U.S. Global Ocean Observing System Workshop Report

14–16 October 1992

Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

Sponsored by the
National Ocean Service
of the
National Oceanic and Atmospheric Administration

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Contents

Executive Summary

This document is the report of a workshop that was held at the Woods Hole Oceanographic Institution on October 14–16, 1992. The purpose of the workshop was to bring together experts from the academic community and government agencies to identify the highest priority measurements that should be made as part of the U.S. contribution to a Global Ocean Observing System (GOOS). The meeting was sponsored by the National Ocean Service (NOS) of the National Oceanic and Atmospheric Administration (NOAA) via the Office of Naval Research (ONR); administrative arrangements were made by Joint Oceanographic Institutions Incorporated.

The workshop was organized into three parts: (1) an initial plenary session to discuss general concepts of GOOS and the state of national and international planning; (2) working groups on each of the subject areas as defined by the modules: climate, coastal processes, living marine resources, health of the ocean, and marine services to agree on definitions of the modules and the priority areas for GOOS measurements; and (3) a final plenary session to discuss and agree on the highest priority measurements and cross–cutting measurements, and next steps for NOAA (i.e. NOS) to take to implement these in a FY 1995 budget initiative.

The workshop agreed on a two–stream effort for GOOS––one stream to involve enhancement of operational measurements (including transition to operations of research efforts like the TOGA TAO array) and the second stream to include a set of observational demonstrations or pilot experiments of new techniques that would be carried out on at least a basin–wide scale (including, for example, large–scale acoustic averaging and mid–depth floats). In addition, the workshop expanded the definitions and identified the priority measurements for each GOOS module.

It was recommended that the near–term NOS contribution to U.S. GOOS should include five major efforts: (1) maintaining existing programs, for example, Volunteer Observing Ships (VOS), drifting buoys, existing long–time series measurements, and global sea level measurements; (2) beginning transition to operations of aspects of some research programs, for example the Tropical Ocean Global Atmosphere (TOGA) observing system, including TOGA Tropical Atmosphere Ocean (TAO) array; (3) initiating cooperation and coordination with other NOAA and non–NOAA federal programs; (4) planning for a FY 1995 NOAA GOOS initiative to provide new money for some U.S. GOOS activities; and (5) considering an office and staff to help coordinate the entire set of U.S. GOOS activities.

Design studies will be a high priority. These should build on the previous NOAA work on the design of the TOGA TAO array to provide optimized wind fields and the examination of the relative merits of ship and drifting buoy contributions to the accuracy of satellite–based Sea Sur–

face Temperature (SST) measurements. Efforts needed include joint NOAA/academic studies on blended observing systems for upper–ocean temperature profiles and heat content, and on combined in situ/satellite wind fields.

Finally, the workshop agreed that an interagency committee was required in order to both promote GOOS and to ensure that each agency with an interest was ready to develop a coordinated budget proposal. The workshop recommended that NOAA/NOS should chair the committee, and that Navy, as the other major operational ocean agency, should co–chair. Other agencies with major interest in GOOS should also be represented. A mechanism for continued interaction with the academic community should be included.

1. Introduction and Scope

1.1 The Rationale

Long–term monitoring of the environment is nowhere more important than in the ocean. With its large heat capacity and circulation, the ocean plays a key role in the climate system as well as affecting the coastal zone, pollution, fisheries, defense, and marine transport. Although our knowledge of the ocean and its processes is limited because of the vast range of time and space scales involved, we do know that regionally the ocean acts as a buffer and affects coastal climate and sea level and that the ocean plays a major role in the global cycling of carbon. Globally, the ocean acts as a heat source that forces atmospheric convection and winds, and transports and stores heat.

Rapid change in satellite and computer technology has allowed us to observe and model the ocean in great detail. Research programs have given us new insights into how the ocean works on global scales. We are becoming increasingly aware that climate change depends critically on the role of the ocean; recent successes with predictions of El Niño show that our understanding is now ready to be made operational. Moreover, with increasing populations and needs for energy and food resources, the nations of the world are looking to the ocean for help. For all of these reasons, we need to be able to document the state and changes in the ocean physics, chemistry, and biology. For this we need a Global Ocean Observing System.

1.2 What is GOOS?

A Global Ocean Observing System (GOOS) would consist of a globally–based set of in situ and satellite–based instruments that would monitor the state and changes in the state of ocean and oceanic ecosystems. It would include a data and information network that connects the instruments and provides information to users and data archives. An international coordinating mechanism with scientific and technical advisory groups and a technical assistance, training, and technology transfer activity would be an essential element.

A Global Ocean Observing System would permit us to monitor and assess the state of the ocean, ocean processes, and ocean ecosystems, globally and in the coastal regions. It would provide information for efficient use of ocean resources and protection of the ocean environment. It would provide information for research on understanding, modeling, and prediction of the state of the ocean.

1.3 Economic Benefits

It is clear that the economic benefits of GOOS are many times greater than the investment needed to actually acquire and make available the observations. For example, in the U.S. agricultural sector alone, economists estimate that a minimum of $240M per year on average would be saved if the data were available to permit forecasts of the El Niño Southern Oscillation (ENSO) events at least 9 months in advance. The world–wide impact of these fluctuations on established fisheries is equally significant. The science is complete to permit these forecasts, but the ocean data are not yet routinely available. The costs to gather this data are probably less than about $50M per year. The economic benefits to the U.S. energy sector are estimated to be even larger than the benefits to the agricultural sector. Current estimates suggest that a $200M annual U.S. investment in GOOS might return a more than $2B total annual benefit to the U.S. economy.

1.4 GOOS as an Operational System

The primary goal of U.S. GOOS is to provide the data needed for detection and forecasts of societally important environmental conditions. This is an "operational" goal. Research will be a key underpinning of GOOS and will help to improve the detection and forecasts. Development of new technology will help improve the observational systems. The data taken for operational purposes, given sufficient quality control, will be useful to the research programs. Both operations and research are needed for success.

In the GOOS context here, we use the term operational to mean (see Appendix D) long–term, routine, systematic, cost–effective, and global (or having global implications). For climate we look for observations that will have a demonstrable impact on climate forecasts or that will be an important indicator or diagnostic of climate change. An equivalent criterion for the other GOOS modules will be developed.

1.5 International Planning

GOOS is an international activity initiated through the Intergovernmental Oceanographic Commission (IOC) which is part of the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the United Nations system of organizations. The climate contributions of GOOS were emphasized during the Second World Climate Conference in 1990 which urged support of GOOS as part of a Global Climate Observing System (GCOS). The U.S. has committed to GOOS through the United Nations Conference on Environment and Development (UNCED) and its action list, AGENDA 21. As part of the planning activity, the IOC has prepared a draft GOOS development plan and is developing a statement called "The Case for GOOS".

The draft development plan of the IOC represents an IOC Secretariat view developed with the input of various experts that have advised on the plan. The plan proposes that the planning for GOOS be divided into specific areas, or "modules". These modules include climate, coastal processes, living marine resources, health of the ocean, and operational marine weather and ocean forecasting. International planning for the climate module of GOOS has proceeded rapidly, with the appointment and vigorous activity of the Ocean Observing System Development Panel (OOSDP) (discussed below under the Climate Module). Planning for the other modules has just begun.

1.6 U.S. Planning

In the U.S., numerous operational, technology, and research activities are underway at NOAA, Navy, the National Science Foundation (NSF), the Department of Energy (DOE), the Environmental Protection Agency (EPA), the Defensed Advanced Research Project Agency (DARPA), and the National Aeronautics and Space Administration (NASA) that are related to the long-term goals and plans of the international GOOS. These activities, properly supported and coordinated, will lead to the U.S. contribution to GOOS. In particular, NOAA planning is underway, but resources have not been identified. NOAA's role in the U.S. GOOS effort, and thus the U.S. role in GOOS, will be unclear until the resource issue is clarified.

In order to carry forward the planning for U.S. GOOS, the National Ocean Service of NOAA sponsored a workshop at the Woods Hole Oceanographic Institution in October 1992. This document is the report of that workshop. The 1992 meeting built upon the results of a 1990 workshop on GOOS which addressed the broader aspects of global ocean observations. The purpose of the 1992 workshop was to bring together experts from the academic community and government agencies to identify the highest priority measurements that should be made as part of the U.S. contribution to a global ocean observing system. The workshop agenda is provided in Appendix B. The discussions included review of the definitions of modules and identification of priority measurements. The workshop also discussed interagency and international coordination. Results of the discussions are summarized in the following chapters.

2. GOOS Modules Definition and Priority Measurements

2.1 Introduction

A large part of the workshop time was spent examining the definition of modules that had been proposed by the international planning effort. In general, the workshop agreed that the general concept of modules was reasonable and that the division of topics was sensible. In terms of definition, each module was discussed in detail by a small working group. The results are presented below. We note that it was not possible to discuss the Health of the Ocean Module in the detail desired, due to the small number of qualified people available at the meeting. Neil Andersen agreed to consult with a number of experts to provide a broader review of this definition and proposals for priority research.

The background material for the workshop included a questionnaire listing a definition of each module and a request for workshop participants to list three priority variables or fields to be measured, with tools and benefits to be identified from such a measurement. The questionnaire is provided in Appendix C. The revised definitions and the list of priority measurements, as identified by each working group are presented below. A shorter list was discussed on the last day of the workshop and is discussed in the next chapter.

2.2 Climate Observations for Assessment and Prediction

Definition. Detection of climate change as well as improving our ability to predict changes in the climate system--ranging from ENSO prediction to interdecadal variability to global warming--requires better data on the behavior of the ocean. In the end, the climate module will have to provide the data required to describe the mean state and variability of the oceans and the impact of biological processes on climate variability. It will also provide the input and validation data required for coupled ocean–atmosphere predictive models of climate variability and change, and for coupled physical, chemical, and biological models. Finally, the module will provide a data base that future generations will be able to employ to distinguish long–term change from shorter variability. To meet such goals, intense quality control of measurements will be required.

One of the first priorities is clearly to provide the data necessary for operational prediction of ENSO events. Current models require surface wind and ocean–temperature data from the Pacific Ocean for predicting ENSO events. Systematic observations from the Indian and Atlantic

Oceans are necessary to improve ENSO predictability and associated regional oceanographic and weather impacts. For longer time scales, global measurements of adequate longevity, homogeneity, and accuracy are needed for early detection of changes in the ocean heat and freshwater cycles. At the same time, these and other long–term observations will better define how these and other ocean cycles work so that changes can be predicted. This module will be planned and implemented in cooperation with the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC), the United Nations Environment Program (UNEP) and the International Council of Scientific Unions (ICSU) through the Global Climate Observing System (GCOS) and will use input from large national and international research programs.

This module builds on those operational measurements that are now carried out in support of operational weather forecasting. Existing operational measurements are included in the Marine Services Module listed below. The design of the Climate Module is now being carried out at the international level by OOSDP, a body sponsored by the WMO–ICSU–IOC Joint Scientific Committee of the World Climate Research Program (WCRP) and the IOC. The OOSDP is charged to formulate the conceptual design of a long–term systematic observing system to monitor, describe, and understand the physical and biogeochemical processes that determine ocean circulation and the effects of the ocean on seasonal to decadal climate changes and to provide the observations necessary for climate predictions.

In terms of priority, this module should come first. It has strong international backing and public awareness. Many of its measurements will be important to other modules, and very long–term records are necessary.

Priority Measurements. It is clearly premature to recommend measurements for the entire spectrum of time scales of climate variability. At this stage, it is possible to define with some degree of certainty the measurements needed as part of the climate module of GOOS which will support continued monitoring of and development of predictive capability for variability on ENSO scales (100 to 1000 days). Recommendations for such measurements have been made by several groups (U.S. TOGA, TOGA SSG, and the OOSDP). Since the justification has been provided in detail by other reports, it will not be included here. The recommended measurements include

- sea surface temperature
- upper ocean heat content
- sea surface and upper ocean salinity
- sea level
- precipitation
- periodic deep temperature/salinity profiles
- transports through key straits
- wind stress
- sea ice concentration and extent
- surface CO_2 and relevant biological parameters

These measurements would be carried out by a combination of satellite and in situ techniques (moorings, drifting floats and surface buoys, and acoustic and other averaging techniques).

2.3 Coastal Observations for Assessment and Management

Definition. The offshore edge of the coastal zone is defined by the outer boundary of the Exclusive Economic Zone (EEZ) and includes: estuaries, flood plains, lagoons, beaches, wetlands, rivers as far inland as exists a tidal signal, the Great Lakes, and the overlying atmosphere.

The suggested approach for a U.S. GOOS is to build incrementally on existing observation systems. Specifically, the present data buoy system can be expanded and made more capable by upgrading the present instrument suite, e.g. by adding downward-looking acoustic doppler current meters, which will provide measurements of currents and estimates of zooplankton biomass. Further, National Marine Fisheries Service (NMFS) activities can be enhanced to include much of the desired information about nutrients and plankton. Cooperative arrangements with other agencies, such as the United States Geological Survey (USGS), may be able to provide other measurements, such as those of sediment conditions.

Priority Measurements. For a generic, international GOOS, the minimal measurement suite must include: temperature, salinity, sea level, winds, currents, nutrients, color, long and short wave radiation, plankton counts and pollutant chemicals.

For a U.S GOOS, the suggested regions for study include the Great Lakes, the south Atlantic bight, the gulf coast, the Washington/Oregon coast, the south coast of Alaska, and the Bering Sea. In the following table, an attempt was made to list parameters of importance for understanding and exploiting the coastal zone. Parameters are identified as being (I) incremental, (E) existing operationally, and (R) research. As we went further down the list, we recognized important issues, but we were not able to make intelligent statements as to the state of the art. Blanks are thus left.

PARAMETER	TOOL (S)	SOCIETAL BENEFIT
GENERAL ATMOSPHERIC/OCEAN MEASUREMENTS		
wind (E) air temperature (E) humidity (I) precipitation (I/R) sea state (E)	buoys ships satellites coastal stations	shipping; stuctures; recreation; search & rescue; research; coastal meteorological models
PROFILING ATMOSPHERIC OCEAN MEASUREMENTS		
balloon profiles acoustic profiles optical profiles	ships (I) buoys (R) buoys (R)	weather forecasts; air quality; air–sea chemical fluxes
SEA LEVEL		
sea level	tide gages (E) bottom pressure gages (E)	tides; storm surge; navigation; construction; property/boundary settlements; salt water encroachment; sea level change
CURRENTS		
currents	ADCP buoys (I/E) ships (I/E) drifters (I)	navigation; search & rescue; dispersal; emergency response; ecosystem models; beach erosion; sediment transport
TEMPERATURE		
sea surface temperature (E) subsurface temperature (E)	satellites buoys VOS (E)	coastal meteorology; fisheries; ecosystem models; climate change; sea level; ice
SALINITY		
surface/deep	ships (I/E) buoys (I/R)	coastal ocean models; ecosystems; fisheries
ICE		
ice edge and extent (E) coastal observations (E)	satellites aircraft SAR (I/R)	navigation; climate change; meteorology; climate models; ecosystems; fisheries
SHORT AND LONG WAVE RADIATION		
aerosols (R) gas exchange (R) precipitation of chemicals (R) Photosynthetically Available Radiation (PAR) (I)		water quality; ecosystems; status; trends

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PARAMETER	TOOL (S)	SOCIETAL BENEFIT
OPTICAL MEASUREMENTS		
pigment	buoys	ecosystems; water quality;
detritus	ships	carbon–flux climate models;
clarity	satellites	habitats; navigation (harbors);
sediment load		toxic blooms
spectral properties		
NUTRIENTS		
NO_3, PO_4, NH_4, NO_2, O_2	ships (E)	water quality; ecosystems;
	buoys (R)	eutrophication; habitat status;
	satellites (R)	trends
PLANKTON		
phytoplankton (E)	ship	nuisance blooms; recreation;
fluorometric estimates (I)	buoy	ecosystems; habitats; carbon
growth (E)	ship	cycle
growth (R)	buoy	
species (E)	ship/shore	
species (R)	buoy	
ZOOPLANKTON		
biomass	acoustics (I/R)	ecosystems; fisheries; habitats;
abundance	optics (R)	carbon cycle
species	nets (E)	
	VOS ship–CPR (E/I) (needs enhancement)	
CHEMISTRY		
POC, DOC, PCO_2, DIC	ships	climate change; habitats; living
	buoys	resources; ecosystems; fisheries;
		carbon cycle
contaminants		(see health of the ocean)
GEOLOGY		
sediment types	cores	coastal erosion
grain size	grabs	beach stability
porosity	echo sounder	storm damage
movement	nets	habitat loss
morphology	incubators	navigation
bathymetry/topography		fisheries
benthic biology		carbon cycles
wetlands sediments and biology		
coastal erosion		
run off		
water (E)		
sediments (E)		
contaminants (E) ?		
nutrients (E) ?		
biota (E) ?		
ground water (?)		

2.4 Living Marine Resources (LMR)

Definition. This module is a monitoring system for the variables that characterize the structure and function of marine ecosystems, and how the systems change over various time and space scales. The module overlaps with (1) the Climate Module, because of ecological processes that determine ocean–carbon flux (primary productivity as modulated by nutrients and zooplankton grazing) and because ecosystems respond to, and indicate, climate change (e.g. the response of fisheries to ENSO off the west coast of South America was well known before the climate phenomena that causes the ecosystem response was known); (2) the Coastal Module, because the most economically important living marine resources are in coastal waters (e.g. 95% of the world's fishery yield is from EEZs); and (3) the Health of the Ocean Module, because ecosystems modulate, respond to, and indicate habitat degradation.

There are a large number of potential variables that could be included (i.e. spatial, temporal, size, and age distribution of numerous plankton, nekton and benthic species) in the LMR Module. Two alternative design approaches can be used to select the specific variables: (1) model driven, and (2) "concept based". The former provides data for predictive models (analogous to data collection for weather forecasts or ENSO forecasts). There are many LMR predictive models (e.g. stock assessment models which used data from pre–recruit surveys of juvenile fish to forecast future stock size). A concept–based design would monitor variables that are known (based on experience and concepts about ecosystem processes) to be important ecosystem variables and that are practical to monitor, indefinitely, over large areas. The model–driven design is efficient in the sense that data is selected if and only if it serves a specific purpose, such as stock assessments for fisheries management. The concept–based design provides broader information on ecosystems, that has the potential to answer questions that have not yet been asked. Both design approaches are useful and necessary. Since very large and expensive model–driven monitoring programs for LMR are already in place to support fisheries management, it is appropriate for the U.S. to implement a broader "concept–based" ecosystem monitoring program as the LMR Module of GOOS. The focus should be on the plankton because (1) this component is critically important to the functioning of marine ecosystems; (2) it reflects change; (3) most valuable LMR species have planktonic eggs and/or larvae; and (4) plankton are practical to monitor. There are also examples of plankton monitoring programs that have provided valuable information (McGowen, J.A. 1990. Climate and Change in Oceanic Ecosystems: The Value of Time–Series Data. Trends in Ecology and Evolution. 5 (9): 293–299; Anonymous. 1992. Monitoring the Health of the Ocean: Defining the Role of the Continuous Plankton Recorder in Global Ecosystem Studies. International Oceanographic Commission. IOC/INF–869. 53 pp; Sherman, K. 1991. The Large Marine Ecosystem Concept: A Research and Management Strategy for Living Marine Resources. Ecol. Applications 1 (4)).

The design and implementation of the LMR Module of GOOS should proceed on four tracks: (1) continuation and enhancement of existing plankton (i.e. large phytoplankton and zooplankton, and icthyoplankton) time series, such as the California Cooperative Oceanic Fisheries Investigations (CalCOFI) and the Continuous Plankton Recorder (CPR); (2) calibration and deployment of ecologically meaningful sensors, such as CPR, fluorometer, transmissometers, Acous–

tic Plankton Profilers (APP) and ocean color imagery, on platforms of opportunity (VOS, buoys, satellites); (3) development of multiple–sensor plankton sampling systems, using state of the art acoustics, optics, and biochemical technology, for future application; and (4) evaluation of the need for additional monitoring, such as variables that characterize benthic communities, or trends in marine mammal and/or sea bird abundance. All four tracks should be pursued simultaneously. There are no technical difficulties with the first track, and the marginal costs of assuring continuation and enhancement of existing time series is relatively small. The second track will require some investment in calibration and sensors, but there are no serious barriers. The third track requires development of new, state of the art systems. Several recent workshops (e.g. Anonymous. 1991. GLOBEC Workshop on Acoustic Technology and the Integration of Acoustics and Optical Sampling Methods. GLOBEC Report Number 4. 58 pp.) indicate that this is feasible, but a significant investment is required. The fourth track keeps options open for expanding the scope of the LMR Module of GOOS should a sound rationale be articulated.

The discussion above has not explicitly noted physical variables, which of course, should be included in ecosystem and LMR monitoring programs. The discussion assumes that the appropriate physical data will be collected either as part of the LMR Module or as part of other modules. It is important to recognize that to provide insight into LMR issues, the physical data must be collected on the same space and time scales as the biological data.

The following table summarizes elements of the LMR Module of GOOS that should be implemented as soon as possible (some are already implemented for large ocean areas).

VARIABLE	SENSOR	PLATFORM	COMMENT
primary production	OCI*	satellite	need calibration against in situ data
primary production	fluorometer*	buoys, VOS, research vessels	some additional calibration needed
phytoplankton	CPR* water samples	VOS	CPR surveys are one of the best methods currently available for monitoring species composition of large phytoplankton over broad areas
transmissiometry	transmissometer*	buoys, VOS, research vessels	data important to interpret OCI measurements
zooplankton species (including icthyoplankton)	nets*	research vessels	CalCOFI is an example of an existing time series that should be continued
zooplankton (volume)	acoustic plankton profilers*	buoys, VOS, research vessels	further calibration needed and technical development for use on VOS
zooplankton size and number	acoustical or optical	buoys, VOS, research vessels	advanced prototypes exist; further development needed
nutrients	autoanalzer	research vessels	autonomous instruments needed for VOS or buoys
dissolved oxygen and partial pressure of carbon dioxide		VOS, research vessels	need devlopment of autonomous carbon dioxide and O_2 instruments

* Most ready and therefore highest immediate priority

2.5 Health of the Ocean: Assessment and Prediction

Definition. The extent of existing pollution in the marine environment is not quantitatively and precisely defined because of the absence of comprehensive information on the presence of contaminants and their effects. This, in turn, is due to the inefficiency and lack of uniformity in monitoring and assessment programs in many parts of the world's oceans. Because of this lack, there exist many problems that are poorly documented--many for which the impact is not recognized and certainly some that are not even recognized. This lack of knowledge has resulted in such extreme events as deaths from mercury poisoning in Japan many years ago to more recent events such as deaths caused by algal blooms and shellfish poisoning, and the extensive hypoxia realized in coastal waters such as the middle Atlantic bight and the Louisiana inner shelf. The dependence on national measurement programs alone for global monitoring is inadequate. This GOOS module aims to establish a framework for monitoring and assessment of the state of the marine environment and the detection of trends in contamination and pollution in a comprehensive manner so as to contribute to a global assessment. A primary objective is to monitor and assess contaminant loads in the marine environment with particular emphasis being given to the state and response of marine ecosystems relative to both anthropogenic impact and natural climate change as well as the quality of the water.

Data collection and analysis in such a program must be based on the use of methods, standards, and collection strategies that produce globally comparable data archived in common formats that allow ready access to users, e.g. modelers. Sampling should also be sufficiently intensive and of sufficient duration to determine the long-term mean (climatology) and anomalies or deviations from that mean. The use of sensitive early bioindicators that can be mechanistically linked to specific chemicals, together with more traditional analytical chemical approaches, is an example of new, yet relatively routine and reliable technologies, that are currently available with which these problems can be addressed. Synopticity over adequate temporal and spatial scales can often be enhanced by using moored arrays of physical, chemical, and bio-optical sensors and also satellite imagery (AVHRR and color) to define such parameters as circulation and pigment distributions. Ideally the monitoring program will include efforts to understand processes to the point that conceptual and numerical models can be developed so that these models, along with reasonable real-time data inputs, can predict the impacts of increased inputs or controls on them.

The module will aim at providing basic information on the levels of contamination and on the sources, transport, and fate and effects of contaminants in the marine environment. Preliminary emphasis will be on measurements being made in coastal regions and on the related biological effects including population changes, with the results also being useful in considerations on, inter alia, human health, seafood safety, and coastal and river/estuarine drainage basin land use and development. The regional elements will include observational networks focusing on specific problems within each region as well as elements allowing equitable comparison among regions as to the effects of more ubiquitously distributed contaminants. This will allow catastrophic events (e.g. fish kills and outbreaks of harmful algal blooms) to be evaluated within the background of climatology derived from the continuous program. These regional elements, in turn, will be linked to a less dense network of oceanic observations to provide a global oceanic perspective. Retrospective studies for variables to be monitored (e.g. by using sediment records) should be developed to allow establishment of an initial climatology and allow interpretation of present day levels of these variables in terms of anomalies in respect to it. The products will also serve the needs for effective national and international implementation of aspects of the United Nations Convention on the Law of the Sea and provisions of the Montreal Guidelines for the Protection of the Marine Environment against pollution from land-based sources as well as other agreements and conventions dealing with pollution of the marine environment.

PARAMETER	VARIABLES	SYSTEMS/TOOLS
human health	algal blooms litter (e.g. hospital waste) aquatic biotoxins microbial contaminants chemical contaminants in seafood	long–term monitoring in situ sampling/measurements instrumented buoys shipboard surveys remote sensing mussel watch ships of opportunity conceptual models autonomous vehicles
environmental quality	herbicides/pesticides PCBs petroleum (floating/dissolved) trace metals artificial radionuclides	
coastal development	suspended matter sediment load	
eutrophication	nutrients oxygen algal blooms	
biofouling	plastics and other litter	
tourism	plastics and other litter algal blooms microbial contaminants suspended matter petroleum	

2.6 Marine Meteorological and Oceanographic Operational Services

Definition. Oceanographic and marine meteorological data are extremely important in the production of operational products and support services. These functions are vital for the safe and efficient operation of ships, aircraft, and all manner of coastal and offshore operations as well as for achieving the full commercial potential for industries such as fisheries, seabed mining, oil and gas extraction, coastal engineering, and tourism. In addition, the national defense and public safety are dependent on timely and accurate data collection.

Improved warnings of severe weather and extreme weather events have the potential of saving thousands of lives per year. This module will aim at enhancing the collection and analysis of oceanographic and marine meteorological data required for this entire range of operational services.

Through this module, the requirements of various users of ocean information will be integrated for inclusion in the GOOS global and regional components. This module should also include intensive training programs on the application of GOOS data and data products for regional and national practical applications as well as assistance to developing countries for establishing national operational oceanographic services.

MARINE SERVICES--CUSTOMERS
shipping fishing offshore operators military OPS (aviation, ship engineering) search & rescue marine recreation coastal zone management federal/state/local government private sector marine service providers
MARINE SERVICE--OBSERVATIONS
temperature (air, surface, three dimensional structure) humidity (water vapor) salinity (surface, three dimensional structure) winds waves currents clouds (fog) ocean color sea ice and icebergs pressure
MARINE SERVICES--PRODUCTS
weather forecasts/warning wave height and direction tides (heights and currents) currents (fronts and eddies) sea temperature (SST and MLD) salinity air temperature humidity (water vapor) pressure sea ice and icebergs (location, extent, and drift) winds (speed and direction) ocean color hazardous spill dispersal

MARINE SERVICES--KEY CONCLUSIONS
1. In situ OBS are essential to correct remotely–sensed OBS and climatology and to initialize models.
2. Existing In Situ Observing System Platforms VOS (surf MET; SST and SSS; XBTs; XCTD; etc.) drifting buoys moored buoys shore stations offshore structures
3. Future In Situ OBS over–the–horizon radar motional induction acoustic tomography/acoustic thermometry new expendable sensors
4. Cost–Effective Enhancement Opportunities improve coverage of expendables by increasing quantities and/or improving deployment strategies increase OBS from offshore structures increase use of moored buoys in coastal zones/EEZs of world's oceans
5. Optimum mixes of observing systems and depolyment strategies for in situ measurements must be determined. To do so requires sensitivity analyses to be performed based on the forecast models used by the operational centers.
6. A focus must be maintained on ensuring adequate coverage and continuity of spaceborne remote sensors that provide near–real time observations of those parameters that are critical to marine services such as sea surface temperature, wind speed, ocean productivity, and sea ice.

MARINE SERVICES--RECOMMENDATIONS
A. Parameters for which we feel the present observing system performance falls short of its potential capability to support marine services globally and this module would benefit form their enhancements: sea temperature (three dimentional structure) winds
B. Recommended areas for methods/techniqes R&D: acoustic thermometry over–the–horizon radar motional induction new expendable sensors (fluorescence, optical, acoustical)

3. NOAA Role in GOOS

3.1 NOS and NOAA GOOS: Priorities and Next Steps

Currently, there are a number of GOOS–like activities now going on in the U.S. For example, the U.S. Navy carries out a regular program of global observations and modeling for its operational needs. These include use of expendable bathythermographs (XBTs), drifting buoys, and ship observations. The data are fed into supercomputer–based models in Monterey, CA, for operational assessments and predictions for the fleet. NOAA supports both operational and research observations including XBTs, drifting buoys, volunteer observing ships (VOS), the TOGA observing system, the satellite–based National Environmental Satellite Data and Information Service (NESDIS) program, and the observations for the Atlantic Climate Change Program (ACCP) and the FOCI program. NSF supports a number of research efforts including TOGA, the World Ocean Circulation Experiment (WOCE), and the Joint Global Ocean Flux Study (JGOFS) that all provide research observations on a global scale. Extension of TOGA is being considered to maintain the long–term TOGA Tropical Atmosphere Ocean (TAO) array. Time–series stations are maintained by JGOFS at Bermuda and Hawaii; other time series are collected by the Scripps Institution of Oceanography and in the Gulf of Alaska. Various fisheries efforts also provide long-term data.

NOAA/NOS is currently one of the key players in the "baseline" U.S. GOOS and, as the major civilian agency, is the logical group to coordinate such efforts. NOAA/NOS will concentrate on the operational aspects of U.S. GOOS and should work with the other parts of NOAA to build on the research results of the U.S. climate and global change program and various coastal and fisheries programs. It will be essential to involve the academic community in these efforts.

The near–term NOS contribution to U.S. GOOS should include five major efforts: (1) maintaining existing programs and time series, for example, VOS, drifting buoys, and global sea level measurements; (2) beginning transition to operations of aspects of some research programs, for example the TOGA observing system, including TOGA TAO; (3) initiating cooperation and coordination with other NOAA and non–NOAA federal programs; (4) planning for a FY 1995 NOAA GOOS initiative to provide new money for some U.S. GOOS activities; and (5) considering an office and staff to help coordinate the entire set of U.S. GOOS activities.

3.2 Design Studies

Design studies will be a high priority. These should build on the previous NOAA work on the design of the TOGA TAO array to provide optimized wind fields and the examination of the relative merits of ship and drifting buoy contributions to the accuracy of satellite–based SST measurements. Efforts needed include joint NOAA/academic studies on blended observing systems for upper–ocean temperature profiles and heat content, and on combined in situ/satellite wind fields.

The module discussion identified many of the measurements needed in the research and operational modes. The initial phases of GOOS should test many of these research techniques to see which are best for operations. For example climate, satellite winds, sea surface salinity, precipitation, average temperature by acoustics, and carbon cycle measurements are research; SST, upper ocean and air temperature, and ice measurements are operational. For coastal observations, moored instrumentation to measure bio–optics and fluorometry are research while near–surface currents and zooplankton biomass are collected operationally (in limited areas). For living resources, satellite ocean color and fluorometry are research; plankton biomass are collected operationally (in limited areas). For health of the ocean, automated observations are now being developed for the research community; nutrients, oxygen and the Mussel Watch are operational programs. For marine and ocean operational services, currents and waves are more on the research side than are upper ocean temperature and winds, which are collected operationally.

3.3 Enhancements of Existing Programs

Based on the discussion of the modules, the initial NOAA studies should include the following:

1. Enhance SST and upper–ocean temperature network and accuracy. This work will target the Climate and Marine Services Modules.
2. Enhance National Data Buoy Center (NDBC) (or other moored–buoy) sensors. This work could have major impact on the Coastal and Living Marine Resources Modules.
3. Calibrate and validate ocean color data from the upcoming SeaWiFS satellite mission. This work will target the Living Marine Resources and Health of the Ocean Modules.
4. Calibrate and validate satellite winds from ERS–1, DMSP, and TOPEX/POSEIDON. This work will target the Marine Services, Coastal, and Climate Modules.
5. Continue existing ocean time series. There are relatively few of these, and all are valuable. This will target the living resources, climate, and coastal modules.
6. Support technology development, for example for sensors and automation aboard volunteer observing ships. This will target all modules.
7. Enhance high–speed data transmission network (including ocean–data telemetry) and infrastructure for data handling. This will target all modules.

4. U.S. GOOS: Priorities and Next Steps

4.1. GOOS Observational Demonstrations Involving Several Agencies

It has been clear in all the discussions about GOOS that it will not be possible to put in place a global ocean observing system without the use of new technology. Enhancement of existing measurements will not do the job. Therefore, there needs to be two parallel tracks: one that enhances existing measurements as noted in Chapter 3 of this report, and one that begins development and use of new technology. This period of two parallel tracks would be the pilot phase of GOOS as proposed by the international planning document. The end of the pilot phase would come when we see convergence of these tracks. The pilot phase would be from five to ten years.

The workshop only briefly discussed the technology track, or GOOS pilot experiments involving new technology. One proposal involved the use of acoustic thermometry together with satellite measurements and various mid–depth and surface drifting buoys in the North Pacific Ocean. Another suggestion was to build on the ACCP of NOAA in the North Atlantic Ocean. In each case, the suggestion was that there be a three to five year period of intensive measurements and special products and data systems used. These would be GOOS pilot experiments. The goal of the pilot experiments is to demonstrate an operational concept, not a process study.

In the pilot phase, such techniques as use of the global network of seismic stations for collecting data, or the Navy acoustic listening stations might be used. This pilot phase would be the time for testing such ideas.

It was agreed at the workshop that the pilot phase should include tests of new technology. Since the plans for such tests and pilot experiments had not been discussed in detail, it was agreed that a later workshop should be called to plan such a pilot phase.

4.2. Building a U.S. Infrastructure for GOOS

The workshop agreed that an interagency committee was required in order to both promote GOOS and to ensure that each agency with an interest was stimulated to develop a coordinated budget proposal.

The terms of reference for the "Interagency Committee for GOOS" were proposed as the following:

- Develop agency plans
- Coordinate plans
- Coordinate agency budget requests regarding GOOS to OMB
- Liaise with FCCSET/CEES/global change and coastal subcommittees
- Provide international contact with IOC and other international planning bodies for GOOS

In terms of membership, the workshop recommended that NOAA/NOS should chair the committee, and that Navy/Office of the Oceanographer, as the other major operational ocean agency, should co–chair. Other agencies with major interest in GOOS should also be represented (NSF, NASA, DOE, USGS, EPA, DARPA, and the Department of State).

In terms of reporting lines, the question was whether the committee should be ad hoc or report in an existing structure. The workshop believed that there were clear links of GOOS to both the U.S. Global Change Research Program (U.S.GCRP) and to the U.S. Coastal Ocean Science program. Links were also seen to pollution and waste disposal programs, as well as to GCOS and weather services. It was agreed that fitting into an existing structure would be best. It was also agreed that the chair or chair–designate of the Interagency Committee would be the logical U.S. representative to international GOOS committees.

There was also discussion about a group of experts that would advise the interagency committee on U.S. GOOS planning. Such a group would include experts from government, industry, and academia. The committee would advise on interagency coordination issues and would be available to address issues in depth as identified by the interagency group. It was agreed that since there were existing committees on a number of specific topics, such as ENSO prediction operational needs, it might be better to wait until the interagency committee decided what it needs in terms of advice. Thus the group agreed that it was premature to set up such a group now and that the interagency committee could decide what was needed once it met and determined its agenda.

S. Wilson agreed to discuss with R. Corell, chairman of the U.S.GCRP Subcommittee, and S. Tilford, Chair of the Panel on Observations and Data of the Subcommittee, about the establishment of such a GOOS committee and where the GOOS committee would best fit in the Federal Coordinating Council for Science, Engineering and Technology (FCCSET) structure.

4.3. U.S. Role in the International Framework for GOOS

It is clear that the U.S. will play an important role in the international GOOS, and that the U.S. should get its own act together before trying to influence other partners in this endeavor. At the moment, the U.S. planning is in the very early stages. Nonetheless, the U.S. can make useful input into the developing advisory structure. The most useful input is advice on what the structure should be.

The primary discussion now is about the proposed international science and technology committee for GOOS, called the Joint GOOS Committee, or J–GOOS. The U.S. should ensure that the terms of reference and membership of that committee are adequately representative of U.S. interests. Reporting to that Committee will be the OOSDP, which focuses on climate issues. Other panels will be needed to address the various modules as they are defined. For example, Neil Andersen has proposed a terms of reference for a body to address the health of the ocean. The draft terms are provided in Appendix H. The U.S. should support the establishment of such a panel.

The U.S. also needs to examine the plans for development and management of GOOS. IOC will play a key role, but other international organizations may also be involved. The U.S. should be involved in all of these discussions.

Appendix A

Attendees

U.S. Global Ocean Observing System Workshop

Mary Altalo	Scripps Institution of Oceanography
Neil Andersen	National Science Foundation
D. James Baker	Joint Oceanographic Institutions Inc.
Bob Beardsley	Woods Hole Oceanographic Institution
David A. Benner	National Ocean Service (NOAA)
Hugo Bezdek	Atlantic Oceanographic and Meteorological Laboratory (NOAA)
Ken Brink	Woods Hole Oceanographic Institution
Mel Briscoe	National Ocean Service (NOAA)
Russ Davis	Scripps Institution of Oceanography
Craig Dorman	Woods Hole Oceanographic Institution
Adam Dziewonski	Harvard University
Dave Evans	Office of Naval Research
Kirk Evans	Department of the Navy
Nic Flemming	Institute of Oceanographic Sciences, United Kingdom
Richard Gasparovic	Applied Physics Laboratory, Johns Hopkins University
Linda Glover	Office of the Oceanographer of the Navy
Ray Godin	Intergovernmental Oceanographic Commission
Dave Goodrich	Office of Global Programs (NOAA)
Gordon Hamilton	Office of Naval Research
Richard Hayes	Office of the Oceanographer of the Navy
Van Holliday	Tracor Inc.
Chet Koblinsky	National Aeronautics and Space Administration
Richard Legeckis	National Environmental Satellite Data and Information Center (NOAA)
Eric Lindstrom	World Ocean Circulation Experiment (U.S. Office)
John McGowan	Scripps Institution of Oceanography
Ron McPherson	National Weather Service (NOAA)
Bob Molinari	Atlantic Oceanographic and Meteorological Laboratory (NOAA)
Brad Mooney	Consultant
Ken Mooney	Office of Global Programs (NOAA)
Dick Moritz	Applied Physics Laboratory, University of Washington
David Mountain	National Marine Fisheries Service (NOAA)
Walter Munk	Scripps Institution of Oceanography
Tom Nelson	Joint Oceanographic Institutions Inc.
Peter Niiler	Scripps Institution of Oceanography
Don Olson	Rosenstiel School of Marine and Atmospheric Sciences, University of Miami
Mike Patterson	Office of Global Programs (NOAA)
Tom Pyle	Joint Oceanographic Institutions Inc.
Mike Reeve	National Science Foundation
Dick Reynolds	National Weather Service (NOAA)
Tom Sanford	Applied Physics Laboratory, University of Washington

Wolfgang Scherer	National Ocean Service (NOAA)
Ray Schmitt	Woods Hole Oceanographic Institution
Mike Sissenwine	National Marine Fisheries Service (NOAA)
Paul Smith	National Marine Fisheries Service (NOAA)
John Stegeman	Woods Hole Oceanographic Institution
Otto Steffin	Pacific Marine Environmental Laboratory (NOAA)
Ron Tipper	Joint Oceanographic Institutions Inc.
Bob Weller	Woods Hole Oceanographic Institutions
Peter Wiebe	Woods Hole Oceanographic Institutions
Stan Wilson	National Ocean Service (NOAA)
Bill Woodward	National Ocean Service (NOAA)
Carl Wunsch	Massachusetts Institute of Technology
Ernest Young	Science Applications International Corporation

Appendix B

Agenda

U.S. Global Ocean Observing System Workshop

WEDNESDAY, 14 OCTOBER

Plenary Session # 1: Setting the Context for U.S. GOOS
Jim Baker, Chair

9:00 a.m.	Welcome to WHOI (Dorman)
9:05 a.m	*The Purpose of U.S. GOOS and this Meeting* (Wilson)
9:30 a.m.	*International Developments: International Planning* (Baker) and *The Ocean Observing System Development Panel* (Weller)
10:45 a.m.	*Setting Priorities and Definition of GOOS* (Briscoe/Wilson)

Plenary Session #2: Reviewing the Potential Elements of U.S. GOOS
Mel Briscoe, Chair

1:30 p.m.	*Climate Monitoring, Assessment, and Prediction* (Baker/Reynolds)
2:00 p.m.	*The Coastal Environment: Monitoring, Assessment, and Prediction* (Bezdek/Brink)
2:30 p.m.	*Monitoring and Assessment of Marine Living Resources* (Mountain/Sissenwine/Smith)
3:30 p.m.	*Environmental Quality: Assessment and Prediction of the Health of the Ocean* (Andersen)
4:00 p.m.	*Marine Meteorological and Oceanographic Operational Services* (Hayes/Woodward)
4:30 p.m.	Open discussion about GOOS Modules
5:00 p.m.	Charges to the working group

THURSDAY, 15 OCTOBER

8:30 a.m. to 3:00 p.m.

Working Groups on Developing a Strategy for U.S. GOOS

1. *Climate*
2. *Coastal*
3. *Living Resources and Environmental Quality*
4. *Marine Services*
5. *Agency Coordination and Institutional Arrangements for U.S. GOOS*

3:15 p.m. Plenary Discussion

FRIDAY, 16 OCTOBER

Plenary Session #3: Agreement on a Plan for U.S. GOOS
Jim Baker and Mel Briscoe, Co–Chairs

8:30 a.m.	*Climate*
9:00 a.m.	*Coastal*
9:30 a.m.	*Living Resources and Environmental Quality*
10:15 a.m.	*Marine Services*
10:45 a.m.	*Institutional Arrangements* (Baker)
11:00 a.m.	Open discussion (M. Briscoe, Moderator)
12:00 noon	Workshop ends
1:30 p.m.	Working group chairs meet with Briscoe and Baker for post–workshop planning, steering committee appointments, and outline of report
2:30 p.m.	All workshop events completed

Appendix C

Definition and Priority Questionnaire

Questionnaire

In each of the areas or modules as defined below, we would like your input on the definition of the module itself and your suggestions for priorities on what needs to be observed; how can we observe it; and how do we benefit, that is, what is the match with a societal benefit?

1. Climate Monitoring, Assessment, and Prediction

(Draft description for discussion at workshop)

Improving our ability to predict the climate system requires a better understanding of the behavior of the ocean. The climate module will be designed to provide the data required to describe the mean state and variability of the oceans. It will also provide the input (initial and boundary conditions) and validation data required for coupled ocean–atmosphere predictive models of climate variability and change. Finally, the module will provide a data base that future generations will be able to employ to distinguish very large–scale secularities from regional non–secular fluctuations.

One of the first priorities is clearly to provide the data necessary for operational ENSO prediction. On the longer scale, it is hoped that the global perspective obtained through global data sets and model outputs will permit early detection of longer–scale change and predictions on longer scales. This module will be planned and implemented in cooperation with WMO and ICSU through the Global Climate Observing System and will use input from large programs like TOGA, WOCE, JGOFS and others. This module does not include those measurements that are now carried out in support of operational weather forecasting--those are included in the Marine Services Module listed below.

CLIMATE MONITORING, ASSESSMENTS, AND PREDICTION		
Parameter	**Tool (s)**	**Societal Benefit**
1. Examples sea surface temperature	AVHRR/satellites plus in situ calibrations	essential input to climate models
2.		
3.		

2. Coastal Processes (based on input from Clint Winant)
(Draft description for discussion at workshop)

The GOOS Coastal Processes module covers monitoring and assessment of changes in coastal and near–shore areas. This will require an interdisciplinary approach that integrates physical, chemical, biological and geological observations. The scientific results are particularly important because of the intimate effects of coastal changes on economic development and human habitation.

Three different geographic areas are being discussed for the coastal module of U.S. GOOS. The first is a focus on processes near Georges Bank, where one of the most productive fisheries in the U.S. occurs; it is also the site of intense traffic. Competing demands need to be resolved. A large amount of data is available, and numerical models have been developed. A second area is the western seaboard of the continental U.S. This is an upwelling area in spring and summer; another important commercial fishery with intense ship traffic and oil spills. An array of NDBC moorings provides a good opportunity for long–term data, but continuation is threatened. A third area of study is the exchange of Atlantic and Mediterranean waters at the Strait of Gibralter; implications are central to processes in both seas. Numerical models have successfully hindcast the circulation.

The three examples represent very different coastal settings where sufficient research has been carried out that operational or decision–making agencies would benefit from the development and implementation of an operational effort. Other areas of the world would also satisfy these criteria. This module will interact with the climate module because ocean basin scale products of physical, chemical and biological parameters which will provide boundary conditions for coastal models. It will also interact with the Marine Living Resources Module and the Health of the Ocean Module.

COASTAL PROCESSES		
Parameter	**Tool (s)**	**Societal Benefit**
1. Examples surface wave fields	satellites and buoys	imapct on shipping, beach erosion, structures, and recreation
2.		
3.		

3. Monitoring and Assessment of Living Marine Resources
(Draft description for discussion at workshop)

Despite interdisciplinary research over the past several decades, we will have insufficient knowledge of the effects of ocean behavior on living marine resources. The ability to ensure sustainable harvesting of fisheries stocks depends on adequate knowledge and predictive capabilities. The marine living resources of the world depend on the ocean environment. Changes to that environment will inevitably change the composition and behavior of the living resources therein.

This module will include the development of a system to monitor physical, biological and chemical variables needed to describe the structure and functioning of marine ecosystems as well as the changes in the marine ecosystems over various space and time scales.

The module will include pelagic and benthic sampling as well as a focus on processes such as upwelling and circulation that affect production. This module will interact with the climate module and the coastal module, since, for example, global and coastal ocean parameters are related to the migration variability and sustainability of commercial stocks. For example, predictions from the ENSO in the Pacific Ocean have shown the value of these data for the management of regional and ocean scale stocks.

MONITORING AND ASSESSMENT OF LIVING MARINE RESOURCES

Parameter	Tool (s)	Societal Benefit
1. Examples A. standing stocks of fish B. high productivity regions	A. acoustical monitoring B. satellite ocean color C. in situ plankton measurements	A. direct information on resources B. prediction of fish stocks
2.		
3.		

4. Assessment and Prediction of the Health of the Ocean

(Draft description for discussion at workshop)

The extent of existing pollution problems is not well–known globally because of the lack of efficient, comprehensive monitoring and assessment programs in most parts of the world. The lack of knowledge can result in extreme events such as the recent outbreak of cholera in Peru. Dependence on national programs alone is inadequate. This module aims to establish a framework for monitoring and assessment of the state and trends in level of pollution on global as well as on regional scales. One objective is to monitor and assess the state of marine ecosystems in relation to anthropogenic impact and climate change. The data collection and analysis is to be based on the use of commonly agreed methods, standards and methodologies.

The module will aim at providing basic information on the level of contamination, transport and fate of pollutants in the ocean with primary emphasis on nearshore regions and the related biological effects. It will include regional components with specific observational networks, geared to problems of each region. The products will also serve the needs for effective national and international implementation of aspects of the United Nations Convention on the Law of the Sea and provisions of the Montreal Guidelines for the Protection of the Marine Environment against pollution from Land–Based Sources as well as other agreements and conventions dealing with pollution of the marine environment.

MONITORING AND ASSESSMENT OF THE HEALTH OF THE OCEAN		
Parameter	**Tool (s)**	**Societal Benefit**
1. Examples A. red tides/toxic blooms B. map PCBs	A. satellite ocean color B. in situ techniques C. chemical detection	A. predict location of toxic areas B. direct use of policy makers
2.		
3.		

5. Marine Meteorological and Oceanographic Operational Services

(Draft description for discussion at workshop)

Marine meteorological and surface oceanographic data from most ocean areas are extremely important for basic short to medium–range weather predictions along with effective response procedures. Improved warnings of severe weather and extreme weather events could save thousands of lives per year. This module will aim at enhancing the collection and analysis of oceanographic and marine meteorological data required for a variety of operational services. The products will give information and predictions to ship's officers, planning and safety authorities, and other organizations concerned with marine operations ranging from tourism to seabed mining and coastal engineering.

Through this module the requirements of various users of ocean information will be integrated for inclusion in the GOOS global and regional components. This module should also include intensive training programs on the application of GOOS data and data products for regional and national practical applications as well as assistance to developing countries for establishing national operational oceanographic services.

MARINE AND METEOROLOGICAL AND OCEANOGRAPHIC OPERATIONAL SERVICES		
Parameter	**Tool (s)**	**Societal Benefit**
1. Examples A. near surface winds B. surface waves (global)	A. VOS packages B. satellites C. in situ measurements	A. weather forecasting B. ship routing
2.		
3.		

Appendix D

GOOS: The Operational Consequence of Quality Research

Melbourne G. Briscoe, NOAA/NOS/OES

21 June 1992; revised 30 September 1992

1. TOGA–related and other large–scale and regional ocean measurements are being considered as part of the U.S. contribution to GOOS. There are two major questions: what measurements will be part of GOOS, and who will pay for them? We note that some funding called "GOOS" may exist in the future; this funding will surely pay for some of the GOOS measurements. We expect, however, that many other measurements should be part of the matrix of measurements but will be supported and managed quite separate from GOOS; a mechanism for coordination with these other measurements should, however, be part of GOOS, even if the responsibility for them is not.

2. Within NOAA, the National Ocean Service is leading the development of the NOAA contribution to GOOS. The reason NOS has the NOAA lead for GOOS is because GOOS is described as an "operational"––not research––program. What does this mean? We offer the following strawman, predicated on the supposition that the purpose of operational measurements is to support analysis (in the meteorological sens...a "nowcast") and prediction efforts, whereas the purpose of research measurements is to support efforts at understanding. We are certain that improved understanding will help the operations. We are also certain that operational measurements of research quality will be used by the research community, and we are certain that efforts at prediction will aid the research programs by pointing at the weak links in the understanding. Hence, we see the research programs and the operational efforts as being closely aligned, and quite interdependent. In this spirit, GOOS Operational Measurements means (not in any special order):

   A. routine (well defined, no new technology needed, replicatable)
   B. long–term (not just an experiment that starts and ends)
   C. recurring and uniterrupted (regularly scheduled, not sporadic)
   D. affordable, cost–effective
   E. global, or global implications

   The final criterion depends upon the purpose of GOOS; for support of a climate module in GOOS, we suggest:

F. demostrable impact on forecasts of climate–related quantities or an important indicator or diagnostic of climate change

These are the suggested "admission requirements" for a meausrements program to become part of an operational GOOS.

3. The source and magnitude of funding are critical. Under the NOAA Climate and Global Change (C&GC) program, the core of the efforts is meant to be research. Under potential GOOS funding, the core of the efforts is meant to be operational. There is no intent to have a complete separation of the two kinds of efforts, but rather to have them closely reated to each otehr, so that the needs of the ooperational ventures can influence what is being researched and the research findings can most efficiently find application in the GOOS measurements. To do otherwise would be counterproductive.

4. Currently, the FY93 budget has not yet been signed, the FY94 budget submission process has been completed and the FY95 budget process is underway. There is no GOOS money in the NOAA FY93 or FY94 budgets. For FY95, NOS will work in coordination with other NOAA components in the development of the budget submission; the focus will likely be the blending of satellite and in situ data, using assimilative models, to provide global fields of the essential variables needed for GOOS, tentatively SST, sea level, surface winds and waves, and ocean color.

5. There are many large–scale ocean research programs underway, for example WOCE, TOGA, JGOFS, and GLOBEC; when is it time to "go operational" based on their results? TOGA is near this stage: TOGA is implementing its TAO array to sample carefully the tropical Pacific wind and upper–ocean temperature fields, and has determined that its research clearly needs the full TAO array. But the case has not been made that the TAO array is what is needed opeationally. Yes, it is undoubtedly needed for the next phase of the research, but it is quite speculative that it is the desirable operational system for GOOS. For example, are all the buoys needed once a scatterometer is flying? Or just some of tehm for calibration and removal of wind–vector ambiguities? Are the current prediction models for ENSO even sensitive to all the wind details? Do drifing buoys remove the need for some of the moored buoy temperatures? The principle at issue here is whether one should edge up to a permanent, operational system, building slowly as it were, or go into the over–sampling mode and then back off as the details are understood. One must balance details against costs, aliasing against robustness, accuracy against expediency.

6. We suggest that TOGA may be officially over at the end of 1994, but clearly much of the research work of TOGA must continue. GOOS, however, is not just more research; GOOS needs other––operaitonal––justifications if it is to make it through the budget process. If GOOS simply becomes another research program, it will not fulfil its requirements to produce operational outputs for use by its customers, who are more than just the reserach community. GOOS is being defined on an interantional scale as an operational program; NOS supports this.

7. It is essential that GOOS be perceived as the operational consequence of quality research, not as simply a new way to fund more research. It is assumed that the data sets from GOOS will be an important part of the data needed for continued research into climate variability and change, and perhaps for other topics too. But GOOS cannot be the entire data set needed for continued research; the research community will need to find other funding for the augmentation fo the GOOS measurements for reserach purposes.

8. We think the key to making the case for a climate module of GOOS and in major GOOS support for TOGA TAO may lie in showing the economic benefits of operational 100–1000 day forecasts, and in showing through trade–off studies that the TOGA follow–on observations are a cost–efficient way to obtain the forecasts. Or, the resolution may lie in demonstrating those observations are essential as indicators or diagnostics of climate change. This brings us full–circle to the criteria for GOOS measurements, in the paragraphs above. The climate aspects of GOOS are beginning to be grappled with and the discussions about the future are underway; other possible modules for GOOS--coastal, pollution, ecosystems, and marine services--are still just topics for consideration. But in all cases, the societal benefits of the measurements and predicitons are fundamental.

Appendix E

Status Report on the NOAA Contribution to U.S. and International GOOS

Briefing material prepared by Melbourne G. Briscoe, 11 December 1992

OBJECTIVES OF U.S. GOOS

1. To Support and to Coordinate U.S. activities related to the International GOOS;

2. To provide or to assist in providing those long-term global ocean observations and predictions needed for monitoring and forecasting of conditions and change in the climate system and in the coastal zone environment, including marine ecosystems, environmental quality, and marine weather and services; and

3. To assist in providing those long-term global ocean observations needed for research activities concerned with understanding of the topics above.

proposed for discussion; not yet ratified

SOME POSSIBLE NESDIS ACTIVITIES IN U.S. GOOS

1. Cooperative work on blending *in situ* and satellite data to produce fields of:

Sea Surface Temperature	-	*well in hand*
Sea Level	-	*in progress*
Ocean Color	-	*just beginning*
Ocean Surface Winds	-	*must begin soon*

2. SAR images of Sea Ice

3. Ocean Data Telemetry....*beyond ARGOS?*

4. Cooperative work on data handling/management; real-time, retrospective, Level 3, naïve users

5. Definition of various "Follow-On" sensors/satellites

CLIMATE-CHANGE MODULE OF NOAA

possible contributions of NOAA offices......

OAR/AOML & PMEL Experimental design and observational techniques

C & GC Understanding and observations from TOGA

NESDIS NOAA/AVHRR - SST
NASA-CNES/TOPEX-POSEIDON
- surface topography
NASA-OSC/SeaWIFs - chlorophyll
NASA/ASF - SAR images of sea ice
NASA-NSCAT/ADEOS - surface winds

NWS/NMC wind data assimilation and Climate Analysis Center work

NMFS chlorophyll and zooplankton

NOS in-situ obs to complement above

ESDIM data systems for above

NOAA, NOS, AND U.S. GOOS

NOAA is currently involved in "baseline" U.S. GOOS...i.e., the set of things we are already doing.

NOAA is trying to define and start its piece of U.S. GOOS; this requires new money in an initiative for FY 1995.

NOAA/NOS will concentrate on the operational aspects of U.S. GOOS...and will work with the other parts of NOAA to build on the research results of the U.S. Climate and Global Change program.

NOAA/NOS wishes to involve the academic community as partners in the operational work, and for advice/review.

GLOBAL OCEAN OBSERVING SYSTEM – U.S. –

INITIAL NOAA THRUSTS

1. Enhance SST and Upper-Ocean Temperature Network and Accuracy
   - *targets Climate, Marine Services*

2. Enhance Moored Buoy Sensors (esp. bio sensors) and Network
   - *targets Coastal, Living Resources*

3. Calibrate/Validate Satellite Ocean Color
   - *targets Living Resources, Health of Ocean*

4. Calibrate/Validate Satellite Winds
   - *targets Marine Services, Coastal, Climate*

5. Continue Existing Ocean Time Series
   - *targets Living Resources, Climate, Coastal*

6. Technology Development, e.g. Volunteer Ship Sensors
   - *targets all modules*

NEEDS FOR NEW RESEARCH/OPS

GOOS MODULE	MOSTLY RESEARCH →	MOSTLY OPS
Climate Change	Sat winds, SSS, precip, avg T, carbon cycle	SST, up-oc temp, Arctic air temp
Marine WX, Services	currents, waves	up-oc T, winds
Coastal Zone	bio-optics, fluorometry	near-surface currents, zooplankton biomass
Health of the Ocean	automated obs	nutrients, oxygen, Mussel Watch
Living Resources	Sat oc color, fluorometry	plankton

not complete, not prioritized

GLOBAL OCEAN OBSERVING SYSTEM
— U.S. —

NOAA LINE/PROGRAM OFFICE MAIN THRUSTS IN NOAA-GOOS

	NWS	OAR	NMFS	NOS	NESDIS	C&GC	COP
Climate Change	○	●		○	○	○	
Marine WX & Services	●	○			○		
Living Marine Resources		○	●				○
Health of the Ocean			○	●			○
Coastal Zone Management			○	●	○		○

● Lead Activity ○ Cooperating Activity

DESIGN STUDIES

PREVIOUS EFFORTS

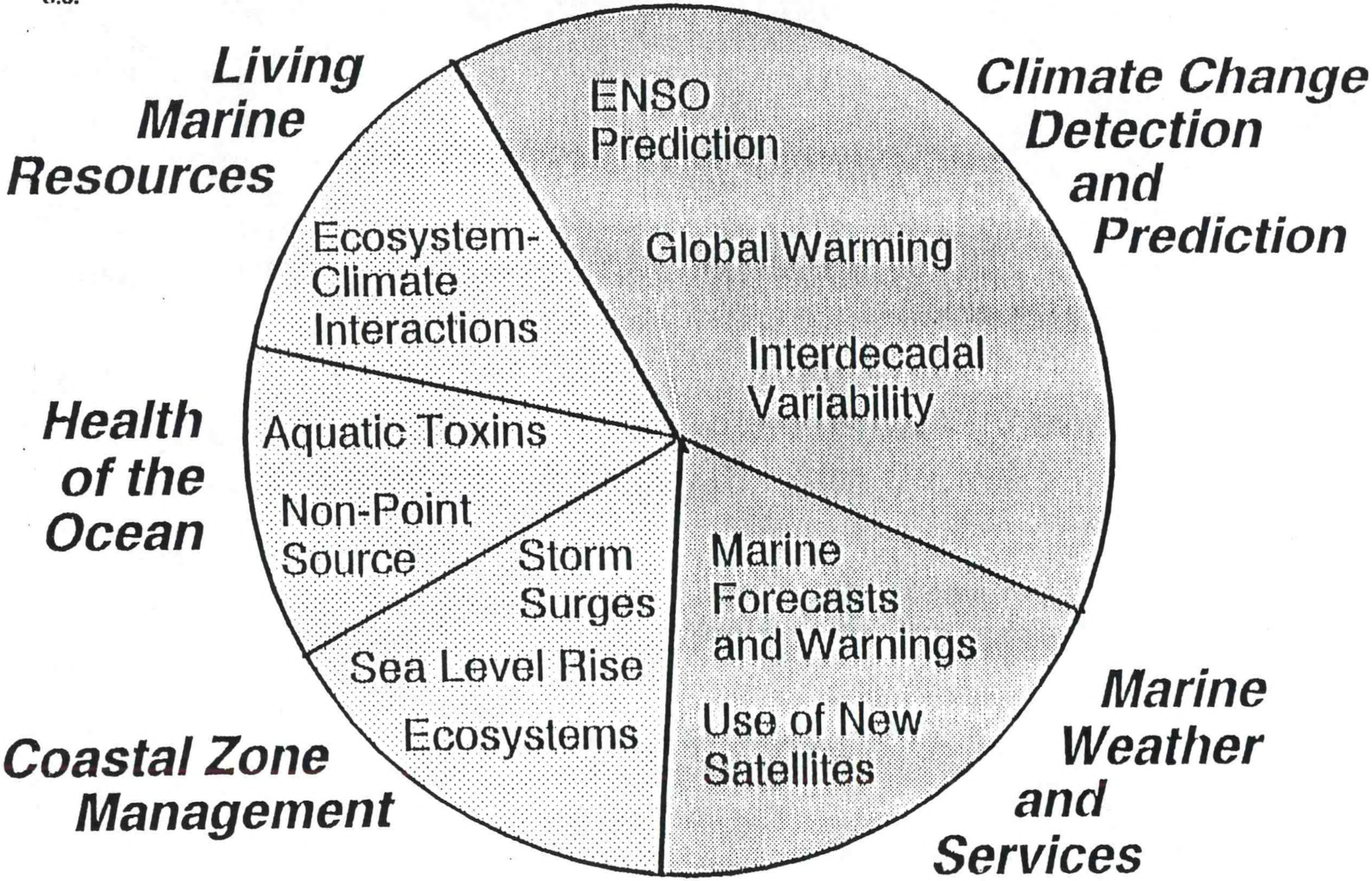
- Harrison, et al (NOAA/OAR/PMEL)
  Design of the TOGA Tropical Atmosphere Ocean (TAO) Array to provide optimized wind fields

- Reynolds and Leetma (NOAA/NWS/CAC)
  Examination of relative merits of ship and drifting-buoy contributions to the accuracy of satellite-based SST

EFFORTS NEEDED

- *Joint NOAA/academic studies on blended observing systems for upper-ocean temperature profiles and heat content, and on combined in situ/satellite wind-fields*

NOAA FOCI IN U.S. GOOS



WHAT MEANS "OPERATIONAL"?

see also: OOSDP Report, July 1992

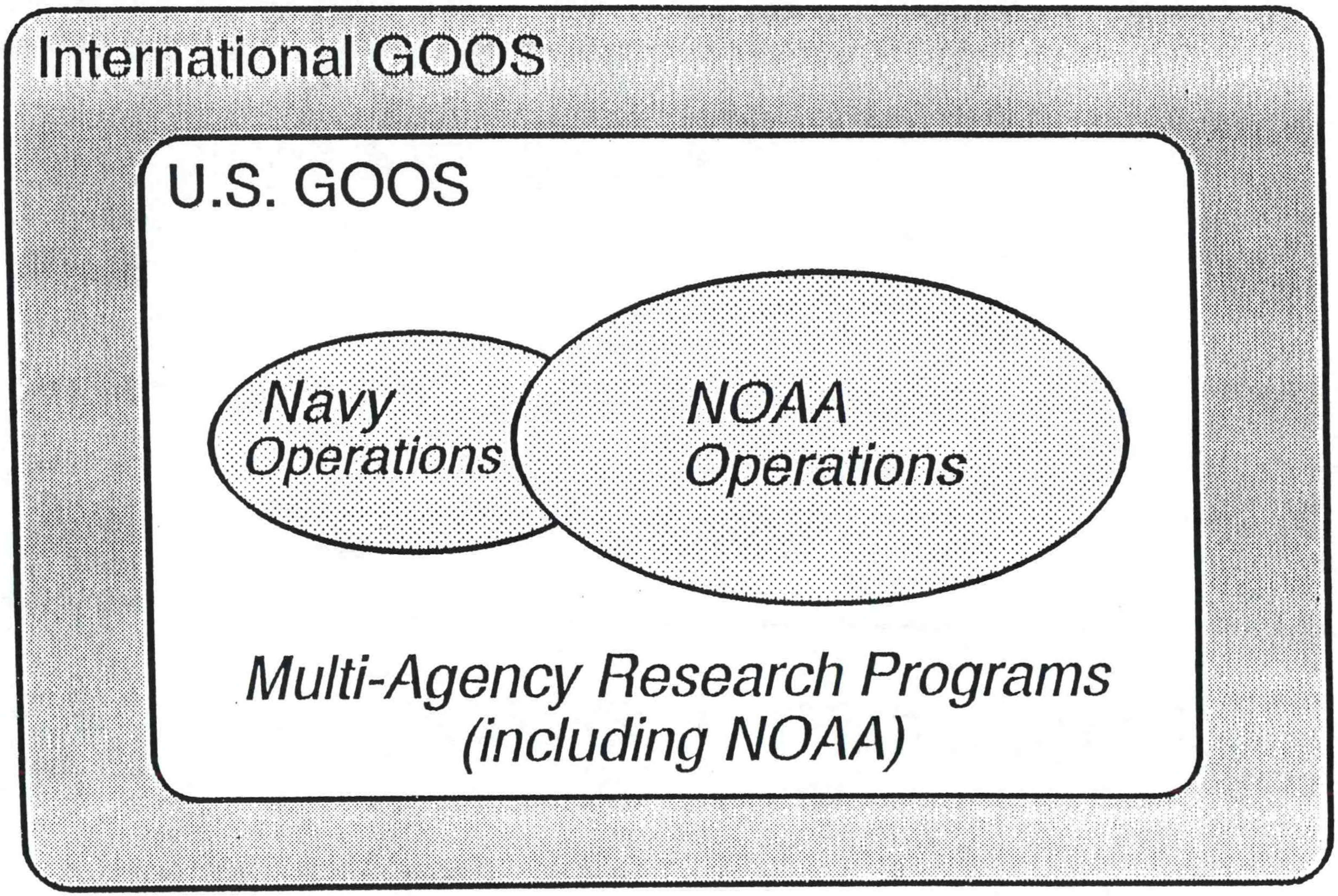
Long-Term
Routine
Systematic
Cost-Effective
Global, or having global implications

And for climate: Demonstrable impact on climate forecasts or an important indicator or diagnostic of climate change;

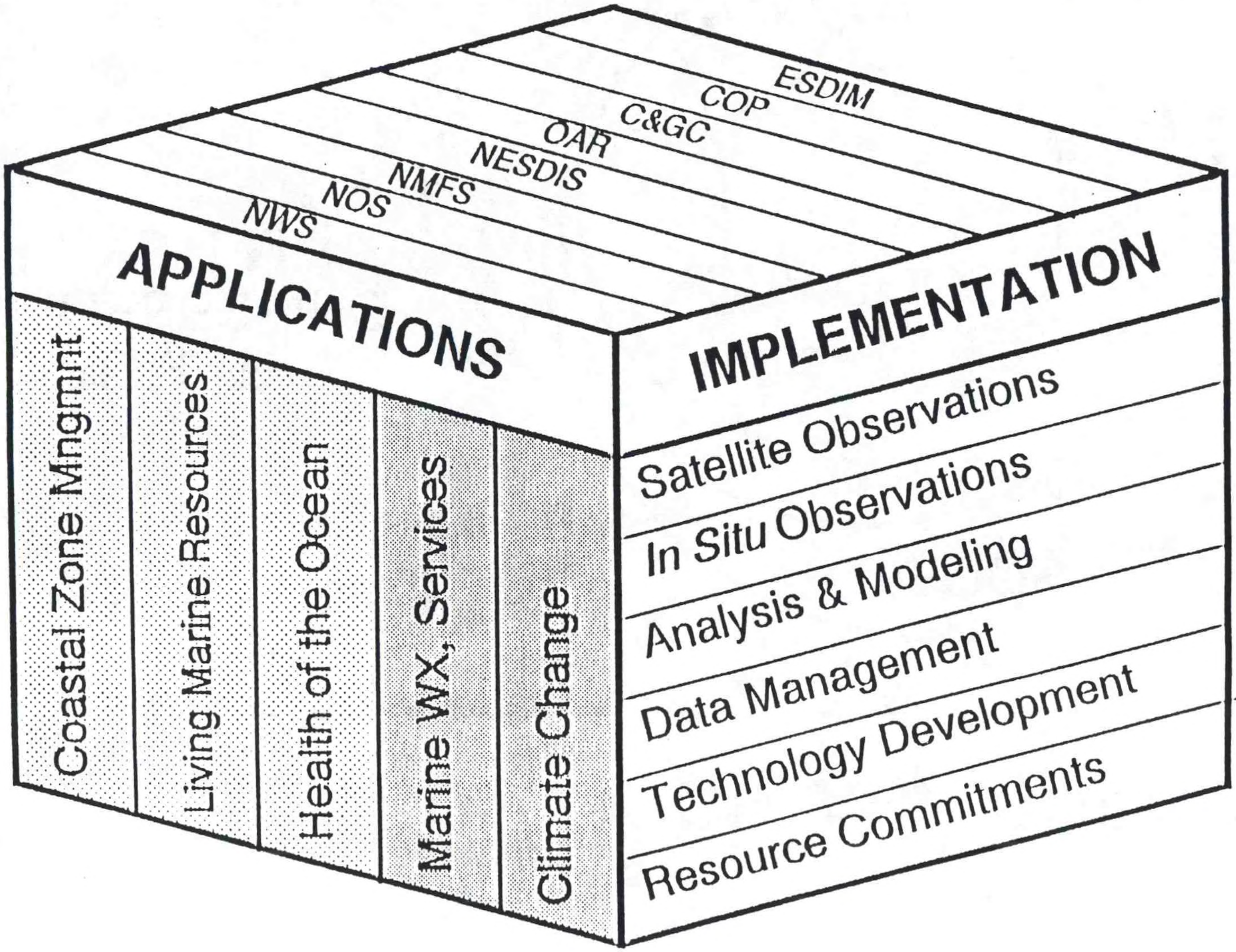
or

Equivalent criterion for the GOOS modules other than climate.

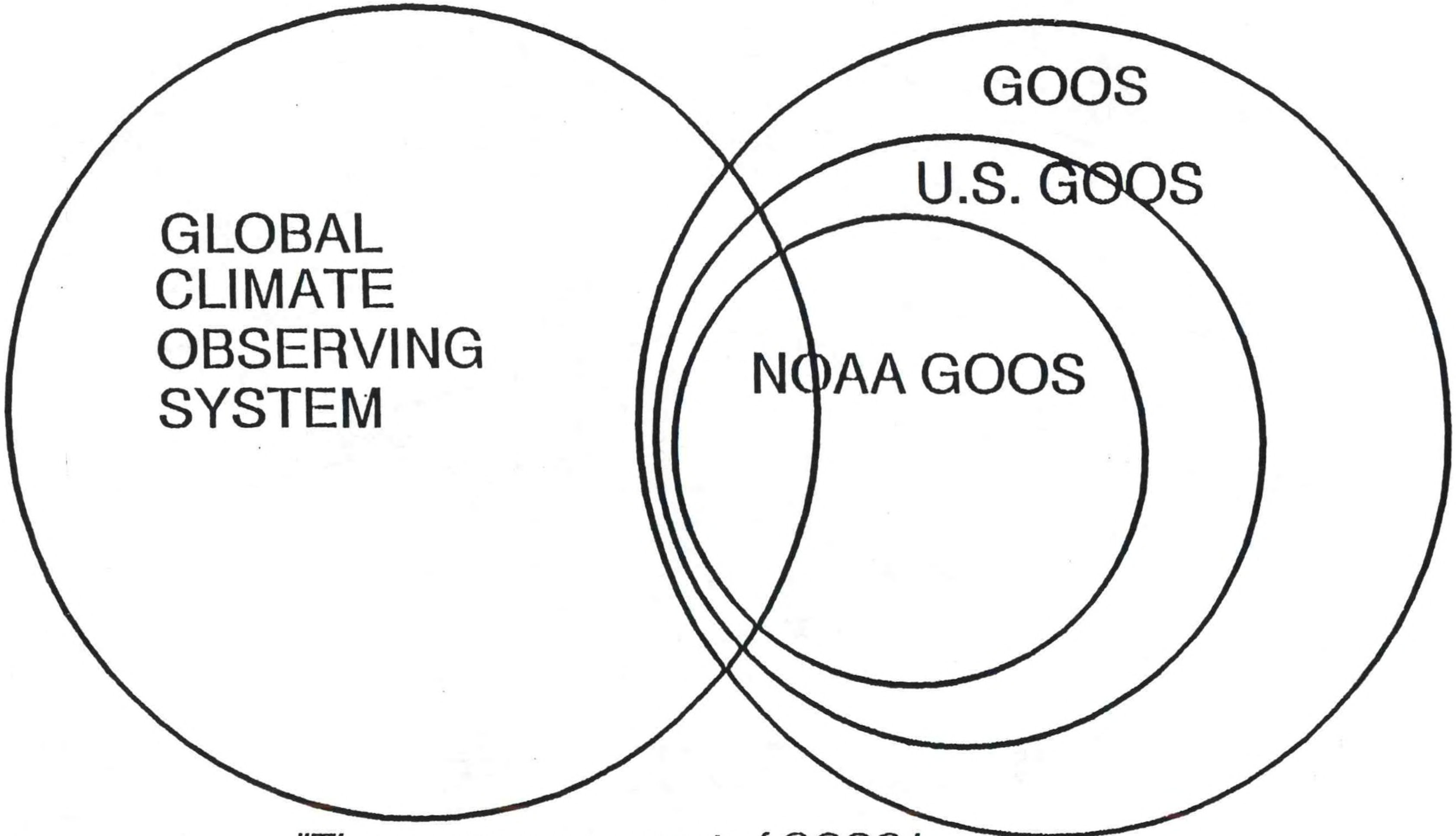
GOOS: RESEARCH and OPERATIONS



NOAA GOOS MODULES

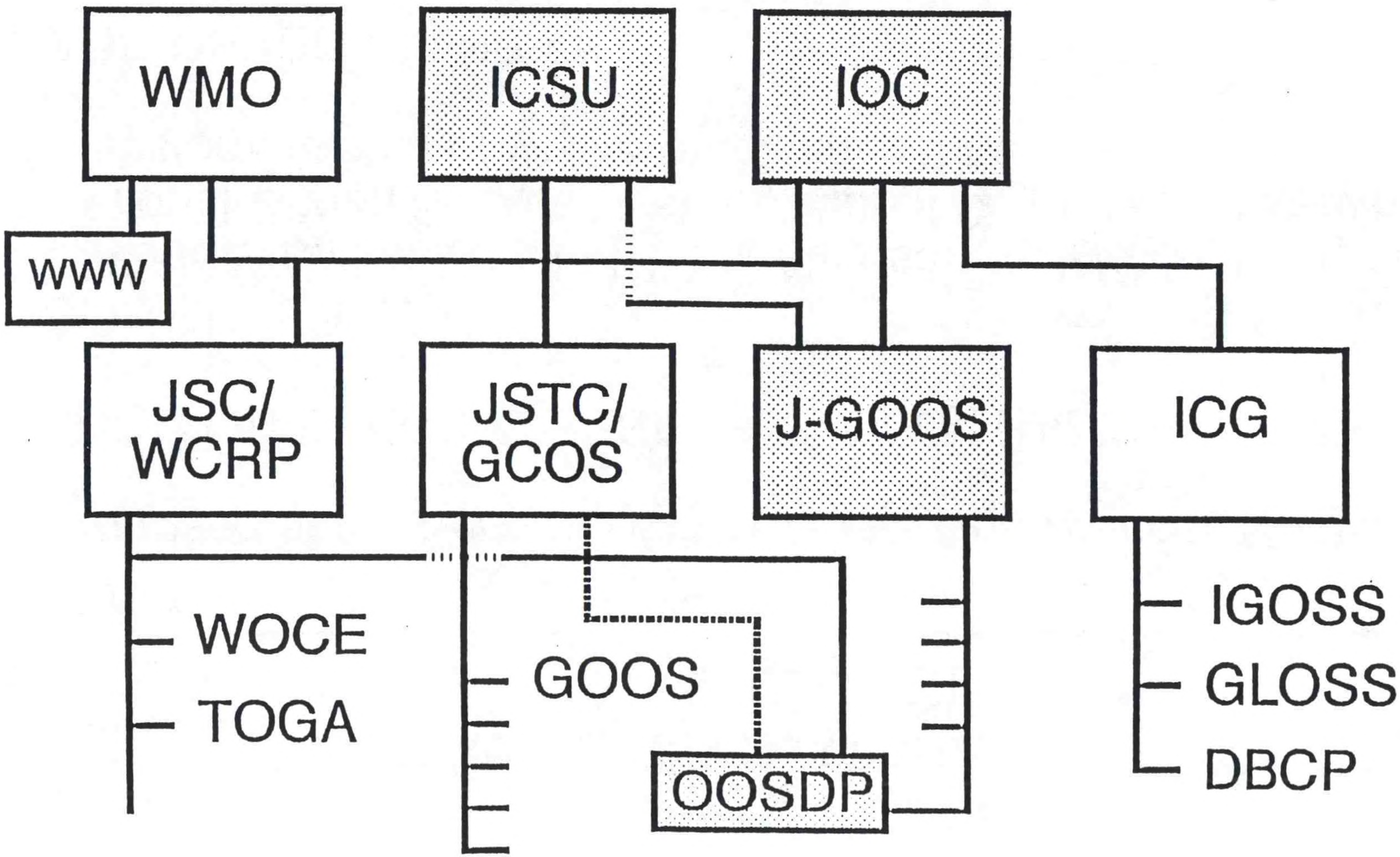


GCOS, GOOS, AND NOAA



"The ocean component of GCOS is the climate component of GOOS..."

GENEALOGY OF GOOS



GLOBAL CLIMATE OBSERVING SYSTEM (GCOS)

Proposed at the Second World Climate Conference, 1990....

BUILD ON EXISTING RESEARCH PROGRAMS -

CONTINUE THE -

World Weather Watch, Global Atmosphere Watch, Integrated Global Ocean Service System, Global Sea Level Observing System, Global Environmental Monitoring System;

AND DEVELOP THE -

Ocean Climate Observing Element (GOOS)
Cloud -Radiation Observing Element
Land Observing Element
Hydrological Cycle Observing Element

HISTORY

1979 FIRST WORLD CLIMATE CONFERENCE
... proposed the World Climate Program

1990 SECOND WORLD CLIMATE CONFERENCE
... proposed GCOS and GOOS

1990 NAVY-NOAA GOOS WORKSHOP, Alexandria, VA
- build on existing operational and research programs
- technology development required
- interagency coordination required
- develop a plan for a U.S. GOOS
- interact with scientific community

1991 JSC WORKSHOP ON GCOS, Winchester, U.K.

1991 NOAA OCEAN OBSERVATIONS PANEL, Seattle, WA
- must focus on users

1992 U.S. GOOS PRIORITIES WORKSHOP, Woods Hole, MA

ECONOMIC BENEFITS OF EL NINO PREDICTION

GLOBAL OCEAN OBSERVING SYSTEM
- U.S. -

ASSUMPTIONS:

Preliminary!!

U.S. Agricultural Sector Only
Value reduced 9% by a severe El Nino event
Value reduced 4.5% by a moderate El Nino event

With 60% skill: assume 15% of sector loss avoidable
With 77% skill: assume 20% of sector loss avoidable

Two moderate and one severe event in 12 years

CONCLUSIONS:

$140M per year benefit; increases to $240M per year with increased skill

Appendix F
List of Acronyms

ACCP	Atlantic Climate Change Program
APP	Acoustic Plankton Profiler
AVHRR	Advanced Very High Resolution Radiometer
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CEES	Committee on Earth and Environmental Sciences
CPR	Continuous Plankton Recorder
DARPA	Defense Advanced Research Project Agency
DMSP	Defense Meteorological Satellite Program
DOE	Department of Energy
EEZ	Exclusive Economic Zone
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Agency
ERS-1	Earth Remote Sensing Satellite
FCCSET	Federal Coordinating Council for Science, Engineering and Technology
GCOS	Global Climate Observing System
GLOBEC	Global Ocean Ecosystems Dynamics
GOOS	Global Ocean Observing System
ICSU	International Council of Scientific Unions
IOC	Intergovernmental Oceanographic Commission
JGOFS	Joint Global Ocean Flux Study
LMR	Living Marine Resources
NASA	National Aeronautics and Space Administration
NDBC	National Data Buoy Center
NESDIS	National Environmental Satellite Data and Information Service
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NSF	National Science Foundation
OMB	Office of Management and Budget
ONR	Office of Naval Research
OOSDP	Ocean Observing System Development Panel
SeaWiFS	Sea-Viewing Wide Field-of-View Sensor
SST	Sea Surface Temperature
TAO	Tropical Atmosphere Ocean
TOGA	Tropical Ocean Global Atmosphere experiment
TOPEX/Poseidon	Ocean Topography Experiment
UNCED	United Nations Conference on Environment and Development
UNEP	United National Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
USGCRP	United States Global Change Research Program
USGS	Untied States Geological Survey

VOS	Volunteer Observing Ships
WCRP	World Climate Research Program
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
XBT	Expendable Bathythermograph

Appendix G

DEPARTMENT OF OCEANOGRAPHY
TEXAS A&M UNIVERSITY
COLLEGE STATION, TEXAS 77843-3146

WORTH D. NOWLIN, JR.
DISTINGUISHED PROFESSOR

TELEPHONE: (409) 845-3900
FAX: (409) 847-8879

26 August 1992

Dr. Melbourne G. Briscoe
NOAA/National Ocean Service
1825 Connecticut Ave NW
Washington, DC 20235

Dear Mel,

At OOSDP-V, the panel again considered what characteristics distinguish measurements which should be included in a Global Ocean Observing System (GOOS). Before presenting the statement prepared by the panel, I call your attention to several points.

First, OOSDP is concerned with the climate module of GOOS — or the ocean component of GCOS. As such we are considering an observing system to detect, understand, and predict climate change. Therefore, we prefer not to characterize GOOS measurements with the adjective "operational", because it has the connotation that such measurements are specifically for predictive models.

Second, while not recommending measurements needed only for research, we recognize that many GOOS measurements will be used by researchers; such measurements will serve multiple purposes. Just because they have value to research doesn't make them of less value for the other objectives of GOOS.

Third, improvements in measurement techniques, enhanced understanding, and changed requirements for modeling mean that the GOOS must be an evolving system. Though long-term, systematic and relevant to the GOOS module, GOOS measurements are not static.

The statement prepared by OOSDP at our fifth meeting in July 1992 is enclosed. I look forward to your comments.

Sincerely,

Worth D. Nowlin, Jr.
Chairman, Ocean Observing
System Development Panel

WDN/sm

xc: Stanley Wilson, NOS
D. James Baker, JOI
OOSDP
CCCO Paris

OBSERVATIONS FOR A GLOBAL OCEAN OBSERVING SYSTEM

The Ocean Observing System Development Panel (OOSDP) is working to develop a plan for a Global Ocean Observing System (GOOS) and for the Global Climate Observing System (GCOS) that addresses the role of the oceans in seasonal to decadal climate change. The plan is based on the belief that the observations required for such a GOOS should be:

- *long–term*
  Measurements, once begun, should continue into the indefinite future. Continuity in the observed quantity is sought, rather than in the method; and it is anticipated that more effective methods may become available with time.

- *systematic*
  Measurements should be made in a rational fashion, with spatial and temporal sampling tuned to address the issues of climate change. Further, measurements should be made with the precision, accuracy, and care in calibration required to provide continuity in the quality of the data in space and time even though different methodology may be used.

- *relevant to the global climate system*
  Measurements should be made either to document the role of the ocean in the climate system or to provide data needed to initialize and validate models that describe and predict seasonal to decadal climate change.

Because of the global scope and intended longevity of GOOS it is realized that there are further practical constraints on the measurements. They should be:

- *cost–effective*
  Repeat observations are required at many locations. To maximize the return possible using the available resources (financial and manpower), efforts should be made to use observational methods in GOOS that are economical and efficient.

- *routine*
  The observations should be considered as part of the normal work load, with the acquisition, quality control, and dissemination of products able to be carried out with regularity. Thus for some variables, the collection of observations and related work may be integrated into agencies capable of making a long–term commitment; for other variables, the desired quality of the routine observations may be best achieved by providing long–term support to research organizations capable of ensuring the quality and continuity of the measurements. This may vary from nation to nation.

Ocean Observing System Development Panel
July 1992

Appendix H

Proposed Terms of Reference for a Health of the Ocean Panel

DIVISION OF OCEAN SCIENCES
OCEAN SCIENCES RESEARCH SECTION

4 December 1992

Dear (See Distribution):

I am writing to you on behalf of Dr. Gunnar Kullenberg, Secretary, Intergovernmental Oceanographic Commission (IOC), concerning developments in the Global Ocean Observing System (GOOS).

GOOS, an initiative of IOC, in cooperation with the World Meteorological Organization (WMO) and the United Nations' Environment Program (UNEP), is being developed to provide a mechanism for the coordinated management of data and products generated from satellite and in-situ observations of major physical, chemical and biological properties of the ocean, including the coastal zone and enclosed and semi-enclosed seas. It will use a globally-coordinated, scientifically based strategy to allow for coordinated monitoring and subsequent prediction of environmental and climate changes globally, regionally and nationally. GOOS will be built, insofar as possible, on existing activities, by accelerating the implementation of existing ocean observation and data management systems as well as progressive implementation of new elements and capabilities. The concept of GOOS has been formally supported by the Rio Conference as a direct response to the needs identified by Agenda 21.

For convenience, the GOOS structure has been divided into different sets of aims and products to be achieved and produced. These sets constitute GOOS Modules. Each module is aimed at fulfilling the data and product requirements of a defined user community. Some products may be unique to the relevant customer community, some may overlap needs of different customers, and some products may be generic to all. The latest draft development plan (IOC/EC-XXV/8 Annex 1, 6 January 1992) defines the following five modules as constituting GOOS:

- Climate Monitoring, Assessment and Prediction
- Monitoring and Assessment of Marine Living Resources
- Coastal Zone Management and Development
- Assessment and Prediction of the Health of the Ocean
- Marine Meteorological and Oceanographic Services

The intergovernmental machinery has been created to cater to the development of GOOS with the transformation of the IOC Ocean Process and Climate Committee (IOC/OPC) into the IOC Committee for GOOS. The reincarnation of the Committee on Climate Change and the Ocean (CCCO) into the Joint Scientific and Technical Committee for GOOS (J–GOOS), anticipated to take place at the next IOC Assembly in early 1993, will continue the scientific advisory element into this process. At the present time, the Ocean Observing System Development Panel (OOSDP) is providing important and competent advice for use in the development of GOOS with regard to the Climate Monitoring, Assessment and Prediction Module. As a result, the situation with regard to the physical measurements of GOOS is in rather good shape. It is now time to create a comparable resource for the marine chemical and biological aspects of GOOS, and I have been asked by the IOC to initiate its implementation. In accepting this charge, it is my intention to have this activity carried out in the context of the IOC Global Investigation of Pollution in the Marine Environment (GIPME) to achieve respective common goals in both GOOS and GIPME in the most efficient manner possible.

I invite you to participate in the advisory body to address the development of the GOOS Module on the Assessment and Prediction of the Health of the Ocean. I sincerely hope that you can see your way clear to become a member of this group. It is my plan to work in the immediate future by correspondence to develop a draft prospectus and then meet in Paris in February 1993, just prior to the next IOC Assembly. A tentative schedule is as follows:

1. Response to this letter by 16 December 1992.
2. A draft white paper with other documents addressing GOOS to you by 11 January 1993.
3. Comments back to me by 1 February 1993.
4. Meeting in Paris the week of 21 February 1993.

I would appreciate your response to this invitation as soon as possible (Tel. 202–357–7910; FAX 202–357–7621; Telemail (Omnet N.ANDERSEN). Have a happy holiday season.

Sincerely,

Neil Andersen, Director
Chemical Oceanography Program
and Chairman, Committee for GIPME

cc: Dr. G. Kullenberg, IOC
Dr. C. Ibe, IOC
Dr. D. J. Baker, JOI Inc.
Dr. M. Ruivo, Chairman, IOC/UNEP Joint Panel for GIPME

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PROPOSED TERMS OF REFERENCE
IOC GOOS HEALTH OF THE OCEAN PANEL

1. To formulate the conceptual design of an observing system to monitor and assess contaminant loads as indicators of the health of the ocean, near–shore waters and marine ecosystems;

2. To maintain close links with research programs to insure that the module on the assessment and prediction of the health of the oceans is based on sound scientific knowledge and updated as new findings become available; and

3. To coordinate with scientific institutions and bodies, including environmental and space agencies, to encourage that the plans of these organizations effectively incorporate the needs of this module of GOOS.