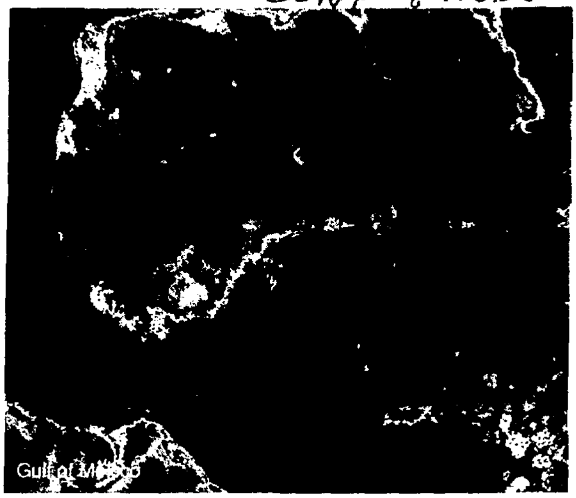
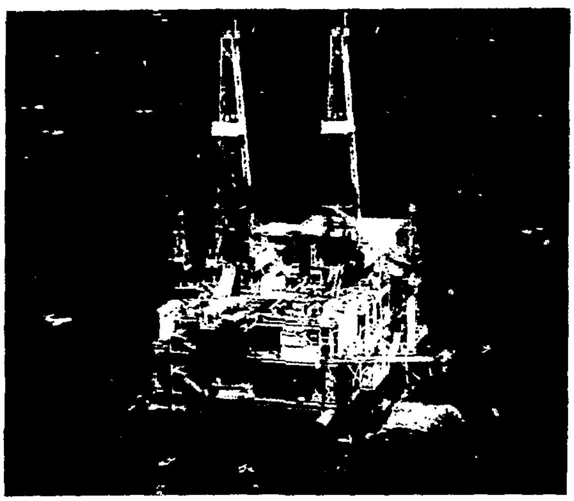
DE-AI05-90ER60929
NATIONAL SCIENCE FOUNDATION

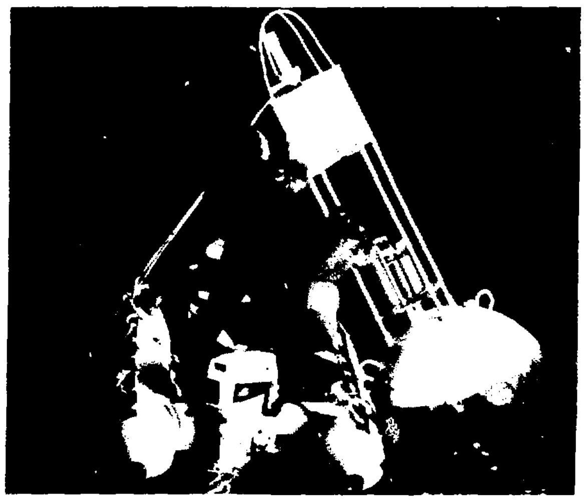
CONF-8910585--Summ.



The Coastal Ocean Prediction Systems Program:

Understanding and Managing Our Coastal Ocean





Synopsis

June 1990

Coastal Ocean Prediction Systems

SYNOPSIS

Co-Sponsoring Agencies

National Oceanic and Atmospheric Administration
Minerals Management Service
Environmental Protection Agency
National Aeronautics and Space Administration
Department of Energy
United States Coast Guard
United States Geological Survey
National Science Foundation
Office of Naval Research

Co-Sponsoring Institution

Ocean Studies Board

Participating Agency

United States Army Corps of Engineers

Participating Institution

Marine Board

June 1990

I. Introduction

In November 1989, eighty scientists and managers from academic institutions, federal agencies involved in coastal ocean activities, and environmental companies met in New Orleans to analyze the research and development needed to implement operational prediction systems for the coastal ocean. The New Orleans workshop was particularly concerned with the transition from ongoing research efforts to operational systems. The workshop report* describes the Coastal Ocean Prediction Systems (COPS) program that will provide the research and development necessary to effect this transition.

The **goal** of COPS is to couple a program of regular observations to numerical models, through techniques of data assimilation, in order to provide a predictive capability for the U.S. coastal ocean including the Great Lakes, estuaries, and the entire Exclusive Economic Zone (EEZ). The **objectives** of the program include: determining the predictability of the coastal ocean and the processes that govern the predictability; developing efficient prediction systems for the coastal ocean based on the assimilation of real-time observations into numerical models; and coupling the predictive systems for the physical behavior of the coastal ocean to predictive systems for biological, chemical, and geological processes to achieve an interdisciplinary capability.

COPS will provide the basis for effective monitoring and prediction of coastal ocean conditions by optimizing the use of increased scientific understanding, improved observations, advanced computer models, and computer graphics to make the best possible estimates of sea level, currents, temperatures, salinities, and other properties of entire coastal regions. Such a technical capability is essential for effective and efficient management of the coastal ocean in the future.

Essentially, the required technology and understanding are at hand to undertake COPS. The resultant, robust operational prediction system will be a major new asset in the national effort to manage and protect our coastal resources and environment. COPS will:

- Catalyze our national effort to understand, monitor, protect, develop, and manage the U.S. EEZ.
- Integrate cutting edge research into the creation of a national operational prediction system and accelerate the development of interdisciplinary methods for combining physical, chemical, biological, and geological measurements and models.
- Focus the efforts of individual agencies and help coordinate these efforts into a truly national program.
- Accelerate partnerships between federal agencies, state and local governments, and regional consortia with the academic and private sectors involved in coastal science and engineering activities.

This synopsis highlights the importance and complexity of coastal ocean issues, the varied needs for the COPS program, the opportunity that it represents, and the technical and managerial issues that must be addressed throughout the COPS program.

* *The Coastal Ocean Prediction Systems Program: Understanding and Managing Our Coastal Ocean*
May 1990
Volume I: Strategic Summary
Volume II: Overview and Invited Papers

II. What Are the Characteristics of the Coastal Ocean?

Different Interests Yield Different Views

Coastal regions are of great economic and cultural importance to the Nation, to coastal states, to large and small communities, and to individuals. The five major earth systems, the atmosphere, geosphere, hydrosphere, biosphere, and, in high latitudes, the cryosphere, all overlap and are integrated in the coastal ocean. These systems interact to produce unique environments that are very different from those found away from the coast.

Perceptions of the coastal ocean differ according to the interests of the parties concerned. To the fisherman the coastal ocean implies a nutrient-rich ecosystem that provides the great fishing grounds of the world. To the resource manager the coastal ocean may encompass the entire EEZ for planning or a few select areas for exploration or disposal operations. To the recreational boater it may extend a few, potentially hazardous, miles from the shoreline. To the engineer it may represent a narrow region of intense currents, swell, or storm surge that affect construction, beach erosion, and the maintenance of rigs. To the environmental planner or recreational manager the coastal ocean is a region increasingly sensitive to pollution and difficult to predict and protect.

Mississippi River plume and delta viewed from Landsat.

To all, the coastal ocean comprises regions with flows on many time and space scales, flows that often exhibit quasi-permanent features as well as features that can change in hours. It comprises regions that affect and are affected by the large-scale circulation of the open ocean, that modify and are vulnerable to atmospheric storm systems, and regions wherein biological, chemical, and physical processes are inexorably linked. The coastal ocean also plays a two-way interactive role in the global effects of long-term, large-scale, climate variations.

Independent fisherman.

Common Issues but Regional Differences

Despite the commonality of activities and related issues such as exploration and development of resources, susceptibility to pollution, and hazards to vessels and structures, there are important regional differences in how the coastal ocean behaves.

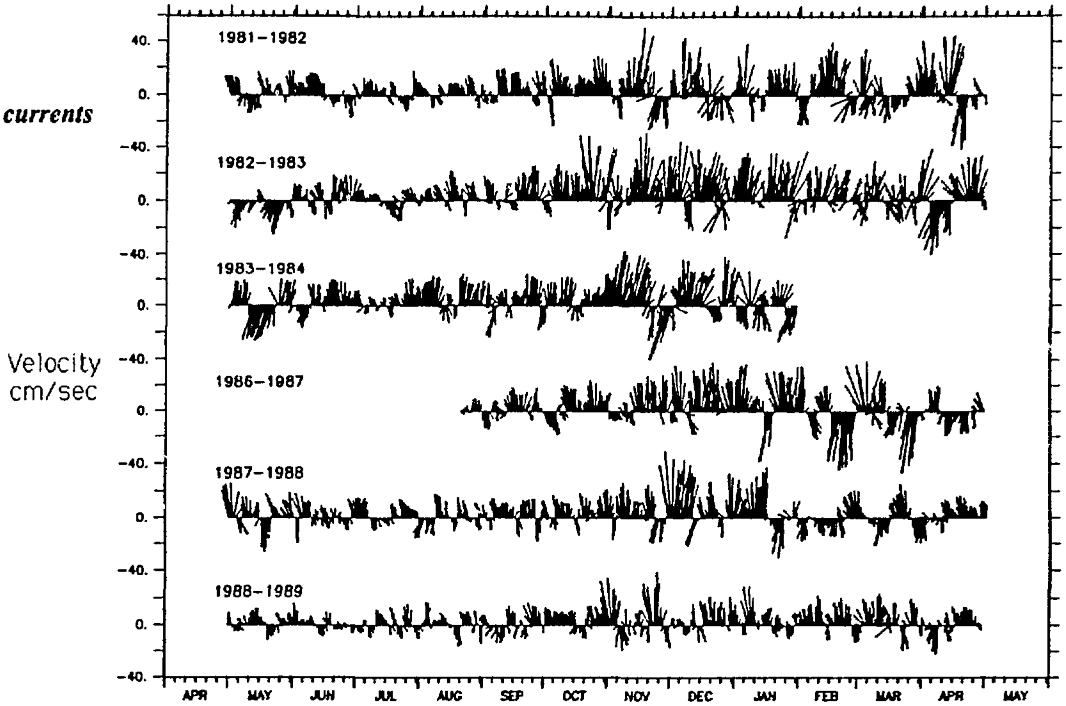
As an example it is appropriate to compare the ocean circulation of two regions of extensive recreational, fishing, and mineral resource activities: the Gulf of Mexico and Northern California. The principal feature of the ocean circulation in the Gulf is the large-scale "Loop Current" whose position varies and which spins off large eddies analogous to Gulf Stream rings. There are other current systems influenced in part by the shallow continental shelf and weather systems such as winter cold fronts or "northers." The entire region is vulnerable to hurricanes.

The mean circulation for the Northern California coast is more complicated, with a variety of interannual, seasonal, and shorter-term fluctuations – including wind-driven upwelling – on many space and time scales. Influences range from interannual El Niño effects to the shorter-term effects of the meandering offshore California Current or to the impact of North Pacific storms. In these and other coastal ocean regions there is a paucity of long-term circulation data necessary to describe and understand such variability. That variability determines the physical transports which affect biological, chemical, and geological processes as well as human activities.

Despite regional differences our knowledge of the coastal ocean has increased considerably over the past decade:

- Coastal ocean circulation is characterized in general by relatively large-scale, alongshore current systems. Much smaller-scale, cross-shelf flow patterns are important in the exchanges that control the dispersion and fluxes of pollutants, nutrients, plankton, fish eggs, and larvae between the coast and the open ocean. Recently, new observing techniques including satellites have identified cross-shelf exchange processes on a variety of space and time scales: jets and filaments off the coast of California or Gulf Stream intrusions into the South Atlantic Bight. Eddies are

West Coast Upwelling
top: Phytoplankton chlorophyll pigment concentration (CZCS, NASA's Nimbus-7 satellite).
bottom: Sea surface temperature (AVHRR, NOAA-6 satellite).



Long-term time series of currents on the Oregon Shelf.

shed from major current systems and can affect outer continental shelf regions. Catastrophic turbidity currents can occur when unusually high waves coincide with strong wind-driven and tidal currents. Open ocean processes, including the intrusion of major ocean currents or eddies onto the shelf or interannual phenomena such as El Niño, also affect cross-shelf transport.

- Variations in topography across and along the continental shelf, from the shoreline to the interface with the open ocean, affect the coastal ocean's behavior. Features such as submarine canyons, banks, basins, capes, embayments, ridges, and islands all serve to modify ocean currents in those regions. They can cause relatively strong coastal currents to change direction or even divide. Knowledge of topography is essential to understanding cross-shelf and vertical fluxes of momentum, heat, salt, particulates, nutrients, contaminants, and biomass.

- Biologically, the coastal ocean can be distinguished from the open ocean in two principal ways. Very high rates of biological productivity occur because of the availability of nutrients in the upper layer from upwelling and mixing, for example, along the coast of California and Oregon, and because of influx from the land, for example, in the Chesapeake Bay estuarine plume. Dynamic processes at the seabed interface, where nutrient-rich sediments can be resuspended and circulated by currents and storms, are another source of enhanced productivity. Coastal areas support the world's richest fisheries.

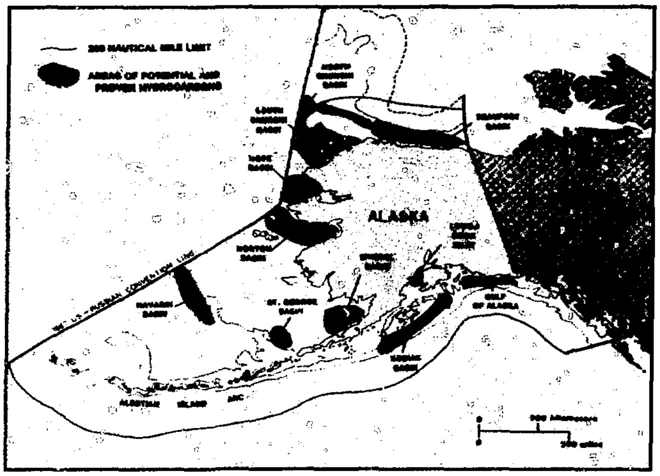
- The coastal ocean and the atmosphere interact strongly. Fluxes of heat, moisture, particulates, and gases across the air-sea interface affect the physical behavior and chemical composition of both atmosphere and ocean. Storm systems influence many continental shelf areas with land-falling marine storms dominating on the West Coast and extratropical cyclones, progressing from the continent to the ocean, dominating on the East Coast. Hurricanes and their associated storm surges and the occasional explosive strengthening of coastal extratropical storms have major effects on coastal circulation, erosion, and flooding.

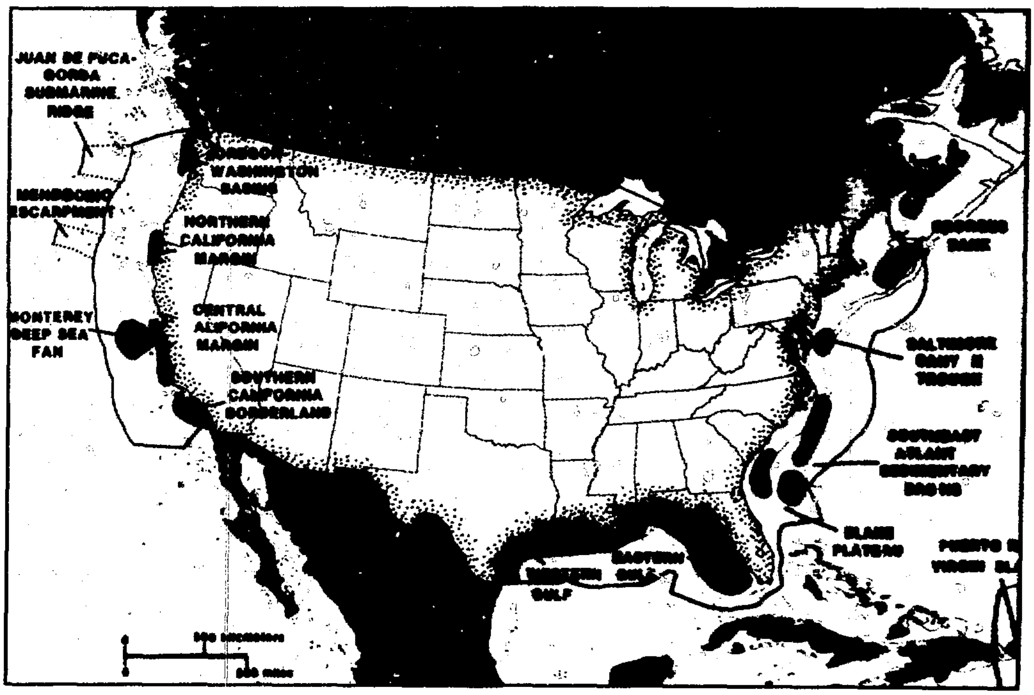
III. Why Do We Need To Understand and Manage the Coastal Ocean?

Resources and Commerce

The coastal ocean provides most of our fishery resources. Its shallow shelves contain energy resources important to the U.S. economy and security. By the year 2000, 75% of the U.S. population will live within 50 miles of the ocean, making increased demands on estuaries and coastal resources.

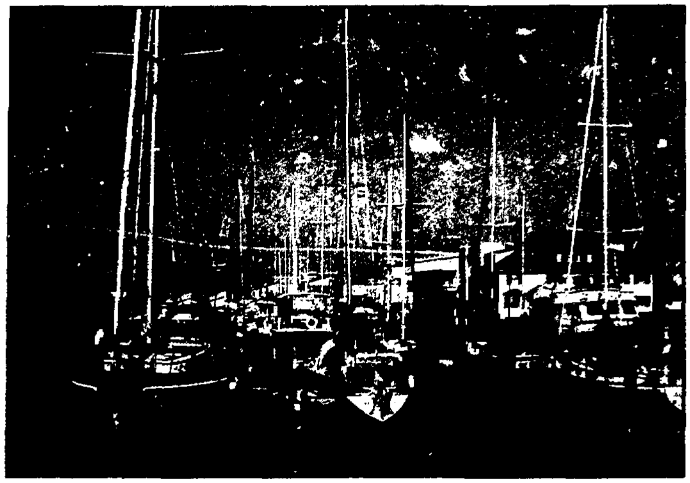
Exclusive Economic Zone (EEZ): Coastal states around the world have assumed new responsibility in the coastal ocean by proclaiming EEZs. The U.S. EEZ, proclaimed in 1983, is a region that extends seaward 200 nautical miles from the coast and brings within the national domain over 3 million square nautical miles of submarine lands. The EEZ contains vital living and non-living resources in the seabed, sub-bottom, and overlying water. Because most of the EEZ has not been thoroughly explored, its resources and their potential remain only partially defined.



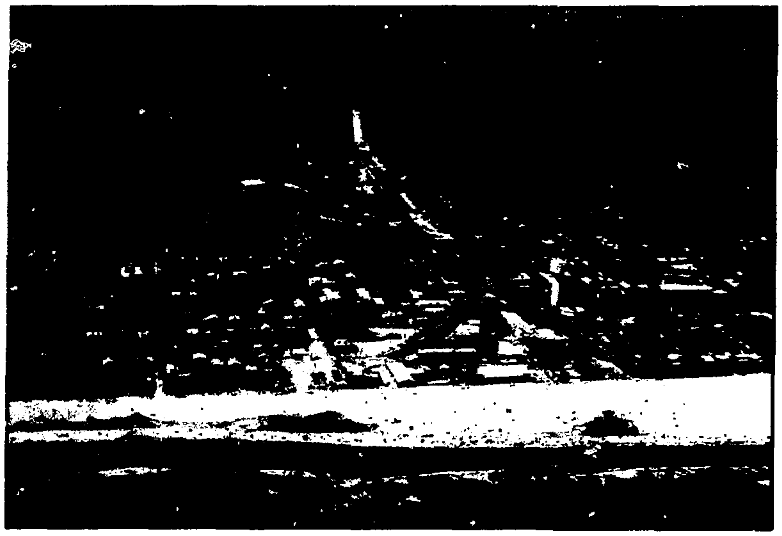


Offshore hydrocarbon potential in the United States.

Coastal Industry: Although the nation has hardly begun to utilize the resources of the EEZ, existing commercial activities in the coastal ocean are important. In 1987, the commercial ocean sector, largely coastal, contributed about $76 billion, or 1.7 percent, to the total GNP. This contribution is of approximately the same scale as other well-recognized segments of the U.S. economy, such as farming, mining (excluding offshore oil and gas), transportation (other than by water), and communications.



Recreational and commercial harbor.



Developed barrier island, North Carolina.

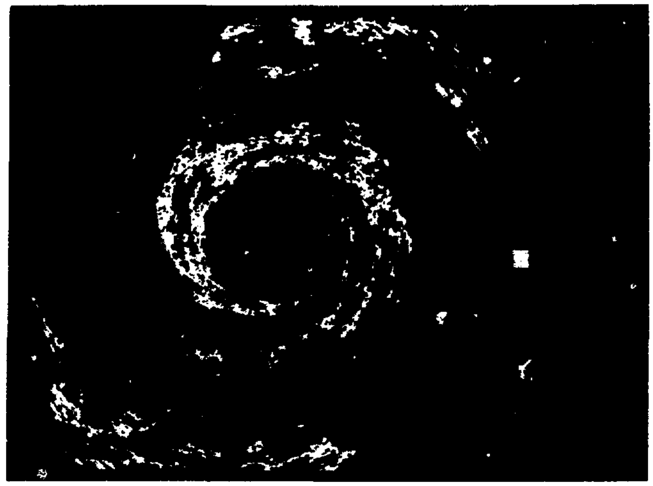
Undeveloped barrier island, North Carolina.

Storm Hazards

The 1989 hurricane season saw the formation of two very intense hurricanes (Gabrielle and Hugo). These storms, and the three intense hurricanes of 1988 (Gilbert, Helene, and Joan), may signal the return to more intense hurricane activity, as during the 1950s and 1960s. The great increase in human activity in coastal regions since that era places significant national assets at risk from such natural hazards.

It was not until Hugo was within 24 hours of landfall in South Carolina that regional models produced reasonable tracks. A twenty mile shift in the storm would have greatly increased devastation in Charleston. Better ocean models and observations are needed to account for air-sea interactions in coastal oceans so that storm surge predictions can be improved.

Extratropical storms, strengthening over coastal waters, can threaten coastal communities and structures. Storm-driven waves and currents must be considered in the design and operation of offshore structures such as oil rigs.



Radar scan of hurricane Hugo from Charleston, S.C.

Winter storm damage, Kitty Hawk, N.C.

National Security

Mastery of the coastal ocean is essential for national security. Maritime defense, amphibious operations, mine warfare, and special warfare are concentrated in the coastal ocean, but our knowledge of our own coastal region or of foreign coastal regions is inadequate to best exploit this environment. Naval history, validated by our experience during the past 50 years, has shown that most conflicts occur in coastal waters. Many navies have a limited open ocean capability, but can present a strong coastal defense. Knowledge of the coastal ocean will be vital to cope with such threats as coastal diesel submarines which are available in the international markets.

Recent political changes in Europe and the U.S.S.R. may portend a heightened emphasis on "Low Intensity Conflicts," where a coastal naval capability will be vital. In addition to military operations, there are other aspects of national security, for example, the maintenance of coastal and harbor access by channel dredging, that require improved knowledge of coastal circulation variability. The availability of critical resources from coastal regions and the protection of people, vessels, and coastal bases from the threat of storms and flooding are important factors also.

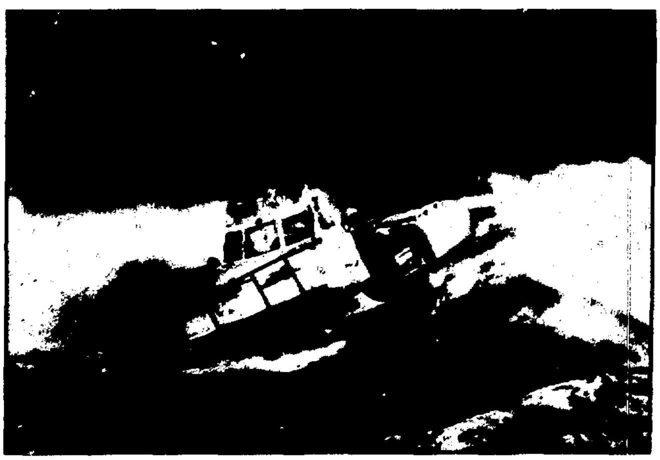
Pollution

The coastal ocean is the ultimate repository for land, river, and many atmospheric discharges. Increasingly, as waste disposal sites are filled on land, the ocean is being used for direct dumping or sewage disposal. Protecting the ocean and its resources requires understanding and an ability to predict physical, chemical, biological, and geological interactions and the transfer of contaminants through food chains and their fate in the oceanic system. Pollution problems arise from both natural and anthropogenic sources:

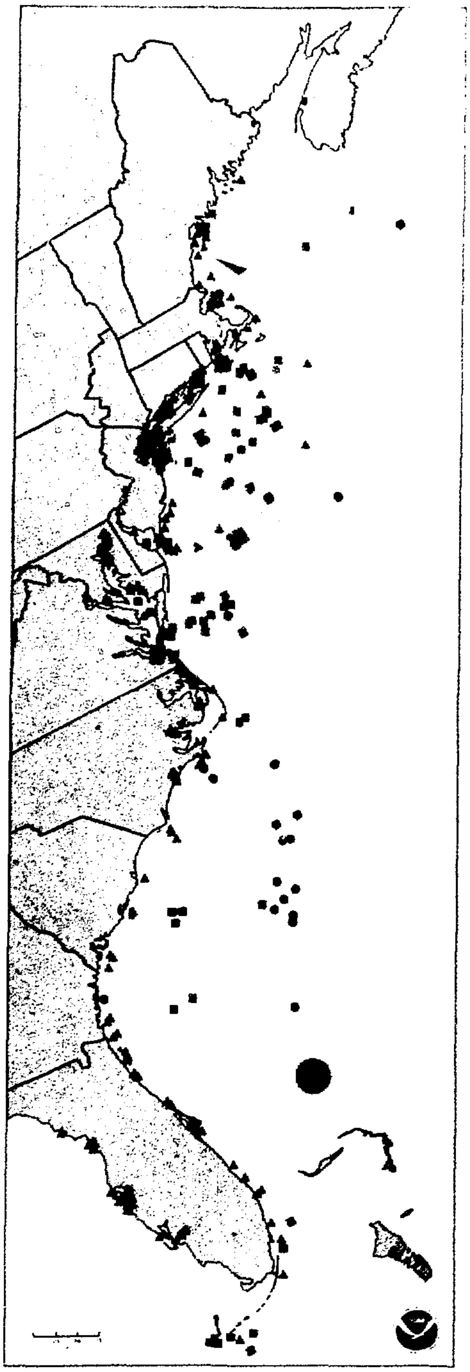
Oil spills: Although the devastating impacts of oil spills are not yet fully understood, we know that they vary greatly between individual ecosystems. For instance, the coast of Alaska exposed to 35,000 tons of oil from the Exxon *Valdez* in April 1989, will probably recover slowly because of the slow breakdown of oil in cold water. Massive mortality among seabirds, marine mammals, and fish is apparent; however, the long-term effect of oil-laden sediments and water on biological processes and repercussions throughout the food chain are unknown.

In the *Valdez* case, the oil moved roughly in accordance with the known climatological ocean circulation in the region thus simplifying response planning. In contrast, an earlier spill, near San Francisco, from the tanker *Puerto Rican* in 1984, although initially moving in accordance with model predictions, eventually traveled in a very different manner from that predicted by the On-Scene Spill Model, of the National Oceanic and Atmospheric Administration (NOAA). Observations of rapidly changing offshore conditions were not available to update the model. In general, such models would benefit greatly from incorporating real-time data on wind, currents, waves and tides. The Oil Spill Risk Analysis (OSRA) model of the Minerals Management Service (MMS) is similarly limited by lack of knowledge of local current variability, for example, in Southern California.

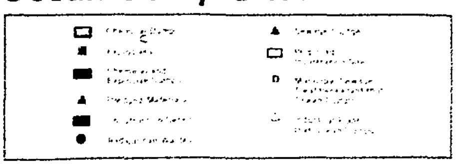
Oil transport hazards.



Search and rescue in high seas.



Ocean Dump Sites



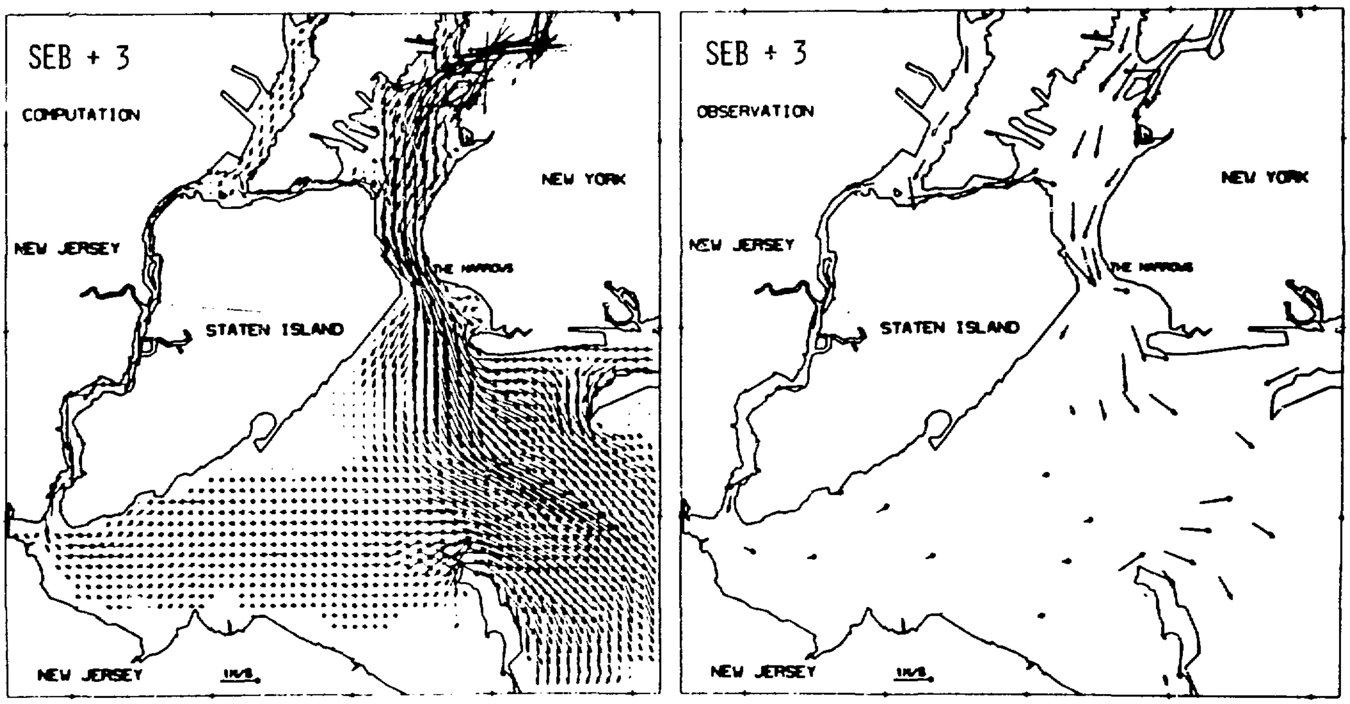
Anoxia: Some naturally occurring impacts have been attributed to pollution because of the lack of information and understanding. In July 1976, a large region off the coast of New Jersey became anoxic and resulted in a loss of shellfish and finfish estimated at $350 million. The cause of this incident was first attributed to increased sewage loading and sludge dumping in the New York Bight. Subsequently, it became clear that this anoxia was due to the combination of an abnormally warm winter, an atypical wind field, and an exceptional algal bloom. These physical conditions resulted in an unusually shallow and strong temperature stratification in the ocean and a strong onshore flow in the lower layer of nutrient-rich water, all of which facilitated the algal bloom. Had there been a real-time, physical-biological-chemical observing system (for which all the necessary sensors now exist) data on flow fields, chlorophyll, temperature, and oxygen concentrations could have been used together with a model to assess the rate of oxygen depletion and a recommendation offered to fish the region before the onset of anoxia and the subsequent fish kill.

Toxic Algal Blooms: There is a disturbing increase in the frequency and distribution of red tides and other toxic blooms. For example, they now recur along much of the New England coast annually. Red tides are dense accumulations of dinoflagellates (microscopic algae) which have rapidly grown, multiplied and become localized by currents, tides, and winds. Toxin from some dinoflagellates may kill marine organisms or concentrate in certain ones (e.g., shellfish) making them dangerous for human consumption. Toxic algal blooms are increasing and are spreading to populated coastal regions - suggesting a relationship to human activity. For New England, conceptual models now exist for red tide progression, including transport by alongshore currents. Management models do not exist.

Search and Rescue (SAR)

Thirty states, representing approximately 75% of the U.S. population, have coastal or Great Lakes access. There are almost 10 million recreational boats in use on the Great Lakes and in our coastal waters. According to the United States Coast Guard (USCG), 72% of vessels requiring assistance in 1987 were recreational boats. A significant number of those emergencies were due to severe ocean and weather conditions. The following 1987 statistics highlight the seriousness of the problem: 5,800 lives endangered with 1,600 lost; over $2 billion in property endangered with $460 million lost; and 40,000 recreational/private boats assisted by the USCG.

SAR efforts require short-term forecasts of currents, winds, waves, and other variables to help estimate drift and sea conditions and to locate the endangered persons or vessels. In addition, NOAA operational satellites provide SAR services in a cooperative effort with France, Canada, and the Soviet Union. At present, the USCG's nearshore SAR efforts depend heavily on local National Weather Service or military marine forecasts and ocean analyses. Present surface current models are very unreliable for the nearshore and only marginally acceptable for offshore SAR. In an actual case the marine forecast may seriously under-predict wind and waves and the model estimated movement of an object may be in gross error because of local current variability. Much higher resolution and a better handling of local conditions in the models are required.



Computed and observed vertically averaged currents at the time of maximum ebb current at the Narrows.

IV. What Is Our Current Technical Capability?

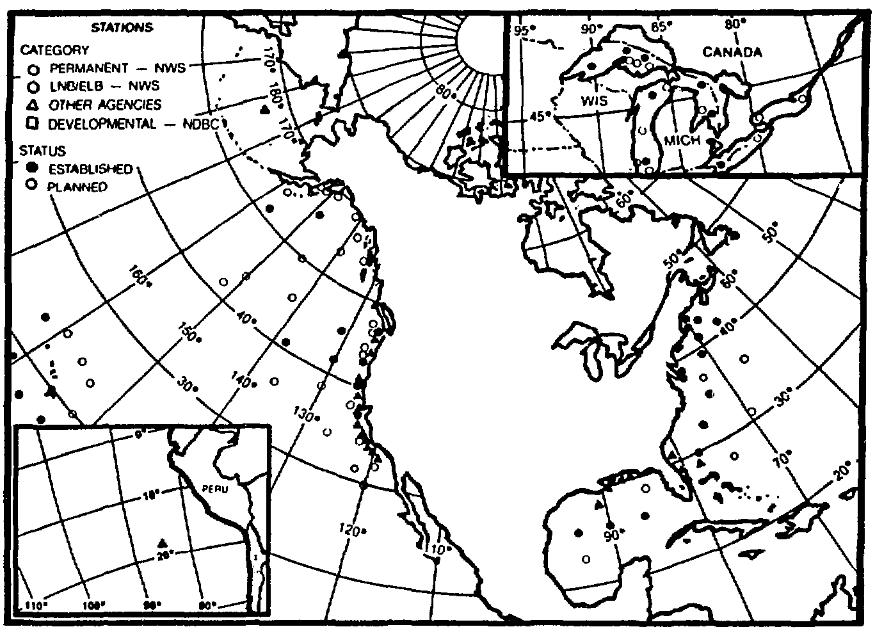
A Mixed Community

At present, more than ten federal agencies, plus numerous state and local organizations, are involved in research activities and management issues concerning the coastal ocean. Typically they employ technical approaches which need improvement. In addition, many academic institutions are engaged in research on the coastal ocean. To date this generally has taken the form of disciplinary studies including modeling efforts and observational campaigns. The private sector is represented by specialized firms with proven coastal ocean observing and modeling competence.

Observations

The operational observing system for the coastal ocean, provided by NOAA, consists of: meteorological buoys (which report in real-time) for wind and sea surface temperature data; coastal tide gauges (the majority of which do not report in real-time) for sea level data; satellite-borne infrared sensors (AVHRR) for sea surface temperature maps; and real-time expendable bathythermographs (XBTs) for temperature fields and meteorological reports from the volunteer ship program. The volunteer ship program is being extended to include coastal ships. The U.S. Army Corps of Engineers (USACE) has an expanding wave observing network on the nearshore of the continental shelf which could contribute to a national coastal ocean observing system. However, other than a few semi-quantitative sea surface temperature analyses provided by NOAA, there are no data products available on a regular basis for the coastal ocean flows, and none based on the dynamical constraints that only numerical models provide. The National Aeronautics and Space Administration (NASA) provides research satellites which demonstrate the value of remote sensing for understanding and monitoring coastal ocean physics and biology.

Other agencies, particularly the Mineral Management Service (MMS), the Department of Energy (DOE), the U.S. Geological Survey (USGS), and the Environmental Protection Agency (EPA) conduct observational programs on a regional basis for specific applications. For defense needs, the Navy acquires ocean data from ships, satellites, and moored and drifting buoys.

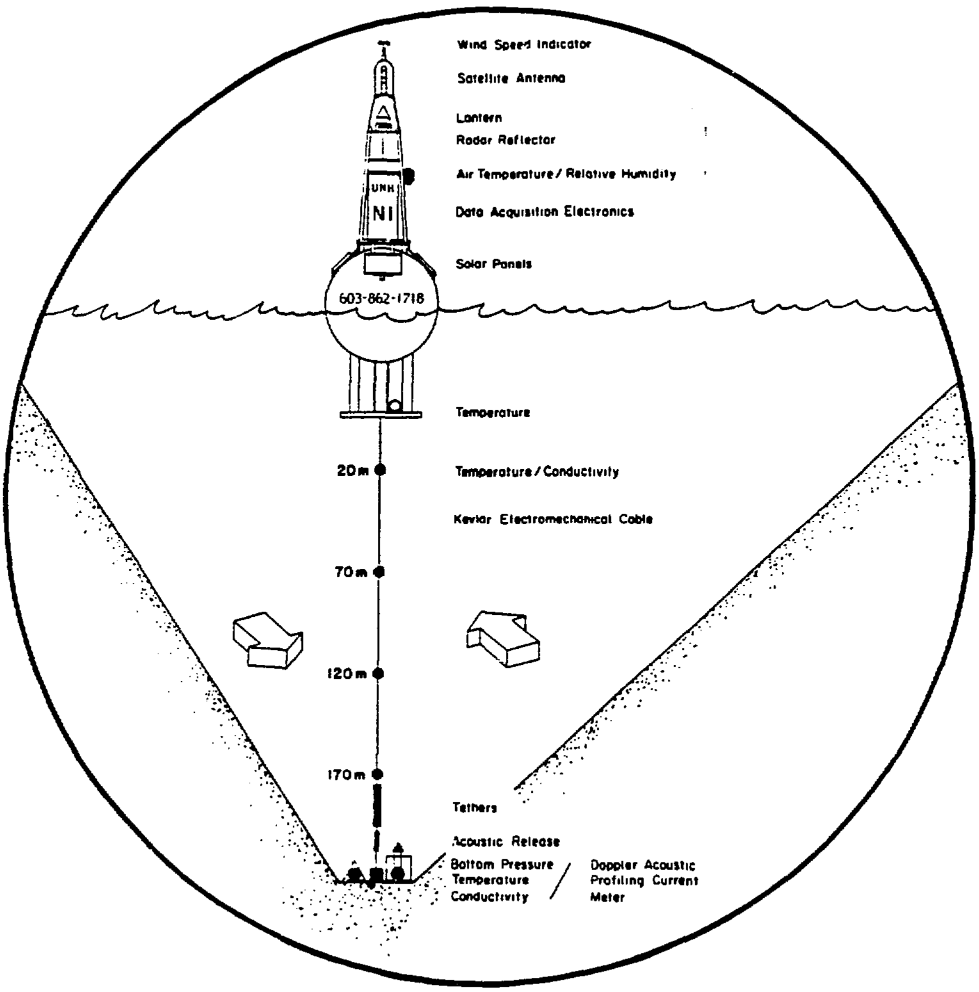


NOAA's NDBC buoy locations.

Current Operational Products

Certain operational products are routinely available to the public. These include marine weather predictions and warnings, fisheries advisories, hurricane warnings, and storm surge predictions from NOAA. Wave forecasts are developed by NOAA and Navy. The Joint Ice Center of NOAA and Navy issues polar ice forecasts. Specific, tailored products are produced by other agencies, for example, the Oil Spill Risk Analysis models of MMS. There is, however, an absence of data and model products describing the coastal ocean's temperature and salinity structure and currents.

In general, the current status of operational products shows certain successes and illustrates opportunities to extend the suite and improve the quality of operational products for the benefit of the public. To grasp these opportunities will require a more sustained effort by and synergism between the agencies. At present the observational capability needs to be upgraded to an operational level, and a strategic plan to convert research knowledge to operational forecast systems must be developed.



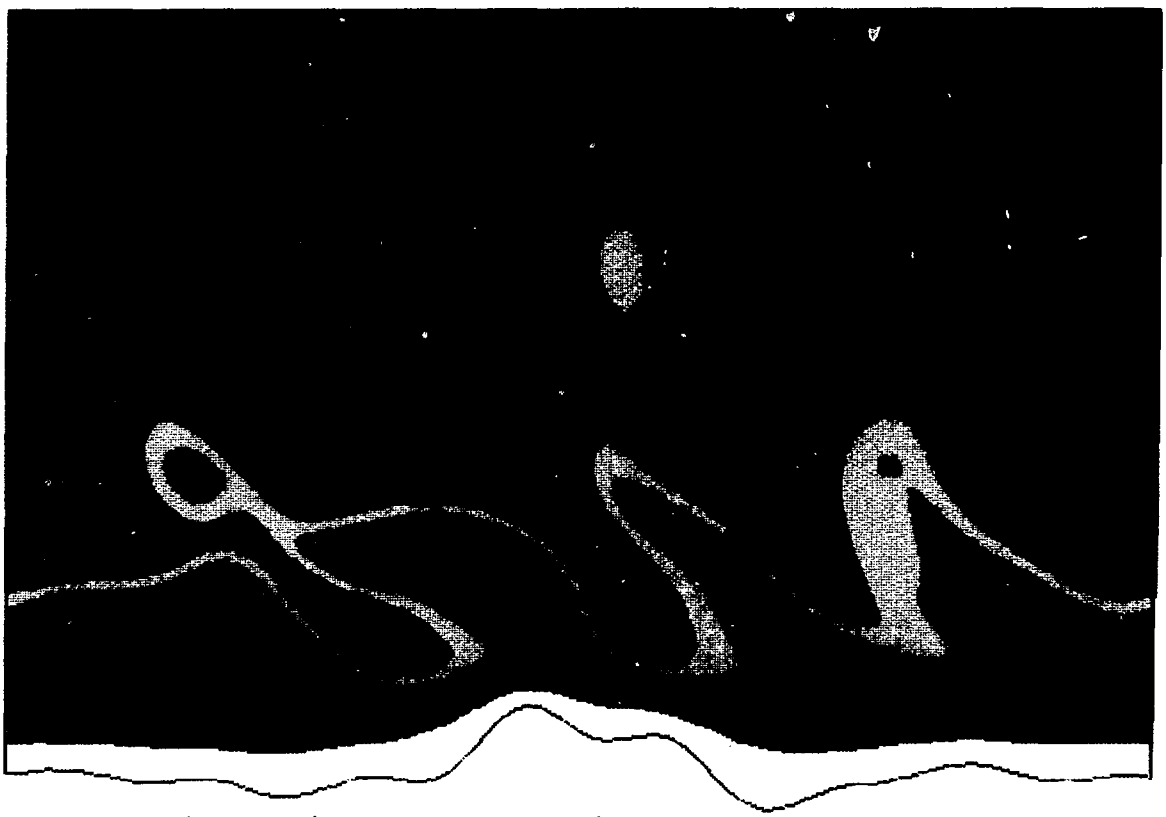
Telemetering temperature and conductivity research array in the Gulf of Maine.

Research and Development Programs

Despite the shortcomings discussed above, the research and development community has made significant progress. The National Science Foundation (NSF) and the Office of Naval Research (ONR) have funded basic research including the development and exploitation of numerical models, with important application to simulating flow in the coastal ocean.

Complementing this basic research, considerable experience in the real-time acquisition of data and the development of specific regional models has been gained through applied research programs focused on measuring and modeling ocean circulation in regions that are important for resource potential or pollution issues.

NOAA has supported the development and application of models for Delaware Bay and Long Island Sound. MMS has supported modeling efforts and observational studies such as the Northern California Coastal Circulation Study (NCCCS). MMS now plans the Louisiana-Texas Shelf program (LATEX). ONR and NSF have supported modeling and observational programs off Northern California. DOE has supported regional studies of coastal transport processes in the Southern California Basin, South Atlantic Bight, and Mid-Atlantic Bight. NOAA, EPA, and USACE jointly support measurements and modeling of the circulation, biogeochemistry, and ecology of Chesapeake Bay. These studies begin to provide regional data bases and a technical underpinning for a national operational program.



Numerical simulation of an unstable coastal jet shedding eddies off Northern California.

V. What More Is Needed?

Increasing activity and population in coastal regions have produced a broad array of issues and problems, some of which are exemplified in this synopsis. The national response to these has been generally fragmented and irregular, although some progress has been made. There is a clear need for a coherent, national approach to provide the tools and organization to understand and manage the coastal ocean rather than a continued reliance on individual agency initiatives and ad hoc approaches.

A major need is to develop a national observation and prediction system that is capable of assimilating observations into numerical models of the coastal ocean. The technical ability to develop this is at hand. Improved observational techniques (including satellites), increased computer power (with improved numerical models), and new methods of data handling can form the basis of such a system.

We must do more with such a system than improve our basic understanding of the coastal ocean. We must develop an operational capability to observe and predict the coastal ocean in a real-time, regular, and reliable manner. There are excellent research programs underway to provide basic understanding and to support the development of such an operational capability, but they must be expanded and utilized.

Basic Research to Enhance Understanding

The importance of the coastal ocean is evidenced by new basic research studies aimed at understanding the physical, chemical, biological, and geological processes of the coastal ocean. These programs will greatly increase our knowledge of the behavior of the coastal ocean. They will also underpin efforts to protect and wisely manage coastal resources that currently are poorly understood, heavily stressed, and increasingly valuable. The proposed Coastal Oceanography Program (CoOP) and the Global Ocean Ecosystems Dynamics Program (GLOBEC) are examples of major, fundamental studies of the ocean that will produce an explosion of new knowledge about coastal processes in a few years.

An Operational Capability to Observe and Predict

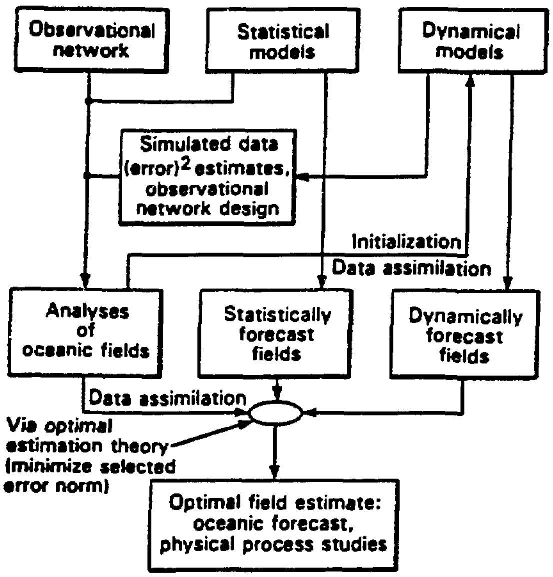
The results of basic research programs must be incorporated in a robust, real-time system of day-to-day, operational observation, nowcasts, and forecasts that will enable managers to assure the safe and productive use of the coastal ocean.

It is the transition from basic research efforts to an operational coastal ocean prediction system that is the focus of COPS. The technical skills exist to develop an operational system. Some preliminary operational data products are already available. The capability exists to observe the coastal ocean in real-time through the use of buoys, aircraft, ships of opportunity and satellites. Models of coastal ocean circulation have been developed for specific regions and the computer power is available to employ them for operational use. Techniques of assimilating observations into such models are available. Modern data handling technology can make regional data available nationally or internationally in real-time. New, interactive, computer graphic techniques make it possible to view several fields of data at one time. A concerted effort is needed to link all of these components together in a system that can be developed and tested for operational use.

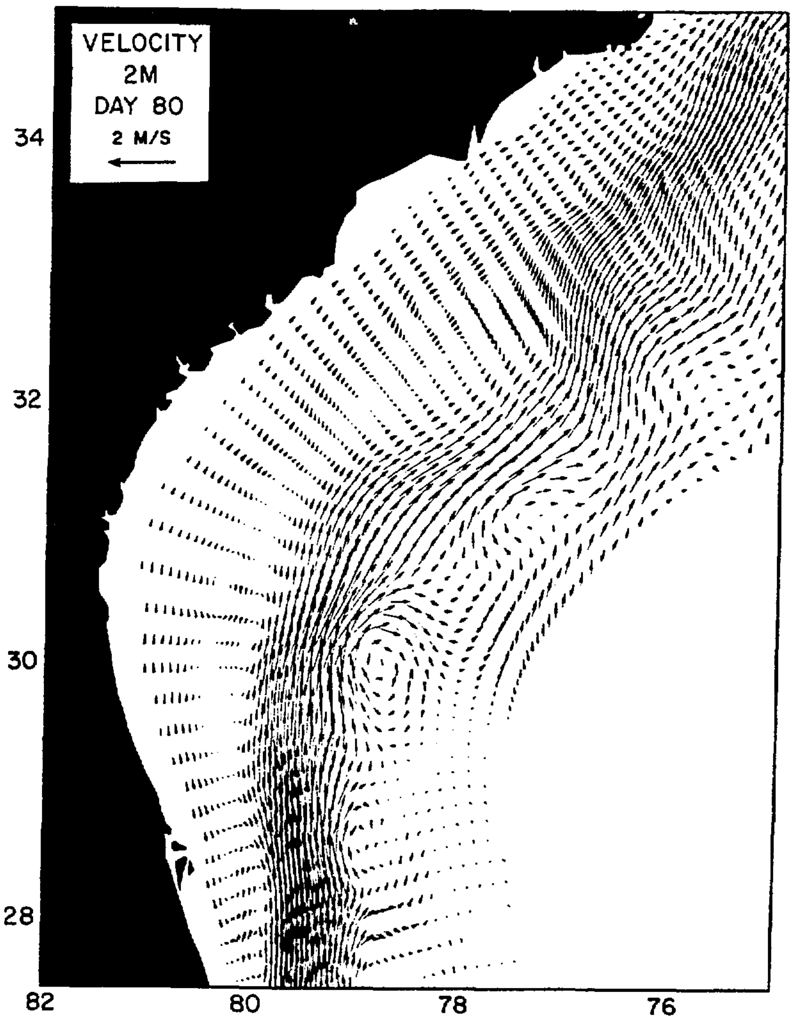
National Management and Coordination of Regional Approaches

Coordination of a national coastal ocean prediction system is of paramount importance. This must be within the the context of a national policy to help coordinate and build upon the current programs of individual agencies. Federal agencies, state and local governments, and the private sector, including both industry and academia, must be involved in this coordination.

The national program must be able to effect the transition from research activities to operational systems. It must be able to coordinate and optimize current programs. It must set and follow a strategy to develop new techniques. It must ensure that real-time observations and computer-model products are available to users with a dependable, robust dissemination process. It is unlikely that a single predictive modeling system will suffice. Coastal circulation and marine ecosystems are regional in nature, exhibiting unique and important features, and most regions are not strongly coupled to one another. Thus there are compelling technical reasons for adopting a regional approach within the national program.



Schematic diagram of an Ocean Descriptive-Predictive System



Velocities two meters below the surface after 80 computational days off the U.S. Southeast coast.

VI. Towards a National Capability for Coastal Ocean Prediction – The Proposed Program

Today the Nation's environmental managers make decisions impacting the ocean environment and commerce with limited knowledge, some of which is derived from data and models. Data will always be limited and models will never be perfect. However, modern techniques of data assimilation that optimize the combined use of observations and models can greatly improve the present situation.

The proposed Coastal Ocean Prediction Systems (COPS) program will provide the basis for a greatly improved capability for technical management of the coastal ocean. This capability must combine regular observations with numerical models through data assimilation. The resulting large-scale, regional system will combine with finer resolution observations and numerical models, that can be deployed on demand, to address specific environmental events or issues. Through the COPS planning process, a strategy for the development of the program was established with the following goal and objectives:

COPS Goal

To develop and validate a predictive system for the U.S. coastal ocean, including the capability to forecast conditions in the EEZ for several days and to simulate them for several years.

COPS Objectives

I. To determine the extent to which the coastal oceans are predictable on time scales of hours-to-days and to understand the processes that relate to this predictability.

II. To develop a set of efficient hindcast, nowcast, and forecast systems including observational networks, dynamical models, and data assimilation techniques, suitable for continuous large-scale regional use, together with intensive, highly accurate, subregional forecasts.

III. To couple the physical predictive system to biological, chemical, and geological components in order to advance interdisciplinary ocean science, to facilitate the management and utilization of coastal marine resources, and to enable simulations of the coastal ocean response to various global change scenarios. The multidisciplinary version of the coastal ocean prediction system should be structured so that it is available for the solution of real-time environmental problems, the study of ecosystem processes, and the management of coastal resources and environmental quality.

In situ and remote sensing technologies and communications systems are now available to develop an expanded network of observations that can report in real-time. Similarly, predictive modeling systems are available to be optimized through an extensive program of development, testing, and evaluation, both on a regional and a national basis. To facilitate the design and development of both the observing and modeling systems, the existing data bases for the coastal ocean need to be organized in an efficient manner. These data bases would also support the study of climatic variations in the coastal ocean.

The initial focus in COPS will be on observing and modeling systems for physical variables for three reasons.

- There is enough capability now in the physical oceanographic, ocean engineering, and meteorological communities to commence development of such systems.

- There are numerous direct applications for predictions of the physical variability, transports, and forces.

- The ability to predict physical variables is needed to describe biogeochemical variability and transports. The strategy to be pursued must foster the simultaneous development, testing, and evaluation of biogeochemical observing systems and predictive models, in an interconnected fashion, with their physical counterparts.

VII. Partnerships for Action

Federal, State, University, and Private Sector

A central point here is that to be effective, a national capability must be developed. Mission-oriented, operational agencies, such as EPA, MMS, USACE and USCG, as well as NOAA and CNOC (Commander, Naval Oceanography Command), must play major roles in implementing observing systems, developing special applications models, and conducting field studies. Goal-oriented research and development must be underpinned by a robust basic research program, involving the academic community, led by NSF, ONR, DOE, USGS, and NASA.

NOAA and other federal agencies have a national responsibility in the coastal ocean and they need a national capability. To implement the national (and regional) program, the combined efforts and relative strengths of the academic, commercial, federal, state and local sectors will be needed. As a start, NOAA has recently created the Center for Ocean Analysis and Prediction (COAP) in Monterey, California, and the Ocean Products Center (OPC) in Camp Springs, Maryland, to begin the exchange of data sets and model products between NOAA, Navy and other agencies, and academic institutions. Also, NOAA together with USCG and state and local entities, is establishing the Physical Oceanographic Real-Time System Program (PORTS) in 1990 with an installation for Tampa Bay, Florida.

Programmatic

The development of national, operational prediction systems will draw upon the broad array of research and applications programs that relate to the coastal ocean. To effect the COPS transition from research findings, observations and models to the consequent operational systems will require close association between the managers and researchers. There is a particular opportunity to use ongoing programs to develop the regional capabilities that must be components of COPS. In many instances the applied and basic research programs can use the same resources; e.g., numerical models, observing systems, computers, telemetry systems, data bases, research vessels and aircraft, and satellites.

Science Disciplines

The basis of COPS is observing and modeling the physical behavior of the coastal ocean and atmosphere. Many of the principal concerns with the state of the coastal ocean however involve biological, chemical, and geological issues. The eventual predictive system must couple to models and observations of the behavior of biological, chemical, and geological systems to be fully beneficial. Developing these links will require active participation in the COPS process by oceanic and atmospheric scientists and engineers involved in all these disciplines.

International

The same problems which beset the U.S. coastal ocean affect coastal nations around the world. There are active programs in some other nations but the U.S. has an opportunity to provide scientific and technical leadership on these problems. There may be technical and economic opportunities for the U.S. private sector to play a role in coastal ocean monitoring and prediction as part of national and international programs. Efforts to coordinate these activities as they relate to potential global change in the coastal ocean can be anticipated. COPS will provide a keystone in any international effort to monitor and predict the coastal ocean's response to global change.

Acronyms

AVHRR - Advanced Very High Resolution Radiometer
CNOC - Commander, Naval Oceanography Command
CoOP - Coastal Oceanography Program
COPS - Coastal Ocean Prediction Systems
CZCS - Coastal Zone Color Scanner
DOE - Department of Energy
EEZ - Exclusive Economic Zone
EPA - Environmental Protection Agency
GLOBEC - Global Ocean Ecosystems Dynamics Program
GNP - Gross National Product
LATEX - Louisiana-Texas Shelf program
MMS - Minerals Management Service
NASA - National Aeronautics and Space Administration
NCCCS - Northern California Coastal Circulation Study
NDBC - National Data Buoy Center
NOAA - National Oceanic and Atmospheric Administration
NSF - National Science Foundation
ONR - Office of Naval Research
OSRA - Oil Spill Risk Analysis
PORTS - Physical Oceanographic Real-Time System
SAR - Search and Rescue
USACE - United States Army Corps of Engineers
USCG - United States Coast Guard
USGS - United States Geological Survey
USN - United States Navy
XBT - Expendable bathythermograph

Acknowledgements

The financial and programmatic support of the co-sponsoring agencies is gratefully acknowledged. Each agency made unique and important contributions. In particular, NOAA, MMS, DOE, NSF, and ONR are recognized for their early and strong support.

Joint Oceanographic Institutions, Inc. provided overall COPS project management. Dr. Christopher N. K. Mooers of the University of New Hampshire convened the COPS workshop which was hosted by the University of New Orleans.

Ultimately, the quality of the Workshop, and of the Report, depended upon the competent and enthusiastic participation of its attendees, other contributors, and the Organizing Committee. The invited speakers, and the working group chairs and rapporteurs, deserve special recognition for their scientific leadership and arduous efforts.

Color illustrations are courtesy of NOAA, NASA, USCG, USGS, MMS, and JOI, Inc. Other figures are referenced in the COPS technical report.