Newsletter of

Coastal Ocean Processes

NSF Ocean Sciences Division Reorganizes

Larry Clark

Head, Ocean Section, NSF

The conduct of ocean science research continues to change as the field evolves and as new knowledge about the oceans is gained. This ongoing transformation has recently prompted an administrative reorganization within the NSF Division of Ocean Sciences (OCE) that moves the program which supports the Coastal Ocean Process (CoOP) initiative. When CoOP was being developed a decade ago, the research community was just starting to appreciate the value and importance of integrated, multidisciplinary research projects. From the outset, CoOP research projects required a high level of interdisciplinary integration and cooperation amongst its projects' various components. Since then a number of other major projects such as JGOFS, GLOBEC, and CLIVAR have been undertaken requiring coordinated and cooperative research efforts. And in looking ahead via various long-range planning documents, cooperative and collaborative efforts are going to become increasingly important. The number of special focused research programs, with their associated planning structures and steering committees, has increased dramatically. And both Congress and the Administration have demonstrated significant interest in ocean science, which has manifested itself in numerous interagency activities such as the National Oceanographic Partnership Program. *(continued on page 11)*

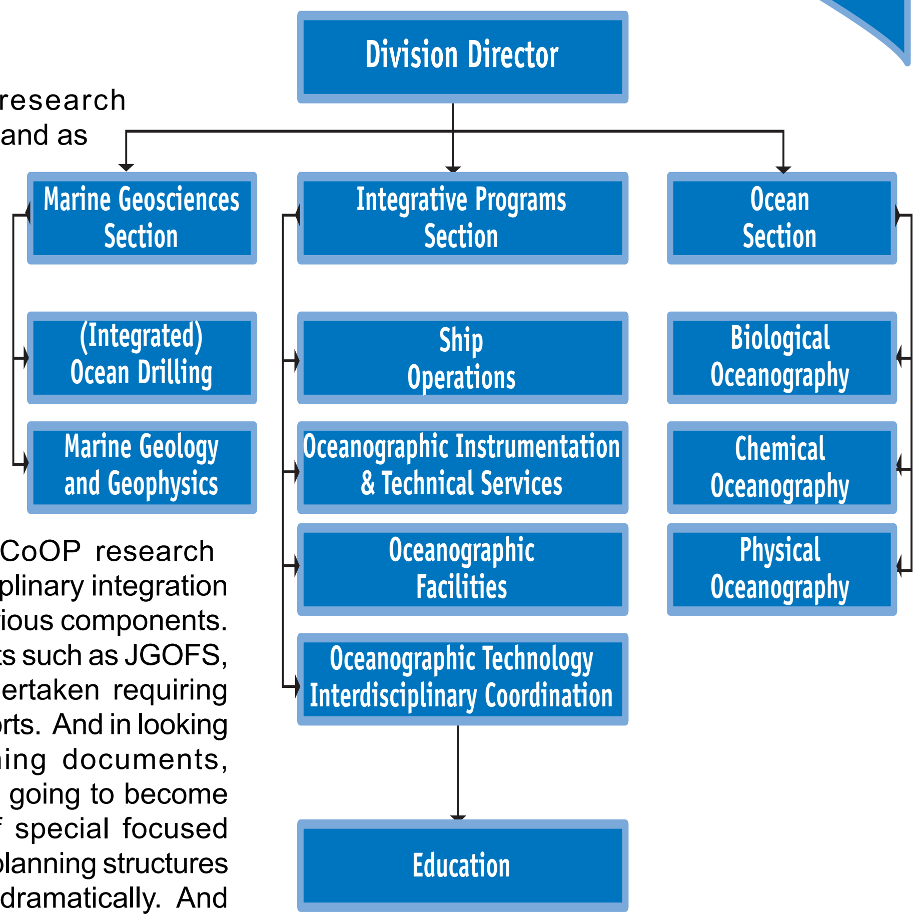

Figure 1: New organizational chart for the Division of Ocean Sciences

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New Applications for Satellite Oceanography in WEST

Raphael Kudela
University of California, Santa Cruz

Ecosystems at continental margins are most directly affected by human activities and are ideal candidates for the synoptic sampling available through the utilization of satellite radiometry. A primary mediator between the biogenic processes occurring in shallow coastal ecosystems and the open ocean is phytoplankton. As primary producers, phytoplankton incorporate reactive inorganic elements into organic compounds. In the process, they can deplete organic and inorganic nutrients (N, P, Si, Fe), produce oxygen while consuming carbon dioxide, bio-accumulate and/or deactivate many toxic trace metals (As, Cd, Ni, Zn), change the form and reactivity of organic compounds, and of course serve as food sources for heterotrophs including bacteria, zooplankton, benthic invertebrates and fishes (Cloern, 1996). Because of the central role that phytoplankton play in the functioning of coastal ecosystems, monitoring of phytoplankton growth and biomass has long been a fundamental challenge to scientists. Numerous satellites and airborne sensors have been used in the coastal ocean. A major problem has been that the instrument platforms that work well in the coastal ocean, with high spatial resolution and the ability to estimate important water quality parameters, perform extremely poorly at determining biological constituents such as phytoplankton pigments due to their wide spectral bands and long return rates. With the launch of the Sea-Viewing Wide Field Sensor (SeaWiFS) in 1997, coastal oceanographers now have the ability to monitor these processes in near-shore coastal environments.

We are providing real-time remote sensing products in support of the WEST program in northern California. Our remote-sensing component provides a mechanism for coupling the high temporal resolution (mooring) and process-study (cruises) efforts with a more synoptic view of the coastal ocean, through data products and model development. Figure 2 provides an example of the data we can provide. In addition to the “standard” products such as temperature and biomass (chlorophyll), we are also fine-tuning regional algorithms for prediction of biological parameters such as new (or export) production and primary production. In collaboration with the Monterey Bay Aquarium Research Institute (MBARI), we operate the west-coast real-time HRPT data center for SeaWiFS ocean color. When combined with the NOAA Coastwatch Advanced Very High Resolution Radiometer (AVHRR) data products, we can disseminate real-time daily, weekly, and monthly composite imagery to other WEST PIs. The WEST program also offers the opportunity to develop new products, such as regionally tuned primary and new production models. These data can be then be used to address some of the central scientific questions, such as the role of shelf retention in bloom development and the spatial-temporal scales over which phytoplankton productivity varies. Details of the imagery presented in the image panel (Fig.2) are provided below.

Sea Surface Temperature: We maintain an archive of NOAA Coastwatch sea surface temperature data for central California. The data are processed and incorporated into several other products, including new and primary production. The accompanying image uses the NOAA night-time NLSST product.

Chlorophyll a: SeaWiFS data are processed in real-time using the SeaDAS software package and the OC4 algorithm for chlorophyll concentrations (mg m^{-3}). Recent advances in atmospheric and turbid water corrections (see http://seawifs.gsfc.nasa.gov for background) have greatly improved these products.

K490: The attenuation coefficient (m^{-1}) at 490 nm provides an index of water clarity, and is also used to estimate the euphotic depth for modeling of phytoplankton productivity. This is a standard product from the SeaDAS processing.

PAR: NASA has recently implemented a new product from SeaWiFS, which provides photosynthetically active radiation (PAR; W m^{-2}). Colleagues at MBARI are currently evaluating this product in comparison to the MBARI mooring meteorological systems; preliminary results suggest that the derived PAR parameter is reasonably accurate.

Wind Speed: NASA has also implemented a wind speed and direction product derived from the ancillary meteorology fields used in the SeaWiFS processing. The wind speed product has been compared to several coastal moorings, and is also reasonably accurate. Wind direction has not yet been implemented fully, but we anticipate that this product will be available for the 2001 field season.

Primary Production: Using the SST, K490 (for euphotic depth), PAR, and Chl a data, we estimate depth-integrated primary production (mg C using the Vertically Generalized Productivity Model (VGPM; Behrenfeld and Falkowski, 1997). We are currently tuning the model using data from the 2000 field season to improve this global model for central California.

New Production: In addition to primary production, we are also modeling new (or export) production (mg-at N m^{-3}) using the SST and Chl a products and a regional model developed for Monterey Bay (Kudela and

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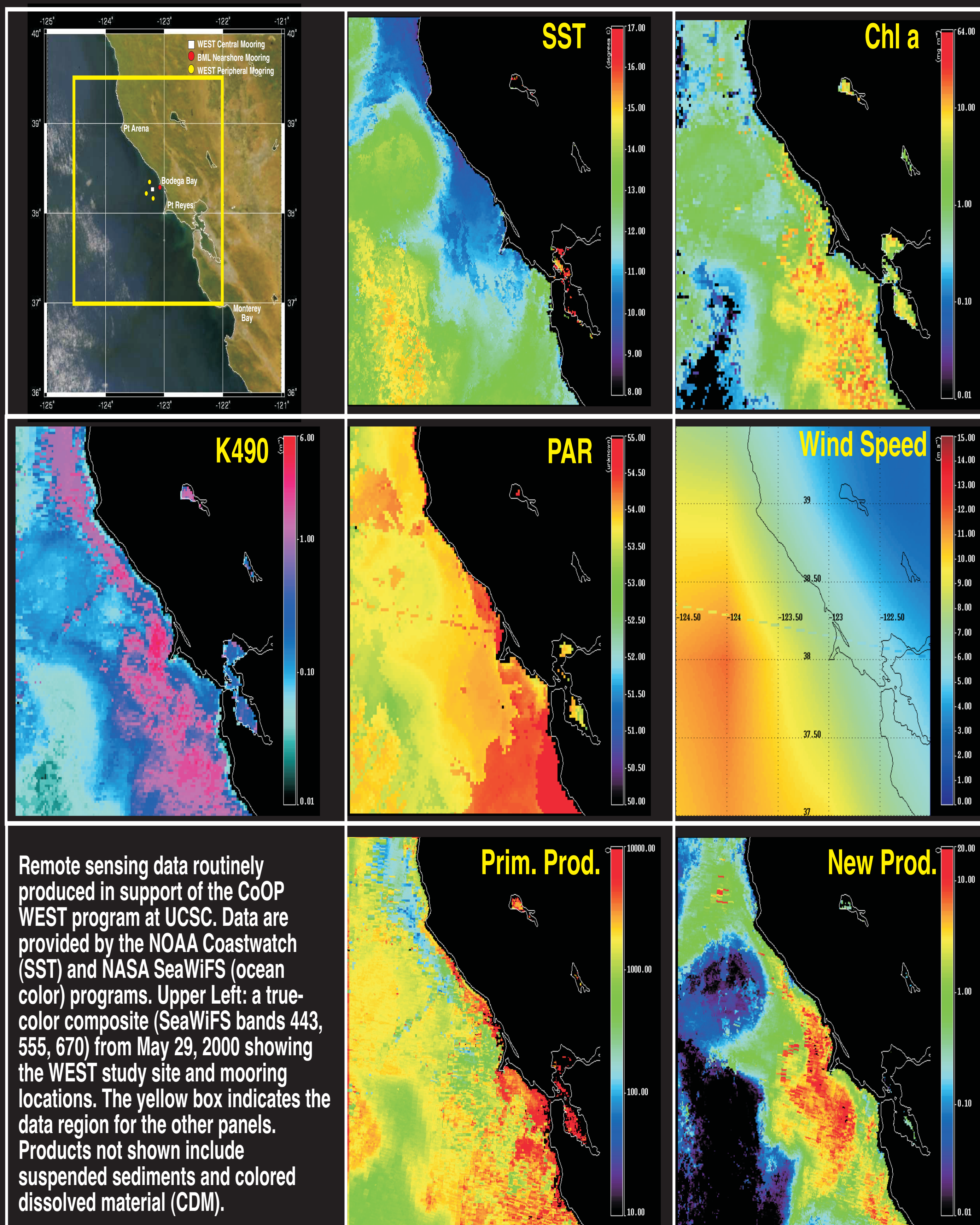

Remote sensing data routinely produced in support of the CoOP WEST program at UCSC. Data are provided by the NOAA Coastwatch (SST) and NASA SeaWiFS (ocean color) programs. Upper Left: a true-color composite (SeaWiFS bands 443, 555, 670) from May 29, 2000 showing the WEST study site and mooring locations. The yellow box indicates the data region for the other panels. Products not shown include suspended sediments and colored dissolved material (CDM).

Figure 2.

Coastal Ocean Advances in Shelf Transport (COAST)

Jack Barth, Yvette Spitz and John Allen
Oregon State University

A cooperative effort among scientists at Oregon State University, the University of North Carolina and the Lamont-Doherty Earth Observatory is investigating cross-shelf transport processes in the wind-driven system off Oregon. Since our first field effort is scheduled for 2001, we have spent much of this year doing continued ocean circulation, ecosystem and atmospheric modeling, analyzing existing data sets and preparing instrumentation for use during next spring and summer. In order to optimize sampling during 2001, we have been analyzing data from the 1999 NOPP-sponsored and 2000 GLOBEC-sponsored field programs off Oregon. In addition, a comparison between satellite scatterometer measured winds and atmospheric model winds has been very enlightening regarding the temporal and spatial scales of the atmospheric forcing off the northwest coast.

We have successfully scheduled two research vessels for both a May-June early-upwelling study and an August mature-upwelling study. Scientists aboard the R/V Wecoma will conduct high-spatial resolution mapping in coordination with those on the R/V Thomas Thompson who will conduct vertical profiling of physical and biological parameters. A test cruise for a new fiber-optic tow cable system which will allow high-data rate instruments (e.g., bio-optical, microstructure) to be flown aboard the undulating vehicle SeaSoar is scheduled aboard R/V Wecoma for January 2001. A second test cruise aboard the R/V Thompson will test a new high-speed vertical pumped profiler system in March 2001. This cruise will also be used to work out a sampling protocol for simultaneous use of the pumped profiler and a microstructure profiler so that the turbulent flux of nutrients and carbonate species may be estimated. Coordination of the aircraft overflights with ship activities is underway and a hyper-spectral ocean color radiometer is being added to the airborne instrument suite. Lastly, effort has been spent on designing the mooring array, including purchasing physical and bio-optical sensors, which will be deployed in mid-May 2001.

To model the upwelling response of the ecosystem off the Oregon coast and address the hypotheses of COAST (CoOP Newsletter, December 1999), we first

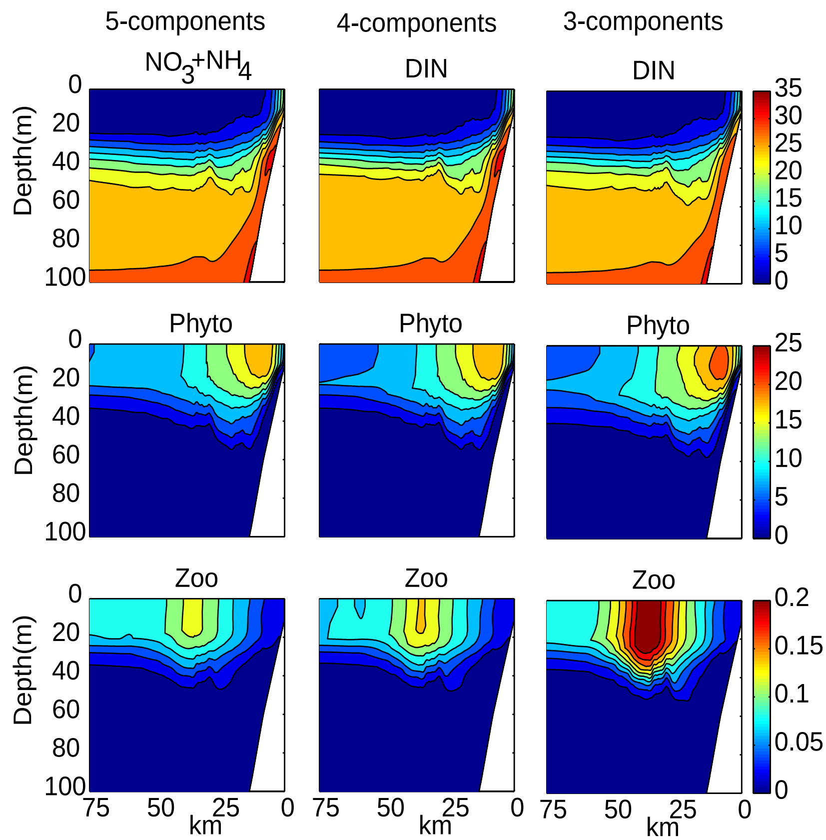

Figure 4. Time mean dissolved inorganic nitrogen, phytoplankton and zooplankton (color contours, mmol N m^{-3}) for the three-, four- and five-component ecosystem models when coupled to a two-dimensional circulation model. Spitz et al., ms. in preparation.

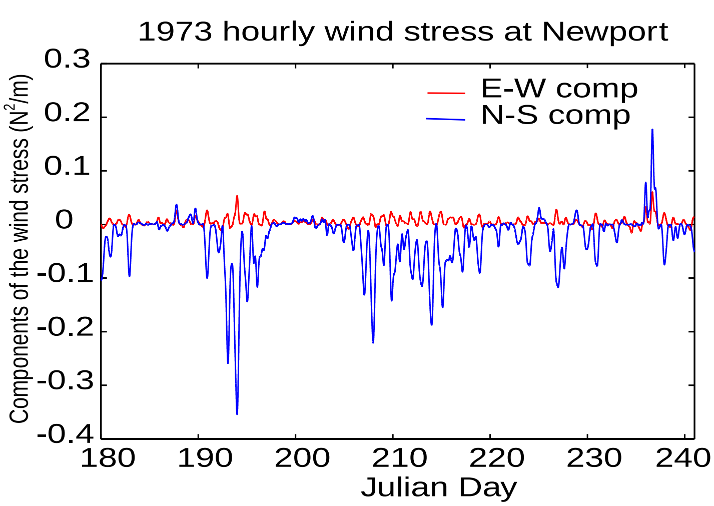

Figure 3. Hourly wind stress components at Newport between June 29 and August 29, 1973. Negative N-S wind stress corresponds to upwelling favorable winds.

(continued on page 5)

have to select an appropriate ecosystem model. While similar in structure (e.g. nitrogen budget), the ecosystem models can vary greatly in their complexity and the parameterization of the processes that they include. We compared the behavior of three ecosystem models. The first ecosystem model has three components (nitrogen-phytoplankton-zooplankton) as in Franks et al. (1986). The second has four components (nitrogen-detritus-phytoplankton-zooplankton) and is based on Denman and Peña (1999). The third, five-component model (Wroblewski, 1977), is similar to the second except that the nitrogen pool is divided into nitrate and ammonium components. The parameterization of the various processes is identical in all three models (e.g., Ivlev formulation for grazing, linear mortality, Michaelis-Menten uptake) and the parameters are chosen to give equivalent steady state solutions for an unforced one-dimensional application.

These three models are first run in wind-forced, one-dimensional experiments with observed winds from July-August 1973 (Figure 3). Comparisons of the model results reveal that it is necessary to have vertical transport due to sinking so that nutrients do not accumulate in the surface layer. For the four- and five-component models, sinking is naturally implemented in the equation for detritus. For the three-component model, it is possible to sink phytoplankton to remove nitrogen from the surface layer, but it is not clear how to choose objectively the sinking rate to mimic the combined effect of sinking and remineralization of detritus that is included in the other two models. In the subsequent two-dimensional model runs, we selected the vertical sinking rate for phytoplankton that leads to the same phytoplankton concentration in the upper 30m in these one-dimensional experiments.

The three models were then coupled to a two-dimensional circulation model (Allen et al., 1995; Federiuk and Allen, 1995) and started with equivalent initial conditions obtained from the wind-forced one-dimensional runs. The model domain is 200 km wide and bounded by a solid wall at the coast and offshore. The shelf and slope topography represent the Oregon shelf at 45º 15' N with a minimum depth of 10 m at the coast and an offshore maximum depth of 500 m. The grid spacing is uniform with 60 vertical sigma levels and a horizontal resolution of 250 m. We find that the general spatial patterns of the mean (Figure 4) and rms concentration fields are similar for the three models. Zooplankton biomass is at a maximum just offshore of the upwelling jet while the phytoplankton maximum is located inshore of the upwelling jet. The magnitudes of the comparable variables of the three-component model can differ appreciably from those of the four- and five-component models, however, depending on the specified sinking rate of the phytoplankton. The effects of variable shelf topography on the across-shelf transport of primary production, on the nearshore retention of phytoplankton and on the alongshore variations of biomass are currently under study using a three-dimensional coupled ecosystem and ocean circulation model.

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The CoOP Office acknowledges the graphics and publishing expertise, assistance and advice provided by Anna Boyette and Suzanne McIntosh, courtesy of the Skidaway Institute of Oceanography. The willingness of the Skidaway Institute Business Office, particularly Sheila Wentz, to accomodate CoOP travel demands is greatly appreciated.

GLOBEC Gulf of Alaska Projects Selected

Beth Turner,
U.S. Globec Program Manager, NOAA

The GLOBEC program managers at NSF and NOAA have selected Principal Investigators to be funded in the Northeast Pacific Gulf of Alaska program. Proposals received in response to the announcement exceeded available funds by almost 4:1, so competition for funds was vigorous. Proposals underwent standard mail and panel review and ranking. While details of specific proposals and cruise plans are still not finalized, the roster of PIs has recently been identified.

The Long-Term Observation Program in the Gulf of Alaska will be anchored by Tom Weingartner (University of Alaska - UA) and Tom Royer (Old Dominion University), who will continue their ongoing monitoring work using nine-day cruises in March, April, May, July, August, October, and December. The roving band of LTOPers consists of Weingartner and Royer on physical measurements; Terry Whitledge and Dean Stockwell (UA) on nutrients, chlorophyll and primary production; Ken Coyle and Russ Hopcroft (UA) on zooplankton (nets and acoustics); and Lew Haldorson (UA) on fish. Evelyn Lessard (University of Washington - UW) will cover microzooplankton biomass and grazing rates on the LTOP cruises.

GLOBEC has long championed and supported the development and use of new technologies. In the Gulf of Alaska, Craig Lee and Charlie Eriksen (UW) will be supported to utilize a new, autonomous, telemetering vehicle (the Seaglider) to make continuous, high resolution sections of the Alaska Coastal Current year-round. The Seaglider measures temperature, conductivity, pressure, chlorophyll fluorescence, dissolved oxygen, and volume scattering; profiling from the surface to within 10 m of the bottom. Horizontal resolution is 2 km. This will augment and extend the temporal and spatial frame of LTOP measurements.

In addition to the collection and sorting of zooplankton and fish that has been ongoing in the Alaska LTOP program, Hopcroft will do copepod incubations to determine growth and reproductive rates, and Haldorson and David Beauchamp (UW) will examine diets, energy content, growth, and condition of salmon, and use spatially-explicit models and bioenergetic models to assess habitat quality and relate salmon condition, growth, bioenergetics, and the environment. Tom Kline (Prince William Sound Science Center) will analyze fish and zooplankton for nitrogen and carbon isotopic ratios to characterize coastal carbon sources isotopically, and relate them to their utilization by fishes.

Additional physical data will come from Phyllis Stabeno (Pacific Marine Environmental Lab - PMEL), who will deploy moorings from April/May 2001 through September 2004. Instrumentation will include meteorological instruments, temperature recorders, SEACATs, ADCP, current meters, fluorometers, nitrate meters, and acoustic transducers. Drifters will also be deployed to map mean currents and continuity of flow in the Alaska Coastal Current, and identify mesoscale features on the shelf and shelf break. Assisting Phyllis in this deployment and interpretation will be Calvin Mordy (PMEL) for nutrients; and Jeff Napp (Alaska Fisheries Science Center, Seattle) and Van Holliday (BAE Systems) for zooplankton acoustics. Data from these moorings and drifters will be used to help determine the processes that control circulation and transport of nitrate and zooplankton in the study area, assess the relationship between physical forcing and cross-shelf fluxes of inorganic nutrients, and construct a time series of zooplankton biomass and size structure to link with physical processes.

Providing a larger-scale view of the region in one snapshot during the year will be an augmentation of the National Marine Fisheries Service Ocean Carrying Capacity surveys, led by Jack Helle and Ed Farley (Alaska Fisheries Science Center, Auke Bay), Ned Cokelet and Phyllis Stabeno (PMEL), and Anne Hollowed (Alaska Fisheries Science Center, Seattle). This survey will occur during July-August in years 2001 - 2004. Physical measurements will include ADCP, temperature and salinity taken while the ship is underway to at least 50 shelf stations and 20 slope stations, where juvenile salmon and zooplankton will be sampled. The physical-biological data collected will allow these investigators to help identify physical factors that might influence juvenile salmon spatial distribution, migration, growth, and condition; and develop a conceptual model of juvenile salmon survival.

Coordinated zooplankton process cruises will occur in early spring, mid-spring, and summer to quantify copepod egg production and viability, and relate these to grazing and the microplankton community. Jeff Napp will measure natural variability in copepod egg production rates and viability, and relate egg production rates to microplankton abundance and composition (in association with Suzanne Strom, Western Washington University). Strom and Mike Dagg (Louisiana Universities Marine Consortium) will measure

GLOBEC *(continued from page 6)*

microplankton abundance and composition, rates of microzooplankton herbivory, and rates of *Neocalanus* spp. grazing on microzooplankton and phytoplankton. These zooplankton process cruises are planned to take place in four different coastal physical regimes to study how variation in the physical environment dictates production levels and food web structure in the Gulf of Alaska.

Modeling will continue to provide larger-scale context for the field data. Dale Haidvogel (Rutgers University), Al Hermann (PMEL), and Sarah Hinkley (Alaska Fisheries Science Center) will refine a spatially nested ocean circulation model for the Gulf of Alaska, and link it to NPZ modeling. They also propose assimilation of the data collected in the field program, and development of web-based 3-D model visualization. Jim Overland (PMEL) and Nick Bond (UW) will model atmospheric forcing of the Alaska Coastal Current by both a large-scale, basin-wide component and a local, coastal zone component. Validation of the model will be done using data from the Stabeno moorings. Ultimately, this effort will explore how interannual and interdecadal changes in atmospheric forcing are communicated to the ACC. All of these modeling efforts relate to similar efforts in the GLOBEC NEP California Current System program.

Retrospective projects will provide a glimpse into the past, and a temporal context for the five years of the CGOA program. Mark Ohman (Scripps Institution of Oceanography) will continue his work funded under NEP Phase 1 to analyze zooplankton population structure in light of measures of atmospheric and oceanic forcing, especially focusing on the 1976-1977 climate regime shift. Bill Heard (NMFS Alaska Fisheries Science Center, Auke Bay Lab) will analyze archived and current collections of salmon scales and correlate growth to biophysical parameters of the environment, and to local abundances of salmon year classes. This project is an enhancement of the Southeast Alaska Coastal Monitoring program of NMFS.

Also considered by this panel was a group of proposals for microzooplankton measurements in the GLOBEC NEP California Current System (CCS) program. Barry and Ev Sherr (Oregon State University) were chosen to analyze microzooplankton abundance, biomass, and general taxonomic composition in conjunction with the CCS LTOP cruises.

Congratulations to all the successful proposers, and GLOBEC looks forward to their expertise, experience, and enthusiasm in the Gulf of Alaska program.

CoOP Office Funds Student Travel

Frugal money management and lower than anticipated printing costs in 2000 allowed the CoOP Office to project a small budget surplus in 2000. The Office used the surplus funds to provide full travel stipends for four EEGLE graduate students from Michigan Technological University, University of Akron and University of Georgia to participate in the EEGLE Allhands meeting at the Homestead Conference Center in Glen Arbor MI, 25-28 September 2000.

In addition, full or partial travel support was provided to 24 students in both the EEGLE and KITES Projects to attend the joint KITES/EEGLE Allhands meeting held at Argonne National Laboratory 29-30 November 2000. Students from Michigan Tech (15), University of Minnesota (1), Rutgers University (1), University of Iowa (2), University of Georgia (2), University of Southern Mississippi (1) and Great Lakes Environmental Research Laboratory (1) participated in and presented posters at the Argonne meeting.

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CoOP Project Websites

Episodic Events - Great Lakes Experiment - EEGLE project: http://www.glerl.noaa.gov/eegle/

Keweenaw Interdisciplinary Transport in Superior - KITES project: http://chmac2.chem.mtu.edu/KITES/

Coastal Ocean Advances in Shelf Transport - COAST project: http://www.oce.orst.edu/po/COAST/

Wind Events in Shelf Transport - WEST project: http://ccs.ucsd.edu/coop/west/

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WEST *(continued from pages 2 and 3)*

Dugdale, 1996; Kudela and Chavez, 2000). This model is also being fine-tuned for the 2001 field year.

We are also testing the Carder (1996) and Garver-Siegel (1997) semi-analytical models; we anticipate routine dissemination of multiple parameters from this model output (pigments, colored dissolved materials, backscatter). Algorithm development done with SeaWiFS data is easily transferred to other coastal (or open ocean) sites, and is compatible with existing and future satellite platforms, including MODIS (Yoder, 2000) which will meet or exceed the data currently available from AVHRR and SeaWiFS.

The dynamics and scales of cross-shelf transport have eluded prior studies, owing to inadequate design or misfortune. The size-structured trophic dynamics and associated spatiotemporal patterns in the plankton have eluded prior studies owing to inadequate technology to resolve plankton size fast enough to measure spatiotemporal distributions. The fluxes of water-borne nutrients have eluded prior studies owing to the absence of in situ sensors that can sample nutrients on the same scale that currents need to be sampled. We offer the first truly integrated view of the high plankton productivity observed over continental shelves dominated by wind-driven transport. This work promises direct benefit to many other research fields, including fisheries, global carbon cycles, satellite remote sensing methodology, coastal water quality, biodiversity, and ecological implications of climate change.

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Episodic Events – Great Lakes Experiment (EEGLE)

Brian Eadie and Dave Schwab
Great Lakes Environmental Research Laboratory and NOAA

EEGLE PIs met at a three day workshop in late September, after the successful completion of our third and final year of field-work, to discuss preliminary findings and foster interdisciplinary activities. The EEGLE program was designed to quantify the impacts of major late winter-early spring storms on sediment-water exchange, nearshore-offshore transport and subsequent influence on the lakes' productivity. At the beginning of the program, it was generally agreed that episodic resuspension and subsequent transport of the large inventories of nutrients and contaminants deposited over the past few decades (e.g. P, ^{137}Cs, PCBs), would result in greater fluxes to the water column than from all external inputs. In addition, control of biological processes could occur as a result of effects on light and substrate availability and the introduction of meroplanktonic species.

Our observation strategy consisted of three components (Fig. 5): (1) moored arrays of current meters, thermistors and sequencing traps, (2) interdisciplinary Lagrangian measurements, and (3) shipboard surveys. In addition, survey, and process measurement cruises were conducted along with special cruises for ROV sediment-water interface sampling, particle transformation measurements, and collection of sediments. The time series and survey data have been supplemented by synoptic coverage from satellite imagery and multi-frequency HF radar observations.

This collaborative Lake Michigan study provides an ideal framework for model testing and development. The modeling objectives are to create a numerical modeling framework and use the extensive observational programs to identify, quantify, and develop prediction tools for the primary physical processes responsible for nearshore-offshore transport and transformation of biogeochemically important materials (BIMS) in Lake Michigan. A lake-scale hydrodynamic circulation model (the Great Lakes version of the Princeton Ocean Model) has been coupled with a wave model and applied to Lake Michigan for selected periods in 1992-1997 during which the springtime turbidity plume has been observed, and for the program's field years. In collaboration with other components of this program the hydrodynamic model will be coupled with sediment transport and lower food web models in order to assess the impact of internal nutrient recycling and nearshore-offshore transport on sedimentary and biological processes. Overall, the program is designed to provide the most comprehensive

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EEGLE (continued from page 8)

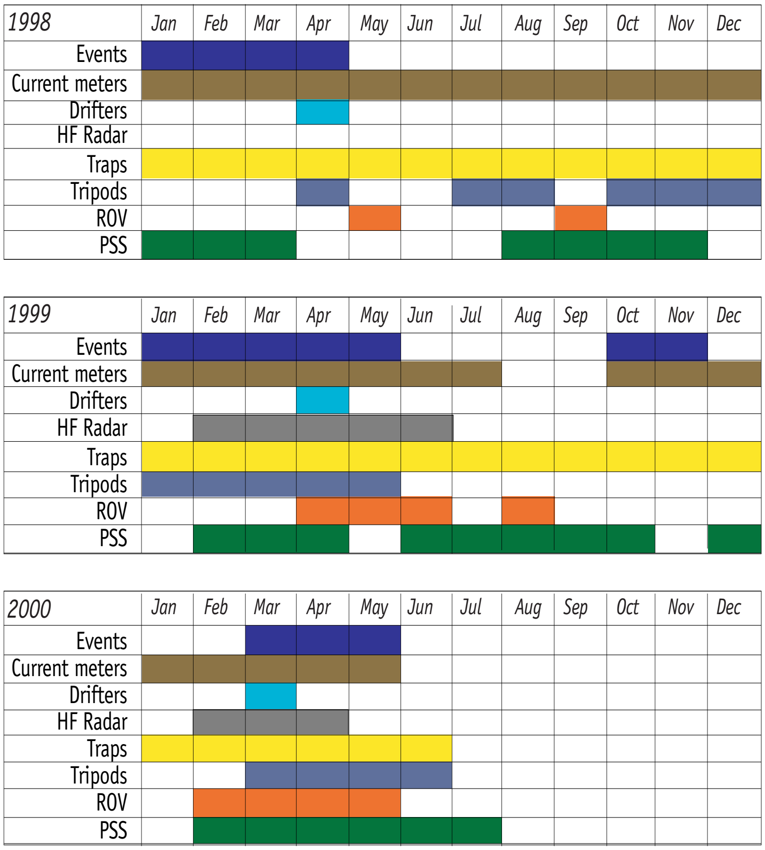
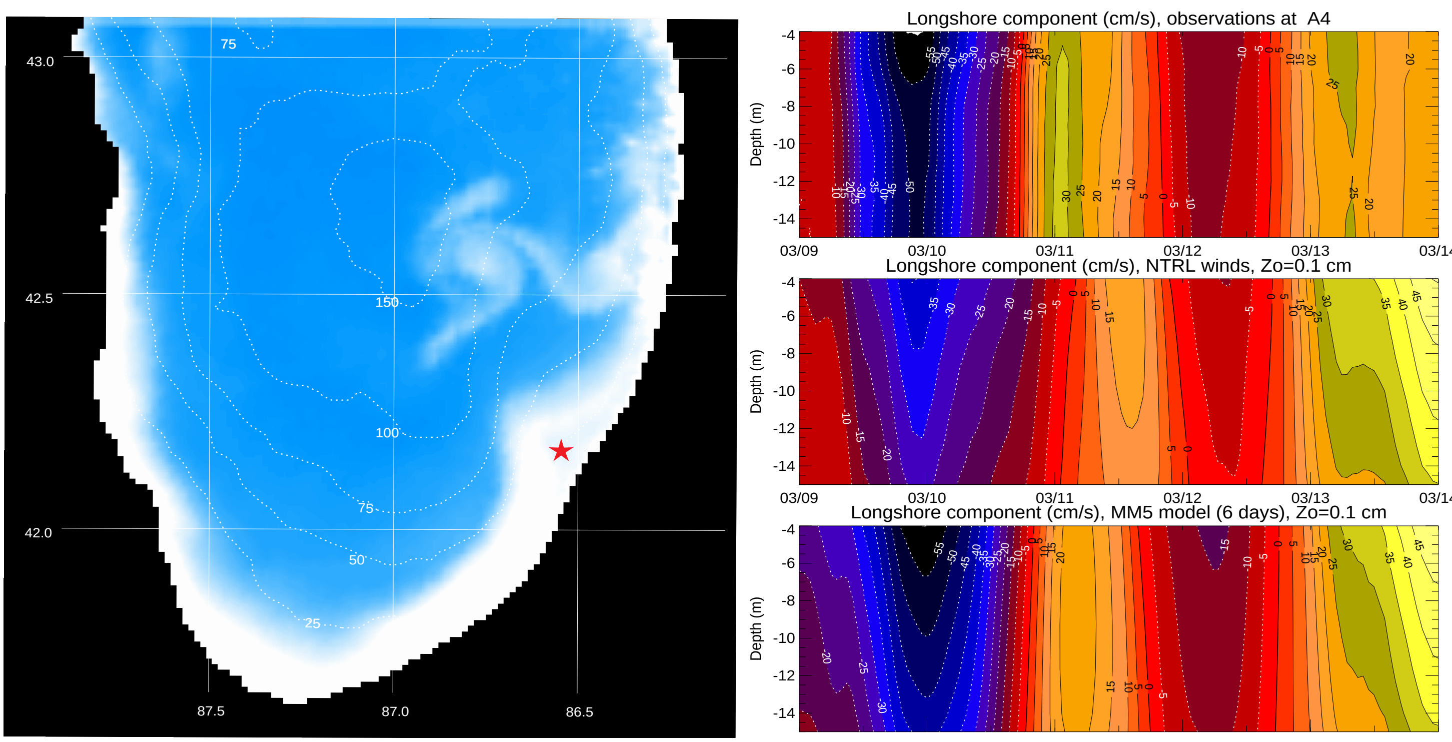


Figure 5 (left). Schematic of the temporal coverage of sediment resuspension events and successful collection of samples and data for the three-year field program. ROV indicates sediment-water interface sampling with a remotely operated vehicle. PSS represents transects with the tow-yoed plankton survey system.

insight into the hydrodynamics of cross-margin transport, transformation and ecological consequences of BIMS ever accomplished on the Great Lakes (Fig 6).

Some of the preliminary conclusions reached at the workshop include: 1) the magnitude of resuspended sediments is in the range of 1-5MMT, larger than annual external input of fine-grained materials to the southern basin, 2) resuspended total phosphorus is several times the annual external input, but only a small fraction appears to be available for primary production, 3) the reduction of light in the plume counteracts the increased nutrients and results in somewhat reduced productivity, 4) the ecological impacts (e.g. greatly increased heterotrophy) may be localized to the region near the plume, and 5) the events generally include substantial offshore transport. Further information can be obtained at the EEGLE website: http://www.glerl.noaa.gov/eegle

Figure 6. Results of hydrodynamic run (right - middle and lower panels) compared to observed longshore currents (right - upper panel) during the large Lake Michigan sediment resuspension event in March 1998. The location of the measured and modeled currents is indicated on a color-enhanced visible-band satellite image from March 12, 1998 (left panel). When forced by winds from a high-resolution meteorological model (right - lower panel), the hydrodynamic models' simulation was much closer to the observed currents (right - upper panel) than when objectively modeled surface winds were used (right - middle panel).



The Keweenaw Interdisciplinary Transport Experiment in Superior (KITES)

Sarah Green
Michigan Technological University

The Keweenaw Interdisciplinary Transport Experiment in Superior (KITES) project completed its third and most intensive field season in October 2000. Field sampling will be complete with recovery of overwintering current moorings, sediment traps, and BASS tripods in spring 2001. Our focus is the western side of the Keweenaw Peninsula, which juts like a thumb northward into central Lake Superior. The dominant physical feature in this region is the Keweenaw Current, a coastal jet which flows to the northeast with velocities reaching 50 cm/s near Eagle Harbor at the tip of the peninsula. Nutrients, terrestrial organic carbon, and suspended particles are delivered to the region from the Ontonagon River at the southern end of the KITES study site, and via several smaller tributaries.

KITES physical measurements, including moored and shipboard acoustic Doppler current profilers (ADCP), an intensive grid of hydrocasts, and Lagrangian drifters, are revealing the behavior of the Keweenaw Current and associated periodic upwelling and downwelling events throughout the year. A preliminary estimate indicates that about 10% of the lake's water passes within 2 km of Eagle Harbor every year. In 1998 temperature sensors on a deep mooring off Eagle Harbor gave a remarkable picture of the fall homogenization event in December (Fig. 7). On December 11th-13th the lake was still stratified with the surface water (≤87 m) about 0.6°C warmer than the bottom water (≥239 m). On the 14th, a parcel of warmer water moved through the deep water with no corresponding signal at the surface. Then, on the 17th, a similar event abruptly broke the stratification and the temperatures coalesced throughout the water column.

Other findings have shown that there is very little sediment resuspension and transport along the peninsula in spring and summer; these processes are much more important in fall when bottom currents and stresses increase. Nevertheless, a benthic nepheloid layer develops in midsummer after the lake becomes stratified and persists throughout the season. Cores provide a record of transport over longer time periods. In particular, copper-rich particles that were deposited at the shoreline during mining activities show that on decadal time scales particle transport is relatively rapid along the shore and slower across the margins and into the central basin.

Lake Superior is severely phosphate-limited and thus, primary production is dependent on terrestrial input. Yet, unexpectedly, C:P ratios and alkaline phosphatase activity indicate that the nearshore zones are more phosphate limited than offshore environments.

Investigation of the dissolved organic carbon (DOC) pool indicates that on the order of 10-20% of the lake

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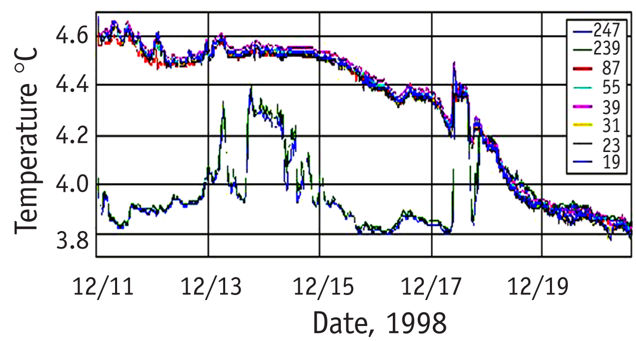

Figure 7. Fall homogenization event in December 1998. Mooring was at 250 m depth north of Eagle Harbor.

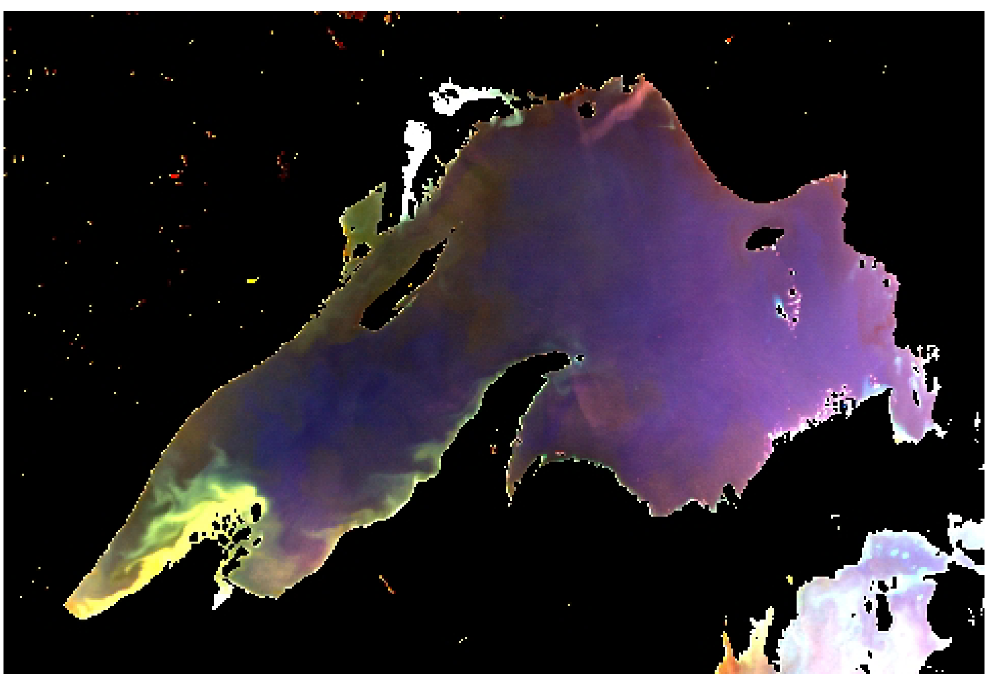

Figure 8. False color SeaWiFs image of Lake Superior, August 29, 1999.

KITES *(continued from page 10)*

DOC appears to be labile to bacterial utilization, and photochemical bleaching of chromophoric DOC has also been documented. We continue to investigate vertical distributions of phytoplankton, zooplankton, and bacteria in light of these observations. Benthic organisms (primarily *dipoeria*) have their highest densities at 4-5 km from shore, and benthic bacteria show a similar distribution.

Our remote sensing effort has produced a set of images showing fascinating patterns of suspended sediment and chlorophyll across the basin. Figure 8 is a false color SeaWiFs scene of Lake Superior from August 29, 1999 (red=670 nm, green=555 nm, blue=490 nm). Bright plumes at the bottom left highlight the suspended sediment derived from eroding bluffs around the Apostle Islands in northern Wisconsin. Further north and east, along the Keweenaw Peninsula, material can be seen leaving the shoreline in several distinct plumes. We also observe fainter patchy concentrations near the northern point of the peninsula. Because the marine procedures give incorrect results for Lake Superior, this image was processed using a new spatially-based algorithm for atmospheric correction developed by Tony Vodacek and his student Kirk Knobelspiesse, now at NASA. Although intriguing patterns are apparent in many SeaWiFs images, much work is still required to generate believable quantitative estimates of particle and chlorophyll concentrations in the lake. Field measurements show that the marine algorithms for chlorophyll greatly overestimate concentrations in the lake; development of a lake-specific algorithm is complicated by the very low chl concentrations, averaging about 0.2 µg/l, and small range of values observed in this system.

At this stage of KITES we have generated an enormous amount of raw data about Lake Superior relative to the paucity of information previously available. We have also made important headway towards identifying the controlling physical and biogeochemical processes in this system. Our continuing challenge is to bring these individual puzzle pieces together into a coherent view of this unique environment.

NSF *(continued from page 1)*

To respond to ongoing changes in the ocean science community and the research it undertakes, and to prepare for increased activity in the decades to come, adding a third research section has restructured OCE. Since 1981, OCE has been divided into two Sections: the Ocean Sciences Research Section, within which all the research programs resided; and the Oceanographic Centers and Facilities Section, which supported the Academic Research Vessel Fleet and the Ocean Drilling Program. The new structure arranges programs into logical groupings by research interests and functions, consisting of three Sections:

Ocean Section (OS): consisting of the Biological Oceanography, Physical Oceanography, and Chemical Oceanography Programs. OS supports research on processes occurring within the water column from the air/sea interface to the ocean floor.

Marine Geosciences Section (MGS): consisting of the Marine Geology and Geophysics and the Ocean Drilling Programs. MGS supports research on processes that occur on and below the seafloor and at the water/sediment/rock interface.

Integrative Programs Section (IPS): consisting of the Oceanographic Technology and Interdisciplinary Coordination (OTIC) program; the Education program; the Ship Operations, Instrumentation and Technical Services programs; and activities related to the National Ocean Partnership Program (NOPP). IPS supports activities, including both research and facility support, that are supportive of the objectives of the Division as a whole, that do not have clearly identifiable disciplinary 'homes', and that are fundamentally important to both OS and MGS. Support for CoOP remains within the OTIC program, which is now located in this new Section.

This new structure is expected to improve internal efficiencies and to better provide for balanced growth across the Division. The addition of a third senior-level Section Head will allow management to give increased attention to strategic issues such as the development of the Integrated Ocean Drilling Program and interagency planning for U.S. integrated ocean observations.

The restructuring will entail several changes in responsibilities. Mike Reeve will serve as Head of the Integrative Programs Section. A search will be initiated for the new Head for the Marine Geosciences Section. I was recently named as Head of the new Ocean Section, so a search will begin to fill my previous position as OTIC Program Director. The staffing at the disciplinary Program level will not be affected by these changes, so community investigators should experience no changes in their routine interactions with Program staff. But this strengthening of the senior management of the Division will enable NSF to continue to play an increasing leadership role in ocean science research and education on both the national and international level.

CoOP Steering Committee 2000-2001

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Coastal Ocean Processes