise and to observe these in unprecedented detail. Preliminary results will be presented at the 2002 Ocean Sciences Meeting (Perlin et al., 2002). Motivated by the detailed structure of thin filaments of high chlorophyll water apparently advected offshore during upwelling and the ubiquitous solitary waves in the region observed in the June cruise, we managed to obtain and deploy a high frequency, rapidly-sampled echosounder in the ship's hull for the August cruise. This provided a unique opportunity to acoustically image the flowfield during our intensive turbulence and ADCP profiling operations.

All of the ADCP data and the ship-based scientific data have been processed and made available to the COAST group on the Ocean Mixing website (<http://mixing.coas.oregonstate.edu/>). As well, an improved bathymetry data set compiled by and obtained from Eric D'Asaro (UW) is available on the website.

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During the two cruises aboard the R/V Thomas G. Thompson in May and August 2001, the nutrient group (Hales) operated a pumping profiler system, making in situ measurements of temperature, conductivity, dissolved oxygen, light intensity, chlorophyll fluorescence, and beam transmission at a frequency of 24 Hz; and shipboard analyses of PCO<sub>2</sub> and concentrations of nitrate, nitrite, ammonium, phosphate, and silicate at a frequency of about 1 Hz. We performed this suite of measurements/analyses on nearly 40 onshore-offshore transects, approximately twice that many fixed-position, discrete-depth sampling stations, and a few fixed-position time-series stations. All told, this resulted in over 10 million shipboard analyses. In addition to the measurements/analyses from the pumped profiler system, we also performed continuous analyses of the surface PCO<sub>2</sub> and nitrate, phosphate, and silicate chemistry in the shipboard intake of the R/V Wecoma on complimentary May and August cruises, accounting for another 200,000 analyses. Preliminary interpretation of the data leads us to believe that the suite of measurements made will allow us to distinguish recently upwelled water, Columbia River plume water, and water upwelled at some time in the past having undergone the effects of biological processes and warming at very fine horizontal resolution. We can identify the effects of photosynthesis, respiration, grazing, and nitrate reduction in these water masses. In the next year we will undertake synchronization of our measurements with the complimentary ADCP velocity and turbulent mixing rate fields provided by the microstructure group to generate estimates of fluxes of the biologically significant chemical parameters.

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Activities of the iron measurement group (van Geen/Chase) centered on the two cruises this season aboard R/V Wecoma (May/June and August, 2001). On both cruises, the pumping and analytical components of the underway mapping system worked well. Iron levels were in general very low, and often near our detection limit (~ 1 nmol/l). In addition to the underway measurements, on each cruise we collected close to 200 discrete samples from the clean sample stream, which will be used to check the underway measurements, and for additional analyses (e.g. other metals, nutrients). Vertical profiles were collected at all CTD stations, and many of the profile samples were filtered through 0.45 micron filters. By comparing filtered and unfiltered pairs we will be able to tell how much of the iron is in the particulate form. Several profiles were analyzed while at sea, but most will be analyzed soon at LDEO. Low levels of Fe detected in offshore profiles confirm that we were able to collect uncontaminated samples. Iron concentrations in the filtered samples were as much as an order of magnitude lower than in unfiltered samples, even nearshore. We deployed two WET Labs backscatter meters, purchased with supplemental NSF funding, on the North Inner Shelf and North Mid Shelf moorings, at depths of 35 and 65 m, respectively. These sensors performed flawlessly for the entire 4 month deployment. We are beginning to analyze these data together with data from the backscatter meters and fluorometers deployed near the surface by Cowles' group, with the aim of better understanding the origin and transport of iron-rich particles. A paper based on a cruise in 1999 in the COAST region is under review at JGR (Chase et al., 2002). A collaboration between MBARI (Z. Chase, K. Johnson, L. Coletti) and OSU (J. Barth) resulted in an In Situ Ultraviolet Spectrophotometer (ISUS) being flown aboard SeaSoar for the detection of nitrate. Results of this effort will be reported at the 2002 Ocean Sciences Meeting (Coletti et al., 2002).

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During 2001 the organic carbon and nitrogen group (Wheeler) completed the May and August cruises aboard R/V Thomas G. Thompson. Sampling included discrete water samples from approximately 30 stations for the calibration of the optical measurements for chlorophyll, and dissolved and particulate organic material. We have completed the laboratory analyses for the chlorophyll and particulate organic material and have started the laboratory analyses for the dissolved organic carbon and nitrogen. Field work in August also included four 10-day deck board incubations to follow the production and utilization of inorganic nutrients and organic carbon and nitrogen during simulated blooms. The latter work will be the basis of Michael Wetz's Masters Thesis. Preliminary results from the 2001 field season will be presented at the 2002 Ocean Sciences Meeting (Karp-Boss et al., 2002).

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The bio-optics group (Cowles) collected data from each research vessel during each of the cruises during 2001. In particular, the survey vessel (R/V Wecoma) mapped the mesoscale distribution patterns of hydrographic and bio-optical properties (nine-wavelength in situ light absorption and attenuation, chlorophyll fluorescence) with the instrumented SeaSoar vehicle on spatial scales of 0.5-100 km over a vertical depth range of 0-110 m. We also acquired continuous surface tracks of the bio-optical properties during the cruises on the same surface water flow-through system used by Van Geen and Chase. We extended the bio-acoustical measurement suite for COAST by conducting selected vertical profiles with a 6-frequency bio-acoustics system (TAPS) in May/June 2001. The frequencies of the TAPS instrument (265, 420, 700, 1100, 1850, 3000 kHz) overlap the two upper frequencies of the HTI system (220, 420 kHz) and extend the measurement range into smaller size classes of acoustic scatters. In collaboration with Dr. William Peterson, we added this 6-frequency bio-acoustics system to the MOCNESS during the August 2001 survey cruise to assess the vertical scales of acoustic backscatter intensity in association with net tows. A presentation on this topic will be made at the 2002 Ocean Sciences Meeting (Sutor et al., 2002).

In contrast to the work on the survey vessel, the process vessel (R/V Thomas G. Thompson), repeated cross-shelf transits along two primary lines. During these transits, we acquired continuous bio-optical data (nine-wavelength particulate and dissolved light absorption and attenuation, chlorophyll fluorescence, fluorescence emission spectra) from the flow stream of the Hales' pumping system. These observations were made coincident with measurements on the same flow stream by a large number of investigators (including Wheeler, Hales, Letelier, Kirkpatrick).

Our group also deployed six sets of bio-optical sensors on the COAST moorings in mid-May 2001. At 15m depth on each mooring we had a fluorometer and an optical backscattering sensor (3-angles). All 12 instruments were recovered successfully at the end of August 2001, and all instruments recorded a full data set for the experimental period.

We now are conducting data quality checks and data calibration on all of the data sets. We expect final data processing to be completed by June 2002.

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During 2001 the phytoplankton physiology group (Letelier/Abbott) participated in both COAST field campaigns on board the R/V Thomas G. Thompson. Our main goal during this year was to characterize the spatial and temporal variability of phytoplankton productivity off the Oregon Coast prior to and during the upwelling season. During both cruises our team collected high frequency profiles of Fast Repetition Rate fluorometry (FRRf) in conjunction with Hales' pumping profiler, as well as discrete samples for algal pigment analyses and particulate absorption spectra. The discrete sampling took place at selected stations where a full suite of optical, particulate and nutrient analyses was carried out by other teams (Cowles, Wheeler, and Hales, respectively). The second cruise also included the generation of Productivity vs. Irradiance curves (P vs. E) using <sup>14</sup>C assimilation protocols at some inshore and offshore stations. Also, during this second cruise, a collection of 7 ADOS drifters were deployed (see <http://oosa.wff.nasa.gov/ADOS.html>). Of the seven released drifters, two were lost due to fishing activity in the area, one moved onshore and then north where it ran aground, and the remaining 4 moved south and offshore. The optical data collected by these drifters will allow the analysis of variability in phytoplankton parameters (biomass and natural fluorescence) in a Lagrangian mode.

Since the end of the first field season, we have processed all the FRRf data and the P vs E experiments. The FRRf data still need to be merged with Hales' profiles in order to develop a two-dimensional picture of algal photosynthetic parameters for each transect. Both the pigment and absorption samples have to be processed. Although we are able to perform a detailed spatial and temporal analysis of the data at present, repeated sampling of inshore and offshore stations during our first cruise suggest high day-to-day variability in photosynthetic and biomass parameters in all these stations. We expect that the analysis of this dataset, in conjunction with the nutrient, particulate, and optical fields will provide a detailed picture of



phytoplankton productivity in the study area.

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The mooring component of COAST (Levine, Boyd, Kosro) deployed six oceanographic moorings for 100 days from mid-May through August 2001. These moorings were deployed along two east-west lines at 44 deg 13'N and 45 deg N, with moorings at the inner shelf (50m), mid-shelf (80m in the north; 100m in the south), and shelf break (130m). Each oceanographic mooring contained: a Doppler current profiler to measure the currents over most of the water column; self-recording instruments to measure temperature (distributed at 8 to 13 depths) and conductivity (distributed at 2 to 4 depths); an upward-looking solar radiometer (Letelier); and a fluorometer and optical backscatter sensor package (Cowles). Two additional optical backscatter instruments (van Geen/Chase) were deployed on the northern inner shelf and northern mid-shelf moorings, at depths of 35 and 65 m, respectively to examine the origin of particles in the water column. The northern mid-shelf mooring was instrumented with two additional high-frequency Doppler current meters to sample the surface and bottom boundary layers. An additional meteorological mooring was deployed adjacent to the northern mid-shelf oceanographic mooring. Wind velocity, air temperature and humidity, barometric pressure, solar radiation, and surface water temperature/conductivity were recorded. Near real-time data was available during the deployment via a cell-phone hookup. During the mooring deployment and recovery cruises, CTD stations and time-series of CTD casts were conducted to augment the survey sampling program and calibrate AXBT probes. Of the nearly 100 instruments only 3 did not work properly. The data are currently being checked for quality. A data report displaying all the observation is in preparation and will be distributed to all PIs in the project.

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In 2001, the surface velocity mapping component (Kosro) used HF radio-wave backscatter to obtain hourly maps of surface currents during all seasons on a 100km-long section of the central Oregon coast, over a band extending 35-40 km offshore. The data are collected by operating five SeaSondes at 12-13 MHz. Processed data are returned from each site to OSU every two hours by telephone, while the more raw (and voluminous) cross-spectral data are archived at each site and collected in person monthly. The processed data are combined in pairs to produce quick-look maps, which can be viewed at <http://bragg.coas.oregonstate.edu/seasonde>. Maps combining data from all five sites are produced in postprocessing (e.g. [http://bragg.coas.oregonstate.edu/seasonde/images/0006\\_sm.avi](http://bragg.coas.oregonstate.edu/seasonde/images/0006_sm.avi)). The strong wind-forced response of the shelf currents is evident in these measurements, and the degree of spatial variation in currents over short distances in the region is striking. The coastal jet which develops under upwelling winds is strongly affected by topography, repeatedly veering offshore at Cape Foulweather (44.8N) around Stonewall Bank. Surface currents during downwelling winds are onshore and poleward, as expected, and show cross-shelf structure which differs from the upwelling season.

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The aircraft observational program (Bane, UNC) conducted twenty-seven flights to observe the structure and evolution of the ocean and lower atmosphere over the Oregon continental margin during the COAST summer 2001 field program. Flights with the instrumented aircraft, which began in mid-May and continued through August, were scheduled to coordinate with and extend measurements made by the COAST ship and moored instrumentation efforts. The aircraft repeatedly measured sea surface temperature, oceanic subsurface temperature down to 500m, upper-ocean color, and atmospheric wind, temperature, humidity and pressure. Atmospheric structure varied throughout the summer on periods ranging from diurnal to several days (the atmospheric synoptic scale), and an atmospheric temperature inversion typically, though not always, developed during episodes of northerly winds. An inversion rarely accompanied southerly winds. The main contributors to the surface wind field in the COAST region were waves in the jet stream, the relative positions of the North Pacific high pressure anticyclone and transient low pressure systems that passed through the Gulf of Alaska towards the northwestern U.S., and the strength of the thermal trough inland over Oregon and northern California. One remnant tropical cyclone and one coastally trapped southerly surge added spice to the variable atmospheric conditions during COAST. The principal oceanic response to atmospheric forcing was the onset of coastal upwelling during sustained northerly wind events. Maps of aircraft-derived sea surface temperature show the development of two upwelling centers in response to these winds, one north of Newport and one extending south from 44.3N. As the northern upwelling center evolved, its southward-flowing coastal upwelling jet separated from the coastline and continued towards the southwest due to topographic steering by Stonewall and Heceta Banks. The chlorophyll field, as indicated by aircraft-sensed upper-ocean color data (upward radiance wavelength ratio 510nm/555nm), generally followed the cool water patters. Small, nearshore regions of elevated chlorophyll concentrations were also seen, and these were related to terrestrial effects such as outflows from coastal rivers. The persistence of upwelled conditions for a number of days after the demise of northerlies (and on occasion the change to southerlies) was observed in ocean temperature and color fields. The nearshore upwelling band and separated coastal upwelling jet over Heceta Bank were clearly delineated in the oceanic temperature field after such wind changes. The extensive, high-quality data sets gathered from the COAST ships, aircraft and instrument arrays will reveal further details of this complex

coastal system as our analyses continue to progress. Preliminary results will be presented at the 2002 Ocean Sciences Meeting (Bane et al., 2002; Haines et al., 2002).

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Progress from the ocean modeling component (Allen, Gan, Spitz) is as follows.

#### Physical Circulation Modeling

Research has proceeded on physical circulation modeling applied to the Oregon shelf, including the region of the COAST project field experiments and also to the northern California shelf including the region of the CoOP WEST field experiments.

In the modeling studies applied to the Oregon shelf, work has proceeded with the development of a set of limited-area high resolution coastal ocean models with realistic Oregon shelf topography. The first model involves use of a channel geometry that is periodic in the alongshore direction. That geometry avoids the necessity of the application of uncertain open boundary conditions. The second model, for use with spatially variable atmospheric forcing obtained from the COAST project mesoscale atmospheric model, has required the development and testing of appropriate open boundary conditions. The initial application of these models has been to the summer 1999 time period of the Oregon State University NOPP project field experiment. At present, the Oregon coast physical circulation models are being utilized together with an ecosystem model (described in more detail below) for studies of the wind-forced shelf flow and ecosystem response during summer 2001 in direct support of the COAST project field experiment.

In the modeling studies applied to the northern California coast, two manuscripts examining the three-dimensional coastal ocean response during the time period of the CODE experiment and including a comparison of model results with CODE observation have been completed and submitted for publication (Gan and Allen, 2001a,b). Work is continuing with applications of this model to studies during summers 2000 and 2001 in direct support of the WEST project field experiments. A new postdoctoral research associate Scott J. Couch joined us in October 2001 to help with the modeling related to the northern California WEST project.

#### Ecosystem Modeling

As a first step towards a three-dimensional simulation of the ecosystem response to upwelling off the Oregon coast, solutions from three different nitrogen-based ecosystem models coupled to a two-dimensional (variations across-shore and with depth; uniformity alongshore) physical circulation model have been analyzed and compared. The first ecosystem model includes three components (dissolved inorganic nitrogen, phytoplankton and zooplankton), the second four-component model has in addition a detrital pool, the third five-component model also distinguishes between nitrate and ammonium. It was found that the addition of the detrital pool has a significant impact on the magnitude of the resultant zooplankton biomass. Characteristic spatial distributions of phytoplankton and zooplankton concentrations were identified with relatively high zooplankton found offshore of a near-coast phytoplankton maximum. These distributions were explained based on the interactions of physical and biological processes during upwelling off Oregon. Two manuscripts with these results have been submitted to the Journal of Geophysical Research (Newberger, Allen and Spitz, 2001; Spitz, Newberger and Allen, 2001).

Three-dimensional simulations with the five-component ecosystem model coupled to the physical circulation mentioned above have been initiated. At first, we utilize a periodic channel with realistic Oregon shelf topography to avoid the complications of open boundary conditions. Additional motivation for this approach comes from the fact that biological observations are not available at the open boundaries. The results of these simulations are being analyzed and compared to the COAST observations from the two cruises in May-June and July-August 2001 as well as to the observations from the GLOBEC LTOP measurements. Sensitivity of the ecosystem response to the model parameters that were found important in the two-dimensional simulations is also under investigation.

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During 2001, this grant provided support for the atmospheric and ocean process modeling component (Samelson). Partial support was provided for two postdoctoral investigators, Soline Bielli and Natalie Perlin, both studying the dynamics of the lower atmosphere along the central Oregon coast and its interaction with and influence on the coastal ocean. This grant has also provided support for additional meteorological observations during the COAST field program, for which low-cost, internally recording surface air temperature and relative

humidity sensors were deployed on the COAST surface moorings, and for Samelson's interaction with and support of the COAST aircraft observation program (Bane, UNC), including flight planning and preliminary interpretation of oceanographic and meteorological aircraft observations. In addition, this grant has provided partial support for Samelson to advise the two post-docs and oversee the COAST real-time meteorological modeling component, and to begin preliminary study of relevant coastal ocean dynamics issues.

Model estimates and scatterometer observations indicate that mean and fluctuating wind stress fields over the Oregon coastal zone have strong, systematic, spatial variations, including intensification of upwelling favorable winds near Cape Blanco, that are likely to exert an important influence on the coastal ocean circulation (Samelson et al., 2001; preliminary analysis of additional model estimates and scatterometer observations during summer 2000 and summer 2001 supports these conclusions). Evidence exists, from previous estimates (Samelson et al., 2001) and preliminary analysis of COAST surface air temperature and aircraft observations, for a significant effect of coastal ocean upwelling on coastal lower atmosphere air temperatures on the 24-48 hr mesoscale meteorological forecast timescale. The diurnal cycle during upwelling favorable winds involves three-dimensional effects apparently associated with meridional gradients in surface heating over land, and cannot be understood using a two-dimensional model in which alongshore gradients in low-level winds are neglected (Bielli et al., 2001).

Surface air temperature and relative humidity data, and supporting calibration files, from the summer 2001 supplementary meteorological measurements have been contributed to the summer 2001 COAST field program data report (in preparation). Some of the meteorological modeling and related results can be found on <http://www-hce.coas.oregonstate.edu>.

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K. C. Ruttenberg (Department of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution), joined our COAST research team and participated in the 2001 field experiment. Water column samples for analysis of dissolved organic phosphorus, dissolved inorganic phosphorus (DIP), Total Dissolved Phosphorus (TDP), Alkaline phosphatase (APase), phytoplankton species composition, and TDP bioavailability studies were collected on the May and August 2001 COAST cruises on the R/V Thomas G. Thompson. May 2001 cruise samples (n = 193) have been analyzed for DIP. Analyses of samples from the August 2001 cruise are underway. After completion of DIP analyses TDP analyses will begin, allowing us to calculate Dissolved Organic Phosphorus (DOP) concentrations (TDP-DIP). Four nutrient incubation experiments were successfully completed on the August 2001 cruise.

As part of this project I am funding a postdoctoral investigator, Dr. Sonya Dyhrman, Dept. of Biology, WHOI, to collaborate with me on analyzing water column phytoplankton samples for Alkaline Phosphatase (APase) activity using the Enzyme Labeled Fluorescence (ELF) method. We are correlating presence/absence of ELF stained cells to DIP and DOP concentrations in the sample water. These samples will also be analyzed for phytoplankton species composition. Analyses of all samples from the May 2001 cruise have been completed, and analyses of samples from the August 2001 cruise are underway.

DIP concentrations in surface waters during the May 2001 cruise ranged as low as 0.01 M. Phytoplankton cell concentrates from surface waters at sites with low DIP showed clear evidence of APase via the ELF staining method, indicating that phytoplankton at these sites were experiencing phosphate stress, and possibly were phosphate limited.

### **Findings:**

See the findings reported under individual COAST subcomponent reports contained under 'Research and education activities' above.

### **Training and Development:**

Three undergraduates (T. Boehland, J. Harman and K. Reser) gained experience in oceanographic research.

Eleven graduate students are receiving training, including extensive sea-going experience: L. Bandstra (nutrients), J. Bosch (organic carbon and nitrogen), R. Castelao (physical oceanography), Lisa Eisner (bio-optics and phytoplankton), G. Gunderson (microstructure), C. Howard (bio-optics), M. Meaux (aircraft measurements, UNC), Sheila O'Keefe (land-based radio mapping of ocean surface currents), R. Sanders (phytoplankton physiology), M. Sutor (bio-acoustics and zooplankton) and M. Wetz (organic carbon and nitrogen).

Ten postdocs are receiving training in oceanic (S. Crouch, J. Gan) and atmospheric (S. Bielli, N. Perlin) modeling, in hydrographic and microstructure measurements (M. Ott), in turbulence measurements and analysis (J. Klymak, A. Perlin), and in assessing the concentration and distributions of iron (Z. Chase, LDEO), particulate and dissolved organic material (L. Karp-Boss) and dissolved organic phosphorus (S. Dyhrman, WHOI). S. Bielli has successfully finished her postdoctoral tenure at OSU, with first authorship on one accepted manuscript and co-authorship on a second, and has moved to a research position in the Department of Atmospheric Sciences at the University of Washington.

**Outreach Activities:**

At the beginning of the second intensive COAST observation period in August 2001, we hosted an Open House with tours of the two large research vessels, R/V Wecoma and R/V Thomas G. Thompson, docked in Newport, Oregon, as they loaded for the COAST cruises. Over 500 people attended and learned about COAST, CoOP and OSU coastal research.

**Journal Publications**

- S. Bielli, P. Barbour, D. Chelton, M. Freilich, R. Samelson, and E. Skillingstad, "Scatterometer and model estimates of orographically intensified coastal winds", Eastern Pacific Ocean Conference abstract, p. 1, vol. , (2000). Conference abstract
- S. Bielli, P. Barbour, R. Samelson, E. Skillingstad, and J. Wilczak, "Numerical simulations of the diurnal cycle along the Oregon coast during summertime northerly flow", Monthly Weather Review, p. , vol. , (2001). Accepted
- Barth, J. A., P. M. Kosro and S. D. Pierce, "A submarine bank's influence on coastal circulation: Heceta Bank, Oregon", Eos, Transactions, American Geophysical Union, p. 1, vol. , (2000). Conference abstract
- Kosro, P. M., J. D. Paduan and L. Washburn, "Time-series mapping of currents in the coastal ocean.", Eos, Transactions, American Geophysical Union, p. 1, vol. , (2000). Conference abstract
- Karp-Boss, L., P. A. Wheeler and R. M. Letelier, "Spatial variability of particulate and dissolved material in relation to hydrographic parameters in an upwelling system.", American Society of Limnology and Oceanography, p. 1, vol. , (2001). Conference abstract
- Bane, J. M., S. M. Haines and M. F. Meaux, "Oceanic and atmospheric structure and evolution observed by aircraft during COAST 2001", Eos, Transactions, American Geophysical Union, p. , vol. , (2002). Conference abstract
- Barth J. A. and S. D. Pierce, "The coastal ocean response to summertime downwelling favorable winds off Oregon", Eos, Transactions, American Geophysical Union, p. , vol. , (2002). Conference abstract
- Chase, Z., A. van Geen, M.P. Kosro, J. Marra, and P.A. Wheeler, "Iron and nitrate supply to Oregon coastal waters: Physical mechanisms and biological response", J. Geophys. Res., p. , vol. , (2002). Submitted
- Coletti, L. J., K. S. Johnson, C. M. Sakamoto, Z. Chase, F. P. Chavez, J. A. Barth, P. G. Strutton, S. E. Fitzwater, N. Tervalon and P. M. Walz, "New insights from high-resolution and long-term chemical measurements with the MBARI In Situ Ultraviolet Spectrophotometer (ISUS): Optical nitrate and bisulfide determinations", Eos, Transactions, American Geophysical Union, p. , vol. , (2002). Conference abstract
- Corwith, H. L. and P. A. Wheeler, "El Nino related variations in nutrient and chlorophyll distributions off Oregon", Progress in Oceanography, p. , vol. , (2002). Accepted
- Edwards, K., P. MacCready, G. Pawlak, J. Moum, J. Klymak, A. Perlin and R. Dewey, "Flow features at a sharp coastal point", Eos, Transactions, American Geophysical Union, p. , vol. , (2002). Conference abstract
- Gan, J., and J. S. Allen, "A modeling study of shelf circulation off northern California in the region of the Coastal Ocean Dynamics Experiment. Part 1: Response to relaxation of upwelling winds", J. Geophys. Res., p. , vol. , (2001). Accepted
- Gan, J., and J. S. Allen, "A modeling study of shelf circulation off northern California in the region of the Coastal Ocean Dynamics Experiment. Part 2: Simulations and comparisons with observations", J. Geophys. Res., p. , vol. , (2001). Accepted
- Haines, S. M., J. M. Bane, M. F. Meaux, "Airborne hyperspectral ocean color measurements off the Oregon coast", Eos, Transactions, American Geophysical Union, p. , vol. , (2002). Conference abstract
- Hill, J. K. and P. A. Wheeler, "Organic carbon and nitrogen in the northern California Current system: Comparisons of offshore, river plume, and coastally upwelled water", Progress in Oceanography, p. , vol. , (2002). Accepted

Karp-Boss, L., P. A. Wheeler, B. Hales and P. Covert, "Organic matter in the Oregon upwelling zone: distributions and processes", Eos, Transactions, American Geophysical Union, p. , vol. , (2002). Conference abstract

MacCready, P., K. Edwards, G. Pawlak, J. Moum, J. Klymak, A. Perlin and R. Dewey, "Tidal headland eddies in deep water", Gordon Conference on Coastal Circulation, p. , vol. , (2001). Conference abstract

Newberger, P. A., J. S. Allen, and Y. H. Spitz, "Analysis and comparison of three ecosystem models", J. Geophys. Res., p. , vol. , (2001). Submitted

Ott, M. W., A. Y. Erofeev, J. A. Barth, J. N. Moum and A. Perlin, "Microstructure measurements from a towed undulating platform and their relationship to mesoscale circulation and bottom topography", Eos, Transactions, American Geophysical Union, p. , vol. , (2002). Conference abstract

Perlin, A., J. N. Moum and J. M. Klymak, "Observations of the details of coastal upwelling response and relaxation across a simple bathymetry", Eos, Transactions, American Geophysical Union, p. , vol. , (2002). Conference abstract

Ruttenberg, K.C. and S. T. Dyhrman, "Examining the occurrence of phosphate-stress in coastal phytoplankton communities using a cell-specific enzymatic assay", Eos, Transactions, American Geophysical Union, p. , vol. , (2002). Conference abstract

Samelson, R. M., P. Barbour, J. Barth, S. Bielli, T. Boyd, D. Chelton, P. Kosro, M. Levine, E. Skillingstad, and J. Wilczak, "Wind stress forcing of the Oregon coastal ocean during the 1999 upwelling season", J. Geophys. Res., p. , vol. , (2001). Accepted

Spitz, Y. H., P. A. Newberger, and J. S. Allen, "Ecosystem response to upwelling off the Oregon coast: Behavior of three nitrogen-based models", J. Geophys. Res., p. , vol. , (2001). Submitted

Sutor, M., J. Lamb, T. Cowles and W. Peterson, "Comparison of acoustic and net sampling systems to determine distribution patterns of zooplankton biomass and taxonomic groups", Eos, Transactions, American Geophysical Union, p. , vol. , (2002). Conference abstract

### Books or Other One-time Publications

#### Web/Internet Site

**URL(s):**

<http://damp.coas.oregonstate.edu/coast>

**Description:**

This web page contains an overview of our COAST project with pointers to all the subcomponent project web pages. It also contains links to near real-time satellite SST imagery, land-based coastal radio system surface current maps and atmospheric model forecasts.

#### Other Specific Products

**Product Type:** Data or databases

**Product Description:**

Near real-time daily-averaged maps of the ocean surface currents between Newport and Waldport, Oregon. These maps are produced by a network of SeaSonde High-Frequency land-based radio systems.

**Sharing Information:**

The near real-time ocean surface current maps are available at a website <http://bragg.coas.oregonstate.edu/seasonde>.

**Product Type:** Atmospheric model forecasts

**Product Description:**

Experimental daily weather forecasts for Oregon and the Pacific Northwest using the ARPS (Advanced Regional Prediction System) mesoscale meteorological model.

**Sharing Information:**

The daily weather forecasts are available at a web site <http://www-hce.coas.oregonstate.edu>.

**Product Type:** Data or databases

**Product Description:**

Shipboard ADCP data and the ship-based scientific data from the two 2001 R/V Thomas G. Thompson cruises is available on the OSU Ocean Mixing group web page. An improved bathymetry data set compiled by and obtained from Eric D'Asaro (UW) is available on the website.

**Sharing Information:**

This data is available at the web site <http://mixing.coas.oregonstate.edu/>.

**Contributions**

**Contributions within Discipline:**

**Contributions to Other Disciplines:**

**Contributions to Human Resource Development:**

**Contributions to Resources for Research and Education:**

**Contributions Beyond Science and Engineering:**

**Special Requirements**

**Special reporting requirements:** None

**Change in Objectives or Scope:** None

**Unobligated funds:** less than 20 percent of current funds

**Animal, Human Subjects, Biohazards:** None

**Categories for which nothing is reported:**

Any Book

Contributions: To Any within Discipline

Contributions: To Any Other Disciplines

Contributions: To Any Human Resource Development

Contributions: To Any Resources for Research and Education

Contributions: To Any Beyond Science and Engineering