OVERVIEW

The Coastal Ocean Modeling and Observation Program (COMOP) was initiated in 1993 by oceanographers at the Rutgers University Institute of Marine and Coastal Sciences working with engineers from the Ocean Systems Laboratory of the Woods Hole Oceanographic Institution. A long-term goal of COMOP is the construction of a real-time, multiplatform, adaptive sampling network coupled to a data-assimilative numerical model for use in coastal nowcasting and forecasting applications. The initial focus of these efforts has been on the New York Bight (NYB), specifically (a) episodic upwelling and the effects on phytoplankton and ocean optical properties; (b) storm-driven sediment transport; and (c) interactions of the coastal ocean with estuaries and inlets. This focus is based on the predictable locations of the upwelling centers, the development of a regional data-assimilation dynamical model, the large impact these recurrent upwelling centers have on nearshore optical properties and the relationship of these centers to recurrent regions of hypoxia/anoxia in the NYB. **Given this, we are requesting real-time access during our summer field season to define the mesoscale dynamics of phytoplankton in the NYB using SeaWiFs. The imagery will be complemented with a full-suite of moorings, shipboard surveys, and numerical modeling exercises.**

Background. There is a growing consensus that multiple driving forces are adversely impacting coastal waters (cf. Sherman et al. 1996) and that effective means to monitor the nearshore coastal ocean need to be developed (IOC 1992). Central to this task is defining biological responses to physical changes in the environment on daily, weekly, seasonal and interannual time scales. Bio-optical techniques can predict algal biomass and primary productivity in a non-intrusive manner over ecologically relevant scales and have shown great promise in offshore waters where phytoplankton represent the dominant optical component (Case 1 Waters; Dickey 1991, Bidigare et al. 1992, Morel 1988, 1991). Application of these approaches however can be problematic in the nearshore coastal waters (often Case 2 waters), especially when episodic events (sediment resuspension, outwelling, onwelling, and upwelling) can dramatically alter the optical complexity on the time scale of hours. Refinement of these approaches will therefore require consideration of the physical forcing of the sources and sinks of radiant energy in the coastal ocean.

Along the New Jersey coast, upwelling begins in response to southwesterly winds as a uniform band of cold water along the coast (Hicks and Miller 1980, Neuman 1996). Over time, the upwelling converges into four cold water patches spaced approximately 50 km apart. These upwelling centers have been observed each summer over the last five years (Glenn et al. 1996). The upwelling centers are each located on the northern side of a topographic high. Modeling studies suggest that during upwelling favorable winds, the upwelled water forms a cyclonic eddy on the downstream side of each topographic high, while the alongshore warm water jet meanders around the eddies (Glenn et al. 1996). CTD and Ocean Surface Current Radar (OSCR) observations confirm the presence of the cyclonic eddy and the meandering jet. The degree to which these transient upwelling centers lead to significant phytoplankton blooms has yet to be demonstrated; however, optical data collected during the summers of 1996 and 1997 confirm that upwelling results in a significant increase in dissolved and particulate matter.

The predictable locations of these upwelling centers are correlated with regions of recurrent low dissolved oxygen (Pearce et al. 1985). The depletion of oxygen can stress benthic organisms and has had a serious economic impact on the New Jersey shell fish industry. A particularly severe example of this occurred in 1976 when bottom water anoxia resulted in a $550 million loss to shell fishing and related industries (Figley et al. 1979). The historic regions of recurrent low DO were thought to be associated with specific estuaries; however, while some estuaries show no recurrent hypoxia, other pristine and anthropogenically impacted estuaries are regions of recurrent hypoxia. The relationship between anthropongenic loading from estuaries and hypoxia in coastal waters is therefore at best ambiguous.

It has been hypothesized that recurrent upwelling centers within the NYB are responsible for declines in bottom water DO. Observations suggest a classical scenario, where upwelling results in phytoplankton blooms which are followed by deposition, increased respiration, and low DO (Warsh 1987). Declines in DO will also be a function of the potential of upwellings centers to trap particulate and/or dissolved material. Observations suggest that most particulate matter produced is remineralized and/or consumed by heterotrophic processes and little material is exported off the continental shelf in the Mid-Atlantic Bight (Biscayne et al. 1994). *The goal of this proposal is to characterize the impact of episodic upwelling events on phytoplankton productivity using an existing multiplatform sampling network which is coupled to regional numerical models. This will allow us to assess the local, regional, and seasonal variability in phytoplankton productivity in the NYB and the biological significance of upwelling for coastal biogeochemistry.*

SCIENTIFIC APPROACH

Our approach in studying upwelling is to utilize the Long-Term Ecosystem Observatory (LEO-15) (von Alt and Grassle 1992). The network can provide data over relevant spatial and temporal scales for both upwelling and algal productivity. An emphasis will be placed on using in situ coastal optics and ocean color viewing satellite imagery to generate a near synoptic picture of phytoplankton biomass for spatial/temporal scales ranging from meters to kilometers and days to months in the nearshore coastal water off the coast of New Jersey. Given the existing observational network and the range of optical water types which can sampled over the course of a single day, this represents an ideal site to develop remote sensing approaches. Therefore, the already extensive in situ optical database which have been collected are being made freely available to the NOAA Coastal Ocean Program "Ocean Color Algorithm Evaluation for Remote Sensing of Coastal and Estuarine Waters: U. S. South Atlantic Bight and Eastern Gulf of Mexico" (PIs Drs. Richard Stumpf, Robert Arnone, Kendall Carder, Patricia Tester, Jonathan Pennock, Carmelo Tomas). Already funded through ONR, NSF, NOAA-NURP, future efforts will collect an extensive in situ database for both inherent and apparent optical properties as well as spectral fluorescence emission, chlorophyll a, phytoplankton pigmentation, and dissolved organic matter. The field work is primarily funded through two large programs. The COMOP program (funded by the ONR) is a five year effort focused on developing a real-time adaptive sampling network and ocean forecasting system. The program will develop a numerical data-assimilation model utilizing data from the NOAA polar orbiting satellites and in situ data from the observational network to create a short-term forecasting system. This program is complemented by a recently awarded National Ocean Partnership Program (NOPP) "Multi-Scale Data-Driven Sampling with Autonomous Systems at a National Littoral Laboratory". Efforts are underway to expand these programs through several joint federal/academic collaborative efforts which includes 1) coordinated aircraft surveys using Hyperspectral optical sensors (field tests by ONR and the Naval Research Laboratory during the 1998 summer field season in support of the upcoming HyCode Program) and 2) the acquisition of Synthetic Aperture Radar (SAR) data .

The observational network allows us to collect data over relevant scales and coordinate sampling of an episodic events. Rutgers is capable of continuous processing of AVHRR satellite data and in situ data from vertical profiling nodes (see below) which allows events to be identified on a hour/daily basis and shipboard surveys to be initiated. This strategy has been used effectively over the last five years. Realtime access to SeaWifs imagery will allow for the coordinated sampling of the biological features. Data from the summer of 1996 and 1997 demonstrated that upwelling resulted in significant changes in the nearshore coastal optical properties. Furthermore, imagery from the OCTS satellite also provided direct evidence that the optical response to episodic upwelling will be observable by ocean color sensors. The spatial picture provided by the satellites will be complemented by both the real-time in situ observation network and ocean forecasting system which will provide pictures of the vertical distribution of hydrographic/optical parameters. Currently, the specific components of the observational and modeling network include:

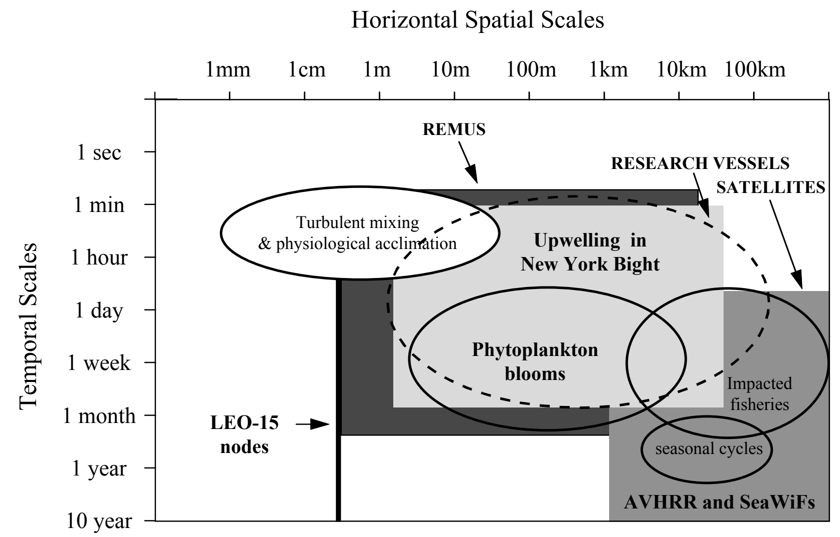

Figure 1. Temporal and spatial scales relevant to phytoplankton productivity and the sampling platforms to be used in the New York Bight. Based upon Dickey (1991). The spatial/temporal sampling scales for both the observational platforms (delineated by darkened squares) and the parameters of interest (delineated by circles) are presented.

Satellite Sampling Capabilities. We have full satellite capabilities which includes a satellite tracking antenna capable of acquiring real-time data (both NOAA polar orbiting satellites and SeaWiFs). The launch of the SeaWiFS satellite has greatly enhanced our ability to track phytoplankton blooms in the New York Bight. In support of SeaWiFS, we are particularly interested in defining the variability of reflectance terms, phytoplankton pigmentation, dissolved organic carbon, and in-water inherent optical properties. The IMCS satellite technician (Mike Crowley) and bio-optical graduate student (Trisha Bergmann) have recently completed the SEADAS software training workshop at Goddard (October 1997). They are now fully versed in the receiving and processing SeaWiFs data into primary data products (chlorophyll a, dissolved organic matter). The IMCS remote sensing capabilities will be complemented during the 1998 and 1999 by a leased CODAR radar system will provide continuous surface current information within the upwelling study site.

Long-Term Ecosystem Observatory (LEO-15) sampling. The LEO-15 system was deployed during the summer 1996, and consists of two nodes which are 1.5 km apart approximately 5 km off the central coast of New Jersey . The LEO-15 nodes are connected to the Rugters Marine Field Station at Tuckerton via an electrofiber-optic cable. A vertical profiler on the sea floor is controlled from a shore station via the Internet to provide water column profiles of temperature, salinity, oxygen, light transmission, and chlorophyll a fluorescence on command. The Marine Field Station also supports a coastal meteorological station outfitted with a suite of WOCE-standard Improved METeorological sensors (IMET) which are accessible over the Internet. Data when collected, is transmitted back to shore and is accessible over the World Wide Web (http://marine.rutgers.edu). The long term database is archived and is made available to the public upon request.

Adaptive shipboard sampling. Real-time satellite, meteorological, and in situ datasets allow episodic events to be identified on a daily basis and provide a mechanism for coordinated sampling. The Tuckerton Marine Field Station has two available research vessels which can be offshore at the onset and throughout the entire upwelling period. This strategy has been used by IMCS researchers since 1992. The episodic nature of upwelling events has always hampered past studies focused on the biology of bloom phenomena; however, the continuous in situ data from LEO-15 combined with spatial data from ship surveys represents a unique opportunity to study phytoplankton dynamics. The IMCS research vessels are equipped with a surface-towed ADCP, an undulating Guild-line CTD/fluoromter, a suite of CTD/bio-optical submersible profiling equipment (Seabird CTD, Biospherical PRR-600 spectroradiometer, 14 channel TBS-OCR Satlantic radiometer, Wetlabs absorption/attenuation meter, Wetlabs fixed wavelength spectrofluorometer SaFire), and Niskin bottles allowing collection of discrete water samples.

Multiple Autonomous Underwater Vehicles. A network of Autonomous Underwater Vehicles (REMUS AUV, von Alt et al. 1994) is being developed for making basic hydrographic observations (CTD/ADCP/OBS). Several of these vehicles will soon be operating within a network of nodes which are capable of recharging batteries and downloading/transmitting data after a transect. The REMUS vehicles have recently completed field trials with a docking station. The complete REMUS infrastructure will be in place for coordinated field studies of the upwelling eddies for the summer of 1998 as part of the National Ocean Partnership Program (NOPP) awarded to Rutgers University. The REMUS vehicles will provide a spatial extension of hydrographic information in and around the LEO-15 nodes and assist in the interpretation of the phytoplankton fluorescence data collected by the node. Through COMOP, ONR has committed to the continued development and deployment of REMUS vehicles into the LEO-15 study site for the next five years.

Modeling Capabilities. A state-of the-art modeling, data analysis and assimilation capacity has been developed by the Coastal Ocean Modeling and Observation Program (COMOP) led by Dale Haidvogel and Scott Glenn. The system includes a coastal circulation model which is based on the latest version of the S-Coordinate Rutgers University Model (SCRUM, Song and Haidvogel 1994). The model is equipped with 1) a coupled surface boundary layer model (Mellor and Yamada 1974, Price et al. 1986, Large et al. 1994) for surface forcing by the NAVY NORAPS U.S. East Coast Model and 2) a coupled bottom boundary layer model (Glenn and Grant 1987, Keen and Glenn 1994, 1995) for inclusion of wave and sediment transport effects on bottom friction. The model is currently being outfitted with data assimilation capabilities using an intermittent Optimal Interpolation (OI) scheme (Gandin 1963, Bretherton et al. 1976, Lorenc 1978). The model is also equipped with full visualization capabilities for data and model results.

Data Management. All data will be maintained in a data management system being used at IMCS (Glenn et al. 1996). Data is managed at three distinct levels. Level 1 is the archived raw data downloaded from individual instruments stored off-line. Level 2 is a series of on-line directories containing calibrated and processed data generated by the individual investigators in a flexible ASCII format. Level 3 is a second set of on-line directories containing composite data sets and model results in NetCDF format (Rew and Davis 1990) for advanced applications. The data sets are maintained on a UNIX disk server controlling a large, multi-stage archiving system. On-line access to each level is provided over the Internet via World Wide Web or anonymous ftp, where local users can log directly in with read-only access.

SATELLITE USAGE AND DATA PRODUCTS

We are requesting real-time access to SeaWiFs data from May through September to complement the already funded field efforts. We have the appropriate software, satellite receiving capabilities. We have trained personnel (by Goddard) to use the SeaWiFs data software and sufficient computer facilities for post-processing of the imagery.

l) Data will be collected for the Mid-Atlantic Bight and used to estimate chlorophyll a standing stock during summer upwelling seasons.

2) Use SeaWiFs, AVHRR, and LEO-15 data to coordinate extensive physical/optical shipboard surveys during upwelling events.

3) Imagery will be used to access the degree which episodic upwelling results in phytoplankton blooms and the potential for it to drive hypoxia/anonxia in the nearshore coastal ocean.

4) Imagery and in situ data will be made available (with appropriate two week delay in data dissemination to other groups), via the IMCS home-page, to the numerous physical, chemical and biological projects funded to work at the LEO-15 site (Table 1).