COASTAL OCEANOGRAPHY:

FUTURE TRENDS AND VESSEL REQUIREMENTS

A Status Report by the

COASTAL OCEANOGRAPHY SUBCOMMITTEE

OF THE UNOLS FLEET IMPROVEMENT COMMITTEE

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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 the deployment, servicing and recovery of moored instruments; and for operational support of small boats and specialized platforms (submersibles, ROVs, AUVs).

Present Situation and Limiting Constraints

The large (> 250 ft) vessels in the UNOLS fleet are capable of carrying out interdisciplinary studies of the coastal zone to water depths as shallow as 10 m. The special characteristics that make the large ships suitable platforms for coastal research include: (1) an ability to accommodate large scientific parties (25 or more); (2) large deck and storage space; (3) considerable laboratory space; (4) capability of handling large arrays; (5) ability to carry specialized vans (isotope/trace metal/organic); and (6) reasonable stability.

The six intermediate vessels are also capable of working as far shoreward as the 7 m isobath. Although these ships cannot carry as many scientists and have more limited laboratory and deck space and storage capacity, they can serve the need of interdisciplinary field programs of moderate size.

To be truly useful, these ships must develop techniques for multiple-point anchoring (or dynamic positioning) and for multiple wire deployments at depths less than 100 m. It is also expected that there will be an increased need to deploy and recover small boats, moorings, AUVs, ROVs, and benthic observing systems.

Recommendations

- Suggested improvements or modifications to existing ships -

(1) Improve wireline gear handling techniques. With better techniques for bringing gear aboard and launching gear, we could extend the usefulness of current vessels into rougher weather conditions.

(2) Shallow water sampling techniques. Because the ship's hull may occupy a substantial portion of the water columns, flow-through intakes cannot be haphazardly located in the hull and towed systems cannot be towed astern. The design must include the capability of towing these devices off the side of the vessel in undisturbed water.

(3) 3-Point anchoring. Strong gradients and spatial variability are encountered in coastal areas. The ship design must maximize the station keeping capabilities. This should include finely-controlled propulsion and thruster systems. Also, for precise work, the ship should be capable of 3-point anchoring at water depths of < 100 m.

(4) Modify for shallow water work. Certain aspects of blue water ship design may not be compatible with very shallow work. An example may be extendable bow-thrusters that are vulnerable to damage if run aground. Tunnels may be more robust for shallow work.

(5) Ship to shore communication. Modify to maximize the use of shore-based communications including navigation signals and cellular phone modem data transfer.

- Science Mission Requirements for a High Capacity, Shallow Draft Coastal Vessel -

Substantial areas of the coastal zone in the Gulf of Mexico, the South Atlantic Bight, and the Mid-Atlantic Bight are inaccessible to existing and planned ships capable of conducting interdisciplinary research. A high capability, shallow draft research vessel is important to coastal oceanography in these regions, and it is strongly recommended that an interagency (e.g. NSF, NOAA, and ONR) effort be initiated to define science mission requirements and to fund the design, construction and operation of such a vessel(s). In light of projected science requirements and operational needs, the following preliminary set of attributes are thought to be desirable:

(1) Large capacity for scientists, science activities, gear, and equipment storage. Interdisciplinary studies will require a large scientific complement. The minimum science berthing capacity should be 20 berths. This is required, in part, because interdisciplinary studies require a diverse mix of science groups to be physically present on board to collect, curate, and process samples, and real time sensor data, and in part, because sample collection is very rapid in shallow settings. Storage, deck, and laboratory space must be provided in proportion to this large scientific complement. Temperature controlled (refrigerated) storage and laboratory space should be included.

(2) Shallow draught. As stated above, existing large vessels adequately meet coastal research requirements where water depths are sufficient for them to operate. To operate in shallower systems, new vessels should have the minimum draught possible and still retain seaworthiness. They should be able to operate effectively at depths of 5 to 10 m.

(3) Sea keeping/stability. Future coastal studies will require sampling in all seasons and during episodic events. While maintaining operations during extreme events such as major storms and hurricanes may not be possible, sea keeping ability should be maximized.

(4) Station keeping capabilities. Strong gradients and spatial variability are encountered in coastal areas. The ship design must maximize the station keeping capabilities. This should include finely-controlled

propulsion and thruster systems. Also, for precise work, the ship should be capable of 3-point anchoring at water depths of < 100 m.

(5) Multi-wire operations. To facilitate and speed interdisciplinary studies, the ship should be equipped with multiple winches which are positioned such that they can be used simultaneously in water depths of £ 100 m.

(6) Launching capabilities. It is anticipated that there will be an increased use of freely launched vehicles such as AUV's ROV's, seafloor mounted observing systems, moorings, surface buoys, etc. Ship capabilities and design should facilitate launching and recovery of these instruments.

(7) Shallow water sampling techniques. Because the ship's hull may occupy a substantial portion of the water columns, flow-through intakes cannot be haphazardly located in the hull and towed systems (nets, seasons) cannot be towed astern. The design must include the capability of towing these devices off the side of the vessel in undisturbed water.

(8) Endurance. Because these vessels will generally be near port, endurance capabilities may be scaled-down from comparably-sized blue water research vessels.

(9) Ship to shore communications. Design should maximize shore based communication to data transfer to and from the ship including cellular phone technology.

THE ROLE OF SMALL RESEARCH VESSELS

Rationale

The inability of large ships to operate close inshore, particularly over shallow shelves, dictates that coastal oceanographers will continue to need smaller vessels. Smaller vessels have the advantages of shallower draught, greater maneuverability, ability to respond more quickly to event-dependent opportunities, and lesser expense. However, they are also limited to smaller scientific parties and crew size. Because small vessels have limited range and endurance, it is important to maintain a fleet of regionally-dedicated vessels. The mission requirements vary from region to region as will vessel designs.

The Synoptic Measurements Working Group emphasized the need for high resolution measurements. They also indicated the importance of measurements in a wide range of sea states. Improved instrumentation and data handling capabilities are also required. The Time Series Working Group emphasized the need for improved capabilities for deploying and servicing moorings and noted the need for improved instrumentation. They felt that quick response is important for measuring during events. They also pointed out that an inventory of available coastal vessels is highly desirable. The Interdisciplinary Working Group expressed a desire for large berthing capacity, preferably in the range of 16 to 20 in the scientific party. They also indicated the need for a broader suite of standard measurement equipment on ships such as flow-through sampler and ADCP. Shallow draft vessels are desirable for nearshore studies.

Clearly, no single vessel type will be able to accommodate the full "wish list" outlined above. However, it is envisioned that a mix of vessels in the under 130-foot size range would permit coastal objectives to be accomplished. In many cases, the smaller vessels might operate in tandem with larger ships to increase synoptic coverage.

Current Situation and Limiting Constraints

Included in the "small vessels" category are day boats for short trips in protected waters (typically less than 80 ft in length) and "small expedition vessels" ranging from 80 to 150 feet in length. Future generations of such vessels should be designed with the aims of (a) keeping the daily cost as low as possible, (b) accommodating parties of 12 to 20 scientists; (c) having endurance and range of one to three weeks and approximately 1200 miles; (d) drawing less than 4 m; and (e) underway sea-keeping at sea state 5 to 6.

- Day Boats -

It was generally agreed that there is an adequate number of vessels in the day boat class throughout the U.S., although they generally do not have adequate scientific equipment for our current needs. Equipment such as differential GPS, ADCPs and flow-through samplers should be available on this smaller class of research vessels. Shared use facilities are warranted, since it does not make sense to dedicate a large amount of expensive equipment to a single small vessel. It would be helpful to the scientists as well as to the operators of the small vessels to have an up-to-date inventory of the available vessels available to scientists.

- Small Expeditionary Vessels -

There is a common need for vessels that are capable of extended (1 to 3 week) trips on the continental shelves of the U.S. but which have daily rates significantly less than the intermediate-sized UNOLS vessels. There are ship needs that are common to scientists throughout the U.S., but the priorities vary among different regions. For example, the harsh conditions during winters in the northeast and Alaska pose constraints on the ships that operate in those regions that are not relevant to lower latitudes. The working group defined the desired capabilities of research vessels that would operate in different regions. Five regions were defined based on their particular requirements for research vessels: Gulf of Maine and Great Lakes, Middle Atlantic Bight, South Atlantic Bight and Gulf Coast, West Coast and Hawaii, Alaska

Each region has special needs and deficiencies that must be addressed in the long-term strategy of fleet improvement. The Gulf of Maine region has very limited capabilities of small coastal research vessels for wintertime operations. The Mid-Atlantic Bight region requires a replacement for the Warfield to perform mooring deployments and interdisciplinary studies in the large estuaries and continental shelf. The South Atlantic Bight and Gulf Coast region requires shallow draft vessels that can also handle large, interdisciplinary scientific parties. The requirements of the West Coast shelf are principally served by larger UNOLS vessels with existing smaller "day boats" serving the needs of estuarine oceanographers.

Recommendations

The main recommendations that emerged from the workshop pertained largely to the "small expeditionary" class of vessels. In general, it was felt that vessels suitable for each of the regions listed above should be designed and built. However, in many cases it is possible that the large capacity coastal vessel described in the previous section would accommodate the needs. In any event, Table 1 lists the desired capabilities for each of the five regions and is based on workshop discussions.

General scientific capabilities expected of future vessels in the "small expeditionary" class include: (a) multiple wire deployment in shallow water; (b) three point moorings and dynamic positioning; (c) mooring deployments of up to 5,000 lbs; (d) support for high resolution bathymetry and side scan; (e) underway flow-through sampling capability; (f) ADCP, sea-soar, and coring capabilities; (g) best available communication systems; and (h) high quality data acquisition.

THE ROLE OF NON-SHIP AND NON-CONVENTIONAL OBSERVING PLATFORMS

Rationale

As emphasized in preceding sections of this report, the coastal domain can exhibit large gradients in biological productivity and constituents, gas exchange, air-sea momentum and heat fluxes, and anthropogenic constituents emitted from nearby coastal sources (industrial, atmospheric and oceanic emissions). Sampling studies designed to elucidate the full suite of processes acting on the coastal domain requires high spatial and temporal resolution imbedded within a continuous time-series which covers several complete cycles.

Given the rigorous requirements for synoptic observations with high spatial resolution and for prolonged time series measurements at many locations, ships alone cannot serve the full spectrum of needs of coastal oceanographers. Complementary and essential are other types of research platforms including aircraft, satellites, moorings, and fixed platforms. Without such platforms it would be impossible to obtain truly synoptic data of very long-term time series. These platforms also facilitate the acquisition of data during extreme storm events when most vessels are ineffective. However, water column measurements (from ships) are essential for "ground truthing" remotely sensed data.

Current Situation and Limiting Constraints

An inventory of existing non-ship platforms and sensor capabilities was offered by workshop participants and follow.

- Satellites -

Satellites and their sensors which are currently available for complementing the existing suite of ship-related data bases include: NOAA Polar Orbiters (including AVHRR); NOAA GOES (currently east coast U.S. only); and DMSP (Including SSM/I, OLS, etc.). These satellites provide estimates of AVHRR sea surface temperature with a four-hour repeat time and footprint of 1.4 km; SSM/I surface winds twice each day at 50 km footprint; and GOES and OLS optical imagery at less than 2 km resolution. The ERS-1 provides radiometric coverage, 25 km scatterometer derived winds, and high resolution SAR imagery. TOPEX/POSEIDON, launched in 1992, provides 10-day exact repeat orbits of sea surface height to a vertical accuracy of 14 cm. The NOAA and DMSP satellites provide high enough resolution and frequency of repeat time that the short time and space scale processes unique to coastal regions can be sampled adequately in order to document large amplitude processes associated with sub-inertial scale forcings. Optical satellites such as SPOT and LANDSAT continue to provide high resolution imagery in the clear sky cases; these satellites provide little quantitative information on geophysical parameters but give clear indication of the presence and spreading of ocean slicks.

TOPEX/POSEIDON's 10-day repeat orbit limits its utility in the study of long temporal and spatial scale processes. TOPEX/POSEIDON is more suited to the study of seasonal-scale and mesoscale processes, e.g., seasonal- to climate-scale variabilities in atmospheric pressure, ocean tides, and marine circulation.

Satellites to be launched in the near future (one to five years) include: SeaWiFS in late 1993, which will provide 1 km resolution LAC of ocean color with a two-day repeat orbit; ADEOS in 1995, which will have the NSCAT scatterometer with 25 km footprint resolution; and the follow-on Geosat altimetric mission, with a 17-day exact repeat orbit and approximately 40 cm vertical accuracy in sea surface height; the Geosat also provides local winds. SeaWiFS will provide information on biogenic activity and its variability within a dynamic coastal domain. EOS-Color will succeed SeaWiFS in 1998, which is also the year of first launch for the EOS platforms. The Canadian RADARSAT mission will be launched in 1995, and will provide synthetic aperture radar imagery of primarily arctic but all coastal regions; these data will provide high resolution (order of 20 m) imagery of surface current patterns, roughness, and wind stress.

The satellites are governed by NASA, NOAA, and DOD; and foreign partners, including ESA and the Japanese NASDA. Issues yet to be resolved by the collective ocean remote sensing community include real-time distribution and collection of data from all satellite sources into a common site for dissemination to the scientific community; analysis and maintenance of data quality per satellite sensor; development of regional remote sensing algorithms for coastal oceanography; and agency constraints on encryption (e.g.

DMSP OLS, and NASA SeaWiFS).

Communication satellites and GPS represent the last category of oceanographic utility, insofar that INMARSAT and ARGOS can transmit compressed intermittent signals from surface platforms to ground based data acquisition systems; and GPS provides continuous, accurate position sensors which are providing contributions to the total coastal data base. GPS is an essential element for documenting data blocks within multi-platform derived data bases.

- Airborne -

Airborne platforms include aircraft, blimps, and remotely piloted vehicles (RPV's). The suite of aircraft can be partitioned into two classes:

(1) Large, long range aircraft typically employed in open ocean missions yet applicable to the coastal regions, e.g. the UK Met Office C-130; NCAR electra; University of Washington C-131; NOAA P-3; NASA P-3; NRL P-3; NADC P-3; and

(2) smaller aircraft which have shorter range and less payload capacity, e.g., single engine NOAA aircraft in Oak Ridge; NCAR and NOAA Kingairs; Sonoma Technologies Cessna; etc.

While the smaller aircraft are less expensive and incur less logistical constraints, the larger aircraft include a wider suite of instrumentation and are shifting their capabilities towards real time data processing with onboard computers (e.g., the British Met Office C-131). Since the larger aircraft are generally governed by agency infrastructure (except for the University of Washington aircraft), their availability for scheduling purposes is easily obtained through the sponsoring organization. Scheduling and availability for small aircraft is more difficult due to the lack of central coordination and advertisement. It is likely that small aircraft will provide routine sampling of coastal ocean and atmospheric parameters, primarily because seasonal cloud cover over the ocean (e.g. over the U.S. west coast) inhibits the use of satellites to map with infrared or visible sensors. Note that the coastal regions are on average cloudier than the open ocean domain. Unlike the surface ship documentation and scheduling with UNOLS, there currently is no coordination office for either large or small aircraft assets available for coastal or open ocean research. The coastal sciences community must therefore rely on a frequently impractical and inefficient approach in developing contacts and connections to obtain the appropriate assets to augment data bases in support of a given oceanographic problem, whether it be coastal or open ocean. Given the scale of important processes acting on the coastal ocean (in a nonlinear interactive way) and the strong air-sea coupling, the use of aircraft to complement surface ship and other oceanographic measurement platforms is essential.

Blimps (airships) are a new research platform during the last several years of U.S. research. Blimps provide the advantage of sampling atmospheric and surface water on extremely high spatial resolution, due to their slow speed relative to aircraft. Slower speed allows remote sensing using infrared and microwave systems to document sea surface temperature patterns, passive microwave and lidar sampling of aerosol, and eddy correlation derived wind stress variabilities. Blimps may also be utilized to support certain types of in-water instrumentation, including radiometric sensors, as well as ocean sensors such as lidars. While the blimp provides easy sampling of the surface and atmospheric constituents, its service to the oceanographic community is maximized with accompanying ship support.

The remotely piloted vehicle (RPV) for marine research represents a new platform becoming available in FY 1994. These platforms are small with long duration missions, and can fly at levels as low as 5 m above the surface. Payloads are on the order of 200 kg. China Lake NAS will soon release to the science community several RPV's which will be reconfigured (under ONR contract) to map ocean surface and lower atmospheric parameters using in situ and remote sensors. Sensors to be installed on the RPV platform are still to be determined, but the package will likely include measurements of sea surface and air temperatures, humidity, aerosol size spectra, and trace gases. Turbulence sensors are likely to be added sometime during the following years. While RPV's are currently driven by the marine meteorology community, there is a capability for including optical and infrared sensors for sampling the biology and dynamics of the upper ocean.

- Moorings and Related Platforms -

Currently available surface platforms include moored and drifting buoys, piers, and hovercraft type vehicles. Moored and drifting buoys have been used extensively by the oceanographic community. Noteworthy is the "spar" buoy. Its open and stable structure with enormous power capacity allows the design of integrated aerosol, gas, and heat flux profile data bases in the atmosphere, and subsurface biology and chemistry sampling. FLIP is a specialized platform that continues to be needed and is being refitted to enhance its capability. Piers support long term monitoring of temperature, salinity, and tides, for long term seasonal and climatological monitoring. Their usefulness in studying the short term processes acting in coastal ocean science remains uncertain.

One proposal that has major scientific advantages with modest budgetary implications involves deploying a number of jack-up platforms in selected coastal areas to serve as long-term observatories and sampling facilities. The rigs can be deployed in water depths up to 100 feet. The cost of maintaining jack-up rigs is relatively small, about $1,000/day. Deployment of several such platforms could become a valuable research facility for coastal studies. It must also be noted that offshore platforms of various types, particularly oil and gas platforms, offer excellent opportunities for obtaining long time series of oceanographic processes at fixed sites. A recent special issue of the Marine Technology Society Journal23 offers details of numerous applications of platforms to oceanographic and atmospheric research.

- Subsurface Platforms -

Autonomous Underwater Vehicles (AUV's) represent a new type of platform for mapping underwater variability of turbulence, temperature, salinity, turbidity, chemistry, and biology. Developed in part for Navy use and mine detection, these platforms are currently becoming available for the scientific community. Studies are currently underway on the engineering required to reconfigure them for scientific problems in coastal oceans.

Sea floor benthic observation stations such as the system developed by Rutgers[(21)] are soon to provide long time series of bottom boundary layer processes, i.e. dynamic , chemical, biological and geological. These platforms are in shallow water, and are close enough to shore that cables provide direct onshore recording.

Recommendations

(1) Educate the coastal ocean community on new platforms and instruments. This should include: usefulness and optimum deployment strategies based on process temporal and spatial scales of interest; analysis of existing capabilities; potential commercial partnerships; ways to enhance sampling strategy with "smart" sensors; optimization of a non-ship sampling "fleet" designed specifically for the support of coastal oceanography.

(2) An index and inventory plan for non-ship data bases should be developed such that it complements data currently destined for EOSDIS. This index will allow the full archiving of coastal data into the global climate archive. TOGA/COARE's data system can be used as a prototype model for initiating such an integrated data base, index, and archive.

(3) Seek a dedicated individual to act as a focal point for non-ship related coastal data management within the NODC. Responsibilities would include data integration, quality control, and interaction with the scientific

community, i.e. procuring and quality-control for data from buoys, aircraft, and satellites. The community should also evaluate creating an optimum sensor package within NDBC specs, and evaluate an oceanographic buoy deployment strategy to meet next generation science and operational needs.

(4) The oceanographic community should advocate a coordination center for airborne platforms which provide data bases which are both routine (for operations) and episodic (for research). The center does not necessarily need to have the same role as UNOLS, but should at least be a referral center to the oceanographic community.

(5) Low cost aircraft. Support development and acquisition of inexpensive aircraft which can provide routine sampling of ocean and marine atmospheric parameters of mutual interest to disciplines studying the coastal domain. Such aircraft should be able to fly low and slow, and can be either RPV or piloted.

(6) Preserve our stable platforms, such as FLIP and the spar buoy for their unique attributes of providing long integrated data bases of the lower atmosphere and upper ocean. FLIP is old, and will need a replacement. The community needs to collectively articulate the scientific basis for a new FLIP, and forge forward as a multidisciplinary team to assure the existence of a platform such as FLIP which will be capable of providing intensive atmos/ocean research activities in coastal and open ocean regions.

FIELD AND SHIPBOARD INSTRUMENTATION

Rationale

Effective data collection at sea requires appropriate matching of new generation seagoing instrumentation and sophisticated platforms to support the instrumentation. Among critical issues that must be considered are costs, calibration facilities, security of moored instruments, standardization of data collection protocols, and training and availability of seagoing technicians to operate aboard research vessels. There are needs for regional pools of shared equipment.

Current Situation and Limiting Constraints

Considering the extensive list of oceanographic instrumentation currently available and the rapidity with which new developments are taking place, an inventory of existing facilities would be long and inappropriate for this report. At the present time some ships routinely monitor certain parameters but there is no universal protocol. Furthermore, regional pools of shared use facilities do not generally exist.

Recommendations

(1) All oceanographic vessels should continually monitor a suite of navigational, meteorological and hydrographic parameters while at sea. These observations should be user accessible in real-time, available at the end of the cruise, and archived. Parameters include: time, date, position, depth, ship speed and heading, wind speed and direction, air temperature, humidity, barometric pressure and par, seawater temperature and conductivity. (See recommendations of the Information Management Working Group.)

(2) A large variety of important scientific equipment (too expensive for an individual user) should be available on a shared-use basis from regional equipment pools. Examples include: ROV, SEASOAR, OSCR, CODAR, MET-SPAR Buoy and Sidescan Sonar. This equipment requires maintenance and technical assistance for its operation.

(3) Small boats deployable from large research vessels are needed for work in coastal environments and to increase the synopticity of observations. These boats require clean electrical power and protection for scientific instruments.

(4) All UNOLS vessels need high speed data connection to the Internet and to be able to acquire telemetry from satellites, moorings and drifting instruments.

(5) Regional or national shore-based facilities will eventually be required to support an increasingly complex fleet of ships and oceanographic network. The purpose of this facility will be multifold and includes:

(a) technician and scientist training and workshop activities to standardize and improve shipboard operational procedures and use of hardware and software onboard;

(b) implementation of computer application products on UNOLS vessels;

(c) standardization and introduction of new technologies and instruments on UNOLS vessels;

(d) calibration and test facilities for marine instruments including dedicated testing facilities with flexible scheduling such as moorings, real-time telemetry and associated delivery vessels ("Ocean Test Beds"); and

(e) these centers may serve to support the shared-use equipment pools (recommendation no. 2).

(6) A high priority should be given to establishing an interagency task force to transfer classified technology and data sets that may be of critical use to the coastal oceanographic community into the public domain.

(7) State and federal agencies will need to be convinced of the advantages of partnerships in supporting and using the UNOLS fleet if more vessels or upgrades are to continue. These commitments will be absolutely necessary if the fleet and its instrumentation is to thrive into the next century. Interagency cooperation should be encouraged at all levels with respect to facility acquisition. Interagency cooperation is essential in ensuring that oceanographic assets are used in the most efficient way possible.

PERSPECTIVES FOR THE FUTURE

As we enter a new era of coastal oceanography, we need to break out of the parochialism that has dominated the thinking of federal agencies and the coastal science community for decades[(2,12)]. A comprehensive understanding of the pressing scientific and societal issues concerning present functions and future changes of coastal environments cannot be achieved in the absence of effective interagency cooperation, coordination and collaboration. No where on the globe do the missions and goals of so many government agencies intersect and interact as in the coastal zone. Likewise, the coastal zone is unique in the concurrent interplay of the atmosphere, biosphere, geosphere, hydrosphere, and, in polar regions, the cryosphere. There can be only one conclusion: The formulation of a comprehensive, national strategy for environmental science and management can only be achieved through a nationally coordinated, regionally organized, interagency effort to develop, implement, operate, and share major (expensive) facilities and information management systems.

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TABLE 1. REGIONALLY-SPECIFIC REQUIREMENTS FOR SMALL EXPEDITIONARY VESSELS

Criterion	Gulf of Maine	Mid-Atlantic Bight	South Coast	West Coast	Alaska
Endurance	1-3 weeks	1-3 weeks	1-3 weeks	1-3 weeks	1-3 weeks
Science Party	12-20	12-20	12-20	12-20	12-20
Draft	4 m	1.5-3 m	1.5-3 m	1.5-3 m	4-5 m
Range	600 mi	650 mi	1200 mi	1200 mi	2400 mi
Speed	10-12 kts	10-12 kts	12-15 kts	10-12 kts	10-12 kts
Seakeeping Underway	sea state 5-6	sea state 5-6	sea state 5-6	sea state 5-6	sea state 5-6
Seakeeping on Station	sea state 5-6	sea state 3-5	sea state 3-5	sea state 3-5	sea state 3-5
Ice Strength	Yes	Yes	No	No	Yes
Ice Loading	Yes	No	No	No	Yes
Deck Working Area	800-1000 sq ft	800-1000 sq ft	800-1000 sq ft	800-1000 sq ft	800-1000 sq ft
Lab Space	300-600 sq ft	300-600 sq ft	300-600 sq ft	300-600 sq ft	300-600 sq ft

See Appendix 2 for help with acronyms.