UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

COASTAL OCEANOGRAPHY:

FUTURE TRENDS AND VESSEL REQUIREMENTS

A Status Report by the
COASTAL OCEANOGRAPHY SUBCOMMITTEE
OF THE UNOLS FLEET IMPROVEMENT
COMMITTEE

June 1994

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AND THE PARTICIPANTS IN

A UNOLS COASTAL OCEANOGRAPHY WORKSHOP

June 1994

UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

FLEET IMPROVEMENT COMMITTEE

June 30, 1994

Dear Colleagues:

All of us in the oceanographic community have become aware of the increasing emphasis being placed on coastal ocean research by federal and state agencies in the past several years. This increase in emphasis has spurred growth of coastal oceanography at academic institutions, especially institutions in coastal states and those bordering the Great Lakes. There are two principal stimuli behind this growth:

The first stimulus is the clear need to better understand coastal processes in order to successfully address critical problems that are related to the fishing industry, pollution of coastal waters, and development of offshore mineral resources. The importance of understanding coastal processes in this regard has long been realized. However, increasing population densities in all coastal countries with the resulting increase in pollution, and the rapidly accelerating exploitation of marine resources with the alarming depletion of once plentiful fish stocks have made it amply clear that coastal waters are stressed. The effects of mismanagement of coastal waters and resources are now reported regularly by the news media and the "news" has awakened policy makers and the public alike to the threat to the world's oceans and shorelines.

The second stimulus is technological advance. Processes in coastal waters occur over much shorter time and distance scales than is typical in the open ocean, and new technology provides the means to capture coastal phenomena at the appropriate scale. Satellite imagery, and precision measurements from aircraft now provide synoptic data of large stretches of coastal water, while sophisticated moorings and seafloor instrumentation provide accurate time-series information for periods of a year or more. Equally important is the remarkable increase in computing power, which allows coastal researchers to develop ever more realistic models of the complex interactions of winds, currents, and the seafloor morphology. A current research strategy is to interactively improve regional models by continually testing it against data that is regularly updated. Such models hold out the prospect of being able to forecast the effects of man-made or natural perturbations of the coastal system.

Foreseeing the need for new types of facilities to support the growth in coastal oceanography and the new approaches made possible by technology, the National Science Foundation asked UNOLS to carry out a study of the existing facilities for coastal oceanography and future needs. UNOLS relayed this task to the Fleet Improvement Committee (FIC). To gain the broadest possible input from the UNOLS community, FIC sponsored a workshop on future facilities for coastal oceanography. The workshop, which was supported by NSF, ONR and

NOAA, was held at the College of William and Mary in Williamsburg, Virginia in February 1993. This report is the outcome of that Workshop. Since the main concern of UNOLS is the academic research fleet, the primary focus of the workshop was on seagoing facilities. However, other types of data acquisition vehicles such as aircraft, moorings, satellites and blimps were discussed in depth since it is recognized that these platforms will play an increasingly important role in the future.

The Workshop was highly successful due in large part to the effort of Don Wright and an active subcommittee listed on the cover page. We also would like to acknowledge the support of the staff of the Virginia Institute of Marine Science for on site arrangements and assistance. We sincerely hope you will find this report informative and stimulating.

Garrett W. Brass
Chair
UNOLS

Marcus G. Langseth
Chair
UNOLS Fleet Improvement Committee

GENERAL RATIONALE AND BACKGROUND

Why Worry Now?

The Long Range Plan of the Geosciences Directorate of NSF identifies the interdisciplinary study of material transports and ecosystem dynamics in the coastal zone as one of its highest priorities. The coastal zone, including the continental shelves, estuaries, bays, lagoons, and the Great Lakes, is a highly productive and dynamic environment. Although estuaries and continental shelf waters comprise less than 10% of the earth's surface, they account for about 25% of global biological production, support over 75% U.S. fisheries, and store 90% of the global sedimentary accumulation of organic carbon. Nearly 50% of the U.S. population inhabits coastal counties that make up 10% of the nation's land area and account for at least 30% of the nation's GNP[1].

The effects of global change and regional human activities have been and are likely to continue to be especially pronounced in the coastal zone. The recent history of environmental change in this transition region between land and sea is characterized by losses of habitat, increased contamination by industrial and agricultural chemicals, excessive nutrient enrichment, and declines in living resources. These and other changes are likely to continue at accelerating rates in the absence of comprehensive environmental strategies based on the predictive understanding of coastal ecosystems[2].

U.S. Coastal Initiatives

Government agencies have responded by planning and implementing major new research initiatives that have generated an increase in research activity and will require dramatic future increases to achieve their collective goals. Examples include interdisciplinary programs such as the Land-Margin Ecosystem Research (LMER) program (NSF)[3], the Coastal Ocean Processes (CoOP) program (NSF, NOAA, ONR)[4], the Coastal Ocean Program (NOAA)[5], the Global Ocean Ecosystems Dynamics (GLOBEC) program (NSF, NOAA)[6], and the Dynamics of Continental Margins program (DOE)[7]. NOAA and EPA have initiated major monitoring programs[8,9] and are jointly responsible for overseeing the Regional Marine Research Program (RMRP). ONR has recently announced a significant increase in its emphasis on coastal research[10]. Additional coastal research activities are in progress or planned by EPA, USGS, MMS, NASA, and the Army Corps of Engineers. The international community has also recognized the need for major new research in the coastal zone. One manifestation of this is the IGBP program on "Land-Ocean Interactions in the Coastal Zone" (LOICZ) which incorporates the goals of both LMER and CoOP[11].

As these activities suggest, the nation is engaged in the initial stages of planning and implementing major research and monitoring efforts that are intended to address a broad spectrum of complex environmental challenges that are emerging in the coastal zone. Recognizing the existence and likely future growth of the specialized needs of coastal oceanography, the UNOLS Fleet Improvement Committee (FIC) established a subcommittee in 1991 to review the potential vessel and facilities requirements. With sponsorship from the National Science Foundation via UNOLS, a workshop was held in Williamsburg, Virginia in February 1993 to address questions related to coastal facilities in general but with emphasis placed on vessels specifically.

At the Williamsburg workshop, a diverse group of about 65 coastal scientists discussed operational goals and regional requirements for research vessels in the context of a broad spectrum of facilities including fixed moorings, drifters, underwater vehicles, benthic observations stations, fixed and drifting platforms, aircraft, blimps, satellites, and instrumentation. The group reached the consensus that there is an urgent need for:

- modernization and upgrading of a diversity of existing platforms and instrumentation; and for

- the design and construction of modern high capability, shallow draft research vessels.

It was also clear that these goals cannot be achieved in the absence of effective inter-agency cooperation, coordination and collaboration[2]. Budget realities and similarities in many of the requirements for research platforms and instrumentation argue for interagency planning and funding of shared use facilities.

THE NEEDS OF COASTAL SCIENTISTS: SOME GENERAL CONSIDERATIONS

Operational Priorities

The coastal zone is a region of transition characterized by high levels of variability over a broad spectrum of scales in time and space. Current deficiencies and projected needs underscore the importance of spatially synoptic observations, time-series, interdisciplinary process studies, and information management. Given the interplay between temporal and spatial variability, spatially synoptic visualizations and high resolution time series over extended periods are required to detect and document short-term, high energy events; establish spatial pattern and temporal trends; and validate model predictions[13,14]. Interdisciplinary, process studies reveal causal relations and are fundamental to understanding how changes in the structure of systems are related to their functions (e.g. relationships among coastal eutrophication, changes in community structure, fisheries, and the role of coastal systems in the global carbon budget). Finally, data management from acquisition, archiving and integration to visualization, interpretation and dissemination, is the primary limiting step to the formulation of fundamental principles and to the translation of scientific knowledge into a broader societal context[15].

Based on these considerations, a greater commitment is urgently needed to:

- establish long-term, time-series measurements in estuarine and continental shelf ecosystems (monitoring);

- conduct interdisciplinary, process studies during all seasons and up to sea state 5;

- increase access to large (> 200 ft) and intermediate (50 - 200 ft) ships;

- improve data links between ships and collateral facilities (e.g. moorings, aircraft, satellites);

- improve interagency coordination of facility development and use, especially ships and moorings;

- develop regional pools of shared use equipment and calibration facilities; and

- develop regional systems for information management and dissemination.

Needs are Regionally Specific

It was recognized at the workshop that the coastal zone consists of a diversity of complex systems and that regional differences in geomorphology and weather patterns must be considered. Five U.S. regions were defined based on their particular requirements for coastal research vessels: The Gulf of Maine and Great Lakes; the Mid-Atlantic Bight; the South Atlantic Bight and Gulf Coast; the West Coast and Hawaii; and Alaska. Each region has special needs and characteristics that should be considered in the development of a strategy for improving the fleet of coastal vessels. For example, the proximity of deep water to the coastlines of the west coast and Hawaii allows large and intermediate research vessels to operate throughout most of the coastal zone and, to a limited extent, into estuaries. Ice is an important factor in coastal waters of Alaska. An arctic research vessel is currently being designed and will probably be constructed in the next several years. The science and operational requirements for this vessel have pushed the current design to greater than 300 feet. Operating conditions in the Great Lakes are similar to those of New England coastal waters. Both the Gulf and East Coasts have broad shallow continental shelves that present special challenges for sea going assets. If a depth of 10 m is used as an operational limit for inshore work by existing large and intermediate research vessels, there is a substantial amount of shelf and estuarine area that can only be studied using shallow draft vessels and other facilities capable of capturing the spectrum of spatial and temporal variability that characterizes this environment. Existing fleet improvement and modernization plans are primarily concerned with ships that will operate in the deeper waters of the continental shelf and open ocean[16,17,18].

Although discussions at the Williamsburg workshop focused largely on research needs in U.S. waters, it must be remembered that interdisciplinary coastal studies by U.S. scientists are often carried out in foreign waters. Vessels and facilities must therefore be versatile enough to accommodate the needs of international coastal research.

The Nature of Coastal Oceanography

Coastal oceanographers must be able to deal with steep, often abrupt spatial gradients in the properties of interest. In addition, they must be responsive to temporal sequences in an environment where seasonality is significant and responses to episodic events, such as storms, can be dramatic. Ongoing and foreshadowed activities of coastal ocean field research can be broadly grouped into four basic categories: (1) synoptic observations; (2) time series measurements; (3) interdisciplinary studies; and (4) information management and communication. These are discussed more fully in the sections that follow. Each was considered in depth by separate working groups at the Williamsburg workshop (see Appendix 1 for a list of working group participants).

SYNOPTIC OBSERVATIONS

Rationale

Synoptic sampling is designed to provide broad spatial coverage of a region at an instant in time, an example being the "snapshot" provided by AVHRR. Recent reviews[19,20] however, have suggested that many studies aimed at understanding patterns in ecology are of limited value because simultaneous measurements were lacking. On the other hand, the working group believed that instantaneous snapshots were not always necessary to achieve synoptic sampling; synoptic sampling simply requires consideration of the temporal and spatial scales that are relevant to the process being studied. Powell[20] suggested that for the coastal ocean, coupling between physical and biological processes at scales between 100 m and 100 km are of special ecological interest. With the advent of new techniques (e.g. satellite observations that provide information on a relatively fine scale) the challenge is to assimilate information gathered using different techniques and at different scales into coherent models.

A synoptic approach is necessary to answer many current problems in coastal oceanography including: the significance of cross-shelf transport processes, the causes of large-scale hypoxic events, benthic-pelagic coupling, recruitment processes for commercial species of fish and invertebrates, and the fate of terrestrial inputs of solutes, particles and productivity in the coastal ocean[4]. Most of the important scientific questions that pertain to these problems are best approached on a regional basis (i.e., not global and not national) and it was generally agreed by the working group that resources (e.g. platforms such as coastal ocean research vessels, small airplanes, moorings for general use) best suited to a task should be designed and distributed with regional conditions and scientific programs in mind.

Research programs in the coastal ocean absolutely require background information on the range of variation possible in the system and this can only be acquired by a long-term commitment to a "monitoring program" on a regional basis. While the intended original objectives of the CALCOFI program may not have been achieved, the program has been judged a success based on the variety of uses to which the long-term observations have been put. Appropriate federal agencies should be encouraged to make long-term measurements in a way similar to that already being done by the National Weather Service and the National Ocean Survey. A new mechanism is needed to support such long-term observations given the invaluable nature of long-term studies to research in a particular coastal region.

Current Situation and Limiting Constraints

Consideration of existing techniques and platforms indicates that they each have their own particular virtues and limitations and that most multidisciplinary studies require several different kinds of platforms. Communication among the various platforms (e.g. among satellites, ships, and moorings) is presently limited. Intense episodic events are of major interest in the coastal ocean e.g. storms and hurricanes, but most existing platforms are limited in their ability to examine the immediate effects of such events. In the following sections we discuss the different types of observational methods that are available and their relevance to synoptic studies.

- Drifters and Other Lagrangian Measurements -

Drifters provide information about transport that cannot be obtained by current meters, ships or other techniques. This is particularly true in regions of complex spatial variability. With enough drifters, considerable information can be obtained about the spatial structure of the flow as well as the transport and dispersion rate. There are important limitations that must be recognized about fluid tracking capabilities of drifters, particularly in convergence zones. Drifters of various sorts have long been used to characterize transport. However, existing drifter technology includes a range of approaches that are too expensive, too labor intensive, and generally not sufficiently accurate for most coastal applications. GPS drifters are now around $3000 and just entering the price range where they can be used in large-scale deployments and low-budget investigations.

- Low-Cost Moorings -

Moorings can be used to monitor important parameters such as temperature, salinity, pressure, chlorophyll, and particle concentrations. Mooring systems used in the open ocean have been transferred to the shelf without sufficient thought and the appropriate modifications. Aside from XBTs, oceanographers have not taken advantage of the economies of scale in producing instrumentation. In the coastal ocean, where precision measurement is less important than having large numbers of synoptic measurements, we have an opportunity to make large numbers of inexpensive moored systems.

- Seafloor Observatories -

In order to understand the processes governing stability and change in the ocean, there is a need for *in situ* observations. Unmanned seafloor observatories provide this *in situ* capability yet the number of seafloor observatories currently in existence do not provide the coverage necessary to achieve synopticity.

- Ships -

Ships are an important tool for obtaining synoptic observations in the coastal ocean. Small ships are particularly important for studies in the coastal ocean because they are generally available on short notice so that scientists can respond to episodic events. Many of these smaller vessels are operated outside of UNOLS however, and often lack sufficient financing to provide good maintenance, equipment, and technicians. Most ships capable of operating in the shallower portions of the coastal ocean carry too few scientific personnel for multidisciplinary investigations. Most small ships cannot operate in heavy weather.

- Satellites -

Satellites have been extremely useful in obtaining synoptic data (e.g. temperature, chlorophyll) over broad geographic regions. An important objective must be to use satellite data in conjunction with moorings and shipboard measurements, on time and space scales needed for modelling. The resolution scales of satellites is important. Present and developing civilian technology is limited to the order of 1 km. The Department of Defense has technology that can provide 10 m resolution, with immediate applicability to studies in the coastal ocean, but its use has been limited. NOAA, NASA, and SEAWIFS contractors, as well as the Japanese ADEOS system have agreements in place to acquire data from satellites, but not to provide the 1 km resolution Ocean Color data. NOAA presently makes AVHRR 1.4 km data products available through Coastwatch.

- Aircraft -

Synoptic sampling of coastal oceans will benefit tremendously from the use of aircraft. Aircraft can function as observing platforms, and carry scientists and camera equipment. They can carry instrumentation to measure parameters like temperature, salinity, and ocean color. In a "mix" of platforms, aircraft occupy an intermediate position in the spectrum of sampling scale and resolution -- between moorings and ships on the one end and satellites on the other.

Two constraints seem predominant at present. The first relates to the types of aircraft available. Most of the aircraft available to the research community are of the high-speed, high altitude (and higher cost) type used, for example, by NASA in atmospheric studies. Coastal ocean studies will require smaller, less-expensive,"low and slow" aircraft that are easily accessible. The second constraint relates to leasing arrangements. There is presently a difficulty with government funding for aircraft. Year to year, high uncertainty, short notice funding commitments do not provide for successful aircraft leases.

Airships (blimps) may contribute to synoptic sampling. Their slow flight, combined with station-keeping capability, is well-suited to a variety of biological and physical sampling requirements.

Recommendations

1) Consideration should be given to regional needs in selecting the appropriate combination of platforms and technologies.

2) Long-term measurement (i.e. monitoring programs) of fundamental parameters is essential to provide insight into the range of variation in systems.

3) Agency support for instrument development and testing should be enhanced.

4) New approaches to the study of important problems should be tested. For example, the impact of episodic events such as hurricanes and storms is important in the coastal ocean. Underwater observatories linked to the shore by electro-optic cable may provide a way to study such events[21]

5) Coastal research ships should be equipped for interdisciplinary studies by relatively large scientific parties. Advantage should be taken of new technologies for studying processes at relatively small spatial scales. New coastal vessels should be constructed that can operate in heavy weather and in shallow inshore regions. New vessels should have capabilities for simultaneous sampling. Ships need to operate for longer periods of time, and under heavy weather to obtain data necessary for understanding many important shelf processes.

6) An infrastructure should be created for adding AVHRR at appropriate coastal nodes. A science and applications infrastructure needs to be established to develop appropriate ocean color data products and to distribute them in a timely, cost-effective manner. Interagency cooperation is needed to establish a science and applications team to identify what satellite products are of utility and then set about to develop them.

7) Aircraft specifically suited to coastal ocean sampling should be identified and their availability improved. Mechanisms should be established that enable longer-term funding commitments and leasing arrangements of coastal research aircraft. An infrastructure for multi-agency, multi-project operation of coastal ocean aircraft should be established.

8) Due to the expensive nature of some equipment, regional pooling of equipment should be considered.

9) Communication between various platforms should be improved so that scientists on ships and in land-based laboratories can receive and interpret data from satellites, moorings, seafloor observatories etc. in real time.

10) Administrative constraints should be minimized; emphasis should be placed upon inter-agency and institution cooperation.

TIME SERIES STUDIES

Rationale

Physical, chemical, biological and geological processes in the coastal ocean are variable on time scales ranging from very short (less than minutes) to very long (glacial periods). In the past, time series studies in the coastal ocean have taken several forms including repeated studies of a limited number of sites using ship-based sensors, repeated grids of stations or continuous surveys, moored arrays of sensors, and remote sensing studies using space-borne, airborne, shorebased, and seabed-based systems. Time series studies of the coastal ocean will continue to be required at a variety of time scales to permit us to understand such phenomena as changes in productivity and climate and the coastal ocean's response to them. Time series are sometimes needed to capture short-lived events, while intense spatial sampling is needed to deal with inherent spatial heterogeneity.

Time series data are vital for the development of insights as well as for checking the validity of models for a region, be they physical, biological, chemical or geological. An expanded time series effort is needed for the coastal ocean to support interdisciplinary process studies, to detect and document possible responses to climate and global change, to detect and document anthropogenic changes on a regional basis, and to support research into prediction (i.e. simulation, hindcast, nowcast, and forecast) models. The current status and future needs of time-series observations in the coastal ocean are subjects of a recent CoOP-sponsored workshop report[22].

Current Situation and Limiting Constraints

Time series studies may include either Eulerian or Lagrangian approaches. Eulerian studies are traditionally done with moorings, which must be deployed and recovered using ships and aircraft, and which require sensors that can be left unattended for extended periods of time. An example of a useful biological Lagrangian time series would be a data set, obtained by following a drifting buoy, monitoring the temporal evolution of organisms as a parcel of water is advected through a system. (An important question, of course, is whether a Lagrangian drifter could actually remain with the same water parcel for an extended period.)

Ships play a role in time series by supporting mooring operations, conducting repeated surveys, and performing experiments to design observing system networks. Processed data collected from shipboard can be used to extrapolate mooring-based or remote sensing data. Remote sensing is increasingly used, where appropriate, to obtain repeated, larger spatial scale coverage of temporally varying phenomena.

Many time series studies, particularly of physical phenomena, have depended heavily on moorings. There are special problems with moorings in the coastal ocean including the severe wave climate, the need for protection from fishing and vandalism, and severe biofouling. Interdisciplinary studies argue for large ships because the shipboard sampling component of time series in the coastal ocean requires very dense station spacing around the clock due to the short spatial and temporal scales, which in turn, requires a greater number of berths to man the equipment and maximize the use of the ship. Concentrated mooring-deployment cruises also need large vessels because the moorings are often large and contain many sensor packages, because of the strong vertical variability found in nearshore systems. Presently, time series studies are hampered by the limited variety of available sensors (especially those for chemical and biological variables).

For many time series studies, research is hampered by the lack of "quick response" vessels that can collect samples and/or service moorings and test and repair or replace instrumentation. The shorter distances of the coastal ocean and the relatively high loss rates of equipment mean that if "quick response" vessels were available, they might be both practical and needed in the coastal ocean. In addition, telemetry of data to shore in real time would maximize the value of mooring-based time series, as instrument failures could be identified more rapidly and replacement of these sensors could, in theory at least, be more effective, and the data could be applied by many programmatic as well as scientific users to make decisions. Telemetry could also be used to identify "events" that could then be "groundtruthed" using rapid response vessels. At present, because most data collected in the Eulerian mode are accessed only when the moorings are recovered, the data cannot be used interactively to plan, in an adaptive mode, ship-based surveys, and airplane overflights, to make environmental management decisions, etc.

For time series, data quality assurance issues are very important. The issue of accuracy (as contrasted with resolution and precision) is especially important for comparison of measurements made by a number of instruments over extended periods. Problems of calibration, instrument drift and so on are particularly acute when instruments are deployed for extended periods on moorings or bottom landers. Present programs are often hampered by the lack of an ability to determine how new instrumentation is performing in the field, frequently leading to very long development times for new equipment. Ship-based studies would be enhanced by calibration programs.

There is also clear need for shared-use facilities for ADCPs and current meters, SEASOAR, profilers, and instrument test beds. Typical coastal researchers have smaller suites of equipment than their blue-water colleagues, and do not have the means to maintain such equipment. Shorter coastal cruises mean that the equipment would not be monopolized by a single user and more groups could have access to it.

Recommendations

(1) There is a need for liaison between the scientific community and local fishing groups in an effort to reduce the loss of gear. There is a need for some organization to provide an interface with local fishermen groups to publicize the scientific activity and to try to minimize the loss of equipment from dragging.

(2) Limitations of moored instrumentation suggest the need for increasing reliance on radar, acoustics, and optical remote sensing systems. Access to time series remote sensing information (e.g., HRPT receivers for AVHRR, color) is needed aboard research vessels. Agencies should consider supporting non-ship facilities that would be particularly desirable for coastal time series measurements including towers, planes, and blimps for remote sensing. Consideration should also be given to maintaining a listing of other platforms that might be available, such as airplanes, airships, and offshore towers.

(3) Interactions between academia and NDBC (National Data Buoy Center) should be encouraged on topics of mooring technology, sensor development, technology testing, and observing system network evolution and utilization (including use of NDBC buoys as relay points in data telemetry) as well as other issues. On regional and national levels, academia could contribute to, and benefit from, coordinating repeated survey grids on an interagency basis.

(4) Real-time telemetry of data from sensors is essential to permit management of sensor failures, to improve quality control, to increase "scientific data integration time", and to control sampling strategy. It also lends greater value to the data acquisition effort because the data become rapidly available to a broader clientele of managers, operators, and other decision-makers.

(5) Calibration centers are needed to ensure that time series data are intercomparable. It is also desirable that instrument development centers and field test beds be encouraged.

(6) A pool of equipment such as current meters, SEASOAR, ROVs, etc. should be made available. This is an issue in coastal oceanography because the traditional groups that have worked in this environment are typically small and have not accumulated as large a stock of instrumentation as will be needed in the next decade.

(7) There needs to be a mechanism for obtaining "quick response" ships to deal with event sampling and equipment maintenance issues. Currently, this is either impossible or is done with local vessels that generally are restricted in range, capability, and availability.

INTERDISCIPLINARY STUDIES

Rationale

Coastal ocean studies in recent years have become increasingly interdisciplinary in the sense that they involve paradigms, ideas, and field efforts that embrace more than one oceanographic discipline. Interdisciplinary studies are needed to address some of the most compelling coastal research questions including those pertaining to sources of materials entering the coastal ocean, the routes through which materials are transported, the processes responsible for biogeochemical cycling and transformation, the health of the coastal ocean with respect to nutrient enrichment, the role of coastal ocean in global change, and societal uses of the coastal ocean. Interdisciplinary studies, as defined here, are those studies that can succeed only when ideas and efforts are contributed by more than one oceanographic discipline.

Questions that require interdisciplinary studies to be properly addressed include the following:

(1) What are the sources of materials, either from land or sea, anthropogenic or natural?

(2) What are the processes responsible for biogeochemical cycling and transformation?

(3) What is the health of the coastal ocean with respect to nutrient enrichment, nuisance algal blooms?

(4) What are the processes that limit the extraction of mineral resources or determine stocks of living resources in the coastal ocean?

(5) What are the short and long term trends that might reveal the role of the coastal ocean in global change?

(6) What are the littoral processes that affect the coastal ocean for recreation, commerce, fisheries or defense?

Current Situation and Limiting Constraints

Interdisciplinary studies in coastal systems require large scientific complements (e.g. 20), in part because of the diverse mix of scientific activities and in part because of the need for rapid sampling for extended periods. The diversity of measurements, experiments, and over-the-side operations require extensive laboratory and deck space in proportion to the magnitude of this effort. The current limitations of coastal ships are with respect to space, performance, and sampling capability.

A wide spectrum of both long term and high density observations are anticipated. This will demand new technologies which may significantly change the way interdisciplinary studies are conducted. These technologies will include new vehicles, shipboard equipment, new sensors, telemetry, and increased data bandwidth. These new technologies should be fostered by forging new partnerships with DOD and industry.

Recommendations

(1) Ships that can support large scientific parties (~ 20 scientists) must be available on a year round basis.

(2) There is a need for an interdisciplinary ship capable of operating in water depths of 5 to 10 m.

(3) Ships must be capable of supporting multiple wire operations and maintaining 3-point anchor stations in shallow water.

(4) Equipment on intermediate and small vessels should be upgraded to state of the art. Included here are underway sampling techniques.

(5) Regional facilities are needed for calibration of shipboard instrumentation.

(6) Infrastructure for regional facility management needs to be established. Increased demands placed on facilities may require a regional management strategy. The need is not to manage at the national level, but rather to have UNOLS encourage organizations that are responsive to regional needs. The regions should be defined by geography.

INFORMATION MANAGEMENT AND COMMUNICATION

Rationale

The expected explosion of data on coastal ocean processes will benefit scientists only insofar as the data are effectively analyzed, managed, and communicated. New technology is now making it easier to acquire, store, analyze, manipulate, and exchange coastal data.

However, we still need to develop infrastructure to support information management needs of coastal marine scientists.

Major efforts are required to establish observation systems consisting of networks of remote (aircraft, satellites) and *in situ* sensors (moorings, underwater vehicles, benthic observations stations, fixed and drifting platforms), to develop new sensors with improved resolution for more variables, and to establish systems of information management ranging from near real time transmission of data and images to the integration, visualization and dissemination of data. Among the specific requirements for information management are distributed management systems, centers for data synthesis and storage, standardized shipboard protocols for all UNOLS vessels for certain types of data, standard arrays of selected sensors on all UNOLS vessels, improved communication links among vessels, buoys, platforms, satellites, and shore facilities.

Current Situation and Limiting Constraints

At the present time, ships generally lack standard data acquisition protocols. There are difficulties in communicating among ships, buoys, platforms, and shore-based users. Further, there is a lack of understanding by the coastal ocean community of the information capabilities and data sets available.

One approach to data transfer has been proposed by JOI. Their system (Sea Net) will provide 24 hour internet communications between ship and shore-based computer systems. However, it must be cautioned that the hardware and software available for data acquisition, management, analysis and communication are advancing rapidly. Therefore, it would be a mistake to become "locked into" existing technology. It is noted that agencies such as NOAA, NASA, EPA, etc. have initiatives to redesign and redefine their data management systems. The coastal ocean community needs to have input into these activities.

Communication links to navigation and observations systems exist and it should be possible to maximize shipboard communication and computer systems for information transfer and data acquisition, storage, visualization and processing between ships, shore-based laboratories, and *in situ* and remote sensors. Coastal research vessels operate near enough to shore that data can be transmitted via telemetry to shore-based receivers. Data acquisitions systems, including satellite downlinks, could be shore- rather than ship-based, in which case coastal vessels would access processed weather information and data generated by satellites, moorings, etc. via telemetry from shore-based laboratories.

Recommendations

(1) Information management systems for the coastal ocean must be distributed. The concept of all data residing on a single host is not sound.

(2) The coastal ocean community needs better center(s) for collection, storage, and synthesis of data. Considerations include redesigned NODC/NOAA data centers.

(3) Standard shipboard protocols should be used on all UNOLS vessels, with standard formats for similar types of data.

(4) A standard array of sensors should be provided on all UNOLS vessels (see recommendations of Instrumentation Working Group). Investigators should be able to walk off the vessel at the end of a cruise with a reduced set of data from this standard array on a diskette.

(5) Standard communication packages should be provided on all UNOLS vessels. Communications links should be provided among ships, buoys, platforms, satellites, and users. The possible links could include a combination of cellular phones, microwave, satellites, and fiber optic cable.

(6) All data sets need to contain meta data. This should include the program objectives for which the data were acquired. Investigators should be encouraged to construct these meta data files while the data are being acquired.

(7) Investigators should use a limited set of formats and protocols for their data.

(8) Raw data needs to remain available for use by other researchers' use for a certain period of time.

(9) The use of models to enhance information management should be encouraged. Models can be used to digest large volumes of data into more usable forms. Information on the model used to compress the data would be provided in the meta data file.

(10) Information management must be considered at the beginning of any coastal ocean project. Funding agencies should be encouraged to recognize that information management is a credible budget item.

THE ROLE OF LARGE AND INTERMEDIATE SHIPS IN COASTAL OCEANOGRAPHY

Rationale

Despite the fact that coastal oceanographers generally operate in water depths less than 100 m and often at depths on the order of 10 m or less, they, like "blue water" oceanographers, also need access to sophisticated research ships. Ships will continue to function as platforms for the conduct of process studies, for ground truth measurements; for